# PORTABLE TRAFFIC MANAGER

By:

Edward Harper
Sarah Kolak
Samira Tungare

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TA: Ruomu Hao

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## Abstract

It is not uncommon for traffic officers to obtain injuries while directing traffic in construction zones, after large events, or at intersections without stop lights. These injuries can range anywhere from a minor sprain to a more serious fracture. In the most extreme cases, a traffic officer may have permanent disability. The Portable Traffic Manager allows traffic officers to properly direct traffic without putting themselves in danger. This is done using a four-sided traffic light device that displays a circular and left turn arrow symbol on each side. A traffic officer utilizes a handheld device associated with the display to control the display from a safe distance. The device can be easily deconstructed so that it may be moved from one location to another. This document outlines the design decisions made for this device and provides preliminary implementation work.

## Contents

# 1 Introduction

## 1.1 Problem Statement

At intersections with either no traffic lights or one that is malfunctioning, a common practice to control the flow of cars is to have a traffic officer direct the vehicles. Similarly, after large events traffic officers are used to help direct traffic out of crowded spaces and parking lots. The traffic control wand they use seems lightweight but, after hours of use, it can lead to fatigue. The directions they give can be hard to understand and the direction quality only decreases as officer fatigue increases. The method of using hand gestures to direct traffic can  not only be confusing but also dangerous and tiresome for the traffic officer.

## 1.2 Background

Many intersections with permanent traffic signals have utility boxes which allow them to be controlled manually by public works personnel. This is helpful for directing vehicle and pedestrian traffic at an intersection after a large event. These utility boxes give the individual the ability to control the pedestrian signals, turn signals, and light signals at a given intersection [1]. Once the event has ended and the traffic at a given intersection has returned to its normal flow, the signals can return to their automated control. While this feature of current traffic signals is very useful, it is only available at intersections that already have traffic signals and the utility box available.

When a traffic signal and utility box is not available at an intersection then a traffic officer is sent to stand in the intersection and manually direct the traffic. The officers standing in the intersection are required to wear reflective clothing and use traffic wands, especially when directing traffic at night. Aside from the gear, they have designated hand signals that signify "stop" and "go" and sometimes also use whistles or voice commands [2]. This is an adequate form of traffic control when a permanent signal is not available but it can still be dangerous for the traffic officer in the event that a driver does not properly understand or follow their command. Additionally, this method can be tiresome for the traffic officer.

In the Spring 2019 semester of ECE 445, Team 16 designed a pair of gloves and vest that could be worn by a traffic officer. The traffic officer can display a hand signal which will correspond to "stop" or "go". The vest can communicate with the gloves to process what gesture was just made and display either "stop" or "go" on the vest in red or green respectively. Both the front and back of the vest will light up so if the front reads "stop" then the back will read "go".  The gloves also have LEDs that indicate the proper color as well. This implementation of traffic control was designed to make the gear more lightweight and the traffic control process safer for the traffic officer [3]. While this process does eliminate the need for wands, it does not guarantee a safer traffic control process for the officer. Displaying the words on the vest may allow drivers to clearly see what they should be doing but it does not mitigate the possibility of human error. Ultimately, the officer must still stand in the intersection to ensure that everyone can see them so if a driver ignores the vest or is not paying attention the officer is still at risk.

### 1.3 Solution

The Portable Traffic Manager is a device that would take the place of the traffic officer in the intersection. This traffic signal display is a four-sided device that will be controlled by the traffic controller with a small controller device. Each side of the display will consist of one circular and one arrow symbol that can emit red, yellow, and green colors. This traffic control system will allow the traffic officer to safely monitor and direct traffic from the side of the road or in a parked vehicle. Additionally, unlike current traffic utility boxes, this standing device would be portable. Therefore, it can be easily removed when it is no longer needed or placed in a new location.

### 1.4 High-Level Requirements

1. The bluetooth communication between the traffic signal display and the controller device will be successful up to a distance of 30 meters.
2. The red, yellow, and green traffic signal display will be seen from 40 meters away.
3. The traffic signal display and controller will successfully run for up to two hours.

### 1.5 Visual Aid

There are various operation modes of the display. Figure 1 contains visual representations of one possible cycle of light control for the straight direction signals. In the left figure, two directions are given green signals while the adjacent directions are given red signals. At this time, the left turn arrows remain red on all sides. The middle image shows the next stage in which all four directions will have red lights and red turn arrows. The right image then shows the other two directions receiving green signals while the adjacent sides have red signals. The left turn arrows remain red in this mode. Following this cycle, a similar pattern may be used for the left turn arrows.

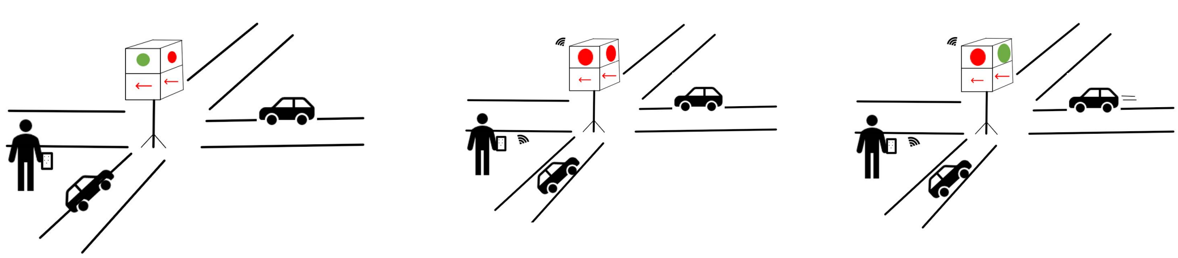

Figure 1: Operation modes for the traffic system

## 1.6 Block Diagram

The Portable Traffic Manager consists of three main parts: a power module, the controller hardware, and the display hardware. Each of these sections utilize specific components and modules to perform their desired operation. The interactions between the various modules mentioned are shown in the block diagram in Figure 2.

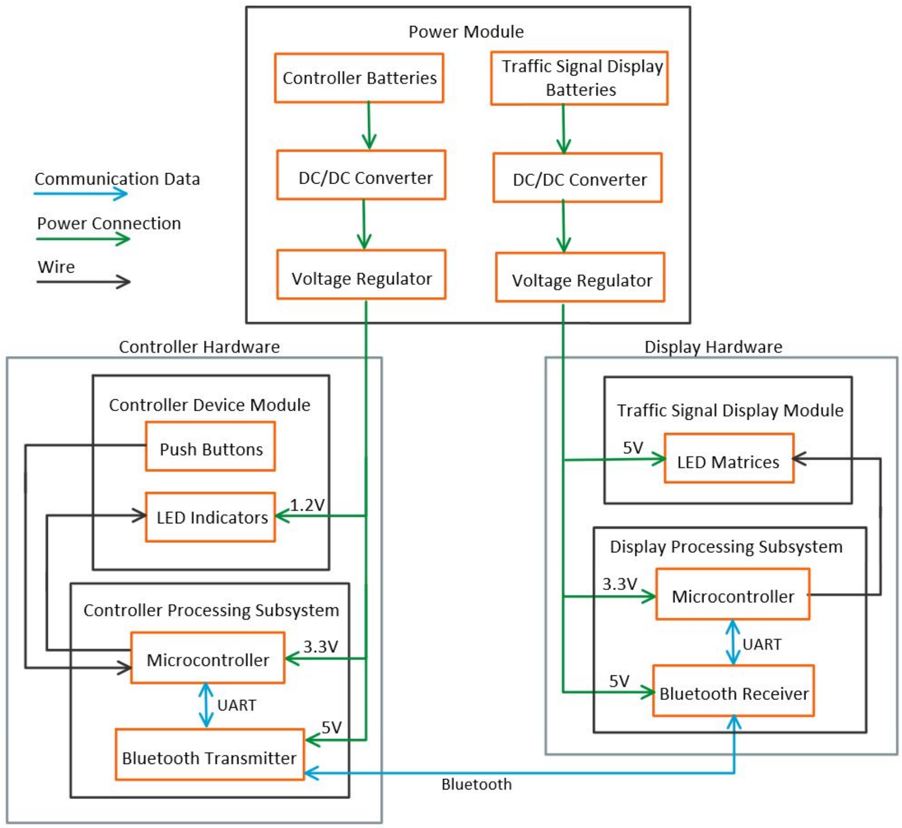


Figure 2: Block diagram for portable traffic manager system

# 2 Second Project Design

## 2.1 Implementation

Preliminary work has been completed for the implementation of the Portable Traffic Manager. Specifically, the schematic and board layouts were completed for three printed circuit boards (PCB) that will be used in the devices. Algorithms have been created using flowcharts and pseudocode to begin the implementation of the software control necessary for the traffic display.

### 2.1.1 Charge Management Integrated Circuit

The display system will use two lithium ion batteries to power each LED matrix. Li-ion batteries were selected primarily because of two factors: voltage supplied and capacity. A requirement of the system is the operation for up to two hours so the capacity of the battery is an important consideration. Additionally, enough current will need to be supplied to the matrices in order to properly illuminate them. The NCR18650B Panasonic Li-ion battery has the desired current and capacity specifications and is also rechargeable. The traffic display device has high power consumption so single-use cells would be an inefficient and wasteful design choice.

Figure 3 shows the schematic for an additional PCB for the BQ24123RHTL IC that will be included in the display system [12]. Its role is to assist in charging the batteries as well as provide monitoring functionality for temperature, charge status, current sensing, and voltage and current regulation. A similar PCB will also be added to the controller device. However, one key difference is that pin 13 will be grounded since only a single battery is used in the controller.

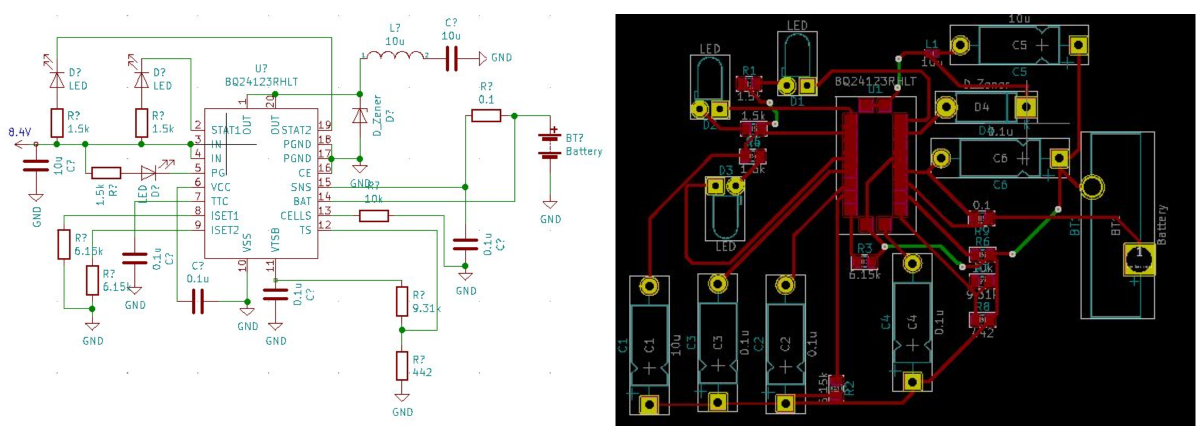


Figure 3: BQ24123RHTL Charge management integrated circuit schematic and board layout

### 2.1.2 Traffic Display Device

The traffic display device will have a PCB that connects the microcontroller, bluetooth module, LED matrices, batteries, and the charge management PCB. Figure 4 below shows the circuit schematic and the implemented board layout for this device.

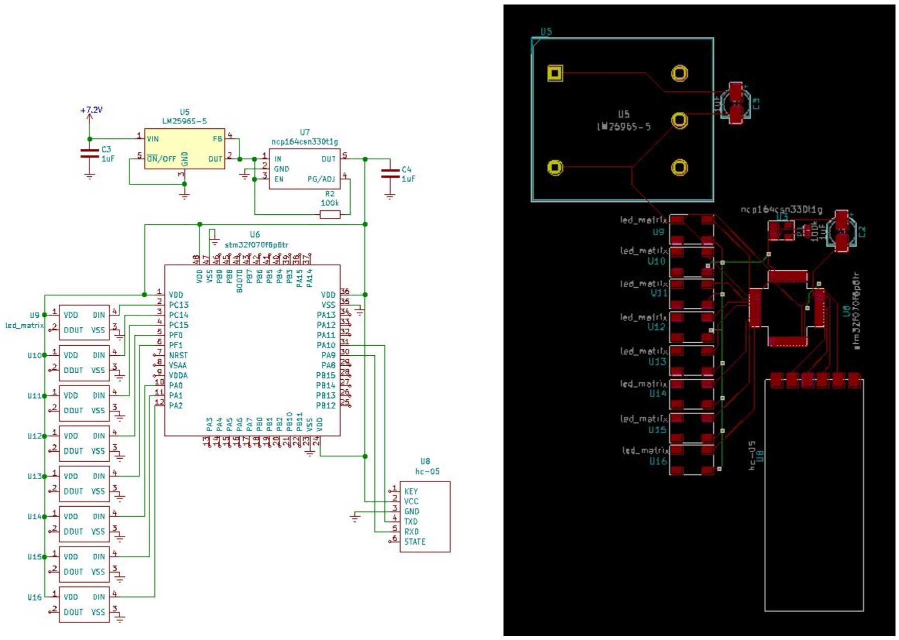


Figure 4: Traffic display device circuit schematic and board layout

Eight WS2812B RGB Flexible 16 cm x 16 cm Pixel Panel Matrix Screens will externally connect to the display PCB. A single LED matrix requires a 5V voltage supply and each pixel consumes 0.3W of power. There are a total of 256 pixels in the matrix. Therefore, when all of the pixels are on the matrix will be consuming 76.8W of power. Using the equation below, this would imply that approximately 15.36A of current needs to be supplied to each matrix.

$$P = I * V$$

Typical traffic signals using LEDs emit approximately 15W of power and these are visible from up to 40 meters away [7][8]. Therefore, an LED matrix would not need all of the pixels to be illuminated, rather it would only need a minimum of 50 pixels illuminated to achieve 15W of output power.

The STM32F070F6P6TR microcontroller will be used on the display system PCB. This microcontroller will be responsible for accurately commanding each LED on the traffic display with respect to the signal received from the microcontroller on the controller device. It will also determine the color of each LED matrix and send a signal to the controller device. This way the traffic officer operating the controller device will be able to know the matrix color on each side of the display even if they are unable to see all four sides from their location. The HC-05 bluetooth module on the PCB will be used for the communication between the controller and display devices.

### 2.1.3 Controller Device

The controller device has a PCB that connects the push buttons, LED indicators, a battery, the charge management PCB, microcontroller, and bluetooth module together. The circuit schematic and implemented board layout is displayed in Figure 5. This PCB is designed to be space efficient, measuring to be 97.7mm x 46.9mm. The PCB will be able to fit into a small handheld device which will allow the traffic control officer to hold and operate the device comfortably.

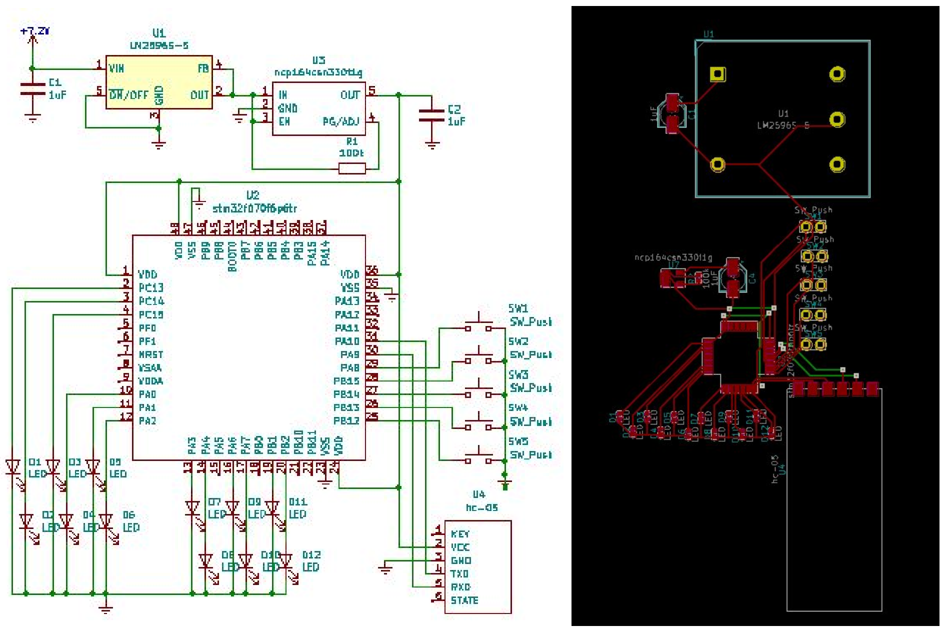


Figure 5: Controller device circuit schematic and board layout

The role of the microcontroller on this PCB is to command the indicator LEDs on the controller device with respect to the signal received from the microcontroller on the display device. It will also need to determine which push button has been pressed and send the corresponding signal to the traffic display microcontroller using the bluetooth module on this PCB. The same microcontroller and bluetooth components used in the display device were selected for the controller device as well.

### 2.1.4 Software

An algorithm has been created to determine the pattern in which the color of each LED matrix symbol should change. This algorithm is outlined in the flowchart as shown in Figure 6. The system will need to check the current color of the matrices and then determine what color to change it to based on the signals provided from the controller device. A "buffer time" was also implemented to ensure that each side will display red signals before any other signal changes to green. This confirms that no two adjacent sides will display green symbols at the same time and reduces the possibility of an accident due to incorrect signal colors. Pseudocode for this algorithm is available in Appendix B.

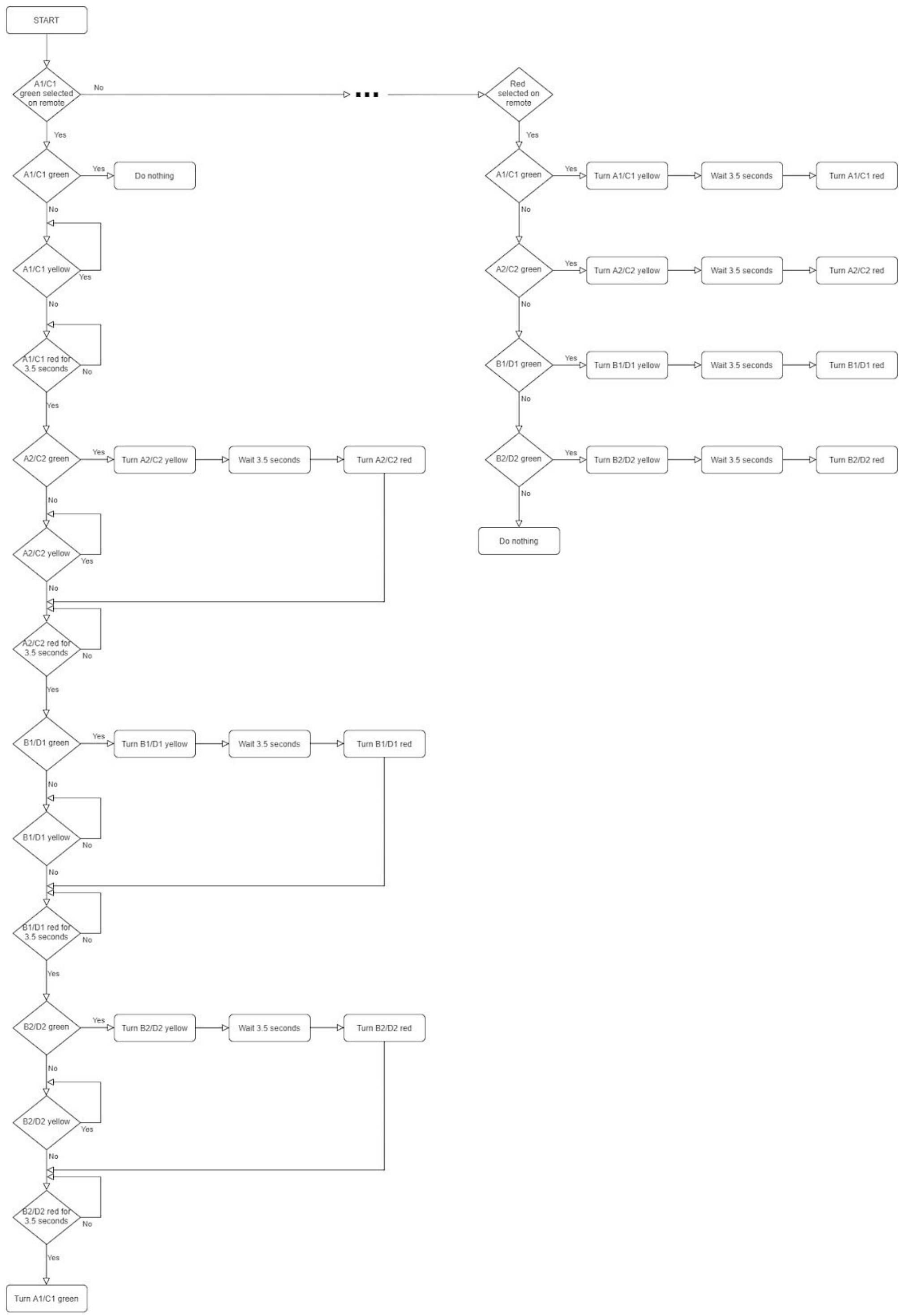


Figure 6: Flowchart for color changing algorithm

The LED matrices each have three wires associated with them: power, ground, and data. Data will be sent from the microcontroller through the data pin to the LED matrix. The Adafruit Neomatrix Library will be used [13]. This library helps construct a matrix so that data can be sent to each individual LED in the matrix. The code for the construction of this matrix is shown in Figure 7. This will be implemented eight times to account for the eight LED matrices that will need to receive data.

```
// Constructor for single matrix:
Adafruit_NeoMatrix::Adafruit_NeoMatrix(int w, int h, uint8_t pin,
  uint8_t matrixType, neoPixelType ledType) : Adafruit_GFX(w, h),
  Adafruit_NeoPixel(w * h, pin, ledType), type(matrixType), matrixWidth(w),
  matrixHeight(h), tilesX(0), tilesY(0), remapFn(NULL) { }
```

Figure 7: Code for creating a data matrix

Once the matrix is constructed, specific RGB values can be sent to each LED location to assign it to a specific color. The RGB variables can take on values in the range of 0-255. The command used for this is displayed in Figure 8. In this line of code, w and h are used to specify the LED location in the matrix.

```
matrix.drawPixel(w, h, matrix.Color(r, g, b));
```

Figure 8: Line of code for assigning colors to LEDs

As mentioned, this line of code will also be repeated for each location in each of the LED matrices. Not all of the LEDs in each matrix will be used so the unused LEDs will remain off.

## 2.2 Tolerance Analysis

The LED matrices will be consuming a large amount of power so it is important to ensure that, when operating at the maximum and minimum loads, the LEDs will still operate for the desired length of time. The maximum number of LEDs will be 56 which will occur for the circular symbol since the arrow symbol will only use 50 LEDs. The LEDs in a given matrix are connected in series. Table 1 displays the discharge current for the WS2812B RGB matrix when operating at the maximum and minimum loads as found in the datasheet[14].

Table 1: Current consumption data for LED matrix panel

| **Discharge Current for 1 LED at minimum load** | **Discharge Current for 1 LED at maximum load** | **Discharge Current for 56 LEDs at minimum load** | **Discharge Current for 56 LEDs at maximum load** |
|---|---|---|---|
| 20mA | 60mA | 20mA*56 = 1120 mA | 60mA*56 = 3360 mA |

Ultimately, if all of the components in the traffic display are not properly powered for the entire length of desired time then the requirement is still not satisfied. For this purpose it is important to also consider the current consumption of the other components such as the microcontroller and the bluetooth module. This data is displayed below in Table 2.

Table 2: Current consumption data for other components

| **Component** | **Discharge Current at minimum load** | **Discharge Current at maximum load** |
|---|---|---|
| STM32F070F6P6TR Microcontroller | 25 mA | 80 mA |
| HC05 Bluetooth Module | 1 mA | 30 mA |

For a maximum load, the total current consumed is 3530mA. Two Panasonic NCR18650B Li-ion batteries will be used to power each LED matrix. Therefore, the usage time can be calculated using the equation below:

$$Operation\ time\ =\ \frac{mAh\ capability\ of\ battery}{total\ current\ discharged\ from\ components}$$

Using the values from the tables above, the total hours of usage that the display will last is calculated to be

$$Operation\ time\ =\ \frac{3500\ mAh * 2}{3360\ mA + 80\ mA + 30\ mA}\ =\ 2.02\ hours$$

This proves that the display satisfies the constraint of expecting the device to work for up to two hours even assuming the device was working at its maximum load the entire time. Since only one LED matrix will be sharing its batteries with the microcontroller and bluetooth modules, the others will be able to run for a little longer when operating at the maximum load as shown below.

$$Operation\ time = \frac{3500\ mAh * 2}{3360\ mA}\ =\ 2.08\ hours$$

Similar calculations can be done for the minimum load case and it can be shown that in both the maximum and minimum case the operation time constraint is satisfied.

$$Operation\ time = \frac{3500\ mAh * 2}{1120\ mA + 25\ mA + 1mA}\ =\ 6.11\ \ hours$$

$$Operation\ time = \frac{3500\ mAh * 2}{1120\ mA}\ =\ 6.25\ hours$$

As demonstrated from the calculations, when operating at both the maximum and minimum loads, all eight matrices will indeed be able to operate for up to two hours before the batteries will need to be recharged.

Furthermore, it is important to also ensure that the controller device will operate for up to two hours. The controller device will consist of the components listed in Table 2 and twelve LEDs. Only four LEDs will ever be on at a time in the controller device which leads to a total discharge current of 80mA. The exact same calculations that were done for the display device can be repeated for the controller device to check that this constraint is met. The results are shown below:

$$Operation\ time\ (max\ load) = \frac{3500\ mAh}{190 mA} = 18.4\ hours$$

$$Operation\ time\ (min\ load) = \frac{3500\ mAh}{106 mA} = 33.02\ hours$$

# 3 Second Project Conclusions

## 3.1 Implementation Summary

Portions of this project's hardware have been implemented through circuit schematics for both the controller device and the display module. PCB layouts have also been created. As previously mentioned, the controller PCB was designed to be small. A charge management circuit schematic and board layout has also been created for the controller and display to create a more robust battery system.

Some of the software design was also implemented. Pseudocode was created for the algorithm to change the LED Matrix light colors. The necessary libraries for programming the LED matrices were also found and key commands were determined. However, components were not ordered and so the microcontroller could not be programmed. Similarly, the bluetooth module could not be configured.

Ultimately, the PCB design and the initial software work are the only parts of the project that could be implemented without the desired components or lab space. Nonetheless, these are key aspects of the project so the implementation work done is significant.

The work done by each teammate for the implementation section is outlined in Table 3.

Table 3: Implementation Tasks Assigned to each Team Member

| Implementation Task | Completed By |
|---|---|
| Traffic Display PCB Design | Sarah |
| Controller Device PCB Design | Sarah |
| Charge Management PCB Design | Samira |
| Pseudocode/flowchart for light algorithm | Sarah/Eddie |
| Software for LED Matrices | Eddie |
| Tolerance Analysis | Samira |

## 3.2 Unknowns, Uncertainties, and Testing Needed

With no access to the labs, the devices could not be constructed and therefore could not be properly tested. The effectiveness of the physical design could not be tested in a real world setting. To realize the physical design would have required collaboration with the machine shop which is closed. One requirement of success depends on the distance at which the display is visible. The physical design created was intended to be tall enough so it can be seen over other cars on the road. Ultimately, without creating the device this requirement cannot be properly verified.

The hardware was designed but the success of the PCBs cannot be accurately determined without soldering on the components and testing the system operation. This prevented the testing of the communication between the two devices. The power module could also not be tested without building the system and checking the output at each stage using oscilloscopes. Lastly, the battery management system could not be tested without obtaining the batteries and the desired IC and soldering the PCB. Proper testing would have required lab equipment such as voltmeters and oscilloscopes.

For the software required in the project, pseudocode for the microcontrollers was created and key code commands were gathered; however without the actual component, the microcontroller could not be programmed. Therefore, the success and accuracy of the algorithm is currently unknown. Since the LED matrices were not ordered, code is unable to be adequately tested which inhibits the completion of the LED matrix requirements.

## 3.3 Safety and Ethics

There are many safety concerns to take into account given that this device will be used in the street to control the flow of traffic. Additionally, since an individual will be given control of the device there are ethical considerations that also must be contemplated. There are also mandatory design constraints for new traffic equipment being developed that need to be followed.

### 3.3.1 Safety

We plan to abide by the Occupational Safety and Health Administration (OSHA) Manual on Uniform Traffic Control Devices (MUTCD) which states that “during any time the normal function of a roadway is suspended, temporary traffic control planning must provide for continuity of function” and also that “effective temporary traffic control enhances traffic safety and efficiency, regardless of whether street construction, maintenance, utility work, or roadway incidents are taking place in the work space” [5]. A traffic officer will have control of the device and manage the flow of traffic by providing clear and efficient signals. This will provide a typical flow of traffic as well as allowing the officer to change signals based on any other work going on in the area. Also, “all workers should be trained in how to work next to traffic in a way that minimizes their vulnerability” [5], so this device should only be operated by officers who have gone through proper training. This will ensure that the user has the proper knowledge and background to control traffic in crowded areas. “It is essential that concern for traffic safety, worker safety and efficiency of traffic movement form an integral element of every temporary traffic control zone, from planning through completion of work activity” [5]. Therefore, safety is a top concern for this product and measures will be taken to ensure the safety of all involved.

### 3.3.2 Ethics

This system will be used to control a large number of people on the road. Therefore, it is important that we follow the IEEE Code of Ethics and agree "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment" [4].

Each state in the United States has their own Department of Transportation which provides standards relating to traffic devices. According to Illinois Department of Transportation (IDOT) specification 39-2.02(d), the display will need to be located such that it will be clearly visible during the night and also special attention should be given to the orientation angle [6]. This standard was taken into consideration when determining the physical design of the traffic signal display.

We also need to consider emergency situations on the road and make a decision in order to keep people safe. This is why there will be an emergency stop button which will stop all four directions of traffic so that an emergency vehicle can easily get by.

Another ethical issue comes from the use of Bluetooth communication. If this product were to become marketable, it is important that there is a secure bluetooth connection so that other devices cannot arbitrarily connect to and control the display device. The HC-05 bluetooth device selected for this application follows IEEE 802.15.1 standardized protocol [10]. However, in the future new forms of wireless communication may need to be explored if this proves to be a major issue.

## 3.4 Project Improvements

If more time was available to work on this project one main focus would be to create a more efficient and robust power module. Currently the design utilizes 17 batteries between the controller and the display. Sixteen of these batteries are used by the LED matrices. One challenge for this project was finding batteries that supplied enough power to the matrices while still being small in size and lightweight to keep the device portable. The total cost of the batteries was also the largest expense for the project, accounting for almost half of the total cost. If given more time, the design would have incorporated a more efficient, robust, and cheaper power module.

It is currently unknown how much heat may be dissipated by the system but this could prove to be an issue. If too much heat is dissipated, then the system will not be able to operate for the proper amount of time and a lot of power would be wasted. Therefore, in the future it would be helpful to incorporate thermal isolation and heat sinks to help with the heat dissipation in specific components.

The primary reason that the display system consumed so much power was because of the demand by the LED matrices. One of the more difficult design decisions made for this project involved determining how many LEDs needed to be illuminated on each side of the display so that it is sufficiently visible. Standard traffic lights consumed too much power so this project's design used LED matrices instead. In the future, the creation of a more robust display with lower power consumption would allow for brighter signals and less confusion for drivers.

The system as a whole could be upgraded by adding signals or alerts for pedestrians for when it is safe to cross the street. More individual displays which all communicate with the main traffic display system could be set up on each of the corners to notify the designated times to cross. The design would be similar to the display module with the substitution of a blue walking symbol or red stop symbol in place of the red, green, or yellow directional signals for the vehicles.

Finally, a camera could be added to the top of the display so the traffic officer could see cars that are approaching from a distance. This would allow the traffic officer to better direct the traffic based on the flow from all four directions.

# 4 Progress made on the First Project

## 4.1 Progress Summary

After the design document review, a PCB was designed for the self-adjusting speaker project. It was sent to the TA after it passed the DRC and the PCBWay audit. The machine shop was also contacted to create the enclosure for the speaker. The physical design with the product dimensions was given to the machine shop so the device construction could begin. Lastly, components were ordered and had arrived.

## 4.2 Circuit Design

The speaker device had one PCB that connects the speakers, push buttons, ADC, audio sensor, filter, microcontroller, and bluetooth module together. The circuit schematic and board layout are displayed in Figure 9 and 10 respectively. Due to the speaker device's size the PCB was made as small as possible, measuring to be 63.7mmm x 69.8mm. This would allow the enclosure to be small and portable.

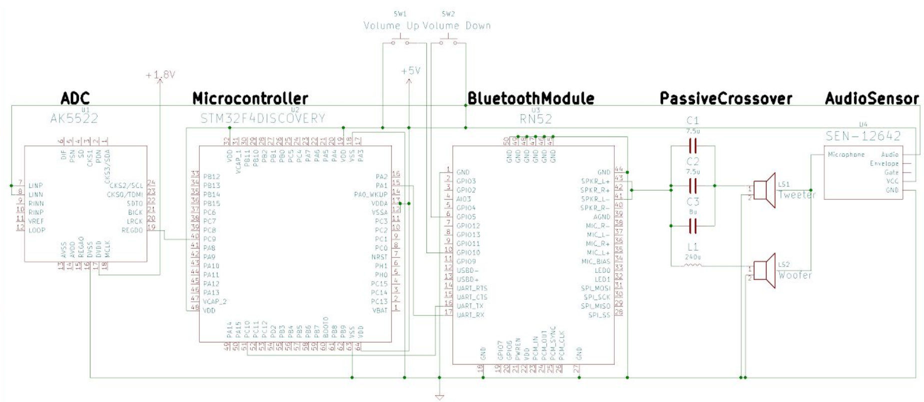


Figure 9: Circuit Schematic for self-adjusting speaker project

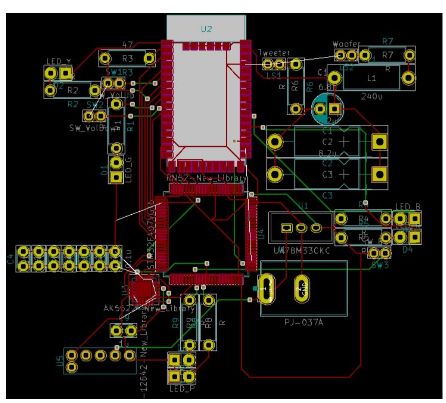


Figure 10: Board layout for self-adjusting speaker project

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## Appendix A Requirement and Verification Table

Table 3: System Requirements and Verifications

| Requirement | Verification | Verification status (Y or N) |
|---|---|---|
| 1. Bluetooth<br>a. The bluetooth modules will be able to communicate with one another at a distance of 30m +/- 5%. | a. Place one bluetooth module in a set location<br>b. Measure 30 meters away from the the stationary bluetooth module<br>c. Ensure that a bluetooth connection still exists between the two devices at this distance. | |
| 2. LED Matrices<br>a. The LED Matrix will be visible up to 40 meters away +/- 5% | a. Place LED matrix in a set location<br>b. Measure 40 meters away from the matrix<br>c. Ensure that the symbols and colors are clearly visible from this distance.<br>d. If not visible, determine approximately where the LEDs become not clearly visible.<br>e. Repeat this test in daylight and at night | |
| 3. LED Matrices<br>a. The LED matrix will display the proper circular and arrow symbols. | a. Program the matrix<br>b. Look at matrix and ensure that the symbols look the way we | |
| 4. LED Matrices<br>a. The LED matrices will operate for up to two hours | a. Program the LED matrix<br>b. Start timer<br>c. Keep LED matrix on and change signal colors every now and then<br>d. Stop the timer when LED matrix no longer receives enough power and check that time is near two hours. | |
| 5. Microcontroller<br>a. Microcontroller outputs correct signals based on the inputs. | a. Probe the output pins of the microcontroller with an oscilloscope<br>b. Check display to ensure correct signals are being output after | |

| | | |
|---|---|---|
| | processing | |
| 6. LED Indicators<br>a. LEDs will indicate what signals are being displayed form the traffic signal display. | a. Change the traffic command with the controller<br>b. Compare the LED indicators with traffic signal display to make sure the correct direction and signal are shown<br>c. Repeat for all directions and signals | |
| 6. Step-Up Converter<br>a. The converter will step up from 3.6V to a steady 5V +/-2% output voltage. | a. Provide a 3.6V input from a power supply<br>b. Connect the output of the converter to a voltmeter.<br>c. Measure the output voltage. | |
| 7. Step-Down Converter<br>a. The converter will step down from 7.2V to a steady 5V +/-2% output voltage. | a. Provide a 7.2V input from a power supply<br>b. Connect the output of the converter to a voltmeter.<br>c. Measure the output voltage. | |
| 8. Voltage Regulator<br>a. The voltage regulator will be able to supply a 3.3V output when given a 5V input. | a. Provide a 5V input from a power supply<br>b. Connect the output of the regulator to a voltmeter.<br>c. Measure the output voltage. | |
| 9. Power Module<br>a. The power module will be able to support the system for at least 2 hours | a. Power up the system<br>b. Run a typical system operation for 2 hours<br>c. Confirm that all parts operate without fail for a minimum of 2 hours | |
| 10. Controller Device | a. Power on display system and controller device<br>b. Start timer<br>c. Use controller device and stop timer when controller device no longer receives power from battery<br>d. Check the timer to confirm that operataion time is near 2 hours. | |

## Appendix B Pseudocode for Light Changing Algorithm

```
IF (A1/C1 green button == 1)
    IF (A1/C1 green == 1)
        Do nothing
    ELSE
        IF (A1/C1 yellow == 1)
            Check again
        ELSE
            IF (A1/C1 red < 3.5 seconds)
                Check again
            ELSE
                IF (A2/C2 green == 1)
                    Call subroutine to turn A2/C2 yellow
                    Wait 3.5 seconds
                    Call subroutine to turn A2/C2 red
                ELSE
                    IF (A2/C2 yellow == 1)
                        Check again
                    ELSE
                        IF (A2/C2 red < 3.5 seconds)
                            Check again
                        ELSE
                            IF (B1/D1 green == 1)
                                Call subroutine to turn B1/D1 yellow
                                Wait 3.5 seconds
                                Call subroutine to turn B1/D1 red
                            ELSE
                                IF (B1/D1 yellow == 1)
                                    Check again
                                ELSE
                                    IF (B1/D1 red < 3.5 seconds)
                                        Check again
                                    ELSE
                                        IF (B2/D2 green == 1)
                                            Call subroutine to turn b2/d2 yellow
                                            Wait 3.5 seconds
                                            Call subroutine to turn b2/d2 red
                                        ELSE
                                            IF (B2/D2 yellow == 1)
                                                Check again
                                            ELSE
                                                IF (B2/D2 red < 3.5 seconds)
                                                    Check again
                                                ELSE
                                                    Call subroutine to turn A1/C1 green
```

```
ELSE IF (A2/C2 green button == 1)
        ...

ELSE IF (B1/D1 green button == 1)
        ...

ELSE IF (B2/D2 green button == 1)
        ...

ELSE            //stop button
        IF (A1/C1 green == 1)
                Call subroutine to turn A1/C1 yellow
                Wait 3.5 seconds
                Call subroutine to turn A1/C1 red
        ELSE IF (A2/C2 green == 1)
                Call subroutine to turn A2/C2 yellow
                Wait 3.5 seconds
                Call subroutine to turn A2/C2 red
        ELSE IF (B1/D1 green == 1)
                Call subroutine to turn B1/D1 yellow
                Wait 3.5 seconds
                Call subroutine to turn B1/D1 red
        ELSE IF (B2/D2 green == 1)
                Call subroutine to turn B2/D2 yellow
                Wait 3.5 seconds
                Call subroutine to turn B2/D2 red
        ELSE
                Do nothing
```