Traffic Control Smart System

By

María Pilar Galainena Marín

Mohit Rawat

William Wang

ECE 445 Design Document

Team No. 16

TA: Dongwei Shi

21st February 2019

1. Introduction

1.1 Objective

Modern day traffic control is conducted using large traffic wands that quickly fatigue traffic officers. They also tend to only have one light setting and on top of this drivers are often not properly educated on traffic control gestures so communication between officer and driver is very vague and can cause confusion.

Our solution alleviates the fatigue associated with traffic control by replacing the heavy wands with lightweight gloves and flexible LED panels that can be attached to the front and back of the officer's vest. They are all lined with LEDs whose colors can be varied and controlled with simple and easily accessible buttons on the gloves and chest. The LED panel will have toggleable settings between displaying "STOP" and "GO" which will make communication clear and easy for the officer, removing any possible confusion at the intersection. Our system is also modular so gloves and body panels are completely separate but can still communicate with each other through wireless transceivers. We also hope to keep everything relatively inexpensive compared to what current traffic wands cost so that our product is affordable for the police department. Lastly, everything is powered separately with lightweight rechargeable batteries.

1.2 Background

Currently, officers on traffic control duty for busy intersections use large wands that are essentially lit up traffic cones with a handle. These traffic wands are very cumbersome and quickly cause a lot of fatigue for the officers as they wave them around directing traffic for elongated timespan. The job of Traffic control usually takes 15-20min but can sometimes last long for 2-3 hours. In addition to this, communication between officers and drivers are conducted through arm gestures that are ambiguous and hard to understand for many. This poses as a large issue to both the officer and drivers in the intersection. Officers get fatigued and lose focus as the shift goes on and on the off chance a careless driver comes to the intersection and does not heed the officer's orders, lives are in danger.

We have partnered with Jake Fava and Ava Bilimoria from the Siebel Center for Design and Sgt. James Carter from the University Police to solve this issue, and have also gone in person to see how a traffic control shift is performed. After interviewing a few police officers on their opinions on these shifts, they all have the same view as us on the problems with how traffic control is currently done and have experiences that support our ideas. One officer has even told us about how a driver almost hit him once because the driver did not understand his gestures.

1.3 High Level Requirement List

- Entire system must be lightweight; gloves should be at most 1 pound and vest should be at most 5 pounds.
- LEDs need to be able to be programmed to exhibit a full range of colors with brightness control. They also should be bright and be comfortably viewable for both Day and night conditions from minimum a 15m distance.
- The system must be entirely powered by lightweight, rechargeable batteries that can sustain power for elongated duration (at least two hours).
- Gloves and Vest should be able to communicate wirelessly.

2. Design

2.1 Block Diagram and Physical Design

- The Power module will used as safe to use, regulated power supply for sensor module, Control System and the LED module for elongated duration.

- Sensor module will used as a trigger for the microcontroller to change animation on the LED module.
- Control System will be listening to trigger generated by Sensor module and will change animation on LED module accordingly. It will transmit the trigger signal to other microcontrollers via the wireless controller.
- LED module will respond to the control signals by the Control system.

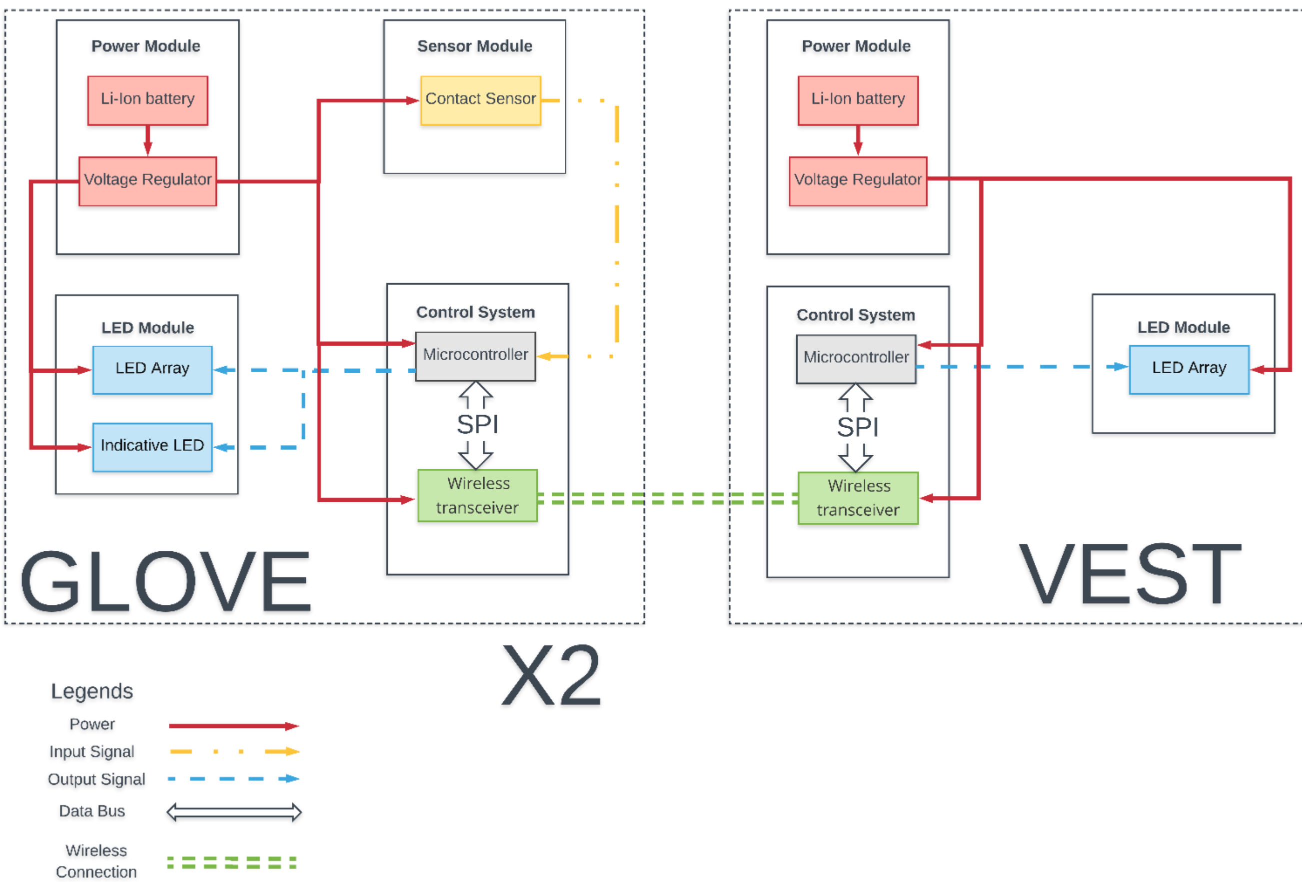

Figure 1: Block Diagram

- For the vest we plan to have a microcontroller with a wireless module which will be essentially communicating with the glove (mainly waiting for the trigger signal from the glove) and controlling the front and the back panel accordingly. The front and the back led panel will be a 14-segment display with 4 characters power by 4 li-ion cells.

- For the gloves we plan to have microcontroller with a wireless module which will be essentially communicating with the vest (mainly sending trigger signal from contact sensor) and controlling the LEDs on the glove based on trigger signal from contact sensor.

Figure 2: Front and Back View Conception of Vest [9]

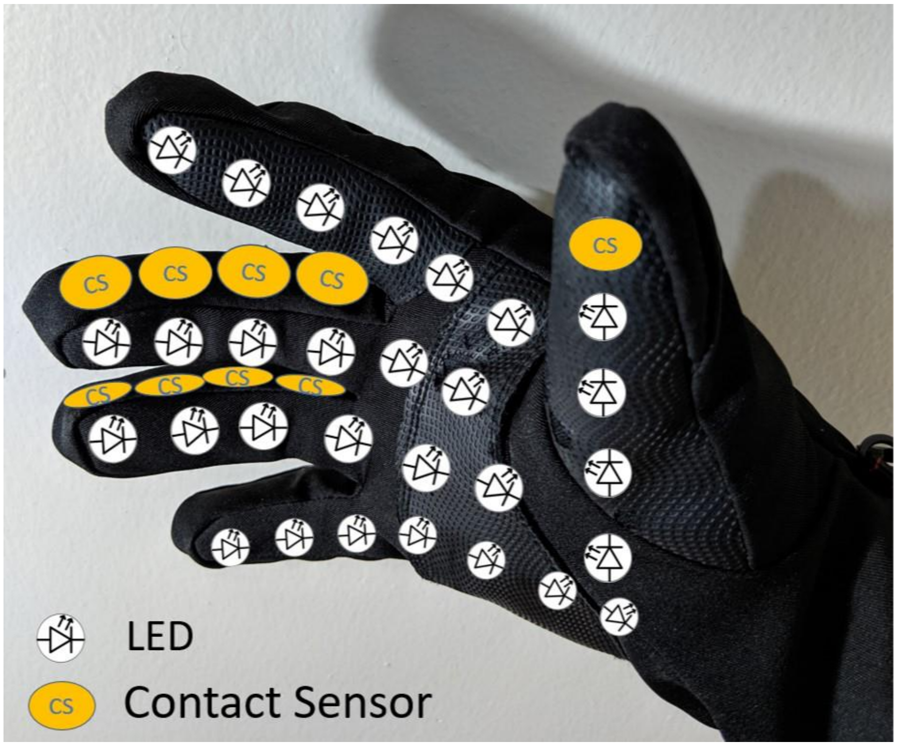

Figure 3: Glove design conception

2.2 Block Description

2.2.1 Li-ion battery

For our project, we have three major power requirements. Microcontroller consuming 50 mAh at 5v, LEDs consuming 60 mAh at 5v per LED and Wireless Transceiver consuming 12 mAh at 3.3V. We plan to use Li-ion batteries (NCR-18650B @ 3.6v - 4.8A) due to their high energy density, as they can typically supply up to 3500 mAh of current charge [5]. Li-ion batteries have dangerous hazards associated with them due to high sensitivity and therefore for safety purposes we plan to use protected Li-ion batteries[4]. These protected Li-ion cells come with built-in protected circuit which can protect from instant discharging of the cell or short circuit. We estimate to have at least 25 LEDs per glove and 112 LEDs for the vest, and therefore we plan to use 2 cells per glove and 4 cells for the vest which can power the gloves for approximately 13.7 hours and vest for 6.2 hours.

For both the glove and the vest we will use 2 Li-ion 3.6V cells in series and feed the 7.2 output voltage into the voltage regulator.

2.2.2 Voltage regulator

The microcontroller and the LEDs require a 5v supply, therefore we need a voltage regulator to regulate the power supply form the Li-ion Batteries. Since our project is a wearable product, heating of the electronics components is serious concern to us. Linear Voltage regulators are easy to use, but they tend to have poor efficiency and as a result dissipate significant amount of heat. Hence, we plan to implement a switching DC-DC converter (buck converter), since they generally have higher efficiency and dissipate less heat compared to linear voltage regulators.

Since we have to reduce the input voltage, we need to design a buck converter as the one shown in Figure 4 to get the desired output voltage from the 7.2V input. It consists of a switch network that reduces the dc component of voltage, and a low-pass filter that removes the high frequency switching harmonics. The LM2596 converter would be a suitable option since it has an input voltage range up to 40V [8]. As for the values of the different components that are going to be used in the design of the converter, we should consider the following:

- R1 should be a value between 240kΩ and 1.5kΩ
- $Vout = Vref * (1 + \frac{R2}{R1})$ (1)
- $C_{FF} = \frac{1}{31 * 10^3 * R2}$ (2)

So, based on these specifications and the data sheet, the design of the voltage regulator would be the following:

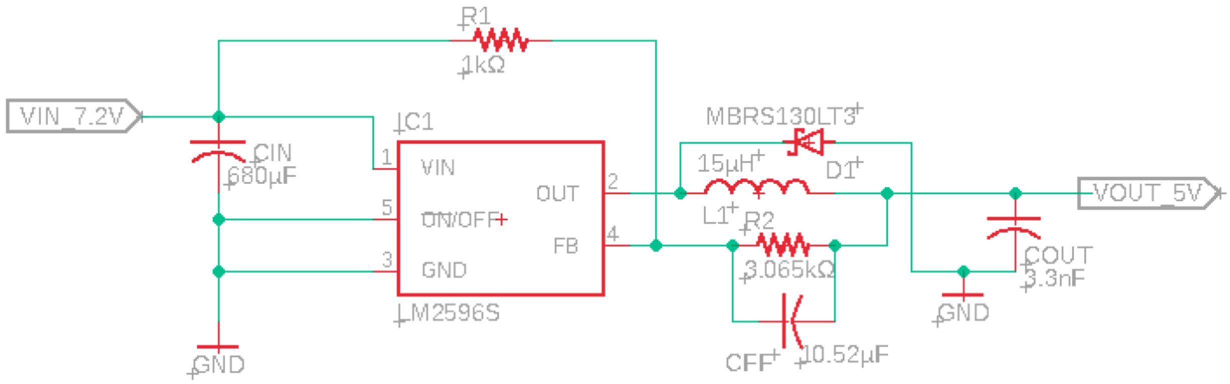

Figure 4: Buck converter design

As the wireless transceiver needs 3.3V we would use a LD1117 converter. The design for an input of 5V and an output of 3.3V would be the following:

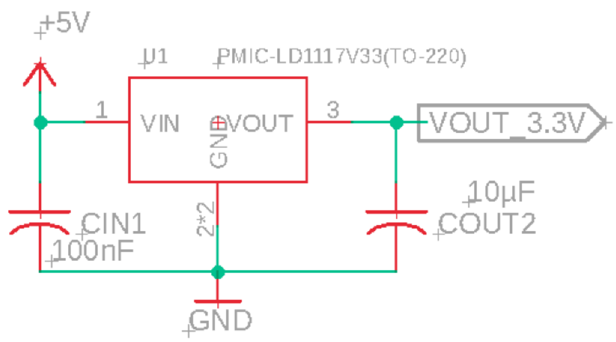

Figure 5: LD1117 3.3v Converter Schematic

Note : We plan use both 3.3v and 5v regulator in cascade setting.

Note: For the vest the LED strip is going to be powered into two pieces. The back and the front panel will be powered differently, however LEDs from both panels will connected in series in terms of control signals. We will be using two voltage regulators for the vest, one will power the front panel and other will power the back panel. There will be only control signal (from ATmega328p) that will controls all LEDs on the front and the back panel (in series).

Requirements	Verification
1) Buck converter should provide 5V+/- 5% from a 7.2V source.	a) Connect the voltage regulator to the 7.2 V Li-ion battery pack. b) Probe the output pin of the Buck Converter using a voltmeter. c) Verify the output reads as 5V with 5% margin error. d) If measured values are out of range, then adjust the variable resistance.
2) LD1117 Voltage regulator provides 3.3v +/- 5% from a 5 V source.	a) Connect a resistor of 10k ohm on the output pin of the 5v Buck Converter. b) Now, connect the input pin of LD1117 regulator to the output pin of buck converter. c) Probe the output pin of the LD1117 regulator using a voltmeter. d) Verify the output reads as 3.3V with 5% margin error.

2.2.3 Microcontroller

For our design we plan to incorporate total of three microcontrollers (two for each glove and one for vest). As the brains of our project, microcontroller should be able to communicate with other microcontrollers, take input from the contact sensors and accordingly be able to controls the LEDs simultaneously. The microcontroller should be able to distinguish between multiple contact sensors for which it must have about 8 inputs pins (since eight contact sensors per glove) free after the I/O pins for transceiver and the LEDs have been utilized. It should be able to send the control signal for LEDs and as also should be able to communicate in SIP protocol. It should also be able to store the state of the LEDs and retain the states while multitasking.

For all the necessities state above ATmega328P microcontroller is good fit for our project as it has ample number (23) of general purpose I/O pins, sufficient memory for software (32kb flash memory) and also supports SPI protocol. We will be using the PU version of the product (Dual-in line Package) as it is breadboard friendly and is practically convenient to work with [6].

The ATmega328P will be always polling the status of the contact sensors and based on the trigger data will generate the control signal for the WS2813 LED strip as well as the nRF24L01 transceiver. ATmega328P will be powered by the 7.2v Li-ion battery pack regulated by the Buck converter at 5v.

An important thing to note is that the contact sensors only output two values, which is a high(+5v) and a low(0v), hence either the analog pins and digital can be used for polling data.

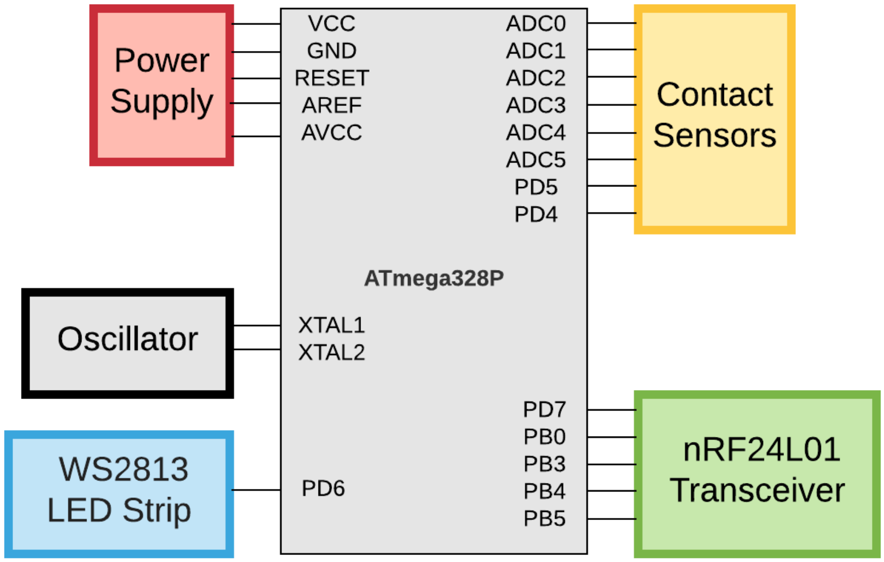

Figure 6: ATmega328P interfaces

Requirements	Verification
1) Should be able to identify which one of the 8 contact sensors was triggered.	a) Define a unique set of LED animations for each contact sensor. b) Program all 8 contact sensors to each unique LED animation respectively on ATmega328p. c) Trigger the microcontroller by bringing sensors in contact, one by one, sequentially. d) Observe and verify the LED animations, triggered by each contact sensor as programmed in step (b).

2) Should be able to transmit the correct signal.	a) Define a unique set of LED animations for the Vest for each contact sensor on the Left Glove. b) Program the ATmega328 accordingly. c) Trigger the contact sensor on the Left Glove one by one sequentially. d) Observe and verify the LED animations on the Vest, triggered by each contact sensor as programmed in step (b). e) Repeat steps (a) to (d) with Right Glove.
3) Should be able to keep track of the current state of the LED strip while multitasking.	a) Set the Left Glove LED strip to certain state. (For eg. Flashing Green Color) b) Bring the sensor in contact on left Glove to transmit an instruction to the Vest (For eg. Display STOP sign). c) Observe and verify the Vest obeys the instructions (For eg. Displays STOP sign). d) Observe and verify the LEFT Glove retains its state (For eg. Flashing Green Color). e) Repeat steps (a) to (d) for Right glove.

4) Should be able to synchronize with other microcontrollers through transceiver.	a) Set the Left Glove on a Green Flashing. b) Set the Right Glove on a Green flashing. c) Observe and verify both gloves are not flashing in synchrony. d) Trigger the contact sensor on either glove. e) Observe and verify both gloves are now flashing in synchrony.

2.2.4 Wireless Transceiver

Since we want the gloves to be wireless and hassle-free, we need three wireless modules connected to each microcontroller which would allow the gloves to communicate with the vest. The wireless transceiver should be able to establish a network of at least three nodes and allow them to have a seamless bi-directional communication. The module should be able to send/receive data from other transceiver about the status of led strip and the contact sensors.

We plan to use nRF24L01 which can communicate at a rate of up to 2Mbps at 2.4GHz frequency [10]. This module also has the capability to receive data from 6 different transmitters over the same frequency concurrently. In addition, nRF24L01 draws very low amount of current (12mA) and therefore will not be a risk for power sink. This module can be easily be interfaced with ATmega328P since it supports SPI protocol [7].

nRF24L01 will be under complete control of the microcontroller through the SPI protocol and will be given instructions based on the sensor data fetched by the ATmega328P. It will be power by 7.2v battery pack regulated by the LD1117 at 3.3v. The nRF24L01 in our project will be configured in a ring topology with glove module being both Sender/Listener whereas the vest module to be only listener. Figure 7 describes the network topology of nRF24L01 in our project.

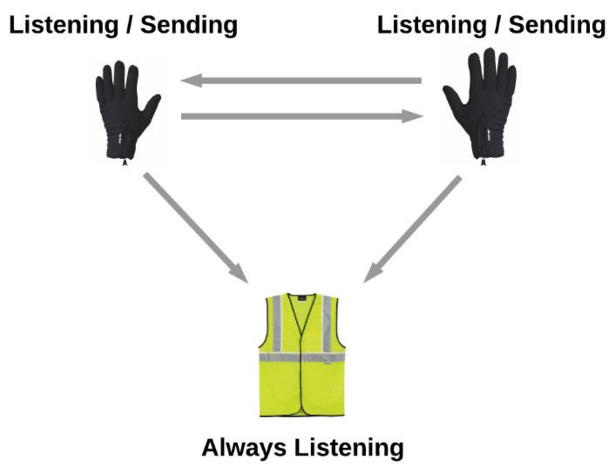

Figure 7: Ring Topology between the gloves and the vest

Requirements	Verification
1) Left and Right glove should be able to establish a bidirectional communication between them.	a) Interface transceivers from both gloves using two Arduino Uno development board with serial monitors enabled. b) Program the Left Glove to send 8-bit binary value to right glove.

	c) Program the right glove to receive that 8-bit binary value and return its complement. d) Observe and verify the results on the serial monitor for both development boards. e) Switch the roles of transceivers and repeat steps (a) to (d).
2) Left and Right gloves should be able to send data packets to each other and the Vest simultaneously.	a) Interface transceivers with three Arduino Uno development board with serial monitors enabled. b) Program the Left Glove to send 8-bit binary value to the right glove and the Vest concurrently. c) Program the right glove and the Vest to receive an 8-bit binary value. d) Observe and verify the results on the serial monitor for all three development boards. e) Switch the roles of Left/Right glove and repeat steps (a) to (d).

2.2.5 Contact sensor

For smooth control of incoming traffic, we need to be able to change LED colors and animations instantaneously. Thus, we need a set of buttons that can trigger the microcontroller to change animations appropriately with each button triggering a different animation. Since multiple hard-buttons can become cumbersome while active usage, we are going to use conductive thread to weave the different conduct points of the glove.

Since we want the final product to be power efficient, we should ensure that contact sensors do not draw any power while there is no contact been made between the sensors. The circuit design for the contact sensors ensures that no power is drawn for separated sensors. In addition, we will use high resistance (1 mega ohm) value to ensure that even on contact, the sensors minimal power is drawn. We will also make sure that contact sensors are debounced and allow only one register input per contact.

The contact sensors will be powered by the voltage regulators and their output pin will be fed into microcontroller.

Requirements	**Verification**
1) Should output +5V when the sensor on the thumb makes contact with a sensor on the finger or else output 0V.	a) Probe the output signal pin of the contact sensor using a voltmeter w.r.t. to GND pin. b) Make contact between thumb sensor and finger sensor. c) Verify the +5v output on the voltmeter. d) Separate the contact sensors. e) Verify a 0v output on the voltmeter.
2) Does not draw power when contact sensors are separated.	a) Probe the VCC pin of the contact sensor with an ammeter. b) Ensure no contact is made between the finger and the thumb.

	c) Verify 0A of current on the ammeter.
3) The contact sensors are debounced and allows a single register per contact.	a) Power the contact sensors. b) Make a single contact between the sensors. c) Verify that LED strip changes its animation only once. d) If not, then Probe the output of contact sensor on an oscilloscope and examine the output signal. e) Measure the duration of the unstable output signal. f) Accordingly increase the delay for debouncing software program.

2.2.6 LED array

To fulfill the main objective for our project, LEDs will be used to display a vibrant color scheme and establish a precise/unambiguous communication between motorists and police officers. They will be arranged in a serial connection and will be controlled via microcontroller. Due to the hasty nature of use-case of our product, we require the LEDS to respond quickly and as long-lasting. For this reason, we are going to use a WS2813 LED strip since it is a dual-signal wires version with signal break-point continuous transmission. That is, even though a LED in the middle of the chain burns, the circuit will remain closed and the other LEDs will still light up. As a digital LED strip, each addressable LED has an integrated driver that allows the brightness and color of each LED to be controlled.

The WS2813 strip have 6 pins: two power pins (+5V for IC and LEDs), the ground pin (GND), two data pins (Din and Dout) 1, 1 backup pin (Bin). The Strip will be powered by the 5v voltage regulator and controlled by microcontroller through the data pins Din and Bin [3].

Note: Although the LED panel on the vest is a 14-segment display, all the LEDs will be connected in series. In our software we are going to have a Look up table, which would specify the LEDS to be lit for a particular letter to be displayed. The LEDs on the glove also will be connected in series.

Requirements	**Verification**
1) Should be individually addressable with color control.	a) Power the WS2813 strip and connect the input signal to the Atmega328p. b) Program the Atmega328p to notify 1st Led to be RED, 2nd to be Green,3rd to be blue and then repeat sequence. c) Observe and verify the color of the LEDs on the strip accordingly.
2) Should be bright and can be comfortable viewed for least 15m such for both day and night conditions.	a) Move to a parking lot during the day. b) Maintain a distance of 15m from the glove and the vest. c) Make sure the Led animations are visible without any strain. d) Adjust the brightness levels if necessary.

2.2.7 Indicative LED

As discussed before, we plan to have an LED panel on the back side of the vest as well. Since the user cannot see, the current animation on back panel, we want an indicative light on the glove which indicates the current animation being displayed. So, this LED should be able to respond synchronously with the back panel. The LED will be powered by the 5V regulator, will be controlled by the microcontroller and will be present on only one of the Left Glove.

Requirements	Verification
1) should be able respond in synchrony with the back panel.	a) Power the Left Glove and the Vest. b) Bring the sensor in contact which will trigger STOP signal (Red Color) on the back panel of the led. c) Observe and Verify the back panel on the Vest shows STOP SIGNAL d) Observe and verify the LED on the glove indicates Red Color. e) Repeat steps (a) to (d) for a different signal.

2.3 Supporting Material

2.3.1 Schematic

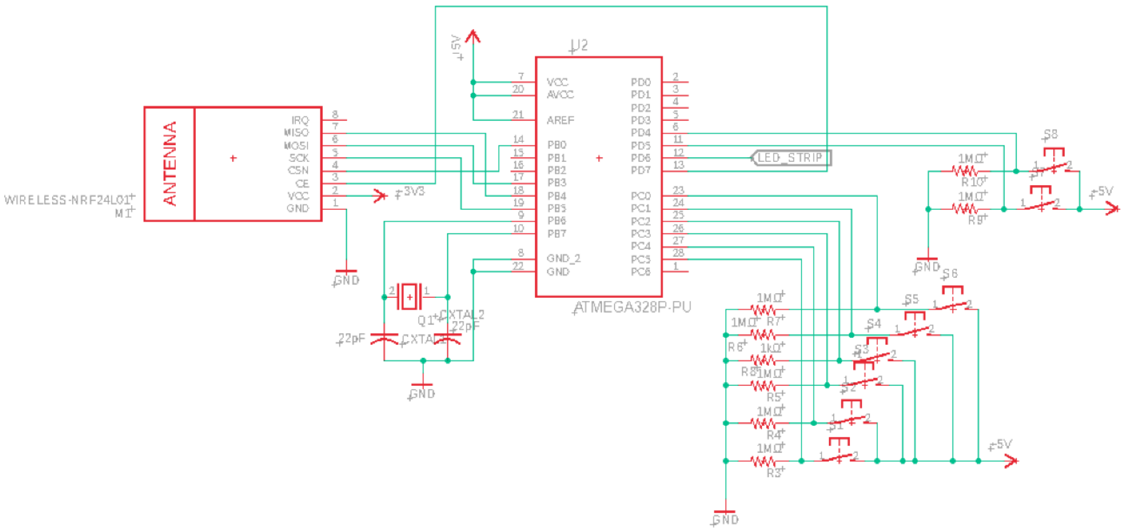

Figure 8: Schematic for Microcontroller Interface (Glove)

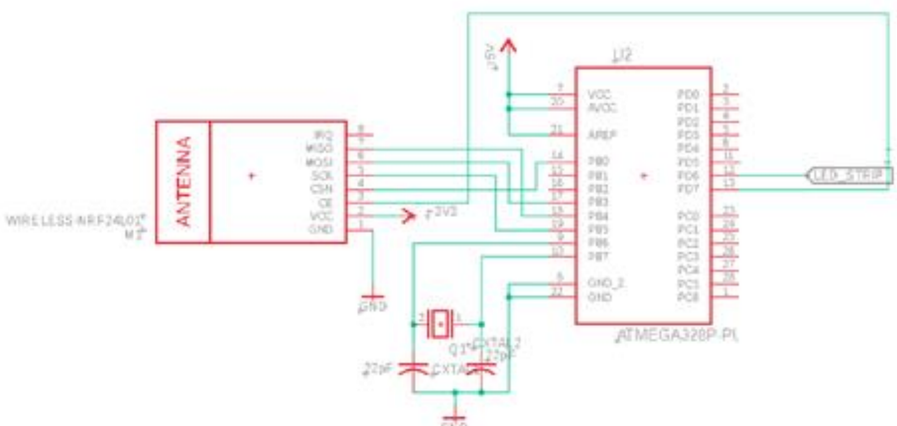

Figure 9: Schematic for Microcontroller Interface (Vest)

Note: A key difference between both schematics is that the Vest does not have contact sensors.

2.3.2 State Machine

Glove:

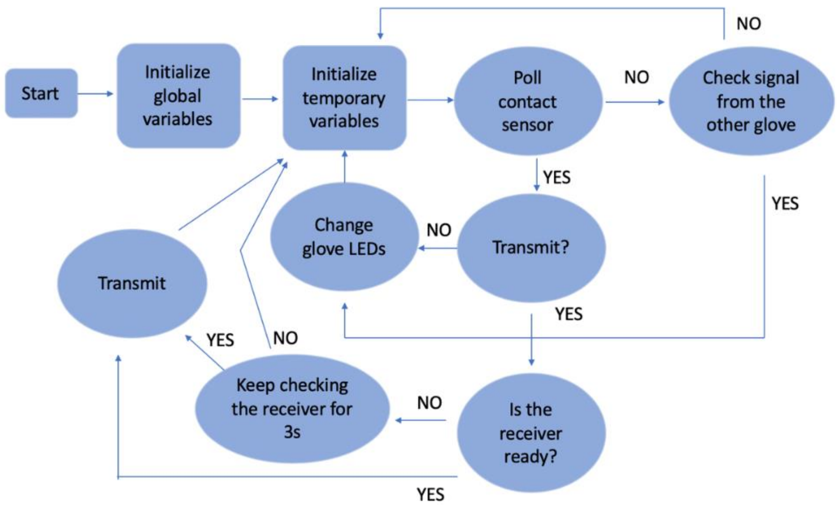

Figure 10: State machine for the gloves

Vest:

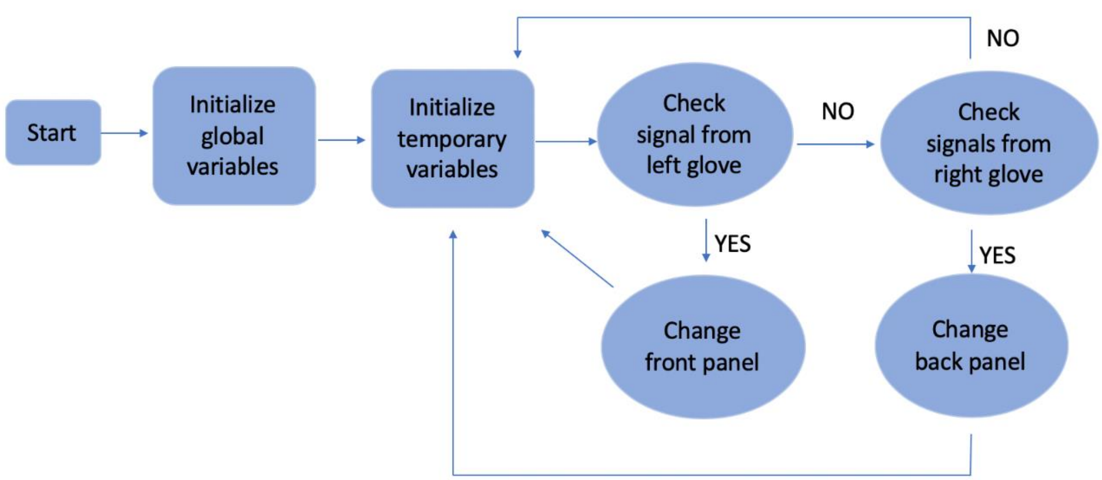

Figure 11: State machine for the vest

2.4 Tolerance Analysis

Since our product is battery powered, the cells need to be charged again after their complete utilization, which can be very inconvenient if the charging is required very frequently. In addition, the product should be at least be functional for prolonged time (at least 2 hours) as discussed earlier in the objective section. Hence, if our product is not able to sustain for prolonged time or needs frequent charging so as to become inconvenient, then our product will not be a better replacement of glow sticks and therefore will fail as problem solution.

To meet the requirement discussed above, we need to critically analyze the WS2813 Led strip which is the biggest consumer of our Li-ion power source. Since, our product offers a dynamic usage of the LEDs the power usage will vary accordingly. User can control not only different brightness level but also different color schemes. As a result, the current draw by the LED strip can vary significantly which will affect the usage time accordingly. So, in spite of the varying current draw by the LEDs, we want the usage time to be tolerant, such that product is still convenient to be used and is a good contender to replace glow sticks.

Firstly, we define the nominal as well as maximum power usage by components.

***MAX LOAD definitions:**

- WS2813: operating at full brightness emitting white color (RGB value [255,255,255]).

- ATmega328P: polling sensor values and driving control logic for LEDs.

- nRF24L01: transmitting and receiving control signals @ 2.4 Ghz.

***Nominal LOAD definitions:**

- WS2813: operating at full brightness emitting a single color (e.g. Red Color [255,0,0]).

- ATmega328P: only polling sensor values.

- nRF24L01: waiting for instructions by microcontroller (idle state).

 # For a single Glove Subsystem

Load	Voltage	Discharge Current (Max Load)	Discharge Current (Nominal Load)	Total Discharge Current (Max Load)	Total Discharge Current (Nominal Load)
25 Units of WS2813 (LEDs)	5v	60 mA	20mA	60*25 = 1500mA	20*25 = 500mA
ATmega328P (microcontroller)	5v	50mA	10mA	50mA	10mA
nRF24L01 (transceiver)	3.3v	12mA	32 μA	12mA	32 μA

 # For the Vest Subsystem

Load	Voltage	Discharge Current (Max Load)	Discharge Current (Nominal Load)	Total Discharge Current (Max Load)	Total Discharge Current (Nominal Load)
112 Units of WS2813 (LEDs)	5v	60 mA per unit	20mA per unit	60*112 = 6720mA	20*112 = 2240mA
ATmega328P (microcontroller)	5v	50mA	10mA	50mA	10mA
nRF24L01 (transceiver)	3.3v	12mA	32 μA	12mA	32 μA

 # For a single Glove Subsystem

Total Number of 18650 Cell = 2

Current Charge Per Cell ≈ 3500 mAh

Total Current Charge = 3500 * 2 = 7000 mAh

 # For the Vest Subsystem

Total Number of 18650 Cell = 4

Current Charge Per Cell ≈ 3500 mAh

Total Current Charge = 3500 * 4 = 14000 mAh

 # usage time equation (Note all quantities in the equation are average values.)

Usage Time = Total Current Charge / Total discharge Current.

Usage time = $\frac{\textbf{Total Current Charge}}{\textbf{LED discharge} * \textbf{number of leds} + \textbf{ATmega328 discharge}+\textbf{transceiver discharge}}$ **hr**

Now let’s assume LEDs discharge current varies linearly from 0 to 60mA per LED due to their dynamic usage for both Max usage and Nominal usage of Atmega328p and nRF24L01 transceiver. Therefore, following will be the equations for usage time for various scenarios.

1) Vest usage at Max Load

Usage time = $\frac{14000 \text{ mAh}}{(\text{LED discharge} * 112) \text{ mA} + 50 \text{ mA} + 12 \text{ mA}}$ hr

2) Vest usage at Nominal Load

$$\text{Usage time} = \frac{14000 \text{ mAh}}{(\text{LED discharge} * 112)\text{mA} + 10 \text{ mA} + 32 \ \mu\text{A}} \text{ hr}$$

3) Glove usage at Max Load

$$\text{Usage time} = \frac{7000 \text{ mAh}}{(\text{LED discharge} * 25) \text{ mA} + 50 \text{ mA} + 12 \text{ mA}} \text{ hr}$$

4) Glove usage at Nominal Load

$$\text{Usage time} = \frac{7000 \text{ mAh}}{(\text{LED discharge} * 25)\text{mA} + 10 \text{ mAh} + 32 \ \mu\text{A}} \text{ hr}$$

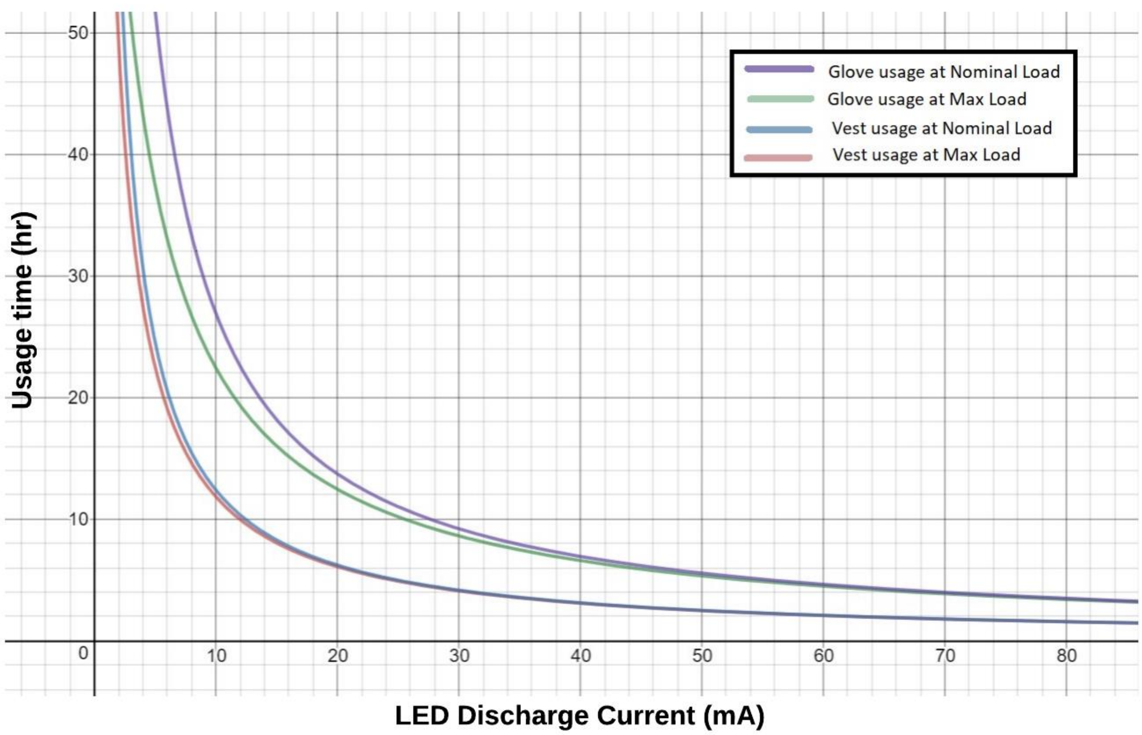

Figure 12. Glove usage and Vest Usage for Various Scenarios.

From the above equations it can be inferred that even if LEDs on the Vest and Gloves draw 60 amps at all times, their respective usage time will be 2.06 hrs and 4.48 hrs.

Hence it is safe to conclude that the usage time of our product is tolerant and can deliver at least 2.06 hrs of operation time for worst case scenario.

However, the above tolerant analysis is high theoretical and is not practical from the actual application point of view. It is very unlikely that all LEDs on the vest will emit white color on full brightness. The vest has a 14 segment display whose main purpose is to display “STOP” in red and “GO” in green, which will only up light up a fraction of LEDs. Hence the actual usage time will much more than 2.06 hrs.

Some other important risk analysis is mentioned as follows:

1) The buck convertor is a switching voltage regulator, whose inductor can interfere with EM waves in the vicinity. However, it will not interfere with the frequency of the transceiver since voltage regulator is using a strict 150Khz oscillator whereas transceiver use the 2.4Ghz band.
2) The Voltage regulator have a current limiting protection, so even if the protection circuit on the batteries fail, voltage regulator will cut off the power supply at high current (approximately 4A).
3) All the LEDs in our product are arranged in a series connection. Despite being in series, even if any one of the LEDs are damaged it will not affect other LEDs on the strip.
4) For making our product suitable for harsh weather condition we will be using Silicon Conformal on electronics to provide a waterproof layer.

3. Cost and Schedule

3.1 Cost Analysis

- **Labor:** Assuming a $35.00/hour salary (estimated from average salary of an ECE graduate), equal wage for each team member, with a total of 100 hours (10 hours/week for 10 weeks), we come up with $7,000.00 per team member which totals to $26,250.00.
- **Parts:**

Description	**Manufacturer**	**Part Number**	**Quantity**	**Cost**
LEDs	ALITOVE	WS2813	1	$43.99
Vest	HiVisible		1	$15.97
Gloves	Terra Hiker		1	$15.99
Wireless Transceiver	BephaMart	101	1	$5.89
Conductive Thread	Adafruit	641	1	$11.63
Batteries	Panasonic	18650	4	$111.16
Battery Holder (2)		48962	2	$3.72
Battery Holder (4)		36859	1	$2.18
Microcontroller	Microchip Technology	ATMEGA328P-PDIP	3	$6.42

Approximately 30 hours will be spent in the shop, totaling to $2,625.00 per person.

- **Total:** $26,250.00 + $216.95 = $26,466.95

3.2 Schedule

Week	**William**	**Mohit**	**María**
Week 1 (2/18)	Design gloves and vest	Design gloves and vest	Design gloves and vest
Week 2 (2/25)	Buy electronic parts	Practice coding LED colors	Research potentially more optimal sensors/batteries
Week 3 (3/4)	Test LEDs and conductive thread	Test wireless transceivers	Test microcontroller
Week 4 (3/11)	Meet with client to update them on progress	Design and order PCB, buy remaining parts	Design PCB and research possible LED designs
Week 5 (3/25)	Research specific requirements by client for weights and dimensions	Begin to assemble prototype	Begin to assemble prototype
Week 6 (4/1)	Begin integration with physical parts	Test and refine prototype	Test and refine prototype
Week 7 (4/8)	Test system with field testing	Test system with field testing	Test system with field testing
Week 8 (4/15)	Demo Project	Demo Project	Demo Project
Week 9 (4/22)	Final Presentation	Final Presentation	Final Presentation
Week 10 (4/29)	Final Paper	Final Paper	Final Paper

4. Ethics and Safety

Many safety and ethical concerns should be considered when creating this traffic control smart system. Both gloves and the vest are designed to be used by police officers in traffic intersection and since our main objective is to protect them while directing the traffic and also avoid accidents by improving communication between them and drivers, our decisions when developing the project must follow the IEEE Code Ethics, #1: “To accept responsibility in making engineering decisions consistent with the safety, health and welfare of the public” [1].

Firstly, it must be ensured that the color of the gloves and the words written in the panel are the ones chosen by the officers, since an error in either of these would probably endanger not only them but also all drivers going through the intersection. So, based on the ACM Code Ethics Section 1.2 [2], in order to avoid harm, we must ensure that the system works as intended. Since the police officers may not have knowledge about the inner working of the gloves, we will make it intuitive for everybody to use it. So as to make the system easy to use, we will mark each contact sensor with its corresponding color so that it will be evident which one should be activated to light the gloves and the vest adequately depending on the situation.

As for the design, the fact that the user wear gloves and a vest with panels in which batteries and electronic circuits are integrated for a long time while being exposed to any weather condition might be an issue. One of the measures taken to prevent accidents will be to hide and isolate all wire connections properly. On the other hand, in order to avoid any problem with the batteries we decided to choose protected 18650. This kind of batteries have a small electronic circuit integrated into the cell packaging that protects the user against common dangers such as overcharge, over discharge, short circuit/over current, and temperature. It ensures then the safety and good performance of the battery. In addition, our voltage regulator has a current limiting protection, hence in case the protection circuit on the li-ion batteries fails, the voltage regulator will still be able to cut off the power supply. These decisions fall into the ACM Code Ethics Section 2.9 [2] since the objective is to achieve a system usably secure.

5. References

[1] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html [Accessed: 5- Feb- 2019].

[2] “The Code affirms an obligation of computing professionals to use their skills for the benefit of society.,” Association for Computing Machinery. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 06-Feb-2019].

[3] *WS2813 datasheet.* [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/Seeed%20Technology/104020109_Web.pdf [Accessed: 20-Feb-2019].

[4] *Electrical Power Generation from Hydrogen Fuels*. [Online]. Available: https://www.mpoweruk.com/lithium_failures.htm. [Accessed: 19-Feb-2019].

[5] NCR18650 Data Sheet. [Online]. Available: http://www.batteryonestop.com/baotongusa/products/datasheets/li-ion/SANYO-NCR18650B-3400mAh.pdf [Accessed: 18-Feb-2019].

[6] ATmega328P Datasheet. [Online]. Available: http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf. [Accessed: 18-Feb-2019].

[7] nRF24L01 Data Sheet. [Online]. Available: https://www.sparkfun.com/datasheets/Components/nRF24L01_prelim_prod_spec_1_2.pdf [Accessed: 18-Feb-2019].

[8] lm2596 datasheet. [Online]. Available: http://www.ti.com/lit/ds/symlink/lm2596.pdf [Accessed: 18-Feb-2019].

[9] “High Visibility Vest. Reflective Running Vest. Reflective Vest for Walking. Safety Reflective Running Gear for Men and Women for Night Running. Reflective Tape Bands Clothing.,” *Amazon*. [Online]. Available: https://www.amazon.com/Visibility-Reflective-Walking-Running-Clothing/dp/B07KXXN9PF/ref=pd_sbs_200_5?_encoding=UTF8&pd_rd_i=B07KXXN9PF&pd_rd_r=3bc592d8-2a1e-11e9-a1a9-5ba6a64d0911&pd_rd_w=JZvkB&pd_rd_wg=pVC6Z&pf_rd_p=588939de-d3f8-42f1-a3d8-d556eae5797d&pf_rd_r=3NJ6G9K69KNJD0PXEP14&refRID=3NJ6G9K69KNJD0PXEP14. [Accessed: 20-Feb-2019].

[10] “Arduino Wireless Communication - NRF24L01 Tutorial,” *HowToMechatronics*, 13-Feb-2019. [Online]. Available: https://howtomechatronics.com/tutorials/arduino/arduino-wireless-communication-nrf24l01-tutorial/. [Accessed: 21-Feb-2019].