LED Globe with the use of Persistence of Vision

Viet Nguyen, Omar Vazquez, and Rhonal Soto

College of Engineering and Computer Science, University of Central Florida, Orlando, FL, 32826, USA

***Abstract* — The LED Globe is an entertainment project that uses light emitting diodes in conjunction with a brushless motor and a high velocity to achieve the phenomenon of persistence of vision. Persistence of vision is the theory that our eyes can capture an image when it persists for approximately 1/25th of a second on the retina after the image is removed. This project uses a constructed ring attached to the motor and a stabilized structure in order to show the 90 LEDs mounted on the ring. The globe image is accomplished by original code sent to the microcontroller that sends data to the 34 shift registers that control and drive the LEDs.**

***Index Terms* — Brushless motors, lighting emitting diodes, microcontrollers, regulators, shift registers.**

I. Introduction

The LED globe is nothing but a display that from the eyes perception looks like a solid sphere of light that. Nowadays, the people are bombarded with information constantly and the most of the time the best way to deliver them this information is visually. There are lots of different types of information needed for people on the daily basics but when people go out to the street and get on the road they rely on signs to provide the directions and at the same time they see banners with information everywhere they go.

On the same token, the way the information is displayed determines the amount of attention drawn from people; therefore, design plays a very important role in information delivery. Regular banners, LED signs, and TV's display information in one plane and only one direction and depending the type of displayer the can be very expensive.

The idea of the LED Globe is to build a device that is able to display information in three planes and depending of the design the resolution can be very high. Just imagine driving on the highway or any dark road with poor visibility conditions and one sees this luminous sphere displaying direction or advertising businesses or products; there is no way that someone can miss this. When the application can be apply to deliver information that can be see horizontally from two opposite sides on the horizontal plane and from the top of the vertical plane, so if we retake the example of the highway exposed above, people on the same highway or on any horizontal plane will be able to see the information displayed by the same device when the travel in both direction of the highway.

The required operation of the LED globe is to be able to display a preprogrammed image or text from the user using the Bluetooth interface by lighting the LEDs at a certain space and time. All of the internal components should consume as little power as possible. Moreover, the system must be safe both for the user and the environment. There are three categories of specifications: power supplies, Voltage regulators and the microcontroller. The specifications are shown in Table 1, Table 2, and Table 3 as follows.

Motor Power Supply	
Input Voltage	120V AC
Output Voltage	9V DC
Output current	<2A
Weight	< 2lb
Microcontroller Power Supply	
Output Voltage	9V
Output Power	<1A
Weight	<.1lb

Table 1

Microcontroller	
Clock Frequency	Low
Serial Ports	Yes
Programming Language	Mixed C and Java
Programming Memory	≥16K
Analog Pins	Yes
Digital input/output Pins	Yes
PWM Output Pins	Yes
Programming Debugging	Yes
Power consumption	Low

Table 2

Voltage Regulator for Motor	
Maximum Voltage	32V
Output Voltage	9V
Voltage Regulator for microcontroller	
Input Voltage	32V
Output Voltage	9V

Table 3

II. SYSTEM COMPONENTS

This section provides a semi-technical introduction and brief description of the components and how they are related/connected to show our final product.

A. Microcontroller

The brain of the project is a ATMEGA328P microcontroller. The ATMEGA328P is a low power, high performance 8 bit microcontroller that has 14 digital input/ output pins, and 8 of this pins can be used for Pulse width Modulation (PMW); also has 6 analog pins and a 16MHz ceramic resonator. It also has a Flash memory of 32 KB, an SRAM of 2KB, and EEPROM of 1 KB with a clock speed of 16MHz. These settings are convenient for coding our project.

B. Voltage Regulators

A voltage regulator is used to maintain a constant voltage level; this can be found after the bridge rectifier and smoothing capacitor circuit. This is necessary to help the motor maintain a constant speed. There are two things that the regulation is specified by: the load and the line or input. The load regulation is the change in output voltage for a given change in load current. Line regulation or input regulation is the degree to which output voltage changes when input voltage changes.

We are using voltage regulators for the motor and microcontroller. We are using the LM25088 and the LM7805 in order to regulate the voltage coming into our device from the wall outlet.

C. Brushless Motor

The HobbyWing XERUN 3.5T 3650-9100KV has a speed of 9100 RPM at the highest setting. It has the possibility to be configured with a PC USB connection which is possible with the HobbyWing LCD program box. Research into this has shown that in order to get the torque required to spin the LED ring structure, the motor will need at least half to one horse power for the initial startup. After that, the motor will need to push out a constant torque in order to keep the LED ring spinning at a constant rate. We need the motor to achieve a constant rpm to get POV to happen. Let's analyze now the LED ring structure and determine the type of motor we will need. Let's start with the speed of the motor

D. LEDs

The diodes are two terminals electric components that have low resistance to current flow in only one direction. In addition, the light-emitting diode (LED) is a semiconductor diode, which emits light through an effect called electroluminescence. Like a regular diode the LED has a positive and a negative terminal called another a cathode respectively. Pursuing this further, for this project, we have chosen to use the common anode RGB light emitting diodes, meaning that these light emitting diodes are able to emit light in three different colors, red, green and blue and as its name describes it, this diode has a common anode and three diodes, one for each color.

E. Shift Registers

The 74HC595 is a Complementary Metal-Oxide Semiconductor (CMOS); this shift register has 16 pins and a serial input (DS) and a serial standard output (Q7S) for cascading, which allows the device to be connected to other shift registers (74HC595). The 74HC595 consists of an 8-bit shift-register and 8-bit D-type latch with three-state parallel outputs (LOW, HIGH, and Hi-Z). The configuration of this device was explained previously when we exposed the microcontroller configuration, and as it was exposed then, the output of the microcontroller are: SH_CP, DS, and ST_CP which represent the clock, data, and latch. Furthermore, these outputs are connected directly to inputs on the 74HC595 shift register which have the same name and have the pin numbers 11 (SH_CP), 14 (DS), and 12 (ST_CP). In addition to these three pins we are going to use pin 9 (Q7" or Q7S), serial data output for cascading inputs, meaning that after receiving eight inputs through the DS pin, the first shift register will transfer the inputs to a second register through the Q7S pin, and after the second shift register receive eight inputs, the second register will transfer inputs to the third one through the Q7S pin of the second register and so on. The pins 8 and 16 are used for ground (GND) and input voltage (VCC = +5 Volts) respectively; the rest of the pins have default values pre-set conveniently.

F. Bluetooth Module

The Bluetooth chosen to perform such a task is the JY-MCU Bluetooth module; the JY-MCU's easy installation and accessible ports make the installation straightforward. Also, the device uses the same serial communication and it can be configured using the same procedure we used for $I2C$ protocol (Master-Slave). The functionality of transmitting data wirelessly is significant because allows us to update and upload new programs without the necessity of having USB interface added to our PCB design; consequently, this improve our design and makes it neater. Also, it is worth to mention now that when configuring this Bluetooth module, the communication ports have to be carefully chosen in the sense that the computer used has to be configured through the device manager, so the bits per second, data bits, parity, stop bits, and flow control match the specifications of the Bluetooth module which are: 9600, 8, none, 1, and none, respectively.

III. SYSTEM CONCEPT

The flowchart below is used to convey the system and its components working together.

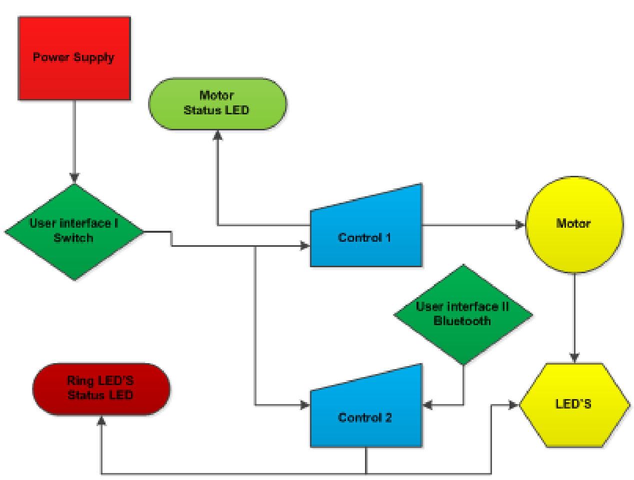


Fig.1 Flowchart showing flow between components

The figure above shows the connections that the components share with one another. The power supply which has a switch is used to power the two control stations and the LEDs as well as the motor.

A. System Hardware Concept

To summarize the hardware design of the LED globe system let us first described the power supply. An AC Voltage of 120rms will be stepped down by the 5:1 transformer and rectified by the bridge rectifier circuit. The rms AC voltage will be 24V and its peak voltage will be 32V before the rectifier. After the rectifier circuit, the rms voltage will be 22 volts and its peak will be 30V. This is due to the forward voltage drops of the two rectifier diodes which is 1V each. Next the smoothing capacitor will try to smooth out the ripple voltage out of the bridge rectifier to a near constant peak voltage of 30 volts.

Next comes the voltage regulators which are part of the power supply. The maximum output power available to the voltage regulators will be 352 Watts. The motor voltage regulator will be in parallel to the microcontroller voltage regulator which is both feeding off of the smoothing capacitor output. The motor and the microcontroller voltage regulator will have a maximum input voltage of 42V and a minimum input voltage of 14V. The output voltage of the motor voltage regulator will have a voltage of 9V with a max current output of 10A. The maximum power dissipated due to the motor will be 90Watts. The motor will spin the ring supports shaft at about 3169 RPMs. The Output voltage of the microcontroller voltage regulator will have a voltage of 9V with a maximum current output of 1A which means it will run at about 9watts max. This output voltage will be available at the slip ring voltage terminals to power up the microcontroller, Bluetooth and give power to all the shift registers and the LEDs.

The Plexiglass encapsulation will house the power supply and the motor. The plexiglass will be perforated on the back side for ventilation of the motor and power supply. The support bar will be mounted on the back and will help stabilize the ring support shaft. The slip ring voltage terminals will supply the slip rings on the support shaft with a constant 9V. The support shaft is responsible for supporting the microcontroller pcb, and the LED ring structure; the support shaft will also rotate the LED ring. The LED ring structure will rotate while it holds all 90 LEDs in place.

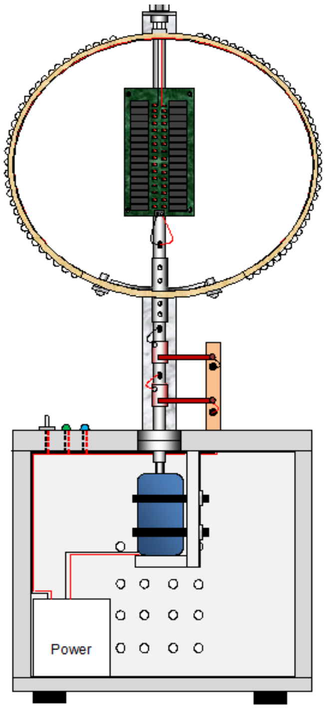


Fig 2. Final Hardware Design Concept

The figure above shows the final tentative design of this project. The literal project should look similar to what is shown above.

B. System Design Concept

In order to get a globe shape, a ring was used as the apparatus to mount the ninety LEDs on. The printed circuit boards are to be mounted in the center of the ring to ensure stability and to better handle the soldering and wiring of the LEDs to the many shift registers.

The thirty-four shift registers that are mounted in the middle of the ring and connected to all ninety of the LEDs on the circumference of the ring. The shift registers are connected to together via a cascading configuration. That means that one shift registers' output is another shift registers' input. That only applies for the Data In and Out. The CLK and Latch pin are actually connected cascading at the inputs only.

IV. HARDWARE DETAIL

A. Microcontrollers

The Atmel ATMEGA328P-PU microcontroller would be used to control the light sequence of the LED Globe; this microcontroller will be pre-loaded with the preference of Arduino Uno boot loader. The Atmel ATMEGA328P-PU counts all the adequate hardware and software capabilities to meet all the design goals for this project, providing enough pins to handle all the outputs, in other words, the 90 LED's the LED Globe has. Moreover, the Atmel ATMEGA328P-PU has serial communication capabilities that make possible controlling the microcontroller via Bluetooth. Finally, another advantage of the Atmel ATMEGA328P-PU is to have 6 digital pins that provides pulse with modulation (PWM) and this capability can help us to control the motor speed if is needed.

Two of the six analog pins would be utilized to detect voltage coming to the motor and LED'S. In the event that multiples microcontrollers are used, the pins 13 (A4 SDA) and 14 (A5 SCL) are going to be used. By using these two ports, we are able to set one of the microcontrollers as the master and the rest of the microcontroller as the slaves. SDA is wire Serial Interface Data and SCK is the wire Serial Interface Clock, both of these pins are set to one (digitally) to enable the 2- wire Serial Interface. The protocol used to implement this communication is called I^2C, and this protocol allows the master microcontroller to interconnect up to 128 different devices using only two-bi- directional bus lines, SDA and SCL.

To connect this microcontroller, a common line for the SDA and another common line for SCL port have to be set and these two lines will be connected to two independent resistors and then to the VCC terminal. If any extra device needs to interact with microcontroller, I^2C compatible parts would be highly recommendable over analog devices. In case that only analog device can be further implemented due to certain limitations, then it is deemed necessary to include analog-to-digital converter in order to be in harmony with I^2C bus.

Finally, the master device will initiate and terminate the transmissions and also generate the SCL clock.

B. Bluetooth

As it was mentioned previously, the ATMEGA328P UART serial communication pins are pin 0 (RX) and pin 2 (TX), and these two ports are going to be connected to TX and RX of the Bluetooth module respectively. Of course, the transmitter device needs Bluetooth capabilities, and the device chosen to perform such a task, is a Samsung HTC mobile device (cellphone). Using one of the device applications (Bluetooth Chatting) that allows sending via Bluetooth, we will send the commands to the microcontroller. Before this, the transmitter and receiver need to paired, and the Samsung HTC will locate the Bluetooth devices available around, including our Bluetooth module, which will appear as a device with the name of Linvor; it will also require a password which is 1234, and after the connection is established a flashing light on our Bluetooth will stop and stay solid.

Lastly, the commands that are sent to the Bluetooth are going to be single characters which are going to be sent individually; each of them will start a sequence of images previously programmed in the microcontroller.

For the Bluetooth algorithm, we used the same serial library we used previously. The algorithm designed to operate this device will establish communication between the JY-MCU Bluetooth module and the device we chose to transmit the commands to the Bluetooth module.

The ATMEGA328P serial library allows the microcontroller to read character through serial read; the algorithm used to receive commands via Bluetooth will be based in conditional statements, so after the wireless connection is established, the microcontroller will receive a character from the transmitter wirelessly, and using a conditional statement depending the type of character received, a light sequence will be displayed. Lastly, using wireless communications, we will activate the execution of specific algorithms that allows us to have complete control only of the LEDs.

C. LEDs

Our light emitting diodes have certain specifications that will be detailed here. The LEDs have a forward current of 20 mA and a forward Voltage 2.0 V to 3.4 V. The LEDs also have a peak forward current 30 mA. The color settings are as follows: Red which is 800 mcd max (millicandela), Green 4000 mcd max, and Blue 900 mcd max.

In final analysis, since the desired amperage of the light emitting diode is 20 mA, a calculated resistor of 150 Ohms (Figure 4.24) is going to be used for each light emitting diode taking in to account an input voltage of 5 volts normally provided for the microcontroller or shift register.

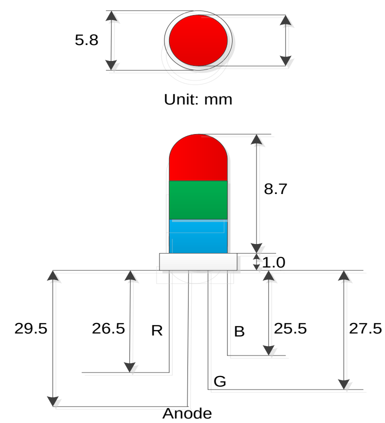


Fig 3. LED Diagram

D. Shift Registers

On the other hand, controlling shift registers through the microcontroller, gives second option to control the outputs. As it was exposed before, each shift registers have the capability to provide eight parallel outputs at the same time, and they can be connected together, so we can have as many outputs as needed. Only three from the microcontroller will be used, one for the data, one for the clock, and one for the latch.

Since the shift register 74HC595 are 8-bit serial-in, the data have to be sent to the register through the data pin, this data is sent digitally; in other words, the data is sent using binary numbers, and this number equivalent to the outputs needed. On the same token, as it has been exposed previously, our LED globe has 270 outputs; therefore, we need 270 binary numbers, and the numbers are coming from the microcontroller imbedded in it through an algorithm programmed previously. The data has logic values (0's and 1's) and it is going to come out from the microcontroller as an array of 270 digits.

This process is executed through synchronous serial communication, and it is required that clocks in the transmitting and receiving devices are synchronized. In contrast I^2C which uses asynchronous serial communication which relies in the sender and the receiver to be set independently to an agreed upon specified data rate.

Using shift register, we will only use three pins of our microcontroller one pin for data (DS), one pin for the clock (SH_CP), and another pin as our latch pin (ST_CP).The 270 digits representing each of the output will come out from the microcontroller through the pin designated to be the DS pin (Serial Data Input), and each of this outputs or digits are going to be detected or taken as outputs at the rising edge of the clock. In other words, every time our pin designated to be the SH_CP (Shift Register Clock Pin) pin goes from LOW to HIGH (0 to 1), one digit for the output is going to be valid; however, after the data is taken (270 digits) using the rising edge, the data have to be latched and to do this we have to designate the latch pin ST_CP (Storage Register Clock Pin); after the 270 digits for data are valid or taken the latch pin has to go from LOW to HIGH (0 to 1), and by applying this procedure the data flow out of the microcontroller and through the shift register until we complete the 270 digit as it can be seen in Figure 4.19. This figure is an scaled version for only 13 outputs; therefore, as it is depicted in the Figure 4.19 there are 13 rising edges in the clock while the real scale for our LED Globe the clock pin will 270 rising edges. Also, notice the data pin is LOW (0) for the first three rising edges, meaning the first three outputs are LOW, so those LED's will be off; for the next two rising edges the data pin is HIGH, meaning those outputs are HIGH, so those LED's are on. Finally, for the last cycle of the clock pin when all the outputs have been set, the latch pin goes from LOW to HIGH, meaning this data is taken and is storage in the shift register to be sent out to the outputs (LED's) in parallel.

E. Power Supply

The power supply needed for the LED Globe is a simple transformer- bridge rectifier circuit. The input voltage will be 120 Vrms and the transformer will step the voltage down to 24Vrms. After the rectification process and some filtering the supply voltage for the motor and the microcontroller will be about 32V RMS. The motor voltage will require 9V and so will the microcontroller. Our power supply must be able to handle these peak voltages at any moment even though these peak voltages are not constant.

The maximum power that our power supply should deliver is a combination of the maximum power available for the motor and the maximum power available for the microcontroller. The maximum power available for the motor is 80 W, and the maximum power available for the microcontroller is about 9 W, so in total our power supply should be able to deliver about 90 W of power.

The transformer there were going to be using is the TR100VA001US. This transformer is a 120 to 24 VAC, 100 VA, 50 or 60 Hz transformer with a circuit breaker included for over current protection and operates at temperature of -30 to 140°F.

The bridge rectifier will be composed of four NTE5812HC diodes. This diode has a maximum recurrent peak reverse voltage of 100 V, maximum RMS voltage of 70 V, maximum DC blocking voltage of 100 V and of ten amps and can operate at temperatures of -55° to 125°C.

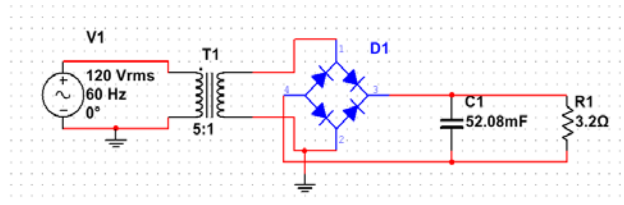


Fig 4. Power Supply Schematic

F. Voltage Regulators

The motor voltage regulator will be based on the LM25117. The LM25117 is a high voltage synchronous buck controller for step-down regulator applications. The input voltage has a wide range from 4.5V to 42V. The pulse-width modulation circuit embedded inside the IC, is programmable from 50kHz to 750kHz. The LM25117 can drive external high-side and low-side NMOS power switches with adaptive dead-time control. The LM25117 also has thermal shutdown capability in case of overheating which can destroy this delicate IC.

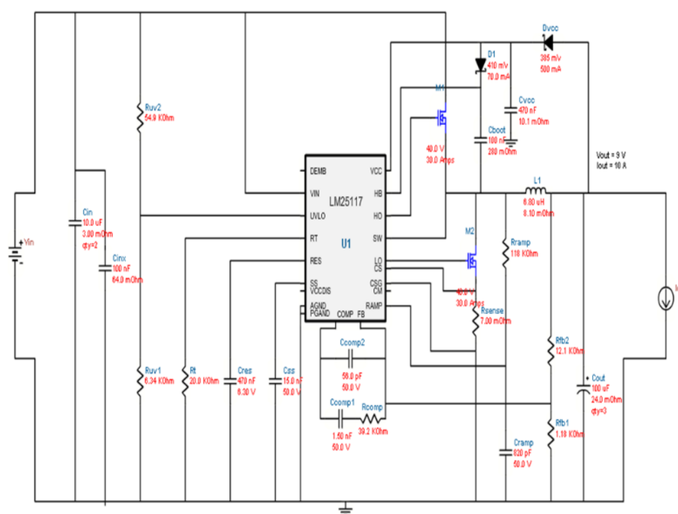


Fig 5. Motor Voltage Regulator

The microcontroller voltage regulator is based out of the LM7809 voltage regulator. C2 is the bypass capacitor which is needed to stabilize the regulator to prevent oscillation and improve transient response.C3 is a coupling capacitor to help suppress any noise coming from the power supply. D1 is a 1N4934 fast recovery diode with a current rating of 1amp. This diode protects the regulator for the following reason: The input smoothing capacitor has a very large value which will cause a temporary short-circuit when it completely discharges. After the power supply is turned off and there is a higher potential at the output of the voltage regulator versus the input, say due to C2 > C3, then the energy stored in the output is greater than the energy stored in the input which can destroy the voltage regulator. Therefore adding a diode across the input and output terminals of the voltage regulator will allow the current to flow through the diode, bypassing the regulator and therefore protect the delicate components inside the regulator.

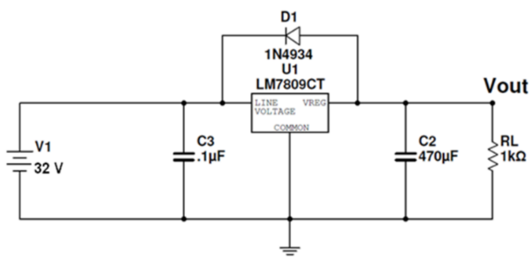


Fig 6. Microcontroller Voltage Regulator

V. SOFTWARE DETAIL

To convey the intended nature of the project in full, a full understanding must be understood and therefore explained thoroughly. The success of this project is dependent on the components all at working order and in conjunction with one another. The components are fully dependent on each other and as such, the programming is most vital. The code will help make the images that we are projecting on the globe to be seen whether custom or standard images are to be shown.

The main control of the LED Globe is the microcontroller which will execute the following functions: Check power status for the LEDs, receive data from two different sources, provide data to 34 shift register, and establish communication with others microcontrollers.

As was exposed previously this few functions are the brain of the LED which allows it to perform its principal function of displaying images, and even though, the other portions of this design are important, nothing is most relevant than the software. The user interfaces the microcontroller uses (USB to TTL module and Bluetooth module) enhance the accessibility to the microcontroller, allowing to update data and consequently to be able to upload new sketches and display new images. This improvement on the design reduces the space limitation the microcontroller has. Also, the method discussed explained the pros and cons of the software design for each of the cases, and basically establish and inversely proportional relationship between amount of hardware and algorithm complexity, meaning that applying methods that uses less hardware such as Charlieplex, we increase the algorithm complexity and also the length. On the other hand, when we implement shift registers, we increase the amount of hardware, but we decrease the complexity of the algorithm and length.

The figures below are snippets of basic code that are used in the programming phase of our project. One section explains the declarations of variables. Another section shows how to define the many arrays we will be using. The final code shown is for the shift registers in order to output all the data at once.

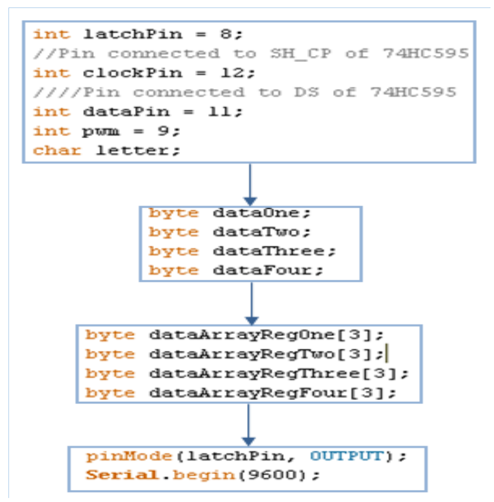
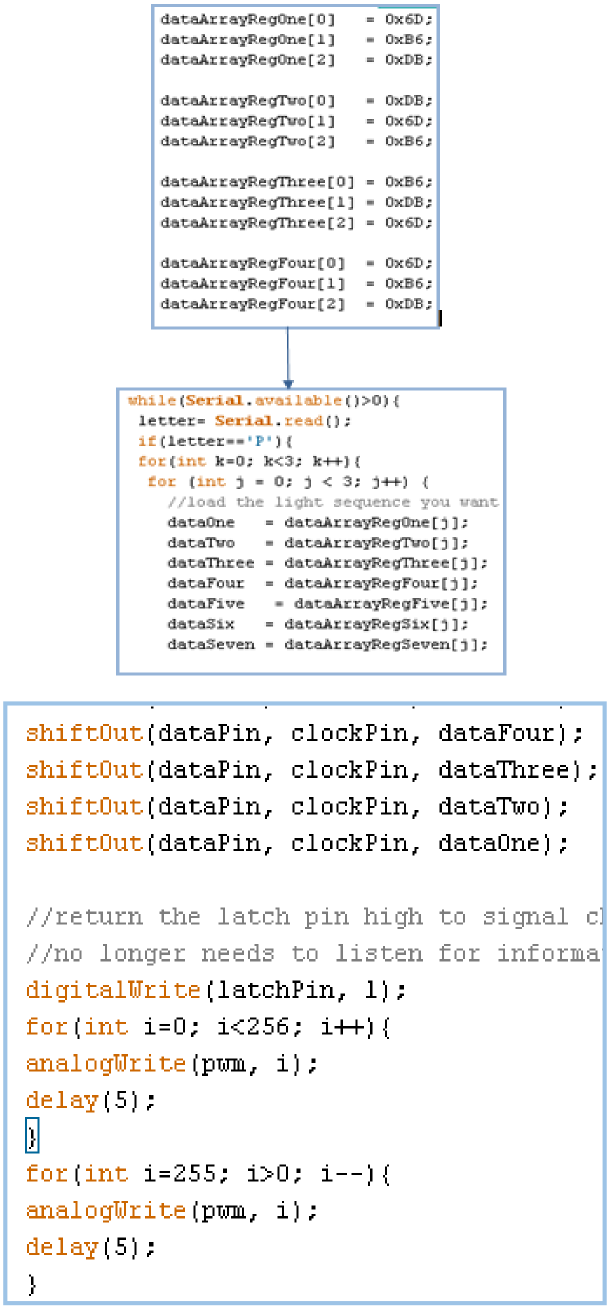


Fig 7. Declaration code



```
dataArrayRegOne[0]   = 0x6D;
dataArrayRegOne[1]   = 0xB6;
dataArrayRegOne[2]   = 0xDB;

dataArrayRegTwo[0]   = 0xDB;
dataArrayRegTwo[1]   = 0x6D;
dataArrayRegTwo[2]   = 0xB6;

dataArrayRegThree[0] = 0xB6;
dataArrayRegThree[1] = 0xDB;
dataArrayRegThree[2] = 0x6D;

dataArrayRegFour[0]  = 0x6D;
dataArrayRegFour[1]  = 0xB6;
dataArrayRegFour[2]  = 0xDB;
```

```
while(Serial.available()>0){
 letter= Serial.read();
 if(letter=='P'){
 for(int k=0; k<3; k++){
  for (int j = 0; j < 3; j++) {
    //load the light sequence you want
    dataOne   = dataArrayRegOne[j];
    dataTwo   = dataArrayRegTwo[j];
    dataThree = dataArrayRegThree[j];
    dataFour  = dataArrayRegFour[j];
    dataFive   = dataArrayRegFive[j];
    dataSix   = dataArrayRegSix[j];
    dataSeven = dataArrayRegSeven[j];
```

```
shiftOut(dataPin, clockPin, dataFour);
shiftOut(dataPin, clockPin, dataThree);
shiftOut(dataPin, clockPin, dataTwo);
shiftOut(dataPin, clockPin, dataOne);

//return the latch pin high to signal c
//no longer needs to listen for informa
digitalWrite(latchPin, 1);
for(int i=0; i<256; i++){
analogWrite(pwm, i);
delay(5);
}
for(int i=255; i>0; i--){
analogWrite(pwm, i);
delay(5);
}
```

Fig 8. Array and Shift Out code

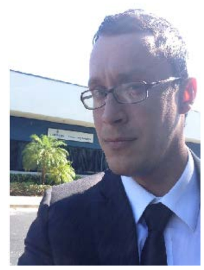
V. CONCLUSION

The experience that was gained in designing, implementing, building and experimenting with electronics and mechanics was well rewarding and will leave a lasting impression on the minds of engineers everywhere. Real firsthand experience and work supported by years of knowledge and research have culminated in the success of this project. Working as a team on this scale of a project was no easy feat, but the experience was deeply rewarding and highly satisfying in confirming that engineering was the correct path to choose. At the end, this project has ignited a passion for design and engineering that will last a lifetime.

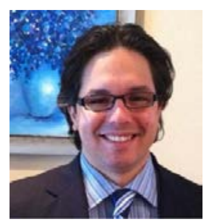
ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance and support of Dr. Richie, Teaching Assistant Mike, Home Depot as well as the facilities of University of Central Florida.

THE ENGINEERS



My Name is **Rhonal Soto**, and I am an Engineering student from Venezuela. Rhonal hopes to pursue a career in power systems, but he also hopes to be able to work with low voltage devices such as micro controllers and FPGAs,His goal is to work for companies such as Duke Energy, Siemens, Mitsubishi Power Systems, Intel, Raytheon, TI, etc. Design and testing through software are two of the areas of interest for him.



Omar Vazquez is an Electrical Engineering student at UCF. Omar interest in electronics started since he was very young; he would like to pursue a career as an RF engineer and would like to work for Harris, CIA, Lockheed Martin or NSA. Omar plans to get his masters in RF engineering.

Viet Nguyen is an Electrical Engineering student at UCF. Viet one day wants to pursue a career in software engineering or in front-end design for apps and websites working for a company like Google or a startup.