# LED Swim Pacer

**ECE 445 Design review**

Spring 2012

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# I. Introduction

## 1. Title

<u>LED Swim Pacer</u>

This project is proposed by Coach Howard. He wants a swim pacer unit as a training tool to help improve the performance of his swimmers. This variable speed sequential LED pacer will help pace swimmers to swim at a faster speed, helping them improve their speed and consistency.

### 1.1 Motivation

A swimming pacer helps swimmers improve their swim time. With a strip of LED underwater, the swimmer can easily see and follow the LED light. The swimmer could also increase the speed of the LED to improve his or her performance.

## 2. Objectives

The goal of this project is to design and build a swim pacer using a strip of LED. It will be 25 meters in length so it will fit most of the swimming pools. There will be a main controller controlling seven bidirectional shift registers. Each of the shift register will be connected to 8 LEDs. The controller will send signal and clock data to the shift registers which will turn on or off the LEDs. The controller will have pre-programmed modes which can be changed easily from the control box. This pacer is only meant for one swimmer, doesn't support multiple swimmers.

### 2.1 Functions

- LED lights to pace swimmers
- Simple user interface, easy to operate
- Different colored LED to warn swimmers that end of pool is close
- Simple to deploy

### 2.2 Benefits

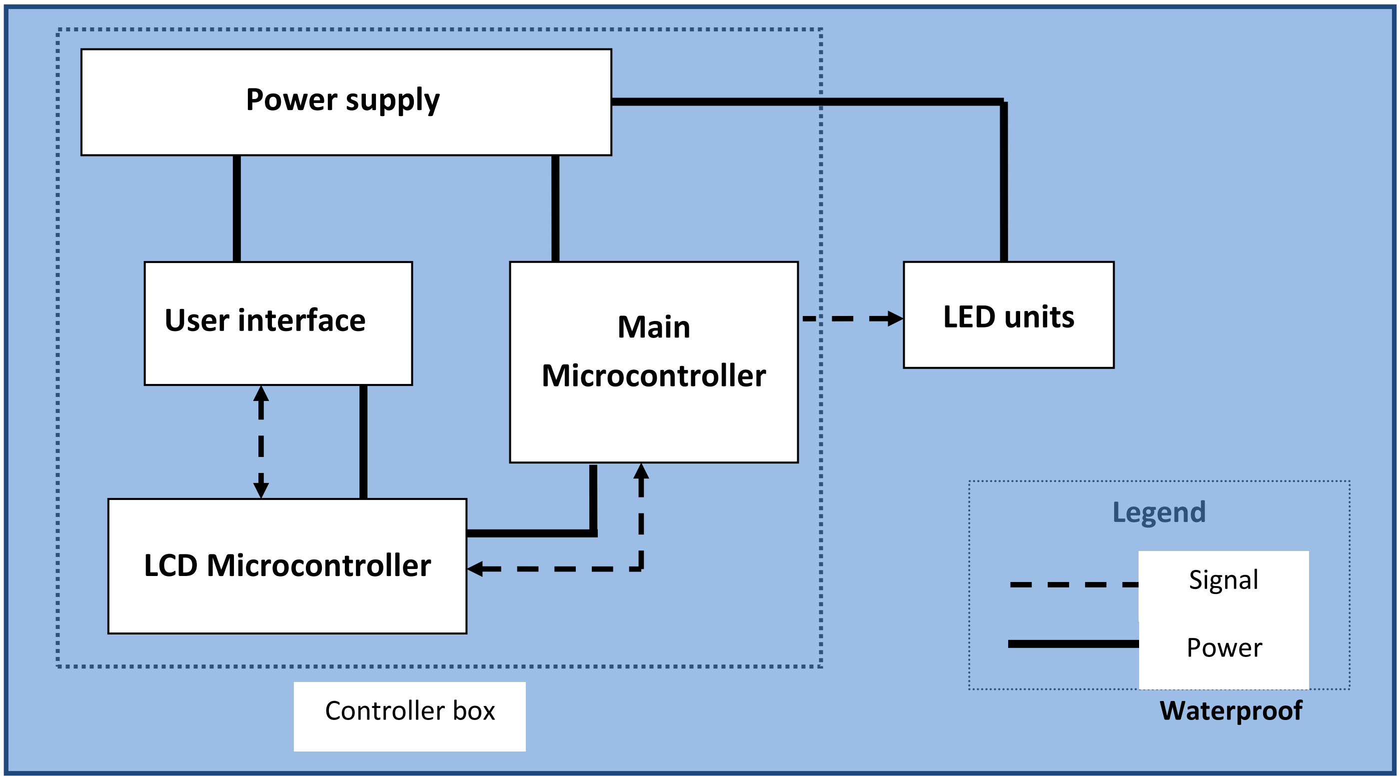
- Allows swimmer to pace and improve himself
- Allows swim coach to interact with swimmers

### 2.3 Features

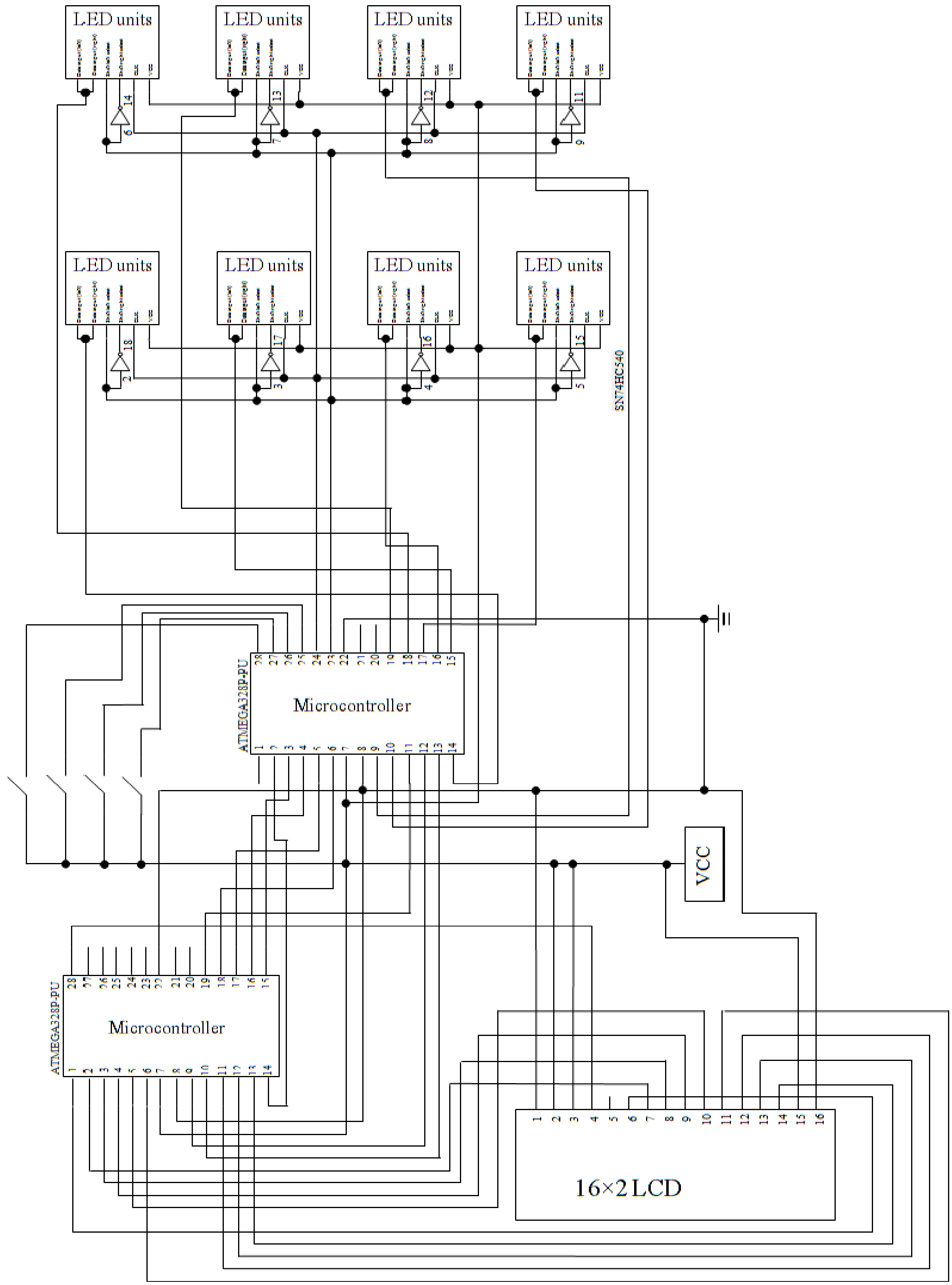
- Strip of green LEDs with a 50cm separation between each LEDs
- Two ends of the strip will have red LEDs to alert the swimmer
- Beginning of LED programmed to be faster as the lap begins
- Waterproof LED strip and control box
- Batteries last at least 4 hours
- Timing increments at 0.5sec
- Maximum of 40 seconds and minimum of 10 seconds

# II. Detailed electrical design

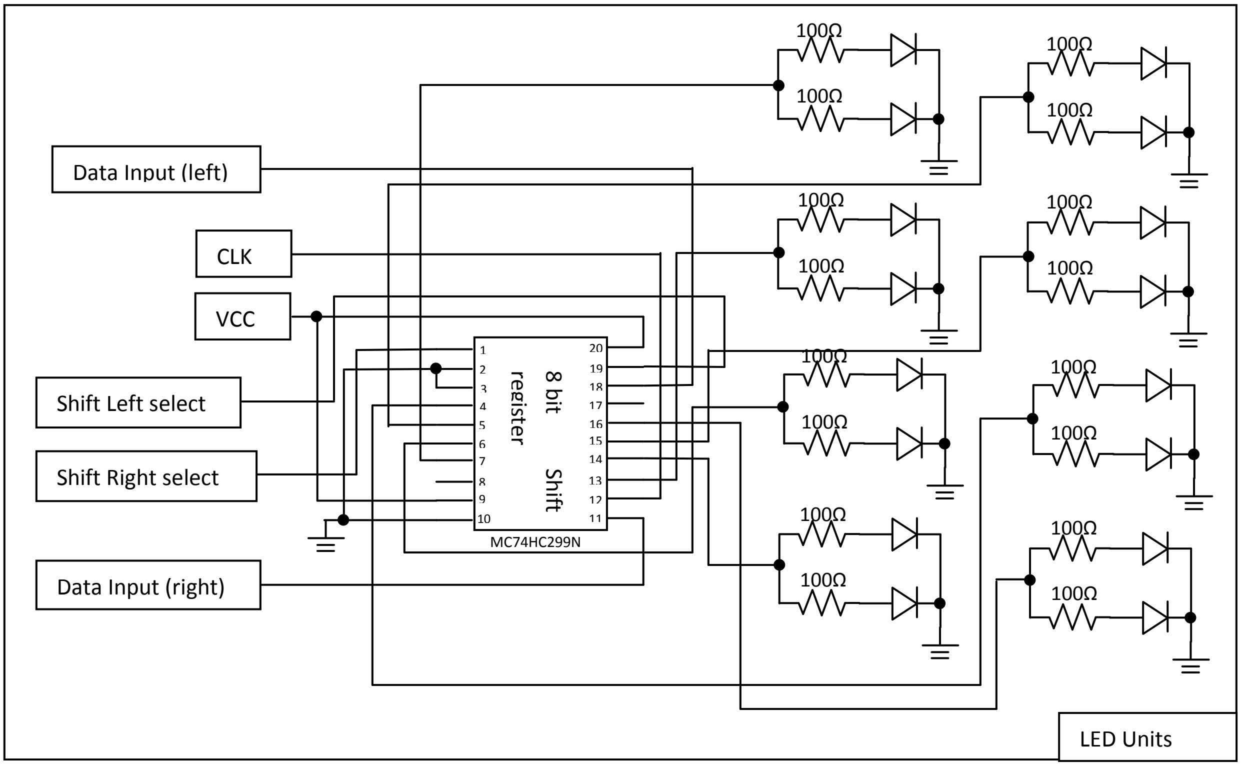
## 1. Block Diagram



## 2. Figures and Schematics



## LED unit



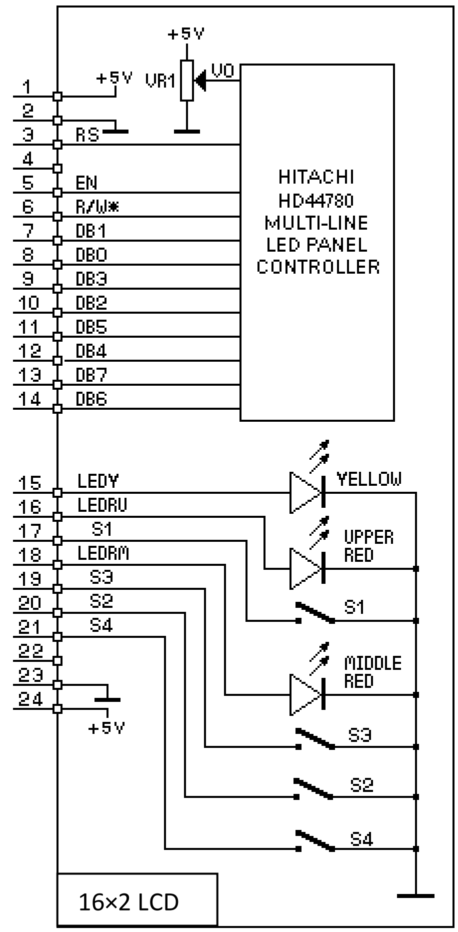

## 8-bit shift register

| Pin NO | Symbol | Function |
|---|---|---|
| 1 | S1 | Mode select |
| 2 | OE1 | Output enable |
| 3 | OE2 | Output enable |
| 4 | $P_G/Q_G$ | Parallel data port outputs |
| 5 | $P_E/G_E$ | Parallel data port outputs |
| 6 | $P_C/G_C$ | Parallel data port outputs |
| 7 | $P_A/G_A$ | Parallel data port outputs |
| 8 | $Q_A'$ | Serial data outputs |
| 9 | Reset | Reset |
| 10 | GND | Ground |
| 11 | $S_A$ | Shift right select |
| 12 | CLK | Clock |
| 13 | $P_B/G_B$ | Parallel data port outputs |
| 14 | $P_D/G_D$ | Parallel data port outputs |
| 15 | $P_F/G_F$ | Parallel data port outputs |
| 16 | $P_H/G_H$ | Parallel data port outputs |
| 17 | $Q_H'$ | Serial data outputs |
| 18 | $S_H$ | Shift left select |
| 19 | S2 | Mode select |
| 20 | VCC | +5V |

The LED unit contains one 8-bit bidirectional shift register (MC74HC299N) and 8 sets of parallel LED bulb, and each LED is connected with a 100Ω resister. The shift register gets input data, shift left/right select, and clock signals from main microcontroller. The shift register will shift the input data to left or right according to the select signal input, and the shift speed is determine by the slow clock we created in microcontroller.

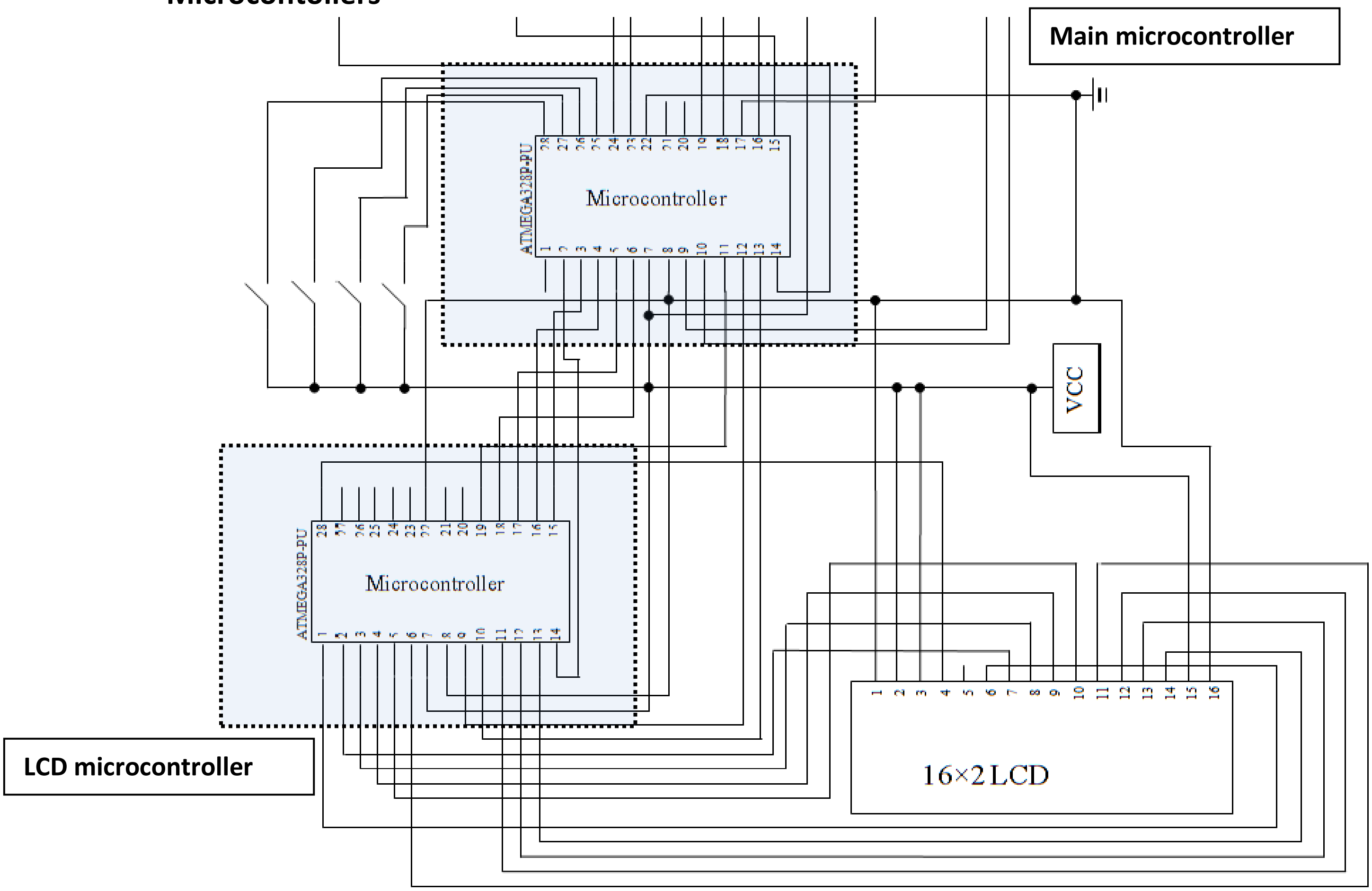
## 16×2 LCD Display

| Pin NO | Symbol | Function |
|---|---|---|
| 1 | $V_{DD}$ | +5V |
| 2 | $V_{SS}$ | Ground |
| 3 | RS | Register select |
| 4 | NC | No connection |
| 5 | E | Read/write enable |
| 6 | R/W | Read/write |
| 7 | DB1 | Data bit |
| 8 | DB0 | Data bit |
| 9 | DB3 | Data bit |
| 10 | DB2 | Data bit |
| 11 | DB5 | Data bit |
| 12 | DB4 | Data bit |
| 13 | DB7 | Data bit |
| 14 | DB6 | Data bit |
| 15 | CLED | LED C(+) |
| 16 | ALED | LED A(+) |
| 17 | S1 | Switch 1 |
| 18 | BLED | LED B(+) |
| 19 | S3 | Switch 3 |
| 20 | S2 | Switch 2 |
| 21 | S4 | Switch 4 |
| 22 | NC | No connection |
| 23 | $V_{SS}$ | Ground |
| 24 | $V_{DD}$ | +5V |




16×2 LCD display will display the message that we pre-program in the LCD microcontroller, and interact with user input signal. User can change menu, select mode, and set up time by using the buttons. The buttons are connected with the LCD microcontroller, once it receives the signal, it will change the display on the LCD.

## Microcontollers




| Pin NO | Symbol | Function |
|---|---|---|
| 1 | PC6 | Port C I/O port |
| 2 | PD0 | Port D I/O port |
| 3 | PD1 | Port D I/O port |
| 4 | PD2 | Port D I/O port |
| 5 | PD3 | Port D I/O port |
| 6 | PD4 | Port D I/O port |
| 7 | VCC | Digital supply voltage |
| 8 | GND | Ground |
| 9 | PB6 | Port B I/O port |
| 10 | PB7 | Port B I/O port |
| 11 | PD5 | Port D I/O port |
| 12 | PD6 | Port D I/O port |
| 13 | PD7 | Port D I/O port |
| 14 | PB0 | Port B I/O port |
| 15 | PB1 | Port B I/O port |

| | | |
|---|---|---|
| 16 | PB2 | Port B I/O port |
| 17 | PB3 | Port B I/O port |
| 18 | PB4 | Port B I/O port |
| 19 | PB5 | Port B I/O port |
| 20 | AVCC | AVCC is the supply voltage pin for the A/D Converter |
| 21 | AREF | AREF is the analog reference pin for the A/D Converter |
| 22 | GND | Ground |
| 23 | PC0 | Port C I/O port |
| 24 | PC1 | Port C I/O port |
| 25 | PC2 | Port C I/O port |
| 26 | PC3 | Port C I/O port |
| 27 | PC4 | Port C I/O port |
| 28 | PC5 | Port C I/O port |

### Main microcontroller

Main microcontroller will receive data from LCD microcontroller for speed data from the user inputs. It will process the data and calculate the clock cycle. Then it will send out individual data input, universal clock and left/right shift select to the 7 LED units. Any adjustment from the user will be updated to the main microcontroller which will alter the speed accordingly.

### LCD microcontroller

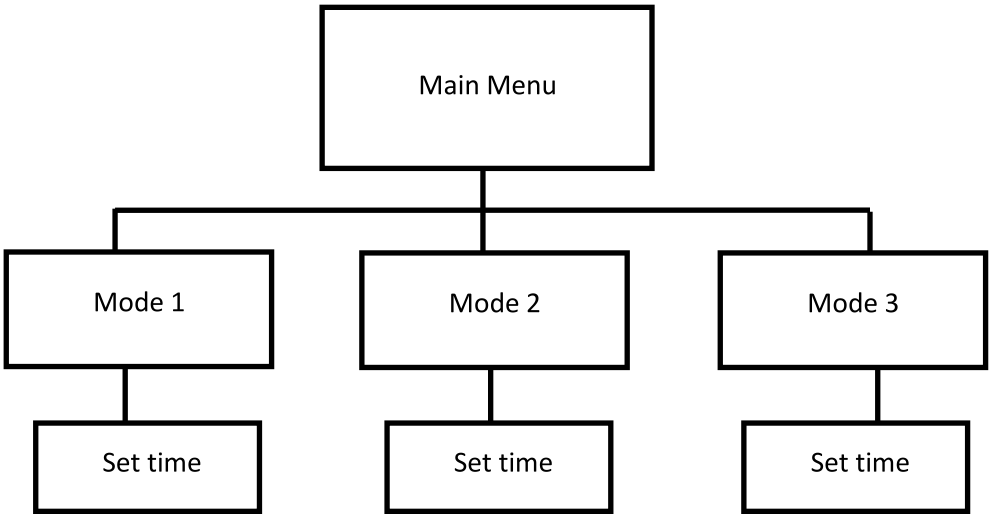
The LCD microcontroller will receive user inputs from the buttons and update the menu. After the users selected the speed they wanted, the microcontroller will send this information to the main microcontroller. Any adjustment from the user will be send to the main microcontroller.

### Batteries

We will be using 8 AA alkaline batteries with a total of 24watts-hour. This will be used to power the main microcontroller and LED unit. The LCD microcontroller and LCD will get their power from the main microcontroller.

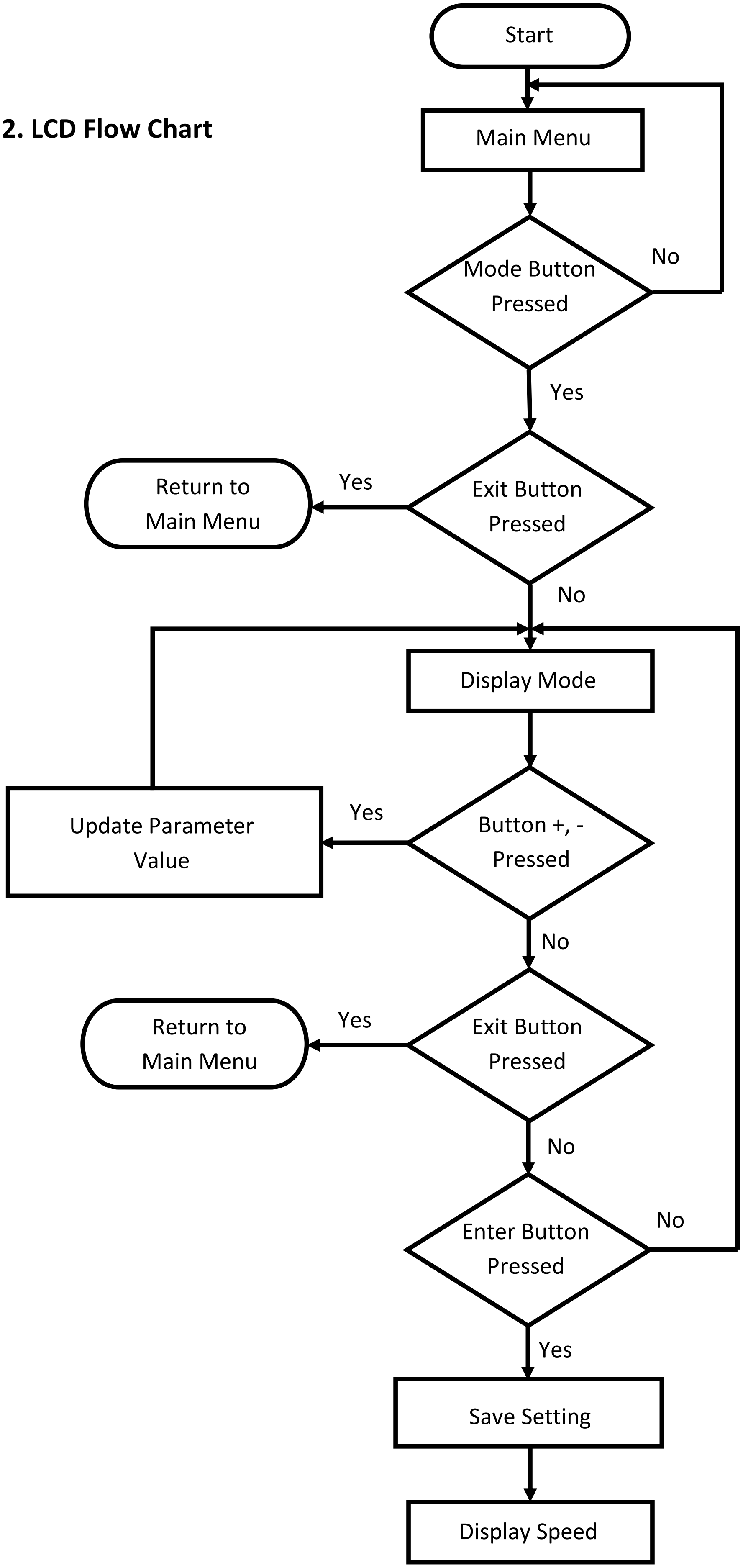
# III. User Interface

## 1. LCD Display

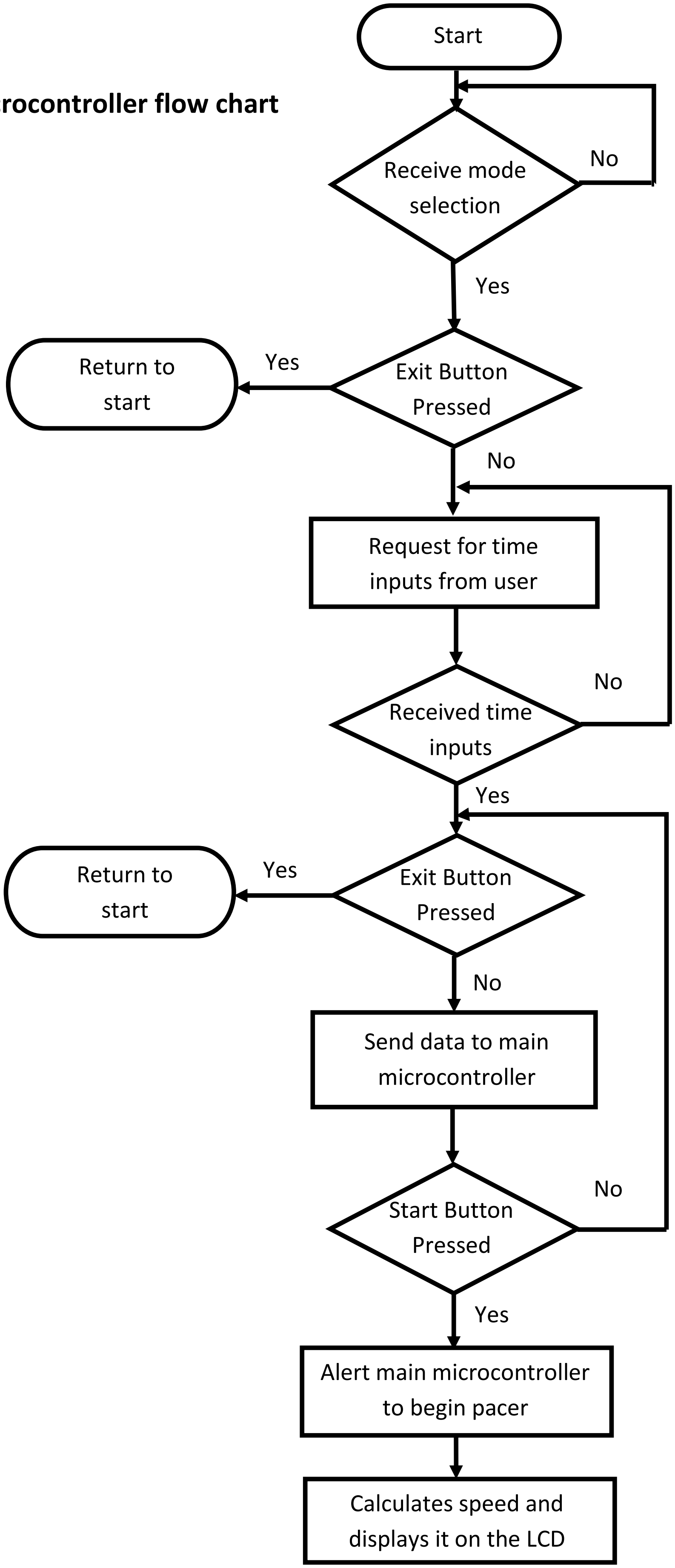



The user interface will have 4 buttons and a LCD to display the menu. In this menu, the users can choose from 3 different modes. The first mode will require the user input the time for one 25m lap. The lap speed will be consistent throughout. The second mode gives the users an option for setting two different speeds. Therefore the user can set a faster pace for the first half and a slower pace for the second half of the lap. The third mode gives the swimmers three different speeds to set. The options are a fast, slow, fast speed, etc.

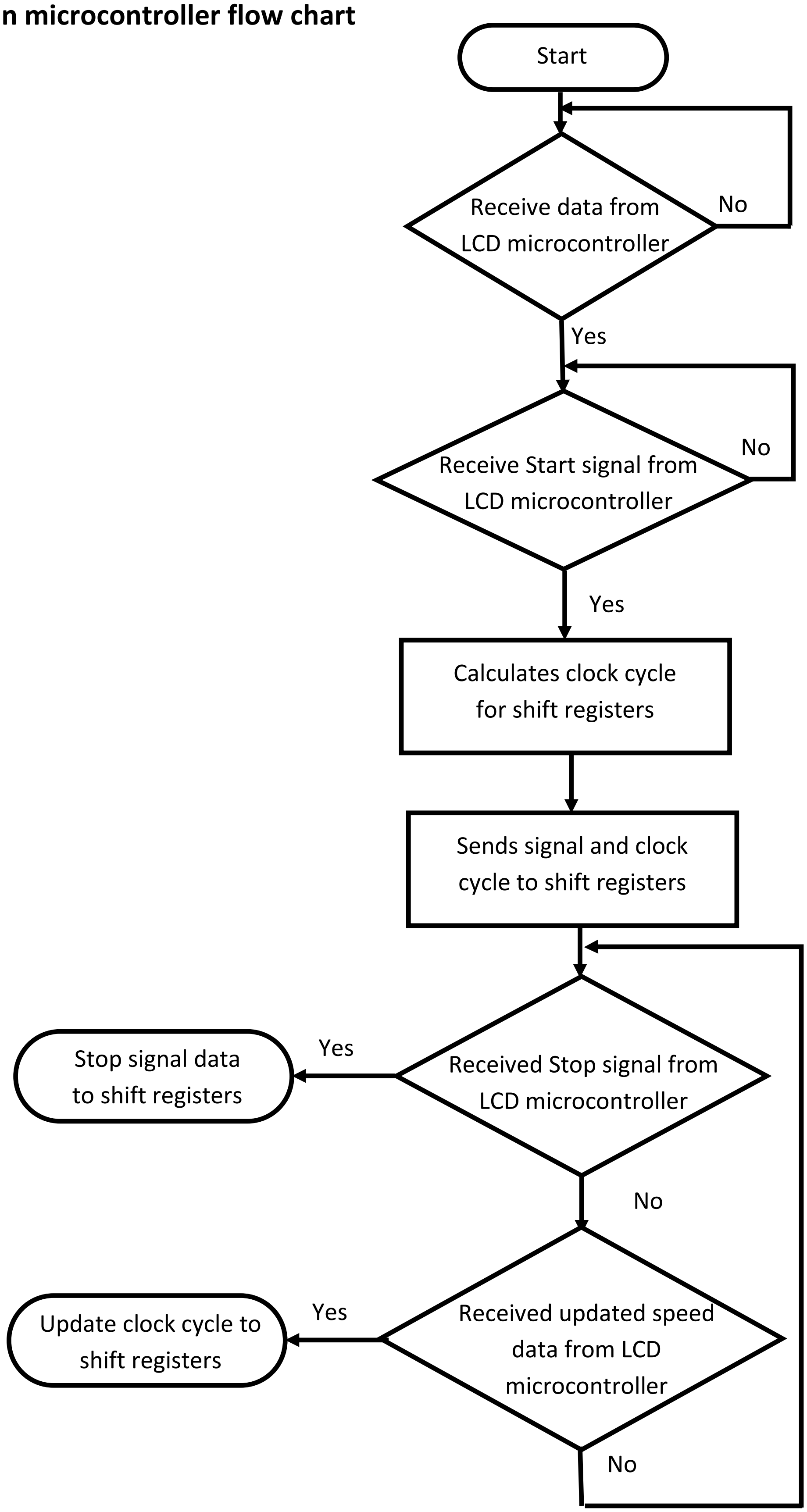
## 2. LCD Flow Chart



### 3. LCD microcontroller flow chart



## 4. Main microcontroller flow chart



# IV. Circuit operation and specifications

### 1. Wire resistance

Since this led pacer will be 25 meters in length, wire resistance will be an issue in this pacer. The shift registers will be connected to the main microcontroller through 9 wires. The furthest shift register will be 24 meters away from the main microcontroller. We will need to calculate the resistance and check if the power and signal is enough to ensure that all the shift registers are functioning correctly

$$R = \rho \frac{\ell}{A}$$

Resistivity of 22 gauges wire: 0.01614 ohm per foot
Diameter: 0.64516mm
Area: 3.6167E-7 $m^2$
Length: 79.74 feet (24m)

R= 0.01614*78.74 feet =1.271 ohms

Wire Resistance= 1.271 ohms

Since the wire resistance is just 1.271 ohms, it won't affect the functionality of the bidirectional shift register. The operating voltage range of the shift register is 2 to 6volts and it has an input current of 20mA. Therefore the wire resistance isn't going to affect the shift register.

### 2. Power battery

We need the battery to power the swim pacer for at least 4 hours continuously. Since we are not using an AC input from a power plug for safety reasons, we will need batteries to power the device.

Each of the LED has a rating of 0.03amps with 2.27V. The power dissipation is 0.068watts. Not all of the 100 LEDs are powered at once; only 2 of them are lit at one time. Therefore the LEDs will use 0.1362watts.

The two microcontrollers each uses roughly 0.042amps at 5v with nothing connected to it. Therefore they add up to around 0.42watts. The LCD has a rating of 0.3amps with 5v, which is 1.5watts. The seven shift registers are rated at 0.75watts each which has a totals of 5.25 watts. However only one led will be lit up when the shift register is running. Using a digital multimeter, the each shift register uses 5v with 0.05 amps, which uses 0.25. The total of seven shift register will use 1.75 watts

0.05

The 8 AA alkaline batteries will have roughly 1.5V each but since each battery is different; we will use 1.2V each for the battery which has a rating of 2amp-hour. Thus the batteries will add up to 24 watt-hour

| Modules | Power usage (watts) |
|---|---|
| LED | 0.1362 watts |
| Microcontrollers | 0.42 watts |
| Shift registers | 1.75 watts |
| LCD | 1.5 watts |
| **Total** | 3.8062 watts |

24watt-hour/3.8062 watts = 6.31 hours

With our design, the battery is able to last more than 6 hours of continuous usage. This is more than enough for a swim session and the users can use rechargeable batteries so that they could save money on batteries and be more environmental.

# V. Performance Requirements

The LED swim pacer consists of five modules: LCD, Main microcontroller, LCD microcontroller, shift register and the LEDS. We will use digital multimeter, lab equipment and test breadboard to simulate and test our circuit.

Since the LED strip will be 25meters long, we will test the LED on a breadboard to simulate its functionality. The shift registers will be tested to make sure the data and clock cycle from the main microcontroller is computed correctly. We will also make sure that the battery power will be enough to power the unit.

## 1. Testing & Verification

| Requirement | Verification |
|---|---|
| 1. LCD display information and interact with user inputs correctly | a. Powered by the microcontroller, LCD will be tested by receiving a test data from the LCD |

| | |
|---|---|
| a. Display main menu when the power is turned on and the mode it's in<br>b. Print and retrieve data<br>c. Transmit data to main microcontroller | microcontroller to confirm that it's displaying the information correctly<br>b. A test data will be sent from the user input which can be displayed on the Arduino serial monitor to confirm accurate information is received.<br>c. A test data from the user input will be transmitted to the main microcontroller and these data will be displayed on the Arduino serial monitor to inspect the correctness of the data |
| 2. Main Microcontroller should be able to receive mode and speed data from LCD microcontroller and decode and calculate clock cycle for the LED<br>a. Receive data and decode it<br>b. Transmit data to shift registers | a. A test data will be sent from the LCD microcontroller to the main controller. The data can be displayed on the Arduino serial monitor to ensure that correct data is received and correct calculations are computed.<br>b. The microcontroller then transmit the clock cycle which can be displayed on the Arduino serial monitor to confirm that it has the correct data |
| 4. LED unit should accurately light up when it receives a high signal from the shift registers<br>a. Turn on and off accordingly | a. The LED and the shift register will be tested on a breadboard to confirm that it can be turned on and off correctly from the signal of the shift registers. |
| 5. The LED strip will have a minimum time of 10 seconds and maximum time of 40 seconds | The LED will be tested both on the breadboard and actual finished product with a stop watch to make sure that it does indeed comply with the minimum of 10 sec and maximum of 40 sec accurately to the 100ms. This test is only for one way (25meters) |
| 6. Power Supply<br>a. Supply +5V to the microcontrollers | a. The power supply will be tested with a multimeter to ensure that it can power the two microcontrollers and all seven of the shift registers. It should measure 5v for a pass and if it's less than 2v or more than 7v, then the test will fail |

# VI. Cost and Schedule

## 1. Schedule

| Week | Task | Member |
|---|---|---|
| 1/16-1/30 | Brain storming for idea<br>Get RFA approved<br>Start working on proposal | Jonathan Lee |
| | Start working on proposal | Yi-Liang Chen |
| 2/6 | Finish proposal | Jonathan Lee |
| | Search parts | Yi-Liang Chen |
| 2/13 | Detail electrical design schematics<br>Research microcontroller implementation | Yi-Liang Chen |
| | Sign up for Design review<br>Verification and tolerance analysis | Jonathan Lee |
| 2/20 | Complete flow charts and calculations<br>Design review | Yi-Liang Chen |
| | Simulation, block diagram<br>Design review | Jonathan Lee |
| 2/27 | Begin implementing microcontroller | Yi-Liang Chen |
| | Order parts<br>Implement LCD and user input | Jonathan Lee |
| 3/5 | Microcontroller programming | Yi-Liang Chen |
| | LCD microcontroller programming | Jonathan Lee |
| 3/12 | Prototype of LED strip on breadboard | Yi-Liang Chen |
| | Implement and build LED strip | Jonathan Lee |
| 3/19 | **Spring Break** | Jonathan Lee, Yi-Liang Chen |
| 3/26 | Sign Up for Mock Presentation<br>Program microcontroller | Yi-Liang Chen |
| | Test LED strip | Jonathan Lee |
| 4/2 | Assemble the product | Yi-Liang Chen |
| | Waterproof test | Jonathan Lee |
| 4/9 | Testing and Debugging | Yi-Liang Chen |
| | Verification of specifications, tolerance analysis | Jonathan Lee |
| 4/16 | Sign up for Demo and Presentation<br>Finish Testing and Debugging | Yi-Liang Chen |
| | Work on final paper | Jonathan Lee |
| 4/23 | Demo and Presentation | Yi-Liang Chen |

| | | |
|---|---|---|
| | Revise Final Report | Jonathan Lee |
| 4/30 | Finish final report | Yi-Liang Chen |
| | Presentation | Jonathan Lee |

## 2. Parts list

| Name | Hourly Rate ($/hr) | Total Hours to complete (hrs) | Total= Hourly Rate*2.5*hours to complete |
|---|---|---|---|
| Jonathan Lee | $32/hr | 150 hrs | $12,000 |
| Yi-Liang Chen | $32/hr | 150 hrs | $12,000 |
| Total | | | $24,000 |

| Part Name | Part Number | Cost ($)/unit | Quantity | Total ($) |
|---|---|---|---|---|
| 16x2 LCD display with 4 push buttons | HD44780 | $13.95 | 1 | $13.95 |
| LED (Green) | LTL-4238 | $0.28 | 60 | $16.80 |
| LED (Red) | LTL-307EE | $0.28 | 40 | $11.20 |
| Wire(100 inches) 22gauge | - | $14.20 | 6 | $85.20 |
| Energizer alkaline Battery AA | - | $1.57 | 8 | $12.56 |
| Resister ¼ watt 100ohm | - | $0.02 | 100 | $2.00 |
| Clear PVC Tubing (3/4 inch) 25 meters | - | $30 | 1 | $30.00 |
| Clear Silicone Sealant | - | $6.95 | 1 | $6.95 |
| Black Acrylic Sheet 24”x 24” x 3/16” | - | $31.85 | 1 | $31.85 |
| 8-CH inverter | SN74LS540N | $0.65 | 1 | $0.65 |
| Arduino UNO board | ATmega328P-PU | $29.95 | 2 | $59.90 |
| Bidirectional Shift register | MC74HC299N | $1.50 | 7 | $10.50 |
| Total | | | | $281.56 |

| Section | Total |
|---|---|
| Labor | $24,000 |
| Parts | $281.56 |
| Grand Total | $24,281.56 |

# VII. Ethical issues

The safety of the users is very important and we don't believe the project have any ethical issues conflicting with the IEEE ethic code. IEEE Code of Ethics issue #9 states, "to avoid injuring others, their property, reputation, or employment by false or malicious action". Since the product will be submerged underwater, there might be a chance of causing electric shock to users. Therefore the product will be sealed tight and waterproofed. The main controller will also be waterproofed even though it will be on the ground most of the time. The power is supplied by batteries, not AC line input therefore it will reduce the potential danger of electric shock.