Swim Pacer Unit

Design Review

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1.0 Terms and Keywords

Demux (DMUX) – Demultiplexer

IC – Integrated Circuit

I/O – Input/Output

LCD – Liquid Crystal Display

LED – Light Emitting Diode

MultiSim – National Instruments® (NI) Multi-purpose electronics Simulator

NI – National Instruments®

nanoWatt Technology – This is currently the industry's lowest power, widest operating voltage range, and most flexible power-managed technology available for embedded systems today.

PIC – Programmable Integrated Circuit

UI – User Interface

Project Specific Acronyms:

CTL – Controller to Light

CTM – Controller to Monitor

SLC – Sequential Lights Circuit

TOL – Tolerance

2.0 Introduction

2.1 History and Motivation

The Swim Pacer Unit proposed by Coach Howard Schein is a swimmer's training tool. Swimmers usually are unaware of how fast they are moving while swimming. We want to be able to create a tool that can provide visual representation of a set pace which will guide the swimmers at various speeds preprogramed by their coach.

We chose this project because it is ambitious, interesting, marketable, and it can potentially improve the performance of many athletes. Swimming is a very competitive sport that the world enjoys. But the hi-tech training tools are often overlooked. This project will revolutionize swimmer's training and create an impact to the electronic training equipment for swimmers.

2.2 Objectives

We will design and build a visual indicator for swimmers through the use of LED sequential lights. A controller with a digital interface will be designed to adjust the speed of the lights moving along the length of the pool. Pace profiles can be preprogramed into the control device. Swimmers can follow these lights to guide them in swimming at speeds that are set at predetermined settings. This device can also be operated on deck by the coach while an athlete is swimming. The pace can be set from the deck as the swimmer begins each length. Different profiles can be preprogramed and can be varied by the coach. The pace ranges from 8 to 30 seconds per length in 0.5 second intervals.

Benefits

- It can help improve the performance of swimmers
- The swimmer and the coach can now see how fast the swimmer is compared to the set pace
- Allows the swimmer to chase a visual cue

Features

- Programmable Pace Profiles and Pace controls
- Profiles can be saved and modified
- User friendly control interface and visual display
- Safe and reliable
- Works with all standard pools
- Waterproof LED sequential light indicator
- LCD monitor display

3.0 Design

3.1 Concept Diagram

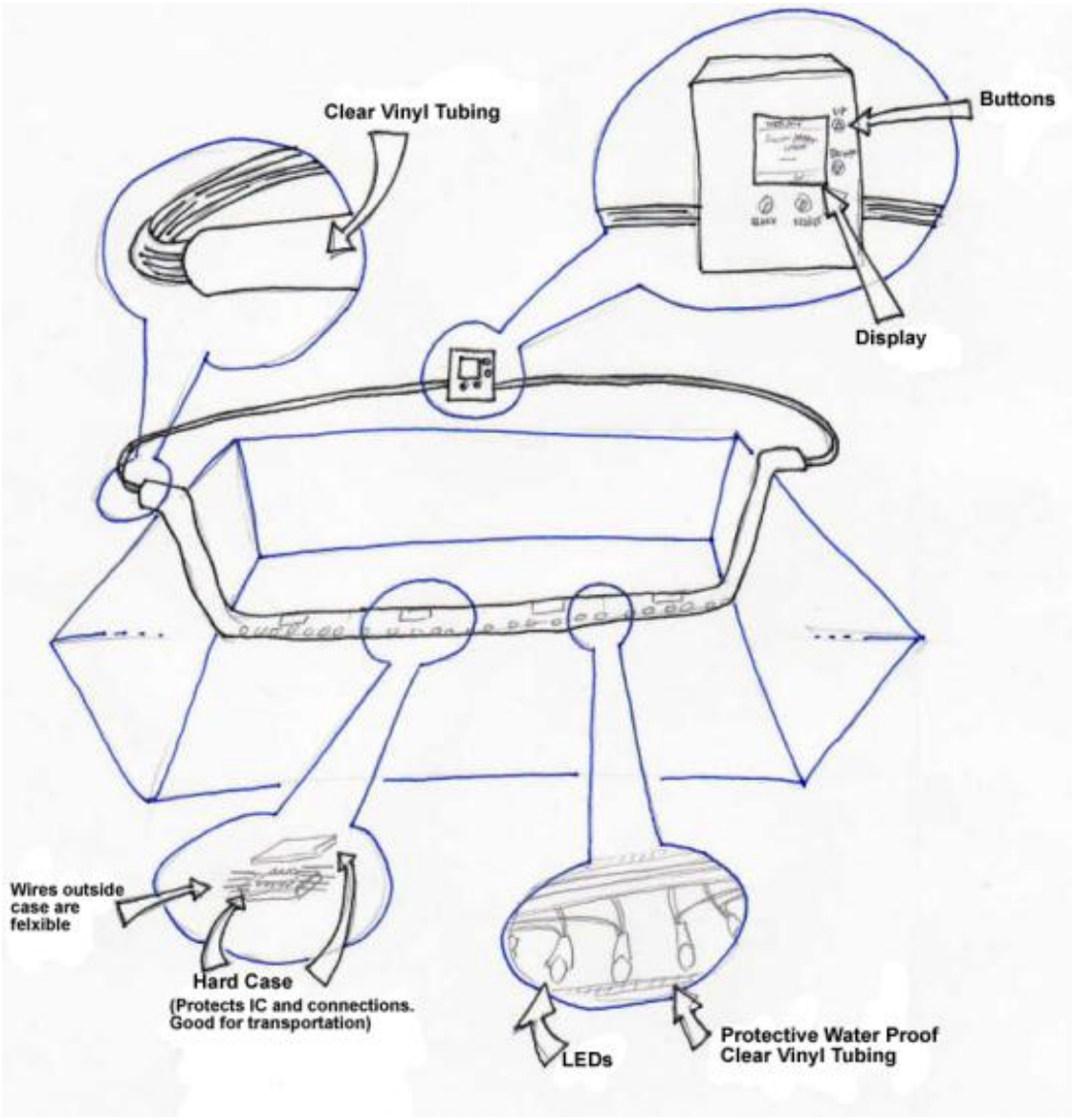


Figure 3a: Swim Pacer Unit Concept Diagram

The swim pacer unit is designed to have a control panel that has several buttons and an LCD display for the user to set the pace of the sequential light indicator. The Sequential Light Indicator will be protected by clear/transparent vinyl tubing, the same material used with aquariums. Since there are several integrated circuits to control the LEDs in the sequential light indicator, a special hard protective case must be prepared for these ICs.

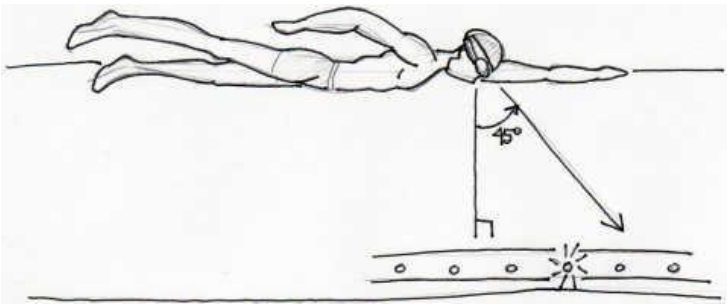


Figure 3b: Swimmer

A typical swimmer is able to see at a 45° angle below the surface of the water. From his perspective and peripheral vision, the swimmer will be able to see the sequential LEDs which would give him an idea of his pace relative to the pace of the LEDs. For instance, if the swimmer does not see the light then he knows that he is swimming faster than the pace. If the swimmer sees the light then he will know that he is slower than the set pace.

3.2 Detailed Block Diagram

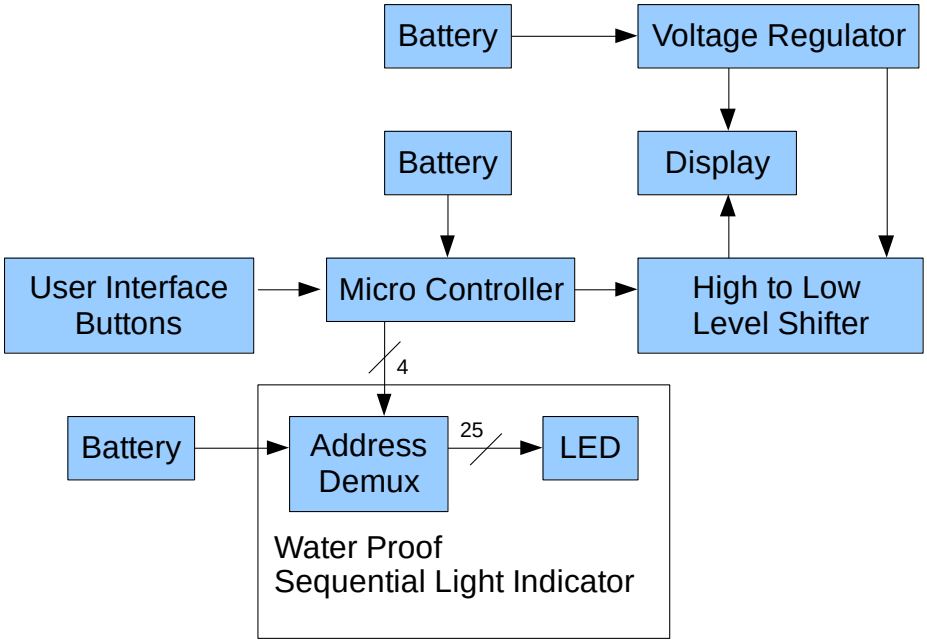


Figure 3c: Detailed Block Diagram

3.3 Block Descriptions

Microcontroller – This is the brain of the Swim Pacer Unit. This will receive user commands in the form of analog input coming from the User Interface block. The Microcontroller will be able to save current settings and profile information then output data to the Monitor Display. The Microcontroller also stores different swimmer pace settings and profiles as programs. Depending on the program called for using the User Interface Buttons, the Microcontroller controls the signals it sends to the Sequential Light Indicator. The Microcontroller also contains Profile information – set of user-defined customizable instructions that determine the output to the Sequential Light Indicator.

Water Proof Sequential Light Indicator – This strip of LED will run across the pool and will be visible to the swimmer. Each LED on this strip has a unique address that is accessed by the Microcontroller. The frequency of each light turning on depends on the settings. This block contains the Demultiplexers and the LEDs. The program saved on the PIC determines what signals to send to the Demultiplexers.

Address Demultiplexers – These demultiplexers are used to address each LED individually and are input only. The microcontroller communicates to these by supplying signals depending on which LED to turn on.

LED – These lights are used as indicators that swimmers should be able to see. These LEDs turn on sequentially as they receive signals from the demultiplexers. The pace of the lights as they turn on per length is controlled by the microcontroller.

High to Low Level Shifter – this IC converts the output from the Microcontroller to be usable by the Display monitor. The output of the PIC's Digital I/O is 5V but the LCD display requires 2V.

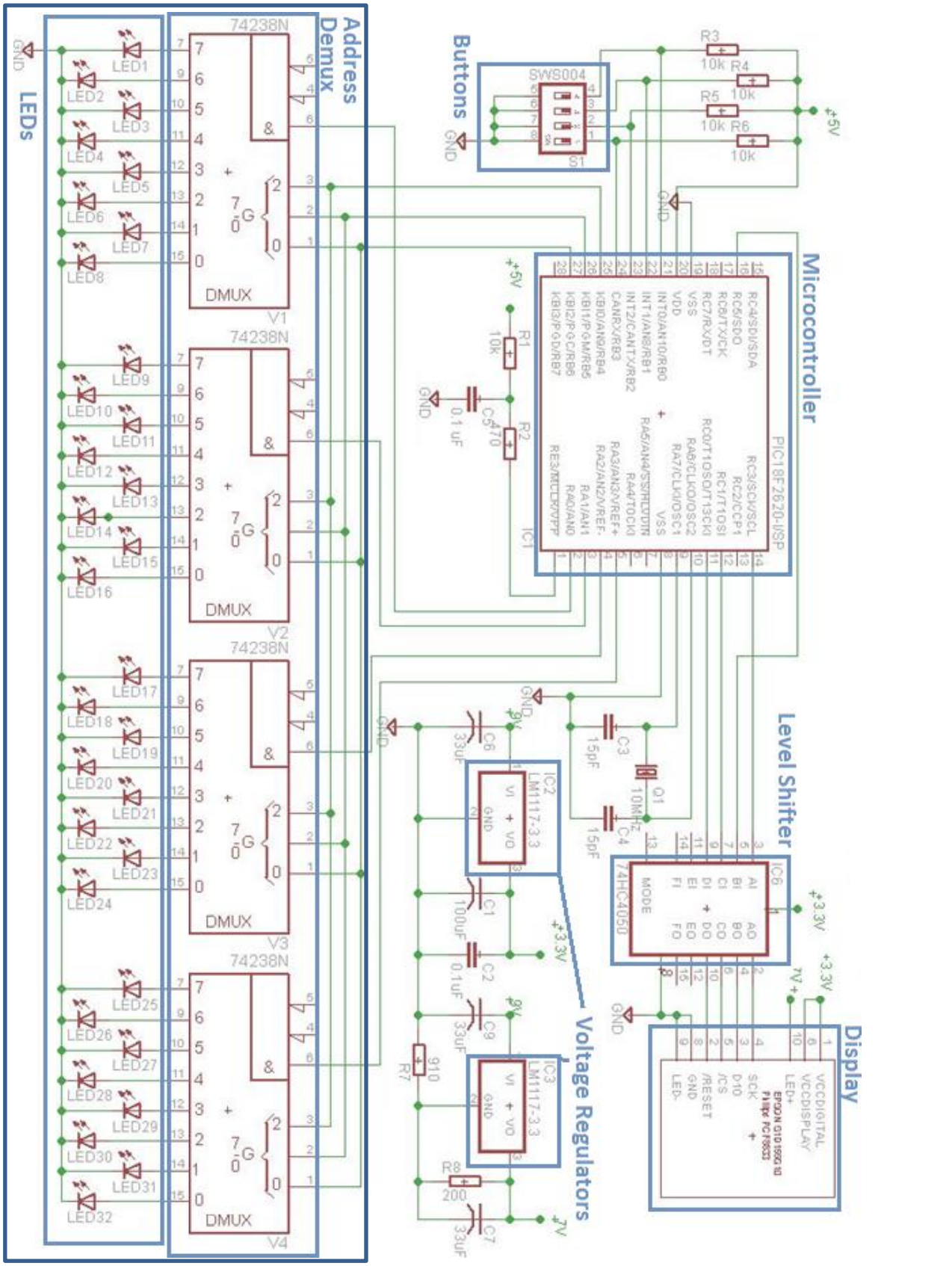
Display Monitor – This display shows the current settings that the sequential light indicator will be running. It will display current speed/pace and current profile being used. User Input will also be displayed. The data to display will come from the Level Shifter.

User Interface – This is the analog control that allows the user to give commands to the Microcontroller. Buttons will be available to customize profiles and change the current pace.

Batteries – These are used as power supply to the Swim Pacer Unit's components. Batteries are used instead of power supplied from an outlet to limit the current produced resulting in a safer product for users.

Voltage Regulators – These convert voltage supplied from the batteries into the required voltage for the level shifter and Monitor Display.

3.4 Schematics



3.5 Schematic Descriptions

This part talks about the detailed explanation of the components used in the schematics. Implementing this circuit will exhibit proof of concept. Certain practical concerns, such as wire resistance, durability, transportation, etc. will be taken into consideration in applying the project to operational use.

PIC18F2620 – This PIC is the Microcontroller that serves as the brain of the Swim Pacer Unit. Input comes from the switches and sends display output signals to the Level Shifter and simple digital output signals to the demultiplexers. This PIC is powered by a 5V battery. From the data sheet, this PIC is a 28-Pin Enhanced Flash Microcontroller with 10-Bit A/D and nanoWatt Technology.

74HC4050 – This IC is a Hex High-to-Low Level Shifter. It is meant to lower the digital output signals from the pic to voltages usable by the LCD.

EPSON S1D155G10/Philips PCF8833 – This is the LCD where all the User Interface output will be visible. The part is ordered from Sparkfun and it is not sure which model will be received but both should work similarly. This component will be powered using the output from voltage regulators. These requirements are detailed in the Data Sheets.

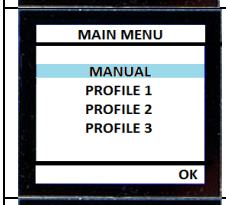
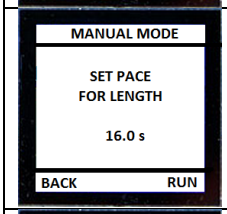
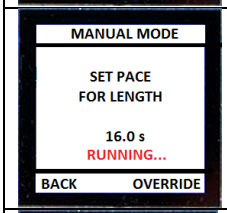
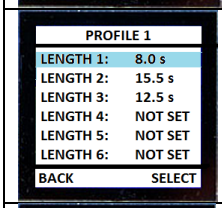
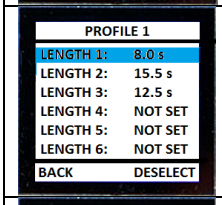
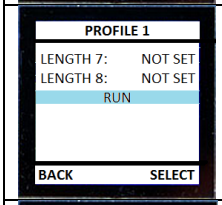
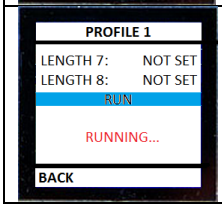
74238N – These demultiplexers are used as addressing bits to address each LED. These take input signals from the PIC and turns on corresponding LEDs.

LM1117 – These parts are Voltage Regulators. 9V are input and these voltage regulators are configured to output 3.3V and 7V which is usable for the Level shifter and LCD.

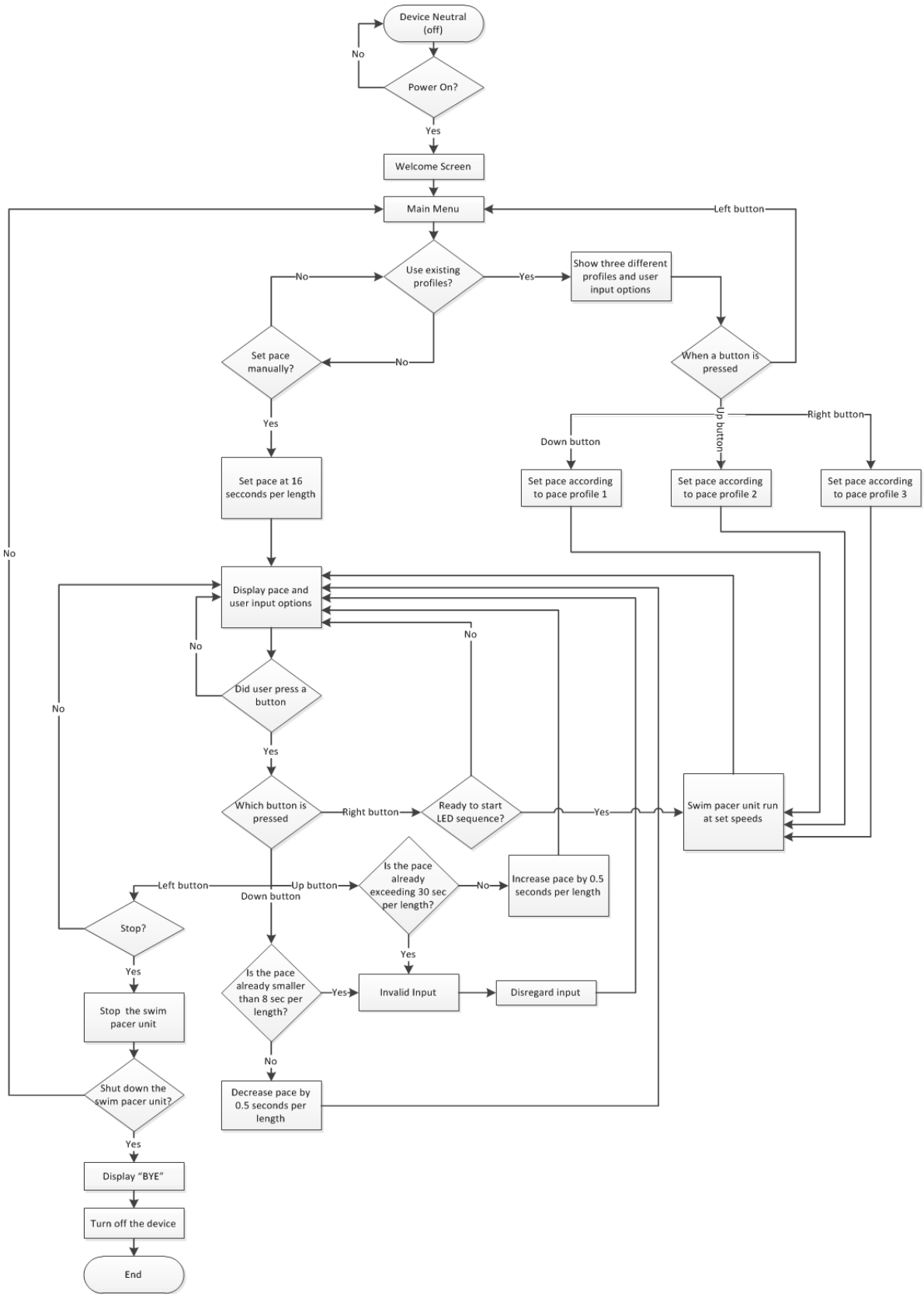
Switches – Although these switches in the schematic are not the actual buttons that will be used for the final product, it can still do the same desired function. These switches provide useful interactive user interface to issue commands to the PIC.

Batteries – These supply 5V and 9V for the PIC and voltage regulators respectively. Several batteries could be connected in series in order to produce the desired voltage.

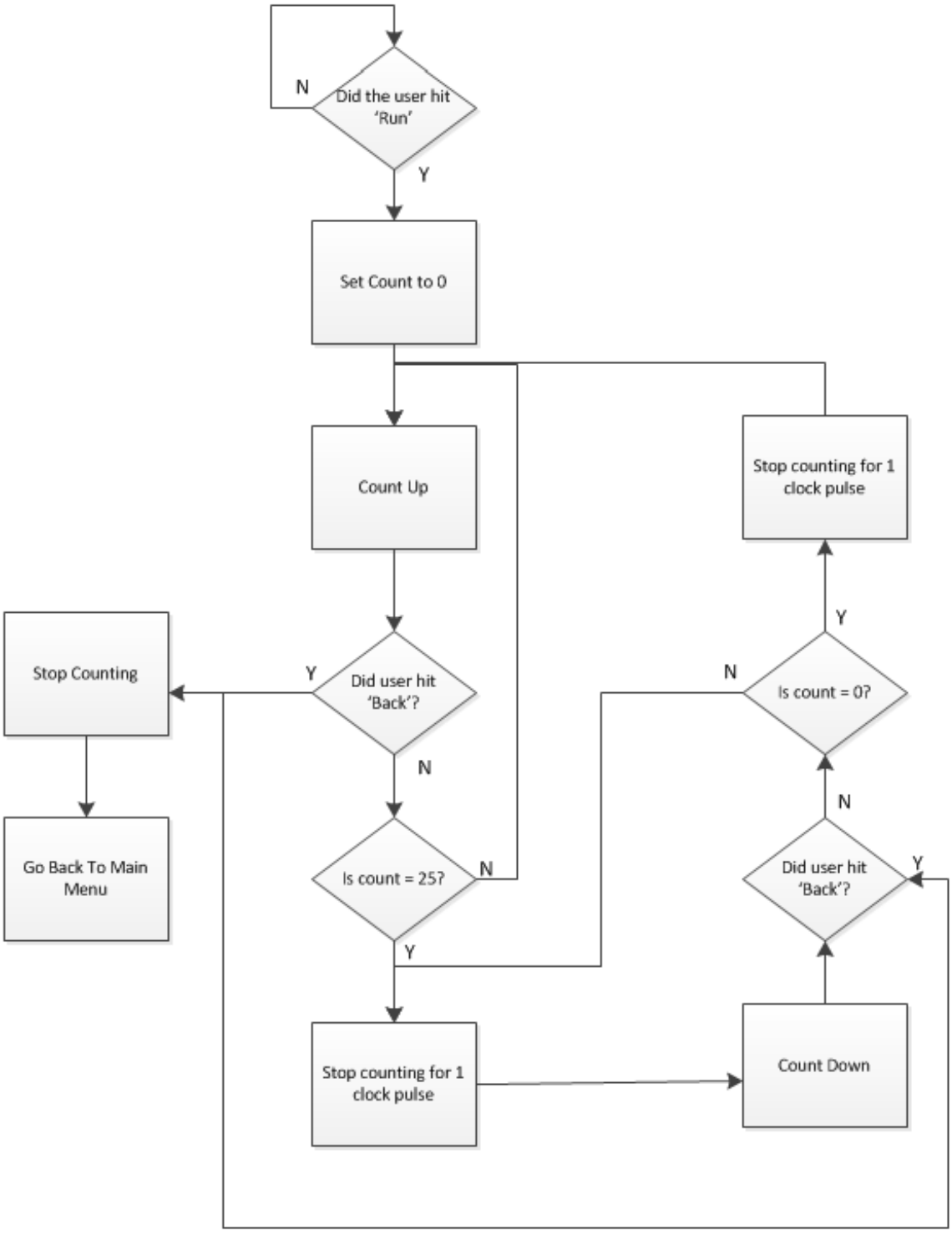
3.6 User Interface Display

	This is the welcome page which displays the device name and some credits.
	This simple menu allows users to navigate between manual-mode or using saved profile settings.
	In manual mode, the user is able to set the pace of the sequential light indicator.
	While running in manual mode, the lights will continuously follow that pace in each length until the user selects “OVERRIDE”. The user is able to increase or decrease the pace manually as it is running.
	When choosing a profile, the user is provided with several options of pre-set lengths which can be changed later. Buttons can be used to navigate through the different lengths and can be selected for modification. The user is only allowed to set lengths in order.
	Selecting a length will allow the user to set the pace of the selected length from 8 to 30 seconds in 0.5 second intervals. Scrolling below 8 seconds or above 30 seconds will show the option to “NOT SET” which disables that length. The user can only disable lengths in order as well.
	There are 8 lengths available for each profile which should be more than enough. Scrolling below the 8th length shows the option to “RUN” current profile.
	When running a profile, the current length will be highlighted

3.7 Flowchart for user interface



3.8 Flowchart for counter (for 25 lights)



4.0 Simulations and Calculations

4.1 Simulation Description

Using NI MultiSim, we produced a simulation that emulates the output to the sequential LED indicator for 1 lap (2 lengths). The PIC we are using cannot be simulated using NI MultiSim; hence, we are emulating its effect using a counter and a function generator for the clock to produce the desired. However, we are still using demultiplexers and lights to emulate our sequential lights operation.

For the simulation, a 4-bit up/down counter was used to determine which light was supposed to turn on at a specific point in time. Using a function generator as clock, we were able to produce square waves with adjustable frequency, accurate up to 10^{-15} hertz (femtohertz, fHz). Each count coming out of the up/down counter corresponded to an LED. Using a two dual 2-line to 4-line decoder/demultiplexer (74LS1550), we were able to specifically indicate what LED to power up. The outputs of the 74LS1550 give low voltage instead of high upon decoding. Therefore, we placed an inverter on every output to get a high signal for LEDs to light up and low signal for LEDs to close.

4.2 Simulations

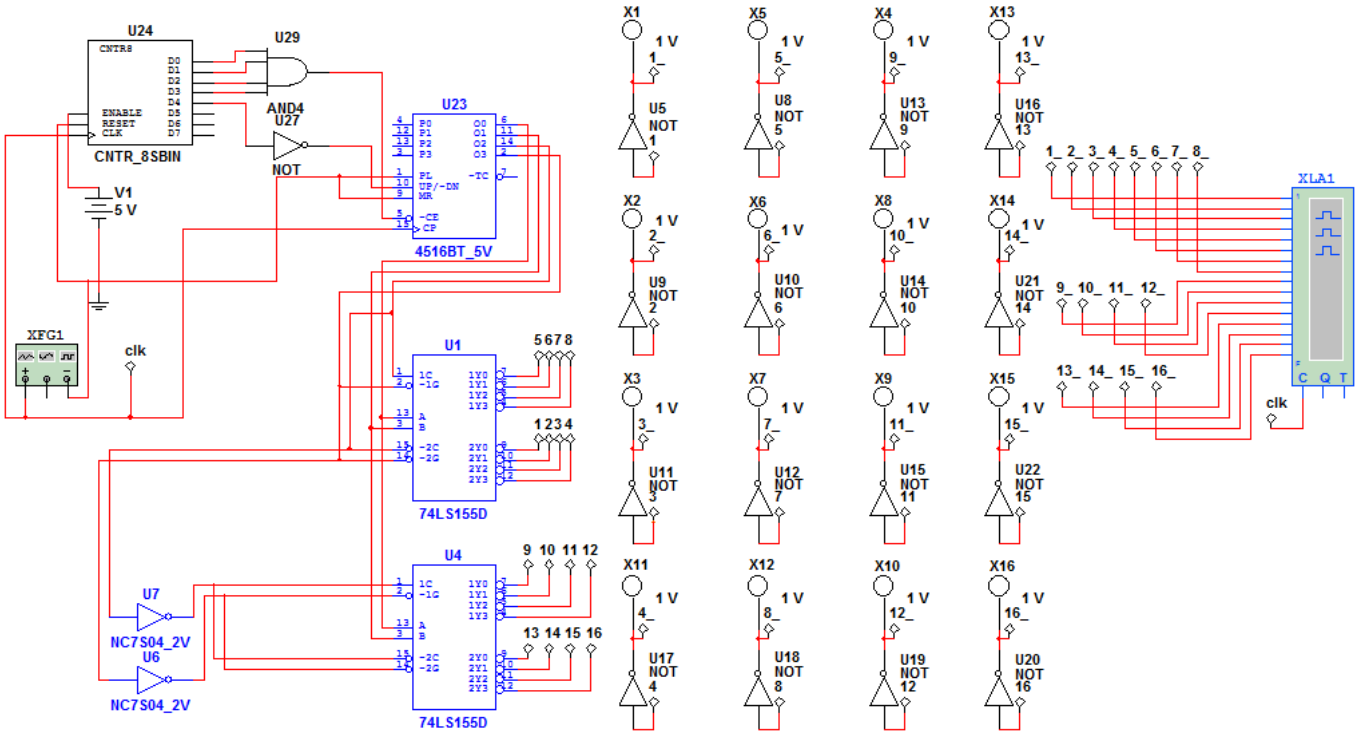


Figure 4a: NI Multisim Simulation

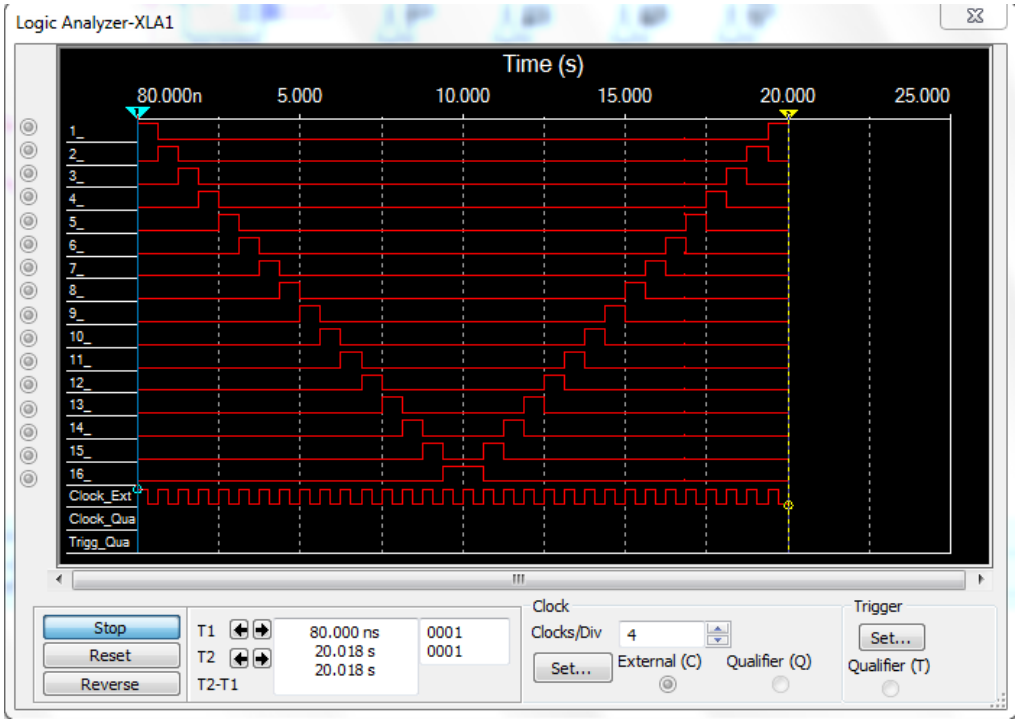


Figure 4b: Logic Analyzer output for 10 sec pace

In this simulation, we set the function generator to 1.6 Hz, which corresponds to a length pace of 10 seconds. As seen in this output, it took 10 seconds to light the LEDs from the first light (1_) until the last light (16_) for the length of the pool. Similarly, it took another ten seconds to for the last light (16_) until the first light (1_) to traverse back for another length.

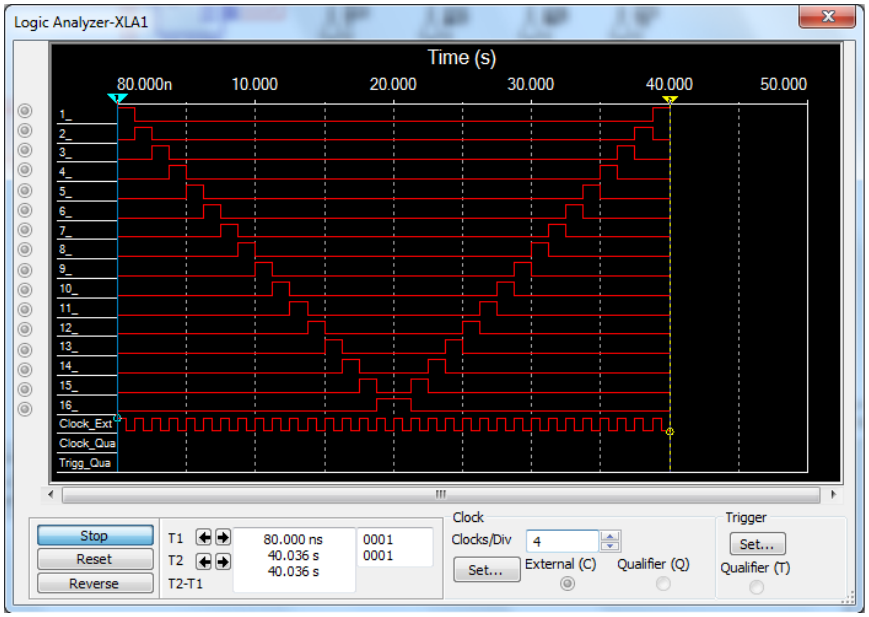


Figure 4c: Logic Analyzer output for 40 sec pace

In this simulation, we set the function generator to 0.8 Hz, which corresponds to a length pace of 40 seconds. As seen in this output, it took 20 seconds to light the LEDs from the first light (1_) until the last light (16_) for the length of the pool. Similarly, it took another 20 seconds to for the last light (16_) until the first light (1_) to traverse back for another length.

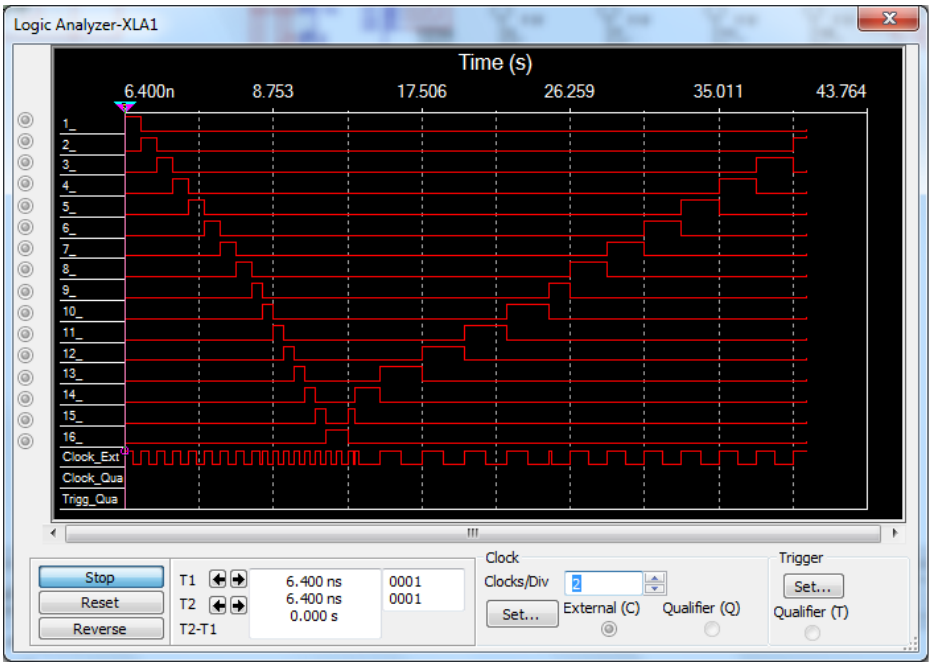


Figure 4d: Logic Analyzer output for 2 lengths with different paces

In this simulation, we set varying frequencies for the function generator. This, in turn, made the lights turn on slower or faster, depending on the function generator frequency. This plot shows that every time an input frequency is changed, it changed how fast each light turns on. This feature corresponds to the “OVERRIDE” feature in manual mode where the user could change the pace anytime within the length of the pool.

4.3 Calculations

Pace [sec]	Frequency for 25 lights [lights/sec]	Transition time from one light to next for 25 lights [sec/light]	Frequency for 50 lights [lights/sec]	Transition time from one light to next for 50 lights [sec/light]
8	3.1250	0.32	6.2500	0.16
8.5	2.9412	0.34	5.8824	0.17
9	2.7778	0.36	5.5556	0.18
9.5	2.6316	0.38	5.2632	0.19
10	2.5000	0.40	5.0000	0.20
10.5	2.3810	0.42	4.7619	0.21
11	2.2727	0.44	4.5455	0.22
11.5	2.1739	0.46	4.3478	0.23
12	2.0833	0.48	4.1667	0.24
12.5	2.0000	0.50	4.0000	0.25
13	1.9231	0.52	3.8462	0.26
13.5	1.8519	0.54	3.7037	0.27
14	1.7857	0.56	3.57141	0.28
14.5	1.7241	0.58	3.4483	0.29
15	1.6667	0.60	3.3333	0.30
15.5	1.6129	0.62	3.2258	0.31
16	1.5625	0.64	3.1250	0.32
16.5	1.5152	0.66	3.0303	0.33
17	1.4706	0.68	2.9412	0.34
17.5	1.4286	0.70	2.8571	0.35
18	1.3889	0.72	2.7778	0.36
18.5	1.3514	0.74	2.7027	0.37
19	1.3158	0.76	2.6316	0.38
19.5	1.2821	0.78	2.5641	0.39
20	1.2500	0.80	2.5000	0.40
20.5	1.2195	0.82	2.4390	0.41
21	1.1905	0.84	2.3810	0.42
21.5	1.1628	0.86	2.3256	0.43
22	1.1364	0.88	2.2727	0.44
22.5	1.1111	0.90	2.2222	0.45
23	1.0870	0.92	2.1739	0.46
23.5	1.0638	0.94	2.1277	0.47
24	1.0417	0.96	2.0833	0.48
24.5	1.0204	0.98	2.0408	0.49
25	1.0000	1.00	2.0000	0.50
25.5	0.9804	1.02	1.9608	0.51
26	0.9615	1.04	1.9231	0.52

26.5	0.9434	1.06	1.8868	0.53
27	0.9259	1.08	1.8519	0.54
27.5	0.9091	1.10	1.8182	0.55
28	0.8929	1.12	1.7857	0.56
28.5	0.8772	1.14	1.7544	0.57
29	0.8621	1.16	1.7241	0.58
29.5	0.8475	1.18	1.6949	0.59
30	0.8333	1.20	1.6667	0.60

According to our tolerance test, our timing should only be off by a maximum of 0.2 seconds per length.

For 25 lights, it is 0.008 seconds allowed error per light transition.

For 50 lights, it is 0.004 seconds allowed error per light transition.

Formulas used:

$$\text{Frequency for lights} = \frac{\text{number of lights}}{\text{pace per length}}$$

$$\text{Transition Time from one light to next} = \frac{\text{pace per length}}{\text{number of lights}} = \frac{1}{\text{Frequency for lights}}$$

$$\text{Allowed error} = \frac{\text{tolerance margin of error}}{\text{number of lights}}$$

5.0 Requirements

5.1 Performance Requirements

- User input reflects on the monitor display 100% of the time.
- Display monitor should be able to display 1 of at least 3 programmed profiles and about 44 speed settings (minimum of 8 to a maximum of 30 sec/length in 0.5 second intervals)
- LED Sequential Lights should be visible to the swimmer and the pace of each sequential light should have a margin of error of at most 0.2 seconds.

5.2 Feature Requirements

Controller-to-Monitor Requirements (CTM)

CTM_1: A "Welcome Screen" should be displayed when the unit is turned on. The users should be given the option on this page to continue using the device.

CTM_2: There should be a "Main Menu" page where the user could select three different profiles and a manual pace feature. The controller should help the users navigate this page.

CTM_3. The "manual pace" page should display the set pace (in seconds) for a length of the pool. The default time is 16 seconds. It should have a minimum of 8 seconds and a maximum of 30 seconds. The user should be able to adjust the pace by 0.5 second intervals. The user should be able to activate the sequential light circuit or go back to the main menu from this page.

CTM_4: Any "Profile" should consist of up to 8 different times for pace lengths. Each pace for a length should be editable. The user should be able to activate the sequential light circuit or go back to the main menu from this page.

CTM_5: Users should not be able to set a length pace in ‘Profile’ mode if any of the length paces prior to it is ‘NOT USED’

CTM_6: When the user activates the sequential light circuit in any profile mode, then the page should not be navigable anymore. Only the “Back” option is available for user use. The display will highlight the current length pace that is being run.

CTM_7: When the sequential light circuit has finished running while in any profile mode, then the page should be navigable again.

Controller-to-Lights Requirements (CTL)

CTL_1: When the unit is just turned on, no lights on the sequential light circuit should be on.
CTL_2: When a user presses "Back" from the "Manual Menu" or "Profile Menu" while the sequential light circuit is on, then the lights should turn off.

CTL_3: Selecting 'Run' from the 'Manual' menu or any 'Profile' menu would start the sequential light circuit.
CTL_4: Changing the pace length in manual mode will make the sequential light circuit move faster/slower only if the "Run" button is pressed again.

Sequential Light Circuits Requirement (SLC)

SLC_1: Only one light should be on at a time when the circuit is running
SLC_2: The lights should sequentially traverse across the pool
SLC_3: All LED's should have the capability to turn on.

Tolerance Requirements (TOL)

TOL_1: The pace set can only be off by 0.2 seconds.
TOL_2: The maximum time it takes the sequential light to travel across a length of the pool should be 30 seconds.
TOL_3: The minimum time it takes the sequential light to travel across the length of the pool should be 8 seconds.

6.0 Verification & Testing Procedures

6.1 Testing Procedures

Controller – to – Display tests

Purpose: The part of this test ensures that the communication between the controller and the monitor works as intended

Requirement	Test Steps	Expected Results
CTM_1	Prerequisite: The Swim Pacer Unit must be turned off. 1. Turn on the Swim Pacer Unit using the controller 2. Observe the screen. 3. Press the 'Continue' Button	1. The display monitor should turn on. 2. The screen should display a 'Welcome Screen'. There should be a 'Continue' option on the lower right of the screen. 3. The display will go to a 'Main Menu' page
CTM_2	Prerequisite: The Swim Pacer Display is turned on and is just accessed the "Main Menu" 1. Observe the screen. 2. Repeatedly press the down button. 3. Repeatedly press the up button. 4. Press OK.	1. The display monitor should show the following options/selections: Manual Profile 1 Profile 2 Profile 3. "Manual" should be initially highlighted. A header on the top should say "Main Menu". There should be an 'OK' button on the lower right. 2. One press of the down button will highlight the option below the current highlighted selection. Pressing the down button when the current selected option is the bottom-most (Profile 3 on this page) will not result in a change of the highlighted selection. 3. One press of the up button will highlight the option above the current highlighted selection. Pressing the up button when the current selected option is the top-most (Manual on this page) will not result in a change of the highlighted selection. 4. The display will enter the currently highlighted option.

CTM_3	Prerequisite: The Swim Pacer Display is turned on and is on the "Manual Pace" page. 1. Observe the screen. 2. Press the up button repeatedly. 3. Press the down button repeatedly. 4. Press the 'Run' button. 5. Press the 'Back' button	1. A text should indicate a pace for a length. When you just accessed the 'Manual Pace' page, the default time should display to 16 seconds. There should be a 'Run' button on the lower right and a 'Back button' on the lower left. 2. The pace time will increase by 0.5 seconds every time the up button is pressed. When the current pace time displayed is 30 seconds when the up button was pressed, then the pace time should still remain at 30 seconds. 3. The pace time will decrease by 0.5 seconds every time the down button is pressed. When the current pace time displayed is 8 seconds when the down button was pressed, then the pace time should still remain at 8 seconds. 4. An additional display should show "Running..." The 'Run' text is now replaced by 'Override' 5. The display will exit the "Manual Pace" page and will go back to the "Main Menu"
CTM_4	Prerequisite: The swim pacer display is turned on and is on any 'Profile' menu. 1. Observe the page. 2. Press the down button repeatedly. 3. Press the down up repeatedly. 4. Press the 'Select' button 5. Repeatedly press the up button. 6. Repeatedly press the down button. 7. Press the 'Deselect' Button 8. Press the 'Down' button repeatedly until you reach the 'Run' option 9. Press 'Select' 10. Press Back.	1. A header should indicate what specific profile was selected. There should be 8 total lengths to be displayed, (named Length 1 to Length 8) with "Length 1" initially highlighted. Right below Length 8 should be a 'Run' option. There should be a "Select" option on the lower right and a "Back" option on the lower left. 2. One press of the down button will highlight the option below the current highlighted selection. Pressing the down button when the current selected option is the bottom-most (Run on this case) will not result in a change of the highlighted selection. 3. One press of the up button will highlight the option above the current highlighted selection. Pressing the up button when the current selected option is the top-most

		(Length 1 on this page) will not result in a change of the highlighted selection. 4. The highlighted option can now be edited as indicated by a darker highlight. The 'Select' button turns into 'Deselect'. 5. The pace time will increase by 0.5 seconds every time the up button is pressed. When the current pace time displayed is 30 seconds when the up button was pressed, then the pace time will be set to 'NOT SET'. 6. The pace time will decrease by 0.5 seconds every time the down button is pressed. When the current pace time displayed is 8 seconds when the down button was pressed, then the pace time will be set to 'NOT SET'. 7. The current highlighted option is now uneditable as indicated by a lighter highlight color. The lower right option on the page now says 'Select' 8. The 'Run' option is now highlighted. 9. An additional display should show "Running..." for brief period of time. Length1 will then be automatically highlighted. The 'Select' button should be not visible. 10. The display return to the Main Menu
CTM_5	Prerequisite: The swim pacer display is turned on and is on any 'Profile' menu. At the very least, Length 1 pace should be set. There should be at least 2 'NOT SET' length paces. 1. Go to a length pace that is 'NOT SET' which is after any 'NOT SET' length pace. 2. Press Select. 3. Press Up. 4. Press Down. 5. Press Deselect 6. Go to a length pace that is 'NOT SET' which is right after a length with a valid set pace.	1. The desired length pace is highlighted. 2. The highlighted button can now be edited as indicated by a darker highlight. The 'Select' button turns into 'Deselect'. 3. Nothing changes. 4. Nothing changes. 5. The current highlighted option is now uneditable as indicated by a lighter highlight color. The lower right option on the page now says 'Select'. 6. The desired length pace is highlighted. 7. The highlighted button can now be edited as indicated by a darker highlight. The 'Select' button turns into 'Deselect'.

	7. Press Select. 8. Press Up repeatedly. 9. Press Down repeatedly. 10. Press Deselect 11. Press Back.	8. The pace time will increase by 0.5 seconds every time the up button is pressed. When the current pace time displayed is 30 seconds when the up button was pressed, then the pace time should still be set to 'NOT SET'. 9. The pace time will decrease by 0.5 seconds every time the down button is pressed. When the current pace time displayed is 8 seconds when the down button was pressed, then the pace timewill be set to 'NOT SET'. 10. The current highlighted option is now uneditable as indicated by a lighter highlight color. The lower right option on the page now says 'Select'. 11. The display return to the Main Menu.
CTM_6	Prerequisite: The swim pacer display is turned on and is on any 'Profile' menu. The sequential light circuit is already running. 1. Observe the monitor. 2. Press the up button. 3. Press the down button. 4. Press the button that used to be 'Select' 5. Wait until the sequential light circuit has reached the end of a length. Observe the monitor shortly after this happens. 6. Press Back.	1. The current length pace is highlighted. The 'Select' button is not visible. 2. Nothing happens. 3. Nothing happens. 4. Nothing happens. 5. The next length is now highlighted. 6. The display is now back to the main menu.
CTM_7	Prerequisite: The swim pacer display is turned on and is on any 'Profile' menu. The sequential light circuit is already running. 1. Observe the monitor. 2. Wait until all the set lengths have finished running, then observe the screen. 3. Perform the test for CTM_4	1. The current length pace is highlighted. The 'Select' button is not visible. 2. The highlight will move from one pace length to the next. When the last length is finished, the 'Select' button should be visible again. 3. The CTM_4 tests should pass

6.2 Controller-to-lights test

Purpose: The part of this test ensures that the communication between the controller and the sequential lights circuit

Requirement	Test Steps	Expected Test Results
CTL_1	1. Turn on the Swim Pacer Unit.	1. The display turns on. No lights on the sequential light circuits are turned on.
CTL_2	Prerequisite: User should be in "Manual Mode" or any of the three "Profiles". The sequential light circuit must be already running. 1. Press the "Back" button	1. The sequential light circuit should turn off.
CTL_3	Prerequisite: User should be in "Manual Mode" or any of the three "Profiles". The sequential light circuit should be off. 1. Press the 'Run' button if in Manual Mode or scroll down to the "Run" button in "Profile Mode" then press the "Select button.	1. The sequential light circuit should turn on.
CTL_4	Prerequisite. User should be in "Manual Mode". The sequential light circuit must be running. 1. Press the "Up" or "Down" button at least 5 times. 2. Observe the sequential light circuit 3. Press ‘Override’ and observe the sequential light circuit.	1. The time displayed for "Length Pace" changes. 2. The speed remains the same. 3. The speed decreased or decreased.

6.3 Sequential Lights Circuit Test

Requirements	Test Steps	Expected Test Results
SLC_1	Prerequisite: User should be in "Manual Mode" or any of the three "Profiles". The sequential light circuit should be off. 1. Press the 'Run' button if in Manual Mode or scroll down to the "Run" button in "Profile Mode" then press the "Select button. 2. Observe the sequential light circuit	1. The sequential light circuit should turn on. 2. Only 1 light is on at a given point in time.
SLC_2	Prerequisite: User should be in "Manual Mode" or any of the three "Profiles". The sequential light circuit should be off. 1. Press the 'Run' button if in Manual Mode or scroll down to the "Run" button in "Profile Mode" then press the "Select button. 2. Observe the sequential light circuit	1. The sequential light circuit should turn on. 2. The lights sequentially "traverse" from right to left or from left to right one by one.
SLC_3	Prerequisite: User should be in "Manual Mode" or any of the three "Profiles". The sequential light circuit should be off. 1. Press the 'Run' button if in Manual Mode or scroll down to the "Run" button in "Profile Mode" then press the "Select button. 2. Observe the sequential light circuit	1. The sequential light circuit should turn on. 2. All lights should be able to turn on.

6.4 Tolerance Tests

Purpose: This test ensures that the sequential lights circuit is accurate up to 0.2 seconds

Requirements	Test Steps	Expected Test Results
TOL_1	Prerequisite: User should be in "Manual Mode" or any of the three "Profiles". The sequential light circuit should be off. 1. Press the 'Run' button if in Manual Mode or scroll down to the "Run" button in "Profile Mode" then press the "Select button. 2. Using a digital stopwatch, record the time it takes for the sequential lights to traverse across a length of a pool. 3. Compare the time you measured with the time displayed on the screen.	1. The sequential light circuit should turn on. 2. The time is recorded in a digital stopwatch. 3. The time should only be off by a maximum of 0.2 seconds.
TOL_2	Prerequisite: The user is in 'Manual' mode. The pace time displayed is set to 30 seconds. The sequential light circuit is not yet running. 1. Repeatedly press the up button. 2. Press Run. 3. Using a digital stopwatch, record the time it takes for the sequential lights to traverse across a length of a pool.	1. The time displayed on the monitor should still be 30 seconds. 2. The time sequential light circuit turns on. 3. It should take 30 seconds for the sequential light circuit to traverse across a length of a pool
TOL_3	Prerequisite: The user is in 'Manual' mode. The pace time displayed is set to 8 seconds. The sequential light circuit is not yet running. 1. Repeatedly press the down button. 2. Press Run. 3. Using a digital stopwatch, record the time it takes for the sequential lights to traverse across a length of a pool.	1. The time displayed on the monitor should still be 8 seconds. 2. The time sequential light circuit turns on. 3. It should take 8 seconds for the sequential light circuit to traverse across a length of a pool

6.5 Tolerance Analysis

To produce sufficient power to each LED, each LED should have a 200 mA current running through it when it is being lit up. We intend on allowing ±10% tolerance current running through an LED (± 20 mA). This could be measured using a current probe on the each line. We plan on placing a resistance on the LED power line. With a measured voltage, and known resistance, we will be able to have an accurate measurement of our current. Since our goal is to have an LED current of 300 mA and we plan on using a relatively high voltage input of around 5 volts, using the equation

$$R = \frac{V}{I} = \frac{5\ V}{200\ mA} = 25\Omega.$$

On 1% resistor tolerance:

$$I = \frac{V}{R} = \frac{5\ V}{25.25\ \Omega} = 198\ mA \text{ or } \frac{5\ V}{19.75\ \Omega} = 202\ mA$$

On 5% resistor tolerance:

$$I = \frac{V}{R} = \frac{5\ V}{26.125\ \Omega} = 191\ mA \text{ or } \frac{5\ V}{23.875\ \Omega} = 209\ mA$$

On 10% resistor tolerance:

$$I = \frac{V}{R} = \frac{5\ V}{27.5\ \Omega} = 182\ mA \text{ or } \frac{5\ V}{22.5\ \Omega} = 222\ mA$$

We can see from here that using a resistor with 10% tolerance, we can incur a current of 222 mA, which is 2 mA higher than our 10% tolerance level for current. Because of this, we are going to use a 5% resistor tolerance, which results in 191 mA and 209 mA are yielded from 26.125 Ω and 23.875 Ω respectively.

7.0 Cost and Schedule

7.1 Cost

Labor

Name	Rate	Hours	Total	Total x 2.5
George Garcia	$60/hour	240	$ 14,400	$ 36,000
Mark Alikpala	$22/hour	240	5,280	13,200
Miao Lu	$35/hour	240	8,400	21,000
			Grand Total	**$ 70,200**

Parts

Part	Quantity	Unit Cost	Total
Color LCD 128x128 Nokia Knock-Off	1	$ 14.95	$ 14.95
Clear Vinyl tubing 1" ID 100'	1	68.63	68.63
Microcontroller (PIC 18F4550)	1	4.59	4.59
Wearable Keypad	1	12.95	12.95
Wires	1	30.01	30.01
LEDs	100	0.15	15.00
Resistors, Capacitors, diodes, inductors		15.00	15.00
IC's		20.00	20.00
Miscellaneous components		10.00	10.00
		Grand Total	**$206.13**

7.2 Schedule

Week	George Garcia	Miao Lu	Mark Alikpala
1/23	Research programmable controller parts	Research interface sequential light control circuit parts	Research monitor display parts and high level design of sequential light circuit
1/30	Proposal: Design	Proposal: Introduction	Proposal: Verification & Requirements
2/6	Research programmable controller implementation	Research interface and sequential light control implementation	Research monitor display implementation
2/13	Complete block diagram, description, contents and simulations	Complete schematics, flow charts and calculations	Complete requirements & verification and tolerance & analysis
2/20 – DESIGN REVIEW	Update block diagram, description, contents and simulations with regards to design review critique	Update schematics, flow charts and calculations with regards to design review critique	Update requirements & verification and tolerance & analysis with regards to design review critique
2/27	-Prototype circuit implementation -Buy circuit parts	Circuit interface implementation	Create prototype of sequential light circuit through a protoboard
3/5	Program the controller	Interface controller with sequential light display	Interface controller with the monitor
3/12	Test interface and monitor display	Test every light turns on	Test light traverses at the set pace
3/19 – SPRING BREAK	Spring Break	Spring Break	Spring Break
3/26 – MOCK UP DEMOS	Add/Program “profile” feature to the swim pacer unit	Research on possible additional features for product enhancement	Test the product with Coach Howard Schein
4/2	Modify program profile feature’s efficiency	Test and implement the feasibility of the features for enhancement with Mark	Test and implement the feasibility of the features for enhancement with Lu
4/9	Test that each controller button works appropriately	Test that each light in the circuit works appropriately	Test that the monitor shows the appropriate displays
4/16	Troubleshoot any bugs regarding microcontroller	Troubleshoot any bugs regarding sequential light circuit	Troubleshoot any bugs regarding monitor display
4/23 – DEMOS	Construct final paper (Design portion)	Construct final paper (introduction, cost and misc.)	Construct Test and Verification
4/30 – FINALS PAPER DUE	Proofread Lu and Mark’s portion of the Final Paper. Work with Lu and Mark in combining the Final Paper together.	Proofread George and Mark’s portion of the Final Paper. Work with George and Mark in combining the Final Paper together.	Proofread George and Lu’s portion of the Final Paper. Work with George and Lu in combining the Final Paper together.

7.0 Ethical Considerations

The major ethical issue for our project is underwater safety. Our goal is to ensure the safety of all potential users. To accomplish this, batteries will be used instead of using the power source of an outlet to reduce the current in order to avoid potential electrocution. Clear vinyl tubing will be used to provide insulation for the LED lights, cables, and microprocessors away from water. We will make sure that the swim pacer unit is safe to use, and that it will not cause potential harm to users.

8.0 Citations

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