Modular Swimming Pace Aid

Project Proposal

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February 8, 2012

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1.0 Introduction

1.1 Statement of Purpose

This project was chosen because presently there are no devices that allow swimmers to visually follow a specific lap pace. As such, there is a high demand for a low cost underwater swim pace aid and we are excited to see if it is possible to make a product that would meet this demand. We have chosen to focus on the modularity of the device to make it easy to transport, assemble, and maintain, if necessary.

1.2 Objectives

1.2.1 Goals:

- Develop an underwater visual aid for swimmers to help maintain a set pace
- Enable modularity to fit any length pool
- Allow wireless control of the LED pace in real time from outside of the pool

1.2.2 Functions:

- High intensity (6500 mcd) green LED lights indicate pace to swimmer
- Wireless communication between modules
- Wireless communication between modules and controller
- Modules powered by batteries to prevent the risk of shocking swimmers

1.2.3 Benefits:

- Cost adaptable to pool size
- Electric shock is prevented by housing the batteries within each panel
- Visual system for clear indication of pace to swimmer
- Simple controller, allowing real time control of the pace

1.2.4 Features:

- LED panels are submergible in up to 2.5 meters of water
- LED lap pace will range between 8 and 45 seconds, in 0.5 second increments
- Underwater panel to panel communication at a distance of up to 3 meters
- Wireless setup, requiring no wiring by the user
- Battery lifetime of 1 year

2.0 Design

2.1 Block Diagrams

Since modularity is a key feature of the design, one controller and 3 modules will be produced to demonstrate the intended operation of the system. Figure 1 shows the overall system layout, with arrows indicating direction of communication between units. Figures 2 and 3 give a high level description of what is inside the display modules and controller, respectively.

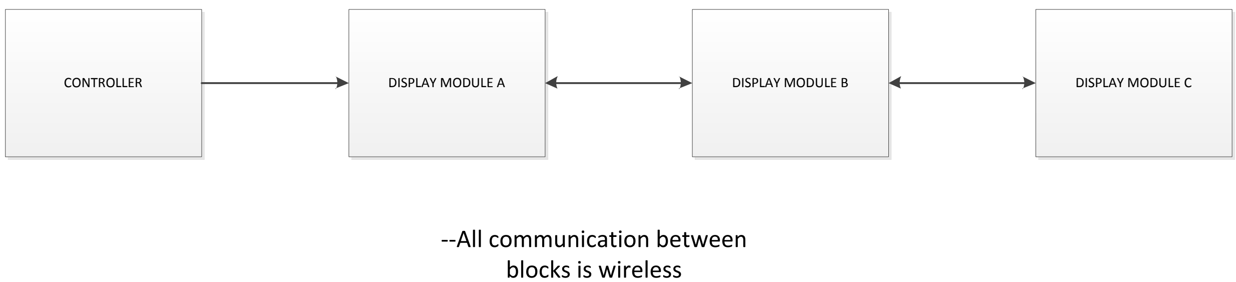

Figure 2. Top level system layout.

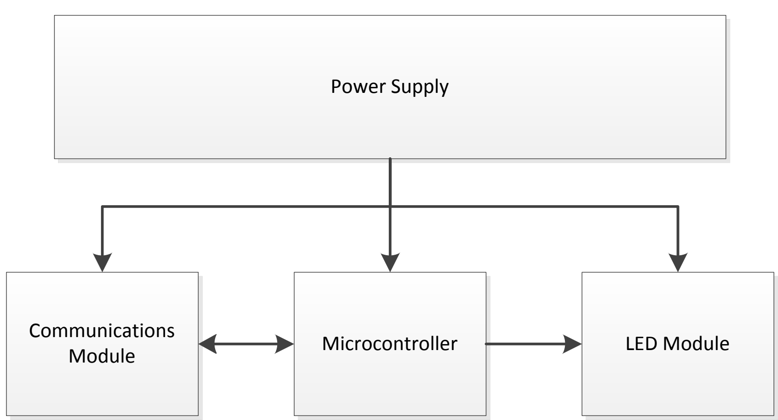

Figure 3. Display Module A, B, C block diagram from Figure 1.

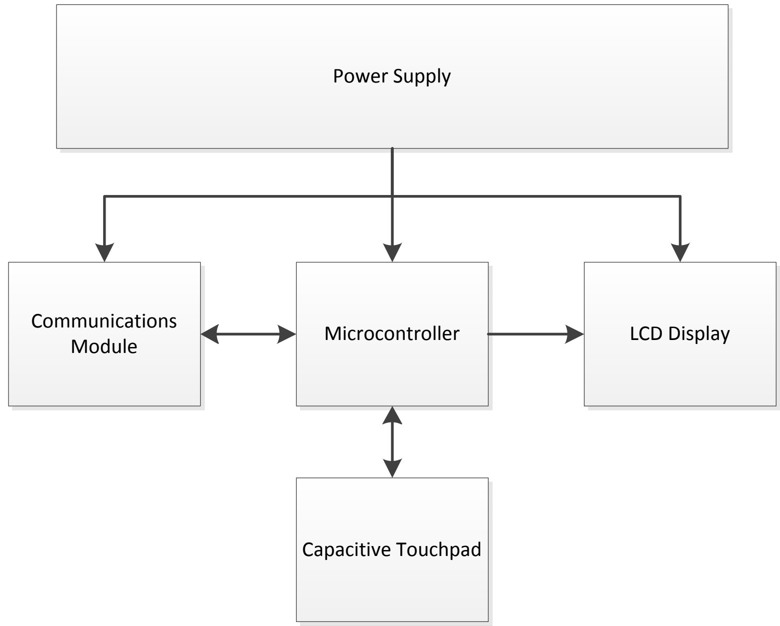

Figure 4. Controller Module block diagram from Figure 1

2.2 Block Diagram

2.2.1 Display Module Block Descriptions

Overall Summary:

The display module will be the underwater component of the system. It will light up to indicate the desired pace to the swimmer. It will consist of an MSP430, power supply, communications module, and an LED array. This will allow for communication between the other display devices and the controller module. The LEDs will light up in order to indicate location with respect to desired pace. The control signals propagate down the line from the beginning to the end of the chain of display modules and back. The LED lights will appear to light up like a wave bouncing back and forth between the end points.

Case Design:

The primary driver of the Display Module block is waterproofing. The design will be based on a clear acrylic box using waterproof sealant to close any seams. The case will also include a compartment that will house the batteries as well as a power switch. This compartment will be waterproof when closed. The boxes will have rectangular edges and dimensions of 1 foot by 1 foot by 3 inches. The dimensions of the display module are scaled down from the dimensions a commercial version would have to mitigate costs, since our goal is as a proof of concept.

Microcontroller:

The microcontroller used in the Display Module will be the MSP430. This device will be used as the primary control of the module. The microcontroller is powered by the source supply, which provides a constant 3V voltage to the device. The microcontroller will output control signals to the LED module through a wire. The microcontroller connects to the communication module through a serial connection. The primary reason for using this device is the low power consumption and low cost of the microcontroller. This unit will do all of the computation for pace, signal processing, and general control functionality of the display module block.

Power Supply:

The power supply will provide power for all of the components in the system. The power supply will consist of 3 AA batteries wired in series to provide a 4.5 V voltage source. The power supply will have reverse voltage protection in the form of a MOSFET reverse voltage protection circuit. The MOSFET circuit is a much more efficient alternative to a diode reverse polarity protection circuit and will increase the lifetime of the batteries in the voltage source. A low dropout regulator (LDO) or linear regulator will be used to step down the voltage source voltage to 3 V in order to provide power for the microcontroller and communications modules. The voltage at the output of the reverse polarity protection circuit (~4 V) will be sent to the LED module.

Communications Module:

The XBee transceiver located on each of the submerged modular LED panels will recognize and wirelessly communicate with the panels in front and behind them. Since these panels are submerged underwater, our system will have to be robust to the side effects of underwater communication. The mesh networking scheme will utilize the XBee RPSMA Series 2 transceiver so that the system can function as a mesh network and high gain antennas can be connected to help ensure signal integrity if necessary. The aforementioned XBee transceiver is also capable of low frequency data transfer, which is a necessity for underwater communication.

The transceiver interfaces with the microcontroller on each panel, providing information about when to begin lighting the LED's on the module and when to alter the pace. The first element in the modular string will need to communicate with the controller that is out of the water and then relay the changes to the last LED panel in the string such that the pacing of the LEDs will reflect the appropriate pace. The RX serial data port on the XBee will be connected to a serial out port of the microcontroller. Similarly, the TX serial data port on the XBee will be connected to a serial in port on the microcontroller. The communications module will receive a 3V voltage supply from the power supply, drawing a maximum current of 250mA.

LED Module:

The LED module will receive control signals from the microcontroller and use those signals to drive rows of high luminosity LED's. Each row will have 2 LED's and there will be 5 rows, spaced 2 inches apart. For the LED's, we will be using 6500 mcd green LED's. These LED's output 9.55 lumens, which is comparable to the minimum lumen output of high power commercial flashlights. The choice of LED color is significant because water absorbs much more light in the infrared side of the spectrum than the ultraviolet.

The LED module will consist of 5 independent circuits, with each circuit receiving one control signal from the microcontroller. Each circuit will have an amplifier stage that will convert the control signal from the microcontroller to a signal powerful enough to drive the row of LED’s. Current limiting resistors will be used to protect the LED’s from burning out.

2.2.2 Controller Module Descriptions

Overall Summary:

The Main Control Module is the out of water control unit that is used to set the pace and start the system. It consists of an MSP430, capacitive touchpad, LCD screen, wireless device, and power unit. The capacitive touchpad will allow the user to set the pace for the whole swim system. It will also allow for the initial set up of the overall system. The LCD screen will display relevant feedback information such as the set pace. This module connects to the others through a wireless interface enabling quick communication and setup without the hassle and risk associated with cords and water. The overall function of this block is to connect the outside user to the underwater panels. This provides a clear center for control over the overall system.

Case Design:

The case for the Controller Module is designed to be small and easy to use. There will be a space on the outside for the capacitive touch pad as well as compartment to house the batteries and a power switch. The internal circuits will be enclosed in a clear acrylic housing that will be sealed with a waterproof sealant. This device will not be designed for underwater usage.

Microcontroller:

The microcontroller that will be used is the MSP430. This was chosen due to its low power usage and cost. This is the same microcontroller that was used in the display modules. The MSP430 connects to the LCD through a serial connection, to the Capacitive Touchpad through the built in headers, and to the Communications Module through a serial connection. This will be the central unit doing calculations and signal routing for the overall controller module.

Power Supply:

The power supply used in the controller will be exactly the same as the one used in the display modules. In this case, the primary function of the power supply will be to power the microcontroller, communications module, and LCD display with a constant 3V source. The capacitive touchpad is powered by the microcontroller itself and therefore does not require its own power circuitry.

Communications Module:

The communications module will be able to relay data to the microcontroller such that it can synchronize the system with all of the LED panels. This will allow the panels to know whether they are first or last in the modular string and which panel is behind them and/or in front of them in the string. Once the system has been synchronized, the controller will only need to communicate with the first module in the string. The power and microcontroller connections are similar to that of the display module.

LCD:

The LCD display will provide a clear way to read out information about the system. This will be done using an MSP430 compatible device. This device will connect with the microcontroller through a serial connection.

Capacitive Touchpad:

The capacitive touchpad provides an input from the user into the Controller Module. This device is touch sensitive and will be used during set up, pace setting, starting, and stopping laps. It connects to the MSP430 through the built in headers.

2.3 Performance Requirements

1. The overall efficiency of the power supply should be over 50% in order to ensure battery lifetime of around 1 year at a usage rate of five hours per week. Initial calculations show that each module will require about 1560 mA-h. Typical AA batteries have a lifetime of 2100 mA-h. Therefore even at 50% efficiency and accounting for any unintended power losses in the system, we can guarantee the desired lifetime.
2. Lit LED's should be clearly visibly to a swimmer underwater if the display module is at a maximum depth of 2 meters.
3. Display module will be 100% waterproof, meaning that the electronics inside of the display module will not fail due to water issues over the entire lifetime of the product.
4. The pace should be updateable while in operation from 8 to 45 seconds in 0.5 second increments.
5. The panels must be able to communicate at distance greater than 3 meters and must be able to automatically connect to each other during set up.

3.0 Verification

3.1 Testing Procedures

1. Initial out of water testing will be done to ensure proper packet transmission and reception between two XBee transceivers. From this point, the next step will be to set up a mesh network between all the XBees to establish proof of mesh network configuration.
2. Once out an out of water network has been established then the next step will be two prove the underwater communication between the XBees.
3. The lifetime of the power supply will be tested by verifying both the efficiency of the power supply and the power requirements of the modules. First, the power drawn by the modules will be tested by connecting a bench voltage source to one of the modules and measuring the current drawn from the voltage source. Normal operation of the modules will be simulated by sending function generator generated signals to the modules in order to drive the LED's at a pace of 30 seconds per lap. The efficiency of the power supply will then be tested by measuring the input power and output power of the power supply under a load that matches the one drawn by the modules under normal operating conditions.
4. The amplifiers in the LED module will be tested by driving them with control signals from a function generator. Various frequencies of control signals will be tested, ranging from 8 to 45 seconds per lap in 0.5 second increments. Proper performance will be tested by measuring the current produced by the amplifiers and comparing it to the current required by the high power LED's.
5. The final verification stages include using the Touchpad and LCD screen to test that the input to the system is correctly relayed to the underwater modules. To do this, the Touchpad will be used to set various paces, displayed on the LCD, and the display module output will be timed to ensure correct functionality of the full system.

3.2 Tolerance Analysis

The tolerance analysis will be based on the sustainability of a specified pace over a long period of time. In order to test this, the system will be set up underwater as normal. The pace will be set at several different rates and a series of timing measurements will be made. The measurements will be of the time for the signal to run through a large number of laps to determine average pace. The goal will be to have an error in the actual pace and set pace to be less than 5% in this small scale set up.

4.0 Cost and Schedule

4.1 Cost Analysis

4.1.1 Labor

Name	Hourly Rate	Total Hours Invested	Total = Hourly Rate x 2.5 x Total Hours Invested
Michael Chan	$35.00	150	$13,125
Igor Fedorov	$35.00	150	$13,125
Ryan Cook	$35.00	150	$13,125
Total		450	$39,375

4.1.2 Parts

Item	Quantity	Cost ($)
LED's	30	12.60
MOSFET's	19	14.82
PCB's	4	132.00
Resistors, Capacitors, Inductors		30.00
Linear Regulator	4	1.72
LCD	1	10.00
Capacitive Touchpad	1	10.00
Acrylic Sheet 48" x 48" x 1/8"	1	60.00
MSP430 Launchpad	4	17.20
Wireless Units	4	140.00
Debugging/Programming Tools	1	30.00
Batteries	12	8.00

4.1.3 Grand Total

Section	Total
Labor	$39,375
Parts	$466.34
Total	**$39,841.34**

4.2 Schedule

Week	Task	Responsibility
2/6	Finalize and hand in proposal	Ryan
	Research reverse polarity and amplifier circuits	Igor
	Order Xbee transceivers	Michael
2/13	Conduct PSPICE simulations of reverse polarity and amplifier circuits	Igor
	Order LCD	Ryan
	Design Review	Michael
	Connect Wireless Device To MSP430	
2/20	Research power supply	Igor
	Order parts for power supply, reverse polarity, and amplifier circuits	
	Learn To Program Touchpad	Ryan
	Two Wireless Devices Detecting Each Other	Michael
2/27	Assemble power supply, reverse polarity, and amplifier circuits for testing	Igor
	Program & Test both Touchpad & LCD	Ryan
	All Wireless Devices Connected To Network	Michael
3/5	Lay out PCB board for display modules and controller	Igor
	Build control box & display box. Test for leaks.	Ryan
	Full Communication Between Devices Out of Water	Michael
3/12	Order display module and controller PCB's	Igor
	Program Visualization on MSP430	Ryan
	Test Underwater Communication	Michael
3/19	Assemble PCBs for controller and display modules	Igor
	Mock Up Demo	Ryan
	Test communication between water & air	Michael
3/26	Completion of modules	Igor
	Tolerance analysis	Ryan
	Verification of specifications	Michael
4/2	Fix remaining issues	Igor
4/9	Ensure completion	Ryan
4/16	Prepare Demo	Michael
	Prepare Presentation	Igor
	Prepare Paper	Ryan
4/23	Demo	Michael
5/1	Presentation	Igor
	Final Paper	Ryan
	Check In Supplies	Michael