Final Documentation

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1 Introduction

1.1 Problem

In the world of recreational and competitive swimming an important skill is necessary to obtain peak performance from swimmer: the flip turn. While not usually a difficult skill to master and implement, visually-handicapped swimmers are at a severe disadvantage due to their inability to judge their distance from the end of the pool. Currently the method of choice is to have a person at each end of the pool tap the swimmer on the head/neck/shoulder area at a swimmer-specified distance from the wall. Even though this is a technologically simple approach to the problem, it requires special personnel at all times because of the tapping consistency necessary to prevent injury to the swimmer (i.e. tapping too close to the wall may cause the swimmer to hit their head, feet, or legs on the wall). These reasons have fueled a development effort to design a more consistent tapping method requiring fewer personnel.

This system has very strict guidelines and requirements as a result of the application and operating environment. Without doubt, the most pressing design constraints deal with the water environment. To prevent shorts in the circuitry and corrosion, anything that could come in contact with water should be waterproof. In addition to this, any devices placed on the swimmer must be done in a manner to reduce aerodynamic drag (a crucial quantity in swimming). Aside from these encasing restrictions, the desire to eliminate physical tapping dictates that this solution implements a reliable wireless signaling method. Also, for competitive sight-impaired swimmers rules exist to prevent the use of auditory signaling methods in competition, limiting this design to a non-audible signaling method (most likely vibrating motors). In addition to these requirements, a flip turn system should be tunable, meaning the swimmer should be able to adjust the point of notification closer to or farther from the wall as they see fit as taller swimmers usually start their flip turn farther out than shorter swimmers.

Throughout the design process various obstacles or realizations have influenced the design requirements. First and foremost was how to power the devices. With the transmitter and receiver being mobile devices, power consumption and battery life become important, and safe operation within a water environment points to low operating voltage and current to prevent serious injury.

1.2 High Level Description

Using these requirements, a functional high-level design can be pieced together. The core ideas behind the design are some method of detecting a swimmer at a desired point in the pool and some method to signal or alert the swimmer that they have reached the desired point. Our method of detecting a swimmer hinges around infrared motion detection using a device known as a Pyroelectric InfraRed sensor (PIR). This device outputs a signal to some processing device that determines when to signal the swimmer utilizing some wireless form of communication. The swimmer wears a device that needs to receive the wireless signal and then use it to actuate a vibrating motor. Therefore, a simple data flow would be PIR to controller, controller to transmitter, transmitter to receiver, receiver to motor through a MOSFET switch.

1.3 Design Performance

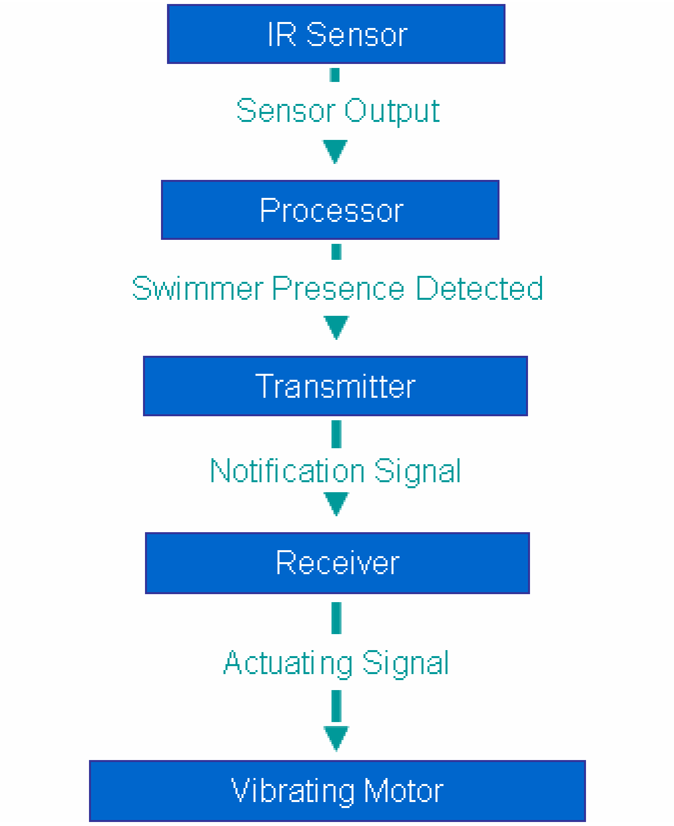
We were able to fulfill most of our design requirements with one major drawback: we are unable to detect a swimmer performing the freestyle stroke. We postulate that this is due to absorption of the main source of infrared, the face, because the face is not exposed. When the swimmer performs backstroke we are able to detect and notify them. This supports our theory because the face is not submerged during the backstroke and as a result more infrared radiation is incident to trigger the motion sensor. We are also able to notify the swimmer manually with a pushbutton, allowing the design to be a digital tapping system incase the PIR fails to detect the swimmer. Therefore, our design behaves mostly as we thought it would with the exception being a lack of autonomous detection for a swimmer performing the freestyle stroke.

2 Detailed Project Description

2.1 Theory of Operation

There are two subsystems involved in the solution to this problem, sensing and signaling. The sensing portion uses infrared technology to detect the swimmer and a microcontroller to analyze the sensor input. The signaling portion use radio frequency transmission to send a signal from the sensing portion and alert the swimmer of their detection. The alert is made by actuating a vibrating motor.

2.2 System Block Diagram



2.3 Sensing: Detailed Operation

The sensing part of the system involves detecting the swimmer accurately when he/she reaches a certain point in the pool and are ready to flip turn. The detection of the swimmer involves taking the output of a sensor and monitoring it on a microcontroller to determine when the swimmer has arrived by checking the sensor output for certain criteria. Once the swimmer has been sensed, the microcontroller outputs the signal that must be transferred to the swimmer.

2.3.1 Sensors Considered

Integral to the success of this portion of the system is the choice of sensor. The sensor must be able to detect the swimmer as he/she passes through water. It must be accurate, precise, and have a range of at least two meters. It must be able to be made water resistant, small, and within our budget. It must also be tunable as each swimmer turns at a different point (based on height and preference). We considered using RFID, ultrasonic, infrared, and ultrasonic through beam sensors. When looking at sensors, we considered all of these criteria in making our decision:

Sensor Type Pugh Matrix

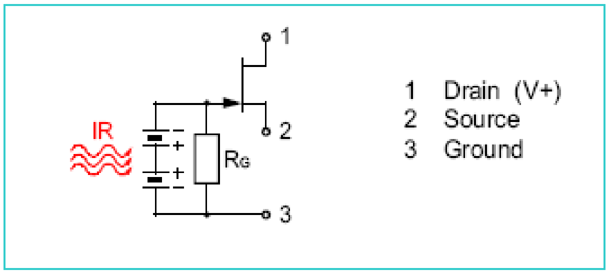
Factor	**Weight**	**Sensor Type:**	*RFID*	*IR*	*Ultrasonic*	*Thrubeam*
Cost	5		-1	1	-1	-1
Underwater use	5		-1	1	1	1
Accuracy	3		0	0	0	0
Range	5		0	0	1	1
Size	3		1	1	1	1
Ease of Use	3		1	1	0	1
Tunable	1		1	1	1	-1
		Total:	**-3**	**17**	**9**	**10**

Based on the evaluation above, we decided to focus on investigating infrared and ultrasonic sensors. Most ultrasonic sensors that somewhat fit our needs were too expensive for our budget. They also faced serious problems when considering the air-water boundary as ultrasonic waves can be reflected by the boundary. Because of these drawbacks, we spent the majority of our time investigating, testing, and ultimately choosing infrared sensors.

2.3.2 Kube Pyroelectric Infrared Sensors

The first infrared sensor we tried was made by Kube, a company in Switzerland. These sensors were pyroelectric infrared sensors (PIR). The sensors take in infrared radiation which in turn controls the gate of an internal JFET. The sensing elements are set up as series opposed dual where the voltage drop across the sensing element depends on the amount of infrared the element sees. If the same amount of infrared radiation (for example from a far away source) is seen by both elements, the voltages cancel out. In order to sense objects within some close range (2m-3m) a divider must be put between the sensing elements to isolate the IR radiation reaching each element.

Internal Circuitry and Pinout

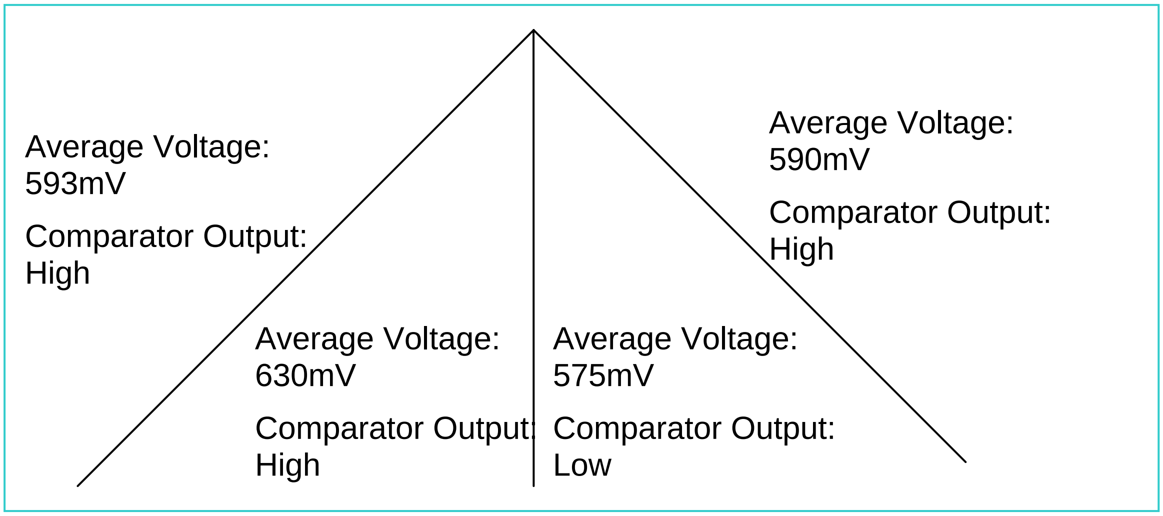


We chose to use a differential circuit where we took the output of the PIR and sent it to the positive terminal of a comparator, and sent the same output signal through a low pass filter to the negative terminal of the comparator.

This circuit was set up so that when the output of the PIR increased, the comparator would output a high signal until the capacitor charged and the negative terminal was a higher voltage than the positive terminal. The time constant of our circuit was approximately 0.33 seconds. We used the comparator included in the microcontroller and wrote a simple program in SourceBoost to set up the comparator inputs and output.

At the interface between the sensing elements (in the center of the field of view) is the separator. We tested the field of view by walking horizontally across the field, taking note of when the comparator switched from high to low and what the voltages were at those points. Taking the field of view of the above horizontal diagram, the following displays the results we obtained in the Learning Center (averages computed as a result of 10 passes):

Kube PIR Output In Lab

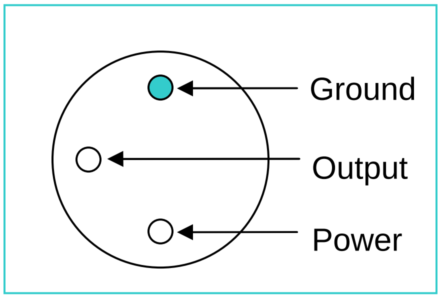


With this setup, we were able to accurately detect the presence of a person in line with the center of the PIR to within 6 inches. With these positive results we took the sensor to the pool to observe its behavior. At Rolf's Aquatic Center, the output of the PIR was very erratic because the lights above the pool output an extremely high level of infrared radiation. This behavior caused numerous occasions of false detection. We were unable to determine whether or not any of the detection was due to the lighting or the swimmer. We then took the sensor to the Rockne Memorial pool (the Rock). The lighting at the Rock is considerably different from Rolf's and our hope was that we wouldn't get false readings and would be able to determine whether or not the sensor was capable of detecting a swimmer in water. While our tests at the Rock produced no false detections due to lighting, we were also unable to detect a swimmer in water. After several runs and analysis of the output voltage, we determined that the sensor was not sensitive enough to detect a person with a layer of water over them.

2.3.3 Panasonic Infrared Sensors

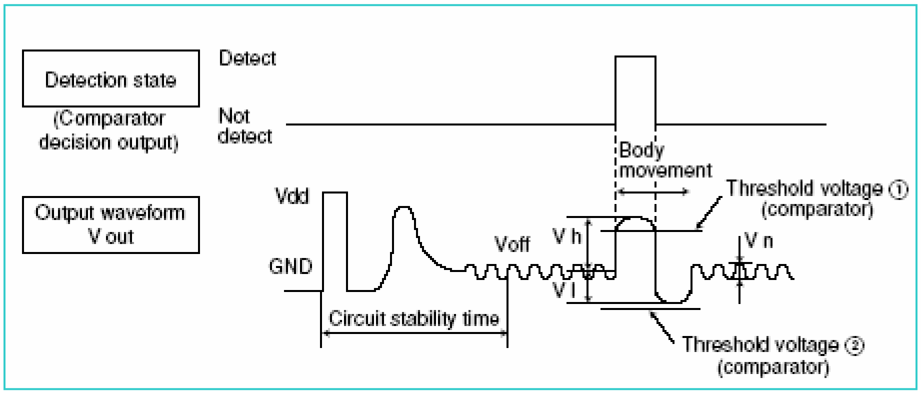
With further investigation we found infrared sensors by Panasonic that were rated to be considerably more sensitive and had built in amplification circuitry. There were several types to choose from: standard, long range, spot detection, and slight motion. We decided that either the spot detection or the long range sensors would be suitable for our application because the spot detection sensor limits the field of view of the sensor so false detection of swimmers in other lanes could be kept at a minimum. If the water did absorb some of the infrared signal, the long range sensor could give us the extra sensitivity we would need to overcome such a loss. Because all of the circuitry is internal to the infrared sensor, the only sources we needed to supply it were power (5 volts) and ground, and the third pin was the analog output of the sensor.

Panasonic Infrared Sensor Pin Out



This sensor output functions by holding steady at approximately 2.5 volts when there is no source of infrared radiation—again, the internal circuitry accounts for cancellation of infrared sources at long distances (i.e. the sun, lights at the pool, etc)—and when a source enters the field of view the output swings high then low. The amplitude and frequency of the swing are dependent on the intensity and speed of the infrared source.

PIR Operation



When the sensor initially receives power, it takes several seconds for it to stabilize and in that time detection is impossible. From testing, this time is less than 10 seconds.

We connected the sensor on a breadboard to a power supply at five volts and tested its behavior in lab. We found that the sensor was not only more stable than the previous infrared sensor, it was considerably more sensitive detecting small movements from a larger range. By looking at the output of the oscilloscope in lab we could see that at equilibrium, the voltage would hover between 2.4 and 2.6 volts and once a person walked in front of the sensor it would swing as high as the input voltage and as low as one volt. This distinct signal allows for easy processing in the microcontroller to determine when a swimmer is in the field of view.

With success in the lab, we took the Panasonic sensor to Rolf's to see its behavior around the pool. Even with the strong infrared signal from the lights, the cancelling circuitry in the sensor allowed the output to stay at the same steady 2.4 to 2.6 volts as in lab. The same was true for positioning the sensor above and directed down at the water. This steady output prompted us to gather data via oscilloscope in the case where a person swims by the sensor. One of our group members acted as the swimmer, swimming past the sensor and producing the following output:

The swimmer swam by twice with a pause in between, indicated by the two fluctuations in signal with the flat break in between. The voltage output was not as high as in lab, but that was an expected result because the infrared radiation is partially absorbed by the water. We repeated this test several times with similar results.

Based on these results and the recommendations from the manufacturer, we decided to set threshold values in the microcontroller that would indicate when a swimmer is in the field of view. We set a high threshold value for the minimum high voltage the signal should exceed and a low threshold value for the maximum low voltage the signal should drop below for detection. For example, in the above figure the threshold values could be set at 3 volts high and 1 volt low to detect the presence of a swimmer. The signal is between these two values when the swimmer is not present and when the swimmer is present, the signal is above the high or below the low value.

2.3.4 Microcontroller and Program

Two crucial components of our system are the microcontroller and the program it implements. At the beginning of the design process we used the PIC18F4620 microcontroller, a large chip with an even larger feature list. However, our system does not require a large amount of processing ability as we are only concerned with a single analog input signal, one digital input signal, and two digital outputs. The most complicated hardware requirement is the ten-bit analog-to-digital converter that converts the PIR analog input into a number that the microcontroller can use. Therefore, we decided on a much smaller package, the PIC16F88 (less than half the pin count of the 18F4620), which has a ten-bit A/D converter. With ten bits of conversion, the output is a number between zero and 1023 with zero corresponding to zero volts/ground and 1023 corresponding to five volts/Vdd. Using this digital information we wrote a program that performs an A/D conversion then loads the two A/D result registers into one usable variable. The A/D result is right justified meaning the least significant bit is bit zero of the ADRESL register, and the most significant bit is bit one of the ADRESH register. To get this information in a usable format, the ADRESH register is set to the 16-bit variable adresult then the adresult bits are shifted eight bits to the left, leaving the eight least significant bits empty for the ADRESL information OR operation with adresult. The final value of adresult is a number between zero and 1023 depending on the voltage level of the analog input.

In addition to the A/D converter, other features of the 16F88 include appropriate number of analog input and digital I/O pins, high-speed external clock ability, serial communication capability, and reprogrammable flash memory. The I/O pins are easy to use and manipulate keeping the program code extremely readable. By setting each pin as a volatile bit with some user-defined handle name, the output pins can be set to either zero or one depending on whether the output needs to be zero or five volts respectively.

Within the program loop, an A/D conversion is performed and the result is loaded into the adresult variable. The program then checks to see if the manual “tap” button has been pressed by checking to see if the digital input pin has been pulled low (zero volts). If the button is pressed the program sets the transmit pin to “on” for as long as the button is pressed. Then the program checks to see if adresult is above or below certain threshold values established during earlier testing. If the thresholds are met, the program transmits a 75% duty cycle square wave with a period of about one second for a programmer-defined number of repetitions. To accomplish this goal we used a millisecond delay function that is not entirely accurate but is easily tuned using trial and error. For the purposes of our project the precision of the wave’s period is not important because the swimmer only needs to be able to feel the vibration for a short time. The pulsing nature of the waveform is intended to give the swimmer multiple attempts to feel a difference between the motor being “on” and “off”.

The above information covers the basic operation of the program, but for troubleshooting purposes the program supports a serial output of the A/D converter values. A serial initialization function is included to prepare all serial transmission and reception registers as well as the baud rate. It also clears the transmission information register. An additional function is included that will write ASCII characters to the serial output that can then be read using the USBee logic analyzer serial decoder. Within the main program, the adresult integer value is converted to four character bits, and each adresult is preceded by a dollar sign ($) and ended by an asterisk (*). A sample serial output could be the following: $0752*$0780*$0800* corresponding to the adresult values of 752, 780, and 800.

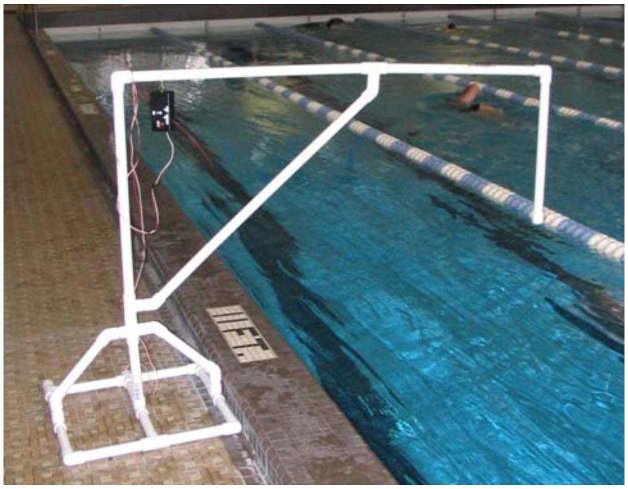
2.3.5 Test Rig

In order to get an effective output from the PIR sensor it needs to be in an appropriate position that will maximize the probability of detection. For this reason some sort of mounting system had to be designed that would allow the PIR to point vertically to the area of detection. For this proof-of-concept design our requirements allowed us to limit ourselves to a single swimmer in a single lane meaning we could build a movable sensor stand along the side of the pool. Using PVC pipe, we constructed a simple structure bearing some resemblance to a hang-man gallows with a special cap at the end of the hanging part that holds the PIR sensor. It is approximately 1.19 meters tall, 1.83 meters long, and 0.57 meters wide with a 0.58 meter down-pipe containing the PIR. In order to power the device and obtain the output signal, three separate wires (Vdd, ground, and signal) were connected to the PIR and strung through the pipes, exiting through a hole in the base. These three wires were attached to a connector that could be used to attach or detach the PIR from the control box.

For the control box, we used a simple black box approximately five inches long by three inches wide by two inches deep. This box shape gives us enough internal area for a printed circuit board containing all circuit elements, as well as enough volume to contain all necessary components. At the same time it is an appropriate size that is not unwieldy or difficult to hold. All exterior components are labeled with printed labels, not embossed labels or Braille because a person with the ability to see will be responsible for pressing the manual “tap” button and a blind person could easily turn the system on with the power toggle switch. Storage of the control box is simply a cup hook on the end of the box that can be attached to a matching cup hook on the PVC rig.

Ideally this sort of system would be extremely portable and easy to set up. However, given the importance of position of the sensor the type of rig constructed is not terribly portable and basically requires a person with the ability to see to properly setup the initial placement of the PIR. Once set, the swimmer may move the rig forward or backward depending on their desired signaling position.

Test Rig



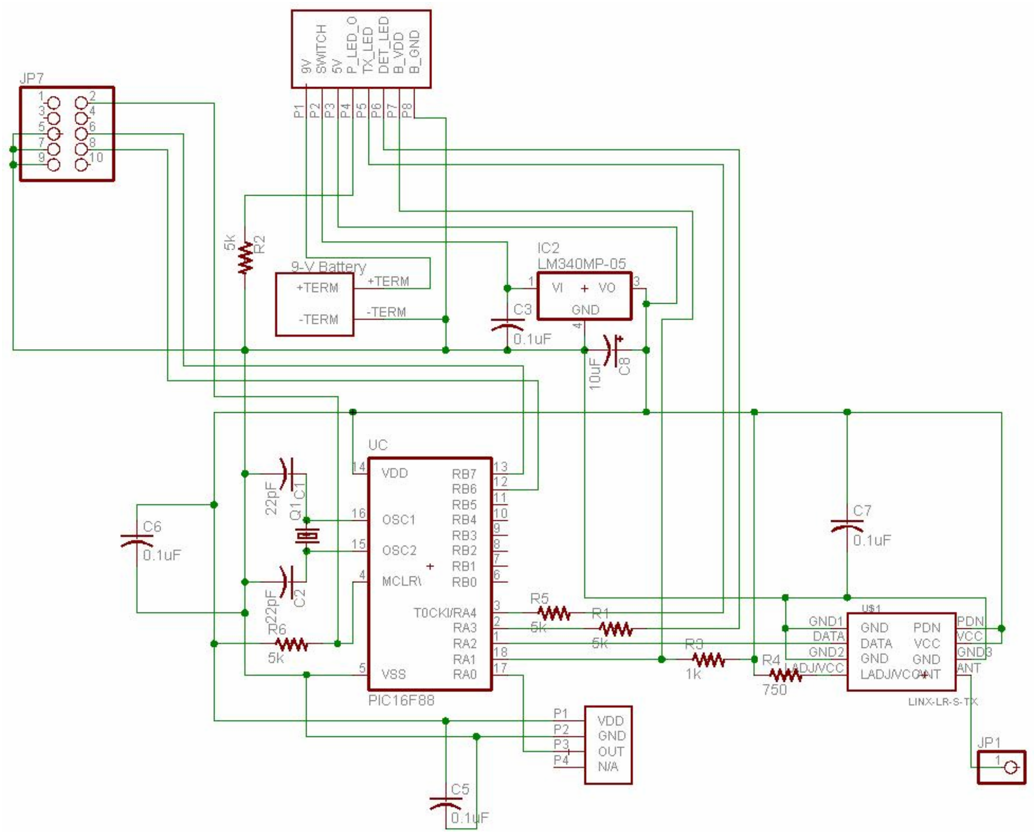
2.3.6 Board Design

In designing our board we had several requirements regarding functionality and size to consider. Our power source needed to be simple yet effective so we designed our board around a nine-volt battery that would provide appropriate voltage and current characteristics along with easy mounting capability. We wanted our board to fit inside the control box and have the ability to control and monitor certain aspects of the board from outside the casing, such as the status of the power system and signal transmission. The controls for the power system involve an on/off toggle switch along with an LED wired between Vdd and ground through a resistor. The controls for the signal transmission system involve a manual button that someone on the pool deck (coach, personnel, etc.) could use to signal the swimmer whenever they feel it necessary and an LED tied between Vdd and a microcontroller output port. By setting the output port to high, no voltage difference exists between Vdd and the port, resulting in an “off” LED, with the opposite output port setting (low) creating a path for current and an “on” LED. This design decision was made on the grounds that the microcontroller can sink more current than it can source, allowing a higher current value and therefore a brighter LED. Thus, to indicate transmission set the LED output port value opposite that of the output port connected to the transmitter data port. This will cause the LED to turn “on” during transmission and “off” when not transmitting.

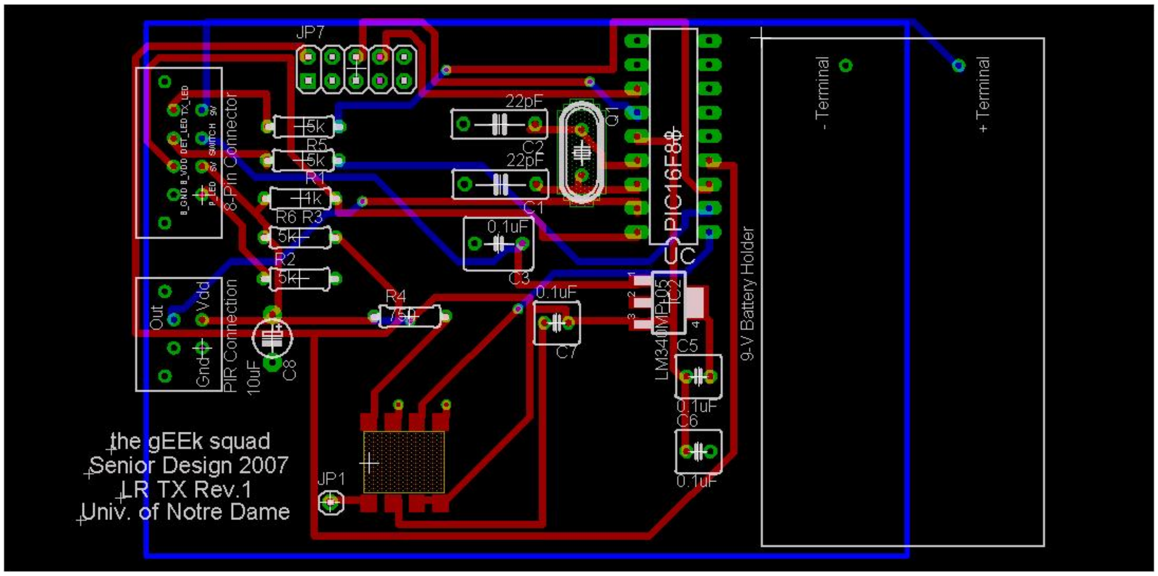
Control Box

With the external hardware devised, the support circuitry on the PCB must be laid out in a logical, space-saving manner. The largest part to consider is the nine-volt battery holder because with the battery connected, it takes up a significant volume and must be placed away from all external mounted hardware due to the limited depth of the box. Therefore, the battery holder is mounted far to one side and the external hardware is mounted above their board connector on the opposite side of the PCB. As for the other electrical components, the only real special placement consideration is with the transmitter. The datasheet specifies that no traces should be run underneath the transmitter package, and for performance purposes the package should be placed far away from other electrical components. The remaining board components (microcontroller, resistors, voltage regulator, capacitors, etc.) were placed in a manner that simplified soldering and path routing. As a result, our board has appropriate topography and all components fit as desired within the confined box volume.

Sensing Schematic



Sensing Board Layout



2.3.7 Sensing Subsystem Testing

The first step in testing our subsystem was to assemble the board we designed. The first step in assembling the board is to connect and test the power source to make sure that we are getting out the appropriate voltage from the regulator. We ran into difficulties when we connected the voltage regulator, but quickly rectified the problem by adding the necessary capacitors. We checked that the switch appropriately activated the power source and that the “power on” light came on when the switch was turned on. Once the power source was working, we proceeded to solder the rest of the components onto the board with no difficulty, checking that the connections were complete with an ohmmeter as we made them. The only other assembly related problem encountered was in crimping the wires into the connectors. We initially used a crimping size too large for the wires and pins we had so we had to re-do all of our connectors with the appropriate size of crimpers.

Once the board was assembled, we connected the infrared sensor to the control box and turned it on. When the control box is turned on for the first time, the transmit light blinks on and off for two detection cycles as the PIR is equilibrating. We used a hand to trigger the PIR detection and we were able to see that the PIR output could cause the microcontroller to send a signal to the transmitter by first watching the transmit LED blink on and off and then checking the voltage on the data pin of the transmitter.

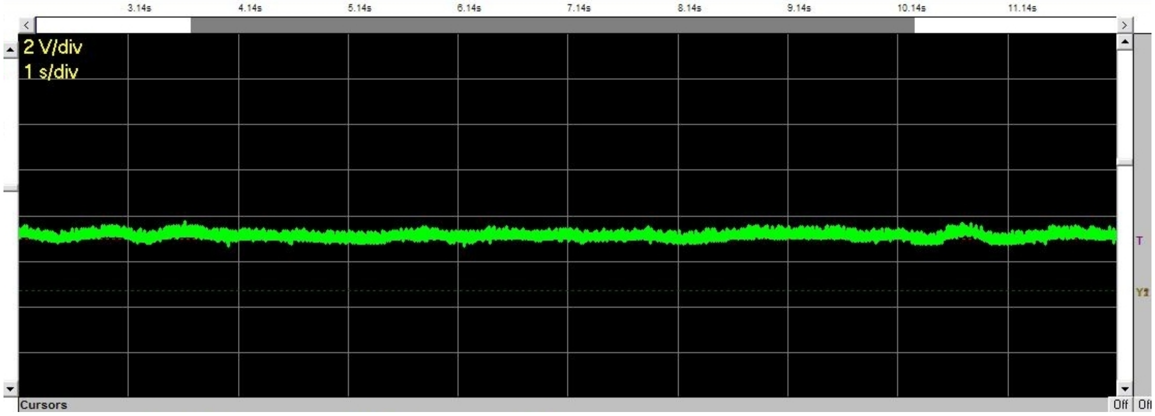
The next step in testing the sensing subsystem was to take the system to the pool to observe the behavior of the PIR in the pool. For varying levels of sensitivity, we programmed three microcontrollers with varying threshold values: one set at 400 low/600 high, one at 350 low/650 high, and one at 300 low/700 high. In the lab, all of our tests were performed with the largest range program (300/700) but because of the absorption of infrared by water, we were unsure of the absolute sensitivity of the PIR in water. From our previous tests in the water, it appears that the signal goes from just above 3 volts to just below 2 volts, corresponding to the 400/600 program.

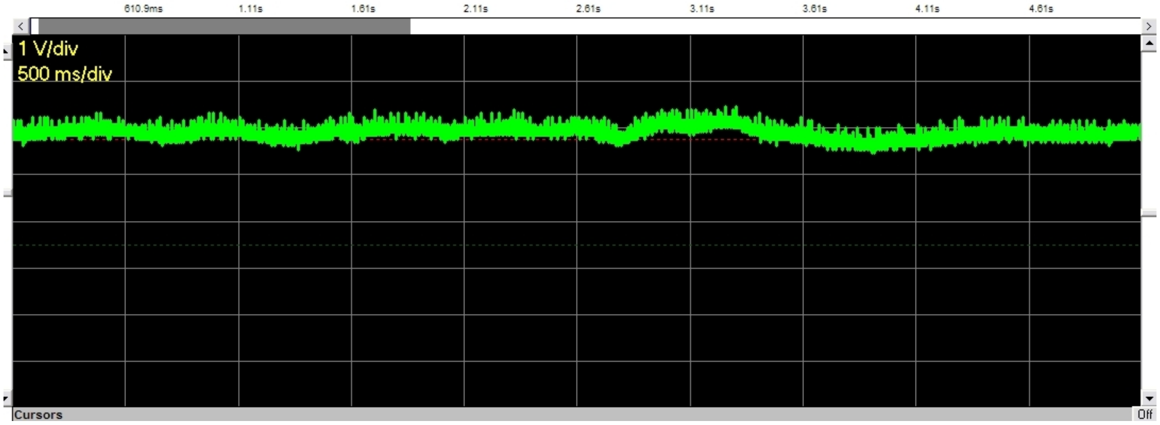
At the pool we set up our test rig above the water so that the PIR was centered over the lane. We started our testing with the 300/700 microcontroller in place. We then turned on the control box and waited for the PIR to equilibrate. Once the transmit light had turned off we waited to see whether or not our threshold values would result in false detection. After several minutes, we decided that the range was wide enough to not result in any false signaling. We then had a member of our team (a different member from the first test) get in the water to test the sensing system.

We first had him move with his head and torso out of water underneath the PIR and we took readings on an oscilloscope:

This output corresponds to him moving under and triggering the sensor, leaving the field of view, and re-entering the field of view, triggering the sensor again. Both of these triggers caused the transmit LED to flash, indicating that the detection signal was being sent to the transmitter.

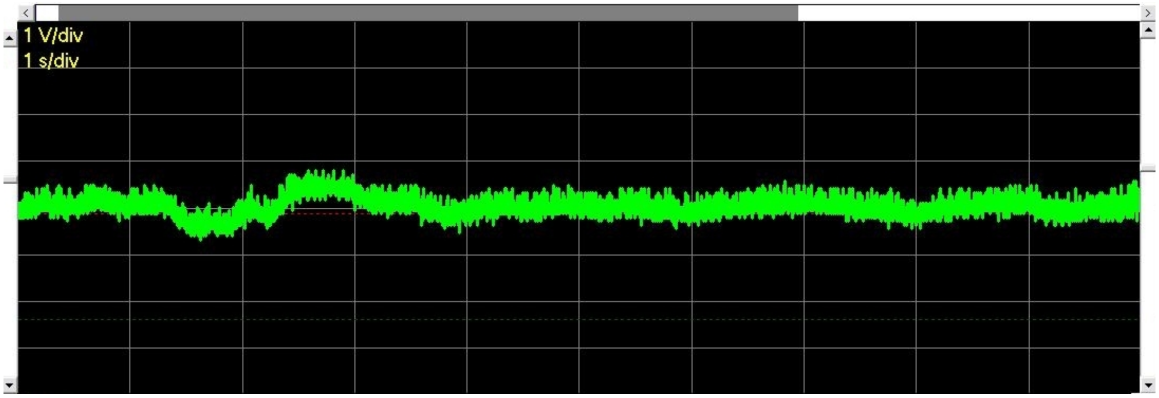
The next test was to swim freestyle past the sensor and view the output. After several passes, we were unable to detect the swimmer swimming past the sensor. We decided to change out our microcontroller in favor of one with more sensitive threshold levels. We installed the 400/600 microcontroller, turned on the control box, and waited for the system to come to equilibrium. The swimmer again made several passes without triggering the sensor. We took data on the oscilloscope to see the signal coming from the PIR and obtained the following:



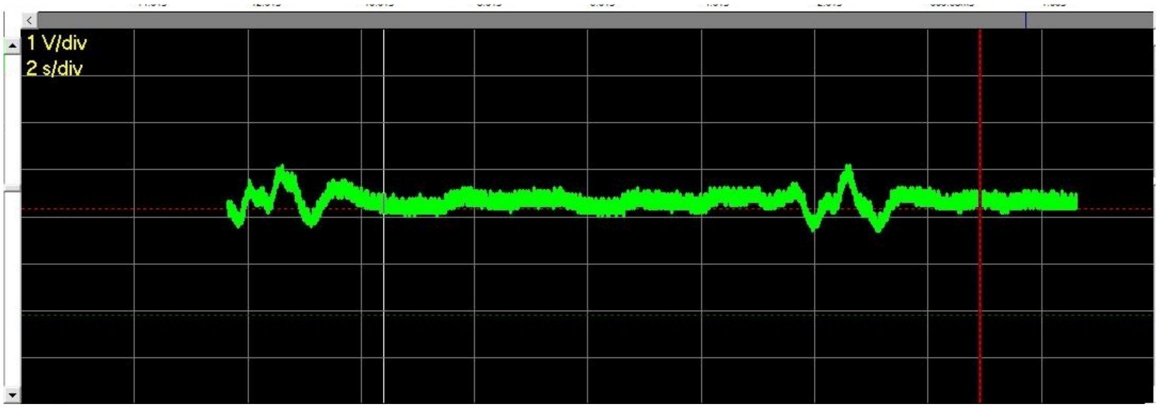


Looking at these outputs, it is apparent that the voltage never reaches a high enough or low enough value to trigger the detection signal in the microcontroller. In fact, it is difficult to tell even by looking at the plots which part of the plot represents the presence of the swimmer.

We postulated that the reason our results were so different from before was because the swimmer in the first test was inexperienced and their technique made it so that a large area of their body and face were out of the water at any point in time. The swimmer in the second test was an experienced swimmer with proper technique whose body was coated by at least a thin layer of water at any point in time and whose face was always submerged. From looking at various images of people taken with infrared cameras, the face is often the warmest part of the body. We thought that perhaps the reason the first swimmer was able to trigger the sensor while the second was not was because the first swimmer's face was out of the water most of the time. We decided to test this theory by having our swimmer attempt to breathe to the side facing the sensor as he passed under it. This produced the following result:



While still not optimal, this test does show that the face produces a more distinct signal than the rest of the body. We decided to further test this theory by having the swimmer swim backstroke under the sensor because during backstroke the face is constantly out of the water. Several trials of this produced similar results:



The output of the wave for backstroke is much stronger than for freestyle. In fact, the signal is strong enough to trigger detection in the microcontroller.

In order to make this sensor work for freestyle, an extensive amount of data must be taken and analyzed to see if there are any distinguishing characteristics that can be identified in the detection software. Another possible solution is to use a more sensitive infrared sensor.

2.4 Signaling: Detailed Operation

2.4.1 Receiving Signal

The signaling portion of the system is done with radio frequency transmitters. RF transmitting involves a transmitter and a receiver. The transmitter takes an input signal from the sensing subsystem. This signal comes from a microcontroller. The signal consists of an on (5V transmitted signal) and off (0V transmitted signal). The signal alternates between on and off 4 times. The transmitter takes this input and sends it at 315 megahertz to the receiver. The receiver then takes this signal and outputs it to the rest of our circuit, which actuates a vibrating motor.

Initially our group narrowed down the choice of signaling technology to two options. These options were ultrasonic and RF (which we ultimately chose). There were several reasons that we finally decided on RF. The ultrasonic sensors that we were testing with ran into several problems. One main problem that we found was that the sensors are very directional. A turn of 90 degrees would completely eliminate any signal. Also, if the sensors were facing each other, but offset slightly, the signal again would be attenuated. This would have resulted in having to line several ultrasonic sensors along the edge of the wall in order to ensure a strong signal received on the swimmer's head. The largest problem we encountered with the ultrasonic technology was that if a person stepped between the two sensors, they would not go through that person. This is a huge problem because the sensor on the swimmer would have to be encased in some sort of waterproof package or under the swimmer's cap. There is also the possibility of the sensor being underwater at times and the ultrasonic technology would not be able to handle these conditions.

RF technology seemed to be the best option for our system. The first RF technology that we worked with was a product by Laipac Technology (http://www.datasheetcatalog.com/datasheets_pdf/T/L/P/4/TLP434A.shtml). At first testing, it seemed as if this technology would work for us. We were able to input a signal and obtain that signal at the receiver. This signal was then used to actuate our vibrating motor. A quick test of standing between the transmitter and receiver showed us that the signal was unaffected by such interference. A range test on this particular transmitter and receiver pair showed that we could receive a signal approximately twenty feet away, which is plenty of distance for our application. The problem that we encountered quickly after these initial tests was when we attempted to send no signal. When the receiver was taken out of range of the transmitter or when the transmitter sent nothing, the receiver was not pulled completely low. The receiver would not drop to zero volts but would instead still receive enough of a signal to actuate the vibrator. We then decided that this was a problem specific to the transmitter/receiver pair that we were using and began searching for more reliable RF options.

After researching RF technology, we found a product made by Linx Technologies. We decided to work with surface mount pieces rather than through-hole for the sake of the size and comfort of our board. With surface mount pieces, we would eliminate a lot of thickness on the board. The two options that we decided between for the Linx parts were the LR or the LC series. We originally decided to use the LR series because the datasheet for this type indicated that it would work at a DC level. This led us to believe that we would not run into the problem of the receiver not being pulled to zero when transmitting nothing. This would also allow to send a straight high voltage signal of 5 V to the transmitter for an amount of time defined by the user. In this case we would not need a wave function, allowing us to implement push button capabilities. There were also three options for which frequency we wanted the transmitter to send at. The three frequencies were 315, 418, and 433 MHz. We decided to test the 315 MHz because the lower frequency would be more likely to travel through water. Dr. Schafer already had some of the LC series receivers on hand so we performed our initial testing with these. Our initial tests were a success. The transmitter and receiver pair behaved as we expected them to. The transmitter would send out the square wave and the receiver was able to output the wave to our circuit. We also tested the technology by standing in the way of the signal and it was unaffected. Our final test was to determine its behavior when sending a zero signal or being out of range. We set the input to the transmitter to the minimal peak-to-peak voltage from the function generator (10 mV) and this was what we received at the transmitter. We also tested this by disconnecting the power to the transmitter and the receiver gave no data out as desired. Finally, we took the receiver circuit out of range of the transmitter and again received no signal.

We performed our tests on the LR series transmitter/receiver pair when we received them in and attached them to our printed circuit boards. These tests, however, were not as successful as those with the LC series. The basic setup was successful. The transmitter could take an on/off signal in and transmit the signal to the receiver. The range of the LR series was similar to the range of the LC series, and they were also uninterrupted by movement between them. However, the final test of no signal left us with similar results to our Laipac RF pair. When we transmitted no signal, the receiver data out was still outputting a constant voltage of around 1.5 volts. This led us to decide that we would use the Linx Technology LC series transmitter and receiver at 315 MHz for our final system.

Out initial tests were performed without an antenna because they were at close range. When we began range testing we had to incorporate an antenna. We began with an arbitrary length of wire (about 8 inches). It did not seem to affect the range. We calculated the appropriate length when we began testing in the pool environment. A quarter wave length antenna is 10.3 inches long.

$$\tfrac{1}{4}\ f/c = (\tfrac{1}{4}*315*10^6)/3*10^8 = .2625\ \text{m} = 10.33\ \text{inches}$$

2.4.2 Actuating Motor

Because competitive swimming prohibits the use of auditory signaling, we needed to find a method of alerting the swimmer in another manner. We decided that the best way to do this was by using a vibrating motor, typically used in cell phones or pagers. There are two types of vibrating motors that we were able to find. These two types are the offset weighted shaft and the DC coin motor. Since these motors are extremely cheap, we decided that we should order two of each kind and perform tests to decide which would be most appropriate for our system. The categories in which we would decide would be base on size, vibration strength, power needed, gradient, and implementation.

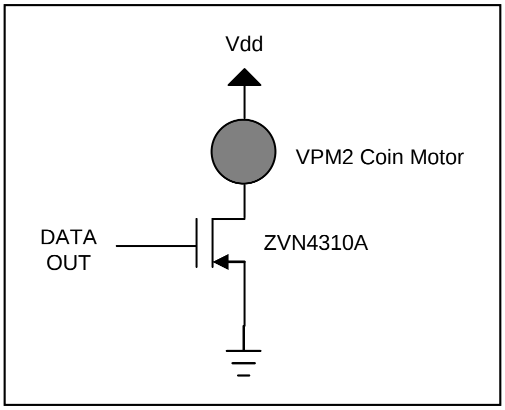
		Type	
Factor	**Weight**	*Offset Weighted Shaft*	*DC Coin Motor*
Small	5	0	1
Vibration Strength	3	1	1
Power needed	3	1	0
Gradient	1	1	0
Implementation	3	-1	1
Total:		**4**	**11**

After receiving the motors, we could obviously see that the DC coin motor was smaller. The coin motor was comparable to the size of an M & M. The offset weighted shaft was not considerably larger but was approximately twice that size. The offset weighted shaft requires 1.5 to 3 volts at 62 mA to operate while the DC coin motor requires 2.5 to 3.5 volts and 80 mA. The offset weighted shaft would be a better choice because it requires less current. When we applied the appropriate constraints to the motors, the strength of each was not noticeably different. Finally, the implementation of the DC coin motor was going to be much easier than for the offset weighted shaft. The DC coin motor was equipped with wire leads which could be soldered to the board where as the offset weighted shaft had metal leads attached which would be difficult to solder. Our final decision came down to one factor that was not initially considered but was extremely important. We noticed during testing that since the weighted shaft was exposed, if anything came in contact with it, the shaft would stop rotating and therefore have no vibration. This ultimately forced us to choose the DC coin motor because we would have had to design an encasing in which the shaft would no longer be exposed. Also, the DC coin motor was much easier to solder onto our board and it was designed with an adhesive side which we could stick to the board to keep it from moving.

Since the output of the RF receiver can only source around 8 mA, we decided that we would need to find a method of powering our motor other than the output of the receiver. The two options we considered were using a bipolar junction transistor setup to amplify the current output or using a MOSFET to act as a switch and use batteries to power our motor. We explored both possibilities.

We first explored the use of BJTs to solve our problem. After obtaining a 2N2369 BJT from the electronics lab, we performed several tests to determine if this would be a viable solution. We quickly realized that using a BJT would make our problem much more complicated than it needed to be. We decided to use a MOSFET to act as a switch instead. The output of the receiver is applied to the gate of the MOSFET. The drain is hooked to our batteries through the motor and the source is grounded. With this setup, whenever the gate is pulled high, the switch is essentially “on” and power flows through the motor to ground making it vibrate. When the gate is sent low, the switch is "off" and power will not flow across the motor. Since we already need batteries in order for our receiver board to be mobile, this setup does not add any additional circuitry.

MOSFET and Motor Schematic



2.4.3 Mobility

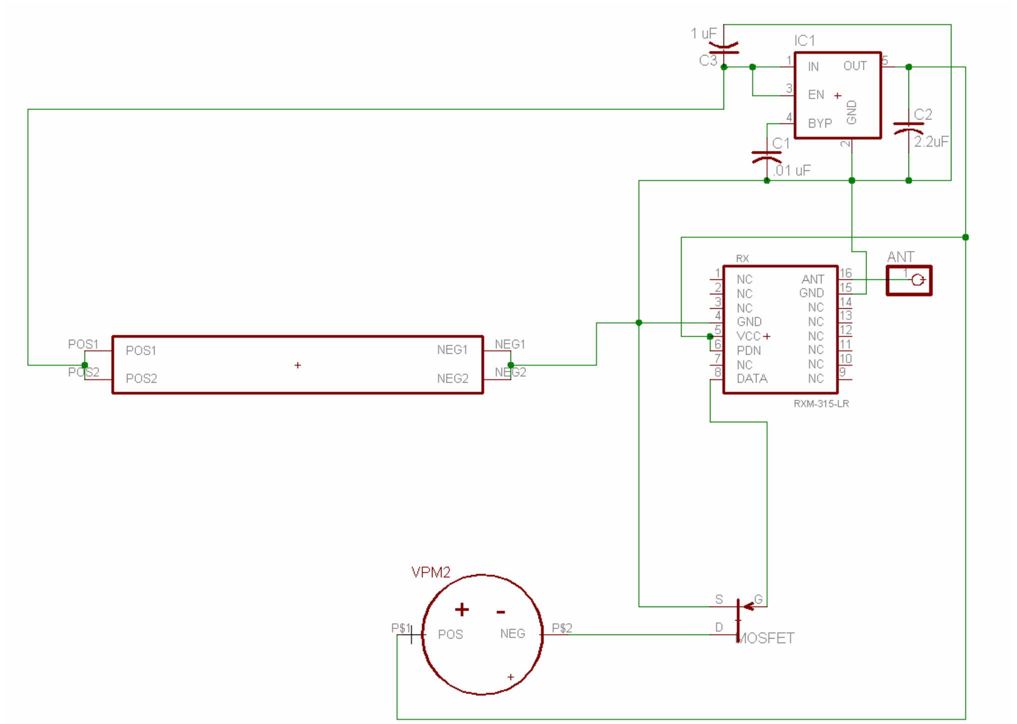
In order for the system to be mobile, the most important aspect was finding the appropriate batteries for our system. The requirements for the battery setup must be providing in the range of 2.5 to 3.5 volts and source at least 80 mA of current. Through testing, we discovered that the motor could actually operate at around 60 mA. The first batteries we decided to test were button batteries and coin batteries. The coin batteries are 3V lithium batteries and the button batteries are Energizer 344/350, 1.55V, silver oxide batteries. In the case of the button batteries to obtain the required range of voltage, we need to connect two of these batteries in series, giving us 3.1V.

An important consideration in choosing batteries is the amount of current that they can source. In our initial tests with the Laipac receiver and transmitter we were able to power the communication system and read the data output of the system as working with the lithium batteries. However, the motor was not vibrating. We realized that this was a current issue, so we tried the series connection of two of our silver oxide batteries. This scheme was able to run both the receiver and the motor with fairly strong vibrations.

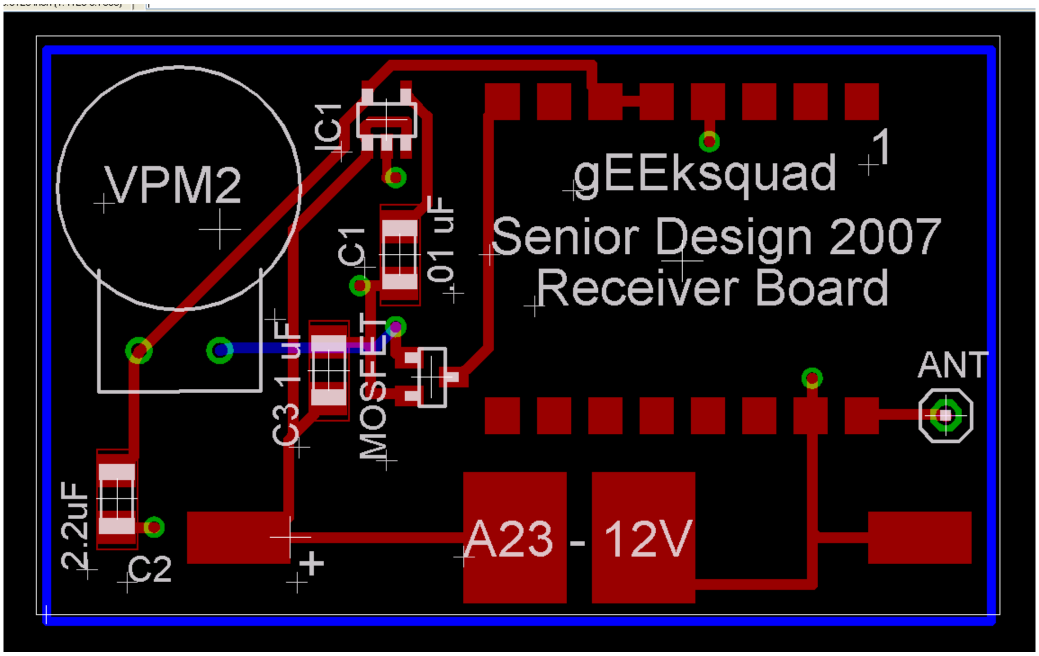
A mini-alkaline Energizer A23 12 V battery with a voltage regulator scheme was also tried to see if the current sourced through the regulator could improve the strength of vibration. This seemed to slightly heighten the strength, and was chosen for the final board design.

The ultimate mobility of the system relies on the board design. We designed a printed circuit board with EAGLE as seen below to handle the signal from the Data Out of the receiver using it to actuate the motor. The signal from the Data Out is V_{cc} -.3V when low and V_{cc} when high. In our case the high voltage is 3V. Our 12 V battery provides this through our voltage regulator and capacitor scheme that converts down to 3V. The Data Out 3V signal is applied to the gate of our MOSFET which acts as a switch. When 3V is applied the switch it tripped to actuate the motor. Otherwise the motor circuit is not powered and no vibration occurs.

Signaling Schematic



Signaling Board Design

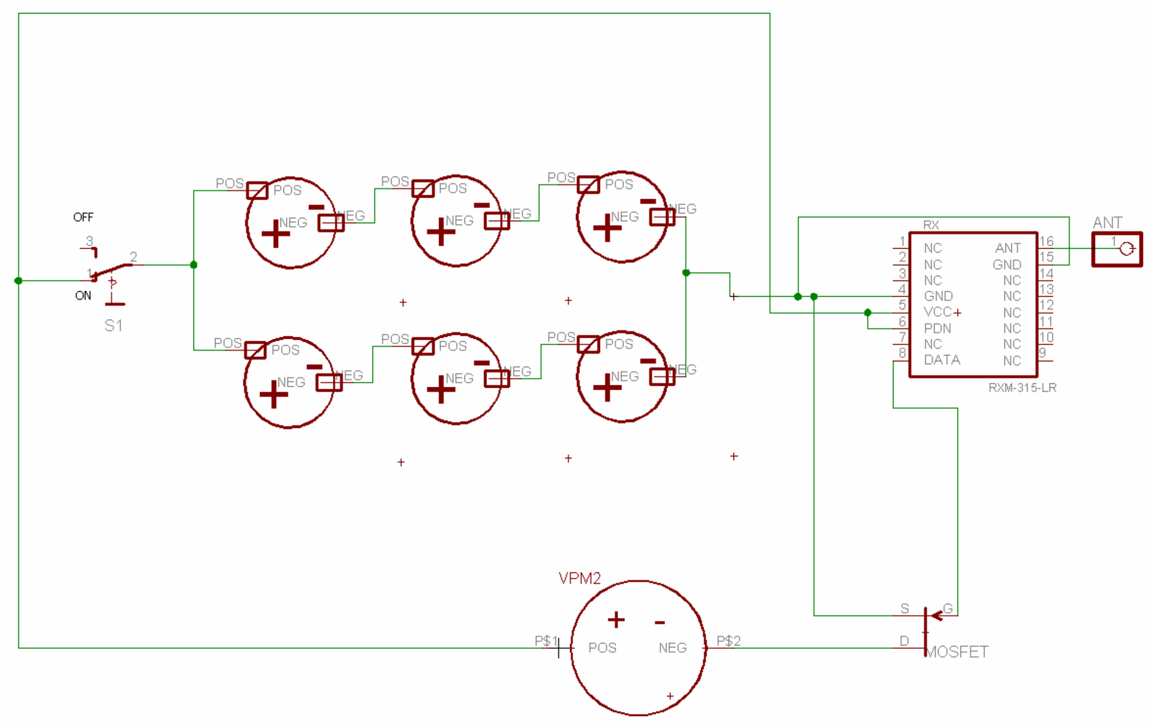


Upon building the boards they did not operate as expected. Before placing the motor onto the board in observing the receiver output it gave a reading of 3V.

However, when connecting the motor this signal went to zero. We had a few problems here. The first was that the library package for the MOSFET we were using was incorrect so our traces were not correct. In addition we found that the current, only .48 mA, from the 12 V battery was not sufficient to maintain operation for extended periods and the batteries quickly drained. We decided to develop a new board by soldering components directly together using a solder proto board. This gave us the flexibility to add a power switch that we had not incorporated into our PCB between the batteries and the voltage regulator. In this case the Energizer 344/350 scheme was returned to, but this time we used a set of two in parallel with a second set of two to ensure that there was enough current to run the motor.

After testing at the pool we realized that the 344/350 batteries were insufficient for our system because they were unable to source enough continuous current. We realized this because during testing the vibrations of the motor were not as strong as we had observed them at its maximum capability. After more research, we found zinc air 1.4 V Energizer C675 batteries that source a continuous 25 mA of current. We combined 2 parallel sets of 3 batteries in series to provide 50 mA of current. This provides a nominal voltage of 4.2V, but when the system is switched on the voltage drops to about 3.95 V when receiving no signal. This voltage is rated above the upper level of operation for the motor, but in testing this does not appear to be a problem. Because the motor is not continuously running, when it is not being actuated, the voltage returns to 3.95V.

New Schematic



2.4.4 Testing

In the individual testing of this subsystem there were several things to consider to determine its usefulness. All tests were initially performed in a dry environment and then converted to an in water test.

Initial tests of the transmitter and receiver pairs were performed on a powered proto board. Both the transmitter and receiver were set up on the board using the two power supplies provided by the board, the transmitter at 5V and the receiver at 3V. A function generator was used to input a 0V to 3V square wave at 1 Hz into the transmitter. The successful operation of the devices was determined by observing the data out of the receiver on an oscilloscope. The desired output from the receiver is also a 3V peak to peak square wave at 1 Hz. Once we determined that the components were communicating we were able to move on to our range test.

Range tests in the lab began with the Laipac transmitter and receiver pairs when the circuit was first mobile. The transmitter was wired to a powered proto board. The receiver was attached to another proto board that was powered through wires connected to the battery terminals. In these initial tests the 3V coin battery was used because the current draw of the receiver is minimal. Keeping the transmitter board at one bench the other board was moved through the Electronics Lab stopping at different benches to observe the receiver data on the oscilloscope. We were able to send a signal from end to end of the Electronics lab, approximately 20 feet.

Materials testing was completed when the MOSFET and vibrating motor scheme was set up on the receiver's proto board. After determining that this circuit would set the vibrating motor off every second in accordance with the transmitted signal's frequency we placed the board inside the swim cap. The vibration continued to work inside the cap so we placed the cap and board into a bucket of water. The motor continued to vibrate under these conditions.

After determining that there was a problem with the Laipac transmitter and receiver pair we acquired the Linx pair. We had to redo our range and materials testing with the new components. At this point the receiver circuit was able to actuate the vibrating motor on the proto board. Again using the function generator as the transmitter input we took the receiver board out of the lab into the hallway. The motor continued to vibrate even when the transmitter and receiver were on different sides of the wall. We placed the receiver system inside two plastic bags and a swim cap. We then submerged the entire system in a bucket of water. Between each set of packaging we observed the motor's vibration and noted that it maintained its strength.

2.5 Interfaces and Sensors

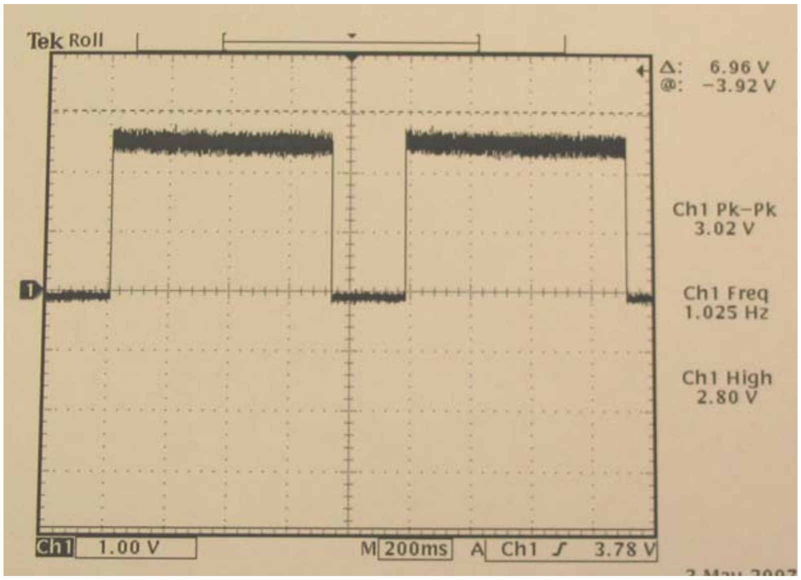
3 System Integration Testing

Our system involves the integration of two separate subsystems. These two subsystems are the sensing and the signaling systems. The sensing system uses an infrared sensor to detect the swimmer. The signal obtained from this sensor is then passed into a microcontroller. The microcontroller then creates an appropriate signal to send to the signaling subsystem. The signaling subsystem takes the output from the microcontroller and inputs it into an RF transmitter. The RF receiver then receives this signal and uses it to actuate a vibrating motor.

3.1 Testing the Integrated Subsystems

Our first method of testing the integrated subsystems was to only use the microcontroller for the input of the RF transmitter. We used the microcontroller to create a signal which would be sent from the transmitter to the receiver. The signal was modeled like a square wave with an off and on setting of 0 or 5 volts respectively. The signal would alternate between being on for one second and off for one second. This test was performed in the Engineering Learning Center and operated as expected. The signal was successfully passed into the transmitter and received by the RF receiver. The success of this test was observed as the vibrating motor would turn on and off every second.

Receiver Output



The second step in completing the integration of the subsystems was to have the infrared sensor detect a person in air and use that signal to activate the microcontroller. This test was also performed in the Engineering Learning Center. Again, the test operated as we expected it to. A person was able to walk in front of the infrared sensor, which triggered the microcontroller to send an input to the receiver. This input was used to actuate the motor at a location across the room.

The final step was to test the system in a pool setting. Initial testing of the signaling portion was performed on the proto board. The microcontroller was used to send a signal to the transmitter and the proto board was held inside the cap and submerged in the pool. The transmitter and receiver were about 5 feet apart and the motor was successfully actuated.

We then put the proto board inside of two Ziploc plastic bags and placed them on the swimmer's head. We carefully helped the swimmer put on the cap and tested the system out of water. We were able to trigger the PIR out of water and cause the motor to vibrate on the swimmer's head out of water. We also tested that pushing the manual/emergency button would also cause the motor to vibrate, which was successful.

Notification Unit

Next, we had the swimmer get in the pool. We tested several different scenarios for the position of the receiver on the swimmer's head with respect to the water: completely above the water, a thin flowing layer of water over the cap, barely submerged (approximately 3 inches underwater), and completely submerged (several feet underwater). We used the push button to signal the receiver in all scenarios and the motor was actuated in all except for complete submersion. Because of the technique used in the strokes involving flip turns, complete submersion will not occur at the point where the swimmer will need to be alerted, so these results are acceptable.

The swimmer then had to swim while we triggered the motor with the push button to see how well the signal transmits while the swimmer is in motion. The swimmer was able to feel the vibration, however it was not a very strong vibration and the ability for the swimmer to feel the vibration improved the slower he swam. According to the swimmer this was because the speed of the water over his head made it somewhat difficult to differentiate the vibration from the feel of the water at faster speeds.

We then attempted to test the full, autonomous system by setting up the PIR test rig and running solely off of the sensor. As stated in the discussion about the sensor performance, when swimming freestyle with the face submerged there is not a large enough infrared signature for the microcontroller to detect. We were able to use the push button to actuate the motor, allowing the swimmer to flip turn upon feeling the vibration.

Because of the difficulties with freestyle, we decided to test our setup with backstroke. The face produces enough infrared radiation to allow the microcontroller to detect the swimmer and send a signal to the transmitter. We were able to repeatedly detect and notify the swimmer while he was doing the backstroke.

3.2 Meeting Design Requirements

3.2.1 Impervious to Water

The system that we have built is impervious to water in all ways necessary. The entire infrared sensor except for the very tip, which is waterproof, is encased in PVC pipe. The PVC rig stands up on the side of the pool and the wiring runs through the inside and up to the base station. The base station is a plastic box with a power switch and emergency button. The hardware is completely contained inside this plastic box which is uninfluenced by splashes but should not by immersed in water.

The receiver board is contained in two plastic bags. These protect the board from any water. These plastic bags containing the receiver board are worn under the swimmer’s cap. Before placing any boards in the swim cap we submerged it in water to make sure that none leaked through. After we were satisfied with this we took the device to the pool and held it inside the cap under water. In our final waterproofing scheme with the plastic bags, we had Mike place the device under his cap and submerge his head under water with the device turned on. We did this before attempting any signaling. No water went through the cap and none of the circuitry was shorted.

3.2.2 Small

The size is primarily a concern for the receiver board. This board must be small because it is worn on the swimmer’s head under the cap. It must not cause any discomfort or significant drag. The board is approximately 1.75” by 2.5”. The board is place inside two plastic bags and worn flat on the head. In testing of wearing the board under the cap, it seems to cause no additional discomfort to wearing the cap alone. This was determined by Mike wearing the cap at the pool.

3.2.3 Non-auditory Notification

The means of notification chosen is a vibrating motor. This is necessary because of the regulations on auditory signaling. The vibrating motor is worn against the head and is an appropriate means of signaling the swimmer without being audible.

3.2.4 Reliable

The behavior of the PIR sensor is not always reliable. We found at the pool that it works better for the backstroke than freestyle. We did find that the push button capability provides for reliable signaling. In these cases when the PIR does not detect the swimmer a helper can use the emergency push button to signal the swimmer when they are approaching the wall.

3.2.5 Tunable

Tunability is a desirable feature but not necessary to the operation of the system. The manner in which the rig was constructed leads to simple tunability. If the rig is placed on the side of the pool, it can easily be slid in either direction if the sensing is too early or late. In our pool testing we found it easy to adjust the distance that the rig was from the edge through this method of sliding. Additional mechanical work on the rig would improve the ease of tenability as it is merely reliant on the physical location of the sensor.

3.2.6 Easy Operation and Setup

Setting up our product is fairly simple. Initially, the swimmer or a helper should place the rig along the side of the pool at the distance at which they would like to be signaled. There is a control box with a power switch and two LEDs to indicate the power status and transmission status. After switching on the power, the setup must cycle through two transmissions to equilibrate to the surrounding environment. This would require the user to simply flip on the switch and wait for approximately 10 seconds before attempting to use the system. The setup for the signaling system is also extremely simple. The swimmer must only position the signaling board beneath the swim cap and set the switch in the on position.

These are additional properties that would improve device quality but are not necessary to solve the problem.

3.2.7 Mobile

Mobility is a convenience for the user. The system was designed to be used at Rolf's Aquatic Center, but is not specific to that pool. The system is completely mobile; however, the rig is large and slightly difficult to walk around with. It essentially can be used in any pool that the swimmer would want to take it to.

3.2.8 Self-monitoring

This particular function was not implemented in the system. It proved to be difficult to find batteries that would appropriately meet the specifications for our system. By the time we found a suitable battery, we were not left with enough time to implement this function.

3.2.9 Record Swimmer Information

This function was also not implemented in the system. After deciding on infrared sensing over RFID, it was no longer possible to identify the swimmer triggering the sensor. This would have been useful so that a swimmer in another lane would not set off the sensor. However, this particular problem can be solved by shielding or directing the infrared sensor so that the area covered does not span into the neighboring lanes. The problem of signaling multiple swimmers can be handled by using transmitter receiver pairs are different frequencies.

4 Users Manual

4.1 Setup

4.1.1 Battery Installation

4.1.1.1. Transmitter

- Use a small to medium sized Philips head screwdriver to unscrew the four (4) corner screws located on the underside of the black control box.
- ***Carefully*** lift the circuit board and avoid putting tension on the connector wires inside the box. Do this until the battery socket is accessible.
- Insert approved nine-volt battery with the indicated polarity (note: battery will only attach in one orientation).
- ***Carefully*** replace the circuit board to the box, lining up the holes on the board with the screw holes. Replace cover and tighten screws using a small to medium sized Philips head screwdriver.
- Verify battery installation by switching the power toggle to the "ON" position and check that the "POWER" LED is lit.

4.1.1.2. Receiver

- Contact manufacturer for more information.

4.1.2 Swim Cap Assembly

- Place receiver unit inside waterproof bag.
- Place waterproof bag on swimmers head with the vibrating motor side contacting the head. Hold in place.
- *Carefully* pull swim cap over head and receiver unit.

4.2 Use

4.2.1 Turning On System

- Switch the black control box power toggle to the “ON” position and check that the “POWER” LED is lit.
- Wait until the “TRANSMITTING” LED has stopped blinking and is not lit.
- Move the receiver switch to the “On” position and push the “MANUAL” button on the control box to verify that the receiver is on and operating normally. The motor should vibrate as long as the “TRANSMITTING” LED is lit.

4.2.2 Manual Signaling

- To signal the swimmer manually, check that the “TRANSMITTING” LED is off and then press and hold the “MANUAL” button for as long as you would like to signal.
- Check that the “TRANSMITTING” LED is lit while the “MANUAL” button is pressed. If it is not lit, consult the troubleshooting section.

4.2.3 Turning Off System

- Move the receiver switch away from the “On” position and push the “MANUAL” button on the control box to verify that the receiver is off. No vibrations should occur.
- Switch the black control box power toggle to the “OFF” position and check that the “POWER” LED is off.

4.3 Troubleshooting

4.3.1 Power Issues

4.3.1.1. Power LED Not Brightly Lit

- If the black control box power toggle is in the “ON” position and the “POWER” LED is not lit or is faintly lit, switch the black control box power toggle to the “OFF” position.
- Use a small to medium sized Philips head screwdriver to remove the corner screws on the black control box.
- Remove the battery and test it with a battery tester or a voltmeter. If the voltage is below 5.5 volts or the battery tester indicates a dead battery, replace battery with a new approved nine-volt battery.
- If the battery voltage is above 5.5 volts and the battery tester indicates a working battery, place the battery back into the holder and wait twenty (20) minutes before trying to turn the black control box power back on.

- If the “POWER” LED still will not light, replace the nine-volt battery with a new approved battery if not already replaced.
- If problem persists, contact manufacturer.

4.3.1.2. Weak/No Vibration

- Check for loose/unconnected wires, ignoring the ten inch red wire (antenna). If a wire is loose or disconnected, contact the manufacturer.
- If wires are secure and connected, replace batteries with ***ONLY*** Energizer C675 cochlear batteries (not AC675, no substitute batteries will work).
- If problems persist, contact the manufacturer.

4.3.2 Transmission Issues

4.3.2.1. “TRANSMITTING” LED Not Illuminated

- Switch the black control box power toggle to the “ON” position and wait until the “TRANSMITTING” LED stops blinking or is not lit.
- Press and hold the “MANUAL” button for two (2) seconds. If the “TRANSMITTING” LED does not light up, switch the black control box power toggle to the “OFF” position and contact the manufacturer.

4.3.3 Other Issues

- For any other problems encountered contact the manufacturer.

5 Conclusions

5.1 Final System

At the end of the design process, our final system is an electronic tapping device that alerts a visually-impaired swimmer of their proximity to the wall. While it is not an effective autonomous detector for freestyle swimming, it is autonomous for backstroke and can be used as a manual wireless tapping system. In order to make a completely autonomous system for both strokes, more research must be done on how to process the incoming signal from the infrared sensor. This will involve acquiring a large amount of data and processing it with a signal processing tool such as Matlab.

5.2 Future Recommendations

There are other improvements that can be made to our existing system that will make it more user-friendly. Our first receiver PCB is flawed because of problems with design parameters for the batteries and MOSFET. With our new batteries and a new PCB design, the receiving board could be more compact and therefore more comfortable and durable.

Another option could be to reframe the problem and use our solution solely as a manual wireless tapping system. This system would be a great improvement on the current tapping method because it allows a single person (i.e. coach) to tap the swimmer at both ends of the pool without having to run back and forth. It would also be a more consistent method that is less intrusive on the swimmer due to no contact with the tapping pole. Also, compared to the full autonomous solution, the wireless tapping system would cost over $100 less. It would also not restrict the swimmer to the side lanes of the pool. This would be an evolutionary step as opposed to a revolutionary step.

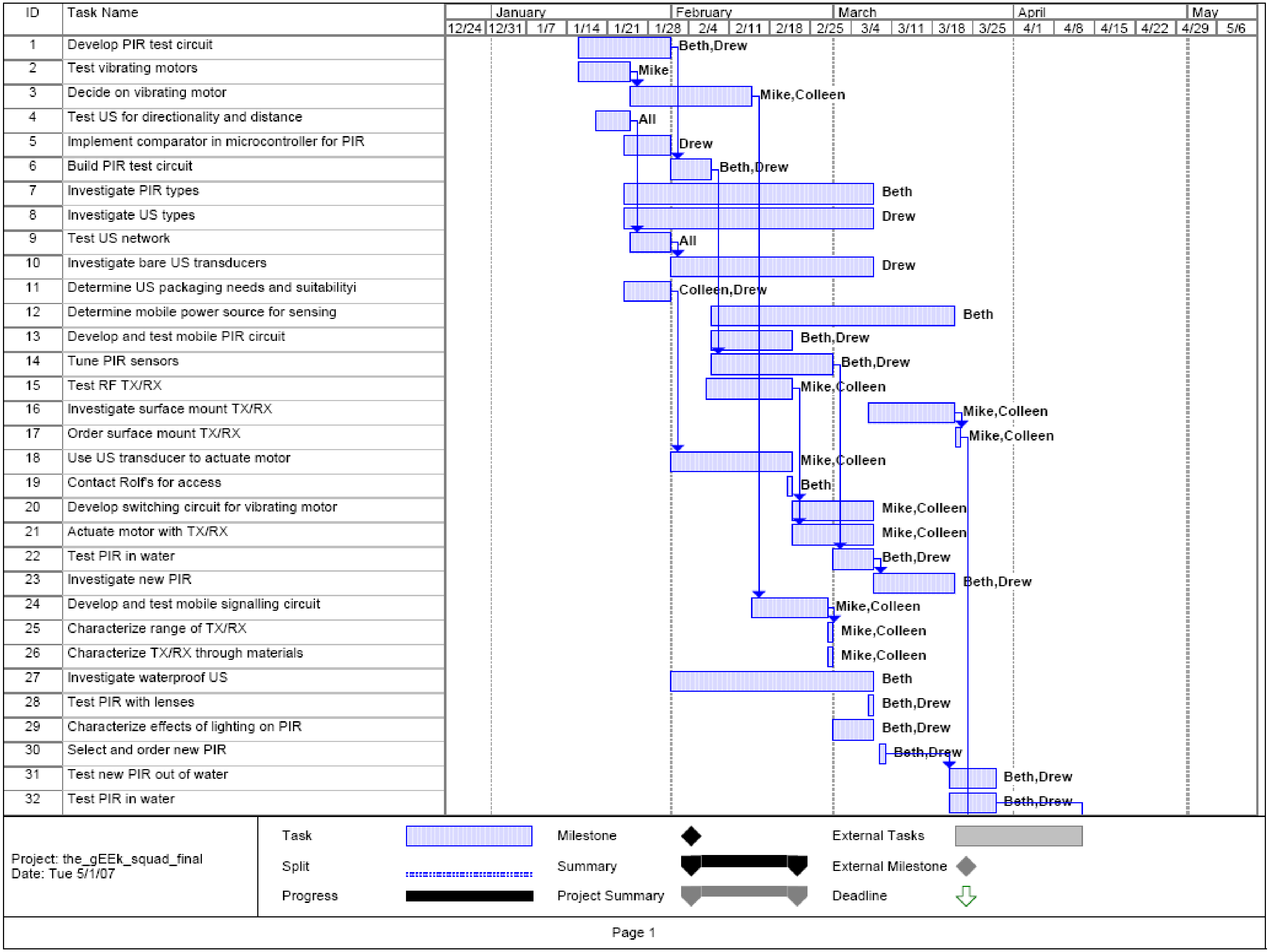
5.3 Final Evaluation

While we did not meet all of our design requirements, we were able to develop a product that improves the current situation greatly and has the prospect of being expanded to a fully-working system.

Appendix A Microsoft Project File

Task	Start	End	Owner
Develop PIR test circuit	1/16	1/31	Beth,Drew
Test vibrating motors	1/16	1/24	Mike
Decide on vibrating motor	1/25	2/14	Mike,Colleen
Test US for directionality and distance	1/19	1/24	All
Implement comparator in microcontroller for PIR	1/24	1/31	Drew
Build PIR test circuit	2/1	2/7	Beth,Drew
Investigate PIR types	1/24	3/7	Beth
Investigate US types	1/24	3/7	Drew
Test US network	1/25	1/31	All
Investigate bare US transducers	2/1	3/7	Drew
Determine US packaging needs and suitabilityi	1/24	1/31	Colleen,Drew
Determine mobile power source for sensing	2/8	3/21	Beth
Develop and test mobile PIR circuit	2/8	2/21	Beth,Drew
Tune PIR sensors	2/8	2/28	Beth,Drew
Test RF TX/RX	2/7	2/21	Mike,Colleen
Investigate surface mount TX/RX	3/7	3/21	Mike,Colleen
Order surface mount TX/RX	3/22	3/22	Mike,Colleen
Use US transducer to actuate motor	2/1	2/21	Mike,Colleen
Contact Rolf's for access	2/21	2/21	Beth
Develop switching circuit for vibrating motor	2/22	3/7	Mike,Colleen
Actuate motor with TX/RX	2/22	3/7	Mike,Colleen
Test PIR in water	3/1	3/7	Beth,Drew
Investigate new PIR	3/8	3/21	Beth,Drew
Develop and test mobile signalling circuit	2/15	2/27	Mike,Colleen
Characterize range of TX/RX	2/28	2/28	Mike,Colleen
Characterize TX/RX through materials	2/28	2/28	Mike,Colleen
Investigate waterproof US	2/1	3/7	Beth
Test PIR with lenses	3/7	3/7	Beth,Drew
Characterize effects of lighting on PIR	3/1	3/7	Beth,Drew
Select and order new PIR	3/9	3/9	Beth,Drew
Test new PIR out of water	3/21	3/28	Beth,Drew
Test PIR in water	3/21	3/28	Beth,Drew
Gather sensing data with AD converter	3/28	4/4	Drew
Develop sensing algorithm	4/6	5/1	Beth
Implement push button actuation capabilities	3/19	4/13	Beth,Drew
Construct test rig	4/6	4/11	Beth,Drew
Test surface mount TX/RX	3/23	4/4	Mike,Colleen
Characterize distance of surface mount TX/RX	3/23	4/4	Mike,Colleen
Determine signalling circuit power supply	3/23	4/4	Mike,Colleen

Characterize surface mount TX/RX through materials	3/23	4/4	Mike,Colleen
Characterize surface mount TX/RX in water	3/23	4/4	Mike,Colleen
Integrate subsystems	4/13	4/13	All
Select smaller microcontroller	4/11	4/13	Beth,Drew
Sensing board design	4/5	4/16	Beth,Drew
Signalling board design	4/2	4/16	Mike,Colleen
Build sensing encasing	4/16	4/16	Beth,Drew
Program and test new microcontroller 16F88	4/16	4/16	Beth,Drew
Assemble boards	4/26	4/28	All
Test boards	4/28	4/29	All
Test sensing algorithm at pool	4/30	5/1	All
Integrate and test subsystems at pool	5/1	5/1	All
Final testing	5/3	5/3	All
Filming and Documentation	5/1	5/4	All



ID	Task Name
1	Develop PIR test circuit
2	Test vibrating motors
3	Decide on vibrating motor
4	Test US for directionality and distance
5	Implement comparator in microcontroller for PIR
6	Build PIR test circuit
7	Investigate PIR types
8	Investigate US types
9	Test US network
10	Investigate bare US transducers
11	Determine US packaging needs and suitabilityi
12	Determine mobile power source for sensing
13	Develop and test mobile PIR circuit
14	Tune PIR sensors
15	Test RF TX/RX
16	Investigate surface mount TX/RX
17	Order surface mount TX/RX
18	Use US transducer to actuate motor
19	Contact Rolf's for access
20	Develop switching circuit for vibrating motor
21	Actuate motor with TX/RX
22	Test PIR in water
23	Investigate new PIR
24	Develop and test mobile signalling circuit
25	Characterize range of TX/RX
26	Characterize TX/RX through materials
27	Investigate waterproof US
28	Test PIR with lenses
29	Characterize effects of lighting on PIR
30	Select and order new PIR
31	Test new PIR out of water
32	Test PIR in water

Project: the_gEEk_squad_final
Date: Tue 5/1/07

Task	▨	Milestone	◆	External Tasks	▨
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

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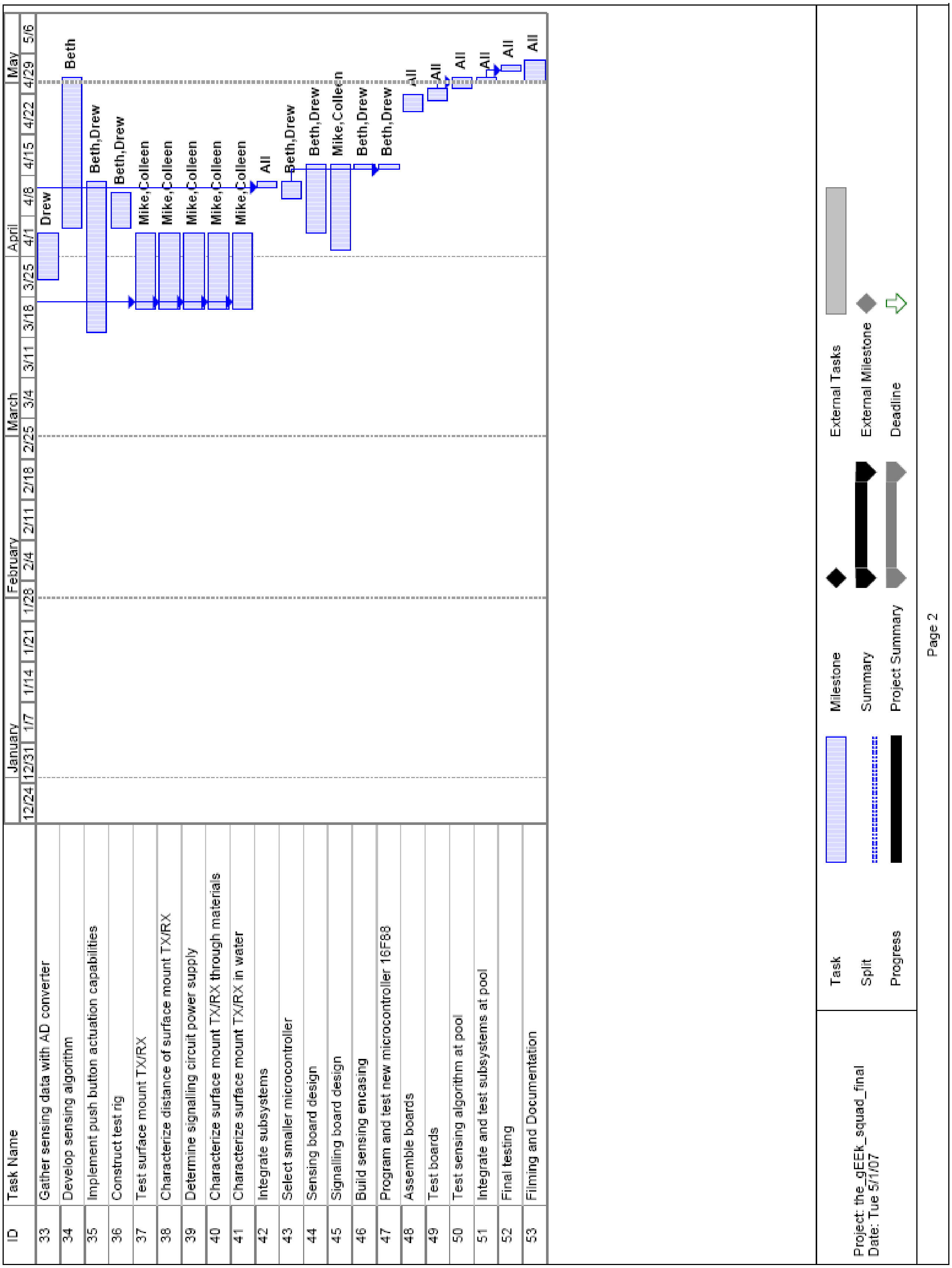
ID
Task Name
33 Gather sensing data with AD converter
34 Develop sensing algorithm
35 Implement push button actuation capabilities
36 Construct test rig
37 Test surface mount TX/RX
38 Characterize distance of surface mount TX/RX
39 Determine signalling circuit power supply
40 Characterize surface mount TX/RX through materials
41 Characterize surface mount TX/RX in water
42 Integrate subsystems
43 Select smaller microcontroller
44 Sensing board design
45 Signalling board design
46 Build sensing encasing
47 Program and test new microcontroller 16F88
48 Assemble boards
49 Test boards
50 Test sensing algorithm at pool
51 Integrate and test subsystems at pool
52 Final testing
53 Filming and Documentation
January
February
March
April
May
12/24
12/31
1/7
1/14
1/21
1/28
2/4
2/11
2/18
2/25
3/4
3/11
3/18
3/25
4/1
4/8
4/15
4/22
4/29
5/6
Drew
Beth
Beth,Drew
Beth,Drew
Mike,Colleen
Mike,Colleen
Mike,Colleen
Mike,Colleen
Mike,Colleen
All
Beth,Drew
Beth,Drew
Mike,Colleen
Beth,Drew
Beth,Drew
All
All
All
All
All
All
Project: the_gEEk_squad_final
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Task
Split
Progress
Milestone
Summary
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External Tasks
External Milestone
Deadline
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Appendix B Data Sheets

Receiver Board Data Sheets

N-Channel MOSFET : ZVN4310A
http://www.zetex.com/3.0/pdf/ZVN4310A.pdf

Silver Oxide Batteries : Energizer 344/350
http://data.energizer.com/PDFs/344-350.pdf

Zinc Air Batteries : Energizer C675
http://data.energizer.com/PDFs/c675.pdf

RF Receiver : Linx RXM-315-LC-S
http://www.linxtechnologies.com/Documents/RXM-xxx-LC-S_Data_Guide.pdf

Vibrating Motor : Solarbotics VPM2
http://downloads.solarbotics.net/PDF/Solarbotics_VPM2.pdf

Transmitter Board Data Sheets

RF Transmitter : Linx TXM-315-LR
http://www.linxtechnologies.com/Documents/TXM-xxx-LR_Data_Guide.pdf

Microcontroller : Microchip PIC16F88
http://ww1.microchip.com/downloads/en/DeviceDoc/30487c.pdf

Voltage Regulator : National Semiconductor LM2937
http://www.national.com/ds/LM/LM2937.pdf

PIR : Panasonic AMN 23112 Spot Passive Infrared Motion Sensor
http://pewa.panasonic.com/pcsd/product/sens/pdf_cat/amn.pdf

9-Volt Battery: Duracell ProCell PC1604
http://www.duracell.com/Procell/productdata/#
Click “View Online” hyperlink for PC1604

Appendix C Cost Analysis

Swimmer's Eye Cost Analysis

Part	Cost per unit	Cost per unit(qty.1000)	Number per system	Cost per System
LM2937 Voltage Regulator	$1.83	$0.77	2	$1.53
PIC16F88	$1.93	$1.93	2	$3.86
Linx TXM-315-LR	$7.46	$5.28	2	$10.56
Linx RXM-315-LC-S	$13.79	$9.85	1	$9.85
PVC Rig Materials	$30.00	$30.00	2	$60.00
ZVN4310A MOSFET	$2.67	$0.76	1	$0.76
Solarbotics VPM2	$3.95	$3.11	1	$3.11
Panasonic AMN23112	$35.28	$20.88	2	$41.76
Energizer C675	$0.83	$0.60	6	$3.62
Duracell PC1604	$2.33	$1.61	2	$3.22
Microfit 3.0 8-Pin Plugs	$0.40	$0.26	2	$0.51
Microfit 3.0 8-Pin Connector	$0.70	$0.45	2	$0.89
Microfit 3.0 4-Pin Plugs	$0.29	$0.19	2	$0.39
Microfit 3.0 4-Pin Connector	$0.40	$0.32	2	$0.63
Toggle Switch	$1.15	$0.65	2	$1.30
Pushbutton Switch	$1.29	$0.87	2	$1.74
Red LED	$0.20	$0.13	4	$0.52
PCB (Swim Cap Board)	$442.71	$1.18	1	$1.18
PCB (Base Station Board)	$409.74	$3.88	2	$7.76
Passive Elements	$4.50	$3.80	2	$7.60
Black Control Box	$7.50	$4.80	2	$9.60
22-Gauge Stranded Wire	$3.00	$3.00	1	$3.00
			Cost per system =	$173.39
			Cost per system (No PVC, PIRs) =	$70.61
			Cost, 1000 systems =	$173,391.90
			Cost, 1000 systems (No PVC, PIRs) =	$70,613.90