the g**EE**k squad

Subsystems

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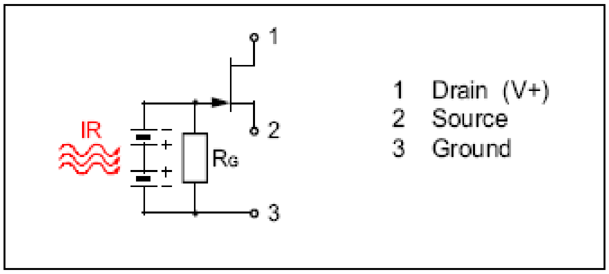
1 Sensing the Swimmer

1.1 Infrared Pyroelectric Sensors

Based on our Pugh chart comparing several different types of sensors, we concluded that infrared sensors would be the most plausible solution for sensing the swimmer. Dr. Bauer recommended sensors from Kube which he had used in applications before. 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.

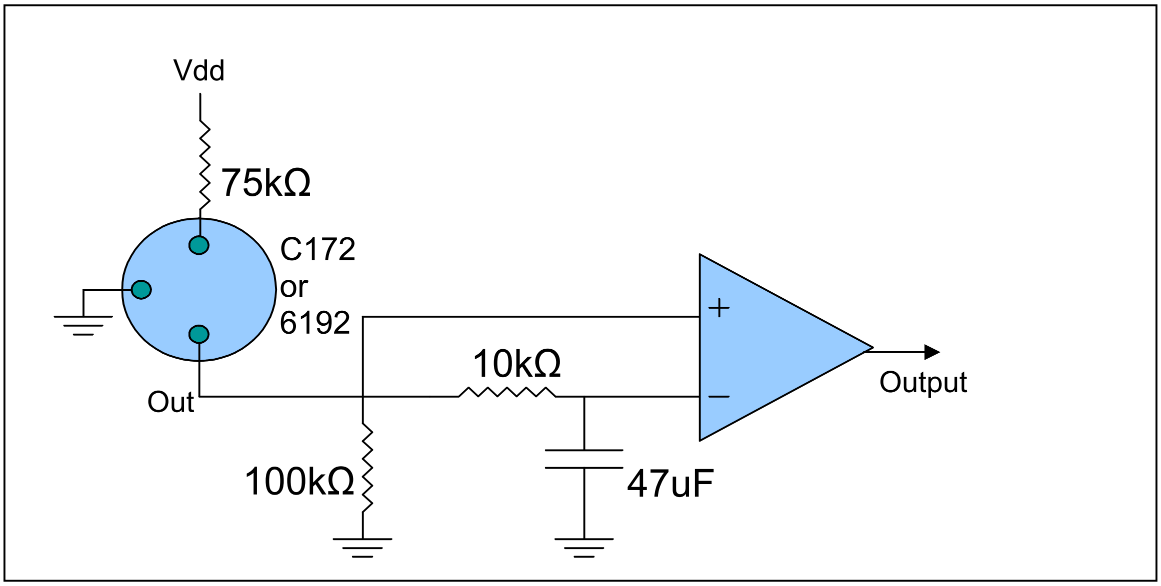
Internal Circuitry and Pinout



1.1.1 Circuit Development and Coding

We obtained these sensors and started our testing by simply powering the sensor, using the specified voltage, drain and source resistors. We initially did not use a separator and our results showed very little change in signal at even at close range (a couple of millivolts). We then included a separator and were able to obtain signal changes of tens of millivolts. This type of signal change, though significant, is difficult to see on multimeters and even oscilloscopes. We chose to use a differential circuit based on the advice of Dr. Bauer 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.

PIR Schematic



This circuit is set up so that when the output of the PIR increases (for example from 590mV to 630mV), the comparator will output a high signal until the capacitor charges and the negative terminal is a higher voltage than the positive terminal. When the output of the PIR decreases (for example from 630mV to 570mV), the comparator will output a low signal. The amount of time it takes for the comparator to go from high to low depends on the resistor and capacitor values chosen. We experimented with several different capacitor and resistor values and found that as we increased the size of the capacitor we were able to detect smaller changes in motion. This is desirable because we are trying to detect a swimmer's location as exactly as possible. The time constant of our circuit is 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:

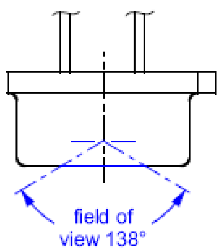
```
//the gEEk squad
//Comparator
//November 2006

#include <system.h>
#include "EESD.h"

#pragma DATA _CONFIG1H, _OSC_HS_1H //10 mhz
#pragma DATA _CONFIG2H, _WDT_OFF_2H
#pragma DATA _CONFIG4L, _LVP_OFF_4L
#pragma DATA _CONFIG3H, _MCLRE_ON_3H
#pragma CLOCK_FREQ 10000000

void main(void)
{
  trisa = 0x4f;
  cmcon = 0x03;
}
```

The trisa register setting of 0x4f sets up A0, A1, A2, and A3 as inputs and A4 as an output on port A. The cmcon setting of 0x03 sets the comparator mode to two non-inverting, independent comparators with outputs (C1 and C2). We use comparator 1 (C1) with inputs A0 and A3, and output A4. A0 is the negative terminal of the comparator and A3 is the positive terminal of the comparator.

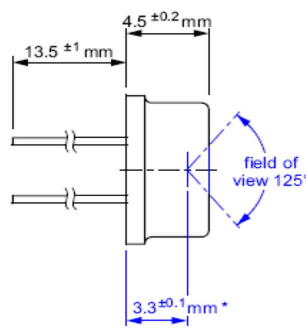
1.1.2 Out of Water Testing:

With the circuit connected as above to our powered protoboard and a crude separator in place (cardboard; ideally we will use aluminum because it reflects IR) we began our out of water testing. The first aspect of our testing involved the field of view of the sensors. From the documentation provided by Kube, the field of view horizontally is approximately 138 degrees and vertically is approximately 125 degrees:

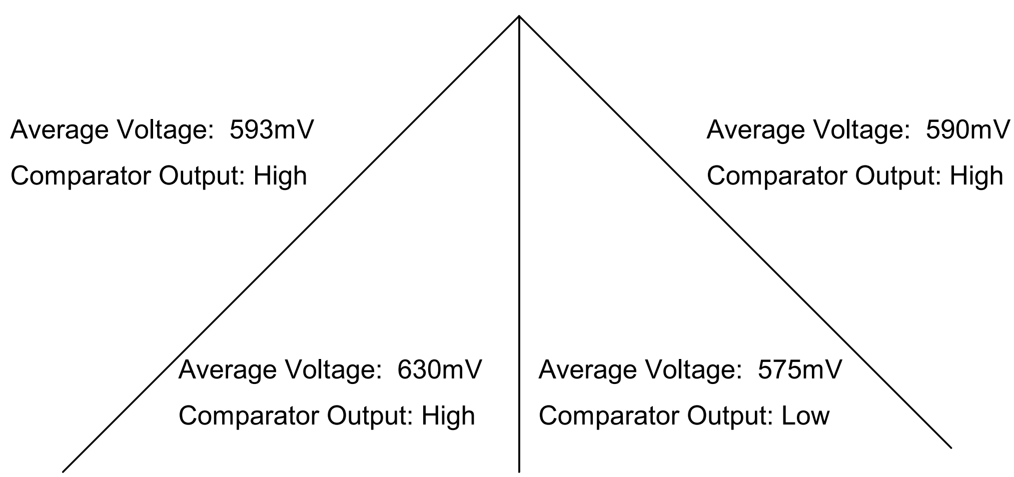
Top View (horizontal field)



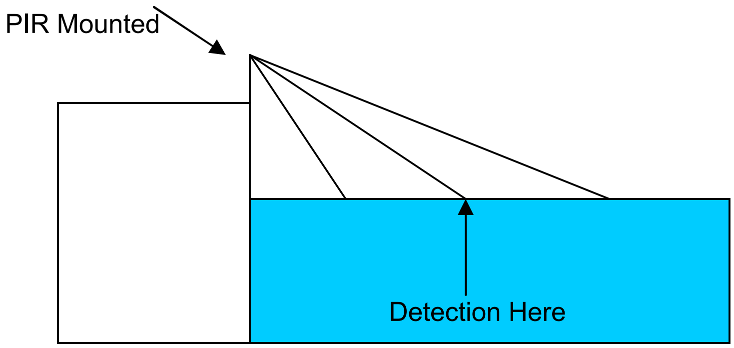
Side View (vertical field)



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):



The edges of the field of view where detection is first made vary between a couple of degrees. This offset does not allow us to get the sharp edge that we would desire to exactly identify the location of the swimmer. However, the center line where the separator is located consistently changed voltages and detected our presence at the same location (to within a couple of inches horizontally at 1.5m away). We determined that this point would be the one we want to be at the point the swimmer should be alerted. To accomplish this, we would need to aim this line of view at the pool by turning the sensor 90 degrees clockwise and then tilting it until it pointed at the pool:



We attempted tests in the lab with this setup and were able to consistently detect a person crawling toward the sensor to within 6 inches. With the results successful for our out of water tests, we then contacted the aquatics director and obtained permission to do testing at the pools.

1.1.3 System Mobility

After showing consistent out-of-water tests in our labs, we attempted to refine our circuit down to a more compact, mobile setup. To do this, we reassembled our PIR-low pass filter circuit on a prototype board and soldered all the pieces in place. However, the PIRs are very sensitive to high temperatures and after soldering ceased to function. This was because we increased the temperature of the device by a higher rate than specified and burnt it out. Therefore, we put a different, working PIR onto a solderless breadboard that is significantly smaller than the large powered board we were using. As for powering the microcontroller board and prototype board, we were able to use a single nine-volt battery connected to the microcontroller board power plug. This board has two different regulated voltages (5 V and 3.3 V) and the PIR circuit functions well using a 3.3 V input, which allows us to power the PIR breadboard using the microcontroller board. This setup proved to be very convenient for our pool tests.

1.1.4 In Water Testing

With our mobile circuit in hand we proceeded to Rolfs Aquatic Center to test our circuit's effectiveness in a water environment. First, to make sure background infrared would not be a problem, we tested our device on the pool deck out of water and confirmed that our circuit works well in the Rolfs air environment. However, we did notice that the voltage output of the PIR was considerably higher than in the lab tests. The ambient, no-detection voltage was around 620 mV (over 30 mV higher). The voltage with a person on the left side of the divider went as high as 640 mV, and on the right side of the divider went as low as 600 mV (note the voltage swing is considerably smaller than in the lab). The observed voltage change of a dry person moving through the sensitive field of view was high enough to trigger the comparator. Next, we had a dry person stand in waist-deep water in the pool and move across the sensitive field of the PIR in a manner similar to our out-of-water tests (similar distances as well). The results from this test produced a large enough voltage change to trigger the comparator circuit as desired. Next we performed the same test with only the swimmer's head exposed resulting in similar findings to the previous two tests.

With more testing around the pool we discovered numerous occasions where the PIR would produce a false trigger presumably due to issues with the lighting/reflection. In some instances the voltage would randomly jump between 600 and 630 mV with no apparent reason (no swimmer or other disturbances). With this situation it was very difficult to determine whether the swimmer or other IR sources were causing the voltage changes out of the PIR. To investigate this further we took similar test measurements at the Rockne Memorial Pool (the Rock), which has very different lighting and water temperatures. We noticed that the output of the PIR was much steadier at the Rock holding pretty close between 615-620 mV. The value is still considerably higher than the lab environment and suggests we may need a way to deal with outside IR sources. In the water, detection was only consistent when the swimmer's body was mostly close to or above the surface of the water with the PIR output voltage reaching approximately 625 mV. When swimming past normally (body submerged a little more) the sensor had difficulty distinguishing the swimmer from the water.

1.1.5 Future Improvements

As a result of our in water testing we have a concern that water has IR absorption qualities that make sensing a swimmer in water more difficult with our current crude setup. It would require our PIRs to be more focused to detect a smaller IR signature moving through the water. Focusing would also restrict our field of view to hopefully block out unwanted IR sources. Hopefully we can do this with Fresnel lenses or other optics. We are also on the search for more sensitive PIRs with a possible choice being Panasonic Motion Sensors.

2 Signaling the Swimmer

1.2 Ultrasonic Sensors

Initially we sought to use an ultrasonic transmitter and receiver pair for signaling the swimmer. The pair that we experimented with has manufacturing number 40TR16F and operates at 40 kHz. We put a 40kHz sine wave into the transmitter and were able to view a similar wave using the oscilloscope on the receiver. The range the signal would travel was about a 3 feet. However, the transmitter and receiver had to be facing directly at each other and no obstructions of any kind could be between them to pick up the signal. This sensor will not work for signaling so we had to consider other options.

1.3 Vibrating Motor

We had two possible types of vibrating motors which we needed to decide between. These two types of motors are the offset weighted shaft and the DC coin motor. The impact of the effectiveness of the vibrating motor will be subject to a qualitative judgment. So, in deciding between these two motors, we did not take quantitative data, rather we attempted to feel the difference in operation. We decided to use the DC coin motor based on several factors. One of the main problems we encountered with the offset weighted shaft was that any contact with the rotating weight would cause the vibration to stop completely.

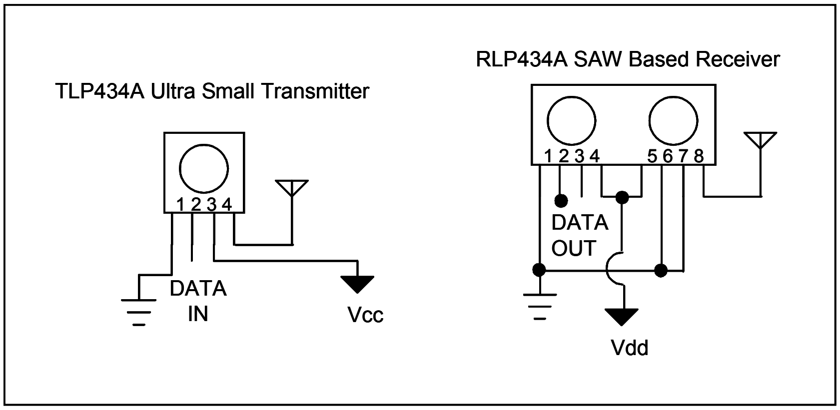
Vibrating Motor Pugh Matrix

		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**

1.4 RF Transmitter and Receiver Pair

We experimented with the TLP434A Ultra Small Transmitter and RLR434A SAW Based Receiver pair as a means of signaling.

RF Transmitter/Receiver Pair Schematic



We used a Vcc for the transmitter of 5V, but it can operate between 2V and 12V. The DATA IN was provided by the Tektronix AFG 3021 function generator. A square wave with a 1 Hz frequency, 3Vpp amplitude, and 1.5V offset was the input.

The DATA OUT of the receiver is dependent on Vdd, so we tried a variety of voltages within the operating range of 3.3V to 6.0V. The goal is to use the output of the receiver with a transistor to turn on a vibrating motor.

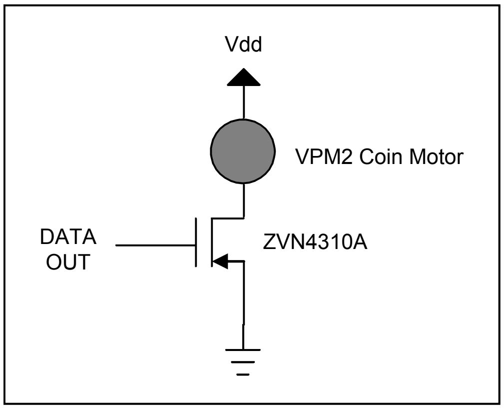
We first used a 2N2369 BJT with the DATA OUT to try to run the motor. While the current output of the receiver is listed as 200 μA in the specifications, our tests showed that this did not appear to be the case. When we hooked the BJT to the digital DATA OUT the output of the receiver, which had been a 4V square wave, became a .4V square wave. In this case the receiver was being powered with 4.5V. To see how a load was affecting our receiver output we tried a range of resistances from DATA OUT to ground with a variety of Vdds.

Receiver DATA OUT Voltages Data

Receiver Vdd: 5.99V **DATA OUT V_{High}: 5.76 V (without load)**	
Resistance	*DATA OUT V_{High}*
50 Ω	0 V
390 Ω	0 V
1.8 kΩ	0 V
21.5 kΩ	.4 V
100 kΩ	1.8 V
Receiver Vdd: 4.49V **DATA OUT VHigh: 4.3 V (without load)**	
Resistance	*DATA OUT V_{High}*
21.5 kΩ	.4 V
100kΩ	1.52 V
1 MΩ	3.68 V

The current coming out of the receiver is too low with any load on it to run the BJT. We then tried using a ZVN4310A N-Channel MOSFET because it would not rely on current to turn it on.

MOSFET and Motor Schematic



The MOSFET acts as a switch. To utilize it this way, since our DATA OUT is a square wave, when the DATA OUT is high, the MOSFET will be turned on and actuate the vibrating motor. When the DATA OUT is low, the MOSFET will be turned off and no current will pass through the motor. To find the optimum operating voltage to achieve the desired current to run the motor, we placed a 50 Ω resistor in the circuit to model our motor. The reason that we chose 50 Ω was because our motor will drop a maximum of 3.5 V at 80 mA. A simple calculation will give you approximately this resistance (actually 43.75 Ω).

50 Ω Resistor Simulation of Motor Data

V_{dd} (V)	DATA OUT $V_{50\Omega}$ (V)	$V_{50\Omega}$ (V)	$I_{Resistor}$ (mA)
5.90	5.80	5.80	111
4.50	4.44	4.44	90
3.34	3.28	3.28	60

Because the minimum operating voltage for the receiver is 3.3 V and this voltage is still in the operating range for the motor, we decided to use this voltage. Also, the current was below the maximum rated current for the motor.

After deciding on the voltage characteristics, we connected our MOSFET and motor setup to the DATA OUT from our receiver and it behaved as expected. We then decided to test its operation through a swim cap. The swim cap did not appear to have any effect on our system.

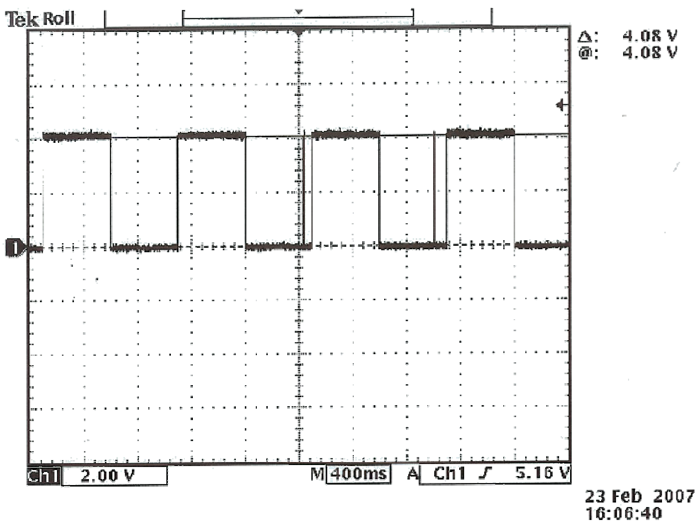
1.5 Future Improvements

Because of the nature of our system, the receiver and motor configuration must be mobile. This raises several concerns with our current solution.

1.5.1 Batteries

The receiver and motor both must run off some sort of power source. Currently, we can run the receiver from a battery but have been unable to drive both the receiver and motor simultaneously. We tested the receiver with two 3 V batteries in series. These batteries had been drained down to 4.5 V. As illustrated by the oscilloscope output, the receiver was outputting a V_{High} of around 4 V.

DATA OUT Signal When Running On Batteries Oscilloscope Output



The optimum voltage for running the receiver is between 3.3 V and 6 V. The motor's range is much lower between 2.5 V and 3.5 V. Using either coin batteries or button batteries we can use a series configuration to achieve 4.5 V or 6 V. This would mean that we can run our power supply directly into the receiver but would require a voltage regulator to drop down the voltage for the motor.

1.5.2 Range

We tried to perform a preliminary range test but ran into several problems. We realized during our testing that if we transmit nothing, the motor behaves similarly to when we are transmitting our square wave. The motor still vibrates on and off; however, the vibration is duller and lengthier. In short range distances, we realized that we could transmit a 10 mV peak to peak square wave with a 1.5 V offset at 1 Hz and the motor would cease its vibration. We decided that we could use this to simulate the swimmer out of range, rather than transmitting nothing. As we reached approximately 18-20 feet distances, the receiver was no longer able to pick up the 10 mVpp wave. To more accurately determine behavior over long ranges, it would be helpful to have a systematic evaluation of the difference between the receiver DATA OUT when we are transmitting our square wave and when we are transmitting nothing at all. We currently have not been using an antenna with our transmitter and receiver pair. This has not appeared to cause any problems in functionality. However, if we wish to achieve longer ranges, we may need to investigate the usage of antennas.