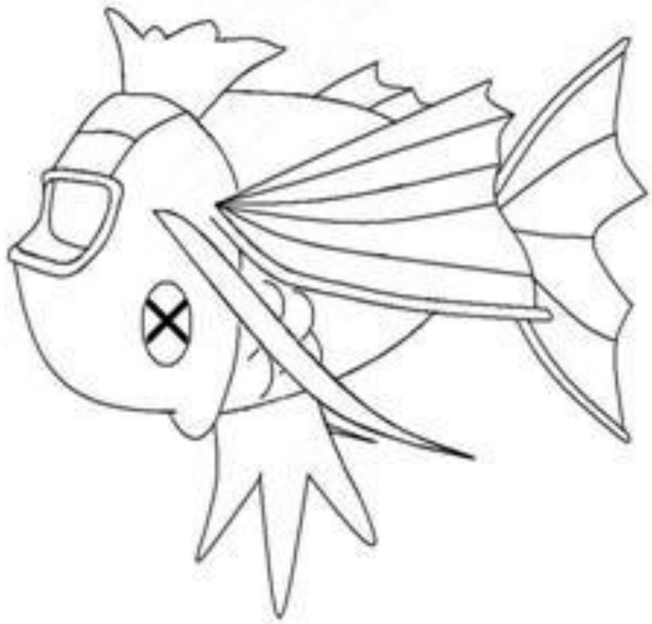
Tilapi-ugghhh



Group 5

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1.0 Introduction

1.1 *Executive Summary*

An issue has arisen in that the cost and time involved in animal care have become unreasonably high. Traditional house pets, such as dogs and cats, have become an extreme inconvenience, particularly in times where commodities such specialty food for animals have spiked in price. In addition, rising animal care prices disqualify the possibility of having others tend to pets whilst owners tend to prior professional or personal engagements. Throughout the lifetime of a cat or dog an owner is expected to pay over $4,000 for food, health care, and grooming.

Because of the excessive price of care required for conventional house pets, low maintenance pets, such as fish, have become an affordable alternative. The lifetime cost of caring for a fish, excluding any exotic species, typically ranges from $50 to $100; including the price of the aquarium kit required to house the animal. In addition, fish do not disperse allergens in the air nor shed onto furniture, a common complaint amongst dog and cat owners.

A common occurrence for new fish owners is that they forget to feed their fish. When minute chores, such as putting food in a fish tank, only take a few seconds it’s very easy to forget to do the chore altogether. When the owner finally realizes that the fish has gone unfed for at least a couple of days, it’s too late and the fish has gone belly up. Tilapi-ugghhh offers a simple solution; why should you own a fish that requires someone to remember to feed it when you can possess a fish that is completely self-sufficient and requires no attention at all?

1.1.1 *Objective*

The objective of this project is to develop a self-sufficient, portable system which resembles that of a fish. Through the use of the knowledge and skills obtained throughout our collegiate years along with extensive research that will be acquired throughout Senior Design I we will design and build a Tilapi-ugghhh prototype. Tilapi-ugghhh is an autonomous submersible system that will be equipped with photovoltaic cells used to convert the energy from the sun into electricity which will be used to sustain the systems battery life. To facilitate a forward motion a propulsion motor will be installed while fins controlled by servos will provide directionality. Tilapi-ugghhh will be outfitted with various types of sensors which will feed information to its onboard central processing. From the data received by the object detection sensors the fish will be able to avoid any object, enabling it to navigate the waters free from obstruction. With the information obtained by the battery level sensors Tilapi-ugghhh will be able to determine if it needs to start seeking light due to a voltage level check. Light sensing components will help the fish swim in areas closer to light until a critical voltage level is detected causing the fish to surface and recharge.

1.1.2 *Project Description*

“Tilapi-ugghhh” is an autonomous, solar-powered, robotic fish. Solar panels will be used to recharge the batteries that will be built in. The fish will be guided through waters by a variety of sensors. The water detection sensor will determine whether or not the fish should operate on the basis of being in or out of water. If the fish senses that it is in water the depth and object detection sensors will be used to help guide the fish through water and to help the fish avoid obstacles. As it maneuvers through water battery life is certain to drain. The battery sensor will determine when the fish needs to start seeking out light sources. Once it is determined that the battery needs to be recharged the light sensor will help the fish find sources of light for energy.

To move left, right and forward the fish will use a mixture of fin manipulation and motors. To move up and down the fish will use a type of counterweight system. Propulsion and turning speed will be controlled through the fins and motors. The placement of the fins along with the structure of the fish will affect how the fish moves through the water.

Artificial intelligence will be achieved through the use of a microcontroller. The microcontroller will be programmed to give the fish its cues. The artificial intelligence will take the information from each of the sensors and will determine what action it should take based from that information.

1.2 *Specifications and Requirements*

For both aesthetic and dynamic purposes the fish must look a certain way. The body of the fish, including the shell, all electrical components, and motors and servos, must weigh less than 20 pounds. The length of the fish’s body, measure from the tip of the fish’s nose to the end of the tail fin, must be less than 20 inches. The body of the fish must be of neutral or slightly positive buoyancy. All electric components within the fish must be capable of withstanding complete submersion in water. The basic dimensions that have been decided on can be seen below as in Fig. 1.2.

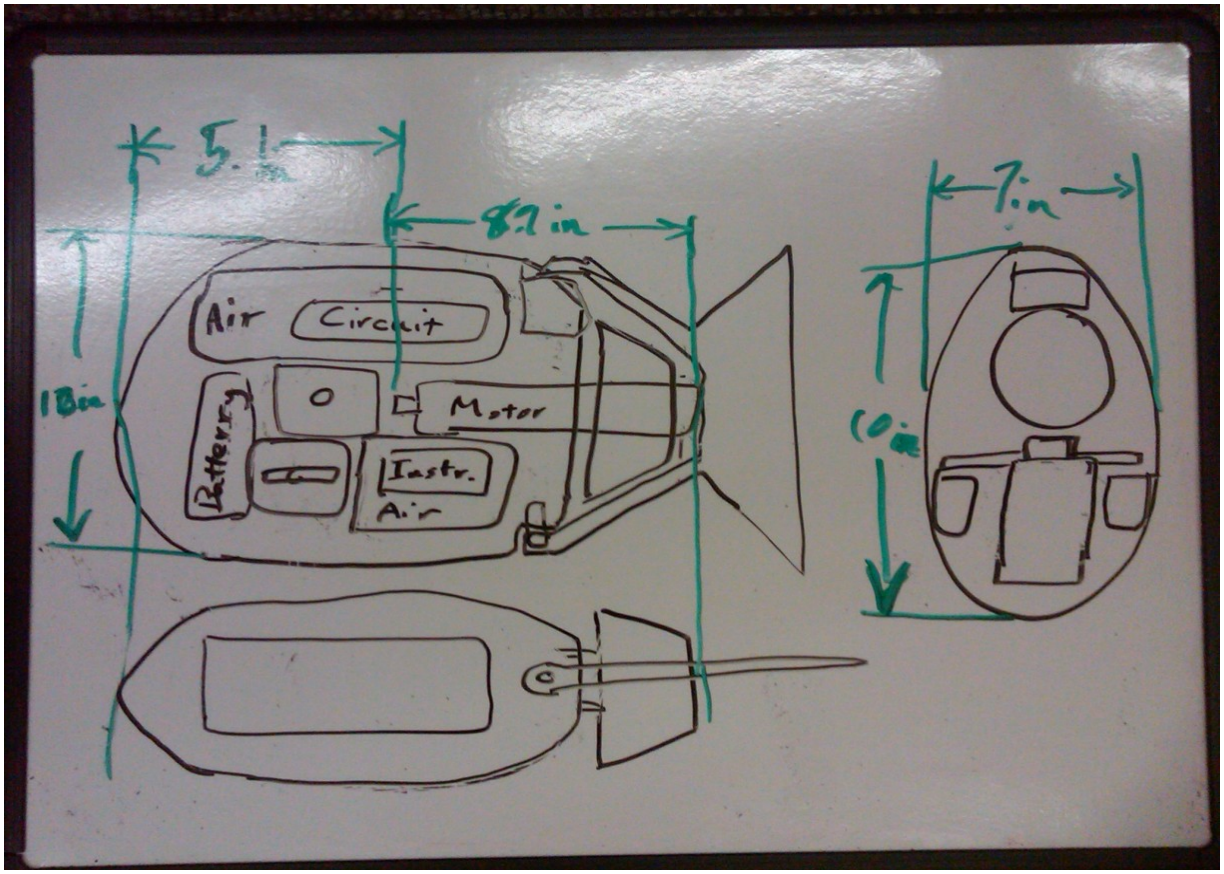


Fig 1.2: Initial Design of Tilapi-ugghhh

A main component in creating this self-sustaining robotic fish is its battery/solar system. The battery system must be able to hold a charge of at least 12 V. The battery system must also be able to charge up to at least 12 V. Lastly, the battery system must be able to supply up to at least 12 V of power. This battery system will be tied to photovoltaic cells. These cells must be able to supply enough power to recharge at least 12 V. These two components, the battery system along with the solar system, will be connected to a Power Control Box. The power control box must be able to regulate and distribute at least 12 V of power to the remaining systems, including the motion systems as well as the artificial intelligence, of the robotic fish.

The fish must be able to move freely without human interference directing its movements. In order to do so the fish will be equipped with a variety of sensors. The fish must be able to detect if it is in water. The fish must also be able to detect if there are objects within 8 inches of its body. The fish will also be capable of detecting its battery levels. Lastly, the fish must be able to detect light.

With the information received from the sensors, the fish must be able to determine a course of action. The fish will be outfitted with a central processing unit to create a type of artificial intelligence. If an object is detected within 8 inches of the fish's body, the fish must be able to avoid said object. The fish must be able to check for various levels of battery remaining. If battery is detected to be at a low threshold, the fish must be able to seek out light. The fish must be programmed with a random path algorithm for the fish to follow.

- When battery level reaches 6 V the fish will begin to seek light.
- When battery level reaches 2 V the fish will surface and recharge.
- When battery level reaches 11 V the fish will re-submerge and continue swimming.

The majority of commands received will be given via the programs used for artificial intelligence. The fish, however, will be equipped with a remote control. If there is a point where the fish malfunctions or the fish clearly requires maintenance a command will be given above water from a user to override Tilapi-ugghhh's normal programming. The manual surface override will cause the fish to surface wherever it is, and can then be retrieved with a net or some other device.

For maneuvering purposes the fish will be equipped with a series of motors and servos. The motor must be able to provide a forward motion. The servos must be able to rotate from 0 to 180 degrees.

1.3 *Estimated Project Budget*

In order to properly manufacture a Tilapi-ugghhh prototype a sufficient budget must be set aside. Initial guesses as to what each system would need in order to be fully realized. Once it was decided what components were necessary, how many of each component could then be determined. With a little rudimentary research each component was given a price. After tabulating all of the components necessary, the original project budget was decided to be $1,010 as seen below in table 1.3a.

SUPPLIES	Quantity	Cost (self-financed)
Battery (12 V)	2	$10
Panel	16-20	$100
Light sensor	8	$50
Power Control Box Circuitry	1	$50
Motherboard	1	$50
Propulsion Motor	1	$50
Piston	2	$100
Solenoids/Motor	10	$200
Object sensor	6	$200
Depth sensor	2	$100
Waterproofing		$100
Total		$1,010

Table 1.3a: Original Project Budget

1.4 *Project Schedule*

Having a project schedule is vital. Without a project schedule it would be very easy to fall behind, causing unnecessary stress. A project schedule is necessary to realize the construction and completion of the Tilapi-ugghhh prototype. One must first decide which components and systems are the most important to the completion of the project. After deciding which components are more important you must estimate how long each component will take to research as well as how long it will take to design and build said component. Once all variables have been taken into consideration an accurate schedule can then be calculated. Table 1.4a shows the projected research schedule while Table 1.4b shows the projected build schedule.

<table>
<tr><th>Phase</th><th>Priority</th><th colspan="3">Component</th></tr>
<tr><td rowspan="3">Research</td><td>1</td><td colspan="3">Motherboard</td></tr>
<tr><td>2</td><td>Solar Panels</td><td>Propulsion</td><td>Ballast</td></tr>
<tr><td>3</td><td>Power Control Box</td><td>Sensors</td><td>A.I. Programming</td></tr>
</table>

Table 1.4a: Research Schedule

Design/Test/ Build	1	Motherboard
	2	Solar Panels
	3	Propulsion
	4	Ballast
	5	Sensors
	6	Power Control Box
	7	Programming

Legend
Semester I
Semester II

Table 1.4b: Design/Test/Build Schedule

2.0 Solar System

2.1 *Battery Type*

For a machine to be truly “self-sufficient” the machine must be able to sustain energy without intervention. Tilapi-ugghhh will not require someone to replace the batteries once one set of batteries is fully discharged, it will instead recharge the installed battery pack. In order to ensure that the machine can continue running without having to recharge after a short amount of time the type of battery used must be considered carefully.

2.1.1 *Rechargeable Alkaline Battery*

Rechargeable alkaline batteries, or Rechargeable Alkaline Manganese (RAM), are different from regular alkaline batteries in that of their blend of materials and in the formula used to create the batteries. The change in chemical composition allows for RAM to be able to recharge and is designed to help resist leakage. Although RAM batteries have a high charge-capacity and are affordable attention must be paid to how far the battery is charged or discharged. A typical 1.5 V nominal RAM battery, if discharged by less than 25%, can be charged to about 1.4 V for hundreds of cycles, while if discharged by less than 50%, RAM batteries can be recharged to about 1.32 V for a few dozen cycles. If a RAM battery is discharged by greater than 50% a full recharge can only be achieved for a few cycles. RAM batteries have a longer lifespan when used in devices that are low-drain, such as remotes, or when used in devices that are used periodically, such as portable radios.

2.1.2 *Lithium-Ion Battery*

Lithium-ion, or Li-ion, batteries are secondary batteries which contain an intercalation anode material which allow the electrochemical reactions to be reversible. Li-ion batteries are much lighter than other secondary batteries and can be formed into various shapes and sizes to efficiently fill, without adding too much extra weight, to the devices that they power. These batteries are not prone to the memory effect in which a battery is recharged that has not been fully discharged repeatedly causing the battery to “remember” the smaller charging capacity. Although Li-ion batteries have a low self-discharge rate, these batteries have relatively poor cycle lives which resembles self-discharge. Deposits, due to charging, form within the electrolyte which reduces transport of lithium ions consequently diminishing the capacity of the cell. Also, the permanent capacity of Li-ion batteries can be decreased because of high charge levels and elevated temperatures. Li-ion batteries are found commonly in portable electronic consumer devices because they are light weight, are not affected by memory, and have a slow self-discharge. Figure 2.1.2 displays the typical battery charge stages for a lithium-ion battery.

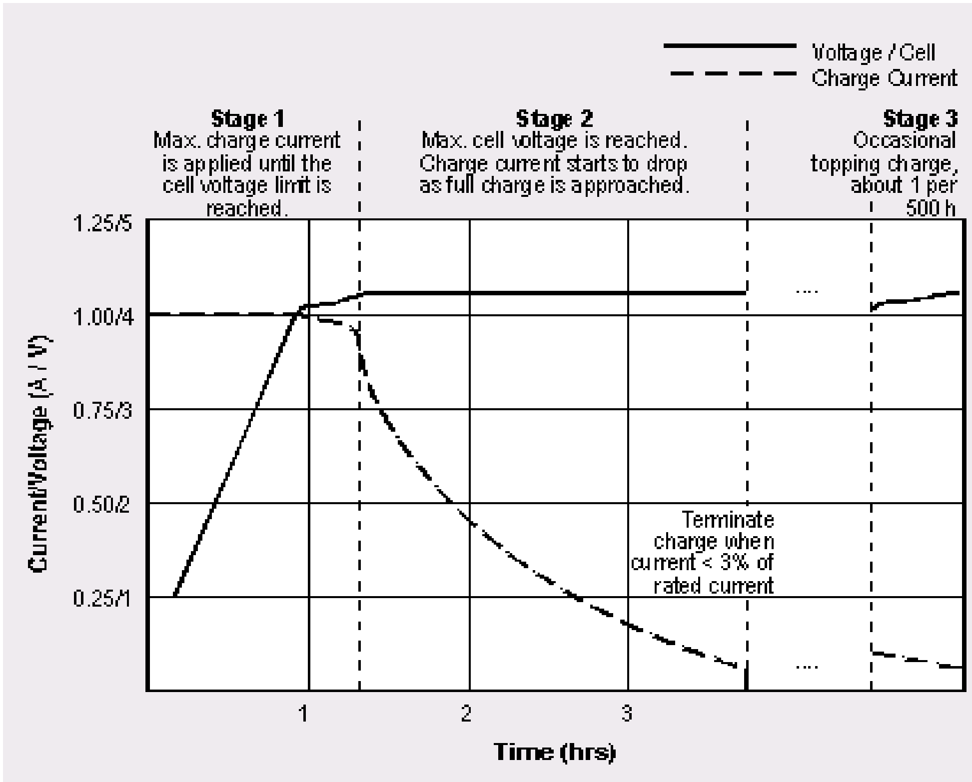


Fig 2.1.2: Lithium-ion Battery Charge Stages

With permission from Battery University

2.1.3 *Nickel-Metal Hybride*

Nickel-metal hybride, NiMH, batteries have a lower volumetric energy density and a higher self-discharge than an equivalent Li-ion battery. Low self-discharge nickel-metal hybride, LSD NiMH, batteries use improvements in separators and positive electrodes to reduce self-discharge rates. NiMH self-discharge rates at room temperature begin at 5-10% and stabilize at 0.5-1.0% per day while the newer LSD NiMH manufacturers claim that the batteries retain 70-85% of their capacity after one year. Due to the large internal resistance LSD NiMH batteries are best suited to high drain devices, such as digital cameras, and because of low self-discharge are appropriate for low drain uses, such as electrical clocks, as well. Figure 2.1.3 displays the typical charge characteristics of nickel-cadmium batteries.

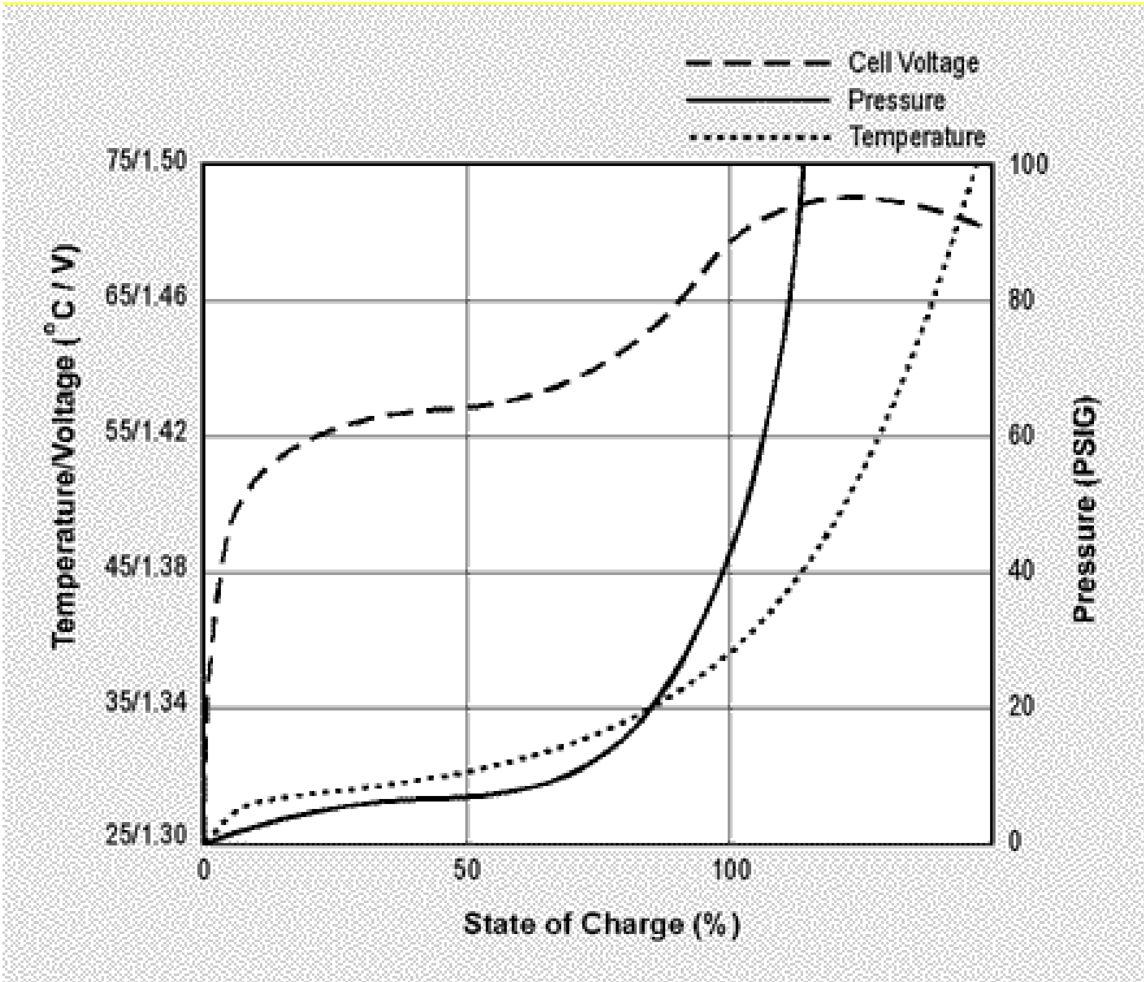


Fig 2.1.3: Charge Characteristics of a Nickel-Cadmium Cell

Characteristics of nickel-cadmium are similar to those of nickel-metal.

With permission from Battery University

2.1.4 *Final Choice*

Nickel-metal hybride, lithium-ion, and rechargeable alkaline batteries are affordable (highest cost to lowest cost, respectively) and can be found at most stores locally. If one chooses to use Li-ion batteries, one would have to make sure to replace the batteries after 1200 cycles, while NiMH batteries would have to be replaced around 500-1000 cycles, and RAM batteries at best would have to be replaced after a couple 100 cycles. If a device will undergo many charge and discharge cycles, one can see that RAM batteries are not the best choice for supplying power. The charge/discharge efficiency of Li-ion batteries is around 80-90% whereas the charge/discharge efficiency of NiMH batteries is around 66%. Although the voltage and performance of NiMH and Li-ion batteries are very similar, the best choice to use to power the Tilapi-ugghhh would be to use NiMH batteries. A possible battery pack configuration is shown below in figure 2.1.4.

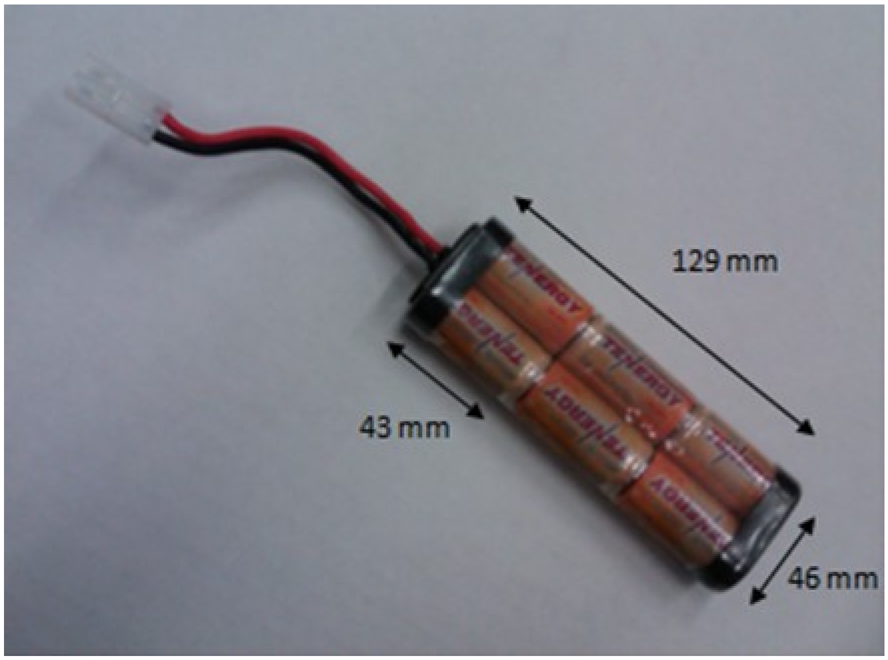


Fig 2.1.4: Battery Pack

2.2 *Recharging*

In order to reenergize the chosen batteries, a circuit that is capable of charging the source must be designed. The circuit to be used to charge the batteries can be seen in Figure 2.2. A blocking oscillator, also known as a feedback oscillator or a single transistor oscillator, has 45 turns on the primary and 15 turns on the feedback winding. Because the primary produces a high voltage during part of the cycle there is no secondary voltage.

As the current begins to flow in the primary winding a magnetic flux is created, decreasing the turns of the feedback winding and produces a voltage that turns the transistor ON. Once the transistor is fully on the magnetic flux within the core of the transformer is at a maximum, and does not produce a voltage in the feedback winding. As the magnetic flux begins to collapse, while the transistor is off, a voltage in the feedback winding opposing the original is produced.

A voltage in the primary winding is produced due to the collapsing magnetic flux. A high voltage spike occurs and is passed through the diode as energy, thus charging the load.

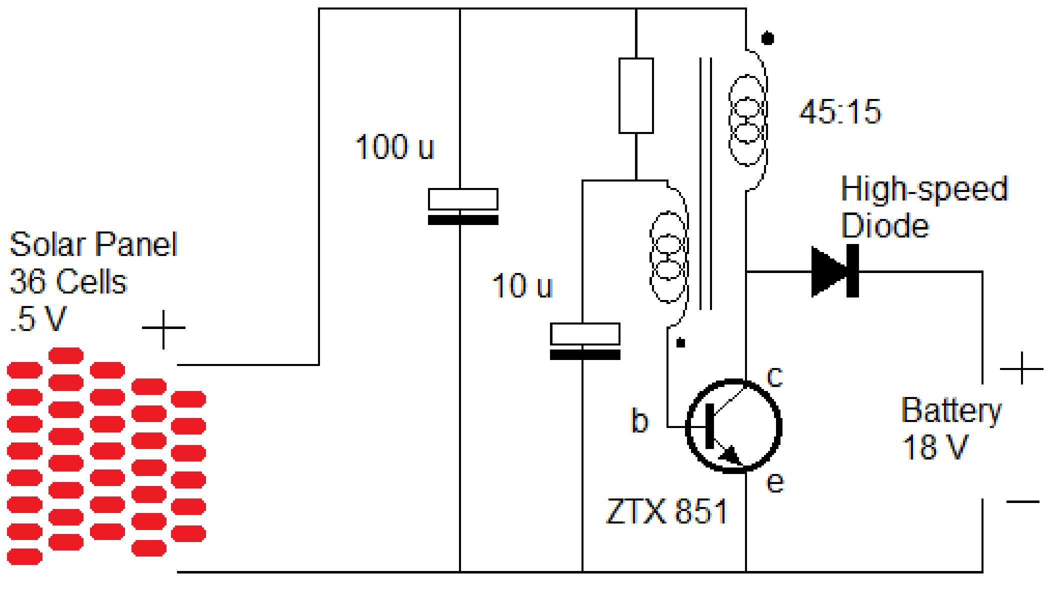


Fig 2.2: Solar Charger Circuit

2.3 *Photovoltaic Cells*

On a clear, bright, sunny day the sun delivers approximately 1,368 watts per square meter to Earth's outermost atmosphere. The Earth's atmosphere attenuates the amount of sunlight that reaches the Earth's surface to about 1,000 watts per square meter. Concentrating solar power and photovoltaics are two ways in which solar power can be harnessed to produce electricity. Concentrating Solar Power (CSP) systems use a series or mirrors or lenses to direct an area of sunlight into a more concentrated beam. Conventional power plants then use the heat generated by the beam as a heat source. Photovoltaic cells convert light directly into electric current by the photoelectric effect. For small scale projects where conventional power plants are not readily available to convert solar energy, photovoltaics are a more feasible option.

The sun emits visible light in tiny packets of energy particles called photons. Photons are the basic unit of light and of all other forms of electromagnetic radiation. When light is shone on a piece of metal a current is induced, this observation is known as the photoelectric effect. More specifically, when a photon of light strikes a metallic surface an electron within the metallic material is knocked loose, allowing the electron to move freely. Photovoltaic

(PV) cells use the properties of semiconductor materials along with the photoelectric effect to convert solar energy in to electricity.

Photovoltaic cells are made of semiconductor materials, most commonly used is silicon (SiO_2). Semiconductor materials have properties akin to both conductors and insulators. Atoms in a semiconductor are bound to their electrons tighter than a conductor but looser than an inductor. Unlike conductors and insulators, electric conductivity can be varied by factors of thousands by doping, introducing impurities to, the semiconductor material.

Silicon is the 14th element. An atom of silicon contains 14 electrons arranged in 3 shells (2 electrons in the first shell, 8 electrons, and then 4 electrons in the outer shell). By sharing electrons with another silicon atom a crystalline structure is formed. When energy is added to silicon a few electrons break free from their bonds and move about until a hole is found. In pure silicon these free carriers are few and useless. However, if doped with a semiconductor such as phosphorous, an n-type semiconductor, free carriers are abundant. If doped with a semiconductor such as boron, a p-type semiconductor, free holes are plenty. When an n-type and a p-type silicon come into contact an electric field is created due to the free carriers from the n-type rushing to fill the holes from the p-type and vice versa.

The electric field allows electrons to flow from p-type to n-type, acting as a diode. Electrons cannot flow in both directions. As a photon of light strikes the photovoltaic cell the energy frees an electron-hole pair, free electrons being sent to the N side while free holes are sent to the P side. Electrons, if provided with an external path, will flow from the N side, through the path, to the P side to combine with the holes. The flow of electrons produces a current, as the electric field creates a voltage, together generating power.

The cell is protected from external stresses by glass or any clear material like plastic, also known as an encapsulate. Electrons are collected through a contact grid, which is made using a good conductor such as metal. Silicon cells tend to be very reflective. To reduce the amount of light, and in turn the amount of photons, reflected an antireflective coating is applied to the top of photovoltaic cells. The antireflective coating helps to reduce reflection losses to less than 5 percent. The back coating then acts as a conductor, covering the entire back surface with metal.

2.3.1 *Photovoltaic Cell Options*

2.3.1.1 *Silicon Solar Cell*

The silicon solar cell is .8 inches by 1.6 inches. The cell delivers about .3 amps at .55 VDC. The Silicon Solar Cell costs around $4.99. In order to achieve the 18V required by the fish a total of 36 Silicon Solar Cells. The total cost of all 33 cells would be about $165.00. The cell is shown below in Figure 2.3.1.1.

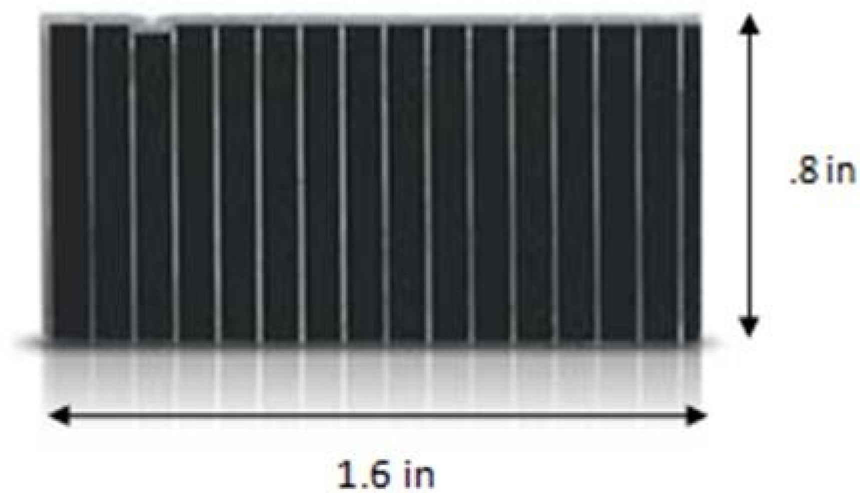


Fig 2.3.1.1: Silicon Solar Cell

Pending Permission from Radio Shack

2.3.1.2 *6V 50mAh Solar Cell Encap*

The solar cell encap is 3.75 inches by 2.5 inches. Within each encap there are 12 solar cells. The encap can be disassembled and rearranged into a new configuration if need be. The 6V 50mAh Solar Encap costs around $14.99. In order to achieve the 18V required to run all functions of the fish a total of 3 Solar Cell Encaps would be necessary. The total cost of all 3 encaps would be about $35.00. The cell encap is shown below in Figure 2.3.1.2.

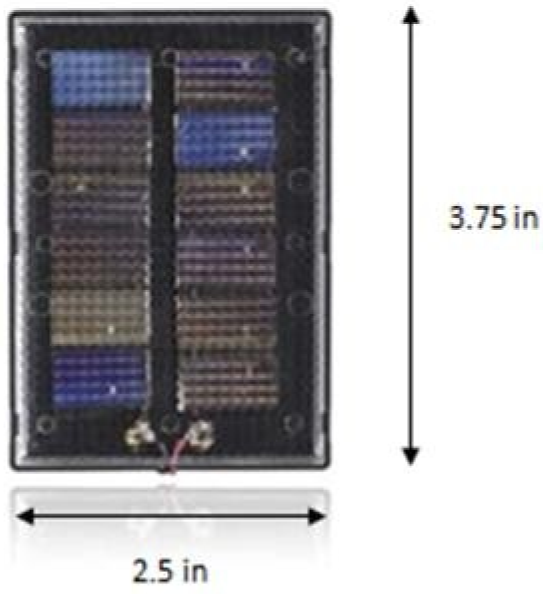


Fig 2.3.1.2: Solar Cell Encap

Pending Permission from Radio Shack

2.3.1.3 *Final Choice*

The efficiency of both the Solar Encap and the Silicon Solar Cell are about the same. Major variations in effectiveness are byproducts of how much sunlight is available. Because there are no major differences in the two options, the decision must then come down to cost. The cost of utilizing the 3 Solar Encaps would be much less costly than the cost of utilizing 33 Silicon Solar Cells. Therefore, the Solar Encaps are the best option.

2.4 *Challenges*

2.4.1 *Properties of Light*

As light hits an object, the light wave will either be reflected or scattered, absorbed, refracted or the light wave will pass through the object. What happens to the wave of light depends on the energy of the wave, the natural frequency at which electrons vibrate and the strength with which the atoms are bound to their electrons. As light hits water the wave will, depending on the angled of incidence, experience reflection and refraction. As light is reflected the wave will undergo loss of light. As water enters the water, which is a substance that is 800 times denser than air, particles within the water molecules will become suspended causing loss of light, diffusion and other effects. The light loss due to reflection is shown below in Figure 2.4.1.

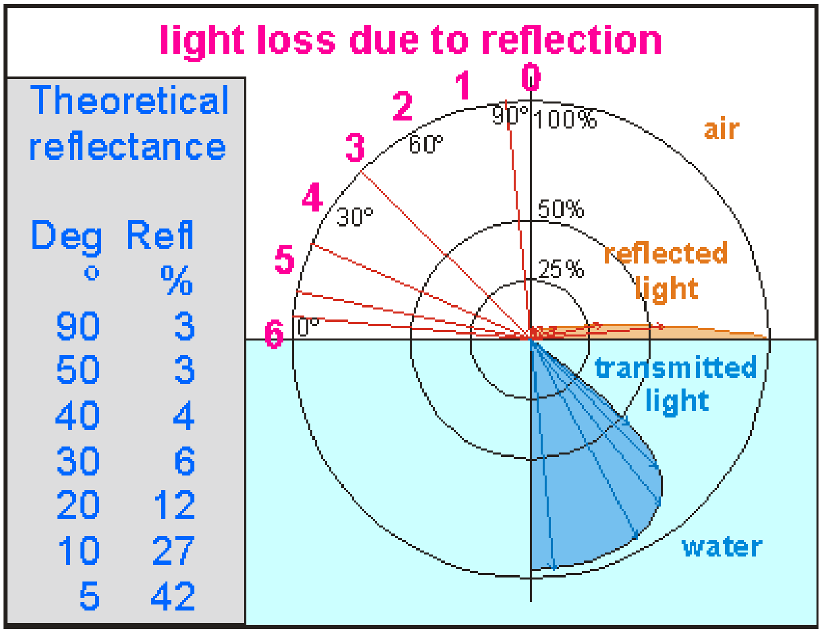


Fig 2.4.1: Light Loss vs. Angle

With permission from Sea Friends

2.4.2 *Light Intensity vs. Water Depth*

As water travels through a dense medium such as water, the intensity of light will diminish. The deeper into the water the fish is, the less intense the light waves will be. At shallow depths (0 - 5m) the amount of light available decreases to about 40%. Past 20 m little to no light is available at all. Figure 2.4.2 displays the characteristics of light percentage versus depth for a clear lake.

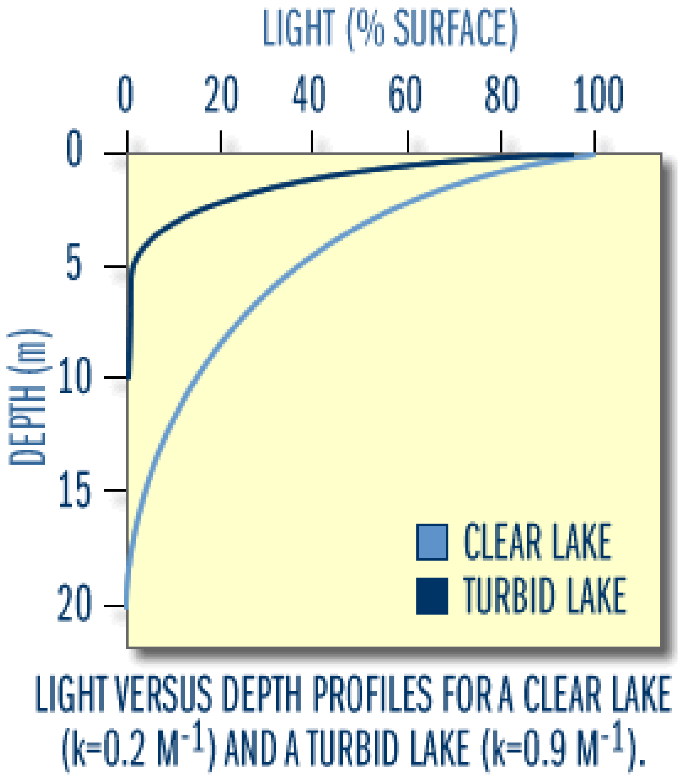


Fig 2.4.2: Light vs. Depth

With permission from Water on the Web

2.4.3 *Environment*

The Earth receives approximately 1,000 watts per square meter due to the attenuation of Earth's atmosphere. On a bright, sunny, clear day the amount of sunlight that actually reaches the surface is relatively great. Add a few clouds, and the entire story changes. In addition to weather conditions, how high the sun is in the sky is another factor that affects the use of photovoltaic cells. The height of the sun varies with each season. As the sun is at its highest point in the sky, during summer, its rays will travel through the atmosphere much quicker over a shorter distance as compared to winter sunlight. A third factor that influences the amount of sunlight that reaches solar cells is the number of daylight hours.

2.4.4 *Solution*

In order to optimize the amount of sunlight that the solar cells will need to charge the batteries the solar cells must be placed where the most amount of surface area can be achieved, such as the side of the fish itself. Although our fish will be tested in shallow waters, the amount of sunlight should still be maximized. The fish must also surface completely, exposing the cells to the sun, in order to avoid any incidence of water reflecting light away from the photovoltaic cells as well as increasing the amount of light intensity.

2.5 *Solar Cell Arrangement*

As the electric field pushes the free electrons and holes around energy is lost and end up with around one-half volt of potential. Solar modules are typically made up of more than one photovoltaic cell to make up for the small potential. The photovoltaic cells are generally connected front to back in series to allow the electrons to flow from cell to cell. Electrons flow along the surface of the cell by means of the contact grid. As the current travels from one photovoltaic cell to another, energized by the photons that strike and enter each cell, a net gain of one-half volt per cell is added. In order to gain 18 volts, current will pass through a typical solar module of 36 cells (36 x 0.5 volts). In cases where more voltage might be needed two solar modules can be connected in series to make a solar array suited to the task. Figure 2.5 shows a possible arrangement for the solar cells required to power the fish.

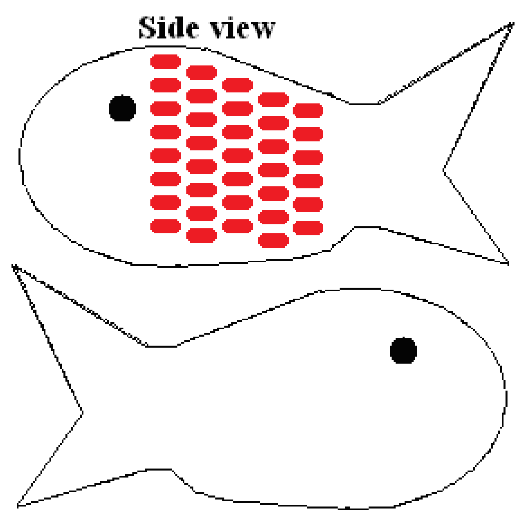


Fig 2.5: Possible Solar Panel Arrangement

The sun's rays should be perpendicular to the panels, as seen below in Figure 2.5b, so sunlight will hit them at a 90 degree angle. If the fish is to be used further from the equator, the photovoltaic cells should be set at a slight angle.

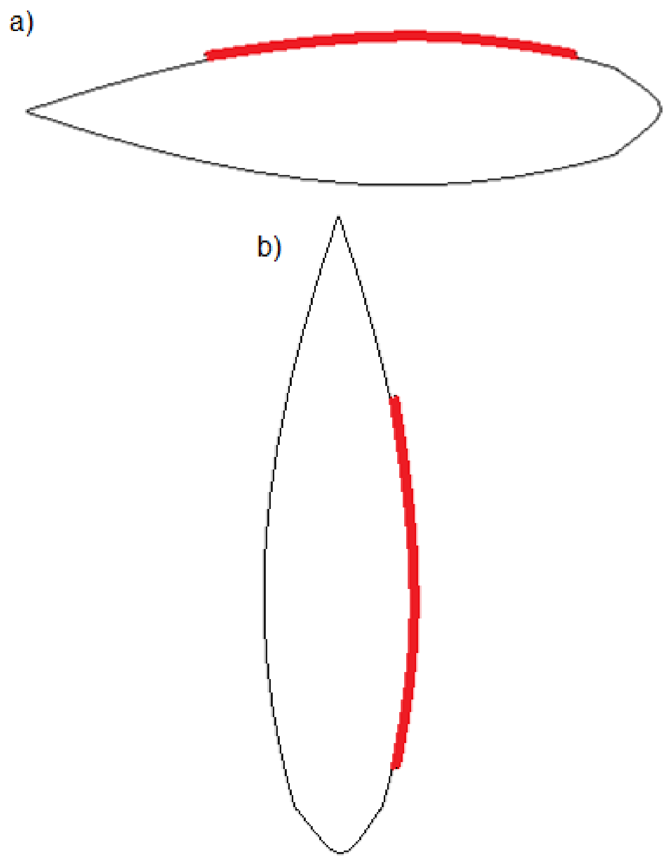


Fig 2.5b: a)Solar Panel Charging View

b) Solar Panel Swimming View

3.0 Sensors

As technology is growing and the designs of mobile robots are becoming more and more versatile, the application of sensor types available becomes broader. The basic design of these sensor applications can range from the simple IR type to the complex GPS.

In this section, many sensor types and layouts that were already designed by other engineers are explored and studied so the effective arrangement of sensors selected will be used based on these references. Since our group does not have any experience in designing robots in general or in building a sensor system array, the requirements for these applications will be very simple and basic.

There are 4 sensor systems that are needed: a battery level detector; water sensor; a light sensor; and an object detection system. Each system will require three characteristics. They must be fast; data collected must be easily processed so that the fish will be able to react in real time. The second requirement must be that it is reliable and power efficient. And finally it must be waterproofed.

3.1 *Water Sensor*

A simple Water sensor is easy to construct. All that is required is an n/p/n transistor a resistor and a potentiometer assembled as shown in Figure 3.1.

The best placement of the water sensors is shown in Figure 3.1 below.

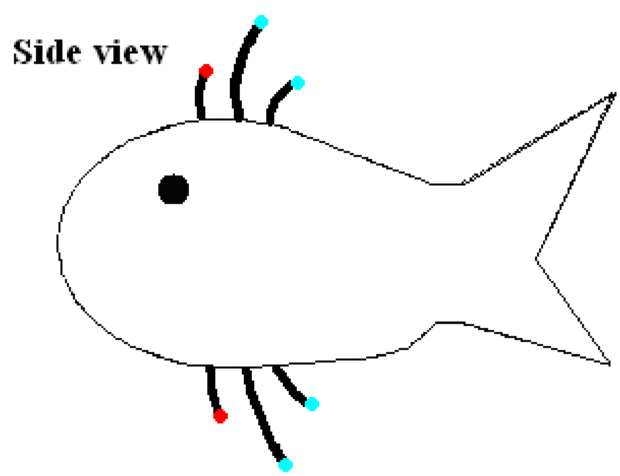


Figure 3.1: Water Sensor Arrangement

3.2 *Battery Level Detection*

A key part to the fish is a way to sense its battery life. Without this component the fish would only surface when we program it to. There are two options to implement the battery level detector.

3.2.1 *Ross Engineering Corporation*

The alternative is the LM3914 and building a circuit around it to transfer the info to the microcontroller. A diagram of the chip and its dimensions can be found in Figure 3.2.1a.

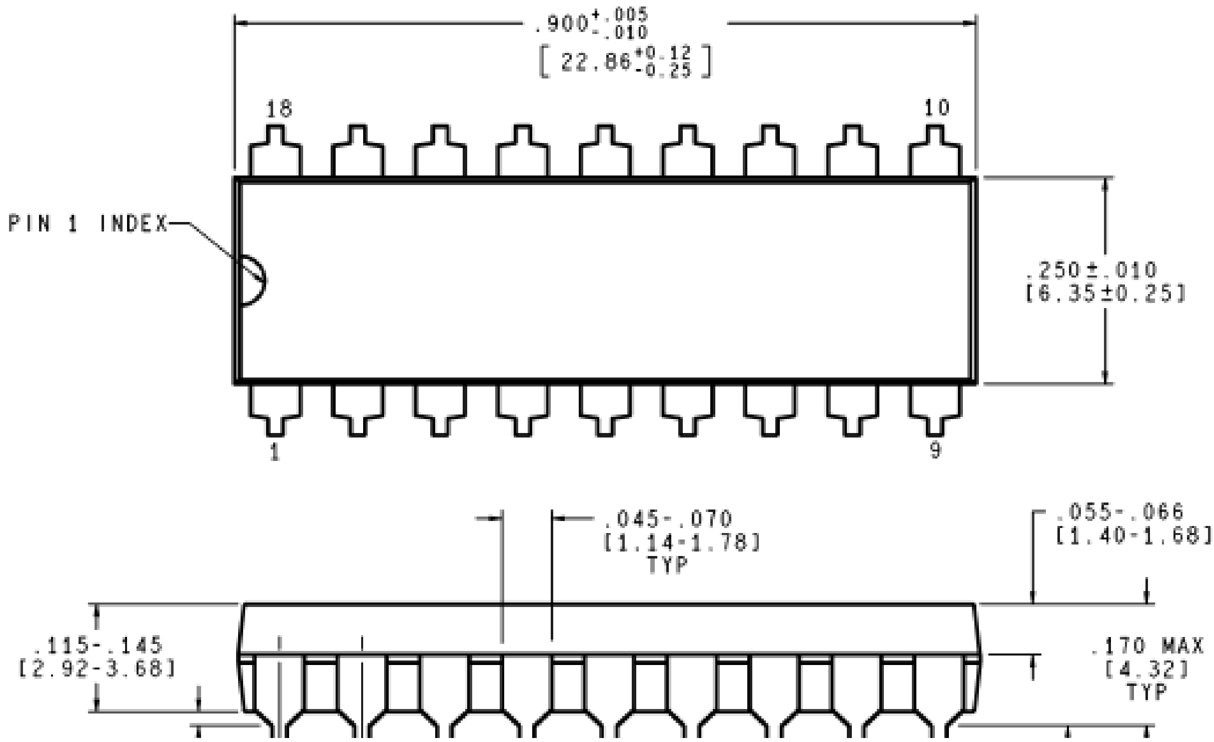


Figure 3.2.1a: Physical Dimensions of a LM3914

With permission from National Semiconductor Corporation

The LM3914 is an integrated circuit that senses analog voltage levels and drives 10 LEDs, providing a linear analog display. A single pin change can turn the display from a moving dot to a bar graph. Current drive to the LEDs is regulated and programmable, eliminating the need for resistors, and allows operation of the whole system from less than 3V. Below in Figure 3.2.1b is a diagram of the chip implemented in a ten step voltage level circuit.

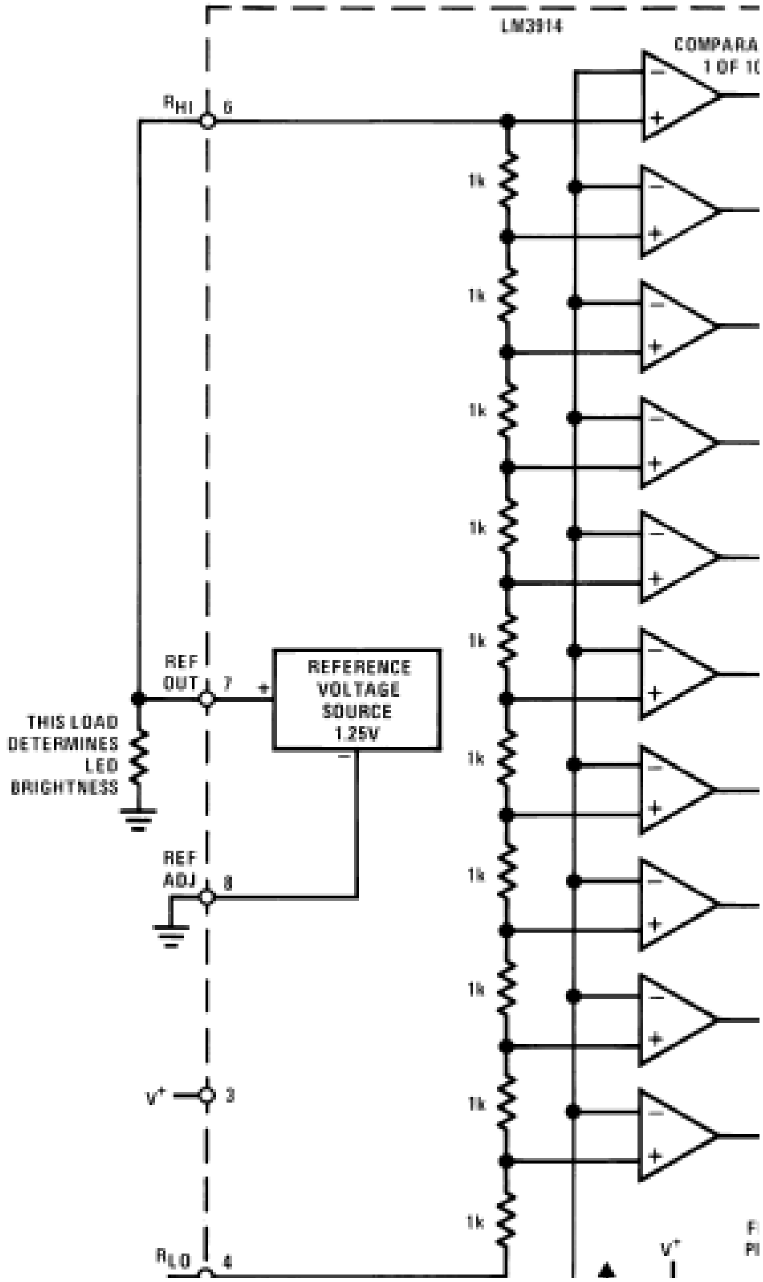


Figure 3.2.1b: Simplest Application of LM3914

With permission from National Semiconductor Corporation

The circuit contains its own adjustable reference and has an accurate 10-step voltage divider. The low-bias-current input buffer accepts signals down to ground, or V-, yet needs no protection against inputs of 35V above or below ground. The buffer drives 10 individual comparators referenced to the precision divider. Indication non-linearity can thus be held typically to ½%, even over a wide temperature range.

The LM3914 is very easy to apply as an analog meter circuit. A 1.2V full-scale meter requires only 1 resistor and a single 3V to 15V supply in addition to the 10 display LEDs. If the 1 resistor is a pot, it becomes the LED brightness control. The simplified block diagram illustrates this extremely simple external circuitry above in Figure 3.2.1b. The circuit can easily be modified to use two LM3914 which would grant greater precision as the max voltage will now be distributed over twenty increments instead of a mere ten. An example of this modification can be found in Figure 3.2.1c below.

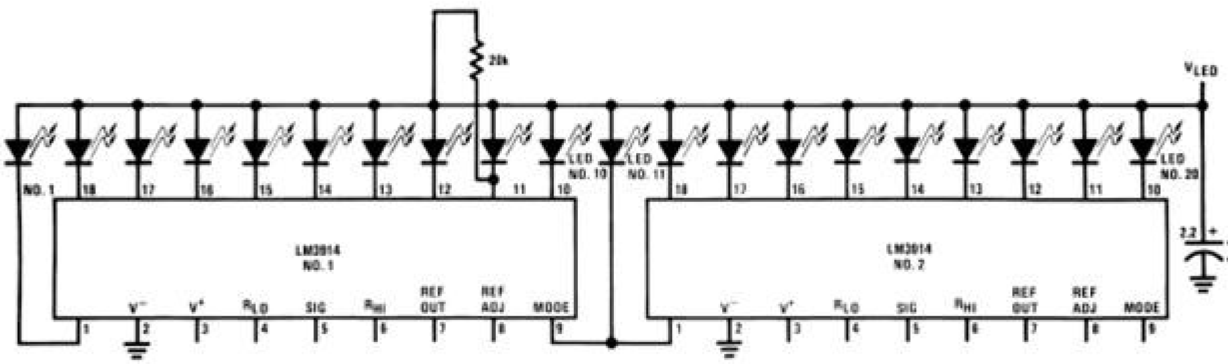


Figure 3.2.1c: Cascading LM3914

With permission from National Semiconductor Corporation

3.2.2 *LM3914 – Dot/Bar Display Driver*

The first option is to get in contact with Ross Engineering Corporation, which builds custom voltage level sensor / indicator / interlock from their basic building blocks. All we would have to do is give them the requirements and they will provide a price for a standard unit or to custom design and build a voltage level sensor to your specific requirements.

3.2.3 *Battery Level Detection Challenges*

3.2.3.1 *Ross Engineering Corporation*

A problem we face by sending our plans to Ross Engineering Corporation for manufacturing is that we cannot anticipate exactly how long it will take to design and build the circuit we require. Another problem we may face is that getting the circuitry right may require multiple attempts as the many nuances of Tilapi-ugghhh may change throughout the building process. Along with the exorbitant amounts of time it may take to send, design, and manufacture the circuitry through the Ross Engineering Corporation it would also necessitate a larger sum of money.

3.2.3.2 *LM3914 – Dot/Bar Display Driver*

Issues with using the LM3914 are that we would have to make the circuitry work and be able to work with the microcontroller. Before implementation we will also need to decide whether we should use the 10 step or 20 step circuit layouts.

3.2.4 *Final Choice*

While sending the requirements off to Ross Engineering Corporation would be easier, it is also potentially the most expensive as the system's power needs have not yet been fully determined. It would be better to go with the LM3914 and build around it.

3.3 *Light Sensing Component Options*

There are many different types of light sensors or photocells available on the markets that are usable in the Fish. From large to small, these sensor types are generally uniform in their nature. The key will be finding ones with the preset characteristics that are needed.

Cadmium Sulfoselenide (CdS) sensors are low cost photoconductive devices for visible light measurement. Their resistance decreases as the light level increases with efficiency characteristics similar to the human eye.

3.3.1 *PDV-P5001*

This photocell changes resistance depending on the amount of light it is exposed to form 300 kΩ in darkness to 8kΩ in light. Its reaction time is 55 ms and 25ms, 55 ms to decrease the resistance from 300 to 8 kΩ and 25 ms to rest after returning to darkness.

3.3.2 *PDV-P5002*

This photocell changes resistance depending on the amount of light it is exposed to form 500 kΩ in darkness to 12kΩ in light. Its reaction time is 55 ms and 25ms, 55 ms to decrease the resistance from 500 to 12 kΩ and 25 ms to rest after returning to darkness.

3.3.3 *PDV-P5003*

This photocell changes resistance depending on the amount of light it is exposed to form 1 MΩ in darkness to 12 kΩ in light. Its reaction time is 55 ms and 25ms, 55 ms to decrease the resistance from 1 MΩ to 12 kΩ and 25 ms to rest after returning to darkness.

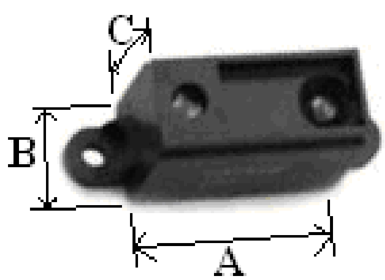
3.4 *Object Detection Component/System*

3.4.1 *IR Sensor Systems*

IR, or Infrared, sensors are among the most common type of sensor to be implemented in a robot. From a simple object detector too information transmission, IR systems are quite common and simple to implement and cheap for any level of robotic hobbyist.

3.4.1.1 *IR Sensor: Sharp IR Range Finder*

The Sharp IR Range Finder is probably the most powerful sensor for the everyday robot hobbyist as seen below in Figure 3.4.1.1a.



A	20.0 mm
B	13.0 mm
C	13.5 mm

Figure 3.4.1.1a: BE-6201 IR Range Finder module A

Pending permission from Society of Robots

It is effective, easy to use, very affordable (about $10 to $20), very small, good range (inches to meters), and has low power consumption.

The Sharp IR Range Finder works by using the theory of triangulation as shown in Figure 3.4.1.1b.

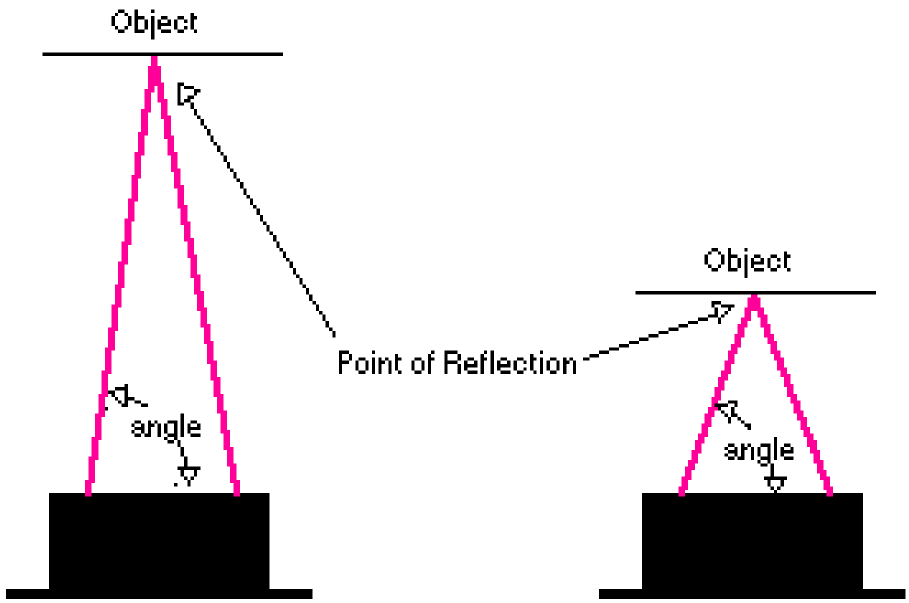


Figure 3.4.1.1b: Process of Triangulation

Pending permission from Society of Robots

A pulse of light of wavelength 850nm +/-70nm is emitted and then reflected back or not reflected at all. When the light returns it comes back at an angle that is dependent on the distance to the reflecting object. Triangulation works by detecting this reflected beam angle, and by knowing the angle, determining the distance.

The IR range finder receiver has a special precision lens that transmits the reflected light onto an enclosed linear Charge-coupled device (CCD) array based on the triangulation angle. The CCD array then determines the angle and causes the rangefinder to then give a corresponding analog value to be read by a microcontroller. Importunely this means that both direct and indirect sunlight can significantly affect results.

3.4.1.2 *Challenges Using IR Sensor*

A major issue with the Sharp IR Range Finder is going below the minimum sensor range. This is when an object is so close the sensor cannot get an accurate reading, and it tells the robot that a really close object is really far. This is bad, as your robot then proceeds to ramp up in speed for a messy collision. A simple solution to this problem is to NOT put your sensor flush with the front of your robot, but to instead back the sensor into the robot so that the front of the robot is located before the minimum sensor range as illustrated in Figure 3.4.1.2b.

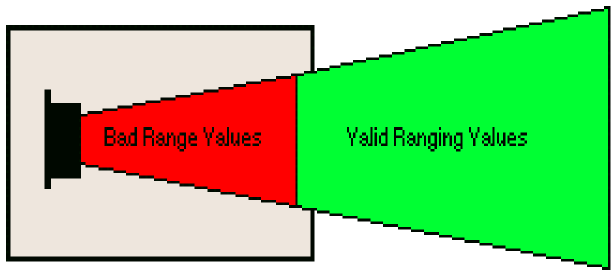


Figure 3.4.1.2a: Process of Triangulation

Pending permission from Society of Robots

A serious issue that makes the IR Sensor unusable in the Fish is the environment, to be specific, the illumination absorption characteristic of water as seen in Figure 3.4.1.2b.

Figure3.4.1.2b: Water’s Light Absorption vs. Wavelength Property

With Permission from Kebes

A key thing to note are the water-vapor absorption lines/spikes at 930, 820, and 730 nm, because IR sensors generally operate at 850nm +/-70nm, meaning the sensor will lose out on a lot of its range. This means a loss of anywhere from 10% to 60% of the IR sensors original range finding ability.

3.4.2 *Visual Sensor System*

3.4.2.1 *Laser Range Finding Vision System*

A method of range finding possible employs the use of a camera and laser, an example of these components can be seen in Figure 3.4.2.1a below.

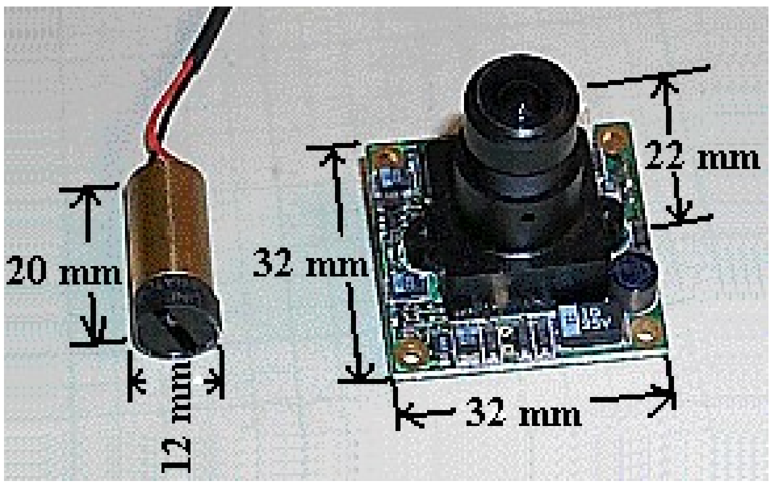


Figure 3.4.2.1a: Laser and Camera

With permission from Kenneth Maxon

A general method of positioning of the camera and laser can be found displayed below in Figure 3.4.2.1b.

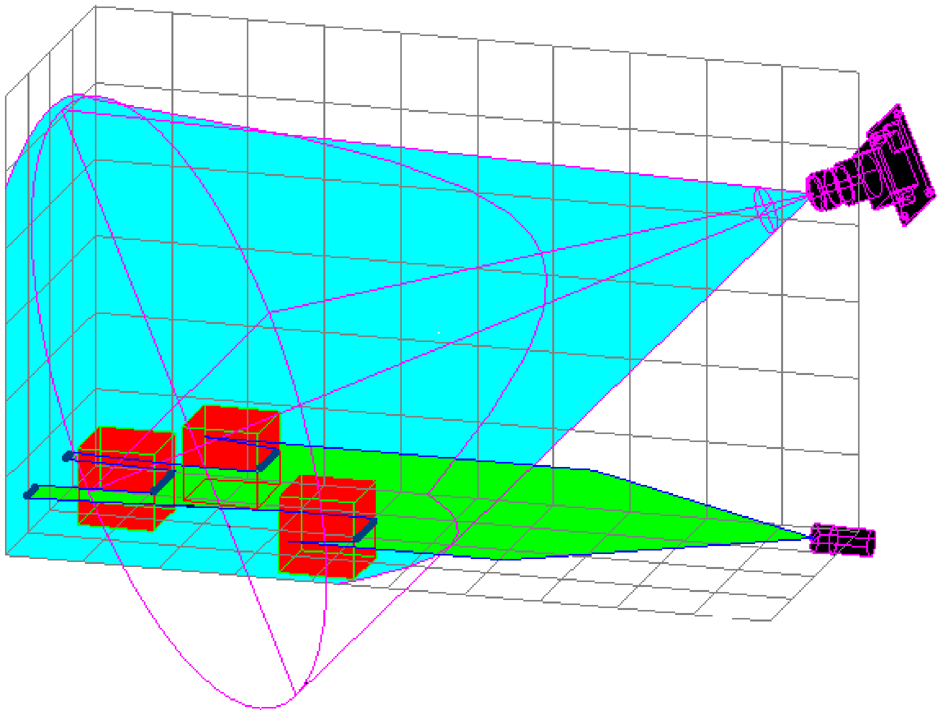


Figure 3.4.2.1b: General Depiction of the Laser and
Camera Setup and How it Works

With permission from Kenneth Maxon

Adjusting the distance and angle between the laser and camera will determine the range finder characteristics. The closer the distance between the two, the more nearsighted the system will be. As for the effect of the angle, the largest area of sight is when the camera is pointed at a 45 degree angle to the lasers plane of illumination.

In order to use a laser and camera range finder system, the Fish would need additional circuitry to operate. The block diagram in Figure 3.4.2.1c is a fully self contained sensor system for range finding only.

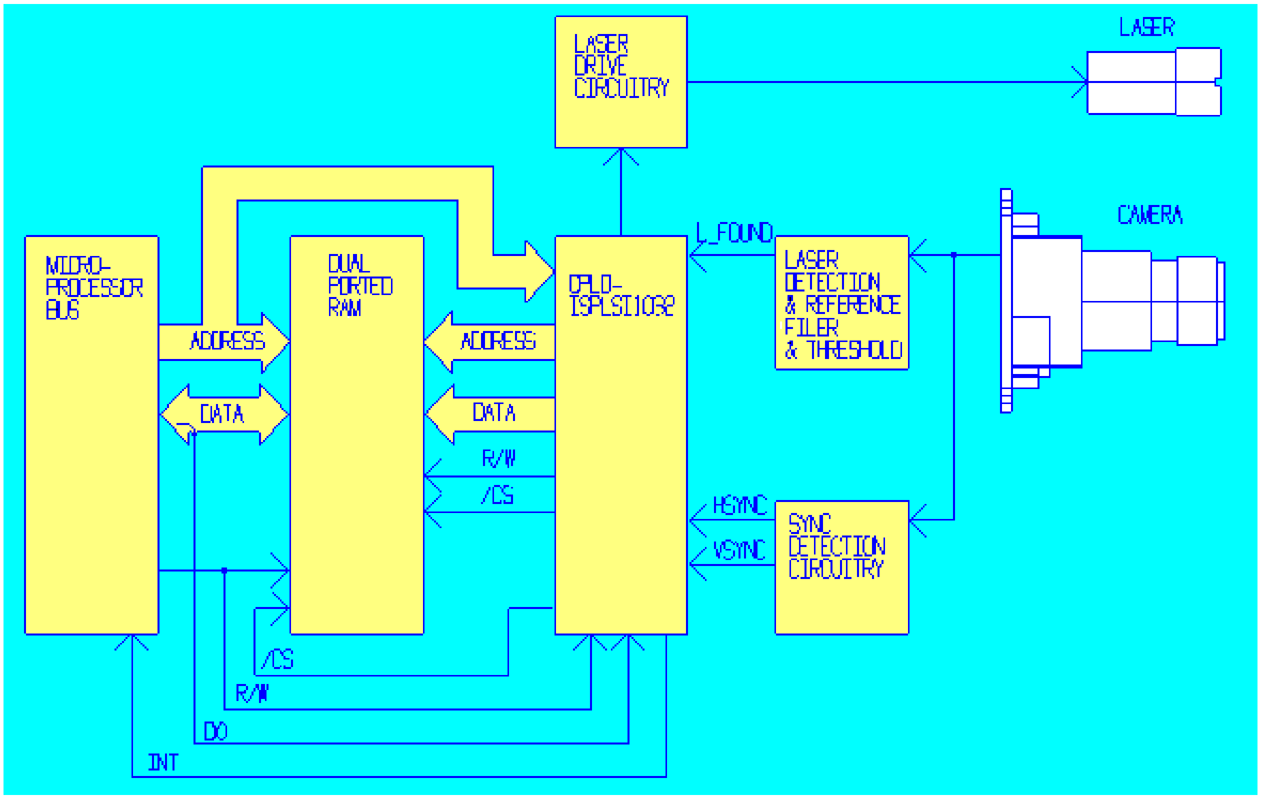


Figure 3.4.2.1c: Block Diagram of Kenneth Maxon's
Real-time Laser Range Finding Vision System

With permission from Kenneth Maxon

3.4.2.2 *Challenges Using Visual Range Finding*

However problems with this system in the environment we will be in are ambient lighting, power, and cost.

3.4.2.2.1 *Ambient Lighting*

A major source of error introduced is that of sunlight causing false readings. Sunlight striking the front of the camera is an absolutely not acceptable, and steps will have to be taken to keep sunlight from striking the lens itself. A second problem from ambient lighting is sunlight striking highly reflective objects and reflecting directly back into the lens/filter system can have many of the same effects. A method to fix these problems is by carefully setting thresholds which can remove some of the unwanted triggering, however this will not fully compensate for this problem.

3.4.2.2.2 *Power Issues*

Power wise, the need to include additional microprocessor and other circuitry elements found in Figure 3.4.2.2.2, will decrease the time that the Fish is alive. This problem is multiplied by the fact that the fish need at least 4 systems of camera, laser, and at least another microprocessor.

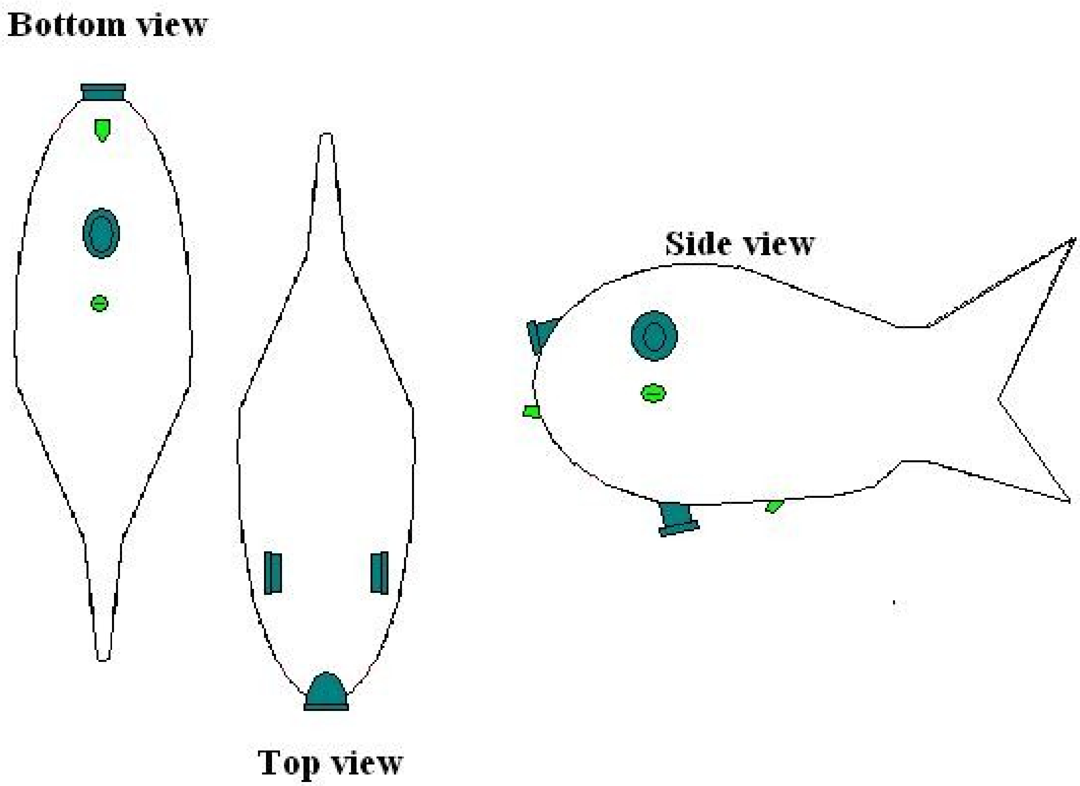


Figure 3.4.2.2.2: Visual Sensor Arrangement.

3.4.2.2.3 *Cost*

The cost break down for this system excluding the microprocessor is fairly high. The lasers range from $14.95 to $44.95 or higher. The camera at a minimum will come to at least $44.95. This means that the system will require, at a minimum, $200, and that is without including the cost of the other circuit elements and microprocessor.

3.4.3 *Sonar*

The use of Sonar/ultrasonic are often dependent on the sensor's beam widths and because of this may not always match their application. Generally, sensors with wider beam widths are better suited for obstacle detection, people detection, collision avoidance, and/or detecting small objects. Sensors with narrow beam widths are less sensitive and as such more useful for clutter rejection, high acoustic noise environments, directional ranging, and room mapping.

The fish will only need to have sensitivity within one to two meters. To be specific, the sensor will need to detect small objects, stable range measurements, small size, low power, and the sensor must be easy to use. The sonar sensors that were considered for use on the fish are from Maxbotix. The figure below contains beam plots form MaxBotix® Inc. Press Release on "Ultrasonic Rangefinders Feature Custom Beam Width". Shown in Figure 3.4.3 are the detection patterns for each sensor type on a one-foot grid background.

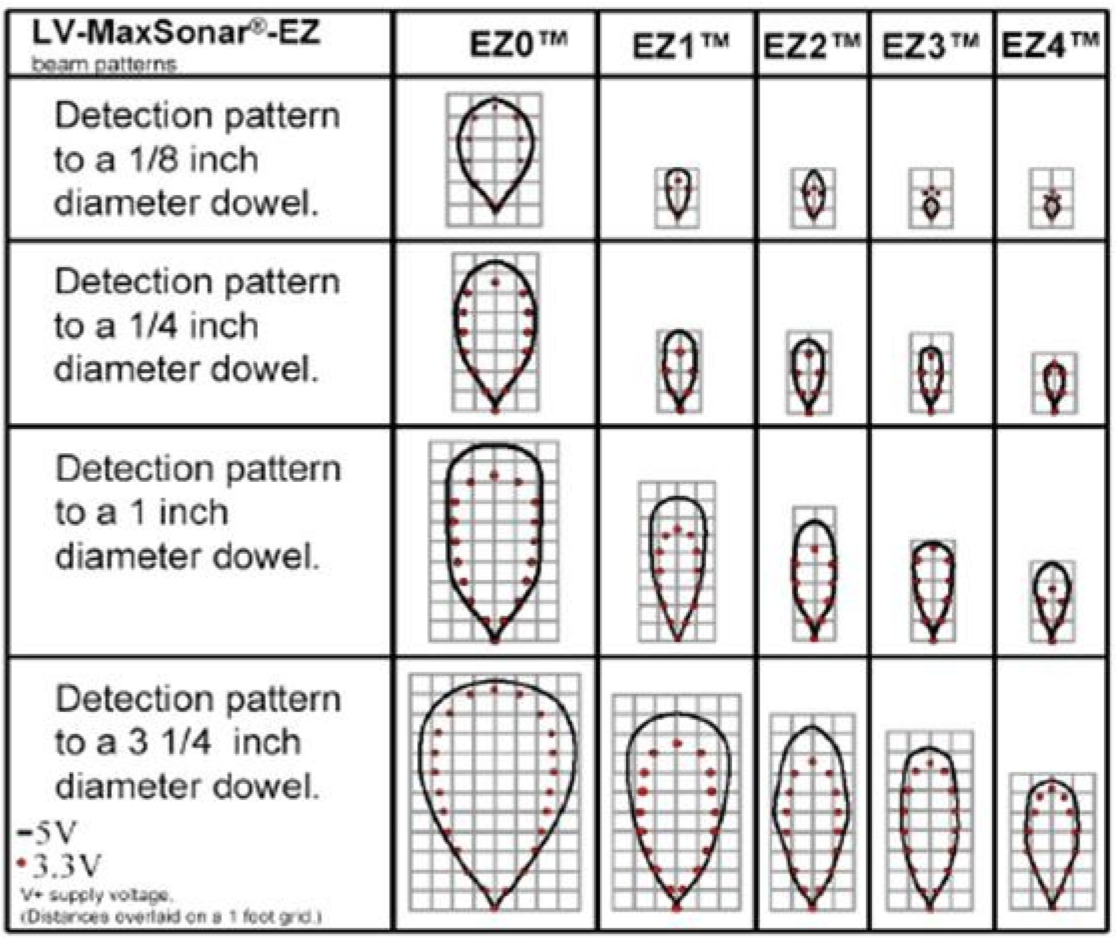


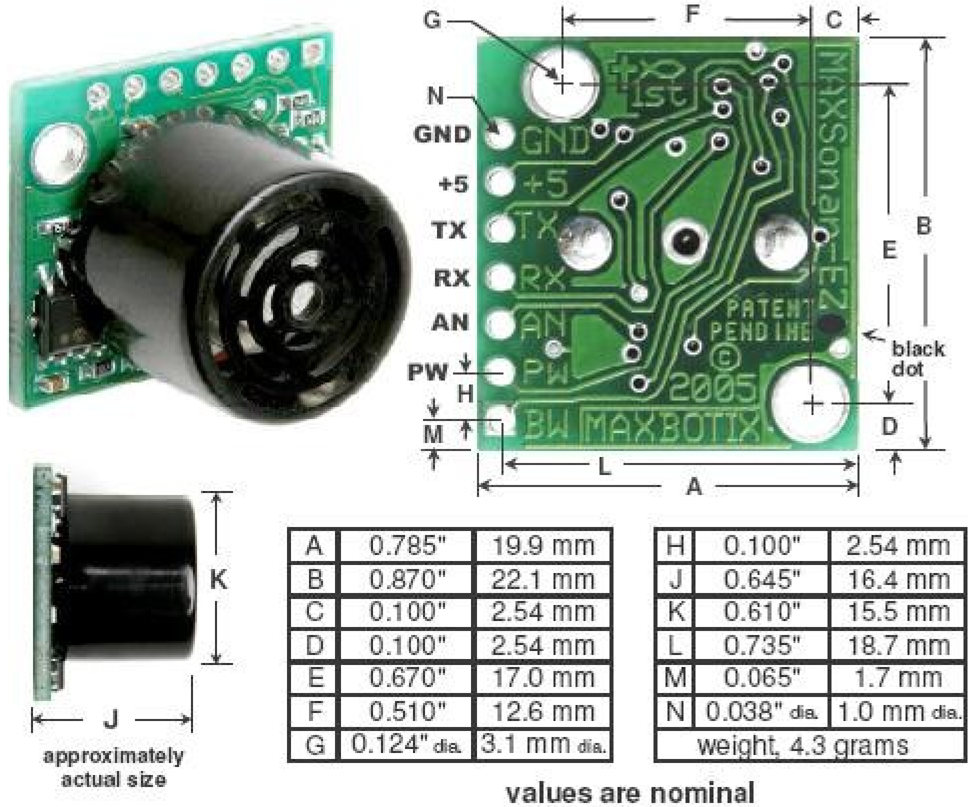
Figure 3.4.3: Range Shown on 1-foot Grid to Various Diameter Dowels (Beam Plots are Approximate)

With permission from **MaxBotix® Inc.**

Detection distances for 5V and 3.3V operation are shown in black lines and red dots respectively. The sensor beam width is widest for the EZ0 with each sensor that follows, EZ1, EZ2, EZ3 and EZ4, is progressively narrower.

3.4.3.1 *Maxbotix LV – EZ0*

The LV-MaxSonar-EZ0 is one of the many sonar sensors available on the market. An image and the dimensions of the LV-MaxSonar-EZ0 can be found in Figure 3.4.3.1a.



A	0.785"	19.9 mm
B	0.870"	22.1 mm
C	0.100"	2.54 mm
D	0.100"	2.54 mm
E	0.670"	17.0 mm
F	0.510"	12.6 mm
G	0.124" dia.	3.1 mm dia.

H	0.100"	2.54 mm
J	0.645"	16.4 mm
K	0.610"	15.5 mm
L	0.735"	18.7 mm
M	0.065"	1.7 mm
N	0.038" dia.	1.0 mm dia.
weight, 4.3 grams		

Figure 3.4.3.1a: Maxbotix LV-EZ0 Dimensions

With permission from **MaxBotix® Inc.**

The LV-MaxSonar-EZ0 will operate at a voltage range of 2.5V to 5V with recommended currents at 2mA and 3mA respectively. Readings can be made up to every 50mS, (20-Hz rate) It provides very short to long-range detection and ranging, with object detection from 0 to 254 inches (6.45-meters) and sonar range information from 6 inches out to 254 inches with 1 inch resolution. The interface output formats included are pulse width output, analog voltage output, and serial digital output.

When the LV-MaxSonar®-EZ0™ is powered up, it will always calibrate during its first read cycle to generate and store a reference range to a close object.

It is important that objects not be close to the sensor during this calibration cycle. Best sensitivity is obtained when it is clear for fourteen inches, but good results are obtainable when clear for at least seven inches. If an object is too close during the calibration cycle, the sensor may then ignore objects at that distance, in other words the device becomes nearsighted.
In Figure 3.4.3.1b below are beam plots depicting the EZ0's sensitivity as well as its accuracy.

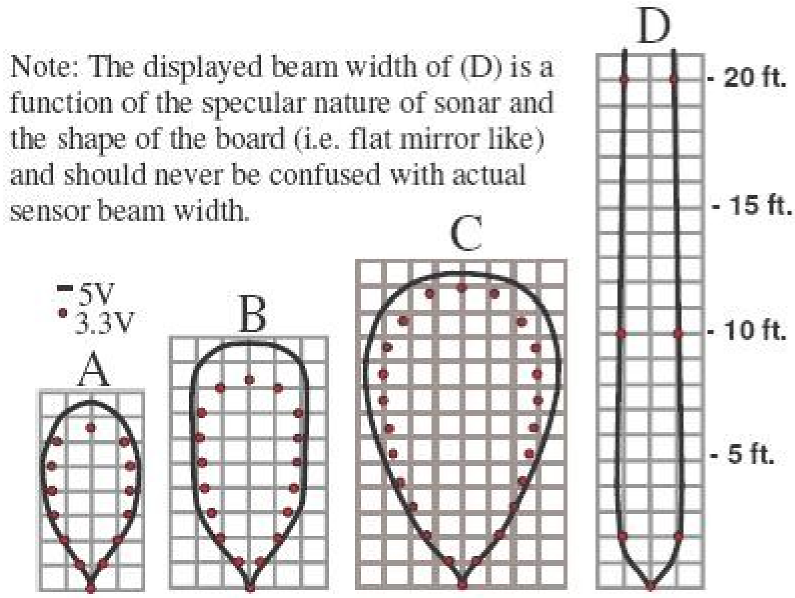


Figure 3.4.3.1b: Beam Characteristics of the EZ0:

(A) 0.25-inch diameter dowel, note the narrow beam for close small objects,
(B) 1-inch diameter dowel, note the long narrow detection pattern,

(C) 3.25-inch diameter rod, note the long controlled detection pattern,

(D) 11-inch wide board moved left to right with the board parallel to the front sensor face and the sensor stationary. This shows the sensor's range capability.

With permission from **MaxBotix® Inc.**

Note that the area marked out by the sonar gets smaller as the objects lining the detection area reduce in size. The accuracy of the device can be linked directly to its operating voltage. Another thing that can be seen is that the EZ0 has a viewing window of 45 degrees as seen in Figure 3.4.3.1c.

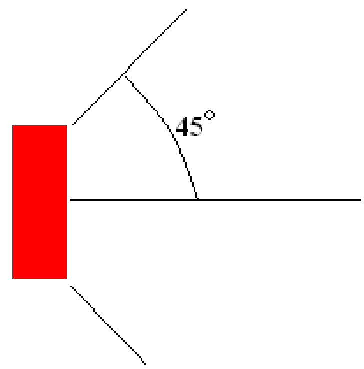


Figure 3.4.3.1c: EZ0 Viewing Window

3.4.3.2 *Maxbotix LV – EZ1*

Like the LV-MaxSonar-EZ0, the LV-MaxSonar-EZ1 resembles the EZ0 in its dimensions and set up. The LV-MaxSonar-EZ1 will also operate at a voltage range of 2.5V to 5V with recommended currents at 2mA and 3mA respectively. Its start up requirements is also similar to the EZ0's conditions. The difference between the EZ0 and EZ1 is in their sensitivity and accuracy. Figure 3.4.3.2a, on page 31, shows the Beam Characteristics of the EZ1. Unlike EZ0, EZ1 operates in a smaller detection/accuracy range as seen in Figure 3.4.3.2a.

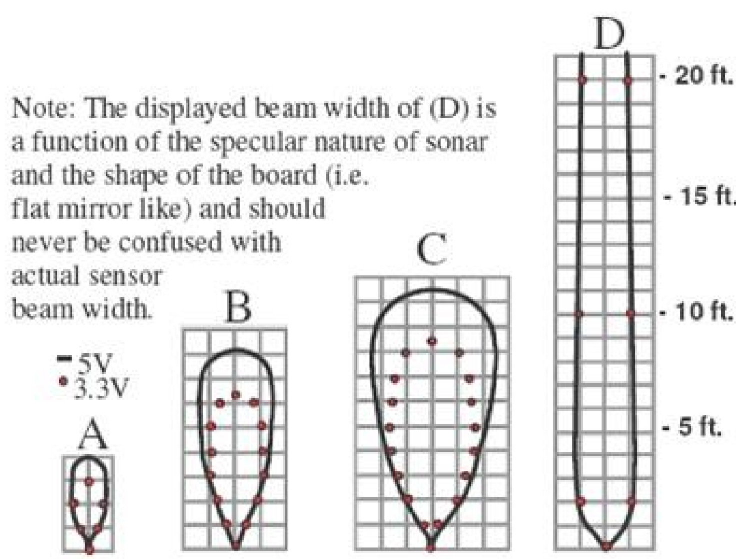


Figure 3.4.3.2a: Beam Characteristics of the EZ1

With permission from **MaxBotix® Inc.**

EZ1 also possesses a smaller viewing angle compared to the EZ0 as seen in Figure 3.4.3.3.

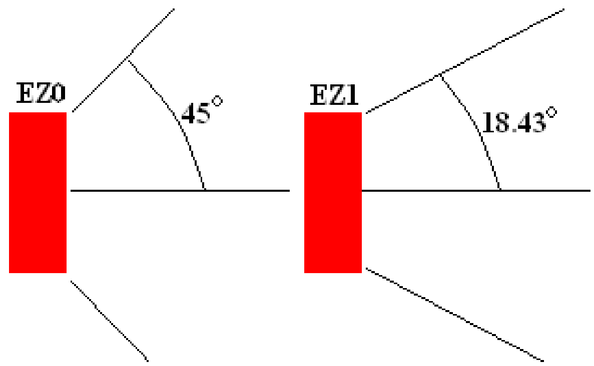


Figure 3.4.3.2b: EZ1 Viewing Window Compared to EZ0

3.4.3.3 *Maxbotix LV – EZ2*

The LV-MaxSonar-EZ2 possesses the same dimensions as its previous incarnations and operates under the same settings but with a smaller detection/accuracy area as seen in Figure 3.4.3.3. The viewing angle is about 30 degrees.

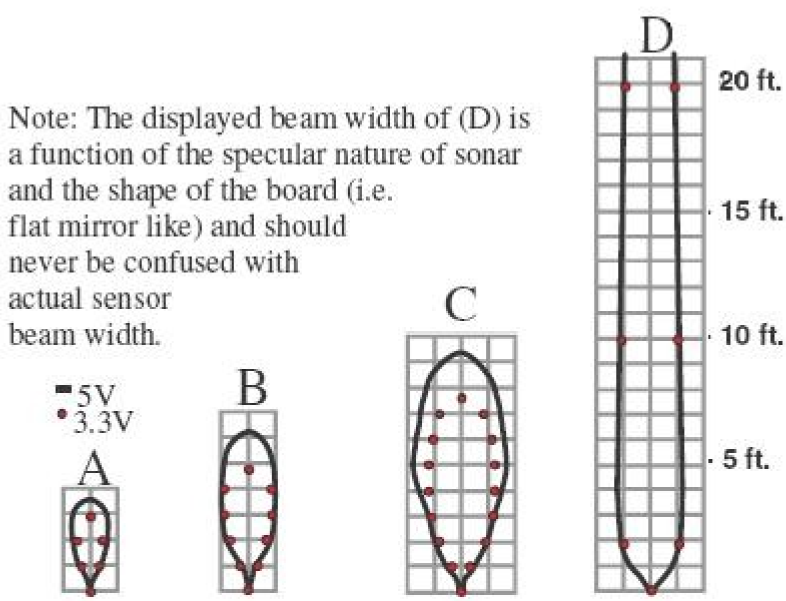


Figure 3.4.3.3: Beam Characteristics of the EZ2

With permission from **MaxBotix® Inc.**

3.4.3.4 *Maxbotix LV – EZ3*

Like all in the previous three variations the LV-MaxSonar-EZ3 possess the same dimensions and operates under the same settings but with a smaller detection/accuracy range as seen in Figure 3.4.3.4. Its viewing angle is similar to the EZ1.

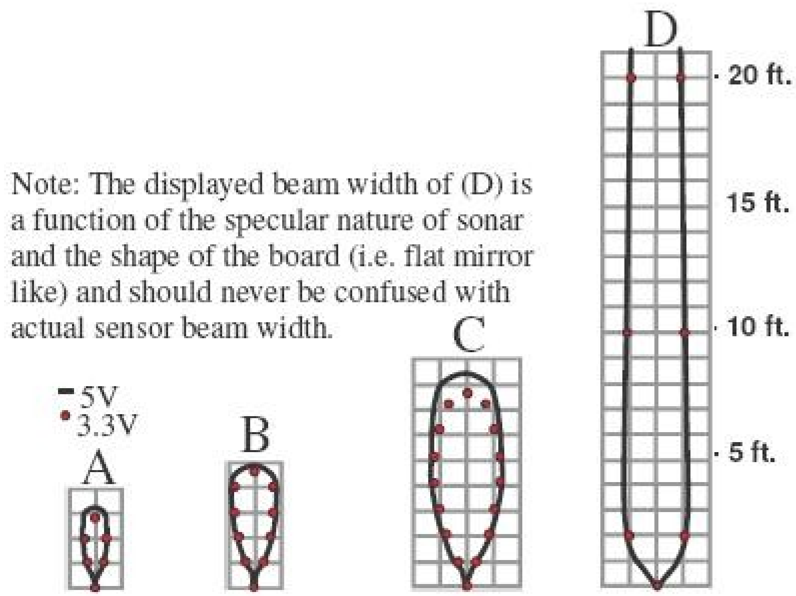


Figure 3.4.3.4: Beam Characteristics of the EZ3

With permission from **MaxBotix® Inc.**

3.4.3.5 *Maxbotix LV – EZ4*

Like its predecessors the LV-MaxSonar-EZ4 has the same dimensions and will operate under the same settings as the previous sonar sensors but with the smallest detection/accuracy range as seen in Figure 3.4.3.5. The viewing angle of the EZ4 is 30 degrees, the same as the EZ2.

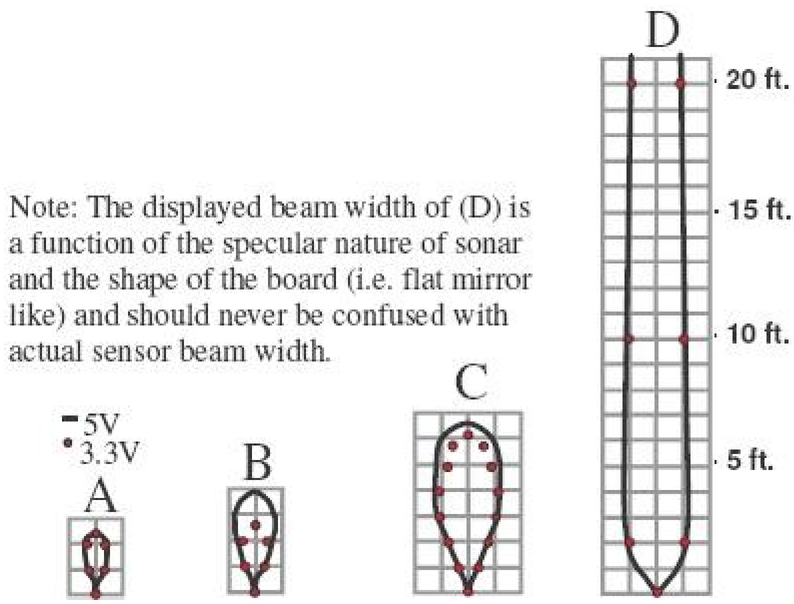


Figure 3.4.3.5: Beam Characteristics of the EZ4

With permission from **MaxBotix® Inc.**

3.4.3.6 *Challenges Using Sonar*

Like all products there are issues that make using them difficult. This is no different for sonar. One of the first obstacles to using sonar in the Fish is that the devices will need to be waterproofed. Unfortunately the Maxbotix Sonar series come pre-built thus are difficult to modify so that they can be used in a submerged environment.

3.4.3.6.1 *Environment*

Another issue that must be resolved is how the water environment will affect the measured results. While it is well know that water's density means that sound travels more readily and farther in it, the difficult that will be encountered if sonar is used is that the sound will need to travel through 5 medians. The first is air since the sonar must be kept to dry. The second median is the material used to insulate the sonar from water and its transference of the sound from the air median to the water and back again. And finally the water median where the speed and distance the sound can be kept stable can affect how the microprocessor must compute the distance.

3.4.3.6.2 *System Design and Cost*

The structure of the fish makes the use of multiple sonar sensors a must. This has two problems that are in some ways tied to each other. A minimum of 4 sonar sensors will be needed so the Fish can see the right and left, anything in front and below the fish. With 4 sonar sensors operating there is a chance of interference between them. While this problem can be resolved by presetting each sensor with a unique transition frequency, this fix's effectiveness cannot be truly determined without testing. The second issue that rises from the use of 4 sonar sensors is the cost. The Maxbotix Sonar sensor are each priced at $29.95, that means that it will cost us around $120, and that is only if none break from our attempts to waterproof them. The possible sonar sensor arrangement can be seen below in Figure 3.4.3.6.2.

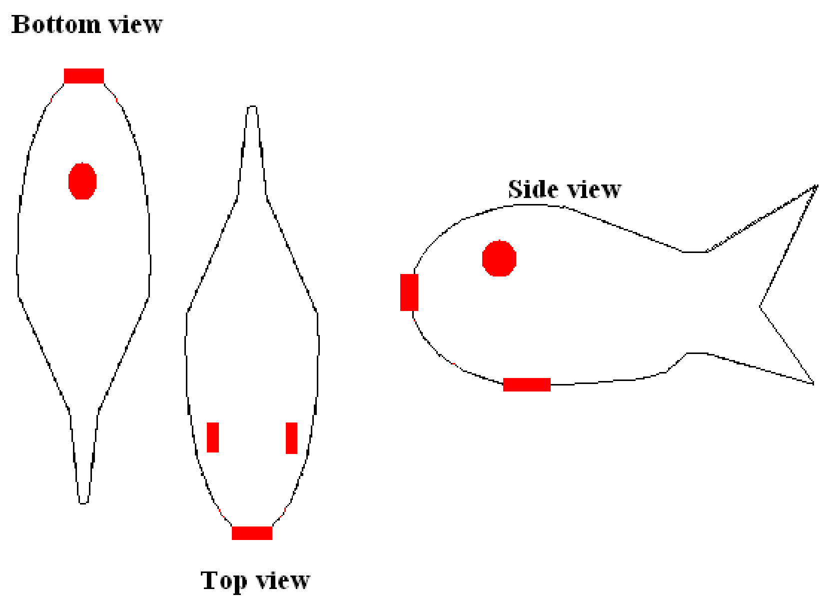


Figure 3.4.3.6.2: Sonar Sensor Arrangement

3.4.4 *Tactile Sensor*

Tactile sensors are best described as a switch that is triggered by a set force. Because of this they are simple to design and implement as well as cheap.

3.4.4.1 *Whisker*

A possible low cost sensor is a tactile sensor. The sensor shown above is created with: "2 paper clips, 'Click type' pen, Sheet of paper, thin piano wire, Soldering iron, Solder, Wire clippers, Tape. By following the instructions provided by Mark Tilden in his “How to make a tactile sensor” a fairly cheap and easy to implement tactile sensor can be made. Possible placement can be seen in the Figure 3.4.4.1a below.

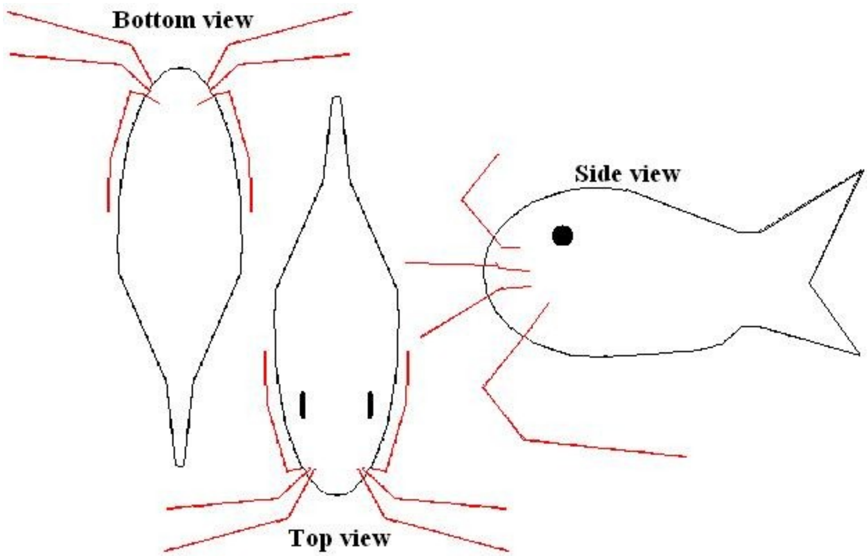


Figure 3.4.4.1a: Possible Whisker Arrangement

Using this arrangement of the whisker on the Fish will allow it to avoid having its' main body from coming in contact with any obstacles. Used in a circuit along with photocells as seen in Figure 3.4.4.1b below would mean needing to allocate fewer pins on the micro processor to be used as data input pins.

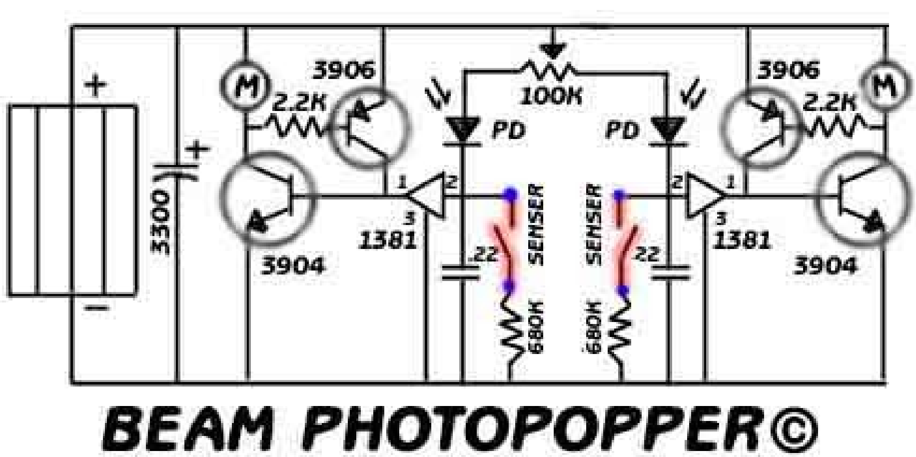


Figure 3.4.4.1b: Light Seeking Object Avoiding Circuitry

With permission from Mark Tilden

If more than two whiskers will be needed a simple solution would be to connect the whisker sensors in parallel circuitry wise. The same can be done with the photocells.

3.4.4.2 *Challenges of Whisker*

The only real flaw in using whiskers as an object detection device is the range. While the whisker length can be changed, the increased length can act as a drag as the fish travels through the water triggering a response from the whiskers to the A.I.

4.0 Physics

One of vital functions of the system is the movement underwater. To achieve the level of displacement wanted, the system will consist of one main propulsion source (rotary motor) and a combination of dual fin control provided by servomotors, allowing the displacement of the prototype. It has been determined that the system will have a slight positively buoyancy. The initial idea is to utilize the fin system to manage the drag coefficient, adjusting the direction and magnitude of the drag force. This will permit the change in both direction angles, given the spherical coordinate system as a reference.

4.1 *Structure and Dynamics*

Force due to drag plays an important role in the overall displacement process. This varies jointly as the surface area, the square velocity, density of water and the drag constant. The surface area or in this case, the orthographic projection of the vehicle, corresponds to the three dimensional translation of the vehicle onto a two dimensional perpendicular plane.

To be able to overcome the force due to the aerodynamic drag created our main propelling will need to have a power specification of at least the power one half the densities of the vehicle times the surface area (Orthographic Projection) multiplied by the drag constant and the cube velocity. Assuming that the environment’s temperature will range between 10 and 40 degrees centigrade, the water’s density will range from 992.2 to 999.7 kilograms per cubic meter.

Accordingly the surface area of the vehicle is constraint by the geometry of the necessary components. However, an initial standard shape for the outside shell vehicle can be compared to a “Streamlined Body” as shown in Figure below. Inside this shell , the components will be secured to a separate structure (Skeleton), where they will be grouped into three main blocks, power control, battery bank and artificial intelligence making the system as compact as possible to minimize the surface area. Drag due to surface area can be seen below in Figure 4.1.

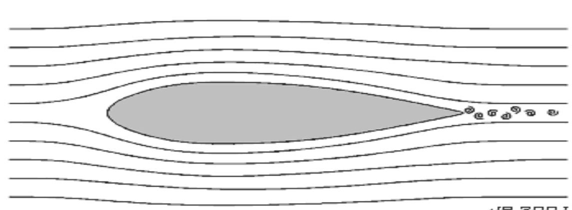


Fig 4.1: Drag Due to Surface Area

For an underwater vehicle of these characteristics the drag coefficient is approximately .04 (Subject to change). The power control block will be composed of the circuital network responsible of charging the batteries and feeding the different devices. As the battery bank block is self-explanatory, this would serve as a case for the batteries. At last, the artificial intelligence block will contain the microcontroller.

4.2 *RC Motor*

As our prime propeller, this component will provide the necessary impulse to the vehicle underwater, with a propulsion force able to reach adjustable magnitudes greater than the initial force acting on the object, due to the water's relative resistance to motion. The vehicle will depend on a battery powered by a solar system, which will be complemented with a network design that will amplify the voltage from the battery to proficiently meet the specified motor's voltage. Since one of the vital functions of the vehicle is to avoid obstacles, this motor will not be required to reach high speeds. However, it will require a relatively high initial torque. For certain maneuvers the vehicle will require less linear speed/torque. Hence the motor will have a fully developed feedback system.

The difference between brushed and brushless motors is the mechanism that each one uses for commutation. However, most brushless motors have a built in circuital switching network to commutate the incoming DC current. We will utilize a brushless motor, due to the significant difference in pricing. For our 20 lb total weight estimation with a max voltage raging between 18-24 V, maintaining a regular speed of 1-2 knots requires a torque of at least 120 oz-in.

4.2.1 *BL2330*

The candidates for the main motor have been narrowed to the BL2330 a 6.25 in by 2.25 brushless motor from Dynetic Systems, which offers a rated torque, power and RPM of 158.84 oz-in, 533.3 W and 5000 respectively.

4.2.2 *M-2331*

On the other hand, Teknic offers the M-2331 a 4.28 in by 2.33 in DC brushless motor, with similar ratings at a lower comprehensive price. Shown below, Figure 4.2.2, of this component with its respective dimensions.

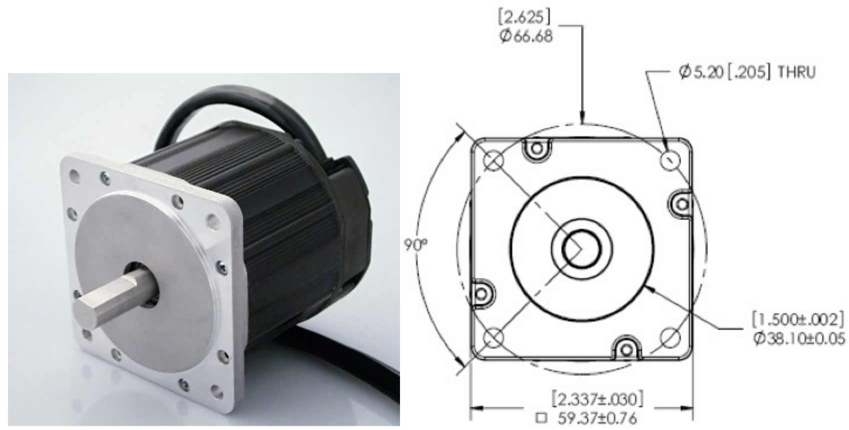


Fig 4.2.2: M-2331 Brushless Motor

4.2.3 *Decision*

However, the components discussed previously will have to be insulated and complemented with an adaptive piece to attach the propeller blade. Therefore, a more tentative component would be the model 260 DC brushless thruster by Tecnadyne shown in the figure bellow with a rated forward thrust of 3 lb-ft, able to operate from 24-330 V requiring an additional 12 V for instrumentation and a +/- 5 V analog speed and direction control signal. Shown below, Figure 4.2.3a, is a figure of both of different views of this component with its respective dimensions.

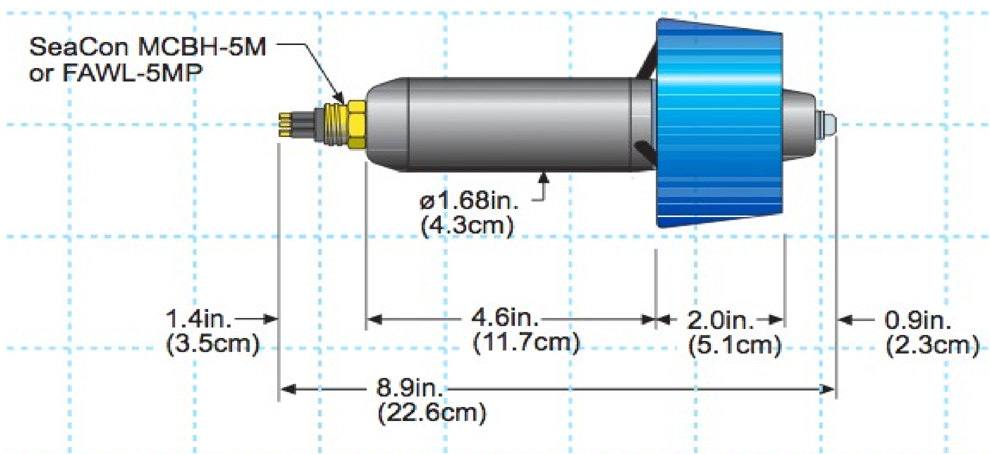


Fig 4.2.3a: 260 Model from Tecnadyne DC Brushless Thrusters Line

Front cross sectional area became an important parameter, as this component was being considered, due to dependability of the rear fin’s on this particular measure. Dimensions of the fin vary directly as the radius of the propeller blade. Shown below, Figure 4.2.3b, is the figure of this cross sectional area.

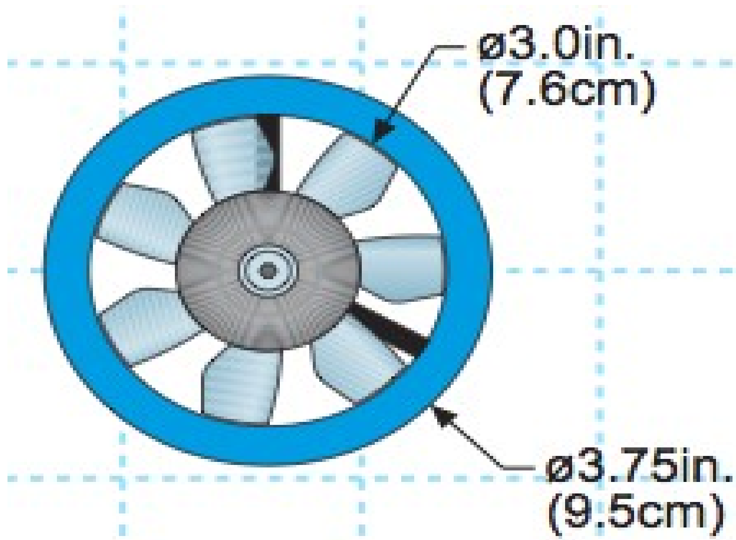


Fig 4.2.3b: Model 260 from Tecnadyne Frontal view

4.3 *Software*

The following sections describe how the DC propelling and directional motors cause motion in the vehicle given commands from the control software. The commands are fed to the motor controller. After receiving a command, the microcontroller sends the appropriate PWM signal to the power electronics to drive the motors at a variable speed or adjust the position angle.

4.3.1 *Speed Control*

Tilapi-ugghhh will be composed of one motor mounted on the back end of the craft. For forward motion, the controller commands the vehicle forward by spinning the motor at full speed. However, depending on the motor selection the microcontroller will need to send an analog or digital signal. For example, if the motor model 260 from Tecnadyne is used, an analog signal ranging between +/- 5 V will be required from the controlling unit. In order to prevent sudden braking and changes in direction, the controller will slow sudden motor commands with an adjustable software parameter.

4.3.2 *Circuit Topologies*

To be able to control the speed of the motor many parameters have to be taken into consideration. The first and most crucial is the rpm. However, from the motor we can only read voltage and current being used. Hence, we will utilize the voltage as an input to determine our rotational status. Shown below, Figure 4.3.2, is a circuit that implements this procedure by the Hobby of Electronic Circuit Engineering.

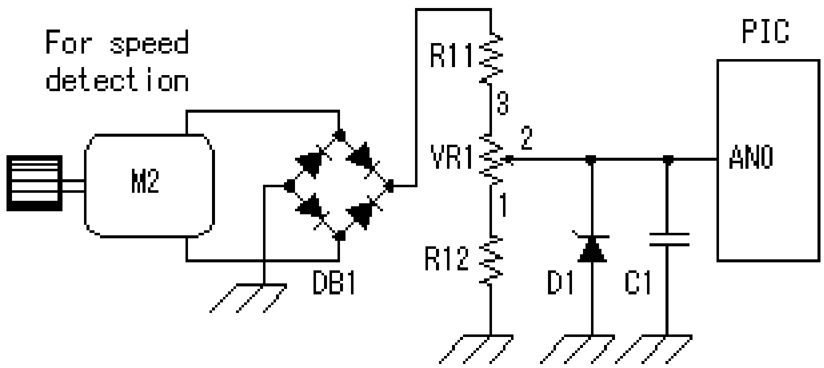


Fig 4.3.2: Speed detection Circuit

The control the voltage input signal, is created by the turning of the motor and then fed to the PIC. The input voltage to PIC, is first converted by an A/D converter. The Changed voltage is used for the PWM function of the CCP to control the motor drive. The input voltage (the control voltage) to PIC is changed by the fluctuation of the number of rotations of the motor. The other way can be used to detect the number of rotations of the motor. It is necessary to change control voltage into proportional quantity to the number of rotations of the motor. PIC controls the drive electric current of the motor for the control voltage to become a regulation value. When the revolution of the motor slows down, i.e. control voltage goes down, the drive electric current of the motor is increased and number of rotations is raised. When the control voltage reaches a regulation value, a drive electric current at the point is held. Oppositely, when the number of rotations of the motor is high, i.e. the control voltage is high, the drive electric current of the motor is reduced and number of rotations is lowered. When the control voltage reaches a regulation value, an drive electric current at the point is held.

DB1 is used to make not conscious of the polarity of the motor. Whenever making a mistake in the connection, to use isn't necessary. When the voltage of the motor for the speed detection is small, it is better not to put.

D1 is used to protect PIC when the voltage of the detection motor is high. C1 is to make bypass the noise of the detection motor. VR1 is the variable resistor to set the number of rotations of the main motor. The input voltage of PIC becomes low when bringing VR1 close to the side 1 and PIC increases the drive electric current of the motor. That is, the revolution of the motor rises. The input voltage of PIC becomes high when bringing VR1 close to the side 3 and PIC reduces the drive electric current of the motor. That is, the revolution of the motor slows down.

4.3.3 *Propulsion Speed*

For turning at fixed angle adjustments and maneuvers, the output of the feedback controller helps balance for unison movements based on the thrust of the motor. There will be various stages to the propulsion speed. Maximum cruising speed will be around 1-2 knots, once the path is compromised with an obstacle then this speed will be reduced at a constant acceleration rate to reach a stopping point, until a new route has been determined by the controlling unit with the help of the sonar and the object detection sensors. Then the motor will be fed with a ramp input to gradually increase the rate complementing the work of the fin system, the direction of the vehicle will be changed until a free obstacle path has been identified by the sensory system. Below, Figure 4.3.3.a, is shown the relationship of the thrust and the voltage for the Model 260 Thruster.

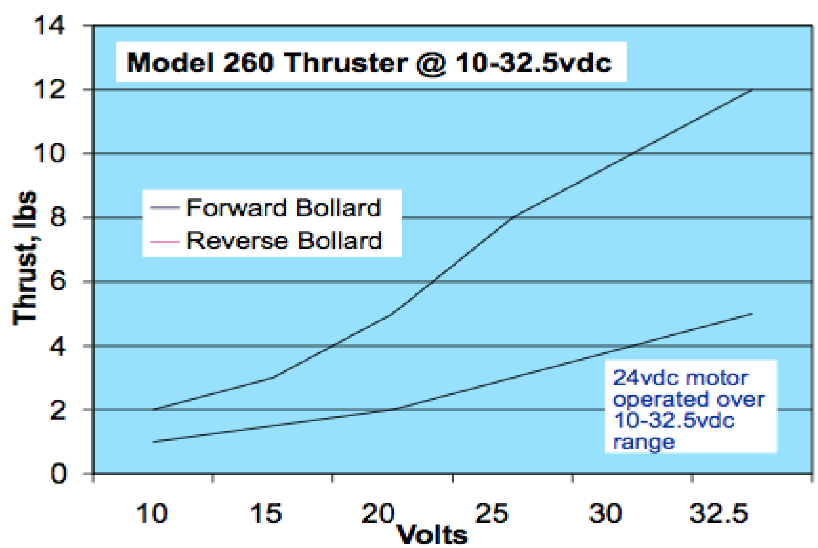


Fig 4.3.3a: Thrust vs Voltage for Model 260 Thruster

Current and voltage relationships with respect to the performance of the components it is very important to set realizable goals for the vehicle. Shown below, Figure 4.3.3b, is the relationship of the current with respect to the thrust.

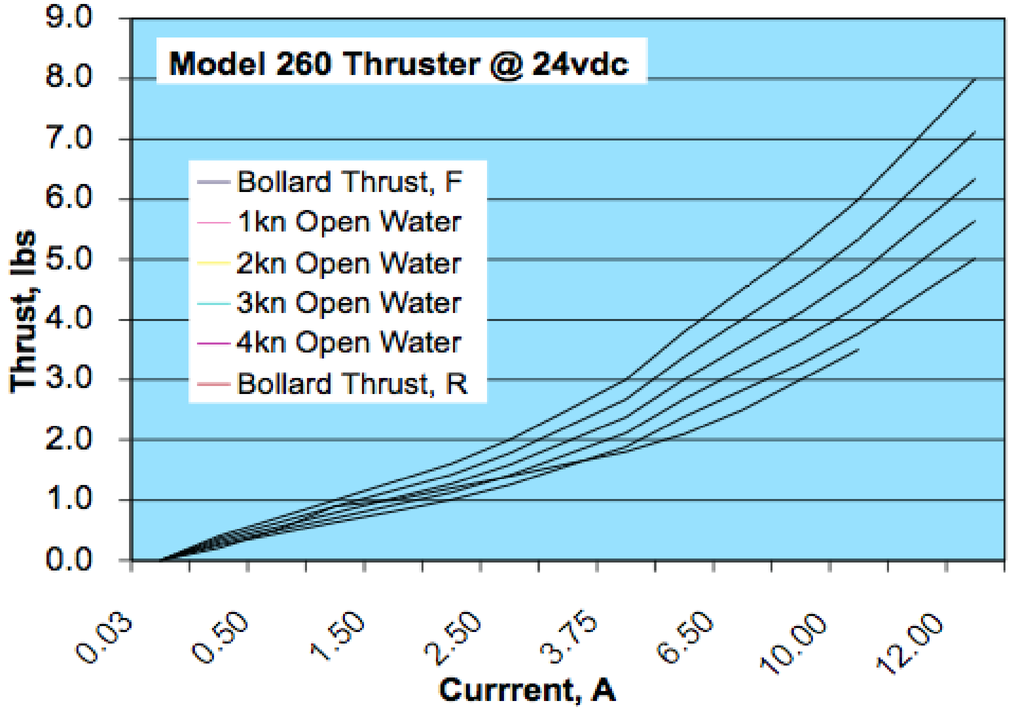


Fig 4.3.3b: Thrust vs Current for Model 260 Thurster

4.4 *Servo Motor*

The servo motor could be described as a small but powerful motor with a rotating shaft that moves limbs or surfaces to a specific angle as directed by a controller. Once the motor has turned to the appropriate angle, it shuts off until it is instructed to turn again. A servomechanism or servo is an automatic device that uses error-sensing feedback to correct the performance of a mechanism. The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position or other parameters. In our case the servomechanism will change the angular position of the shaft through the feedback control.

A servomechanism is unique among control systems in that it controls a parameter by commanding the time-based derivative of that parameter. For example, a servomechanism controlling position must be capable of changing the velocity of the system because the time-based derivative (rate change) of position is velocity. A hydraulic actuator controlled by a spool valve and a position sensor is a good example because the velocity of the actuator is proportional to the error signal of the position sensor. A standard DC servomotor could be observed on the figure below, Figure 4.4.

Fig 4.4: BL series DC Brushless Motor from Dynetic

Servos use a position-sensing device (also called a digital decoder) to ensure that the shaft of the motor is in the right position. They usually use power proportional to the mechanical load they are carrying.

4.4.1 *Decision*

BL2330 DC brush servo motors are easy to use and relatively low cost. The smooth rotation and often the electronics to drive a brush motor are easy and inexpensive. However, Brushless servo motors have no brushes to replace and are "maintenance free". Brushless motors offer very high speed performance and because they lack brushes can be used in almost any environment. A typical servo has a particular geometry, which makes it easy to mount on any structure. Dimensions for the standard DC brushless motor could be observed in the figure below, Figure 4.4.1.

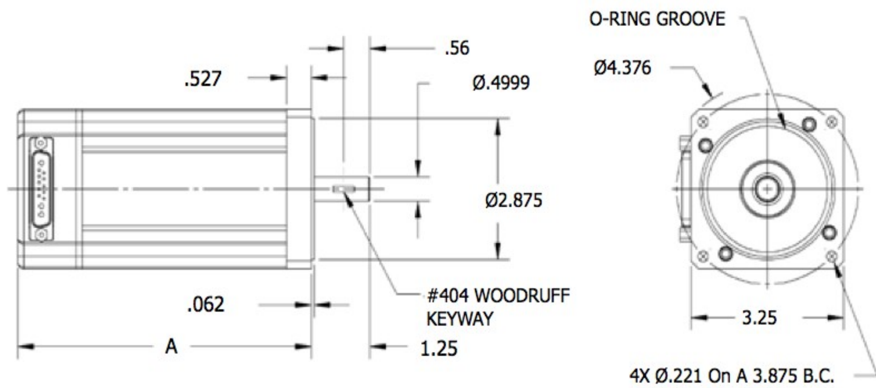


Fig 4.4.1: Servo Diagram

Where the length labeled as A varies depending on the particular model. However, this measured usually ranges from 4.2 to 6.2 in. For our design, we will try to accommodate for the 4.2 in model, to reduce the cross sectional area of the vehicle, since drag force is dependent on this parameter.

For our particular design we have chosen to go with a DC Brushless Motor from Dynetic, which will serve as our dual servo system that will simulate the fin movement. This component requires a 24 V feed with a rated power of 560 watts and a rated torque of 180 oz-in, meeting our requirements for the fin system.

4.4.2 *Standard Servo Operation*

The servo will move based on the pulses sent over the control wire, which set the angle of the actuator arm. The servo expects a pulse every 20 ms in order to gain correct information about the angle. The width of the servo pulse dictates the range of the servo's angular motion. Figure 4.4.2 shows the amplitude versus time for the servo.

A servo pulse of 1.5 ms width will set the servo to its "neutral" position, or 90°. For example a servo pulse of 1.25 ms could set the servo to 0° and a pulse of 1.75 ms could set the servo to 180°. The physical limits and timings of the servo hardware varies between brands and models, but a general servo's angular motion will travel somewhere in the range of 180° - 210° and the neutral position is almost always at 1.5 ms.

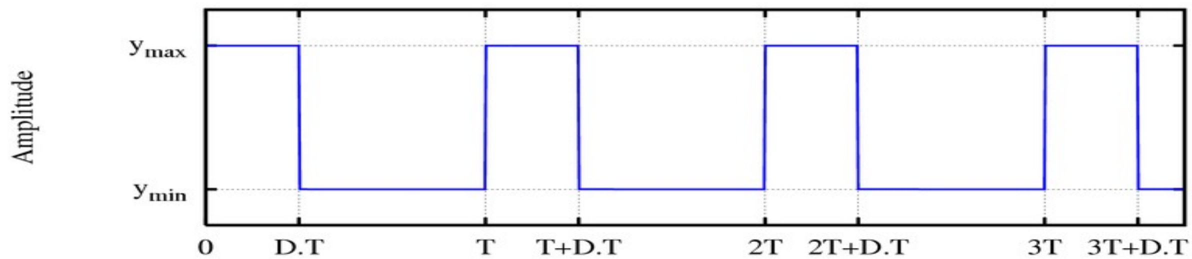


Fig 4.4.2: Servo Graph

4.4.3 *Servo Control*

Current motor position is fed back to the servo controller with a potentiometer or a rotary encoder. The motor position is compared to commanded position, the motor is driven according to the position error, and the motor is moved and held to the commanded position.

The servo operator consists of error amplifiers and PID filters. Up to the 1980's, the servo operator was realized with op-amps, F-V converter, differential counter, D-A converter and many analog components. However, now days the most common implementations use digital signal for the servo controller, and new servo algorithms, such as AI control, robust control and fuzzy control. A typical arrangement is shown below in Figure 4.4.3.

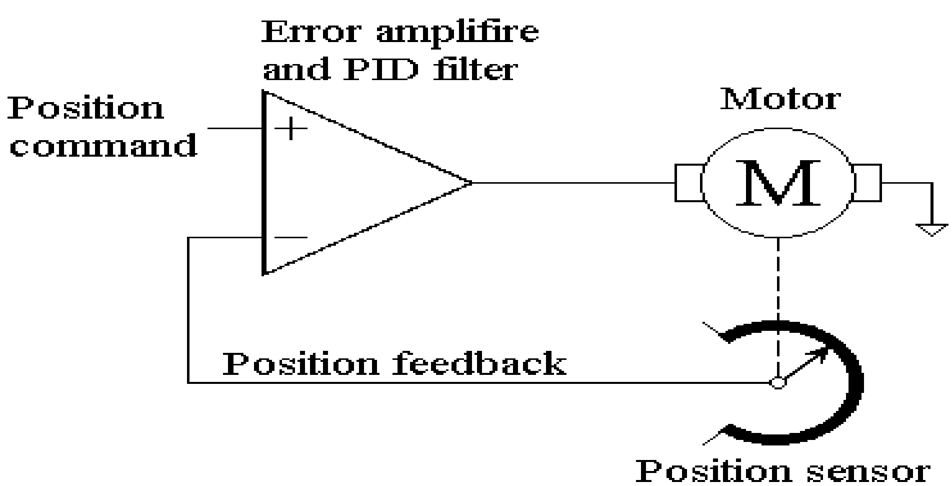


Fig 4.4.3: Standard Servo Control Diagram

Servo control could be realized through four different means, Voltage, torque, velocity and position. For the different maneuvers the microcontroller will require different parameters to make a proper decision. However, for the fin application we will use angular position to determine the fin positioning.

Usually the output response of the servo motor lags that of the input, we are introduced to a system called the deflection counter.

4.4.3.1 *Deflection Counter*

The servomotor rotation lags behind the command pulses from the microcontroller. This means that when the microcontroller completes outputting a number of pulses equivalent to the preset amount, the encoder will take some time to return all of the pulses. Hence, a controller will need to be complemented with a deflection counter, making sure that the output and the desired input match at a pulse level.

This counter compares the number of command pulses from the microcontroller and the number of pulses returned from the encoder. If the number of command pulses output is greater than that of pulses returned from the encoder, then the motor will need to rotate some more. On the other hand, If the number of pulses returned from the encoder is larger than the number of command pulses output, the driver will attempt to run the motor backward. When the number of command pulses output from the microcontroller and the number of pulses returned from the encoder match, the motor stops.

4.5 *Fin Manipulation*

The fin system design will directly affect the ease of displacement, especially when a change in direction is to be implemented. This system will be composed of flat surfaces made of rigid material, in order to withstand and redirect the opposing forces due to drag.

4.5.1 *X/Y Movement*

Basing much of the prototype's displacement procedures on the natural displacement of a fish, the vehicle will be propelled forward by a DC brush motor simulating the wave-like fashion propulsion provided by the tail of the fish. These creatures use their pectoral fins, which are situated horizontally on the body of fish who are fast swimmers. In combination with the pelvic fins, these help to stabilize the fish to keep it from rolling over as it moves through the water.

In the same manner, the vehicle will be composed of two pectoral fins simulated with a dual servomechanism that will naturally keep the fin horizontally for stability, keeping the vehicle from rolling. Rotating the fin 90 degrees from its natural position (horizontal or with the normal to the surface perpendicular to the forward direction) will create a torque in the positive or negative z direction about the central axis providing the vehicle with a tendency to change its direction at any given time.

As we create torques to turn the vehicle with the fin system, a reverse maneuver will be implemented to stop turning once the desired direction has been reached.

4.5.2 *Z Movement*

Due to the constant forward propulsion, upward or downward movement will be directly dependent on the fin manipulation. This motion will be implemented with the two lateral servo motors, that will be complemented with an elongated flat material that will serve as a fin to manage the drag force produce by the motion of the vehicle. Utilizing the force due to drag, we will achieve the change in the inclination angle.

To be able to maintain stability, before every maneuver the speed will be reduced to a minimum. The upward movement will be managed with a positive voltage signal sent to both servos simultaneously which will indicate the new angular position to be an angle theta, where theta ranges from 0˚ to 90˚ with the horizon as a reference, this loop will be maintained until the desired height has been reached. As for the downward movement of the vehicle a similar procedure will be implemented where theta ranges from 0˚ to -90˚, however, higher speeds are required due to the pressure at much greater depths. This particular loop will be terminated when a change in the whisker system is detected, meaning that the bottom has been reached.

4.6 *Ballast System*

4.6.1 *Active Ballast*

One of our main design problems was to be able to surface the vehicle on its side to meet optimal conditions for the photovoltaic system, due to the high sensitivity of the system with respect to stability. The vehicle will be designed for stable positive buoyancy, resistant to rolling motions. Hence, the vehicle will be composed of a weight distribution system.

The idea is to create a clockwise or counterclockwise angular momentum about the central axis, making it possible to control the rolling motion. This feature is not only crucial prior the charging phase but also afterwards, once the battery system is fully charged, the vehicle should regain its normal erect posture to start the submersion process. Many ideas to realize this feature have been studied; however, it is a particularly difficult motion to implement due to the extensive list of mechanical factors that would have to be considered.

Usually ballast systems used in underwater vehicles consist of air chambers being pressurized or unpressurized with air. On the other hand, other implementations make the use of water chambers that could be filled or emptied at any point, to either increase or decrease the net weight of the vehicle, to submerge or surface the vehicle. However, these systems are rather complex and difficult to implement for such a small vehicle.

The weight distribution system will be simulated with individual actuators that will be responsible for displacing a mass over a rail, providing the vehicle with the capability to create counterclockwise or clockwise angular moment about the central axis. Once on its side the vehicle will need to reinstate its initial position. By placing two rails perpendicular to each other and also perpendicular to the horizon, angular momentum is created for the rolling motion.

4.6.2 *Passive Ballast*

Maintaining neutral buoyancy on the vehicle will facilitate a majority of maneuvers once submerged. To achieve this state of equilibrium the apparent weight of the system has to be zero. The system's actual weight has been limited to 20 lbs, so calculations will be made based on this maximum quantity. Though that the total net weight of the heaviest components does not exceed 10 lbs, if once finalized the vehicle falls below the estimated max, we would be dealing with a force due to buoyancy greater than the actual weight, making this system positively buoyant. Also air chambers will be implemented throughout the internal body composition to counteract the outside pressure. Shown below, Figure 4.6.2, is the body diagram of the vertical forces acting on the vehicle.

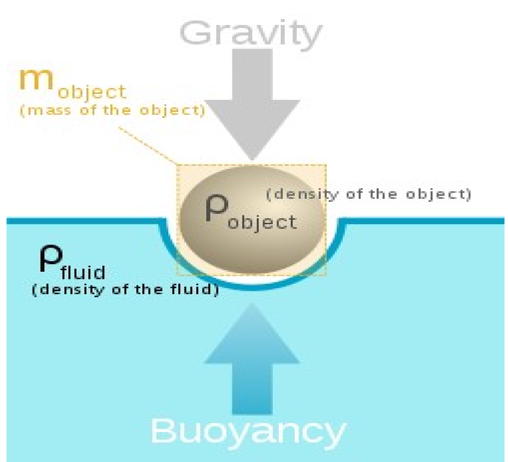


Fig 4.6.2: Vertical force analysis diagram of the vehicle

5.0 Microcontroller

The design will require one microcontroller to process all of the data obtained from the sensors and to modulate the control systems. The microcontroller should be miniscule and compact in order to adhere to the desired body dimensions. Since embedded processors are usually used to control devices, they sometimes need to accept input from the devices they are controlling. The A/D converter will be used to convert the incoming data from the sensors into a form that the processor will recognize. It should consist of a minimum of six analog-to-digital converter pins. Similarly, a D/A converter will be necessary to regulate the motors. This will allow the processor to send data to the device it is controlling.

The microprocessor should also have some kind of a timer, preferably similar to the Programmable Interval Timer (PIT). This timer counts down from a certain value down to zero and then sends an interrupt to the processor indicating that it has finished counting. A PIT will become handy when measuring the charging time of the battery. Other mandatory features include a pulse width modulation block (PWM) and a universal asynchronous receiver/transmitter (UART).

The PWM block makes it possible for the CPU to control motors without using lots of CPU resources in tight timer loops. The UART block makes it possible to receive and transmit data over a serial line with very little load on the CPU. Lastly as a preference, the board should be able to be programmed with some sort of C-based language in conjunction with a compiler to process the higher-level functions.

5.1 *Microcontroller Options*

5.1.1 *ATmega64P*

The ATmega164P is a high performance and low power AVR 8-bit microcontroller from Atmel. It has an advanced RISC architecture, which will allow for rapid processing to occur for a small and simplified set of frequently used instructions and can offer up to 16 MIPS throughput at 16 MHz. The throughput allows the system designer to achieve optimal power consumption in relation to processing speed. It also offers 16 kilobytes of in-system programmable flash memory, which is very useful for code storage and other applications.

Among some of its advantages is the size of the integrated circuit. Its 2.6 in. x 2.6 in. dimensions are a major factor in the selection of this component because the goal is to construct a body, not larger than 8.5 in. x 11 in. However, the ATmega164P certainly falls within range of the necessary dimensions for implementation of the system and therefore, it is considered as a suitable fit. The board also consists of 8 A/D channels in which only half of them will interact with the sensors from the system. The ATmega164P AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits. The block diagram for an ATmega164P microcontroller can be seen below in Figure 5.1.1.

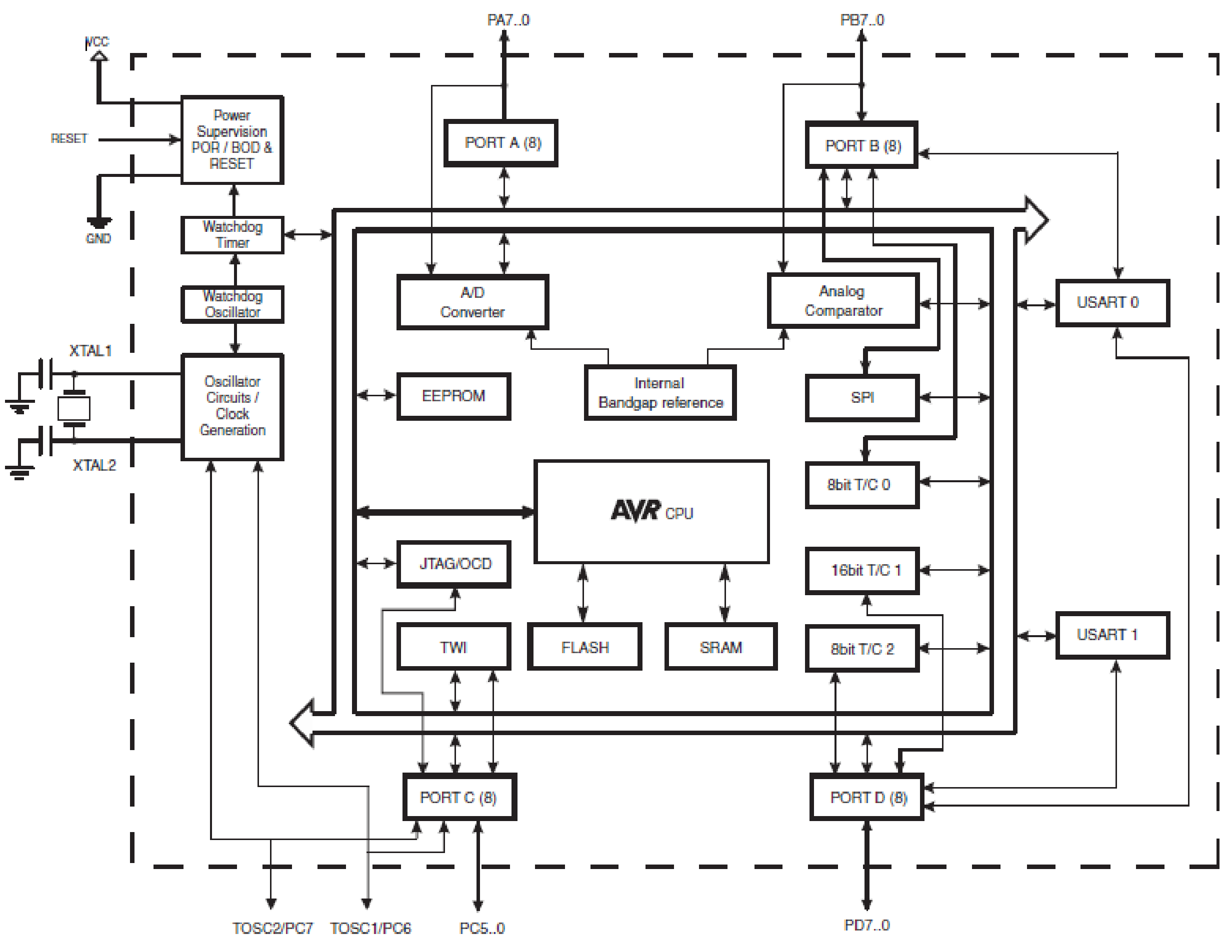


Figure 5.1.1: Block Diagram of ATmega164P microcontroller

Pending permission from ATMEL

One exceptionally attractive feature of the chip is the power management and sleep modes. The sleep modes enable the application to shut down unused modules, thereby saving power. This is a special advantage for this design because not all of the sensors will have to function at all times. The current draw of the microcontroller during active mode is 8 mA, 2.4 mA during the idle mode, and 0.8 uA during power-down mode. Also, since the board consumes power in the range of 2.7 – 5.5 V, it will be compatible with the power supply of the system.

In reference to peripheral features, it has an on-chip comparator, which is useful for sensor input comparisons. The six pulse width modulation channels are advantageous for providing intermediate amounts of electrical power to the motors without fully shutting them on or off. There are two 8-bit timer/counters with separate prescalers and compare modes. These modules allow for accurate program execution timing and wave generation.

5.1.2 *ARMite PRO*

The ARMmite PRO is a low-cost, dense, and compact single board computer by Coridium Corporation. It is about the size of a business card with a prototype area measuring approximately 2.05 x 2.1 inches, which makes it perfect for small volume applications, especially ones that require customization. This microcontroller is programmed from a host computer via a USB port configured to challenge the venerable asynchronous serial port. Coridium Corporation supplies an evaluation kit which includes the USB dongle, cable, BASIC and C compilers along with the board to make the programming process and connections as untroubling as possible. This board is shown in Figure 5.1.2a below.

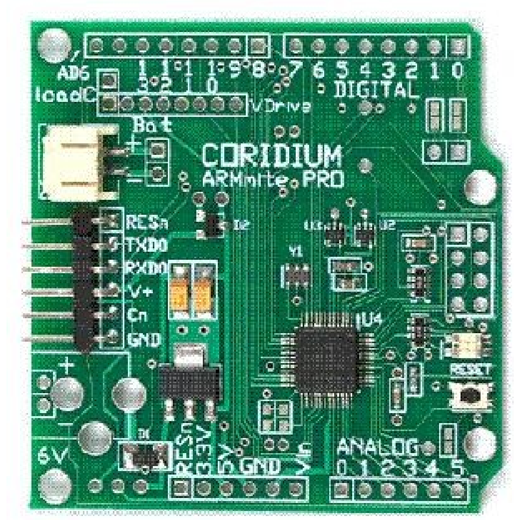


Fig 5.1.2a: ARMmite PRO from Coridium Corporation

More of the board's tangible features include 21 TTL compatible digital I/Os shared with 7 10-bit A/D pins and an easy-to-use USB interface. The seven A/D converter channels will be useful in connecting the sensors to the main control box. Also, the regulated power supply can run off of a 5-12 V input which in this case is the battery. One particularly essential feature of the board is to be able to supply voltages (5, 3.3, and 1.8 V) to any output. This is a very convenient specialty because the microcontroller can also serve as a backup source to the battery, if anything fails and it can power up another motor if necessary. It is also pin compatible with the Arduino PRO and the compilers, both BASIC and C, are extremely facile to learn. For the AD pins, they are configured as AD inputs. To change those to digital IOs, the user must individually specify a control direction using INPUT x, OUTPUT x, DIR(x), or IO(x) commands. After that they will remain digital IOs until the next reset or power up. Refer to Figure 5.1.2b for details.

IO0 IO1 IO2 IO3 IO4 IO5 IO6 IO7 IO8 IO9 IO10 IO11 IO12 IO13 IO14	RXD1 TXD1 EINT0	PWM1 PWM2 PWM8 PWM4 PWM3 PWM6 PWM7 PWM5	Input/Outputs -- user controlled 0-3.3V level 4mA drive when configured as Outputs 5V tolerant - use limiting resistor when connecting to a 5V supply
IO15			IO15 connected to LED -- no other connection
AD0 AD1 AD2 AD3 AD4 AD5 AD6 AD7*	IO16 IO17 IO18 IO19 IO20 IO21 IO22 IO23		10 bit A/D inputs may also be used as digital Input/Outputs IO(16-23) -- user controlled when used as analog lines, voltage levels should not exceed 3.3V AD6 connected to Arduino AREF pin AD7 connected to a via

Fig5.1.2b: IOs description

5.1.3 *BL1800*

Another option for a microcontroller is the BL1800 from Rabbit. Like the ARMmite PRO, it is a compact and low cost C-programmable single-board computer. This microcontroller is extraordinary for small volume applications that have significant cost and size constraints. Measuring approximately 3.5 in. x 2.5 in., this board has a high processor speed of 29.5 MHz, faster than the Atmel microcontroller.

The BL1800 provides 24 CMOS-compatible I/O pins, 3 analog channels, and 4 high-power outputs. Three of the high-power outputs can sink up to 1 amp each and are protected for direct driving of inductive loads. There are two RS-232 ports and 1 RS-485 port support serial communication and are rated at 15 kV for ESD protection. The fourth serial port is a 5 V CMOS-compatible programming port that can also be used in the user's application after programming is completed. It also contains five 8-bit timers and one 10-bit timer in addition to the watchdog timer (WDT). Four of the 8-bit timers can be cascaded from the first timer. The WDT is used to trigger fail-safe control systems to move into a steady state, such as turning off the motors, until the fault is cleared or resolved.

Lastly, the board features a switching regulator that provides a wide range of input voltages (8–40 V DC), thus reducing power consumption while minimizing heat.

5.1.4 *Decision*

Due to a sudden change of the team's size, new priorities have been set for the project. Lacking the time to make the proper research on the controlling unit, we have decided to utilize the dsPIC30F5015 unit from Microchip Technology Inc. Being a High performance, 16-bit digital signal controller, this unit offers 64 pins, 8 channels for motor control PWM, 16 channels for 10 bit Analog to Digital at 1 Msps. Making it a great fit for our vehicle, since we will be making use of multiple motors.

5.2 *dsPIC30F5015*

Being a High performance, 16-bit digital signal controller, this unit offers 64 pins, 8 channels for motor control PWM, 16 channels for 10 bit Analog to Digital at 1 Msps. Making it a great fit for our vehicle, since we will be making use of multiple motors. To become familiar with this type of component, testing was done. By isolating the simplest case scenario, then a DC brush motor servo controller was implemented during testing. Even though, that the elements used are not the ones destined for the project; However, these components were donated for the cause. This practical test case helped further improve understanding on the desired operation of the vehicle. The dsPIC30F5015 diagram can be seen below in Figure 5.2a.

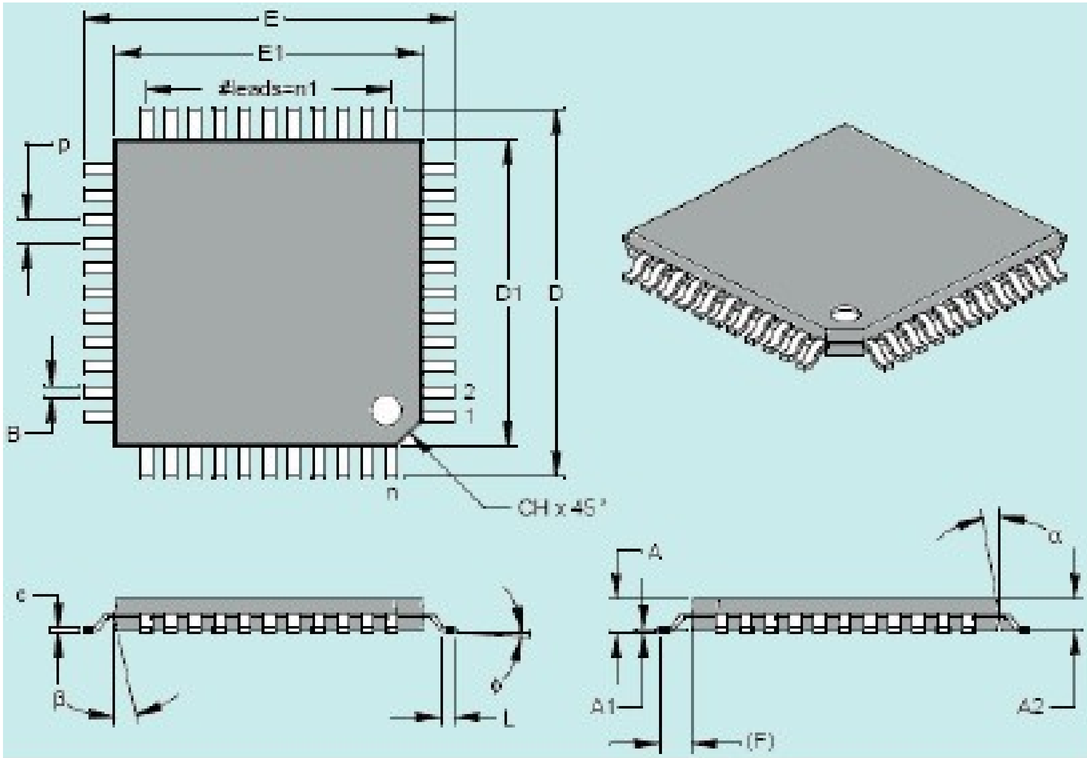


Fig 5.2a: Microchip Diagram

The system used for testing had been already implemented by one of our passive sponsors. A programmable logic device (PLD), a single-chip H-bridge driver along with the PIC17C42 Microchip was the components used.

Through testing, it was shown that a PID (Proportional, Integral, and Differential) control calculation could be performed in approximately 200 μs (@16 MHz) allowing control loop sample times in the range of 2 kHz. The Microchip used (PIC1742) offered high speed peripherals handling encoder rates up to 3 MHz. For the PID control, generalized set coding instructions were found. This is shown below in Figure 5.2b.

```
typedef struct {
     fractional* abcCoefficients;  /* coeffs derived
from Kp, Ki & Kd */
     fractional* controlHistory;   /* state variables
(delay line)in Y-data
     fractional controlOutput;     /* PID Controller
Output */
     fractional measuredOutput;      /* Measured
Output sample */
     fractional controlReference;    /* Reference
Input sample */
} tPID;
extern void PIDCoeffCalc( fractional* kCoeffs, tPID*
controller );
extern void PIDInit ( tPID* controller );
extern fractional* PID ( tPID* controller );
```

Fig 5.2b: Example Code

The three PID functions have been implemented in the source file pid.s available in the DSP library. The source file main.c demonstrates how the PID functions can be called in a closed-loop control application. A PID controller responds to an error signal in a closed control loop and attempts to adjust the controlled quantity in order to achieve the desired system response. The controlled parameter can be any measurable system quantity, such as speed, voltage, current, or stock price. The output of the PID controller can control one or more system parameters that will affect the controlled system quantity. For example, the speed control loop in this application can control the PWM duty cycle directly or it can set the current demand for an inner control loop that regulates the motor currents. The benefit of the PID controller is that it can be adjusted empirically by adjusting one or more gain values and observing the change in system response.

As the gateway between the main computer and the power electronics connected to the motor, the microcontroller interprets RS-232 serial data from the computer into PWM signals. Hence, at least six signal generating pins are utilized for interfacing motors and six digital logic inputs for speed sensors. The controller is specifically designed for typical brushless sensor requirements therefore the sensor and motor parameters are already available. However, the sonar and light sensors are grouped into a different device communication protocol to provide scalability.

5.2.1 *DC Motor Control*

A single pin of the 30F5015 PIC microcontroller is limited to a maximum output current of approximately 30 mA. The motors to be used within the vehicle require a higher current value to be power directly. A solution to this issue will be to just use the output of the pin to turn on or off a transistor that will be responsible to control the current needed to run the motors. The choice for the transistor will be constraint to one that can output a maximum current of 4-5 A. A candidate for this job is the TIP120 NPN Darlington transistor, which is a medium power, 5-A maximum current, and low-speed switching component.

5.2.1.1 *Circuit Topology*

A similar implementation for this procedure could be realized through the following topology, seen below in 5.2.1.1a, according to the Hobby of Electronic Circuit Engineering.

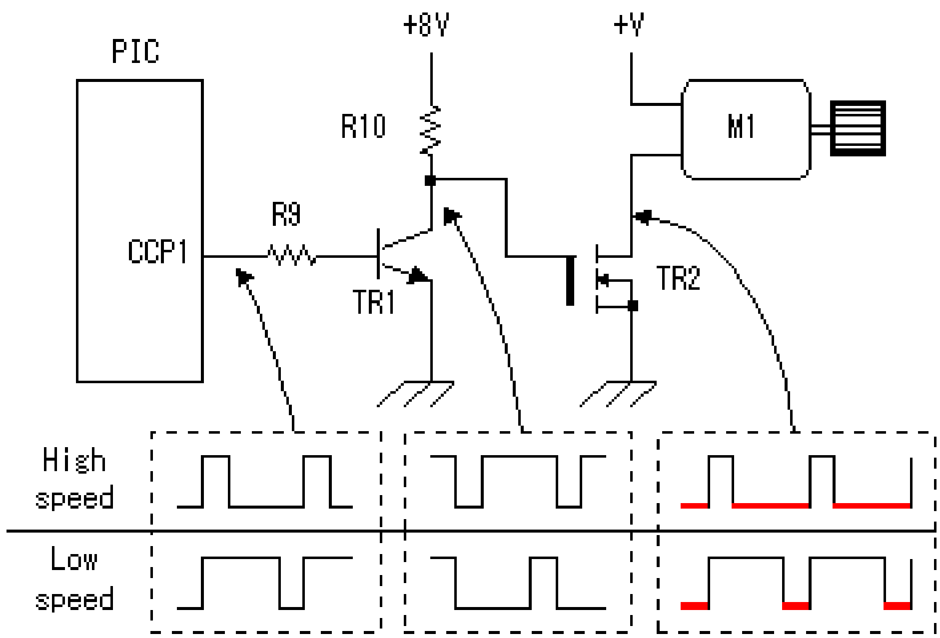


Fig 5.2.2.1a: Motor Drive Circuit by The Circuit of Electronic Circuit Engineering.

PWM can change the duty of the pulse to output into CCP1 by the data. When the time which is made the H level of the pulse of CCP1 is short, the time of ON (the L level) becomes long in TR2, that is, the drive electric current of the motor increases. Oppositely, when the H level time of the pulse of CCP1 is long, the ON time of TR2 becomes short and the drive electric current of the motor decreases.

The duty of the pulse of CCP1 is controlled in the voltage (the control voltage) which was taken in with the control voltage input circuit. When the control voltage is higher than the regulation value, the H level time of the CCP1 pulse is made long and the number of rotations of the motor is lowered. When the control voltage is lower than the regulation value, the H level time of the CCP1 pulse is made short and the number of rotations of the motor is raised. Also a clock generator circuit should be implemented to determine the periodicity of the voltage control signal. This circuit is shown in Figure 5.2.2.1b below.

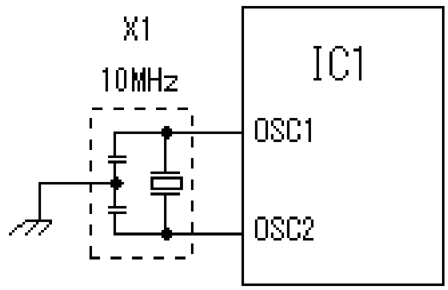


Fig 5.2.2.1b: Clock Generator by the Hobby of Electronic Circuit Engineering

5.2.2 *Servo Motor Control*

There are three wire leads to a servomotor. Two leads are for power, +5V and GND. The third lead feeds a position control signal to the motor. The position control signal is a single variable-width pulse. This pulse could be varied from 1 to 2 ms. The Width of the pulse controls the position of the servomotor shaft. As mentioned in a previous section a pulse-width variance from 1-2 ms will provide a full 90° of rotation. To extend this range up to 180°, we will need to use pulses smaller than 1 ms and greater than 2 ms.

However, the risk of extending the rotational movement from the servo may introduce particular undesirable issues. In particular, the servomotor has end stops that limit how far the shaft can rotate in either direction. If the PIC is sending a signal to the servomotor that is past either end stop, the motor will try to continue to fight with the end stop. In this stalled condition, the servomotor will start drawing higher values of current and/or wearing the gearing inside the motor.

As we experimented with servomotors, it was observed to be necessary to feed the pulse signal to the servo motor 50 to 60 times per second, especially when both servos are being tested.

5.3 *Feedback Control*

To understand the process of a microchip, it is crucial to analyze that of the component to be controlled shown in the figure below. To control a servo motor it is necessary to have an incremental feedback block (Encoder). Along with the encoder counter, a processor, a D/A (Digital-to-Analog) converter, and a power amplifier which will deliver voltage or current to the motor are needed for optimum operation. A digital PID controller is executed at a periodic sampling interval and it is assumed that the controller is executed frequently enough so that the system can be properly controlled.

For example, the current controller in this application is executed every PWM cycle, since the motor can change very rapidly. The speed controller in this application is executed at the medium event rate (100 Hz), because motor speed changes will occur relatively slowly due to mechanical time constants. A PID algorithm is then used as a servo compensator and position trajectories are derived from linear velocity ramp segments. The system used about 40%-null PWM as the D/A conversion technique. The power stage is a high current output switching stage which steps-up the level of the PWM signal. Encoder signal decoding is accomplished using an external PLD. A typical flow diagram of this control is shown below in Figure 5.3.

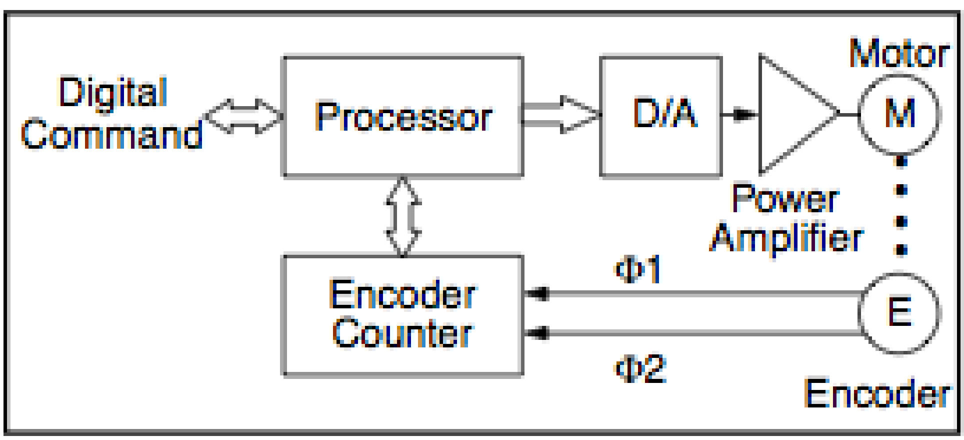


Fig 5.3: Feedback Control Loop

Closed-loop servo motor control is usually handled by 16-bit, high-end microcontrollers and external logic. Today most of these systems tend use DSPs (Digital Signal Processors) in an attempt to increase performance. However, the very high performance of this Microchip makes it possible to implement these servo control applications with a reduction in the overall cost.

5.3.1 *Feedback from Sensors*

The vehicle will be composed of a variety of sensors that will responsible to help the dsPIC controlling unit make path decisions. Many of these sensors have a resistive signal that will need to be read. The Pot command is powerful in scope and capabilities. It will allow to easily and accurately read resistive components and sensors. This command can read resistive values up to 50 kΩ in a single program line. The corresponding programming line should be in the format of :*Pot Pin, Scale, Var.* This command reads a potentiometer or other resistive component on the *Pin* specified. We have the chance to choose from any of the many pins from the designated port. Resistance is measured by timing the discharge of a capacitor through the resistor, usually ranging from 5 to 50kΩ. *Scale* is used to adjust varying R/C constants. For large constants we will have to set the *Scale* to 1. On the other hand for smaller constant we would set the *Scale* to its maximum value of 255.

As mentioned previously the vehicle will be composed of many different types of transducers that may be read with the Pot command, keeping in mind that this command is not an analog-to-digital (A/D) converter, which we will only be able to read resistances and not voltages. One of our first sensors to be considered is the flex sensor, which will use whiskers for bump and wall sensors. To test this sensor a LCD display will be required to provide visual readout. The numeric readout, with the sensor at its maximum resistance, should provide the proper scale factor to use in the command in order to achieve the greatest range with this particular sensor.

One of the main goals of the vehicle will be to seek light. The sensor needed for this tracker light feature is a cadmium sulfide (CdS) photocell. Since its resistance varies in proportion to the intensity of light falling on its surface, this perfectly suits our need to track light. To test this sensor, we will need to ascertain the proper scale factor, by first deciding what capacitor should be used for optimum ranges proceeding to connect the sensor to the PIC unit so we could run the scale program.

5.4 *Battery Check*

To implement the various maneuvers to be completed by the vehicle, the controlling unit will have to rely on the input data coming from the sensors. One of the crucial input parameters for the microchip will be the battery levels, which will constraint the number and duration of operations while submerged.

The battery level will need to always sustain the necessary voltage to surface and position the vehicle for the charging face. This upward movement which is explained in the previous section requires of full thrust by the motor and repositioning of the fins. Once the vehicle has surfaced, the actuator system will proceed to rotate the vehicle on its central axis. By making this the lower bound threshold voltage, the controlling unit will be set to surfacing mode once it detects a slightly higher voltage level (Threshold voltage + 1 V).

Depending on the necessary energy required to successfully surfacing the vehicle, other maneuvers will be considered. So there will be an active library containing the approximate amount of energy needed to execute any possible movement.

5.5 *Software Simulator*

The MPLAB SIM Software Simulator allows code development in a PC-hosted environment by simulating the PIC MCUs and dsPIC DSCs on an instruction level. On a given instruction, the data areas can be revised or modified. Registers can be logged to files for further run-time analysis. The trace buffer and logic analyzer display allows the simulator to record and track program execution, actions on I/O, most peripherals and internal registers, giving us a complete control over the unit.

The MPLAB SIM Software Simulator fully supports symbolic debugging using the MPLAB C18 and MPLAB C30 C Compilers, and the MPASM and MPLAB ASM30 Assemblers. This software offers the flexibility to develop and debug code using almost any environment, making it an excellent, economical software development tool.

5.6 *Test and Evaluation*

The sensor and power components are relatively easy to quickly evaluate. Given that many of the components have not been acquired yet, testing has been done on similar parts to the chosen components. Majority of these testing parts have been donated to us various passive sources throughout the semester. On this section is described the process of testing that led to the choice of the dsPIC unit. The PIC has ample resources for programming and debugging different sensors.

However, the level of complexity and troubleshooting guidelines for the brushless motor signals make the microcontroller difficult to test. The inexpensive initial cost of the PIC microcontroller allows for quick evaluation of the brushless motor system. If the PIC has sudden failures or shortcomings, it could be efficiently replaced right away. Matlab is one of the much simulation software that offers a variety of tools for testing control and motor units.

Matlab could be used to determine the behavior of the Microchip GUI for sensing current, voltage, and torque at any given time as shown in Figure 5.6.

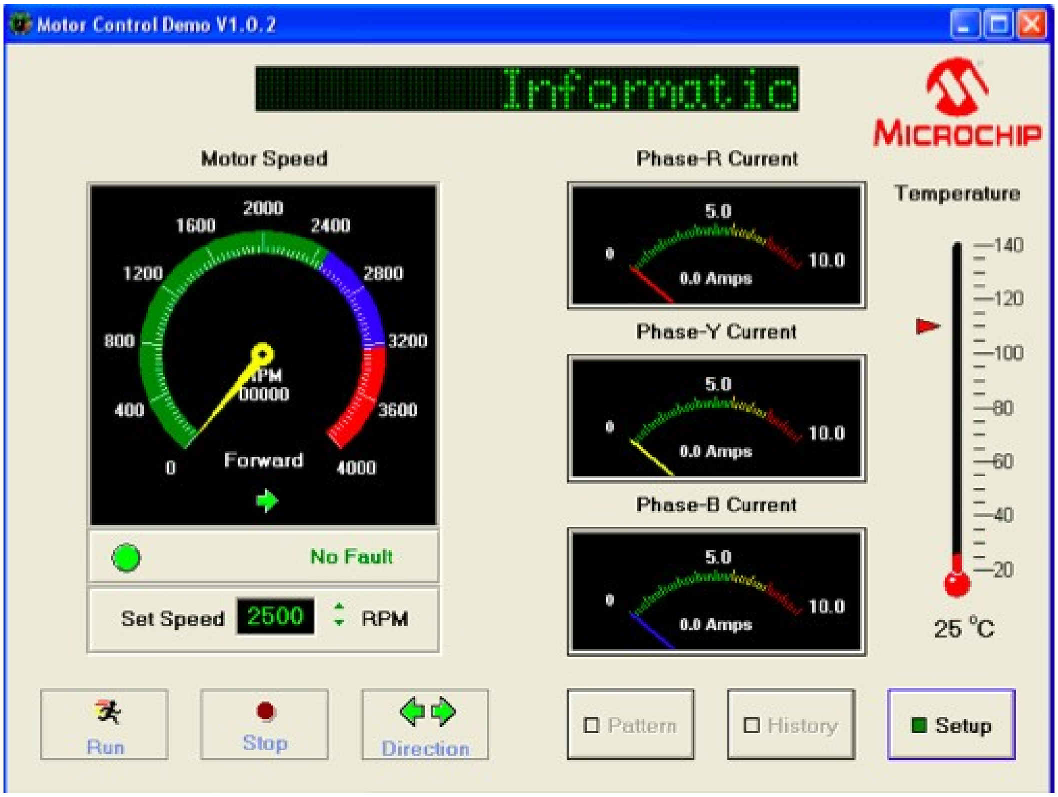


Fig 5.6: Microchip GUI Matlab Simulation

6.0 Artificial Intelligence

Rather than controlling the fish remotely, the goal is for the fish to be automated. This means that we will need to learn the intricacies of the microcontroller and at the same time try to keep the system as power efficient as possible. The following are sections and subroutines that will need to be developed and programmed in order for the project to be considered successful. A key feature to note is that the fish will have nine states of operation as seen below in Figure 6.0.

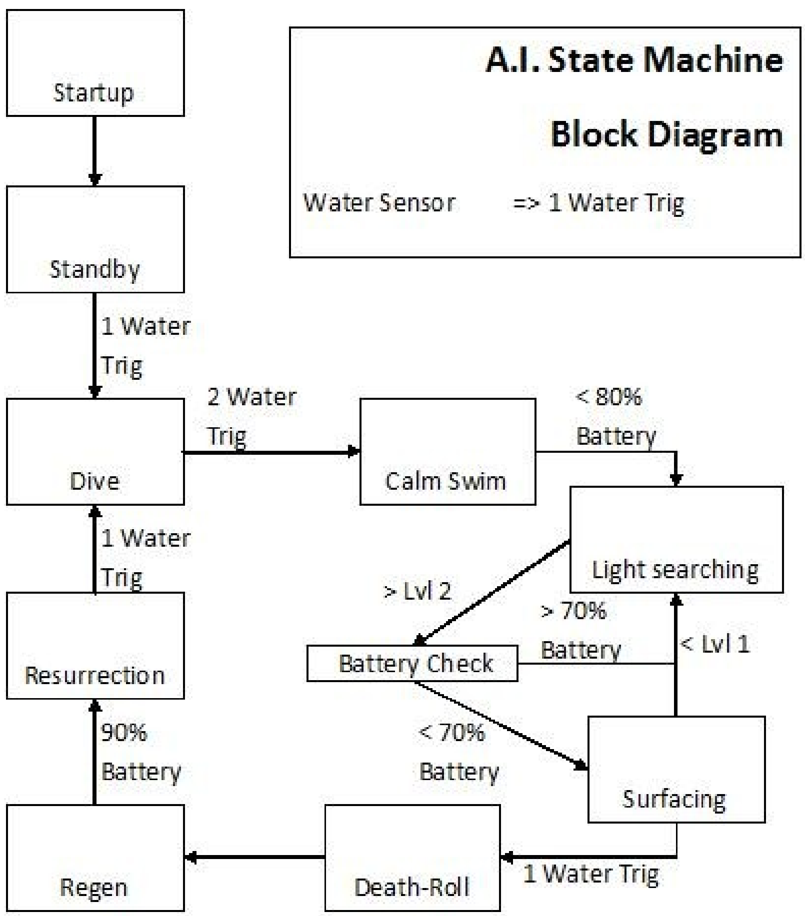


Figure 6.0: A.I. State Machine Block Diagram

6.1 *Software Sensing*

All changes to the fish’s operation state will depend on the sensors and the ability to transform the signals from the sensors to the microcontroller.

6.1.1 *Battery*

6.1.1.1 *Battery Interface*

The battery level will be determined by 10 pin inputs, each input representing 10%, and this will be stored in the variable *blvl*.

6.1.1.2 *Battery Check*

The battery check will call the battery interface and use the *blvl* and determine the mode of the A.I.'s operation. The battery check process and resulting A.I. mode can be seen below in Figure 6.1.1.2.

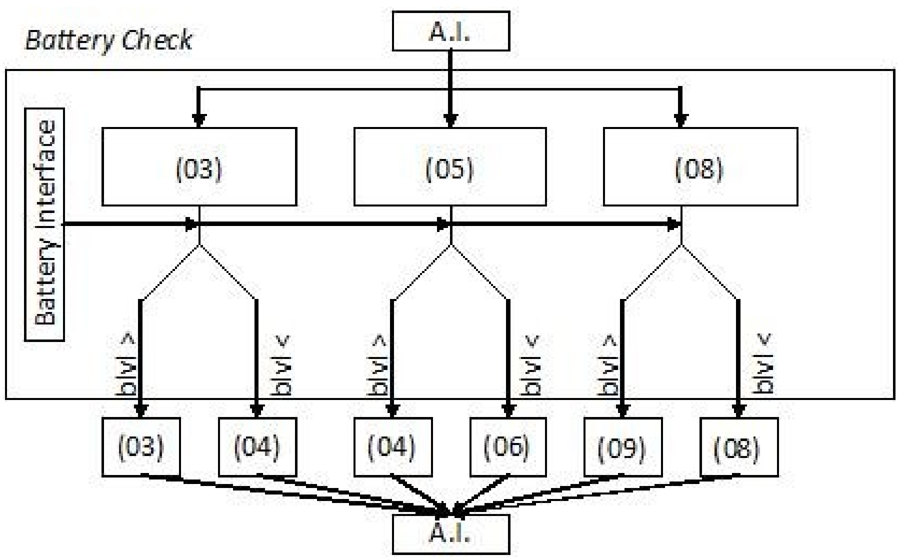


Figure 6.1.1.2: Battery Check Process and Resulting A.I. Mode

6.1.2 *Water Sensor Interface*

The water sensors will report 3 triggered states and these states will be stored into the variables wsupH, wsupL, and the wsB.

6.1.3 *Light Interface*

The light sensor subroutine will need 4 variables, a variable representing the right (*rcell*), left (*lcell*), and the center (*mcell*) photocells. The final variable, *Lcon*, will represent the number of photocells triggered.

6.1.3.1 *Triggering*

The Trigger check is what will sample the photocells states and store them to their respective variables.

6.1.3.2 *Light Intensity*

The light intensity routine will count the number of triggered photocells.

6.1.4 *Object/Depth Interface*

This Sensor Interface section will contain 2 parts. The first part will be the whiskers, with a variable, *proxX*, that will store a 0, 1, or 2, and *proxY*, that will store 0, 1. These numbers represent either no triggers, left triggers, or right trigger respectively for *proxX,* while *proxY* will either be no trigger or floor triggered. The second part of the subroutine will trigger the sonar to ping and return the response, which is store into a variable, *echo*.

6.1.4.1 *Distance Conversion*

Taking the time stored from the sonar, this routine will convert this value from time to length, *range*, by multiplying the time by the speed at which it travels through the water.

6.1.4.2 *Critical Range Check*

The Critical Range Check routine calls the Object/Depth and the Distance Conversion and takes the *proxX, proxY,* and *range* values and makes a decision based on their value. Located below, in Figure 6.1.4.2, is a block diagram of the *Critical Range Check*.

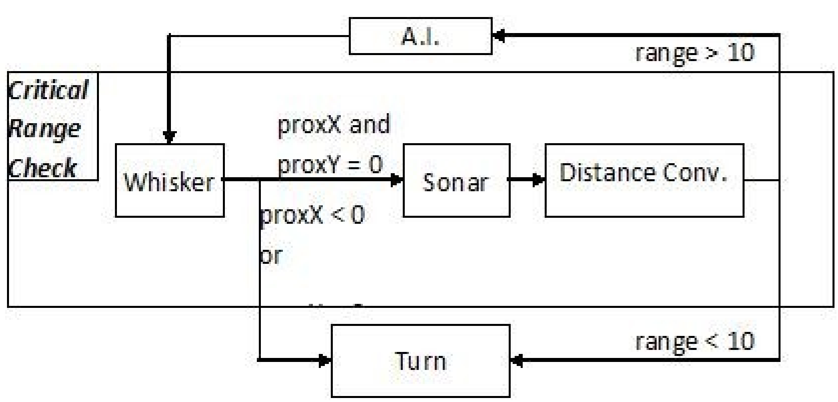


Figure 6.1.4.2: Critical Range Check Priority and Decision Making

6.2 *Software Motion Control*

6.2.1 *Modes*

6.2.1.1 *Startup (00)*

This Mode will by initiated on start up. The Mode will then run through a series of checks, as listed below in Table 6.2.5.1.

Startup checks	
1	Sonar
2	Left Fin
3	Right Fin
4	Tail
5	Propeller
6	LED

Table 6.2.5.1: Startup Checks

Once initial checks are done the Mode of the AI will shift to *Standby (01)*.

6.2.1.2 *Standby (01)*

The AI will remain in standby until the lower water sensors trigger as seen in Figure 6.2.5.2 below.

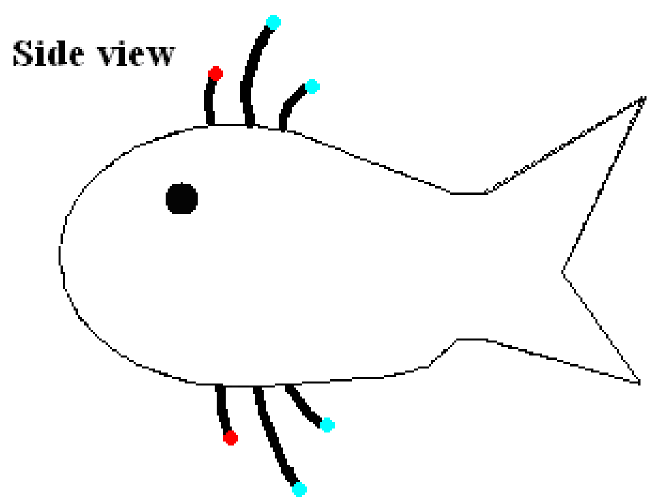


Figure 6.2.5.2: Water Sensor Arrangement

6.2.1.3 *Dive (02)*

Fins will reposition until at optimal dive angle and then the motor will kick in. The fish will continue to dive until top upper water sensor triggers. After the top upper sensor triggers the mode will be shifted to *Calm Swim (03)* mode.

6.2.1.4 *Calm Swim (03)*

The AI will check for *proxX*, *proxY,* and *range* and then run the battery check and then loop. The fish will continue swimming at SLOW setting unless a turn correction is needed.

The fish will also randomly adjust its heading as long as there is no interference. The plan is for the fish to rise, dive, or make a minor turn all while running the Critical Range Check and check the battery level (*blvl*). The AI will only switch out of this mode to the next, *Light Searching (04)*, when the *blvl* drops below 80%.

6.2.1.5 *Light Seeking (04)*

The AI will continue to check for *proxX*, *proxY,* and *range*, but will switch out of this mode when all three light sensors vectors are triggered positioned as seen in Figure 6.2.5.5.

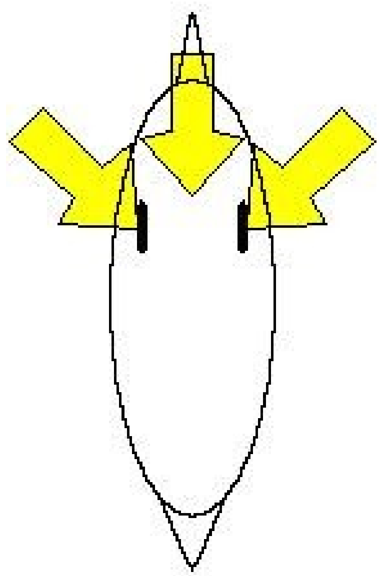


Figure 6.2.5.5: Light Sensor Vectors

The fish will also be swimming at the FAST setting unless turning.

6.2.1.6 *Battery Check (05)*

The battery check routine will immediately be called and if the *blvl* is below 70% will go on to *Surfacing (06)* mode. If the *blvl* is not less than 70% the mode will switch back to *Light Searching (04)* mode.

6.2.1.7 *Surfacing (06)*

The AI will begin the fish's assent will begin with light level checks to monitor light levels as well as turn if the need should arise. This will continue until either the light Level drops to low, which will cause the mode to jump back to *Light Seeking (04)* mode, or if the upper water sensors un-trigger move onto the *Death Roll (07)* state.

6.2.1.8 *Death Roll (07)*

After stopping the motors, the fish will double check that the top water sensors are un-triggered. If this is not the case the fish will jump mode back to *Surfacing (06)* mode, this jump is not expected to occur but better safe than sorry. When the fish is determined to have indeed surface, the fish will redistribute is internal weight to cause the fish to roll on to its side, as shown in Figure 6.2.5.8, and begin the recharging in the *Regen (08)* mode.

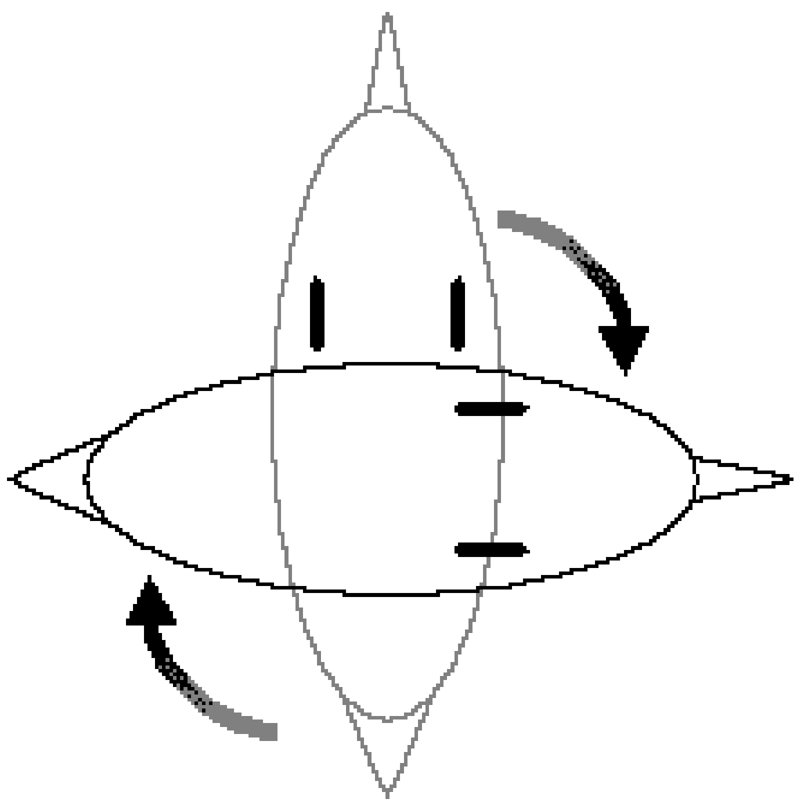


Figure 6.2.5.8: Death Roll

6.2.1.9 *Regen (08)*

The fish resting on its side, which has the exposed solar cell arrangement, will begin recharging until its battery level reaches 90%. After reaching 90% battery level the fish will switch to *Resurrection (09)* mode.

6.2.1.10 *Resurrection (09)*

During the *Resurrection (09)* mode the fish will reverse the Death roll, and once done enter *Dive (02)* mode as can seen below in 6.2.1.10.

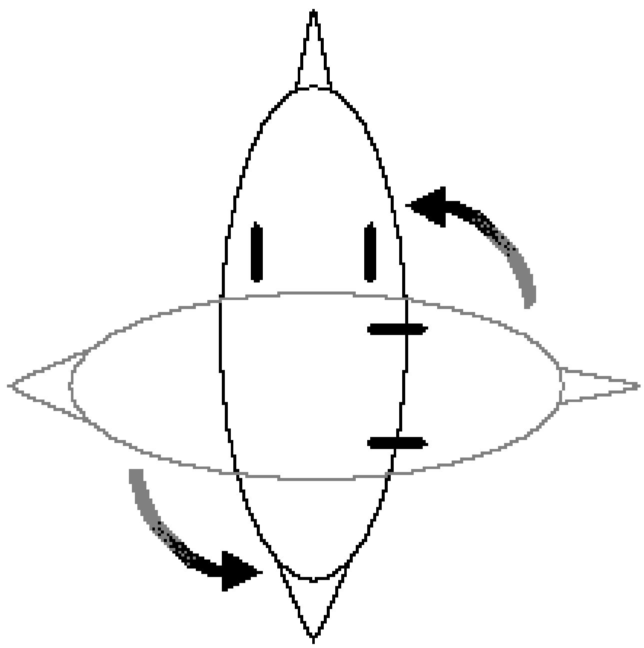


Figure 6.2.5.10: Resurrection

7.0 Features

In addition to Tilapi-ugghhh's main functions there is room for a couple of features. Features that are capable of being done are categorized as "Targeted Features." Features that are capable of being done, but are considered to be excessive or require too much, are categorized as "Extra Features."

7.1 *Targeted Features*

7.1.1 *LED Spine*

While testing the fish above water it may become difficult to see whether or not the fish is doing what it is programmed to do. To overcome the inability to tell whether or not Tilapi-ugghhh is functioning properly, several LEDs will be placed into the spine of its body as seen below in Fig 7.1.1.

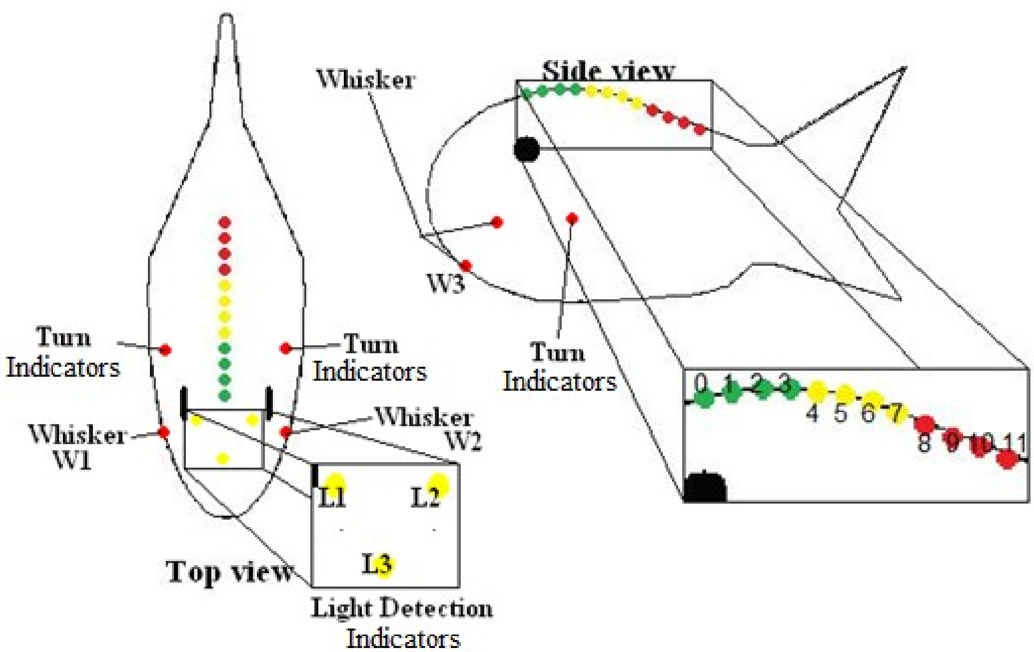


Fig 7.1.1: LED Placement

A series of LEDs will turn on according to what function of the fish is operational at the moment. For each of the main command prompts the fish can be given, as well as for when a sensor is activated, a configuration of lit LEDs will be preset. Which indicators activate which LED can be seen below in Table 7.1.1.

Indicators	Node
Light Detectors	
Right	L1
Left	L2
Forward	L3
Whisker Trigger	
Right	W1
Left	W2
Bottom	W3
Battery Level	
High	8
Med	9
Low	10
Water	
Below	0
Above	11

Motion	1	2	3
Forward			
Slow			
Turning			

Modes	4	5	6	7
Startup				
Standby				
Dive				
Calm Swim				
Light Seek				
Battery Chk.				
Surface				
Death Roll				
Regen				
Resurrection				

Table 7.1.1: LED Configuration

7.1.2 *RC Control*

In order to add some method of control an optional remote control can be added. To choose a proper radio system we must first decide how many commands, in essence exactly how much control, we would like to have over Tilapi-ugghhh.

7.1.2.1 *Two Channel*

In order to have the most basic control over Tilapi-ugghhh all that is required is a two channel receiver and transmitter. With these two channels we would only have control over the ballast, to go in and out of roll, control over the fins, to angle up or angle down, or control over the motor, to go forward or to go in reverse. To be able to command only one aspect of motion is simply not enough, although a cheaper solution as compared to four channels, two channels simply will not suffice.

7.1.2.2 *Four Channel*

It is clear that in order to have any control over the robotic fish four channels are necessary. With these four channels one would have complete control over the main mechanisms that cause the fish to swim. In order to override Tilapi-ugghhh's normal program and cause the fish to surface on its charging side one would simply use the remote control. The first step would be to angle the fins so that from the tail to the nose the fins point upward. The next step would be to activate the ballast so the fish would start to swim on its side.

To create an RF four channel transmitter suited to our device one would only need to follow the circuit diagram as seen below in figure 7.1.2.2a. All parts required can be obtained from various places.

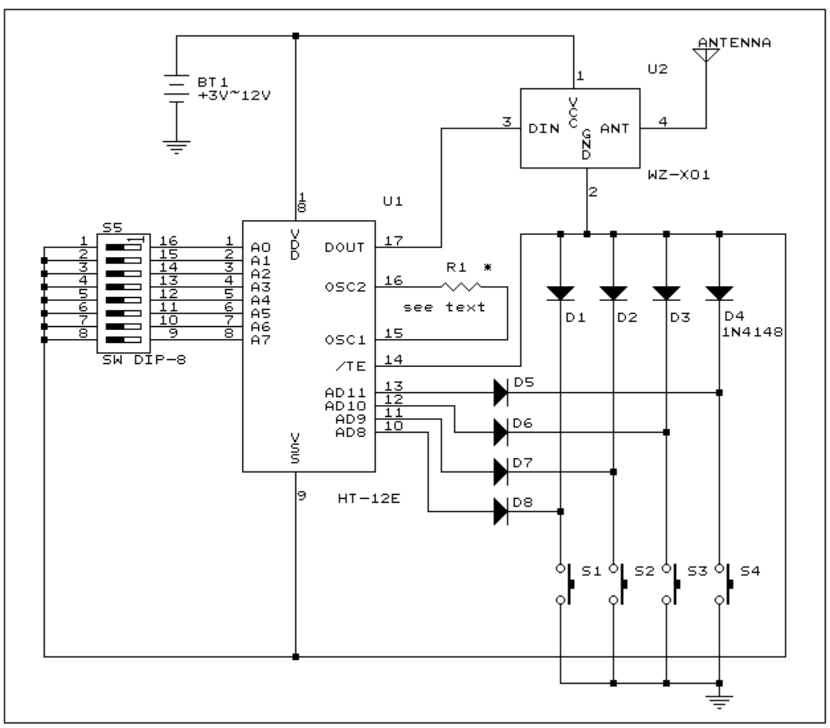


Fig 7.1.2.2a: RF Four Channel Transmitter

Pending permission from WZmicro

To create an RF four channel receiver suited to our device, which would pick up the correct signal from the aforementioned transmitter, one would only need to follow the circuit diagram as seen below in figure 7.1.2.2a. All parts required can be obtained from various places.

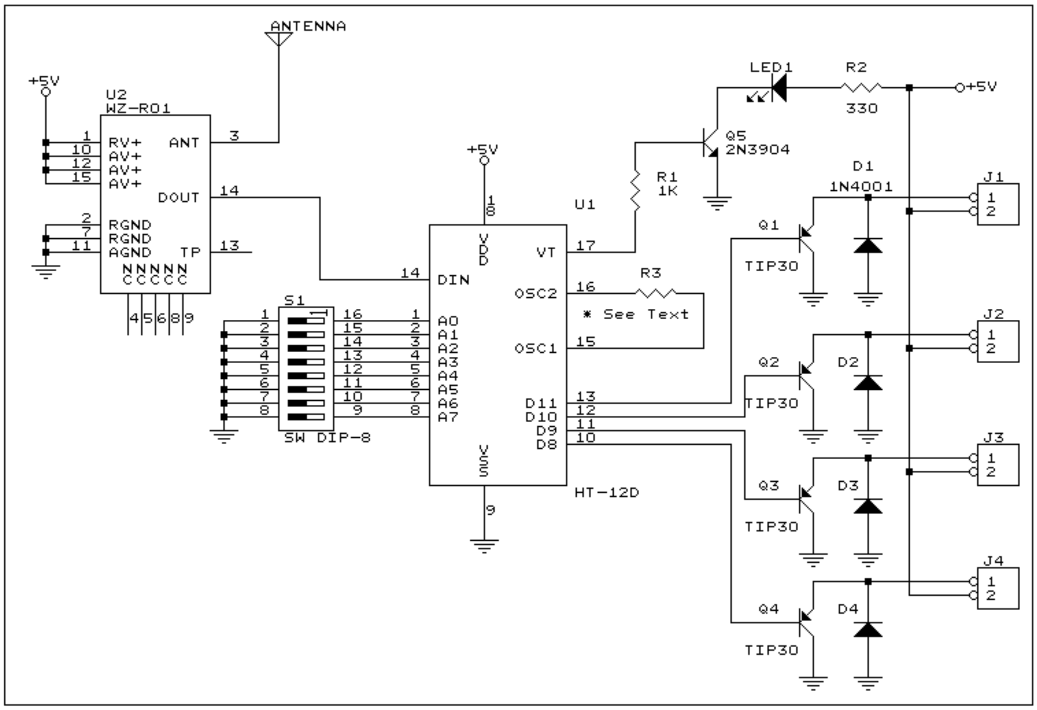


Fig 7.1.2.2b: RF Four Channel Receiver

Pending permission from WZmicro

7.2 *Extra Features*

7.2.1 *Game Demo*

A point and shoot game demo can be added as an optional feature for once the Tilapi-ugghhh prototype has been perfected. A camera would be mounted somewhere on the top of the fish, closer to the head, as can be seen in Figure 7.2.1. The users' objective would then be to shoot the camera with the laser gun provided. The difficulty with the game demo is that one would have to configure the camera to only recognize the light emitted from the laser gun, although, this problem could easily be remedied by using a camera and laser pair.

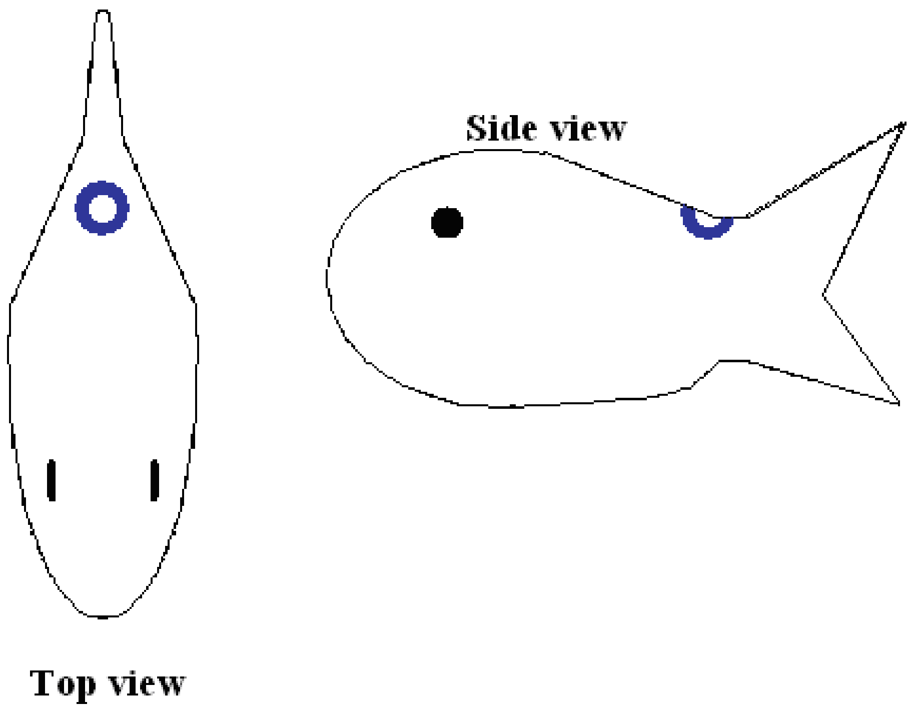


Fig 7.2.1: Game Demo Camera Placement

7.2.2 *"Moan and Groan"*

The name Tilapi-ugghhh was inspired by the noise one hears as zombies approach. The "Moan and Groan" would feature built in speakers that would emit a moaning zombie-like noise while the fish is surfaced for recharging. The fish could also be programmed to emit these noises while in the water, but that would probably deem futile as sounds underwater are greatly damped. The problem one faces with attaching speakers to a submersible vehicle is that the speakers would have to be completely waterproofed.

7.2.3 *Chomping*

Zombies are notorious for their ceaseless quest for brains, chomping at whatever falls into their paths. The fish could be designed to chomp through the water. In order to do so, an extra motor would have to be put in place along with a jaw that hinges, as can be seen in Figure 7.2.3. Although feasible, for the prototype, the extra motor would take up too much space and would use up too much voltage.

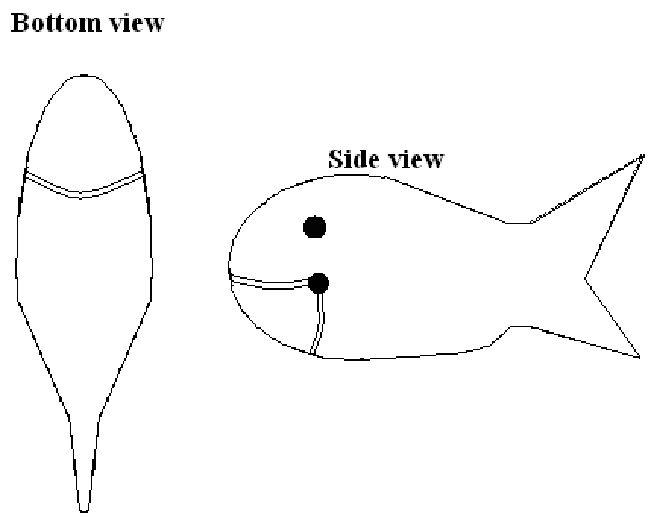


Fig 7.2.3: Motor Placement and Hinged Jaw

7.2.3.1 *Vomit*

Instead of the cells being placed on the side of the fish, the fish once surfaced will “vomit” the cells onto the surface of the water, as can be seen in Figure 7.2.3.1. There are many mechanical issues with trying to get the fish to expel the solar cells. First one would have to create a rig to disperse the cells. If one chooses to create the chomping mechanism, one could take it a step further and create the vomiting mechanism as well. Also, the cells would require some way of ensuring that the cells face in the upright direction, lest they become completely useless during the charging process by remaining charging side face down. With the cells expunged in some manner, their connections while on the surface would become rather difficult to maintain.

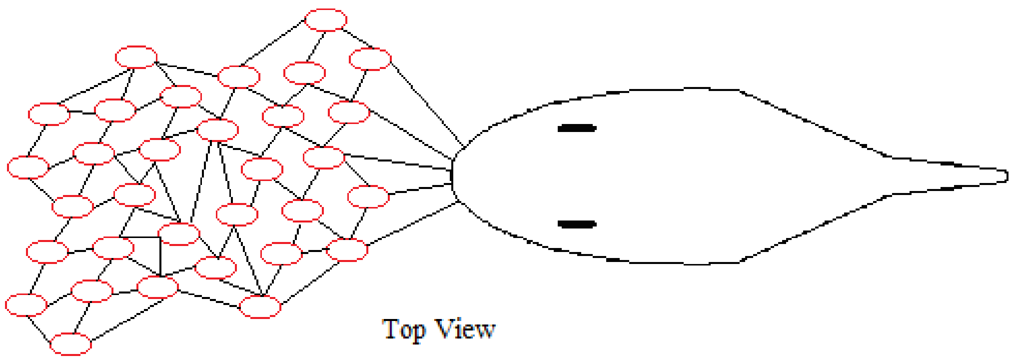


Fig 7.2.3.1: Charging Via Vomit of Solar Cell Mesh

7.2.4 *Temperature Sensor*

If whimsy isn't quite what one is after, a simple temperature sensor can be used to make Tilapi-ugghhh more than just a toy. The LM34 is a precision Fahrenheit temperature sensor, and is relatively easy to use. The temperature sensor topology can be seen below in Figure 7.2.4.

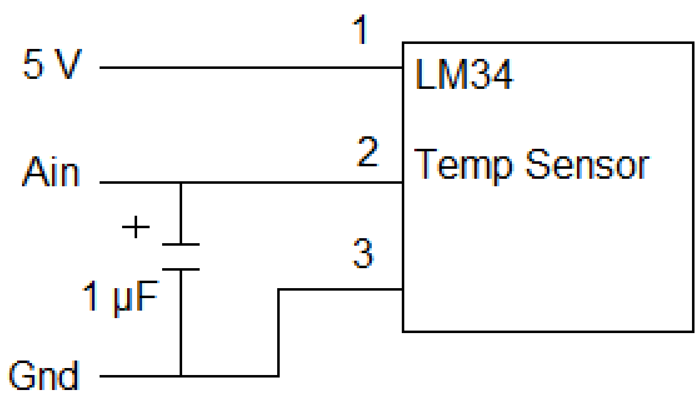


Fig 7.2.4: Temperature Sensor

Once the temperature sensor is wired the output can now be read. The minimum output should be set to 0.0 and the maximum should be set to 500.

The input has been designed for 0 V to represent 0 degrees F and 5 V to represent 500 degrees F.

7.2.4.1 *Data Log*

Additionally the fish can have allocated space to use for memory that can be used to log the temperature data measured, since there will be no LCD display to show the current temperature. The data log could also be used to recall any functions the fish processes.

8.0 Design

Tilapi-ugghhh has several main systems, comprised of smaller subsystems. The solar system powers the battery system. The battery system is regulated by the power control box. From the power control box the voltage is distributed to the sensors systems as well as to the motion systems. From the data collected by the sensors the microcontroller, which has been programmed with an artificial intelligence of sorts, decides which course of action should be taken, as seen below in Figure 8.0.

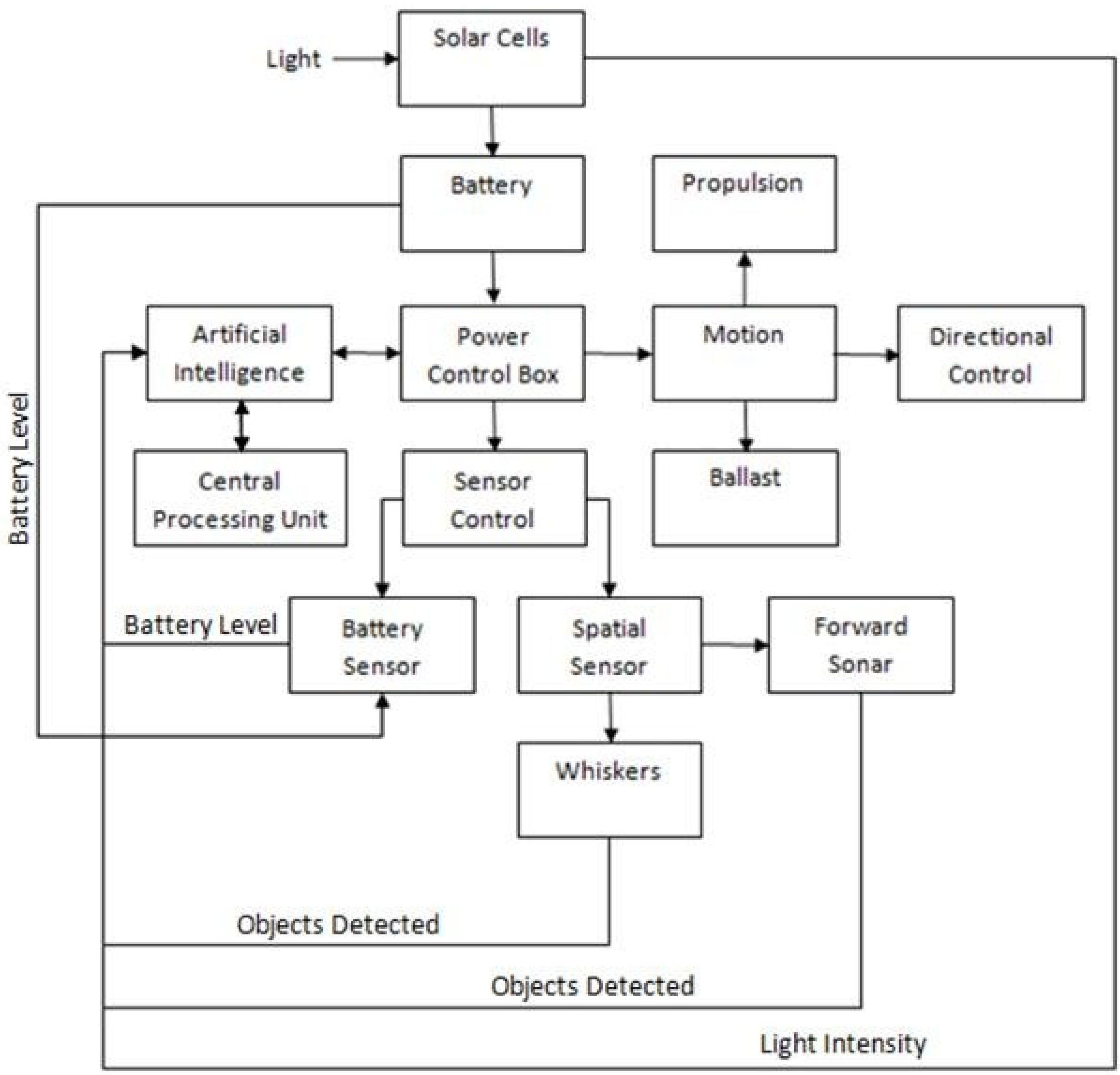


Fig 8.0: Basic Overall Block Diagram

8.1 *Systems*

8.1.1 *Body*

The body of Tilapi-ugghhh has been stream-lined as best possible. One possible arrangement can be seen below in Figure 8.1a. The dorsal fin along with the pectoral fin helps to add stability. The fins are attached to servos that can rotate from 0 to 180 degrees.

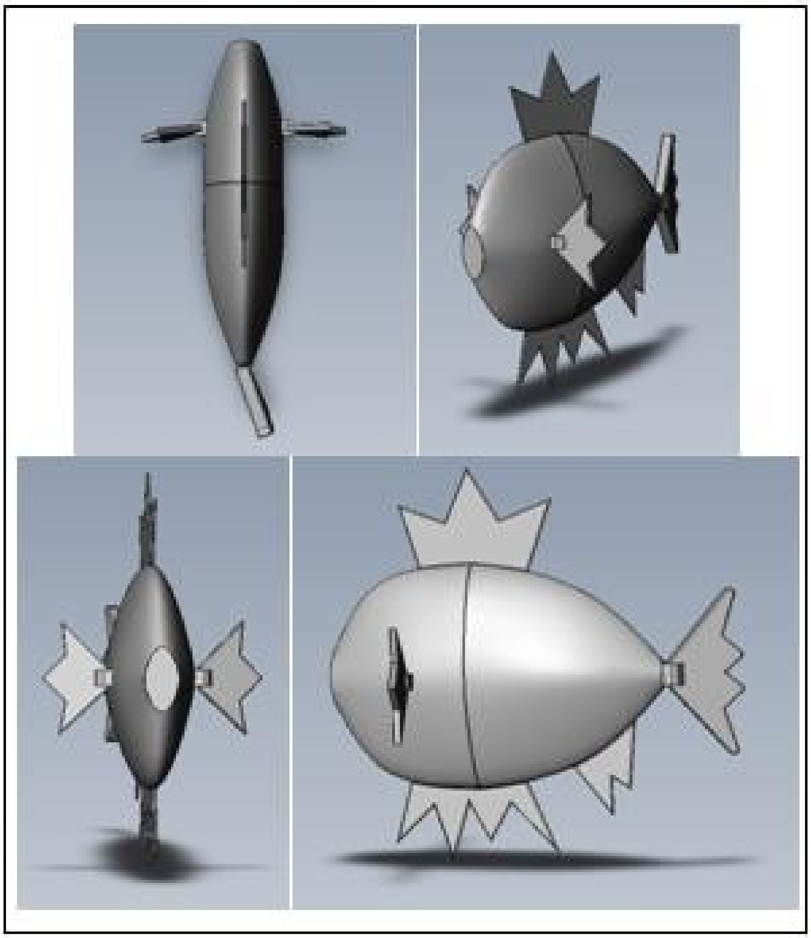


Fig 8.1a: Possible Tilapi-ugghhh Body

What is not reflected in figure 8.1a is that the fins along with the tail will probably be bigger when it comes to construction of the body. The fin joints are also not accurate; the fin joints once built will have a rotating joint instead of a swinging joint. The back end of the fish will have a rotated cut in order to properly house the motor that will be used for propulsion, as can be seen in figure 1.2. The last point to take note is that the entire body of the fish will be split in half and can be taken apart and reassembled for maintenance and testing purposes. These details are similar to those depicted below in Figure 8.1b.

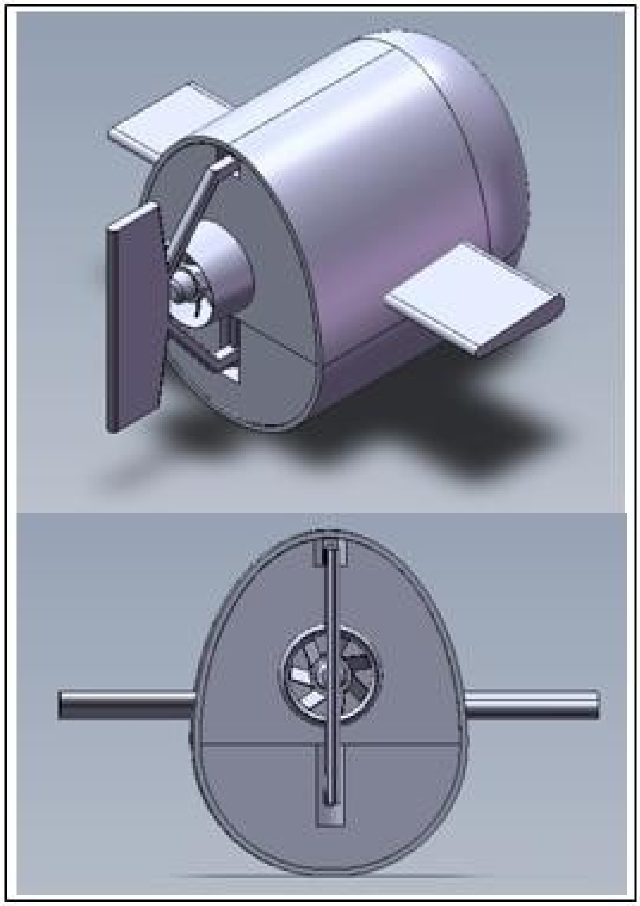


Fig 8.1b: Possible Tilapi-ugghhh Body

8.1.2 *Solar/Battery System*

The solar system will comprise of 3 solar encaps from Radio Shack that have been taken apart. The 12 photovoltaic cells contained within each encap will be rewired to the external shell of the body. After they have been reassembled a coat of clear plastic will encase the entire circuit. The solar system will be connected to 12 nickel metal sub-c batteries. The 12 sub-c batteries will be connected in series to act as one 18 V power supply. The solar and battery system will be combined to create the solar charging circuit as seen in figure 2.2.

8.1.3 *Sensors*

The Sensor Systems of the fish will 5 sub systems for optimal efficiency. These subsystems can be split between two categories, the passive and the active systems.

The passive systems will consist of systems that will be constantly on and constantly relaying information to the microcontroller and will not cause the fish to react other than changing modes. Of the subsystem of the fish, two of the five subsystems will be considered passive. The first passive subsystem to be implemented will be the Battery Level Sensor using the LM3914N chip. This will be a key circuitry in the fish as it will be what is used to determine when the fish's mode is to change. The last passive system will consist of two water sensors that will allow the fish to determine if it is in water and if it is submerged or not.

The remaining sensor subsystems can be classified as active systems. They are considered active because the fish will react to the stimulus provided by these systems. The first are the Whiskers which will act as a proximity system. They are for when the fish begins to approach to close to the wall or floor. The next active system that will be implemented will be the Sonar system using the Maxbotix LV-EZ1. This will prevent the fish from colliding head first into a wall/barrier. And the final active system to be setup will be the Light sensor array which will allow the fish to see and seek light.

Four of the five subsystems and their external probes and possible placement can be found in Figure 8.1.3 below. The Battery Level Sensor is located internally.

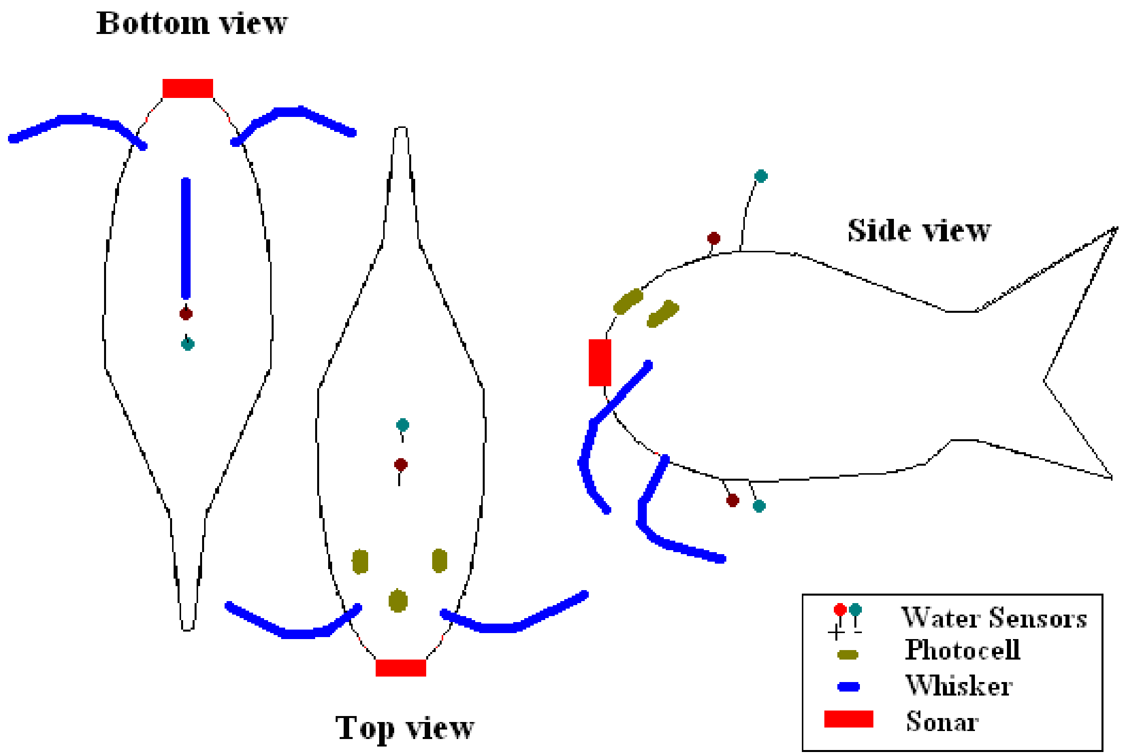


Figure 8.1.3: Four of Five Sensor System probe arrangement.

8.1.4 *Motors/Servos*

The system will be composed of one main propeller motor that will provide the vehicle with the necessary thrust for underwater displacement. This component presented many challenges. DC low power consumption, highly efficient and water-proof, was some of the constraints on this component. Motors with these particular characteristics are only possible through customization processes, becoming really expensive. However, Model 260 DC brushless motor from Tecnadyne is the best choice to get the job done, due to the focus of the company on underwater motors for RC vehicles with prices ranging between $280 and $340, not deviating from our estimated budget by much.

As the motor, servos have a crucial function. That is to give the vehicle direction when navigating at any time, by attaching a flat surface serving as a fin redirecting water flow to acquire relative change in direction. These servos will be manipulated through the angular position parameter to determine the inclination of the fins at any given time with respect to the vehicle's direction of motion.

Usually servos are used in environments that do not resist their rotational motion. In our particular case, the underwater environment imposes a counteracting reaction to any particular motion. Therefore, the servo specification will be constraint by the locked in position torque, which will have to be greater in magnitude to the opposing torque created by the drag force due to the motion on the fins. The choice for this component is the BL4310 DC Brushless motor from Dynetic.

8.1.5 *Microcontrollers*

In the need of merging the necessary components for the vehicle, as well as introducing an autonomous decision maker, capable of communicating with each element interpreting their parameters in order to determine the position of the vehicle with respect to surrounding obstacles or its environment and decide a new path for the vehicle, giving each component the right instruction. However, the microcontroller is a complex component that requires a vast amount of time and testing. Hence, we will utilize the dsPIC30F5015 from Microchip inc.

8.2 *Final Budget*

After having finished initial research, it was decided that a new budget must go into account. It seems as though the original budget was not as generous as once thought. The final project budget, as seen below in table 1.3b, reflects the research done into each component necessary to create the Tilapi-ugghhh prototype.

Component	Amount	Cost Per Unit	Total Cost
Solar Cell Encap	3	$15.00	$45.00
Sub-C Battery	12	$4.00	$48.00
Beginner Parts Kit	1	$24.95	$24.95
Volt Regulator - Adjustable	2	$1.95	$3.90
BJT (min. numbers)			
NPN 2N3904	5	$0.75	$3.75
PNP 2N3906	5	$0.75	$3.75
LED			
Green	4	$0.35	$1.40
Red	9	$0.50	$4.50
Yellow	7	$0.50	$3.50
Mini Photocell	4	$1.50	$6.00
Maxbotix LV-EZ1	1	$24.95	$24.95
LM3914N	2	$1.50	$3.00
4 Channel Tx Kit	1	$20.00	$20.00
4 Channel Rx Kit	1	$24.00	$24.00
Thruster Motor	1	$345.00	$345.00
Servomotor	2	$225.00	$450.00
Microcontroller	2	$5.25	$10.50
Transistors	6	$1.25	$7.50
Encoder	1	$37.85	$37.85
Miscellaneous/Waterproofing	-	$200.00	$200.00
Total			$1,267.55

Table 1.3b: Final Project Budget

9.0 Testing

In order to successfully construct the Tilapi-ugghhh prototype testing will need to be done throughout the duration of the construction of the fish. In order of priority: the directional/propulsion, recharging/solar-cell system, sensors, microcontroller, and the integration of all components which will also be used for demo testing, will all need to be tested.

9.1 *Directional/Propulsion Control Testing*

The Directional/Propulsion Control testing will involve testing three attributes, the ballast, propulsion, and turning. The ballast testing will involve testing the body and air seal electrical component container and simulated weights of the other components. The test will be considered successful if the system remains stationary in its depth or floats to the surface at a slow rate (i.e. doesn't shoot to the surface or sink after being released). The death roll feature will also be determined at this time.

The next characteristic to be tested in this category is the propulsion which will involve determining minimums and needed voltage/current to move forward at two differing settings then a repeat connected to the ballast system. The final attribute to be tested in the Directional/Propulsion Control testing is the turning. This testing will be done using the ballast system combined with the motor and the servo-fins.

9.2 *Recharging/Solar-Cell System Testing*

We will need to test that the assembly/circuitry will recharge the batteries as well as test to determine the recharge rate. In order to do so, we will hook up the batteries to the solar cells provisionally. The solar system temporarily wired to batteries that have been drained to 80% of their original capacity. This assembly will be placed under a light and will be timed. If the batteries can regain 70% of their voltage, the test can be determined successful. By timing how long it takes the batteries to recharge we can then calculate the rate at which we can expect the batteries to recharge.

9.3 *Sensor Control Testing*

A major part of Tilapi-ugghhh's automation is the sensors that have been built in. Five sensor tests will need to be done. The five sensors to be tested include water, light, battery, whisker, and sonar sensors.

9.3.1 *Water Sensor Testing*

The water sensor test will involve assembling the circuitry and insuring the output will be clear on whether the sensor is triggered or not. This will need to be done at least three times for the three water sensors that are needed. Once the circuitry is assembled we will simply place each of the sensor tips into water and read the output. If the sensor is immersed in water and the sensor outputs the same information, we can determine the test successful and the assembly to have been done correctly.

9.3.2 *Light Sensor Testing*

The light sensor testing will involve the same thing as the water sensor testing. There will be three light sensors on the fish that will need to be tested and the testing will consist of determining the Light Sensor sensitivity and optimization of positioning.

9.3.3 *Battery Level Testing*

This testing will involve assembling the voltage step using the LM3914 and checking whether voltage/current levels differ when a step/level is active and inactive. While the solar recharging circuit is tested, we can also determine whether or not the battery level can be measured.

9.3.4 *Whisker Testing*

The whisker testing will involve testing whether the whisker triggers correctly, the sensitivity of the whiskers and adjusting so that the drag from moving through the water will not cause false triggering. This test will need to be done in water, seeing as that is the medium the whiskers will be placed in. In order to test the accuracy of the whiskers we will simply need to run them through water to make sure they do not trigger. If they are triggered, then a new material will need to be used that is marginally stiffer. If they do not trigger from movement in water alone, we can continue on to the next step. We then must run them near an object, eventually hitting the object, to see if they trigger. If they do not trigger, then a slightly more flaccid material will then need to be chosen. If a new material is chosen, the first test will need to be done again.

9.3.5 *Sonar Testing*

The sonar must be tested to see how it is that they function and what type of data it returns. The sonar used will be waterproofed, so we must also determine how it is the waterproofing affects the output. Testing the sonar must be done with the use of the microcontroller. The sonar will be placed in the water and we will move it closer to and away from objects. Upon experimentation we will be able to establish a base line for what it is that the sonar is outputting.

9.4 *Microcontroller Testing*

This testing will mainly involve determining what it can and what it cannot do. Another aspect of the microcontroller testing will be the integration of the sensor information/readings, propulsion signal output, and correctly setting up how they interact/read. Once all the other components have been successfully assembled, we can trigger each sensor to see if the microcontroller does what it has been programmed to do. We can determine whether or not it is doing what it is supposed to by either hooking up the LEDs, or by reading a simple voltmeter.

9.5 *Demo Testing*

Once all of the systems and subsystems are complete a full integration testing will need to be done, this will also serve as the demo test. In this test all of the sensors must be triggered, causing the artificial intelligence to respond appropriately. The fish will be placed in a shallow pool. This pool will contain a solid pipe which will be wide enough for the fish to fit through. The proximity objective of this test is for the fish to turn when it senses a wall in its proximity, and to swim through the tunnel. With the demo testing the voltage levels will be set at much higher voltages. The fish will start seeking light at 80%, and will surface in Death Roll mode at 60%. The fish will enter Regen mode once the battery level reaches 80% and will continue swimming. In essence, demo testing will put Tilapi-ugghhh through each command prompt.

10.0 Conclusion and Summary

Ultimately, “Tilapi-ugghhh” will successfully able to remedy each foreseen problem involved with owning conventional house pets. By eliminating the exorbitant cost and incessant requirement for physical care associated with dogs, cats and even live fish, “Tilapi-ugghhh” will have established itself as a viable alternative for those who seek animal companionship but lack the time and/or resources to care for living entities.

“Tilapi-ugghhh” will operate as an autonomous, solar-powered, entirely self-sufficient animatronic fish replica. In an effort to both reduce the environmental implications caused by the disposal of conventional battery acid, and maximize the efficiency of the charging process, solar panels will be utilized to charge Nickel-Metal Hydride batteries.

First, in order to mimic the natural movement of a fish, “Tilapi-ugghhh” will use a mixture of pectoral fin manipulation and motors to propel and steer the device through water. Axial (upward and downward) motion will be achieved via a counterweight system, while propulsion and lateral turning speed will controlled entirely by the structural placement of the fins and motors and the consequent hydrodynamic effect.

In addition, “Tilapi-ugghhh” will utilize state-of-the-art artificial intelligence (A.I.) to process data received from a multitude of sensors to control the magnitude of propulsion and direction of the creature. A.I. will be implemented through use of a microcontroller programmed to work based on specific cues and information from the aforementioned sensors.

A water detection sensor will be employed to determine the operational state of the fish (based on the surrounding environment of the apparatus). From there depth and object detection sensors will be used to help guide the fish through water and to help the fish avoid obstacles.

Finally, in anticipation of “Tilapi-ugghhh” losing battery power as it maneuvers, a battery sensor will be implemented to determine when the fish needs to start seeking out light sources. Upon the subsequent conclusion that they battery requires recharging, an installed light sensor will help the fish find sources solar power for energy.

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Fig 2.1.2 & Fig 2.1.3 (Approved)

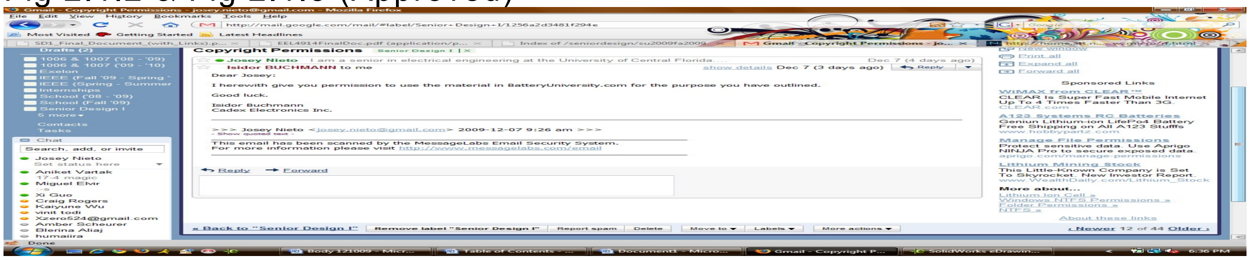

Fig 2.3.1.1 & Fig 2.3.1.2 (Pending)

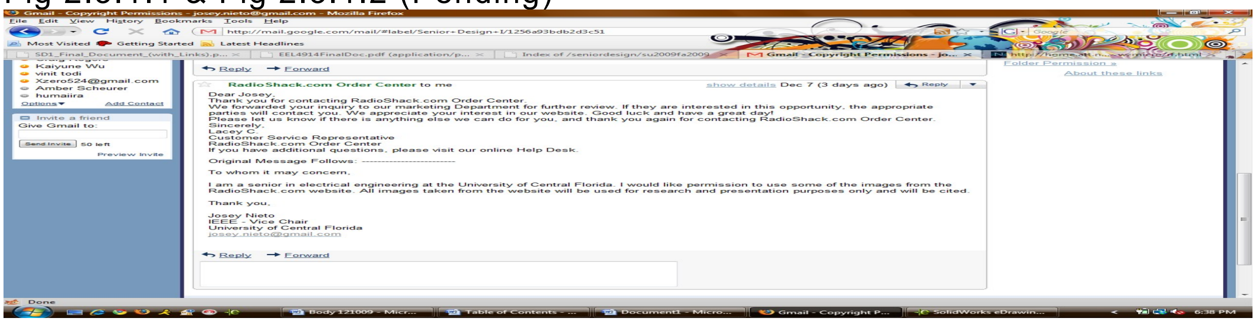

Fig 2.4.1 (Approved)

Fig 2.4.2 (Approved)

Fig 3.2.1a, 3.2.1b, 3.2.1c (Approved)

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Kaiyune Wu <jfun99@gmail.com> Fri, Dec 11, 2009 at 8:08 PM
To: robots@societyofrobots.com

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Thank you

Kaiyune Wu

Fig 3.4.1.2b (Approved)

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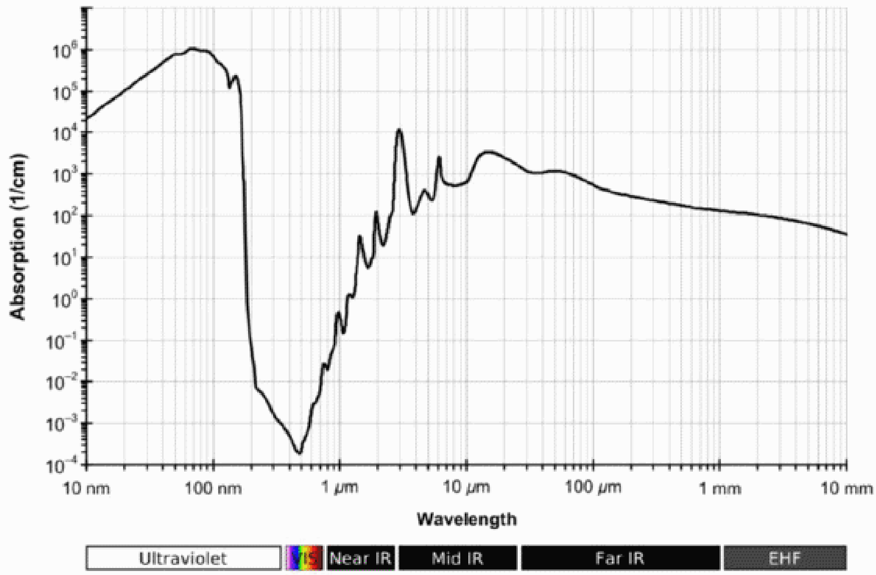

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Source	I created this work myself. The data curve is based upon various reported values of water absorption in the literature. (E.g. see http://omlc.ogi.edu/spectra/water/abs/index.html for a list of references.)
Date	
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Kenneth

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To: <kmaxon@uswest.net>
Sent: Monday, November 02, 2009 6:28 AM
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Bob Gross <bob@maxbotix.com> **Mon, Nov 2, 2009 at 11:48 AM**
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Please use them. If you post to the web, please sens us a link to the paper, and also please provide a link to our web page.

Regards,

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Fig 3.4.4.1b (Approved)

BEAM ONLINE

- Circuits -

Note: All of the circuits on this page are for Personal use only. Commercial usage is prohibited unless arrangements are made with the patent holder Mark W. Tilden mwtilden@lanl.gov.

Printable quick reference guide

Solar engines - SE's are small circuits that gather energy from the sun, store it in a capacitor, and then release the energy to drive a motor, coil, another circuit.... Note that the 1381 and FLED SE's can only drive a motor or coil.

1381 SE - One of the more popular SE's because it's simple and easy to build.
FLED SE - If you can't find the 1381 voltage detector in your area try this SE. It uses a much more common FLED.
D1 SE - Charges all day, runs at night. Think noctibot here.
PM1 SE - This circuit it like the 1381 SE except you can run not just motors and coils. Use it for just about anything.

Photovores - A photovore is a robot that moves towards the brightest source of light, or if it's solar powered, food.

Photopopper - The photopopper is the most common solar powered photovore.
iVore - The iVore is great because it's VERY easy to build and tracks the light perfectly. A favorite when I'm doing demos.
BEAMant - A bicore controlled photovore. Works good but doesn't track very well in low light.

Bicore circuits - The bicore is the foundation for allot of BEAM robots. It's just a simple oscillator but when grouped together can produce complex behaviors.

Suspended bicore - Basic bicore.
Light seeking head - The motor "neck" turns the electronics "head" to look at the brightest source of light.

Walker circuits - A few complete designs I've put together.

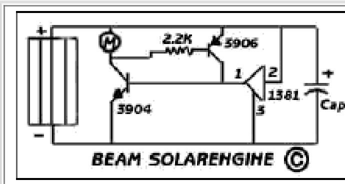
CW1 - Simple to build and has a reversing sensor so when your walker bumps into an object it will respond and backup.
CW2 - Slightly more complex than CW1 and will make your walker turn when it encounters an object.
CW3 -Same as CW2 except that it will backup and then turn after bumping an object.
CW4 - A basic four motor walker utilizing a dual CW1 circuit architecture.

Motor drivers - All the walker designs above require motor drivers. A motor driver basically can take a weak signal from an input and amplify it. H-bridge - A good but slightly complex motor driver.

ALS245 driver - Simple design.
Servo driver - This circuit will allow you to drive standard hobby servos without the need to modify them.

Sensor circuits - Sensors and circuits to add to your bots to make them more adaptable or just plain cool.

240 Signal inverting circuit - AKA: Reverser. This circuit is used to make walkers backup and on four motor designs, turn.
IR object detector - A cool circuit that will enable your robot to detect an object before it even touches it. Other - Some other useful circuits that may not nesasarilly be used for BEAM.
Battery Charger - Want to but a rechargable batteries on your walker but need a way to charge them? Look no further.
FM radio transmitter - A simple circuit that could be used for say, a wireless mic.



1381 Solar Engine

Parts

3v+ Solar Cell Motor 2.2K Resister NPN 2N3904 Transistor PNP 2N3906 Transistor 2500uF to 10F Capacitor CMOS 1381J Voltage Detector

Notes: This is the most popular SE because of it's efficiency and reliability. It uses a 1381 Voltage Detector that can be found at Digi-Key in transistor and SMT packages. What this circuit does is..... 1. The solar cell starts charging the capacitor and the voltage rises 2. As soon as the capacitor reaches 2.7v the 1381 turns pin 1 high and turns the 3904 ON 3. When the 3904 turns on it brings the base of the 3906 low which turns it ON 4. With the 3906 ON current is supplied to the base of the 3904 which keeps it ON 5. Now current can flow through the motor and it turns 6. When the voltage gets down to .7v the transistors turn OFF and the process is repeated Check out some solarollers I've built with this circuit.

Fig 7.1.2.2a & Fig 7.1.2.2b (Pending)