Tilapi-ugghhh

Gerardo Caicedo, Josey Nieto, Kaiyune Wu

School of Electrical Engineering and Computer Science, University of Central Florida, Orlando, Florida, 32816-2450

***Abstract* — Environmentally and self aware, the submersible has multiple sensors integrated into its system. Tilapi-ugghhh will only operate when water sensors are triggered. In order to avoid obstacles Tilapi-ugghhh utilizes both a sonar and whisker system. As Tilapi-ugghhh maneuvers through water, voltage levels are continuously monitored. Once voltage level has dropped to a specific threshold, the vehicle will begin seeking light. Light intensity is monitored through the use of light sensors. When the voltage level reaches the second threshold, Tilapi-ugghhh will then surface, where light is most intense, to recharge. Equipped with photovoltaic cells, Tilapi-ugghhh will remain surfaced until the voltage level reaches the third pre-set voltage level.**

***Index Terms* — Autonomous, environmentally-aware, photovoltaic, robotic, self-sustained, solar-powered, submersible.**

I. Introduction

Engineering research is rooted in the continuous goal to improve the performance and cost of both new and existing methods and products. One of the newest trends within this realm has been the “Green Revolution” which focuses on developing new protocols and refining existing ones from an ecological perspective. This shift to an eco-friendly approach has also lead to tremendous manufacturing innovation. Take into consideration a few facts. Merely 0.007% of the world’s water supply is readily accessible and potable, because of this nearly 1.5 billion people lack safe drinking water. An estimated 5 million deaths per year can be attributed to waterborne diseases. Major sources of drinking water need some means of monitoring without continuous human interaction.

Tilapi-ugghhh is a self-sufficient, portable, submersible vehicle that resembles a fish. The onboard central processing unit takes information obtained from various sensors facilitating a sense of artificial intelligence. Tilapi-ugghhh will only operate when the water sensors have been triggered. Once in water, the fish will swim in a random path until an object or obstacle is detected. Tilapi-ugghhh is equipped with multiple proximity sensors to detect any obstruction in its path. Motion is enabled with the use of three motors to move left-right, forward-reverse, and up-down. As Tilapi-ugghhh swims through water, voltage levels are constantly monitored. There are three pre-set voltage levels which trigger different modes. As voltage level decreases to the first threshold, Tilapi-ugghhh will begin seeking light with the use of light sensors. When the second threshold is reached, Tilapi-ugghhh will begin to surface where it senses the light is most intense. Once surfaced, Tilapi-ugghhh will use photovoltaic cells to recharge. Once the third voltage level is detected, Tilapi-ugghhh will submerge and continue to swim.

Tilapi-ugghhh will act as the framework for later development to help in the plight of finding clean water resources. In the future one could install additional sensors, such as temperature and chemical sensors. To record and store the data read from the temperature and chemical sensors, data logging could also be enabled. To retrieve the data recorded and to send commands, wireless communication could be set up. For example, once foul waters are detected Tilapi-ugghhh could send a message to a remote location signaling its find. Tilapi-ugghhh would then act as a long-term aquatic environment monitoring probe.

II. Solar System

A. Photovoltaic Cells

For a machine to be truly “self-sufficient” the machine must be able to sustain energy without intervention. Tilapi-ugghhh does not require someone to replace the batteries once one set of batteries is discharged; instead, it recharges the installed battery pack of 6 NiMh Sub-C batteries. To recharge the batteries, the batteries are wired to 12 37x33mm monocrystalline solar cells, as seen in figure 2.1. Each cell is capable of outputting 6.7V at 31mA.

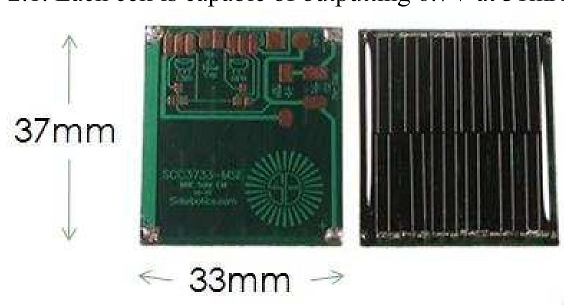

Fig. 2.1. The 37x33mm monocrystalline solar cell to be used in recharging the battery pack.

The solar cells will be connected to variable regulator, resistor, and diode circuit to ensure a proper current for charging as well as to prevent feedback from the batteries to the photovoltaic cells. In order to maximize the amount of current outputted, the 12 cells will be hooked in series of pairs in parallel to achieve 13.4V at 186mA, as seen in figure 2.2.

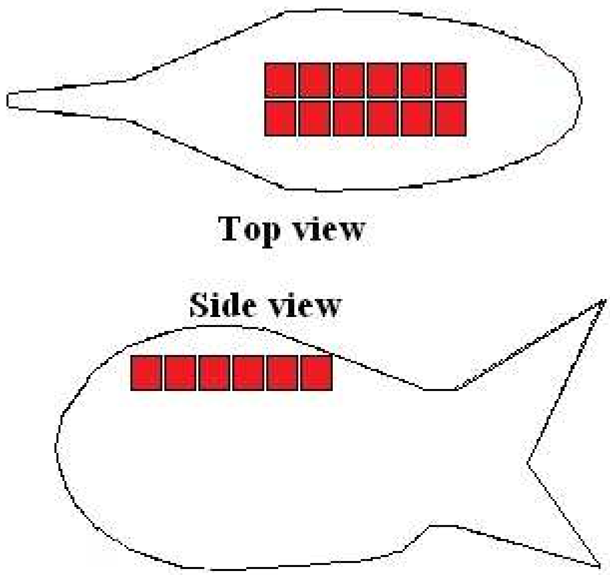

Fig. 2.2. The solar cell arrangement as seen from the top and the side.

B. Challenges With Solar

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 angle 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.

Another issue incurred by charging in aquatic environments is that as water travels through a dense medium such as water, the intensity of light diminishes greatly. The deeper into the water the fish is, the less intense the light wave will be. At shallow depth (0 – 5m) the amount of light available decreases to about 40%. Past 20m little to no light is available at all.

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, at an appropriate angle. The fish will surface to a point where the solar cells are completely emerged, in order to avoid any incidence of water reflecting light away from the photovoltaic cells as well as increasing the amount of light intensity.

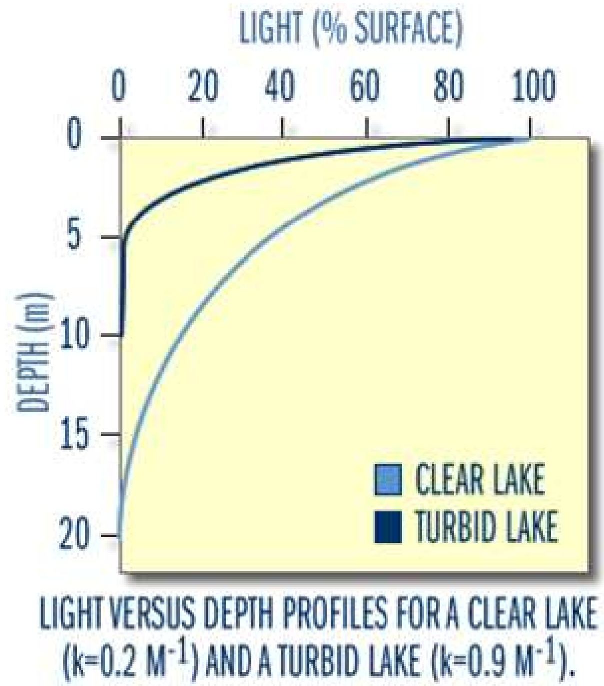

Fig. 2.3. The percentage of light that penetrates the surface as the depth of the water increases.

III. Power

NiMh Sub-C batteries have a standard charge of 15 hours at 300mA and a rapid charge of 1.5 hours at 3000mA. The Tilapi-ugghhh system draws 1.3A at peak operation. With 5 batteries connected in series with 3800mAh, the total system will have 19000mAh of life time at 6V. Running at peak conditions Tilapi-ugghhh has a total life time of about an hour. Because of how Tilapi-ugghhh recharges it's battery, and because of how long it takes for the final threshold to be reached, the system will probably utilize all of the daytime hours to recharge only to swim for a few hours at night.

In order to properly distribute power to each of the subsystems we are using a series of isolated sytems. To distribute the proper amount of power to the motors we will be using two 2.6 – 14V switching regulators (AnyVolt Micro). The remaining subsystems will utilize 5V (L7805C) and 12V (L7812CV) regulators.

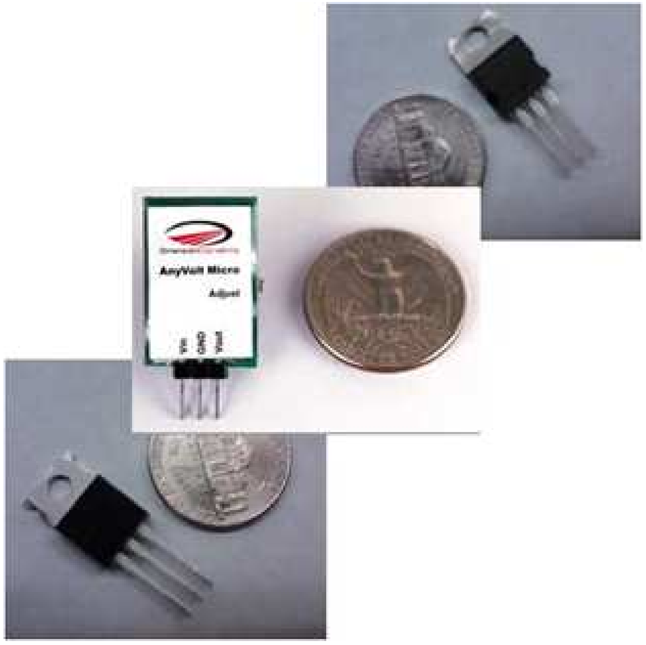

Fig. 3.1. The voltage regulators that are being used to distribute power to all operating systems.

IV. 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.

V. 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 our main propelling will need to have a power specification of at least the power one half the density of the vehicle times the surface area (Orthographic Projection) multiplied by the drag constant and the cube velocity. Assuming the environment’s temperature to range between 10 and 40 degrees centigrade, the water’s density would 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.

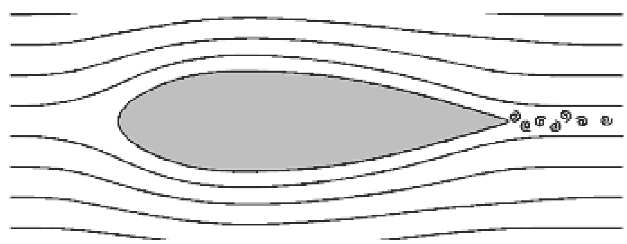

Fig. 5.1. A flow model diagram depicting drag experienced.

For an underwater vehicle of these characteristics the drag coefficient is approximately 0.04. 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

Fig. 5.2. An image showing the skeleton of Tilapi-ugghhh.

VI. 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.

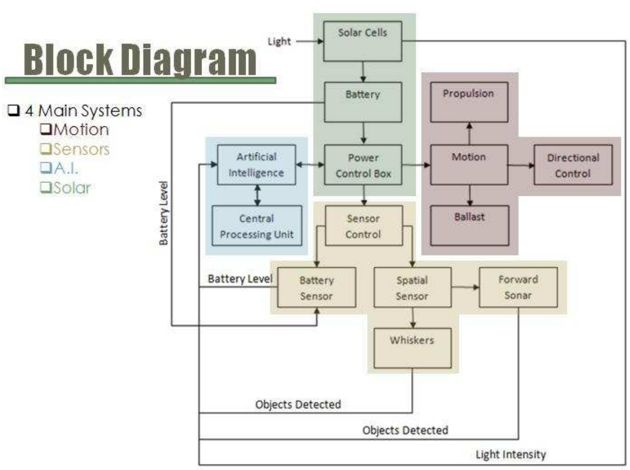

Fig. 6.1. The block diagram of all the subsystems of Tilapi-ugghhh.

VII. DC MOTOR CONTROL

A single pin of the ds30F5015 PIC microcontroller is limited to a maximum output current of approximately 25 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.

The L298 integrates two power output stages. The power output stage is a bridge configuration and its outputs can drive an inductive load in common or differential mode, depending on the state of the inputs. The current that flows through the load comes out from the bridge at the sense output. An external resistor allows to detect the intensity of this current. This integrated circuit chip will take care of the motor control managed by the microcontroller.

VIII. 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 consider is the flex sensor, which will use a 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.

IX. 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 level, 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 forward and top motor repositioning the vehicle an inclination angle of less than 45^{o}. Once the vehicle is at an optimum charging position the vehicle will remain at this location until 90 percent of the battery has been replenished. By making 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.

Modes	
Startup	00
Standby	01
Dive	02
Calm Swim	03
Light Seeking	04
Battery Check	05
Surfacing	06
Death Roll	07
Regen	08
Resurrection	09

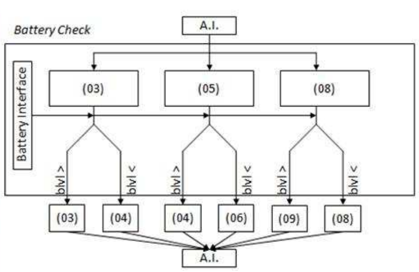

Fig. 9.1. The battery check block diagram.

X. 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.

XI. Passive Ballast

Maintaining a 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 is the body diagram of the vertical forces acting on the vehicle.

XII. Sensors

In order to allow the fish to swim and react to its environment, an appropriate combination of sensors are needed. The sensor system will include a water sensor, light sensors, and proximity sensors.

A. Water Senor

A simple Water sensor is easy to construct using resistors. The sensor will feed 2.5 V if the fish is out of water and 0 when the fish is placed in water. Placement of the water sensor's leads can be seen in Figure 9.1 below.

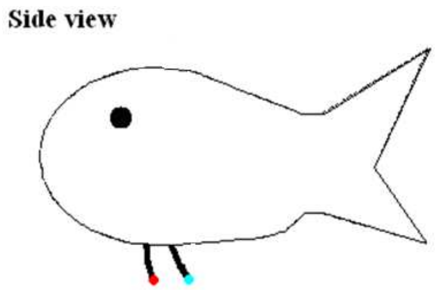

Fig. 12.1. The water sensor arrangement.

B. Light Sensors

There are many types of photo sensor options available however to keep things low to keep things low in power demand and simple in implementation we are using two photo resister and resistor combination as seen below in Figure 12.2.

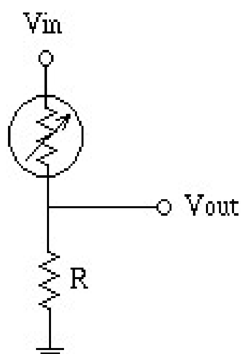

Fig. 12.2. The light sensor circuit diagram.

The photoresistor to be used can be found in figure 12.3 as seen below.

Fig. 12.3. Photo of the photoresistor to be used, which has already been waterproofed..

C. Sonar

In order to assist the fish's object avoidance, a sonar unit will be employed on the front of the fish. This will allow the fish enough time to avoid walls that should emerge.

Fig. 12.4. Image of the LV-MaxSonar WR1 which is being used as the primary means of object detection.

We have set the microcontroller to react to objects within 1.5 feet.

D. Whiskers

In order to avoid objects brushing into the fish whiskers will are being used. This is done using wires that when the whiskers come in contact with something will connect. The whisker can be seen below in Figure9.10 with a covering for water proofing.

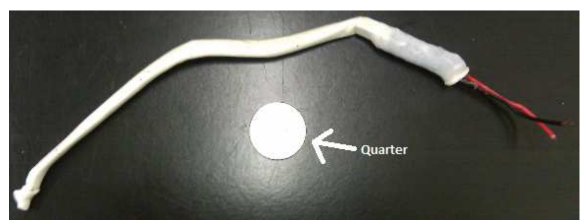

Fig. 12.5. Photo of the waterproofed whisker.

The Whisker is then connected in series with a resistor such that when the whisker is un-triggered the voltage read by the microcontroller will be 0 V and when triggered the voltage read will be 2.5 V. Placement of the whiskers can be seen below in Figure 9.11

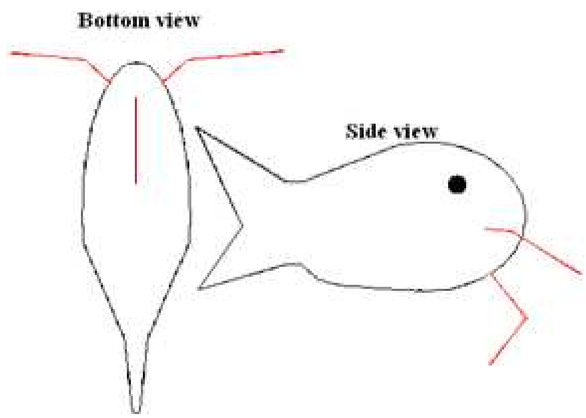

Fig. 12.6. An image depicting the final whisker arrangement.

E. Final Sensor Arrangement

The Sensors that are being used will be consists of a water sensor, one sonar, two light sensors, and three whiskers.

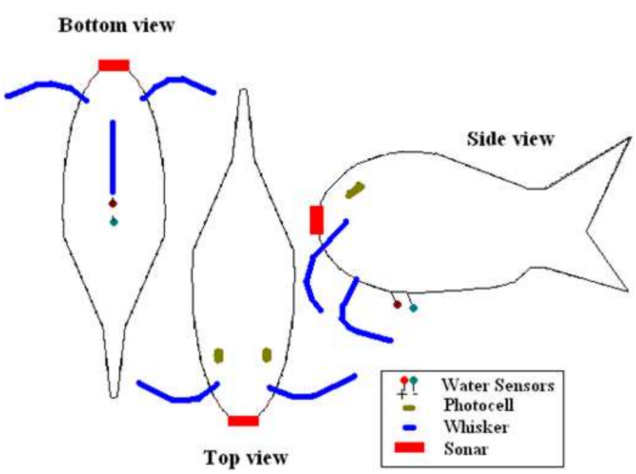

Fig. 12.7. The final sensor system arrangement.

In Figure 9.12 to the left, the final placement of the sonar, whiskers, water sensors and light sensors can be found. The circuits for each of the sensors can be seen above it in Figure 9.13.

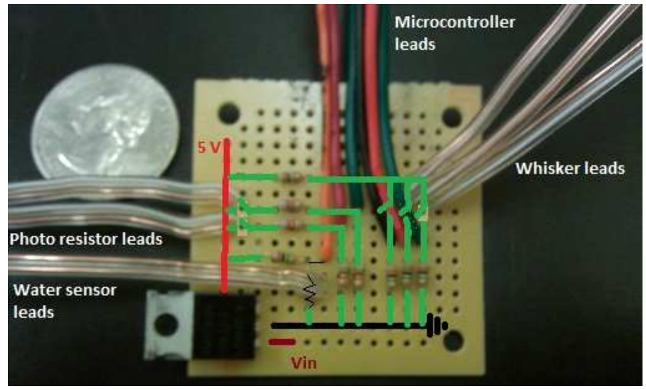

Fig. 12.8. The actual circuitry to be used to enable the sensor system.

XIII. Conclusion

Ultimately, Tilapi-ugghhh will act as framework for a later long-term aquatic environment monitoring probe. Tilapi-ugghhh is equipped with various sensors that can detect light, voltage, proximity, and water. The water sensor will engage the fish into the on position. Once in water the fish will swim "randomly" through water until an obstacle is detected. The onboard sonar will detect objects between 1 and 2 feet away. If Tilapi-ugghhh encounters an object within a foot, the whisker sensor will trigger. The central processing unit will then activate the motors causing the fish to turn. As battery voltage decreases, the first threshold will cause Tilapi-ugghhh to start seeking out light with the use of light sensors. As the second threshold is reached the fish will begin to surface where it detects the strongest sense of light. The fish, once surfaced, will charge until the battery reaches the final threshold and will the re-submerge and continue to swim, repeating the cycle.

VII. Conclusion

Although reading these instructions may have been an unpleasant experience, following them will improve the quality of your paper and the RFIC Digest. Table I summarizes much of the detail provided and illustrates one of the rare instances where the double column format can be violated. If you have comments, suggestions, or are willing to volunteer your time to improve these instructions, please contact one of the RFIC TPC Chairs.

Acknowledgement

The authors wish to acknowledge the assistance and support of the University of Central Florida's Center for Entrepreneurship and Innovation.

ABOUT THE AUTHORS

Gerardo E. Caicedo, an undergraduate Electrical Engineering major, with a minor in mathematics and physics, concentrating in power generation systems. Active member, of (SHPE) Society of Hispanic Professional Engineers, and (COLSA) Colombian Student Association. Enrolled in the SUPERB CSIS program in engineering research at UC Berkeley as of the summer of 2010.

Josey Nieto is an Electrical Engineering undergraduate student whose studies concentrate in Power Systems. She has previously worked at Exelon, one of the leading producers of nuclear energy in the U.S. and is an active member of the Society of Women Engineers (SWE) and the Institute of Electrical and Electronics Engineers (IEEE). Currently, she serves as the Vice-Chair for the University of Central Florida's chapter of IEEE, for whom she coordinates the technical and professional strategy for the society.

Kaiyune Wu is an undergraduate student in the School of Electrical Engineering and Computer Science, majoring in Electrical Engineering. He is interested in the Power Electronics, Analog Electronics, Optics, and Solar Electronics fields. He will be graduating Spring 2010.

REFERENCES

[1] http://wattsupwiththat.com/2009/06/04/nasa-goddard-study-suggests-solar-variation-plays-a-role-in-our-current-climate/, Accessed 09/30/09

[2] http://waterontheweb.org/under/lakeecology/04_light.html, Accessed 09/30/09

[3] Serway, Raymond A.; Jewett, John W. (2004). Physics for Scientists and Engineers (6th ed.). Brooks/Cole.

[4] Halliday, David; Resnick, Robert; Walker, Jearl. Fundamentals of Physics (7th ed.).

[5] Lynch, Andrew, Design Review: Brushless Motor Controller for an Unmanned Underwater Vehicle (UUV) as an EE464H senior design project for Summer 2006, Univ. of Texas, November. 2009.

[6] Microchip dsPIC30F5015 Datasheet, Microchip., Chandler, A.Z.., November 2009. Available: http://ww1.microchip.com/downloads/en/DeviceDoc/70149D.pdf.

[7] DC Brushless Motors datasheet, Dynetic Systems, Elk River, MN., November 2009. Available: http://www.dynetic.com/pdfs/Brushless/DYNETIC SYSTEMS BRUSHLESS FLYER.pdf.

[8] DC Servomotor Controller, ELM. Saitama prefecture, Japan, November, 2009. Available: http://elm-chan.org/works/smc/report_e.html

[9] Freescale BLDC Documentation. Austin, TX, October 2009. Available: http://www.freescale.com/files/training_presentation/TP_FTF2008_MOTORCTRL_PART4.pdf.

[10] Maxim/Dallas 1 wire Interface. Dallas, TX, September 2009. Available: http://www.maxim-ic.com/appnotes.cfm/appnote_number/1796

[11] Maxon Motors EC Flat Series Products. Pittsburgh, P.A., November 2009. Available: http://www.maxonmotorusa.com/products/motors.cfm?prod=ecf.

[12] Mouser Electronics. Dallas, TX., November 2009. Available:http://www.mouser.com/ .