Depth Perception and Sustainment System

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The SeaPerch project is an exciting introduction into engineering and the sciences for junior high students in which they build, modify, and compete with underwater ROVs. While competing, the pilot will find it difficult to determine the depth of the ROV due to the refraction of light on the surface of the water. Because the competition is based on the pilot's speed and skill, it is important that the ROV be as simple to operate as possible. The purpose of this project was to provide students with an inexpensive depth measuring system that they, themselves, could build. It was designed to attach onto the ROV and instantly report its position to a desired depth selected by the pilot. Utilizing water pressure, the system uses a series of LEDs that report the ROV's depth, making the misconception of depth no longer an issue.

Introduction

Depth Perception and Sustainment System (DPSS)

The Depth Perception and Sustainment System (DPSS) is a device that measures depth by receiving water pressure as its primary input and light verification as its output. There are many projects that resemble that of the DPSS such as the "An Inexpensive Depth Gauge for Penguins", done by Rory P. Wilson, Professor of Aquatic Biology at Swansea University. This project used an inexpensive capillary type depth gauge to measure the amount of time penguins spend swimming at certain depths (R. Wilson, 1984, p. 1077). However, most of them are expensive, require computer aid, and do not present instantaneous data.

The DPSS is designed not only to be a useful device for piloting the SeaPerch ROVs but also an extensive learning experience for students interested in recreating this project. It was created to be affordable, work without the aid from any other system, and present immediate readable data. It teaches basic concepts of physics and electrical engineering and provides students with a fun "build it from scratch" opportunity. All parts to the DPSS were meant to be constructed by the student to further interest them in engineering concept and design.

Light

The refraction of light is the manipulation of the direction in which the light is traveling. This is due to the phase change that it experiences when it travels between two different substances. Because water is denser than air, the speed at which the light is traveling will be diminished when it hits the surface of the water. This causes a change of the angle at which the light is traveling. To the chagrin of many anglers, this change will cause an image to appear closer and larger than it actually is.

Refraction, however, is not the only affect water has on light. Different colors have varying wavelengths and water has a unique affect on all of them. Once again, because water is denser than air it will dampen the light wave quicker. Colors with shorter wavelengths, such as blue and purple, will travel further in clear water. Interestingly, on the other hand, colors with shorter wavelengths, such as red and yellow, have a tendency to travel further in murky water. (thinkquest.org, accessed 2013).

Pressure

Newton's third law is an important concept to understand when studying pressure. This law states that "the forces of action and reaction between interacting bodies are equal in magnitude, opposite in direction, and collinear" (M. Plesha, et. al., 2010, p. 7). Relating this to pressure, it is understood that a body that is not condensed contains a force inside that body that is pushing outward. This inner force equals the force outside that body that is pushing inward; be that atmospheric pressure, water pressure, etc.

As an object travels deeper underwater the pressure that it suffers increases. This phenomenon is expressed by the equation:

$$P = \rho * g * h$$

(D. Giancoli, 1988, p. 291-293). If the object's inner force does not acclimate to the changing conditions, the object's support structure will eventually fail from the increased and unmatched outer force.

Methods

Depth Gauge

The DPSS depth gauge utilizes differences in internal and external pressures (see section: Pressure). The internal pressure of the syringe will be acclimated to the atmospheric pressure in which it is built. Sealing the syringe (see fig. 1) will deprive it from acclimating to its changing surroundings underwater. This will allow the increasing water pressure to press down on

fig.1

the balloon, which, in turn bends the strain gauge (see fig. 2). When the ROV returns to the surface the internal and external pressures will equalize, allowing the strain gauge to return to its original position.

The depth gauge consists of a sealed syringe topped with a balloon. On the inside of the syringe a strain gauge, running from top to bottom (see fig. 2), will be the variable resistor that will change the output from the wheatstone bridge.

fig.2

Wheatstone Bridge

The two functions of the DPSS are to allow the pilot to select a certain depth and report back the ROV's position to that depth. As such, the depth can be selected by manipulating a potentiometer, another variable resistor besides the strain gauge. The purpose of the Wheatstone bridge is to "(measure) resistance with a high measure of accuracy and sensitivity" (R. Figliola, et. al., 2011, p. 584). The two voltages received on opposite ends of the Wheatstone bridge (see fig. 3) will output varied results, depending on the state of the variable resistors. These changing voltages will tell the DPSS the information it needs to read back to the pilot.

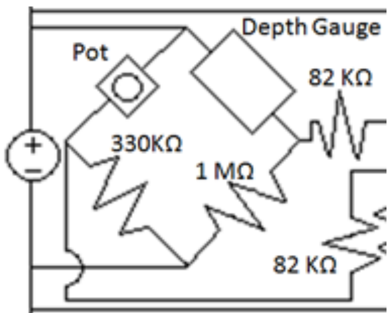


fig.3

A Wheatstone bridge is made by seperating two pairs of resistors forming a diamond shape (see fig. 3 and 4). The relation between the paired resistors will supply a unique voltage for the opposite corners of the Wheatstone bridge.

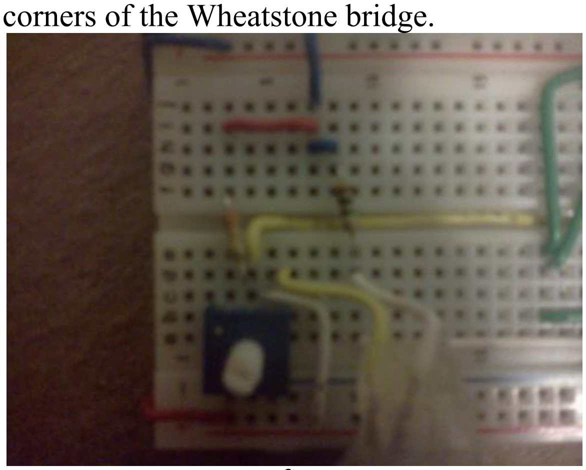


fig.4

Differential Amplifier

Relating the two voltages that are output from our Wheatstone bridge is an important step in DPSS's system. This is done in the differential amplifier which is a type of operational amplifier that "finds frequent use in situations where the difference between two signals needs to be amplified" (G. Rizzoni, et. al., 2007, p. 421). The equation for calculating the output from the differential amplifier is:

$$Vout = \frac{R2}{R1}(V1 - V2)$$

(R. Figliola, et. al., 2011, p. 233). Whereas the difference between the two voltages from the Wheatstone bridge is found and multiplied according to the resistor values (see Parts List) (see Appendix D). The output voltage is the data used to signal the Schmitt triggers to turn on or off.

Knowing the orientation of the chip when building a differential amplifier is extremely important (see fig. 5 and 6). If the chip is placed in the wrong direction, all the resistor, input, and output locations must be changed as well. The LF347 datasheet must

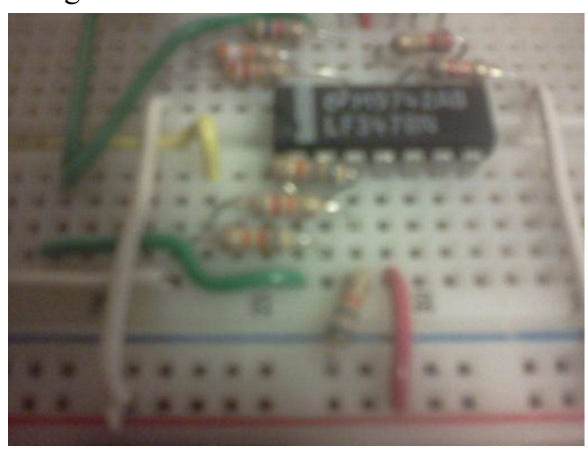


fig.5

be referenced often to make sure the components are placed with the correct prong of the chip (see Appendix B).

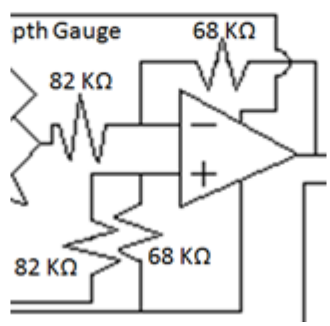


fig.6

Schmitt Trigger

The brain of the DPSS system is its series of Schmitt triggers. Like the differential amplifier, the Schmitt trigger's resistor value and orientation instruct it how to act (see Parts List) (see Appendix D) (See fig. 7, 8, and 9). They contain a voltage threshold that when crossed by the input voltage from the differential amplifier the Schmitt trigger changes from a digital output of 1 (on) to an output of 0 (off). The website random-science-tools.com provides a useful inverting Schmitt trigger calculator that was used to calculate the resistor values for the DPSS's Schmitt triggers.

The threshold of the DPSS's Schmitt triggers contains a different value from one another. This allows the corresponding LEDs to be turned off and on at different times. If both LEDs are on or off the DPSS is informing the pilot that the ROV is above or below the selected depth respectively. If only the red LED is on the selected depth has been reached and can be sustained.

fig.7 "Red LED Schmitt Trigger"

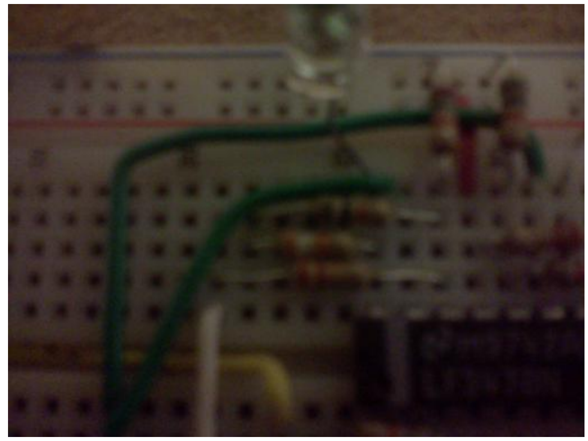


fig.8 "Green LED Schmitt Trigger"

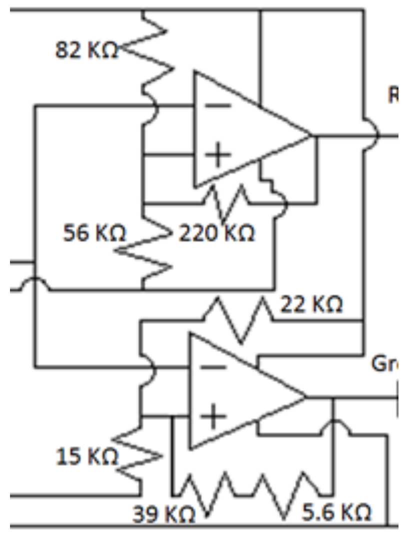


fig.9

Power Source

The DPSS uses a 9 volt battery as its power supply. This power source is used extensively throughout the circuit as it supplies power to the Wheatstone bridge, acts as the positive and negative source voltages for the LF347 chip, and supplies the voltage reference for the Schmitt triggers.

The positive power supply comes from the positive end of the battery. Likewise, the negative power supply comes from the negative end of the battery as well as ground. The orientations of the sources need to be correct so the circuit's components can be positioned correctly (see Appendix A: fig. 10 and 11).

Waterproofing

Every part of the DPSS needs to be contained in a water tight container except the depth gauge. A small slit, which will later be resealed, may be placed on the surface of the container allowing the depth gauge to reconnect with the circuit. The potentiometer was placed near the entrance of the container to allow a depth selection change without removing the DPSS from its container (see Appendix A: fig. 12).

Testing

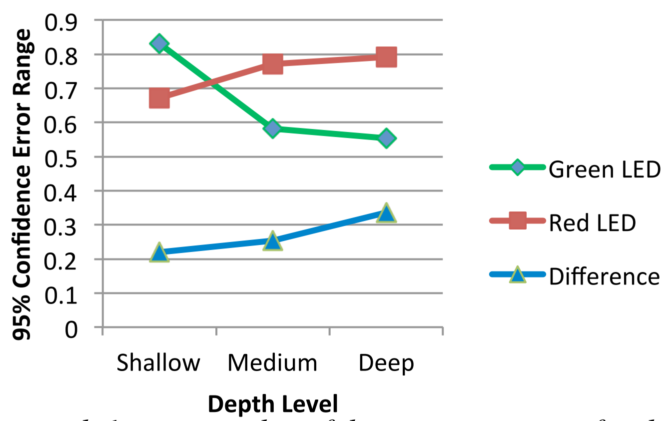
Testing jointly serves as a calibrating step for the DPSS. Every one built will have a level of variability one from another. This may be caused by how far the syringe was cut down, the tightness of the balloon, the variable values of the resistors, etc.

The tests performed for the project were conducted at three marked depth levels: shallow, medium, and deep, with three repetitions for each depth. The tests measured the depth at which the green and red LEDs turned off. A standard measuring tape, with an accuracy range of (1/16) inch, was used to calculate the depths. Each repetition was done in random order.

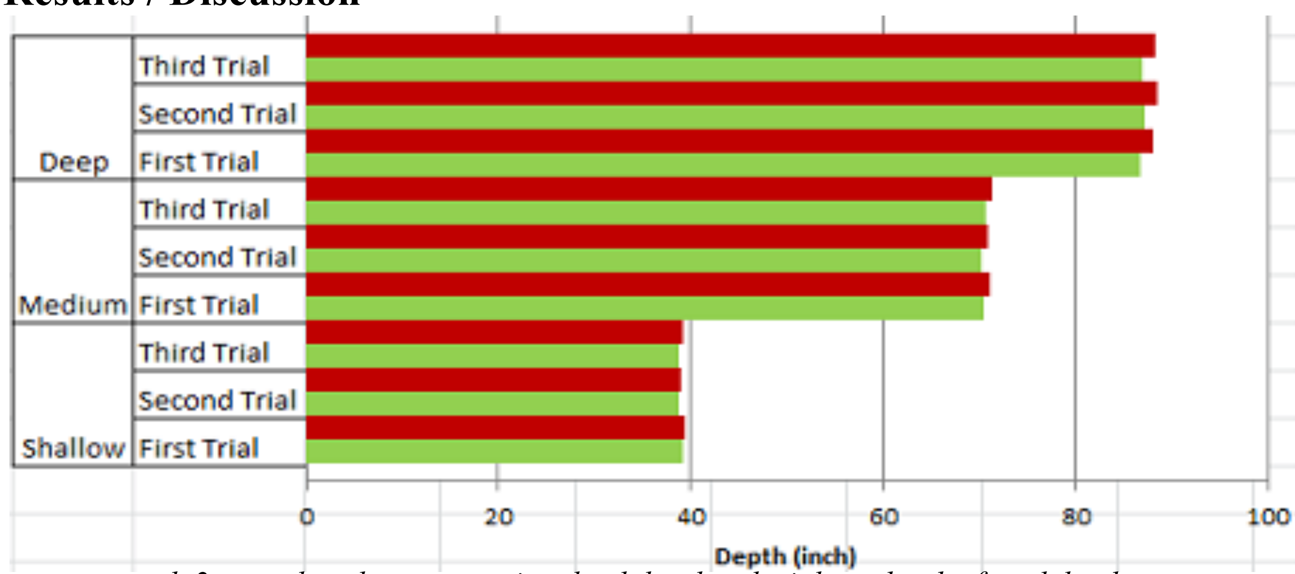
Results / Discussion

The results received from the test and calibration proved intriguing. It was previously hypothesized that the confidence error range would increase as the depth increased. This would signify an increase in the amount of error from the DPSS's measurements. However, as the depth increased, the confidence error range for the green LED decreased. This showed opposite results than what was hypothesized and found for the red LED and the difference (see graph 1).

The most important part of this test was to determine the standard deviation of the differences and its range of confidence



graph 1: compared confidence error ranges for the LEDs and their differences



graph 2: sample values comparing depth level and trial number by found depth

(see graph 1). The confidence error range for the difference increased, as hypothesized. The data shows a 95% confidence range of 0.21959 in. for the shallow level, 0.25356 in. for the medium level, and 0.33542 in. for the deep level. These measurements coincide with the difference's standard deviation of 0.05103 in. for shallow, 0.05893 in. for medium, and 0.07795 in. for deep.

The results obtained from calculating the 95% confidence error range shows an interesting phenomenon that occurs in the DPSS. While depth is increased most of the DPSS's systems loose accuracy and reliability; however, the green LED increases in accuracy at greater depths. Because the level of confidence of the differences decreases at greater depths the pilot cannot rely on the DPSS as well as at shallow depths. The increase of accuracy on the green LED may be used in these situations as a guide to compensate for the falling reliability of the difference.

Analyzing the standard deviation of the differences closer shows healthy results, however (see graph 2). Even though the accuracy of the differences does decrease at greater depths, it doesn't change rapidly. Even at the deepest depths the difference reading from the DPSS is small enough to provide sufficient results for the ROV's purposes.

Conclusion

The purpose of the Depth Perception and Sustainment System was to provide SeaPerch project participants with an inexpensive way to obtain depth readings from an underwater ROV so as to eliminate misconception of depth due to refraction of light on the surface of the water. It was also designed to serve as an introduction to electrical engineering concept and design, and to animate young students about the sciences.

This project was successful in creating a device that is self-reliant, it does not require outside devices to function; inexpensive, conservatively estimating a cost of less than $15 to build, and accurate, even at varying depths the device gives accurate approximations to selected depths sufficient for the ROVs purposes. As a "build it from scratch" project, it gives students hands-on as well as analytical experience, serving well as an introduction to a pursuit of engineering and science.