An Efficient Flood Basin Water Depth Sensor

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Abstract

An inexpensive yet efficient sensor package, designed to measure the depth of water in a flood basin over an extended period of time, was needed to replace the current units. The current units are not only very expensive, but are in danger of being lost during a heavy storm. They are also designed for a laptop to be brought into the field which creates another inconvenience and monetary risk. A budget was set at $200 and a sensor package consisting of pressure sensors and temperature sensors was built to be used with a HOBO type data logger to facilitate this need. A durable and weather proof enclosure will be designed to house the sensor package and HOBO logger.

Theory

By measuring pressure under water one can measure the depth of the water itself. It is relatively simple and straight forward to do so. Using:

$$p = p_o + \rho g h$$

Where p is the pressure measured, p_o is the atmospheric pressure, ρ is the density of water, g is the acceleration due to gravity and h is the depth below the surface of the water. It was determined that the simplest method to measure the pressure was to attach tubing to a pressure sensor, which was part of an electronic circuit package, and drop the tubing into the water, keeping the open end at the bottom of the water. This presented a problem however. The air within the tubing, being a gas was compressible. As the water depth increased, this caused a proportional amount of water to enter the tubing itself, leading to an inaccurate depth measurement.

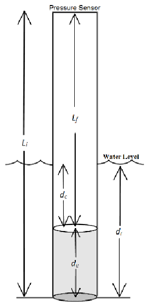

Figure 1.

Examining Figure 1. Where d_e is the amount of water that has entered the tube, d_c is the length of tubing below the surface of the water and not containing water, d_r is the actual depth of the water and L_i is the entire length of the tubing. Making the appropriate substitutions one finds:

$$p_f = p_o + \rho g\left(d_r - (L_i - L_f)\right)$$

Some further rearranging yields the final equation for the corrected water depth as a function of measured pressure:

$$d_r = \frac{p_f - p_o}{\rho g} + \left(L_i - \frac{p_o L_i}{p_f}\right)$$

Where d_r is the actual depth, p_f is the measured pressure and L_i is the length of the tubing

Experimental Design

For this design, a setup that was small and simple was needed. It also needed to be inexpensive and conveniently designed. It was decided that the most convenient method to log data would be to have a design that is set up to automatically acquire data and store it on some removable storage device, such as a memory stick, in order to alleviate the necessity of bringing a laptop into the field. Because of this, it was decided to build a sensor package that would work with a HOBO data logger made by Onset Computer Corporation. The sensor package could then be left in the field, while the data logger could be exchanged in order to extract data. This design also allows convenience for the user in that a wide array of sensor packages can be designed and used with the same data loggers.

For this particular experiment it was decided to include a pressure senor and a temperature sensor. Both the temperature sensor and pressure sensor chosen were designed to have a varying output voltage based on the temperature and pressure each sensor is respectively submersed in. The data logger used could log data between 0 and 2.5volts. The initial output voltages on the temperature sensor and pressure sensor fell outside this range. To accommodate this, a voltage divider was applied to the temperature sensor, and an amplifier was applied to the pressure sensor.

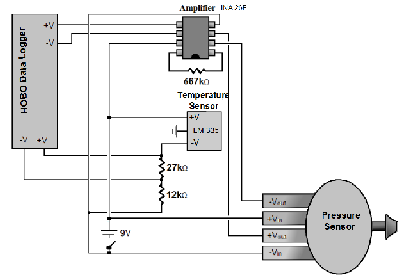

Figure 2. Sensor Package Circuit Diagram

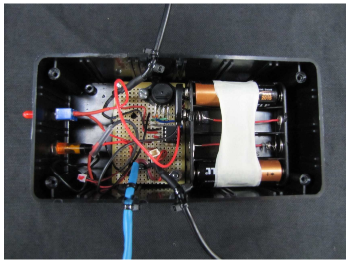

Figure 3. Sensor Package Assembly

Calibration

To calibrate the temperature sensor in this system the sensor was submersed in ice water while the temperature of the water was raised to near boiling. Simultaneously a thermocouple was used to record temperature, while the voltage was being recorded from the temperature sensor. A linear fit was done on the data and thus an equation developed to relate voltage to temperature. This was done several times throughout the building of the sensor package for quality assurance. Calibrating the pressure sensor was slightly more involved. To do so, a tube of known length, was attached to the sensor. The open end was inserted into an open volume of water. The tube was lowered into the water in measured increments while simultaneously measuring the varying voltage of the pressure sensor. Using the previously developed equation the pressure was calculated. This was then compared to the theoretical pressure for the given depths

Future Plans

Future plans include the implementation of a timed relay switch to help manage power consumption of the system. A sturdy, weatherproof enclosure will need to be designed to contain the system while it is deployed in the field. Also for consideration, is developing multiple sensor packages to collect a variety of data types.

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