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In Situ Temperature And Depth Observations For Ocean Monitoring

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ABSTRACT

In the marine field, the observation of the ocean environment is a vital job. For that, three main parameters are necessarily needed; Temperature, Depth and Conductivity measurements are significant for ocean observation.These measurements are obtained by sensors. In order to arrange this device in large numbers, an inexpensive version is needed; especially if it is used as an expendable system.These kinds of devices are most important for research related in the oceanographic field and it should be reliable and precise; mainly in the underwater applications. These measurements can be found in every marine and its related institute, and since they are used to produce the salinity profile for the area of the ocean under examination.These kinds of devices are most important for any study or research being done on the ocean. This paper describes about the integration of electronic devices attached and development of device and the testing results also showed.The unit observes the tailor-made readings from the onsite and send through zigbee protocol and values are used for ocean monitoring and can be stored for future reference. The future work of this paper work is designing the conductivity cell and integrating all three sensors as a single PCB and the design can be optimistic by choosing of the electronic components used.

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INTRODUCTION

The CTD (Conductivity, Temperature and Depth) observes the onsite salinity and temperature at a specific depth. This information is a key part in understanding deep ocean currents and the ocean's acoustical properties. Salinity provides the reliable measurements related to deep sea currents is important to oceanographers. Salinity measurements provide relevant information to all fundamental fields of oceanography including chemical, biological, physical and geological. The cost of the standard CTD instruments (Brown, N., 1994), whether expendable or not, is veryexcessive in terms of cost. In turn to setup large numbers of CTD sensors, an inexpensive version is needed, especially if used as an expendable system.

Salinity is one of the primary measurements to be determined by oceanographers when analyzing a sample of seawater. The salinity profile is important because it gives onsite varying water densities in the ocean. By determining salinity, oceanographers can calculate other important properties of seawater, such as density, conservative element concentrations.

In General, CTDs are very large in size (refer Fig1) and also very expensive, and are connected to a support vehicle, usually a boat lowering it down into the water. Albeit, it can also be smaller like it is used in a glider, but unlike their size, their cost increases for smaller versions. So because of their price, CTDs are not used in smaller versions. While these were designed to be throwing away (Downing, J., 1992), the cost of these CTDs prevent them from being used with most oceanographic expeditions, whose budgets are tight and cannot spare the cost of a single use CTD.

Oceanography:

Oceanography is the study of the deep sea and shallow coastal oceans. The field’s like biology, chemistry, geology and physics together make oceanography a richly interdisciplinary science (Garrison, T., 1998). The CTD plays a significant role in the oceanographic field. With the help of CTD measurements the ocean environment is

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continuously monitored. In order to cover the vast area of the ocean, more number of CTDs is required. To deploy large number of CTDs a low cost version is needed.

Fig. 1: Conductivity, Temperature and Depth.

CTD's:

Generally CTDs are used by the scientists, to get the salinity profile of a water column in the ocean. These sensors give scientists explicit and inclusive values and variation of water temperature, salinity, and density that helps and understand how the oceans affect both marine and outside life of the ocean. These measurements help the oceanographers to study the ocean properties and clear how the variations in density affect the acoustical properties of the water. In General, CTDs are large, expensive, and are attached to a support vehicle i.e., the CTD is lowered down from the boat into the water column of the ocean, and descends to the ocean. However, CTDs can be small e.g., the CTD units used in aglider. Their size decreases when it is attached to the above mentioned vehicles. Consequently, due to their price CTDs are not usually one-time used system.

The main sensors that make a standard CTD package include temperature sensor, pressure sensor and a conductivity unit.The temperature sensor provides measurements at the instrument's onsite location in the water column of the ocean. The pressure sensor of course measures pressure,which is a function of depth. The conductivity unit measures conductance, which is the amount of electrical current that can pass through the water. With the help of the readings observed from the above sensors salinity profile of the ocean can be calculated; with a few calculations and input from the temperature probe, salinity is determined. So, obviously as the instrument is lowered into the water column it observes readings using the different sensors used and with the on the ship calculations and data processing it provides temperature and salinity readings.

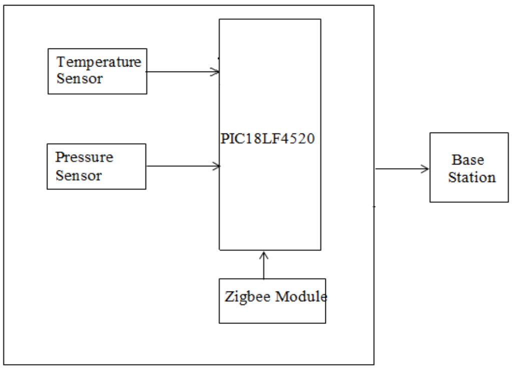

Fig. 2: Block diagram.

The block diagram (refer Fig2) describes clearly the modules presented in the CTD. The base station in the aboverefers either thesupporting vehicle or the base station presented in the sea shore. In most of the cases, the data observed from the sensors are sent to the supporting vehicle via the communication protocol such as zigbee.

Salinity Profile:

Salinity provides the measurement of the amount of salt by mass, to a unit mass of seawater. Oceanographers and researchers are also interested in the salinity of the ocean, because along with water temperature, it determines the density of the ocean water. The salinity profiles give a snapshot of the density variations in the ocean in and around the location, and those profiles are important to the oceanographers because as the ocean water cools or the salinity increases the ocean water turn into either more or less in density. The change in water density drives the ocean circulation at greater depths then wind driven circulation near the surface. These profiles are extremely important aspect in understanding the ocean so oceanographers in the science community all use these measurements in great quantities. By keeping track of the ocean's surface salinity/density, scientists can monitor the fluctuations in the water cycle and get a better understanding of how the ocean interacts with various environments on a global scale.

To measure salinity, there are a few calculations that must be done using the following equations provided by Bibby Scientific (Jenway, 2013). First of all, a probe with a set cell constant K will have to be known, K can be calculated by dividing the Distance between the probes D by the Surface Area of the Probes

A: $K = D/A$ (1)

And by passing a current and voltage with known value across the probe while submerged in the salt water a conductance reading can be measured in units of Siemens (S').

To get Conductance G, the current I is divided by the noted voltage

V: $G = I/V$ (2)

With the known conductance and the probe cell constant noted, conductivity C can be calculated by dividing the conductance by the probe cell constant

K: $C = G(K)$ (3)

Once conductivity is calculated it will then need to be converted into Resistivity R, which is the reciprocal of conductivity C.

$R = 1/C$ (4)

Now with the help of resistivity value, temperature reading and salinity S can be calculated by using the Practical Salinity Scale (Edward Lewis, E., 1980) of 1978 (PSS) equation discussed by Edward Lewis. It requires a temperature reading along with the unity k of the CTD instrument (Inexpensive Expendable Conductivity Temperature and Depth, 2013). The unity can be determined by taking the conductivity value of a known solution and comparing it to the conductivity reading of that solution. With the combination of those variables and a few given constants, the Practical Salinity Scale (PSS) equation (5) can be calculated.

$$S = a0 + a1R^{1/2}_T + a2R_T + a3R^{3/2}_T + a4R^2_T + a5R^{5/2}_T + \frac{(T - 15)}{1 + k(T - 15)} (+b0 + b1R^{1/2}_T + b2R_T + b3R^{3/2}_T + b4R^2_T + b5R^{5/2}_T) \quad (5)$$

Where:

a0 = 0.0080 b0 = 0.0005
a1 = -0.1692 b1 = -0.0056
a2 = 25.3851 b2 = -0.0066
a3 = 14.0941 b3 = -0.0375
a4 = -7.0261 b4 = 0.0636
a5 = 2.7081 b5 = -0.0144

k is the cell constant

1. Saltwater should be 10,
2. Fresh water 0.1 cell constant and
3. Brackish water 1

$R_T$and T are the resistance and the temperature of the water sample.

Equation 5 is valid for temperatures between -2^0C and 35^0C and salinity between 2 and 42. Albeit, this equation is good enough for a wide salinity range, the probe which is measuring the conductivity of the sea water must have the appropriate cell constant. Since most of the times we used to check the salinity in salt water only. So the cell constant used be k=10 as constant.

Ctd Types:

CTDs is classified into several types, in that we are concentrating in the casting CTD and the expendable CTD (XCTD)s (Moored profiler, 2013). CTD casting methods include ship assisted casting/manual casting and remote sensing. Ship assisted casts are when manual input is needed to complete a CTD cast (the lowering and raising of the CTD through the water column). For remote sensing, the operation of the CTD is completed through an AUV, Remotely Operated Vehicle (ROV), or glider without the assistance or presence of the scientist.

A. Ship Casting:

Ship assisted CTDs are mostly very large. For analysis (refer Fig3), the data are sent back to the base station or support vehicle either by means of a communication cable or logged on a memory chip used to store the data observed by the sensors and a cable is required to be plugged into the unit in order to download the measurements. If a communications cable is used, scientists can observe the water and its acoustical properties in real time. A standard CTD (Sea-Bird Electronics, 2013) cast, depending on water depth and its density level; usually it requires a couple of hours to collect a complete and sample set of data.

B. XCTD:

The ship casting also, can be re-used, but it requires human resource starting from dropping till retrieving the data. But in this type once the CTD is dropped by UUV (Unmanned Underwater Vehicle) or any supporting or aerial vehicle (Aerial Unmanned Vehicle) the position and the path is automatically set by the defined algorithm. Once the floating unit (refer Fig4) is dropped from the vehicle the unit uses the mechanism and descends to the water surface by making negative buoyancy by means of flooding the air chamber or by means of connected load that depends on the design of the floating unit. Till now the weight anchored to the unit is popular and the water flooding is pretty expensive.

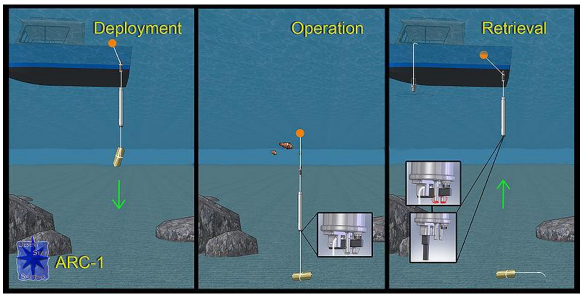

Fig. 3: Ship casting.

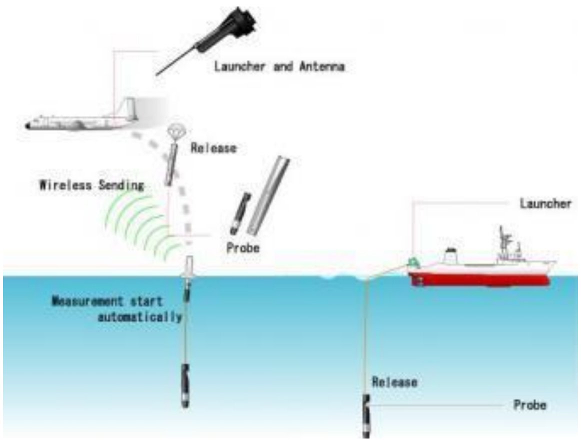

Fig. 4: XCTD.

System Electronic Integration:

The floating unit contains the following electronic units: Temperature and Depth sensor, zigbeeand controller. Each one plays a significant role in the operation of the unit. The CTD system assesses the water samples [11], and is the primary system component of the device. The communications system allows the data to be discharged and it is unshipped; but as a backup, a micro SD card is on the ship to store all data in case of communication letdown. Finally, the controller of the device is a PIC16F877A microchip.

A. ***Temperature and Depth:***

The temperature sensor designed was a linear resistive temperature device. The Pt100-sensor (refer Fig5) is used for precise temperature monitoring applications, where errors in measurement are omitted. The direct tie up between the resistor and temperature, elucidates its role in many electronic applications. The electrical resistance of the conductor at any temperature can be calculated by using the formula:

$$R_t = R_r\,(1 + \alpha\,(T-T_r)) \qquad (6)$$

Where:
R_t = Electrical resistance
T_r = reference temperature
R_r = resistance of conductor at T_r
α = temperature coefficient at T_r

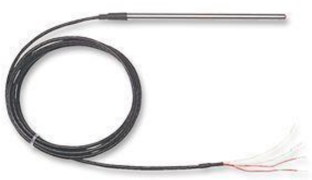

Fig. 5: Pt100.

The MBS3000 (refer Fig6) OEM pressure transducer / transmitter remain the most popular configuration. With its fused stainless steel covering and various electrical connections, the MBS3000 can be packaged for virtually any OEM pressure transducer application.

Fig. 6: MBS3000.

B. Communications:

The communication system of CTD Unit is used for the transmission of the observed data to be unshipped to the supporting vehicle or base station. For that it uses zigbee Protocol and it gives a data transfer range of about one hundred and twenty meters line of sight, which was the problem with this communications system. To retrieve any data the receiver has to be located fairly close as the data transfer range is rather optimistic. Once the data is unpacked the CTD start its cycle once again.

C. Controller:

The controller system uses a PIC16F877A chip from Microchip to control the unit's functions. PIC16F877A is an 8-bit microcontroller. In this application it controls when the sensors like temperature and pressure are switched on and off. It controls and interacts with all the systems connected to it.

RESULTS AND CONCLUSIONS

The interface of the temperature and depth sensor with the microcontroller and the communication via zigbee is shown below (Fig7). The unit is examined under different test conditions and the result (Fig8,9) is successfully obtained.

LabVIEW is used as user interface to the oceanographers to visualize the data and load the unshipped values and it is stored for the future reference. Proteus (procedural programming language) is used for circuit design and verification.

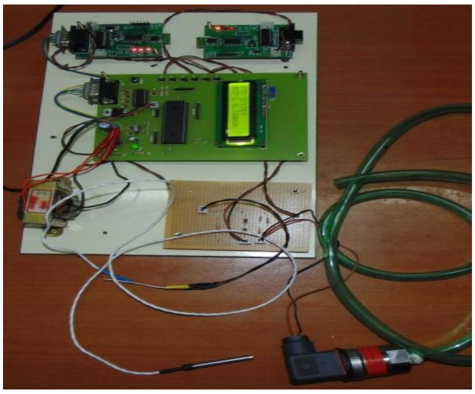

Fig. 7: Sensorsinterfacing with microcontroller.

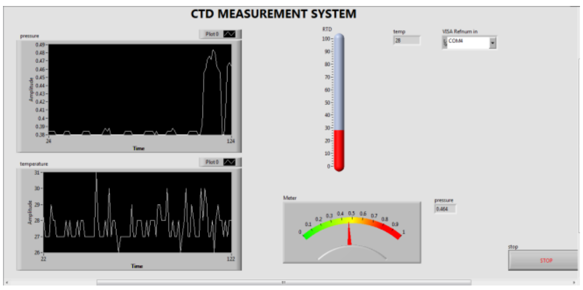

Fig. 8: LabVIEW simulation 1.

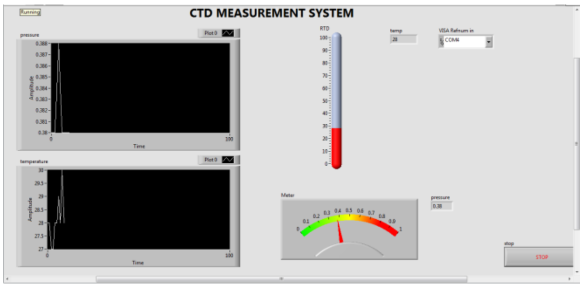

Fig. 9: LabVIEW simulation 2.

The unit observes the tailor-made readings from the onsite and send through zigbee protocol and values are used for ocean monitoring and can be stored for future reference.

The future work of this paper work is designing the conductivity cell and integrating all three sensors as a single PCB and the design can be optimistic by choosing of the electronic components used.

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