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RESEARCH ARTICLE

AQUATIC ECOSYSTEM MONITORING REMOTE VEHICLE.

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Abstract

This paper reports the Underwater Vehicles for Surveillance and Monitoring Aquatic Ecosystem. The acceptable range of pH for aqua environment is between pH 6.0 to pH 8.0. Different problems associated with aquatic ecosystem due to water pollution are increasing pH and temperature due to global warming and decrease of dissolved oxygen. This is endangering the various aquatic species. Besides this, water becomes unusable for drinking, farming and for general work. So a microcontroller based un-manned vehicle for monitoring the water purity parameters viz.; pH and temperature using wireless communication is presented here. It has a aqua monitoring unit which continuously monitors the purity of water and sends an alarm to the central monitoring unit in case the water turns abnormal acidic/alkaline and gives an information on speed of wind, floating debris, possibility on earth quake through earthquake signals sensed in water etc. This helps for ensuring the safety of aquaculture as well as human being.

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Introduction:-

The ocean occupies approximately 71% of the earth surface and still has a lot of unexplored parts. Therefore, various studies and development about the ocean such as marine environment, earthquake, ocean life, and marine resources research and so on are carried out. Plenty of survey data and observation of the actual sea is available for the studies and the development. Remotely operated vehicle can play an important role in monitoring, protecting and maintaining the aquatic ecosystem which is polluted by waste chemicals from factories, oil spilling in oceans, accidents caused due to ships etc. Hence there is a need of a low cost, highly efficient underwater vehicle which can serve multiple applications. Indian aquaculture is facing a number of problems today. Indian shrimp production went low to 2% of total world shrimp production and contributed to an export of 1730 million dollars in 2009. There are several reasons for such a low production. The acceptable range of pH for aqua environment is in the range of pH 6.0 to pH 8.0. When pH of water is above 9, then it is very alkaline, then ammonium in water is converted to toxic ammonia, which is dangerous to survival of shrimps. On the other hand, pH of water below 5 makes it acidic water which leeches metals from rocks and sediments. The correct pH, alkalinity and hardness are essential for a successful aqua life where fertilizers containing nitrogen, phosphorous and potassium are added to encourage the growth of aqua culture.

Anuradha A. Maindalkar, Saniya M. Ansari designed an instrumentation for underwater vehicle using a wireless module, and software for real-time in-field sensing and control of a site-specific precision system. The conceptual

layout is useful for the transmission and reception of information through wireless module [1]. A low Cost Remote Controlled Underwater Rover is useful for studying the underwater life and all the underwater activities to learn about the underwater life[2]. In paper by G. Divya Priya and Mr.I. Harish describes an application of a wireless module and Raspberry Pi for low-cost wireless controlled underwater vehicle that removes the need for workmanship for monitoring water resources for its pollution. The Arduino an Embedded Computing platform, uses the hardware and software that can interact with it's environment [3]. Koushik Reddy, et al. have reported the details about Dissolved Oxygen sensor, PH sensor, Ultra Sonic Sensor etc. which are connected to a base device called Arduino Board. The device automated using the internet. The conceptual layout is useful for the design of aquatic ecosystem monitoring vehicle [4]. Underwater Remotely Operated Vehicle (ROV) for a shallow water environment (up to 10m depth) was developed using Fuzzy Logic motion control and electronic power control. The main controlling unit of the electronics is a Raspberry pi microcomputer operates the video. Very satisfactory operation were observed for test trials of the ROV conducted in a laboratory water tank to a depth of about 1.5 m[5]. An autonomous underwater vehicle (AUV) an interdisciplinary coastal research was deployed to collect chlorophyll fluorescence, optical backscattering (880nm), and physical data. It sampled the region to quantify various features in both physical and bio-optical properties in the Bays[6].

Based on the literature survey, we aim to develop & implement aquatic ecosystem monitoring system for aqua culture of shrimps by monitoring the water purity parameters such as pH, and temperature of water using wireless communication for ensuring the safety for aquaculture as well as human being.

Methodology:-

A. Block Diagram of Aquatic System

Figure 1 shows the block diagram of our project. This figure gives the requirement of the system i.e. microcontroller block, LCD, sensors, battery bank and mechanical arrangement.

The block diagram of our project consists of mainly two parts, viz., Part-1 consists of central monitoring unit and Part-II Atmega based aqua monitoring unit is as shown in Figure 1. Different subblocks of the system are as follows, a) Arduino with ATmega 328. 2)Temperature sensor, 3)pH sensor, 4)Wind speed sensor, 5)Vibration sensor, 6)Ultrasonic sensor, 7)LCD display, 8)Zigbee Module, 9)DC motor and mechanical assembly , 10)Battery bank.

1) ATmega 328 microcontroller:

The purpose behind the selection of ATmega 328 microcontroller is that it is very simple to use and very powerful device. It has in built ADC section, 8 and 16 bit timer section, watch dog timer, Low voltage programming and PWM control.[7].

2) Temperature sensor: Temperature sensor DS18B20 is used to detect temperature of water resource. It is a smart digital temperature sensor which gives 12 bit digital output with resolution of 0.069v/0C. It works at low voltage and gives precise temperature values.

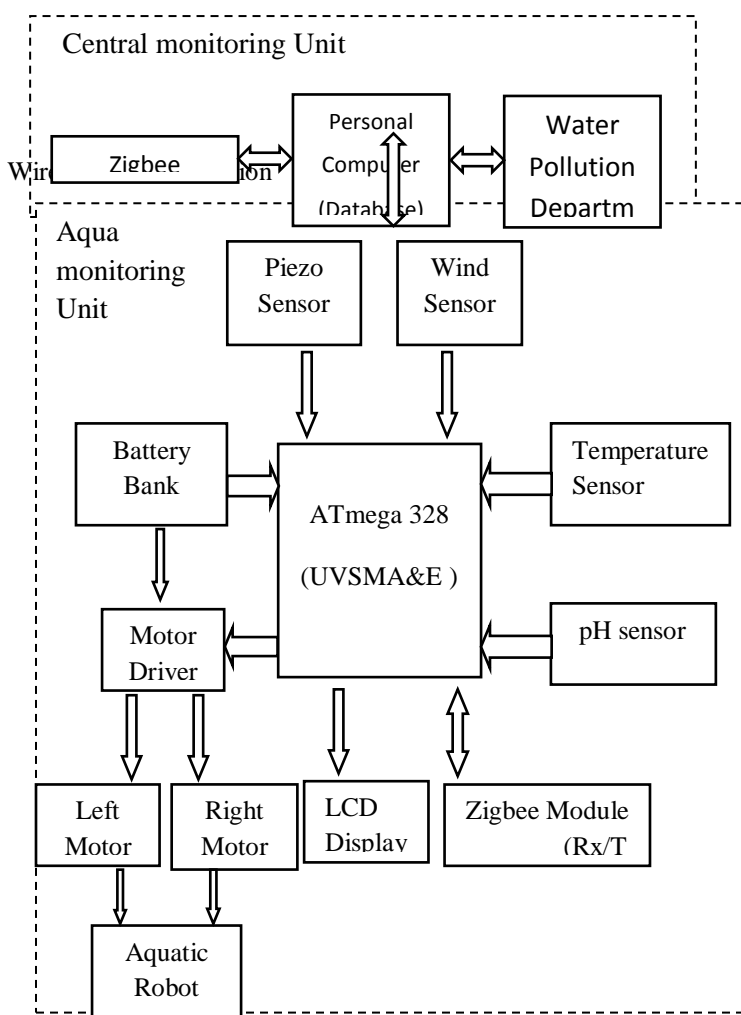


Figure (1):- Block diagram of implemented system

3) *pH sensor*: pH sensor is used indicate the acidity/alkalinity of a water resource. CSL 31 is an analog sensor with glass body, refillable, ceramic diaphragm pH electrode with low noise co-axial cable.

4) *Wind speed sensor*: Wind speed sensor used in this project is a 5V DC voltage which generates dc voltage in accordance with wind speed. By using a standard formula we can calculate the speed of air.

5) *Vibration sensor*: Vibration sensor based on Piezo-electric principle is used to detect the turbulence of water resource. It produces voltage proportional to the vibration present around the aquatic vehicle.

6) *Ultrasonic sensor*: Ultrasonic sensor is used to detect the obstacles coming in front of AEMV which produces a trigger pulse and echo pulse to detect the obstacle. If the obstacle is too close to AEMV, then AEMV gets automatically reversed.

7) *LCD display*: LCD is used to display the measured values of temperature and pH of water with the help of 16X2 LC.

8) *Zigbee Module*: Aquatic signals monitored by AEMV are sent to central unit to using wireless control. Hence, Zigbee module CC2500 is used as the wireless transmission and reception of data.

9) *DC motor and mechanical assembly*: DC motors operating at 12 volts are used for the movements of AEMV such as forward, backward and left, right movements. Also we require geared DC motors along with appropriate DC driver IC i.e. L293D. Also some mechanical arrangement is used for the movements.

A. System Requirement

1) In this, arduino development board is used to dump the aqua monitor code in the IC ATmega328. Components used for AEMV are tabulated in Table I.

- i. *DC motor* : DC motor with operating voltage of 12.0VDC output, Speed of 30 +/- 10% RPM, No-Load output current is less than 50 mA, Rotation Output has noiseless Gear with clockwise and counterclockwise motion. and No-Load Speed of 5700 RPM & No-Load Current of 30Ma
- ii. *Motor driver IC L293D*: As arduino328 is a low power device, driver IC, The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages in the range of 4.5 V to 36 V. All inputs are TTL compatible. A high enable input enables the associated drivers and make their outputs are active and in phase with their inputs.

Table 1:- List of Components used for UVSMA&E

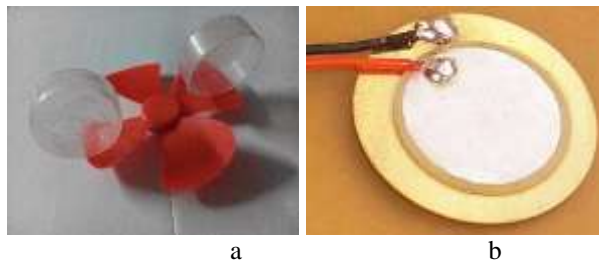
Sr. No.	Name of component	Basic Feature
1	Arduino328 microcontroller	8bit controller with low power operation
2	Power supply IC7805	Constant voltage regulator
3	DC motor	Geared 12V DC motor
4	Motor driver IC L293D	Quadruple high current H drivers
5	Temperature sensor DS18B20	12 bit digital thermometer
6	pH sensor CSL31	glass body, ceramic diaphragm pH electrode
7	Wind sensor	5V DC motor
8	Vibration sensor	Analog Piezo-electric sensor
9	Zigbee module	2.4 GHz Transceiver
10	LCD Display	16X2 LCD display in 4Bit mode
11	Battery	4V ,1A batteries
12	Ultrasonic Sensor	Echolocation sensor

- iii. *Temperature sensor*: A water resistant temperature sensor which gives precise temperature readings at low power supply digital sensor, DS18B20 which is very accurate and operates at 5V supply voltage. The digital thermometer (DS18B20) has 9-bit to 12-bit Celsius temperature measurements and has an alarm function with non volatile user programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus for communication with a central microprocessor. For water resistance feature this sensor is enclosed in steel bar[10].
- iv. *Power Supply Range*: 3.0V to 5.5V ,Temperatures Range: -55°C to +125°C (-67°F to +257°F) , ±0.5°C Accuracy from -10°C to +85°C , Thermometer Resolution is User Selectable from 9 to 12 Bits, Converts Temperature to 12-Bit Digital Word in 750ms (Max)
- v. *pH sensor Operating Temperature*: 0°C to 100°C Response Time: <10 seconds for 95% response from 7 pH to pH 4.01, has a Glass Membrane Impedance of 200 M, sustain Pressure: Upto 87 psi, and measure pH range: 0 to 14.00 pH[10].
- vi. *Wind speed sensor*: For the constant flow of water, it is required to have constant air flow surround water resource. To detect the wind speed, a 5V dc motor with turbines is used. Whenever the air flow appears across turbines, turbines starts rotating and creating a dc voltage. This voltage value is taken as input and by using a standard formula in (1) the wind speed in meter/seconds is computed. The formula used to derive wind speed is as follows.

$$\text{SensorVoltage} = \text{SensorValue} * \text{VoltageConversionConstant} \quad (1)$$

$$\text{windspeed} = (\text{sensorVoltage} * 10) / (2.223694) \quad (2)$$

$$\text{Where, voltageConversionConstant} = 0.004882814 \quad (3)$$

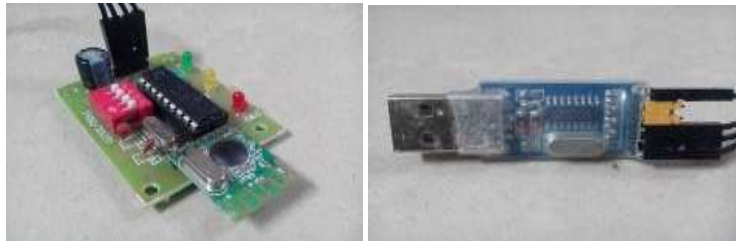


Figure(2):- a) Wind Speed Sensor b) Vibration sensor



Figure(3):- Ultrasonic Sensor

- vii. *Vibration sensor*: As the epicentre of maximum earthquakes are in water resources, so a vibration sensor has been used to detect sudden change in water turbulence. AEMV will be rerouted and it will sink in water. A piezo-electric sensor is used to detect the turbulence which is simple and has high sensitivity.
- viii. *Ultrasonic distance sensor* : Invento INVNT_8 Ultrasonic Module Hc Sr04 is a precise, non-contact distance measurements from about 2 cm to 3 meters. It requires only two I/O pins of Propeller chip, or Arduino. This sensor transmits a burst in the form of an output pulse that corresponds to the time required for the burst echo to return to the sensor. Measurement of the echo pulse width, helps to compute the distance to target. Specifications are as further.[11]
 - Ultrasonic Range is from 2 cm to 3 m, has a burst indicator LED to show sensor activity.
 - It has a bidirectional TTL pulse interface on a two I/O pins can communicate with 5 V TTL or 3.3 V CMOS microcontrollers.
 - Input trigger is a positive TTL pulse of 2 μ s minimum typ
 - Echo pulse is a positive TTL pulse, with 10 μ s to 18.5 ms.
 - Supply voltage requires +5V DC Voltage and Supply current: 30 mA typ & 35 mA maximum.
 - Communication uses Positive TTL pulse.
- ix. *RF Transceiver CC2500*: A transceiver CC2500, a low-cost, 2.4 GHz transceiver designed for very low-power wireless applications is used in this project[10]. The circuit is intended for the 2400-2483.5 MHz Industrial, Scientific and Medical(ISM) and Short Range Device(SRD) frequency band. The RF transceiver is integrated with a highly configurable baseband modem CH341SER. The modem supports various modulation formats and has a configurable data rate up to 500 kBaud. The main operating parameters and the 64-byte transmit/receive FIFOs of CC2500 can be controlled via an SPI interface. [10]



Figure(4):- RF Transceiver CC2500

- Has a Frequency range : 2400 – 2483.5 MHz
 - High sensitivity of 104 dBm at 2.4 kBaud, 1% packet error rate.
 - Low current consumption of the order of 13.3 mA in RX, 250 kBaud, input well above sensitivity limit.
 - It has a Programmable output power up to +1 dBm and excellent receiver selectivity and blocking performance with Programmable data rate from 1.2 to 500 kBaud.
 - Small size (QLP 4x4 mm package, 20 pins) Supports for asynchronous and synchronous serial receive/transmit mode for backwards compatibility with existing radio communication protocols.
 - Takes only 400 nA SLEEP mode current consumption with fast startup time of 240 μ s from SLEEP to RX or TX mode
 - Wake-on-radio functionality for automatic low-power RX polling
 - It has a Separate 64-byte rx and tx data fifos
- **Battery**: A power supply of 12V, 1A is designed to drive i)the motor which needs 600mA current and ii)to drive the wireless module CC2500 which needs 20mA current and iii) for different sensors. Hence, rechargeable Li-ion batteries of 4V and 1A in series to provide a supply of 16V, 1A is used here.

System implementation:-

A. Hardware Implementation:

In this project ATmega328 microcontroller, temperature sensor, pH sensor, wind speed sensor, piezoelectric sensor and 16X2 LCD for displaying different parameters are used.

1) Selection of ATmega328 pins for peripheral interfacing

Table II gives the detail of the port pins of ATmega328 controller used for interfacing the peripherals such as ADC, LCD, Motor driver, sensors etc. The component used, port pins of Arduino, for interfacing various pins of components are tabulated in Table II. Total of 18 port pins of processor are used for this purpose.

TABLE II:- Details of Interfacing to ATMEGA328

Port Pin	Function	Component	Component Pin
18	Port B pin used as general I/O	LCD	RS
17			EN
11,6,5,4			D0-D3
26	Port C pin as Analog I/P	Piezo sensor	-
25	Port C pin as Analog I/P	Wind sensor	-
24	Port C pin as Analog I/P	pH sensor	-
28,27	Port C pin as general I/O	L293D	Motor(In)
16,15	Port D pin as general I/O	L293D	Motor(In)
12		Temp. sensor	D0
2	Port B pin as general I/O	Zigbee module	Rx
3	Port B pin as general I/O	Zigbee module	Tx
13	Port B pin used as general I/O	Ultrasonic sensor	Echo pin
14			Trigger pin

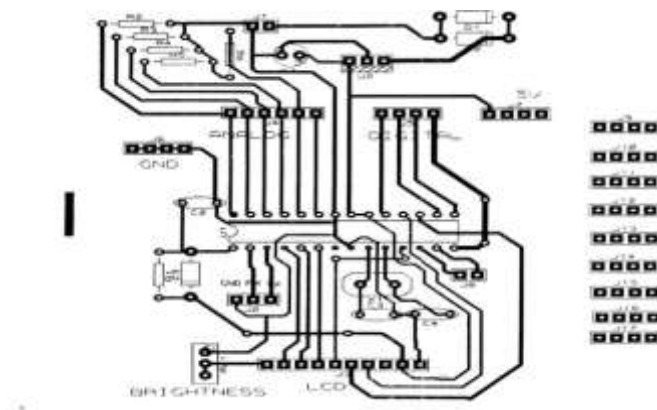
Wi-Fi module CC2500 a wireless transceiver help to transmit the parameters of water pH, temperature. Wind sensor measured by ATMEGA328 from DS18B220, CSL 31 sensors respectively to the controller of AEMV. According to these values status of aqua water is detected by AEMV.

IC L293D is used to drive the DC motor.[9] A 5V supply is directly used as Enable input for the Driver IC. Also we have used pins 15, 16, A5 and A4 to control the backward and forward motion of DC motors. The purpose of these technique is to control the movement of AEMV.

A 16X2 LCD display in 4 bit mode is used to display the status of temperature and pH sensor and wind speed. Data lines of LCD from D0-D3 are connected to the port pins 11,6,5,4 respectively. Pin no. 17 is used for Enable input of LCD. And RS is given to pin no. 18 of ATmega 328.

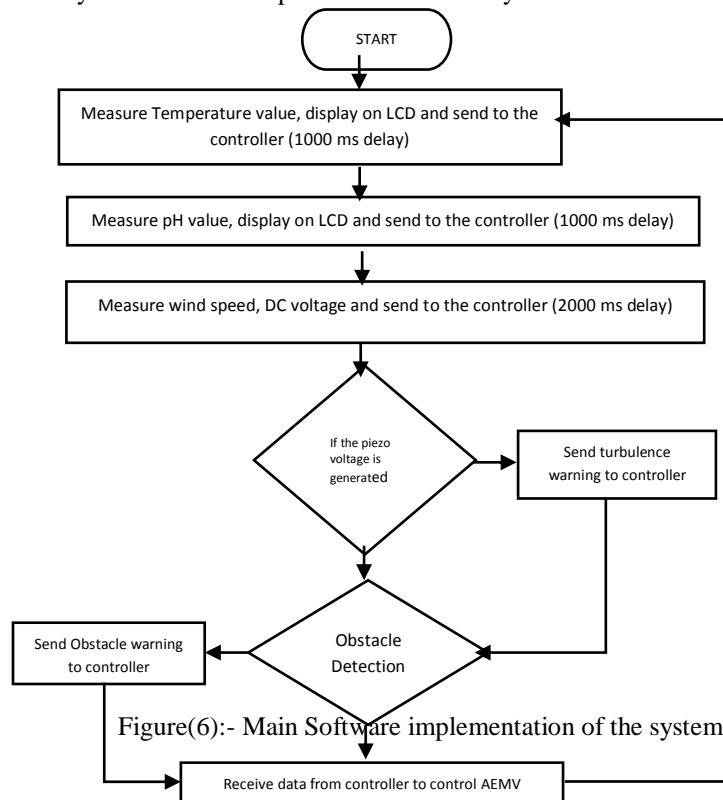
Another important concept of our project is obstacle avoidance coming in the way of AEMV. Echo pin and trigger pin is connected to 13 and 14 pin of ATmega 328 microcontroller respectively. Whenever an obstacle comes at a distance of 2 feet's the microcontroller sends a warning to the controller of AEMV and if the vehicle is too close to obstacle at distance minimum than 20cm AEMV automatically starts move in backward direction for 5 seconds and alert the operator to change the direction of AEMV, which gives enough distance to the AEMV to avoid the obstacle.

PCB Design of the implemented Circuit



Figure(5):- Circuit diagram of Arduino PCBS**B. System Software design and Implementation:**

Main Flow chart of overall system Software implementation of the system is as shown in the flow chart of figure 6.

**Figure(6):-** Main Software implementation of the system

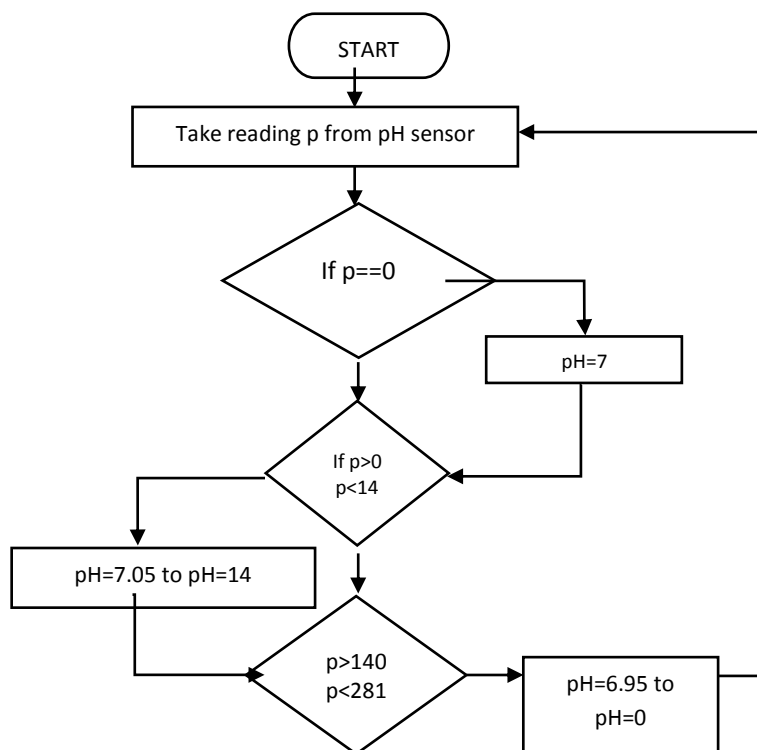
Flowchart consists of three sub routines as stated further.

- a. Sub routine for pH sensor.
- b. Sub routine for Piezo-electric sensor.
- c. Sub routine for Ultrasonic sensor.

Aquatic ecosystem monitoring vehicle starts its operation by taking the readings from temperature pH of water, and voltage corresponding to wind speed sequentially. These measured value are displayed on 16x2 LCD and then transmitted to AEMV controller via wireless module CC2500. The samples are taken every one second. After this the program control checks regularly for turbulence and presence of obstacle warning every 2 and 5 sec respectively which then are sent wirelessly to AEMV. For obstacle too close to AEMV, it automatically reverses AEMV to avoid accident and give enough distance to AEMV to change its direction.

1) Decision Flow chart of pH sensor

Sensor used to measure the pH value of water is CSL 31 which is an analog sensor gives voltage variations as an output which is again mapped from 0 to 1023 by using internal 10 bit ADC of ATmega 328. For output is zero, <7, and >7 the pH reading corresponds to neutral, Acidic and Alkaline nature of water respectively. Resolution of pH sensor is 0.05.



Figure(7):- Flow chart of pH sensor

Results and Discussions:-

1) DS18B20 Result:

The temperature readings are taken using DS18B20 with respect to normal room temperature and higher temperature readings are taken with respect to heated water. The observation table of measured values with comparison of thermometer values is given below. The accuracy of DS18B20 is $\pm 1\%$. –Error obtained is in the range of -0.68% to 0.59% which is within $\pm 1\%$.

TABLE III:- Measured Temperature Readings and Error Computation

Sr. No	1	2	3	4	5	6	7
Sensor Value	28.69	29.81	33.51	39.16	42.63	53.21	73.31
Thermo. Value	28.63	29.80	33.53	39.13	42.60	53.23	73.26
%Error	-0.314	-0.34	0.59	-0.77	-0.70	0.37	-0.68

2) pH Sensor Result:

The pH readings are taken with respect to different acids and bases such as HCL, KCl, H₂SO₄, NaOH, KOH etc. The different readings taken by pH sensor are compared by the traditional method of burette and conical flask method as stated in Table III. Error Range obtained is within ± 3.28 to 2.38%.

TABLE IIIII:- Measured pH Readings and Error Computation

Sr. No	1	2	3	4	5	6	7
Sensor Value	0	27	67	83	223	210	157
Mapped Value	7.00	8.35	10.85	11.15	2.85	3.10	6.15
Traditional Method	7.06	8.37	10.98	11.27	2.74	3.01	6.11
%Error	0.85	2.38	1.18	1.06	-3.28	-2.99	0.65

3) AEMV Results:

AEMV is integrated with different analog and digital sensors. Readings taken by the various AEMV unit sensors are transmitted using wireless system to the controller or supervisor continuously. Figure 8 shows the full system Set up. The readings taken by temperature sensor DS18B20 and pH sensor CSL 31 are shown on 16x2 LCD display of in Figure9.



Figure(8):- 8 Full system Set up



Figure(9):- Measured temperature and pH sensor reading display.

4) Wireless module CC2500 on Hyper Terminal

The data from AEMV is transmitted to supervisor using wireless module CC2500 which uses 2.4 GHz ISM band. CC2500 module is used as a transceiver antenna which transmits and receives data simultaneously. The data transmitted via CC2500 module is received by receiver antenna connected to CH341SER module which converts the serially received data into supportable universal serial system of USB drivers. CH341SER is connected to USB port of personal computer from which the data is received and transmitted.

Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.31	Windspeed=6.95
Temp=30.31	pH=7.00	DC Voltage=0.03	Windspeed=0.65
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
High turbulence			
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Medium turbulence			
Temp=30.37	pH=7.00	DC Voltage=0.24	Windspeed=5.43
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Obstacle ahead=1.25		Reverse AEMV	
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Medium turbulence			
Temp=30.31	pH=7.00	DC Voltage=0.39	Windspeed=8.69
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Obstacle ahead=1.18		Reverse AEMV	
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00
Temp=30.31	pH=7.00	DC Voltage=0.00	Windspeed=0.00

Figure(10):- Data received on a HyperTerminal

HyperTerminal is a open source free software which is used as a intermediate media between received data and personal computer. HyperTerminal is used to show the received data i.e temperature value, pH value, wind speed in meter/seconds, generated DC voltage, turbulence and warning if an obstacle comes in front of AEMV. Figure 10. represents the data received on a HyperTerminal.

Conclusion & Future Scope:-

Remotely operated unmanned vehicle is implemented for monitoring, protecting and maintaining the Aquatic Ecosystem which is polluted due to waste chemicals from factories, oil spilling, accidents caused due to ships etc. It is found to provide a suitable solution to solve this aquatic problems. As the research in this field enhances and other innovations are introduced into the operations of unmanned underwater vehicles (UUVs), Underwater Vehicles and make more common and highly cost effective.

Future Scope:

- To install the device in the field, solar energy is a eco-friendly solution to meet the continuous power supply requirement for working of AEMV .
- For the transmission of the data from the field to the control room and Pollution Control Department internet can be used for storing the data on cloud.

- For the centralized data storage and also for the data maintenance we can use cloud computing and also we can develop the android application for the interfacing of the data.

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