Design and Development of Biosensors for Detecting Marine Water Quality Based on ESP32 Microcontroller Devices

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Abstract: Water quality in cultivating marine organisms is a very important part to pay attention to. Prevention of pollution in marine waters needs to be done by recognizing changes in physical, chemical and biological parameters in these waters from normal conditions. To find out these changes, it is necessary to carry out measurements which include parameters that determine the quality of a liquid and carry them out periodically. The measurement parameters measured include pH, Dissolved Oxygen (DO), Electrical Conductivity (EC) and temperature. The use of technological developments, especially in the world of microcontrollers, namely the ESP32 device, makes it possible to design measurement instruments in determining the quality of sea waters to be more efficient and comprehensive. The instrument created in this research will be equipped with several sensors that will read the parameters that determine water quality. The sensors used are pH sensors, DO sensors, EC sensors and temperature sensors. This research aims to create an integrated instrument (pH, DO, ED and Temperature) with instrument performance specifications that have good accuracy and a portable design so that it is easy to use in the field. The research results show thatdevelopment of a biosensor instrument for measuring seawater quality based on the ESP32 DevKit V1 can work well and can display temperature, degree of acidity (pH), DO and EC parameters on the LCD screen according to actual conditions with a difference range in percent between 0.2% - 4.16 %. The accuracy level of the designed tool is classified as having a high accuracy above 95%.

Keywords: Biosensors; Dissolved oxygen sensor, ESP32; EC Sensors; pH sensors

Introduction

Indonesia is an archipelagic country that has a water area of 65% of the total area with a coastline of 81,000 km (Gerungan, 2018). The potential for sea area is very large, producing fish resources reaching 12,011,125 tons per year as well as from several other types of marine fisheries (Anugrah et al., 2021). This condition shows that the potential of Indonesia's fisheries resources needs to be utilized and managed well, especially for the process of cultivating marine fish. Water quality is a very important part that must always be considered in maintaining the preservation of the marine ecosystem (Susanto, 2020). One of the consequences of decreasing the quality of waters due to anthropogenic activities is contamination due to community/industrial activities around the waters so that it can have a direct impact on changes in marine

ecosystems and indirectly on the people living around the area (Dutta et al., 2020; Jiyah et al., 2017; Gholizadeh et al., 2016). Prevention of pollution in marine waters needs to be done by recognizing changes in physical, chemical and biological parameters in these waters from normal conditions. To find out these changes, it is necessary to carry out measurements which include parameters that determine the quality of a liquid and carry them out periodically. Parameters in determining the quality of marine waters can be tested physically, chemically and biologically (Abdul Maulud et al., 2022; Purba et al., 2023; Tanjung et al., 2019).

The Dissolved oxygen (DO) parameter is used to determine the dissolved oxygen content in a liquid which indicates water quality. Oxygen dissolved in water comes from phytoplankton during photosynthesis and plants in the water (Mariyam et al. 2017). In water, oxygen acts as an oxidizer and reduces chemicals into simpler compounds into the form of nutrients needed by aquatic organisms Fakhriyah et al. (2022), so that a water system is said to be good if DO increases and vice versa (Harvenda et al., 2019). Riadhi et al. (2019), stated that changes in temperature affect water oxygen levels, thereby affecting the fish ecosystem.

The next parameter is potential hydrogen (pH), to determine the acid-base content of a solution (Pratami et al., 2020). The pH parameter determines the characteristics and behavior of a material being chemically tested (Khan et al., 2017). It is important to measure pH in sea water regularly, because changes in water pH are very influential and sensitive to marine ecosystems which can result in fish death (Fakhriyah et al., 2022).

The Electrical Conductivity (EC) parameter is used to determine the ability of water to conduct electricity which is influenced by the presence of inorganic and organic dissolved solids (Hudaya et al., 2019). The level of fluid conductivity will be influenced by temperature as well as both organic and inorganic dissolved solids (Mathur, 2018).

The temperature parameter in waters is an important parameter to know. From the explanation of the previous parameters, temperature parameters greatly influence changes in pH parameters, EC parameters and DO parameters.

The use of technological developments, especially in the world of microcontrollers, namely the ESP32 device, makes it possible to design measurement instruments in determining the quality of sea waters to be more efficient and comprehensive. The ESP32 is a microcontroller, produced by the Espressif Systems company which has the advantage of a resolution of up to 12 bits, a smaller size and a cheaper price (Pratama et al., 2023; Alexander et al., 2017; Promput et al., 2023).

Another advantage of the ESP32 device is that it has a WIFI module so that it can be connected to an internet signal (Dhobi & Tevar, 2017). The instrument created in this research will be equipped with several sensors that will read the parameters that determine water quality. The sensors used are pH sensors, DO sensors, EC sensors and temperature sensors. Previous research conducted by Fakhriyah et al. (2022) carried out measurements including pH, TDS and salinity, so there are still many parameters that need to be measured and combined in one instrument. This research aims to create an integrated instrument (pH, DO, ED and Temperature) with instrument performance specifications that have good accuracy and a portable design so that it is easy to use in the field, one of which is in cultivating marine organisms.

Method

The design of sea water quality equipment is carried out in four stages, namely electronics design, algorithm design, calibration process and overall test process. Determining the quality of the water to be measured includes pH measurements, electrical conductivity measurements, Dissolved Oxygen (DO) measurements and temperature measurements. Figure 1 shows the flow diagram of the design process for sea water quality equipment.
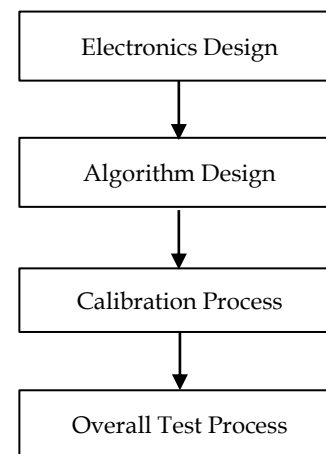
Figure 1. Flowchart for Design and Construction of Sea Water Water Quality Tools

Electronics Design

The electronics design process uses sensors, namely an analog pH sensor which has electrodes in a glass tube (Fajrin et al., 2020), an analog electrical conductivity sensor K=10, an analog dissolved oxygen sensor and a DS18B20 temperature sensor. The output of these four sensors is in the form of analog signals. Apart from that, an ESP32 module, I2C module and 16x2 LCD are needed to display measurement results. The four sensors require

a voltage of 5 volts so as a voltage source a 9V battery is used which will be connected to a DC to DC voltage regulator, namely LM2596. The LM2596 output is regulated to reduce the voltage from 9 volts to 5 volts.

Figure 2. DO, EC, pH and temperature sensors

Based on figure 3, the four sensors are connected to the ESP32 via analog pins. The ESP32 module reads data sent by the sensor in real time and then displays it on the LCD. The LCD is connected to the SCL pin, the SDA ESP32 and the LM2596 module are connected to the Vin pin.
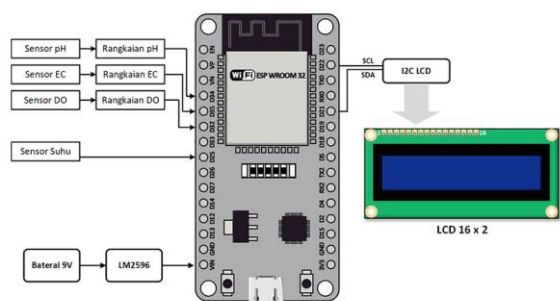

Figure 3. Data acquisition system

Algorithm Design

After the electronics design is carried out, the next step is algorithm design.The algorithm design or coding will be created and uploaded to the ESP32 DevKit V1 module using the Arduino program or Arduino IDE C language. C language is a language that can be used for creating operating systems, image processing and creating new programming language compilers so it is widely used in creating monitoring systems with microcontrol (Wiyono et al., 2017; Pramuda et al., 2023). An algorithm created to read the analog sensor signal connected to the ESP32 ADC pin.

The working principle of the algorithm created is in accordance with the flow diagram shown in Figure 4. Arduino IDE program workflow diagram starts withThe initialization process in the Arduino IDE includes WIFI, I2C for LCD, ADC pins connected to sensors. Next is reading the sensor data on the ADC pin using the "analogRead" command, then converting the ADC value

to a voltage value. Convert the voltage values to values corresponding to the variables of each sensor based on the conversion equation. Next, the data is sent to the LCD to be displayed. If the measurement is not complete, the process of collecting data from the sensor will be repeated.
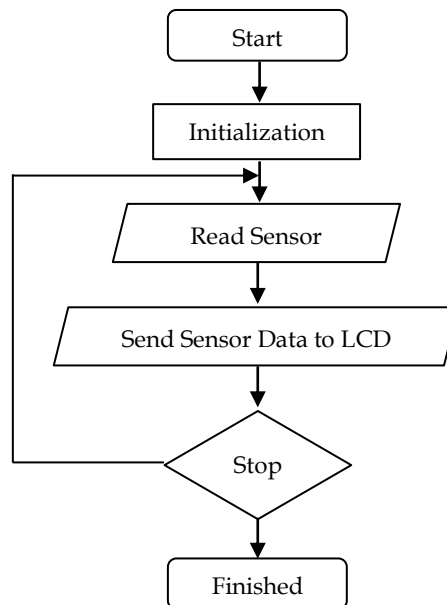

Figure 4. Arduino IDE Program Workflow Diagram

pH Calibration Process

pH analog calibration is carried out using buffer solution (figure 2) which has standardized pH values, namely pH 4.00 and pH 7.00. Changes in liquid temperature can affect changes in liquid pH (Pratami et al., 2020), so the calibration process must maintain a stable buffer solution liquid temperature of 28ºC. The pH sensor's analog output is in the form of an analog voltage in volts which changes with changes in the pH of the liquid. Measurements are carried out 5 times on each buffer solution liquid and the average voltage is calculated, then it will be graphed as a calibration graph. The calibration results are shown in graphical form according to Figure 5.
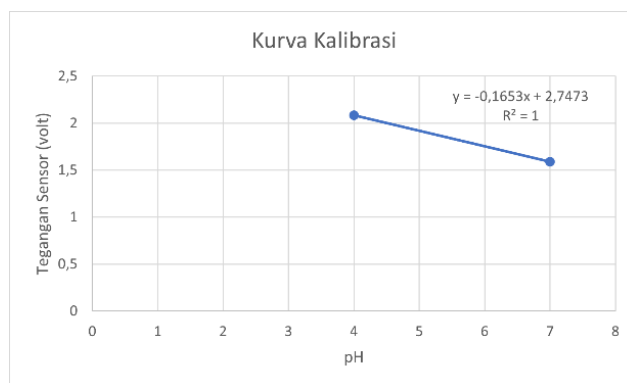

Figure 5. Analog pH sensor calibration graph

Overall Test Process

The overall test process is a complete test between the electronic devices that have been designed and the algorithm designs that have been entered into the ESP32 DevKit V1. The four sensors are used to measure each variable and can be displayed on the LCD. The measurement sample taken was 75 mL of sea water and put into a 100 mL measuring cup.

Results and Discussion

The results of the tool design are shown as in Figure 6. From this picture, the shape of the design is visible from the inside. The design has relatively small dimensions so it is easy to move.

Figure 6. Tool Design Results

The following are the results of measuring sea water quality using a designed tool which is compared with a standardized measuring tool as in Table 1. The water temperature for living fish is between 27°C to 30°C (Saraswati and Sari, 2017).

Table 1. Sea water measurement results using standard tools and designed tools

Measuring instrument	Temperature (°C)	pH	DO (mg/L)	EC (ms/cm)
Standard tools	28.1	7.20	5.68	31.2
Design tools	28.26	7.10	5.71	32.5

Figure 7 and Figure 8 show the results of sea water measurements using the designed tool which are displayed on the LCD. Based on the results of these measurements and compared with the measurement results of standard measuring instruments shown in table 1, the percent error level of the tool and the level of accuracy of the tool are shown in table 2 below and the percent accuracy level of the tool has been calculated and shown in table 3.

Figure 7. Display of pH and temperature measurement results

Figure 8. Display of DO and EC measurement results

Table 2. Design Tool Error Percent

Temperature (%)	pH (%)	DO (%)	EC (%)
0.212	0.280	1.38	4.16

Table 3. Percent Accuracy of Design Tools

Temperature (%)	pH (%)	DO (%)	EC (%)
99.78	99.72	98.62	95.84

Conclusion

The sea water quality monitoring system based on the ESP32 DevKit V1 can work well and can display temperature, pH, DO and EC parameters on the LCD screen according to actual conditions with a difference range in percent between 0.2% - 4.16%. The accuracy level of the designed tool is classified as having high accuracy above 95%.

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Author Contributions
Conceptualization, M.R and F.M; methodology, R.M.K and F.M; validation, M.R and R.M.K; formal analysis, R.A.E; investigation, M.R, and R.M.K; resources, R.M.K and F.M; data curation, F.M and R.M.K: writing—original draft preparation, F.M and R.M.K; writing—review and editing, M.R and M.R:

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