PROTOTYPE OF THE WELL-WATER CONDUCTIVITY SENSOR SYSTEM BASED MICROCONTROLLER

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ABSTRACT

In this paper, the prototype of the well-water conductivity sensor system is presented which consists of the power supply, temperature sensor circuit, conductivity sensor circuit, Arduino UNO microcontroller, 16x2 I2C LCD characters and the conversion equation. The sensor is designed for conductivity measurements at various temperature and conductivity at 25°C by conversion equation. Furthermore, it measured the conductivity of water 15.24 - 1031.60 μS/cm in a range with error 0.39 – 21.48 μS/cm and the temperature of water 20.10 – 50.20°C with error 0.13 – 0.72°C. The measurement of 11 sample points in the Pesayangan Martapura and Antasan Senor East Martapura, Banjar, South Kalimantan, Indonesia showed the conductivity of the well-water at the actual temperature was at the range of 128.50 – 364.51 μS/cm and the 161.97 – 364.51 μS/cm at 25°C.

Keywords: Arduino UNO; conductivity; temperature; well water

Introduction

Conductivity value is an early indication of water pollution.[1] The conductivity of drinking water by WHO standards should not exceed 400 μS/cm.[2] The conductivity value is also related to other water quality parameters such as salinity.

Prompak[3] made a conductivity measurement instrument of electrolyte solution using a Wheatstone bridge and differential amplifiers. Another research by Hemanth and Sowmya[4] developed a pollution detection apparatus for drinking water by using a conductivity sensor and an Arduino microcontroller, but the effect of temperature on conductivity measurement has not been considered.

An approach for conductivity measurement of water quality can use the reference temperature or the characterized temperature parameter in which the conductivity and the concentration of the other dissolved substances in water are connected. Eq.1 shows the relationship of conductivity at the actual temperature σ_T with conductivity at 25°C σ_{25}, where β is a coefficient temperature.

$$\sigma_T = \sigma_{25}\,[1 + \beta(T - 25)] \quad (1)$$

$$\sigma_{25} = \frac{\sigma_T}{[1 + \beta(T - 25)]} \quad (2)$$

The value of β in these equations is $0.0187^{o}C^{-1}$. Eq.2 can be used to estimate the conductivity at 25°C based on the σ_T value.[5]

This research presents the prototype of the well-water conductivity sensor system based on microcontroller. This prototype is able to measure the conductivity of water at the various temperature and convert it to the conductivity value at 25°C using the conversion equation, i.e., Eq.(1) and Eq. (2). The conductivity sensor system constructed with two electrodes made of stainless steel, Wien bridge circuit, Wheatstone bridge circuit, differential amplifier circuit, a rectifier circuit, and microcontroller Arduino UNO. The prototype of the conductivity sensor system equipped with a temperature sensor circuit composing a non-inverting

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amplifier circuit and an LM35 sensor to measure the water temperatures.

Samples were taken from the well-water in the areas Pasayangan Martapura and Antasan Senor East Martapura, Banjar, South Kalimantan, Indonesia. Residents in Martapura and surrounding areas prefer to use the well-water as drinking water. Pasayangan and Antasan Senor are located around the Martapura River and considered as a dense populated residential area. High populations and sanitation issues are at risk of increasing the pollution of water. Therefore, measuring the conductivity of water needed as an initial water quality parameter. The value of salinity of well water samples also measured as the supporting data.

Methods

Fig. 1 shows a block diagram of the sensor system.

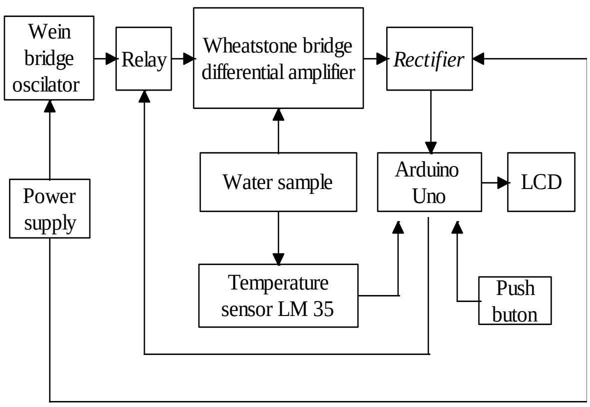

Figure 1. Block diagram of the system

Power Supply Circuit

The power supply is made to convert 220 Vrms AC voltage into +9 V DC, +12 V DC, and -12 V DC. This DC voltage applied to the prototype components such as ICs, microcontroller, and LCD.

Temperature Sensor Circuit

The temperature sensor circuit created in this research is shown in Fig. 3.

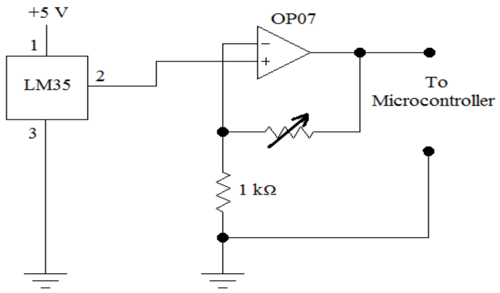

Figure 3. Temperature sensor circuit

The water temperature measured by a digital thermometer compared with an output voltage generated by the temperature sensor circuit to characterize the temperature sensor circuit. Water is heated using a hot plate and cooled using ice blocks within 20^{o}C - 50^{o}C. The output voltage value from the temperature sensor circuit is recorded every change of 1^{o}C while the water heated and cooled.

Conductivity Sensor Circuit

The conductivity sensor circuit consists of a Wien bridge oscillator, Wheatstone bridge, a differential amplifier, rectifier, and voltage follower. The Wien bridge oscillator circuit produces a sine wave voltage with a frequency of 1 kHz. This wave amplitude is arranged to 1 Vrms and applied to the Wheatstone bridge circuit. The Wheatstone bridge circuit connected to a differential amplifier to increase the output voltage.[6]

The rectifier created without using diode but made use of saturation from the operational amplifier with a single supply voltage. Therefore, the rectifier performance increased as there is not disturbed by the characteristics of the diode.[7]

The voltage follower circuit with bootstrap added to function as a buffer circuit and act as a low-frequency noise filter.[8] The relay added to the circuit to control the sine wave applied to the Wheatstone bridge circuit.

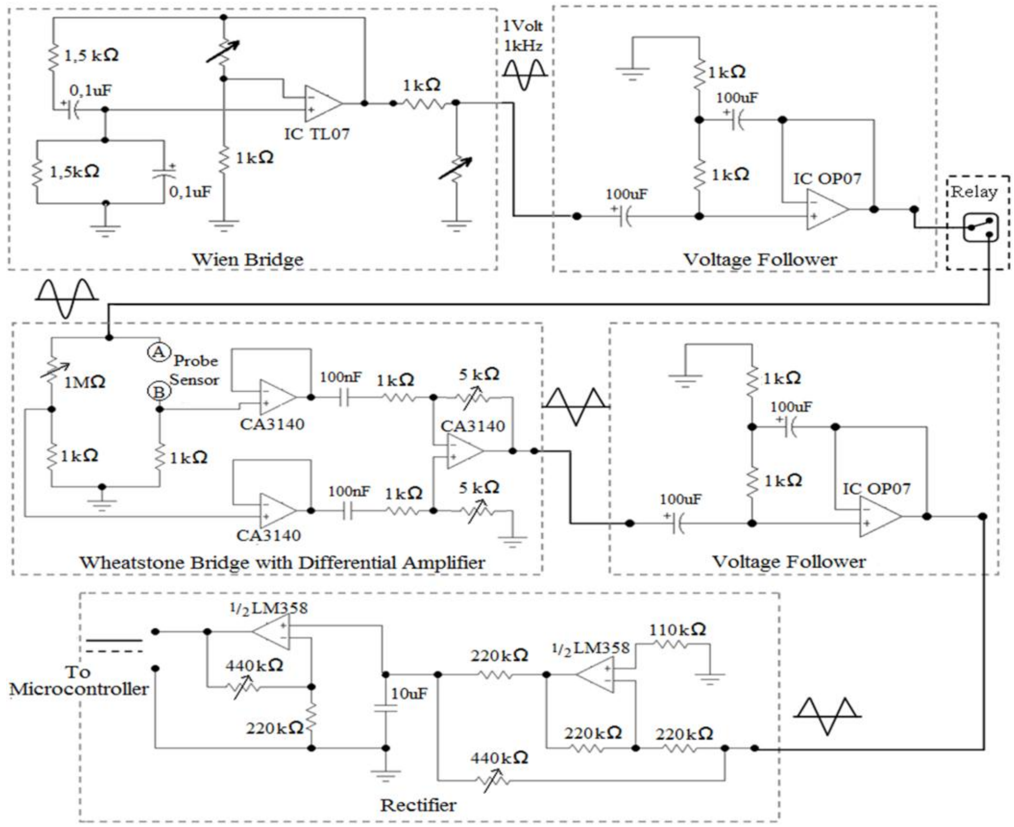

Figure 4. Conductivity sensor circuit

In Fig.4, one of the resistors in the Wheatstone bridge circuit replaced with a conductivity probe. The conductivity probe consists of two parallel plates made of stainless steel with a design as shown in Fig.5.

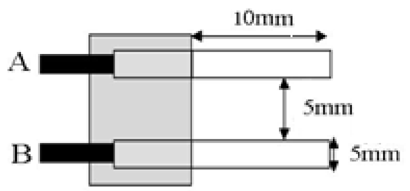

Figure 5. Design of the conductivity probe

The circuit of the conductivity sensor shows in Fig.4. The output voltage generated by the conductivity sensor circuit compared with the conductivity value of NaCl solutions measured by the conductivity meter at 25^{o}C to characterize the conductivity sensor circuit. The NaCl solutions with concentrations of 500 mg/L, 400 mg/L, 300 mg/L, 200 mg/L, 150 mg/L, 100 mg/L, 50 mg/L, 20 mg/L, 10 mg/L, and 5 mg/L was prepared for this process.

Test Measurement

The result of temperature measurement by prototype sensor compared with a digital thermometer. The temperature of the water heated from 20^{o}C to 50^{o}C using a hot plate. The temperature value from the thermometer and the prototype of the sensor recorded every 2^{o}C while the water was heating up.

The conductivity value of the test solutions measured by the prototype sensor and compared with a standard conductivity meter while the temperature of solutions kept in the range of 25^{o}C for every measurement. After the measurement test by maintaining the temperature, the prototype was used to measure the conductivity of three NaCl solutions at various temperature. It is intended to test the measurements of conductivity values at different temperatures. Eq.7 used as conversion equation to convert actual conductivity to conductivity at 25^{o}C. This test carried out by heating up the test solution from 20°C to 50°C. The conductivity value recorded every 5°C increase of temperature.

The well-water conductivity measurement test was carried out by measuring the conductivity value of the well water of Pasayangan Martapura and Antasan Senor East Martapura using the prototype.

Result and Discussion

Power Supply

The power supply circuit that has been made converts the AC voltage 220 Vrms to a DC voltage of +9.16 V, +11.96 V, and –11.87 V. The +9.16 V used to turn on the Arduino UNO, +11.96 V and -11.87 V is used to turn on amplifiers on the conductivity sensor circuit and temperature sensor circuit.

Temperature Sensor

Characterization of temperature sensor circuit divided into heating and cooling stages. The result of the characterization, the temperature sensor circuit shows the linear pattern as shown in Fig.6.

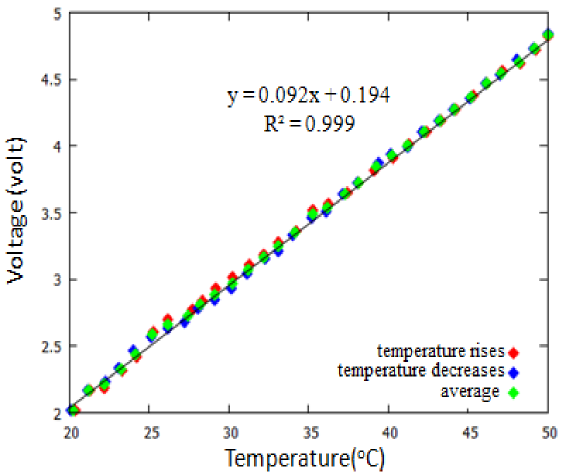

Figure 6. Temperature sensor characterization result

$$T = \frac{Vt - 0.194}{0.092} \quad (3)$$

Eq.3 formulated from the characteristic equations in Fig. 6 where T is temperature and Vt is the temperature sensor output voltage. Eq.3 embedded into the microcontroller programs to convert the output voltage of temperature sensor circuit in volt to a temperature in degree Celsius.

Conductivity Sensor

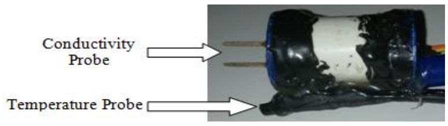

Figure 7. Conductivity and temperature probe

The conductivity sensor probe and temperature sensor probe are incorporated as presented in Fig.7 for simplifying the process of further measurement.

The comparison result between the measured conductivity by the standard conductivity meter and the output voltage generated by the conductivity sensor circuit at 25°C shown in fig.8.

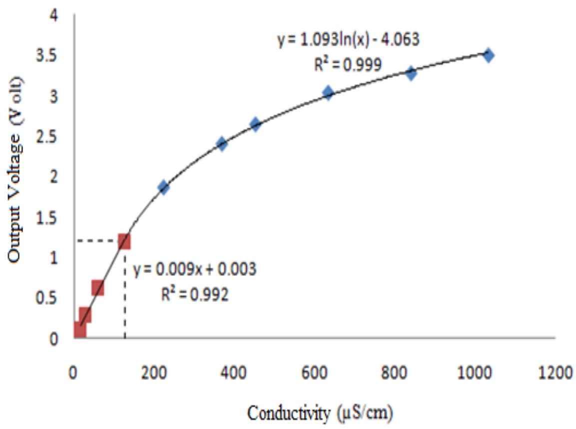

Figure 8. Conductivity sensor characterization result

The relation of the conductivity value to the sensor output voltage approximated by the pattern of linear and natural logarithmic equations. Eq.5 formulated from the characteristic equations in Fig.8. Eq.5 is used to change the value of the sensor output voltage Vk in volts to the conductivity value in µS/cm.

$$\sigma = \begin{cases} \frac{Vk - 0.003}{0.009}, 0.109 \le Vk \le 1.186 \\ e^{\left(\frac{Vk + 4.063}{1.093}\right)}, 1.186 < Vk \le 3.500 \end{cases} \quad (5)$$

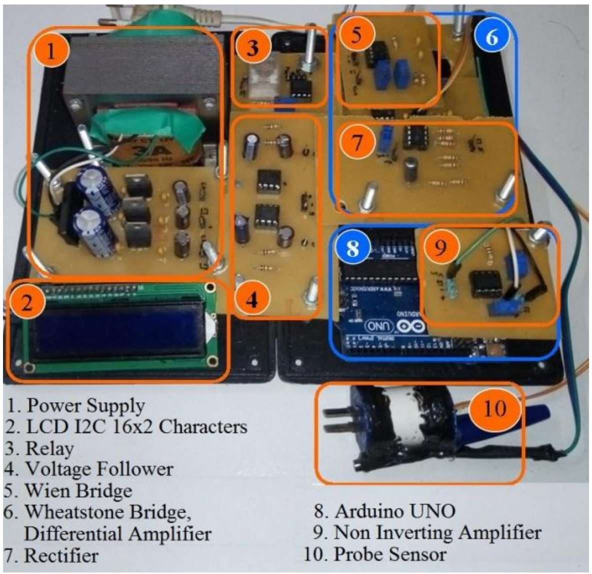

Figure 9. The components of the prototype

Fig.9 shows the realization of the prototype components. Components placement made of two levels to minimize the size of the prototype. The Wheatstone bridge, a differential amplifier and Arduino UNO placed under the Wien bridge, rectifier, and non inverting amplifier circuit.

Temperature Measurement Test

The temperature measurement test is carried out by measuring the water temperature from 20°C to 50°C. The temperature measurement from the thermometer and the prototype sensor recorded every temperature rise of 2^{o}C. The comparison of temperature measurement between the digital thermometer with the prototype sensor has an error 0.13^{o}C to 0.72^{o}C.

Conductivity Measurement Test

The first conductivity measurement test of the solutions at 25^{o}C show the prototype sensor error from 0.39 µS/cm to 21.48 µS/cm. Tests of conductivity measurements with the variations of temperature were performed using three NaCl solutions with different conductivity values. The actual conductivity and conductivity calculated with the conversion equation recorded every temperature rise of 5°C from 20^{o}C to 50^{o}C. The result of this test presented in Fig.10.

Fig.10 shows the result of conductivity measurement using the conversion equation approaching a value of conductivity measured at 25°C with error 0.06 µS/cm to 31.56 µS/cm. The prototype will display the measured conductivity at the actual temperature (σ) and conductivity at 25°C by using the conversion equation (σ25).

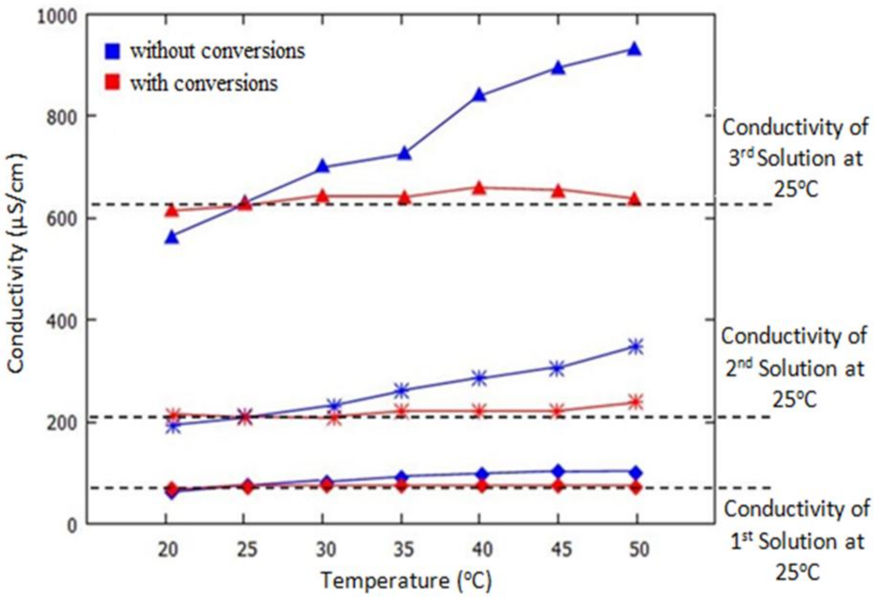

Figure 10. The result of measurement of the conductivity with the temperature variation

Well Water Conductivity Measurement Result

Measurements of well water conductivity held in Pasayangan subdistrict of Martapura and Antasan Senor subdistrict of East Martapura, Banjar Regency, South Kalimantan, Indonesia at 15.00 WITA. Fig.11 shows the sampling points. The 1st and 2nd points located at Martapura River. While point 3, 7, and 10 are conventional (dug) wells water samples obtained and At the point 4, 5, 6, 8th, and 9 are artesian wells water obtained.

Table 1 shows the results of measurements from water samples by prototype sensor where (σ) shows measured real conductivity values at the actual temperature and (σ25) shows measured conductivity values at 25°C with the conversion equation.

The second measurement held after the samples stored for three days long. The second measurement carried out by using prototype and standard conductivity meter.

The second measurement of water conductivity using a standard conductivity meter carried out by keeping the water temperature at 25^{o}C. The measurement conductivity with a prototype carried out without conditioning the water temperature at a specific point. The salinity value used as supporting data and measured at 25^{o}C by salinity meter.

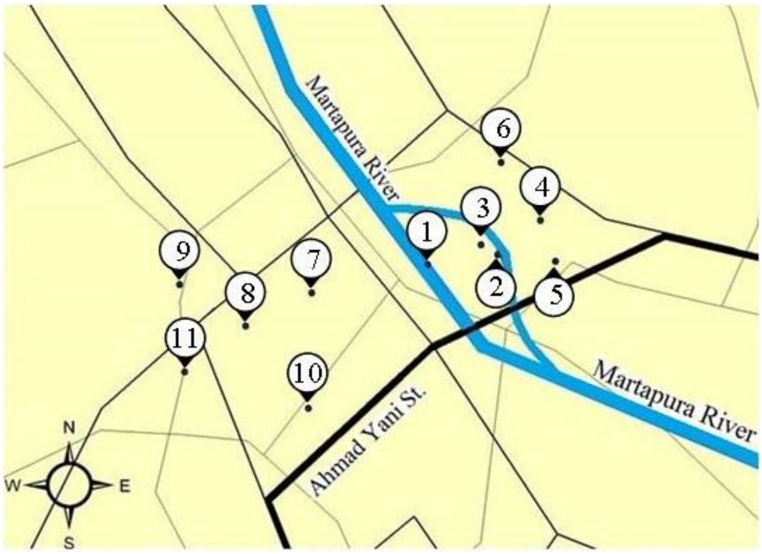

Figure 11. The well-water sample points in areas

Table 1. The result of conductivity and temperature measurement of the water sample

Sample	Coordinate	Conductivity (μS/cm)		Temperature (^{o}C)
		σ	σ25	
1	3°24'04.4"S 114°50'49.6"E	129.53	118.11	30.17
2	3°24'03.8"S 114°50'53.8"E	129.47	118.47	29.96
3	3°24'03.2"S 114°50'52.8"E	224.89	203.96	30.48
4	3°24'01.7"S 114°50'56.4"E	157.92	145.20	29.68
5	3°24'04.2"S 114°50'57.3"E	401.44	364.51	30.42
6	3°23'58.2"S 114°50'54.0"E	307.44	282.55	29.71
7	3°24'06.1"S 114°50'42.6"E	128.50	116.97	30.27
8	3°24'08.1"S 114°50'38.6"E	197.77	179.87	30.32
9	3°24'05.6"S 114°50'34.6"E	156.25	141.92	30.40
10	3°24'13.1"S 114°50'42.4"E	192.64	175.56	30.20
11	3°24'10.9"S 114°50'34.9"E	157.77	144.35	29.97

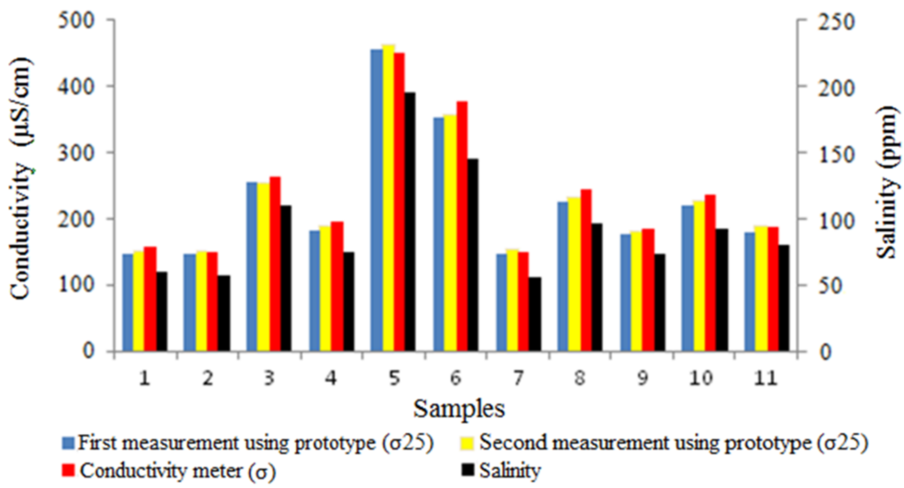

Figure 11. Graphical comparison of conductivity measurements and salinity of water samples

Fig.11 presented the result of the first measurement and second measurement the conductivity and salinity of water samples. The conductivity and salinity measurements of each sample have similar characteristics. The result of the second measurement of conductivity (σ25) using prototype and real conductivity (σ) using a conductivity meter indicates a measurement error from 2.17 µS/cm to 16.59 µS/cm.

Conclusion

The prototype sensor system is capable of measuring the conductivity of water from 15.24 µS/cm up to 1031.60 µS/cm with error 0.39 µS/cm to 21.48 µS/cm and measure the water temperature from 20.25°C up to 50.20°C with error 0.13°C to 0.72°C. The result of measurement test from 11 sample points in Pasayangan Subdistrict of Martapura and Antasan Senor Subdistrict of East Martapura show the value of well water conductivity from 128.50 µS/cm to 401.44 µS/cm at 29.68°C to 30.48°C and measurement conductivity at 25°C using conversion equation ranging from 116.97 µS/cm to 364.51 µS/cm.

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