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Submission date: 09-Mar-2021 05:54PM (UTC+0800)

Submission ID: 1528283107

File name: prosiding-semester-genap-2017-2018-acquisition_of_electrical.pdf (582.79K)

Word count: 2259

Character count: 11752

Acquisition of electrical signals using commercial electronic components for detection system of Lead ion in distilled water

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Abstract. Development of lead ion detection systems is expected to have an advantage in terms of simplicity of the device and easy for concentration analysis of a lead ion with very high performance. One important part of lead ion detection systems are electrical signal acquisition parts. The electrical signal acquisition part uses the main electronic components: non inverting op-amplifier, instrumentation amplifier, multiplier circuit and logarithmic amplifier. Here will be shown the performance of lead ion detection systems when the existing electrical signal processors use commercial electronic components. The results that can be drawn from this experimental were the lead ion sensor that has been developed can be used to detect lead ions with a sensitivity of 10.48 mV/ppm with the linearity 97.11% and had a measurement range of 0.1 ppm to 80 ppm.

1. Introduction

Several measurement methods of the chemical concentration have been carried out using optical fiber sensors [1,2,3]. The optical method developed to measure the concentration of the material using a displacement phenomenon between the two ends of optical fibers. The phenomenon of displacement between the two ends of optical fibers has been successfully developed as a displacement sensor that can measure object displacement to micron-scale resolutions [4,5,6]. Furthermore, the displacement sensor may be used as an attractive approach to the measurement of non-contact hydroxyapatite thickness of the material [7,8,9]. The displacement sensor has been shown to be used as a good approach to measuring transparent plate thickness based on transmission and reflection phenomena [10]. Fiber optic sensors using tapered fiber optics can be used to detect potassium in distilled water [11]. Fiber optic displacement sensors using bundled probe can be used for medal detection [12].

The overall development of the method of measuring the concentration of a chemical by using fiber optic sensor that has been done still has not produced a direct reading of its concentration value. This work was attempted to develop optical fiber spectrophotometry technique that can measure the concentration of lead ions with direct concentration reading. To allow for a direct reading of the value of concentration, a signal acquisition system is required using commercial electronic components that available on the market. Conceptually the signal acquisition process can be shown through the block diagram as Figure 1. Each block is described by a transfer function (TF) which expresses the relationship between output and input. If the input is expressed with V_i and the output is expressed by V_k , the statement $TF = V_k / V_i$. After going through the entire of the acquisition process, it is expected output voltage V_o is proportional to concentration (c).

The sensor probe consist of a light source, directional coupler and silicon photo detector. A violet 405 nm light from Light Emitting Diode (LED) is launched into directional coupler and directed to a



region where the light interact with lead ion liquid. This interaction results in a modulation of optical intensity and modulated light is collected by the another optical fiber to be transmitted to the optical detector. By an optical detector, the received light intensity was converted into electrical voltage signal and then forwarded to acquisition system. The interaction of light with lead ions is an absorption phenomenon. Therefore, based on lambert-beer law, V_k / V_i is proportional to e^{-c} . At non-inverting operational amplifier, V_k / V_i is a gain of amplifier so that the output V_2 is proportional to e^{-c} . In amplifier instrumentation, one of the input voltages is given a certain reference voltage (V_r) which has greater value than V_2 so that V_k / V_i is proportional to $(V_r - V_2)$. The output voltage V_3 of the amplifier instrumentation is proportional to e^c . The output voltage V_3 after multiplied by the number k (selected $k = 100$) and passed the amplifier logarithmic will be obtained output voltage V_o is proportional to c . This is because V_k / V_i for logarithmic amplifiers proportional to $\ln(V_4)$. Since the output voltage of V_o proportional to c , it is possible to read the results of direct ion concentration detection directly.

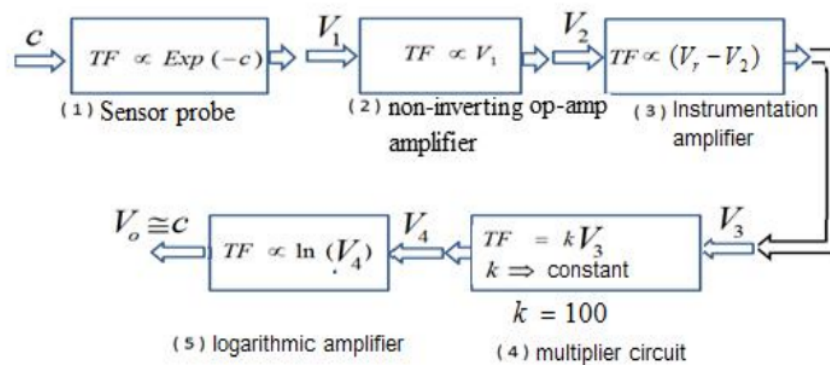


Figure 1. Block diagram of the electrical signal acquisition process.

2. Methods

This work was attempted to develop optical fiber spectrophotometry technique that can measure the concentration of lead ions with direct concentration reading. The main focus of this work was electric signal acquisition systems design using commercial electronic components and of optical probes. Probe sensor using asymmetric directional coupler 1×4 tree.

Procedures of this work focused on the design of electrical signal acquisition system devices using commercial electronic components for lead ion detection systems in distilled water were carried out through the following stages: 1) the design and manufacture of electric signal acquisition systems using commercial electronic components 2) the design and manufacture of optical probes 3) design of experiment setup for detection of concentrations of lead ions in distilled water, 4) sample preparation for testing, 5) data collection and data analysis. Conceptually the electrical signal processing in acquisition system was designed following the block diagram in Figure 1. The non-inverting amplifier output voltage (V_2), the output voltage of the multiplier circuit (V_4) and the output voltage of the logarithmic amplifier (V_o) were measured as the function of the lead ion concentration.

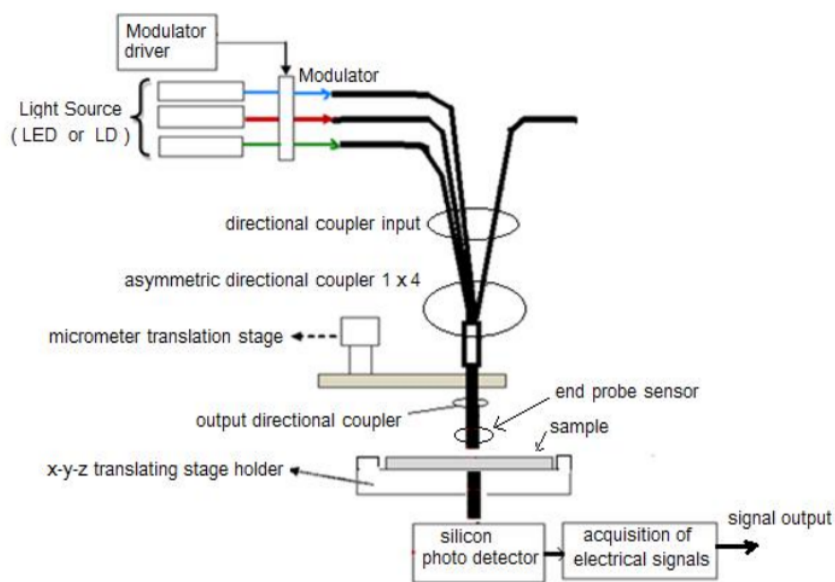


Figure 2. Experimental setup for concentration detection lead ions in water.

The design of the main optical system was the design of the probe sensor detecting the concentration in distilled water. Probe sensor concentration of several heavy metal ions were made from optical fiber displacement system using asymmetric directional coupler 1×4 tree. The directional coupler output was enabled to transmit light from the light source to the sample. The sensor probe integrated with the cuvette where the sample placed.

The experimental setup for the detection of concentrations of heavy metal ions in the water were shown in Figure 2. The main components of the experimental setup were light sources (violet LED) and concentration sensor probes.

In Figure 2, the light from a modulated LED light source (405 nm) through an electronic modulator with a certain frequency were fed into directional coupler input and transmitted to the sample through directional coupler output. The light passing through the sample guided through fiber optics to be transmitted to the optical detector. By an optical detector, the received light intensity was converted into electrical voltage signal. This voltage signal was amplified by a non-inverting OP-amplifier and then forwarded to the instrumentation and logarithmic amplifier. Output voltage non-inverting amplifier, output voltage of multiplier circuit and output voltage of logarithmic amplifier will be determined for the value as a function of the sample concentration.

The experiment was begun with the preparation of samples of lead ions. The lead sample of nitrate $\text{Pb}(\text{NO}_3)_2$, dissolved in water. Samples of $\text{Pb}(\text{NO}_3)_2$ were fed ethylene tetra acetate acid reagent ($\text{EDTA} = \text{C}_{10}\text{H}_{16}\text{N}_2\text{O}_8$). Each sample was made variation of concentration from 0.1 ppm to 80 ppm.

The data taken were the output voltage value of each part of the electrical signal acquisition system as its input function. The main data taken and to be analysed is the final output voltage value as a function of the concentration of lead ions in water.

Theoretically, the final output voltage as a function of concentration is linear. The result of the analysis gave the same data with a linear function.

3. Results and Discussion

Data obtained from this research were non-inverting amplifier output voltage, output line voltage multiplier and output voltage of logarithmic amplifier as a function of concentration of lead solution in water. The output voltage data as a function of lead ion concentration for Op-Amp amplifier, Multiplier Circuit and logarithmic amplifier presented in Table-1 and regression for each data presented in Figure 3. In Figure 3, it showed that the relationship between the output voltage Op-Amp amplifier (V_2) to the lead ion concentration can be approximated by function which decays exponentially with the equation $V_2 = 369.89 e^{-0.0003 c}$ with the coefficient of determination value 96.59%. The relationship between the output voltage Multiplier Circuit (V_4) to the lead ion concentration can be approximated by function exponential with the equation $V_4 = 157.13 e^{0.0105 c}$ with the value of coefficient of determination value 94.32%. The coefficient of determination value stated the level of data conformity with a particular function model. The form of voltage function V_2 and V_4 corresponded to the expected form of transfer function in the Op-amp amplifier and the multiplier circuit.

Table 1. Output voltage as a function of lead ion concentration (c) for Op-Amp amplifier, multiplier circuit and logarithmic amplifier.

(c) Concentrations of lead ions (ppm)	(V_2) Op-amplifier output voltage (x10 mV)	(V_4) Multiplier Circuit output voltage (x 0.01 mV)	(V_o) Logarithmic amplifier output voltage (x 0.1 mV)
0.1	371.0	136.2	309.0
1	369.4	164.5	497.7
10	368.7	178.7	580.8
20	367.3	206.9	727.4
40	365.2	253.3	929.3
60	363.1	306.8	1121.0
80	362.0	336.1	1212.0

In Figure 3, it showed that the relationship between the output voltage to the lead ion concentration can be approximated by linearity function with the value $R^2 = 0.9431$ (regression coefficient $R = 0.9711$) with the equation $V_o = (1.0483 c + 45.205)$. In this case, V_o presented as the magnitude of the output voltage of the logarithmic amplifier, whereas c presented as the concentration of lead ions. Based on the value of R , it could be concluded that there were linearity correlation between the output voltages with lead ions. From the results of linear regression test can be known the sensors performance including sensitivity, linearity and measurement range. The performance of the lead ion sensor can be expressed in Table 2.

Table 2. Performance of lead ion sensor.

Parameter	Parameter Value for sample:
Sensitivity	10.48 mV/ppm
Measurement range	0.1 – 80 ppm
Linearity	> 97 %

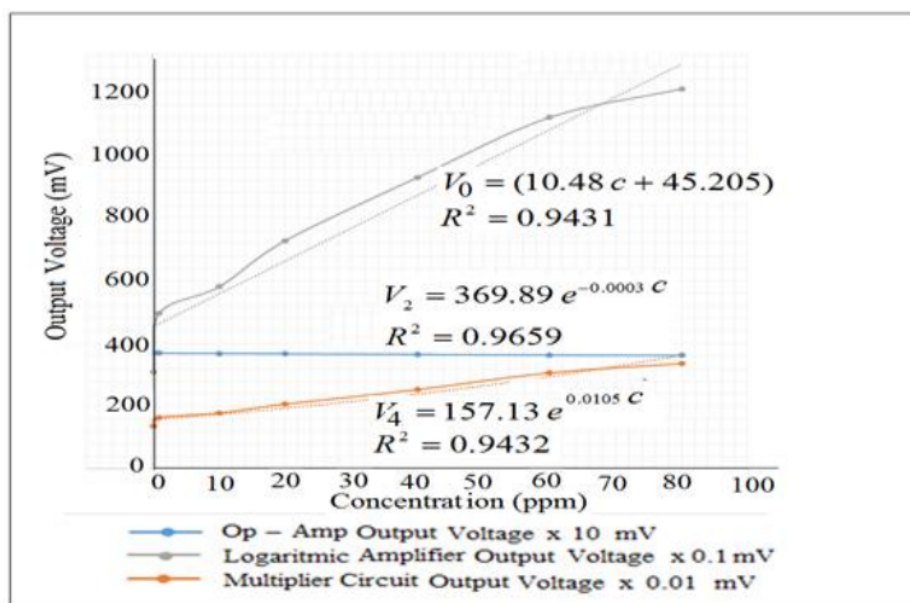


Figure 3. Voltage output of Op-Amp, Instrumentation and Logarithmic Amplifier as a function of Lead ion concentration.

4. Conclusion

Development of lead ion detection systems for concentration analysis of a lead ion is presented and demonstrated. The output voltage of the detector shows a linear relationship to the change of lead concentration in distilled water. The 1 x 4 tree asymmetric directional coupler sensor probes were used and it enables to detect the concentration of several heavy metal ions simultaneously. The results that can be drawn from this experimental were the lead ion sensor that has been developed can be used to detect lead ions with a sensitivity of 10.48 mV/ppm with the linearity 97.11% and had a measurement range of 0.1 ppm to 80 ppm.

Acknowledgment

This research was supported by grant of PTUPT from Ministry of Research, Technology, and Higher Education of The Republic Indonesia.

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