Journal of Telematics and Informatics (JTI)
Vol.9, No.1, 2021, pp. 45~51
ISSN: 2303-3703

Development of SpO2 Monitoring System for Early Stroke Detection

Brama Sakti Handoko, Arief Marwanto, Suryani Alifah
Universitas Islam Sultan Agung, Semarang, Indonesia
e-mail: arief@unissula.ac.id

Abstract

Within this paper, we will discuss about a development process of SpO2 monitoring system that will be used for detecting a patient in the early stage of stroke. This system will measure and compare the SpO2 from both right and left arm at the same time. Stroke patients who experience weakness in the muscles of the one hand can experience different values with hands that do not experience muscle weakness. Stroke patients who are hospitalized with an intravenous infusion in one arm can cause differences in SpO2 values between the right and left fingers. Therefore this measurement method held from that phenomenon. From the monitoring system design, the system should have two sensors to measure the blood saturation, a microcontroller to process the data, and a monitor, buzzer, and micro sd card module to store and display the data. The research shows that the system has been developed and can be used to measure patient's SpO2 from both hands at the same time, an indicator that will rings when there is an error in the measurement, and a lcd display to show the measurement data. This system also has a microSD card writer to store the measurement data from time to time.

***Keywords**: SpO2, SpO2 monitoring system, stroke patient*

1. Introduction

Stroke is the first-on-the-list cause of disability and the second cause of death in the world. This disease has become a global health problem and is increasingly important, with two-thirds of strokes occurring in developing countries in which stroke patients may experience impaired oxygen transfer or decreased cerebro blood flow resulting in decreased tissue perfusion, which can lead to ischemia[1]. Ischemic stroke is a local or global nerve function disorder that appears suddenly, progressively and rapidly. Impaired nerve function in ischemic stroke is caused by non-traumatic cerebral blood circulation disorders. Non-traumatic circulatory disorders such as blockage (atherothrombosis) in the cerebral arteries and internal carotid arteries. These neurological disorders cause symptoms including: facial or limbs paralysis, unfluent speech, unclear speech, changes in consciousness and visual disturbances[2].

Rough blood flow in stroke patients causes hemodynamic disturbances including oxygen saturation. Therefore, proper monitoring and treatment is needed because hemodynamic conditions greatly affect the function of oxygen delivery in the body which in turn will affect heart function [3]. Stroke patients who experience weakness in the muscles of the one hand can experience different values with hands that do not experience muscle weakness. Moreover, stroke patients who are hospitalized with an intravenous infusion in one arm can cause differences in SpO2 values between the right and left fingers.[2]

SpO2 (Saturation of Peripheral Oxygen) or Oxygen saturation is a measure of how much oxygen percentage is able to be carried by hemoglobin. Hemoglobin is a protein molecule in the blood that can bind oxygen. One of the most important indicators of oxygen supply in the body is oxygen saturation (SpO2). Because oxygen saturation can indicate whether hemoglobin can bind oxygen or not. SpO2 is a method of using a tool to monitor the state of oxygen saturation in the patient's blood (arterial), to assist in the physical assessment of the patient, without having to go through blood test analysis. Saturation is the percentage of hemoglobin that binds oxygen compared to the total amount of hemoglobin in the blood. [4]

The method of measuring oxygen saturation levels with hemoglobin can use 2 methods, namely the invasive method and the non-invasive method. In the invasive method, to measure oxygen levels the sensor is inserted into the body by injuring body tissues, causing discomfort to

Received May 9, 201x; Revised August 3, 201x; Accepted August 16, 201x

the patient due to illness, and the possibility of infection and bleeding is a weakness of this method. Then the non-invasive method used in this study. This non-invasive method uses different wavelengths of red light (660 nm) and infrared light (940 nm) from infrared sensors. Then the red light and infrared light pass through the veins and capillaries on the fingers, and are captured by the detection sensor. Data from the detection sensor is sent to the microcontroller and then displayed to the LCD. SpO2 uses red and infrared LEDs and a photodiode inside. Red and infrared LEDs have different wavelength absorptions. The wavelength for red LED is 660nm while infrared LED has a wavelength of 940nm. Both LEDs function as transmitters and photodiodes as receivers. This LED transmits light through the veins and the photodiode receives the output of the two LEDs. The output of the photodiode can then be used to calculate the percentage concentration of oxygen. [5]-[7]

Several tools on the market or existing tools from some researchs,[5]-[8] had focused in the SpO2 measurement system by using a single sensor so that it cannot be used to display an accurate SpO2 value in stroke patients. Oxygen levels in stroke patients who experience weakness in the muscles of the one hand can experience different values with hands that do not experience muscle weakness. There is no tool that uses an SD card as data storage. SD card needed to store measurement's data so that we can analyze it later and also it can be used to compare a real time measurement value with the previous measurement result.[9] So we need a tool that can measure the performance of monitoring vital signs completely and accurately using 2 SpO2 sensors and equipped with an SD card as a data storage medium to make it easier for doctors to analyze the history of SpO2 results over a certain time span.

2. Research System Model

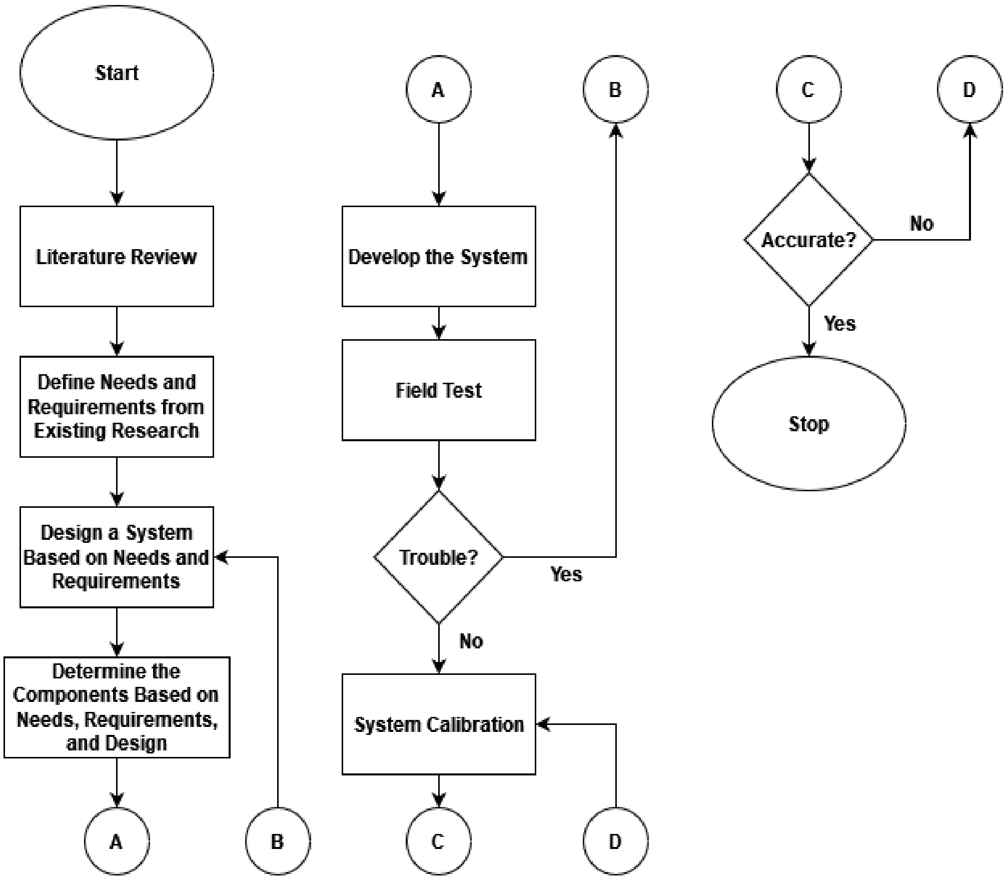

Figure 1. *Research Method*

The research method used in this paper can be seen in Figure 1. The first step of this research is doing a literature review to get the reference for defining the needs and requirements of the system. From the defined needs and requirements, we design a suitable system to accomplish them. After we get the system's design, the next step is to choose the most suitable components to fulfill the needs and requirements from the system. The next step is develop the system by integrating all the components base on the system's design. The next step is testing the developed system to see wether there is a system malfunction or not. If the system running well, then the research continue to the calibration process. In this calibration process, we use a well-calibrated SpO2 measurement device from Mindray, this device has used by several hospitals in Bantul Region to calibrate their SpO2 measurement device. From the calibration process we check wether our developed device has already met the maximum error allowed or not.[10] If the calibration result has met the standard which is ±2% different in value from the calibrated device, the research finished.

3. Results and Analysis

From literature review, there are three steps that have to be fulfilled in this research. The first one is the system's design, the next one is the finished product, and the last one is the calibration process. We will discuss them separately in three sub-section.

3.1. System's Design

The system's design is created base on the needs and requirements that we acquired from literature review. The diagram block of the designed system can be seen in Figure 2.

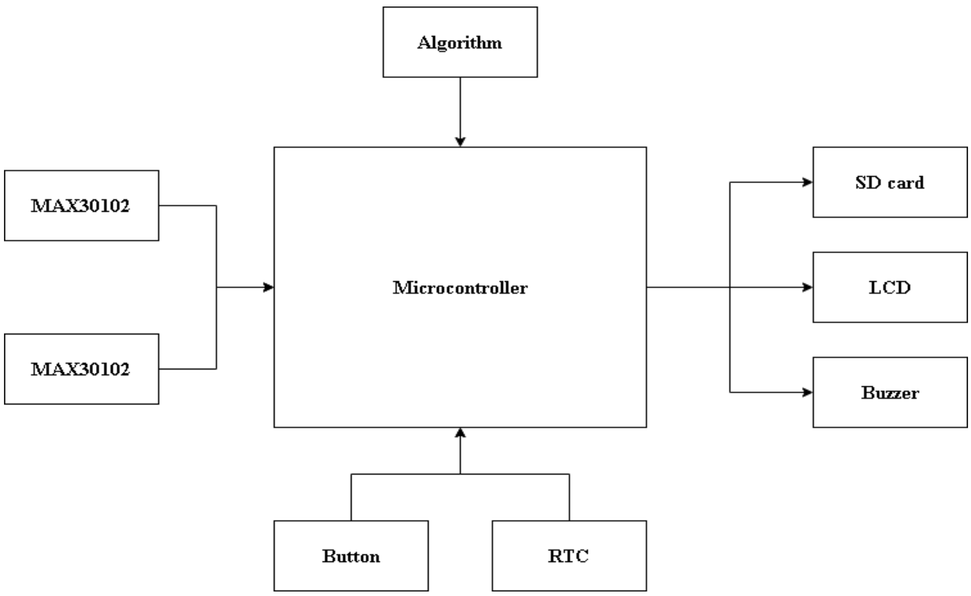

Figure 2. *Diagram Block of System*

From Figure 2, we get a system that has four inputs such as two MAX30102 to measure the SpO2 value, one RTC to get the timestamp of the data, and some button to select some features in the system. This system use a microcontroller to control the whole process from the given algorithm. Some of the algorithm is to turn the buzzer on if the measurement result is below 60. For the output, there are three component used. The microSD to store the realtime data and show the previous data, a buzzer as a reminder if the measurement result is below 60, and a LCD to display the current measurement and previous measurement of the user.

3.2. Finished Product

From the design, we develop a system that uses Arduino Mega as microcontroller. The prototype can be seen in Figure 3.

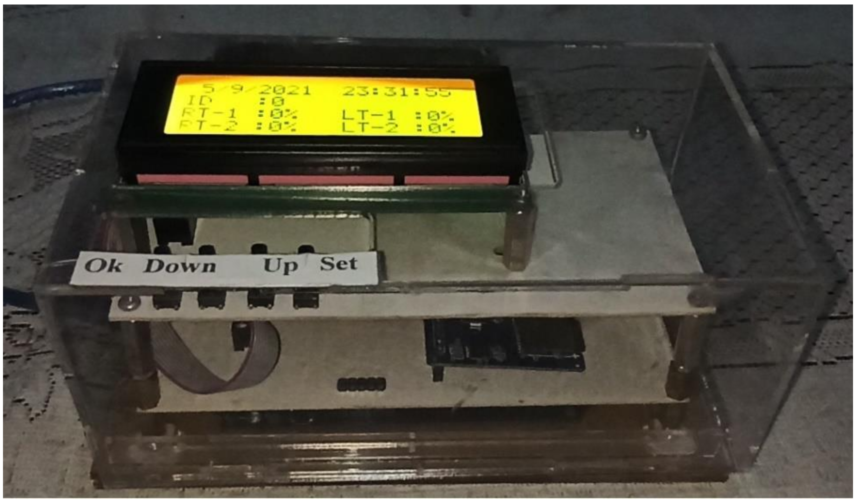

***Figure 3**. The prototype*

The LCD can be used to display timestamp, user id, realtime measurement value, and previous measurement value. The display can be seen in Figure 4.

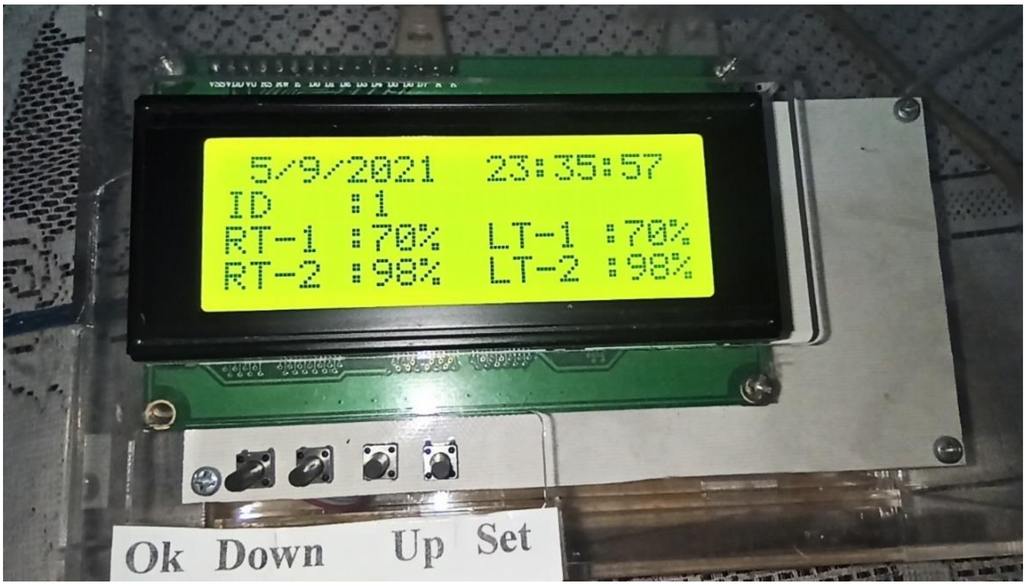

***Figure 4.** LCD Display*

The RT and LT display the real time and previous measurement value simultaneously. The RT-1 means the real time measurement value of sensor 1 and RT-2 means the real time measurement value of sensor 2 while LT-1 means the previous measurement result of sensor 1 and LT-2 means the previous measurement result of sensor 2. As for the buzzer, we conduct a test to see wether if the algorithm is running or not. The test conducted by giving a various value to the system by changing the output value manually in the source code. The test result can be seen in Table 1.

Table 1. *Buzzer algorithm test result*

Number of measurement	MAX30102 Right	MAX30102 Left	Buzzer
1	0%	10%	On
2	30%	50%	On
3	50%	55%	On
4	70%	76%	Off
5	80%	98%	Off
6	97%	99%	Off
7	98%	98%	Off
8	97%	100%	Off
9	99%	100%	Off
10	97%	100%	Off

From Table 1 we know that the algorithm running well because it turn the buzzer on everytime the measurement value is below 60.

3.2. Calibration Process

For the calibration process, we used Mindray Oxymeter as the calibrator. The calibration held by using both calibrator and developed device on the same hand for 30 minutes and compare the measurement output every 30 seconds. The calibration process' data can be seen in Figure 5 and Figure 6.

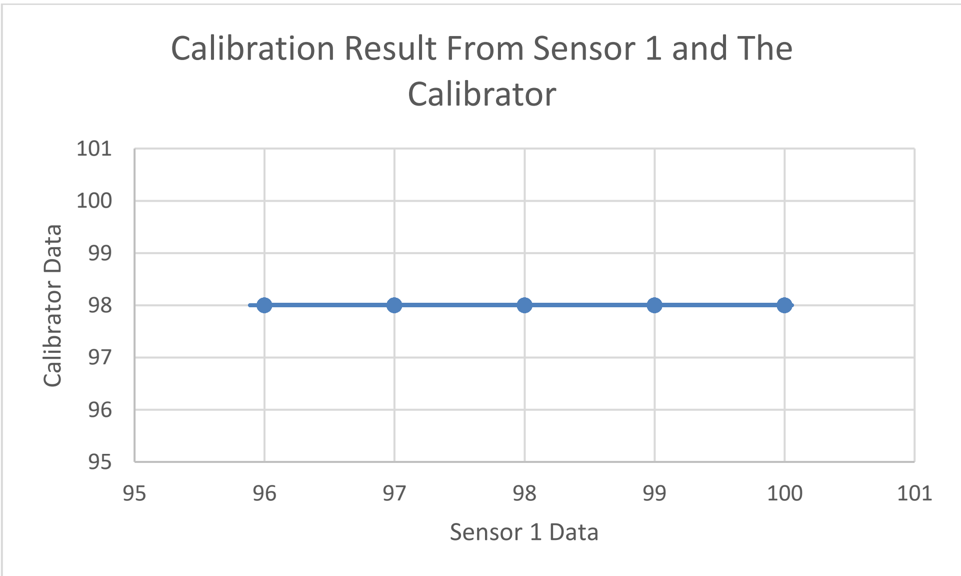

Figure 5. *Calibration data from sensor 1 and calibrator*

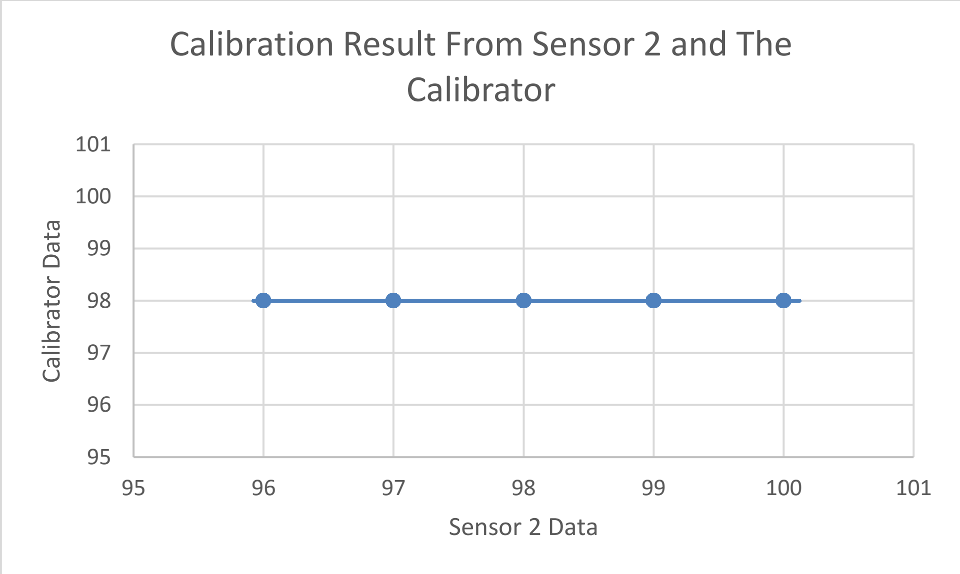

Figure 5. Calibration data from sensor 2 and calibrator

From Figure 5 and Figure 6 above, we get the difference in data from our developed device and the calibrator. The next step is check the error statistically to determine wether the developed device has passed the error standard for medical device or not. The results can be seen in Table 2.

Table 2. *Calibration Result*

Sensor1-Caibrator	Sensor2-Calibrator
Average Different	
0.033	0.183
Maximum Different	
2	2
Minimum Different	
0	0

From Table 2, we get the maximum different of 2% for sensor 1 and sensor 2. By the standard from Ministry of Health [10] which is maximum of 2% error, the developed device has passed the error standard for medical device and can be used to measure SpO2.

4. Conclusion

This research has successfully develop a SpO2 monitoring system that can be used to measure the amount of SpO2 from both right and left hand of the user at the same time. This system can be used to detect an early-stage stroke patient. This system also provide an alarm as a reminder if the amount of SpO2 measured is below 60. MicroSD has successfully used to store the measurement data for some time span.

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