Long Distance Dual SpO2 Monitoring in Premature Babies Via Bluetooth Communication

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Abstract
Monitoring the baby's health status is very important, especially for babies born prematurely. Measurement of oxygen saturation levels in newborns can help detect early congenital abnormalities in infants. The baby is usually placed in a baby incubator located in a special treatment room. The room is separate from the supervisory nurse's room. This study aims to design an equipment system to monitor oxygen saturation conditions in newborns continuously using equipment that is connected wirelessly between the baby room and the nurse's room. This study developed a long distance SpO2 monitoring equipment from 2 babies in 2 infant incubators in a separate room with a monitoring room. Each incubator has an SpO2 detector which simultaneously sends data to a PC in the nurse's room. The Neonatal Fingertip sensor is attached to the baby's big toe then the signal and the value of SpO2 obtained are sent by the microcontroller to the PC via Bluetooth communication HC-O5. The PC will display the oxygen saturation (SpO2) values and signals from the 2 incubators. Based on the results of tests and measurements in 5 different patients with a pulse oximeter comparison, the difference value of 1% in each patient's results was obtained. This system has successfully monitored SpO2 of 2 babies in 2 baby incubators from separate rooms. The results of this study are very helpful in facilitating the work of paramedics in monitoring the vital conditions of newborn babies.

Keywords: Monitoring, SpO2, Fingertip Neonatal, HC-05, Arduino

I. INTRODUCTION
Health monitoring systems are highly dependent on technology [1]. In an agency such as a hospital, the existence of a monitoring tool is very necessary to monitor the condition of patients who require rapid treatment so that any changes to the patient's condition must always be monitored [2]. This also applies to monitoring premature babies. Preterm birth was defined as all births before 37 complete gestational weeks [3]. According to another study, as many as 20 million babies are born prematurely, and it is estimated that 450 of them die every hour [5]. Premature birth is one of the main risk factors for newborn mortality [6]. Premature babies experience more complicated health conditions and cause death [7]. In contrast to term babies, premature babies are a group of babies who are at high risk. This is caused by the immaturity of the body's organ systems in premature infants, such as the lungs, heart, kidneys, liver, and digestive system [8]. Baby incubators play an important role in saving the lives of premature babies [9]. Continuous monitoring of health parameters is also very important for premature infants admitted to the neonatal intensive care unit (NICU) in hospitals [10]. In the neonatal intensive care unit (NICU), heart rate, respiratory rate, and oxygen saturation are vital signs (VS) that are continuously monitored in infants[11], due to the importance of oxygen supply in the human body. 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. So that the lack of oxygen is at risk of damage to important organs in the body and death can be overcome [12]. The percentage of normal oxygen saturation in humans is the same at all age levels, ie 95%-100% for both newborns and the elderly [13]. Oxygen saturation levels in newborns are very important to know because when the oxygen saturation levels in newborns are low, it is necessary to watch out for hemodynamic abnormalities in the baby. Measurement of oxygen saturation levels in newborns can help detect early
congenital abnormalities in infants [14]. Therefore, SpO2 levels must be continuously monitored [15].

Currently monitoring of premature babies who are placed in the baby incubator is still done manually, so medical personnel in the neonate room must visit the babies in the baby incubator one by one periodically to monitor the vital conditions of the babies inside. Therefore, to reduce the workload of medical personnel, and reduce the possibility of data reading errors in patients, a device that can monitor vital conditions is needed, especially the SpO2 vital parameters of several infants at a distance far enough, so that medical personnel can continuously monitor vital conditions, baby in one place.

In 2015 Mr. Mamun conducted research by making a wireless monitoring system for temperature, humidity, and light intensity in infant incubators [16]. In this study, there was no monitoring used for infant SpO2. In 2015 Pallerla Akhsay Kumay et al conducted a study by making real time monitoring and control of infant incubators using LabVIEW [17]. In this study, the vital condition of the baby in the incubator was monitored closely. In 2016 M.Priya et al conducted a study by creating a wireless patient health monitoring system using LabVIEW [18]. The study used zigbee communication and was intended for adult patients. In 2017 Sujithanand A et al conducted a study by making a baby incubator monitoring system with remote access but without the vital parameter SpO2 [19]. In 2017 Vikramsingh R. Parihar et al conducted a study by creating a heart rate and temperature monitoring system for remote patients using Arduino so they have not monitored SpO2 parameters [20]. In 2018 Lanny Agustine et al conducted a study by making a heart rate monitoring device for arrhythmias using an android-based pulse oximeter sensor [21]. Researchers made a BPM monitoring system for arrhythmic patients using a pulse oximeter sensor but did not calculate SpO2. In 2019 Alexander Guber et al conducted a study by making pulse oximeter with wrist sensor that allows prolonged patient monitoring [22] Wrist sensors are not suitable for use in infants. In 2021 Dr. B. Annapurna et al conducted a study to implement the max 30100/30102 sensor for the detection of viral infections based on the SpO2 pattern and heart rate [23] but the sensor is not suitable for use in newborns.

Based on the identification of the problem, the researcher wants to design a remote SpO2 monitoring equipment for 2 babies in 2 baby incubators in a separate room from the monitoring room. The Neonatal Fingertip sensor is attached to the baby's big toe then the signal and the obtained SpO2 value are sent by the microcontroller to the PC via Bluetooth communication HC-05. The PC will display the oxygen saturation (SpO2) values and signals from the 2 incubators. The nurse can monitor the SpO2 condition of 2 babies without having to go to the incubator.

II. MATERIALS AND METHODS

A. Experimental Setup

In this study, 2 modules were made that can monitor 2 patients (infants) at the same time that sends SpO2 signal data to 1 PC with a considerable distance (1-5m). Data collection was carried out on 5 respondents with variations in the distance between the baby incubator and the PC.

1) Materials and Tool

This study uses 2 SpO2 sensors (Neonatal Fingertip). The two sensor leads will be processed by Arduino and sent using the HC-05 and then displayed simultaneously on a PC.

2) Experiment

In this study, after the module was successfully created, a test was carried out using pulse oximetry to compare the SpO2 results.

B. The Block Diagram

![Fig. 1. The block diagram of the system](image-url)

The system was built based on the block diagram as shown in Fig.1. Power Supply provides power for all components in one incubator. Neonatal fingertip serves to capture the SpO2 signal from the big toe of premature babies. The signal is processed by the Analog Signal Processing circuit and forwarded to the Arduino Microcontroller. Arduino Program runs Arduino Microcontroller to display SpO2 value on LCD and sends SpO2 signal to PC via Bluetooth Transmitter.

PC program runs the PC so that the PC receives the SpO2 signal data via the Bluetooth Receiver and displays the SpO2 signal from the two babies on the PC screen.
C. The Flowchart

The process on the baby incubator and the program on the Arduino are built based on a flowchart as shown in Fig. 2. The SpO2 sensor will be used to take input data in the form of oxygen saturation values and signals. When the sensor is installed, it detects the level of oxygen in the blood (SpO2) and to get the lead value on the sensor, the results will be processed in an analog signal processing circuit.

The output of the analog signal processing circuit will enter and be processed by the microcontroller. In the microcontroller there is processing of incoming data from the output of the analog signal processing circuit, such as changing the shape of the signal from analog to digital, determining the signal reference automatically and calculating the SpO2 value. Furthermore, the microcontroller will send the processed data to the PC via bluetooth communication. Finally, the microcontroller will display the SpO2 value data on the LCD.

III. RESULTS

In this study, measurements were made on random respondents. Measurement results obtained normal SpO2 percentage for each respondent, which is between 97%-100%

1) Calculation of SpO2 Value

Fig. 4 is the physical form of the system that has been made, in the picture it can be seen that each module is being installed with 3 sensors, namely the SpO2 sensor, temperature sensor and BPM sensor (temperature and BPM are not discussed here). The technique of taking the SpO2 signal can be explained from Fig. 5 below.

Fig. 5 shows the process that occurs in the analog signal processing circuit. There is a 1 KHz astable circuit that functions to regulate the on and off of the red lamp and infrared, the circuit will be active alternately by providing logic 1 and logic 0. The output of the astable circuit is connected to a module installed on the baby incubator is already connected to the PC, the wireless module on the PC will function as a receiver. The data received by the wireless module contained in the PC will be prepared for display. Next the PC will display the SpO2 value and signal on the screen.
transistor circuit that functions as a driver for the photodiode in the neonatal fingertip sensor. So the sensor will work to detect the blood flow that passes through the sensor according to the logic given. Then, the resulting output will be connected to a demultiplexer circuit which will separate the output of the finger sensor leads into an infrared signal and a red lamp signal. This circuit serves as a switching so that no output comes out simultaneously. The demultiplexer output is also an input to the BPF filter circuit to separate the output of the finger sensor leads into an infrared signal and a red lamp signal.

Furthermore, the process of calculating the value of SpO2 can be seen in Fig.6. The first process is to calculate the multiplication of AC RED and DC IR. Then calculate the multiplication of AC RED and DC RED. Furthermore, the results of the first process are divided by the results of the second process. The result is multiplied by 25 and subtracted by 110. The final result is the SpO2 value.

![Fig. 5. The Analog Signal Processing of SpO2](image)

![Fig. 6. The Calculation Flowchart of SpO2 Value](image)

Then the data (signal and value) of SpO2 will be sent by the microcontroller to the PC via Bluetooth HC-05.

2) The Measurement Result

The validation of the SpO2 value shown in the Delphi programming was compared with the pulse Oximetry device. The error was showed in Table I (for incubator 1) and Table II (for incubator 2).

| Respondent | Error(%) |
|------------|----------|
| 1          | 2.91     |
| 2          | 0.99     |
| 3          | 0.99     |
| 4          | 0        |
| 5          | 1.96     |

| Respondent | Error(%) |
|------------|----------|
| 1          | 0.97     |
| 2          | 0.99     |
| 3          | 0.99     |
| 4          | 0.98     |
| 5          | 0.97     |

TABLE III. THE TEST RESULTS OF THE SUCCESS OF DATA SENDING TO THE MEASUREMENT DISTANCE
Tables 1 and 2 are data recorded in each incubator with a neonatal fingertip sensor placed on the tip of the respondent’s right big toe and compared directly with pulse oximetry placed on the tip of the left big toe. In each respondent there is a difference of 1% against the comparison.

The weakness of the system that has been built is that it can only monitor two incubators and the furthest distance is 3 meters with obstacles.

The results of this study are very helpful in facilitating the work of paramedics in monitoring the vital conditions of newborn babies.

V. CONCLUSION

Based on the results of the discussion, it can be seen that a system with a neonatal fingertip sensor can perform its function in displaying oxygen saturation values and signals. The bluetooth module also works well, so the system that has been created can monitor 2 patients (infants) simultaneously with a long distance. Far enough in accordance with the plans that have been made. The average error of measurement is 1%. The next development is to increase the number of incubators that can be monitored and try to use a more powerful wireless system.

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