Microcontroller Based Portable Incubator Monitoring Tool with Short Message Service (SMS) notifications

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Abstract. The aim of this research was applied a microcontroller, temperature sensor, weight sensor, heart rate sensor and GSM module to monitoring and notification of the condition of premature babies in portable incubators. The hardware used consists of a DS18B20 sensor, Load Cell, Pulse Heart Rate Sensor, Buzzer, LCD and SIM800L Module. The results showed the Pulse sensor and DS18B20 sensor could measure and detect the baby's heart rate and baby temperature. The result was on the LCD with an average error of 4.354% for heartrate and 1.437% for temperature. The loadcell sensor can detect weight with an error of 2.16%. The duration of sending SMS to Smartphone is 8s for each delivery. SMS was sent if the baby weak and critical condition.

1. Introduction

Globally 1.1 million children passed away in the first month of life in 2013. Almost 3000 newborn deaths every day, all child deaths under the age of 5-years around 47 %, up from 40% in 1990. Nearly 965,000 of all under-five child deaths are among newborn infants, babies in their first 28 days of life or the neonatal period. 125,000 child death before 1st birthday, and child mortality under 5 [1]. The babies with abnormal condition after they were born would help survive in new environmental using the incubator while in the neonatal intensive care unit (NICU). Premature babies, also known as preemies, put in an incubator with temperature in the incubator is controlled to keep baby's body temperature where it should be. After premature baby was moved to the incubator, lie or she may follow a number of tests such as measuring the amount of oxygen in child’s blood or oxygen saturation monitoring, collected through a needle or a heel stick inserted into a vein and Monitoring of baby's vital signs, sensors may be taped to the baby's body to monitor blood pressure, heart rate, breathing and temperature[2][3] and body weight [4]. It has been many Infant Incubator Project, one of these the infant incubator made by Prof. Dr. Ir. Raldi Artono Koestoer [5]. An infant-incubator using natural circulation and natural convection system. Profiting the Buoyanci force due to the difference of temperature between upper-side and lower-side, hot-air flow to the cabin where the baby’s sleeping, It flows by itself without any force neither a fan or blower. Smallest power of 20-40 Watt will be sufficient to make a convenient limited environment for the newborn baby. And due to the small energy supply, the incubator doesn’t need to be equiped by the electronic control system. In dry season of Indonesian climate, less power of 20 W can be used. But in the middle of rainy season due to lower average ambient temperature, the power of bulb heater should be increased to 40 Watts. Many similar studies have also been conducted.
in general, the research conducted is more on monitoring [8] [10] and controlling temperature and humidity[6][7][11], whereas in addition to the temperature of the incubator the condition of the weight and heart rate are also important parameters to see the condition of premature babies health [4]

We designed and developed a monitoring system for measuring body temperature, heart rate and premature baby weight, all measurement data is displayed on the LCD and stored on the database server. The condition of the baby inside the incubator can be monitored by the parents and the medical team on the smartphone by utilizing the internet facilities through an Android-based website and mobile application in real time. The Websites will display baby identity and result of all parameter data measurement which known as medical record. Incubators made using the Grashof method based on research [5].

Figure 1. The proposed infant incubator monitoring system

On this study we only discussed three parameters of the system we made, namely heart rate, body temperature and baby body weight. Whole data is displayed on the LCD. The tool will send an SMS notification to the doctor if the baby is in a weakening or critical condition and the weight of a premature baby is normal. By this tool, the baby put in the incubator can be monitored in detail and deeply, while the doctor and the parents of the baby are easier to monitor.

2. Research Method

2.1. Block diagram System

This section discuss about the design and production of the system and how the system works not only in hardware and but also software. Figure 2 is a block diagram of the tool to be created.

Figure 2. Tool Design Diagram Block

This tool has 3 measurement parameters, namely heart rate, body temperature and weight of the baby, with a device controller was a microcontroller. Measuring heart rate in infants is done by placing the heart sensor on the baby's wrist. Temperature sensor serves to measure the baby's body temperature placed in the armpit, where the normal body temperature is measured at 36OC-37.5OC per minute. The
weight sensor is placed as a baby's sleeping pad which will weigh the baby's weight regularly. The microcontroller functions as a signal / data processor from the input variable. The signal / data is then processed and will produce output variables and are displayed on the LCD. if abnormal condition detected the buzzer will sound, the doctors will receive SMS, notice that condition of the baby is abnormal through GSM modules SIM800L V.2.

2.2. Circuit design

Figure 3 shows the electronic circuit of the device. This system consists of pulse sensors, DS18B20 sensors and Load Cells. Light was detected by pulse sensors. While this sensor was placed on skin’s surface, organs and tissues (skin, bones, muscles, blood) would absorb or reflected the light of sensor but if they are thin enough some light would pass through body tissues. If the light intensity amount regarding the pulse sensor remains, then the signal value would the middle of the 10-bit ADC range be around 512. The ADC value depend on the light intensity. The signal produced by the sensor a wave called photoplethysmogram (PPG) as seen in Figure 4. PPG in the medical world is used to measure the respiratory rate [13] and heart rate[14].

![Circuit Diagram](image)

Figure 3. Electronic circuit monitoring system for premature infants

Blood would throughout the body while the heart pumps, every pulse that occurs is accompanied by the appearance of pulse waves like shock waves travel through arteries to the capillary layer of the hand (fingers), where the pulse sensor is installed. Blood speed flows slower than pulse waves. The number of heart beats per minute (BPM = beat per minute) is determined by sensor trough dividing 60000 (in milliseconds), the average value of ten IBI (inter beat intervals) that have been passed. IBI is the time difference between one point and the next point with the point value is 50% of the value of P (peak) minus T (valley) when the graph occurs extreme increase. Table 1 indicate the limits of a baby's heart rate from 1 to 60 days.

| Baby Age | BPM (Beat Per Minute) | Explanation |
|----------|-----------------------|-------------|
| 1-2 days | 123-159/Minute        | The activity of baby or child would influence the heart rate. For example, the heart rate |
can reach 180 times/minute while crying or pain. This heart rate would increase if child has fever or dehydration.

1-2 months 121-179/Minute

Figure 4. Pulse Sensor

Pulse sensor has 3 different purpose pins. Pin 1 was a data pin connected to pin A0 on the microcontroller. Pin 2 was Vcc resource and Pin 3 was Ground. To measure the baby's body temperature, the waterproof DS18B20 temperature sensor is used. Pin 1 is connected to Vcc, pin 2 is connected to ground and finally pin 3 is connected to pin D6 on the microcontroller. The three pins use a pin header that can be directly connected to the microcontroller. Load cell sensors are used to measure body weight. The load cell was put as a heavy sensor with 4 different function pins. The load cell used is equipped with an amplifier module, the 24X HX711 ADC module. The working principle of the loadcell sensor and hx711 module is when the baby put in, at that time the baby will put pressure or load on the loadcell sensor. The changing of force to the sensor would effect to the resistance and a voltage, so the value of the load also changes. This change in load value is used to inform the maximum value has been reached or not. Pin 1 connected to a + 5V source, pin 2 for data directly to pin A10 on the Atmega 2560 microcontroller, pin 3 as a clock which is also directly connected to the A11 pin microcontroller, while pin 4 is used for ground. To display the sensor readout value on the LCD used I2C LCD, this module is controlled serially synchronously with the I2C / IIC (inter integrated circuit) protocol or TWI (Two Wire interface) with addresses of 0x27 and 0x37. If the baby's condition is abnormal, the buzzer will sound as an indicator for the baby's parents. The doctors would receive an SMS if the condition of patient was abnormal through the SIM800L V.2 GSM module. The condition of an abnormal baby can be seen in table 2.

Table 2. Abnormal baby condition

| No | Age (Year) | Heart rate (BPM) | Body Temp. (°C) | Cond.  |
|----|------------|------------------|----------------|-------|
| 1  | 1-2 days   | <123             | < 35           | weakened |
|    | 3-6 days   | < 129            | < 35           |       |
|    | 1-3 weeks  | < 107            | < 35           |       |
|    | 1-2 months | < 121            | < 35           |       |
| 2  | 1-2 days   | > 159            | > 37.5         | weakened |
|    | 3-6 days   | > 166            | > 37.5         |       |
|    | 1-3 weeks  | > 182            | > 37.5         |       |
|    | 1-2 months | > 179            | > 37.5         |       |
| 3  | 1-2 days   | > 159            | < 35           | critical |
|    | 3-6 days   | > 166            | < 35           |       |
1-3 weeks > 182 < 35
1-2 months > 179 < 35

The monitoring tool algorithm can be seen in Figure 5. Data from the heart rate sensor, body temperature and body weight are then processed on the Arduino, and the sensor value will be displayed on the LCD. There are five conditions. The first condition of the value of the sensor data indicates under normal circumstances. The second to four conditions indicate the condition of the baby is weak and critical. If in this condition the buzzer on the device will be active and alert text will be sent to the doctor / health worker. Condition five is the condition of reading the baby's weight with a limit of 5000 grams, if the baby's weight has 2500 gram, the LCD show "the baby comes out of the incubator and the sms will be sent to the doctor / health worker"

Note : sign * can be seen in table 3

Table 3. Description of the condition of the baby on the Flowchart

| Condition | Heart rate | Body Temperature | Weight |
|-----------|------------|------------------|--------|
| 1*        | 1-2 days : 123-159/Minute  
3-6 days : 129-166/Minute  
1-3 weeks : 107-182/Minute  
1-2 months : 121-179/Minute | | 35-37.5 |
| 2*        | 1-2 days < 123/Minute  
3-6 days < 129/Minute  
1-3 weeks < 107/Minute  
1-2 months < 121/Minute | | < 35 |
| 3*        | 1-2 days > 159/Minute  
3-6 days > 166/Minute  
1-3 weeks > 182/Minute  
1-2 months > 179/Minute | | > 37.5 |
| 4*        | 1-2 days > 159/Minute  
3-6 days > 166/Minute  
1-3 weeks > 182/Minute  
1-2 months > 179/Minute | | < 35 |
| 5*        | | | 2500 gram |

Figure 5. Flowchart monitoring tool
3. Experiment Results

This section explain the results of testing of the tools that have been made will be shown. First, testing of the tool as a whole is done. The results of the third reading of the sensors displayed on the LCD are then compared with manual measuring devices. Furthermore, testing system alerts, buzzers and SMS will be active according to the conditions that have been determined. Figure 6 is a picture of the tool as a whole.

![Picture of the tool as a whole](image)

Figure 6. Testing Device for monitoring heart rate, body temperature, weight of premature babies

3.1 The Baby Heart Rate and Body Temperature Series (circuits)

This series of heart rate and body temperature consists of pulse sensors, microcontrollers, buzzers and LCDs. The reading of the BPM value (Bit Per Minute) was periodically and is in the range 50 / minute - 180 / minute, if the range of readings detected is above the specified range, the buzzer would on as a warning sign and the LCD show the BPM values. The number of samples of the people tested were 10 babies and children of different ages. Testing is carried out for 60 seconds / person. Tests and measurements were made by compared the measurements results between using a Pulse Oximeter and the results of circuit in this research. Pulse Oximeter used for premature babies or patients in special conditions to measure heart rate (HR = heart rate). The heart rate measure by place a pulse sensor at the tip of the index finger.

| Testing (person number) | Age (month) | Measurement result using Pulse Oximeter (BPM) | Measurement circuit result using Pulse Sensor on LCD (BPM) | Error (%) | Measurement result using Thermometer Digital (°C) | Measurement result using Sensor DS18B20 on LCD (°C) | Error (%) | Buzzer |
|-------------------------|-------------|-----------------------------------------------|----------------------------------------------------------|-----------|-----------------------------------------------|-------------------------------------------------|-----------|--------|
| 1                       | 4           | 108                                           | 112                                                      | 3.70      | 36.9                                          | 36.3                                            | 1.62      | off    |
| 2                       | 8           | 177                                           | 181                                                      | 2.25      | 38.1                                          | 37.7                                            | 1.04      | on     |
| 3                       | 13          | 111                                           | 117                                                      | 5.40      | 37.3                                          | 36.8                                            | 1.34      | off    |
| 4                       | 14          | 101                                           | 106                                                      | 4.95      | 37.4                                          | 36.8                                            | 1.60      | off    |
| 5                       | 17          | 113                                           | 118                                                      | 4.42      | 37.4                                          | 36.9                                            | 1.33      | off    |
| 6                       | 21          | 103                                           | 107                                                      | 3.88      | 37.4                                          | 36.9                                            | 1.33      | off    |
| 7                       | 24          | 89                                            | 93                                                       | 4.49      | 37.6                                          | 37                                              | 1.59      | off    |
| 8                       | 35          | 98                                            | 103                                                      | 5.10      | 37.6                                          | 37                                              | 1.59      | off    |
| 9                       | 40          | 94                                            | 98                                                       | 4.25      | 37.3                                          | 36.8                                            | 1.34      | off    |

**Table 4. Test results and measurements of the baby's heart rate and body temperature**
The average error can be seen in Table 4, this shows the results of testing and measuring the heart rate and temperature running well. DS18B20 pulse sensors could measure and detect heart rate, infant body temperature and display on LCD with an average error of 4.354% and -1.437%. Table 4 shows, testing was carried out with qualifying infants 4 - 50 months old. In the range of babies from 4-17 months the heart rate measured using pulse Oxymeter 103-108 BPM, while in the series 107-112 BPM. In the infant range of 21-50 months a heart rate measured using pulse Oxymeter 89-98 BPM, while in the 93-107 BPM series. Table 4 also shows the active buzzer when the heart rate is >179 BPM and body temperature is above 37.5 ° C in 8 months old babies.

3.2 Baby Weight Measuring Series
The weight measuring circuit or series consists of loadcell sensors, HX711 amplifiers, microcontrollers, and LCD. Load cell sensor and amplifier HX711 to retrieve baby's weight data, process data by microcontroller, and LCD show the result of measurement the baby weight data. It shows information about the normal condition of baby's weight so the baby can be removed. For loadcell testing by giving different loads were 500 grams, 1000 grams, 1500 grams, 2000 grams, 2500 grams and 3000 grams. The load cell output voltage was too small, so the HX711 module was used as an amplifier as well as an analog data converter from load cell to digital data before this sensor connected to microcontroller. Load cell programming using a library of HX711 modules on Arduino and the digital output will be converted by an Arduino microcontroller through the HX711 library to a heavy scale. The test results and measurements of the weight measuring circuit using loadcell sensors show in Table 5.

| Load Weight (gram) | Test | Result of Testing (gram) | Average Weight of measure (gram) | Error (%) | LCD Indicator |
|-------------------|------|--------------------------|-------------------------------|-----------|---------------|
| 500               | 1    | 515                      | 512.8                         | 2.5       | _             |
|                   | 2    | 513                      |                               |           |               |
|                   | 3    | 512                      |                               |           |               |
|                   | 4    | 513                      |                               |           |               |
|                   | 5    | 511                      |                               |           |               |
| 1000              | 1    | 1028                     | 1027                          | 2.7       | _             |
|                   | 2    | 1028                     |                               |           |               |
|                   | 3    | 1027                     |                               |           |               |
|                   | 4    | 1025                     |                               |           |               |
|                   | 5    | 1027                     |                               |           |               |
| 1500              | 1    | 1532                     | 1530                          | 2         | _             |
|                   | 2    | 1530                     |                               |           |               |
|                   | 3    | 1527                     |                               |           |               |
|                   | 4    | 1528                     |                               |           |               |
|                   | 5    | 1535                     |                               |           |               |
| 2000              | 1    | 2045                     | 2041                          | 2.1       | _             |
|                   | 2    | 2038                     |                               |           |               |
|                   | 3    | 2042                     |                               |           |               |
|                   | 4    | 2041                     |                               |           |               |
|                   | 5    | 2039                     |                               |           |               |
| 2500              | 1    | 2539                     | 2542.8                        | 1.7       | baby out of the incubator |
|                   | 2    | 2542                     |                               |           |               |
|                   | 3    | 2540                     |                               |           |               |
|                   | 4    | 2545                     |                               |           |               |
Testing is done by compared between the load measured data and the loadcell sensor with reference to the real weight of the load as shows in table 5. The measurement result of loadcell sensor data and the circuit works well. Loadcell sensor could detect the weight measured by the pressure or the weight measured through the LCD. When measuring with a weight of 500 grams, error is 2.5% of the actual load weight, 2.7% for 1000 grams, 2% for 1500 grams, 21% for 2500 grams, 2500 gram was 1.7%, and 2% for 3000 grams. So that the average error of the measurement of the weight of the load is 2.16%. In Table 5 we can also see that when testing and measuring the weight of the load is 500, 1000 and 2000 grams and LCD have no information. While the weight were 2500 and 3000 grams the LCD have information "baby out of the incubator" will appear. This inform the baby's weight has on normal weight condition means the baby can be put out the incubator.

### 3.3 GSM Modem Series (SIM800L)

Testing of the SIM800L GSM Module is done to find out that this GSM modem can work properly. To be able to communicate between networks with a microcontroller module must be set when and to what number the short text message will be sent and the contents of a short text message that want to send. It send the conditions, namely the weakening and critical state. The duration of sending messages to a smartphone is around 2 seconds. The time depends on what we want by setting the delay. For warnings of weakening conditions and critical SMS sending takes place every 1 second and continues repeatedly before undesirable conditions occur in the patient. After the sensor reads the patient's condition the form of message / SMS that will be received to the medical staff's smartphone. The form of the signal sent by Arduino to the GSM SIM800L module. It is done to see the signal sent from the Arduino TX pin to the SIM800L GSM module. This test is done by sending the command "AT + CMGF" which is used by Arduino as the SMS sender command to the SIM800L module. The output voltage on SIM800L is 5 V, with the duration of sending SMS to Smartphone that is for 8s per shipment. SMS is sent if the patient is weak and critical can be seen in Figure 7.

![Figure 7. SMS notification of baby's condition if it is not in normal condition](image)

### 4. Conclusion

Testing results shown the whole series can work well: DS18B20 pulse sensors and sensors detects heart rate and body temperature measured, the buzzer active and sent text as a danger sign if the baby's
heart rate and body temperature are read above the specified range, loadcell sensor detects the weight measured, and displays inform the baby can be taken from inside incubator if the baby has weight more then 2500 grams. So, the tool can be implemented for babies in the incubator.

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