Manuscript received October 8, 2021; revised October 26, 2021; accepted November 6, 2021; date of publication November 7, 2021
Digital Object Identifier (DOI): https://doi.org/10.35882/ijeeemi.v3i4.3

Monitoring And Notification Tools on Portable Incubator with Microcontroller and Short Message Service (SMS)

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ABSTRACT Portable incubator was one solution to help premature baby. In general, the baby in the incubator monitored by observer manually. The aim of this research was applied a microcontroller, temperature sensor, weight sensor, heart rate sensor and GSM module to monitor and give notification the premature babies condition in portable incubators. The observation can be done by read the display on LCD and SMS. The hardware used consists of a DS18B20 sensor, Load Cell, Pulse Heart Rate Sensor, Buzzer, LCD and SIM800L Module. The results showed that the Pulse sensor and DS18B20 sensor can measure and detect the baby's heart rate, body temperature and are displayed on the LCD with an average error of 4.354% and 1.437%. 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 patient conditions weak and critical. This monitoring and notification tools hopefully can inform the condition of the baby in the incubator immediately.

INDEX TERMS Incubator, Microcontroller, Short Message Service, Load Cell.

I. INTRODUCTION

Globally 1.1 million children died in the first month of life in 2013. There are approximately 3000 newborn deaths every day, amounting to 47% of all child deaths under the age of 5-years, 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 deaths before 1st birthday, and child mortality under 5 [1]. To help these babies survive outside of the womb, they will be placed in an apparatus known as an incubator which provides the newborn the environmental conditions needed to thrive 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 is moved to the incubator, he or she may undergo a number of tests. They are: Oxygen saturation monitoring measures the amount of oxygen in your child's blood, collected through a heel stick or a needle 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. Profitting 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 Watt 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 [6-12]. 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 heart rate and weight are also important factors to see the health condition of premature babies [4].

In this paper, we designed and built a portable monitoring and notification tool for body temperature, weight and heart rate on an incubator based on a microcontroller and SMS. The

incubator made using the Grashof method is based on research [5]. The aim of this study built and apply a microcontroller, heart sensor, weight, body temperature and SIM800L for monitoring the health condition of premature babies in the incubator. Using of this tool, the baby's condition can be monitored and also provide a warning about the baby's condition via SMS which will be sent to the medical personnel concerned.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

This study used ten normal people with age criteria 16-50 years, data collection was repeated six times. This study also uses an experimental method by comparing the measurement results of heart rate, weight and body temperature sensors with commercial tool.

1. MATERIALS AND TOOL

The material we use consists of a DS18B20 temperature sensor, Load Cell, pulse sensor, Arduino Mega 25660 microcontrollers, the LCD serves to display the results of temperature, weight and heart rate measurements that are read by the sensor and the SIM800L module serves to send processed data from Arduino in the form of SMS. In this study, the research tools we used were multimeter, smartphone and oscilloscope.

2. EXPERIMENT

In testing body temperature measurements, measurements are made by comparing the sensor measurement data to the digital thermometer measurement value. This temperature sensor is mounted on the armpit of an adult human. This weight meter consists of a loadcell sensor and an HX711 amplifier which functions to measure the baby's weight. In this measurement, the baby's weight is replaced by the weight of the sand bag with weights ranging from 1000 grams, 1200 grams, 1400, grams, 1600 grams, 1800 grams, 2000 grams, 2200 grams, 2400 grams, 2600 grams, and 2800 grams.

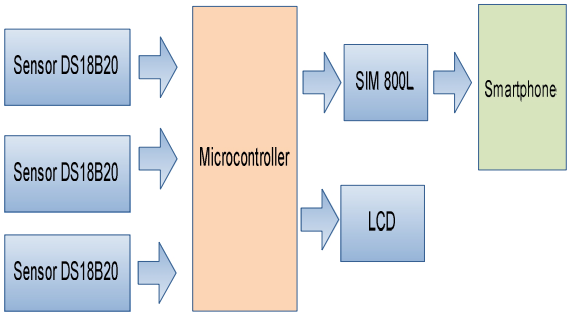

FIGURE 1. Experimental setup of Portable Incubator Monitoring Tool with Short Message Service (SMS) notifications

For heart rate testing, it consists of a Pulse Sensor, SIM800L as a notification that will send an SMS when the heart rate is less than 60 BPM or more than 110 BPM.

For the measurement of human heart rate using an adult human object. This test is done to find out how the heart sensor works (FIGURE 1). This test also aims to observe how accurate the measurement of human heart rate is by comparing the measurement results of the pulse sensor with an oximeter. In this experiment, measurements were made by placing a pulse sensor on the fingertip of an adult human hand.

B. THE DIAGRAM BLOCK

In this section, explained about the design and manufacture of the system and how it works both hardware and software. FIGURE 2 is a block diagram of the tool to be created. This tool has 3 measurement parameters, namely heart rate, body temperature and baby weight, with a microcontroller as a device controller. 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

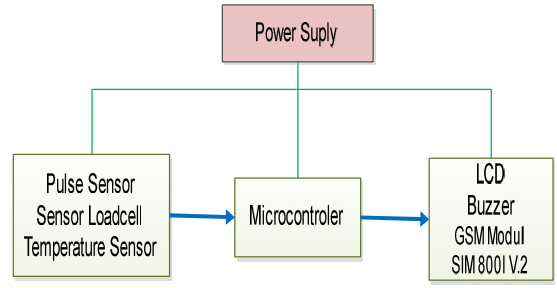

FIGURE 2. The Diagram Block of Portable Incubator Monitoring Tool with Short Message Service (SMS) notifications

C. HARDWARE DESAIN

The electronic circuit of the tool can be seen in FIGURE 3. This tool consists of pulse sensors [13-16], DS18B20 sensors [17-20] and Load Cells [21-23]. Pulse sensors work by using light. When this sensor is placed on the surface of the skin, most of the light is absorbed or reflected by organs and tissues (skin, bones, muscles, blood), but some light will pass through body tissues if they are thin enough. If the amount of light intensity regarding the pulse sensor remains, then the signal value will be around 512 (the middle value of the 10-bit ADC range). the greater the light intensity the higher the ADC value. The signal produced by the sensor produces a wave called photo-plethysmogram (PPG). PPG in the medical world is used to measure the respiratory rate [24] and heart rate [25].

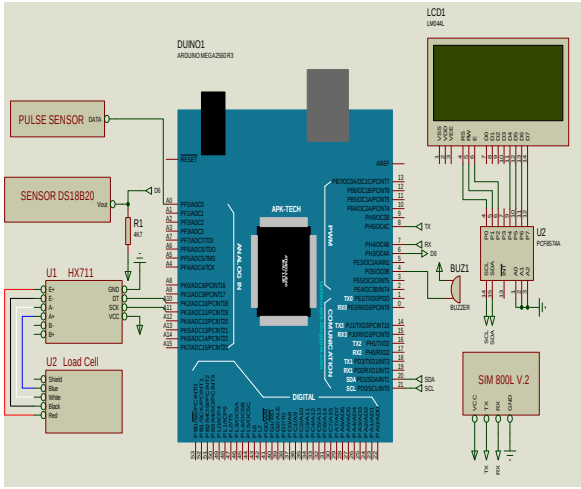

FIGURE 3. Electronic circuit of Portable Incubator Monitoring Tool with Short Message Service (SMS) notifications

When the heart pumps blood throughout the body, 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. Determination of the number of heart beats per minute (BPM = beat per minute) with this sensor is done by 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 shows the limits of a baby's heart rate from 1 to 60 days.

TABLE 1
BABY'S RANGE BPM

Baby Age	BPM (Beat Per Minute)	Explanation
1-2 days	123-159/Minute	Heart rate also depends on the activity of baby and child. For example, when crying or pain, the heart rate can reach 180 times/minute. When a child has fever or dehydration, heart rate also increases
3-6 days	129-166/Minute	
1-3 weeks	107-182/Minute	
1-2 months	121-179/Minute	

Pulse sensor has 3 different function pins. Pin 1 is used as a data pin connected to pin A0 on the microcontroller. Pin 2 is used as a Vcc resource and Pin 3 is used as a Ground. To measure the baby's body temperature, the waterproof DS18B20 temperature sensor is used. This sensor has 3 pins with different functions. 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. In this case the load cell is used 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. This will change the resistance caused by the change in force, changed to a voltage value, so that the value of the load also changes. This change in load value is used to tell the value has reached the maximum or not. Pin 1 is connected to a + 5V voltage source, pin 2 is used for data directly connected to pin A10 on the At mega 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 will receive an SMS if the patient's condition is 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. (0C)	Condition
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	

D. FLOWCHART

The monitoring tool algorithm can be seen in FIGURE 4. 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 reached 2500 gram, the LCD will display "the baby comes out of the incubator and the sms will be sent to the doctor / health worker. Programming in this study uses Arduino IDE. Programs can be seen in listings program 1 and 2. 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 (°C)	Weight (gram)
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

Listing Program 1: Monitoring and notification tools on portable incubator with microcontroller and short message service (SMS)

Declaration :

```
sensorSuhu.requestTemperatures();
    suhu = sensorSuhu.getTempCByIndex(0);
    berat = scale.getGram();
    weight = berat;
    jantung = BPM;
  Stringsuhu = String(suhu, 0);
    Stringberat = String(berat, 0);
 Stringjantung = String(jantung, 0);
```

Implementation:

```
  int str_lensuhu = Stringsuhu.length() + 1;
   int str_lenjantung = Stringjantung.length() + 1;
  int str_lenberat = Stringberat.length() + 1;
   sim.println("at+cmgf=1");
    if (suhu > 37.5 && jantung > 110)
    {
     if (count_sms < maks_sms) {
      sim.println("AT+CMGS=\"082288410xxx\"\r\n");
      delay(100);
      sim.print("\n\nKONDISI BAYI MELEMAH!!!");

     if (count_sms < maks_sms) {
      sim.println("AT+CMGS=\"082288410xxx\"\r\n");
      delay(100);
      sim.print("\n\nKONDISI BAYI MELEMAH!!!");
```

In this study, the there are five conditions and each condition the system will notify using SMS communication. The overall system was shown ini Flowchart (FIGURE 4)

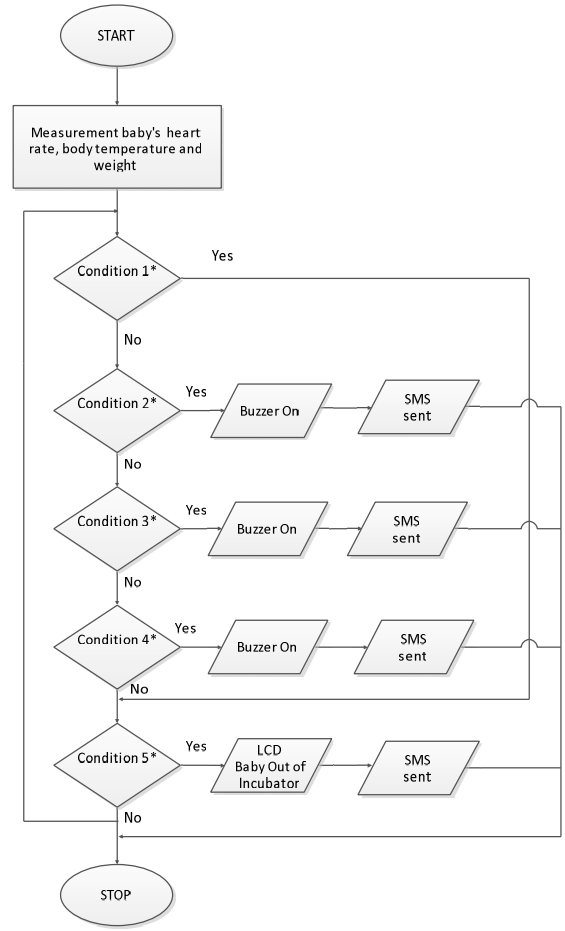

FIGURE 4. The flowchart of portable incubator monitoring tool with short message service (SMS) notifications

III. RESULT

In this section 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 5 and FIGURE 6 is a picture of the tool as a whole.

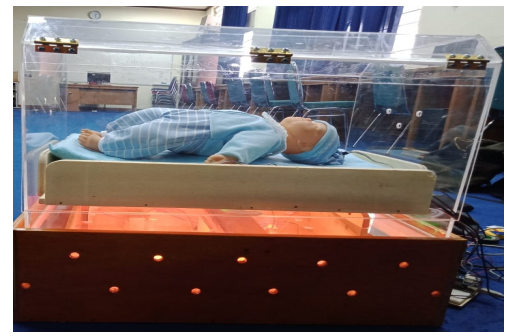

FIGURE 5. The incubator baby prototype

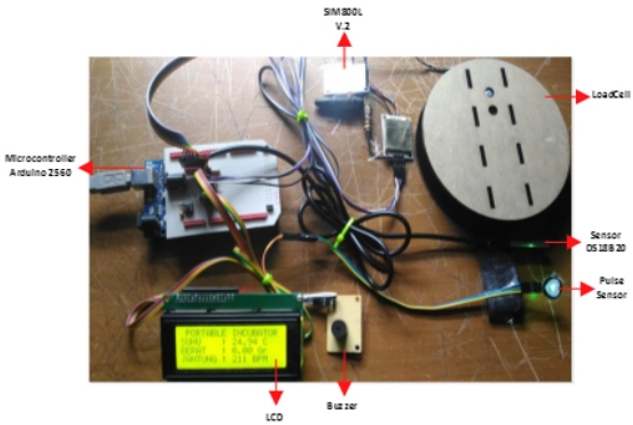

FIGURE 6. Device of Portable Incubator Monitoring Tool with Short Message Service (SMS) notifications

A. *TESTING HEART RATE AND BODY TEMPERATURE 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) is done periodically and is in the range 50 / minute - 180 / minute, if the range of readings detected is above the specified range, the buzzer will be active as a warning sign and the LCD will display readable BPM values (FIGURE 7). 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 comparing the results of measurements using a Pulse Oximeter with the measurement results of the heart rate measurement circuit made. Pulse Oximeter is a device used to measure heart rate (HR = heart rate) and is usually used for premature babies or patients in special conditions. Measure the heart rate by placing a pulse sensor at the tip of the index finger as shown in TABLE 4 and TABLE 5.

FIGURE 7. Testing heart rate and body temperature circuits of portable incubator monitoring tool with short message service (SMS) notifications

TABLE 4
TEST RESULTS AND MEASUREMENTS OF THE HEART RATE

Testing (person number)	Age (Year)	Measurement result using Pulse Oximeter (BPM)	Measurement circuit result using Pulse Sensor on LCD (BPM)	Error (%)
1	16	108	112	3.70
2	17	177	181	2.25
3	118	111	117	5.40
4	19	101	106	4.95
5	20	113	118	4.42
6	21	103	107	3.88
7	24	89	93	4.49
8	35	98	103	5.10
9	40	94	98	4.25
10	50	98	103	5.10
Error average in measurement				4.354

TABLE 5
TEST RESULTS AND MEASUREMENTS OF BODY TEMPERATURE

Testing (person number)	Age (Year)	Measurement result using Thermometer Digital (oC)	Measurement circuit result using Sensor DS18B20 on LCD (oC)	Error (%)
1	16	36.9	36.3	-1.62
2	17	38.1	37.7	-1.04
3	118	37.3	36.8	-1.34
4	19	37.4	36.8	-1.60
5	20	37.4	36.9	-1.33
6	21	37.4	36.9	-1.33
7	24	37.6	37	-1.59
8	35	37.6	37	-1.59
9	40	37.3	36.8	-1.34
10	50	37.6	37	-1.59
Error average in measurement				-1.437

B. *TESTING WEIGHT MEASURING CIRCUIT*

In this test, the baby's weight was replaced with a sand bag. The weight measuring circuit or series consists of loadcell sensors, HX711 amplifiers, microcontrollers, and LCD. Load cell sensor and amplifier HX711 function to retrieve baby's weight data, microcontroller to process data, and LCD to display information on baby weight measurement data and display information that the baby's weight has reached normal weight so the baby can be removed from the incubator (FIGURE 8).

FIGURE 8. Testing weight measuring circuit of portable incubator monitoring tool with short message service (SMS) notifications.

For testing loadcell on the circuit is carried out by giving different loads the weight is 500 grams, 1000 grams, 1500 grams, 2000 grams, 2500 grams and 3000 grams. The output voltage of the load cell is too small, so the HX711 module is needed which acts as an amplifier as well as an analog data converter from load cell to digital data. Where Loadcell output is connected HX711, while HX711 output is connected to the microcontroller (TABLE 6).

TABEL 6
RESULT OF TESTING AND MEASURING WEIGHT MEASURE CIRCUIT

Load Weight (gram)	Test	Result of Testing (gram)	Avarage 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			
	5	2548			
3000	1	3065	3060,8	2	baby out of the incubator
	2	3060			
	3	3058			
	4	3060			
	5	3061			
average error on measuring				2,16%	

Load cell programming is done by using a library of HX711 modules on Arduino where 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 can be seen in Table 6.

C. TESTING 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. SMS is sent if the patient is weak and critical can be seen in **FIGURE 9**.

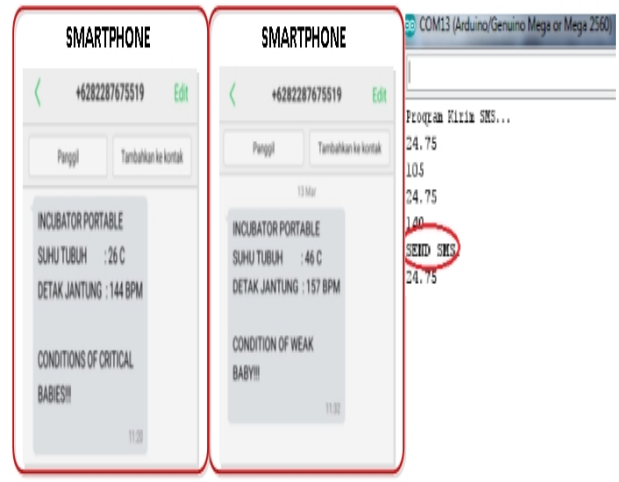

FIGURE 9. SMS notification of baby's condition if it is not in normal condition

IV. DISCUSSION

The average error can be seen in table 4 and table 5, this shows the results of testing and measuring a series of heart rate and body temperature running well. The pulse sensor and the DS18B20 sensor can measure and detect heart rate, body temperature and are displayed on the LCD with an average error of 4.354% and -1.437%. Tables 4 and 5 show the test was carried out with a qualifying age of 16-50 years. In the age range of 16-21 years, the heart rate is measured using a pulse oximeter 103-108 BPM, while in the 107-112 BPM circuit. In the age range of 41-50 months, the heart rate measured using a pulse oxymeter is 89-98 BPM, while in the 93-107 BPM series.

Data presented in table 6 shows the test results. The measurement data can be read by the loadcell sensor and the circuit works well. Loadcell sensor can detect the weight measured by the pressure or the weight measured through the LCD. When measuring with a weight of 500 grams, the average measurement error is 2.5% of the actual load weight, the weight of the load is 1000 grams, the average measurement error is 2.7% of the actual load weight, the weight of the load is 1500 grams. - measuring error rate of 2% of actual load weight, 2000 gram of load weight is an average measurement error of 2.1% of actual load weight, 2500 gram of load weight is an average measurement error of 1.7% of actual load weight, a weight of 3000 grams occurs an average measurement error of 2% of the actual load weight. 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 grams, 1000 grams and 2000 and there is no information on the LCD. When the weight of 2500 grams and 3000 grams on the LCD information "baby out of the incubator" will appear. This

indicates that the baby's weight has reached normal weight so that can be put out he incubator.

The duration of sending messages to a smartphone is around 2 seconds. The time depends on the setting of 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. The limitation of the prototype was the number of smartphones to sent sms just one number. It still develops to send on some numbers.

V. CONCLUSION

The aim of this study built and apply a microcontroller, heart sensor, weight, body temperature and SIM800L for monitoring the health condition of premature babies in the incubator. Using of this tool, the baby's condition can be monitored and also provide a warning about the baby's condition via SMS which will be sent to the medical personnel concerned. 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 critical sign if the baby's heart rate and body temperature are read above the specified range, loadcell sensor detects the weight measured, and displays information that the baby can be removed from the incubator if the weight was above 2500 grams. So, the tool can be implemented for babies in the incubator. In the future work, hopefully the using of SMS can be replace by telegram of WhatsApp because the message the sent into group not personally.

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