

DESIGN AND APPLICATION OF PORTABLE HEART RATE AND WEIGHT MEASURING TOOL FOR PREMATURE BABY WITH MICROCONTROLLER BASE

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ABSTRACT: Nowadays, premature baby can be caring by the parent using rental incubator. But it needs high cost and lack of direct medical supervision of nurses and doctors. Many researches about incubator have been conducted such as monitoring and controlling to temperature and humidity. Besides those parameters, heart rate and baby weight is needed to be considered. The objective of this study is a portable monitoring system for temperature, weight and baby heart rate in incubators. This system monitored using LCD on the incubator and using WEB on smartphone/PC to check the system from another place. The data system is displayed in real time and saved in database server. The client web server is used to microcontroller communication on Ethernet network for monitoring system, so it can be accessed via internet through web interface. Then, the application of Ethernet Shield as Web interface protocol for data transmission between monitoring system devices using http interface protocol for long distance communication. The results of monitoring data are expected to be a medical record of baby health conditions in incubators using this portable system. In this paper is discuss two input parameters, the baby weight measurement section using loadcell sensor and baby heart rate measurement using pulse sensor. The sensors are controlled by microcontroller, LCD to display the output of sensor parameters and buzzer as indicator alert. The test results of both parameters show the device has operated well and can be applied to measure the heart rate and measure the baby's weight on incubator.

Keywords: Pulse sensor, Heart rate, Load cell, Weight, Microcontroller, LCD, Buzzer

1. INTRODUCTION

The baby's health very important for parents, especially for those who unlucky and have a premature baby which required baby treatment using incubator. Premature labor is the process of give birth before the age of pregnancy reaches 37 weeks complete or less than 259 days, which is calculated from the first day of the last menstrual period. If the gestational age is not known certainty, the weight of the baby born is used as a reference in ranges 1,000 - 2,500 grams [1]. One of the incubator functions is keeping baby temperature to remain stable between 31 °C -36 °C. Generally, premature babies need to be placed in an incubator with controlled room temperature. It means, the babies place in the appropriate temperature such as they are in the womb.

Nowadays, some parents choose caring a premature baby at home using incubators by hiring from the hospital. In this case, there are some problems such as high cost of incubator rent and lack of direct medical supervision of nurses and doctors because the incubator in the patient's home.

Researches on infant incubator have been widely developed, one of them made by Prof. Dr. Ir. Raldi Artono Koestoer [2]. This incubator uses natural circulation and convection according to medical standards. It works by drain the air from the bottom to up without a fan but using a special ducting system and fresh air hole system. The heater uses a low power lamp which has been measured according to the room temperature requirement for premature babies. Dr. Ir. Raldi Artono Koestoer base on the results of his research devotes himself to produce the incubator and borrow it to the patients without rent. Several similar studies also have been conducted in this area [3-8], some of studies conducted on monitoring [5-7] and the other in controlling temperature and humidity [3,4,8]. Besides the incubator temperatures and humidity, the heart rate and weight are important factors to caring the health condition of premature babies [9].

In this paper, the authors developed a portable baby incubator including a monitoring system to overcome the problems of an incubator rented by the hospital and incubator Ir. Raldi Artono's research results as seen in figure 1. In this system there are 3 parameters to be measured and

monitored i.e. baby's temperature, heart rate and weight which controlled by microcontroller. The data result of three parameters displayed on the LCD. In addition, the baby's condition on this incubator can be monitored from another place in real time using smartphone by the baby's parents and medical team by utilizing internet facilities through WEB. On this WEB will be displayed baby's medical record such as baby identity and measurement results of the three parameters. The measurement and monitoring data will be saved on the database server.

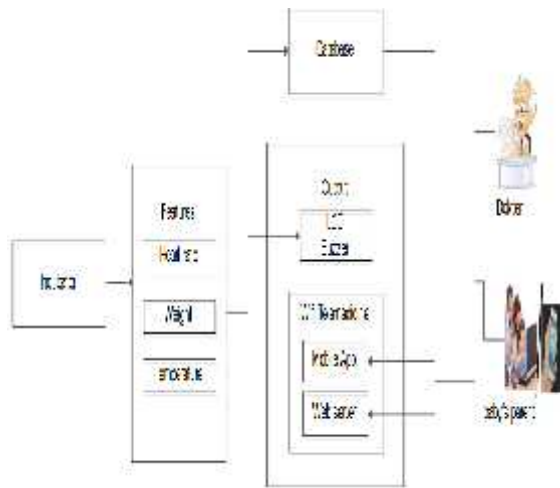


Fig.1 Block Diagram of System Designed

In this paper, author will discuss two parameters of this system, the baby's heartbeat and weight and the data is displayed on the LCD.

2. METHODOLOGY

2.1 Block Diagram

In this section, explained about the design and manufacture of the system and how it works both hardware and software for 2 parameters measured and monitored as shown in Figure 2.

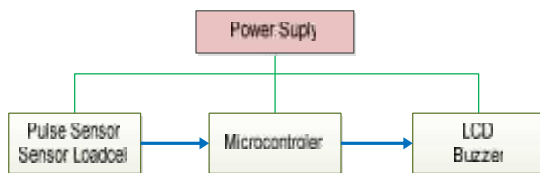


Fig.2 Block Diagram of system designed to 2 parameters

This system has 2 measurement parameters are heartbeat and baby weight with a microcontroller as a system controller. Measurement of baby's heartbeat by placed the cardiac sensor on the baby's wrist and the microcontroller will read BPM data and directly processed it. Then, the data

process result will be displayed on LCD. A load cell sensor is placed on baby bedding and measured the baby's weight periodically and also displayed on the LCD. The limitation of baby's heartbeat rate reading in this device is neonatal condition with BPM 107 to 180 every minute. If sensor read the BPM value break the specified limitation, the buzzer will on as sign of the baby in emergency condition.

2.2 Circuit of Heart rate Detection

Pulse Sensor is a sensor to detect heart rate, in this research pulse sensor is used to detect baby's heartbeat. Pulse sensor works by utilizing light. While these sensors are placed on the skin surface, most of the light is absorbed or reflected by organs and tissues (skin, bone, muscle and blood), but some light passes through body tissues if they are thin enough. If the amount of light intensity on the pulse sensor remains then the signal value will be around 512 (the middle value of 10 bit ADC ranges). The greater the light intensity, the ADC value will the higher. The signal generated by the sensor in a wave called photoplethysmogram (PPG) as shown in Figure 3. PPG in the medical world is used to respiratory rate measurements [10] and heart rate [11].

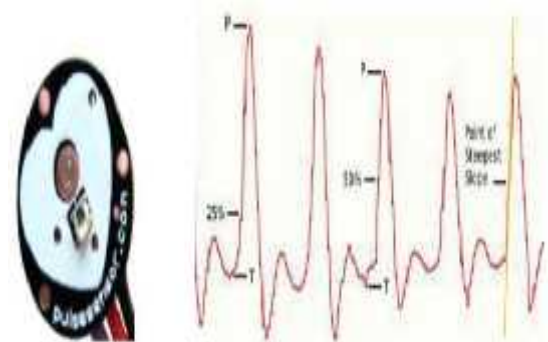


Fig.3 Pulse Sensor

While the heart pumps blood throughout the body, every pulse occurs is accompanied by the appearance of pulse waves such as shock waves that propagate through the arteries to the capillary layer of the hand (fingers) where the pulse sensor is placed. The blood velocity flows more slowly than the pulse wave. As shown in figure 3, after the point T, the signal appears with a sharp rise, this occurs because the pulse wave propagates through the pulse sensor and the signal returns to normal state. Determining the amount of heart beats per minute (BPM = beat per minute) with this sensor is calculated 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 with the next point and the point value is 50% of the value of P (peak) minus T (valley) when the graph is a sharp rise. Table 1 shows the limitation of baby's heart rate from the age 1 to 60 days.

Table 1 Baby's Range BPM

Baby Age	BPM (Bit 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.
3-6 days	129-166/minute	
1-3 weeks	107-182/minute	
1-2 months	121-179/minute	When a child has fever or dehydration, heart rate also increases

Pulse sensor has 3 pins with different function. Pin 1 is used to data pin which connected to pin A8 at microcontroller. Pin 2 as power supply Vcc and pin 3 as a ground. The baby heart rate detection circuit connected to microcontroller. The hardware of baby heart rate detection circuit as shown in figure 4.

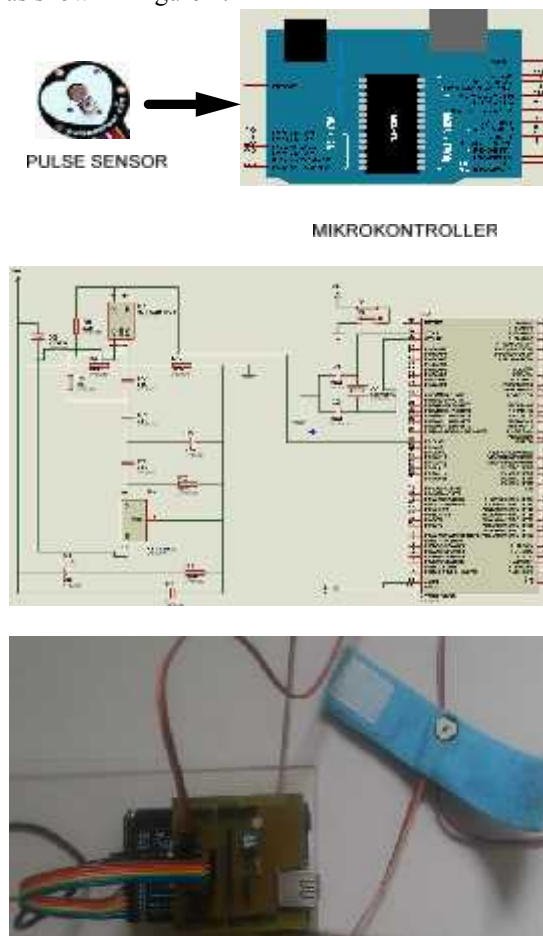


Fig.4 Pulse sensor, Circuit of baby's heart rate detection connected to microcontroller and hardware circuit of baby's heart rate detection

2.3 Circuit of Baby's Weight Measurement

Load cell is an instrument to measure weight. In this case, the load cell is used as a weight sensor. It has 4 pins and each pin has different function. The load cell used in this system have module HX711 ADC 24 bit as shown in Figure 5. The load cell sensor and HX711 module active if the baby is placed on the sensor and pressure the load cell sensor. This will change the sensor resistance caused by the change of force. This changing converted to a voltage and influence load value as a measurement result. The result of load cell sensor is used to inform the value has reached the maximum or not. Pin 1 is connected to voltage source +5V, pin 2 is used for data connected to pin A10 on microcontroller Atmega 2560, pin 3 as clock connected to microcontroller pin A11 and pin 4 grounded. In this device, the load cell range of measurements is 0 to 5000 grams. Figure 5 shows the circuit of weight measurement connected to microcontroller and hardware of baby weight measurement.

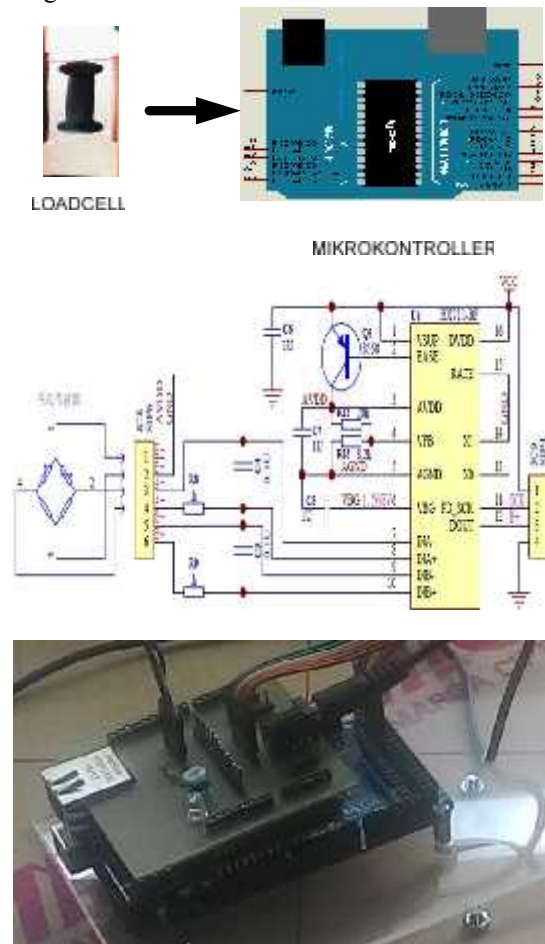


Fig.5 Loadcell sensor, circuit of weight measuring connected to microcontroller and hardware of baby's weight measuring

2.4 Circuit of LCD and Buzzer

LCD is used to display the baby's heart rate and weight which detected by each sensor. LCD connected to pin 32, 30, 28, 26, 24, 22, pin Vcc and ground on Atmega 2560 microcontroller. Buzzer connected on pin 3 on microcontroller Atmega 2560. The circuit of LCD and buzzer connected with microcontroller as shown in figure 6.

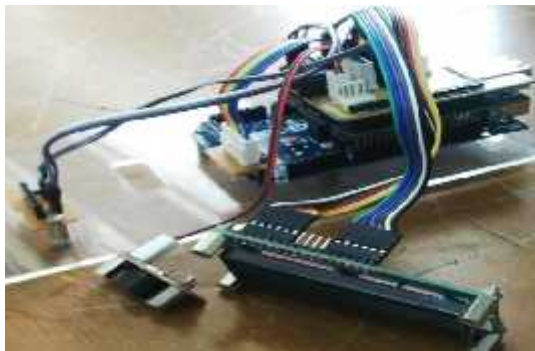
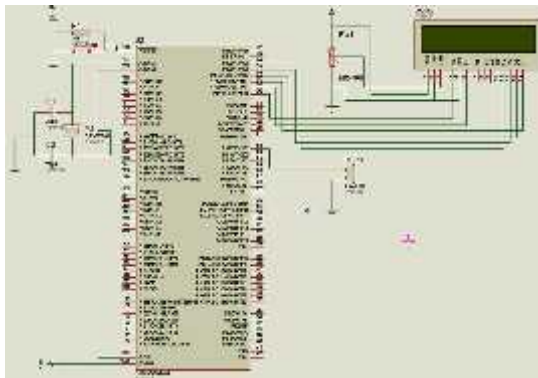
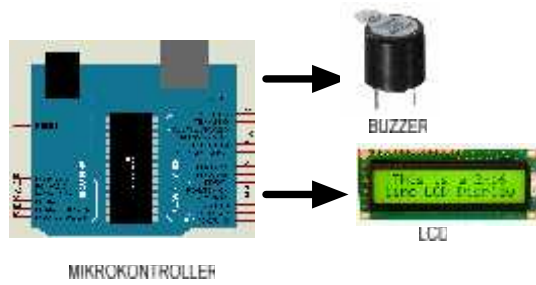


Fig.6 LCD circuit and buzzer connected to microcontroller and hardware of LCD and Buzzer

2.5 Algorithm of Baby's Heartrate and Weight Detector

The algorithm of baby's heart rate and weight detector can be seen in figure 7. The first reading of baby's BPM (Bit Per Minimum) value in periodically and range 107/min - 180/min. If the value detected is more than the specified range then buzzer will be ON as emergency alert, and LCD display the BPM value legible. The reading of baby weight can be done from 0 to 5000 grams, but in this case if the weight of the baby has

reached 2500gram, the LCD will display "take baby out of the incubator".

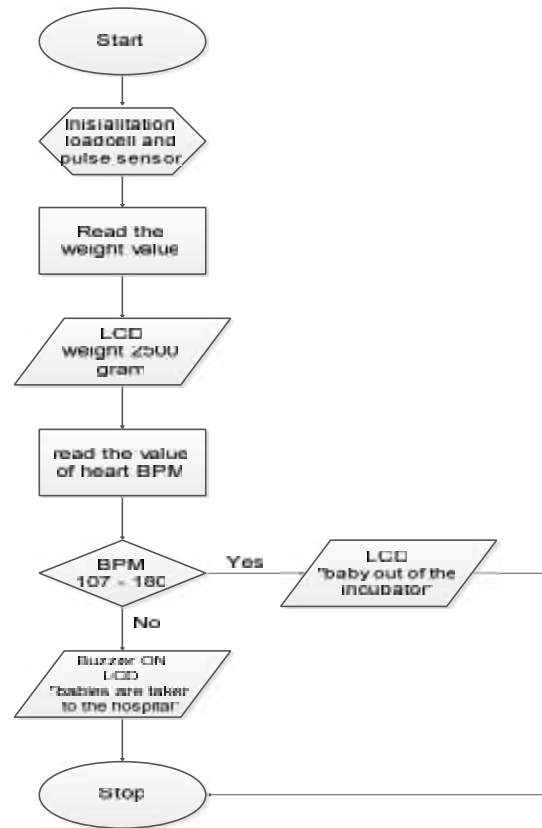


Fig.7 Flowchart of baby's heart rate and weight detector

3. Result and Discussion

3.1 Circuit of Baby's Heart Beat Gauge

This heart beat circuit consists of pulse sensors, microcontroller, buzzer and LCD as shown in Figure 8. Pulse sensor serves to retrieve baby's heartbeat data and microcontroller process the data. The BPM (Bit Per Minute) value reading is done periodically and in the range of 50/min - 180/min, if the range of detected readings is 107-180 BPM then the buzzer will be active as a critical warning alert and LCD will display the readable BPM value. The number of sample people tested is 10 people with different ages and testing time is 60 seconds/person. In this testing and measurement is compared the result of measurement using Pulse Oximeter tool and heart rate measure by this circuit. Pulse Oximeter is a tool used to measure heart rate and usually used for premature infants or patients under special conditions. Testing and measurement of heart rate by place a pulse sensor on the tip of the index finger.

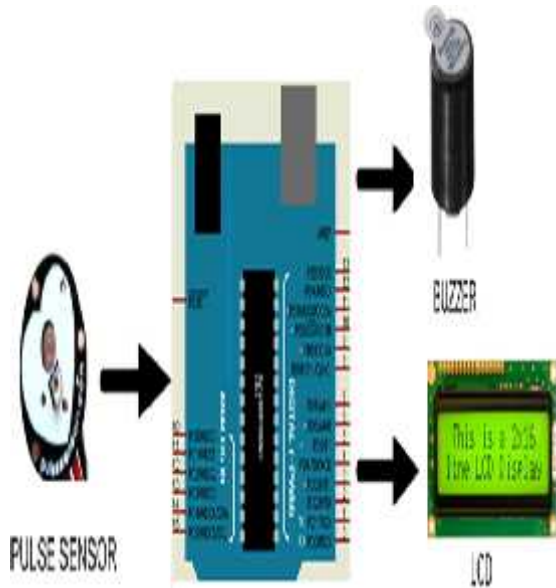


Fig.8 Circuit of testing and measure baby’s heart beat

Table 2 Result of testing and measurement of heat beat circuit

Testing (person number)	Age (year)	Measurement result using Pulse Oximeter (BPM)	Measurement circuit result using Pulse Sensor on LCD (BPM)	Error (%)	Buzzer
1	1	110	115	4,5	on
2	5	105	107	1,9	on
3	10	90	95	5,5	off
4	13	85	88	3,5	off
5	17	79	81	2,5	off
6	18	70	73	4,2	off
7	25	72	75	4,1	off
8	35	72	77	6,9	off
9	40	70	74	5,7	off
10	50	60	63	5	off
Error average in measurement				4,38%	

The average error of weight data presented in table 2, it shows the test results of testing and measurement can be read by the pulse sensor and the circuit works well. Pulse sensors can detect and measured heart rate well and display through the LCD. The average error of weight measurement result is 4.38%.

Table 2 shows the tests were performed on people with age qualifications are 1-12 months or 1 year, pre-school 2-5 years, school 6-13 years, adolescence 14 -18 years, adulthood over 19 years and old age above 50 years. At the range infancy to school age the measured heart rate ranges from 85-110 BPM using Pulse Oximeter while using a circuit data result between 88-115 BPM. In adolescence to adulthood a measured heart rate ranges from 70-79 BPM if using Pulse Oximeter while using a circuit between 74-81 BPM. At the old age measured heart rate is 60 BPM while using a circuit is 63 BPM.

Table 2 also shows the result of testing and heart rate measurements from ages 1 and 5 years using a circuit, buzzers is active because of a measured heart rate with a range of 107-115 BPM. While the testing and measuring of heart rate from the age of 10-50 years using a circuit, buzzers is inactive because the heart rate is measured a range of 63-95 BMP.

3.2 Circuit of Baby’s Weight

This weight measurement circuit consists of load cell sensor, HX711 amplifier, microcontroller, buzzer and LCD as shown in figure 9. Load cell sensors and HX711 amplifier have function to get baby weight data, microcontroller to process data, buzzer as indicator baby weight is normal and LCD to display data information of baby's weight measurement results and display information that the baby's weight has reached normal weight so the baby can be taken from the incubator. Load cell testing on circuit is carried out by loading different weights of 500 grams, 1000 grams, 1500 grams, 2000 grams, 2500 grams and 3000 grams. The output voltage of the load cell is too small, so it needs the HX711 module as an amplifier as well as load cell’s analog data converter to digital data. Load cell output is connected HX711, while the HX711 output is connected to the microcontroller. For load cell programming is done by using the library of HX711 module in arduino which digital output will be converted by arduino microcontroller through library HX711 to weight scale. The results of testing and measuring the weight circuit using load cell sensor can be seen in table 3.

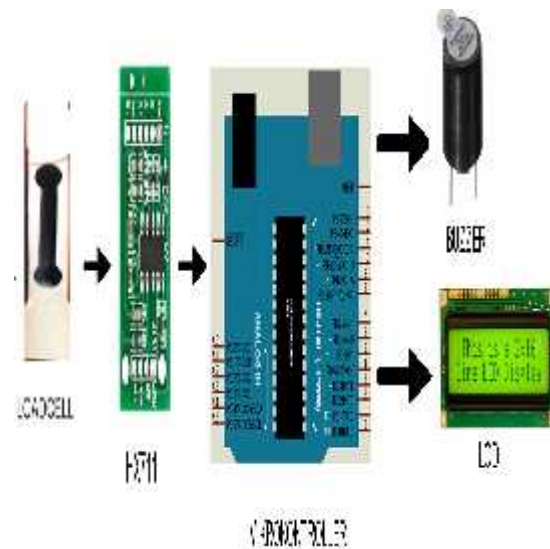


Fig.9 Testing circuit and measurement of baby’s weight

Table 3 Result of testing and measuring weight measure circuit

Load weight (Gram)	Testing	Measurement result	Weight average of measurement result	Error (%)	Buzzer	LCD
500	1	512	512,8	2,5	off	-
	2	511				
	3	512				
	4	513				
	5	511				
1000	1	1028	1027	2,7	off	-
	2	1028				
	3	1021				
	4	1025				
	5	1027				
1500	1	1530	1530	2	off	-
	2	1530				
	3	1527				
	4	1528				
	5	1535				
2000	1	2045	2011	2,1	off	-
	2	2036				
	3	2042				
	4	2031				
	5	2039				
2500	1	2539	2512,8	1,7	on	baby out of the incubator
	2	2527				
	3	2540				
	4	2545				
	5	2538				
3000	1	3060	3062,6	2	on	baby out of the incubator
	2	3060				
	3	3056				
	4	3060				
	5	3061				
Error average of measurement				2,16%		

The test is performed by comparing the weight of the load measured by the load cell sensor with the actual weight reference. From the data presented in table 3 shows the test results of measurement data can be read by the load cell sensor and the circuit works well. The load cell sensor can detect the measured weights well through the pressure or weight of the load that is measured through the LCD. Measurement of load weight 500 grams occurred an average measurement error is 2.5% of the actual load weight, the weight 1000 grams occurred an average measurement error of 2.7% of the actual load weight, 1500 gram load weight occurred the measurement error of 2% of the actual load weight, the weight of 2000 gram occurs an average measurement error of 2.1% of the actual load weight, the weight of 2500 gram occurs an average error measurement of 1.7% of the weight of the load in fact, the weight of 3000 gram load occurs an average error measurement of 2% of the actual load weight. So the average error of weight measurement results is 2.16%.

Table 3 shows the condition of buzzer and LCD while testing and measuring the weight of 500 grams, 1000 grams and 2000 grams. The buzzer is off and no information appears on LCD. At the load weight of 2500 grams and 3000 grams then the buzzer will be active and on the LCD will display information "baby out of the incubator".

This indicates later that the baby's weight has reached a reasonable weight / normal so it can be taken from the incubator.

4. CONCLUSION

From the results of testing the heartbeat measurement circuit and weight measuring circuit can work well so that it can already be implemented for infants who are in the incubator. Pulse sensors can detect the measured heart rate well through the LCD and buzzer will be active as a critical signal if the heart rate is read in 107-180 BPM range. The load cell sensor can detect well the measured weight through the measured pressure or weight of the load through the LCD while it will display information that the infant can be taken from the incubator if the weight is above 2500 grams followed by buzzer activation. In the next writing will be discussed one more parameter of the system made is the design and manufacture of a series of body temperature measurements of infants and data is displayed on the LCD.

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