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Infant Incubator Temperature Controlled and Infant Body Temperature Monitor using Arduino Mega2560 and ADS1232

Mochamad Sofiyan Mardianto[1], Anggun Indra Saputra[2], Candra Sukma[3], Anas Nasrulloh[4]
1(FakultasTeknologiInformasi, Universitas Budi Luhur, Jakarta
Email: 1711600161@student.budiluhur.ac.id)
2(FakultasTeknologiInformasi, Universitas Budi Luhur, Jakarta
1711600351@student.budiluhur.ac.id)
3(FakultasTeknologiInformasi, Universitas Budi Luhur, Jakarta
candra.csukma@gmail.com)
4(FakultasTeknologiInformasi, Universitas Budi Luhur, Jakarta
anas.nasrul02@gmail.com)

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Abstract:
An infant incubator has been designed with temperature and humidity control using Arduino based on the ATMega2560 microcontroller using the Arduino programming language for temperature, humidity control, button settings, and seven-segment display. The working principleof this infant incubator is to maintain the temperature conditions inside the incubator by utilizing the DS18B20 sensor module to measure temperature and humidity inside the incubator, optocoupler sensor to ensure the airflow fan is spinning, solid-state relay to control the AC supply current of heating element, also electric current sensor and LM35 sensor uses for monitoring feedback current consumption and temperature measurement of heating element. When the temperature in the incubator rises or decreases, the elements as a heater and fan as a heat spreader will work according to the instructions of the microcontroller ATMega2560 to normalize the temperature inside the incubator as desired. Also, RTD YSI 400 series as thermistor sensor for infant body temperature measurement and 24-bit ADC ADS1232 has implemented. The proposed method is to integrate temperature and humidity incubator monitoring systems and also monitoring the baby's body temperature.

Keywords —**Infant Incubator, temperature, humidity control, seven-segment display, Arduino, ATMega2560, DS18B20, optocoupler, solid state relays, electric current sensor, LM35, thermistor sensor, ADS1232, body temperature measurement.**

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I. INTRODUCTION

A infant incubator is a closed container in which the warmth of the environment can be regulated by heating the air to a certain temperature which serves to warm the infant. Infant incubators need a stable temperature so that the conditions in the incubator are maintained in accordance with the set point. Theincubator temperature rules are adjusted for the age and weight of the infant.

The number of deaths in infants is a parameter used to determine the state of health in a country. The number of deaths in infants is caused by premature labor. Premature labor is labor that occurs at less than 37 weeks' gestation [1]. Usually babies are born at 37–41 weeks of pregnancy. Babies with premature or abnormal births have various problems such as a very high risk of death, vision problems, breathing difficulties and deafness. This is because premature babies are less able to adapt to conditions outside the womb due to organ system immaturity, such as the temperature of the external environment, which is more unstable [2].

The high rate of infant mortality is caused by premature labor. Premature is labor before the mature gestational age when reaching gestational age between 20-36 weeks. Premature babies need intensive care because they are very susceptible to disease, mostly caused by bacteria and viruses due to environmental temperature and humidity due to the physical condition of infants who have not fully grown and have not been able to adjust to the ambient temperature.

Care of newborns in terms of maintaining the warmth of the infant's body is recommended using the method of kangaroo, by positioning the infant in the arms of the mother and the baby's skin attaches directly to the skin of the mother skin of the kangaroo animal. However, not every condition of the mother can apply this method. This is due to sometimes the condition of the mother who is unconscious or still lying limp after the birth process. On the other hand, not all people and childbirth clinics, especially rural areas can afford to buy expensive infant incubators. Therefore a low-cost infant incubator prototype was created that can help normalize temperature and humidity around the infant's body. The incubator will function to maintain the temperature around the infant so that it remains stable, or in other words can maintain the infant's body temperature within the normal range of around 36.5ºC-37.5ºC. In addition, the humidity conditions in the incubator itself usually range between 50% RH-60% RH [2].

II. DESCRIPTION AND BLOCK DIAGRAM

A. RTD (Resistance Temperature Detectors)

The RTD is a temperature sensor that changes resistance over temperature. There are several different types of RTD construction, but the resistance for any given temperature is well characterized. RTD are often used to make precision temperature measurements. The measurement circuit RTD requires [3]:

1. Single dedicated DAC output pin
2. AINP (Analog Input Positive) and AINN (Analog Input Negative) inputs.
3. External reference input
4. Precision reference resistor

B. Wheatstone bridge

A Wheatstone bridge, also called a null comparator, is used for measuring accurate resistance [4]. In the Wheatstone bridge of Fig. 1. R1, R2, and R3 are known and Rx is the unknown resistance. When the potential (voltage) P1 is the same as potential P2, the bridge is said to be balanced. The major challenge of accurate resistance measurement is to alleviate the loading effect of the circuit by the meter. Such an inaccuracy is caused by the drawing of power by the meter, although the amount of power drawn is negligibly small, from the circuit, even if it has a very high-impedance (e.g 10 MΩ). For accurate measurement of Rx, the Wheatstone bridge plays a great role, as the galvanometer, in balanced condition, does not draw any power from the circuit. This increases accuracy by alleviating the "loading" effect of the circuit by the meter [5].

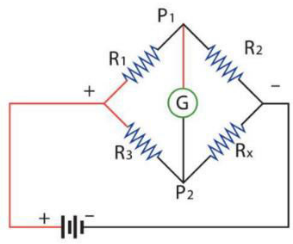

Fig. 1The Wheatstone Bridge [5]

C. ADS1232

The ADS1232 are precision 24-bit analog-to-digital converters (ADCs). With an onboard also low-noise programmable gain amplifier (PGA).The ADS1232 output 24 bits of data in binary two's complement format. The least significant bit (LSB) has a weight of $0.5V_{REF}/(2^{23} - 1)$.The ADS1232 data rate is set by the SPEED pin. When SPEED pin is low (0 V), the datarate is nominally 10SPS (Samples per-second),eventhough at low speed data rates provides the lowest noise, also has excellent rejection of both 50 Hz and 60 Hz line-cycle interference. If SPEED pin is high (3V) output data rate of nominally 80SPS with higher noise ouput [6].

D. Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports)[7][8].Weuse Arduino Mega2560 because it is cheap, also have 10-bit internal ADC with memory program capacity is large enough, and the durability is quite good.

E. DHT22

DHT22 is are digitaltemperature sensors that measure temperature and humidity.The DHT22 sensor has a better resolution than DHT11 and a wider temperature -40 to 80ºCand humidity resolution approximately 0.1%. However it can only request readings with 2 seconds interval.

F. SSR (Solid State Relays)

SSR has no moving parts, unlike electro-mechanical relays (EMR), instead uses the electrical and optical properties of solid state semiconductors to perform its input to output isolation and switching functions. In this research we uses SSR Alternate Current type that designed only for switch AC currents using TRIAC, or switching transistor for application in the switching of an AC load, whether that is to control the AC current for heating element so that the temperature of the incubator room can be set more precisely.

G. Electric Current Sensor

We uses SCT-013-030 or current transformer to be clamped around the supply line of an electrical load to measure the heater current. It does this by acting as an inductor and responding to the magnetic field around a current-carrying conductor. By reading the amount of current produced by the coil, we measure the current passing through the cable conductor and identify whether the heating element is on or off.

H. LM35

The LM35 series is are semiconductor integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature.The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling.We use LM35 to monitor the temperature of the heater in realtime and through a program defined ideal temperature through a direct testing process.

I. Block Diagram

There are six types of sensors used. Such as infant body temperature, temperature and humidity incubator sensors, electric current and temperature sensors for monitoring heating elements, as well as optocouple sensors to monitor the rotation of the air distributor fan.Also YSI RTD sensor type 400 or thermistor is used for measuringinfant body temperature were analog values are converted into digitalvalues uses ADC 24-bit ADS1232 to get better measurement precisionas shown in Fig.2.

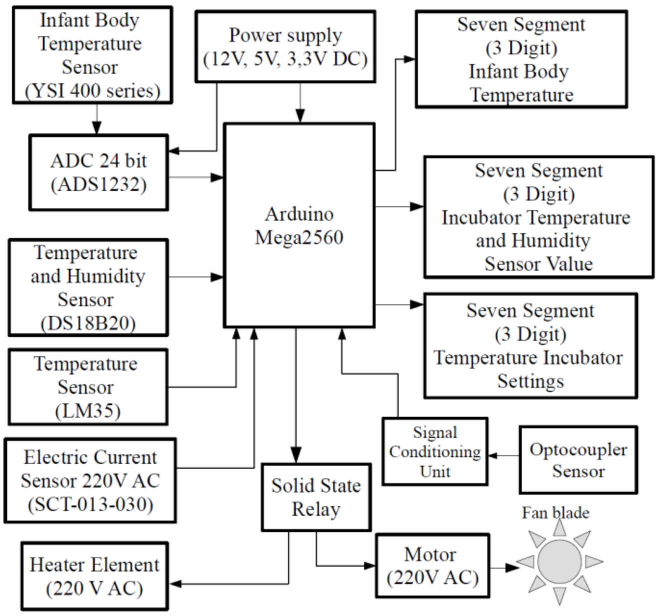

Fig. 2 Block Diagram of Infant Incubator Temperature Controlled and Body Temperature Monitor

Analog sensors (LM35, electric current) output were still analog value converted to digital using internal ADC of ATMega2560. Optocoupler sensor connected to pin digital input to detect rotation of the fan. Electriccurrent sensors and LM35 sensors to detect malfunctions from heaters, for example overheating circuit. Optocoupler sensor to detect malfunctions from air-flowing fans, for example, if suddenly the fan stops spinning due to mechanical damage.

III. FLOWCHART AND METHODOLOGY USED

In previous research infant monitoring system just based on temperature and humidity using DHT11 temperature and humidity sensor [9] also other research is focused on design and implement a closed-loop control system to regulate the temperature and humidity inside a neonatal incubator [10], which it has not been integrated with monitoring infant's body te-mperature. In Fig.3shows flowchart diagram of the incubator room temperature and humidity measurement, and the infant's body temperature measurement.

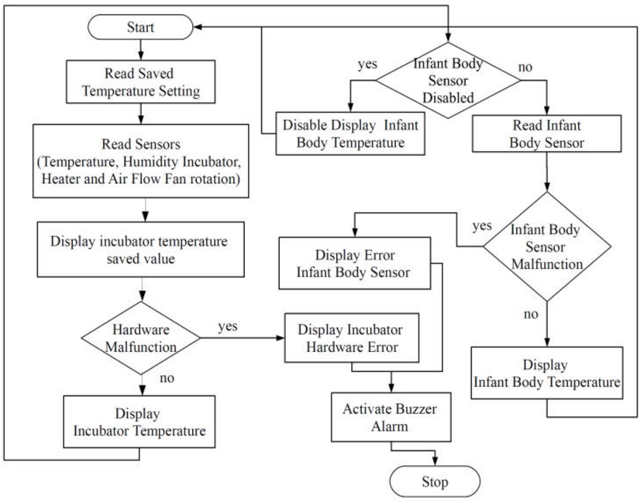

Fig. 3Flow chart diagram infant inbator

The infant's body temperature is measured using RTD or thermistor sensor which is a product of YSI 400 series [11] by using both differentialchannels of the ADS1232 (Fig. 4), the temperature change factor of the RL resistor can be eliminated [6].

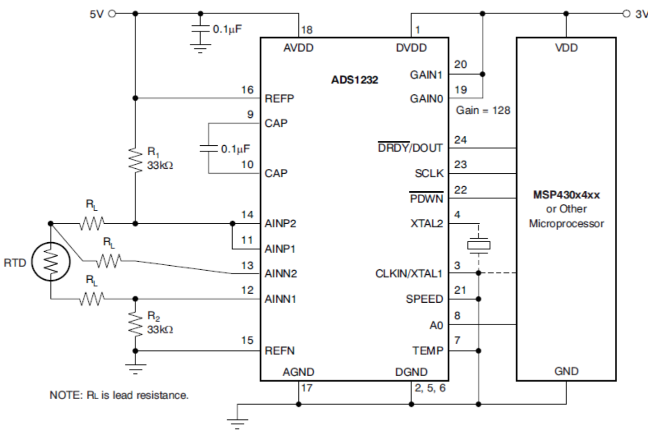

Fig. 4 RTD Three-Wire Schematic from Atmel Datasheet [6]

The program reads the previous configuration that has been recorded in the ATMega 2560 EEPROM memory block, then from the information of the incubator chamber temperature sensor and the temperature sensor installed around the electric heater. High and low temperatures and humidity are determined by the level of activity of the heater and fan depending on the pulse width provided from ATMega 2560. The amplified optocoupler sensor signal to monitor the airflow fan rotation. If a malfunction occurs the seven-segment displays a warning and an alarm buzzer sounds.Inthe Fig. 5and Fig. 6are PCB'stop and bottom layer layout of infant incubators.Theleft one PCBfor display and connection to the Arduino Mega 2560, and the right one for power supply, signal conditioners, and ADC ADS1232.

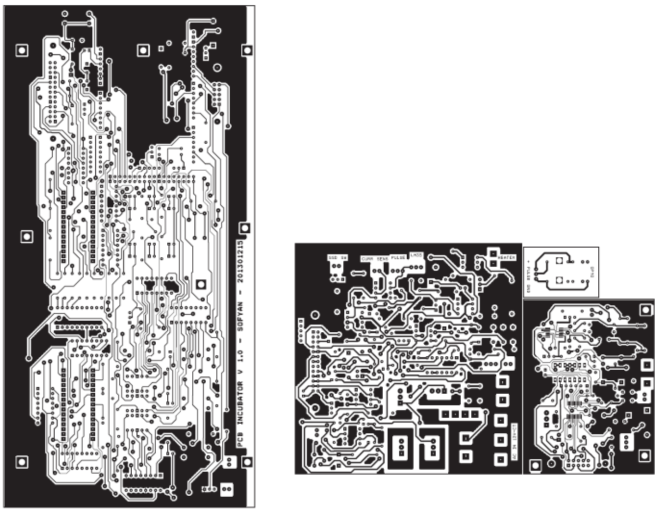

Fig. 5PCB design top layer infant incubator

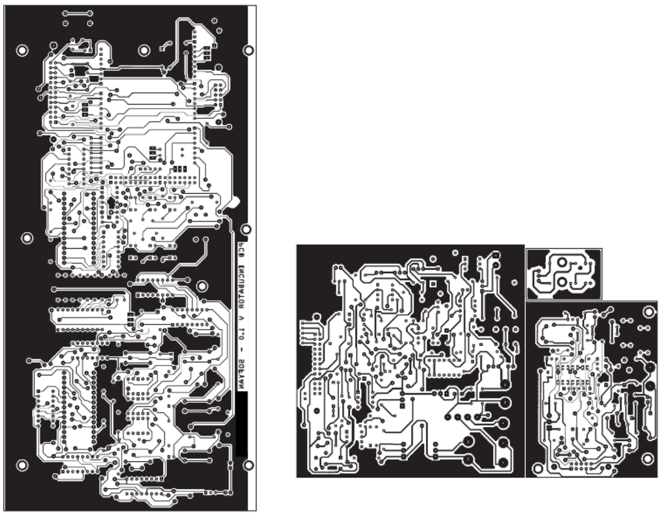

Fig. 6PCB design bottom layer infant incubator

IV. RESULT AND DISCUSSION

The systems continuously measure the temperature and humidity of the incubator, as well as the infant's body temperature, and display the value of the incubator's target temperature set by the nurse. if there is a sudden change in temperature, for example, the changes of the outside temperature air, or the incubator is opened during baby care, the system will automatically adjust the temperature of the incubator by turning on the heater periodically and the air supply motor is turned on.

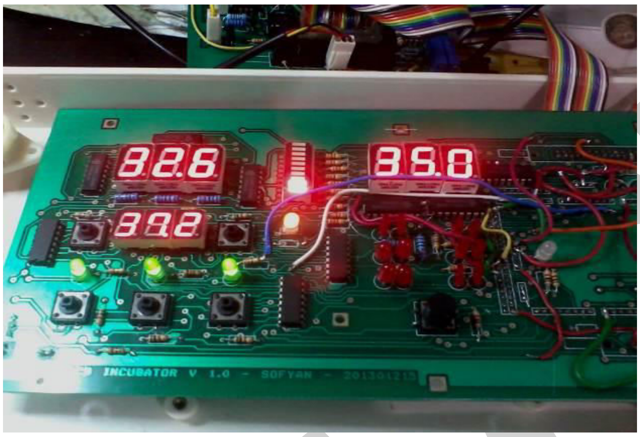

Fig. 7Infant incubator PCB prototype

When the electric current for the heater and the airflow fan is disconnected, resulting in the incubator room temperature can not match the desired temperature, the malfunction detection system will sound an alarm as well as a seven-segment display showing an error. If the infant's body temperature is abnormal, for example below 36° C or above 38° C will also sound the alarm.

Fig. 8.Incubator testing and mattress where the baby lies completely enclosed by a fiberglass canopy

V. CONCLUSION AND FUTURE ENHANCEMENTS

A. Conclusion

The air temperature and humidity always monitored continuously. Initial parameters such as variable width of the pulse for the SSR to the heater adjusted to the desired temperature target and the amount of temperature difference when it is turned on until it approaches the target temperature.Also parameters for minimum and maximum voltage of the electric current sensor to avoid a system fault.

B. Future Enhancement

The additional display is required for the temperature value of the heater and the fan rotation speed, also needs to develop a serial interface method (via USB port) to more easily to configure parameter values without the need to deactivate the incubator monitoring system, for example, when changing the airflow design and canopy cover.

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