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Design, Development & Comparison of Temperature Regulation Units for Neonatal Incubator by Analogous Methods

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ABSTRACT
According to the World Health Organization (WHO), an estimated 15 million infants worldwide are born preterm every year; 4 million infants die within a month of birth. 25% of these deaths are caused due to complications of prematurity, most often due to improper heat regulation, water loss and neonatal jaundice and due to other complications that could be avoided by use of simple interventions, such as keeping the infant warm for the first several weeks of life. An infant incubator provides stable levels of temperature, relative humidity and oxygen concentration. Temperature control system is the most important part of a baby incubator which has to be maintained around $37^{o}C$. This paper focuses on the comparison of temperature control between advanced temperature control system and microcontroller based control system. The advanced temperature control system has been designed and developed incorporating a combination of Pulse Width Modulation (PWM) and simple ON-OFF control system, where thermistors have been used as temperature sensors. The range of variation of temperature against the set temperature ($37^{o}C$) has been found to be $2^{o}C$. The system components of the microcontroller based control system includes DHT11 temperature sensor, relay, LCD display, fans, bulbs, heater and Arduino Uno microcontroller. For implementation, a software program has been developed in language C. It can control the temperature at the set level $37^{o}C$ very precisely with negligible temperature swing. At the same time it is cost effective, free of health hazard. It can be used commercially in the hospitals, at home and can be further modified in the laboratory.

Keywords: Temperature controlling method, Pulsed Width Modulation (PWM), Automatic controller, Intelligent infant incubator, Premature baby

1. Introduction

The premature infant care is one of the most sensitive and delicate areas in biomedical field. Until recently, there was just little attention for the care of newly born babies in developing countries. New-born babies with growth problems usually have a net body area greater than normal babies from same age. This in turn makes their heat loss greater than normal babies. Moreover, their net mass is less than the normal babies and makes them unable to keep their body temperature to the required level. With regard to sick babies, they usually can't control their body temperature without an external aid. The current recommended method of providing infant temperature regulation in resource constrained settings is Kangaroo Mother Care (KMC), the practice of placing new-borns directly onto the mother's chest [1]. But at the same time, KMC also has important limitations. As a consequence, preterm or premature infants in developing countries need a warm, clean environment to grow stronger. Incubators can provide millions of at risk infants with shorter hospitals stays and can enable infants who might otherwise have faced a lifetime of severe disability to experience active lives. The incubator is an isolated area environment with no dust, bacteria, and has the ability to control temperature, humidity, and oxygen to remain them in acceptable levels. [2]

2. Background

The first incubator was developed in 1857 named warmwännaen. In 1833, Pierre-Victor-Adolph published an account of another incubator, developed by Etienne Stephane Tarnier for use of enormous Paris Maternite named couveuse. In 1891 reports came of a new incubator design in France, designed by Alexander Lion of Nice. In early 21st century the incubator has become highly technological and improved.[3] Today developments are still constantly underway to try and create an ever more womb-like environment; controlling oxygen levels and other vital systems, with an array of sensors, monitors and alarms [4]. Hence till the world is here, infant incubator technology will be developing to next stage. There are different types of incubator such as Open box type incubator, Close type incubator, manually controlled incubator, Servo controlled incubator and Transport incubator [5]. Temperature regulation is of primary importance in an incubator. This is an analogy between two temperature controlling methods with the suggestion of the best one.

3. Controlling Methods

Temperature control system is an important integral part of a baby incubator. Selection of an appropriate temperature sensor is important for effective control of temperature in the incubator. There are a number of

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temperature controlling methods available for infant incubator. Here two methods are designed and developed where one is an advanced control system consists of a PWM circuit & ON-OFF circuit, the other one is based on microcontroller. This paper illustrates the best & accurate method of temperature controller for an infant incubator.

3.1 Advanced temperature control system

The advanced temperature control system is the combination of simple on-off control and PWM control systems. Comparing the sensitivity and response time of available temperature sensors like thermistor, thermocouple, RTD in the range of temperature 25-40ºC along with accuracy, repeatability, term stability, linearity, self-heating thermistor has been used for the advanced temperature control system. [6] The block diagram of the ON-OFF control circuit is shown below.

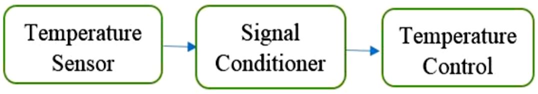

Fig. 1 ON-OFF control block diagram

To improve the temperature sensitivity of the system, the thermistor was placed in one arm (R4) of a Wheatstone bridge, as shown in Fig.2, rather than in a voltage divider circuit. Firstly a balance is obtained through adjustments of the resistors in the other arms (R1/R3 = R2/R4).

The unbalanced output voltage of the bridge as shown was used to give a measure of the temperature change. It is well known that this sensitivity is the greatest when R4 is almost equal to R2 [7].

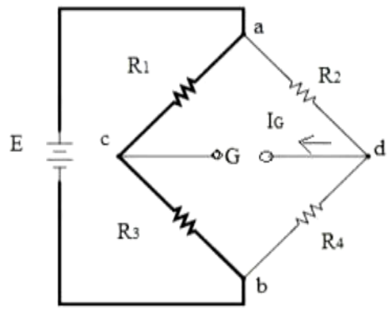

Fig. 2 Wheatstone bridge circuit

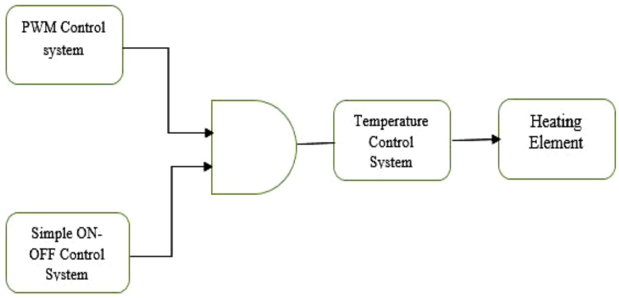

Fig. 3 Block diagram of the combined enhanced temperature control system

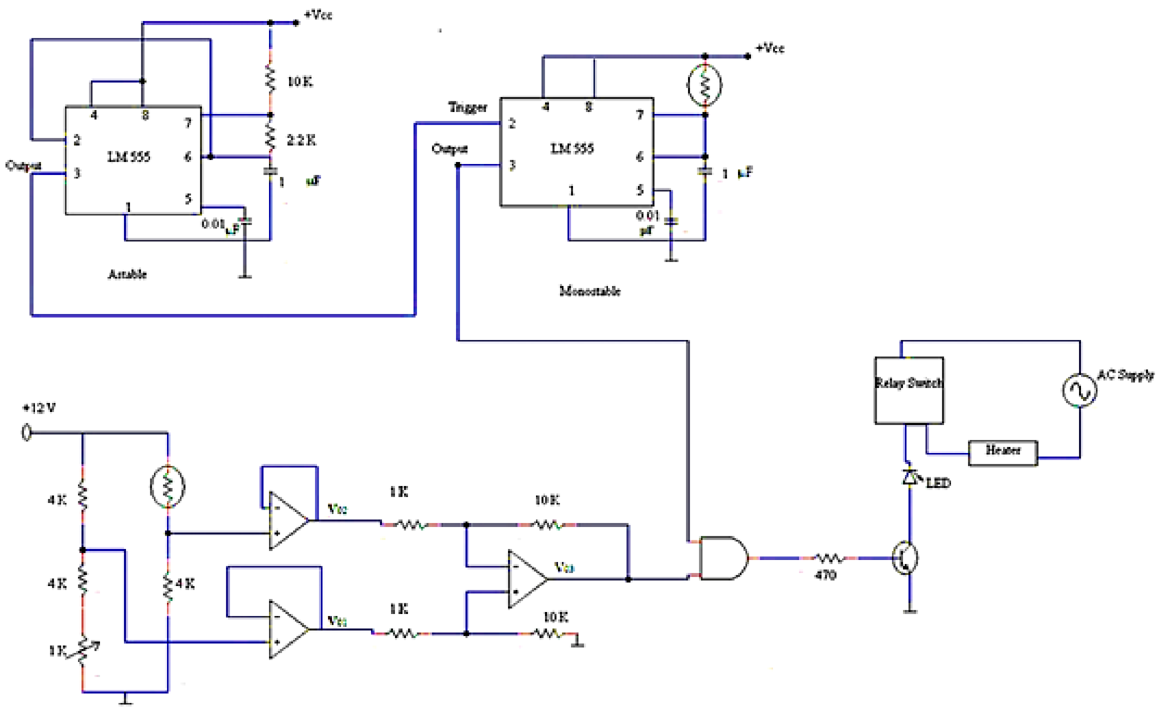

Fig. 4 Circuit diagram of a combined advance temperature control system

3.2 Temperature Control System with Microcontroller

The temperature in the neonatal chamber need to be sensed and read before controlling it. A sensor is placed in the compartment where the baby is kept and the sensed temperature is given to the Arduino Uno Microcontroller. Output devices for keeping temperature within the desired range are connected to the digital output pins of the microcontroller. The temperature is sensed using a DHT11 sensor.

Fig. 5 DHT11 sensor

This is a multifunctional sensor that gives temperature and relative humidity information at the same time. It can meet measurement needs of general purposes. It provides reliable readings when environment humidity condition is in between 20% RH and 90% RH, and temperature condition is in between 0°C and 50°C, covering needs in most home and daily applications that don't contain extreme conditions. [8]

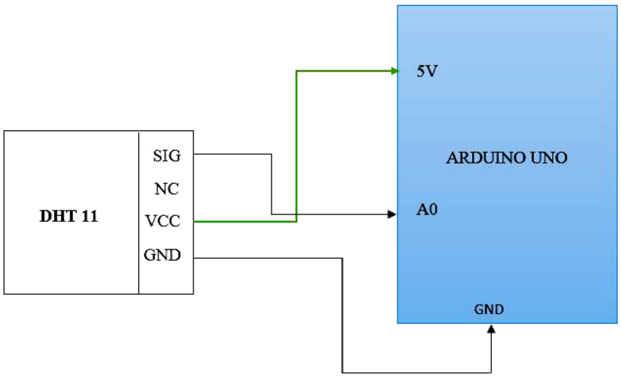

Fig. 6 Circuit for temperature sensing

The temperature sensed by DHT11 is given to Arduino Uno which is connected to a laptop/Computer. Signal pin of the sensor is connected to the analogue input pin A0 of the microcontroller. A program is written and uploaded to the Arduino which makes the temperature to be controlled within the desired range.

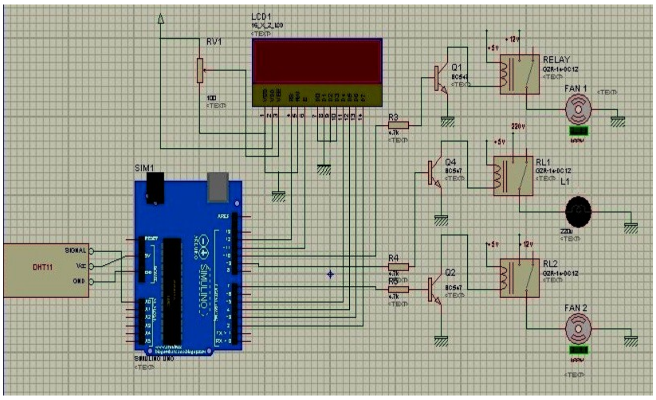

Fig. 7 Microcontroller circuit for temperature sensing

For controlling temperature there are two units; (a) Heating unit (b) Cooling unit. The heating unit consists of a 12 V dc fan and a 220V bulb. These are connected through relays with the digital output pin of Arduino board. The program is written to control the bulb and fans. The cooling unit consists of an Aluminum vessel containing ice and a 12V dc fan. This fan is connected with the digital output pin of the Arduino board through the relay. Whenever the temperature in the chamber goes beyond 37ºC the bulb automatically switches off and the fan in the cooling unit turns ON. The program to run the control unit has been uploaded to the system through USB cable from computer. Fig 8 illustrates the logical expression for the program. It gives signal to the output when temperature is not set to 37ºC. When it goes below this prescribed temperature the program switch ON the heating device and when it gets high the program start the cooling unit of the neonatal incubator.

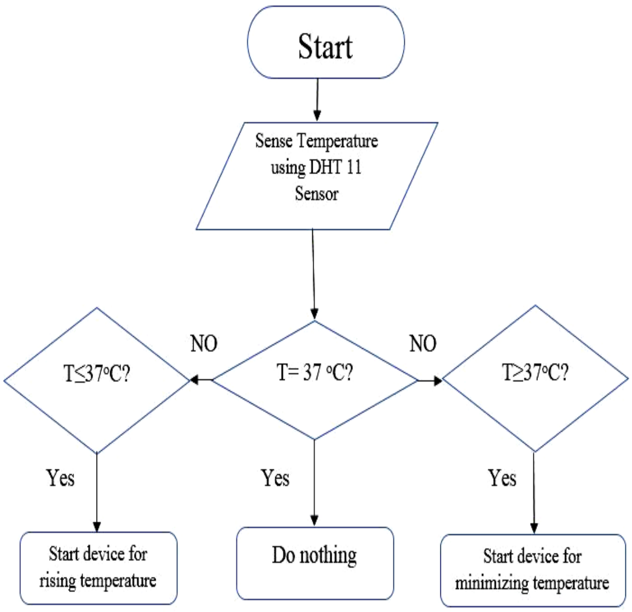

Fig. 8 Flowchart for system software development

4. Result Analysis

Two methods described above functioned to keep the temperature of an infant incubator within the desired range. Readings from two systems have been taken after implementing the systems with total incubator unit with same ambient condition at the same day.

4.1 Advanced temperature control system

The performance of the advanced temperature control system is shown in Fig 8. Once the temperature reaches the set value it remains almost constant, varying within a maximum and minimum of 37.9ºC and 36.0ºC, giving the range of variation of temperature of ≈2ºC.

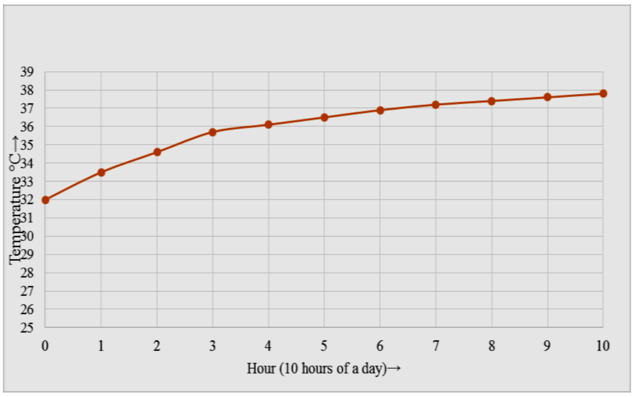

Fig. 9 Variation of temperature with respect to time for advanced temperature control system

4.2 Arduino controlled unit

Temperature of the incubator needs to be maintained at level of 37ºC. When temperature falls below 37ºC, digital output pins become high which are connected to the heating element according to the coding written in Arduino Uno. As a result, the heating unit is turned ON. When temperature goes above 37ºC, a relay is turned ON with which a cooling unit is connected. When the temperature is 37ºC both the heating and cooling units are OFF.

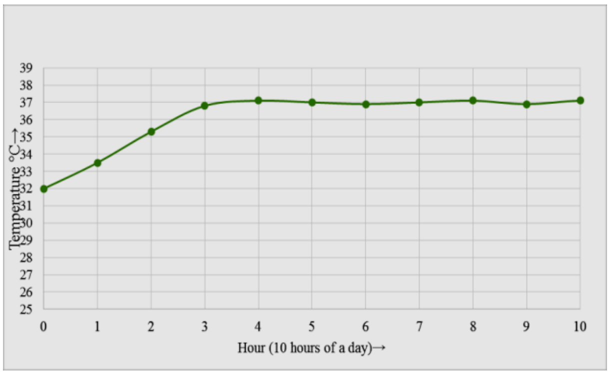

Fig. 10 Maintained temperature in the incubator using Arduino Uno microcontroller

5. Discussion & Result Interpretation

To achieve thermo-neutrality in neonatal body temperature controlling is most significant part. To keep the temperature of the compartment of an incubator in the desired level (37ºC) an advanced regulation system has been developed based on the combination of a PWM circuit and ON-OFF circuit. This unit keeps the temperature of the baby containing vessel within 36ºC to 37.9ºC. This result shows that the temperature is not constant at the desired value. The temperature swing of 2ºC is not acceptable in that case. To improve the system a new unit is designed using a microcontroller. Where temperature is read by a DHT 11 sensor and its signal is processed by an Arduino Uno board. The program helps Arduino to send signal to both heating and cooling devices for keeping the temperature at the constant level. This unit provides the baby compartment a temperature of 37ºC throughout the time. It can be easily stated that using microcontroller instead of a PWM circuit is more effective and efficient in case of controlling temperature for an infant incubator. However, both systems can be regulated for various temperature by only changing the program incorporated within the circuit.

6. Conclusion

Every year, about 1 million infants in the developing world die due to prematurity complications. Premature infants are born before the developing organs are mature enough to allow normal postnatal survival. An incubator is the only solution to avoid diseases of baby. The vital part of an incubator is to have a constant temperature and humidity desired for the neonatal during the time being. The microcontroller based system provides the constant temperature. But humidity control has not been included in this unit. It is achievable through this system by only enlarging the program of the Arduino to control the humidity. The DHT 11 is capable of sensing both temperature and humidity. For future development humidity controlling unit can be included in the existing system with a LCD display. There should be available oxygen supply in the incubator in case of emergency. An active noise control system for infant incubators can be introduced.

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