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DESIGN AND IMPLEMENTATION OF LOW COST ENHANCED NEONATAL INCUBATOR

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Abstract

The concept of Neonatal Stabilisation has grossly been area of growing interest in recent time, because of increasing number of mortality annually. Approximately four million of the said infants belong to developing world and their death were caused by complication of prematurity, mostly due to improper thermal regulation, water loss and neonatal jaundice. Subject to the fact of Primary Health Care Centre cannot afford imported Neonatal Incubator due to insufficient funding. This work develops a low cost enhanced Neonatal Incubator using digital humidity and temperature sensor (DHT11), microcontroller (ATMEL AT89S52), Humidifier and Heating Element and LCD were integrated so as for the medical personnel to have access to displayed value of temperature and humidity. The whole circuit was incorporated into a transparent, insulated flexi glass. It was discovered that this developed system is capable of providing the crucial care for the infant at a very low [redacted] *cost. It can also maintain environmental temperature and Humidity for patient. Hence, improvement on this can go a long way to solve immediate needs of the society especially the Rural Health Care Centre.*

KEYWORDS: *Humidity, Incubator, Infant, Neonatal, Sensor, Temperature*

INTRODUCTION

An estimated 340 babies die in the first week of birth, with preterm birth and asphyxia, being two of the leading causes, mostly in low and middle-income countries. However, low-cost approaches such as the Embrace Infant Warmer are available to prevent heat loss, they lack cooling capabilities, temperature control, and need regeneration of thermal material by hot water, which may not be available. In many tropical countries, temperatures in the shade can reach >40 ^{0}C which may put babies at risk of hyperthermia, the incubator that serves this purpose costs thousands of dollars(Tran et al). Most developing countries like Nigeria rely on over 90% of imported medical technology for the running of her healthcare delivery systems. This poses a great limitation in the efficiency of the health because of insufficiency, poorly managed, or difficult to replace. Thus, in the face of this bad economy, the health sector seems to fail with consequent high mortality and morbidity. A typical Nigerian tertiary hospital would require a minimum of 20 functional incubators to adequately handle its high admission delivery resulting from high population of people within its catchment zones. Amadi et al. reported that the national centres of most of the Nigeria's premier tertiary hospitals were without an adequate number of functional incubators to handle their numerous referral cases. The hospitals were rather littered with carcases of old and obsolete models of incubators that had long been phased out by the manufacturers and hence without available spare parts for maintenance. It became obvious that Nigeria needed some kind of locally manageable engineering approach to save the teaming population of her neonates for which an estimated 284,000 die each year or 778 per day.

Since the 19th century, remarkable progress has been made on the devices termed incubators which were developed to maintain thermal stability in low birth weight (LBW) and sick newborns, thus improving the chances for survival(Roberto et al). Recent advances in technology in terms of sensors and communication enables a new trends in health care monitoring systems with wearable photonics and electronics which led to development of electrocardiogram(ECG) and Reflectance Pulse Oximeter (Sibrecht et al). To this end, [1]Amadi et al. developed the

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"recycled incubator technique", reporting its cost-effectiveness and locally driven spare parts production. This paper presents how Recycled Incubators may have contributed to reverse a deteriorating neonatal delivery system in Nigeria. Amira et al proposed an indispensable intensive care with low income for developing countries with 3-D printed prototype and claimed that overall performance of the Handy incubator was 91.7%.

Shvam Yadav (2018) developed his own system by Incorporating phase change materials to store the latent heat belongs to the most functional technique for thermal energy which is isothermal in nature, purposely to incubate the baby and therefore control the fundamental parameters. The objective of the creation of microenvironment for babies is accomplished by the combination of PCMs, thermal energy storage devices, thermal insulators. Thus, the development of PCM into nano-HVAC components was developed.. This method was used to manufacture cost effective and portable baby incubators to make the babies sustain in adverse environment conditions.

Methodology

The method entailed Design Components (Electronic and Mechanical parts) and Software Implementation, the following factors were considered for the designed elements

- A simple Incubator case that can be easily had access to insulating and sound reducing and compact
- The incubator should be in modular forms that can be easily assembled and dismantled in case of maintenance
- With effective thermally driven air filtration and purification because of bacterial infection
- The incubator should be able to maintain ambient temperature of 34°C to 37°C and humidity greater than 70%RH

Hardware Design; Electronic component

Fig.1 shows block diagram of integral parts of the Electronic components

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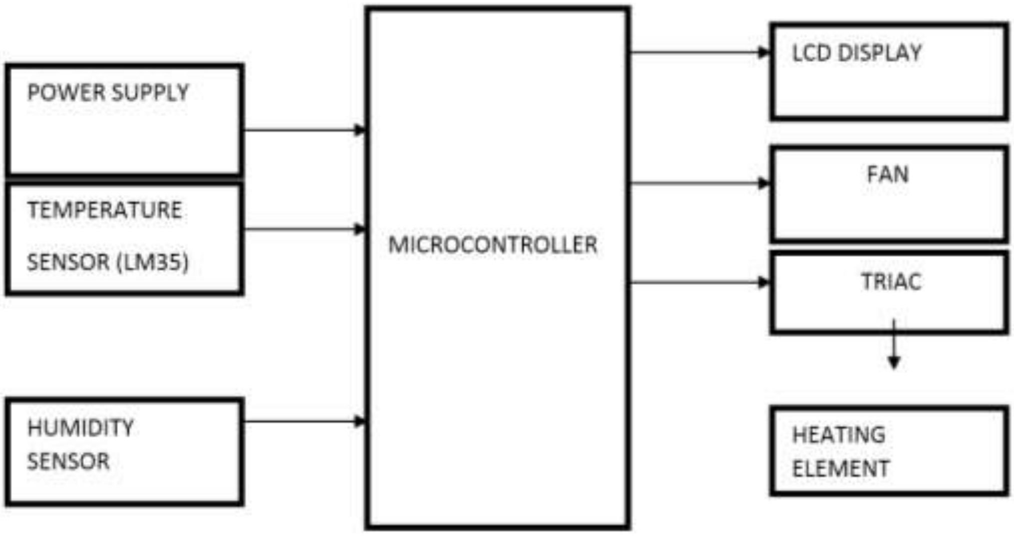

Fig. 1: Block by Block Diagram

A. Temperature and Humidity Control Section

A 240V AC incandescent bulb was used as heating element with normally opened 12volt DC relay (RL2A) while cooling system was adapted 12V DC fan energise through RL1. The humidity control had two circuits, one for driving humid air into the chamber and the other for reducing humidity. Humidifying of the system was done using an external humidifier circuit. The external humidifier used a 12V DC humidifier to raise water to the steam. This was driven into the baby compartment using electric drive2. Reduction of humidity was minimised by driving in dry air with 12V DC drive . DHT11 is the temperature and humidity sensor that will be used to take the measurements from the controlled environment of the incubator. The variation of the humidity is also detected by the DHT11 sensor

B. LCD Display and Incubator Alarm

User Interface was designed as means to display the extract features and monitor any malfunction of the neonatal incubator. It was designed in such a way that whenever the temperature in the baby compartment dropped below 34.5°C or exceeded 37°C or humidity dropped below 70% or exceeded 75% the buzzer would beep and a warning message would be displayed on the LCD showing the parameter that has gone into unsafe range. Ditto for the buzzer for alarm by connecting the buzzer's positive to the dedicated microcontroller output pin and the negative to ground. This means that whenever the output pin status was set to 'HIGH' the buzzer would be powered and ring.

C. **Microcontroller and Software implementation**
In order for the sensor and other electronic part to communicate and interact, microcontroller was designed to have main routine and subroutines. The main loop algorithm was:

Algorithm 1

Temperature and humidity control pseudo code
if temperature _ 36:5_ then
Fan heating = ON
Heating resistor = ON
LED indicator = ON
else
Fan heating = OFF
Heating resistor = OFF
LED indicator = OFF
end if
if humidity _ 70% then
Fan humidifier = ON
Humidifier = ON
LED indicator = ON
else
Fan humidifier = OFF
Humidifier = OFF
LED indicator = OFF
end if

Mechanical Components

It is better that the neonatal incubator is light in weight so that it can be portable at the same time provides strong support for the component used and can bear the weight of the infant. Isolation of the component from where the baby is kept from the controlling unit is a necessary requirement. The casing was divided three sub-systems which is the enclosure, the shell, and bed (figure 3). Mechanical materials that were used to build the prototype of the incubator are listed:

- Wood
- Plastic film
- Screws
- Wood sealing machine

By choosing wood and plastic film, the prototype of the baby incubator is easily portable and also quite cheap. The incubator is divided in two main areas. The area where the baby will be placed is located in the upper part of the incubator and the other one (in the lower part) is for the electronics that will be in charge of providing the right conditions for the area of the premature baby.

A. Enclosure: the enclosure is the sub-system that houses the electrical components such as the fans, heating element and the humidifier. The enclosure was divided into units, the temptation and humidifier control unit. The exterior is comprised of aluminium, sheet metal screw, Arco board and LCD screen. The aluminium was chosen for its ease in machining and repair, low cost, low density, resistance to corrosion, and available. The Aluminium were held together with sheet metal screws to reduce total number of part required, the Arco board is use to cover the sides of the aluminium. The other component found on the exterior of the enclosure is the LCD, the LCD allow the user to see the temperature and humidity readings.
B. SHELL: the shell is the section that the patient is housed; it was designed in the shape of a simple rectangular. It is made of transparent acrylic plastic, the material is used because of it sufficient thermal insulating properties for the application and relatively low in cost. The acrylic transparent plastic was fixed to a aluminium steel at each angle with a metal screws, the upper acrylic panel function as a door which can be remove so as to have full access to the infant. The transparent acrylic plastic allow the patient to be monitored from outside. While the Frame structure materials including printing speed (40–100 mm/s), maximum printable size (220 × 220 × 220 mm), and nozzle size (0.4 mm). With printing material supports: poly-lactic acid (PLA) and others. The diameter included the positioning accuracy of X and Y (0.01mm) and in Z (0.00025 mm). The melting temperature: 157–170°C, tensile strength of 61–66 MPa and flexural strength: 48–110 MPa.

Test Baby Model Design

A proper means of testing the incubator was needed in order to validate all the proposed goals were considerably fulfilled. An aquarium heater was immersed in a milk carton containing a salt solution to mimic the infant. The newer model was constructed out of aluminum casing which contains a salt solution to model the body of the infant. Immersed in this will be an immersion heater that has both a 2 watt and a 10 watt setting. The lower

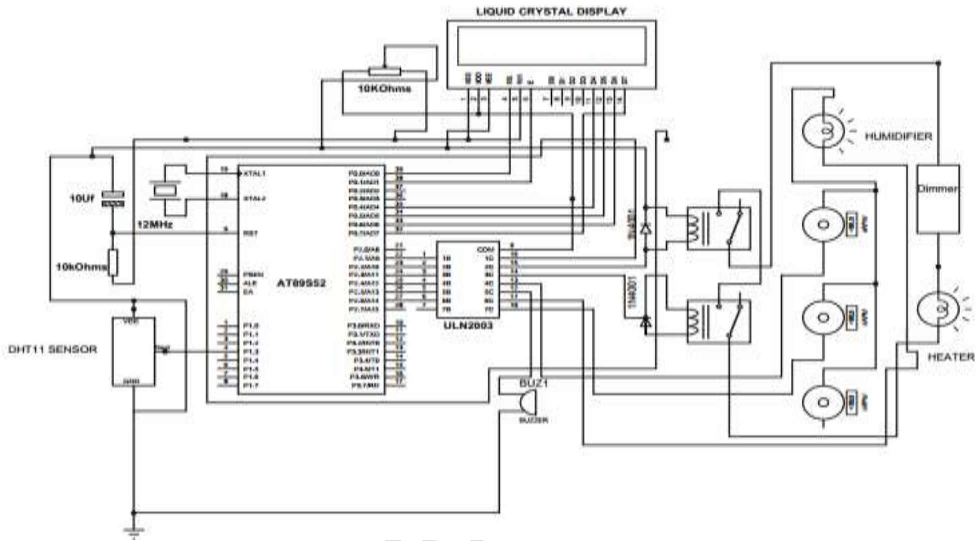

Figure 2: Circuit diagram of Neonatal Incubator

Figure 3: Casing of Neonatal Incubator

Watt heater was used to mimic the heat output of a live infant while the higher watt heater to maintain human body temperature when testing took place. Both the volume of the test model and the power source were chosen to mimic a 1 kg preterm

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infant which is at the lower spectrum of preterm infants. The device contained temperature monitoring circuit in order to control the heating and used LED's to notify the operator when the model was at the testing temperature and if it had dropped below a healthy temperature during testing.

Results and Discussion

The temperature and the humidity sensor were able to sense the temperature and humidity of the environment and the result was displayed on the LCD. But there is a 30°C swing in temperature range against the set value. This could be due to the fact that, it took time for the distribution of heat energy from the heater to the surroundings and there was a lag of response time for the temperature sensor to respond to the change in temperature. The temperature increased by only 0.5°C, i.e., to 37.5°C which is an acceptable value. While the incubator cooled off, the heater switched on again at 36.5°C. Thus using the enhanced control system in future the temperature swing may be reduced by only 10°C, which is satisfactory and acceptable for a neonatal incubator.

The DHT111 gave a satisfactory performance as can be seen through the response of heating elements and monitoring of the temperature directly through LCD display. However, a slight overshoot of temperature up to 37°C was noted after the heater had switched off and this increase was attributed to the DHT11 sensor being a relatively slow sensor. The overshoot was quickly noted and the drive 3(fan) was quickly set ON to offset this temperature increase.

The alarm circuit designed worked satisfactorily too. It produced a loud sound alarm to draw the attention of medical attendants if the temperature went above 38°C or went below 26°C. Thus the present work paves the way to design and develop a complete incubator that could save lives in rural areas of developing countries like Nigeria

Conclusion and Recommendations

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. To provide a sound environment for the baby temperature in an infant incubator must be maintained at a proper level, generally set at 37°C. The developing system is one of the most practical solutions for addressing the lack of proper care for infants, affected preterm and other complications in impoverished regions. The system is capable of providing the most crucial aspects of patient care at a cost low enough. The prototype is capable of maintaining a proper environmental temperature (34.5°C to 37°C) and Humidity (70% to 75%) for a patient, which are the primary functions of an incubator. Once set, the temperature and humidity are maintained automatically by the microcontroller which makes the neonatal incubator easy to operate.

Any work, whatsoever precise it may be, has always some scope of improvement. Some of the future aspects of this project Neonatal Incubator in terms of improvements were listed below;

1. Parameters such as pulse measurement can be introduce for close monitoring of the infant in the incubator
2. Wireless transfer of data regarding parameters from the infant unit to the nurse monitoring station.
3. Additional Oxygen consumption, which is necessity for human growth

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