# Fault Tolerance and Real Time Monitoring Infant Incubator Model

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**ABSTRACT**

*This paper present the development of fault redundant infant incubator model, the framework used here is both hardware fault monitoring and software fault monitoring. The purpose of a Fault tolerant system is to ensure that faults do not result in malfunctioning and system failure and to achieve the best performance even with minimum number of sensors working. It is developed in such a way that the hardware fault monitoring module connects the two basic functional units with separate components to a central controlling unit. This control unit performs the function of a back up to support the whole system, that is redundant Sensing for the critical parameter such as temperature and the humidity has been incorporated using triple modular redundancy. Software fault monitoring involves transmitting of information and notifying of personnel about faulty parts through the graphical user interface (GUI) during operation for better performance of the incubator. The proposed model was developed using a PIC16F688 micro controller, Temperature sensors (DS18S20), Humidity sensor (DHT11).*

*Key Words: Perspect, Neonatal, Vascomuscular*

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## 1. INTRODUCTION

Premature are babies which born before complete 37 weeks of pregnancy period. There for they are subjects to multiple serious health problems which could be calamitous for their life. For instance they suffer from mental retardation, learning and behavioral problems, cerebral palsy, lung problems and vision and hearing loss [8]. Vasomuscular responses of a neonatal are not adequate to create sufficient heat metabolically. In the case of new-born infants, especially preterm infants, immaturity of the thermo-regulatory system makes the infant more vulnerable to changes of environmental temperature. As the body temperature decreases, the baby becomes less active, lethargic, hypotonic and sucks poorly. As the condition progresses, it causes profound changes in body metabolism resulting in impaired cardiac function, hemorrhage, jaundice and death. 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 such as (36°C-38°C) for temperature,(70%-75%) for humidity [5], [3]. In an incubator the temperature of an infant is probed by the sensor. Now a day's many sensors such as thermocouples, thermistors, liquid thermometers and bimetallic strips are analogue sensors available in market [4]. Fault tolerant control (FTC) has been increasing in the last few years because FTC system has the ability to increase complex systems reliability and performance requirement in the events of faults. Fault may lead to system degradation or any unacceptable performance of the system (ANSI/AAMI/IEC Std 60601-2-19; 2009.). The new design and development of system is required to control the faults by self-calibrated Digital Sensor with on-chip DAQ. MEMS based digital temperature sensors are more advantageous due to On-chip ADC, fast conversion and programmable. It reduces errors, cable losses and gives more accurate measurement. ADT7410isMEMS based digital temperature sensor manufactured by Analogue devices is chosen for this purpose and interfaced to PIC18F8720microcontroller. Microcontroller acts as core of servo-control system, controls the peripherals like LCD, keypad, relays, buzzer, sensor and warmer in an incubator. Inter-Integrated Circuit (I2C) is a protocol developed by Phillips for synchronous serial communication for data transfer between a microcontroller and peripheral devices. Furthermore, the main purpose of this interface is that it uses only two communication lines, which are bidirectional [3,9]. The data transfer between ADT7410 Temperature sensor and microcontroller Master

Synchronous Serial Port (MSSP) module takes place through the I2C bus. A variety of principles for the measurement of the parameters have been assessed for the integration into the garment. Prototypes have been manufactured incorporating the chosen sensing principles with textile and textile-compatible technologies. A non-invasive infant monitoring system includes $CO_2$ sensors to non-invasively monitor the exhaled air from an infant in order to reduce the potential risks for Sudden Infant Death Syndrome (SIDS) [5]. $CO_2$ sensors placed in the crib around an infant to non-invasively monitor the exhaled air concentration variation from him/her. By monitoring the outputs of $CO_2$ sensors, we can detect if there is anything unusual with the infant's respiration. The output data is sent wirelessly to activate an alarm or logged for further diagnoses. The Developed Cot Death for Infants in Day Care system also worked on infant's respiration. There are some proposed infant monitoring systems, such as cardiopulmonary monitoring, vision monitoring, oxygen consumption monitoring and multi-purpose monitoring. Many of these approaches are invasive making both the infant and parents uncomfortable while some of the monitoring systems are not effective enough due to the unrecognized signs or low response of SIDS [9]. In many SIDS cases, the infants stop breathing without any signs of trauma. Not only careful nursing but also new techniques and instruments now played a major role as in adult intensive-care units, the use of monitoring and life-support systems became routine. These needed special modification for small babies, whose bodies were tiny and often immature. Adult ventilators, for example, could damage babies' lungs and gentler techniques with smaller pressure changes were devised. The many tubes and sensors used for monitoring the baby's condition, blood sampling and artificial feeding made some babies scarcely visible beneath the technology. Fault tolerance avoids service failure when faults are introduced to the system. An example may include control systems for ordinary nuclear reactors. The normal method to tolerate faults is to have several computers continually test the parts of a system, and switch on hot spares for failing subsystems. As long as faulty subsystems are replaced or repaired at normal maintenance intervals, these systems are considered safe. Interestingly, the computers, power supplies and control terminals used by human beings must all be duplicated in these systems in some fashion. This paper is organized as follow, next section gives a review of related work, section 3 represent the methodology and designs. Section 4 discusses the future work and conclusion follows in section 5.

## 2. RELATED WORKS

Incubators provide warmth and prevent heat loss to significantly improve survival rates. The use of air-heated incubators has been the standard method of providing a stable, individualized thermal environment for the newborn infant at risk. One of the very first incubators, invented by Stéphane Tarnier in the late 19th century, reportedly reduced mortality among infants with birth weights between 1200 and 2000 g from 66% to 38%2. The availability of incubators and radiant warmers in industrialized countries has made neonatal hypothermia uncommon, except in infants transported over long distances. In developing countries, however, hypothermia still poses a significant threat to the survival of low birth-weight and preterm infants. Even where incubators are available, their use is often fraught with operational difficulties. These include maintaining incubator air temperature, air flow and relative humidity within a narrow range in order to provide a thermo neutral environment for the infant being nursed naked. This level of regulation requires sophisticated modern equipment, neonatal intensive care units, highly skilled professionals and a constant electricity supply. The cost of such infrastructure is often prohibitive in developing countries such as Nigeria. [8].

[5] Depicted the development of a Wireless Monitoring System for Neonatal Intensive Care Unit (NICU), which is an isolated room for a premature/weak new-born baby. System provides the environmental condition similar to its mother's belly. Lack of attention to thermoregulation continues to be a cause of unnecessary deaths in the neonatal population.

[11] Described the design and implementation of a fully digital and programmable temperature system for the Oxygenaire Servo Baby Incubator. The transmitter circuits is also designed and implemented for all the variables of the incubator that are used as control signals like the air temperature sensor (Thermistor), baby skin temperature sensor (Probe), humidity sensor and air flow sensor. Two modes of operation are implemented in the control algorithm: air or skin mode. The AVR microcontroller is used as a control device and the control program is developed using assembly language programming. The control unit is sensitive to change of 0.1ºC. At start up, based on a unique control strategy, the incubator reaches its steady state in about 14 minutes.

[8] Proposed a novel technique by using Artificial Neural Network (ANN) in order to simulate the premature infant incubator control system by implementing the back propagation method. Sensors are used to indicate temperature, humidity, and oxygen concentration of the incubator internal environment. Sensors output are entering to the ANN, which identify the corresponding case and decide the suitable reaction upon previous training. The proposed ANN premature incubator control system in all conditions that can occur in the premature infant incubator environment proved right decision technique. The proposed Artificial Neural Network (ANN) based to control the premature infant incubator system is tested with a set of different cases including very extreme cases. The % errors of this system are ranged between 1.6e-2 to 4.6e-2 in controlling the temperature, between 0.10 to 0.12 in controlling the humidity and are between 0.12 to 1.30 in controlling the oxygen concentration.
[10] Designed a Smart Jacket for neonatal monitoring with wearable sensor. The smart Jacket aims for providing reliable health monitoring as well as a comfortable clinical environment for neonatal care and parent-child interaction. In this paper the author explores a new solution for skin-contact challenges that textile electrodes pose. The jacket is expandable with new wearable technologies and has aesthetics that appeal to parents and medical staff.
[5] Has done the study on designing an infant incubator for improved usability. This study helped to arrive at customer needs which were later converted into technical voice for the development of quality functional deployment (QFD), based on which final design specification (PDS) was listed. Five different concepts were generated. Final concept is selected based on Pugh's method of concept selection. From the study the finalized concept has superior usability features compared to that in the present market. The first official neonatal intensive-care unit (NICU) for neonates was established in 1961 at Vanderbilt University by Professor Mildred Stahlman, Incubator is a device in which premature or unusually small babies are placed and which provides a controlled and protective environment for their care. [12]. Every year, about 1 million infants in the developing world die due to heat loss and dehydration that can be prevented by an intensive care unit i.e. incubators [12]. Thus incubators provide congenial atmosphere for the infants, which helps in thermoregulation and the block diagram is as represented as below.

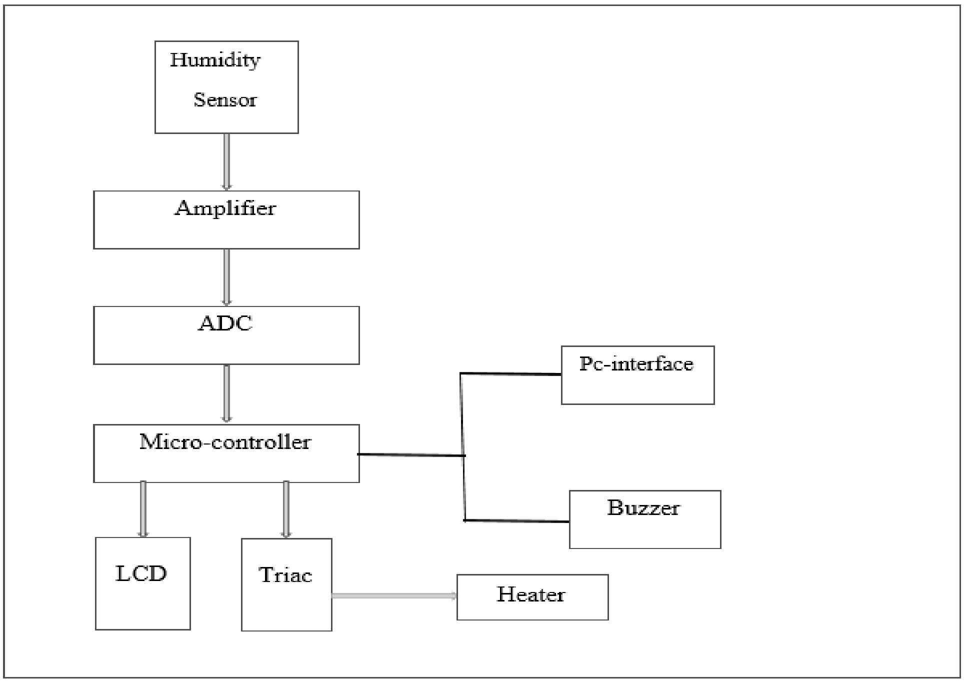


**Fig. 1: The Block Diagram of an Infant Incubator.**

## 3. METHODOLOGY AND DESIGN

Herein, components would have multiple backups and would be separated into smaller "segments" that act to contain a fault, and extra redundancy is built into all physical connectors, sensors, power supplies, wireless transceivers and microcontrollers. Multiple temperature and humidity sensors would be used to monitor the temperature and humidity in the incubator. Physical connectors to this sensor would also be in multiples while the power supply to the monitoring unit would be sourced from more than one source.

To remotely monitor the incubator, wirelessly, and to allow for fault tolerance the receiving end of the monitoring unit is designed and pre-programmed *expect* packet loss, duplication, reordering and corruption, so that these conditions do not damage data integrity, and only reduce throughput by a proportional amount.

The components (subsystems) used in order to achieve the set objectives of this paper are Hardware Subsystem and Software Subsystem. This subsystem focuses on the firmware and various hardware components used for the design as well as how they were interfaced with each other to realize the set objectives of this paper. The main hardware requirements for this paper are Microcontrollers (PIC16F688), Temperature sensors (DS18S20), Humidity sensor (DHT11), Wireless transceivers (Bluetooth) and Power supply. The software subsystem includes the use of Atmega and Graphical user interface.

### 3.1 Design

The design of the component involves various component in which all the components are replicated in three (3) different units so as to allow redundancy.

### 3.2 Component of functional unit

i. Power supply unit
ii. Temperature and humidity sensor
iii. Microcontroller

### 3.3 The power supply unit

The power supply unit would supply power to the microcontroller, the sensor board and other electronic components. The power supply unit employed herein is designed to have a battery backup to ensure uninterrupted supply to the monitoring unit.

### 3.4 Temperature and humidity sensor

The DHT11 sensor comes in a single row 4-pin package and operates from 3.5 to 5.5V power supply. It can measure temperature from 0-50 °C with an accuracy of ±2°C and relative humidity ranging from 20-95% with an accuracy of ±5%. The sensor provides fully calibrated digital outputs for the two measurements.

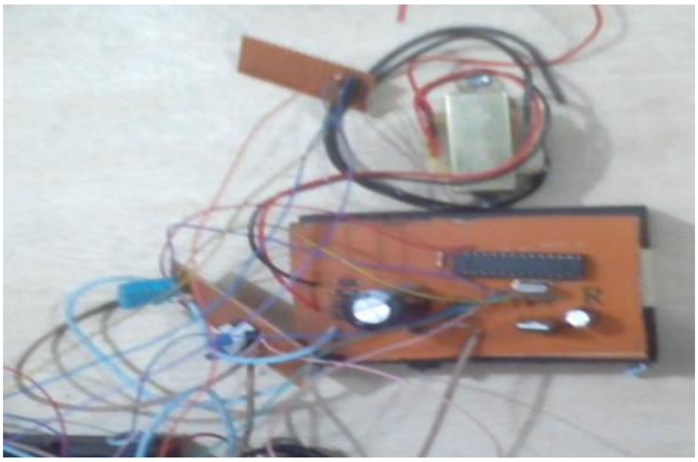

**Fig. 2: A functional unit of the components.**

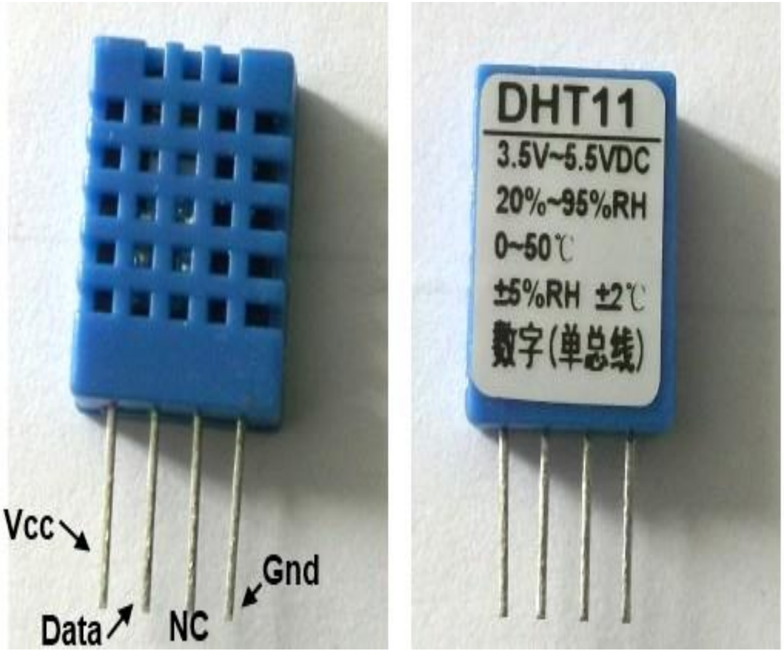


**Fig. 3: DHT11 temperature and humidity sensor.**

### 3.2.3 Micro controller

The PIC16F688 was chosen because of its following features: Precision Internal Oscillator: Factory calibrated to ±1%; Software selectable frequency range of 8 MHz to 31 kHz; Two-speed Start-up mode; Crystal fail detect for critical applications; Clock mode switching during operation for power savings, Power-saving Sleep mode, wide operating voltage range of (2.0V-5.5V) Industrial and Extended temperature range.

## 3.3 Graphical user interface

The graphical user interface (GUI) allows the user to interact with the hardware through graphical icons and visual indicators. The GUI was designed using Microsoft Visual studio (C#).

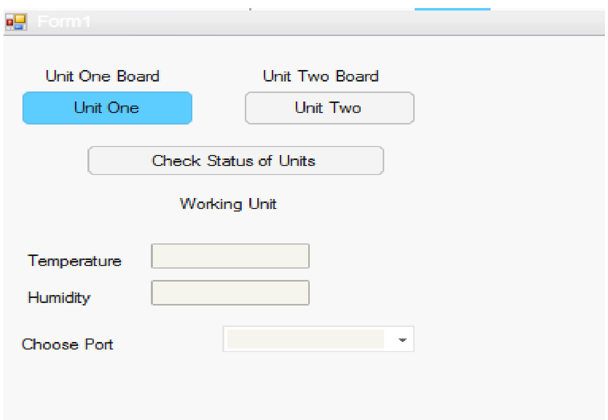


**Fig. 4: The graphical user interface.**

## 4. RESULT AND DISCUSSION

In The goal of this paper is to design and implement a fault tolerance infant incubator model that can be easily managed and monitored by individuals. The paper objectives were achieved by the creation of this model in question and a user friendly enabled interface.

## 4.1 Information relay interface

The diagram below shows how the information is being displayed concerning the operational condition of the model.

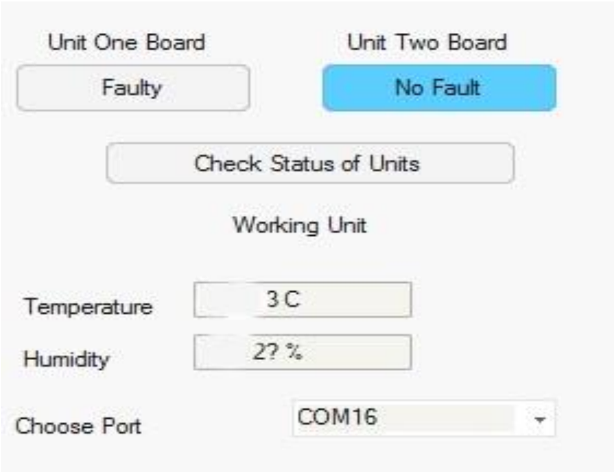


**Fig. 5: The information relay interface.**

## 4.2 The Incubator Model

This paper was coupled using aluminum rod as the main support for the box to make it withstand slightly heavy object such as neonates and also has standing knobs to prevent contact of the box with the ground, the aluminum stand is lined with rubber cable which helps to prevent heat loss to the environment and also humidity. The whole box is covered with a material called "perspect" which is quite different from glass material, the perspect is easy to work with, flexible and unto it the panel which houses the whole control unit is fastened. The control unit is fastened to the top and enclosed with a power supplying cable attached to each unit. The incubator box is as shown below in figure 6.

**Fig. 6: The infant incubator model.**

## 5. CONCLUSION

This paper which is the design and construction of infant incubator system with wireless information mechanism and PC interface was designed considering some factors such as economic application, design economy, availability of components and research materials, efficiency, compatibility and portability and also durability. The performance of this paper after test met design specifications. However, the general operation of the paper and performance is dependent on the user who is prone to human error such as entering wrong timing. Also the operation is dependent on how well the soldering is done, and the positioning of the components on the Vero-board. If poor soldering lead is used the circuit might form dry joint early and in that case the paper might fail. Also if logic elements are soldered near components that radiate heat, overheating might occur and affect the performance of the entire system. Other factors that might affect performance include transportation, packaging, ventilation, quality of components, handling and usage. The construction was done in such a way that it makes maintenance and repairs an easy task and affordable for the user should there be any system breakdown. The paper really gave a good exposure to digital and practical electronics generally which is one of the major challenges in this field now and in future. The design of the automatic phase with wireless control and PC interface. This paper was quite challenging and tedious but eventually was a success.

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