IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Affordable And Portable Artificial Incubator For Premature Babies

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Abstract: Prematurity is the considered to be a leading cause of childhood mortality worldwide. The primary cause of these deaths is the high cost or inaccessibility of keeping infants in hospital incubators. The objective of the work done is to design and implement a wireless incubator that is both inexpensive and portable for premature infants. The project's major goal is to reduce the causes of early death; hence it contains strategies to do that. As a result, the incubator's additional goals include minimizing the incidence of malaria and SIDS. It has sensors to monitor the incubator's vital environmental conditions. It gives this information to the pediatrician, allowing them to identify any issues that may jeopardize the baby's health. To maintain the proper temperature, the incubator can be powered by both the grid and a battery keep the temperature at the desired level all the time.

Index Terms **-** ESP32, MQ-2 Gas Sensor, DHT11 ,Incubator, LCD display.

I. Introduction

Premature birth is considered to be one of the major global health concerns, contributing significantly to neonatal and infant mortality. In 2015, the World Health Organization (WHO) predicted that around 1 million out of every 15 million preterm newborns died [1]. Complications are usually associated with premature birth are the primary cause of child mortality globally. This frightening number emphasizes the importance of developing effective measures to help premature infants, especially in low-income areas where access to healthcare facilities is limited.

Infants born two months or more prematurely are at an especially high risk. In low-income areas, approximately half of such babies die owing to a lack of basic but critical medical care, such as temperature regulation, lactation support, and infection treatment. Inadequate healthcare facilities and the prohibitive cost of clinical incubators worsen the crisis. Premature babies are more likely to develop hypothermia, infections, respiratory problems, and, eventually, death if they do not receive sufficient care. In India, the neonatal mortality accounts for about half of all baby deaths. This indicates that approximately half of all baby deaths in the country occur within the first twentyeight days of life, with preterm and accompanying complications accounting for a major fraction of the total.

Furthermore, premature newborns suffer disproportionately from Sudden Infant Death Syndrome (SIDS), accounting for around 18% of all SIDS cases [2]. Premature newborns' underdeveloped respiratory and neurological systems render them more vulnerable to catastrophic consequences, particularly in settings where effective monitoring and preventive measures are absent.

In addition to preterm, malaria is a substantial factor to child mortality, particularly in Africa and malaria is considered to be the top cause of mortality among children under the age of five, accounting for 90% of all malaria-related fatalities in Africa [3]. Malaria has an especially severe impact in Sub-Saharan Africa, where access to preventive and therapeutic care is frequently limited. Infants, particularly those born prematurely, have weakened immune systems, leaving them extremely vulnerable to infections and serious malaria consequences.

The financial burden of neonatal care is a pressing challenge faced by parents in low-income settings. Many mothers cannot afford to keep their premature babies in hospital incubators because of high medical costs, limited hospital resources, and long distances to healthcare facilities. As a result, many preterm infants do not receive the necessary thermal support and medical attention, increasing their risk of mortality.

Furthermore, the high prevalence of SIDS in premature infants necessitates immediate intervention. Babies who roll onto their sides or stomachs while sleeping are more likely to suffocate and die. This risk is especially high for preterm infants, whose underdeveloped respiratory systems render them more vulnerable. A well-designed incubator that guarantees appropriate resting posture and monitoring has the potential to drastically minimize the incidence of SIDS while also providing parents and caregivers peace of mind.

Malaria-related infant mortality is another serious problem, especially in areas where the disease is prevalent. Premature children, who are already delicate and susceptible, are more likely to develop difficulties if exposed to malaria. Providing an environment that protects young newborns from mosquito bites and infection is critical for lowering malaria fatality rates.

Given these limitations, the proposed work aims to create an inexpensive, efficient, and portable incubator tailored to low-income families. By tackling the major causes of premature infant mortality, such an incubator has the potential to save thousands of lives each year.

To address the high death rate among preterm infants, the work intends to create and execute a low-cost, portable incubator capable of maintaining a constant temperature of 37°C. This incubator is designed to meet the demands of families in resource-constrained environments, thus ensuring critical care for their premature newborns.

II. Related Work

Premature babies can die from a several different causes, one of which is an inability to control and maintain their body temperature [1]. Every year, approximately 20 million premature and low birth-weight babies are born in underdeveloped nations, with 4 million dying within the first month due to the unreliability and inaccessibility of standard incubators [1]. Mothers in low-income communities cannot afford to maintain their premature kids in clinical incubators. SIDS is often linked to a sleep cycle and risk factors include as prone/face-down sleep, bed sharing, soft bedding, and overcrowding in the sleeping area.

As a result, a custom dating back to the 1930s has been developed to make sure that all children, regardless of background, get an equal start in life by providing expectant mothers with a cardboard box with a mattress in the bottom that serves as the baby's first bed. Because of this, Finland has one of the lowest infant mortality rates [2]. Malaria is another major cause of infant mortality that requires urgent care. According to the World Health Organization [6], "Every two minutes, a kid suffers from malaria. Every year, almost 200 million new cases of the disease are reported. Although countries have significantly reduced the total number of malaria infections and deaths since 2000, progress has slowed in recent years.Worryingly, malaria is becoming more prevalent in several regions."

As a result, infants, particularly premature babies, should not be subjected to mosquito bites. This can be accomplished by using an insecticide-treated mosquito net. Hypothermia, which is clinically defined as a body temperature of less than 36.5 degrees Celsius, is a substantial contributor to neonatal death and morbidity worldwide [4]. A temperature-controlled environment is critical for newborn survival [5]. The goal of temperature monitoring is to keep the youngster in a thermoneutral environment [6]. Even though modern incubators exist today, they are pricey to satisfy the demands of developing countries [4].

Embrace Infant Warmer Embrace Innovation is a medical innovation business dedicated to developing and delivering sophisticated, cost-effective, and dependable medical products to emerging countries. Their initial product is a low-tech newborn warmer, a portable, low-cost incubator designed to lower the risk of death among premature infants in underdeveloped countries. The Embrace Infant Warmer is small and light, resembling a tiny sleeping bag. It is readily transported to rural settlements.

Inflatable Incubator James Roberts, a Lough-borough University graduate, designed a manually inflating incubator that is warmed using ceramic heating components. It contains a screen that shows the temperature and humidity based on the baby's age, an alert that sounds if the required temperature changes, and a photo-therapy unit for babies with jaundice. It is comparable to a modern incubation system and costs £250 to produce and test. The device can be collapsible for portability and runs off a battery that lasts 24 hours, in case of power outages [4].

The objective of work is the creation of a smart infant incubator monitoring and control system using the IoT technology to tailor the care and monitoring of premature and severely ill neonates. The system is integrated with modern sensors, actuators, and connectivity systems to create a smart and responsive incubator environment. The system incorporates many key components, including a temperature and humidity sensor for precise environmental monitoring, a gas sensor, a heartbeat sensor, a sound sensor, and an accelerometer to monitor the infant's conditions inside the incubator, and actuators such as a Peltier module and a humidifier to adjust the environmental conditions based on the threshold range on the processed sensor data.

The advances in technology have ensured better survival rates, mainly for extremely preterm babies. While skilled medical therapy is critical to infant survival, social factors and care-giving practices are major predictors of infants' future outcomes. As a result, data is collecting to illustrate the crucial involvement of mothers and families in the best developmental outcome of premature babies.

III. Methodology

The block diagram depicts an ESP32-based monitoring and control system with multiple sensors and actuators for automation and safety applications. The system is powered by a dedicated power source that provides a consistent voltage to the ESP32 and its related components. The ESP32 takes data from sensors, including the MQ-2 gas sensor, which detects dangerous chemicals like LPG and CO, and the DHT11 sensor, which monitors temperature and humidity. A buzzer is linked to send alerts when predetermined conditions are fulfilled, and an LCD display presents real-time sensor readings for user monitoring. These components enable the system to serve as an intelligent monitoring solution for environmental and safety management.

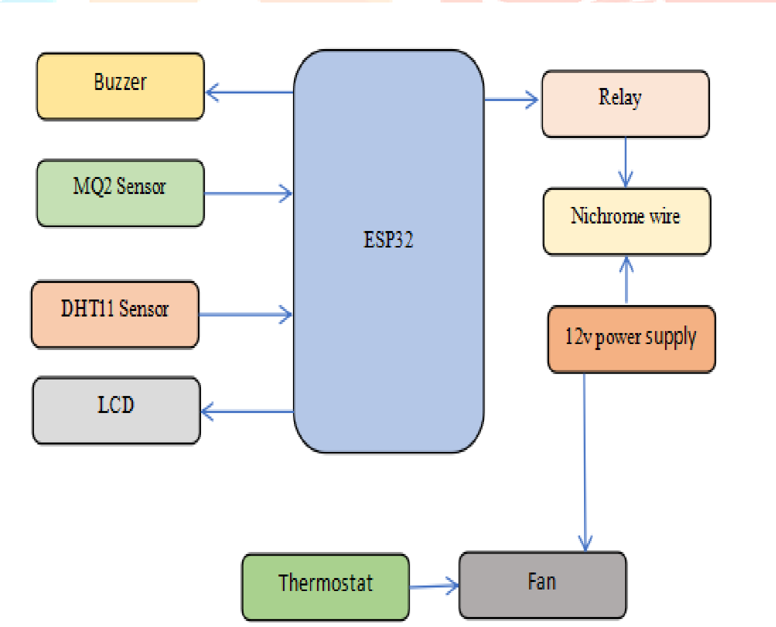

Fig 1: Block diagram of infant incubator

On the output side, the ESP32 activates a relay, which turns a Ni-chrome wire heating element fed by a 12V power source. This heating device can be utilized for temperature control or incubation purposes. A thermostat is also included in the system to monitor and regulate temperature by regulating a 12V DC fan, ensuring adequate ventilation when necessary. The ESP32's mix of sensors and actuators allows it to regulate ambient conditions independently using real-time data.

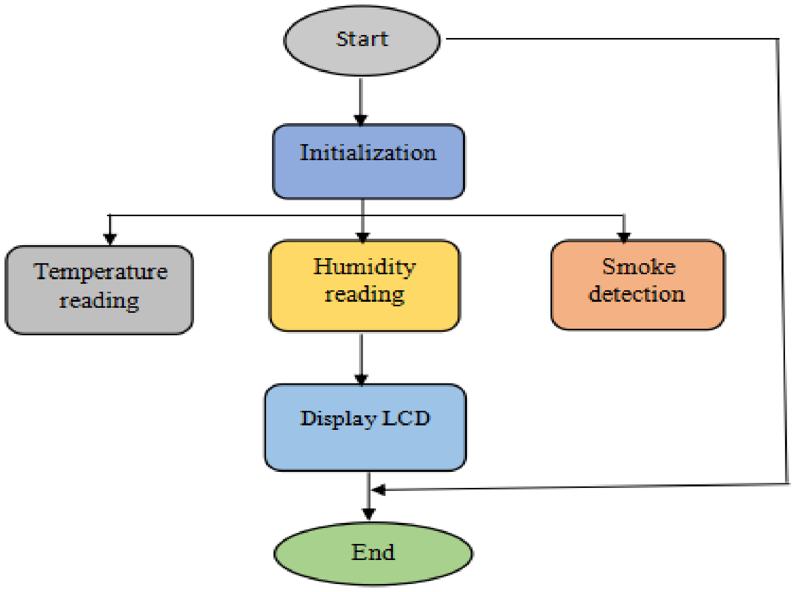

Fig 2: Flow diagram for infants' incubator

The flowchart displays a system that begins with an initialization phase to configure the necessary components and sensors. After initialization, the device takes three simultaneous readings: temperature, humidity, and smoke detection. These parameters are obtained from the respective sensors, ensuring that the environmental conditions are continuously monitored. The temperature sensor monitors the ambient temperature, the humidity sensor records the moisture content of the air, and the smoke detector detects the presence of smoke or hazardous gases. The data from temperature, humidity, and smoke detection sensors is collected and presented on an LCD display for visualization. This stage provides real-time values for monitoring. The process subsequently comes to a close, but a feedback loop returns it to the beginning, proving that the system runs in a loop. This setup is useful in applications such as environmental monitoring, fire detection, and smart home automation, where real-time data gathering and display are crucial to decision-making.

IV. IMPLEMENTATION

The diagram displays a model of an incubator's heating system and how ambient temperature influences the incubators inside temperature.

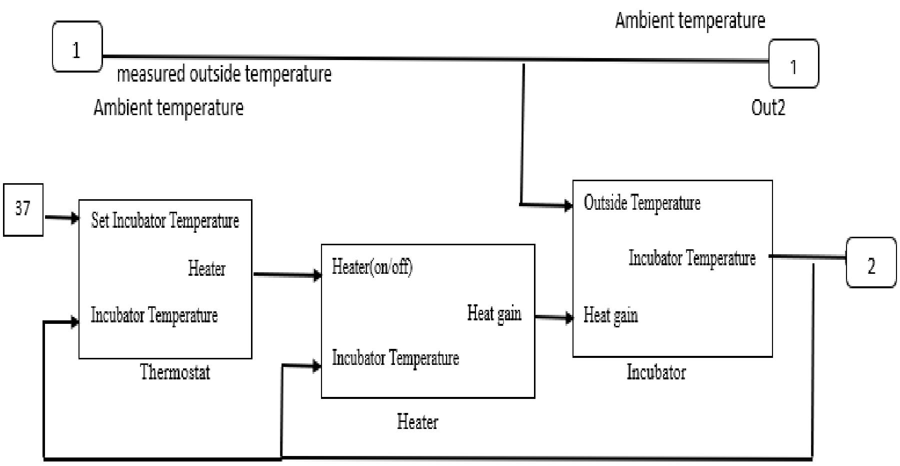

Fig 3: Model of the incubator heating system

The device includes a thermostat that controls a heater (Nichrome wire) to keep the incubator at a constant temperature of 37°C. The observed outside (ambient) temperature is viewed as an input that effects the heat gain within the incubator. The thermostat adjusts the incubator's temperature and turns on or off the heater to maintain optimal conditions. The amount of heat gained within the incubator is determined by the ambient temperature and the operation of the heater. When heater is turned on, the incubators temperature is raised so as to compensate for any heat loss to the surrounding environment. When the heater is turned on, it raises the temperature of the incubator to compensate for the heat loss to the surrounding environment. The system constantly adapts itself to preserve stability and provide optimal conditions for egg incubation, medical applications, or other regulated environments. The ambient temperature and the incubator temperature are two of the output elements that are considered critical for understanding the heating model's performance, as illustrated in Figure 3. The heating system was simulated to demonstrate how changing ambient temperature impacts the incubator temperature. The circuit diagram in illustrated in Figure 4.

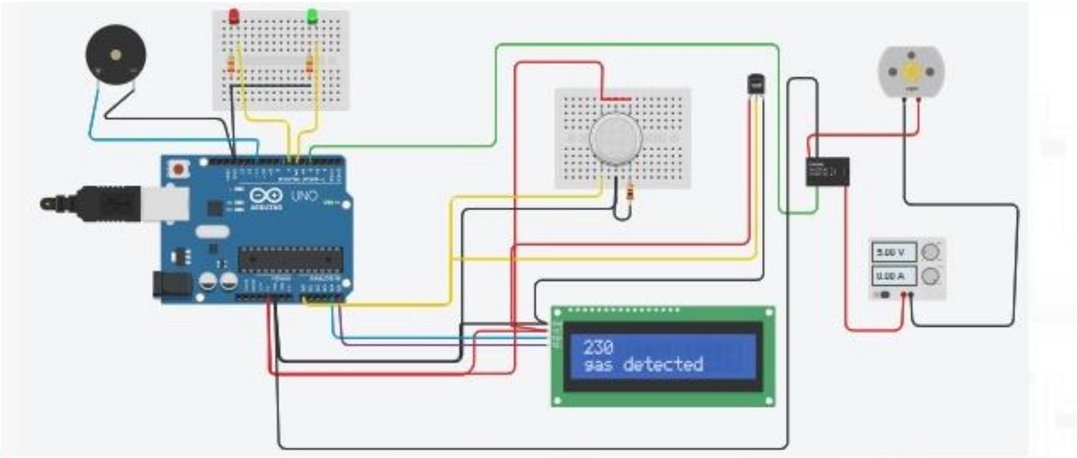

Fig 4: Circuit diagram

V. RESULTS AND DISCUSSION

This advanced incubator for preterm infants presents a cost-effective and portable solution, leveraging wireless technology to enhance mobility and maintain stable temperature control. The device is designed to support multiple power sources, allowing for both conventional electrical connections and battery operation. It is equipped with a battery level indicator to ensure reliable performance and to avert any interruptions due to power issues. Emphasizing ease of use, the incubator features a comprehensive array of sensors that continuously monitor essential environmental factors, such as temperature, humidity, levels of potentially harmful gases (including smoke detection), and ambient light conditions.

The data collected is displayed on a local LCD screen, providing parents with real-time information, while also being transmitted wirelessly to the pediatrician. This dual-display system facilitates timely and informed clinical decisions, enhancing the overall care provided to the infant. Additionally, the incubator incorporates insecticide-treated mosquito nets as a proactive measure against malaria transmission. This feature is particularly significant in regions where malaria poses a serious risk to infant health, contributing to efforts aimed at reducing mortality rates associated with the disease. By integrating these innovative elements, the incubator not only addresses the immediate needs of preterm infants but also supports broader public health initiatives.

In summary, this incubator represents a significant advancement in neonatal care, combining affordability, mobility, and advanced monitoring capabilities to ensure the well-being of vulnerable infants. Its thoughtful design and features reflect a commitment to improving health outcomes and providing peace of mind to both parents and healthcare providers.

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