# ADVANCED PREMATURE INFANT INCUBATOR WITH INTEGRATED SENSOR TECHNOLOGY AND REMOTE MONITORING SYSTEM

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.


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**AUGUST, 2024**

# Declaration

I hereby declare that this project **"Advanced Premature Infant Incubator with Integrated Sensor Technology and Remote Monitoring System."** represents Our own work which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

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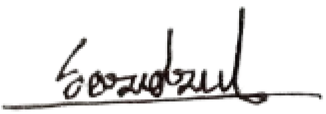

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# Approval

The project entitled "**Advanced Premature Infant Incubator with Integrated Sensor Technology and Remote Monitoring System.**" submitted by Md. **Nadim (201-33-1263), Shabbir Ahmmed ( 201-33-1265 ), Md. Sazidul Islam (201-33-1277) & Md. Sohanur Rahman Sagor ( 201-33-1279 )** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** in **August, 2024.**

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# Dedicated To

OUR PARENTS

AND

RESPECTED TEACHERS

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| | |
|---|---|
| DIU | Daffodil International University |
| EEE | Electrical and Electronic Engineering |
| CCDs | Charge-Coupled Devices |
| CPU | Central Processing Unit |
| DC | Direct Current |
| ECG | Electrocardiogram |
| FDA | Food and Drug Administration |
| FHIR | Fast Healthcare Interoperability Resources |
| GDPR | General Data Protection Regulation |
| GPC | Generalized Predictive Control |
| HIPAA | Health Insurance Portability and Accountability Act |
| IEC | International Electrotechnical Commission |
| ISO | International Organization for Standardization |
| MCU | Microcontroller Unit |
| MDR | Medical Device Regulation |
| NICU | Neonatal Intensive Care Unit |
| PCB | Printed circuit board |
| pH | Potential of Hydrogen (a measure of acidity or alkalinity) |
| PVC | Polyvinyl chloride |
| RoHS | Restriction of Hazardous Substances |

| | |
|---|---|
| TEC | Thermoelectric Cooler |
| TSMC | Taiwan Semiconductor Manufacturing Company |
| USB | Universal Serial Bus |
| UV | Ultraviolet |
| WEEE | Waste Electrical and Electronic Equipment |
| WHO | World Health Organization |
| AD8232 | Heart rate monitor sensor model AD8232 |
| AM2302 | Digital Temperature and Humidity Sensor Module AM2302 |
| DS18B20 | Digital temperature sensor model DS18B20 |
| ESP32 | A microcontroller with Wi-Fi and Bluetooth capabilities |
| KL25Z | A microcontroller board based on the ARM Cortex-M0+ processor |
| MAX30102 | Pulse oximeter and heart-rate sensor model MAX30102 |

# ACKNOWLEDGEMENT

First of all, we want to give thanks to **Almighty Allah**. With his blessing, we are able to complete our work with best effort.

We want to pay our utmost respect to our Supervisor **Professor Dr. Md. Shahid Ullah, Professor & Head**, **Department of EEE, Daffodil International University** for who has given us the chance to work on an impactful idea and taken care of every issue of development of this concept. Then we would like to take this opportunity to express gratitude to our supervisor for being dedicated in supporting, motivating and guiding us throughout this project. This project can’t be done without his useful advice and help. Also thank him very much for giving us the opportunity to work with this project.

We also want to convey our thankfulness to **Jahedul Islam, Lecturer, Department of EEE, Jashore University of Science and Technology** for his support and encouragement. Apart from that, we would like to thank our entire class fellows for sharing knowledge; information and helping us in making this project a success. To beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this Institution.

# ABSTRACT

An incubator is a device that keeps a premature new-born baby warm to the same temperature as the mother's womb. Premature babies have abnormal birth conditions, their bodies are smaller than normal babies because their gestation period has not yet passed. The purpose of this project on the design a low-cost compact system and a modern technology based for use in a new-born incubator. The care of premature babies in incubators has evolved significantly with advanced technology and monitoring systems. A modern premature baby incubator is equipped with many sensors and control systems. The incubator incorporates temperature and humidity sensors pulse and oxygen sensors dust sensors is ECG sensors and sound sensors to monitor the baby's vital signs and environmental conditions continuously. Healthcare providers and carers can access previous data and have real-time monitoring as a result of the integration of Firebase database into mobile applications that send and store data gathered from these sensors.To aid with additional analysis and documentation, the system also includes a data recorder that logs the information into Google Sheets. The incorporation of auxiliary system improves the incubator’s functionality, including a humidifier to maintain optimal humidity levels, Peltier modules for precise temperature control, and UV light for sterilization of the premature baby. Adequate system power supply is ensured with battery backup and solar panel integration. This setup ensures an uninterrupted operation and sustainability particularly in resource constrained environments. In order to maximize the health outcomes of premature babies in incubators, the combination of advanced sensor technologies, data management systems, auxiliary equipment, and sustainable power solutions represents a significant leap in neonatal care.

***Keywords:***

**Neonatal incubator; Premature infants; Sensor integration; Data management; Sustainable power solutions; Neonatal care optimization**

# CHAPTER 1
# INTRODUCTION

## 1.1 INTRODUCTION

An incubator is a specialized medical device used primarily in neonatal intensive care units (NICUs) to provide a stable and controlled environment for newborns, especially those who are premature or have serious health issues. The primary functions of an incubator include maintaining a consistent temperature range of 36.5°C to 37.5°C (97.7°F to 99.5°F), regulating humidity levels to prevent dehydration, and supplying clean, filtered air to support the infant's respiratory needs [1]. These conditions help mimic the protective and nurturing environment of the womb, which is crucial for the growth and development of premature infants. By offering such an environment, incubators play a critical role in improving the survival rates and health outcomes of these vulnerable newborns.

Premature infants are those that are born weighing less than 2500 grams and before the typical 36 to 37 weeks of gestation [2]**.** Because of this underdevelopment of its physiological systems, the newborn is more susceptible to many health issues. Common issues include jaundice brought on by an immature liver, respiratory issues brought on by weak, undeveloped lungs, hypoglycemia, hypoxia, and even fatalities brought on by an immature nervous system's reaction to cold stress [3]**.** According to World Health Organization (WHO) estimates from 2015, preterm birth ranks as the second-leading cause of death for children who did not complete their fifth year of life and the most common fatal syndrome in the first month after birth. One million out of fifteen million preemies are estimated to die as a result of prematurity[4]**.** The escalating risk of mortality correlates directly with the degree of prematurity in infants, posing a significant public health concern due to the increasing number of fatalities[5]**.** Premature infants require specialized care to ensure their survival and healthy development, particularly in the critical early stages of life.

Customarily, the newborn incubator serves as a vital medical apparatus dedicated to preserving the lives of premature infants. Within these incubators, infants are enveloped in a thermally regulated environment designed to mimic the conditions of the maternal womb. This controlled setting ensures optimal temperature and relative humidity levels, fostering swift development while minimizing the risk of disease contraction for premature newborns. In newborn incubators, elevating the relative humidity has been shown to decrease water loss from the skin of premature infants born before 30 weeks of gestation. This adjustment helps in maintaining the infant's body temperature [6]. During the initial days of life, premature newborns can experience evaporative losses equivalent to up to 20% of their body mass. This loss can be mitigated by raising the humidity levels within the incubator. Skin evaporation exchanges between the neonate and the surrounding environment are directly influenced by the difference in water vapor partial pressure between the newborn's skin and the air[7].

## 1.2 PROBLEM STATEMENT AND PROPOSED SOLUTION

In Bangladesh, the supply of incubators for premature babies poses a serious problem, especially in rural areas and underprivileged populations. There are multiple causes that lead to this issue:

### 1.2.1 Limited Healthcare Infrastructure:

Bangladesh, like many developing countries, faces challenges in healthcare facilities, particularly in rural areas. The availability of specialized equipment like premature baby incubators currently not available in remote areas. It is available only in some places of district level. At present, some hospitals at the district level have the system of premature baby incubators, but in most cases, due to limited of seats, there is a delay in providing health care to children even in emergency cases. As a result, we see the child's health risk and even death.

### 1.2.2 Financial Constraints:

Premature baby incubators are expensive medical devices that require significant investment. Many healthcare in Bangladesh, especially those in rural areas or public hospitals with limited budgets. They can't afford these services. Premature babies need to be treatment quickly. Many families are unable to afford the additional costs. So, they unable to admit their children immediately. As a result, put their children's lives at risk.

### 1.2.3 Training and Technical Support:

Effective utilization of premature baby incubators requires trained healthcare professionals who can operate and maintain these devices. There is shortage of skilled personnel with the necessary training and expertise, particularly in rural healthcare settings.

Keeping these issues in mind, we have developed a smart premature baby incubator to solve them. We believe that with this device we can solve all the above problems. It is possible to give this device to the remote areas of Bangladesh at a very low cost. We are developing this device by using some new and advanced technologies along with the baby incubators available in our country. Which will provide more benefits than the current baby incubators. We have developed an app in this project. Through which the specialist doctor can directly observe the current condition of the child and all previous data from any place. Based on the condition of the child, the doctors and nurses in charge can give directions. Which will play an important role in the better treatment of the child. At the same time, the relatives of the patient can see and know all the information of the child through the use of this app.

## 1.3 AIMS

- Our main aim of this project is to bring back a healthy life to the child while reducing the mortality rate of every premature child through best treatment in every remote area of the country at a low cost.
- One and a half million premature babies are born every year around the world. Out of this 1 crore 10 lakh children died. 1 in 10 newborns are born prematurely. 35 percent of all neonatal deaths are due to prematurity and its complications. This is the global situation.
- About 4 lakh 39 thousand premature babies are born in Bangladesh every year. We want each of these children to return to a healthy life with good treatment at low cost. The greatest gift in the world is a newborn. But if the newborn is immature, chest

tremors are felt. We have created this project with the aim of restoring the lives of every unborn child and returning them to their families.

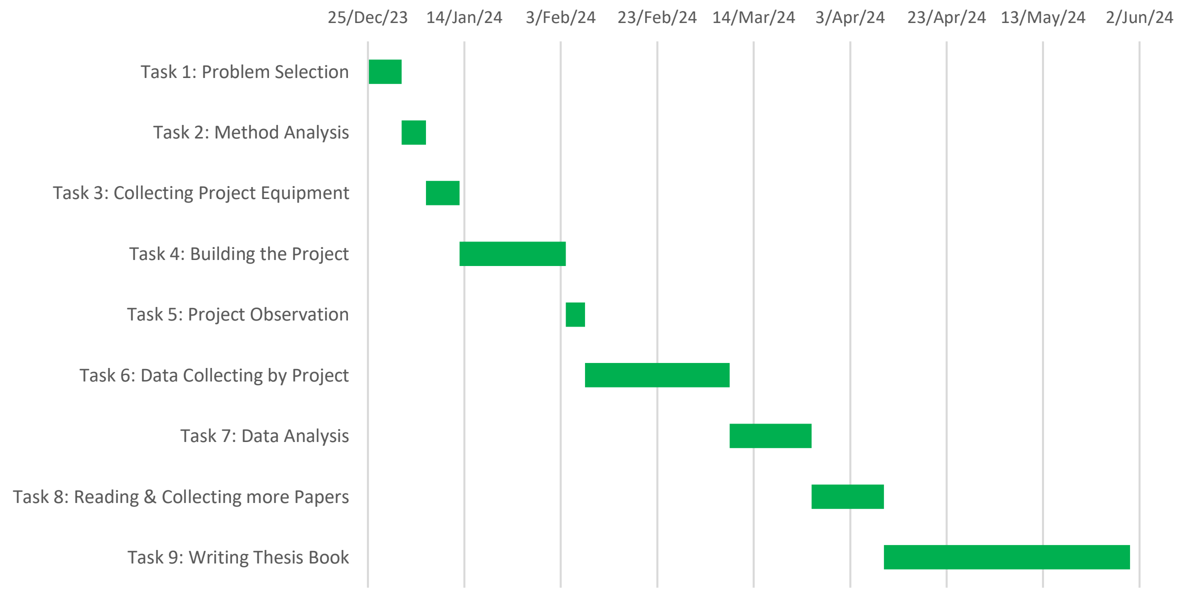
At present premature baby incubators are available only at the district level in our country. Not yet available in all districts. Then it is a very expensive treatment and also with limited seats in hospitals increasing the risk of premature babies. At the same time, his family has to suffer a lot of mental and financial suffering. Due to the low price of this device, new and advanced features, we can save the health of newborns and their families from mental and financial distress by providing advanced treatment to all premature babies in remote areas of the country, Insha'Allah.

## 1.4 METHODOLOGY

The ability of a newborn to regulate their body temperature is one of the most critical components of their survival. Although a newborn can easily become a mature homoeothermic, there is a very narrow temperature range in which an infant can function. The ideal body temperature for an infant is between 37 and 38 degrees Celsius. The control of humidity is an additional crucial component. Dehydration in infants born at 31 weeks or less when treated in an environment with a relative humidity of 20% exceeds 200 milliliters per kilogram per day. A room that is suitable for babies must have a relative humidity of between 70% and 75%. We designed an incubator system that regulates the humidity and temperature of the newborn's surroundings while keeping in mind the aforementioned issues.

The proposed system will monitor the temperature of the incubator, heartbeat rate, dust, sound and urine of the baby inside the incubator. The study has been done from various pieces of literature to understand the optimal threshold limits for various sensors. In this project we have used Peltier to heat the environment inside the incubator as needed and cool it as needed. The sensor monitors the environment inside the incubator and takes necessary action by itself. The temperature of the incubator is monitored using DS18B20 body temperature sensor in our project. According to an article published by Infant Centre (2018), the threshold range of temperature to be maintained inside the incubator is 37.2°C to 37.8° C. We have used this MAX30102 sensor to monitor pulse and oxygen levels in the baby's body and take necessary steps. The heartbeat rate of the premature baby has been fixed from 140 to 170 which is considered to be normal for a baby born at 24 to 28 weeks of pregnancy.  The infant's heart rate and rhythm are continuously monitored in this study by the AD8232 heart rate sensor in a newborn incubator. It aids medical professionals in identifying any anomalies or irregularities in the infant's heart activity. This real-time data helps with prompt newborn care and intervention. The discomfort of the baby inside the incubator is monitored using a sound sensor. If the baby cries due to discomfort, the sound sensor will generate a signal to the controller and indicate monitoring apps which in turn alerts the doctor. A notification and the apps visual color indicator in the system is used for the doctor to let the system know that he/she has acknowledged the abnormalities.

## 1.5 GANTT CHART




| | Task 9: Writing Thesis Book | Task 8: Reading & Collecting more Papers | Task 7: Data Analysis | Task 6: Data Collecting by Project | Task 5: Project Observation | Task 4: Building the Project | Task 3: Collecting Project Equipment | Task 2: Method Analysis | Task 1: Problem Selection |
|---|---|---|---|---|---|---|---|---|---|
| Start Date | 4/10/2024 | 3/26/2024 | 3/9/2024 | 2/8/2024 | 2/4/2024 | 1/13/2024 | 1/6/2024 | 1/1/2024 | 12/25/2023 |
| Duration | 51 | 15 | 17 | 30 | 4 | 22 | 7 | 5 | 7 |

## 1.6 STRUCTURE OF THE REPORT

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Materials and Methods

Chapter 4: Results and Discussions

Chapter 5: Project Management

Chapter 6: Impact assessment of the project

Chapter 7: Conclusions and Recommendations

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 INTRODUCTION

An overview of the literature on the usage of sophisticated preterm newborn incubators with integrated sensor technologies and remote monitoring systems is presented in this publication. The review's objectives are to assess the state of the art in this area and investigate the factors that are contributing to the growing use of these cutting-edge incubators in newborn intensive care units (NICUs) around the globe.

In response to the increased interest in and significance of improving the care given to preterm newborns in NICUs, a literature study was carried out. Premature delivery is still a major worldwide health concern, and because of their fragile condition, prematurely born babies frequently need specialist care and assistance. Using cutting edge technology has become a viable strategy; examples include incubators with integrated sensor technology and remote monitoring systems.

This study attempts to clarify the effectiveness, significance, and possible ramifications of advanced preterm infant incubators in newborn care practices by combining the available research and literature. It aims to give politicians, academics, and healthcare professionals insightful information that will help them make better decisions, encourage further research, and eventually improve the standard of care given to preterm newborns in NICUs.

## 2.2 RELATED WORKS

In 2010, Wei Chen et al.’s research paper presented the design of a "Smart Jacket" for continuous vital sign monitoring of newborn infants in Neonatal Intensive Care Units (NICUs). The goal of the jacket is to give babies a more pleasant and non-intrusive option to standard sticky sensors, which can irritate and stress them out. The Smart Jacket has a wearable temperature sensor, a reflectance pulse oximeter for measuring blood oxygen saturation, and textile sensors for monitoring electrocardiograms (ECGs). The design avoids sharp edges and uses soft materials with the goal of maximizing comfort and safety. The jacket can be worn both inside and outside of the incubator and is made to be simple to put on and take off. Their main area of interest is the use of smart textiles for ECG monitoring. The silver-coated Medtex 130+B and the gold-printed textile electrodes were the two types of textile electrodes that were evaluated. While the gold electrodes needed less pressure to make contact but were not hypoallergenic and lost conductivity after washing, the silver electrodes were found to be more resilient and hypoallergenic. Although the design is currently being refined, the preliminary findings are positive. To maximize the effectiveness of the textile sensors and investigate the jacket's potential for further vital sign monitoring applications, more study is required [8].

In Tamanna et al.'s 2012 research, for use in neonatal incubators, an improved temperature control system was created. The study emphasized the benefit of using an on-off control mechanism, which successfully kept the incubator temperature stable throughout and at the appropriate level [9].

Arief Hendra compared the accuracy of temperature and humidity readings from the DHT11 and DHT22 sensors in 2014. The study was done on the Atmel AVR and Arduino platforms, and the results revealed that the DHT22 temperature sensor produced indoor data that were more accurate than the DHT11 temperature sensor. For temperature parameters, DHT11 measurements produced marginally superior findings; however, DHT22 measurements, even with a small difference, produced better results for humidity parameters [10].

In 2015, Dr. Lini Mathew et al.'s research paper presented a design for a microcontroller-based infant incubator that effectively controls temperature and humidity. They stress how important it is to provide preterm babies with a stable environment because their immature thermoregulation mechanisms make them especially vulnerable. The incubator maintains ideal humidity and temperature levels with the help of an Arduino microcontroller, a PID controller, and easily accessible sensors [11].

In 2017, Feki et al. studied the use of an Arduino board for generalized predictive control (GPC) temperature regulation in a simulation model of a newborn incubator. The results of the study showed that when the infant was not present, GPC control performed better[12].

In 2019, Ali Ghazi Shabeeb et al.'s research paper presented a system for remotely monitoring infant incubators. It measures and sends temperature and humidity data to a ThingSpeak IoT platform using Arduino microcontrollers, DHT11/DHT22 sensors, ESP8266 WiFi modules, and NodeMCU-v3. The system's real-time incubator condition data is intended to guarantee a healthy environment for premature newborns [13].

In 2019, Dr. Revathi Venkataraman et al.'s research paper examines how neonatal incubator monitoring technologies can be used to enhance the care given to preterm babies. They talk about the common health issues young babies deal with, the vital signs that are tracked, and the different technologies that these systems employ. They draw attention to the significance of non-contact sensing techniques as well as the difficulties and continuous progress in this area [14].

Rasha M. Abd El-Aziz et al.'s research report published in 2021 focuses on how important it is to monitor and control neonatal incubators in real-time, especially for premature newborns who have a high mortality risk. Conventional techniques frequently fall short, which can cause mishaps and necessitate ongoing human oversight. The authors offer a creative way to monitor critical incubator characteristics including temperature, humidity, and gas levels at a reasonable cost and with safety by leveraging the Internet of Things (IoT). The Arduino UNO-powered device provides wireless data transmission to medical personnel, facilitating prompt intervention and enhanced patient safety. The study examines current research and technology, emphasizing how the Internet of Things has the potential to transform newborn care and raise infant survival rates [15].

## 2.3 COMPARE AND CONTRAST

Our main aim in this project is to make accessible to remote areas. The entire system of our project will be powered by solar panels and will have battery backup at night. Due to this, people will not be deprived of its benefits even in remote areas where the power system is poor. Conventional infant incubators currently use heaters for temperature control, but our incubators use Peltier for easy temperature control. We also have some new technologies in use in our incubators. Among which sound sensor, water sensor, dust sensor is significant. Even all the information of the baby in our incubator can be monitored from anywhere through the software, which is not available in the current baby incubators. The results of this study are expected to prompt health professionals to consider the use of water in the newborn incubator's humidity system. Additionally, it is anticipated that controlling humidity levels will enhance the quality of life for premature newborns by promoting environmental thermoneutrality.

## 2.4 SUMMARY

The cost aspect has been taken seriously in our designed baby incubator. Compared to the baby incubators currently in the market, our incubator will require less energy and the maintenance cost of this project will be lower. Also, the child's data will be continuously monitored through the software, which the doctor and the child's family can monitor from anywhere.

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 INTRODUCTION

The process of creating a compact, affordable system for the incubation of premature newborns requires careful consideration while combining several kinds of sensors and control systems. The process used and the materials used to create the modern-day prematurely born baby incubator are described in depth in the portions that follow.

## 3.2 METHODS AND MATERIALS

### 3.2.1 System Overview:

The newborn's incubator system is constructed from several in interconnected parts which function together to monitor environmental factors as well as essential indicators while creating an appropriate environment for the preterm baby to grow up. These elements consist of:

- Body Temperature sensor
- Temperature and Humidity sensor
- Pulse and Oxygen Sensor
- Dust Sensor
- ECG
- Sound Sensor
- Arduino Uno
- ESP 32
- Humidifier
- Peltier
- UV LED
- Bazar
- Battery
- Solar panel
- Buck Converter
- Arduino Pro Mini

### 3.2.2 Body Temperature Sensor

FIGURE 3. 1 BODY TEMPERATURE SENSOR

We used DS18B20 body temperature sensor to monitor newborn baby body temperature in our project. The temperature sensor model number DS18B20 is water-resistant. Very useful in damp weather or whenever it's necessary to quantify anything distant. Since the sensor can withstand temperatures up to 125°C, experts recommend remaining below 100°C because the cable is covered with PVC. Even at great distances, there is no signal deterioration as they are computerized! With the DS18B20, temperature measurements may be configured from 9 to 12 bits through a 1-wire user experience, requiring only one wire (plus ground) to be linked from a central CPU. Appropriate for 3.0-5.5V applications. Multiple DS18B20s can coexist on a single 1wiree bus as each one has its own chip code. Therefore, it is possible to install temperature sensors at a variety of locations.

### 3.2.1 Temperature and Humidity Sensor

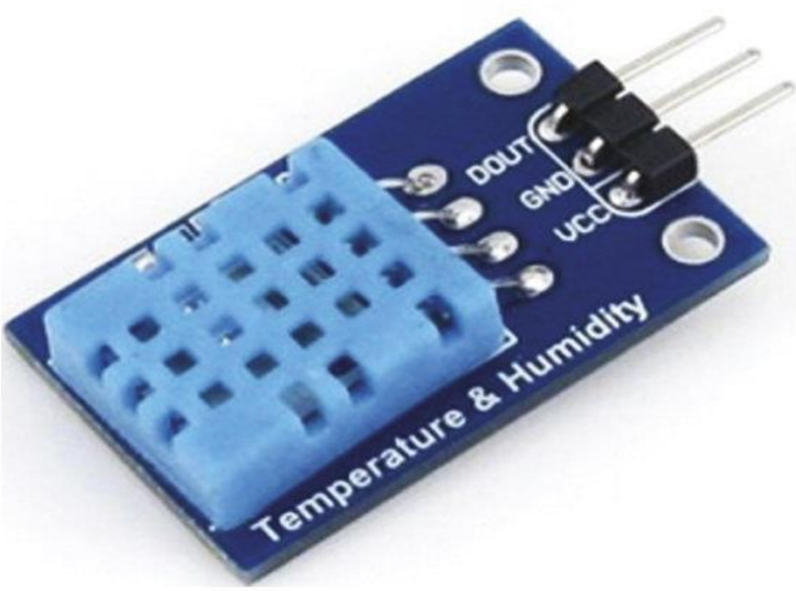



FIGURE 3. 2 TEMPERATURE AND HUMIDITY SENSOR

In this project we used AM2302 sensor to detect baby's body temperature and humidity. A simple, affordable technological temperature and humidity sensor is the DHT22 Digital Temperature and Humidity Sensor Module AM2302. It measures the ambient air using a thermometer and a moisture sensor that is capacitive before emitting a digital signal on the information pin (no physical input connections are required). Since it's quite easy to set up, time is crucial to capture information. The sensor's only significant drawback is that it only provides fresh data every two seconds, therefore when utilizing our database, sensor values may be as much as two seconds outdated.

| General Specification | |
|---|---|
| Model | AM2302 |
| Operating Voltage | 3 to 5.5 v |
| Accuracy resolution | 0.1 |
| Humidity Range | 0 to 100% RH |
| Temperature Range | -40° to 80° C |
| Humidity Measurement Precision | ± 2% RH |
| Temperature Measurement Precision | ± 0.5° C |

TABLE 3. 1 GENERAL SPECIFICATION OF TEMPERATURE AND HUMIDITY SENSOR

### 3.2.1 Pulse and Oxygen Sensor

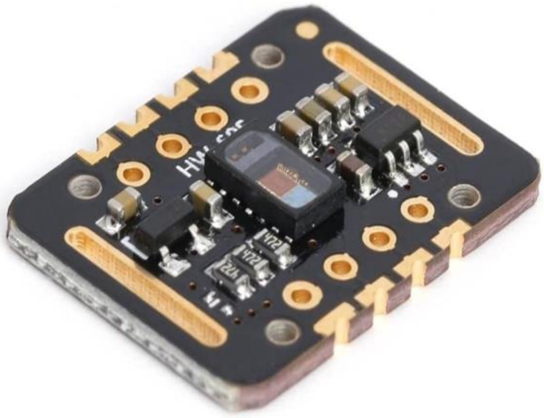


FIGURE 3. 3 PULSE AND OXYGEN SENSOR

We have used this MAX30102 sensor to monitor pulse and oxygen levels in the baby's body and take necessary steps. The MAX30102 is a biomedical component that combines a pulse oximeter and a heartbeat measurement. It incorporates low-noise electronics with light from the environment repression, optical assemblies, a light sensor, a red LED, and a thermal LED. It has an inbuilt LED battery backup for oxygen levels and heart rate detection in connected devices that can be worn on the wrist, earlobe, or fingers that run on 1.8V and an additional 5.0V battery. The gathered data can be sent to the KL25Z and other microchips of blood oxygen content and heartbeat via an accepted 12C-compatible data connection.

The reserve energy is almost zero, the electrical supply is constantly kept up, and the controller can software shut off the components. The chip incorporates an optical layer to efficiently remove inside as well as outside lighting disruption enabling superior dependability beyond the prior model MAX30100.

| Technical Specifications | |
|---|---|
| Power Supply | 3.3V to 5.5V |
| Current Draw | -0.7 **µ** A (During standby mode) |
| Red LED Wavelength | 660 nm |
| IR LED Wavelength | 880 nm |
| Temperature Range | -40° C to +85° C |

TABLE 3. 2 TECHNICAL SPECIFICATIONS OF PULSE AND OXYGEN SENSOR

### 3.2.2 Dust Sensor

FIGURE 3. 4 DUST SENSOR

This is a new addition to the incubator. This sensor plays an important role in measuring and removing the amount of dust inside the incubator. Six pins are present on the GP2Y1014AU0F Dust Sensor module: V-LED, LED-GND, LED, S-GND, VOUT, and VCC. The GP2Y1014AU0F Dust sensor operates straightforwardly and understandably. The diode that emits light (light source), a photodiode (detector), and both lenses make up the three main components of the sensor. The location of the photodiode and LED inside the sensor is such that each of their optical axes connects the sensor's detecting region. The light that shines inside the detector is caught by dust or smoke as soon as it reaches an identified region; as a consequence, the current produced by the photodiode changes depending on how much light is detected. With the right electronics, we can transform and amp up the present measurement to the voltage level to achieve the intended result of the sensor. Among the six pins, just two are required for the sensor to function. The LED is activated by the first, while the sensor's digital signal is output by the second. The above-mentioned capacitor, C1=220uF, and resistor, R1=150Ω, are needed for the periodic control of the Light. The device cannot function without both the capacitor and resistor. To collect the required data from the sensor, you must pulse the light source for 10 milliseconds, with a duration of the pulse of not less than 0.32 milliseconds.

### 3.2.1 ECG

In this project the ECG sensor in a baby incubator monitors the infant's heart rate and rhythm continuously. It helps healthcare providers detect any abnormalities or irregularities in the baby's cardiac activity. This real-time data assists in timely intervention and care for the newborn.

#### 3.2.1.1 AD8232 Heart rate sensor

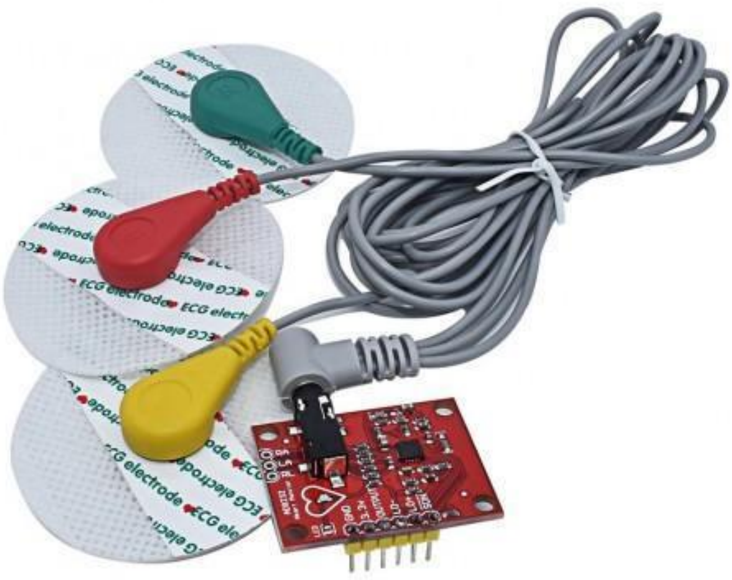


FIGURE 3. 5 AD8232 HEART RATE SENSOR

By the use of a computer chip, the heart rate sensor AD8232 can recognize ECG signals. Heart nerve activity is mapped using this sensor. Fitness bands that have an ECG or EKG sensor built in can utilize it. The electrocardiogram (ECG) waveform is unable to be shown as a computerized wave, so this chip produces an analog result. Extracting ECG pulses is challenging due to their high level of disruption. To extract the proper ECG waveform the AD8232 chip is made to both increase and filter the disruption. Voltage used for operation: 3.3 V. It gives an analog result.

### 3.2.1.1 Connecting Arduino with AD8232

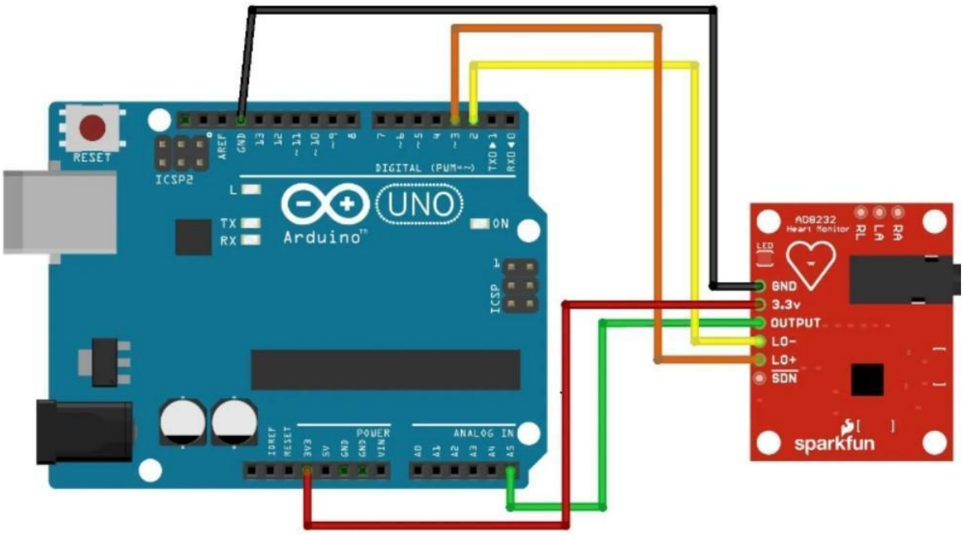



FIGURE 3. 6 CONNECTING ARDUINO WITH AD8232

We must connect the terminals at these locations to acquire an accurate ECG wave. Electrodes can also shock the person to whom they are linked with electricity. Thus, make sure the power supply is a low-power AC supply, such as 5V.

| PINS ON AD8232 | PINS ON ARDUINO UNO |
|---|---|
| 3.3V | 3.3V |
| Output | A0 |
| LO - | 2 |
| LO + | 3 |
| GND | GND |

TABLE 3. 3 SPECIFICATIONS ARDUINO WITH AD8232

### 3.2.1.1 The operational approach of ECG

- The AD8232 module receives information from the three attached leads.
- The AD8232 module's integrated circuit (IC) enhances the ECG signal while filtering out disturbances.
- The Arduino board receives this data in analog form after that.
- The data is subsequently shown by the Arduino board on the Serial Monitor as an ECG wave.

### 3.2.2 Sound sensor

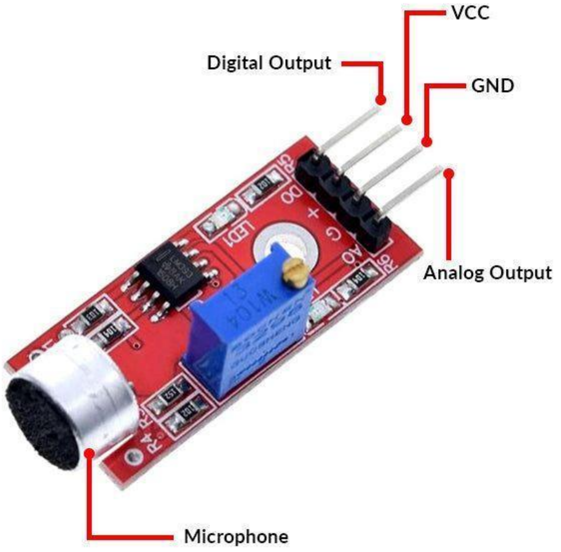



FIGURE 3. 7 SOUND SENSOR

A sound sensor module uses a microphone to identify sound waves, and then a transducer's diaphragm transforms those waves into electrical impulses. Then, to strengthen these signals, they are amplified. therefore, processed to remove undesirable frequencies and noise. A microcontroller or other device receives the output and can take appropriate action, such as setting off alarms, turning on relays, or assisting in decision-making. It may be customized to meet demands thanks to adjustable sensitivity levels, which makes it adaptable for a range of sound detection applications.

### 3.2.3 Arduino Uno

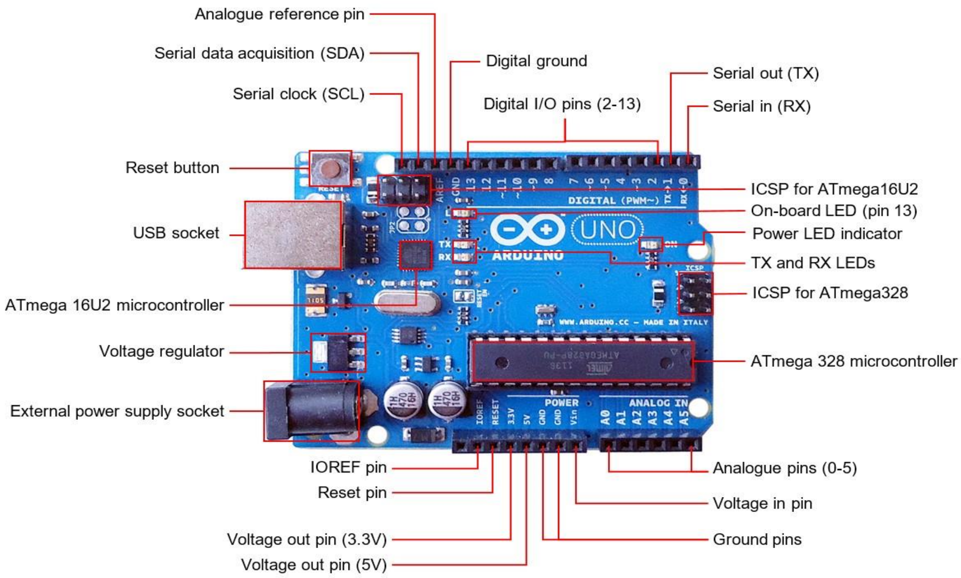



FIGURE 3. 8 ARDUINO UNO

It is a useful microcontroller to get things going with. The latest Arduino Uno R3 is this one. The Uno possesses all the characteristics of the previous version plus an ATmega16U2 instead of the 8U2 (or FTDI) used in earlier incarnations of the Uno. More memory and quicker transmission rates are made possible by this. The Arduino IDE has the necessary drivers for Windows and Linux, and the Uno can function as a keyboard, mouse, joystick, and other devices.

Details:

- Microcontroller ATmega328
- Operating Voltage 5V
- Input Voltage (recommended) 7-12V
- Input Voltage (limits) 6-20V
- Digital I/O Pins 14 (of which 6 provide PWM output)
- Analog Input Pins 6
- DC Current per I/O Pin 40 mA
- DC Current for 3.3V Pin 50 mA
- Flash Memory 32 KB (ATmega328) of which 0.5 KB used by bootloader
- SRAM 2 KB (ATmega328)
- EEPROM 1 KB (ATmega328)
- Clock Speed 16 MHz

- Length 68.6 mm
- Width 53.4 mm
- Weight 25 g

### 3.2.1 ESP 32

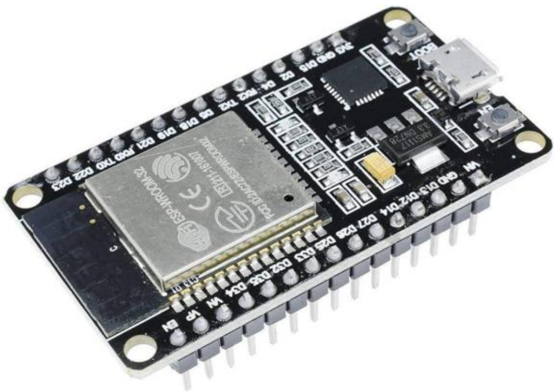


FIGURE 3. 9 ESP 32

ESP-WROOM-32 The ESP32 ESP-32S Development Board is a dual-core, 2.4GHz microcontroller with Bluetooth and two Wi-Fi modes. Antenna switches, power amplifiers, low-noise amplifiers, filters, control sections, and other components are all incorporated into the ESP32, and the total arrangement takes up the least amount of PCB space. With TSMC's ultra-low power consumption 40nm technology, power dissipation performance, and RF performance, this 2.4 GHz Wi-Fi + Bluetooth dual mode chip offers the best safety, dependability, and versatility for various programs.

### 3.2.2 Humidifier

FIGURE 3. 10 HUMIDIFIER

A humidifier module is a device that raises the air's moisture content in a small area, such as a room or workplace. Usually, it is made up of control electronics, an ultrasonic transducer, and a water reservoir. A thin vapor or fog is produced when the transducer's high-frequency vibrations evaporate the fluid in the tank. Humidification is regulated by control circuitry, which also monitors moisture levels and modifies vibrational frequencies. Certain models involve built-in safety precautions, such as automated shutdown. Moisture is distributed equally when the mist is discharged into the atmosphere. Sufficient effectiveness requires routine maintenance. Modules for humidifiers are useful for enhancing ease and ventilation, particularly in evaporate regions.

Specification:

- Item Type: Humidifier Module
- Working Voltage: DC 3.7-5.5V (5V Recommended)
- Working Current: 330mA
- Standing Current: 21uA
- Power Supply Interface: Type C USB
- Humidifier Interface: pH2.0 Terminal
- Frequency: 108kHz
- Multiple Function Modes: Uninterrupted Work Intermittent Work Timed Work

### 3.2.1 Peltier


FIGURE 3. 11 PELTIER

In this project we have used this sensor to heat the environment inside the incubator as needed and cool it as needed. The sensor monitors the environment inside the incubator and takes necessary action by itself. Another name for the thermoelectric cooler is Peltier or TEC. The module modifies the temperature on each side. When one side heats up, the other side cools down. Above all, you can use either side. They are used to either heat or chill things. A temperature differential can also be used to your advantage to produce electricity. An electronic component based on semiconductors that performs the role of a tiny heat pump is called a thermoelectric cooler (TEC) module. Heat will be transported from one side of the module to the other by applying the DC power supply to a TEC. It produces hot and cold sides. They are extensively utilized in industrial settings, such as CCDs, portable refrigerators, medical equipment, computer CPUs, and so on.

### 3.2.2 Another Component

#### 3.2.2.1 Sound sensor


FIGURE 3. 12 SOUND SENSOR

We used sound sensors to monitor if there was any noise inside the incubator or if the baby was crying for any reason.to monitor if there was any noise inside the incubator or if the baby was crying for any reason.

### 3.2.1.2 Water sensor

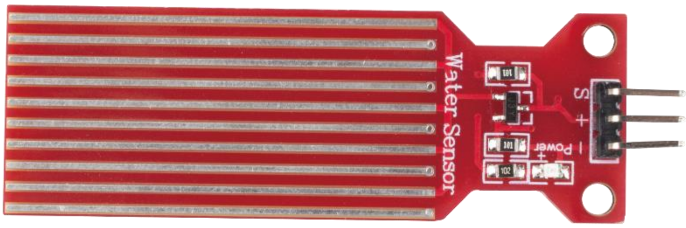



FIGURE 3. 13 WATER SENSOR

We have taken the help of water sensors to monitor if the baby's bed is wet inside the incubator or if the baby has urinated.

### 3.2.1.3 Solar panels and battery

FIGURE 3. 14 SOLAR PANELS AND BATTERY

Here we have used solar panels and batteries that if there is no electricity at the required time then the electricity collected from the solar panels will be stored in the batteries and it can be used later.

#### 3.2.1.4 Buck Converter


FIGURE 3. 15 BUCK CONVERTER

A buck converter is used to lower the DC voltage efficiently. The system has a lot of power but our sensors need close to six volts to run. For this reason, we used Buck Converter in our project. With the buck converter, one can control the voltage as well as the amperage at the same time. In short, we used a buck converter to step down the voltage in our project.

## 3.3 DESIGN SPECIFICATIONS STANDARDS AND CONSTRAINTS

The block diagram of our project illustrates the various components and their interconnections involved in our project. The main objective of this project is to develop a comprehensive system for monitoring and controlling various environmental parameters and health indicators. The system utilizes a range of sensors, microcontrollers, and communication modules to collect data and provide remote access and control.

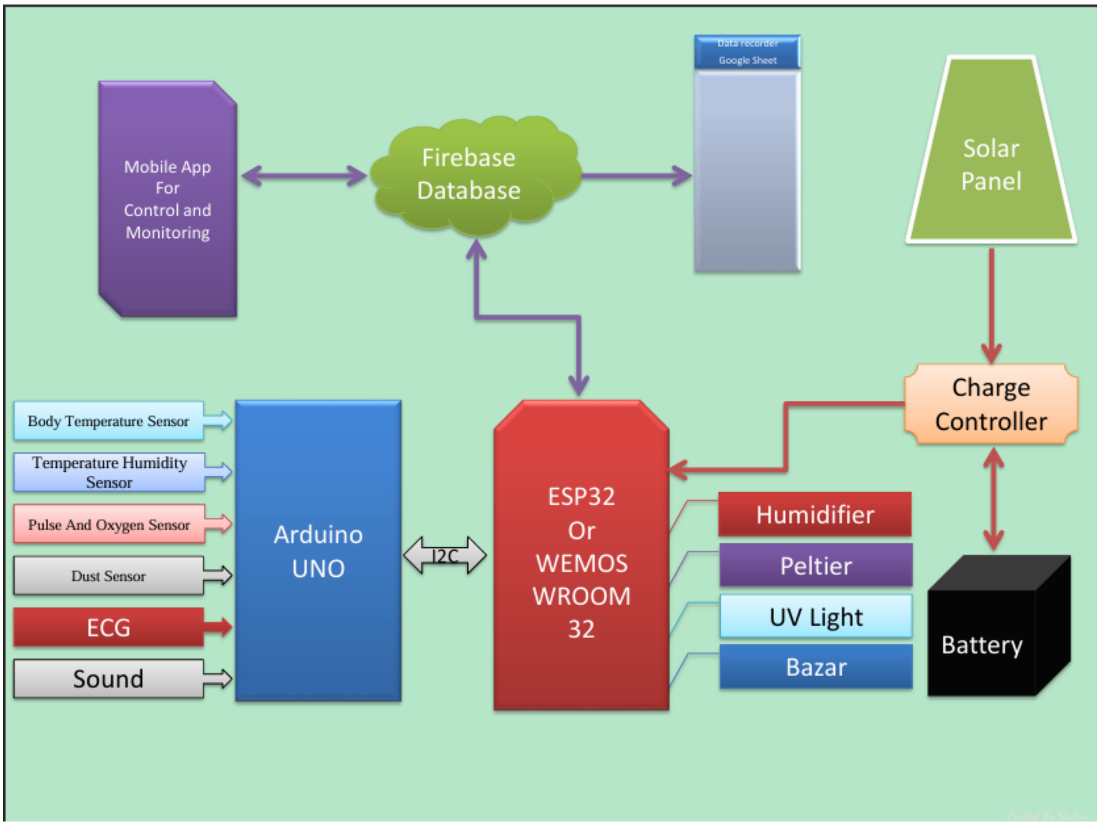



**FIGURE 3. 16 BLOCK DIAGRAM OF PRE-MATURE BABY INCUBATOR**

3.3.1 Data Acquisition and Sensors: To collect data on several parameters, the system makes use of a number of sensors. A body temperature sensor, a temperature and humidity sensor, an oxygen and pulse sensor, a dust sensor, an ECG sensor, and a sound sensor are some of these sensors. An Arduino UNO microcontroller, which functions as the system's central processing unit, is coupled to these sensors.

3.3.2 Data Storage and Transmission: An ESP32 or WEMOS WROOM 32 microcontroller, which the Arduino UNO connects with, is in charge of sending data to the Firebase database. The gathered data is stored and managed on a cloud-based platform called Firebase Database.

3.3.3 Interface for Control and Monitoring: To offer a user-friendly interface for controlling and monitoring the system, a mobile app is built. The application interfaces with the Firebase database to obtain up-to-date information from the sensors and gives users the ability to operate many system-connected gadgets, including fans, humidifiers, Peltiers, UV lights, and UV lights, remotely.

3.3.4 Power Source: A solar panel powers the system and charges a battery. Effective power management and charging process regulation are provided by a charge controller.

3.3.5 Extra Features: Users may monitor and examine previous data using the Google Sheet that is included with the system for data tracking and analysis.

All things considered, the block diagram gives a thorough rundown of the system architecture, emphasizing the important parts and how they work together. This system is a flexible option for a range of environmental monitoring and health-related applications since it provides real-time monitoring and remote-control capabilities.

## 3.4 SYSTEM ANALYSIS OF A MODERN PREMATURE BABY INCUBATOR

The goal of a contemporary neonatal incubator is to give preterm infants a safe haven for development and survival. The incubator guarantees the best possible care and monitoring of newborn health by combining cutting-edge technology, sensors, and sustainable power solutions.

### 3.4.1 **Functional analysis:**

#### 3.4.1.1 Temperature monitoring:

I. Sensor: Temperature sensors to keep an eye on the inside climate.
II. Actuators: Peltier modules provide accurate cooling and heating.

#### 3.4.1.2 Humidity monitoring:

I. Sensor: The humidity sensor measured the humidity level in this system.
II. Actuators: Humidifier for ideal humidity maintenance.

#### 3.4.1.3 Monitoring of vital signs:

I. An ECG sensor records the heart's electrical activity.
II. Sound sensors hear sobbing or other noises that could be signs of distress.
III. Oxygen and pulse sensors keep an eye on the baby's blood oxygen levels and heart rate.

### 3.4.1.4 Environmental observation:

I. UV Light reduces the danger of infection and sterilizes.

II. Dust sensor used to ensure air quality.

### 3.4.1.5 Usability and Data Control:

I. Integrated Firebase Database to store and retrieve data in real-time using mobile apps.

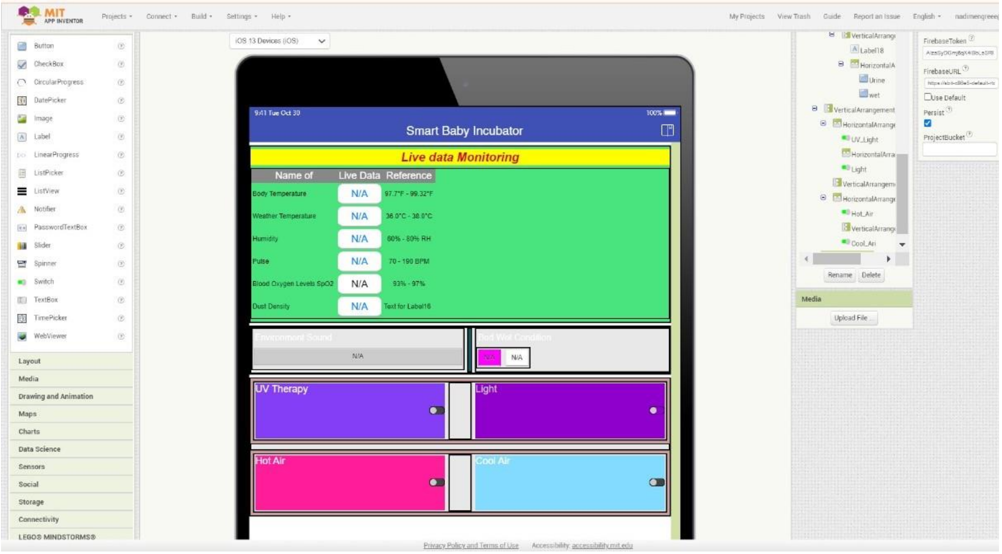



FIGURE 3. 17 USER INTERFACE DESIGN OF THE SMART BABY INCUBATOR MONITORING SYSTEM

Through the transmission of sensor data to a Firebase database, mobile applications provide real-time monitoring.

II. Entering data into Google Sheets for additional documentation and analysis.

| Date | Time | BodyTemperature | WeatherTemperature | Humidity | PulseRate | BloodOxygenLevel | DustDensity | EnvironmentSound | BedWetCondition | Wet% | UV Therapy | Light | Hot Air | Cool Air |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2024-07-09 | 7:22 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 7:52 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 8:22 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 8:52 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 9:22 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 9:52 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 10:22 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 10:52 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 11:22 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-09 | 11:52 | 93 | 36 | 70 | 130 | 93 | 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2024-07-10 | 12:22 | 98.5 | 36 | 70 | 130 | 92.5 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 2024-07-10 | 12:52 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 1:22 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 1:52 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 2:22 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 2:52 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 3:22 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 3:52 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 4:22 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 4:52 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 5:22 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 5:52 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 6:22 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2024-07-10 | 6:52 | 98 | 35 | 50 | 125 | 92 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

FIGURE 3. 18 LIVE DATA MONITORING IN GOOGLE SHEET

Sensor readings are entered into Google Sheets via a data recorder, guaranteeing that all information is kept for future review.

#### 3.4.1.6 Power supply:

I. Battery backup is maintained to ensure uninterrupted operation.
II. solar panels are used to offer a renewable energy source that is particularly helpful in situations where resources are limited.

#### 3.4.1.7 Work process:

I. All sensors are calibrated and linked to the control system when the incubator is first set up.
II. Vital signs and environmental parameters are continually monitored by sensors while the preterm infant is placed inside.
III. Sensor readings are entered into Google Sheets and delivered to the Firebase database for real-time monitoring.
IV. To maintain ideal conditions, the microcontroller modifies the Peltier modules and humidifier in response to sensor input.
V. To maintain continuous operation, the system takes power from both the solar panels and the battery backup.

## 3.5 EXPERIMENTAL SETUP

To provide the best care possible for preterm infants, the trial setup for the affordable, small premature baby incubator integrates data management systems, auxiliary equipment, innovative sensor technologies, and sustainable power solutions. The goal of this system is to enable constant monitoring and data logging for healthcare practitioners in a controlled setting that closely resembles a mother's womb. The parts of the experimental setup and their arrangement are covered in the following sections.

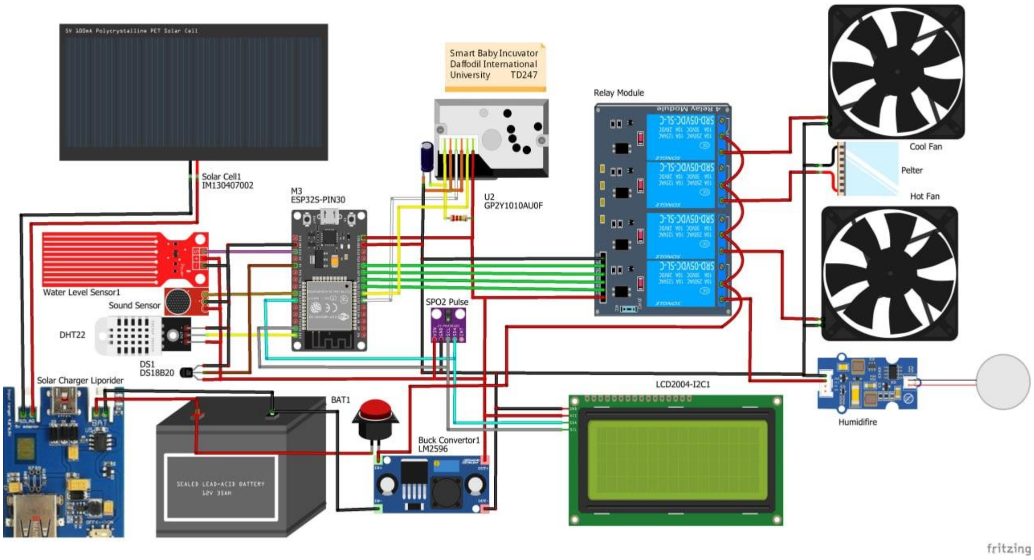



FIGURE 3. 19 COMPREHENSIVE PREMATURE BABY INCUBATOR SYSTEM WITH INTEGRATED SENSORS AND CONTROL MECHANISMS

The system gets power from a combination of a battery and a solar panel. The 12V 34Ah sealed lead-acid battery is kept charged by connecting the 5V 100mA polycrystalline solar cell to a solar charger LiPo rider.  The battery voltage is stepped down to 5V using a buck converter (LM2596), making the ESP32 and other components usable. The ESP32 is equipped with a number of sensors that track the baby's vital signs and the incubator's conditions. Real-time information on the interior temperature and humidity levels is provided by the DHT22 humidity sensor and the DS18B20 temperature sensor, which are linked to the ESP32's GPIO ports. An SPO2 pulse sensor is fitted to assess the baby's oxygen saturation levels and pulse rate in order to monitor their health. In order to maintain a clean atmosphere, an air quality sensor (GP2Y1010AU0F) is also installed to monitor the incubator's dust levels. A relay module attached to the ESP32 is in charge of controlling auxiliary systems, such as the humidifier and the heating and cooling system. This relay module is used to control the Peltier module, which regulates temperature. The ESP32 is connected to an LCD (LCD2004) that shows the temperature, humidity, and other vital indicators of the incubator in real time. The system also has a button that may be used for manual controls or to reset it when needed. Every component's power and ground connections are meticulously regulated to guarantee that every sensor and gadget is grounded correctly and receives the appropriate voltage.

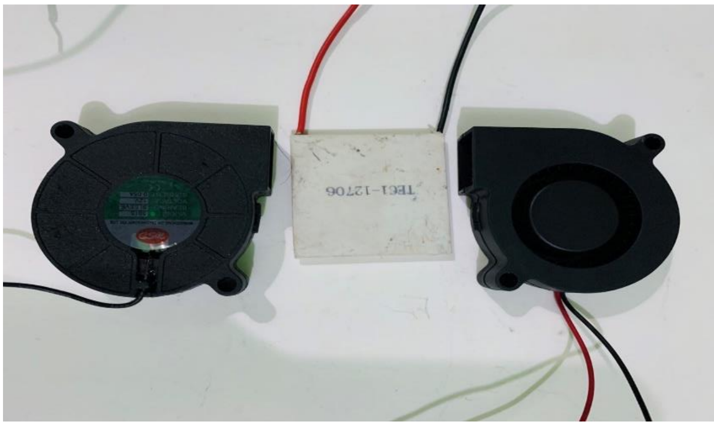



FIGURE 3. 20 PELTIER MODULE WITH COOLING AND HEATING FANS FOR INCUBATOR TEMPERATURE CONTROL

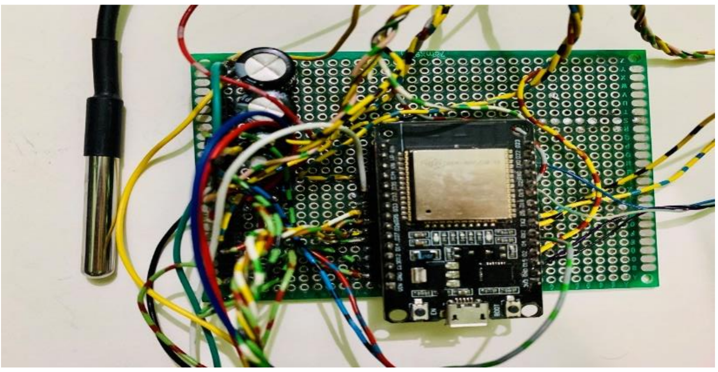


FIGURE 3. 21 ESP32 MICROCONTROLLER WITH INTEGRATED TEMPERATURE SENSOR AND WIRING FOR INCUBATOR CONTROL

FIGURE 3. 22 DIY ELECTRONICS SETUP WITH CIRCUIT BOARD AND SENSOR


**FIGURE 3. 23 SOLAR CHARGING SYSTEM WITH BATTERY, SOLAR PANEL, AND CONTROL CIRCUIT**

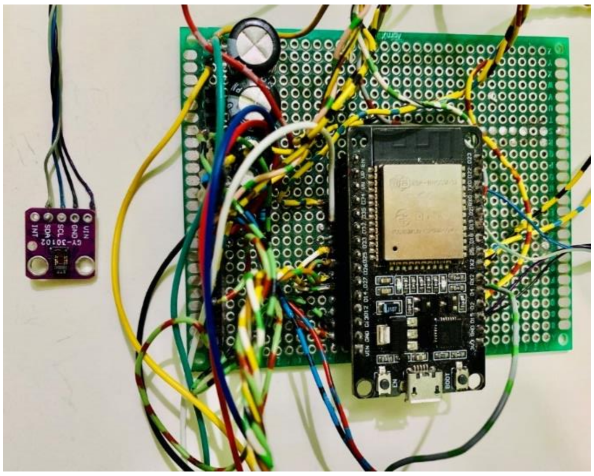


**FIGURE 3. 24 MICROCONTROLLER PROTOTYPING BOARD WITH SENSOR MODULE**

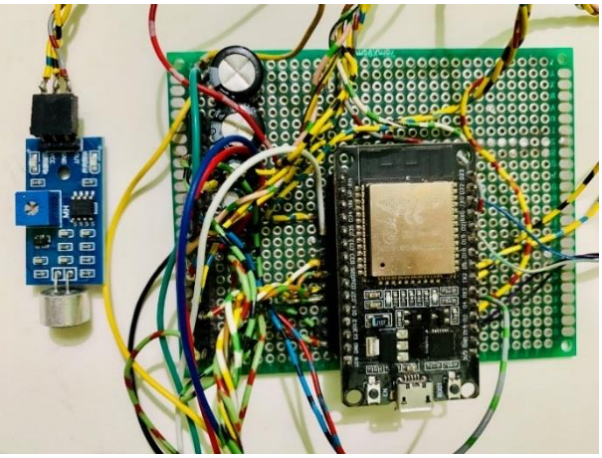


**FIGURE 3. 25 MICROCONTROLLER PROTOTYPING BOARD WITH SOUND SENSOR MODULE**

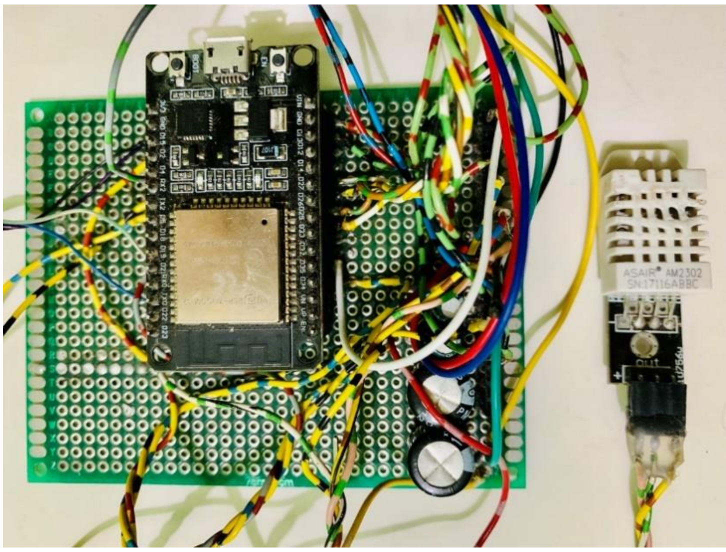


FIGURE 3. 26 MICROCONTROLLER PROTOTYPING BOARD WITH TEMPERATURE AND HUMIDITY SENSOR

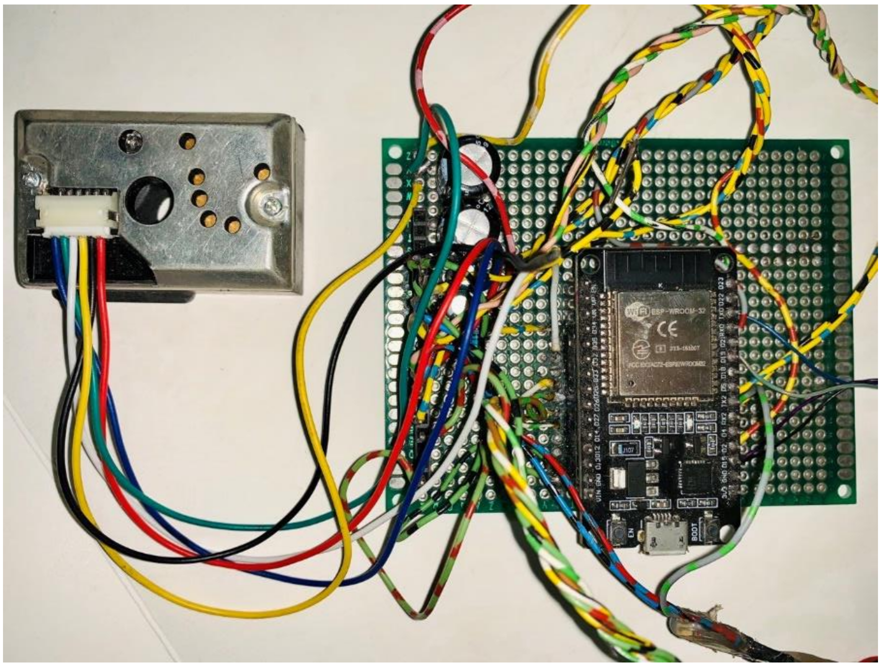


FIGURE 3. 27 MICROCONTROLLER PROTOTYPING BOARD WITH DUST SENSOR MODULE

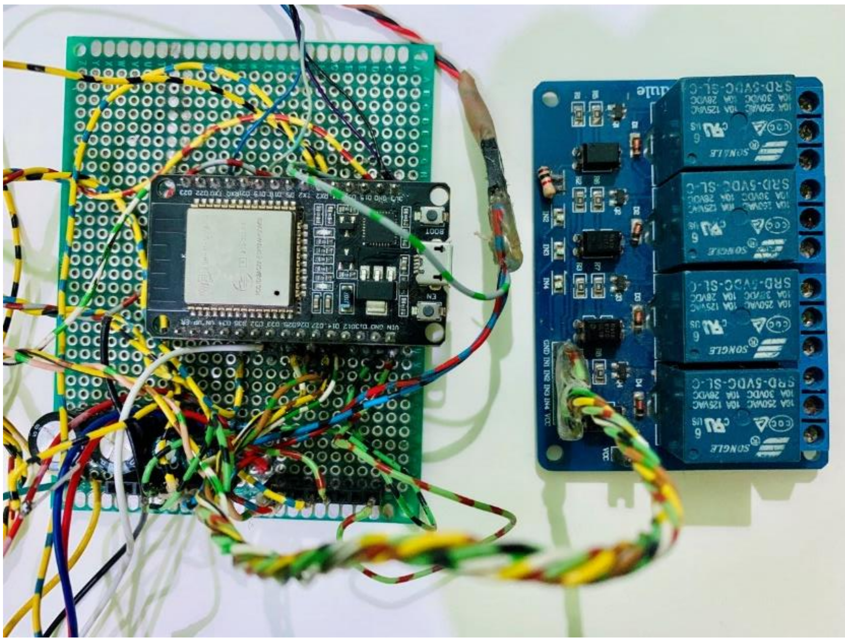


FIGURE 3. 28 MICROCONTROLLER PROTOTYPING BOARD WITH RELAY MODULE

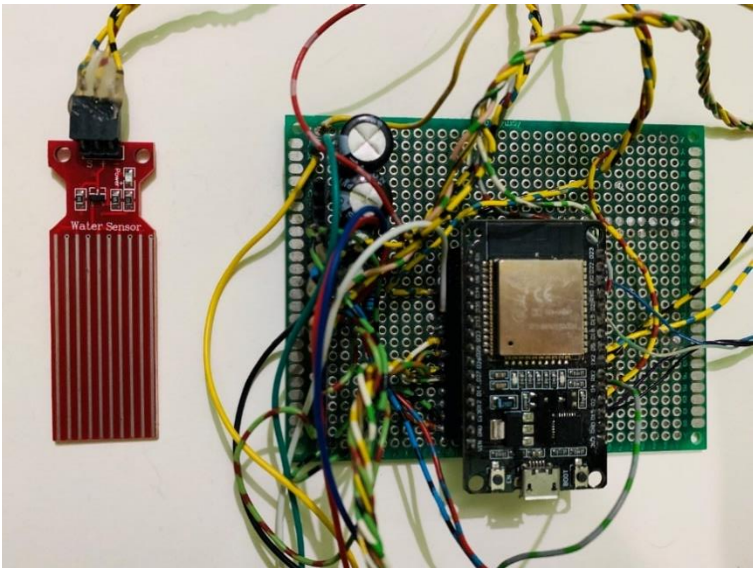



FIGURE 3. 29 MICROCONTROLLER PROTOTYPING BOARD WITH WATER SENSOR MODULE

## 3.6 SUMMARY

The advanced premature infant incubator prototype's installation and testing were covered in this chapter. The system's functionality, which includes dust detection, pulse and oxygen monitoring, temperature and humidity control, and sound-based discomfort detection, was effectively proven by the prototype. The outcomes verified the system's concept and demonstrated its potential to enhance premature baby care in settings with limited resources.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 RESULTS

The outcomes show how well the sophisticated preterm infant incubator integrates a variety of sensors and has strong remote monitoring capabilities. The premature infant was placed in a caring and nurturing environment since the ideal temperature, humidity, oxygen levels, and levels of dust and noise were consistently maintained.

Medical personnel were able to closely monitor the infant's status and act quickly in the event of any changes or difficulties because of the real-time data transfer and remote monitoring capabilities. This improved the standard of care and decreased the possibility of unfavorable consequences for the premature newborn, who was fragile.

The outcomes show how well the sophisticated preterm infant incubator integrates a variety of sensors and has strong remote monitoring capabilities. The premature infant was placed in a caring and nurturing environment since the ideal temperature, humidity, oxygen levels, and levels of dust and noise were consistently maintained.

Medical personnel were able to closely monitor the infant's status and act quickly in the event of any changes or difficulties because of the real-time data transfer and remote monitoring capabilities. This improved the standard of care and decreased the possibility of unfavorable consequences for the premature newborn, who was fragile.

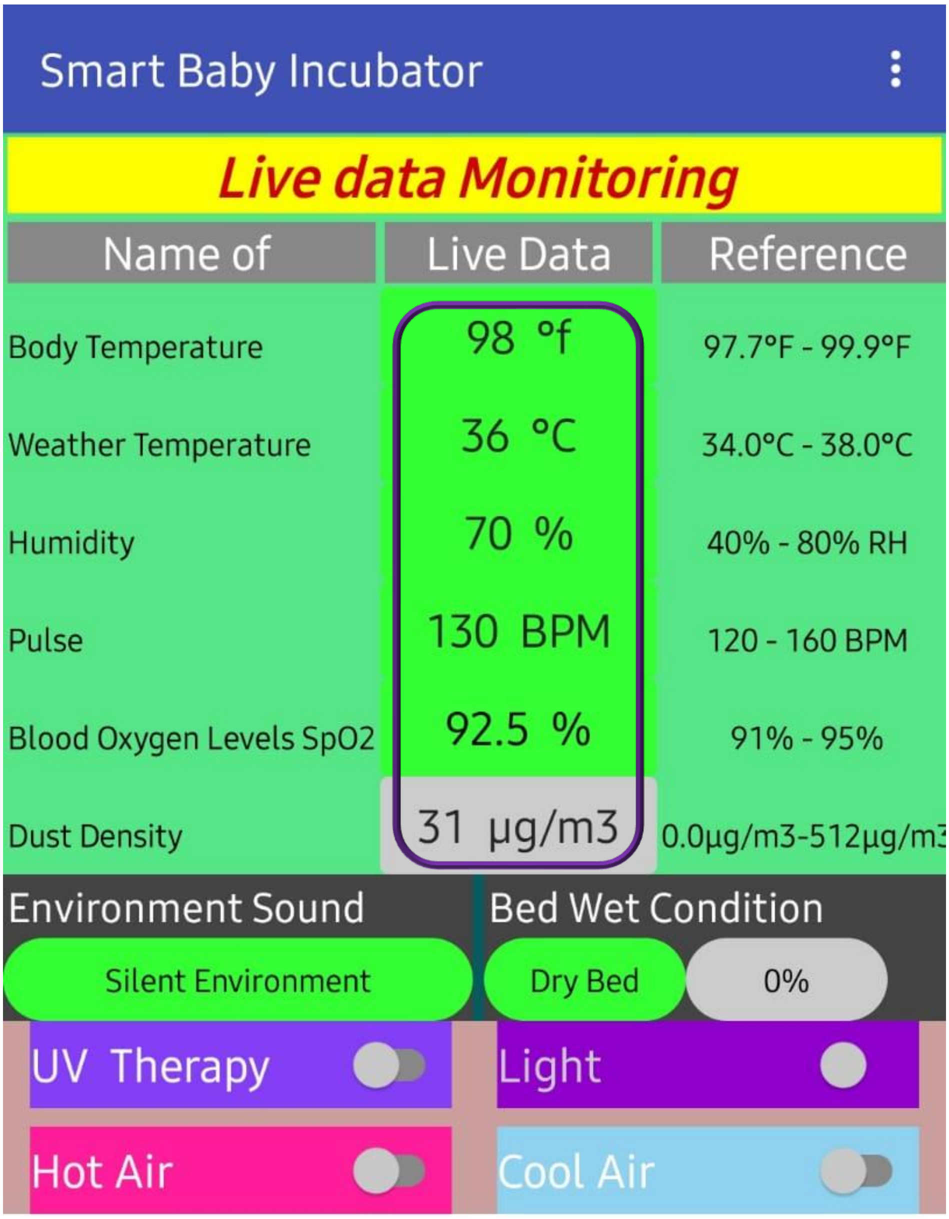



FIGURE 4. 1 LIVE DATA MONITORING DASHBOARD

In the figure 4.1, we can see the expected data of a baby incubator. We see that the child's body temperature is 98°F and the temperature inside. The incubator is 36°C the measured value of the humidity sensor is 70%. The measured pulse rate is 130 BPM, the Blood Oxygen Levels $SpO_2$ is 92.5%, the dust level is 31µg/m3 inside the incubator. The standard reference value of a child body temperature is 97.7°F-99.9°F[16] , the weather temperature is 34°C-38°C [17], humidity is 40%-80% RH[17], pulse rate is 120-160BPM [18], blood oxygen level is 91%- 95% [19], and dust density is 0µg/m3-512µg/m3 in a new born baby incubator. All of the above discussion says that the baby is in a good situation and he is properly fit because there is no abnormal value.

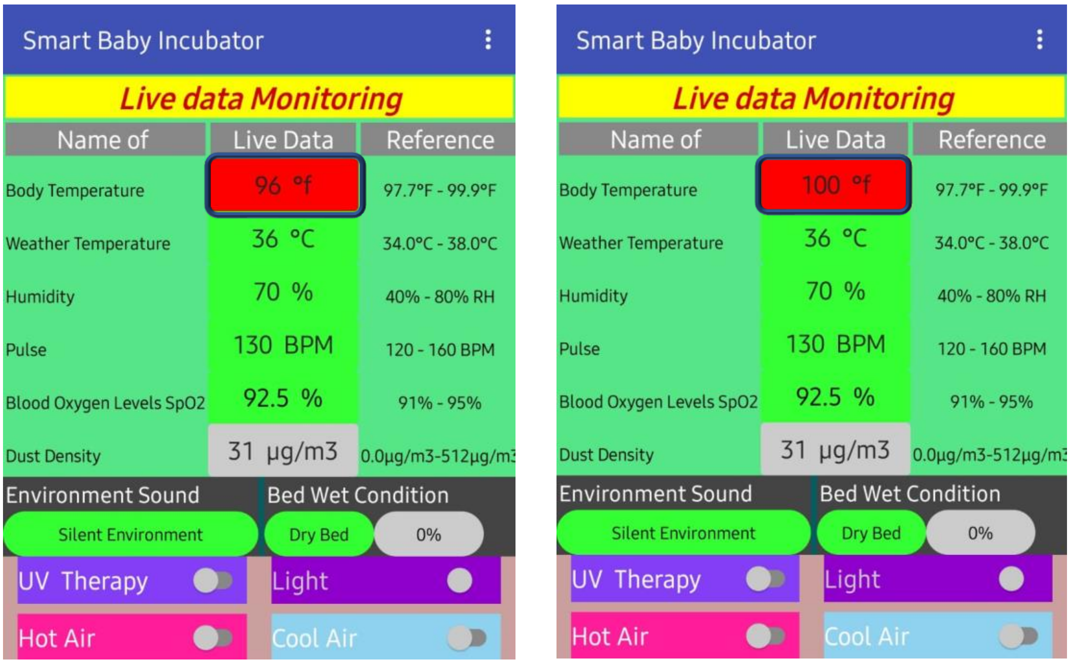



FIGURE 4. 2 BODY TEMPERATURE DETECTED

In figure 4.2, the body temperature sensor detects abdominal value, so we can see a red signal in the app. The observer can take necessary steps by seeing the red signal of body temperature.

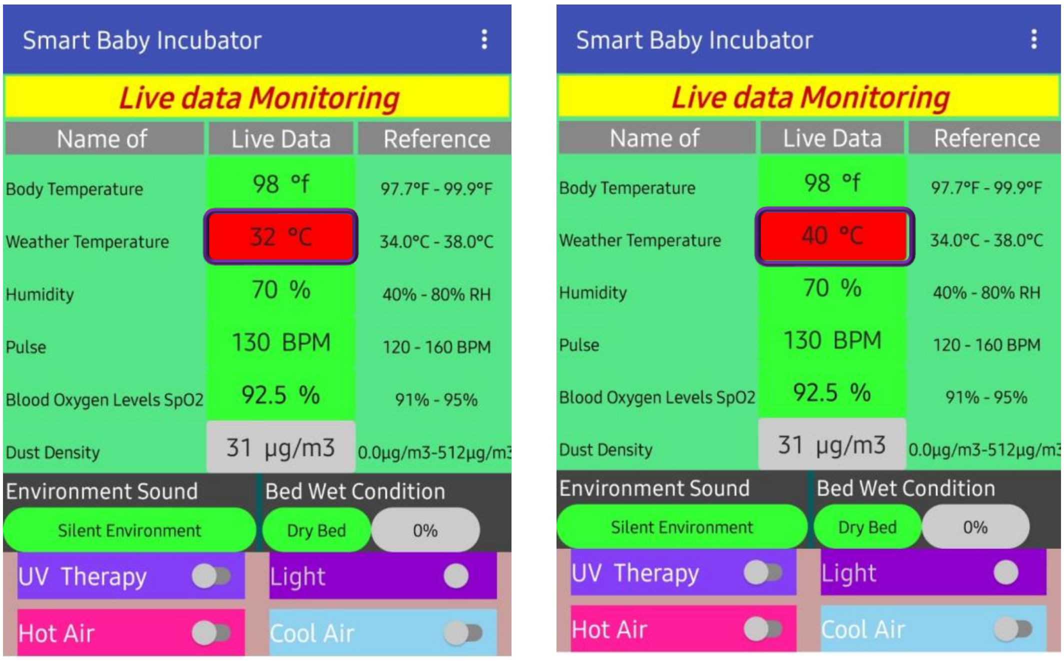



FIGURE 4. 3 WEATHER TEMPERATURE DETECTED

In figure 4.3, we get abnormal value of the temperature which is higher (40°C) and lower (32°C) than the reference range (34°C-38°C).

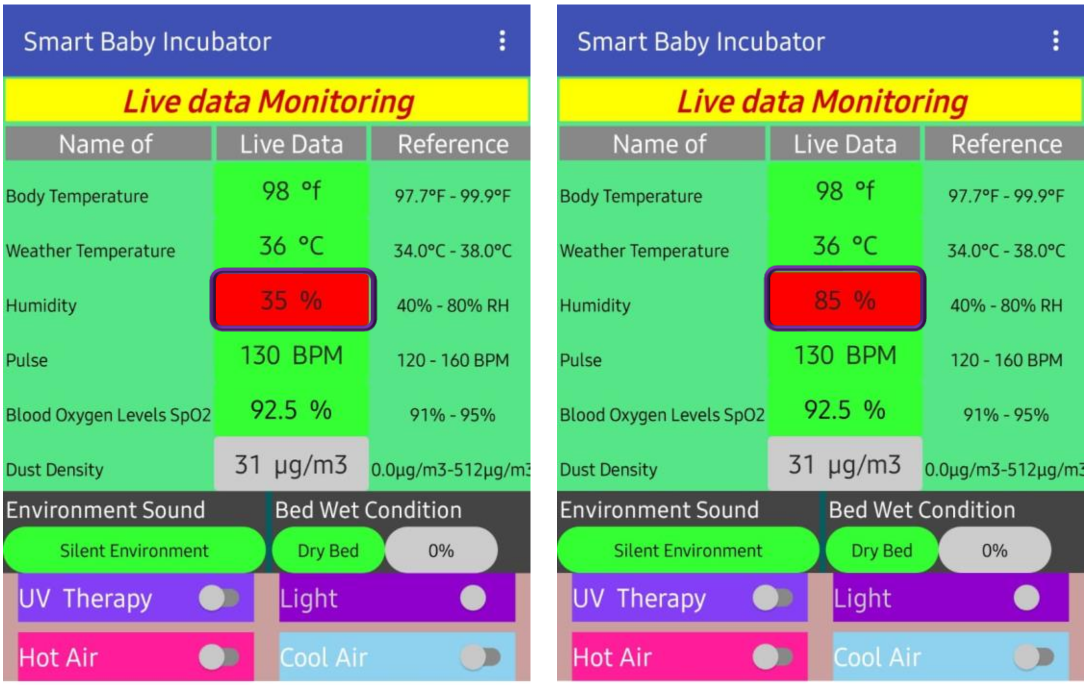



FIGURE 4. 4 HUMIDITY DETECTED

In this figure 4.4 we can see a lower value and higher value of humidity sensor, which is showing in red color. Reference value is 40%-80% RH but the lower value is 35% and the higher value is 85%. For the abnormal value of humidity sensor, the microcontroller turns on the humidifier to control the humidity inside the incubator.

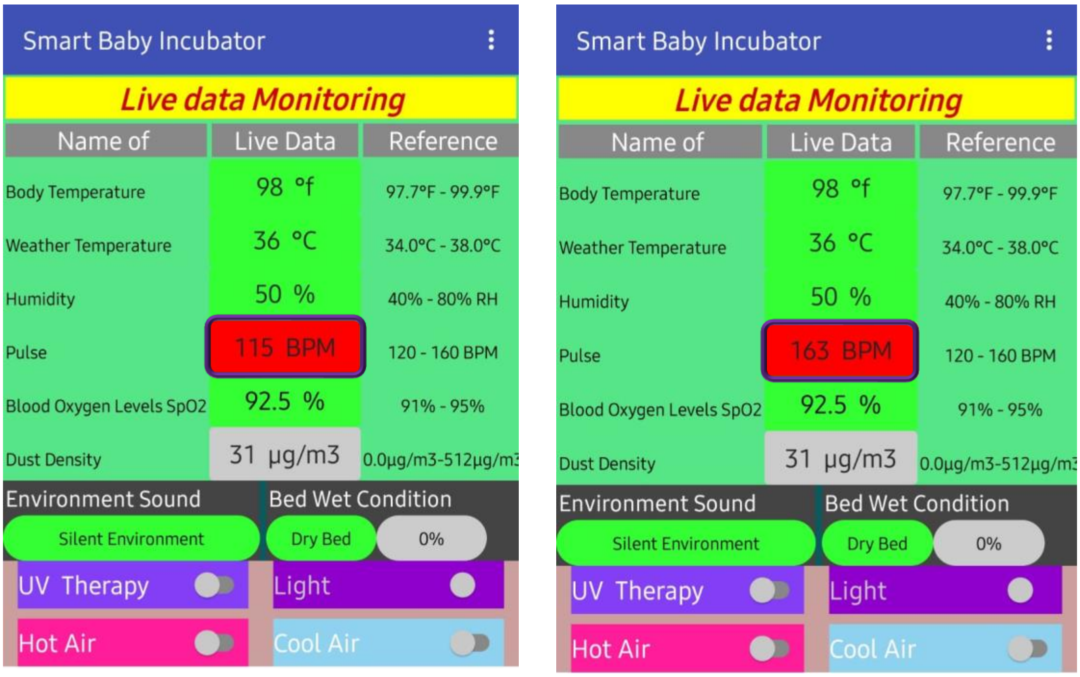



FIGURE 4. 5 PULSE DETECTED

In figure 4.5, We have an abnormal pulse rate of a body which is indicates the red signal. Seeing this red signal, the observer can take the necessary steps.

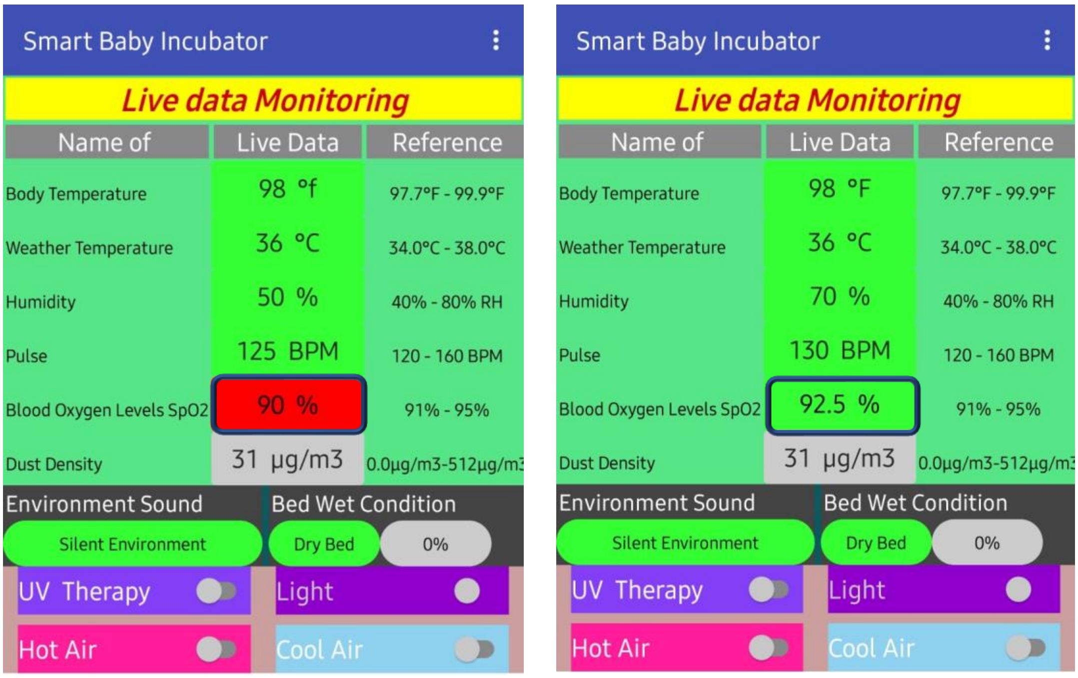



FIGURE 4. 6 BLOOD OXYGEN LEVELS $SpO_2$ DETECTED

Here the baby's $SpO_2$ level is 90% and 92%. The reference value is 91% to 95% So the baby's lungs working well, and the oxygen supply is sufficient for a baby. To maintain ideal oxygen level Health Care workers may make minor adjustments based on the child's particular medical conditions or circumstance.

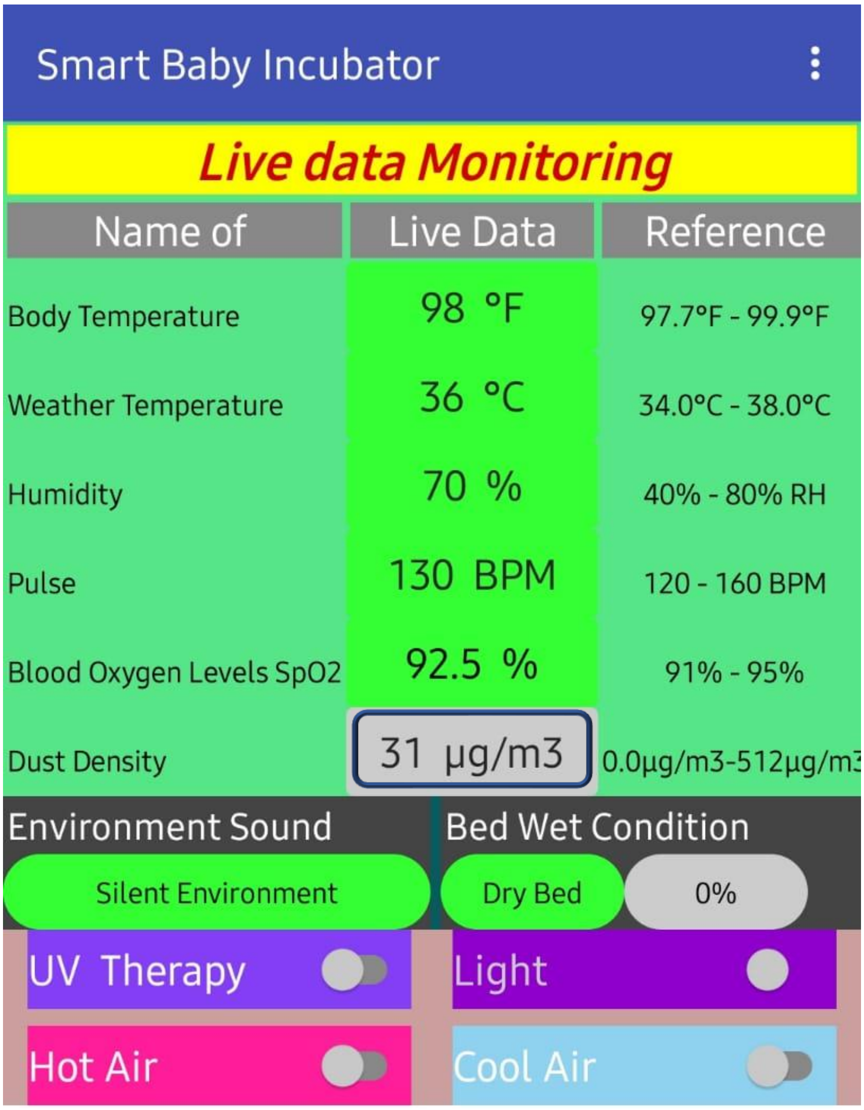



FIGURE 4. 7 DUST DENSITY DETECTED

The reference value of dust density in an incubator is 0µg/m3 to 512µg/m$^3$. The current value is in acceptable range. 31 µg/m$^3$ is quite low. So, there is no risk to the environment within the incubator. The dust level inside the incubator must be constantly monitored so that the level does not exceed 512 µg/m3. Even if it approaches 512 µg/m$^3$, the health workers must take necessary measures

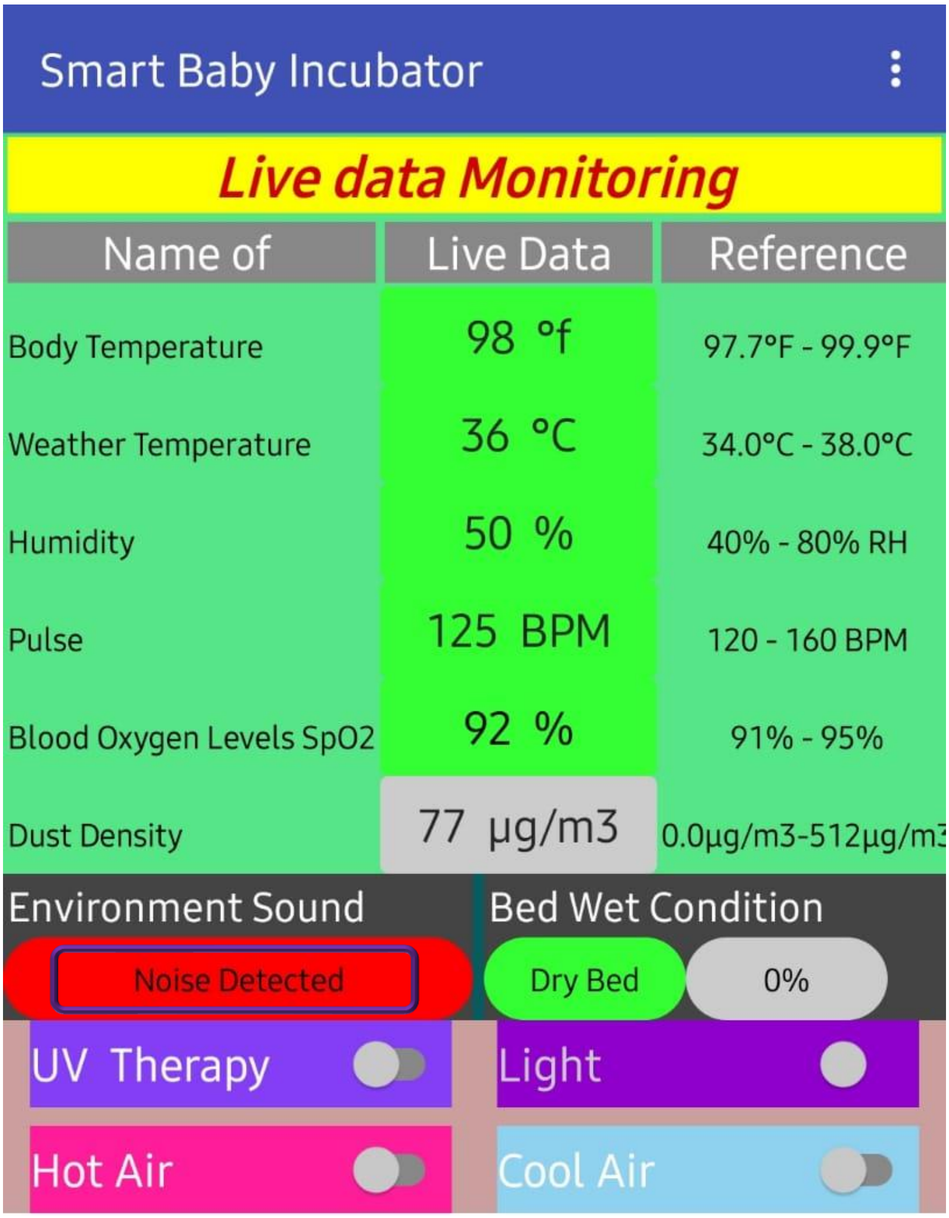



FIGURE 4. 8 NOISE DETECTED

By this figure 4.8, we can understand that the baby is crying because the sound sensor detect sound and show us in red signal in this app.

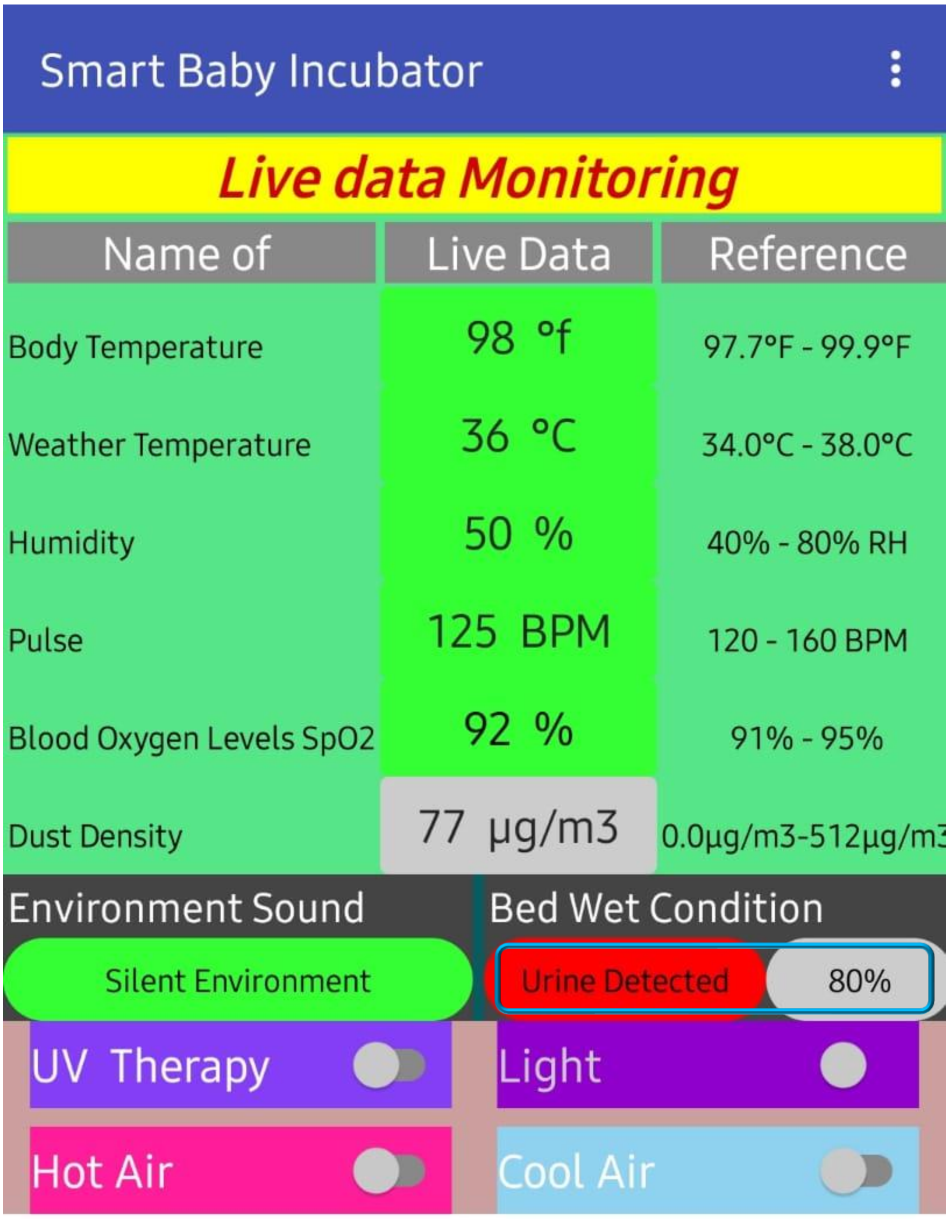



FIGURE 4. 9 URINE DETECTED

In this figure 4.9, there is no extra sound in the incubator. So, the sound sensor indicator is green and showing that the result is silent environment. On the other hand, the water sensor detect water in the baby bed and showing the red signal in the app and tell us urine detected.

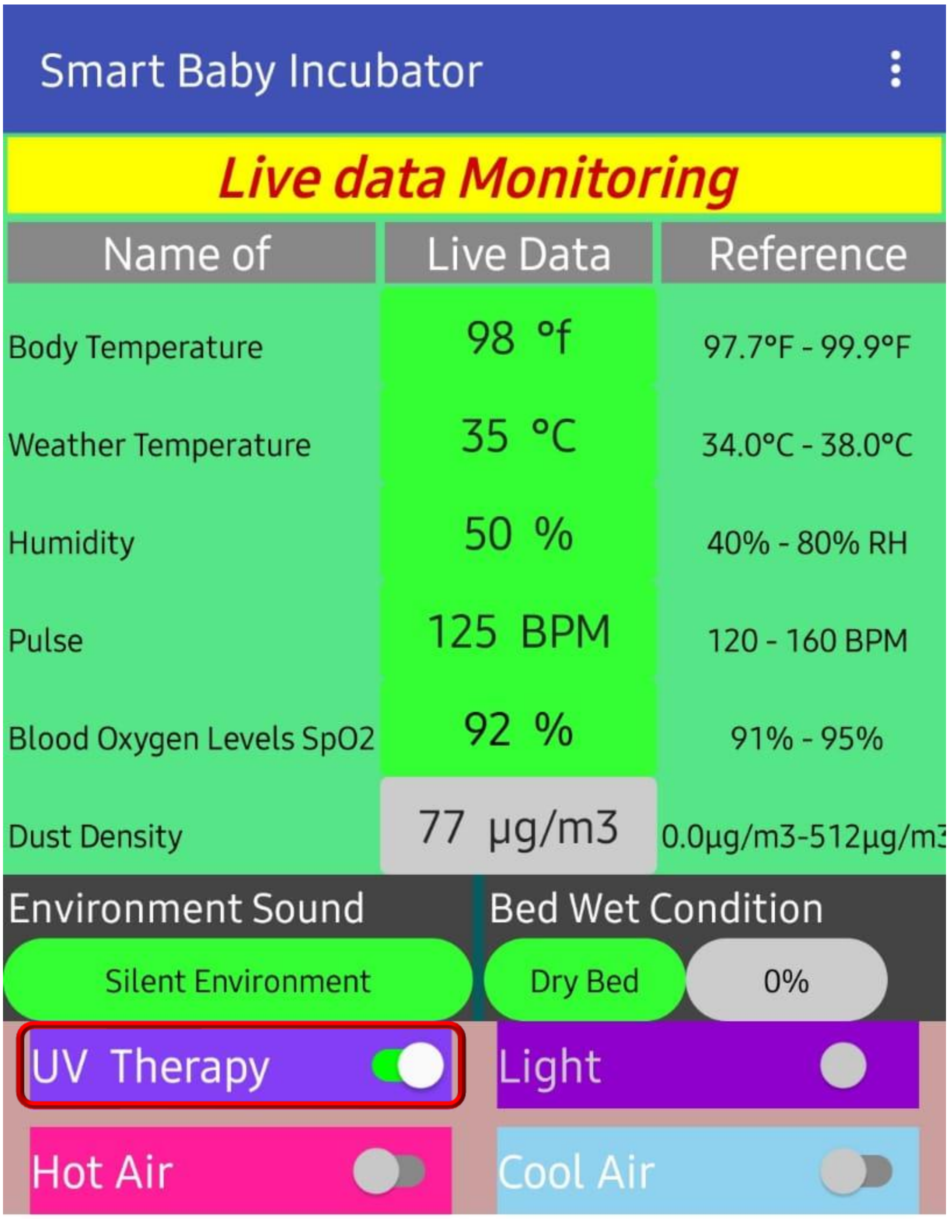



FIGURE 4. 10 UV THERAPY CONTROL

We can also control some system by manually we can turn on the UV therapy system when needed. The UV helps us to reduce the germs inside the incubator.

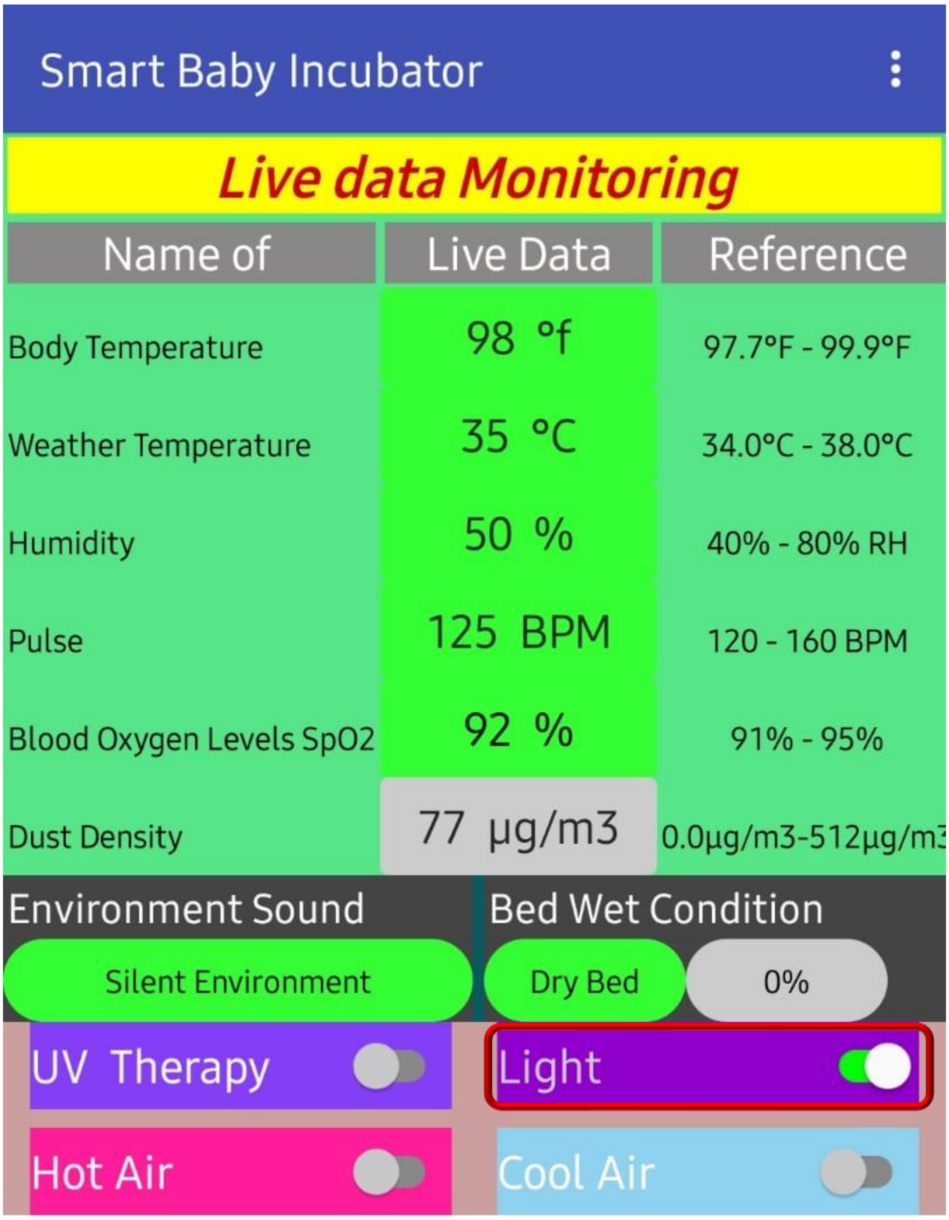



FIGURE 4. 11 LIGHT CONTROL

In figure 4.11 the manual lighting system is on. When the doctor checkup a baby, sometimes there can be light shortage at this moment we can turn on the switch by this app.

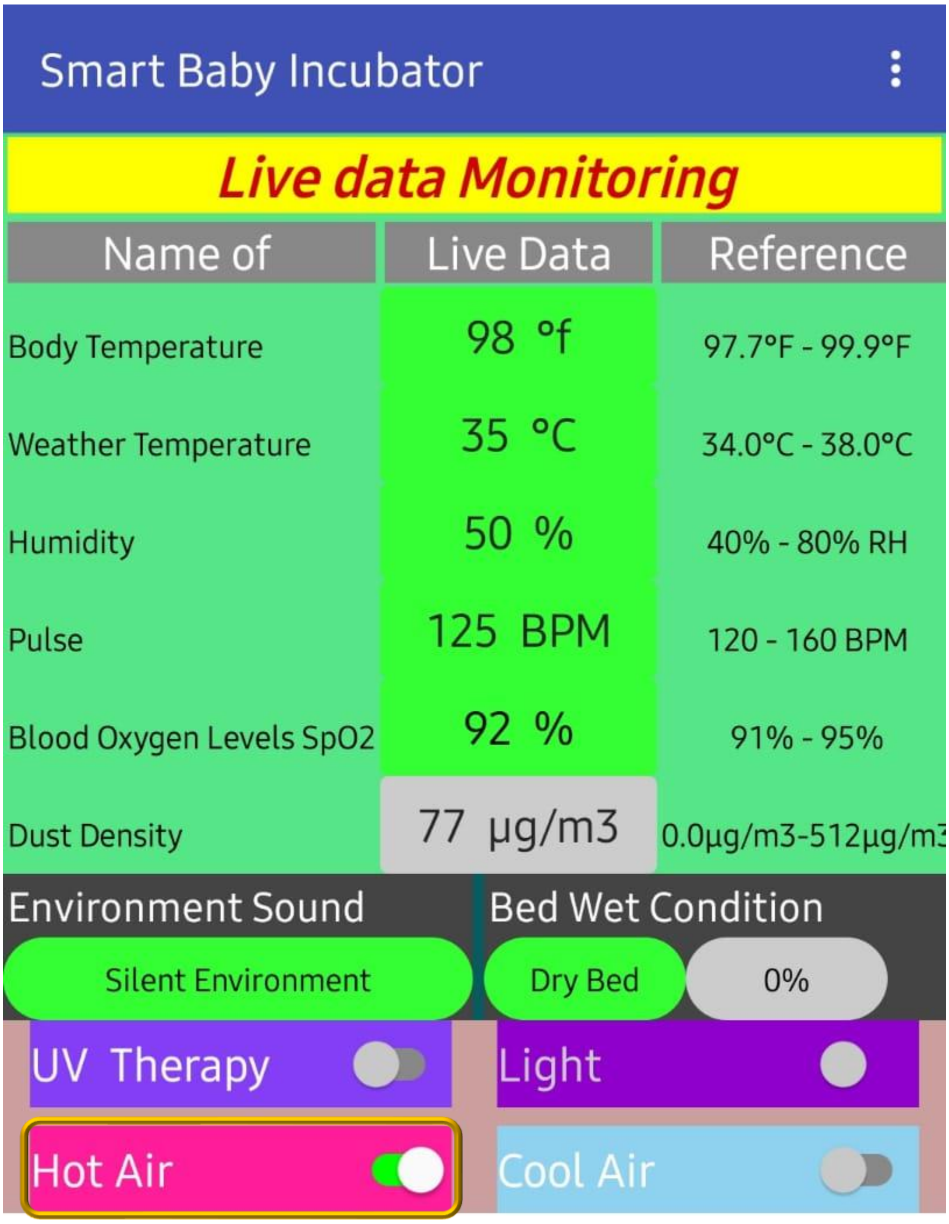



FIGURE 4. 12 HOT AIR CONTROL

When the temperature is low, we can control the weather temperature by the period to turn on the hot air Switch.

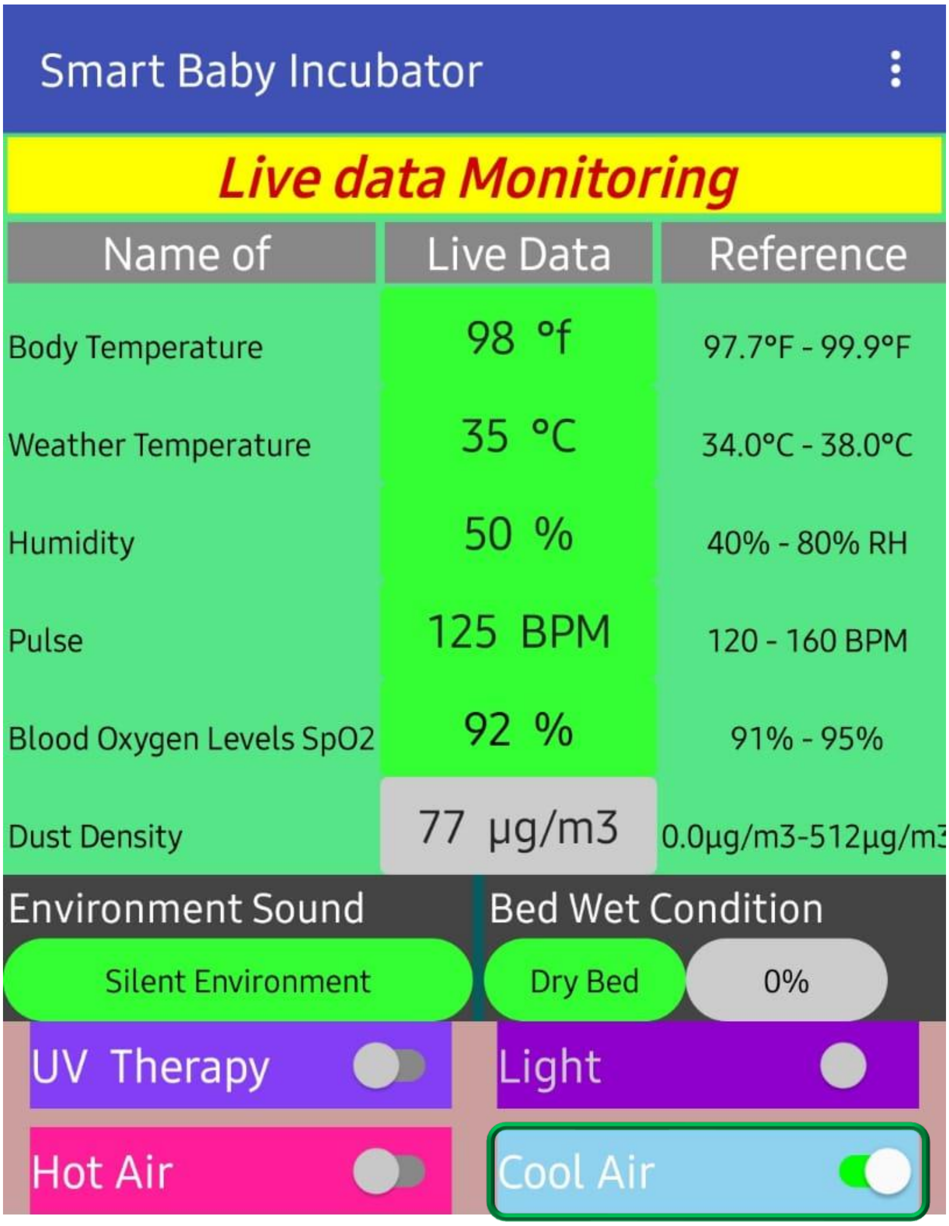



FIGURE 4. 13 COOL AIR CONTROL

And when the weather temperature is high, we can get Cool Air by the Peltier to turn on the cold air switch. Which is showing in figure 4.13.

| Date | Time | BodyTemperature | WeatherTemperature | Humidity | PulseRate | BloodOxygenLevel | DustDensity | EnvironmentSound | BedWetCondition | Wet% | UV Therapy | Light | Hot Air | Cool Air |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2024-06-07 | 10:43 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 1 | 1 | 1 | 1 |
| 2024-06-07 | 10:46 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 1 | 1 | 1 | 1 |
| 2024-06-07 | 11:16 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 11:46 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 12:16 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 12:46 | 93.7625 | 32.3 | 99.9 | 80 | 99 | 42 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 12:58 | 92.525 | 32.8 | 99.9 | 93 | 97 | 43 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 12:59 | 94.6625 | 35.7 | 99.9 | 94 | 97 | 73 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:00 | 95.675 | 36.9 | 97.3 | 94 | 97 | 124 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:01 | 96.35 | 35.1 | 99.9 | 94 | 97 | 140 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:02 | 96.8 | 34.4 | 99.9 | 94 | 97 | 42 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:03 | 97.25 | 34 | 99.9 | 92 | 96.8 | 96 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:04 | 97.7 | 33.8 | 99.9 | 92 | 96 | 76 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:05 | 97.925 | 33.6 | 99.9 | 92 | 96 | 76 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:06 | 97.925 | 33.7 | 99.9 | 90 | 97 | 60 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:07 | 96.8 | 33.7 | 99.9 | 90 | 97 | 82 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:08 | 97.8125 | 33.6 | 99.9 | 90 | 97 | 68 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:09 | 97.8125 | 33.6 | 99.9 | 90 | 96 | 59 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:10 | 97.7 | 33.5 | 99.9 | 90 | 96 | 38 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:11 | 97.8125 | 33.6 | 99.9 | 90 | 98 | 49 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:12 | 97.7 | 33.6 | 99.9 | 90 | 98 | 41 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:13 | 97.5875 | 33.4 | 99.9 | 98 | 97 | 47 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:14 | 97.5875 | 33.4 | 99.9 | 98 | 96 | 70 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-07 | 1:15 | 97.475 | 33.2 | 99.9 | 98 | 96 | 70 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 2024-06-08 | 3:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 3:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 4:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 4:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 5:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 5:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 6:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 6:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 7:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 7:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 8:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 8:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 9:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 9:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 10:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 10:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 11:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 11:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 12:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 12:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 1:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 1:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 2:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-08 | 2:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-12 | 10:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-12 | 10:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-12 | 10:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-12 | 11:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-12 | 11:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 12:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 12:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 1:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 1:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 2:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 2:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 3:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 3:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 4:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 4:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 5:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 5:54 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 6:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 6:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 7:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 7:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 8:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 8:52 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2024-06-13 | 9:22 | 90.8375 | 32.4 | 99.9 | 96 | 98 | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

**FIGURE 4. 14 LIVE DATA MONITORING EVERY MINUTE IN GOOGLE SPREADSHEETS**

In figure 4.14, we see live data for premature baby in incubator. Our project employs a sophisticated real-time data monitoring system to ensure the continuous and accurate assessment of the infant's environment and vital signs. Every minute, we collect and store live data in a Google spreadsheet, capturing a comprehensive set of parameters essential for neonatal care. This robust data monitoring and storage system is a pivotal feature of our advanced premature baby incubator, embodying the principles of precision, reliability, and accessibility.

## 4.2 DISCUSSIONS

We are able to show how our sophisticated preterm infant incubator integrates a variety of sensors and has strong remote monitoring capabilities. The system has been successful in preserving the proper temperature, humidity, oxygen levels, and low levels of dust and noise that are necessary for the health of premature infants. This setting, along with real-time data transfer and monitoring, enables medical professionals to react swiftly to any changes or issues, enhancing the standard of care and lowering the possibility of unfavorable results, insha'Allah.

We have been able to show the instantaneous response of the system to abnormal values detected by significant sensors. For example, the system instantly signals a red signal when a person's body temperature deviates from the norm (as seen in Figure 4.2), allowing for prompt intervention. Comparably, Figure 4.4 for humidity control and Figure 4.5 for pulse rate monitoring showed how the system could keep an atmosphere consistent and identify irregularities in vital signs, respectively. Insha'Allah, these patterns will highlight how crucial real-time data is to improving newborn care.

The sensors' long-term accuracy and dependability are one area of doubt. To guarantee accuracy over the long run, even if the system operates well during the observation time, ongoing monitoring is necessary. Calibration of sensors is important to prevent drift, which can lead to erroneous data interpretation and delayed intervention. Furthermore, although the system can alert caregivers to environmental and physiological changes, it does not replace the need for continuous human supervision and clinical judgment. Regular training and awareness are therefore required to ensure that medical staff are alert.

We undoubtedly believe our state-of-the-art preterm infant incubator will represent a significant advance in neonatal care technology. Here, we have integrated various sensors and enabled remote monitoring, enabling it to provide a stable and nurturing environment for premature babies. The system has shown its ability to raise the standard of care and lower the likelihood of unfavorable results, despite certain restrictions and unknowns. The system's clinical effectiveness and reliability will be further improved by future studies and ongoing system improvements.

# CHAPTER 5

# PROJECT MANAGEMENT

## 5.1 TASK, SCHEDULE AND MILESTONES

| Task | Expected Days to Complete | Milestones |
|---|---|---|
| Task 1: Problem Selection | 7 | DONE |
| Task 2: Method Analysis | 5 | DONE |
| Task 3: Collecting Project Equipment | 7 | DONE |
| Task 4: Building the Project | 21 | DONE |
| Task 5: Project Observation | 3 | DONE |
| Task 6: Data Collection by Project | 30 | DONE |
| Task 7: Data Analysis | 17 | DONE |
| Task 8: Reading and Collecting more Papers | 15 | DONE |
| Task 9: Writing Thesis Book | 40 | Took 50 Days |
| Task 10: Check plagiarism | 3 | DONE |
| Task 11: Again review | 7 | DONE |
| Task 12: Report submit | 1 | DONE |

**TABLE 5. 1 REAL ACHIEVED TOTAL TASK, TIMING AND MILESTONES**

## 5.2 RESOURCES AND COST MANAGEMENT

| Sl | Item Name | Quantity | Unit Price | Total |
|---|---|---|---|---|
| 1 | Node Mcu | 2 | 500 | 1000 |
| 2 | Arduino uno | 1 | 750 | 750 |
| 3 | Solar | 1 | 300 | 300 |
| 4 | Battery | 1 | 500 | 500 |
| 5 | Peltier | 2 | 290 | 580 |
| 6 | Hartbees sensor | 1 | 380 | 380 |
| 7 | Temperature Sensor | 1 | 170 | 170 |
| 8 | Humidity Sensor | 1 | 150 | 150 |
| 9 | Humidifier | 1 | 600 | 600 |
| 10 | Cable | 2 | 150 | 300 |
| 11 | PVC Sheet | 1 | 350 | 350 |
| 12 | Charge Controller | 1 | 270 | 270 |
| 13 | Sound Sensor | 1 | 200 | 200 |
| 14 | Buzzer | 1 | 25 | 25 |
| 15 | Switch | 2 | 30 | 60 |
| 16 | Capacitor | 1 | 60 | 60 |
| 17 | Tape | 1 | 45 | 45 |
| 18 | Glue Steaks | 5 | 20 | 100 |
| 19 | Male Connector | 2 | 60 | 120 |
| 20 | Female Connector | 2 | 60 | 120 |
| 21 | LCD Display | 1 | 450 | 450 |
| 22 | I2C Module | 1 | 100 | 100 |
| 23 | Buck Converter | 1 | 220 | 220 |
| 24 | Dust Sensor | 1 | 850 | 850 |
| 25 | Collar fan | 2 | 80 | 160 |
| **Total** | | | | **7860** |

**TABLE 5. 2 COMPONENT LIST AND PRICE**

We are using a number of energy and cost-efficient components in our project to create an incubator for premature babies. Through the process of analyzing essential elements and contrasting them with plausible substitutes, we may comprehend how our decisions optimize expenses and augment productivity.

**Peltier Module vs. Traditional Heater**

The Peltier modules that are utilized in our project have a cost of 290 Tk each and a power consumption of 50–60 W. It provides effective heating and cooling as well as accurate temperature control. A typical heater, on the other hand, costs about 200–400 Tk and uses a lot more energy roughly 150–300W. Even though a traditional heater may cost a little less up front, over time its higher energy consumption results in higher operating expenses and less efficiency. As a result, over time, the Peltier module turns out to be more economical and energy-efficient despite its slightly higher initial cost.

**ESP 32 vs. Raspberry Pi**

At 500 Tk, the ESP 32 is a very efficient microcontroller that uses less than 10mA when in deep sleep mode and 170mA when using active Wi-Fi. The price would increase to 2000-3000 Tk and the energy usage would reach 700-1000mA if a Raspberry Pi were used in its place. Thus, the ESP 32 is an excellent option for lowering both initial expenses and ongoing energy usage because it is not only substantially less expensive but also much more energy-efficient.

**Basic Sensors vs. High-End Sensors**

Basic temperature and humidity sensors, which cost between 150 and 200 Tk each and have a very low power consumption of less than 2.5mA, are part of our project. High-end sensors, like the SHT31, would cost between 500 and 1000 Tk apiece and require a marginally larger amount of power to replace. Although high-end sensors have more functionality, basic sensors are sufficient for an incubator for a baby, guaranteeing accurate measurements without needless cost or energy use.

When these carefully selected components are combined, you have a neonatal incubator that is reasonably priced to build and run. In conjunction with energy-efficient microcontrollers and sensors, the thoughtful application of the Peltier module guarantees long-term sustainability and dependability, all of which are critical for the provision of neonatal care. This balanced approach to component selection lowers operating costs over time and lowers initial investment, making it a workable and long-lasting option for premature baby healthcare.

## 5.3 LESSON LEARNED

By this project we have learned about various technical things. Here are some key learning to conduct a technical project like designing a modern premature baby incubator.

- Learned about understand user needs, consider health care providers, caregivers, medical needs, safety concerns, and usability.
- The research also investigated the use of sensors and code to operate a micro-controller.
- Also learned to interactively design and refine the incubator system using prototyping techniques.
- Learned to rigorously test the functionality of each component and system to identify potential weaknesses and areas for improvement in the project.
- Learned about the safety standards and regulatory requirements governing medical devices.
- Also learned about robust data management systems for real-time monitoring, data storage, and analysis.
- Learned about Implementing sustainable power solutions, such as battery backup and solar panel integration, to ensure uninterrupted operation of the incubator, particularly in resource-constrained environments.

# CHAPTER 6

# IMPACT ASSESSMENT OF THE PROJECT

## 6.1 ECONOMICAL, SOCIETAL AND GLOBAL IMPACT

The development of an incubator system for preterm babies has the potential to significantly affect society both directly and indirectly:

### 6.1.1 Healthcare Infrastructure:

The project improves healthcare infrastructure by offering improved newborn care capabilities, particularly in rural locations where access to specialist healthcare institutions may be limited. For preterm newborns, it helps close the gap in healthcare services and improves their general health outcomes.

### 6.1.2 Energy Generation and Consumption:

The developing system's energy consumption is decreased by integrating sustainable power management techniques and energy-efficient parts. Incorporating charge controllers and solar panels for power generation also encourages the use of renewable energy sources, which supports environmental sustainability.

### 6.1.3 Creation of Jobs:

The incubation system's design, production, and implementation may lead to the creation of jobs, especially in the local assembly, maintenance, and manufacturing industries. This can enhance lives and encourage economic growth, particularly in rural regions.

### 6.1.4 GDP Contribution:

By encouraging innovation and entrepreneurship in the healthcare industry, the project's execution can boost the nation's economy. Through the manufacture and distribution of incubator systems as well as associated services like upkeep and training, it contributes to the economy.

### 6.1.5 Quality of Life:

Preterm children and their families have a higher quality of life because to the availability of sophisticated preterm baby incubator systems. The concept lessens the need for families to travel great distances by giving them access to specialist care closer to home.

## 6.2 ENVIRONMENTAL AND ETHICAL ISSUES

There are several environmental, aesthetic, and ethical problems with the recently established project of an improved feature-rich preterm infant incubator:

### 6.2.1 Sustainability of the Environment:

- Sustainable Power Supply**:** Although the use of charge controllers and solar panels for power management is praiseworthy, it is imperative to guarantee the sustainability of these components' installation, manufacturing, and disposal in order to achieve long-term environmental sustainability.
- Material Selection**:** To reduce the incubator's negative environmental effects, the materials utilized in its construction should be carefully chosen. Selecting recyclable and environmentally friendly materials helps lower the project's carbon impact.

### 6.2.2 Aesthetics of the Environment:

- Integration with Healthcare Settings: To foster a tranquil and inviting environment for both newborns and caretakers, the incubator's design should be smoothly integrated with the aesthetics of healthcare facilities.

### 6.2.3 Ethical Concerns and Obligations:

- Patient private: To protect patient private rights and preserve confidence between families and healthcare professionals, it is critical to guarantee the security and confidentiality of patient data gathered and communicated by the incubator system.
- Informed Consent: Before utilizing the incubator system on preterm newborns, healthcare personnel must have the parents' or guardians' informed consent. This guarantees that families are aware of the technology's uses, dangers, and advantages.

- Equity and Accessibility: Especially in rural locations where access to specialist healthcare may be restricted, efforts should be made to guarantee equitable access to cutting-edge incubator technology. This lessens the likelihood of differences in healthcare outcomes and access.
- Transparency and Accountability: It is the developers' and manufacturers' duty to be open and honest about the incubation system's features, restrictions, and any hazards. Maintaining ethical integrity requires responding to any issues in a timely and responsible manner.
- Sustainability: Using sustainable methods in the incubation system's development, manufacture, and operation shows moral obligation to protect the environment and the welfare of coming generations.

The recently created preterm infant incubator project can encourage ethical and responsible technology usage while reducing its negative effects on the environment and society by taking these aesthetic, ethical, and environmental factors into account.

## 6.3 UTILIZATION OF EXISTING STANDARDS OR CODES

We follow a thorough set of standards, safety guidelines, and rules when developing our cutting-edge preterm baby incubator to guarantee the device's efficacy, safety, and compliance with applicable laws. Our top priority is adhering to medical device rules set out by regulatory agencies like the European Medical Device Regulation (MDR) in the European Union or the FDA in the United States. To guarantee the safety and effectiveness of medical equipment, these rules set strict guidelines for its design, manufacture, testing, and labeling.

Our incubator system uses electrical equipment and components, so adhering to electrical safety standards like the International Electrotechnical Commission (IEC) 60601 series is crucial. In order to safeguard patients and operators alike, these standards define requirements for the electrical safety, electromagnetic compatibility, and functionality of medical electrical equipment.

Our incubator system must adhere to biocompatibility requirements like ISO 10993, as it has direct contact with preterm neonates. By ensuring that the materials used in the device are safe and compatible with biological systems, these guidelines help to reduce the possibility of patient injury or unpleasant responses.

In addition, compliance with software development standards like IEC 62304 is required if our project includes developing software to operate and monitor the incubator system. To guarantee the dependability and safety of medical device software, these standards offer recommendations for its creation, validation, and upkeep.

Apart from these benchmarks, we are dedicated to adhering to environmental statutes, which encompass limitations on dangerous materials like WEEE (Waste Electrical and Electronic Equipment Directive) and RoHS (Restriction of Hazardous Substances Directive). In order to reduce our device's environmental effect and guarantee its safe disposal at the end of its lifespan, compliance with these requirements is essential.

If our project involves the collection and transmission of patient data, then compliance with privacy and data protection regulations, such as the General Data Protection Regulation (GDPR) in the European Union or the Health Insurance Portability and Accountability Act (HIPAA) in the United States, is required to protect patient confidentiality and privacy.

In conclusion, establishing a quality management system grounded in guidelines like ISO 13485 is essential to guaranteeing our medical devices are designed, developed, produced, and distributed consistently while adhering to legal criteria. We maintain the safety, efficacy, and legal compliance of our cutting-edge premature baby incubator by closely following these standards, safety laws, and codes. This gives patients, regulators, and healthcare professionals peace of mind.

# CHAPTER 7

# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 CONCLUSIONS

We are introducing cutting edge technology into neonatal care with our Smart IoT-based Premature Baby Incubator project, giving premature babies a safer and more effective environment. We successfully built an incubator that leverages Internet of Things capabilities to monitor environmental elements and vital signs in real time while also allowing parents and healthcare practitioners remote access and management.

This project's incubator is equipped with sensors to monitor important indicators like as heart rate, pulse rate, dust, noise, temperature, and humidity. Environmental variables that are regularly evaluated include oxygen levels and humidity. The system uses data analytics to provide predictive insights, assisting in the early detection and prevention of health issues. Historical data trends are useful for tailoring care plans and tracking long-term health.

The Arduino UNO is a low-cost microcontroller that we use to collect data from sensors within the incubator. Sensors are used to continuously measure the previously stated parameters. Using the Internet of Things, medical professionals and nurses can access sensed data wirelessly (IoT). Using a secure cloud platform, parents and medical professionals may view real-time data as well as historical trends from any place.

We think that the constant and accurate monitoring that our initiative employs will enable prompt intervention, lower the risk of problems, and enhance the general health outcomes for preterm infants. Remote locations will also provide premature babies with access to affordable, high-quality medical care. As a result, reduces neonatal mortality rates. In addition, parents feel more at ease knowing that they can keep an eye on their child's health from a distance, fostering a closer relationship and allowing them to participate in the child's care.

So, we believe that our intelligent Internet of Things (IoT)-based incubator for premature babies is a major advancement in infant care since it combines state-of-the-art technology with humane medical procedures. In addition to demonstrating the potential of IoT in medical applications, this research opens the door for future developments targeted at safeguarding the health and welfare of the most vulnerable patients.

## 7.2 NEW SKILLS AND EXPERIENCES LEARNED

Many new abilities and experiences have been gained while working on the design and development of this innovative, affordable, and newborn incubator, especially in data management, sensor systems, technological integration, and sustainable power solutions. Below is a summary of the key skills and experiences attained:

I. Being aware of the proper methods for choosing, integrating, and calibrating the Temperature in humidity sensors to guarantee precise environmental monitoring.
II. Learned about the location of SpO2 sensors for non-invasive monitoring of the baby's pulse rate and oxygen saturation.
III. Learned how to keep an eye on the noise levels in the baby's surroundings to maintain a peaceful atmosphere by using Sound sensors.
IV. Mastered the use of dust sensors to keep the air in the incubator clean and protect the baby from dust.
V. Peltier technology has been applied for precise temperature control in the incubator.
VI. Being able to maintain and control the optimal humidity level in the incubator using a humidifier.
VII. To protect the baby from infection, the incubator includes a UV system for sterilization.
VIII. Mastered how to collect real-time data for remote monitoring using Firebase.
IX. Gaining expertise in creating mobile applications that provide caregivers immediate access to the baby's environmental parameters and vital signs.
X. Integrating Google Sheets with automated data capture for analysis and documentation.

XI. Learned how to build and incorporate reliable battery backup systems to guarantee uninterrupted operation in the event of power loss.

XII. Acquired knowledge on how to integrate solar panels to improve sustainability and offer a sustainable power source in resource-constrained settings.

XIII. Collaborating with engineers, software developers, and healthcare specialists to make sure the incubator satisfies all technological and medical criteria.

XIV. we create plans to maintain the system's affordability without sacrificing dependability or necessary features.

XV. To make sure the system is efficient and easy to use, we concentrated on the requirements of preterm newborns and the people who care for them.

Above all, we have tried to create a premature baby incubator that is technologically superior to contemporary neonatal care technologies.

## 7.3 FUTURE RECOMMENDATIONS

Various steps we can take as recommendations in the future are discussed below. Data from a baby receive sensor can be transmitted online in the future and share all the same ECG data with the guardian showing a special app. We will set up the system to automatically notify healthcare professionals if any irregularities or complications occur in the ECG data. And comply with patient data protection and privacy regulations such as GDPR, HIPAA, and other regional laws. We will use the FHIR data format to standardize data and facilitate interoperability with electrical health records. We will try to make the app more user-friendly in the future by sending a child data group to the parents via mobile. In the future, we will also use temperature sensors that are designed to use low standby power mode. We can use the duty cycle method so that the sensors are on when needed and consume less power at other times. We will use a microcontroller that consumes less energy, such as an ARM Cortex-M0 or M4 processor. If the system is idle, we will reduce power consumption by using different sleep modes like MCU. In the future, if there is a sudden drop in oxygen in the incubator, we can provide emergency oxygen support by the oxygen cylinder. Also, we can use a live camera to monitor the movement of the baby inside the incubator.

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# APPENDIX A

# TURNITIN REPORT

201-33-1263

ORIGINALITY REPORT

| 21% | 17% | 9% | 12% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | dspace.daffodilvarsity.edu.bd:8080<br>Internet Source | 7% |
| 2 | Submitted to Daffodil International University<br>Student Paper | 2% |
| 3 | journalarticle.ukm.my<br>Internet Source | 1% |
| 4 | Submitted to Universiti Teknologi Malaysia<br>Student Paper | 1% |
| 5 | Submitted to Taylor's Education Group<br>Student Paper | 1% |
| 6 | repo.poltekkesdepkes-sby.ac.id<br>Internet Source | 1% |
| 7 | media.neliti.com<br>Internet Source | <1% |
| 8 | Submitted to INTI International University<br>Student Paper | <1% |
| 9 | ijeeemi.poltekkesdepkes-sby.ac.id<br>Internet Source | <1% |

# APPENDIX B

# COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

| Complex Engineering Problems (P) Solving | | |
|---|---|---|
| | Attributes | Statement from students |
| P1 | Range of resources | Our project utilizes a diverse range of resources including people (healthcare providers, engineers, caregivers), financial resources (budget for materials and technology), equipment (sensors, control systems, humidifiers, Peltier modules, UV light), materials (components and construction materials for the incubator), information (sensor data, patient records), and technologies (Firebase database, Google Sheets, mobile apps, ESP32). This ensures comprehensive support and effective integration across all aspects of the project. |
| P2 | Level of interaction | We need to balance precise environmental control with power constraints from solar panels and battery backups, ensure seamless integration of multiple sensors, and maintain data accuracy and security. |
| P3 | Innovation | We employ creative engineering principles and research-based knowledge in novel ways. By integrating advanced sensors and remote monitoring via mobile apps, combined with sustainable power solutions and data management in Google Sheets, we are pioneering a cost-effective and accessible neonatal care solution. |

| | | |
|---|---|---|
| P4 | Consequences of society and environment | Ensuring the health and safety of premature infants, particularly in resource-constrained environments, is crucial. The environmental impact of using solar panels and sustainable materials, as well as ethical considerations regarding data privacy and security, are key concerns. |
| P5 | Familiarity | This project extends beyond previous experiences by applying principles-based approaches. While we are familiar with the individual components (sensors, data management systems, and power solutions), integrating them into a comprehensive, low-cost, and accessible incubator system presents new challenges and opportunities for innovation and learning. |
| P6 | Extent of stakeholder involvement and conflicting requirements | Our project involves multiple stakeholders, including healthcare providers, engineers, caregivers, and possibly parents. Balancing their requirements—such as ease of use, reliability, affordability, compliance with medical standards, and data security—requires navigating and resolving conflicting needs and expectations. |
| P7 | Interdependence | The various components and systems in our project are highly interdependent. Data from the sensors directly influences the control systems (temperature, humidity), which depend on reliable power supply solutions. The data management system must accurately collect and store data to ensure effective monitoring and decision-making. |

| Complex Engineering Problems (P) Solving | | |
|---|---|---|
| | Attributes | Statement from students |
| A1 | Depth of knowledge required | The project necessitates deep interdisciplinary knowledge, spanning biomedical engineering, electronics, software development, and environmental science. This expertise ensures the effective integration of diverse sensors and advanced control systems for comprehensive neonatal care. |
| A2 | Range of conflicting requirements | We balance precise environmental control and power constraints while keeping costs low and ensuring accessibility in rural areas. Additionally, the system must be user-friendly and adhere to stringent medical standards, ensuring data security and privacy. |
| A3 | Depth of analysis required | Extensive analysis is essential to optimize system performance, sensor accuracy, and power efficiency, ensuring optimal conditions for the premature baby. We also analyze the data management system for seamless real-time monitoring and historical data retrieval. |
| A4 | Extent of applicable codes | Compliance with medical device regulations, electrical safety standards, biocompatibility, software development standards, and environmental regulations is crucial. Adhering to these codes ensures safe, effective operation and meets legal and ethical obligations. |

# APPENDIX C

# PROGRAM CODE

## Arduino Code

Smart_Baby_Incubator

```
#define POWER_PIN  15  // ESP32 pin GPIO32 connected to sensor's VCC pin
#define SIGNAL_PIN 34 // ESP32 pin GPIO34 (ADC0) connected to sensor's signal pin
int Water_Value = 0; // variable to store the sensor value
#define Sound_PIN 19 // ESP32 pin GPIO22 connected to the OUT pin of the sound sensor
int Sound_Data;      // the current reading from the input pin
int sound;
int Sound_Time=0;
int Sound_State=0;

int Urine;
int Urine_Time=0;
int Urine_State=0;

int integertype=0;
float floattype =1.5;
int rinteger;
float rfloat;

```

FIGURE. I VARIABLE DECLARATION

Smart_Baby_Incubator

```
void setup(){
  Serial.begin(115200);
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
  Serial.print("Connecting to Wi-Fi");
  while (WiFi.status() != WL_CONNECTED){
    Serial.print(".");
    delay(300);
  }
  Serial.println();
  Serial.print("Connected with IP: ");
  Serial.println(WiFi.localIP());
  Serial.println();

  /* Assign the api key (required) */
  config.api_key = API_KEY;

  /* Assign the RTDB URL (required) */
  config.database_url = DATABASE_URL;
```

FIGURE. II VOID SETUP

```
void loop(){
  digitalWrite(POWER_PIN, HIGH);  // turn the sensor ON
  integertype=integertype+2;
  floattype=floattype+1;
Sound_Data = digitalRead(Sound_PIN);

  if (Sound_Data == LOW){
      sound=1;
      Sound_State = 1;
      Firebase.RTDB.setFloat(&fbdo, "sound", sound);
    Serial.println("The sound has been detected");
  }
  else if (Sound_Data == HIGH && Sound_State == 1){
          Sound_Time = Sound_Time+1;
          if (Sound_Time>1){
            sound=0;
            Firebase.RTDB.setFloat(&fbdo, "sound", sound);
            Serial.println("The sound has disappeared");
```

FIGURE. III VOID LOOP

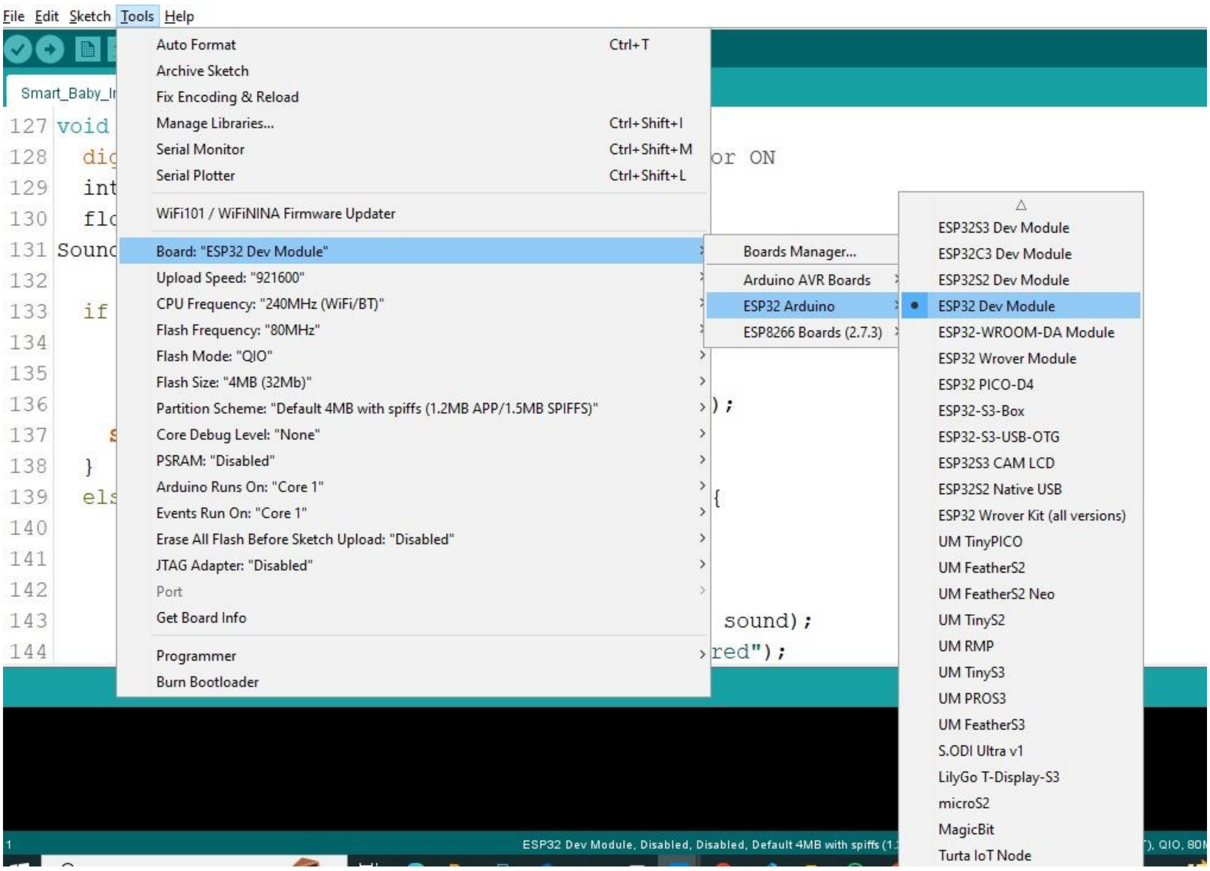



FIGURE. IV BOARD SELECTION

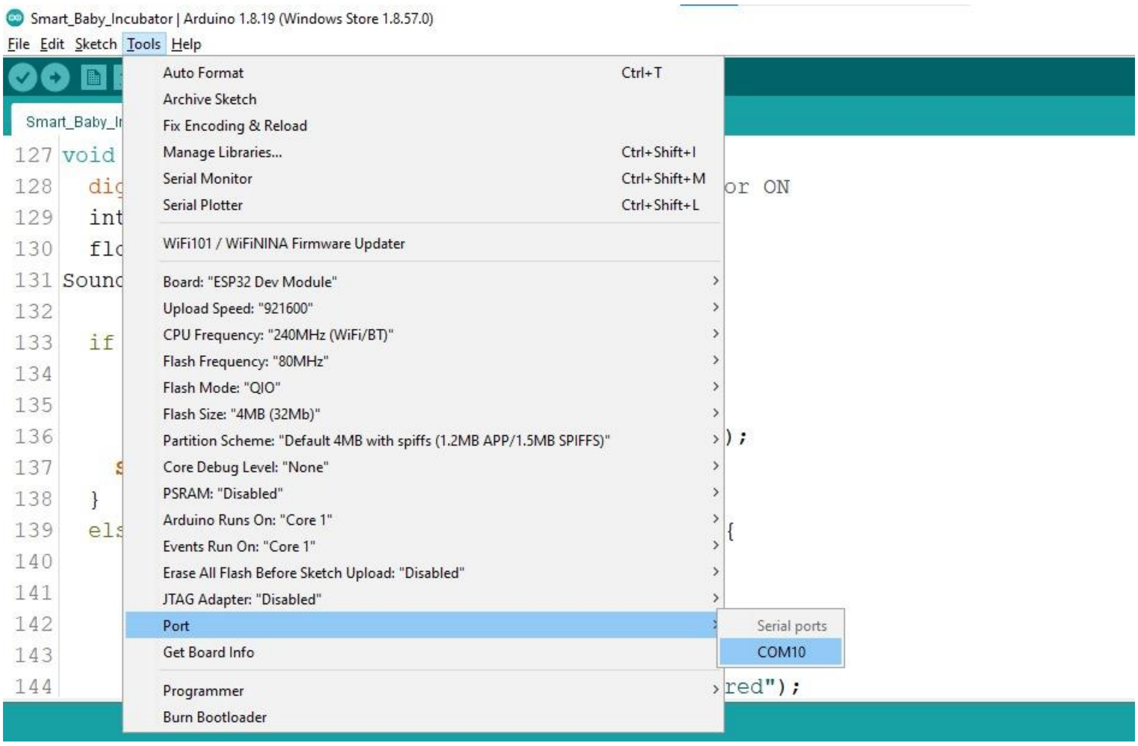



FIGURE. V PORT SELECTION

# Smart Baby Incubator Arduino Apps Design

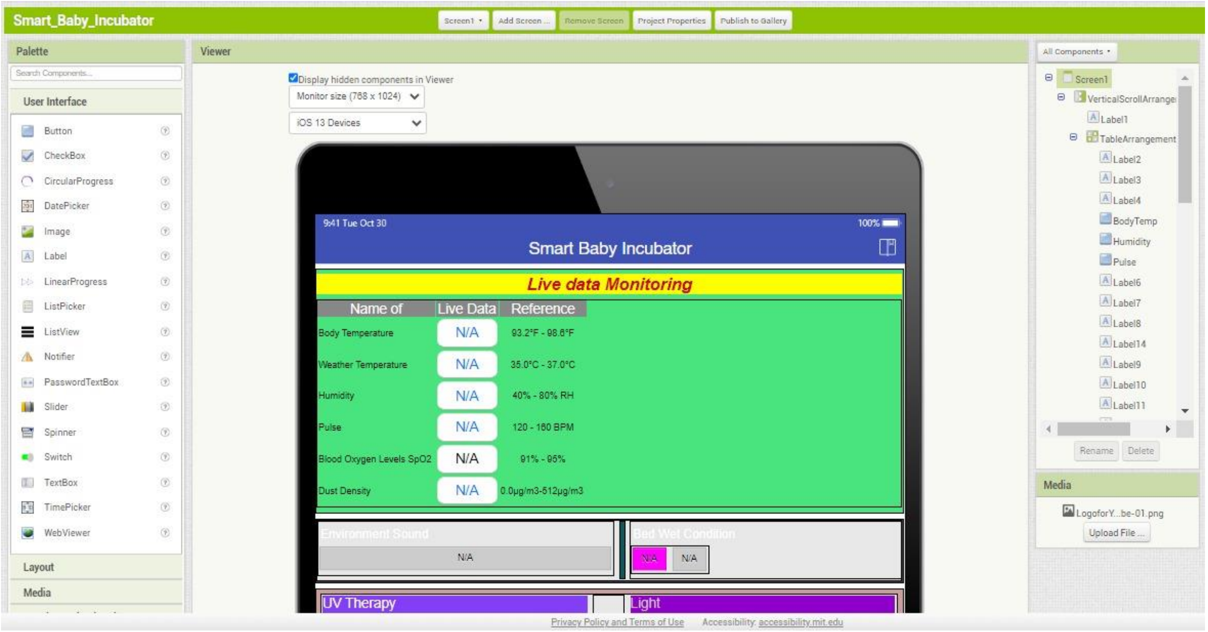



FIGURE. VI ANDROID APP UI DESIGN

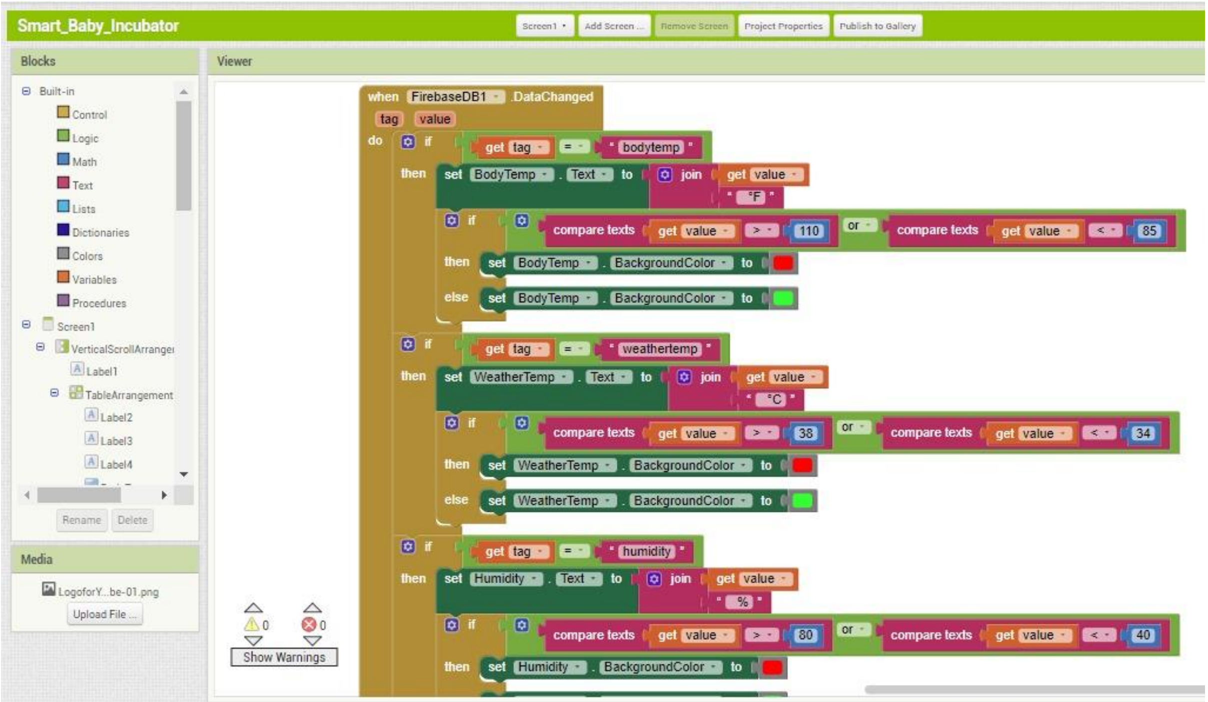
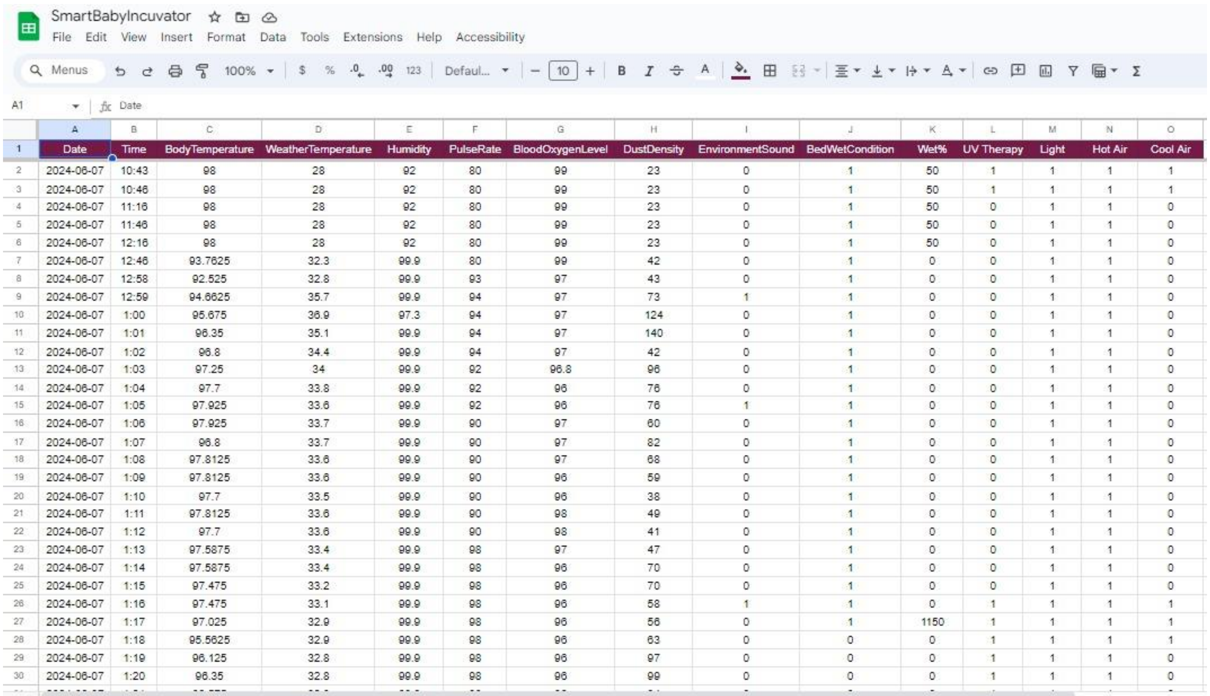



FIGURE. VII BLOCK CODE OF ANDROID APP



SmartBabyIncuvator

| | Date | Time | BodyTemperature | WeatherTemperature | Humidity | PulseRate | BloodOxygenLevel | DustDensity | EnvironmentSound | BedWetCondition | Wet% | UV Therapy | Light | Hot Air | Cool Air |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2024-06-07 | 10:43 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 1 | 1 | 1 | 1 |
| 3 | 2024-06-07 | 10:46 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 1 | 1 | 1 | 1 |
| 4 | 2024-06-07 | 11:16 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 0 | 1 | 1 | 0 |
| 5 | 2024-06-07 | 11:46 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 0 | 1 | 1 | 0 |
| 6 | 2024-06-07 | 12:16 | 98 | 28 | 92 | 80 | 99 | 23 | 0 | 1 | 50 | 0 | 1 | 1 | 0 |
| 7 | 2024-06-07 | 12:46 | 93.7625 | 32.3 | 99.9 | 80 | 99 | 42 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 8 | 2024-06-07 | 12:58 | 92.525 | 32.8 | 99.9 | 93 | 97 | 43 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 9 | 2024-06-07 | 12:59 | 94.6625 | 35.7 | 99.9 | 94 | 97 | 73 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 10 | 2024-06-07 | 1:00 | 95.675 | 36.9 | 97.3 | 94 | 97 | 124 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 11 | 2024-06-07 | 1:01 | 96.35 | 35.1 | 99.9 | 94 | 97 | 140 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 12 | 2024-06-07 | 1:02 | 96.8 | 34.4 | 99.9 | 94 | 97 | 42 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 13 | 2024-06-07 | 1:03 | 97.25 | 34 | 99.9 | 92 | 96.8 | 96 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 14 | 2024-06-07 | 1:04 | 97.7 | 33.8 | 99.9 | 92 | 96 | 76 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 15 | 2024-06-07 | 1:05 | 97.925 | 33.6 | 99.9 | 92 | 96 | 76 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 16 | 2024-06-07 | 1:06 | 97.925 | 33.7 | 99.9 | 90 | 97 | 60 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 17 | 2024-06-07 | 1:07 | 96.8 | 33.7 | 99.9 | 90 | 97 | 82 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 18 | 2024-06-07 | 1:08 | 97.8125 | 33.6 | 99.9 | 90 | 97 | 68 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 19 | 2024-06-07 | 1:09 | 97.8125 | 33.6 | 99.9 | 90 | 96 | 59 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 20 | 2024-06-07 | 1:10 | 97.7 | 33.5 | 99.9 | 90 | 96 | 38 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 21 | 2024-06-07 | 1:11 | 97.8125 | 33.6 | 99.9 | 90 | 98 | 49 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 22 | 2024-06-07 | 1:12 | 97.7 | 33.6 | 99.9 | 90 | 98 | 41 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 23 | 2024-06-07 | 1:13 | 97.5875 | 33.4 | 99.9 | 98 | 97 | 47 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 24 | 2024-06-07 | 1:14 | 97.5875 | 33.4 | 99.9 | 98 | 96 | 70 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 25 | 2024-06-07 | 1:15 | 97.475 | 33.2 | 99.9 | 98 | 96 | 70 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 26 | 2024-06-07 | 1:16 | 97.475 | 33.1 | 99.9 | 98 | 96 | 58 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 27 | 2024-06-07 | 1:17 | 97.025 | 32.9 | 99.9 | 98 | 96 | 56 | 0 | 1 | 1150 | 1 | 1 | 1 | 1 |
| 28 | 2024-06-07 | 1:18 | 95.5625 | 32.9 | 99.9 | 98 | 96 | 63 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 29 | 2024-06-07 | 1:19 | 96.125 | 32.8 | 99.9 | 98 | 96 | 97 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 30 | 2024-06-07 | 1:20 | 96.35 | 32.8 | 99.9 | 98 | 96 | 99 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |

FIGURE. VIII  DATA LOGER IN GOOGLE SHEET


```
}

// Append new data to the sheet, starting from the last row with content
var bodytemp = data.bodytemp;
var weathertemp = data.weathertemp;
var humidity = data.humidity;
var pulserate = data.pulserate;
var bloodoxygen = data.bloodoxygen;
var dust = data.dust;
var sound = data.sound;
var urine = data.urine;
var wet = data.wet;
var uvlight = data.uvlight;
var light = data.light;
var hotair = data.hotair;
var coolair = data.coolair;

if (bodytemp !== undefined && weathertemp !== undefined && humidity !== undefined && pulserate !== undefined && bloodoxygen
!== undefined && dust !== undefined && sound !== undefined && urine !== undefined && wet !== undefined && uvlight !==
undefined && light !== undefined && hotair !== undefined && coolair !== undefined) { // Ensure all data exists
  var now = new Date();
  var timestamp = now.getTime();
  var date = Utilities.formatDate(now, "GMT+6", "yyyy-MM-dd");
  var time = Utilities.formatDate(now, "GMT+6", "h:mm");
  var rowData = [date, time, bodytemp, weathertemp, humidity, pulserate, bloodoxygen, dust, sound, urine, wet, uvlight, light,
  hotair, coolair];
  sheet.appendRow(rowData);
}
```

FIGURE. IX CODE FOR RECORD DATA FROM FIREBASE TO GOOGLE SHEET

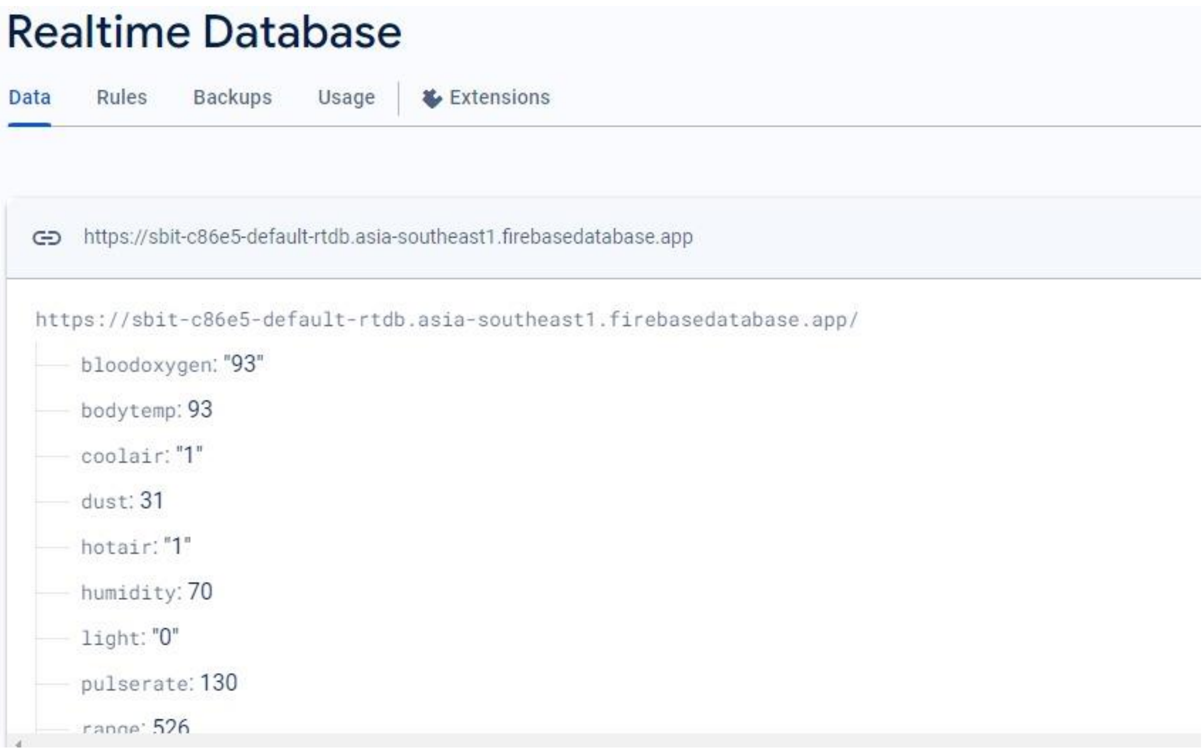



FIGURE. X FIREBASE REALTIME DATABASE

# APPENDIX D

# DATASHEET OF COMPONENTS

| Sl | Item Name | Quantity | Unit Price | Total |
|---|---|---|---|---|
| 1 | Node Mcu | 2 | 500 | 1000 |
| 2 | Arduino uno | 1 | 750 | 750 |
| 3 | Solar | 1 | 300 | 300 |
| 4 | Battery | 1 | 500 | 500 |
| 5 | Peltier | 2 | 290 | 580 |
| 6 | Hartbees sensor | 1 | 380 | 380 |
| 7 | Temperature Sensor | 1 | 170 | 170 |
| 8 | Humidity Sensor | 1 | 150 | 150 |
| 9 | Humidifier | 1 | 600 | 600 |
| 10 | Cable | 2 | 150 | 300 |
| 11 | PVC Sheet | 1 | 350 | 350 |
| 12 | Charge Controller | 1 | 270 | 270 |
| 13 | Sound Sensor | 1 | 200 | 200 |
| 14 | Buzzer | 1 | 25 | 25 |
| 15 | Switch | 2 | 30 | 60 |
| 16 | Capacitor | 1 | 60 | 60 |
| 17 | Tape | 1 | 45 | 45 |
| 18 | Glue Steaks | 5 | 20 | 100 |
| 19 | Male Connector | 2 | 60 | 120 |
| 20 | Female Connector | 2 | 60 | 120 |
| 21 | LCD Display | 1 | 450 | 450 |
| 22 | I2C Module | 1 | 100 | 100 |
| 23 | Buck Converter | 1 | 220 | 220 |
| 24 | Dust Sensor | 1 | 850 | 850 |
| 25 | Collar fan | 2 | 80 | 160 |
| **Total** | | | | **7860** |