NEORAKSHA: SMART INCUBATOR FOR PRETERM INFANT SAFETY

Project Reference No.: *49S_BE_6686*

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Keywords:

Preterm Infant Monitoring, Neonatal Monitoring, Temperature Monitoring, Humidity Monitoring, Sensor-Based System, IoT Monitoring, Real-Time Monitoring, Infant Safety Monitoring

Introduction:

1. Premature infant mortality continues to be a serious global health challenge, requiring urgent attention and innovative solutions. Many infant deaths occur suddenly and without clear prior medical warning, often linked to factors such as irregular body temperature, unsafe sleeping positions, or exposure to harmful gases like carbon monoxide.
2. To reduce such risks, continuous monitoring of an infant's vital parameters becomes crucial. Key indicators such as CO_2 levels, heart rate, body temperature, humidity, and weight provide valuable insights into the baby's health condition and can help detect abnormalities at an early stage.
3. With advancements in technology, IoT-based wireless monitoring systems offer an effective solution by enabling real-time tracking of these vital signs. These systems can promptly alert parents or caregivers when any irregularities are detected, allowing for immediate preventive action.
4. Such innovations significantly enhance neonatal care by ensuring constant supervision, minimizing delays in response, and ultimately reducing infant mortality rates. In addition, the development of a cost-effective incubator integrated with a protective pouch aims to support underprivileged communities, making advanced neonatal care more accessible and inclusive.

Objectives:

1. To design and develop an a smart, IoT-based incubator system that ensures a safe and controlled environment for preterm infants.
2. To monitor key physiological parameters such as heart rate, body temperature, and oxygen level in real time.
3. To enable automatic adjustment of environmental parameters based on sensor readings.

4. To reduce risk such as sudden infant death syndrome through continuous supervision and alerts.
5. To implement wireless communication (wi-fi / Bluetooth /GSM) for remote monitoring through mobile or web applications.
6. To provide an easy- to -use interface for doctors, nurses, and parents to monitor infant health.

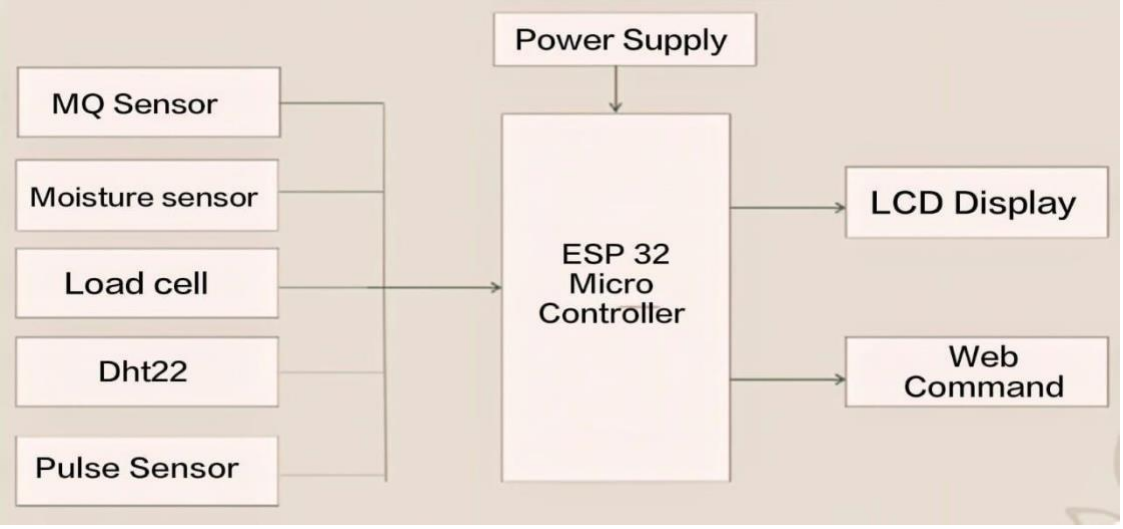

Figure 1: Block Diagram

Methodology:

1. System Design and Architecture
   - The system consists of multiple sensors, a microcontroller, communication modules, and control units integrated into an incubator.
   - Sensors are used to measure vital and environmental parameters.
   - A microcontroller (e.g., Arduino/ESP32) acts as the central processing unit.

2. Sensor Integration

   Various sensors are deployed inside the incubator to collect real-time data:
   - Temperature Sensor – monitors infant body and incubator temperature
   - Humidity Sensor – maintains proper moisture levels
   - Pulse Sensor – measures heart rate
   - Gas/CO_2 Sensor – detects air quality
   - Weight Sensor – tracks infant growth

3. Data Processing Unit

   - The collected sensor data is processed using a microcontroller.
   - Real-time data is continuously analyzed
   - Values are compared with predefined safe thresholds
   - Decision-making algorithms determine necessary actions

4. Control Mechanism

   The system automatically maintains optimal incubator conditions:
   - Heating element controls temperature

- Humidifier maintains humidity levels
- Oxygen supply system regulates oxygen concentration

5. Monitoring and Alert System

The system ensures infant safety through continuous monitoring.

- Buzzer alerts are triggered during abnormal conditions
- LED indicators provide visual warnings
- Emergency notifications are sent to caregivers

6. IoT-Based Remote Monitoring

The system uses IoT technology for remote access and monitoring.

- Data is transmitted via Wi-Fi (ESP32)
- Cloud platforms store real-time data
- Doctors and parents can monitor via mobile application

7. Testing and Calibration

The system is tested to ensure accuracy and reliability:

- Sensors are calibrated for precise readings
- Tested under different environmental conditions
- Performance is validated with standard values

Result and Conclusion:

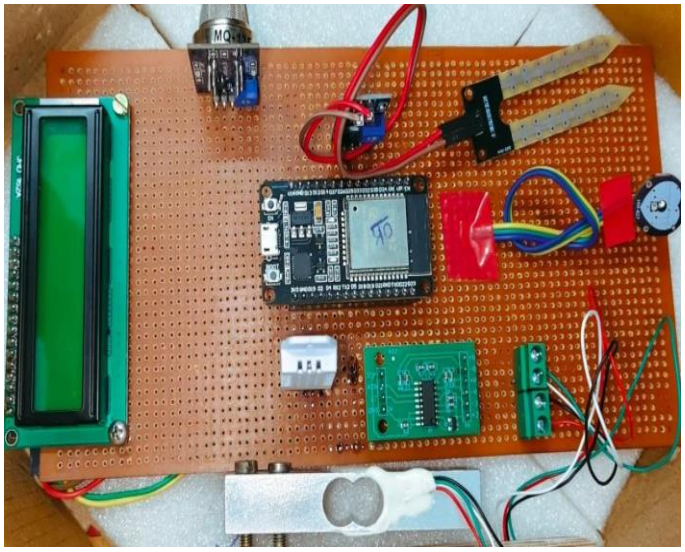

Figure 2: Working Model

The Neo-Raksha Smart Incubator for Preterm Infant Safety project successfully demonstrates how modern technology can be integrated with neonatal care to improve the survival and well-being of preterm infants. By providing a controlled and stable environment with continuous monitoring of vital parameters such as temperature, humidity, and heart rate, the system helps reduce health risks and ensures timely intervention in critical situations. The smart features of Neo-Raksha enhance infant safety while also reducing the burden on healthcare staff through automation and real-time alerts. Its cost-effective and user friendly design makes it suitable for use in hospitals, primary health centers , and resource limited settings. Overall, the project highlights the potential of IoT-

based healthcare solutions in saving lives and improving the quality of neonatal care, paving the way for safer and more accessible incubator systems in the future.

Project Outcome & Industry Relevance:

The NeoRaksha system holds strong relevance in the healthcare and biomedical engineering industries, particularly in neonatal intensive care units where continuous monitoring of preterm infants is critical. It reflects the growing adoption of IoT-based smart healthcare solutions, enabling remote patient monitoring and improved clinical decision-making. The project demonstrates the practical application of embedded systems in medical devices, making it highly valuable in the biomedical and medical device manufacturing sectors. Furthermore, it can be integrated into hospital infrastructure to enhance existing incubator systems with advanced features. The system is especially beneficial for rural and underdeveloped healthcare facilities, where access to expensive neonatal equipment is limited. It also aligns with government and public health initiatives aimed at reducing infant mortality rates. In addition, the project provides a strong foundation for future research and development, including the integration of artificial intelligence for predictive health monitoring and advanced diagnostics.

Working Model vs. Simulation/Study:

The NeoRaksha project primarily focuses on the development of a working model rather than being limited to simulation or theoretical study. A physical prototype of the smart incubator is designed and implemented using hardware components such as sensors, a microcontroller (Arduino/ESP32), control units, and communication modules. This working model continuously monitors vital parameters like temperature, humidity, heart rate, and oxygen levels in real time and automatically controls the incubator environment using actuators such as heating elements and fans. The system also provides alert mechanisms and IoT-based remote monitoring, thereby demonstrating practical functionality and real-world applicability**.**

Project Outcomes and Learnings:

1. The NeoRaksha smart incubator project successfully demonstrates the development of a reliable and efficient system for monitoring and ensuring the safety of preterm infants. The project outcomes include the implementation of real-time monitoring of vital parameters such as temperature, humidity, heart rate, and oxygen levels, along with automated environmental control to maintain optimal conditions inside the incubator. The system is capable of detecting abnormalities and providing timely alerts to caregivers, thereby reducing risks and improving neonatal care. Additionally, the integration of IoT enables remote monitoring, data logging, and better accessibility for doctors and parents. Overall, the project results in a cost-effective and practical solution that can be further enhanced for real-world medical applications.
2. Through the development of this project, significant learning outcomes were achieved in both technical and practical domains. The project provided hands-on experience in working with sensors, microcontrollers such as Arduino/ESP32, and IoT technologies. It helped in understanding system design, circuit integration, and real-time data processing. The team also gained knowledge in troubleshooting

hardware issues, calibrating sensors, and improving system accuracy. Furthermore, the project enhanced problem-solving skills, teamwork, and project management abilities. It also provided insight into biomedical applications of embedded systems, highlighting how technology can be used to address real-world healthcare challenges.

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Future Scope:

The future scope of this project includes:

1. AI/ML integration for early prediction of infant health issues
2. Addition of advanced biosensors to monitor more parameters such as blood pressure, respiration rate, and CO_2 levels.
3. Implementation of cloud-based data storage for maintaining long-term medical records and improving clinical decision-making
4. Development of a user-friendly mobile application for real-time monitoring by doctors and parents.
5. Enhancement with real-time video monitoring for better observation of the infant.
6. Integration with hospital management systems for seamless data sharing and coordination.
7. Improvement in design and safety standards to meet medical device regulations for commercialization.
8. Development of a portable and compact version suitable for rural and remote healthcare centers.
9. Implementation of automated emergency response systems for critical situations.
10. Expansion into a scalable smart healthcare solution for wider adoption in hospitals and clinics.