ATME College of Engineering

Department of EEE
Emitting Elite Energy

Project Phase-II Review-2

Course Code: BEE786

PORTABLE NEONATAL INCUBATOR WITH SLEEP APNEA MONITORING

Presented By,

Chinthan A D	4AD22EE013
Kruthin H K	4AD22EE026
N Likitha	4AD22EE036
Sanjana B R	4AD22EE044

Under the Guidance of,

Mr. Shreeshayana R

Assistant Professor

Department of Electrical & Electronics Engineering

ATME College of Engineering, Mysuru

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CONTENTS

PREAMBLE

BABY INCUBATOR

- ✓ A **baby incubator** is a specialized medical device designed to provide a controlled environment for newborns, especially premature infants. It maintains optimal **temperature, humidity, and oxygen levels** to support neonatal development.

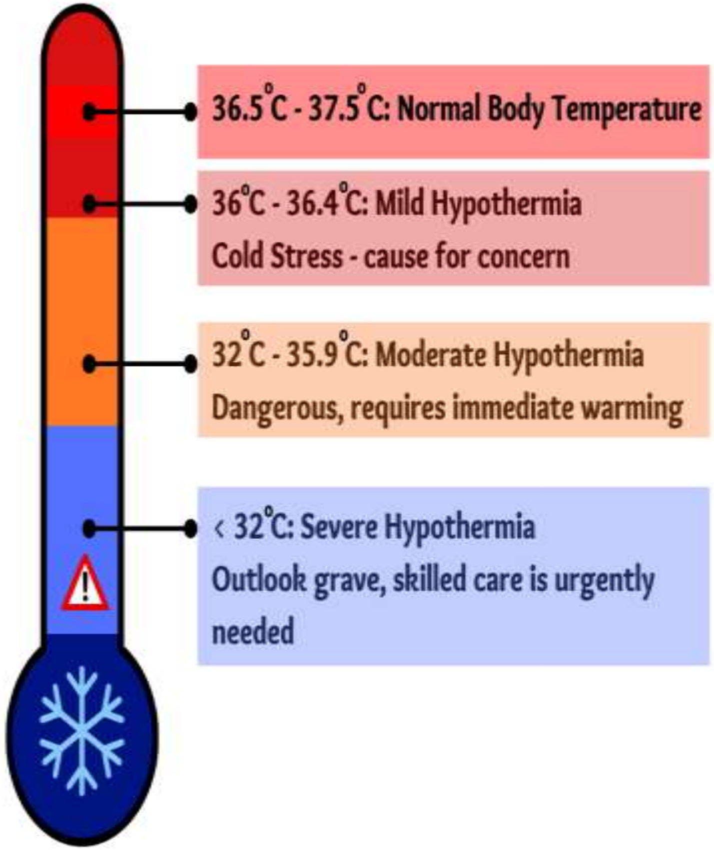
Baby Incubator

SLEEP APNEA

- ✓ **Sleep apnea** is a condition where a baby experiences temporary pauses in breathing during sleep, leading to **oxygen deprivation** and potential health risks. Detecting and addressing apnea early is crucial to prevent complications.

Sleep Apnea

PREAMBLE



What is Hypothermia ?

Hypothermia is a condition in which the body temperature drops below the normal range needed for bodily functions, typically below 36.5°C . In newborns, especially preterm babies, hypothermia occurs more easily because they lose heat quickly and can't regulate their body temperature well.

If not addressed, hypothermia can lead to serious complications, such as:

- **Low blood sugar (hypoglycemia)**: The body uses more energy to stay warm, depleting glucose levels.
- **Respiratory issues**: Cold stress can make it harder to breathe.
- **Organ stress**: Major organs, like the heart and brain, may function poorly at low temperatures.

To monitor such medical conditions baby warmer is helpful.

TYPES of INCUBATOR

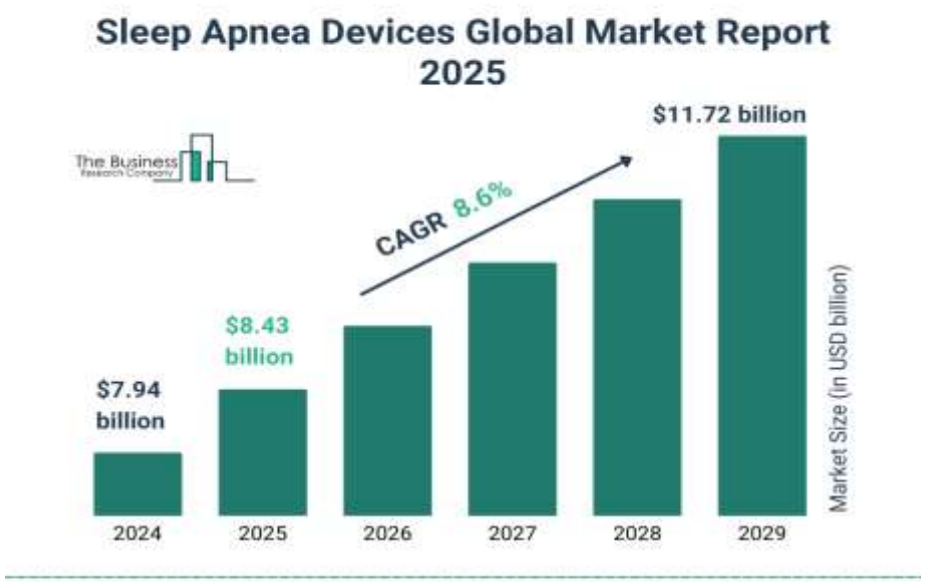
- **Open Incubator**: They are also called as Radiant warmer. Here the temperature is affected the external factors

- **Transport Incubator**: Portable incubator used to transport neonates between hospitals or within medical facilities.

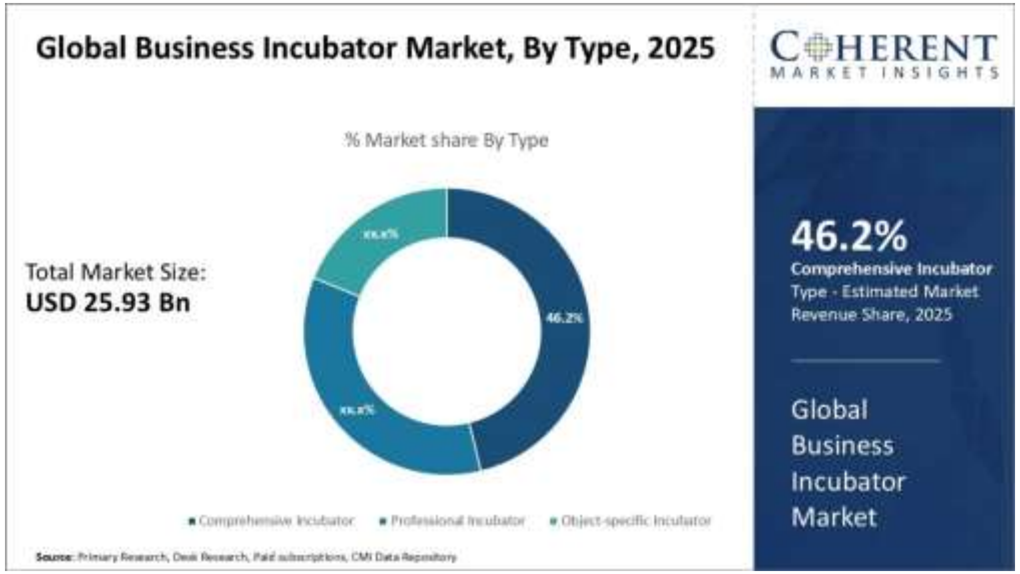
- **Closed Incubator**: The temperature, humidity, and oxygen levels are all controlled completely

- **Hybrid Incubator**: This is a combination both open incubator and closed incubator

MARKET STATISTICS



Market Statistics of Sleep Apnea device



Market Statistics of Incubator

FEILD SURVEY




- We visited the Government Hospital, Bannur, during our interaction we observed that they had 2 units where Incubators were present
- All the incubators were very bulky and not portable

MARKET SURVEY

Sl. No	Commercial	Bed weight range	Cost	Figures
1	GE Healthcare Giraffe Incubator	300g-8kg	$2,574 to$6,655	
2	NICU product transfer baby incubator model name: Nugen	0-25kg	$400 to$10,000	
3	PBI1200	0-20kg	$400 to$10,000	
4	Incubator and Infants warmers dual incubator	Up-to 13kg	$3,500 to$5,415	

PROBLEM DEFINITION

- One of the most serious problems for new-born's is sleep apnea, a disease in which breathing temporarily pauses, resulting in oxygen depletion and potentially fatal complications.

- Furthermore, a lot of traditional incubators lack real-time vital sign monitoring, which is essential for identifying early indicators of distress including temperature swings, weight loss, or reductions in oxygen levels.

Sleep Apnea

PROBLEM DEFINITION

Questions answered by the staff :

1. **How frequently do you need to monitor the baby's temperature manually while using the warmer?**

Ans- Every 10 mins after delivery for about an hour or two.

2. **Are there any specific temperature regulation issues that you encounter with premature or low-birth-weight infants?**

Ans- Standard Temp - 36.5 deg celcius
cold weather - 37.5 deg celcius
Hot weather - 35 deg celcius
Premature - 37.5 deg celcius

LITERATURE SURVEY

[1] Solomon Nwaneri, Beatrice Ezenwa1, Akinniyi Osuntoki2, Veronica Ezeaka1, Folasade Ogunsola "A review of infant apnea monitor design", Clinical and Labora Research (2024)

Inference: From this paper ,there are various new-born apnea monitoring devices available, ranging from impedance pneumography and piezoelectric sensors to camera- based and capacitive sensing systems, each has inherent limits in terms of accuracy, comfort, cost, and susceptibility to false alarms.

[2] Cansu Celebioglu and Ayca Kumluca Topalli "IoT-based incubator monitoring and machine learning powered alarm predictions.", Technology and Health Care (2024)

Inference:**This paper discusses an IoT-based incubator monitoring system that continuously tracks important parameters like temperature and humidity, utilizing multiple sensors and machine learning for anomaly detection. This system is designed for real-time monitoring and alarm notifications, which could potentially be adapted for sleep apnea tracking in neonatal care. The focus remains on ensuring the safety and health of infants in incubators.**

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LITERATURE SURVEY

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[3] Srinivasan Balapangu Shankar, Mark Konyele Kuuziile, "Design of an Apnea Monitoring Device for Preterm Baby", Research Square (2024)

Inference: Designing and implementing an apnea monitoring system for preterm neonates is the main subject of the study report. Vital indicators like heart rate, body temperature, and breathing rate are tracked using non-invasive sensors. Neonatal apnea episodes are detected by the device, which instantly notifies caretakers.

[4] Shreeshayana R1, Raghavendra L2, Manjunatha K B3 and Hemanth B S4 1Assistant Professor, Department of Electrical and Electronics Engineering, ATME College of Engineering, Mysuru, India "Portable Baby Incubator for Monitoring Sleep Apnea", Grenze International Journal of Engineering and Technology (2023)

Inference: The study describes a portable infant incubator that uses DHT11 and pulse sensors to track neonatal vital signs like temperature and pulse rate. To enable remote monitoring, data is gathered using an ESP8266 microcontroller. In environments with limited resources or that are mobile, the system seeks to guarantee the security and dependability of newborn monitoring. LCD display is used for visualizing the readings.

LITERATURE SURVEY

[5] Indira Chandrasekar 1, *, Mary Anne Tablizo 2,3, Manisha Witmans 4, Jose Maria Cruz 5, Marcus Cummins 6 and WendyEstrellado-Cruz 5 “Obstructive Sleep Apnea in Neonates”, Children, volume 9 (2022)

Inference: Neonates have distinctive anatomic and physiologic features that predispose them to obstructive sleep apnea (OSA). If remained unrecognized and untreated, neonatal OSA can lead to impaired growth and development, cardiovascular morbidity, and can even be life threatening. Polysomnography and direct visualization of the airway are essential diagnostic modalities in neonatal OSA.

[6] Hanna-Leena Kukkola1,2 and Turkka Kirjavainen1 “Obstructive Sleep Apnea in position dependent in young infants”, Pediatric Research, volume 93 (2022)

Inference: The study examines the effects of ambient noise on preterm newborns' early brain development in neonatal intensive care units (NICUs). According to the findings, sound management is crucial in NICUs, and quieter, developmentally appropriate settings are recommended to help vulnerable neonates' healthy neurodevelopment. This study provides important new data that connects early sensory experiences to the anatomical and functional consequences of the preterm infant's brain.

LITERATURE SURVEY

[7] Kazim Sekeroglu-Southeastern Louisiana University, Harun Sumbul-Ondokuz Mayis University, Turkey, Ahmet Hayrettin Yuzer-Karabuk University, Turkey “A Novel Portable Real-Time Low-Cost Sleep Apnea Monitoring System based on the Global System for Mobile Communications (GSM) Network”, Medical and Biological Engineering and Computing, volume 60 (2022)

Inference: The paper focuses on a portable real-time low-cost sleep apnea monitoring system utilizing the GSM network, specifically designed for adult patients with sleep apnea. It does not address a portable neonatal incubator or its integration with sleep apnea tracking for neonates.

[8] Emmanuel Owusu, Felix Kwakye Darko “Portable Smart Neonatal Incubator with Improvised Alarm System”, Research square (2021)

Inference: The paper discusses a portable smart neonatal incubator that automates the monitoring of neonatal vitals using Internet of Things (IoT) technology. While it emphasizes improving alarm systems to combat alarm fatigue, it does not specifically mention sleep apnea tracking.

[9] Gozde Cay, Dhaval Solanki, Vignesh Ravichandran, Laurie Hoffman, Abbot Laptook, James Padbury, “Baby-Guard: An IoT-based Neonatal Monitoring System Integrated with Smart Textiles”, Conference paper (2021)

Inference: A rising number of preterm babies demands innovative solutions to monitor them in the Neonatal Intensive Care Unit (NICU) continuously. NICU monitors various kinds of vital signs. Among them, there is a strong demand for an accurate and sophisticated technology to monitor respiration rate (RR) and detect critical events such as apnea.

[10] Rasha M. Abd El-Aziz, Ahmed I. Taloba “Real Time Monitoring and Control of Neonatal Incubator using IoT”, International of Grid and Distributed Computing, volume 14, (2021)

Inference: The neonatal incubator is a device used to nourish the premature babies by providing a controlled and closed environment. This incubator provides the babies with optimum temperature, relative humidity, optimum light and appropriate level of oxygen which are same as that in the womb.

LITERATURE OUTCOME

- There are problems with current apnea monitors, including false alarms, accuracy, comfort, and expense. Non-invasive, wearable, and low-power solutions are required.
- Neonatal monitoring in real time with sensor-based alarms is made possible by IoT-enabled equipment. Both NICUs and remote locations benefit from these solutions' increased safety.
- There is a focus on portable, affordable gadgets that use microcontrollers like the ESP8266. In places with limited resources, such methods are perfect.
- Few apnea monitoring systems are designed specifically for neonates; the majority target adults. Babies' distinct physiology necessitates specialized monitoring systems.
- Environmental elements that impact baby brain development include noise levels in NICUs. Additionally, monitoring systems ought to accommodate developmental demands.

PROJECT OBJECTIVE

- **Objective-1:** To develop an open-type modular incubator designed specifically for newborn and premature infants. The incubator will feature interchangeable components to enhance maintenance, adaptability, and future upgrades. A microcontroller-based system (Arduino) will monitor and regulate the artificial light source and ambient temperature. An integrated display unit will provide real-time feedback of environmental conditions.
- **Objective-2:** To develop an integrated unit for **continuous monitoring of the baby's weight** using a **load cell**, interfaced with a **microcontroller** and a **digital display**. This unit will be embedded within the incubator model, enabling real-time weight tracking to support clinical decisions and early detection of neonatal health issues.
- **Objective-3:** To Monitor the Sleep Apnea in infants/Premature babies through observing the Readings of Vital stats such as SpO2 and Heart Rate along with Display and IoT integration. This shall be integrated in the model using Sensors, Controller and Display device.

A wearable device also will customized to monitor Temperature, Heart Rate, SpO2.

Objective 1

Hardware				
Microcontroller (Arduino UNO)	DHT22 Sensor	OLED Display	Relay	Li-ion Rechargeable Battery (1200 mAH): 02 Quality
				
ATmega328: Operation Voltage: 5V Current: 20-50mA Pins: Analog Input Pins (6), PWM Digital I/O Pins (6) SRAM: 2 KB EEPROM: 1 KB.	Temperature Range: 0-50°C- Humidity Range: 20-90% RH- Accuracy: ±2°C, ±5% RH- Operating Voltage: 3.3V to 5V	- Screen Size: 0.96 inch- Resolution: 128x64 pixels- Operating Voltage: 3.3V to 5V- Interface: I2C	Operating Voltage: 5V or 12V DC Current Consumption: 70–100 mA Channel: NO, NC Com	Li-ion Rechargeable Battery: Normal Voltage: 3.7V Battery Capacity: 1200mAh Charge Voltage Range: 4.2V to 5.5V

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Objective 2

Hardware				
Microcontroller (Arduino UNO)	Load cell	HX711	LCD display	Battery
				
ATmega328: Operation Voltage: 5V Current: 20-50mA Pins: Analog Input Pins (6), PWM Digital I/O Pins (6) SRAM: 2 KB EEPROM: 1 KB.	Rated Capacity: 5 kg Rated Output: 1.0 ± 2.0 mv Input Resistance: ~1,000 Ω Output Resistance: ~1,000 Ω	Operating Voltage: 2.6V to 5.5V Current Consumption: < 1.5 Ma-< 1 µA	Display Type: Alphanumeric LCD Characters Displayed: 2 rows × 16 characters Character Size: 5×8 dot matrix Operating Voltage: 4.7V to 5.3V	Li-ion Rechargeable Battery: Normal Voltage: 3.7V Battery Capacity: 1200mAh Charge Voltage Range: 4.2V to 5.5V

Objective 3

Hardware			
Microcontroller (ESP8266)	MAX30100	OLED Display	Battery
			
ATmega328: Operation Voltage: 5V Current: 20-50mA Pins: Analog Input Pins (6), PWM Digital I/O Pins (6) SRAM: 2 KB EEPROM: 1 KB.	Sensitivity: ±5V- Output Range: 0.5V to 3.5V (proportional to heart rate)- Operating Voltage: 3.3V to 5V	- Screen Size: 0.96 inch- Resolution: 128x64 pixels- Operating Voltage: 3.3V to 5V- Interface: I2C	Li-ion Rechargeable Battery: Normal Voltage: 3.7V Battery Capacity: 1200mAh Charge Voltage Range: 4.2V to 5.5V

SOFTWARE	
OBJECTIVE-1	Arduino IDE and Language used : C
OBJECTIVE-2	Arduino IDE and Language used : C
OBJECTIVE-3	Arduino IDE and Language used : C

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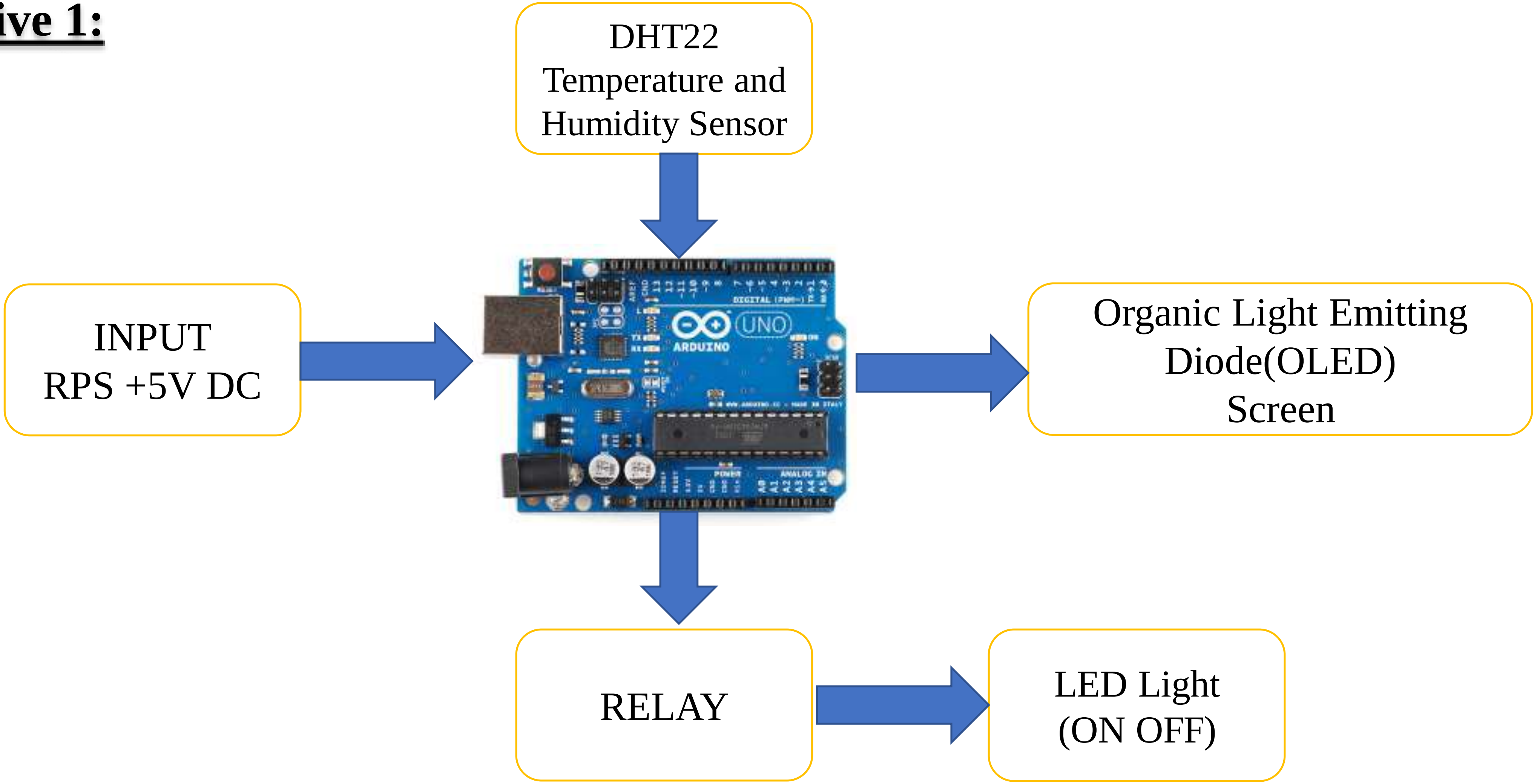
METHODOLOGY

Objective 1:



METHODOLOGY

Objective 2:

LOAD CELL
with HX711

LCD Display

METHODOLOGY

Objective 3:

ARDUINO UNO

OLED

HCO5

PHASE-II CONTINUE

Mathematical Calculation

1.For obtaining Humidity:

Formula:

$$\textbf{Humidity(\%RH)} = k \times \text{sensor signal output}$$

Where:

- k is a calibration constant specific to the DHT11.
- The signal output is proportional to the capacitance change caused by humidity.

2. For obtaining Temperature:

The thermistor's resistance R is related to the temperature T (in Kelvin) by the **Steinhart-Hart equation**:

$$1/T = A + B\ln(R) + C(\ln(R))^3$$

3. For obtaining Heart Rate:

$$\text{Heart Rate (BPM)} = \frac{60}{\text{Time Interval Between Peaks (seconds)}}$$

4. For obtaining SpO_2 :

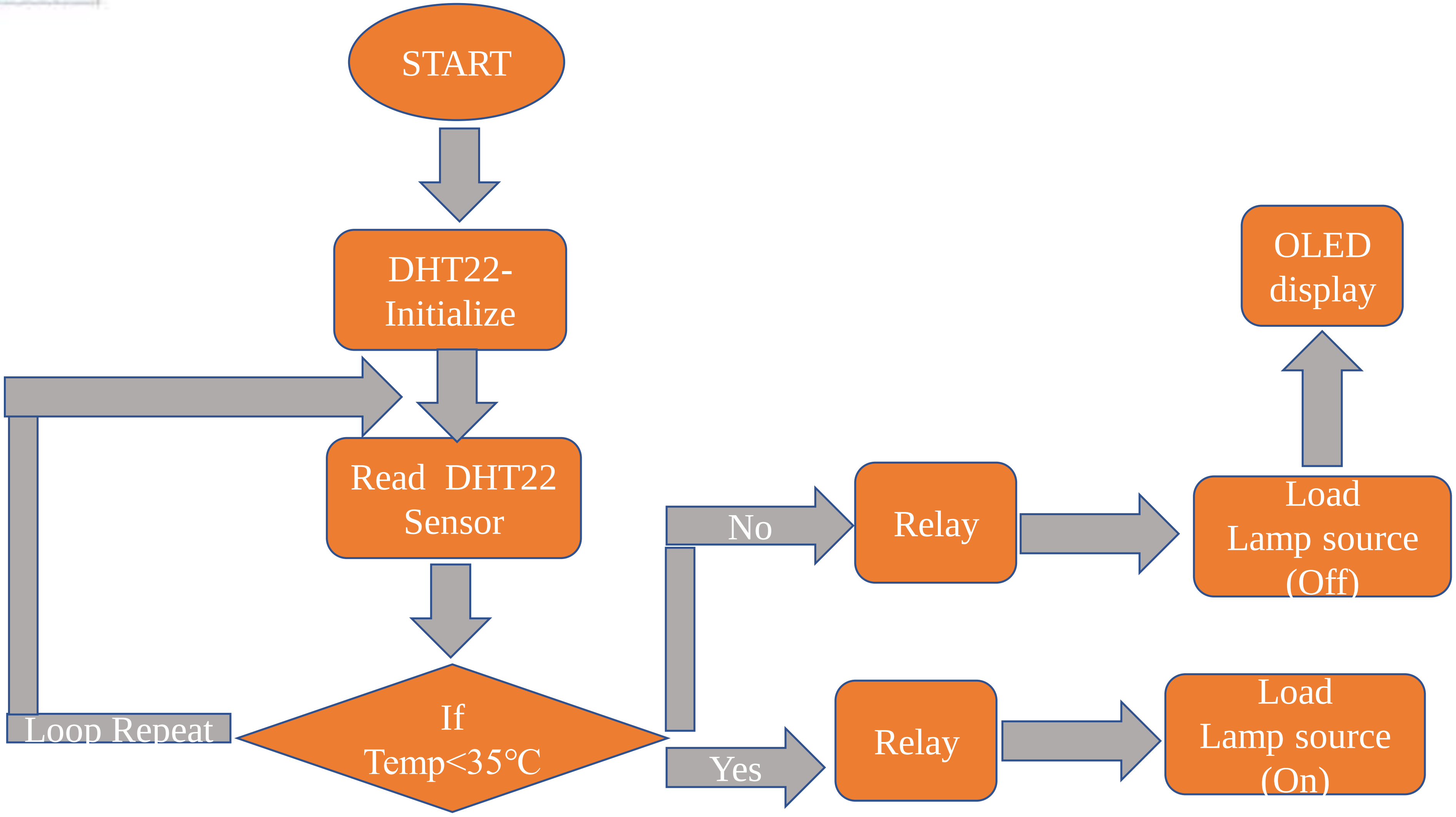
SpO2 Calculation

Using an empirical formula derived from calibration:

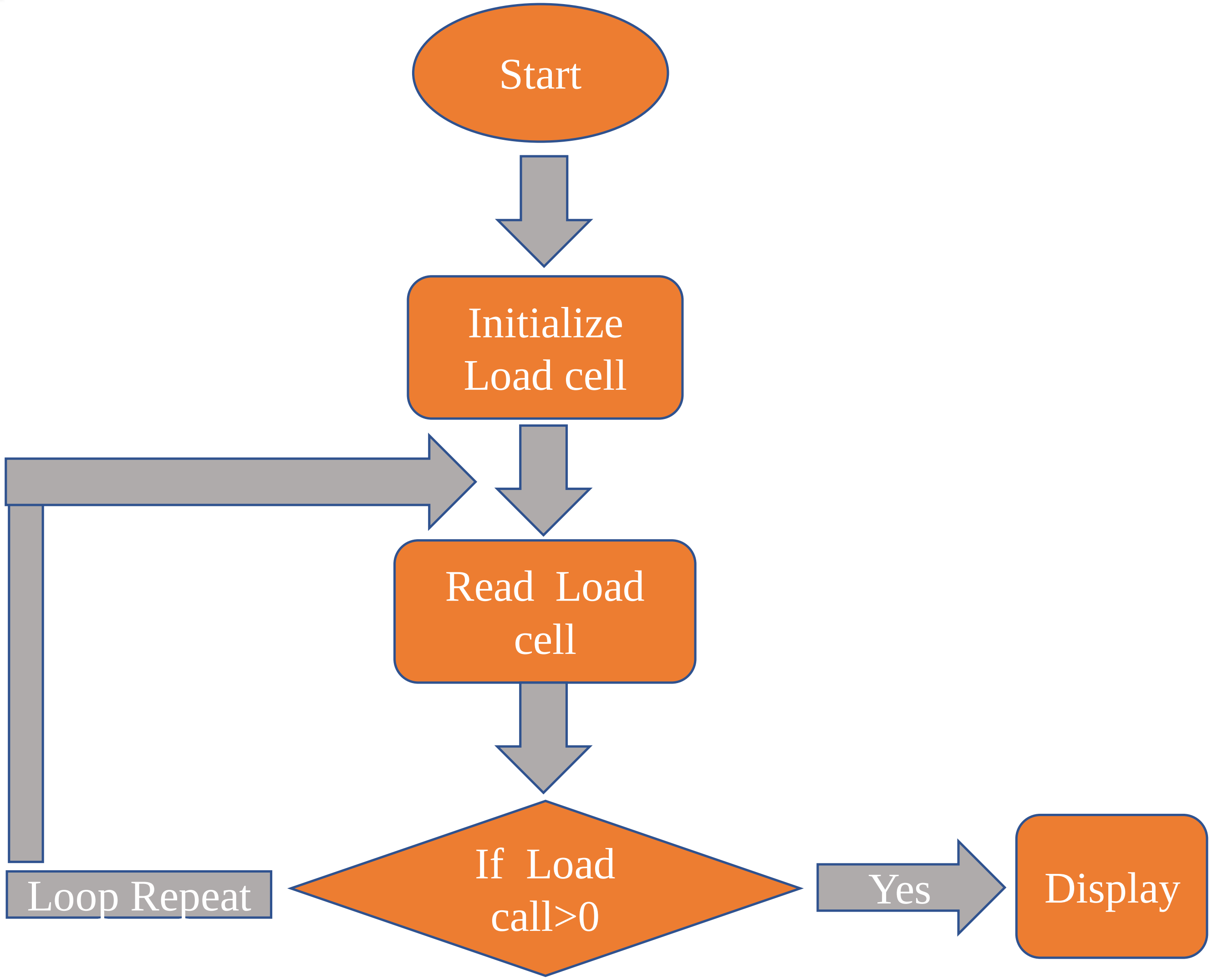
$$\mathbf{SpO2(\%) = 110\text{-}25\cdot R}$$

The constants (110 and 02) are specified to the MAX30110 calibration

Flow Chart

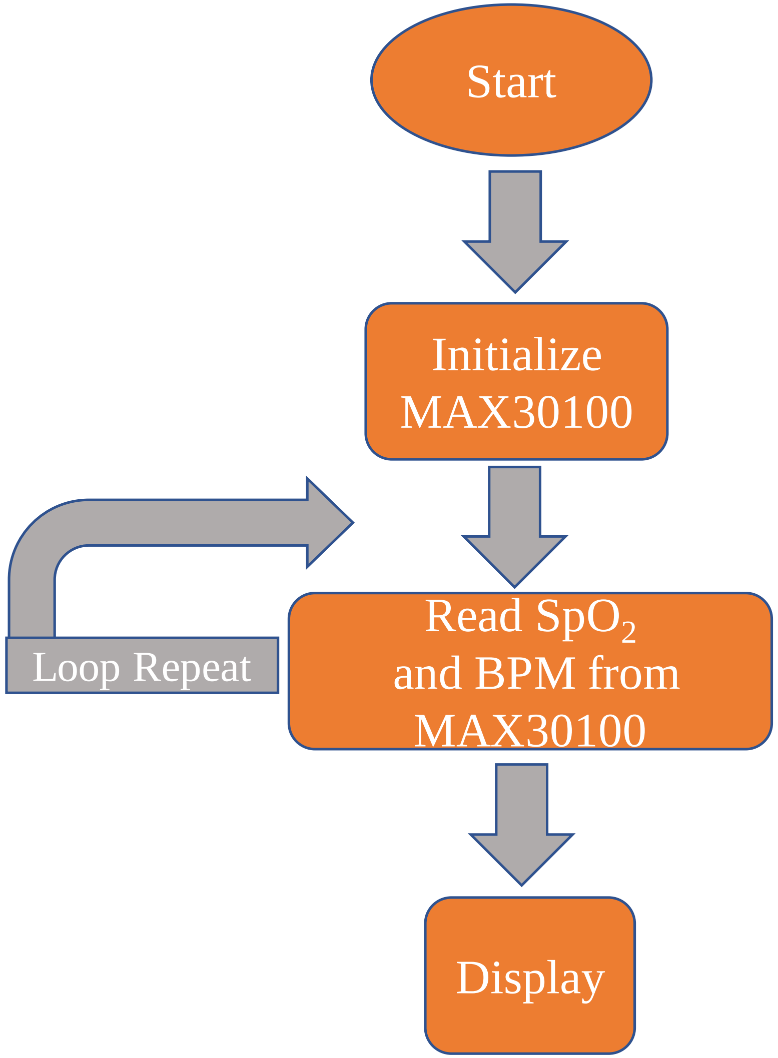

START
DHT22-
Initialize
Read DHT22
Sensor
If
Temp<35°C
Loop Repeat
No
Yes
Relay
Load
Lamp source
(Off)
OLED
display
Relay
Load
Lamp source
(On)

Flow Chart



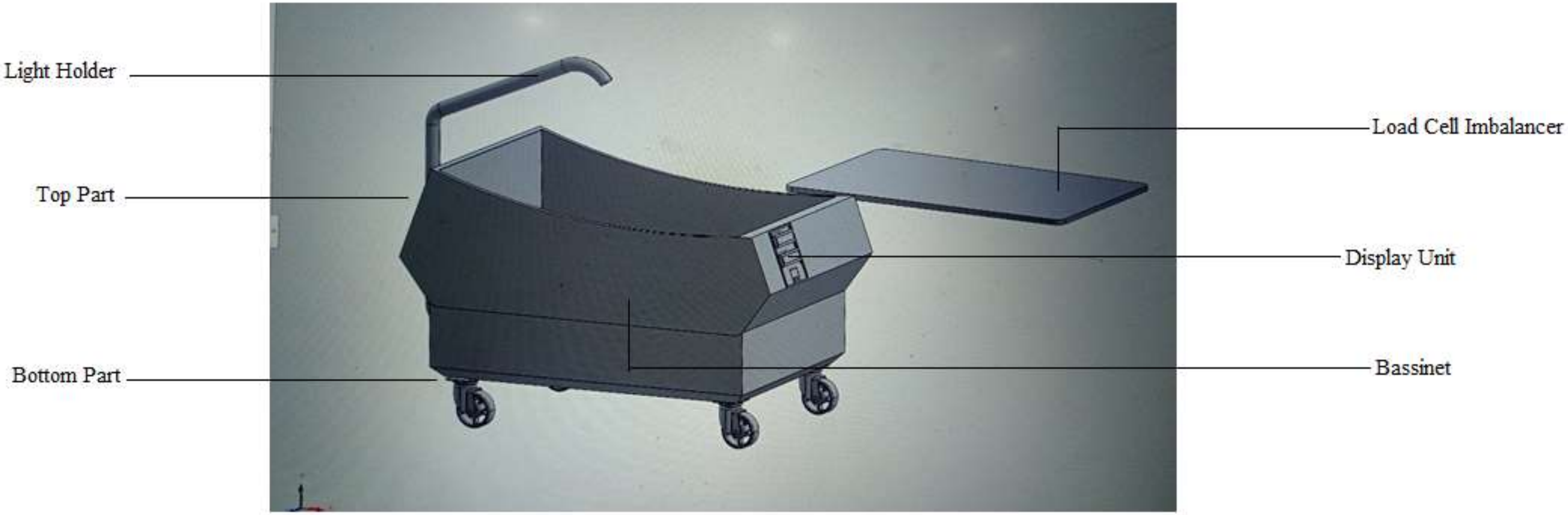
Start
Initialize Load cell
Read Load cell
If Load call>0
Yes
Display
Loop Repeat

Flow Chart


Start
Initialize MAX30100
Loop Repeat
Read SpO_2 and BPM from MAX30100
Display

Design

- **3D Design**



Open Type

Result

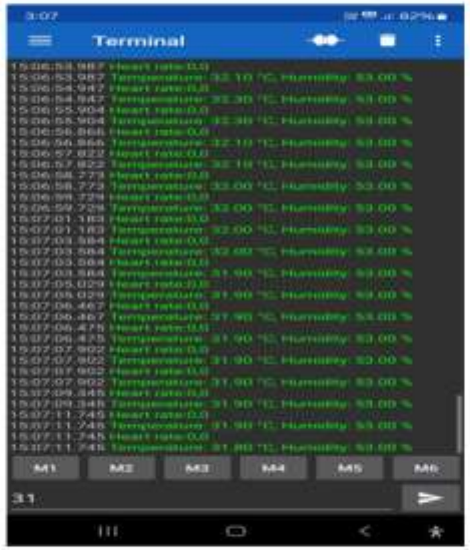
Testing:

Sl. No	Temperature	Bulb Status
01	27°C	ON
02	35°C	OFF
03	36°C	OFF
04	32°C	ON
05	33°C	ON

Bulb Status values

Sl. No	Weight	Displayed Weight
01	4kg	3.90kg
02	2kg	1.80kg
03	1kg	0.9g

Weight monitored values



Results in App

Result

Sl. No	BPM	SpO2
01	60	96
02	75	98
03	84	97
04	77	87
05	87	90

Sleep apnea monitored values

Model Working

Results Displayed in Model Display

Result

Final Model

Model Working

BUDGET

SI NO.	Description	Cost in ₹
1	Hardware components	10,000
2	Fabrication	6,000
3	3D-Design	41,300
4.	Project Report	1,000
5	Miscellaneous	10,000
TOTAL		68,300

TIMELINE

Sl NO	PHASES	Feb 2025	March 2025	April 2025	May 2025	June 2025	August 2025	Sep 2025	Oct 2025
1	Project Feasibility study								
2	Time schedule and analysis								
3	Required analysis								
4	Components availabilities and purchase								
5	Design and implementation of Incubator with apnea monitor								
6	Testing of the model								
7	Report draft								
8	Report submission								
9	Paper draft								
10	Paper publication								

REFERENCE

[1] Solomon Nwaneri, Beatrice Ezenwa1, Akinniyi Osuntoki2, Veronica Ezeaka1, Folasade Ogunsola “A review of infant apnea monitor design”, Clinical and Laboratory Research, 2024

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Thank You!