Development of a Web-Based Health Monitoring System for Neonates

Ridwan Gbolahan Olayiwola[1*] Olusola Kunle Akinde[1] Oluwadara Joel Odeyinka[1] Oludamilare Bode Adewuyi[2]

1. Department of Electrical and Biomedical Engineering, First Technical University Ibadan, KM 15, Lagos-Ibadan Express Way, Ibadan, Oyo State, Nigeria
2. Institute of Systems and Information Engineering, University of Tsukuba, 1 Chome-1-1 Tennodai, Tsukuba, Ibaraki, 305-8577, Japan

* E-mail of the corresponding author: olayiwola.ridwangb@gmail.com

Abstract

Premature birth is a global health concern, contributing to a significant portion of infant mortality worldwide. Preterm infants require specialized care but the current neonatal infrastructure often lacks remote and real-time monitoring. To address these challenges, a web-based health monitoring system was developed. The system incorporates a NodeMCU-ESP8266 microcontroller as the central component that processes data from a temperature sensor (DS18B20), a pulse rate and oxygen saturation sensor (MAX30100), and a weight sensor (load cell with HX711) and communicates these sensors' data with a web server for visualization via built-in WiFi connectivity. Experimental testing revealed the system's responsiveness with the DS18B20 measuring an average temperature of 36.545°C with 97% accuracy and an error of 0.0713. The MAX30100 recorded an average SPO2 of 93.75% and an average heart rate of 99.325BPM, with accuracies of 96% and 71% respectively, and errors of 2.9369 and 2.8879. The load cell with HX711 measured an average weight of 2.39kg with 96% accuracy and an error of 0.0552. All acquired data were successfully uploaded to the web server at 15s intervals for remote monitoring. In conclusion, the implementation demonstrated responsiveness and the reliability of the sensors and the successful transmission of the data to the web server which aims at premature care through continuous monitoring of their vital signs.

Keywords: Preterm Births, Neonatal Intensive Care Unit (NICU), Remote Monitoring, Sensor Integration, Real-time Communication

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1. Introduction

The high mortality rate of premature infants is a major public health concern across the world with the percentage of premature births varying across the regions, with North Africa exhibiting a rate of 13.4% and Europe showing a figure of 8.7% (Pavlyshyn et al., 2022), and the difficulties arising from their health issues are thought to contribute to 35% of the annual 3.1 million global infant deaths, making it the second most prevalent reason for high mortality among children below the age of five, following pneumonia. The World Health Organization (WHO) estimates that more than one in ten pregnancies results in preterm delivery globally, which results in an estimated 15 million premature infants being born each year (Sendra et al., 2019). Based on the statistics that were made by WHO in 2015, the approximate worldwide newborn mortality rate for infants of age between 0 and 28 days stood at 19.5 per 1000 live births. This figure suggests that out of the 135 million babies born annually, approximately 2.8 million, or an average of 7100 per day, do not survive beyond their first month of life (Binns & Low, 2015).

Preterm delivery significantly raises the chance of mortality from other causes, particularly newborn infections, and it is the top cause of infant death in virtually all high-income and middle-income nations (Blencowe et al., 2012). Due to the vulnerability of preterms to various infectious and non-infectious diseases (Sharma et al., 2012; Yu et al., 2018), they are placed in incubators in NICU to protect them from the environment and also to provide them with a warm atmosphere that mimics their mother's womb to enhance the development of their organ systems. Some critically ill neonates and premature infants have breathing and heart disorders that require them to be oxygenated, and during this oxygenation, their oxygen levels must be appropriately monitored with an oximetry system to assess both oxygen saturation level and heart rate which will aid in early detection of congenital defects. The relationship between heart rate and oxygen saturation in preterm is critical to understand due to the fact that inadequate oxygen saturation levels in premature infants can lead to abnormalities (Lamidi et al., 2021).

Neonates are extremely tiny and delicate (Chen et al., 2008) because their bones are not fully grown which makes them fragile, thus they need to be handled with care when moved out of the incubator for weight assessment and any other purposes. Body weight is one of the most significant health markers of a preterm (Al'Aziz et al., 2021; Widianto et al., 2018) and should be regularly examined to identify the evolution of a premature infant's development (Sendra et al., 2019). Furthermore, premature newborns are vulnerable and should not be moved frequently but the majority of the initial infant weight has been accomplished by placing the baby on a conventional baby scale manually, outside the incubator (Widianto et al., 2018) which may expose them to infections in the environment. Most existing incubators are integrated with the functions of regulating environmental temperature and monitoring skin temperature only and are incapable of providing real-time monitoring (Noor et al., 2017). Every incubator in the Neonatal Intensive Care Unit (NICU) requires constant manual supervision by doctors and nurses to monitor the neonates. However, hospital employees are obligated to perform other tasks concurrently (Noor et al., 2017). Premature infants in the incubator are connected to external patient monitors to measure, record, and monitor the vital signs like temperature, SPO2 (saturated blood oxygen), pulse rate, heart rate, and respiratory rate to detect abnormal conditions displayed by the neonates, but these monitors lack communication capabilities, which limits the sharing of patient health information.

The high rate of mortality of premature infants in NICU placed in the incubator is due to the lack of a remote health monitoring system integrated with the incubator that detects and communicates the abnormal conditions exhibited by neonates to the doctors and nurses, and exposure to infections in the environment when the infant is being moved out of the incubator for weight assessment. There is a need for a system designed to record the vital signs and weight of infants in real-time, to aid in the measurement and monitoring of the neonates without moving the infant out of the incubator. Thus, there is a need to monitor the preterms vital signs remotely while in the incubator to aid early detection of abnormalities exhibited by the preterm during drastic changes in the vital signs that may result in their death. Thus, this study aims to develop a web-based health monitoring system that can be integrated with existing incubators to monitor neonates' vital signs like temperature, heart rate, oxygen saturation and weight infants and to enable real-time communication between the neonate monitoring system and medical staff as this will allow for the early detection of abnormal conditions in the incubator and prompt notification of the medical staff.

2. Related Works

Neonates are a living complex that is constantly changing and vulnerable to various infectious and non-infectious illnesses and disorders (Sharma et al., 2012; Yu et al., 2018) which renders the initial stages of life outside the womb the most precarious periods of existence. According to the World Health Organization's 2015 statistics, the approximate worldwide newborn mortality rate for infants of age between 0 and 28 days stood at 19.5 per 1000 live births. This figure suggests that out of the 135 million babies born annually, approximately 2.8 million, or an average of 7100 per day, do not survive beyond their first month of life (Binns & Low, 2015). The various factors that contribute to infant mortality cause changes in vital signs that must be continuously monitored to ensure their survival throughout the infant period so that they enjoy the benefit of the good life without problems such as neurological impairment in the future (Chen et al., 2008).

To monitor critically ill neonates or premature infants closely, various systems or devices have been designed that are used by healthcare providers to provide an update on the infant's health status. The current NICU practice includes the use of various electronic gadgets such as pulse oximeters, electrocardiograms (ECG), infrared or clinical thermometers, etc. to monitor vital parameters (Bonner et al., 2017), support clinical care and improve the health safety of the patients.

(Pak & Park, 2012) developed an advanced pulse oximetry system that measures a patient's oxygen saturation level and sends data to the personal monitoring server which analyzes the acquired data and shows the result that enables remote monitoring and management to the patient. The proposed system utilized a fingerprint SPO2 sensor equipped with ATmega 128-16AC MCU to detect SPO2 and pulse rate using LEDs and photodiode which is amplified, filtered, and converted to a digital signal with an ADC (analog to digital converter) and records the pulse oximetry data within the MCU, the system implemented a PHD (personal health device) agent to access the archived pulse oximetry data and identify four distinct operational errors: sensor_disconnected, sensor_off, signal_non-disconnected and signal inadequate and a Bluegiga WT12 Bluetooth module to communicate with external devices. The verification process confirmed the efficiency and suitability of the proposed system for remote monitoring and management. It exhibited an average response time of 251ms when transmitting pulse oximetry data or encountering errors. However, it lacks integration of an internet protocol for establishing connections between personal monitoring servers and health service providers.

(Jahan et al., 2014) studied how heartbeat and arterial saturated oxygen are measured, processed, and displayed from fingerprints to provide information regarding health most especially cardiovascular diseases. The study is based on a small lightweight design with standardized signal processing capability. The design is composed of an optical sensor that consists of two LEDs of different wavelengths to detect a low amplitude signal by the photodetector which is then pre-processed by a signal conditioning circuit (LM358-op amp) to remove noise. The output of the amplifier was input into a microcontroller (PIC18F452) which has built-in ADC to convert the signal to digital form and calculate the SPO2 reading and heart rate in BPM displayed by LCD. The microcontroller also has built-in USART on board at pins 25 and 26 that send data to the PC to be accessed by a doctor and the system is incorporated with an alarm to notify of any changes other than the reference reading. (Mittal et al., 2015) aimed at designing and developing microcontrollers and closed-loop control systems based on temperature, humidity, oxygen concentration, and light controllers for infant incubators. The system utilized a microcontroller (Arduino mega2560) as the heart control unit which has a built-in ADC converter that reads and processes the temperature from the temperature sensor (DS18B20), humidity from DHT11, light intensity from LDR, CO from the MQ-7 sensor and is being displayed on LCD screen. The system was able to provide automatic control of the temperature, relative humidity, light, and concentration of gas for the infant using closed-loop control systems. The system only focused on the incubator parameters and did not consider the infant's vital signs as the parameters that must be monitored closely

(Mallick et al., 2016) proposed a system to describe the non-invasive method of measuring heart rate through fingertip and Arduino based on photoplethysmography which utilized an optical sensor that consists of IR LED and photodiode to detect signals from the fingertip which is fed to the signal conditioning circuit (MCP602 OPamp) to filter undesired signal and is then send to Arduino which is a microcontroller board based on the ATmega to process the signal and send short message service(SMS) alert to mobile phone

(Ali et al., 2018) aimed at providing a proficient system to enhance the productivity and efficiency of personnel in the Neonatal Intensive Care Unit (NICU) at work by designing a system that measures the pulse rate and humidity level in an incubator that is transmitted to a personal computer (PC) through an Arduino microcontroller. The proposed system utilized an Arduino UNO microcontroller (on-board ATmega 328) to analyze data from sensors (SN-PULSE pulse rate sensor and SN-model-MOD HMD humidity sensor) with LCD displays to show readings. Significant readings from the pulse rate sensor and humidity were recorded but the system does not incorporate an alerting system for a heart rate below or above the threshold.

(Oyebola et al., 2017) proposed a system that utilized a microcontroller (ATmega328) as the control unit that monitors the temperature with LM35 as the temperature sensor and humidity with DHT11 as the humidity sensor of the incubator detected by the temperature and humidity sensor. The system electronic circuit was designed and simulated with the aid of Proteus and does not incorporate measurement of the skin temperature and pulse for close monitoring. No alerting system and webcam were integrated with the system to help doctors and parents monitor the baby's health condition. (Zakaria et al., 2018) proposed a system that monitors the baby's temperature continuously using wearable sensors that transfer information to the patient through a wireless network and alert the patient when the temperature is beyond the normal range. The system utilized an LM35 sensor sensing the body temperature accomplished by the Arduino ESPresso lite 2.0 microcontroller's control. The ESPresso microcontroller sends data wirelessly to the thing Speak or Blynk with the aid ESP8266 module to enable the mother to view the data. The system is integrated with a buzzer to alarm the patient when the temperature is not normal range. The system was only limited to temperature measurement and cannot be efficiently used on the infant that requires close monitoring of the vital signs.

(Shalannanda et al., 2020) outlined the configuration of an IoT-based Incubator monitoring system, which comprises a microcontroller, a data acquisition sub-module, and a data communication sub-module. The system utilized Arduino UNO ReV3 based on ATmega328 as the microcontroller in the processing of sensors (LM35, DHT11, MQ-3, and MQ-135) integrated with Wi-Fi module (ESP2866) to serial communication. The system was efficient but still needs improvement through the introduction of other components such as a pulse oximeter, and RTC (Real-Time Clock) for data logic.

(Shalannanda et al., 2020) research revolved around substituting the Arduino UNO Rev3 and ESP8266 with an Arduino UNO+wifi configuration, accompanied by an extra sensor for the purpose of monitoring pulse rate and pulse oximetry. The proposed system employed the Arduino UNO+WiFi as both the microcontroller and wireless communication module in the project to process the biosensors (LM35 and MAX30102) and environment sensor (DHT11, MQ3, and MQ135) in the monitoring of the infant and incubator they are placed and send the data generated by these sensors to phone or pc via the module in the board. The related measuring tools data were compared with the data acquired from the max30102 and the findings indicate that the mean pulse rate was less than 1% and SPO2 is slightly above 3% but the device memory had reached its maximum capacity. (Lamidi et al., 2021) proposed designing an economical, space-efficient system for an infant incubator to monitor the oxygen saturation and heart rate of an infant placed in stabilized temperature-controlled infant incubator to identify early signs of congenital defects. The system utilized an LM35 sensor as a sensor for temperature that reads chamber temperature in the form of analog data and a DHTT2 sensor to measure the compartment humidity integrated with Arduino to stabilize the chamber environment. To achieve detection of early congenital symptoms, the system adopted a thermistor as the skins temperature sensor and SPO2 sensor that identify ADC information represented as ACred, ACir, DCred and DCir to measure SPO2 and heart rate (BMP) processed by an Arduino to be displayed on the LCD with an alarm to alert physician in case of danger. The error at ambient temperature stands at 0.15 °C, while the variation observed on the skin sensor registers at 0.17 °C. The disparity in the Humidity parameter is noted as 0.21%, with the mean SpO2 parameter resting at 98%, and the mean BPM parameter at 82 beats per minute. The system does not incorporate a real-time communication means for the information gathered by the sensors and the healthcare providers.

(Widianto et al., 2018) introduced a weight monitoring system tailored specifically for neonatal incubators, which enables weight measurement without the necessity of removing the infant from the incubator. This system relies on pressure sensing in conjunction with load cells. The proposed setup comprises a load-sensing device, an electronic circuit responsible for conditioning the signal, and a microcontroller unit, specifically the Arduino UNO R3. The load cell's output is subjected to filtering and amplification via the electronic circuit to meet the operational voltage of the Arduino R3. Subsequently, the analog signal is converted into a digital format for display on an LCD, providing the weight information. Notably, their experimental results highlighted a 12.5 g reduction in weight measurements for distributed loads in comparison to centered loads. Moreover, their findings established that the suggested system for measuring weight exhibits a linear correlation with object weight within the ranging from 0 to 3000 g, with a threshold of 12.5 g and resolution. Nevertheless, it is evident that there is room for enhancing the system's sensitivity. (Mishra et al., 2023) introduced a premature infant monitoring system that relies on wireless technology for tracking vital parameters in infants, including body temperature, pulse rate, crying episodes, and movement. This system employs a GSM network to transmit data to parents and triggers control measures in case of emergencies. The Arduino UNO R3 microcontroller was employed in the system for processing the reading taken from the sensors (sound detection sensor, pulse sensor, PIR sensor, and temperature sensor). A GSM module was integrated into the system to communicate the data generated to doctors and parents and alert them in case of emergency with an alarming system. As a microcontroller, the suggested system used an Arduino UNO R3 for processing the reading taken from the sensors (sound detection sensor, pulse sensor, PIR sensor, and temperature sensor). A GSM module was integrated into the system to communicate the data generated to doctors and parents and alert them in case of emergency with an alarming system. (Al'Aziz et al., 2021) proposed a system that integrated a digital weight scale with an infant radiant warmer to aid easy measurement of the infant on the radiant warmer by the nurses. The proposed system utilized a load cell with a maximum capacity of 5kg to detect the weight of the load by 0.7mV a load of 1kg which is amplified by PSA circuit with AD620 IC, processed by Arduino UNO (microcontroller) and is being displayed on the LCD screen. According to the conducted experiments, the scales designed for assessing weight comparisons using lead as the material exhibit a maximum error of 1 kg, corresponding to 0.08%, and a minimum error of 3 kg, equivalent to 0.01%.

3. Materials and Methods

The methodology employed in the designing of a web-based health monitoring system for neonates for continuously monitoring neonates' vital signs involved software that was programmed with Arduino UNO and embedded into the microcontroller to actualize the sensors.

3.1 Temperature Sensor

The DS18B20 digital thermometer in Figure 1 acts as temperature sensor and offers temperature measurements in the range of 9 to 12 bits in Celsius, along with an alarm function featuring user-programmable upper and lower trigger points that persist even when power is off. Communication with a central microprocessor is facilitated through a 1-Wire bus, which inherently necessitates just a single data line (along with ground). Furthermore, the DS18B20 can draw power directly from the data line, a method known as “parasite power," eliminating the need for an external power source. Each DS18B20 possesses a unique 64-bit serial code, enabling multiple DS18B20s to operate on the same 1-Wire bus, making it straightforward to control numerous DS18B20s spread across a wide area using a single microprocessor. This capacity is useful in HVAC environmental controls, temperature monitoring systems in buildings, equipment, or machinery, as well as process monitoring and control systems.

Figure 1. Temperature Sensor (DS18B20)

3.2 Pulse Rate and Oxygen Level Sensor

The MAX30100 in Figure 2 was integrated for simultaneously monitoring pulse oximetry and heart rate. This module is equipped with internal LEDs, photo protectors, optical components, and low-noise electronics that incorporate ambient light rejection capabilities. Offering a comprehensive system solution, the MAX30100 streamlines the design process for wearable devices. Communication is facilitated through a standard I2C-compatible interface. It employs the technique of Photoplethysmography (PPG) to measure pulse rate and oxygen levels, which involves emitting light into the skin and assessing alterations in light absorption attributed to blood flow. Two light sources are utilized: a red LED with a peak wavelength of 660nm and an infrared LED with a peak wavelength of 940nm. These LEDs emit light into the skin, while a photodetector within the MAX30100 gauges the reflected light.

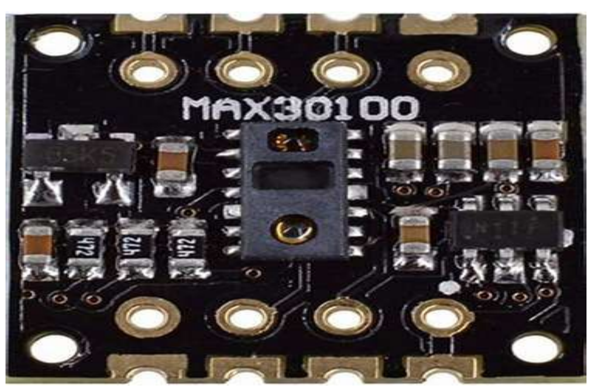

Figure 2. Pulse Rate and Oxygen Saturation Sensor (MAX30100)

3.3 Weight Sensor

A load cell with HX711 amplifier shown in Figure 3 was employed as the weight sensor. A load cell weight sensor typically consists of a strain gauge or multiple strain gauges mounted on a metallic structure, which deforms or strains when subjected to an applied force or weight. The strain gauges are connected in a Wheatstone bridge configuration, and changes in the resistance of the strain gauges due to deformation are converted into an electrical output signal that is proportional to the applied force or weight. They are known for their accuracy, reliability, and durability, and are essential in many applications where precise weight measurement is critical. The HX711 amplifier acts as the analog-to-digital converter to convert the physical weight measured by the load cell to digital form and no programming is needed for the internal registers.

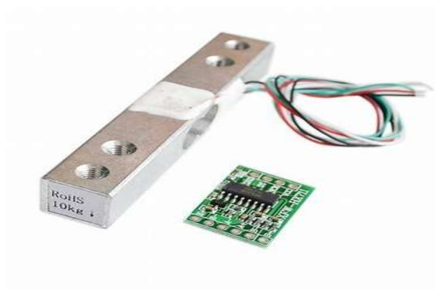

Figure 3. Load Cell with HX711

3.4 Microcontroller

ESP8266NodeMCU shown in Figure 4 is the microcontroller employed in the designing of the system. The ESP8266 NodeMCU is a versatile development board featuring the ESP8266 WiFi module. It offers a low-cost solution with a 32-bit microcontroller, integrated WiFi connectivity, and USB-to-UART support for easy programming. It has GPIO pins for hardware interfacing, operates at 3.3V, and is commonly used in IoT projects with extensive community support.

Figure 4. ESP8266NodeMCU Development Board

3.5 Web-Based Neonatal System Architecture

The systems is intended to monitor infants' vital signs and weight and allows real-time communication with the medical personnel to ensure fair survival and quality of life for any neonate placed in incubator for close monitoring through sensors.

The design system comprises of the sensors (temperature sensor (DS1B820), heart rate and oxygen saturation sensor (SPO2), and weight sensor (load cell (20kg) with HX711)) that are placed on the neonate's skin to collect and transmit data to the central system (NodeMCU-ESP8266) for processing.

The NodeMCU-ESP8266 which is the main controller is interfaced with the sensors to receive the data acquired by the sensors for processing (that is filter the noise), and uses its built-in WiFi module to send data to web server to enhance continuous and remote monitoring of the neonate's vital signs. A 20 x 4 LCD is connected with the microcontroller to display the data generated by the sensors to assist the user in monitoring the status of the neonate's health and when the sensors parameter exceeds a threshold value, the NodeMCU-ESP8266 is programmed to trigger the buzzer alarm.

The webserver received the data from the NodeMCU-ESP8266 and stored it in a database. The web-platform also provide a user interface for displaying the collected neonate's health data for real-time monitoring

3.5.1 Block Diagram

In this design, the system utilized a 5V power pack which consists of two batteries (3.7V) connected in parallel to ensure long battery life whose output is connected to a 5V buck converter to generate 5V to the system. The microcontroller (NodeMCU-ESP8266) is powered by 5V supplied by the power pack through the pin Vin on the microcontroller. The system utilized MAX30100 as heart rate and oxygen saturation sensor, DS1B820 as temperature sensor that send the digital data to the NodeMCU-ESP8266 through the pin D7 (GPIO13) and load cell (20kg) with HX711 amplifier as weight sensor that are connected to the microcontroller to process the data generated by them. A 20 x 4 LCD is connected to the microcontroller (NodeMCU-ESP8266) through the data pins (SCL and SDA) on the microcontroller to display the result generated by the sensors, also a buzzer alarm is interfaced with the microcontroller (NodeMCU-ESP8266) to trigger the alarm when the sensors parameters are not within the normal range. The microcontroller then sends the data generated by the sensor to the web server through its built-in WiFi for easy visualization and access to real-time monitoring of the data generated. The entire schematic is depicted in Figure 5

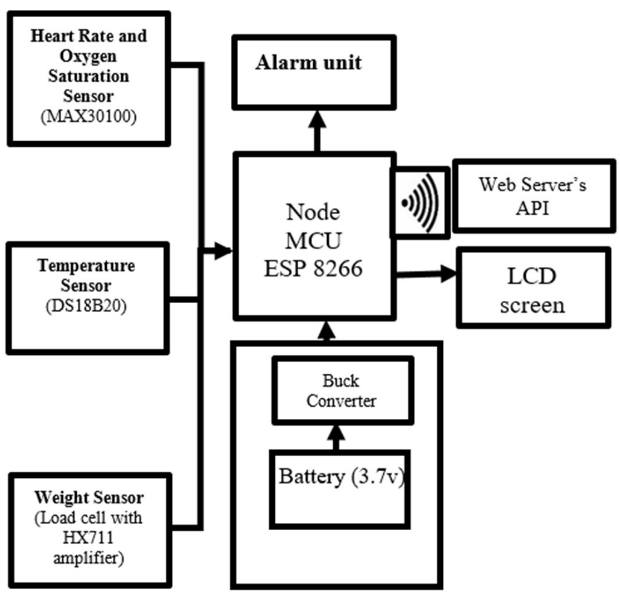

Figure 5. Block Diagram of a Web-Based Health Monitoring for Neonates

3.5.2 Data Acquisition and Transmission Flowchart

When the system is activated then the sensor for temperature (DS1B820), heart rate and oxygen saturation (MAX30100) and weight sensor (load cell with HX711) initialize the data, and the WiFi module on the NodeMCU also initialize data. The system is connected to local WiFi network and read the sensor data. The NodeMCU initialize the HTTP client to send the sensors' data to the web server's API end point and display the data gathered on the web server (ThingsSpeak) for visualization. Concurrently, the sensor data are also displayed on the 20 x 4 LCD, while measuring and monitoring the data if the sensor parameter are not within the normal range (that is if temperature < 36.5 or >37.5, or SPO2 < 95% or BPM < 80 BPM or > 150 BPM) then activates the alarm. The proposed system's flowchart for data acquisition and data transmission is illustrate in Figure 6.

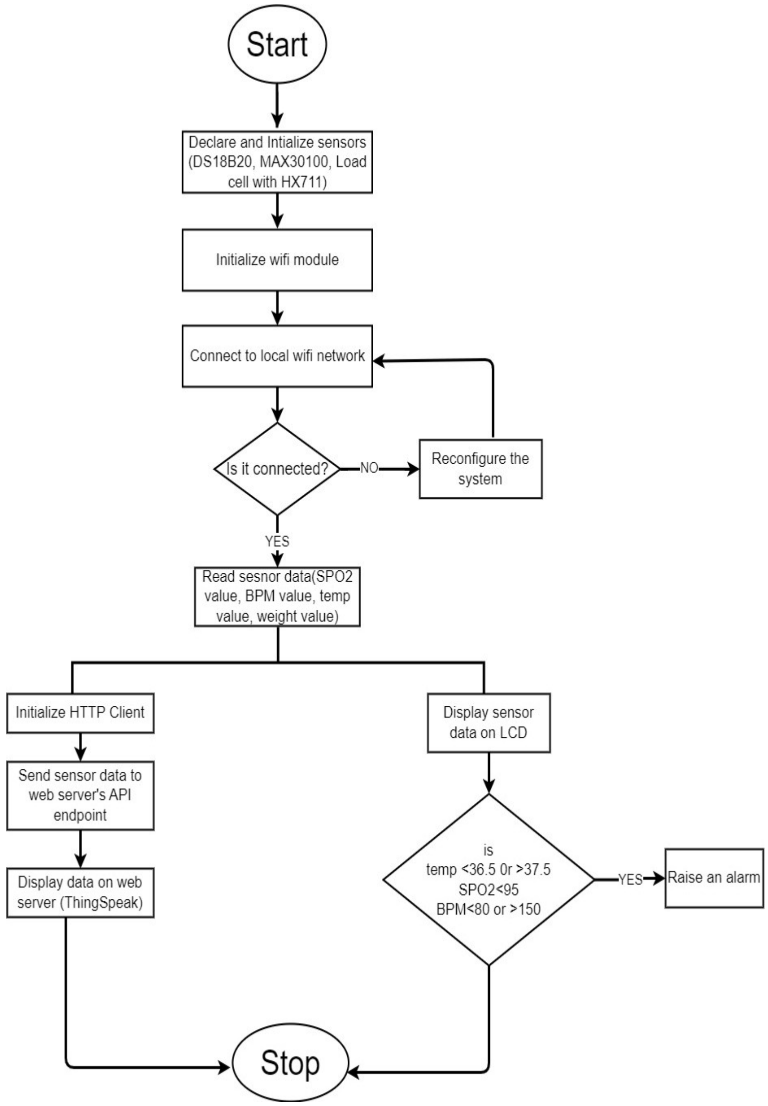

Figure 6. Data Acquisition and Data Transmission Flowchart of the System

4. Results and Discussion

4.1 Circuit Simulation of the Web-Based Neonatal Monitoring System

The temperature sensor input pin DQ was connected to the pin D7 on the NodeMCUESP8266 4.7kΩ resistor was connected across the VCC pin and DQ pin and the VCC pin was connected to 3.3V from the NodeMCU, pulse rate and oxygen saturation (MAX30100) sensor input pins SCL and SDA were connected to the pin D1 and D2 of the ESP8266NodeMCU respectively, and the VCC pin of MAX30100 was connected to the 3.3V on ESP8266NodeMCU, the wires of the load cells red, black, white and green were connected to the E+, E-, A-, and A+ of the HX711 respectively, the input pins of the HX711, SCK and DT were connected to D5 and D6 of the ESP8266NodeMCU respectively, 20 x 4 LCD input pins SCL and SDA were also connected to the D1 and D2 pins of the ESP8266NodeMCU respectively, the VCC pin of the 20 x 4 LCD was connected to 5V from power supply and all the GND were connected together as illustrated in Figure 7

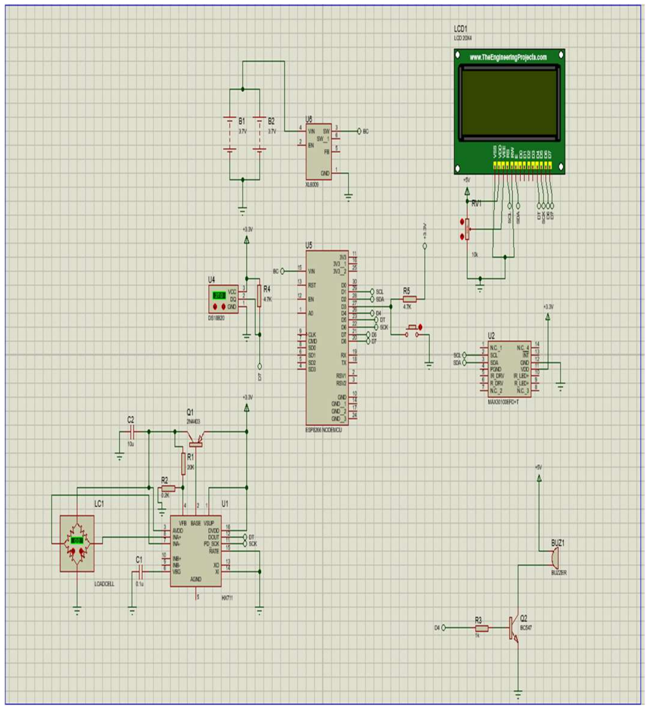

Figure 7. Circuit Simulation of the System

4.2 Design, Implementation and Assembly of the System

The design was implemented on breadboard as shown in Figure 8 to measure and monitor the vital signs and weight of the neonates. The LCD displayed weight of 2.9kg, heart rate of 99.9 beat per minute (BPM), oxygen saturation (SPO2) of 115.0%, and temperature of 34.4 and temperature of 34.4℃ as depicted on Figure 9. In another experiment, a weight of 0kg, SPO2 of 96.0%, heart rate of 79.3 BPM and temperature of 34.3℃ were displayed on LCD shown on Figure 10 and the acquired data are sent to the webserver as visualized in Figure 11 for visualization which was demonstrated in Figure 12 that at a particular time that the SPO2 reading is 97%, temperature is 36.5℃, heart rate is 99 BPM and weight is 22.9kg to enhance remote monitoring and real-time communication of vital parameters to the healthcare professionals for early detection of congenital abnormalities. The design was assembled and packaged in a case as shown in Figure 13 and tested in an experiment to validate the efficiency of the sensors. The packaged system consists of DS18B20 that measure the skin temperature placed on the abdominal region of an infant, MAX3010 placed on the finger of an infant measure the heart rate (BPM) and oxygen saturation and load cell with HX711 that measure the weight of an infants by placing directly under the mattress of an infant.

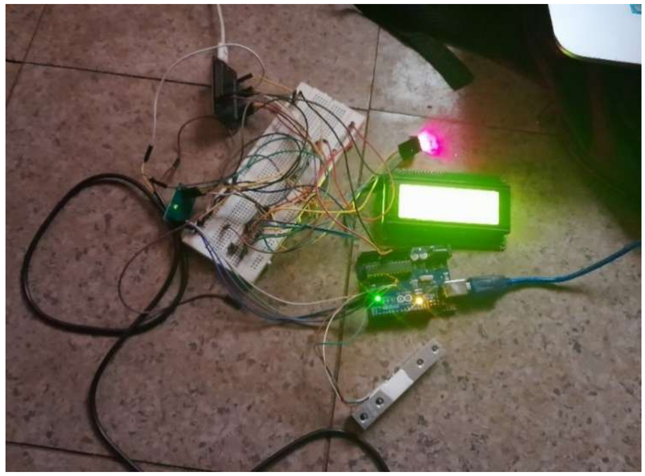

Figure 8. Implementation on the Breadboard

Figure 9. Result Obtained by the Sensors on LCD during Experiment 1

Figure 10. Result Obtained by the Sensors on LCD during Experiment 2

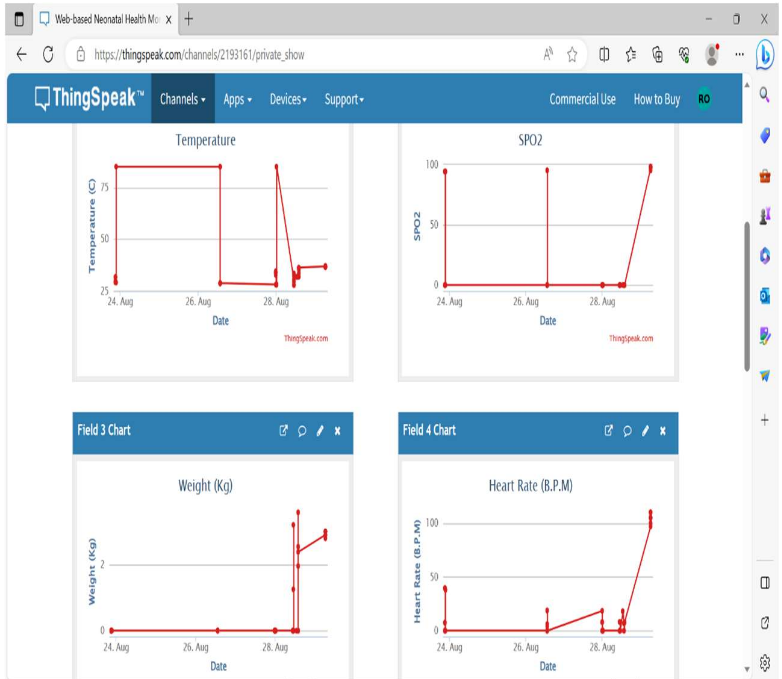

Figure 11. Visualization of the Sensor's data uploaded to ThingSpeak

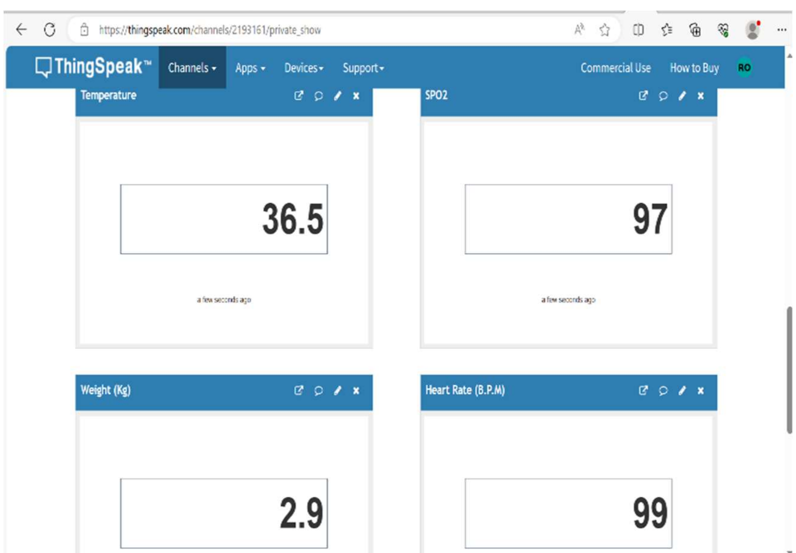

Figure 12. Result of the Sensor's data uploaded to ThingSpeak

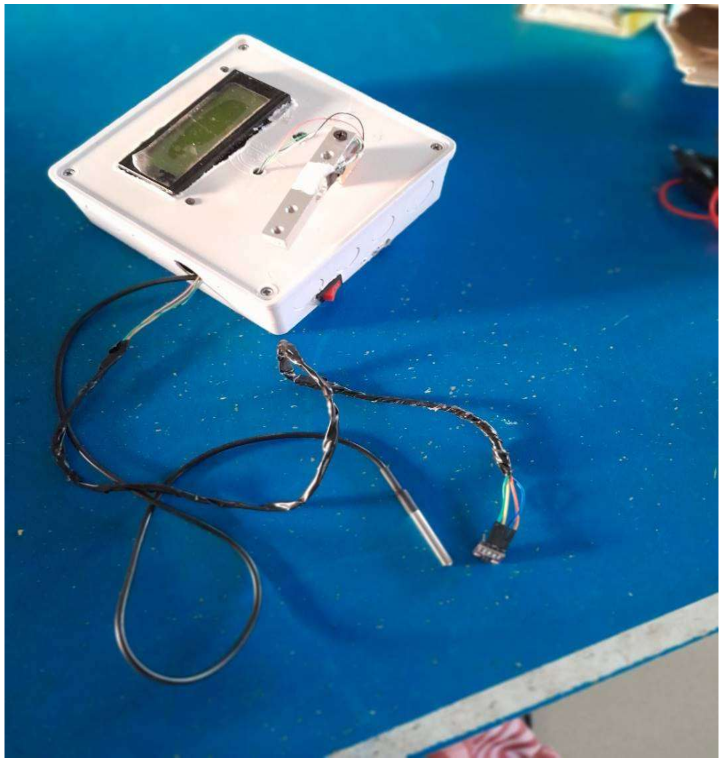

Figure 13. Assembling and Packaging of the System

4.3 Web-based Neonatal Monitoring System Simulation Study

The measurement of the body temperature, heart rate, oxygen saturation, and weight for 300s at intervals of 15s between successive measurements that were obtained from testing the system after packaging it in a case are shown in Table 1

Table 1. Body Temperature, Heart Rate, Oxygen Saturation and Weight Obtained from the Sensors While Testing the System

Measurement	Temp (℃)	SPO2 (%)	Heart Rate (BPM)	Weight(Kg)	Time(s)
1	36.8	97	92.5	2.3	15
2	36.3	95	56	2	30
3	36	112	123	2.4	45
4	36.2	54	102	2.3	60
5	36.1	79	115	2.1	75
6	36.9	78	110	2.5	90
7	36.5	98	100	2.4	105
8	37	94	99	2.3	120
9	36.7	88	99	2.3	135
10	36.4	93	103	2.4	150
11	36.5	94	105	2.4	165
12	37	96	110	2.9	180
13	37	95	105	2.7	195
14	36.3	97	95	2.3	210
15	36.6	96	94	2.1	225
16	36.7	98	94	2.2	240
17	36.9	120	96	2.4	255
18	36.2	104	95	2.7	270
19	36.5	93	95	2.9	285
20	36.3	94	98	2.2	300

Figure 14 shows the temperature data acquired by DS18B20 sensor and the acquired values from the DS18B20 senor is being uploaded to ThingSpeak at interval of 15s. However the readings from the DS18B20 sensor has good data precision with an average value of 36.545℃ which shows 97% accuracy of the sensor. The error obtained from this sensor is 0.0713.

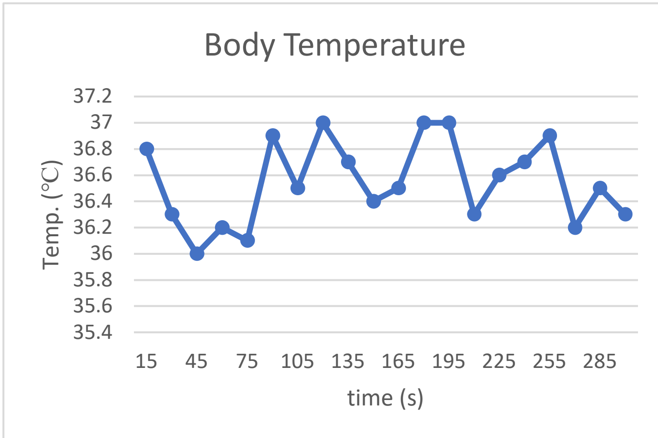

Figure 14. Temperature Data Uploaded to ThingSpeak at Interval of 15s

Figure 15 and Figure 16 shows the SPO2 and heart rate data obtained from MAX30100 respectively and uploading of the acquired values from the sensor to ThingSpeak at interval of 15s. To some extent the sensors data may be proven to be accurate. However, the graph shows anomalies of the data sensor. For instance, the SPO2 is 54% when uploaded to ThingSpeak at 60s and heart rate is 54BPM when uploaded to ThingSpeak at 30s. These anomalies may be due to the asynchronous characteristic of the MAX30100 during its operation with other sensors in the system. The error obtained from measuring SPO2 and heart rate are 2.9369and 2.8879 respectively.

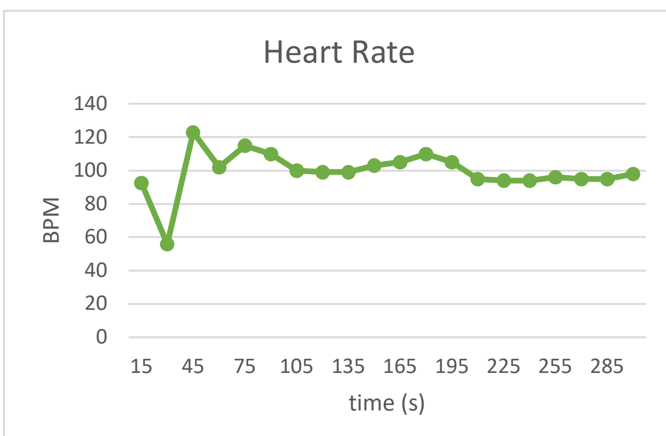

Figure 15. Heart Rate Data Uploaded to ThingSpeak at Interval of 15s

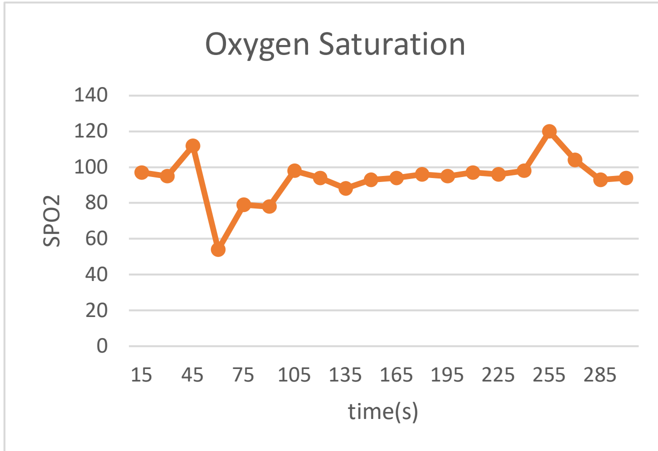

Figure 16. SPO2 Data Uploaded to ThingSpeak at Interval of 15s

Figure 17 shows the value of weight obtained from load cell with HX711 module whose average value is 2.28kg. The sensor has an error of 0.05 which indicates its sensitivity and responsiveness while in use

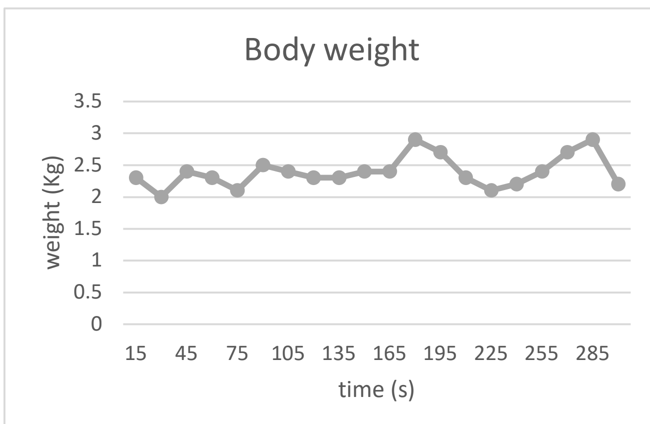

Figure 17. Body Weight Uploaded to ThingSpeak at Interval of 15s

5. Conclusion

The development of a web-based health monitoring system for neonates is a critical step in addressing the challenges associated with preterm births and the care of premature infants. This system aims to provide real-time monitoring of vital signs and weight, enabling early detection of health issues and facilitating communication between medical staff and neonatal care providers.

The system utilizes various sensors and components, including a temperature sensor (DS18B20), a pulse rate and oxygen level sensor (MAX30100), and a weight sensor (Load Cell with HX711). These sensors are strategically placed on the neonates to collect data, which is then processed by a central microcontroller (NodeMCU-ESP8266). The microcontroller uses its built-in WiFi module to transmit the data to a web server (ThingSpeak) for remote monitoring and storage.

From the experiment done for testing the developed system, the sensors are responsive with DS18B20 measuring average temperature of 36.545℃, whose accuracy is 97% and has an error of 0.0713. MAX30100 measured average SPO2 of 93.75% and average hear rate of 99.325 BPM whose accuracy are 96% and 71% respectively and their errors 2.9369 and 2.8879 respectively. The load cell with HX711 measures average weight of 2.39Kg whose accuracy is 96% and has an error of 0.0552 and all the acquired datas are successfully uploaded to the web server at interval of 15s. The system makes an alarm system to alert medical staff when sensor parameters fall outside the normal range, ensuring timely intervention and this system aim to improve premature care by providing continuous monitoring of vital signs that enable healthcare providers to detect abnormalities early. For further research, the work can be improved on through the development of a machine learning algorithm and artificial intelligence (AI) that can be integrated with the mobile apps to detect pattern, anomalies and trends in neonatal health data.

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