# Design of Hardware Module of IoT-based Infant Incubator Monitoring with Cooling And Security System

***Afreen Tabassum*[1], *Adiba Maimanath*[2], *Mariyah Ahmed*[3], *Shubhakar P*[4]**

***Students*[1,2,3], *Asst professor*[4]**

***Department of ECE*[1,2,3,4]**

***Abstract*—This paper describes the design of the hardware module of IoT-based infant incubator monitoring system. The hardware module consists of microcontroller, data acquisition submodule and data communication submodule. In this research, the microcontroller used is Arduino Uno Rev3 along with a body temperature sensor as the representation of biosensors and ambience temperature sensor, humidity sensor, and gas sensor as the representation of environment monitoring sensors with addition of RFID sensor named EM-18 for security. The Arduino board connected with an ESP8266 WiFi as a data communication submodule**

***Keywords—IoT, sensor data acquisition, sensor data communication, Arduino Uno Rev3, ESP8266, EM-18***

## I. INTRODUCTION

Neonatal Intensive Care Unit (NICU) gives special medical attention to newborn babies in needs. The babies who admitted to the NICU are mostly premature. Premature babies are infants who are born before 37 weeks of pregnancy and have low birth weight (less than 2.495 kg) or have any medical condition which needs special attention. [1][2]2 Over a decade ago, there are more than 130 million babies are born annually, and nearly 8 million of them die before their first birthday because of prematurity complications. [3] Recently, NICU is equipped with sophisticated instruments to monitor the vital signs of the infants, such as body temperature, blood pressure, pulse rate, and respiratory rate. [2] The advancement of the Internet-of-Things enables medical professionals to monitor these parameters remotely.

There are myriads of research about IoT based baby incubator monitoring systems. Some of them are focused on solely monitoring aspects [4] [5] [6] [7] while the others were also embedded controlling aspects [8] [9] [10] [3] [11] into their system. Almost all those works were using incubator temperature and humidity as the main parameters. Reference [5] used humidity and pulse rate sensor as parameters to be monitored, while [4] only monitored the incubator temperature.

Reference [6] designed a system that was based on a microcontroller that is equipped with weight, motion, temperature, and humidity sensors along with LoRa module and NFC module for communication. This system was also equipped with local memory and using a database server to store the acquired data. Reference [6] designed a microcontroller-based system that is equipped with a temperature sensor, humidity sensor, LCD, and a WiFi module and used Thingspeak Platform to store the sensor data. Some researches that also adds the controlling capability to their systems were mostly designed their actuators to be automatically activated as responses to the sensors values. Reference [8] designed a system that monitors environmental parameters such as temperature, humidity, oxygen level, and water reservoir level that might trigger the heater and fan devices as the actuators. Reference [9] monitored temperature sensor and infant's heartbeat and used infrared bulb and buzzer as actuators. The system also used a WiFi module to communicate and web-based GUI for remote monitoring. Reference [10] acquired air temperature, humidity, and skin temperature from the sensors and used motor driver, suction, and alarm as actuators. It also used LCD and RTC module in the system. Even more, [3] designed a microcontroller-based system that monitors environment temperature, humidity, body temperature, heart rate, and video footage. This system also equipped with a biometric fingerprint reader for tracking the parameter changelog. It used a GSM module to communicate and store the data in a web server and developed a web and android app for monitoring purpose. The actuators employed in this system are a fan, heater, and nebulizer. Reference [11] designed a system with [6] and added a cooling fan to be controlled as an actuator.

## II. SYSTEM OVERVIEW

### *A. Block Diagram*

The full system is consist of three main parts: an IoT-based hardware module, web and database subsystem, and remote monitoring applications (Fig. 1). The hardware module aims to automatically acquire data from sensors (biosensors and environment monitoring sensors, process the data in the microcontroller board, and then send them to a database server via the Internet. In this design, a WiFi communication module carries out the data communication process (Fig. 2).

The web and database subsystem consists of two parts: a data communication API and data processing part. The former part is simple PHP scripts that receive and store the data sent by the hardware module into a table in the database. It enables the hardware module to initiate communication and login to the database. The later part processes the IoT data from a database using a particular data calculation and analysis and then stores the results to other tables inside the database.

The remote monitoring applications are a collection of means provided for the users to access the processed data in real-time. The users can use android-based handsets or access the web application via web browsers.

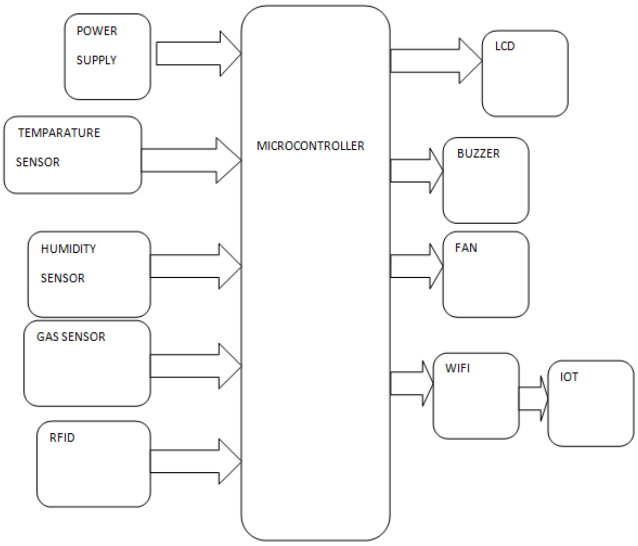


Fig. 1. The block diagram of the full system

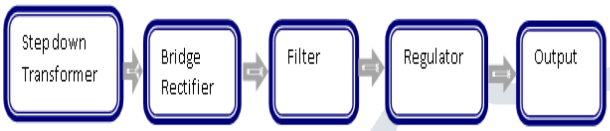


Fig. 2. Power supply Block diagram

*B. Related Components*

There are three groups of components and devices to be used in the hardware module: a microcontroller board, a communication module, and sensors.

*1) Microcontroller board*

The module uses a low-power microcontroller board which mainly acquires the data from sensors and composes them into a specified format of a message. The board forwards this message to the communication module or send the message to the serial monitor.

*2) Communication module*

The communication module receives a message from the microcontroller board and sends it to the database. This design employs a WiFi module with assumptions that the full system will be used indoor along with the availability of a wireless connection.

*3) Sensors*

This group consists of biosensors and environmental monitoring sensors. The biosensors are a smaller group of sensors which detects changes in external physical characteristics that indicate potential changes inside the body. [11]

Environment monitoring sensors are components or devices that capable of providing various information regarding natural phenomena, such as location, position, air composition, vibration, et cetera. Typical uses of this category of sensors are air pollution monitoring, forest fire detection, earthquake detection, and ambient temperature and humidity monitoring.

## III. System Design

This section describes the detail of system design. The contents to be covered in this section are the components and sensors used in this module and the Arduino sketch flowchart. The design objectives are: the system has to be able to acquire the data from various sensors (biosensors and environment monitoring sensors), the system has to be able to send data to a database server

*.A. Arduino Uno R3*

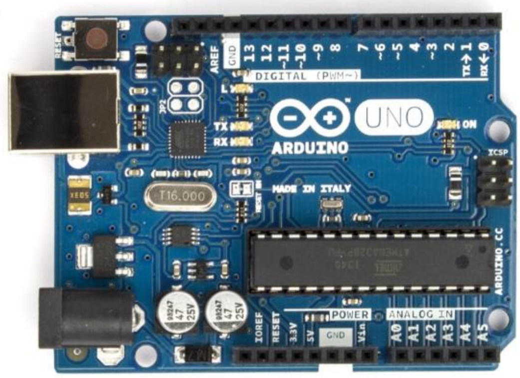


Fig. 3. Arduino Uno Rev3

The microcontroller board used in this research is Arduino Uno Rev3 board based on ATmega328P (Fig. 3). Its operating voltage is 5 volts with input voltage limit may vary from 6-20 volts (7-12 volts recommended). This board has six analogue inputs, fourteen digital I/O pins which six of them could act as pulse-width modulation outputs, and a 16 MHz clock. It also has six PWM digital I/O pins. The direct current per I/O pin is 20 mA and 50 mA for 3v3 pin.

*B. ESP8266 WiFi Module*

ESP8266 (Fig. 4) is a system-on-chip module which able to provide WiFi access for the microcontroller using TCP/IP stack. It can also deliver networking functions from other application processors. This module is preloaded with firmware and AT command interface. This module will send the message from the Arduino board to the server via the Internet.

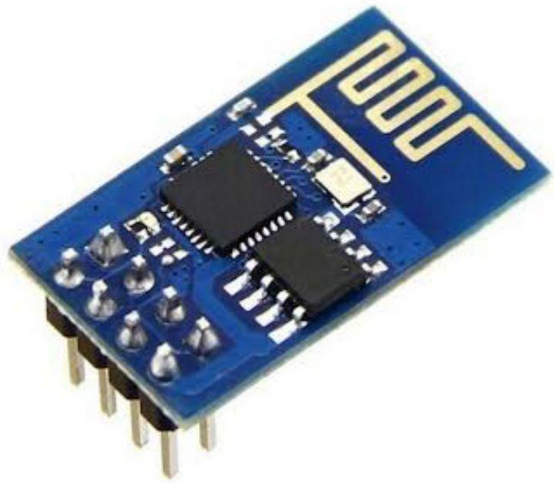

Fig. 4. ESP8266 WiFi Module

*C. Sensors*

*1) LM35*

In this research, the body temperature sensor used is LM35, one of IC temperature sensors which gives output proportional to temperature in degree Celsius. LM35 sensor (Fig. 5) is one of the easy-to-use temperature sensors with minimal external circuitry. The sensor's internal circuitry to minimize oxidation or other performance reduction processes. It has excellent linearity and does not need data preprocessing to rescale the temperature reading. The features of this sensor are listed below.

1. The sensor already calibrated the output into Celsius (centigrade).
2. Scale factor linearity +10-mV/ºC., non-linearity around 0.25 ºC (typically)
3. Measurement range from -55 ºC to 150 ºC

4. At 25 ºC, the accuracy ensured 0.5 ºC
5. Low-cost and suitable for remote applications
6. Operates from 4 volts to 30 volts with low impedance output, around 0.1 Ω for one milliampere load
7. Current drain less than 60 microamperes
8. This sensor generates low self-heating (around 0.08 ºC) in still air.


Fig. 5. LM35 sensor with pin outbreak

*2) DHT11*

Temperature and humidity measurement is essential for environmental monitoring. To simplify the design, the sensor used for these parameters is DHT11. DHT11 is a basic sensor which consists of two parts: a thermistor for temperature measurement and a capacitive humidity sensor to measure relative humidity. The output of this sensor is a digital signal of measured temperature and humidity. In specification-wise, this ultra-low-cost sensor needs 3-5 volts input with a maximum of 2.5 mA current use during conversion. It has a 5% deviation in humidity readings and good for 20-80% humidity. It is also suitable for 0-50 ºC temperature readings with ±2% deviation. The maximum sampling rate of DHT11 is one sampling per second. However, in this design, the logging duration is set to once per minute.

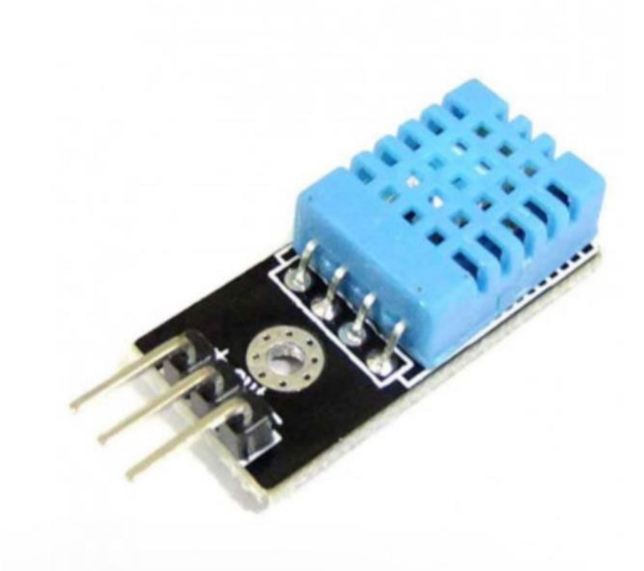

Fig. 6. DHT11 sensor

*3) MQ-3*

The MQ sensors are metal oxide semiconductor type and also known as chemiresistors. This sensor can detect the presence of certain substances (various gases and smoke) when they are in contact with the sensing material of the sensor. By using a simple voltage divider network, the sensor can detect the concentration of gas. This research used two MQ sensors: MQ-3 sensor module (Fig. 7) and MQ-135 sensor module (Fig. 8). Both sensors are having quite similar specifications, such as circuit and heating voltage of 5 volts, heater resistance around 33 ohms, standard detecting temperature around 20 degree Celsius with humidity 65%±5%. They also have the same preheat time over 24 hours and using mostly the same materials such as $SnO_2$, Au as the electrode, Pt electrode line, and Ni-Cr alloy as heater coil. The clamp ring, resin base, and tube pin for both sensors are made from copper plating Ni, bakelite, and copper plating Ni respectively.

The different technical parameter for both sensors at least are concentration slope rate ≤0.65% for MQ-135 while for MQ-135 are less than 60%, and the sensing resistance is 30-200 kΩ for MQ-135 while 1-8 MΩ for MQ-3.


.

Fig. 7. MQ-3 sensor module

4)EM-18

**EM-18** is used like any other sensor module. First we choose the mode of communication between MODULE and CONTROLLER. Next we will program the controller to receive data from module to display. Next power the system. When a tag is brought near the MODULE it reads the ID and sends the information to controller. The controller receives the information and performs action programmed by us.Consider a TAG is brought near the MODULE. The MODULE reads the ID and sends the information to controller in 12 ASCII CHARACTERS. In them, 10CHARACTERS represent the TAG ID and 2 CHARACTERS are XOR of previous 10 CHARACTERS.So DATA sent = 10ASCII DATA (tag no.) + 2ASCII DATA (XOR result)Once the Information is sent, the MODULES stop sending DATA. This serial DATA received by the controller though RX pin contains TAG information which is ready for processing. We can program the controller to save the DATA or process it to provide response immediately.

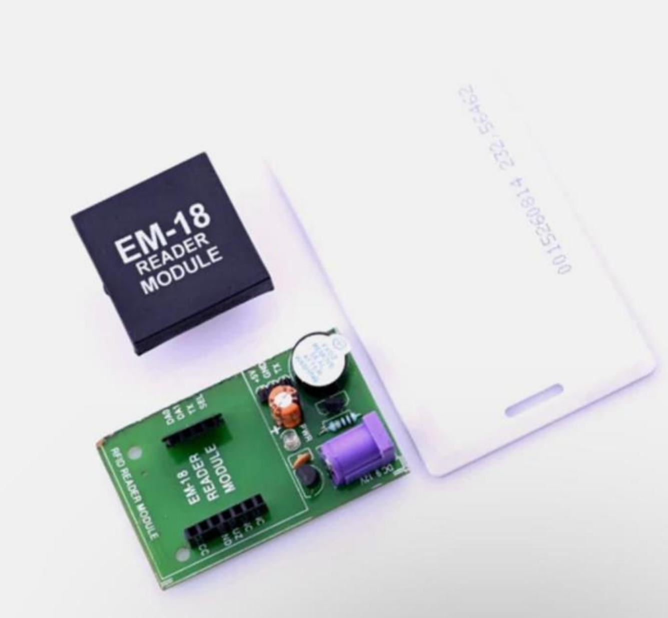


Fig. 8. EM-18 Reader module

## III. Results and Discussions

Fig. 11 displays the prototype of the hardware module for IoT-based infant incubator monitoring systems. It consists of several parts, such as the Arduino board, ESP8266 WiFi module, a temperature sensor LM35 as a biosensor (red breadboard), and MQ-3, , and DHT11 as environment monitoring sensors.

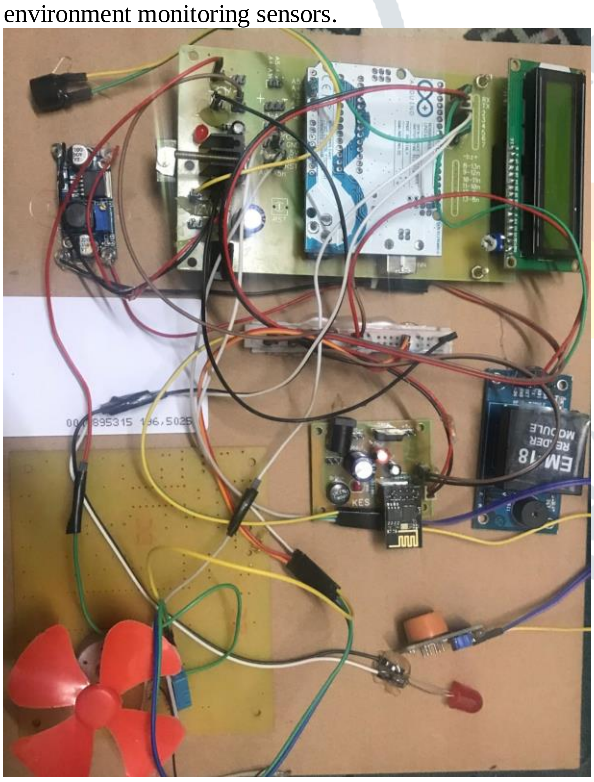

Fig. 9. Hardware module

We also added EM-18 reader module is used to detect any authorised and unauthorised access to the incubator. By the help of IoT we will get notified on the mobile telnet application regarding humidity, gas leak, temperature and unauthorised access to the incubator as shown in Fig 10,11,12

In addition the buzzer and LED will also turn on to notify the surrounding authorities


Fig 10 Gas leak notification


Fig 11 unauthorised access notification

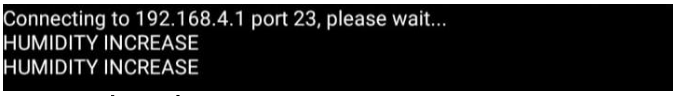


Fig 12 Humidity notification

## V. Conclusion and Future Work

This research has achieved the primary design objectives: (1) the system can acquire the data from various sensors, and (2) the system can send those data to a database server. Three parameters were being compared to the measurement result from other instruments/devices: (1) humidity, (2) ambient temperature, and (3) body temperature.

The value of humidity and ambient temperature acquired by DHT11 were higher than the measurement results from the digital clock, while the measurement results of the body temperature were within the same range. The manual process of measuring parameters by other devices may generate delay to the result.

Also we added RFID sensor for security which works by using the authorised cards

There are several improvement plans to be carried as future work: introducing other components to the system (such as pulse oximeter, RTC module for data logging, et cetera), calibrating the sensors, and using a proper measurement tools/instruments for validation purpose.

Also the addition of AI will improve its performance drastically

## References

[1]W. Shalannanda, I. Zakia, E. Sutanto and F. Fahmi, "Design of Hardware Module of IoT-based Infant Incubator Monitoring System," 2020 6th International Conference on Wireless and Telematics (ICWT), 2020, pp. 1-6, doi: 10.1109/ICWT50448.2020.9243665.

[2] A. Rajalakshmi, K. A. Sunitha and R. Venkataraman, "A Survey on Neonatal Incubator Monitoring System," *Journal of Physics: Conference Series*, vol. 1362, p. 012128, November 2019.

[3] P. T. Kapen, Y. Mohamadou, F. Momo, D. K. Jauspin, N. Kanmagne and D. D. Jordan, "Development of a neonatal incubator with phototherapy, biometric fingerprint reader, remote monitoring, and heart rate control adapted for developing countries hospitals," *Journal of Neonatal Nursing*, vol. 25, no. 6, pp. 298-303, December 2019.

[4] B. Ashish, "Temperature monitored IoT based smart incubator," in *2017 International Conference on ISMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, Palladam, India, 2017.

[5] D. N. F. M. Ishak, M. M. A. Jamil and R. Ambar, "Arduino Based Infant Monitoring System," *IOP Conference Series: Materials Science and Engineering*, vol. 226, p. 012095, 2017.

[6] S. Sendra, P. Romero-Diaz, J. Navarro-Ortiz and J. Lloret, "Smart Infant Incubator Based on LoRa Networks," in *2018 IEEE/ACS 15th International Conference on Computer Systems and Applications (AICCSA)*, Aqaba, Jordan, 2018.

[7] A. G. Shabeeb, A. J. Al-Askery and Z. M. Nahi, "Remote monitoring of a premature infants incubator," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 17, no. 3, pp. 1232-1238, March 2020.

[8] S. S. M. Sheet, Z. G. Mohammed, K. N. Khaleel and

A. A. Abbas, "Smart Infant Incubator Based On Mega Microcontroller," in *2019 2nd International Conference on Engineering Technology and its Applications (IICETA)*, An-Najef, Iraq, 2019.

[9] M. Koli, P. Ladge, B. Prasad, R. Boria and N. J. Balur, "Intelligent Baby Incubator," in *2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA)*, Coimbatore, India, 2018.

[10] M. Ali, M. Abdelwahab, S. Awadekreim and S. Abdalla, "Development of a Monitoring and Control System of Infant Incubator," in *2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE)*, Khartoum, Sudan, 2018.

[11] M. Suruthi and S. Suma, "Microcontroller Based Baby Incubator Using Sensors," *International Journal of Innovative Research in Science, Engineering, and Technology,* pp. 12037-12044, 2015.

[12] Z. Zhu, T. Liu, G. Li, T. Li and Y. Inoue, "Wearable Sensor Systems for Infants," *Sensors*, vol. 15, no. 2, pp. 3721-3749, February 2015.

Authorized