JTEIN: Jurnal Teknik Elektro Indonesia, Vol. 6, No. 2, pp. 172-181, 2025
e-ISSN 2723-0589

Smart Egg Incubator Monitoring System Based on IoT and Blynk Connectivity

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Abstract

The success of hatching poultry eggs is greatly influenced by the stability of temperature, humidity, and the ability to detect hatching time. Conventional incubators not yet providing monitoring in real-time, making it vulnerable to failure. The purpose of this research is to develop a smart incubator system based on the Node MCU ESP32equipped with temperature and humidity sensors, a MAX9814 microphone, an MG996R servo motor, and an ESP32-Cam and can be monitored online via the Blynk application. Testing includes testing temperature and humidity sensors compared to with standard measuring instruments, servo motor rotation monitoring, chick sound detection, and video streaming from the ESP32-Cam. This test use 10 free-range chicken eggs for 21 days incubation period and the result , 3 eggs hatched successfully, 2 in the pipping stage, and 5 did not hatch So level success rate is 30% . This system It was able to maintain an average temperature of 37.4°C with an error of 0.27% (99.73% accuracy) and humidity of 52% with an error of 0.67% (99.33% accuracy). The system also successfully detected hatching sounds and provided real-time visual confirmation. Compared to previous research, this tool excels because it has notification features, camera visualization, and automatic sound detection. This innovation provides a practical and efficient solution to increase the success of poultry hatching, especially in areas with limited resources. power .

Keywords : DHT22 ; ESP32-Cam; Internet of Things (IoT); MAX9814; Node MCU ESP32

1. Introduction

The demand for chicken meat and eggs as a source of animal protein continues to increase in line with population growth and increasing awareness of the importance of nutrition. To address this challenge, increasing the efficiency of the hatching process is crucial [1]. Modern incubators with automated systems have been widely used to maintain stable temperature and humidity, replacing less efficient natural hatching methods[2], [3], [4].

In previous research by by Muzamil Haq et al. Design and construction of an egg hatching incubator based on an Arduino Uno microcontroller equipped with a DHT 22 sensor[5]. Another research conducted by Aji and Sulistyowati used ESP32-CAM for IoT-based visual monitoring and control of temperature and humidity[6].

Research presents a new approach by integrating the MAX9814 sound sensor to detect hatching sounds, ESP32-Cam for visual monitoring, and the DHT22 sensor in one system connected via the Blynk application[7], [8], [9].

The research methodology that will be done This includes the stages of design, manufacture, testing, and analysis of the effectiveness of the technology applied. Testing is carried out by comparing the temperature and humidity sensors against standard measuring instruments, monitoring the movement of the servo motor according to the specified time interval, testing the MAX9814 sound sensor using sound , as well as testing the ESP32-Cam 's ability to stream video in real-time over an IoT network[4], [9], [10].

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Thus, this system not only provides data , but is also capable of providing real-time voice and visual-based notifications, making it more responsive, adaptive, and comprehensive than previous research.

2. Materials and methods

For stages research in accordance with flowchart as shown on Figure 1. Stages research This project covers the design, manufacturing, testing, and effectiveness analysis of an ESP32-based automatic egg incubator system. The research began with problem identification through a literature review of literature, media, and scientific journals to formulate the background and innovation of the system to be developed. Next, hardware and software design was carried out, including the user interface and assembly of components such as the DHT22 sensor, MAX9814 microphone, servo motor, and ESP32-Cam module. Testing was carried out by comparing temperature and humidity sensors to standard measuring instruments, monitoring servo motor movements at certain time intervals, testing hatching sound detection using chick sound recordings, and testing the ability to stream real-time video over an IoT network using ESP32-Cam[6], [9], [11]. All test results were analyzed to evaluate whether the developed system met the functional criteria and supported the achievement of the objectives research .

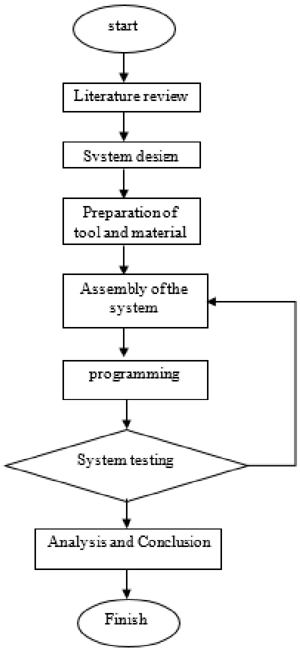

Figure 1. Flow Chart Research

2.1 Block diagram of Designed Device

In general Design refers to the process of planning or conceptualizing before the creation of an object, system, component, or structure, which is important to ensure that the resulting system has practical value and functionality.

This smart egg incubator system is controlled by an Node MCU ESP32microcontroller , which acts as the central control for all components. The DHT22 sensor is used to detect temperature and humidity inside the incubator. Data from this sensor is sent to the Node MCU ESP32, which then decides whether to turn on the cooling fan or heating lamp via a relay module. to maintain the ideal temperature between 37.3°C to 37.7°C. The MAX9814 amplifier microphone sensor is connected to an Node MCU ESP32to detect the sound of chicks hatching. If sound is detected, the Node MCU ESP32will be activated . Sends an automatic notification to the Blynk app , notifying the user that the egg has hatched. To ensure even temperature and humidity distribution, the DS3231 RTC provides accurate time to the ESP32 Node MCU. in order to be able to control the servo MG996R periodically. This servo is responsible for automatically rotating the egg racks according to a schedule. The ESP32-C am camera module allows real-time visual monitoring of the condition of the eggs inside the incubator. All data and images are sent to the Blynk app , which users can access remotely. as shown on Figure 2.

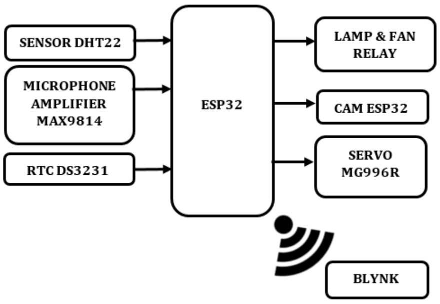

Figure 2. Block Diagram

2.2 Designed Tool Wiring

For wiring each component is assembled according to the schematic diagram that has been prepared The Node MCU ESP32 wiring process is connected to various sensors and actuators used in the automatic incubator. The components to be connected include a DHT22 sensor for temperature and humidity measurement, a MAX9814 microphone amplifier for detecting hatching sounds, an ESP32-Cam camera for real -time video streaming , and relays for controlling lights and fans. A detailed wiring diagram serves as a guide in assembling the circuit . And ensure each component can communicate effectively with the ESP32 Node MCU and the Blynk app. As shown on Figure 3. This wiring process must carried out with care to ensure all electrical connections are secure and the system is functioning properly. optimal should be .

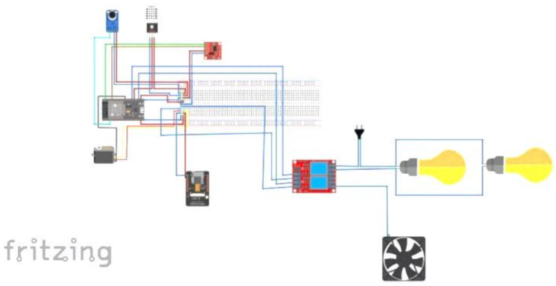

Figure 3. Wiring Diagram

2.2 Smart Egg Incubator Design

Device design is the process of creating and/or developing a device by applying various specific methods and techniques, where the technical aspects are carefully and thoroughly considered by the designer to ensure the efficiency and productivity of the resulting product.

This incubator measures 40 cm long , 30 cm wide , and 55 cm high. It is designed to hold 20 eggs. The design aims to test the system's efficiency and effectiveness on a small scale before being implemented on a large scale. The following is the design and wiring layout of an automatic egg incubator using the Node MCU ESP32. as shown Figure 4 .

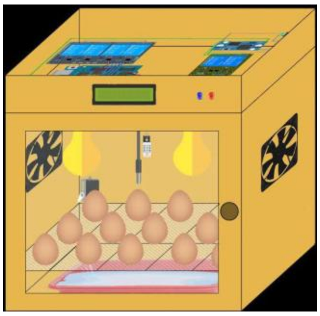

Figure 4. Smart Egg Incubator Design

2.3 Equipment and materials used

Following The equipment used in this research was carefully selected based on its function to support the automatic incubator system that will be designed like as shown in table 1.

Table 1. Equipment used

Equipment	Specification
ESP32 MCU Node	ESP32 MCU Node is a low-power microcontroller with built-in Wi-Fi connectivity that supports AP, STA, and AP+STA modes. The input voltage range is 3.3V and the input voltage range is 7–12V. The module has 25 digital I/O pins, 6 analog input pins, and 2 analog output pins. The communication interfaces include 3 UARTs, 2 SPIs, and 3 I2C. The module has 4 MB of flash memory, 520 KB of SRAM, and runs at a clock speed of 240 MHz. The module uses a CP2102 USB controller.
DHT22 Sensor	Operating voltage: 5V. Current consumption during measurement: 1–1.5 mA. Very low power consumption. Digital output signal rate: 5 ms. Sensing element: polymer capacitor. Humidity range: 0–100 RH (accuracy ±2 RH). Temperature range: -40 to 80°C (accuracy ±0.5°C). Sampling interval: 2 seconds.
MAX9814 Microphone Amplifier	Three-level settings: 40dB, 50dB, 60dB. Programmable start time. Supply voltage range: 2.7V–5.5V. Input noise density reference: up to 30nHz. THD (Total Harmonic Distortion): as low as 0.04. Includes low-power auto-off mode. Operating temperature: -40°C to +85°C. Dimensions: 25.4mm x 14.1mm.
ESP32-C am	This ultra-compact SoC module supports 802.11b/g/n Wi-Fi and Bluetooth/BLE, and features a low-power 32-bit dual-core CPU up to 240 MHz (600 DMIPS). Equipped with 520 KB of SRAM and 4 MB of PSRAM, it supports UART, SPI, I2C, PWM, ADC, and DAC interfaces. It is compatible with OV2640/OV7670 cameras and supports image upload via Wi-Fi, TF card, and various sleep modes. Integrated with LwIP and FreeRTOS, it supports STA, AP, and STA+AP modes, as well as Smart Config, FOTA, and secondary development features.
RTCDS3231	The DS3231 is a high-precision RTC module with a time deviation of only about 1 minute per year. Equipped with 4kB of memory and a temperature sensor, this module uses an I2C interface, an internal crystal oscillator, and a tuning circuit to maintain

	accuracy. Compared to the DS1307, the DS3231 offers superior performance and stability.
MG996R servo motor	This servo motor weighs 55 g and measures approximately 40.7 × 19.7 × 42.9 mm, with a rotation angle of up to 360°. It delivers torques of 9.4 kgf·cm (4.8 V) and 11 kgf·cm (6 V), and speeds of 0.17 s/60° (4.8 V) and 0.14 s/60° (6 V). It operates at 5–7.2 V, with a current of 500–900 mA and a stall current of 2.5 A. It has a deadband width of 5μs and an operating temperature range of 0°C–55°C.
2 - channel relay	The relay module supports a maximum load of AC 250V/10A or DC 30V/10A and has 2 channels. It operates at 5V with active LOW and active HIGH trigger options. The module weighs approximately 33 grams.
DC adapter	This adapter measures 8.5 x 4.8 x 3.3 cm and weighs approximately 250g . It supports AC 230V (50–60Hz) input and DC 5V/3A output via the Micro USB port, with a maximum power of 15W. It comes with a 5.5/2.1mm jack, a 1-meter AC cable, and a DC cable.
12 Vdc Fan	The DC fan operates on 12V with a current of 0.15A. Its body measures 8cm x 8cm and is 2.5cm thick. It comes with a cable approximately 25cm long and a small connector socket.

2.4 Software

In this research, three main software were used: Arduino IDE , Fritzing And Blynk . Arduino IDE is used to write and upload programs to the NodeMCU ESP32 microcontroller. Using the C++ programming language and supporting cross-platform operating systems, Fritzing is used to visually design circuit schematics and component layouts. Blynk is IoT (Internet of Things) platform that allows users to build graphical interfaces to monitor and control microcontroller-based devices such as ESP32, NodeMCU, Arduino, and others via smartphone. [5] . [11] .

2.5 Error and Accuracy Tool

The error and accuracy levels of the tool can be determined using the following equation 1[12]:

$$\text{Error (\%)} = \left|\frac{\text{Measurement of the comparison device} - \text{measurement of the designed device}}{\text{Measurement of the comparison device}}\right| \text{X100\%} \qquad (1)$$

And to look for mark accuracy tool can used equations 2 and 3

$$\text{Accuracy(\%)} = 1 - \left|\frac{\text{Measurement of the comparison device} - \text{measurement of the designed device}}{\text{Measurement of the comparison device}}\right| \text{X100\%} \qquad (2)$$

$$\text{Accuracy (\%)} = 100\ (\%) - \text{Error(\%)} \qquad (3)$$

3 Results and Discussion

For see performance from tool This so will done a number of testing including temperature sensor testing , servo motor testing , MG996R servo motor testing , testing microphone MAX9814 and ESP32-Camtesting. Figure 5 shows the results of the tool that has been completely fabricated.

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Figure 5. Smart Egg Incubator Shape

3.1 Testing Temperature and humidity

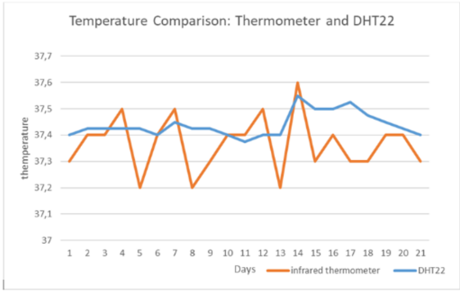
Temperature and humidity testing is carried out with compare DHT22 sensor with infrared thermometer and two 10 watt incandescent bulbs as heat sources. This test was conducted during the 21-day incubation period, starting from the first day the eggs are placed in the incubator until the day the eggs hatch, like as shown in Table 2.

Table 2. DHT22 Monitoring Test

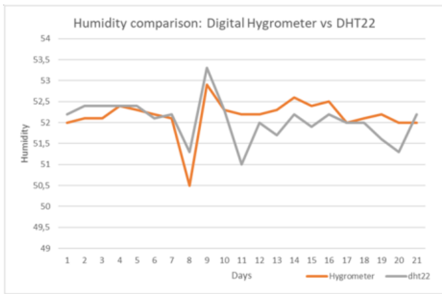
Day	Infrared thermometer		DHT22 Sensor		Error (%)	
	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)	Temperature	Humidity
1	36.8	52.0	37.4 0	52.2	0.2 7	0.38
2	37.5	52.1	37.4 3	52.4	0.0 7	0.5 8
3	37.6	52.1	37.4 3	52.4	0.0 7	0.62
4	37.5	52.4	37.4 3	52. 4	0.2 0	0. 10
5	37.2	52.3	37.4 3	52.4	0.60	0.19
6	37.1	52.2	37.4 0	52.1	0	0.19
7	37.6	52.1	37.45	52. 2	0.13	0.14
8	37.2	50.5	37.4 3	51. 3	0.60	1.53
9	37.3	52.9	37.4 3	53. 3	0.33	0.7 1
10	37.1	52.3	37.4 0	52.3	0	0.0 5
11	37.4	52.2	37.3 8	5 1.0	0.0 7	2.3 5
12	37.5	52.2	37.4 0	52.0	0.2 7	0.3 4
13	37.2	52.3	37.4 0	51.7	0.5 4	1. 10
14	37.6	52.6	37. 60	52. 2	0.13	0.8 1
15	37.3	52.4	37.5 0	51.9	0.5 4	0.95
16	37.4	52.5	37.5 0	52. 2	0.2 7	0.6 2
17	37.3	52.0	37.5 3	5 2 . 0	0.60	0.0 5
18	37.1	52.1	37.4 8	5 2 . 0	0.4 7	0.2 9
19	37.4	52.2	37.45	51.6	0.13	1.1 5
20	37.4	52.0	37.43	51. 3	0.0 7 5	1.44
21	37.3	52.0	37.4 0	52.2	0.2 7	0.38
Average error					0.2 7	0.6 7

From the results measurement obtained DHT22 temperature error value is 0.27% with 99.73% accuracy with average temperature 37.4 ^{0} C and humidity by 0.67% with accuracy 99.33 %. with Average humidity was 52%. This condition indicates that the system's automatic control functioned effectively in maintaining stable temperature and humidity according to the required incubation parameters.

these data can made chart comparison For temperature And humidity as shown on Figure 6 (a) and Figure 6(b)



(a)



(b)

Figure 6(a)Graphic Of A Comparison Of Temperature. (b) Humidity Between A Reference Tool And A Designed Device

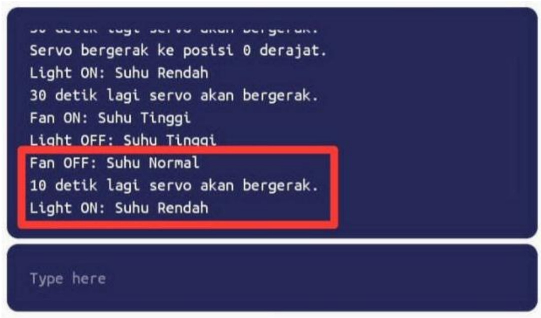


Figure 7. Blynk Notifications of temperature In Mobile Phone

3.2 MG996R Servo Motor Testing

The MG996R servo motor was tested to ensure precision, consistency, and reliability of movement according to commands from the ESP32 microcontroller. The servo was set to move every 4.8 hours with a duration of 15 seconds from 0° to 180° or vice versa, to maintain shelf stability and minimize shocks during the incubation process. To monitor the time and position of the servo motor, see table 3 and Figure 8 notification Blynk in mobile phone.

Table 3 Monitoring Time Servo Movement No burden

No	Testing Time	Initial Position (°)	Position End (°)	Time to Reach Position (seconds)	Information
1	04:51	0	180	15	Moving Normally
2	09:39	180	0	15	Moving Normally
3	14:27	0	180	15	Moving Normally
4	19:15	180	0	15	Moving Normally
5	00:03	0	180	15	Moving Normally

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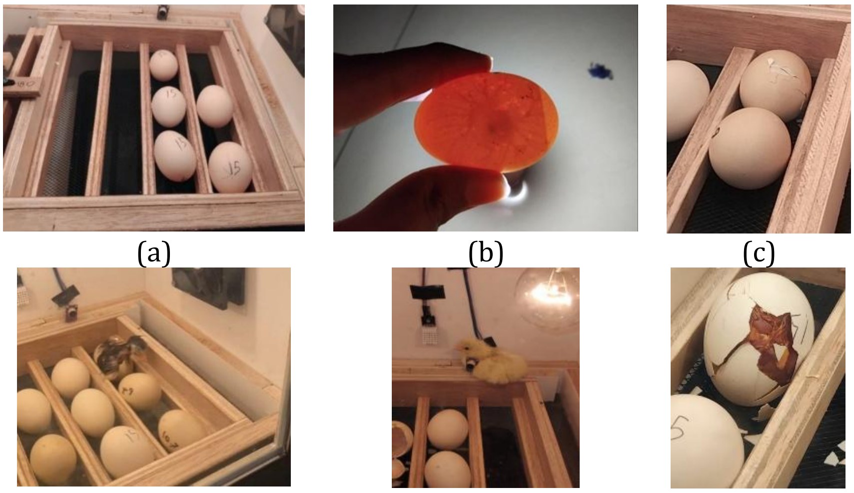
Figure 8. Blynk Notification Monitoring Servo Motor Movement in Mobile Phone

3.3 Hatching Results

Hatching tests were conducted over 21 days to evaluate the effectiveness of the automated incubator in maintaining optimal conditions for embryo development. Quality chicken eggs were placed in an incubator maintained at a temperature of 37.3°C–37.7°C and a humidity of 50–55%. On day 7, signs of embryonic development began to appear, and on day 14, candling indicated organ formation and blood circulation. Day 19 showed signs of pipping, indicating the chick was ready to hatch. On day 21, the chick successfully hatched under stable environmental conditions. other than the hatched ones There is also starting to pip as shown on Figure 9.

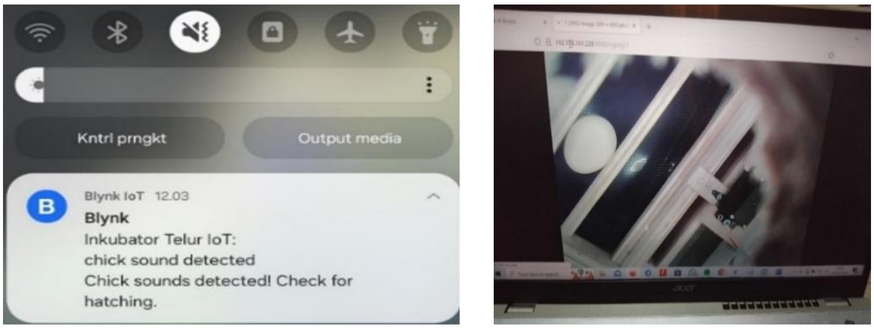


(a) (b) (c)

(d) (e) (f)

Figure 9. (a) Observation On Day 1. (b) Observation On Day 7. (c) Observation On Day 19 And (d) Observation On Day 21. (e) Eggs Start Partially Hatched (f) Some Egg Started Pipping .

Chicks voice are detected by the MAX9814 sensor which sends an automatic notification to the user's device when the ADC threshold exceeds 2500, marking the system's success in providing real-time monitoring. as shown on Figure 10(a). On Figure 10(b) shows conditions inside incubator hatching successful egg displayed by ESP32 CAM module that shows that module camera capable show live streaming with clear and details.



(a) (b)

Figure 10 (a) . Notification On Mobile Phone. (b) ESP32 Live Streaming – Cam

4 Conclusion

This research has successfully developed a smart egg incubator system that utilizes IoT technology, specifically the NodeMCU ESP32 microcontroller. integrated with DHT22, MAX9814, and ESP32-C modules, all managed through the Blynk app. This system not only achieves stable environmental conditions for egg incubation, but also allows for remote monitoring and real-time alerts. This trial use 10 free-range chicken eggs for 21 days incubation period and the result , 3 eggs hatched successfully, 2 in the pipping stage, and 5 did not hatch with level 30% success rate. This system was able to maintain an average temperature of 37.4°C with an error of 0.27% (99.73% accuracy) and humidity of 52% with an error of 0.67% (99.33% accuracy). The system also successfully detected hatching sounds and provided real-time visual confirmation.
Future enhancements could include AI-based embryo development analysis, solar-powered operation for off-grid use, and integration with cloud-based data analytics to optimize incubation cycles and hatching rates. The development and implementation of sustainable IoT-based systems can contribute significantly to food security and economic resilience in the rural agricultural sector.

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