THE DESIGN OF POULTRY EGG INCUBATOR CONTROL AND MONITORING SYSTEM

MUHAMMAD AZIZI BIN MOHD ZAIN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MUHAMMAD AZIZI BIN MOHD ZAIN

This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DECLARATION

I declare that this report entitled "The Design of Poultry Egg Incubator Control and Monitoring System" is the result of my own work except for quotes as cited in the references.

Signature :

Author : Muhammad Azizi Bin Mohd Zain

Date : 25 June 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature :

Supervisor Name : Dr. Yusmarnita Binti Yusop

Date : 25 June 2021

DEDICATION

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge, and understanding. He has been the source of my strength throughout this project. I dedicate this thesis also to my mother, Amrah Binti Othman and all my siblings. This thesis is purely of your tremendously support and sacrifice. May Allah always bless every each of you.

ABSTRACT

This project describes the design of the poultry egg incubator control and monitoring system which is fully powered by a solar photovoltaic (PV) energy system. Poultry eggs incubator can be found easily with many kinds of features that are offered with the amount of hatching capacity is diverse, but some of those incubators still work manually. The stability of temperature and humidity in poultry egg hatchery will be less effective if the monitoring is done manually. The manual control has not efficient anymore for the poultry farmers because it spends much time. Therefore, it needs a modern poultry egg incubator tool that makes it easier for the farmer to control and monitor it anytime and anywhere. As a solution, a new method of poultry eggs incubator design is suggested which could be used to hatch eggs using solar PV as a power supply and hence could reduce the usage of power and thus maximize the usage of solar power which is a renewable source of energy. Furthermore, by applying the solar PV, the incubator can be placed in the areas that are not connected directly to the national grid system. Apart from that, to further fully utilize the system, this project uses the technology of "Internet of Things" (IOT) that allows the poultry breeders to control and monitor the process in distance by using the internet optimally in doing their job. The integration of Arduino microcontroller technology which is combined

with temperature and humidity sensors, light sensors, motor servo, webcam, and relay to produce a control and monitoring system of poultry eggs incubator machine which can be accessed through the website. As the ultimate objective of this project, a complete system of poultry eggs incubator with the integration of PV energy system and IOT technology will benefit the egg breeder as a whole in the technical aspects. This system will able to help the poultry industry that has experienced positive trends in the artificially hatched eggs which will enable poultry farmers to increase production volumes to fulfil the market demand.

ABSTRAK

Projek ini menerangkan reka bentuk sistem kawalan dan pemantauan inkubator telur unggas yang dikuasakan sepenuhnya oleh sistem tenaga solar (PV). Inkubator telur unggas dapat dijumpai dengan mudah dengan banyak jenis ciri-ciri yang ditawarkan dengan jumlah kapasiti penetasan yang pelbagai, tetapi beberapa inkubator masih berfungsi secara manual. Kestabilan suhu dan kelembapan untuk penetasan telur ayam akan kurang berkesan sekiranya pemantauan dilakukan secara manual. Pengendalian manual tidak lagi berkesan untuk penternak ayam kerana ianya menghabiskan banyak masa. Oleh itu, ia memerlukan alat inkubator telur unggas moden yang memudahkan petani mengawal dan memantaunya bila-bila masa dan di mana sahaja. Sebagai penyelesaian, satu kaedah baru disarankan bagi reka bentuk inkubator telur unggas yang dapat digunakan untuk penetasan telur menggunakan tenaga PV sebagai bekalan kuasa dan sekaligus dapat mengurangi penggunaan tenaga dan dengan demikian dapat juga memaksimumkan penggunaan tenaga suria yang merupakan sumber yang boleh diperbaharui. Selanjutnya, dengan menggunakan PV suria, inkubator dapat ditempatkan di kawasan yang tidak terhubung langsung ke sistem grid nasional. Selain itu, untuk memanfaatkan sistem ini dengan lebih lengkap, projek ini menggunakan teknologi "Internet of Things"

(IOT) yang memungkinkan penternak unggas untuk mengendalikan dan memantau proses dari jarak jauh dengan menggunakan internet secara optimum dalam melakukan tugas mereka. Integrasi teknologi mikrokontroler Arduino yang digabungkan dengan sensor suhu dan kelembapan, sensor cahaya, servo motor, kamera web, dan relay untuk menghasilkan sistem kawalan dan pemantauan mesin inkubator telur unggas yang dapat diakses melalui laman web. Sebagai objektif utama projek ini, sistem inkubator telur unggas yang lengkap dengan penyatuan sistem tenaga PV dan teknologi IOT akan memberi manfaat kepada pembiakan telur secara keseluruhan dalam aspek teknikal. Sistem ini juga akan dapat membantu industri unggas yang mengalami perubahan positif dalam buatan penetasan telur yang akan membolehkan penternak unggas meningkatkan jumlah pengeluaran untuk memenuhi permintaan pasaran.

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Last but not least, many thanks goes to my supervisor, Dr. Yusmarnita Binti Yusop whose have given her full effort in guiding the team in achieving the goal as well as his encouragement to maintain our progress in track. I would to appreciate the guidance given by other supervisor as well as the panels especially in the project presentation that has improved our presentation skills by their comment and tips.

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LIST OF SYMBOLS AND ABBREVIATIONS

LDR	:	Light Dependent Resistor
IoT	:	Internet of Things
DC	:	Direct Current
AC	:	Alternating Current
PV	:	Photovoltaic
OLED	:	Organic Light Emitting Diode
LCD	:	Liquid Crystal Display

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter presents an overview of the project. This chapter will explain about the project, objectives of the project, problems statements, and scope of project, methodology and the outline report.

1.1 Background of project

Poultry egg incubator is an insulated enclosure with in which temperature, humidity, and other environmental conditions can be regulated at level optimal for growth, hatching or reproduction. The poultry egg incubator are used to keep the fertilized eggs of poultry warm until they are ready to hatch.

There are three main importance factors that are included in incubating egg artificially. The elements are temperature, humidity, and turning. The most crucial element among the factors are temperature. However, humidity tends to be overlooked and causes many hatching problems. Extensive research has shown that the optimum incubator temperature is 38°C when relative humidity is 65% to 75% percent. The concentration of oxygen should be above 20 percent, carbon dioxide should be below 0.5 percent, and the air movement past the egg should be 12 cubic feet per minute [1].

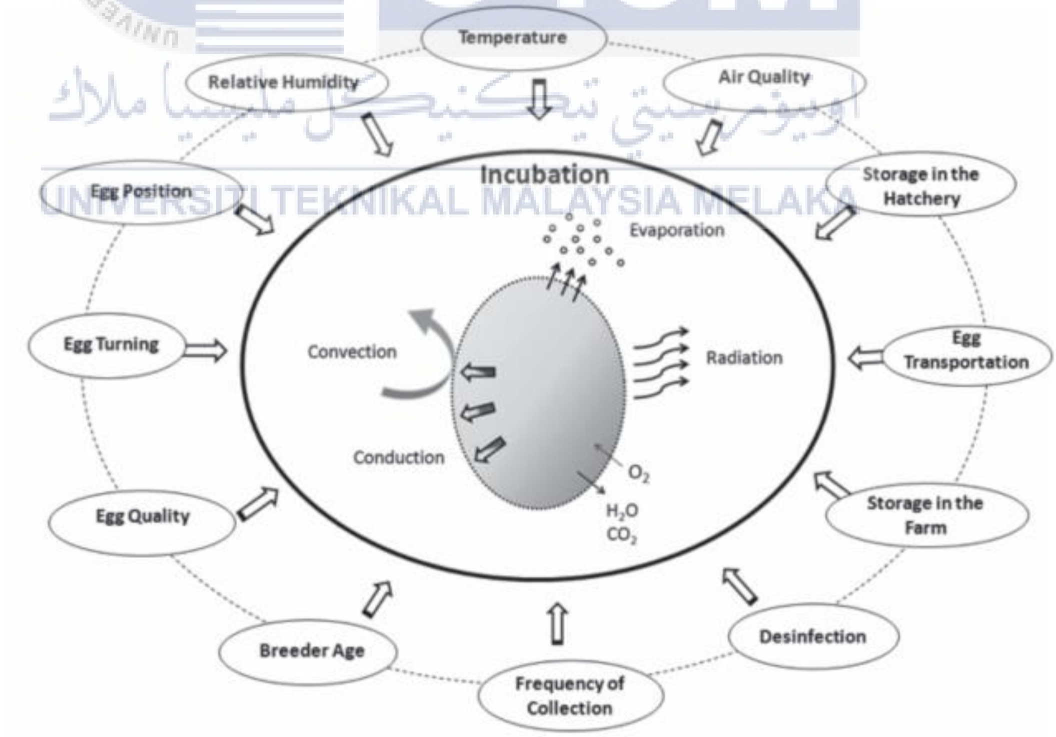


Figure 1.1: The elements involved in incubation period of the poultry egg.

Poultry egg incubator that are using manual system operations contribute to lot of disabilities includes it spends much of time for the poultry farmers to monitor and control their egg incubator. Therefore, the modern egg incubator tool will be built in order to make it easier for the poultry farmers to control and monitor their incubator anytime and anywhere. This kind of system will capable for the poultry farmers to save their time. As a solution, new method of poultry egg incubator design is suggested which could be used to hatch eggs using solar Photovoltaic (PV) as a power supply and hence could reduce the usage of power and thus maximize the usage of solar power which is one of the renewable source of energy.

Besides that, applying the solar Photovoltaic (PV) will enable the incubator to be place in the area that are connected directly to the national grid system. In addition, to further fully utilize the system, this project uses technology Internet of Things (IoT) that allows the poultry breeders to control and monitor the process in distance by using the internet optimally in doing their job. The integration of Microcontroller Arduino technology which is combine with certain input and output integration such as temperature and humidity sensors, stepper motor, webcam, and relay to produce a control and monitoring system of poultry egg incubator machine which can be accessed through the website.

As the ultimate objective of this project, a complete system of poultry egg incubator with the integration of PV energy system and IoT technology design will benefit the egg breeder as a whole in the technical aspects. This system will able to help the poultry industries that has experienced positive trends in the artificially hatched eggs which will enable poultry farmers to increase the production volumes to fulfill the market demand.

1.2 Problem Statement

The project research comes out from several problem statement gain from the previous research and study to get the idea of the implementation for the poultry egg incubator. Based on the study, there are several problem statement can be made in order to perform the implementation in designing the poultry egg incubator. The problem statement are as follows:

Problem Statement 1:

In order to maintain the time quality of the poultry farmers to monitor and control their incubator, the poultry egg incubator will be design with automatic features of control and monitoring system for temperature, humidity and turning point of the egg shell.

According to research conducted by M. E. Schmitt. D in 2015, the most reasonable poor hatches process occur in manual incubator system is due to the uncontrolled temperature set by the poultry farmers and users until the temperature is unstable, which is the temperature is too high, too low, and too variable during incubation period.

Besides that, according to research supported by O. E. Aru in 2017 stated that the unstable condition of the humidity on the surroundings of the egg shell in the incubator also be the reason for the fail in hatchery process.

Thus, the automatic control system for the user to control the temperature and humidity by their phone and computer will be design in poultry egg incubator system.

Problem Statement 2:

In order to monitor the condition of the hatchery process in incubator, the design of poultry egg incubator will be focuses on interface camera monitoring system for the user to monitor the condition of the incubator frequently without they need to be there.

According to A. M. Mohammad Adid by his research in 2016, the hatchery process that are done by using incubator system needed lot of time for the user to monitor the egg condition especially during first and second period of the incubation process. This is important to ensure the egg embryo will gain enough amount temperature and surrounding humidity to avoid from the egg embryo to die in its process cycle.

Problem statement 3:

In order to make sure the amount of temperature and humidity will be spread evenly among the egg shell, the poultry egg incubator will be design with turning process for the egg shell in certain of time daily.

According to research conducted by M. S. Wahab and H. P. Lim in 2017, the egg shell of the poultry egg need to have equal amount of the temperature in order for the egg being fertilized smoothly. The unequal amount of the temperature spread among the egg shell will disturb the hatchery process and unfortunately will make the egg embryo to die during incubation process.

Thus, the turning process for turn the egg shell will be design in the poultry egg incubator to make sure the egg embryo will having its incubation process smoothly.

1.3 Objective

The objectives of this research project are summarized as follows:

i. To design a poultry egg incubator control and monitoring system with integration of photovoltaic (PV) energy system and IoT Technology.

ii. To analyze the proposed system performance in term of poultry egg hatching percentage and overall system efficiency.

1.4 Scope of work

The scope of this project is to design a poultry egg incubator system which the system can be control and monitor by the user. A control and monitoring system has to be designed where it works with the aid of Arduino Microcontroller. In this project, the IoT devices will be use interface with the Arduino Microcontroller as the signal of transmitter and receiver.

In this project, the solar power will be used as the main power supply for overall system. The solar supply will having specifications of 18W of maximum power together with the solar charge controller, Inverter and DC battery of 12V, 7AH.

The input contribute to fulfill the design of poultry egg incubator are temperature and humidity sensor and LDR sensor.

The output use to control and monitor the process in incubator system are relay, bulbs, fans, servo motor, and USB Web Camera.

The expected final prototype in this work expected for this project to able in monitor and control by using the output that will be located in the incubator.

1.5 Report Structure and Arrangement

To complete this thesis, 5 requirements need to be complete which are Introduction, Background Research, Methodology, Result and Discussion, and the last chapter is a Conclusion and Further Development of the project.

Chapter 1 is about the introduction of the project. Discuss on basic idea of the project, the objective and overall view about the project.

Chapter 2 is about the background research related with the current research in order to gain the comparison and research gap between the projects.

Chapter 3 is about the design and methodology of the project. General concept of the project like the component that have been use to the project

Chapter 4 is about the analysis all the result and the limitation barrier in completing this project.

Chapter 5 is consists of the conclusion and recommendation of the project.

CHAPTER 2

BACKGROUND STUDY

In completing this project, some background researches has been done on several resources. The theory and description plus details about the project have taken as guidance in completing this project. By this chapter, an overview of some application that similar to the project and related project design is present.

The first part of this background study will begin with the overview of Control and Monitoring System. It will be based on the concept, working principle and equipment.

The overall layout of this background study will focuses on previous research, the table of comparison and the gap research between current research with the another research.

2.1 Overview of the Poultry Egg Incubator

Poultry Egg Incubator is one of the device and system for incubation and hatchery process for fertile egg. Incubation is the process occur in the poultry egg incubator system.

Incubation is known as the process of applying heat to eggs and control of this process is critical for successful hatching. Most of the poultry applying heat to their egg by sitting on them. By using the incubator, the process of incubation will take parts for around 21 to 27 days.

2.1.1 Incubator Parameter during Hatching Process.

Temperature and Humidity are the two main factors and elements that take parts in successful of the egg fertilization. Table 2.1 shows the ideal parameters of the temperature and humidity of the incubator.

Table 2.1: Temperature and Humidity during 21 days of incubation process.

Optimum Temperature	Temperature Range	Relative Humdity (Day 1-17)	Relative Humdity (Day 18-21)
38°C	37.5°C – 38.5°C	65% - 75%	70%

Table 2.2 provides the data of the Incubation process for different types of the poultry eggs. The data shown the different parameters in terms of incubation days, the temperature and humidity needed by each of the types of the poultry eggs. From the data that has been shown, the range of the incubation process take place for 14 days up to 42 days which means around 2 weeks up to more than a month. Besides that, the range of temperature is set are 38°C up to 38.2°C and humidity is around 32% up to 75%.

Table 2.2: Temperature, Humidity and Days parameters for incubation process with various kind of eggs.

Common Name	Incubation Process		
	Days	Temperature (°C)	Relative Humidity (%)
Chicken	21	38	65-75
Duck	28	38	58-62
Dove	14	38	58
Domestic Goose	30	38	60
Lovebird	22-25	38	58-62
Parrot	18-28	38	58-62
Pigeon	17-19	38.2	58
Swan	33-37	38	58-62
Turkey	28	38	54-58
Ostrich	42	36	32-40
Quail	23	38	54-58
Raven	20-21	38	58-62

2.1.2 Incubation Revolution

Artificial egg incubation system development allowed the transition from manual incubation to large incubation machines and hatcheries, which contribute much greater number of eggs using less labor result in increasing the chick production throughout the year. Several elements such as heat, moisture, the air renewal of the incubation environment as well as the egg turning were take parts into consideration for the principle of artificial egg incubation. Based on historical record by Paniago in 2005 and supported by Van Den Sluis in 2011 stated that in ancient Egypt, eggs were incubated in mud-brick buildings which is known as incubation house divided in incubation chambers similar to oven separated by a central hallway and accessible through manholes. In this incubation system, the main elements which is temperature within the incubation chambers was managed by controlling fire intensity and opening the manholes, vents, and the hallway. The humidity was controlled by placing moistened jute on eggs, which were manually turned twice per day.

2.1.3 Temperature and Humidity during Incubation process

The egg embryo need specific amount of temperature and humidity in hatching process. The fertile egg should be stored between 37.5°C to 38.5°C. If the fertile egg reaches temperature above 38.5°C, the egg embryos will develop and growth abnormally, weaken and die. Besides that, if the embryos stored below 37.5°C, it will contribute to the high risk in embryo mortality. The room temperature is generally too warm and the refrigerator is too cold for storing the fertilize eggs.

Humidity is one of the important factor contribute to the development and growth of the egg embryos. The best amount of humidity for the fertilize egg to be stored is between 65 to 75 percent of the relative humidity. The condition of very low and very high than the ideal range of humidity will affect the egg embryos. The high humidity can cause condensation to form on the egg shell. This can clog the pores on the egg shell and cause contamination the same way washing does. Clogging the pores can also suffocate the embryo. The low humidity can make the egg lose internal moisture and kill the embryo.

2.1.4 Position and Turning Eggs during process.

The position and turning eggs is important in order to make sure the condition of the egg shell is in the right position for the egg to fertilize smoothly. During 10 days of incubation period, the position of the egg need to be in flat condition. This flat position need to be maintain at least for a week up until 10 days of the process. The position of the egg need to be change up to 45 degree when the incubation period comes to more than 10 days. The process of turning the egg need to be done at least twice to four times daily, which means that around every 6 or 12 hours.

2.2 Overview of Control and Monitoring System

Control and Monitoring system is one of the real-time system that can react quickly enough to data input to affect the real world [1]. The output of the system must be produced quickly enough to produce on the effect on the outside world before that world has enough time to change [1]. A controlling system typically comprises of a microcontroller and control program which handles data from sensors and sends signals to output devices and an interface box to convert signals between the sensors and the processor [1].

2.2.1 Solar Photovoltaic Panel System

The increasing political and environmental problems associated with fossil fuels are the main disadvantages of this energy exploitation. The use of solar photovoltaic systems to convert solar energy from sunlight into electricity is a way to overcome these difficulties and meet the growing worldwide demand for electricity. This clean technology has inspired the performance of various systems designed to monitor the solar photovoltaic panel and maximize low cost photovoltaic production. The photovoltaic monitoring system collects and analyzes the number of parameters measured in a photovoltaic panel to monitor its performance. As for this project, photovoltaic panel will be connected to small single board computer which is and solar controller are conducted to make sure the ability amount of power consumption and also to make sure correct value of power for solar panel.

Figure 2.1: Solar Photovoltaic Panel System

2.2.2 DC to AC inverter

Inverter is one of the crucial role in solar system and it is function as main parts in any project related to solar energy. The real function of solar inverter is to invert Direct Current (DC) power source into Alternating Current (AC) power source. This is because AC is the standard uses of commercial appliances, which is many view inverter as the gateway for between the Photovoltaic system and the energy off taker. The solar inverter also have many types of power consumed based on the project needed to be done. Example of power consumed by the solar inverter are 200 Watts, 500 Watts, 1000 Watts and 2000 Watts.

Figure 2.2: Dc to Ac Inverter

2.2.3 Sensors

A sensor is an input devices that captures physical data. It converts physical quantities into electrical voltages [1]. The examples of sensors is thermistors which converts temperature to resistance, microphone which converts sound to voltage, variable resistor which converts angle position to resistance, and LDR which converts light brightness to the resistance [1].

2.2.3.1 Temperature and Humidity Sensor

Temperature and humidity sensor is one of the components that containing two features parameters in measuring the surroundings performance in terms of temperature and humidity. There are several components and devices used for temperature and humidity sensor in industry such as DHT11, DHT22, LM35, DS18B20, BME280, and BMP180. The difference of the sensor types having difference features in terms of supply voltage, temperature and humidity range, languages libraries used for the code program.

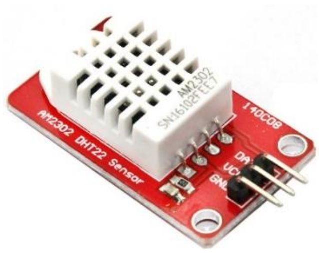


Figure 2.3: Temperature and Humidity sensor

2.2.4 Relay Module

Relay is one of the electronics component that is defined as an electricity operated switch. The main function for relay is to control circuits by a low power signal or when several circuits must be controlled by one signal. There are many types of relay module channel such as single channel relay module, dual channel relay module and four channel relay module. For dual channel relay module, the relay is designed to allow and controls two relays in a very simple and intuitive manner. Besides that, dual channel relay module also is compatible with Arduino where the most immediate way to use it is to connect the relay module to an Arduino board using flexible jumper. Another characteristics of relay module is it is possible to controls motors, inductive loads and other devices. Relay module channel consumed 5V for its supply voltage, and 144mA for its supply current.

Figure 2.4: 2 Channel Relay Module.

2.2.5 Servo Motor

Servo motor is used with servo driver to complete the servo system. The servo motor includes the motor that drive the load and a position detection component, such as an encoder. The servo motor system varying in the controlled amount such as the position, speed and torque according to the set target value to precisely in controlling the machine operation. There are three sections contribute in applications of servo motor which is the command section, control section and the drive and detection section. Besides that, servo motor have three kind of loop includes the fully-closed loop, semi-closed loop and the open loop.

Figure 2.5: The servo motor.

2.2.6 Webcam

Webcam is one of the device that capable to be integrate with electronics project as monitoring system that can be seen through any website in World Wide Web. The parameters is easy to handle as it using any USB port, integrate with Wi-Fi connection. The function of the webcam can be used as image capture or video representation to monitor the condition of the surroundings.

Figure 2.6: The webcam module.

2.2.7 Arduino Microcontroller

Arduino is device used as microcontroller to control any input data and signal that is given by code program that is been set in the software implementation such as arduino IDE. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can be communicated with software running on your computer. The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free. The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment. [2]

Figure 2.7: The Arduino Uno.

2.2.8 Node MCU ESP8266

Node MCU is the open source LUA based firmware developed for ESP8266 Wi-Fi chip. It is the low-cost open source for the Internet of Things (IoT) platform. It has the analog and digital pin for input and output of the board and support for serial communication protocol such as UART, SPI and I2C. The ESP8266 can be program by using the ESplorer IDE and arduino IDE. In term of languages, the ESP8266 can be program using LUA language or C++ language.

Figure 2.8: The Node MCU ESP8266 Module.

2.2.9 ESP32 Cam Module

ESP32 Cam module is the small size and low power consumption camera module based on ESP32. It comes with OV2460 camera and provide onboard TF card slot. It was used widely in IoT platform project and applications for image and video monitoring system.

Figure 2.9: The ESP32 CAM module.

2.3 Internet of Things (IoT)

Internet of Things (IoT) is the network of physical objects accessed through the internet, as defined by the technology analyst and visionaries. These objects containing the embedded technology to interact with internal states or the external environments [3]. There are few applications that are using the Internet of Things in industry such as the transportation or logistics, the smart home application, the smart factory application, also in the retail and health industry application.

2.4 Previous Research

In order to study and investigate the important parameters, the best design of the poultry egg incubator that will perform the best incubation process and high in hatching percentage, the research will be carried out on several last research analysis that has been done by previous researcher that are likely similar to the design of the incubator that run their project with control and monitoring system. There are five last research that has been study which is contribute to the different design of incubator including the system used, the range of temperature and humidity consumption, the integration system that will be used and the performance of their egg incubator.

2.4.1 Monitoring Incubator Space of Chicken Telemetry-Based Chicken Hatching Using Arduino Uno R3.

In view by the authors (*Gusti Putu Sila Adnyana, Nyoman Piarsa, Kadek Suar Wibawa, 2018*), this research is to make a device that is used to measure the temperature in the eggs incubator and the data will be send telemetrically. The device will provide the the data anytime it was needed and this will give the advantage to poultry farmers to monitor their incubator anytime and anywhere they are.

Based on the research by author, the device having two parameters which is the receiver and transmitter. Arduino Uno R3 integrate with RF Module Board 433Mhz will be functions as the transmitter to process signal data from temperature sensor before it will be send to the receiver. The weakness of the research was the limitation of distance that is caused by the radio wave. Besides that, the data only used temperature without humidity elements and even the control system is not using in this project research.

2.4.2 Development of Cloud Based Incubator Monitoring System using Raspberry Pi.

Based on the project by author (*Sruthi, B. M. S. Jayanthy, 2017*), the project are made with the function to monitor the temperature and humidity of the incubator system by using the raspberry pi microcontroller. The output of the research project will using incandescent bulb as heating elements for automatic temperature control. In order to monitor and control the heating elements, the integration of DHT11 sensor with Raspberry Pi microcontroller has been set together. The egg will be turn using stepper motor as the output elements. The Internet of Things that has been used in this project is the researcher using the android app to control the intensity of the light by varying the cycle of PWM remotely. The difference was shown at temperature control through Android application by setting the intensity of the light bulb. Besides, the monitoring system that was made did not use web camera, so that users could not monitor the condition inside the incubator machine itself.

2.4.3 Development of an Automatic Bird Egg Incubator.

From the research by (*Shittu S., Abu Bakar Saddiq Muhammad, Muyiddin Jimoh, Abu Bakar Sani Muhammad, Jimoh N. Olaunkanm,2017*) stated that the aim of project is to develop an automatic egg incubator and hatchery system with automated humidity and temperature control. The main study of this research is to improve the design of incubator system that is capable to hatching large number of chicks at a time and also attaining high hatchability. The main device used for heating process are 3 sets 60W of bulb to provide the warmth needed in the incubator. Data from the sensor will be sent and processed by PIC16F877A and the various control elements were activated to moderate the condition in the incubator by using C codes. The main supply for the system was powered by electricity from the national grid. The range of temperature used in this system are 37°C to 38°C and the humidity is in range of 32 percent to 35 percent. Besides that, in this research work by author, a cost-effective embedded model of a bird incubator was developed that contains a smart sensor for monitoring temperature and humidity. It was incorporated with mechanical egg tilting mechanism for tilting the egg at an angle of 45° alternatively on hourly basis. The energy used in this system is around 200W on power consumption.

2.4.4 Egg Hatching Incubator Using Conveyor Rotation System.

The study has been made by author (*Mohd Badli Ramli, Hong Peng Lim, Md Saidin Wahab, Mohd Faiz Mohd Zain, 2015*) has an aim to design and develop a force air system of egg incubator to incubate various types of eggs through a conveyor rotating system. Temperature and humidity elements has been control by using sensor located in the incubator. Most of the material used for designing the incubator is by using the stainless steel elements. The design of incubator is set to encourage various kind of eggs to be put in the incubator. The microcontroller has been used via LAB VIEW as monitoring elements for vie the temperature and humidity. The incubator chamber has been set at 37.5°C for temperature reading and 49.86% for humidity parameter. The motor used in this system will rotate at 45° angle by using the conveyor system. This incubator project is tested using he quail eggs and perform for 94.17% of hatching percentage gained.

2.4.5 The Design of Semi-Automatic Artificial Incubator

Based on the research made by the (*Ngnassi Djami Aslain Brisco, Nzie Wolfgang, 2018*), the purpose of the research is to design an artificial incubator using simple technologies accessible to communities. The applications involved in the study are related with the process of cleaning and disinfection of hatching eggs, the adjustment of incubation temperature and humidity, the position of the eggs and their reversal in the incubator, the ventilation and mirage of eggs in the incubation. For the adjustment of incubation temperature and humidity process, this project make the incubator to turned on at least 1 hour before loading the eggs to allow for various adjustments of the temperature to 37.7°C.

2.5 Summary of Literature Review

Table 2.3 provides the comparison of the previous research that has been study to differentiate the elements involved in the system used by the last researcher for them to create and build their poultry egg incubator. Based on the table shown in Table 2.3, the difference between every research in designing their poultry egg incubator will having different parameters in term of temperature, humidity, the egg turning angle, web camera used and also the system application that has been used for control and monitoring the incubator. The result of the difference shown that the range of humidity used for the previous research is around 37°C up to 38°C with the range of humidity for 49.86% to 70%. Besides that, in term of turning angle of the egg to make sure the embryo get the temperature evenly, the angle used in previous project research is 45°. Furthermore, the system application can be categorized in three main system which is using Arduino, Raspberry Pi and PLC system.

Table 2.3: The table comparison of previous research study.

Research Title	Author	Year	Result			
			Temperature (°C)	Humidity (%)	Egg Turning Angle (°)	System Application
Monitoring Incubator Space of Chicken Telemetry-Based Chicken Hatching Using Arduino Uno R3	Gusti Putu Sila Adnyana, Nyoman Piarsa, Kadek Suar Wibawa	2018	37.7	55 to 65	None	Arduino Uno R3 interface with RF Module Board 433 MHz.
Development of Cloud Based Incubator Monitoring System Using Raspberry Pi.	Sruthi, B. M. S. Jayanthy	2017	37 to 38	60 to 70	45	Android Apps with Interface with Raspberry Pi.
Development of an automatic Bird Egg Incubator.	Shittu S., Abu Bakar Saddiq Muhammad, Muyiddin Jimoh, Abu Bakar Sani Muhammad, Jimoh N. Olaunkanm	2017	37 to 38	32 to 35	45	PIC16F877A

Egg Hatching Incubator using Conveyor Rotation System.	Mohd Badli Ramli, Hong Peng Lim, Md Saidin Wahab, Mohd Faiz Mohd Zain	2015	37.5	49.86	45	Lab VIEW
The Design of Semi-Automatic Artificial Incubator	Ngnassi Djami Aslain Brisco, Nzie Wolfgang	2018	37.7	none	None	none

2.6 Research Gap

Table 2.4 shown the research gap between the previous research and the current research for designing the poultry egg incubator control and monitoring system. In order to show the gap different between all those research in term of control and monitoring system design, the main important elements parameter has been categorized includes temperature control, humidity control, turning egg rotation control, and monitoring camera used in each of the research.

Table 2.4: The table of research gap.

Research Title	Temperature Control	Humidity Control	Turning Egg	Monitoring Camera
Monitoring Incubator Space of Chicken Telemetry-Based Chicken Hatching Using Arduino Uno R3	Yes	Yes	None	None
Development of Cloud Based Incubator Monitoring System Using Raspberry Pi.	Yes	Yes	Yes	None
Development of an automatic Bird Egg Incubator.	Yes	Yes	Yes	None
Egg Hatching Incubator using Conveyor Rotation System.	Yes	Yes	Yes	None
The Design of Semi-Automatic Artificial Incubator	Yes	None	None	None
The Design of Poultry Egg Incubator Control and Monitoring System.	Yes	Yes	Yes	Yes

CHAPTER 3

METHODOLOGY

In the methodology, it will explain the implementation and solution in doing this project. It consist the overall system and the structure needed in the system. Methods used in this project are clearly pointed out such as data collection, data process and analysis, system model and flowchart.

3.1 Introduction

In order to satisfying the objective mention in chapter 1, the project process implementation has been built to make sure the Design of Poultry Egg Incubator Control and Monitoring System project will be run as a plan. Therefore, the flow chart of project completion procedure is refined to illustrate the methodology of the study. The flow chart is quite important as it defined on how the research works done step by step.

Several planning implementation has been built in order to make sure the process of project run well. One of the step is research study by journal, internet sources, article, books and other related sources in completing the research study. The journals and article that related to this project is expected to use as an essential design and calculation of parameters in order to achieve the objectives of the project.

In simulation implementation, the solar module as a main supply that needed to be used in the project has been design by using MATLAB R2020b software with the Simulink block. The design will focuses on creating the solar module as expected parameters needed which is to design 18V of maximum output voltage and 10W of output power create by the solar module. This solar module design also focuses on analysis of the various voltage, current and output power by having various amount of irradiance and temperature for the solar module. This simulation is to analyze and ensure that the physical parameters used in prototype will get the same value of various output voltage, current and power.

3.2 Project Completion Procedure

Figure 3.1 shows the project completion procedure flowchart that will explain on the planning of the overall project procedure. In overall planning procedure, the planning will take place in several configurations including the proposed project to panel to present the idea of the project. Once the project proposal has been approved, the system of the project design will be implemented and integrate with coding program for the control and monitoring system which include the temperature and humidity and the monitoring camera that will be used as the system in the project implementation. The performance of the control and monitoring system used for this project will need the real design of the prototype in order to analyze the system performance. Lastly, the best design of incubator and overall system that has been analyzed will be presented. Therefore, this flowchart is function to show the flow process of the overall project research.

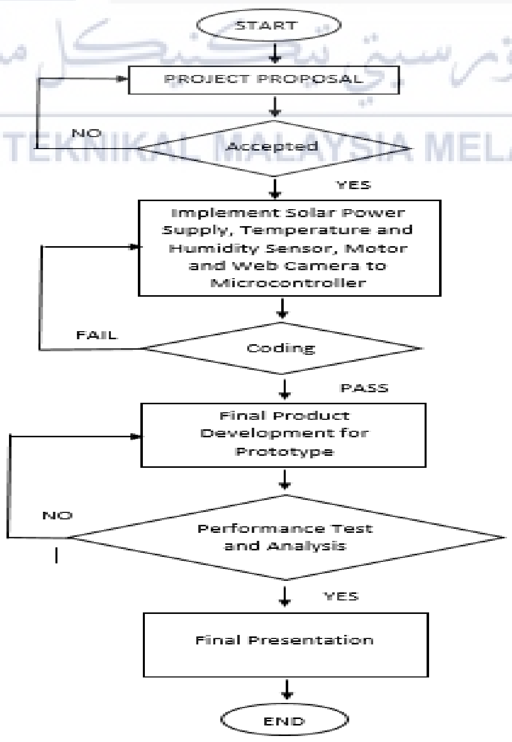


Figure 3.1: Flowchart of Project Completion Procedure.

Figure 3.2 shows the flowchart of the programming process. The process begins the programming writing. The languages chosen for this project is by using C++ language as the microcontroller use in the project using arduino that integrate with ESP8266 and ESP32 cam which all the devices are using the same languages appeared in the Arduino IDE software. The program is written in a way that it works with the designed circuit to deliver an outcome. As a result of complement, the program is tested using Arduino software. Finally, the program is attached to the circuit and the whole complete project is tested and analyzed.

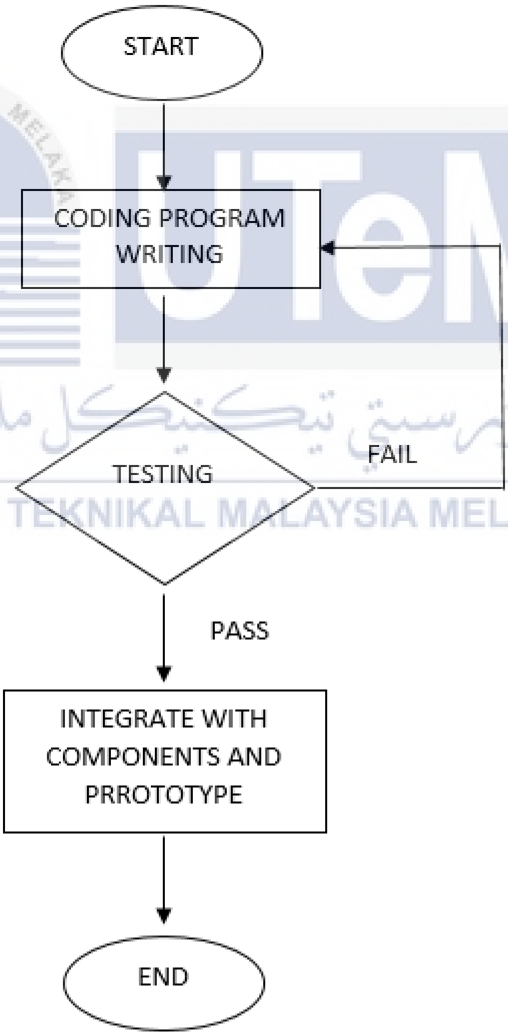


Figure 3.2: Flowchart of Coding Programming process.

Figure 3.3 shows the flowchart of the analysis solar system. The process begin with designing the solar module on the MATLAB simulation to gain the expected solar module parameters in term of output voltage and power consumption. The solar module that has been design will be integrate with prototype to analyze the value difference between output voltage gain in simulation and testing hardware part. The parameters value of output voltage and power designed in solar system is expected able to supply the power to run the prototype 24 hours.

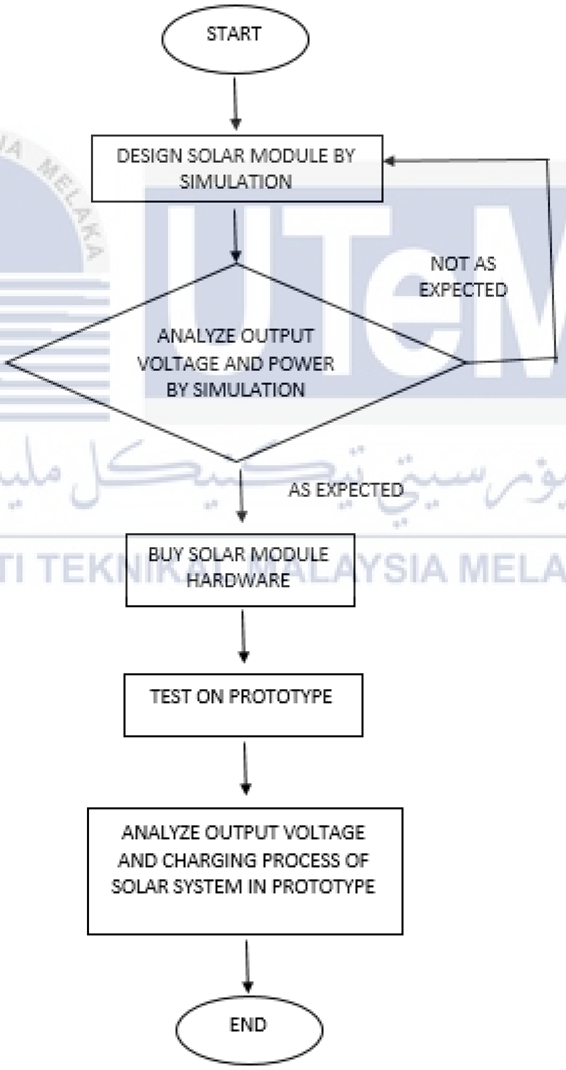


Figure 3.3: Flowchart of Analysis Solar System.

Figure 3.4 shows the flowchart of temperature and humidity system. The process start with designing the control and monitoring system for temperature and humidity by hardware implementation. The system that has been designed will be set to the prototype and calibrated with the thermometer to ensure the parameter of the sensor is a good condition before using it. The temperature and humidity sensor will be set to 38°C and 62.5% up to 72.5% respectively. Lastly, the temperature and humidity will be analyze time by time for data collection.

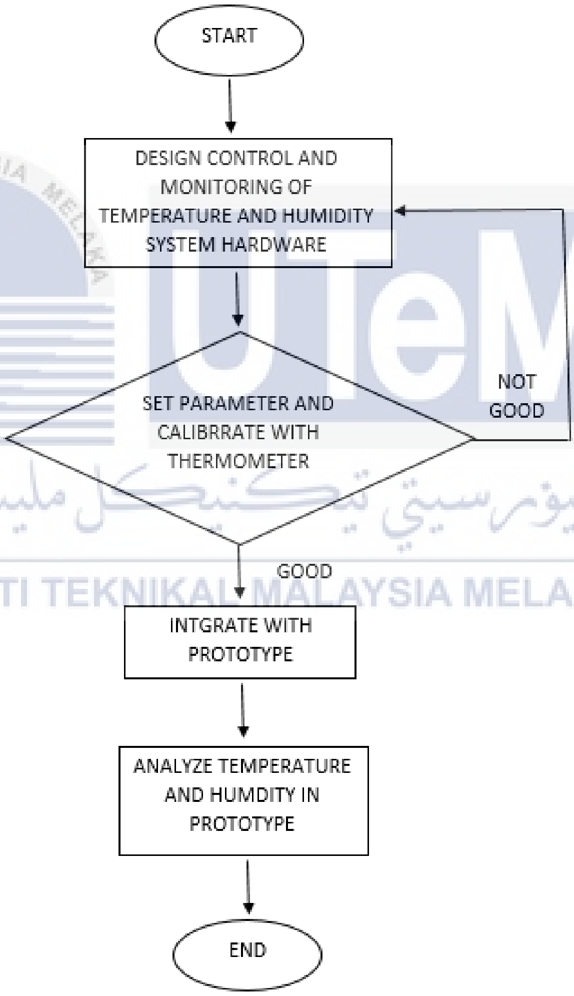


Figure 3.4: Flowchart analysis of temperature and humidity system.

Figure 3.5 shows the flowchart of hatching percentage. The process start with put the various number of egg in prototype and analyze the hatching percentage by batch number of egg that has been put. The analysis of the egg includes the incubation and hatching process involves during 21 days of the incubation period to analyze the condition of the egg shell and embryo every single day. Besides that, the hatching percentage will be categorized in certain performance indicator including the embryo that is fully hatch, the egg shell containing the embryo but cannot be hatch and the egg shell that is not having any absence of the embryo inside. All the parameters of the hatching performance analysis will be recorded in a certain of time.

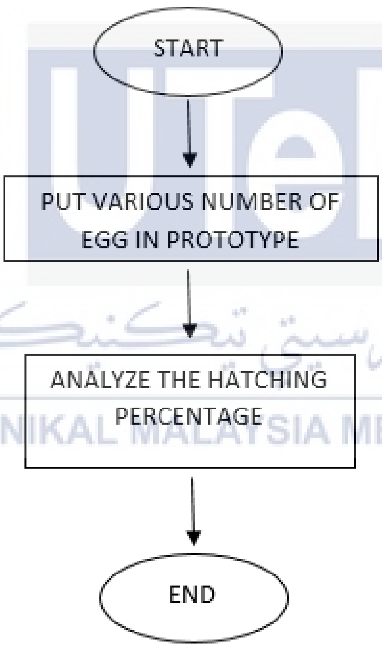


Figure 3.5: Flowchart analysis of Hatching Percentage.

Figure 3.6 shows the project block diagram that will be implemented in the project research. The power supply for the project research will be contribute on solar system supply of 10W and 18V parameters. In terms of input and output, the input of this system will using DHT22 which is temperature and humidity sensor as the input signal while several devices such as stepper motor, relay, and web camera will be function as the output of the control and monitoring system. In order to achieve the objectives of the research, the system will be integrate with IoT technology which is using the Blynk application that will integrate with microcontroller for the user to control and monitor the poultry egg incubator.

Figure 3.6: Project Block Diagram.

3.3 Research Activities.

The research activities contribute to the several stages of activities includes in the project research which is the Literature Review, Designing parameters of solar module, the simulation of the overall system, the hardware design of the project, and the performance analysis in order to perform the objectives needed by the research project.

3.3.1 Literature Review

The first stage of the project process is implementing the research study for literature review getting from journal and article related with designing of the poultry egg incubator with several features needed to make sure the egg embryos will be fertilized smoothly during incubation process. From the research that has been done, several parameters and elements that are very important in designing the poultry egg incubator system includes the temperature, humidity, egg turning process. Besides that, from the study that has been done, the most of the poultry egg needed around 14 to 50 days for its incubation period with the temperature and humidity range between 97.5° Fahrenheit to 100.5° Fahrenheit and 32 % to 62 % respectively. In addition, most of the research related to this kind of poultry egg incubator project using several microcontroller and microprocessor in order for monitoring and controlling system design. The most microcontroller used are Arduino, Raspberry Pi and also the Programmable Logic Controller (PLC).

3.3.2 Solar Module Parameter.

The solar module in this project research system expected to have the several configuration of the output voltage and power performance. The expected maximum voltage and power consumption used for the solar performance is at 18V and 10 W respectively. Therefore, to design the solar module, several parameter will be needed to get the expected solar module for this project. Five main elements needed by the solar system in performing the solar module. The elements required are photo-current, saturation current, reverse saturation current, current through shunt resistor and output photovoltaic current. The parameters of these five elements will set in terms of mathematical equation.

3.3.2.1 Photo-Current

The photo current is obtained by first solving the continuity equation for electrons

$$0 = D_n \frac{d^2 n}{dx^2} + \mu_n \varepsilon \frac{dn}{dx} - \frac{n}{t} + g_{op}$$

as well as a similar equation for holes. The photo current is obtained from

$$I_{ph}(V_{a)} = \frac{qA}{d^2}(\boldsymbol{\phi}_i - V_{a)} \int_0^d (\mu_n n + \mu_p p) dx$$

By combining the constant and variable of the solar module elements, the formula for the photo current is

$$I_{ph} = [I_{sc} + k_i.(T - 298)].\frac{G}{1000}$$

3.3.2.2 Saturation Current

The saturation current formula used for designing the solar module is

$$I_o = I_{rs}.\left(\frac{T}{T_n}^3\right).\exp\left[\frac{q.E_{go}.(1/T_{n-1/T})}{n.K}\right]$$

3.3.2.3 Reverse Saturation Current

The reverse saturation current can be calculate by

$$\boldsymbol{I_{rs} = \frac{I_{sc}}{e^{\left(\frac{q.V_{oc}}{n.k.T.Ns}\right)} - 1}}$$

3.3.2.4 Current through Shunt Resistor

The current through shunt resistor can be obtained from

$$I_{sh} = \left(\frac{V + I.R_s}{R_{sh}}\right)$$

3.3.2.5 Output Photovoltaic Current

Therefore, the total output solar current will be gain through

$$\boldsymbol{I = I_{ph} - I_o\left[Exp\ \left(\frac{q.(V + I.R_s)}{n.K.T.N_s}\right) - 1\right] - I_{sh}}$$

3.3.3 Simulation Design.

The design simulation of the system will be categorized into two main parts which is the solar system simulation design and the control and monitoring design. The simulation involved will be used as the parameters to study the analysis performance of the system before hardware implementation.

3.3.3.1 Solar System Simulation Design

In order to analyze the input power supply used in this project design, the first simulation will be focuses on designing the solar system. The simulation is done through the MATLAB R2020b software in order to analyze the specifications of solar module includes current, voltage, and power with various irradiance and temperature input from surroundings.

In a Photovoltaic System, the device used for converting sunlight to DC electricity is the solar module. In order to design the solar module, there are several specification and calculation needed to ensure the right solar module will be chosen in the project implementation. There are five elements needed to be focus which is photo current, saturation current, reverse saturation current, current though shunt resistor and output current. All of these elements have its own calculation combine with several constant and variable to make sure the best design of solar module be created.

Table 3.1 provides several parameters needed for the constant and variable in designing the solar module specification. All of these parameters will be set in simulation to perform the solar module design.

Table 3.1: The constant and variable for designing solar module.

Symbol	Name	Variable Value
I_{ph}	Photo Current (A)	I_{ph}
I_{sc}	Short Circuit Current (A)	I_{sc}
k_i	Short-circuit current of cell at 25°C and 1000 W/m^2	0.0032
T	Operating Temperature (K)	T
T_n	Nominal Temperature (K)	298
G	Solar Irradiation (W/m^2)	G
q	Electron charge (C)	1.6×10^{-19}
V_{oc}	Open Circuit Voltage (V)	V_{oc}
n	The ideality factor of the diode	1.3
K	Boltzmann’s Constant (J/K)	1.38×10^{-23}
E_{go}	Band gap energy of the semiconductor (eV)	1.1
N_s	Number of cell connected in series	N_s
N_p	Number of PV modules connected in parallel	N_p
R_s	Series Resistance (Ω)	0.221
R_{sh}	Shunt resistance (Ω)	415.405
V_t	Diode Thermal Voltage	

Table 3.2 shows the parameters and specifications for expected design of solar module. In order to get maximum output power of 10W with maximum output voltage of 18V for the solar module, several specification need to be taken. The parameters involves includes the series and shunt resistance, the open-circuit voltage, and the short-circuit current.

Table 3.2: The parameters and specification for expected design of solar module.

Parameters	Name	Value
k_i	Short-circuit current of cell at 25°C and 1000 W/m^2	0.0032
q	Electron charge (C)	1.6×10^{-19}
K	Boltzmann's Constant (J/K)	1.38×10^{-23}
n	The ideality factor of the diode	1.3
E_{go}	Band gap energy of the semiconductor (eV)	1.1
R_s	Series Resistance (Ω)	0.221
R_{sh}	Shunt resistance (Ω)	415.405
T_n	Nominal Temperature (K)	298
V_{oc}	Open-Circuit Voltage (V)	21.6
I_{sc}	Short-Circuit Current (A)	0.61
N_s	Number of cell connected in series	30

Figure 3.7 to figure 3.15 shows the simulation of solar module that has been designed using block diagram in MATLAB Software. Figure 3.7 to figure 3.11 shows the design of elements includes the photo-current, saturation current, reverse saturation current, current through shunt resistor and photovoltaic current.

Figure 3.12 to figure 3.15 indicates the result shown for provide the expected specification for 10W of output power and 18V of output voltage solar module.

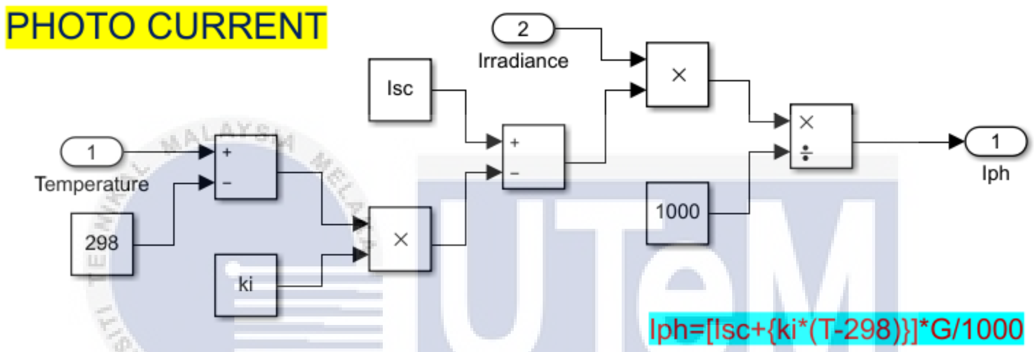


Figure 3.7: The photo-current Simulink block.

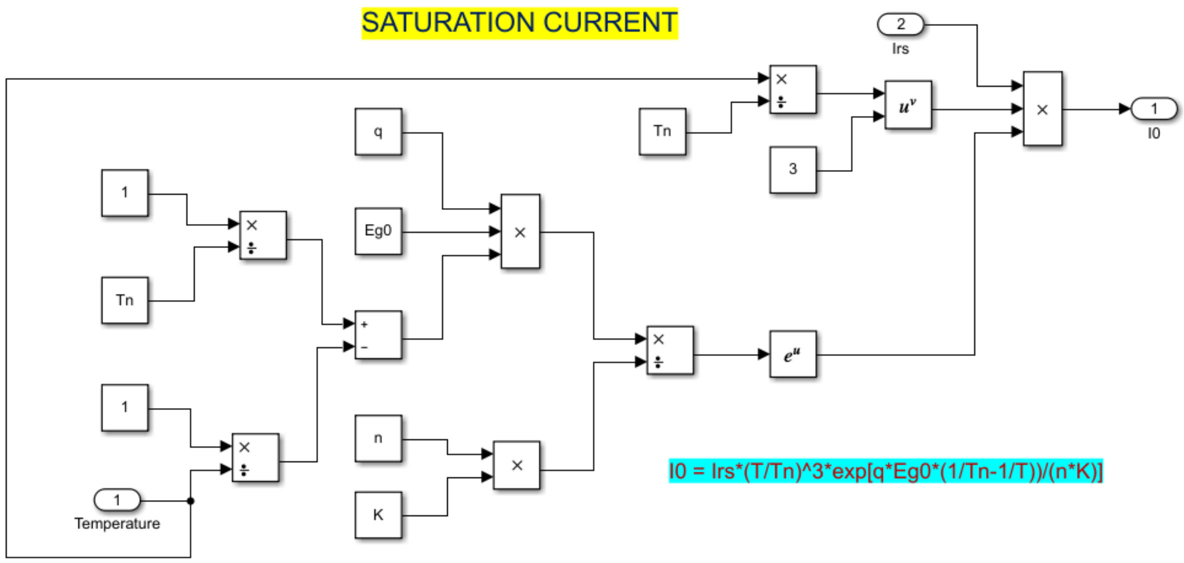


Figure 3.8: The saturation current Simulink block.

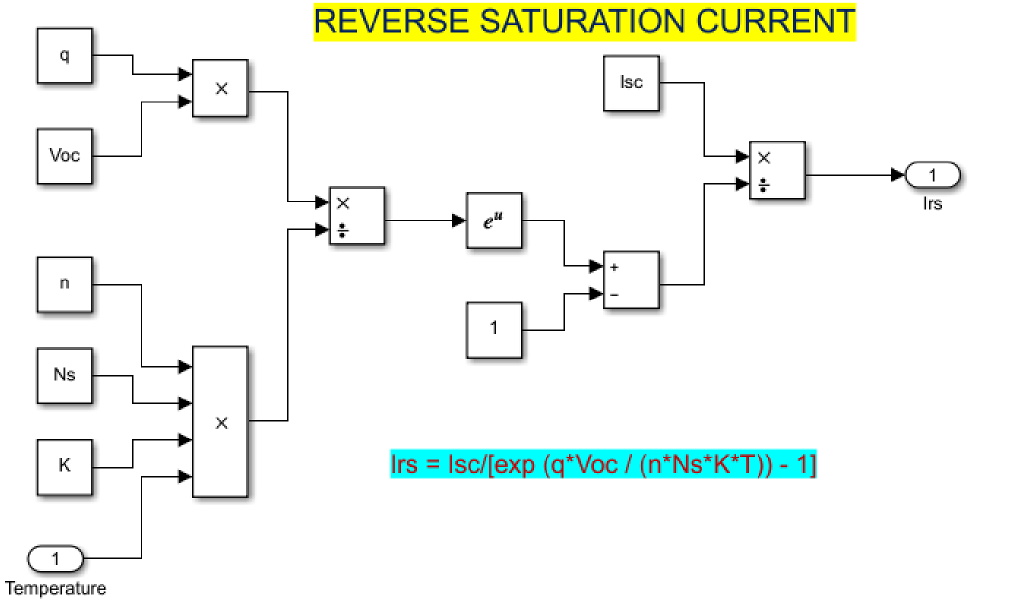


Figure 3.9: The reverse saturation current Simulink block.

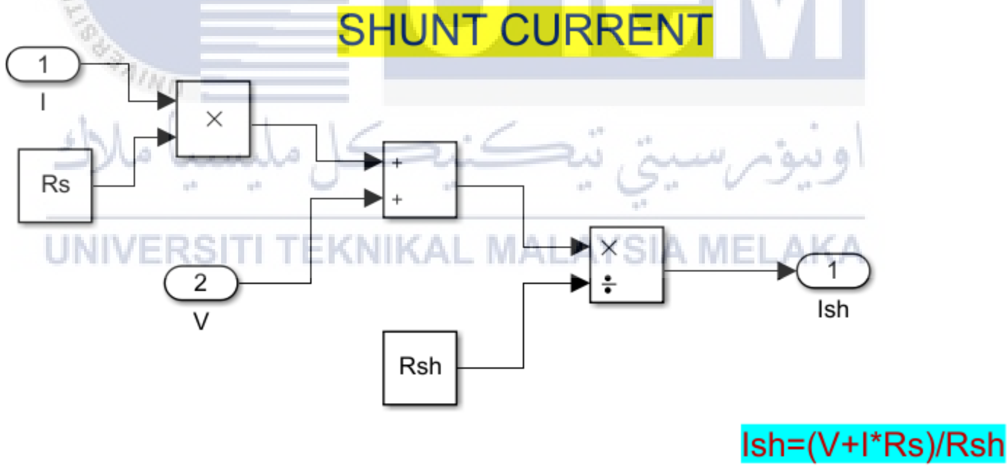


Figure 3.10: The shunt resistance current Simulink block.

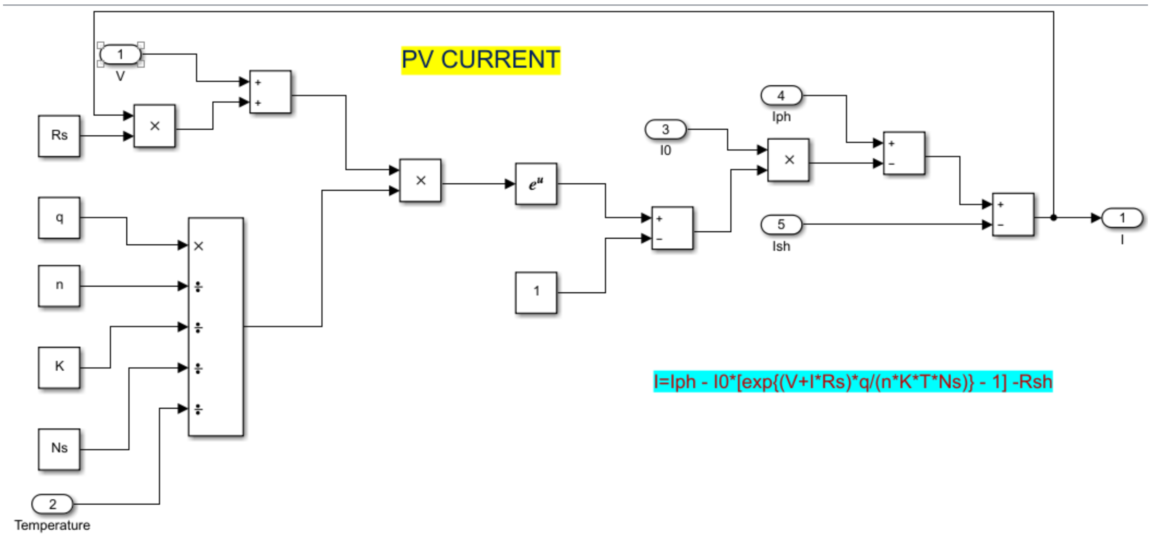


Figure 3.11: The Photovoltaic current Simulink block.

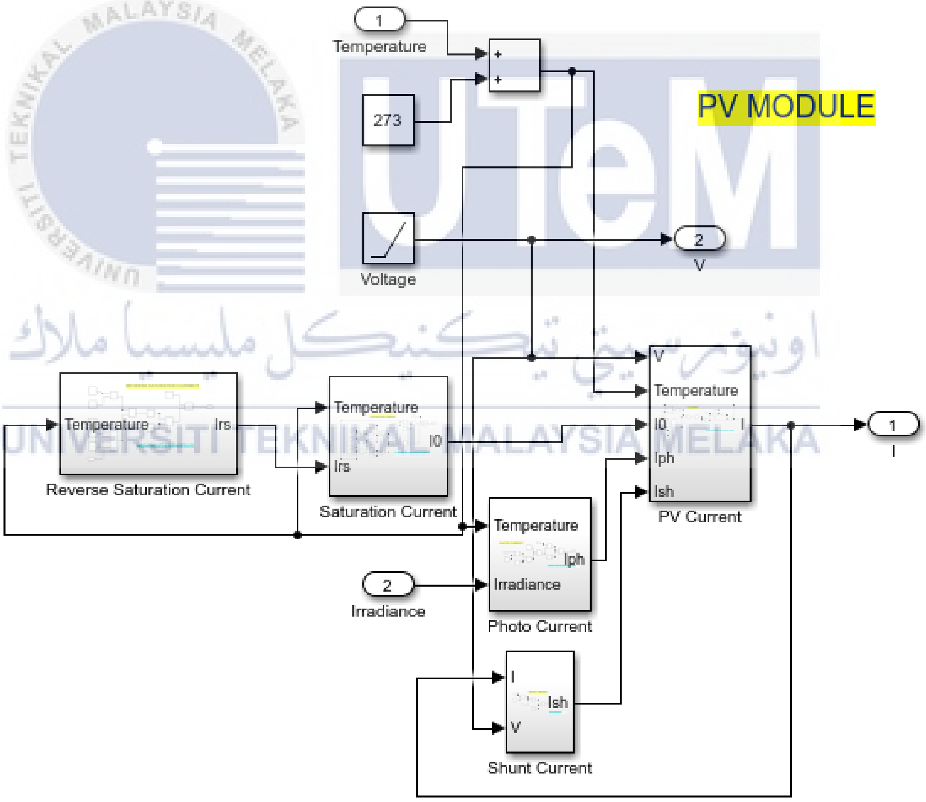


Figure 3.12: The full block of Solar Module.

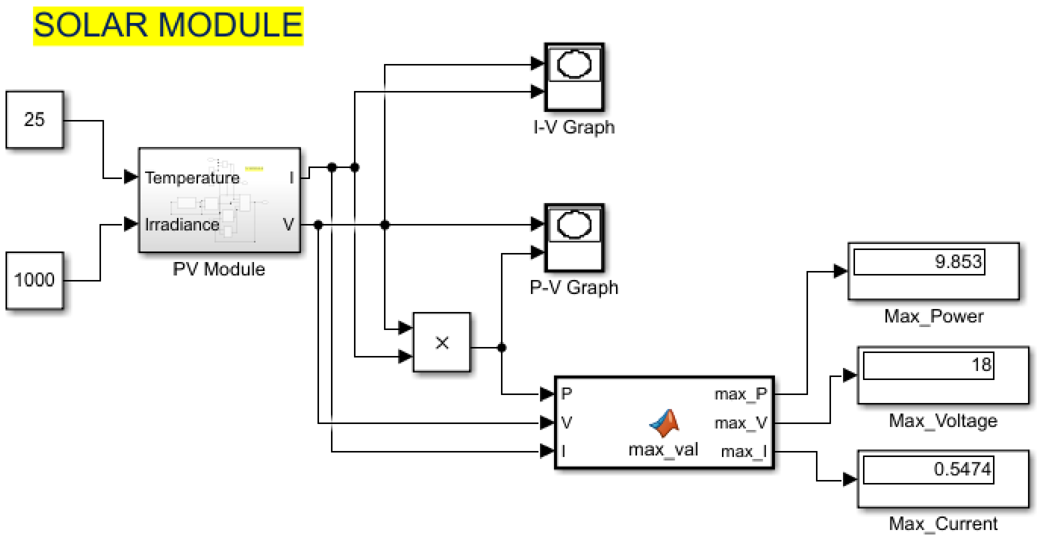


Figure 3.13: The output maximum value of solar module design.

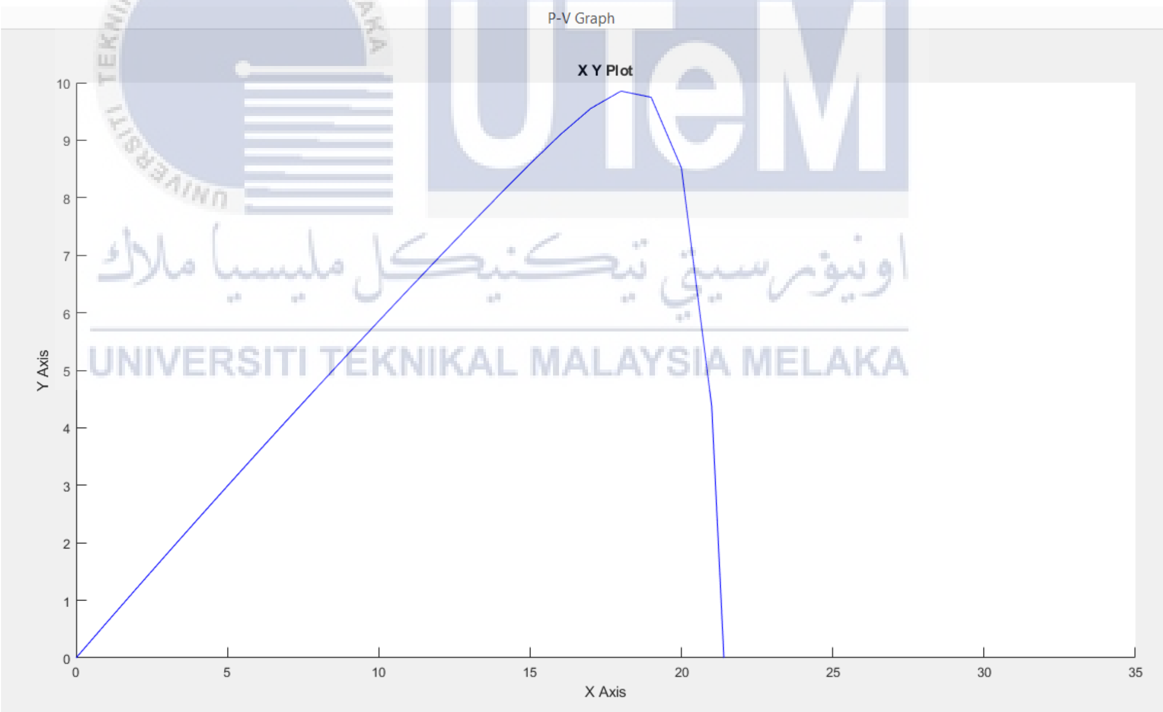


Figure 3.14: The P-V Graph for maximum specifications.

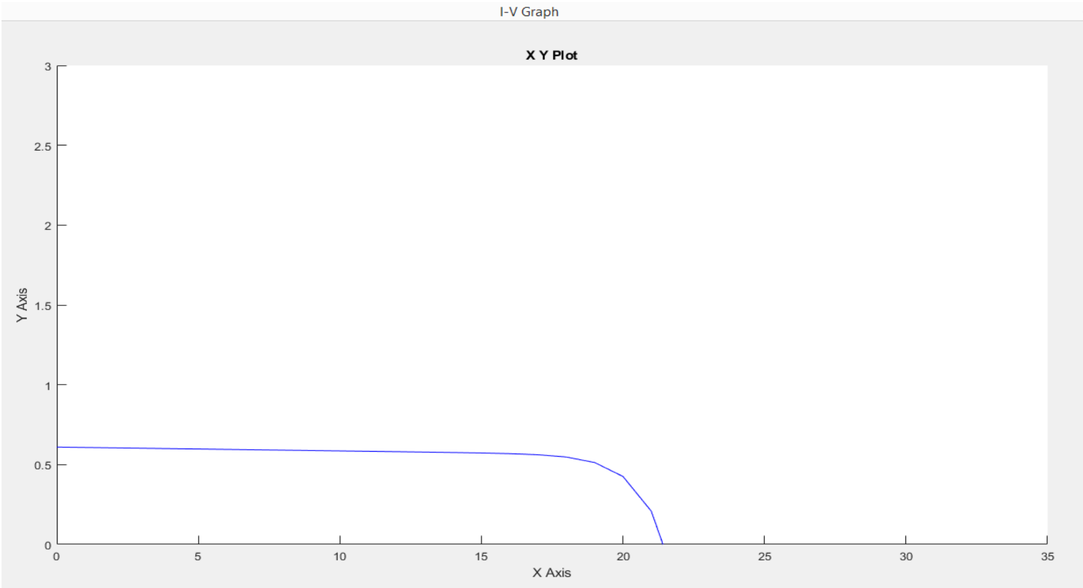


Figure 3.15: The I-V Graph for maximum specifications.

The design of solar module will having different amount of voltage and power consumption based on the variety value of the temperature in a day. Therefore, in order to expect into that situation, the analysis of simulation output power and voltage has been analyzed through simulation based. Table 3.3 provides the various output voltage and power for solar module specifications based on the various value of the temperature presence. From the simulation analysis, the lowest temperature value has been expected to analyze at 30°C while the highest value contribute to 38°C. The various range of temperature will contribute to the various range of output voltage and power consumption. Based on the table, the output power expected to have a range between 3.2W to 8.3W while the voltage expected range is between 12.2V to 17V.

Table 3.3: The various output voltage and power for solar module specification

Temperature (°C)	MATLAB Simulation	
	Output Voltage (V)	Output Power (W)
30.0	12.2	3.2
31.5	12.9	3.8
32.0	13.5	4.0
32.5	13.8	4.3
33.5	14.5	5.0
34.0	14.9	5.3
34.5	15.3	5.9
36.5	16.2	7.1
38.0	17.0	8.3

3.3.3.2 Control and Monitoring System Simulation Design.

The control and monitoring system simulation design using Fritzing software. The design has been set to two circuit diagram which is the design of temperature and humidity control and monitoring system, and the circuit diagram of live camera monitoring system design.

Figure 3.16 and figure 3.17 shows the schematic circuit diagram of the control and monitoring system for both temperature and humidity and live camera system. The circuit diagram used to be implemented in the hardware implementation.

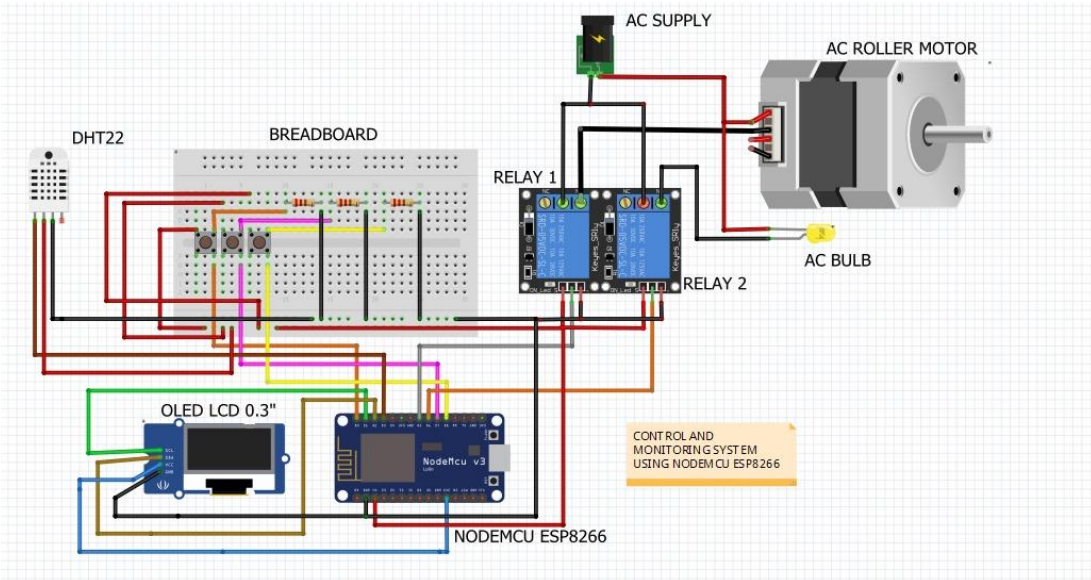


Figure 3.16: Control and Monitoring Temperature and Humidity Schematic Diagram.

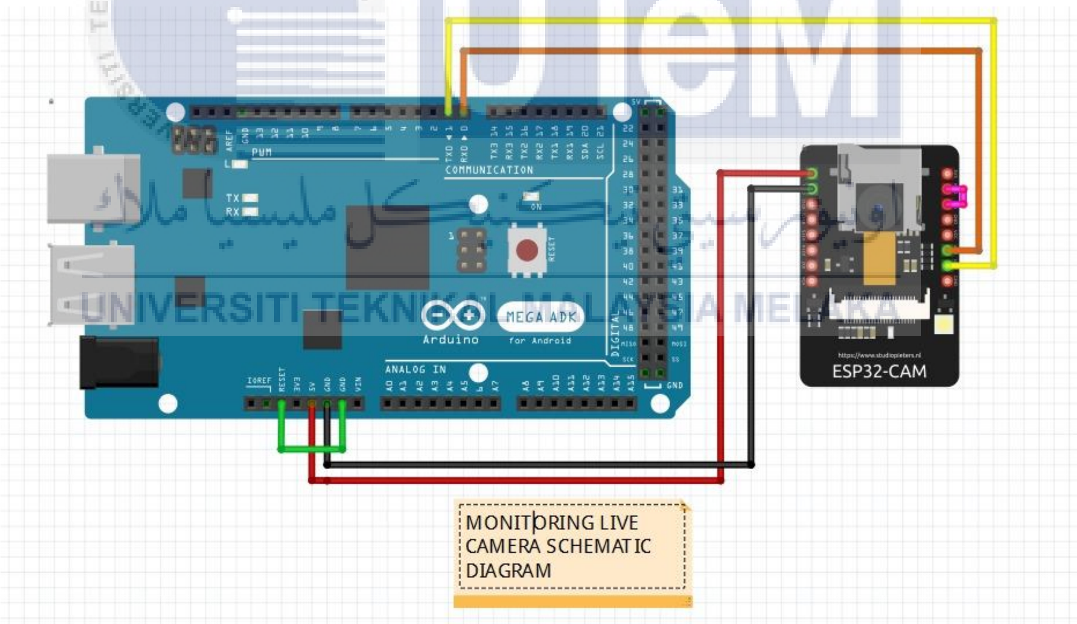


Figure 3.17: The Live Camera Monitoring Schematic Diagram.

3.3.4 Designing the Incubator.

The incubator will be planning to design in two storage box by using several materials such as woods. The first upper storage will be used to store the solar system devices and components used for the circuit implementation while the second lower storage will be the place of the incubator design to store the eggs and several output devices such as the motor, incandescent bulb, fan and temperature and humidity sensor.

3.3.5 Designing Internet of Things (IoT).

The system of poultry egg incubator will be design by using the Internet of Things (IoT) elements. Therefore, the IoT medium that will be used in the system for the user is by using Blynk application. The IoT devices will having several features in order to control and monitor the incubator. The first features configuration contribute for the user capable to monitor the reading of temperature, humidity and the condition inside the incubator via Blynk application by using their smartphone. Second features will be design the control system which enable the user to control the output used in the system which is incandescent bulb and fan. The features will be design in to main configuration which is manual and automatic system. The automatic system will run the incubator in automatic mode, while the manual system will run the system in manual mode. Therefore, the user can easily to turn ON or OFF the output devices as they want via their smartphone in Blynk application.

3.3.6 Performance Analysis on Overall Efficiency.

In order to achieve the second objective of the research project, the analysis will be made to get the data performance of the system efficiency. The overall system efficiency includes the performance of the solar system, temperature and humidity system and battery charging process analysis.

The solar system efficiency will be analyzed for its performance via collecting the data of output voltage and power consumption used for the system and be compared with simulation. Besides that, to analyze the efficiency of solar system, the battery will be analyzed on charging process performance which includes the value of the battery voltage charged based on the temperature in a day.

For the system of control and monitoring performance, the performance will be analyzed through the temperature and humidity analysis which includes the analysis of the temperature and humidity in the incubator surrounding in order to make sure the egg shell having the right amount of temperature and humidity.

3.3.7 Performance Analysis on Incubation process and Hatching Percentage.

Analysis of performance will be analyzed in second stages including the incubation process and hatching percentage. The incubation process analysis will be done through candling method which is to seen the condition of the embryo inside the egg shell for 21 days of incubation process.

Besides that, the hatching percentage analysis will take place for at least twice for the egg entry in incubator. The first and second entry of the egg will be recorded and analyzed its performance in terms of types of eggs, the date entry, the days of incubation process and the condition after 21 days of the incubation process. The hatching performance will be analyzed through three category which is fully hatch, the presence of embryo in the egg shell but cannot to be hatch and the egg that is not having any embryo presence in the egg shell.

3.4 Summary.

In a summary, the methodology involves the method used in each of the process and stages for achieve the objectives mention before. The method has been categorized in several stages which includes the previous research study, the simulation design for solar system and also the control and monitoring system, the hardware implementation for overall system and followed by the analysis performance method for overall system efficiency. Last but not least, subsection 3.3.1 to 3.3.5 is the method used for achieve the objective 1 in the research study, while subsection 3.3.5 and 3.36 is the method used for achieve the objective 2 of the research project.

CHAPTER 4

RESULTS AND DISCUSSION

Chapter 4 will explain the findings and data collected from the simulation and the realistic experimental work in details. Besides that, the analysis and the explanation will be discussed in this chapter.

4.1 The design of Incubator.

In order to make sure the process of incubating and hatching process run smoothly, the best prototype based need to be made for stability in temperature and humidity. Therefore, several equipment have been used to make sure the prototype is in a good condition before using.

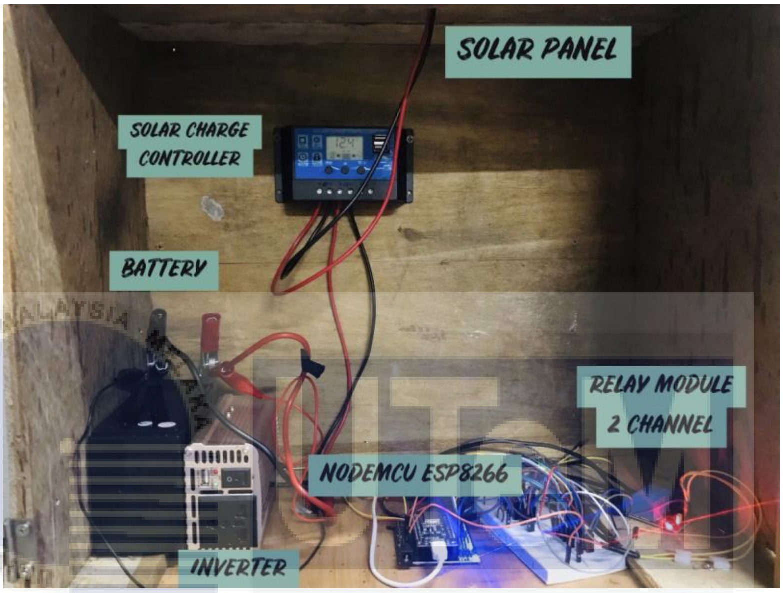


Figure 4.1: The component and solar system parts.

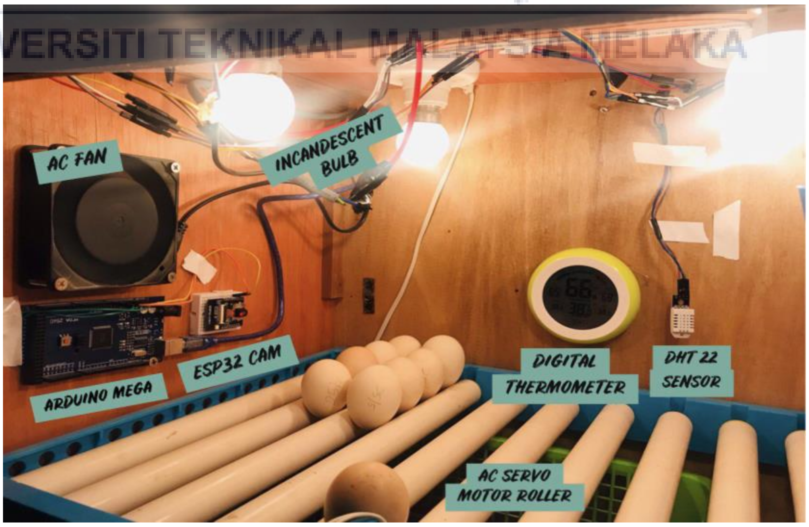


Figure 4.2: The components and parts inside incubator.

4.2 The Iot platform design.

In this research project, the Internet of Things (IoT) platform has been used to control and monitor the incubator. The IoT platform that has been take place in this control and monitoring system is by using Blynk application as the medium of IoT. The specification and parameter has been set using Arduino IDE to integrate with Blynk application. The parameter of temperature has been set to be 39.5°C. If the temperature lower than 39.5°C, the bulb will on to heat and if the temperature is higher than 39.5°C, the bulb will off to cool down the temperature. In terms of humidity, the humidity has been set to 68.5% to 72.5% of the surroundings relative humidity. Whenever the humidity below 68.5%, the fan will be on to react with water in the incubator to increase the humidity, while if the humidity reading higher than 72.5%, the fan will off until the humidity decreasing to the lower value. Besides that, in this system of incubator, the mode has two features which is in manual mode and automatic mode. Manual mode is the system where users capable to handle and control the system by using switch button located at the incubator and IoT platform using Blynk application, while in automatic mode, the user capable to monitor the condition of the incubator using camera and the temperature and humidity reading in Blynk application. In terms of the control system in automatic mode, the sensor of temperature and humidity which is DHT22 will take place as the medium to control the temperature and humidity.

Figure 4.3: The features of Blynk application in automatic mode.

Figure 4.4: The features of Blynk application in manual mode.

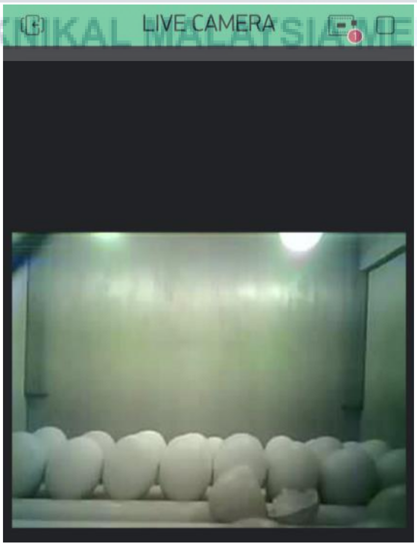


Figure 4.5: The features of Blynk application in for live camera.

4.3 Solar Efficiency Result.

The design of solar module has been simulated in figure 3.4 until figure 3.10. Based on the parameters in table 3.2, the solar module that has been designed capable to get the maximum output voltage at 18V with maximum current of 0.55A and maximum power contribute to 10W. Table 4.1 shows the various maximum output value in terms of voltage, current, and power of the solar module that has been created based on the variable of temperature.

Table 4.1: The comparison of Output Voltage and Power between Simulation and Experiment.

Temperature (°C)	MATLAB Simulation		Hardware Experiment	
	Output Voltage (V)	Output Power (W)	Output Voltage (V)	Output Power (W)
30.0	12.2	3.2	12.0	2.5
30.5	12.5	3.5	12.7	2.7
31.5	12.9	3.8	13.0	3.0
32.0	13.5	4.0	13.0	3.2
32.5	13.8	4.3	13.2	3.4
33.5	14.5	5.0	13.5	4.0
34.0	14.9	5.3	13.5	4.5
34.5	15.3	5.9	13.8	4.9
36.5	16.2	7.1	14.0	5.3
38.0	17.0	8.3	14.2	6.8

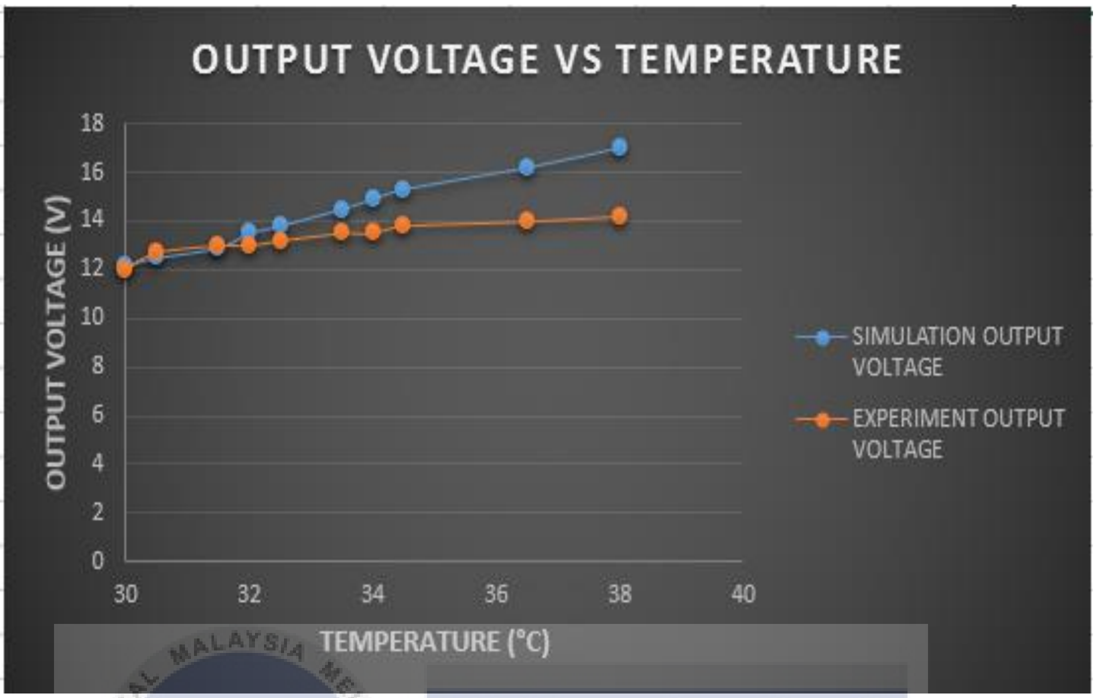


Figure 4.6: The graph comparison of output voltage for solar system between simulation and experiment.

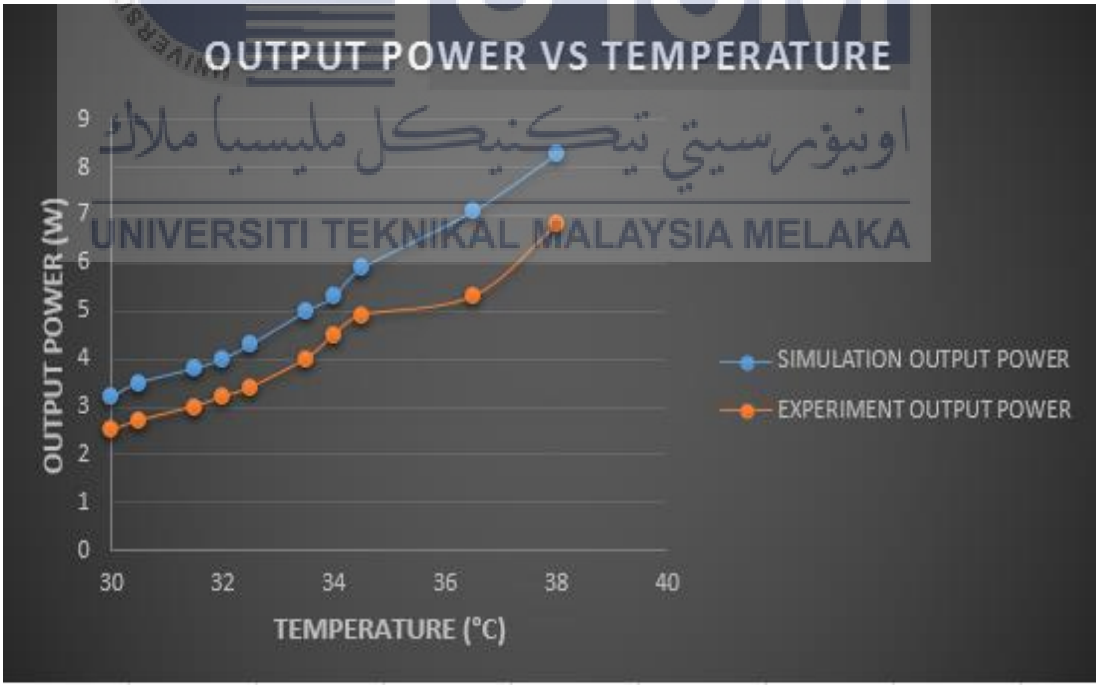


Figure 4.7: The graph comparison of output power for solar system between simulation and experiment.

The approximation percentage error can be gain in order to perform the percentage value difference between actual value observed by experiment and the expected value gain from simulation. The percentage approximation error can be gain through the formula of approximation error which is

$$\delta = \left|\frac{V_A - V_E}{v_E}\right| X\ 100\%$$

Where,

δ = Percent error

V_A = Actual experiment value

V_E = Expected value from simulation

Therefore by using the formula, the approximate percentage error for output voltage and power can be analyzed in the table.

Table 4.2: The approximate percentage error for output voltage between simulation and experiment.

Temperature (°C)	Output Voltage (V)		Approximate Percentage Error (%)
	Simulation(V_E)	Experiment (V_A)	
30.0	12.2	12.0	1.63
30.5	12.5	12.7	1.60
31.5	12.9	13.0	0.78
32.0	13.5	13.0	3.70
32.5	13.8	13.2	4.34
33.5	14.5	13.5	6.89
34.0	14.9	13.5	9.39
34.5	15.3	13.8	9.80
36.5	16.2	14.0	13.58
38.0	17.0	14.2	16.47

Table 4.3: The approximate percentage error for output power between simulation and experiment.

Temperature (°C)	Output Power (W)		Approximate Percentage Error (%)
	Simulation	Experiment	
30.0	3.2	2.5	21.87
30.5	3.5	2.7	22.85
31.5	3.8	3.0	21.05
32.0	4.0	3.2	20.00
32.5	4.3	3.4	20.93
33.5	5.0	4.0	20.00
34.0	5.3	4.5	15.09
34.5	5.9	4.9	16.95
36.5	7.1	5.3	25.35
38.0	8.3	6.8	18.07

In discussion for solar efficiency result, the solar module that has been build based on parameters that be needed in order to run the incubator has lower in percentage error in terms of voltage and power used. It can be seen that for the voltage error, the highest percentage are around 16.5 percent between the real solar module with the designed solar module in simulation, while for the output power contribute the highest approximation error to 25.32 percent between simulation and experiment of solar module efficiency. However, in terms of experiment, the efficiency of solar module are capable to charge the battery and run the incubator prototype in well conditions.

4.4 Battery Charging Process Result.

Battery is one of the important elements as input supply in the project. This is because the battery will be used as input power to the inverter to run the system that are using the Alternating Current (AC) power source. Therefore, in order to analyzed the system efficiency, the data of battery charging process will be taken to make sure the solar system is in good efficiency to run the incubator. The data of charging process collected based on the temperature and battery voltage coefficient with specific of time.

Table 4.4: The value of battery charging process every one hour.

Time	Temperature (°C)	Voltage(V)
9:00 A.M	30.5	11.6
10:00 A.M	32.3	11.9
11:00 A.M	34.8	12.3
12:00 P.M	35.7	13.3
1:00 P.M	36.5	13.6
2:00 P.M	36.0	13.2
3:00 P.M	34.5	13.0
4:00 P.M	33.6	12.7
5:00 P.M	32.3	12.6
6:00 P.M	31.5	12.2

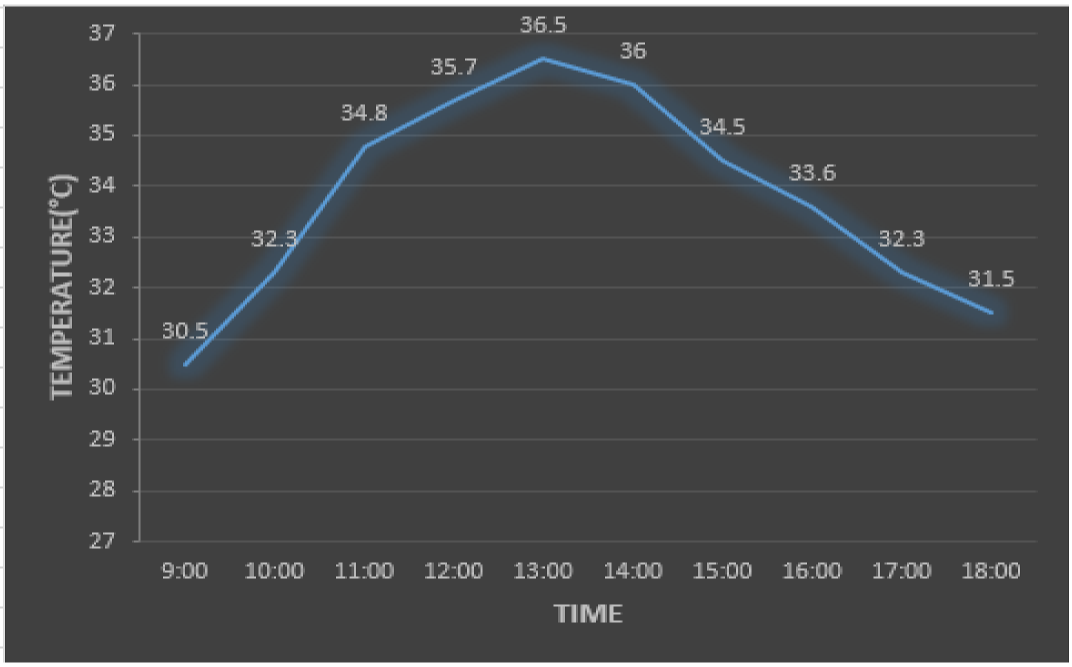


Figure 4.8: The graph value of temperature versus time.

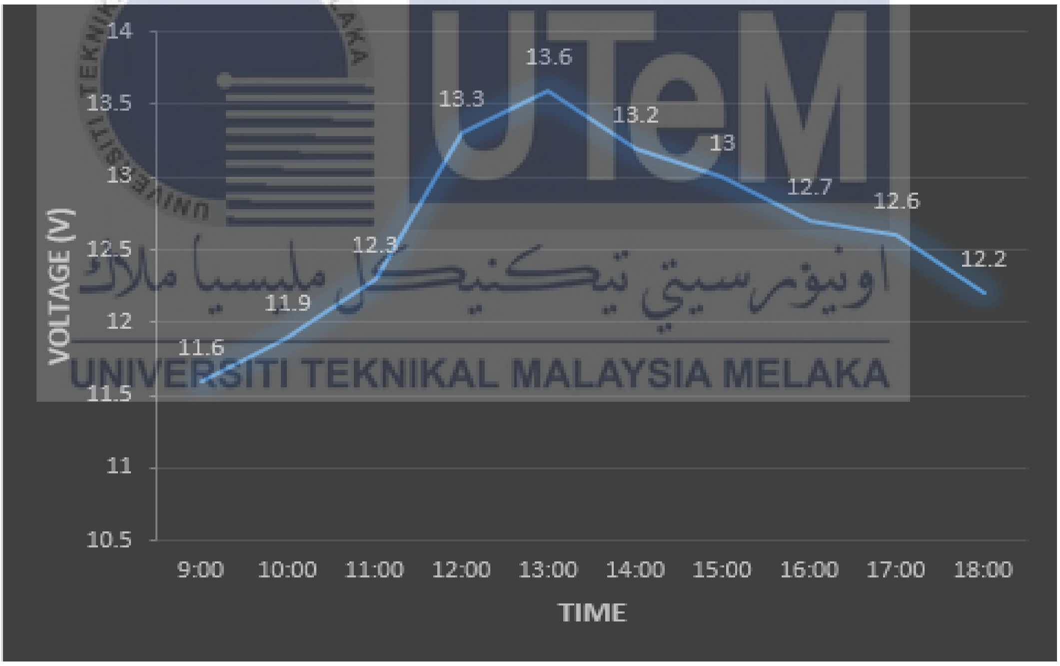


Figure 4.9: The graph value of battery voltage versus time.

There are several discussion that can be made through battery charging process analysis. First, in practical parameter, the highest value of temperature capable to gain is around 36.5 °C which is located at 1:00 P.M. From the data and graph result that has been gain, the value of temperature increase during morning to afternoon. Whenever in the evening, the temperature start to decrease. Besides that, for both analysis graph, it shows that the higher the temperature value will increase the charging process of the battery. This result analysis is acceptable with the simulation that has been done through MATLAB which is the voltage output of the solar as input of charging process will be slightly increasing due to the higher temperature value gain by the solar panel. In addition, the charging process capable to reach up to 13.6 V at the temperature value comes up for highest value.

4.5 Analysis Temperature and Humidity in Egg Incubator.

Temperature and Humidity of this research project is the main elements to make sure the process of hatching run smoothly. The analysis of temperature and humidity are needed in order to analyze the prototype function in order to stabilize the temperature and humidity of the surroundings. DHT22 sensor has been used as the main component to detect the surrounding temperature and humidity. The data analysis of humidity and temperature will be analyze by time every one hour started from 9:00 A.M to 9:00 P.M which is 12 hours to see the stability of the sensor integrate with prototype that has been designed to run the project. The incandescent bulb and AC fan will be used in order to control the temperature and humidity of the surrounding. In order to analyze the real value of temperature and humidity, the thermometer has been placed in the incubator as element to calibrate the sensor reading.

Table 4.5: The data of Temperature and Humidity reading from thermometer for 12 hours in the egg incubator.

Time	Temperature (°C)	Relative Humidity (%)
9:00 A.M	38.1	68.7
10:00 A.M	38.1	68.7
11:00 A.,	38.1	68.5
12:00 P.M	38.2	68.0
1:00 P.M	38.2	67.0
2:00 P.M	38.2	66.0
3:00 P.M	38.1	67.5
4:00 P.M	38.0	68.0
5:00 P.M	38.0	68.5
6:00 P.M	37.9	69.0
7:00 P.M	37.9	69.0
8:00 P.M	37.8	69.5
9:00 P.M	37.8	69.5

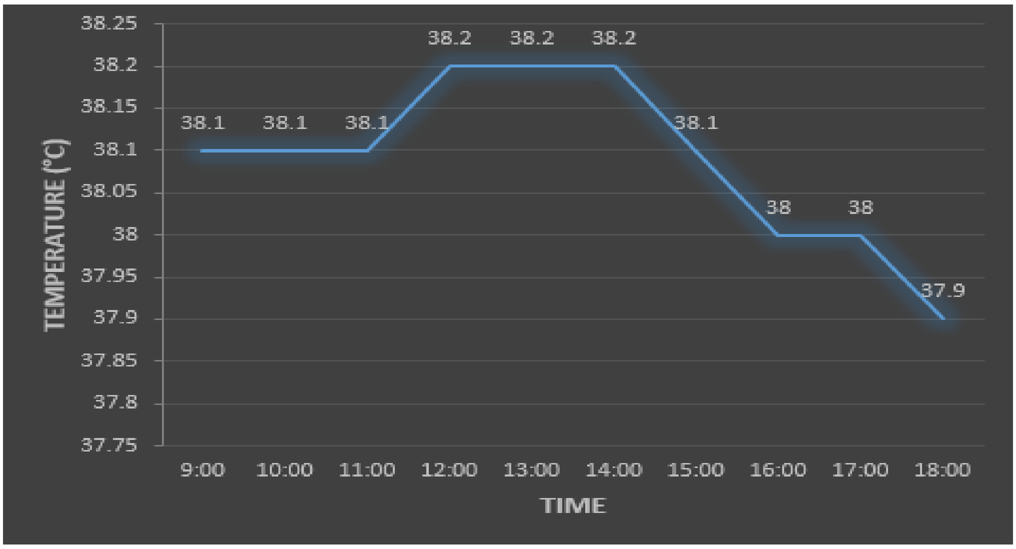


Figure 4.10: The graph result of Temperature versus Time by thermometer.

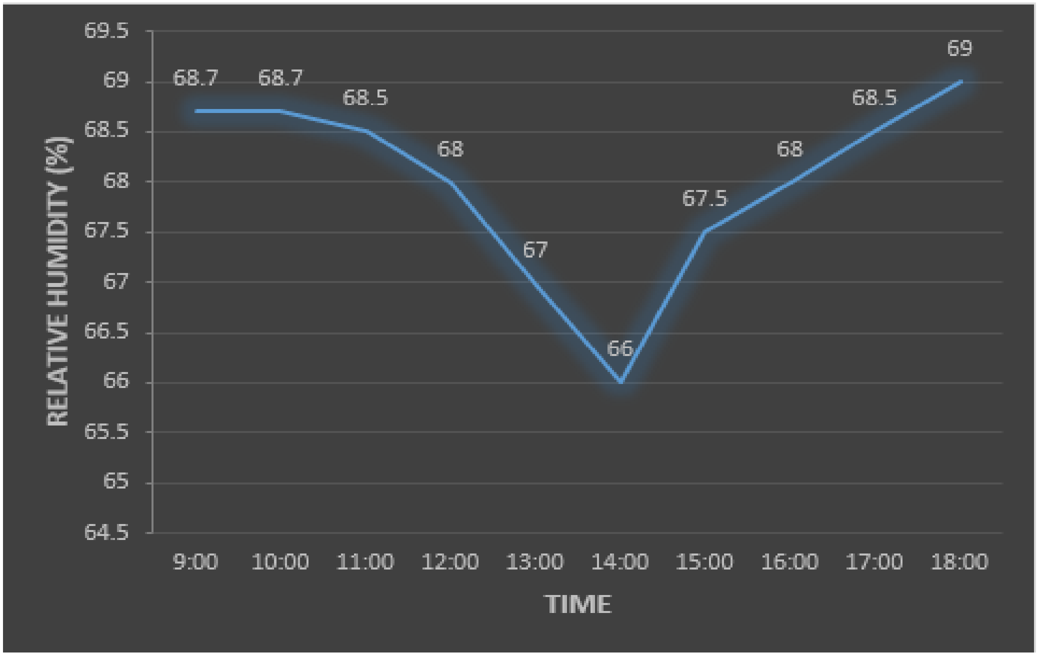


Figure 4.11: The graph result of relative humidity versus time by thermometer.

From the data and graph result that has been obtained, the temperature and humidity in the surrounding of the incubator is in stable condition. It can be seen when the temperature range gain from thermometer reading can be as low as 37.8°C up to 38.2°C while the relative humidity can be obtained as low as 66% up to 69.5%. In research that has been made, the value of the temperature and humidity is suitable and acceptable as the value is in range for incubating and hatching process of poultry egg. The thermometer has been used as a device to calibrate the real value of temperature and humidity in surrounding of incubator. In order to gain the best range value of temperature and humidity by the thermometer, the value of temperature and humidity from DHT22 has been program to be set at 39.5°C for temperature and 68.5% to 72.5% for humidity.

Table 4.6: The percentage error of temperature and humidity reading.

Elements	DHT 22 Sensor (°C)	Thermometer Reading	Approximate Percentage Error (%)
Temperature (°C)	39.5	37.8 to 38.2	3.29 to 4.3
Humidity (%)	68.5 to 72.5	66 to 69.5	2.94 to 4.13

Figure 4.12: Temperature and Humidity Reading from OLED LCD.

Figure 4.13: The temperature and humidity reading from thermometer display.

Furthermore, the percentage error gain for calibrate the value set for DHT22 sensor with real value output reading by thermometer is acceptable and low percentage error. From the data result and analysis, the percentage error of temperature is in the range of 3.29% up to 4.3% while for humidity the range of percentage error is around 2.94% up to 4.13%.

4.6 Analysis of Hatching Percentage

The system efficiency and achievement can be seen by the analysis of hatching percentage of the poultry egg. This project has been tested by using chicken egg as the first source to analyze the hatching percentage parameter. The analysis has been done and the data has been collected by number of eggs to be put in the incubator, the time taken for the egg to be hatch, and the number of eggs that is capable to hatch perfectly.

Table 4.7: The data of egg hatching percentage.

Types of egg	Number of egg per entry	Time taken for egg to hatch	Date	Percentage		
				Fully Hatch	Die with embryo	No embryo
Chicken	30	21 days	20/5/2021	1 (3.3%)	18 (60%)	11 (36.7%)
Chicken	10	21 days	22/5/2021	6 (60%)	4 (40%)	0 (0%)

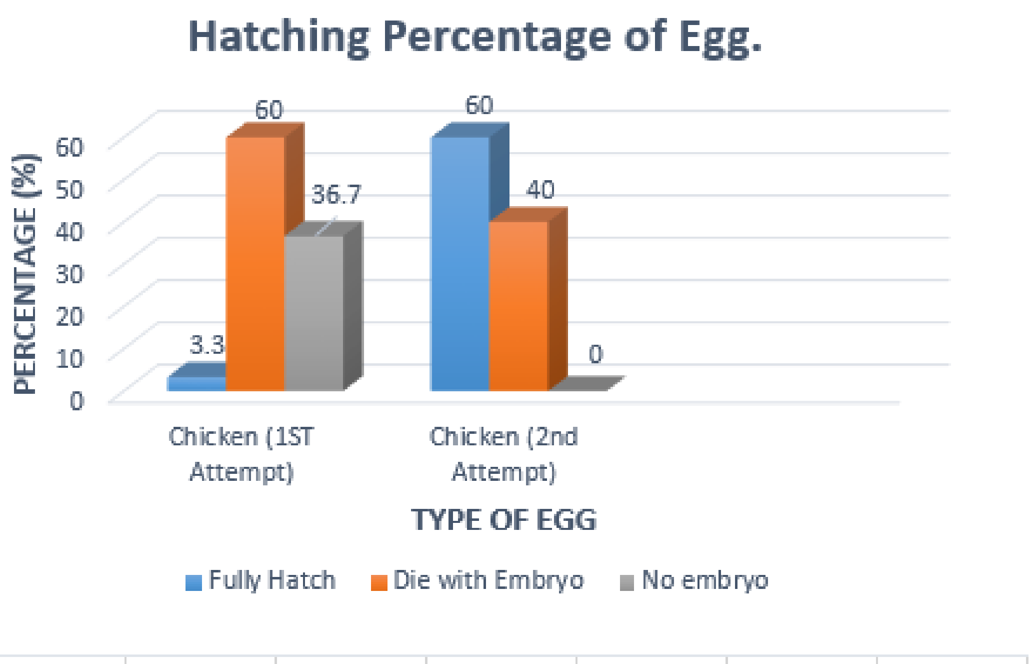


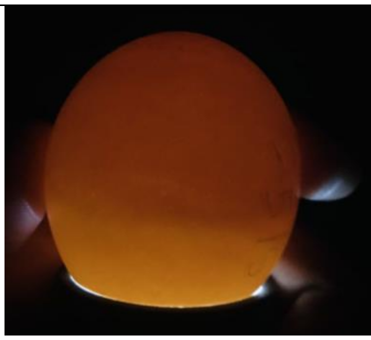
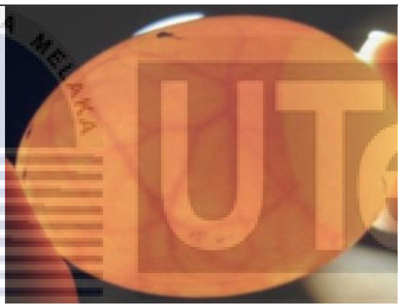
Figure 4.14: The Hatching Percentage of Chicken Egg.

From the data and graph that has been obtained, several discussion can be made. First, from the data it shows that the hatching process takes place for 21 days for the chicken egg. The different types of egg will having different time of hatching process. Besides that, from the graph, it can be seen that second attempt of chicken egg have higher potential in order to hatch the egg as the percentage for fully hatch is more than half percent. Furthermore, even though the egg cannot be hatch perfectly, the balance of the egg that cannot be hatch is probably the egg that contain the embryo which means that it supposedly achieved the target to makes sure the presence of embryo in the egg shell.

4.7 The Hatching Process.

Incubation process for the chicken egg contribute to 21 days. The presence of embryo will start on day 3 to day 5 to see the abilities for the egg to be fertilized. The condition of the embryo has been recorded in order as the data for analyzed the incubation and hatching process of the chicken egg by using incubator. The procedure to look at the condition in the egg shell is given name as candling process.

Table 4.8: The condition of the egg shell during day 1 to day 21.

Time	Condition in the Egg shell.	Remarks
Day 1		No nerve or embryo presence in the egg shell.
Day 5		The nerve of the embryo start to spread inside the egg shell.
Day 10		The embryo start to build in the egg shell and the embryo start to move inside it.
Day 15		The embryo start to become bigger around the egg shell.

Day 18		The full embryo start to presence inside the egg shell and movement of embryo begin to invisible.
Day 20		The outer of the egg shell start to crack.
Day 21		The chicken fully hatch from the egg shell.
		The embryo die in the egg shell around day 7

CHAPTER 5

CONCLUSION AND FUTURE WORKS

Chapter 5 will conduct on overall conclusion regarding the research project that has been done and several recommendation in order to perform the better parameter for project to be run successfully.

5.1 Conclusion

The project of Design Incubator Control and Monitoring System has successfully function well. This project research has achieved the two main objectives mention which is to design a poultry egg incubator control and monitoring system with integration of photovoltaic (PV) energy system and IoT technology and to analyze the proposed system performance in term of poultry egg hatching percentage and overall system efficiency.

The first objective has been achieved by comparing simulation result using MATLAB and hardware testing in order to choose the best solar module system for running the incubator daily during project implementation. Besides that, the propose incubator has been designed with two stages which is place to locate all components and solar system parameters and second stage is for locate the incubator system parts. Furthermore, the IoT platform has been integrate in this system by using Blynk application to ease the user in order for them to control and monitor the incubator.

The second objective has been achieved by analyzing the overall performance which is has been separated in to parts. First part is analyzing the performance of solar system in terms of output voltage and power produce by the solar panel as the main supply for overall system and also the battery charging process analysis in order to run all the components and apparatus in the incubator system. In addition, the analysis of the research project has been achieved by analyzing the temperature and humidity in the incubator, the analysis of hatching percentage and the condition of the egg shell for 21 days during incubation and hatching process.

Last but not least, the system design of poultry egg incubator control and monitoring design is capable in market demand as the system used is highly needed by the poultry farmers nowadays as it can easy the control and monitoring performance and also increase the hatching percentage of the poultry egg. Besides that, the overall system is environmental friendly system as it not using any conventional power source in order to run the system, meanwhile it using the solar system as the renewable energy sources as the main supply to the overall system.

5.2 Future works recommendations

There are few recommendations and suggestion that can be improve in order to maintain and increase the performance of the project. First, this project needed 24 hours to run the system, therefore the higher amount of power in main supply needed to make sure the system being stable all the time. Therefore, for the next research project recommendation, the power supply can be modify by adding the solar panel and battery sources or increase the power and output voltage of the solar panel by choosing the higher power parameter in solar panel and battery device.

Besides that, this system capable to be run in bigger quantity of the egg. Therefore, in the next project research recommendation, the project can be design in bigger prototype in order to increase more hatching percentage of the egg.

In addition, the IoT platform used in this system is by using the ESP8266 as the transmitter to the blynk application and the range of transmit can be around 5km. Therefore, it can be improve by using the wider range of transmitter module such as LoRa or LoRaWAN module as the devices can transmit up to 15km in range. This is easier for the user to handle the system.

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APPENDICES

Appendix will be categorized in several parts including the code program for temperature and humidity system, the camera live applications system, the wiring hardware components implementation and several datasheet of components and devices.

Appendix A: The coding program for temperature and humidity system.

```
#define BLYNK_PRINT Serial
#include <BlynkSimpleEsp8266.h>
#include <DHT.h>
#include <Adafruit_SSD1306.h>

void checkPhysicalButton();

int toggleState_1 = 0;
int pushButton1State = LOW;

int toggleState_2 = 0;
int pushButton2State = LOW;

int toggleState_3 = 0;
int pushButton3State = LOW;

float temperature1 = 0;
float humidity1    = 0;
int   switchMode = 0;

//Set values for Auto Control Mode
const float maxTemp = 39.5;
const float minTemp = 39.5;
const float maxHumi = 72.5;
const float minHumi = 68.5;

#define AUTH "XDzTb9YPlVVlhQvFtaUAehTk-ScLyiIq"
#define WIFI_SSID "AZIZI"
#define WIFI_PASS "ziziekacakk"
```

```
#define DHTTYPE DHT22   // DHT 22, AM2302, AM2321
#define DHTPIN              0 //D3  pin connected with DHT

#define RELAY_PIN_1      14   //D5
#define RELAY_PIN_2      12   //D6


#define PUSH_BUTTON_1    16   //D0
#define PUSH_BUTTON_2    13   //D7
#define PUSH_BUTTON_CMODE  15 //D8

#define VPIN_BUTTON_1    V1
#define VPIN_BUTTON_2    V2
#define VPIN_BUTTON_3    V3
#define VPIN_BUTTON_C    V4

#define VPIN_HUMIDITY    V5
#define VPIN_TEMPERATURE V6

#define SCREEN_WIDTH 128
#define SCREEN_HEIGHT 32

#define OLED_RESET
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

DHT dht(DHTPIN, DHTTYPE);
BlynkTimer timer;



void changeMode(){
  delay(200);
  if (switchMode == 0){
    switchMode = 1;
  }
  else if (switchMode == 1) {
    switchMode = 0;
  }
  display.clearDisplay();
  display.setCursor(5,2);
  display.print("Set Mode: ");
  display.println();
  display.drawLine(0,18, display.width()-1,18, WHITE);
  display.setCursor(15,24);
  display.print(modeDecode(switchMode));
  display.display();
  delay(500);
  Blynk.virtualWrite(VPIN_BUTTON_C, switchMode);
  //display.clearDisplay();
}

void relayOnOff(int relay){

    switch(relay){
      case 1:
             if(toggleState_1 == 0){
              digitalWrite(RELAY_PIN_1, HIGH); // turn on relay 1
              toggleState_1 = 1;
              }
             else {
              digitalWrite(RELAY_PIN_1, LOW); // turn off relay 1
```

```
            delay(100);
        break;
        case 2:
            if(toggleState_2 == 0){
             digitalWrite(RELAY_PIN_2, HIGH); // turn on relay 2
             toggleState_2 = 1;
             }
            else{
             digitalWrite(RELAY_PIN_2, LOW); // turn off relay 2
             toggleState_2 = 0;
             }
            delay(100);
        break;
        default : break;
        }

}
String modeDecode(int count){
  if (count == 0){
    return " Manual Mode ";
  }
  else if (count == 1){
    return " Auto Mode ";
  }
}

void displayData(){
  display.clearDisplay();
  display.setTextSize(1);
  display.setCursor(8,2);


  display.setCursor(8,2);
  display.print(temperature1);
  display.print(" ");
  display.print("C    ");
  display.print(humidity1); // display humidity
  display.print(" %");

  display.drawLine(0,18, display.width()-1,18, WHITE);

  display.setCursor(15,24);
  display.print(modeDecode(switchMode));
  display.display();

  Serial.print(F("Temperature: "));
  Serial.print(temperature1);
  Serial.print("   ");
  Serial.print(F("humidity: "));
  Serial.print(humidity1);
  Serial.print("   ");
}

void readSensor(){

  float h = dht.readHumidity();
  float t = dht.readTemperature(); //

  if (isnan(h) || isnan(t)) {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }
  else {
```

```
  else {
    humidity1 = h;
    temperature1 = t;
  }
}

void sendSensor()
{
  readSensor();
  Blynk.virtualWrite(VPIN_HUMIDITY, humidity1);
  Blynk.virtualWrite(VPIN_TEMPERATURE, temperature1);
}

BLYNK_CONNECTED() {

  Blynk.syncVirtual(VPIN_BUTTON_1);
  Blynk.syncVirtual(VPIN_BUTTON_2);
  Blynk.syncVirtual(VPIN_BUTTON_C);
}

BLYNK_WRITE(VPIN_BUTTON_1) {
  toggleState_1 = param.asInt();
  digitalWrite(RELAY_PIN_1, toggleState_1);
}

BLYNK_WRITE(VPIN_BUTTON_2) {
  toggleState_2 = param.asInt();
  digitalWrite(RELAY_PIN_2, toggleState_2);
}

BLYNK_WRITE(VPIN_BUTTON_C) {
```

```
BLYNK_WRITE(VPIN_BUTTON_C) {
  switchMode = param.asInt();
}

void checkPhysicalButton()
{
  if (digitalRead(PUSH_BUTTON_1) == HIGH) {
      relayOnOff(1);
      Blynk.virtualWrite(VPIN_BUTTON_1, toggleState_1);
    }
  if (digitalRead(PUSH_BUTTON_2) == HIGH) {
      relayOnOff(2);
      Blynk.virtualWrite(VPIN_BUTTON_2, toggleState_2);
    }
}

void setup()
{
  Serial.begin(9600);

  if(!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {
    Serial.println(F("SSD1306 allocation failed"));
    for(;;);
  }
  delay(1000);
  display.setTextSize(1);
  display.setTextColor(WHITE);
  display.clearDisplay();

  pinMode(RELAY_PIN_1, OUTPUT);
  pinMode(PUSH_BUTTON_1, INPUT);
```

```
    pinMode(RELAY_PIN_2, OUTPUT);
    pinMode(PUSH_BUTTON_2, INPUT);
    digitalWrite(RELAY_PIN_2, toggleState_2);

    Blynk.begin(AUTH, WIFI_SSID, WIFI_PASS);
    timer.setInterval(500L, checkPhysicalButton);

    dht.begin();
    timer.setInterval(1000L, sendSensor);
    timer.setInterval(2000L, displayData);
  }

  void loop()
  {
    if (digitalRead(PUSH_BUTTON_CMODE) == HIGH){
      changeMode();
    }
    else{
      if(switchMode == 1){
        if(temperature1 < minTemp){
        if(toggleState_1 == 1){
            digitalWrite(RELAY_PIN_1, LOW);
            toggleState_1 = 0;
            Blynk.virtualWrite(VPIN_BUTTON_1, toggleState_1);
          }
        }
        else if (temperature1 > maxTemp){
          if(toggleState_1 == 0){
            digitalWrite(RELAY_PIN_1, HIGH);
            toggleState_1 = 1;
            Blynk.virtualWrite(VPIN_BUTTON_1, toggleState_1);


          toggleState_1 = 0;
          Blynk.virtualWrite(VPIN_BUTTON_1, toggleState_1);
        }
      }
      else if (temperature1 > maxTemp){
        if(toggleState_1 == 0){
          digitalWrite(RELAY_PIN_1, HIGH);
          toggleState_1 = 1;
          Blynk.virtualWrite(VPIN_BUTTON_1, toggleState_1);
        }
      }
      if( humidity1 < minHumi){
        if(toggleState_2 == 1){
          digitalWrite(RELAY_PIN_2, LOW);
          toggleState_2 = 0;
          // Update Button Widget
          Blynk.virtualWrite(VPIN_BUTTON_2, toggleState_2);
        }
      }
      else if (humidity1 > maxHumi){
        if(toggleState_2 == 0){
          digitalWrite(RELAY_PIN_2, HIGH);
          toggleState_2= 1;
          Blynk.virtualWrite(VPIN_BUTTON_2, toggleState_2);
        }
      }
    }
    timer.run();
    Blynk.run();
  }
}
```

Appendix B: The coding program for live camera application system.

```
#include "src/OV2640.h"
#include <WiFi.h>
#include <WebServer.h>
#include <WiFiClient.h>

#define CAMERA_MODEL_AI_THINKER

#include "camera_pins.h"

#define SSID1 "Muhammad Azizi"
#define PWD1 "ziziekacakk"

OV2640 cam;

WebServer server(80);

const char HEADER[] = "HTTP/1.1 200 OK\r\n" \
                      "Access-Control-Allow-Origin: *\r\n" \
                      "Content-Type: multipart/x-mixed-replace; boundary=123456789000000000000987654321\r\n";
const char BOUNDARY[] = "\r\n--123456789000000000000987654321\r\n";
const char CTNTTYPE[] = "Content-Type: image/jpeg\r\nContent-Length: ";
const int hdrLen = strlen(HEADER);
const int bdrLen = strlen(BOUNDARY);
const int cntLen = strlen(CTNTTYPE);

void handle_jpg_stream(void)
{
  char buf[32];
  int s;
```

```
  WiFiClient client = server.client();

  client.write(HEADER, hdrLen);
  client.write(BOUNDARY, bdrLen);

  while (true)
  {
    if (!client.connected()) break;
    cam.run();
    s = cam.getSize();
    client.write(CTNTTYPE, cntLen);
    sprintf( buf, "%d\r\n\r\n", s );
    client.write(buf, strlen(buf));
    client.write((char *)cam.getfb(), s);
    client.write(BOUNDARY, bdrLen);
  }
}

const char JHEADER[] = "HTTP/1.1 200 OK\r\n" \
                       "Content-disposition: inline; filename=capture.jpg\r\n" \
                       "Content-type: image/jpeg\r\n\r\n";
const int jhdLen = strlen(JHEADER);

void handle_jpg(void)
{
  WiFiClient client = server.client();

  cam.run();
  if (!client.connected()) return;
```

```
  client.write(JHEADER, jhdLen);
  client.write((char *)cam.getfb(), cam.getSize());
}

void handleNotFound()
{
  String message = "Server is running!\n\n";
  message += "URI: ";
  message += server.uri();
  message += "\nMethod: ";
  message += (server.method() == HTTP_GET) ? "GET" : "POST";
  message += "\nArguments: ";
  message += server.args();
  message += "\n";
  server.send(200, "text / plain", message);
}

void setup()
{

  Serial.begin(115200);

  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
  config.ledc_timer = LEDC_TIMER_0;
  config.pin_d0 = Y2_GPIO_NUM;
  config.pin_d1 = Y3_GPIO_NUM;
  config.pin_d2 = Y4_GPIO_NUM;
  config.pin_d3 = Y5_GPIO_NUM;
  config.pin_d4 = Y6_GPIO_NUM;
```

```
  config.pin_d4 = Y6_GPIO_NUM;
  config.pin_d5 = Y7_GPIO_NUM;
  config.pin_d6 = Y8_GPIO_NUM;
  config.pin_d7 = Y9_GPIO_NUM;
  config.pin_xclk = XCLK_GPIO_NUM;
  config.pin_pclk = PCLK_GPIO_NUM;
  config.pin_vsync = VSYNC_GPIO_NUM;
  config.pin_href = HREF_GPIO_NUM;
  config.pin_sscb_sda = SIOD_GPIO_NUM;
  config.pin_sscb_scl = SIOC_GPIO_NUM;
  config.pin_pwdn = PWDN_GPIO_NUM;
  config.pin_reset = RESET_GPIO_NUM;
  config.xclk_freq_hz = 20000000;
  config.pixel_format = PIXFORMAT_JPEG;

  // Frame parameters
  //  config.frame_size = FRAMESIZE_UXGA;
  config.frame_size = FRAMESIZE_QVGA;
  config.jpeg_quality = 12;
  config.fb_count = 2;

#if defined(CAMERA_MODEL_ESP_EYE)
  pinMode(13, INPUT_PULLUP);
  pinMode(14, INPUT_PULLUP);
#endif

  cam.init(config);

  IPAddress ip;

  WiFi.mode(WIFI_STA);
```

```
  pinMode(14, INPUT_PULLUP);
#endif

  cam.init(config);

  IPAddress ip;

  WiFi.mode(WIFI_STA);
  WiFi.begin(SSID1, PWD1);
  while (WiFi.status() != WL_CONNECTED)
  {
    delay(500);
    Serial.print(F("."));
  }
  ip = WiFi.localIP();
  Serial.println(F("WiFi connected"));
  Serial.println("");
  Serial.println(ip);
  Serial.print("Stream Link: http://");
  Serial.print(ip);
  Serial.println("/mjpeg/1");
  server.on("/mjpeg/1", HTTP_GET, handle_jpg_stream);
  server.on("/jpg", HTTP_GET, handle_jpg);
  server.onNotFound(handleNotFound);
  server.begin();
}

void loop()
{
  server.handleClient();
}
```


Appendix C: The full prototype design.

Appendix D: DHT22 Datasheet

3. Technical Specification:

Model	DHT22
Power supply	3.3-6V DC
Output signal	digital signal via single-bus
Sensing element	Polymer capacitor
Operating range	humidity 0-100%RH; temperature -40~80Celsius
Accuracy	humidity +-2%RH(Max +-5%RH); temperature <+-0.5Celsius
Resolution or sensitivity	humidity 0.1%RH; temperature 0.1Celsius
Repeatability	humidity +-1%RH; temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH
Long-term Stability	+-0.5%RH/year
Sensing period	Average: 2s
Interchangeability	fully interchangeable
Dimensions	small size 14*18*5.5mm; big size 22*28*5mm

Appendix E: ESP8266 Datasheet.

Table 1-1. Specifications

Categories	Items	Parameters
Wi-Fi	Certification	Wi-Fi Alliance
	Protocols	802.11 b/g/n (HT20)
	Frequency Range	2.4 GHz ~ 2.5 GHz (2400 MHz ~ 2483.5 MHz)
	TX Power	802.11 b: +20 dBm
		802.11 g: +17 dBm
		802.11 n: +14 dBm
	Rx Sensitivity	802.11 b: –91 dbm (11 Mbps)
		802.11 g: –75 dbm (54 Mbps)
		802.11 n: –72 dbm (MCS7)
	Antenna	PCB Trace, External, IPEX Connector, Ceramic Chip
Hardware	CPU	Tensilica L106 32-bit processor
	Peripheral Interface	UART/SDIO/SPI/I2C/I2S/IR Remote Control
		GPIO/ADC/PWM/LED Light & Button
	Operating Voltage	2.5 V ~ 3.6 V
	Operating Current	Average value: 80 mA
	Operating Temperature Range	–40 °C ~ 125 °C
	Package Size	QFN32-pin (5 mm x 5 mm)
	External Interface	-
Software	Wi-Fi Mode	Station/SoftAP/SoftAP+Station
	Security	WPA/WPA2
	Encryption	WEP/TKIP/AES
	Firmware Upgrade	UART Download / OTA (via network)
	Software Development	Supports Cloud Server Development / Firmware and SDK for fast on-chip programming
	Network Protocols	IPv4, TCP/UDP/HTTP
	User Configuration	AT Instruction Set, Cloud Server, Android/iOS App

Appendix F: Arduino Mega 2560 Datasheet.

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Appendix G: ESP32 Web Cam Datasheet.

Module Model	ESP32-CAM
Package	DIP-16
Size	27*40.5*4.5（±0.2）mm
SPI Flash	Default 32Mbit
RAM	520KB SRAM +4M PSRAM
Bluetooth	Bluetooth 4.2 BR/EDR and BLE standards
Wi-Fi	802.11 b/g/n/
Support interface	UART、SPI、I2C、PWM
Support TF card	Maximum support 4G
IO port	9
UART Baudrate	Default 115200 bps
Image Output Format	JPEG(OV2640 support only),BMP,GRAYSCALE
Spectrum Range	2412 ~2484MHz
Antenna	Onboard PCB antenna, gain 2dBi
Transmit Power	802.11b: 17±2 dBm (@11Mbps) 802.11g: 14±2 dBm (@54Mbps) 802.11n: 13±2 dBm (@MCS7)
Receiving Sensitivity	CCK, 1 Mbps : -90dBm CCK, 11 Mbps: -85dBm 6 Mbps (1/2 BPSK): -88dBm 54 Mbps (3/4 64-QAM): -70dBm MCS7 (65 Mbps, 72.2 Mbps): -67dBm
Power Dissipation	Turn off the flash lamp:180mA@5V Turn on the flash lamp and turn on the brightness to the maximum:310mA@5V Deep-sleep: Minimum power consumption can be achieved 6mA@5V Moderm-sleep: Minimum up to 20mA@5V Light-sleep: Minimum up to 6.7mA@5V
Security	WPA/WPA2/WPA2-Enterprise/WPS
Power Supply Range	5V
Operating Temperature	-20 ℃ ~ 85 ℃
Storage Environment	-40 ℃ ~ 90 ℃ , < 90%RH