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Theme:

Management of an intelligent greenhouse system

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Thanks

Above all, we thank Almighty God for His success and for giving us the courage and patience to achieve this.

We dedicate this humble work:

To our dear parents, may God protect them and prolong their lives, for their moral and financial support, encouragement and sacrifices. To our brothers and sisters, to our cousins, to our grandfathers, to our grandmothers, and to our dear friends.

to our teachers. To all our college friends, club mates and classmates.

Dedicate

First and foremost, we express our gratitude to God, who has granted us the strength, courage, and patience to complete this humble work throughout our years of study.

We extend our heartfelt appreciation to our parents for their unwavering support during the long journey of our education.

A special thanks goes to our supervisor, Dr. DJARAH DJALAL, for their invaluable guidance. We are also grateful to the members of the jury for their willingness to evaluate and judge our work.

Furthermore, we would like to express our gratitude to all the teachers and department heads in the Electrical Engineering Department at OUARGLA University for their assistance and encouragement.

Summary

Summary: In this thesis, we have addressed the topic of management and control systems in agricultural greenhouses. The thesis consists of three chapters. In the first chapter, we explore the concept of the Internet of Things and its applications in agricultural greenhouses. In the second chapter, we discuss the key factors influencing plant growth, as well as the sensors and devices used to create a control and management system for agricultural greenhouses. Finally, in the third chapter, we delve into the manufacturing process of this device.
The added value of this thesis lies in providing a comprehensive overview of the management system for agricultural greenhouses, including the technology used and its practical application. This enables stakeholders in the field to understand the fundamental concepts of greenhouse agriculture and effectively implement them in their agricultural practices.

keywords: greenhouse, The Internet of Things (IoT), sensors, Greenhouse management, and control device.

Résumé : Dans cette thèse, nous avons abordé le sujet des systèmes de gestion et de contrôle dans les serres agricoles. La thèse est composée de trois chapitres. Dans le premier chapitre, nous explorons le concept de l'Internet des objets et ses applications dans les serres agricoles. Dans le deuxième chapitre, nous abordons les principaux facteurs influençant la croissance des plantes, ainsi que les capteurs et les dispositifs utilisés pour créer un système de contrôle et de gestion des serres agricoles. Enfin, dans le troisième chapitre, nous examinons le processus de fabrication de ce dispositif.La valeur ajoutée de cette thèse réside dans la fourniture d'une vue d'ensemble complète du système de gestion des serres agricoles, y compris la technologie utilisée et son application pratique. Cela permet aux parties prenantes du secteur de comprendre les concepts fondamentaux de l'agriculture sous serre et de les mettre en œuvre efficacement dans leurs pratiques agricoles.

Mots-clés : serre, Internet des objets, capteurs, Dispositif de gestion et de contrôle de serre

الملخص: في هذه المذكرة، تناولنا موضوع نظام الإدارة والتحكم في الدفيئة الزراعية. تتألف هذه المذكرة من ثلاثة فصول، حيث استعرضنا في الفصل الأول مفهوم "إنترنت الأشياء" وتطبيقاته في الدفيئة الزراعية. في الفصل الثاني، استعرضنا أهم العوامل المؤثرة في نمو النباتات والحساسات والأجهزة المستخدمة لإنشاء جهاز للتحكم وإدارة الدفيئة الزراعية. أما في الفصل الثالث، فقد قدمنا طريقة تصنيع هذا الجهاز. تتمثل القيمة المضافة لهذه المذكرة في توفير نظرة شاملة لنظام إدارة الدفيئة الزراعية، بما في ذلك التكنولوجيا المستخدمة وتطبيقها، بهدف تمكين المهتمين بالمجال من فهم المفاهيم الأساسية للدفيئة الزراعية وتنفيذها بفعالية في أعمالهم الزراعية.

الكلمات المفتاحية: الدفيئة الزراعية، إنترنت الأشياء، الحساسات، جهاز الإدارة والتحكم في الدفيئة الزراعية.

Table of Contents

List of Figure :

List of Tables:

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Agriculture plays a crucial role in sustaining human life as it serves as the primary source of food and raw materials. Therefore, the growth and advancement of the agricultural sector are vital for the overall economic development of a country.[1]

Greenhouse cultivation offers an excellent environment for the production of vegetables and fruits. It provides controlled conditions where various environmental factors can be regulated. Within a greenhouse, factors such as temperature, humidity, irrigation, nutrition, carbon dioxide levels, and light intensity can be carefully monitored and adjusted to create an ideal climate for plant growth. Moreover, the controlled environment of a greenhouse offers protection against external elements such as wind, pests, and diseases, allowing for better control and management.[1]

In summary, agricultural greenhouses serve as an efficient solution for optimizing plant growth by providing favorable conditions and enabling effective control over pollination, disease prevention, and pest management.

The objective of our work is to integrate intelligent technologies, specifically the Internet of Things (IoT), into agriculture, with a particular focus on greenhouse cultivation. By harnessing new technologies such as a wireless "WiFi" network, we aim to collect data from diverse sensors within the greenhouse. This data will be transmitted to "THING SPEAK" platforms using specific "HTTP" protocols and interconnected control cards. This interconnected system will allow us to automate and control greenhouses and their climates from any location. [2]

The implementation of this intelligent system offers several advantages. Firstly, it provides a conducive environment for plants by ensuring optimal conditions, independent of external climate variations. This enables year-round agricultural production within the greenhouse. Additionally, the system promotes automation and control, granting the ability to remotely regulate various aspects of greenhouse operations. [2]

By leveraging data collected from sensors, the intelligent system facilitates informed decision-making and precise adjustments to maximize plant growth. Moreover, the wireless connectivity and remote-control capabilities of the system offer flexibility and convenience for greenhouse management from anywhere. [2]

Overall, our goal is to transform greenhouse cultivation by integrating IoT technologies, enabling automation, remote control, and the creation of an ideal environment for plants. This approach promotes year-round production, increased efficiency, and improved agricultural practices.

The description of the work carried out is sanctioned by a dissertation structured into three chapters:

- In the first chapter, we present an overview of the different types of agricultural greenhouses, as well as the climatic parameters that control plant growth, and also the latest automatic systems that are used to control and regulate climatic parameters.

- The second chapter II gives an overview and details for the conceptual study, to realize our device, with an explanation of the global system elements and the electronic components of each unit with a view on our man-machine interface (Web application).

- In the third chapter, we provide an overview of the practical implementation of our prototype and present the results obtained from the conducted tests. The focus is on showcasing the tangible realization of our project and evaluating its performance.

Furthermore, we conclude our work by providing a comprehensive summary and general conclusion. We also discuss potential avenues for future research and development to further enhance the project's capabilities.

Chapter I:

General information on intelligent greenhouses

I.1. Introduction

The way we interact with the world around us has been completely transformed by the Internet of Things (IoT). IoT devices have improved the convenience, effectiveness, and connectivity of our lives everywhere from our homes to our workplaces. The management of greenhouse systems is one area where the Internet of Things has a big impact. Better yields, lower costs, and a more sustainable future can all be achieved by monitoring and managing greenhouse systems with the Internet of Things. Greenhouse management is crucial in contemporary agriculture. In any climate, they enable year-round crop production and offer a controlled environment for optimum plant development.[3]

In this chapter, we will detail the study of the concept of "Internet of Things" and its various applications in the field of agriculture, specifically in the greenhouse system. This study will be useful to understand how to employ the "Internet of Things" to improve the performance and productivity of the greenhouse system.

I.2. Internet of Things

I.2.1. Definition of Internet of Things:

The Internet of Things (IoT) is a “global infrastructure for the information society, which makes it possible to have advanced services by interconnecting objects (physical or virtual) thanks to existing interoperable information and communication technologies. or evolving. In reality, the definition of what the Internet of Things is is not fixed. It cuts across conceptual and technical dimensions.

From a conceptual point of view, the Internet of Things characterizes connected physical objects having their own digital identity and capable of communicating with each other. This network somehow creates a bridge between the physical world and the virtual world.

From a technical point of view, the IoT consists of the direct and standardized digital identification (IP address, smtp protocols, http...) of a physical object thanks to a wireless communication system which can be a chip RFID, Bluetooth or Wi-Fi. [3] [4]

I.2.2. Application areas:

The potential offered by the IoT and its ubiquitous aspect make it possible to develop numerous applications. However, only a few applications are currently deployed. The use of IoT will allow the development of several smart applications in the future which will essentially affect: home automation, cities, transport, health and industry.

- Modern homes and buildings
- Energy
- Transportation
- Health
- The industry
- Agriculture

In order to measure or detect the media, sensors send out an output signal. When West controllers devices get that output, they have the ability to display, record, and/or control the process of altering the media's attributes to suit the application. [4]

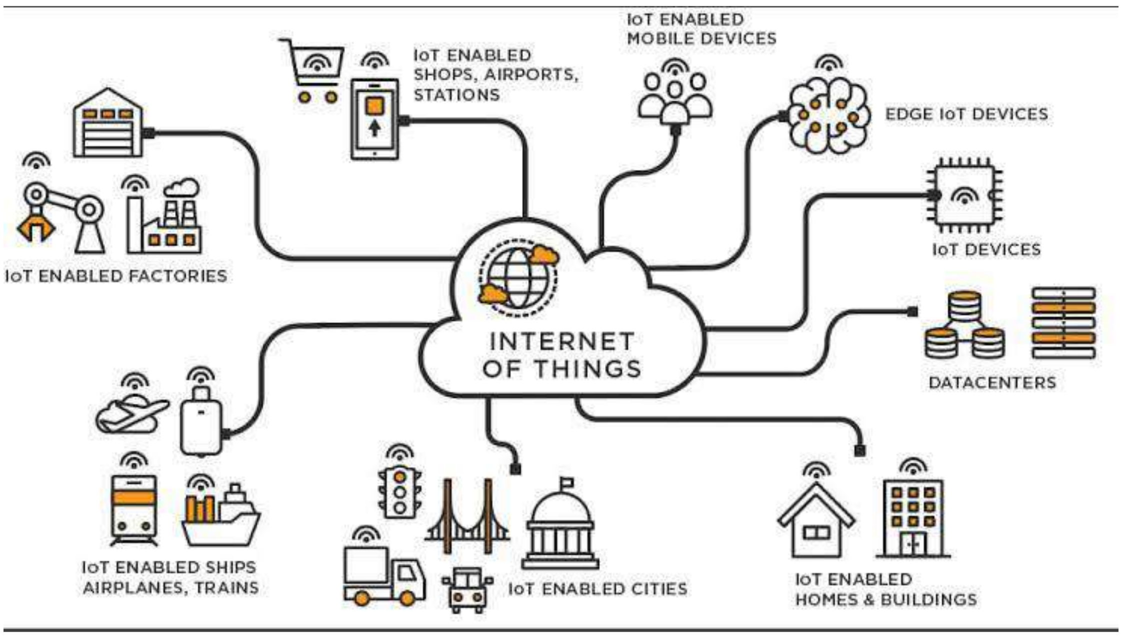


Figure I. 1: The Application areas of IOT[4]

I.3. General information on agricultural greenhouses

I.3.1. Definition and advantages of the greenhouse:

A greenhouse (Picture I.1) is a structure, which can be closed, generally intended for agricultural production. It aims to protect crops produced for food or human pleasure from the climatic elements for better management of plant needs and to accelerate their growth or produce them in all seasons. Growing in greenhouses is called greenhouse farming.[1] [5]

Advantages:

• Higher production thanks to the possibility of controlling the climatic conditions of the crop and favoring production in all seasons, increase in yield and quality of the harvest.

• Earliness and delay in production.

Figure I. 2: Example of an agricultural greenhouse[5]

I.3.2. Structure and materials for the greenhouse:

A. Framing Materials: greenhouses may be constructed from several different materials. Among the most popular are aluminum, steel and wood. [6]

- **Aluminum:** is by far the most economical and longest lasting. Aluminum may be extrude in various shapes and thicknesses. This material can then be formed into rafters, side posts and other structural components.

- **Wood:** is less commonly used because it deteriorates quickly in the moist environment of the greenhouse. If wood is used, it is best to obtain pressure treated lumber that "resists" decay. There are several satisfactory types of this treated wood available commercially. PENTA, however, has been found to give off fumes that can be harmful to plants.

B. Covering Materials: greenhouse coverings must be clear enough to provide optimum light transmission and at the same time be durable as well as economical. [6]

- **Glass:** provides the best light transmission for greenhouse production. However, the structural components required to support glass are costly. Also, the initial investment as well as the necessary maintenance has restricted the use of glass houses by Texas producers.
- **Fiberglass**: is another covering material that is frequently used on commercial greenhouses. Fiberglass is ridged, extremely durable, and does not require the extensive structural components of a glass house. However, fiberglass is prone to deterioration this results in a dramatic reduction in light transmission when the fibers swell, In specific circumstances, fiberglass's lifespan can be as brief as five years.
- **Double sheets of polyethylene (PE) film inflated with air:** is the most common covering on commercial greenhouses in Texas. PE is not rigid, but will provide the support necessary for normal operation. Most currently available PE film will last for approximately two years before it needs to be replaced. Although this frequent maintenance is costly, the reduced initial investment required, as well as the limited structural components needed to support this covering, has made PE most economical for producers.

I. 4. Create a microclimate with a greenhouse

The climatic factors that most influence the climate inside the greenhouse are temperature, air humidity, solar radiation and external wind. In reality, each of these factors generates a combination of effects that may or may not be favorable to the operation of the greenhouse depending on the prevailing local conditions. In Algeria, the climatic zones are diverse, for example from the Mediterranean climate to the desert climate.. In the north, rainy and cold winters, hot and dry summers while in the south, temperatures are very high during the day (35°) and very low at night (0°) and the aridity of the soils is extreme . [7]

Temperature and humidity play a major role in the growth and development of vegetation since the species for which protected cultivation techniques are implemented are essentially warm season species adapted to average monthly air temperatures. between 17°C and 28°C [7], and for this subject to the following conditions: which corresponds
subject to the following limiting conditions:
Average monthly minimum temperature: 12°C
Average monthly maximum temperature: 32°C.

I.5. Environmental conditions in greenhouses

Certain unique climatic conditions are required for the growth of plants in swales. Following is a general presentation of these conditions. [7]

- **Temperature:** the temperature of the interior and exterior environment, of the ground and of the water must also respect certain standards.
- **Humidity:** air and soil humidity are two important factors for plant growth.
- **Light:** Most vegetables require at least 8 hours of light per day to produce satisfactorily. In very cloudy areas or during short winter days additional lighting may be required.
- **Carbon dioxide:** Commercial greenhouses commonly use CO_2 generators to maximize their production. When designing a CO_2 system, yields will only increase if CO_2 is the "limiting factor". This means that if all other variables are not optimal (light, fertilizer, temperature/humidity, pH, etc.), the benefits of increased CO_2 levels will not be realized.
- **Air movement:** it is also an important factor that affects plant growth, modifying energy transfers, transpiration and CO_2 absorption, which affects leaf size, as well as the growth of the stem and yield. The rate of photosynthesis can be increased by 40 percent if the wind speed increases by 10 to 100 centimeters per second.

Figure I. 3: Main climatic parameters 7]

I.6.Conclusion

The main determinant of the quality of work in the forest is the choice of structure, equipment and climate control in the greenhouse. In this chapter, we have identified several environmental elements and conditions required for effective climate management in a greenhouse. In order to better manage the climate, it is necessary to understand the physiology of the plant to ascertain its needs and the influence of the environment on its growth.

Chapter II:

Description of the Hard & Soft involved

II.1. Introduction

the traditional greenhouse monitoring and control system mostly adopts wired connection and complex wiring. Therefore, wireless transmission technology has become one of the most urgent requirements, and in the context of technology, it is best to enable this technology in greenhouse sensors, it cannot Sensors equipped with a wireless network not only save time and facilitate monitoring, but also save a large number of human resources. [8]

in this chapter , we will learn about microcontrollers, sensors, and cloud platforms, whether hard or soft that we chose in our project to help us efficiently manage the climate system inside the greenhouse.

II.2. Hard part

II.2.1.ESP32-Pico-KitV4 D4:

The ESP32 makes it as simple as possible to program microcontrollers, which are the components that give objects the same level of interactivity as the ARDUINO [8]. The ESP32 is the successor to the ESP8266. It adds extra CPU cores, faster Wi-Fi, more GPIO, and supports Bluetooth 4.2 and Bluetooth Low Energy. Additionally, the ESP32 comes with touch-sensing pins that can be used to wake the ESP32 from deep sleep, a built-in hall effect sensor, and a built-in temperature sensor.[9]

ESP32-PICO-KIT (Picture II.1) is an ESP32-based mini development board produced by Espressif.

The core of this board is ESP32-PICO-D4 - a System-in-Package (SiP) module with complete Wi-Fi and Bluetooth functionalities. Compared to other ESP32 modules, ESP32-PICO-D4 integrates the following peripheral components in one single package, which otherwise would need to be installed separately: [10]

- 40 MHz crystal oscillator
- 4 MB flash
- Filter capacitors
- RF matching links

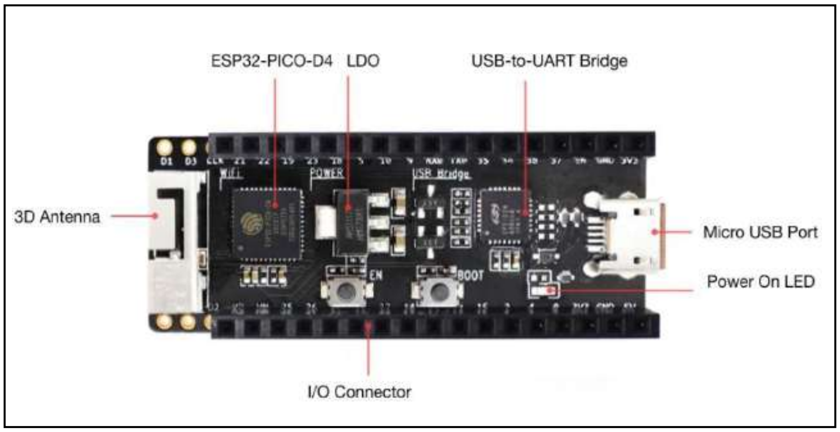


Figure II. 1: ESP32-PICO-KIT board layout (with female headers)[10]

This setup reduces the costs of additional external components as well as the cost of assembly and testing and also increases the overall usability of the product.

Pin Layout:

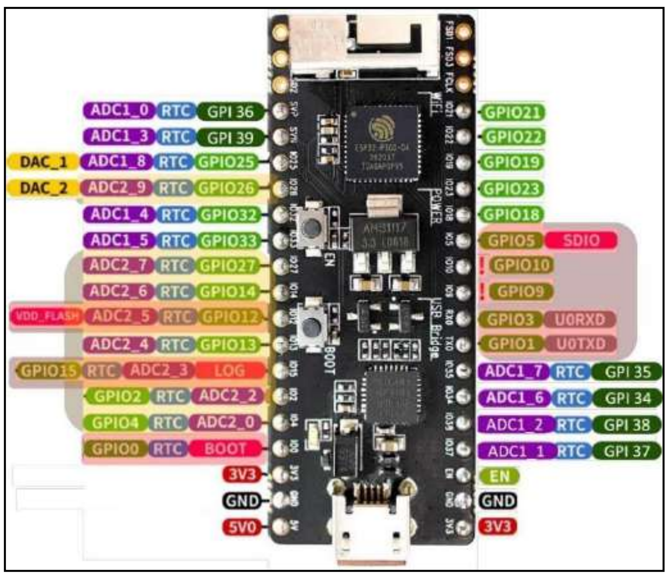


Figure II. 2 : Esp32 Pico kit pinout[10]

Key Component:

- **ESP32-PICO-D4:** Standard ESP32-PICO-D4 module soldered to the ESP32-PICO-KIT board. The complete ESP32 system on a chip (ESP32 SoC) has been integrated into the SiP module, requiring only an external antenna with LC matching network, decoupling capacitors, and a pull-up resistor for EN signals to function properly.

- **LDO:** 5V-to-3.3V Low dropout voltage regulator (LDO).
- **USB-UART bridge:** Single-chip USB-UART bridge: CP2102 in V4 provides up to 1 Mbps transfer rates and CP2102N in V4.1 offers up to 3 Mbps transfers rates.
- **Micro USB Port :** USB interface. Power supply for the board as well as the communication interface between a computer and the board.
- **5V Power On LED:** This red LED turns on when power is supplied to the board. For details, see the schematics in Related Documents.
- **I/O**: All the pins on ESP32-PICO-D4 are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, I2C, I2S, SPI, etc. For details, please see Section Pin Descriptions.
- **BOOT Button:** Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.
- **EN Button:** Reset button.[10]

II.2.2.Sensors

II.2.2.1. Definition and characteristics of a sensor:

A sensor is a device that detects and responds to some type of input from the physical environment. The input can be light, heat, motion, moisture, pressure or any number of other environmental phenomena. The output is generally a signal that is converted to a human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.

Sensors play a pivotal role in the internet of things (IoT). They make it possible to create an ecosystem for collecting and processing data about a specific environment so it can be monitored, managed and controlled more easily and efficiently. IoT sensors are used in homes, out in the field, in automobiles, on airplanes, in industrial settings and in other environments. Sensors bridge the gap between the physical world and logical world, acting as the eyes and ears for a computing infrastructure that analyzes and acts upon the data collected from the sensors.[11] [12]

II.2.2.2. Classification of sensors:

There are several ways to classify sensors. We cite two:

a. Classification according to the nature of the output signal:

There are many different types of sensors available, both analogue and digital, as well as input and output. The type of input or output transducer used is determined by the type of signal or process being "Sensed" or "Controlled," but sensors can be defined as devices that convert one physical quantity into another.[12]

- **Analog sensor:** produce a continuous output signal or voltage which is generally proportional to the quantity being measured. Physical quantities such as Temperature, Speed, etc. are all analogue quantities as they tend to be continuous in nature.
- **Digital Sensor:** produce a discrete digital output signals or voltages that are a digital representation of the quantity being measured. Digital sensors produce a Binary output signal in the form of a logic “1” or a logic “0”, (“ON” or “OFF”).

b. Classification according to the principle of operation:

Also, sensors can be categorized in multiple ways. One common approach is to classify them as either active or passive.[12]

- **Active sensor**: an active sensor is one that requires an external power source to be able to respond to environmental input and generate output. For example, sensors used in weather satellites often require some source of energy to provide meteorological data about the Earth's atmosphere. meteorological data about the Earth's atmosphere.
- **Passive sensor:** a passive sensor, on the other hand, doesn't require an external power source to detect environmental input. It relies on the environment itself for its power, using sources such as light or thermal energy. A good example is the mercury-based glass thermometer. The mercury expands and contracts in response to fluctuating temperatures, causing the level to be higher or lower in the glass tube. External markings provide a human-readable gauge for viewing the temperature.

II.2.2.3. DHT11 Humidity Sensor:

The DHT11 sensor (Figure II.3) provides digital information proportional to the measured temperature and humidity. It consists of a temperature sensor based on NTC thermistors, a resistive humidity sensor, and a microcontroller that handles the measurements, converts them, and transmits them. It interfaces using the OneWire protocol, which allows for data transmission and reception on a OneWire. This technology used by the DHT11 sensor ensures high reliability, excellent long-term stability, and very fast response time.[13]

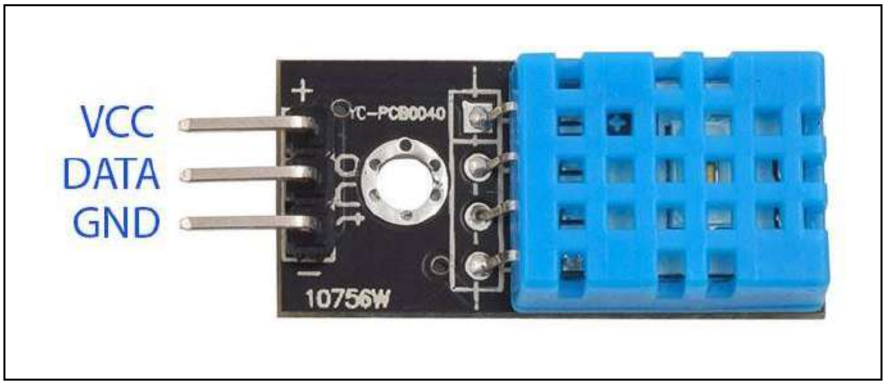


Figure II. 3:DHT11 Humidity Sensor[13]

Specifications:

This sensor contains the following features [13]**:**

- 3 to 5V power and I/O
- 2.5mA max current use during conversion (while requesting data)
- Good for 20-80% humidity readings with 5% accuracy
- Good for 0-50 °C temperature readings +-2 °C accuracy
- No more than 1 Hz sampling rate (once every second)
- Body size 15.5mm x 12mm x 5.5mm
- 4 pins with 0.1" spacing
- RoHS compliant

II.2.2.4. The Soil Moisture Sensor:

The soil moisture sensor (Figure II.4) is a simple tool used to measure moisture in the soil and similar materials. The soil moisture sensor is quite easy to use. The sensor's fork is inserted vertically into the ground. The electrical resistance between the two electrodes is measured. The more water there is in the soil, the better the conductivity between the pads, resulting in a more reliable resistance measurement [14].

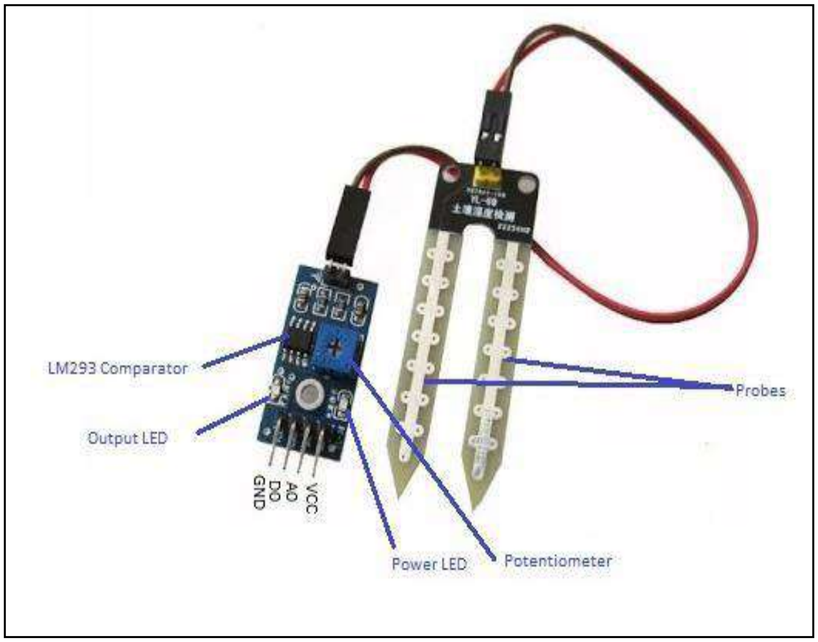


Figure II. 4 :The soil moisture sensor examples[14]

Features & Specifications:

This sensor contains the following features [14]:

- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15mA
- Output Digital - 0V to 5V, Adjustable trigger level from preset
- Output Analog - 0V to 5V based on infrared radiation from fire flame falling on the sensor
- LEDs indicating output and power
- PCB Size: 3.2cm x 1.4cm
- LM393 based design
- Easy to use with Microcontrollers or even with normal Digital/Analog IC
- Small, cheap and easily available

II.2.2.5. MQ135 Air Quality Sensor:

An MQ135 air quality sensor (Figure II.5) is one type of MQ gas sensor used to detect, measure, and monitor a wide range of gases present in air like ammonia, alcohol, benzene, smoke, carbon dioxide, etc. It operates at a 5V supply with 150mA. Preheating of 20 seconds is required before the operation, to obtain the accurate output [15].

Figure II. 5: MQ135 Air Quality Sensor[15]

Features & Specifications:

This sensor contains the following features:

- It has a wide detection scope, and High sensitivity and faster response, also had long life and stability.
- The operating voltage: +5V.
- Measures and detects NH3, alcohol, NOx, Benzene, CO2, smoke etc.
- Used as an analog or digital sensor, and range output voltage for two type is: 0V-5V (TTL logic).
- Heating Voltage: 5V±0.1.
- Load resistance is adjustable.
- Heater resistance: 33ohms±5%.
- Heating consumption:<800mW.
- Operating temperature: -10°C to -45°C.

- Storage temperature: -20°C to -70°C.
- Related humidity: <95%Rh.
- Oxygen concentration: 21% (affects the sensitivity).
- Sensing resistance: 30 kiloohms to 200 kiloohms.
- Concentration slope rate: ≤ 0.65.

II.2.2.6. Light Sensor LDR:

A light sensor is the most common electronic component which can be easily found. The simplest optical sensor is a Photoresistor LDR **(**Figure II.6) or photocell which is a light sensitive resistor [16].

A photoresistor or light dependent resistor is an electronic component that is sensitive to light, when light falls upon it, then the resistance changes. Values of the resistance of the LDR may change over many orders of magnitude the value of the resistance falling as the level of light increases [16].

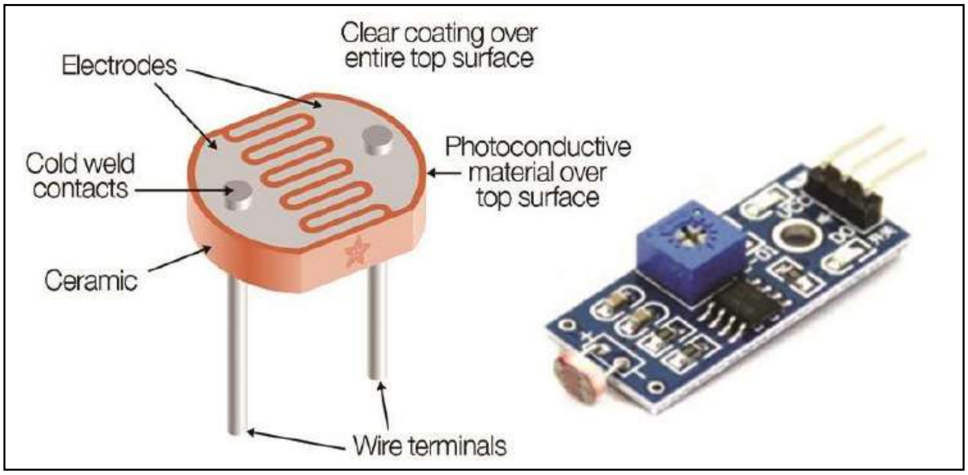


Figure II. 6: Light Sensor LDR[16]

Advantages:

- Sensitivity is High
- Simple & Small devices
- Easily used

- Inexpensive
- There is no union potential.
- The light-dark resistance ratio is high.
- Its connection is simple

Disadvantages:

- The spectral response is limited.
- The best materials have limited temperature stability due to the hysteresis effect.
- Its chemical reaction in stable materials.
- LDR Sensor is only used in situations when the light signal fluctuates dramatically.
- It is not a particularly responsive tool.
- As soon as the operating temperature changes, it gives the wrong results.

II.2.2. Actuators:

II.2.3.1. Ventilation fan:

Air removal equipment in greenhouses includes a set of tools used to ventilate and remove excess air from inside the greenhouse. Among these equipments, the ventilation fan (Figure II.7) comes to the fore, as it moves air and removes excess moisture and heat from inside the greenhouse. A ventilation fan helps provide fresh airflow and reduce moisture build-up and disease in the agricultural environment. The use of a proper ventilation fan contributes to achieving suitable conditions for plant growth and improving air quality inside the agricultural house.[17]

Figure II. 7: Ventilation fan[17]

II.2.3.2. Air humidifier:

The air humidifier is used to increase the humidity levels inside the greenhouse. It helps create an ideal environment for plants that require high humidity, preventing them from drying out and reducing the negative effects of dry air on plant growth. The air humidifier ensures a balanced and suitable humidity level, promoting healthy plant development.[18]

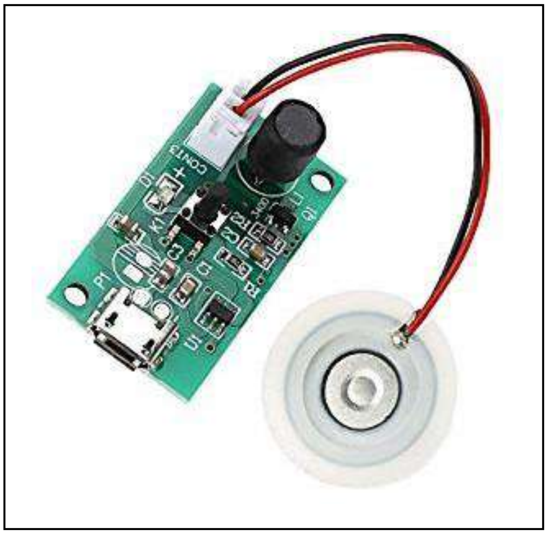


Figure II. 8 : Air Humidifier Driver Board Mist[18]

II.2.3.3. Heater:

An **electrical heater** (Picture II.9) is a device used to generate heat in greenhouses through electricity. It relies on converting electrical energy into heat through the electric heating elements it contains.[19]

Figure II. 9 : Electrical heater[19]

Electrical heaters have several advantages [19], including:

- Easy operation: Electrical heaters are simple to operate by connecting them to a power source and turning them on.
- Clean and no harmful emissions: Electrical heaters do not require fuel or combustion, meaning there are no harmful emissions such as exhaust gases.
- Precise temperature control: Some electrical heaters are equipped with temperature sensors and control devices to allow for precise adjustment of the desired temperature and maintaining it accurately.
- Energy efficiency: Electrical heaters are efficient in using energy, as most of the electrical energy is converted into heat.

It is important to choose the appropriate electrical heater based on the size of the greenhouse, the area to be heated, as well as other considerations such as available electrical power and the desired heat efficiency .

II.2.3.4. LED Grow Lights:

LED Grow Lights (Picture II.10) are specialized lighting fixtures designed to provide artificial light that promotes the growth and development of plants. They utilize light-emitting diodes (LEDs) as the light source, which emit specific wavelengths of light that are crucial for photosynthesis and plant growth.[20]

Figure II. 10:LED Grow Lights[20]

LED Grow Lights have the following advantages [21] :

- Energy Efficiency: LED technology utilizes energy efficiently, resulting in energy savings and reduced operational costs.
- Spectrum Control: LED Grow Lights can be customized to emit specific wavelengths of light, providing the ideal light spectrum for each stage of plant growth.
- Long Lifespan: LED lights have a much longer lifespan compared to traditional lighting sources, reducing replacement and maintenance costs.
- Heat Management: LED Grow Lights produce significantly less heat than traditional sources, contributing to lower environmental temperature and improved plant comfort.

By using LED Grow Lights, farmers can achieve healthy and productive plant growth in artificial light environments, allowing for efficient cultivation of plants indoors and improving crop yields.

II.2.3. 5. Irrigation Pump:

An irrigation pump (Picture II.11) is a device used in agricultural irrigation to pump water from a water source (such as a well or reservoir) and distribute it to the crops. The purpose of irrigation pumps is to provide an adequate amount of water and suitable pressure for watering plants and meeting their water requirements [22].

Figure II. 11: Irrigation Pump[22]

The pump operates using a motor that drives the pumping process, where water is drawn from the source and pumped through irrigation pipes to the agricultural areas. Irrigation pumps are available in a variety of sizes and capacities, and the appropriate type is chosen based on the size of the farm and irrigation needs [22].

II.2.3.6.Relay:

The benefit of using a relay in a greenhouse is the control it provides for operating and stopping various devices in the greenhouse automation system. The relay (Picture II.12) can be used to control pumps, ventilation equipment, lighting systems, and other important devices in the greenhouse.

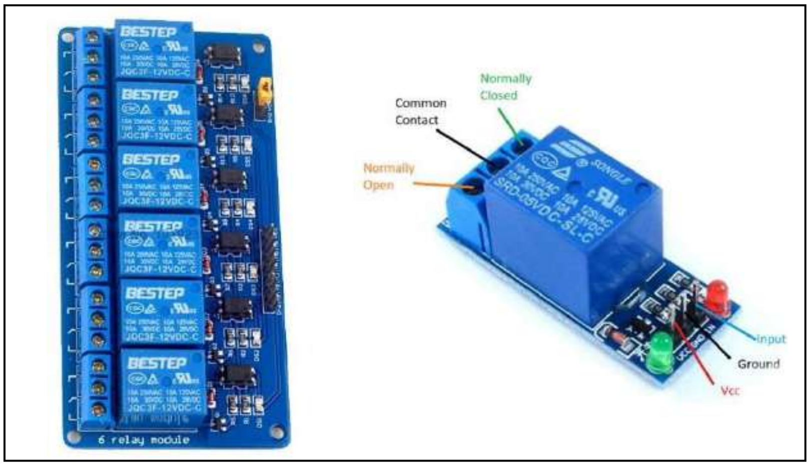


Figure II. 12 : Relay 6 channel[23]

By utilizing a relay in the greenhouse, it can be programmed to execute specific functions at designated times, such as activating pumps for plant irrigation, operating ventilation equipment to provide necessary airflow, or turning on lighting systems to achieve proper plant growth. The use of a relay in greenhouses contributes to improving system efficiency and energy savings, while ensuring optimal conditions for plant cultivation.[23]

II.3. Soft part:

II.3.1. Arduino IDE:

Arduino IDE (Integrated Development Environment) is an open-source software application for programming Arduino boards. It provides a user-friendly platform for writing, compiling, and uploading code to Arduino microcontrollers. Beginners and experienced developers alike widely use the Arduino IDE, as it offers a simple interface and a rich set of features to facilitate the development of Arduino-based projects.[8] [24]

Alike widely use Arduino IDE [24] ,Here are some key features of the Arduino IDE:

- Code Editor: The IDE includes a text editor where you can write and edit your Arduino code. It offers syntax highlighting, auto-completion, and indentation to enhance code readability and productivity.
- Library Manager: Arduino IDE comes with a library manager that allows adding and managing external libraries easily. These libraries contain pre-written code that can be used to extend the functionality of your Arduino projects.
- Sketches: In Arduino terminology, a program is called a "sketch." The IDE organizes code into sketches, making it easy to manage and switch between different projects. Each sketch consists of two essential functions: setup() and loop(), which are executed once and repeatedly, respectively.
- Board Manager: Arduino boards come in different variations, and the IDE supports a wide range of them. The board manager lets you select the specific Arduino board you are using and ensures that the code is compiled and uploaded correctly for that particular board.
- Serial Monitor: The IDE provides a built-in serial monitor tool that allows you to communicate with your Arduino board through the serial port. It enables you to send and receive data, debug your code, and monitor sensor readings or other outputs from your project.
- Code Compilation and Uploading: The Arduino IDE compiles code into a binary file that can be uploaded to the Arduino board. It handles the entire process seamlessly, making it easy to write, compile, and upload the code with a single click.

- Examples and Tutorials: The IDE offers a collection of example sketches and tutorials to help to understand different Arduino functionalities and get started quickly

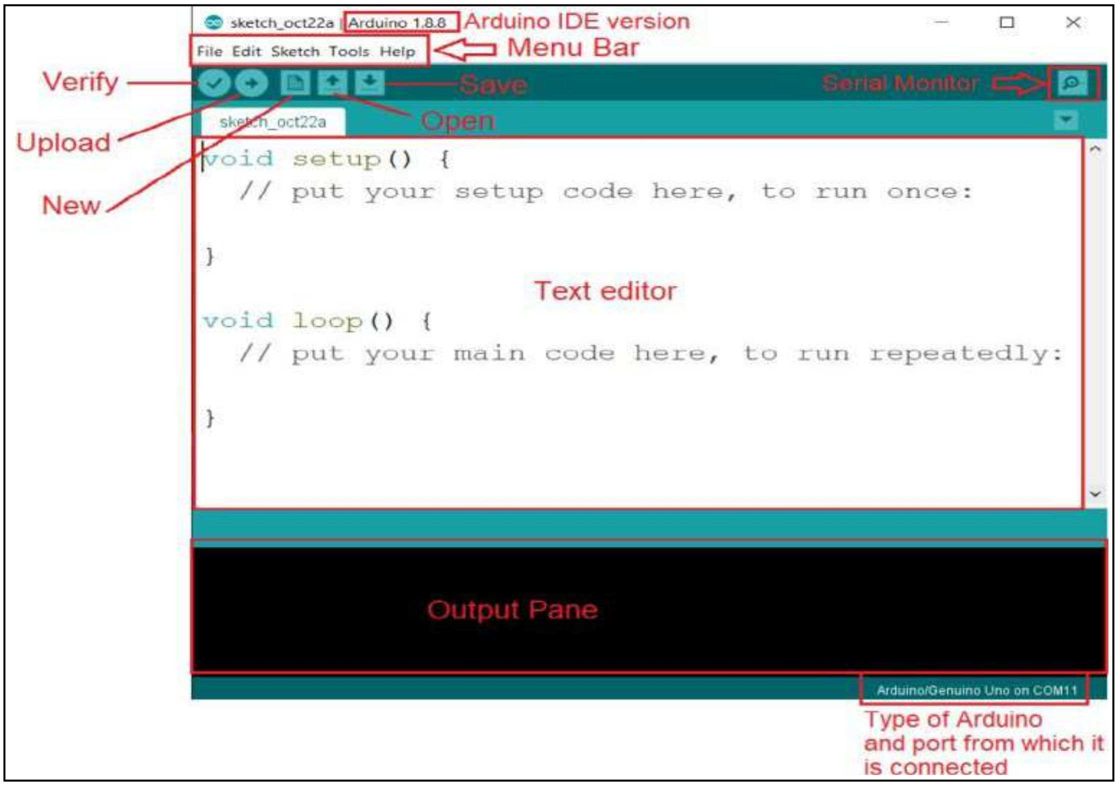


Figure II. 13: Arduino IDE [24]

II.3.2. Wokwi Simulator:

Wokwi Simulator is a web-based virtual simulation platform that allows you to test and debug Arduino and other electronic circuits without the need for physical hardware. It provides a realistic environment where you can design and prototype your electronic projects, helping you save time and resources during the development process.[25]

Here are some key features of Wokwi Simulator:

- Breadboard-based Simulation: The simulator emulates a virtual breadboard, where you can place and connect electronic components, including Arduino boards, resistors, capacitors, LEDs, sensors, and more. You can easily drag and drop components onto the breadboard and connect them using virtual wires.[25]

- Arduino Compatibility: Wokwi Simulator specifically supports Arduino boards, allowing you to simulate and test your Arduino projects. You can choose from a variety of Arduino board models, such as Arduino Uno, Nano, Mega, and more, depending on your requirements.
- Real-time Circuit Simulation: As you build your circuit on the virtual breadboard, the simulator provides real-time feedback by simulating the behaviour of the components and the flow of electricity. You can observe how your circuit responds to input signals, monitor sensor readings, and visualize the behaviour of LEDs and other output devices.
- Code Execution and Debugging: In addition to circuit simulation, Wokwi Simulator enables you to write and execute Arduino code directly within the platform. You can use the integrated code editor to write your program, and the simulator will run the code and interact with the virtual circuit accordingly. It allows you to debug your code, set breakpoints, step through the code line by line, and observe variable values.
- Interactive User Interface: The simulator provides a user-friendly interface with intuitive controls. You can interact with buttons, switches, sliders, and other input components to test the behaviour of your circuit. The interface also includes a console or serial monitor window where you can view program output or communicate with your virtual Arduino board.
- Collaboration and Sharing: Wokwi Simulator allows you to share your circuits and projects with others. You can save and share your designs as URLs, making it easy to collaborate with teammates, seek feedback, or provide demonstrations without physical hardware.
- Extensive Component Library: The simulator offers a wide range of electronic components and modules that you can use in your circuits. It includes various sensors, actuators, displays, communication modules, and more. Additionally, you can import custom components or libraries to extend the simulator's capabilities.

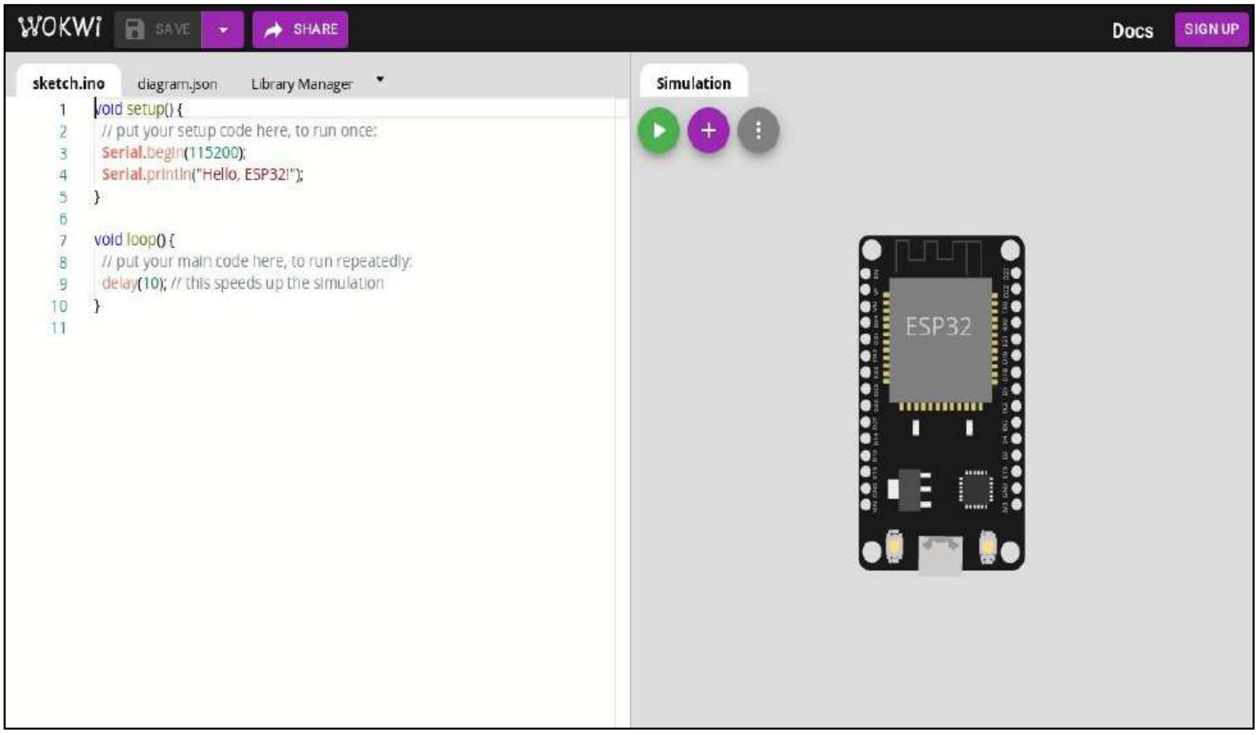


Figure II. 14: WokWi website[25]

II.3.3.EasyEDA:

EasyEDA is a popular web-based PCB (Printed Circuit Board) design tool that offers a user-friendly interface and a comprehensive set of features for designing electronic circuits and PCB layouts. It is designed to be accessible to both beginners and experienced engineers, providing a seamless experience from schematic capture to PCB fabrication.[26]

the key features of EasyEDA PCB Designer:

- Schematic Capture: EasyEDA allows you to create circuit schematics using a drag-and-drop interface. You can choose from a vast library of components and symbols, place them on the canvas, and connect them using wires. The schematic editor provides an intuitive environment for designing complex circuit diagrams.[26]
- PCB Layout Design: Once you have created the schematic, EasyEDA offers a powerful PCB layout editor to convert your design into a physical PCB layout. You can define board dimensions, place components on the board, and route traces to establish connections. The

editor provides advanced features like auto-routing, copper pour, design rule checking (DRC), and netlist import/export.[26]

- Simulation and Analysis: EasyEDA integrates simulation capabilities, allowing you to test and verify your circuit designs. It supports both transient and steady-state analyses, enabling you to evaluate the behavior of your circuit under different conditions. You can perform DC, AC, and transient simulations to assess voltage levels, current flows, and component characteristics.[26]
- Collaboration and Sharing: EasyEDA provides collaboration features, allowing multiple users to work on the same project simultaneously. You can invite team members, share projects, and collaborate in real-time. Additionally, EasyEDA supports project sharing via URLs, making it easy to share your designs with others or seek feedback.[25]
- Community and Resources: EasyEDA has a thriving community of users and provides various resources to support designers. You can find tutorials, documentation, and design examples to learn from and get inspired. The community also offers a platform for seeking help, sharing knowledge, and connecting with other electronics enthusiasts[26]

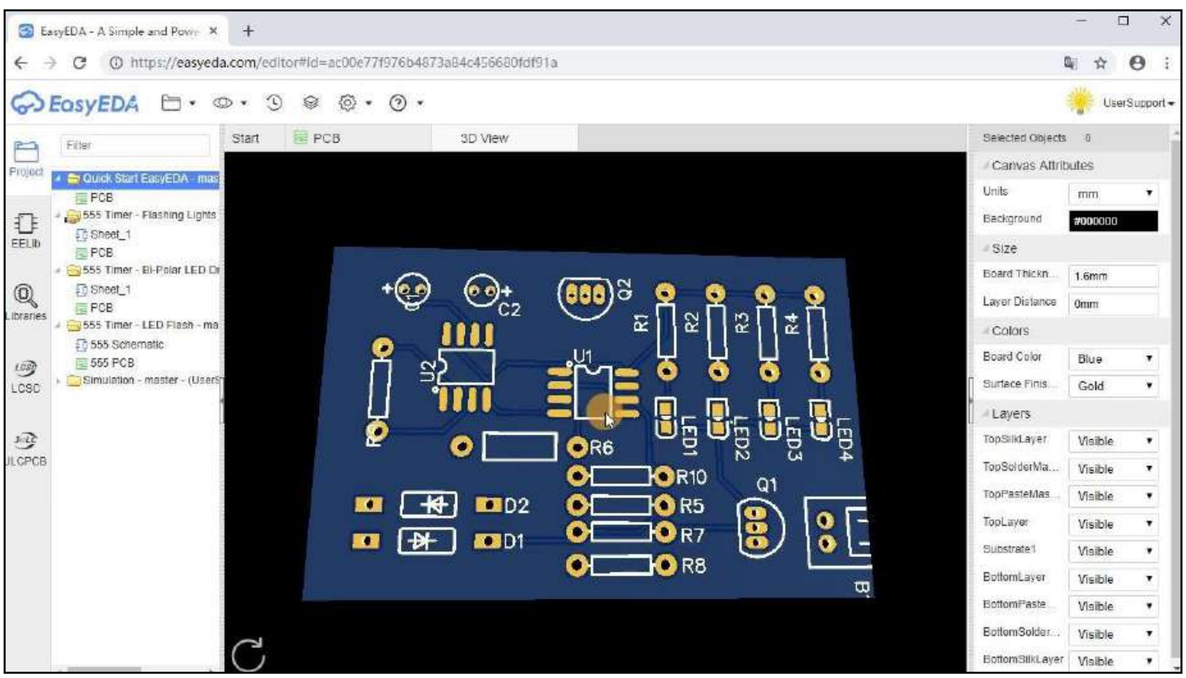


Figure II. 15 :3D cercuit by EasyEDA [26]

II.3.4.ThingSpeak Cloud:

ThingSpeak is an IoT (Internet of Things) platform and cloud service provided by MathWorks. It enables users to collect, store, analyze, and visualize data from connected devices or sensors. ThingSpeak simplifies the process of building IoT applications by providing an easy-to-use interface and a range of features for data management and visualization.[27]

The key features of ThingSpeakr:

- Data Collection: ThingSpeak allows you to collect data from various IoT devices, sensors, or external sources. It provides RESTful APIs (Application Programming Interfaces) that enable devices to send data to the cloud platform securely. You can also use MQTT (Message Queuing Telemetry Transport) protocol for efficient and lightweight data transfer.[26]
- Channel-based Data Storage: In ThingSpeak, data is organized into channels. Each channel represents a collection of data from a specific source or device. You can define and customize the fields within a channel to store different types of data, such as temperature, humidity, GPS coordinates, or any other sensor readings.[27]
- Data Visualization: ThingSpeak provides built-in tools for visualizing and analyzing data. It offers customizable charts, graphs, and gauges to represent data in real-time or historical views. You can monitor sensor readings, track trends, and identify patterns or anomalies in your data using the visualization features.[27]
- Data Processing and Analysis: ThingSpeak supports MATLAB analytics, which allows you to apply complex data processing algorithms and perform advanced analysis on the collected data. You can create MATLAB scripts or use predefined functions to analyze data, derive insights, and trigger actions based on specific conditions.
- IoT Integrations: ThingSpeak integrates with other IoT platforms and services, enabling seamless data exchange and interoperability. It supports integration with popular platforms like IFTTT (If This, Then That), which allows you to create automation rules and trigger actions based on data events. [27]

- Real-time Data Access: ThingSpeak provides real-time access to data through its APIs, making it easy to retrieve and use the collected data in your applications. You can access data using RESTful APIs or MQTT subscriptions, enabling real-time monitoring or integration with external systems.
- Open and Extensible: ThingSpeak is an open platform that allows developers to extend its capabilities. It supports custom plugins and MATLAB code integration, enabling you to add specific functionalities or implement custom data processing algorithms according to your application requirements.

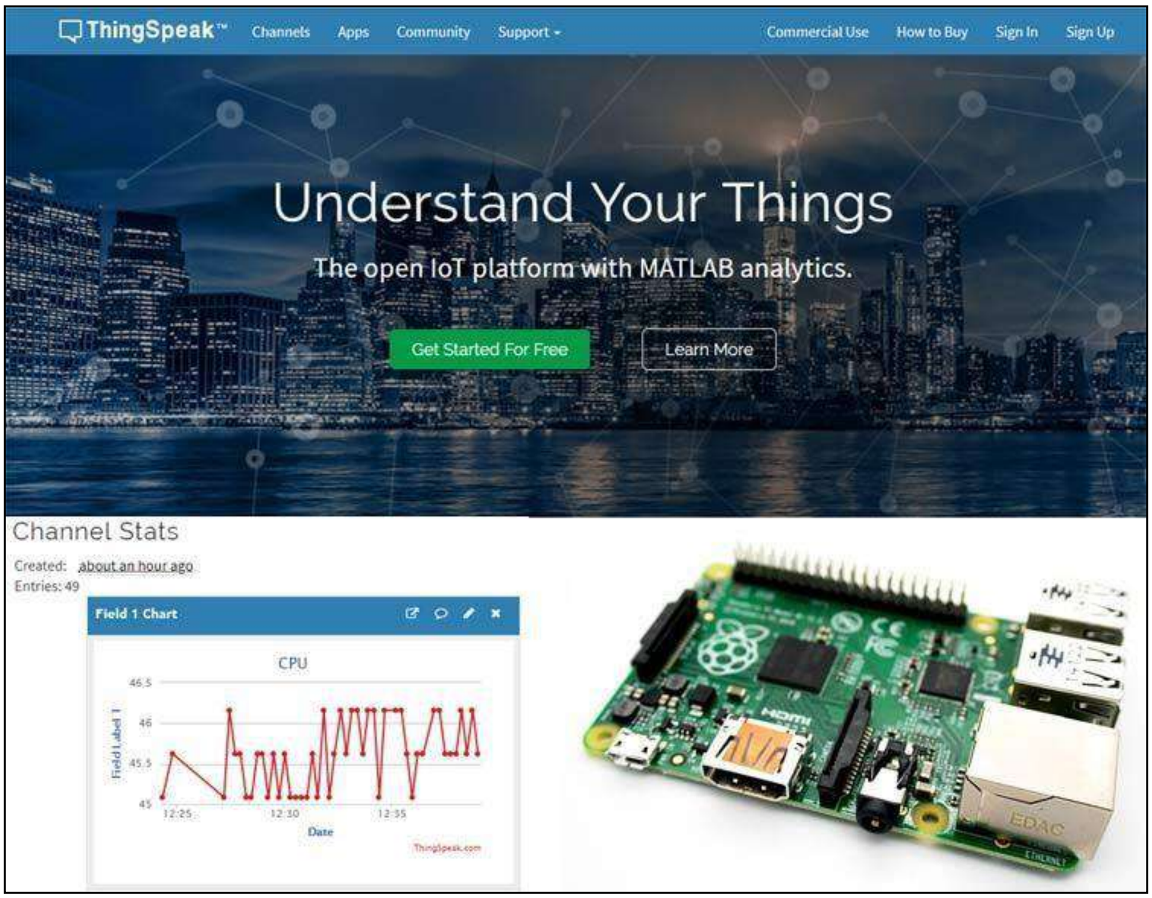


Figure II. 16: Save Data to ThingSpeak Cloud[27]

II.4. Conclusion:

In this chapter, our primary emphasis has been on elucidating the greenhouse control circuit, which serves as the fundamental basis for our project. We have also outlined and elucidated the necessary accessories required for the implementation of our project. Furthermore, we have expounded upon the benefits and significance of these accessories in relation to our project. Notably, the utilization of the pico microcontroller enables us to efficiently oversee and regulate a multitude of sensors and actuators, facilitating seamless task execution while simultaneously recording data in our cloud storage.

Chapter III:

Realization and Testing of the agricultural greenhouse

III.1.Introduction

Intelligent agriculture revolves around the integration of finance and technology in farming and crop production. Intelligent greenhouses, in particular, face the following challenges:

- Ever-changing climatic conditions.
- Varied farming requirements for different plants.
- The cost of producing plastic houses.
- Determining the type and quantity of sensors for each individual greenhouse.
- Establishing connectivity of the greenhouses to the Internet.
- Uncomfortable interfaces for human-system interaction.

III.1.1. Project Objective:

The objective of this project is to develop a connected and intelligent greenhouse system. The primary goal of this greenhouse is to create optimal growing conditions for plants by gathering data from sensors strategically positioned within the greenhouse.
This system offers the following functionalities:

- Automated and intelligent control of greenhouses to create optimal climatic conditions for each specific plant species.
- Remote collection of data from the greenhouses and their surrounding environment through a website.

III.1.2. Principle of the Proposed Solution:

The proposed solution operates on a two-part system (Figure III.1):

The first part involves the physical capture and actuation sub-system, which serves as the interface between the greenhouse and the rest of the system. Its main function is to gather real-time data on various parameters such as temperature, humidity, brightness, and more, from the greenhouse's interior environment. Additionally, it translates system commands into physical actions within the greenhouse, such as activating or deactivating lights. This sub-system is implemented using an ESP32 microcontroller board, along with physical sensors and actuation components.

The second part is developed as a dynamic website, which is hosted on an Internet server. The website serves as an IoT platform, providing the following capabilities:

- Real-time data collection, with a frequency of at least 15 seconds.
- Visualization of collected data in the form of graphs.
- Creation of plugins and applications to integrate with web services, social networks, and other APIs, enabling collaboration and extended functionality.

III.2. How the system works

The greenhouse control system depends on measuring factors and physical phenomena that control plant growth and survival. The following figure (Figure III. 1) shows how this system works:

- In this project, we connect the sensors to the microcontroller esp32 pico kit v4(the connection scheme given by the manufacturer must be respected)
- The microcontroller is then connected to the internet through a router
- The microcontroller compares the data from the sensors with the Optimum conditions required for plant growth
- Based on this analysis, the microcontroller gives orders to regulate these environmental factors
- Moreover, the collected data is then transferred to the “ThingSpeak” cloud for further processing and analysis.

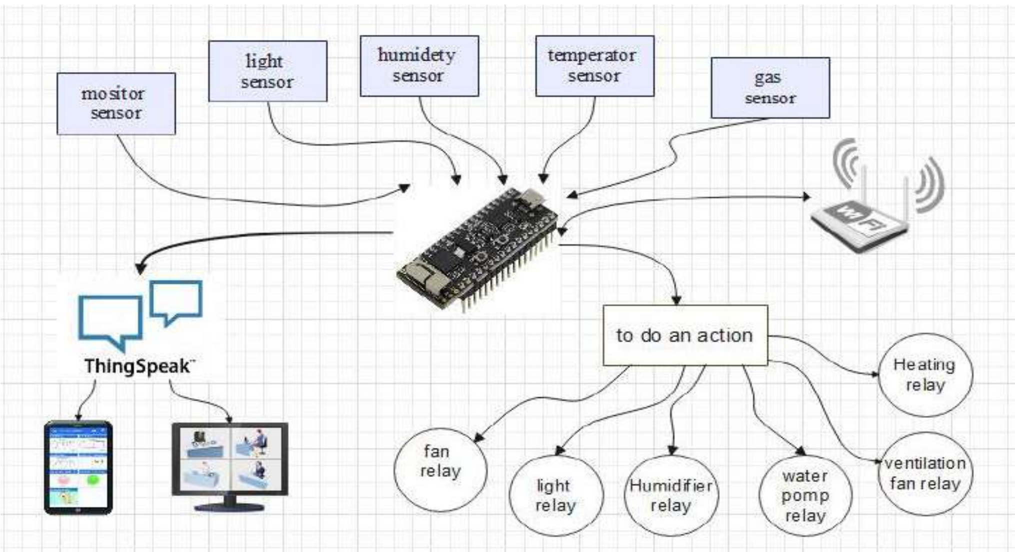


Figure III. 1: Flowchart of the Greenhouse System

III.3.Mounting sensors and actuators:

III.3.1 Controlling the temperature according to the dht11 temperaturesensing:

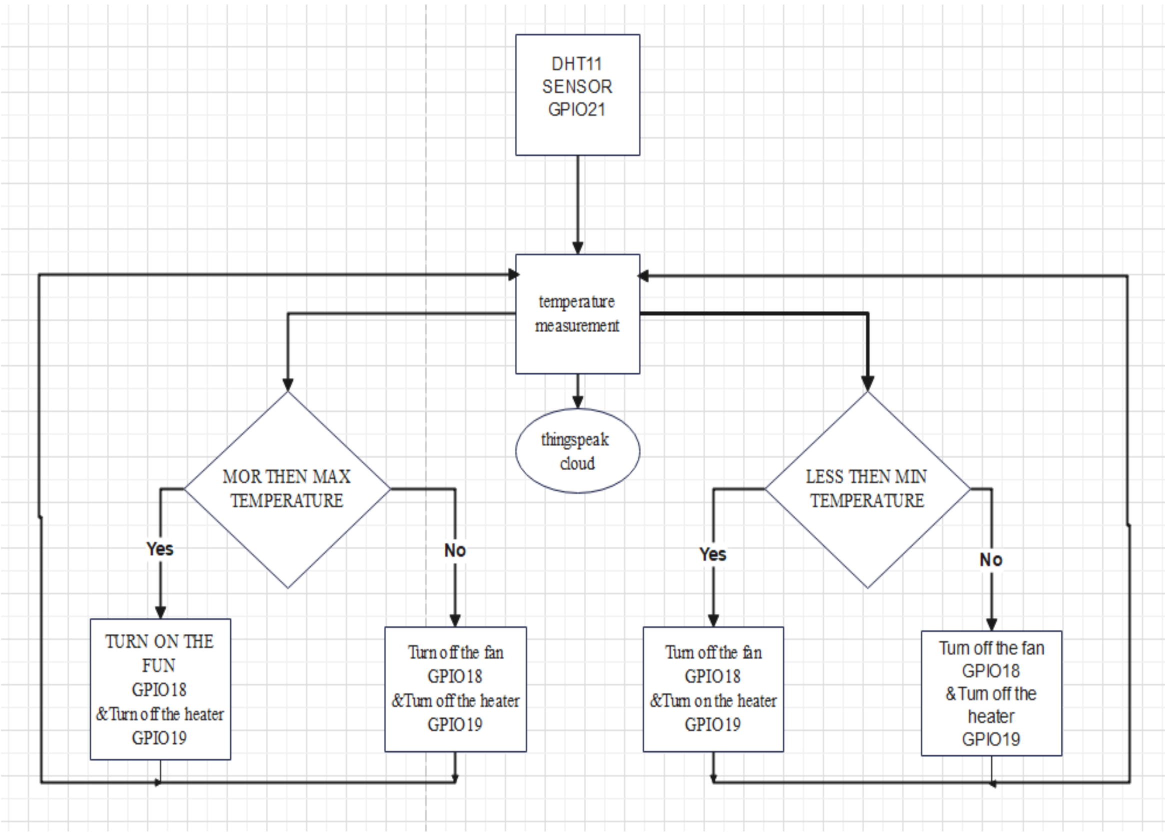


Figure III. 2: the operation of the sensor and temperature control

- the DHT 11 sensor measures the temperature and sends the value to the microcontroller (esp32) then send it to the “thing speak” cloud
- the microcontroller compares the value according to the user's setup
- if the temperature is more than the “MAX” specified value the fun turns on and the heater turns off
- else if the temperature is less than the “MIN” specified value the fun turns off and the heater turns on
- else turn off both the heater and the fan

III.3.2 Controlling the humidity according to the dht11 humidity sensing:

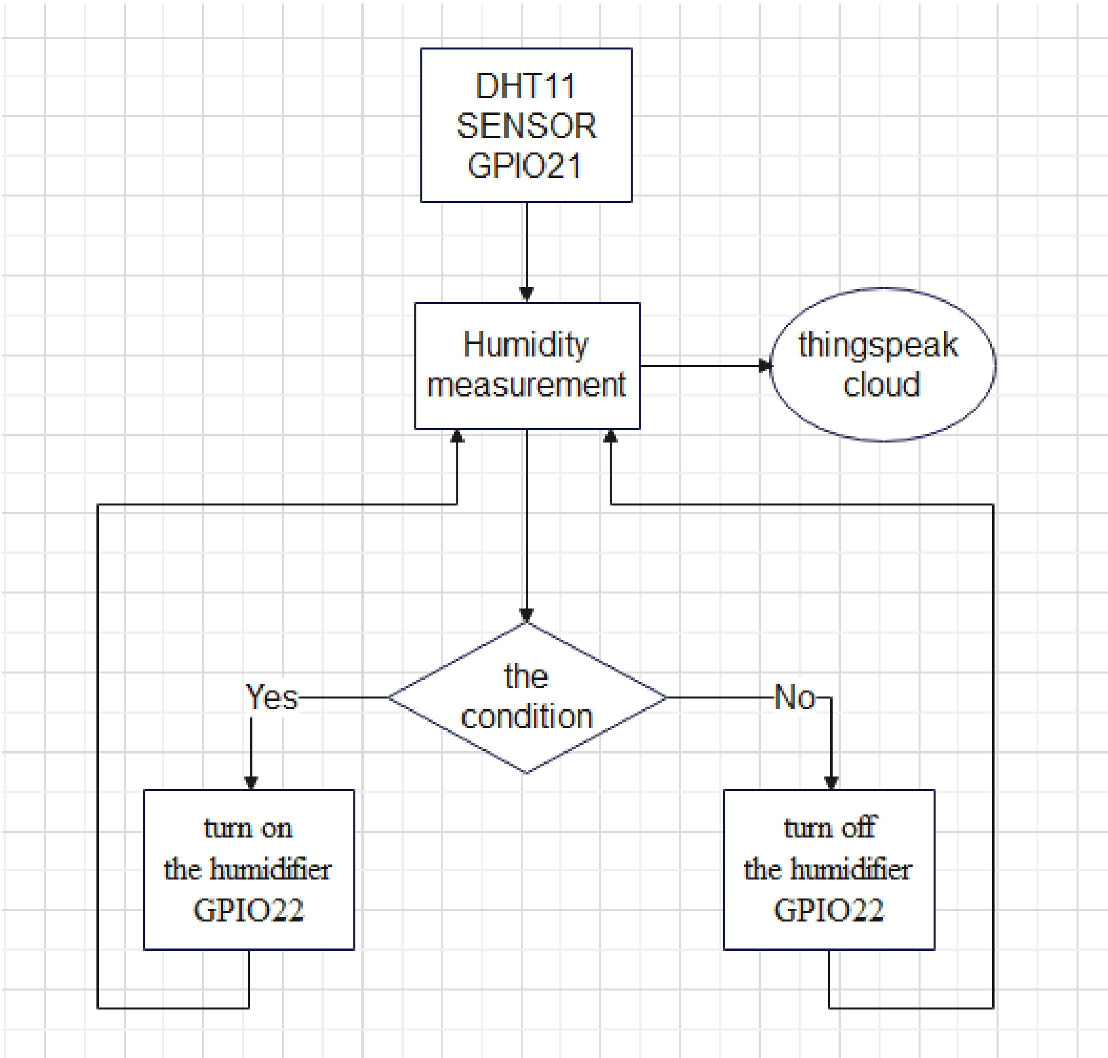


Figure III. 3: This diagram presents the operation of the DHT 11 sensor and humidity control

- ✓ the DHT 11 sensor measures the **humidity** and sends the value to the microcontroller (esp32) then send it to the "thing speak" cloud
- ✔ the microcontroller compares the value according to the user's setup
- ✓ if the **humidity is** less then the MIN specified value the humidifier turns on
- ✔ else the humidifier turns off

III.3.3 Soil moisture measurement and watering control diagram:

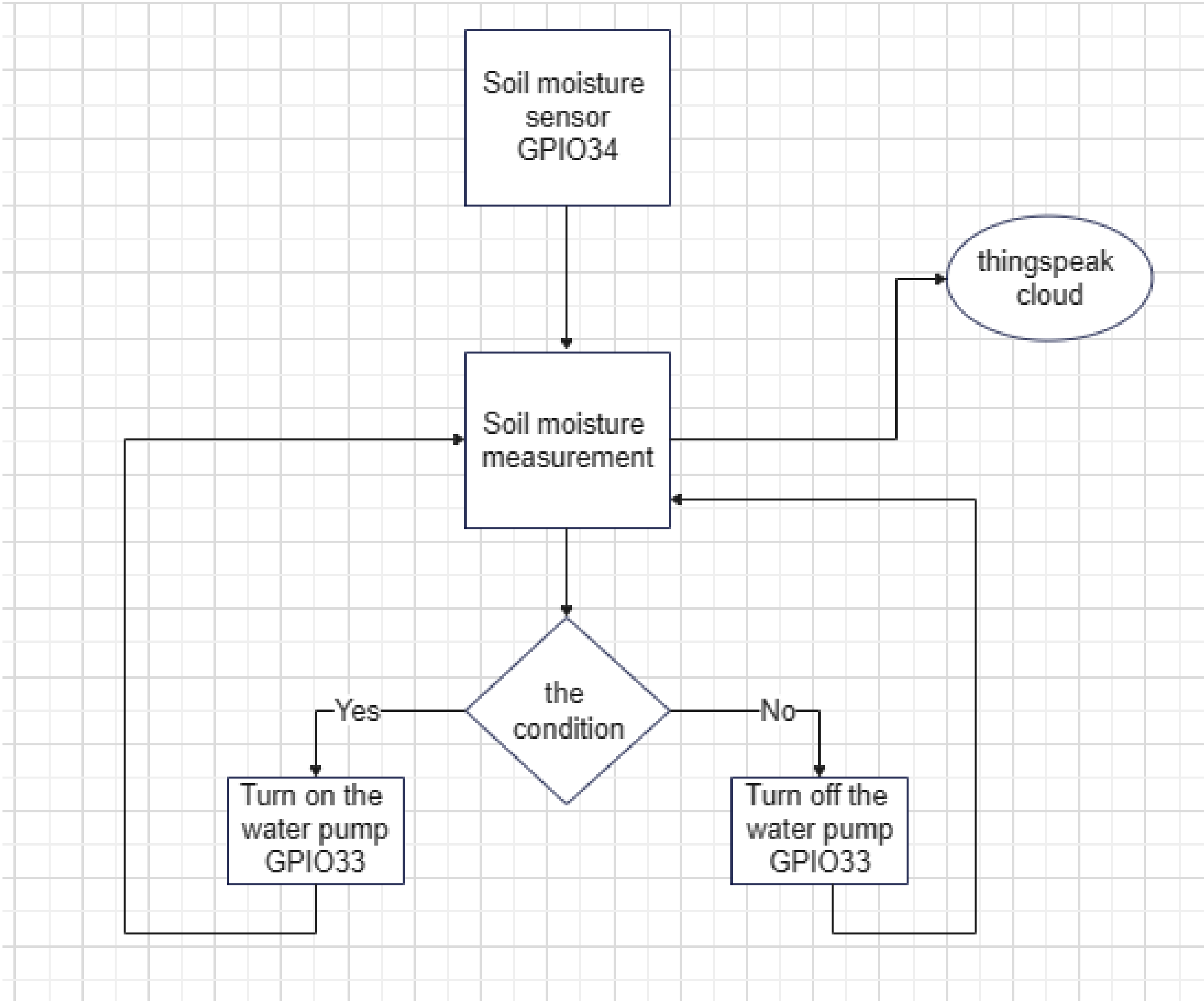


Figure III. 4: Soil moisture measurement and Watering control

- ✓ the soil moisture sensor measures the **soil moisture** and sends the value to the microcontroller (esp32) then send it to the "thing speak" cloud
- ✔ The microcontroller compares the value according to the user's setup
- ✓ if the **soil moisture value is** less than the "MIN" specified value the water pump turns on
- ✔ else the water pump turns off

III.3.4 Controlling the Intensity of illumination working diagram:

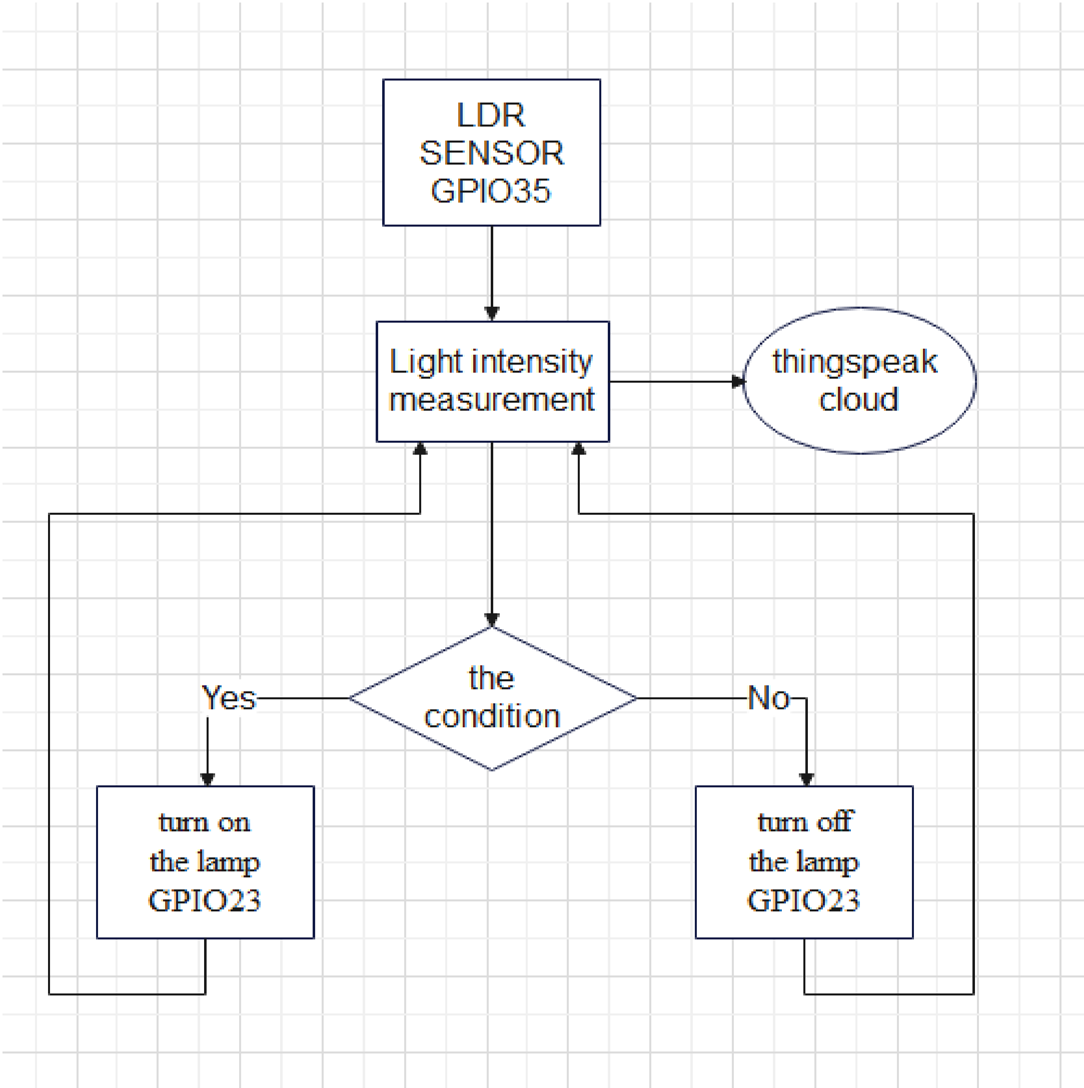


Figure III. 5: controlling of the Intensity of illumination

- ✓ The LDR sensor measures the Intensity of illumination and sends the value to the microcontroller (esp32) then send it to the “thing speak” cloud
- ✔ The microcontroller compares the value according to the user's setup
- ✓ if the Intensity of the illumination **value is** less than the MIN specified value the lamp turns on
- ✔ else the lamp turns off

III.3.5 Controlling the air quality working flowchart:

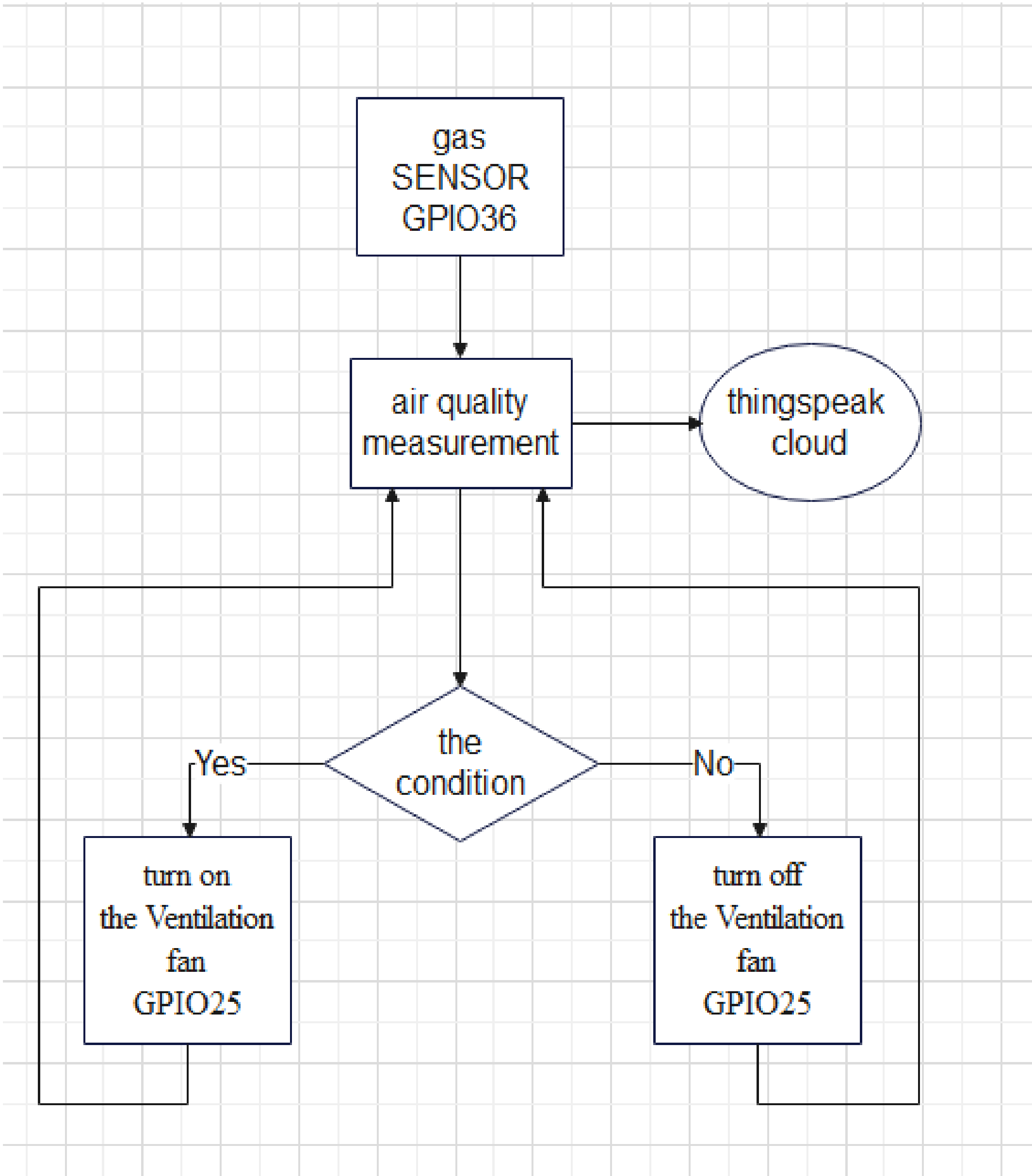


Figure III. 6: controlling of the air quality

- ✓ The gas sensor measures the air quality and sends the value to the micro-controller (esp32) then send it to the "thing speak" cloud
- ✓ The micro-controller compares the value according to the user's set-up
- ✓ if the air quality **value is** less then the MIN specified value the Ventilation fan turns on
- ✓ else the Ventilation fan turns off

III.3.6 The complete control model of the system:

The flowchart for the greenhouse system is shown in the next Figure (Figure III.5). It shows the flow sequence of the system. The actions taken are in this order:

1. The system is turned on and It starts to work
2. The gas, soil moisture, temperature, humidity, and intensity of light sensors start measuring
3. The microcontroller(esp32 pico kit) checks the data read if they are above the threshold value for each environmental parameter
4. and controlling the actioners fan, heater, ventilation fan, light

source, and the water pump according to the settings then updated this data on the "ThingSpeak" platform.

5. This process is repeated as far as the system is powered.

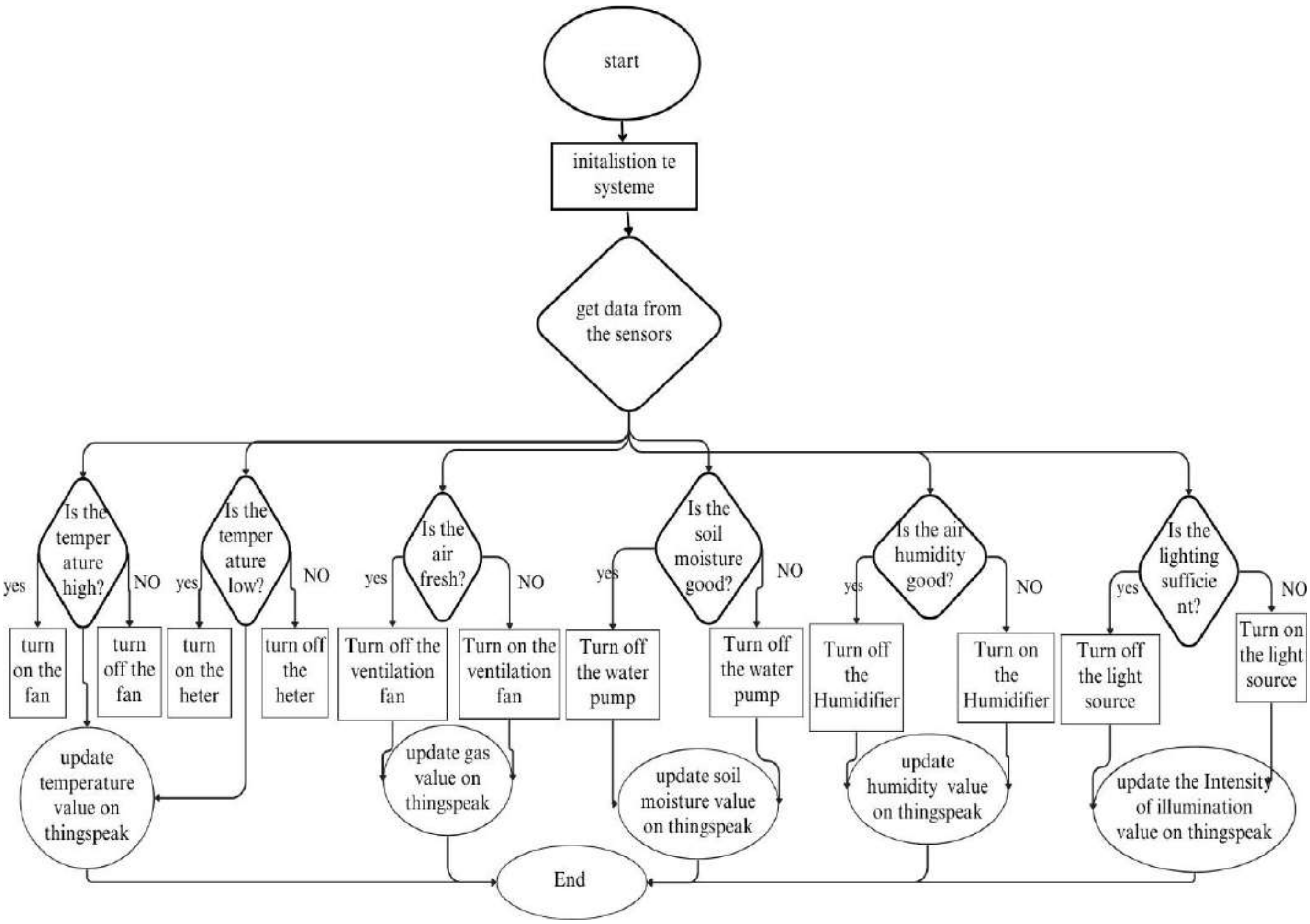


Figure III. 7:The flowchart for the greenhouse system

III.4.Simulation and manufacturing:

III.4.1. System simulation using WOKWI:

Simulation of pre-industrial electrical circuits plays a crucial role in developing electronic devices. It helps to analyse, test and improve the performance of electrical circuits before building the actual model. Many benefits are achieved through this process.

First, circuit simulation reduces the costs and time required to fix errors and make necessary adjustments at an early stage.

Second, it helps detect and correct potential issues and challenges before production begins.
Third, it allows engineers to optimize circuit performance and achieve the perfect design to meet customer needs.

Finally, circuit simulation allows the testing of new ideas and innovations without the need to build physical models.

In general, it can be said that simulating electrical circuits before rendering enhance efficiency and quality and speeds up the technical development process

The following figure(III.7) shows the simulation of the system using

Wokwi software:

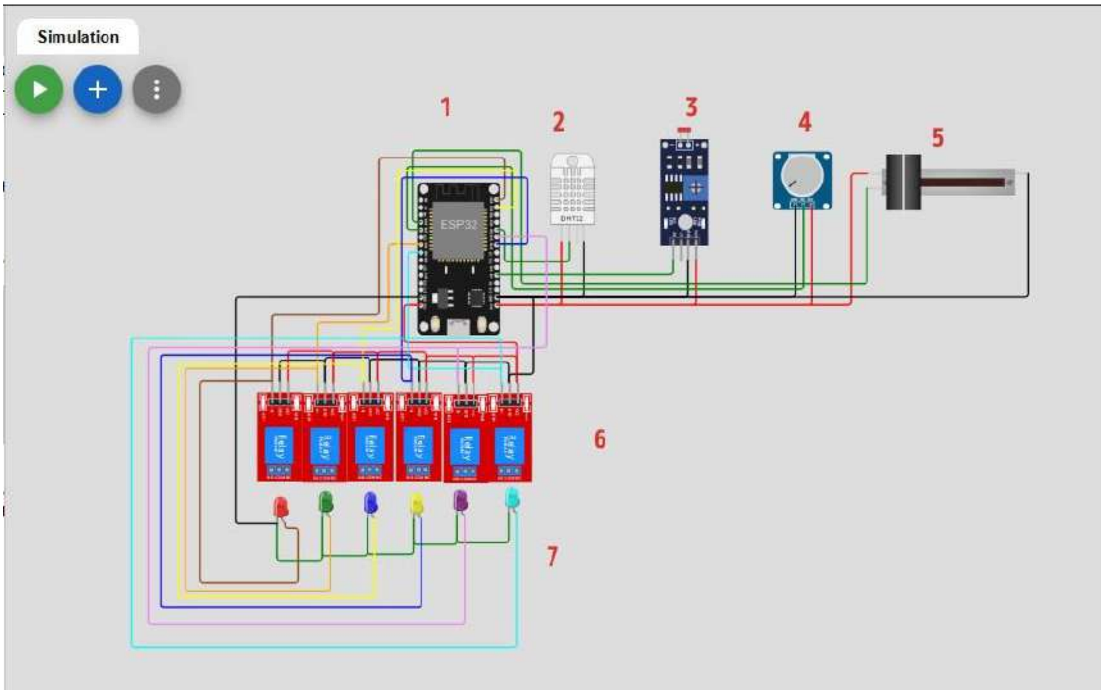


Figure III. 8: simulation of the greenhouse system

We connect all sensors DHT 22, LDR, GAS, and the soil moisture Indicated in the diagram by consecutive numbers (2,3,4,5,6)to the microcontroller (1)
the 6 channels relay model Indicated in the diagram by the number (6)

The number (7) refers to the LED lights that help to know the operation of the relays
NOTE: "Wokwi Simulator" is an excellent program for simulating electronic circuits. However, it may have a limited range of available electronic components. Therefore, you may need to choose alternative components that perform the same function and incorporate them into the programming code.

III.4.2. Assembly and testing of electronic components:

After testing and simulating the components in the Wokwi software, we now move on to a real-world application. We assemble all the components on the breadboard, program them, and monitor their functionality:

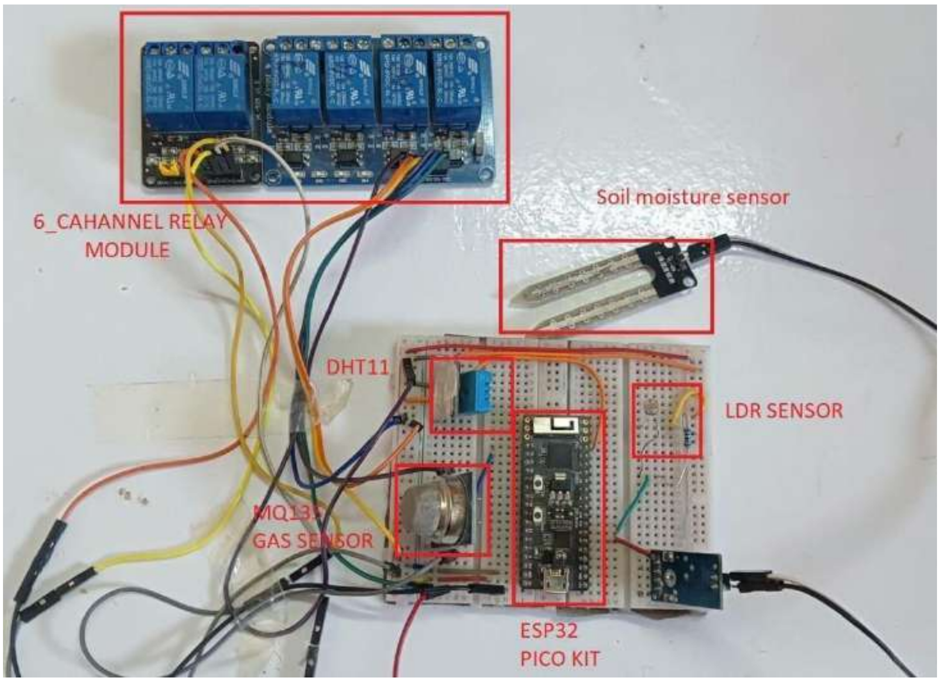


Figure III. 9: Connecting the sensors with the microcontroller

sensors	DHT11			LDR		
Connections	GND	5V	IO 21	GND	5V	IO35

sensors	SOIL MOISTURE			GAS SENSOR		
Connections	GND	5V	IO 34	GND	5V	IO36

TABLE III. 1: Connections pins the link between the sensors and the microcontroller.

III.4.3. programing the system:

After connecting all the sensors to the microcontroller, we proceed to program the system. For programming, we use the Arduino code editor, which is specifically designed for programming Arduino boards. However, it is also possible to program ESP 32 by adding it to the editor, as explained in the **Annexe**. After programming and uploading the code to the board, we open the serial monitor to observe the changes in the values outputted by the sensors.

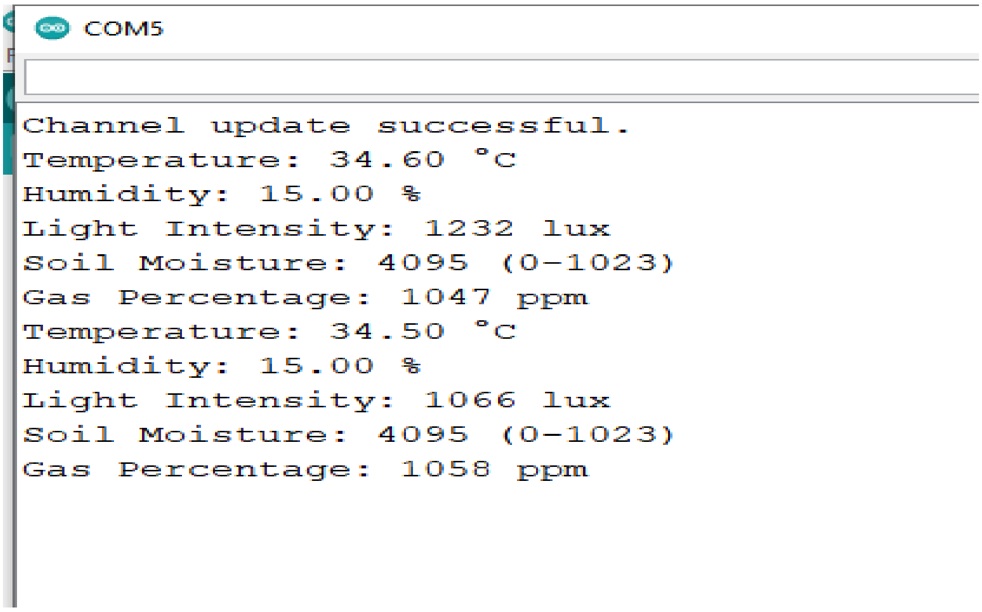


Figure III. 10: Reading the sensor data in the serial monitor

III.4.4. View data in the “ThingSpeak” cloud:

after fully assembling the electronic components with the microcontroller and connecting the power supply, we proceed to the “ThingSpeak” platform to display the data output from the sensors.

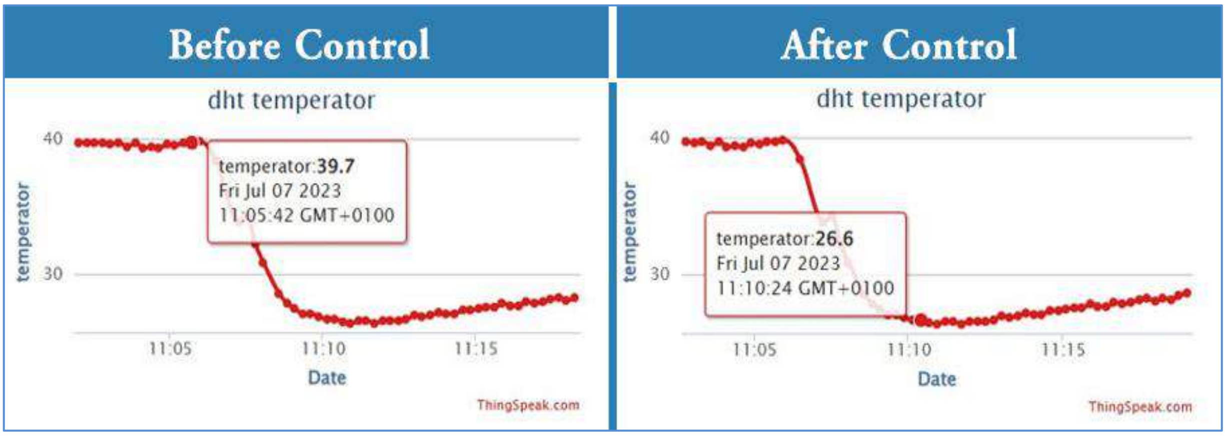


Figure III. 11: data of temperature

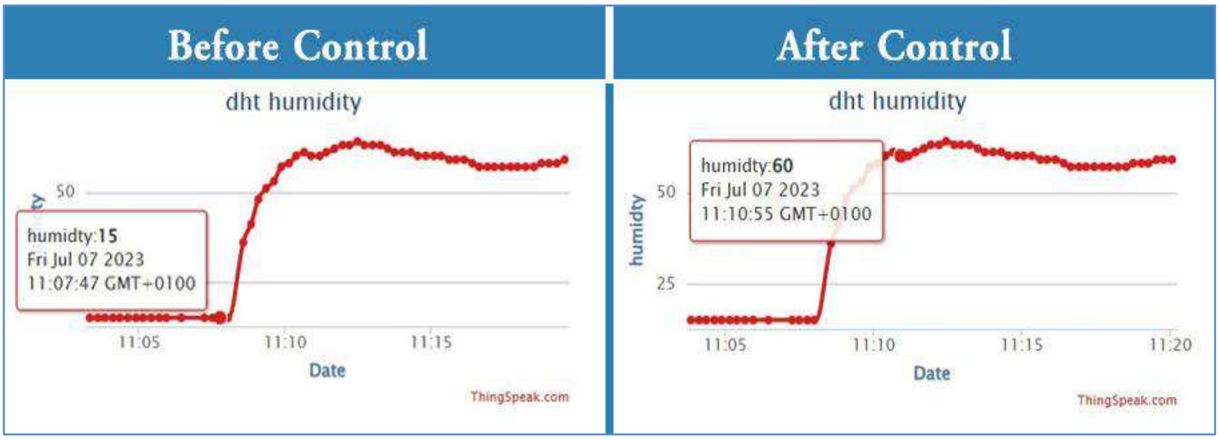


Figure III. 12: data of the humidity

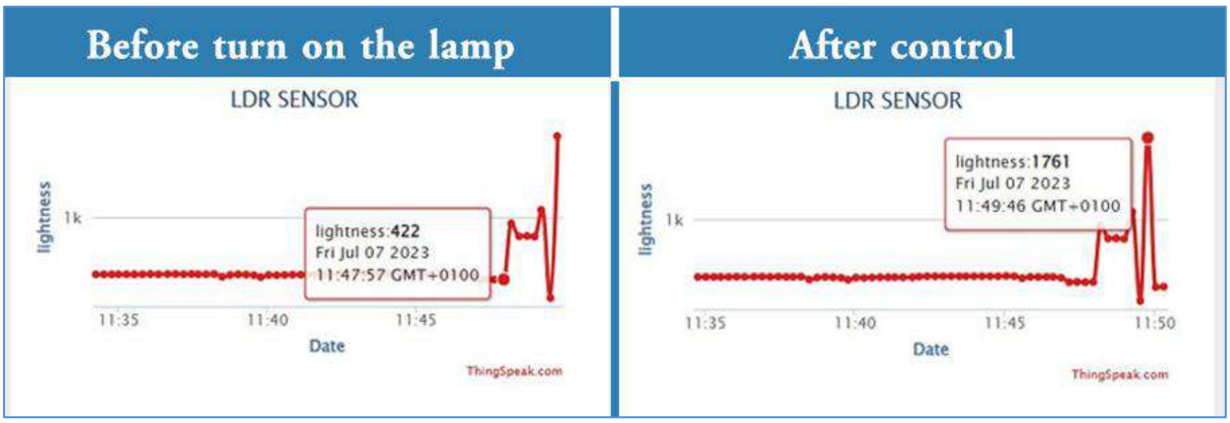


Figure III. 13: data of the Intensity of illumination

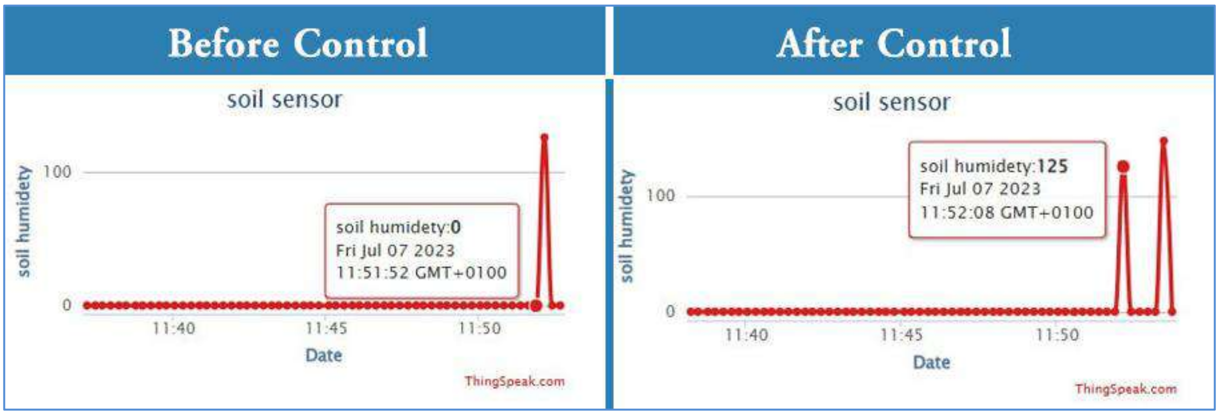


Figure III. 14: data of soil moisture

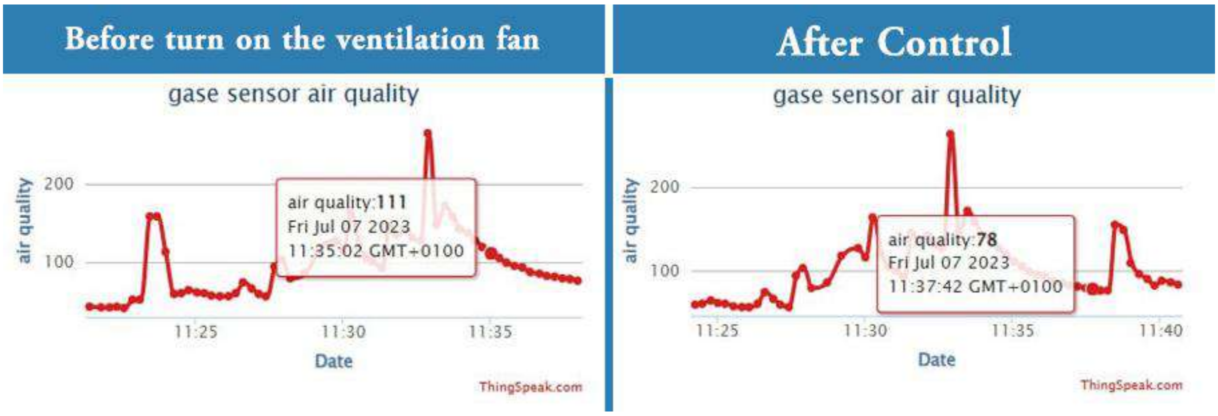


Figure III. 15: data of air quality

<u>Note:</u>

- ✔ **The time taken to send the data to the ""ThingSpeak"" cloud platform may vary, usually around 15 seconds or more.**

In the future, we may need to study the data obtained from the sensors during different agricultural periods to optimize the environmental conditions or determine the best crops that can be grown in a more efficient manner. This capability is available in the "ThingSpeak" cloud platform, as it provides the option to download data in various formats and allows for analysis using MATLAB software simultaneously

Export recent data ×

green hous system Channel Feed:	JSON XML CSV
Field 1 Data: temperator	JSON XML CSV
Field 2 Data: humidty	JSON XML CSV
Field 3 Data: soil humidety	JSON XML CSV
Field 4 Data: lightness	JSON XML CSV
Field 5 Data: air quality	JSON XML CSV

TABLE III. 2: data exporting

III.5.The final design of the prototype using" EasyEDA" software:

Designing a final greenhouse management and control device PCB board prototype using" EasyEDA" software involves a set of steps:

1. **Define Operational Requirements:** Clearly defines PCB board functional requirements and specifications, taking into account inputs, outputs, power supplies, and integration with the greenhouse management system.
2. **Component selection:** We select components that meet the requirements of Project
3. **Schematic Design:** We use" EasyEDA" software to create a detailed schematic diagram of the PCB to be manufactured. We place all components such as microcontrollers, sensors, actuators, and connectors, and make the appropriate connections.

4. **Design Check(DRC):** We perform a comprehensive design check using the built-in" EasyEDA" functionality to validate the design against manufacturing and assembly requirements. We fix any errors identified during the scan.

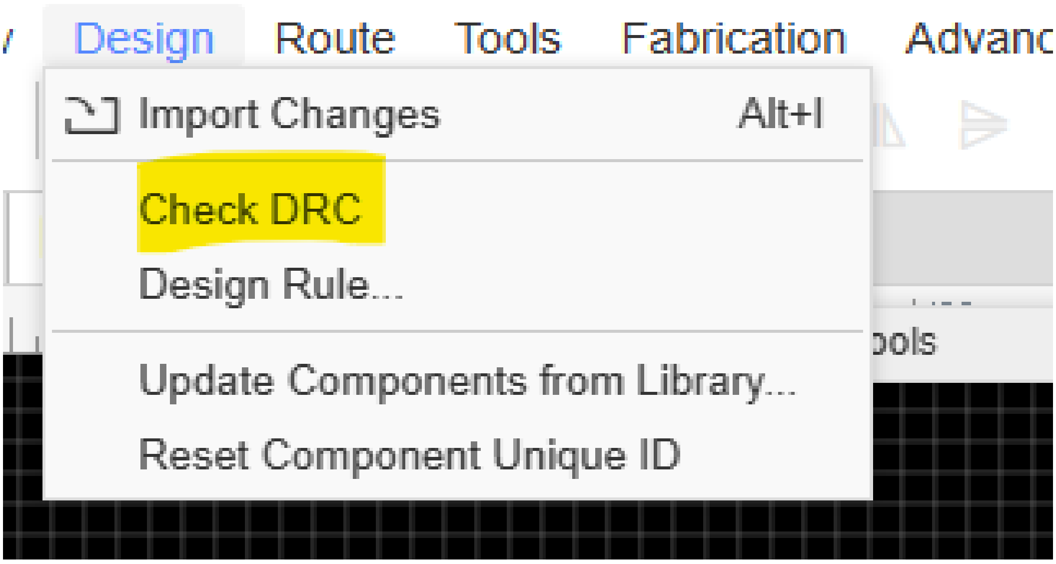


Figure III. 16: Design Check(DRC) TOOL

5. **The final form**: After assembling all the components and verifying the integrity of the design, we get the final form shown in the following figures:

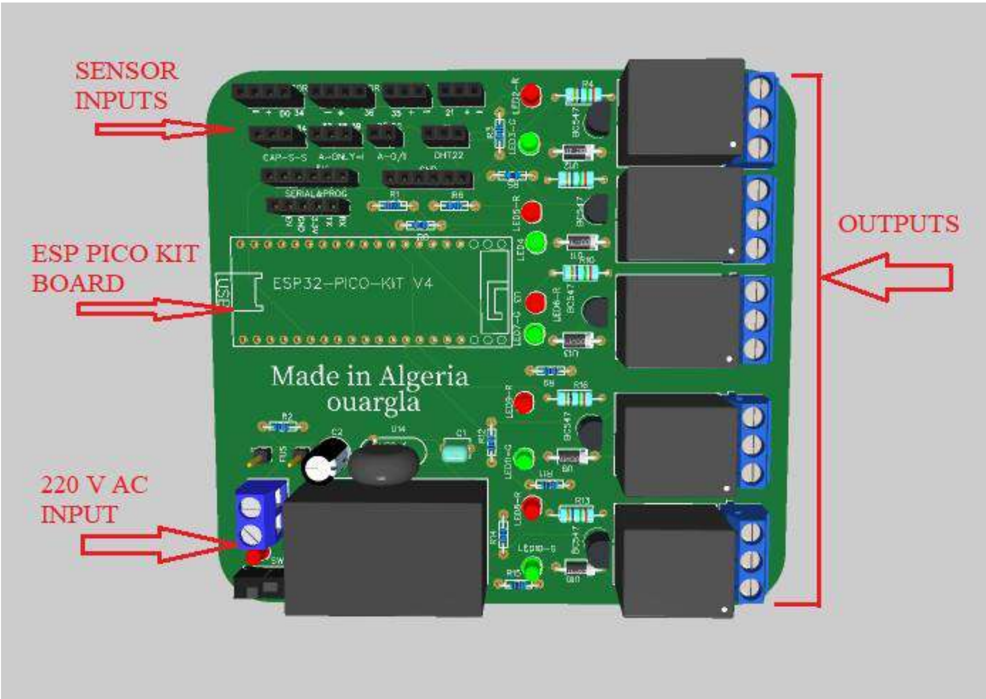


Figure III. 17: Greenhouse control and management device version N1

The preceding figure depicts the first version of the agricultural greenhouse management and control device. This version incorporates a microcontroller ESP 32 PICO KIT D4, sensor inputs, a 220-volt AC power source port, and outputs for temperature control, humidity control, lighting intensity, soil moisture, and air quality monitoring**.**

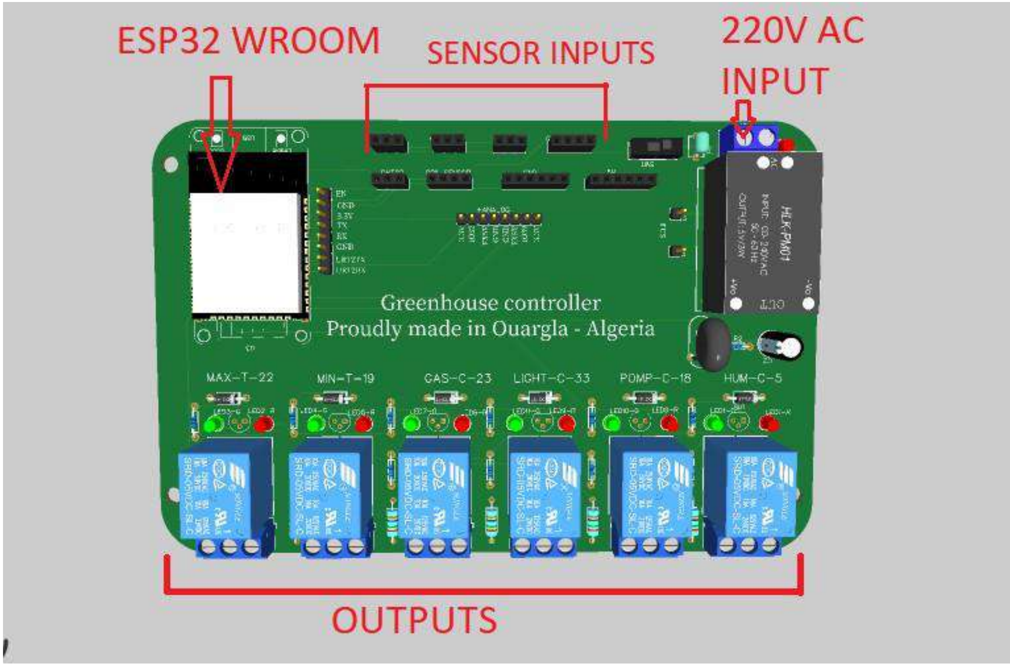


Figure III. 18 : Greenhouse Control and management device version N2

The previous figure shows the second version of the Greenhouse Management and Monitoring Device. This version includes an ESP32-WROOM -BOARD microcontroller, sensor inputs, a 220V AC power supply port, and outputs for controlling temperature, humidity, light intensity, soil moisture, and air quality.

<u>Notes:</u>

- ✔ We have prepared two versions of the device, differing only in the microcontroller used, while the operational method remains the same.
- ✔ A 220-volt AC power source port has been included to facilitate the installation process of this device.
- ✔ The Microcontroller ESP32 WROOM were used in the second version, as they are more commonly available and cost-effective in Algeria.
- ✔ This model represents an initial prototype that is subject to further development and improvement.

III.6.Conclusion:

in this chapter, we have detailed the fabrication process of the prototype greenhouse management and control system. We discussed electronic component selection, PCB design using“ EasyEDA” software, and hardware assembly. In addition, we explored microcontroller integration, sensor inputs, and power supply, as well as control outputs for temperature, humidity, light intensity, soil moisture, and air quality. This prototype lays the foundation for further development and improvement, paving the way for the most advanced and effective greenhouse management solution.

GENERAL CONCLUSION

GENERAL CONCLUSION

The climate within an agricultural greenhouse is a highly intricate and dynamic system. The temperature and humidity inside the greenhouse exhibit nonlinear behavior and are strongly interconnected by the principles of thermodynamics. Consequently, employing precise and robust control methods becomes necessary. We implemented TOR control in our project, which yielded highly satisfactory and real-time results.

The integration of a web application into our project proved to be advantageous in remotely controlling the agricultural greenhouse from any location worldwide. This endeavor allowed us to thoroughly test and enhance our theoretical and practical understanding of electronics and computing. Moreover, it served as a catalyst for exploration and learning in diverse fields of study, including agriculture (climate management, greenhouse types, and equipment), embedded electronics, and the utilization of various tools such as C/C++ and Thingspeak.

This project focuses on the agricultural aspect, specifically greenhouse cultivation. Our main achievement lies in the successful implementation of IoT technology for greenhouse automation and remote monitoring. Through our web application, we were able to detect and analyze various climatic measurements. It is worth mentioning that our primary focus was on climatic factors rather than plant growth.

Effective management of climatic parameters within greenhouses necessitates the selection of appropriate technologies that ensure the optimal climate for plants. This involves monitoring their characteristics and requirements in real-time at every stage of their growth.

Before proceeding with the project realization, a crucial step involved conducting a conceptual study. This study centered around the prototype of a mini agricultural greenhouse and devising appropriate solutions to effectively control the climatic parameters. In our case, the website played a pivotal role in implementing these solutions.

Throughout the project, a significant amount of time was dedicated to exploring and familiarizing ourselves with various technologies. We delved into the functionalities and capabilities of ESP32, Arduino IDE, and Thingspeak Realtime Database, among others. Our objective was to understand how these technologies could be integrated and interconnected to lay the groundwork for an IoT project.

Perspectives

In terms of future perspectives, we have outlined several areas for improvement and expansion in our project:

- Scaling for Large-Scale Greenhouses: We aim to adapt our system to effectively manage larger greenhouse volumes, including multi-chapel greenhouses. This will involve enhancing the scalability and robustness of our system to handle the increased complexity and requirements of larger agricultural setups.

- Integration of Renewable Energy: We propose incorporating renewable energy sources, such as solar power, to reduce the ecological footprint of greenhouse operations. By harnessing clean energy, we can make the system more sustainable and environmentally friendly.

- Networked Control of Multiple Greenhouses: Our goal is to enable the centralized control and monitoring of multiple greenhouses within a network. This would allow for efficient management of multiple agricultural sites, streamlining operations, and facilitating data analysis across different locations.

- Integration of Intelligent Farm Systems: We plan to integrate intelligent farm systems used in developed countries, such as fertilizing irrigation systems, CO2 injectors, water heating, and other advanced technologies. This integration will further optimize the cultivation process, enhance resource utilization, and improve overall agricultural productivity.

- Utilization of Industrial-Grade Actuators and Sensors: To achieve better industrial outcomes, we aim to incorporate industrial-grade actuators and sensors into our system. These high-quality components will enhance precision, reliability, and durability, leading to improved performance and efficiency.

- Expansion of Controlled Parameters: We intend to expand the range of parameters that can be controlled within the greenhouse, including soil temperature, pH level, and electrical conductivity. By monitoring and adjusting these additional factors, we can fine-tune the growing conditions and optimize plant health and yield.

- Exploration of Advanced Control Techniques: We propose exploring advanced control techniques, such as neural networks, to further enhance the intelligence and adaptability of our system. These techniques can enable more sophisticated decision- making and automation, leading to improved efficiency and productivity.

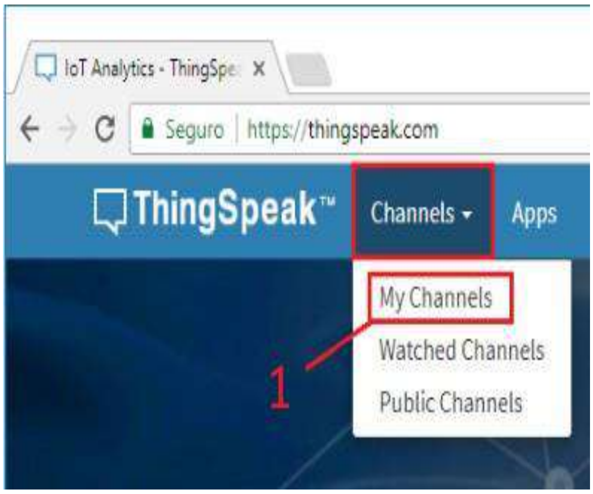
- By focusing on these future perspectives, we aim to continually enhance and advance our project, making it more adaptable, sustainable, and effective in meeting the evolving needs of greenhouse cultivation.

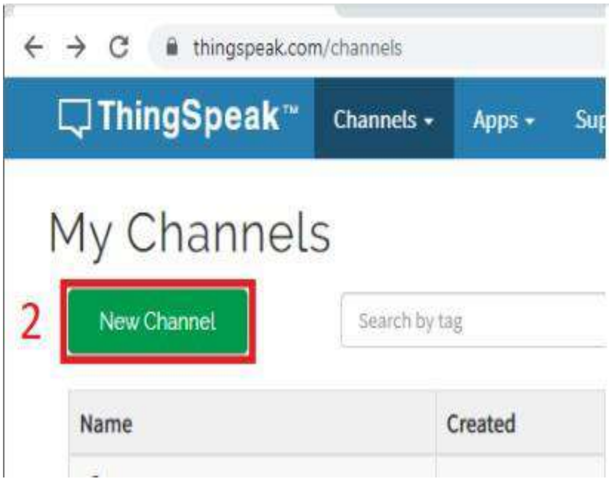
Annexe

1. How to configure the "ThingSpeak" cloud to receive data

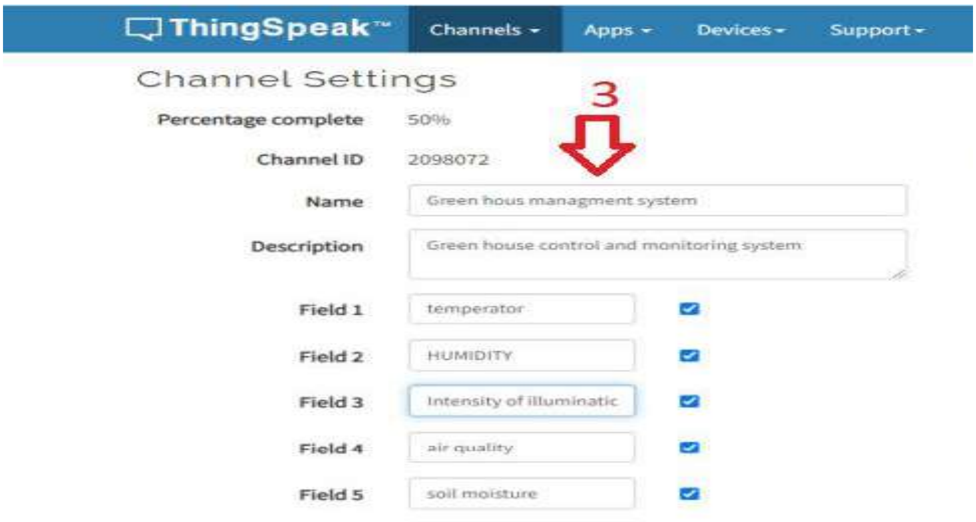
Go to "ThingSpeak" and click the "Get Started For Free" button to create a new account. This account is linked to a Mathworks account. So, if you already have a Mathworks account, you should log in with that account.[28]

1. After your account is ready, sign in, open the "Channels" tab and select "My Channels".
2. Press the "New Channel" button to create a new channel.



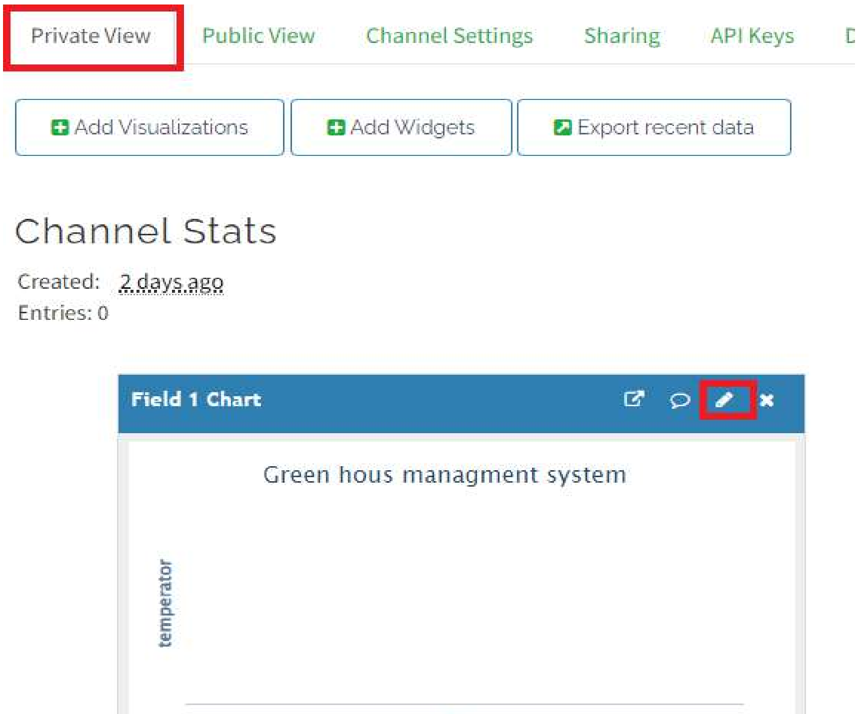


3. give your channel a name and add a description. In this project, we'll publish the temperature, humidity, air quality, soil moister, and Intensity of illumination. So we need five 05 fields [28]

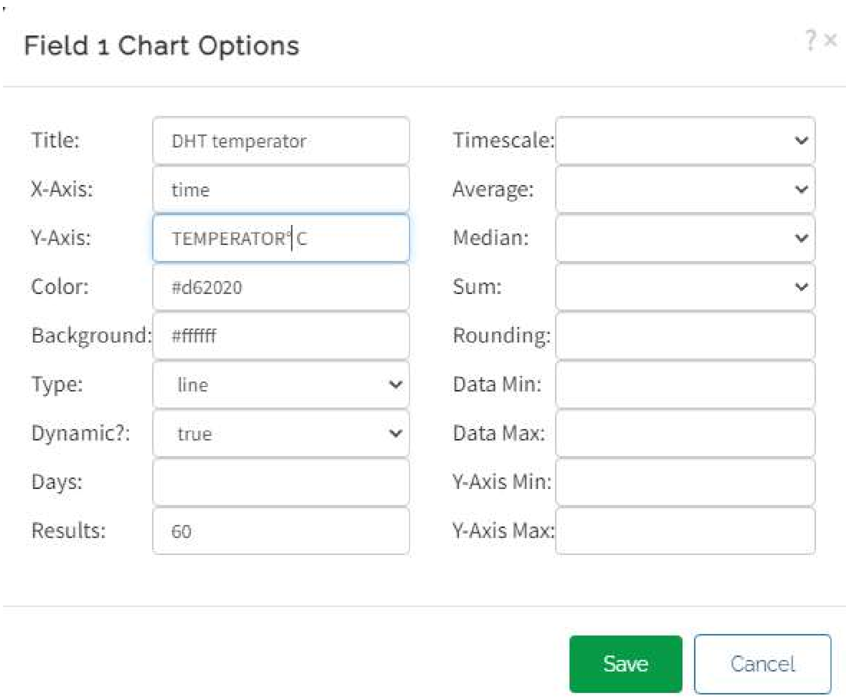


4. Click the **Save Channel** button to create and save the channel.

5. The chart can be customized, go to your **Private View** tab and click the edit icon.

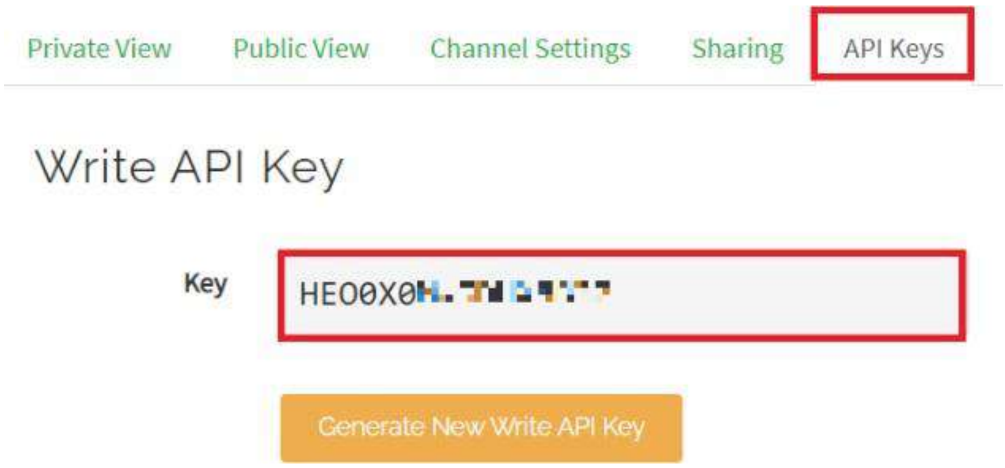


6. You can give a title to your chart, customize the background color, x, and y-axis, and much more then click save [29]



To send values from the ESP32 board to "ThingSpeak", we need the "Write API Key".

7. Open the "**API Keys**"
tab and copy the Write API Key we'll need in writing the code.[29]

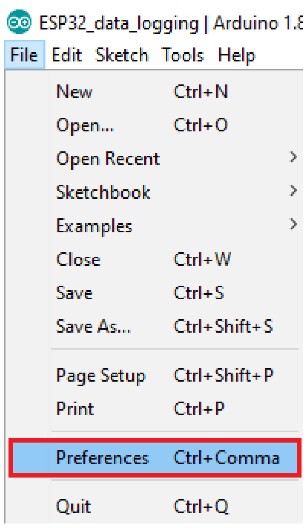


2. Preparing Arduino IDE to start programming the esp 32 pico kit board

1. First, we must install the Arduino IDE code editor on the computer from the official website"https://www.arduino.cc/en/software"

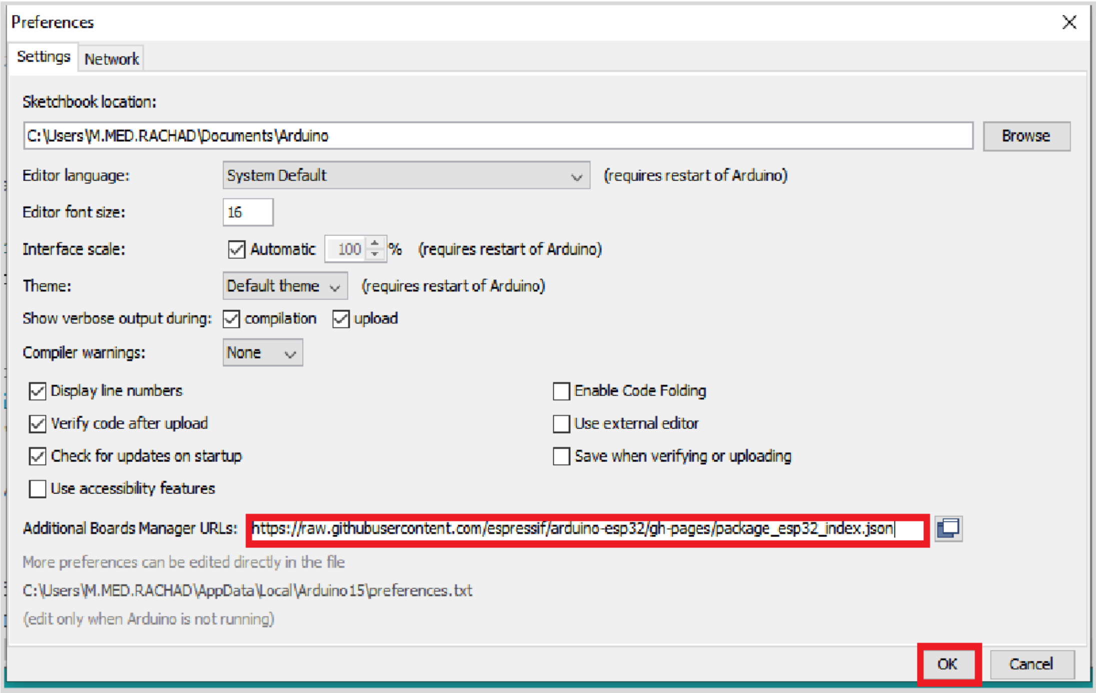
2. The steps to install the ESP32 board in the Arduino IDE: [29]

2.1 In the Arduino IDE, go to **File**> **Preferences**

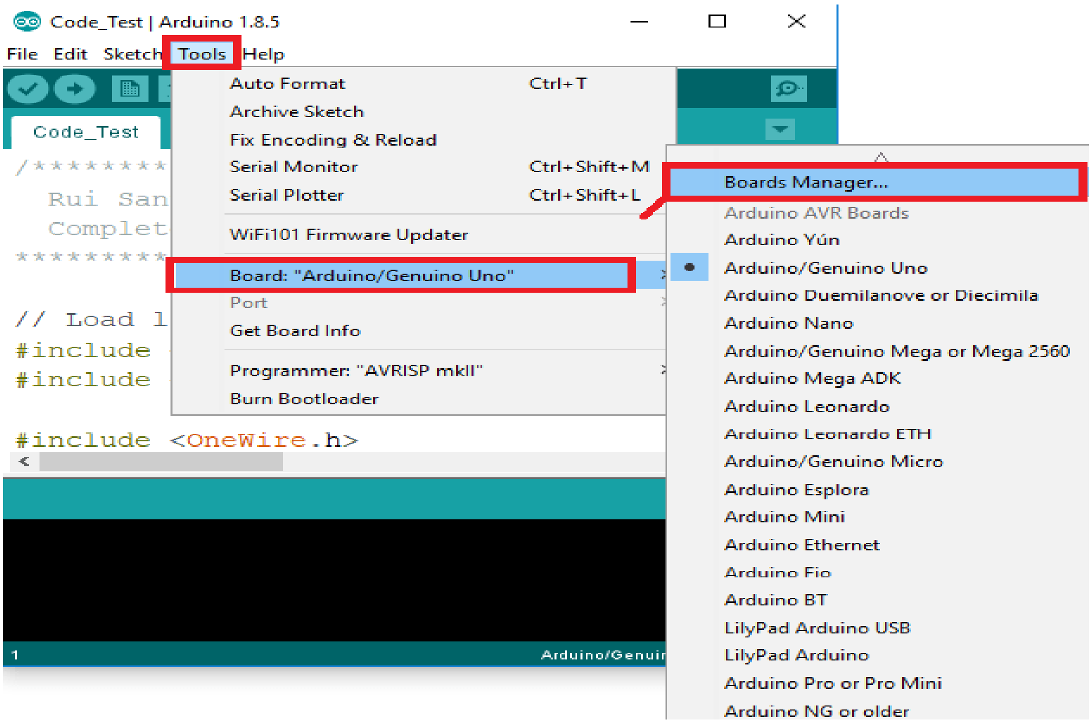


2.2 Enter the following into the “Additional Board Manager URLs” field then press the “OK” button [30]

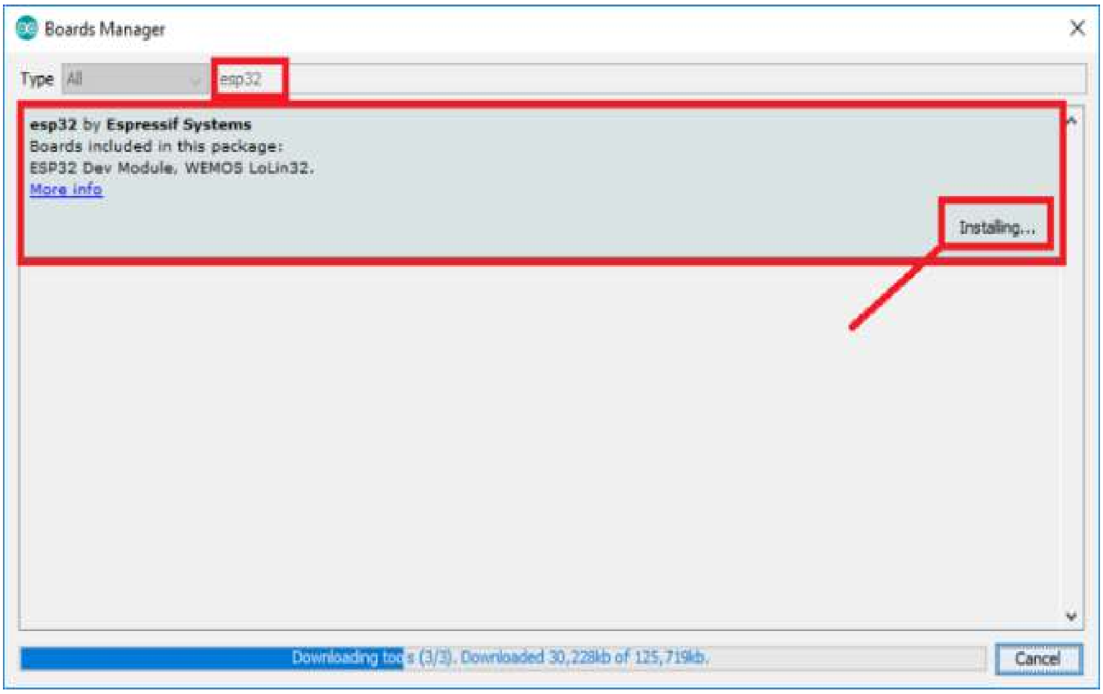
https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json



2.3 Open the Boards Manager. Go to **Tools** > **Board** > **Boards Manager…**



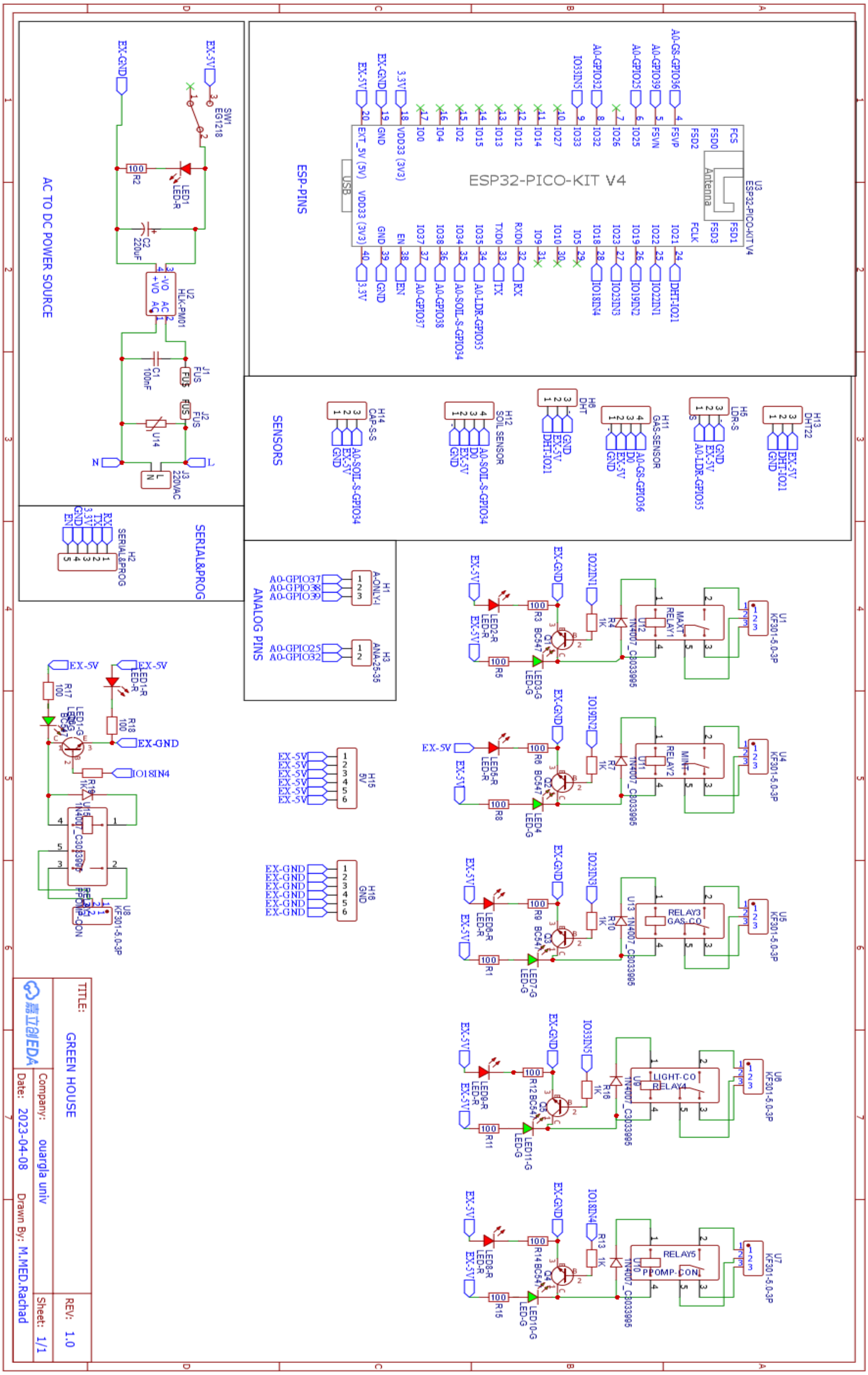
2.4 Search for **ESP32** and press the install button for the "**ESP32 by Espressif Systems**"[30]



Now, to confirm that the process has been completed successfully

2.5 Go to **Tools** > **Board** then you find the esp 32 pico kit added to your boards

Schematic diagram of the PCB :



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[25] https://wokwi.com

[26] Hundreds of Thousands of Open Source/Private Projects https://easyeda.com/

[27] https://www.mathworks.com/products/thingspeak.html.

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