Palestine Polytechnic University

College of Engineering

Design and Implementation of a Bacteriological Incubator

By:

Tasneem Abo Al-Kibash

Safa Dana

Supervisor: Dr. Ramzi Qawasma

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الإهداء

بسم من يحمد آناء الليل و أطراف النهار؛ الله العليّ القهّار، الأول و الآخر و الظاهر و الباطن، الذي أغرقنا بنعمه التي لا تعد ولا تحصى، المغدق علينا رزقه الذي لا يفنى، المنير دروبنا المعتمه، لك ربي جزيل الحمد و عظيم الثناء.

الى معلمنا الاول، منارة العلم و الامام المصطفى، الى الأميّ الذي أرسله الله رسولاً من أنفسنا عزيزٌ على قلوبنا رؤوفٌ بنا، أرسله الله بالقرآن المبين، علمنا ما لم نعلم و حثنا على طلب العلم، فعليه منا أفضل الصلاة و أتم التسليم - صلى الله عليه و سلم - .

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Tasneem Abo Al-Kibash

Safa Dana

Abstract

As a result of the technological development taking place in the world and the emergence of processed and genetically modified foods, Pathogenic bacteria enter the human body causing diseases that leave him suffering for years or may cause him to die, without the ability of doctors to know the type of bacteria and prescribe the appropriate treatment, as many antibiotics have become over time unable to combat some types of bacteria, it is difficult to determine the type of bacteria causing the disease when examining the blood sample due to the incomplete growth or low density within the sample.

Simulation of the human body, like made a farm for these bacteria can solve this problem, where the bacterial incubator is used to provide an ideal medium from humidity, temperature and CO_2 suitable for the growth and reproduction of the types of bacteria that infect the human body causing diseases, so a large number of bacteria are obtained determine their type and even determine the appropriate type of antibiotic to successfully deal with it to treat the patient.

In this project, a bacterial incubator was designed, where temperature, humidity and CO_2 can be controlled.

An alarm system was built based on giving a sound and a light to indicate that the door is not closed. Two types of incubators available in the market are combined, namely, a CO_2 incubator and a portable incubator.

ملخص المشروع

نتيجة للتطور التكنولوجي الحاصل في العالم و ظهور الاطعمة المصنعة و المعدلة وراثيا, تدخل البكتيريا الممرضة إلى جسم الإنسان مسببة أمراضًا تتركه يعاني لسنوات أو قد تتسبب في وفاته دون قدرة الأطباء على معرفة نوع البكتيريا ووصف العلاج المناسب ، حيث أصبحت العديد من المضادات الحيوية بمرور الوقت غير قادرة على مكافحة بعض أنواع البكتيريا من الصعب تحديد نوع البكتيريا المسببة للمرض عند فحص عينة الدم بسبب النمو غير الكامل أو الكثافة المنخفضة داخل العينة.

محاكاه جسم الانسان, مثل انشاء مزرعة لهذه البكتيريا يمكن ان تحل هذه المشكلة، حيث يتم استخدام الحاضنة البكتيرية لتوفير وسط مثالي من الرطوبة ودرجة الحرارة وثاني أكسيد الكربون المناسب لنمو وتكاثر أنواع البكتيريا التي تصيب جسم الإنسان مسببة الأمراض. لذلك يتم الحصول على عدد كبير منهم لتحديد نوعها وحتى تحديد النوع المناسب من المضادات الحيوية للتعامل معها بنجاح لعلاج المريض.

في هذا المشروع ، تم تصميم حاضنة بكتيرية ، حيث تم التحكم في درجة الحرارة والرطوبة وثاني أكسيد الكربون.

تم بناء نظام إنذار يعتمد على إصدار صوت وضوء للإشارة إلى أن الباب غير مغلق. يتم الجمع بين نوعين من الحاضنات المتوفرة في السوق ، وهما حاضنة ثاني أكسيد الكربون وحاضنة محمولة.

1

Chapter One

Project Introduction

1.1. Introduction

People were created in ancient times, with the presence in this world, people's development them life throughout history, seeking different ways to sleep, coexistence and multiple requirements, and the need for different materials has increased the great expansion of his places of life and lifestyle that varied with him. The causes of disease and calamity increased, and the sick person at the time was dying during his illness or impairment throughout his life without treatment, which prompted him to Search in nature for ways and means to get rid of disease and with the development of science and the introduction of knowledge, many scientists and inventors appeared. [1]

Throughout history, one of the most important fruits of the efforts of scholars is the microscope, through which a person can now know the cause of the disease and the scourge, which are the microorganisms that contain viruses and others, and with the development of the scientific for our time incubators have been obtained for these germs they provide the right environment for its growth and reproduction within the required conditions.

The presence of the incubator in the laboratories is of great importance and necessary indispensable. An incubator is based on the principle that microorganisms require a particular set of parameters for their growth and development. A bacterial Incubator, in microbiology, is an insulated and enclosed device that provides an optimal condition of temperature, humidity, and other environmental conditions required for the growth of microorganisms. [2]

All incubators are based on the concept that when organisms are provided with the optimal condition of temperature, humidity, oxygen, and carbon dioxide levels, they grow and divide to form more organisms.

In this way, it is possible to identify the virus in the sample, and thus determine the disease that affects the human being and rid him of it.

1.2. Motivation and Problem Statement

Reasons for low availability of CO2 incubators in laboratories, high import costs, obsolescence of old models and to help paves the way for biology research amongst students, hobbyists, and non-experts were motivated to the provision of alternative sources of heat and humidity and removable and made of.

materials widely available and at low costs and can be used in all laboratories and maintains temperatures for 24 hours and are not affected by ambient temperature and consumes energy Little electricity through which the temperature, humidity, and CO2 are easily controlled to reach better results, through a set of steps systematically arranged to identify bacteria behavior, reproduction, and growth in different conditions.

Hence, making a low-cost, easy-to-use laboratory incubator, with a suitable size, greater accuracy in temperature and humidity, high efficiency, and widely available.

An incubator is an essential tool for several biological experiments and is often used in bacterial cell culture experiments. Given the higher price range of the commercially available incubators (upwards of several thousand dollars), non-professional biology enthusiasts might not afford to add an incubator to their stock.

1.3. Main Objective

The main objective of this research work is to design and implement an insulated and enclosed laboratory incubator with low cost and low malfunctions that provides the ideal medium for the growth and reproduction of bacteria from temperature, humidity, oxygen, and carbon dioxide levels. Reducing risks and obtaining results with more chances of success and keeping pace with scientific development.

1.4. Sub objectives

During design of the bacterial incubator, the following objectives will be implemented

1. Design a temperature measurement and control circuit.
2. Design a humidity measurement and control circuit.
3. Design supply CO_2 for the incubator.
4. Design the open door alarm system.
5. Connect all system component with microcontroller to control the level of temperature, humidity and CO_2 inside the incubator by simulation program.

6. Assembling the electronic parts based on the programmed code and connecting them with the control unit, and then assembling the external parts of the incubator.

1.5. Literature Review

The first research is Environmental microbiology by Faculty of Chemical Engineering and Technology, University of Zagreb, Marulićev trg 19, HR-10000 Zagreb, Croatia 2017, This study shows that microorganisms they are everywhere and are the dominant form of life on planet Earth. It also explains the evolution of microorganisms at the microbial world: classification, metabolism and growth, microbial diversity in the environment and the eutrophication process. Environmental microbiology is concerned with the study of microorganisms in the soil, water and air and their application in bioremediation to reduce environmental pollution through the biological degradation of pollutants into non-toxic or less toxic substances. [1]

Second paper is Effective Contamination Control with CO_2 Incubators by Ines Kristina Hartmann, James Jarvis, Eppendorf AG, Eppendorf, Inc. This study shows that CO_2 incubators provide an optimal cell growth environment by maintaining a humidified atmosphere with temperature and carbon dioxide control. These conditions not only promote cell growth, but also the growth of contaminants, like bacteria, yeast, molds and other fungi. In this paper, compared various strategies for preventing contamination in CO_2 incubators, from the functional design of the device to self-disinfection programs. also given some useful tips to prevent contamination when using CO_2 incubators. [2]

Third study is Incubator Using Arduino with Automatic Temperature and Humidity Control Last updated on September 4, 2021 by SWAGATAM. This study shows that in this paper constructed an incubator using Arduino which can self-regulate its temperature and humidity. Incubator Using Arduino with Automatic Temperature and Humidity control. Incubator is an enclosed apparatus whose internal environmental is isolated from ambient environment. This is to create favorable environment for the specimen under care. For example, incubators are used to grow microbial organism in laboratories. [3]

1.6. Project Cost

Table (1.1): Project Cost.

Equipment's	Expected price	Quantity
Arduino	1	**30$**
Small Fridge	1	**200$**
Temperature and Humidity sensor(DHT22)	1	**5 $**
Fan	1	**4 $**
Heater	1	**6 $**
Humidityfire (Ultrasonic Nebulizer)	1	**30$**
CO_2 Gas cylinder	1	**30$**
Display (LCD)	1	**6 $**
MH-Z19 CO_2 Sensor	1	**35 $**
CO_2 Regulator	1	**20 $**
HEPA Filter	1	**60 $**
Power supply	1	**140$**
Relay	-	**150$**
Resistors	-	**30$**
Keypad	1	**20$**
Other	-	**200$**
Total	-	**1000$**

1.7. Project Action Plan

The project selection, formulation its ideas, identification a good previous studies and the collection for a basic information and documentation to starting up in the project were the most important tasks carried out at the first semester. Also, determine the specifications of the bacterial incubator and start collecting its information for the variables to ensure the multiplication of bacteria. Table (1.2) shows the distribution of the first semester over a period of (15) week.

For done the project implementation and building, the automatic distribution of tasks needed to implement the project during the second semester. Table (1.3) shows the distribution of the second semester over a period of (15) week.

Table(1.2): Distribution of Tasks on the First Semester.

Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Finding Project Idea	■	■													
Proposal		■	■	■											
Search and Collecting data		■	■	■	■	■	■	■	■						
Documentation			■	■	■	■	■	■	■	■	■	■	■	■	
Preparing for presentation													■	■	■
Print documentation															■

Table(1.3): Distribution of Tasks on the second Semester.

Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collecting components															
Building and testing the system															
Analysis															
Documentation															
Preparing for presentation															
Print documentation															

After defining a general introduction to this study and explaining the project's motives, to begin implementing the proposed idea, it is first necessary to define the microorganisms and incubators and their history, and bacterial incubators in particular, and the influence of factors. Sample reproduction is required, and this will be explained in chapter two.

2

Chapter Two

Theoretical Background

2.1. Brief History.

2.2. Microbiology.

2.3. Incubators.

2.3.1. Incubator Definition.

2.3.2. Incubator Type.

2.3.2.1. Bacteriological Incubators Types.

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2.5. Procedure for Running an Incubator.

2.6. Effect of Time, Temperature, Humidity and CO2 at Incubator on Bacterial Growth.

2.7. Bacterial Culture Media.

2.1. Brief History

History of the laboratory incubator from aiding in hatching chicken eggs to enabling scientists to understand and develop vaccines for deadly viruses, the laboratory incubator has seen numerous applications over the years it has been in use. The incubator has also provided a foundation for medical advances and experimental work in cellular and molecular biology.

The earliest incubators were found thousands of years ago in ancient Egypt and China, Use of incubators revolutionized food production, where they were used to keep chicken eggs warm, as it allowed chicks to hatch from eggs without requiring that a hen sit on them

In the 19th century, researchers finally began to recognize that the use of incubators could contribute to medical advancements. They began to experiment to find the ideal environment for maintaining cell culture stocks. These early incubators were simply made up of bell jars that contained a single lit candle. In the late 19th century, doctors realized another practical use for incubators: keeping premature or weak infants alive. The first infant incubator, used at a women's hospital in Paris, was heated by kerosene lamps.

In the 20th century: Shaking incubator, doctors realized that they could use CO_2 incubators to identify and study pathogens found in patients' bodily fluids. To do this, a sample was harvested and placed onto a sterile dish and into the incubator. The air in the incubator was kept at 37 degrees Celsius, the same temperature as the human body, and the incubator maintained the carbon dioxide levels necessary to promote cell growth.

Today: Incubators serve a variety of functions in a scientific lab. Incubators generally maintain a constant temperature, however additional features are often built in. Many incubators also control humidity. Shaking incubators incorporate movement to mix cultures. Gas incubators regulate the internal gas composition. Some incubators have a means of circulating the air inside of them to ensure even distribution of temperatures. Incubators are made in a variety of sizes, from tabletop models, to warm rooms, which serve as incubators for large numbers of samples. [4]

2.2. Microbiology

- **Definition:**

Microbiology is the study of microscopic organisms, such as bacteria, viruses, archaea, fungi and protozoa. This discipline includes fundamental research on the biochemistry, physiology, cell biology, ecology, evolution and clinical aspects of microorganisms, including the host response to these agents. [5]

- **Microorganisms:**

For most people, microorganisms are out of sight and therefore out of mind but they are large, extremely diverse group of organisms, they are everywhere and are the dominant form of life on planet Earth. Almost every surface is colonized by microorganisms, including our skin; however, it can be being harmless and it may can kill humans. Some microorganisms can live in boiling hot springs, whereas others form microbial communities in frozen sea ice. [5]

2.3. Incubators

2.3.1. Incubator Definition:

Incubator, in microbiology, is an insulated and enclosed device that provides an optimal condition of temperature, humidity, and other environmental conditions required for the growth of organisms.

An incubator is a piece of vital laboratory equipment necessary for the cultivation of microorganisms under artificial conditions. An incubator can be used for the cultivation of both unicellular and multicellular organisms. [6]

2.3.2. Incubator Type:

There are three principal kinds of incubators: [6]

1. **Poultry Incubators:**

Poultry incubators are used to keep the fertilized eggs of chickens warm until they are ready to hatch. These are the oldest type of incubators; rooms heated by fires to hatch chicken eggs, and later incubators used kerosene lamps to heat air or water in proximity to the eggs. Modern incubators are rooms heated by electricity. Large electric fans circulate the air to maintain uniform temperatures.

2. **Infant Incubators:**

Infant incubators are used to provide a warm environment for babies born prematurely or for other infants who are unable to maintain a normal body temperature. The infant incubator is a relatively small, glass-walled box. Most infant incubators are fitted with special devices that can control the concentration of oxygen inside the incubator; this is necessary because some infants need either greater or lesser amounts of oxygen owing to particular diseases they may have. Infant incubators also regulate the humidity inside the enclosure.

3. **Bacteriological Incubators:**

Bacteriological incubators provide a controlled environment in order to promote the growth of bacteria or other microorganisms in various culture media. They are insulated enclosures that are thermostatically regulated to maintain a constant temperature. Hot air is circulated over racks or shelves containing the Petri dishes, flasks, or other culture media. In medicine, such incubators are used to identify disease-causing microorganisms taken from patients. A sample of the patient's blood, sputum, mucus, or other secretion is placed in a culture medium inside the incubator, and, after the microorganisms in the sample have multiplied, they can be identified with greater certainty. Bacteriological incubators are also used in microbiology and biochemistry, in the dairy and other food-processing industries, and in water and sewage treatment plants.

2.3.2.1. Bacteriological Incubators Types:

1- **CO_2 Incubators:**

The special kinds of incubators that are provided with automatic control of CO_2 and humidity. This type of incubator is used for the growth of the cultivation of different bacteria requiring 5-10% of CO_2 concentration. For humidity control, water is kept underneath the cabinet of the incubator.

2- **Cooled Incubators:**

For incubation at temperatures below the ambient, incubators are fitted with modified refrigeration systems with heating and cooling controls.

3- **Shaker Incubator:**

Its advantage is that it provides a rapid and uniform transfer of heat to the culture vessel, and its agitation provides increased aeration, resulting in acceleration of growth.

4- **Portable Incubator:**

Are smaller in size and are used in fieldwork, e.g. environmental microbiology and water examination.

2.4. Components and Parts of Incubator:

A microbial incubator is made up of various units, some of which are: [6]

1. Cabinet

- Is the main body of the incubator consisting of the double-walled cuboidal enclosure with a capacity ranging from 20 to 800L.
- The outer wall is made up of stainless steel sheets while the inner wall is made up of aluminum.
- The space between the two walls is filled with glass wool to provide insulation to the incubator.
- The insulation prevents heat loss and in turn, reduces the electric consumption, thereby ensuring the smooth working of the device.
- The inner wall of the incubator is provided with inward projections that support the shelves present inside the incubator

2. Door

- A door is present in all incubators to close the insulated cabinet.
- The door also has insulation of its own. It is also provided with a glass that enables the visualization of the interior of the incubator during incubation without disturbing the interior environment.
- A handle is present on the outside of the door to help with the maneuvering of the door.

3. Control Panel

- On the outer wall of the incubator is a control panel with all the switches and indicators that allows the parameters of the incubator to be controlled.
- The control panel also has a witch to control the thermostat of the device.

4. Thermostat

- A thermostat is used to set the desired temperature of the incubator.
- After the desired temperature is reached, the thermostat automatically maintains the incubator at that temperature until the temperature is changed again.

5. Perforated Shelves

- Bound to the inner wall are some perforated shelves onto which the plates with the culture media are placed.
- The perforations on the shelves allow the movement of hot air throughout the inside of the incubator.

- In some incubators, the shelves are removable, which allows the shelves to be cleaned properly.

6. Asbestos Door Gasket

- The asbestos door gasket provides an almost airtight seal between the door and the cabinet.
- This seal prevents the outside air from entering the cabinet and thus, creating an isolated hot environment inside the cabinet without being interrupted by the external environment.

7. HEPA Filters

- Some advanced incubators are also provided with HEPA filters to lower the possible contamination created due to airflow.
- An air-pump with filters creates a closed-loop system so that the air flowing inside the incubator generates less contamination.

8. Humidity and Gas Control

- The CO_2 incubators are provided with a reservoir underneath the chamber that contains water. The water is vaporized to maintain the relative humidity inside the chamber.
- Similarly, these incubators are also provided with gas chambers to give the desired concentration of CO_2 inside the incubator.

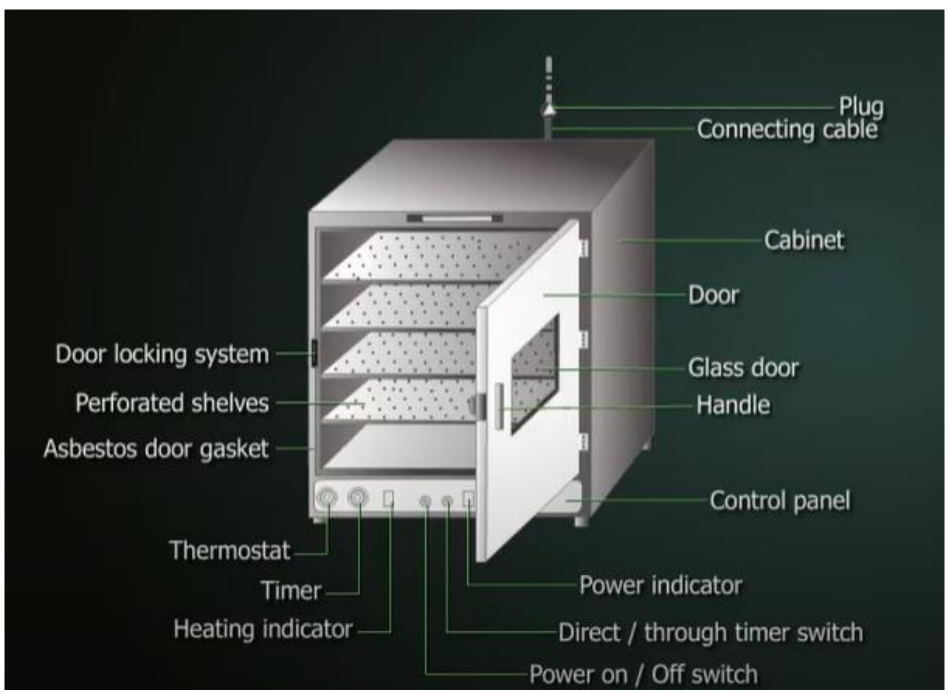

Figure (2.1): Components and Parts of Incubator. [6]

2.5. Procedure for Running an Incubator:

Once the cultures of organisms are created, the culture plates are to be placed inside an incubator at the desired temperature and required period of time. In most clinical laboratories, the usual temperature to be maintained is 35–37°C for bacteria.

The following are the steps to be followed while running an incubator: [6]

1. Before using the incubator, it should be made sure that no remaining items are present in the incubator from the previous cycles.
2. The door of the incubator is then kept closed, and the incubator is switched on. The incubator has to be heated up to the desired temperature of the growth of the particular organism.
3. In the meantime, if the organism requires a particular concentration of CO_2 or a specific humidity, those parameters should also be set in the incubator.
4. Once all the parameters are met, the petri dish cultures are placed on the perforated shelves upside down, i.e., media uppermost. This is necessary because if the plates are incubated normally, condensation collects on the surface of the medium and prevents the formation of isolated colonies.
5. If it is necessary to incubate Petri dish cultures for several days, the plates are sealed with adhesive tapes or are placed in plastic bags or plastic food containers.
6. The door is locked, and the plates are kept inside for the required time before taking them out.

2.6. Effect of Time, Temperature, Humidity and CO_2 at Incubator on Bacterial Growth

1- Time Effect:

Most clinical pathogens grow easily over 24 to 48 h in plate media, but several bacterial species require a much longer time, whereas most routine laboratories maintain cultures within 5 days. As a common example, Helicobacter pylori, the bacterium causing most gastrointestinal ulcers, requires a longer incubation period. [7]

2- Temperature Effect:

bacteria cells cannot grow at temperatures higher or lower than those prevailing in their natural environments. The temperature range that allows bacteria to grow in general ranges from zero to 75, and for each bacterial species a temperature range that falls within the limits of the minimum and maximum degrees, and between them lies the ideal temperature for its growth. The ideal temperature is the temperature that allows the fastest growth to occur during a relatively short incubation period ranging between 12-24 hours.

Low temperature effect: the harmful effect on the cellular protein is reduced if the temperature does not reach a significant degree below freezing.

high temperatures effect: increasing temperatures on bacteria cells is to increase the speed of chemical reactions in the cell, which would build protoplasm and produce energy. The speed of cellular metabolic processes increases with increasing temperature to a limited extent, as the increase in metabolic activity at high temperatures is accompanied by an increase in protein enzymatic degradation as well. [8]

3- CO_2 Effect:

It is needed as part of the media buffer system to regulate the PH. The most commonly used CO_2 bicarbonate buffering system depends on a chamber atmosphere of 5 - 10 % CO_2, providing a pH of 7.2 to 7.4. [9]

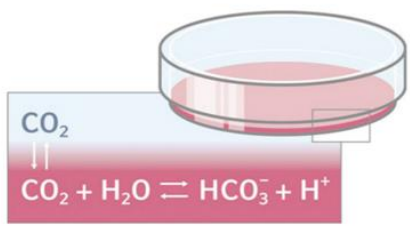

Figure (2.2): CO_2 Effect at Sample. [9]

4- Humidity Effect:

Humidity in the incubator has always been a tricky thing. Too much of it or too little of it can ruin growth rate. Humidity starts out at one percentage but then needs to be raised at just the right point This full maximum can increase as the temperature rises.

During incubation, can control humidity through the use of vents to monitor the amount of fresh air entering the incubator. The fresher air entering, the lower the humidity. [10]

2.7. Bacterial Culture Media

Classification based on consistency: [11]

1. **Liquid Media:** These are available for use in test-tubes, bottles or flasks. Liquid media are sometimes referred as "broths" (e.g. nutrient broth). In liquid medium, bacteria grow uniformly producing general turbidity. No agar is added. Mostly used for inoculums preparation.

2. **Solid Media:** An agar plate is a Petri dish that contains a growth medium (typically agar plus nutrients) used to culture microorganisms. 2% of agar is added. Agar is the most commonly used solidifying agent. Colony morphology, pigmentation, hemolysis can be appreciated. Examples include Nutrient agar and Blood agar.

3. **Semi-Solid Media:** Such media are fairly soft and are useful in demonstrating bacterial motility and separating motile from non-motile strains. Examples of Semi-solid media (Hugh & Leifson's oxidation fermentation). 0.5% agar is added.

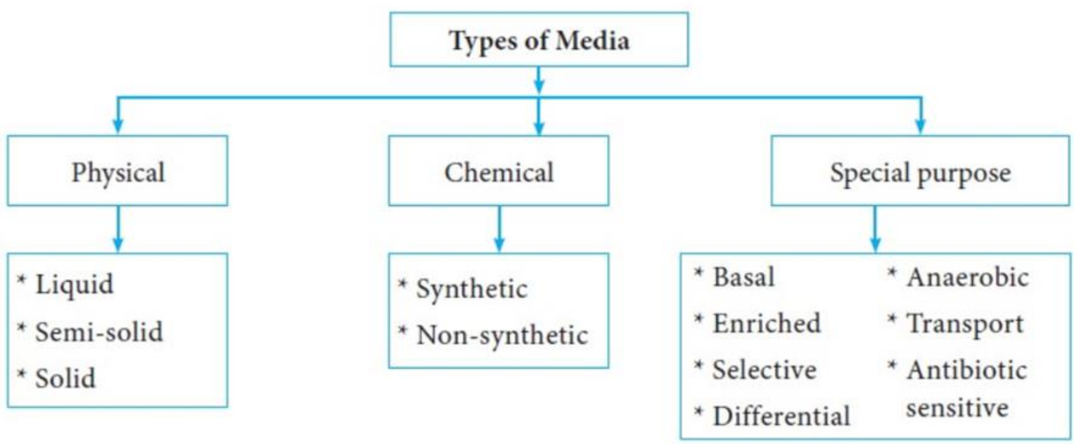

Figure (2.3): Types of Media. [11]

Classification Based on Nutritional Components: [11]

1. Simple Media: Simple media such as peptone water, nutrient agar can support most non-fastidious bacteria. It is also called as basal media. Nutrient Broth consists of peptone, yeast extract and NaCl. When 2% of agar is added to Nutrient Broth it forms Nutrient agar.

2. Complex Media: Media other than basal media are called complex media. They have special ingredients in them for the growth of microorganisms. These special ingredients like yeast extracts or casein hydrolysate, which consists of a mixture of many chemicals in an unknown proportion.

3. Synthetic Media/Chemically Defined Media: Specially prepared media for research purposes where the composition of every component is well known. It is prepared from pure chemical substances. E.g.: peptone water (1% peptone + 0.5% NaCl in water).

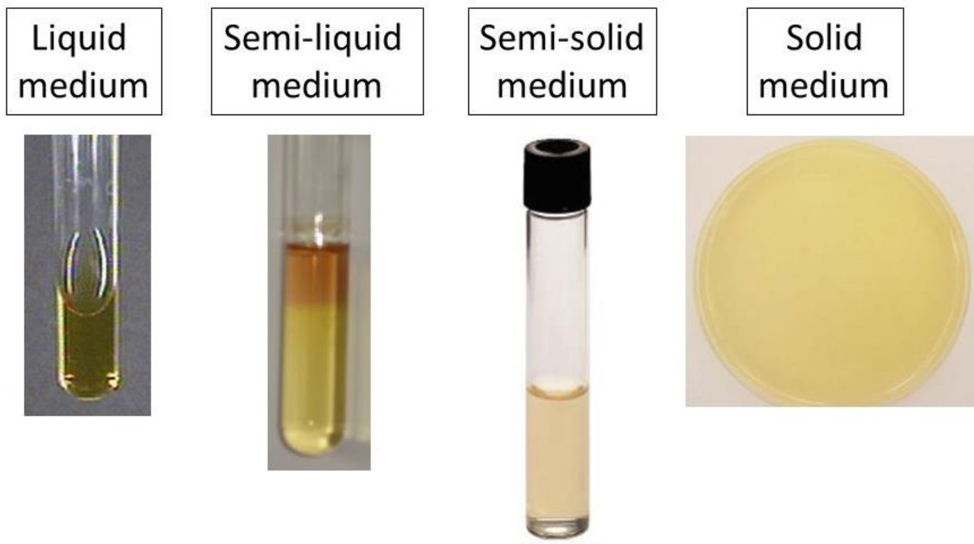

Figure (2.4): Physical Media. [12]

- **Culturing of Bacteria**

A microbial culture, is a method of multiplying microorganisms by letting them reproduce in predetermined culture media under controlled laboratory conditions. Microbial cultures are used to determine the type of organism, its abundance in the sample being tested, or both. [12]

- **Purpose of Culturing Isolation of Bacteria.**

Properties of bacteria i.e. culturing bacteria is the initial step in studying its morphology and its identification. To create antigens for laboratory use. Certain genetic studies and manipulations of the cells also need that bacteria to be cultured in vitro. Culturing on solid media is another convenient way of separating bacteria in mixture. [12]

- **Uses:**

Provides a pure growth of bacterium for slide agglutination and other diagnostic tests.

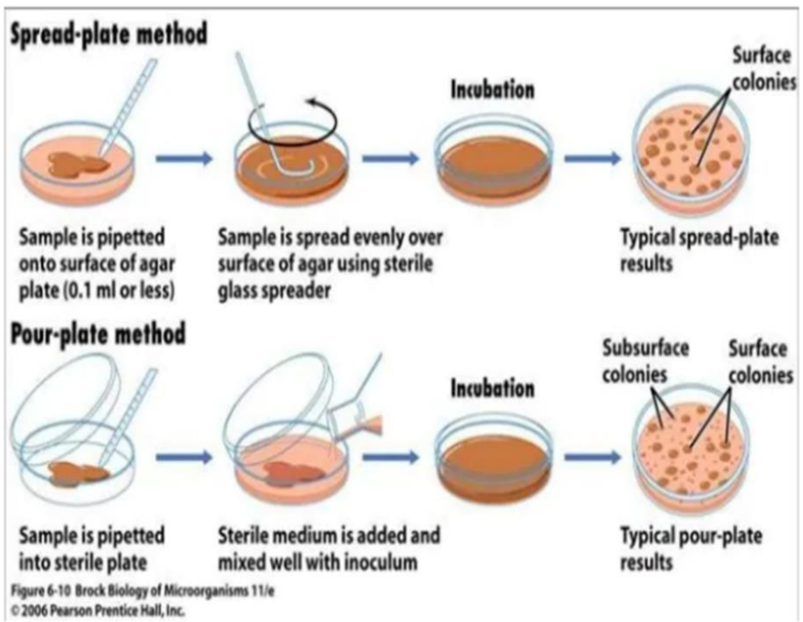

Figure (2.5): Methods for Growth Bacteria. [12]

After the clarification of the incubators, especially the bacterial incubator used for microorganisms, its components and method of use and the effect of time, temperature, humidity and carbon dioxide on the reproduction of the sample, in the third chapter will be clarified the method of designing this incubator with available components and low cost compared to the market.

3

Chapter Three

Project System Design

3.1 Introduction

Commercially available incubators are often costly, difficult to transport, not flexible in terms of volume, and poorly adapted to local field conditions where access to electricity is unreliable. The purpose of this study was to develop an adaptable, low-cost and transportable incubator that can be constructed using readily available components.

This chapter describes the design method for building an adaptable, low-cost and transportable incubator for microorganism testing. The design is based on widely available materials and can operate under a range of field conditions, while still offering the advantages of higher-end laboratory-based models.

- **To design this incubator, the following steps need achieved:**

1. will be build the outer frame of the incubator from two layers of rust-resistant, including an insulating material to ensure the insulation of the incubator,

2. In the beginning, we must search for the appropriate values for the reproduction of bacteria in terms of temperature, humidity, oxygen and carbon dioxide.

3. The programming to measure the temperature and humidity inside the incubator will be writing, and operating the fan or heating based on the value set by the doctor on the external display.

4. Simulation of connecting the electronic parts necessary to achieve the goal of the bacterial incubator based on what was written in the code programmed on the Arduino piece on the Proteus program.

5. In the end, connect the electronic parts practically will be doing and checking the work of the incubator as required.

- **Limitations of Bacteriological Incubators**

Biological incubator, a growing field of study is the limitations of CO_2 incubators as they relate to oxygen levels. Common sense would tell us that since living tissue like human cell cultures thrive in 20.9% oxygen-filled air, that this should be the desired oxygen level inside a cell incubator. Since ambient air is 20.9% oxygen, CO_2 incubators need not be sealed from outside air. [13]

CO_2 incubators are typically heated to35- 37°C and maintain 95% relative humidity and a CO_2 level of 5 percent. Microbiological incubators are essentially mostly used for growing and storing bacterial cultures. They are required to maintain the same conditions as inside the human body, 7.4 pH neutral, 98.6°F (37°C), > 90% relative humidity. [14]

These three numbers create the optimal conditions for biological cell growth.

3.2 General Block Diagram of the Project

The description of system components for building a bacterial incubator is shown in the following Figure (3.1) that contains general block diagram of the project.

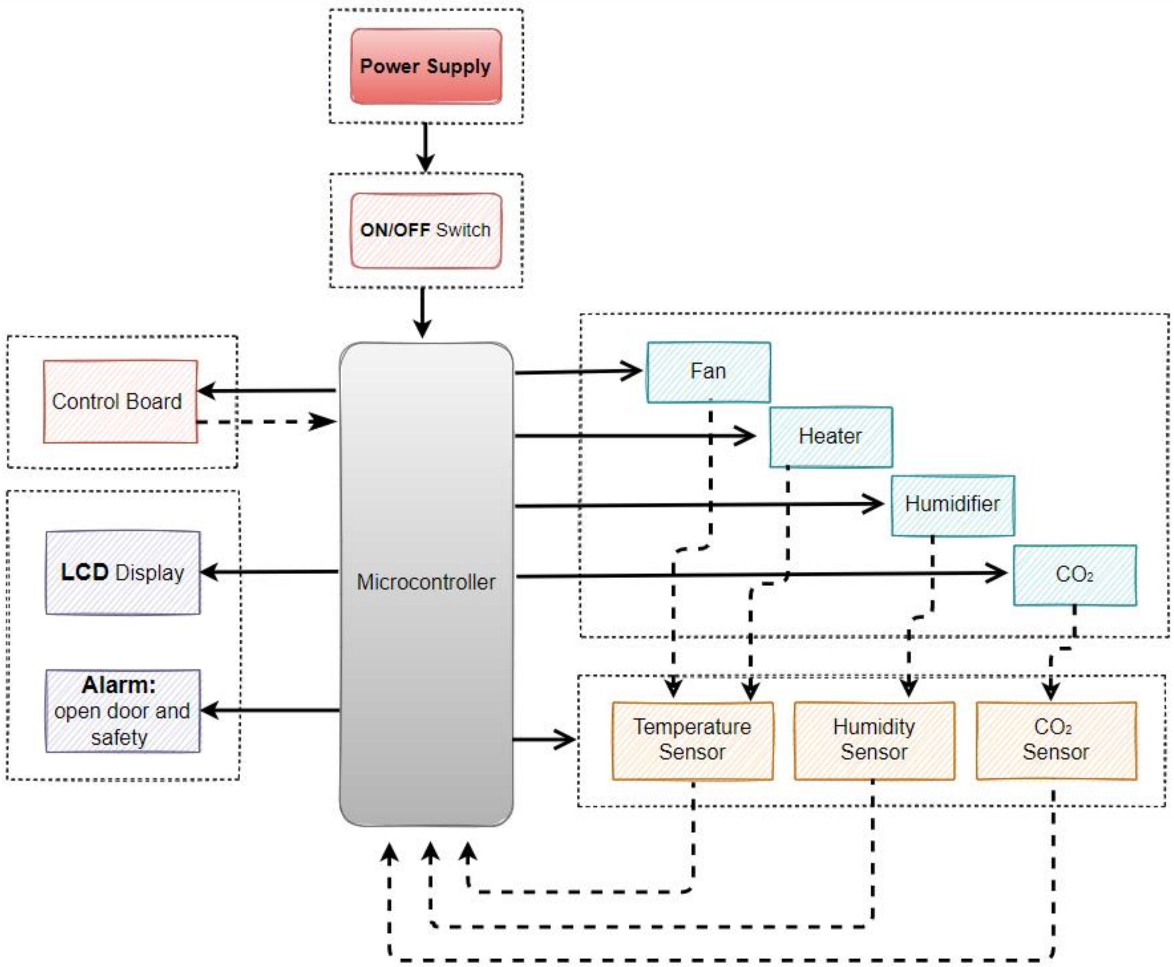

Figure (3.1): General Block Diagram

3.3 Hardware Components of the Project

Through this section of chapter all hardware components used in the project are discussed, so that features and specifications are discussed.

3.3.1 Microcontroller

Microcontroller is a compressed microcomputer manufactured to control the functions of embedded systems in office machines, robots, home appliances, motor vehicles, and a number of other gadgets. A microcontroller is comprising components like - memory, peripherals and most importantly a processor. Microcontrollers are basically employed in devices that need a degree of control to be applied by the user of the device. [15]

- **Arduino:**

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on computer, used to write and upload computer code to the physical board.

The Arduino platform has quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board, can simply use a USB cable [15]. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

They operate at 5 volts and each pin can provide or receive a maximum of 40 mA.

- **Arduino MEGA:**

Arduino mega have been used because of its bigger memory than memory in the Arduino Nano, MP3 shield easily connected to the Arduino mega. The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button as shown in figure 2., It contains everything needed to support the microcontroller, simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno. [Appendix A]

Figure (3.2): Arduino mega. [Appendix A]

3.3.2 LCD Display

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly.

In this project we're going to use a monochromatic 20x4 alphanumeric LCD. 20x4 means that 20 characters can be displayed in each of the 4 rows of the 20x4 LCD, thus a total of 80 characters can be displayed at any instance of time. And LCD operating temperature:

(-20 _ +70) °C. [Appendix B]

- **LCD-Pinout:**

The LCD we are using has 16 pins. Description of each pin is as follows:

Pin No Symbol Level Description:

1. VSS 0V Ground
2. VDD 5V Supply Voltage for logic
3. VO (Variable) Operating voltage for LCD
4. RS H/L H: DATA, L: Instruction code

5. R/W H/L H: Read (MPU Module) L: Write (MPU Module)
6. EH H->L Chip enable signal
7. DB0 H/L Data bus line
8. DB1 H/L Data bus line
9. DB2 H/L Data bus line
10. DB3 H/L Data bus line
11. DB4 H/L Data bus line
12. DB5 H/L Data bus line
13. DB6 H/L Data bus line
14. DB7 H/L Data bus line
15. A 5V LED +
16. A 0V LED-

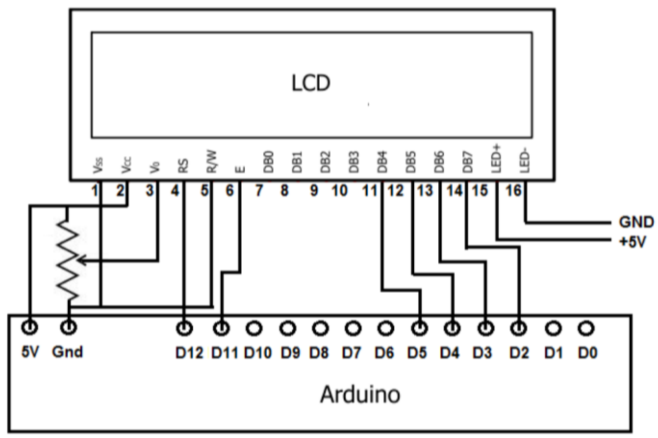

Figure (3.3): LCD Display Pinout**.**

- Connecting of LCD need 10K potentiometer, or can use a 1k resistor and connect Pin 3 of LCD to V_{cc} via the resistor.

Figure (3.4): LCD Display. [16]

3.3.3 Humidity and Temperature Sensor

Humidity and temperature are closely related from the physical quantity itself to the bacterial lives. [17]

Temperature: it is one of the 7 basic physical quantities in the International System of Units, and it is a physical quantity used to measure the degree of heat and coldness of objects.

Humidity: It is the concentration of water vapor present in the air. The relative humidity of air is commonly used in life, expressed in %RH.

Relative humidity is closely related to temperature. For a certain volume, the higher the temperature, the lower the relative humidity, and the lower the temperature, the higher the relative humidity.

The temperature and humidity of incubator environment will directly affect bacterial temperature regulation function and heat conduction effect. Therefore, we need temperature and humidity sensors

- **Common Temperature & Humidity Sensors for Arduino**

the most common temperature and humidity sensors which are suitable for Arduino Project.

DHT & AM & AHT

1) **DHT11:**

For temperature and humidity sensor, DHT series is the most common used. They are all automatically calibrated, very easy to use and have a very good Arduino software library, which is very popular with maker.

Table (3.1): DHT11 Specifications [17]

Num.	Item	Value
1.	Operating Voltage	DC：3.3-5.5V
2.	Temperature Range	-20~+60℃
3.	Humidity Range	5-95 %RH
4.	Temperature Accuracy	±2℃
5.	Humidity Accuracy	±5% RH
6.	Sensor Type	Capacitive humidity sensor

2) **DHT22/AM2302:**

DHT22 is a high-end model in the DHT series, also known as AM2302 or RHT03. It has a wide measurement range and high measurement accuracy.

DHT22 has excellent long-term stability and can be used in medical, meteorological and other professional fields.

Table (3.2): DHT22 Specifications [17]

Num.	Item	Value
1.	Operating Voltage	DC：3.3-5.5V
2.	Temperature Range	-40~+80℃
3.	Humidity Range	0 – 99.9 %RH
4.	Temperature Accuracy	±0.5℃
5.	Humidity Accuracy	±2% RH
6.	Sensor Type	Capacitive humidity sensor

3) **AM2311A:**

Table (3.3): AM2311A Specifications [17]

Num.	Item	Value
1.	Operating Voltage	DC：3.3-5.5V
2.	Temperature Range	-40~+80℃
3.	Humidity Range	0 – 99.9 %RH
4.	Temperature Accuracy	±0.5℃
5.	Humidity Accuracy	±3% RH
6.	Sensor Type	Capacitive humidity sensor

4) **AHT20:**

Table (3.4): AHT20 Specifications [17]

Num.	Item	Value
1.	Operating Voltage	DC：2.0-5.5V
2.	Temperature Range	-40~+85℃
3.	Humidity Range	0 – 100 %RH
4.	Temperature Accuracy	±0.3℃
5.	Humidity Accuracy	±2% RH
6.	Sensor Type	MEMS semiconductor capacitive humidity sensing element

Different temperature and humidity sensors have large performance differences and large price differences, to select the best one sensor for project need determined: [17]

1) Measure Range

The selection of the humidity sensor must first determine the measurement range. temperature and humidity measurement and control generally do not require full humidity (0-100% RH) measurement. Generally speaking, the wider the range, the price higher

2) Humidity Accuracy

The accuracy of measurement is the most important index of the humidity sensor. For every percentage point increase, it is a step or even a grade for the humidity sensor. Because different precisions are to be achieved, their manufacturing costs vary greatly, and their selling prices vary widely.

In normal projects, DHT11 is sufficient. The measurement range of 5 ~ 95% RH will satisfy most applications. If Arduino project needs a wider measurement range and higher accuracy, such as medical, weather station, then we recommend DHT22. If the interference is strong and the environment is harsh, AM2311A will be a good choice. When project requires industrial-grade sensors, then AHT20 will be very suitable. [16]

- **Based on the above, DHT22 was selected for incubator design.**

3.3.4 Heater

Electric heating is a process in which electrical energy is converted to heat energy. Common applications include space heating, cooking, water heating and industrial processes. An electric heater is an electrical device that converts an electric current into heat.

The heating element inside every electric heater is an electrical resistor, and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy. Most modern electric heating devices use chrome wire as the active element. Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, that draws heat energy from a source such as the ground or outside air and directs that heat into the space to be warmed. Some systems can be reversed so that the interior space is cooled and the warm air is discharged outside or into the ground. [17]

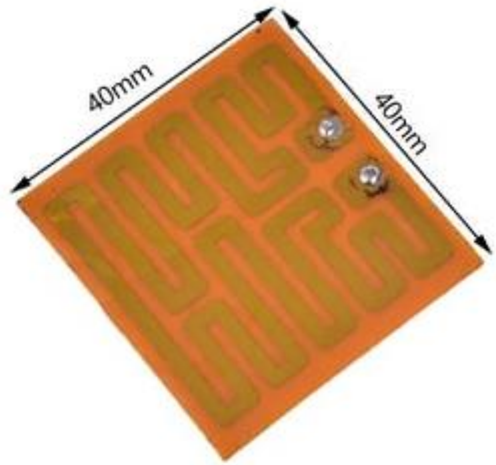

Figure (3.5): Heater [16]

- **Heater Feature:**

- Waterproof
- corrosion resistant
- high thermal efficiency

- **Specifications:**

- Voltage:3.7V-5V
- Resistance:3.7 ohms
- Temperature:35~55 °
- Size: 40*40MM

But this heater piece did not provide a temperature higher than 35 degrees, so after a lengthy search, the use of car bulbs (Brick bulbs for cars) was approved, where they were connected to a unified line to work together, thus providing the correct temperature of (35-40) degrees. As shown in figure.

Figure (3.6): Brick bulbs for cars (used as heater).

3.3.5 Fan

A fan is a powered ma/chine used to create flow within a fluid, typically a gas, such as air. A fan consists of a rotating arrangement of vanes or blades, which act on the air. Usually, it is contained within some form of housing, or case. This may direct the airflow, or increase safety by preventing objects from contacting the fan blades. Most fans are powered by electric motors, but other sources of power.

Typical applications include climate control and personal thermal comfort (e.g., an electric table or floor fan), machinery cooling systems (e.g., inside computers and incubators), ventilation.

Figure (3.7): Fan [16]

- **Features:**

- 9 Blades
- Connector: XH2.54-2pin
- Rated Volt: DC 5V/12V (Optional)
- Rated Current: 0.2Amp±10%
- Rated Speed: 11300RPM±10%
- Air Flow: 2.35CFM
- Noise Level: 25±10%dBA
- Bearing Type: Sleeve bearing
- Fan Life 30000 hrs.
- Size: 25×25×7mm/0.98×0.98×0.28in (Approx.)
- Cable length: 15cm/0.59in (Approx.)

3.3.6 Humidifirer

Humidification Systems:

Humidification is the artificial regulation of humidity in environments. When the atmosphere becomes too dry, moisture is drawn from surrounding materials within the environment such as furniture, paper, textiles, fruit, animals and even people. Low relative humidity is not only uncomfortable, it can be damaging to equipment and materials. It also causes static electricity to generate which in turn produces unpleasant effects in many cases.

Every humidification system has the same goal: to add water to the air. There are four different systems which can be divided into two humidification categories: active and passive humidification. [18]

- **Active Humidification:** temperature does not play a role. What that means is that water is added to the air regardless of the room temperature or the current level of humidity. Vaporizers and nebulizers are both types of active humidification systems. The advantage of an active humidification system is that it can increase the indoor humidity very quickly and efficiently.

- **Passive Humidification:** the air is humidified depending on the room temperature and the current level of humidity. What that means is that with this process, the air only absorbs as much humidity as it actually needs based on the current temperature until it becomes saturated. This involves the process of evaporation which is carried out by means of the technology within the evaporator. Passive humidification is suitable for all degrees of water hardness and is highly energy-efficient, without causing over humidification.

Three humidification systems explained in simple terms: [19]

1) Vaporizer:

The water is brought to boiling point in the appliance, for example. Boiling the water produces germ-free water vapors which is emitted by the unit directly into the room and distributes optimally into the air. It is important for lime scale to be removed regularly from vaporizers. as the significant lime scale and salt deposits would have to be removed from appliance very frequently.

2) Ultrasonic Nebulizer:

As the name suggests, this type of humidification system turns water into mist. An oscillating ultrasonic membrane in the nebulizer atomizes the water, turning it into tiny droplets. A built-in fan in the appliance transports them into the air as mist which humidifies the room air.

In principle, the mist emitted by the device is cold because the water inside it is also cold. This makes nebulizer systems suitable for nurseries. With this system, the process of humidification is made visible due to the mist, which is why these devices are also known as atomizers.

3) Evaporator:

The way that an evaporator works is based on the natural principle of evaporation. The humidifier filters inside the unit are soaked with water. A built-in fan draws the room air inside the unit where it is guided through the moist humidifier filters. In the process, the air absorbs the humidity required according to the current temperature and humidity level, i.e. as it flows through, the indoor air absorbs tiny water droplets and then is released into the room air along with this humidity.

- Based on the above, Ultrasonic nebulizer was selected for Incubator design

- **<u>Ultrasonic Nebulizer Specifications:</u>**

Table (3.5): Ultrasonic Nebulizer Specifications [16]

Num.	Item	Value
1.	Capacity	<1L
2.	Power	5W
3.	Noise	<36 dB
4.	Operating Voltage	5 (V)
5.	Currant	500 mA
6.	Humidity control	Manual
7.	Humidifying capacity	30ml/h
8.	Size	5*5*2.5 cm
9.	Working temperature	5 ~ 45 Celsius

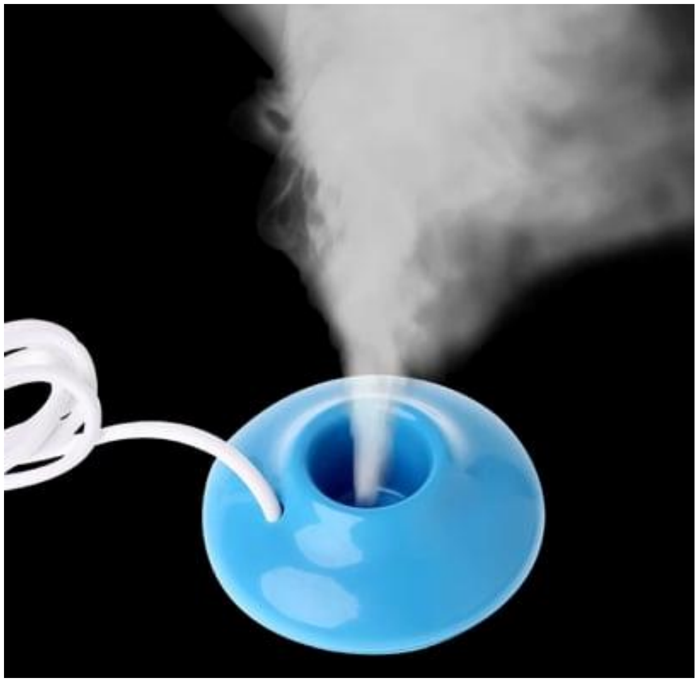

Figure (3.8): Ultrasonic nebulizer [16]

3.3.7 CO_2 Sensors.

Humans are most comfortable at CO_2 levels at or slightly above 400 ppm (0.04%) which raises the question, a CO_2 incubator that is used to grow tissue cultures need CO_2 levels of 5 - 10%. [20]

In order to culture cells under optimum conditions, the media they grow in needs to stay at neutral pH (around pH 7). The H_2O in the cells can be turned into a carbonic acid (H_2CO_3) buffer by adding additional CO_2. The combination of H_2O and CO_2 results in bicarbonate (HCO_3-) and H_2CO_3 which keeps the pH neutral, and therefore has been found to affect the growth of biological cells the least.

In other words, by adding additional CO_2 at the right level you prevent the PH inside the cells from becoming either alkaline or acidic, which both inhibit cell growth.

- **Incubator CO_2 Sensors**

The MicroSENS IR Incubator 0-20% CO_2 Sensor to measure 5% by volume of CO_2 in cell incubators to manage ideal cell and tissue growth.

Unlike typical CO_2 sensors, this sensor is designed to be resistant to heat and moisture. It can be permanently mounted inside the incubator since it can withstand up to 190° C heat. And because it can be calibrated in-place, it does not need to be returned to the factory for calibration. This minimizes down time between cell culture growth cycles.

Intelligent Infrared CO_2 Module (Model: MH-Z19B). [Appendix D]

- **Principle Introduction:**

MH-Z19B NDIR infrared gas module is a common type, small size sensor, using non-dispersive infrared (NDIR) principle to detect the existence of CO 2 in the air, with good selectivity, non-oxygen dependent and long life. Built-in temperature compensation; and it has UART output and PWM output. It is developed by the tight integration of mature infrared absorbing gas detection technology, precision optical circuit design and superior circuit design.

- **Applications:**

MH-Z19B NDIR infrared gas module is widely used in

- HVAC refrigeration
- Indoor air quality monitoring.
- Smart home appliances
- School
- Air cleaner

- **Main Functions and Features**
  - High sensitivity, high resolution
  - Low power consumption
  - Output modes: UART and PWM wave
  - Temperature compensation, excellent linear output
  - Good stability
  - Long lifespan
  - Anti-water vapor interference
  - No poisoning

○ Technical Parameters and Structure

Table (3.6): MH-Z19B Technical Parameters and Structure [16]

Product Model	MH-Z19B
Target Gas	CO2
Working voltage	4.5 ~ 5.5 V DC
Average current	< 60mA (@5V)
Peak current	150mA (@5V)
Interface level	3.3 V (Compatible with 5V)
Output signal	UART(TTL interface level 3.3V)
	PWM
	DAC (default 0.4-2V)
Preheat time	3 min
Response Time	< 120 s
Working temperature	0 ~ 50 ℃
Working humidity	0 ~ 90% RH (No condensation)
Dimension	33 mm×20 mm×9 mm (L×W×H)
Weight	5 g
Lifespan	> 5 years

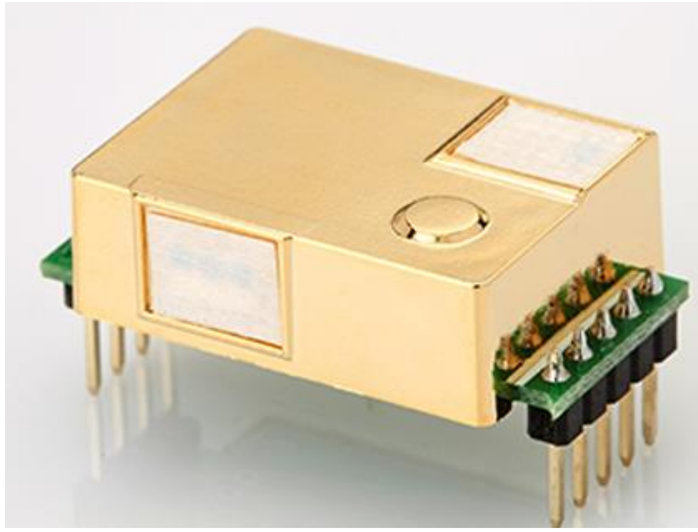

Figure (3.9): MH-Z19B CO_2 Sensor. [16]

3.3.8 CO_2 Regulator and Cylinder.

1. CO_2 Regulator:

Description:

CO2 Carbon Dioxide Pressure Reducer Reducing Valve Flowmeter 1-25L/min

Specification:

- Flow: 1-25L/min
- Diameter of thread: 14mm
- Best used for Carbon dioxide pressure reducer, flowmeter, carbon dioxide reducing valve.

Figure (3.10): CO_2 Regulator. [16]

2. CO_2 Cylinder:

4500Psi Paintball Cylinder Aluminum CO2 Air Tank Safety

Parameters:

- Aluminum Tank Pressure: 3000 PSI, Output: 800PSI
- Diameter: 61mm / 2.4inch
- Capacity: 0.25L
- Applicable medium: Oxygen, Carbon Dioxide.
- Certification: CE / EN Certificated Product Analysis

Figure (3.11): CO_2 Cylinder. [16]

3.3.9 Filtration

Airflow system: Optimized air flow system ensures the temperature and CO_2 concentration to be stable and uniform within the chamber.

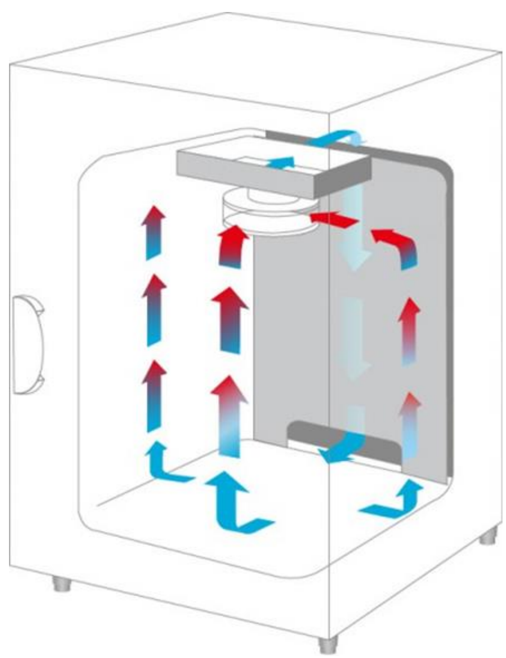

Figure (3.12): Airflow system [21]

- **HEPA Filter:**

HF160W applies long term effectiveness of the HEPA filter to protect cultures. The filter is very efficient to entrap particulates larger than 0.3µm at 99.97%. The HEPA filter system runs continuously and within every 60 seconds, the volume of entire chamber is disinfected. With help of HEPA filter, the air quality achieves Class 100 clean room levels within 5 minutes following a door opening. [21]

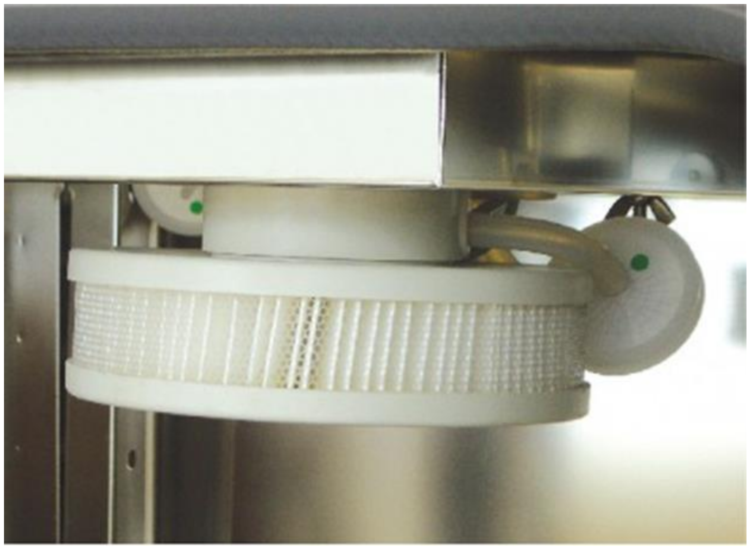

Figure (3.13): HEPA Filter. [21]

3.3.10 Keypad

Description:

This high quality 4x4 Keypad Matrix lets quickly add controls to electronics projects. It offers 0-9 numerals, standard star (*) and hash (#) symbols.

This type of control unit is ease to use for control the value of temperature and humidity to apply inside incubator.

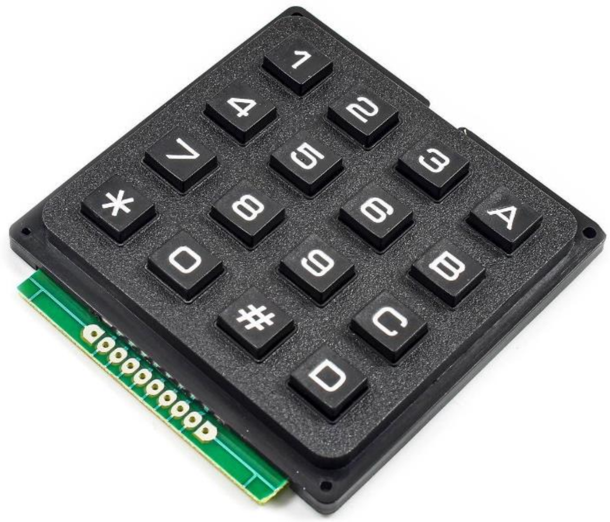

Figure (3.14): Keypad Control Unit. [16]

3.4 Power Supply

3.4.1 Introduction

It is necessary to find an appropriate power source to feed the system by current and voltage required, so the hardware system needs power supply to provide its components with the required power. As the system may be required to be portable a battery that has the following characteristics is required:

- Light weight.
- Provide required system power.
- Has relatively long life.

Due to limitation of power supply in the system, choosing of system parts should fulfill the need for an optimal with minimum current consumption leading to increase the life time of the battery.

The system intended to operate using a rechargeable battery, but all stages need to operate within a voltage supply of (+12) volt, from the battery keeping in mind the current consumption of all electrical parts used in the system. Section (3.4.2) explain the name of different parts used in the system with the power consumption relate to each one to find the overall system current consumption and verify that the power source able to give this desired value, also calculate the expected life time for the battery.

3.4.2 Power Consumption Calculation

In this subsection will be reviewing the calculations of the expected power consumption of each part according to the manufacturer's instructions and then will calculate the total consumption of the system so that the battery specifications required to run the project efficiently can be determined.

For all component the voltage did not exceed from 12V, so that 12V battery will be appropriate choice to this project. But 12 V not enough to supply all project so can use two batteries with 12 volts with connect them parallel to get high current with 12 volts. that is most appropriate for this project, by the following accounts.

Power consumption can be determined by equation

$$P = I * V$$

Where:

P is the power (W)

I is the current (A)

V is the voltage (V)

- **Current Consumption:**

1) Arduino mega = 1*50mA =50mA
2) LCD Display = 1*75mA = 75 mA
3) DHT22 Sensor = 1*1.5mA = 1.5mA
4) Fan = 1* 1.35 A = 135 mA
5) Heater = 2* 1.6 mA = 333 mA
6) Ultrasonic nebulizer = 1* 500 mA = 500 mA
7) CO_2 Sensor = 1* 150mA = 150mA

Total Current = 1263 mA

- **Voltage:**

1) Arduino mega : (5 - 12)V → 12V
2) LCD Display: (3 – 5) V → 5V
3) DHT22 Sensor: (3.3 – 6) V → 5V
4) Fan: 12 V → 12V
5) Heater: 12 V → 12V
5) Humidifire: 12 V → 12V
6) CO2 Sensor: (4.5 – 5.5)V → 5V

- **Power Consumption:**

1) Arduino mega = 5 V * 50 mA = 0. 250 W
2) LCD Display = 5V * 75mA = 0.375 W
3) DHT22 Sensor = 5V * 1.5mA = 0.75 W
4) Fan = 12V * 1.35mA = 16.2 W
5) Heater = 12V * 3.33 mA = 39.96W
6) Humidifire = 5 W
7) CO_2 Sensor = 5V* 150mA = 0.75 W

Total Power = 63.285 W

- For safety → Power + 20 % → **Total Power =~ 64 W**

3.4.3 Battery

After this estimation about the expected current and voltage values of all system components, now it’s important to choose the power supply parameters to meet these requirements reaching to optimal system operation. Polymer Lithium 12V rechargeable battery with (50000mA/h) current capability, this battery is good enough to supply the portable system with its required power.

Referring to the previously calculated current, 1263 mA was a total system current consumption. The design required supplying all the components with a required current and voltage for hours (for one chargeable cycle), the equation will determine the capacity of the battery that can operate the project.

$$\boldsymbol{T = \left(\frac{C_h}{I}\right) * 0.7}$$

Where:

T is the battery life (hour)

$\mathbf{C_h}$ is the battery capacity (amperes. hour)

I is the load current (amperes)

The factor of 0.7 makes allowances for external factor which can affect battery life

$$T = \left(\frac{2 * 50000}{1263}\right) * 0.7$$

***T* = 55.42 hour**

3.5 Bacterial Incubator Design.

Figure 3.15 illustrates the method of initially connecting the parts of the bacterial incubator to achieve the desired goal.

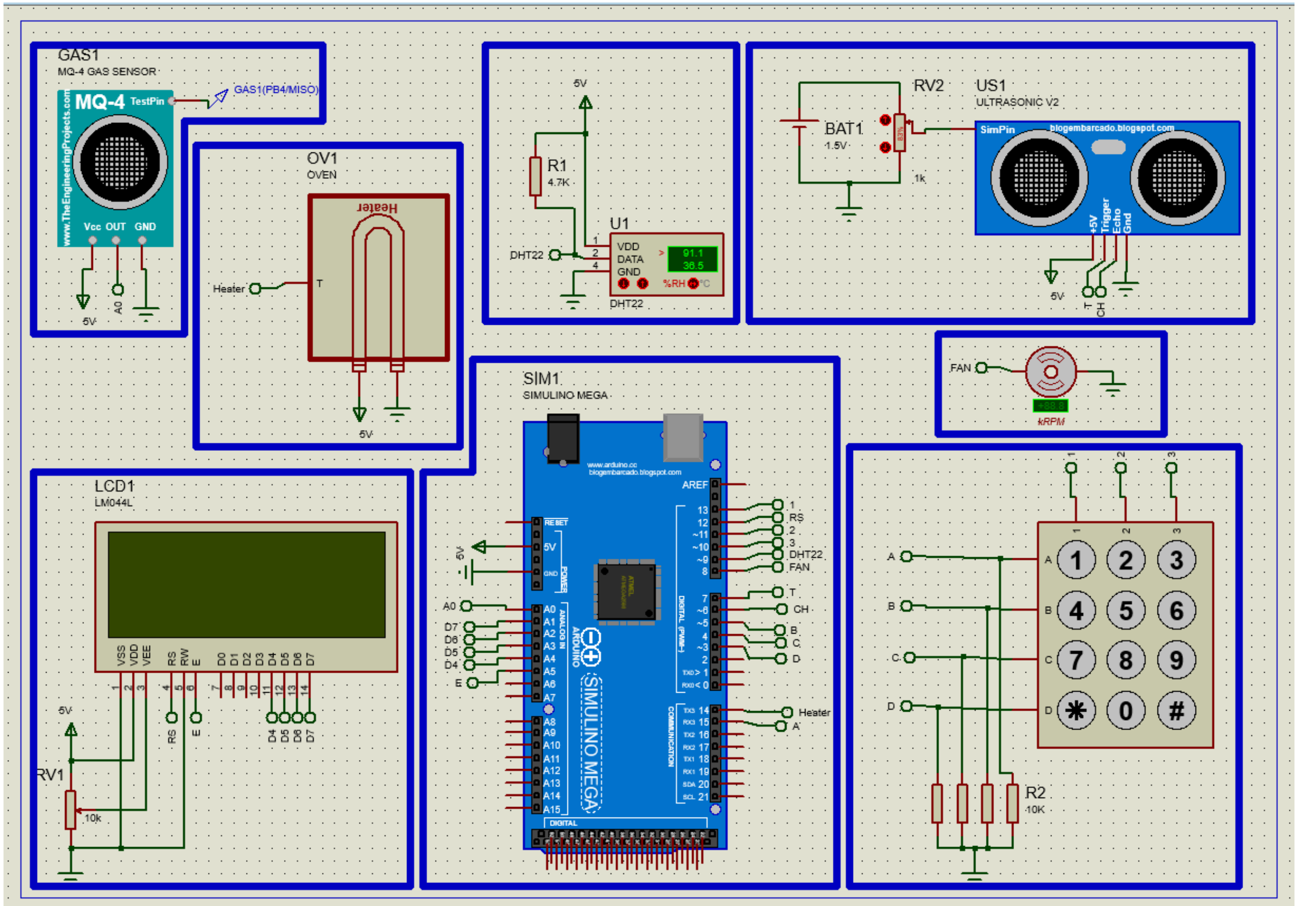

Figure (3.15): Bacterial Incubator Design.

3.6 System Flowchart.

An Arduino microcontroller is necessary in the project to acquire the data from the sensor, analyze them, and provide the display system with the results. It will have programmed to work according to the following flowchart.

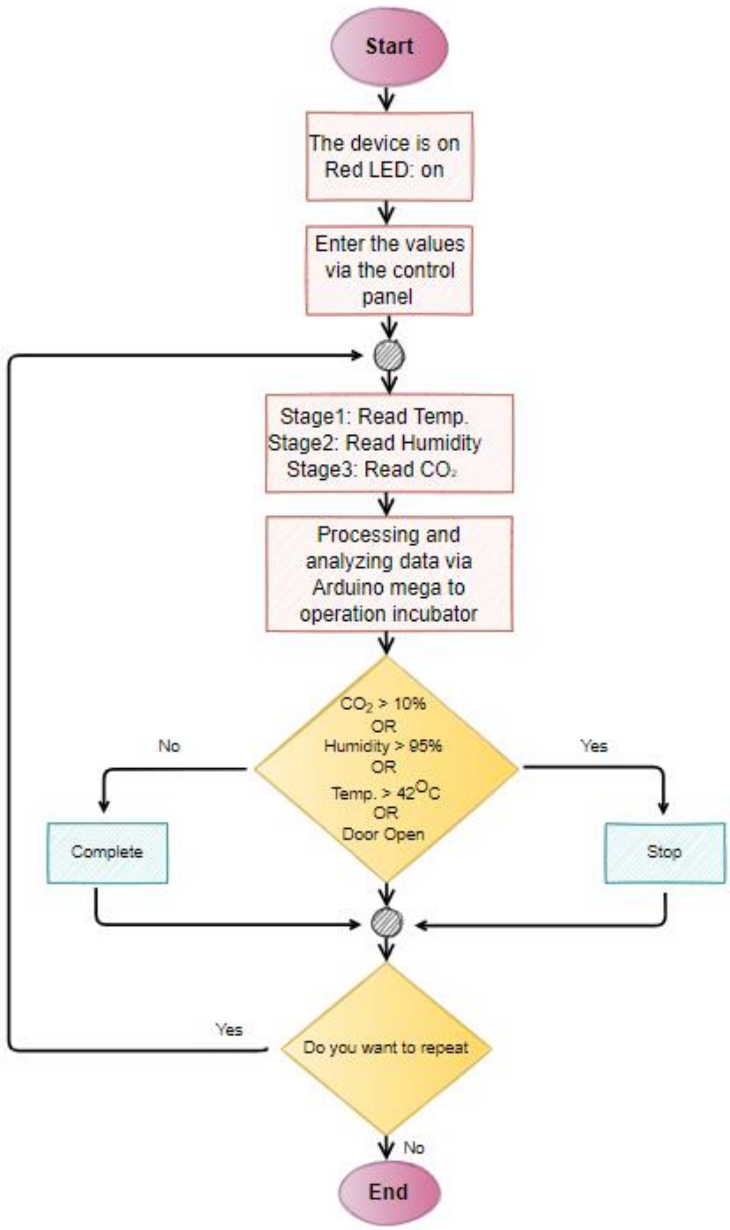

Figure (3.16): System Flowchart.

4

Chapter Four

System Implementation

4.1. Introduction.

4.2. Practical procedures.

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- 4.2.6. Input Unit.
- 4.2.7. Filtration.

4.3. Power Supply Design.

4.1. Introduction:

In this chapter we will mention the method of connecting a circuit which attached to the pictures, linking the temperature, humidity and CO_2 sensors that provide the appropriate conditions for cell growth and reproduction.

The method of linking the heater that is the source of heat in the project laboratory incubator and the fan that helps to circulate the heat inside the incubator and the rest of the circuit. As well as recording the values of temperature, humidity and CO_2 before the incubator is turned on and also during its operation as well as upon arrival for required temperature or humidity or CO_2 because the bacterial cells must have an appropriate degree in terms of temperature and humidity. The internal incubator environment reaches the required magnitudes corresponding to appropriate temperature, humidity and CO_2 for any material that should save in a laboratory incubator and these values can be provided and determined by a code which must be programmed inside the device microcontroller, the meter within the device will give a counter to stop the operation.

4.2. Practical procedures:

In this section, the method of practical installation of the parts used in the project will be explained in general details.

4.2.1. DHT22 and MH-Z19B Sensor:

1. <u>DHT22:</u>

It is easily used but it needs a specific time for an operation. This sensor measure moisture content and temperature, this sensor is easily connected with other microcontrollers.
DHT22 sensor consists of thermistor for temperature measurement and capacitive humidity sensor humidity measurement, as show in Figure (4.1). [22]

It consists of 4.7 K to 10 K resistor, which can be used as pull up from data pin to Vcc.

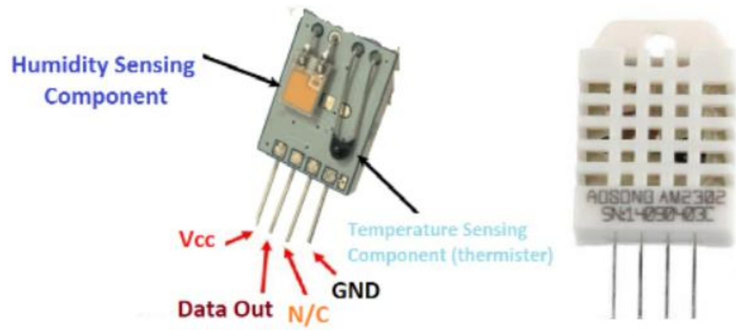


Figure (4.1): DHT22 Consists. [22]

There are main four pinouts of DHT22 we use three pins which are discussed below:

Table (4.1): DHT22 Pinouts. [22]

Num.	Pin Type	Parameters
7.	Vcc	This is Power Pin at this pin we apply 3.5 v to 5.0 volts.
8.	Data	Through this pin, we get outputs both Temperature and Humidity through serial Data.
9.	Ground	Ground Pin (Connected to 0V or GND)

➢ Working of DHT22:

It consists of two main parts one measure temperature and other is used for humidity measurement it also has IC to send data to Microcontroller.

- Humidity Sensing Component:

For humidity measurement, it uses the humidity measurement component, which has two electrodes with moisture holding substrate between them.
As humidity changes, the conductivity of substrate changes or resistance between electrodes changes. This changes in resistance are measured, then processed by IC which make it ready to be read by Microcontroller. [22]

- Temperature Measuring Component:

To measure temperature this sensor uses an NTC temperature sensor or Thermistor.

A thermistor is a variable resistor that changes its resistance with a change of temperature. These sensors are made by sintering of semi conductive materials, such as ceramic or polymers in order to large change in a resistor with small changes in temperature. As temperature changes, there is a change in the value of resistance by which we measure the temperature of our environment.

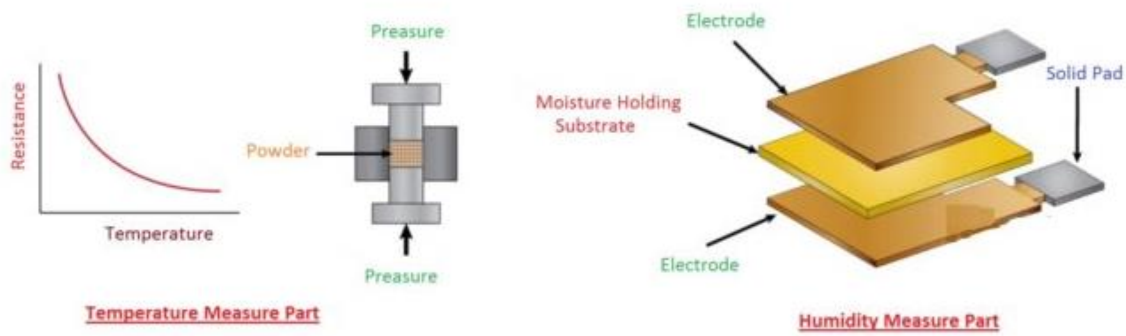


Figure (4.2): DHT22 Working. [22]

➢ DHT22 Serial Protocol:

DHT22 sensor is calibrated in industries it is designed for serial output data transmission. I have to interface it with Microcontroller for its serial data transmission.

The data pin is connected with an input-output pin of Microcontroller and 5k pull up resistor is used. This data pin sends output values of both temperature and humidity as serial data. [22]

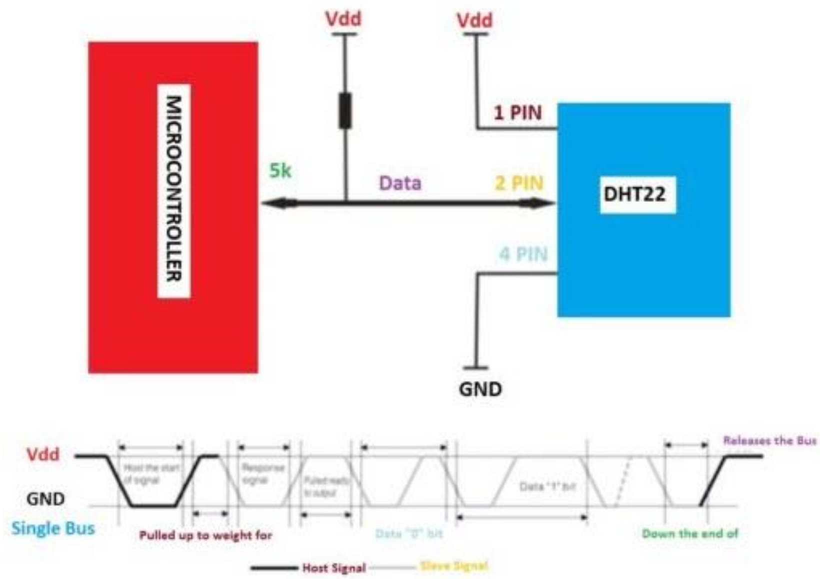


Figure (4.3): DHT22 Serial Transmission Protocol. [22]

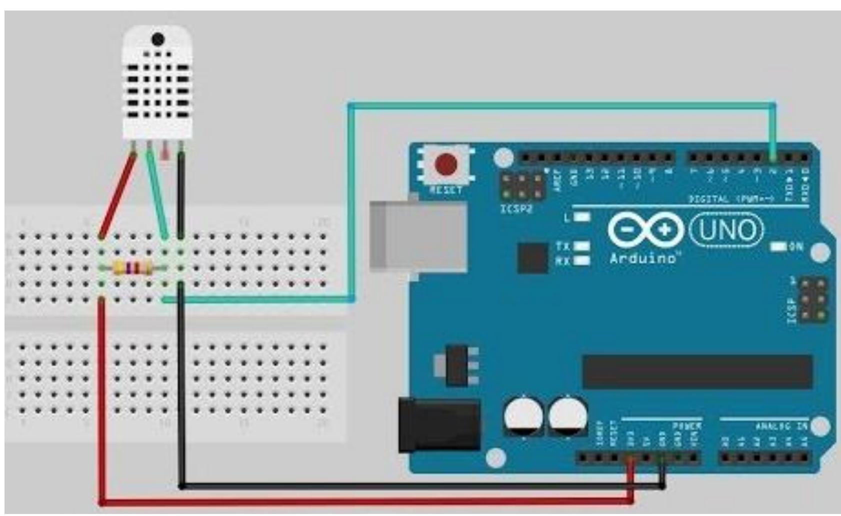


Figure (4.4): DHT22 Arduino Interfacing. [22]

2. MH-Z19B Sensor:

The measurement method used is based on the non-dispersive infrared (NDIR) principle to detect the existence of CO_2 in the air.
A nondispersive infrared sensor (or NDIR sensor) is a relatively simple spectroscopic sensor often used as a gas detector. It is nondispersive in the sense of optical dispersion since the infrared energy is allowed to pass through the atmospheric sampling chamber without deformation. [23]

➢ Principle of operation:

The main components of an NDIR sensor are an infrared source (lamp), a sample chamber or light tube, a light filter and an infrared detector. The IR light is directed through the sample chamber towards the detector. In parallel there is another chamber with an enclosed reference gas, typically nitrogen. The gas in the sample chamber causes absorption of specific wavelengths according to the Beer–Lambert law, and the attenuation of these wavelengths is measured by the detector to determine the gas concentration. The detector has an optical filter in front of it that eliminates all light except the wavelength that the selected gas molecules can absorb.

features an UART serial interface and Pulse Width Modulation (PWM) output. pulse width modulated (PWM) output where the duty cycle changes with CO_2 concentration which could be buffered and low pass filtered to get an analog signal representing the CO_2 level. [24]

Figure (4.5): MH-Z19B Pinouts. [24]

Table (4.1): MH-Z19B Pinouts Description. [24]

Num.	**Pinout**	**Description**
10.	Pin 1 – Vo	Vout – Output Voltage 3.3V, Output Current lower than 10mA
11.	Pin 2 – RX	UART RXD – digital input
12.	Pin 3 – TX	UART TXD – digital output
13.	Pin 4 – SR	factory reserved
14.	Pin 5 – HD	factory reserved – zero calibration
15.	Pin 6 – Vin	Input Voltage
16.	Pin 7 – GND	GND
17.	Pin 8 – AOT	factory reserved
18.	Pin 9 – PWM	Pulse Modulation

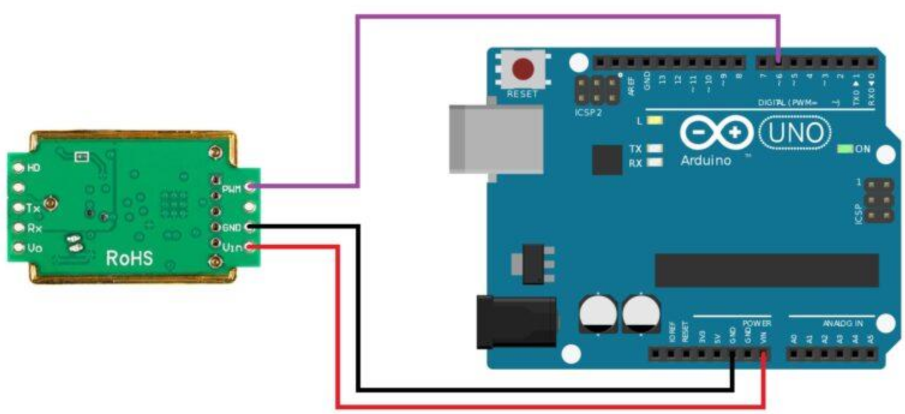


Figure (4.6): MH-Z19B Arduino Interfacing. [24]

4.2.2. The Fan:

The project implemented incubator works at electrical source of 5 volts, from Arduino which is controlled by the used relay to be connected from the source to 12-volt power supply to run the fan. The incubator fan is located in a position near the heater in order to distribute the generated heat by the heater inside the room because the temperature will be greatest near the heater. [25]

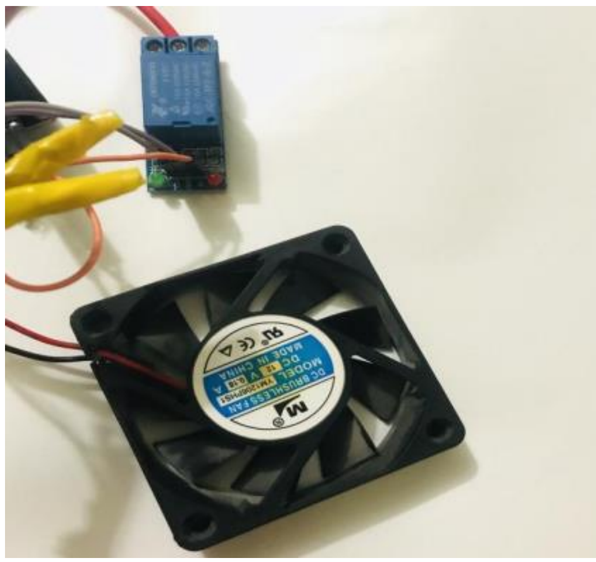


Figure (4.7): Fan Connect with Relay. [25]

- **Relay:**

A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. The switch may have any number of contacts in multiple contact forms, such as make contacts, break contacts, or combinations thereof.

Relays are used where it is necessary to control a circuit by an independent low-power signal, or where several circuits must be controlled by one signal.

The traditional form of a relay uses an electromagnet to close or open the contacts, but other operating principles have been invented, such as in solid-state relays which use semiconductor properties for control without relying on moving parts. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called protective relays.

Latching relays require only a single pulse of control power to operate the switch persistently. Another pulse applied to a second set of control terminals, or a pulse with opposite polarity, resets the switch, while repeated pulses of the same kind have no effects. Magnetic latching relays are useful in applications when interrupted power should not affect the circuits that the relay is controlling. [26]

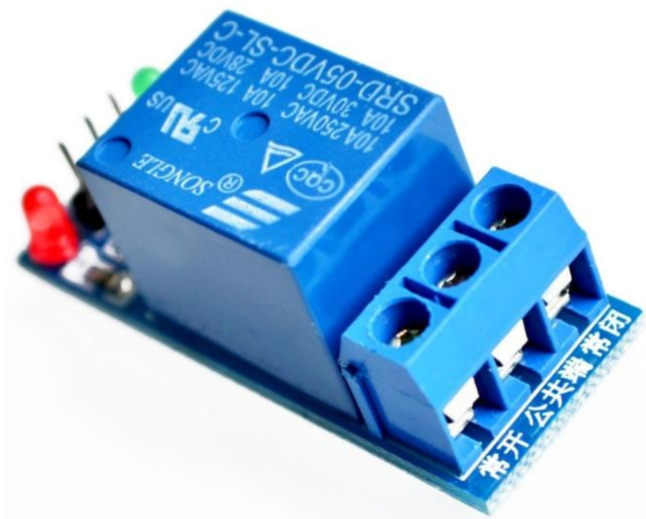


Figure (4.8): Relay. [26]

4.2.3. The Heater:

To Control Heating Element: If 12V Heating Element is powered by 12V power supply, it emits heat. To control a Heating Element, we need to use a relay in between Arduino and Heating Element. Arduino can control the Heating Element via the relay, like the following figure:

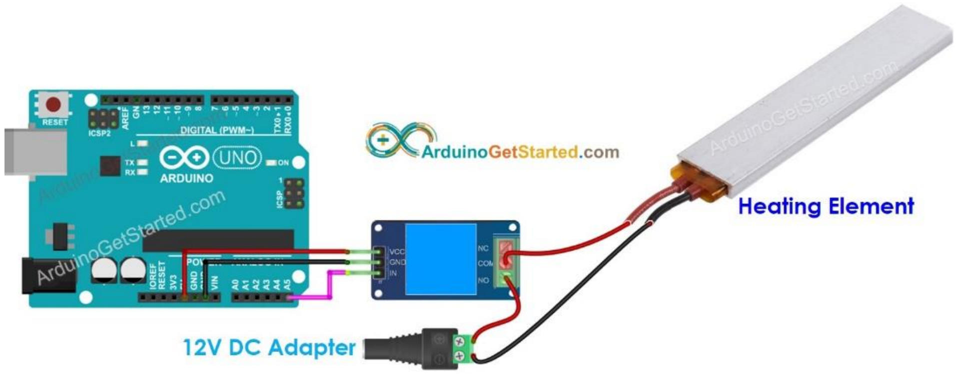


Figure (4.9): Heater Connect with Relay. [27]

4.2.4. The Humidifire:

The steam is already used to increase the required humidity inside the incubator according to the needs of the sample and according to the humidity that we can enter inside the incubator. As it evaporates the water quickly and at the same time it does not increase the water temperature (i.e. raising the humidity inside the incubator space without influencing the temperature).

The Humidifire is placed inside a special container and submerged by water, then the vessel is installed outside or at bottom the incubator to prevent the influence of high temperature inside the incubator on both the aroma and the temperature of the water.

When the circuit is turned on, after a specific time the steam is transferred through a special tube from the container to the inside of the room through a small sealed hole at the side of the incubator at a level that ensures the distribution of steam. The fan is used to distribute the heated air in all corners of the incubator. [28]

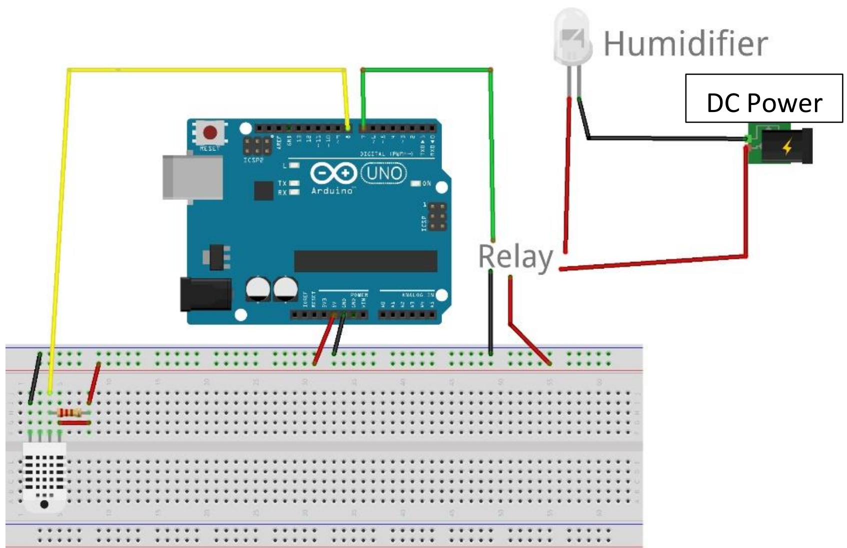


Figure (4.10): Humidifire Connect. [28]

4.2.5. CO_2 Supply:

- **Supply CO_2 gas need two main part:**

1) The CO_2 Pressure Regulator:

The CO_2 regulator reduces the high pressure inside of a CO_2 cylinder to a lower. The pressure reducing regulator takes a pressure of 800 – 1000 PSI (pounds per square inch) from the CO_2 cylinder, and regulates it to provide a controlled, reduced pressure output in the range of 1 – 40 PSI. The solenoid valve of the CO_2 regulator is the powerhouse of the regulator. It is an electromechanical ON / OFF valve that controls the output of carbon dioxide gas into the aquarium. [29]

2) The CO_2 Cylinder

The CO_2 Cylinder is a high pressure storage cylinder for carbon dioxide (CO_2). Carbon dioxide in a cylinder exists primarily in the form of liquid CO_2, only the head space of the cylinder contains gas. The liquid allows the cylinder to maintain a constant high pressure. Because the cylinder contains liquid gas, it must always remain in the upright position.

At first we must connect CO_2 gas cylinder to reducing valve or regulator. Failure to do so could result in an explosion with possible death or injury when the cylinder valve is opened. So never connect gas cylinder directly to keg. And must secure gas cylinder in 'upright" position, keep gas cylinder away from heat. [29]

- **The main components of a regulator:**

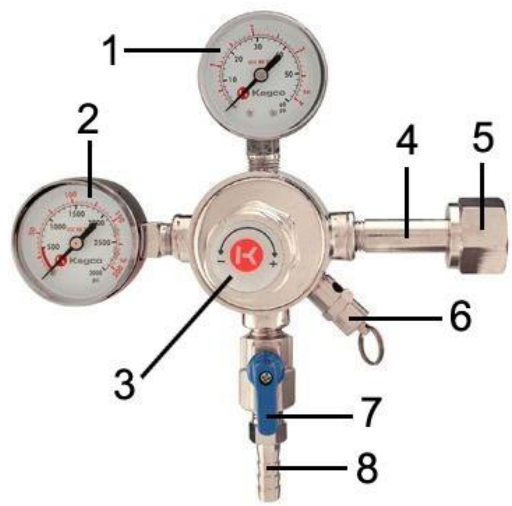


Figure (4.11): CO_2 Regulator. [29]

1. Low pressure gauge (reads the amount of internal keg pressure).
2. High pressure gauge (indicates existing pressure in the CO_2 cylinder).
3. Pressure adjustment (before tapping the keg, screw clockwise until low pressure gauge indicates the desired pressure).
4. CO_2 inlet nipple.
5. CO_2 inlet nut.
6. Pressure relief valve.
7. Optional shut-off valve.
8. Outlet fittings.

4.2.6. Input Unit:

16-Button Numeric Keypad Matrix, Rubber-domes beneath each button provide satisfying key travel with each button press. Each key is emblazoned with a legible white character molded into its surface.

Four mounting holes allow solid and easy mounting to a panel. The single-row 0.1-inch-pitch solder pads are breadboard friendly. Only eight of the ten solder pads carry signals - the solder pads on the ends of the row are purely for mechanical attachment. The keys are connected in a 4x4 matrix configuration.

On the underside of each key in a membrane keypad is a membrane switch (hence the name). In each row of the membrane is a horizontal trace that connects every membrane switch together. In every column is a vertical trace that also connects each switch together. With four rows and four columns, this allows 16 keys to be read with only 8 pins. When a key is pressed down it causes the trace on one row and one column to make electrical contact.

To determine which button is pressed the Arduino detects a connection at a certain row and column within the matrix. [30]

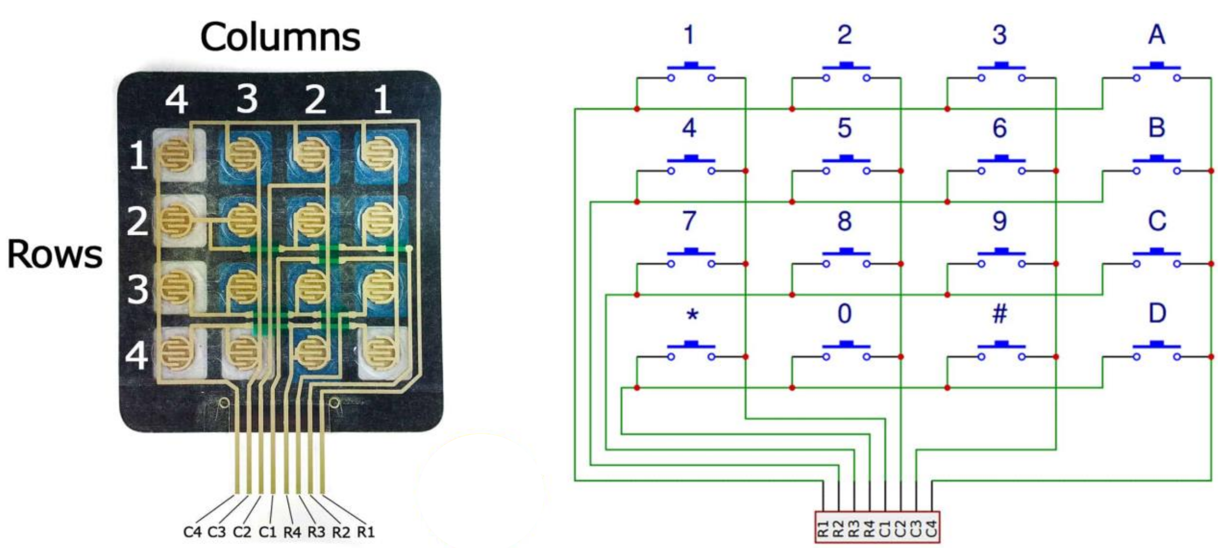


Figure (4.12): Keypad Inside Connect. [30]

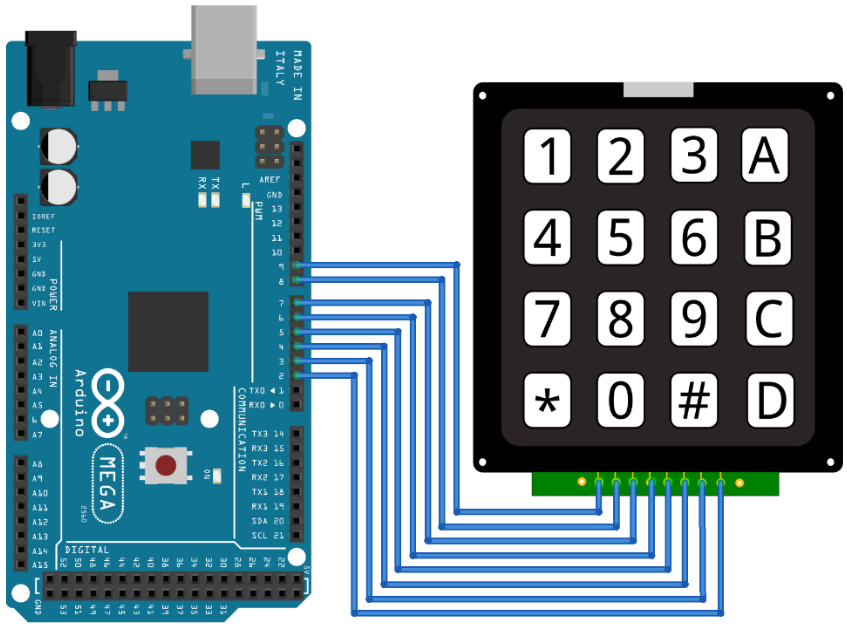


Figure (4.13): Keypad Arduino Connect. [30]

4.2.7. Filtration:

A HEPA filter is placed at the top of the incubator with a tightly closed hole located at the top of the filter to the outside air, which allows gas exchange with the work of an air purification process to simulate the respiratory system in the human body, which purifies the air and reaches 20% of the purified oxygen inside the incubator, and thus Better completion of the incubator's work, as well as ensuring the renewal of air inside the incubator. [31]

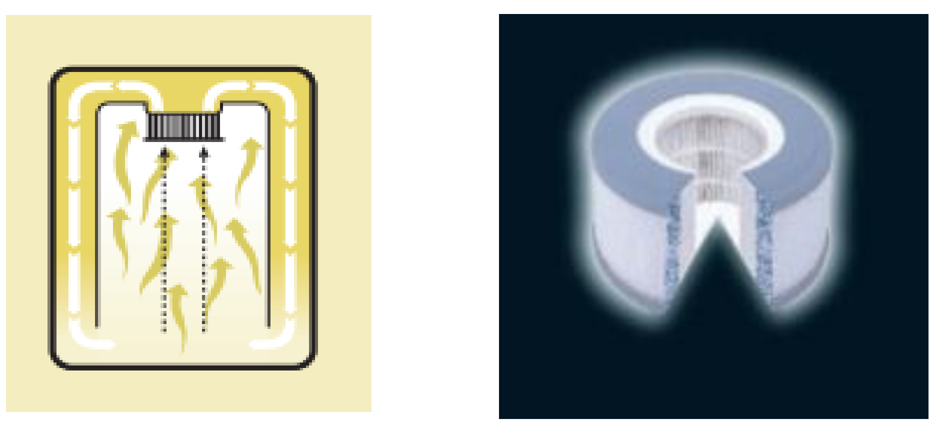


Figure (4.14): Filtration in Incubator. [31]

4.3. Power Supply Design:

In our project, two batteries will be used, the first 5 volts to feed the Arduino and the second 12 volts to feed the rest of the incubator pieces, after studying the characteristics of all the pieces and choosing the appropriate feeding for its work, or we can use battery 12 volts to supply all project.

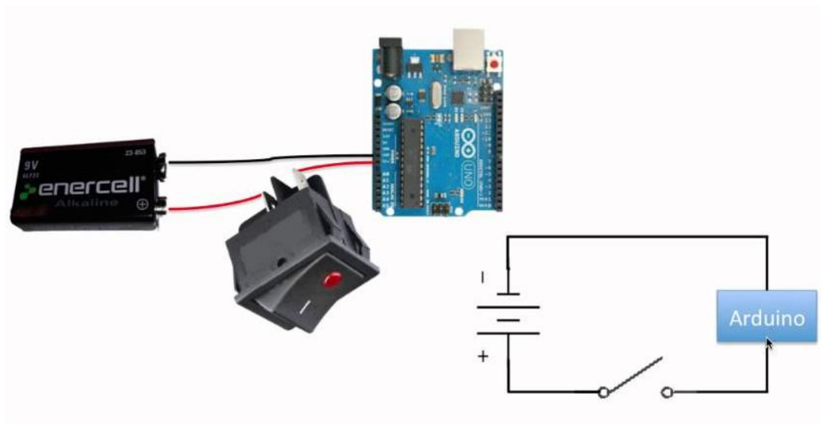


Figure (4.15): Power Supply Design.

5

Chapter Five

Results and Analysis

5.1 Introduction:

This chapter explains in specific details the results generated from this work based on the performed methodologies that are mentioned in Chapter four. And explain the practical application for every part in this project, and add the programmed Arduino code to work the all system as required, With the addition of pictures of the final incubator work.

5.2 The Practical application:

5.2.1 Incubator Cabinet:

To facilitate the work of completing the project, a small office refrigerator was used instead of building a frame consisting of two insulating layers interspersed with insulating rock wool.

Where the refrigerator was brought and empty of the parts used for its previous work as a refrigerator, then the middle was prepared to place the electronic parts of the incubator, while making holes in the incubator for the filter and supplying the incubator with CO_2 gas, as shown in the figure.

(a) (b)

Figure (5.1) (a, b): refrigerator used before modification.

(a) (b)

Figure (5.2) (a, b): Incubator Cabinet after modification.

5.2.2 Input Unit Connection:

The input board (Keypad) was connected to the Arduino and programmed to enter the required values of temperature and humidity. As shown in the picture.

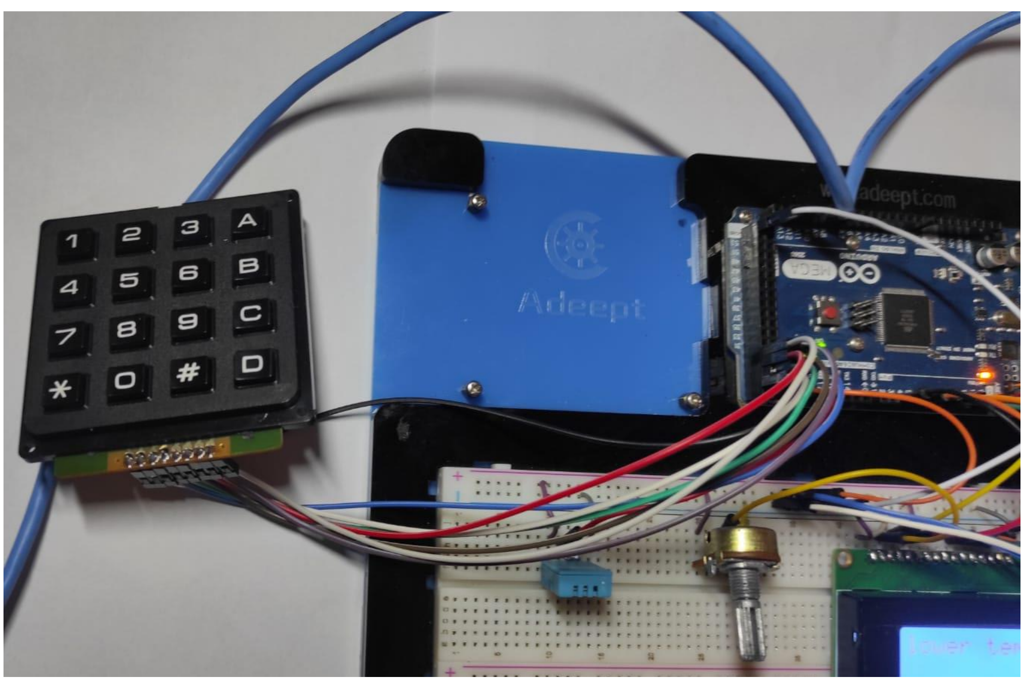


Figure (5.3): Input Unit Connection.

5.2.3 Fan Connection:

To complete the work of the incubator as required to simulate the human body and to cool the incubator from a high degree to the degree required to be applied to the sample, a fan operating on a voltage of 12 volts was used.

Therefore, the fan was connected to the Arduino using a relay that works on a voltage of 5 volts from the Arduino to control the work of the fan with a voltage of 12 volts, when it needs to work according to the value entered through the control panel, after reading the value from DHT22 sensor for temperature and humidity. As shown in the figures.

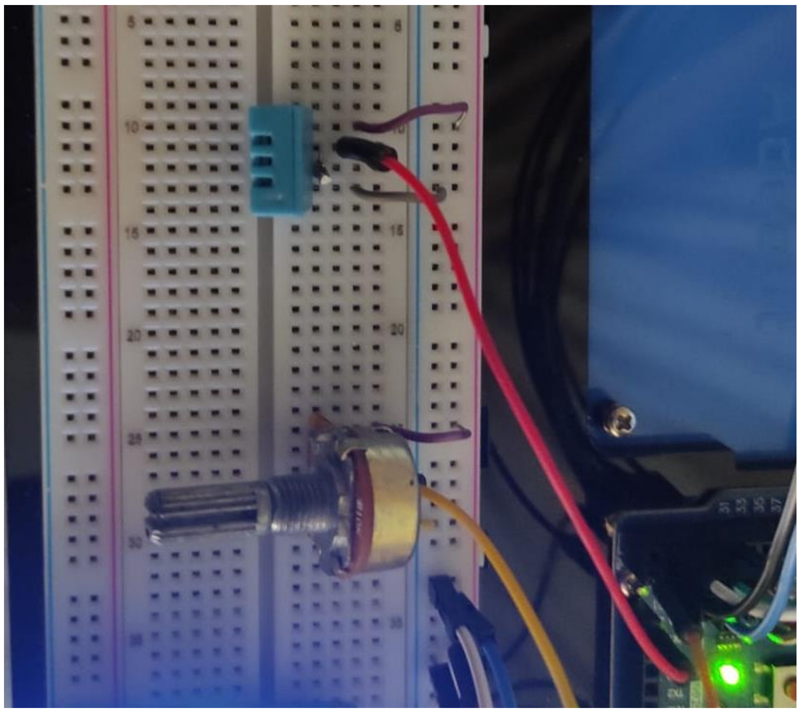


Figure (5.4): DHT22 Sensor Connection.

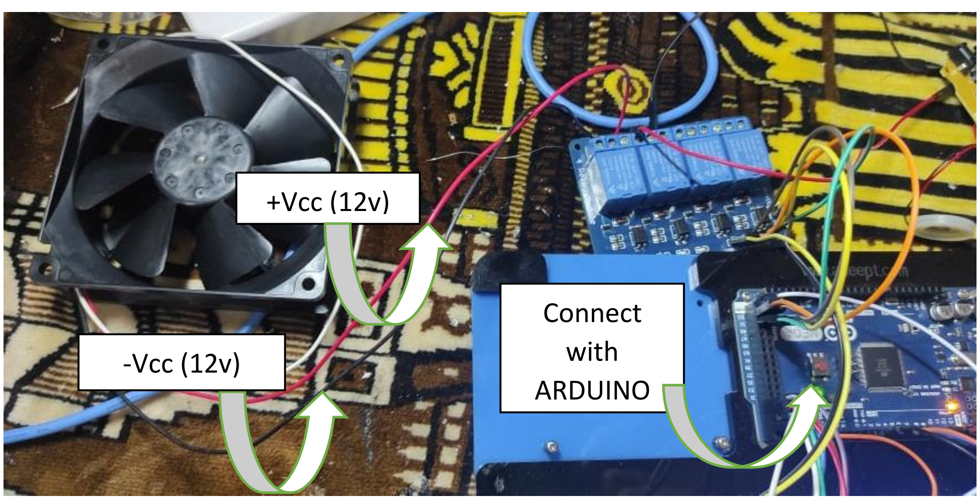


Figure (5.5): Fan Connection.

5.2.4 Heater Connection:

To achieve the goal of designing a portable incubator that relies on a battery to operate, and after experimenting with the heater with DC feeding due to obtaining very little heat, the heater was dispensed, and after prolonged research, bulbs were used that depend on feeding 12 volts and provide the required heat.

Figure (5.6): Heater Connection.

5.2.5 Humidifier Connection:

To provide the incubator with the required humidity, a 12-volt humidifier was used and controlled via the Arduino when needed via a connection with a relay. As shown in the figure.

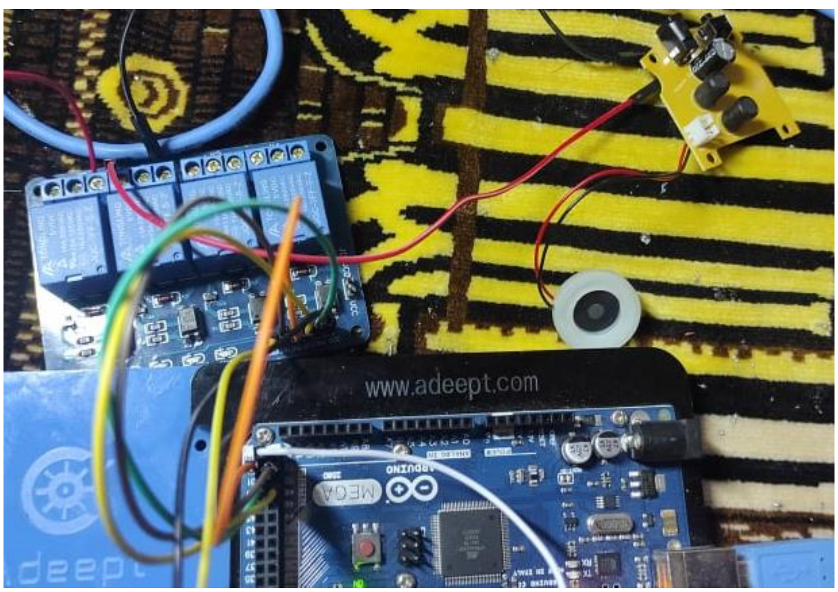


Figure (5.7): Humidifier Connection.

5.2.6 CO_2 Supply Connection:

Providing the incubator with CO_2 gas takes place in two stages. At first, a CO_2 gas sensor was connected inside the incubator, where it reads the gas value and prints it on the screen. Therefore, according to the gas value, the gas is entered from an external cylinder through the control of the regulator located on the cylinder, and the gas is entered through a pipe installed in a tightly closed hole, connecting the pipe from the outside of the cylinder to the inside of the incubator. As shown in the figure.

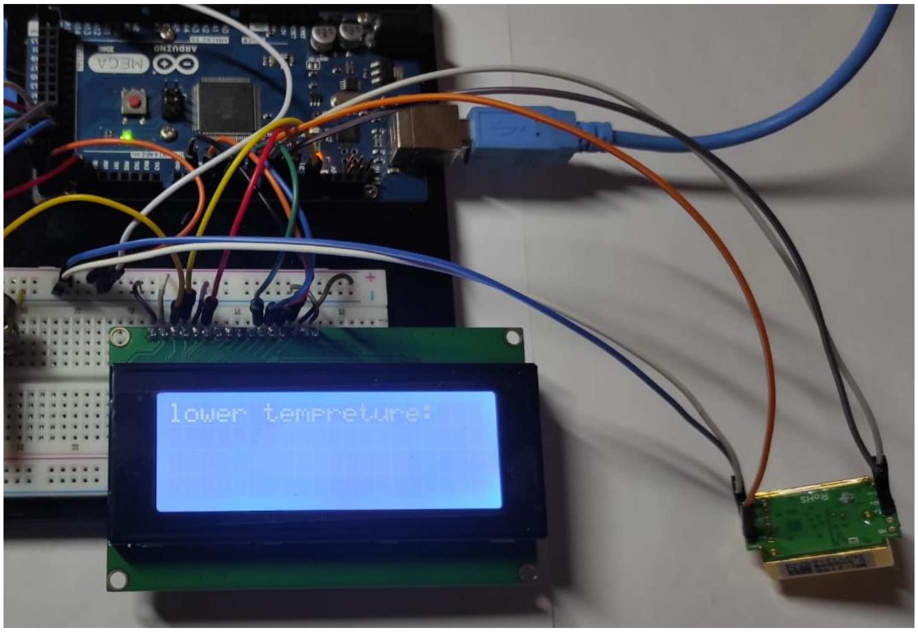
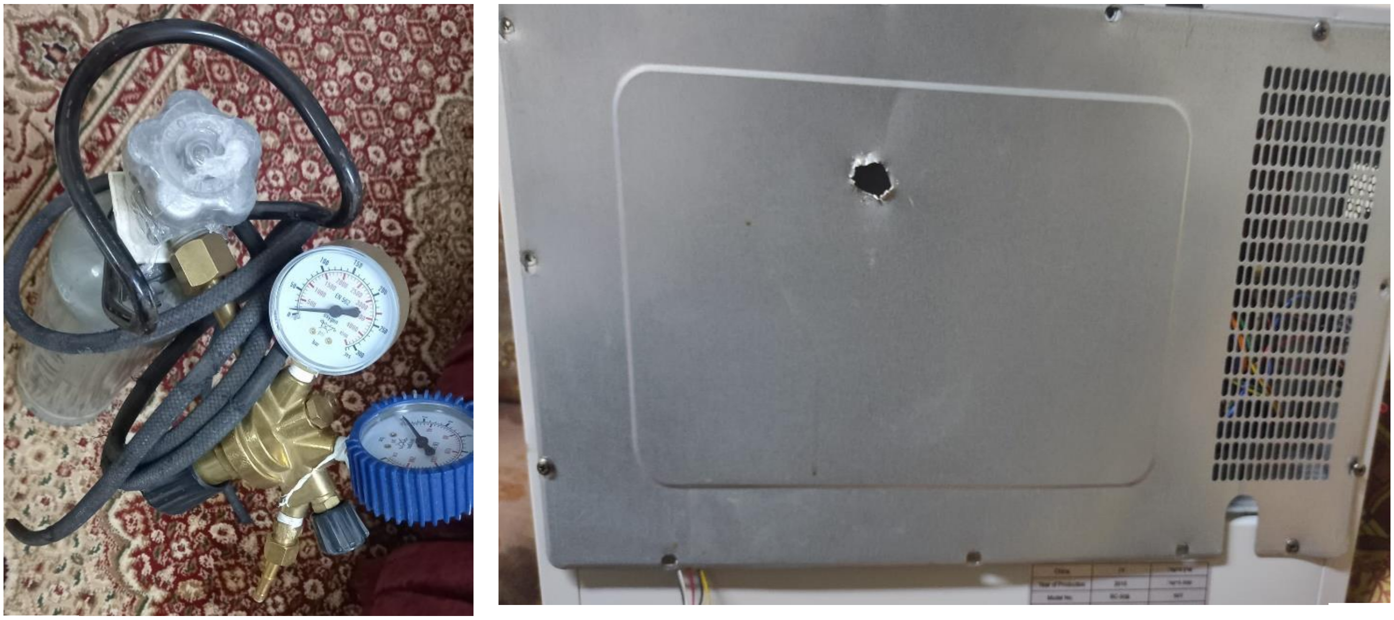


Figure (5.8): CO_2 Sensor Connection.

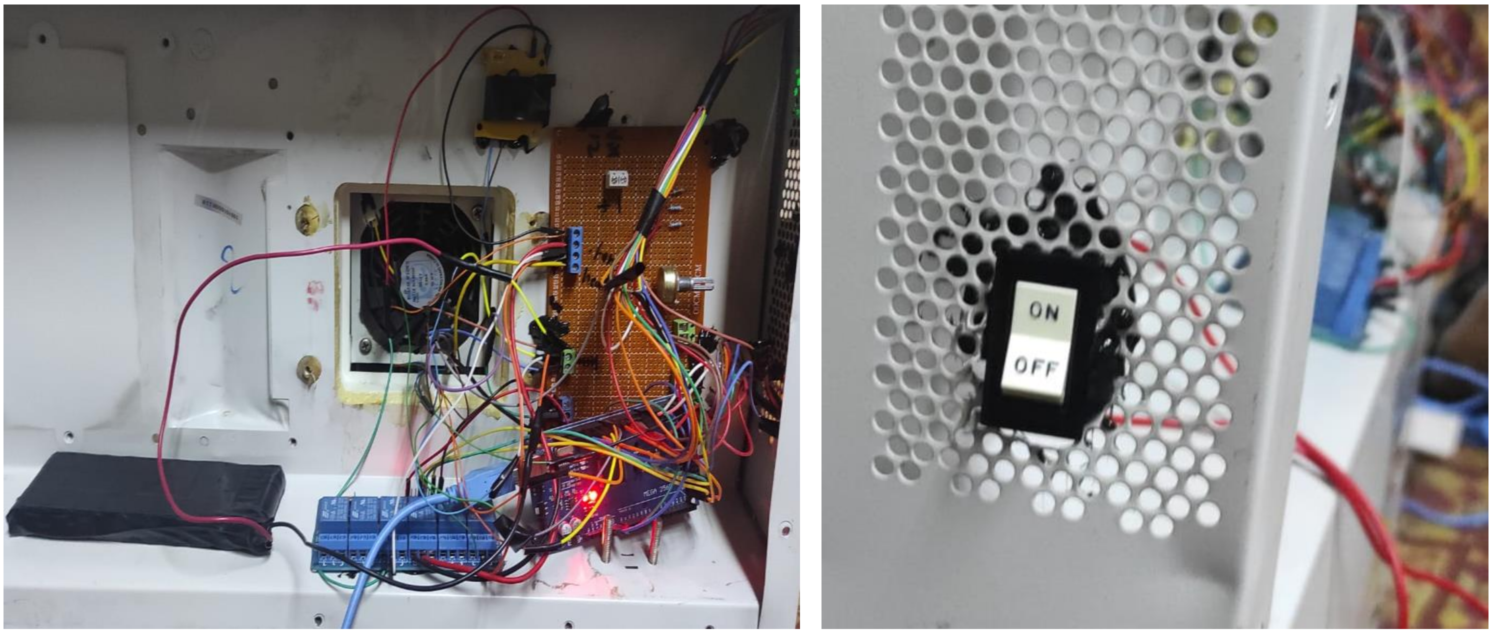


(a) (b)

Figure (5.9) (a, b): CO_2 Cylinder Connection.

5.2.7 Power Supply Connection:

We must connect battery to white connector, then press the key to turn on incubator.



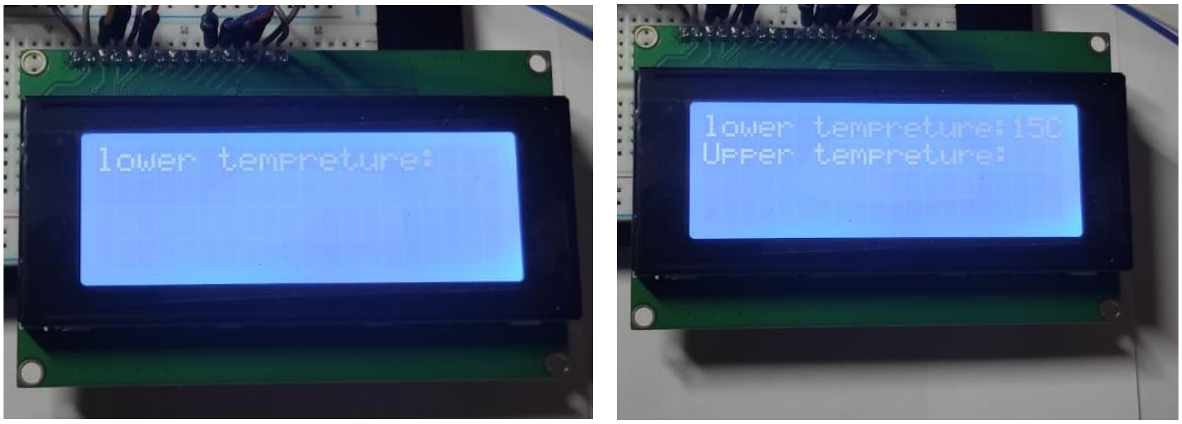
(a) (b)

Figure (5.10) (a, b): Power Supply Connection.

5.3 Results of System Circuits:

5.3.1 Fan Circuit and Heater Circuit:

To ensure that the incubator works at a higher efficiency, it has been programmed to enter the minimum and maximum value of the required temperature via the keypad within the appropriate range for bacteria multiplication, and thus either the work of the fan or the heater is controlled to achieve the goal. As shown in figure.

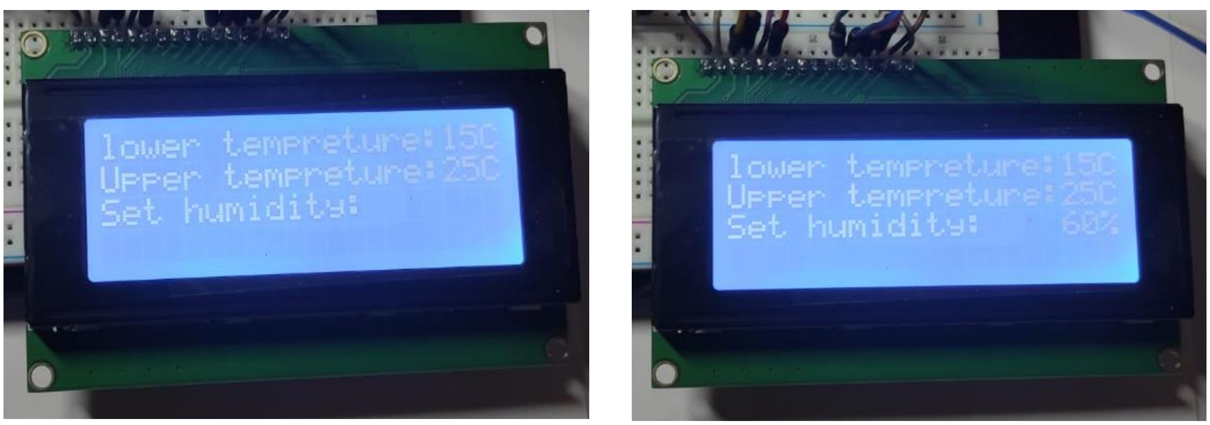


(a) (b)

Figure (5.11) (a, b): Temperature setting screen.

5.3.2 Humidifier Circuit:

The minimum required humidity is entered into the incubator via the input plate, after setting the temperature value. As shown in figure.



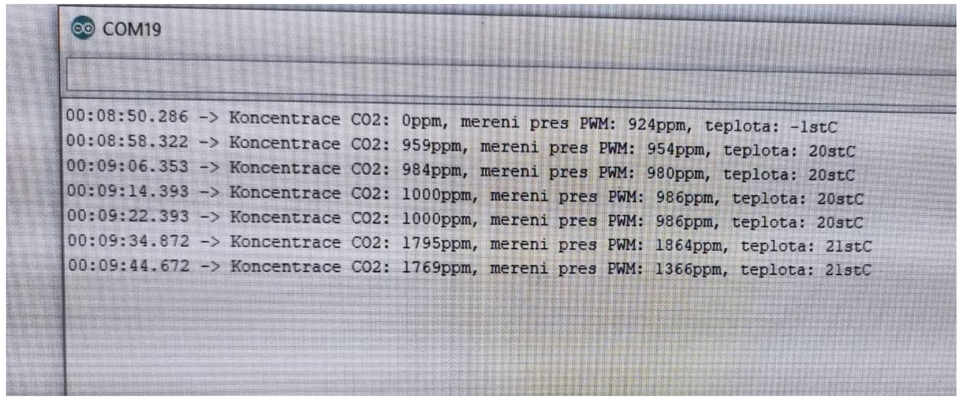
(a) (b)

Figure (5.11) (a, b): Humidifier setting screen.

5.3.3 CO_2 Circuit:

The required value is entered within the required range of carbon dioxide gas through the gas regulator installed on the cylinder and the gas value is read inside the incubator, until an appropriate value is obtained.

(a)



(b)

Figure (5.12) (a, b): CO_2 Result.

5.4 The Programmed Arduino Code:

```
#include "DHT.h"
#define DHTPIN 21
#include <LiquidCrystal.h>                //include the LiquidCrystal library

LiquidCrystal lcd (12, 10, 5, 4, 3, 2);           //define LCD pins (RS, E, D4, D5, D6, D7)

#define DHTTYPE DHT11                   // DHT 11
    //#define DHTTYPE DHT22   //
    //#define DHTTYPE DHT21   //

DHT dht (DHTPIN, DHTTYPE);
int fan=52; //relay 1
int fan2=51; //relay 2
int heater= 50; // relay 3
int humi=49; //relay 4
float x=15.0;
```

```
int led1=17;//temperature
int led2=15;//humidity
int led3=16;//co2
int but=18;
int buzzer=19;

#include "MHZ19.h"
#define rx_pin 9
#define tx_pin 8
#define pwmpin 7

MHZ19 *mhz19_uart = new MHZ19(rx_pin, tx_pin);
MHZ19 *mhz19_pwm = new MHZ19(pwmpin);

#include <Keypad.h>
const byte ROWS = 4;                                    //four rows
const byte COLS = 4;                                    //three columns
char keys[ROWS][COLS] = {
{'1', '2', '3', 'A'},
  {'4', '5', '6', 'B'},
  {'7', '8', '9', 'C'},
  {'*', '0', '#', 'D'}
};
byte rowPins[ROWS] = {26, 27, 28, 29};            //connect to the row pinouts of the kpd
byte colPins[COLS] = {22, 23, 24, 25};            //connect to the column pinouts of the kpd

Keypad keypad = Keypad(makeKeymap(keys), rowPins, colPins, ROWS, COLS);
```

```
unsigned long loopCount;
unsigned long startTime;
String msg;
int val1;
int val2;
int val3;
int t=0;
int buttonState = 0;
                    *********************************
void setup() {
  pinMode(fan, OUTPUT);
  pinMode(fan2, OUTPUT);
  pinMode(heater, OUTPUT);
  pinMode(humi, OUTPUT);
  digitalWrite(fan, HIGH);
  digitalWrite(fan2, HIGH);
  digitalWrite(heater, HIGH);
  digitalWrite(humi, HIGH);
  pinMode(led1, OUTPUT);
  pinMode(led2, OUTPUT);
  pinMode(led3, OUTPUT);
  pinMode(buzzer, OUTPUT);
  pinMode(but, INPUT);

  digitalWrite(led1, HIGH);
  digitalWrite(led2, HIGH);
  digitalWrite(led3, HIGH);
  delay(2000);
```

```
 digitalWrite(led1, LOW);
 digitalWrite(led2, LOW);
 digitalWrite(led3, LOW);
 lcd.begin(20, 4);
 dht.begin();

 lcd.clear();
 Serial.begin(9600);
 lcd.setCursor(3, 0);
lcd.print("WELCOME IN OUR");
lcd.setCursor(6, 1);
lcd.print("PROJECT");

 mhz19_uart->begin(rx_pin, tx_pin);
 mhz19_uart->setAutoCalibration(false);
        // mhz19_uart->setAutoCalibration(false);
delay(5000);

   val1= getKeypadIntegerMulti1();
   val2= getKeypadIntegerMulti2();
   val3= getKeypadIntegerMulti3();

  delay(10000);
  Serial.println("Value 1 is");
  Serial.println(val1);
  Serial.println("Value 2 is");
  Serial.println(val2);
   }
```

****

```
void loop() {
            // Wait a few seconds between measurements.
  delay(2000);
  while (t==0) {
  lcd.clear();
  t=1;  }
 buttonState = digitalRead(but);
  if(buttonState == LOW){
    digitalWrite(buzzer, HIGH);
} else {
      digitalWrite(buzzer, LOW);
      }

            // Reading temperature or humidity takes about 250 milliseconds!
           // Sensor readings may also be up to 2 seconds 'old' (its a very slow sensor)float h =
dht.readHumidity();
           // Read temperature as Celsius (the default)
 float t = dht.readTemperature();

          // Check if any reads failed and exit early (to try again).
if (isnan(h) || isnan(t)) {
        // Serial.println(F("Failed to read from DHT sensor!"));
    return;
  }

        // Compute heat index in Celsius (isFahreheit = false)
  float hic = dht.computeHeatIndex(t, h, false);
  lcd.setCursor(0, 0);
```

```
lcd.print("Humidity: ");
lcd.setCursor(12, 0);
lcd.print(h);
lcd.setCursor(18, 0);
lcd.print("%");
lcd.setCursor(0, 1);
lcd.print("Temperature: ");
lcd.setCursor(13, 1);
lcd.print(t);
lcd.setCursor(18, 1);
lcd.print("C ");

 measurement_t m = mhz19_uart->getMeasurement();
int co2ppm = mhz19_pwm->getPpmPwm();

Serial.print(map(m.co2_ppm, 0, 5000, 0, 2000));
lcd.setCursor(0, 2);
lcd.print("CO2 Con. : ");
lcd.setCursor(13, 2);
lcd.print(co2ppm);
if(co2ppm >=1000){
   lcd.setCursor(17, 2);
lcd.print("ppm");
  }
  else{  lcd.setCursor(16, 2);
lcd.print("ppm"); }
       //lcd.setCursor(0, 2);
       //lcd.print(val1);
```

```
        // lcd.setCursor(0, 3);
        //lcd.print(val2);
       //Serial.print(F("Humidity: "));
       //Serial.print(h);
         //Serial.print(F("%  Temperature: "));
        //Serial.print(t);
       //Serial.print(F("°C "));
     //Serial. print('\n');

 if(t >= val2){ //greater than upper temp
 digitalWrite(fan, LOW);
 digitalWrite(fan2, LOW);
    } else  {
    digitalWrite(fan, HIGH);
    digitalWrite(fan2, HIGH);
         // digitalWrite(led1, HIGH);
    }

if (t <= val1){ //lower than lower temp.
   digitalWrite(heater, LOW);
   digitalWrite(led1, HIGH);
  }
  else {
    digitalWrite(heater, HIGH);
    digitalWrite(led1, LOW);  }
if (h <=val3){
  digitalWrite(humi, LOW);
  digitalWrite(led2, HIGH);
```

```
  } else {
    digitalWrite(humi, HIGH);
    digitalWrite(led2, LOW); }
if (co2ppm >=1000){
  digitalWrite(led3, HIGH);                                            //lcd.clear();
  } else {
    digitalWrite(led3, LOW); }

  if (t>=40){
    digitalWrite(led1, HIGH);
    } else {
    digitalWrite(led1, LOW); }
delay(1000);
}

long getKeypadIntegerMulti1()
{
  long value = 0;                                              // the number accumulator
  long keyvalue;                                              // the key pressed at current moment
  int isnum;
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("lower tempreture: ");
  lcd.setCursor(19, 0);
           //Serial.println("Enter the lower tempreture: ");
           //Serial.print("You have typed: ");
  do
  {
```

```
    keyvalue = keypad.getKey();                                        // input the key
    isnum = (keyvalue >= '0' && keyvalue <= '9');                    // is it a digit?
    if (isnum)
    {
      Serial.print(keyvalue - '0');
      value = value * 10 + keyvalue - '0';                         // accumulate the input number
    }

  } while (isnum || !keyvalue);                            // until not a digit or while no key pressed
        //Serial.println(" ");
        //Serial.print("Returning from funtion: ");
  lcd.setCursor(17, 0);
  lcd.print(value);
  lcd.setCursor(19, 0);
  lcd.print("C");
          //Serial.println(value);
  return value;
}         //getKeypadInteger

long getKeypadIntegerMulti2()
{
  long value = 0;                                                // the number accumulator
  long keyvalue;                                               // the key pressed at current moment
  int isnum;
  lcd.setCursor(0, 1);
  lcd.print("Upper tempreture: ");
  lcd.setCursor(19, 1);
              //Serial.println("Enter the upper tempreture: ");
```

```
        //Serial.print("You have typed: ");
  do
  {
    keyvalue = keypad.getKey();                         // input the key
    isnum = (keyvalue >= '0' && keyvalue <= '9');       // is it a digit?
    if (isnum)
    {
      Serial.print(keyvalue - '0');
      value = value * 10 + keyvalue - '0';              // accumulate the input number
    }

  } while (isnum || !keyvalue);                         // until not a digit or while no key pressed
      //Serial.println(" ");
      //Serial.print("Returning from funtion: ");
     // Serial.println(value);
 lcd.setCursor(17, 1);
  lcd.print(value);
  lcd.setCursor(19, 1);
  lcd.print("C");
  return value;
}//getKeypadInteger

long getKeypadIntegerMulti3()
{
  long value = 0;                                       // the number accumulator
  long keyvalue;                                        // the key pressed at current moment
  int isnum;
     // lcd.clear();
```

```
  lcd.setCursor(0, 2);
  lcd.print("Set humidity:");
  lcd.setCursor(19, 2);
        //Serial.println("Enter the lower tempreture: ");
       //Serial.print("You have typed: ");
  do
  {
    keyvalue = keypad.getKey();                       // input the key
    isnum = (keyvalue >= '0' && keyvalue <= '9');     // is it a digit?
    if (isnum)
    {
      Serial.print(keyvalue - '0');
      value = value * 10 + keyvalue - '0';            // accumulate the input number
    }
  } while (isnum || !keyvalue);                       // until not a digit or while no key pressed
        //Serial.println(" ");
       //Serial.print("Returning from funtion: ");
  lcd.setCursor(17, 2);
  lcd.print(value);
  lcd.setCursor(19, 2);
  lcd.print("%");
       //Serial.println(value);
  return value;
}
```

5.5 Final Project Testing:

As we explained previously how to design and connect the electrical circuit of the incubator, explained the tasks of each of its main parts. How to enter the values digitally and treat them to obtain heat, humidity and pressure in the form of actual values. So, we are now implementing a simple practical application that includes entering the following values through the input unit:

- Temperature: 39 ° C
- Humidity: 80%

The project outputs are as shown in the table 5.1 below:

Table (5.1): Project Test.

Time	Humidity	Temperature	Fan	Heater	Humidifire
0	40	35	OFF	ON	ON
3	45	36	OFF	ON	ON
7	55	38	OFF	ON	ON
10	70	40	ON	OFF	ON
20	80	39	OFF	OFF	OFF

5.6 Conditions for Installation:

The following instructions should be taking into consideration when installing the incubator:

1. You should avoid placing inflammable materials inside the device and make sure of the effect of this heat on the materials.
2. Fumes and dust must be avoided inside and around the device to ensure work.
3. Be careful while the device is operating at high temperatures.
4. The feed outlet must be removed before removing the device cover when necessary.
5. The device must be fed with a voltage of 12 volts, and make sure to recharge the battery.
6. Before operating the device, you must make sure of the correct installation of the temperature sensor in a position because it can slip during vibration.
7. The device must be placed in an external medium at a temperature of 5 to 31 degrees Celsius so that the room is air-conditioned in order to avoid any rise in temperature.
8. The doctor must wear sterile gloves while taking the sample.
9. The addition and sterilization of the laboratory should be maintained by considering any sample inside the laboratory as a germ sample in order to avoid diseases.

6

Chapter Six

Challenges and Conclusions

6.1 Introduction.

6.2 Challenges.

6.3 Conclusions.

6.4 Recommendations.

6.1 Introduction:

In this chapter, all the problems that we faced during the completion of the project will be summarized. A general summary, achievements, goals and difficulties of the project will also have expressed, in addition recommendations and future plans for development and improvement of the project will summarized to enhance the role of the project in the market and laboratory use.

6.2 Challenges:

Each success is crowned with many challenges, and the amount of success in a particular project highlights the ability to overcome these challenges, even if it is in a way close to success, and among the most prominent challenges that we faced to get our project to this level of success is:

1. One of the most important challenges that we faced is achieving one of our most important goals is building a mobile incubator, so we faced the problem of providing the appropriate temperature within the range (35-40) inside the incubator. Depends on battery feeding. It was difficult to get a heater that would provide the required temperature with DC feeding. Since the majority of current heaters are based on AC power, the heater was ordered online from foreign countries, but it did not provide the required temperature range as the highest value available was 35 degrees.

   Then the use of tungsten bulbs was considered, and after the experiment it did not reach the required temperature, as it only gave a maximum of 37 degrees, so all experiments here failed. After a lengthy research and experiment, the Brick bulbs for cars which adopt DC feeding and provide the required heat within the range are used, thus the temperature problem has been solved.

2. Another problem the team faced is running out of battery stock in a short time after one 12-volt battery was enough for the project, but the bulbs that were used as heater needed a high current, the problem was overcome by using two 12 volt batteries and connecting them in parallel to provide enough current for the project with a number Suitable working hours.

3. Due to the Covid-19 epidemic and the presence of some closures, some supplier companies were apologized for sending a piece of the Ultrasonic nebulizer humidifier because of its high advantages, which includes an internal fan that distributes humidified steam throughout the incubator. To overcome this problem, the team used a humidifier that did not have a fan with specifications close to Ultrasonic nebulizer humidifier. This humidifies did the same job.

6.3 Conclusions:

The success of the incubator depends on the effective implementation of the services provided by the incubator to the clients. Even though all the listed factors are important, their role in influencing the success of the incubator depends on the ownership, nature of the incubator, objectives, age, number of incubates, number of incubates graduated.

The incubators have recently emerged as an important role in the laboratory environment for the reproduction and growth of microorganisms and then providing them with heat humidity and suitable condition for their reproduction and growth. The laboratory incubator has achieved great results in its use in the laboratory and has been widely resonated in the laboratory.

Praise be to God who appreciated us to achieve the goals of our project by building a portable laboratory incubator that is operated in various places without the need to connect it to electricity, with a charger that can be charged during the period of non-use, and to achieve the ability to control the temperature value within a certain range and control the required value of humidity Through the input unit and get the desired results. praise be to God almighty who succeeded in presenting this research and here are the last drops in the research process the research was talking about the laboratory incubator we have made every effort to get the research out in this way.

6.4 Recommendations:

All projects and despite the success they have achieved, there is always opportunities for development and improvement, the public and users interest were taken in consideration, some weaknesses of the project were discussed so that researchers in the future can work on and develop, to build a portable bacterial incubator ready for use in laboratories:

1. One of the important recommendations for the development of the project is to replace the bulbs with a heater that works on DC and gives the necessary heat, as well as replacing the normal humidifier used with an Ultrasonic nebulizer humidifier, to obtain higher efficiency inside the incubator, as well as better results for the samples.

2. To further develop the incubator and make it ready for laboratory use, all parts inside the incubator installation can be developed if a portable generator is provided inside the incubator, and then the fan, heater and humidifier can be used with high efficiency, thus achieving the highest results from the portable laboratory incubator.

3. One of the developments that can be made in the bacterial incubator is to make it connected via the Internet, so the user can adjust the variables and monitor the work of the system remotely.

4. Developing the incubator and making it lighter in weight than it is, to serve the purpose of the portable incubator more.

5. To make the incubator more advanced, it is possible to replace the input unit from the keyboard to the touch screen.

6. Developing an alarm system to display a message about the type of defect that occurred, in addition to one of the possible solutions.

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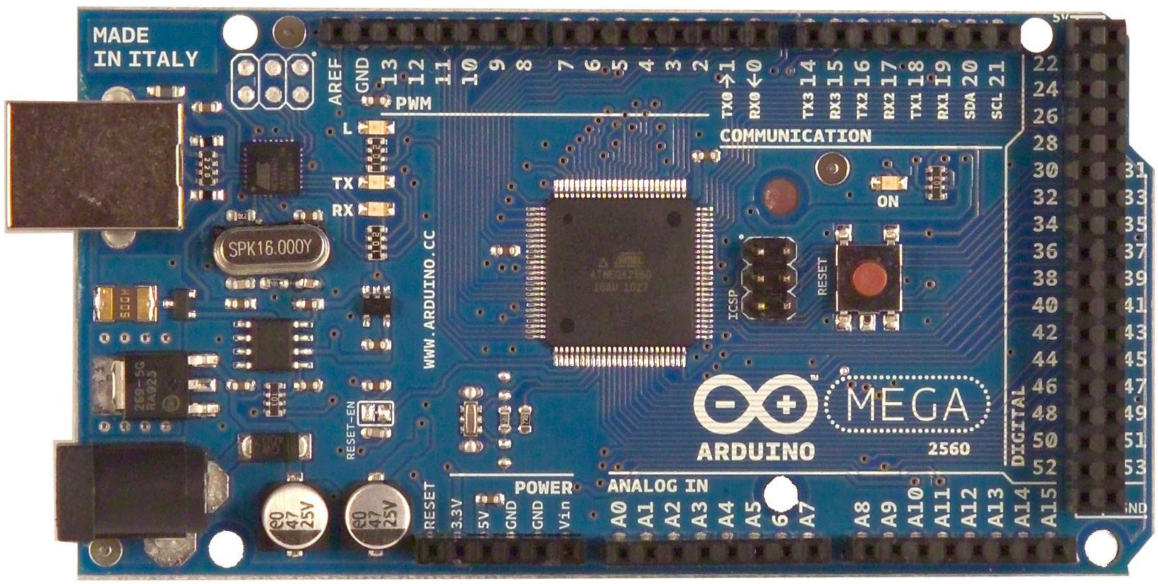
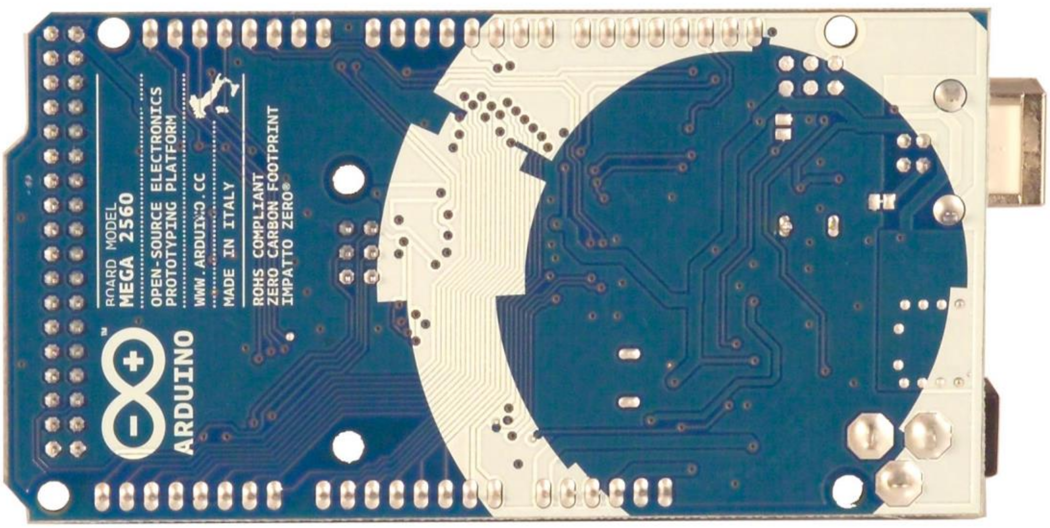
Appendix A

Arduino Mega

Arduino Mega 2560 Datasheet





Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a ACto-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Schematic & Reference Design

EAGLE files: arduino-mega2560-reference-design.zip

Schematic: arduino-mega2560-schematic.pdf

Summary

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

Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-toserial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode() , digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS).** These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- **I_2C: 20 (SDA) and 21 (SCL).** Support I_2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I_2C pins on the Duemilanove or Diecimila.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Mega2560's digital pins.

The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation on the Wiring website for details. For SPI communication, use the SPI library.

Programming

The Arduino Mega can be programmed with the Arduino software (download). For details, see the reference and tutorials.

The ATmega2560 on the Arduino Mega comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (InCircuit Serial Programming) header; see these instructions for details.

Automatic (Software) Reset

Rather then requiring a physical press of the reset button before an upload, the Arduino Mega2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload. This setup has other implications. When the Mega2560 is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Mega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Mega2560 contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Mega2560 has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics and Shield

Compatibility

The maximum length and width of the Mega2560 PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

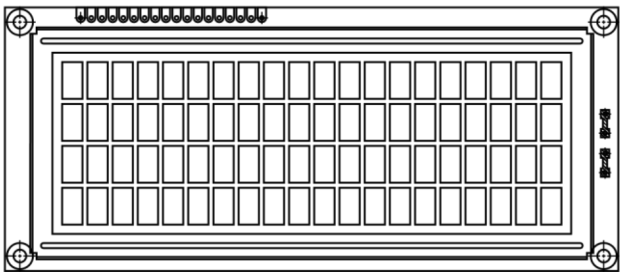
The Mega2560 is designed to be compatible with most shields designed for the Uno, Diecimila or Duemilanove. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the Mega2560 and Duemilanove / Diecimila. *Please note that I_2C is not located on the same pins on the Mega (20 and 21) as the Duemilanove / Diecimila (analog inputs 4 and 5).*

Appendix B

LCD 20 x 4

Vishay

20 x 4 Character LCD



FEATURES

- Type: Character
- Display format: 20 x 4 characters
- Built-in controller: ST 7066 (or equivalent)
- Duty cycle: 1/16
- 5 x 8 dots includes cursor
- + 5 V power supply (also available for + 3 V)
- LED can be driven by pin 1, pin 2, pin 15, pin 16 or A and K• N.V. optional for + 3 V power supply
- Material categorization: For definitions of compliancеplease see www.vishay.com/doc?99912

MECHANICAL DATA		
ITEM	**STANDARD VALUE**	**UNIT**
Module Dimension	146.0 x 62.5	mm
Viewing Area	123.5 x 43.0	
Dot Size	0.92 x 1.10	
Dot Pitch	0.98 x 1.16	
Mounting Hole	139.0 x 55.5	
Character Size	4.84 x 9.22	

ABSOLUTE MAXIMUM RATINGS					
ITEM	**SYMBOL**	**STANDARD VALUE**			**UNIT**
		MIN.	**TYP.**	**MAX.**	
Power Supply	V_{DD} to V_{SS}	- 0.3	-	7.0	V
Input Voltage	V_I	- 0.3	-	V_{DD}	

Note

- V_{SS} = 0 V, V_{DD} = 5.0 V

ELECTRICAL CHARACTERISTICS						
ITEM	**SYMBOL**	**CONDITION**	**STANDARD VA UE**			**UNIT**
			MIN.	**TYP.**	**MAX.**	
Input Voltage	V_{DD}	V_{DD} = + 5 V	4.7	5.0	5.3	V
		V_{DD} = + 3 V	2.7	3.0	5.3	
Supply Current	I_{DD}	V_{DD} = + 5 V	-	8.0	10.0	mA
Recommended LC Driving Voltage for Normal Temperature Version Module	V_{DD} to V_0	- 20 °C	5.0	5.1	5.7	V
		0 °C	4.6	4.8	5.2	
		25 °C	4.1	4.5	4.7	
		50 °C	3.9	4.2	4.5	
		70 °C	3.7	3.9	4.3	
LED Forward Voltage	V_F	25 °C	-	4.2	4.6	V

LED Forward Current	IF	25 °C	-	540	1080	mA
EL Power Supply Current	IEL	V_{EL} = 110 V_{AC}, 400 Hz	-	-	5.0	mA

OPTION 5

PROCESS COLOR						BACKLIGHT			
TN	**STN Gray**	**STN Yellow**	**STN Blue**	**FSTN B&W**	**STN Color**	**None**	**LED**	**EL**	**CCFL**
x	x	x	x	x		x	x	x	

For detailed information, please see the “Product Numbering System” document.

DISPLAY CHARACTER ADDRESS CODE

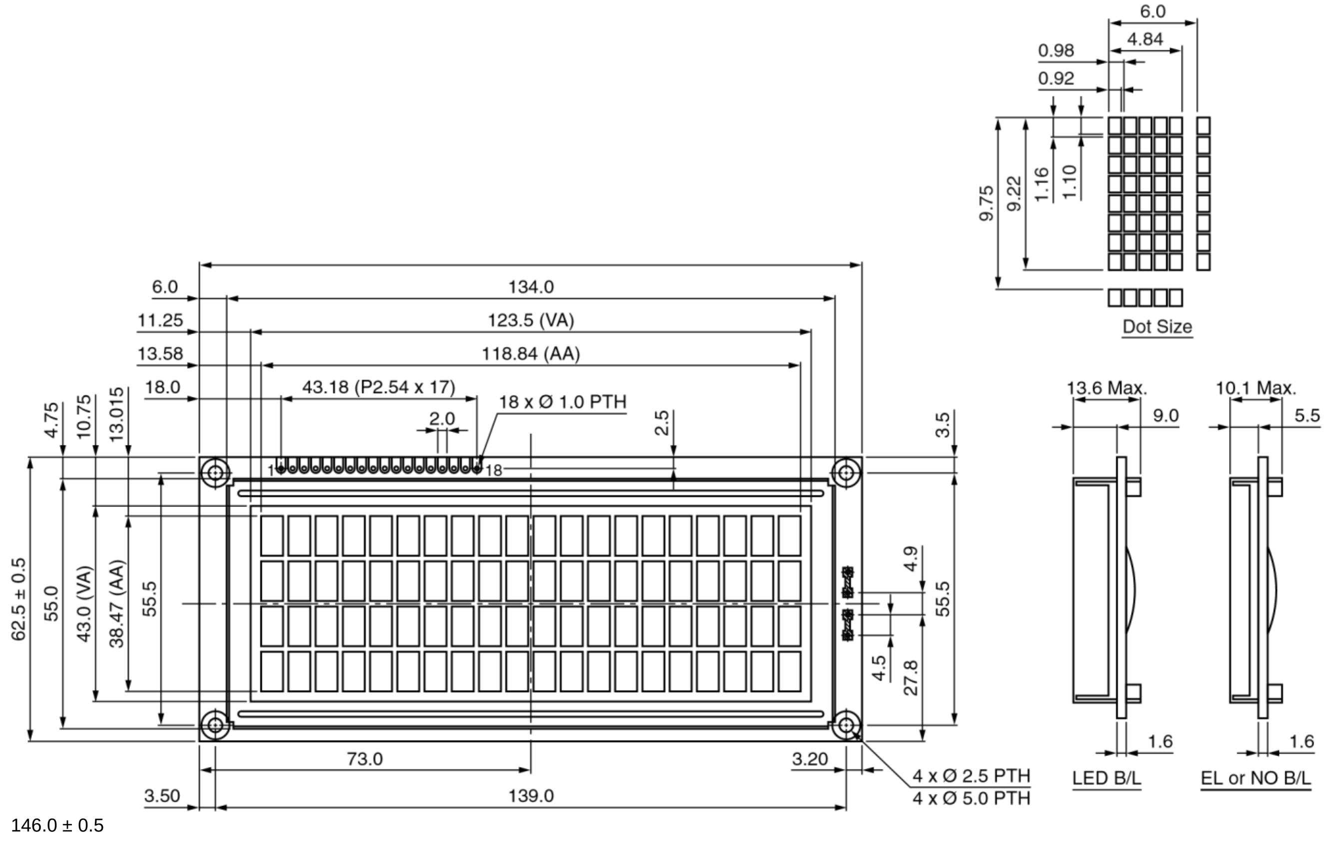
Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
DD RAM Address	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	10	11	12	13
DD RAM Address	40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F	50	51	52	53
DD RAM Address	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F	20	21	22	23	24	25	26	27
DD RAM Address	54	55	56	57	58	59	5A	5B	5C	5D	5E	5F	60	61	62	63	64	65	66	67

INTERFACE PIN FUNCTION

PIN NO.	SYMBOL	FUNCTION
1	VSS	Ground
2	VDD	+ 3 V or + 5 V
3	V_0	Contrast adjustment
4	RS	H/L register select signal
5	R/W	H/L read/write signal
6	E	H □ L enable signal
7	DB0	H/L data bus line
8	DB1	H/L data bus line
9	DB2	H/L data bus line
10	DB3	H/L data bus line
11	DB4	H/L data bus line
12	DB5	H/L data bus line
13	DB6	H/L data bus line

14	DB7	H/L data bus line
15	A	Power supply for LED (4.2 V)
16	K	Power supply for B/L (0 V)
17	NC/V_{EE}	NC or negative voltage output
18	NC	NC connection

DIMENSIONS in millimeters

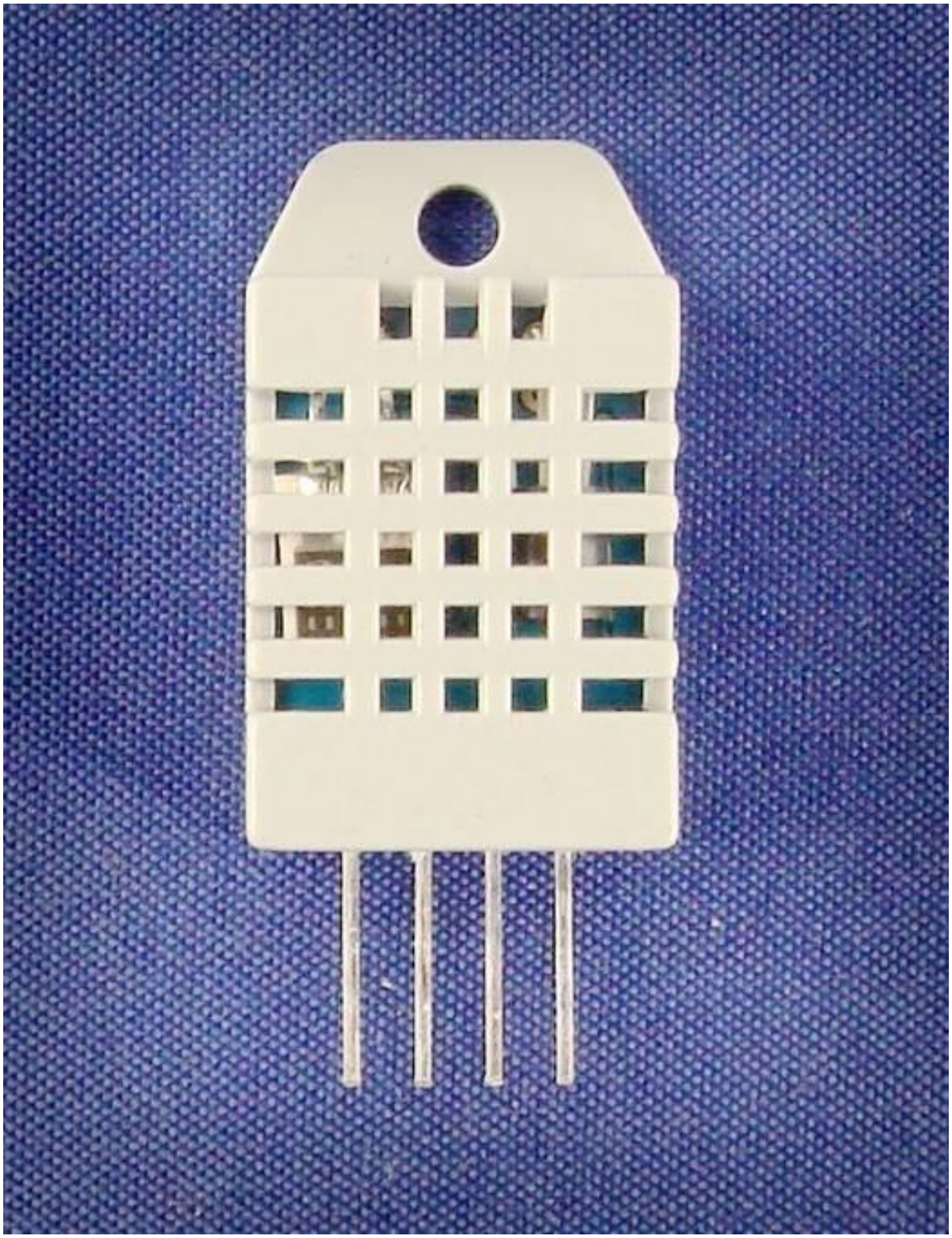


Legal Disclaimer Notice

Appendix C

DHT 22

Digital-output relative humidity & temperature sensor/module DHT22 (DHT22 also named as AM2302)



Capacitive-type humidity and temperature module/sensor

1. Feature & Application:

* Full range temperature compensated * Relative humidity and temperature measurement
* Calibrated digital signal *Outstanding long-term stability *Extra components not needed
* Long transmission distance * Low power consumption *4 pins packaged and fully interchangeable

2. Description:

DHT22 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability.Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.

Small size & low consumption & long transmission distance(20m) enable DHT22 to be suited in all kinds of harsh application occasions.

Single-row packaged with four pins, making the connection very convenient.

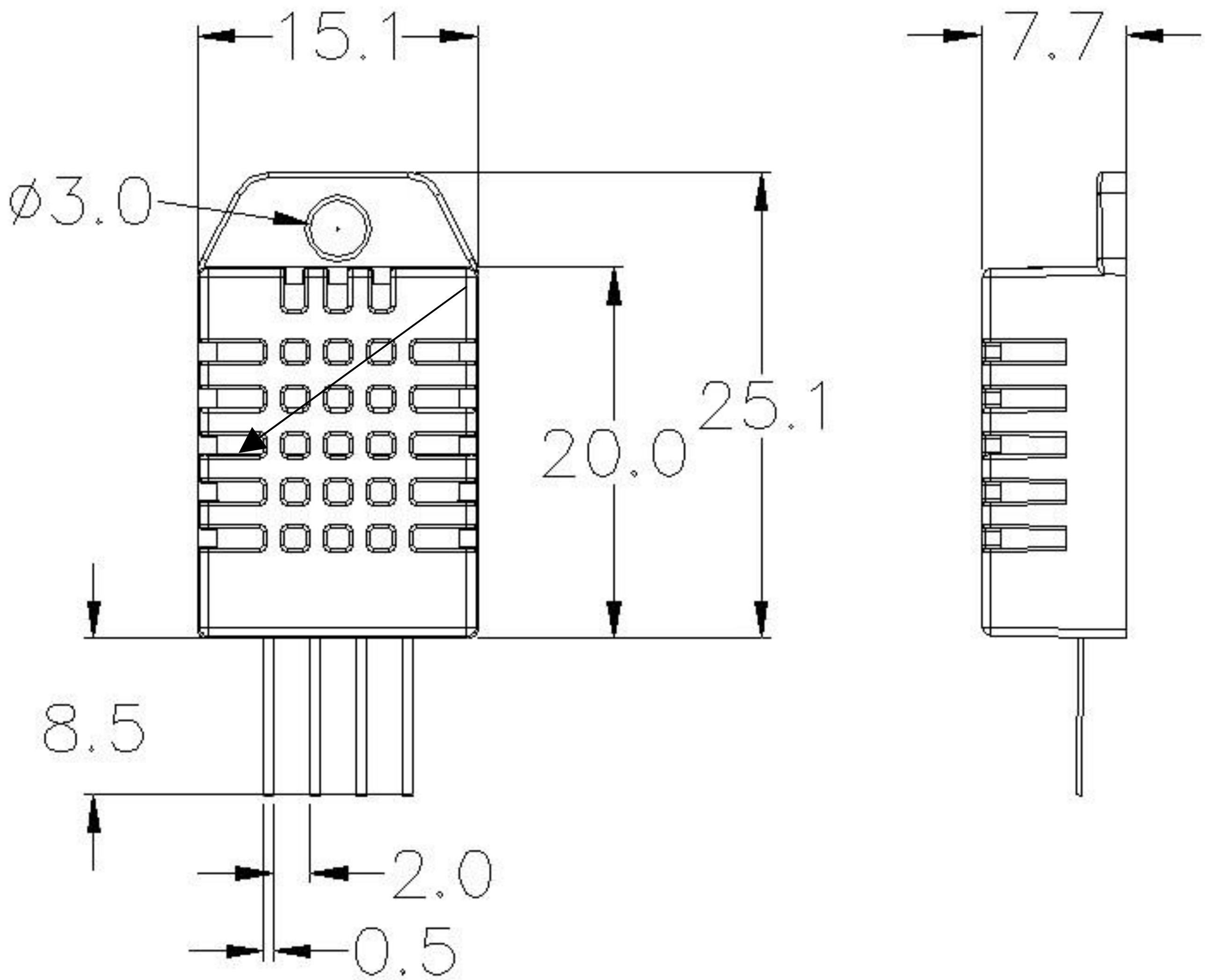
3. Technical Specification:

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

4. Dimensions: (unit----mm)

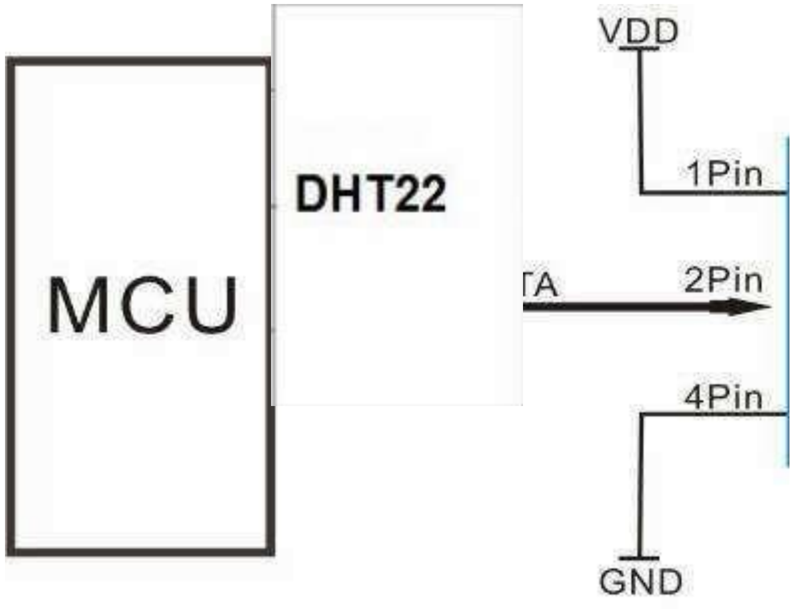
1) Small size dimensions: (unit----mm)

Pin sequence number: 1 2 3 4 (from left to right direction).



Pin	Function
1	VDD----power supply
2	DATA--signal
3	NULL
4	GND

5. Electrical connection diagram:



3Pin---NC, AM2302 is another name for DHT22

6. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-6V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

Single-bus data is used for communication between MCU and DHT22, it costs 5mS for single time communication.

Data is comprised of integral and decimal part, the following is the formula for data.

DHT22 send out higher data bit firstly!

DATA=8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data+8 bit check-sum If the data transmission is right, check-sum should be the last 8 bit of "8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data".

When MCU send start signal, DHT22 change from low-power-consumption-mode to running-mode. When MCU finishs sending the start signal, DHT22 will send response signal of 40-bit data that reflect the relative humidity and temperature information to MCU. Without start signal from MCU, DHT22 will not give response signal to MCU. One start signal for one time's response data that reflect the relative

Appendix D

MH-Z19B

Intelligent Infrared CO2 Module

(Model: MH-Z19B)

User's Manual

(Version: 1.0)

Valid from: 2016.01.21

Zhengzhou Winsen Electronics Technology Co., Ltd

ISO9001 certificated company

Statement

Thanks for purchasing our product. In order to let customers use it better and reduce the faults caused by misuse, please read the manual carefully and operate it correctly in accordance with the instructions. If users disobey the terms or remove, disassemble, change the components inside of the sensor, we shall not be responsible for the loss.

The specific such as color, appearance, sizes &etc., please in kind prevail.

We are devoting ourselves to products development and technical innovation, so we reserve the right to improve the products without notice. Please confirm it is the valid version before using this manual. At the same time, users’ comments on optimized using way are welcome.

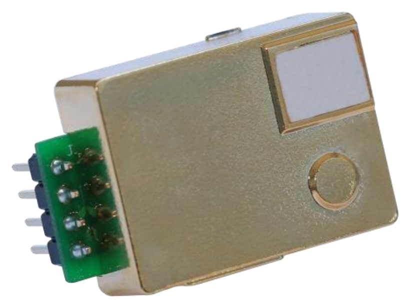
Please keep the manual properly, in order to get help if you have questions during the usage in the future.

Zhengzhou Winsen Electronics Technology CO., LTD.

MH-Z19B NDIR CO2 Module

1. Profile

MH-Z19B NDIR infrared gas module is a common type, small size sensor, using non-dispersive infrared (NDIR) principle to detect the existence of CO 2 in the air, with good selectivity, non-oxygen dependent and long life. Built-in temperature compensation; and it has UART output and PWM output. It is developed by the tight integration of mature infrared absorbing gas detection technology, precision optical circuit design and superior circuit design.



2. Applications

MH-Z19B NDIR infrared gas module is widely used in

* HVAC refrigeration

*Indoor air quality monitoring.

*Smart home appliances

*School

*Air cleaner

3. Main Functions and Features

High sensitivity, high resolution
Low power consumption

Output modes: UART and PWM wave

Temperature compensation, excellent linear output

Good stability
Long lifespan

Anti -water vapor interference
No poisoning

4. Technical Parameters and Structure

Product Model	MH-Z19B
Target Gas	CO_2
Working voltage	4.5 ~ 5.5 V DC
Average current	< 60mA (@5V)
Peak current	150mA (@5V)
Interface level	3.3 V(**Compatible** with 5V)
Measuring range	refer to Table 2
Output signal	UART(TTL interface level 3.3V)
	PWM
	DAC(default 0.4-2V)
Preheat time	3 min
Response Time	$T_{90} < 120$ s
Working temperature	0 ~ 50 ℃
Working humidity	0 ~ 90% RH (No condensation)
Dimension	33 mm×20 mm×9 mm (L×W×H)
Weight	5 g
Lifespan	> 5 years

Table 1 Main Technical Parameters

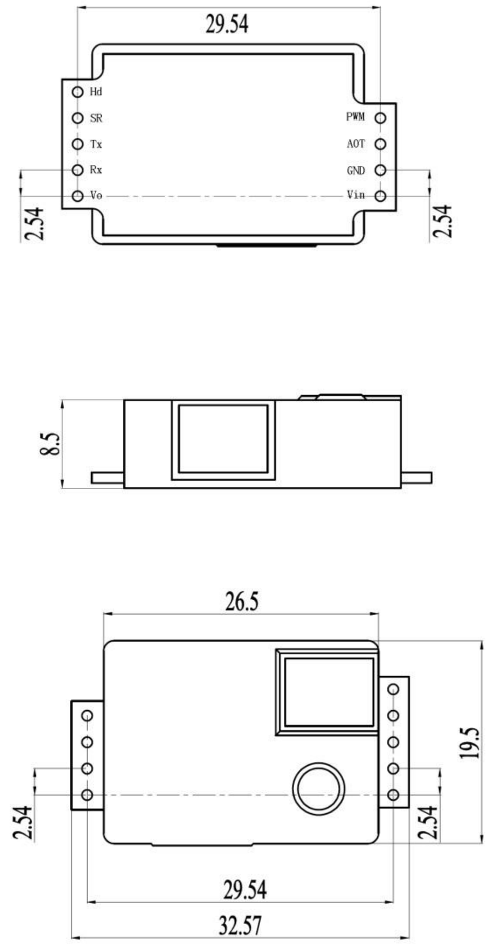
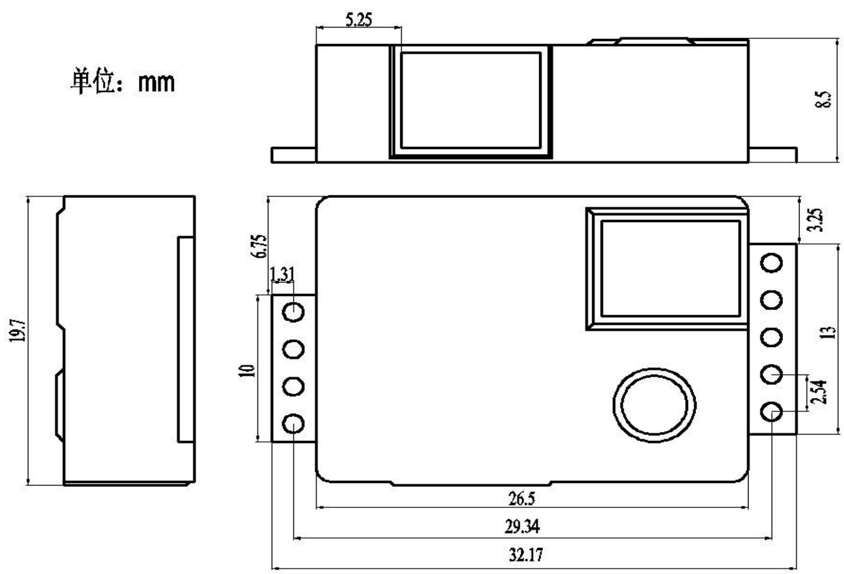


Figure 1 Structure

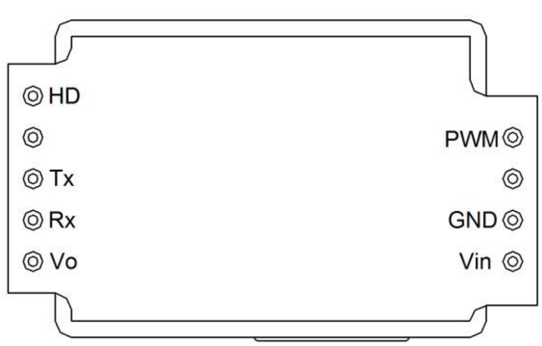
Target Gas	Formula	Measuring Range	Accuracy	Remark
Carbon Dioxide (CO2)	CO_2	0～2000 ppm	± (50ppm+3% reading value)	Temperature compensation
		0～5000 ppm		Temperature compensation

Table 2 Measuring Range and Accuracy

5. Product Dimensions



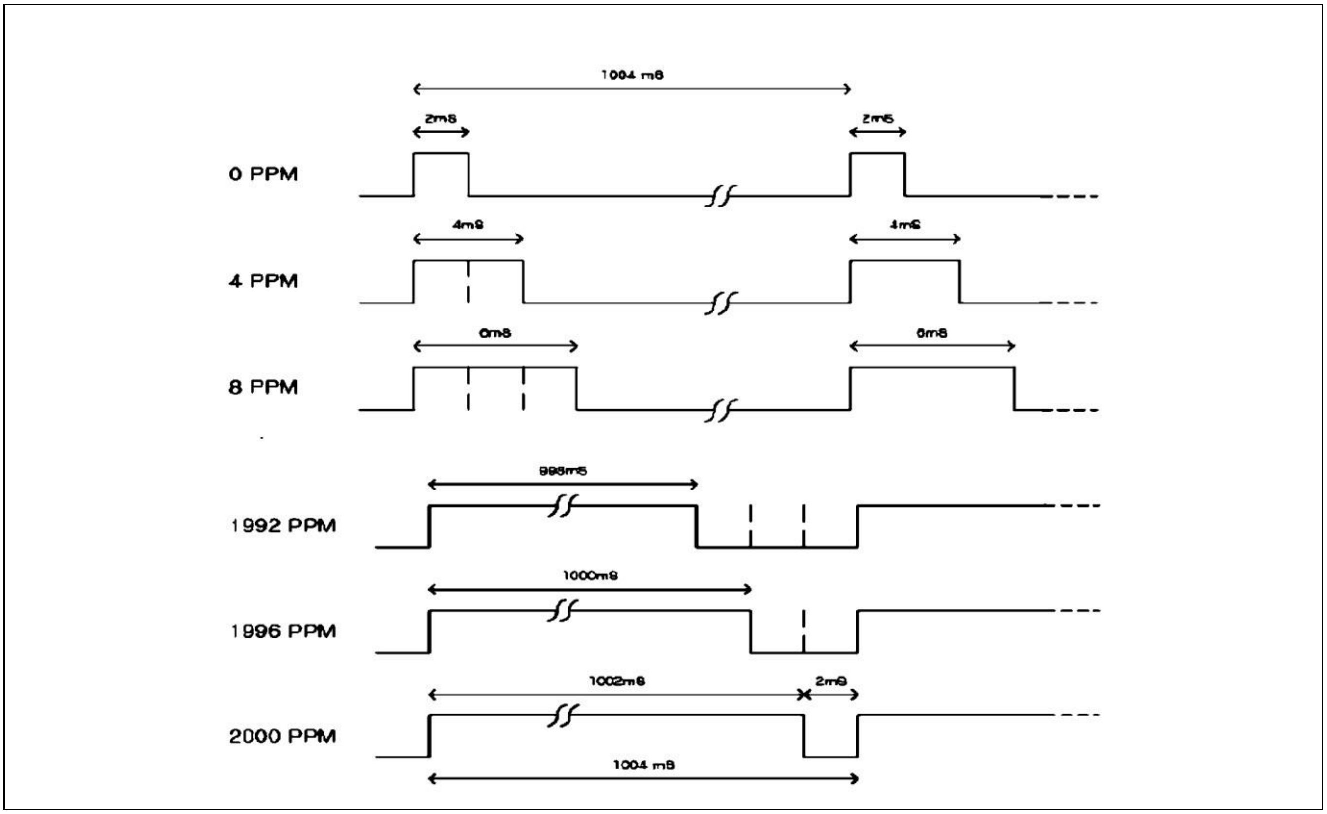
6. Pins



Pin	Definition
Vin	Vin
GND	GND
Vo	Analog output(0.4～2 V)or (0~2.5V)
PWM	PWM
HD	HD(zero calibration， low level lasting for over 7s under low level is effective)
Rx	UART(RXD)TTL Level data input
Tx	UART(TXD)TTL Level data output

7. Output

PWM output	
Take 0~2000ppm for e.g	
CO_2 range	0～2000ppm
cycle	1004ms±5%
Cycle start high level output	2ms(theoretical value)
The middle cycle	1000ms±5%
cycle end low level output	2ms(theoretical value)
CO_2 level：C_{ppm}=2000×(T_H-2ms)/(T_H+T_L-4ms)	
$C_{ppm:}$ CO2 level which calculated by PWM output T_H: high level output time during cycle T_L low level output time during cycle	



UART OUTPUT Hardware

Connect sensor pin Vin-GND-RXD-TXD with 5V-GND-TXD-RXD.（Customers must use TTL level. RS232 level needs **conversion**）。

Software

General Settings

Baud Rate	9600
Data Bits	8
Stop Bits:	1
Parity(check bits):	0(NO)

Commands	
0x86	Read CO_2 concentration
0x87	Calibrate Zero Point (ZERO)
0x88	Calibrate Span Point (SPAN)
0x79	ON/OFF Auto Calibration
0x99	Detection range setting

0x86- Read CO2 concentration

Request

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Start Byte	Sensor #	Command	-	-	-	-	-	Checksum
0xFF	0x01	0x86	0x00	0x00	0x00	0x00	0x00	0x79

Response

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Start Byte	Sensor #	Concentration (High Byte)	Concentration (Low Byte)	-	-	-	-	Checksum
0xFF	0x86	HIGH	LOW	-	-	-	-	Checksum

CO2 concentration = HIGH * 256 + LOW

0x87-ZERO POINT CALIBRATION

Request

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Start Byte	Sensor #	Command	-	-	-	-	-	Checksum
0xFF	0x01	0x87	0x00	0x00	0x00	0x00	0x00	校验和

NO RESPONSE

NOTE：ZERO POINT is 400PPM, PLS MAKE SURE THE SENSOR HAD BEEN WORKED UNDER 400PPM FOR OVER 20MINUTES

0x88- SPAN POINT CALIBRATION								
Request								
Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Start Byte	Sensor #	Command	Span (High Byte)	Span (low Byte)	-	-	-	Checksum
0xFF	0x01	0x88	HIGH	LOW	0x00	0x00	0x00	Checksum
No response E.g.: SPAN is 2000ppm， HIGH = 2000 / 256 ；LOW = 2000 % 256 Note: Pls do ZERO calibration before span calibration Please make sure the sensor worked under a certain level co2 for over 20 minutes. Suggest using 2000ppm as span, at least 1000ppm								

0x79- ABC logic on/off								
Request								
Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Start Byte	Sensor #	Command	-	-	-	-	-	Checksum
0xFF	0x01	0x79	0xA0/0x00	0x00	0x00	0x00	0x00	Checksum
No response Note: Byte3 is **0xA0,ABC on; Byte3 is 0x00, ABC off** **All Winsen sensor with ABC logic on before delivery if no special reques** :.								

0x99- Sensor detection range setting								
Request								
Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Start Byte	Sensor #	Command	Detect range (high Byte)	Detect range (low Byte)	-	-	-	Checksum
0xFF	0x01	0x99	HIGH	LOW	0x00	0x00	0x00	Checksum

No response **Note: Detection range is 2000 or 5000ppm** **Detection range high byte=detection range/256** **Detection range low byte=detection range/% 256**

Checksum								
Checksum = (NOT (Byte1+Byte2+Byte3+Byte4+Byte5+Byte6+Byte7))+1								
Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Start Byte	Sensor #	Command	-	-	-	-	-	Checksum
0xFF	0x01	0x86	0x00	0x00	0x00	0x00	0x00	Checksum
Calculating Checksum ： 1、 0x01 + 0x86 + 0x00 + 0x00 + 0x00 + 0x00 + 0x00 = 0x87 2、 NOT：0xFF - 0x87 = 0x78								
3、NOT+1：0x78 + 0x01 = 0x79								
C language								

```
char getCheckSum(char *packet)
{
        char i, checksum;
        for( i = 1; i < 8; i++)
        {
              checksum += packet[i];
        }
        checksum = 0xff – checksum;
        checksum += 1;
    return checksum;
}
```

8.ZERO point calibration

Three methods:

A: Manual calibration

Sensor HD pin with low level(0V) and lasting for over 7s(under 400ppm for at least 20 minutes)

B:Command calibration(see above)

C: ABC logic function

Automatic Baseline Correction (ABC logic function)

ABC logic function refers to that sensor itself do zero point judgment and automatic calibration procedure intelligently after a continuous operation period. The automatic calibration cycle is every 24 hours after powered on. The zero point of automatic calibration is 400ppm. From July 2015, the default setting is with built-in automatic calibration function if no special request.

This function is usually suitable for indoor air quality monitor such as offices, schools and homes, not suitable for greenhouse, farm and refrigeratory where this function should be off. Please do zero calibration timely, such as manual or commend calibration.

9. Notes

9.1 Please avoid the pressure of its gilded plastic chamber from any direction, during welding, installation, and use.

9.2 When placed in small space, the space should be well ventilated, especially for diffusion window.

9.3 The sensor should be away from heat, and avoid direct sunlight or other heat radiation.

9.4 Do not use the sensor in the high dusty environment for long time.

9.5 To ensure the normal work, the power supply must be among 4.5V~5.5V DC rang, the power current must be not less than 150mA. Out of this range, it will result in the failure of the sensor. (The concentration output is low, or the sensor can not work normally.)

8.6 During the zero point calibration procedure by manual, the sensor must work in stable gas environment (400ppm) for over 20 minutes.

Connect the HD pin to low level (0V) for over 7 seconds.

Zhengzhou Winsen Electronics Technology Co., Ltd
Add: No.299, Jinsuo Road, National Hi-Tech Zone, Zhengzhou 450001 China
Tel: +86-371-67169097/67169670
Fax: +86-371-60932988
E-mail: sales@winsensor.com
Website: www.winsen-sensor.com