My Smart Garden

Automated Growing Pot

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Student Declaration

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Acknowledgements

I'd like to present my gratitude for the will and patience to complete the project to the extent that one could think it exceeded expectations. It has been a great challenge for a professional carrying a settled life to study and come up with product of a such a scale as a part-time student. I'd like to acknowledge my family who has been supporting me through the whole process. I truly appreciate my project supervisor Mary Camden for her guidance and honest feedback as well as the administration of the Engineering Department at Atlantic Technological University in Sligo for providing the knowledge I needed to build this project. I'd like to thank my external tutors in Digital Signal Processing, Data Communications, Embedded Systems, Systems Design Integration and Testing, and Mobile Apps Development courses which contributed with their knowledge and study material, helping to understand electronics and computing to its extent.

Abstract

In the modern world of automation and wireless communication, we can push the boundaries of innovation to a point where an individual is comfortable and prosperous with technology that serves the greater good of humans. The project aims to fulfil the need for automated indoor growing, making anybody a better gardener, who has limited access to green space and time to alter the plant's growth pattern, remotely via smart device at users' convenience. Nowadays, using a smartphone to handle and operate a device is much more common than it once was. In general, smart devices become our everyday companions, allowing for close-range Bluetooth, wi-fi, or more distant 4G communication to interact with appliances found in households.

The idea is to produce a sophisticated system with software and hardware, sensing the inputs, and complementing outputs accordingly, behaving appropriately to guarantee the right and regular flow of supplies for a plant to thrive. To deliver the final project in accordance with its idea, the goal is for the student to acquire skills and knowledge in a variety of settings.

In conclusion, the implementation of an automatic growing system can also leave space for future improvement in situations where the present traditional planting may become constrained. One can anticipate that autonomous indoor cultivation systems will spread among home products that feature IoT (Internet of Things) integration in the near future. It may be a part of components interlinked with smart house control systems, too.

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Chapter 1 - Introduction

In this chapter is included a detailed introduction, with where the idea came from and the general concept theory of operation

1.1 Introduction

This report contains research on how to automate a small-scale indoor growing pot and use this concept to grow desired plants indoors with the least human input. Application of the device can vary from house plants to herbs for garnishing the meals, or to vegetables to improve daily diet.

My Smart Garden is an automated indoor growing pot, intended to make anybody a better gardener, who has limited access to green space and time to alter the grove pattern. The importance of the engineering proclamation is great responsibility towards the general public, providing a healthier and safer environment to live in. Therefore, in this controlled plant growing station, the automation applies the water to the plant as per a need. The automated watering system operates on computed decisions from precisely obtained data, resulting in an accurate cut-off water point, which makes it a more effective system. Unlike conventional outdoor gardening requires favourable weather conditions, the automated growing pot utilises the advantage of technology to maintain the ideal growing conditions instead. The study led to the careful selection of sensors to suit technical and ethical concerns to maintain a low impact to financial and environmental aspects of society.

For presentation purposes the system itself is designed to house and maintain 3+ medium-sized plants. The Herb plants are chosen for the research because they are easy to maintain. Compared to other plant species, herbs grow faster than others. According to Charlotte Glen, Ed.D., mentioned in the article [1] “Perennial herbs such as oregano, thyme, and rosemary need less water than vegetables and fruits.”

Methodically, the project imposes challenges in comprehending the involved coding, the brainstorming in product design, and also the ability to test and troubleshoot issues arising while engineering the project. Due to the uniqueness of the concept, the challenge is at a high level, as there are no particular procedures to follow in such cases. Therefore, achieving the defined system functions properly is a milestone in the subject. For instance, the analytical skills required using technology to solve engineering design problems, also as the developer skills are being learnt in the whole process. It is intended to implement technologies to keep track of the parameters shown below:

- Soil moisture
- Water tank level
- Air temperature
- Air humidity
- Lighting

Recording such values and their analysis can contribute to decision-making in order to achieve a greater harvest and promote self-sustainability, which can be implemented in the program code. According to Patrick Hearn [2], "If you're following the growing steps, you should see anywhere from 3.5 to 4 pounds of produce per month"

1.2 Background

In the project, the innovation is not only a tackle but an intention to deal with a daily struggle through the application of water to plants to maintain their healthy growth. Developing a new useful product, such as an automated plant watering system should promote a daily routine with ease and introduce innovation in our everyday life. The product is intended to perform the act of plant watering automatically, putting off the need of every avid gardening enthusiast to water their plants regularly.

The system is proposed on one basic problem statement - to innovate the daunting routine of gardening and protect the environment by preventing the rounding off the water, plus reducing the CO2 emissions in conjunction with the need to travel for daily sources of green food supplies. Paul Allen, BBC says [3] "For example, if you regularly drive to large, out-of-town supermarkets, the miles add up. In fact, each of us travels around 135 miles a year in the car to do our food shopping. (Given that over 50 per cent of the population doesn't own a car, it's closer to 270 miles.)"

According to research and my knowledge I am aware of the climate change and carbon footprint each individual leaves behind. For that reason, it has been decided to develop a grooving pot which sustains the growth of the plants precisely according to data received from sensors. Implementation of engineering in such a methodology can improve our daily diet alongside sustaining the environment.

1.3 Concept Features

The device measures the surrounding habitat of an indoor plant without having the user physically interact with it. Hence, the fertile environment is managed by the microcontroller, which is the heart of the whole complex system. The microcontroller is called ATmega328PU, it is the integrated circuits chip, which can be programmed with instructions to read and process input signals from soil moisture, temperature, humidity, water level, and light intensity sensors and then power on or off outputs, connected to the water pump, cooling fan, growing LED.

Collected data is displayed on a 16x2 liquid crystal display(LCD) and simultaneously transmitted to a smart device. Communication with an Android smart device is managed through a Bluetooth circuit module and based on the instructions received from the user via an application installed on the smart device, the threshold values are set. Once desired growing profile is selected via a user-friendly interface, the appliance is fully automated.

If the system recognizes that the Soil moisture level is not optimal, it will automatically compensate by adding more water to the soil. The device is intended to be placed indoors by the window to thrive from natural sunlight, but in cases of insufficient lighting conditions, the appliance is equipped with 3W growing LEDs, which are triggered accordingly to light intensity, sensed with a light detective resistor. In addition, the microcontroller is programmed a way that in winter time LEDs turn on in the early morning and late evening, to satisfy light deficiency. When temperature and humidity increase above ambient level in the environment where the automated growing pot is placed, the fan turns one to maintain the pre-set air temperature. The temperature range is chosen accordingly to the geographic location of the device application to suit the climate in a room placed. The fan's revelation per minute(RPM) increases exponentially according to the temperature readings, utilizing the pulse width modulation (PWM) function of the microcontroller.

Chapter 2 - Project Design and Methodology

In this chapter, the methodology is explained on how the hardware is implemented and its theory of operation. As well as how the concept is turned into a fully functional device, capable to operate on its own, and maintaining healthy growth of the plants.

2.1. Approach and System Overview

The initial approach in the project development, involved the functionality test for each module individually, including the coding. The program code prototype Version 1 is then created containing the code of each module and uploaded to the Arduino developer board linked with the stock modules by jumper wires. Certain modules were developed in-house to facilitate the design. These custom-made modules are as follows: LED Array for indicating water level, Power on/off and fan speed control for the re-used PC power supply. The overall system setup is shown below in Figure 1. In the high-level design with the aid of a block diagram. Each module is broken down in relation to technical specifications in subsequent chapter 3.

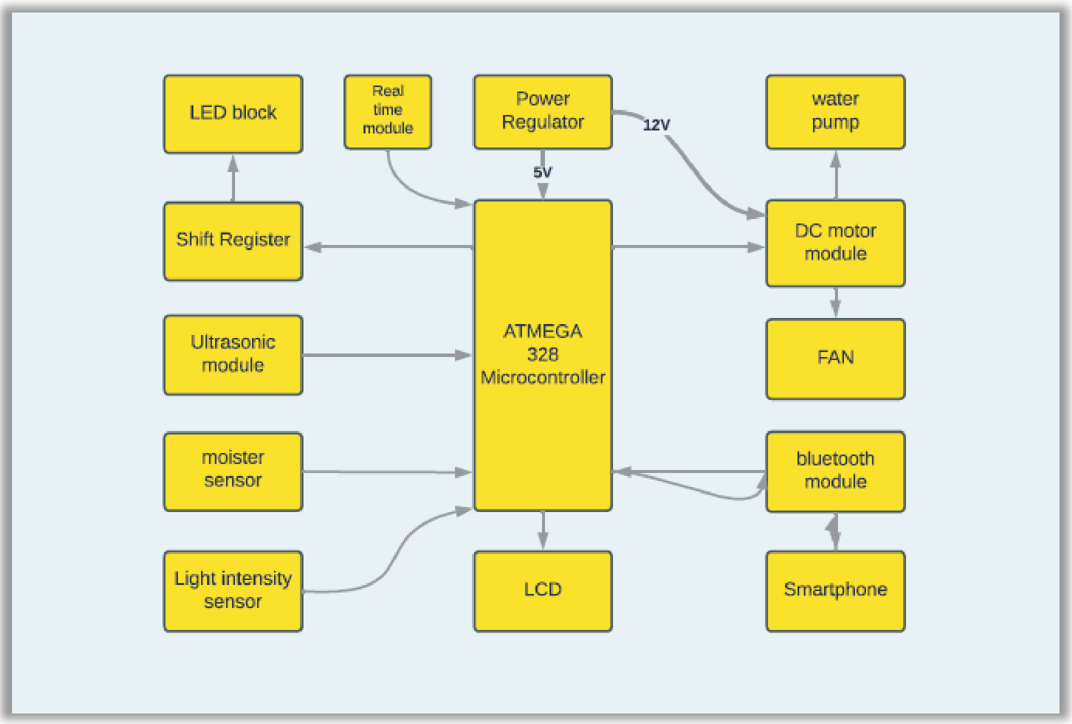

Figure 1. The high-level design of the hardware setup

2.2. Power Distribution Overview

With the aim to integrate all the modules to a single PCB board, the project prototype is re-arranged with solely the Atmega328 microcontroller and external oscillator – 16 MHz Crystal linked with all other modules as in the initial set-up to prove a functionality including power management. A PC 12V Power supply is anticipated to be used with Voltage regulators which are providing 5V to the microcontroller, L298N DC motor driver, sensors and communication components. As the whole concept involves multiple modules and general power consumption is estimated to be more than 2 Amps. As per the datasheet, 2 Amps is at the limit of a single voltage regulator, for that reason to prevent power cut-offs the two 5V regulators are used instead to provide seamless operational voltage. The two power circuits are designed, as shown in the high-level design diagram in Figure 2.

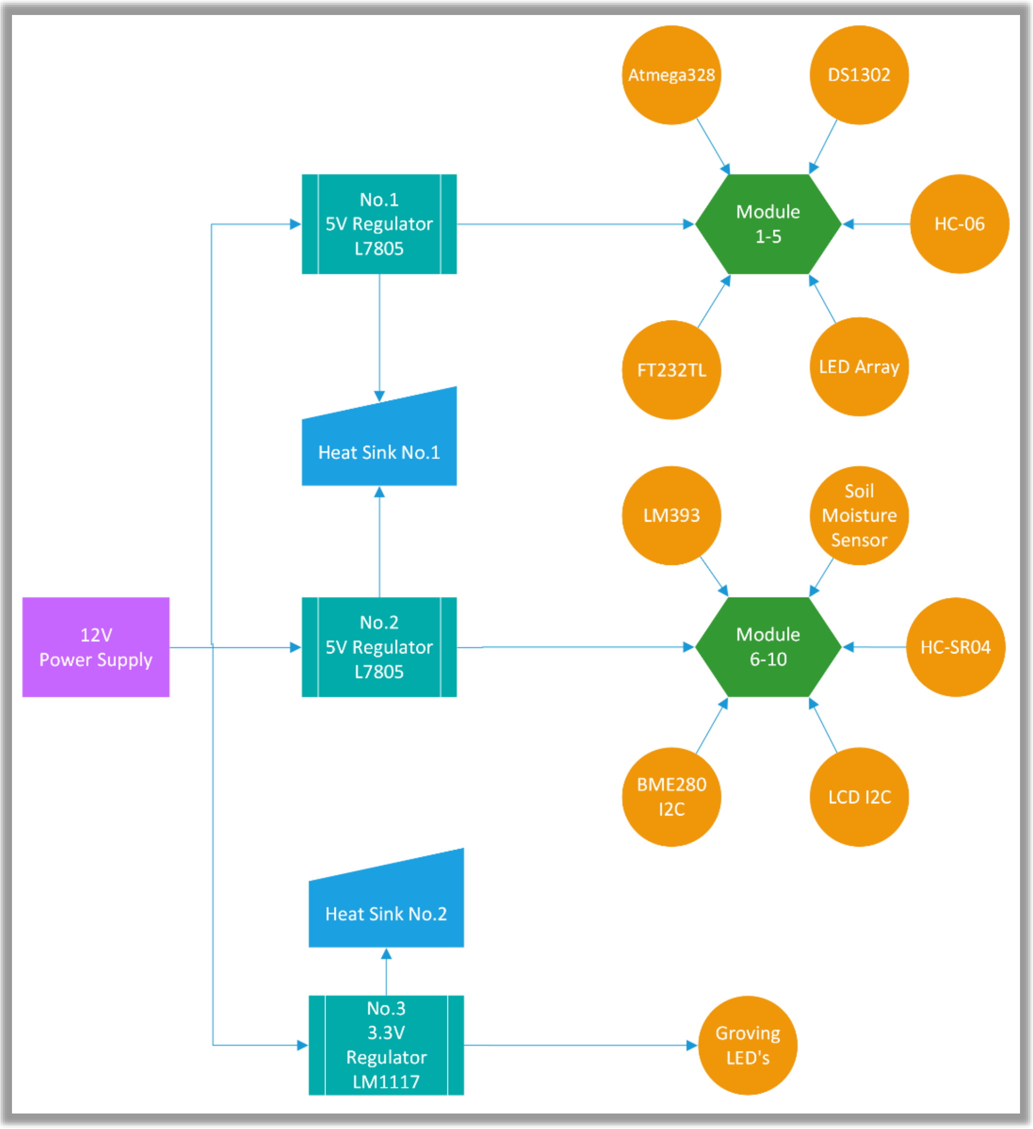

Figure 2. The high-level design of the power management

2.3. PC power supply control circuits design

In order to Turn ON and OFF the 12 V Power Supply, the Flip -Flop switch circuit design shown below in Figure 19. To be used as the momentary switch is developed using 555 Timer IC [4]. The PSU Fan would be controlled by circuits on the PC motherboard, as this circuit does not exist anymore. In order to slow down the Fan's speed, an Astable multivibrator – PWM Generator is required shown below in Figure 20. A simple PWM Oscillator has been developed by using 555 Timer IC and relevant components [5].

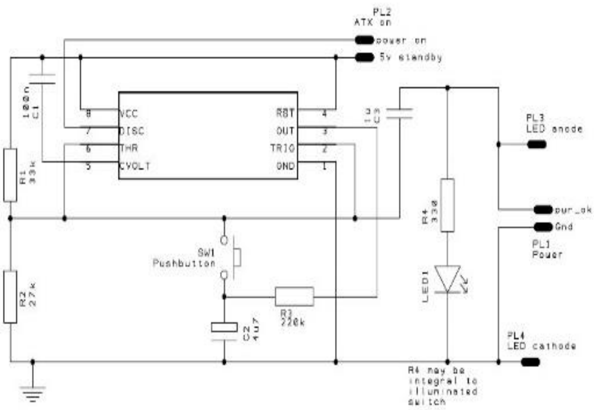

Figure 3. Flip-Flop switch

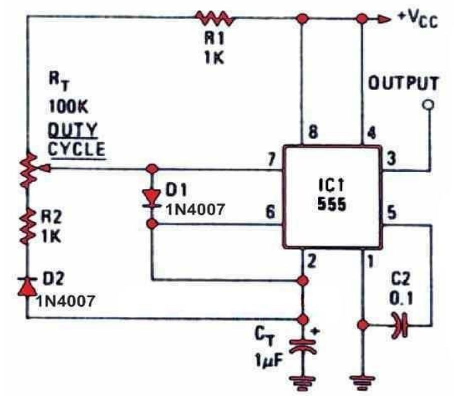

Figure 4. Figure 45. Astable multivibrator – PWM Generator

2.4. Preparation for first code upload

Before the first code is uploaded to the Atmega328 chip, the microcontroller received from the manufacturer arrived as a blank IC, which requires a boot loader, also called a boot manager. It is a small program that places the user's program code into microcontroller RAM [6]. Boot-loader code is flashed onto the Atmeg328 chip with the aid of an Arduino UNO developer board [7]. This involves wiring as seen in Figure 3. Once the boot-loader procedure is completed, the program code can be uploaded via the FT232RL programmer.

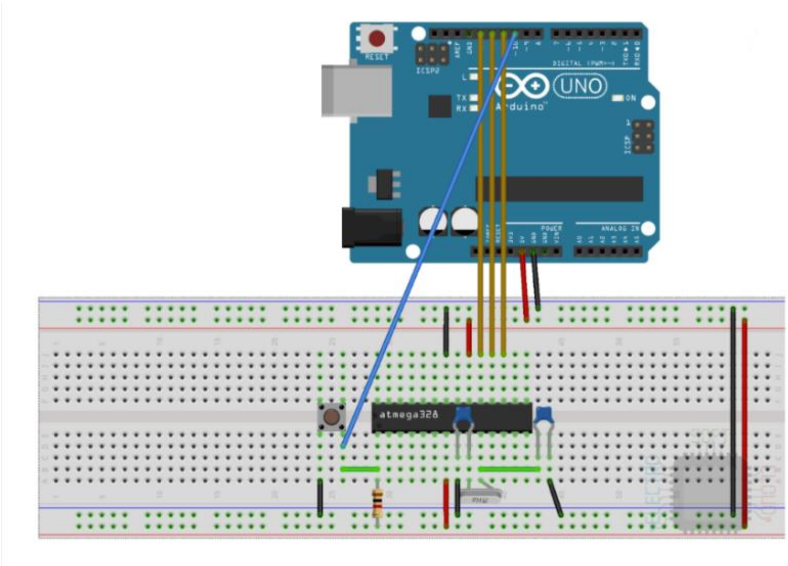

Figure 5. Using Arduino UNO to upload the Bootloader

2.5. Software flow overview and implementation

In order to upload the code to the microcontroller, a computer is connected to UART communication pins via an FT232RL programmer using a compatible USB cable [8]. The programmer input is then extended by a USB socket on the side of the enclosure panel for future access in development and troubleshooting, or just monitoring the serial communication port. The concept and the flow of the program code can be seen in the high-level block diagram shown below in Figure 3. The full program code can be found attached in the appendix.

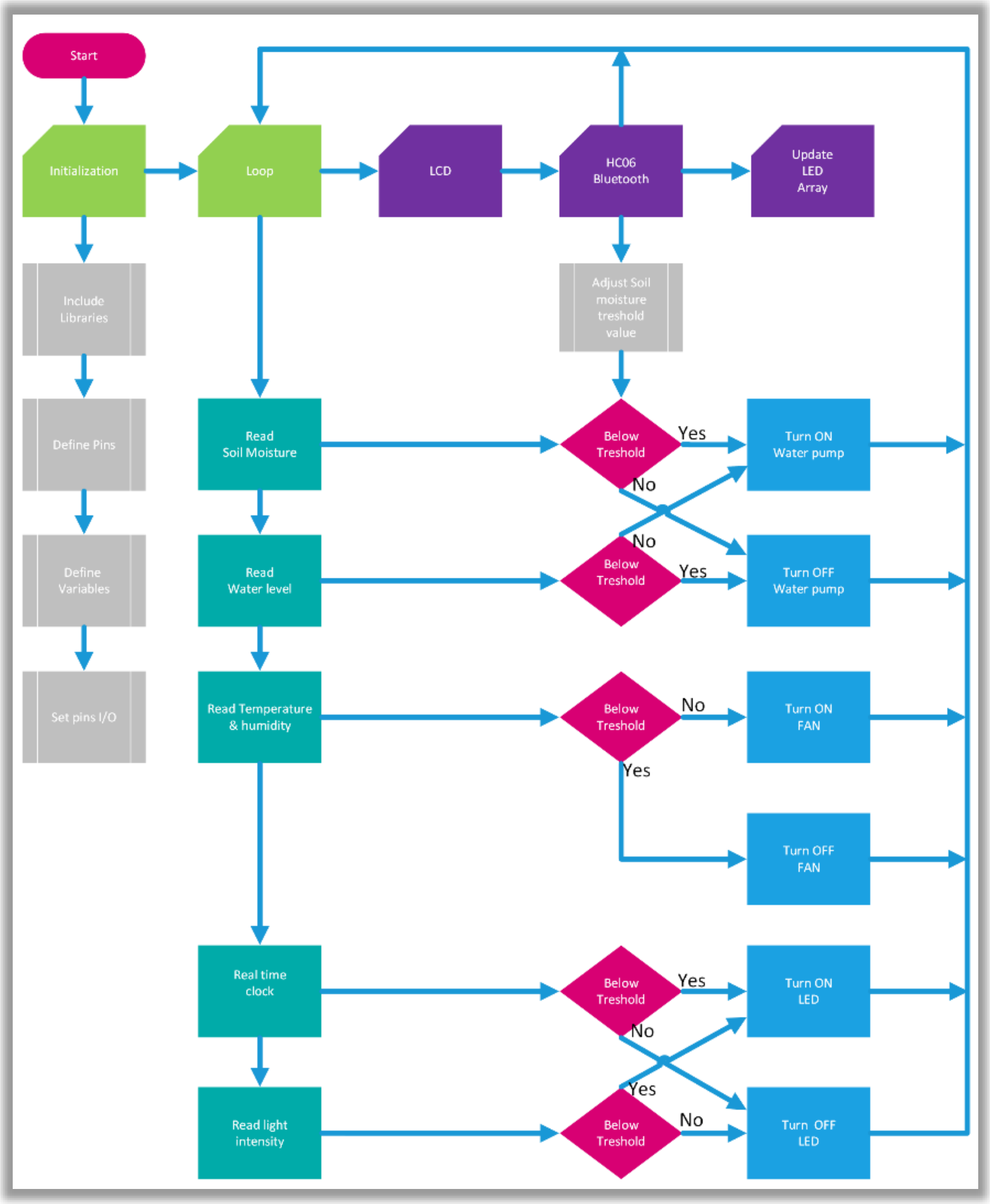

Figure 6. The high-level design of the software flow

2.6. Application of duplex communication

The monitoring and control of the device are intended to function with the Android app via Bluetooth module connected to digital I/O pins of the microcontroller. Through the development, it was learned the fundamentals of duplex (to way) communication [9], and the principle of the theory of operation are shown in Figure 7. Therefore, the importance to write the program code as efficiently as possible, achieving the fastest response time for seamless communication. Also, part of the project is to develop/ write a program for Android devices using the MIT Inventor software.

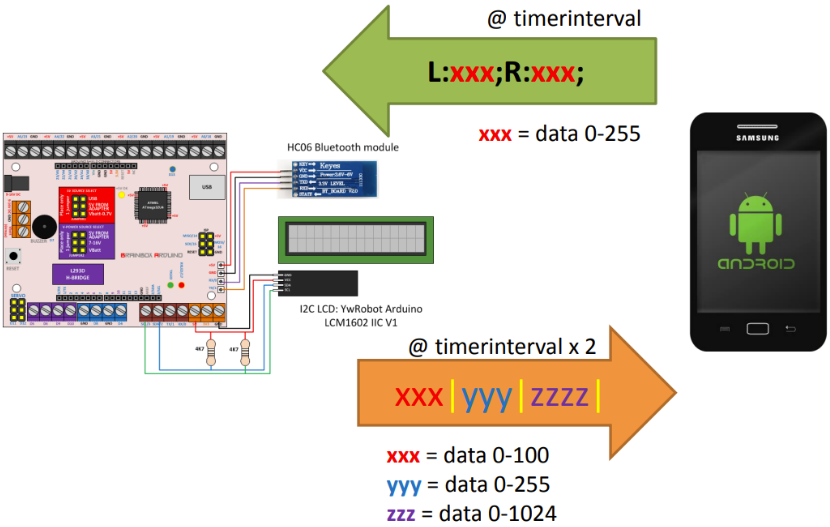

Figure 7.Bluetooth duplex communication timing diagram

2.7. Smart device App development

Figure 8. MIT App inventor branded logo

Figure 9. App Logo design

MIT App Inventor is an intuitive, visual programming environment that allows everyone even children to build fully functional apps for smartphones and tablets [10]. The branded icon can be seen in Figure 8. Those new to MIT App Inventor can have a simple first app up and running in less than 30 minutes. In conjunction with the appliance itself, a user-friendly app is developed to provide interaction between user and device, where data received by the microcontroller are altering variables in program code, which then operates outputs accordingly. The owner of such a device can monitor data being sensed by various sensors installed in an automated growing pot via an App which can be installed from the Google play store. The branded logo of My Smart Garden App can be seen above in Figure 9. The program code in the form of blocks is reviewed in next chapter 3.

2.8. Wiring diagram and PCB design

The overall schematic is drawn in the Proteus. Proteus is the software for developing electronic circuits and PCB design [11]. Using this professional software allows the development of the three PCB layouts. The PCB boards were developed based on the wiring diagram shown in Figure 10. The Main PCB board contains the components as are following: ATmega328 microcontroller, two 5V Voltage regulators, one 3.3 V Voltage regulator, Relay, L298N diver, and DS1302 Timer module shown below in Figure 11. Sensors and external outputs are interfaced via JST-XH connectors and terminals. The second PCB design is located to the left of the device enclosure to indicate the water level, therefore Shift registers and LED arrays were placed on individual boards. The third PCB board is designed to turn ON the power at Power Supply, which requires a Flip Flop momentary switch designed by 555 IC and the second 555 IC circuit is used to slow down the speed of the Power Supply Fan as without the control it is very loud.

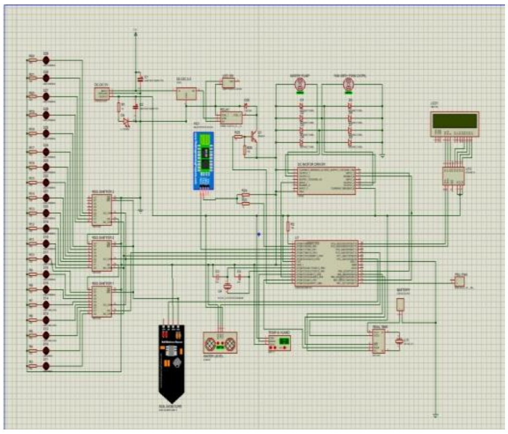

Figure 10.Wiring diagram designed and tested Proteus

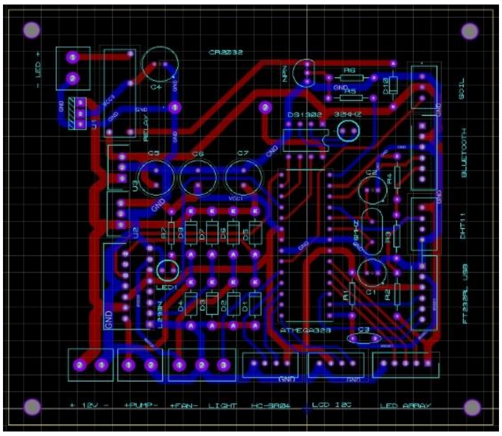

Figure 11.PCB designed in Proteus

Once the concept is proven to operate with no issue, a 2-layer PCB board design is completed for the Mainboard, LED array, and Power supply module, for PCB production the Gerber file was forwarded to the manufacturing company NEXT PCB [12] Their branded logo can be seen in Figure 12. and production facilities preview in Figure 13.

Figure 12. PCB manufacture logo

Figure 13. Next PCB production facilities overview

2.9. Water management and distribution

In order to store and distribute the water to plants, the custom water reservoir was made from acrylic plastic sheet material, using an assembly technique for an acrylic aquarium water tank [13]. The same material is used to build an overflowing pot, which is designed to fit under the growing pot preventing an excess of water from flooding the electronics. Water is delivered to a plant by a water pump through a micro irrigation system made of a 7mm hose and sprinkle fittings, which theory of operation can be seen below in Figure 14. The amount of water fed through is given by soil moisture condition measured by the capacitive sensor and setting of the threshold value which triggers the water pump.

Figure 14. Micro irrigation system theory of operation

2.10. Water level in reservoir monitoring

To provide an instant indication of the water level in the reservoir, the custom module is developed with two 10-LED bar blocks, which can be seen in Figure 15. With the application of the module, users can easily recognize water level - instantly, without reading the information on the LCD screen or the App. In order to free multiple I/O pins at the microcontroller, only three logic I/O pins are used instead, these three I/O pins manage the logic at 74HC595 Shift registers as shown in Figure 16. As the microcontroller processes the data received from the ultrasonic distance sensor, this data is used and then fed to Shift Registers [14]

Figure 15. Custom-made LED bar graph module

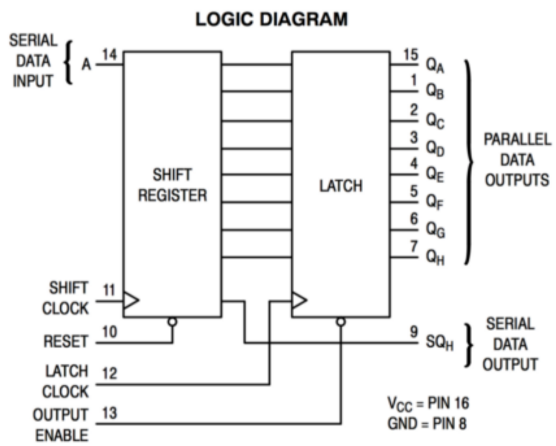

Figure 16. logic block diagram of Shift register IC

The actual water level in the reservoir is measured by an ultrasonic distance sensor, which sends the sound ping and records the time of receiving [15]. Also known as a sonar to determine the distance, the visual presentation can be seen below in Figure 17.

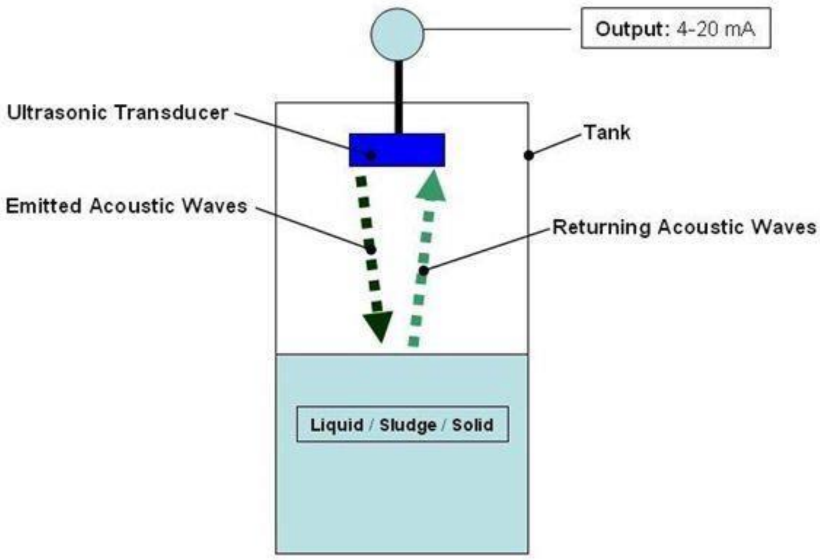

Figure 17. Water level measurement - theory of operation

Using the time difference between emitted acoustic wave and receiving the returning wave is used in the calculation of distance as seen in Equation 1. The speed of sound is multiplied by time and then divided by two.

Equation 1.

$$\text{Distance} = (343\ \text{m/s} * \text{Time})/2$$

Note: '343 m/s' in the above Equation 1. indicates the sound speed in air medium considered at room temperature.

The timing sequence of the ultrasonic distance sensor operation is shown below in Figure 18.

1. The ultrasound transmitter (trig pin) emits a high-frequency sound (40 kHz).
2. The sound travels through the air. If it finds an object, it bounces back to the module.
3. The ultrasound receiver (echo pin) receives the reflected sound (echo)
4. The propagation delay promotes the distance, which is calculated as mentioned above

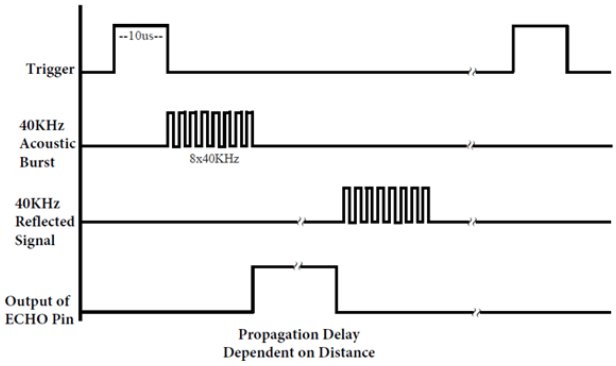

Figure 18. Ultrasonic Timing diagram

2.11. Data display methodology

In order to display data recorded by sensors, a 16x2 Liquid crystal display is used to interface with the user. To display multiple data, the scrolling sequence is coded using counters instead of general delays, which prevents the program code from being stuck waiting for the delay to pass. The LCD is interfaced with the I2C module, which logic block diagram can be seen in Figure 19. The Inter-Integrated Circuit or I2C communication protocol with a microcontroller is used to reduce the usage of microcontroller I/O pins, rather than connecting LCD via six I/O pins [16].

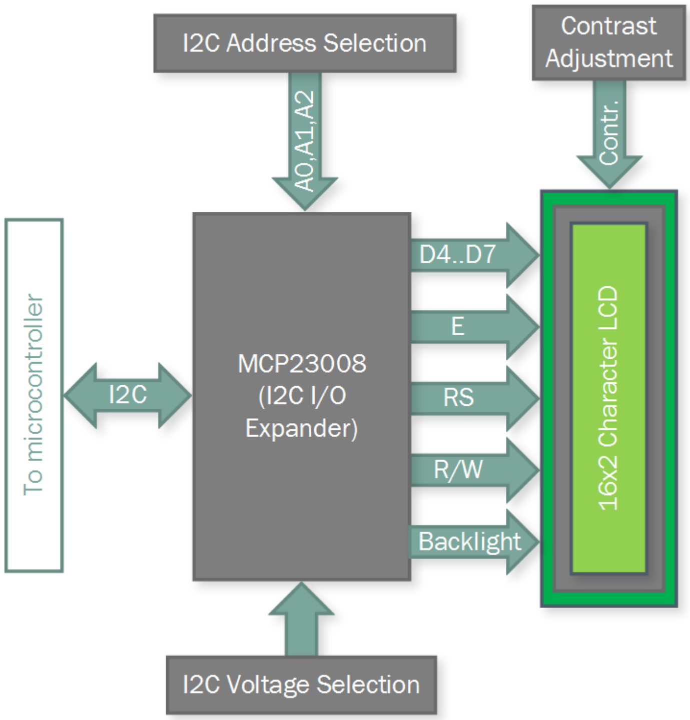

Figure 19. I2C module connected to 16x2 LCD block diagram

With the I2C protocol, there is the master which can communicate to multiple slaves with different addresses via two communication lines. The data is transferred in the messages, which can be seen in Figure 20. The Messages are broken up into frames of data. Each message has an address frame that contains the binary address of the slave, and one or more data frames that contain the data being transmitted. The message also includes start and stop conditions, read/write bits, and ACK/NACK bits between each data frame.

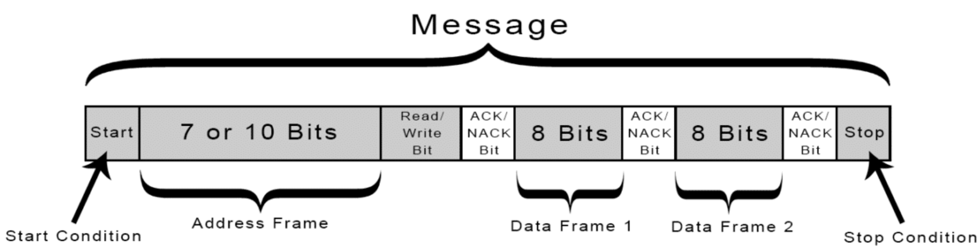

Figure 20. Composition of a message in I2C com. Protocol

2.12. Growing light management

In order to choose the correct growing LEDs the research is carried out. It is stated that violet light is commonly used for plants grown indoors, and in greenhouses, depending on the need. The additional lighting promotes effective and faster plant growth and has an impact on the flowering processes [17]. Therefore, the 3W growing LEDs are chosen for the application in this project. The Full Spectrum LED provides high-quality illumination in the full range of visible light 380 nm to 840 nm as seen below in Figure 21., when there is insufficient natural light – sunlight. The artificial lighting is triggered by the light intensity level, measured by a light-sensitive resistor which is wired back to comparator LM393. Then the received values are processed via a comparator, which gives the digital state as true or false. The threshold level of true and false decisions is set by a potentiometer integrated into the comparator module. The power to LEDs is fed through the Relay module to provide a safe switching method.

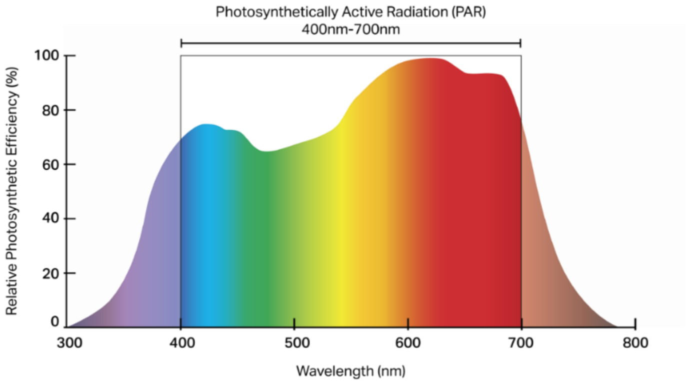

Figure 21.Ideal light spectrum window for growing plants

2.13. Date and Time management

To recognize the day and night time, The Real-time modular has an external oscillator of 34 kHz and contains 31 bytes of RAM, it has its power backup, to keep the crystal ticking when the device is OFF. The block diagram can be seen below in Figure 22. The microcontroller does not have the function of the real-time clock, therefore DS1302 IC is implemented in circuit. Then, the program code is written the way, that LEDs turn on early in the morning and late evening, regardless of the light intensity to provide boost time for plants. This way it enhances the growth, especially in winter time, when days are too short.

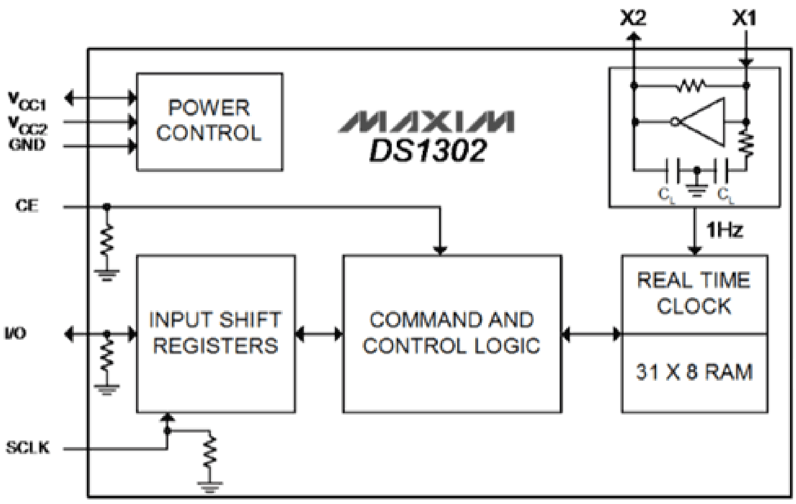

Figure 22.Block diagram of DS1302 Timing chip

2.14. Revision of the PCB design

After the device is tested again, there are still interferences to sensor readings present, At closer examination of the PCB, it is observed that some tracks are placed near noisy components. For that reason, the second PCB board is designed to apply the knowledge gathered from the System design course. Implementing PCB designer's rules and concepts as follow: partitioning of components, 4 copper layer, 3H and 20W rule. Adhering to these rules improved noise reduction and balanced power distribution, and stabilized reading values from sensors. High-speed communication tracks were shielded by via's to reduce EMI (Electromagnetic Interference) coupling to other tracks. Similarly, the wires with highspeed signals were braided. Shielded with steel wire, preventing any noise to couple. The new PCB design is shown below in Figure 25. including other electronic components and leads shielded to prevent electromagnetic interference (EMI) in the device

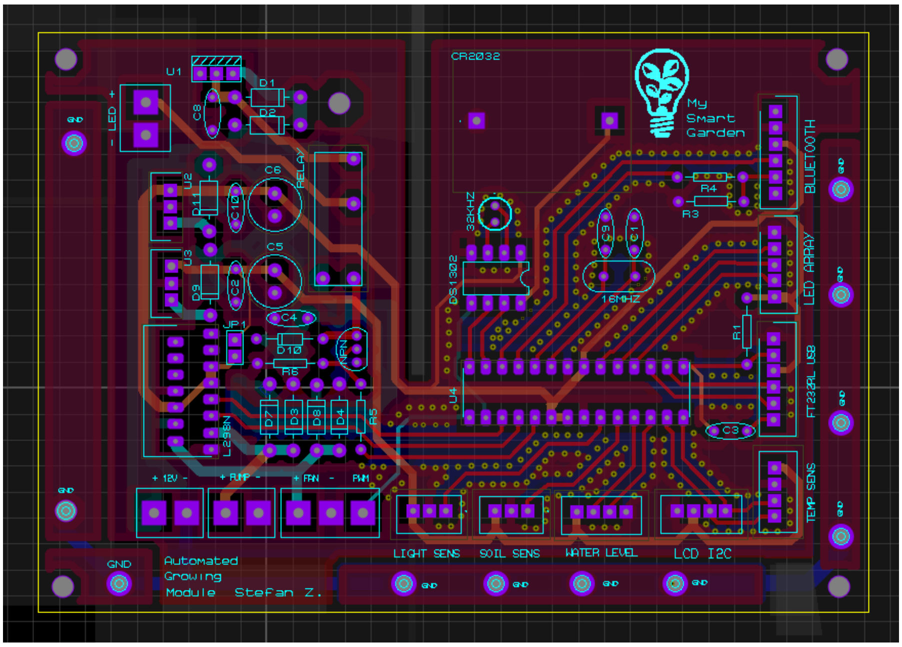

Figure 23. Second PCB development in order to eliminate noise

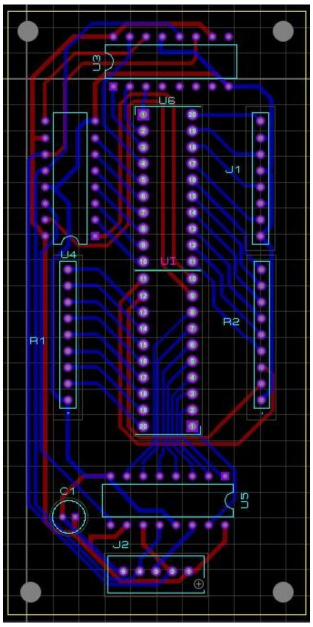

Figure 24. LED Array PCB design

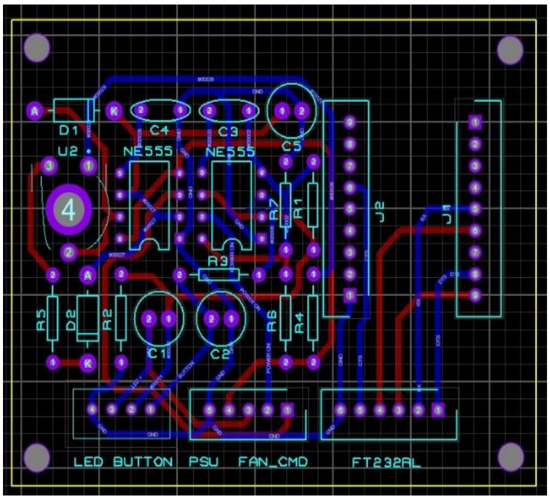

Figure 25. Flip-Flop switch and Oscillator PCB

2.15. Enclosure design

The enclosure housing is designed using Tinkercad software, shown below in Figure 27., to visualize the concept and dimensions of main components such as the power supply, electronics modules, smart device charging station, cooling fan, growing LED gantry, the plant pot, overflow pot, water tank and pump taking in account to distribute them in a strategic manner accommodating free space within the main body.

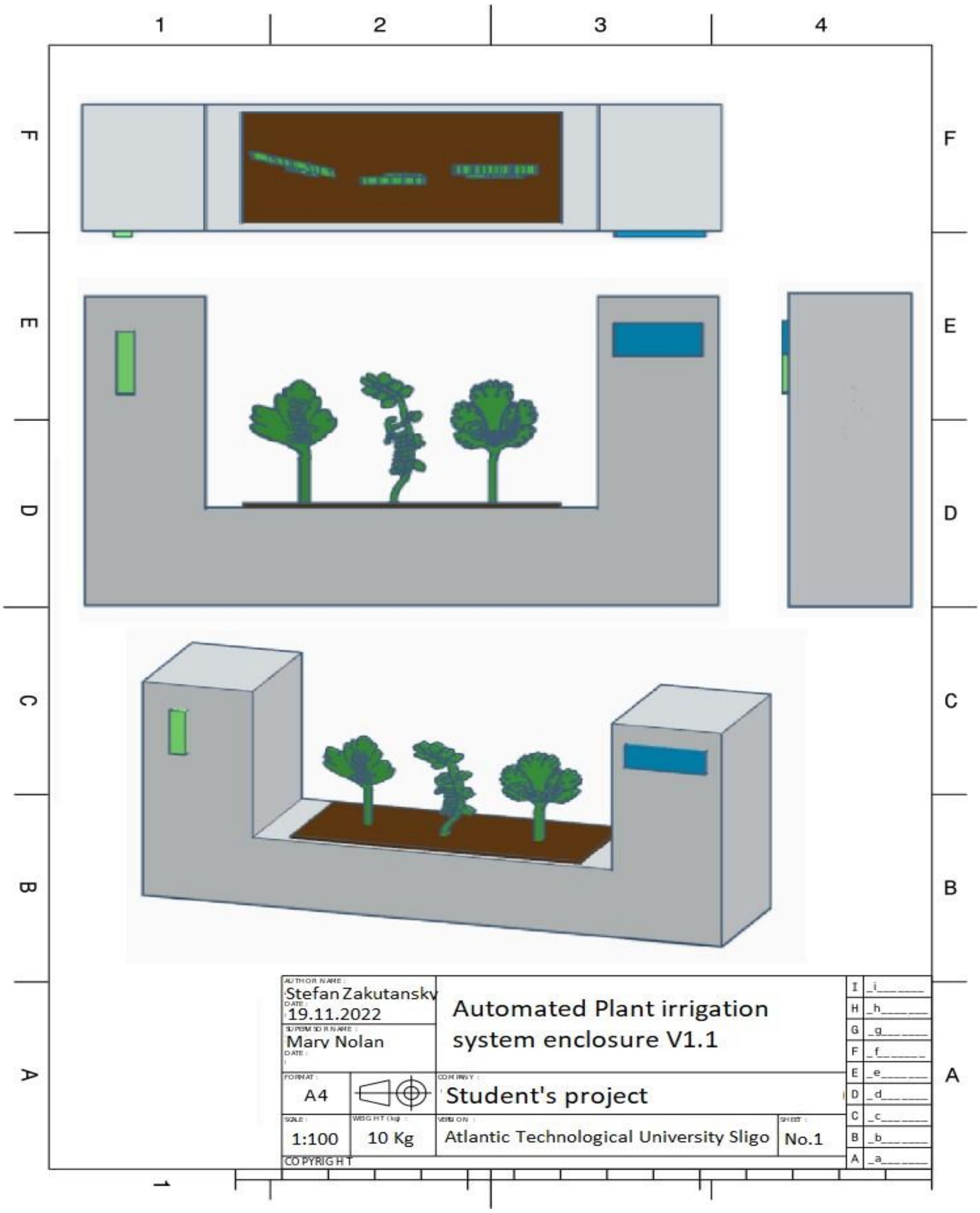

Figure 26.Design of enclosure in Tinkercad

Chapter 3 - Technical Implementation

This chapter is elaborated on what hardware and software are used for this project

3.1. Hardware Overview

3.1.1. ATmega328P Microcontroller

ATmega328 is a high-performance, low-power controller from Microchip [18] shown in Figure 27. is an 8-bit microcontroller based on AVR RISC architecture. It is the most popular of all AVR controllers as it is used in ARDUINO developer boards. It has 14 digital I/O pins, of which 6 can be used as PWM outputs and 6 analogue input pins. These I/O pins account for 20 of the pins. The pin layout can be seen below in Figure 28. The operating temperature range is -40 to 125˚C. The ATmega328p is a multipurpose microcontroller that is frequently used in manufacturing due to its low price. Further specifications are provided in Table 1

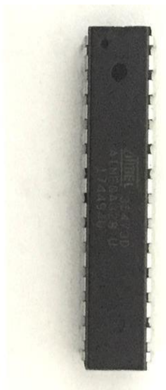

Figure 27. ATmega328p is a multipurpose microcontroller

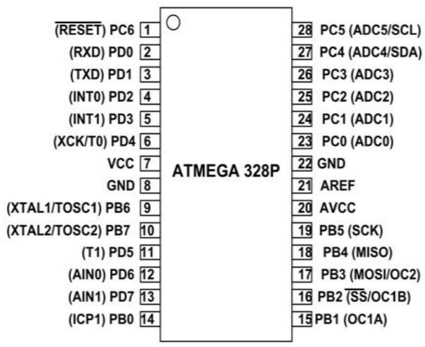

Figure 28. ATmega328 pin layout

Table 1. ATMEGA328P – Simplified specifications

CPU	8-bit AVR
Number of Pins	28
Operating Voltage (V)	+1.8 V TO +5.5V
Number of programmable I/O lines	23
Communication Interface	Master/Slave SPI Serial Interface (17,18,19 PINS) [Can be used for programming this controller]
ADC Module	6channels, 10-bit resolution ADC
PWM channels	6
Internal Oscillator	8MHz Calibrated Internal Oscillator

Program Memory Type	Flash
Program Memory or Flash memory	32Kbytes [10000 write/erase cycles]
CPU Speed	1MIPS for 1MHz

3.1.2. FTDI Serial Adapter FT232RL TTL USB UART Programmer

In order to load the software to the microchip, The FT232RL USB to TTL 3.3V/5V FTDI Serial Adapter Module [19], shown in Figure 29., is used to connect a device to a PC via a USB mini to establish communication via RX/TX pins. This converter module has options for different output voltage options which are set by the jumper on the board. FT232RL USB to TTL Serial Adapter Module can be used to monitor

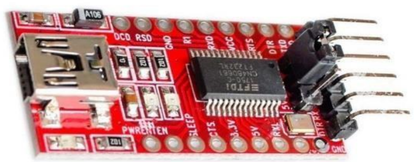

Figure 29. FT232RL TTL programmer

- Operating Voltage: 5V/3.3V DC
- Max Current Draw: 5V - 500mA; 3.3V - 50mA
- Connector: Mini USB
- Fully integrated 1024-bit EEPROM storing device
- Data transfer rates from 300 baud to 3 Mbaud (RS422, RS485, RS232) at TTL levels
- 128 byte receive and 256 bytes transmit buffer
- Transmit and receive LED drive signals
- Fully integrated clock generation with no external crystal required

3.1.3. Bluetooth HC-06 module

The HC-06 is a Bluetooth module [20] shown in Figure 30. which is used for wireless communication. It has four pins, 5 volts, ground, transmit and receive. The receive pin requires 3.3 volts only so it is important to include a voltage divider if necessary. This Bluetooth device offers UART communication.

Figure 30. HC-06 is a Bluetooth

- Bluetooth Protocol standard V2.0
- USB Protocol v1.1/2.0
- Frequency Band: 2.4GHz-2.48GHz
- Power Level Class2(+6dBm)
- Transmission Speed (Mbps) 2.1 Mbps
- Safety features Authentication and encryption
- Supported Configuration Bluetooth Serial Port
- Supply Voltage +3.3V to +6V
- Operating Current 40mA

3.1.4. Liquid Crystal Display 16x2 interfaced with I2C Serial Interface Adapter Module

Due to limited pin resources in a microcontroller, controlling an LCD as seen in Figure 31. could be tedious. Serial to Parallel adapters such as the I2C serial interface adapter module shown in Figure 32. contains PCF8574 chip that makes the work easy with just two pins. [21] The serial interface adapter can be connected to a 16x2 LCD and provides two signal output pins (SDA and SCL) which can be used to communicate with an MCU/MPU.

Figure 31. LCD 16x2

- 16 Characters x 2 Lines
- 5 x 8 Dots with Cursor
- Built-in Controller (HD44780 or equivalent)
- +5V Power Supply
- 1/16 Duty Circle

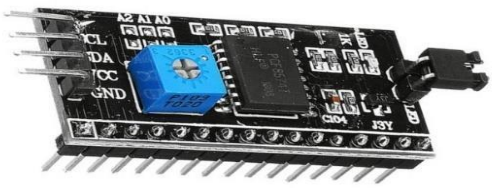

Figure 32. I2C Serial Interface Adapter Module

- Operating Voltage: 5V DC
- I2C control using PCF8574
- Can have 8 modules on a single I2C bus
- I2C Address: 0X20~0X27 via the onboard jumper pins

3.1.5. Ultrasonic Distance sensor HC-SR04

The water stored in the tank is monitored by an Ultrasonic Distance sensor HC-SR04 [22] as seen inn Figure 33. to measure the actual water level. When the minimum water level in the tank is bridged, the microcontroller will disable the water pump to run empty preventing the failure.

Figure 33. Ultrasonic Distance sensor

- Operating voltage: +5V
- Measuring Distance: 2cm to 450cm
- Practical Measuring Distance: 2cm to 80cm
- Accuracy: 3mm
- Measuring angle covered: <15°
- Operating Current: <15mA
- Operating Frequency: 40Hz

3.1.6. Capacitive Soil Moisture Sensor v1.2

The Capacitive soil moisture sensor [23] shown in Figure 34. measures soil moisture levels by capacitive sensing rather than resistive sensing like other sensors on the market. It is made of corrosion-resistant material which gives it excellent service life. Insert it into the soil around your plants and impress your friends with real-time soil moisture data! The module includes an onboard voltage regulator which gives it an operating voltage range of 3.3 ~ 5.5V. It is perfect for low-voltage MCUs, both 3.3V and 5V.

Figure 34. Capacitive Soil Moisture Sensor

- Operating Voltage: 3.3 ~ 5.5 VDC.
- Operating Current: 5mA.
- Interface: PH2.54-3P.
- Dimensions mm: 98 x 23 x 4.
- Supports 3 pin
- Analogue output.
- Weight (gm):1. g

3.1.7. BME280 Temperature Sensor and 12V Fan with PWM control

BME 280 sensor module [24] temperature, humidity and pressure sensor as seen in Figure 35. Is simple to use. It communicates via the I2C or SPI interface. In this project, the data received will be used to control the Foxconn Cooling Fan PV701512EBSF shown below in Figure 36. in order to cool the environment around the plants. The 12V Fan is connected to the L298N DC driver and PWM is controlled by the microcontroller. The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%. Therefore, the sensor is a perfect fit for this project to measure in the specified range.

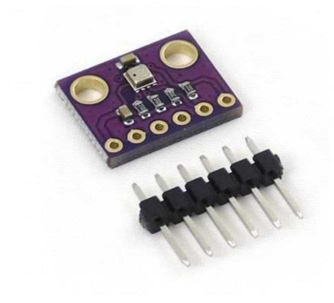

Figure 35. Temp. and Humid. Sensor

Figure 36. Foxconn Cooling Fan PV701512EBSF

- Input voltage 3.3V – 5V
- Current consumption 1mA
- Temperature -40°C to 85°C (±1.0°C accuracy)
- Humidity 0 to 100% RH (±3% accuracy)
- Pressure 300Pa to 1100 hPa (±1 hPa accuracy)
- Altitude 0 to 30,000 ft.

- Brand: FOXCONN - PV701512EBSF
- Size: 70 * 70 * 15mm
- Voltage: 12V
- Current: 0.70A
- Bearings: Ball
- Speed and temperature control

3.1.8. Growing 3W LED controlled by Light Intensity LM393 Sensor

The Full Spectrum LED is pictured in Figure 37. is a high-quality illumination in the full range of visible light 380 nm to 840 nm [25]. High-quality Power LEDs are used in plant cultivation from sowing to harvesting. Violet light is used by plants grown indoors, and in greenhouses, depending on the need for light in individual stages of growth. The additional lighting promotes effective and faster plant growth and has an impact on the flowering recesses. Red light and a combination of red and blue colours support photosynthesis, and vitamin production, and regulate the level of nitrates. They are suitable for growing many types of plants. The big advantage of LEDs is their long life, which can work up to 50,000 hours, emitting a light beam of 40-50 lumens.
The Light Sensor Detector LM393 module [26] shown below in Figure 38. is equipped with a photoresistor. It has a built-in voltage comparator - a binary signal is generated at the output. The potentiometer is used to adjust the sensitivity of the device. It is also possible to connect the module to the microcontroller also by direct output from the sensor.

Figure 37. 3W Full Spectrum LED

- Spectrum: 380 - 840 nm
- Brightness: 40-50 lm
- Beam angle: 120 °
- Service life: 50,000 h
- Working current: 700 mA
- Working voltage: 3.0-3.5V

Figure 38. Light Sensor Detector LM393 Module

- 5V power supply
- TTL output (0 or 1)
- Sensitivity adjustable with a potentiometer
- LM393 comparator used
- Module dimensions: 33mm x 15mm
- Operation is indicated by the LED

3.1.9. Single 10A Relay module

The Single Relay Board module [27] can be used to turn lights, fans and other devices on/off while keeping them isolated from your microcontroller. The Single Relay Board as seen in Figure 39. allows you to control high-power devices (up to 10 A) via the onboard relay. This relay is serving as LED switching device in this project.

Figure 39. Single 10A relay module

- Voltage requirements 5 VDC (Relay Power), 3.3-5 VDC (Input Signal)
- Current requirements: ~85 mA (Relay Power)
- Communication: Logic High/Low (3.3–5 VDC)
- Dimensions: Approximately 33 x 26 x 17 mm
- Operating temp range: -25 to +70 °C

3.1.10. Water pump with R385+ motor controlled by LN298N driver

A 12V water pump with an R385+ motor [28] pictured in Figure 40. is required in order to provide enough force to move the water from the water source to the plant pot to be irrigated. This is usually achieved by connecting the water pump to the water source, in my case it is a water tank and the irrigation pipes. The pump will be controlled and operated by a microcontroller module through DC motor driver L298N [29] shown in Figure 41. Which is a driver for high-power motors. It allows you to control two DC motors or one two-phase stepper motor.

Figure 40. Water pump with 12 V R385+ motor

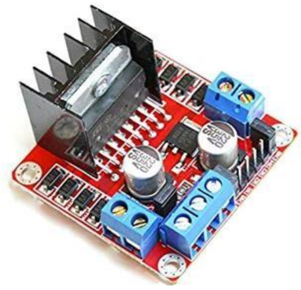

Figure 41. DC motor driver L298N

- Voltage: DC / 12V
- Current: 0.25A
- Power: 3W
- Pump capacity: 1.5 - 2L / min
- Suction height: 2m
- Height of the water column: 3m
- Liquid temperature: up to 80 degrees

- Maximum current per channel 2A
- Supply current 36mA
- Supply voltage up to 46V
- Maximum power loss 20W
- is equipped with a heat sink
- PWM signal to control the engine speed

3.1.11. Real-time clock DS1302 module

The DS1302 Real Time Clock Module [30] is pictured below in Figure 42. provides a DS1302 real-time clock with a 32 kHz crystal and onboard battery backup, all in a small SIP module that can be easily plugged into a breadboard. The DS1302 provides seconds, minutes, hours dates, day of week and year with leap-year compensation up to the year 2100. You can use 24-hour mode or 12-hour mode with AM/PM indication and 31 bytes of RAM are also battery-backed. Give our project the ability to tell time, store time or make time-based decisions with 1-second resolution in a small, compact form factor.

Figure 42.Real-Time Clock module

DS1302 module technical data:

- Power Requirements: 3.3-5 VDC
- Current Requirements: 3.2 mA @ 5 VDC
- Communication Interface: SPI @ VDD (3 or 4 wire)
- Operating temperature: 0 to +70 °C
- Dimensions: 31.2 x 15.5 mm

3.1.12. LED Array block with 74HC595 Register shifter

The project intends to update two blocks of the DC10GWA LED Array of 10 [31] bars shown in Figure 43. The water level can be monitored from a greater distance. DC10GWA LED. To indicate the actual water level limit the bottom led block includes a red led to show the warning of low level. The data are managed by three 74HC595 shift registers IC [32] shown in Figure 44. The intention of using the shift register is to free I/O pins on the microcontroller

Figure 43. DC10GWA LED Array of 10 Bar

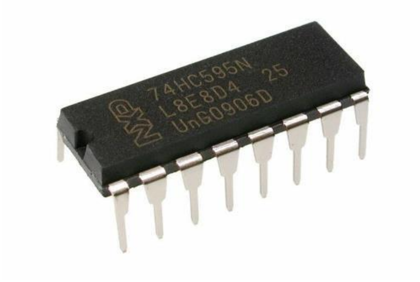

Figure 44. 74HC595 shift registers

- Current 25 mA
- Forward Current 20 mA
- Forward Voltage 2.2 V
- Illumination Colour - Green, Orange Red
- Lens Style Diffused
- Operating Temperature -40 ° - 85 °C
- Operating Supply Voltage 2.2 V

- 8-bit serial-in, parallel-out shift
- Wide operating voltage range of 2 V to 6 V
- High-current 3-state outputs can drive 15
- Low power consumption: 80-µA ICC
- TPD = 13 ns (typical)
- ±6-mA output drive at 5 V
- Low input current: 1 µA (maximum)

3.1.13. Re-used HP PC Power Supply unit

The HP Power Supply Unit (PSU) [33] as seen in Figure 45. is used to supply 12V power to the device with a bias Current of up to 14 Amps. In order to Turn ON and off the 12 V Power Supply, the Flip - Flop is shown below in Figure 46. the momentary switch is produced using 555 Timer IC [34].

Figure 45. HP Power Supply Unit (PSU)

Figure 46. NE555 IC utilized as Flip flop switch

- AC input voltage 110 - 220 V
- Efficiency 90 %
- Output connections Four 12VDC
- Notal power 240 Watt
- Number of fans 1 fan(s)

- Powered by 12 V
- IC used NE555
- Components Resistors, Capacitors
- Switch type momentary with Led
- Integrated on PCB board

3.2. Software Overview

To create this project as one functional unit, the code was developed for each sensor relative to output individually on the Arduino UNO developer board programming in Arduino IDE to simulate the project to ensure it works properly as intended. Besides that, a custom application for the smart device is developed in MIT App Inventor platform. Proteus 8 is used to develop a wiring diagram and plot the PCB layout.

3.2.1. The Arduino Integrated Development Environment (IDE)

The Arduino Integrated Development Environment (IDE) [35] is shown in Figure 47. contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. The integrated Development Environment that utilizes the C programming language. This software provides a real-time data visualiser and offers simulated I/O pins so a prototype program's functionality can be tested. The compiler converts the C code into machine code which is sent to the physical device. The libraries are imported to suit the components being used for this project. With the prototype setup mentioned above the core of the code is written for each module individually, the final golden version is developed along the long term testing period where sensors are calibrated accordingly to environment. The complete code adhering the coding ethics can be seen in GitHub repository [36] or by following the link here

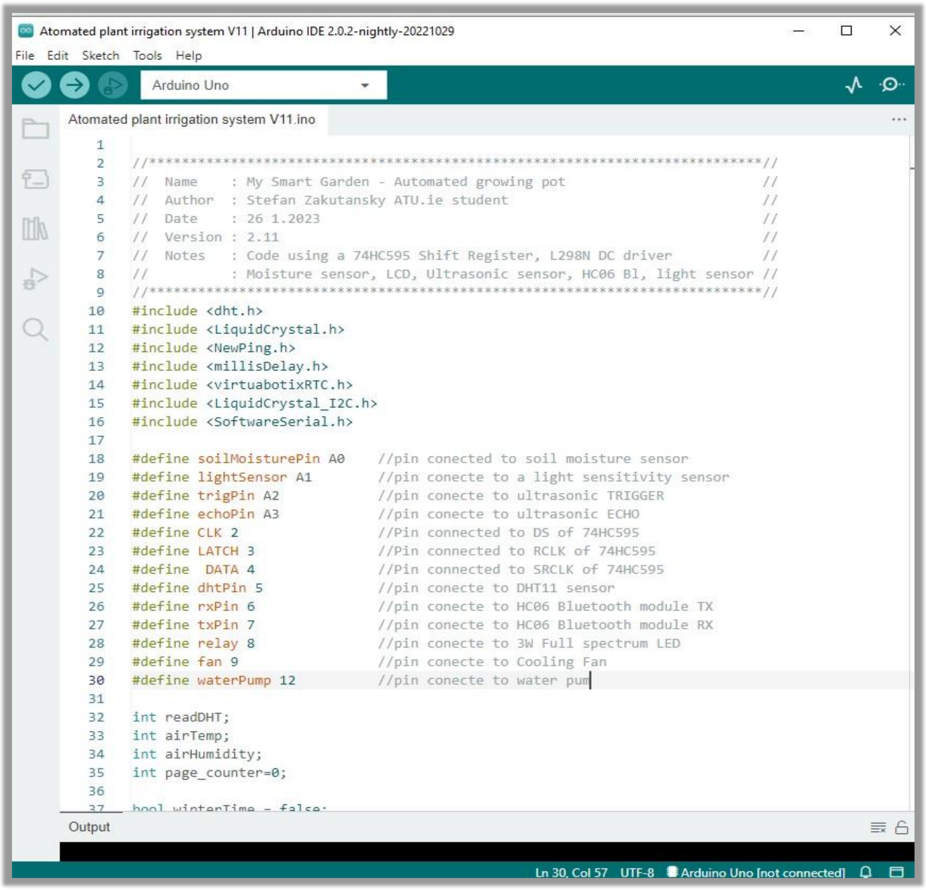

Figure 47. Program coding in Arduino IDE preview

3.2.2. Custom-made application by MIT app inventor

Coding in the MIT app inventor [37] consists of building a block in clusters, The block code can be seen below in Figure 48. These blocks vary by functionalities and actions. With basic coding knowledge and hints gathered from other developers, one can achieve a great deal in creating custom-made applications. Complete module of blocks can be seen below in Appendix.

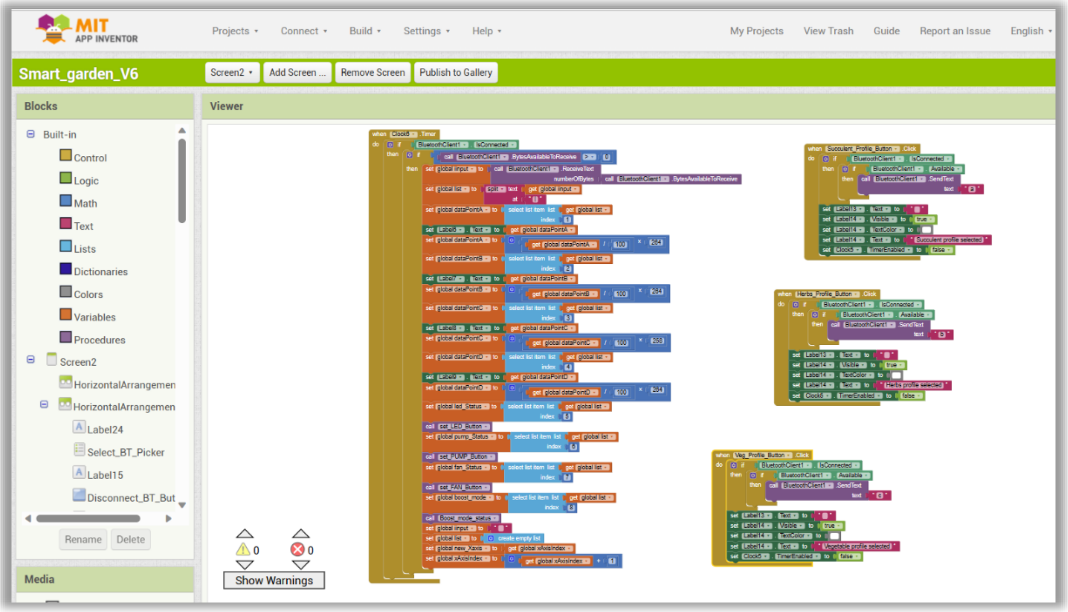

Figure 48. MIT App inventor code preview

3.2.2. Schematics and PCB layout in Proteus 8

Proteus 8 is a simulation software [38]. This software as seen below in Figure 49. is used to test the functionality of the device safely before it was tested on the breadboard. The prototype circuit is sketched and the PCB boards layout is plotted according to the wiring diagram.

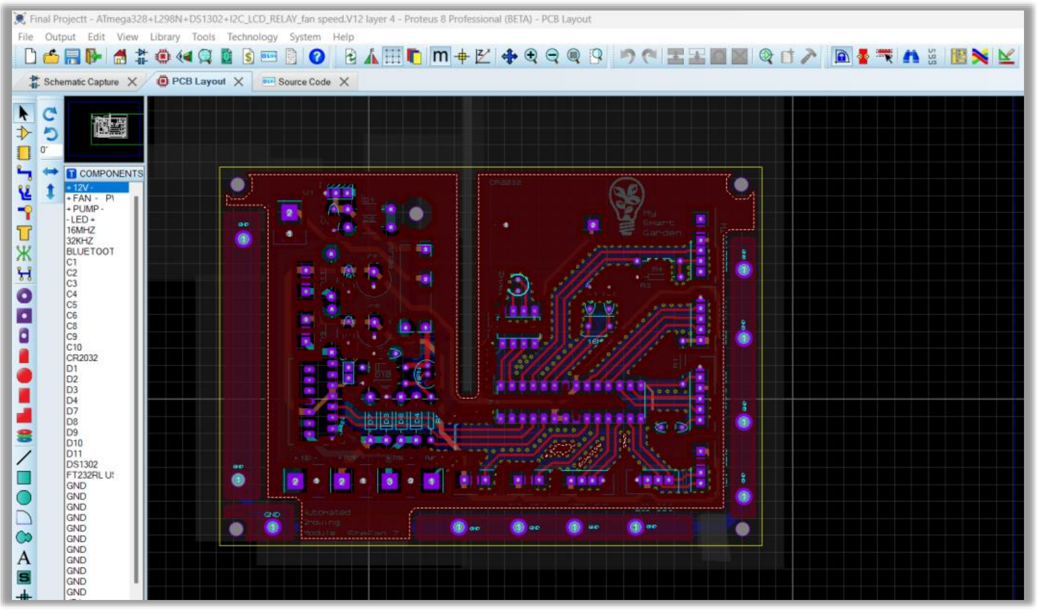

Figure 49. Proteus 8 is used to design wiring diagrams and PCB layout

Chapter 4 - Simulation, Testing and Results

4.1. Prototyping

In the project development, prototyping is involved to test the functionality of each module individually, including the particular coding to calibrate the reading values of sensors especially. The program code prototype Version 1 is created containing the code of each module and uploaded to the Arduino developer board linked with the stock modules by jumper wires. In the next stage of prototyping, the Arduino UNO developer board was replaced with the ATmega328 microcontroller including basic set-up, such as an external oscillator, in this case 16 MHz Crystal as seen below in Figure 50.

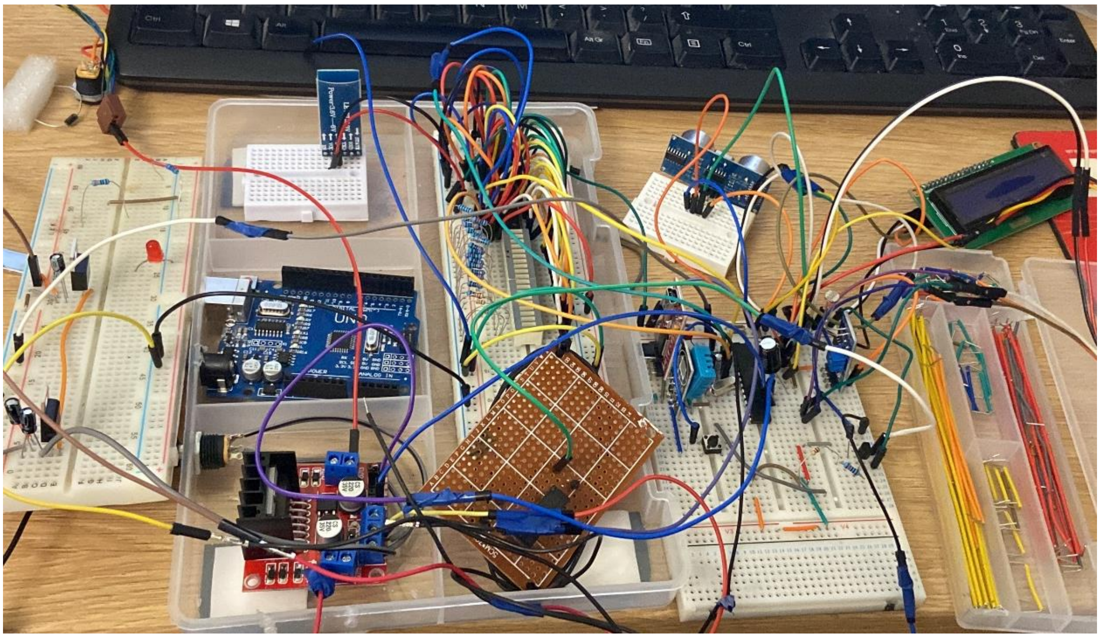

Figure 50. The second stage of prototyping with the ATmega 328 microcontroller

4.2. Testing and troubleshooting

Throughout the testing period, it is observed that readings from sensors are changing when other components are turned on, such as the water pump, 3W growing LED or Cooling fan. The conclusion was raised that these output signals are emitting electromagnetic fields around the leads, coupling onto the signals coming from sensors. In order to eliminate the RF noise being coupled, the DC motor of the pump is installed with de-coupling Ceramic capacitors [39] as shown below in Figure 51. The leads to the mentioned components are braided, and further tests are carried out.

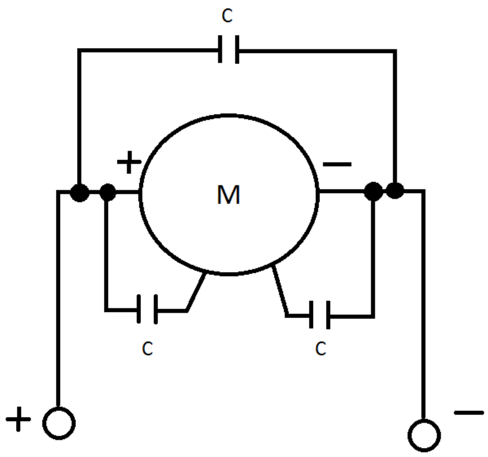

Figure 51. Decoupling DC motor with Ceramic capacitors

4.3. PCB Assembling and Soldering

Once all passive components are placed on the PCB board and soldered. The progress of soldering can be seen below in Figure 52. The installation of components is happening progressively, starting with power management components, then the power supply is connected and points with the expected outcome are tested. When the function of power components is verified, then logic components are installed and soldered. The solder job is examined by a magnifier glass, and soldering is re-visit if necessary. The completed Main PCB board is then interfaced with all external modules. Once power is applied, the program code is loaded and each module is tested and calibrated for the correct functionality. The device is then long-term tested.

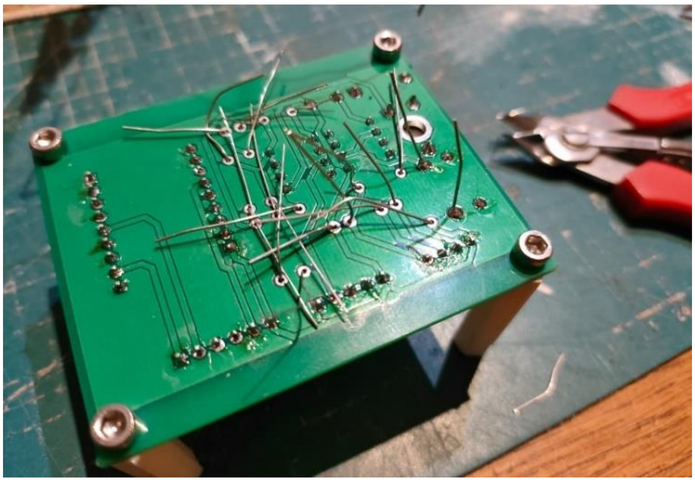

Figure 52. passive components being soldered to PCB

Once the new version of the PCB Mainboard is received the installation procedure is carried out in the same manner as mentioned earlier, the product of the completed PCB can be seen below in Figure 53.

Figure 53. PCB Version no.2 fully assembled

The replacement PCB board is swapped over and the appliance is tested in the long term. The swap-over job can be seen below in Figure 54. After the second stage of long-term testing, it is observed the great improvement in reducing the noise coupled on.

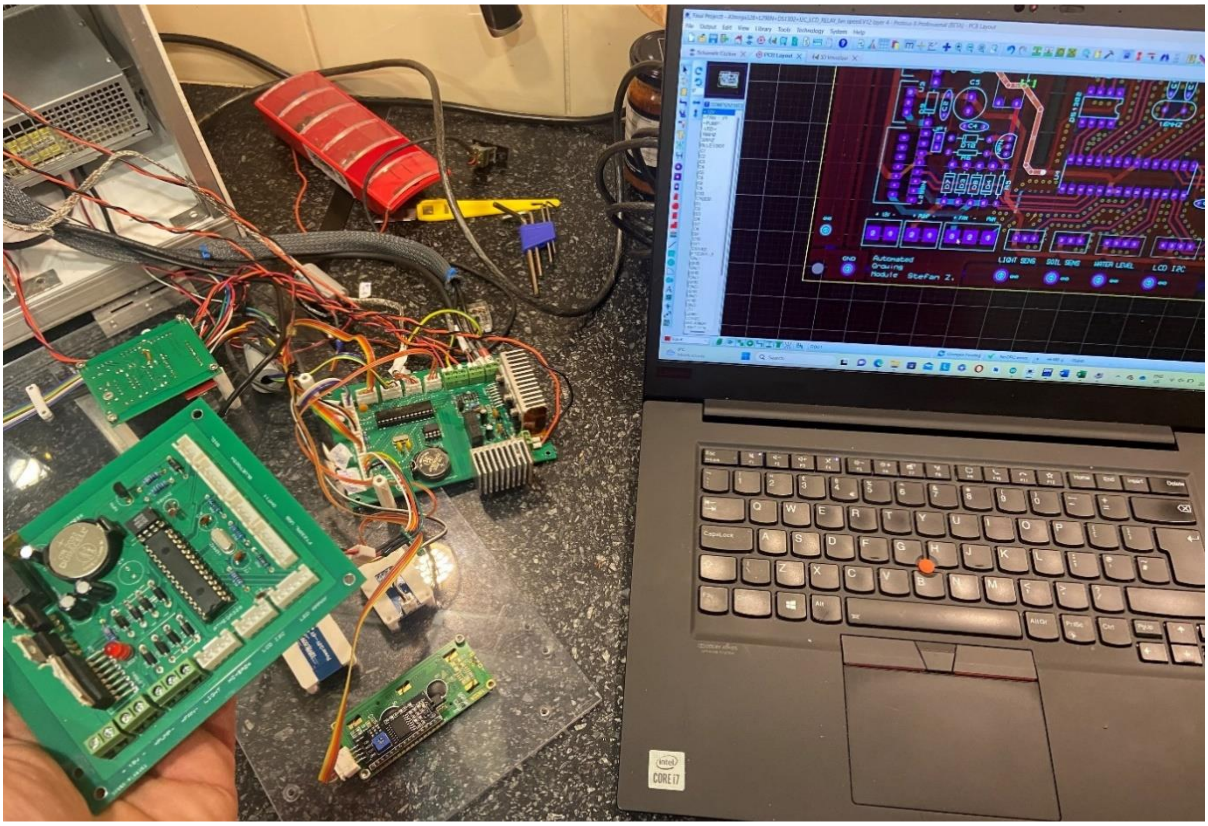

Figure 54. Swapping over the new PCB design

4.5. 3D Printing of the assembly parts

To 3D print, Creality Ender 3 V2 Neo printer [40] is used and parts are printed layer by layer utilizing PLA material. For example In Figure 55. is shown one of the components - the LED shield frame. This part helps in the production of the LED lighting shield, to prevent emitted bright light by LEDs to disturb the user's sight.

Figure 55. Growing LED shield installed with aid of 3D printed assembly parts

4.6. Android App for smart device

The custom made application starts with welcome screen, shown in Figure 56., which indicates loading the main frame of the App. The Second, main screen as shown in figure 57. appears with the text message, encouraging user to choose the Bluetooth device and connect to it. Once connected, the text suggests the user to choose one of the growing profiles out of three options, pictured as plants in the pot. There are four buttons for turning ON/OFF the sensor, the values are plotted on graph in real time. The numeric values are shown at bottom in the centre of the graph as well. In the bottom left of the screen is the switch between AUTO and MANUAL mode. When MANUAL mode is selected, control switches at bottom right can be operated by user. The last very bottom part of the screen, informs the user in which boost time mode the device currently is, whether the summer or winter time. This application can be downloaded from Google play store by following the QR code pictured in Figure 58.

Figure 56. My Smart Garden App Welcome screen

Figure 57. My Smart Garden Main screen

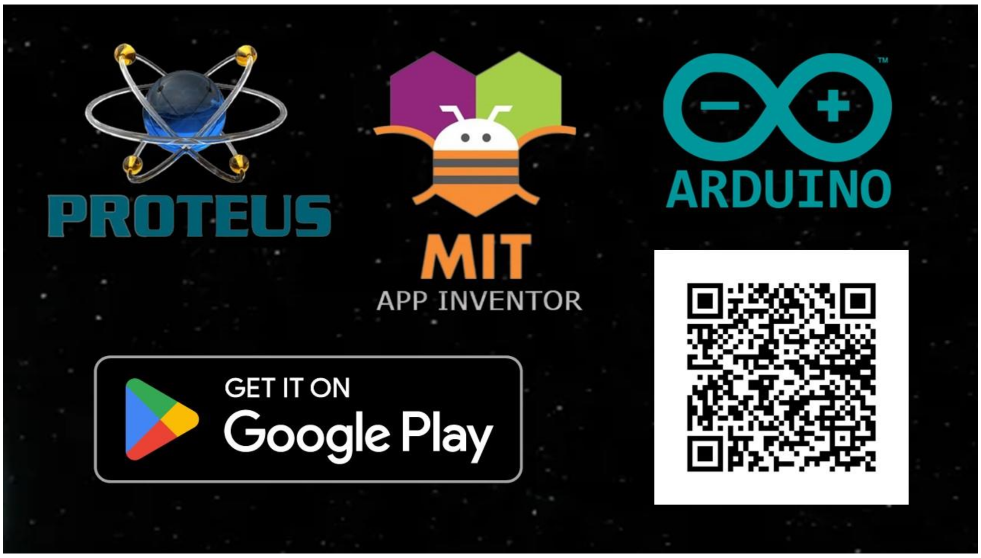

Figure 58. Scan the QR code to download My Smart Garden App

4.7. Manufacturing and completion of the project

The housing is manufactured from recycled materials The enclosure structure was built from recycled pop-up tent frame profiles. Once the structure is assembled, then re-claimed commercial banner panels are cut to suit the enclosure framework and installed in their place. The panels were spray painted to desired colour/effect before the installation. The main components such as the power supply, electronics modules, smart device charging station, cooling fan, growing LED gantry, plant pot, overflow pot, water tank and pump are installed in place and the appliance is completed, which can be seen below in Figure 59., ready to be used in the real world, not just only as a prototype.

Figure 59. Complete enclosure unit assembled from recycled materials

4.8. Ethical Considerations

Reflecting on the argument - of how to reduce the runoff of water and nutrients, the appropriate management of the water flow is in place, it is maintaining a low impact on to financial and environmental aspects of society. According to Gardening Guru [41] “GreenIQ Technologies company from Israel which is also dedicated to the topic of sustainability in smart irrigation, claims that the smart gardening system can save garden owners up to 50 per cent on water use in the garden.”

Equally important to note is that the components were selected to satisfy environmental safety concerns. Through the engineering of the project, it was noticed that the resistive soil moisture sensor when exposed to water/wet soil the electrolysis process releases a toxic compound from the sensor that can leak into the soil. Therefore, as seen below in Figure 60. capacitive soil moisture sensor was chosen over a resistive exemplar instead and has been tested to be safe from hazardous conditions. The very same symptoms are observed by other engineers executing experiments with resistive soil moisture sensors [42]

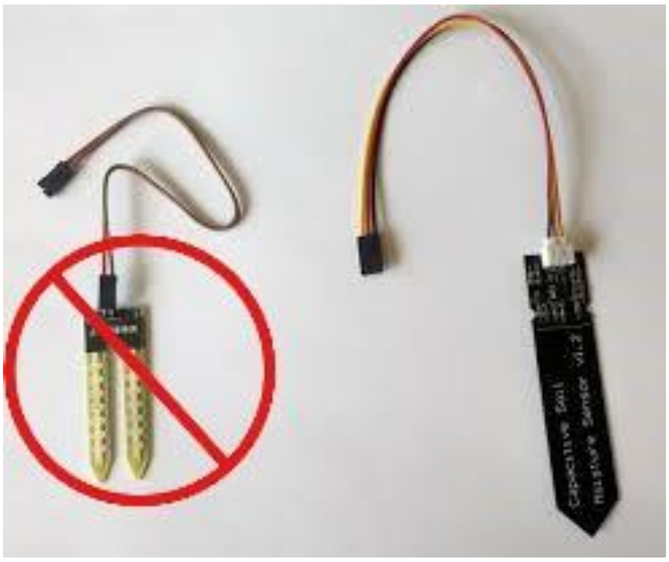

Figure 60. Capacitive soil moisture sensor preferred in the application

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Appendix

1. MIT App inventor complete code

My Smart Garden complete code written in MIT App Inventor pictured in Figure 61.

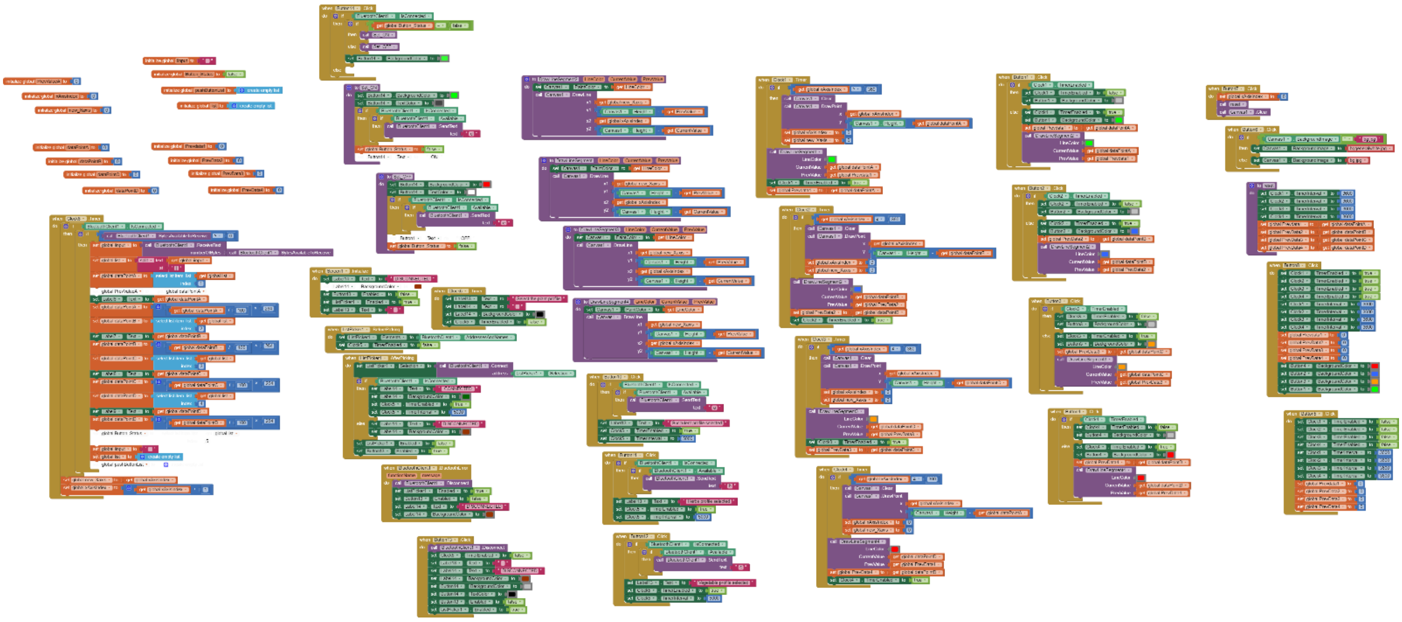

Figure 61. Complete App program code

2. 3D printed parts

Complete content of 3D Designs pictured below Figures 62-69.

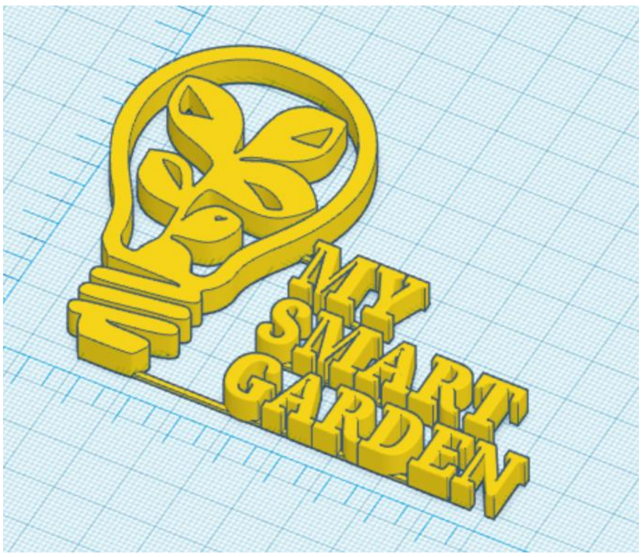

Figure 62. 3D design of branded logo

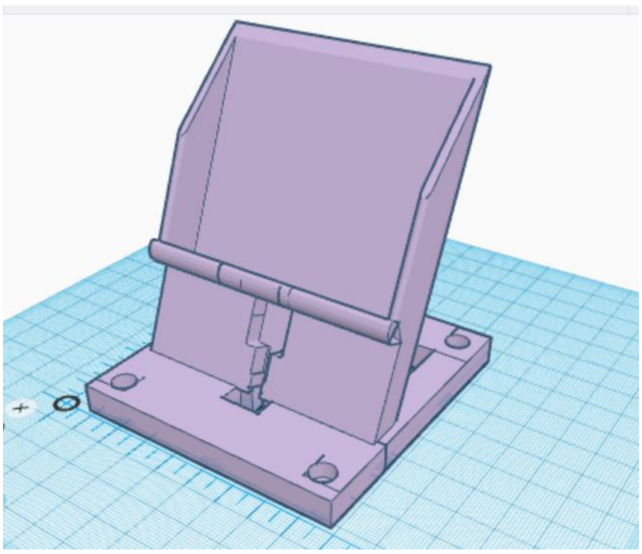

Figure 63. 3D design of Docking / charging station

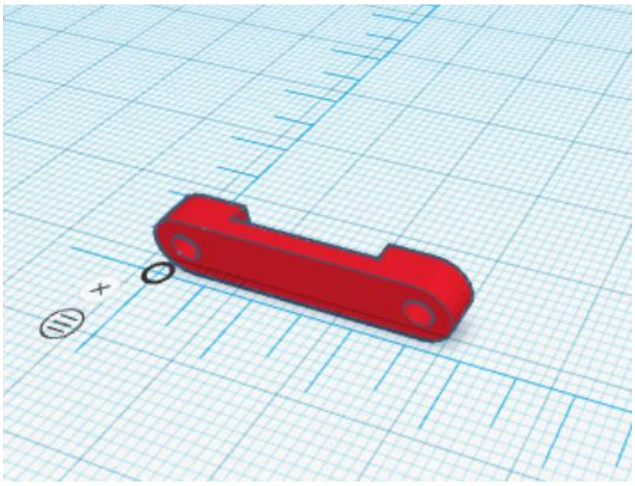
Figure 64. 3D design of cable clip

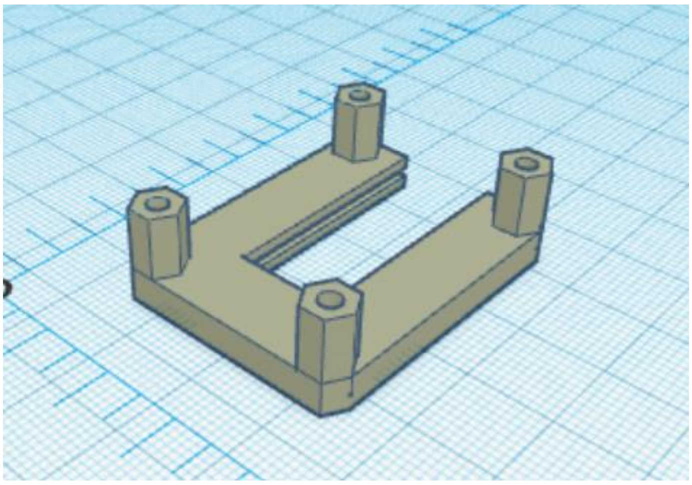
Figure 65. 3D design of Bluetooth module holder

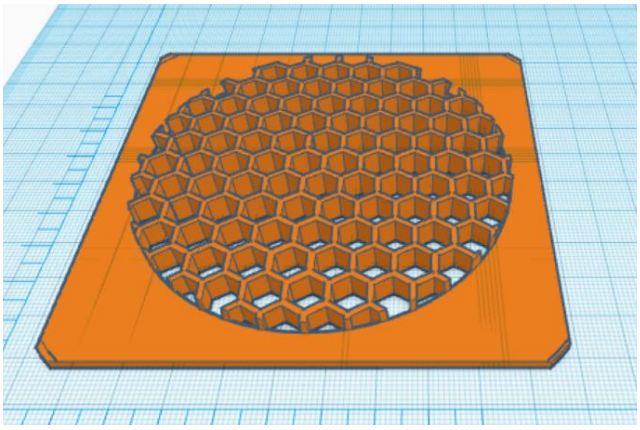
Figure 66. 3D design of Cooling Fan grid

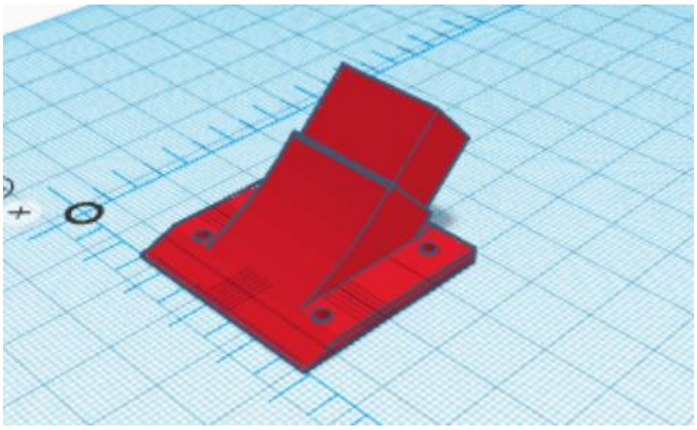
Figure 67. 3D design of gantry support platform

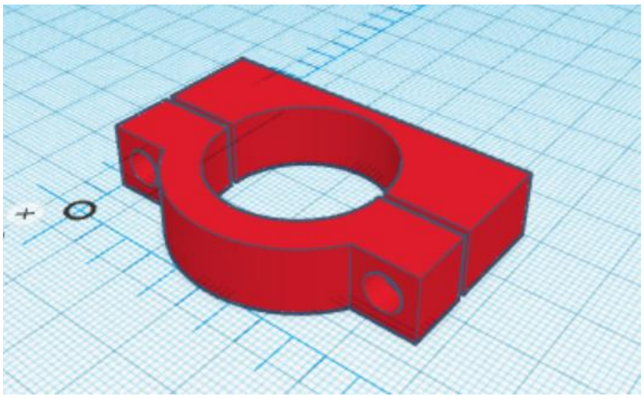
Figure 68. 3D design of water pump holder

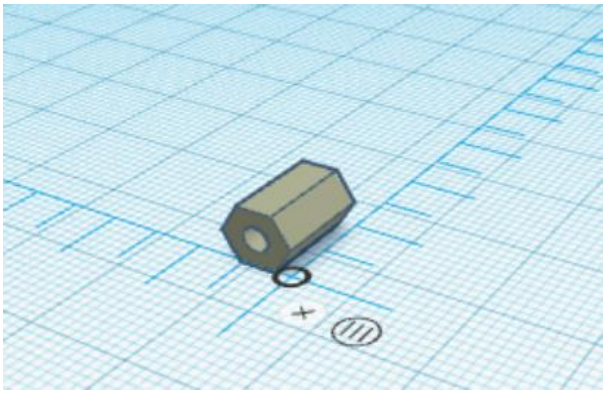
Figure 69. 3D design of PCB stand-off