Eco-Smart Home

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Abstract

Smart houses depend on the implementation of Internet of Things (IOT) in order to produce efficient housing and ensure smart consumption in our current scarce economic state. Machines have proven their ability to control a home system in different aspects like; security, electricity, water consumption, air conditioning, and lighting. Results also show the significant change in the statistics comparing consumption under human control vs under machine control.

This research will explore the new field of IOT and address the current global crises that we face and will try to show the roles that IOT installation will play in trying to lower the human domestic impact on increasing the global eco crisis and over consumption. It will introduce the proposed smart home project and provide further information on its components, their function and programming.

Finally, this dissertation will conclude with showing the efficiency factor that this house excels in and prove that it is capable of reducing consumption and be as ecofriendly as possible.

Table of Contents

Table of Figures

1 Introduction

1.1 What is IOT?

Technology has come a long way since its emergence and in every era of its existence, it managed to create new ways and possibilities for machines to interact and communicate with the outside world. One of the newest of these interaction technologies is the significant work being done in IOT (Internet of Things).

Internet of Things (IOT) or Internet of Everything (IOE) is a system that deals with the interaction of machines to perform certain tasks or transfer data over a network without requiring human interaction. [1]

1.2 How does it work

The interaction noted above is usually performed by different machines. It can be sensors, actuators, user interfaces, smart devices, and the list goes on… Each of them has a different task to perform in order to form a fully working unit that provides assistance for humans in some way or another. For example, sensors can detect different stimuli from the environment based on what they are built for, these stimuli can vary in their type and the sensors detect them and send them to another machine like a microcontroller to analyze them and respond to the stimuli based on how it is programmed. [2] In other words, it operates like a human body and makes dumb devices smarter by allowing to send and receive information over the internet. As specified by a group of scientists from Shenzhen academy in China, IOT can be divided into three layers, which are perception layer, network layer, and application layer respectively. Perception layer is responsible for data collection in IOT. It consists of all kinds of sensors, like temperature sensor, humidity sensor, RFID tags and related readers, camera, GPS and so on. Network layer is composed of all kinds of networks, like the internet, the 2G and 3G communication networks, broadcast networks. Network layer is mainly used to collect data from perception layer and processing these data for the application layer. Application layer is the interface between users and IOT. Many applications including smart homes, agriculture, industry, environmental monitoring, etc. are enabled. [3]

1.3 IOT in a developing ideology over the environment

As mentioned before, smart homes are a pertaining concept of IOT and there is a lot of new innovative work being done in this field, different sensors and actuators are being developed to make the lives of people easier in their houses, especially for those who might have some kind of physical disability, assisting them in daily tasks and chores inside any common household. However, recently; there has been a lot of effort by people, companies, and countries to be more environmentally friendly. So, this raises a question on whether these developing households are taking in consideration the environmental factor and implementing it in the operating system of a smart house to make it more efficient and eco-friendlier.

1.4 The inefficiency of homes not being controlled by machines

Due to recent issues in the environment, such as global warming, sustainability has become the most important factor that needs to developed in this century. When we look at the current state of houses around the globe, we notice that if a house is under the control of people, it won't be as efficient and sustainable as intended. A study was conducted involving 100,000 citizens in European countries. It reported that 80% of the respondents have shown concern in environmental problems and yet they take little actions to reduce energy consumption at homes. [4] On average, they carried out 1.4 of the 6 key energy efficient behaviors (i.e. cut down on heating and air conditioning, cut down on lighting and use of electrical homes appliances, preserved water, and more). This is mainly because humans tend not to be strict in such matters and cannot always function as good aa machines. A study from the Lebanese American University (LAU) in 2005 specifies that the annual consumption of the average Lebanese household is 6709kWh, these measurements are seasonal and, in the summer, they increase by a whopping 28%, probably due to the increased use of air conditioning. [5] In addition to that, according to the Environmental Protection Agency, the average American household spends 300 gallons of water daily 12% of which are only leaked water that is wasted without any beneficial use. [6] as shown in Figure 1-1

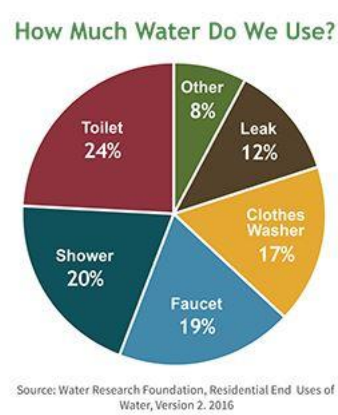

Figure 1-1 The Daily Consumption of Water

1.5 The importance of reducing consumption

There are many reasons to why being more conservative in our use of electricity and water is beneficial for our environment. Firstly, we are living in an economy ruled by scarcity, mainly because of the increasing population and the limited resources we have in our planet. So, being aware of how we use our water supply helps us in conserving as much of it as possible. In addition to that, the more we consume and waste electricity, the more the electricity that needs to be generated by factories and generators. These industrial buildings emit millions of tons of Carbon into the atmosphere resulting in the greenhouse effect and increasing global warming. The more we decrease in the use of electricity, the more we can stop factories from generating bigger amounts until enough renewable energy generators are built to replace factories that depend on natural resources like oil. According to the US Energy Information Administration, 1,619 million metric tons of carbon dioxide CO_2 were emitted by electrical power sectors. [7] Shown in Figure 1-2

CO2 emissions by U.S. electric power sector by source, 2019

Source	Million metric tons	Share of sector total
Coal	973	60%
Natural gas	619	38%
Petroleum	16	1%
Other[2]	11	<1%
Total	1,619	

Figure 1-2 The CO2 emissions of various waste materials

2 The Proposed Project

The project being proposed in this dissertation is called the ECO-Smart Home. This house is an example of how different electronic devices and sensors installed within a household can function together in synchronization in order to create a comfortable home and effective lifestyle. They function under the IOT system where they communicate either through serial communication or the internet using Google Assistant. They were applied on a miniature house of length 120 cm, width of 60 cm and height of 65 cm where different sensors were installed in order to perform a wide range of tasks required in any modern household. These sensors and actuators installed within this smart house are all used under the consideration of making the house sustainable and eco-friendly.

Moreover, it’s equipped with electronic machines that generate sustainable energy like solar panels and different sensors are used inside the house in order to reduce the consumption of electricity. As for water, there are different sensors used to manage water usage and control it without human interference. These electronic parts all work together in an effort to make the house more sustainable and eliminate human error by only depending on each other to perform the tasks required.

The house has the ability to communicate with its owner through a mobile application and a central Infrared remote inside the premises.

3 Background

3.1 History of smart homes

The idea of smart homes is not new, it has been in talk since the beginning of the 20th century. In 1984, it was first used officially by the American Association of House Builders. [8] The 20th century saw a dramatic revolution in domestic technology, which took wider attention with emergence of the first smart home concept at its end and making the unimaginable possible. It first began with the introduction of electricity into homes in the first quarter of the century. [9] This provided a new source of clean, convenient power for appliances and spurred the introduction of novel equipment for the home. This saw the rise of home appliances like vacuum cleaners, food processors, and sewing machines. With the shortage of domestic servants that the middle class were experiencing at the time, these appliances witnessed a lot of fame and spread quickly in countries like the UK where the industrial revolution was developing the country. [10] The second major leap was the introduction of information technology (IT), which opened up possibilities for exchanging information between people, appliances, systems and networks in and beyond the home, possibilities which are still being explored. [9] In the 1960s, the idea of "wiring" homes was largely famous among hobbyists and most people considered it a matter of science fiction. However, in the 1980s, manufacturers of consumer electronics and electrical equipment have been developing digital systems and components suitable for use in domestic buildings. [9] The most important are the replacement of electromechanical switching with digital switching. And in 1984, commercial interest in home automation had grown sufficiently for the National Association of Home Builders in the USA to form a special interest group called "Smart House" to push for inclusion of the necessary technology into the design of new homes. It came along with interest in the electronic fields of building electronics, architecture, energy conservation, and telecommunication. Social scientists showed no real interest in the smart home concept but it was a very promising field for computer scientists and engineers who saw the potential of this field and its great effects on our society as a whole. Following, more and more advances came in computer technology and electronics, especially in domestic use to make this field prominent in the market.

3.2 History of the environmental movement

The ideology of the preservation of the environment first appeared in the early 19^{th} century. However, it first started getting serious attention in the industrial revolution when great levels of smoke were being emitted into the atmosphere and causing significant levels of air pollution. The movement was being called the Conservation Movement [11]. But, in the 20^{th} century, this movement starting seeing more fame due to the great increase in air pollution and the disastrous catastrophes it caused like the tear in the Ozone layer. Furthermore, in the 1950s and 1960s, a new set of public concerns began to take shape and came to be called the “Environmental Movement”. This took place after the massive social and economic changes that took place in global societies after World War II. [12] As this ideology progressed, it became more important to make efforts in order to preserve our nature and wildlife, all of which were being threatened by the polluting of humans and their interference in the ecosystem. The problem didn’t stop there, as we developed, we started using so much of our resources and a new conundrum emerged and that is the need to be more conservative of our natural resources. Therefore, the ecofriendly movement started invading almost all of the working fields and daily lifestyle choices. Awareness was being raised all over the globe and people even started using it inside their houses.

People started implementing environmental designs inside their houses in an effort to save resources and electricity and make it more sustainable. This trend also transcended into the smart homes development and made it even more efficient because machine have the ability to function more efficiently and control the wastage of resources.

The idea of smart houses existed since Greek times where palaces, homes, and street layouts were designed to maximize the use of solar energy from the sun. This was used in our modern urban design. And in the future, all houses will adhere to the process of sustainability and being more energy efficient because if we don’t do anything quickly, we will not be able to fix our current environmental and economic crises.

4 Methodologies & Results

4.1 Problem Statement

To restate the problems, houses in general are not very efficient in conserving electricity and water. This is because of the inability of humans to control this aspect to a point where maximum sustainability is achieved. However, smart homes that take in consideration the environmental status, making it an ecofriendly smart house with machines controlling electrical and water gadgets and following their programming to ensure maximum sufficiency and trying to use renewable energy instead of the traditional method in an effort to make the house as sustainable as possible. So, the ECO Smart Home proposed in this dissertation contains the mentioned specs on a miniature prototype using multiple software and hardware components, all working together to make it functional.

4.2 Hardware Components

Many different types of hardware components were installed in this house and controlled by a set of microcontrollers the components include; sensors, actuators, and electronic devices.

4.2.1 Microcontrollers

The microcontrollers included in this house are the brains of it. They control all the sensors and allow for communication among all of them. They usually contain a central unit processor that governs the input and output of the device in an embedded system. [1] This CPU can be programmed using an IDE on a PC. All the microcontrollers used in this project are Arduino Microcontrollers of different types and sizes.

4.2.1.1 Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board. It has 54 digital input/output pins, of which 15 can be used as PWM (Pulse Width Modulation) outputs, 16 analog inputs, 4 UARTs (hardware serial ports), 8 communication pins (TX, RX, SCL, and SDA), a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; its connected to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. It's programmed using the Arduino IDE software. [13] A picture is shown in Figure 4-1.

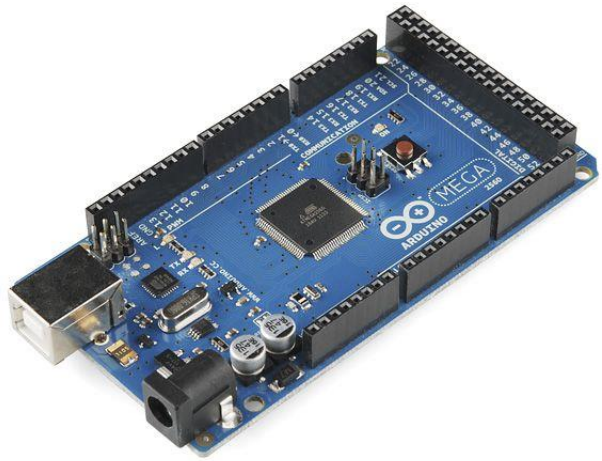

Figure 4-1 The Arduino Mega 2560

4.2.1.2 Arduino Uno Rev3

The Arduino Uno Rev3 is a microcontroller board. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; It can also be connected to a computer with a USB cable or power with an AC-to-DC adapter or battery. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Programmable by the Arduino IDE as well. This microcontroller is the best to get started with electronics and coding. It is the most used and documented board of the whole Arduino family. [13] Shown in Figure 4-2.

Figure 4-2 The Arduino Uno Rev3

4.2.1.3 Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board. It has more or less the same functionality of the Arduino Mega and Uno, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. [13] Shown in Figure 4-3.

Figure 4-3 Arduino Nano

4.2.1.4 NodeMCU

The NodeMCU Is a low-cost open source IOT platform. It is also a microcontroller, similar to the Arduino family, but; what makes it special is that its firmware is built in with an ESP 8226 WIFI system. This controller was not produced by Arduino, it was developed by Espressif Systems, but; it’s compatible with its boards and can be programmed using Arduino IDE. [14] Shown in Figure 4-4.

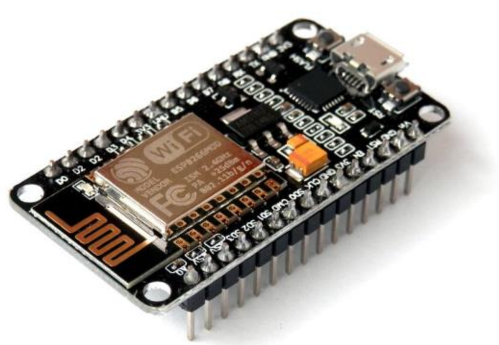

Figure 4-4 NodeMCU

4.2.2 Modules & Sensors

The sensors installed in this project were responsible for detecting all inside and outside events and stimuli and sending the information to the microcontrollers. They are present in all the functioning systems of the house and allow its function to take place. Regarding the modules, two of them were included, the motor and Bluetooth modules. They were responsible for receiving and sending information to the microcontrollers and, unlike the sensors, they don’t detect events, but; they have the ability to control actuators, other sensors, and electronic equipment.

4.2.2.1 Bluetooth Module HC05

The HC-05, shown in Figure 4-5, is an easy to use, fully qualified Bluetooth modulation designed for transparent wireless serial connection setup. It uses a 2.4GHz radio transceiver and baseband. We use the module in order to connect the application that we created to control the different devices inside the house. [15]

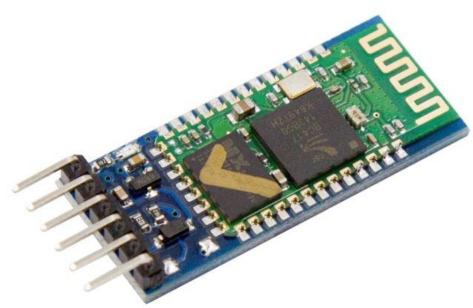

Figure 4-5 Bluetooth Module HC-05

4.2.2.2 Motor Driver Module L298n

The L298 is a motor driver, shown in Figure 4-6, is a chip that is used to give commands to motors to function. It receives logic signals and is needed to operate motors, solenoids. It has two inputs to enable and disable the particular device attached to its output. It can take up to 46V but we are giving it 12V only in this house project. [16]

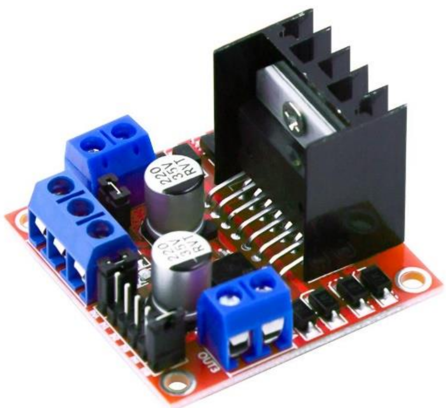

Figure 4-6 Motor Driver Module L298n

4.2.2.3 RFID Module

RFID or Radio Frequency Identification shown in Figure 4-7, is a system consisting of two main components, a transponder/tag attached to an object to be identified, and a transceiver also known as Tag/Reader. The reader can communicate with a microcontroller over a 4-pin serial communication. Also, the operating voltage of the sensor in 3.3V, so it can be easily connected to the Arduino 3.3V pin. [16]

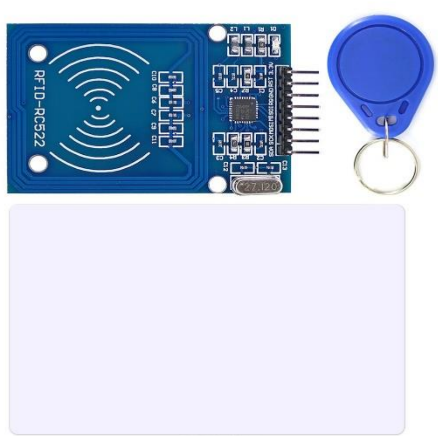

Figure 4-7 RFID RC522 Module

4.2.2.4 Relay Modules

Relays are usually included to control AC or DC powered devices like lamps, fans, or other household devices that the Arduino cannot control with its voltage limit of 5V. They operate by opening and closing a switch and transmitting current through wires into the different devices of the house. The main electricity enters through the common in COM pin, it can be the ground or VCC wire. There is a switch between the COM and the two terminals of the relay, NO (Normally Open) and NC (Normally Close), which connects the COM with one of these terminals based on the status of our device, whether it should be HIGH or LOW. [16] There are different types of relay modules, there are one, two, four, or eight channel relays, some are shown in Figure 4-9 and Figure 4-8.

Figure 4-9 2-Channel Relay Module

Figure 4-8 4-Channel Relay Module

4.2.2.5 Humidity & Temperature DHT11 Module

This sensor is used to measure the temperature and humidity and portray the readings. It uses a capacitive humidity sensor; it has two electrodes with moisture holding substrate sandwiched between them to measure humidity. As for the temperature, it contains a thermistor to measure the surrounding air. This module is simple to use but requires careful timing to capture data. [16] Show in Figure 4-10.

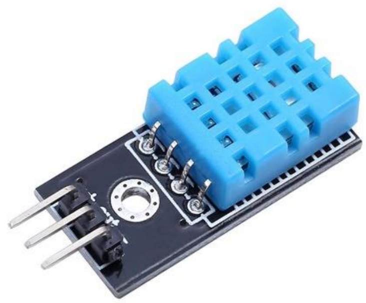

Figure 4-10 DHT11 Module

4.2.2.6 Water Level Sensor

This sensor brick, shown in Figure 4-11, is designed to detect and measure the water level. which can be used in sensing rain fall, water level, and even liquid leakage. It has parallel conductors that act together as a resistor whose resistance vary according to the water level. The more water present, the higher the conductivity which will result in lower resistance and vice versa. [16]

Figure 4-11 Water Level Sensor

4.2.2.7 Soil Moisture Sensor

The sensor shown in Figure 4-12, is manufactured to measure soil moisture. It is placed inside the soil and it detects the water level inside the soil the same way that the water level sensor detects it. It contains a resistor that is inversely proportional to the soil moisture and outputs the reading to a microcontroller in order to take the necessary

Figure 4-12 Soil Moisture Sensor

action. [16]

4.2.2.8 Rain Sensor

The sensor shown in Figure 4-13, is designed to be placed on surfaces to detect rain water. The way it works is similar to that of the water level and soil moisture sensors but this sensor is placed horizontally and not vertically and its module is separate from the sensor. [16]

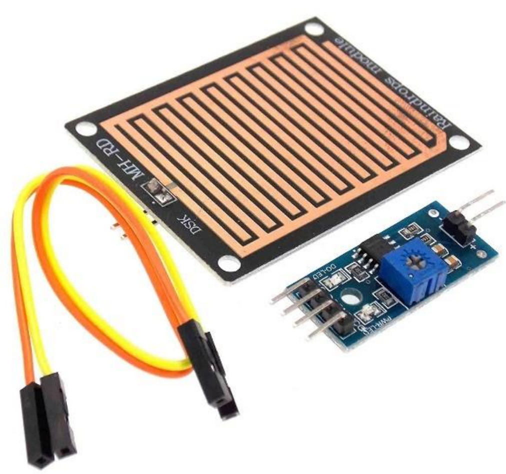

Figure 4-13 Rain Sensor

4.2.2.9 Flame Sensor

A flame detector is a sensor designed to detect and respond to the presence of a flame or fire. Responses to a detected flame depend on the installation, but can include sounding an alarm, deactivating a fuel line, and activating a fire suppression system. In this project, it sounds an alarm, cuts off the electricity, and signals the pump to pump water through sprinklers. There are different types of flame sensors, some detect ultraviolet light, others use thermal imaging but the one used in the prototype uses an infrared (IR) detector to detect fires. [17] This sensor is shown in Figure 4-14.

Figure 4-14 Infrared Flame Sensor

4.2.2.10 Gas & Smoke Sensor MQ2

The MQ series gas sensors are very commonly used in Arduino projects. They detect a range of different gases including; LPG, Smoke, Alcohol, Propane, Hydrogen, Methane, and Carbon Monoxide concentrations in the air from 200 to 10000 ppm. The sensor is contained in two layers of fine stainless-steel mesh to ensure that the sensor will not cause an explosion, as we are sensing flammable gases. It also filters out other gases and suspended particles in the air. [16] The sensor used is the MQ2, shown in Figure 4-15.

Figure 4-15 MQ2 Gas & Smoke Sensor

4.2.2.11 PIR Sensor (HC-SR501)

The PIR sensor, shown in Figure 4-16, is a motion sensor designed to detect movement by detecting fluctuations in the IR signals. It has a polyelectronic sensor and lens that focuses the infrared light into it. This sensor doesn't light when it detects IR signals but instead, it looks for a change the signals it detects, so if a human or animals passed by it, it first detects positive IR signals but waits a bit and signals the same place, if it detects negative signals then the object movement so, it signals the lights to turn on. [16]

Figure 4-16 PIR Motion Sensor (HC-SR501)

4.2.2.12 Touch Sensor

The touch sensor, shown in Figure 4-17, focuses on detecting touch and it functions as a switch, if the sensor is touched, it sends a HIGH signal and if it's touched again it sends a LOW signal. It is usually used instead of a button to make it look neater. [18]

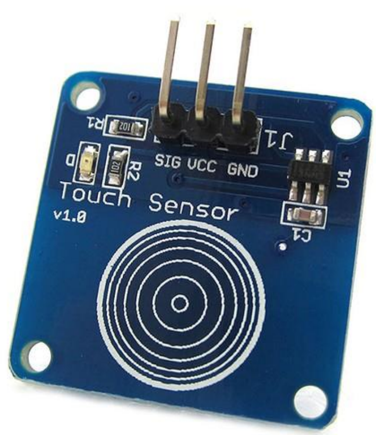

Figure 4-17 Touch Sensor

4.2.2.13 IR Receiver

The IR receiver is a device that scans IR signals in a specific frequency range and converts them to electronic signals on its output pins. They are usually used to transmit commands, and in this prototype, it is used as a command board used to control the sensors inside and outside the house. It consists of a small sensor placed and connected to the microcontroller and remote-control device. [19] A picture of both is shown in Figure 4-18.

Figure 4-18 The IR receiver and its remote-control device

4.2.3 Actuators

The actuator is a part of a device or machine that helps it in achieving physical movement by converting energy, that can be electrical or hydraulic, into mechanical force. Almost all motors are actuators and, in this project, multiple actuators were included to enable the movement of multiple parts like doors, lids and liquids. Pumps, DC Motors, and a Stepper Motor were included in different systems.

4.2.3.1 Pump

The pump is a device that raises, transfers, delivers, or compresses fluids and pump it through certain mediums. Three pumps were used in order to pump water to perform certain functions for different systems. A picture of the pumps used are shown in Figure 4-19.

Figure 4-19 Pump

4.2.3.2 DC Motor

The DC Motor is a (direct-current motor), shown in Figure 4-20, is an electrical machine that rotates by converting direct current into mechanical energy. They usually generate force using magnetic fields and they are the first type of motors to be used widely. Two DC Motors were used in the making of the house. [20]

Figure 4-20 DC Motor

4.2.3.3 Stepper Motor

The stepper motor 28BYJ-48 with ULN2003 Driver is a great motor of position control. It is a special brushless motor that divides a full rotation into a number of equal “Steps”. It has countless applications and can be found in desktop printers, 3D printers, and anything else that requires precise measurements. Usually, this motor comes with a ULN 2003 base driver board, which is one of the most common motor driver ICs. The motor is connected to the board and the board is wired to the microcontroller. [16] A picture of the motor and its driver are shown in Figure 4-21.

Figure 4-21 Stepper Motor 28BYJ-48 with ULN2003

4.2.3.4 Servo Motor

The Servo Motor SG90 is a smart kind of motor that contains a central unit that receives the signal form the Arduino, analyzes its speed and direction, and then sends it to the motor to perform the command. Usually, this series of motors can rotate approximately 180 degrees. [16] The picture is shown in Figure 4-22.

Figure 4-22 Servo Motor SG90

4.2.4 Electronic Components

These devices, differ in function, definition, and control range. They are components for controlling the flow of electrical currents for the purpose of information processing and system control. They include transistors, diodes, boards, and more.

4.2.4.1 LED Light

LED stands for Light Emitting Diode. It produces light 90% more efficiently than incandescent light bulbs. They contain a microchip that allows current to pass through it and it illuminates the tiny light sources we call LEDs and the result is visible light. [21] In this project, LEDs of different voltages are used a 5V LED, shown in Figure 4-25, and a 12V LED, shown in Figure 4-24. There is a third type of LEDs called RGB LED, shown in Figure 4-23, which can change its color into three different colors red, green, and blue as well as combining these lights to create almost every light color possible. It usually has a driver in order to control the color change. [22]

Figure 4-25 5V LEDs that can come in a range of different colours; green, red, and yellow.

Figure 4-24 12V LED that also comes in different colours and can come in strings.

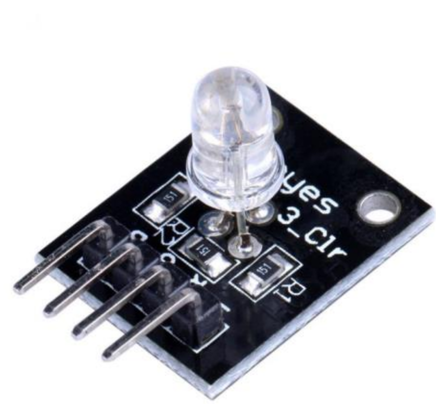

Figure 4-23 RGB Light

4.2.4.2 Breadboard

The breadboard, shown in Figure 4-26, is a solderless device for temporary prototype with electronics and test circuit designs. Most electronic components in electronic circuits can be interconnected by inserting their leads or terminals into the holes and then making connections through wires where appropriate. The breadboard has strips of metal underneath the board and connect the holes on the top of the board. It comes in different sizes, large, medium, and small. [23]

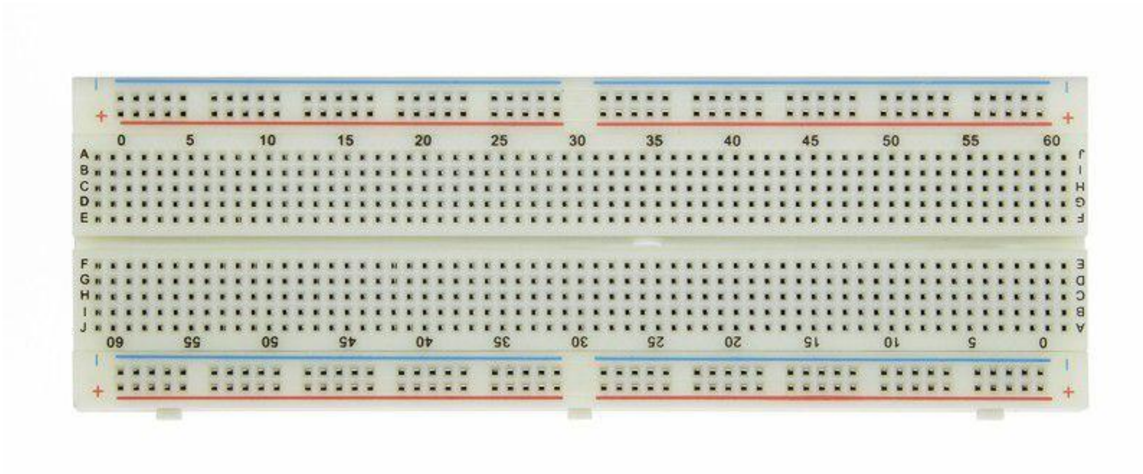

Figure 4-26 The Breadboard

4.2.4.3 Fan

The fan, shown in Figure 4-27, is a DC powered device that works on blowing cool air into computer cabinets and rooms. They come in multiple sizes and can cool individual chips inside electronic devices. Fans of multiple sizes were used in this prototype to cool rooms and suck harmful gas concentrations outside rooms. [24]

Figure 4-27 The electric fan

4.2.4.4 Solar Panels

Devices that are used to absorb the sun rays and convert them into electricity or heat. Most solar panels are made up of special crystalline silicone to perform the process photovoltaic cells absorption that generate electricity. Not only do they transfer electricity, but also, they can be used to charge batteries. [25] A concept is shown in Figure 4-28.

Figure 4-28 Solar Panel

4.2.4.5 Buzzer

A buzzer is a small yet efficient component to add sound features to the project. It’s a small component having only two pins. It is a widely used component in many systems. It has two types; one produces a continues sound and the other produces a sporadic sound and it is the one used in this project. [26] A picture of the buzzed used is shown in Figure 4-29.

Figure 4-29 Active Passive Buzzer

4.2.4.6 Button Switch

The button, shown in Figure 4-30, is an electronic switch that has only one function, it cuts off electricity and connects it. It usually has two types, NO (Normally Open) and NC (Normally Close), one for connecting and the other for cutting. The button used is a NO button used to bring back electricity. [27]

Figure 4-30 Button Switch

4.2.4.7 OLED Display

The OLED display is an Organic Light Emitting Diode, model number SSD1306, with a 0.96-inch display and 128x64 pixels, shown in Figure 4-31. It doesn’t require a back light like a digital display and results a nice contrast visual. Its pixels consume energy only when they are on so the OLED consumes less power than other displays. It has only four pins that are connected to the microcontroller (Arduino) and they communicate with it using the l2C communication library on the IDE. [28]

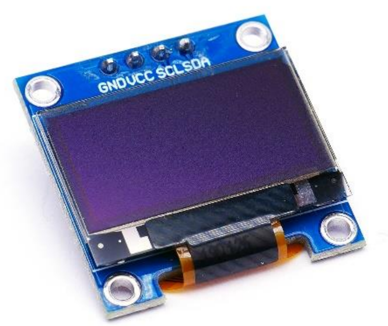

Figure 4-31 0.96-inch OLED Display

4.2.4.8 LCD Screen

The LCD is an electronic display which uses liquid crystal to produce visual images. The component used in a 16x2 LCD display that has 16 pins that are connected to the Arduino. [29] The display used is shown in Figure 4-32.

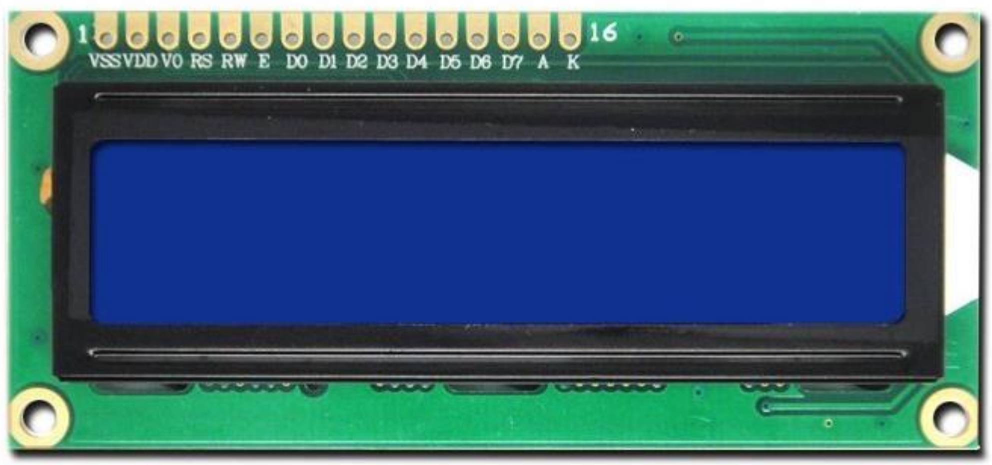

Figure 4-32 16x2 LCD Screen

4.2.4.9 Jumper Wires

The jumper wires, shown in Figure 4-33, are electrical wires that have three different types; male-male, male-female, and female-female. They also come in multiple lengths 10cm, 20cm, and 30cm. All the different types and lengths were used in the smart home.

Figure 4-33 Jumper Wires

4.3 Design Plan and Wiring

The design for the house's electrical system is composed of multiple electrical systems, each is responsible for a certain function that is inside and outside the house. These systems are mostly serial communications, but; some of them communicate using Bluetooth and others using the internet. The systems implemented in the house include; Security System, Fire System, Irrigation System, Water Level System, Rain Detection System, Gas and Smoke Leakage System, Heating and Cooling System, IR Receiver System, Motion Detection System, and a Lighting System. The wires of all the sensors and actuators were all passed through a pre-prepared electrical plan, the wires of the outside were placed under the house by clearing space for them in the foam board under the house, after that, all the wires that reached the house and that are in the house were all gathered in two shafts in different sides of the house and directed upward to the attic level were the central control unit of everything resides.

4.3.1 Serial Communication

Serial communication basically means that all the communication and connection between the different electronic devices are passed through electrical wires. It is the most used way of communication in the project because all of the interfacing is done in a small space so wires prove to be more effective than its wireless counterparts.

4.3.1.1 Water Level System

This system is controlled by the main Arduino Mega and is responsible for detecting the water level inside the pool. It measures the water and based on its level it sends a signal to the Arduino informing it of the water level if its high, medium or low, the Arduino command the pool pump to pump water or to stop pumping based on its programming. The water level sensor takes three pins, GND (Ground), VCC (Power), and Signal. The signal pin is connected to the analog pin A1 in the Mega, the ground pin in the sensor is connected to the ground pin in the microcontroller, and the power is connected to the 5V pin in the Arduino. As for the pump, its connected to a relay, the positive to the NO (Normally Open) of the relay and the negative is connected to the 12V battery. Finally, the relay is connected to the Arduino by the signal pin which goes to the digital pin 22, the ground to the ground, the positive to the 5V pin, and the (COM) common out of the relay is connected to the battery and other relays. Simulation is shown in Figure 4-34.

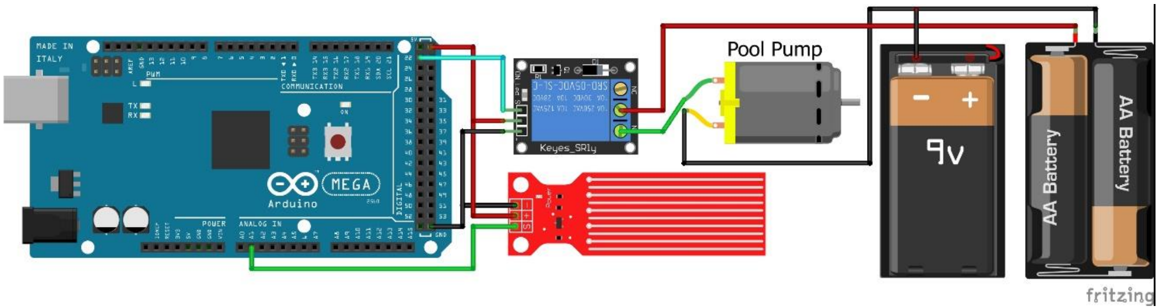

Figure 4-34 Water Level System

4.3.1.2 Irrigation System

The irrigation system implemented is a smart farming system responsible for monitoring the soil moisture level. It is controlled by the main Arduino Mega and it functions by measuring the soil moisture through the sensor placed and signaling the Arduino with the level of water in the soil and signaling it to command the irrigation pump placed to either pump water or stop pumping. Its communication is very similar to the water level system. The signal pin is connected to the analog A3 pin in the Mega, the ground to the ground and the VCC to the 5V. The irrigation pump is also connected to a relay, by; connecting the positive to the NO and the negative to the 12V battery. The relay's signal is connected to the 23-digital pin in the microcontroller and its ground and power are also connected to the Arduino's ground and 5V pins respectively. The Out COM of the relay is connected to the positive 12V pin. Simulation shown in Figure 4-35.

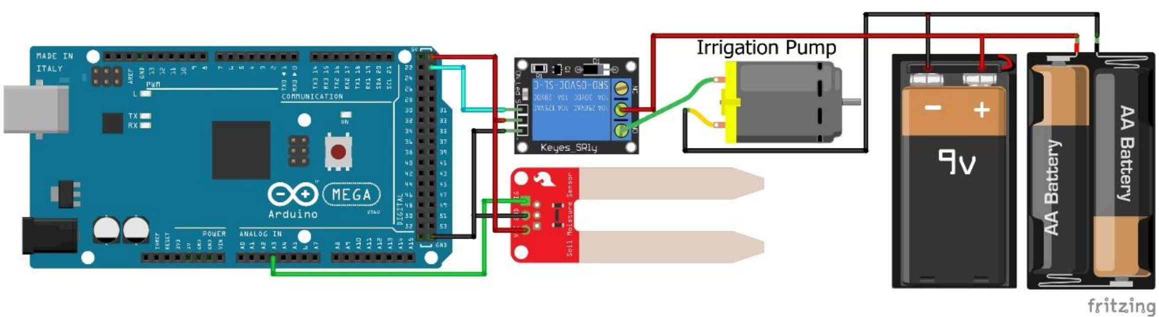

Figure 4-35 Irrigation System

4.3.1.3 Security System

The security system is responsible for the entrances of the house, the main gate entrance and the door entrance. They are locked and controlled through an RFID lock. Regarding the gate's RFID, it's responsible for reading the RFID tag and signaling the microcontroller to determine whether its code is correct in order to decide whether to open the gate or not. It is connected to the Arduino Nano, the RST pin in the sensor is connected the D9 in the Nano, the MISO is connected to the D12, the MOSI to the D11, the SCK to the D13, the SDA to the D11, the VCC to the 3.3V pin, and the ground to the ground in the nano. If the Nano reads the correct code, it commands the servo controlling the gate to open and if the code is wrong, it doesn't signal it. A picture of the connection is shown Figure 4-36.

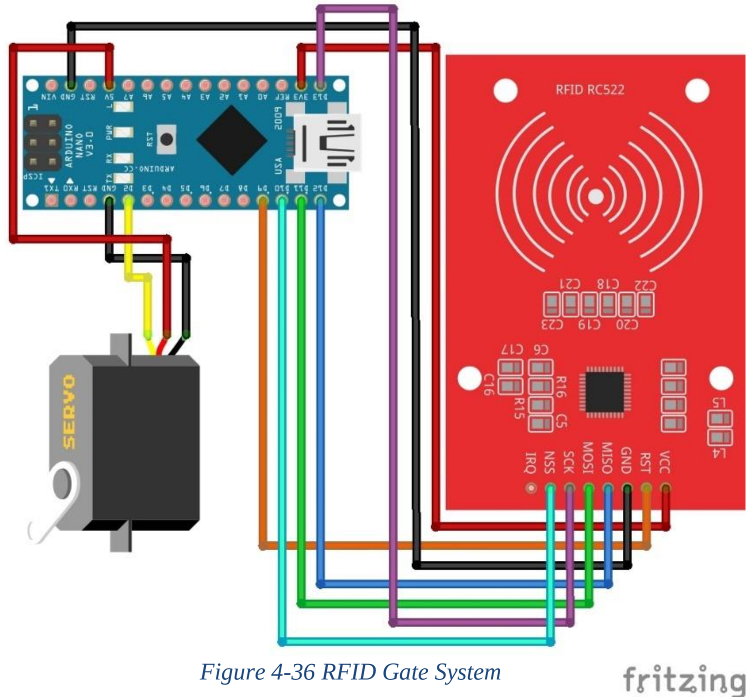

Figure 4-36 RFID Gate System

As for the RFID of the main door entrance, it is composed of four components, an RFID reader, an LCD screen, RGB light, and a DC motor to control the door along with a motor driver to control the motor. The microcontroller here signals the RGB to the light Red and the screen to output "Access Denied" if it receives a wrong code from the RFID reader and it signals the RGB to light to light green, the screen to output "Welcome Home", and the door to open if the code is correct. The RFID sensor is connected to the Arduino Uno by; RST is connected to the 8 pin in the Uno, MISO to the 9 pin, MOSI to the 10 pin, SCK to the 11 pin, SDA to the 12 pin, VCC to the 3.3V pin, and ground to the ground. The rest of the components are connected to the second Arduino Mega. The Uno communicates with the Mega by connecting the 0 (RX) and 1 (TX) pins in the Uno to the

0 (TX) and 1 (RX) of the Mega respectively, their grounds are also connected. The motor driver is connected the Mega by; END, IN 1, and IN 2 pins to the 34, 36, and 38 pins of the Arduino respectively and the ground of the driver is connected to the Mega and a 12V battery and the VCC to the positive of the 12V battery. The DC motor is connected to the motor driver's outputs. Regarding the RGB light, its ground is connected to the mega, red pin to the 22 pin and the green pin to the Mega pin 23. The screen's pins are connected to the 40, 42, 44, 46, 48, and 50 pins of the Arduino Mega. The simulation is shown in Figure 4-37.

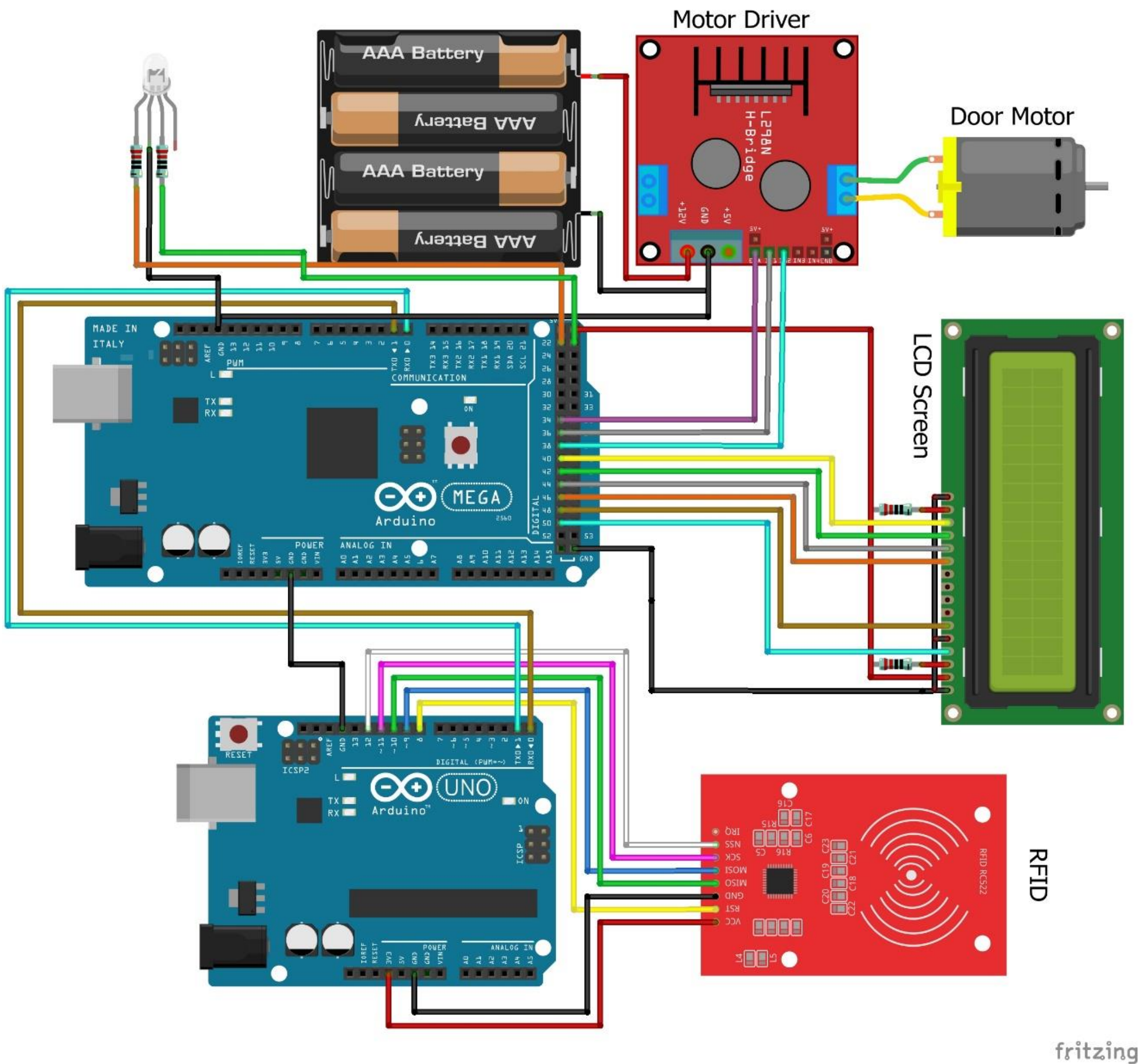

Figure 4-37 RFID Main Entrance System

4.3.1.4 Fire System

The fire system, shown in Figure 4-38, is one of the biggest and most important systems in the house. It is responsible for detecting indoor fires and putting them out. This system consists of flame sensors, servo motors, and RGB lights installed in each room. It also contains a buzzer to sound an alarm, a relay to cut off the electricity, a switch to reset the electricity, and a pump in order to pump water through the sprinklers in each room. When the flame sensor reads a large thermal signature, it signals the main Arduino Mega to command the relay responsible for cutting off the electricity in such situations, open the servos door to allow water to pass through, the RGB light to light red in the room where the fire is, and the relay opens turning on the pump and pumping water through the pipes as well as sounding the buzzer alarm. A switch is installed to turn the electricity back on manually after the fire is dealt with. This system works the same for the 5 flame sensors inserted. The GND and the VCC pins of all the components are united using the breadboard and connected to the ground pin and 5V pin of the Mega. As for the signal pins, each of the flame sensors were connected to an analog pin and the five servos and RGBs were connected to multiple digital pins. The signal button of the relay was connected to a digital pin in the Mega. As for the pump, its connected to a relay the same way the previous systems were connected.

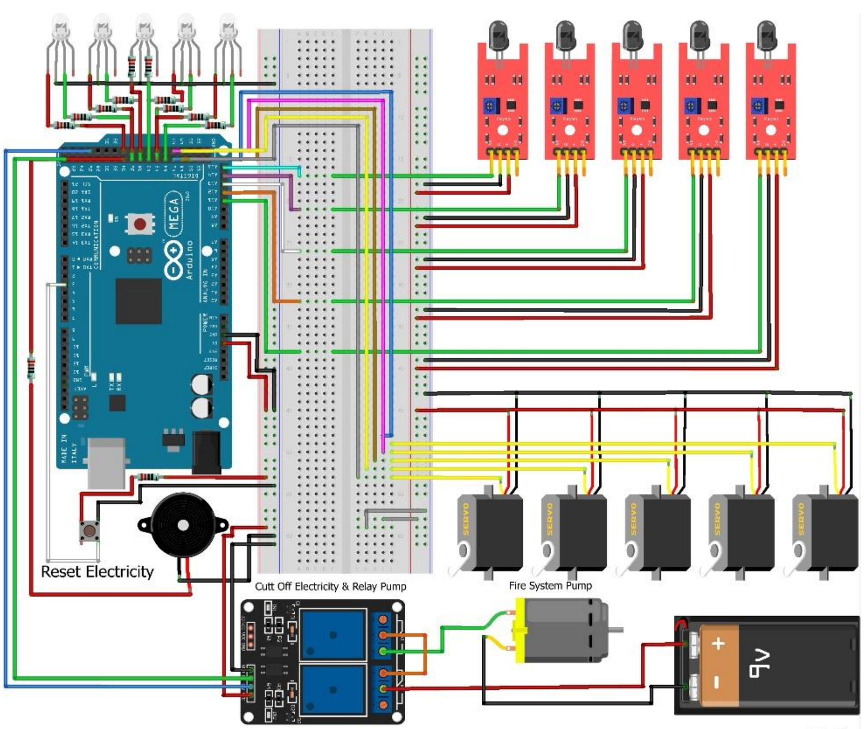

Figure 4-38 Fire System

4.3.1.5 Cooling & Heating System

The cooling and heating system shown in Figure 4-39, is responsible for controlling the atmosphere inside the living room. It’s connected to the main Arduino Mega and is composed of a DHT sensor, fan, an OLED screen, and a heater represented by a 5V LED due to the boundaries of the house. The sensor read the temperature and humidity inside the living the room and signals the Mega the results and the microcontroller acts based on these results, if the temperature is high, it will signal the fan to turn on, and if the temperature is low, it will signal the heater to turn on. The signal pin of the DHT sensor is connected to the A3 pin of the Mega, its ground and power are united with the grounds and powers of the OLED screen and the 5V LED by a breadboard and connected to the ground and 5V power of the Arduino. As for the OLED pins, its SCL and SDA are connected to the 21 and 20 pins respectively. The relay’s signal is connected to the 32 pin and the 5V LED’s pin is connected to pin 43. Regarding the fan, its negative is connected to a 12V battery and its positive is connected to the NO of the relay.

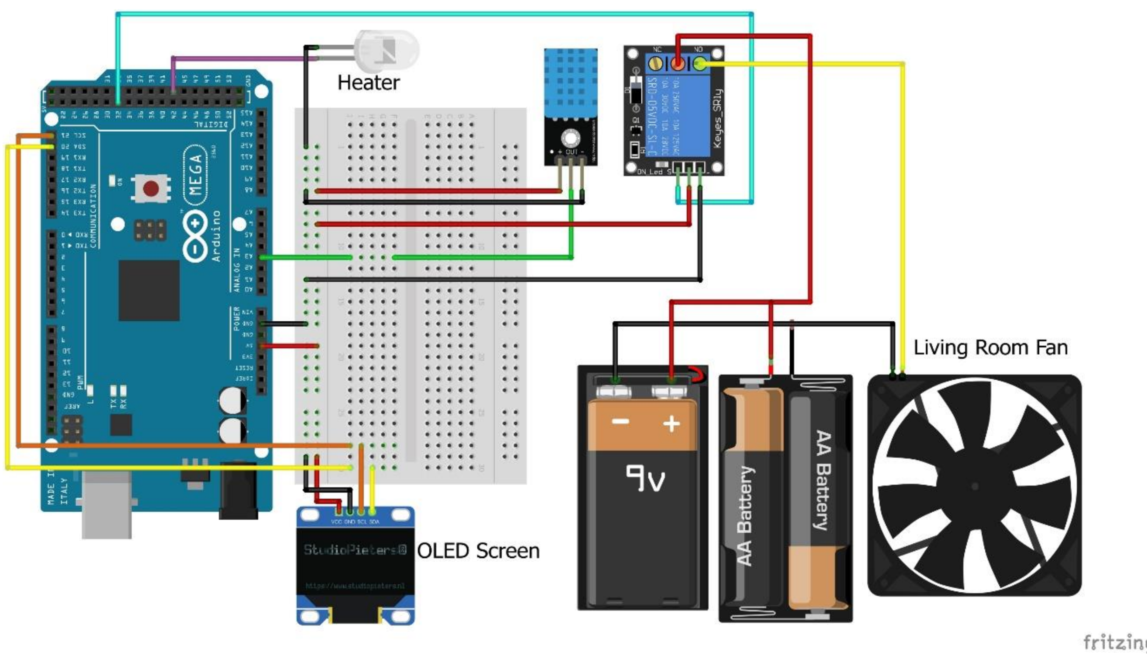

Figure 4-39 Cooling & Heating System

4.3.1.6 Gas & Smoke Leakage System

The gas and smoke system are installed inside the kitchen and is responsible for detecting any high concentrations of harmful gas materials. It also communicates with the main Arduino Mega signaling it of any significant increases. It's composed of an MQ2 gas sensor, a fan, and the buzzer. The Arduino turns the fan on when it receives high signals allowing air to flow in more easily and sucking out the gaseous material thus decreasing its concentration and not causing any suffocation. The signal pin is connected to the analog A0 of the Arduino pin, the signal pin of the relay controlling the fan is connected to the 33 pin of the Arduino. The ground and power of the sensor, buzzer, and relay are connected to the ground of the Mega and the 5V pin respectively. As for the fan, its ground is connected to the 12V battery and its VCC is connected to the NO of the relay. The relay's common is connected to the positive power of the battery. A simulation is shown in Figure 4-40.

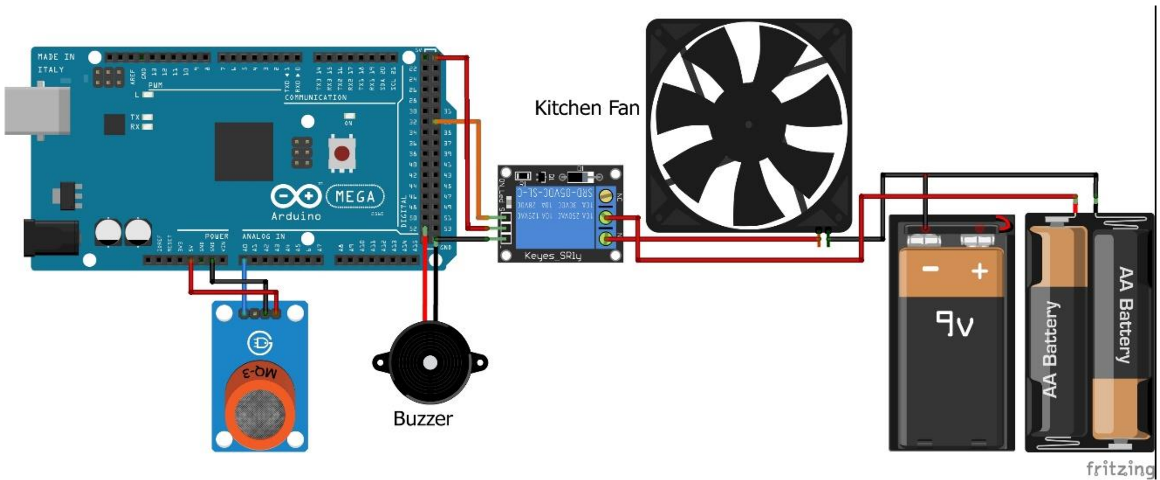

Figure 4-40 Gas & Smoke System

4.3.1.7 Lighting System

The lighting system is a small system responsible for lighting the globe light in the bedroom. Its composed of only a touch sensor and a 5V LED. As shown in Figure 4-41, the touch sensor's signal pin is connected to digital pin 44 of the main Mega and the its GND and VCC are connected to the GND and 5V. The globe's signal pin is connected to the to the 45 pin of the Arduino. When the sensor is touched it switched the light on or off based on its previous state.

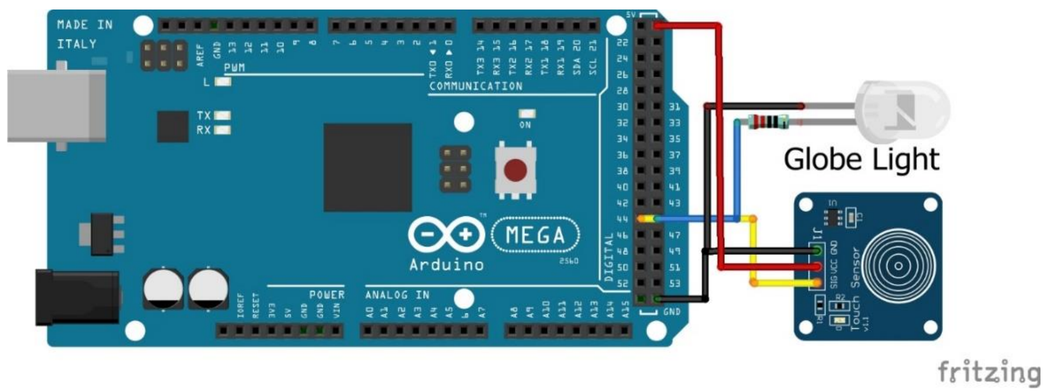

Figure 4-41 Lighting System

4.3.1.8 Motion System

The motion system is implemented in the bathroom and its function is to detect any motion and turn on the lights. It consists of a PIR motion sensor, a relay, and 12V LED lights. The PIR sensor detects motion and sends it to the main Mega and the mega orders the relay to turn the lights on. The signal pin of the PIR is connected to the pin 48, the GND to the GND, and the VCC to the 5V. as for the relay, its connected to the 25 pin, GND to GND and VCC to 5V. The ground of the LED is connected to the battery and the power to the NO. The COM of the relay is connected to the positive of the battery. Simulation shown in Figure 4-42.

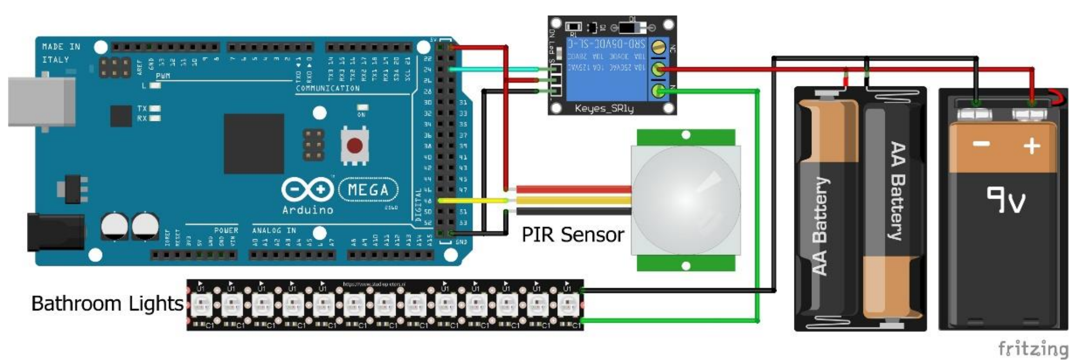

Figure 4-42 Motion System

4.3.1.9 IR Receiver System

This system is the biggest system in the house and it allows the person to control multiple aspects of the house. This system has control over all the house lighting, the garage door, the bedroom curtains, the three pumps, the two fans installed, and the LEDs symbolizing the coffee machine and the heater. This system functions by setting an IR receiver which receives signals from its remote control. Based on the button, it sends a signal to the main Mega and the microcontroller analyzes the button and performs its preprogrammed function by commanding the relays to switch open or close. All the grounds and powers of the relays, stepper motors, and 5V LEDs were unified using a breadboard and connect to the Arduino GND and 5V. The grounds of all the other components were also unified and connected to the negative of the 12V battery. The positive for every piece was connected to the NO of the relay and the relays COMs were unified as well and connected to the positive battery wire. All the signal wires of the relays were connected to digital pins on the Arduino with the assistance of the breadboard as shown in Figure 4-43.

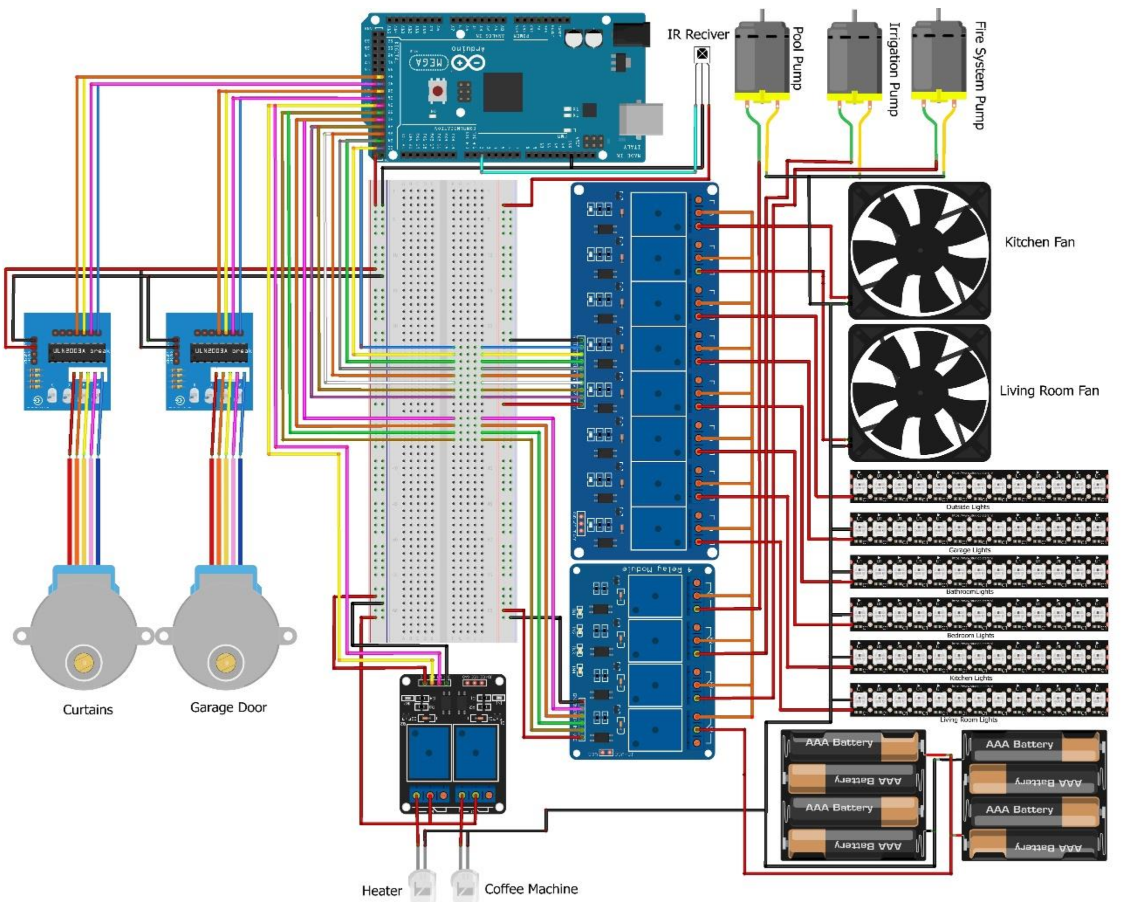

Figure 4-43 IR Receiver System

4.3.1.10 Rain Detection System

The rain detection system's function is to detect when it is raining and send signals to the main Mega in order to close the swimming pool door. It consists of a rain detector sensor, a motor driver, a relay, and a DC motor. When the Mega receives signals that it is raining, it commands the motor driver to close the pool's door and when the rain stops it open it. The rain detector is connected to a special module with a GND and VCC connection and the module is connected to the Arduino Mega by a GND and VCC also to the GND and 5V as well as a signal put to pin number 2 in the Arduino. The motor driver's IN3 and IN4 are connected to pin numbers 49 and 50 respectively its ground is unified with the Arduino and a 12V battery. The positive 12V pin on the driver is connected to the positive battery wire. Finally, it controls the DC motor by connecting two out pins to the positive and negative wires of the motor. Simulation shown in Figure 4-44.

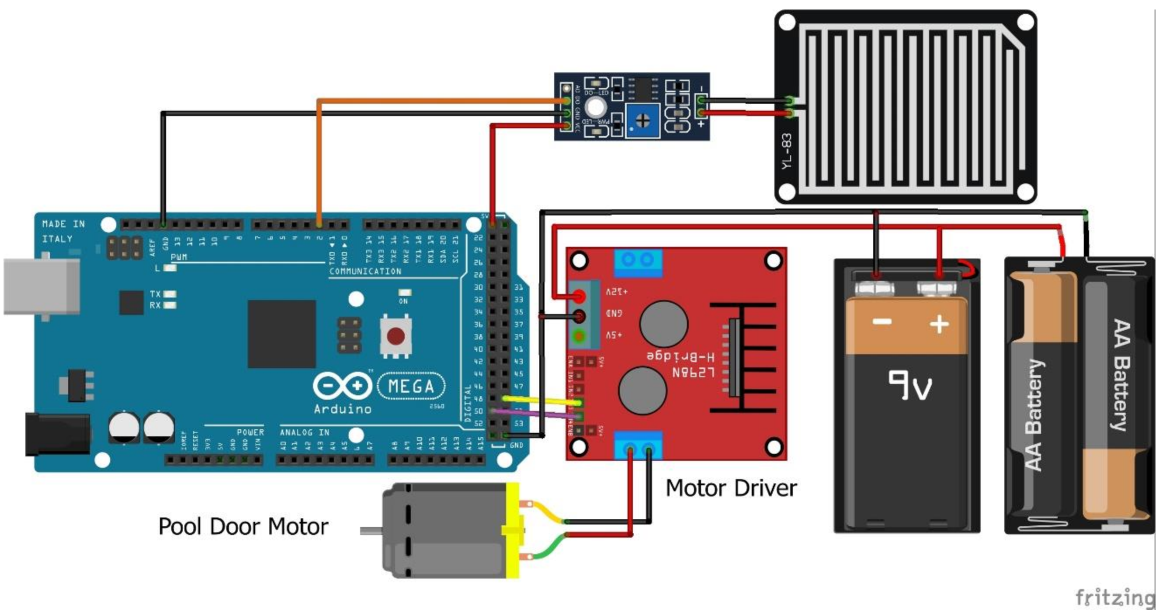

Figure 4-44 Rain Detection System

4.3.2 Bluetooth Communication

Bluetooth communication is one of the most efficient ways of communication because it fast, secure due to its point to point communication without outside interferences. This form of communication was implanted in the house by allowing communication between the microcontroller and house residents through their mobile phones. The person with the special made house app installed on their phone can connect to the Bluetooth module installed and he or she have the power to control every piece of electronic equipment running the house. Also, they can monitor certain sensors like the DHT, soil moisture, and water level. The Bluetooth module HC05 installed allows smooth connection to the mobile phone and sends and receives data form the device and send it to the microcontroller to act accordingly. This ensures that if something malfunctioned or the user wanted to change something, he/she can do so with the click of a button and send to the central command unit in the attic. The module is connected to the main Arduino Mega using serial communication, the GND and VCC are connected to the GND and 5V, and the TX and RX of the Bluetooth are connected to TX (1) and RX (0) of the Arduino. Simulation shown in Figure 4-45.

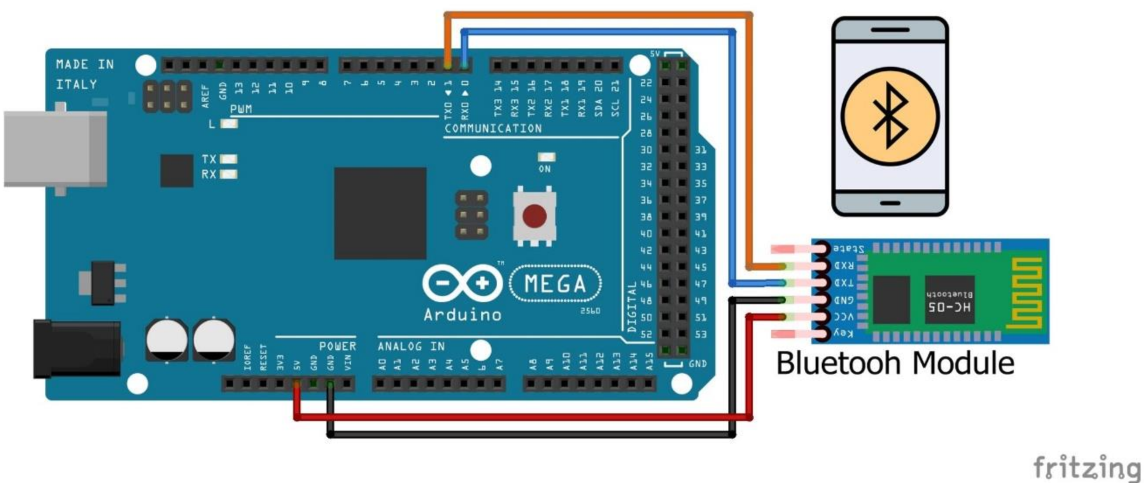

Figure 4-45 Bluetooth System

4.3.3 Internet Communication

The internet communication is a method of communication that allows monitoring and control of the farthest range because its connected to the world wide web. It is the most effective way to control your house when you are far away from it. This form of communication is simulated through this house by controlling the house's logo lights. It is also made possible by using a mobile application that is specially made and a NodMCU microcontroller. This type of microcontrollers receives its signals from the internet and control other components. In the house prototype, the NodMCU is connected to the relay controlling the house using serial communication, the D0 pin is connected to the relay's signal pin, the GND and 5V are connected to the GND and VCC of the relay. The relay is connected to the light by connecting its NO to the light's positive pin and the negative pin of the light is connected to the GND of the battery. The internet component used to send signals is called Google Assistant, which receives voice commands from the user and send them, more information on the matter will follow in the software design part. A simulation of the communication is shown in Figure 4-46.

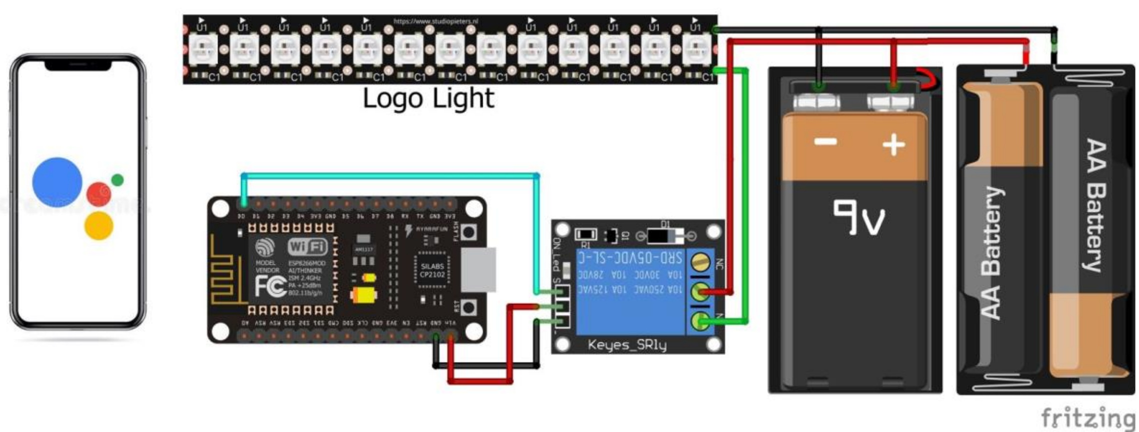

Figure 4-46 Internet Communication

4.4 Software & Design

All of the electronic components included are controlled by the five microcontrollers installed. These devices were programmed by the Arduino IDE in order to perform the specified tasks and be able to analyze all the signals received from the different sensors. Each system had its own code and they were all unified in five programs and uploaded to the different microcontrollers. The Arduino IDE code is divided into three main parts. The first part is where libraries are included and devices are defined as “int, double, char, etc…”. The second part is the setup of the program where devices’ pinModes are specified as INPUT or OUTPUT. Finally, the third part is where the program is written inside a continues loop.

4.4.1 Main Arduino Mega

This microcontroller included almost all of the systems implemented in the smart home including; Water Level System, Irrigation System, Fire System, Cooling and Heating System, Lighting System, Motion System, Gas & Smoke Leakage System, Rain Detection System, and the IR Receiver System. Flowcharts of the systems were created using Raptor and will be included in this dissertation.

4.4.1.1 Water Level System

The sensor was defined as an “int” with analog pin A1 in the Arduino, the pool pump was defined as “int” taking digital pin 22. The sensor’s pinMode was defined as an INPUT to send data to the Mega. As for the pump, its pinMode was defined as an OUTPUT to receive commands from the Arduino and perform its function by turning the pump on or off. Inside the third part, a nested if/else statement was opened with 4 conditions for the level of water inside the people based on the reading of the sensor. The first condition is that if the analogRead of the sensor is less than 25, the pump will turn on and the water level will be displayed as empty, the second condition is when the sensor level is greater than 25 and less than or equal to 275, the pump will stay and the water level will be low. The third condition is when the sensor’s level is greater than 275 and less than or equal to 330, the pump will stay on but the level will be printed as medium. Finally, the last condition is that if the water level exceeds 330, the pump turn off and the level will be printed as full. Flowchart of the system shown in Figure 4-47.

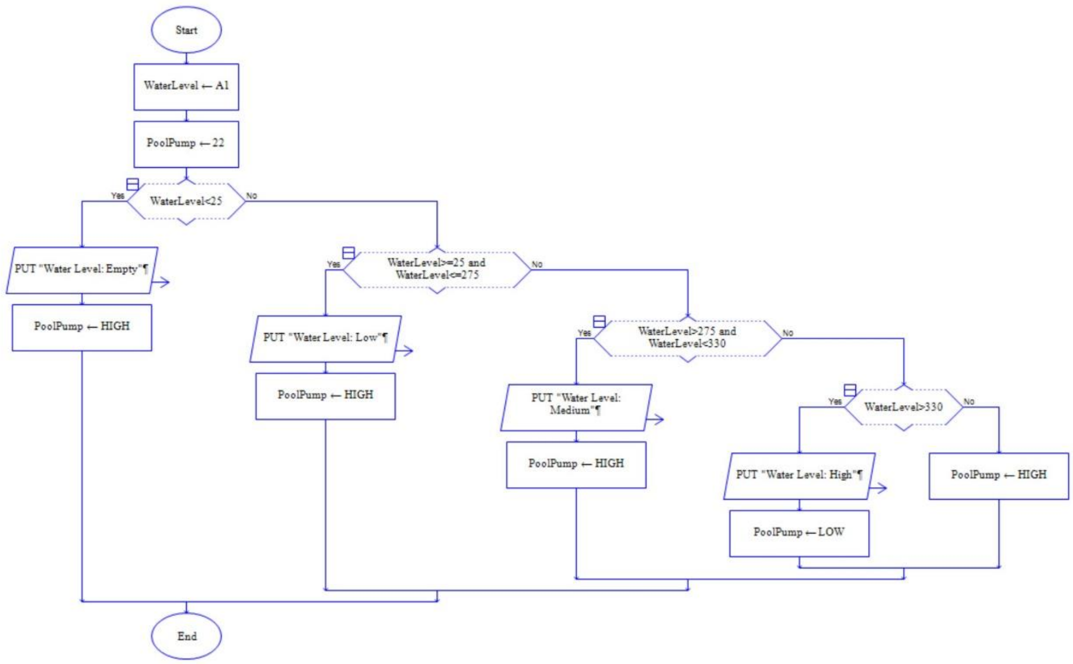

Figure 4-47 Water Level System Flowchart

4.4.1.2 Irrigation System

The sensor was defined as an "int" with analog pin A3 in the Arduino, the irrigation pump was defined as "int" taking digital pin 23. The sensor's pinMode was defined as an INPUT to send data to the Mega. As for the pump, its pinMode was defined as an OUTPUT to receive commands from the Arduino and perform its function by turning the pump on or off. Inside the third part, an if/else statement was included, if the soil moisture is greater than 50, the pump will turn on, else, the pump will stay off. Flowchart shown in Figure 4-48.

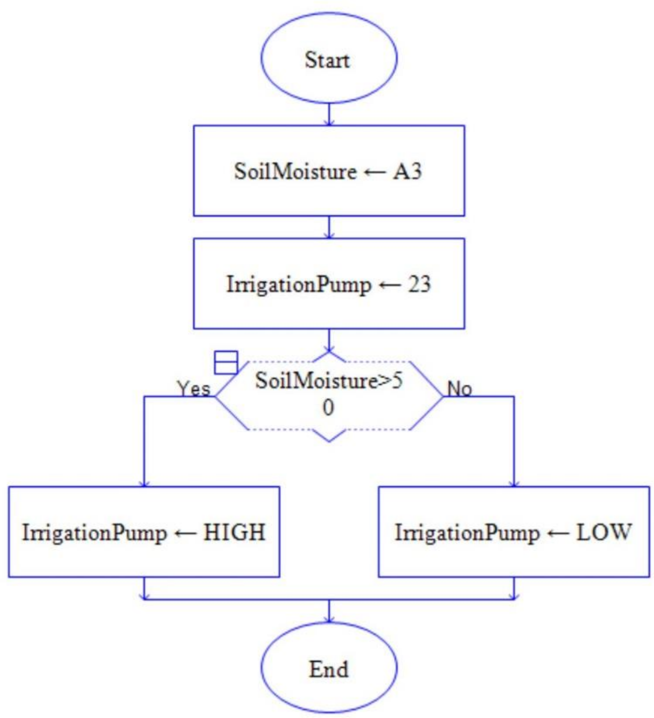

Figure 4-48 Irrigation System Flowchart

4.4.1.3 Fire System

An example of two fire sensors and their components will be included in the following scheme and flowchart, shown in Figure 4-50 and Figure 4-49. A library called <servo.h>[1] was included to allow the servo to move. The two sensors were defined as “int” with analog pins A14 and A15 in the Arduino, the fire system pump was defined as “int” taking digital pin 31. A variable called “SensorThreshold” was defined “int” with initial value of 150. Also, the buzzer included was defined as “int” with pin number 52 and the RGB was defined as “int”; Bedroom Red on 38, BedroomGreen on 39, LivingRoomRed on 42, LivingRoomGreen on 43 where all the green RGBs are always on unless a fire broke out. Regarding the cut off relay, it was defined on pin 30 and the switch on pin 2. The button state of the switch was defined as 0. The sensor and the switch’s pinMode were defined as INPUT. As for the pump, buzzer, and RGB their pinModes were defined as an OUTPUT. Inside the third part, a nested if/else statement was included of two conditions, if one of the sensor’s reading exceeds the value of the sensor threshold; the RGB where the fire broke out will turn Red, the Buzzer will sound the alarm and the relay will cut the electricity. These conditions are repeated for all the if/else statements in the different rooms. The switch will be pressed after the fire is taken care of and the electricity is safe to come back on.

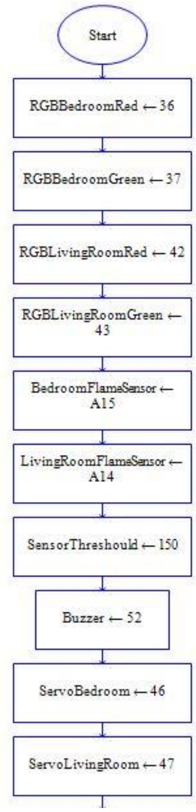

Figure 4-49 Fire System Identities Flowchart

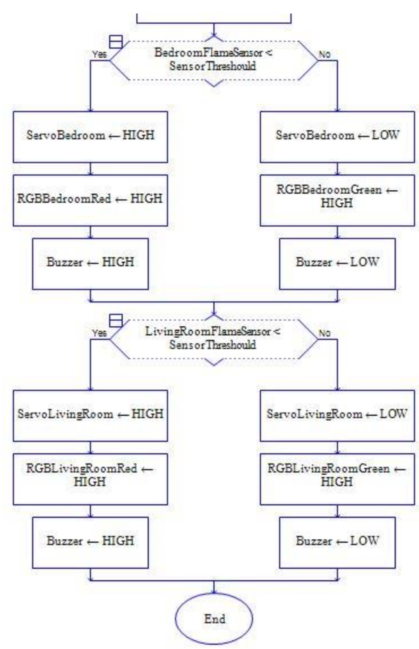

Figure 4-50 Fire System Function Flowchart

[1] Arduino Library Allows boards (Uno, Mega, etc.) to control a variety of servo motors. [13]

4.4.1.4 Cooling & Heating System

The libraries included for this system are; <DHT.h>[2], <Wire.h>[3], <Adafruit_GFX.h>[4], <Adafruit_SH1106.h>[5], and <Adafruit_Sensor.h>[6]. The DHT sensor was defined as an "int" with analog pin A3 in the Arduino, the fan was defined as "int" taking digital pin 32 and the heating LED on pin 34. The screen was connected to pins SDA and SCL. The sensor's pinMode was defined as an INPUT to send data to the Mega. As for the fan and the LED, their pinMode was defined as OUTPUT. Inside the third part, we defined three variables with type "Float" to take the read temperature and humidity from the sensor. After that, we opened and if statement; if one of these "isnan", it will print "Failed to read" on the screen. Regarding the screen, it was assigned a certain font size and style to display the temperature and humidity in. Following that, we opened a nested if/else statement stating; if the temperature is at least 25 and at most 30, the fan and the heater will turn off, else, if the temperature is less than 25, the heater will turn on, else if the temperature exceeds 31, the fan will turn on. Shown in flowchart in Figure 4-51.

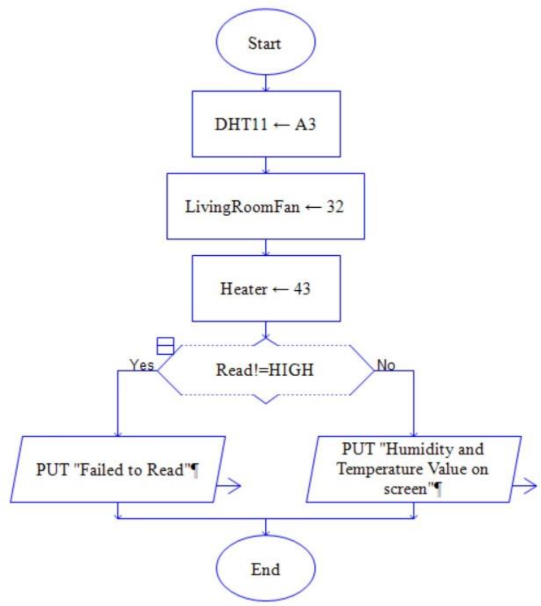

Figure 4-51 Cooling & Heating System Flowchart

[2] Arduino library for DHT11, DHT22, etc Temp & Humidity Sensors. [37]
[3] Arduino Library that communicates with I2C devices like OLED Screen. [35]
[4] Adafruit library that responsible for the display of hardware. [37]
[5] Adafruit library that supports all print() and write() for the OLED Screen with SSD1106 Model. [37]
[6] A unified Library used by many Adafruit sensor. [37]

4.4.1.5 Gas & Smoke Leakage System

The sensor was defined as an "int" with analog pin A0 in the Arduino, the kitchen fan was defined as "int" taking digital pin 33. The buzzer was defined on pin 52. The sensor's pinMode was defined as an INPUT to send data to the Mega. As for the fan and the buzzer, its pinMode was defined as an OUTPUT. Inside the third part, the sensor threshold defined in the fire system is used in this system as well. An if/else statement is opened; if the sensor reading is greater than the threshold, the fan will turn on and the buzzer will sound the alarm, else, the fan and buzzer will stay off. Shown in Figure 4-52.

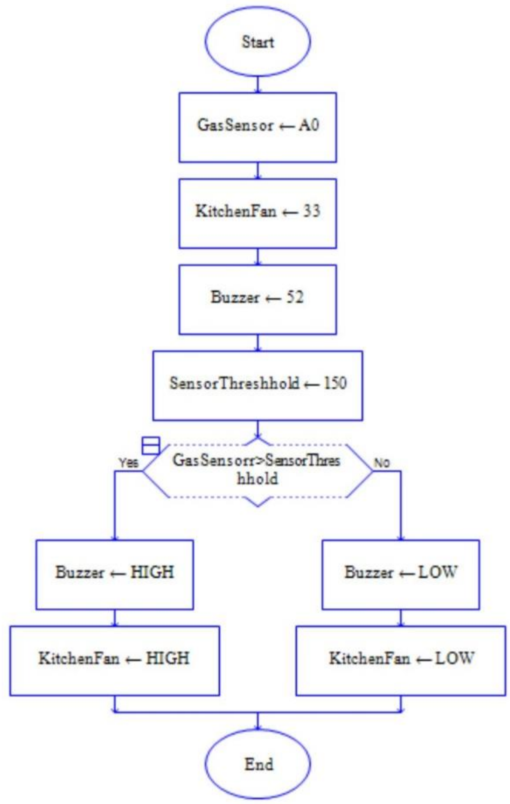

Figure 4-52 Gas & Smoke Leakage System Flowchart

4.4.1.6 Motion System

The sensor was defined as an "int" with digital pin 48 in the Arduino, the bathroom light was defined as "int" taking digital pin 25. The sensor's pinMode was defined as an INPUT to send data to the Mega. As for the light its pinMode was defined as an OUTPUT. Regarding the third part, an if/else statement was implemented; if the motion sensor read any movement, the lights will turn on, else, the lights will stay off. Flowchart shown in Figure 4-53.

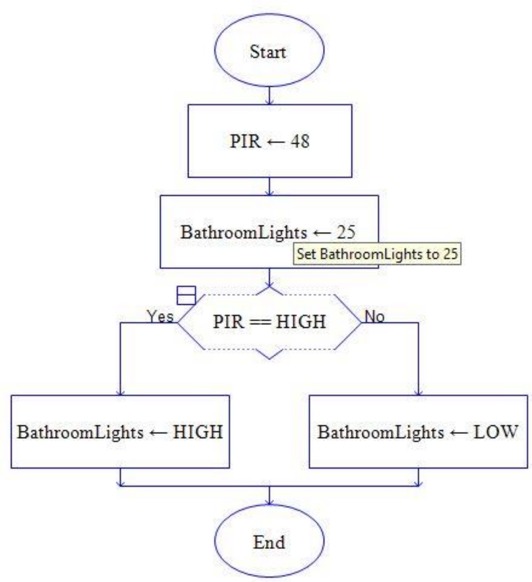

Figure 4-53 Motion System Flowchart

4.4.1.7 Lighting System

The sensor was defined as an "int" with digital pin 44 in the Arduino, the globe light was defined as "int" taking digital pin 45. A variable called "CurrentState" was defined with type "int" to specify the state of the sensor. The sensor's pinMode was defined as an INPUT to send data to the Mega. As for the globe light, its pinMode was defined as an OUTPUT. The third part includes an if/else statement stating; if the sensor is touched, it checks the current state of the globe, if it is on, it turns it off and vice versa. Flowchart shown in Figure 4-54.

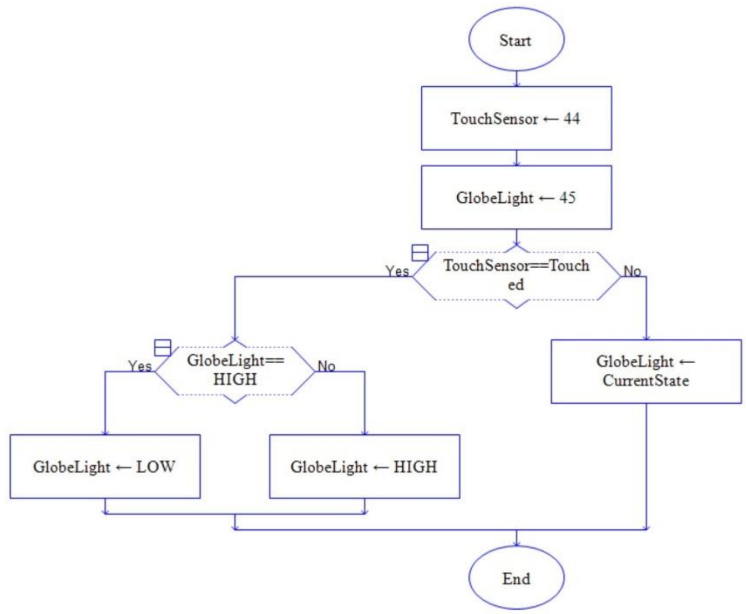

Figure 4-54 Lighting System Flowchart

4.4.1.8 Rain Detection System

The sensor was defined as an "int" with digital pin 11 in the Arduino, the motor driver was defined as "int" taking digital pins 49 and 50. Flowchart shown in Figure 4-55. The sensor's pinMode was defined as an INPUT to send data to the Mega. As for the motor driver, its pinMode was defined as an OUTPUT. Inside the third part, an if/else statement to check if the rain detector is HIGH, the motor driver will command DC to close the pool cover, else, the door will remain open.

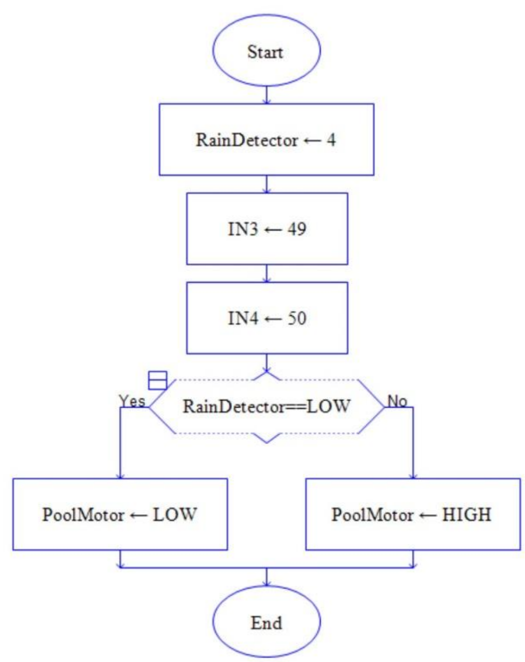

Figure 4-55 Rain Detection System

4.4.1.9 IR Receiver System

We included two libraries in this system; "Stepper.h"[7] and "IRremote.h"[8]. we defined two stepper motors. The curtains stepper motors took pins 8, 10, 9, 11. The garage stepper motor took pins 4, 6, 5, 7. We defined a variable called "STEPS" with initial value 32 to control the number of steps per revolution of internal shaft. The Receiver was defined as "int" with digital pin 3 on the Mega. Also, the Bedroom Lights, Living Room Lights, Kitchen Lights, Garage Light, Outside Light, and Coffee Machine were defined on 26, 24, 28, 27, 29, and 35 respectively. All of the components mentioned above were defined as OUTPUT except for the Receiver which was defined as INPUT. In the third part of the program; an if statement was created, if the receiver received information, in enter the switch case statement that was created with 16 cases and a condition if the result is the value the IR remote; Case 1: if frequency "0xFF9867" (+100); it opens the curtain with speed set to 500/700 and rotation 8192 clockwise. Case 2: if frequency "0xFFB04F" (+200); it lowers the curtain with same speed and number of revolutions but the rotation is counter clockwise. Case 3: if frequency "0xFFE01F" (VOL-); it opens the garage door with speed 500/700 and rotation 4096 clockwise. Case 4: if frequency "0xFFA857" (VOL+); it lowers the garage door with the same speed and rotation but also counter clockwise. Case 5: if frequency "0xFF6897" (Button 0); it turns on the living room lights. Case 6: if frequency "0xFF30CF" (Button 1); it turns off the living room lights. Case 7: if frequency "0xFF18E7" (Button 2); it turns on the bedroom lights. Case 8: if frequency "0xFF7A85" (Button 3); it turns off the bedroom lights. Case 9: if frequency "0xFF10EF" (Button 4); it turns on the garage lights. Case 10: if frequency "0xFF38C7" (Button 5); it turns off the garage lights. Case 11: if frequency "0xFF5AA5" (Button 6); it turns on the kitchen lights. Case 12: if frequency "0xFF42BD" (Button 7); it turns off the kitchen lights. Case 13: if frequency "0xFF4AB5" (Button 8); it turns on the outside lights. Case 14: if frequency "0xFF52AD" (Button 9); it turns off the outside lights. Case 15: if frequency "0xFF22DD" (PREV); it turns off the coffee machine. Case 16: if frequency "0xFF02FD" (NEXT); it turns on the coffee machine. It then resumes reading signals.

---

[7] This library allows boards to control with unipolar or bipolar stepper motors. [37]
[8] This Library allows to send and receive infrared signals with multiple protocols. [37]

4.4.2 Arduino Nano

This microcontroller is only responsible for controlling the RFID system of the outside gate with its components.

4.4.2.1 RFID Gate System

Three libraries were included in this system; <VarSpeedServo.h>[9], <SPI.h>[10], <MFRC522.h>[11]. We defined the servo as a “const int” on digital pin 2 and the angle of the servo was specified as zero. The RFID’s SS pin, responsible for reading the tag, was connected to digital pin 9. The RST pin, responsible for allowing the reader to repeat its function, was connected to the digital pin 10. In the third part, an if/else statement was opened; if the RFID reader reads the pin code of the tag “43 E1 5F 2E”, it sends the tag to the Arduino to authorize the servo to turn a degree of 100 with speed 50/255 and wait 7 seconds to return to its initial state (closing the door), else, the door will remain closed because the pin code of the tag will be incorrect. Flowchart shown in Figure 4-56 .

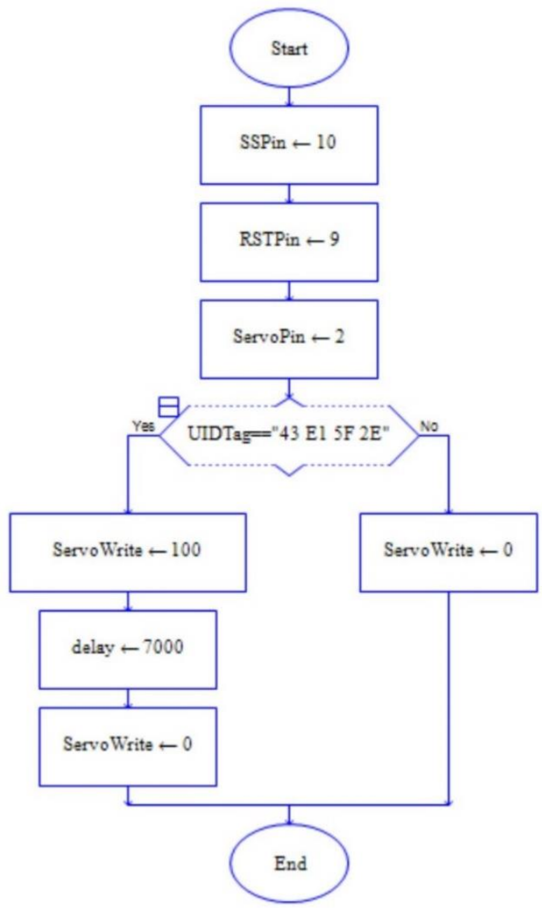

Figure 4-56 RFID Main Gate System Flowchart

[9] Arduino library for servos that extends the standard servo.h library with the ability to set speed, and wait for position to complete. [36]
[10] This library allows boards to communicate with SPI devices like RFID’s. [37]
[11] Read/Write a RFID Card or Tag using the ISO/IEC 14443A/MIFARE interface. [37]

4.4.3 Arduino Uno

This Arduino is responsible for the most important parts of the RFID entrance door system and works with the secondary Arduino Mega in order to make the system fully functional. This was done because of the lack to pins needed to perform the function fully.

4.4.3.1 RFID Door Entrance System

Two libraries were implemented; <SPI.h>, <MFRC522.h>. The SS pin of the RFID was connected to digital pin 10. The RST pin was connected to digital pin 9. The motor driver was connected to the Arduino with pins 6 and 7. An if/else statement was used in the third part; if the RFID reader reads the pin code of the tag “AB BB CB 73”, it sends the tag to the Arduino to authorize the motor driver to open the door and wait 5 seconds to return to its initial state (closing the door) and sends character ‘a’ to the Arduino Mega, else, the door will remain closed because the pin code of the tag will be incorrect and send character ‘b’ to the Mega. The Arduino Mega then then completes the rest of the function in the system. Flowchart shown in Figure 4-57.

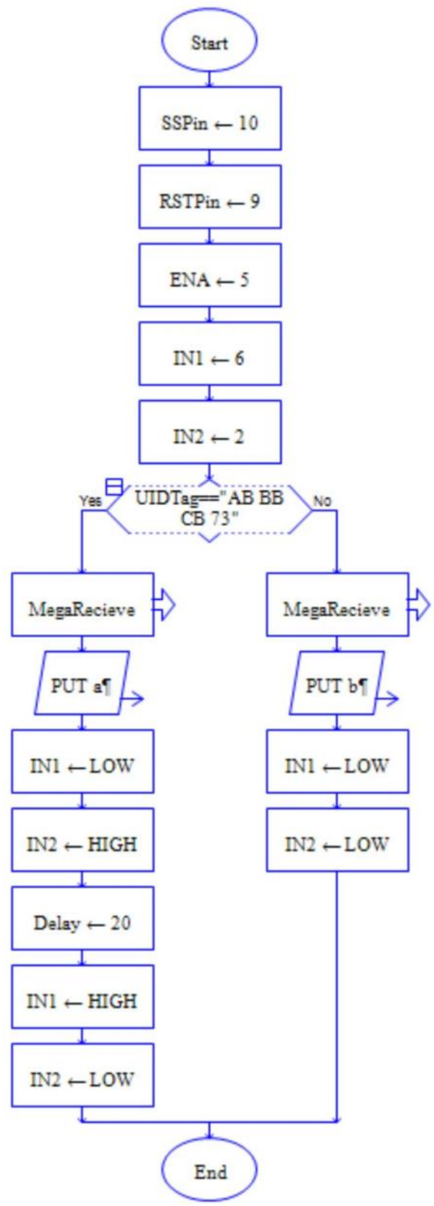

Figure 4-57 RFID Door System on Uno Flowchart

4.4.4 Secondary Arduino Mega

This Arduino is responsible for completing the tasks of the components included in the RFID entrance door system. It is responsible for controlling the screen on the entrance as well as the RGB light.

4.4.4.1 RFID Door Entrance System

A library called <LiquidCrystal.h>[12] is included. The RGB light is defined on 23 for the red and 22 for the green. The LCD screen was defined on pins 24, 25, 26, 27, 28, 29. The RGB lights were defined as OUTPUT and they will off in the beginning. A text is printed on the screen saying “Place Your Card”. In the third part, an if condition statement is included; if the serial reads character ‘a’, the green light of the RGB will turn on and “Welcome Home” will be printed on the screen. Another if condition was used, if the serial reads character ‘b’, the red light of the RGB will turn on and the screen will display “Access Denied”. Flowchart shown in Figure 4-58.

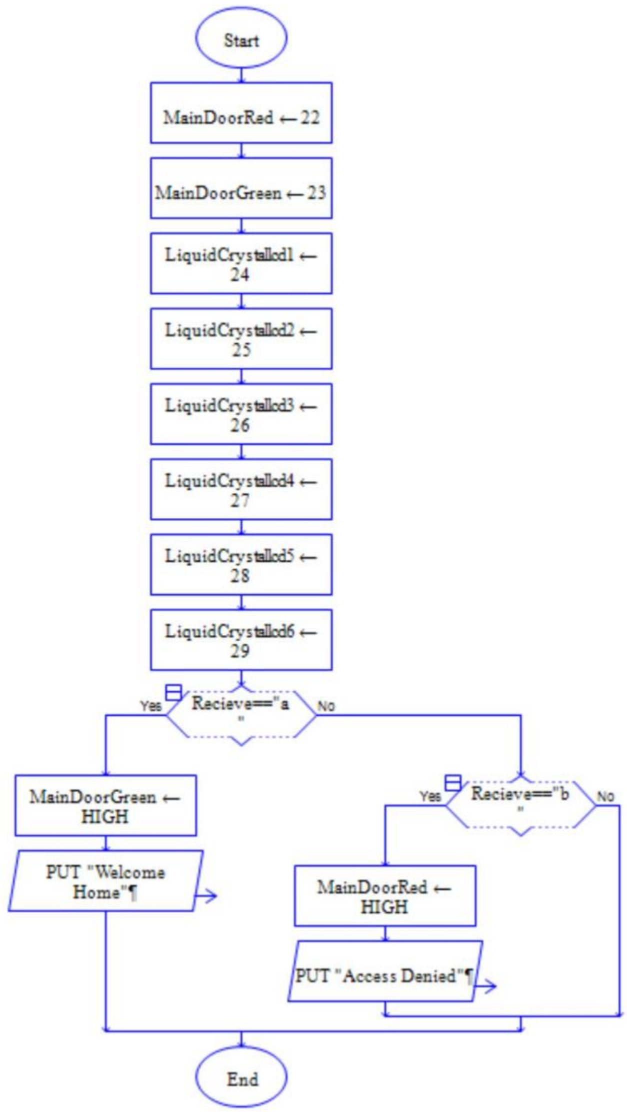

Figure 4-58 RFID Door Entrance on Mega Flowchart

[12] This library allows an Arduino board to control Liquid Crystal displays (LCDs). [13]

4.4.5 NodMCU

This microcontroller is responsible for controlling the house's logo lights. It receives its signals from a server on the internet called Google Assistant. In order to setup Google Assistant, two components are needed to be setup before working with the code of NodMCU on the IDE. First of all, the Adafruit IO which is an IOT platform built around the Message Queue Telemetry Transport (MQTT) Protocol. MQTT is a lightweight protocol that allows multiple devices to connect to a shared server, called the MQTT Broker, and subscribe or write to user defined topics. When a device is subscribed to a topic, the broker will send it a notification whenever that topic changes. MQTT is best suited for applications with low data rates, strict power constraints, or slow Internet connections. [30]

Second is the IFTTT which stand for "If this then that". It is a platform which allows hundreds of different services to trigger actions in a variety of other services. One of these services is Google Assistant where we can create commands and actions.

After configuring the Adafruit we write the code, which will be explained in the system code and flowchart shown in Figure 4-59, and then, we use the IFTT to allow setup communication with google Assistant. [31]

4.4.5.1 Logo Lights System

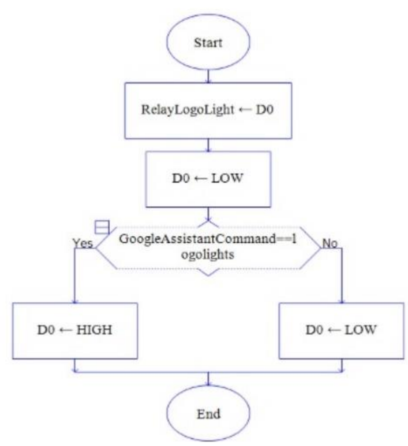

Figure 4-59 Logo Lights System

Three libraries were included; <ESP8266WiFi.h>[13], "Adafruit_MQTT.h"[14], "Adafruit_MQTT_Client.h"[15]. The Wifi SSID and Password were defined. The MQTT server and port were by default "io.adafruit.com" and "1883". The MQTT name and password are autogenerated when the adafruit account is created. The logo lights were defined on pin number D0 on the NodMCU. The light is setup as OUTPUT. In the third part, an if condition is created; if the NodMCU receives the command from Google Assistant it either turns the light on or off.

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[13] Allows you to connect to the ESP8266 wifi module.
[14] Simple MQTT library that supports the bare minimum to publish and subscribe to topics.
[15] Same definition as footnote 14.

4.4.6 Mobile Application

A mobile application was designed in order to control the house and its appliances using the MIT App Inventor Software which is a web application integrated development environment originally provided by Google and now maintained by Massachusetts Institute of Technology (MIT). It allows the creation of software for two operating systems, Android and IOS. It is a free and open source software and it uses a graphical user interface which allows users to drag and drop objects to create an application that can run on Android devices by installing an application called MIT App Companion. Its IOS development software is still under beta testing. [32] The mobile application was designed specifically for the smart house project and it includes multiple services like Bluetooth, and Google Assistant. It was divided into the different rooms of the house in which each room had its own page to control its components.

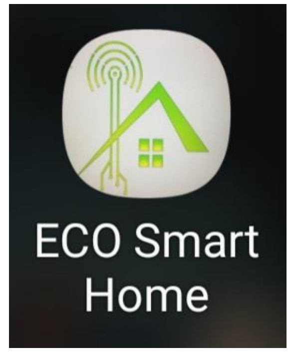

Figure 4-60 Mobile App Icon

4.4.6.1 Home Screen

The home screen included six buttons, each taking the user to a different room in the house, the Bluetooth list picker, and the Google Assistant button. It was assigned a horizontal arrangement and each button when clicked, changes the page for the user and allows him/her to control the components inside the button of the room clicked. Code and design shown in Figure 4-61 and Figure 4-62.

Figure 4-62 Home Screen Design

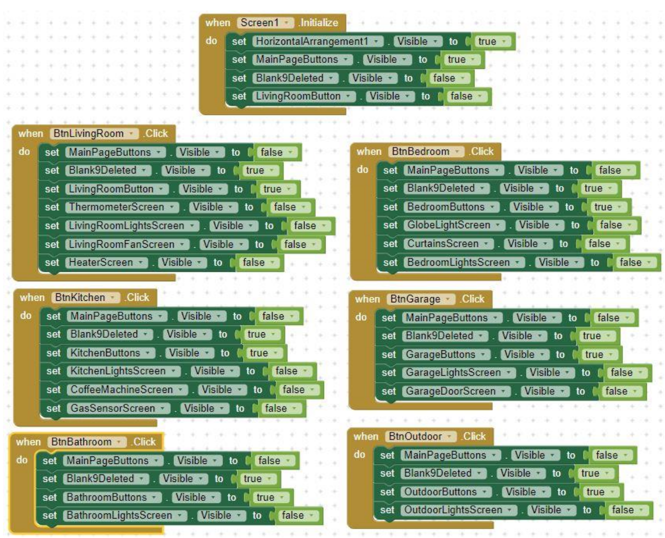

Figure 4-61 Home Screen Code

4.4.6.2 Bluetooth & Google Assistant

The Bluetooth implemented is a list picker. When the button is chosen, it will connect to the Bluetooth list allowing the user to pick the intended device to connect to. After that, if the connection was successful, it will print "CONNECTED" with green color and if the connection was unsuccessful, it will print "DISCONNECTED" in red color. As for the Google Assistant, it is an activity, when clicked will start the application installed called "Google Assistant". Codes of both are shown in Figure 4-64 and Figure 4-63.

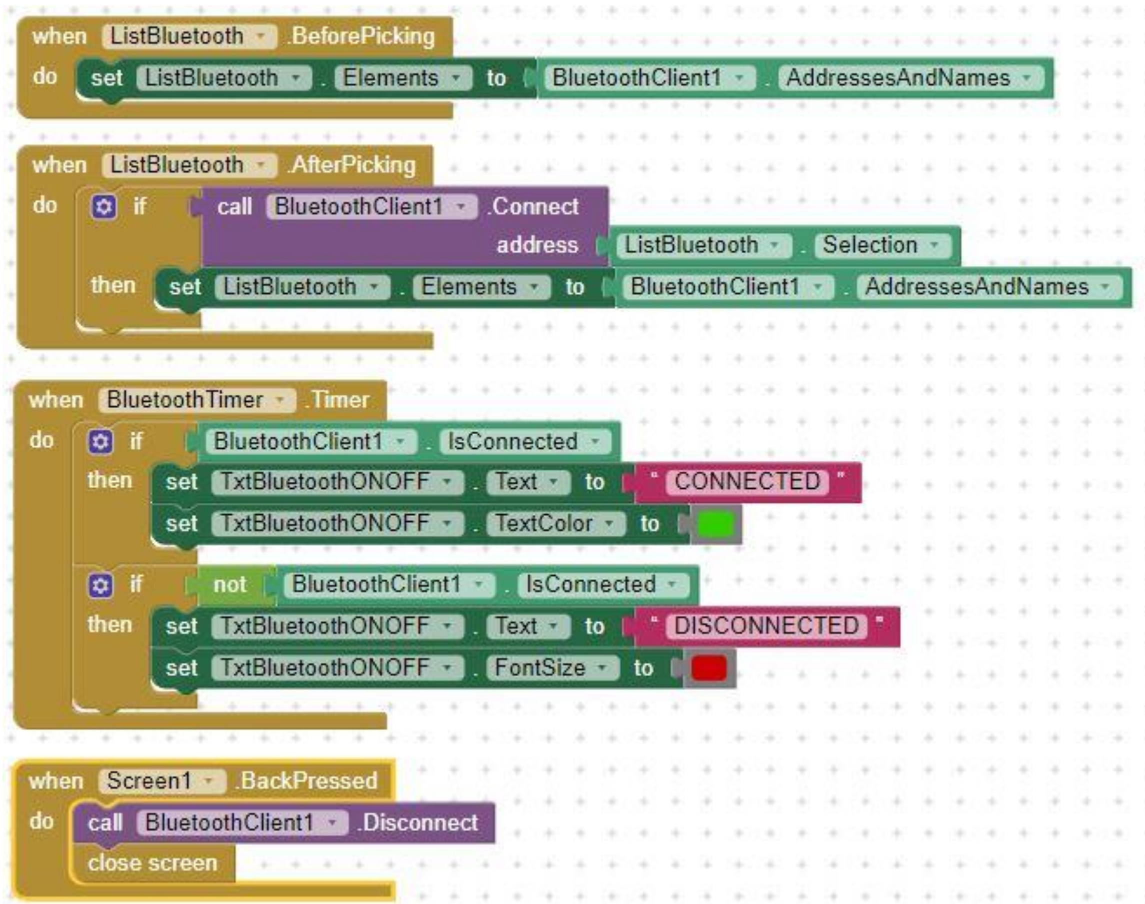

Figure 4-64 Bluetooth Code

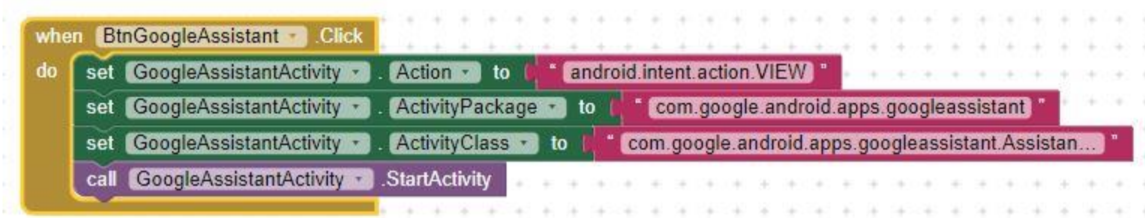

Figure 4-63 Google Assistant Code

4.4.6.3 Living Room

When the living room button is clicked, it will display four buttons; one controlling the heater, another controlling the lights, the third controlling the thermometer, and the last controlling the fan. When any of these buttons are clicked it sends a specific character associated with a task specified on the Arduino code to the serial in Arduino, for example; for the lights to turn off, it gets long clicked and the app sends ’x’ to the Arduino and send ‘w’ to turn on. It will check the state of the component based on what the Arduino is sending and will allow the user to change the state from HIGH to LOW or vice versa using Bluetooth. Code and design shown in Figure 4-66 and Figure 4-65.

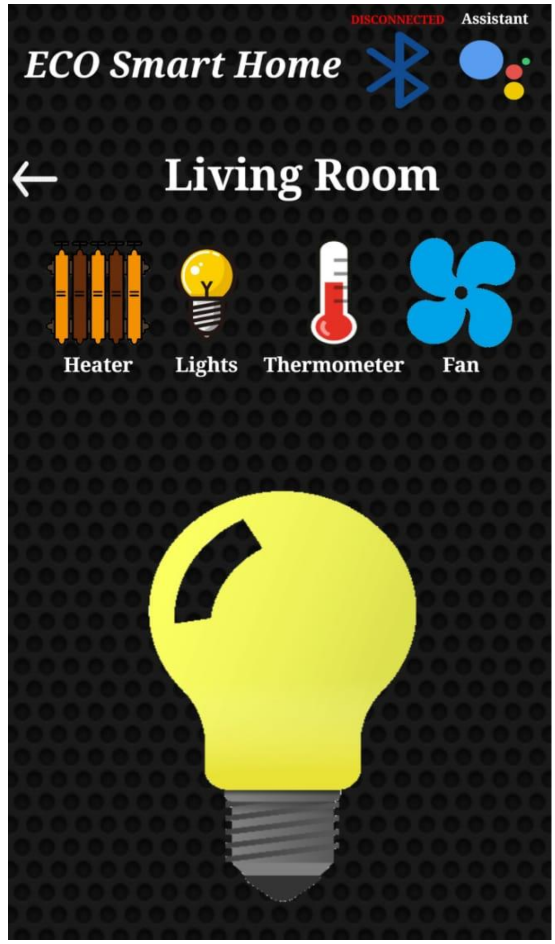

Figure 4-65 Living Room Design

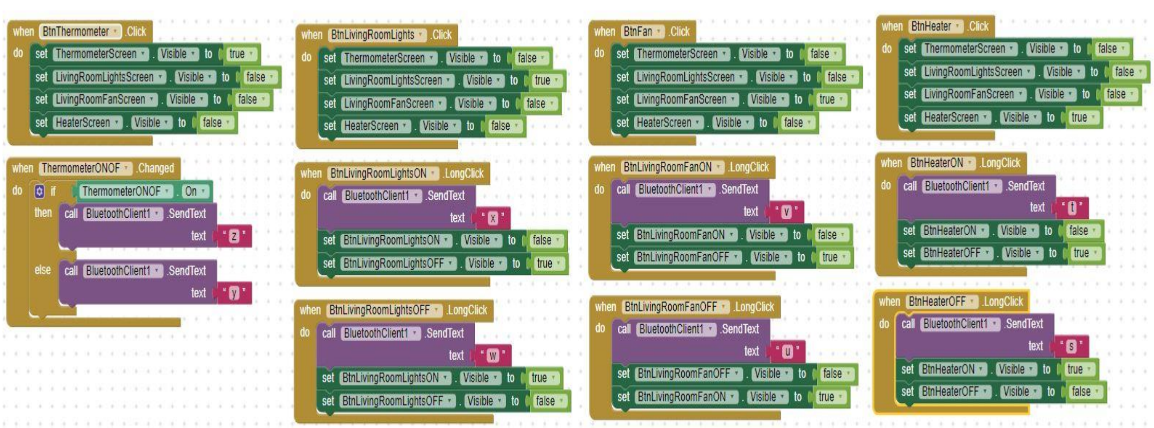

Figure 4-66 Living Room Code

4.4.6.4 Bedroom

The bedroom gives three choices when clicked, one controls the lights, another controls the curtains, and the last controls the globe light. The code is similar to that of the living room, when one is clicked it will send a specific character for each command of on or off. For example; for the curtains to open, it needs to get long clicked and it will send character ‘n’ and the curtains will open. It will send ‘m’ in order to lower the curtains. The app will check its status and allows the user to change it using Bluetooth. Code and design shown in Figure 4-68 and Figure 4-67.

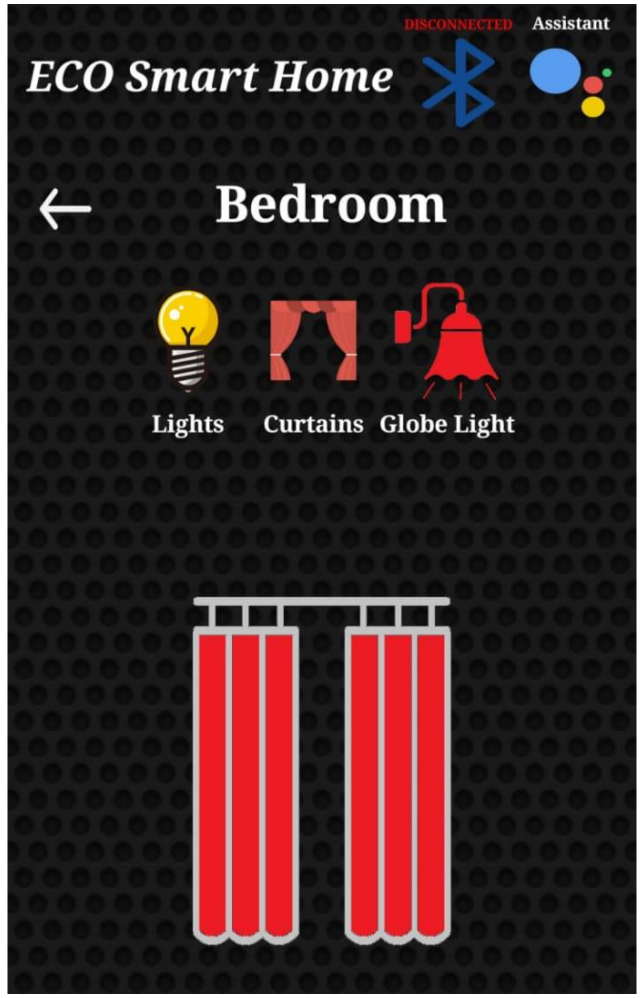

Figure 4-67 Bedroom Design

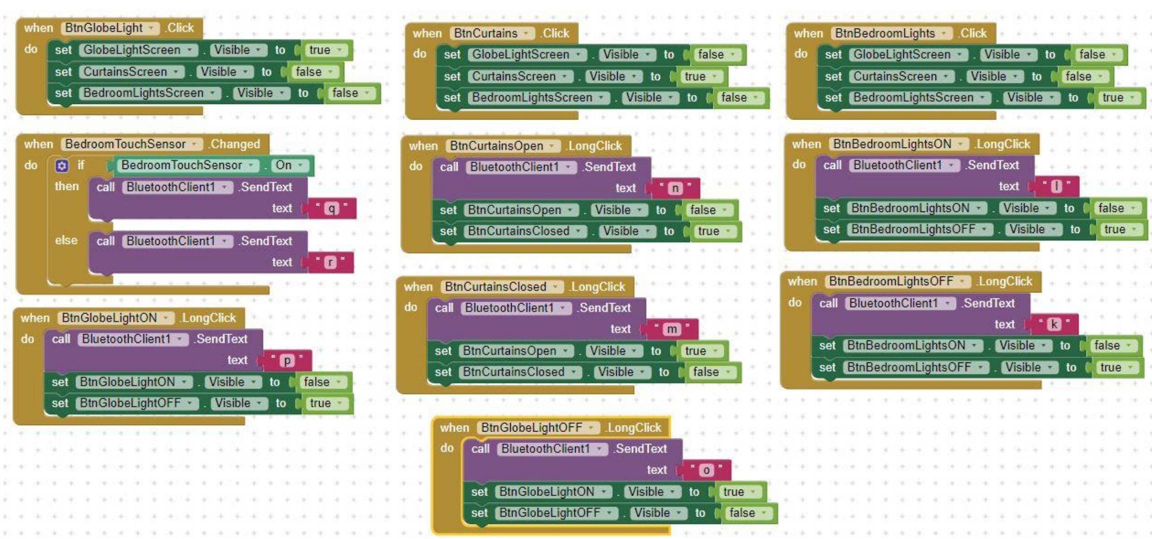

Figure 4-68 Bedroom Code

4.4.6.5 Kitchen

The kitchen also has three choices when clicked, one controls the lights, another controls the coffee machine, and the last controls the gas and smoke sensor. The code is similar to that of the living room and bedroom, when one is clicked it will send a specific character for each command of on or off. For example; for the coffee machine to poo coffee, it needs to get long clicked and it will send character ‘f’ and the curtains will open. It will send ‘e’ in order to stop pouring. The app will check its status and allows the user to change it using Bluetooth. Code and design shown in Figure 4-70 and Figure 4-69.

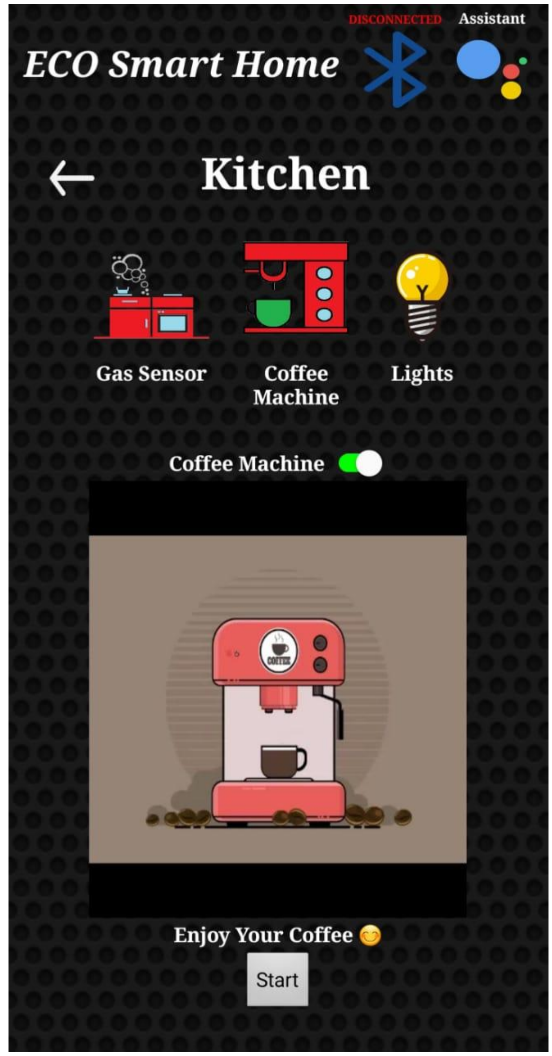

Figure 4-69 Kitchen Design

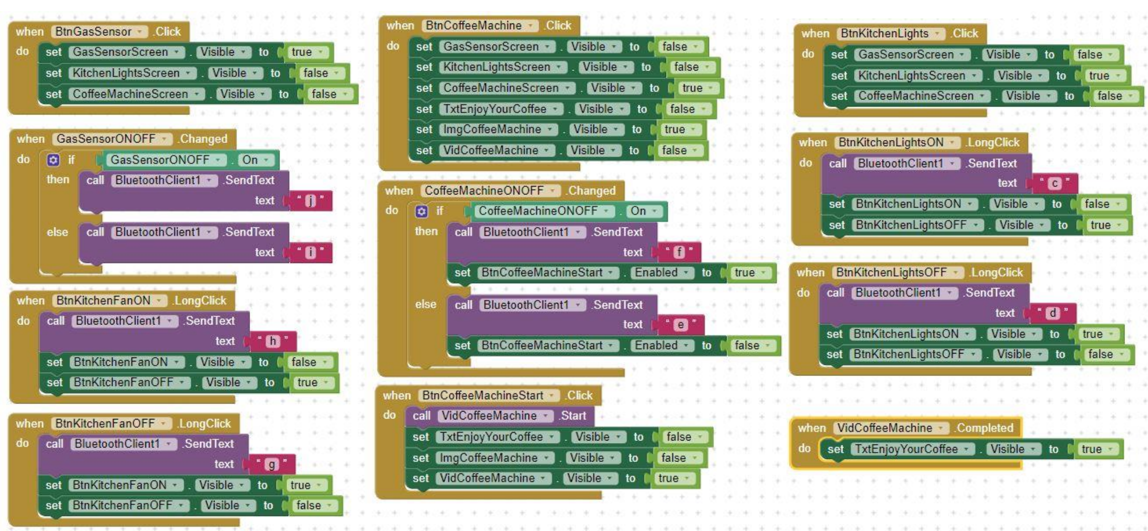

Figure 4-70 Kitchen Code

4.4.6.6 Bathroom

The bathroom has only one choice when clicked, to control the lights. The code is similar to that of the living room, when one is clicked it will send a specific character for each command of on or off. The app will check its status and allows the user to change it using Bluetooth. Code and design shown in Figure 4-72 and Figure 4-71.

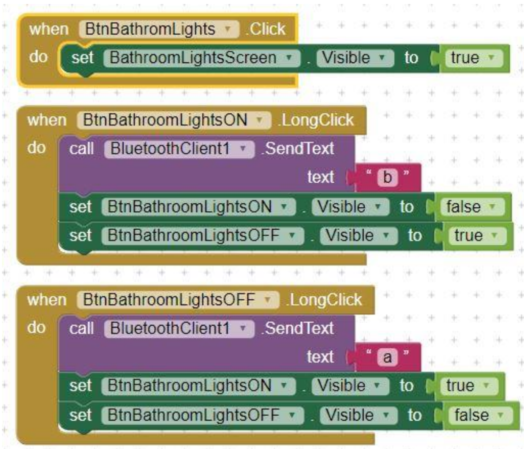

Figure 4-72 Bathroom Code

Figure 4-71 Bathroom Design

4.4.6.7 Garage

The garage has choices when clicked, one controls the lights, and another controls the garage door. The code is similar to that of the living room, when one is clicked it will send a specific character for each command of on or off. The app will check its status and allows the user to change it using Bluetooth. Code and design shown in Figure 4-74 and Figure 4-73.

Figure 4-73 Garage Design

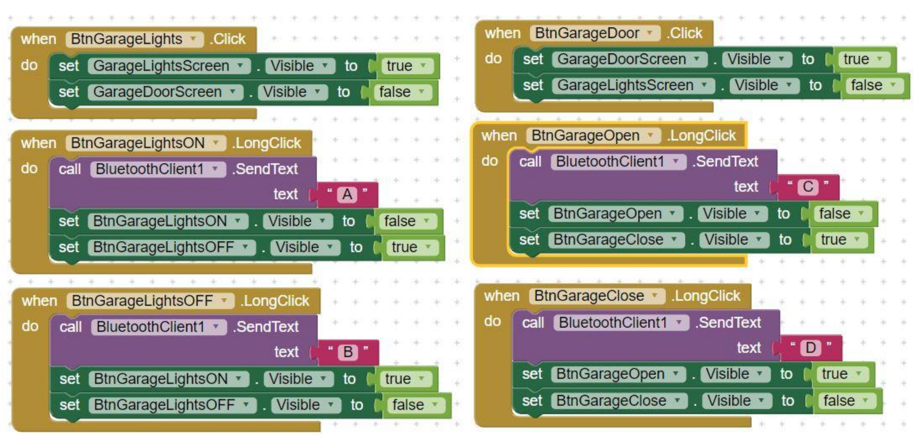

Figure 4-74 Garage Code

4.4.6.8 Outside

The outside has only one choice when clicked, to control the lights. The code is similar to that of the living room, when one is clicked it will send a specific character for each command of on or off. The app will check its status and allows the user to change it using Bluetooth. Code and design shown in Figure 4-76 and Figure 4-75.

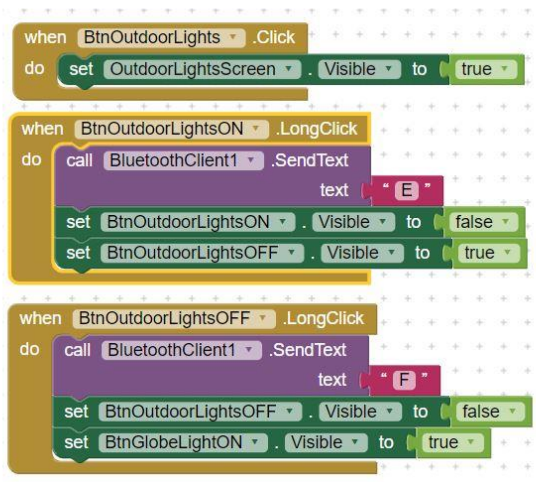

Figure 4-76 Outside Code

Figure 4-75 Outside Design

4.4.6.9 Back Button

The back buttons were implemented in all the pages to allow the user to return to the home page. It was placed on the top left corner of each page of the app bellow the name. Six of these buttons were used. The code is shown in Figure 4-77.

Figure 4-77 Back Button Code

4.5 Prototype

All the different systems were implemented inside the house prototype of dimensions 120x60x65 of length, width, and height. This prototype was performed using different materials like; Plexiglass, Balsa, Stereo Board, Plastic Covers, Grass Sheets. The base of the prototype was created from the plastic covers and the stereo board, the house's ground and floor grounds were also made form plastic covers, the house's walls were made from plexiglass, and its frontier and fence were made form Balsa. The pieces were made separate and assembled from ground up in order to ensure the house's electrical wiring can pass smoothly. Figure 4-79 and Figure 4-78 show the base and ground of the house.

Figure 4-79 Base of the house

Figure 4-78 Ground floor, pool, and tank

The wires that came form outside the house were passed through two shafts on different sides of the house. As for the pipes and wires of the systems inside the house, they were passed through the floors to the shaft and directed to the attic where they were connected to the microcontrollers. Figure 4-81 and Figure 4-80 show the wiring design and outside views.

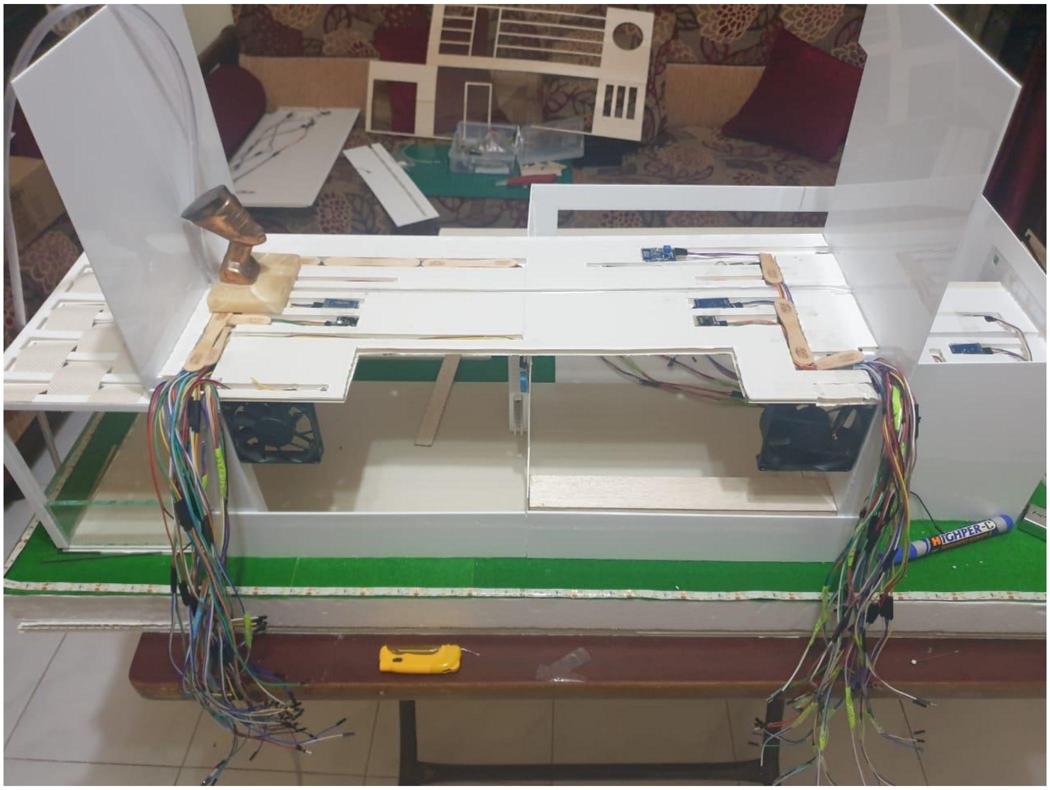

Figure 4-81 The floor plan and the wires inside the shaft

Figure 4-80 Outer view of the plan and wiring

4.6 Results

The result was the ECO-Smart Home, shown in Figure 4-82 and Figure 4-84, which includes a fully functioning fire system, security system, temperature system, lighting system, irrigation system, water level system, and more. All are working together in order to ensure that the house is functioning according to plan with the efficiency and eco-friendly factor in mind.

The fire system, for example, only sprays water in the room where the fire is active and only starts spraying other rooms if the fire spreads. The unused water also flows back to the tank to ensure that it doesn't empty its load. Another example is the irrigation system and water level where they stop any water flow to the pool or garden if its full or does not require any additional water. Both of these examples show the effort to consume water in an economical and efficient way.

The house works on saving electricity by many examples; one example is the cooling and heating systems which only work when the temperature increases or decreases from the average range in which people can sit comfortably. Another example is the work of the PIR sensor in the bathroom which only turns on the light if it senses movement and turns it off when there is no motion detected. Moreover, the solar panels installed, shown in Figure 4-83, also generate clean energy that the house can use and reduce its dependency on electricity generated by fossil fuels and other unclean sources.

Figure 4-82 Elevation of the house

Figure 4-84 Side view of the house

Figure 4-83 Top view of the house

5 Conclusion & Future Work

To sum up, the work of the systems together and the implementation of the Internet of Things ensures a safer and more reliable future where domestic houses can be more energy and resource efficient, thus; providing a healthier lifestyle for people and making sure the ecosystem’s resources are preserved and not tarnished by the excess of the factories generating electricity.

The effort to make our lifestyle more ecofriendly depends highly on machines and their utilization in our everyday lives because they have proven to be more effective in setting limits to the increasing consumption of humans.

5.1 Future Works

This house can be modified on and upgraded with additional sensors and actuators that can control the house and its consumption even more. An example of this is the Photocell sensor which can help the house identify when there is sunlight or no to automatically control the lights without waiting for human interference. Another example are filters that can be placed under the pool in order to direct the used pool water into irrigation and not wasting it somewhere else. This can also be made more secure by installing a read switch sensor which blocks any forced attempt to open the entrance door. IR systems can be installed as well to keep gates open when someone cuts the IR transition between the two sensors.

6 References

[1] M. Rouse, "IOT Agenda," February 2020. [Online]. Available: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT.

[2] "Trend Micro," Trend Micro, [Online]. Available: https://www.trendmicro.com/vinfo/us/security/definition/internet-of-things.

[3] J. Y. P. L. J. G. Y. X. W. Yin Jie, "Smart Home System based on IOT Technologies," in *International Conference on Computational and Information Sciences*, Shenzhen, 2013.

[4] Y.-J. K. S. Y. Y. H. L. S. L. S. C. C. H.-J. C. Yun-Gyung Cheong, "An Ontology-Based Reasoning Aproach Towards Energy-Aware Smart Homes," in *The 8th Annual IEEE Consumer Communications and Networking Conference - Emerging and Innovative Consumer Technologies and Applications*, Las Vegas, 2011.

[5] S. I.-K. Ahmad Houri, "Residential energy consumption patters: the case of Lebanon," *International Journal of Energy Research*, vol. 29, pp. 755-766, 2005.

[6] "Environmental Protection Agency," Environmental Protection Agency, 2015. [Online]. Available: https://www.epa.gov/watersense/how-we-use-water.

[7] "US Eneregy Information Administration," Independent Statistics & Analysis, 26 May 2020. [Online]. Available: https://www.eia.gov/tools/faqs/faq.php?id=77&t=11.

[8] R. Harper, "Inside the Smart Home: Ideas, Possibilities and Methods," in *Inside the Smart Home*, London, Springer, 2003, pp. 1-13.

[9] F. K. Aldrich, "Smart Homes: Past, Present and Future," in *Inside the Smart Home*, London, Springer, 2003, pp. 17-39.

[10] J. Gerhart, Home Automation & Wiring, New York: McGraw-Hill, 1999.

[11] G. McConnell, "The Conservation Movement: Past and Present," *Political Research Quarterly*, vol. 3, no. 7, pp. 463-478, 1954.

[12] S. P. Hays, "The Environmental Movement," *Forest & Conservartion History*, vol. 4, no. 25, pp. 219-221, 1981.

[13] "Arduino," Arduino, [Online]. Available: https://arduino.cc/.

[14] "NodeMCU Documentation," Espressif Systems, [Online]. Available: https://nodemcu.readthedocs.io/en/master/.

[15] "Bluetooth Module HC05," Itead, [Online]. Available: https://www.itead.cc/wiki/Serial_Port_Bluetooth_Module_(Master/Slave)_:_HC-05.

[16] "Last Minute Engineers," Last Minute Engineers, [Online]. Available: https://lastminuteengineers.com/.

[17] S. Kumar, "Interfacing Flame Sensor with Arduino to Build a Fire Alarm System," Circuit Digest, 2 8` 2018. [Online]. Available: https://circuitdigest.com/microcontroller-projects/arduino-flame-sensor-interfacing#:~:text=Flame%20sensor%20module%20has%20photodiode,turning%20on%20buzzer%20and%20LED.

[18] "Arduino Touch Sensor," Arduino Get Started, [Online]. Available: https://arduinogetstarted.com/tutorials/arduino-touch-sensor#:~:text=Sensor%20Electronic%20Circuit-,Arduino%20%2D%20Touch%20Sensor,control%20devices%20(e%2Cg.&text=It%20is%20used%20instead%20of,the%20touch%20sensor%20with%20Arduino..

[19] "Using Infrared Sensor with Arduino," Instructable Curcuits, [Online]. Available: https://www.instructables.com/id/Using-Infrared-Sensor-With-Arduino/#:~:text=

An%20IR%20sensor%20is%20an,(typically%20called%20signal%20pin)..

[20] "Arduino - DC Motor," Tutorials Point, [Online]. Available: https://www.tutorialspoint.com/arduino/arduino_dc_motor.htm#:~:text=A%20DC%20motor%20(Direct%20Current,most%20common%20type%20of%20motor.&text=If%20you%20switch%20the%20leads,driver%20Circuit%20or%20an%20IC..

[21] "Energy Efficient Products," Energy Star, [Online]. Available: https://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_led_bulbs.

[22] "What does RGB mean?," Phillips, [Online]. Available: https://www.lighting.philips.com/main/support/support/faqs/white-light-and-colour/what-does-rgb-led-mean.

[23] "What is a breadboard," Wiring, [Online]. Available: http://wiring.org.co/learning/tutorials/breadboard/.

[24] "The Electric Fan," Edison Tech Center, [Online]. Available: https://edisontechcenter.org/Fan.html.

[25] "Definition of 'Solar Panel'".*The Economic Times.*

[26] "Active Passive Buzzer," Components 101, 25 September 2017. [Online]. Available: https://components101.com/buzzer-pinout-working-datasheet.

[27] "Arduino Button," Java T Point, [Online]. Available: https://www.javatpoint.com/arduino-button.

[28] "Guide for I2C OLED Display with Arduino," Random Nerd Tutorials, [Online]. Available: https://randomnerdtutorials.com/guide-for-oled-display-with-arduino/.

[29] "How 16x2 LCDs work," Electronics for u, 4 December 2018. [Online]. Available: https://www.electronicsforu.com/resources/learn-electronics/16x2-lcd-pinout-diagram#:~:text=An%20LCD%20is%20an%20electronic,5%C3%977%20pixel%20matrix.

[30] "IO Adafruit," Adafruit, [Online]. Available: io.adafruit.com.

[31] "IFTTT," IFTTT, [Online]. Available: ifttt.com.

[32] "MIT App Inventor," Massachusetts Institute of Technology, [Online]. Available: https://appinventor.mit.edu/.

[33] "Arduino Light Sensor," Arduino Get Started, [Online]. Available: https://arduinogetstarted.com/tutorials/arduino-light-sensor#:~:text=About%20Light%20Sensor,level%20of%20the%20ambient%20light..

[34] "DC Motors," Wikipedia, [Online]. Available: wikipedia.com/dcmotor.

[35] Arduino, [Online]. Available: https://www.arduino.cc/en/Reference/Libraries.

[36] "Code Bender," [Online]. Available: https://codebender.cc/library/VarSpeedServo#keywords.txt.

[37] "Arduino Library List," [Online]. Available: https://www.arduinolibraries.info/.