AUTOMATED MEDICATION SYSTEM

by

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Mechatronics Engineering

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Abstract

The basic concept of this Automated Medication System (AMS) device is to dispense medicines such as pills and capsules up to 8 different categories at a certain time and to the correct person. This device will have an inbuilt buzzer and RGB LED's which buzzes and flashes light at a certain programmed time to call the user to collect their pill, when the user is near the dispenser and places the hand under the dispensing nozzle, the device will automatically detect and dispense the proper medicine to the user. This AMS device uses ATMega 2560 as the main microprocessor, along with mini display OLED. The AMS device is controlled by the smart phone app designed using an online app inventor, which communicates using the Bluetooth module (HC-06). This device will also give advices, medications and prescriptions to new patients for minor health problems such as head ache, stomach ache, acidity, fever, sore throat and etc.

This AMS device will be very useful in homes, offices, factories or other departments where there are people who take multiple medications per day. There are companies manufacturing automated pill dispensers and medication systems, but what makes this project different is that this Automated Medication System operates using preprogrammed decision tree flowchart which can be altered by different doctors to improve the efficiency of the device. Also its unique because the device works with different feature based on different arduino codes without altering the device hardware. These features will be explained in detail.

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Chapter 1: Introduction

1.1 What is medication? and How do they work?

What is Medication?

Simply speaking, medication is a substance or a type of treatment that is taken by the body to do things like curing a disease or condition, treating a medical condition, relieving symptoms from an illness or to prevent getting infected from any diseases. There are different type of medicines for different situations, for example antibiotics, anti-depressants, pain killers, and flu vaccine are used to prevent infection, depression, pain and flu respectively.

How do medications work?

Usually a medical substance such as pills, tablets, liquid, capsules or inhalers enter our body orally, which is through mouth. Some medications like injections and drops enter our body through skin and eyes or ears. These different ways of medicines entering our body is called "routes".

When a medicine enters our body orally, it passes through the digestive system and gets broken down in the stomach or the intestines and gets absorbed. Most of the orally taken medicines passes through the liver before doing its actual functions. Some medications have direct affect on the particular organ like inhalers are inhaled and directly absorbed by the lungs without entering the digestive system.

Other different medication routes:

- **Nasal** (into the nose) medications are absorbed through the thin mucous membrane that lines the inside of the nose and mouth and enters the bloodstream in this way.
- **Topical** medications can be applied directly to the skin and tend to have a very localized effect. They do not usually enter the bloodstream in significant amounts.
- **Transdermal** (through the skin) medications are applied to the skin either by patch or in creams or lotions and pass through the skin into the blood vessels.


Figure 1: Transdermal


Figure 2: Nasal


Figure 3: Topical

1.2 Automated pill dispenser

There are many commercial Automated pill dispensers manufactured and sold every day, some examples are, pill organizers, medication reminders, smart pill dispensers.

The main function an automated pill dispenser is to dispense right medication at the right time. They may not help saving a life more than real doctor or pharmacist, but it will definitely avoid stress and anxiety from forgetting to take the medication at right times. Some examples are stated below

Figure 4: App based pill dispensers

Figure 5: Timing based pill dispensers

Figure 6: Timing based manual pill dispensers

Chapter 2: Project overview/Initial study/Background study/Theory

2.1 Project overview

The Automated Medication System (AMS) device was designed to perform three main functions/feature without making any alteration to the device's hardware. The brain of the AMS device is the Arduino Mega 2560 microcontroller. However, it can be connected to the Omron PLC and HMI also based on the future decision flowchart designs.

The three main features are:

- The AMS device interacts with the Smartphone using Bluetooth communication and dispense the right pill based on the decision tree.
- Dispense pill using Radio Frequency Identification (RFID) tags.
- Call the users using buzzer (used as alarm) and flashes light at the right time for medication.

However the third feature (pill reminder) will be left uncoded, the components will be attached for future project development.

The components in the device such as sensors, actuators and displays are not soldered directly to the main board, which makes it easier to switch between different microcontrollers based on different features.

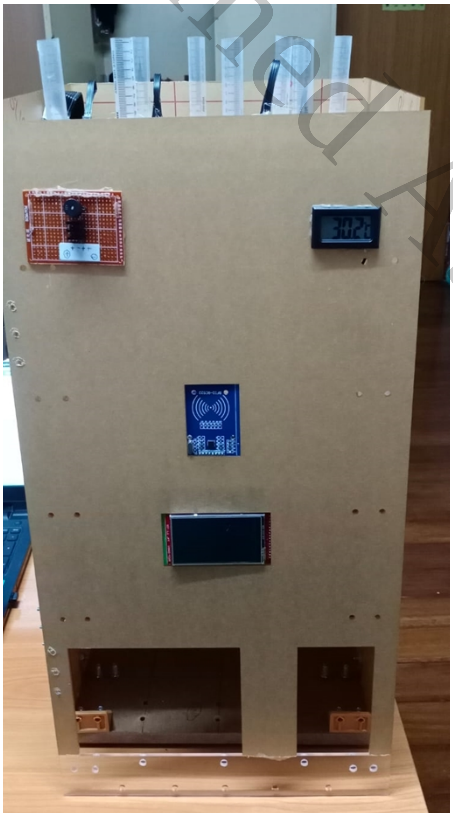

Figure 7: AMS device (lamination not removed)

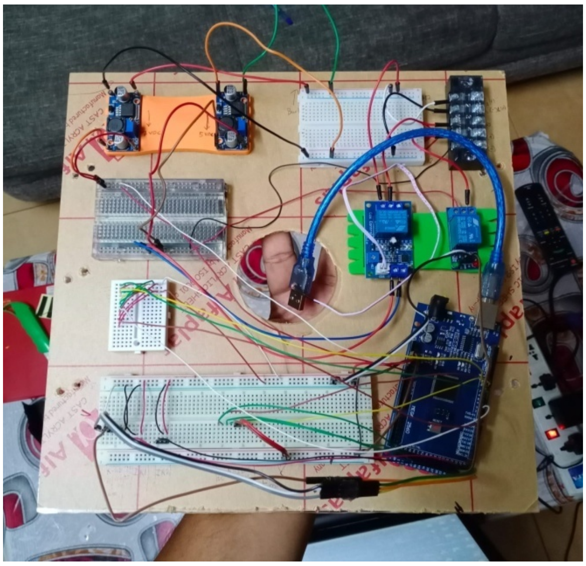

Figure 8: Main Board

The modules and cables are connected in breadboards and block connectors for initial testing purposes. After the testing, the shield for arduino mega was designed using eagle CAD software.

2.2 Initial and background studies

The AMS device is just a prototype and not designed for commercial purpose, therefore the device won't use real pills for the medication, so the standard pill size was selected for this project, which is a cylindrical pill with **13 mm** diameter and **3 mm** height (500mg paracetamol).

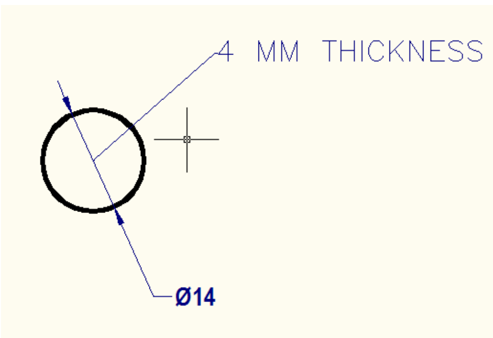

Figure 9: Pill dimension

Figure 10: Actual pill used in AMS device

The entire project was to express the concept of this device instead of the structure and design, anyhow the dispensing mechanism was completely designed from scratch using only acrylic layers, a servo and few bolts and nuts.

The entire layouts and designs were drawn using Auto cad tool.

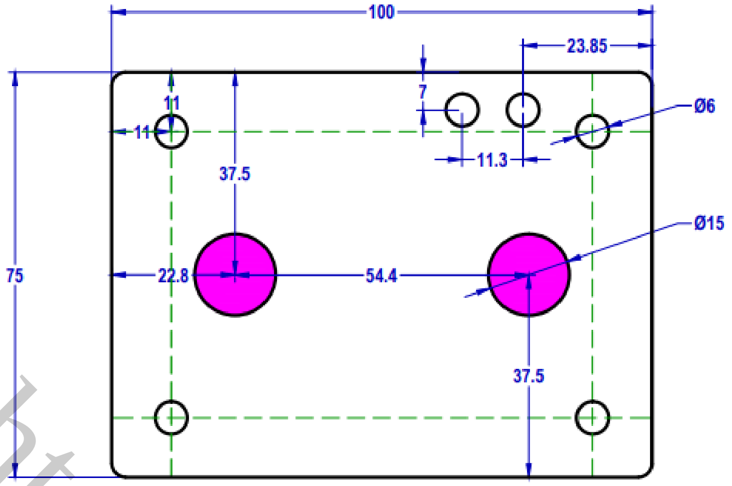

Figure 11: Top layer acrylic for pill dispenser mechanism

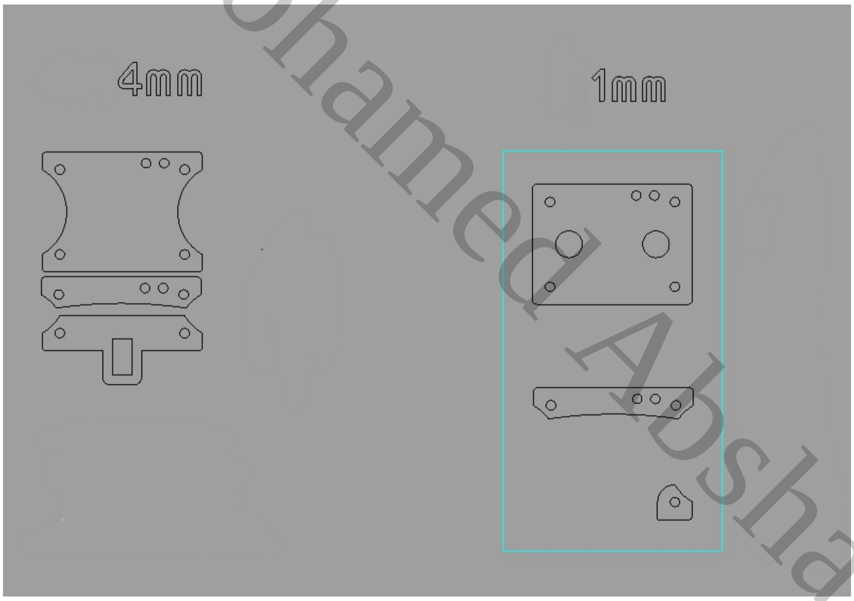

Figure 12: Acrylic parts for mechanism (prepared for laser cutting)

2.3 Medication studies and theory

Even though the device is just a prototype, it was necessary that the decision flowchart should make a proper sense. So pharmacist and doctors were used in helping to design the decision tree flowchart. And some frequently asked questions by the doctors were considered important, like:

- What brought you here?
- Are you sure about your issue?
- Is there anything else you want to add on?
- Have you consulted a doctor before?
- Are you currently in any medication?

Dosages based on age and weight:

When it comes to prescribing pill, the most important factor to consider is the user's weight or age group. Some medication charts from open source medical websites were taken into consideration for this project. Different pill has different dosage to prescribe, the AMS device will use the chart for commonly used painkiller, i.e. Paracetamol. This pill's dosage is based on the user's weight.

Calculate the amount of paracetamol per 1 dose		Example
Child Body weight 12 kilograms	12 x 10 to 12 x 15 mg i.e. 120 to 180 mg	**Liquid form for children with dosage on a label** Choose the drug with paracetamol 120 mg / 5 ml Taking 5 ml (1 teaspoon)
Adult Body weight 60 kilograms	60 x 10 to 60 x 15 mg i.e. 600 to 900 mg	**Sara tablet** Contains 500 mg paracetamol Taking 1 ½ tablets

Figure 13: Paracetamol dosage chart

Chapter 3: Methodology/Method of implementation/Project system

3.1 Implementation Method

For the **first two months** of project, the dispensing mechanism was roughly sketched and made using the acrylic layers and bolts. After many attempts, the mechanism was working how it is supposed to work. Meanwhile other components were ordered and tested to make sure every components and modules were working fine. Also the devices exterior body was made using the clear acrylic. All the acrylic part were cut manually by cutter, which made the dimensions less accurate.

The mechanism was designed roughly to test its concept, which worked perfectly

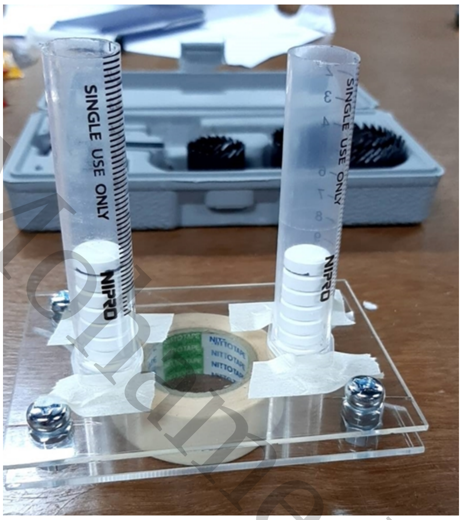

Figure 14: Pill dispensing mechanism (rough design)

The holes were drilled in the acrylic and pipes were cut attach to the base of the device.

Figure 15: Cutting plastic pipes to attach at base

Figure 16: Drilling holes to the frames

On the **third month** of the project, it was observed that the mechanism was not working properly after dispensing more than about 10 pills after we realized the mistake, which was expected because the boards were cut manually with low precision. So we decided to draw the CAD diagrams use CNC laser cutter to cut the acrylics.

Top layer (clear acrylic)

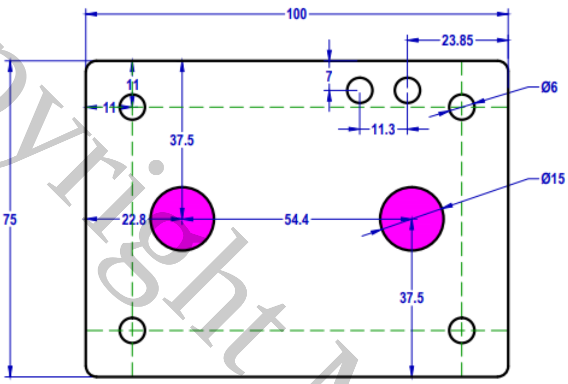

Figure 17: Top layer acrylic (CAD)

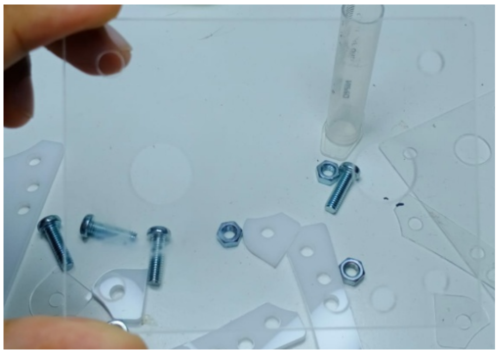

Figure 18: Top layer acrylic (Actual part)

Bottom layer (white acrylic)

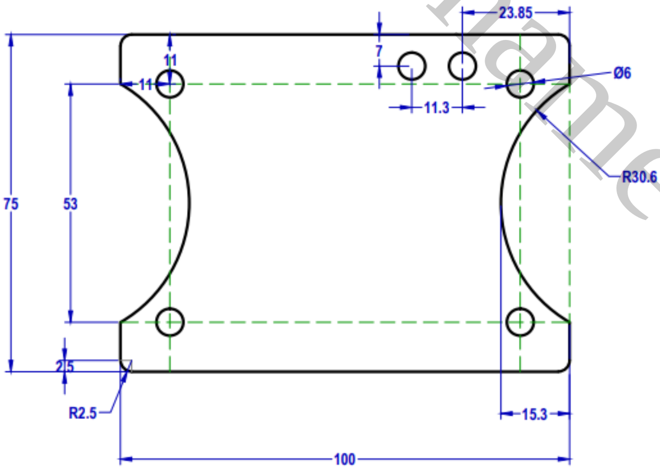

Figure 19: bottom layer acrylic (CAD)

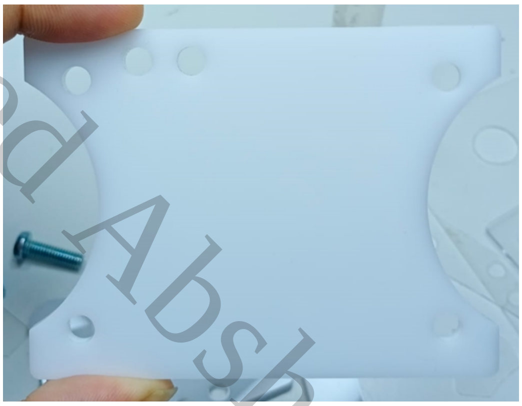

Figure 20: bottom layer acrylic (Actual part)

Mover (white acrylic)

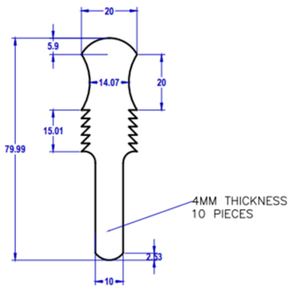

Figure 21: Pill mover (CAD)

Figure 22: Pill mover (Actual part)

All acrylic parts for the dispensing mechanism were made ready

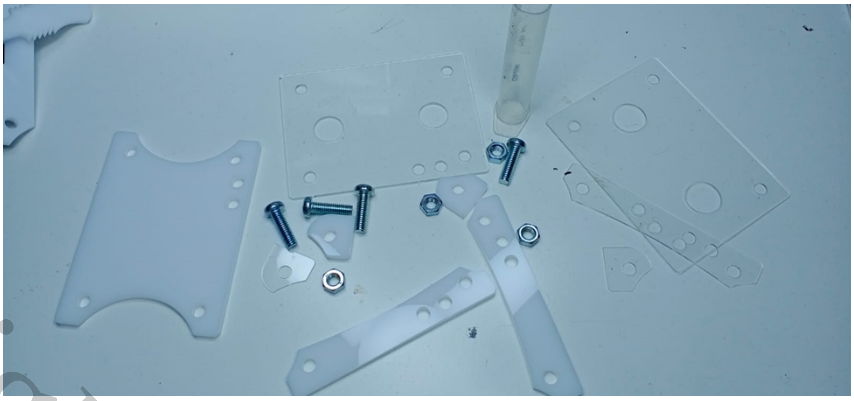

Figure 23: Acrylic parts prepared for building the mechanism

After Assembly

Figure 24: dispensing mechanism assembled

Testing the dispenser

(a) Servo position at 45° (b) Servo position at 90° (c) Servo position at 180°

Figure 25: Mover positions tested

Approximately on the **fourth month** of the project, the entire exterior design was completed with laser cut acrylic board, and it was time to move onto the electrical wirings.

Exterior body of the device with all components attached

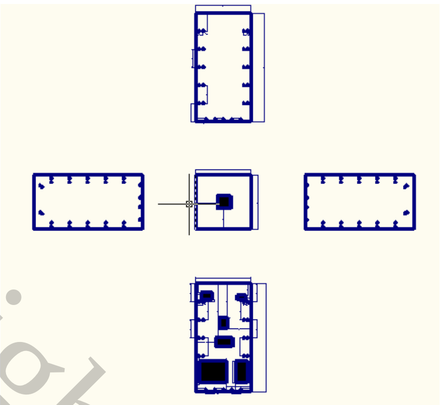

Figure 26: Exterior body (CAD)

Figure 27: Complete exterior body

Main board

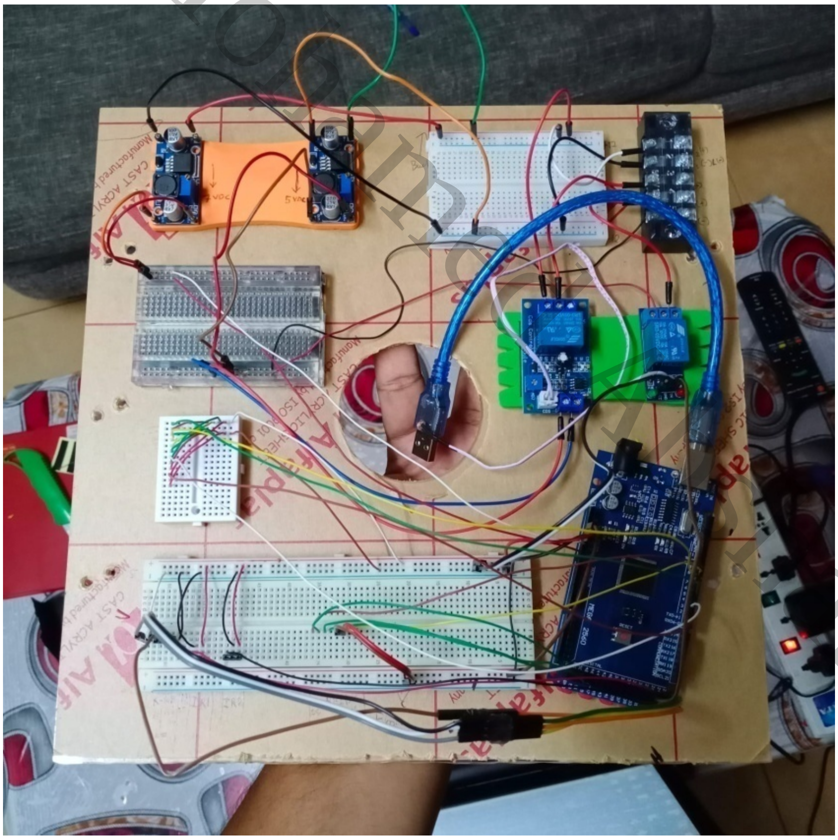

Figure 28: Main board

The base of the main board is acrylic, and the board contains almost 80% of the electrical components such as relay's, power supply modules, the main microcontroller Arduino Mega and connector points for the actuators and sensors.

Finally at the **fifth/last month** of the project, the programming of the board was done, the app was developed by the MIT app inventor, which will be further explained.

3.2 Flow chart design for the AMS app

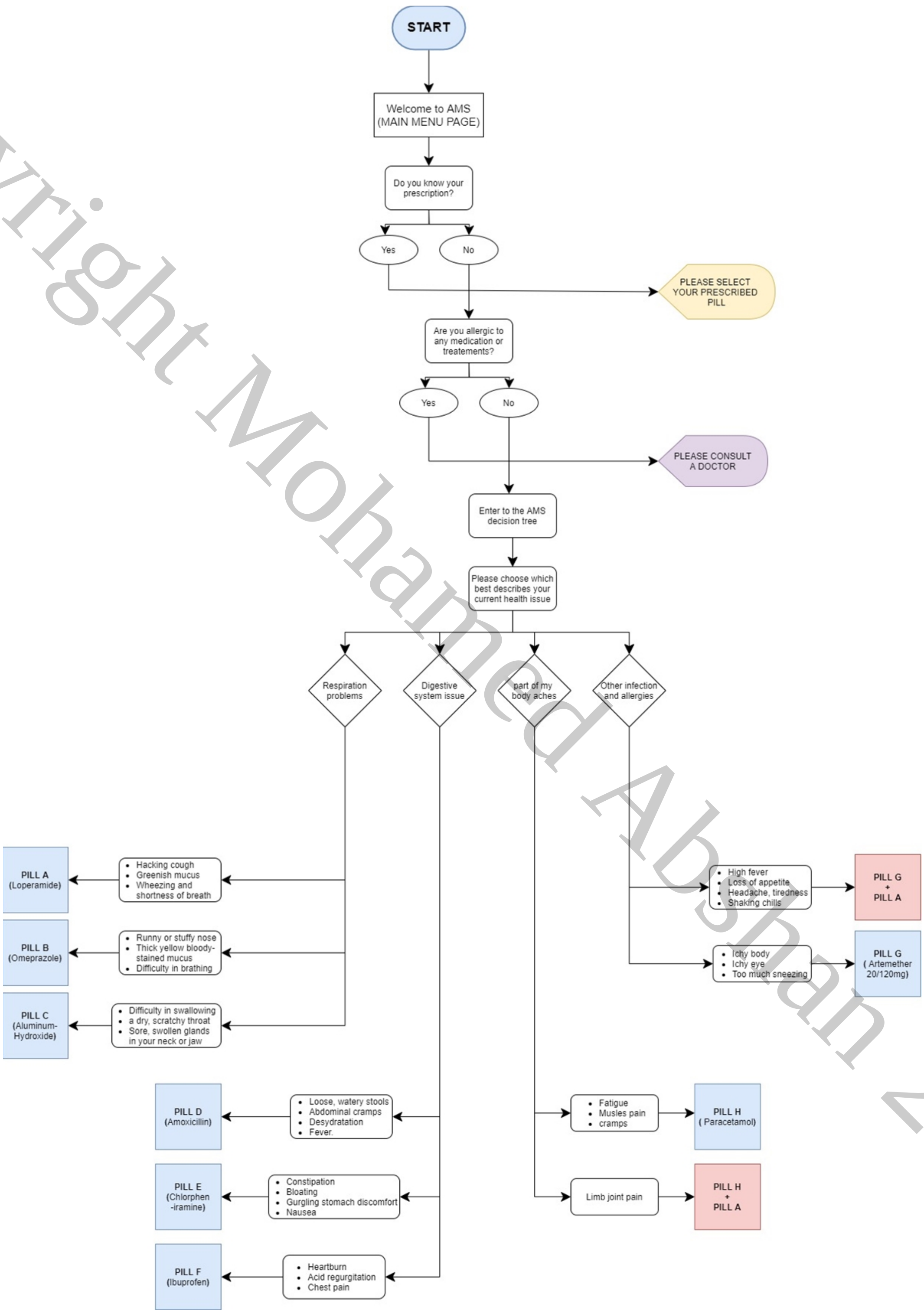

Figure 29: AMS App flow chart

Flowchart explained:

This flowchart only explains how the system works when a new user uses the AMS app in an android smart phone for receiving a prescription or a medicine. The flowchart can be devided into two sections, "Basic questions" and "AMS decision tree"

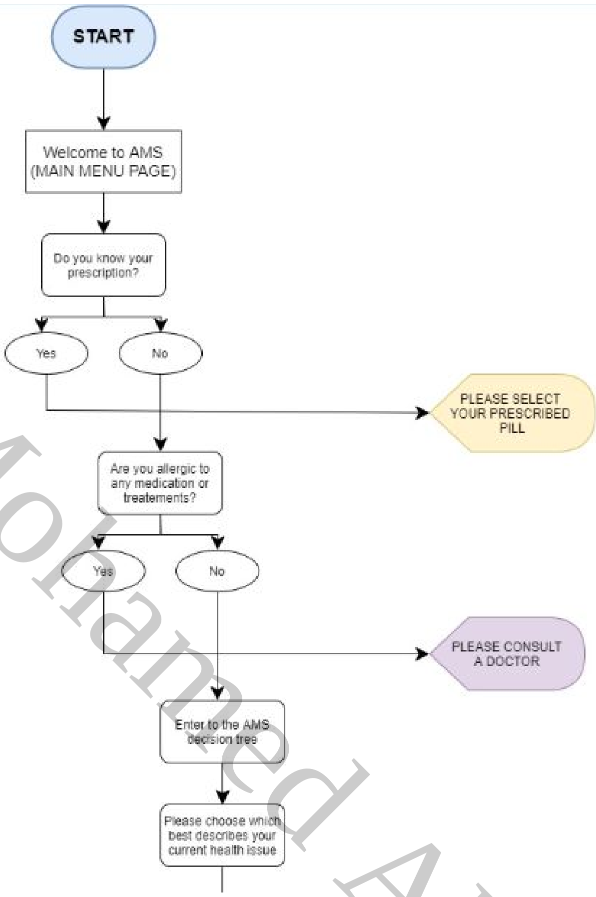

Figure 30: AMS Basic questions

When the users starts using the app, the screen displays/asks the user whether they know what medicine they want. If the user knows the medicine required, they can simply select the medicine they need. If they user is not sure on what medicine to take for their current health issue, they will have to first answer if they are allergic to any medicine or treatement. If they have any allergies, the system prompts them to consult a doctor since the AMS is not programmed professionally. If the user does not have any allergy, they will be prompted to the next step which is the explanation of their health issue.

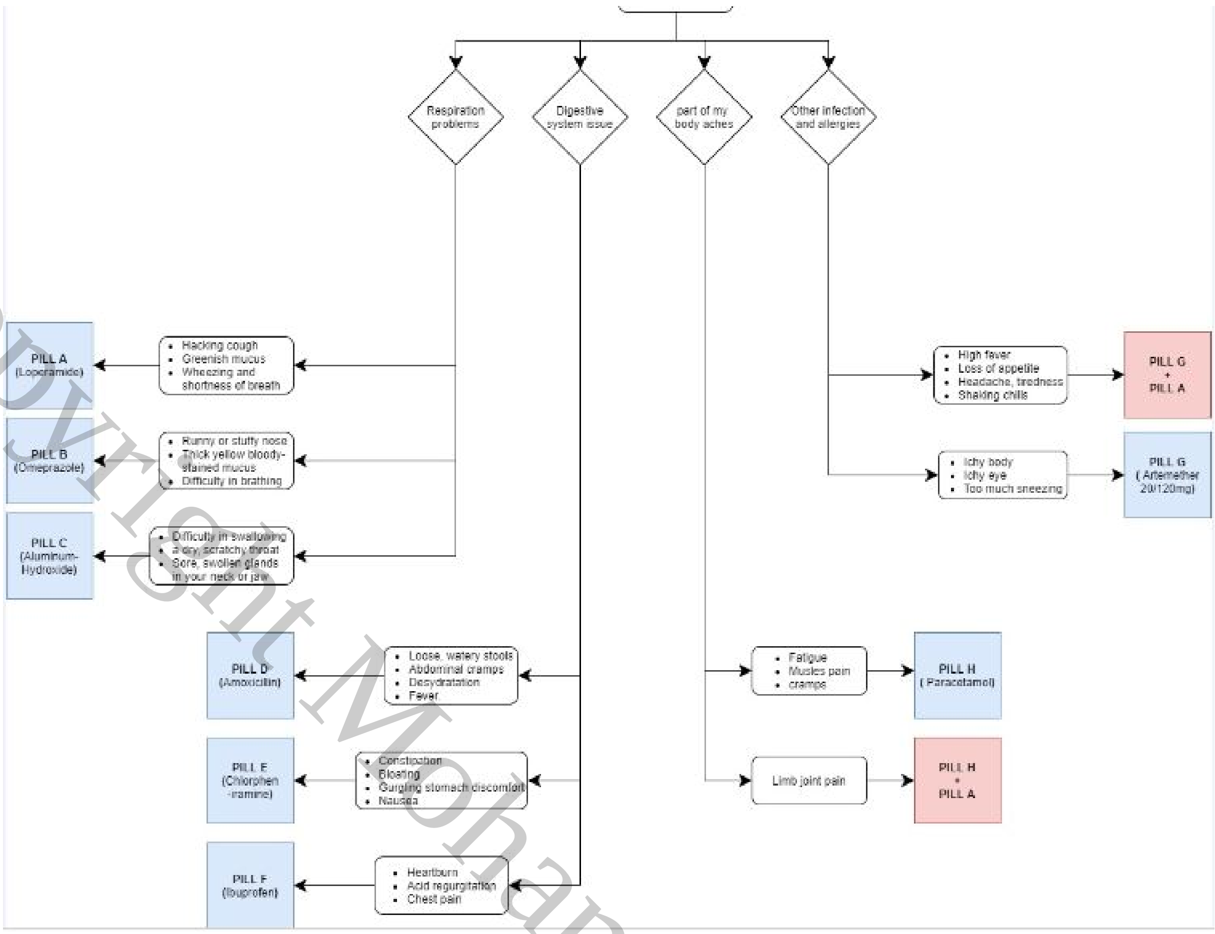

Figure 31: AMS Decision tree flow chart

The systems operation for selecting a proper medicine is complex and long in real life situation. In our prototype, only common pills are used. At this point, the user will answer series of multiple choice questions asked by the system based on the decision tree flowchart.

Finally the right medication will be displayed (based on the flowchart) on the screen. The screen will then prompt the user to select "DISPENCE PILL A", (in case if it's pill A), once its selected, the AMS device will receive the signal and select the right servo to move the position of the mover stick to push out the right pill.

3.3 AMS design and implementation

3.3.1 AMS Exterior design

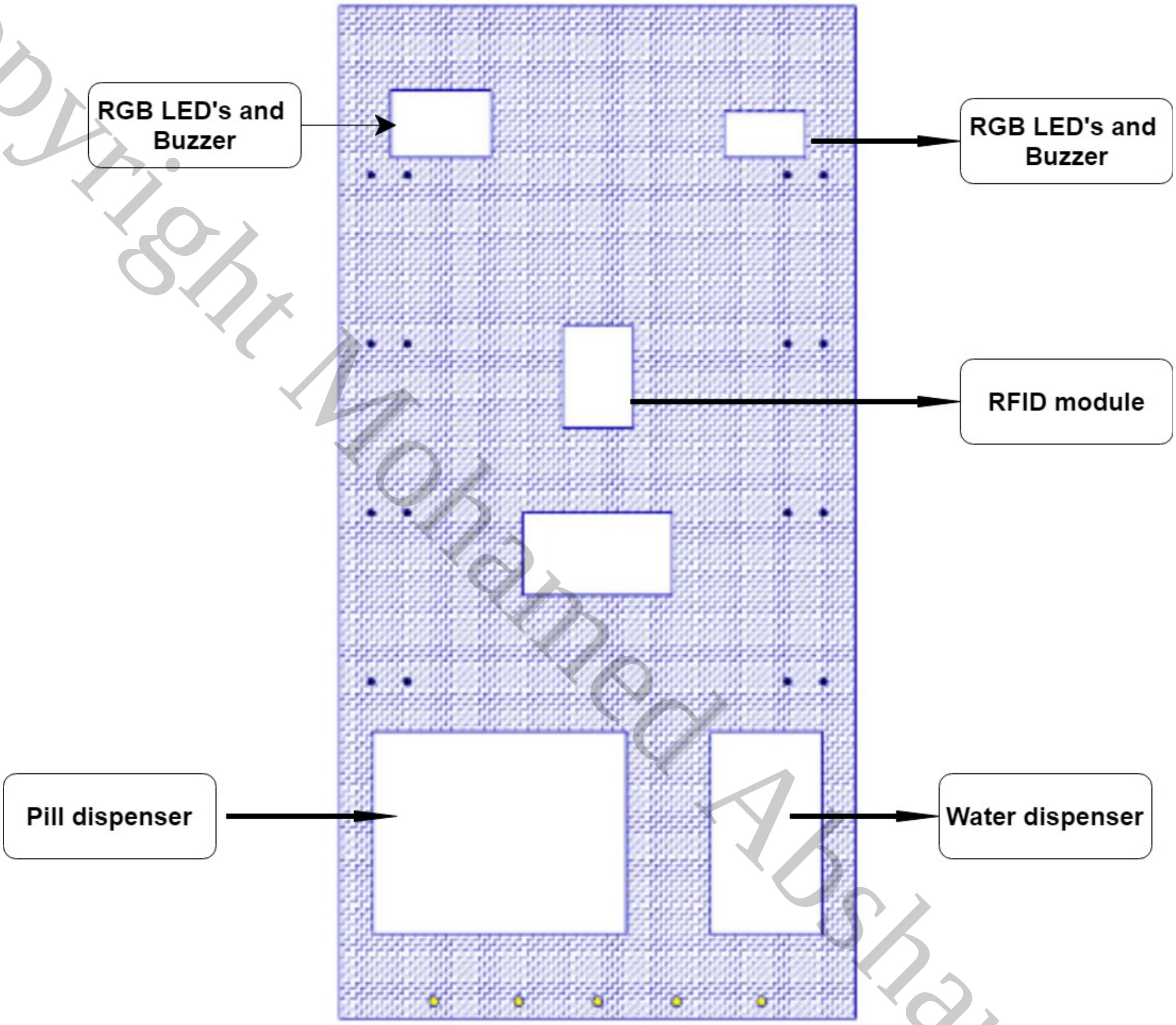

Figure 32: AMS device labled (exterior front view)

3.3.2 Circuit Explained

Block diagram explanation: This explanation is just an overview of the system, components and modules will be explained further

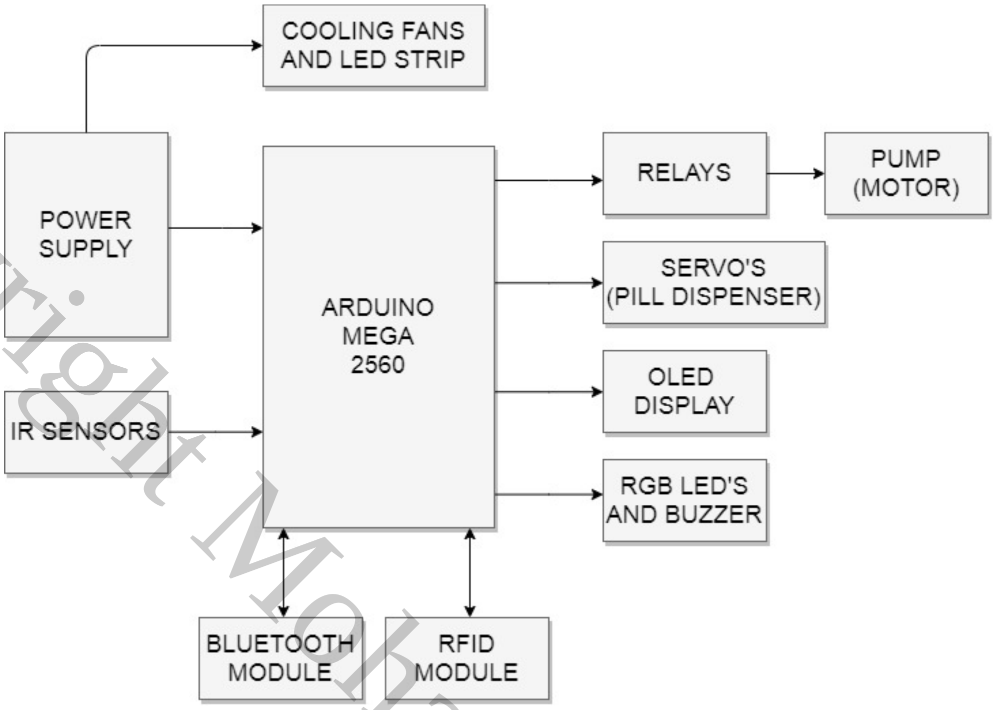

Figure 33: AMS block diagram

Schematic diagram: The Following schematic diagrams are separated into two sections, one will be the connections on arduino and the other schematic will be the power management system. These schematics were designed using eagle CAD software. Some modules such as HC-06, and RC522 will be mentioned as only connector points since these modules will be attached to the body and not on the main board.

Figure 34: Autodesk Eagle software

Power management system: This part of the circuit contains two LM2596 buck converter, one for powering the arduino and the other one is used as external power supply for relays and LED's. This system contains two cooling fans to keep the 2596 IC from overheating and cooling other electrical components.

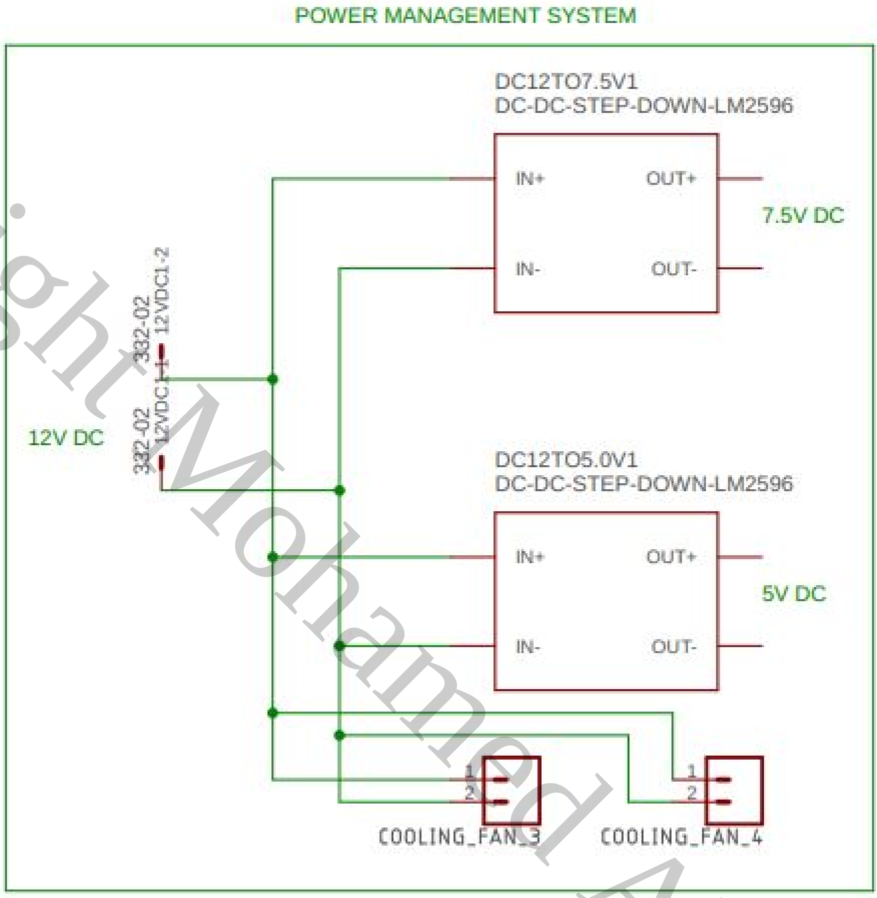

Figure 35: Power supply circuit (Power management system)

Schematic for arduino connections: The components attached to the arduino mega and its pin out configurations are stated in the table below.

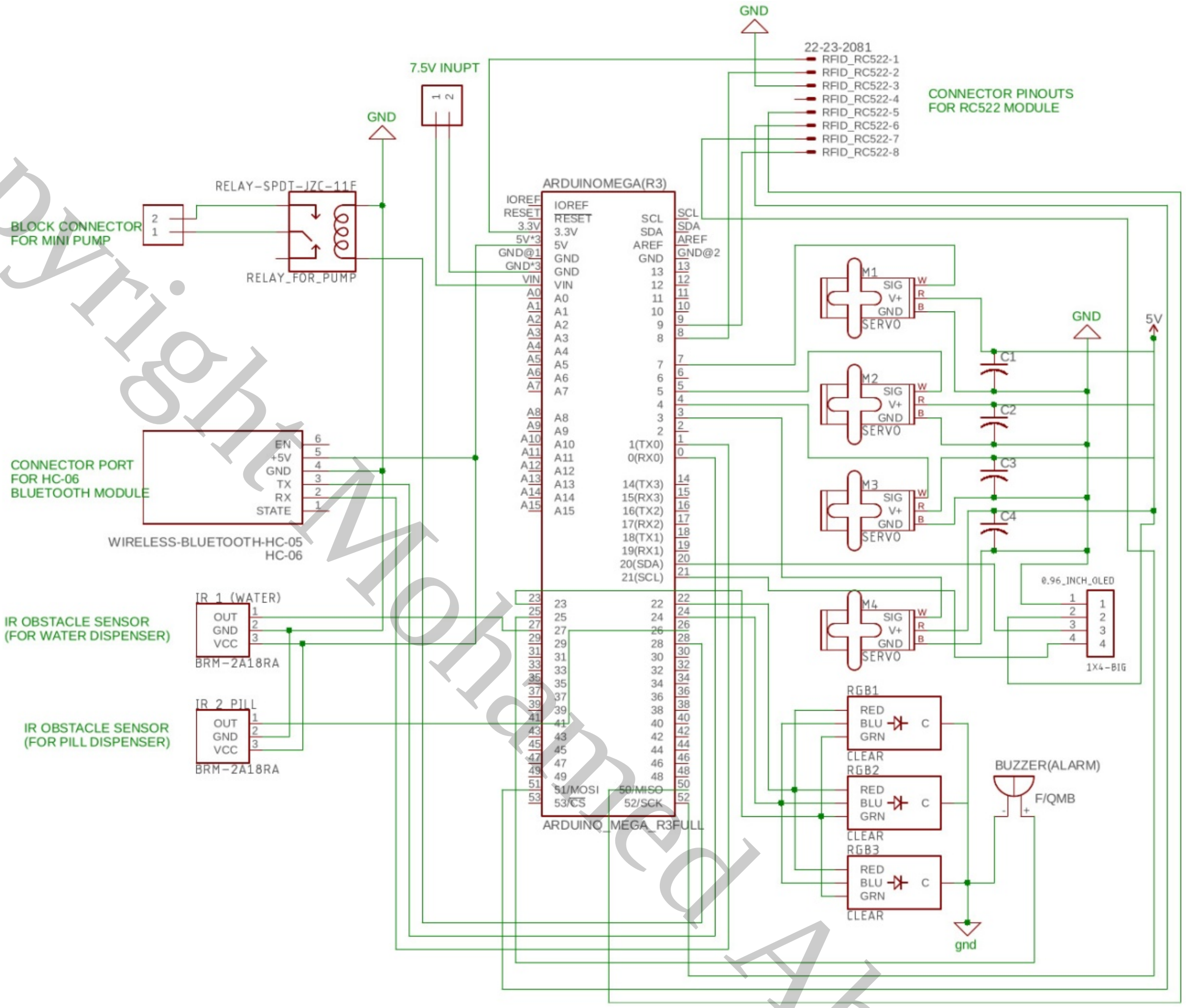

Figure 36: Complete schematic of arduino and other components connections

ARDUINO PIN	RFID	0.96" OLED	RGB	BUZZER	IR1	IR2	RELAY FOR PUMP	SERVO MECHANISM	HC-06
D0									TX
D1									RX
D2									
D3								PWM1	
D4								PWM2	
D5								PWM3	
D7								PWM4	
D8	RST								
D9	SS								
D20		SDA							
D21		SCL							
D22			R						
D23			G						
D24			B						
D25				BUZZER					
D26					OUT				
D27						OUT			
D28							IN		
D50	MISO								
D51	MOSI								
D52	SCK								
3.3V	3.3V								
5V		VCC			VCC	VCC	VCC	VCC	VCC
GND	GND	GND	GND	GND	GND	GND	GND	GND	GND

Table 1: Arduino and other components pin-out configuration

Power supply: The power supply part has two buck converter modules (12 to 5 V and 12 to 7.5 V) which step downs the 12 V dc to 5V and 7.5V lines.

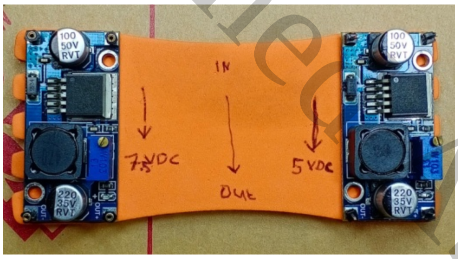

Figure 37: 2 x LM2596 buck converter

Cooling fans and LED strip: The device has two 12VDC cooling fans to cool down the main board when too much current is drawn by the buck converters. The LED strip is connected to an Light Dependant Resistor (LDR) relay module, which turns on automatically when the device is in dark.

Figure 38: LDR relay module

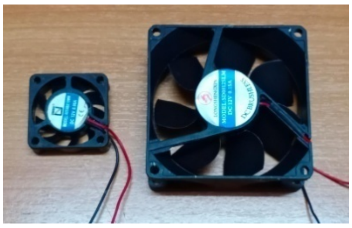

Figure 39: 12VDC PC cooling fans

IR sensors: The device will have two IR obstacle sensors at the side of the water dispenser and at the top of the pill dispenser, which makes sure that the water and the pills are dispensed only when the cup or hand is placed under to collect.

Figure 40: IR obstacle sensor (real picture)

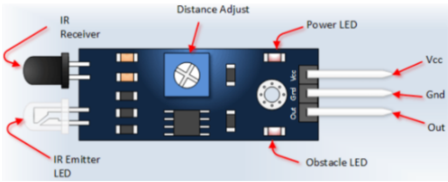

Figure 41: IR obstacle sensor (pin out diagram)

Relay for mini pump: For dispensing water, the device has a mini 12 VDC water pump (motor), which can't be driven directly by the Arduino Mega, so the motor is connected to the 5V relay, which is connected to the Arduino mega, so that the current is not directly drawn from the Arduino mega for the dc motor, instead the board just sends a 5V signal to the relay for few seconds to activate the motor

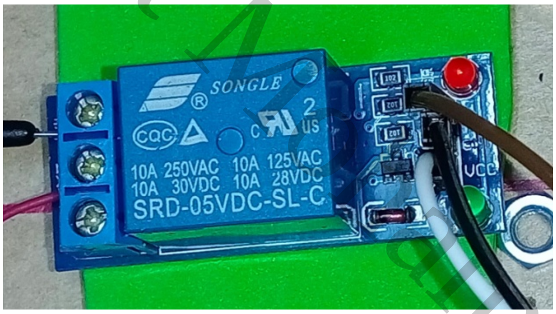

Figure 42: 12V relay module

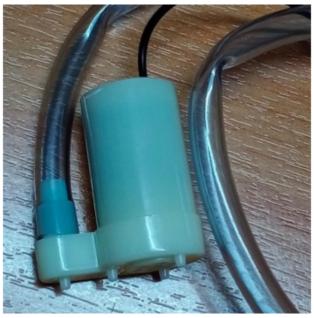

Figure 43:Mini DC pump

Pill dispenser system (servo's): This is separate system with 4 pill dispensing mechanism, i.e. 4 servo motors, this frame has 4 mechanisms attached, which dispenses 8 kinds of pill. The output cable from this frame is a 12 pin cable.

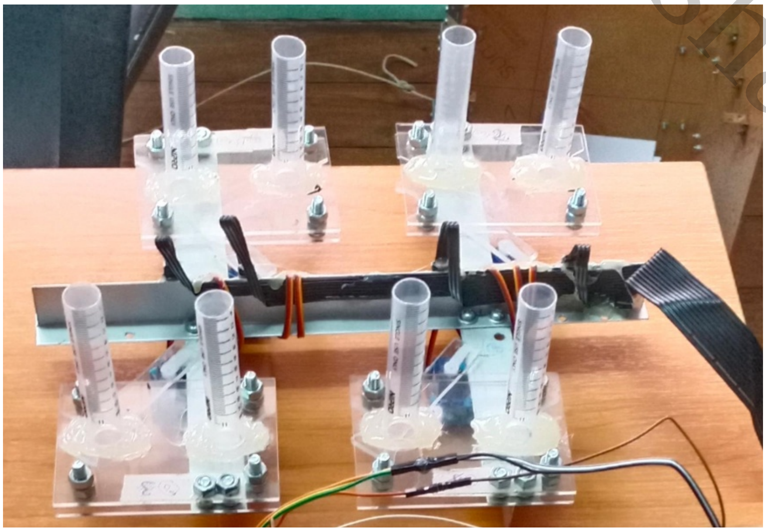

Figure 44: Pill dispensing mechanism (fixed frame)

OLED display: This mini 1inch 4 pin OLED will display texts like "please collect your pill", "Pascal, It's time to take your pill ", and other small statements based on the functions.

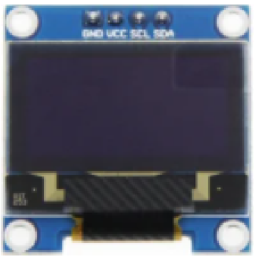

Figure 45: 0.96 inch OLED display

RGB LED's and Buzzer: This board is soldered with 3 RGB LED's in parallel and one buzzer, which will be connected to the digital pins of the Arduino. Its purpose is to use as alarm sound to call user to take their pill at the right time, and the led's will flash in different colors based on the functions. Only the connecter pins are soldered to the board, so that the LED's or buzzer can be changed in case they are burnt.

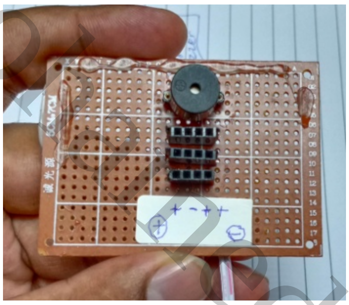

Figure 46: RGB and Buzzer

Bluetooth module: This module is the main bridge to connect our smart phone app to our AMS device. It's a HC-06 Bluetooth module, where the TX and RX pin will be connected to one set of the transmitter and receiver pins in arduino.

Figure 47: HC-06 Bluetooth module

RFID module: This Radio Frequency Identification (RFID) module is a reader which detects small memory from the RFID tags, this module will be used for the device to detect the user and dispense the right pill.

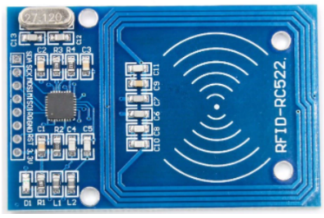

Figure 48: RC522 RFID module

3.3.3 Parts and components

The pictures below are list of all electrical and electronics components and modules used in this project. Some modules specifications are explained further.

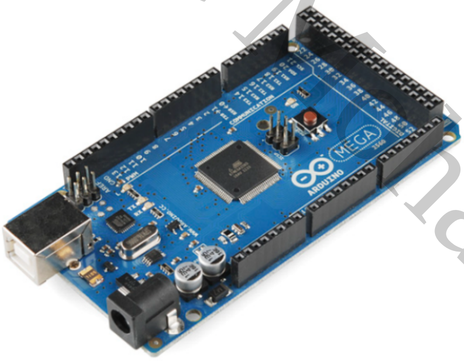

Figure 49: Arduino Mega R3

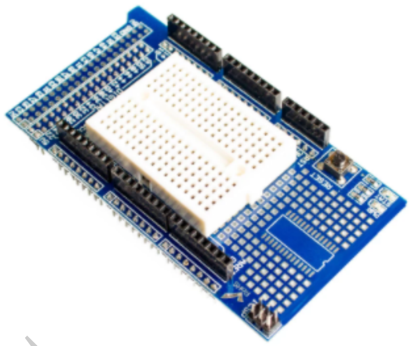

Figure 50: Arduino Mega prototype shield

Figure 51: 12V DC adapter

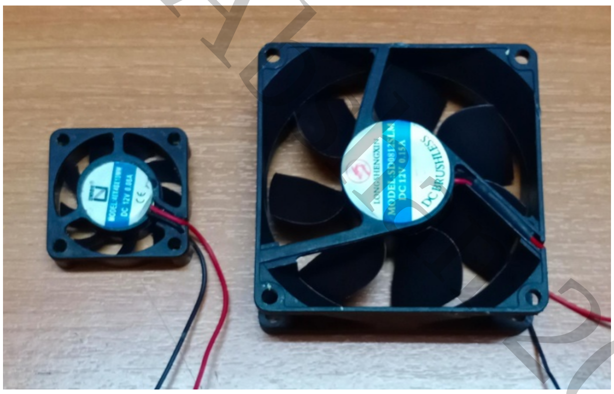

Figure 52: Cooling fan's (12VDC)

Figure 53: LM2596S buck converter

Figure 54: 12V LED strip

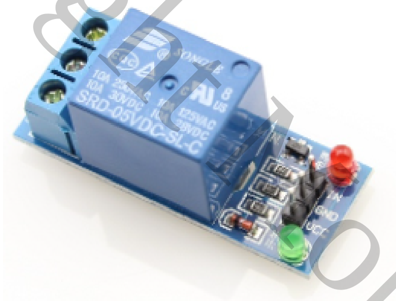

Figure 55: 5V SPDT relay module

Figure 56: XHM131 LDR relay module

Figure 57: RGB LED (CC)

Figure 58: 5V Buzzer

Figure 59: 0.96 Inch OLED

Figure 60: SG90 micro servo motor

Figure 61: 5V mini water pump

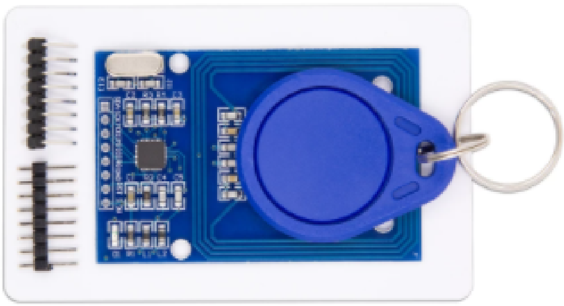

Figure 62: RC522 RFID module

Figure 63: HC-06 Bluetooth module

Figure 64: IR obstacle sensor

3.3.4 Hardware specifications

Some key components in this project are entitled below and will have brief hardware descriptions explained.

LM2596 Buck converter: It is an voltage step down (buck) module which is capable of driving up to 3A current, and outputs with low fluctuation and no ripples. The input voltage can be from 3 to 40V and the output voltage can be adjusted by the small fixed potentiometer ranging from 1.1 to 37 V. In this project the modules output voltages were adjusted and fixed to 7.5 V and 5 V dc.

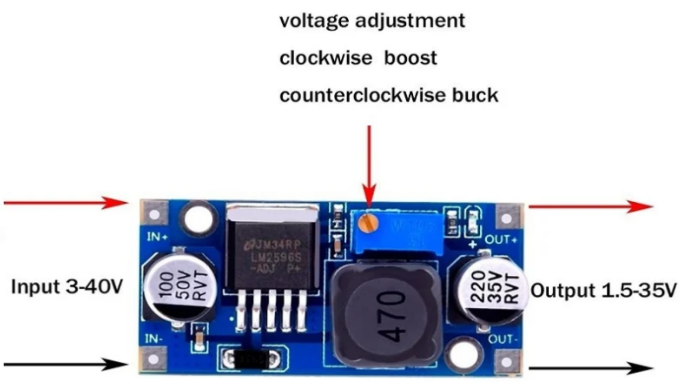

Figure 65: LM2596S labeled description

Arduino Mega prototype shield R3: This shield comes with an solder less bread board, and the digital and analog pins are organized which makes it easier for the components to solder to the shield and not the board, this way we can change the board easily without removing the components and sensor pins.

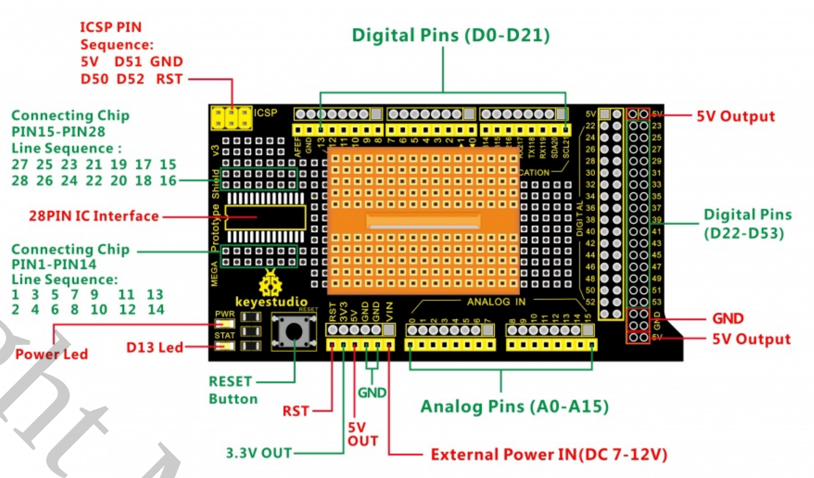

Figure 66: Arduino mega prototype shield pinout

3.4 Issues and challenges during progress

The most common issues faced during the testing was the servo motor. This project requires the servo position to be moved precisely, but due to the bad output signal from the arduino, the servo's were lagging and vibrating when two or more servo's worked together.

To solve this issue, the program was modified in a way that only one servo worked at a time, and also a 100uF capacitor was added in parallel to the VCC and GND inputs of the servo motor to avoid unstable power supply.

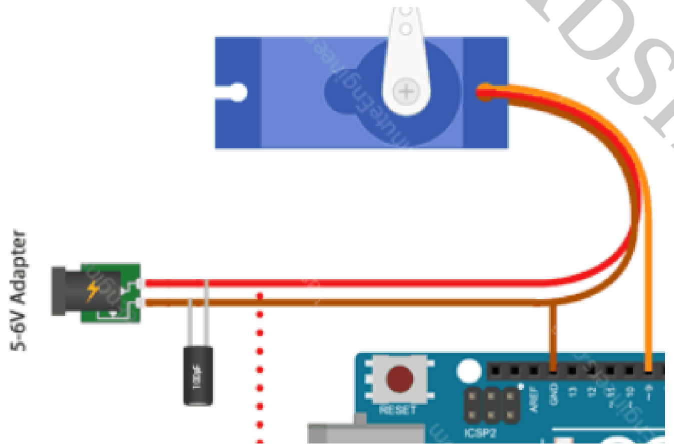

Figure 67: Capacitor connected in parallel with servo input power

Chapter 4: Experiments and results/Tests

4.1 Experiment and results

4.1.1 Testing methods

To test this system, standard checklist was designed as below.

- After answering the questions asked by the AMS app, the final pill decided by the system should obey the AMS decision tree flowchart.
- Once we click on dispense pill on our smart phone (AMS app), the AMS device should wait till the hand is placed under to collect the pill.
- Same way, the water should dispense only when a cup is placed under.
- Correct pill should be dispensed based on the RFID tag.

4.1.2 Testing and trouble shooting

For testing the device, firstly the RFID tags were programmed and tested with the reader module to make sure the reader catches the information string.

A test code in Arduino was created to check the servo's efficiency before exhibiting. This test was mandatory as the only precised moving part was to be the pill dispensing mechanism.

4.1.3 Results and analysis

The main function to test was, that the smart phone should interact with the AMS device and dispense the right pill, which worked perfectly fine. And based on the checklist above, all functions worked fine.

And the next function to test was the RFID tags. Once the programmed tags were taken near to the module, the AMS devices OLED displayed a message "please place your hand to collect your pill", once the hand was placed below the dispenser, the device dispensed the pills.

Chapter 5: Conclusion/Discussion/Recommendations

5.1 Conclusion

To wrap up the projects outcome, the expected outputs were observed and the pills were dispensed without any hardware or software errors.

From working on this project we learnt new things on the medications field and we learnt on how do we work as a team and realized that we could complete certain tasks faster and efficiently when worked together.

5.2 Project outcomes

Apart from the results and analysis, the outcome of the project is the skills accuired during the project and different techniques learnt to troubleshoot errors.

5.3 Discussions and future recommendations

The reults from this project were expected. Since this AMS device is a prototype, completely made by scratch, this device can be used as training purpore and to express the concept of this system.

This project can be upgraded by future students by adding motors and drivers to the base of the device, which can move through mapped locations to dispense pill. For example, dispencing pills to patients in the same ward with more than 20 patients. As we can see the mechanism of this AMS device is not so professional since that was not the main point of this project. Its the idea and the concept which makes this project unique.

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