Automatic Pill Dispenser

Integral project journal

Electronics Engineering

Tenth semester

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2. Introduction

Older people usually need to take different pills (Figure 1), several times a day. This can get tricky due to the different frequencies and doses that each different pill requires.

This activity of taking medications prescribed by specialists at the times they indicate is simple for many people, however, but as we know, not everyone finds it easy to do this at their own times. To help all these people to take their medications at the required time, either because they have to be taken strictly at certain times or simply because the person is very forgetful, it was decided to create an intelligent pill dispenser, so that it helps them to take the medicines they need at the time they are needed and the dose they need.

Figure 1- Example of Pads Supplied

This medicine dispenser (Figure 2) is intended for elderly people who usually forget things, as well as people with Alzheimer's, or people who usually forget to take their medicine on time. This is to have a centralized way of making it easy to take medications, including keeping track of what pills have been taken, when, and the dosage.

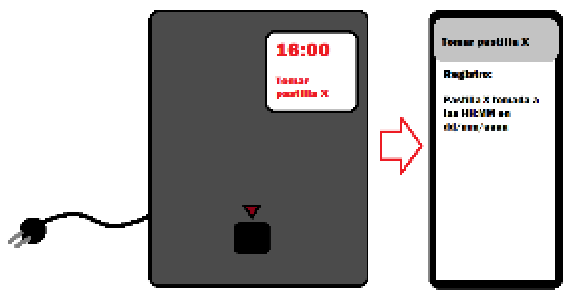


Figure 2- Conceptual image of the design

3. Justification

This device was contemplated to facilitate the process of taking medication for people who are mainly at home. Dispensing a specific dose with the required pills, at the time it is needed, as recommended by the medical specialist (Figure 3).

Figure 3- Example of medication intake

The main advantage of this system is that it eliminates the fact of trying to remember when and how many pills to take (Figure 4), automating the process so that the user is only notified that it is time to take their medicine, already with the required dose ready to be taken.

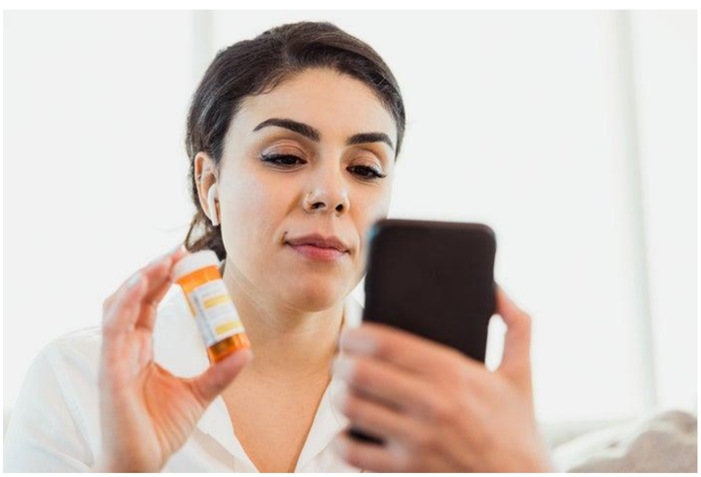


Figure 4- Person trying to remember when to take pills

4. Approach

The problem of knowing when a medicine with a specific dose should be taken would be solved by this device through an internal system. This system automatically manages, through an initial configuration, the times and days that different pills need to be taken. When it is time to prepare a dose, thanks to an internal classification and separation system, the necessary medicines are obtained and deposited directly in a container so that the user can take them without any problem.

Figure 5- Different solutions and methods of taking medication

Similarly, the user is notified that a dose is ready through a notification system. This system works directly from the dispenser through a sound notification (through a small horn) as well as with the LCD screen; and/or through a smartphone application that sends notifications to the user's cell phone. Similarly, the user is notified when the system detects that a ready dose has not been collected after a certain time.

Thanks to the smartphone application, you can have a detailed record of which pills were taken, at what time and on what day. This to help the medical specialist know in an easy and simple way the follow-up and adherence to a medical prescription.

5. Objectives

Develop a pill dispenser that can be programmable by the user, both directly on the dispenser and through an application on a smartphone.

The dispenser must supply the different pills (maximum 4 different ones) at intervals specified by the user and notify them so that they know that a dose is ready to be withdrawn from the dispenser.

The main objectives of the dispenser are the following:

User interface

- LCD screen to display messages
- Navigation buttons:
    - Up
    - Down
    - Right
    - Left
    - Enter/Accept
    - Recoil

Containers for four different pills

- A container for each type of pill
- System for obtaining individual pills

Notification system by sound, LED and screen

- When a dose is ready:
    - play a sound
    - turn on an LED
    - Display a warning on the screen

Automatic dose based on settings (amount and time)

- directly programmable
- Pickup Type Selection
- Pickup number selection
- Selection of schedule and what days should be taken

Dispensed pill counter

- By means of a sensor that is activated when a pill falls
- Keep an internal account by type of pill

Sensor to detect if the pills have been taken

- By means of a switch that detects when the tray has been removed
- In case the switch is not activated send notifications in a set time interval

6. Theoretical framework

6.1. Existing systems on the market

In the current market there are three main products with characteristics similar to our proposal, which solve this problem, however, they are too expensive and difficult to obtain in Mexico (Caro, 2021).

Hero

Characteristics (Hero Health, Inc., 2022)

- LCD screen
- Stores up to a 90-day supply for 10 medications
- Supports any type of solid pickup
- Synchronization with a smartphone app
- No battery in case of power loss

Cost

This system (Ilustración 6) is based on a subscription model. There is an initial payment of USD 99.99 plus USD 29.99 per month; the cost to use this product for one year would be 460 USD (**9,500 MXN** [1]).

Ilustración 6 - Dispensador Hero

Livi

Characteristics (Pharmright Corporation, 2019)

- LCD screen
- Stores up to a 90-day supply for 15 medications
- Supports any type of solid pickup
- It does not have synchronization via smartphone, but it does have connectivity via cellular networks
- It has a battery in case of power loss (6-8 hours of backup)

Cost

Ilustración 7 - Dispensador Livi

It works through a subscription model. There is an initial payment of USD 49 plus USD 99 per month; the cost to use this product (Ilustración 7) for one year would be 1,240 USD (**25,500 MXN** [1]).

[1]Exchange rate 1 USD = 20.62 MXN as of 03/02/2022

Medacube

Ilustración 8 - Dispensador MedaCube

Characteristics (PharmAdva, LLC., 2022)

- LCD touch screen
- Stores up to a 90-day supply for 16 medications
- Supports any type of solid pickup
- Notifications by text message, email
- It has a battery in case of power loss (24 hours of backup)

Cost

Unlike the Hero and Livi dispenser, for the MedaCube dispenser (Ilustración 8) a single payment of 1,699 USD (35,000 **MXN) is made** [1].

6.2. Advantages of our solution

Our solution encompasses the main features of these three previous devices, in order to offer a good and easy user experience for them to take their necessary medications.

The main advantage of our solution is the cost, since, in our social context, the average Mexican citizen cannot afford to spend as much money as the previous options need, so it is sought to have a system that is inexpensive, but that offers functionality similar to today's existing smart pill dispensers.

For example, the cost for two years of service for the three dispensers on the market is shown in Table 1.

Cost for two years		
hero	**Livi**	**medacube**
MXN17,000	MXN50,500	MXN35,000

Table 1- Comparison of costs [1]for two years of service

6.3. Most common pill sizes

The pill dispenser works with a pneumatic suction system, so research (Capsule Sizes, s.f.) (Federico Domenech S.A., 2018)on the most common types and sizes of pills had to be done in order to choose a suitable system that could pick up these pills.

Figure 9 and Figure 10common pill shapes.

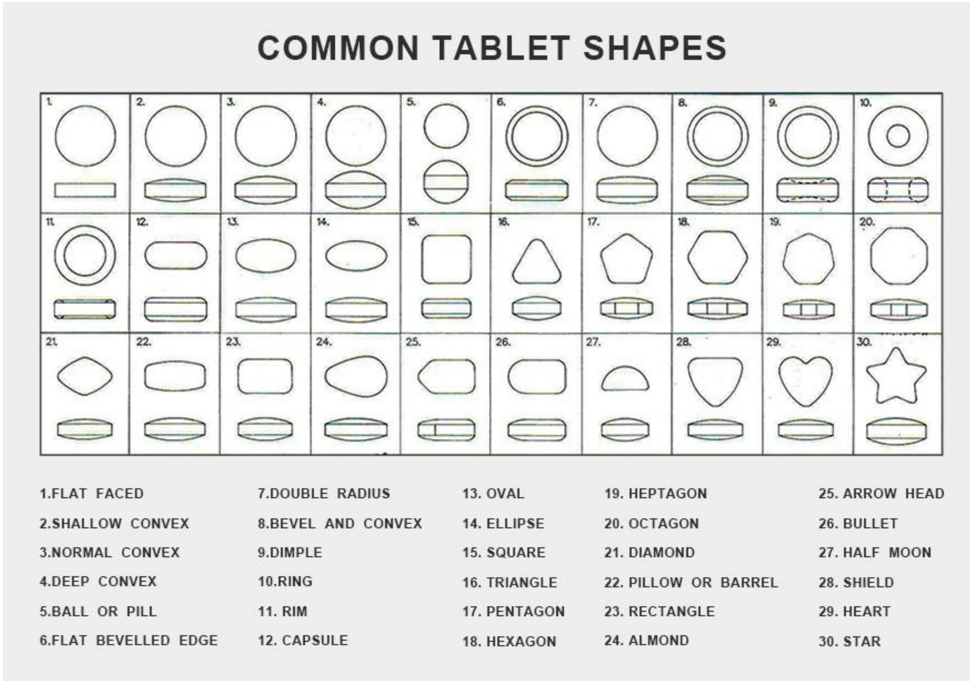


Figure 9– Table of common forms of medicine

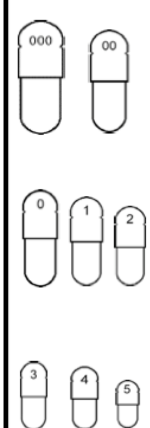
Representative (approximate) Capsule Sizes	Capsule Size	**Typical Fill Weights (mg)** Actual Fill Weights may vary and depend on powder characteristics			Volume Theoretical	Locked Length		External Diameter	Cut Length	Single Wall Thickness	Weight (Avg. of 100)
		Powder Density 0.45 (Light)	0.70 (Typical)	1.00 (Heavy)	(ml)	+/- 0.76 (mm)	Tolerance Component	(mm)	+/- 0.51 (mm)	+/- 0.03 (mm)	+/-10% (mg)
	000	615	960	1370	1.37	26.14	Cap	9.91	12.95	0.112	163
							Body	9.55	22.20	0.110	
	00	430	665	950	0.95	23.30	Cap	8.53	11.74	0.109	118
							Body	8.18	20.22	0.107	
	0	305	475	680	0.68	21.70	Cap	7.65	10.72	0.107	96
							Body	7.34	18.44	0.104	
	1	225	350	500	0.50	19.40	Cap	6.91	9.78	0.104	76
							Body	6.63	16.61	0.102	
	2	165	260	370	0.37	18.00	Cap	6.35	8.94	0.102	61
							Body	6.07	15.27	0.099	
	3	135	210	300	0.30	15.90	Cap	5.82	8.08	0.092	48
							Body	5.56	13.59	0.890	
	4	95	145	210	0.21	14.30	Cap	5.31	7.21	0.096	38
							Body	5.05	12.19	0.091	
	5	60	90	130	0.13	11.10	Cap	4.91	6.20	0.089	28
							Body	4.68	9.32	0.086	

Figure 10– Capsule size

7. Developing

7.1. Work methodology

To start with the development of the project, it was decided to choose the work methodology of the author Stuart Pugh, shown in Figure 11.

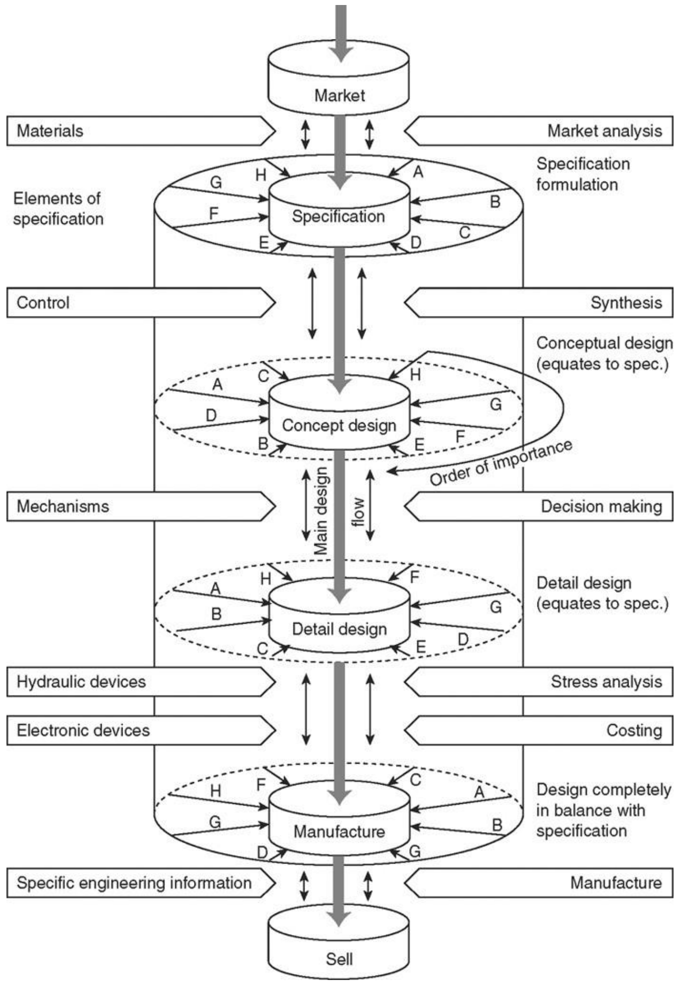


Figure 11– Design process according to S. Pugh

This work methodology was chosen as we felt that it was well suited to our project, due to market analysis, specifications, conceptual design, etc.

7.2. Preliminary approach

In the block diagram (Figure 12), you can see graphically the main blocks that make up the design of the pill dispenser, using an Arduino Mega microcontroller based on the AVR ATmega2560 architecture.

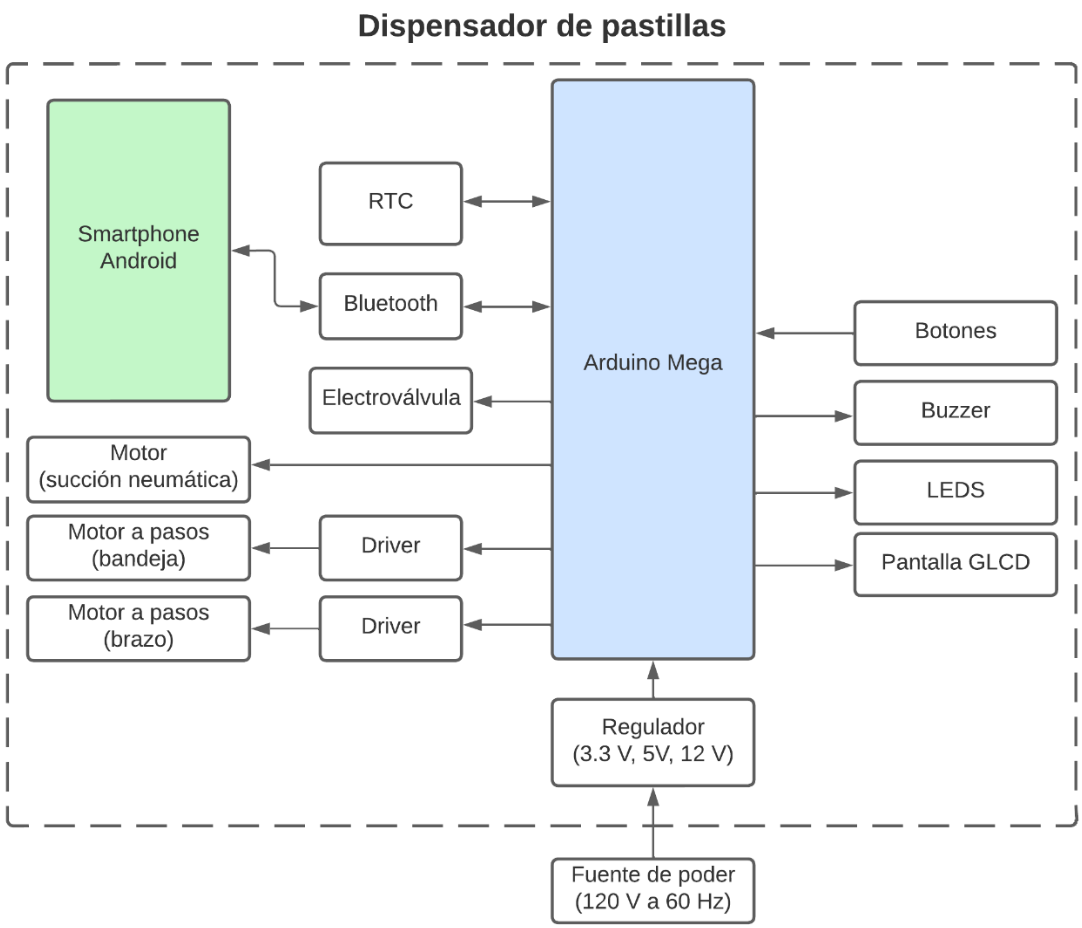


Figure 12– Proposed block diagram of the system

The program for the pill dispenser was made in C++ using Microsoft's Visual Studio Code IDE together with the PlatformIO extension, which allows us to directly program the microcontroller.

It was decided to use C++ and not C because object-oriented programming offers many improvements in terms of code understanding, as well as being able to make it more modular and take advantage of the instantiation of user-created objects.

7.3. Initial prototype

Once the work methodology and a general idea were defined thanks to the block diagram, the development of the first prototype of the pill dispenser began (Figure 13). This first prototype in its initial phase consisted of two stepper motors, a pneumatic motor and an Arduino Uno, through which a simple program was programmed to test the operation of the motors.

This program simply rotated the tray, lowered the arm to the bottom of the container on the tray, and finally turned on the air motor, repeating the operation.

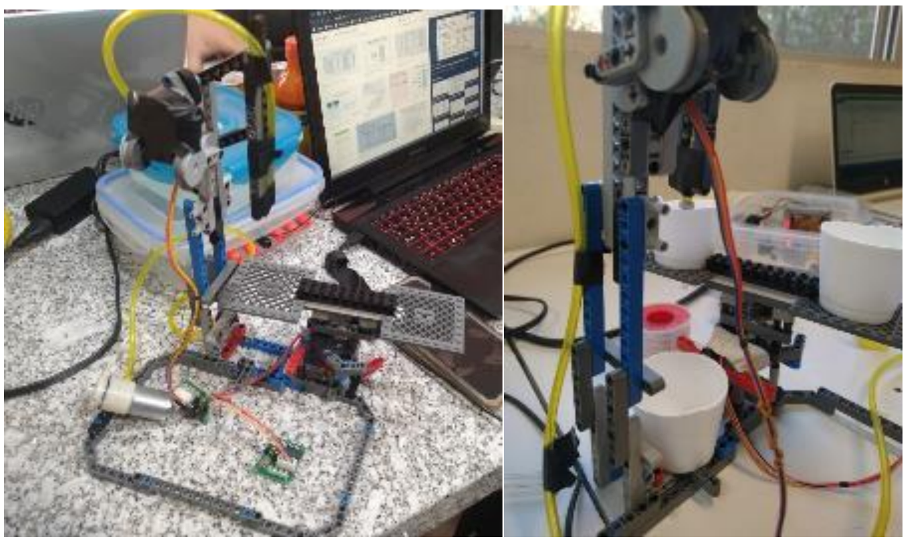


Figure 13– Initial prototype of the project

Later, it was decided to change the simple tray that allowed having only two containers, for a circular tray allowing to have 4 different containers and a hole through which the pills would fall into the container to be picked up by the user (Figure 14).

Figure 14– Prototype with a circular tray

Graphical User Interface (GUI)

In parallel, using a second Arduino uno, the development of the graphical user interface (GUI) was started using a GLCD screen with a resolution of 128x64 pixels. To this was added a 4x4 button matrix keyboard to be able to test the user interactions and the graphical interface (Figure 15).

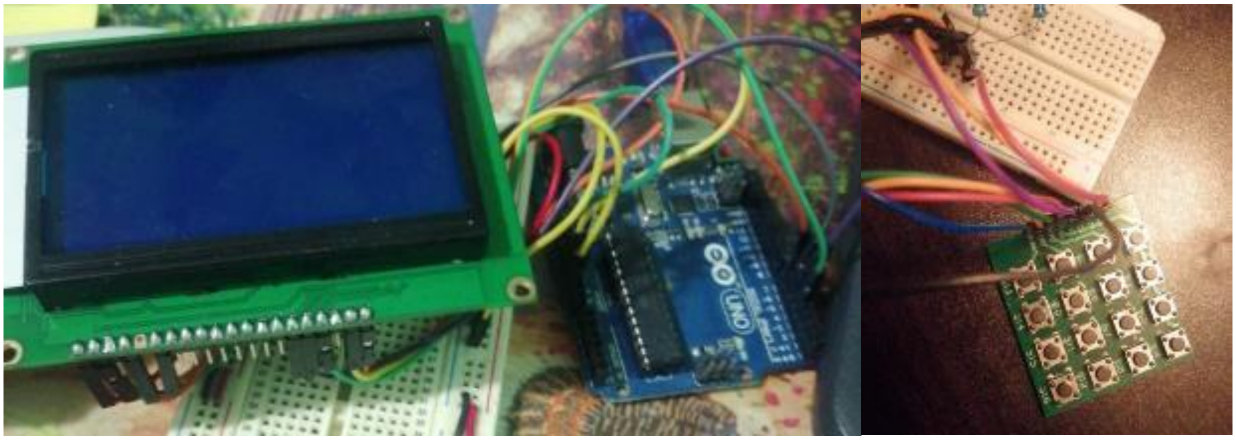


Figure 15– 4x4 display and keyboard connected to an Arduino UNO

Subsequently, it was decided to make a keyboard with a perforated plate already with the buttons that would be used (up, down, left, right, ok, back) so the button matrix was discarded (Figure 16).

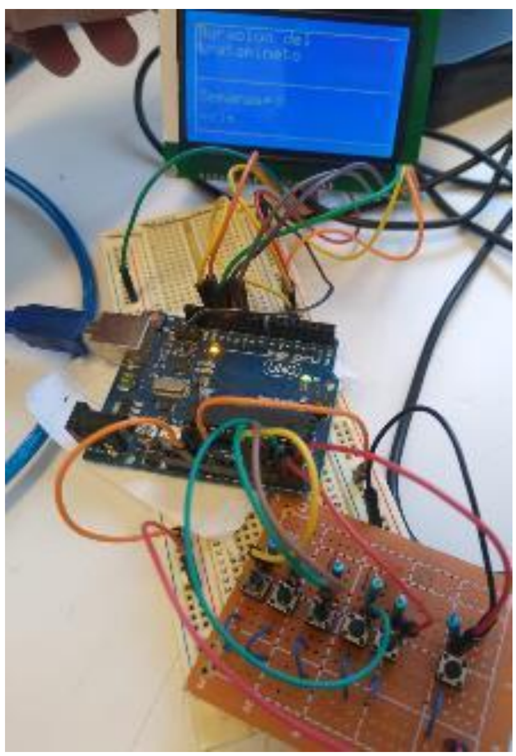


Figure 16– Graphical interface with the new keyboard

were designed through which the user could interact to configure the dispenser using the U8glib library [2].

The first four screens were the main menu, pill selection, treatment duration and frequency (Figure 17).

Figure 17- Some screens of the graphical user interface

Real Time Clock (RTC)

Afterwards, the programming of the RTC began using the DS1302 integrated circuit (Figure 18) in order to obtain the real time and thus be able to base the intervals to dispense the pills, as well as the specific days that the user has configured. Similarly, it also serves to be able to notify when the pills contained in the dispenser expire.

Figure 18– RTC DS1302 used

[2]Repository where the library is located (https://github.com/olikraus/u8glib)

Wireless connectivity

Moving forward with the project, work began with the ESP32 board to be able to wirelessly configure the dispenser through the cell phone application. It started with a small program to be able to create an online server and be able to control an LED wirelessly (Figure 19), testing the connectivity of the device.

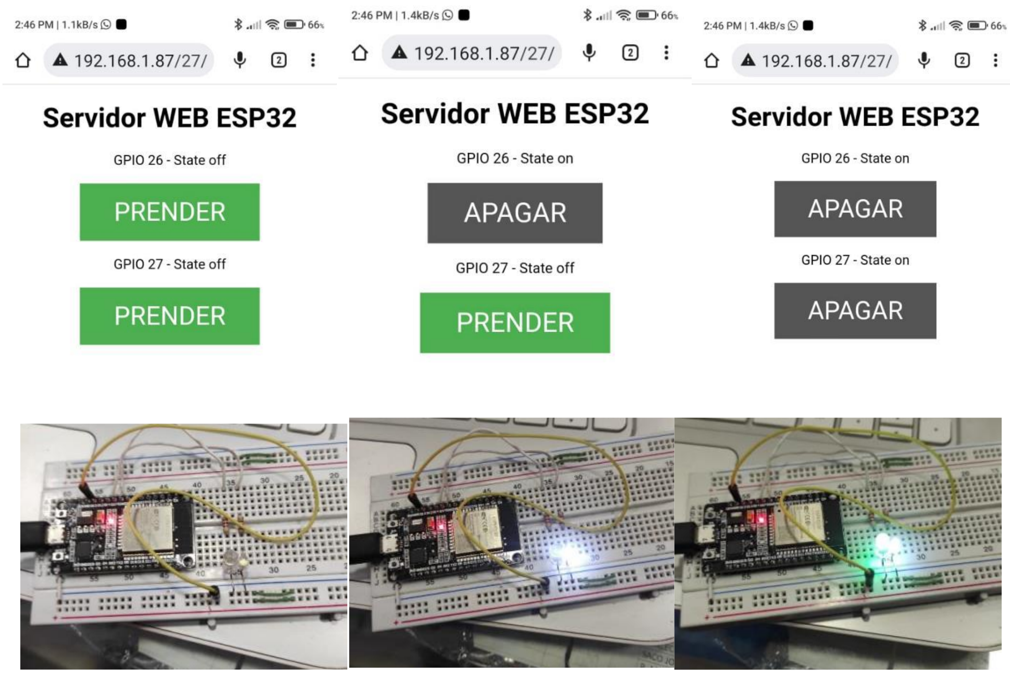


Figure 19– Example of the server created using ESP32

Although the web server was an initial requirement, due to the limited amount of time we had, it was decided to use only the Bluetooth protocol to communicate with the microcontroller. For this, we discard the ESP32 and use the HC-05 module as a slave (Figure 20) simplifying the process of developing wireless connectivity.

Figure 20– HC05 Bluetooth module

7.4. Initial Android Application

Parallel to the development of the physical prototype, the development of the first version of the application began using the Android Studio IDE (Figure 21).

It started with an initial menu with 3 buttons (Add pickup, configuration and registration). Selecting the configuration button takes you to a screen with selectors for the 7 days of the week.

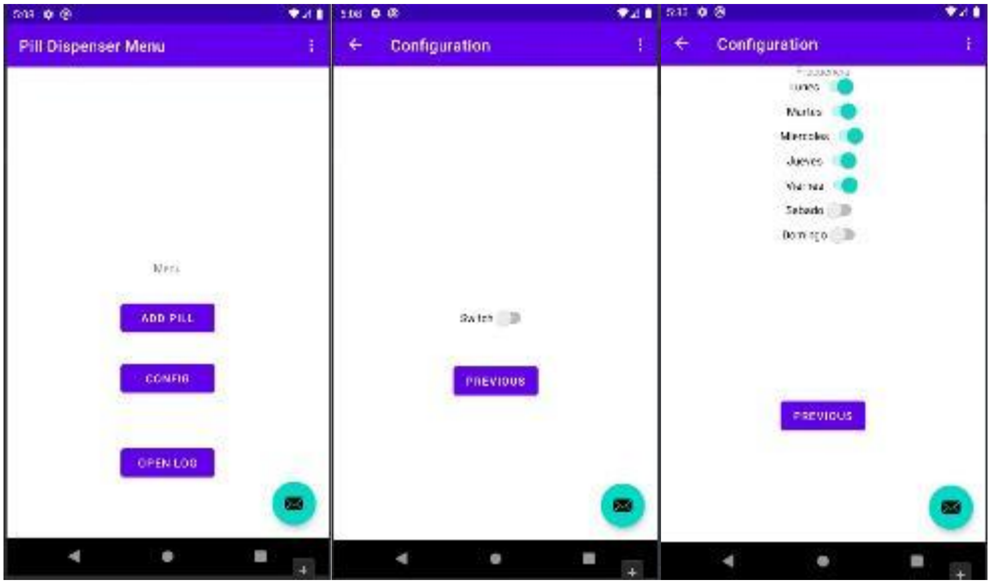


Figure 21– Initial version of the application in Android Studio

Changes were then made to the application, adding more buttons and text fields to be able to configure the pills (Figure 22). It was during this point in the development of the app that we realized that it was going to take too long to program all the necessary logic using Android Studio, so it was decided to find a faster alternative.

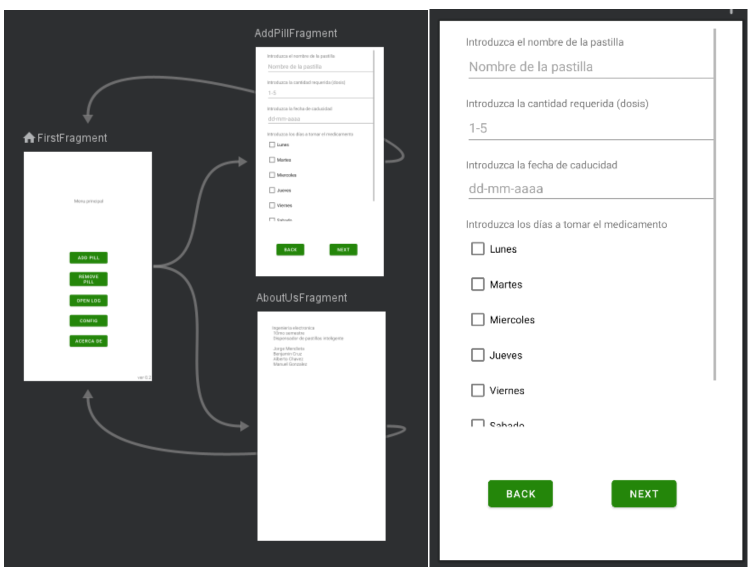


Figure 22– Improved screens of our app

7.5. Second prototype

Mechanical arm

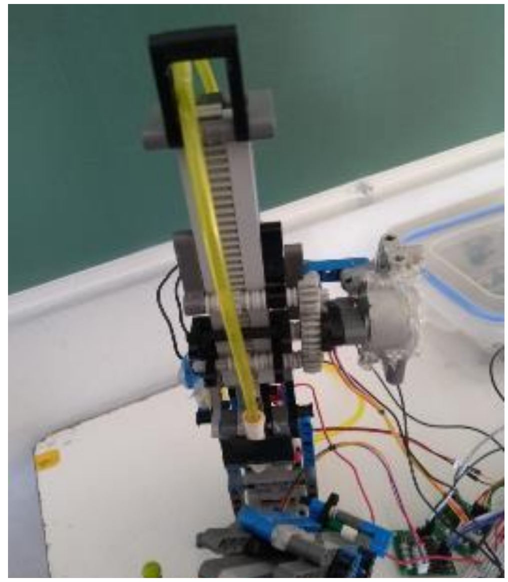


Ilustración 23 – Prototipo modificado

After working on the first prototype, we were able to realize that there were design errors which affected the correct operation of our product.

The first major modification made to this new prototype was the arm gear system. Previously it was a mechanical arm that lowered in an arc to be able to take the pill. The problem with this mechanism was that it did not always fall at the same point due to the arc that it made, so the suction cup did not always reach the same point, so it was decided to make a new system that moves the arm of straight way, making the suction cup always reach the same coordinate in the horizontal plane regardless of the depth (Ilustración 23).

Suction system

A second problem was that the vacuum created by the bellows suction cup when sucking a tablet when the pneumatic motor was turned off was not anticipated, so the tablet remained sucked and did not fall into the glass.

To solve this problem, a solenoid valve had to be ordered (Figure 24) which was going to be added to the pneumatic system to be able to control it by means of the microcontroller. By activating the solenoid valve, the pressure equalizes with the environment, and thus be able to release the pill when required.

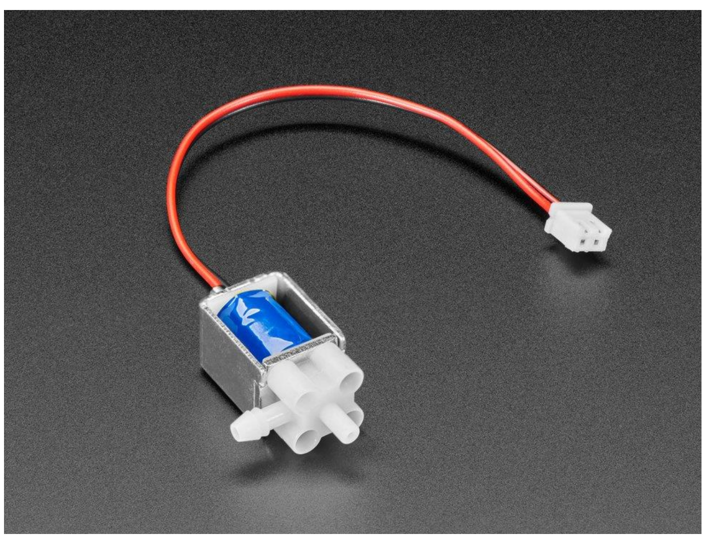


Figure 24– Air Solenoid Valve Used

Pill containers

Similarly, we found that our air motor was not powerful enough to be able to suck up tablets when the suction cup nozzle was not directly on the surface of the tablet, so when using the initial cups there were small gaps between the tablets. pills preventing them from being sucked out.

To solve this problem, it was decided to make containers suitable for the shape of each pill with Lego pieces so that due to the same effect of gravity they would always rest on the same point, facilitating the suction process since it would ensure that the suction cup always cover the surface of the pill to be collected (Figure 25).

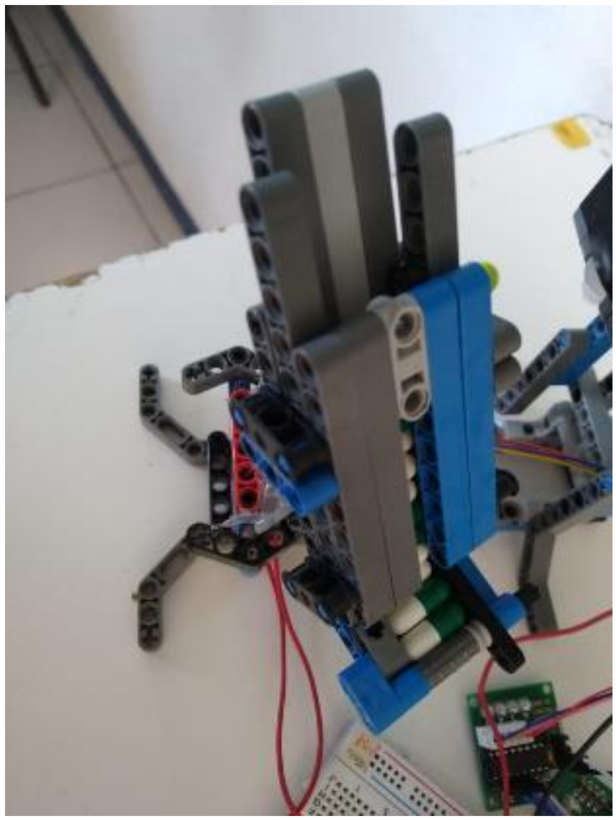


Figure 25– Container made from Legos for capsules

Graphic interface

Another of the important modifications to our prototype were those that were made to the graphical user interface shown on the screen. It was migrated to a new version of the graphics library (U8g2 [3]) to be able to use the new functions available, as well as to reduce memory use thanks to the optimizations of this new version.

These modifications were not only part of the *backend*, but changes were also made to the *frontend*, in other words, the graphical interface that the end user would see in the dispenser. The screens were standardized

[3]Repository (https://github.com/olikraus/u8g2)

so that there was better "cohesion”, and it was more pleasing to the eye, as well as to facilitate navigation between screens, as well as to choose different options (Figure 26).

Figure 26– New screens with a standard design

7.6. Final version of the Android app

After spending some time working on the Android application using Android Studio, we realized that the time needed to make a good application was too much due to the complexity of application development (something that was ignored at the beginning of the project proposal).).

To avoid devoting too much time to the development of the application, it was decided to use the free software MIT App Inventor 2 (Figure 27). This software to create applications greatly simplified the process so that more could be done, in less time.

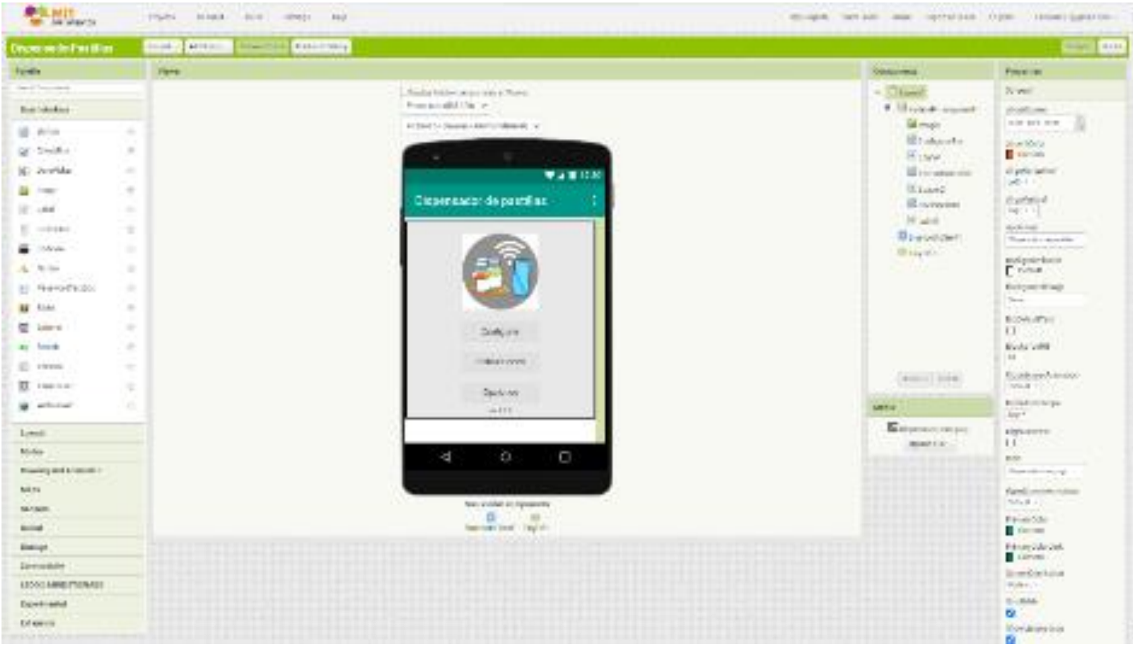


Figure 27– Screenshot of MIT App Inventor 2

The main difference between MIT App Inventor 2 and the Android Studio IDE is that the former is based on graphical programming, using code blocks to facilitate development. The main disadvantage is that when making a relatively complex application like the one we required, the blocks ended up being too long, making navigation a bit difficult to find function blocks (Figure 28).

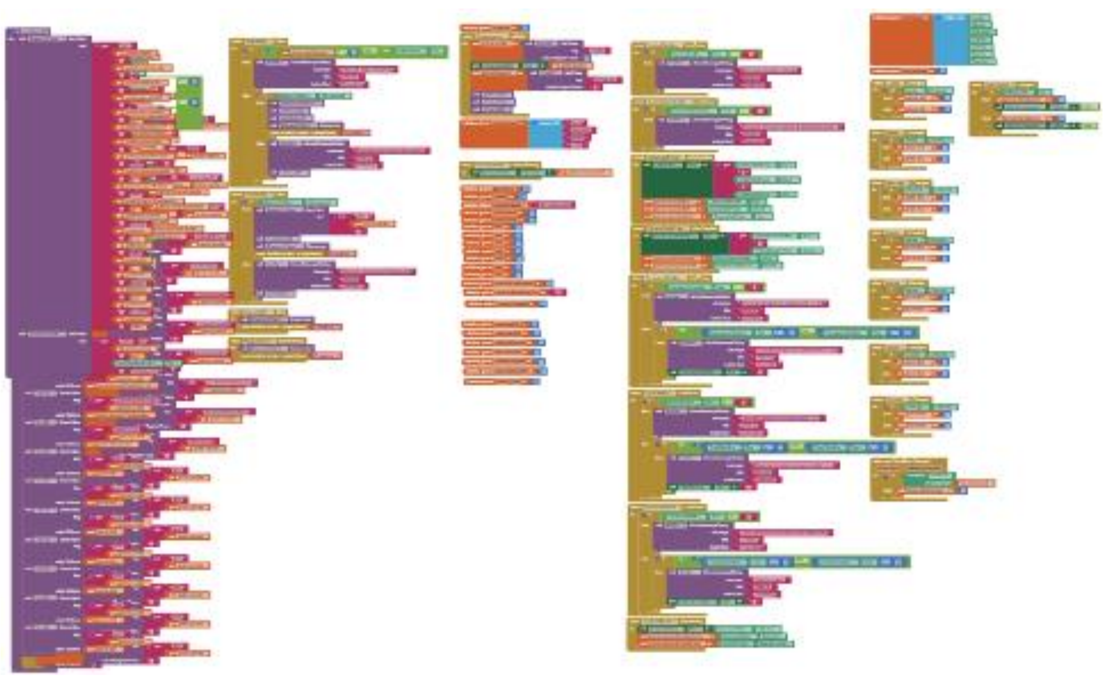


Figure 28– Code blocks for the application

Once the application was programmed, a screen was obtained with buttons that, when touched, lead to different configuration screens and options to program the automatic pill dispenser shown in Figure 29.

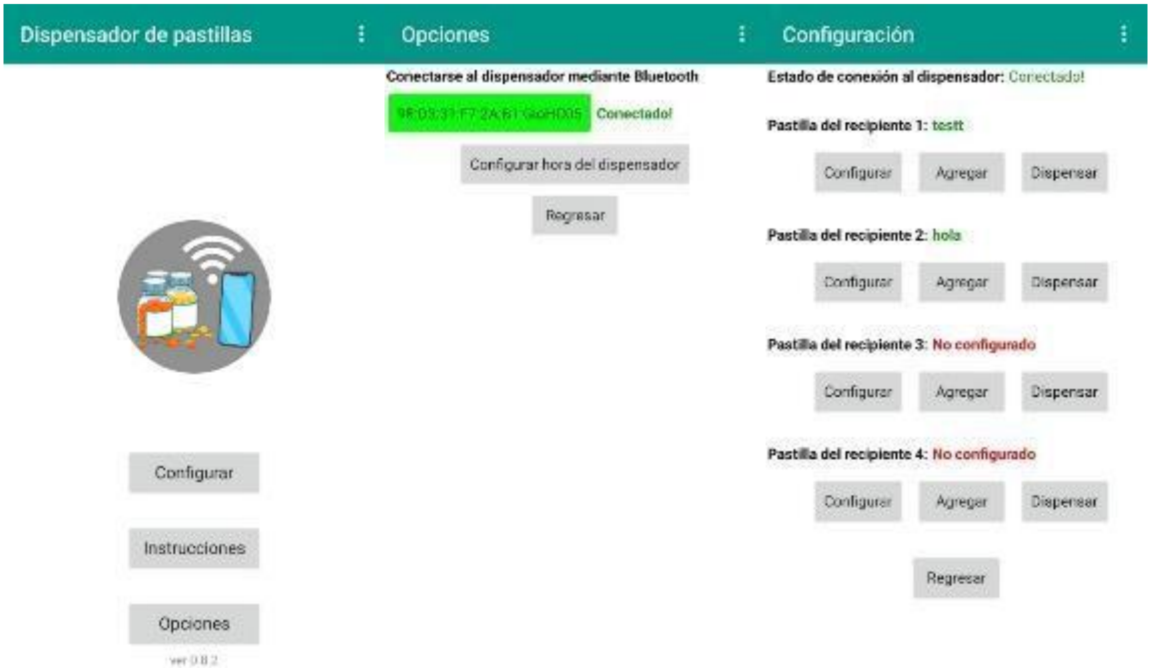


Figure 29– Screens of the created application

7.7. Integration of all modules

For the third version of the prototype, it was necessary to integrate all the modules (RTC, Display, Keyboard, Bluetooth, Dispenser) in the same microcontroller, so we ended up using an Arduino Mega based on the ATmega 2560 architecture (Ilustración 30). The choice of this microcontroller was that it had a greater number of GPIOs, as well as more space in Flash memory and RAM compared to the Arduino Uno.

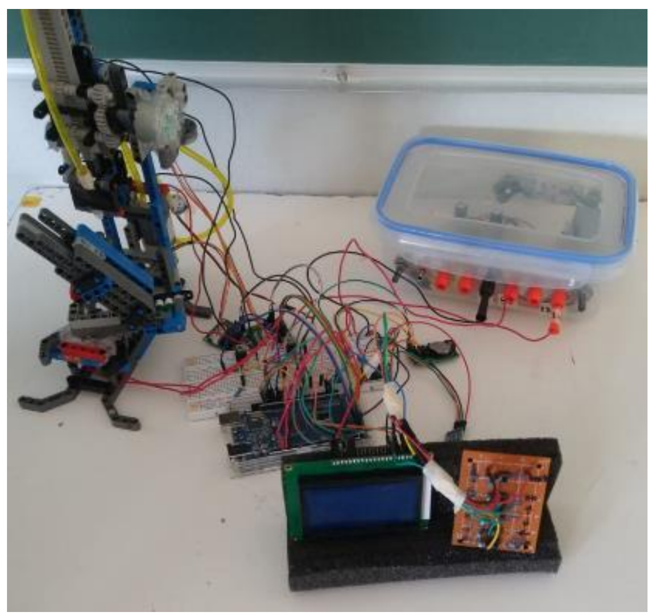


Ilustración 30 – Integración de todos los módulos

7.8. 3D part design

In order to continue with the development of the dispenser, it was necessary to stop using Lego pieces and create custom pieces based on our needs, so it was decided to use pieces designed in 3D to be sent to print.

For this it was necessary to use the Fusion 360 program together with a student license. We had to inform ourselves about the basics of 3D design in order to develop the designs for the custom pieces. Subsequently, the designs were exported to the Ultímate Cura free software to finish giving the parameters to our files and thus be able to send them to print.

The first piece to be designed in 3D was the container for the circular pills (Figure 31).

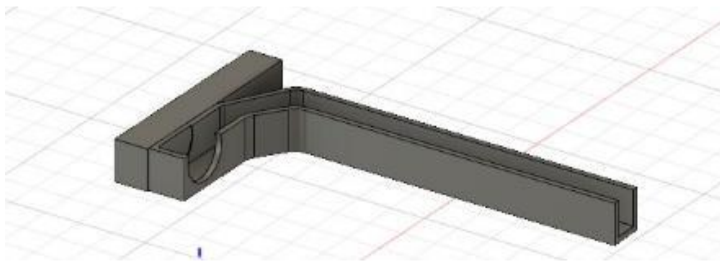


Figure 31– First design of one of the containers

Once the design was finished, it was sent to print with an Ender 3 printer. Unfortunately, this first attempt was unsuccessful because the printer was damaged (Figure 32). In order to continue the development of the project, we had to investigate other places that could print in 3D.

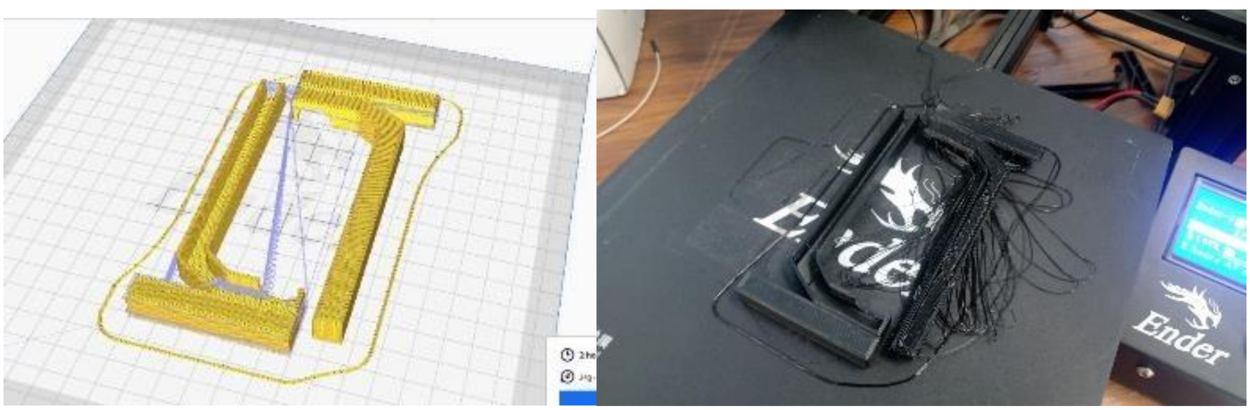


Figure 32– First print attempt

The design of the three remaining containers was completed (Figure 33), finally obtaining a way to store four different pills as specified in the initial proposal.

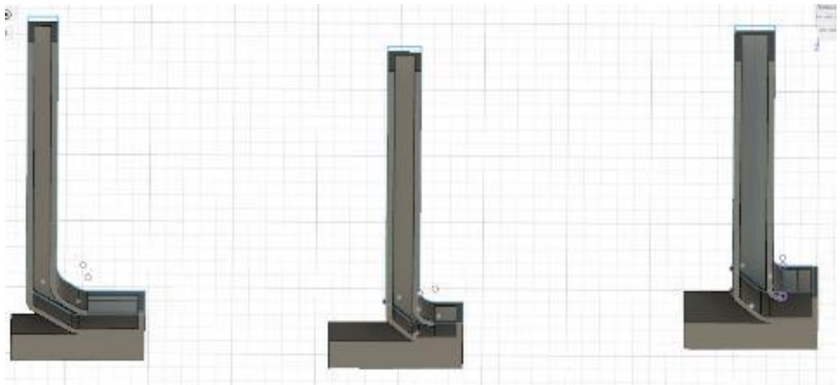


Figure 33– Updated design of the containers for the pills.

The next component that had to be designed was the rotating tray where the four containers for the pills are placed, as well as a hole through which the suctioned pill would fall. A design had to be created that would allow the containers to jam and hold in place to prevent them from falling out when the tray rotated (Figure 34). Similarly, a small hole had to be created in the middle of the bottom of the tray where it would join one of the stepper motors, as well as another hole to add a magnet to mark the home position in conjunction with a reed switch.

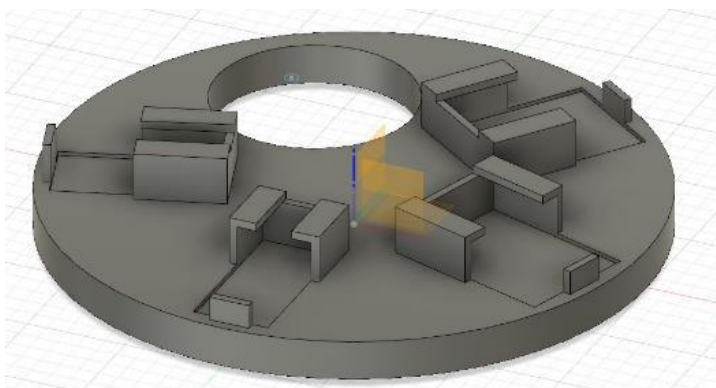


Figure 34– Turntable

So that the arm could go down straight with the stepper motor, a small gear and a rail were devised, leaving a hole in the middle through which the pneumatic system hose would pass (Figure 35).

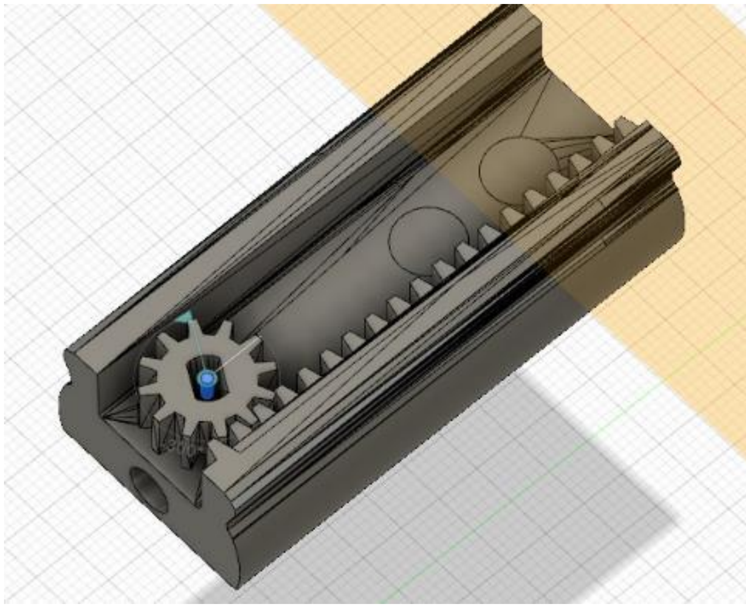


Figure 35- Rail and Gear System for Arm with Hose Hole

Finally, the base that would hold the tray and the containers for the pills (Figure 36) was designed.

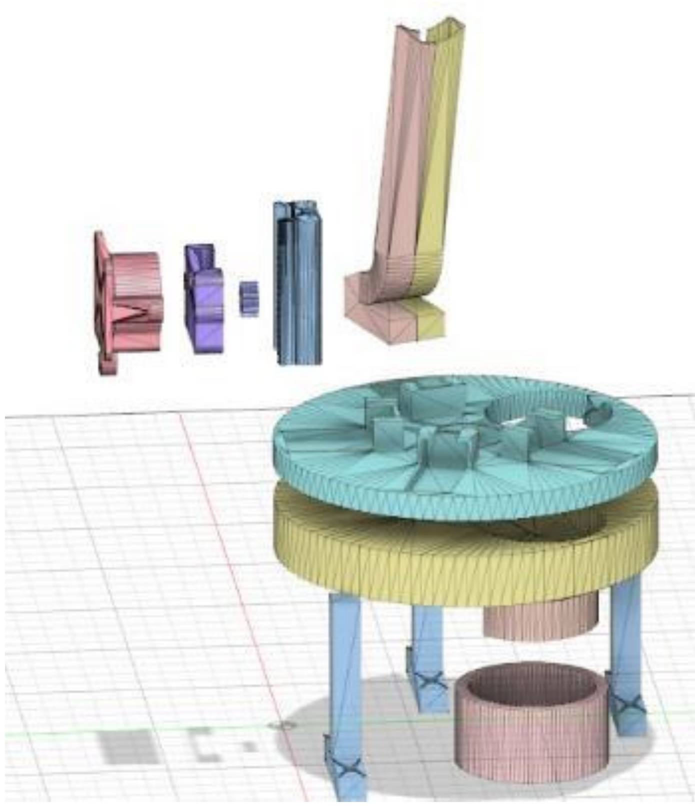


Figure 36– General image of all the pieces designed in 3-D

7.9. Printed circuit boards

To avoid having several loose wires on a breadboard and to obtain a more compact design, different printed circuit boards (PCBs) were designed. Unfortunately, because the design of the printed circuit boards started late, there was not enough time to have them professionally manufactured, so it was decided to make the printed designs at home using copper plates and acid as shown. in Figure 37.

The three PCBs that were created were for the keyboard, the voltage regulator and the motherboard, which would be connected by cables to each other since they would be placed in different parts of the dispenser.

Figure 37- Different stages for the elaboration of the printed circuit of the keyboard

Keyboard

Subsequently, we proceeded with the elaboration of the schematic (Figure 38) to place the six navigation buttons (up, down, right, left, ok, back) in a more orderly and compact way.

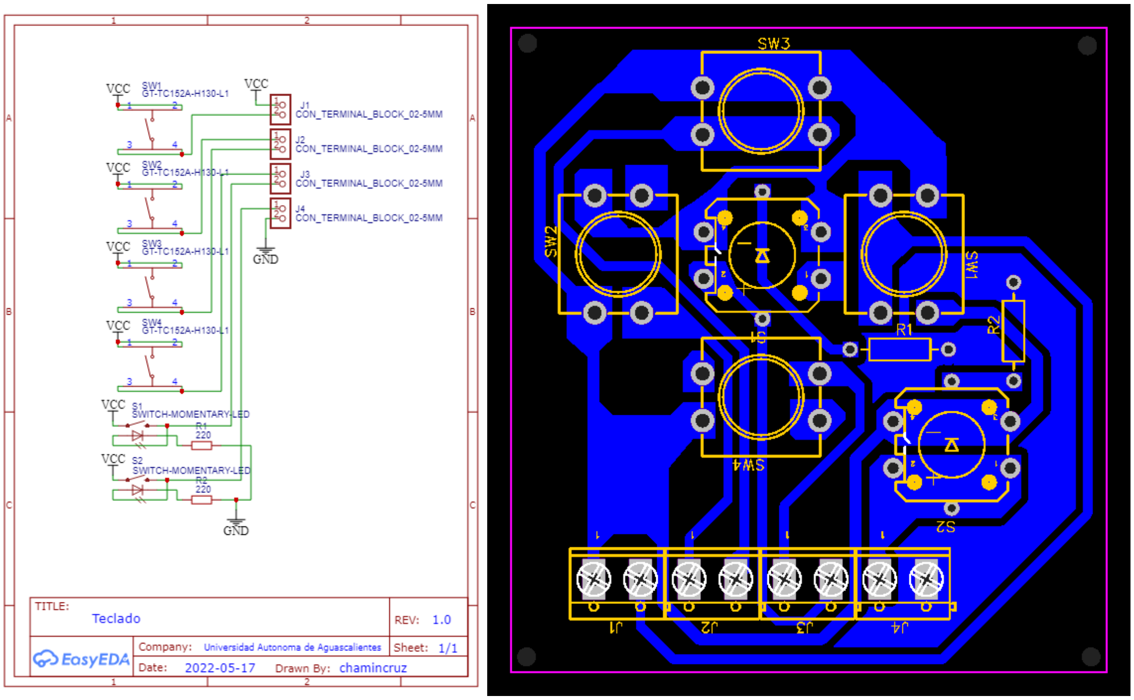


Figure 38– Keyboard (left) and PCB (right) schematic

The completed keyboard is shown in Figure 39.

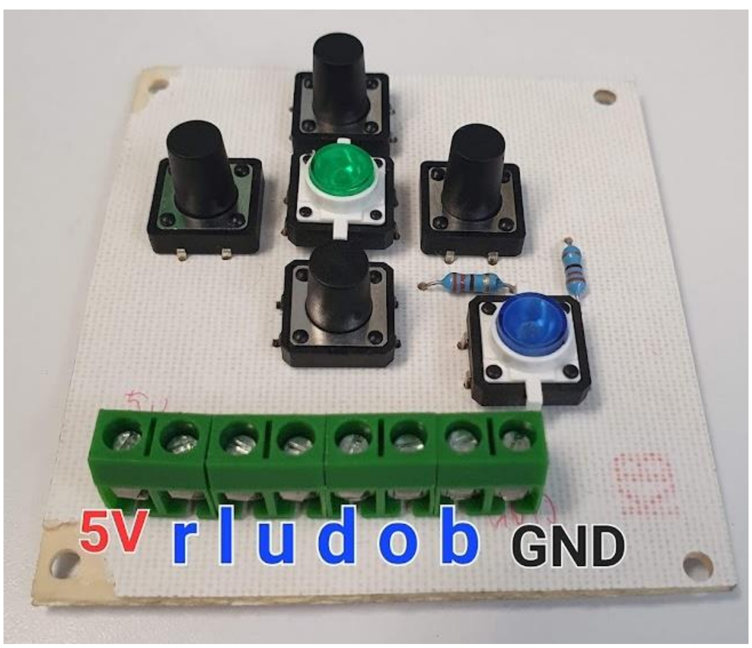


Figure 39- Assembled Keyboard

Voltage regulator

The voltage regulator (Figure 40) is responsible for supplying three different stages of voltage necessary for the electronic components of the dispenser. The voltage stages are: 3.3V, 5V and 12V.

Input voltage is supplied by an adapter from 110VAC - 230VAC to 12VDC / 2A.

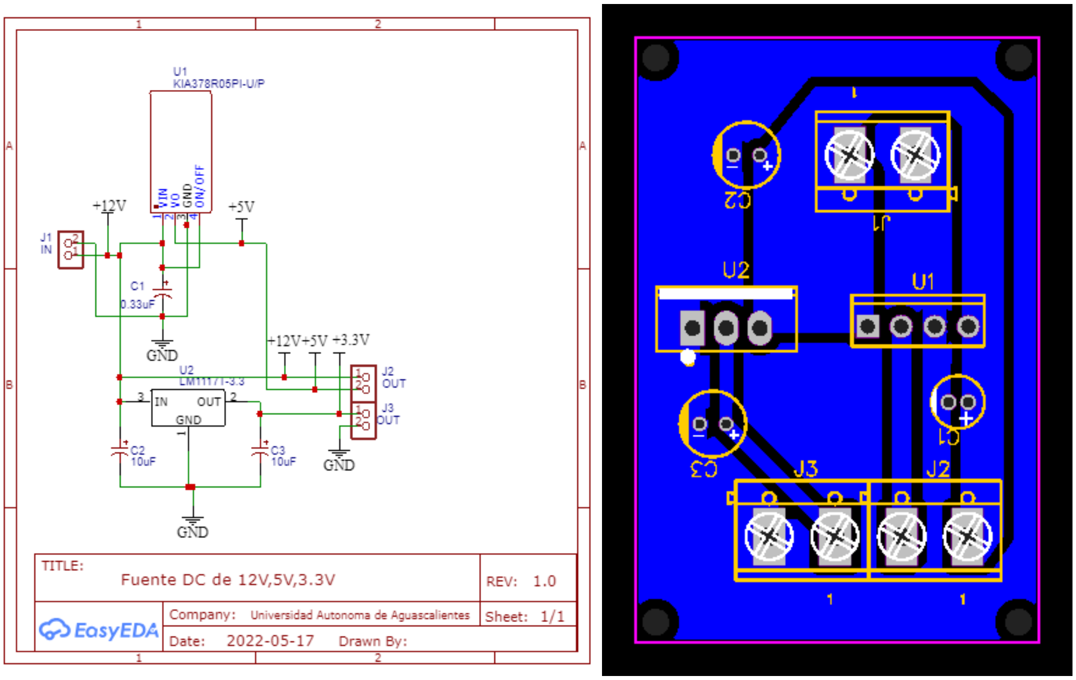


Figure 40– Voltage Regulator Electrical Schematic (Left) and PCB (Right)

The completed three - stage voltage regulator is shown in Figure 41.

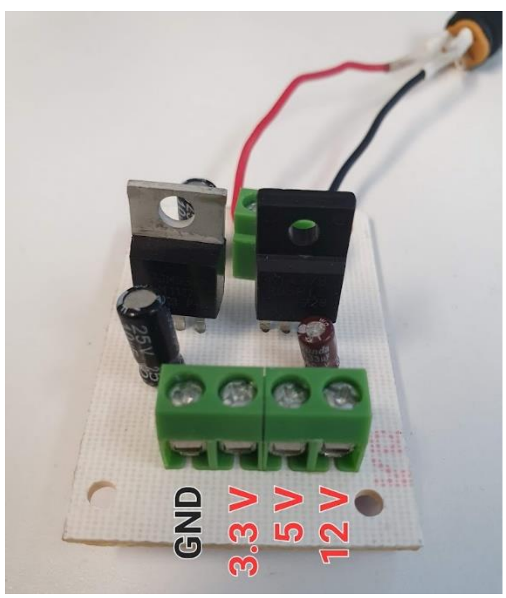


Figure 41- Assembled Voltage Regulator

Motherboard

Finally, the most important printed circuit was the motherboard or *shield* that would be connected on top of the Arduino Mega microcontroller (Figure 42).

This printed circuit contains all the main circuitry that joins the PCBs of the keyboard and the voltage regulator, as well as the other peripherals (buzzer, RTC, Bluetooth) and electronic components that would be used for the operation of the dispenser (drivers, capacitors, resistors, etc.).

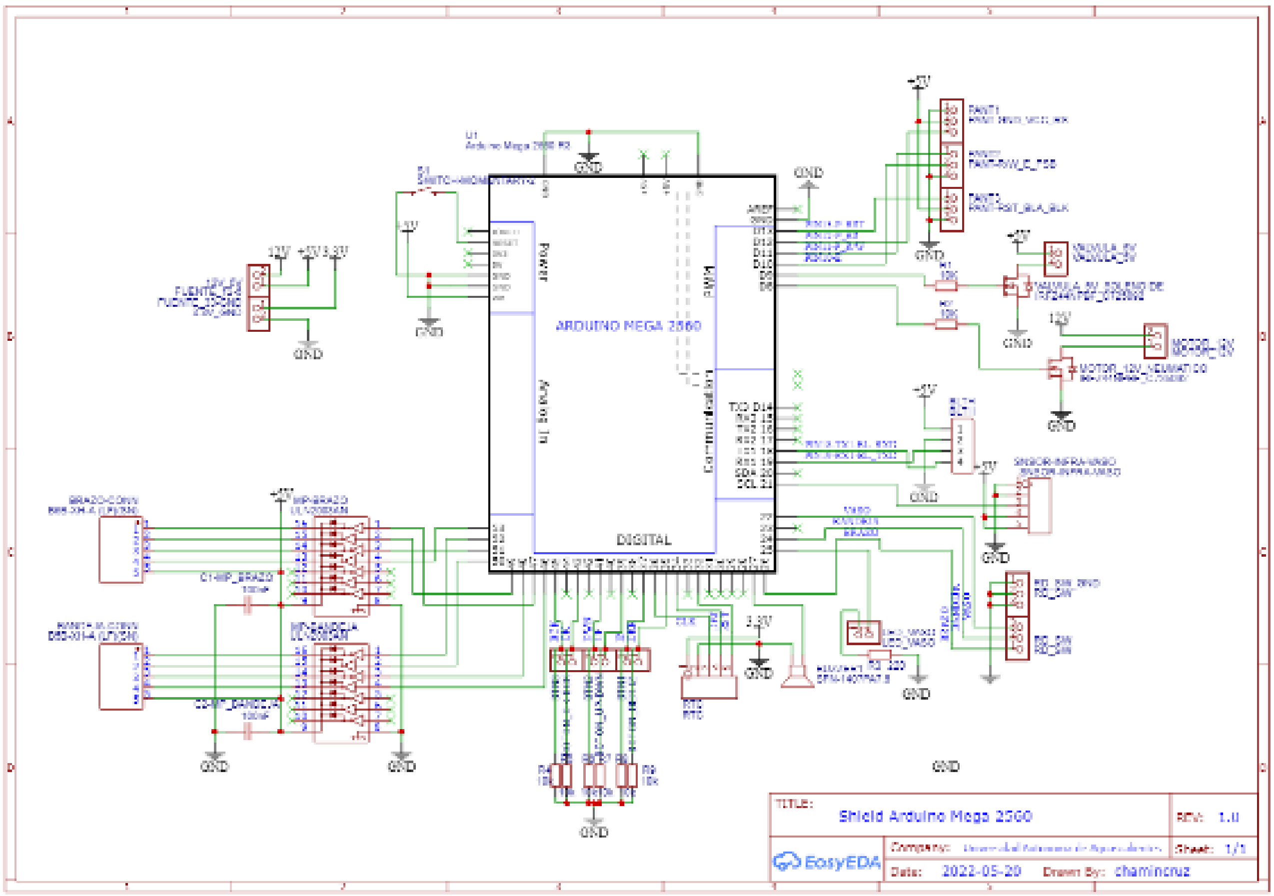


Figure 42– Schematic of the motherboard

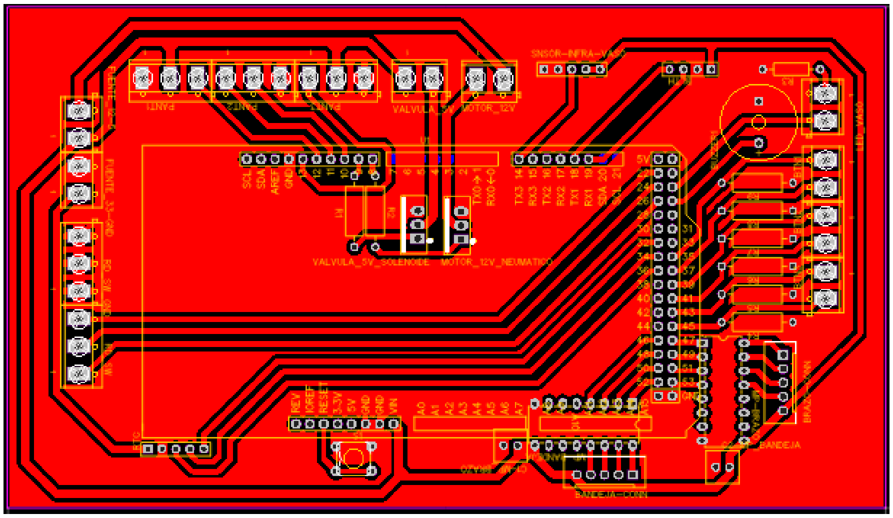


Figure 43– Motherboard PCB

The finished motherboard is shown in Figure 44.

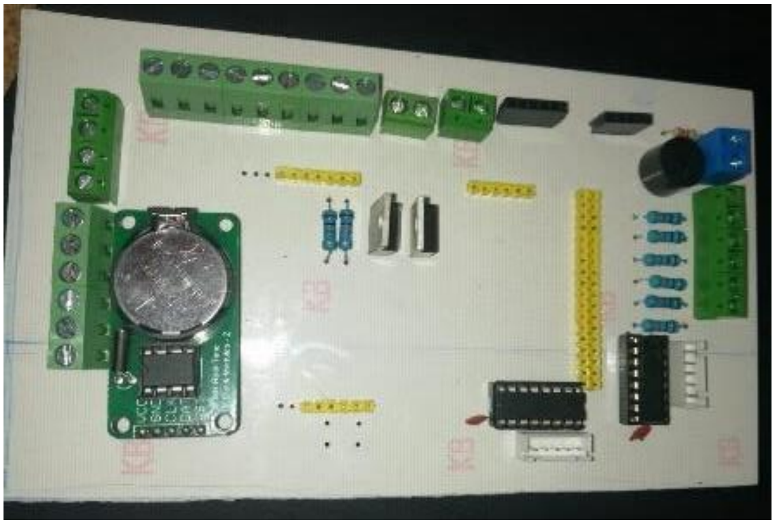


Figure 44- Assembled Motherboard PCB

7.10. Housing construction

For the elaboration of the casing, the measurements of the PCBAs were taken, as well as of the 3D pieces to have an idea of the space that the fully assembled dispenser would require. A rectangular design was chosen, with an intermediate horizontal plane on which the 3D base would rest and below it would be the microcontroller together with the motherboard (Figure 45).

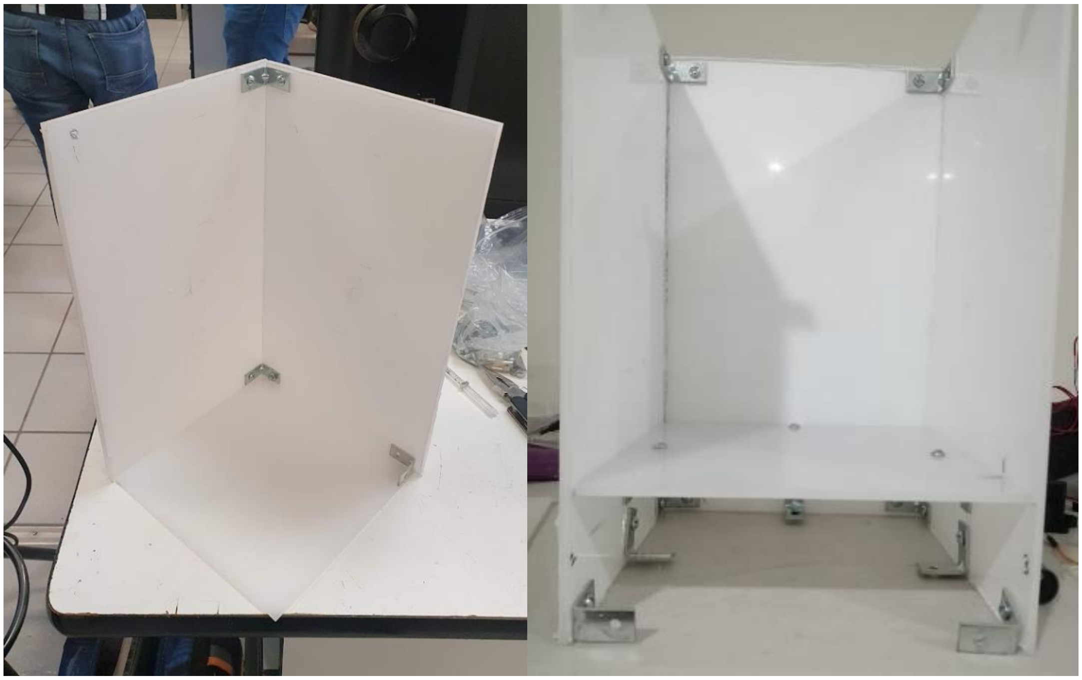


Figure 45– Open Housing Front View Showing Intermediate Level

On the sides of the casing, the screen (1) would go along with the keyboard (2), a hole where the glass would go where the dispensed pills would fall to be picked up by the user (3) as well as the adapter connector voltage switch (4) and power switch (5) shown in Figure 46.

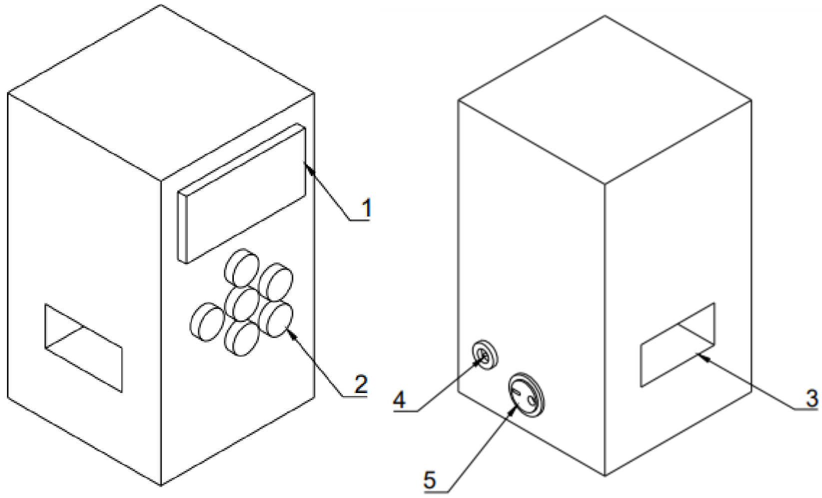


Figure 46- Dispenser Isometric View

7.11. Dispenser assembly

Once the casing was obtained, its different faces were cut to begin with the final assembly of the pill dispenser.

Certain adaptations had to be made to the shell faces. Figure Figure 47shows how the cut is made where the dispensed pills are going to be collected.

Figure 47– Carcass cut being made

The electrical connections of all the modules began to be made and the electronic components were inserted into the casing (Figure 48).

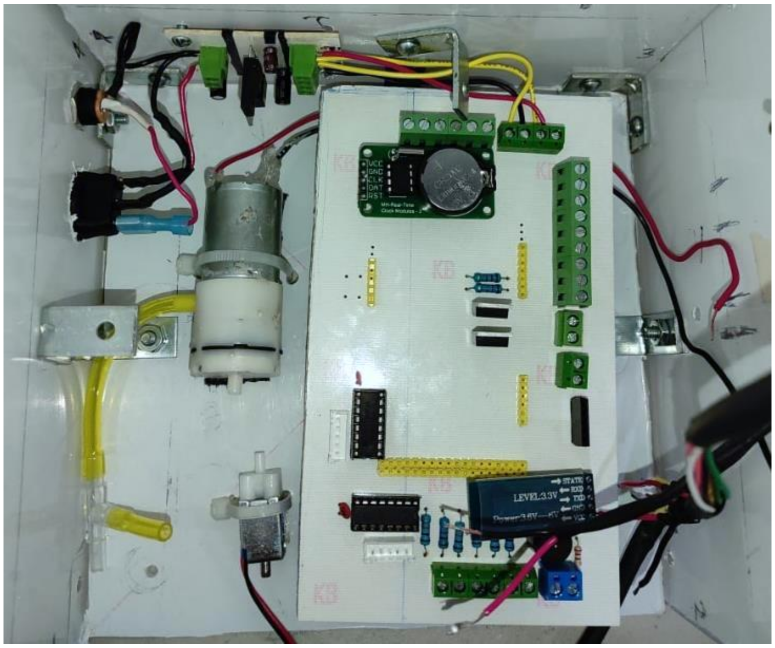


Figure 48– Electrical Connections

8. Results

A functional prototype of the automatic pill dispenser was obtained (Figure 49), fulfilling the main objective of dispensing the pills configured by the user at the specified time.

The device allows entering up to four different pills to be dispensed, and through a graphical user interface made up of a screen and navigation buttons, these pills can be easily configured to let the dispenser work automatically.

In the same way, the development of the Android application was completed, to be able to link with the dispenser via Bluetooth and to be able to transmit data to configure the dispenser.

Figure 49. Different views of the dispenser

9. Observations

Due to the fact that there was little time to plan how this project was going to be developed, there were difficulties in the different stages of development, mainly in terms of mechanical and electrical design.

The main unknown at the beginning of the development of the project that was not defined from the beginning, was the system for obtaining pills. Several options were in mind and finally it was decided to choose a pneumatic system using a pneumatic pump. An example of something that was not anticipated due to the limited time of the approach phase, was that sucking in the pills created a vacuum, so the pins did not fall out. It was not until later that we realized that we needed a solenoid valve that would open to equalize the pressure and thus be able to throw the pill to be dispensed.

An important point that we had to modify in the middle of the development of the prototype, was that the air motor did not provide enough flow in liters per minute. When using the initial containers for the tablets, when the arm lowered if the suction cup was not exactly on top of a tablet it would not be sucked. Due to this big problem, we had to change the shape of the containers to ensure that the pills always fell on the same point to be collected with the suction cup, significantly reducing the number of pills available per container.

A possible solution to the above problem would be to use a higher flow motor so that it can suck the pads even when the suction cup nozzle is not on a pad due to the same pneumatic suction action.

On the other hand, there were no full considerations of the budget that the dispenser was going to take, so the construction of the casing was not the best. Holes and nuts with protruding screws were left, so if a second version were made, these would be important points to correct.

As for the power supply of the device, if it is cut it stops working, so in a second version a battery would be added in case of power loss.

Due to limited budget, with RoHS standards required. Many times, the components with these standards tend to cost more.

10. Conclusions

Despite the limited time and budget for the conception of this automatic pill dispenser, it was possible to create a functional product. Although it was not perfect, the development of a project on this scale was something we had never done, integrating different disciplines learned throughout the career such as PCB design, electrical diagrams, 3D part design, pneumatics, programming, etc.

The elaboration of this product left us with many lessons to be able to elaborate a second model, this would be clear with a more adequate budget and avoiding the errors that were made in the initial model, we believe that this is the process that every successful product takes, they always tend to be several phases and models until reaching the right one. However, with the passage of time and technology there will always be something to improve.

Additionally, we had to learn on the fly concepts with which we had no experience, such as the design of 3D parts or the development of Android applications; it took us more time to learn how to use the necessary tools to conceive the dispenser.

Despite the setbacks encountered, it helped us a lot to learn what it means to be an engineer, to “devise ways” to solve problems. This was quite enriching since it forced us to be self-taught and to learn to handle new tools. Another important point to highlight was that we learned a little about design methodologies, and how to obtain a final and functional product from an idea in mind, detailing each step of the process.

Finally, with this project we learned new knowledge that ranges from using new design software to knowing ourselves better, including finding ways to work as a team efficiently. We realized that creating a team where we are all productive is difficult as we all think differently and have very different ways of working.

11. Points to improve

- **Professional elaboration of PCBs** (due to lack of time and budget the PCBs were elaborated in a "home" way)

- **Best mobile application** (although our application is functional, it is not a very aesthetic application, so it could be made even more enjoyable for the user, however, this was not achieved because the developers of the product did not have the knowledge for this part of the project, and what was applied was what was learned in this short delivery time, we believe that with more development time we would have achieved a better app)

- **RoHS Standard** (Most of our components could not meet this standard because they are often more expensive, however, the commitment to the environment must be an important point, so the optimal thing would be to make it with all the components complying with the standard)

- **Battery system** (this is an interesting point to have two options of use for our product either at home or in a place without electricity, however, due to lack of resources and time it was not possible to attach that part to our product)

- **Pneumatic motor with greater flow** (it would be optimal to have a motor with greater suction to avoid the use of guided cups)

- **Wi-Fi connection** (An ideal thing for this product would be the use of Wi-Fi to create records on a web server, however, due to time this was not possible.)

- **More pills per container** (this idea is based on the fact that due to the guidelines that had to be drawn up, the number of pills was reduced, so the ideal would be to increase that amount.)

- **Better casing** (due to the high material costs, the acrylic casing was made, this could have been made by 3D printing, but the prices could rise quite a bit, that is why it was not made)

- **Fix the glass** (due to a design error, the glass that receives the pill moves a little, so in the future, the ideal would be to make a small hole so that it remains fixed)

- **Greater insulation** (although an insulation was developed, it was not optimal, we believe that with a better design it could be isolated in a better way)

12. References

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