ING. MECATRÓNICA

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DESIGN AND IMPLEMENT A PROTOTYPE TO CAP AND COUNT 600ML BOTTLES ACCORDING TO THEIR CONTENT

QUITO I ECUADOR 2023

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DESIGN AND IMPLEMENT A PROTOTYPE TO CAP AND COUNT 600ML BOTTLES ACCORDING TO THEIR CONTENT

1. Mechanical Design

This section describes the mechanical process of the implemented module as well as the technical calculations, dimensions and selection method depending on the desired characteristic or application to fulfill.

1.1. Technical specifications

For the realization of a bottling company, in charge of capping bottles, for the mechanical part it is necessary:

- Band is in charge of transporting the items of interest.
- Structure that supports all the elements of the bottling plant.
- Rotating wheel that positions the bottles in each section of the module.
- The dimensions of the module are: 100x50x140 cm

1.2. Design Thinking

The module design contemplates a conveyor belt mechanism that allows the objects of interest to be moved, which in this case are 600ml bottles, these bottles will have two different colored liquids, once the bottle enters the band, a gate will It will give way to enter a rotating wheel where in each passage of the wheel an action will be carried out, the first action will be to partially place the stopper in the bottle, in the second action the bottle will be screwed to finally be sent back to the band and finish the process. Once the cap has been placed on each bottle, it will continue the process to the classification module, in which, through the use of a color sensor, the color of the content of each of the bottles can be identified, once it has been Once the liquid is identified, a count will be carried out, concluding the process of capping and classifying the bottles.

To determine the best option that meets the module requirements, the options are analyzed. to assess each possibility and contrast them with the knowledge of the state of the art.

The bottles to be used with dasani bottles made of plastic with dimensions of 21 cm with a diameter of 12 cm, the cap of said bottle is also made of plastic with a diameter of 26.9 mm

Figure 1. Dasani bottle.

1.3. CAD Sketch

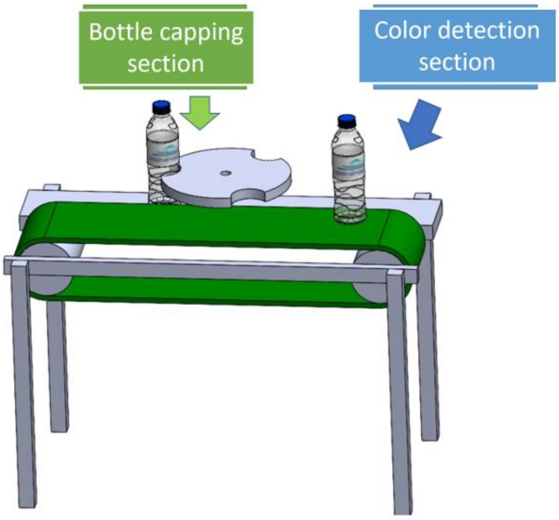

Figure 2. Bottling plant sketch.

1.4. Design

Next, each mechanical element of the module to be implemented is dimensioned, such as calculations and adequate analysis for the selection of material and dimensions.

Belt

The conveyor belt must be able to handle the weight of the load being transported. The load capacity of the conveyor belt is typically specified by the manufacturer and depends on factors such as the type of material being transported, the weight per unit length or per unit area of the load, the width and speed of the conveyor belt are important factors that depend on the size and shape of the load, the production rate, and the required throughput of the conveyor system [1]. The belt width should be wide enough to accommodate the load without causing excessive spillage or product damage. Conveyor belts are available in various types and materials, including fabric belts, rubber belts, plastic belts, and metal belts. The selection of the belt type and material depends on factors such as the type of load.

For the selection of the conveyor belt, the following parameters must be taken into account: desired length, diameter of the rollers used as pulleys, and the load to be transported, data already defined for the application.

$$Torque = F * r = Wsen(\vartheta) * r \tag{1}$$

Another parameter to consider are the efforts applied to the belt, in addition to an acceptable safety factor for correct operation, as it has been determined in the state of the art, a safety factor for a conveyor belt ranges from 8 to 10, so for the calculation established a value of n = 9 [2], consider young's modulus with respect to the material of the band, the most common material for this type of application is PVC, where it was determined that E = 2.7GPa [3].

$$\sigma = E * \frac{Lf - Lo}{Lo} \tag{2}$$

Considering the safety factor previously established, we have:

$$\frac{S}{n} = E * \frac{Lf - Lo}{Lo} \tag{3}$$

With this, it is possible to determine a conveyor belt that meets the requirements for the bottling plant, and in terms of deciding the width of the belt, the diameter of the 600ml dasani bottle is taken into account, which is approximately 6 cm [4].

So it remains to review a distributor with the required conveyor belt specifications.

Once the material has been selected, we proceed to make the calculations of the structure capable of maintaining the conveyor belt and of the resistances on it. Calculation of forces and resistances.

Upper branch main resistance:

$$R_u = \mu * g * L * [(q_1 + q_2) * cos\vartheta] \tag{4}$$

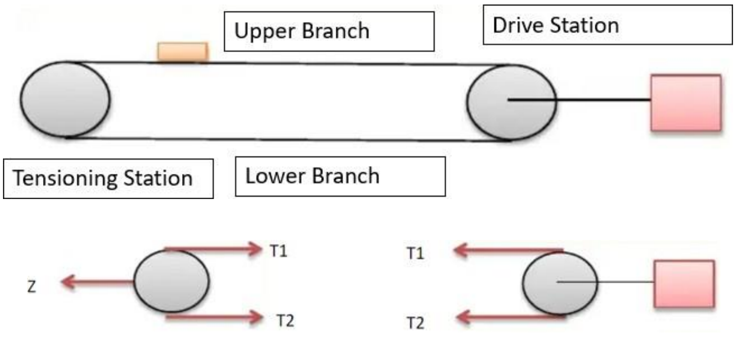

Figure 3. Free Body Diagram of the Conveyor Belt.

Where

$$q_1 = 0.78kg/m$$

Mass per linear meter of the band

$$q_2 = 1.2kg/m * 0.12m = 0.144kg/m$$

Mass per linear meter of the band

$$\mu = 0.6$$

Friction coefficient in the band

Finally, the resistance of the upper branch is obtained

$$R_u = 0.6 * 9.81 * 0.7 * [(0.78 + 0.144) * cos0] = 3.807N$$

The same criteria will be taken into account for the lower branch with the detail that load 1 (q_1) is not taken into account because the weight of the bottles is not found in that branch.

Lower branch main resistance:

$$R_l = \mu * g * L * q_2 * cos\vartheta] \quad (5)$$

Using the same data from equation 4, the resistance of the lower branch is obtained.

$$R_l = 0.593N$$

Circumferential force (Fc)

Circumferential force refers to the force exerted perpendicular to the circumference of a rotating object or component. It is also known as tangential force or tangential load. When an object rotates, such as a wheel, pulley, or gear, there is a force acting tangentially at any given point along its circumference.

Calculation of circumferential force (Fc)

$$F_c = T_1 - T_2 \tag{6}$$

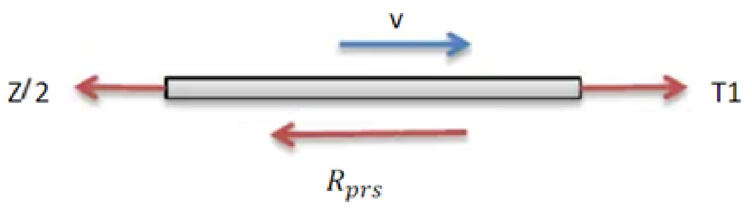

Figure 4. Upper Branch Free Body Diagram.

$$\sum F_x = 0$$

$$T_1 = z/2 + R_u \tag{7}$$

The forces in the x axis must be calculated, obtaining a sum of forces equal to 0 in the upper branch of the band.

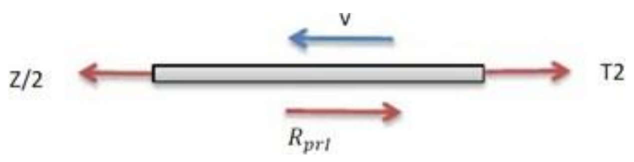

Figure 5. Lower Branch Free Body Diagram.

$$\sum F_x = 0$$

$$T_2 = z/2 - R_l \tag{8}$$

In the same way it is important to consider that the force in the lower branch must also be 0.

Because by replacing the equation 7 and 8 in 6 it is obtained that the circumferential force is:

$$F_c = 3.807 + 0.593 = 4.4N$$

Rowlock

Row locking is a technique used in database management systems (DBMS) to control concurrent access to database rows. It is employed to ensure the consistency and integrity of data when multiple transactions are accessing or modifying the same rows simultaneously.
Using the calculation of the circumferential force, it is possible to obtain the tensions to which the pillow block to be used will be subjected, for them the relation of tensions is used to determine the value of the constant of the pillow block socket [5]. The relation is the following.

$$\frac{T_1}{T_2} = e^{f*\alpha} \quad (9)$$

Where

$$f = 0.4$$

Coefficient of friction

$$\alpha = 180$$

Hug angle
To obtain the value of $e^{f*\alpha}$ it is necessary to use the table for the calculation of forces applied in pillow blocks [6].

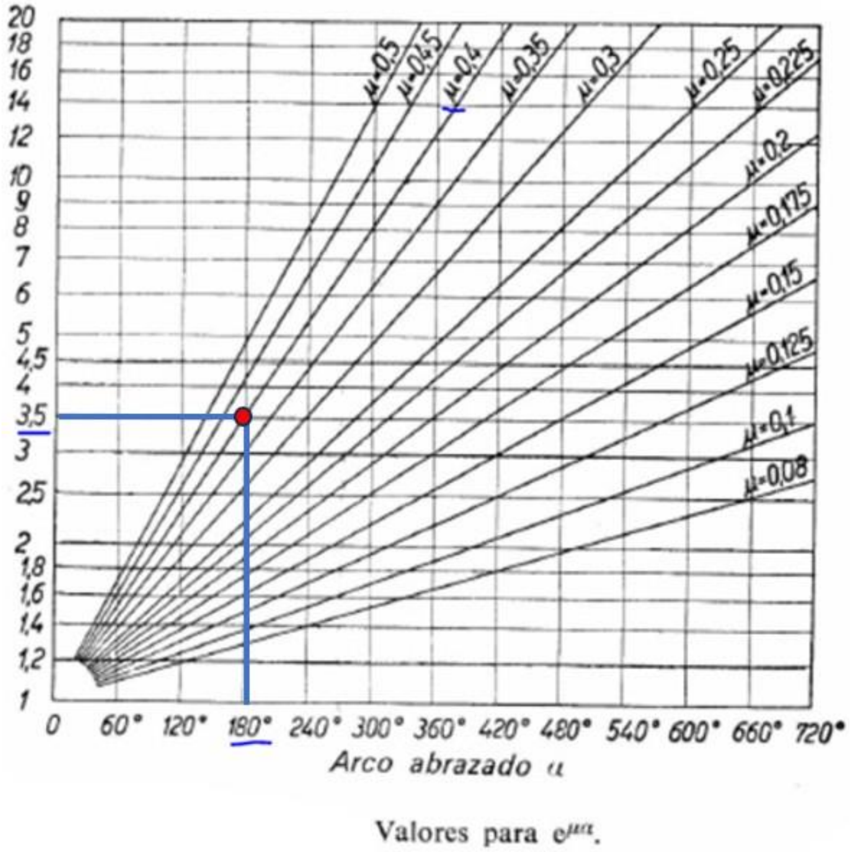

Figure 6. Calculation of stresses on Rowlock .

Using the graph [6], it is obtained that the relationship is equal to:

$$\frac{T_1}{T_2} = 3.5 \tag{10}$$

Replacing what is obtained in equation 6 in equation 10 can obtain a system of equations that allows the calculation of each one of the applied tensions. Getting:

$$T_1 = 6.16N$$

$$T_2 = 1.76N$$

With this it is determined that the journal must have a diameter of at least 22 mm and a thickness of 4 mm.

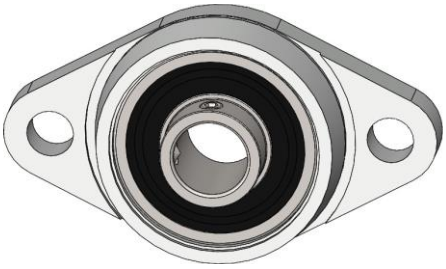

Figure 7. Rowlock.

Optimate Speed

For the optimal calculation of the speed at which the band must move, the steps at which the motor rotates are taken into account, for them a test was carried out where it is observed at what step the motor must be so that at the moment of the bottle colliding with the bottle separator does not fall and there is a high load on the gate, where the following Table was obtained. It

Table 1. Determine the optimal speed

Number of Steps per Revolution	Bottle falls
20	No
23	No
26	Yes
30	Yes

can be seen in the table that at 20 steps and at 23 steps there are no problems with the bottle, however at 23 steps it has a more considerable speed that allows a more continuous process, so the selected steps are 23. With them you can calculate the speed at which the band will go with the following equation:

$$Speed = 0.095 * 60/Steps \quad (11)$$

$$Speed = 0.025m/s$$

Roller

Selecting rollers for a conveyor belt involves several factors to consider, such as the weight of the load, the speed of the conveyor belt, the type of material being transported, and the environment in which the conveyor system operates.

To calculate the diameter of the rollers, you will need to consider the weight of the bottles and the speed of the conveyor belt.

$$Diameter = 15 * Load * Distance/Speed * 3.1416 \quad (12)$$

Where:

- Diameter: Diameter of roller
- Load: Load Capacity
- Distance : Distance between Roller Centers
- Speed: Speed of Belt

$$Diameter = 24mm$$

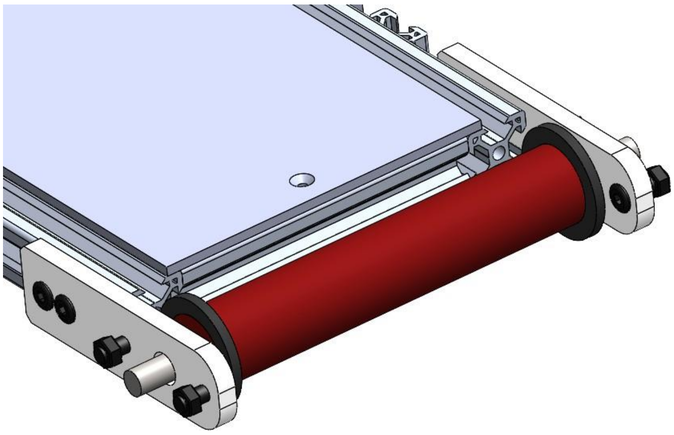

Figure 8. CAD Model of Roller.

Endless screw

An endless screw, also known as a screw conveyor or an auger, is a mechanism that consists of a rotating helical screw blade inside a tube or trough. The screw rotates, and as it does so, it moves materials along the length of the tube or trough.

For the mechanism in charge of locating the motor to cover, it will be an endless screw, which will allow this motor to go up and down through it, that is, when the rotating wheel reaches the capping section, the motor will go up to give space to the bottle to enter and then the motor lowers until it reaches the bottle cap and exerts a force of pressure that allows contact between the cap and the bottle and screwing, at the end of the process the motor will rise again to give step to the bottle to enter the band again.

Said shaft will be made of steel and will have a height of 453mm and radius of 8mm.

Figure 9. Endless screw.

Cap Dispenser

To supply the caps to the bottles made of PLA, an assembly will be placed that has the caps that, by means of a hook system, will fit the cap into the bottle until the bottle pulls the hook and releases the cap. This mechanism will serve as a cap dispenser. Gravity tops will fall. For the sizing of the system, the diameter and height of the covers plus a certain tolerance are taken into account, allowing the entry of a maximum of 3 covers.

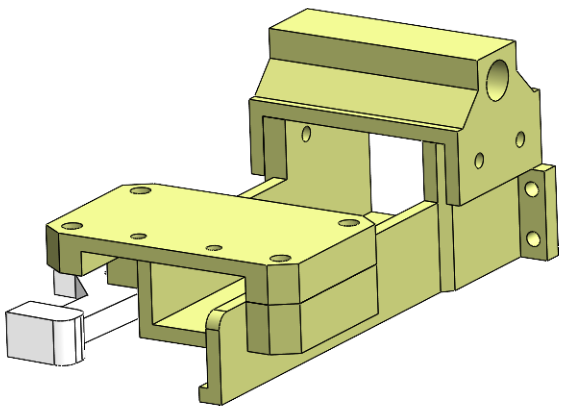

Figure 10. Cap Dispenser.

Servo Gates

Gates used to separate the bottles, that are made of PLA and one in acrylic, when a bottle is at the beginning of the process, the gate will give way to a bottle to complete the entire process, then wait for another bottle to enter, when the entire process is completed, that is, the bottle has left the wheel back to the band at the end of the process will open one more gate to end the process.

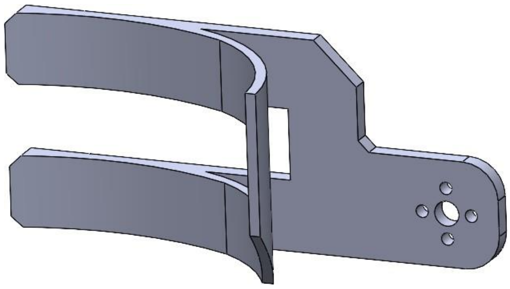

Figure 11. Separating Gate.

Cover Disk

Disc designed for the rigid support of the rotating wheel and thus avoid failures or fractures in the structure,also allow to adding a more aesthetic model.

For the selection of the material for the rotating wheel, a review was made of materials that meet a certain resistance to stresses, including acrylic of different thicknesses, single glass for sales, double glass for windows, laminated glass, and wired glass. Observed in the following Table 2 [7].

Table 2. Crash test results.

Material	Thickness mm	Load weight	Breaking Energy
Acrylic	2.5	0.25	3.0
Acrylic	3.0	2.00	4.7
Acrylic	6.0	5.00	18.1
Simple glass for windows	2.5	0.25	1.1
Double glass for windows	3.2	0.25	1.1
Safety laminated glass	6.4	0.25	1.1
Wired glass	6.4	0.25	2.2

As its observe, acrylic with a thickness of 6 mm is the material that has the most resistance, allowing it to be optimal for the desired application. In addition to the previous table, impact tests were also reviewed to verify that the thickness selected for the acrylic is correct, and this is shown in Table 3 [7].

Table 3. Acrylic impact resistance.

Thickness mm	Energy used by a baseball	Speed km/h
3.0	24	75
6.0	84	135
10.0	113	170

According to the previous analysis, the model of the rotating wheel can be designed using acrylic with a thickness of 6mm.

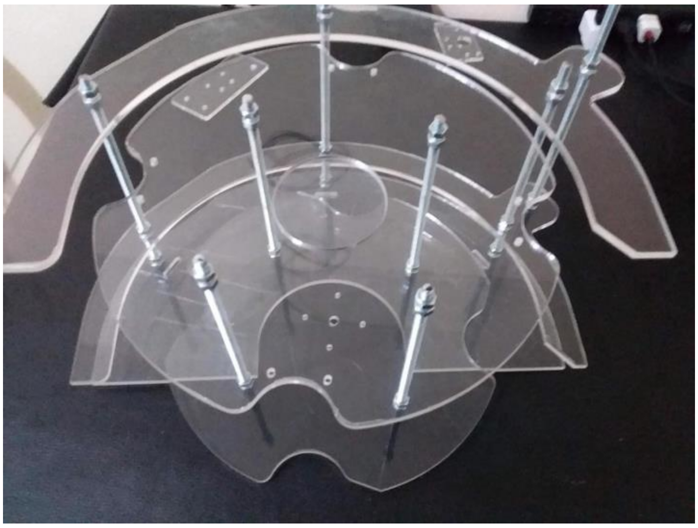

Figure 12. Acrylic caster wheel.

Bottle cap holder

Dispenser that allows the cap to be correctly located on the bottle,this piece is also made of PLA, preventing it from falling or coming out of the cap socket in the process. With dimensions of 90x98x23 mm

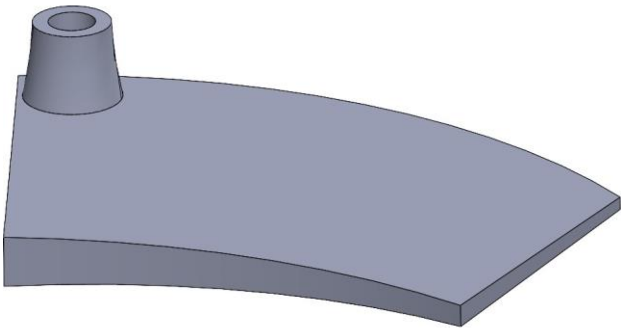

Figure 13. Box Cap dimension.

Cap screwer

A piece that can be adapted to a motor is dimensioned in order to hold the covers and in turn screw them, for this the dimensions of the covers are considered as their diameter and height, with this a structure with the following dimensions is implemented.
its observe, the inner diameter must be greater than the lid diameter to prevent it from being tight and getting stuck inside this holder.

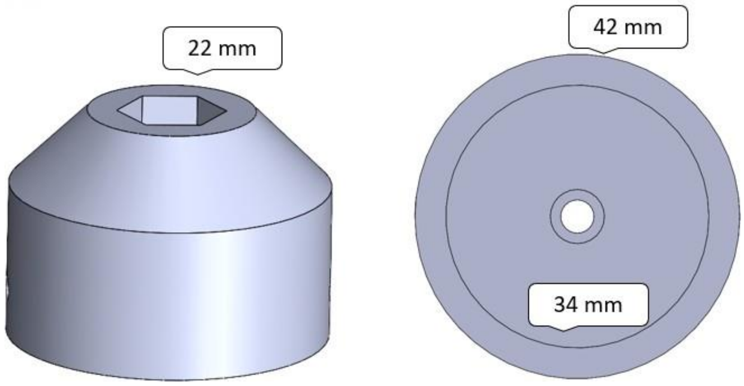

Figure 14. Box Cap dimension.

Folding table

Finally, when all the mechanical elements that will be part of the Module have been dimensioned and selected, a structure capable of containing all the mechanical and electronic elements will be dimensioned. The final dimensions in millimeters of the table are shown in Figure 15.

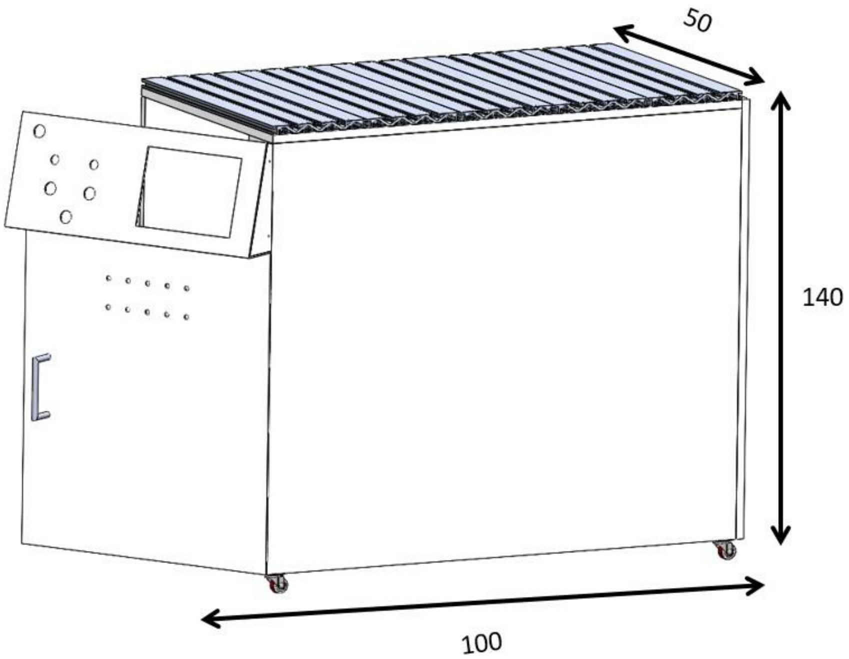

Figure 15. Box Cap dimension.

1.5. Simulation

In the Simulation of considering the critical part of the rotating wheel, said critical moment will be when there are two full bottles on the wheel at the same time and enough torque has to be exerted so that the material resists and does not yield to a possible fracture,the material chosen for the rotating wheel was acrylic, in order to determinate the stresses it uses the software ANSYS, where a total force is applied to 3 full bottles where they are approximately 2 kg, and considering the diameter of the rotating wheel of 32 cm. It is important to consider the speed of the wheel for this analysis. it will also help determine that the given thickness is correct.

Through this stress analysis, the following results were obtained:

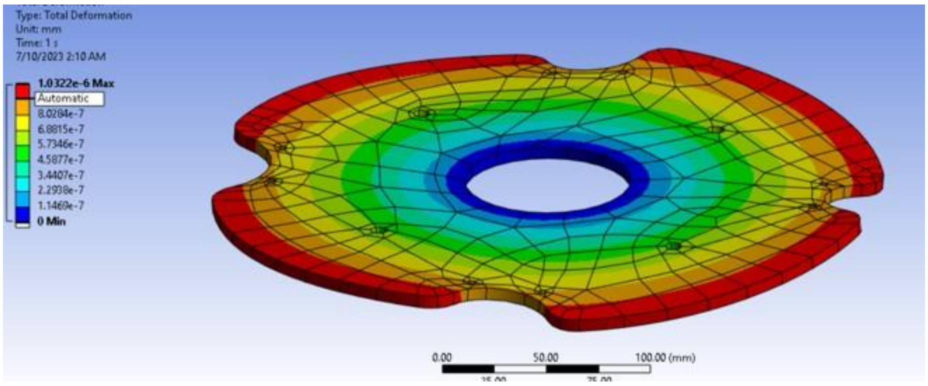

Figure 16. Result of the deformation.

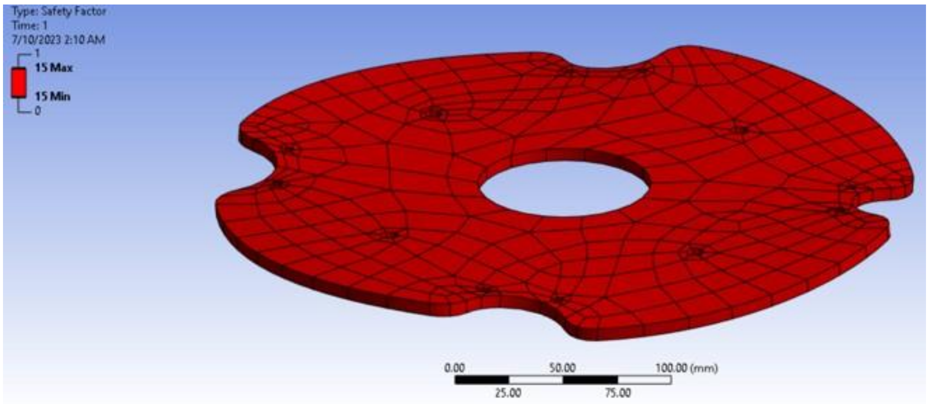

Figure 17. Safety factor analysis.

As can be seen in Figures 16 and 17, the greatest stresses are concentrated at the ends where the bottles are located, however, there is no greater deformation that could cause defects in the material, also indicating that a great torque will not be needed to execute this movement. And specifically in figure 14 it can be seen that the part has a safety factor of 15, which indicates that there will be no failures for a long period of time.

1.6. 3D CAD Model

For the design of the module, Solidworks software is used, which allows the 3D modeling of the elements that will make up the bottling station, it will also allow us to carry out the calculations of efforts and safety factors to corroborate with the calculations previously made.

Conveyor Belt Assembly

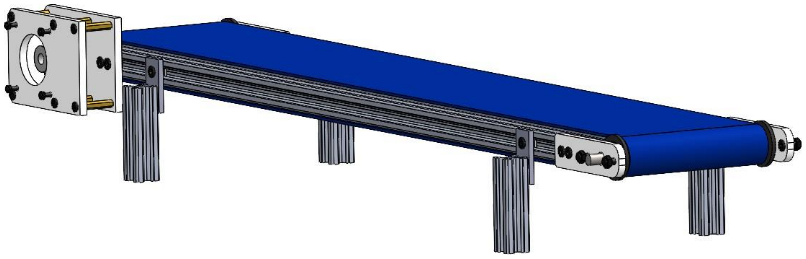

Figure 18. Module conveyor belt.

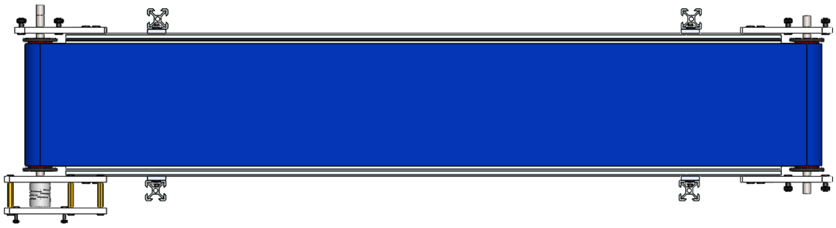

Figure 19. Module conveyor belt from top.

Caster wheel assembly

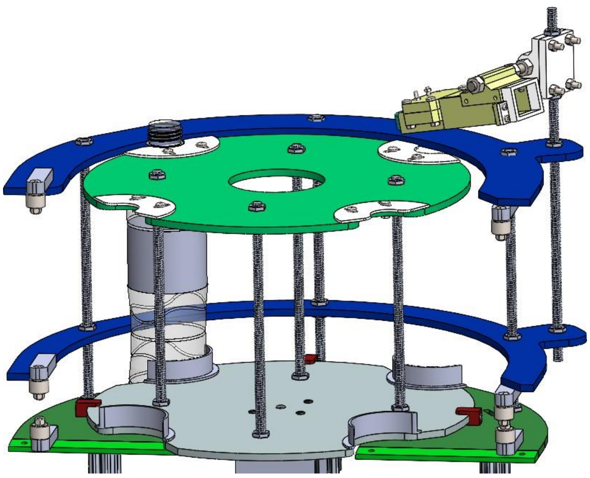

Figure 20. Caster wheel assembly.

Final assembly

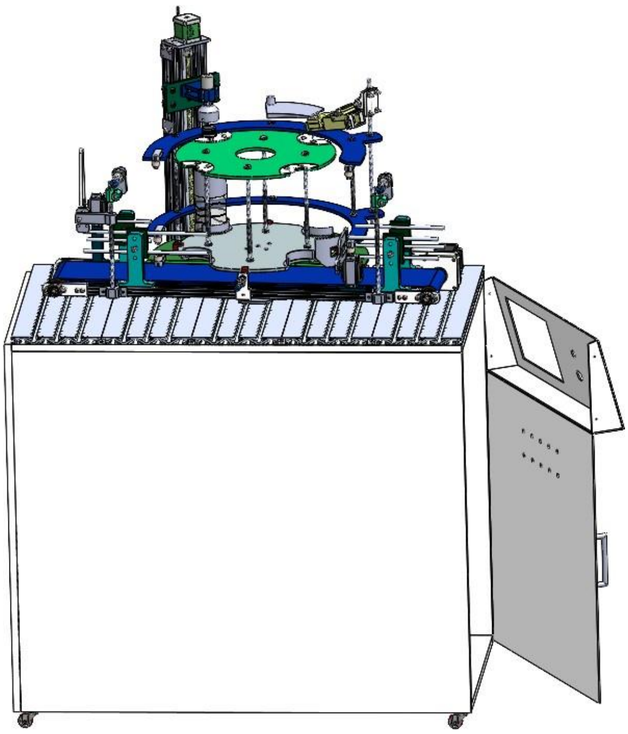

Figure 21. Module Final assembly.

1.7. Summary of mechanical components

After having carried out an analysis and having a sketch of the elements to be used, the following table was determined on the mechanical elements and their material.

Table 4. Selection of the material of the mechanical elements.

Mechanical Dimensioning			
Component	Material	Dimension	Function
Module structure	Aluminium profile	100x50x140 cm	Hold Structure
Conveyor belt	PVC	750x130x30 mm	Transport Bottles
Roller	ABS	127mm x R12mm	Transmit Movement
Rotating wheel	Acrylic	R160mm	Locate Bottles
Endless crew	Steel	453mm x R8mm	Transmit Movement
Cap dispenser	PLA	120x37x41 mm	Place the cap
Rowlock	Steel	36x4xR13mm	Clamping
Bottle cap Holder	PLA	121x100x24 mm	accommodate lid
Cap screwer	PLA	R42mm x R 22mm	Screw cap

2. Electronic and Control Design

The following section describes the selection of electronic components and their use within the project, such as the proper configuration of the actuators for the proper functioning of the system.

2.1. Technical specifications

For the realization of a bottling company, in charge of capping bottles, for the electronic part it is necessary:

- Motors that allow mobility to certain components.
- Sensors that detect the color of the bottle content and the apposition of the bottle.
- PLC controller of the entire process done in the module.
- HMI graphical interface that indicates the process at all times.

2.2. Electronic block diagram

A block diagram of the electronic process that is carried out in the bottle capping module is shown, Figure 22.

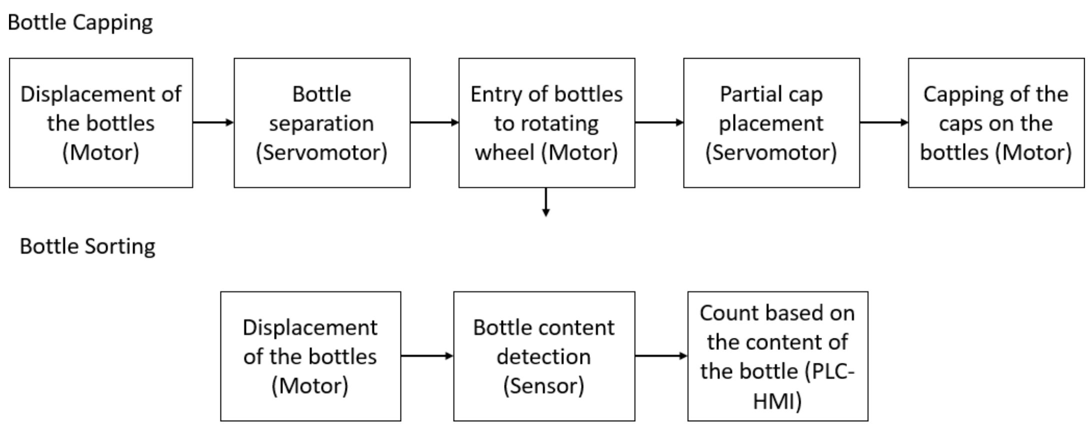

Figure 22. Block diagram of the electronic process.

The electronic block diagram that summarizes the connections between elements is shown in Figure 23.

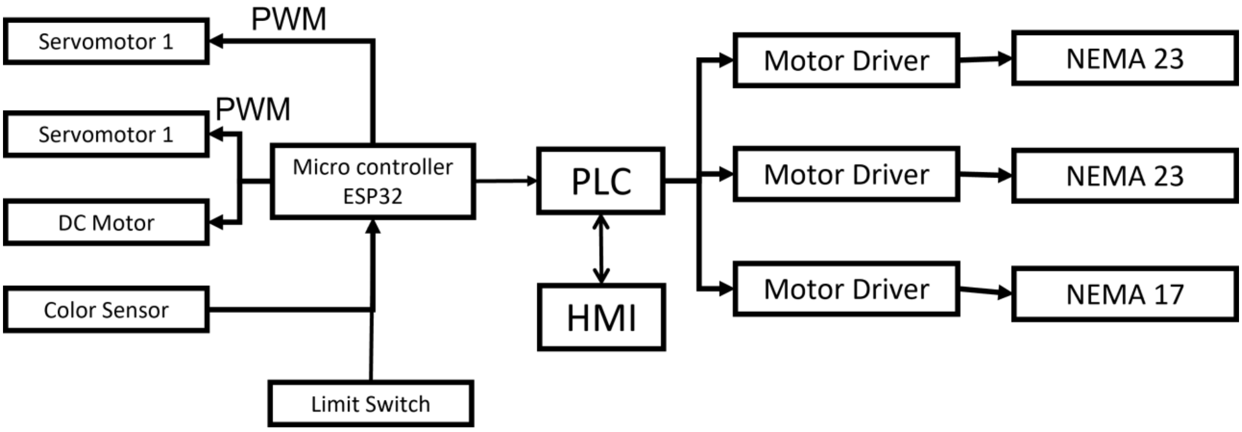

Figure 23. Electronic block diagram between Elements.

2.3. Component Selection

Conveyor belt motor

Selecting a DC motor with for a conveyor belt application, several factors need to be considered, including the required speed, torque, and positional accuracy of the conveyor belt. NEMA 23 DC Motor is a cost-effective option for conveyor belt applications that do not require high speeds or high levels of positional accuracy [8]. NEMA 23 DC motors are simple and easy to control, making them suitable for many conveyor belt applications. The driver provides feedback on the motor's position, which can be used for speed control and basic positional accuracy.

Calculating the torque required for a direct current (DC) motor on a conveyor belt involves considering several factors, such as the load to be transported, the desired speed, the diameter of the belt pulley or drum, and the efficiency of the system.

$$Torque = Force * Radius \tag{13}$$

The force will start from the mass of the load due to the gravity of the earth g = 9.81m/s^2, while the radius will be the radius of the pulley that will allow the band to roll. For the mass of the bottle, the case is considered where it is completely empty where it has a mass of approximately 20 g and when it is half full with a mass of 330 g, While the radius of the pulley will be 4 cm [9]. Therefore, in the case that the bottle is half full, we have the following calculation

$$Torque = 3.23kg * 0.04m$$

$$Torque = 0.192kg.m$$

Motor for screwing

Using a motor to cap bottles typically involves the use of an electric motor in conjunction with a specific capping mechanism, such as a capping head or capping machine, to apply caps to bottles efficiently and precisely.

The parameter to determine the motor that is in charge of closing the bottles by means of the screwing of the cap, is to determine the necessary torque, for this the coefficient of friction between the cap and the bottle must be determined.

$$Torque = Force * Radius \tag{14}$$

The distance from the center of rotation to consider is the radius of the cap, as the diameter of the 600ml Dasani bottle has been determined to be 28mm, that is to say that there is a radius of 14mm, while the force to close a cap It can be calculated from the coefficient of static friction and the clamping force, as shown below:

$$Force = Clamping * Coefficient \tag{15}$$

Where:

- Force: Force to close a cap.
- Campling: Clamping force.
- Coefficient: Static coefficient.

By reviewing the state of the art, it is obtained that the clamping force is equal to 12N [10] while the static coefficient is 0.25 [11], so the force is obtained as follows:

$$Force = 12N * 0.25$$

$$Force = 3N$$

With the value of the force determined, the necessary torque can be obtained for screwing on the lid:

$$Torque = 3N * 0.014m$$

$$Torque = 0.042 N.m$$

With the torque necessary to close the lid defined, the rpms necessary to close the bottle lid can be determined [12], for this we will use the following formula:

$$RPM = Torque * Ratio/2 * pi * Axis \tag{16}$$

Where:

- Torque: Required Torque, it is the force required to close the lid, expressed in Nm or lb-ft.
- Ratio: Transmission ratio, it is the transmission ratio of the system, expressed as a fraction or a dimensionless number.
- Axis: Motor shaft diameter, it is the diameter of the motor shaft.

$$RPM = 1.87$$

And it shows, the minimum speed in rpm to repeat the capping is 1.87.

Motor to turn the wheel

To calculate the torque required for a direct current (DC) motor used to turn a wheel, several factors must be taken into account, including the diameter of the wheel, the coefficient of friction between the wheel and the surface on which moving [13], the desired turning speed and the weight or load to be moved.

$$Torque = Force * Radius \tag{17}$$

Where:

- Torque: Torque in units of measure.
- Force: Force required to move the load, in units of measure.
- Radius: Distance from the center of rotation of the wheel to the motor shaft, in units of measure.

The force required to move the load depends on the weight of the load and the coefficient of friction between the wheel and the surface on which it is moving [11]. To calculate the force, the following formula can be used:

$$Force = Mass * Gravity * \mu \tag{18}$$

Where:

- Mass: Mass of the load in kilograms or pounds.
- Gravity: Acceleration due to gravity.
- μ : Coefficient of friction between the wheel and the surface (dimensionless, varies depending on the type of surface and the design of the wheel).

Once the force required to move the load has been calculated, it can be used in the torque formula along with the radius of the wheel to determine the torque required for the DC motor. It is important to note that these calculations are approximate and that other factors, such as motor efficiency and friction losses, can also influence the actual torque required.

$$Torque = (1.2kg + 0.900kg) * 0.16m$$

$$Torque = 0.336Nm$$

With this we can determine that the appropriate motor for the application can be a NEMA motor in the same way as for the band, that is, a NEMA 23.

Servomotor MG995

In the case of the bottle separator, a servomotor will also be used, however for this case the mg995 servomotor will be used, because it generates more torque, which allows stopping the entry of the bottles [14], in addition to the fact that the separator will be a heavier element, demonstrated in the following calculation:

$$Torque = Force * Radius \tag{19}$$

The force in this case will be the weight of the 3D printed sheet used as a separator, however, the force generated by the bottle when it comes into contact with said plate must also be taken into account because the force would be:

$$Force = Weight * Contact \qquad (20)$$

Where:

- Weight: Separator weight strucutre.
- Contact: Bottle contact force.

Once the total force is determined, the distance from the center to the axis of rotation is taken into account.

$$Torque = (0.072kg) * 0.045m$$

$$Torque = 0.0234N$$

Color Sensor

The selection of a color sensor will depend on the specific needs of the application. Spectral range refers to the colors that the sensor is capable of detecting, resolution refers to the sensor's ability to detect subtle differences in colors, response time refers to the time it takes for the sensor to detect a change in the color.
Sensor Resolution Calculation: This calculation can help determine the required sensor resolution for a specific application. Resolution is typically expressed in bits, and refers to the number of color levels that the sensor can distinguish. The higher the resolution, the better the sensor's ability to detect subtle differences in color.

$$Resolution = log2(n) \qquad (21)$$

Where:

- n: is the number of color levels to be detected.

For this case, the value of ”n” is equal to 2, due to the fact that in the application of this module two bottles with different color content will be detected, which will make the red and the yellow, through a configuration of ranges of the color It is possible to establish which color we are going to recognize in order to be sensed in the near future through the selected color sensor, and to inform the operator of the number of bottles that have been processed.

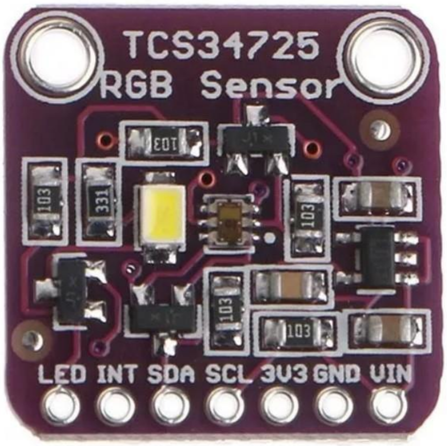

Figure 24. Color Sensor tcs34725.

PLC 1214 DC/DC

The Siemens 1214 DC/DC is a small footprint controller, making it suitable for applications where space is limited. This PLC is designed to work with a direct current (DC) power supply, making it suitable for applications where the availability of power in the form of DC is more convenient, offers an adequate number of digital inputs and outputs, as well as some analog inputs. This allows the connection of different devices and sensors for monitoring and control, such as motors and sensors.

Figure 25. PLC Simens 1214 DC/DC.

- Programming package STEP 7 V11.0 SP2 or higher supply voltage 24V DC
- Allowable range, lower limit (DC) 20.4 V
- Allowable range, upper limit (DC) 28.8 V
- Allowable range, lower limit (DC) 5 V

- Allowable range, upper limit (DC) 250 V
- Consumption (nominal value) 500mA; typically consumption max. 1.2A; 24V DC
- Closing current, max. 12A; with 28.8V

The selection of this PLC is due to the fact that it will only work with elements where DC direct current is used, in addition to complying with the necessary inputs for the configuration of the module, such as digital for motor control and analog for sensor control. All the configuration of these components is done through the LADDER programming in the Simens own software, that is, TIA PORTAL, in this case version 16 (V16) was used.

In PLC, it is in charge of controlling the herd motors, the rotating wheel and the motor that allows the motor structure to go up and down, which is in charge of screwing the bottle.

ESP32 38 Pines

When it comes to a range of applications, including IoT projects, automation, and control systems, the ESP32 is a well-liked and wise choice. Many developers and manufacturers find it to be an appealing alternative due to its mix of computing capability, wireless connection, low power consumption, and reasonable price.

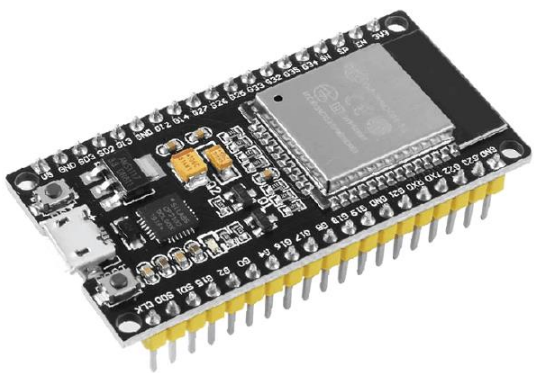

Figure 26. ESP32 Pines.

- Xtensa® single-/dual-core 32-bit LX6 microprocessor(s)
- 34 × programmable GPIOs
- 12-bit SAR ADC up to 18 channels

- 2 x 8-bit DAC

The ESP32 micro controller is a device that allows us to control devices where it is necessary to send signals such as PWM for servo control,These PWM signals are set for time, and analog inputs for sensor control. In the module, the ESP32 controls the servos in charge of giving way to the bottles to the rotating wheel to continue with the capping process, and the control of an output servo that fulfills the function of retaining or giving way to the bottles that have finished. the capping process.

For the programming of the ESP32, the Arduino Software is used because this environment allows us to configure the ESP32 by adding the respective library.

2.4. HMI Interface

If the PI3070ig offers a high-quality screen and adequate resolution for your needs, it might be a recommended option. Good display quality is essential for a clear and readable graphical interface, the size and ergonomic design of the PI3070ig can be important factors. Whether the size of the HMI is appropriate for the specific application and environment, and whether it is easy to use and interact with, Figura 28.

- CPU A35 1.2GHz, 128M Flash, 128M DDRAM
- Display:7 inches
- Resolution: 800*480; Color display: 16,000k colors
- Interfaces: a serial port. COM1: RS232, RS422 or RS485(choose one of two), RS485.
- USB interfaces: USB Host/USB Client

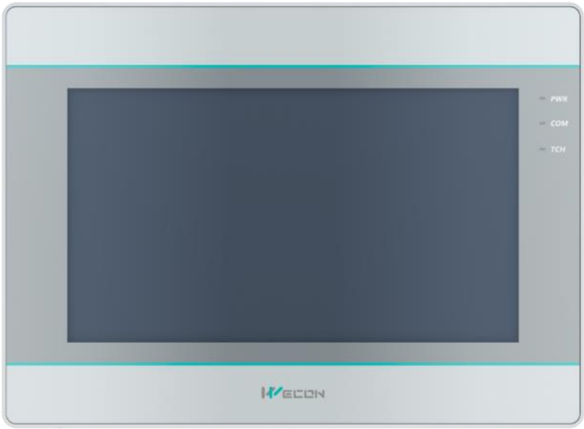

Figure 27. HMI PI3070ig.

The HMI allows us to have communication between the operator and the machine through a graphical interface, which allows control as information of the process that occurs in the system, in this module the HMI allows us to control the module in two different ways, such as the Manual mode and Automatic mode, Figure 29.

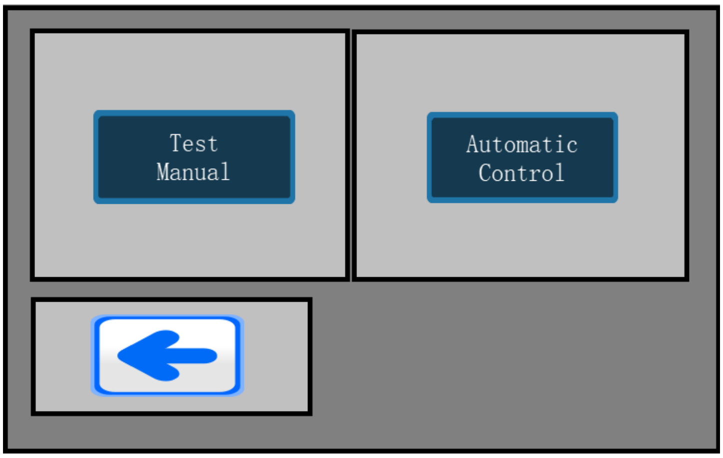

Figure 28. Operation Modes.

Within Manual mode we can activate each of the actuators present in the module, such as: Servo 1 or input gate, Servo 2 or output gate, Motor 1 or belt, Motor 2 or rotary wheel, Motor 3 or worm, Motor 4 or screw motor.

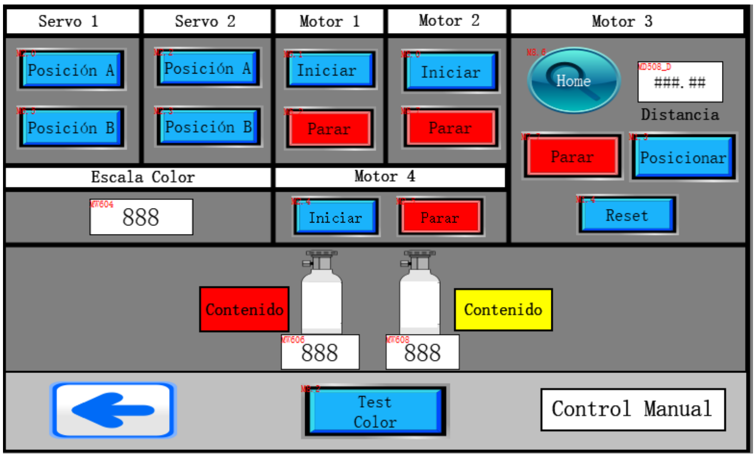

Figure 29. Manual Mode.

While in Automatic mode we have two buttons that allow us to Activate and Deactivate the process, in addition to having a bottle count indicator that will depend on the color of the content, as well as buttons that will allow us to reset the counter variable a, shown in Figure 31.

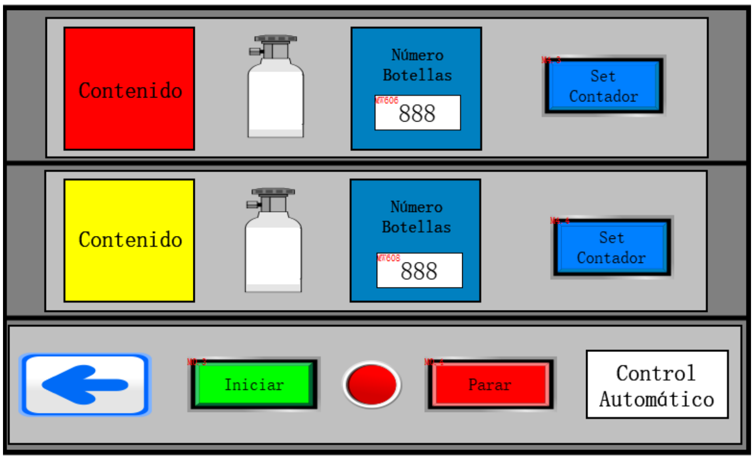

Figure 30. Automatic Mode.

Position Sensor

Position sensors typically have high precision in measuring and sensing the position of an object. They can provide accurate and repeatable measurements, they often have high resolution, which means they can detect small changes in the position of the object. Position sensors typically have a fast response rate, which means they can detect position changes in real time. This is essential in applications that require real-time and dynamic control, such as tracking systems.

The capacitive sensor allows the bottle to be detected, which sends a signal to open the gate and allow the bottle to pass to the rotating wheel to continue with the capping process.

Figure 31. Capacitive Sensors LJC18A3.

- Operating Voltage: 6-36VDC.
- Maximum Output Current: 300mA.
- Output Type NPN DC NO(normally Open).
- Cable length: 1.80m.
- Outside diameter: F18.
- Total length: 127 cm.
- Detection method: Capacitive.
- Range: 1-10mm

On the other hand, the capacitive sensor detects the variation in the change in the electro-magnetic field, which works only with metals. that is why small metal indicators are used to determine the rotation of the wheel in 90 degrees

Figure 32. Inductive Sensor PNP LJ12A3.

- Operating Voltage: 6 to 36 V DC
- Current Consumption: 300mA
- 3-wire cable connection (VCC, GND, Output)
- Output type: PNP (ON:VCC / OFF:GND)
- Output: Normally Open

- Response frequency: 100 Hz
- Detection range: 4mm +-10
- Detectable Materials: Iron/Steel Alloys

2.5. Control Algorithm

The algorithm diagrams represent the operation of the entire process in a programming method. Such as the one of advancing the band, opening gates to enter the rotating wheel, giving way to the wheel to turn, screwing the cap on the bottle and finally detecting the color of the bottle's content. Another algorithm are show in D.

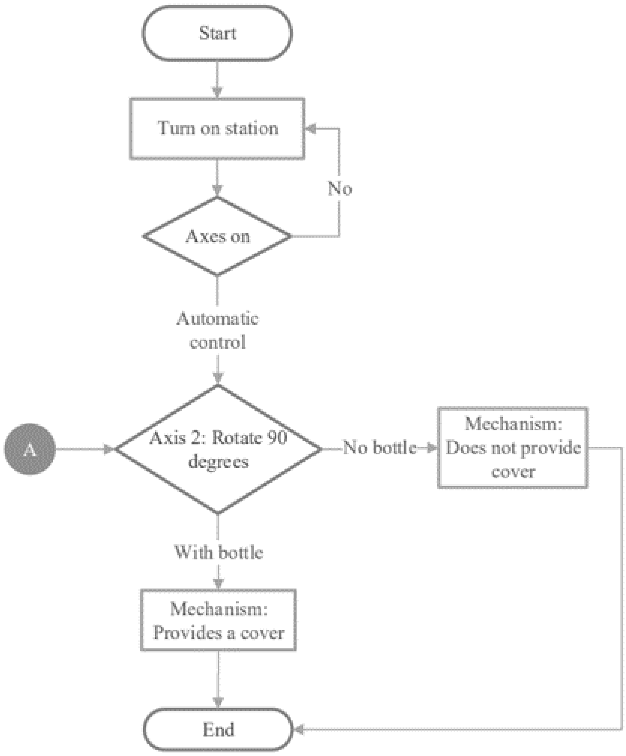

Figure 33. Diagram of dispensing caps.

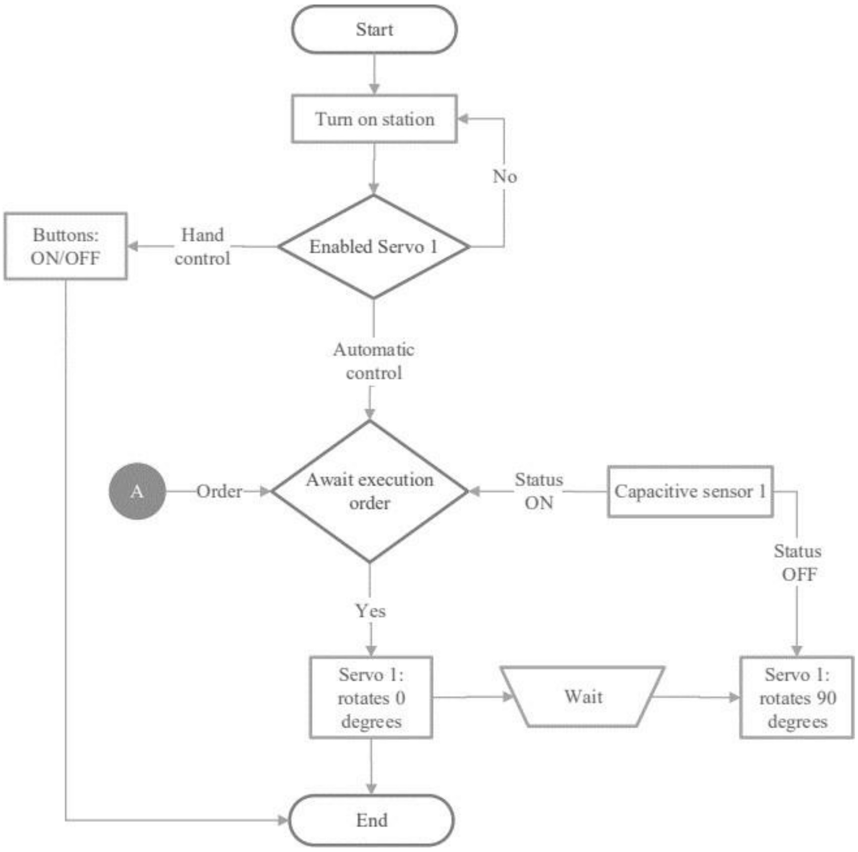

Figure 34. Bottle retention diagram.

2.6. Summary of electronic components

After having carried out an analysis and having a sketch of the elements to be used, the following table was determined on the electronic elements.

Table 5. Functionality and Current Consumption per Element.

Electronic components				
Component	Amount	Function	Current(mA)	Total Current(mA)
NEMA 23	1	Move Band	3500	3500
NENA 17	2	Move Endless crew and Cap	1800	1800
NEMA 23	1	Move Wheel	3500	3500
Servo Motor m995	2	Open/Close Gate	900	1800
PLC 1214 DC/DC	1	Control Process	500	500
HMI Wecon PI3070ig	1	Show Process	625	625
ESP32 module	1	Control Elements	400	400
RGB TCS230	1	Detect Color	100	100
Capacitive sensor	2	Bottle position	300	600
Router tp link	1	Connect HMI and PLC	500	500
DC Motor	1	Screw cap	84	84
-	-	-	-	Total: 13469

It must be taken into account that these current consumption specifications are for the modules without considering a load, likewise for PLC and HMI devices they are without considering external modules. However, with this table it is possible to have an estimate of the total consumption of the module and provide a provisional source until the calculations of all the elements with load are made.

With Table 5 it is possible to determine a source that is capable of supplying the entire circuit, however, since it has control and power components, it is necessary to separate these components, which is why two independent sources are obtained that will supply 24 V DC but each one will feed different components.

Figure 35. Power Source.

Figure 36. Control Source.

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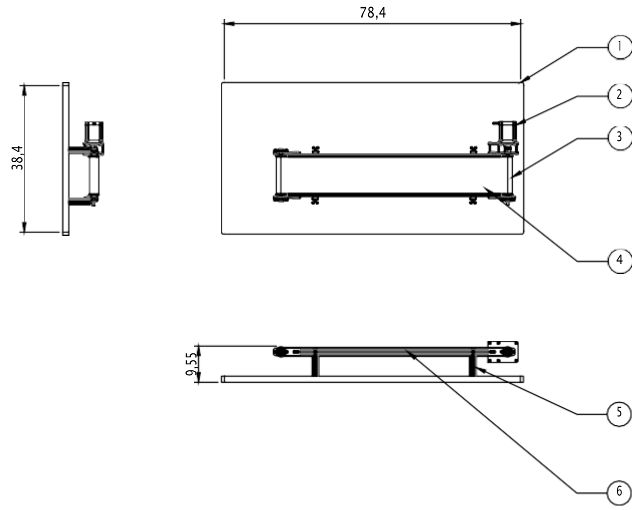
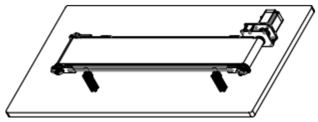
Appendix A

Mechanical drawings





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5	C4	PLACA UNION	4	ALUMINIO	D03-303	
4	B4	BANDA	1	CAUCHO		
3	B4	RODILLO	2	ABS	D03-302	
2	B4	MOTOR DC ENCODER	1	VARIOS		
1	A4	MESA	1	ALUMINIO	D03-301	

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		REV.	JONATHAN C.	24/04/2021

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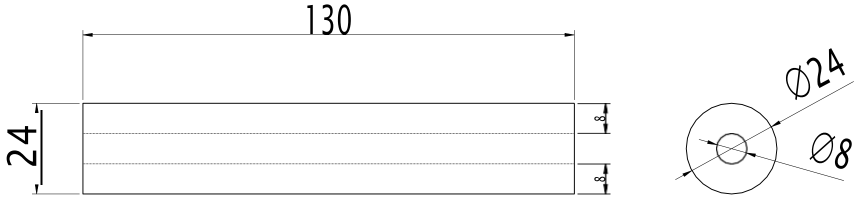

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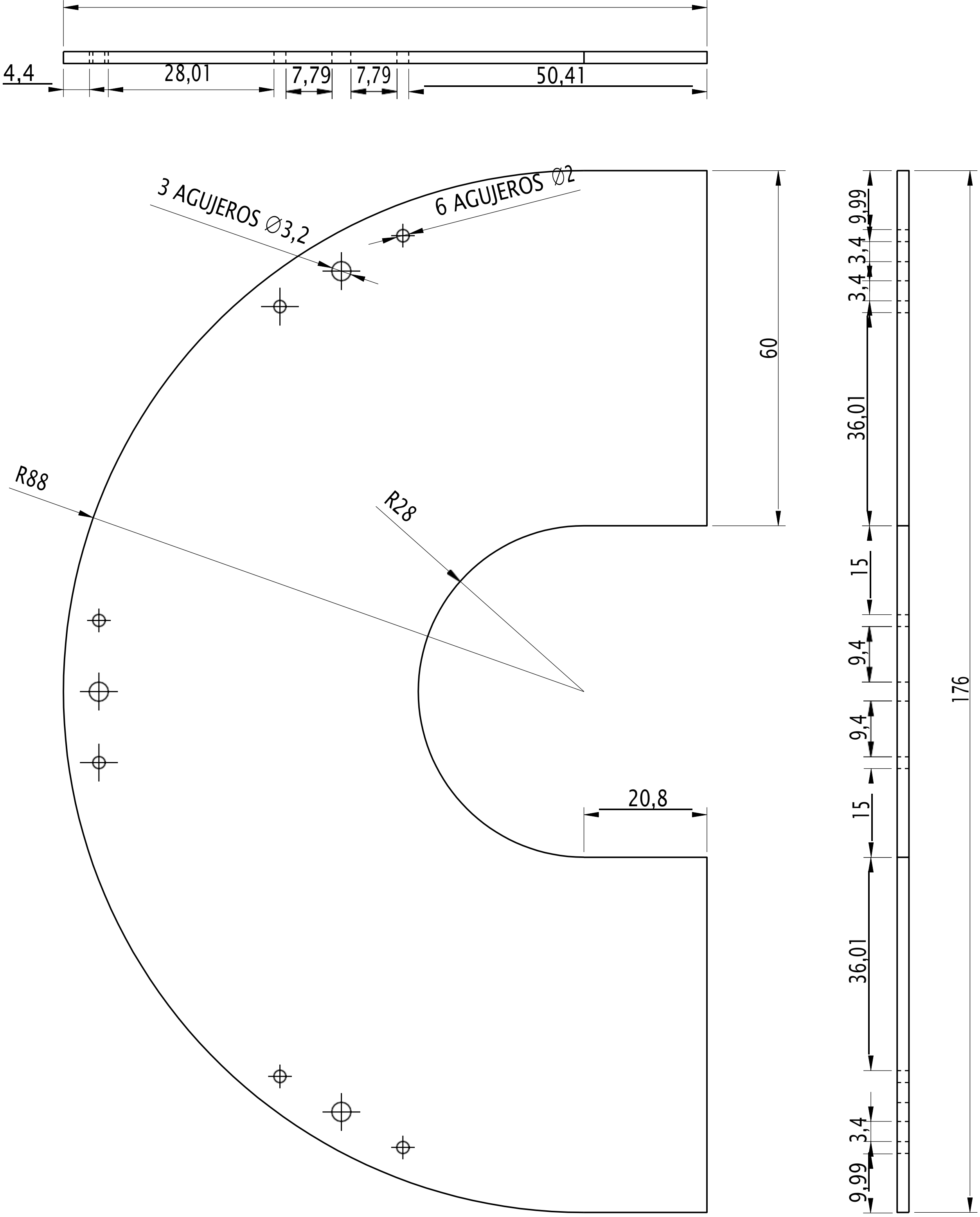

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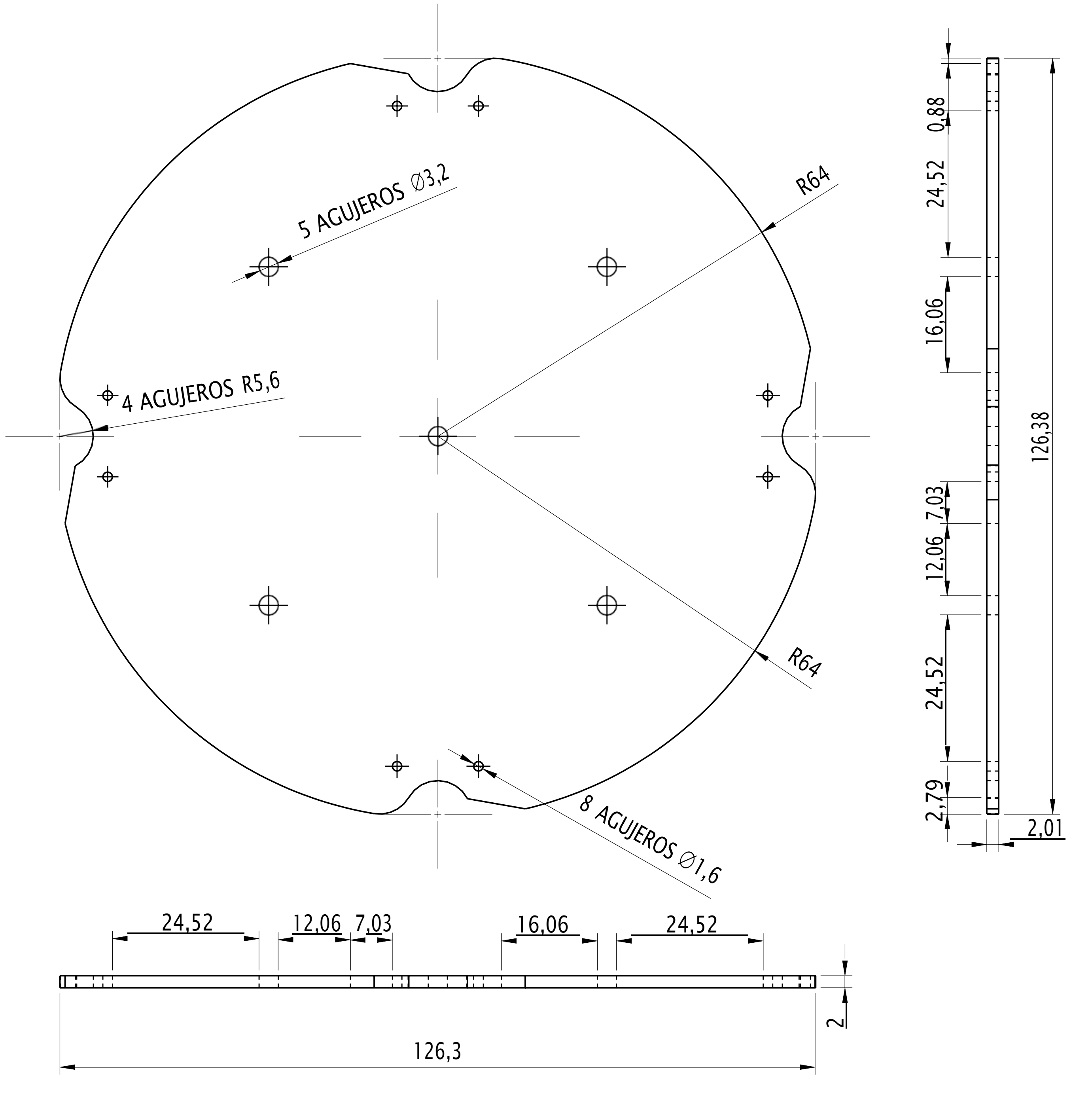

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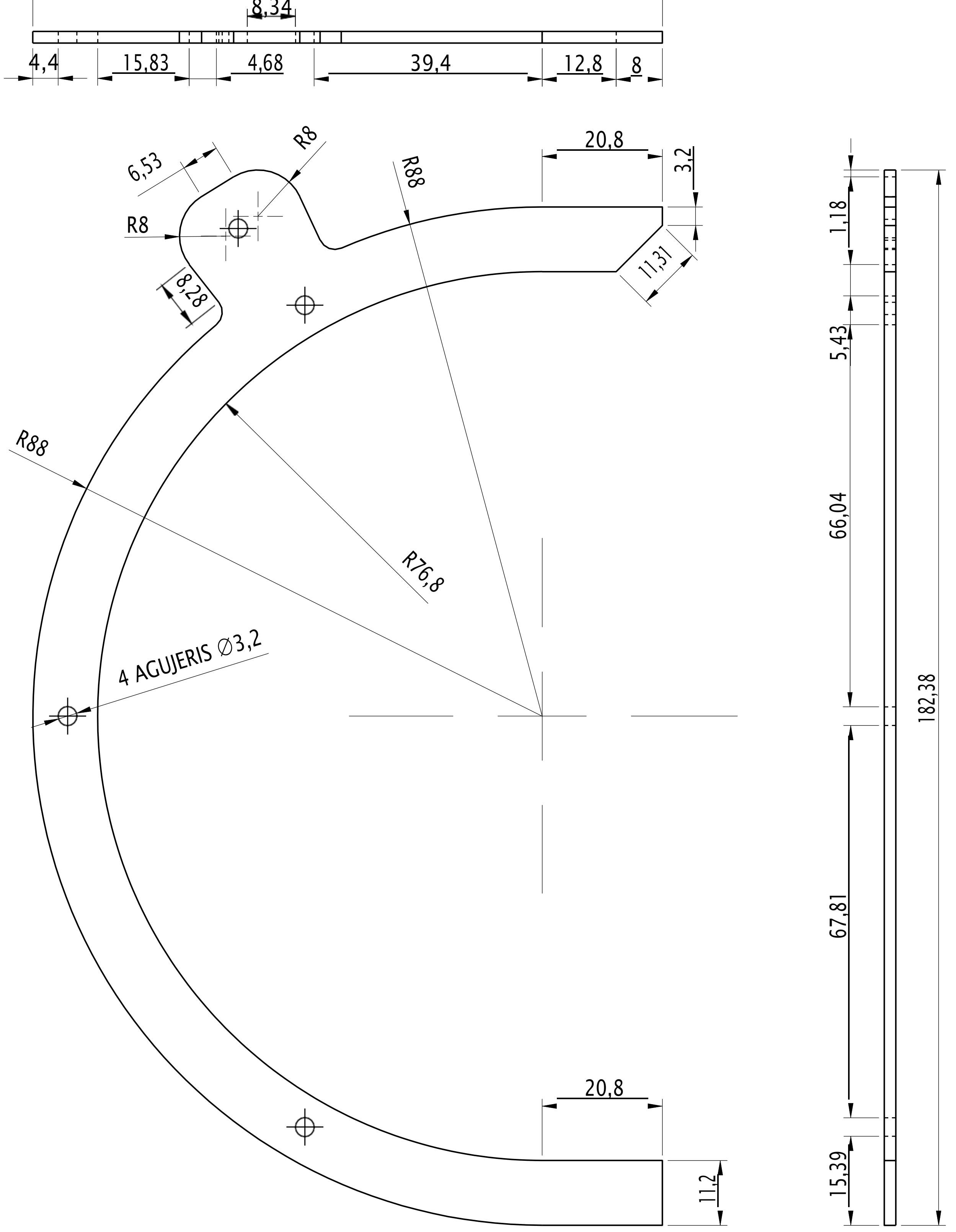

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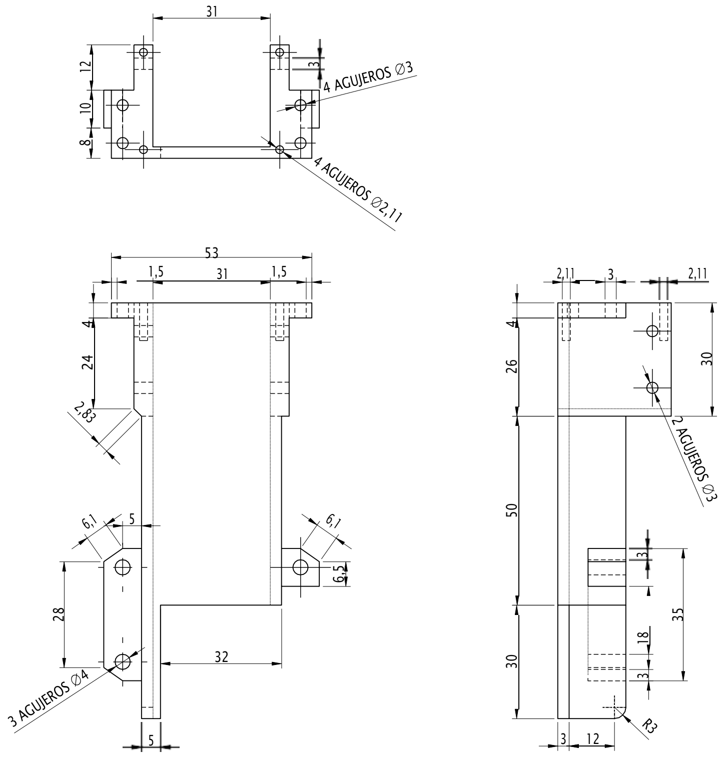

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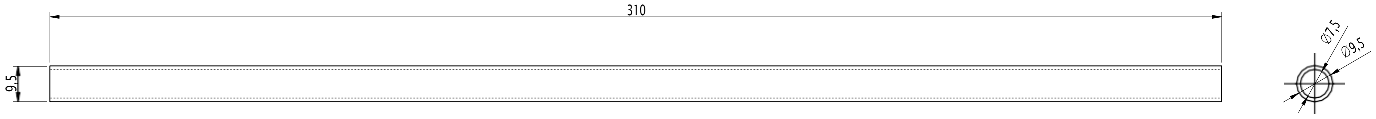

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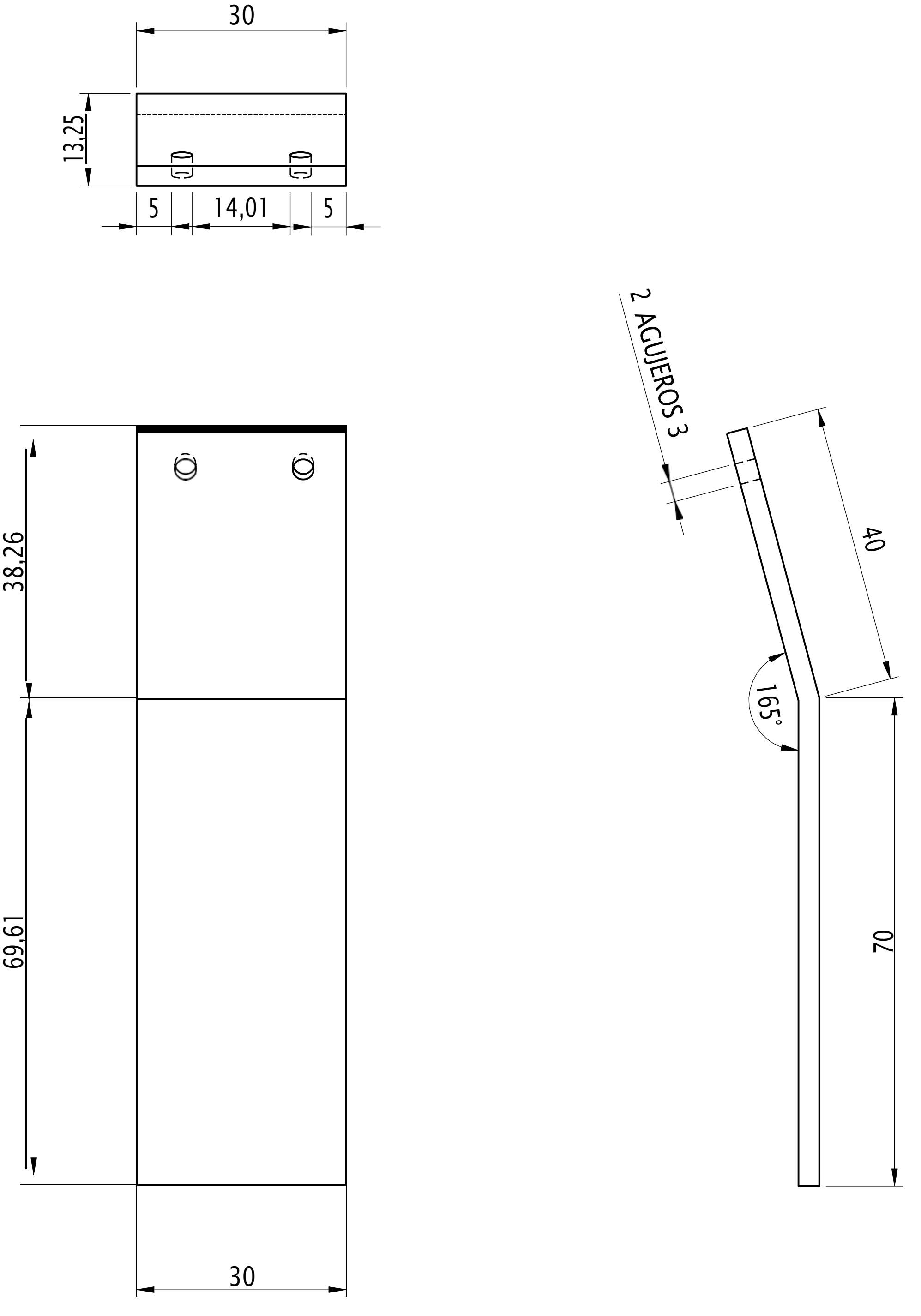

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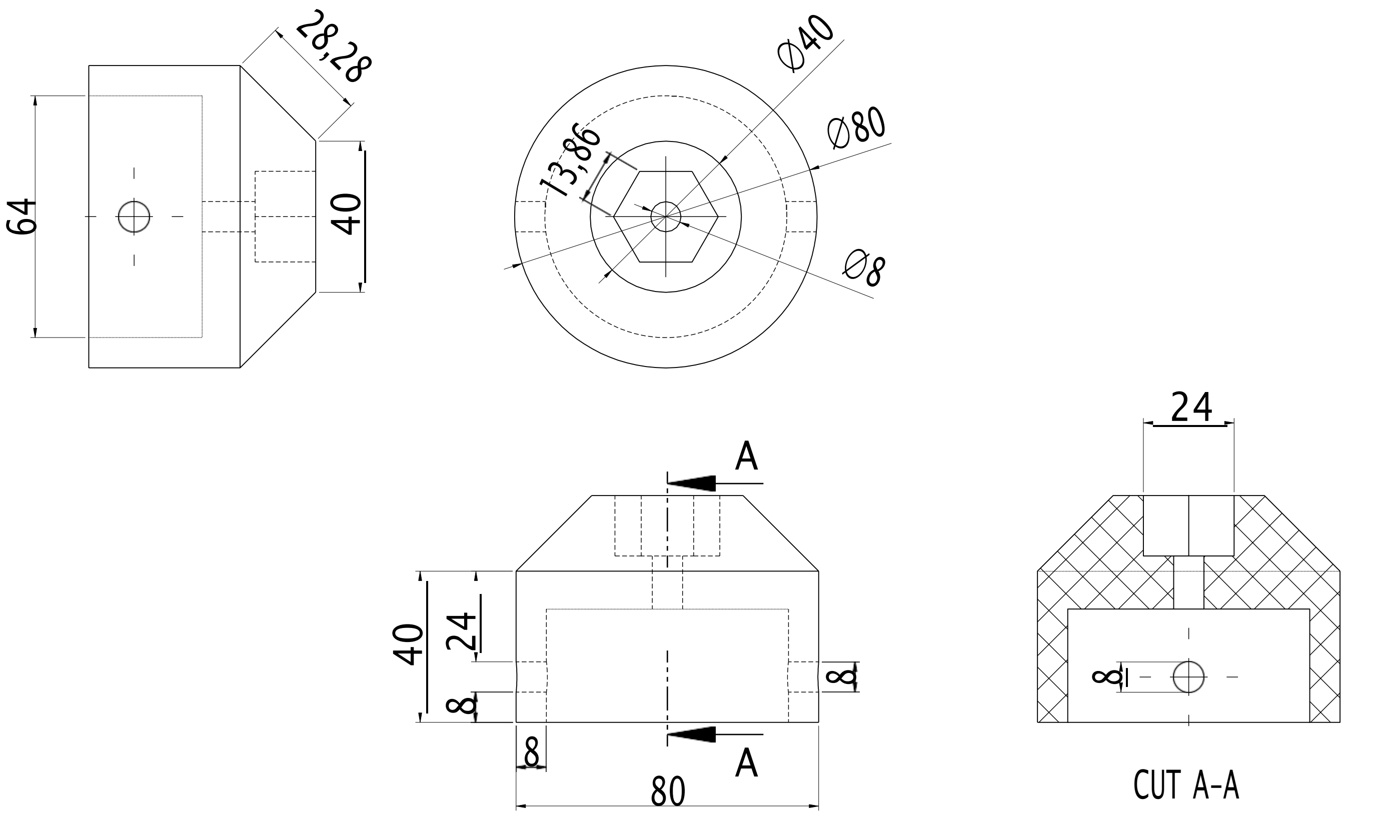

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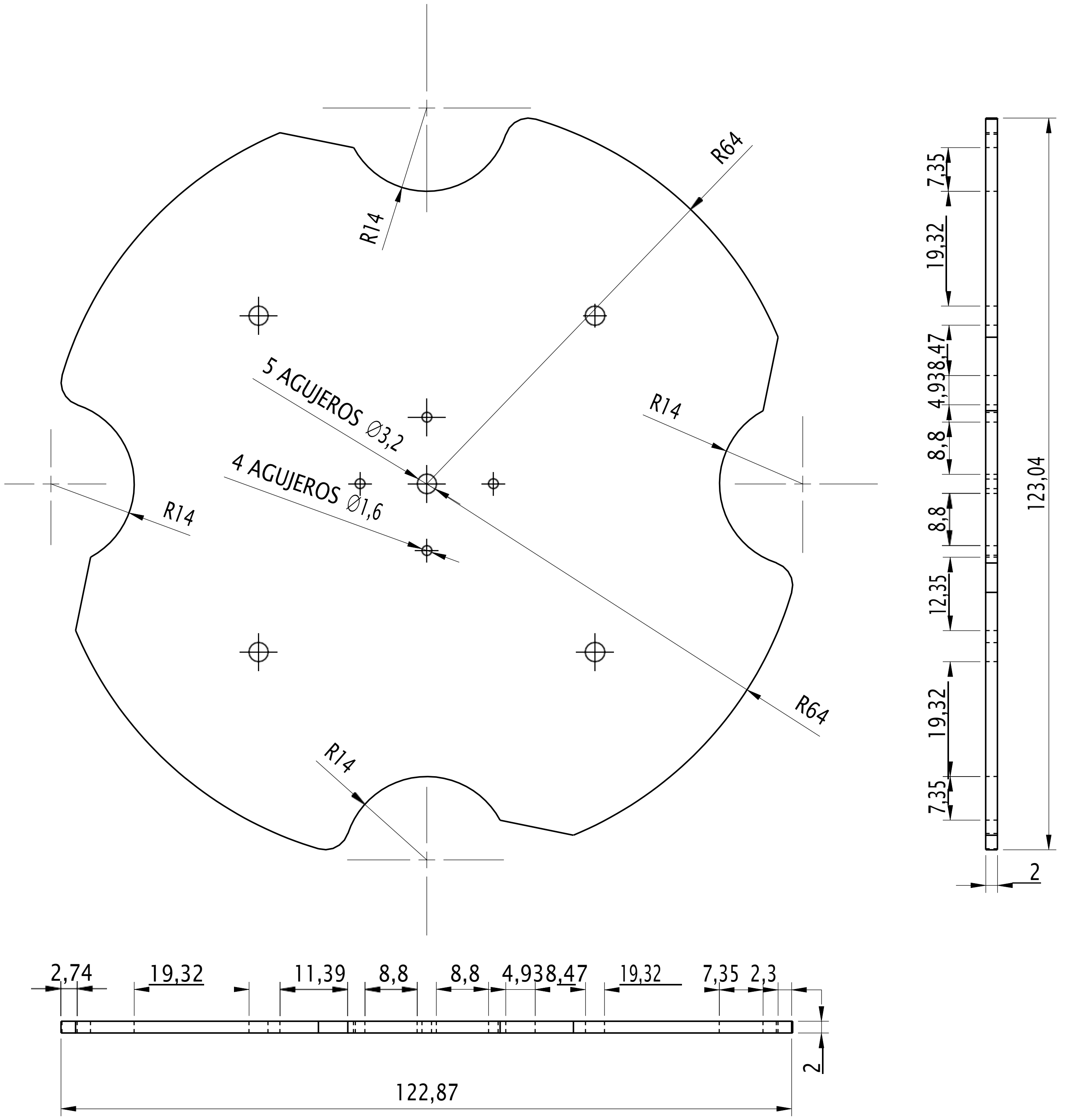

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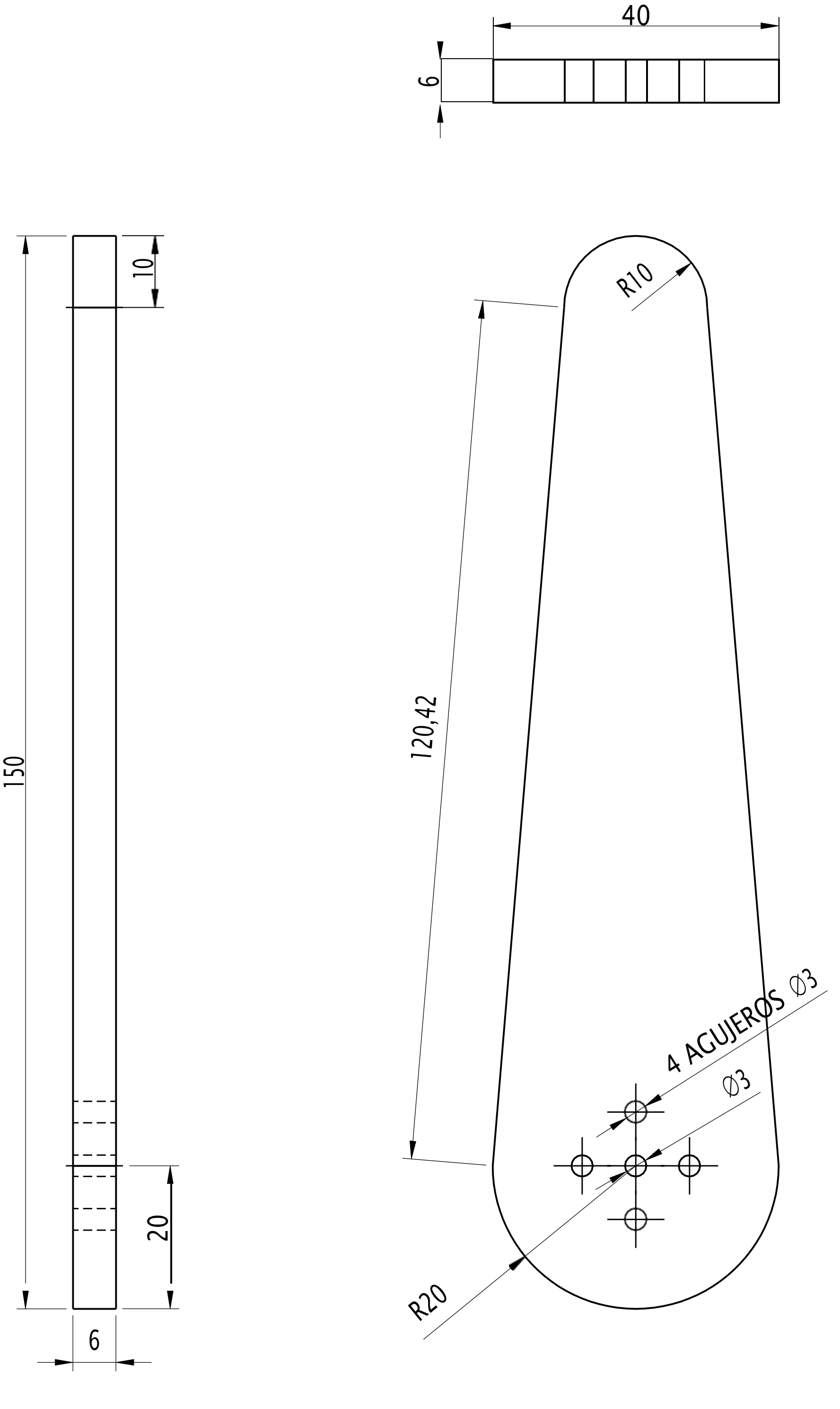

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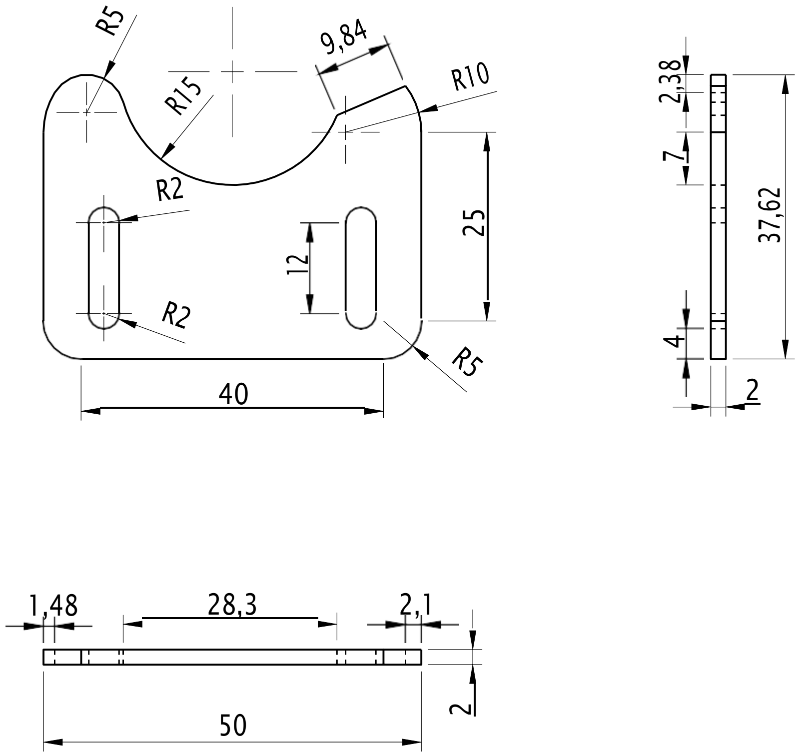

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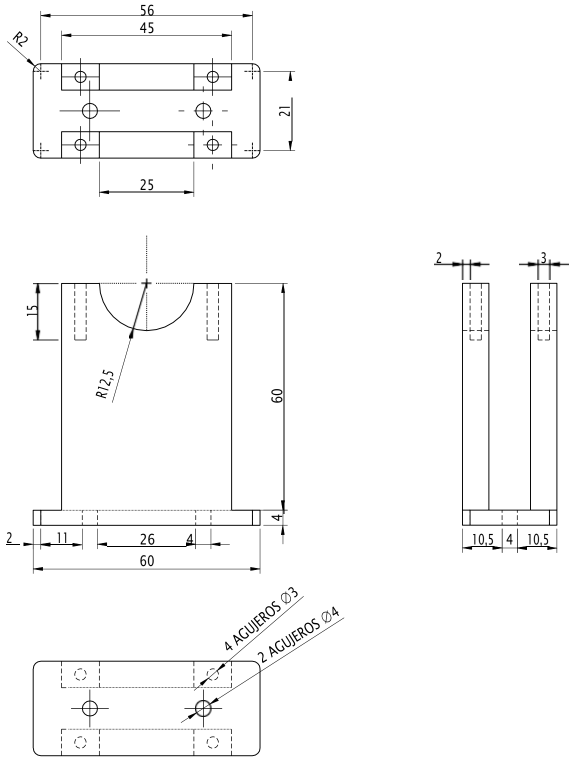

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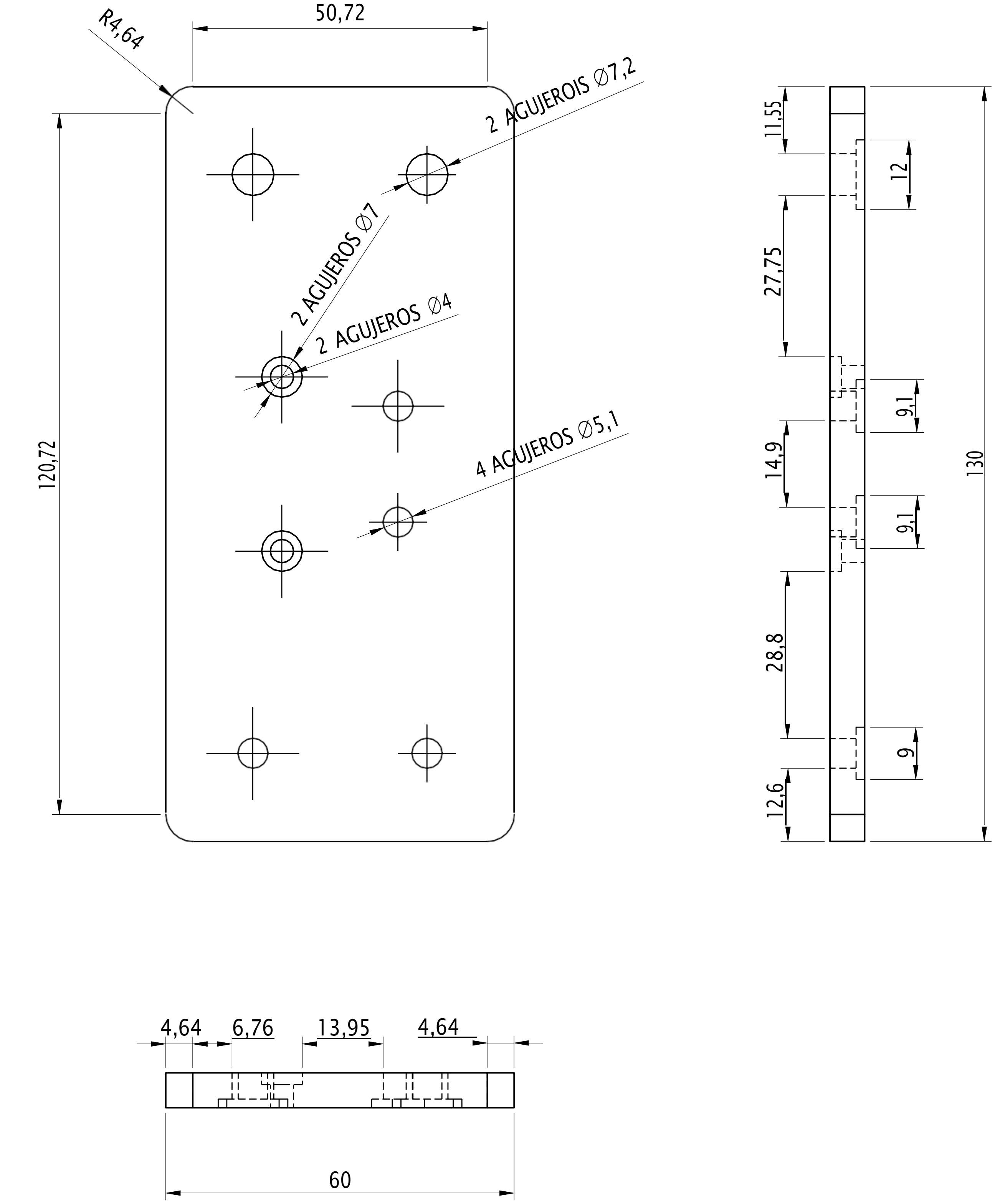
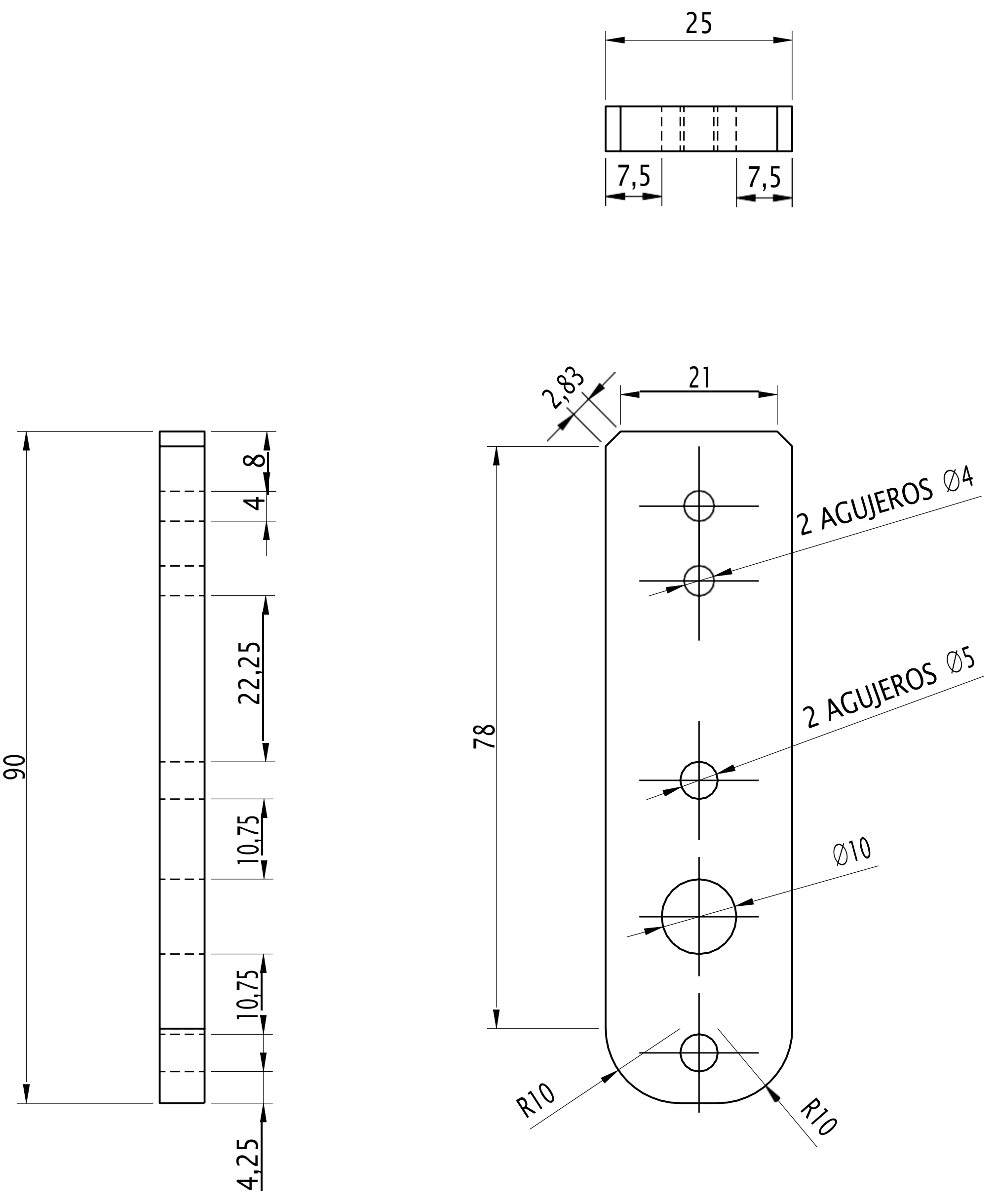
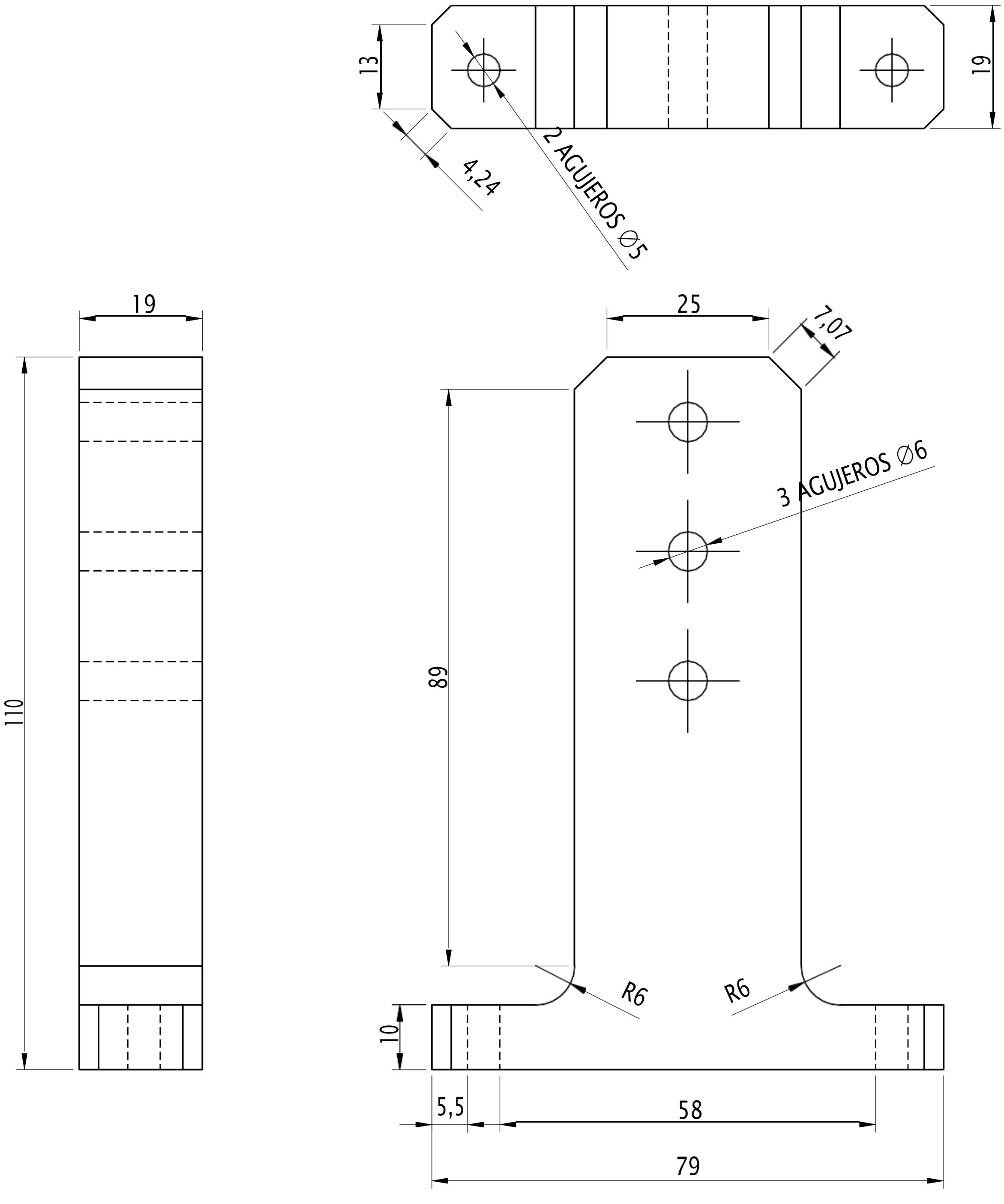
				REV.	PILCO A.	25/03/2021
MOTOR MOUNT			D03-313			



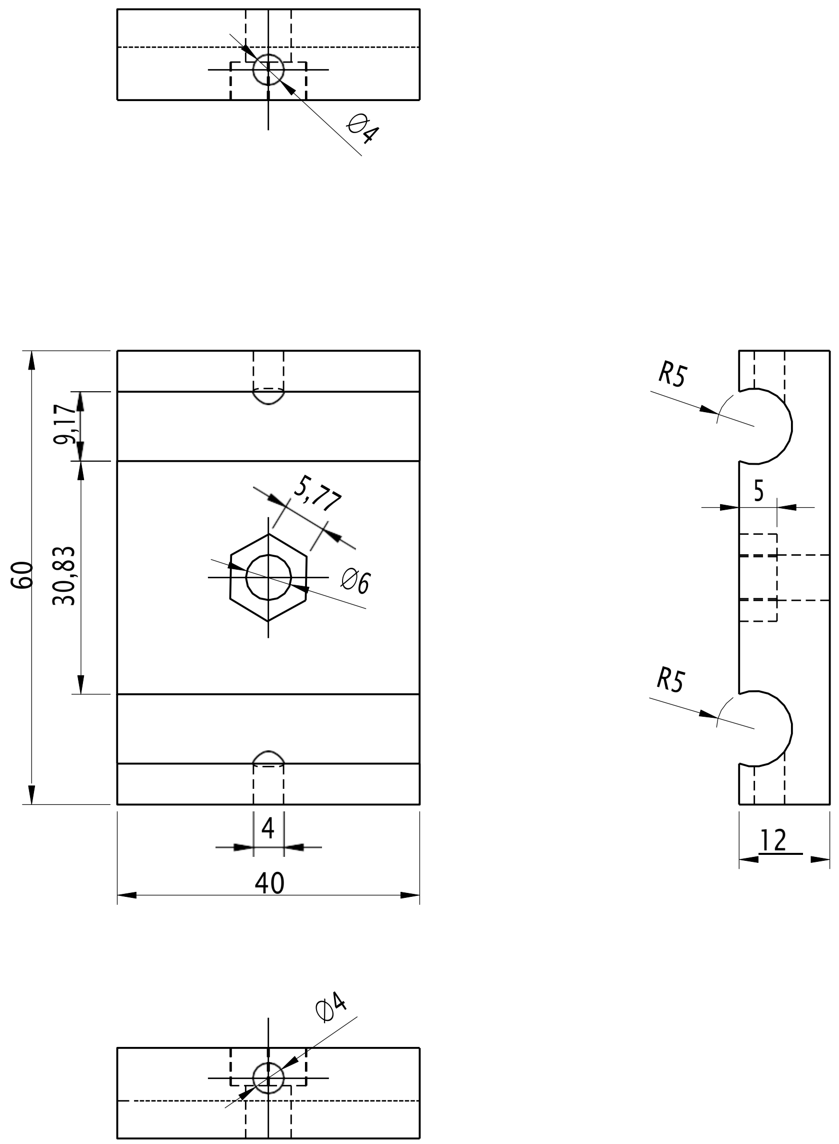
TREATMENT: NO TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COVERING: WITHOUT COVER					
MATERIAL: PMMA	TOL.GRAL: ±0,2	SCALE: 1:1	DIB.	BETANCOURT S..	11/03/2021
			DIS.	BETANCOURT S..	11/03/2021
			REV.	PILCO A.	25/03/2021
LACE SUPPORT		D03-314			



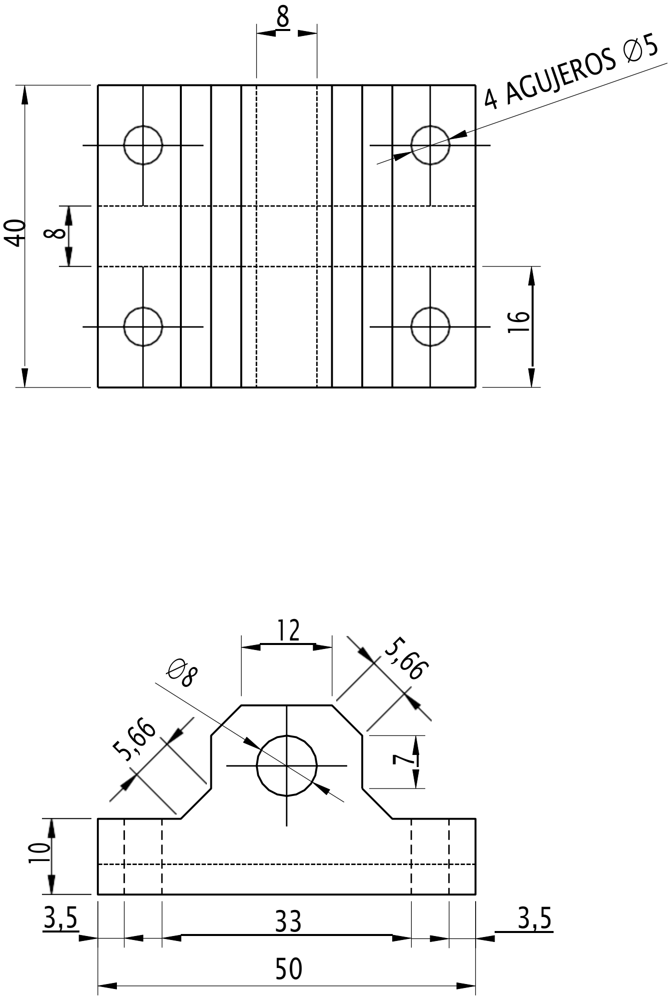
TREATMENT:	NO TREATMENT		UIDE	MECHATRONICS ENGINEERING	
COVERING:	WITHOUT COVER				
MATERIAL: PMMA		TOL.GRAL: ±0,2	SCALE: 1:1	DIB. BETANCOURT S..	11/03/2021
				DIS. BETANCOURT S..	11/03/2021
				REV. PILCO A.	25/03/2021
BAND SUPPORT			D03-315		



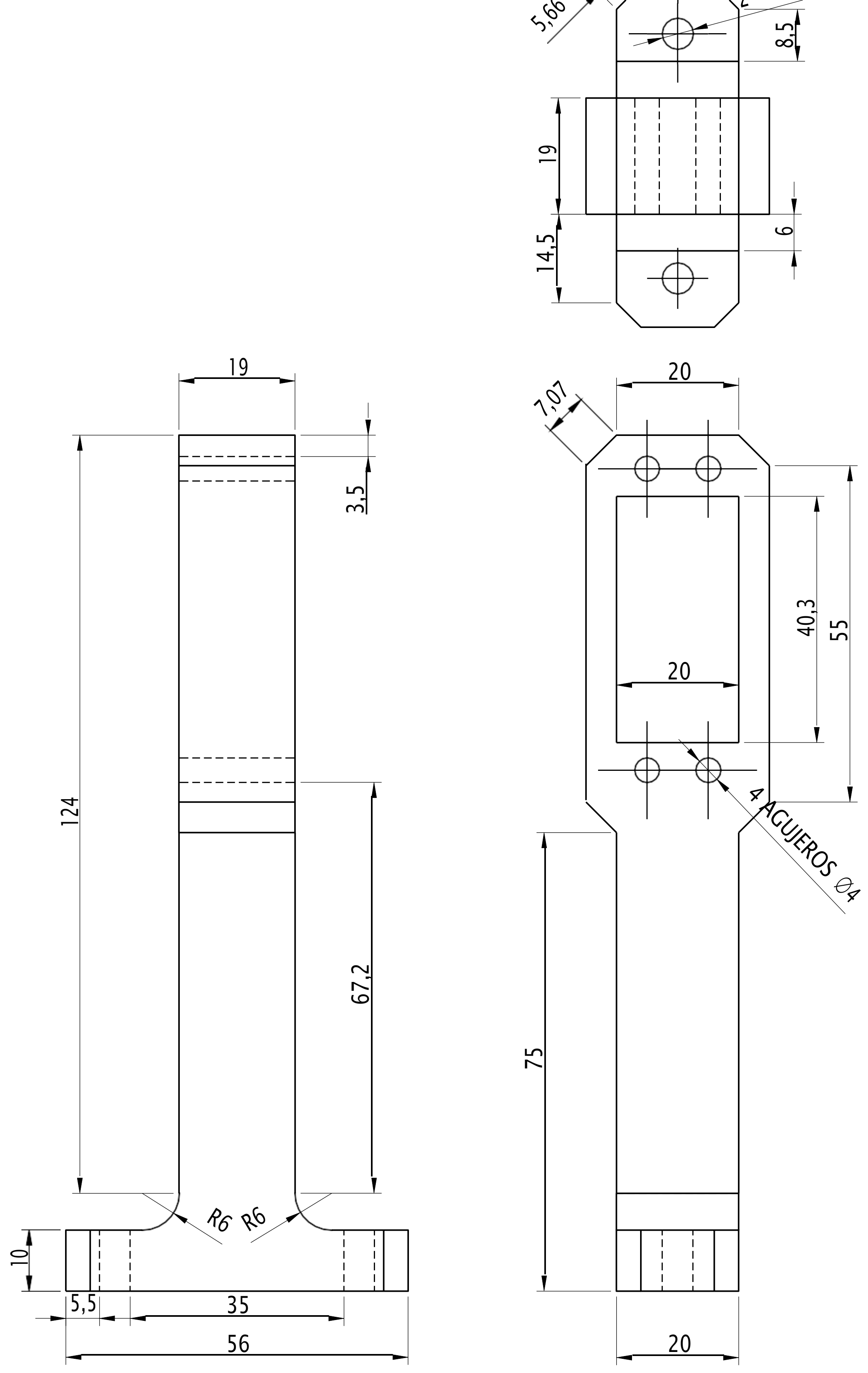
TREATMENT: NO TREATMENT		UIDE	MECHATRONICS ENGINEERING			
COVERING: WITHOUT COVER						
MATERIAL: ABS	TOL.GRAL: ±0,2	SCALE: 1:1	DIB.	BETANCOURT S..	11/03/2021	
			DIS.	BETANCOURT S..	11/03/2021	
			REV.	PILCO A.	25/03/2021	
HOLDER		D03-310				



TREATMENT:	NO TREATMENT	UIDE	MECHATRONICS ENGINEERING		
COVERING:	WITHOUT COVER				
MATERIAL: ABS	TOL.GRAL: ±0,2	SCALE: 1:1	DIB.	BETANCOURT S..	11/03/2021
			DIS.	BETANCOURT S..	11/03/2021
			REV.	PILCO A.	25/03/2021
SHAFT HOLDER		D03-317			



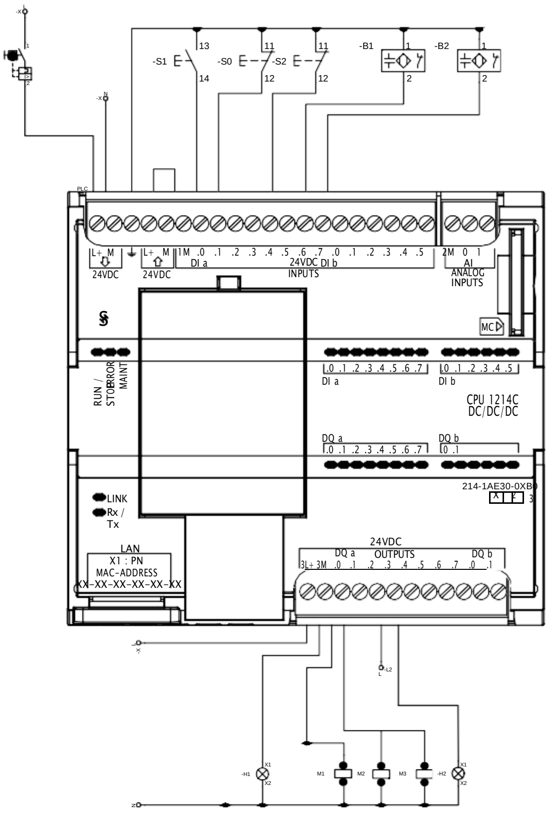
TREATMENT: NO TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COVERING: WITHOUT COVER					
MATERIAL: ABS	TOL.GRAL: ±0,2	SCALE: 1:1	DIB.	BETANCOURT S..	11/03/2021
			DIS.	BETANCOURT S..	11/03/2021
			REV.	PILCO A.	25/03/2021
DISPENSER HOLDER		D03-318			



TREATMENT: NO TREATMENT		UIDE	MECHATRONICS ENGINEERING
COVERING: WITHOUT COVER			
MATERIAL: ABS	TOL.GRAL: ±0,2	SCALE: 1:1	DIB. BETANCOURT S.. 11/03/2021
			DIS. BETANCOURT S.. 11/03/2021
			REV. PILCO A. 25/03/2021
SERVO HOLDER		D03-316	

Appendix B

Electronic and control drawings

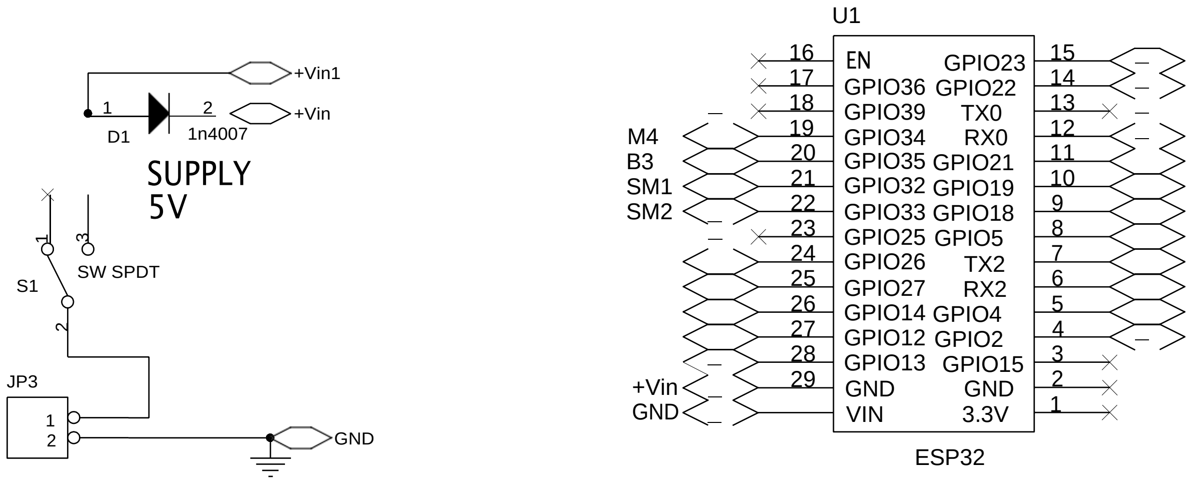


VOLTAGE REGULATORY SUPPLY	
VCC	+24V DC
GND	0V DC

UIDE	MECHATRONICS ENGINEERING	DIB.	BETANCOURT S.	18/05/23
		DIS.	BETANCOURT S.	18/05/23
		REV.	PILCO A.	18/05/23
BOTTLER COVERING SECTION ELECTRONIC DRAWING		D02-001		ESCALA: N/A
				N/A

SOURCE			
B1	POWER SUPPLY	1	25V-7A-168W
B2	POWER SUPPLY ESP32	1	5V - 3A
DEVICE			
U1	PLC SIMENS	1	1214 DC/DC
U2	ESP32	1	30 PINES
MOTORS			
J1-J2	MOTOR NEMA 23	2	CONVEYOR BELT AND ROTATING WHEEL
J3-J4	MOTOR NEMA 17	2	SCREW AND END SCREW
SENSORS			
S1-S2	CAPACITIVE SENSOR	2	POSITION SENSORS
S3	COLOR SENSOR	1	COLOR DETECTION SENSOR

UIDE	MECHATRONICS ENGINEERING	DIB.	BETANCOURT S	18/05/23
		DIS.	BETANCOURT S.	18/05/23
		REV.	PILCO A.	18/05/23
BOTTLING MACHINE COVERING SECTION COMPONENT LIST		D02-101	ESCALA N/A	N/A

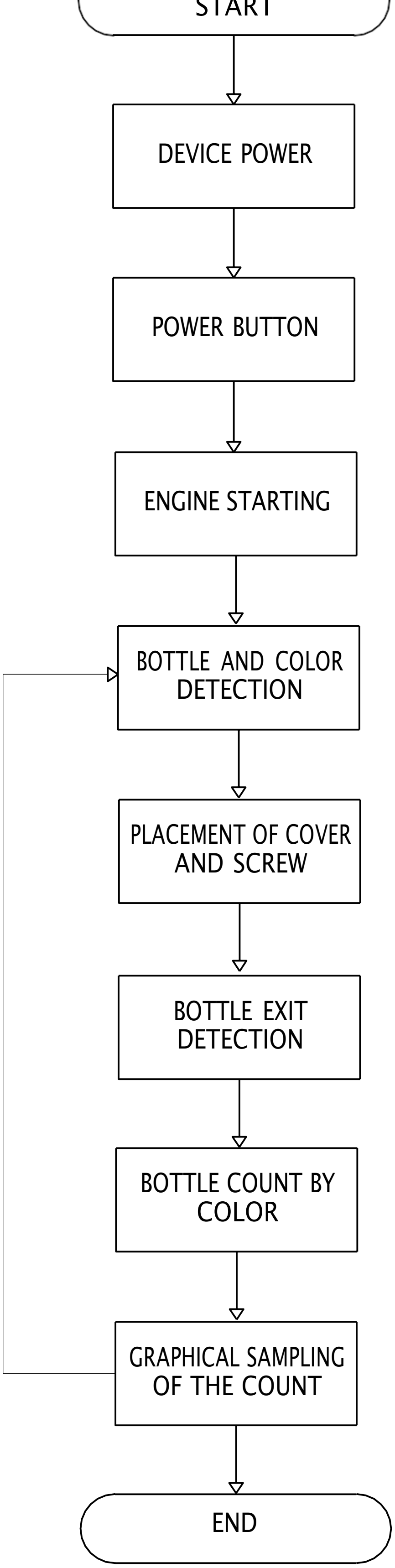


VOLTAGE REGULATORY SUPPLY	
VCC	+5V DC
GND	0V DC

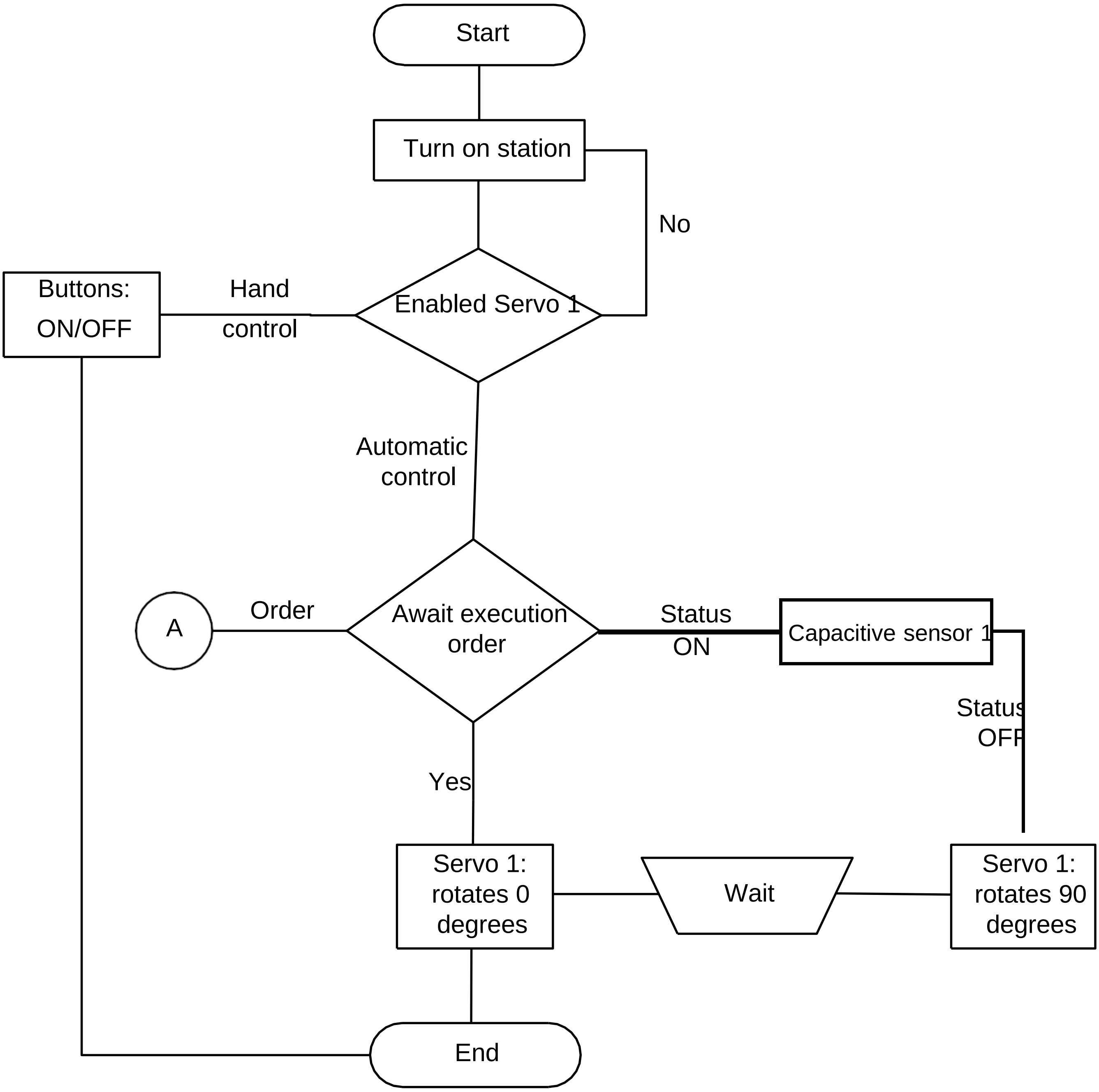
UIDE	MECHATRONICS ENGINEERING	DIB.	BETANCOURT S.	18/05/23
		DIS.	BETANCOURT S.	18/05/23
		REV.	PILCO A.	18/05/23
ESP32 CONNECTIONS ELECTRONIC DRAWING		D02-002	ESCALA: N/A	N/A

Appendix C

Programming flux drawings



UIDE	MECHATRONICS ENGINEERING	DIB.	BETANCOURT S.	11/03/2021	
		DIS.	BETANCOURT S.	11/03/2021	
		REV.	PILCO A.	25/03/2021	
BOTTLING MACHINE COVERING SECTION COMPUTER PLANE		D01-001			ESCALA: N/A N/A



UIDE	MECHATRONICS ENGINEERING	DIB.	BETANCOURT S.	17/06/2023
		DIS.	BETANCOURT S.	17/06/2023
		REV.	PILCO A.	17/06/2023

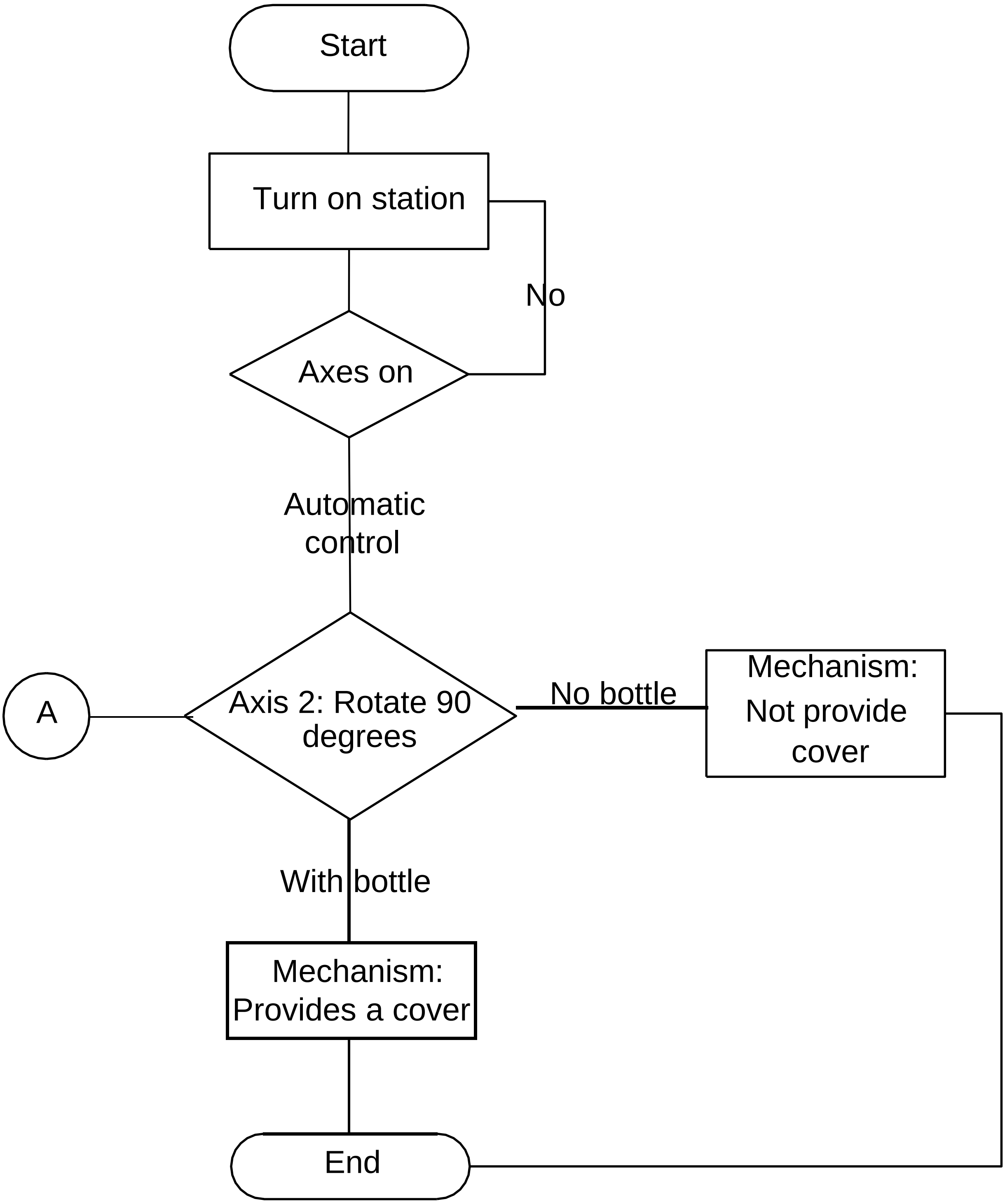
BOTTLING MACHINE POSITION DETECTION SECTION

COMPUTER PLANE

D01-002

ESCALA: N/A

N/A



UIDE	MECHATRONICS ENGINEERING	DIB.	BETANCOURT S.	17/06/2023
		DIS.	BETANCOURT S.	17/06/2023
		REV.	PILCO A.	17/06/2023
BOTTLING MACHINE DISPENSING SECTION COMPUTER PLANE		D01-003		ESCALA: N/A N/A

Appendix D

Costs

Mechanical Components			
Component	**Quantity**	**Unitary Price $**	**Total $**
Festo-type profiles	8	37.45	299.6
Threaded rod	1	7.18	7.18
2m Aluminum tube	1	4.40	4.40
Bronze poles	6	0.5	3
Table manufacturing	1	150	150
KFL08 rowlock	4	0.75	3
Wheels Kit	4	3	12
3D Print	20	6.6	132
Acrylic	12	4	48
Nuts	20	0.35	7
Total		633.18 $	

Electronic Components			
Component	**Quantity**	**Unitary Price $**	**Total $**
Capacitive Sensor	2	8.25	16
Pushbuttons	6	4.67	28.02
HMI PI3070ig	1	230	230
Router Tp Link	1	18.29	18.29
Ethernet Cable	1	3.5	3.5
Bakelite	1	6.3	6.3
Servomotors	2	7.5	15
NEMA 23	2	45	90
NEMA 17	1	30	30
Motor DC	1	27.10	27.10
Color Sensor	1	9	9
PLC 1214 DC	1	567	567
24V SUPPLY	1	47,96	47.96
Total		1088.17 $	

Total Cost of the Project	
Mechanical Components	633.18
Electrical Components	1088.17
Worked hours	1200
Total	2921.35