



ING. MECATRÓNICA

**Tesis previa a la obtención del título de Ingeniera en
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DESIGN AND IMPLEMENTATION OF A DIDACTIC SYSTEM FOR
HANDLING WITH PNEUMATICS

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CONTENTS

1	MECHANICAL DESIGN	1
1.1	Technical Specifications	1
1.2	Design thinking	1
1.3	Components dimension	5
1.4	Components selection	16
1.5	Simulation	18
1.6	3D Model	19
1.7	Summary of mechanical components	22
2	Electronic and Control Design	22
2.1	Components Selection	23
2.2	Specification Components	24
2.3	PID Control	32
2.4	Programming	37
A	Operation block diagram	39
B	Electronic Drawing	40
C	List of Electronic Drawing	41
D	Control Drawing	42
E	List of Control Drawing	43
F	Assembly Drawings	44
G	Mechanical Drawings	45

LIST OF FIGURES

1	Block diagram of the Conveyor Belt	2
2	Roller Conveyor belt [1]	3
3	Tension Conveyor belt [2]	3
4	Block diagram of the Robotic Arm	4
5	Gantry cranes [3]	4
6	3D Printer	5
7	Power Screw Data	6
8	Compression in the Power Screw	7
9	Factors of fixation of the end [4]	9
10	Sum of Moments	10
11	Conveyor Belt data	15
12	Components	17
13	Power Screw	18
14	Simulation Piece	19
15	3D Model	20
16	Plate	20
17	Conveyor Belt	21
18	Robotic Arm	21
19	Electronic Block Diagram	22
20	Components	23
21	Motors and Drivers Selection	24
22	Xinje XC3-24RT-E PLC	25
23	HMI Kinco 4.3"	26
24	ESP32-WROOM-32	27
25	Pneumatic System	28
26	Limit Switch	28
27	Presence Sensor	29
28	Color Sensor	29

29	Servomotor MG90s	30
30	8-channel 5V relay module	30
31	Motor and Driver	31
32	Motor with Encoder and Driver	32
33	Connection Diagram ESP32 and Encoder Motor	33
34	system Identification	34
35	Model Output	34
36	Time-Domain	35
37	Ziegler-Nichols first method	36
38	Block diagram of thesis operation	37

LIST OF TABLES

1	Technical Parameters	1
2	Transfer function values	35

DESIGN AND MATERIALS SELECTION

1. MECHANICAL DESIGN

1.1. Technical Specifications

For the degree project, it consists of the design and implementation of a didactic system of manipulation with pneumatics, for which the technical characteristics must be established, which is shown in Table 1:

Technical features	Technical Parameters
Dimensions of the didactic system similar to Festo didactic systems	The dimensions of the didactic system shall be width ≤ 350 mm, length ≤ 750 mm and height ≤ 750 mm.
Modules with standardized materials	The materials used are aluminum profiles, aluminum parts and non-load bearing PLA parts.
Electronic control devices used in industrial processes	The electronic control device used is a PLC with LADDER programming.
Implement a pneumatic actuator	Implement a pneumatic gripper that will allow to grasp the part to be manipulated.
Implement closed loop control	Implement closed loop control on the conveyor belt.

Table 1. Technical Parameters

Once the technical specifications have been established, a conceptual design begins to be carried out in which all the requirements are captured.

1.2. Design thinking

For the complete design of the project, it must be divided into three parts: mechanical design, electronic design, and programming implementation. To achieve this, the mechanical design and electronic design must be carried out simultaneously, so that the mechanical part can determine the tolerances, spaces, and operation of the electronic part. This section will only explain the mechanical part, but both parts were developed at the same time.

The analysis of the mechanical part will be divided into two parts, since each one will have its respective structure and electronics.

1.2.1. Conveyor Belt

A conveyor belt's design is a crucial step in developing a trustworthy and effective conveying solution. To do this, it is crucial to develop a thorough model that illustrates the conveyor belt's construction and functionality. This will enable you to plan and picture how the material in issue will be delivered.

A block diagram depicting how the conveyor belt will function is shown in Figure 1. Once there is a clear understanding of how the conveyor belt will function, it is possible

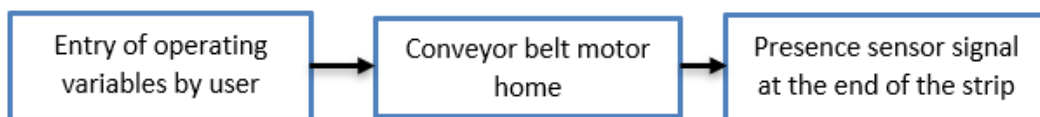


Figure 1. Block diagram of the Conveyor Belt

to begin creating a detailed conceptual design of the conveyor belt. This may involve creating sketches, drawings and scale models showing the structure, components and operation of the conveyor belt.

Today, conveyor belts are used in a large number of industries for automation purposes. Some design ideas can be drawn from them. For example, the roller conveyor belt as shown in Figure 2 is often used to transport boxes or bottles.

In this particular case, since it is a part weighing less than 100 grams, a belt with rollers to support the weight of the part is not required, which simplifies the design process. A viable option for conveyor belt design is to use a tensioned belt as shown in Figure 3, which consists of a continuous belt of rubber-type material that is tensioned between two support points and moves along a given path. This type of conveyor belt is very useful for transporting light objects, as it does not require the installation of rollers or additional support elements.

In addition, the use of a tensioned belt can allow greater control over conveying speed

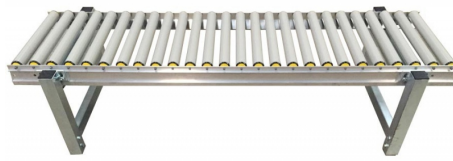


Figure 2. Roller Conveyor belt [1]

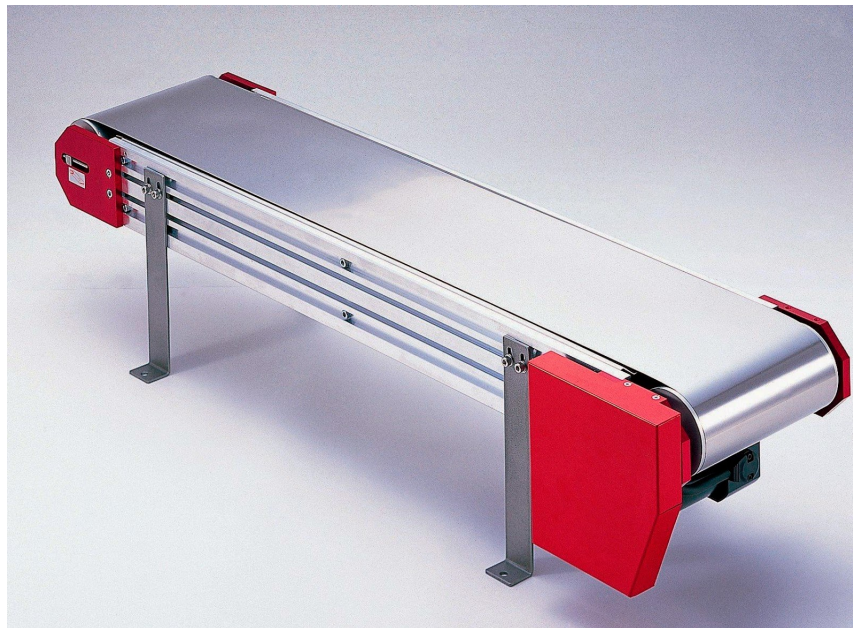


Figure 3. Tension Conveyor belt [2]

and direction, which can be advantageous in some production processes.

1.2.2. Cartesian robotic arm

The robotic arm must be designed with the specific purpose of gripping the part at the end of the conveyor in mind. This involves taking into account the size, shape and weight of the part being conveyed, as well as knowing the distance between the arm and the conveyor, where the part will be and where it should exit the conveyor. Depending on these factors, it may be necessary to equip the arm with specific tools or end effectors to enable safe and effective gripping of the part. The operation of the robotic arm is shown in a block diagram in Figure 4.

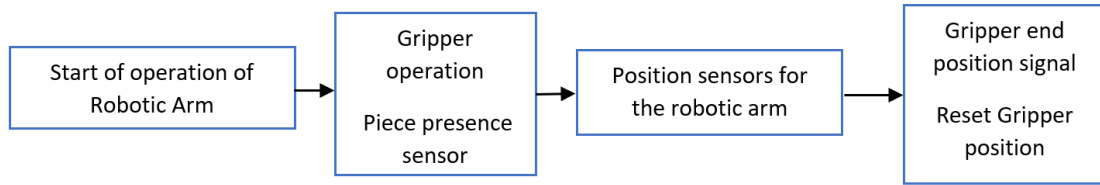


Figure 4. Block diagram of the Robotic Arm

Several ideas can be considered for designing the robotic arm that will be responsible for manipulating and moving the piece from one place to another. A structure that could be useful in this sense is gantry cranes [3], which are machines designed to lift different types of loads and are usually manually operated by an operator. With the help of these cranes, it is possible to move heavy loads from one place to another.



Figure 5. Gantry cranes [3]

Another interesting idea for designing the robotic arm is to use the structure of a 3D printer, but only using two axes, the X-axis and the Y-axis. This structure allows for precise and controlled movement in two dimensions, which can be useful for manipulating small and light pieces.



Figure 6. 3D Printer

The advantage of using a 3D printer structure to design the robotic arm is that there are already many solutions and components available in the market that can be adapted and used. Additionally, most 3D printers use stepper motors, which are ideal for precise motion control.

Once more defined ideas have been developed on what can be designed, sketches can be started and mechanical calculations carried out to verify that the design will work correctly.

1.3. Components dimension

In developing the initial sketch of the project, it is essential to perform a series of mechanical calculations to ensure that both the robotic arm and the conveyor belt can function properly.

The properties of the materials should be examined to determine which is most suitable for the project before the material is utilized across the full structure of the project. Aluminum or steel are the best materials in this situation since they both have high mechanical qualities and are frequently utilized in the building of constructions. Yet it should be remembered that steel is a denser and heavier material than aluminum, which may have an impact on the overall structure's weight and the load capacity of the individual parts.

Contrarily, aluminum is less heavy and more resistant to corrosion, making it the perfect

material for projects that will be exposed to harsh conditions like salt or humidity. Also, compared to steel, aluminum is simpler to form and work with, which might speed up project building.

1.3.1. Robotic Arm Power Screw

1.3.1.1. Shear stress

A shear stress analysis is carried out on the power screw for the robotic arm. This analysis is based on the axial force applied to the screw to join the parts, which results in a uniform stress distribution along the screw cross-section. It is critical to consider the shear stress when selecting a suitable power screw to ensure its ability to withstand the load and resist plastic deformation or fracture. In the Figure 7 we have the data we need from the bolt.

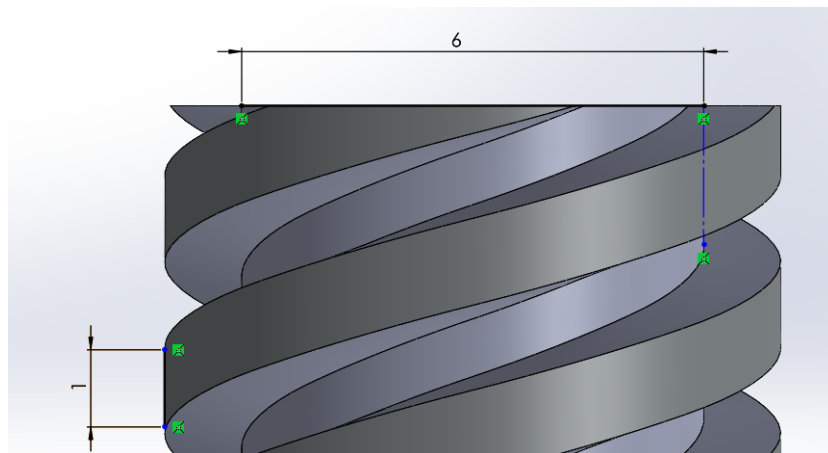


Figure 7. Power Screw Data

When calculating, we do so with the most critical point in mind, which would be that weight is supported on a single bolt thread. Now we provide the necessary data to perform the calculations, such as the thread width of the power screw of 1 mm, the screw diameter of 6 mm commonly available, and the maximum load to be supported of 18.14 N. We also take into account the yield strength of the screw material, which in this case is 200 MPa and is obtained from the tables for steel. We apply the following formula:

$$\sigma_{shear} = \frac{W}{A} \quad (1)$$

Where:

W: Is the weight to be supported.

A: Is the area by the width of the screw thread.

The overall outcome shows that the shear stress amounts to 0.4814 MPA. By utilizing this information, we can incorporate a safety factor to ensure that the shear stress does not pose any issues.

$$n_{shear} = \frac{0.7 * S_y}{\sigma_{shear}} \quad (2)$$

Where:

S_y: Yield Strength

The power screw is exceptionally sturdy and can sustain a larger shear stress than anticipated in the project, according to the derived safety factor value of 290.81. It is crucial to note that a number of variables contributed to the safety factor value being so high. First off, the information utilized for the computation is accurate and was gathered from dependable sources. Furthermore, the screw is a common market screw, making it a dependable and secure choice.

1.3.1.2. Compression

The robotic arm's design depends heavily on the compression calculation to make sure the screw can support the weight without breaking. The screw may experience plastic deformation, fracture, or even catastrophic failure if it is overloaded. To guarantee that the load is distributed evenly over the screw's cross-sectional area and prevent plastic deformation and fracture, it is crucial to calculate the compression that will be induced in the screw.



Figure 8. Compression in the Power Screw

We establish the data provided by the worm screw, we have a total diameter of the

screw of 8 mm counting the threads of the screw. And the other necessary data are the ones used in the previous calculation. We apply the data in the formula (3).

$$\sigma_{compression} = \frac{W}{A} \quad (3)$$

$$\sigma_{compression} = \frac{18.1485 \text{ N}}{\frac{\pi}{4} * 8^2} = 0.36 \text{ [MPa]}$$

The computation of screw compression is critical for determining the danger of system failure. Following the computations, a value of 0.36 MPa is derived for the compression caused by the weight that the screw must sustain.

$$n_{compression} = \frac{S_y}{\sigma_{compression}} \quad (4)$$

$$n_{compression} = \frac{200}{0.36} = 553.93$$

Calculating the appropriate safety factor is crucial for ensuring system safety. The screw is found to have a safety factor of 555.56, meaning the specified load may be supported by it without any chance of failure.

1.3.1.3. Buckling

To ensure that the screw will not buckle when it supports the weight at the highest point, it is necessary to carry out a buckling analysis, which allows determining whether the length of the screw is sufficient to withstand the buckling stress it may undergo.

Buckling occurs when an elongated piece subjected to axial loading deviates laterally from its original position, and if not taken into account in the screw design, it can cause failures and damage to the robotic arm.

The buckling formula is given by:

$$P_{cr} = \frac{\pi^2 * E * I}{(L * K)^2} \quad (5)$$

Where:

E: Modulus of elasticity.

I: Moment of Inertia.

L: Column length.

K: Factor of fixation of the ends.

In this case the value of K would be 2, since the column at the bottom will be embedded and at the bottom it is free. As shown in Figure 10.

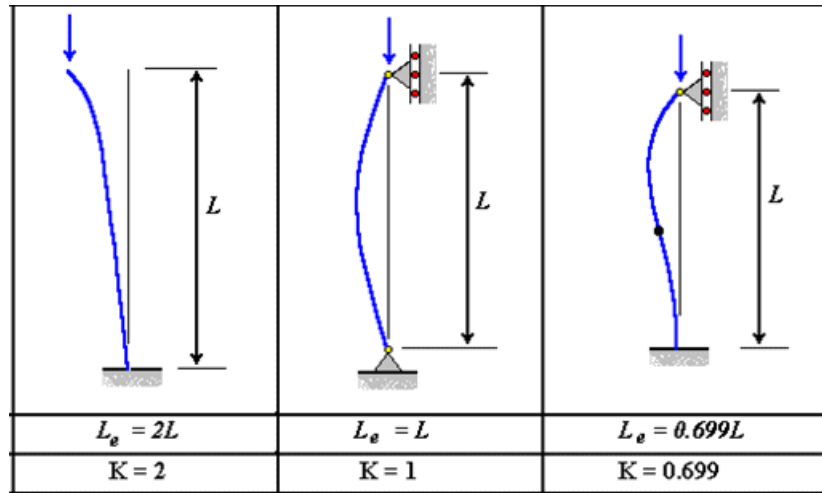


Figure 9. Factors of fixation of the end [4]

The modulus of elasticity is 200 [GPa], the total length of the column is 230 mm and the moment of inertia is determined with the total diameter of the bolt of 8 mm. Now we obtain the value of the critical load.

$$P_{cr} = \frac{\pi^2 * 200000 [MPa] * \left(\frac{\pi}{64} * 8^4\right)}{(230 * 2)^2} = 1875 N$$

To determine the safety factor with respect to buckling, the critical buckling load of the bolt must be compared to the maximum load it is expected to withstand. If the maximum load is less than the critical buckling load, then the factor of safety will be greater than 1, indicating that the bolt will not buckle.

$$n_{Buckling} = \frac{P_{CR}}{W} \quad (6)$$

$$n_{Buckling} = \frac{1875}{18.14} = 103.35$$

All of the safety factors that were estimated for the power screw were larger than 1, as can be seen, and had extremely high values. A screw with a smaller diameter or made of a different material may be produced, but doing so would raise the cost of the screw and the cost of the entire machine, as well as lengthen the time needed to build the machine.

However, even if a very high safety factor value was attained, it is crucial to remember that potential variables, such as corrosion or wear and tear from repeated usage, must always be taken into account. As a result, it is advised to routinely inspect the screw's condition as well as that of the robotic arm's other parts to guarantee correct functioning and guard against any problems or mishaps.

1.3.2. Robotic arm beam

Beam analysis is an important tool in engineering to determine if a beam can withstand the loads that will be applied to it. For this project, it is crucial to ensure that the beam supporting the pneumatic actuator can support the weight of the parts that will be manipulated without suffering excessive deformation or breakage.

It is known that the weight to be loaded is 9.1 N, the length of the beam is 425 mm, and the total weight including the beam is 18.15 N. We calculate the summation of moments generated in the beam.

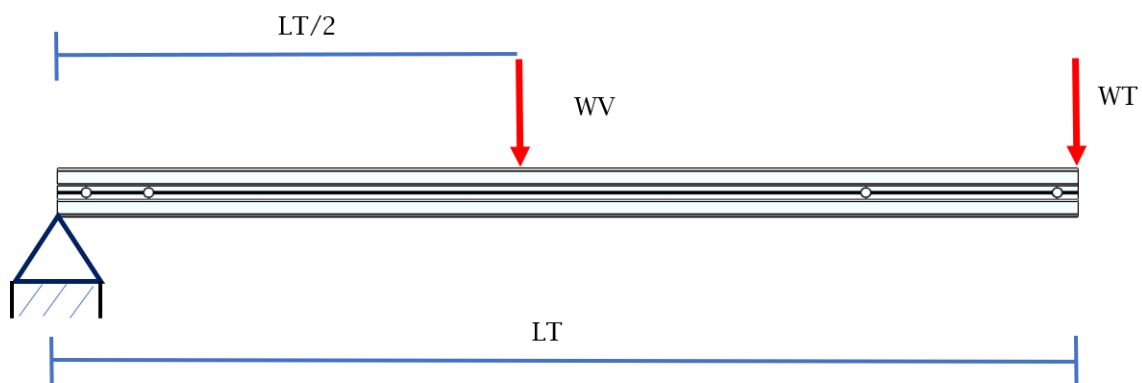


Figure 10. Sum of Moments

$$M = (WT * LT) + \left(\frac{LT}{2} * WV\right) \quad (7)$$

$$M = (9.08 * 425) + \left(\frac{425}{2} * 18.15\right) = 7713[Nmm]$$

We calculate the Stress :

$$\sigma = \frac{M * c}{I} \quad (8)$$

$$\sigma = \frac{7713 [Nmm] * 10 [mm]}{7370.98 [mm^4]} = 10.46[MPa]$$

With the value of the effort taken out we shop with the Yield Strengths of different materials to determine which one benefits us the most. The S_y value for aluminum is 276 MPa and S_y for steel is 200 MPa.

$$n = \frac{S_{yMaterial}}{\sigma} \quad (9)$$

$$n_{Aluminium} = \frac{S_y}{\sigma} = \frac{207}{10.46} = 26.38$$

$$n_{Steel} = \frac{S_y}{\sigma} = \frac{200}{10.46} = 19.12$$

The results of both safety factors are greater than 1, indicating that both steel and aluminum can function properly. Although the safety factor of steel is lower than that of aluminum, both materials are suitable for the project.

1.3.3. Motors analysis

Motor analysis is a critical step in the design of the robotic arm, as it is necessary to determine the amount of torque required to move the entire structure, including the power screw.

The data we need to get is the coefficient of friction which is 0.8 between the steel and the copper which are the surfaces that will be in contact to transmit the force. It is known that the total weight including the beam is 18.15 N and the angle that the power screw has between its wires is 16.8° . With these data, the force and friction force are

determined.

$$F = u * w \quad (10)$$

$$Fr = u * w * \text{Cos } \theta \quad (11)$$

Where:

F: Force.

Fr: Friction Force.

u: Coefficient of friction

w: Total weight

θ : Angle of inclination of the screw threads.

$$F = 0.8 * 18.15 \text{ N} = 14.52 \text{ N}$$

$$Fr = 0.8 * 14.52 * \text{Cos} (16.8) = -6.69 \text{ N}$$

With the calculated forces, a summation of forces is made and with the total force, the torque we need can be calculated.

$$F_{total} = F + Fr \quad (12)$$

$$F_{total} = 14.52 + (-6.69) = 7.83 \text{ N}$$

Now, calculate the required torque.

$$T = F_{total} * d \quad (13)$$

Where:

T: Torque.

F: Total Force

d: Inner radius of the power screw + half the tooth distance.

$$T = 7.83 [N] * (3 + 0.5)[mm] = 27.40[Nmm]$$

To ensure proper operation of the motor, it is necessary to have at least 27.4 Nmm of torque. If the motor has a higher torque, it would be even better as it would prevent the motor from overloading and overheating.

1.3.4. Pulley

Calculating the minimum torque required to move the pulley on the X axis is crucial to ensure proper operation of the system. This calculation depends on the weight and dimensions of the object being moved with the pulley, as well as the physical properties of the pulley itself, such as its radius. The minimum required torque must be sufficient to overcome the friction and weight of the moving object, and ensure smooth and stable movement.

The pulley has pre-established dimensions and the toothed belt must be adjusted to fit the aluminum profile space, which means that the input data cannot be modified. Therefore, to ensure proper operation, it is necessary to calculate the required torque and power of the motor and select one that can move the structure with the fixed characteristics of the pulley.

It is known that the weight of the piece to be moved is 0.75 Kg, the radius of the pulley is 6 mm, the revolutions per minute will be 300 rpm, the time will be 1 second. With the data is applied to the different formulas of speed, acceleration and force to obtain the torque.

$$V = n [rpm] * \frac{1 \text{ min}}{60 \text{ s}} * 2\pi * \frac{r}{1000} [m] \quad (14)$$

$$A = \frac{V[m/s]}{t[s]} \quad (15)$$

$$F = W[Kg] * A[\frac{m}{s^2}] \quad (16)$$

$$T = F [N] * r[mm] \quad (17)$$

Where:

V: Velocity.

A: Acceleration,

F: Force.

T: Torque.

$$V = 300 [rpm] * \frac{1 \text{ min}}{60 \text{ s}} * 2\pi * \frac{6 \text{ mm}}{1000} [m] = 0.189m/s$$

$$A = \frac{0.189}{1} = 0.189 \frac{m}{s^2}$$

$$F = 0.75 \text{ Kg} * 0.189 \frac{m}{s^2} = 0.15 \text{ N}$$

$$T = 0.15 [N] * 6 [mm] = 0.84Nm$$

The fixed dimensions and properties of the pulley were taken into consideration while calculating the necessary torque to move the X axis, the piece, and the toothed pulley. The findings show that in order to complete the movement without any issues, a motor must have a minimum torque of 0.84 Nm. For optimum performance and to prevent potential failures or overheating, it is crucial to choose a motor that complies with this standard. In order to ensure dependable and long-lasting performance, it is also advised to take a safety margin into account when choosing the motor, picking one with a larger torque than is necessary.

1.3.5. Conveyor Belt

Calculating the required torque for the conveyor belt is essential to ensure that the selected motor can move both the transported piece and the belt smoothly.

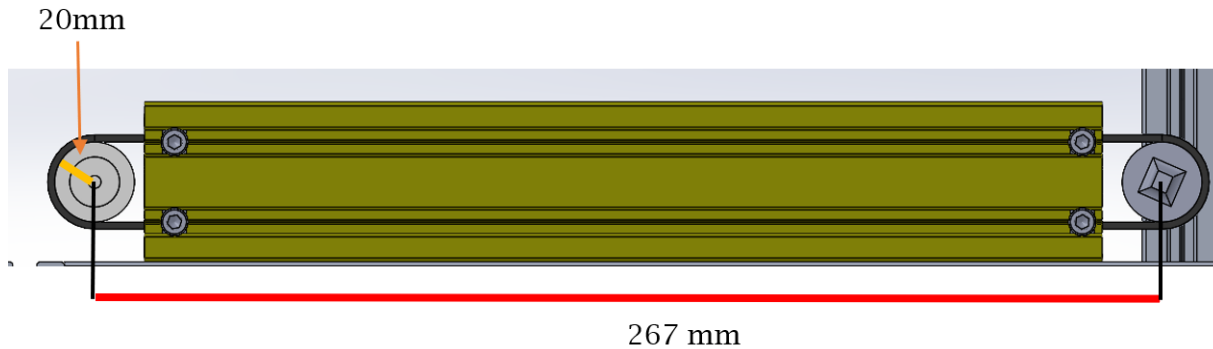


Figure 11. Conveyor Belt data

Different data relevant from the Figure 11 to the analysis of the conveyor belt were obtained, such as the length between axes which is 267 mm, the belt speed which is 0.3 m/s, the efficiency factor which is 10, diameter of the roller is 20 mm, the weight of the piece to be moved which is 0.08 kg and the weight of the belt which is 1.8 kg. In addition, important technical specifications of the belt were provided such as the modulus of elasticity of 0.03 GPa, the Yield Strength of 1.5 MPa and a coefficient of friction of 0.35.

We need to determine the final length by applying the following formula:

$$L_f = \frac{S_y * L_o}{E * n} + L_o \quad (18)$$

Where:

L_f : Final Length.

S_y : Yield Strength.

E : Modulus of elasticity.

n : Safety Factor.

L_o : Initial Length.

$$L_f = \frac{1.5[MPa] * 267[mm]}{0.03[GPa] * 10} + 267[mm] = 268.34mm$$

With the final length, we can obtain the angle of deformation that the belt has due to the weight.

$$\theta = \cos^{-1} \left(\frac{L_o}{L_f} \right) \quad (19)$$

$$\theta = \cos^{-1} \left(\frac{267}{268.34} \right) = 1.54$$

Then calculate the total force and with it the torque.

$$F_{total} = W * \sin(\theta) * e^{0.5*\pi} \quad (20)$$

$$F_{total} = 1 = 88 [N] * \sin(1.54) * e^{0.5*\pi} = 88.67N$$

$$T = F_{total} * d \quad (21)$$

$$T = 88.67 N * \frac{20}{1000} m = 1.77 Nm$$

Therefore, the minimum torque that the motor must have to be able to perform all the belt movement is 1.77 Nm for optimum performance.

1.4. Components selection

In fact, you may start choosing the components once the essential calculations have been done to define the qualities that must be satisfied by each of them. To achieve this, it is necessary to explore the market for components that fit the budget while also meeting the technical requirements.

1.4.1. Material

Aluminum was chosen as the material because it must be used to create profiles so that the other components may be removed and positioned differently. Aluminum profiles with a long useful life and high corrosion resistance are now available on the market.

On the other hand, with steel, the project would need to be created with the profiles, which would increase weight and make it harder for the project to be removed.

Another advantage of aluminum is that it is more environmentally friendly, as it is 100% recyclable and requires less energy to produce than steel. In summary, aluminum is an ideal choice for this project due to its mechanical properties, ease of use and environmental sustainability.

1.4.2. Pulley and Timing Belt

It is important to choose a toothed pulley that have the right size to fit the robot's frame and a high enough friction coefficient to prevent slippage. The weight of the component to be moved must also be taken into consideration since it affects both the belt choice and the calculation of the torque needed to move the component.

For the pulley and timing belt, a belt has been chosen that is compatible with profiles having a width of 6 mm, this is because the aluminum profiles selected for the project structure have a width of 6 mm. In addition, the belt must have a length that allows the movement of the part to be transported, and that is resistant and durable.

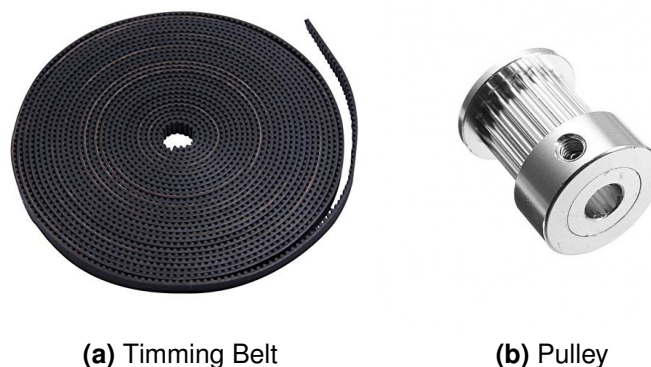


Figure 12. Components

1.4.3. Power Screw

Use an existing stem bolt rather than building one since making one is far more expensive than purchasing an existing one. We want one that is constructed of steel and has an 8 mm diameter. In addition to the diameter and material, the length and accuracy of the stem bolt to be utilized must be considered. It is best to choose a screw that is

the correct length for the structure in which it will be used and has enough accuracy for the desired movement.

Therefore, a stainless steel power screw with a length of 300 mm 8 mm in diameter and 8 mm in diameter was selected as shown in the Figure 13.



Figure 13. Power Screw

1.5. Simulation

Simulations are a fundamental tool to predict the behavior and strength of components before building them. In this case, a simulation is performed to verify the capacity of the designed part to support the weight of the beam and the effort that the power screw will make to move it.

The modeling of the component specimen shown in Figure 14 demonstrates that the structure will not exhibit substantial deformations during operation. However, the most essential regions of the section, i.e. the corners and the bent part, may suffer some deformation as a consequence of the stresses to which the structure would be subjected.

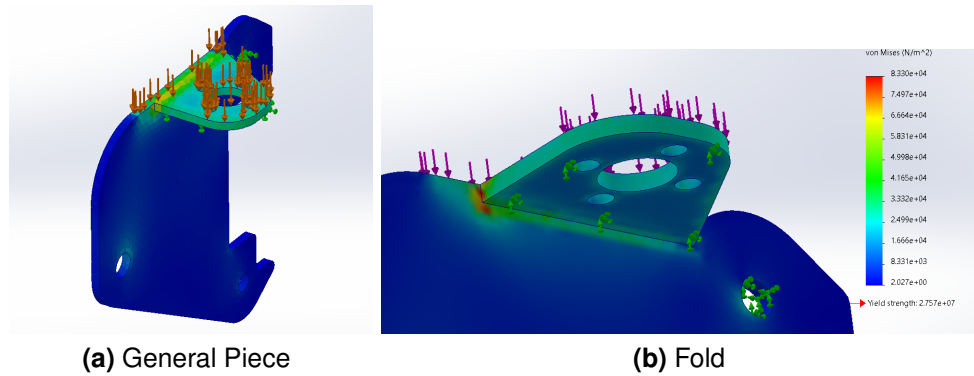


Figure 14. Simulation Piece

In the simulation result we have a von Mises value of 0.0083 N/mm^2 is a measure of the equivalent stress at a given point in the material. In comparison, the steel strength limit of 250 MPa is a measure of the maximum amount of stress the material can withstand before failing in a tensile test.

Since the von Mises value is significantly less than the steel strength limit, it can be concluded that the material is not experiencing excessive stress and, therefore, should be able to withstand the applied load without permanent deformation or failure.

1.6. 3D Model

The complete design of the project is depicted in the picture below, which depicts both the conveyor belt and the part that will be moved by it, as well as the robotic arm in charge of handling the part. The graphic depicts the overall structure and operation of the system by providing an overview of the design and its spatial arrangement.

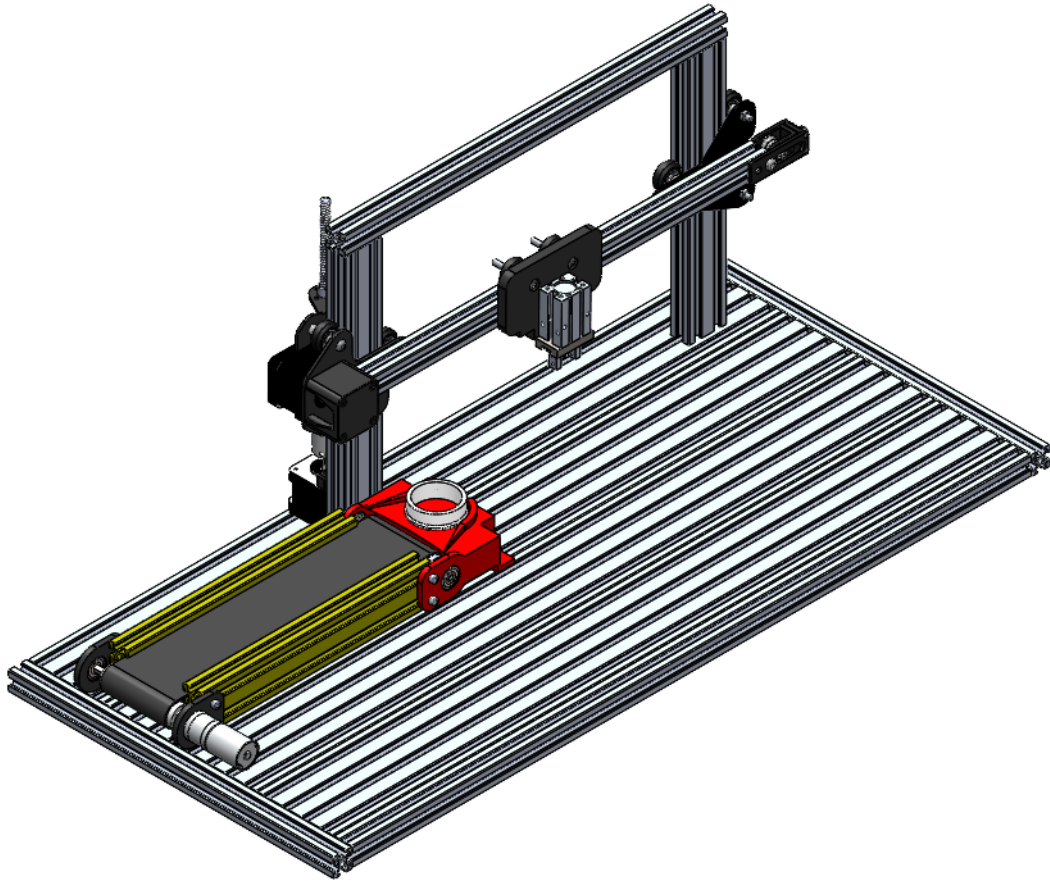


Figure 15. 3D Model

The project's base will consist of a plate located at the bottom with aluminum profiles, as illustrated in the Figure 16, and it will serve as the foundation for the components.

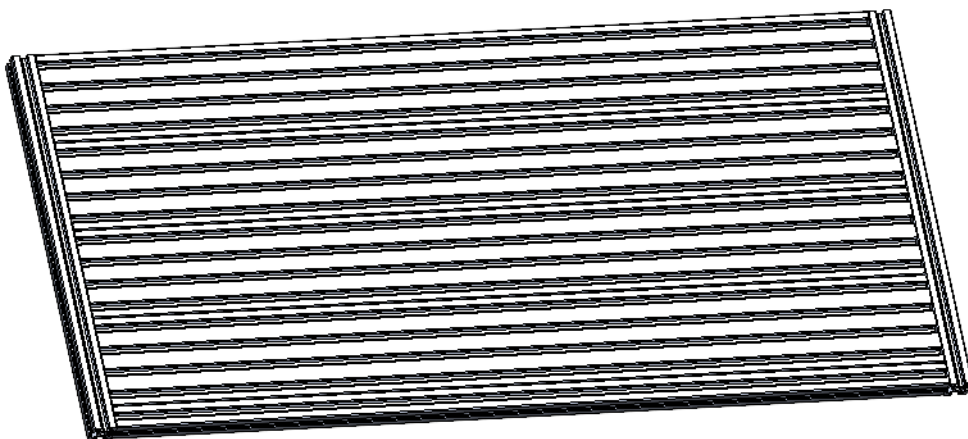


Figure 16. Plate

The 3D design is divided into two parts, the conveyor belt and the robotic arm.

1.6.1. Conveyor Belt

The Figure 17 shows the conveyor belt with its bearings, the belt, the motor, the rollers, the lateral structure, the structure where the part to be handled will arrive.

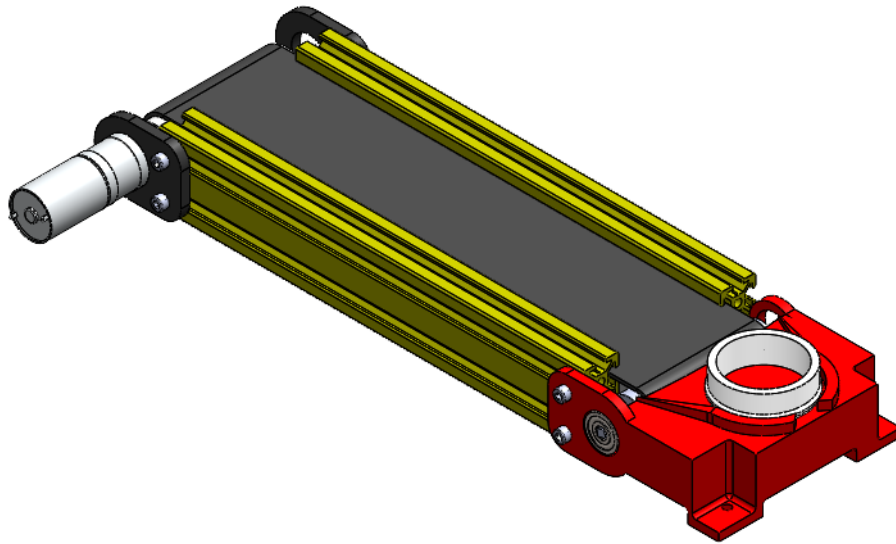


Figure 17. Conveyor Belt

1.6.2. Robotic Arm

The robotic arm shows bearings, rubber wheels, aluminum profiles, structural parts, motors, pneumatic actuator, power screw and couplings.

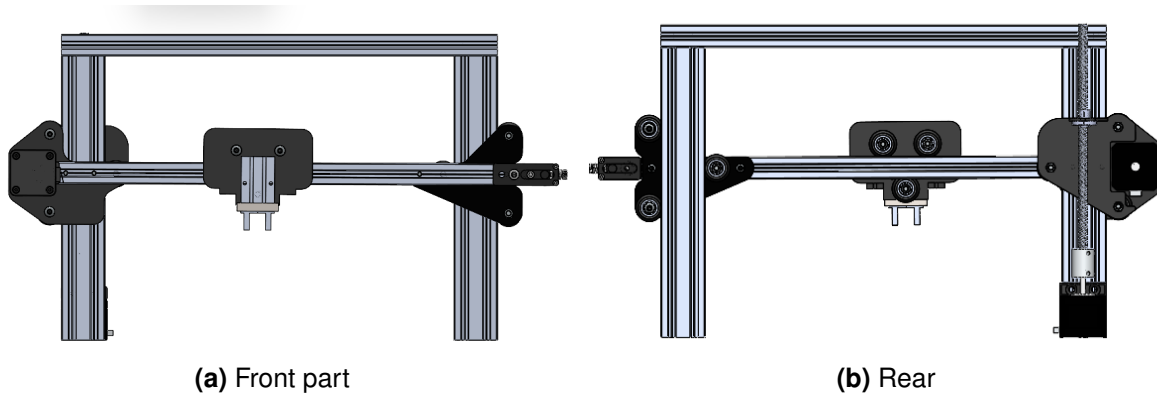


Figure 18. Robotic Arm

1.7. Summary of mechanical components

The conveyor belt and robotic arm project requires several mechanical components, including: motor, pulley and timing belt, power screw, aluminum profiles, bearings, sensors, among others. For the selection of these components, factors such as the motor torque, the strength and durability of the materials, and the required load capacity must be taken into account. In addition, stress simulations have been performed to ensure the structural strength of the parts and 3D modeling has been carried out to visualize the complete design of the project.

2. Electronic and Control Design

To understand the electronic components necessary for the project, a block diagram has been designed that illustrates the logic of connection between the different elements. This diagram is essential to have an overview of how the electronic system will work and what components will be needed for its construction.

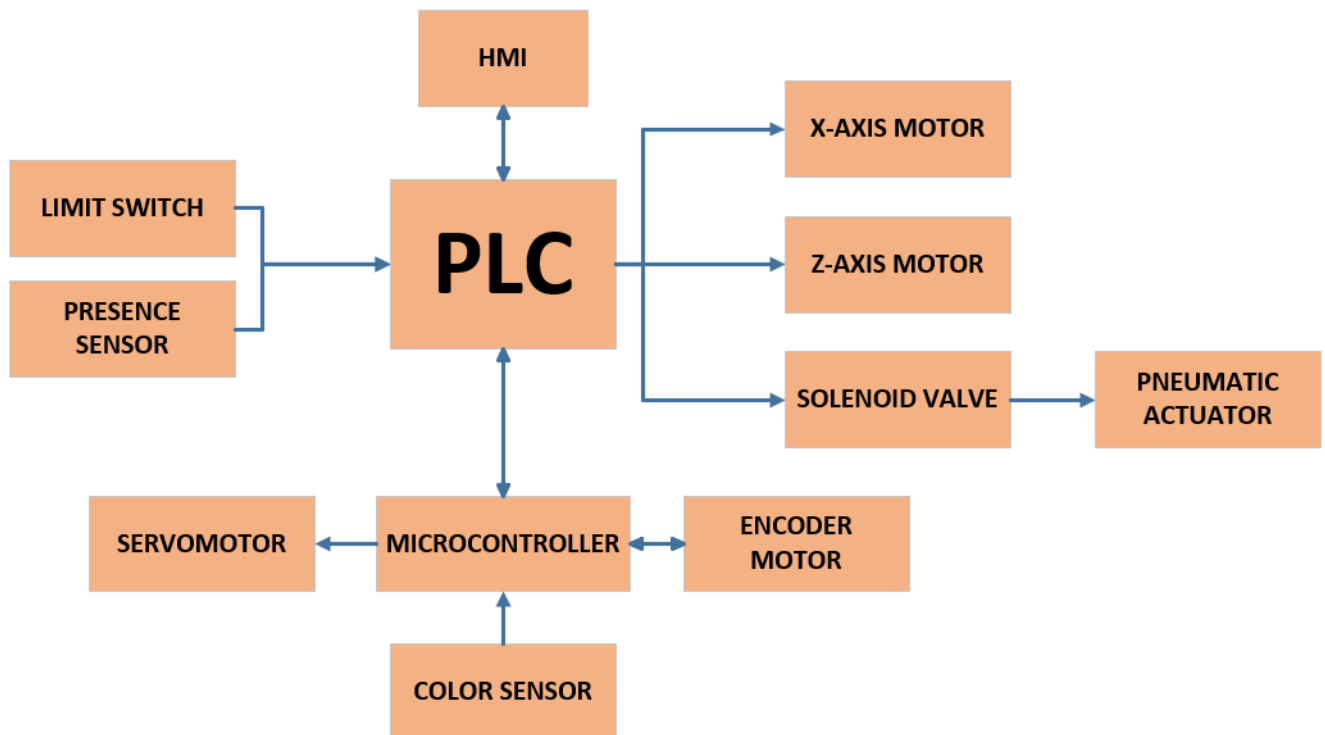


Figure 19. Electronic Block Diagram

2.1. Components Selection

Proper selection of electronic components is critical to ensure proper operation of the overall electronic system. It is important to consider factors such as the capacity, voltage and current handled by the components, as well as their speed and accuracy characteristics.

Component	Characteristics
PLC	XINJE XC3-24RT-E EXPANSIBLE 90-260 VAC INPUTS: 14 OUTPUTS: 10 <u>TYPE</u> : Relay
HMI	KINCO 4.3"
MICROCONTROLLER	ESP32 2.4 GHz WIFI BLUETOOTH 30 pins 2 Cores
SOLENOID VALVE	TAILONZ PNEUMATIC 12 V 5/2 NPT ¼ ALUMINIUM
PNEUMATIC ACTUATOR	TAILONZ PNEUMATIC MHZ2-16D 0-1.0 MPA
LIMIT SWITCH	GUBCUB 3 PINS Rated Load: AC 250V 1A
PRESENCE SENSOR	HiLetgo 5v Detection reflection distance: 1 ~ 0.984 in.
SERVOMOTOR	MG90S Size: 22.8x12.2x28.5 (mm) Weight: 13.6 grams Maximum angle: 180° Torque: 2kg/cm Voltage: 4.8V Temperature range :0 °C -- 55 °C
COLOR SENSOR	TCS230 Voltage: 2.7-5.5 V. Error range typically 0.2% at 50 kHz. Temperature coefficient 200 ppm/°C.
RELAY	8-CHANNELS 5V MODULE RELAYS

Figure 20. Components

MOTOR ROBOTIC ARM	NEMA 17 BIPOLAR 2 PHASES 1.5A 42 N.cm Step accuracy: $\pm 5\%$ (synchronizing, no-load)
MOTOR CONVEYOR BELT	JGA25-370 12V with Encoder 400 RPM Torque: 0.55 kg-cm 1.2A Peak Current 50 mA without load
TB6600	9-42V 4 A Semi-automatic power- saving current blocking function, integrated temperature protection and overcurrent protection.
HW-166	Power Voltage (VMOT): 5V - 15V Operating Voltage (VCC): 2.7V - 5.5V Current rating: 1.2A (peaks up to 3A) Channels: 2 (supports 2 DC motors or 1 PAP motor)

Figure 21. Motors and Drivers Selection

2.2. Specification Components

The components listed in the table above have been selected for the following features and functions:

2.2.1. PLC

The PLC will be responsible for monitoring and controlling various processes in the project. From sensor monitoring and actuator activation, to coordinating multiple devices, the PLC will play a fundamental role in executing all these tasks. It will also be responsible for ensuring safety in the operation of the project, as different levels of access and permissions can be established for users. In addition, the bidirectional communication that can be established between the PLC and the HMI will allow for

smooth interaction and constant feedback of the information collected in the project, enabling continuous improvements in efficiency and productivity.

For this reason, the Xinje XC3-24RT-E PLC [5] was chosen, as it has 14 inputs, 8 relay outputs, and 2 transistor outputs. The transistor outputs will be used to control the motor speeds, and the relay outputs will be used for the various signals required for the project's operation.



Figure 22. Xinje XC3-24RT-E PLC

In addition, the Xinje XC3-24RT-E PLC shown in the Figure 23 is a very reliable and durable device, perfect for industrial applications. It has a large amount of memory for storing programs and fast processing speed to perform tasks quickly and correctly. It also has various communication functions, allowing it to integrate with other systems and devices in the automation process. The use of this PLC ensures that the project runs smoothly and efficiently, with the ability to regulate and coordinate all machine activities reliably.

2.2.2. HMI

The 4.3-inch Kinco HMI has various benefits that make it a good choice for automating tasks. For starters, its high-resolution touch screen enables for intuitive and simple

system interaction, making it user-friendly for operators. Its ergonomic and small form also makes it simple to install in any workstation.



Figure 23. HMI Kinco 4.3”

Another significant benefit is that it is compatible with many communication protocols, allowing it to be readily integrated with other systems and devices on the automation network. It also features numerous communication connections, including Ethernet, RS232, and RS485, allowing it to link to other equipment and devices in a variety of ways.

2.2.3. Micro-controller

To accomplish the closed-loop control, an ESP32 microcontroller will be utilized, which provides a high level of adaptability and processing power for control operations. The ESP32 microcontroller contains a 32-bit dual-core CPU that operates at up to 240 MHz, making it ideal for executing complicated real-time control computations. It also contains up to 4 MB of inbuilt flash memory and 520 KB of SRAM memory, allowing it to manage massive quantities of data and applications.

The ESP32 microcontroller will play a crucial role in the project as it will be responsible for establishing a connection between the motor with an encoder and performing the PID control. By receiving feedback from the encoder, the ESP32 will calculate the error between the desired and actual positions of the motor and adjust the motor's speed accordingly using the PID algorithm.



Figure 24. ESP32-WROOM-32

In addition to connecting a color sensor that will identify parts that do not have the allowed color for the process, the system will also be equipped with a servomotor that will restrict the passage of such pieces. The servomotor will be connected to the microcontroller, which will receive signals from the color sensor and use them to control the servomotor's movement. When a part with the wrong color is detected, the microcontroller will send a signal to the servomotor, which will then move to block the passage of the part.

2.2.4. Solenoid-Valve and Pneumatic Actuator

The solenoid valve is a key component in the pneumatic system, as it is responsible for controlling the airflow that reaches the pneumatic actuator, in this case the pneumatic clamp. Activation of the solenoid valve through a 12V signal will allow compressed air to flow to the pneumatic actuator and exert the necessary force for the clamp to hold the piece during the translation process. It is important to ensure that the solenoid valve has the ability to handle the appropriate pressure and airflow for the proper operation of the pneumatic actuator and therefore the pneumatic clamp.

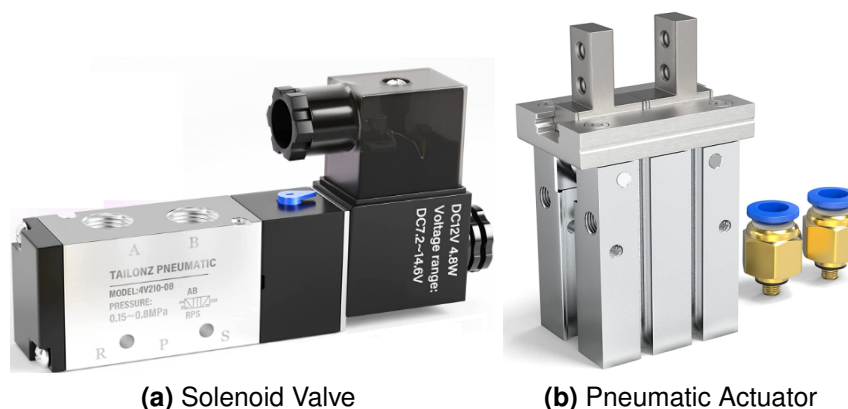


Figure 25. Pneumatic System

2.2.5. Limit Switch

Limit switches are devices that are used to indicate the end of motion of the robotic arm gripper at the extreme ends of its movements. These devices are of utmost importance in process automation as they ensure that the gripper does not move beyond the established limits, preventing possible damage to the system or the object being manipulated.

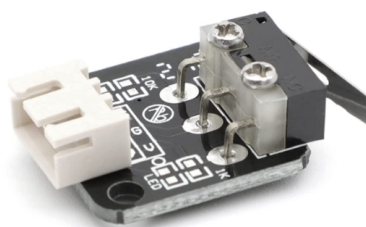


Figure 26. Limit Switch

Limit switches typically operate by interrupting an electrical circuit when the gripper reaches its limit position, sending a signal to the microcontroller to stop the motion. This allows for greater precision and safety in the manipulation of objects by the robotic arm, which is especially important in industrial processes where a high degree of automation and quality control is required.

2.2.6. Presence Sensor

The presence sensor is a device that allows the detection of the presence or absence of objects in a specific space. In this case, it will be used to detect the final position of

the piece on the conveyor belt. Once the piece reaches this position, the sensor will send a signal to the microcontroller indicating that it is ready to be picked up by the robotic arm.

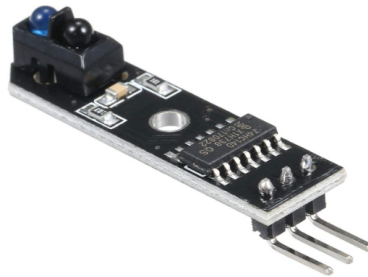


Figure 27. Presence Sensor

The use of this sensor is crucial for the proper functioning of the system, as it ensures that the robotic arm is only activated when the piece is in its final position. In this way, errors or accidents that could occur if the arm moved too early or if an attempt was made to grab a piece that is not in its corresponding place are avoided.

2.2.7. Color Sensor

The color sensor is in charge of recognizing and differentiating the various colors that will be placed on the conveyor belt. When the color of the moving item is determined, the sensor sends a signal to the microcontroller indicating whether or not the color is permitted.

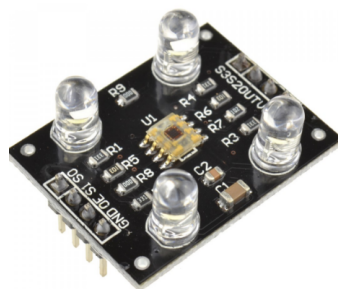


Figure 28. Color Sensor

If the item is the correct color, the system will continue to run normally, enabling the piece to proceed up the conveyor belt. If the piece does not match the necessary color, the sensor will send a signal to the microcontroller, which will then engage the

servomotor to limit the passage of the non-permitted piece, stopping it from continuing in the manufacturing process.

2.2.8. Servomotor

Once the color sensor detects that the piece does not have the appropriate color, the servomotor comes into action to restrict the passage of the piece through the conveyor belt. This restriction ensures that the piece does not reach the next stage of the process and prevents unnecessary work from being done on a piece that does not meet the requirements.



Figure 29. Servomotor MG90s

The servomotor also allows the passage of the piece once it has been verified to meet the color requirements, allowing the piece to advance to the next stage of the process

2.2.9. Module Relay

The 8-channel 5V relay module will serve as a link between the sensors and the PLC input. This module is required to protect both the sensors and the PLC from system voltage spikes or surges. The 5V relay module has the benefit of being compatible with the 5V sensors being utilized, assuring correct signal transmission.

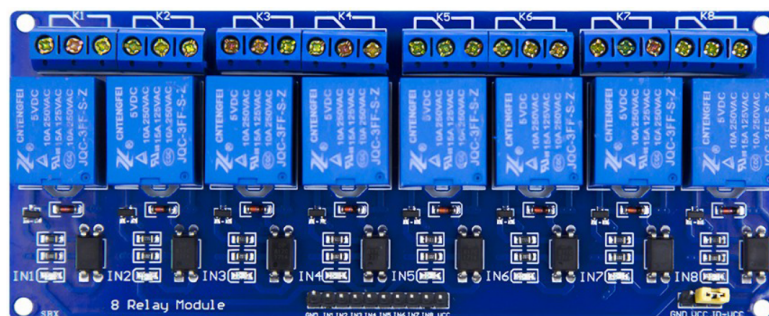


Figure 30. 8-channel 5V relay module

Furthermore, the use of a relay module simplifies switching between different sensors because they may be simply attached and detached from the module. This boosts the system's flexibility and versatility, making future modifications and upgrades easy. Overall, using a relay module is a practical and efficient way to ensure correct communication between sensors and the PLC.

2.2.10. Motor Robotic Arm

The decision to use Nema 17 stepper motors for the movement of the robotic arm was a deliberate and carefully considered one. These motors offer exceptional precision and control over the arm's movement. Their high output torque ensures that they can move the weight of the robotic arm with ease. Furthermore, Nema 17 motors are known for their reliability and durability. They also provide a much higher torque than what was calculated on the mechanical side.

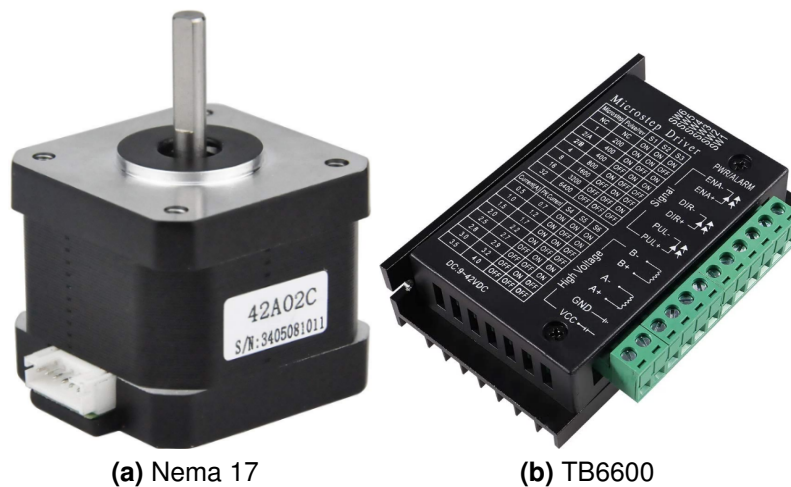


Figure 31. Motor and Driver

To operate the Nema 17 motor, a TB6600 driver will be utilized. This driver allows for the selection of the current at which the motor operates, as well as the step that will be taken. The driver will be responsible for connecting the PLC to the motor and sending it various operation signals.

2.2.11. Motor Conveyor Arm

The use of a motor with encoder for the conveyor belt operation, along with the implementation of a PID control system, allows for precise control over the belt speed.

This is crucial for ensuring that the pieces being transported are moved at a consistent rate throughout the manufacturing process. The HW-166 driver provides a simple and efficient way to connect the motor to the microcontroller, allowing for easy control over the direction and speed of the motor. Additionally, the use of PWM signals from the microcontroller provides a smooth and precise control over the motor speed. With this setup, the conveyor belt can be operated with a high degree of accuracy and reliability, helping to ensure the quality and consistency of the manufacturing process.

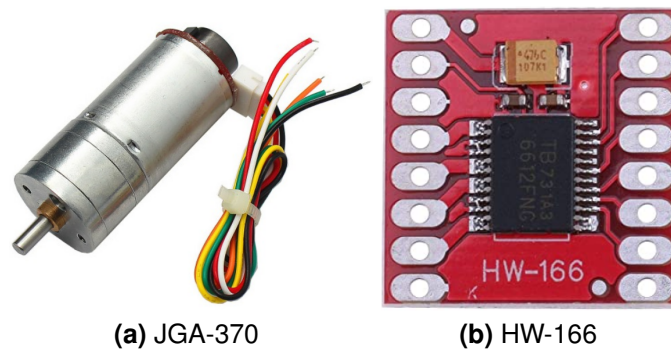


Figure 32. Motor with Encoder and Driver

2.3. PID Control

The realization of the PID control of the motor that will be in charge of moving the conveyor belt will require a microcontroller and an encoder. The microcontroller used will be the ESP32, which will be responsible for connecting the motor with encoder and perform the PID control to achieve the nominal speed of the conveyor belt.

The encoder will be used to measure the speed of the conveyor belt and feed back to the PID controller. In this way, it will be possible to adjust the motor speed and ensure that the conveyor belt moves at a constant and accurate speed.

To perform the PID control of the motor driving the conveyor belt, it is necessary to collect data from the motor. In this process, PWM values are changed to vary the motor speed, and a maximum limit of 400 rpm is reached. This data is used to determine the transfer function of the motor, which is essential for designing the PID controller.

In Figure 33 depicts a comprehensive and detailed connection diagram that shows how to connect an H-bridge to the motor and the ESP32 microcontroller. The H-bridge is used to control the motor's direction and speed, while the ESP32 microcontroller

is responsible for performing PID control on the motor. This diagram includes the connection of the motor and the H-bridge, as well as the connection of the H-bridge and the microcontroller. It also shows the power source and ground connections for the motor and the microcontroller.

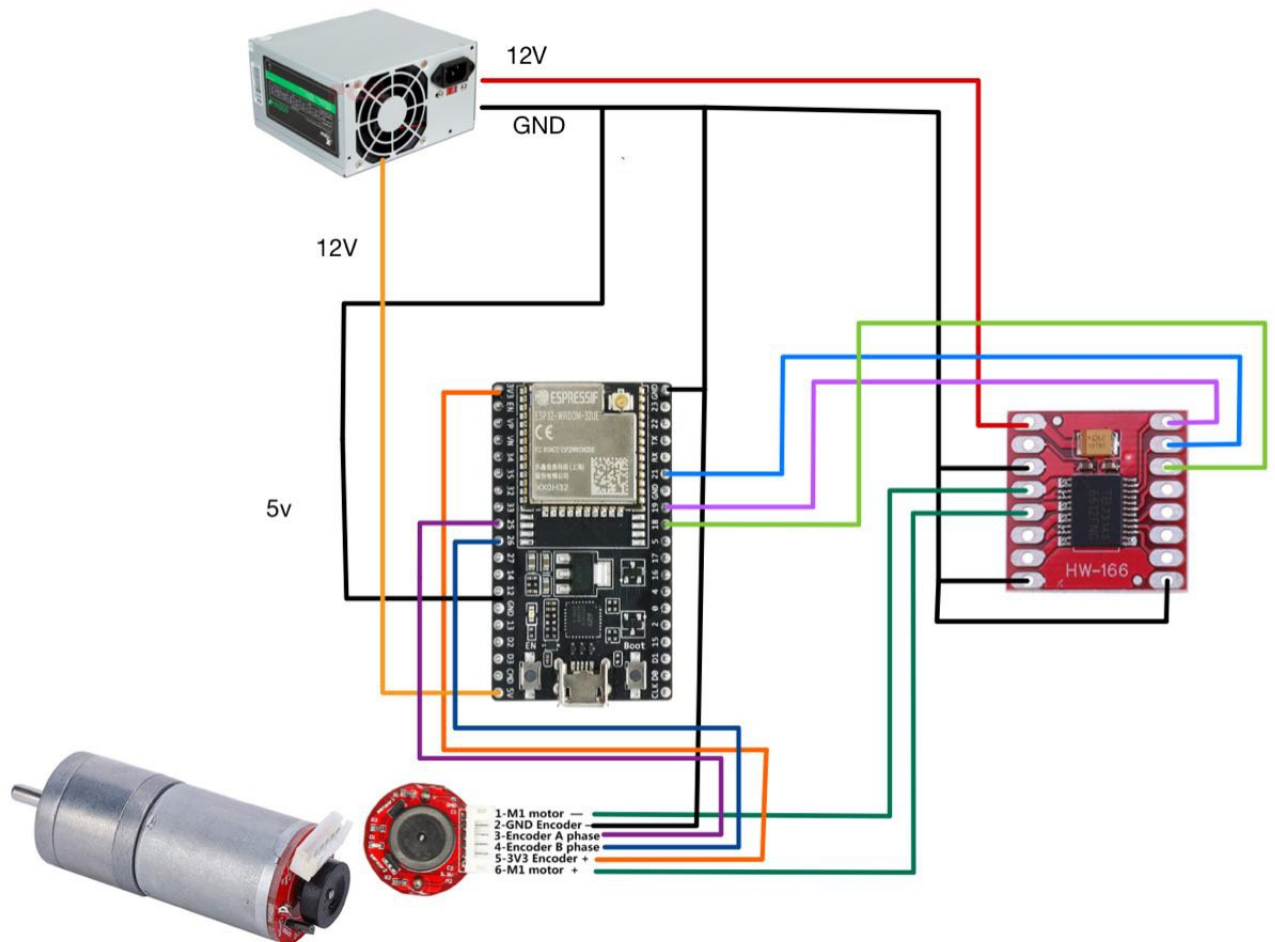


Figure 33. Connection Diagram ESP32 and Encoder Motor

This process involved collecting data of the motor speed as a function of time, by varying the PWM of the control signal. Then, the curve fitting technique was applied to determine the coefficients of the mathematical model that best fit the obtained data. The transfer function was obtained using MATLAB software with the curve fitting technique method. The system-identification function was utilized to input the motor's collected data and determine the transfer function with the highest level of accuracy.

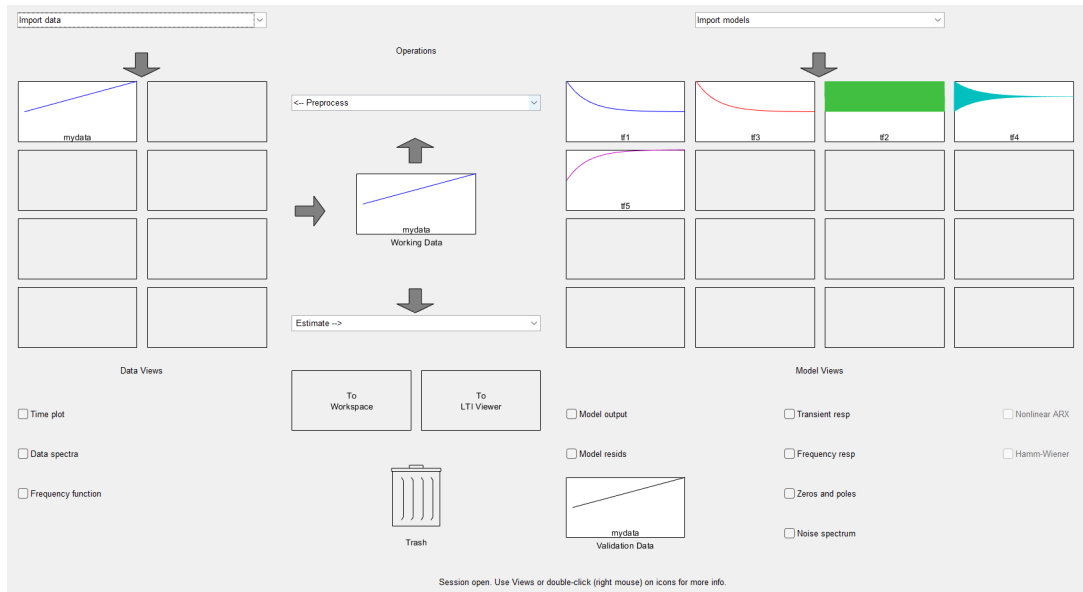


Figure 34. system Identification

The transfer function that had one pole and zero zeros was the closest to the original data and had an approximation of 85.65%, which was the highest value. Adding more poles or zeros would cause oscillation, which is not desired with this method.

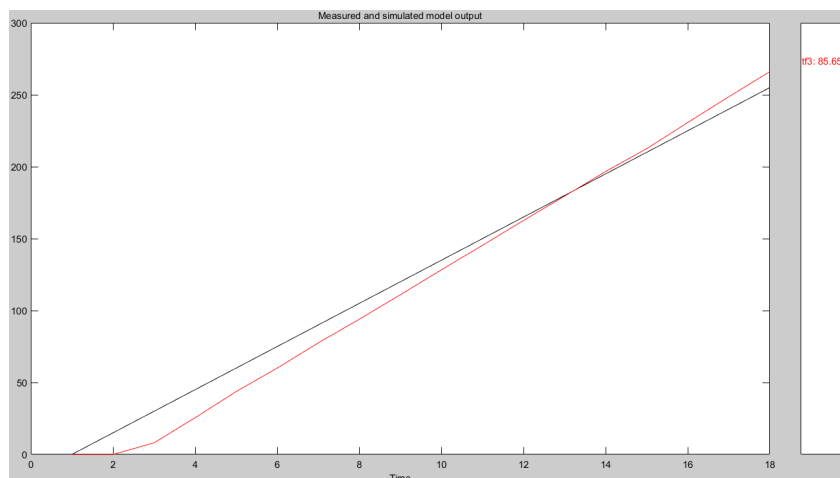


Figure 35. Model Output

In this case, it was found that the transfer function of the system was of first order, with one pole and zero number of zeros, which was expressed in the form:

$$G(s) = \frac{K}{s + a} \quad (22)$$

Where K is the system gain and "a" is the pole time constant. This mathematical model allowed to determine the behavior of the motor and to design the PID controller, in order

to achieve a uniform and constant movement of the conveyor belt. Giving as transfer function of the whole system the following:

$$G(s) = \frac{19.49}{s + 27.77} \quad (23)$$

The step Response plot of the obtained transfer function is shown below:

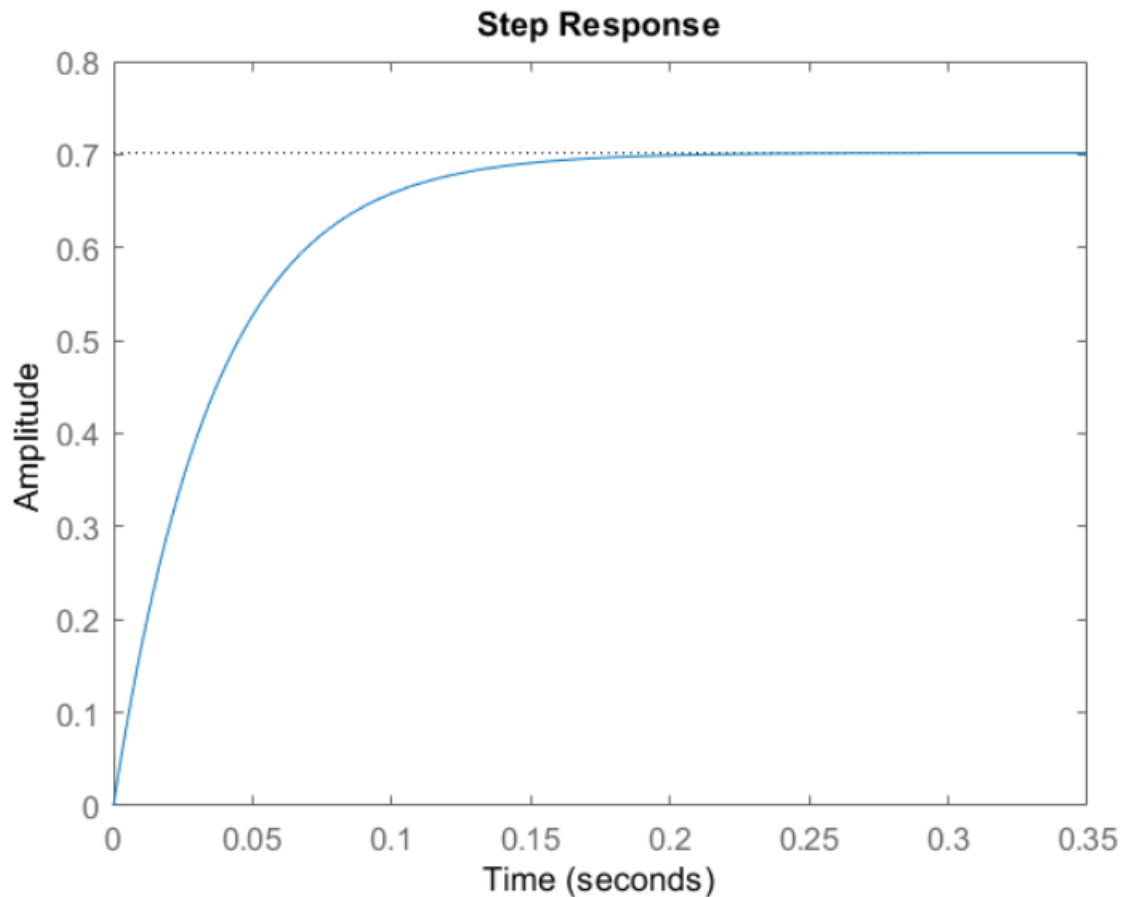


Figure 36. Time-Domain

And the initial values that are obtained are: Rise-Time = 0.0465, Settling Time = 0.0828, Overshoot = 0 and error of 30%.

	Mp	Ts	Tr	Error
Original	0	0.0828	0.0465	30%

Table 2. Transfer function values

The Ziegler-Nichols first method is widely used for tuning PID controllers to obtain optimal system performance. This method involves applying a step input to the system

and measuring the response to determine the ultimate gain and ultimate period. With these values, the values of K, L, and T can be obtain.

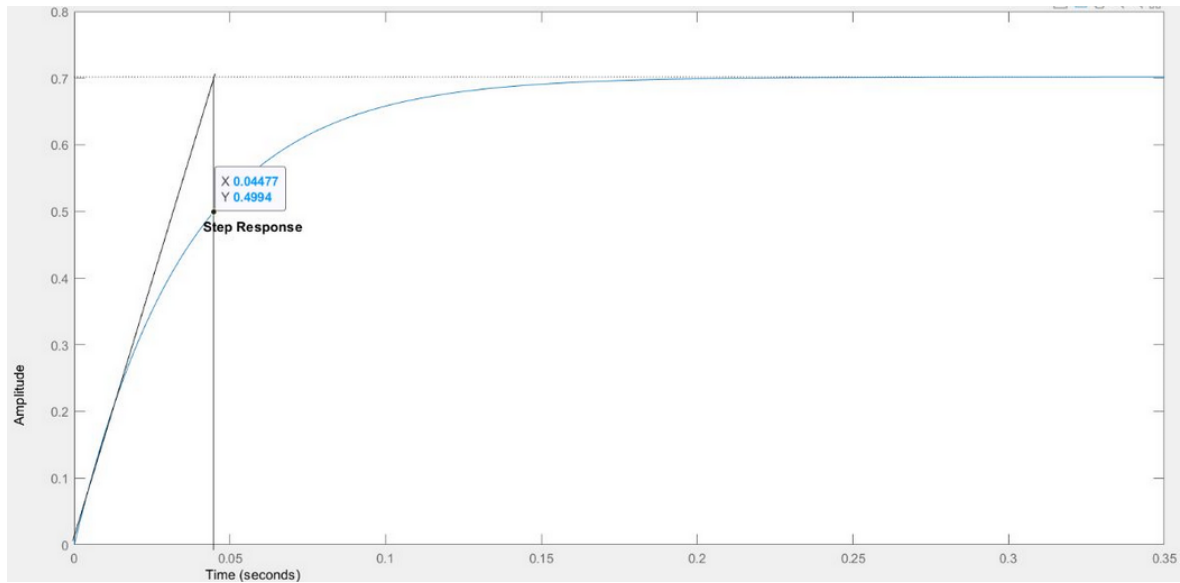


Figure 37. Ziegler-Nichols first method

The values of $L = 0.003317$, $K = 0.7018$ and $T = 0.041453$. Then, the Cohen-Coon formulas are applied to calculate the values of K_p , T_i and T_d . And using these values, obtain the other values of K_i and K_d .

$$K_P = \frac{\tau}{KL} \left(\frac{4}{3} + \frac{L}{4\tau} \right) \quad (24)$$

$$T_I = \frac{\tau(32\tau + 6L)}{13\tau + 8L} \quad (25)$$

$$T_D = \frac{4L}{11\tau + 2L} \quad (26)$$

After applying the Cohen-Coon formulas to the obtained values of K, L, and T, it was found that $K_p = 23.7436$, $T_i = 0.0987$, and $T_d = 0.0012$. These values were then used to calculate the corresponding values of K_d and K_i using the formula.

$$K_I = \frac{K_P}{T_I} \quad (27)$$

$$K_D = T_D \bullet K_P \quad (28)$$

The resulting values of $K_d = 0.0282$ and $K_i = 240.5430$ were essential for the implementation of the PID control algorithm, as they are used to adjust the response of the system in real-time to maintain the desired output. With the complete set of PID parameters determined, the algorithm was implemented on the microcontroller, which enabled precise control over the conveyor belt motor, allowing it to run at a consistent speed and ensuring that the items being transported are moved smoothly and efficiently along the assembly line.

2.4. Programming

The operation of the graduation project is shown in the Figure 38.

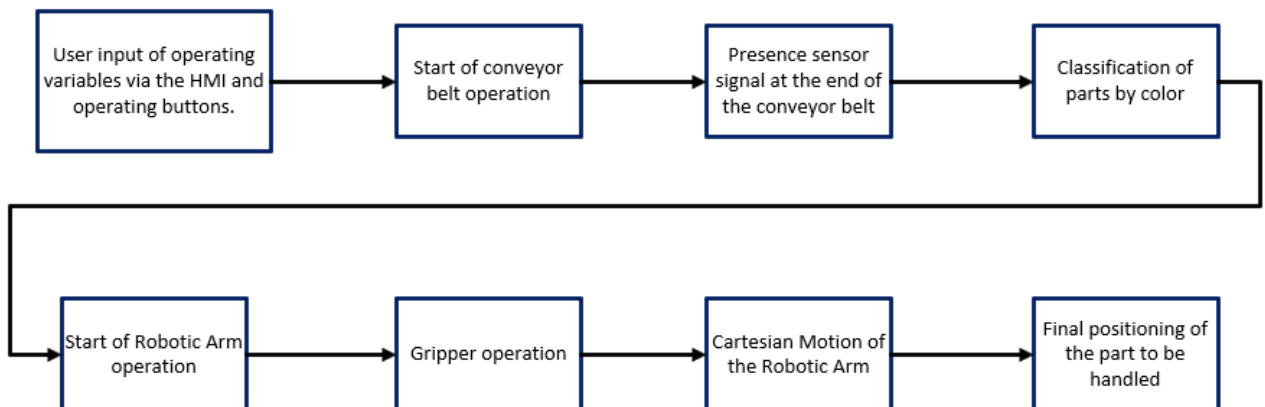


Figure 38. Block diagram of thesis operation

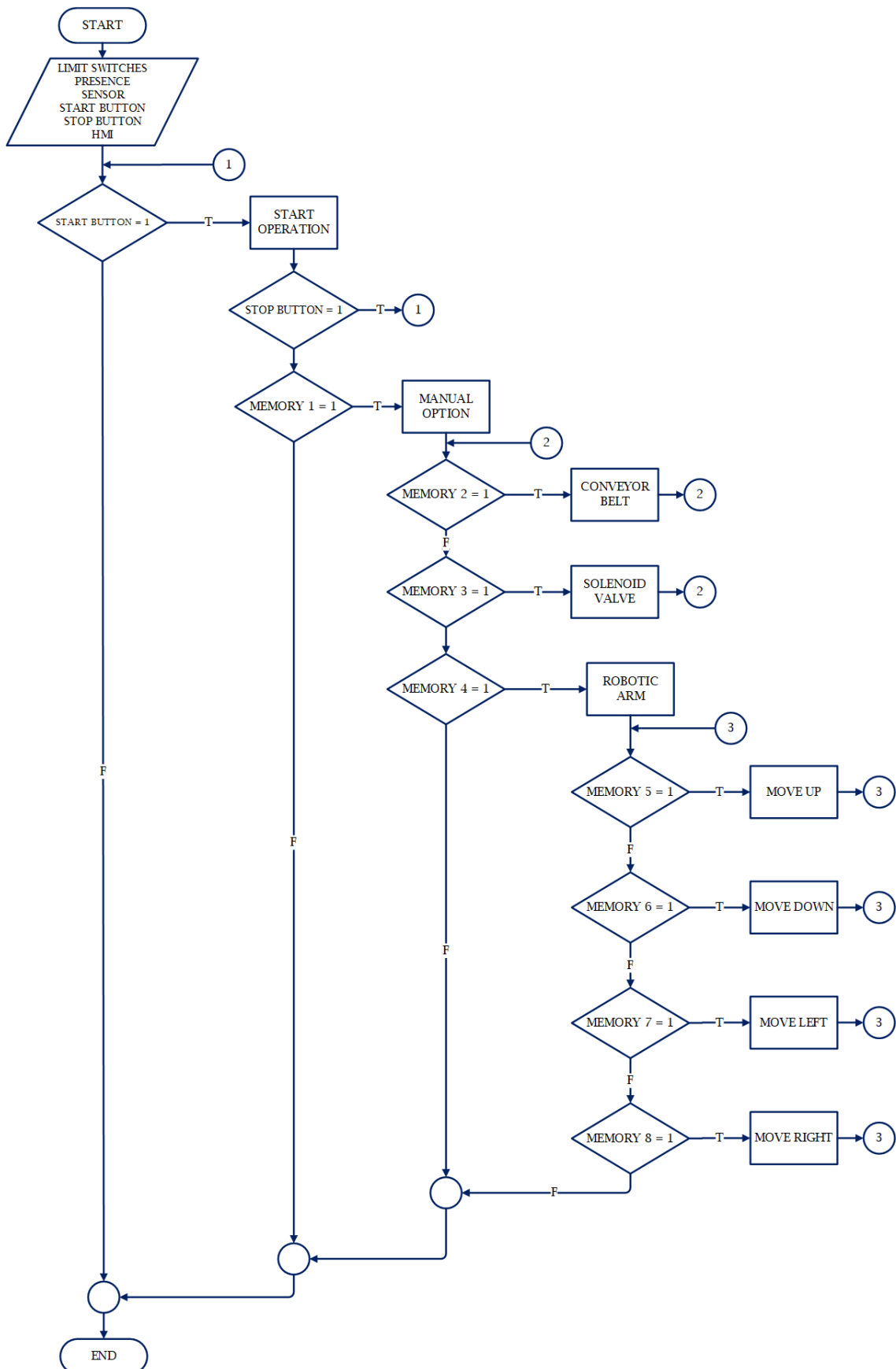
The programming for the correct operation of the graduation project was carried out using the LADDER programming language with the XC Series Program Tool, which is a specific software designed for Xinje XC model PLCs. The LADDER programming language allows a visual representation of the control logic, which facilitates the design and implementation of complex automation sequences. Using the XC series programming tool, the instructions and logic required to control the various components of the project, including motors, sensors and actuators, were programmed. The block diagram of the programming logic and the control and electronic drawings can be found in the annexes part of the document.

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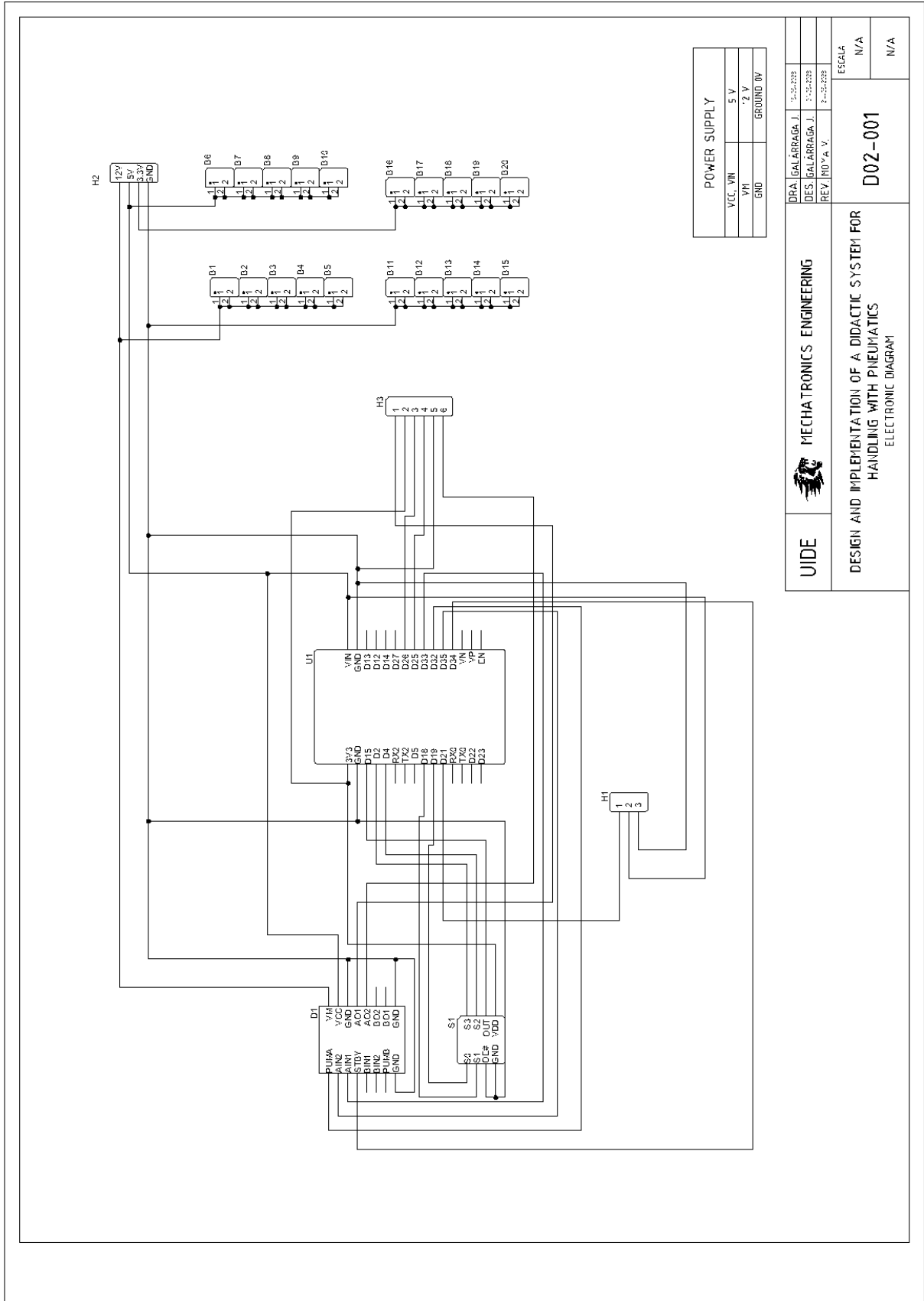
Appendix A


Operation block diagram



Appendix B


Electronic Drawing



 MECHATRONICS ENGINEERING	DIRA	GALARRAGA, J.	1-25-2022			
	DES	GALARRAGA, J.	2-25-2022			
	REV	HOVA, V.	2-25-2022			
UIDE	D02-001					
				DESIGN AND IMPLEMENTATION OF A DIDACTIC SYSTEM FOR HANDLING WITH PNEUMATICS ELECTRONIC DIAGRAM		
				ESCALA N/A N/A		

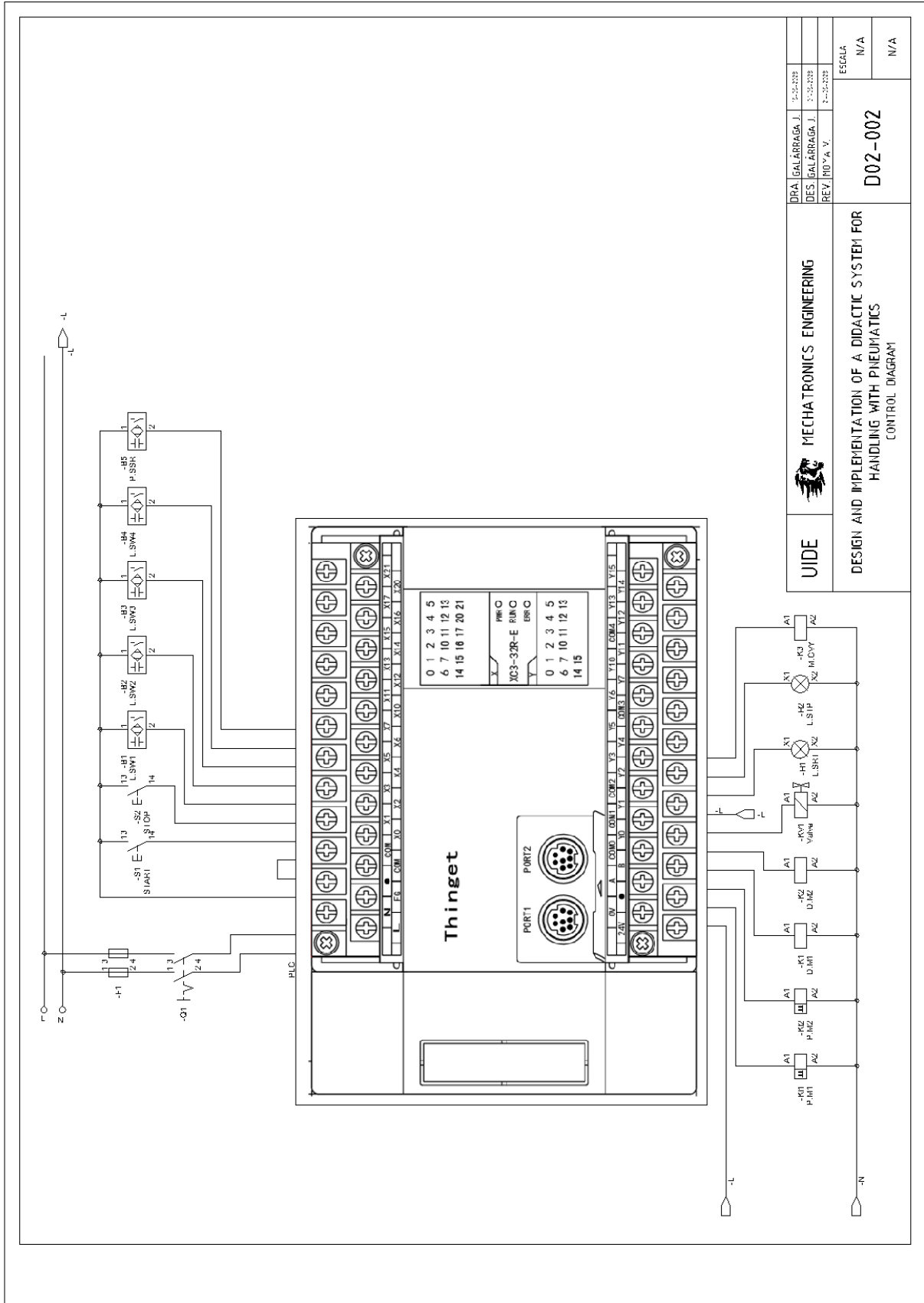
Appendix C

List of Electronic Drawing

POS.	DESCRIPTION	QUANT.	REMARKS
BORNERS			
B1-B20	BORNERS	2	2 PINS
DRIVER			
D1	DRIVER MOTOR CONTROL	1	TB6612FNG chip, 2-Channels, Motor power supply: 15V max, Output current: 1.2A
MICROPROCESSOR			
U1	ESP32	1	ESP32 integrated with antenna switches, RF balun, power amplifiers and low noise amplifiers.
PIN HEADER			
H1	FEMALE HEADER	1	1X3 Female header
H2	FEMALE HEADER	1	1X4 Female header
H3	FEMALE HEADER	1	1X6 Female header
SENSOR			
S1	COLOR SENSOR	1	TCS3200 Operating voltage: 2.7-5.5 V.
UIDE	 MECHATRONICS ENGINEERING	DRA. GALÁRRAGA J.	15-05-2023
		DES. GALÁRRAGA J.	01-05-2023
		REV. MOYA V.	21-05-2023
DESIGN AND IMPLEMENTATION OF A DIDACTIC SYSTEM FOR HANDLING WITH PNEUMATICS ELECTRONIC LIST			SCALE N/A
D02-101			N/A

Appendix D


Control Drawing



UIDE		MECHATRONICS ENGINEERING
DESIGN AND IMPLEMENTATION OF A DIDACTIC SYSTEM FOR HANDLING WITH PNEUMATICS		
CONTROL DIAGRAM		
D02-002		ESCALA
		N/A
		N/A

Appendix E

List of Control Drawing

DISPOSITION OF INPUTS					
TYPE	INPUT	DESCRIPTION	NAME		
DIGITAL	X0	START	-S1		
DIGITAL	X1	STOP	-S2		
DIGITAL	X2	LIMIT SWITCH 1	-S3		
DIGITAL	X3	LIMIT SWITCH 2	-S4		
DIGITAL	X4	LIMIT SWITCH 3	-S5		
DIGITAL	X5	LIMIT SWITCH 4	-S6		
DIGITAL	X6	PRESENCE SENSOR	-B01		
DISPOSITION OF OUTPUTS					
ANALOG	Y0	PULSE MOTOR 1	-K11		
ANALOG	Y1	PULSE MOTOR 2	-K12		
DIGITAL	Y2	DIRECTION MOTOR 1	-K1		
DIGITAL	Y3	DIRECTION MOTOR 2	-K2		
DIGITAL	Y4	SOLENOID VALVE ACTUATOR	-KV1		
DIGITAL	Y5	PILOT LAMP (START OPERATION)	-H1		
DIGITAL	Y6	PILOT LAMP (STOP OPERATION)	-H2		
DIGITAL	Y7	MOTOR CONVEYOR BELT	-K3		
UIDE	 MECHATRONICS ENGINEERING		DRA. GALÁRRAGA J. 15-05-2023 DES. GALÁRRAGA J. 01-05-2022 REV. MOYA V. 21-05-2023	SCALE N/A N/A	D02-201
DESIGN AND IMPLEMENTATION OF A DIDACTIC SYSTEM FOR HANDLING WITH PNEUMATICS LIST OF COMPONENTS					

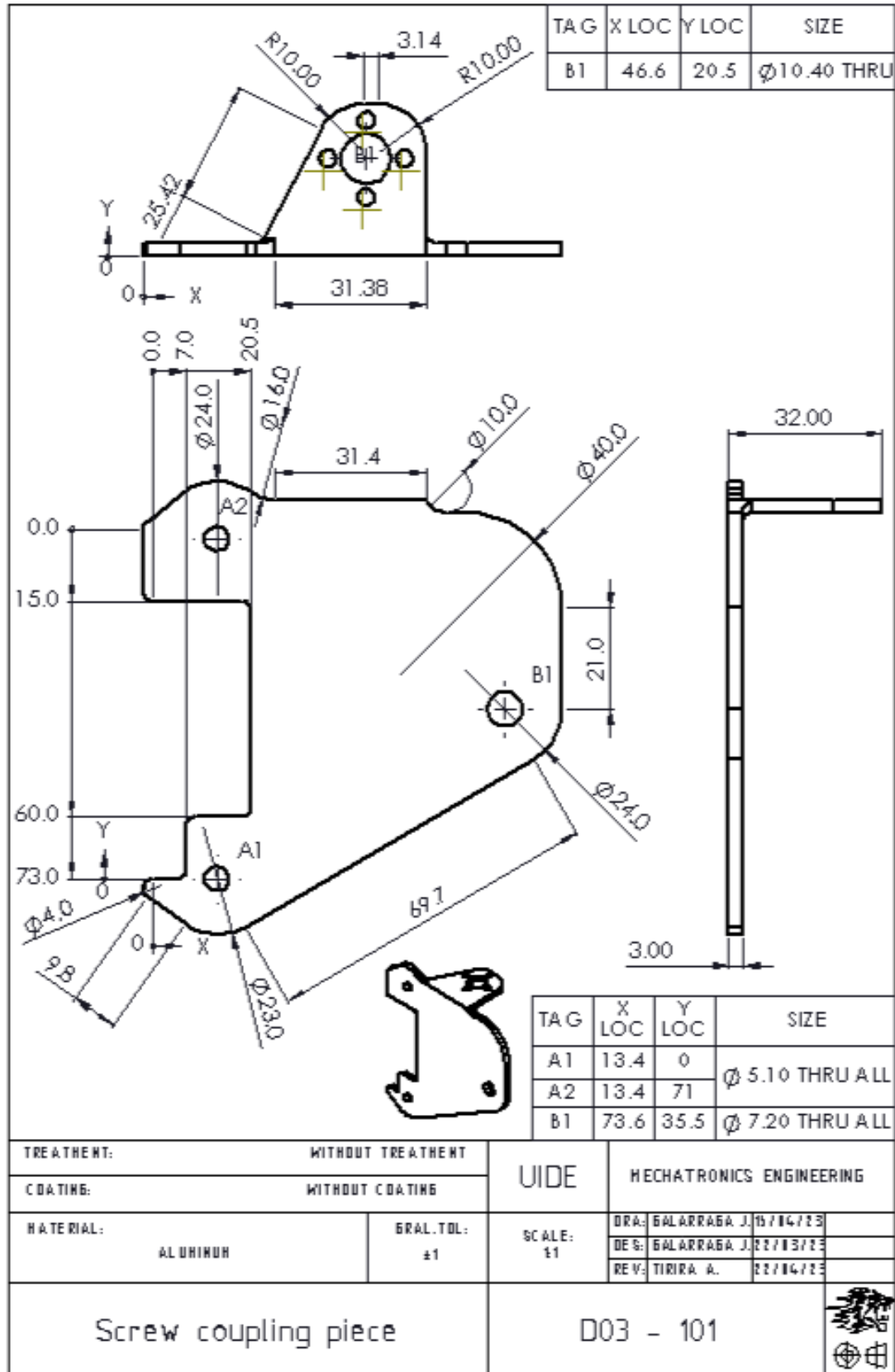
Appendix F

Assembly Drawings

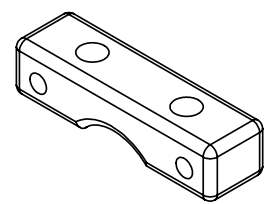
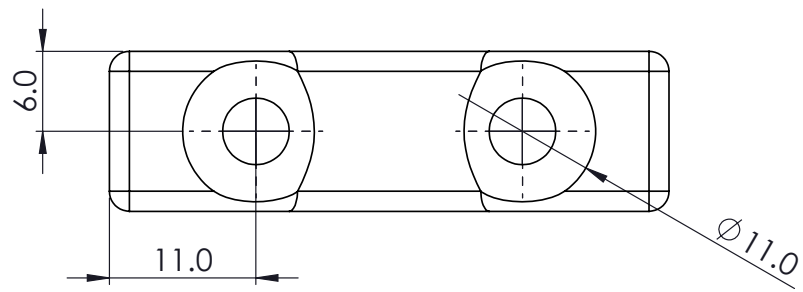
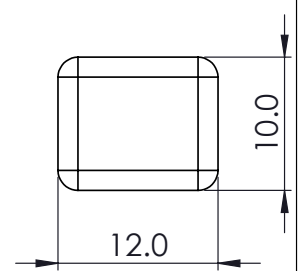
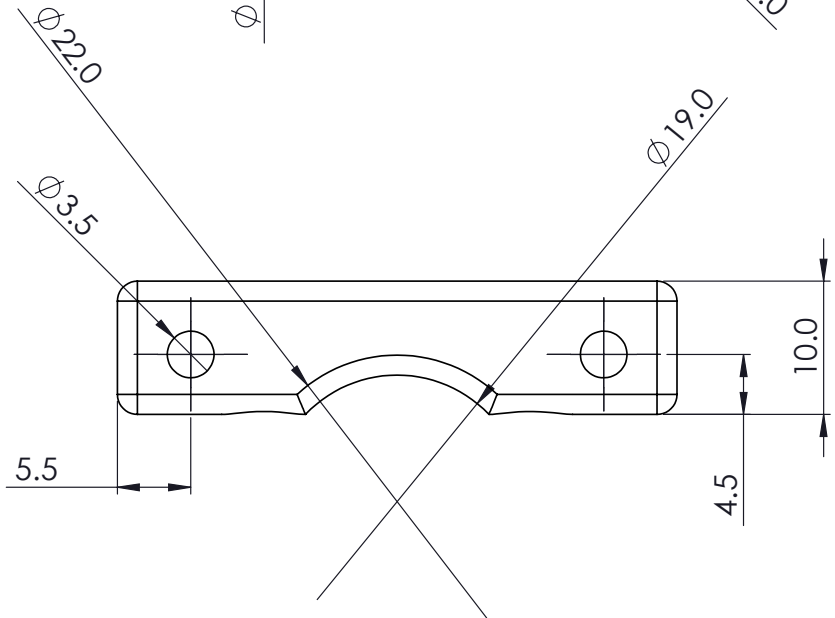
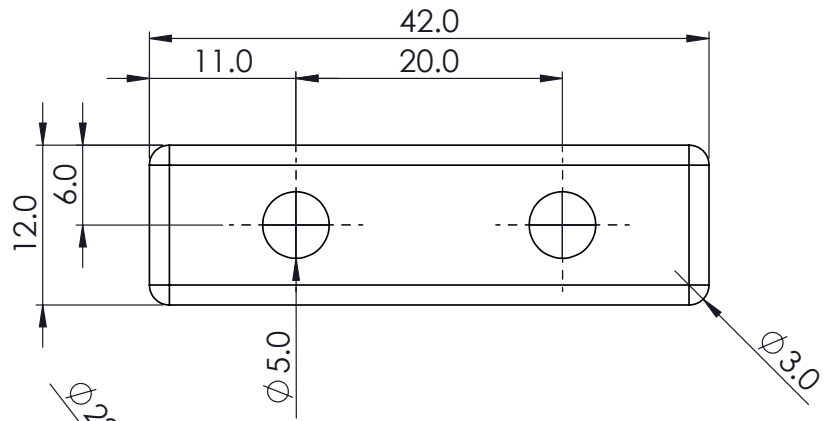
NO	QTY	DESCRIPTION	UNIT	REMARKS	REF
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Appendix G

Mechanical Drawings

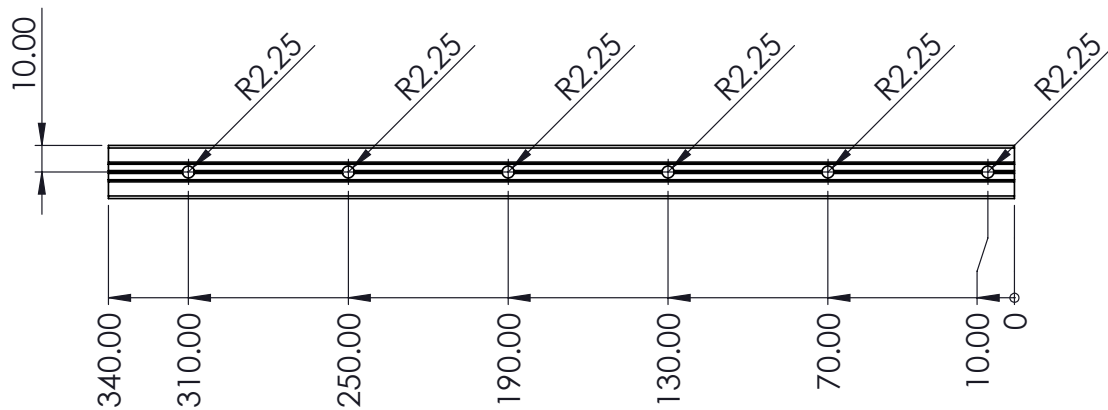


N7




PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 25%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

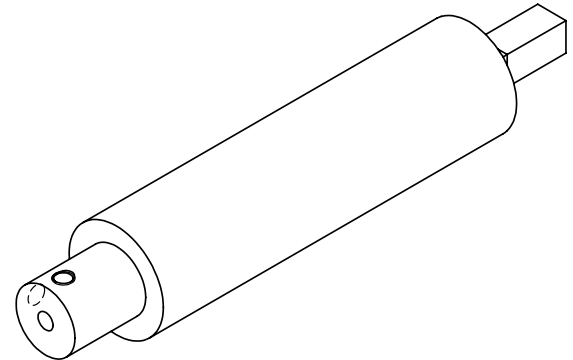
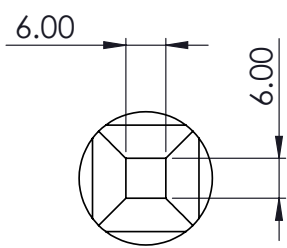
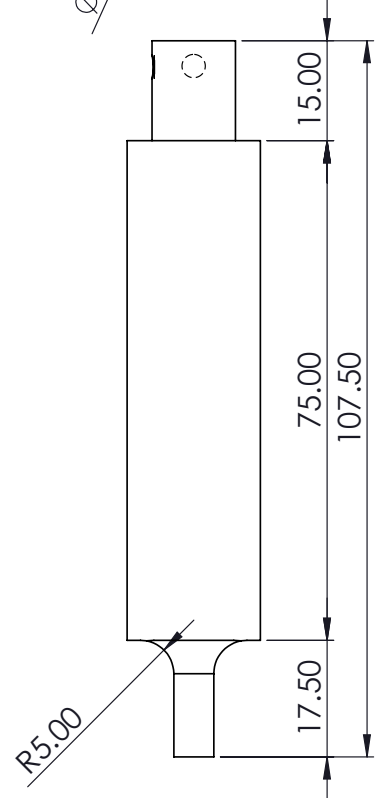
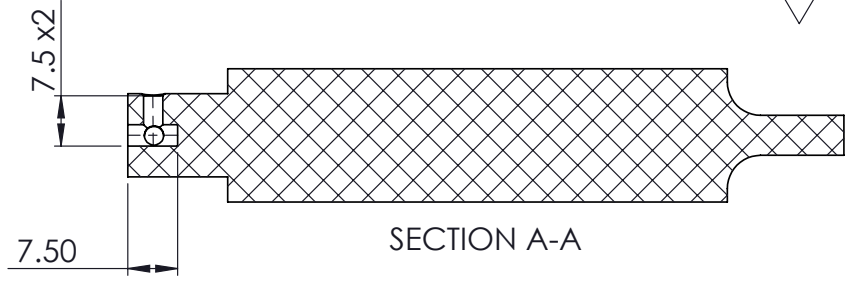
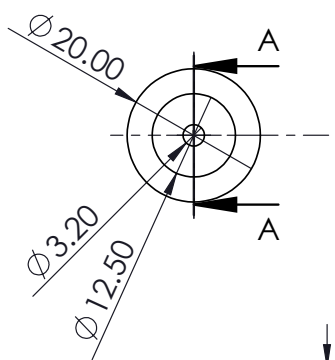
TREATMENT:	WITHOUT TREATMENT	UIDE	MECHATRONICS ENGINEERING			
COATING:	WITHOUT COATING					
MATERIAL:	PLA	GRAL.TOL:	SCALE:	DRA:	GALÁRRAGA J.	15/04/23
		±1	2:1	DES:	GALÁRRAGA J.	01/04/23
				REV:	TIRIRA A.	22/04/23
Motor coupling to Z-axis			D03 - 102			



MATERIAL: ALUMINUM
 ALUMINUM PROFILE 20X20
 LENGTH: 340 mm

TREATMENT: WITHOUT TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COATING: WITHOUT COATING					
MATERIAL: ALUMINUM		GRAL.TOL: ±1	SCALE: 1:2.5	DRA: GALÁRRAGA J. 10/04/23	
				DES: GALÁRRAGA J. 25/03/23	
				REV: TIRIRA A. 22/04/23	
Aluminum profile 20x20 base			D03 - 103		

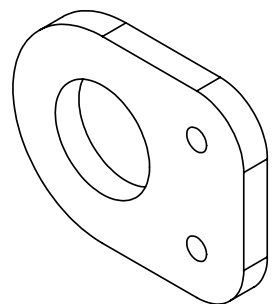
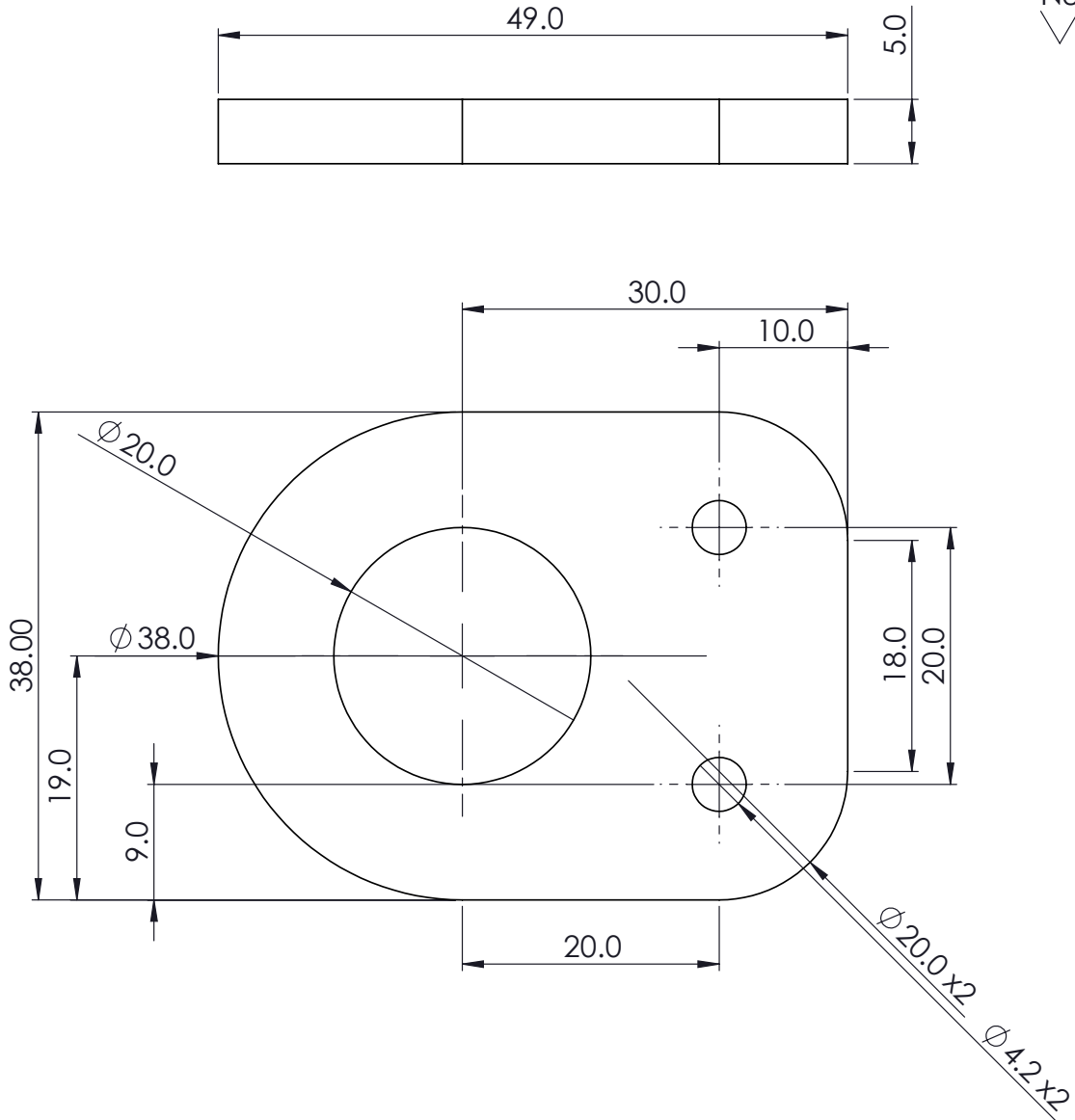
N8



PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 25%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

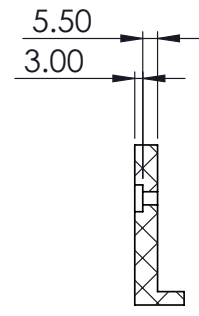
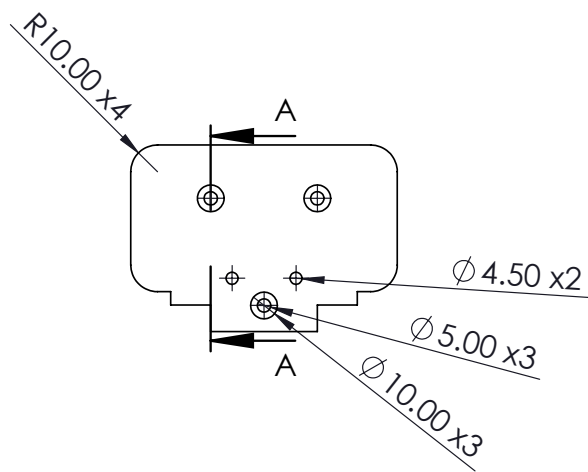
TREATMENT:	WITHOUT TREATMENT	UIDE	MECHATRONICS ENGINEERING			
COATING:	WITHOUT COATING					
MATERIAL:	PLA	GRAL.TOL:	SCALE:	DRA:	GALÁRRAGA J.	15/04/23
		±1	1:1	DES:	GALÁRRAGA J.	10/04/23
				REV:	TIRIRA A.	22/04/23
Belt Roller Motor			D03 - 104			

N8

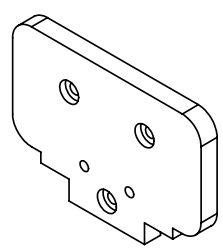
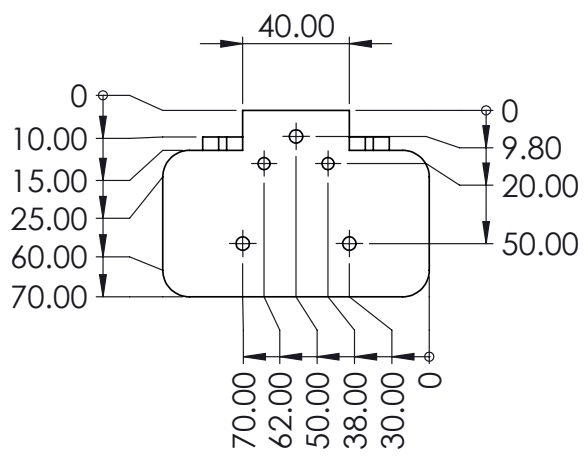
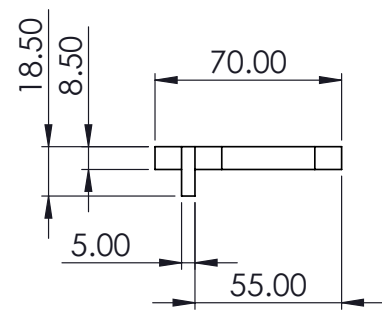
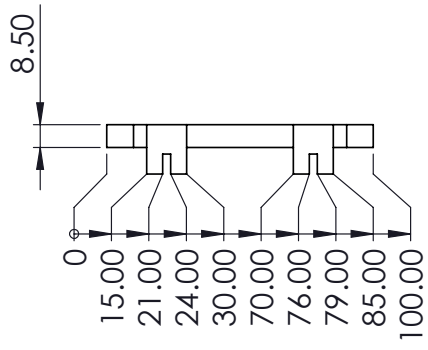


PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 20%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

TREATMENT: WITHOUT TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COATING: WITHOUT COATING					
MATERIAL: PLA	GRAL.TOL: ±1	SCALE: 2:1	DRA: GALÁRRAGA J.	15/04/23	
			DES: GALÁRRAGA J.	05/04/23	
			REV: TIRIRA A.	22/04/23	
Bearing Support		D03 - 105			



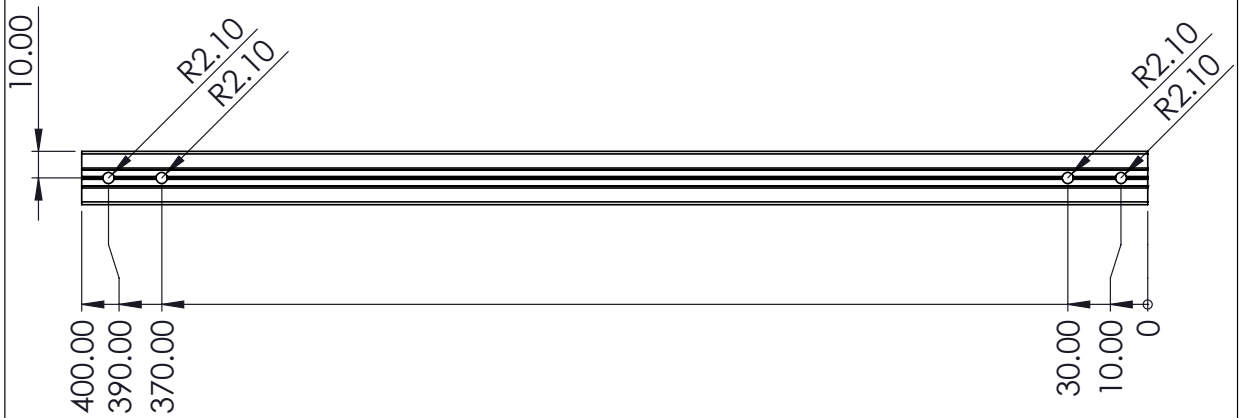
SECTION A-A



PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 25%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

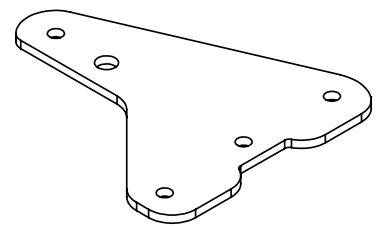
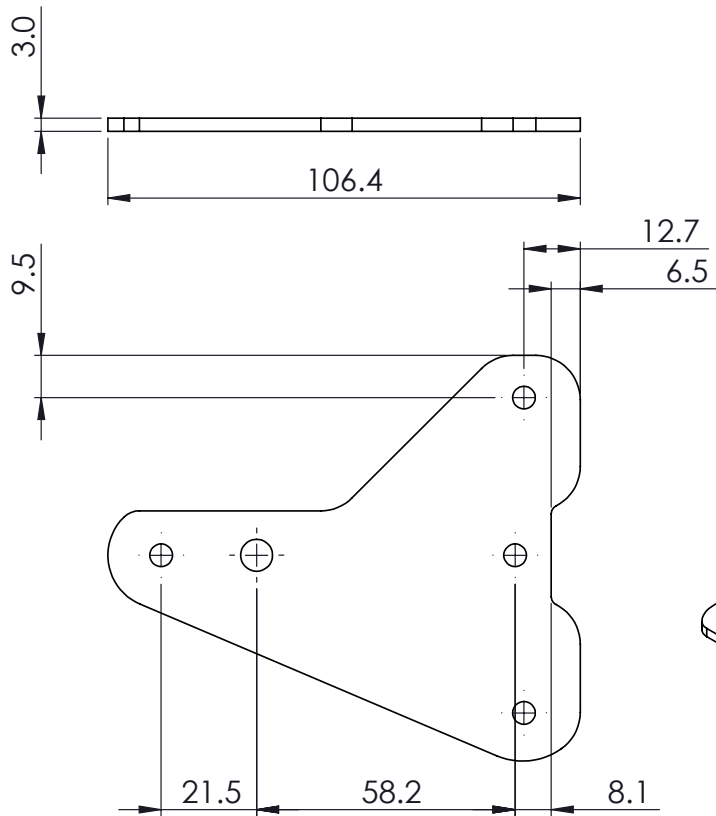
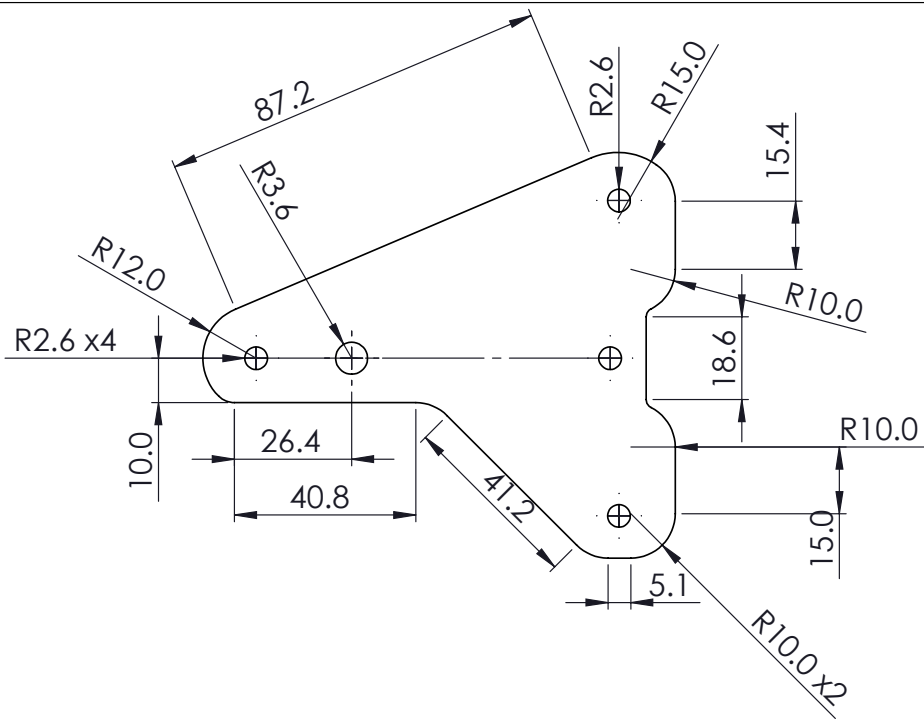
TREATMENT:	WITHOUT TREATMENT	UIDE	MECHATRONICS ENGINEERING			
COATING:	WITHOUT COATING					
MATERIAL:	PLA	GRAL.TOL:	SCALE:	DRA:	GALÁRRAGA J.	22/04/23
		±1	1:2.5	DES:	GALÁRRAGA J.	22/04/23
				REV:	TIRIRA A.	10/05/23
Actuator Coupling			D03 - 106			




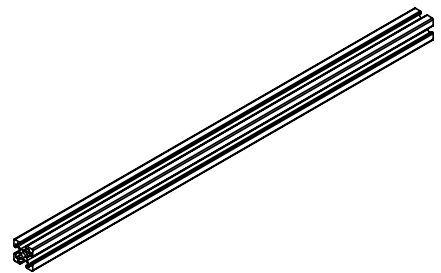
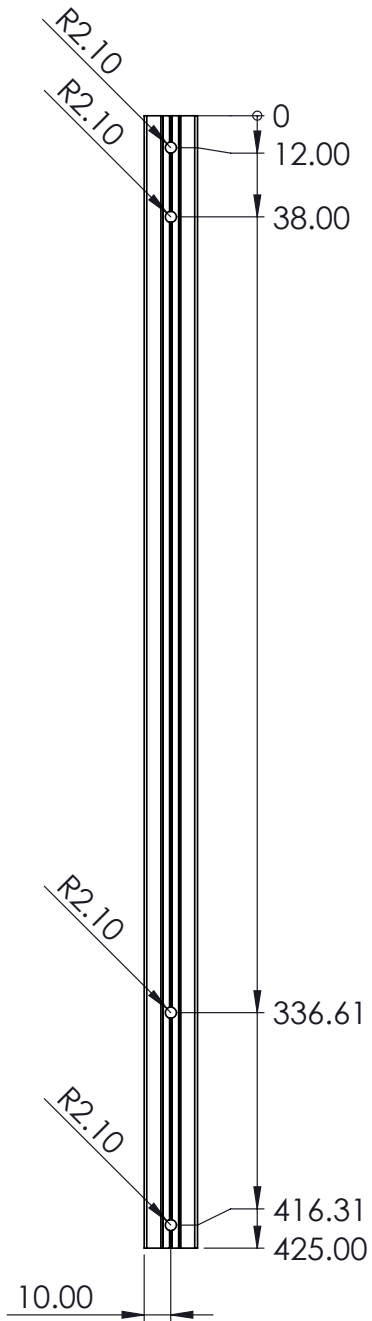


MATERIAL: ALUMINUM
 ALUMINUM PROFILE 20X20
 LENGTH: 400 mm


TREATMENT:	WITHOUT TREATMENT	UIDE	MECHATRONICS ENGINEERING			
COATING:	WITHOUT COATING		DRA:	GALÁRRAGA J.	15/04/23	
MATERIAL:	ALUMINUM	GRAL.TOL:	SCALE:	DES:	GALÁRRAGA J.	25/03/23
		±1	1:2.5	REV:	TIRIRA A.	22/04/23
Aluminum Profile Lower robotic arm			D03 - 107			

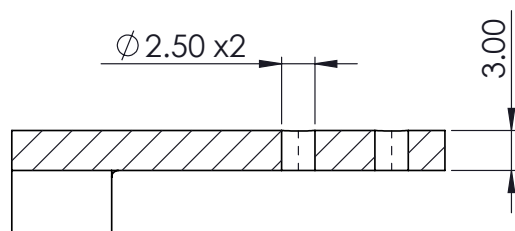
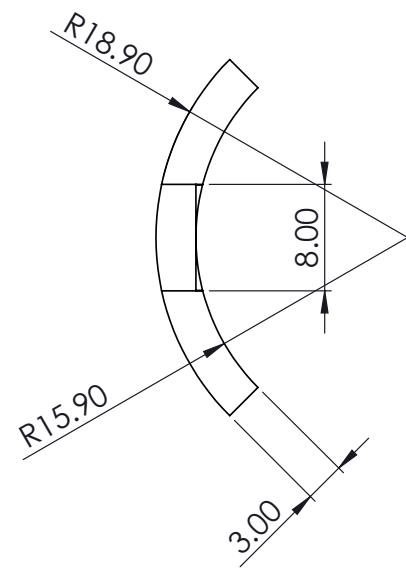
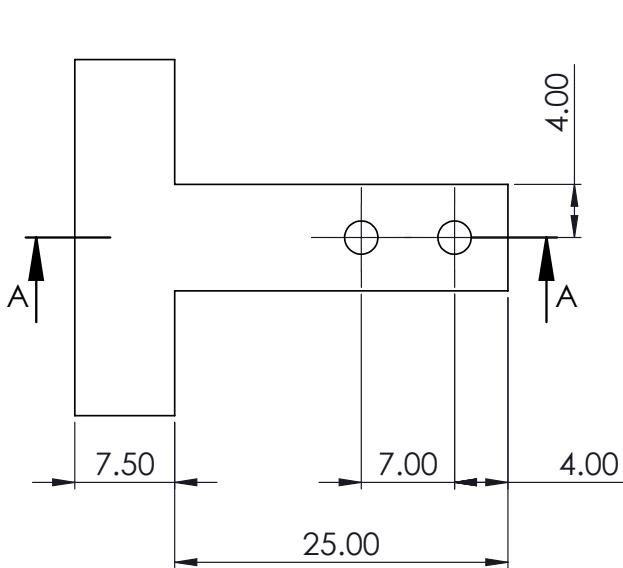


TREATMENT: WITHOUT TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COATING: WITHOUT COATING					
MATERIAL: ALUMINUM	GRAL.TOL: ±1	SCALE: 1:1	DRA: GALÁRRAGA J.	15/04/23	
			DES: GALÁRRAGA J.	25/03/23	
			REV: TIRIRA A.	22/04/23	
Right X-Axis Support		D03 - 108			

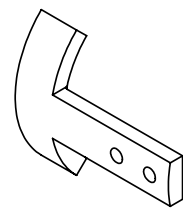


MATERIAL: ALUMINUM
 ALUMINUM PROFILE 20X20
 LENGTH: 400 mm

TREATMENT: WITHOUT TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COATING: WITHOUT COATING					
MATERIAL: ALUMINUM	GRAL.TOL: ±1	SCALE: 1:2.5	DRA: GALÁRRAGA J.	15/04/23	
			DES: GALÁRRAGA J.	25/03/23	
			REV: TIRIRA A.	22/04/23	
Aluminum Profile X-Axis		D03 - 109			

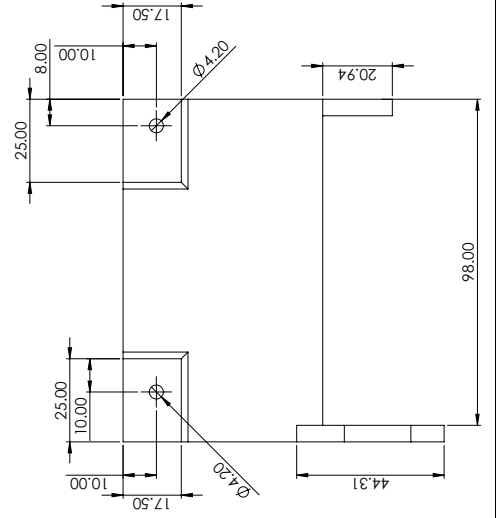
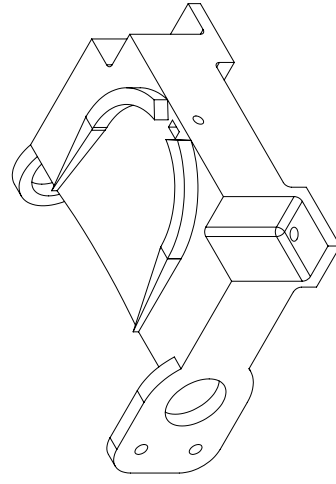
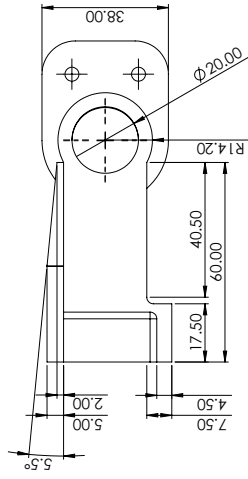
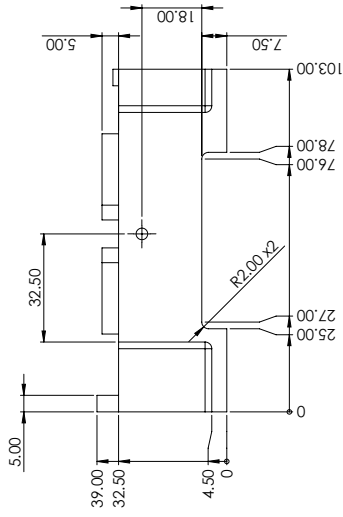
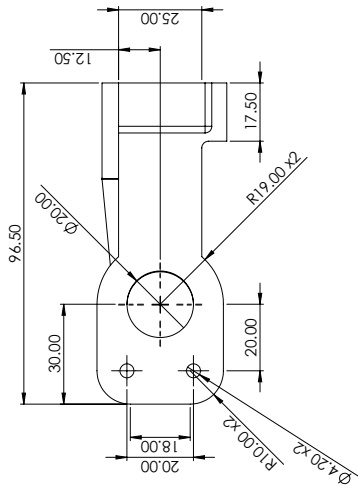
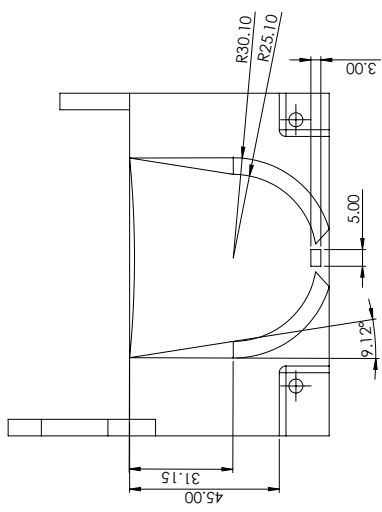


SECTION A-A

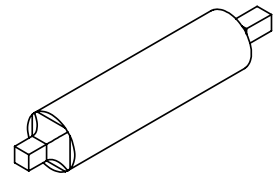
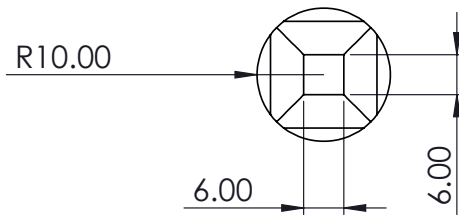
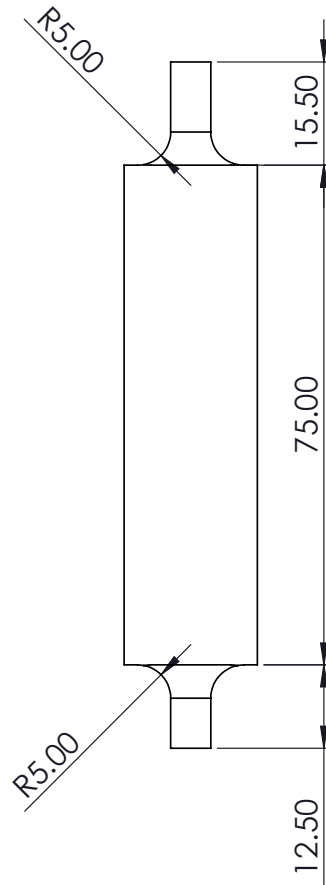


PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 25%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

TREATMENT:	WITHOUT TREATMENT	UIDE	MECHATRONICS ENGINEERING		
COATING:	WITHOUT COATING				
MATERIAL:	PLA	GRAL.TOL:	SCALE:	DRA:	GALÁRRAGA J.
		±1	2:1	DES:	GALÁRRAGA J.
				REV:	TIRIRA A.
Actuator part coupling			D03 - 110		

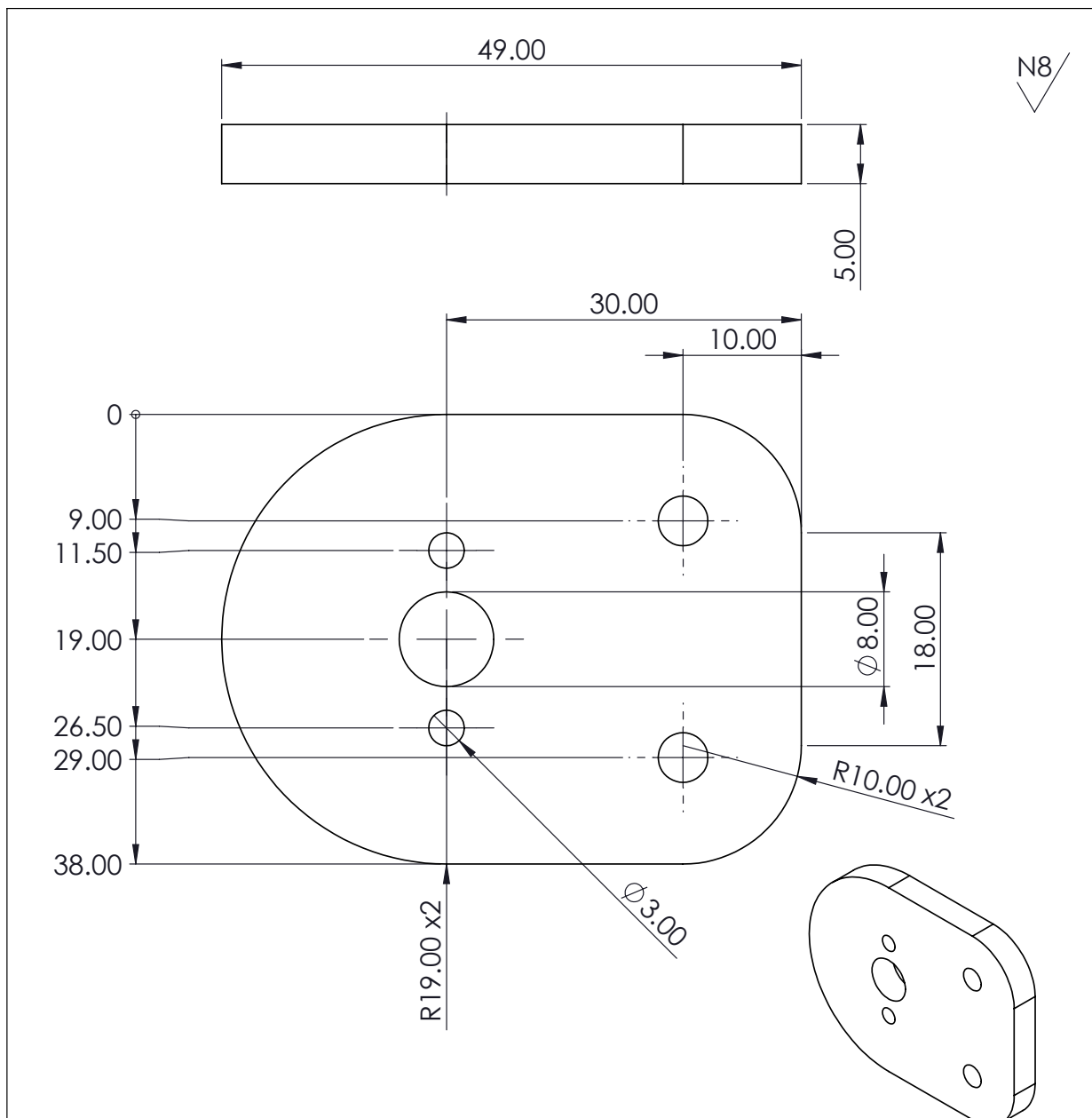


MECHATRONICS ENGINEERING		UIDE	
DRD GALARRAGA 15/04/23	DES GALARRAGA 25/03/23	GRAL. TOL ±1	SCALE 1:1
REV TIRRA A	22/04/23	D03 - 111	
TREATMENT: WITHOUT TREATMENT		End Position Support	
COATING: WITHOUT COATING			
MATERIAL: ALUMINUM			



PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 25%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

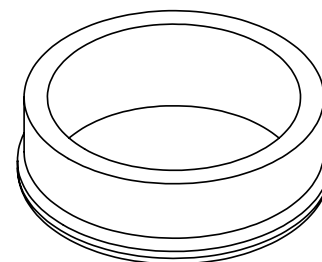
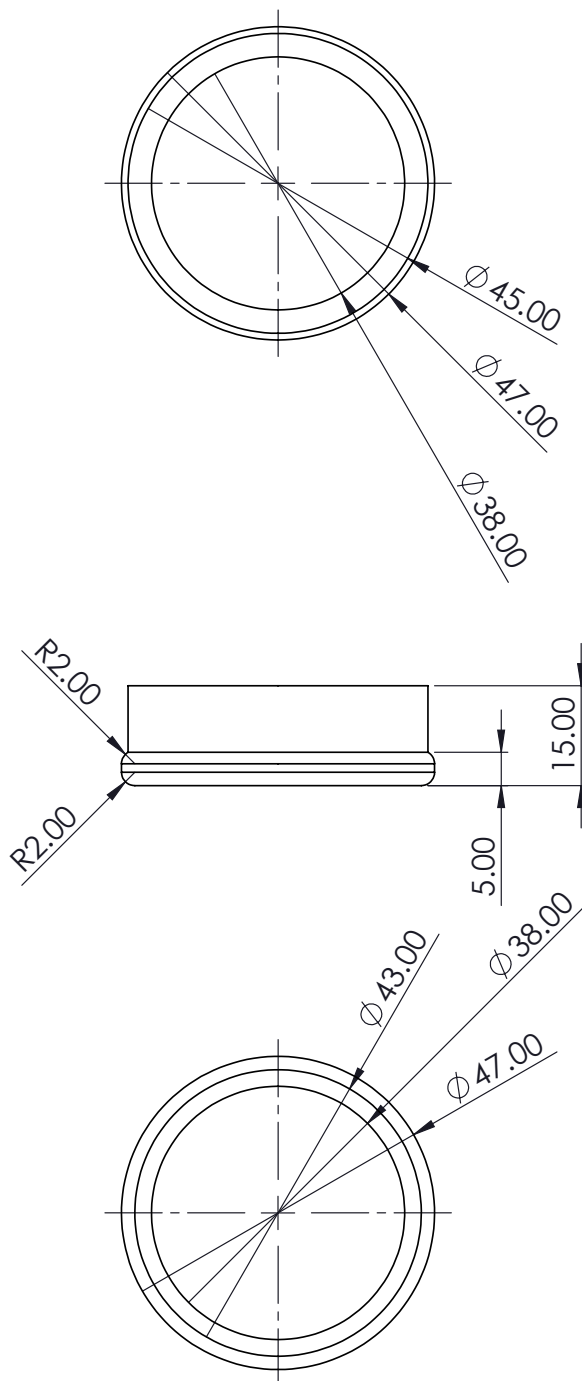
TREATMENT: WITHOUT TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COATING: WITHOUT COATING					
MATERIAL: PLA	GRAL.TOL: ±1	SCALE: 1:1	DRA: GALÁRRAGA J.	15/04/23	
			DES: GALÁRRAGA J.	25/03/23	
			REV: TIRIRA A.	22/04/23	
Belt Roller		D03 - 112			



N8

PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 25%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

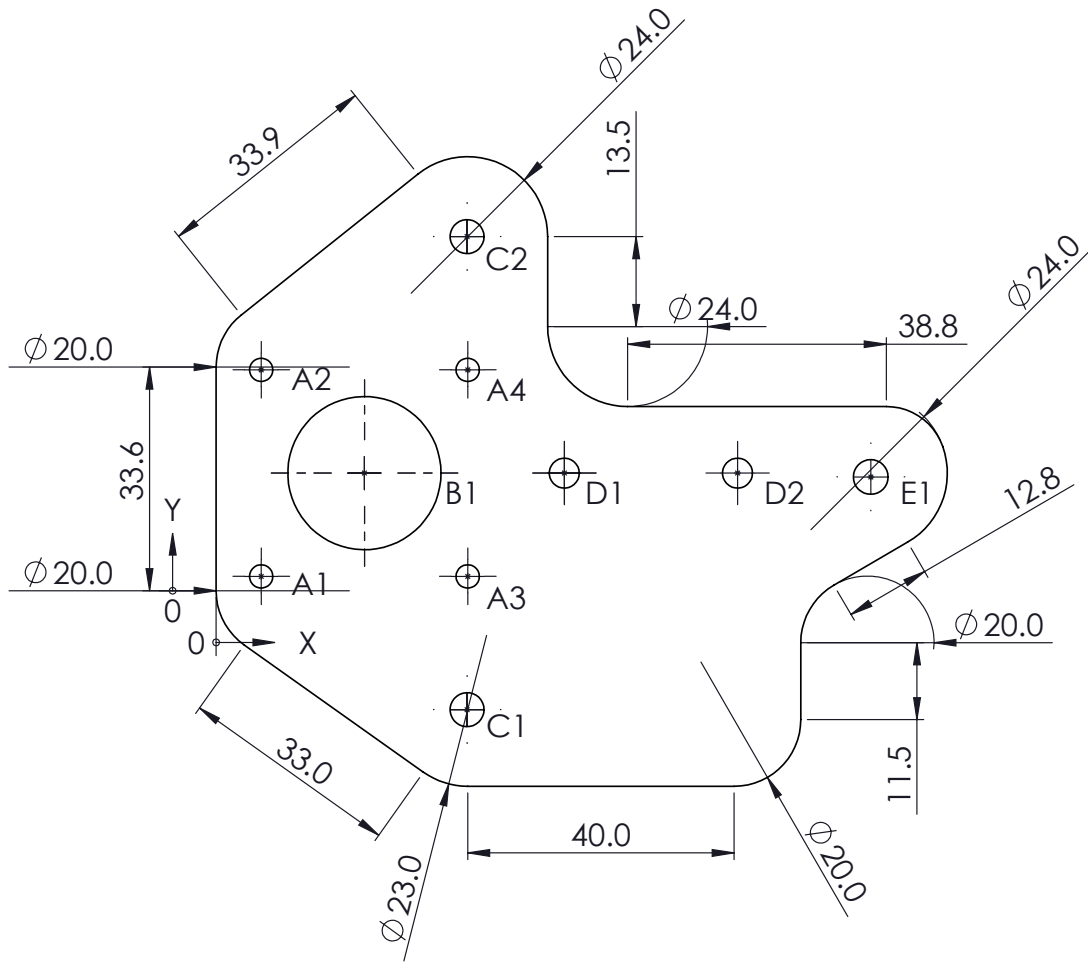
TREATMENT:	WITHOUT TREATMENT	UIDE	MECHATRONICS ENGINEERING		
COATING:	WITHOUT COATING				
MATERIAL:	PLA	GRAL.TOL: ±1	SCALE: 2:1	DRA: GALÁRRAGA J. 15/04/23	
				DES: GALÁRRAGA J. 25/03/23	
				REV: TIRIRA A. 22/04/23	
Motor Support			D03 - 113		



PRINTING SPECIFICATIONS:
 MATERIAL: PLA
 PROCESS: FDM
 PRINTER: ENDER 3 v2
 INFILL TYPE: TRIANGULAR
 INFILL PERCENTAGE: 25%
 COLOR/BRAND: WHITE/CREALITY
 BED TEMPERATURE: 60°C
 EXTRUSION TEMPERATURE: 205°C
 LAYERS: INITIAL 3-FINAL 3

TREATMENT:	WITHOUT TREATMENT	UIDE	MECHATRONICS ENGINEERING		
COATING:	WITHOUT COATING				
MATERIAL:	PLA	GRAL.TOL: ±1	SCALE: 1:1	DRA: GALÁRRAGA J.	15/04/23
				DES: GALÁRRAGA J.	25/03/23
				REV: TIRIRA A.	22/04/23
Piece to be handled			D03 - 114		





TAG	X LOC	Y LOC	SIZE
A1	6.8	2.2	Ø 3.50 THRU
A2	6.8	33.2	
A3	37.8	2.2	
A4	37.8	33.2	
B1	22.3	17.7	Ø 23.00 THRU
C1	37.7	-17.8	Ø 5.10 THRU
C2	37.7	53.2	
D1	52.3	17.7	Ø 4.50 THRU
D2	78.3	17.7	
E1	98.3	17.1	Ø 5.20 THRU

Thickness of 3 mm

TREATMENT: WITHOUT TREATMENT		UIDE	MECHATRONICS ENGINEERING		
COATING: WITHOUT COATING					
MATERIAL: ALUMINUM		GRAL.TOL: ±1	SCALE: 1:1	DRA: GALÁRRAGA J. 15/04/23	
				DES: GALÁRRAGA J. 25/03/23	
				REV: TIRIRA A. 22/04/23	
Left X-axis Support			D03 - 115		

