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ING. MECATRÓNICA

Tesis previa a la obtención del título de Ingeniera en Mecatrónica.

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DESIGN AND CONSTRUCTION OF A STORAGE STATION TO CLASSIFY OBJECTS ACCORDING TO THEIR COLOR

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DIRECTOR DEL TRABAJO DE TITULACIÓN

ACKNOWLEDGMENTS

I would like to express my gratitude to my family for their unwavering support throughout my journey towards attaining this degree. Their unconditional encouragement has been invaluable. I am also grateful to my friends who have consistently cheered me on and provided a listening ear while I pursued my dreams. Additionally, I extend my heartfelt thanks to my teachers, who have served as excellent mentors and provided invaluable guidance to help me accomplish this goal.

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DESIGN AND MATERIALS SELECTION

1. Mechanical design

To develop a mechanical design, the components must be analyzed taking into account all the constraints that the project would have during its functionality. The following parts provide a step-by-step explanation of how the module was design mechanically.

1.1. Technical specifications

The main structures to develop the station are the following:

Table 1. Technical specifications table

Structure	Objective to analysis
Object	-Dimensions -Shape -Color -The cartesian arm is going to manipulate
Base	-Dimensions -Material -Characteristics
Cylinder	Pneumatic movement in the Y axis -Characteristics -Force analysis -Material
Power Screw	Mechanical movement in the Z axis -Dimensions -Force analysis -Material
Gripper	Grab the object -Characteristics -Material
Pulley	Mechanical movement in X axis -Force analysis -Characteristics -Dimensions
Carrying station	Fit the complete project -Dimensions -Easy to moves

1.2. Thinking design

The objective of the design process is to integrate all the required components to fulfill the mechanical task, which in this case involves moving a cartesian arm to pick up and place a piece. The components necessary for this task are listed in Table 1. The following steps outline the process of assembling these components to ensure they function properly in solving the problem of classifying objects. It is crucial to ensure that the components can withstand the forces they will be subjected to, and this approach is chosen based on the availability of components in the market.

1.3. CAD sketch

The project's layout is outlined in Figure 1 and must be capable of supporting all the stresses and weights necessary to complete the work. It is essential to make sure that the calculations are carried out correctly since the design section details the calculations required to choose the suitable dimensions and materials for the project.

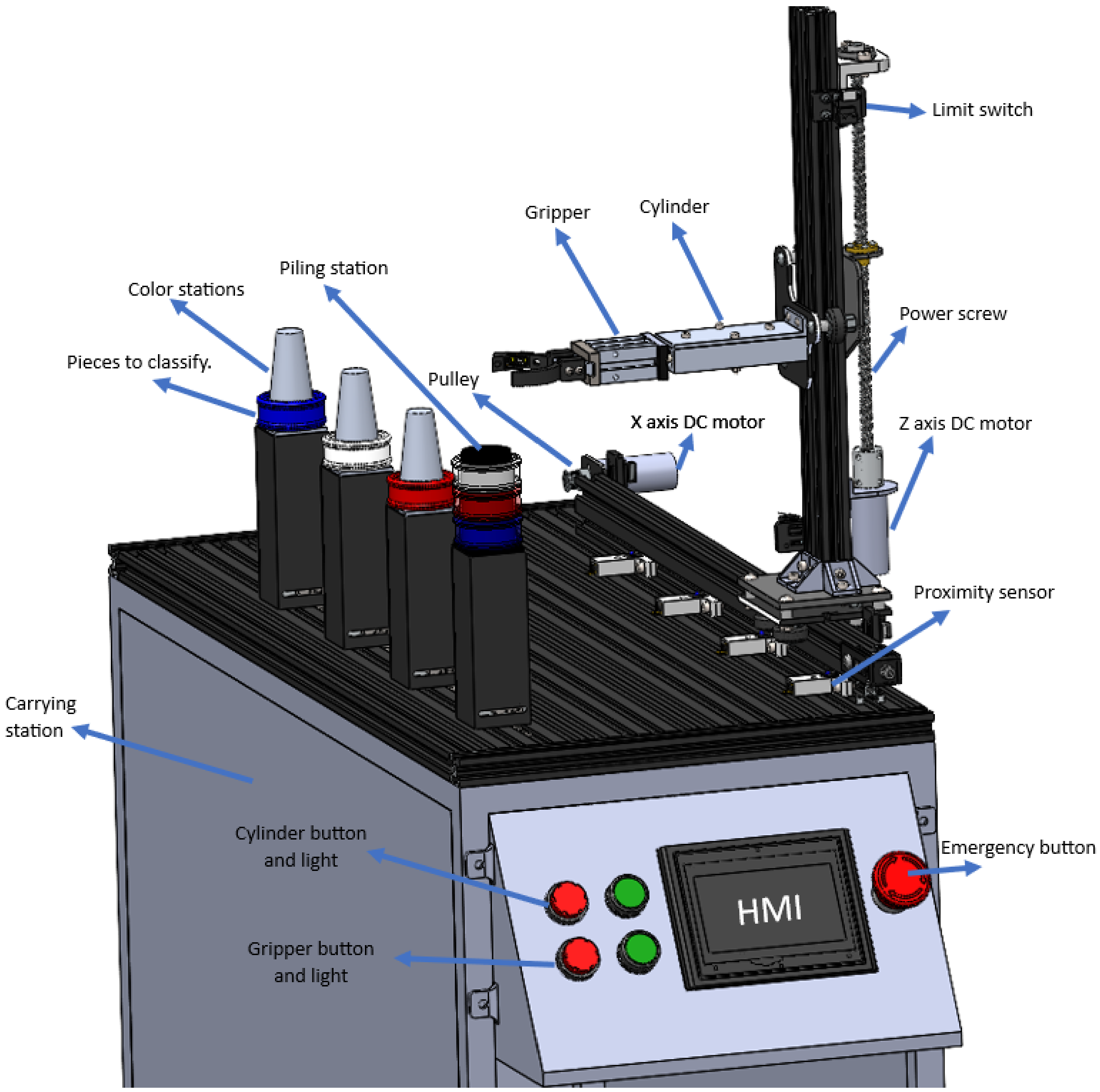


Figure 1. Sketch design of the module.

1.4. Design

Object specifications There are two components that complete one object which the arm must manipulate around its space work to classify, depending on the color, the pieces are the following

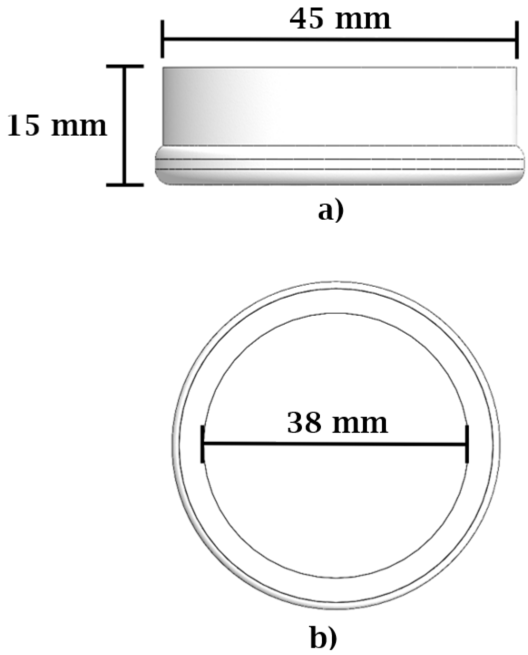


Figure 2. Female piece dimensions.

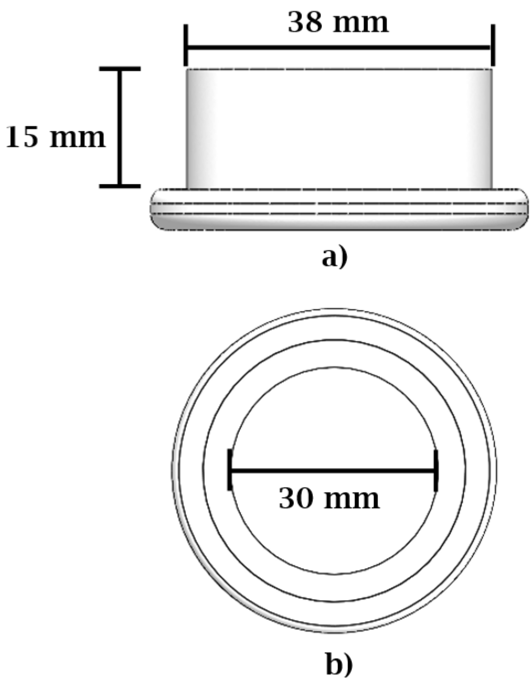


Figure 3. Male piece dimensions

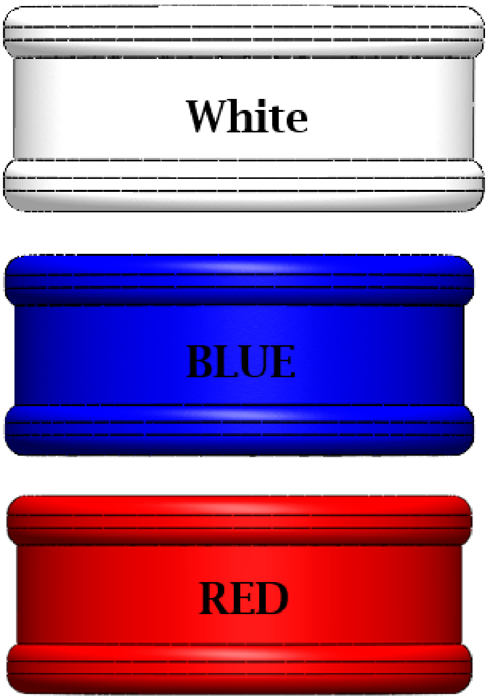


Figure 4. Male & female pieces respective colors

The male on Figure 3 and the female piece on Figure 2 are the components that joined together look like the objects in Figure 4 additionally with the specific color that must be classified red, blue and white.

Base specifications

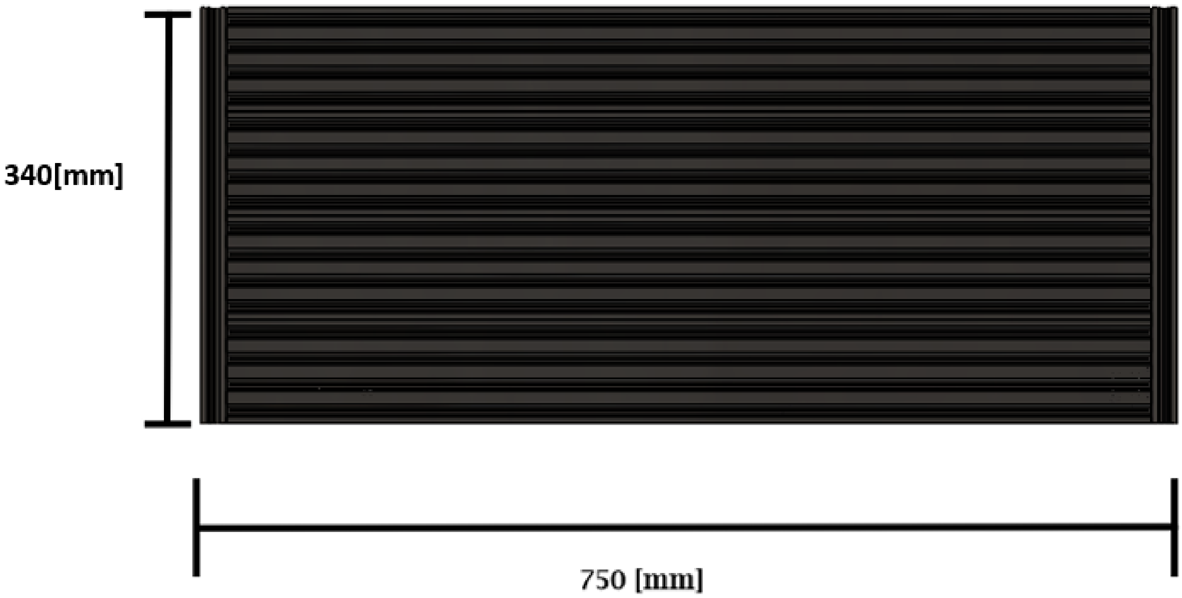


Figure 5. Base dimensions

The base dimension can be seen in Figure 5 as 750 mm x 340 mm x 20 mm this are black color CNC aluminium profiles.

Double acting cylinder specifications

- **Brand:** Tailonz
- **Material:** Aluminium
- **Bore:** 10 mm
- **Stroke:** 50 mm
- **Working pressure:** 0-10PSI
- **Dimensions:** 110.24mm x 41.9mm
- **Weight:** 230g

Parallel air gripper specifications

- **Brand:** Tailonz
- **Material:** Aluminium
- **Bore:** 20mm
- **Opening closing stroke:** 10mm
- **Working pressure:** 14.50 - 101.5PSI
- **Dimensions:** 67.3mm x 38mm
- **Weight:** 235g

Beam

It has to be taken in consideration that the cylinder is mainly made out of aluminium which are the material characteristics that are going to be taken in consideration for this analysis.4.

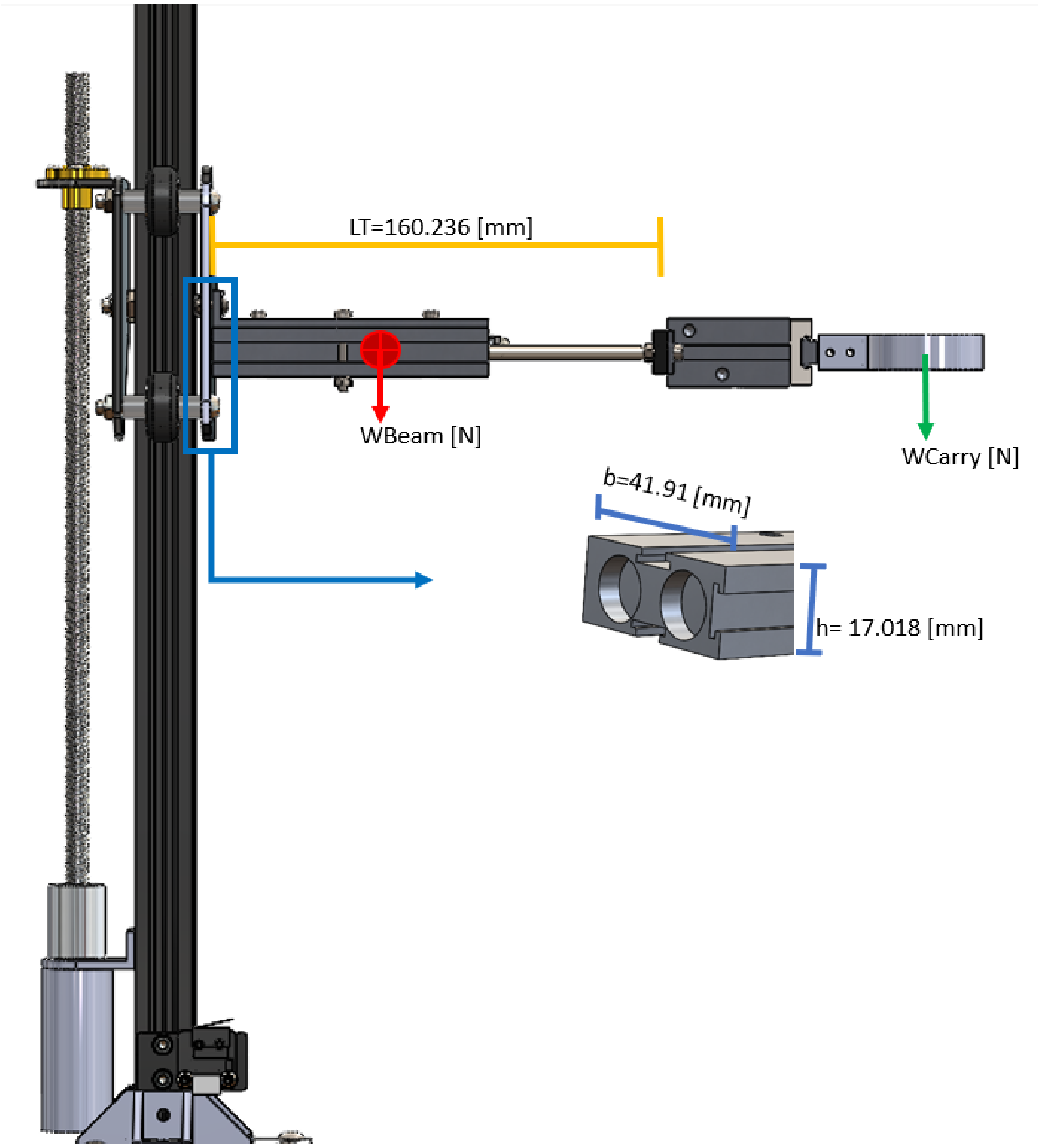


Figure 6. FBD of the beam.

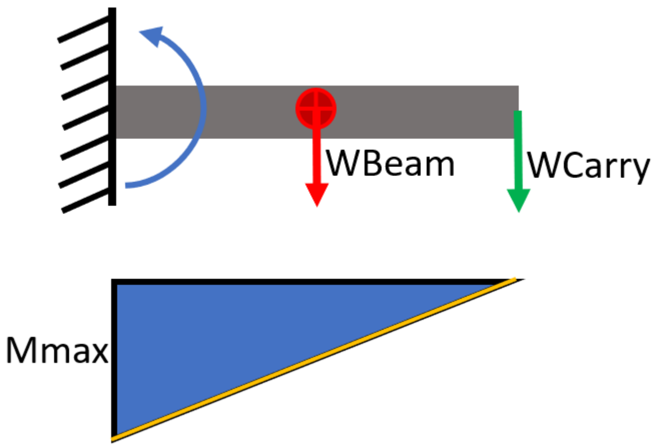


Figure 7. Moment diagram of the beam.

The moment from Figure 6. can be better understood in Figure7. The objective of this calculation is to determine if the cylinder can carry the weight of the pneumatic gripper with the piece that is going to be classified.

$$\sum M = 0$$

$$M = (W_{Carry} * L_T) + (\frac{L_T}{2} W_{Beam})$$

$$W_{Carry} \; = Weight \; of \; the \; Gripper \; + \; Weight \; of \; the \; piece \tag{1}$$

$$W_{Carry} \; = \; 3.14N$$

$$W_{Beam} = CylinderWeight + W_{Carry}$$

$$W_{Beam} \; = \; 5.10N$$

$$\sum M = 911.71Nmm$$

$$\sigma = \frac{M * c}{I} \tag{2}$$

From equation 2 Mc is the moment that it was determined as 17.018 Nmm [1]

$$I = \frac{b * h^3}{12} \tag{3}$$

I in is the second moment of area determined by the cylinder base dimensions assumed to be a rectangle

$$\sigma = 0.45MPa$$

With σ and the Sy [2] of the material the safety factor can be determined by

$$n_{Beam} = \frac{Sy}{\sigma} \tag{4}$$

$$n_{Beam} = \frac{276MPa}{0.45MPa}$$

$$n_{Beam} = 612.40$$

This safety factor n from equation 4 of the beam indicates that the weights that are going to be carried by the cylinder are safe, in this case a cylinder with lower dimension can be consider due to the high safety factor, but this is already the smallest cylinder available in the market with the characteristics required to extend 50 mm for the application, additional the space that is needed to attach the cylinder with other components must be taken in consideration.

Power screw When using power screws, it is essential to consider the potential deformations that may occur during their application. In this particular case, the weight that the power screw will carry in the Z-axis is of high importance. The design anticipates that the screw will bear the weight of several components, including the cylinder, the gripper, the object being moved, and additional structures necessary to ensure linear movement along the axis.

Screw specifics

- **Thread width** t=1 mm
- **Diameter with out the thread** D=6 mm
- **Weight to carry in Z axis** W= 4.90 N
- **Length** L= 300 mm
- **Screw material steel** Sy= 200 GPa [2]
- **Elastic module** E=200MPa [2]
- **Friction coefficient between the steel of the screw and the brass nut** u= 0.44
- **Angle of the thread** $\theta = 16.8°$

Safety factors

Shear strength

The data required to determine the power screw won't break while its operating, for this the safety factor has to be determined. From Figure 6. It can be seen the weights that are going to be carried by the screw additionally with the weights of the Z linear structure with out the rails that will be only as a path.

$$T_{Shear} = \frac{W}{A} \tag{5}$$

$$A = P * t$$

$$P = 2\pi D$$

$$T_{Shear} = 0.13MPa$$

$$n_{Shear} = \frac{0.7S_Y}{T_{Shear}} \tag{6}$$

$$n_{Shear} = 1.07e + 03$$

From equation 5 W refers to the weight caring by the power screw and A the area of contact, with this component the allowable safety factor from equation 6 can be obtained Equation2.

Compression

Figure 8. Type of buckling of the power screw

The force F that compress the screw is the weight of that all the Z axis is carrying

$$D_{Total} = D + 2t = 8mm$$

$$A = \frac{\pi * {D_{Total}}^2}{4} \tag{7}$$

$$\sigma = \frac{W}{A}$$

$$\sigma = \frac{W4}{\pi {D_{Total}}^2} = 0.0976MPa$$

From4 it can applied the same principal to get the safety factor for the compression.

$$n_{Compression} = \frac{Sy}{\sigma} = 2.049e + 03$$

The same method to obtain the safety factor 4 can be applied to obtain the safety factor for the case of compression [3].

Buckling

To determine if this deformation is critical for the screw the safety factor must be obtained following the formulas:

$$k = 1$$

$$E = 200GPa$$

$$I = \frac{\pi D^4}{64}$$

$$Pcr = \frac{\pi^2 EI}{L^2 k} \tag{8}$$

$$n_{Buckling} = \frac{Pcr}{W} = 899.038$$

Pcr from the Euler equation 8 is the critical buckling load [4] in this case due to the type of restrains a k must be taken into consideration, this equal to 1 as the worst case scenario [3].

Torque needed

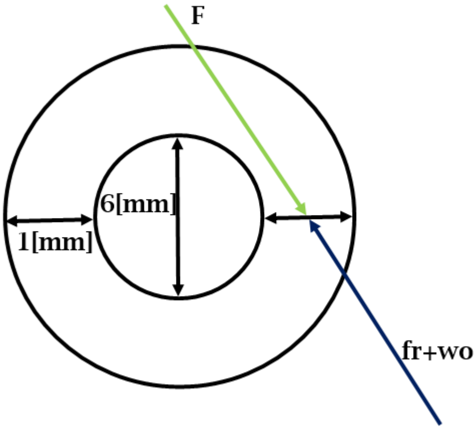


Figure 9. Forces applied upper view of the screw

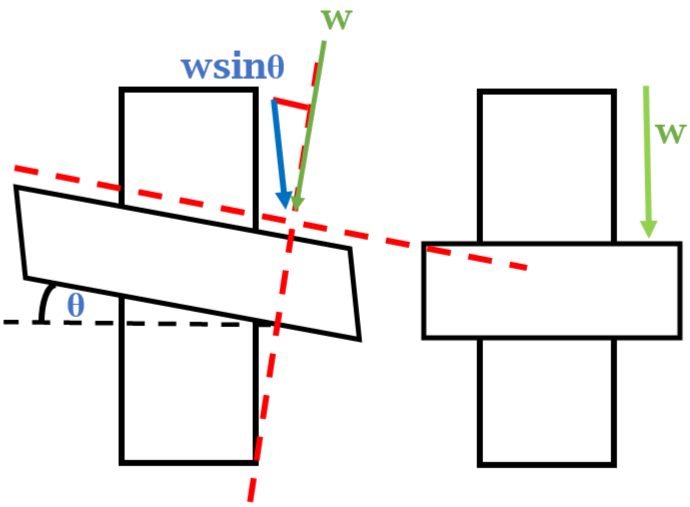


Figure 10. Forces applied lateral view of the screw

$$W_o = uW$$

$$fr = uWcos(\theta)$$

$$F = fr + W_o$$

$$\tau = F(\frac{D+t}{2}) = 16.84Nmm$$

As the all safety factors for shear, compression and buckling are higher than 1, the screw will carry the weight with out the possibility of breaking or having deformations, as they are high safety factors the dimensions of the power screw can be reduced, but as its a standard screw in the market, manufacturing a smaller screw will be more expensive and take more time.

Pulley

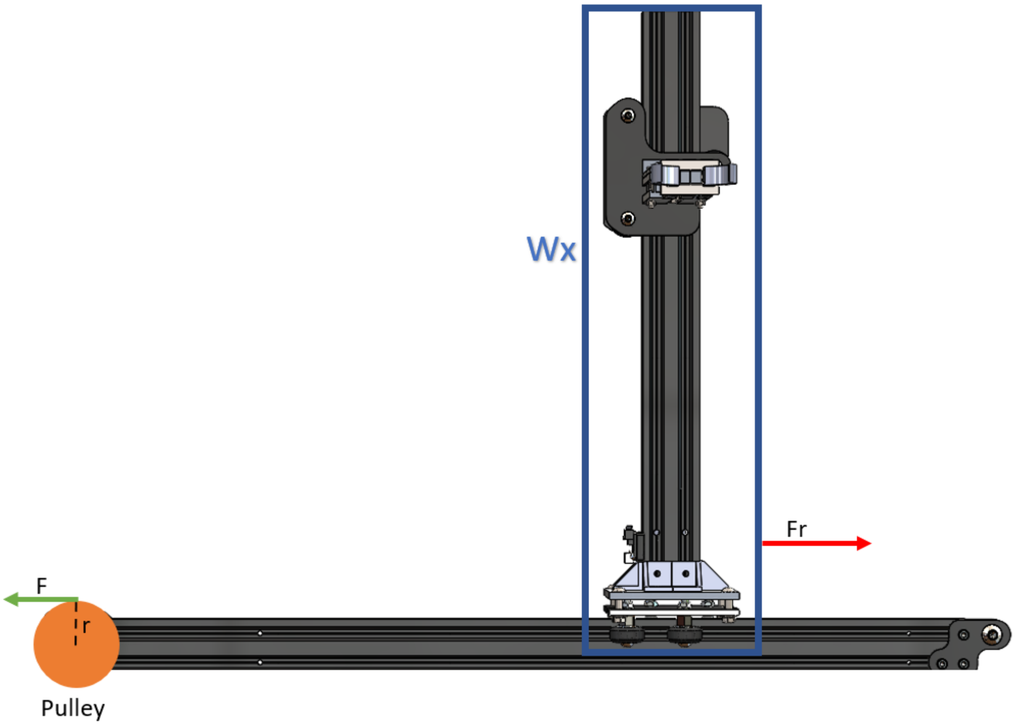


Figure 11. Pulley analysis situation, FBD

The radio of the pulley is a fixed characteristics due to the space the band has to pass through radio = 6mm, the motor angular velocity is set to 464 rpm distance set to travel 1 cm in the time t=1s and the mass that is going to carry is m=1.64Kg

$$V_{fo} = w_{ang} * \frac{2\pi r}{60}$$

$$aceleration = \frac{V_{fo}}{t}$$

$$F = m * a$$

$$\tau_{Pulley} = F * r = 2.9Nmm$$

Carrying station

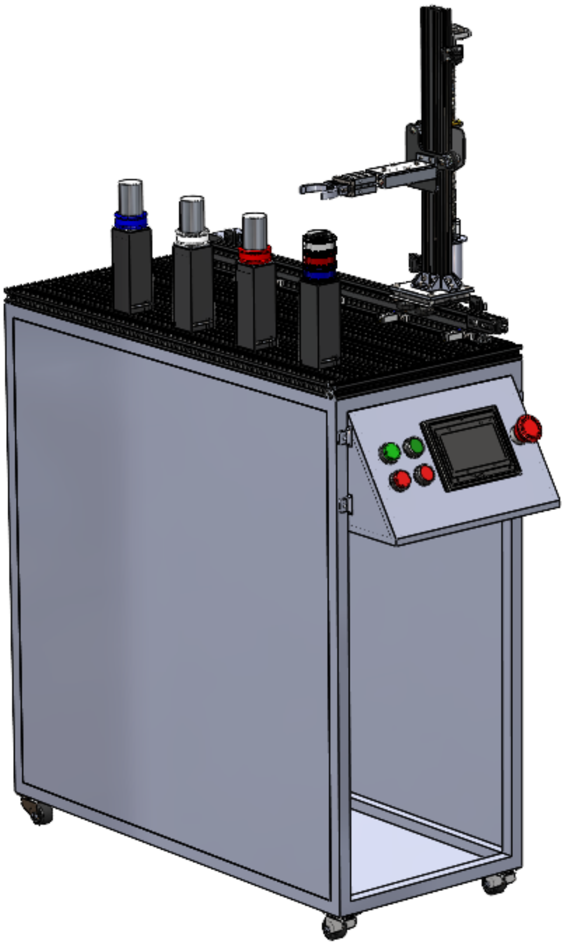


Figure 12. Carrying station

The carrying station, is where all the project is going to be placed on, this case called station can be referred to in Figure 12, the objective of this is to move the project and have space for connecting all the electronic design and have space for push buttons, indicators lights and the HMI so the user can manipulate and control the hole module.

1.5. Simulation

To understand where are the most critical spots in the structure, simulations are of interest to understand how the forces affect arm, in this case the deformation was the most important to be determined.

Buckling

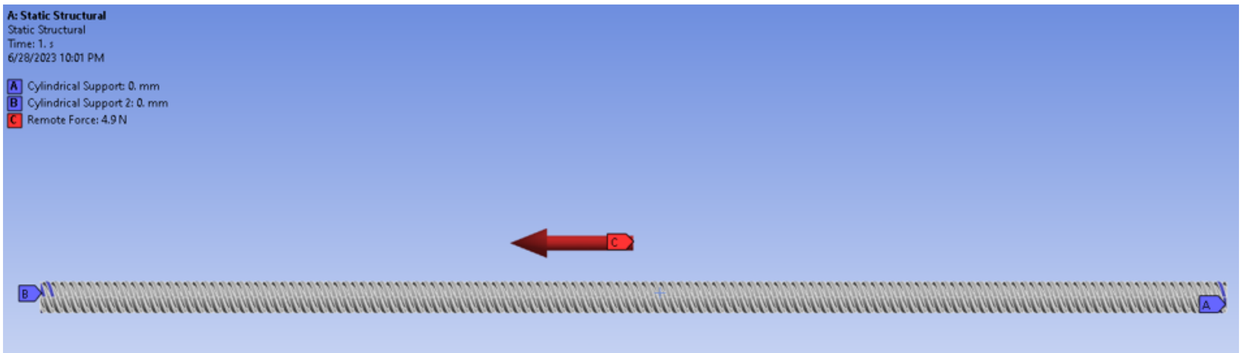


Figure 13. Boundary conditions

Boundary conditions in Figure 13 are the ones to consider having the most similitude with the real life scenario on how is working with this application.

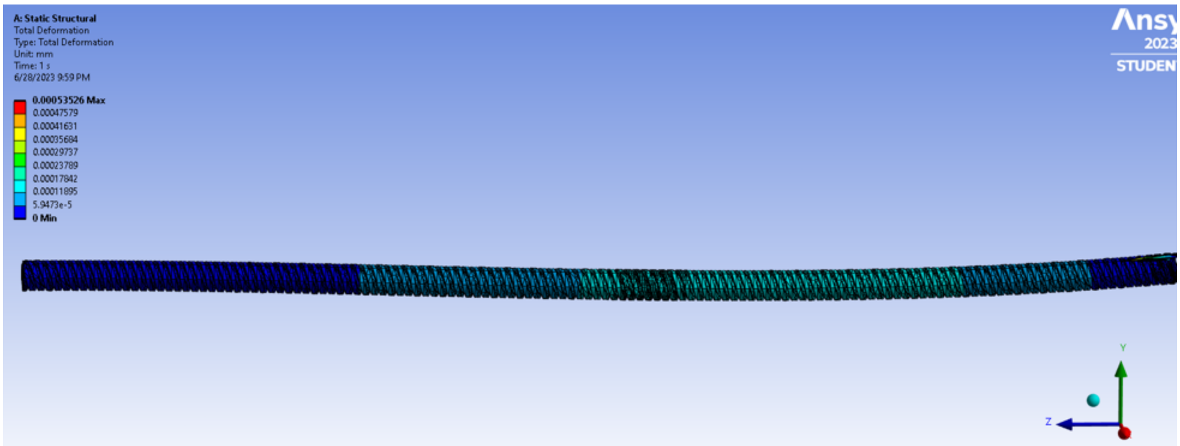


Figure 14. Buckling simulation in the power screw Z axis

Where it can be seen that the most crucial area of the power screw is actually in the middle on Figure 14, this is the case when the arm is completely extended in the Z axis, nevertheless the safety factors assured that this isn't going to be deformed in any way.

1.6. CAD 3D model

- **X Axis pulley mechanism**

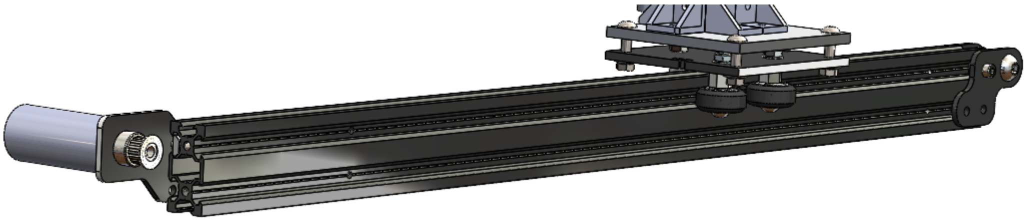


Figure 15. X axis pulley mechanism

- **Y axis mechanism pneumatic cylinder**

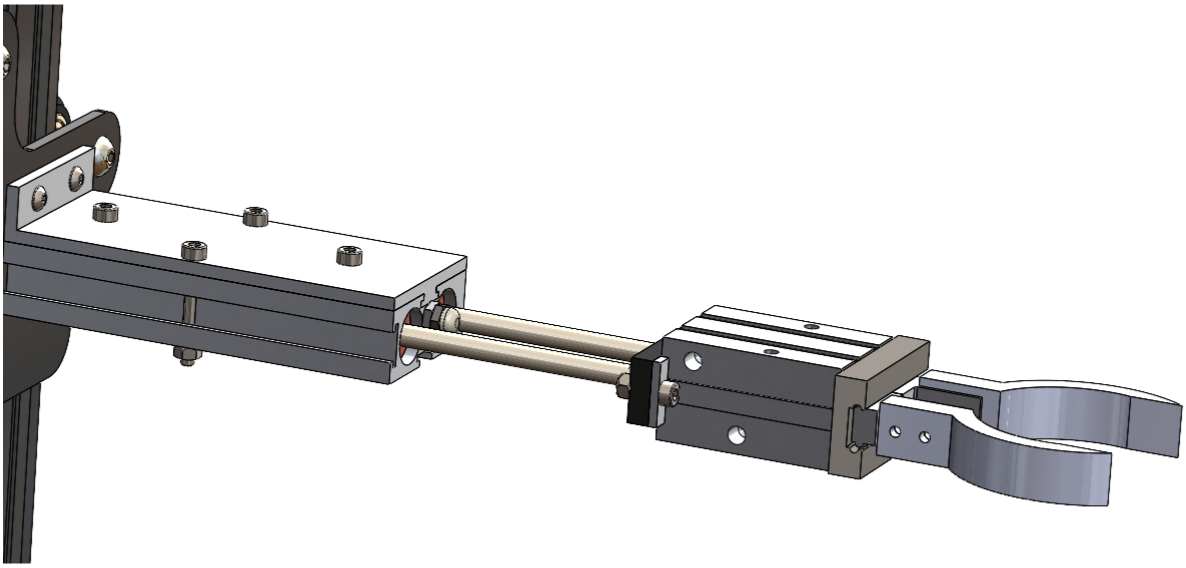


Figure 16. Y axis pneumatic cylinder

- **Z axis mechanism power screw**

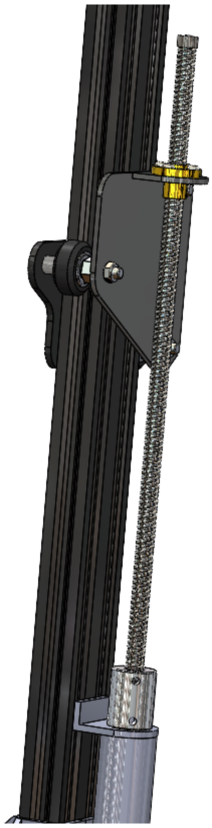


Figure 17. Z axis power screw mechanism

- **Gripper axis mechanism**

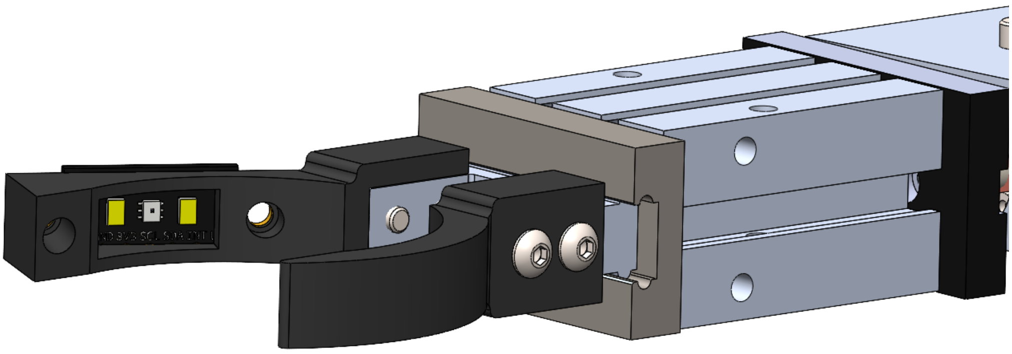


Figure 18. Gripper axis mechanism

Figure 15 illustrates how the pulley moves the mechanism in the X axis using a toothed belt. This belt is attached to the base of the structure shown in Figure 17, which incorporates a power screw mechanism for vertical movement along the Z axis. Figure 16 demonstrates how the cylinder is connected to the gripper, enabling the arm to manipulate objects along the Y axis. Specifically, it allows the gripper to grasp and place the object in its designated location.

In order to determine the color of each piece, the gripper is equipped with a specialized claw, as depicted in Figure 18. This claw includes a space for the color sensor to be positioned. Additionally, a hollowed box is employed to reduce environmental light interference during the color identification process.

1.7. Components review table

Table 2. Object specifications review table

Structure	Characteristic
Male Object	-45 mm External diameter -15 mm Height -38 mm Inner diameter -Red, white & blue color
Female Object	-38 mm External diameter -15 mm Height -30 mm Inner diameter Red, white & blue color

Table 3. Components that act under forces

Structure	Characteristic
Double acting cylinder	-Brand Tailonz -Material aluminium -Bore 10 mm -Stroke 50 mm -Working pressure 0-10 PSI -Dimension 110.24 mm x 41.9 mm -Weight 230 g
Parallel air gripper	-Brand Tailonz -Material aluminium -Bore 20 mm -Opening and closing stroke 10 mm -Working pressure 14.5-101.5 PSI -Dimension 67.3 mm x 38 mm -Weight 235 g
Power screw	-Thread width =1mm -Total diameter 8mm -Length 300mm -Steel material
Pulley	-Torque required to move the weight in X axis τ=2.9 Nmm with a velocity of 1 cm/s - radio of the pulley 6 mm - 400 rpm

On Table 2 are the object specification summarized, and on Table 3 are the mechanicals parts that requiered analysis to verify functionality.

2. Electronic & control design

2.1. Technical specifications

The characteristics of the electronic components, the reason why they are needed and functionality of what they are going to be developing in the station are specified in the Following Table 4

Table 4. Electronic components technical specifications

Components	Characteristics	Quantity
Color sensor	To detect red,white & blue colors in three different positions	3
Proximity sensor	Detect the presence of the arm in the stations positions	4
Limit Switch	Are for the boundays of the arm in the X and Z axis	4
Solenoid Valve	Open and close aire gaps for the pneumatic actuators, the gripper and the cylinder for Y axis	2
Micro Controller	2 to detect analog values that the PLC can't	2
Motor	Encoders to control speed and direction motion of the arm in X and Z axis	2
H-bridge	Allow the change of directions of the motors	1
HMI	Control the PLC and have a counting system	1
PLC	Receive sensor information and take desicion by sending pulses to the actuators.	1
I2C driver paths	Comunication for the same color sensor path coneted to the I2C protocol of the Microcontroller	1
Relay modules	Help the interaction between microcontrollers and PLC	14
Push butons	Activate manually the solenoid valves	2
Emergency button	Turn off the machine in case of malfunctioning	1
Lights	Indicators of the pneumatic actuators activation	2
Power Source	Supply all the electronic components	1

2.2. Electronic block diagram

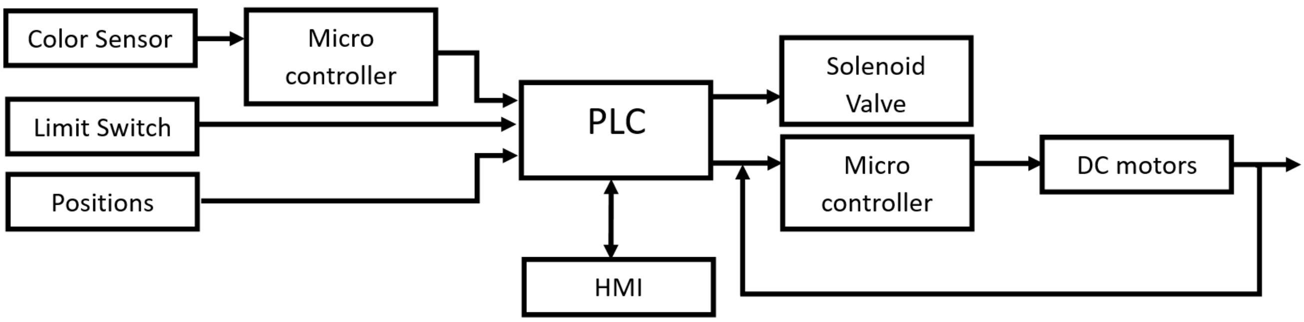


Figure 19. Electronic block diagram

The flow of how the components are going to be interacting between each other can be seen in Figure 19, this diagram indicates specifically which components interact with the PLC as inputs and which components are going to be controlled by as outputs.

2.3. Selection and design

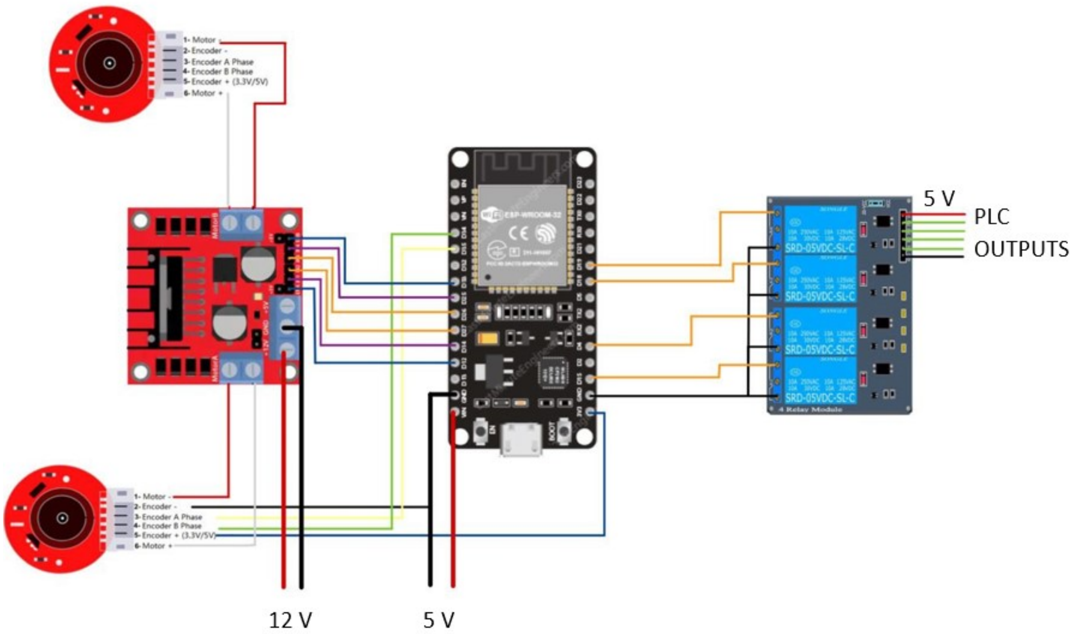


Figure 20. Schematic diagram for the control of the DC motors

In Figure 20, the connection for controlling the DC motors can be observed. The ESP32 plays a crucial role in controlling the motor speed [5] by utilizing the L298N H-bridge to facilitate direction changes. The PLC outputs send signals to the relay modules, which function as switches, closing the circuits for the ESP32, this is because the PLC work with higher voltages that can damage the operation of the micro controller.

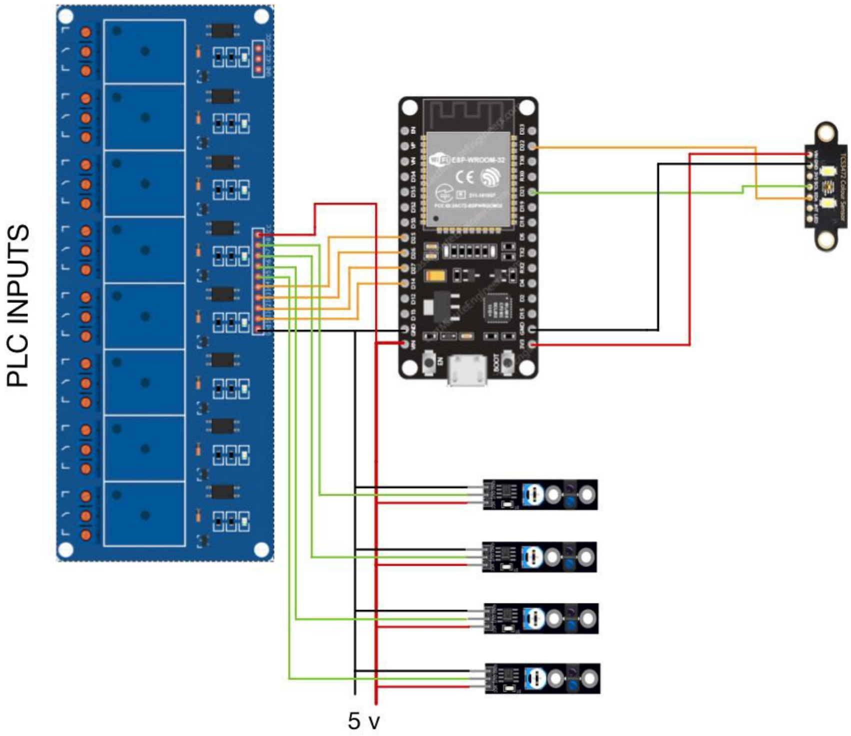


Figure 21. Schematic diagram for the color detection and position

In Figure 21, the design for color detection and positions of the stations is shown. The ESP32, receives the data from the color sensor TCS3472 . The TCS3472 plays a crucial role in this circuit by sending RGB Analog detectors signals, as the PLC does not have Analog inputs instead of using additional expensive modules for analog readings, this circuit was designed.

The proximity sensors are not directly connected to the ESP32. Instead, they share a common 5V power source and are connected to an 8-channel relay module. The relay module is responsible for sending signals to the PLC inputs because this components don't work with the same voltages. The proximity sensors detect the arm's position as it reaches the stations, enabling the arm to determine when to stop in the X-axis and place the piece in the designated station.

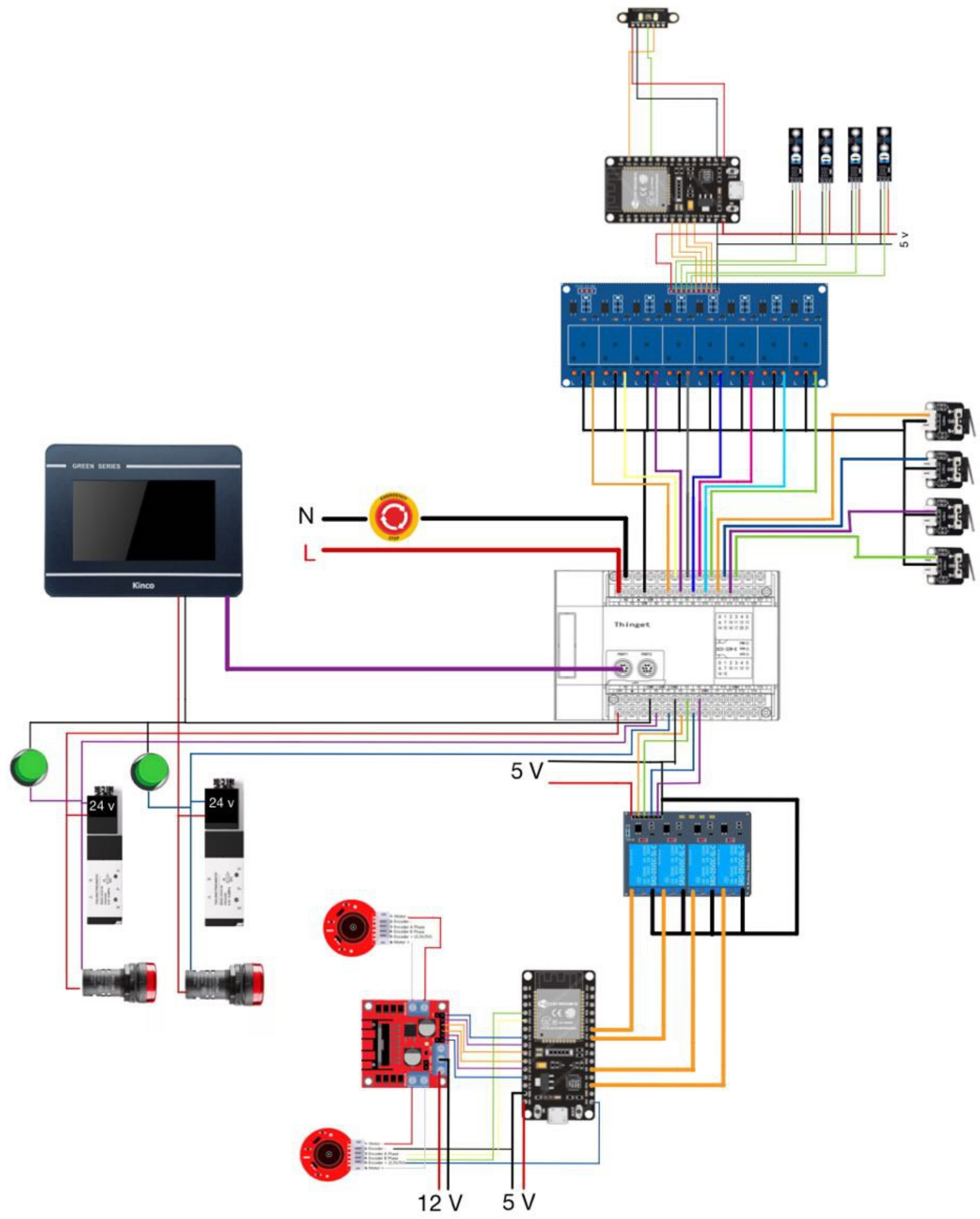


Figure 22. Complete schematic diagram

In Figure 22, the complete connection of the entire system can be observed, showcasing the integration of various components. Building upon the previously mentioned schematic parts from Figure 21 and Figure 20, this comprehensive diagram includes additional elements crucial to the system's functionality.

To ensure precise control and positioning of the arm, limit switches are incorporated into the design. These limit switches act as indicators, signaling the boundaries of the arm's movement and preventing it from exceeding its predetermined range. By detecting these limits, the system can accurately determine when to halt the arm's motion in the X-axis, ensuring precise placement of the piece at the designated station. Furthermore, the system utilizes solenoid valves, which play a vital role in manipulating the actuators responsible for grabbing and manipulating the piece. These solenoid valves effectively control the flow of compressed air, enabling the actuators to move and perform their intended tasks with precision.

It is worth noting that both the limit switches and solenoid valves work in direct conjunction with the PLC. This close integration ensures efficient communication and coordination between these components and the overall system. By operating within the voltage tolerances of the PLC, these components seamlessly interact with the control signals provided by the PLC, allowing for seamless control and coordination of the entire automation process.

Table 5. Power source analysis

Components	Characteristics	Quantity
Color sensor	-Functioning voltage 3.3 V DC -20mA	1
Proximity sensor	-Functioning voltage 5 V DC -20mA	4
Micro controller	-5 V DC input -250 mA	2
Motor sensor hall	-3.3 V DC -20mA	1
Motor	-12 V DC -2A	2
Relay	- 54 V DC -80 mA	12
H-bridge	-12 V DC -20 mA	1
Total	-5600mA	

With the complete sketch and all the components already selected, it is possible to make a power source analysis. the components that need a DC power source can be seen in Table 5, where the DC power source is needed, the components that need 3.3 V, as seen Figure 22 are connected to the 3.3 V output source of the micro controller, the voltage needed is 5V for and 12V just for the DC motors and H-bridge direction controller, overall a power source with two exist of 5V and 12V is necessary with a current consumption of 5600 mA in the case that all the components are working at the same time.

The other components as the PLC is required to be connected to 110 AC directly and provide 24V for the solenoid valves and the HMI.

2.4. Control algorithms implementation

To understand more easily the implementation of the algorithms, flow diagrams are the best option to demonstrate the logic of how is going to be working the code of both of the ESP32. The first code is for the motor control, for the speed and direction.

Speed & direction control code ESP32

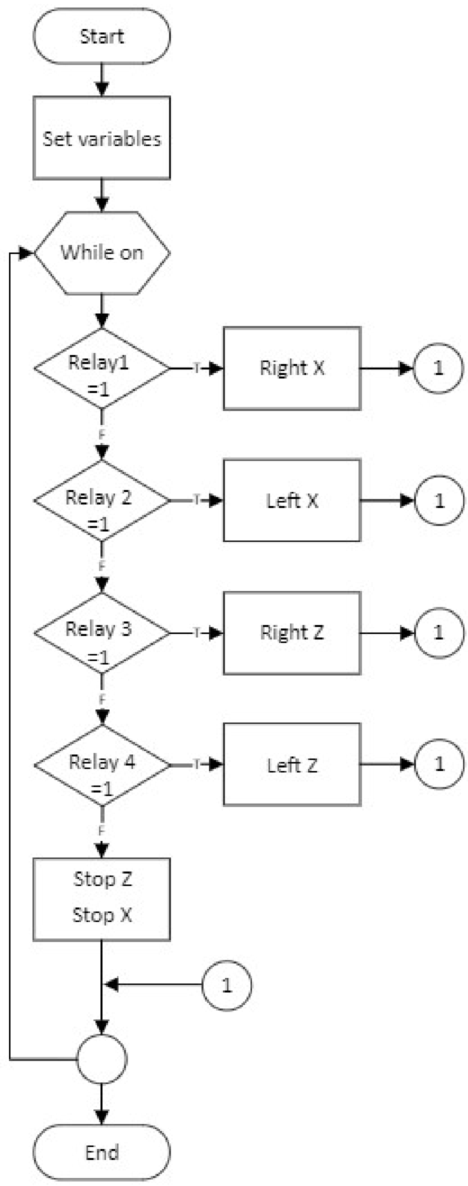


Figure 23. Flow diagram of the speed and direction control

In Figure 23 it can be appreciated how the ESP32 controls the directions, but each of the functions:

- Right X
- Left X
- Right Z
- Left Z
- Stop X
- Stop Z

must be specified apart.

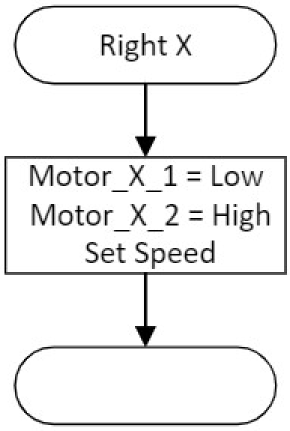


Figure 24. Flow diagram right X function

Figure 24 specifies which poles of the X axis motor must be turned positive and negative by declaring it High and Low and additionally, the speed is set to an specific value.

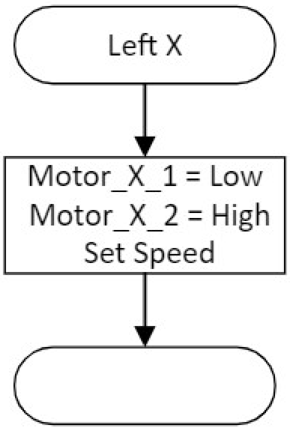


Figure 25. Flow diagram left X function

Figure 25 is the opposite of the previous flow diagram in the right direction this way when the high and low statements are changed, then direction will change to the opposite.

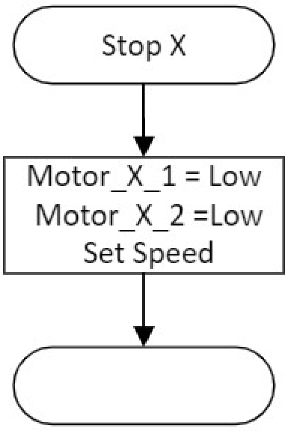


Figure 26. Flow diagram stop X function

Figure 26 is the condition when is going to be stopped the motor, in Figure 23 it can be noted that this motor will stop when the relay doesn’t close the circuit.

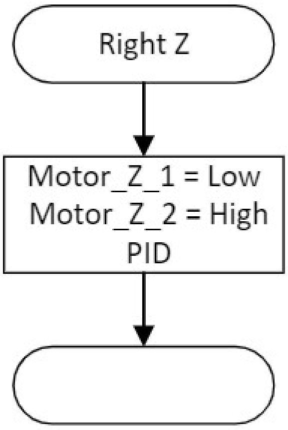


Figure 27. Flow diagram right Z function

Figure 27 specifies which poles of the Z axis motor must be turned positive and negative by declaring it High and Low and additionally, the speed calls another function which contains the PID control.

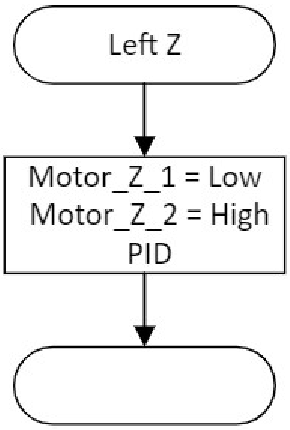


Figure 28. Flow diagram left Z function

The Left Z function of Figure 28 is the opposite of the Right Z which changes the direction of the motor, and calls the same PID speed control function.

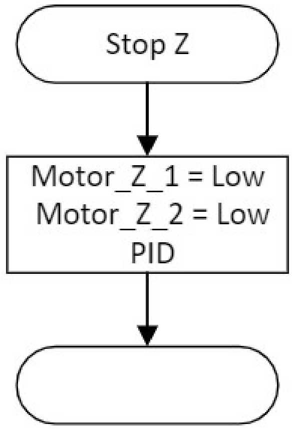


Figure 29. Flow diagram stop Z function

Figure 29 refers to the logic of when is going to be stopped the motor of the Z axis, as the same for the function to stop the X axis motor this is going to be activated all the time, and only while the relay activates the direction this will are false, the difference with the function to stop the X axis motor is the PID which is called to reset the values.

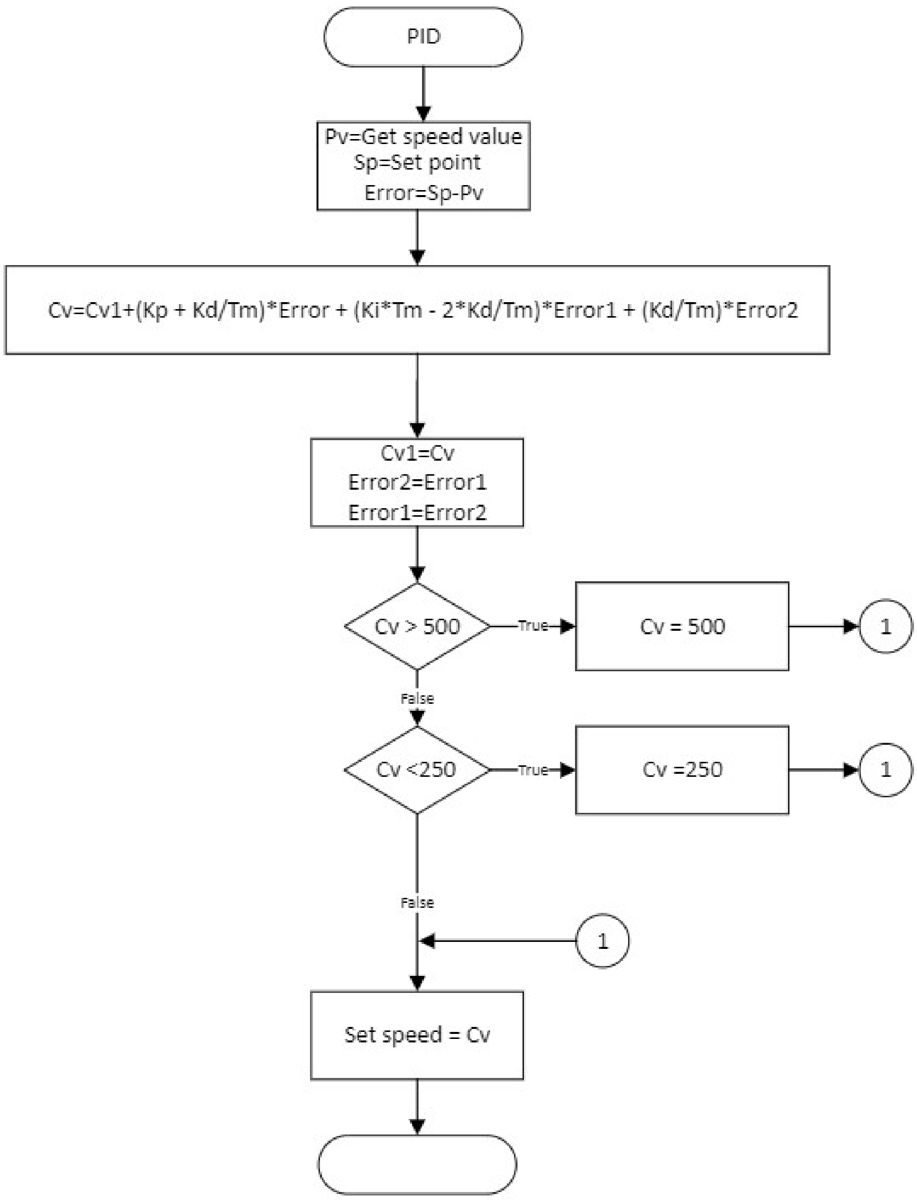


Figure 30. Flow diagram PID function

The Figure 30 is an iterative method in which the encoder of the motor send pulses that interpreted by the micro controller to know at what actually speed the motor is going, this would be the variable Pv , the Sp set point variable is the speed that is set and the motor has to reach. then comes the formula to vary the velocity with Kp, Ki and Kd. to get this values the motor of the X axis had to be analyzed.

A data-set was obtained from the speed of the motor in rpm increasing constantly in a period of time, the response of the motor can be seen in Figure 31.

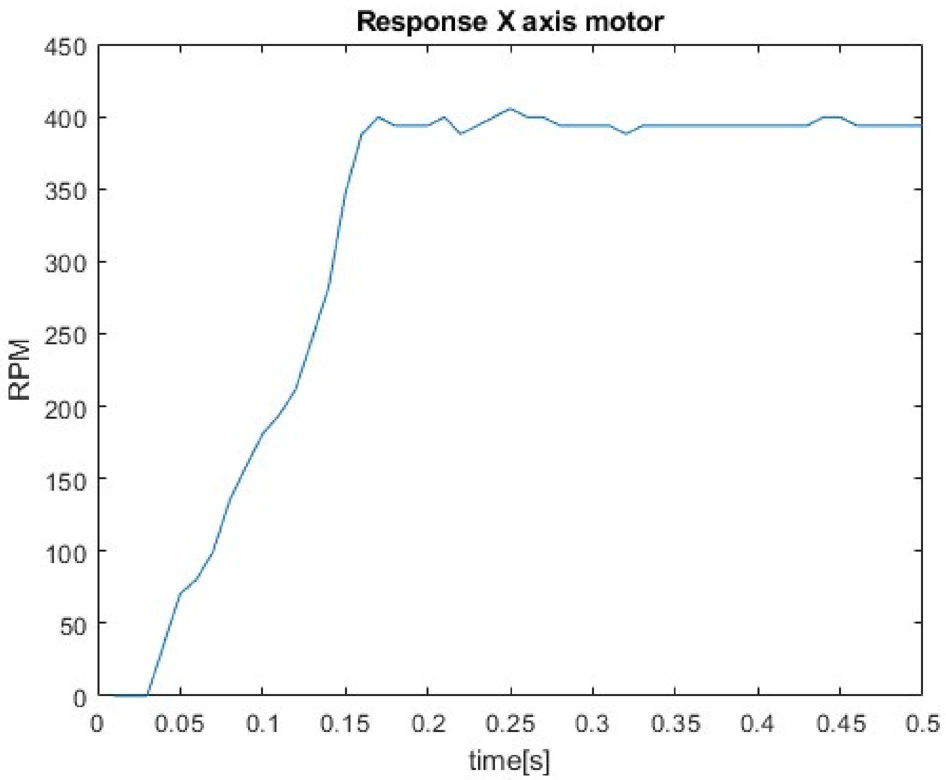


Figure 31. Response X axis motor

The Ziegler-Nichols rules for tuning PID controllers was applied.

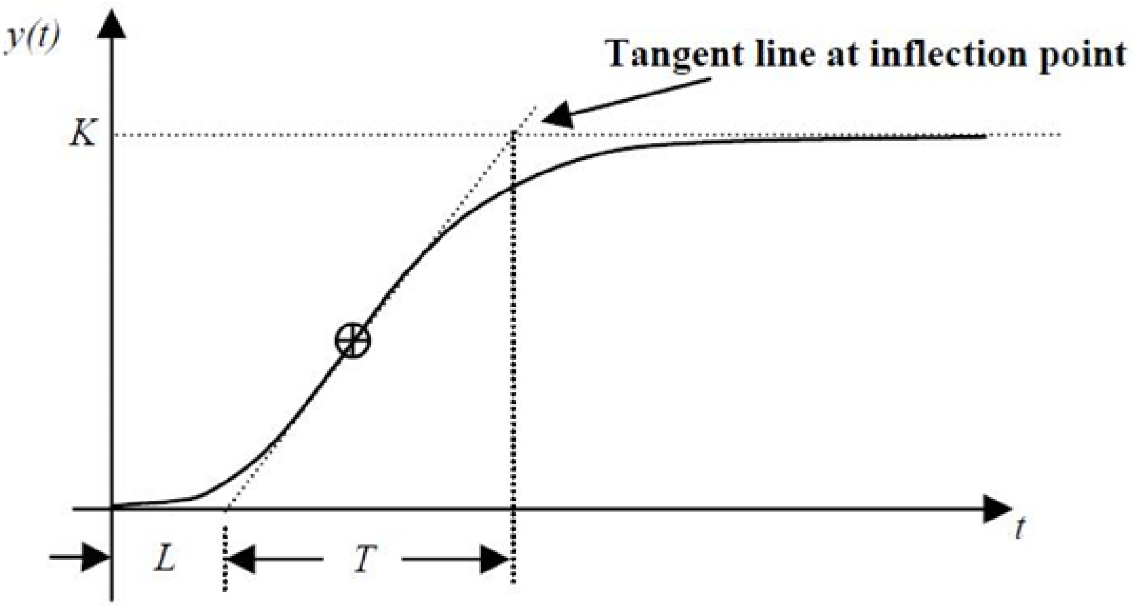


Figure 32. Response curve of Ziegler-Nichols method

From the example on Figure 32 L T and K values are obtained from the real case of the X axis motor on Figure 31

$$L = 0.05$$

$$T = 0.12$$

$$K = 395$$

Then the formulas to get Kp , Ti and Td are obtained [6]:

$$kp = 1.2\frac{T}{KL} \tag{9}$$

$$Ti = 2L \tag{10}$$

$$Td = 0.5L \tag{11}$$

$$kp = 1.8228e - 05$$

$$Ti = 0.1000$$

$$Td = 0.0250$$

The values obtained are the ones that are going to be used to modify the velocity with the feedback from the sensor of the encoder of the motor 3. using the main formula from Figure 30 where is applied where the PID is applied in the micro controller [7]

Color sensor code ESP32

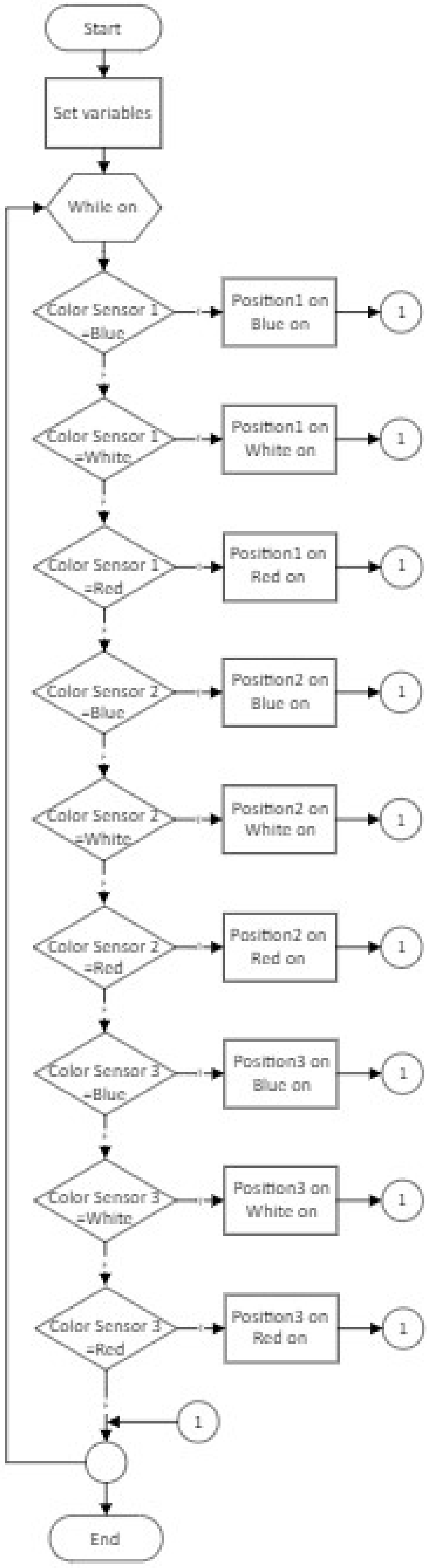


Figure 33. Flow chart color detection ESP32

The logic of the code is a loop where 3 sensors are detecting RGB values, once the values are in a range where the color of the pieces are detected the in classifies the color into blue , red or white, additionally the sensor that detect close a relay to indicate the PLC in which positions in that color.

2.5. HMI interface

The HMI has to be the most simple to be understood to be controlled, there will be two modes to use the prototype and one part to count how many pieces have been classified.

- Manual
- Automatic
- Counting

Figure 34. Initial frame HMI

The initial screen on Figure 34 will have all the modes which the user can choose by user access to be determined.

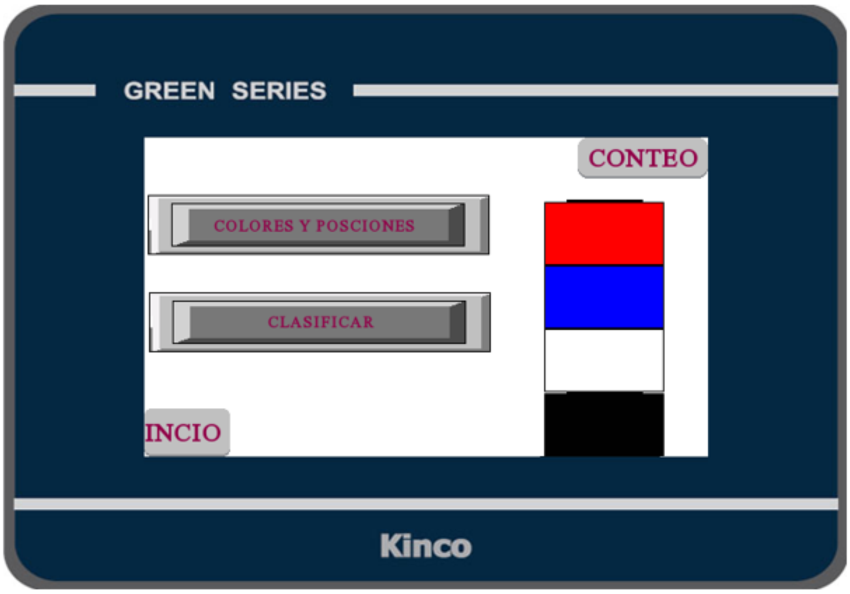


Figure 35. Automatic frame HMI

The automatic mode will be able to identify the color and the positions of each piece , the buttons can be seen on Figure 35, one the colors and positions are identified it can be seen on the right how are identified by the sensors, then the robotic arm can move by using the start button to just see how the robot pick and places in the assigned stations, if the user wishes to stop the process then it can press the stop button to pause the arm and reset the process.

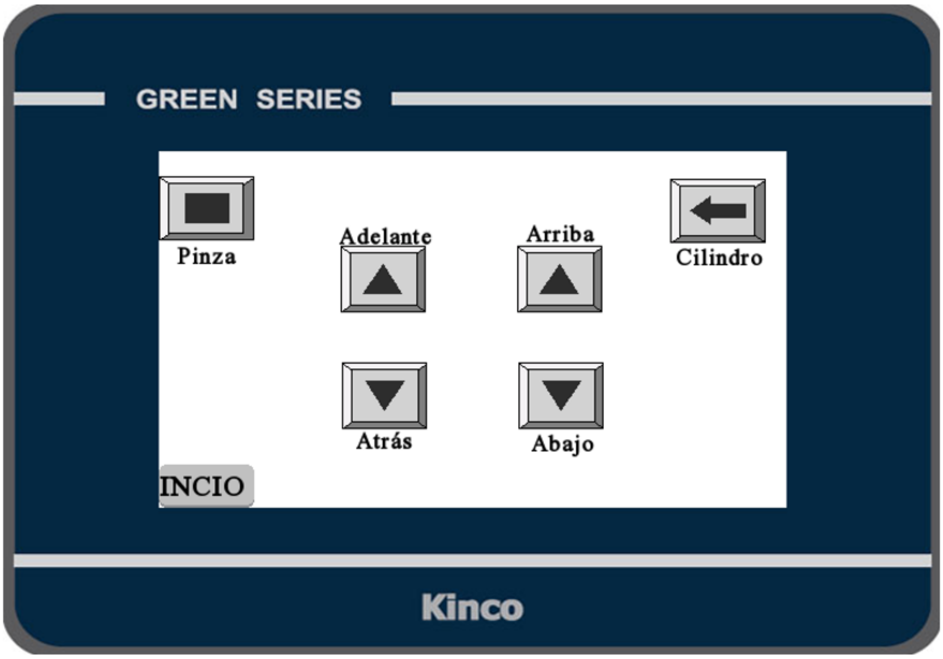


Figure 36. Manual frame HMI

Manual mode will allow the user to control manually the position and robotic arm, with the up, down,left and right arrows in the middle of the screen, while to control the pneumatic actuators, on the right top side the cylinder can be activated once pressed and retracted shile pressing it again. on the left top side square button allows the gripper to open and close like a toggle button. this can be appreciated on Figure 36

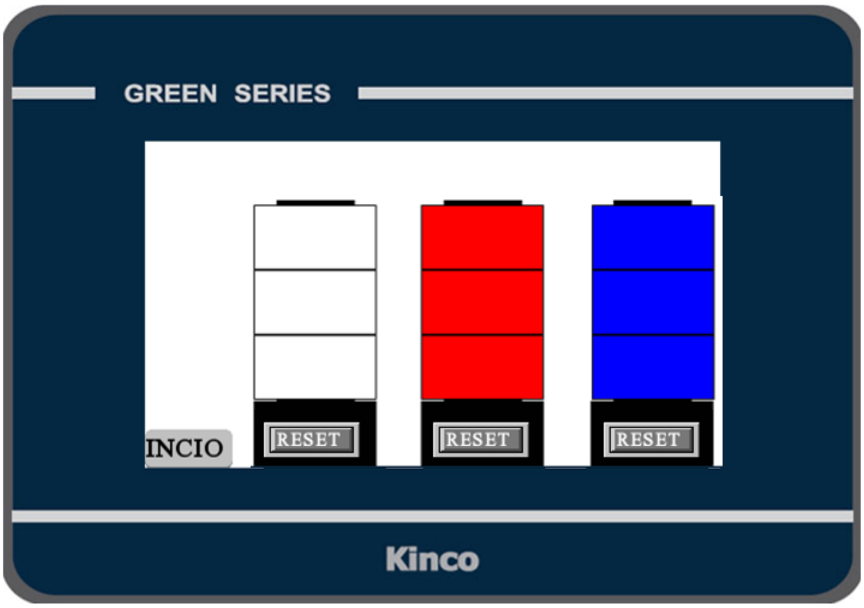


Figure 37. Counting frame HMI

The counting frame on Figure 37 is the last step where it will show how many pieces have been classified in each station. this counting frame is important so the user knows why the robot shouldn't allow to make an automatic classification, or to have the knowledge of the storing in real life aplications of industries.

2.6. Components review table

Table 6. Direct interaction with the user components

Components	Characteristics	Quantity
HMI	-Modbus,Serial,USB -Color -4.3” -GL043E -24v	1
PLC	-PLC Xinje XC3-24RT-E -90-260VAC -14 inputs -10 outputs -2NPN+8relay -Modbus ASCII -RTU,RS232	1
Solenoid Valve	-Tailonz 4v210-08 -Pneumatic 5/2 -24 v	2
Push butons	-Green and red color -NO (Normally Open)	2
Emergency button	-Mushroom Shaped -NC (Normally closed) -NO (Normally Open)	1
Lights	-Red Color -Blue Color -24 v	2

Table 7. Micro controller interaction components

Components	Characteristics	Quantity
Color Sensor	-Alinan TCS34725 -Color Recognition RGB -Infrared -I2C communication -Functioning voltage 3.3 v -20 mA	1
Proximity Sensor	-TCRT5000 -Infrared reflection sensor -Detection range 0.1 mm /25 mm -Functioning voltage 5 v -20 mA	4
Limit Switch	-Rated load AC 250 AC	4
Micro Controller	-ESP32 -5 inputs only pins -33 input/output pins -3.3 v output -5 v input 250 mA	2
Motor	-12 v 2 A Motor -3.3 v 20 mA Encoder	2
H-bridge	-L298N -12v 20 mA	1
Relay Modules	-80 mA -5 v	12
Power source	-12v -5v -5600mA	1

In Table 6 & 7 are specified the characteristics as Serial codes, working voltages and maximum current consumption of each component , adding up all the current requirements with the assigned voltage then it is required a 12v 2 A and a 5v 2 A power supply for all the project, the PLC has a AC power supply directly and the HMI, solenoid valves and light indicators work with the 24 v output of the PLC.

REFERENCES

[1] R. G. Budynas, J. K. Nisbett, y J. E. Shigley, *Normal Stresses for Beams in Bending*. McGraw-Hill, 2008, ch. 3-10, p. 90.

[2] F. P. Beer, J. E. Russell Johnston, y E. Elliot R, *Momentos de inercia de áreas compuestas*. McGraw-Hill, 2007, ch. 9.7, p. 487.

[3] J. M. Gere y B. J.Goodno, *Summary of Results*. Cengage Learning, 2012, ch. 11, p. 928.

[4] J. A. Collins, H. Busby, y G. Staab, *Columns with Other End Constraints*. John Wiley Sons, 2010, ch. 2, p. 38.

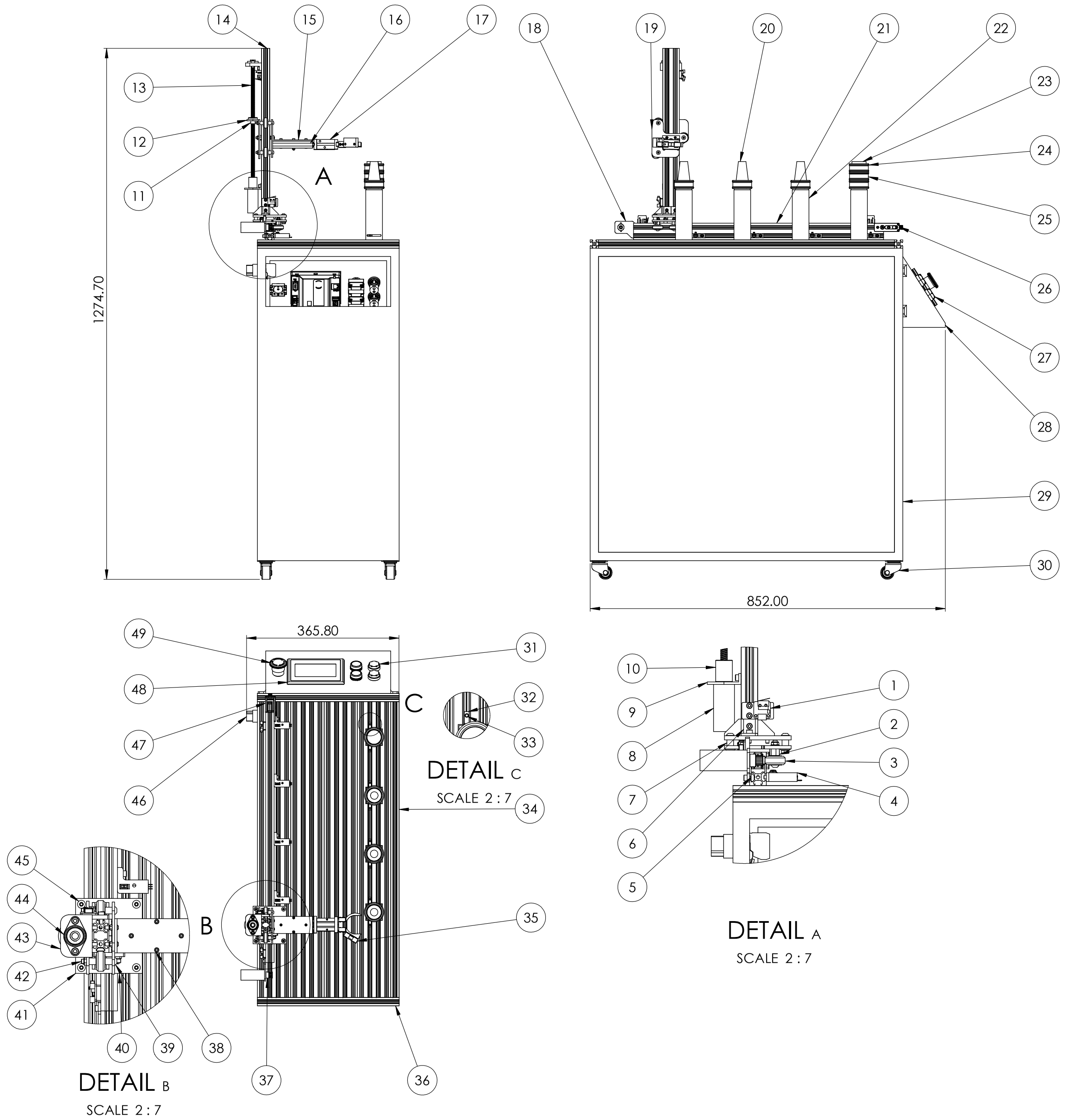
[5] I. Saleh, A. A. Bature, S. Buyamin, y M. A. Shamsudin, "Speed control of a bldc motor using artificial neural network with esp32 microcontroller based implementation," in *Control, Instrumentation and Mechatronics: Theory and Practice*. Springer, 2022, pp. 358–368.

[6] K. Ogata, *Reglas de Ziegler-Nichols para sintonizar controladores PID.* Pearson, 2010, ch. 8, p. 570.

[7] I. A. R. Ruge, "Metodo basico para implementarun controlador digital pid en unmicrocontrolador pic paradesarrollo de aplicaciones abajo costo," *Robots Argentina*.

Appendix A

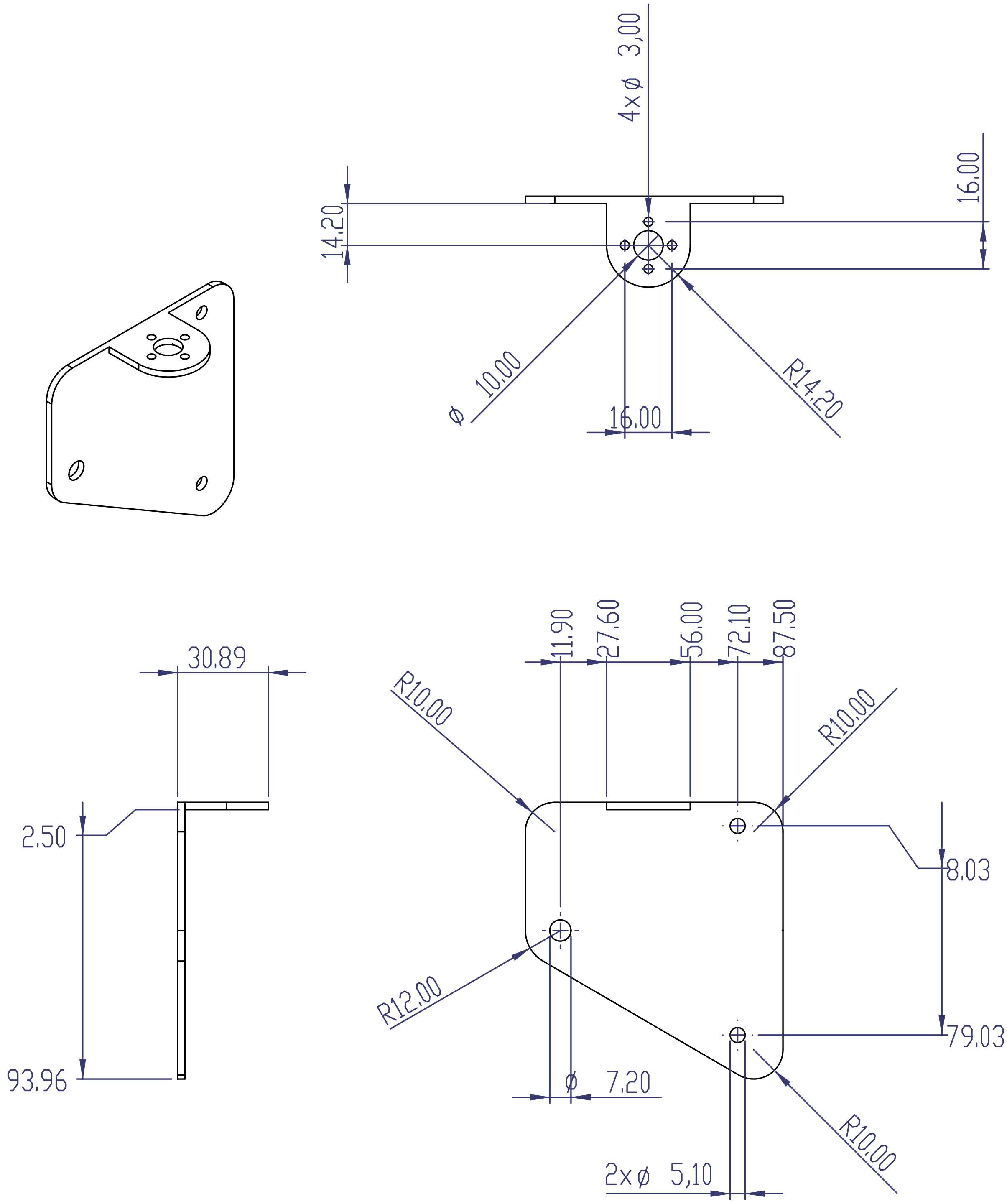
Mechanical Drawings



TECNICAL SPECIFICATIONS	
WEIGHTAPROX.	71.113kg
HEIGHT	1274.7mm
WIDTH	365.8mm
DEPTH	852mm
ALIGNMENT	5V DC 12V DC

POS	ZONA	DENOMINACIÓN	CANT	MATERIAL	PLANO/NORMA	OBSERVACIONES
49	1D	EMERGENCY MUSHROOM BUTTON	1			240 V AC
48	1D	HMI	1			KINCO 4.3" GL043E
47	1D	TOOTHED BELT	1	RUBER		1400mm
46	1E	ON /OFF SWITCH	1			240 V AC
45	1E	M4 HEXOGONAL BOLT	4	STAINLESS STEEL		16mm
44	1E	POWER SCREW COUPLING BEARING	1	STEEL		
43	1E	COUPLING BEARING HOLDER	1	PLA	D03-113	
42	1F	SECURITY NUT	19	STAINLESS STEEL		M4
41	1F	X AXIS BELT ATTACHMENT	1	STAINLESS STEEL	D03-112	
40	1F	CNC PROFILE ATTACHMENT	1	STAINLESS STEEL	D03-111	
39	2F	M4 HEXOGONAL BOLT	3	STAINLESS STEEL		40mm
38	2F	M3 HEXOGONAL BOLT	4	STAINLESS STEEL		20mm
37	2F	TOOTHED PULLEY	1	ALUMINUM		6 mm DIAMETER
36	3F	CNC PROFILE 20x20	2	ALUMINUM		BLACK COLOR 80mm
35	3E	COLOR SENSOR GRIPPER	1	STAINLESS STEEL	D03-110	
34	3E	CNC PROFILE 20x80	4	ALUMINUM		BLACK COLOR 710mm
33	3D	GRUB SCREW	6	STEEL		3 mm M4
32	3D	L CNC COUPLING	6	STEEL		
31	3D	PILOT LIGHT	2			GREEN COLOR
30	6D	WHEEL	4			70 mm DIAMETER
29	6C	CARRYING STATION	1	STEEL	D03-109	
28	6C	CONTROL PANEL	1	STEEL		
27	6C	PUSH BUTTON	2			GREEN COLOR
26	6B	PULLEY TENSOR	1	ALUMINUM		
25	6B	FEMALE OBJECT PART	1	PLA	D03-108	
24	6A	MALE OBJECT PART	1	PLA	D03-107	
23	6A	STACKING STATION	1	PLA	D03-106	
22	5A	HOLOWED PROFILE 40X40	1	ALUMINUM		BLACK COLOR 30mm
21	5A	CNC PROFILE 20x40	1	ALUMINUM		BLACK COLOR 600mm
20	4A	PNEUMATIC GRIPPER	1	ALUMINUM		
19	4A	Z AXIS CYLINDER HOLDER	1	STAINLESS STEEL	D03-105	
18	3A	X AXIS MOTOR HOLDER	1	STAINLESS STEEL	D03-104	
17	3A	PNEUMATIC GRIPPER	1	ALUMINUM		
16	3A	PNEUMATIC CYLINDER	1	ALUMINUM		
15	2A	CYLINDER HOLDER	1	STAINLESS STEEL	D03-103	
14	2A	CNC PROFILE 20x40	1	ALUMINUM		BLACK COLOR 400mm
13	1A	POWER SCREW	1	STEEL		
12	1A	Z AXIS POWER SCREW NUT HOLDER	1	STAINLESS STEEL	D03-102	
11	1B	POWER SCREW NUT	1	BRASS		
10	4D	POWER SCREW CONETION	1	ALUMINUM		
9	4D	Z AXIS MOTOR HOLDER	1	STAINLESS STEEL	D03-101	
8	4E	DC MOTOR	2			12 V DC ENCODER
7	4E	Spacer	11	ALUMINUM		8mm
6	4E	M4 HEXOGONAL BOLT	31	STAINLESS STEEL		10mm
5	4E	CNC PROFILE M4 NUT	23	STEEL		
4	5E	PROXIMITY SENSOR	4			TCRT5000
3	5D	CNC PROFILE MOVEMENT BEARING	7			
2	5D	CALIBRATION SPACER	3	ALUMINUM		
1	5D	LIMIT SWITCH	4			240 V

UIDE	INGENIERÍA MECATRÓNICA	DIB. PROAÑO S.	26/05/2023
		DIS. PROAÑO S.	26/05/2023
		REV. PILCO A.	28/05/2023
STORAGE STATION TO CLASSIFY OBJECTS ACCORDING TO THEIR COLOR		D03 - 002	ESCALA: 1:7



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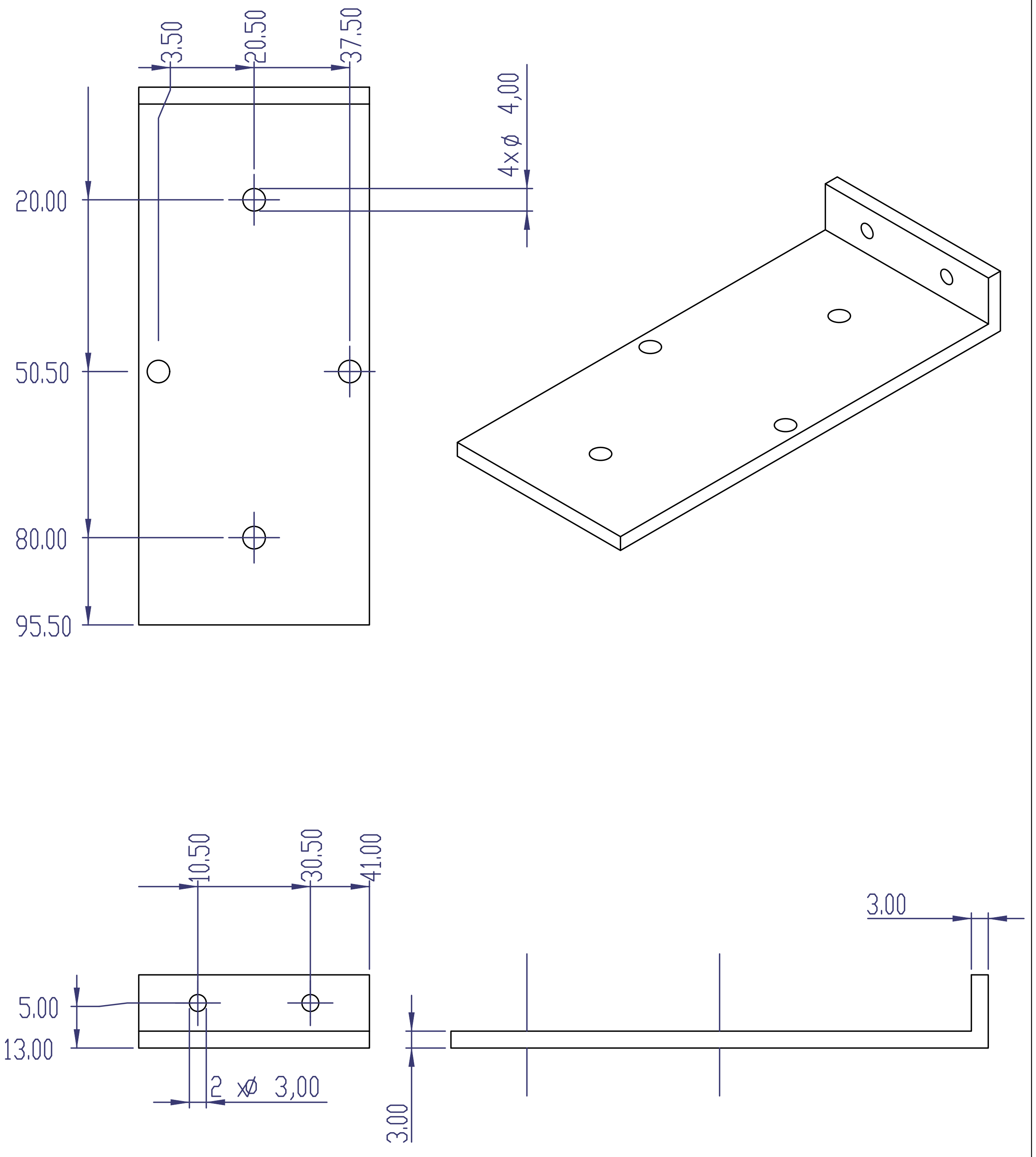
Z AXIS POWER SCREW NUT HOLDER		D03 - 102	



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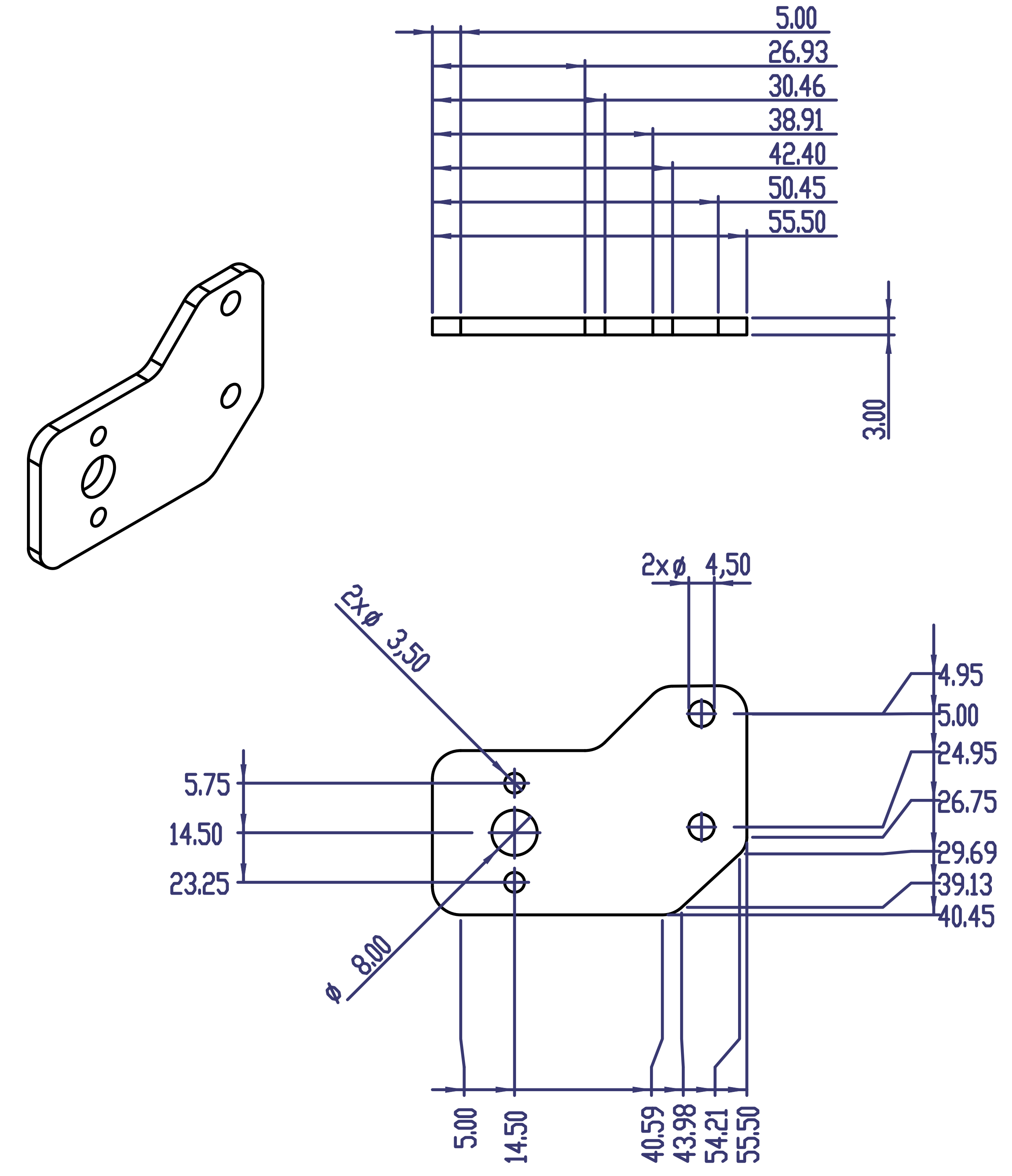
CYLINDER HOLDER		D03 - 103			



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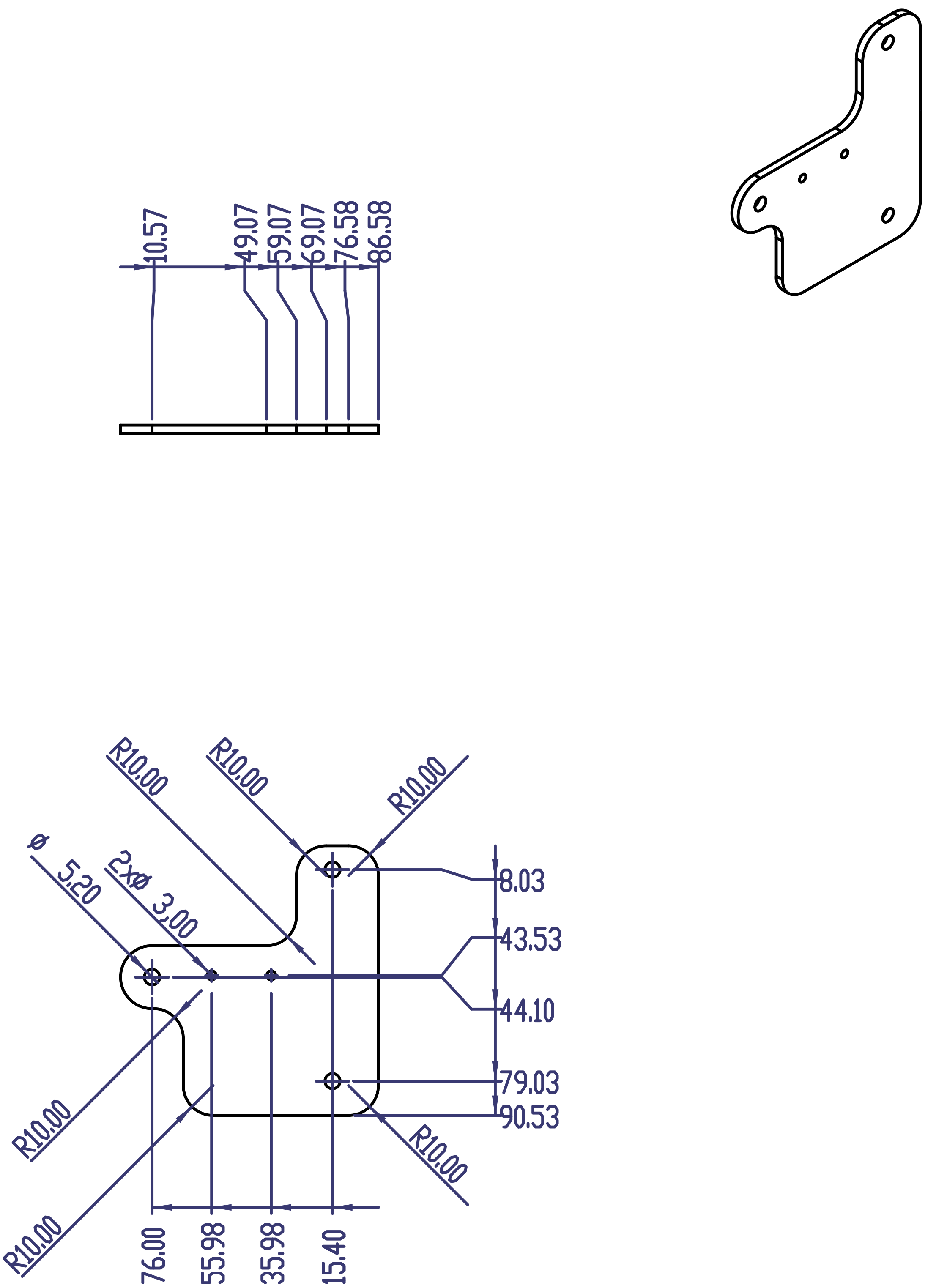
X AXIS MOTOR HOLDER		D03 - 104		



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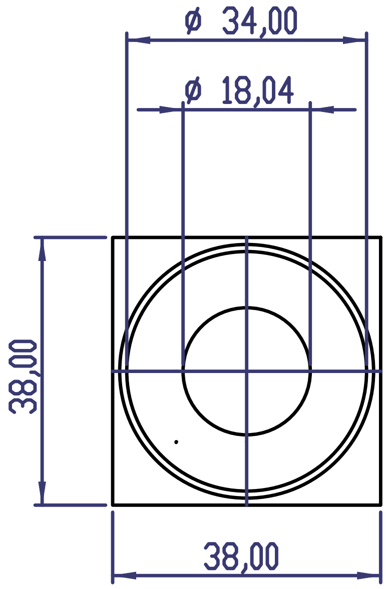

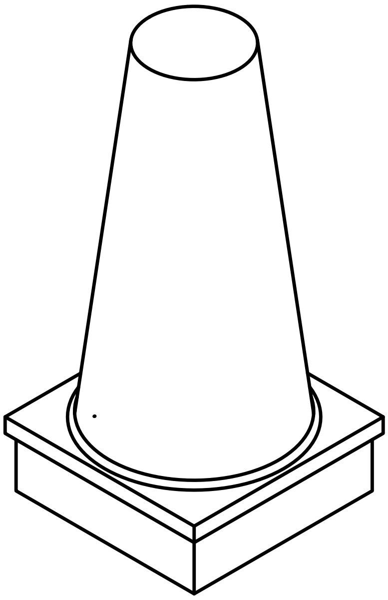

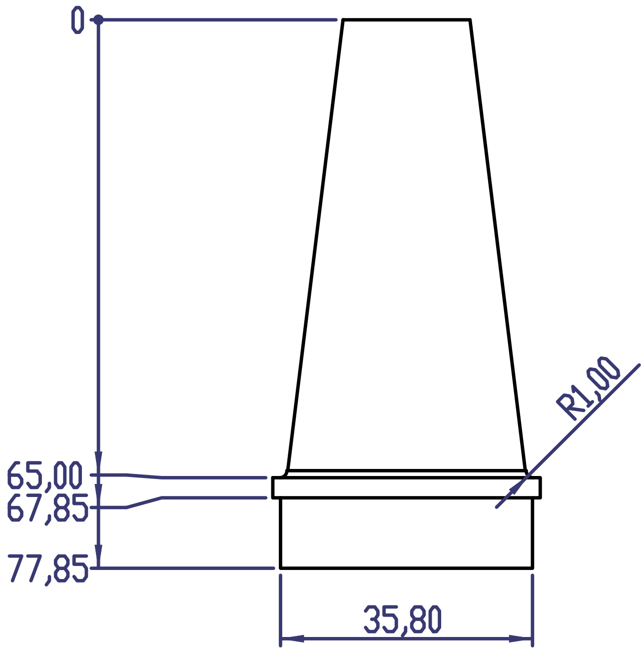

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TEMPERATURA DE EXTRUSIÓN: 215 C°
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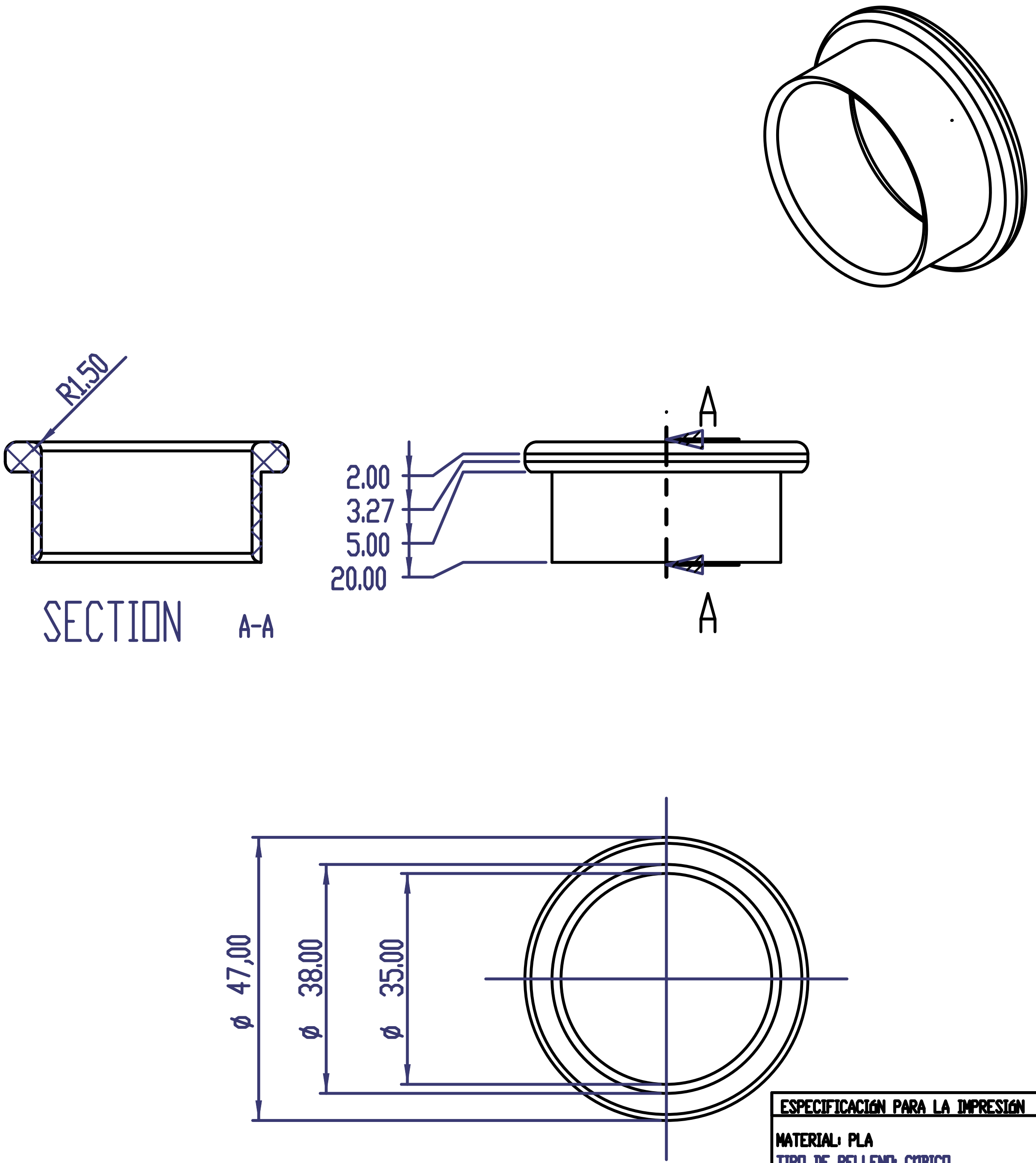

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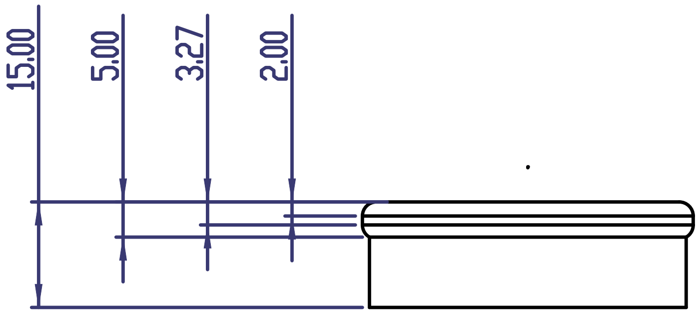

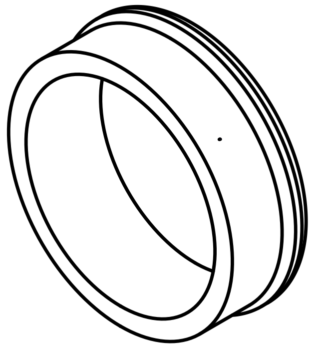

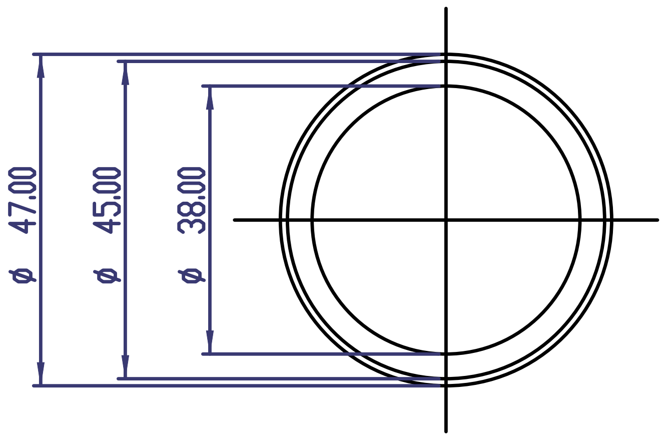

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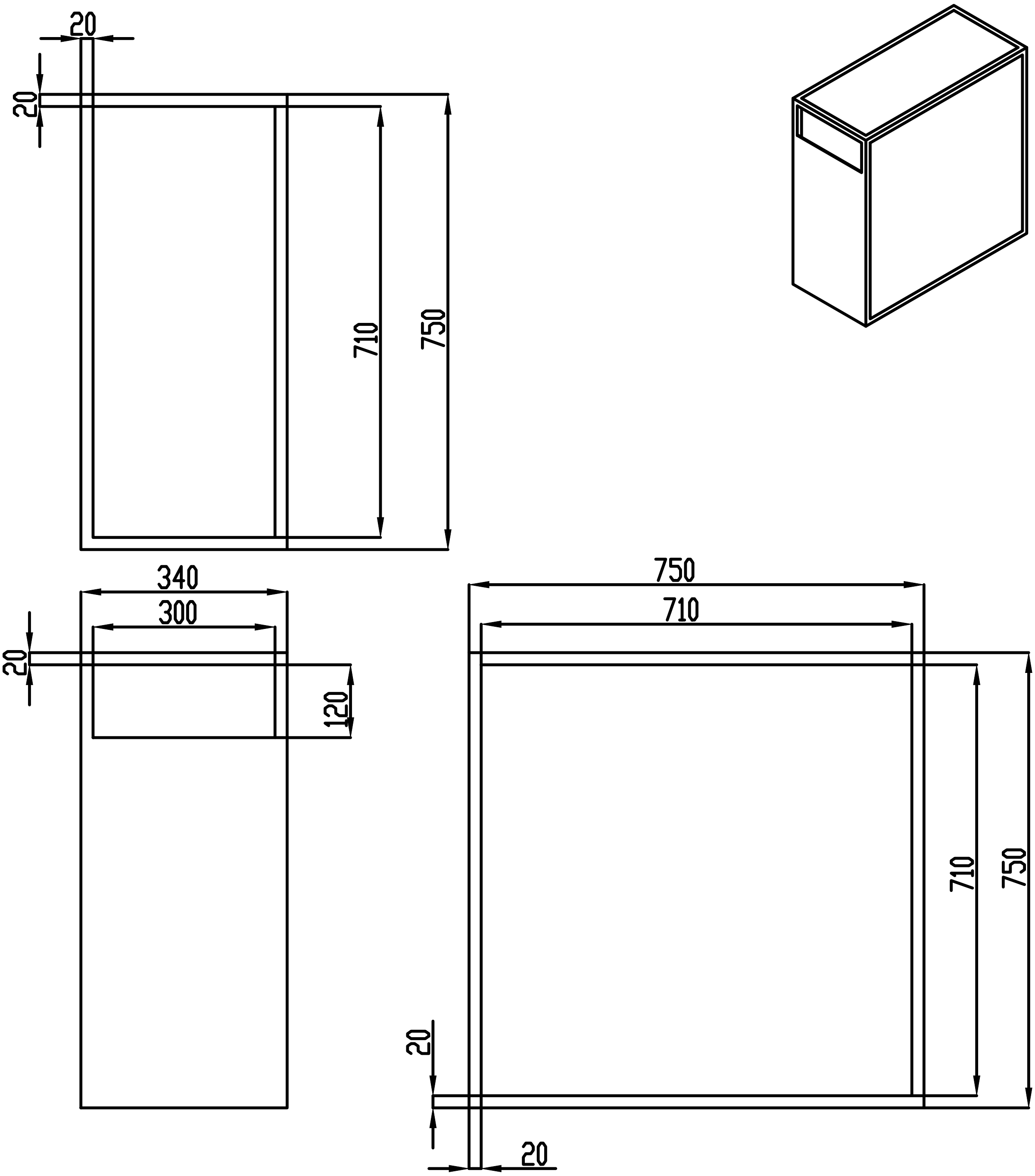
FEMALE OBJECT PART		D03 - 108			



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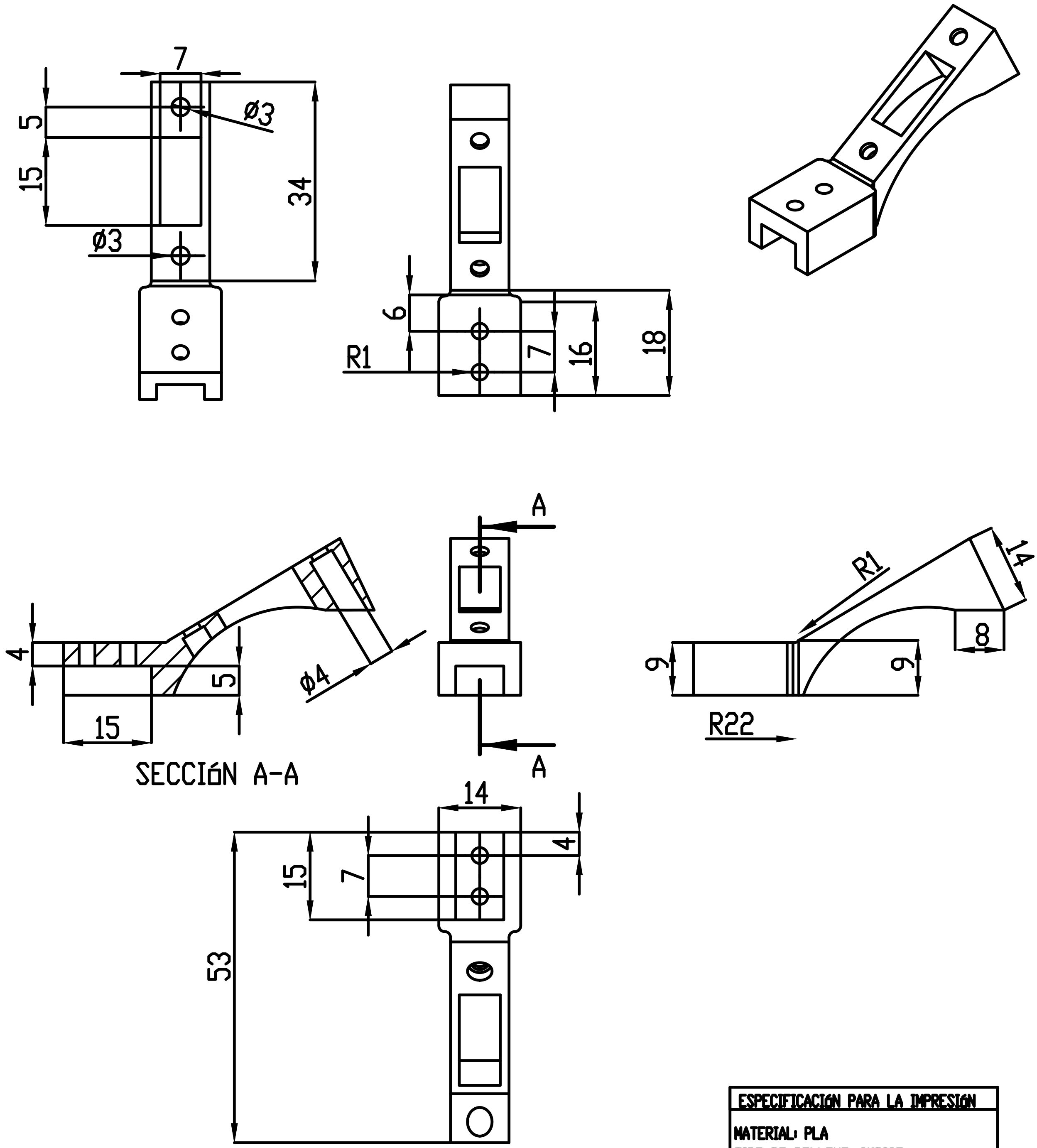
CARRYING STATION		D03-109			



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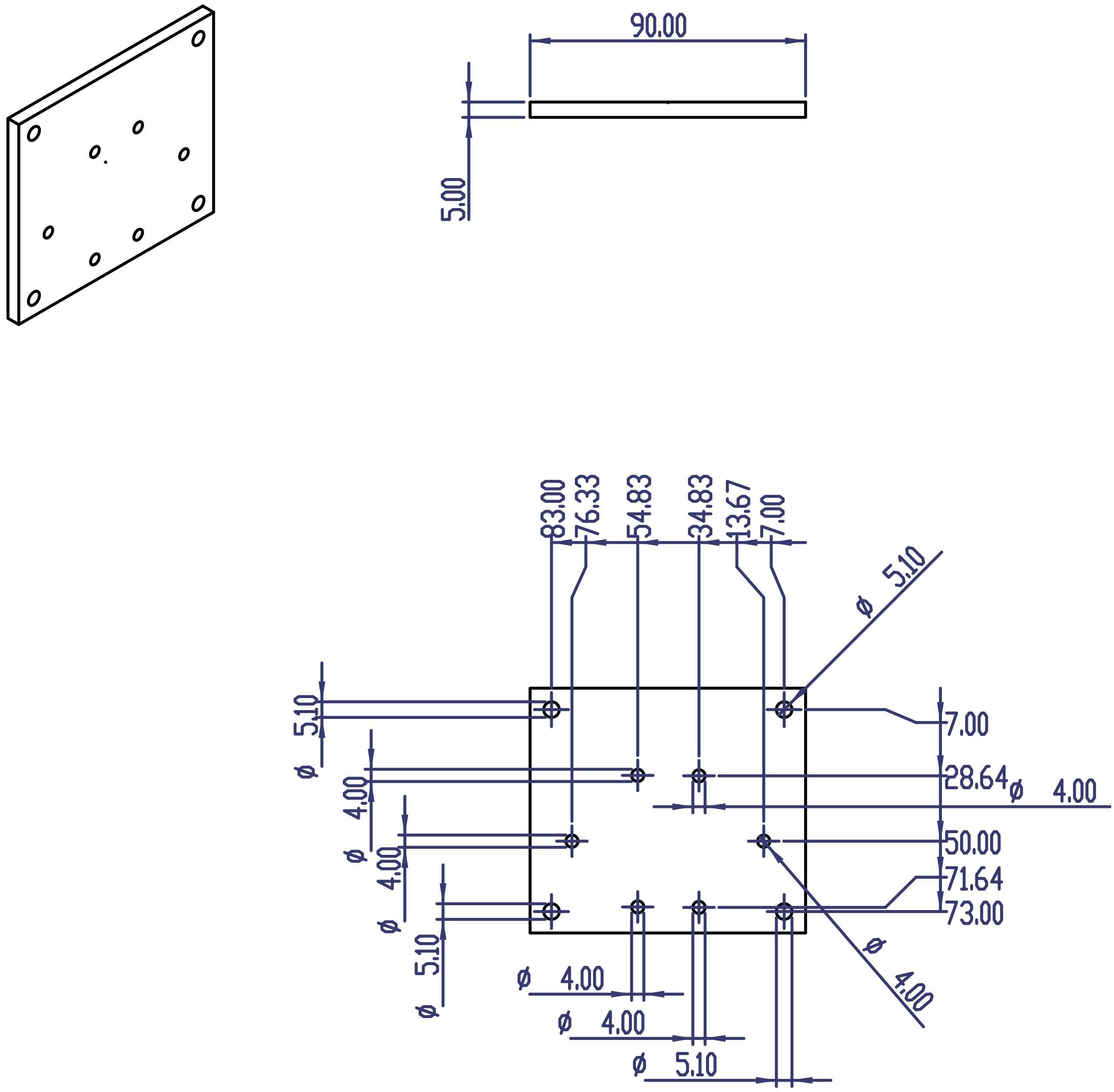

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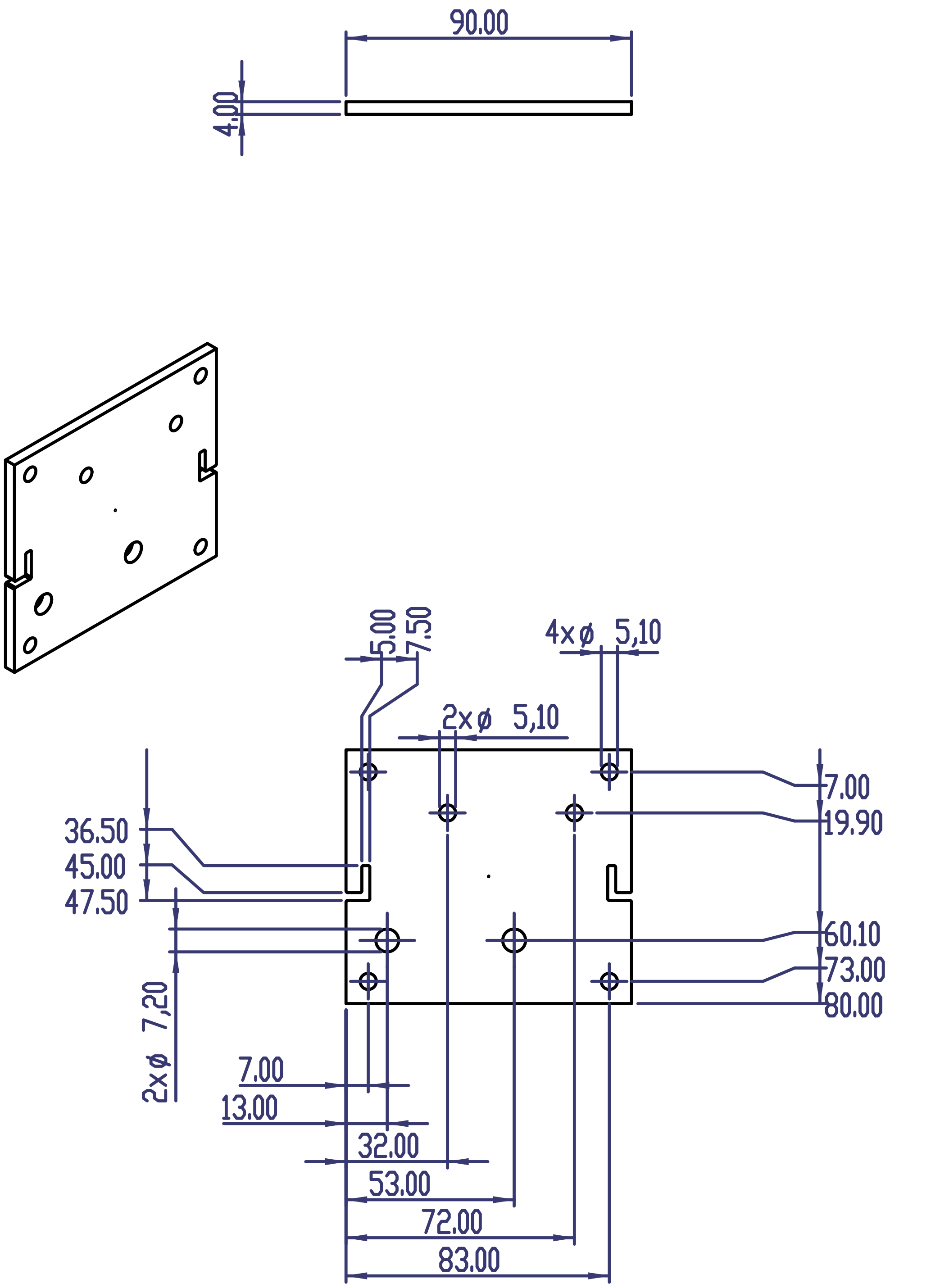

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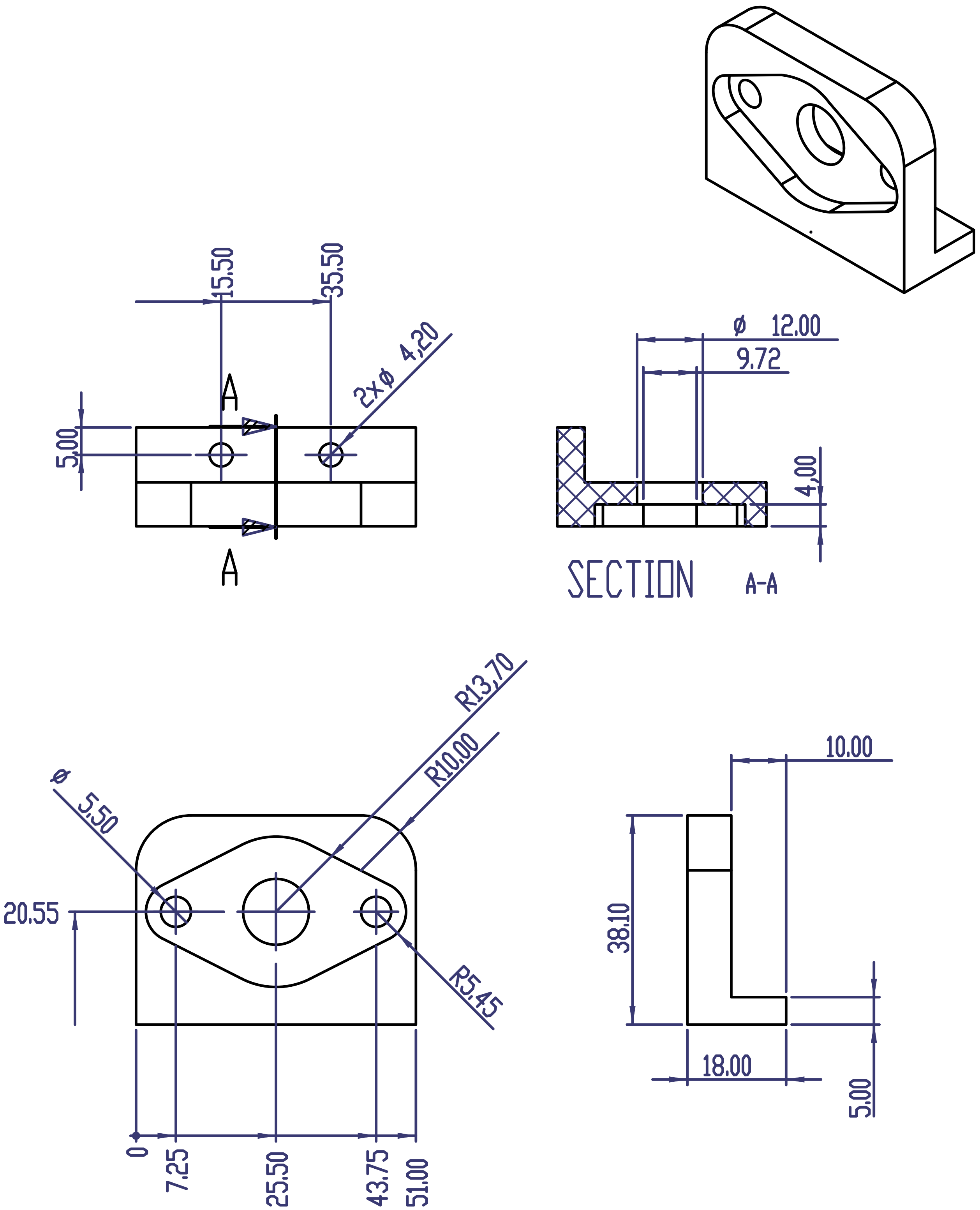

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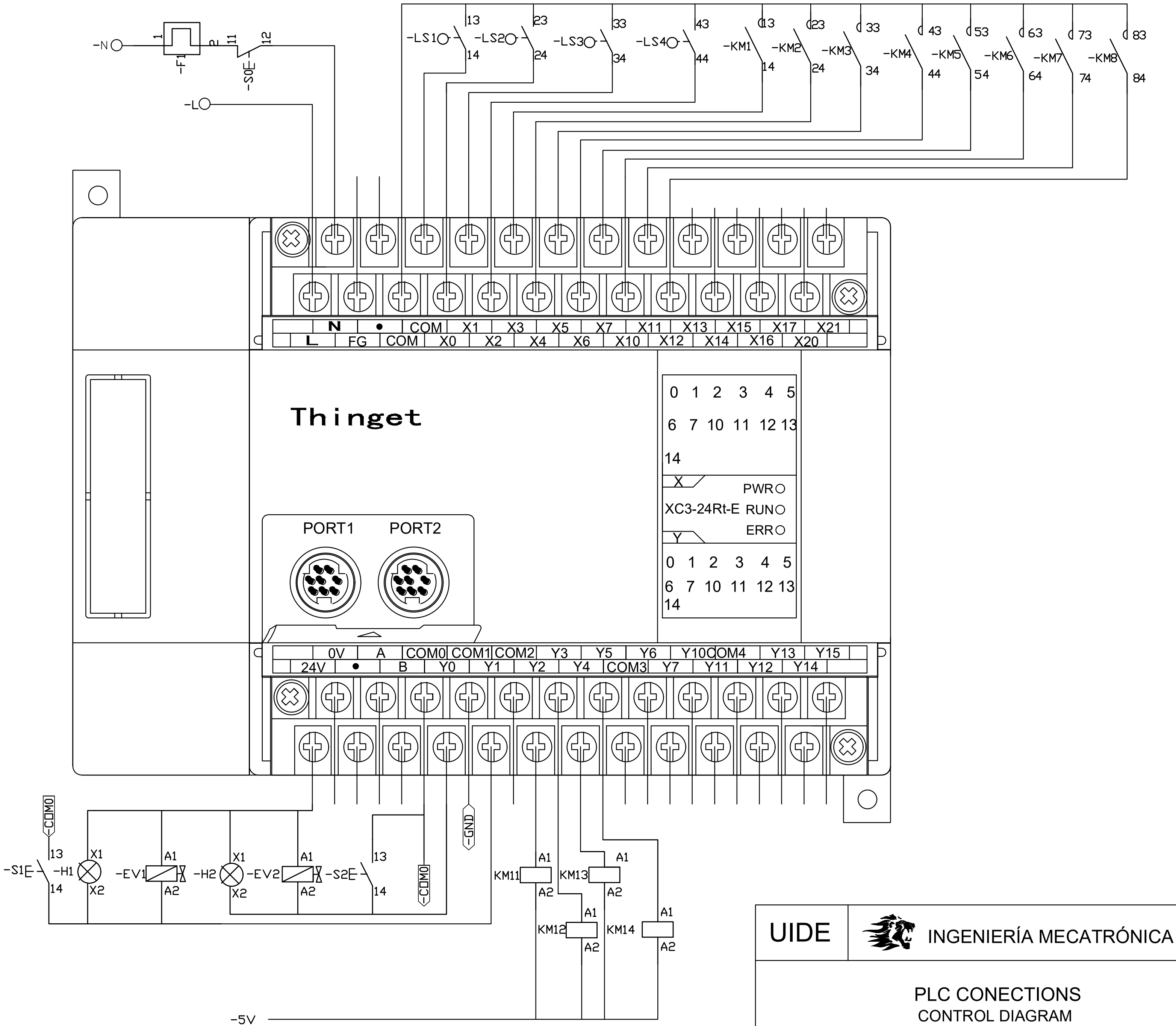
COUPLING BEARING HOLDER			D03 - 113				

Appendix B

Electronic Drawing



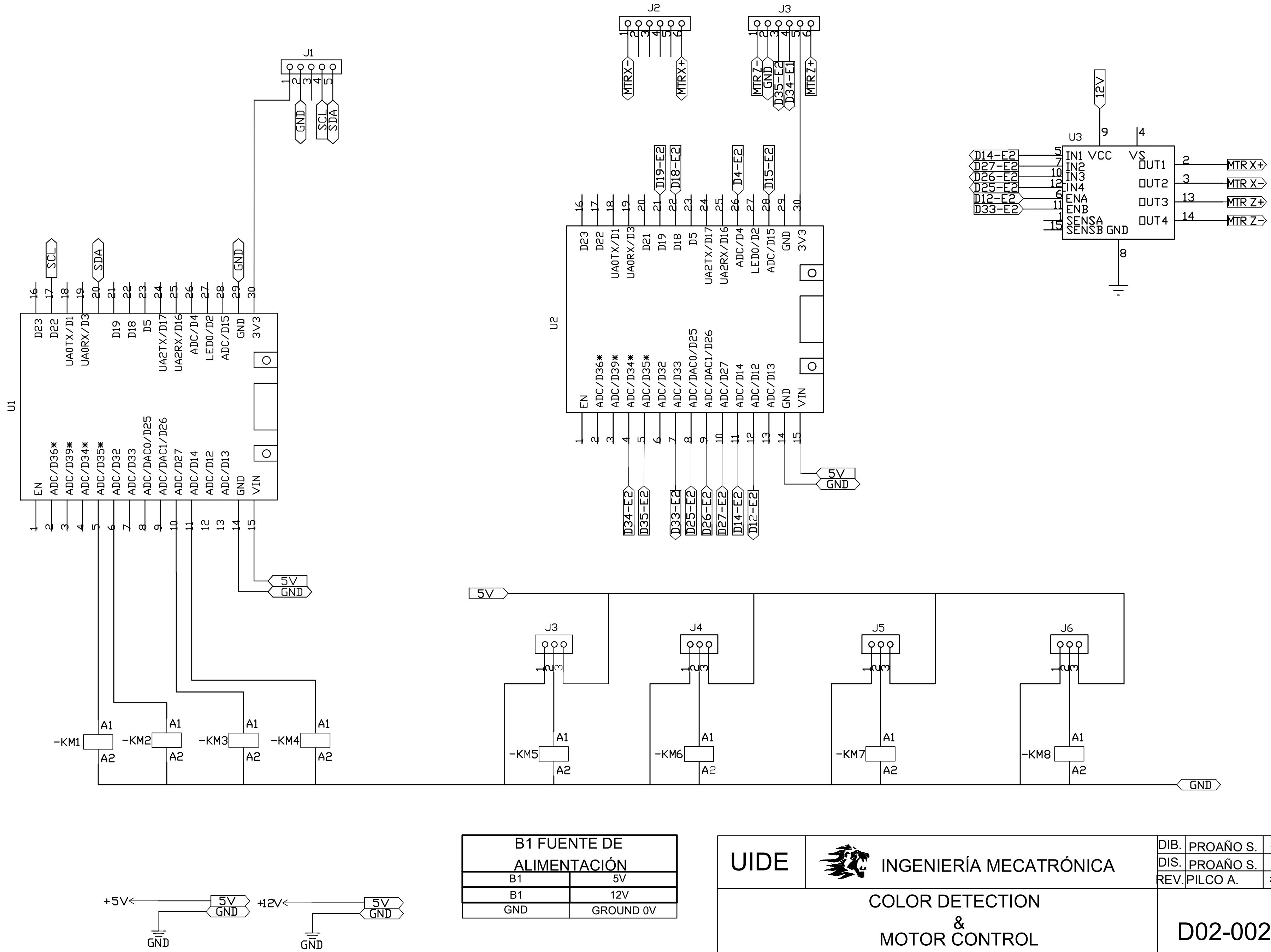
UIDE	INGENIERÍA MECATRÓNICA	DIB.	PROAÑO S.	25-05-2023
		DIS.	PROAÑO S.	25-05-2023
		REV.	PILCO A.	25-05-2023

PLC CONECTIONS
CONTROL DIAGRAM

D02-001

ESCALA
N/A

N/A



B1 FUENTE DE ALIMENTACIÓN	
B1	5V
B1	12V
GND	GROUND 0V

UIDE	INGENIERÍA MECATRÓNICA	DIB.	PROAÑO S.	25-05-2023
		DIS.	PROAÑO S.	25-05-2023
		REV.	PILCO A.	25-05-2023
	COLOR DETECTION & MOTOR CONTROL CONTROL DIAGRAM	D02-002	ESCALA N/A	N/A

POS	DESCRIPCIÓN	CANT	OBSERVACIONES
INTERRUPTORES			
S0	EMERGENCY MUSHROOM BUTTON	1	240 V AC
S1-S2	PUSH BUTTON	2	NORMALLY OPEN
FUSE			
F1	FUSE	1	
LIMIT SWITCH			
LS1-LS4	LIMIT SWITCH	4	LIMIT SWITCH MODULE 240 V
PROXIMITY SENSOR			
J3-J6	SACKING STATIONS	4	TCRT5000
COLOR SENSOR			
J1	BLUE, RED ,WHITE & NO COLOR	1	TCS342
RELAY			
KM1-KM8	8 RELAY MODULE INPUT TO PLC	8	5V DC
KM11-KM14	4 RELAY MODULE INPUT TO PLC	4	5V DC
SOLENOID VALVE			
EV1	GRIPPER	1	4V210-08 24V
EV2	CYLINDER	1	4V210-08 24V
PILOT LIGHTS			
H1	GREEN	1	24V
H2	YELLOW	1	24V
MICRO CONTROLLER			
U1	COLOR DETECTION	1	ESP32S
U2	MOTOR SPEED & DIRECTION CONTROL	1	ESP32S
U3	MOTOR SPEED & DIRECTION CONTROL	1	L298N
DC MOTOR			
J2-J3	X & Z AXIS MOVEMENT	2	UXCELL ENCODER 12V DC MOTOR

UIDE	INGENIERÍA MECATRÓNICA	DIB.	PROAÑO S.	25-05-2023
		DIS.	PROAÑO S.	25-05-2023
		REV.	PILCO A.	25-05-2023

STORAGE STATION TO CLASSIFY OBJECTS ACCORDING TO THEIR COLOR COMPONENT LIST	D02-103	ESCALA N/A
		N/A