**AIN SHAMS UNIVERISTY**

**FACULTY OF ENGINEERING**

**Senior-1 MECHATRONICS ENGINEERING**

# MCT333 : Mechatronics System Design

# TEAM ( 5 )

## Project First Summation

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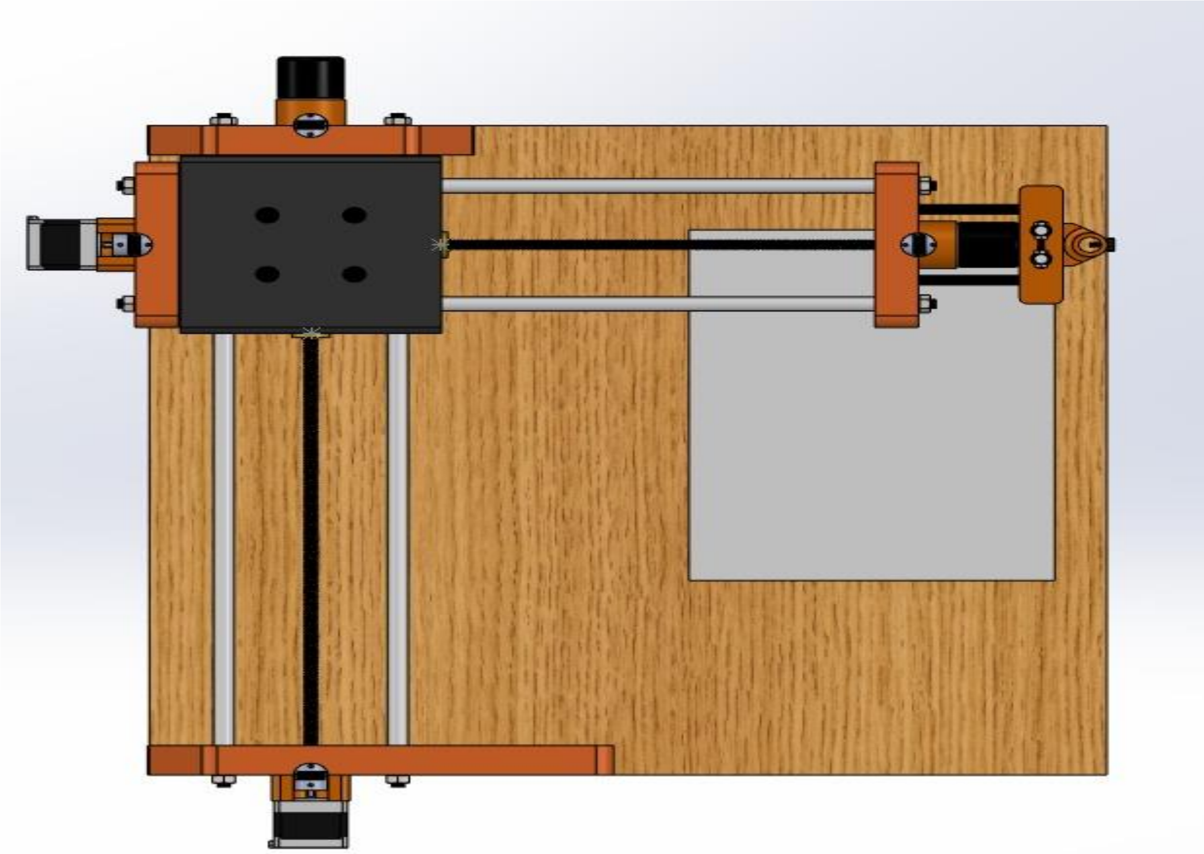
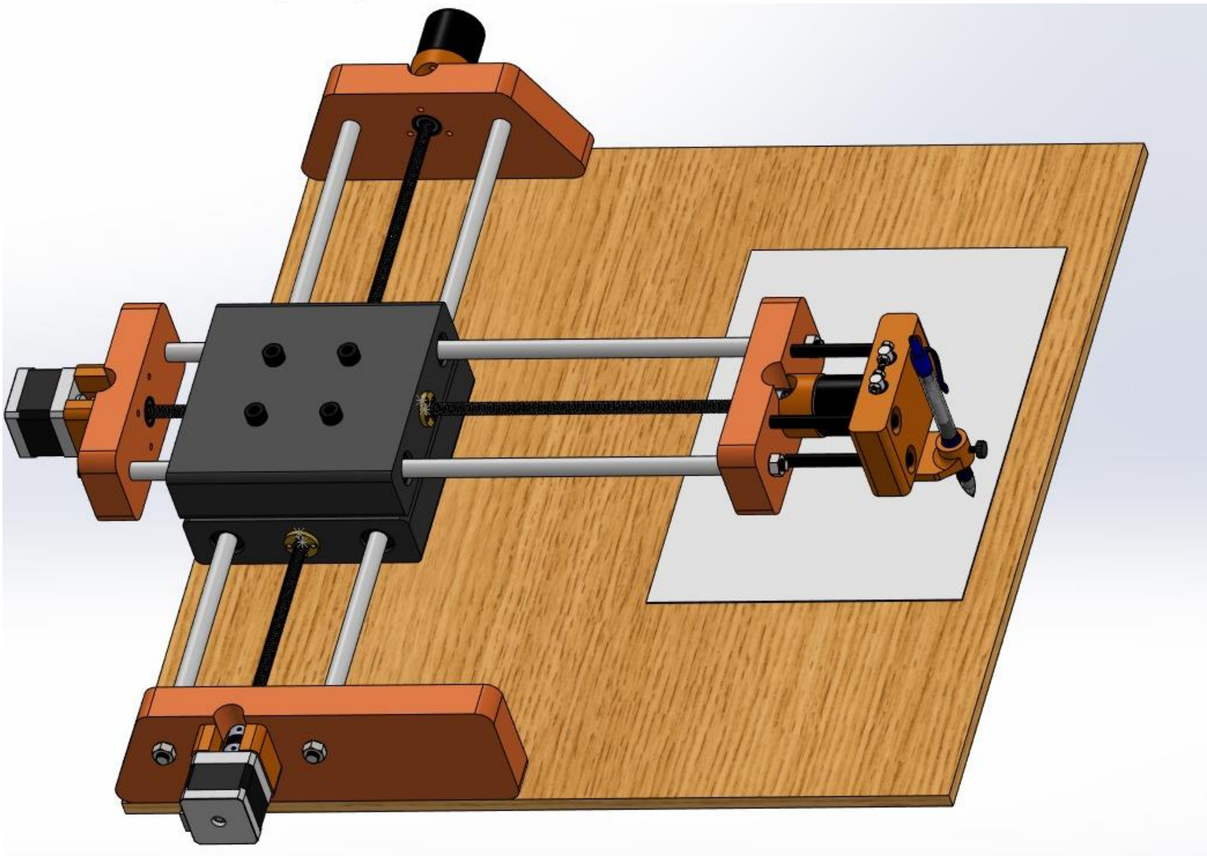
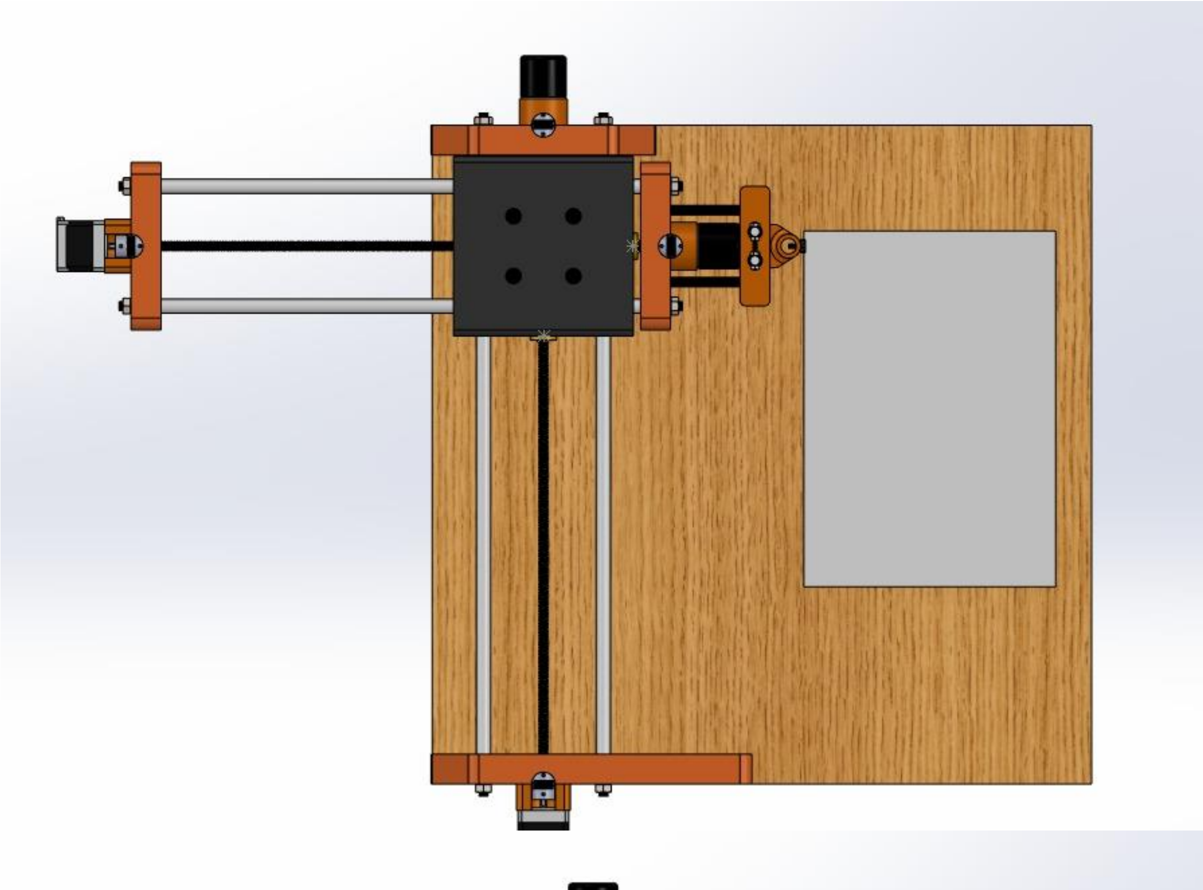
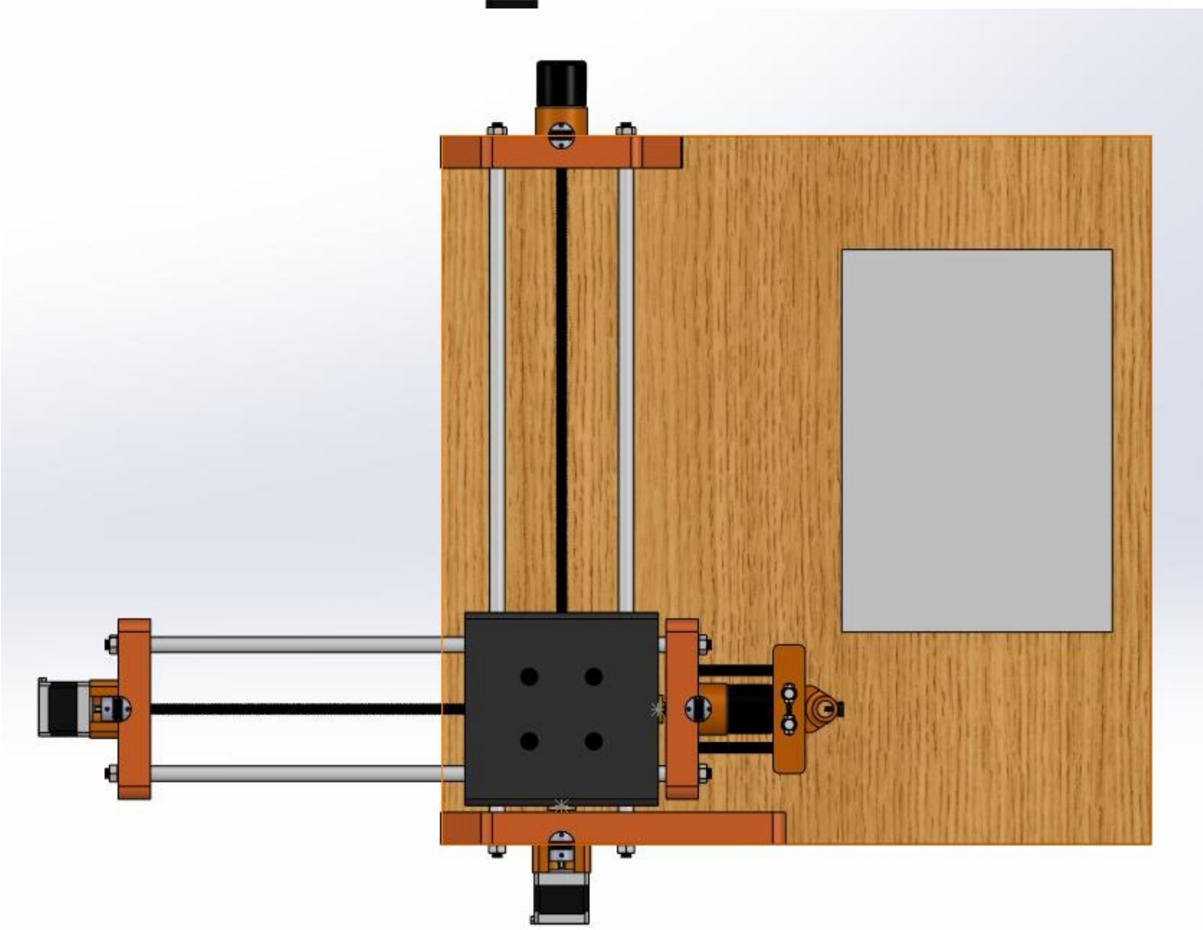
## *1) <u>Mechanical System</u>*

## ***a.*** Design









## ***b.*** Actuator Sizing

$m_1 = 0.1345\ Kg\ ,\ m_2 = 1kg\ ,\ A = 0.0155\ ,\ P = 2$

$A = \pi d^2 \rightarrow d = 0.07\ m$

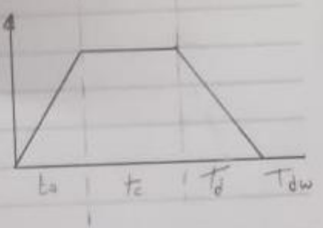
$$J_{eff} = J_1 + J_2 = \frac{1}{2} m_1 r^2 + \frac{m_2}{(2\pi P)^2}$$

$$= \frac{1}{2} * 0.1345 * \left(\frac{0.07}{2}\right)^2 + \frac{1}{(2*2*\pi)^2}$$

$$= 5.22 \times 10^{-7}$$

$J_m / J_{eff} = 1/1 \rightarrow J_m = 5.22 \times 10^{-7}$

$J_t = J_{eff} + J_m = 1.044 \times 10^{-6}$




$\dot{\theta}_m = 56.55$

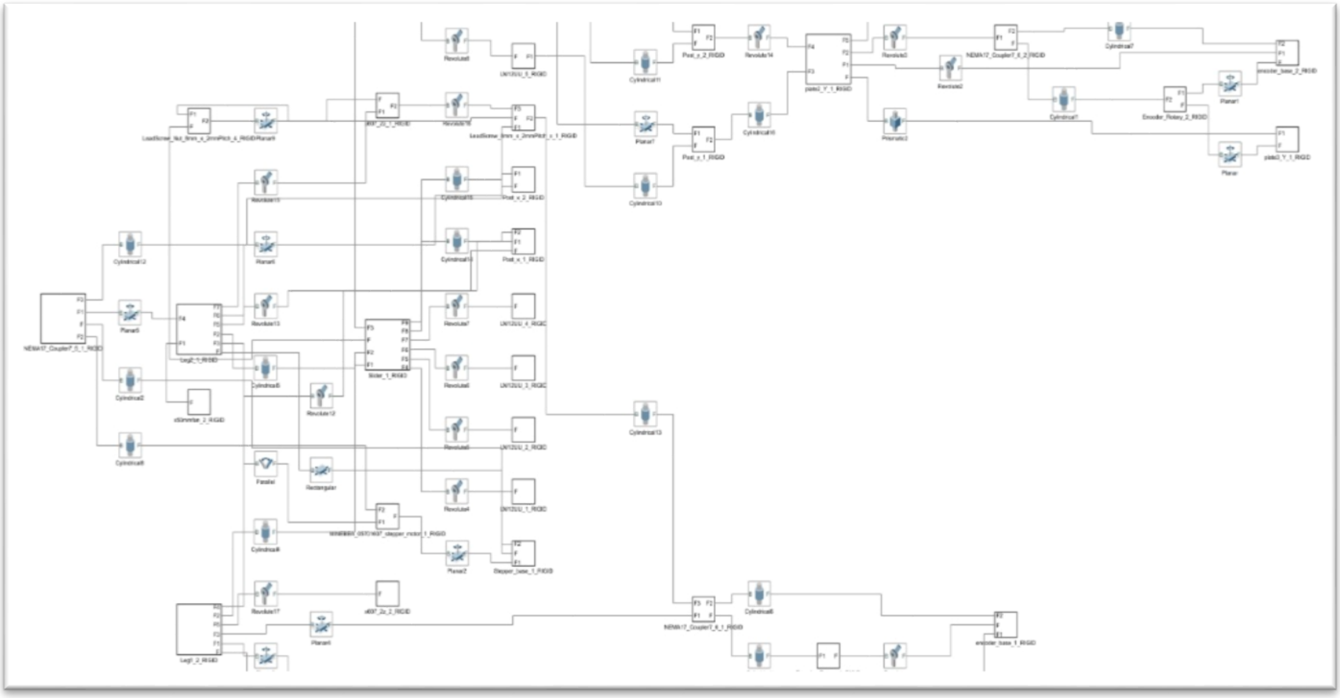
$\ddot{\theta}_m = 957854.4$

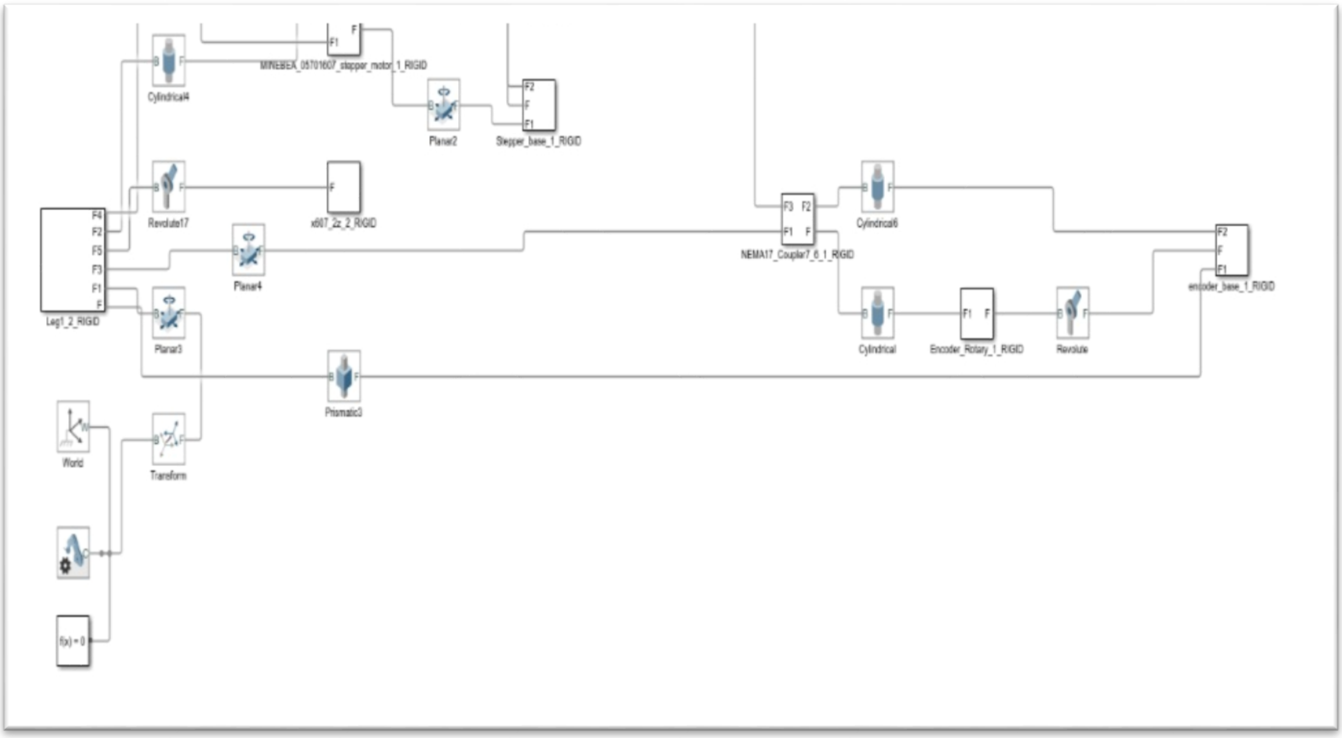
$$t_a = \frac{\dot{\theta}_m}{\ddot{\theta}_m} = 5.9 \times 10^{-5}\ sec$$

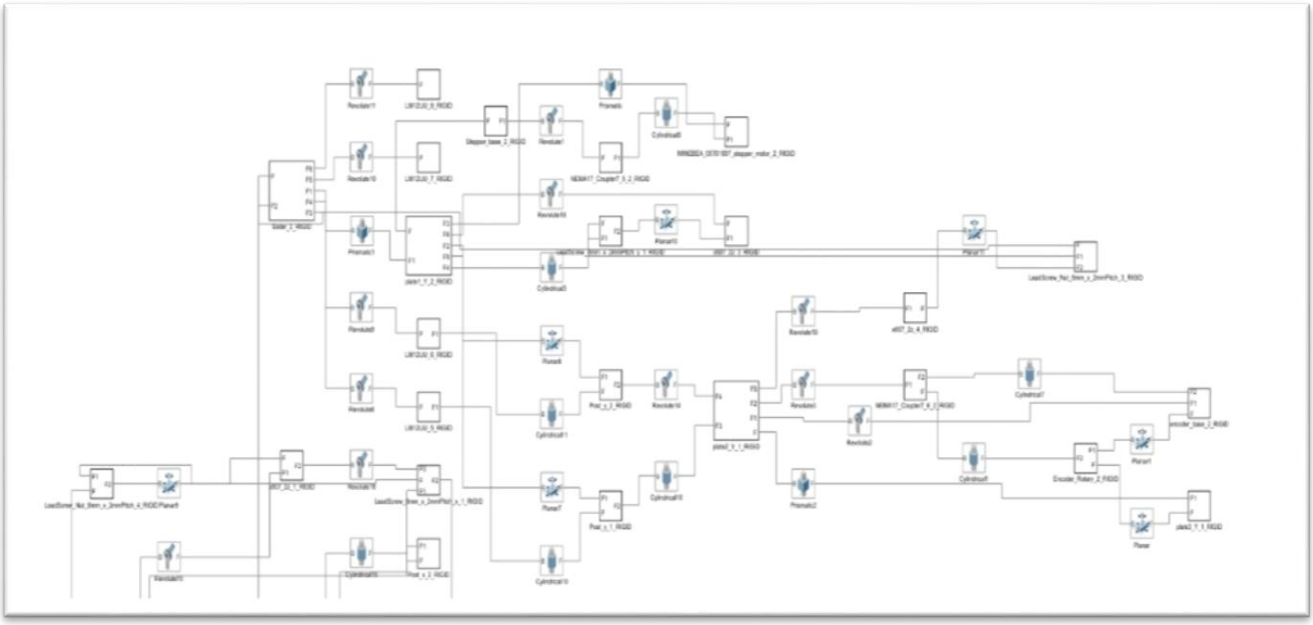
$$t_d = \frac{\dot{\theta}_m}{\ddot{\theta}_m} = 5.9 \times 10^{-5}\ sec$$

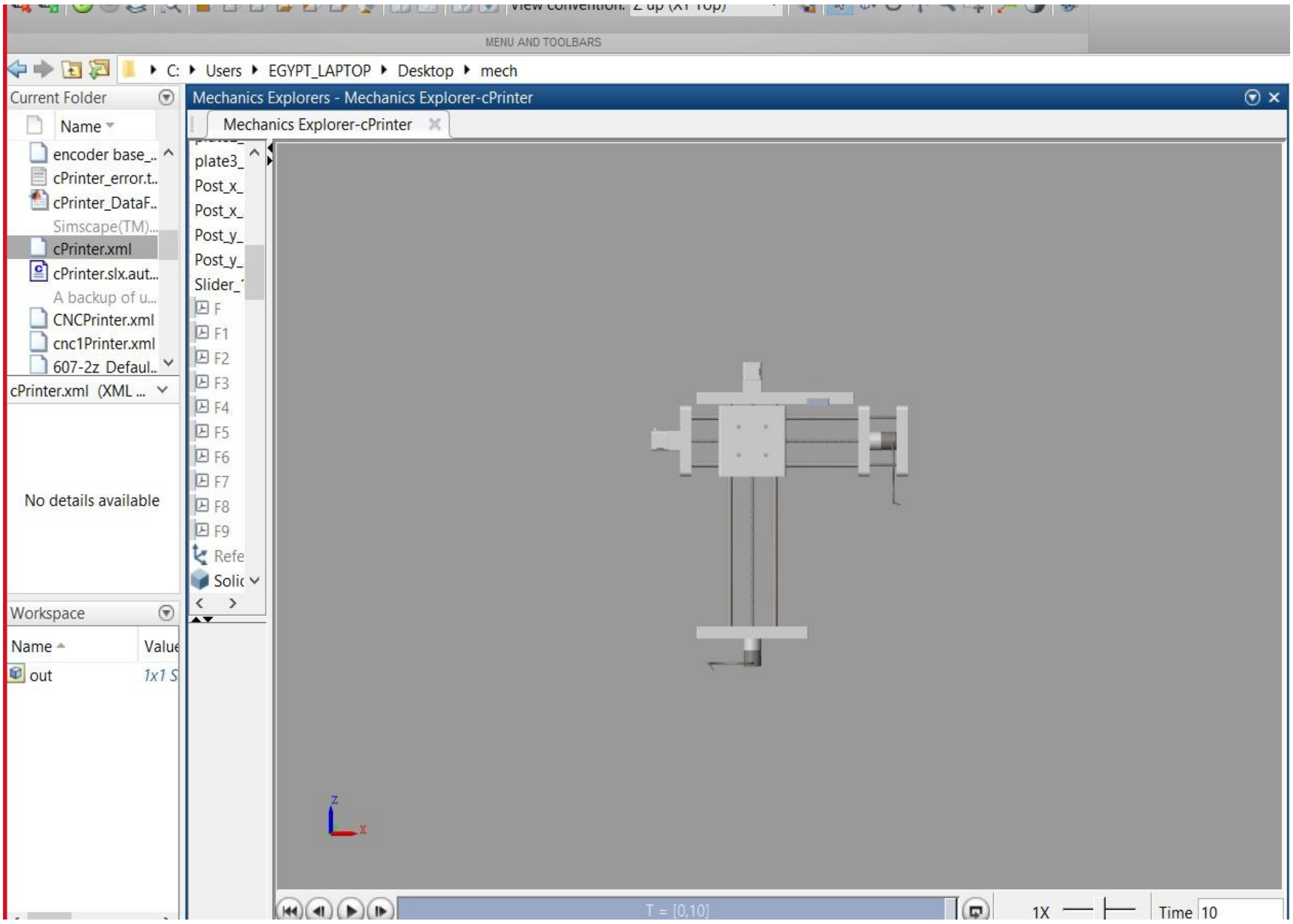
# ***c.MatLab***

## ➢ Simulink blocks





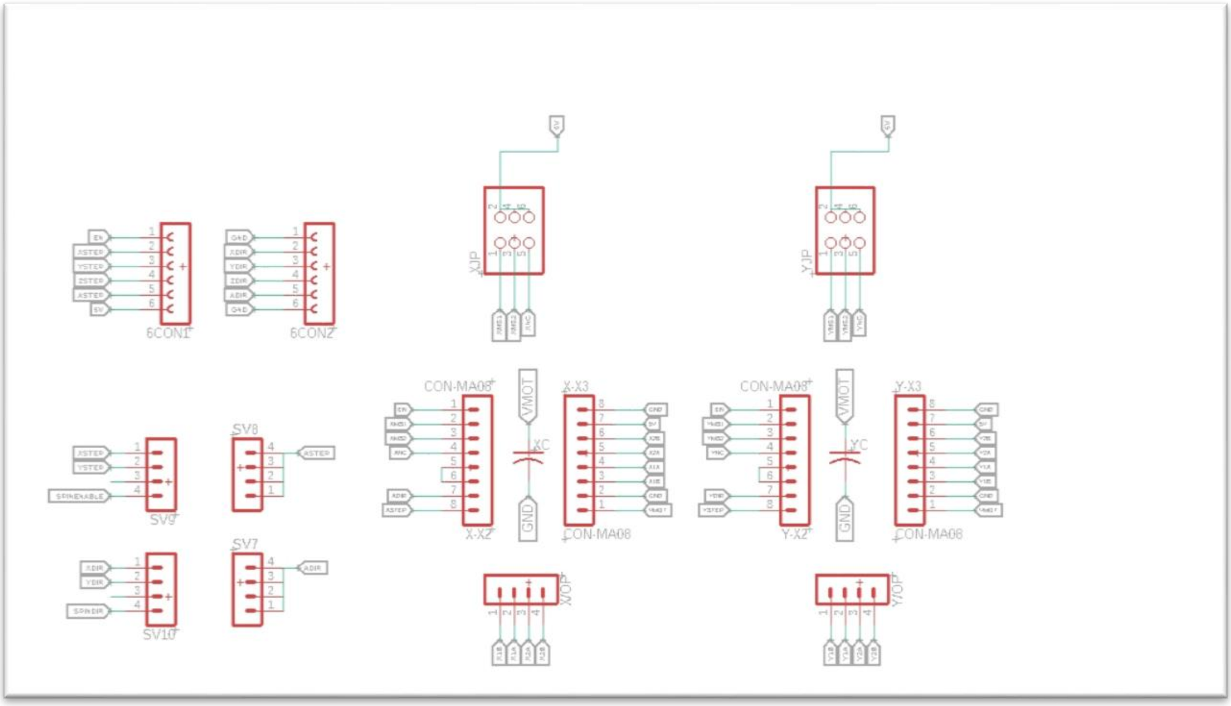


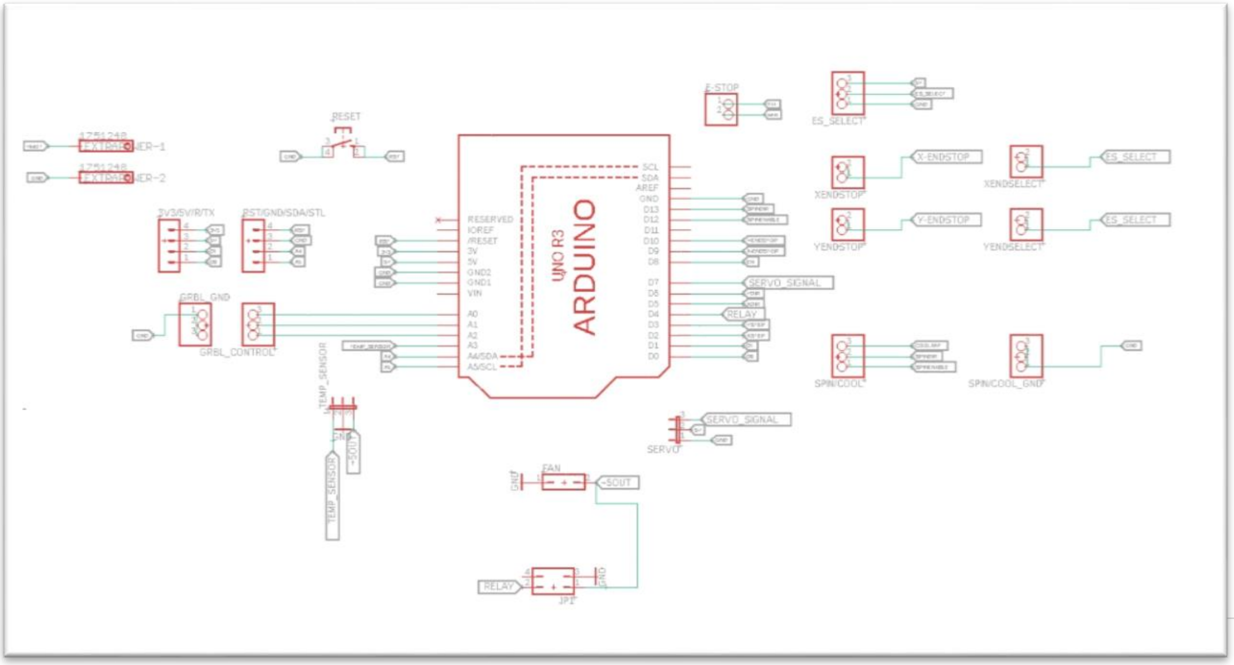

MENU AND TOOLBARS
C: Users EGYPT_LAPTOP Desktop mech
Current Folder
Name
encoder base_..
cPrinter_error.t..
cPrinter_DataF..
Simscape(TM)...
cPrinter.xml
cPrinter.slx.aut...
A backup of u...
CNCPrinter.xml
cnc1Printer.xml
607-2z_Defaul..
cPrinter.xml (XML ...
No details available
Workspace
Name
Value
out
Mechanics Explorers - Mechanics Explorer-cPrinter
Mechanics Explorer-cPrinter
plate3_
Post_x_
Post_x_
Post_y_
Post_y_
Slider_
F
F1
F2
F3
F4
F5
F6
F7
F8
F9
Refe
Solic
T = [0,10]
1X
Time 10

# *2) Electrical System*

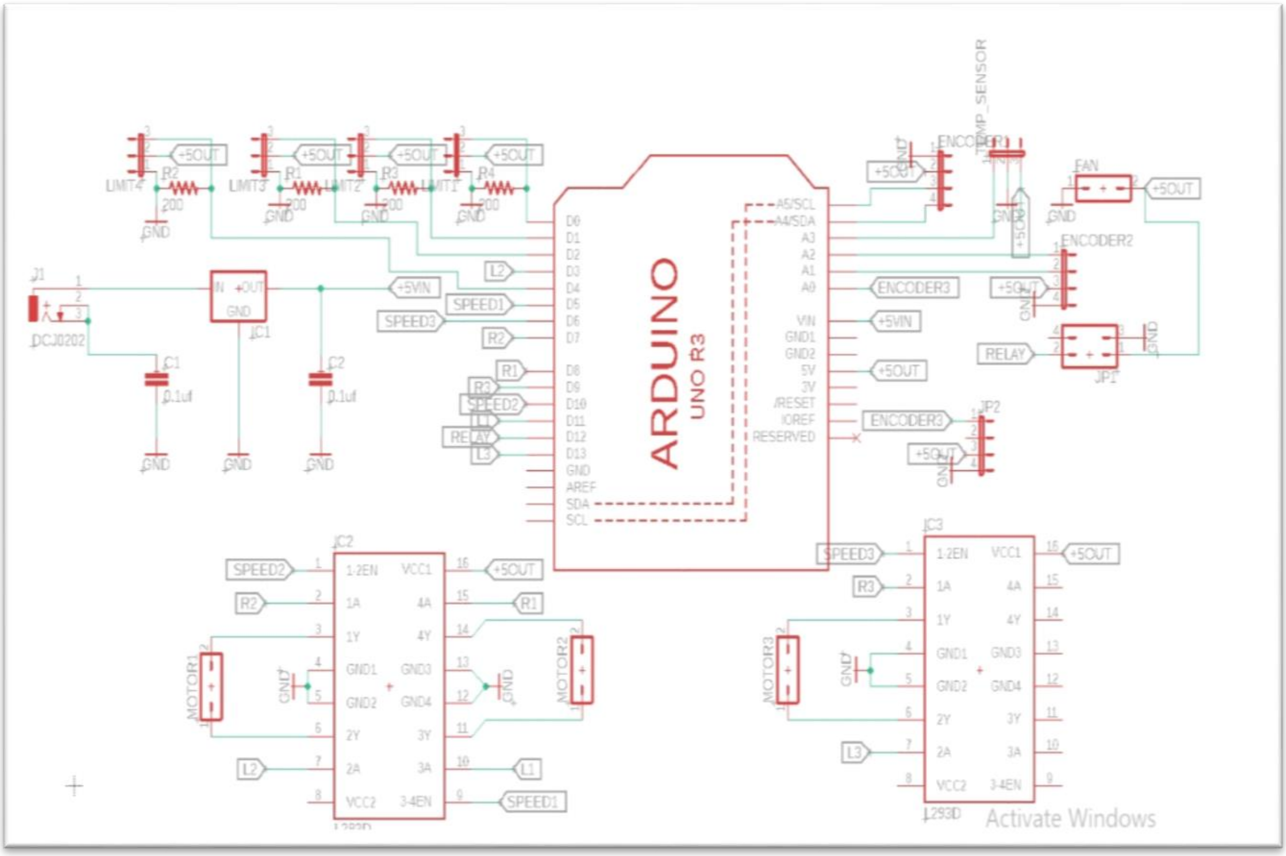
## a. PCB

### I. For Open Loop



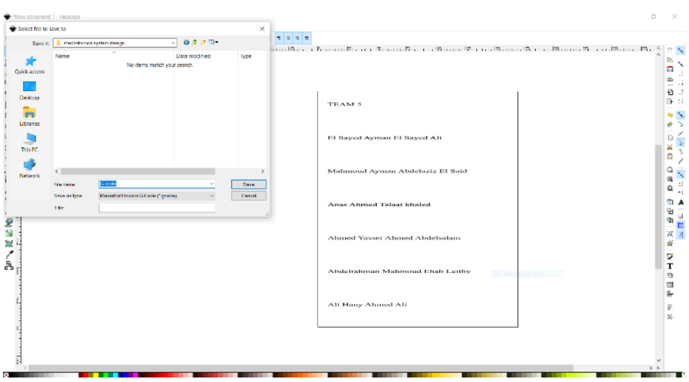
## II. *For Closed* Loop

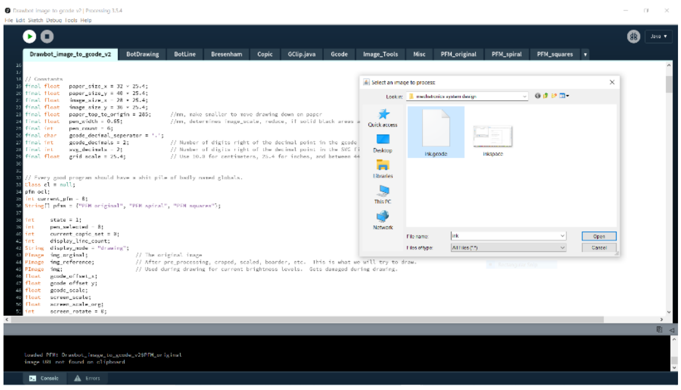


# *3) Control System*

## a. Introduction:

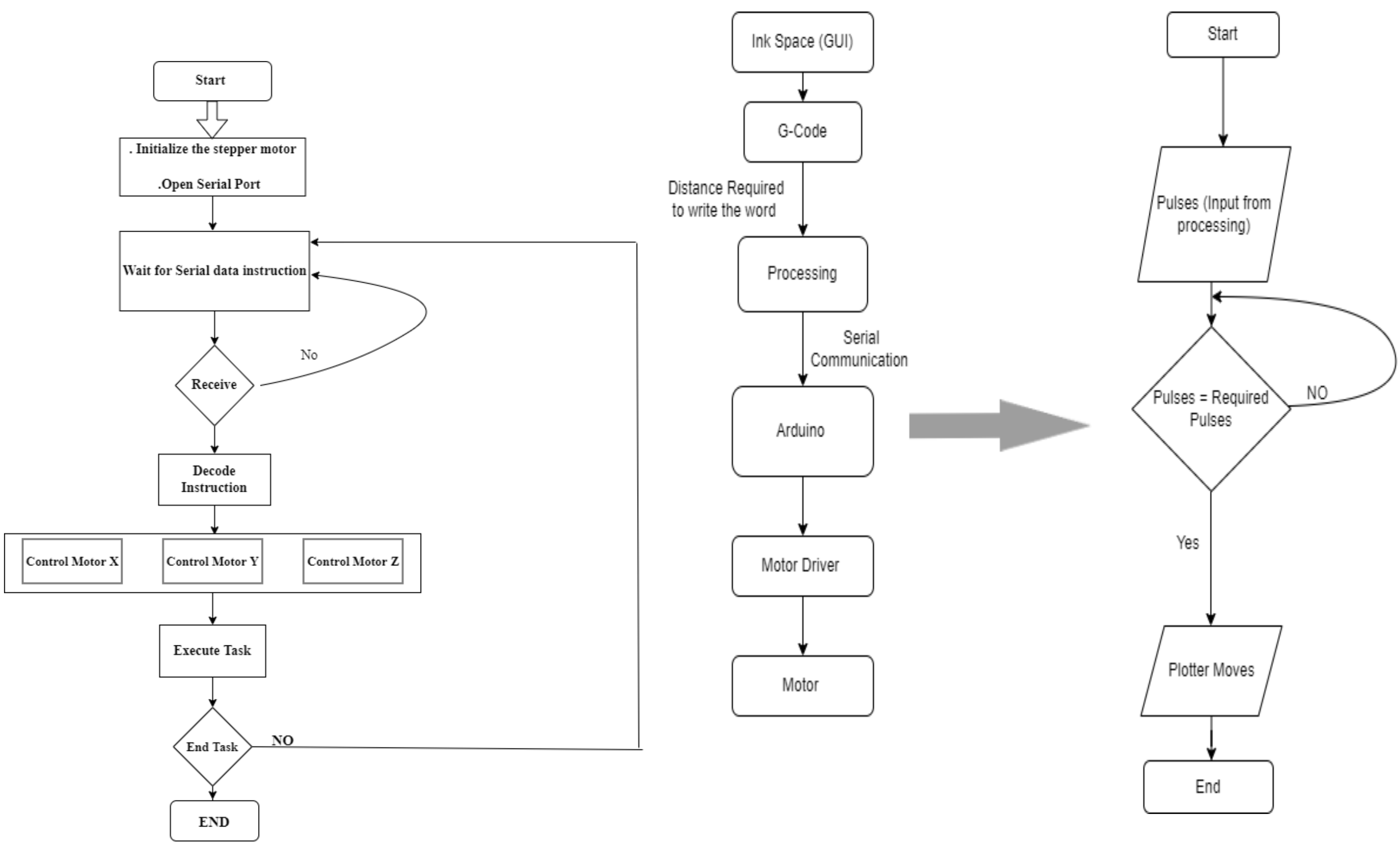
The CNC stands for Computer Numerical Control. CNC operates on digitized data, a computer. CAM program is used to control, automate, and monitor the movements of a machine. The CNC controller works together with a series of motors and drive components to move and control the machine axes. Open-source software (inkspace and universal G-code) is used for executing the G-code for machining applications. In addition to using flexible software sketchbook (processing) to generate G-code-based code.





# b. Software Implementation

The flow chart of application execution. At start, power supply and computer are turned on. After that all motors are initialized to its zero position. These zero positions are given through software. The circuit board is ready to accept instructions from computer. These instructions are in the form of G-codes. It will wait still instructions to be received. After instructions are received, it starts to decode it into its own language that is in the voltage and current form. As per instruction, when task is completed, it is the end of the flow of execution.



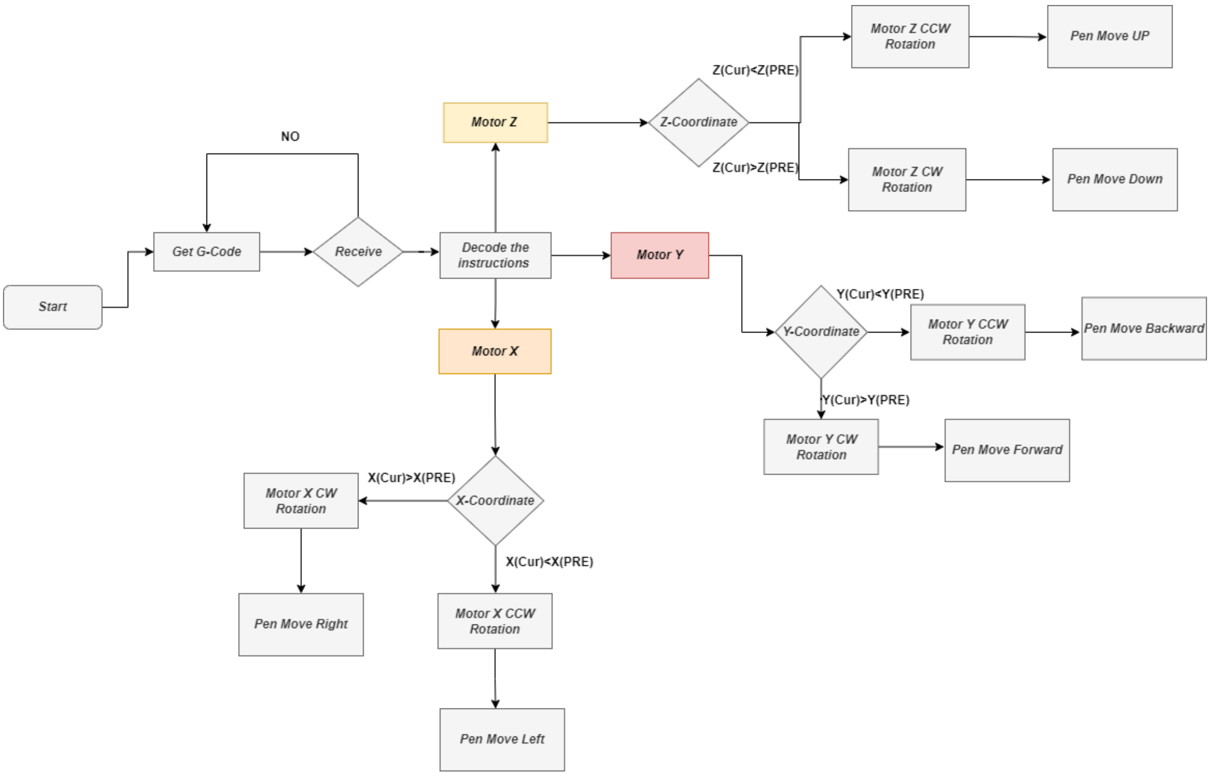
# c. Open Loop:

Power supply on if (G-code generate) →

No → all three motors will stop (two stepper motor in X-Y direction and one servo in Z direction).

Yes → all motors will move depends on G-code

1. servo (in Z direction) will move up or down.
2. Two stepper motors will move (in the XY direction), but if the point to which the pen will move is less than the point at which it was coordinated, the motor will rotate CCW and if the point to which the pen will move is greater than the point at which it was coordinated, the motor will rotate CW.



## d. The P.I.D Controller

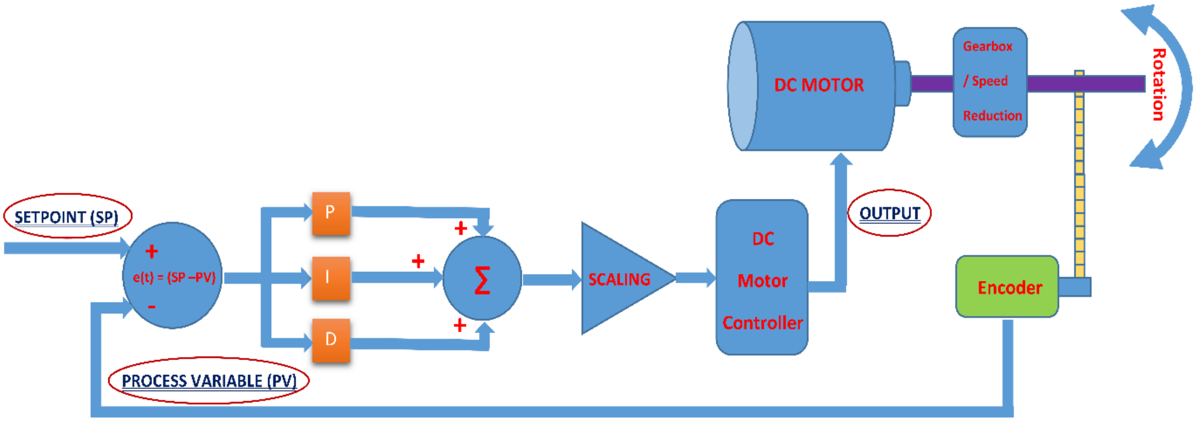
The goal of PID controller is to adjust the control value at the OUPUT by continuously evaluating the :

ERROR e(t) = (SP (set point) – PV (PROCESS VARIABLE))

between a SETPOINT (SP) and the PROCESS VARIABLE (PV) being controlled and applies a correction based on proportional, integral, and derivative terms, to achieve the stability and rapid response in the system.

$$\text{Output} = K_P e(t) + K_I \int e(t)\,dt + K_D \frac{d}{dt} e(t)$$

$$\text{Where : } e = \text{Setpoint - Input}$$



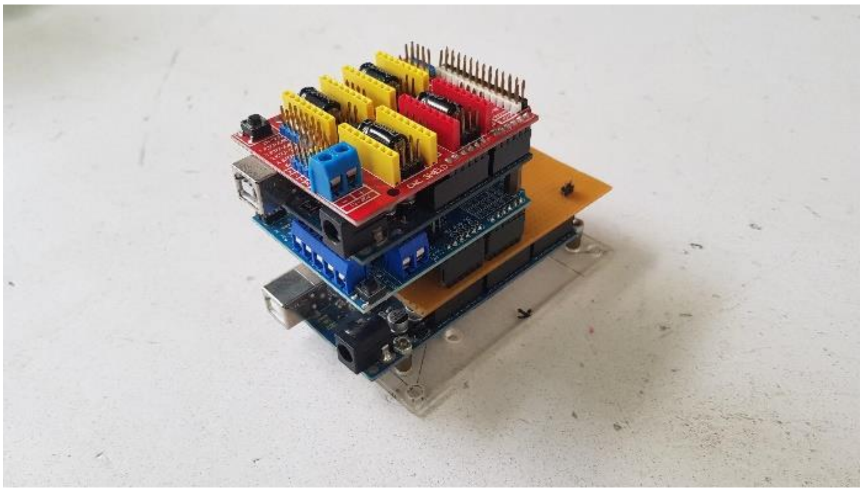

- In my project, **Arduino Mega 2560** is used just like a **DC servo controller**. It performs **P.I.D control** for the X and Y axis DC motors.

- Motor will be driven by speed or position but with this PID controller, the setpoint are (**step**) + (**direction**) signals from **Arduino Uno** which has **GRBL firmware** pre-installed.
- The PID control signals are as follows:

**SETPOINT - SP**: They are (**(step) + (direction) signals in x-axis)** + **((step) + (direction) signals in y-axis)** signals that are sent from Arduino Uno R3 with a CNC Shield to Arduino Mega 2560, and the Arduino Uno has GRBL firmware pre-installed.

**PROCESS VARIABLE - PV**: The measured feedback value from quadrature magnetic encoders to Arduino Mega 2560.

**OUTPUT**: The PWM signals from Arduino L293D Motor Shield (controlled by Arduino Mega 2560) to printer DC motors.



- The **STEP** and **DIR** signals are sent from **GRBL** CNC Shield of (**Arduino Uno to Arduino Mega 2560)**. Arduino Mega 2560 receive these **STEP** and **DIR** signals of each axis X/Y, then combine them to create the **SETPOINT** values for each PID controller.

$$double\ SETPOINT\_X\ =\ 0;$$

$$double\ SETPOINT\_Y\ =\ 0;$$

- **INPUT_X/ INPUT_Y**: They are feedback signals which are read from magnetic encoders of X/ Y DC motors.

$$double\ INPUT\_X;$$

$$double\ INPUT\_Y;$$

- **OUTPUT_X/ OUTPUT_Y**: They are PWM output signals which control the X/Y motors.

$$double\ OLD\_INPUT\_X\ =\ 0;$$

$$double\ OLD\_INPUT\_Y\ =\ 0;$$

- **K_P/ K_I/ K_D**: They're tuning parameters. These affect how the PID will change the output.

1. **For motor X**:

$$double\ KP_X\ =\ 20.0;$$

$$double\ KI\_X\ =\ 0.03;$$

$$double\ KD\_X\ =\ 0.01;$$

2. **For motor Y**:

$$double\ KP\_Y\ =\ 9.0;$$

$$double\ KI\_Y\ =\ 0.02;$$

$$double\ KD\_Y\ =\ 0.01;$$

# e. Closed Loop:

Power supply on if (G-code generate) →

No → all three motors will stop (three DC motor integrated with magnetic encoder in XYZ direction)

Yes → all motors will move depends on G-code

three DC motors will move, but if the point to which the pen will move is less than the point at which it was coordinated, the motor will rotate CCW and if the point to which the pen will move is greater than the point at which it was coordinated, the motor will rotate CW. And in the end, I will know when the execution procedure has been completed at the end of the pulses at the encoder.