ISSN No:-2456-2165

PLC Based Automatic Cutting Machine

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Abstract:- In the industrial world, automation is one of the most important elements for development. It helps to reduce the manpower and plays a significant role in maintaining efficiency, uniformity and productivity. Automatic cutting machine is one of them, which is widely used in industrial proposes.

The main objective of this project is to design a three axis cutting machine by using PLC which gives a good precision and accuracy in cutting the objects compared to the manual cutting machine

Keywords:- *PLC, Automatic Cutting Machine, Cutting Machine.*

I. INTRODUCTION

➢ *Three Axis Control*

In this fast growing smarter world, automatic cutting tools are of great need. Three axis control of a robotic arm would include control of the arm on the entire three axes (x, y and z). Control on the entire three axis would help the arm to move freely draw figures. This robotic arm holds a blade which moves up and down (z axis) with the help of pneumatic supply. The base movable plate slides in both the axis (x and y) driven by two stepper motors. The left and right movement is given by X axis stepper motor and the forward and backward movement is given by Y axis stepper motor. Apart from this, 6 inductive proximity sensors have been installed (3 on each axis), to have position adjustment for the base plate so that the drawing of the figure could be started from where the user wishes to. The entire system is controlled by MITSUBISHI PLC (GX developer software). The control of the length to be drawn is done by controlling both the speed of the stepper motor and duration for which it has to be driven. PLC based robotic arm would be a highly customized system and would have the facility for extensive input/output arrangements. The programs (ladder logic) written produces a computer file that is interpreted to extract the commands needed to operate the system. This would allow cutting in the required shapes and sizes.

➢ *What is PLC?*

A Programmable Logic Controller (PLC or programmable controller) is a device that a user can program to perform a series or sequence of events. These series of events are written as logics in the program. The entire system can be divided into three parts.

- Ladder Logic
- Sequential Flow Chart
- Functional Block Diagram
- Structures text
- Instruction list

II. LITERATURE REVIEW

Many authors have clearly projected the design of robotic arm and the benefits of using PLC instead of other microcontrollers or processors. As a whole, among many authors PLC stands as a most customized, reliable and flexible. The details of the literatures referred for this project work and abstract of the reported work is discussed in this chapter.

Kanchan Pandita, Yamini Sharma, Vijay Kumar Kamble 'Stepper Motor Driven Three Axis Robot using PLC' [1] describes how to prepare a PLC program that calculates the path coordinates and also drives the stepper motor. They have also prepared a HMI program that allows the user to control the system directly using buttons. Here a joystick has been used. Initially, a joystick is used to teach the robot learn the path and then the robot will perform the same function after some desired accuracy.

Leonard Sokoloff ' PLC Stepper Motor Controller' [2] has clearly projected how to control a stepper motor using PLC. They have concentrated on both the hardware connections and software programs. The logic for the programs are clearly depicted using flowcharts. They have used a PLC whose outputs are of transistors type (Darlington pair). They have explained the internal structure of the motor as well as the stepping angle using phase exciting timing waveforms. They have projected the software programs using Ladder logic.

Abhishek Kumar Mishra, Karan Muley, Lakshmi Gautam 'Interfacing Stepper Motor with PLC' [3] has focused on how to interface a stepper motor using PLC. In this paper they have used a stepper motor driver similar to that of what has been used in this project. The connections between the motor driver to the PLC as wellas the connections between the motor driver and motor is clearly explained with suitable diagrams. The software part has also been explained with suitable waveforms. The software part focusses on how to send the pulse and direction signal from the PLC. They have explained the coding part with ladder logic and functional block diagrams.

Amer Ali Ammar 'Step Motor Control by Using PLC ' [4] a thorough theoretical and practical study of PLC control is presented to provide information required to understand the PLC, its main hardware component and how these components interact with each other. It aims to study the stepper motor, how it works and how it can be interfaced with PLC. This paper focuses to drive the motor without using a driver. They have written the program in Ladder logic using GLOFA simulation software.

ISSN No:-2456-2165

Patidar, Virentra and Tiwari Ritu 'Survey of robotic arm and parameters'[5] gives a technical discussion on robotic arm and the development. It focuses on axis degree of freedom, working envelope and space, kinematics, payload, speed and acceleration, accuracy and readability of robotic arm.

AR.Suhas ' Design and implementation of robotic arm using Proteus design tool and Arduino Uno'[6] have designed a robotic arm where it would be controlled by the interaction with the human hand using flux sensor , Arduino Uno, RF module and servo motor. The signals are transmitted and received by the Wi-Fi modules.

Kadiyam Sasidhar, Shaik Faiz Hussain 'Design and development of a PLC based automatic objects sorting'[7] have developed sorting system which has color sensors, proximity sensors and stepper motors. This paper has clearly projected both on hardware and software part of PLC. They also have implemented on SCADA.

Yujie Chong, Haimei Feng ' One kind of control method based on PLC or stepper motor'[8] have implemented a precise control of stepping motor steps has been discussed with ladder logic and block diagrams. They have also focused on the wiring of stepper motors along with its control actions from PLC.

J.Swider, K.Foit 'The use of Mitsubishi PLC systems for realizations of industrial task'[9] explains on the internal structure of Mitsubishi PLC. It also focuses on the specifications and feature of all FX series. They have also projected a real time interface with lift.

X. Y. Bu and P. Liu, 'PLC applied in the three-phase stepper-motor control system' [10] gives the introduction of characteristics and the working principle of three phase stepper motor. They have done both the position and speed control of the motor using Siemens PLC.

III. PROJECT DESCRIPTION

The project consists of several hardware and software parts whose specifications and features have been discussed here. Mitsubishi is a programmable logic unit (PLC), which is a digital computer to control various processes in the external world. It consists of a microprocessor whose programs are written on suitable software. It has a provision to connect various inputs and outputs. The suitable software used for programming is GX developer. Version 8 has been used in this project. The inputs are the proximity sensors of inductive type connected to the three axis setup. The six proximity sensors provide the position of the base plate to the PLC. The logics are written in GX developer software in ladder logic.

The logics are written using various functions such as timers and DDRVI. These logics are then dumped into the PLC. The PLC then interprets the logic into system understandable. The outputs are the two stepper motor and the cylinder. The stepper motors are driven using the DDRVI command and the cylinder works on simple on/off command. The DDRVI command includes specifying the number of pulses, speed and the pulse and direction of the stepper motor. Initially based on the sensors output, position adjustment is done . Once it is done, the stepper motors are driven based on the logics to cut the required figure.

➢ *Mode of Operations*

There are two modes of operation that is , the figures can be obtained in two ways.

One is manual and the other is automatic.

- Manual Mode

In Manual mode of operation, the user assigns the input switches to drive each motor and also the cylinder. Timers are not required in this mode. The user operates the switches for the required duration in order to obtain the desired length.

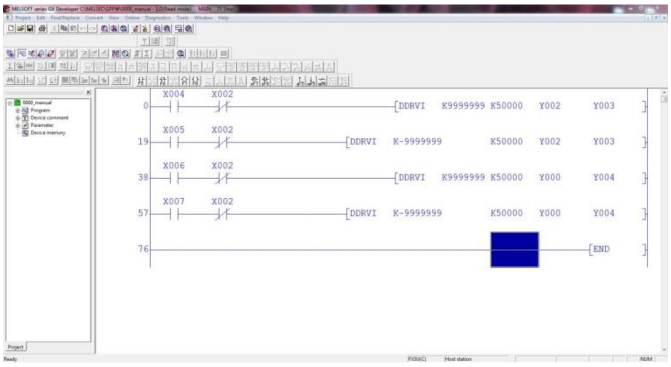


Fig 1:- MANUAL MODE

The code shown in the figure 1 is for manual mode operation, the switches and their corresponding functions are tabulated below.

Table 1 Input switch and its function

SI. No	Input Switch	Function
1	X005	Drive X axis motor in Reverse direction
2	X006	Drive Y axis motor in Forward direction
3	X004	Drive X axis motor in Forward direction
4	X007	Drive Y axis motor in Reverse direction
5	X002	Cylinder moves down

- Automatic Mode

In automatic mode of operation, the switches are used only to Start and Stop the operation. The programs are written for each shape (rectangle, square, triangle, and trapezium). Timers and proximity sensors used in order to get the required length. For example, to obtain a line of 5cm in X axis direction, X axis motor has to be driven either in forward or reverse direction for a duration of 100ms. Hence calculations for the figures are made based on the speed and the timer value.

Logics are also written in such a way that the cylinder moves up whenever it is not necessary .The inputs here include only the sensor. A snapshot of this mode of operation is shown in the figure 2.

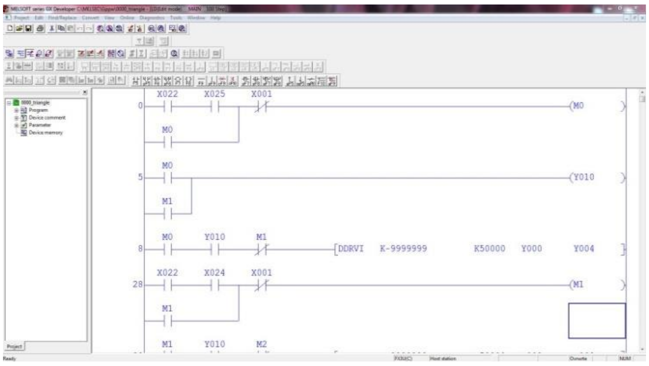


Figure 2 AUTOMATIC MODE

IV. HARDWARE IMPLEMENTATION

➢ *PLC (MITSUBISHI)*

The PLC used here is MITSUBISHI FX3U series. The micro programmable logic series requires a power supply of 100-240 VAC or 24 V DC. The number of inputs and outputs it can support is 8 -64. The digital outputs are of relay and transistor types. The program cycle period per logical instruction is 0.065µs.The power consumed is 25W.

Fig 3 MITSUBISHI PANEL

The MITSUBISHI PLC used here is shown in the figure 3. It consists of 16 input pins, out of which 8 are of switch type and remaining 8 are of push button type. It also has a provision to connect 24 input and outputs from external and an emergency stop button. The PLC used in this project is FX series whose specifications are explained in the next section.

➢ *FX3U CONTROLLERS*

The FX3U processors (in figure 4) are designed as the next evolution of the FX2N. The FX3U is more expandable, has more memory, and is faster than the FX2N.

Figure 4 MITSUBISHI FX SERIES

Some of the features of FX3U are as follows

- 64K program memory standard
- Input Power supply 230 VAC
- Control Supply is 24 VDC
- RS 232 Communication
- Program memory - 64000 steps
- Cycle time per log is 0.065 (µs)
- Special function instructions -218
- Maximum Special function modules -18 (8 right, 10 left)
- Extension capacity I/O- 384
- More data registers and file registers
- Maximum of 3 serial communication ports.
- New left side adapter bus for new analog, pulse input, pulse output, and communication options.
- Full featured Ethernet module available
- Profibus master available
- 6 sizes are available
- Even number of inputs and outputs
- 16 I/O
- 32 I/O
- 48 I/O
- 64 I/O
- 80 I/O
- 128I/O

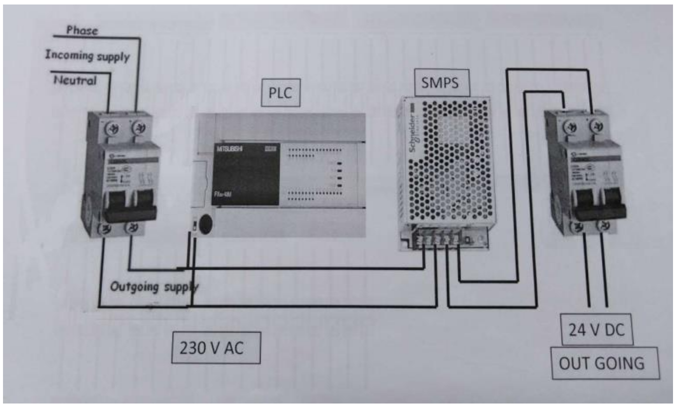


Figure 5 PLC AND POWER SUPPLY

There are 6 basic programming devices. Each devices has its own unique use. To enable quick and easy identification each device is assigned a single reference letter which are shown below,

- X: This is used to identify all direct, physical inputs to the PLC.
- Y: This is used to identify all direct, physical outputs from the PLC.

ISSN No:-2456-2165

- T: This is used to identify a timing device which is contained within the PLC.
- C: This is used to identify a counting device which is contained within the PLC.
- M : This is used as internal operation Flags within the PLC.

➢ *GX DEVELOPER SOFTWARE*

GX Developer supports all MELSEC controllers from the compact PLCs of the MELSEC FX series. GX Developer supports the MELSEC instruction list (IL), MELSEC ladder diagram (LD) and MELSEC sequential function chart (SFC) languages. A Snapshot of the software is shown in the figure 6. It involves the following features in whole:

- Standard programming software for all MELSECPLCs
- Comfortable prompting under Microsoft Windows
- Ladder Diagram, Instruction List or Sequential

Function Chart

- Changeable during operation
- Powerful monitoring and test functions
- Offline simulation for all PLC types
- No hardware needed

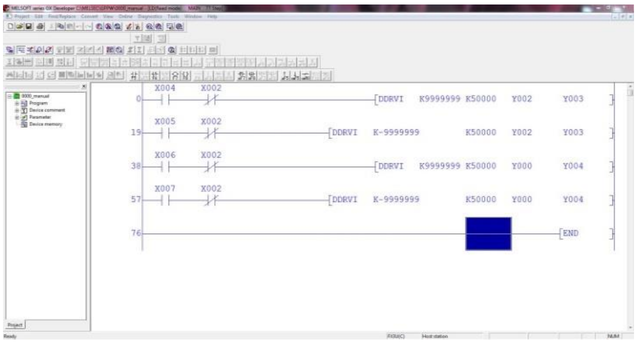


Figure 6 GX DEVELOPER SOFTWARE

➢ *STEPPER MOTOR*

A stepper motor is a motor used to have precise angle control. It is a brushless DC motor which can control the angular position without a closed feedback loop. It is a simple , accurate and open loop system. The most commonly used stepper motor is variable reluctance type motor. Unlike AC or DC motor which rotates the shafts continuously, the stepper motor rotates the shafts in steps. The number of pulse required for one complete rotation is equal to the number of internal teeth present on its rotor. The stator and the rotor teeth uses the locking principle to fix the angle of the shaft. The angle ‘A’ can be calculated as A= 360 ° / No. of rotor teeth.

Where ‘A’ denotes that the rotor rotates by one teeth position.

Two steppers motors as shown in the figure 7 are used. The internal structure is shown in the figure 7.

Figure 7 STEPPERMOTOR

The count for rotating the shaft of the stepper motor through a specified angle may be calculated from the no. of rotor teeth.

C = No. of rotor teeth / 360 * ϴ Where ϴ is the specified angle.

They have multiple coils that are organized in groups called "phases". By energizing each phase in sequence, the motor will rotate, one step at a time. With a computer controlled stepping one can achieve very precise positioning and/or speed control.

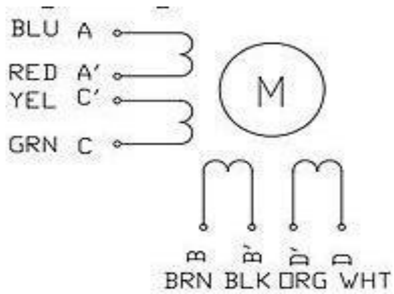


Figure 8 EIGHT WIRE MOTOR

The 8-wire unipolar as shown in the figure 8 is the most versatile motor of all. It can be driven in several ways:

- 4-phase unipolar - All the common wires are connected together - just like a 5- wire motor.
- 2-phase series bipolar - The phases are connected in series - just like a6-wire motor.
- 2-phase parallel bipolar-The phases are connected in parallel .This results in half the resistance and inductance - but require twice the current to drive.

The advantage of this wiring is higher torque and top speed.

➢ *STEPPER MOTOR DRIVER*

The stepper motor cannot be connected directly to the PLC, an interfacing component has to be present to drive the motor. The 2DM 542 stepper motor driver is used in this project. This driver has been used because of its low vibration, low noise and low heating. The features of the driver are as follows –

- 15 kinds of micro step.
- Maximum step number is 25600 steps/ rev .

ISSN No:-2456-2165

Figure 9 2DM 542 STEPPER MOTOR DRIVER

The stepper motor driver 2DM 542 as shown in the figure 9 acts as an interface between the PLC and the stepper motor. Q0, Q1, Q2 are the inputs of PLC which are connected to pulse, direction and enable of driver respectively. Any motor should not be directly connected to the microcontroller or microprocessor, a driver has to be interfaced. The 2DM 542 driver has pulse, direction and enable signal. The connections between the PLC and the driver are shown in the figure 10.

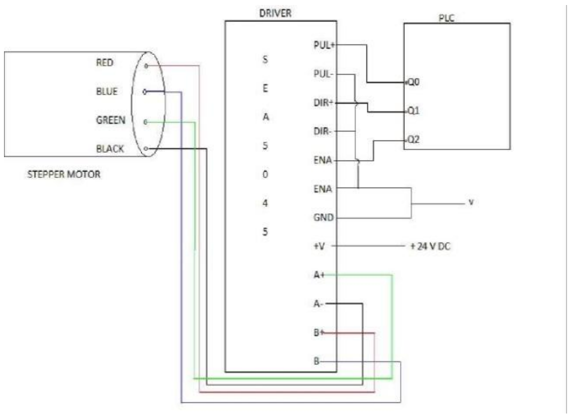


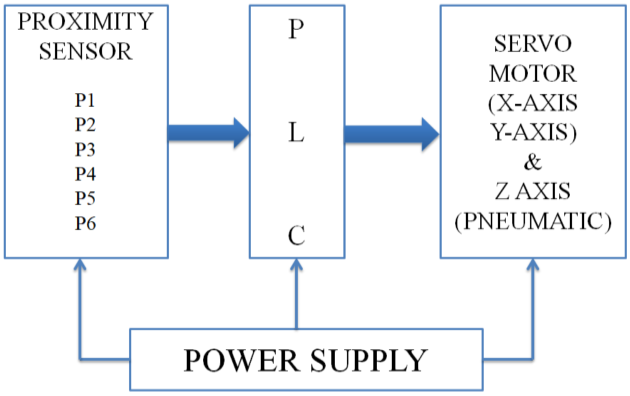
Figure 10 CONTROLLER STEPPER MOTOR CONNECTIONS

➢ *PROXIMITY SENSOR (INDUCTIVE TYPE)*

A proximity sensor (as shown in the figure 11) is a device used to detect the presence of objects without being in contact with it. In this project, proximity sensor is used to detect the position of the base plate. There are two proximity sensors, one is of inductive type and another is of capacitive type. The proximity sensor of inductive type which is used in this project can sense only metal objects. It uses the principle of electromagnetic induction. The proximity sensor consists of an inductor in which current is passed through it. Due to this current a magnetic field is produced around the coil. When a metal objects comes near this magnetic field, eddy currents are produced. The eddy current electromagnetic field will oppose the magnetic field in the conductor. This opposition acts as an indicator for the presence of the metal object.

Figure 11 PROXIMITY SENSOR

V. BLOCK DIAGRAM



VI. HARDWARE SETUP

In this setup as shown in the figure 12, the base plate moves left and right when X axis motor is driven and it moves front and back when Y axis motor is driven. Six inductive type proximity sensors have been installed, with three on either side.

Figure 12 THREE AXIS SETUP

The proximity sensors are used to detect the position of the base plate. With the help of these sensors, the user can decide from which position, the drawing has to be carried out. The pen moves up and down with the help of pneumatic supply. The pneumatic supply is turned on with the help of a compressor.

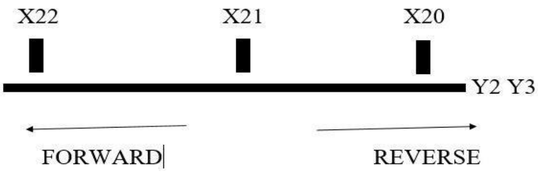


Figure 13 X AXIS DIRECTION

The X-Axis direction of the plate is shown in the figure 13 . The description of the sensors and the motor terminals are shown in the table 2.

Table 2 X axis Inputs and Outputs

Number	Description	Type
X22	X axis Forward	Input
X21	X axis Home	Input
X20	X axis Reverse	Input
Y2	X axis Pulse	Output
Y3	X axis Direction	Output

The Y axis direction of the plate is shown in the figure 14 . The motor terminals and the sensors are shown in the table 3.

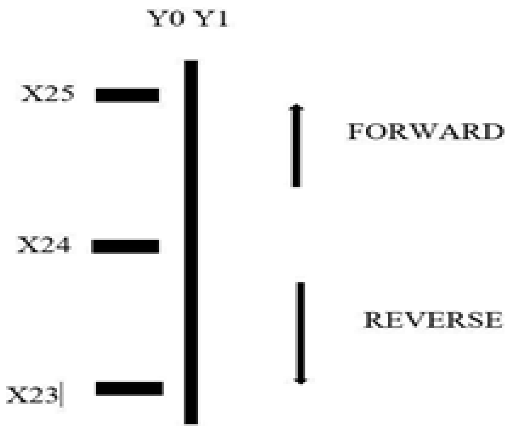


Figure 14 Y AXIS DIRECTION

Table 3 Y axis Inputs and Outputs

Number	Description	Type
X25	Y axis Forward	Input
X24	Y axis Home	Input
X23	Y axis Reverse	Input
Y0	Y axis pulse	Output
Y1	Y axis Direction	Output

The stepper motors are driver by the command DDRVI as shown in the figure 15

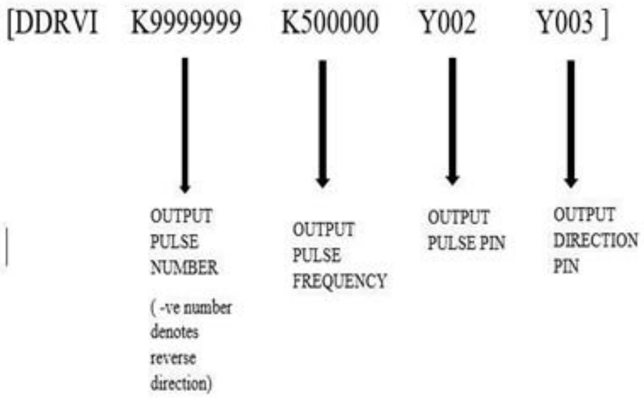


Figure 15 DDRVI Command

The direction of the stepper motor can be reversed by adding a '-ve' sign in the pulse number (k-9999999). By appropriate selection of the speed and the duration for which the motor has to run , required length for figures can be obtained. The time for which the motor has to run can be decided by specifying the timer value in timer function. To have diagonal lines, two stepper motors have to be driven simultaneously at the same time. By properly selecting the direction of both the motors, required diagonal lines can be obtained.

The additional input and output pins used are shown in table 4.

Table 4 Additional inputs and output

Number	Description	Type
X7	Start	Input
X5	Emergency Stop	Input
Y10	cylinder Forward	Output

➢ *STEPS TO PROGRAM AND UPLOAD*

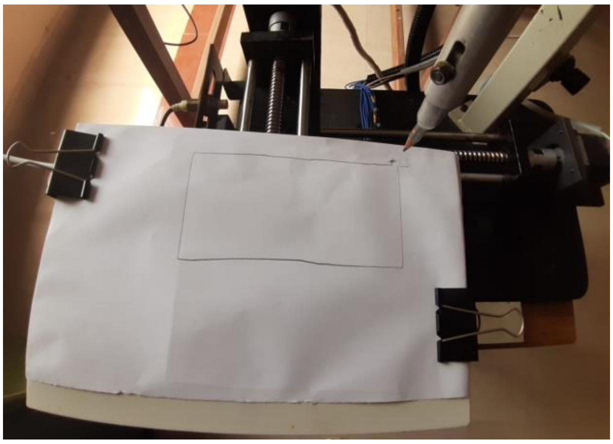
- Open GX Developer Version 8.
- To create new project , select Project -> New Project.
- Click Ok to create new project.
- Program the required logic suitable using ladder diagram.
- Convert the program Convert -> Enter.
- Go to online and select transfer setup, Online -> Transfer Setup.
- Select the suitable COM Port
- After selecting the COM Port , do the connection test.
- Assure successful connection with PLC.
- Transfer the program to PLC.
- Select Online -> Write to PLC.
- Select all the options and execute.
- Go to Online -> Monitor -> Monitor Mode.
- Check the results using the ON/OFF switches in PLC and observe the expected results in the LED panel in the PLC.
- The results can also be visualized in the GX Developer by means of the green glow on the output coil.

VII. RESULTS AND DISCUSSIONS

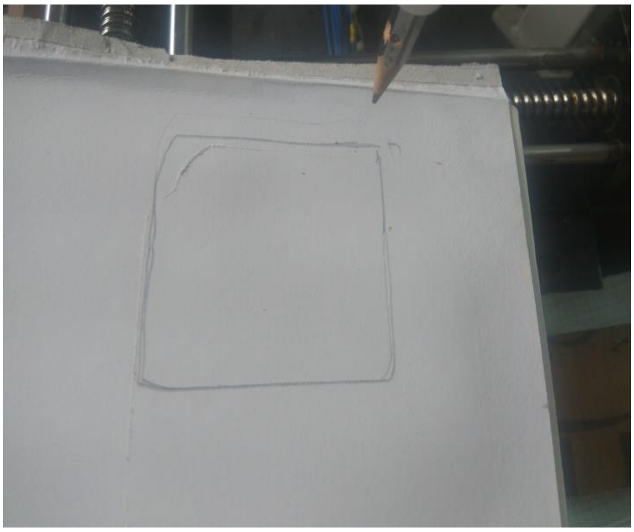
Control of three axis setup with MITSUBISHI PLC has been done and the cutting of the following shapes has been implemented.

- Rectangle
- Square.
- Triangle.
- Trapezium.

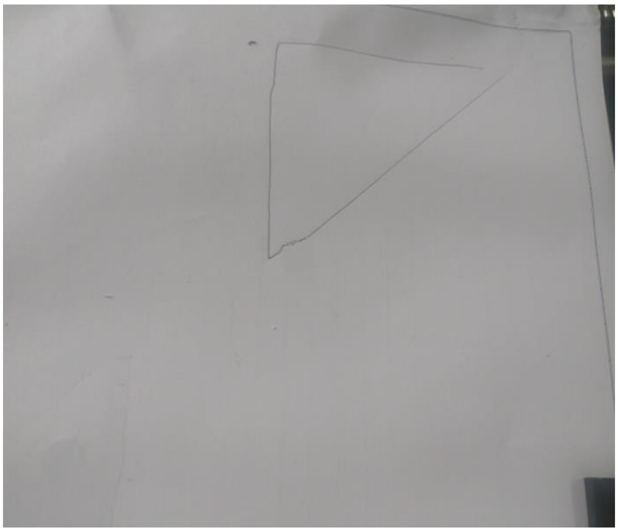
Separate program has been written for all the above shapes. Position adjustment has been done for all the programs. Initially the setup adjusts itself for the home position, once the home position has been reached, the cylinder comes down and starts cutting. Lifting of the blade whenever not necessary while cutting figures has been done.



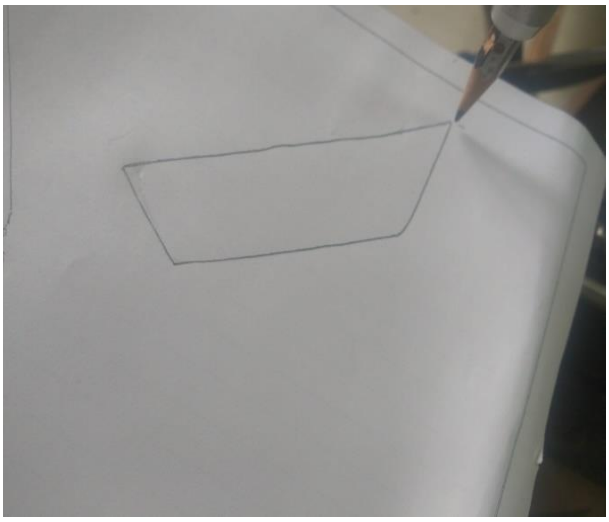
RECTANGLE



SQUARE



TRIANGLE



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ISSN No:-2456-2165

VIII. CONCLUSION

This project includes interfacing of the three axis setup with Mitsubishi PLC both in hardware and software. The software part involves programming in Ladder logic diagram. The programs include finding the logics to drive both the stepper motor as well as the cylinder in each case. The work done so far includes manual and automatic cutting of shapes such as Rectangle, Square, Trapezium and triangle. Further this project can be extended to obtain non-symmetrical and three dimensional shapes by utilizing the timers and positioning functions.

REFERENCES

[1]. Kanchan Pandita, Yamini Sharma, Vijaykumar Kamble "Stepper motor driven three axis robot using plc", International Journal of Enginnering Research and General Science , Vol.4 (2): pp: 5-8.
[2]. Leonard Sokoloff "Plc stepper motor controller" International Journal of Advanced Research in Computer Engineering, Vol.7(5):pp:525-527.
[3]. Abhishek Kumar Mishra, Karan Muley , Lakshmi Gautam "interfacing of stepper motor with plc" International Journal of advanced Research in Computer Engineering and Technology , Vol.7(5):pp: 1-4.
[4]. Amer Ali Ammar "step motor control by using plc", Industry Research conference , Vol. 2(16):pp:23-58.