

# TWO AXIS MOTION CONTROL WITH INTERPOLATION USING PLC

Manjula BK<sup>1</sup>,Guru Prasad Agali<sup>2</sup>,Ravi raj<sup>3</sup> , Girish Kumar LN<sup>4</sup>,Raj kavin<sup>5</sup>

Assistant Professor, EEE Department, BMSIT&M, Bangalore, Karnataka, India

EEE Department, BMSIT&M, Bangalore, Karnataka, India.

**Abstract:** This paper is designed to implement of a two-axis motion control with interpolation using PLC (Programmable Logic Controllers). Linear motion is one of the fundamental movements and an absolute necessity for any motion controller. High precision, repeatability and direction-independent are the three important factors to evaluate the performance of two axis motion control with Interpolation. To achieve this, PLC based algorithm is implemented, which avoids complex on-the-motion computation with skillful combination of the accumulator and multiplier-based hardware structure. In addition to employ high speed and high precision equipment such as linear motor-driven stages, the precision of the machined contours is highly dependent on the capabilities of the servo controllers or stepper motor controllers. In this paper, the design of a precise controller for a two-axis LMDS has been investigated for interpolating applications.

**Index Terms** - Motion control, Two axis motion control, PLC, Linear Motion, Interpolation, Stepper Motor

## I. INTRODUCTION

Many times, because of human errors lots of accidents occur. Improper lifting/overexertion is one of them. Industrial accidents occur when there is a failure to follow proper procedures, including taking shortcuts, improper handling of materials, misuse of equipment, fatigue and over confidence about abilities. This project is dedicated to adding extra facilities with the existing system of motion control. Decreasing settling time allows the controller to move more rapidly from one position to the next position where the further process will begin. All multi axis motion control involves coordinated motion. In reality, coordinated motion is very specific subset of motion control. Control schemes that involve multiple axes operating independently to position the load are much simpler to execute than those requires very fast control loops with high-resolution feedback.

A PLC is an industrial computer control system that continuously monitors the state of input devices and makes decision based upon a custom program to control the state of output devices. Most of the production line, machine or process can be greatly enhanced using this type of control system. However, the biggest benefit in using a PLC is the ability to change and replicate the operation or process while collecting and communicating vital information. Another advantage of a PLC system is that it is modular. That is, we can mix and match the types of Input and Output devices to best suit for application. Because of the move and settle nature of the process, this type of equipment has traditionally used stepper motors. Now, that is changing. "One of the big trends we are seeing is a move from stepper motor technology to servo motor technology.

## II. Introduction to motion control

Motion control is an exciting automation technology that has become the cornerstone of modern industrial machinery design. It is about making a mechanism move under complete control, how you want, when you want. It incorporates the finer elements of motor control and requires careful mechanical design. Motion technology is advancing to provide improved performance and increased ease of use, enabling servo and motion controls to be applied more widely than ever before. Motion control can provide greater accuracy, performance and efficiency in many production machine applications. Motion control technology can be applied to rotary servo motors, asynchronous AC and DC motors and various linear motor technologies, to provide ever more flexible and dynamic production systems. The result is that every automation engineer should now have some background knowledge of motion control systems and their mechanical requirements.

### Two Axis Motion Control

The term "axis of motion" refers to one degree of freedom, or forward and backward motion along one direction. It may be linear or rotary motion, and may take the form of a conveyer belt, a rotary knife, or many other types. When two or more axes of motion are involved on a single machine, that machine is employing multi-axis motion. The axes may be working independently, or moving together. The need for multi-axis synchronization arises whenever the axes must move together, and the relationship between their respective motion is important.

The most familiar example of a multi-axis application requiring synchronization is that of an X-Y plotter. Here there are two axes, the X direction and the Y direction. Each may move independently of each other, but if a two-dimensional figure is to be drawn accurately, their motion must be coordinated. The figure below illustrates what happens to a 45-degree line if the X axis starts and ends later than the Y axis.

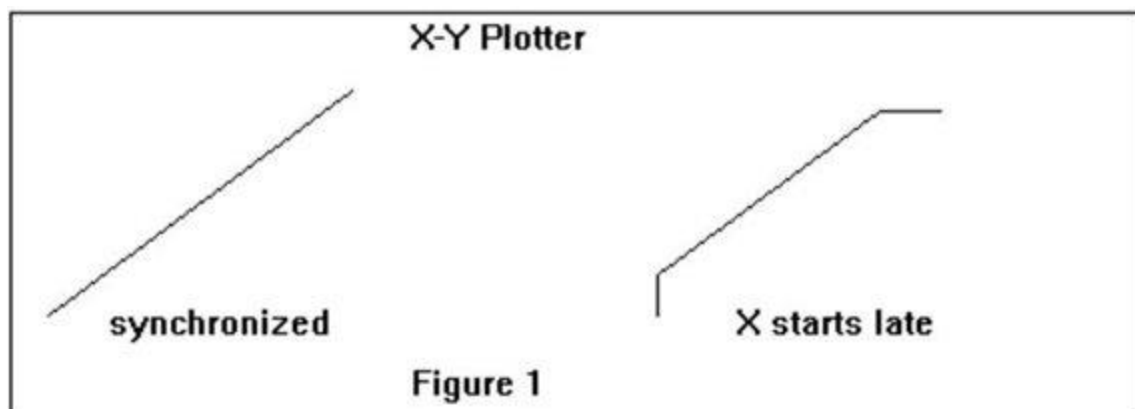


Fig: Example of XY Plotter

### III. Stepper and Servo Motion Control Systems

The availability of electronic motion control has brought solutions to the problems inherent with the mechanical approach to synchronization. To understand how these solutions are achieved, it is helpful to review basic electronic motion control systems. One axis of electronic motion control consists of the motor, the motor drive, and the controller. The controller accepts motion commands from a host computer or an internally stored program. These commands are interpreted by the controller to generate continuously updated position commands (motion profiles) to the drive. The motor drive controls the current to the motor which will result in the commanded position. In a multi-axis system, one controller can control several motor and drive combinations.

The motion control system may be a **stepper or servo system**. Stepper systems tend to be less expensive than servo systems, but have less speed and power for a given size of motor. In stepper systems, the drive receives position commands in the form of low voltage pulses (steps), and adjusts the *phase* of the current in two sets of motor coils to align the motor shaft. Each new step received corresponds to an additional increment of rotation on the shaft. Current is maintained in the motor coils, even when the motor shaft is in the correct position. Common step motor resolutions range from 200 steps per revolution (full stepping) to 50,000 steps per revolution (micro-stepping).

Servo systems employ motor shaft position feedback, either from an incremental encoder or from a resolver. The actual position and velocity derived from the feedback is compared to that commanded in the motion profile to result in a torque command to the drive. In servo motors, the phase of the current is adjusted according to the actual position of the shaft. It is continuously adjusted to produce maximum torque for a given current amplitude. This process is called commutation, and is done mechanically in brushed motors, and electronically in brushless motors. The drive controls the amplitude of the current to the motor in proportion to the torque command. In analog servo systems, the feedback goes to the controller, and the controller's output is an analog torque command. In digital servo systems, the drive accepts steps as the position commands, and the shaft feedback goes only to the drive. Servo systems must be tuned to match the load they are moving for the best performance. A properly tuned system results in powerful and precise positioning of the load. The choice of motion control system will depend on the particular application

### IV. PLC (PROGRAMMABLE LOGIC CONTROL)

A Programmable Logic Controller, or PLC, is a ruggedized computer used for industrial automation. These controllers can automate a specific process, machine function, or even an entire production line.

#### *How does a PLC work?*

The PLC receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, a PLC can monitor and record run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Programmable Logic Controllers are a flexible and robust control solution, adaptable to almost any application.

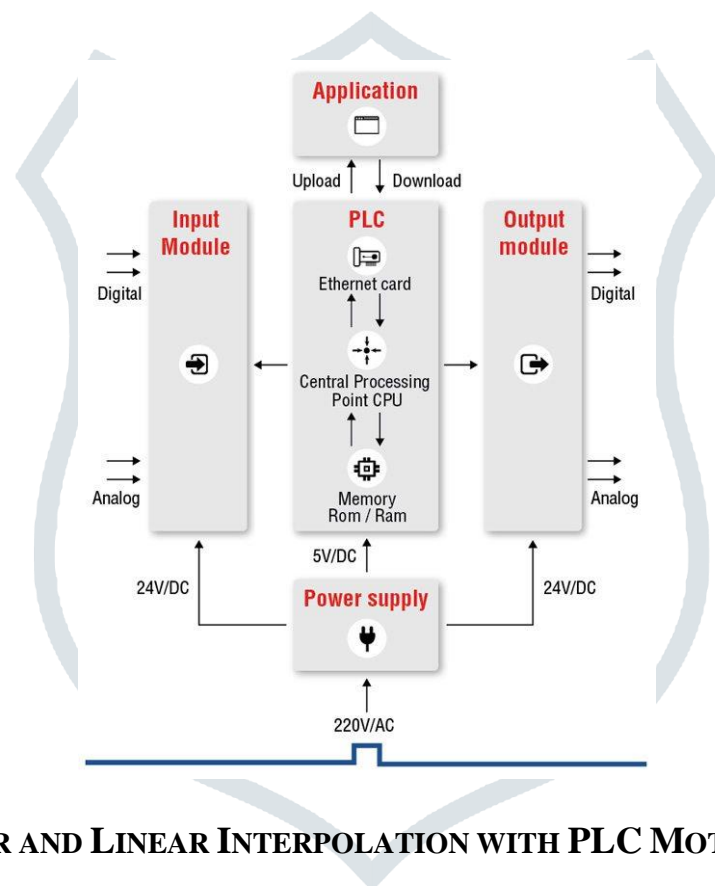
There are few key features that set PLC'S apart from industrial PC'S, Microcontrollers and other Industrial control solutions:

- I/O** – The PLC's CPU stores and processes program data, but input and output modules connect the PLC to the rest of the machine; these I/O modules are what provide information to the CPU and trigger specific results. I/O can be either analog or digital; input devices might include sensors,

switches, and meters, while outputs might include relays, lights, valves, and drives. Users can mix and match a PLC's I/O in order to get the right configuration for their application.

**II. Communications** – In addition to input and output devices, a PLC might also need to connect with other kinds of systems; for example, users might want to export application data recorded by the PLC to a supervisory control and data acquisition (SCADA) system, which monitors multiple connected devices. PLCs offer a range of ports and communication protocols to ensure that the PLC can communicate with these other systems.

**III. HMI** – In order to interact with the PLC in real time, users need an HMI, or Human Machine Interface. These operator interfaces can be simple displays, with a text-readout and keypad, or large touchscreen panels more similar to consumer electronics, but either way, they enable users to review and input information to the PLC in real time.



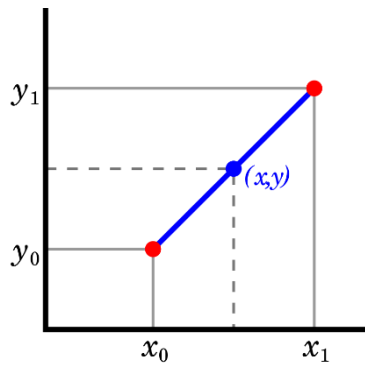
## V. CIRCULAR AND LINEAR INTERPOLATION WITH PLC MOTION CONTROL

**Interpolation** : Is a type of estimation a method of constructing new data points within the range of a discrete set of known data points. The interpolation is either linear or circular, but we consider linear interpolation.

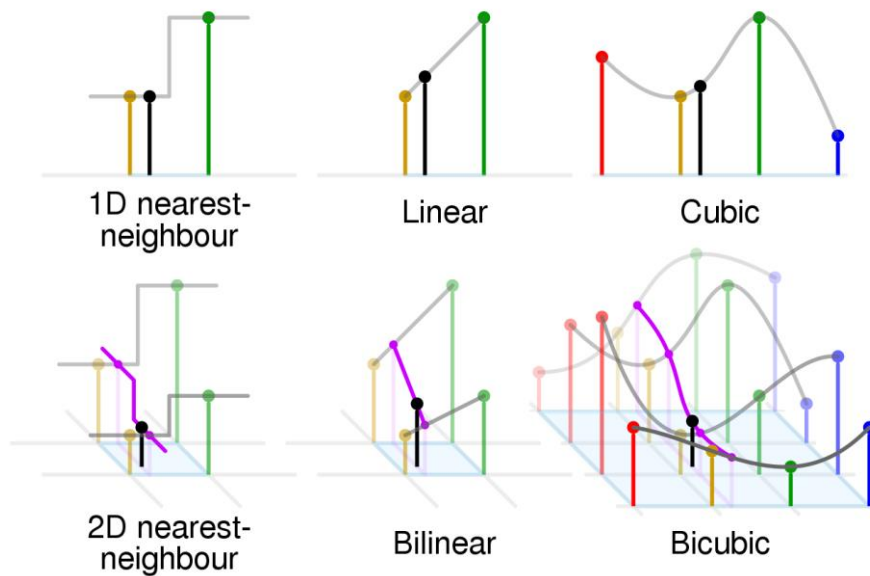
**Linear interpolation**: Is a method of curve fitting using linear polynomials to construct new data points within the range of a discrete set of known data points.

**Circular interpolation**: Since not all parts are made of flat surfaces, end mills will invariably need to move in a non-linear path. In the case of machining circular tool paths, the path of the end mill's centerline is circular. This is referred to as Circular Interpolation.

**Linear interpolation between two known points:**



Given the two red points, the blue line is the linear interpolant between the points, and the value  $y$  at  $x$  may be found by linear interpolation.



Comparison of linear and bilinear interpolation some 1- and 2-dimensional interpolations. Black and red/yellow/green/blue dots correspond to the interpolated point and neighboring samples, respectively. Their heights above the ground correspond to their values.

**Circular Interpolation:**

All rotating end mills have their own angular velocity at the outside diameter. But when the tool path is circular, there is an additional component that is introduced, resulting in a compound angular velocity. Basically, this means the velocity of the outside diameter is travelling at a substantially different velocity than originally expected. The cause of the compound angular velocity is seen in the disparity between the tool path lengths.

When G02 (clockwise circle, CW) or G03 (counter-clockwise circle, CCW) is selected, the programmed path is traversed with a feedrate given by the F-word, on a circular movement to the target position. Circular movements can be run in the three main planes of the spatial coordinate system (X-Y, Z-X, Y-Z). The selection of the main plane is done using the functions G17, G18, G19. All programmed tracking axes are moved with linear velocity in such a manner that the start and the end of their movement take place simultaneously to that of the main axes.

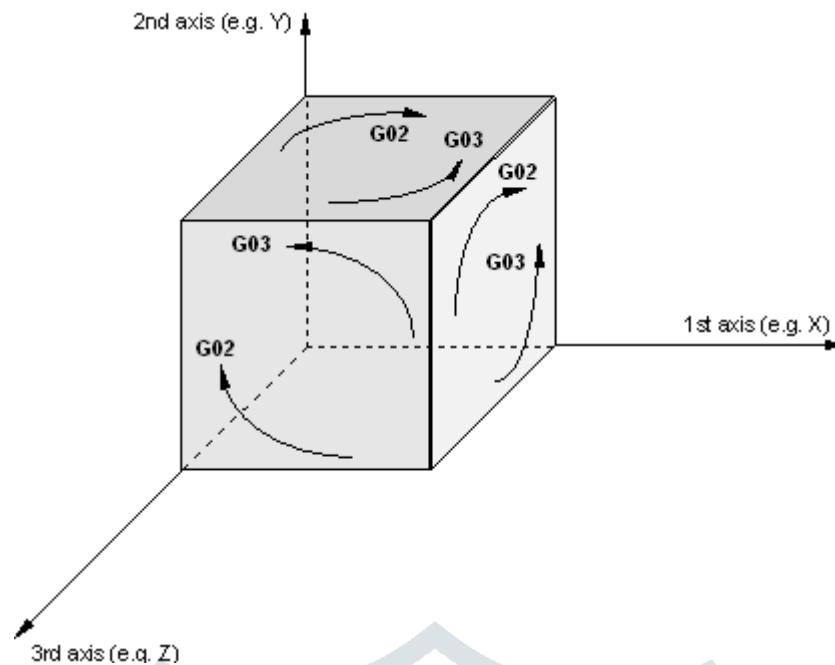


Fig: Elucidation of circle functions G02 and G03

<p><b>G02</b> Circular interpolation clockwise circle (CW) (modal)</p> <p><b>G03</b> Circular interpolation counter-clockwise circle (CCW)</p>
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## INTERPOLATION ALGORITHM RESEARCH

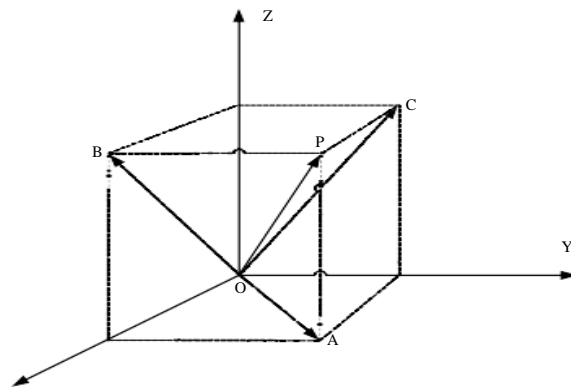
In all curves, straight line is the most fundamental curve; any complex curve can be approximated by a mass of short lines, so the linear interpolation is very important in motion controller.

Generally, linear interpolation methods include Plus-minus Method, Point-to-point Comparison Method, and Differential Analytical Method, etc. All of those interpolation methods, usually implemented by software in MCU or PC, are classified as Incremental Method which needs interpolation calculation, error/destination judgment, and pluses feeding in every interpolation process. With this implementation mode, plenty of software resource is occupied, which result in slow speed in drawing picture and time-consuming in CPU, so one CPU sometimes may be not competent for burdensome tasks such as drawing management and drawing execution, etc. To enhance the drawing speed, linear interpolation method implemented by hardware circuit such as FPGA is sought, and the particular structure of FPGA make it have an excellent time performance in interpolation calculation. This method suits to apply in machining and drawing instrument under numerical control. At the same time, a novel linear interpolation algorithm is employed, and this interpolation algorithm does not require a large amount of complex mathematical calculation, so it is fast enough to be used in real-time applications.

### 3-D line movement inspace

Line movement in space can be decomposed into line movement in plane through mapping transformation, as shown in figure 3. In the figure, space line from O to P has three decomposition methods: OB and OC, or OB and OA, or OA and OC. It is an example for pulse output of the linear interpolation driving. We define the longest distance movement in interpolation as "long axis". the other two axes are called "short axis". Long axis decides the decomposition method of the space movement, for example, if Z axis is the long axis, the linear movement OP should decompose into OB in XOZ plane and OC in YOZ plane.

When the interpolation begins, Z-AMM outputs an average pulse train, whose frequency is set firstly by CPU, to LIM, the driving pulse of two short axes depends on the long axis and the relationship of this axis with the long axis. At last, the linear interpolation of 2-D line movement OB and OC implements the 3-D line movement OP.



**Fig: Decomposition of 3-D Line movement in XYZ space**

## VI. SPECIFICATIONS:

### 1. PLC and Supporting Function (DVP-SA2, PLC)

❖ A PLC is a computer, or more precisely an industrial computer. PLC's are designed to withstand harsh environments; assembly lines, food-processing plants, automotive plants and more. Most PLC's are modular; they can be scaled up or down as needed. Inputs cards, output cards, communication cards, motion control cards all can be added or removed to satisfy most engineering needs.

❖ They are designed for a very specific purpose, machine control. The PLC is the brain of any intelligent control system. Just as the integrated circuit chip replaced multiple transistor circuits in electronics, the PLC replaced multiple electromechanical relays in industrial circuits. Complex machines contained thousands of relays. Today a single PLC can replace all the logical relays, timers, and other peripheral devices common in the machines of the past.

### PLC (DVP SA2)

- ❖ Adopt 32-bit CPU
- ❖ Program capacity: 16K steps/Data register:10K words
- ❖ Execution speed: LD: 0.35us,MOV:3.4us
- ❖ Built-in 1 RS-232 and 2 RS-485 port (Master/slave)

### 2. Stepper Motor

#### GENERAL SPECIFICATION

Stepper Motor Model	EMM57HS51-605
Step Angle	1.8 Degrees per step
Optimum motor Temperature	80 Degrees C Maximum
Operating Ambient Temperature	-20°C TO +50° C
Storage Temperature	-20°C TO +60°C
Operating Ambient Humidity	90% RH ,40' MAX (no condensation)
Insulation Resistance	100M OHM MIN,500V DC Megger at normal room temperature and humidity

Dielectric Strength	At normal room temperature and humidity motor can with stand 1500V AC applied between winding and motor body for 1 minute
Shaft Radial Play	0.02mm Maximum (450 Gms – Load)
Shaft Axial Play	0.08mm Maximum (450Gms – Load)
Maximum Radial Force	75N (20mm from the flange)
Maximum Axial Force	15 N-M
Thermal Class	CLASS B (+130 Degree C)
Protection Grade	IP40
Mounting Direction	Can be mounted in both horizontal and vertical direction

**ELECTRICALS SPECIFICATION****MECHANICAL SPECIFICATION**

No of Phase	2 Phase
Stepping Angle	1.8 Degrees per step
Voltage Per Phase	3.3. Volts
Current Per Phase	1 Amps
Resistance Per Phase	6.6 Ohms
Inductance Per Phase	5.5m H
No of Leads	4 Wire

Holding Torque	10 Kg-Cm
Detent Torque	300 Gm-Cm
Rotor Inertia	230 Gm-cm
Motor Mass	0.59 Kg

**VII. PROPOSED METHODOLOGY:**

This project is designed using PLC (Programmable Logic Controllers). In practice, two-axis motion control systems are typically applied to processes with slow contour motion such as fine machining. In a typical motion control system, there are three basic components: the controller, the drive and the motor. The path planning is performed in the controller, which sends low-voltage command signals to the drive, which in turn applies the necessary voltage and current to the motor, resulting in the desired motion. Servo systems operate in a closed loop fashion and vary output torque to move into/stay at the command position. The classic 'pulse and direction' signals that are widely used with PLCs provide an inexpensive, noise free method for precision motion control. While typically limited to a few axes of control and where coordination between axes is limited, PLC controllers with pulse and direction capability are an excellent fit for many motion applications.

**VIII. Conclusion**

This paper introduces the implementation of linear interpolation module in 2-axis PLC controller. High performance and configurable stepper motor drive is implemented in two axis motion control drive using interpolation. The implementation of 2-axis linear interpolation module is discussed. By practical analysis of linear interpolation, has excellent performance and can be used for practical motion control.

**Future Scope**

1. Two axis motion control applications can be used for controlling applications by using PLC.
2. Used in controlling applications such as Movement of Docking doors, Sortation and placement machines, Bagging Machines etc
3. PLC with interpolation can be used in Art and Craft industries.
4. Can be implemented in Packing industries.



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