Step Motor Control by Using (PLC) Programmable Logic Controllers

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ABSTRACT:

In this paper a thorough theoretical and practical study of the PLC control is presented to provide information required to understand the PLC, its main hardware component, how these components interact with each other, and how the PLC can be used to control other systems. It aims to study the step motor , understand how it works and understand how a step motor is controlled by using PLC without a driver .

keywords. *Step motor, PLC(software &hardware).*

Introduction:

Early machines were controlled by mechanical means using cams, gears, levers and other basic mechanical devices. As the complexity grew, so did the need for a more sophisticated control system. This system contained wired relay and switch elements. These elements were wired as required to provide the control logic necessary for the particular type of machine operation.

The PLC designed to be rugged. Unlike their personal computer cousin, they can typically withstand vibration, shock , elevated temperatures, and electrical noise to which Manufacturing equipment is exposed. As more manufacturers become involved in PLC production and development, and PLC capabilities expand, the programming language is also expanding. This is necessary to allow the programming of these advanced capabilities. Also, manufacturers tend to develop their own versions of ladder logic language (the language used to program PLCs). This complicates learning to program PLC's in general since one language cannot be learned that is applicable to all types. However, as with other computer languages, once the basics of PLC operation and programming in ladder logic are learned, adapting to the various manufacturers' devices is not a complicated process. Most system designers eventually settle on one particular manufacturer that produces a PLC that is personally comfortable to program and has the capabilities suited to his or her area of applications.[1]

PLCs :

Programmable Logic Controllers are a solid-state, digital electronic device that controls the operation of a machine. another words Programmable Logic Controllers (PLCs) are digital devices that are used to control the state of output ports based on the state of input ports It uses Logic functions, which are programmed into its memory via programming software .also referred to as programmable controllers, are in the computer family. They are used in commercial and industrial applications. A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine as shown in the figure (1)

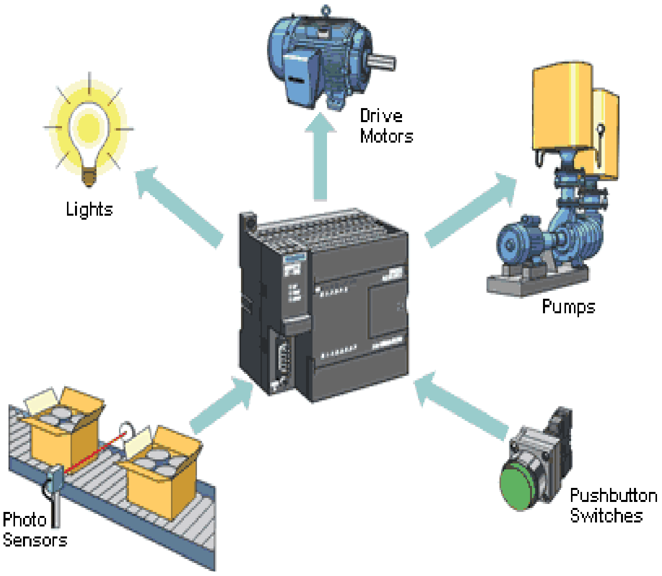


Figure. 1 Automate a process or machine

The typical system components of PLC:

A. CPU:

Central Processing Unit (CPU) is the brain of a PLC controller. The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decision making unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory. The CPU performs relay, counting, timing, data comparison, and sequential operations.

B. Memory:

Memory is the component that store information, programs and data in a PLC.the process of putting information into a memory location is called writing. the process of retrieving information from memory location is called reading.

C. Type of memory:

- RAM:

Random Access Memory (RAM) is memory where data can be directly accessed at any address. Data can be written to and read from RAM. RAM is used as a temporary storage area. RAM is volatile, meaning that the data stored in RAM will be lost if power is lost. A battery backup is required to avoid losing data in the event of a power loss.

- **ROM:**

Read Only Memory (ROM) is a type of memory that data can be read from but not written to. This type of memory is used to protect data or programs from accidental erasure. ROM memory is nonvolatile. This means a user program will not lose data during a loss of electrical power. ROM is normally used to store the programs that define the capabilities of the PLC.

- **EPROM:**

Erasable Programmable Read Only Memory (EPROM) provides some level of security against unauthorized or unwanted changes in a program. EPROMs are designed so that data stored in them can be read, but not easily altered. Changing EPROM data requires a special effort. UVEPROMs (ultraviolet erasable programmable read only memory) can only be erased with an ultraviolet light. EEPROM (electronically erasable programmable read only memory), can only be erased electronically.

- **FIRMWARE:**

Firmware is user or application specific software burned into EPROM and delivered as part of the hardware. Firmware gives the PLC its basic functionality.

D. **Types of inputs and outputs:**

- **Discrete Input:**

A discrete input, also referred to as a digital input, is an input that is either in an ON or OFF condition. Pushbuttons, toggle switches, limit switches, proximity switches, and contact closures are examples of discrete sensors which are connected to the PLCs discrete or digital inputs. In the ON condition a discrete input may be referred to as a logic 1 or a logic high. In the OFF condition a discrete input may be referred to as a logic 0 or a logic low.[2]

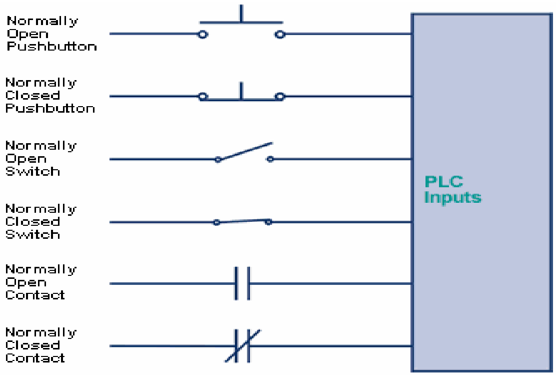


Figure 2 Discrete input

- Analog Inputs:

An analog input is a continuous, variable signal. Typical analog inputs may vary from 0 to 20 milliamps, 4 to 20 milliamps, or 0 to 10 volts. In the following example, a level transmitter monitors the level of liquid in a tank. Depending on the level transmitter, the signal to the PLC can either increase or decrease as the level increases or decreases.

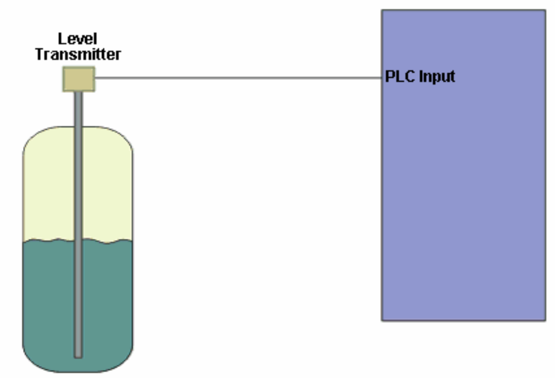


Figure 3 analog input

- Discrete Outputs:

A discrete output is an output that is either in an ON or OFF condition. Solenoids, contactor coils, and lamps are examples of actuator devices connected to discrete outputs. Discrete outputs may also be referred to as digital outputs. In the following example, a lamp can be turned on or off by the PLC output it is connected to.

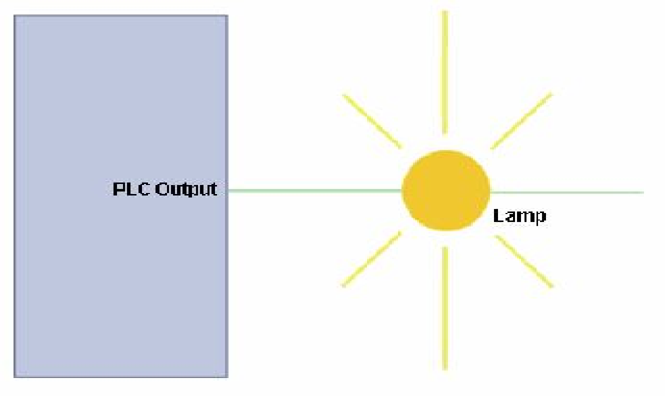


Figure 4 discrete output

- **Analog Outputs :**

An analog output is a continuous, variable signal. The output may be as simple as a 0-10 VDC level that drives an analog meter. Examples of analog meter outputs are speed, weight, and temperature. The output signal may also be used on more complex applications such as a current-to-pneumatic transducer that controls an air-operated flow-control valve.

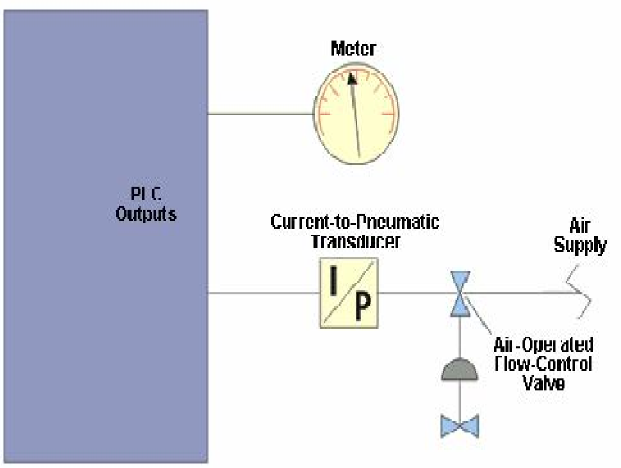

Meter
PLC Outputs
Current-to-Pneumatic Transducer
I/P
Air Supply
Air-Operated Flow-Control Valve

Figure 5 analog output

- **Power supply**:

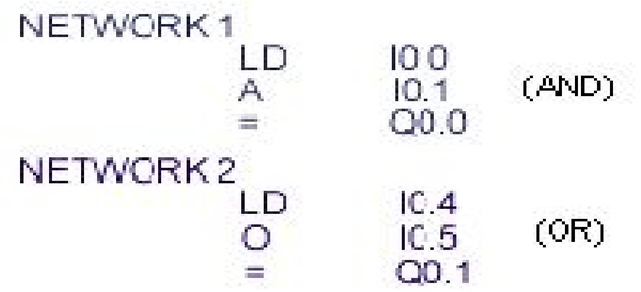
The power supply specified depends upon the manufacturer's PLC being utilized in the application. As stated above, in some cases a power supply capable of delivering all required power for the system is furnished as part of the processor module. If the power supply is a separate module, it must be capable of delivering a current greater than the sum of all the currents needed by the other modules. For systems with the power supply inside the CPU module, there may be some modules in the system which require excessive power not available from the processor either because of voltage or current requirements that can only be achieved through the addition of a second power source. This is generally true if analog or external communication modules are present since these require _ DC supplies which, in the case of analog modules, must be well regulated.

Programming:

A program consists of one or more instructions that accomplish a task. Programming a PLC is simply constructing a set of instructions. There are several ways to look at a program such as ladder logic, statement lists, or function block diagrams.

- **Statement list:**

A statement list (STL) provides another view of a set of instructions. The operation, what is to be done, is shown on the left. The operand, the item to be operated on by the operation, is shown on the right. A comparison between the statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure. The set of instructions in this statement list perform the same task as the ladder diagram.[3]



```
NETWORK 1
          LD       I0.0
          A        I0.1     (AND)
          =        Q0.0
NETWORK 2
          LD       IC.4
          O        IC.5     (OR)
          =        Q0.1
```

Figure 6 statement list

-Function Block Diagrams

Function Block Diagrams (FBD) provide another view of a set of instructions. Each function has a name to designate its specific task. Functions are indicated by a rectangle. Inputs are shown on the left-hand side of the rectangle and outputs are shown on the right-hand side. The function block diagram shown below performs the same function as shown by the ladder diagram and statement list.

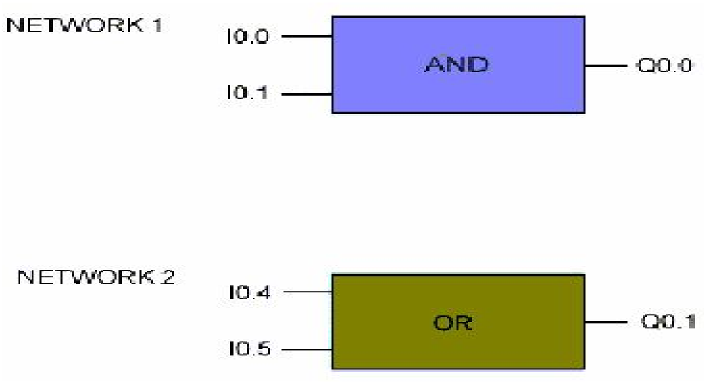


Figure 7 function block diagram

- Ladder Logic Diagram:

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control.

The left vertical line of a ladder logic diagram represents the power or energized conductor. The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

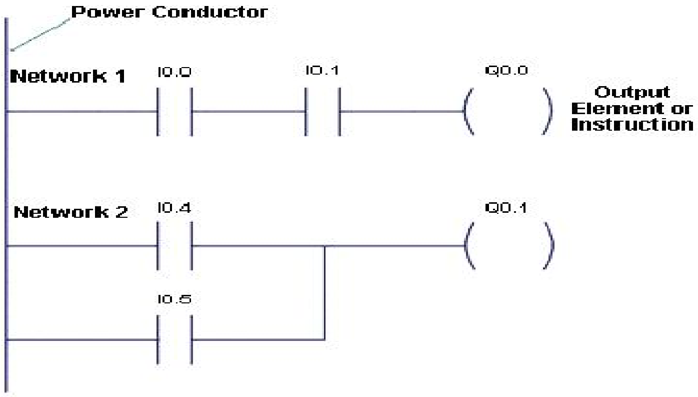


Figure 8 Ladder Logic Diagram

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E. Symbols:

In order to understand the instructions a PLC is to carry out, an understanding of the language is necessary. The language of PLC ladder logic consists of a commonly used set of symbols that represent control components and instructions.

-Contacts:

One of the most confusing aspects of PLC programming for first-time users is the relationship between the device that controls a status bit and the programming function that uses a status bit. Two of the most common programming functions are the normally open (NO) contact and the normally closed (NC) contact.

Symbolically, power flows through these contacts when they are closed. The normally open contact (NO) is closed when the input or output status bit controlling the contact is 1. The normally closed contact (NC) is closed when the input or output status bit controlling the contact is 0.

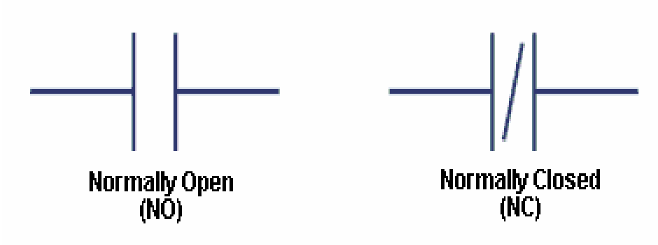

Figure 9 contact symbols

-Coils:

Coils represent relays that are energized when power flows to them. When a coil is energized, it causes a corresponding output to turn on by changing the state of the status bit controlling that output to 1. That same output status bit may be used to control normally open and normally closed contacts elsewhere in the program

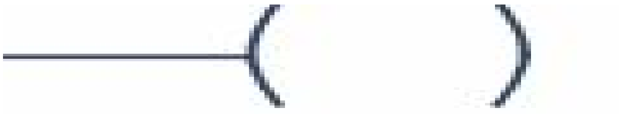

Figure 10 coils symbol

- Boxes:

Boxes represent various instructions or functions that are executed when power flows to the box. Typical box functions are timers, counters, and math operations.

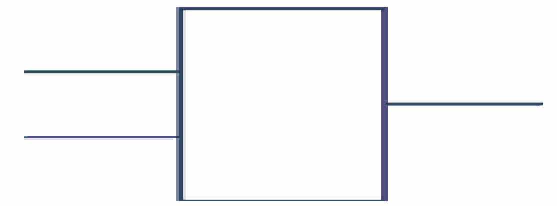

Figure 11 boxes symbol

F. PLC Scan:

The PLC program is executed as part of a repetitive process referred to as a scan. A PLC scan starts with the CPU reading the status of inputs. The application program is executed using the status of the inputs. Once the program is completed, the CPU performs internal diagnostics and communication tasks. The scan cycle ends by updating the outputs, then starts over. The cycle time depends on the size of the program, the number of I/Os, and the amount of communication required.

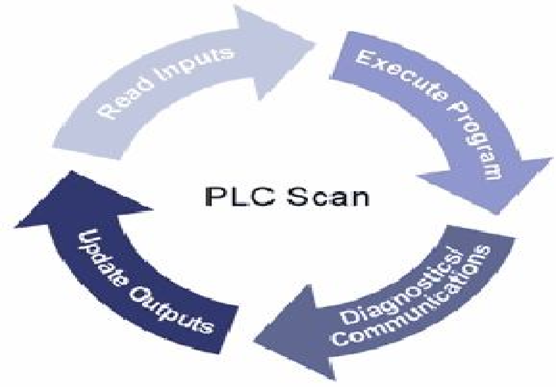

Figure 12 PLC scan

G. Software:

Software is any information in a form that a computer or PLC can use. Software includes the instructions or programs that direct hardware.

H. Hardware:

Hardware is the actual equipment. The PLC, the programming device, and the connecting cable are examples of hardware

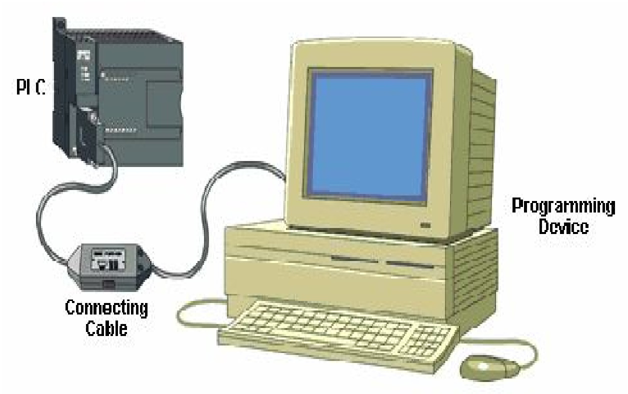

Figure 13 hardware

I. Basic Requirements:

In order to create or change a program, the following items are needed:

- PLC
- Programming Device
- Programming Software
- Connector Cable

Stepper Motor:

A step motor (or stepper motor as they are commonly referred) is a digital device, in that digital information is processed to accomplish an end result, in this case, controlled motion. It is reasonable to assume that a step motor will faithfully follow digital instructions just as a computer is expected to. This is the distinguishing feature of a step motor.

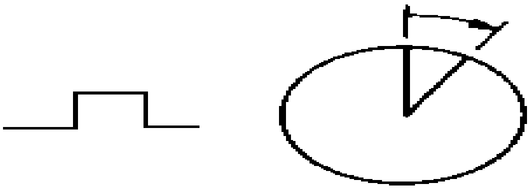

Figure 14 one pulse one step

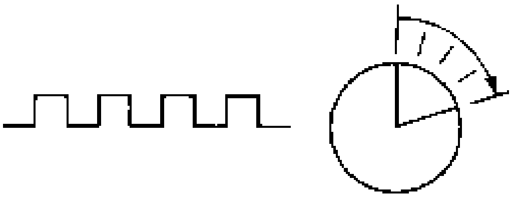

Figure 15 pulses count equals

In essence, step motors are electrical motors that are driven by digital pulses rather than a continuously applied voltage. Inherent in this concept is open-loop control, wherein a train of pulses translates into so many shaft revolutions, with each revolution requiring a given number of pulses. Each pulse equals one rotary increment, or step (hence, step motors), which is only a portion of one complete rotation.

Therefore, counting pulses can be applied to achieve a desired amount of shaft rotation. The count automatically represents how much movement has been achieved, without the need for feedback information, as would be the case in servo systems.

Precision of step motor controlled motion is determined primarily by the number of steps per revolution; the more steps, the greater the precision. For even higher precision, some step motor drivers divide normal steps into half-steps or micro-steps. Accuracy of the step motor is a function of the mechanical precision of its parts and assembly. Whatever the error that may be built into a step motor, it is no cumulative. Consequently, it can be negligible.

Step motor work :

A step motor is an electromagnetic, rotary actuator that mechanically converts digital pulse inputs to incremental shaft rotation. The rotation not only has a direct relation to the number of input pulses, but its speed is related to the frequency of the pulses.

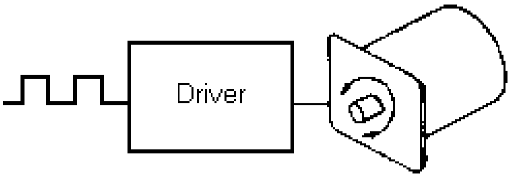

Figure 16 Motor with Driver

Between steps, the motor holds its' position (and its' load) without the aid of clutches or brakes. Thus a step motor can be precisely controlled so that it rotates a certain number of steps, producing mechanical motion through a specific distance, and then holds its load when it stops. Furthermore, it can repeat the operation any prescribed number of times. Selecting a step motor and using it advantageously depends on three criteria: desired mechanical motion, speed, and the load.

Type of step Motors :

* Variable Reluctance (VR) Stepper Motors:

VR motors are characterized as having a soft iron multiple rotors and a wound stator. They generally operate with step angles from 5 degrees to 15 degrees at relatively high step rates, and have no detent torque (detent torque is the holding torque when no current is flowing in the motor). In Figure (17), when phase A is energized, four rotor teeth line up with the four stator teeth of phase A by magnetic attraction. The next step is taken when A is turned off and phase B is energized, rotating the rotor clockwise 15 degrees; Continuing the sequence, C is turned on next and then A again. Counter clockwise rotation is achieved when the phase order is reversed

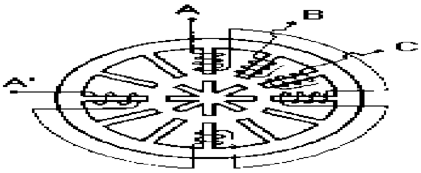

Figure 17 Variable Reluctance Motor

* Permanent Magnet (PM) Stepper Motors:

PM motors differ from VR's by having permanent magnet rotors with no teeth, and are magnetized perpendicular to the axis. In energizing the four phases in sequence, the rotor rotates as it is attracted to the magnetic poles. The motor shown in Figure (18) will take 90 degree steps as the windings are energized in sequence ABCD. PM's generally have step angles of 45 or 90 degrees and step at relatively low rates, but they exhibit high torque and good damping characteristics.

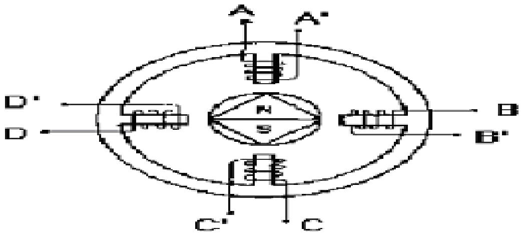

Figure 18 Permanent Magnet (PM)

* Hybrid stepper motor:

Hybrid - Combining the qualities of the VR and the PM, the hybrid motor has some of the desirable features of each. They have high detent torque and excellent holding and dynamic torque, and they can operate at high stepping speeds. Normally, they exhibit step angles of 0.9 to 5 degrees. Bi-filer windings are generally supplied as depicted in Figure (19), so that a single-source power supply can be used. If the phases are energized one at a time, in the order indicated, the rotor would rotate in increments of 1.8 degrees. This motor can also be driven two phases at a time to yield more torque, or alternately one then two then one phase, to produce half steps or 0.9 degree increments.

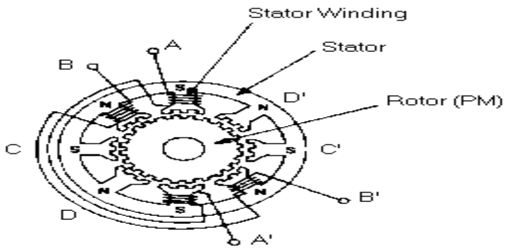

Figure 19 Hybrid Motor

Stepper motor control circuit :

Figure 20 shows the block diagram for a stepper motor driving circuit. The controller decides on the number and direction of steps to be taken (based on the application). The pulse sequence generator translates the controller's requests into specific stepper motor coil voltages. The driver amplifiers boost the power of the coil drive signals. It should be clear that the stepper motor is particularly well suited for digital control; it requires no digital-to-analog conversion, and because the field poles are either on or off, efficient class C driver amplifiers can be used.

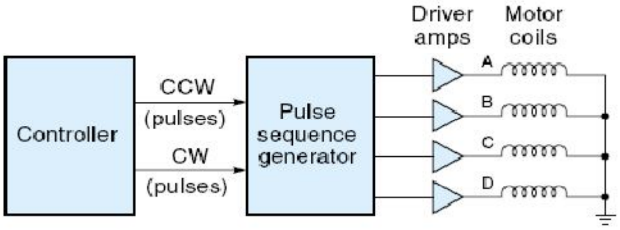

Figure 20 Block diagram of stepper motor control circuit.

Practical Implementation :

A. Programming PLC to control step motor :

Step motor needs a driver to control the pulses distribution of the motor points. That's to get the motor rotate.In this implementation we are able to exchange the driver by using plc to control motor rotation and position control .Through searching in the Internet (W.W.W) and studying some references, we have gotten PLC, type (GLOFA GM), The advantage of this device is that it has a simulation program through which we can notice how the program, which controls the step motor works.

B. Control Circuit :

We need to design control circuit by using PLC to generate a signal (pulse) for both the speed and the angle location. The circuit controls the stepper motor.We will control of stepper motor without driver by set program produce four output(Q0,Q1,Q2,Q3) and connecting this output to for phase(coils) of steppe motor(A,B,C,D) . In this figure below is showing block diagram how connecting the plc with stepper motor.[4]

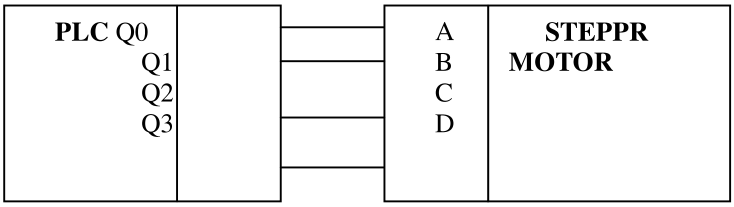

Figure 21 Block diagram of control circuit

We know from specification of stepper motor each pulse gives 1.8° and if we want to get angle 45° for example, we have to calculate the number of continuous pulses as following:

□= □ s* N

Where:-

□ = required angle

□ s = small angle for one pulse

=1.8°

N = number of pulses

N = □ / □ s

= 45°/1.8°=25 pulse

So if we want the stepper motor rotate by angle 45° we need 25pulse

So we will use the (PLC) as generate pulses and same time it distribute pulses to coils, and design program in ladder diagram generate 25 pulse.

If we want control the speed of motor then change preset time (PT) of each timer.

In this program we will use the timer and counter to generate pulses as shown in the program.

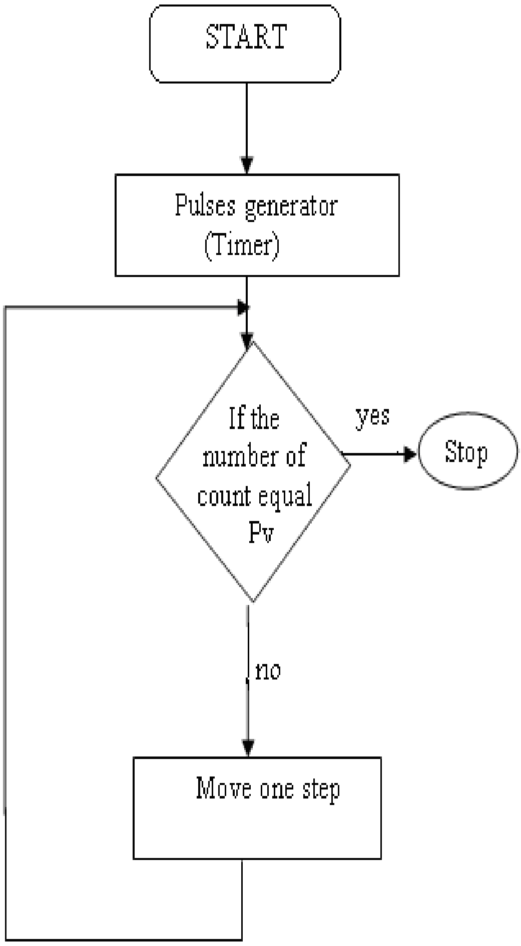

Figure 22 Flowchart program

Now we need write program to control of step motor as shown in the flowchart program , by using (LAD) Ldder Logic Diagram ,Simulation **GLOFA PLC** and GMWIN version 4 of LG .

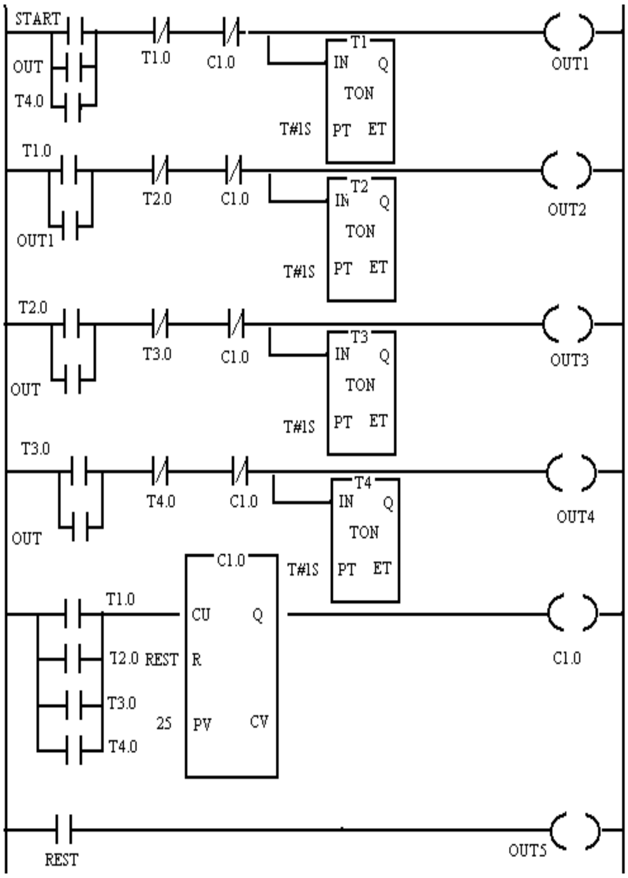

Figure 23 Ladder Logic Diagram for step motor control

TABLE I Address Assignment

SYMBOL	ADDRESS	DESCRIPTION
START	I0.0.0	Switch on.
stop	I0.0.1	Switch off.
reset		Reset to the counter.
T1	-	On delay timer 1
T2	-	On delay timer 2.
T3	-	On delay timer 3.
T4	-	On delay timer 4.
C	-	Count up counter
Out0	Q0.1.0	Input to phase A.
Out1	Q0.1.1	Input to phase B.
Out2	Q0.1.2	Input to phase C.
Out3	Q0.1.3	Input to phase D.

Conclusion :

Today we have many step motor application all around us.They are used in printers (paper feed ,print wheel), disk drives ,photo-typesetting ,X-Y plotters,clocks and watches, factory automation ,of applications.
For that ,In this paper we try control in the step motor (speed & position) by using PLC with out driver.
after write program by (LAD)- by using -GLOFA- simulation and ,The system was tested many times and tuned to give the best results .

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