Palestine Polytechnic University

College of Engineering & Technology
Electrical & Computer Engineering Department

Graduation Project

Design and Building Back-Gauge Systems For Press Brake Machine

Project Team
Wael Nieroukh Mohammad Fannoun

Project Supervisor
Eng. Nizar Amro

Hebron-Palestine

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Palestine Polytechnic University
College of Engineering & Technology
Electrical &Computer Engineering Department
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According to the orientations of the supervisor on the project and the examined committee is by the agreement of a staffers all, sending in this project to the electrical and computer engineering department are in the college of engineering and technology by the requirements of the department for the step of the bachelor’s degree.

Project supervisor signature

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Committee signature

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Department head signature

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الإهـــداء

- إليك يا من اهديت عقولنا وقلوبنا أهـديك هـذا العمـل المتواضع ليكون خالصا لوجهك الكريم . . .

- إليك يا فلسطيننا يا من فني في سبيلك الجسد والمال . . .

- إليكم يا من ضحيتم بأشلاء أجسادكم لنعيش مـن بعـدكم أحرارا. .

- إليكم يا من أسكنكم الظلم زنازينه القاتلة . . .

- إليكم يا من أبعدتم عن ديـاركم وتنفســتم هــواء غيـر هواءكم

- إليكم يا عمال المستقبل ورواد العمل. . .

- إليكم يا مدرسينا الأفاضل أهدي هذا المشروع راجي من الله التوفيق والقبول وحسن الجزاء

فـريـق الـعـمـل

شكر وتقدير

نتقدم بالشكر الجزيل إلى الأفراد والأهالي الذين قدموا لنا المساعدة ، والى من وقف بجانبنا وساندنا لإ□از هذا العمل المتواضع، والأهم الفضل الكبير □شرف ا□شروع الأستاذ نزار عمرو الذي كان بمثابة النبراس الذي أضاء لنا الخطى في جميع مراحل ا□شروع فله كل التحية والإكبار، ولا ننسى زملاءنا السابق□ الذين ساعدونا بمشورتهم وخبرتهم، فلهم وللجميع نتقدم بجزيل الشكر والعرفان

فريق العمل

Abstract

- ✓ This project aims to upgrading Press Brake machine. The works in the traditional gauge system. It doesn't have a safety system, and therefore the machine must be upgraded to include a complete safety system for the

protection of the machine and the workers. In addition to that, a Back-Gauge System will be provided to determine the distance required to fold the block automatically. After determining the most suitable control system for the machine, we will choose PLC for controlling in the machine , Consequently, the achievement of the quality, safety, easier ,economy and accurate.are Achieved in the machine.

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Chapter 1
Introduction

1.1 General description of the project:

The Press Brake machine is considering technologies that the human was discovered, since it collects between several of techniques: electrical, Programmable logic controller, HMI, and mechanical techniques.

The Press Brake machine operations based on fold of Iron Sheet automatically using some of a high technology controller was discovered.

The reasons of using the Press Brake machine to Automate the Back-Gauge system instead of manual operation which consider more cheap, that the process become difficult, don't satisfy the ask of accuracy and consume along of time, so that the process must be automated.

To satisfy the automatic operation, one type of controller like, PC, PLC, and microprocessor can be used, the comparison between these controllers is taken from many aspects i.e. ease of control, time response, range of control for speed and position.

Since the use of the PLC, and PLC Touch Screen is flexible and make the control of the machine more safety, easier, faster, beside that the Press Brake machine need high accuracy, difficult time response, high range for speed and position control, and control of two dimensions, it is represented as the ask controller, by this we reached the highest technical machine which is PLC

The plant (machine) consists of (in general) tow motor, sensors. The First motor use to control the moving of the two fingers (Gauge) that used to determine the distance that wont to fold (Z-axis); The second motor for Y-axis, motor that is an AC synchronous motor used to move up and down the fingers carrier part. All moving of the fingers is restricted in specific range determined by the sensors.

1.2 Project selection

- ✓ The project makes the Press Brake machine safety, faster, easier, and more accurate.
- ✓ Development of machine by cost equal10%of new machine.
- ✓ Saving and increasing the proportion of profits accruing to the factory.
- ✓ To meet the needs of the Palestinians market in the field of industry.

1.3 Previous studies

There is lake in researches and papers considered CNC machine and servo motor .The literature review describes of this title are mainly in form of papers, sections in textbooks, projects, and Internet sources.

In internet sources we found many projects about servomotor and stepper motor used in different applications such as Engraving CNC machine, Fluted-Bit Cutting Machine, and optical scanner.

1.4 Time plan

1st week to 8th week we studied the project and collected data from the Internet and books about the machine and its components, from 8th week to 14th week we wrote some of the documentation, and from 16th to 30th we built the machine hardware and complete the documentation and the simulation .Table 1.1 explains the time plan.

Table 1.1 :Time plan

# Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collecting data about the machine and its components and understanding it.															
Write some of the documentation and simulating the project.															
# Weeks	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Building hardware of the machine															
Performing the simulation programs															
Experiments and testing to the machine operations.															
Complete the Documentation															

1.5 Finance study

The estimated cost of project listed in table 1.2:

Table 1.2 :The estimated cost of the project

Part	Cost ($)
AC servo systems	**1150**
AC Inductionsystem	**225**
Slides (4)	**250**
Linear bearings (6)	**250**
Ball Screws system	**1750**
Connecting Wires ladders	**50**
HMI	**200**
PLC System	**700**
Encoder	**150**
Gears (2)	**188**
Emergence	**10**
Contactors (2)	**60**
Signal Lamp (3)	**8**
Limit Switch (4)	**68**
Bush button (6)	**40**
Body iron	**300**
Other equipment	**376**
Total cost	**$(5775)**

CHAPTER 2
Controller

2.1 Introduction.

Control engineering has evolved over time .In the past humans were the main method for controlling a system .More recently electricity has been used for control and early electrical control was based on relays .These relays allow power to be switched on and off without a mechanical switch .It is common to use relays to make simple logical control decisions .The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller PLC.The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls.

2.2 Controllers:

Definition of Control: Control is a process in a system in which one or more Inputquantities affect other quantities output quantitiesaccording to specific legality program.

2.2.1 Control Types:

Control types separated into two types:

1- Specification of control processes according to the form of signal representation.

2- Specification of control processes according to the form of signal processing.

2.2.1.1 Specification of control processes according to the form of signal representation

1- Analog Control :Control follows by using continues signals .The most important devices of analog control are Motors, valves, amplifiers… etc.

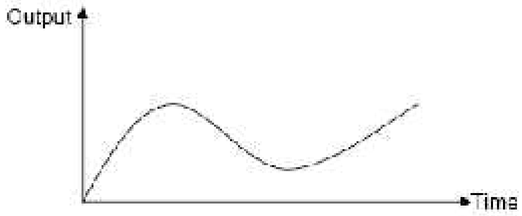


Figure 2.1: Signal representation of analog control

2- Binary Control: Binary controls work with dual-valued signals with only ON or OFF states (1 or 0). If the control signal is generated by the combination of more than one input-signal, so control process is called logic control.

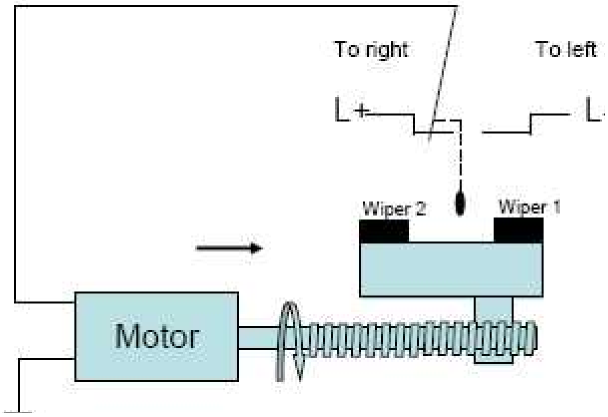


Figure 2.2: Example of binary control.

3- Digital Control: the digital control system generates binary coded BCD codes, Gray codes…etc.signalsaccording to the desired input value.
Most important devices of digital control are coders, micro-processors, digital memories.

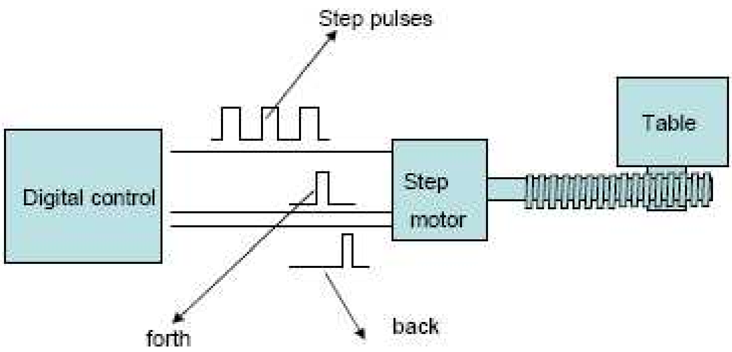


Figure 2.3: Example of digital control.

2.2.1.2 Specification of control processes according to the form of signal processing.

1- Logic control.

- Is control in which the control signals depend only on a logicalcombination of the inputs signals.For the logical combination, thefunctions AND, OR, NOT can be used. no storage memory or (A logic control provides usually time characteristic).
- Control problems that have to deal with protection and security are usually independent on time, thus theycan be managed with logic control.

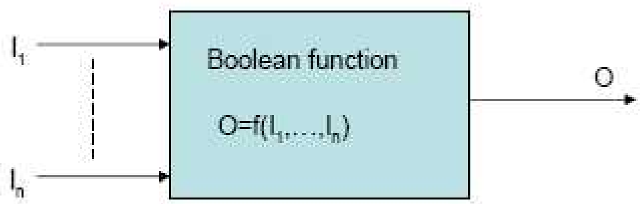


Figure 2.4: Logic control.

2- Sequence control

- Is a control where the control procedure runs step by step? Only one step orderis active and thetransfer from one step to the next one depends on according to in the program specified conditionTransition.
- To realize sequence control, memory elements like Flip Flops are needed.

- For complex control problems, sequence control is more suited than logic control.
- Hence logic control tools exhibit memory devices, the differentiation between logic and sequence controlis often difficult .

2.3 Comparison between some controllers.

To automate a machine option is best: the machine has fairly complicated actionwhich Automation using microprocessor like Pentium and using c/c ++programming or using Programmable logic controller PLC.

The selection criteria are speed of action and speed of responses to inputs, availability of controlling schemes and accuracy.

Here some comparison between some of controller as seen below in the table 2.1:

Table 2.1: comparisons between controllers

In Comparison	**Relay systems**	**Computers**	**PLC systems**
Price Per Function	Fairly Low	High	Low
Physical Size	Bulky	Fairly Compact	Very Compact
Operating Speed	Slow	Fairly Fast	Fast
Noise Immunity	Excellent	Fairly Good	Good
installation	TimeConsuming in All Phases	Time Consuming in Programming	Easy in All Phases
Complex operation	None	Yes	Yes
Ease of Changes	Very Difficult	Quite Simple	Very Simple
Easy Of maintenance	Of .large No-Poor Contacts	several -Poor Custom Boards	few -Good Standard Cards

2.4 PLC Controller.

2.4.1 Introduction.

PLC's have coming into wide use, both to replace electromechanical control devices such as relays, timers, and drum switches, and to provide control functions that are beyond the capacity of the control provided by electromechanical means.

PLC is an industrial computer that controls a machine or process .A PLC interfaces with the field input and output devices that are part of a control application . Then, through the control program stored in its memory, the PLC uses the data supplied by the input devices to manipulate or control the output devices .The overall PLC process, which is shown in Figure 2.5, is very simple .A PLC measure or sense signals coming from a machine or process .Then, through its internal program, the PLC provides control back to the machine or process.

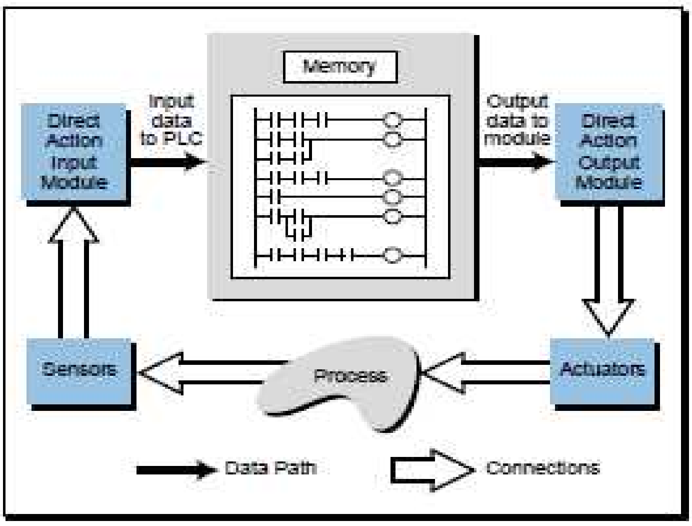


Figure 2.5: PLC Operation.

2.4.2 Advantages of PLC

- PLCs are easy to program and install.
- The speed with which internal times operate is much faster than conventional time delay relay systems.
- Access to PLCs could be restricted or protected.
- PLCs have the advantage of problem-solving capabilities, over any other type of control system.

- PLCs are usually designed with communication capabilities that allow interfacing with local or remote computer systems or operator.

- PLCs are extremely reliable

2.4.3 Components of PLC

Figure 2.6shows the all component of PLC.

1. The Power Supply .External or internal 24Vdc,120Vac, 220Vac.

2. CPU and MEMORY.

3. Input /output interface.

4. Program.

5. Programming Languages.

6. Programming Device or Programming Terminal.

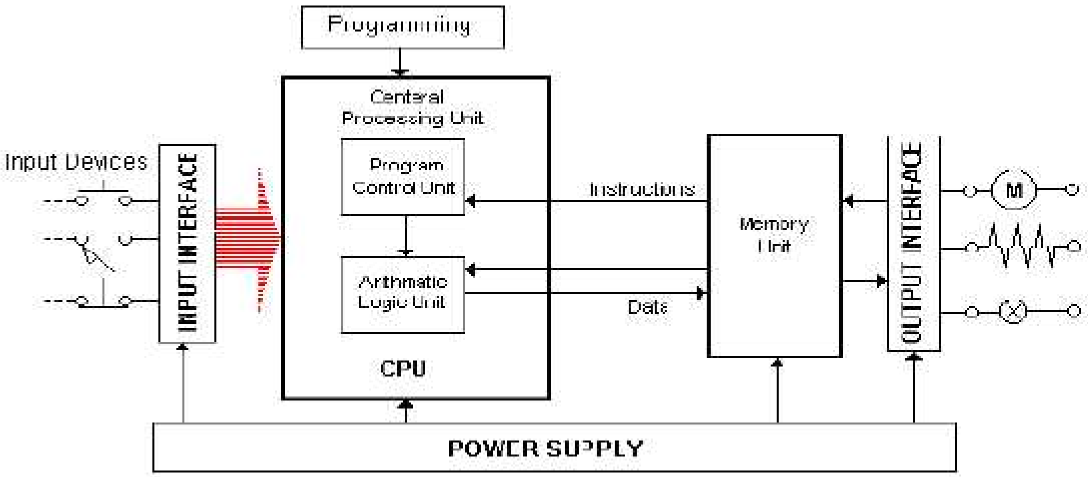


Figure 2.6: PLC components.

2.4.4 How PLC works

Basis of a PLC function is continual scanning of a program .Under scanning we mean running through all conditions within a guaranteed period .Scanning process has three basic steps as seen in theFigure 2.7:

<u>*Step 1*</u>:Testing input status .First, a PLC checks each of the inputs with intention to see which one of them has status ON or OFF .In other words, it checks whether a

sensor or a switch etc .connected with an input is activated or not .Information that processor thus obtains through this step is stored in memory in order to be used in the following step .

*Step2:*Program execution .Here a PLC executes a program, instruction by instruction . Based on a program and based on the status of that input as obtained in the preceding step, an appropriate action is taken .This reaction can be defined as activation of a certain output, or results can be put off and stored in memory to be retrieved later in the following step .

Step 3: Checkup and correction of output status .Finally, a PLC checks up output status and adjusts it as needed .Change is performed based on the input status that had been read during the first step, and based on the results of program execution in step two .Following the execution of step three PLC returns to the beginning of this cycle and continually repeats these steps .Scanning time is defined by the time needed to perform these three steps, and sometimes it is an important program feature.

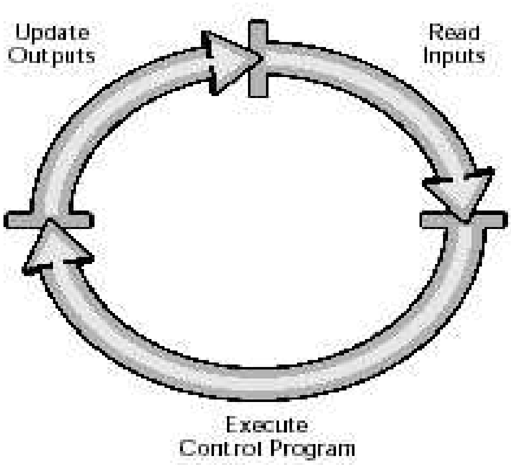


Figure 2.7: The three parts of a PLC's scan :reading the inputs, executing the control program, and updating the outputs.

2.4.5 Programming Devices

Although the way to enter the control program into the PLC has changed since the first PLCs came onto the market, PLC manufacturers have always maintained an easy human interface for program entry .This means that users do not have to spend much time learning how to enter a program, but rather they can spend their time programming and solving the control problem .

Most PLCs are programmed using very similar instructions .The only difference may be the mechanics associated with entering the program into the PLC, which may vary from manufacturer to manufacturer .This involves both the type of instruction used by each particular PLC and the methodology for entering the instruction using a programming device .

The two basic types of programming devices are:

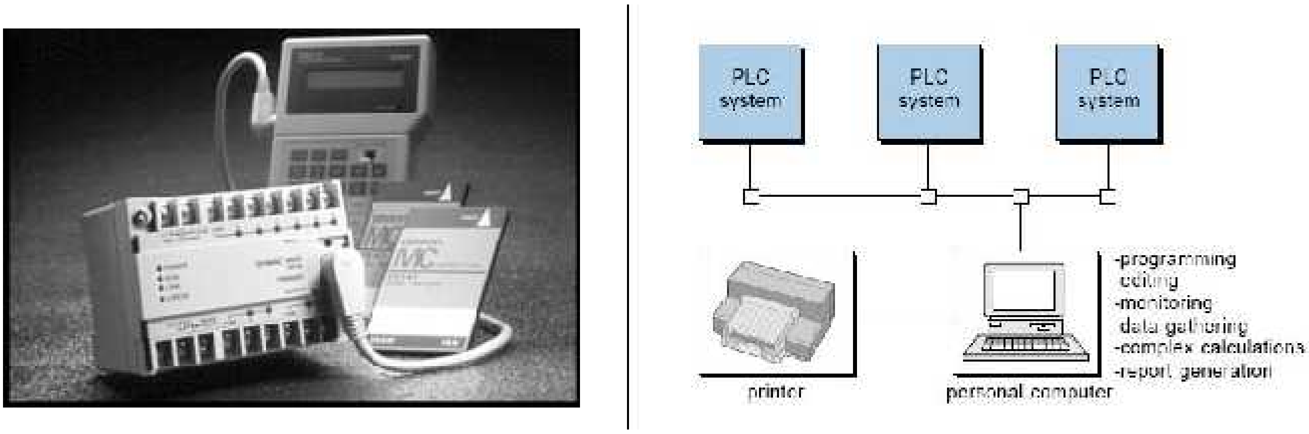


Figure 2.8:programming devices: a-Miniprogrammers.

b-Personal computers.

Chapter 3
Machine Block Diagram

3.1 Introduction

The automatic Press Brake machine system configuration is closed loop, so before discussion its block diagram we show the comparison between the two control systems configuration: open loop and closed loop.

Definition of Control: Control is a process in a system in which one or more Inputquantities affect other quantities output quantitiesaccording to specific legality program.

We now describe the two-control systems configuration :open loop and closed loop, as the following:

3.2 Open loop systems

A generic open-loop system is shown in Figure 3.1 .It starts with a subsystem called and input transducer, which converts the form of the input to that, used that uses by the controller .The controller drives a process or a plant .The input is sometimes called the reference, while the output can be called the controlled variable . Other signals, such as disturbances, are shown added to the controlled and process outputs via summing junctions, which yield the algebraic sum of their input signals using associated signs .For example, the plant can be a furnace or air conditioning system, where the output variable is temperature .The controller in a heating system consists of fuel valves and the electrical system that operates the valves.

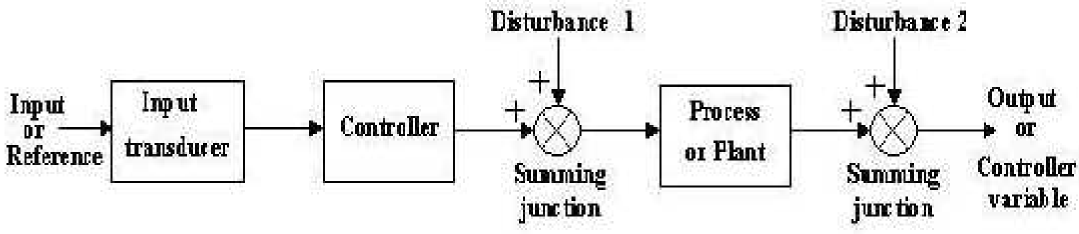


Figure 3.1 :Open loop system

The distinguishing characteristic of an open loop system is that add to the controllers driving signal Disturbance (1) in Figure 3.1 .For example, if the controller is an electronic amplifier and Disturbance (1) is noise, then any additive amplifier noise at the first summing junction will also drive the process, corrupting the output with the effect of the noise .The output of an open-loop system is corrupted not only by signals that add to the controllers command but also by disturbances at the output disturbance to the Figure 3.1 .The system can't correct for these disturbances, either.

Open-loop systems then do not correct for disturbances and are simply commanded by the input .For example; Gauging are open-loop systems, as anyone with folding can attest .The controlled variable (output) of a gauging is the distance of the foldingof device is designed with the assumption that the gauge will be incorrectfold distance it is subjected to gauge .The gauge doesn't measure the distance of the gauge; it doesn't correct for the fact that the fold distance long, short.

3.3 Closed loop (feedback control system)

The disadvantages of open loop systems, namely sensitivity to disturbance and inability to correct for these disturbances, may be overcome any closed loop systems .The generic architecture of a closed loop system is shown in Figure 3.2.

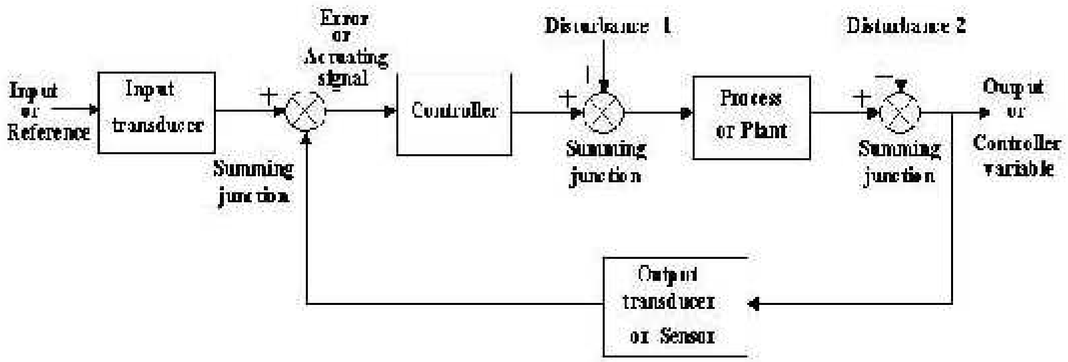


Figure 3.2 :Closed loop system

The input transducer converts the form of the input to the form used by the controller .An output transducer, or sensor, measures the output response and converts it into the form used by the controller .For example, if the controller uses electrical signals to operate the gauge of a distance control system, the input position and the output distance are converted to electrical signals .The input position can be converted to a pulses by encoder, and the output distance can be converted to a pulses by a encoder a device whose electrical pulses changes with distance.

The first summing junction algebraically adds the signal from the input to the signal from the output, which arrives via the feedback path, the return path from the output to the summing junction .In Figure 3.2, the output signal is subtracted from the input signal .The result is generally called the actuating signal .However, in systems where both the input and the output transducers have unity gain that is, the transducer amplifies its input by 1, the actuating signal's value is equal to the actual difference between the input and the output .Under this condition, the actuating signal is called the (error).

The closed loop system compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction .If there is any difference between the two responses, the system drives the plant, via the actuating the signal, to make a correction .If there is no difference, the system doesn't drive the plant, since the plant's response is already the desired response.

Closed loop systems, then, have the obvious advantage of greater accuracy than open loop systems .They are less sensitive to noise, disturbances, and changes in the environment. Transient response and steady-state error can be controlled more conveniently and with greater flexibility in closed loop systems, often by a simple adjustment of gain amplification in the loop and sometimes by redesigning the controller .We refer to the redesign as compensating the system and to the resulting hardware as compensator .On the other hand closed loop systems are more complex and expensive than open loop systems .A standard, open loop gauge serves as an example :it is simple and inexpensive .A closed loop gauge is more complex and more expensive since it has to measure both distance through encoder Thus, the control systems engineer must consider the trade-off between the simplicity and low cost of an open loop system and the accuracy and higher cost of a closed loop system.

In summary, systems that perform the previously described measurement and correction are called closed loop systems .Systems that don't have this property of measurement and correction are called systems.

3.4 Introduction to project

The Automatic Press Brake Back-Gauge system contains of two AC motors; one AC synchronous motor (Y-axis), and one AC servo motor (Z-asiz), these two motors are controlled automatically by the PLC -which include a controlling programs which give the user the ability to choose the specific program that content the two dimension wonted that applied on the Back-Gauge system.

The power required to operate the AC synchronous motor is directly connected to it from the 3-ph source, but the power required to operate each of the three AC servo motors is connected to them through a transformer.

The sensors in the machine are used to restrict the motors motion in specified rang.

From the previous paragraphs, the machine divided into three major components: Software component, Interfacing circuit, and Hardware component, the following simple block diagram shows the arrangement of these parts, as shown in Figure 3.3:

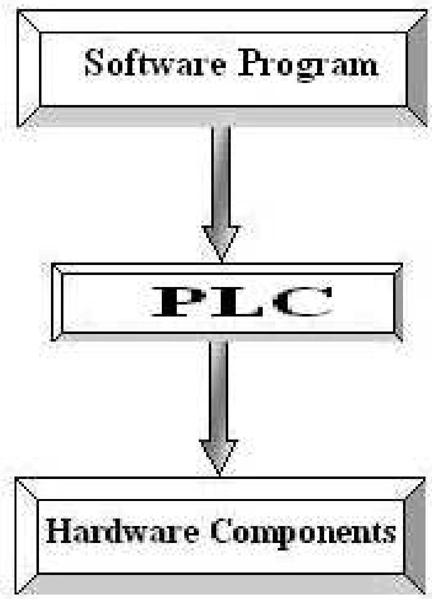


Figure 3.3 :Simple block diagram

3.5 The general block diagram:

Figure 3.4 shows the automatic Press Brake machine block diagram, that is the controller is the PLC, the process is the machine which consist of in general tow motors, the input is the desired position and speed, the output is the actual position and speed, and the transducer is the four sensors.

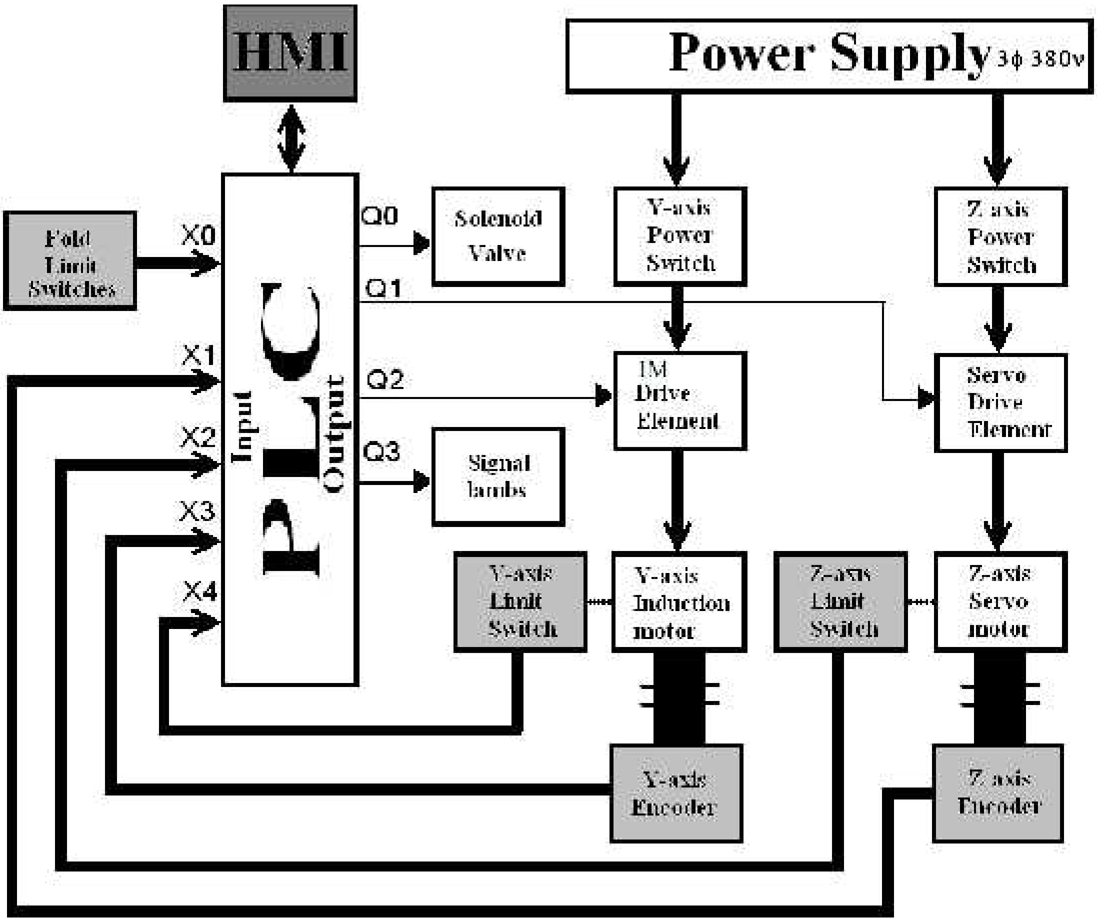


Figure 3.4 :General block diagram

The components of the machine block diagram are explained in the following subsections :

3.5.1 Servo motors

It is a type of special motors, it is used in the position, speed and torque control, thus is sometimes called a “control motor”.

There are many applications using the servo motor such as :the radar devices, the antennas, the printing devices, and in moving the airplanes wings, from the mentioned applications we can notice that these applications work on low speeds, so the servo motor characterizes in low speeds.

To operate such previous loads the following properties must be existed in the servomotors:

1. Fast response that is the motor speed reaches the rated value (steady state) at once when switching it on with the input supply, also at once stops when disconnecting the supply .
2. The relation between the voltage and the speed is linear to simplify the control system and its components, and to improve it effectively.
3. The motor accepts connecting and disconnecting operations whatever they repeated.

Thus when designing the servo motor, the previous properties must be existed, for example to obtain the fast response, the value of the rotor moment of inertia must be reduced, and this can be done by reducing the rotor diameter and increasing its length.

The servomotors are classified into two types :AC servomotors, and DC servomotors, most of these motors depend on the armature control way to satisfy the position control by varying the voltage value.

Each of AC servo and DC servo motors has advantages and disadvantages, for example the DC servo motor characterized with :Linear relation between the voltage versus speed, and between the torque versus the speed; so the control system of them is effective and simple, but it is more expensive, has a higher weight than the AC servo motor, needs the maintenance, and we can't use it in the dangerous places because of sparks they may occur when operating.

The AC servo motor characterized with simple constitution, low cost, and power of endure, but it is a type of high-coupled machines, that the angle between rotor and stator fields isn't (90^o), and the relation between the speed and the voltage and the relation between the speed and the torque isn't linear.

We will use One AC servomotors to operate the machine, one to moving the Fingers part in the Z-axis .This motors receive the information that reaches from the Interfacing circuit and the interfacing circuit receiving the information from the PLC through the parallel port or from the microcontroller and perform it on the Sheet of metal.

The Fingers part moves in the Y-axes in whole directions but the movement with a specified fold in the (Z-axis) one direction.

3.5.2 Asynchronous motor

The synchronous motor is a type of the AC motors, and it is called "synchronous" because its speed is directly related to the line frequency:

$$ns = \left(\frac{120 \times f}{P}\right)\left(\frac{rev}{min}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (3.1)$$

Where:

ns :the synchronous speed.
f :the source frequency.
P :number of poles.

In our project we need the synchronous motor to move the fingers up and down from the zero (Y-axis) zero Y-axis is the level of the base that sheet put on, thus it must be put the fingers in zero Y-axis when the machine starts its operation.

3.5.3 PLC controller

The controlling of the machine operation's would be done using the PLC, this can be performed by using one of the programming languages like Ladder, or function block, or statement list ,these languages contain an instruction which goes to the input and output module and to the interfacing circuit, and then we can take them as digital or analog signals .

3.5.4 The power supply

It is 3-ph380Vused to supply the machine the motorswith request power, and it has a switch between it and the motors to turn the motor On or Off.

3.5.5 The sensors

A sensor is a transducer, which converts a physical parameter to an electrical signal.

In our project, we need four sensors situated on different locations on the machine, two of those sensors limits the movement of the motor with respect to the Z-axis,
the other two sensors limits the movement of the motor with respect to the Y-axis.

Where:

Sensor Z :+It is the sensor used to restrict the movement of the Z-servo motor in the positive Z-direction .

Sensor Z :-it is the sensor used to restricted the movement of the Z-servo motor in the negative Z-direction .

Sensor Y :+It is the sensor used to restrict the movement of the Y -Synchronous motor in the positive Y-direction.

Sensor Y : -It is the sensor used to restrict the movement of the Y -Synchronous motor in the negative Y-direction.

Chapter 4

AC Motor Systems

4.1 Introduction

The main part in the Automatic Press Brake Machine hardware is the motors, which must be used to perform its operation .The servo or stepper motor can be used in the Automatic Press Brake Machine, but we used the servo motor instead of stepper, this refers to the following reasons:

-:Servos are better because

1- Dynamic response, accelerate faster when starting and stopping, and changing direction.

2- Easy to setup, plug and play.

3- Always cool to the touch, no thermal effects.

4- More Power, Servo motor torque curve is linear. Full power is available at both low and high rpm.

5- No lost steps, if the motor is asked to position where it cannot like through a vise, it will fault and stop.

6- Faster feed and rapid speeds .

7- Fault condition stops all axes.

8- Closed loop system always knows where it is located, and following error is less than the accuracy of the machine.

9- Higher resolution than steppers.

Steppers-not because:

1- Much slower acceleration without losing steps.

2- Heat buildup affects machine accuracy and axis linearity.

3- Resonance causes lost steps at certain speeds and cutting loads.

4- Requires slower speeds to avoid losing steps.

5- Much higher voltages required approaching servo speeds, and then thermal losses increase geometrically.

6- Noisy -stepper drivers and motors make an audible hissing and stepping noise.

7- Machine slide and lead screw maintenance is critical as the least bit of sticking, binding, or bumping can cause loss of position.

4.1.1 Comparison between servo and stepper motors

The main differences between servo and steeper motors in some of contrast fields are shown in the following:

1 .Maintenance

Steeper motors :stepper motors are brushless .They experience little or no wear, and are virtually maintenance-free .

Servomotors :brush-type servomotors require a change of brushes, typically, after 5,000 hours of heavy use otherwise they are virtually maintenance free.

2 .Cost

Steeper motors :in general, stepper motor systems tend to be only slightly less expensive than servo motor systems and the price difference is getting smaller.

Servomotors :Servomotors tend to be 5 %to 15 %more expensive than similar stepper systems .

3 .Resolution and accuracy

Steeper motors :for a given screw pitch, typical four phase stepper motors can produce 200 full steps, 400 half steps, and up to 25,000 micro steps per revolution .It is significant to note that since the stepper motor is open loop, it does not necessarily achieve the desired location, especially under load .Particularly poor positional accuracy can result when using micro stepping, which is mostly useful for smoothness of motion.

Servomotors :servo motor resolution depends upon the encoder used .Typical encoders produce 2,000 to 4,000 pulses per revolution, and encoders with up to 10,000 pulses per revolution are available .Since servos are closed loop, they can and do achieve the available resolution and they are able to maintain positional accuracy.

4 .High speed and power

Steeper motors :steppers have very poor torque characteristics at higher speeds .This condition is improved only slightly by micro stepping; however, unless the stepper is used in a closed loop mode, it does not usually perform as well as a servo .Once the stepper is used in a closed loop mode, it usually becomes more expensive than the servo system of comparable size.

Servomotors :servos can produce speeds and powers two to four times that of similarly sized steppers .This improvement is a direct result of the closed loop)i.e., constant position feedback(, which allows for higher speed and greater reliability . The closed loop nature of the servo also allows such a system to better utilize peak torque capabilities.

5 .Open loop compared to closed loop

Steeper motors :stepper motors are almost always used in an open loop configuration . This means that the motor is commanded to move a certain amount but the computer does not know if the motor has or has not moved that amount .In some cases, resonance or vibrations can cause a stepper motor to lose steps or stall out before completing the motion .This is an ever-present possibility.

Servomotors :by nature, servomotors have constant position feedback from the optical encoder .This device sits on the back of the motor and keeps the controller informed of how far the motor has actually moved .This position feedback is used to correct any discrepancy between a desired and an actual position .This constant corrective action results in faster speed up to three times the throughputand increased power up to three times the torque at high speeds, closed loop nature of the servo also ensures that stalling cannot occur unless there is an immovable object in the path.

2.2 AC servo system

The permanent magnet dc servo system or brush-type servo has served as the industry workhorse for many decades .While it is straightforward to control torque with a permanent magnet dc servomotor, the mechanical commutator introduces many serious limitations as listed in the previous section .The brushless servo system was developed to eliminate the limitations imposed by the mechanical commutator of a dc servo system.

The first implementation of a brushless servo system used three-phase permanent magnet motors and square-wave or rectangular shaped currents .The back EMF waveform of the brushless motors ranged from sinusoidal to trapezoidal .The basic idea was to emulate the brush-type dc servomotor by electronically “commutating” the current from one pair of motor windings to another .Completing the analogy with a brush-type servo system, the motor-mounted feedback devices for a velocity controlled brushless servo system included a commutation encoder and brushless tachometer .The commutation encoder provided the position signals used to transition the current electronically from one pair of windings to another .The analogy to the dc servo system resulted in names for these early brushless servo systems such as brushless dc servo, ECM (electronically commutated motor), six-step servo, and trapezoidal brushless servo.

With careful design, these early brushless servo systems had good performance and they demonstrated the possibility for replacing the brush-type servomotor with a brushless servomotor .However, the design challenges and extra cost of these early brushless servo systems limited applications to larger power levels and situations where the extra cost could be justified .This early type of brushless servo is rarely used today in high performance servo systems.

Fortunately, the analogy to a dc servo system can also be extended to sinusoidal current excitation of a permanent magnet motor with sinusoidal back EMF . This technology is commonly referred to as “field-oriented” or “vector” control . Compared to the first generation of brushless servo systems with square-wave currents, a brushless servo system with sinusoidal back EMF and sinusoidal current is much more practical to manufacture and inherently has much smoother torque production due to the gradual commutation process .This type of brushless servo system is commonly referred to as an ac servo, PM (permanent magnet) ac servo, or sinusoidal brushless servo .

The field-oriented or vector control can also be extended to ac induction motors .Variable speed drives VSDswith this technology are referred to as vector drives .Vector drives can be applied as servo drives but the induction motors do not have the performance of the permanent magnet ac servo motors due to higher inertia and larger size .However, vector drives are adequate for some servo applications particularly larger power applications where permanent magnet ac servo systems are not readily available.

4.2.1 Torque production with an AC servo motor

The best way to understand the principle behind the ac servo system is to develop an analogy to the dc servo system .As discussed earlier, the dc servo motor has a magnetic field that is fixed in space and the mechanical commutator causes the armature current vector to be perpendicular to the field vector at any motor speed or position .The torque produced by the dc servo motor is easily adjusted by controlling the armature current level .As we will soon see, we have an analogous method for controlling the torque of an ac servo motor using vector or field-oriented control.

Let’s start with the magnetic field of the ac servo motor .Figure 4.1 shows a simple representation of an ac servo motor with a permanent magnet rotor and three-phase stator where the windings are spaced by 120 degrees .The magnetic field vector established by the permanent magnets is labeled B .Unlike the dc servo motor where the permanent magnets are stationary, the magnets of the ac servo motor move as they are mounted on the rotor .The challenge of the field-oriented control strategy is to generate the three-phase stator currents in such a way as to keep the composite current vector perpendicular to the magnetic field vector at all times.

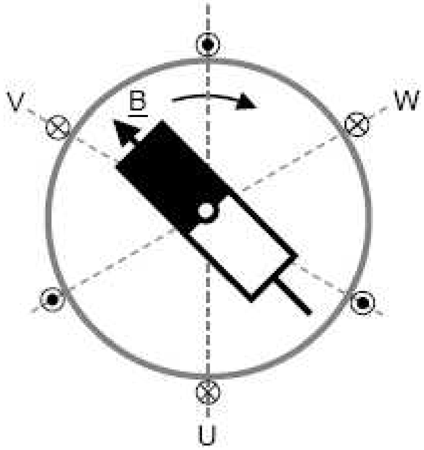


Figure 4.1 :AC servo motor with permanent magnet field and three-phase stator.

Now let’s review the generation of the composite current vector using Figure 4.2 .The three-phase stator currents are represented as three sine waves that are displaced in space by 120 degrees with axes labeled as U, V, and W .As examples, the composite current vector is developed for angles of 60 and 90 degrees .Notice for every angle that the composite current vector has a magnitude equal to 1.5IT where IT is the amplitude of the phase currents and 1.5IT has an angular position equal to the angle δ.

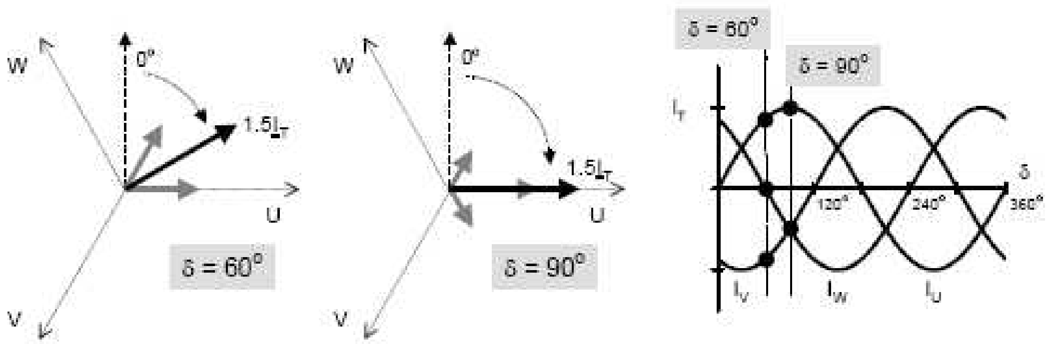


Figure 4.2 :Current vector for three-phase AC servo motor

Let's stop and review .We have a fixed amplitude magnetic field vector created by the permanent magnets that rotates synchronously with the rotor of the motor .We also have a composite current vector that rotates at the angular frequency of the phase currents and has amplitude that is proportional to the peak value of the sinusoidal phase currents .Maybe you can see that we have our answer on how to simply control the torque of the ac servo motor.

Let the angle of the motor rotor be called δ and let δ be the angular frequency of the sinusoidal phase currents .Then, we just establish δ =00 so that the current vector is perpendicular to the magnetic field vector .In practice, this is accomplished by physically orienting the rotor position sensor usually an encoder or a resolver so that the composite current vector is perpendicular to the magnetic field vector . Actually, the motor BEMF signal is easier to measure and is uniquely related to the magnetic field vector so the position feedback device is oriented to the BEMF signals during the manufacturing process .In this way, no matter what motion the rotor might make, the current vector will always be perpendicular to the magnetic field vector . We now have an ac servo system where the torque can be controlled just like the dc servo system and where the ac servo motor "looks" just like the dc servo motor to the speed and position regulators .Let's draw a picture of the vector control for an AC servo motor as shown in Figure 4.3.

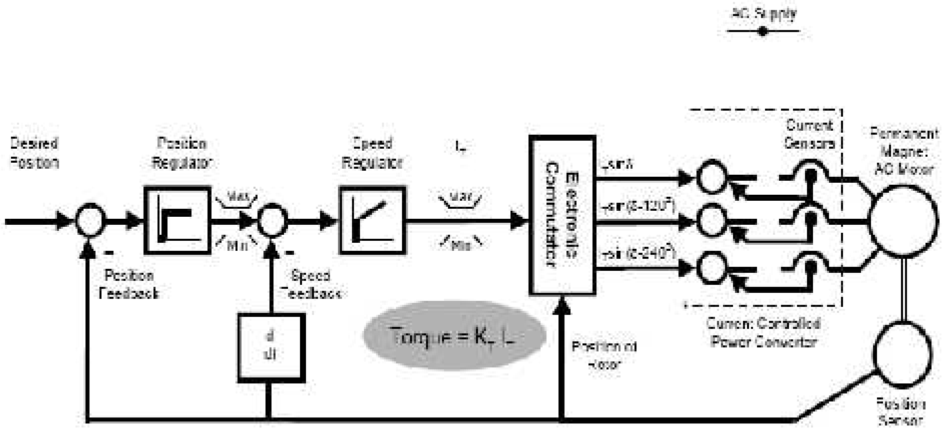


Figure 4.3: Cascade control structure of the high performance AC servo system with field-oriented control

4.2.2 AC servo system modes of operation

The digital ac servo system is typically available with six modes of operation:

1 .Torque Control Mode

Analog input is the current command signal, which we know from earlier discussions, is proportional to motor torque .No tuning is required but some adjustment may be required to scale the analog input to current or torque.

2 .Velocity Control Mode

Analog input is the velocity command .The velocity regulator is tuned for the motor and load.

3 .Position Control ModeStep and Directionstepper emulationis the position command. Both the velocity regulator and the position regulator must be adjusted for a specific motor and load.

4 .Velocity-Torque mode: This mode is used when the process require velocity and torque control.

5 .Velocity-Position mode: This mode is used when the process require velocity and position control.

6 .Position-Torque mode: This mode is used when the process require position and torque control.

4.2.3 Block diagram of AC servo system

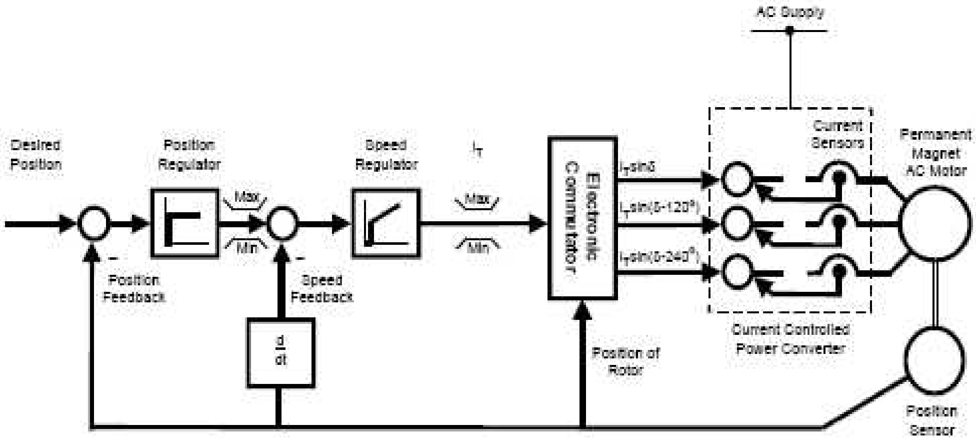


Figure4.4: Block diagram of AC servo system.

4.2.4 The AC servo motor

The permanent magnet ac servomotor has a very straightforward and rugged construction.

The stator has three symmetrical windings, which are internally connected in a wye configuration .The neutral connection is not brought outside the motor so only three power wires are available from the motor .Compared to the dc servomotor, the construction of the ac servomotor is thermally more effective because almost all of the losses are in the stator where they can be more easily routed to the outside ambient.

The rotor contains the permanent magnets, which can be mounted in different ways depending on a specific supplier’s technology .The permanent magnet material ranges from low cost ceramic (ferrite) to the more expensive rare-earth materials such as samarium cobalt or neodymium iron boron “neo”. Most recent ac servo motor designs use “neo” as a good compromise between magnetic properties, availability, and cost .The rotor also includes a rotary position sensor .The multi-purpose position sensor is used for commutation or generation of the sinusoidal current commands, velocity feedback, and position feedback.

The equivalent circuit of an ac servomotor is shown in Figure 4.5 .This figure is very useful in developing an understanding of the relationship between voltage and current in the ac servomotor.

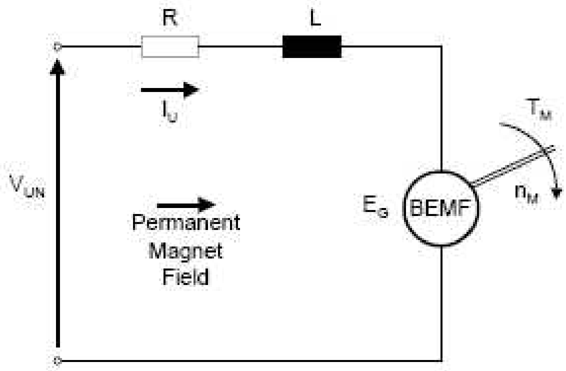


Figure 4.5 :Per phase equivalent circuit of an AC servo motor

R :per phase resistance.

R: Phase-to-phase resistance =2

L: per phase inductance.

L: Phase-to-phase inductance =√3

VUV: Phase-to-Phase Voltage =√3 VUN.

n_m: motor speed.

T_m:motor torque.

J_m: motor moment of inertia.

E_G: back emf voltage line to neutral.

$$E_G = n_m \times K_e \psi \qquad (4.4)$$

The vector control of the ac servomotor allows the phase current to be kept in phase with the BEMF at all times and by controlling the amplitude of the phase current we can adjust the level of motor torque .The voltage relationships and torque-speed curve for an ac servo system are shown in Figure 4.6 as developed from the ac servo motor equivalent circuit in Figure 4.5.

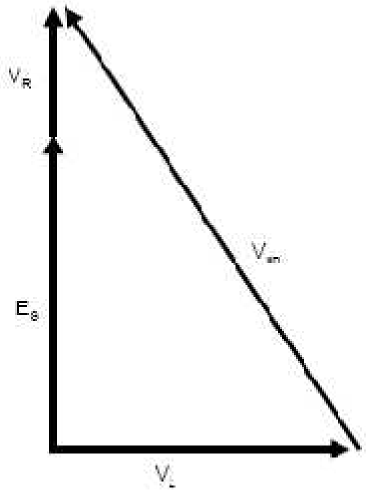


Figure 4.6 :Voltage relationships

V_{un} :required phase to neutral terminal voltage to establish the desired phase current.

V_L :voltage across the phase inductance.

V_R :voltage across the phase resistance

$$V_L = 2\pi . f . L . I_U \ldots\ldots\ldots\ldots\ldots (4.5)$$

$$V_R = I_R . R \ldots\ldots\ldots\ldots\ldots (4.6)$$

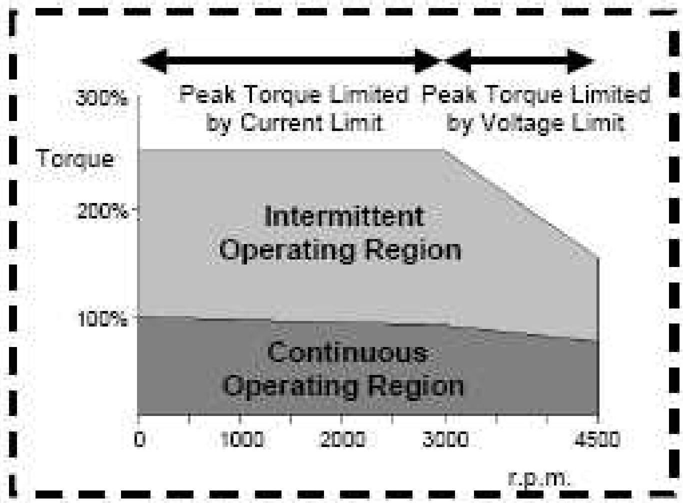


Figure 4.7: Torque-Speed curve for AC servo system

The voltage and current relationships are important because they determine the torque-speed operating boundary for the ac servo system .With vector control, the torque is adjusted by the level of phase current and by keeping the phase current in phase with the BEMF .The terminal voltage required to create the necessary phase current can be determined as shown in Figure 4.6.

The current controlled power converter has a maximum available voltage as determined by the ac supply .When the maximum available terminal voltage has been reached due to requested torque (current) or speed, then the phase current can no longer be properly controlled and we no longer have the proper relationship between torque and current.

The following equations can be used to calculate the ideal maximum voltage available from the power converter .The actual voltage will be lower due to various voltage drops in the system.

$$V_{BUS} = \sqrt{2} \times V_{AC} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.7)$$

Where:

VAC :AC Supply Voltage.
VBUS : DC Bus Voltage

$$Maximum\ V_{UN} = \frac{V_{BUS}}{(\sqrt{2} \times \sqrt{3})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.8)$$

Where:
Maximum V_{UN}: Maximum available line to neutral volts.

4.2.4.1 The position sensor

The ac servomotor has a rotary position sensor, which is mounted on the non-drive end of the motor .As we have seen in Figure 4.7, the position sensor is used for the electronic commutation of current, speed feedback, and position feedback .The most common position sensor used with ac servomotors is the optical incremental encoder .In special cases, where homing the load on power-up is not acceptable, a more costly multi-turn absolute position feedback device is used instead of the incremental encoder.

Today's ac servo systems are almost all digital optical incremental encoders, which provide digital information is easily interfaced to digital servo, drives where they offer high resolution and accuracy at an attractive cost .The basic operation of a "wire saving" incremental encoder is shown in Figure 4.8 .The low-resolution absolute position start-up signals are only necessary during power-up to initialize the rotor angle inside the digital servo drive .The high-resolution data tracks and marker pulse C signalare used after power-up and during normal operation of the system .By using the "wire-saving" design, the same 6 wires can be used for both start-up and normal operation, which minimizes the cost and diameter of the cable running between the driver and motor .Including the dc supply wires, the "wire-saving" encoder only requires 8 total wires .However, in practice, small gauge wire is used so it is common to double or even triple-up on the supply lines in order to minimize voltage drop over longer cable lengths .As an alternative, some drives use a pair of voltage sensing lines to measure supply voltage at the encoder and then adjust the supply voltage at the drive to maintain the proper voltage at the encoder.

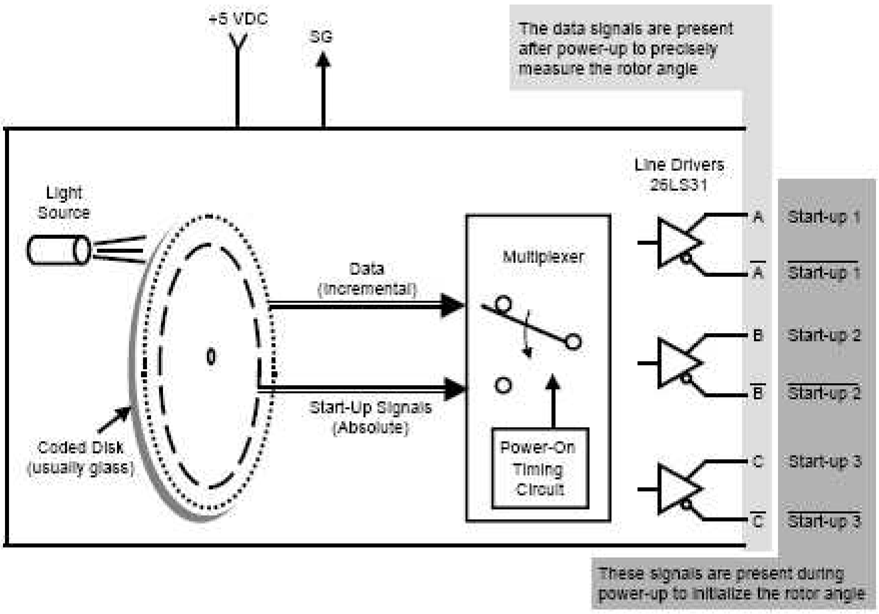


Figure 4.8 :Principle of operation for a "Wire-Saving" incremental optical encoder

A representation of the signals from the incremental optical encoder is shown in Figure 4.9 .For simplicity, the signals are shown without the complement signals from the line drivers .However, in practice, differential feedback signals are essential to eliminate noise problems and to facilitate long cable lengths.

The encoder is attached to the ac servomotor in a very particular and precise way during the assembly of the motor .From earlier discussions, the rotor angle must be defined so that the composite current vector is kept perpendicular to the magnetic field at all times .The start-up signals provide low-resolution absolute position information to initialize the rotor angle in the servo drive .The resolution of the start-up signals provide for ± 30 degree accuracy of the torque angle.

As torque is proportional to the Sine of the torque angle, we have at least 86 % of maximum torque available to move the load up to one mechanical revolution until we pick-up the C signal or marker pulse .After we detect the marker pulse, the torque angle is set to the exact value necessary for a 90-degree torque angle.

The marker pulse has a unique position relative to the start-up signals which is determined by the manufacture of the encoder and which is specified by the supplier of the servo system .The marker pulse also has a unique relationship to the motor BEMF signal and is precisely aligned during the installation of the encoder onto the motor .The accuracy of the marker pulse to the motor BEMF signal is usually at least ± 2 mechanical degrees, which provides more than 99 %of maximum torque for 4, 6, and 8 pole motors.

Finally, the A and B data signals typically provide 2000 cycles per mechanical revolution .The servo drive encoder interface circuit is designed to detect all of the edge transitions for the data signals so the 2000 "line" encoder provides 8000 counts or Pulses Per revolution PPr.

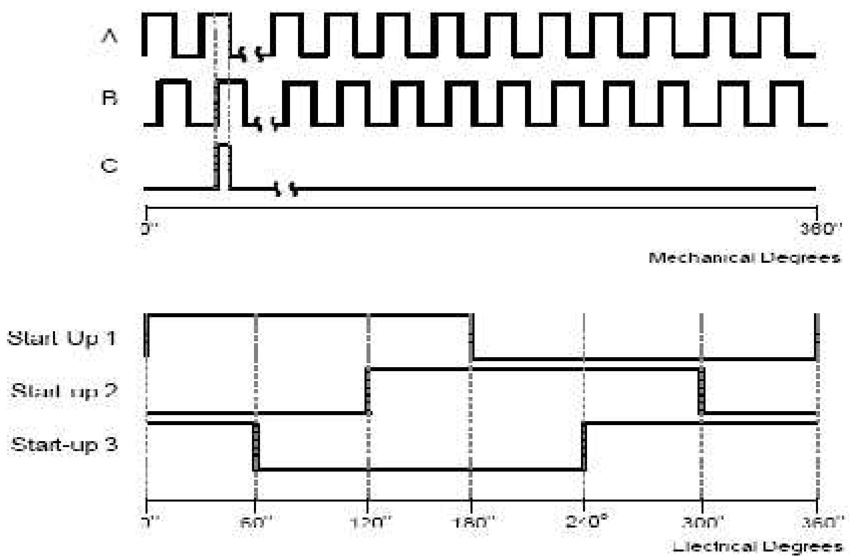


Figure 4.9: Representation of the incremental encoder signals.

Electrical Degree= (Mechanical Degrees)$\times$(Pole Pairs)

Example :a 4- pole motor has 2 -pole pairs.

4.2.4.2 The current controlled power converter

As discussed earlier, the ac servo motor produces torque, which is proportional to the amplitude of the composite current vector .As you can imagine, the ac servo drive must produce current accurately and with high response .This extremely important task is the work of the current controlled power converter as shown in Figure 4.10.

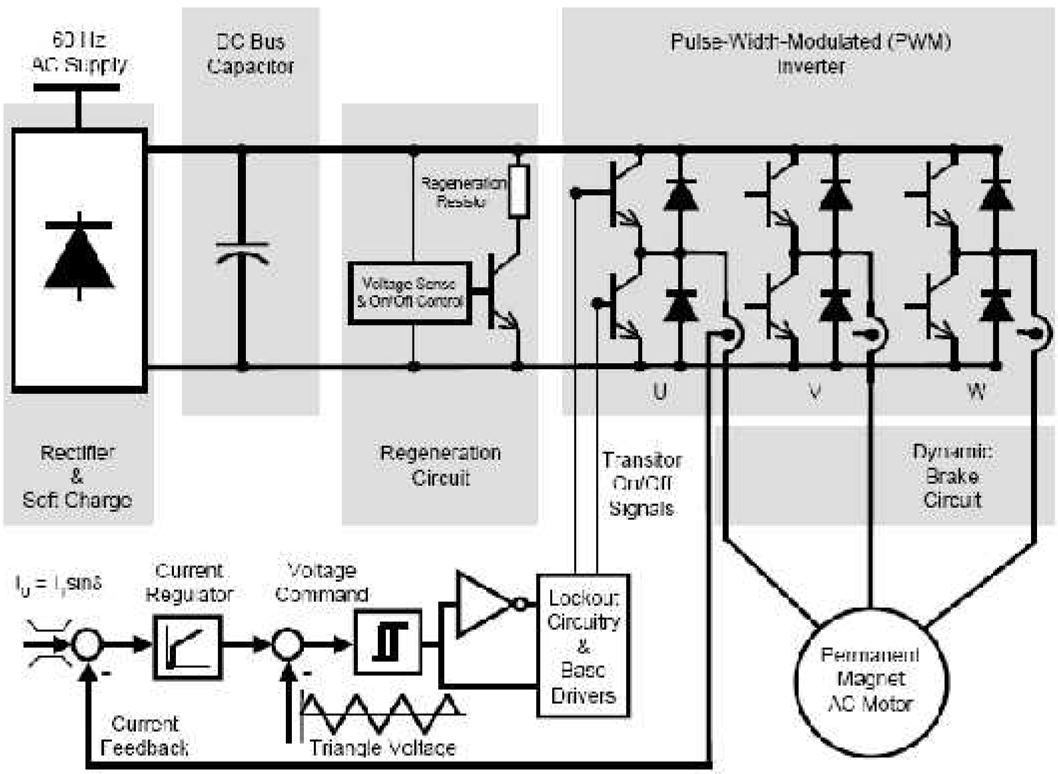


Figure 4.10: Block diagram of the current controlled power converter

The system is supplied by the ac mains, which typically is required to be single phase or three phase voltage at 230 Vrms± (10%-15%) and (60Hz± 3Hz). Sometimes the ac supply is buffered by a transformer in order to provide the correct voltage level .The primary attribute of the ac supply is that it needs to maintain the required voltage level even as it is loaded by the servo drives or other items attached to the supply.

The diode rectifier converts the ac input into a dc voltage, which is called the "dc bus"Included with the diode rectifier is a circuit to control the inrush currentsduring power-up .Without the "soft start" or "soft charge" circuit there would be very large inrush currents to charge the dc bus capacitor .After initial power-up, the rectifier circuit is free to provide the necessary energy to the servo system as required.

The dc bus capacitor has a large value, which serves two purposes .One purpose is to act as a large filter so that a smooth dc bus voltage is available to the inverter .The second purpose is to help absorb energy during regeneration or braking of the motor and load .While the diode rectifier can supply power during motoring or driving, it cannot return power to the ac supply during braking .The regeneration energy is absorbed by the dc bus capacitor until it charges to a maximum allowable voltage and then the regeneration circuit "dumps" excess energy in the regeneration resistor where it is eliminated in the form of heat .Most ac servo drives include a small built-in regeneration resistor while having the provision for adding an external resistor with a much larger wattage.

The inverter is designed with power switches that are turned "on" or "off" . These power switches can be bipolar transistors or power FETs but most ac servo drives today use a newer switch referred to as an IGBT insulated-gate bipolar transistor. The IGBT combines the rugged output of the bipolar transistor with the gate drive and fast turn-off time of the power FET .The inverter topology, with the six switches and the "fly back" diodes, provides four quadrant operation of the ac servo motor by allowing energy to flow to and from the motor.

Let's take a look at the current controller design for one of the three phases . The other two phases operate in an identical fashion.

The desired current or current command is I_U and it can be limited to a user defined value up to a maximum as determined by design limit.The current command is compared to the current feedback to produce a current error .As you can imagine, the current sensors must be very accurate and responsive devices, as they must absolutely produce a faithful reproduction of actual current.

The current error is processed by the current regulator to produce the voltage command .The current regulator has a high-gain to minimize the current error over the operating range of the system .The voltage command is compared to a triangle voltage to generate the PWMpulse width -modulatedsignals that command the power switches to turn-on and turn-off .The switching frequency of the PWM inverter is usually in the range of 5 to 20 kHz in order to support the high current loop bandwidth and to minimize the audible noise and level of current ripple .The –3dB bandwidth of the current loop is usually well over 1,000 Hertz.

The power switches are not perfect and they do take some time)typically a few μsecsto turnoff after receiving the command to turn-off .Unfortunately, the switches respond to the turn-on signal more rapidly so the “on” and “off” commands are processed by some special circuitry to prevent the upper and lower switches from simultaneously conducting current .Such a condition is referred to as a “shoot-through” and it is as bad as it sounds .The “lock-out” circuitry introduces a small delay in the turn-on signal to prevent shoot-through conditions.

Now for the best news of all current controller is the domain of the ac servo system manufacturer and requires no user adjustment at all !The operation of the current controller is absolutely critical to the performance of the servo system and the necessary adjustments only involve knowledge of the servo drive design and the motor design .Therefore, the servo system manufacturer has all the information necessary to provide for the optimum set-up with a minimum of user intervention .At most, the user will be asked to supply the drive with the motor model number or similar identifier.

Finally, a dynamic brake DBcircuit is shown between the inverter and the ac servo motor .The DB is used in the event of a servo drive fault condition to help brake the motor .Often, the DB circuit is included inside the servo drive, which is very convenient .The DB circuit uses contactors to disconnect the motor from the inverter and to connect the motor windings together through resistors .If the motor is rotating, the BEMF causes current to flow in such a way as to retard rotation or to dynamically brake the motor.

4.3 Three phase Induction motor

AC induction motors are the most common motors used in industrial motion control systems, as well as in main powered home appliances. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of AC induction motors.

A poly-phase electrical supply is available, the three-phase (or poly-phase) AC induction motor is commonly used, especially for higher-powered motors. The phase differences between the three phases of the poly-phase electrical supply create a rotating electromagnetic field in the motor.

These motors are self-starting and use no capacitor, start winding, centrifugal switch or other starting device.

Induction motors are the workhorses of industry and motors up to about 500 kW (670 horsepower) in output are produced in highly standardized frame sizes,

Three-phase AC induction motors are widely used in industrial and commercial applications There are two types of rotors used in induction motors: squirrel cage rotors and wound rotors (slip-ring rotor).

4.3.1Squirrel Cage rotors

An electric motor with a squirrel cage rotor is sometimes called a squirrel cage motor. In overall shape it is a cylinder mounted on a shaft. Internally it contains longitudinal conductive bars of Al-minimum or copper set into grooves and connected together at both ends by shorting rings forming a cage-like shape. The name is derived from the similarity between this rings-and-bars winding and a hamster wheel (presumably similar wheels exist for pet squirrels).

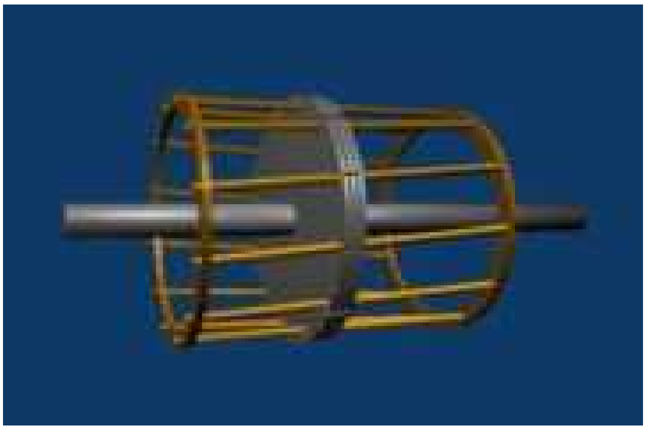


Figure 4.11: Squirrel Cage rotors

The field windings in the stator of an induction motor set up a rotating magnetic field around the rotor. The relative motion between this field and the rotation of the rotor induces electrical current flow in the conductive bars. In turn these currents flowing lengthwise in the conductors react with the magnetic field of the motor to produce force acting at a tangent to the rotor, resulting in torque to turn the shaft. In effect the rotor is carried around with the magnetic field but at a slightly slower rate of rotation. The difference in speed is called “slip” and increases with load.

In figure (4.12) shows atypical poly-phase squirrel-cage induction motor torque-speed curve.

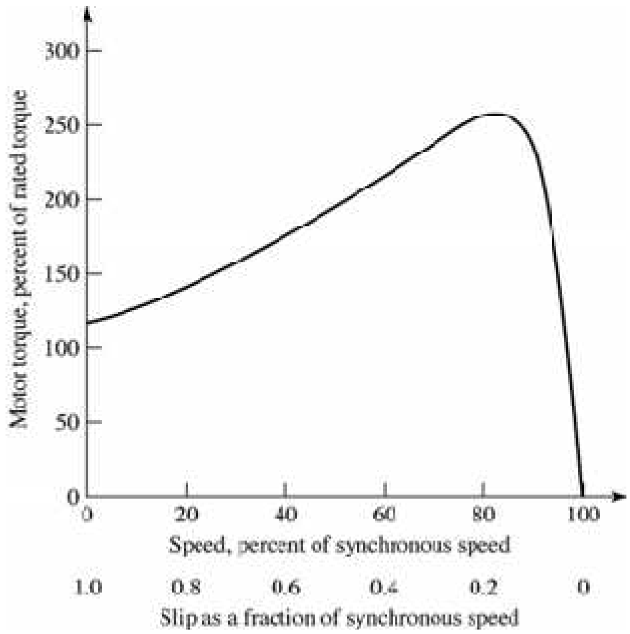


Figure 4.12: typical induction-motor torque-speed Curve for constant-voltage, constant-frequency operation.

The conductors are often skewed slightly along the length of the rotor to reduce noise and smooth out torque fluctuations that might result at some speeds due to interactions with the pole pieces of the stator. The number of bars on the squirrel cage determines to what extent the induced currents are fed back to the stator coils and hence the current through them. The constructions that offer the least feedback employ prime numbers of bars.

Iron core serves to carry the magnetic field across the motor. In structure and material it is designed to minimize losses. The thin laminations, separated by varnish insulation, reduce stray circulating currents that would result in eddy current loss. The material is a low carbon but high silicon iron with several times the resistance of pure iron, further reducing eddy-current loss. The low carbon content makes it a magnetically soft material with low hysterics loss.

The same basic design is used for both single-phase and three-phase motors over a wide range of sizes. Rotors for three-phase will have variations in the depth and shape of bars to suit the design classification.

An alternate design, called the wound rotor, is used when variable speed is required. In this case, the rotor has the same number of poles as the stator and the windings are made of wire, connected to slip rings on the shaft. Carbon brushes connect the slip rings to an external controller such as a variable resistor that allows changing the motor's slip rate. In certain high-power variable speed wound-rotor drives, the slip-frequency energy is captured, rectified and returned to the power supply through an inverter.

Compared to squirrel cage rotors, wound rotor motors are expensive and require maintenance of the slip rings and brushes, but they were the standard form for variable speed control before the advent of compact power electronic devices. Transistorized inverters with variable-frequency drive can now be used for speed control, and wound rotor motors are becoming less common. (Transistorized inverter drives also allow the more-efficient three-phase motors to be used when only single-phase mains current is available, but this is never used in household appliances, because it can cause electrical interference and because of high power requirements).

Several methods of starting a poly-phase motor are used. Where the large inrush current and high starting torque can be permitted, the motor can be started across the line, by applying full line voltage to the terminals (Direct-on-line, DOL). Where it is necessary to limit the starting inrush current (where the motor is large compared with the short-circuit capacity of the supply), reduced voltage starting using either series inductors, an autotransformer, thyristors, or other devices are used. A technique sometimes used is (Star-Delta, YΔ) starting, where the motor coils are initially connected in wye for acceleration of the load, then switched to delta when the load is up to speed. This technique is more common in Europe than in North America. Transistorized drives can directly vary the applied voltage as required by the starting characteristics of the motor and load.

This type of motor is becoming more common in traction applications such as locomotives, where it is known as the asynchronous traction motor.

The speed of the AC motor is determined primarily by the frequency of the AC supply and the number of poles in the stator winding, according to the relation:

$$N_S = \frac{120f}{p} \qquad (2.1)$$

Where:

Ns = Synchronous speed, in revolutions per minute.

f = AC power frequency.

P = Number of poles per phase winding.

The slip of the AC motor is calculated by:

$$S = \frac{N_S - N_r}{N_S} \qquad (2.2)$$

Where:

Nr = Rotational speed, in revolutions per minute.

S = Normalized Slip, 0 to 1.

The speed in this type of motor has traditionally been altered by having additional sets of coils or poles in the motor that can be switched on and off to change the speed of magnetic field rotation. However, developments in power electronics mean that the frequency of the power supply can also now be varied to provide a smoother control of the motor speed.

Chapter 5
Machine Design

5.1 Body of the machine

Figure 5.1describes the body of the Back-gauge system for press brake machine, we can divided this body into two major parts: Part one is thedirection of movement in Z -axis, and Part two is thedirection of movement in Y -axis, The Dimensions ofthis system is 204cm length and 90cm width and height is not limited.
The body contain two motors, one AC servo motors Z-axis and one AC synchronous motor, two encoder, oneBall-Screw, and two gear .The AC servo motors is used to drive the load in Z direction where he is to move the fingers forward and backward to determine thedimensions of discourage.

The AC asynchronous motor used to drive the load in Y -direction where it is tolift the finger up and down .The Ball-Screw used to reduce the friction and to make the equilibrium .And gear used fortorque stronger and better used to reduce speed.

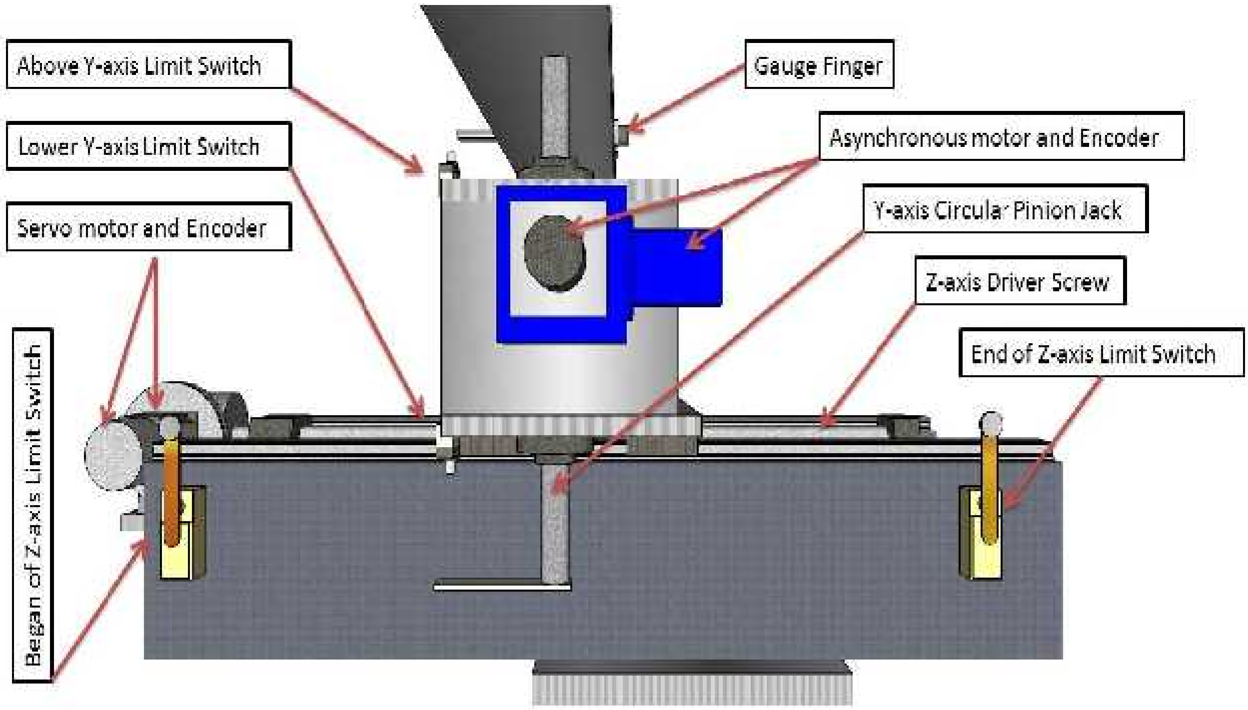


Figure 5.1: The body of the Back-Gauge System

5.2 Selection of Motors-:

5.2.1 Selection of Induction Motor Y-axis Motion-:

Formulae for determining performances and torques:

comment	Unit	Equation
	m/s^2	$a = \frac{V}{t_b}$ ………………………………………………… (5.1)
For lifting Y-axis	N	$F_u = m.g + m.a$ ………………………………………………… (5.2)
For driving Y-axis	N	$F_u = m.g.\mu + m.a$ ………………………………………………… (5.3)
	N.m	$T_{2req} = \frac{F_u.d}{2}$ ………………………………………………… (5.4)
	min^{-1}	$n_2 = \frac{v}{d.\pi}$ ………………………………………………… (5.5)
		$i_{gear} = \frac{n_1}{n_2}$ ………………………………………………… (5.6)
		Safety factor f=2
	N.m	$T0=2\ .T_{2req}$ ………………………………………………… (5.7)
	kw	$P_{req} = \frac{T_0.n_2}{9550.\eta}$ ………………………………………………… (5.8)

Formalization:-

Parameter	comment	Unit
a	Acceleration/deceleration	m/s^2
bB	Operating time factor	
d	Pitch diameter of pinion	Mm
g	Acceleration due to gravity	9.81 m/s^2
m	Mass	Kg
n_1	Gear input rpm	min^{-1}
n_2	Gear output rpm	min^{-1}
tb	Acceleration time	Sec
i	Gear ratio	
ν	Travelling/lifting speed	m/s
Fu	Peripheral load at the pinion	N
Ka	Load factor	
P_1	Gear input power	Kw
S	Safety coefficient	
T_2	Gear output torque	N.m
η	Gear efficiency	
μ	Coefficient of friction	
π	3.14159	

Calculation's:-

Values given:-

Comment	Parameters Values
Mass to be moved	M=55kg
Speed	v=3.3 m/min
Acceleration time	tb=0.1s
Acceleration due to gravity	$g=9.81\ m/s^2$
Coefficient of friction	μ=0.1
Pitch dia .of pinion	d=20mm
Safety coefficient	S=2
Motor speed	$n1=1500min^{-1}$

calculations
$a=\frac{V}{t_b}=\frac{0.055m/min}{0.5}=0.2\ m/s^2$
$F_u=m.g+m.a=55\times 9.81+55\times 0.2=550.55\ N$
$T_{2req}=\frac{F_u.d}{2}=\frac{550.55\times 70mm}{2}=19.3\ N.m$
$n_2=\frac{v}{d.\pi}=\frac{0.055m/min\times 60}{70mm\times 3.14}=15min^{-1}$
$i_{gear}=\frac{n_1}{n_2}=\frac{1500}{15}=100$
Safety factor =2
$P_{req}=\frac{T_0.n_2}{9550.}=\frac{38.6\times 15}{9550\times 0.4}=151.6watt$
$P_{motor}=0.2\ HP\approx 0.25HP$

5.2.2 Selection of Servo Motor Z-axis Motion:-

$T_p = K\frac{P_L L}{2\pi}(N.m)$……………………………………………………………..…….(5.9)

$K = 0.5\ (\tan\beta)^{-\frac{1}{2}}$………………………………………………………………..(5.10)

Where:

P_L :Preload (N)

L :Ball Screw Lead (cm)

D :Thread Outer Diameter (mm)

K :Coefficient of Internal Friction.

β :Lead Angle

$\beta = \tan^{-1}\left(\frac{L}{\pi D}\right)$……………………………………………………………(5.11)

When selecting a driving motor, it is necessary to satisfy the following conditions:

1- Ensure a marginal force sufficient to counter the load torque exerted on the motor's output thread.

2- Enable starting, stopping at prescribed pulse speeds, sufficiently powered to counter the moment of inertia exerted on the motor's output thread

3- Obtain the prescribed acceleration and deceleration constants, sufficient to counter the moment of inertia exerted on the motor's output thread

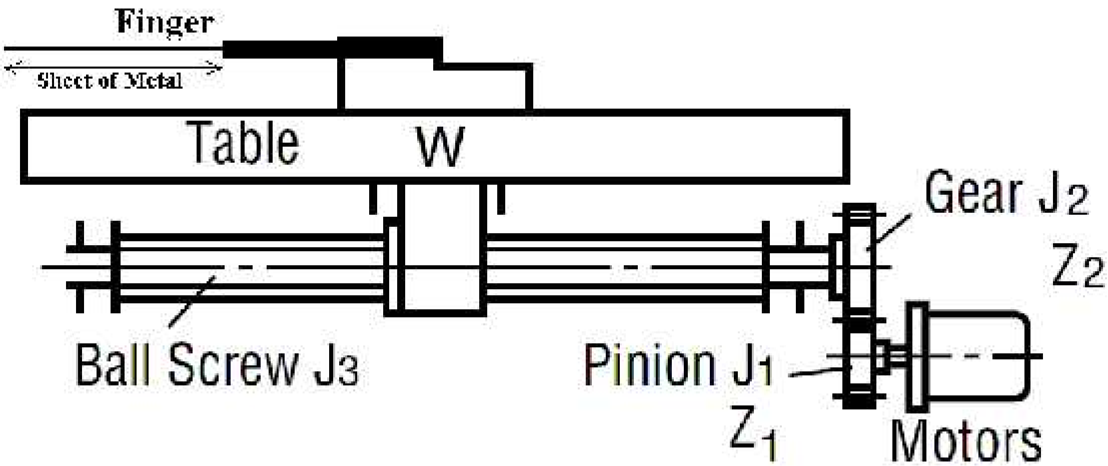


Figure 5.2: Illustrative picture of the system.

Constant Speed Torque Exerted on the Motor Output Thread:-

This is the amount of torque required to drive the output thread against the applied external load, at a constant speed.

$$T_1 = \left(\frac{PL}{2\pi\eta} + T_P \frac{(3P_L - P)}{3P_L}\right)\frac{Z_1}{Z_2}(N.m) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.12)$$

Where : $P \leq 3P_L$

T_1: Driving Torque at Constant Speed $(N.m)$.

P: External Axial Load (N) $(P = F + \mu M.g)$

F: Thrust Reaction Produced in Cutting Force (N)

M: Masses of Table and Work Piece(Kg)

μ:Coefficient of Friction on Sliding Surfaces

g:Gravitational Acceleration $(9.8\ m/s^2)$

L: Ball Screw Lead (m)

η : Mechanical Efficiency of Ball Screw or Gear

T_P: Friction Torque Caused by Preloading (N.m) Refer to Formula (5.9)

P_L: Preload. (N)

Z_1: Number of Pinion's Teeth

Z_2:No .of Gear's Teeth

Acceleration Torque Exerted on the Motor Output Thread:-

This is the amount of torque required to drive the output shaft against the external load during acceleration.

$$T_2 = J_M \omega = J_M \frac{2\pi N}{60t} \times 10^{-3}(N.cm) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.13)$$

$$J_M = J_1 + J_4 + \left(\frac{Z_1}{Z_2}\right)^2\{(J_1 + J_4)\} + M\left(\frac{L}{2\pi}\right)^2 (kg.cm^2) \ldots\ldots\ldots\ldots (5.14)$$

Where:

T_2 :Driving Torque in Acceleration (N.m)

ω:Motor Thread Angular Acceleration (rad/s^2)

N: Motor Thread Revolutions (min^{-1})

t: Acceleration Time (s)

J_M :Momentof Inertia Exerted on the Motor (Kg.cm^2)

J_1: Moment of Inertia Exerted on Pinion (Kg.cm^2)

J_2: Moment of Inertia Exerted on Gear (Kg.cm^2)

J_3: Moment of Inertia Exerted on Ball Screw (Kg.cm^2)

J_4: Moment of Inertia Exerted on Motor's Rotor (Kg.cm^2)

M :Masses of Table and Work Piece (Kg.cm^2)

L: Ball Screw Lead (m)

Moment of inertia exerted on cylinders as screws and cylinders such as Gears Calculation of (J_1~J_4).

$$J = \frac{\pi\gamma}{32} D^4 (kg.cm^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.15)$$

Where:

D :Cylinder Outer Diameter (m)

ℓ: Cylinder Length (m)

γ: Material Specific Gravity $\gamma = 7.8 \times 10^3 (kg/m^3)$

Total Torque Exerted on the Motor Output Thread-:

Overall torque can be obtained by adding results from formulas 6 and 7.

$$T_m = T_1 + T_2 = \left(\frac{PL}{2\pi\eta} + T_P \frac{(3P_L - P)}{3P_L}\right)\frac{Z_1}{Z_2} + J_M \frac{2\pi N}{60t} \times 10^{-3}(N.m) \ldots\ldots\ldots (5.16)$$

Where:
T_M :Total Torque Exerted on the Motor Output Thread (N.m)
T_1 :Driving Torque at Constant Speed (N.m)
T_2 :Driving Torque at In Acceleration (N.m)

Once you have temporarily found the type of motor need, to check-:

1 .Effective torque,

2 .Acceleration constant and

3 .Motoroverload properties and heat tolerance during repeated starting, stopping.

It is necessary to ensure a sufficient margin for these parameters.

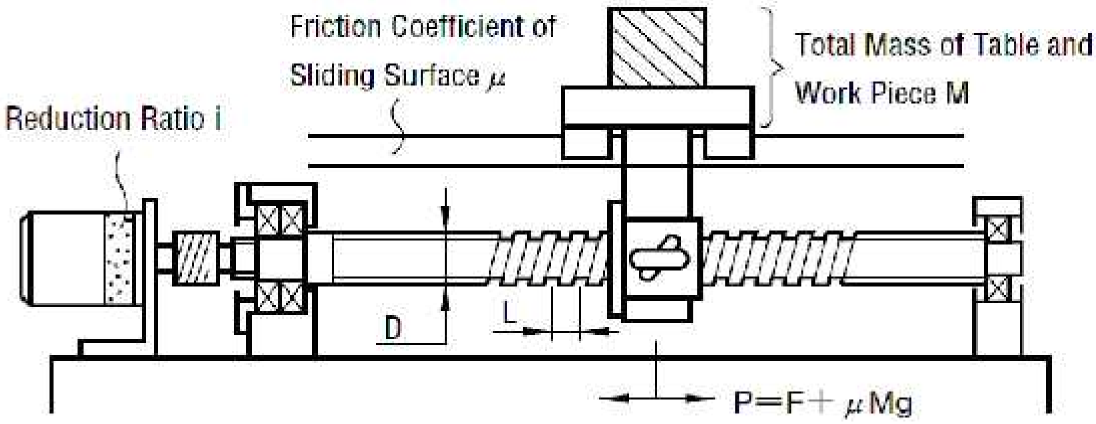


Figure 5.3 :shows the content of the internal system

Specification-:

Comment		Parameters values	
Total Mass of Table and Work Piece		M=90kg	
Coefficient of Friction on sliding surfaces		μ=0.5	
External Force		F=50N	
Reduction Ratio		i=10	
Ball Screw Size	Outer Dia Φ=32mm	Pitch L=20mm	Lead Length 900 mm
Mechanical Efficiency of Ball Screw		η=0.9	
Threading Speed		v=6m/min	
Acceleration Time		t=0.5s	
Motor Thread Revolutions		$n_1 = \frac{v.60}{L} = \frac{6m/min \times 60}{20mm} = 3000min^{-1}$	

Calculation's:-

Calculate		Equation
1	constant speed torque T_1 $g=9.81 m/s^2$	$T_1 = \frac{\left(F + \mu . M . g \times 10^{-3}\right) L}{2\pi\eta} = \frac{(50 + 0.2 \times 90 \times 9.81) \times 0.032}{2\pi \times 0.9} = 1.28\ N.m$
2	Moment of Inertia exerted on ball screw J_3	$J_3 = \frac{\pi \times 7.7 \times 10^{-3}}{32} \times 3.2^4 \times 90 = 7.13 (kg.cm^2)$
3	Moment of Inertia Exerted on Moving Parts J_5	$J_5 = 90 \times \left(\frac{3.2}{2\pi}\right)^2 = 23.41\ kg.cm^2$
4	Required Driving Torque Tm $J_4 \geq \frac{J_3 \cdot J_5}{3\sim5} \cong 33.38$ k	$T_m = 1.2 N.m + (J_4 + 5.8 kg.cm^2) \times \frac{2\pi \times 3000}{90 \times 1s} \times 10^{-3} = 1.28 + 1.21 + 0.21 \times J_4 = 2.49 + 0.42. J_4\ N.m = 2.49 + 0.21 \times 33.38 = 9.4775\ N.m$
5	Rated Torque Safety factor (1.2)	$T_o = 1.2. T_m = 1.2 \times 9.4775 = 11.373\ N.m$
6	Power of the motor required to drive the screw	$P_{motor} = \frac{T_o . n_2}{9.55 \times \eta} = \frac{11.373 \times 300}{9.55 \times 0.88} = 406 Watt$

Chapter 6

Machine Simulation

6.1 Simulation

As we have mentioned in the previous chapters that the Back-gauge system for press brake machine contains two motors :one servomotors, and one synchronous motor .To make a simulation to these motors and to the machine we would use a computer program called SIMPLPORER.

The simulation process passed through number of steps:

- Construction of the equivalent circuit of each motor.
- Construction of the control circuit of each motor individually.

6.1.1 The AC servo motor equivalent circuit

To construct the equivalent circuit of the AC servo motor we need the following elements from the (SIMPLPORER) program:

- Voltage sources (1X :)Basics\Circuit\Sources\Voltage source.
- Thyristors (4X):Basics\Circuit\Semi conductors System Level\Thyristor.
- Capacitor (1X) :Basics\Circuit\Passive Elements\Capacitor.
- Ideal Switch (6X) :Basics\Circuit\Ideal Switches\Ideal Switch.
- Diodes (6X):Basics\Circuit\ Semiconductors System Level\Diode.
- PM AC Motor (1X) :Basics\Circuit\Electrical Machines\PM Synchronous With Damper.

After collecting these elements we construct the equivalent circuit of the AC servomotor as shown in Figure 6.1 :

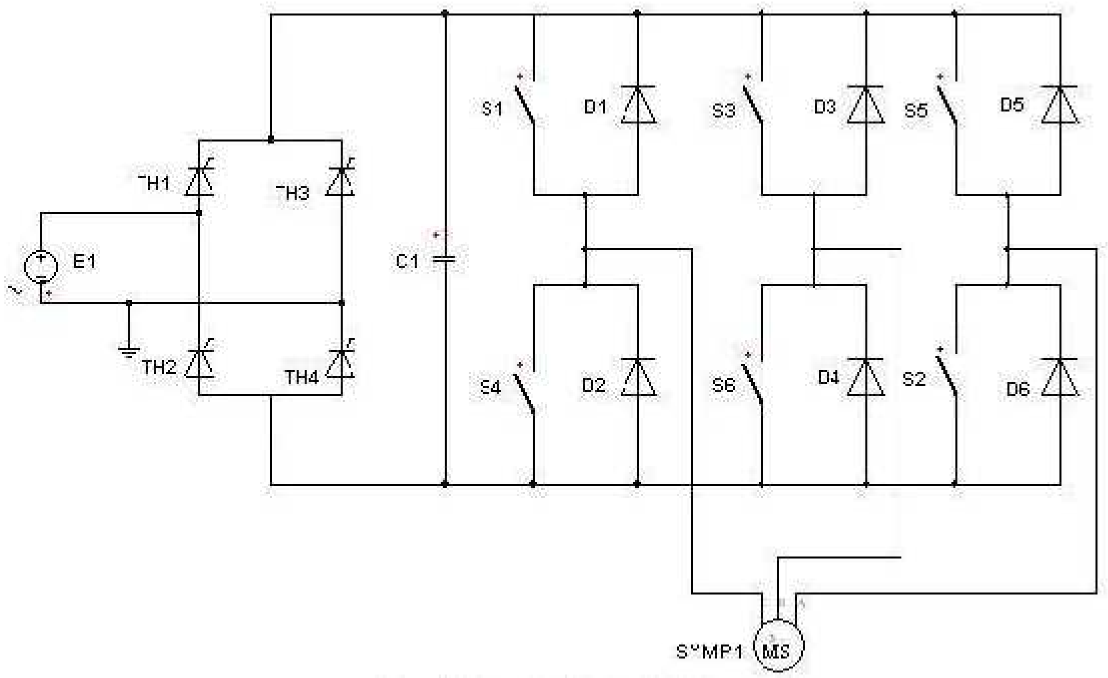


Figure 6.1 :The equivalent circuit of AC servo motor

6.1.2 The AC servo motor control circuit

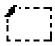
To construct the control circuit to the previous equivalent circuit we need to the following elements from the)SIMPLPORER (program:

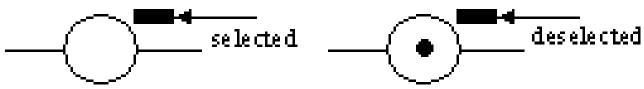
- State (10X): Basics\States\State11.
- Transition (10X) : Basics\States\Transition .
- Constant (1X): Basics\Blocks\Sources blocks\Constant value.
- Saw Tooth (2X): Basics\Tools\Time Functions\Saw-Tooth.

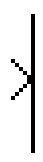
We need tow control circuits one to trigger the thyristors in the controlled rectifier (B6C)which used to control the input DC voltage, and the second to control the 3-PH inverter operation and the sequence of the switches to use it to convert the voltage from DC to AC.

Before explaining the control process procedures, we will show the function of each element used in it :

6.1.2.1 State graphs

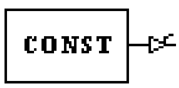
Control process can be realized in SIMPLPORER very fast and easy using State Graphs .This concept is based on analyzing the control task in States with dominant properties .An actual state is designed as active .The process procedure is represented as sequence of states .To specify the action of each stat, double-click on the state and then on the icon  and choose from the list the desired action .At the simulation start, a start state must be defined .Definition of start stat is achieved by clicking on the square area as shown in the following Figure:



In the Transition  , the conditions for the switching from one state to the next are defined .The switching from one state to the other will follow if the transition has the logic value “ true”.

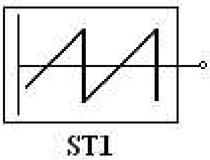
6.1.2.2 The constant

It’s a block where the firing angle will be later saved.



6.1.2.3 Saw-Tooth

It is a function which will be used as a help function for comparing the firing angle with the value of it.



6.1.2.4 The control circuit of the inverter

The control circuit of the inverter is shown in Figure 6.2 :

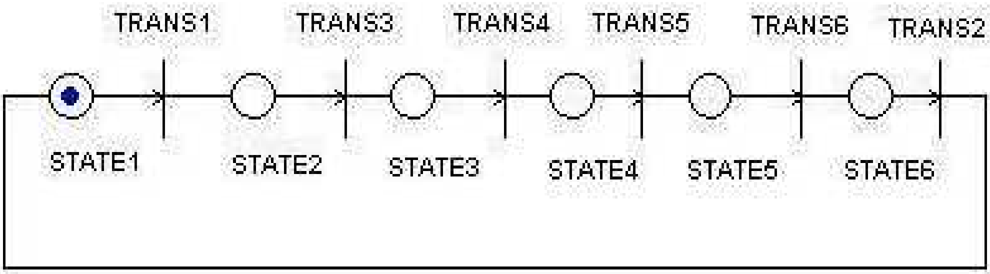


Figure 6.2 :The control circuit of the inverter

The states and the transitions in the Figure used to control the states of the switches in the AC servomotor equivalent circuit to satisfy the inversion .The control process must consider the graphs of Figure 6.3, which show when the switch is ON or OFF .

From the Figure6.3, we noted that at every (60º)the switches cases are changing, that is three switches are turned on, and the other three switches are turned off.

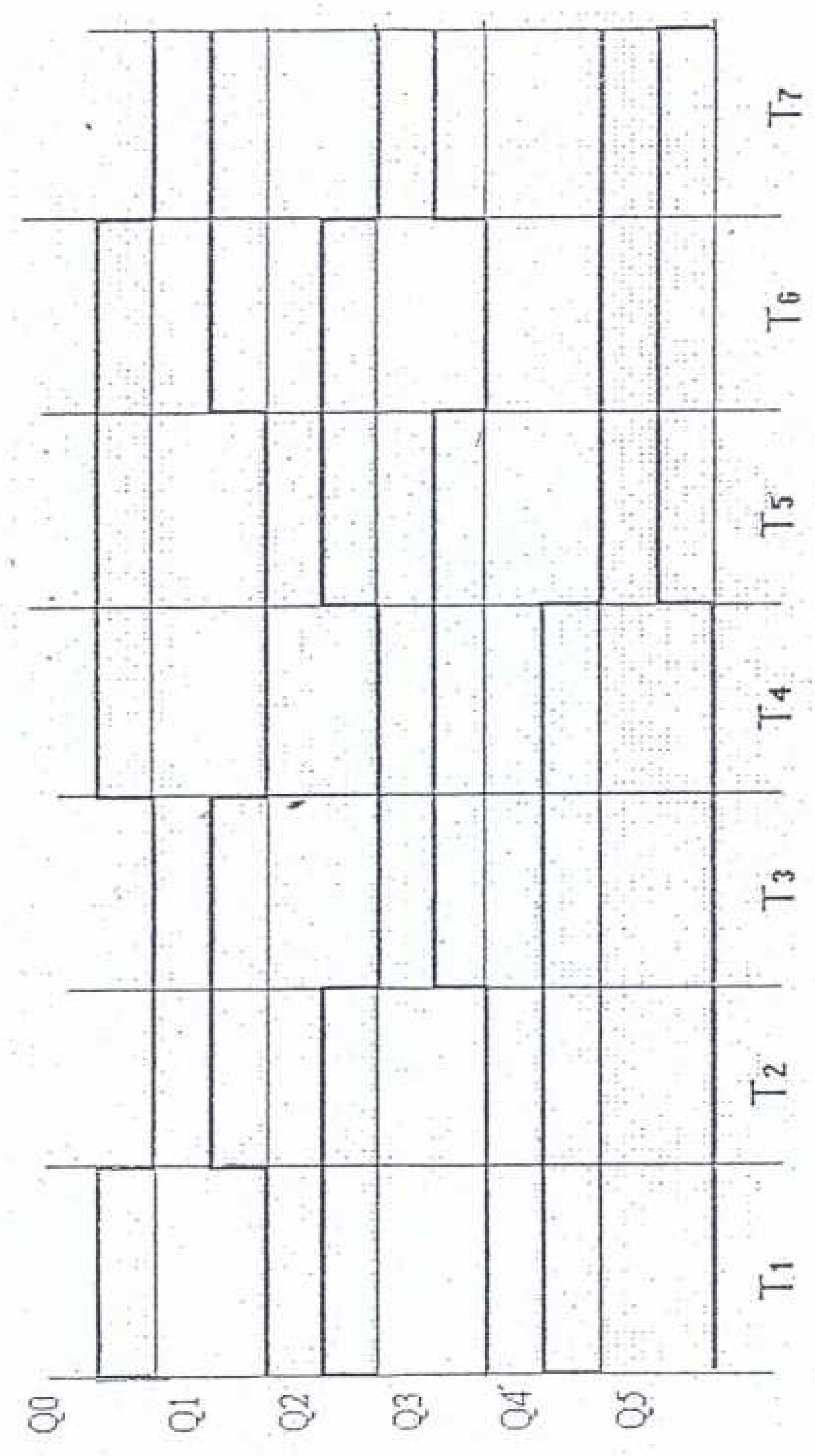
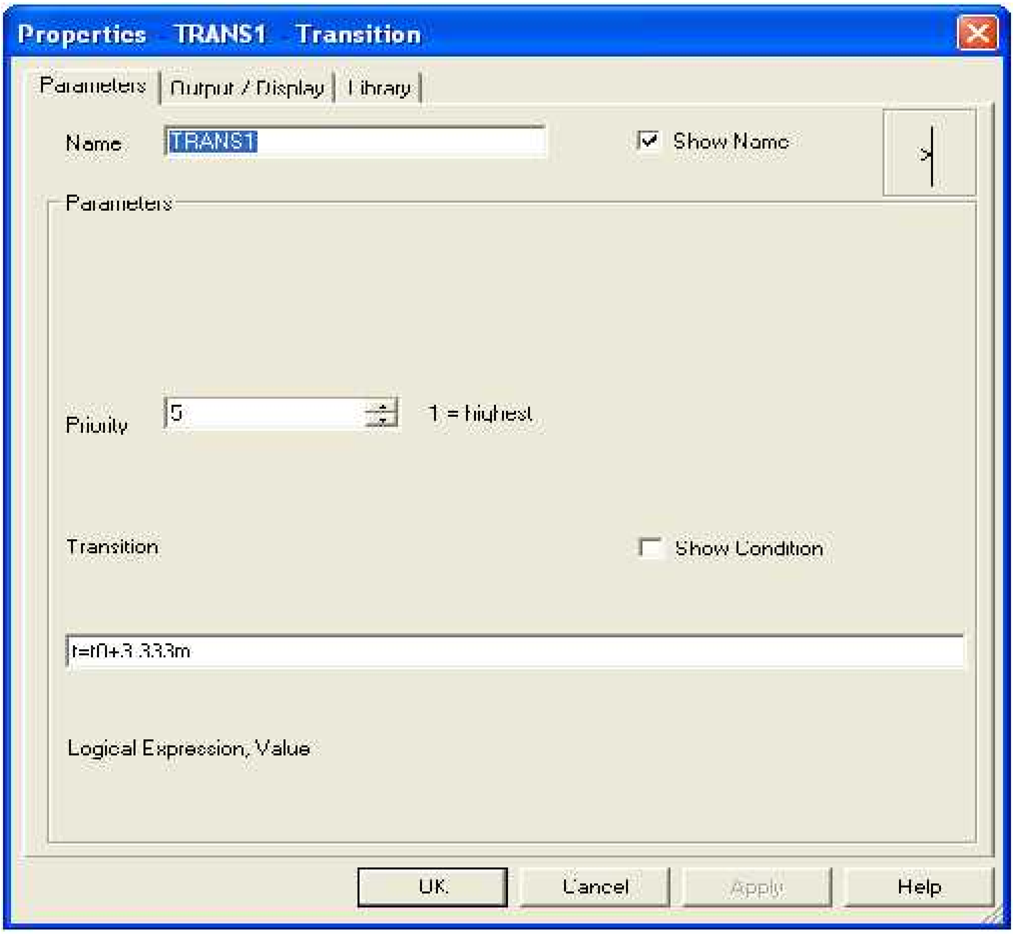


Figure 6.3 :Inverter switches timing diagram

The control process is done as the following:

- Named the control signal of each switch by double click on the switch and choose a suitable name to its control signal, for example control signal of switch (S1) is (SC1)
- Determine the start state as we have mentioned.
- Determine the period of switches signal according to the voltage source frequency, to determine the time at (60°).
- Double-click on the transition and determine the time which you would like the case of the state is transferred to the next after it here the time that matching (60°).

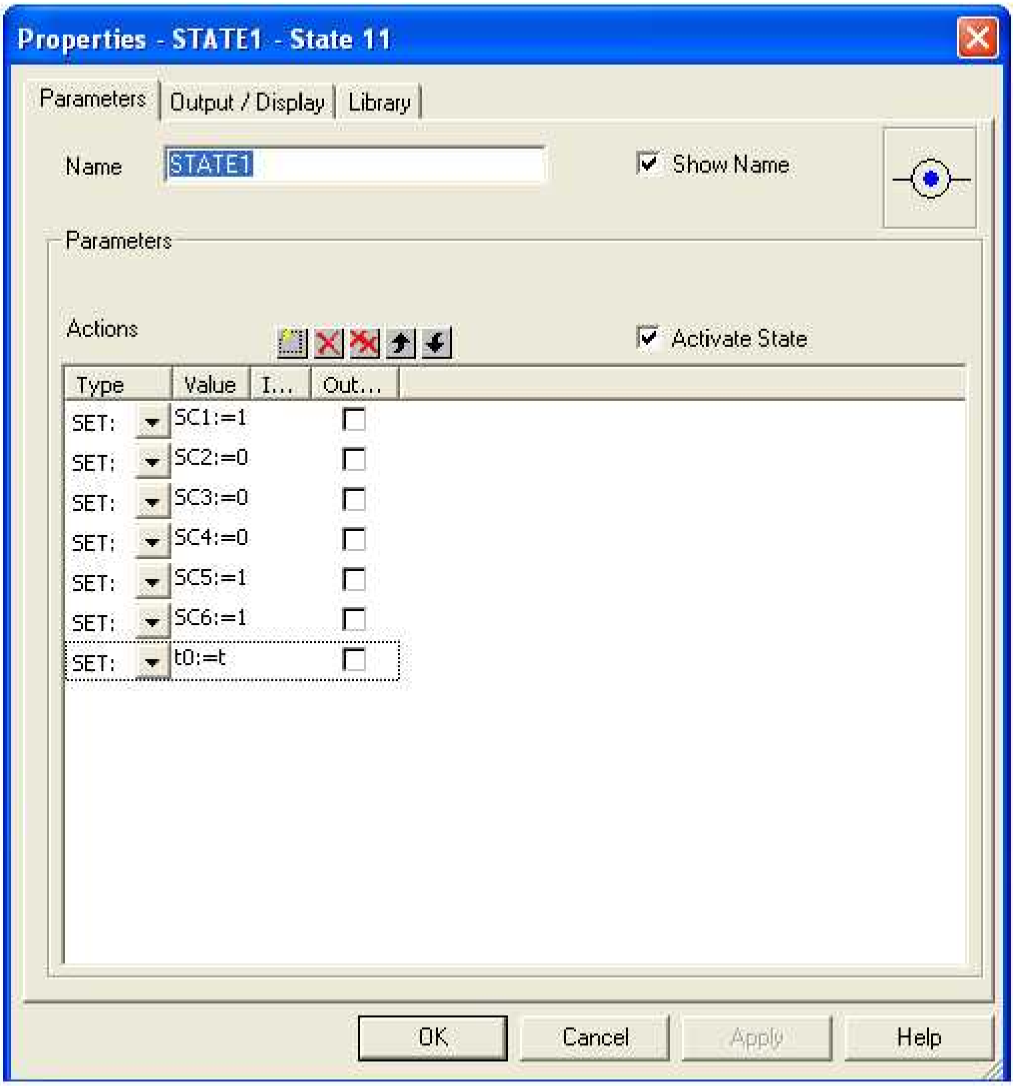
The following Figure shows that for (Transition 1):



- Each state works after (3.333ms) from the previous state.

- The time at (60º)equal here to 3.333ms as the input source period equal to 20ms(F=50Hz).
- Double-click on each state and determine which switch is ON or OFF according to the Figure 6.3 .

For example, in the first 60º , S1, S5, and S6 are switched ON, and S2, S3, and S4 switched OFF, this could be done in the SIMPLPORER as the following Figure :for State 1



- (SET :t0 =:t) to load the first state with the time in the finish step (after the period is ended)to repeat the process, which makes the output, signal periodic.

✓ The control circuits of the controlled rectifier (B6C) are shown in Figure 6.4 and Figure 6.5.

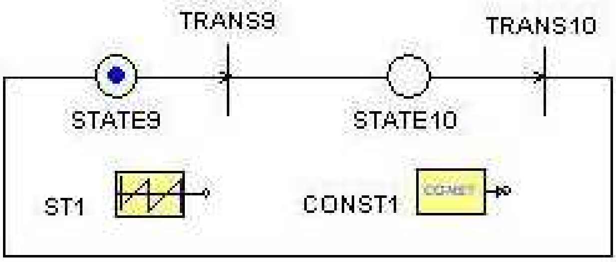


Figure 6.4 :Control circuit for triggering the firing angles of TH1 and TH4

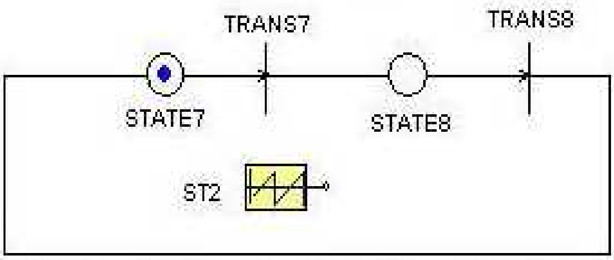


Figure 6.5 :Control circuit for triggering the firing angles of TH2 and TH3

The first circuit used to trigger the firing angles of the thyristors TH1 and TH4 as these two thyristors are working at the same time(in the positive half wave of the voltage source).

The second circuit used to trigger the firing angles of the thyristors TH2 and TH3, as they are working at the same time (in the negative half wave)

- The frequency and period of ST1 must be identical with the frequency and period of the voltage source (here F=50Hz and T =20).
- The phase of ST1 must be synchronized to the phase of the voltage at the terminals of TH1 and TH4 (the positive half wave of the source).
- The amplitude of ST1 must be equal to (180 V).

Figure6.6 shows the form of ST1:

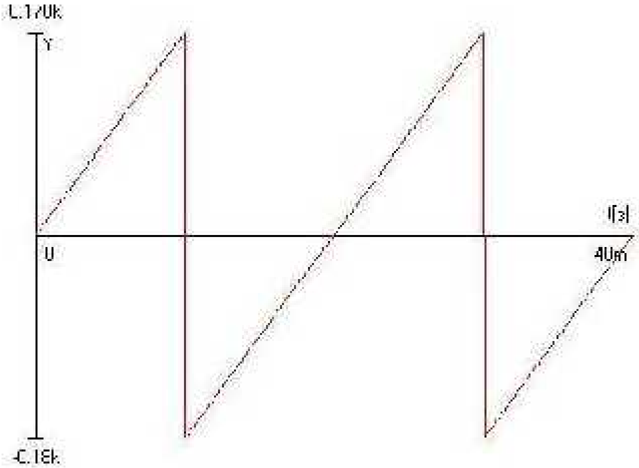


Figure 6.6 :The form of ST1

- The frequency and period of ST2 must be identical with the frequency and period of the voltage source(here F=50Hz and T =20).
- The phase of ST2 must be synchronized to the phase of the voltage at the terminals of TH2 and TH3 (the negative half wave of the source).
- The amplitude of ST2 must be equal to (180 V).

Figure 6.7 shows the form of ST2:

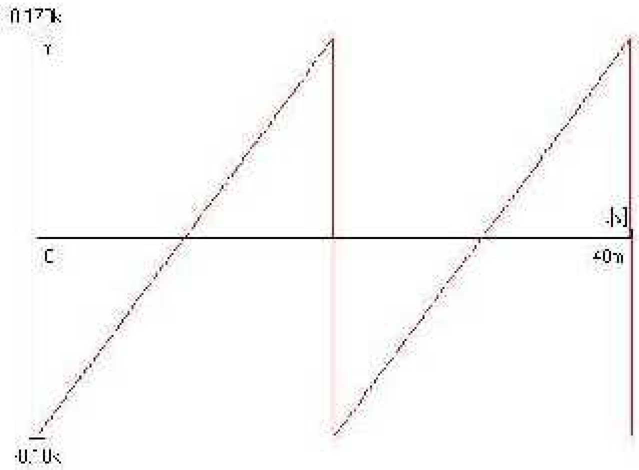


Figure 6.7 :The form of ST2

- Now name the control signal of each thyristor, (the control signal name of TH1 and TH4 must be identical and the control signal name of TH2 and TH3 must be identical too).
- In Transition 9 write(ST1.VAL>=CONST1.VAL).
- In Transition 10 write(TH1.I=0).
- In Transition 7 write(ST2.VAL>=CONST1.VAL).
- In Transition 8 write(TH2.I=0).
- Specify the value of firing angle of the thyristors by double-click on the CONST block.
- In State 9 set the value of the control signal of the TH1 and TH4 to (0) to switch off them as the pervious transition of it say that their holding current is equal to zero(TH1.I=0).
- In State 10 set the value of the control signal of the TH1 and TH4 to (1) to switch on them, as the pervious transition of it say that the firing angle of them it reached(ST1.VAL>=CONST1.VAL).
- Do the same thing to the other two thyristors.

From the previous control circuits we can control the speed of the AC servomotor.

Figure 6.8 and Figure 6.9 show the curves of the speed and the torque of AC servo motor at 50Hz frequency and 20º firing angle:

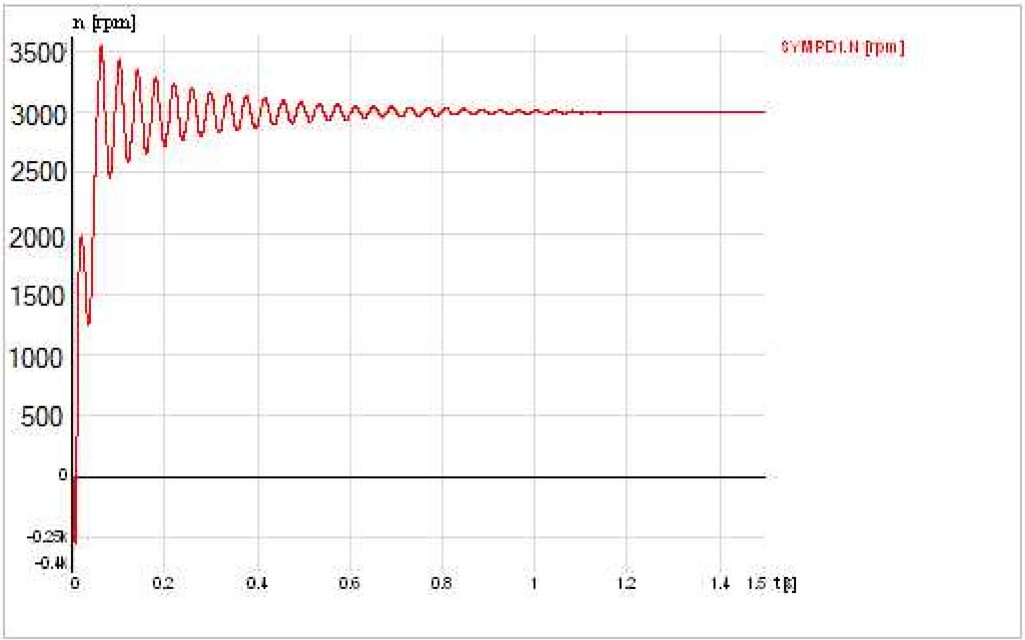


Figure 6.8 :The AC servo motor speed curve

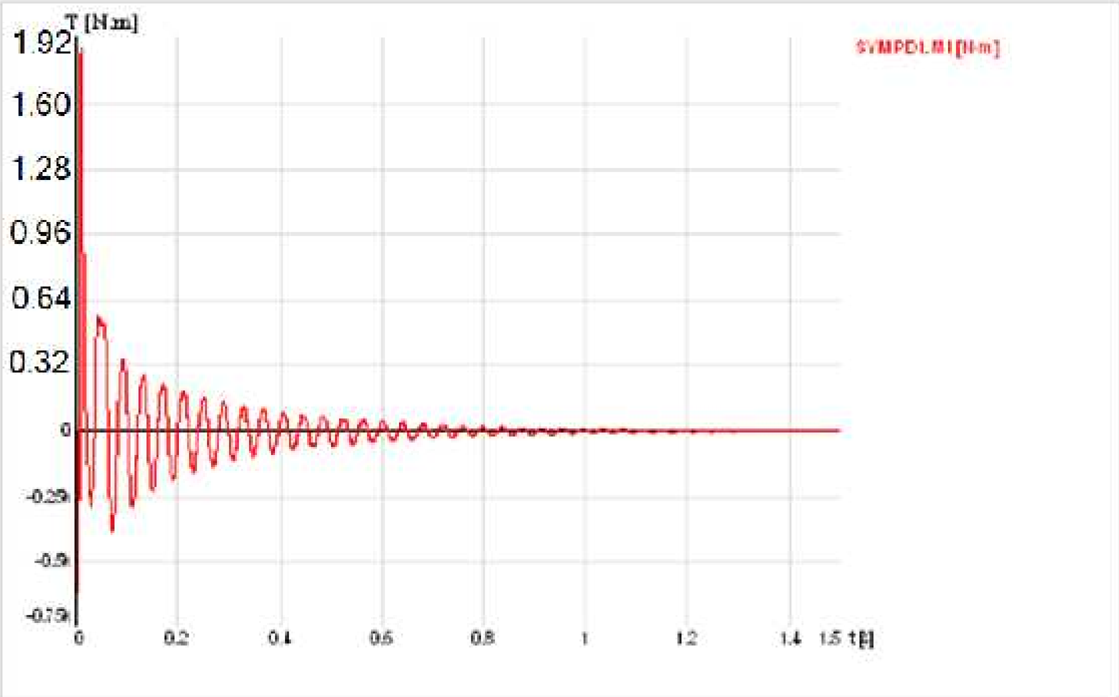


Figure 6.9 :The AC servo motor torque curve

Chapter 7

Conclusions and Recommendations

7.1 Conclusions

1. The trial work in the project give us experience in several ways:-
   - he good management and exploitation of time in suitable form to achievement of work in little possible time.
   - he good management of work to do it without occurrence any losses in money or time.
   - he ability of choosing of suitable electrical and mechanical parts to the machine.
   - o know how to make the suitable connection between the electrical and mechanical parts .
   - o know how to connect of the electrical devices and circuits , the control circuits and the control program
2. henever the mechanical things are decreased the control operations become easier and more accurate.

3. Using of the linear bearing and ball screw in the machine reduce the friction, simplify the motion, and satisfy the equilibrium in the machine.

4. Using ball screw and slide's help us to choice motor less than power expected because little fraction.

5. The advantage of using a PLC is that many loops can be controlled or compensated by the same PLC through time-sharing. Furthermore, any

adjustments of the compensator parameters required, to yield a desired response can be made by changes in Parameters by HMI rather than hardware.

6. Operation of HMI help the work to choice the program is suitable for piece work and change the parameters of distance and number of steps directly.

7. Application of project in fail accompli take us the experience and scientific experience in driving and controlling .

7.2 Recommendations

We recommend the next researchers in this subject to tom doing the following:

1. Developing our machine from (2-axis) machine to (6-axis) machine .

2. Application of project in other machine have another work system like cutting machine, milling machine,…etc.

3. We wish from the university to develop the course plan to include the teaching course about advance PLC ,CNC, HMI, scada system and servo system.

4. Develop the project so that become full automatic by adding robot to replace the worker .

5. Adding additional system to controlling in the fold angle.

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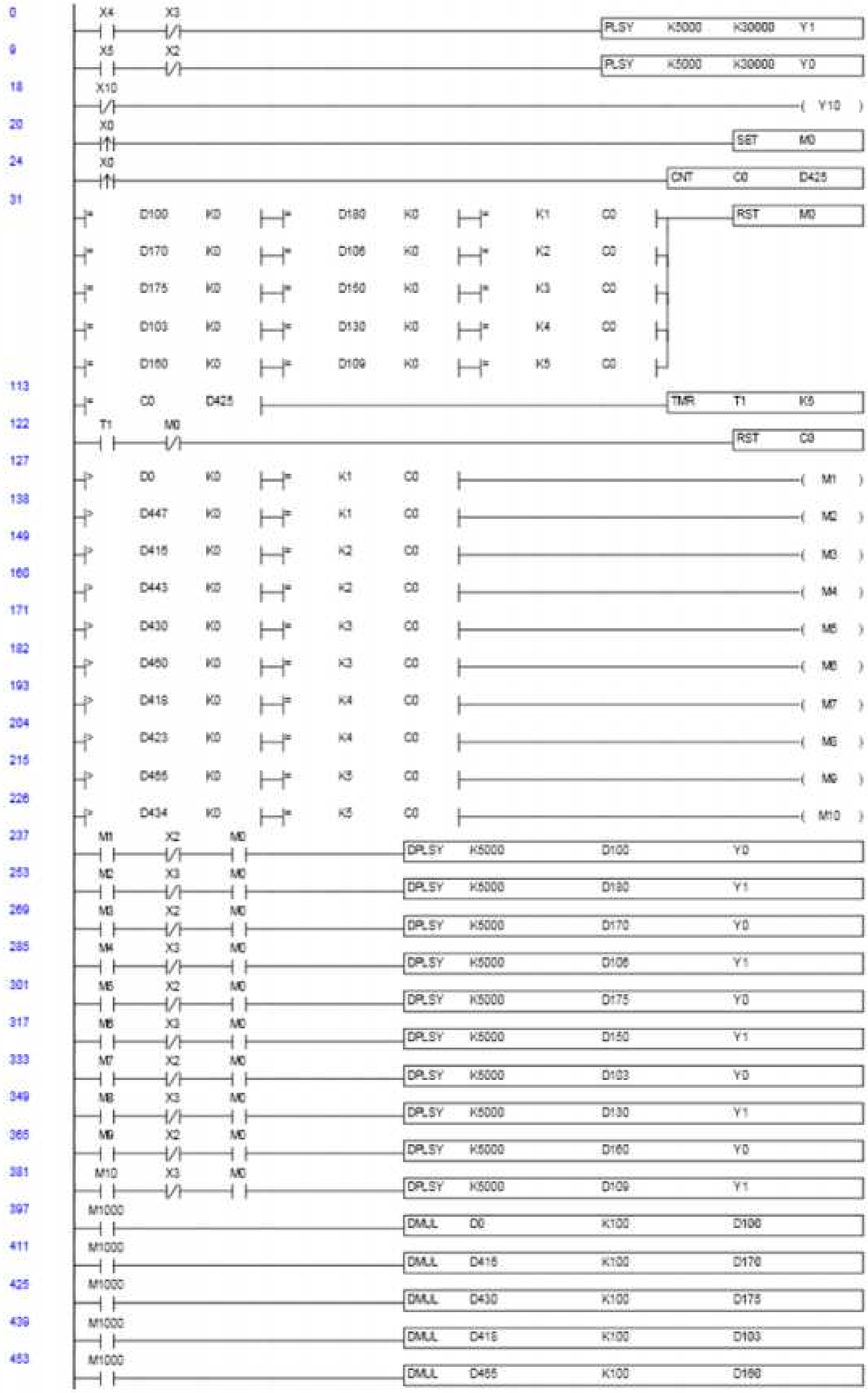
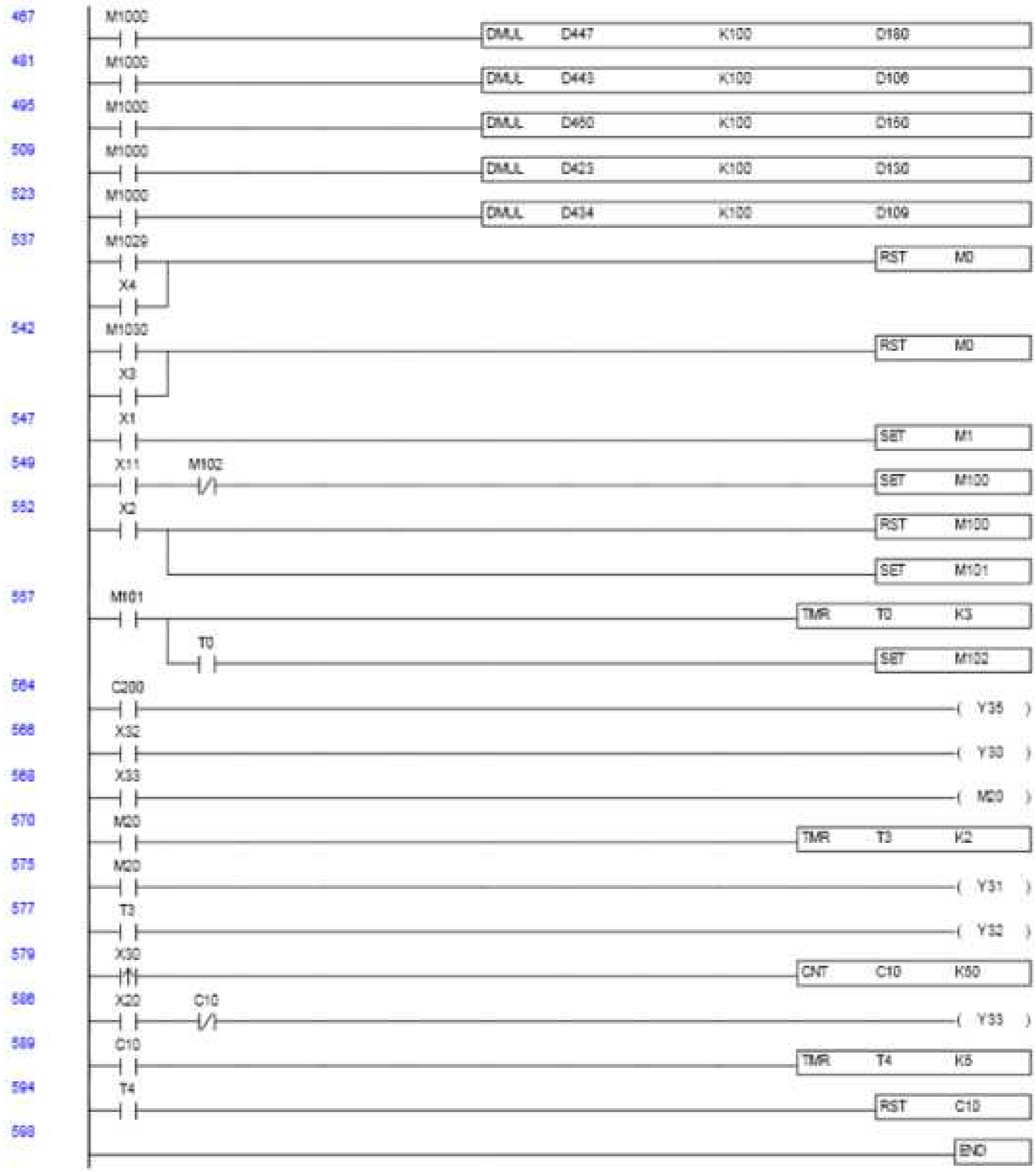
Appendix

- **Appendix(A)**
  - **PLC**
- **Appendix(B)**
  - **Data Sheets**
- **Appendix(C)**
  - **Machine Pictures**

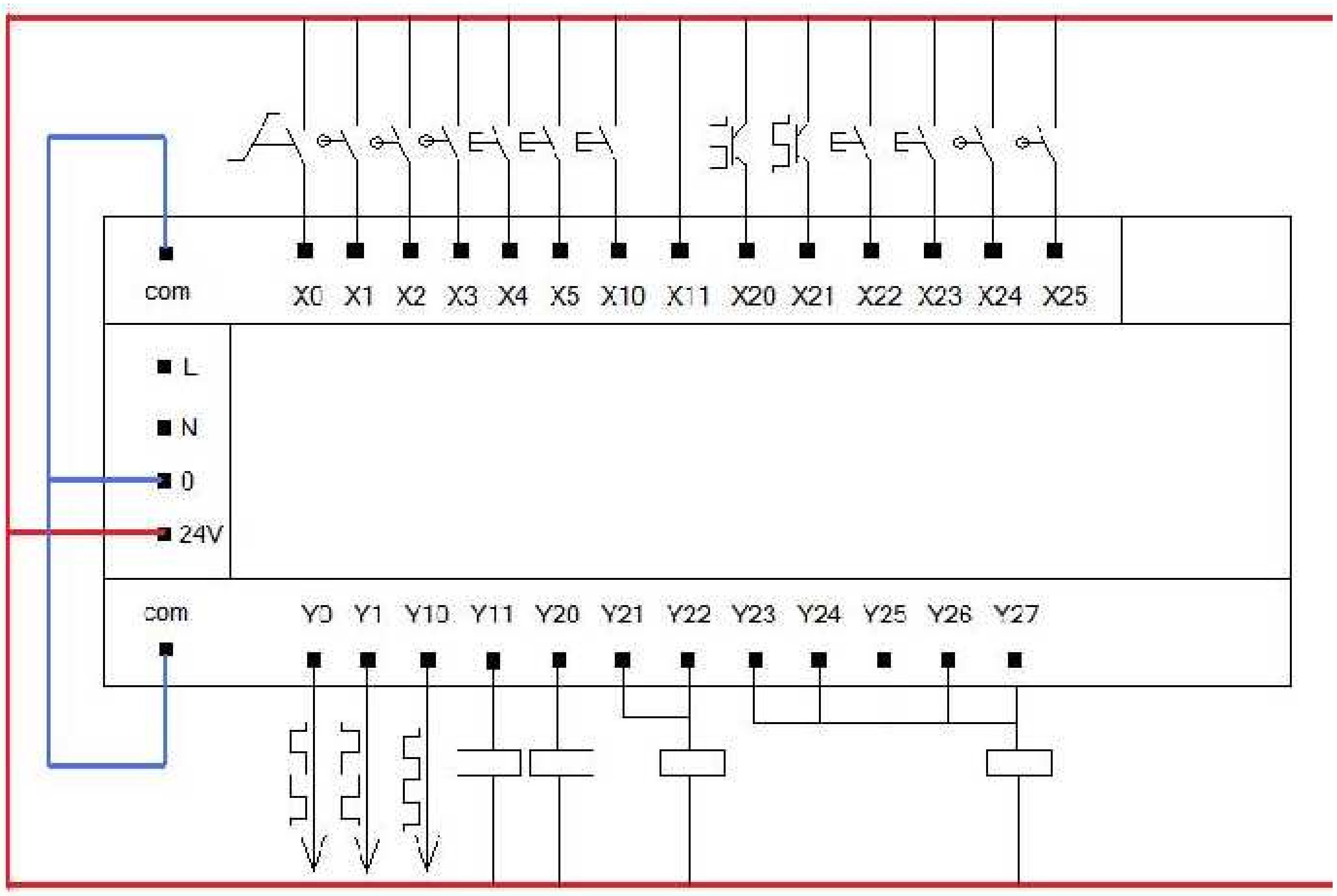
	I/O	Comment
1	X0	Foot Push Button
2	X1	Folding Limit Switch
3	X2	Z-axis Home Limit Switch
4	X3	Z-axis End Limit Switch
5	X4	Negative Z-axis Manual Moving Push Button
6	X5	Positive Z-axis Manual Moving Push Button
7	X10	Emergency Push Button
8	X11	Homing
9	X20	Encoder +A Signal
10	X21	Encoder +B Signal
11	X22	Y-axis UP Manual Moving Push Button
12	X23	Y-axis DOWN Manual Moving Push Button
13	X24	Y-axis UP Limit Switch
14	X25	Y-axis DOWN Limit Switch
15	Y0	Positive Servo Drive Pulses
16	Y1	Negative Servo Drive Pulses
17	Y10	Servo ON
18	Y20	Press Brake Machine Folding Motor Relay
19	Y21	Folding Enable Solenoid Relay
20	Y22	Y-axis UP Relay
21	Y23	Y-axis UP Relay
22	Y24	Y-axis Reverse Direction
23	Y25	Y-axis Reverse Direction
24	Y26	Y-axis Reverse Direction
25	Y27	Y-axis Reverse Direction



0 X4 X3 PLSY K5000 K30000 Y1
9 X5 X2 PLSY K5000 K30000 Y0
18 X10 Y10
20 X0 SET M0
24 X0 CNT C0 D425
31 = D100 K0 = D180 K0 = K1 C0 RST M0
= D170 K0 = D106 K0 = K2 C0
= D175 K0 = D150 K0 = K3 C0
= D103 K0 = D130 K0 = K4 C0
= D160 K0 = D109 K0 = K5 C0
113 = C0 D425 TMR T1 K5
122 T1 M0 RST C0
127 > D0 K0 = K1 C0 M1
138 > D447 K0 = K1 C0 M2
149 > D416 K0 = K2 C0 M3
160 > D443 K0 = K2 C0 M4
171 > D430 K0 = K3 C0 M5
182 > D460 K0 = K3 C0 M6
193 > D418 K0 = K4 C0 M7
204 > D423 K0 = K4 C0 M8
215 > D465 K0 = K5 C0 M9
226 > D434 K0 = K5 C0 M10
237 M1 X2 M0 DPLSY K5000 D100 Y0
253 M2 X3 M0 DPLSY K5000 D180 Y1
269 M3 X2 M0 DPLSY K5000 D170 Y0
285 M4 X3 M0 DPLSY K5000 D106 Y1
301 M5 X2 M0 DPLSY K5000 D175 Y0
317 M6 X3 M0 DPLSY K5000 D150 Y1
333 M7 X2 M0 DPLSY K5000 D103 Y0
349 M8 X3 M0 DPLSY K5000 D130 Y1
365 M9 X2 M0 DPLSY K5000 D160 Y0
381 M10 X3 M0 DPLSY K5000 D109 Y1
397 M1000 DMUL D0 K100 D100
411 M1000 DMUL D416 K100 D170
425 M1000 DMUL D430 K100 D175
439 M1000 DMUL D418 K100 D103
453 M1000 DMUL D465 K100 D160



467
M1000
DMUL D447 K100 D180
481
M1000
DMUL D443 K100 D106
495
M1000
DMUL D450 K100 D150
509
M1000
DMUL D423 K100 D130
523
M1000
DMUL D434 K100 D109
537
M1029
X4
RST M0
542
M1030
X3
RST M0
547
X1
SET M1
549
X11
M102
SET M100
552
X2
RST M100
SET M101
557
M101
TMR T0 K3
T0
SET M102
564
C200
Y35
566
X32
Y30
568
X33
M20
570
M20
TMR T3 K2
575
M20
Y31
577
T3
Y32
579
X30
CNT C10 K50
586
X20
C10
Y33
589
C10
TMR T4 K5
594
T4
RST C10
598
END



PLC CONTROL CIRCUIT

Appendix (B)

Data sheets

1. Delta AC servo motor system
2. AC Induction motor system
3. PLC
4. Ball Screws system
5. Linear bearings
6. Rectangular hollow sections

Delta AC servo motor system

DELTA ELECTRONICS, INC.

DELTA AC SERVO SYSTEM

ASDA-A Series

User Manual

www.delta.com.tw/industrialautomation

Chapter 1 Unpacking Check and Model Explanation

1.1 Unpacking Check

After receiving the AC servo drive, please check for the following:

- **Ensure that the product is what you have ordered.**

  Verify the part number indicated on the nameplate corresponds with the part number of your order (Please refer to Section 1.2 for details about the model explanation).

- **Ensure that the servo motor shaft rotates freely.**

  Rotate the motor shaft by hand; a smooth rotation will indicate a good motor. However, a servo motor with an electromagnetic brake can not be rotated manually.

- **Check for damage.**

  Inspect the unit to insure it was not damaged during shipment.

- **Check for loose screws.**

  Ensure that all necessary screws are tight and secure.

If any items are damaged or incorrect, please inform the distributor whom you purchased the product from or your local Delta sales representative.

A complete and workable AC servo system should be including the following parts:

Part I : Delta standard supplied parts

(1) Servo drive

(2) Servo motor

(3) 5 PIN Terminal Block (for L1, L2, R, S, T)

(4) 3 PIN Terminal Block (for U, V, W)

(5) 3 PIN Terminal Block (for P, D, C)

(6) One operating lever (for wire to terminal block insertion)

(7) Instruction Sheet

Part II : Optional parts, not Delta standard supplied part (Refer to Appendix A)

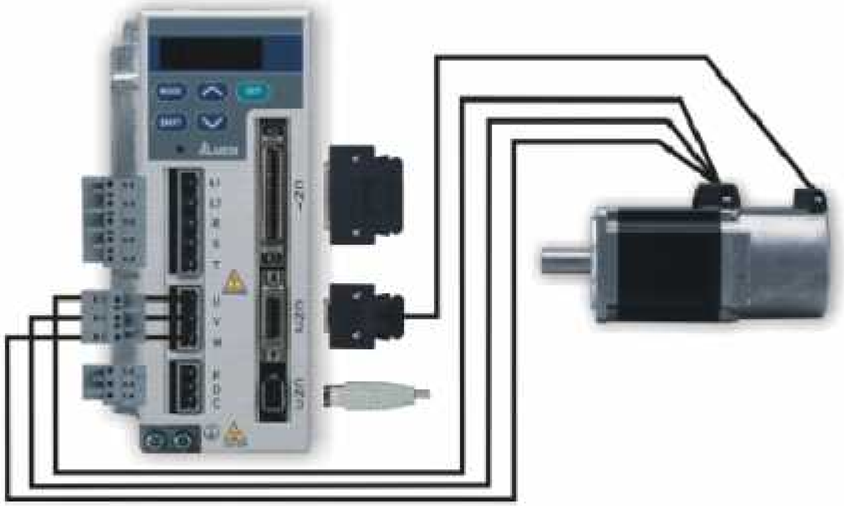
(1) One power cable, which is used to connect servo motor and U, V, W terminals of servo drive. This power cable is with one green grounding cable. Please connect the green grounding cable to the ground terminal of the servo drive.

(2) One encoder cable, which is used to connect the encoder of servo motor and CN2 terminal of servo drive.

(3) CN1 Connector: 50 PIN Connector (3M type analog product)

(4) CN2 Connector: 20 PIN Connector (3M type analog product)

(5) CN3 Connector: 6 PIN Connector (IEEE1394 analog product)



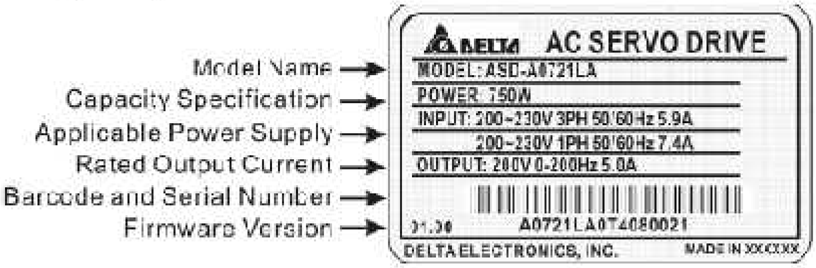
Delta AC Servo Drive and Motor

1.2 Model Explanation

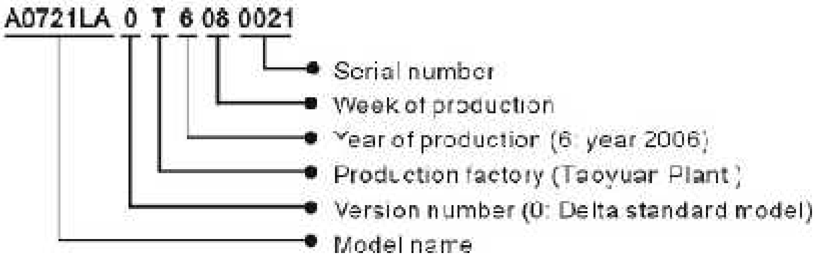
1.2.1 Nameplate Information

ASDA-A Series Servo Drive

- Nameplate Explanation

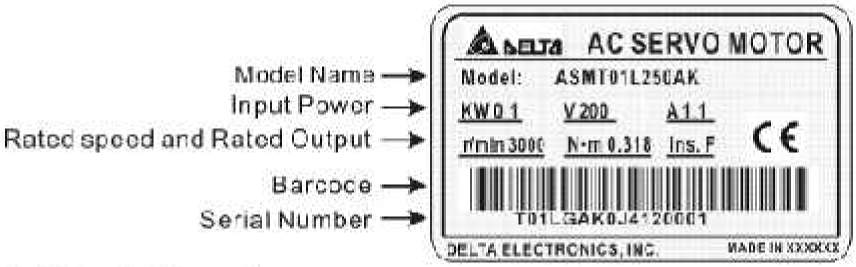


- Serial Number Explanation

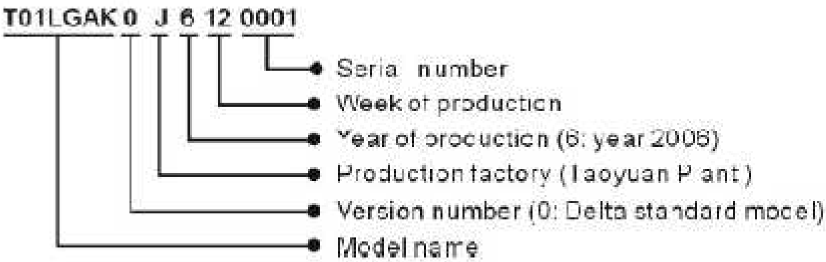


ASMT Series Servo Motor

- Nameplate Explanation

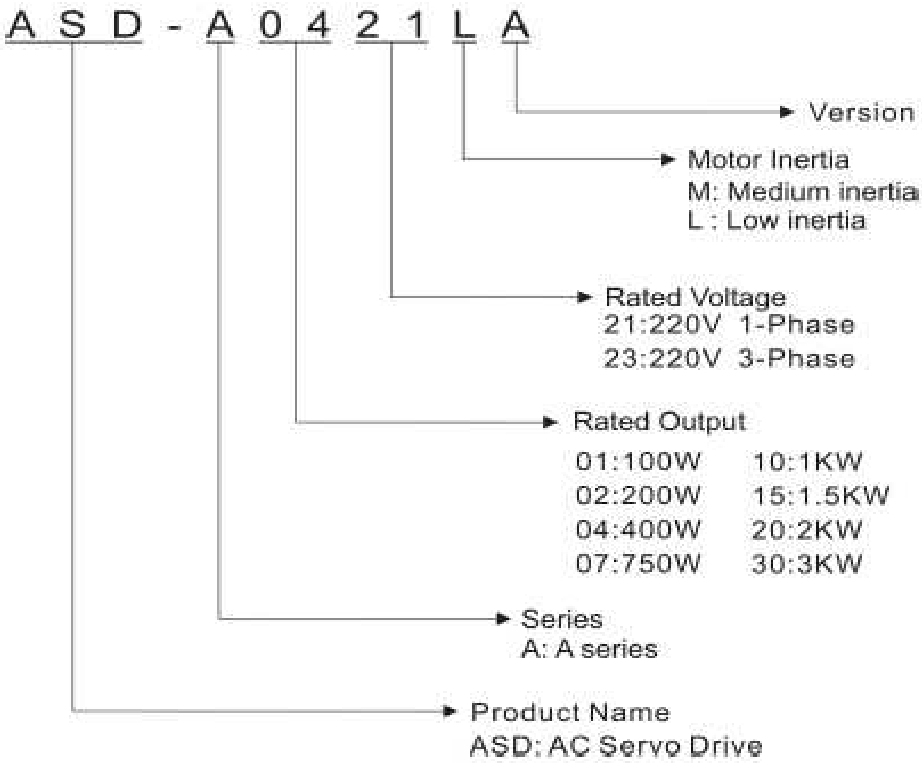


- Serial Number Explanation



1.2.2 Model Name Explanation

ASDA-A Series Servo Drive



ASMT Series Servo Motor

A S M T 0 1 L 2 5 0 A K

Symbol	Keyway	Oil seal
K	Y	N
O	N	Y
M	Y	Y

Electromagnetic brake
A: Without electromagnetic brake
B: With electromagnetic brake

Encoder Resolution
250: 2500ppr

Motor Inertia
M: Medium inertia
L : Low inertia

Rated Output Power

01:100W	10:1KW
02:200W	15:1.5KW
04:400W	20:2KW
07:750W	30:3KW

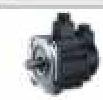
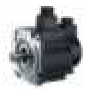
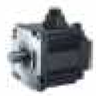
Motor Type
T: T Type

Product Name
ASM: AC Servo Motor

1.3 Servo Drive and Servo Motor Combinations

The table below shows the possible combination of Delta ASDA-A series servo drives and ASMT series servo motors. The boxes (□) in the model names are for optional configurations. (Please refer to Section 1.2 for model explanation)

		Servo drive		Servo motor	
Low inertia	100W	ASD-A0121L□		ASMT01L250□□	
	200W	ASD-A0221L□		ASMT02L250□□	
	400W	ASD-A0421L□		ASMT04L250□□	
	750W	ASD-A0721L□		ASMT07L250□□	
	1000W	ASD-A1021L□		ASMT10L250□□	
	2000W	ASD-A2023L□		ASMT20L250□□	
	3000W	ASD-A3023L□		ASMT30L250□□	

		Servo drive		Servo motor	
Medium inertia	1000W	ASD-A1021M□		ASMT10M250□□	
	1500W	ASD-A1521M□		ASMT15M250□□	
	2000W	ASD-A2023M□		ASMT20M250□□	
	3000W	ASD-A3023M□		ASMT30M250□□	

The drives shown in the above table are designed for use in combination with the specific servo motors. Check the specifications of the drives and motors you want to use.

1.4 Servo Drive Features

Heatsink
Used to secure servo drive and for heat dissipation

Charge LED
A lit LED indicates that either power is connected to the servo drive OR a residual charge is present in the drive's internal power components.
DO NOT TOUCH ANY ELECTRICAL CONNECTIONS WHILE THIS LED IS LIT. (Please refer to the Safety Precautions on page i).

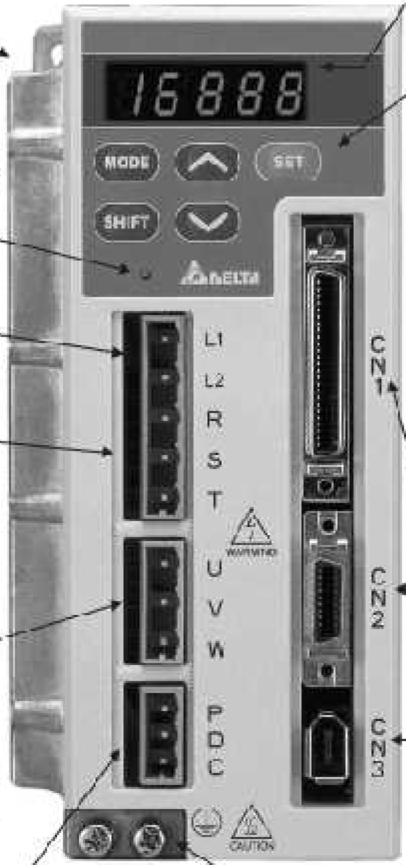
Control Circuit Terminal (L1, L2)
Used to connect 200~230Vac, 50/60Hz single-phase VAC supply.

Main Circuit Terminal (R, S, T)
Used to connect 200~230V, 50/60Hz commercial power supply

Servo Motor Output (U, V, W)
Used to connect servo motor. Never connect the output terminal to main circuit power. The AC servo drive may be destroyed beyond repair if incorrect cables are connected to the output terminals.

Internal / External Regenerative Resistor Terminal

1) When using an external regenerative resistor, connect P and C to the regenerative resistor and ensure that the circuit between P and D is open.
2) When using the internal regenerative resistor, ensure that the circuit between P and D is closed and the circuit between P and C is open.



LED Display
The 5 digit, 7 segment LED displays the servo status or fault codes

Operation Panel
Used function keys to perform status display, monitor and diagnostic, function and parameter setting.

Function Keys:
MODE : Press this key to select/change mode
SHIFT : Shift Key has several functions: moving the cursor and indexing through the parameter groups. Press this key to shift cursor to the left
UP : Press this key to increase values on the display
DOWN : Press this key to decrease values on the display
SET : Press this key to store data

I/O Interface
Used to connect Host Controller (PLC) or control I/O signal

Encoder Interface
Used to connect Encoder of Servo Motor

Serial Communication Interface
For RS-485 / 232 / 422 serial communication
Used to connect personal computer or other controllers

Ground Terminal

1.5 Control Modes of Servo Drive

The Delta Servo can be programmed to provide six single and five dual modes of operation.

Their operation and description is listed in the following table.

Mode		Code	Description
Single Mode	External Position Control	Pt	Position control for the servo motor is achieved via an external pulse command.
	Internal Position Control	Pr	Position control for the servo motor is achieved via by 8 commands stored within the servo controller. Execution of the 8 positions is via Digital Input (DI) signals.
	Speed Control	S	Speed control for the servo motor can be achieved via parameters set within the controller or from an external analog -10 ~ +10 Vdc command. Control of the internal speed parameters is via the Digital Inputs (DI). (A maximum of three speeds can be stored internally).
	Internal Speed Control	Sz	Speed control for the servo motor is only achieved via parameters set within the controller. Control of the internal speed parameters is via the Digital Inputs (DI). (A maximum of three speeds can be stored internally).
	Torque Control	T	Torque control for the servo motor can be achieved via parameters set within the controller or from an external analog -10 ~ +10 Vdc command. Control of the internal torque parameters is via the Digital Inputs (DI). (A maximum of three torque levels can be stored internally).
	Internal Torque Control	Tz	Torque control for the servo motor is only achieved via parameters set within the controller. Control of the internal torque parameters is via the Digital Inputs (DI). (A maximum of three torque levels can be stored internally).
Dual Mode		Pt-S	Either Pt or S control mode can be selected via the Digital Inputs (DI)
		Pt-T	Either Pt or T control mode can be selected via the Digital Inputs (DI)
		Pr-S	Either Pr or S control mode can be selected via the Digital Inputs (DI)
		Pr-T	Either Pr or T control mode can be selected via the Digital Inputs (DI)
		S-T	Either S or T control mode can be selected via the Digital Inputs (DI)

The above control modes can be accessed and changed via by parameter P1-01. If the control mode is changed, switch the drive off and on after the new control mode has been entered. The new control mode will only be valid after drive off/on action. Please see safety precautions on page iii (switching drive off/on multiple times).

Chapter 3 Configuration and Wiring

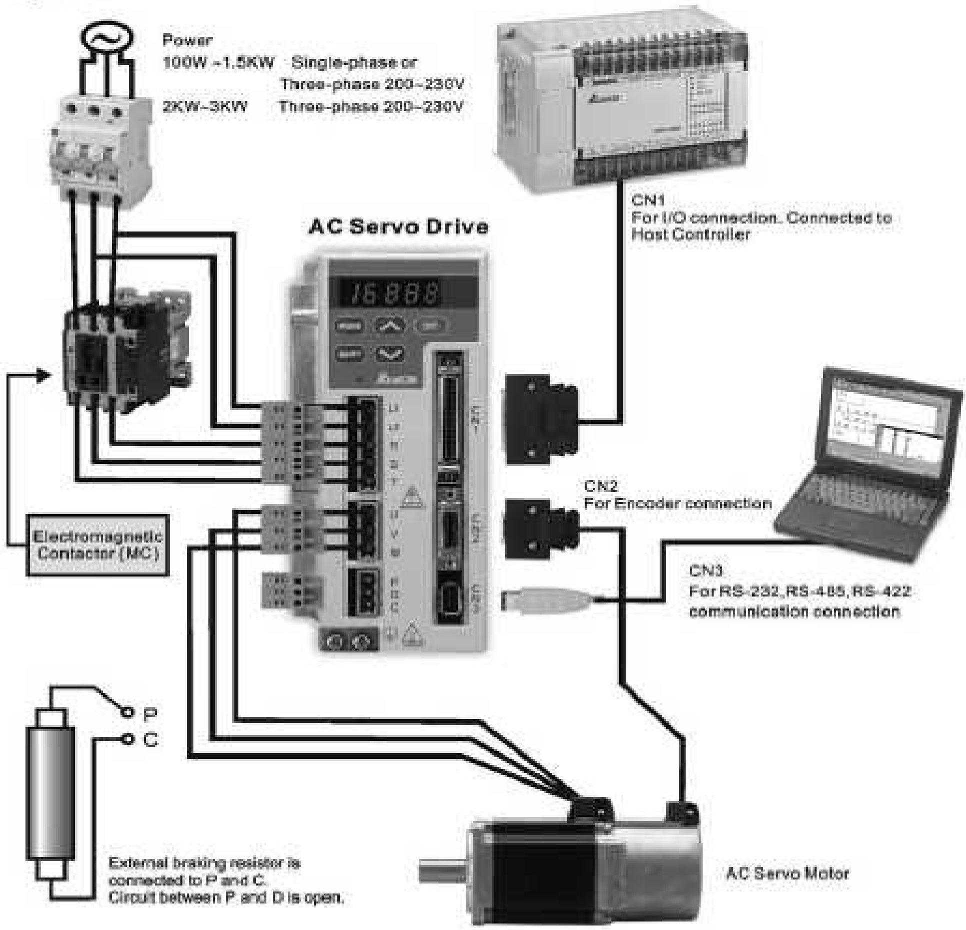
This chapter provides information on wiring ASDA-A series products, the descriptions of I/O signals and gives typical examples of wiring diagrams.

3.1 Configuration

3.1.1 Connecting to Peripheral Devices

In Figure 3.1, it briefly explains how to connect each peripheral device.

Figure 3.1



"When using an external regenerative resistor, ensure P and D is closed, and P and C is open. When using an internal regenerative resistor, connect regenerative resistor to P and C, and ensure an open circuit between P and D."

3.1.2 Servo Drive Connectors and Terminals

<table>
<tr><th>Terminal Identification</th><th>Terminal Description</th><th colspan="3">Notes</th></tr>
<tr><td>**L1, L2**</td><td>Control circuit terminal</td><td colspan="3">The servo Control Circuit requires an independent 220V single-phase VAC supply.</td></tr>
<tr><td>**R, S, T**</td><td>Main circuit terminal</td><td colspan="3">The Main Circuit Terminal is used to supply the servo with line power. If a single-phase supply, is used connect the R and S terminals to power. If 3-phase, connect all three R, S, & T terminals. To provide Control Circuit power two jumpers can be added from R and S to L1 and L2.</td></tr>
<tr><td rowspan="6">**U, V, W**
FG</td><td rowspan="6">Servo motor output</td><td colspan="3">Used to connect servo motor</td></tr>
<tr><td>Terminal Symbol</td><td>Wire Color</td><td></td></tr>
<tr><td>U</td><td>Red</td><td></td></tr>
<tr><td>V</td><td>White</td><td></td></tr>
<tr><td>W</td><td>Black</td><td></td></tr>
<tr><td>FG</td><td>Green</td><td></td></tr>
<tr><td rowspan="2">**P, D, C**</td><td rowspan="2">Regenerative resistor terminal</td><td>Internal resistor</td><td colspan="2">Ensure the circuit is closed between P and D, and the circuit is open between P and C.</td></tr>
<tr><td>External resistor</td><td colspan="2">Connect regenerative resistor to P and C, and ensure an open circuit between P and D.</td></tr>
<tr><td>⏚ **two places**</td><td>Ground terminal</td><td colspan="3">Used to connect grounding wire of power supply and servo motor.</td></tr>
<tr><td>**CN1**</td><td>I/O connector</td><td colspan="3">Used to connect external controllers. Please refer to section 3.3 for details.</td></tr>
<tr><td rowspan="10">**CN2**</td><td rowspan="10">Encoder connector</td><td colspan="3">Used to connect encoder of servo motor. Please refer to section 3.4 for details.</td></tr>
<tr><td>Terminal Symbol</td><td>Wire Color</td><td></td></tr>
<tr><td>A</td><td>Blue</td><td></td></tr>
<tr><td>/A</td><td>Blue/Black</td><td></td></tr>
<tr><td>B</td><td>Green</td><td></td></tr>
<tr><td>/B</td><td>Green/Black</td><td></td></tr>
<tr><td>Z</td><td>Yellow</td><td></td></tr>
<tr><td>/Z</td><td>Yellow/Black</td><td></td></tr>
<tr><td>+5V</td><td>Red</td><td></td></tr>
<tr><td>GND</td><td>Black</td><td></td></tr>
<tr><td>**CN3**</td><td>Communication connector</td><td colspan="3">Used to connect PC or keypad. Please refer to section 3.5 for details.</td></tr>
</table>

NOTE

1) U, V ,W , CN1, CN2, CN3 terminals provide short circuit protection.

3.2 Basic Wiring

Figure 3.4 Basic Wiring Schematic of 100W ~ 1.5kW models

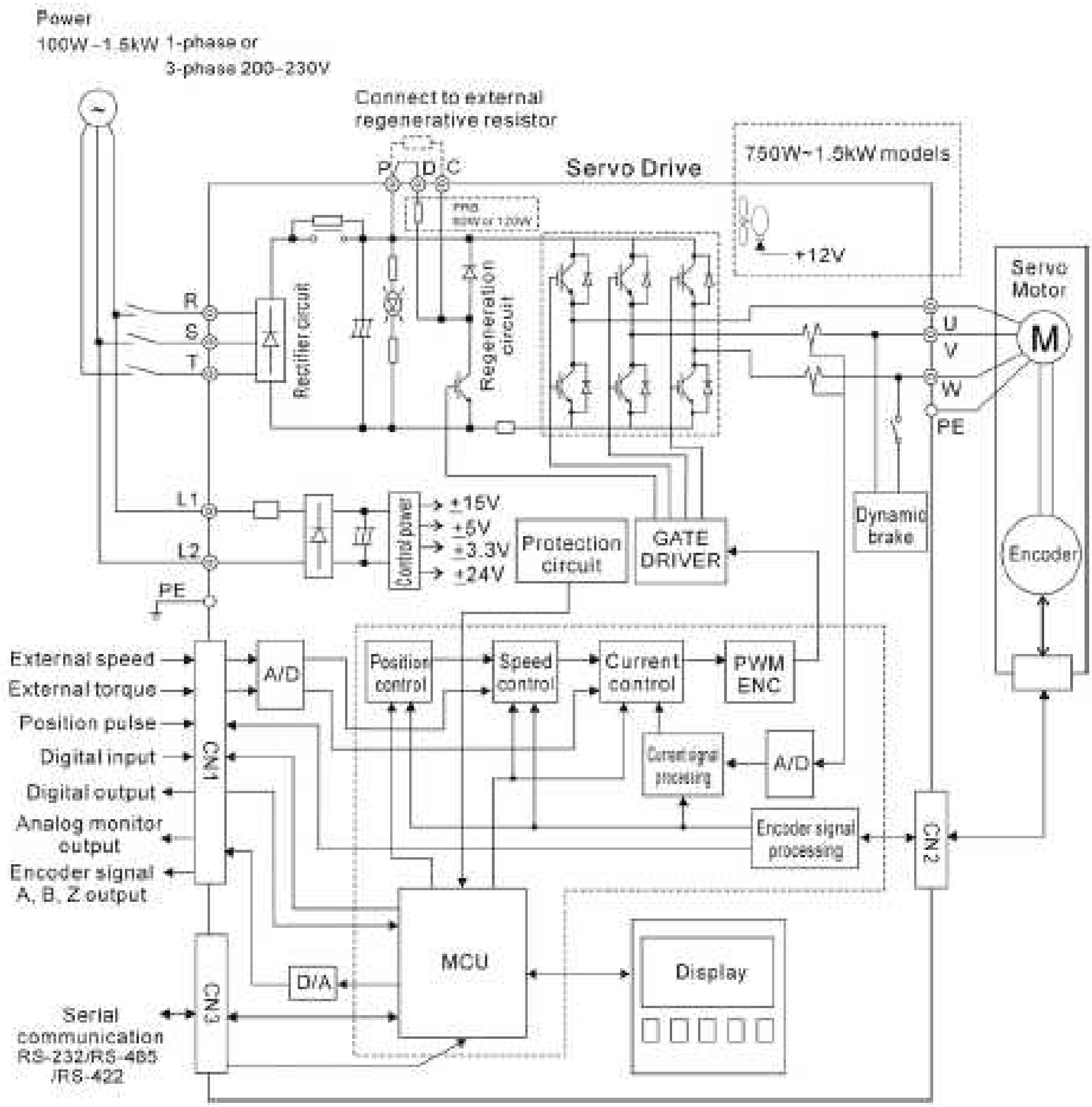
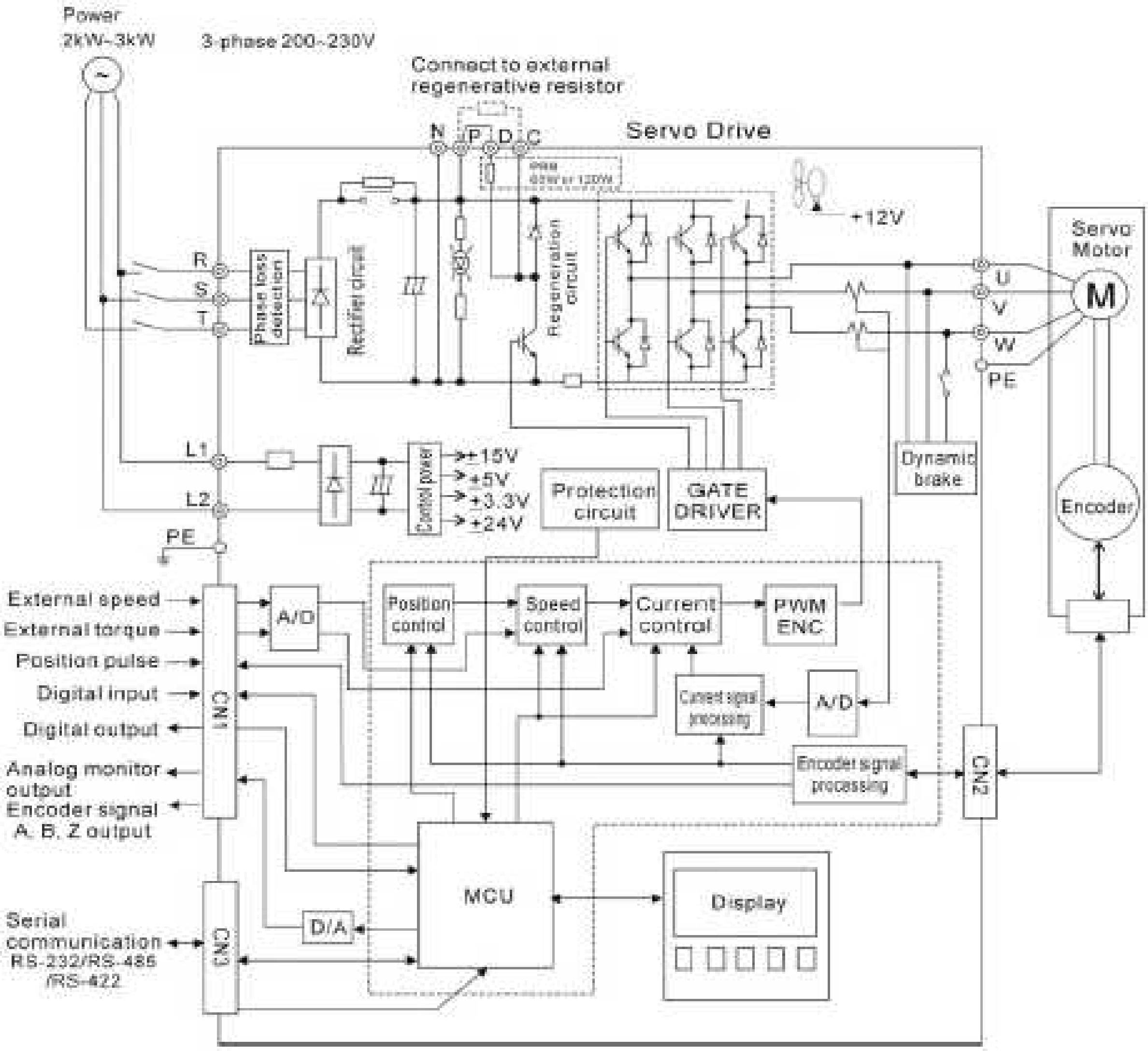


Figure 3.5 Basic Wiring Schematic of 2kW ~ 3kW models



3.3.2 Signals Explanation of Connector CN1

The Tables 3.A, 3.B, & 3.C detail the three groups of signals of the CN1 interface. Table 3.A details the general signals. Table 3.B details the Digital Output (DO) signals and Table 3.C details the Digital Input (DI) signals. The General Signals are set by the factory and can not be changed, reprogrammed or adjusted. Both the Digital Input and Digital Output signals can be programmed by the users.

Table 3.A General Signals

Signal		Pin No	Details	Wiring Diagram (Refer to 3-3-3)
Analog Signal Input	V_REF	42	Motor speed command: -10V to +10V, corresponds to the maximum speed programmed P1-55 Maximum Speed Limit (Factory default 3000 RPM).	C1
	T_REF	18	Motor torque command: -10V to +10V, corresponds to -100% to +100% rated torque command.	C1
Analog Monitor Output	MON1 MON2	16 15	The MON1 and MON2 can be assigned drive and motor parameters that can be monitored via an analogue voltage. Please reference parameter P0-03 for monitoring commands and P1-04 / P1-05 for scaling factors. Output voltage is reference to the power ground.	C2
Position Pulse Input	PULSE /PULSE SIGN /SIGN	41 43 37 36	The drive can accept two different types of pulse inputs: Open Collector and Line Driver. Three different pulse commands can be selected via parameter P1-00. Quadrature , CW + CCW pulse & Pulse / Direction.	C3/C4
	PULL HI	35	Should an Open Collector type of pulse be used this terminal must be lulled high to pin 17.	C3
Position Pulse Output	OA /OA	21 22	The motor encoder signals are available through these terminals. The encoder output pulse count can be set via parameter P1-46.	C11/C12
	OB /OB	25 23		
	OZ /OZ	50 24		
Power	VDD	17	VDD is the +24V source voltage provided by the drive. Maximum permissible current 500mA.	-
	COM+ COM-	11 45 47 49	COM+ is the common voltage rail of the Digital Input and Digital Output signals. Connect VDD to COM+ for source mode. For external applied power sink mode (+12V to +24V), the positive terminal should be connected to COM+ and the negative to COM-.	
Power	VCC	20	VCC is a +12V power rail provided by the drive. It can be used for the input on an analog speed or torque command. Maximum permissible current 100mA.	-
	GND	12,13, 19,44	The polarity of VCC is with respect to Ground (GND).	

Signal		Pin No	Details	Wiring Diagram (Refer to 3-3-3)
Other	NC	14,29, 38,39, 40,46, 48	See previous note for NC terminals CN1 connector on page 3-11.	-

The Digital Input (DI) and Digital Output (DO) have factory default settings which correspond to the various servo drive control modes. (See section 1.5). However, both the DI's and DO's can be programmed independently to meet the requirements of the users.

Detailed in Tables 3.B and 3.C are the DO and DI functions with their corresponding signal name and wiring schematic. The factory default settings of the DI and DO signals are detailed in Table 3.G and 3.H.

All of the DI's and DO's and their corresponding pin numbers are factory set and non-changeable, however, all of the assigned signals and control modes are user changeable. For Example, the factory default setting of DO5 (pins 28/27) can be assigned to DO1 (pins 7/6) and vise versa.

The following Tables 3.B and 3.C detail the functions, applicable operational modes, signal name and relevant wiring schematic of the default DI and DO signals.

Table 3.B DO Signals

DO Signal	DO Code	Assigned Control Mode	Pin No. (Default)		Details [*1]	Wiring Diagram (Refer to 3-3-3)
			+	-		
SRDY	01	ALL	7	6	SRDY is activated when the servo drive is ready to run. All fault and alarm conditions, if present, have been cleared.	C5/C6/C7/C8
SON	02	Not assigned	-	-	SON is activated when control power is applied the servo drive. The drive may or may not be ready to run as a fault / alarm condition may exist. Servo ON (SON) is "ON" with control power applied to the servo drive, there may be a fault condition or not. The servo is not ready to run. Servo ready (SRDY) is "ON" where the servo is ready to run, NO fault / alarm exists. (P2-51 should turn servo ready SRDY off / on)	
ZSPD	03	ALL	5	4	ZSPD is activated when the drive senses the motor is equal to or below the Zero Speed Range setting as defined in parameter P1-38. For Example, at factory default ZSPD will be activated when the drive detects the motor rotating at speed at or below 10 rpm. ZSPD will remain activated until the motor speed increases above 10 RPM.	

DO Signal	DO Code	Assigned Control Mode	Pin No. (Default) +	Pin No. (Default) -	Details[*1]	Wiring Diagram (Refer to 3-3-3)
TSPD	04	ALL	3	2	TSPD is activated once the drive has detected the motor has reached the Target Rotation Speed setting as defined in parameter P1-39. TSPD will remain activated until the motor speed drops below the Target Rotation Speed.	C5/C6/C7/C8
TPOS	05	Pt, Pr, Pt-S, Pt-T, Pr-S, Pr-T	1	26	1. When the drive is in Pt mode, TPOS will be activated when the position error is equal and below the setting value of P1-54. 2. When the drive is in Pr mode, TPOS will be activated when the drive detects that the position of the motor is in a -P1-54 to +P1-54 band of the target position. For Example, at factory default TPOS will activate once the motor is in -99 pulses range of the target position, then deactivate after it reaches +99 pulses range of the desired position.	
TQL	06	Not assigned	-	-	TQL is activated when the drive has detected that the motor has reached the torques limits set by either the parameters P1-12 ~ P1-14 of via an external analog voltage.	
ALRM	07	ALL	28	27	ALRM is activated when the drive has detected a fault condition. (However, when Reverse limit error, Forward limit error, Emergency stop, Serial communication error, and Undervoltage these fault occur, WARN is activated first.)	
BRKR	08	ALL	1	26	BRKR is activated actuation of motor brake.	
HOME	09	Pt, Pr	3	2	HOME is activated when the servo drive has detected that the "HOME" sensor (Digital Input 24) has been detected and the home conditions set in parameters P1-47, P1-50, and P1-51 have been satisfied.	
OLW	10	ALL	-	-	OLW is activated when the servo drive has detected that the motor has reached the output overload level set by the parameter P1-56.	
WARN	11	ALL	-	-	Servo warning output. WARN is activated when the drive has detected Reverse limit error, Forward limit error, Emergency stop, Serial communication error, and Undervoltage these fault conditions.	

Footnote *1: The "state" of the output function may be turned ON or OFF as it will be dependant on the settings of P2-18~P2-22.

NOTE

1) PINS 3 & 2 can either be TSPD or HOME dependent upon control mode selected.

2) PINS 1 & 26 are different depending on control mode either BRKR or TPOS.

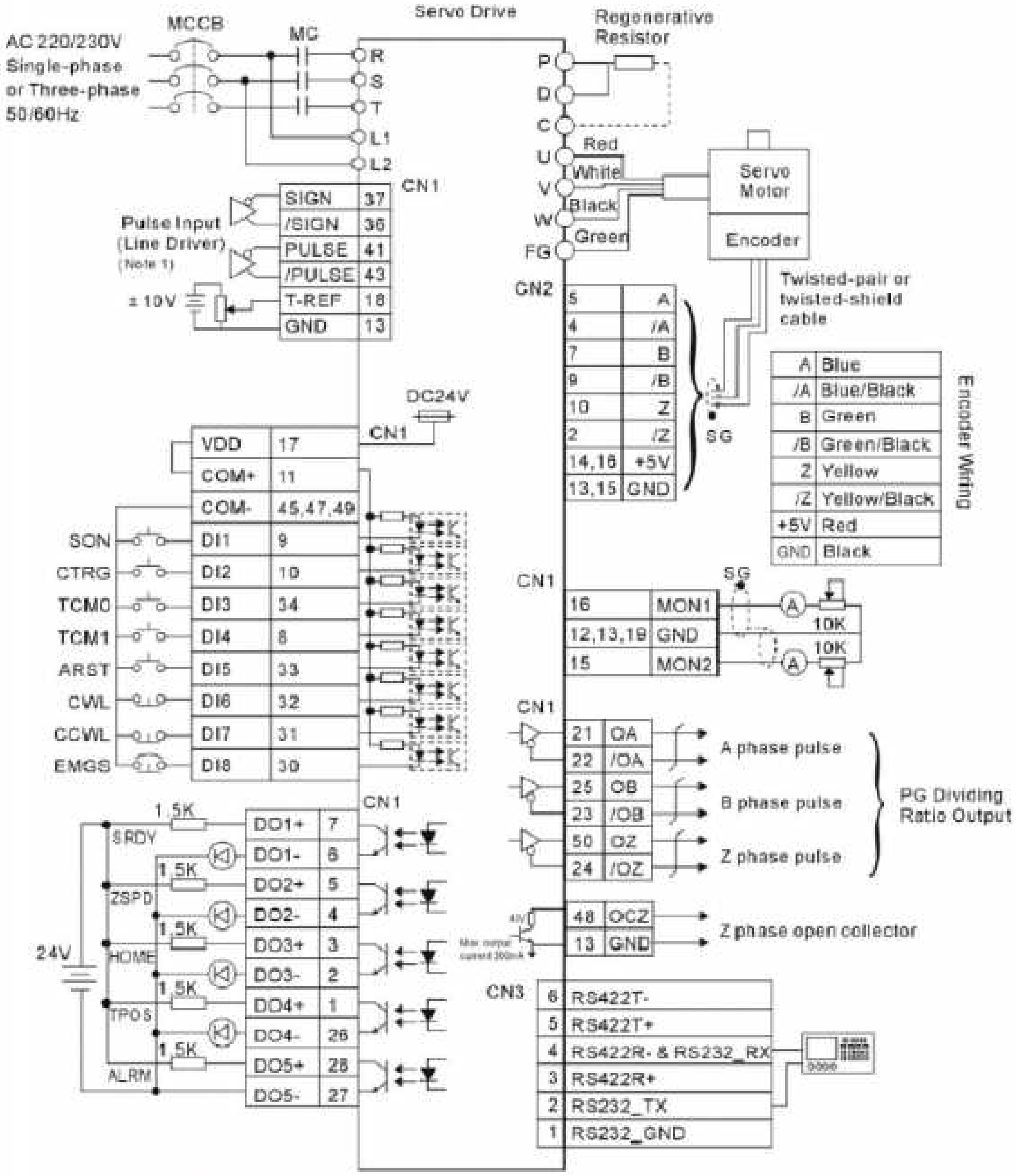
Table 3.C DI Signals

DI Signal	DI Code	Assigned Control Mode	Pin No. (Default)	Details [*2]	Wiring Diagram (Refer to 3-3-3)
SON	01	ALL	9	Servo On. Switch servo to "Servo Ready". Check parameter P2-51.	C9/C10
ARST	02	ALL	33	A number of Faults (Alarms) can be cleared by activating ARST. Please see table 10-3 for applicable faults that can be cleared with the ARST command. However, please investigate Fault or Alarm if it does not clear or the fault description warrants closer inspection of the drive system.	
GAINUP	03	ALL	-	Gain switching	
CCLR	04	Pt	10	When CCLR is activated the setting is parameter P2-50 Pulse Clear Mode is executed.	
ZCLAMP	05	ALL	-	When this signal is On and the motor speed value is lower than the setting value of P1-38, it is used to lock the motor in the instant position while ZCLAMP is On.	
CMDINV	06	Pr, T, S	-	When this signal is On, the motor is in reverse rotation.	
HOLD	07	Not assigned		Internal position control command pause	
CTRG	08	Pr, Pr-S, Pr-T	10	When the drive is in Pr mode and CTRG is activated, the drive will command the motor to move the stored position which correspond the POS 0, POS 1, POS 2 settings. Activation is triggered on the rising edge of the pulse.	
TRQLM	09	S, Sz	10	ON indicates the torque limit command is valid.	
SPDLM	10	T, Tz	10	ON indicates the speed limit command is valid.	
POS0	11	Pr	34	When the Pr Control Mode is selected the 8 stored positions are programmed via a combination of the POS 0, POS 1, and POS 2 commands. See table 3.D.	
POS1	12	Pr-S, Pr-T	8		
POS2	13	-	-		
SPD0	14	S, Sz, Pt-S, Pr-S, S-T	34	Select the source of speed command: See table 3.E.	
SPD1	15		8		
TCM0	16	Pt, T, Tz, Pt-T, Pr-T, S-T	34	Select the source of torque command: See table 3.F.	
TCM1	17		8		
S-P	18	Pt-S, Pr-S	31	Speed / Position mode switching OFF: Speed, ON: Position	
S-T	19	S-T	31	Speed / Torque mode switching OFF: Speed, ON: Torque	

DI Signal	DI Code	Assigned Control Mode	Pin No. (Default)	Details (*2)	Wiring Diagram (Refer to 3-3-3)
T-P	20	Pt-T, Pr-T	31	Torque / Position mode switching OFF: Torque, ON: Position	C9/C10
EMGS	21	ALL	30	It should be contact "b" and normally ON or a fault (ALE13) will display.	
CWL	22	Pt, Pr, S, T Sz, Tz	32	Reverse inhibit limit. It should be contact "b" and normally ON or a fault (ALE14) will display.	
CCWL	23	Pt, Pr, S, T Sz, Tz	31	Forward inhibit limit. It should be contact "b" and normally ON or a fault (ALE15) will display.	
ORGP	24	Not assigned	-	When ORGP is activated, the drive will command the motor to start to search the reference "Home" sensor.	
TLLM	25	Not assigned	-	Reverse operation torque limit (Torque limit function is valid only when P1-02 is enabled)	
TRLM	26	Not assigned	-	Forward operation torque limit (Torque limit function is valid only when P1-02 is enabled)	
SHOM	27	Not assigned	-	When SHOM is activated, the drive will command the motor to move to "Home".	
INDEX0	28	Not assigned	-	Feed step selection input 0 (bit 0)	
INDEX1	29	Not assigned	-	Feed step selection input 1 (bit 1)	
INDEX2	30	Not assigned	-	Feed step selection input 2 (bit 2)	
INDEX3	31	Not assigned	-	Feed step selection input 3 (bit 3)	
INDEX4	32	Not assigned	-	Feed step selection input 4 (bit 4)	
MD0	33	Not assigned	-	Feed step mode input 0 (bit 0)	
MD1	34	Not assigned	-	Feed step mode input 1 (bit 1)	
MDP0	35	Not assigned	-	Manually continuous operation	
MDP1	36	Not assigned	-	Manually single step operation	
JOGU	37	Not assigned	-	Forward JOG input. When JOGU is activated, the motor will JOG in forward direction. [see P4-05]	
JOGD	38	Not assigned	-	Reverse JOG input. When JOGD is activated, the motor will JOG in reverse direction. [see P4-05]	
STEPU	39	Not assigned	-	Step up input. When STEPU is activated, the motor will run to next position.	

3.6 Standard Connection Example

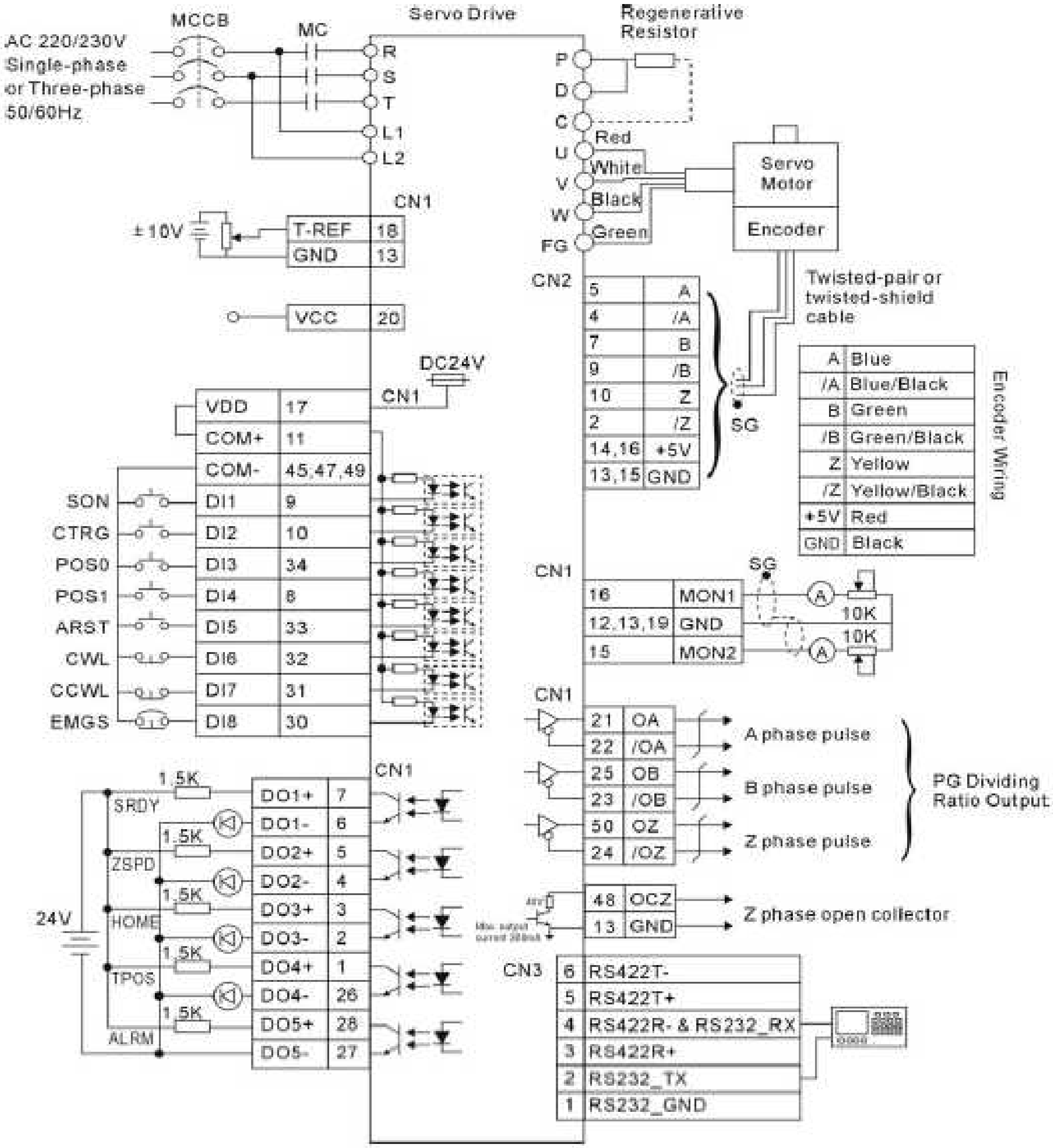
3.6.1 Position (Pt) Control Mode



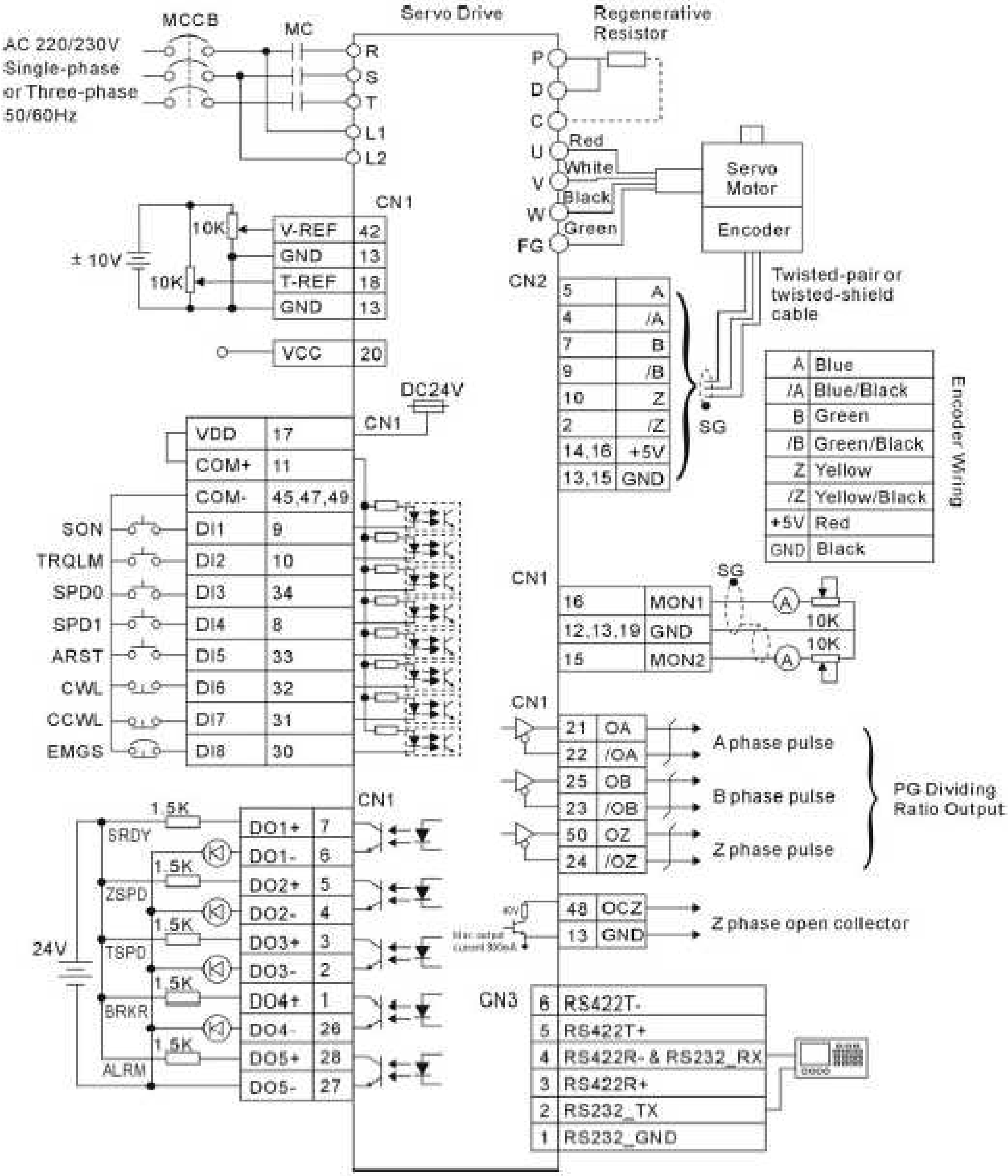
NOTE

1) Please refer to C4 wiring diagram on page 3-26. If it is open-collector input, please refer to C3 wiring diagram on page 3-26.

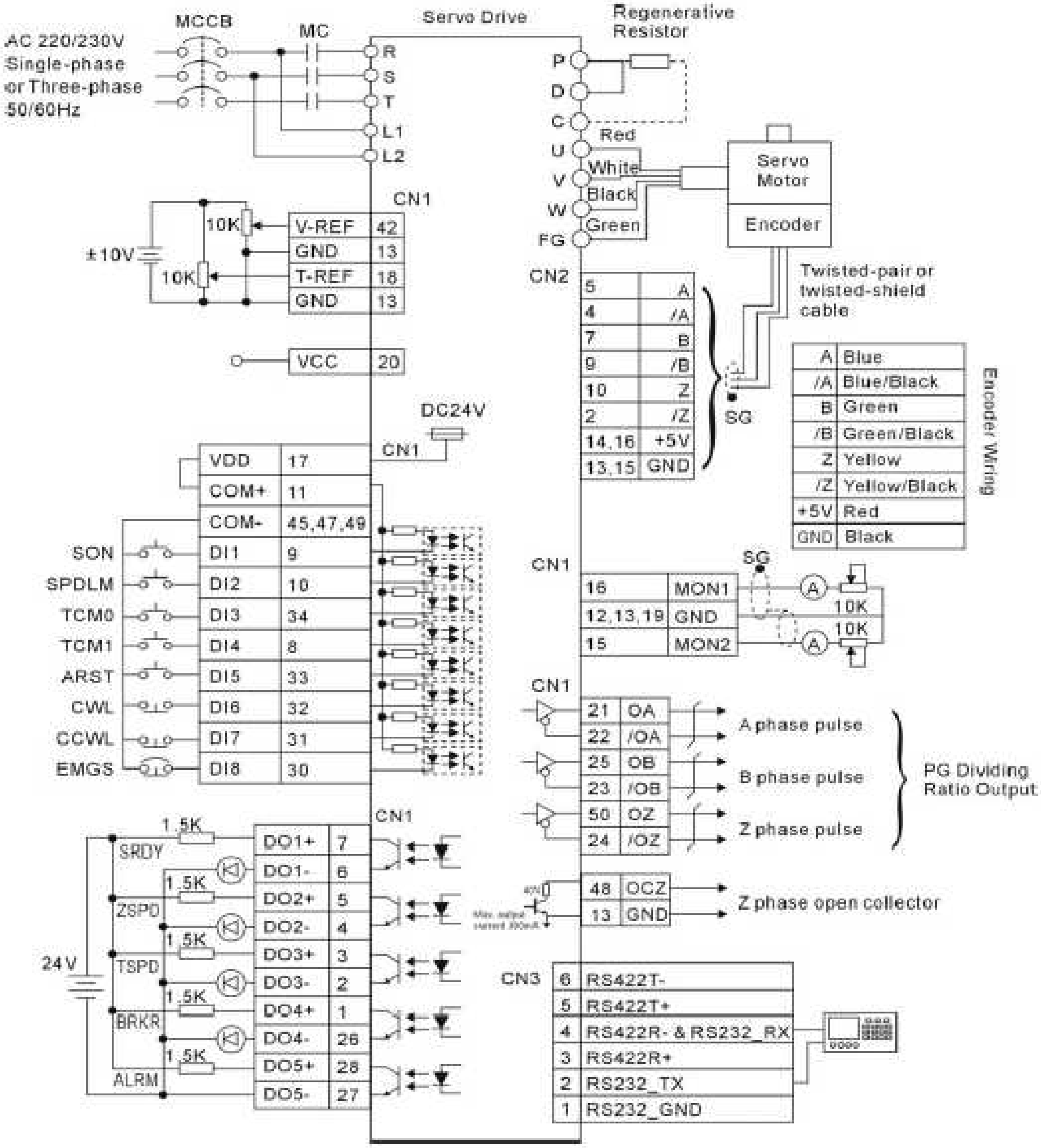
3.6.2 Position (Pr) Control Mode



3.6.3 Speed Control Mode



3.6.4 Torque Control Mode



AC Induction motor system

PLC

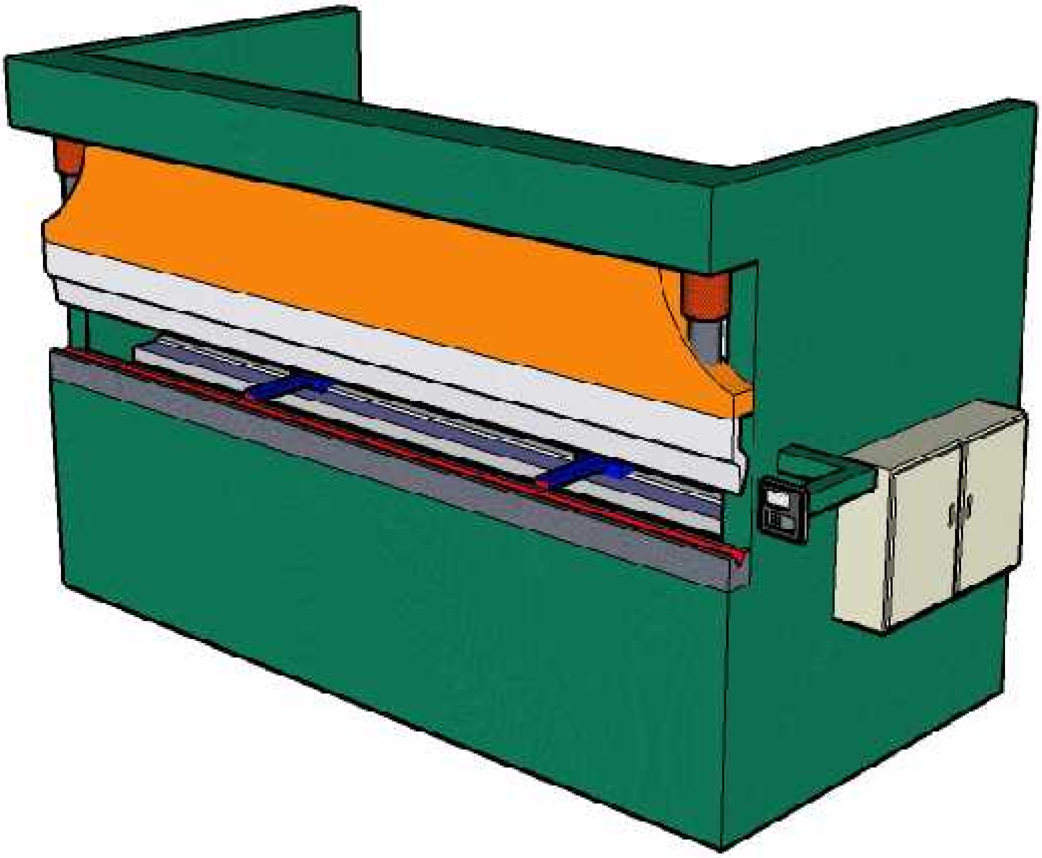
Ball Screws system

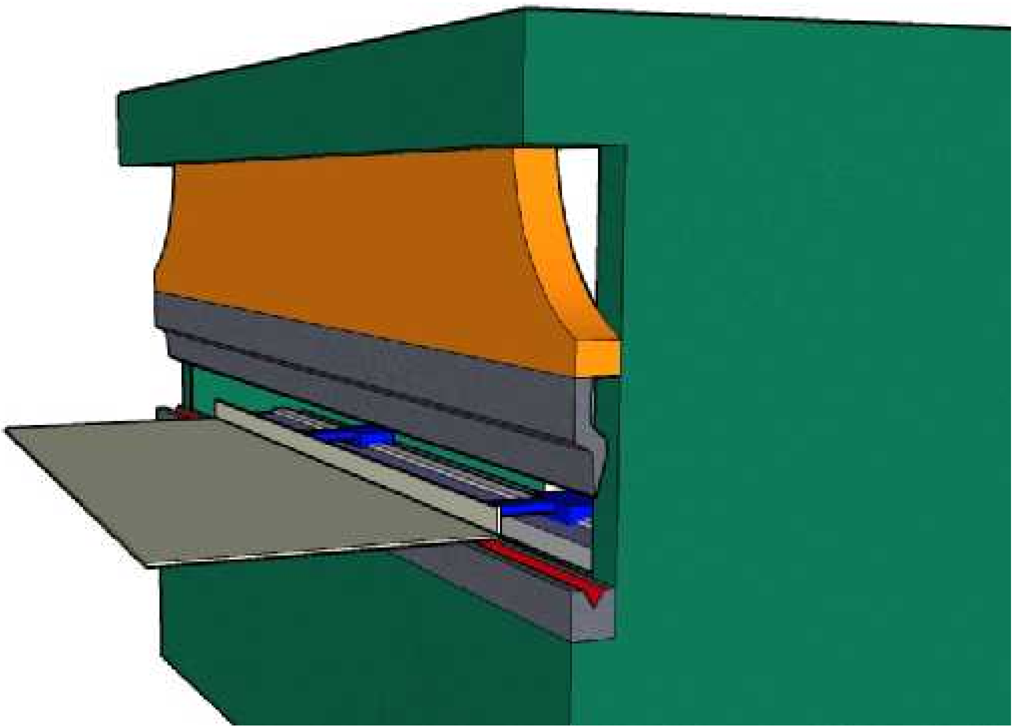
Linear bearings

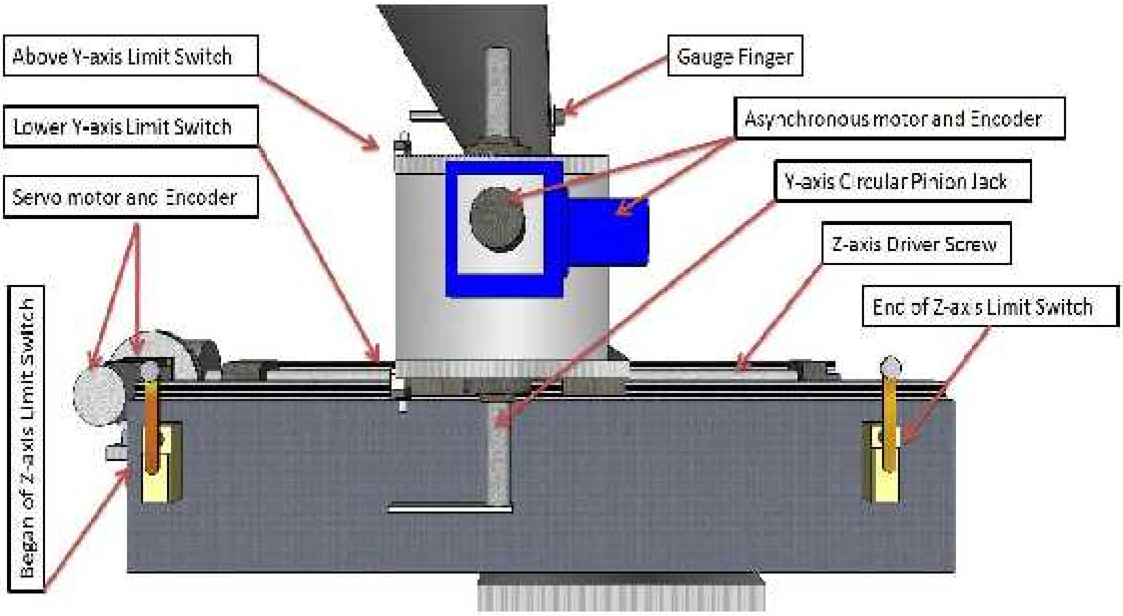
Rectangular hollow sections

Appendix (C)

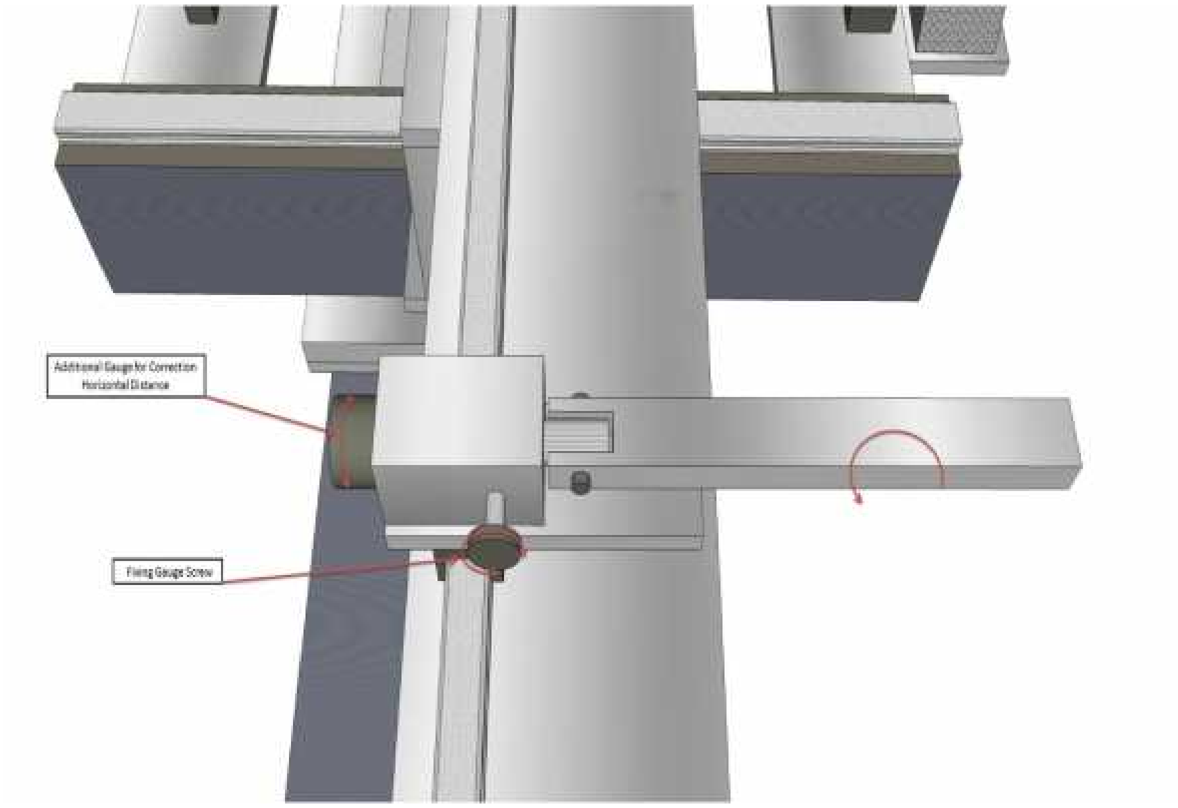
- ***Machine Pictures***







Above Y-axis Limit Switch
Gauge Finger
Lower Y-axis Limit Switch
Asynchronous motor and Encoder
Servo motor and Encoder
Y-axis Circular Pinion Jack
Z-axis Driver Screw
End of Z-axis Limit Switch
Began of Z-axis Limit Switch


Additional Gauge for Correction
Horizontal Distance
Fixing Gauge Screw