International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

# Role of servomotor in case study: Servomotor Failures to determine and control the performance of Mechanical Position or other parameter estimate the value of reduced the error and saving cost using error sensing feedback signal

**Dr. Amresh Kumar[1], Megha Vatsayan[2],**

[1]Dr.Amresh Kuma ,EEE ,Assistant Professor, R. R. S .D. College of Engineering, Begusarai, Bihar
[2]Megha Vatsayan, Control & Instrumentation, Research Scholar, B. R .A. Bihar University, Muzaffarpur, Bihar

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract –**

A servomotor (also called as servo) is an electromechanical device that uses error-sensing feedback to correct the performance of a mechanism. The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position or other parameters. For example the car's cruise control uses closed loop feedback, which classifies it as a servomechanism. Important fact is, that servomechanism may or may not use a servomotor in its design. An example of this could be a household furnace. The furnace which is controlled by thermostat is a servomechanism, however there is no motor being controlled directly by the servomechanism. In my work, I am using servomotor as an object of exploration and I will be generally concentrating on the motor devices. Usually, servos operate on the principle of negative feedback, where the control input is compared to the actual position of the mechanical system as measured by some sort of transducer at the output. Any difference between the actual and wanted values (an "error signal") is amplified and used to drive the system in the direction necessary to reduce or eliminate the error. This procedure is one widely used application of control theory. In other words servomotor is device that has an output shaft. This shaft can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. As the coded signal changes, the angular position of the shaft changes. In practice, servos are used in radio controlled airplanes to position control surfaces like the elevators and rudders, automatic machine tools, satellite-tracking antennas, automatic navigation systems on boats and planes, and antiaircraft-gun control systems. They are also used in radio controlled cars, and of course, robots. Servo mechanisms were first used in military fire-control and marine navigation equipment. Many autofocus cameras also use a servomechanism to accurately move the lens, and thus adjust the focus. A modern hard disk drive has a magnetic servo system with sub-micrometer positioning accuracy.

***Key Words*:** Servomotors, Duty cycle, CCA,TCP,PSI,

## 1. INTRODUCTION

### 1.1 Basics of Servomechanism

A servo system mainly consists of three basic components - a controlled device, an output sensor, a feedback system. This is an automatic closed loop control system. Here instead of controlling a device by applying variable input signal, the device is controlled by a feedback signal generated by comparing output signal and reference input signal. When reference input signal or command signal is applied to the system, it is compared with output reference signal of the system produced by output sensor, and a third signal produced by feedback system. This third signal acts as input signal of controlled device. This input signal to the device presents as long as there is a logical difference between reference input signal and output signal of the system. After the device achieves its desired output, there will be no longer logical difference between reference input signal and reference output signal of the system. Then, third signal produced by comparing theses above said signals will not remain enough to operate the device further and to produce further output of the system until the next reference input signal or command signal is applied to the system. Hence the primary task of a servomechanism is to maintain the output of a system at the desired value in the presence of disturbances.

### 1.2 General Principles of Operation

The servo motors used in industry today are used in a closed-loop servo system. To understand how the servomotor is used in the system, it is first necessary to review the entire system. Figure 2 indicates a block diagram of a typical servo system.

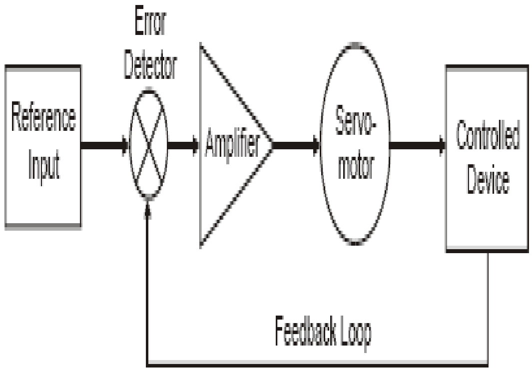


**Figure - 1 Block Diagram of Servo System**

A reference input (typically called a velocity input) is sent to the servo amplifier, which controls the speed of the servomotor. Directly mounted to the machine (or to the servomotor) is a feedback device (either an encoder or resolver). This device changes mechanical motion into electrical signals and is used as a feedback loop. This feedback loop is then sent to the error detector, which compares the actual operation with that of the reference input. If there is an error, that error is fed directly to the amplifier, which makes the necessary corrections.

In many servo systems, both velocity and position are monitored. It is important to note that in servo systems, the word "velocity" is often used to describe speed control. Velocity indicates a rate of change of position, with respect to time. It also indicates a rate of motion in a particular direction, with respect to time. The velocity loop control may take its command from the velocity loop feed

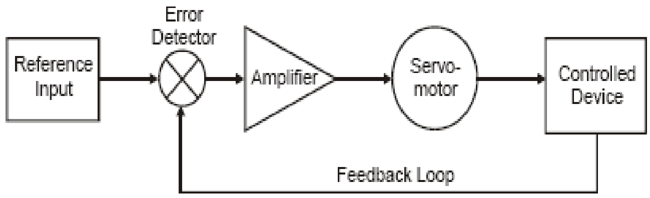


Figure- 2

back device-a resolver or tachometer mounted directly to the motor. The position loop control may take its command from the position feedback device-an encoder. Depending on the system, both devices may be mounted to the actual machine or controlled device.

The stability of the entire system is dependent upon the tuning of the components in the system and how well those components are matched. Tuning the system involves working with a PID (proportional integral derivative) control. This type of closed loop control is standard on all high accuracy systems. The main factors in this closed loop system are the gain, integration time, and derivative time of the loop.

The amplifier gain must be set satisfactorily. The gain sets how responsive the amplifier will be during changes in error signal. A high gain will cause the motor to overshoot the intended speed target. Too low of a gain may mean that the target is reached late in the cycle, or possibly not at all.

The integration time allows the amplifier to respond to changes in the error signal, mostly at zero speed. The zero speed error signal is multiplied by the gain setting, and results in increased motor responsiveness (stiffness) and accuracy.

The derivative function is the most difficult to accurately adjust. This controls the dampening or oscillations of the system. This function basically dictates the amount of correction given per unit of error. The error signal can be corrected immediately (in milliseconds), or throughout a longer period of time (seconds).

If there is a difficult part to the tuning task, it would be during the derivative setup. The gain and integration time is interactive. One setting affects the other. Proper setup of the derivative function involves multiplying the position error by the position error rate (how much correction should take place per unit of time). If the system components are not matched, oscillations, overshoot, or undershoot of velocity can result, which means unstable operation.

Servomotors are special electromechanical devices that operate in precise degrees of rotation. This type of motor quickly responds to positive or negative signals from a servo amplifier. Fast and accurate speed, torque, and direction control are the mark of a servomotor's characteristics. Very high starting torque must be obtained from the servomotor. The standard AC induction motor's torque is measured in pound-feet. By contrast, the servomotor's torque is measured in inch-pounds.In today's servo systems, three basic types of servo motors are used: AC, DC, and AC brushless. As one might expect, the AC design is based on AC induction motor characteristics. The DC design is based on the design of a DC motor. The brushless DC design is based on that of a synchronous motor. The basic principles of the DC and brushless DC servomotor have already been reviewed. Therefore, it becomes essential to review the general characteristics of the AC servomotor.

**2. Basic concept of Controlling servomotors**

**2.1. Introduction**

There are basically two types of controlling methods of servo motors: using open-loop and closed-loop system.

In an open loop, the task of the system is to send electrical signals to the actuator to perform a certain action. Although the precise signals and commands are sent, there is no way built into the system to confirm if the actuator is truly in the desired position, speed etc., However, if the system comprises electronics which constantly provides feedback on the position and velocity of the actuator, then the motor control system is a closed loop. Feedback could be the number of revolutions per minute, angle of the shaft, etc. Operational control and feedback control combined together is a complete motion control system.

An open-loop system operates with no feedback from the object being controlled. This is sort of a “fire and forget” approach to control. An input stimulus is provided and the 9 controller commands the system to go to a particular location, speed, and hopes that the system responds accordingly. There is no information from the system under control to indicate that it even received the command.

The key to a closed-loop control system is the introduction of feedback. If speed is being controlled, a measure of the current speed is provided back to the controller, allowing it to adjust its commands as the system responds to the commands. Likewise is true with position. We can compare it to gymnast on a balance beam. They are constantly commanding their muscles to adjust the pressure and position of their feet to maintain a set position. This is done based on inputs from vision, sense of balance, and even tactile feedback from contact with the beam itself. This is a perfect example of a closed-loop system.

The performance of a closed-loop system is partially a function of the speed at which the feedback is returned to the controller. This closing of the loop will always take a set amount of time, and the longer that time is the less responsive the controller will be to fast changing conditions. For example, if the gymnasts are very tired they are not able to perform as adeptly due to slow response to the feedback received and as conditions change more rapidly they are more likely to fall off the bar.

The graphical representation shows the difference between open and closed loop.

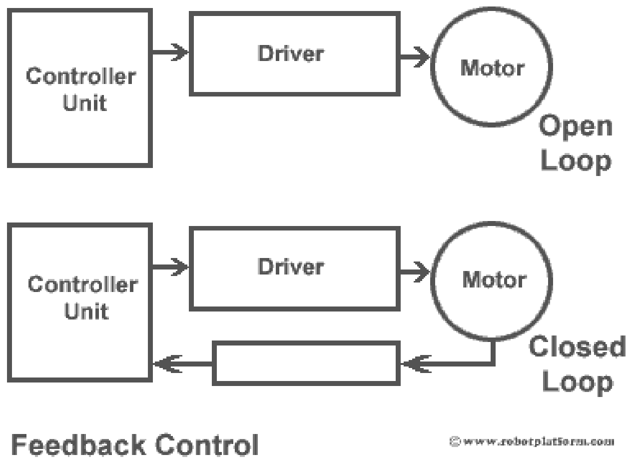


**Figure - 3 Block Diagram of Open-closed Loop System**

As shown in the image, both the systems contain a controller unit and a driver. However a closed loop has an additional feedback control which provides information on rotor position (shaft), velocity etc. Feedback control is mostly important in DC motors as it does not have any built-in control circuitry. However, the same feedback control can be implemented in other rotary actuators too.

There are different types of feedback controllers available. I will try to comprehend the most generally used feedback devices.

**Shaft encoders / rotary encoders**

These devices are most commonly used in DC motors. An encoder disk made of glass or plastic containing opaque and transparent areas is attached to the motor shaft. A light source (generally infrared light) passes through these transparent areas to read the disc pattern. This output is processed further in a controller unit which determines the speed, distance, revolutions and position.

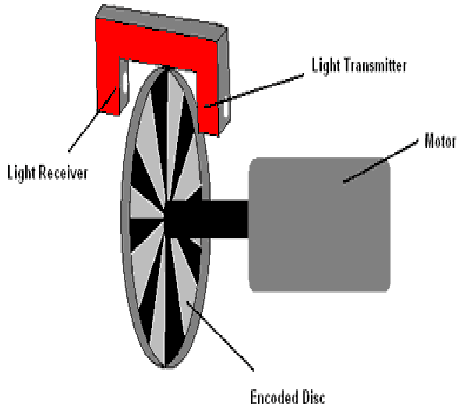


**Figure – 4 Shaft encoders**

Rotary encoders come in different shapes and sizes. However, the working principle is almost the same and these devices can be used for precise information on speed, distance, revolutions and position.

Resolvers, proximity probes, pots are also widely used for measuring speed and distance. However, they are rarely used in robotics.

**. 2.2. Control Aspects of Servo Motor**

An open-loop system has no feedback from the system being controlled. This is sort of shoot and forget approach to control. An input signal or value is provided and the controller commands the system to go to a definite speed, whatever, and hopes that the system responds accordingly. There is no information from the system under control to show that it even got the command or acted upon it. In a closed-loop control system there is feedback. If speed is being controlled, a small amount of the current speed is provided back to the controller, allowing it to adjust its commands as the system responds to the commands. Likewise true with position. The performance of a closed-loop system is partially a function of the speed at which the feedback is returned to the controller. This closing of the loop will always take a set amount of time, and the longer that time is the less responsive the controller will be to fast changing conditions.

Depending on the performance requirements of the application, either a closed-loop or open-loop control system can be used to control motor position, speed, or other similar application (Servo Motor Control).

Servos are controlled by sending them a pulse of variable width. The parameters for this pulse are that it has a minimum width, a maximum width, and a repetition rate. These values are not standard but there are conventions that are generally accepted. The convention is that a pulse of approximately 1500 µs (1.5 ms) is the neutral point for the servo. Given the rotation constraints of the servo, neutral is defined to be the position where the servo has exactly the same amount of potential rotation in the counter clockwise direction as it does in the clockwise direction. It is important to note that different R/C servos will have different constraints on their rotation but they all have a neutral position, and that position is always around 1500 µs..

### 2.3. Servo Motor Control

Controlling a servo involves sending a modulated square-wave pulse which is known as pulse-Width-Modulation (PWM) or Pulse-Duration-Modulation (PDM). If signal voltage from peak to peak (amplitude) is taken care as per the datasheet (which is generally 3V to 5V), then there two other main factors to be considered while sending a PWM signal to servo; “Frequency” and “Duty cycle”.

**Frequency**

Servo expects continuous pulses to move or hold its position. Frequency (or repetition time, or cycle time) is the number of times a positive pulse is fed to servo in a unit time (which is generally measured in seconds); for analog servos, frequency is generally 50 times a second (50Hz) and for digital servos it is 300 times a second (300Hz).

50Hz = Positive pulse 50 times a second; i.e. 1/50 = 0.02 seconds = 20ms (timeout period). This means every 20 milliseconds servo expects a pulse to retain its corresponding angular position.

300Hz = Positive pulse 300 times a second; i.e. 1/300 = 0.0033 seconds = 3.33ms (timeout period). This means every ~3 milliseconds servo expects a pulse to retain its corresponding angular position.

If servo does not receive a pulse before the timeout period, then servo releases its hold and can move to any forced position.

Required pulse frequency for few servos may be less, or more depending on the particular model and manufacturer.

**Duty Cycle**

“Duty cycle” is the width of positive pulse (square wave) and a deciding factor for servo’s angular position. For example, if you have a servo with 180° turn, then 90° is the center position of the servo with 0° being minimum, and 180°, being the maximum. Now, if a positive pulse of 1.5ms is sent, then the servo stays at 90° (servo center) as long as it receives the same pulse. If another pulse of 1ms is sent, the circuit tries to move the shaft to 0°, and a pulse of 2ms tries to move the output shaft to 180°. This means, a pulse shorter than 1.5ms moves the servo in one direction and wider than 1.5ms moves it in another direction. Duty cycle is shown in fig 11.

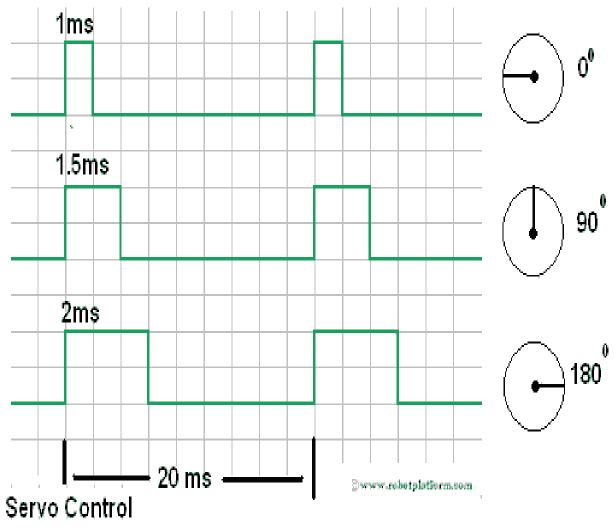


**Figure – 5 Duty Cycle**

Different servo models have different minimum and maximum pulse requirements. For example, a Hextronik servo has a minimum pulse requirement of 0.5ms to move to 0° and maximum pulse duration of 2.5ms to move to 180°. Sending a pulse of 1ms moves it to 45° and 2ms moves it to 135°. Another servo requires 1ms pulse to move to 0°, 1.5ms to move to 45° and 2ms to move to 90° and maximum angular rotation being 90°. The de-facto standard is 1ms for minimal angle, 1.5ms for servo center and 2ms for maximum angle. Servo center is almost always 1.5ms and minimum and maximum should be verified in product's datasheet.

For understanding servo motor control, let us consider an example of servomotor that we have given a signal to rotate by an angle of 45° and then stop and wait for further instruction.

The shaft of the DC motor is coupled with another shaft called output shaft, with help of gear assembly. This gear assembly is used to step down the high rpm of the motor's shaft to low rpm at output shaft of the servo system.

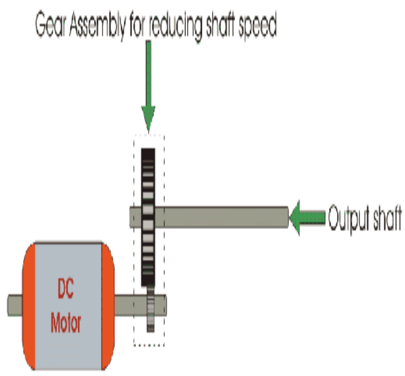


**Figure – 6(a) Servo Motor Control**

The voltage adjusting knob of a potentiometer is so arranged with the output shaft by means of another gear assembly, that during rotation of the shaft, the knob also rotates and creates a varying electrical potential according to the principle of potentiometer. This signal i.e. electrical potential is increased with angular movement of potentiometer knob along with the system shaft from 0° to 45°. This electrical potential or voltage is taken to the error detector feedback amplifier along with the input reference commends i.e. input signal voltage.

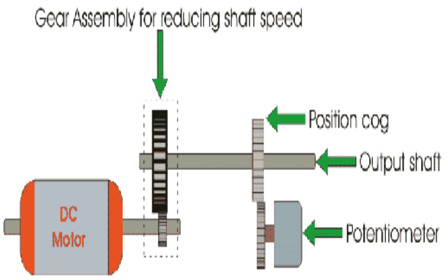


**Figure – 6(b) Servo Motor Control**

As the angle of rotation of the shaft increases from 0° to 45° the voltage from potentiometer increases. At 45° this voltage reaches to a value which is equal to the given input command voltage to the system. As at this position of the shaft, there is no difference between the signal voltage coming from the potentiometer and reference input voltage (command signal) to the system, the output voltage of the amplifier becomes zero.

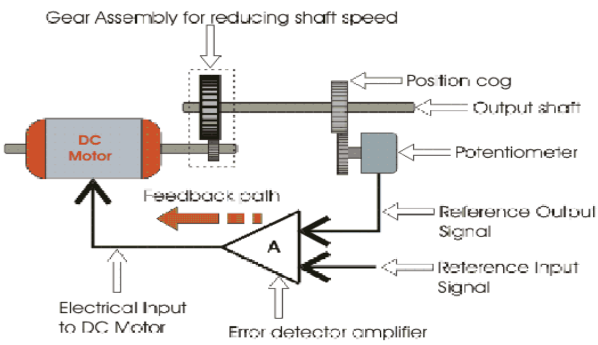


**Figure – 6(c) Servo Motor Control**

As per the picture given above the output electrical voltage signal of the amplifier, acts as input voltage of the DC motor. Hence the motor will stop rotating after the shaft rotates by 45°. The motor will be at this rest position until another command is given to the system for further movement of the shaft in desired direction. From this example we can understand the most basic servo motor theory and how servo motor control is achieved. Although in practical servo motor control system, instead of using simple potentiometer we use digital or analog position sensor encoder.

From this basic working principle of servo motor it can be concluded. The shaft of the servo is connected to a potentiometer. The circuitry inside the servo, to which the potentiometer is connected, knows the position of the servo. The current position will be compared with the desired position continuously with the help of an Error Detection Amplifier. If a mismatch is found, then an error signal is provided at the output of the error amplifier and the shaft will rotate to go the exact location required. Once the desired location is reached, it stops and waits.

**Servo motor controlling by using Serial Port**

The main intention of this project is to control servo motor by using a personal computer. It needs a single control line from the microcontroller and serial input line, from the personal computer serial port to send commands to the circuit. The timing source is provided by the crystal oscillator. Designed servo motor circuit interfaced to the computer with help of the serial cable and level shifter then open 'Hyper Terminal' software in the PC as to select the comport of the computer.

**Figure – 7 Servo motor controlling by using Serial Port**

Once the commands are sent from the personal computer (PC) to the microcontroller through the hyper terminal with a level shifter, the microcontroller obtains this data and compares them with the predefined data and generates corresponding signals to activate the motor driver to drive it at the desired speed. Many microcontroller projects developed based on servo motor such as balancing robots, runway helicopters and so on. We can use servo motor for security purpose by interfacing with wireless camera as we can possible to control camera 360 digress.

**Self-Balancing Robot**

The self-balancing robot is capable of balancing itself with the help of the servo motors. This robot has assembled using with structural, mechanical and electronic components that produces visibly unbalanced platform that is highly disposed to tipping in one alignment. The wheels of the robot are capable of independent rotation in two ways, which driven by a servo motor. Information about the angle of the device relative to the ground will be obtained from tilt sensors on the device. Self-balancing robot is shown in fig 14.

**Figure – 8 Self-Balancing Robot**

The tilt sensor may be an accelerometer, gyroscopic sensor, or IR sensor (to distance measure to the ground). The sensors sends information to the control unit, which will process the feedback using a basic proportional, integral, derivative (PID) algorithm to generate compensating position control signals to the servo motors in order to balance the device.

**2.4. Parameters Characterizing Servo motors**

In general, the servos are "active" devices. Thus this means that, when commanded to move they will actively hold their position. In other words, if a servo is commenced to the neutral position and then an external force is used to push against the servomechanism (supposedly through the mechanical linkage), it would result in actively resist being moved out of that position.

The maximum amount of force that the mechanism can utilize is the torque rating of the servomotor. The typical value of this quantity is about the equivalent of 1kg at 1 inch away from the shaft of the servo motor. Like in every similar case, the servo motors can't hold their position forever. The generation of position pulse must be repeated after a specific amount of time, in order to instruct the mechanism to stay in the desired position. The maximum value of this time, which can pass before the device will stop holding its position, is called the command repetition rate. Typical values for the command repetition rate are chosen from the range of 20 to 30 ms. Of course the pulse can be repeated more often (in shorter time ranges) than these boundaries, but it can't be generated less often. When the settled timeout expires and there still hasn't appeared another pulse, then servomechanism de-energizes the motor. In this state it can be manually pushed out of its position and later it will not return to the commanded position, as it normally should.

Other case is when the pulse sent to the device is less than 1500 µs. The servo positions and then holds its output shaft for some number of degrees anti-clockwise from the neutral point. Secondly, when generated pulse is wider than 1500 µs, then the opposite effect takes place. As a result of above facts, we can say that the minimal width and the maximum width of pulse that will command the servomotor to turn into the desired valid position are functions of each servo. On the world market, there are of course different brands, and even different servomechanism of the same specific brand, which are specified with different maximums and minimums. But generally, the typical ranges were set so that minimum pulse will be about 1000 µs wide and the maximum pulse will be 2000 µs wide. However, these are just guidelines and every case of usage should be individually established on the servos of ones use. Especially if there is a need to command the servomotor over its maximum or minimum rotation, it could occur in use of the maximum amount of current, resulting in unsuccessful attempts to achieve that position.

Another parameter which describes and varies different servo mechanisms is called the slew rate. This attribute is a time which takes the device from changing from one position to another. The worst case of the slewing time value is when the servo is holding at the minimum rotation and then it is being commanded to change to a maximum rotation. Such operation can take several seconds when performed on very high torque servo motors (to compare, the typical time of this action takes less than two seconds).

Sticking friction of the actuator is another very important parameter which describes and differs w.r.t. each servomotor device. When the actuator is at rest, there is need of using an extra force in order to initiate motion of the mechanism.

After a while, when the actuator begins to move, there is also an unwanted possibility that it may suddenly perform a slight jump (which depends on how tight the mechanical tolerances of the actuator are). In each case while we are determining response times required for the control systems, this rapid rate of change should be considered, to avoid problems of usage.

The last property which I am describing is the ratio of output movement to feedback data acquisition. This attribute also highly affects the accuracy and response of the control system. For example, I have considered a basic actuator, where the motor and output shaft has been joined by a series of gears and the potentiometer (used as a feedback mechanism) is connected to another gear in the system. So the ratio of movement parameter of the output shaft to the movement of the potentiometer shaft is required to relate rate of change of the actuator output to the rate of change of the feedback.

### 2.5. Controlling a Servo Motor with Angle rotations

Servo motor working principle mainly depends upon duty cycles. It uses Pulse Width Modulated (PWM) waves as control signals. The angle of rotation is resolute by the pulse width of the control pin. Here the servo motor used for angle of rotation from 0 to 180 degrees. We can control the precise angular position by varying the pulse among 1ms to 2ms.

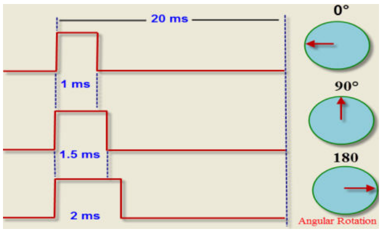


**Figure - 9 Controlling a Servo Motor with Angle rotations**

**Servo motor programming with angular rotations**

```
#include<reg51.h>
sbit servomotor_pin=P0^5;
void delay (unsigned int);
void servo_delay  (unsigned int);
void main()
{
servomotor_pin=0x00;
do
{
// turn to 0°
servomotor_pin=0x01;
servo_delay(50);
servomotor_pin=0x00;
delay(1000);
//turn to 90 degrees
servomotor_pin=0x01;
servo_delay(82);
servomotor_pin=0x00;
delay(1000);
//turn to 180 degrees
servomotor_pin=0x01;
servo_delay(110);
servomotor_pin=0x00;
delay(1000);
while(1);
}
}
void delay(unsigned int a)
{
unsigned int p;
for(p=0;p<a;p++)
for(p=0;p<250;p++);}voidservo_delay(unsignedinta){unsign}
```

**3. SELECTION OF A SERVO MOTOR**

**3.1. How to select a servo to fit our application**

A servomotor is an electric drive with a feedback mechanism. The feedback loop allows the motor input current to be adjusted automatically to properly position the servo shaft when the sensors tell the controller that it's time to move the shaft or that the motor is not performing as it should.

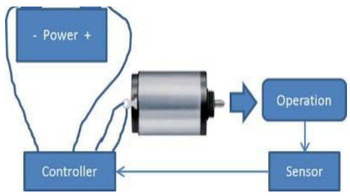


**Figure – 10 Mechanism & Selection of Servo Motor**

For example, if I am driving a car up a hill. As a driver, I am the Controller. The speedometer is the sensor and the motor is (of course) the motor. I adjusted the power to the motor based on the feedback received from the sensor, pushing harder on the gas pedal to maintain the speed up the hill.

Servo motors are available as either AC or DC. The main things that have to be considered when making a servomotor from any electric drive are

- They must be able to operate at a wide range of speeds without overheating

- They have to be able to hold torque on a load at zero speed
- They have to be able to operate at low speeds for a long time

Servo motors are generally considered to have the following advantages:

- Wide range of speeds
- Hold torque at zero speed
- Operate at low speeds for long time

While servo motors can deliver excellent performance and high speed in a small size, the additional controls in the feedback mechanism make them cost more than stepper motors. Another challenge I faced in selecting a servomotor is tuning the motor to ensure that it is performing optimally for the application.

In selection of servomotor, following points need to be considered:

- What shaft speed we'll need. Manufacturers identify their shaft speeds as the no-load speed at the rated terminal voltage.
- The terminal voltage
- The continuous current we have available, which is the maximum rated current that can be supplied to the motor without overheating
- The continuous torque we will need in constant running conditions
- The continuous output power, which is the mechanical power the application requires.
- It is also essential to consider our physical space in terms of shape, diameter and housing length

Even if I carefully specify any motor, the tuning stage may take a while. We may have to purchase a few samples in different sizes and test them before placing a larger order.

There are various types of servo motors. Some of the most common types and their applications include:

- Permanent magnet and shunt wound motors which provide constant speed with varying load, so they are a good fit for machine tools, fans and blowers.
- Series wound motors provide high starting torque, so they are good for constant loads such as in heavy industrial applications.
- Compound wound motors provide a heavy starting torque and are typically used where adjustable speed is not required, such as in elevators and hoists.

That's a high-level outline on selecting a servomotor for any particular application.

Selection approach on choosing proper servo motor type which brought the most benefit to any application;

- The first selection approach is to choose a servo motor large enough for the machine that has already been in the designing phase.
- The second step is to select the best available servomotor with a specific feature and then build the system around it.
- Later step is to study the servo performance and our system requirements - and then meet the two

requirements.

- The last and final step is servomotor system design which finally meets our performance specifications reliably.

Selecting different servomotor requirements may include such parameters as: control of acceleration, speed, and position to very close tolerances. This means that when we are designing a servo, we must define the whole system carefully, establish the servo motor's performance specifications, determine critical areas, and set up tolerances. This would be the only moment when we will be able to propose an adequate servo system and choose a servo motor type for it. Selecting the motor for initial installation or for a replacement, we must consider parameters like: rated power rated speed, rotor inertia and for maintenance purposes even the motor weight and size. Another approach to select a suitable servo to fit our needs would start with the consideration if whether the motor will be used for continuous duty or intermittent duty (we need to select device that can produce proper amount of continuous stall torque). The second rating which should be thoroughly considered is the amount of peak torque. Finally the maximum continuous AC input power and the rotor inertia would be the later properties which we should take under consideration.

### 3.2. Formulas for a Servo Motor

- **Formulas for Operating Patterns**

  Determine the relationship between time and speed for each item that is being controlled, then convert the operating pattern for these items into a servo motor shaft operating pattern.

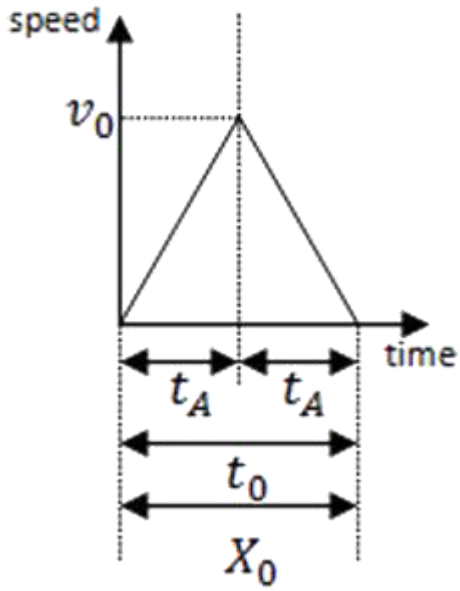


**Figure – 11 Formulas for Operating Patterns**

- **Triangular Operating Pattern**

  Maximum Speed: $v_0 = \underline{X_0}/t_A$

  Acceleration/Deceleration Time: $t_A = \underline{X_0}/v_0$

  Travel Distance: $X_0 = v_0 * t_A$

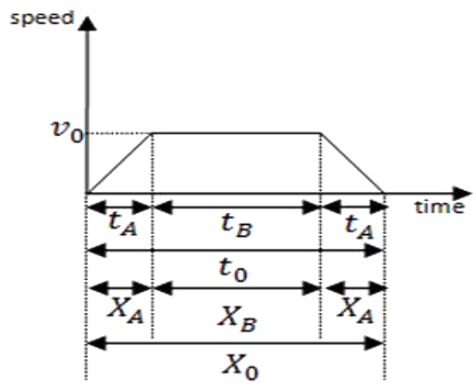


**Figure – 12 Triangular Operating Patterns**

- **Trapezoid Operating Pattern**

Maximum Speed: $v_0 = X_0/(t_0-t_A)$

Acceleration/Deceleration Time: $t_A = t_0 - X_0/v_0$

Total Travel Time: $t_0 = t_A + X_0/v_0$

Constant-Velocity travel time: $t_B = t_0 - 2 * t_A$

Total Travel Distance: $X_0 = v_0 (t_0 - t_A)$

Acceleration/Deceleration Travel Distance

$X_A =( V_0 * t_A)/2$

Constant-Velocity travel time: $X_B = v_0 - t_B$

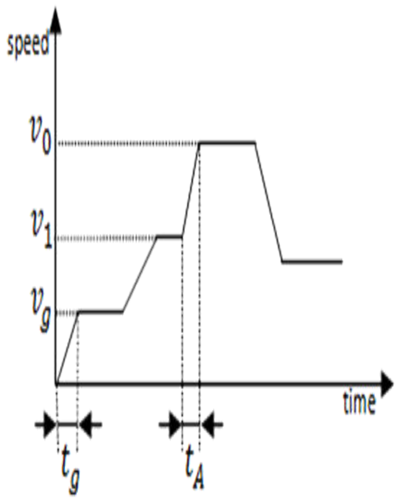


**Figure – 13 Trapezoid Operating Patterns**

- **Speed and Slope When Ascending Operating Pattern**

Ascending Time: $t_A = (v_0-v_1)/\alpha$

Ascending Time (tA) including distance moved:

$X_A = ½ \alpha*t_A^2 + v_1 * t_A$

Speed after ascending: $v_0 = v_1+\alpha*t_A$

Speed Gradient: $\alpha = v_g/t_g$

## 4. CASE STUDY: SERVO MOTOR FAILURES:

### 4.1. PSI Repair Services puts an end to excessive servo motor failures

| | |
|---|---|
| **Customer:** | Motor Manufacturer |
| **Challenge:** | The customer was experiencing a high rate of servo motor failures. |
| **Root Cause:** | PSI determined that the failures were due to inefficient design and inferior parts. |
| | |
| **Solution:** | PSI installed an enclosure to protect the motor from severe trauma and reinforced the wiring area to survive in a high stress application. |
| **Result:** | PSI reduced servo motor failures from two per month to one per year, resulting in a savings of approximately $83,000. |

**Table – 1 Servo Motor Failure**

**4.2. Case Study: Detecting Degraded Circuit Card Assembly (CCA) Components**

**PSI Repair Services detects stressed CCA components that were overlooked by a major prime contractor's in-house test system**

| | |
|---|---|
| **Challenge:** | A major prime contractor sent PSI a circuit card assembly (CCA) for repair that had already passed its own in-house test inspection. To the customer's surprise, PSI discovered 8 stressed microchips and one hard-failure microchip. If they were not replaced, MTBF would decrease and maintenance costs would increase, ultimately jeopardizing critical missions. |
| **Solution:** | PSI's state-of-the-art equipment proved that the prime contractor's in-house system test did not detect components that were degraded by stress/usage. |
| **Result:** | PSI made the repairs, which saved the contractor crucial time and money in future repairs. |

**Table – 2 Detecting Degraded Circuit Card Assembly (CCA) Components**

**8.3. Case Study: TCP Monitor Failures**

**PSI Repair Services gets to the root cause of TCP monitor failures**

| | |
|---|---|
| **Customer:** | Tire Manufacturer |
| **Challenge:** | TCP monitors were failing within six months of installation. |
| **Root Cause:** | PSI discovered that 72% of the failures were due to one button being pressed at a high rate during the production day. |
| **Solution:** | PSI ruggedized the keyboards, which eliminated the problem. |
| **Result:** | The solution from PSI saved the manufacturer an average of $70,000 per year. |

**Table – 3 TCP Monitor Failures**

### 4.4. Case Study: Premature Vacuum Pump Failure

**PSI Repair Services resolves issue of ongoing vacuum pump failures and saves customer over $800K annually**

| | |
|---|---|
| **Customer:** | Manufacturer of Machined Parts |
| **Challenge:** | Premature vacuum pump failures. |
| **Root Cause:** | The manufacturer’s maintenance staff was improperly installing the vacuum pump assemblies. Coolant lines were not connected, oil lines were missing and vacuum sealant was replaced with Teflon tape. |
| **Solution:** | PSI determined the premature failures were due to overheating, improper lubrication and vacuum leaks, so they provided the manufacturer with digital photos of the assembly, illustrating and describing the correct installation procedures for coolant and lubrication. To resolve the issue, PSI recommended a cooling system that would extend service life from two months to three years. |
| **Result:** | The PSI cooling system corrected the leaks with an epoxy solution, allowing the vacuum pumps to operate to OEM specifications. This resulted in a 90% failure reduction and a cost-savings of approximately $840,000 annually for the manufacturer. |

**Table – 4 Premature Vacuum Pump Failure**

### 4.5. Case Study: Refurbished Vacuum Pumps

**PSI Repair Services brings obsolete vacuum pumps back to like-new condition and saves customer $370k**

| | |
|---|---|
| **Challenge:** | A major prime contractor wanted to extend the life of five obsolete vacuum pumps, which had been in operation for over 30 years, but needed major reconditioning to run for the next 30 years. |
| **Solution:** | PSI disassembled the pumps and did a thorough inspection on each unit. As expected, there was significant wear and tear in each unit. As a result, **PSI did a complete remanufacture on each pump.** In some instances, PSI was able to clean and reuse original components, customize solutions for units that were missing components, as well as replace obsolete components with newer, more efficient parts, which improved upon the original design. In the end, PSI brought all five pumps back to like-new condition, at a total cost below $130,000. |
| **Result:** | The cost to retrofit these obsolete pumps would have cost in excess of $500k, so PSI saved the customer a minimum of $370,000 by remanufacturing them. |

**Table – 5 Refurbished Vacuum Pumps**

#### 4.6. Case Study: Part Design Improvement

**PSI Repair Services improves part design and saves customer $90k**

| | |
|---|---|
| **Customer:** | Transmission Manufacturer |
| **Challenge:** | The customer was experiencing a high rate of robot amplifier failures. Even after the customer sent the amplifiers to the robot OEM for repair, the parts kept failing. |
| **Root Cause:** | PSI determined that the failures were due to inefficient design and inferior parts. |
| **Solution:** | PSI upgraded the existing capacitors, IC chips, connectors and seal to prevent contamination from entering the enclosure. |
| **Result:** | Amplifier failures were reduced from 168 to 70 per year, saving the customer $90,000. |

## 5. SERVO MOTOR ENVIRONMENTAL & SAFETY ASPECTS

### 5.1. Servo Motor Environmental Considerations

The following environmental and safety considerations must be observed during all phases of operation, service, and repair of a Servo Motor system. Failure to comply with these precautions violates safety standards of design, manufacture, and intended use of the Servo Motor and drive. It is important that even well-built servo motor products operated and installed improperly can be hazardous. Precaution must be observed by the user with respect to the load and operating environment. The customer is ultimately responsible for the proper selection, installation, and operation of the Servo Motor system.

The atmosphere in which a Servo Motor is used must be conducive to good general practices of electrical/electronic equipment. It is advisable not to operate the Servo Motor in the presence of flammable gases, dust, oil, vapor, or moisture. For outdoor use, the Servo Motor and drive must be protected from the elements by an adequate cover, while still providing adequate air flow and cooling. Moisture may cause an electrical shock hazard and/or induce system breakdown. Due consideration should be given to the avoidance of liquids and vapours of any kind. It is wise to install the Servo Motor and drive in an environment which is free from dust, metal chips, condensation, electrical noise, vibration and shock.

Additionally, it is preferable to work with the Servo Motor and Drive system in a non-static protective environment. Exposed circuitry should always be properly guarded and/or enclosed to prevent unauthorized human contact with live circuitry. No work should be performed while power is applied. Do not plug in or unplug the connectors when power is ON. Wait for at least 5 minutes before doing inspection work on the Servo Motor system after turning power OFF, because even after the power is turned off, there will still be some electrical energy remaining in the capacitors of the internal circuit of the servo motor drive.

Plan the installation of the Servo Motor and drive in a system design that is free from debris, such as metal debris from cutting, drilling, tapping, and welding, or any other foreign material that could come in contact with circuitry. Failure to prevent debris from entering the Servo Motor system can result in damage and/or shock.

Meeting CE Requirements mandates a ground system; and the method of grounding the AC line filter and the servo motor drive must match. Failure to do this renders the filter ineffective and may result in damage.

**5.2. Servo Motor Wiring - Safety First**

**Extension Cord Safety**

When installing new technology, we may be dealing with extension cords to help plug our products on a test bench for prototyping. Use them on a temporary basis. Extension cords are not meant for permanent wiring.

Here are some general electrical cord safety tips when dealing with extension cords, in part, courtesy of the National Electrical Safety Foundation, which develops safety policies and procedures for electronics.

**Extension Cords:**

- Should not be used as a substitute for permanent wiring.
- Should not be used on equipment drawing more than 15 amps.
- Should not run through, behind or in walls, ceilings or floors or oth
- Should not be run through ventilation ducts, under carpets, under abrasion or damage.
- Should not be placed across walkways or doorways because they w
- Should not be spliced or taped, nor should broken cords or cords wi Automation products.
- Should not be used near flammable gases or vapors or explosive du
- Should not be overloaded.

Water and electricity don't mix. Don't leave plugged-in electronics where they might come into contact with water. If they do fall in water, never reach in and pull them out, even if they are turned off. First, turn off the power source and then unplug the unit. If you have a servo motor, drive or controller that has gotten wet, don't use it until it has been checked by our qualified repair staff.

**High-Temperature Braided Sleeving**

The life of cables, wires and hoses can be greatly extended with high-temperature braided sleeving. Braided sleeving is a protective cover for the vulnerable material of common wires. High temperatures can cause cracks, frays, or fires, especially for wires and cables that are used in industrial settings or exposed to outdoor elements. In addition to protecting the wires from high temperatures, braided sleeving can shield wires and cables from abrasions, chemicals, dirt, and even freezing temperatures.

**5.3. Electrical Safety in the Workplace**

When establishing electrical safety policy in the workplace, some important points need to be considered, in part, courtesy of the National Electrical Safety Foundation:

1. Have a good idea of what could go wrong.
2. Use the right tools for the job.
3. Always follow procedures, drawings and other product documentation.
4. Isolate equipment from energy sources.
5. Identify hazards that may be present.
6. Establish approach limitations to machinery and moving parts to minimize hazards.
7. Be sure you are properly trained for the job.
8. Work on the servo motor and drive, as well as all other Anaheim Automation products and all other electrical equipment only when de-energized.
9. Check and double-check safety regulations and product documentation
10. Treat de-energized equipment as energized until performing a lockout/tagout test (a test used to disable machinery or equipment to prevent the release of potentially hazardous energy while the machine is being serviced)

**5.4. Why So Many Electrical Safety Requirements**

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

Organizations, such as the Standard f Safety Requirements for Employee Workplaces, steps companies must take to be in federal con safety. They include:

1. A safety program with defined responsibil
2. Calculations for the degree of an arc flash
3. Electrical safety equipment for workers
4. Training for workers
5. Electrical safety tools
6. Electrical safety labels on equipment

An emphasis on safety is largely due to the fear of what an arc flash can do. An arc flash is a short circuit through the air that can happen when conductors can't support the voltage. An arc flash can be as hot as 5,000 F and creates a brilliant flash of light and loud noise. As radiant energy explodes out of the electrical equipment, hot gases and melted metal can endanger human life. This is why there are four separate industry standards or electrical safety requirements in place to protect workers against arc flashes and electrical safety equipment on the market in the form of boots, suits, gloves and more. It is the responsibility of the installer/user of servo motors and drives, and all other Anaheim Automation products, to become familiar with all safety requirements.

**Avoid Working with Live Wires**

A "live" wire is one that has electricity running through it. If one is installing or repairing anything electrical, always isolate the equipment from the power source. In addition to turning any circuit breakers off, it is always good to test any circuit or conductor before one touches it. This can be done very simply with a hand-held voltage tester. Use this multi-meter every time when one handles something that is potentially live.

**5.5. Electrical Hazards**

The following are the four main hazards involved with the installation of electrical equipment:

1. **Electric Shock**- An electric shock or burn occurs when an ele conducts through the body. If high-voltage electricity runs throu
2. **Arc Flash Burn**- An arc flash occurs when a conductive ob object. This flash can cause intense heat in the surrounding air,
3. **Arc Blast Impact**- When a metal object triggers an arc flash concussion. Also, this blast can cause lacerations from flying easily knock a worker off a high platform, such as a ladder or p

**5.6. Required Maintenance for a Servo Motor**

Servo Motors are not prone to wear over time, and therefore require little maintenance. However, periodic maintenance checks should be performed so that the servo motor keeps running like new. Upon first arrival of the servo motor one should double-check the following: the motor is the correct model, motor does not have any visible damage, shaft can be rotated by hand, the brake works correctly, and there are no loose bolts. Operators should periodically check the motor for vibration and noise while the motor is not rotating, rotating at low speeds, and accelerating and decelerating. Inspect the motor for scratches or cracks on the motor casing. If crevices or cracks are found on the motor, action should be taken immediately by repairing or replacing the damaged unit. Check the motor casing for oil or cutting fluid because this can corrode the coating – possibly leading to future failure. Use an insulation level tester to check insulation resistance between motor coil and motor frame and refer to the owner's manual to see if insulation value falls within an operable range. Observe the normal voltage waveforms on an oscilloscope periodically and take notes for future comparison purposes and report any inconsistencies to manufacturer. Check cables and wiring for cracks and frays. Replace if found worn, as this could be dangerous.

## 6. CONCLUSION, SUGGESTIONS & FURTHER SCOPE OF STUDY

### 6.1. CONCLUSION

On the basis of the findings of the present studies, the following conclusions can be arrived at:

- The servo motor is most commonly used for high technology devices in the industrial application like automation technology. It is a self-contained electrical device that rotates parts of a machine with high efficiency and great precision. The output shaft of this motor can be moved to a particular angle. Servo motors are mainly used in home electronics, toys, cars, airplanes, etc.

- Servo motors are used in applications requiring rapid variations in speed without the motor getting overheated. In Industries they are used in machine tools, packaging, factory automation, material handling, printing converting, assembly lines, and many other demanding applications robotics, CNC machinery or automated manufacturing.

- For accurately detecting the rotor position of each servomotor, it is provided with a measuring device, which detects the current position (for example, the angle of rotation covered in relation to a starting position) which determines the movement of the motor. This is measured through an encoder, for example, a resolver or an incremental encoder or an absolute encoder. The electronic control system compares the signal from this sensor to a predetermined position set point. If a difference is found, the motor is rotated in the direction that ensures to get the set point. This leads to the fact that the deviation decreases. The procedure is repeated until the current value incrementally limits or done via approximation within the tolerance limits of the set point. This is the simplest case, of position control. Alternatively, this principle can also be applied for producing torque and speed can be controlled. Thus, for example uniform motion profiles are possible with fluctuating loads. In synchronous or asynchronous mode, it is usually below the position of speed controller.

### 6.2. SUGGESTIONS

- Many things are not always what they seem. Servos are one of those. Here are some ideas for servo systems that may help improve productivity, and delay the arrival of a gray hair or two.

- Overlooking simple details during servo installation or specification may degrade performance instead of improving it. For example, a ground may not always be a ground. And a poor ground connection often leads to erratic system operation or even servo self-destruction. In addition, neglecting to consider application requirements when specifying a power supply can produce sluggish machine acceleration, reducing productivity.

- Despite an unfavorable economic climate, demand for automated machinery continues to increase. Sales are being driven by lower maintenance costs, improved efficiency, and superior control to be gained from replacing pneumatic, hydraulic, or mechanical systems with servo controlled systems.
  The shift in favor of servo systems has been accelerated by growth in the number of applications requiring faster, more flexible, and more accurate machines. For instance, in packaging the increasing development of new applications call for more servo control. The so-called "Generation 3" machines are all electric, with servo control synchronizing multi-axis movements. Servo motors and drives are also increasingly replacing high-end stepper motors and drives in industrial applications.

- Price reductions have had a beneficial effect on growth in the North American servo motors and drives market. Although falling prices mean that volume growth can be expected to exceed revenue growth, demand for servo motors and drives is price elastic. Price reductions are expected to stimulate volume growth to such an extent that revenues in the market would increase, despite prices being lower.
  The decreasing price for servo technology is also serving as an incentive for customers to replace their stepper, hydraulic, pneumatic, or mechanical technologies with servo technology as to ensure higher production & product value. However, while this does support demand growth, the impact on total revenues can be mixed, particularly if price wars occur between manufacturers as they attempt to gain volume orders.

More competitive prices should serve to drive unit demand.

- The servo drives sector is benefiting from the popularity of intelligent drives that combine drive and controller capabilities. Whilst intelligent drives are more expensive than standard servo drive products, they are able to deliver cost savings to the purchaser. Due to reduced wiring and assembly costs, intelligent drives can be priced more than 30 percent lower than separate drives and controllers. These cost savings served to stimulate demand during the downturn of 2001. Leading suppliers are increasingly focusing attention on technological developments in the drives sector, and revenues from intelligent drives can be expected to rise further in the future.

- Servo Technology improvements for motion control spur user interest and allow for greater sales. One of the other main factors is overall confidence in the technology. Manufacturers are reporting greater interest in slight design advances. The market environment has become more conducive to more advanced technology with users increasingly prepared to invest in designs that offer greater performance and reliability as well as higher efficiency. Greater customer confidence and understanding of these benefits has acted to strengthen demand. As users become increasingly convinced of the benefits to be gained from design developments, this should advance overall demand and revenues. As the customer base faces greater pressures to improve their own cost and performance levels, a move towards improved motion control solutions is inevitable. Additionally, many customers are facing greater pressures as a result of increased globalization of business, with manufacturers in North America having to focus on value-added and improved profitability as a means to maintain their own competitiveness. This has created a climate where these customers need to invest more strongly in newer and more advanced technology such as servos.

### 6.3. SCOPE FOR FURTHER STUDY

- Servo technology is considered to be on the forefront of electric motors and drives. Servo drives, alternatively known as servo amplifiers, provide the electrical energy that produces movement in a servo motor. Intermediating between the motor and controller, they take the control signals generated by the motion controller and transform them into power signals for the motor. Similar to stepper drives, servo drives are used for speed and torque control. Unlike stepper drives, however, they also offer positioning capabilities. Acting on signals sent from the feedback device attached to the motor, servo drives are able to determine the servo motor's position and to energize the motor in order to achieve both the position and speed desired by user. Servo motors are particularly suited to controlling the movement of machines.
- Servo motors are the most sophisticated motion control devices. They incorporate precise dimensional tolerance, high-force magnet materials, and advanced design methods.
- Technological developments in the servo technology market have been focused around reductions in the size and weight of products and in increasing torque. The latter has been achieved via a shift in favor of rare earth magnets. Suppliers such as GE Fanuc have introduced motors offering a high and continuous torque rating, for use in applications such as injection molding. Yaskawa Electric is focusing on the winding techniques and improvements in high-energy product magnet materials.
- As prices come under pressure, production techniques are becoming increasingly important. Just-in-time manufacturing is now widespread, and the production of servo motors is itself increasingly automated.
- While servo technology has traditionally been incorporated with feedback devices, an increasing

number of servos are also sold as complete systems, accompanied by drives and controllers. This is changing the nature of the market. Focus is increasingly placed on system integration, and individual products, particularly the motor.

**ACKNOWLEDGEMENT:**

This case study is without doubt the most critical achievement in my life and it would be unimaginable without who back me and confidence in me. I want to appreciate the guidance and support provided by my parents. I want to thanks Mr. Piyush kumar who taught me to the quality of diligent work by his case.

REFRENCE:

1. IEEE Industry Applications Magazine March/April 1996, page 74

2. http://zone.ni.com/devzone/cda/ph/p/id/234

3. http://www.pc-control.co.uk/servo_control.htm

4. http://www.baldor.com/products/servo motors

5. http://www.electricmotors.machinedesign.com

6.http://www.aida-global.com/metalforming-solutions/servopro.cfm

7.http://jyotsnaj.wordpress.com/2009/07/26/servo mechanisms-and-its-applications/

8. http://www.cadsoft.de

9. http://neil.fraser.name/hardware/stepper/