Servo Drive

About the College

Basaveshwar Engineering College was started in the year 1963 offering bachelor degrees in Civil, Mechanical and Electrical Engineering. At present it offers degree programs in ten disciplines and ten post graduate programs including MBA & MCA. The College is a Government aided institution affiliated to Visveswaraiah Technological University (VTU), Belgaum in Karnataka and approved by All India Council for Technical Education (AICTE), New Delhi. Eight departments of the college have been recognized as Research Centers by VTU. Also five departments are recognized as QIP Centers for Ph.D programs by AICTE New Delhi. The college was granted autonomous Status by VTU and UGC in the year 2007. Since then the college has introduced Academic reforms by restructuring the curriculum keeping in view the technological developments and needs of the industry. The College has been selected under TEQIP phase II for scaling up PG and demand driven Research programs. Under this program new research laboratories and facilities have been created for the benefit of PG Students and research scholars to carry out high quality research work.

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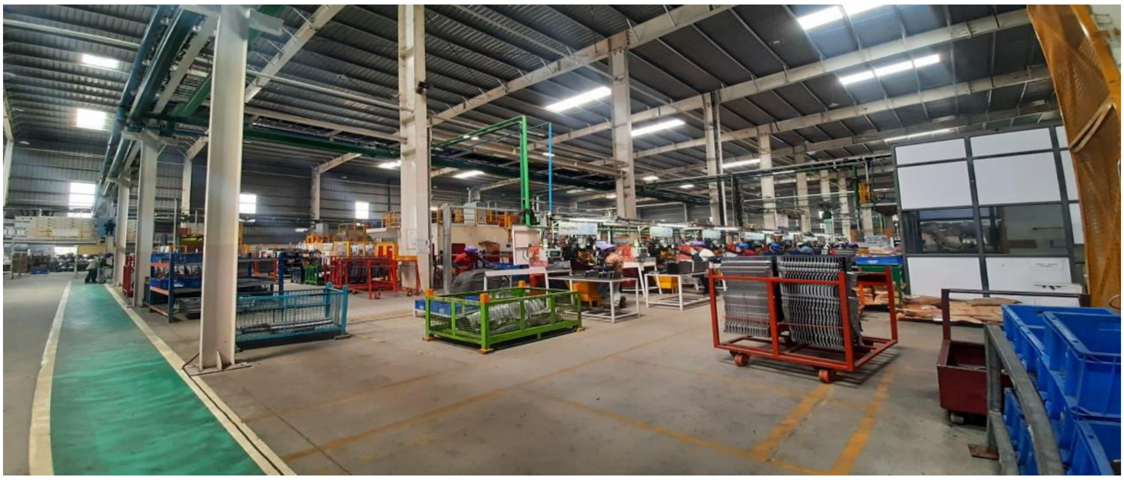
About the Company

Headquartered in Haryana, India, JBM Ogihara Automotive India Lmt. was founded by a pool of live wire professionals having several years of combined technical and corporate expertise in providing high quality, cost-effective and complete end-to-end solutions to its valued customers. All our team members are highly qualified in their respective fields and have years of industrial experience behind them.

JBM Ogihara is specialized in the manufacture of Japan machines and tools. As an Automotive company, we are known for our expertise in automated assembly lines, process automation, data acquisition and visual inspection. JBM Ogihara is one of the leading companies in manufacturing the automotive car components for reputed companies like Maruti, Toyota etc.



Contents

1. Introduction:

A servo drive is an electronic amplifier used to power electric servomechanisms. It monitors the feedback signal from the servomechanism and continually adjusts for deviation from expected behaviour.

A servo drive receives a command signal from control system, amplifies the signal and transmits electric current to a servomotor in order to produce a motion proportional to the command signal. Typically, the command signal represents a desired velocity, but can also represent a desired torque or position. A sensor attached to the servo motor reports the motors actual status back to the servo drive. The servo drive then compares the actual motor status with the commanded motor status. It then alters the voltage, frequency or pulse width to the motor so as to correct for any deviation from the commanded status. In a properly configured control system, the servo motor rotates at a velocity that very closely approximates the velocity signal being received by the servo drive from the control system.

The servomotor rotates at a velocity that very closely appropriates the velocity signal being received by the servo drive from the control system, several components such as stiffness, damping and feedback gain can be adjusted to achieve this desired performance. The process of adjusting these parameters is called tuning.

Servo drive can be controlled with analog or digital inputs. In essence, the role of the servo drive is to translate low power command signal from controller into high power voltage and current to the motor. Depending on the application, the servo drive can regulate and properly co-ordinate the motors desired position, speed, torque etc. The servo drive is responsible for regulating the difference between actual motor status with requested motor status by making the necessary current or voltage adjustments. For automatic systems, that require position control, this makes the use of a servo drive ideal.

2. Types of Servo drive:

There are 3 main types of servo drive that are commonly used:

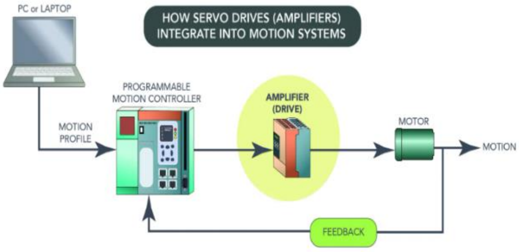
I. **Analog Servo drive:** These use analog signals for controlling the motor position, velocity and torque. They are simple and cost effective but may have limited performance compared to digital drives.
II. **Digital Servo drive:** These utilize digital control techniques, offering more precise and advanced control over the motor. They can handle complex profiles and feedback systems.
III. **Integrated servo drive**: These combine the servo drive and motor into a single unit, providing a compact and convenient solution for certain applications. Servo drives were originally stand-alone components, separate from the motor and controller. But in the past 15 years or so, numerous motor manufacturers have developed integrated drive-controller offerings … as well as integrated motor-drive systems … and even complete motor-feedback-drive-controller systems. Slightly complicating matters is that these integrated designs (which include the motor, feedback, controller, and drive) are sometimes simply called drives for their axis-driving function. They tend to reduce wiring, make sizing and selection easier, and save considerable space and setup time.

Each type has its advantages and is chosen based on the specific requirements of the motion control system.

3. Main Components of servo drive:

There are 4 main components that servo drive is connected:

I. The motor windings
II. The controller
III. The power supply
IV. Feedback



1) **The motor windings:** An electric motor has two main parts: a rotor that spins and is attached to the shaft, and a stator that stays still and is attached to the frame. One of these components will have regular magnets, and the other has wire windings or "electromagnets" that can be turned on by running electrical current through them. By turning the different windings on and off in succession, you can get a rotating magnetic effect. This pushes against the regular magnets and causes the rotor to spin. Brushed motors have windings in the rotor and magnets in the stator, while brushless motors have the windings in the stator and magnets in the rotor. Either way, the amount of current through the windings controls the amount of torque (how hard it turns), while the voltage controls the motor's speed (how fast it turns). By regulating the current and voltage supplied, the servo drive controls the motor shaft's torque, speed, and position. In a brushless motor, electromagnets in the stator are powered on and off to rotate the magnetic rotor.
2) **The Controller and Command:** By the help of controller and we can easily say that what torque, speed, and position that servo drive aim for. The controller sends a signal (a small, but specific pulse of voltage) to the servo drive's command input. The servo drive then essentially amplifies the signal to the desired current or voltage for the motor. More specifically, the controller is responsible for calculating the path or trajectory required and sending low-voltage command signals to the drive.
3) **Power Supply:** The servo drive is connected to some sort of power supply unit (a battery or a device that plugs in) that provides a constant voltage. The servo drive then takes this supply voltage and sends power to the motor as necessary based on the command signal.
4) **Feedback:** As humans, we use feedback devices all the time. The speedometer on our car tells us how fast we're going so we know whether to speed up or slow down. Most of the servo motors are equipped with

some sort of feedback device, such as an encoder, that can connect directly to a servo drive. Having a feedback loop allows the servo drive to make real-time corrections to the current and voltage it's sending to the motor. This ensures that the motor spins with the desired torque, at the desired speed, and to the desired position regardless of interference.

From a macro point of view, the servo drive is mainly divided into two parts, **the power board and the control board**, among which the power board is the strong current part, and the control board is the weak current part. The power board can be subdivided into two units, namely **the power drive unit IPM** and **the switching power supply unit**. Here, the power drive unit is used to drive the motor, and the switching power supply unit is used to provide digital and analog power for the entire servo system.

The control board part of the servo drive is the control core of the whole system. It outputs the pulse width modulation (PWM) or pulse frequency modulation (PFM) signal through the corresponding algorithm as the drive signal of the drive circuit to change the output power of the inverter to achieve the purpose of controlling the AC servo motor. The most commonly distributed servo systems mostly use independent drives, with **rich interfaces, large loads, and good heat dissipation capabilities**, but the connection is cumbersome and bulky. The integrated servo combines the drive encoder and the motor together, highlighting a compact and easy to integrate, but the power and torque of the motor are not particularly large.

4. Working Principle:

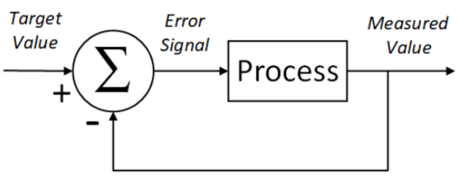
The servo driver adopts digital signal processor (DSP) as the control core, an realize the complex control algorithm, digitization, networking and intelligentialization. The power device generally adopts intelligent power module (IPM) as the driving circuit of the core design. IPM integrated drive circuit with over-voltage and over-current, overheating, undervoltage fault detection and protection circuit. The soft start circuit is also added in the major loop, so as to reduce the impact on the drive in the start-up process.

First, the power drive unit is rectified by the three-phase full bridge rectifier circuit to input the three-phase electric or municipal power, and the corresponding DC power is obtained. The three-phase power or electric supply after rectifying can drive the AC servo motor through three-phase sine PWM voltage source inverter frequency conversion. The whole process of the power drive unit can be simply described as the process of AC-DC-AC. The main topology of the rectifier unit (AC-DC) is the three-phase full bridge uncontrolled rectifier circuit.

Servo drive main function is to receives a command signal from a control system, amplifies the signal, and transmits electric current to a servo motor in order to produce motion proportional to the command signal. Typically, the command signal represents a desired velocity, but can also represent a desired torque or position.

In brief description:

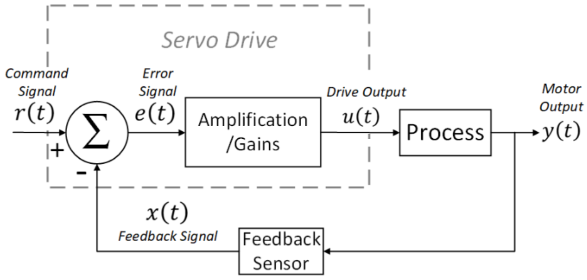
I. **Negative feedback loop:** Servo drives are often known as servo amplifiers. They amplify a command signal. But it's the development of feedback-based control that makes them more sophisticated and useful devices. As we know that, servo drives uses feedback loops to correct for error. In motion control and most other controls processes, errors are corrected using negative feedback loops. In a negative feedback loop, the system output signal (from the measured value) is subtracted from the system reference input (the target value) to create the new input value (the error signal).



A simple negative feedback loop.

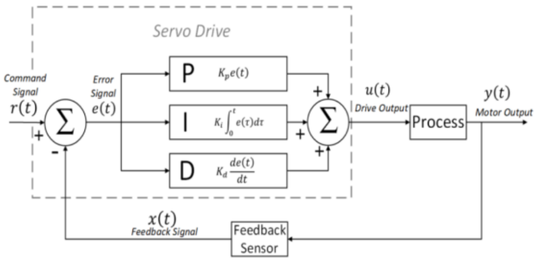
So if a systems output is too high, the error signal will be negative, and the system will respond in the negative direction to bring the output down. If the system's output is too low, the error will be positive, and the system will respond in the positive direction to bring the output up. This process cycles through continuously, keeping the error as close to zero as possible. This negative feedback is essential. If the feedback was positive (in other words, if you added the measured value to the target rather than subtracting it), a system going too fast would compensate by going even faster or a system going too slow would grind to a halt or eventually run in reverse. Almost all servo drives are capable of closing the current loop, but others can also close the velocity loop and even the position loop. If a system has a servo drive that can only close the current loop, but the machine needs to also close the velocity and position loops then those additional loops will need to be closed by the controller.

II. **Gain:** The error signal goes through the system gains, the amplification step that takes the system input to produce the system output. In some systems, this is a simple proportional gain.



A basic feedback loop in a motion control system with a servo drive. The servo drive compiles the error signal and then "amplifies" it to get the servo drive output.

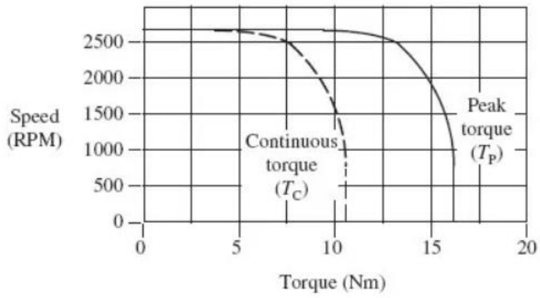
III. **PID Control**: For some processes, a proportional gain is good enough for control. But for most processes, such as robotics, more precise control is desired. One of the most widespread control schemes is (Proportional, Integral, Derivative) control. In PID, you have the proportional gain multiplied by the present error value, but also have the integral gain multiplied by the accumulation of error over time (integral) and the derivative gain multiplied by the change in error over time (derivative). This almost always results in a much more precise correction of error, reducing problems like overshoot and oscillation.



A basic feedback loop in a motion control system with a servo drive featuring PID control.

One of the most important tools for sizing a servo motor is its torque-speed curve. But often, the torque-speed curve is specific to a certain motor-drive combination. This is because the continuous and peak torque capabilities of the motor are affected by the thermal properties of both the motor and of the drive. Inefficiencies in the motor cause it to produce heat, which can degrade bearing lubrication and insulation around the windings. Excessive heat — typically caused by running a motor above its peak torque — can demagnetize the motor’s magnets.

Although the drive has no moving parts, heat can damage its power transistors.



The torque-speed curve of a servo motor is often based on a specific motor-drive combination.

5. Control Methods:

There are 5 main control methods for servo drive:

I. **Position Control Mode:** It can determine the rotational speed generally through the external input pulse frequency and the rotation angle by the number of pulses. Some servo systems can assign velocity and displacement directly by means of communication. Because the position mode can control the speed and position strictly, it is generally used in the positioning device.

II. **Torque Control Mode:** It is assigned by the external analog input or direct address to set the external output torque of motor shaft. The torque can be changed by changing the setting of the analog immediately and the corresponding address value can be realized by the change of communication mode. The main application has strict requirement for the material on stress in the winding and unwinding device, such as winding device or fibre optic equipment. The setting of the torque should be changed at any time according to the radius of the winding so as to ensure that the force of the material does not change with the change of the winding radius.

III. **Speed Control Mode:** It can have control for the rotation speed through the input of analog quantity or the pulse frequency. The outer loop PID with the upper control device can be positioned. But the position signal of the motor or the position signal of the direct load should be sent to the upper feedback for calculation. The position mode also supports direct load loop detection position signal. At this moment, the coder at the motor shaft end can only detect the motor speed and the position signal is provided by the detection device directly of the final load end. The advantage of this method is that it can reduce the error in the intermediate transmission process and increase the positioning accuracy in the whole system.

IV. **Pulse Control Mode:** As the name implies, the motor is controlled by taking pulse outputs from the PLC or controller, for exact movement of the motor as commanded. The PLC will give a set number of pulses to the drive. Suppose you have to feed 10000 pulses to the drive, at a frequency of 40 hertz. Then, the PLC will divide the pulses in such a way that it is fed continuously at the set frequency to the drive. When the total number of counts is given, it will accurately stop the feed and the drive will too, stop at that accurate position. This is one of the most commonly and simple means of control used in servo drive. Length and position based applications use this type of control.

V. **Speed Control Mode:** This can be considered as an advanced version of a simple VFD (Variable Frequency Drive) based induction motor. In this mode, the motor speed is used to control the motor behaviour. The servo drive obtains the actual speed from an encoder and continuously compares it with the set speed; to maintain the desired speed. The speed is varied by varying the voltage given to the motor. In a simple VFD, you just give the run command with a set speed to move the motor. But here, apart from taking speed, the drive will run in closed-loop control to constantly monitor the speed and correct if any deviation. This works great under varying loads.

All the above five methods work in closed loop control. It is not sensible to run the servo applications with feedback control. Due to its high precision factor, it is of great use in machine automation.

6. Servo drive in Motion Control System:

I. **Power Levels**: Not all servo drives are created equal. Every servo drive has a nominal operating voltage and maximum peak and continuous current ratings. While many advancements have been made to increase power density (especially in recent years with our Flex Pro drive family), larger servo drives are usually going to be more powerful and have a lower resolution of current control.

II. **Form Factor:** Servo drives come in various shapes and sizes, some better suited for different applications.

III. **Panel Mount:** Panel mount servo drives have a metal baseplate and a plastic or thin metal cover that enclose the PCB. Holes or notches in the baseplate are used to mount the drives to a flat surface using bolts or screws. These are the traditional form of servo drives, typically used in machinery.

Panel Mount Servo Drive

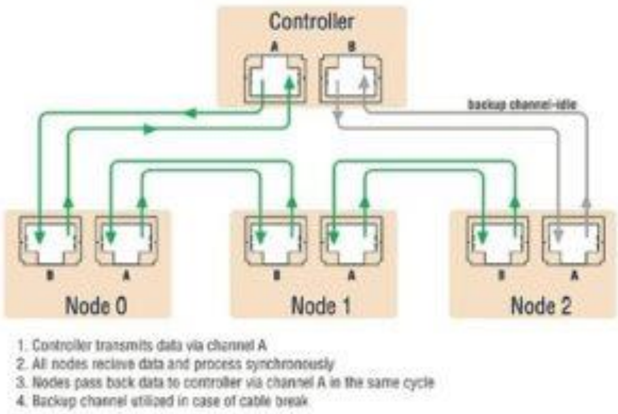
IV. **PCB Mount:** PCB mount servo drives are made without any case or coverings. They're designed to mount directly to another circuit board using pins or soldering, similar to how a sub-component might be attached. These are very compact and offer reliable connectivity, but are less protected from the elements. These are often used in both fixed and mobile robotics. PCB mount drives are sometimes plugged into a mounting card to offer more traditional connections with wires and cables while maintaining their compact nature. This can save the machine designer the trouble of designing a PCB with the exact pin connectors to match the drive.

PCB Mount Servo Drive

V. **Vehicle Mount:** Vehicle mount servo drives are tightly enclosed by a thick plastic shell and a heavy baseplate. Screw terminal lugs are used to allow high current. As the name implies, these are used in mobile applications. Regardless of the form factor, performance-wise they all work the same. The difference is more to do with ease of installation for different industries and different applications.

Vehicle Mount Servo Drive

VI. **Networks:** In robots, mobile vehicles, machines, and other motion control systems, chances are there are going to be more than one axis of motion. That means more than one motor, which typically means more than one servo drive. The controller needs to send the commands to all of these servo drives. There are two ways for the controller to handle this. With analog servo drives, a centralized control scheme is necessary where the controller is connected individually to each servo drive.

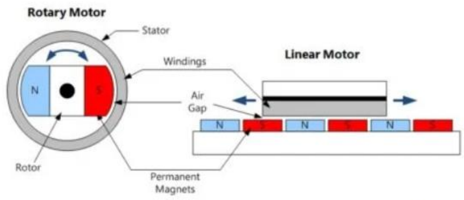


Having the servo drives on a network simplifies wiring. Data and commands can flow along a single network bus to each node, so the controller doesn't need a direct connection to each one.

With digital servo drives, however, a distributed control scheme is made possible through the use of a network. A network chains the servo drives together. Messages or data packets can be sent through the network and the servo drives will respond to the data that is addressed to them. There are a variety of different network protocols. Real-Time networks such as Ether CAT or EtherNet/IP allow for incredibly fast response times, sending updates in less than a millisecond. Other networks like CAN open or Mod Bus are not as fast, but are easier and less expensive to implement. Every ADVANCED Motion Controls digital servo drive model is designed for a specific network protocol, with many options available, including customs.

Other types of Motors:

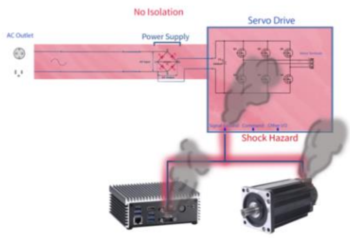
In this era, servo drives can do much more these days than just run servo motors. Besides standard brushed and brushless servo motors, servo drives can also be used to control linear motors, two-phase and three-phase stepper motors, AC induction motors, voice coils and more. Even if our system has multiple motor types, its very possible that you can control them all using the same or similar models of servo drive, simplifying your design.



A linear motor is electrically analogous to an "unrolled" brushless servo motor, so it is easily controlled by digital servo drives.

i. **I/O:** Even if your system has multiple motor types, it's very possible that you can control them all using the same or similar models of servo drive, simplifying your design.

ii. **Isolation:** Either your servo drives or your power supply is going to need electrical isolation. Otherwise, you might end up with a floating ground that ends up frying your servo drives and other components in the system. You either need servo drives with built-in optical isolation or a power supplies with an isolation transformer. The exceptions to this rule are battery powered systems and systems with servo drives that are designed to take AC power directly.



7. Features:

- Configurable feedback
- Firmware customization
- 2 configurable digital inputs
- 2 configurable digital outputs
- 2 configurable analog inputs
- 3 internal temperature sensors
- 1 inclinometer for safe monitoring in case of dangerous vehicle behavior
- Configured and controlled via TKSED, with options of:
- Parameter configuration

- Current, speed and position adjustment
- Basic configuration
- I / O Debugger
- CAN Debugger
- Unit programmer
- Purpose

8. Advantages and Disadvantages of Servo drive:

Advantages	Disadvantages
✓ Low Cost	✓ Resonance effects are dominant
✓ Simple and rugged	✓ Rough performance at low speed
✓ Very reliable	✓ Open- loop operation
✓ Maintenance free	✓ Consume power even at no load
✓ No sensors needed	✓ Torque unequal because of unbalanced motor current
✓ Widely accepted in Industry	✓ Uncontrolled harmonic currents even when slight magnet field distort

9. Applications of servo drive:

In many applications and industries servo drives are used. Some application where servo drives are used include Marine, Aerospace, Laboratory Automation, Arctic Drilling, Satellite Communication, Ground Mobile, Extreme Outdoor Operation, and Aviation.

Some more precise applications where servo drives are used:

I. Robotics: On the arm of robot servo motors are used on the joint for monitoring the angle and speed of movement.
II. Printing press: The print heads movement of starting and stopping can be controlled by a servo motor themselves and the paper exact movement ensure right printing.
III. Conveyor belts: In many industrial environment, servo drives are utilized to start and stop conveyor belts.
IV. Metal cutting machines: The exact movement control that servo motors can offer make them ideal for different metal cutting and forming machines such as pressing, punching, lathes, grinding and milling.
V. Camera focusing: In cameras, servo motors are installed in very smaller form helping the camera to set the auto focus functionality on the lenses.
VI. Automatic Doors: This is highly common application where servo drives are used. Automatic doors are widely installed in shops and hotels and servo motors are useful to control the door movement after receiving the signal from anyone.