Dr. Norbert Cheung's Lecture Series

Level 5 Topic no: 2

Introduction to Motion Systems

Contents

1. What is an intelligent motion system
2. Structure of typical motion systems
3. Products related to intelligent motion systems
4. The closed-loop motion control system and its interface
5. Requirements, structures, characteristics and applications of different operating modes
   - Velocity tracking system
   - Point-to-point motion system
   - Trajectory path tracking system
   - Force and tension control
   - Compliance control
   - Vibration damping
6. Mixed mode operation and switching between modes

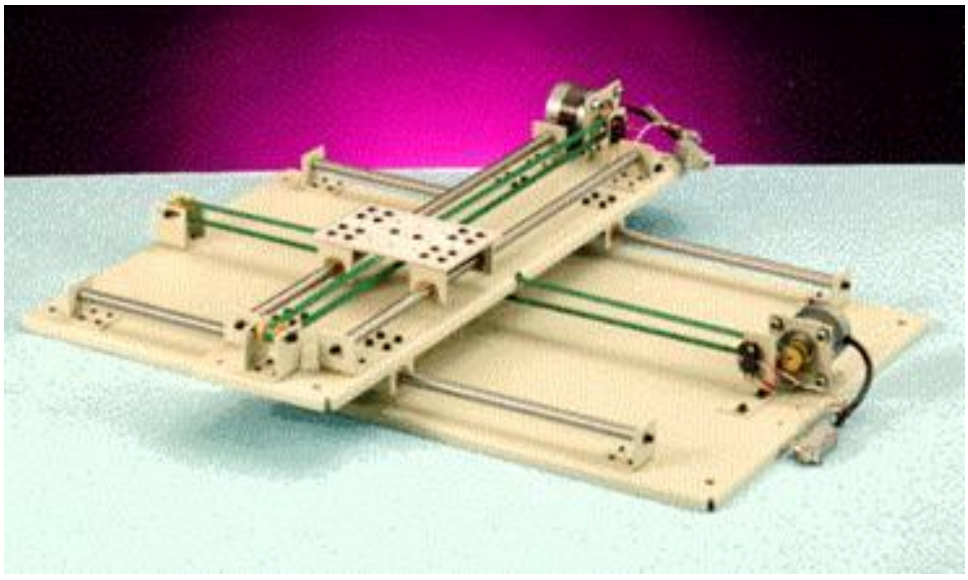
1. What is an Intelligent Motion System?

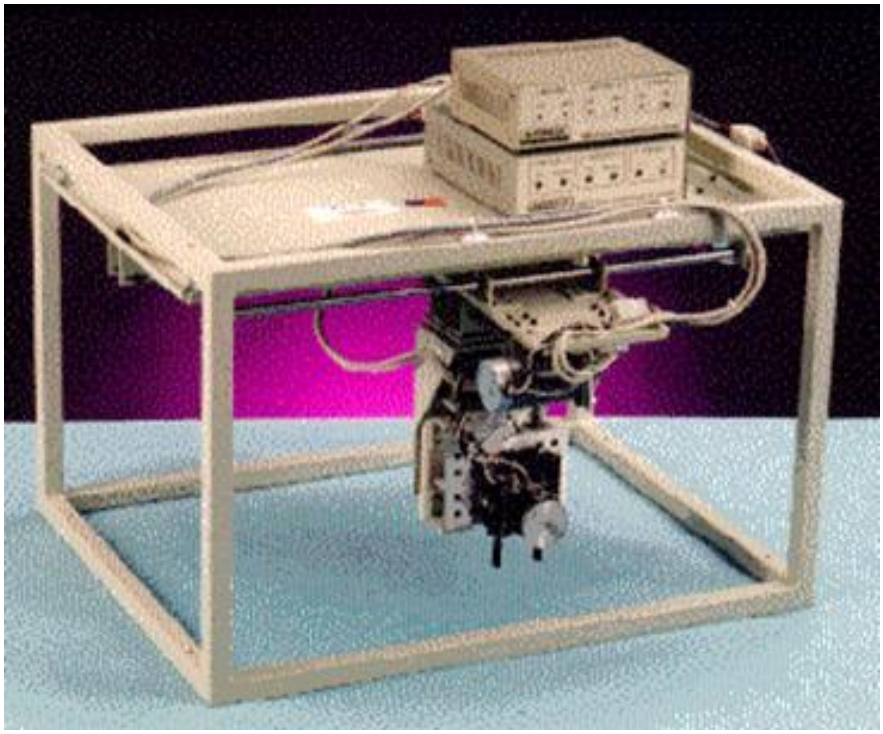
Form of an intelligent motion system can be:

- A single or multi-axis mechatronics system
- Can be programmed to move in a controlled and coordinated manner
- Can be position, velocity, force, torque, tension…. controlled
- It can be a combination of a few control modes

"Intelligent" means that it has artificial intelligent functions built into the system. Intelligent functions can be:

- Shortest or easiest-to-travel path
- Ability to adapt to operating environment
- Path planning, environment exploring, collision avoidance
- Learn from experience
- Configuration and characteristics change with environment





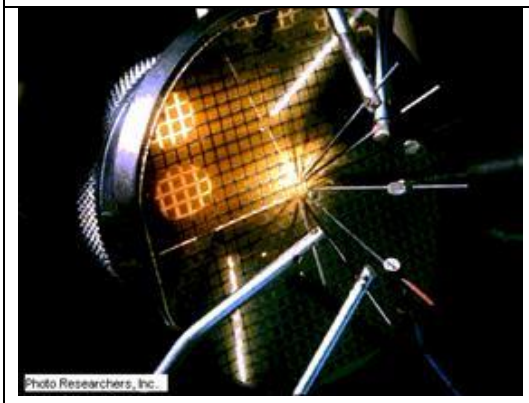
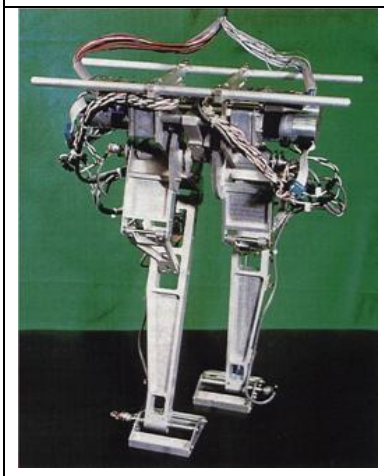
Intelligent motion control system must include:

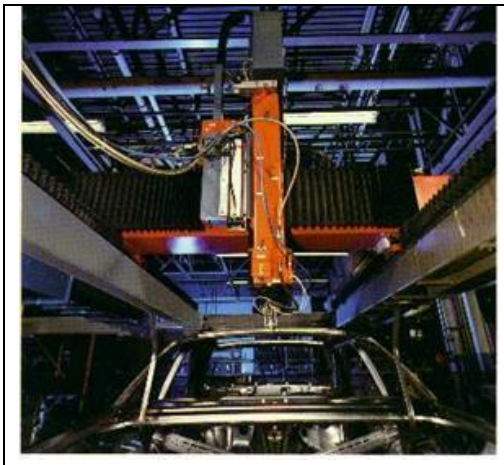
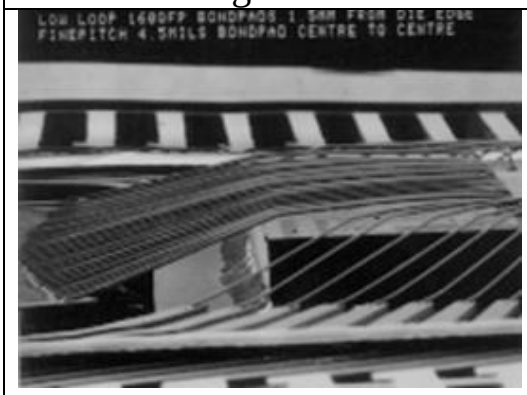
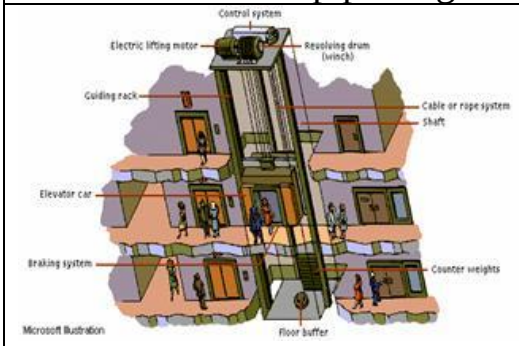
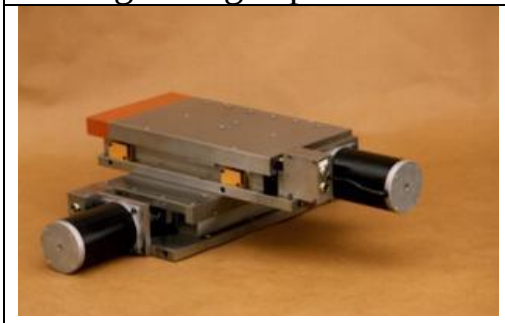
- Computation power
- Appropriate interface electronics
- Flexible motion drivers
- Monitoring sensors

Typical applications of intelligent motion systems:

- Applied to everything which moves in a controlled manner.
- Exists in all high-tech manufacturing machines: I.C. packaging machines, Electronic Manufacturing Machines
- Robotics and CNC machines.
- In transportation systems: Elevators, fly-by-wire systems, missiles, flight simulators
- Exists in most consumer and commercial products: CD and DVD player, home robotic pets, disk drives, tape transport
- Can be very large: Jumbo jet control, building elevator, etc
- Can be very small: micro-motion robotics, micro-reflective mirrors.

Applications Examples

Applications	No of axis Resolution order	Intelligent functions
 A “flying probe” semiconductor tester		
 A self balancing walking robot		
 Two finger robotic gripper		

 A gantry robot for car manufacturing		
 Wire bonding in semiconductor chip packages		
 Intelligent high speed elevator		
 A 2D metal cutting X-Y table		

2. Typical Structure of an Intelligent Motion System

The structure includes:

Motion planner – Calculation of the best possible route

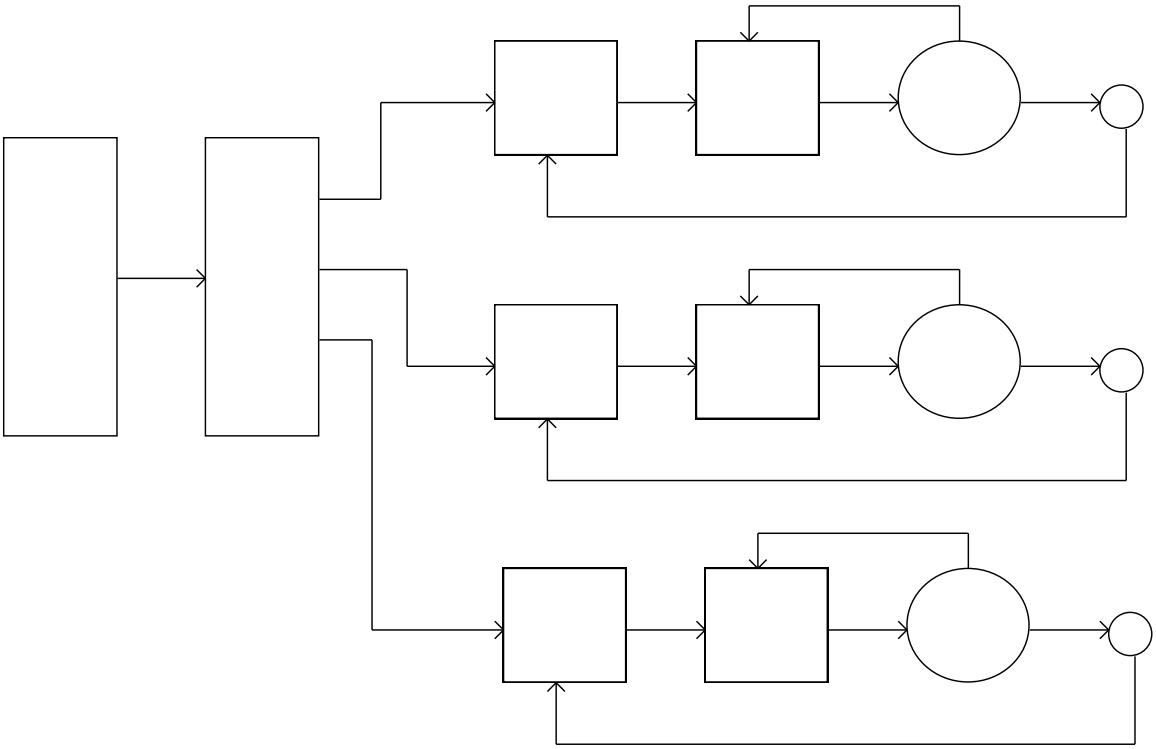
Trajectory generator – generate the co-ordinates of the actual path

Controller – control the mechanics to move according to command

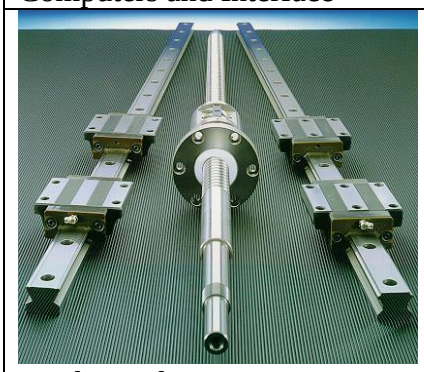
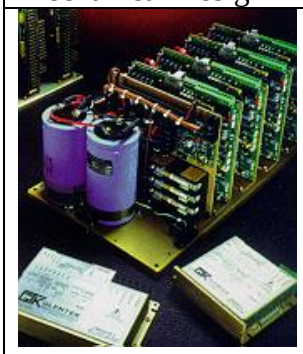
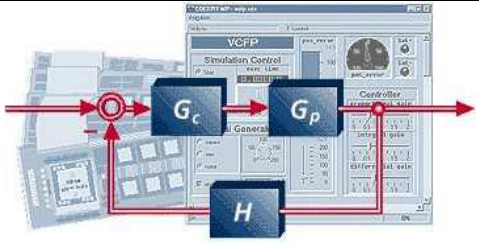
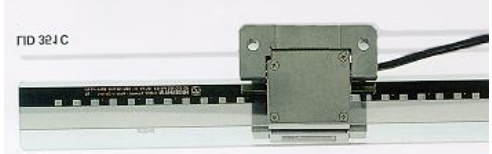
Power electronics – provide electrical power the motors

Motion actuators – the actual force/torque producing component

Feedback sensors – monitor on the actual motion



Intelligent Motion System is a multi-discipline subject

Discipline Area	Issues
 Motors	FEMA Motor structure Driving technique
 Computers and Interface	Real time computing Digital signal processing Digital filtering Interface techniques
 Mechanical Design	Rigidity Mechanical structure Resonance Vibration Ball bearing structure
 Power electronics	Current control Switching topology Power efficiency Commutation Vector control
	Robust control Parameter estimation Fuzzy and neural control Sampling frequency
	Resolution Quadrature encoding Interpolation

3. Products Require Motion Systems for Manufacturing

- IC, CPU, LCD, Smart Card, Octopus Pass
- Pagers, Mobile Phones, all electronic products
- Plastic moulds, machine tooling
- Precision film plotting, artwork
- All high tech manufacturing

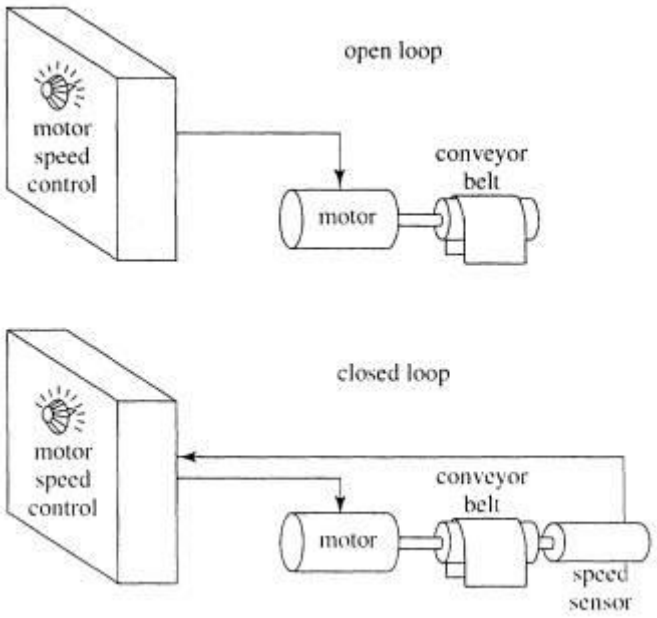
Companies involved in Intelligent Motion Systems

- Motorola, National Instruments, Intel
- ASM, Hitachi, Panasonic
- V-tech, Ban Dai, Tamiya
- IBM, Segate, Maxtor
- Nearly all Hi Tech manufacturing companies

4. Closed Loop Motion Control System and its Interface

Open Loop:
Simple structure
Drive the motor according to the system's physical behavior
Less accurate
Performance changes with external environmental factors
Examples: Stepper drives, cam-shafts, on-off control

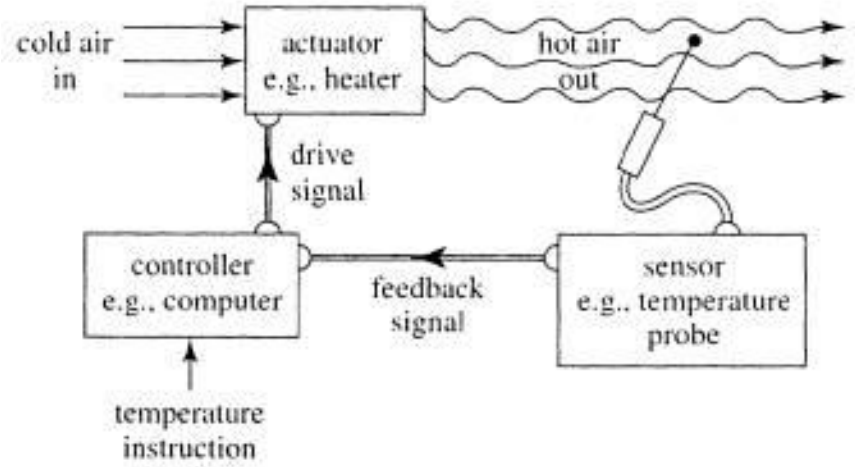
Closed Loop:
Need a sensor or estimator
A real-time controller must be present
Has the ability to correct errors
Disturbance rejection, has the ability to correct errors
Examples: Servo drives, vision-based alignment system



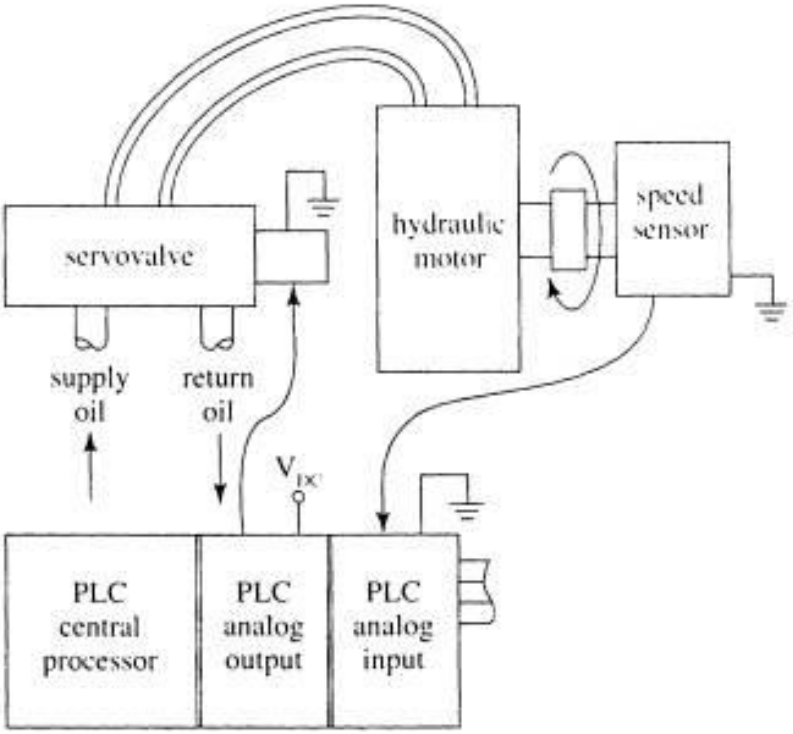
The essential components of a closed-loop system consist of:
- The actuator (which does the work)
- The controller (which "tells" the actuator to do work)
- The sensor (which provides feedback to the controller)

The Controller as an Automation Component

A controlled system may be a simple digital system. An example is shown in figure below.



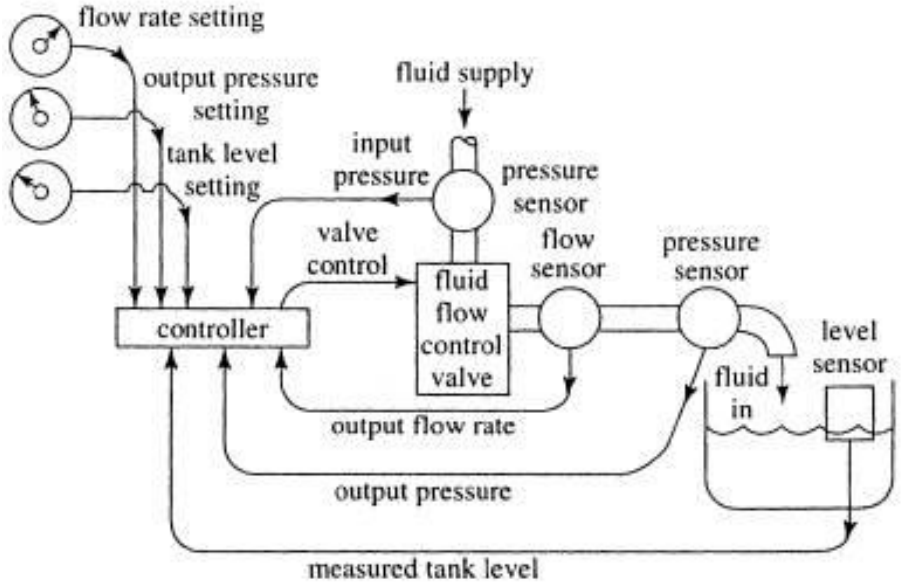
Components of a simple controlled automation system – an example of a hydraulic servo motor driven by the PLC (Programmable Logic Controller)



Sensors as Motion Control Components

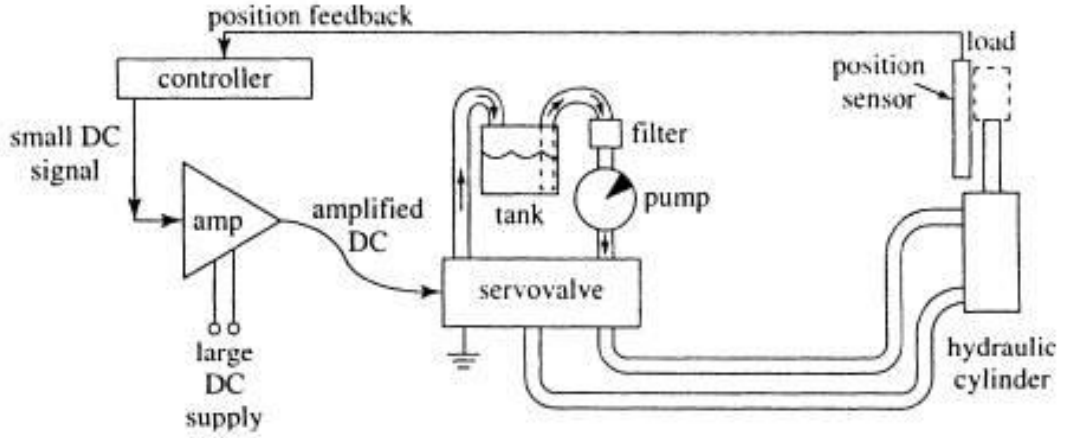
Obviously, controlled automation requires devices to sense system output. Sensors also can be used so that a controller can detect and respond to changing conditions in its working environment.

A wide range of sensors exists. Some sensors, known as switches, detect when a measured condition exceeds a pre-set level (e.g., closes when a work piece is close enough to work on). Other sensors, called transducers, can describe a measured condition (e.g., output increased voltage as a work piece approaches the working zone).

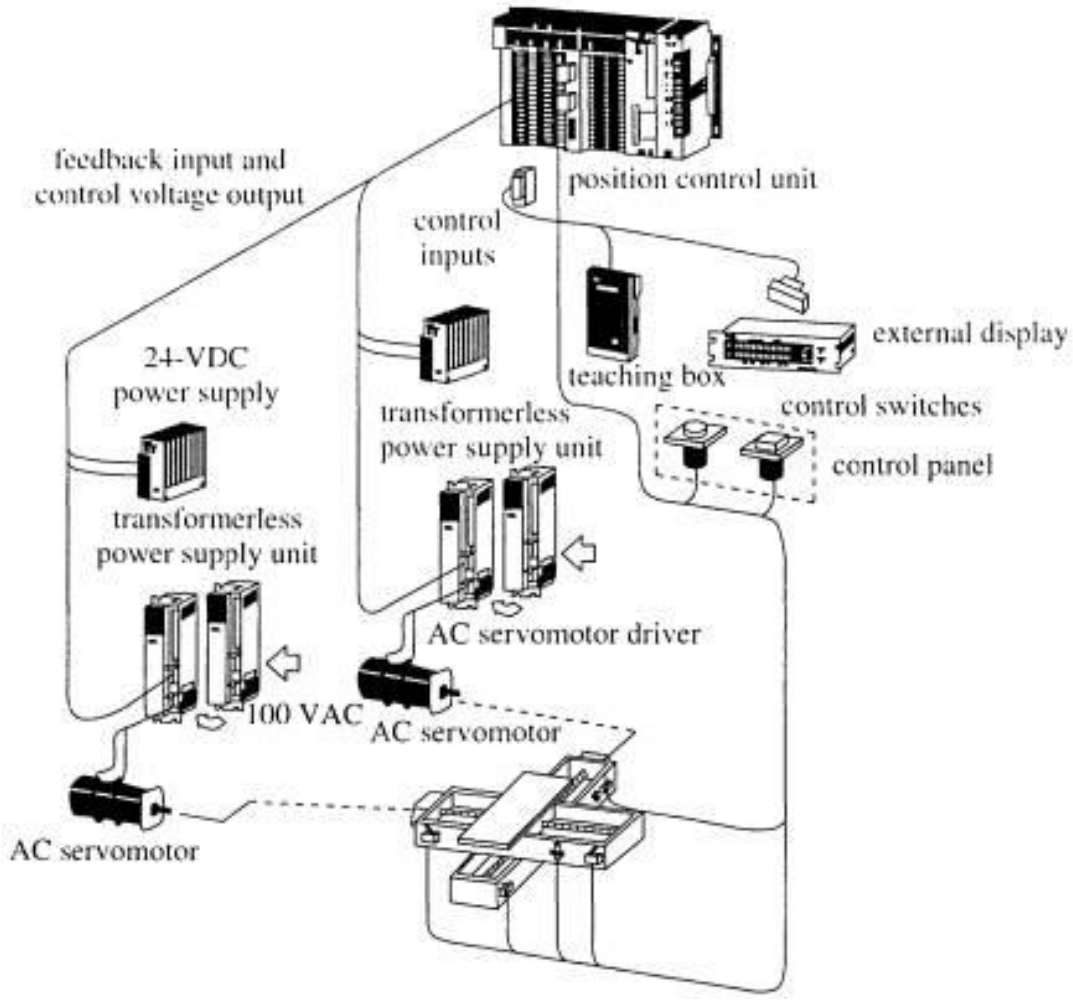


Sensing in an automated system

The "controller" controls an actuator. The actuator, in turn, changes the output of the automated process. The "actuator" in an automated process may in fact be several actuators, each of which provides an output that drives another in the series of actuators. An example can be found in figure in the next page, in which a hydraulic actuator controls the position of a load.



A PLC in a position control application. (Illustration by permission, OMRON Canada Inc., Scarborough, Ontario, Canada.)



5. Requirements, structures, characteristics and applications of different operating modes

In this section, 6 types of motion control configurations are studied:

- Velocity tracking system
- Point-to-point motion system
- Trajectory path tracking system
- Force and tension control
- Compliance control
- Vibration damping

Velocity tracking system

Operation	Follows a particular speed, or speed profile. Zero speed is seldom used. Position is not important
Characteristics	Controller is relatively simple for fixed speed drive. In some case open-loop drive is already adequate. For variable speed drive, the controller becomes more complicated.
Applications	Fan blower, traction transportation, pump, hard disk drives, tape transport
Structure	

Point-to-point motion system

Operation	Moves between points. The profile between points is not important.
Characteristics	Usually, speed and accuracy are the most important performance factors. Sometimes a speed profile is employed to speed up the point-to-point speed.
Applications	Pick and place machines, hard-disk arms, cargo transport crane
Structure	

Trajectory path tracking system

Operation	Must follow the command trajectory path exactly. Can be viewed as a point-to-point motion system with very small distance between points
Characteristics	Controller must be a variable speed drive with continuous position feedback and continuous command input. Controller configuration is more complicated than other driving modes
Applications	CNC lathe, plotter, air-craft navigation and control
Structure	

Force and tension control

Operation	Produce a certain force or force profile; or to produce a certain tension or tension profile. Displacement is unimportant, or does not exist.
Characteristics	Controller is relatively simple and it can have various configurations. In some cases the feedback element does not exist.
Applications	Testing load, yawn pulling system, metal sheet rolling system, robotics gripper
Structure	

Compliance control

Operation	Controls the rigidity of the system. A spin-off from the force control systems
Characteristics	Configuration is very simple to the force control system. In most cases the compliance effect is controlled from the internal control structure.
Applications	Hybrid force-motion control in robotics. Testing device.
Structure	

Vibration damping

Operation	Active damper to damp out the harmful vibrations
Characteristics	Controller is based on an active damping cylinder. In some cases, a motion actuator is used to counter-act the vibration.
Applications	Active suspension system in cars
Structure	

6. Mixed mode operation and switching between modes

Can you figure out what operating modes they are in?

- An electric train is coming to a stop at a railway station
- A robot gripper starting to grip on an object
- A high speed pick-and-place machine glues a component on a PCB
- An epoxy dispensing machine produces a 2D mark on the flat surface
- A robot arm presses a roller with a down force, and moves horizontally on an uneven surface
- A robot arm "blinded folded" searches a threaded hole, then screws the screw into the hole

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