Assembly Technology

Lecture 5: Supporting hardware component for automation

Outline

- Sensors
- Actuators
- Analog-to-Digital Conversion
- Digital-to-Analog Conversion
- Input/output Devices for Discrete Data

Intended Learning Outcomes

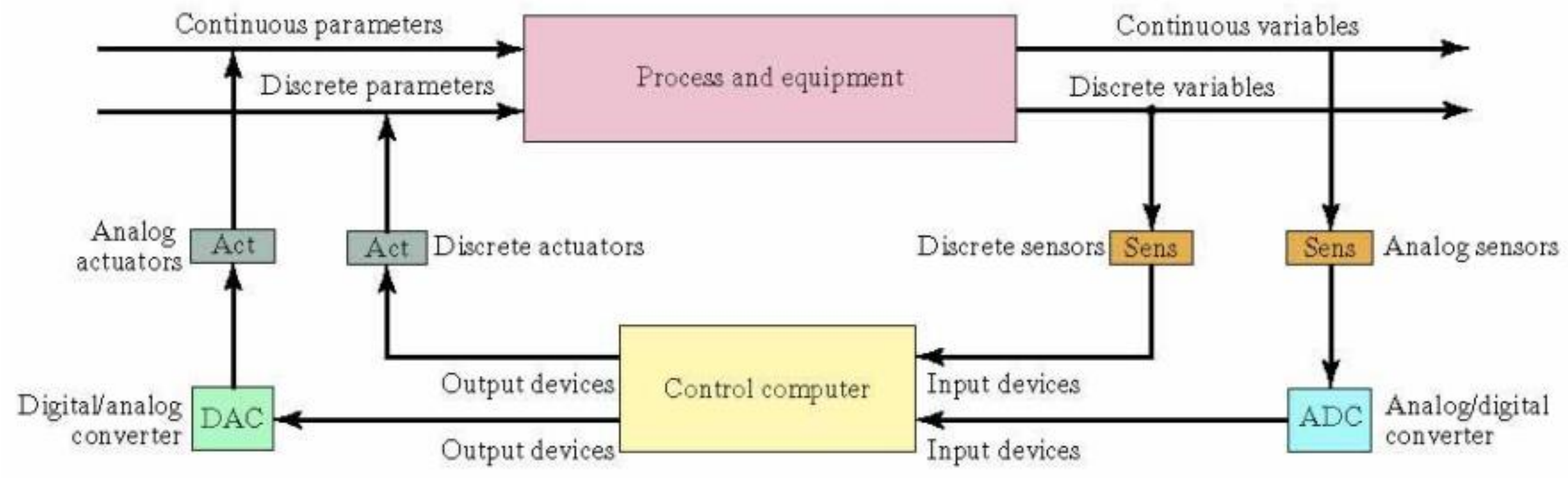
- Describe a typical computer process control system, with the main components and related roles.
- List the different kinds of sensors and actuator used in industry and provide some example with descriptions
- List and describe the phase and features of an ADC as well as the steps of a DAC

Computer-process interface

- To implement process control, the computer must collect data from and transmit signals to the production process
- Components required to implement the interface:
  - Sensors to measure continuous and discrete process variables
  - Actuators to drive continuous and discrete process parameters
  - Devices for ADC* and DAC*
  - I/O devices for discrete data

*analogic-discrete conversion and discrete-analogic conversion

Computer process control system



Sensors

A sensor is a transducer that converts a physical stimulus from one form into a more useful form to measure the stimulus.

Two basic categories:

1. Analog
2. Discrete
    1. Binary
    2. Digital

Sensor Transfer Function

The relationship between the value of the physical stimulus and the value of the signal produced by the sensor in response to the stimulus

$$S = f(s)$$

where S = output signal, s = stimulus, and f(s) is the functional relationship between them □

Ideal functional form is simple proportional relationship:

$$S = C + ms$$

Sensor description

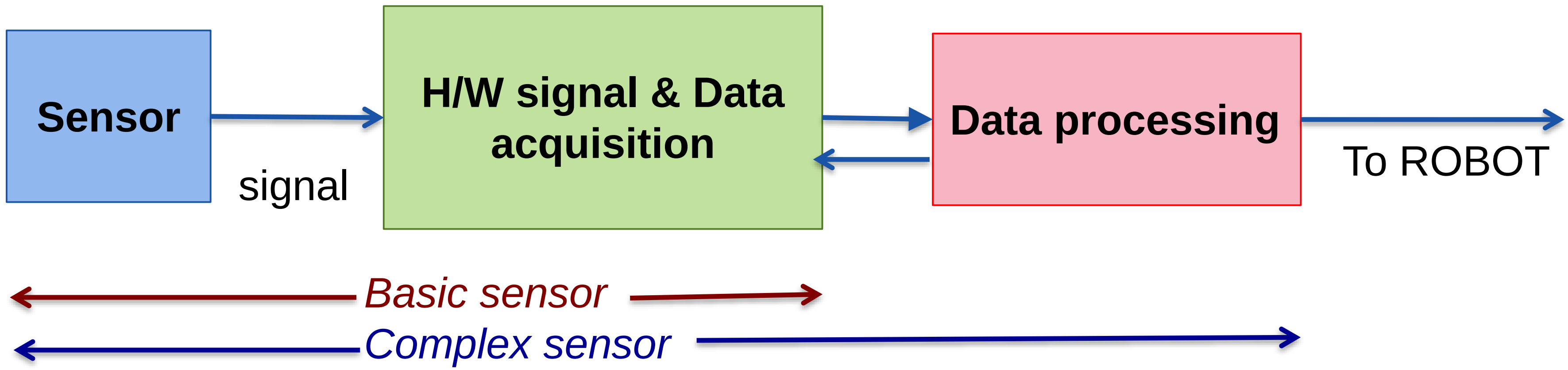
- Sensors exist as simple entities or complex ones.
- The distinguishing feature is based on how much data analysis is carried out at sensor level.
- Basic/simple sensors simply convey the data to any other device. This data needs to be translated and analysed, which may take time.
- Complex sensors carry out data analysis on-board; examples: your mobile’s camera, your PC’s keypad, etc.

Sensors for industry

Sensors are used to correct disturbances or to determine non-predefined conditions existing within robot environment. Note: sense around & about robot, not within it!

Sensors are inevitably modelled on human characteristics; however, their performance often surpasses human possibilities.

Structure:



Sensor Classes

Sensors, particularly the basic ones, are sometimes called transducers.

Classification based on physical phenomena

- Mechanical: strain gage, displacement (LVDT), velocity (laser vibrometer), accelerometer, tilt meter, viscometer, pressure, etc.
- Thermal: thermal couple
- Optical: camera, infrared sensor
- Others …

Classification based on measuring mechanism

- Resistance sensing, capacitance sensing, inductance sensing, piezoelectricity, etc.

Classification based on operating principle

- ❖ Visual
- ❖ Tactile
- ❖ Auditive

Applications

- ✧ Quality control
- ✧ Task completion control
- ✧ Positioning & orientation of objects for robot
- ✧ Surveillance
- ✧ Grasp control
- ✧ Stop/start of processes
- ✧ Etc.

Sensors are being used in all applications and their use is becoming greater.

Specifications of Sensor

Linearity of actual sensor (avoid hysteresis, complex data processing)

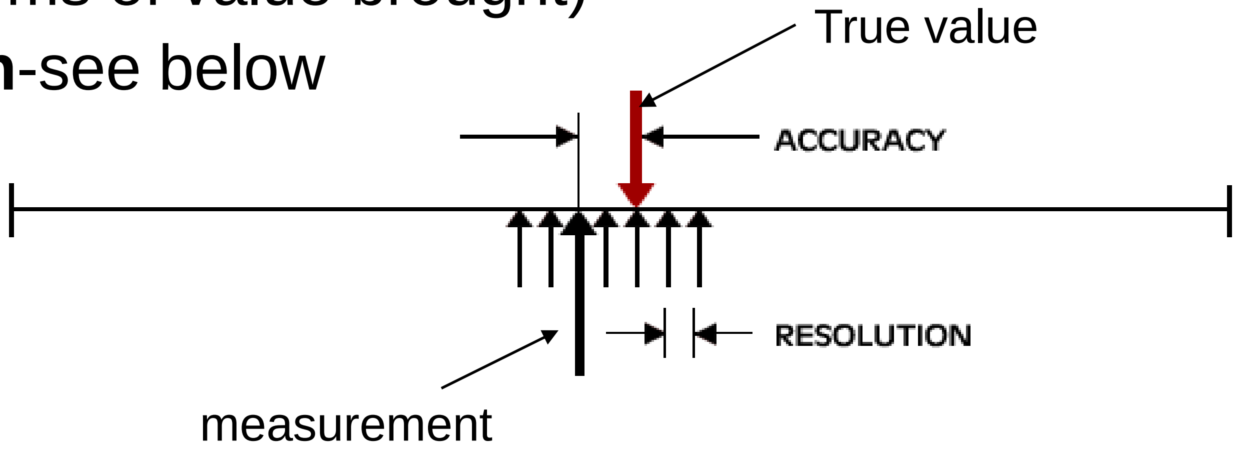
Robustness to industrial environment (oil, water, heat, dust resistance- see IP67 classification)

Minimal spatial intrusion (robots collisions to be avoided)

Real time data acquisition (robot should not wait)

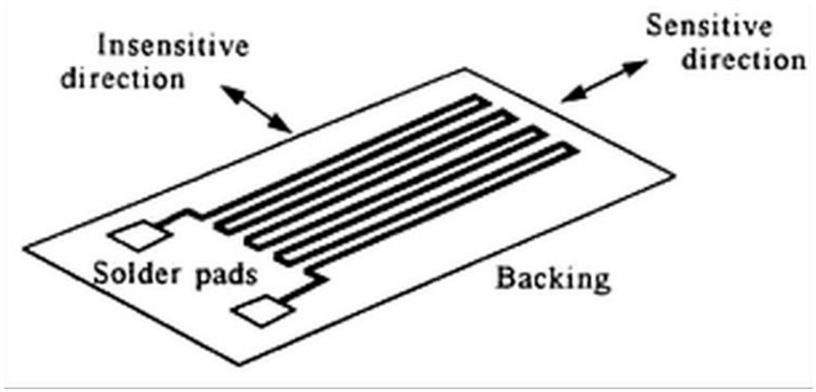
Low cost (in terms of value brought)

High resolution-see below



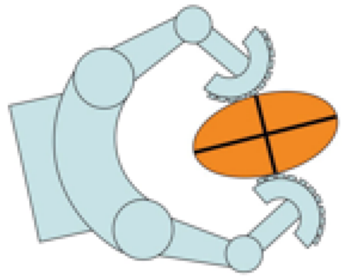
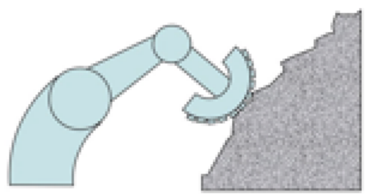
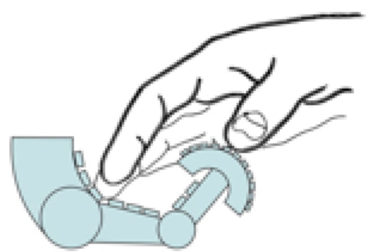
Tactile Sensors

- Come in many versions, almost all based on contact between sensor and part.
- Strain gauge (foil, vibration wire,Fibre optic, etc.)
- Capacitive (piezoelectric)
- Pressure sensor
- Force/Torque sensors



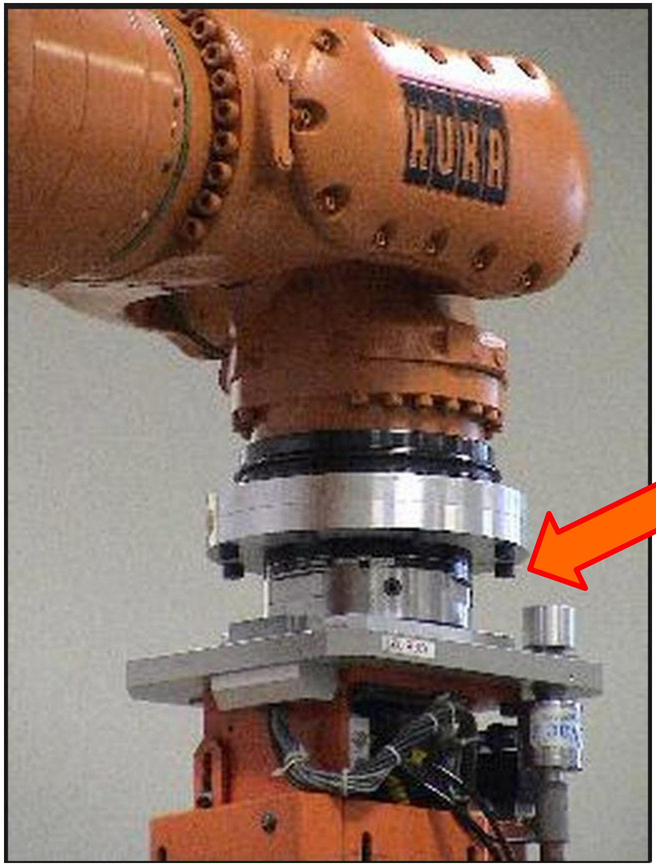
Tactile sensors

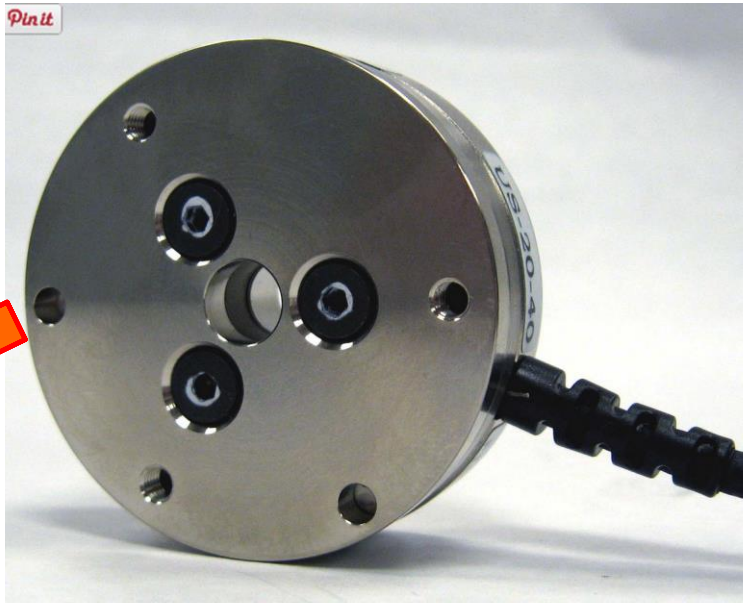
Table I. Uses of tactile sensing in robotics

	*Manipulation:* Grasp force control; contact locations and kinematics; stability assessment.
	*Exploration:* Surface texture, friction and hardness; thermal properties; local features.
	*Response:* Detection and reaction to contacts from external agents.

Tactile sensor

Force/Torque sensor is most common:





Tactile sensor, F/T

Typical application: engine valve insertion, ball bearing assembly.

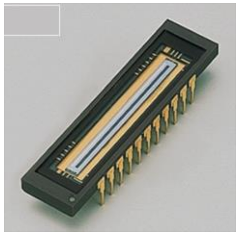
Accuracy must be maintained for the whole length of the valve/bearing.
No scratches allowed.
Very high accuracy, ± 0.05mm
Repeatable 100 000 times

Vision sensors

Exist in many variants:

- Single optical sensor (opto-switch)

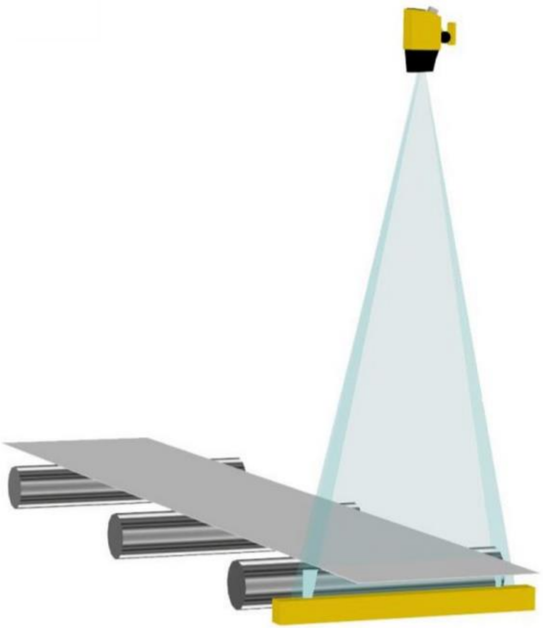
- Linear array



- CCD array (vision)

Vision sensing

Arrays: used for “scanning”, object detection, quality control



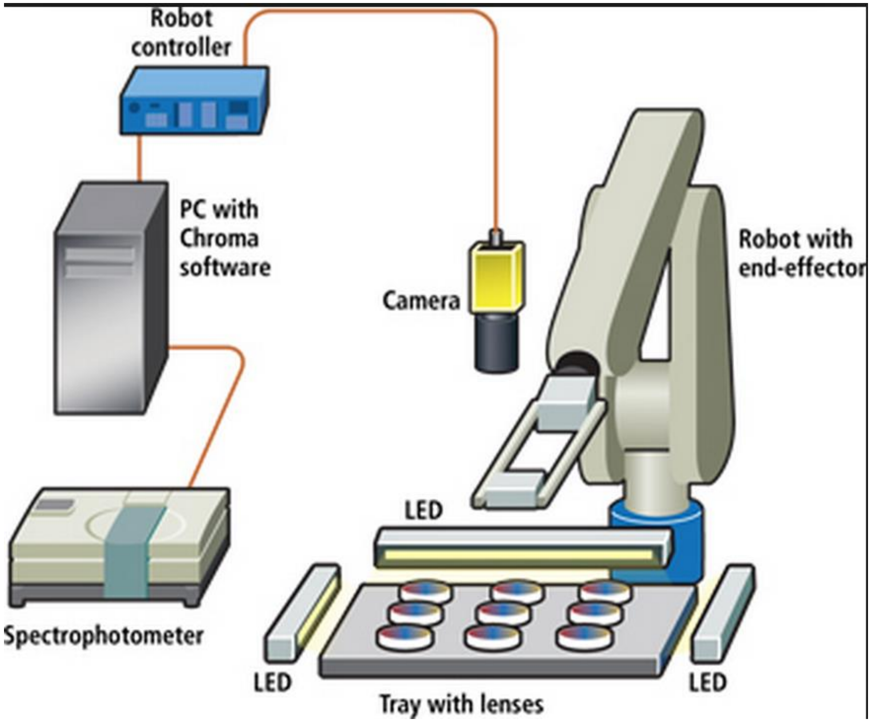
The array is a 2-D picture.

The motion of the conveyor creates the 3rd dimension

Height of sensor and speed of conveyor determine the accuracy

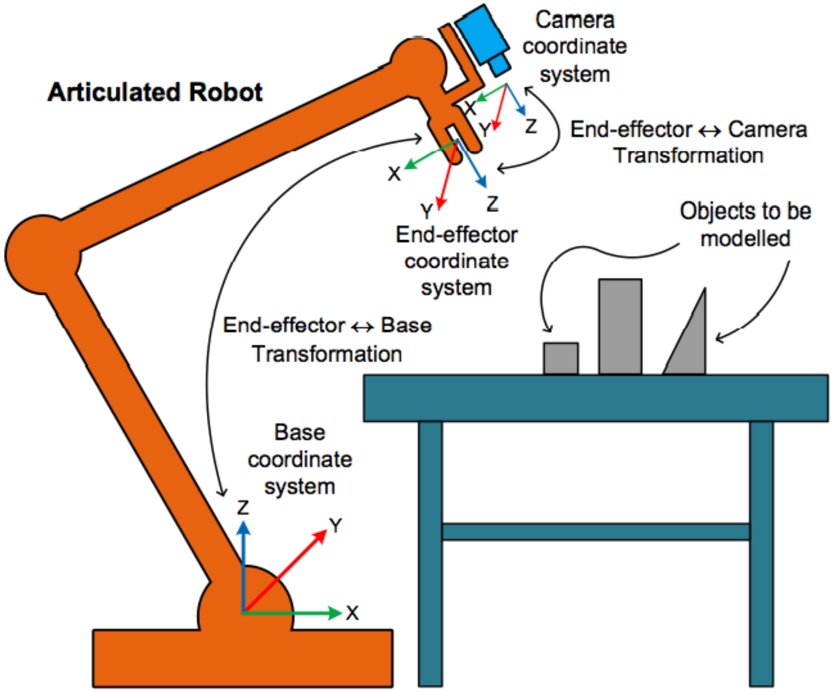
Vision sensing

3-D vision becoming most popular. Cameras often mounted on the robot!



Vision sensing

Vision requires a translation of camera coordinates to robot coordinates! Camera must also be calibrated.



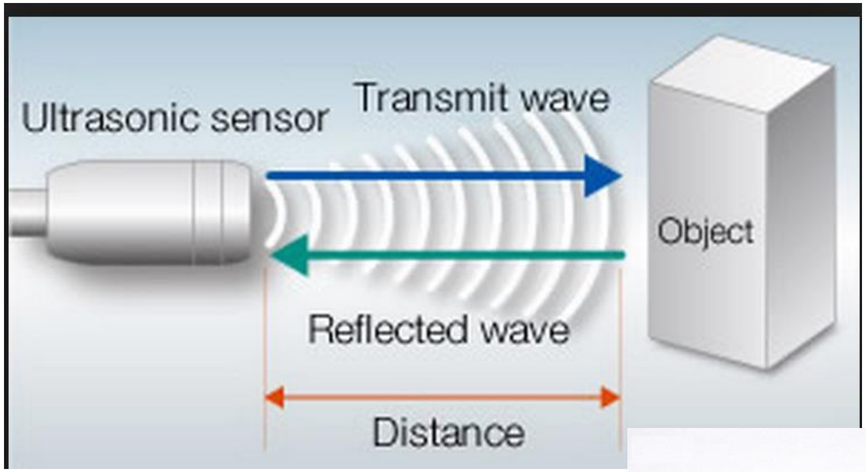
Vision

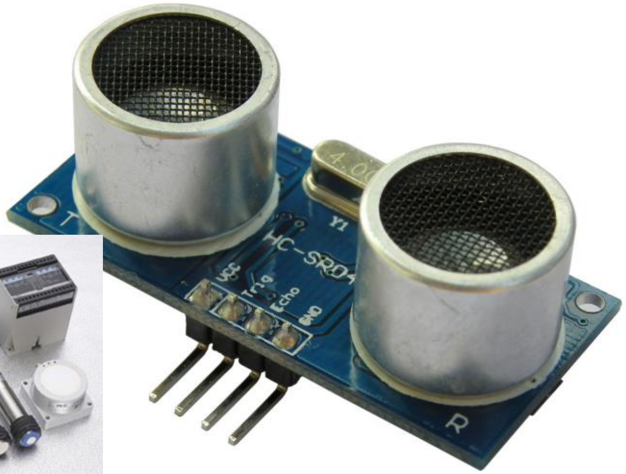
Important issues for vision:

- Lighting. Vision systems will act differently during sunny & cloudy days, night & day, etc.
- MUST have stable lighting that does NOT affect results during different conditions.
- The camera MUST be fixed such that it will NOT move from this position: when translating coordinate system this will have enormous impact.

Auditive sensing

Ultrasonic sensors are the major type in this category.





Auditive/Ultrasonic

These sensors can be static or scanned sideways for obstacle detection, and 2-3 of them together can form accurate "pictures" of surroundings.

Other forms: proximity, distance sensing.

Actuators

Hardware devices that convert a controller command signal into a change in a physical parameter □

- The change is usually mechanical (e.g., position or velocity) □
- An actuator is a transducer because it changes one type of physical quantity into some alternative form □
- An actuator is usually activated by a low-level command signal, so an amplifier may be required to provide sufficient power to drive the actuator

Types of actuators

1. Electrical actuators
   A. Electric motors
      1. DC servomotors
      2. AC motors
      3. Stepper motors
   B. Solenoids
2. Hydraulic actuators : use hydraulic fluid to amplify the controller command signal
3. Pneumatic actuators: use compressed air as the driving force

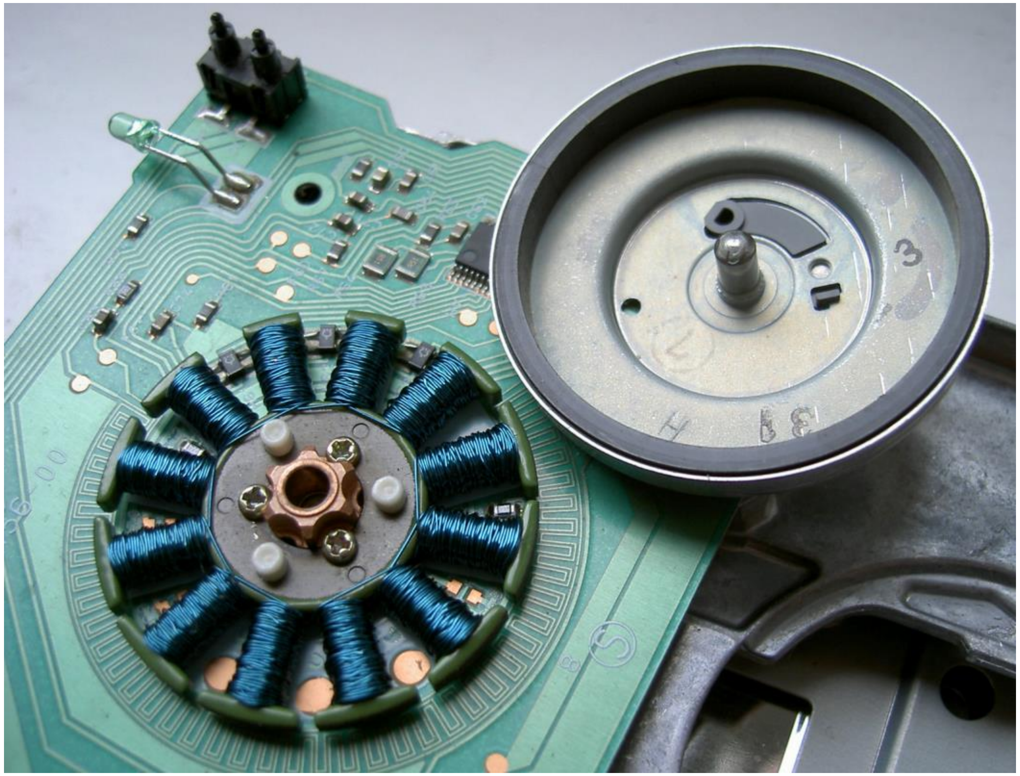
Electrical – DC servo motors, brushless

These come in a large variety of sizes.

The important issue is to have the ENCODER integrated within the motor. See figure.

Electrical – DC servo motors, stepper

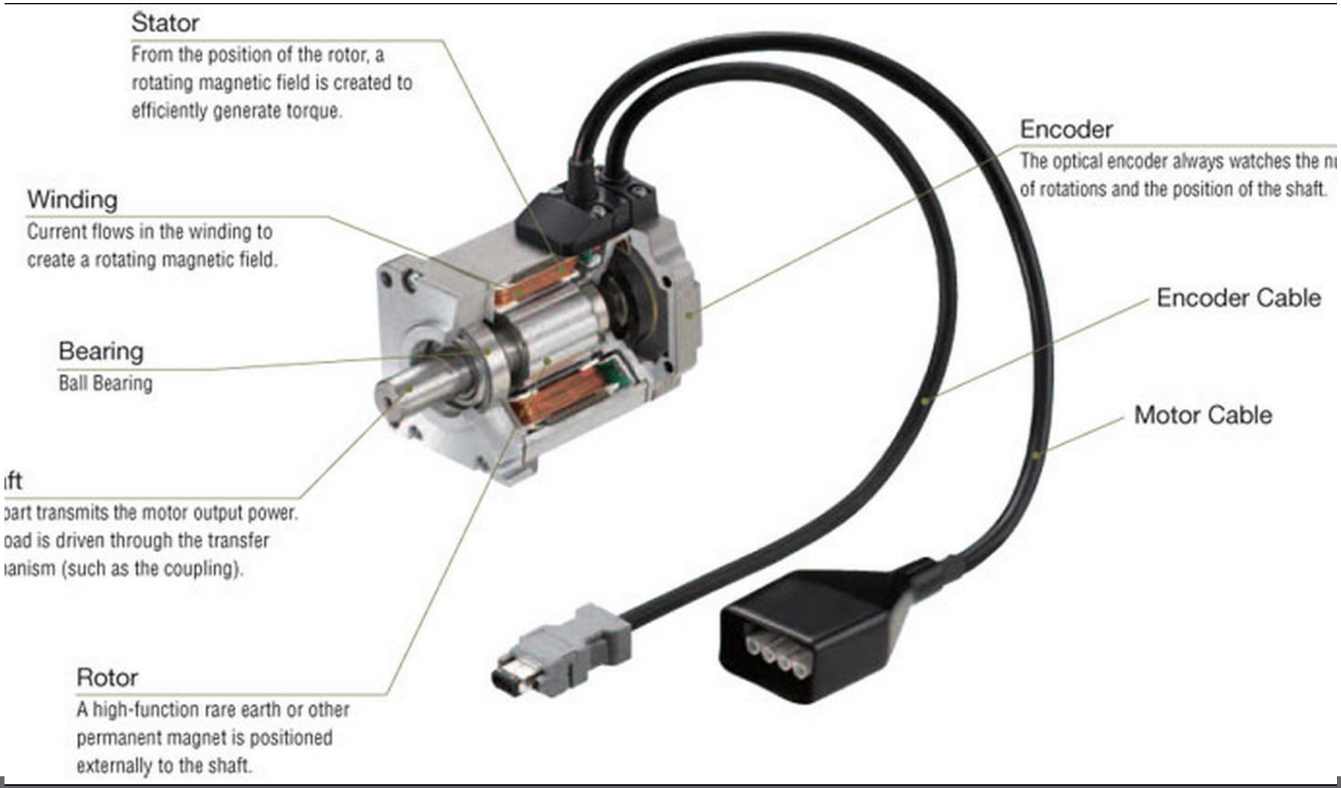
Brushless motors may be described as stepper motors; however, the term stepper motor tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position.



STEPPER motors are DC servos that move to pre-determined positions, or “steps”.

Electrical – AC servo motors, brushless

Brushless motors offer several advantages over brushed DC motors, including high torque to weight ratio, more torque per watt (increased efficiency), increased reliability, reduced noise, longer lifetime.



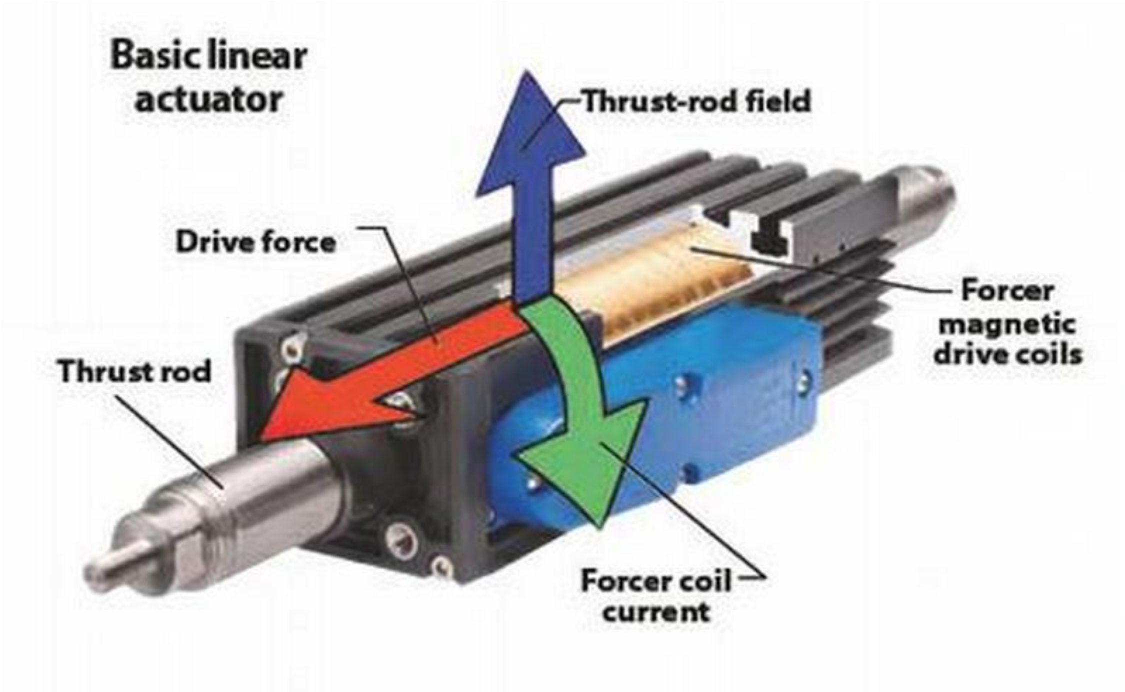
Hydraulic actuators

These actuators exhibit very high strength/force and are to used where large payloads are handled.

Hydraulic actuators do NOT have a linear response and are slower at reaching nominal strength.

Pneumatic actuators

Extremely common now: easy to control, light-weight and have rapid response times. Also linear response.



Fixtures

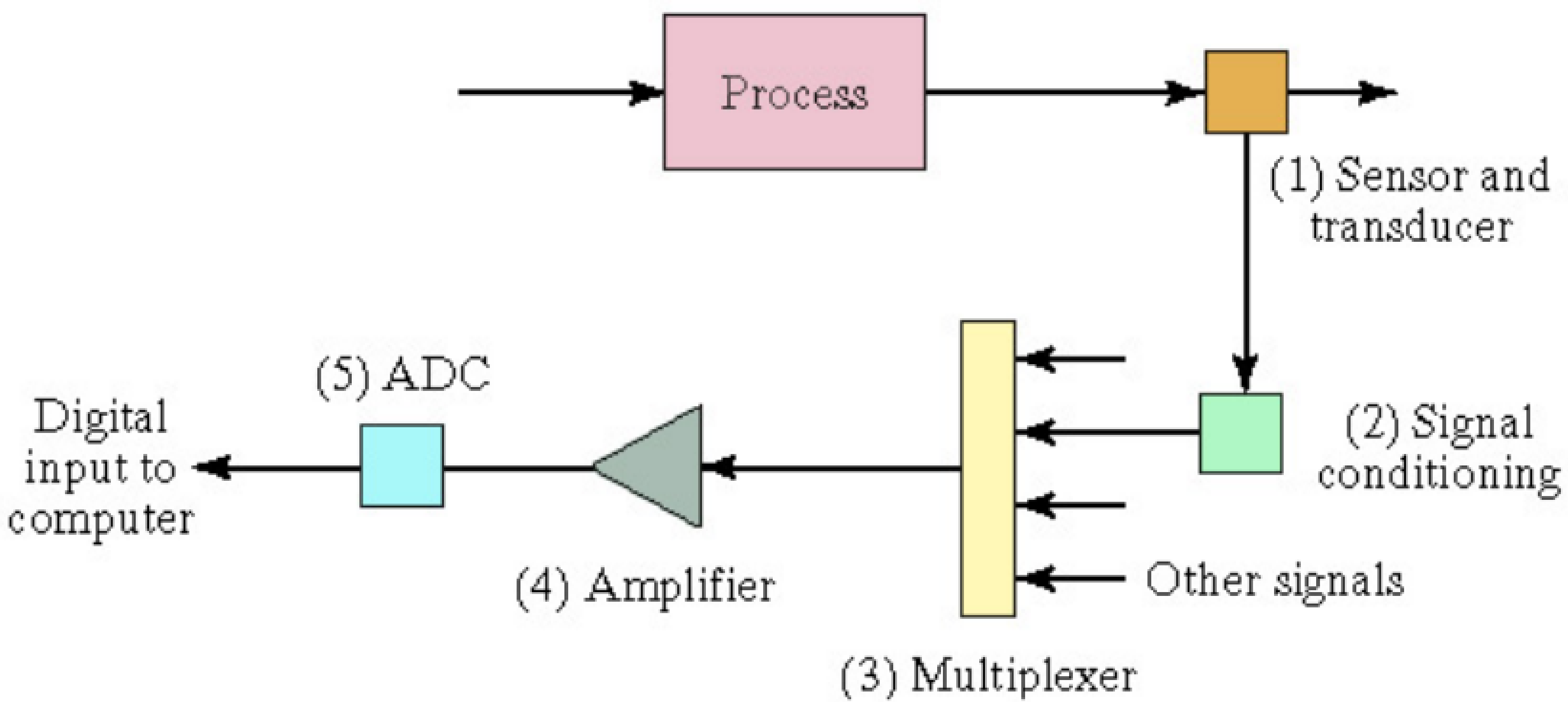
Analog-to-Digital Conversion

An ADC converts a continuous analog signal from transducer into digital code for use by computer □

ADC consists of three phases:

- *Sampling* – converts the continuous signal into a series of discrete analog signals at periodic intervals
- *Quantization* – each discrete analog is converted into one of a finite number of (previously defined) discrete amplitude levels
- *Encoding* – discrete amplitude levels are converted into digital code

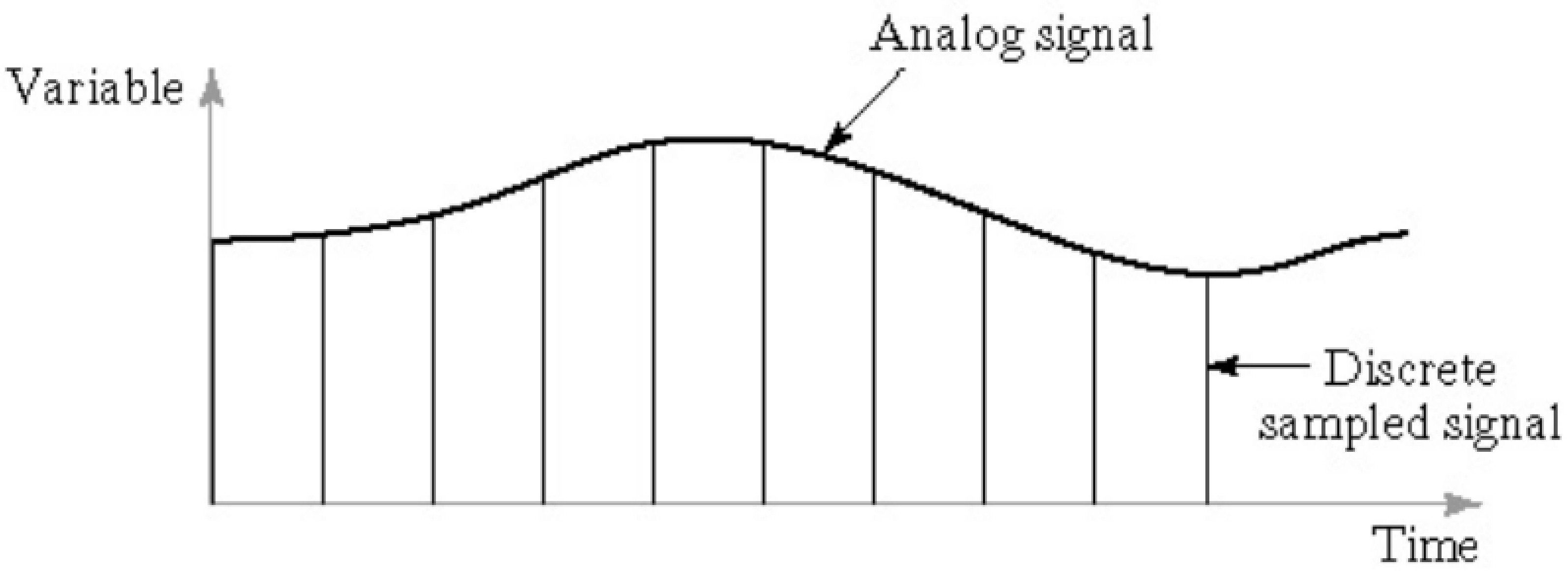
Hardware Devices in Analog-to-Digital Conversion



Feature of an ADC

- *Sampling rate* – rate at which continuous analog signal is polled □
- *Conversion time* – how long it takes to convert the sampled signal to digital code □
- *Resolution* – depends on number of quantization levels □
- *Conversion method* – means by which analog signal is encoded into digital equivalent □

Analog Signal Converted into a Series of Discrete Data by A-to-D Converter

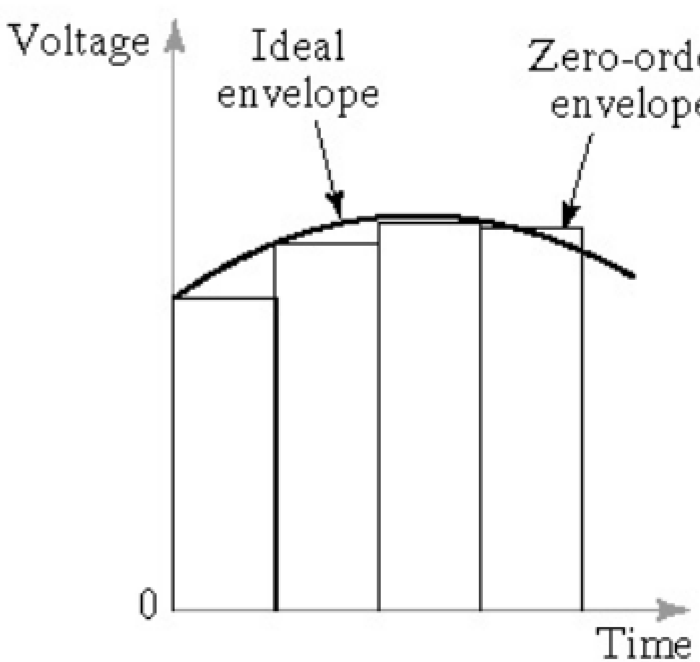


Digital-to-Analog Conversion

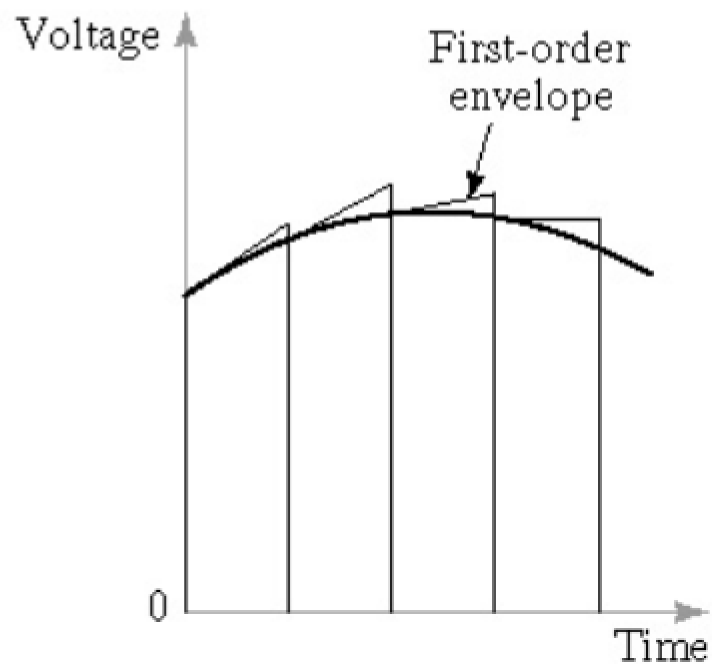
Converts the digital output of the computer into a continuous analog signal to drive an analog actuator (or other analog device) □

- DAC consists of two steps:
    1. *Decoding* – digital output of computer is converted into a series of analog values at discrete moments in time
    2. *Data holding* – each successive value is changed into a continuous signal that lasts until the next sampling interval

Data Holding Step in DAC



(a) Zero Order Hold



(b) First-Order Hold

Input/Output Devices for Discrete Data

Binary data: □

- Contact input interface – input data to computer □
- Contact output interface – output data from computer

Discrete data other than binary: □

- Contact input interface – input data to computer □
- Contact output interface – output data from computer

Pulse data: □

- Pulse counters - input data to computer □
- Pulse generators - output data from computer

Contact Input/Output Interfaces

Contact input interface – series of contacts that are open or closed to indicate the status of individual binary devices such as limit switches and valves □

- The computer periodically scans the contacts to update values in memory □
- Can also be used for discrete data other than binary (e.g., a photoelectric sensor array)

Contact output interface – communicates on/off signals from the computer to the process □

- Values are maintained until changed by the computer

Pulse Counters and Generators

Pulse counter – converts a series of pulses (pulse train) into a digital value □

- Digital value is then entered into the computer through its input channel □
- Most common – counting electrical pulses
- Used for both counting and measurement applications

Pulse generator – a device that produces a series of electrical signals □

- The number of pulses or frequency of the pulse train is specified by the computer

Video

- Cam shaft with force sensor (3:10)
- Artificial Skin - Tactile sensor (3:33)
- Wolf Robotics Tactile Sensing (2:35)
- Ultrasonic Sensors for the Factory Automation Industry (3:25)
- Vision system for part localization in bins for robotic bin-picking (2:46)

Question for the formative assessment

1. Represent graphically a typical computer process control system including all the main component (block) and interaction (arrow)
2. List the different kinds of sensor used for process control and provide some example with descriptions
3. List the different kinds of actuator used for process control and provide some example with descriptions
4. List and describe the phase and features of an ADC
5. List and describe the steps of a DAC