

Seminar on Industrial Automation

Sensors & Actuators:

Sensing & Actuating Devices

Binary Input/Output devices

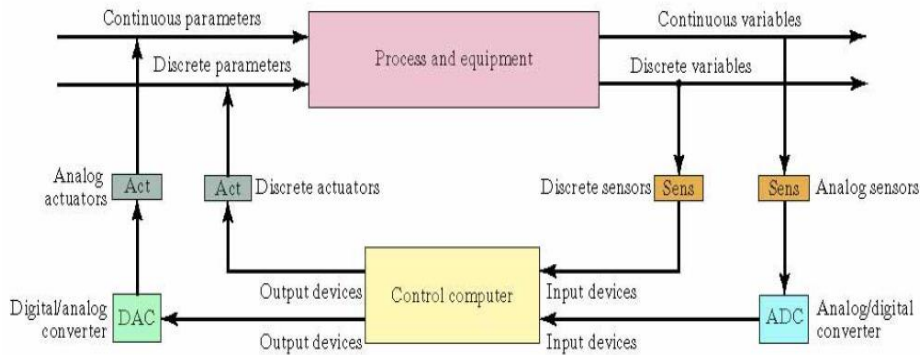
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Sensors and Actuators

Sections:

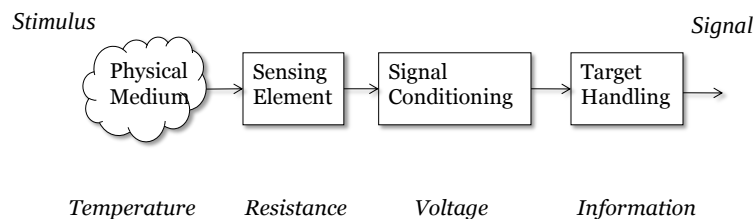
1. Sensors
2. Actuators
3. Input/Output Devices for Discrete Data

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



Sensors

- Two basic categories:
 1. Analog
 2. Discrete
 - Binary
 - Digital (e.g., pulse counter)



Touch



Sound
(db pressure)



Ultrasonic
(distance)



Light
(light intensity)

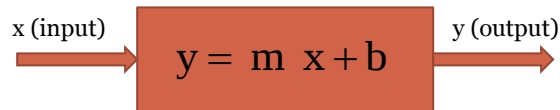
Other Sensors

- Temperature
- Level
- Pressure
- Flow
- Proximity
- Position
- Speed
- Tilt/Acceleration
- Vision
- etc.



Analog Sensors

The ideal functional form for an analogue measuring device is a simple proportional relationship, such as:



where b = output value at a stimulus value of zero
and m = constant of proportionality (sensitivity)

For binary sensors: $y = 1$ if $x > 0$ and $y = 0$ if $x \leq 0$

Example

- The output voltage of a particular thermocouple sensor is registered to be 42.3 mV at temperature 105°C.
- It emit zero voltage at 0°C, Since an output/input relationship exists between the two temperatures, determine:
 - (1) the transfer function of the thermocouple
 - (2) the temperature corresponding to a voltage of 15.8 mV

Solution

$$y = mx + b$$

$$42.3 \text{ mV} = 0 + m(105^\circ\text{C}) = m(105^\circ\text{C})$$

$$\text{or } m = 0.4 \text{ mV} / ^\circ\text{C}$$

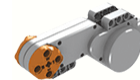
$$y = 0.4 x$$

$$15.8 \text{ mV} = 0.4 x$$

$$x = 15.8 / 0.4$$

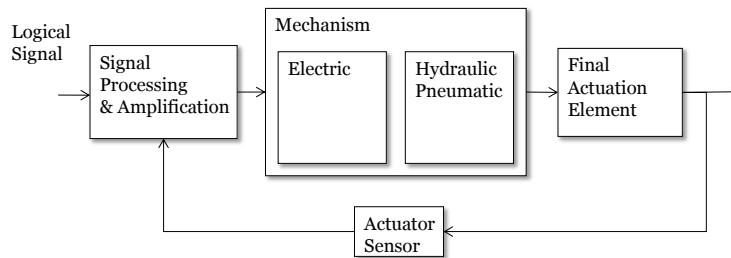
$$x = 39.22 ^\circ\text{C}$$

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 also 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

Actuators



Types of Actuators

1. Electrical actuators

- Electric motors
 - DC servomotors
 - AC motors
 - Stepper motors
- Solenoids

2. Hydraulic actuators

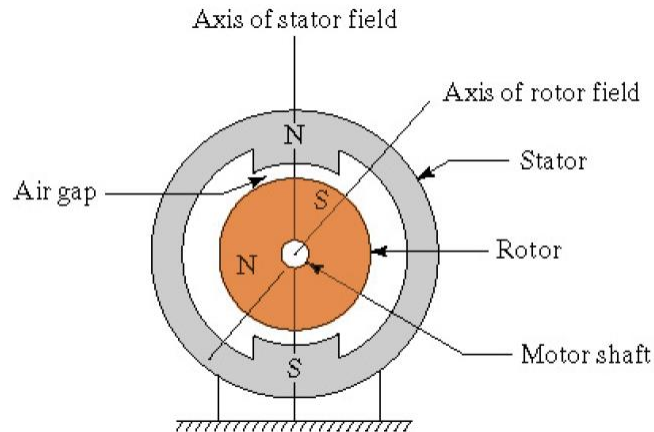
- Use hydraulic fluid to amplify the controller command signal

3. Pneumatic actuators

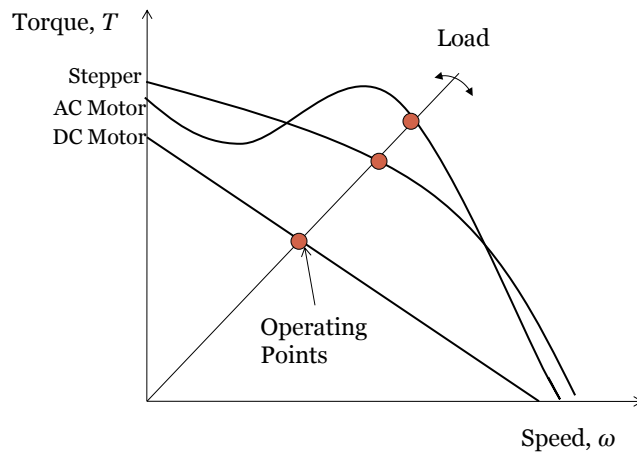
- Use compressed air as the driving force



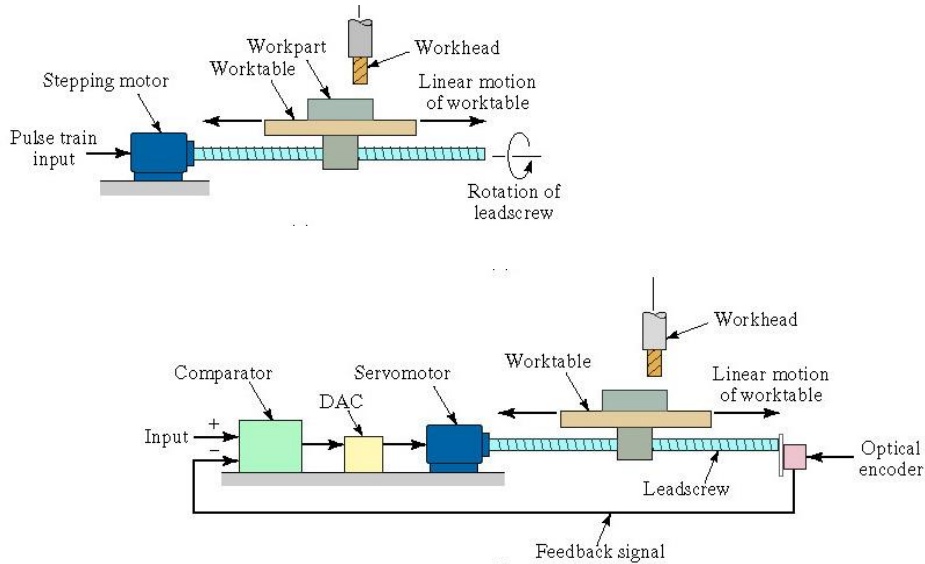
Actuators: a rotating electric motor



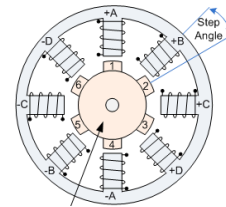
Torque-Speed Curve of Electric Motors



Stepper motor and Servomotor



Stepper Motors



Step angle is given by: $\alpha = \frac{360}{n_s}$

where n_s is the number of steps for the stepper motor (integer)

Total angle through which the motor rotates (A_m) is given by: $A_m = n_p \alpha$
 where n_p = number of pulses received by the motor.

Angular velocity is given by: $\omega = \frac{2\pi f_p}{n_s}$ where f_p = pulse frequency

Speed of rotation is given by: $N = \frac{60 f_p}{n_s}$

Example

- A stepper motor has a step angle = 3.6°
 - (1) How many pulses are required for the motor to rotate through ten complete revolutions?
 - (2) What pulse frequency is required for the motor to rotate at a speed of 100 rev/min?

Solution

$$\alpha = \frac{360}{n_s}$$

(1) $3.6^\circ = 360 / n_s$; $3.6^\circ (n_s) = 360$; $n_s = 360 / 3.6 = 100$ step angles

$$A_m = n_p \alpha$$

(2) Ten complete revolutions: $10(360^\circ) = 3600^\circ = A_m$
Therefore $n_p = 3600 / 3.6 = 1000$ pulses

$$N = \frac{60 f_p}{n_s}$$

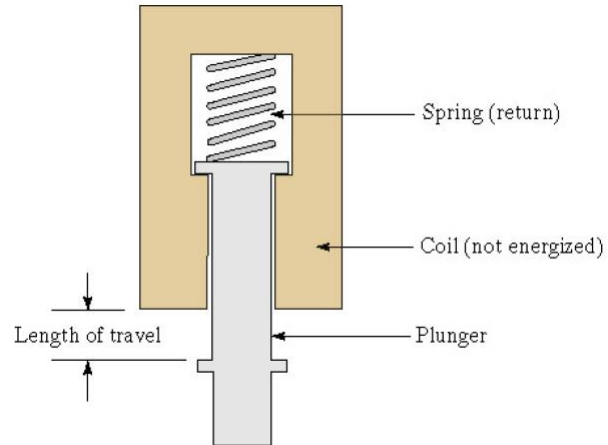
Where $N = 100$ rev/min:

$$100 = 60 f_p / 100$$

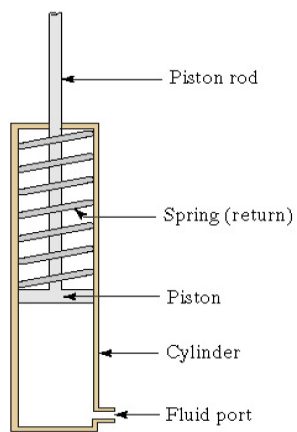
$$10,000 = 60 f_p$$

$$f_p = 10,000 / 60 = 166.667 = 167 \text{ Hz}$$

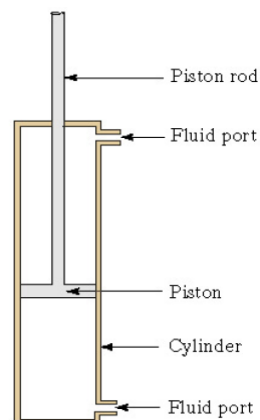
Actuators: Solenoid



Actuators: cylinder and piston



Single-acting



Double-acting

Input/output devices for discrete data

- Contact input interface (Data input to controller)
 - 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 (Data output from controllers)
 - Communicates on/off signals from the controllers to the actuators and the process
 - Values are maintained until changed by the controller

Input/output devices for discrete data

- Binary data:
 - Discrete inputs to connect binary sensors
 - Discrete outputs to energize binary actuators
- Discrete data other than binary:
 - Cam switches
- Pulse data:
 - Pulse counters
 - Pulse generators

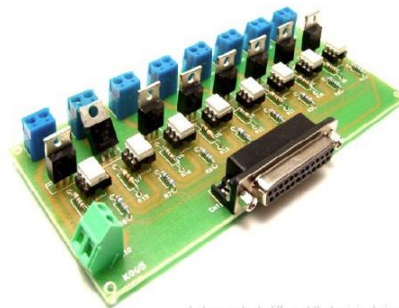


photo may look different than original circuit

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

Bibliography

- *Automation, Production Systems, and Computer-Integrated Manufacturing, Third Edition, by Mikell P. Groover, Third Edition, Prentice Hall, 2008*