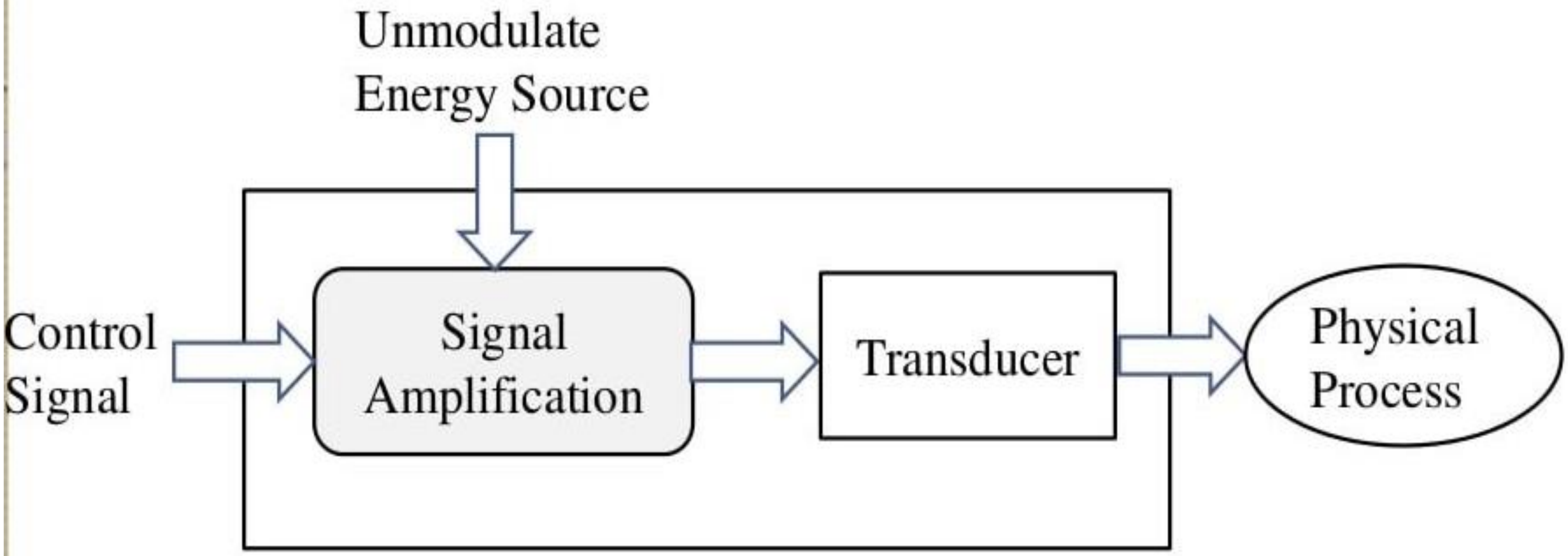
Actuators

What is An Actuator?

- Devices used to produce action or motion
- Operated by source of energy(mainly electrical signal, air, fluids) and converts that energy into motion.
- It is a mechanism by which a control system acts upon environment
- Actuator's output is usually mechanical i.e. linear displacement or velocity
- Actuation can be from few microns to few meters

Actuator – Functional Diagram



Attributes

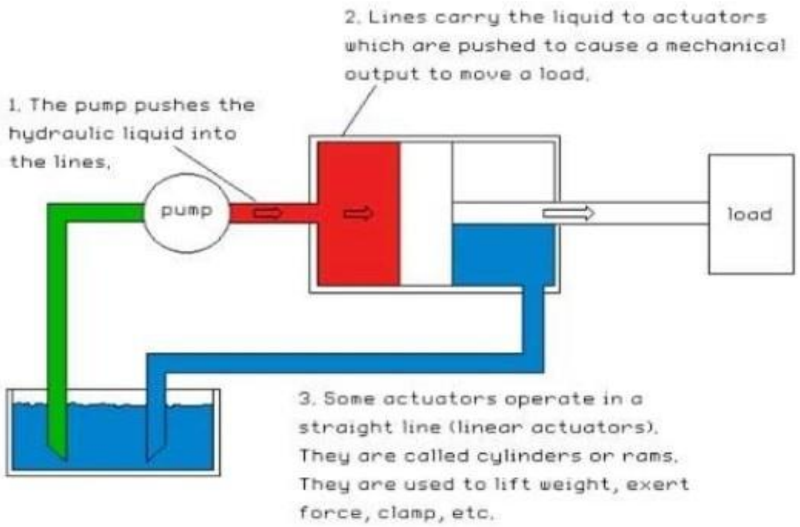
- Size of operating forces and torques
- Operating environment
- Linear or rotational movement
- Energy source
- Speed of response and motion
- Degree of precision

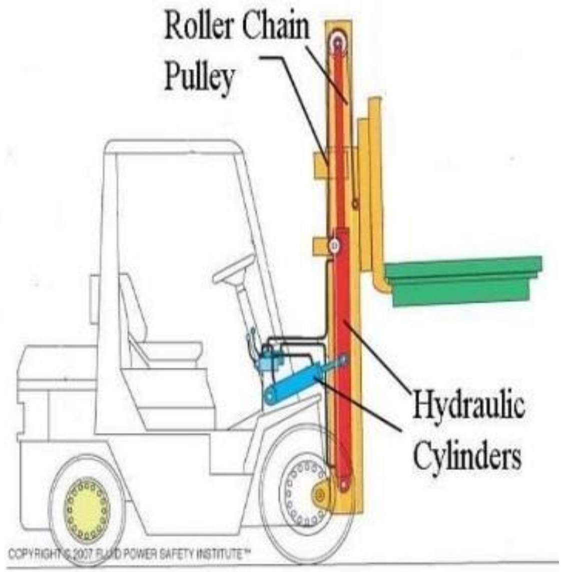
Types of Actuators

- Hydraulic
- Pneumatic
- Mechanical
- Electrical
- Piezoelectric
- Thermal/Magnetic

Hydraulic Actuators

- Consists of cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation
- Mechanical motion gives output in terms of linear, rotary or oscillatory motion
- Pump driven by prime mover (electric motor) creates flow of fluids





Types of Hydraulic Actuator

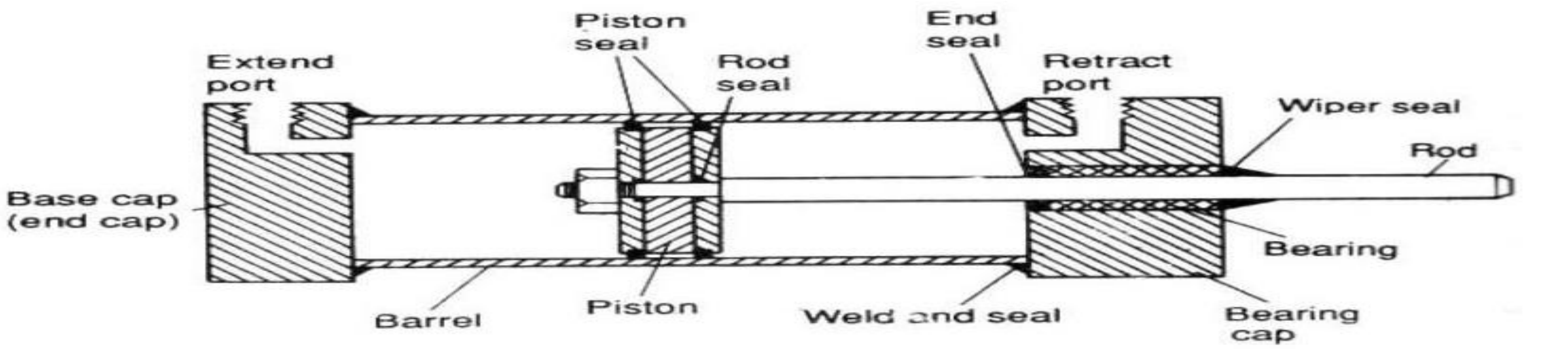
- Linear actuator (hydraulic cylinder)
  - Provides motion in straight line
  - Linear displacement depends on stroke length
  - Usually referred to as cylinders rams (single acting cylinders) or jacks
- Rotary actuators (hydraulic Motors)
  - Produces continuous rotational motion
  - Pump shaft is rotated to generate flow
  - Motor shaft is caused to rotate by fluid being forced into driving Chambers

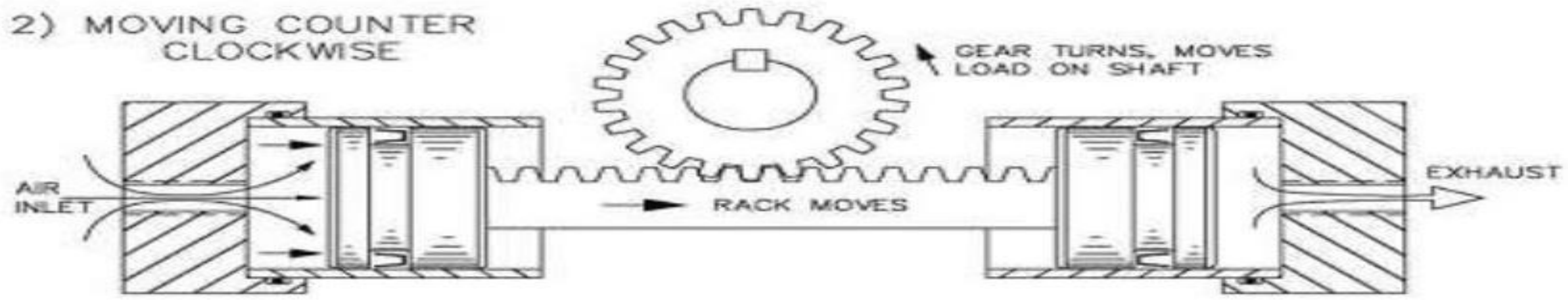
Applications of Hydraulic Actuators

- Hydraulic Jack
- Hydraulic brake
- Hydraulic ram
- Used as sensor
    - closed loop velocity controlling
    - highly precise positioning for heavy loads

Pneumatic actuator

It converts high pressure energy of compressed air into either linear or rotary motion quickly respond in operation

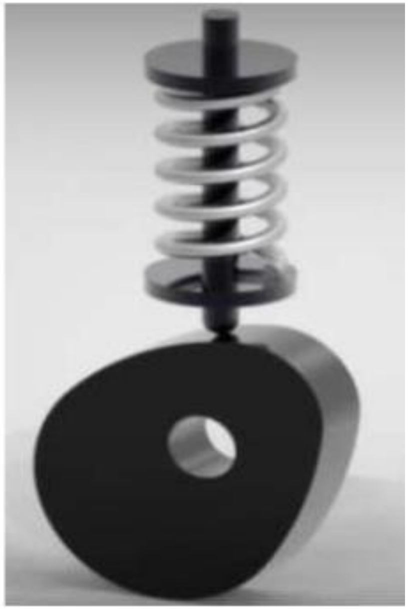




Pneumatic actuator

- like hydraulic except power from compressed air
- fast on/off type tasks
- big forces with elasticity
- no leak problems

Mechanical actuator



Mechanical linear actuators typically operate by conversion of rotary motion into linear motion

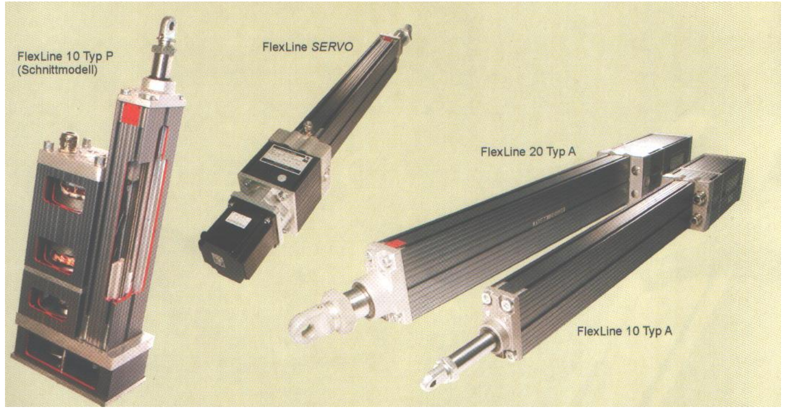
Examples:

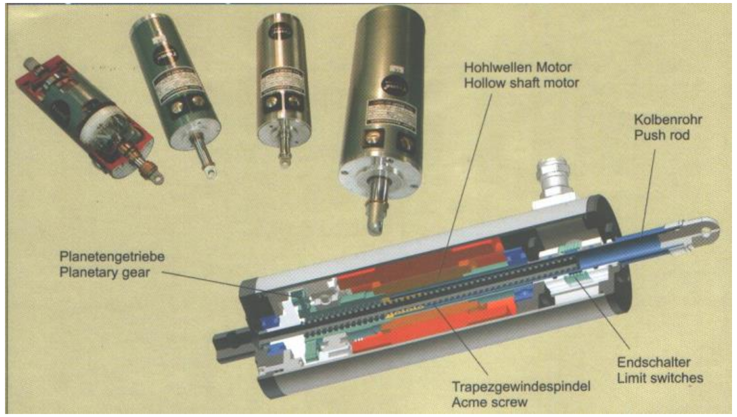
- Screw Jack
- Wheel and axle
- Cam

Electrical Actuator

- Electric actuator is actuated by motor that converts electrical energy into mechanical torque

  - easy to control
  - normally high velocities 1000 - 10000 rpm
  - several types
  - accurate servo control
  - ideal torque for driving
  - excellent efficiency
  - autonomous power system difficult



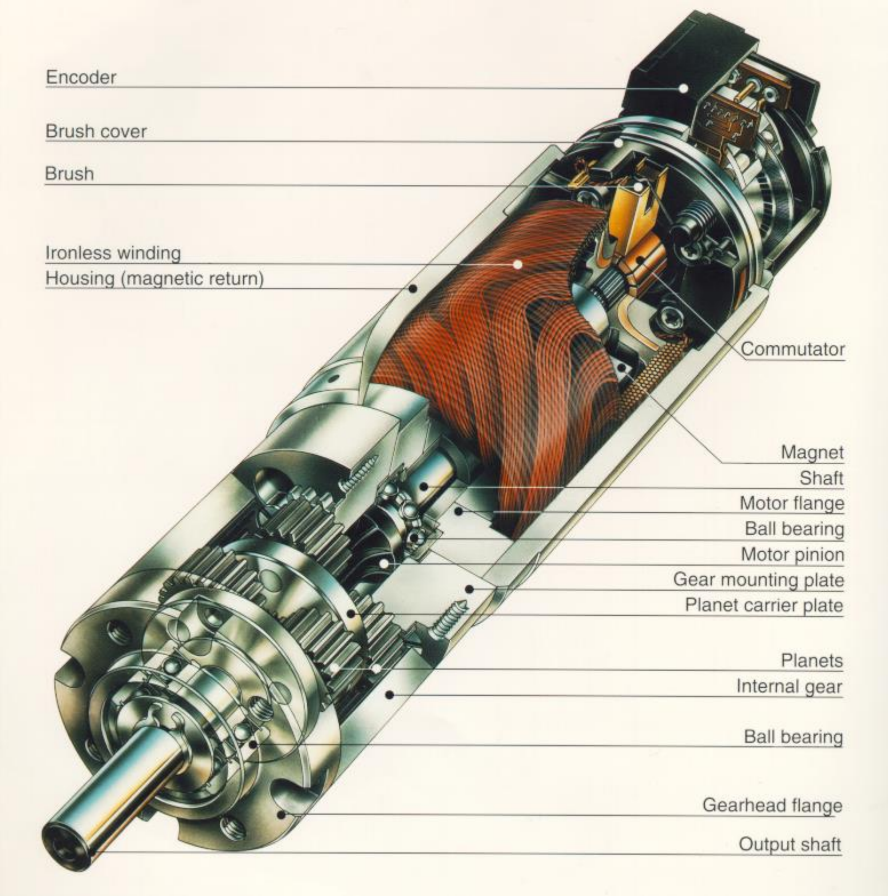


Electrical Actuator Types

- DC-motors
- brushless DC-motors
- asynchronous motors
- synchronous motors
- reluctance motors (stepper motors)

DC-Motors

- simple, cheap
- easy to control
- 1W - 1kW
- can be overloaded
- brushes wear
- limited overloading on high speeds



Brushless DC-Motors

- no brushes → no wearing parts → high speeds
- coils on cover => better cooling
- excellent power/weight ratio
- simple
- needs both speed and angle feedback
- more complicated controller
- From small to medium power (10W – 50kW)

Asynchronous Motors

- very simple, very popular in industry
- 0.5kW - 500kW
- More difficult to control (frequency)
- nowadays as accurate control as DC-motors
- In mobile machines also (5kW →)

Synchronous Motors

- usually big 100 kW - XXMW
- also small ones ~ brushless DC-motors from 50W to 100 kW
- controlled like as-motors (frequency)
- ships
- industry
- Mobile machines

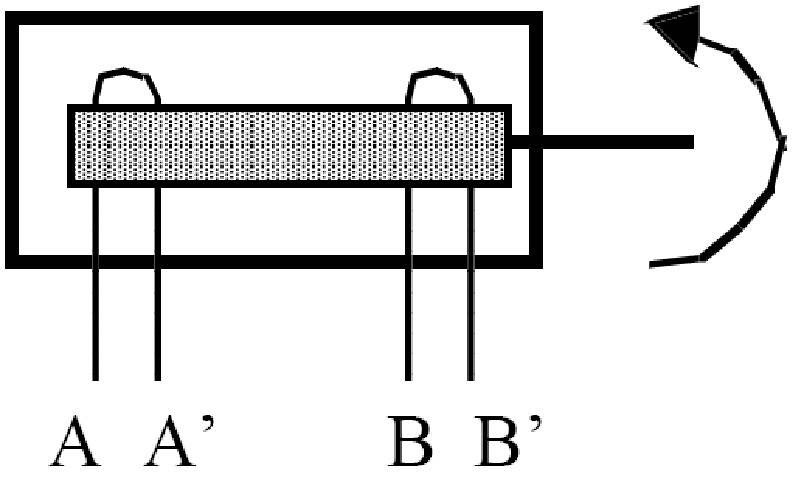
Reluctance (Stepper) Motors

- angle control
- slow
- usually no feedback used
- accurate positioning
- with out feedback not servos
- easy to control

Stepper Motors

- Stepper motors are another kind of motors that do not require feedback
- A stepper motor can be incrementally driven, one step at a time, forward or backward
- Stepper motor characteristics are:
  - Number of steps per revolution (e.g. 200 steps per revolution = 1.8° per step)
  - Max. number of steps per second ("stepping rate" = max speed)
- Driving a stepper motor requires a **4 step switching sequence** for *full-step mode*
- Stepper motors can also be driven in **8 step switching sequence** for *half-step mode* (higher resolution)
- Step sequence can be very fast, the resulting motion appears to be very smooth

Stepper Motors



Using two independent coils on motor shaft

Full Step Sequence

Step	A	A'	B	B'
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF

Clockwise rotation: 1,2,3,4,1,2,3,4,..

Counterclockwise: 4,3,2,1,4,3,2,1,..

Pulse-Width Modulation

- **How does this work?**
  - We do not change the supplied voltage
  - Power is switched on/off at a certain pulse ratio matching the desired output power
- Signal has very high frequency (e.g. 20kHz)
- Motors are relatively slow to respond
  - The only thing that counts is the supplied power
  - ⇒ **Integral** (Summation)
- Pulse-Width Ratio = t_{on} / t_{period}

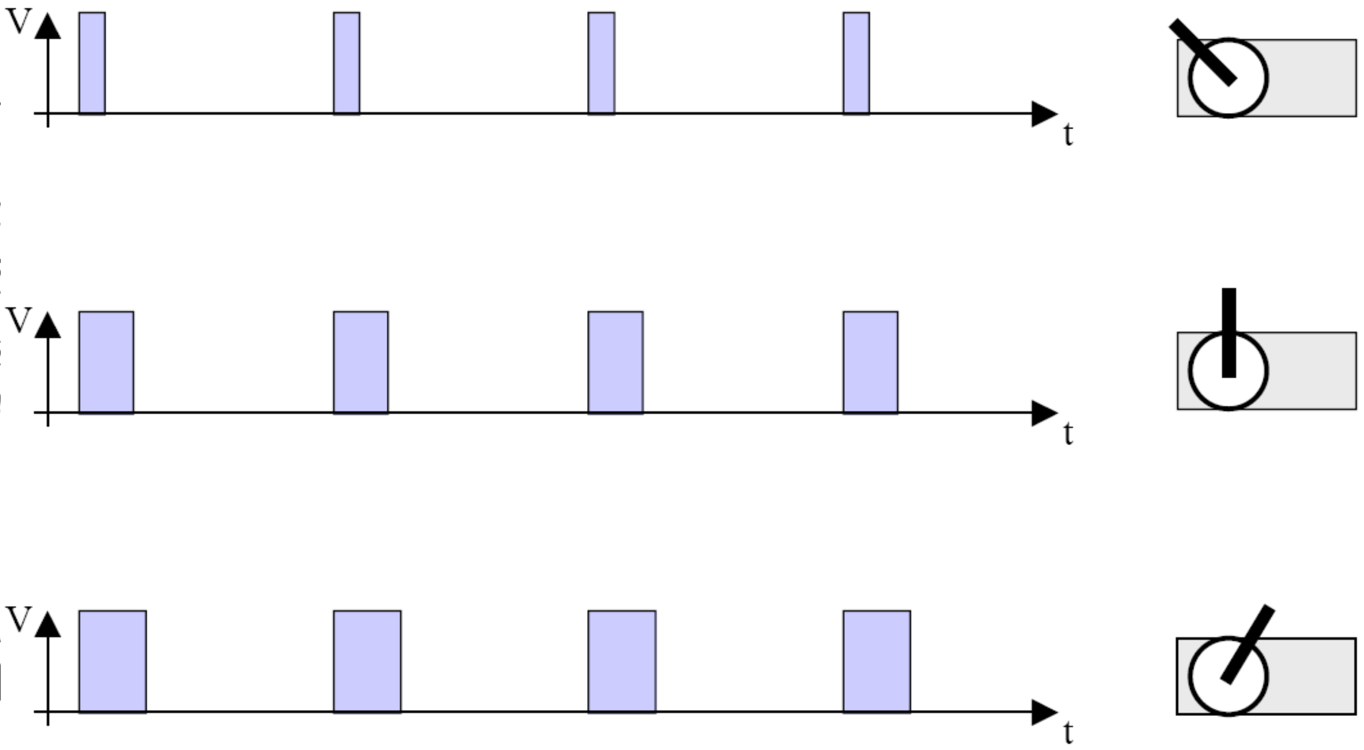
Servos

Photos: HiTec

- A servo is a unit combining motor and simple feedback electronics for position control
- A servo is set by supplying a PWM signal of a certain ratio
- Ratio determines servo position, not speed!
- Servos are usually used in model airplanes, etc.

Bräunl 2004

Servos



- Servos usually have three cables: pc
- Servos require a PWM signal with 5
- The pulse should be between 0.5 ms
  this sets the servo to its extreme left or righ

Remember:

- Servo speed cannot be set
  servo tries to get to new position as fast as
- Servos do not provide feedback to tl

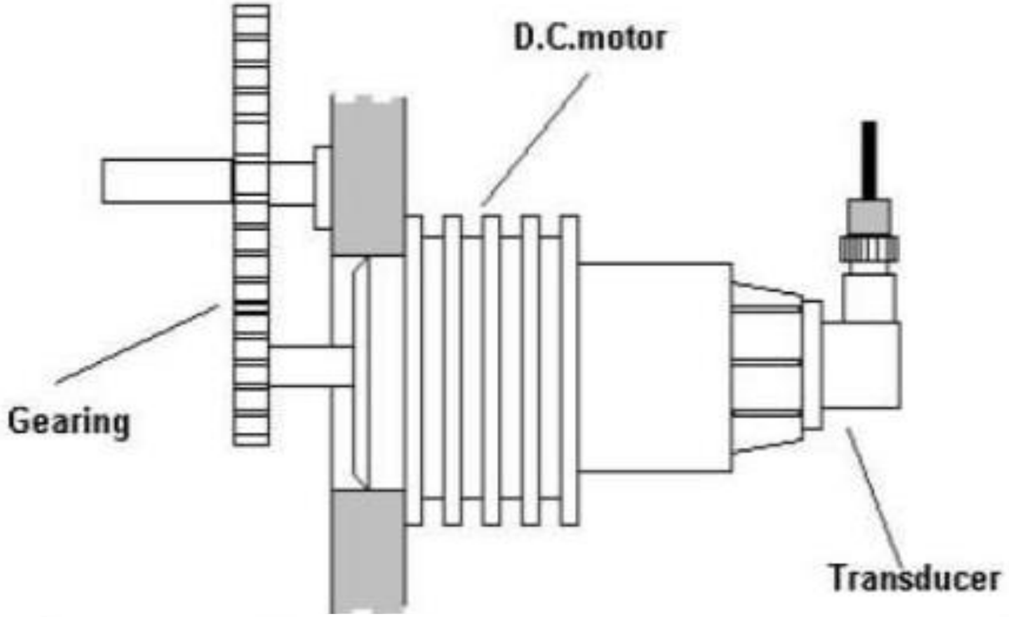
Servos

- Terminology:
- Do not confuse “servos” with “servo motors”
- DC motors (brushed or brushless) are also sometimes also referred to as “servo motors”
  - See: http://www.theproductfinder.com/motors/bruser.htm
- “So when does a motor become a servo motor? There are certain design criteria that are desired when building a servo motor, which enable the motor to more adequately handle the demands placed on a closed loop system.
- First of all, servo systems need to rapidly respond to changes in speed and position, which require high acceleration and deceleration rates.
- This calls for extremely high intermittent torque.

Servos

- As you may know, torque is related to current in the brushed servo motor.
- So the designers need to keep in mind the ability of the motor to handle short bursts of very high current, which can be many times greater than the continuous current requirements.
- Another key characteristic of the brushed servo motor is a high torque to inertia ratio.
- This ratio is an important factor in determining motor responsiveness.
- Further, servo motors need to respond to small changes in the control signal.
- So the design requires reaction to small voltage variations."

DC Servo Motor



- Any electrical motor can be utilized as servo motor if it is controlled by servomechanism. Likewise, if we control a DC motor by means of servomechanism, it would be referred as **DC servo motor**.

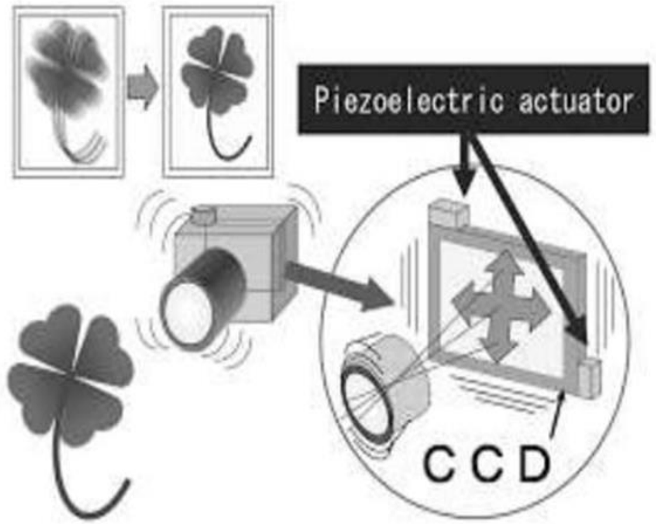
Piezoelectric Actuator

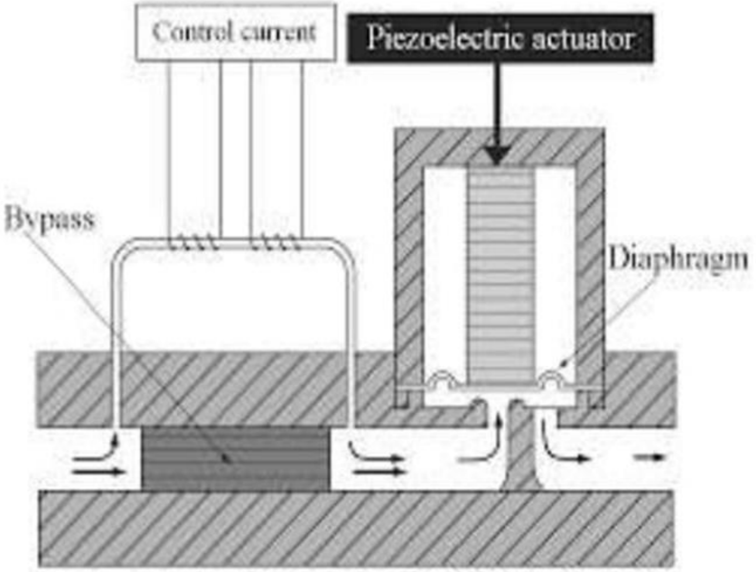
- Piezoelectric actuator is a device that makes use of the inverse piezoelectric effect(generates mechanical energy when subjected to electrical energy)
- Piezoelectric materials are: Quartz, Ceramics, etc.
- Advantages:
  - Short response time
  - Ability to create high forces
  - Higher displacement accuracy
  - High energy efficiency
- Disadvantages:
  - Have small strains(01. to 2 %)
  - High supply voltage needed (60 to 1000V)
  - Large hysteresis (Actuator doesn't go back to exactly where it started)

Applications

Hand blurring correction of digital cameras

Ultra precise mass flow controller





Magnetic Actuator

- These Actuators are actuated by applying thermal or Magnetic energy.
- These use shape memory materials (shape memory alloys or magnetic shape-memory alloys).
- They tend to be compact, lightweight, economical and with high power density.
- MEMS(Micro-Electro-Mechanical Systems) **thermal actuator** where small amount of thermal expansion of one part of the device translates to a large amount of deflection of the overall device.
- A device is considered to be MEMS device if its size is between 0.1 μm and hundreds of micrometers.
- MEMS **Magnetic Actuator** is device that uses microelectromechanical systems (MEMS) to convert an electric current into a mechanical output.

Examples

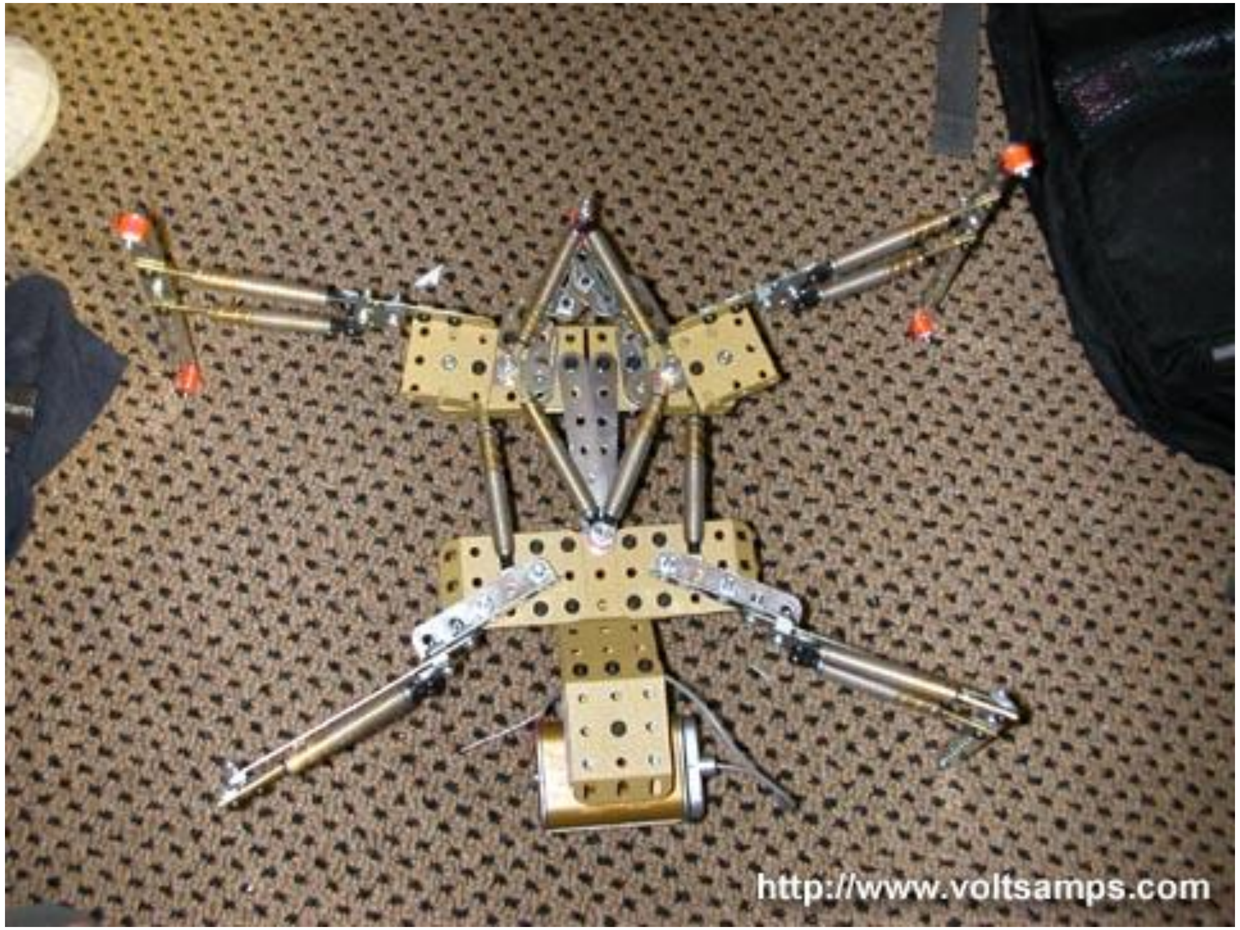

LENS EF 17-40mm 1:4 L USM
17-40mm
17 20 24 28 35 40


http://www.voltsamps.com

Arska

Workpartner

Shape Memory Alloy Robot



Thank you!