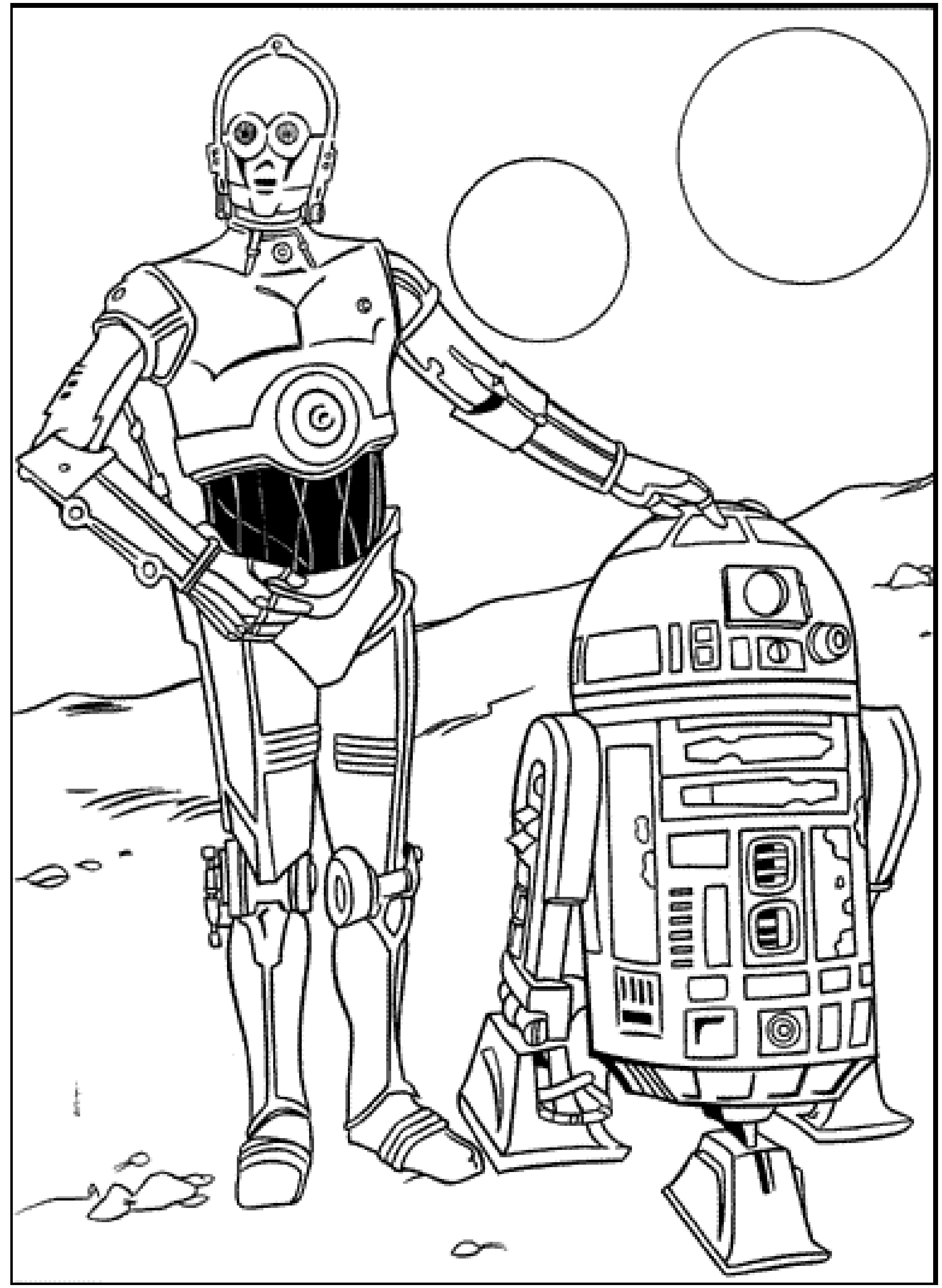
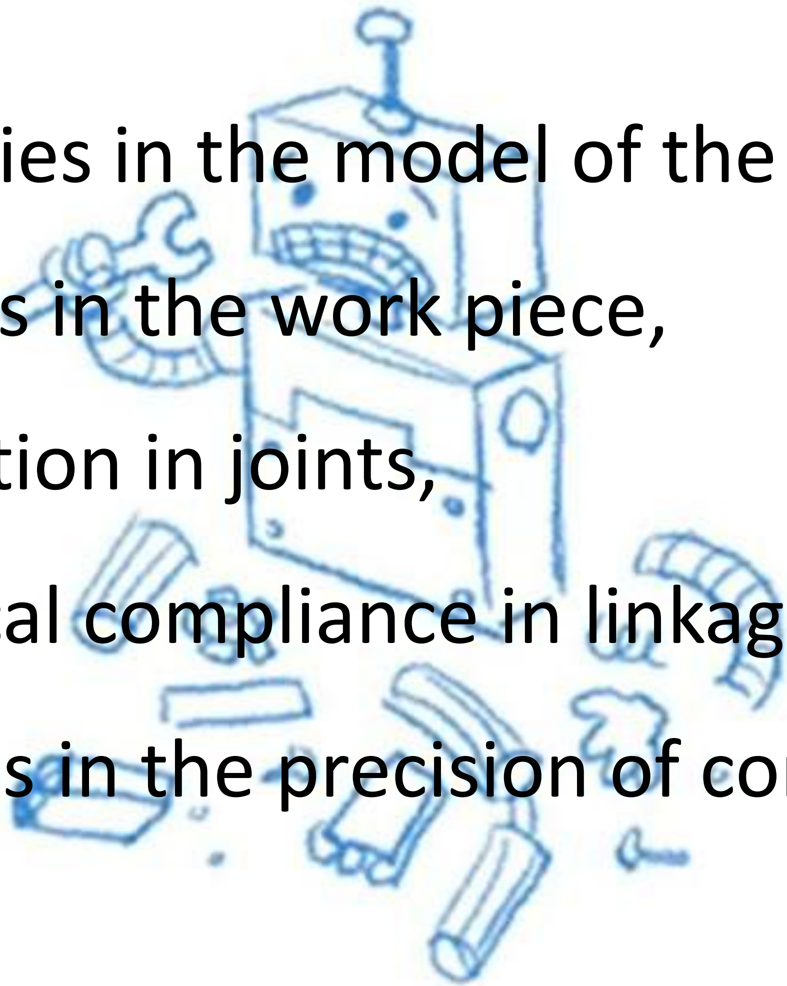
Actuators



Control system

Causes of errors in physical robotic systems



– inaccuracies in the model of the robot,

– tolerances in the work piece,

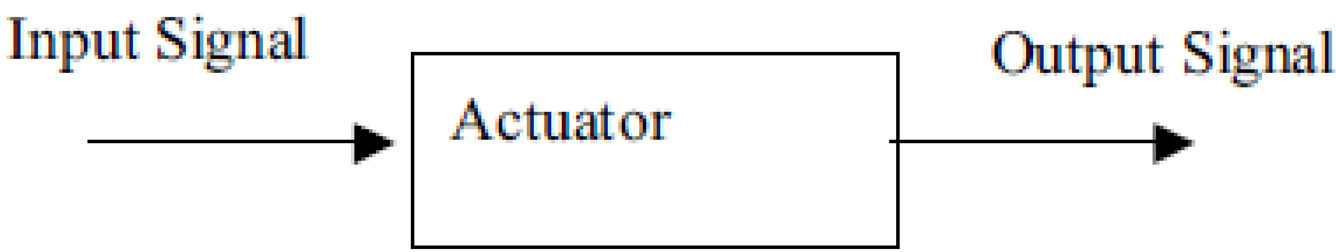
– static friction in joints,

– mechanical compliance in linkages,

– limitations in the precision of computation

Steady state error

Open loop control system



computes its input into a system using only the current state and its model of the system

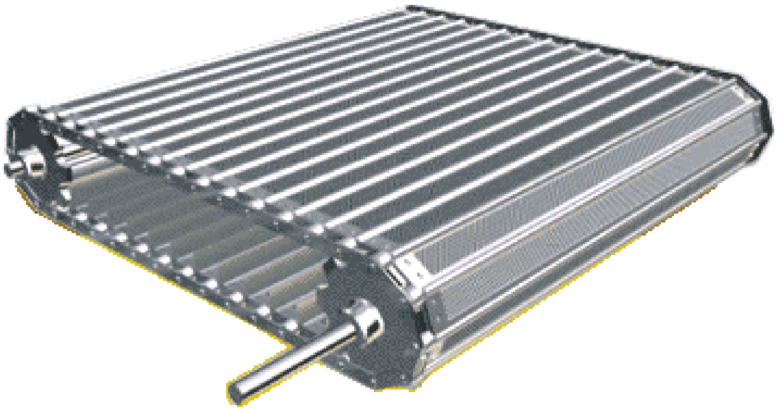
Where it is applicable

Used for "well-defined systems" which have a proper relationship between input and resultant state

Advantage: simplicity and low cost

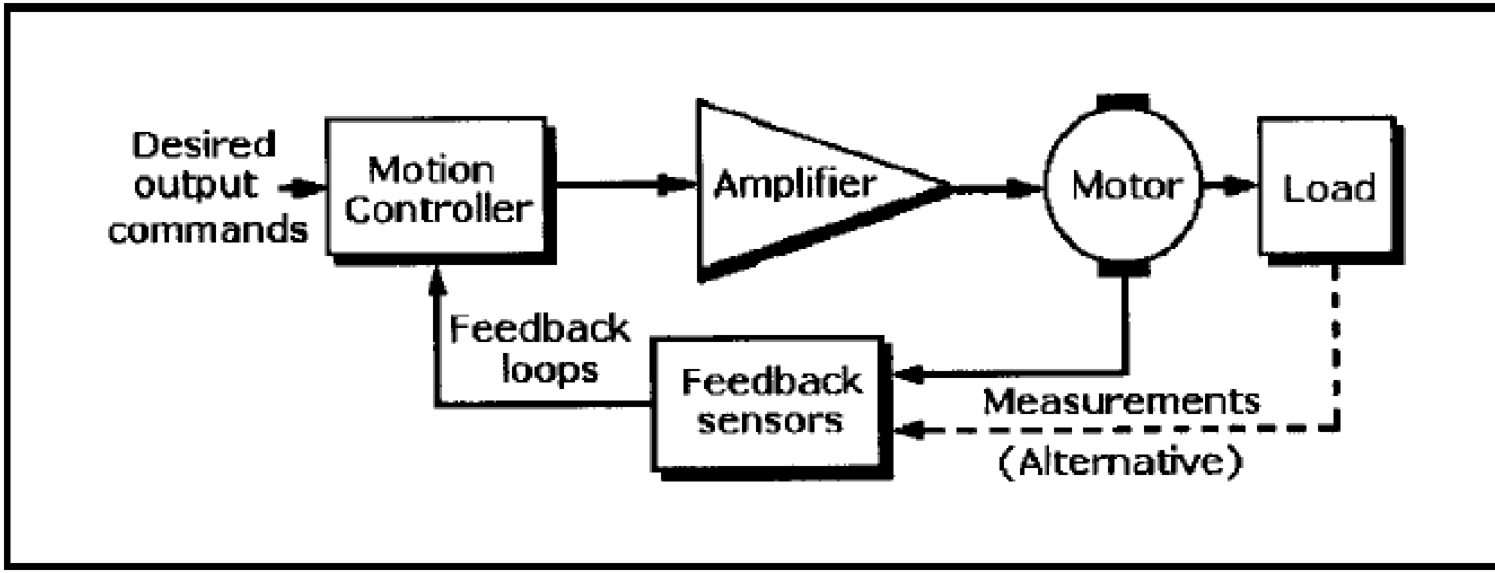
Disadvantage: High SSE (steady state error)

A typical example of an open loop control system can be the voltage being fed to a motor driving a constant load to achieve a constant speed.

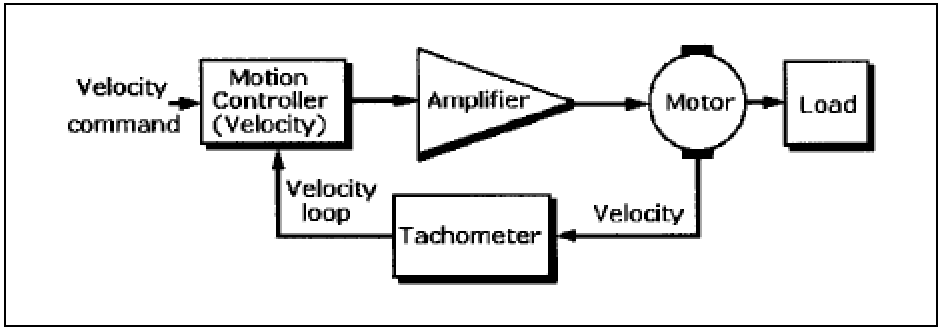


Closed Loop control system

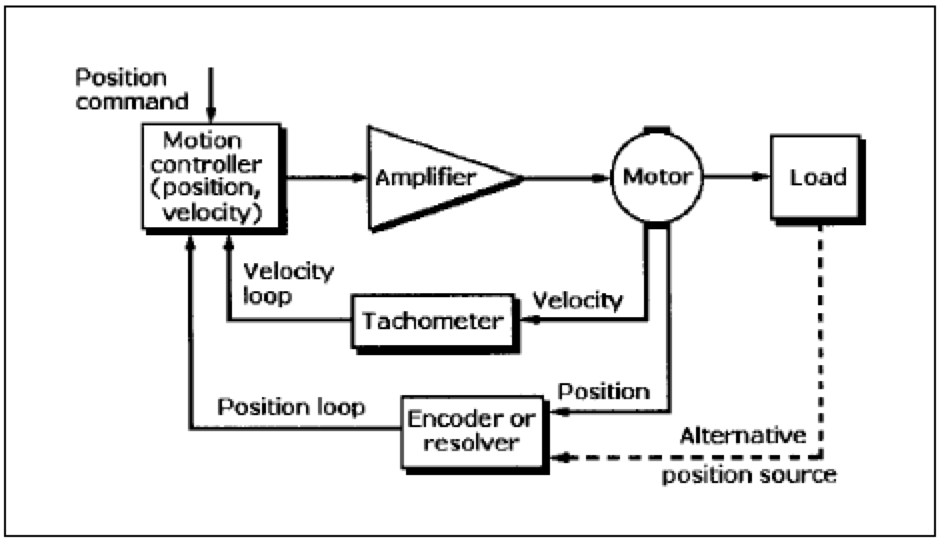
Basic closed loop system



The inverse flowing information is called "feedback"



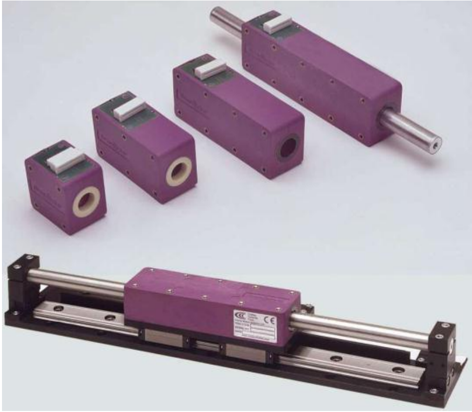
Velocity control loop



Position control loop

Electric Motors

- An **electric motor** is an electromechanical device that converts electrical energy into mechanical energy.
  - –DC Motors
  - –Stepper Motors
  - –Servo Motors
  - –Linear Motors

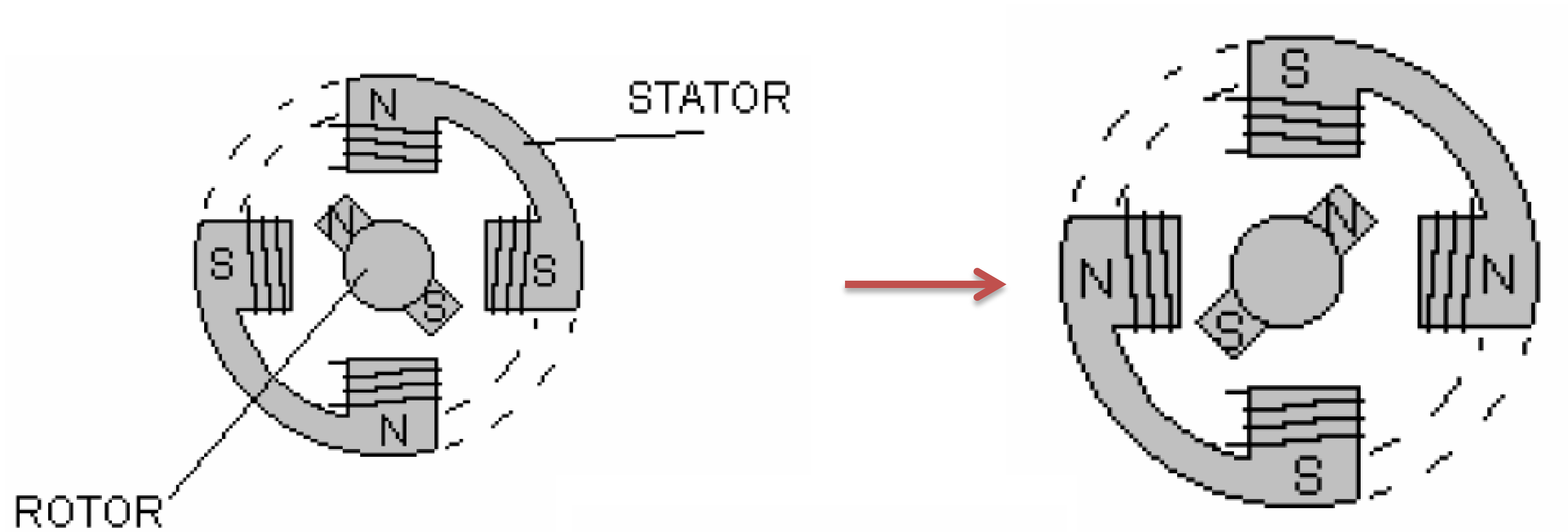


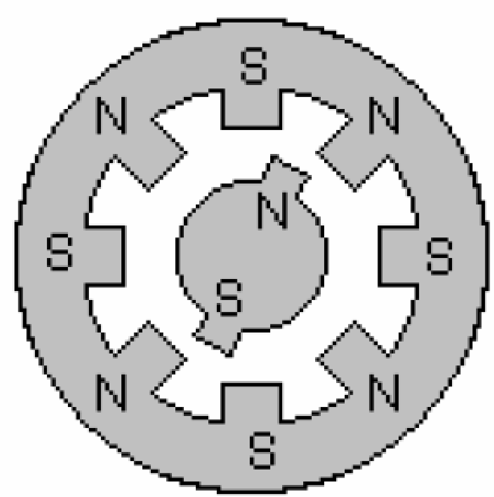
DC Motor

- Designed to work on DC power.

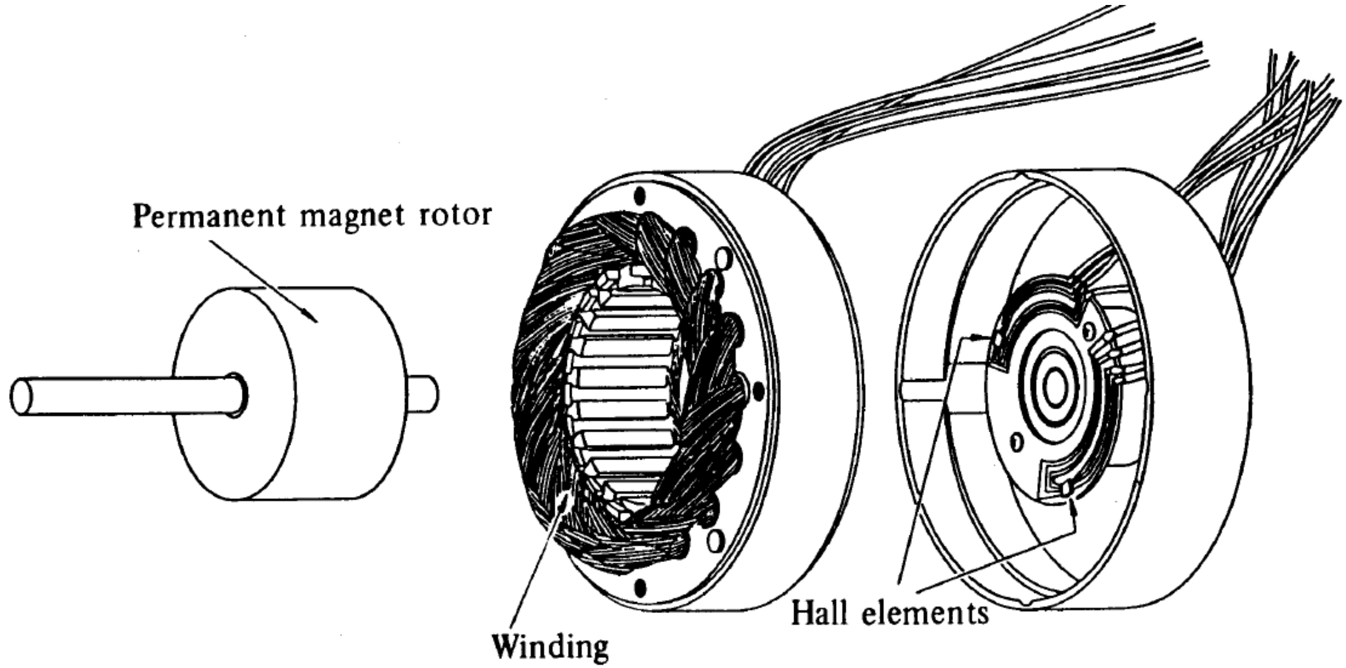
- Mainly of three types :
  - Permanent Magnet Type
  - Brushed DC Motors
  - Brushless DC Motors

Permanent Magnet Motor





Brushless Motor

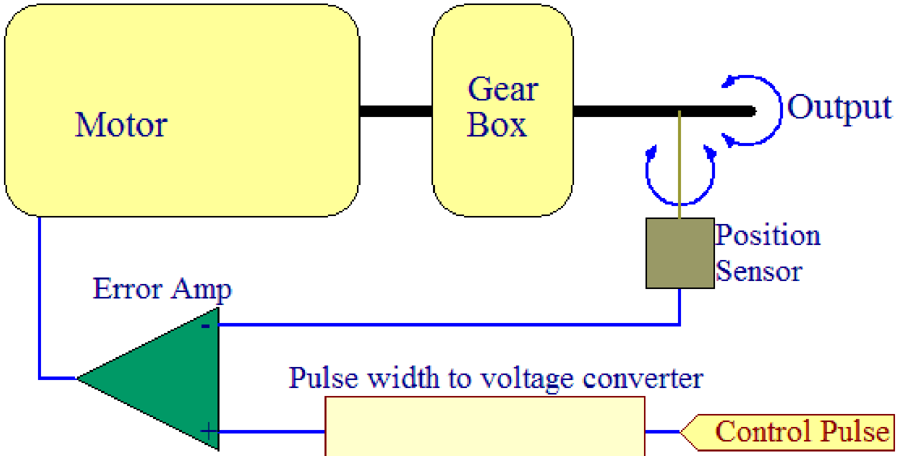


Advantages of Brushless over Brushed:

- Better Speed Vs. Torque
- High Efficiency
- Long operating life (No brushes)
- Noiseless Operation
- Higher Ratio of Torque wrt Size

Theory of Servomechanisms

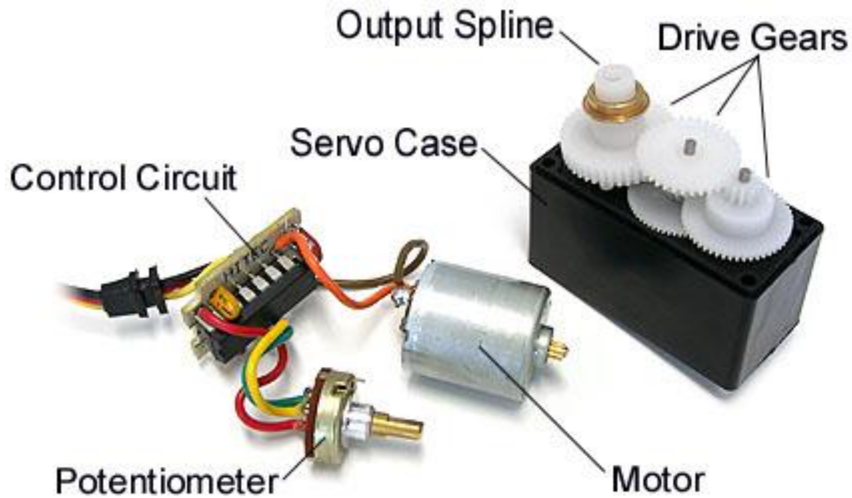
- Closed loop control whose output is some mechanical position or velocity set by a reference input(required output).
- Two types
  - Positional Control



  - Velocity Control
    - Instead of Position sensor, Hall Sensors are used.

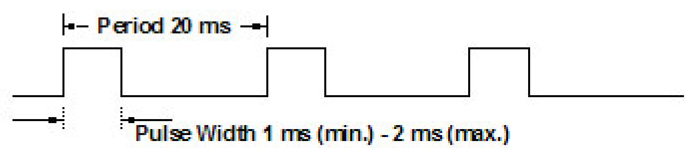
Servo Motor

The basic behind Servo Control is *Pulse Width Modulation*.

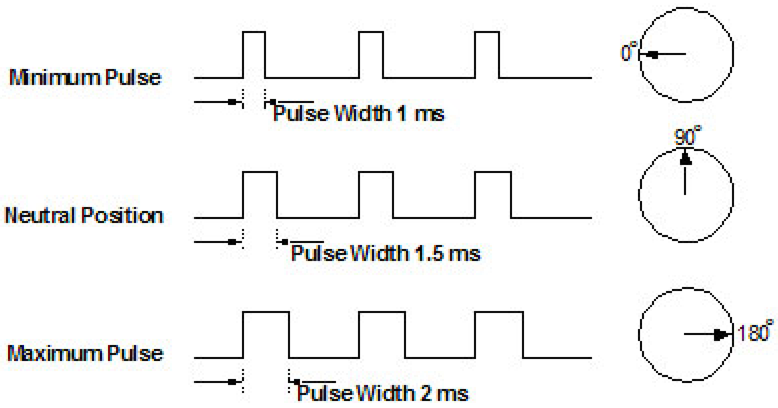


Pulse Parameters :

- Minimum Pulse
- Maximum Pulse
- Repetition Rate



- All servos have three wires:
  Black or Brown is for ground.
  Red is for power (~4.8-6V).
  Yellow, **Orange**, or **White** is the **signal** wire (3-5V).
- The general concept is to simply send an ordinary logic **square wave** to your servo at a specific wave length, and your servo goes to a particular angle (or velocity if your servo is modified). *The wavelength directly maps to servo angle*.



Stepper Motors

Steppers are used when incremental motion is required.

A stepper motor possesses the ability to move a specified number of revolutions or fraction of a revolution in order to achieve a fixed and consistent angular movement.

Movement is achieved when power is applied for short periods to successive magnets

Advantages

- High accuracy of motion possible
- Cheaper and effective in open loop systems
- Brushless construction

Disadvantages

- Low torque capacity compared to DC motors
- Limited speed
- High vibrational levels
- Large errors and vibrations if a pulse is missed

Motor Drivers

a device or group of devices that serves to govern in some predetermined manner the performance of an *electric motor.*

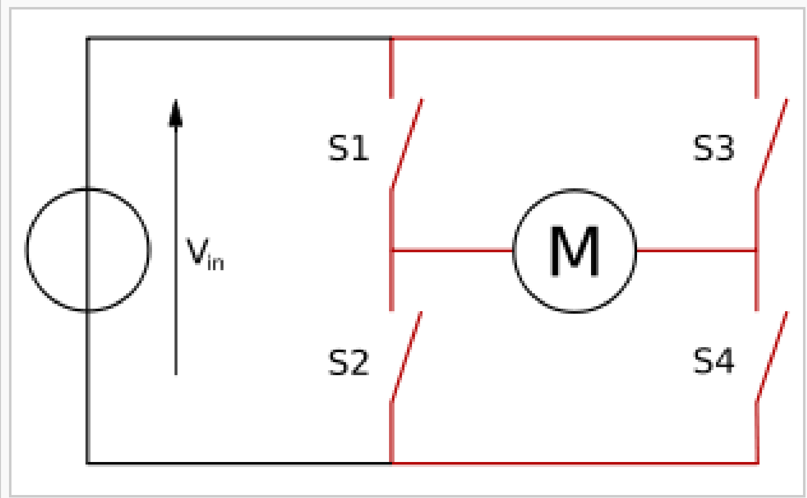
Mainly used Motor Drivers :

- L293/L293D
- L298
- L297
- Stepper Motor Controllers
- Servo Motor Controllers

H-Bridge

- An electronic circuit that enables a voltage to be applied across a load in either direction.

S1	S2	S3	S4	Result
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
0	0	0	0	Motor free runs
0	1	0	1	Motor brakes
1	0	1	0	Motor brakes



Structure of an H bridge (highlighted in red)

How to run motors through an MCU ?

- Never connect the MCU pins directly to the motors.
- The Atmega16 has a current rating of 5-10 mA.
- The normal DC motor's current ratings start from 150 mA and above which arises a need for a Motor and MCU interface.
- So the motor cannot be directly attached to the ATmega, hence a **motor-driver** is used… (eg: L293/L293D, L298, etc…)

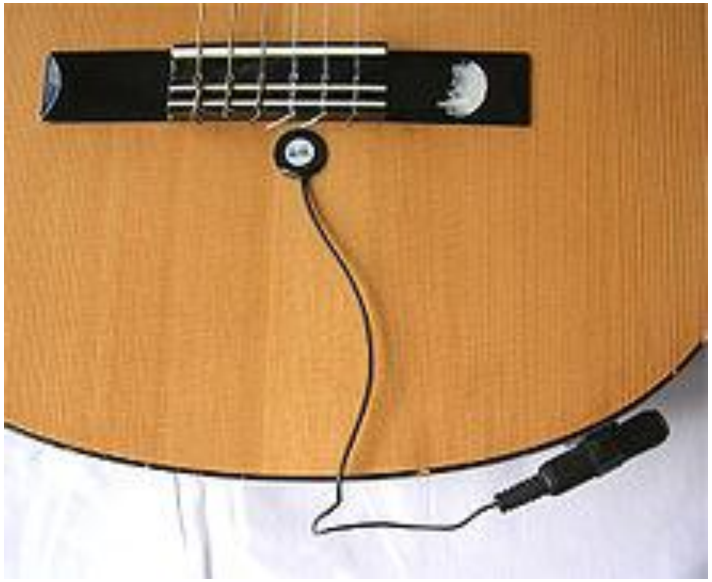
Piezoelectric actuators

Piezoelectric effect is the generation of electric charge resulting from an applied mechanical force.

Applications

Used both as a sensor and actuator

A piezo disc in an electric buzzer



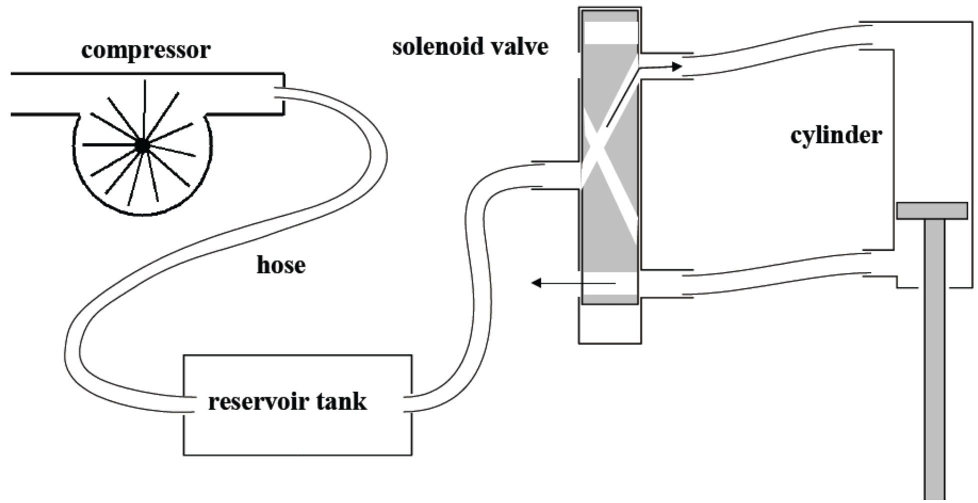
A piezo disc in a guitar pick up

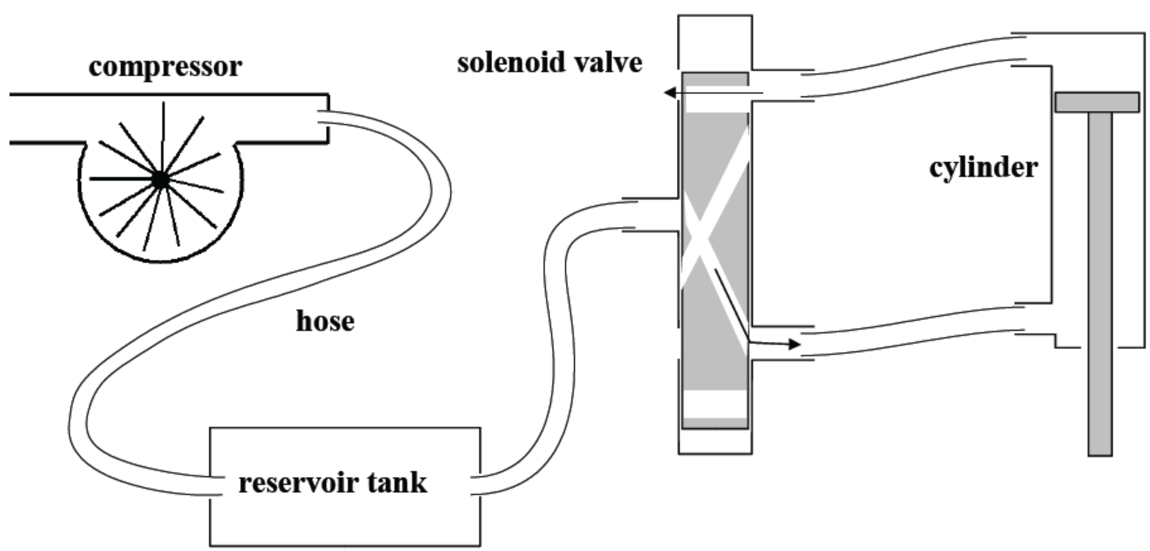
Chain And Sprocket

Rack And Pinion

- **Can convert rotational motion into linear motion**

Pneumatic principle



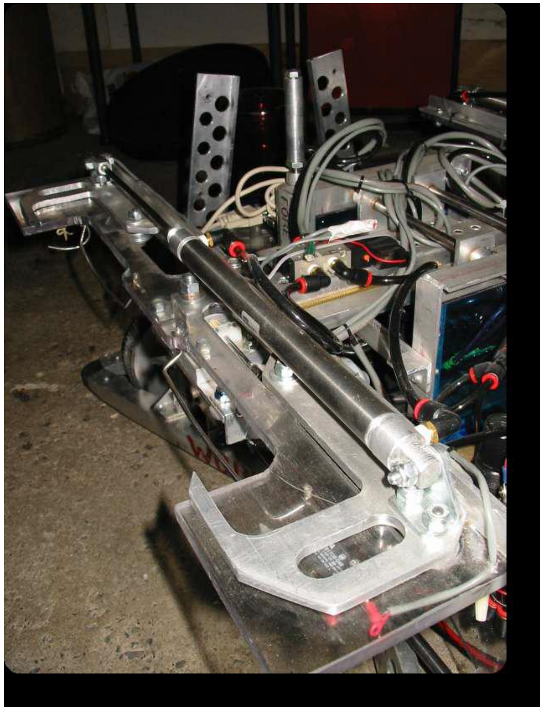


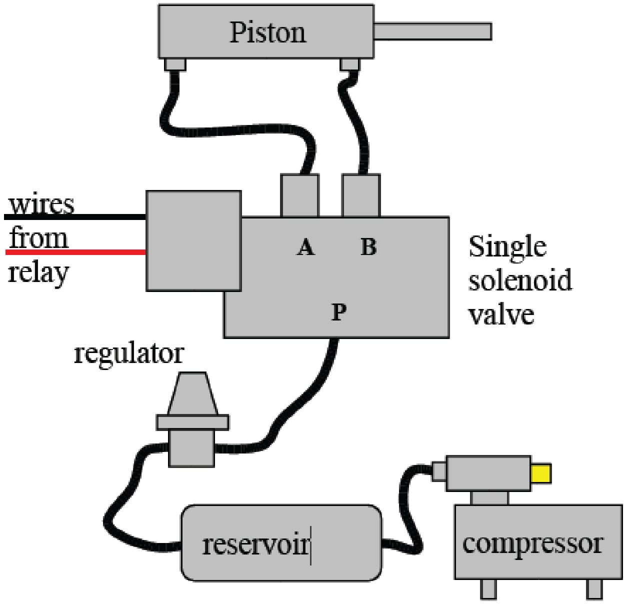
Why Pneumatics ?

- Weight
  - Much lighter than motors (as long as several used)
- Simple
  - Much easier to mount than motors
  - Much simpler and more durable than rack and pinion
- More rugged
  - Cylinders can be stalled indefinitely without damage
  - Resistant to impacts
- Disadvantage: All the way in or all the way out

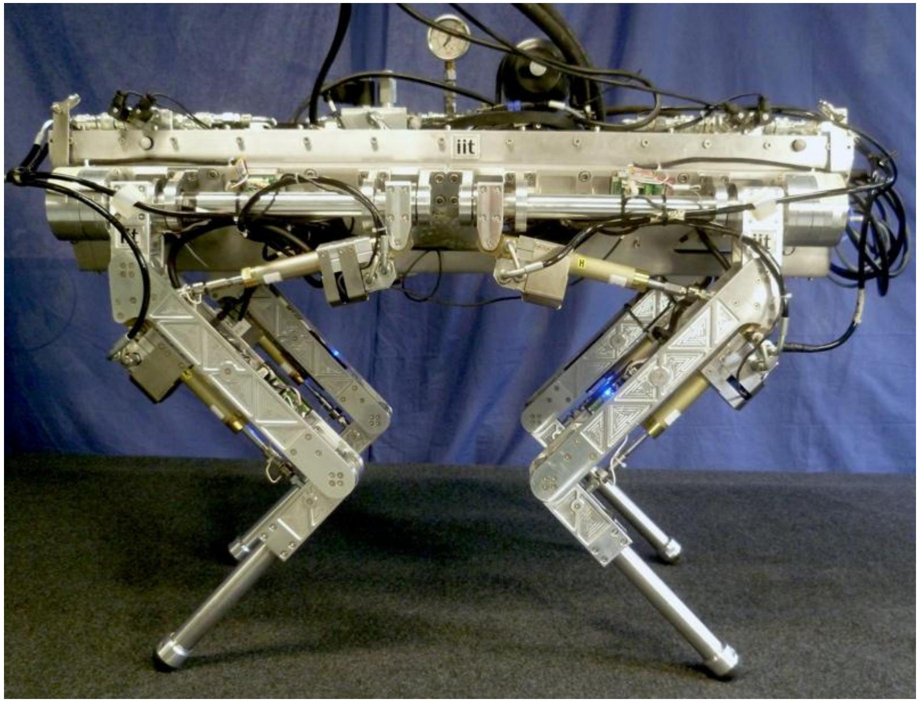
Linear Motion

- Much simpler, easier, more durable than rack and pinion
- Can maintain constant force





Applications

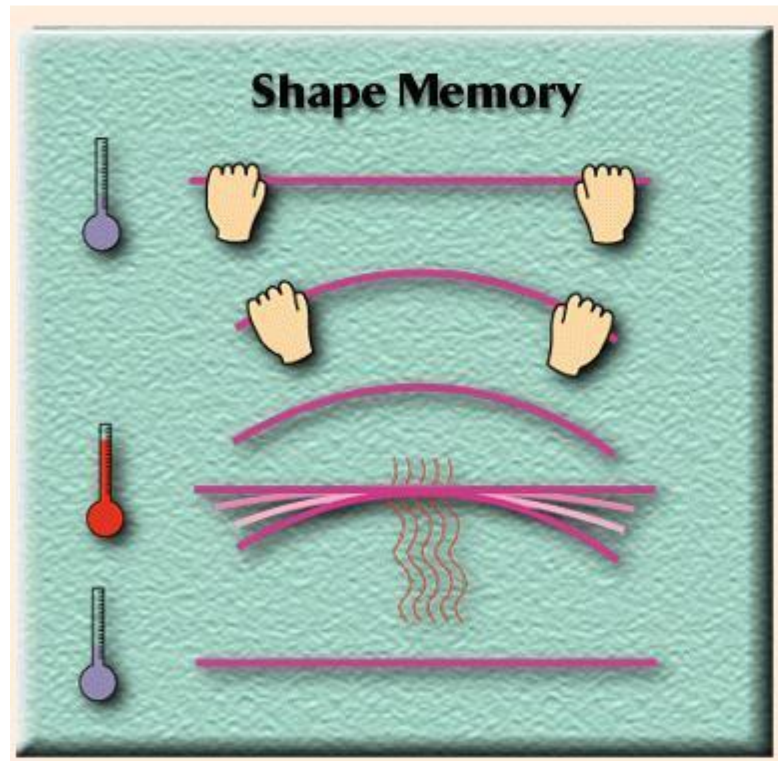


Short Rotation

- Arm Joints
- Grabbers

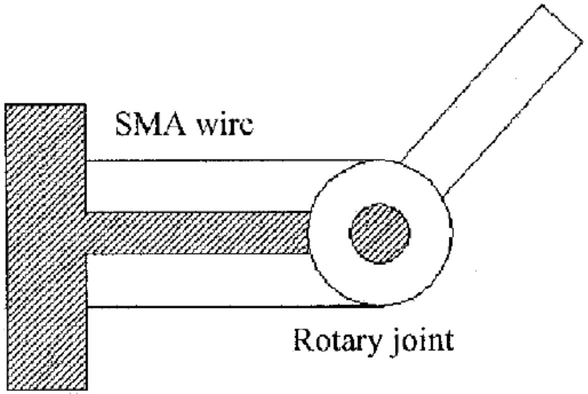
SMA's, or Shape Memory Alloys

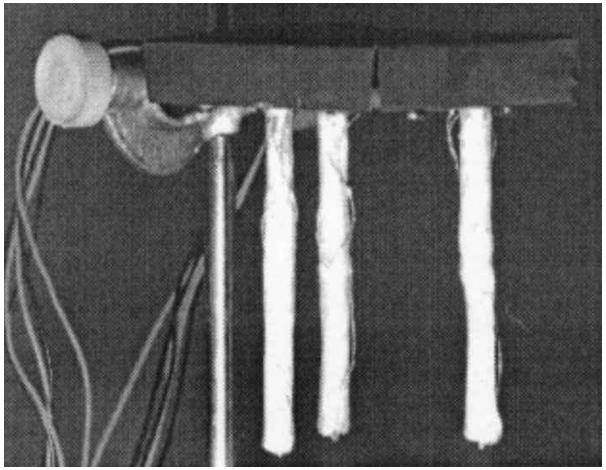
materials that *change shape* when energy is applied to, or removed from, them.
The most commonly used alloy is NiTinol.

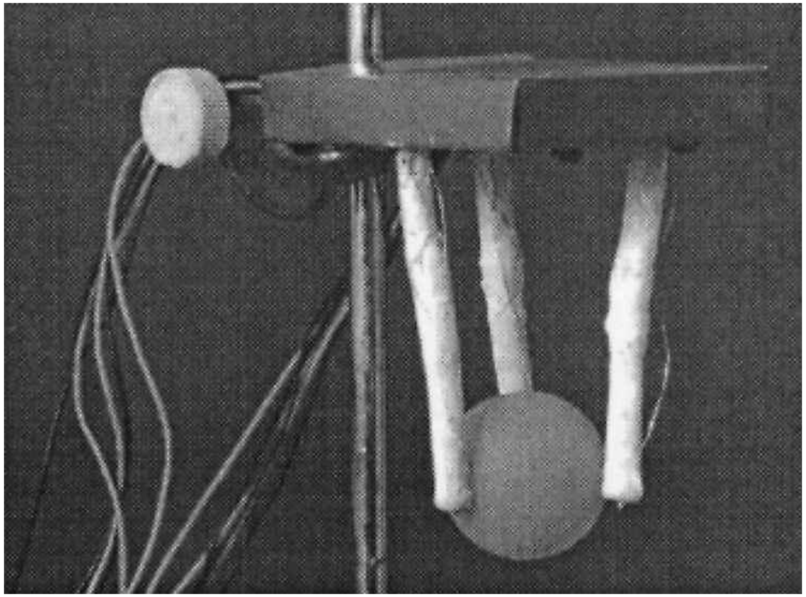


- Have a shape memory.
- Tries to achieve the *memorized* energized.
- A restoring force(spring action) is needed.

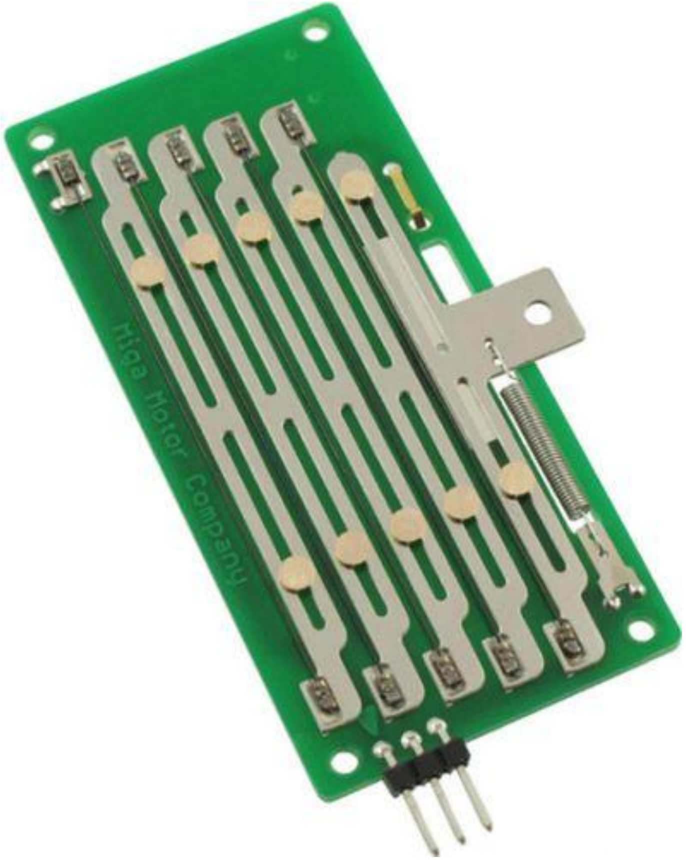
SMA Robotic Hand





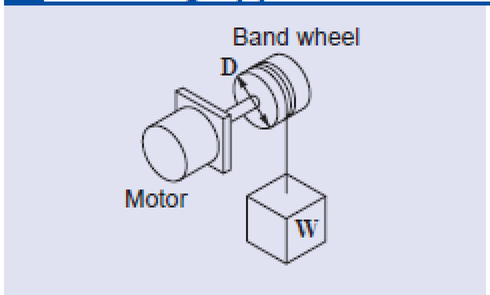


Applications



Estimating load torque

Hoisting application

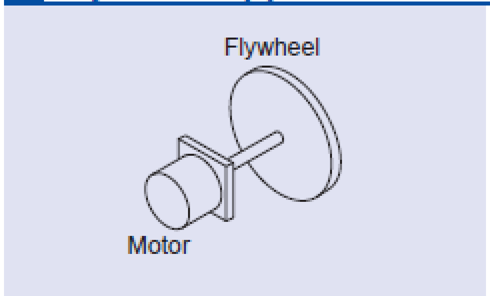


- SI units

$$T = \frac{1}{2} D \cdot W \ (N{\cdot}m)$$

D : Diameter of drum (m)
W : Load (N)

Flywheel application

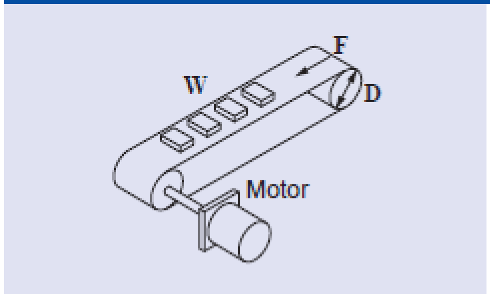


- SI units

$$T = \frac{J}{9.55 \times 10^4} \cdot \frac{N}{t} \ (N{\cdot}m)$$

N : Rotating speed (r/min)
J : Inertia ($kg{\cdot}cm^2$)
t : Time (s)

Belt conveyor application

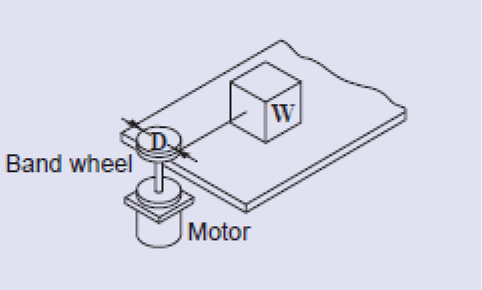


- SI units

$$T = \frac{1}{2} D\ (F + \mu W g)\ (N{\cdot}m)$$

D : Diameter of roll (m)
W : Mass of load (kg)
g : Gravitational acceleratio
μ : Friction coefficient
F : External force (N)

Horizontal travel on contact face

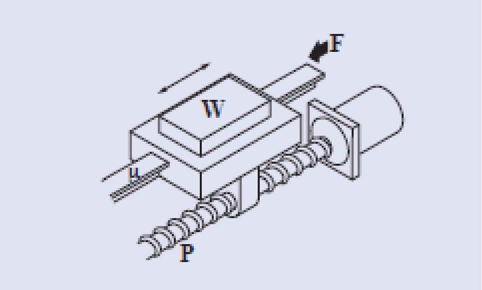


- SI units

$$T = \frac{1}{2} D \cdot \mu W g \ (N{\cdot}m)$$

D : Diameter of drum (m)
W : Mass (kg)
μ : Friction coefficient

Ball screw drive



- SI units

$$T = \frac{1}{2\pi} P\ (F + \mu W g)\ (N{\cdot}m)$$

F : External force (N)
W : Mass of load (kg)
μ : Friction coefficient of sliding surfaces (approx. 0.05 to 0.2)
g : Gravitational acceleration (m/s^2)
P : Lead of ball screw (m)

Determination of the driving mechanism

Calculation of motor speed and load

Selection of motor model

Temporary selection of the motor

Final determination of motor & gear head

Linear actuator selection

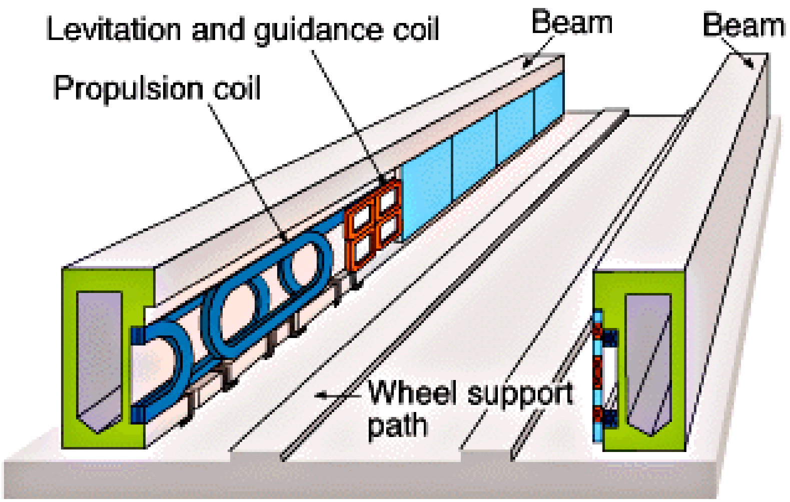
Parameter	Spring	Pneumatic	Rack and Pinion	Solenoid	Shape Memory Alloy
Speed	+	-	0	+	+
Accuracy	+	-	-	+	+
Weight	-	=	=	+	++
Space required	-	-	+	+	++
Simplicity	-	+	+	+	+
Power	-	+	0	+	+
Safety	+	-	+	-	++
Time between shots	+	-	+	+	+
Cost	-	+	-	+	0

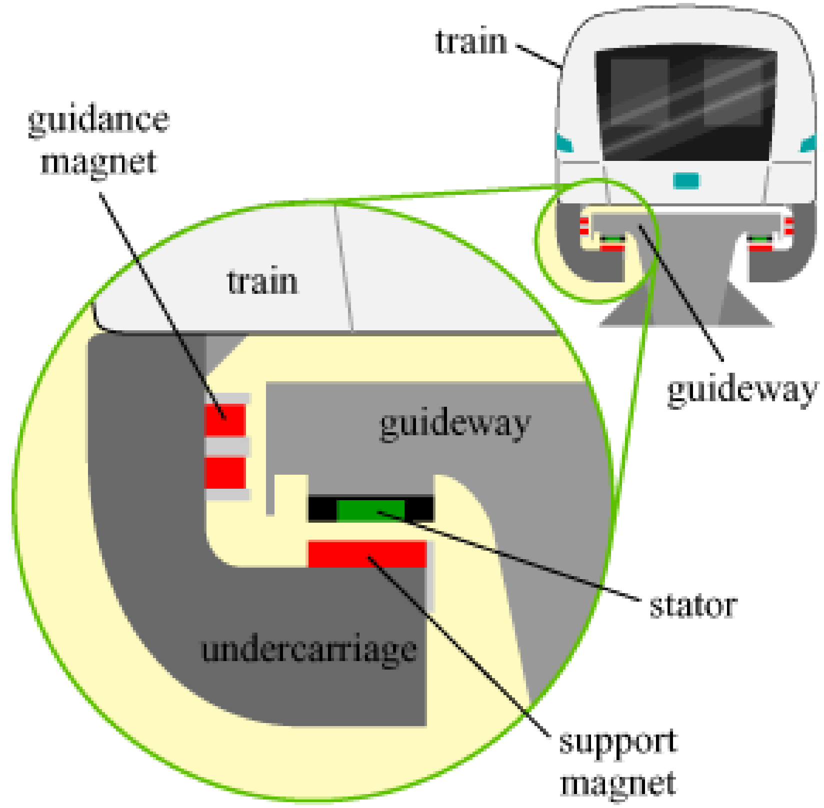
Inside some famous robot (how do they actuate)

- MagLev :

Autumn concept MagLev

MagLev in Shanghai



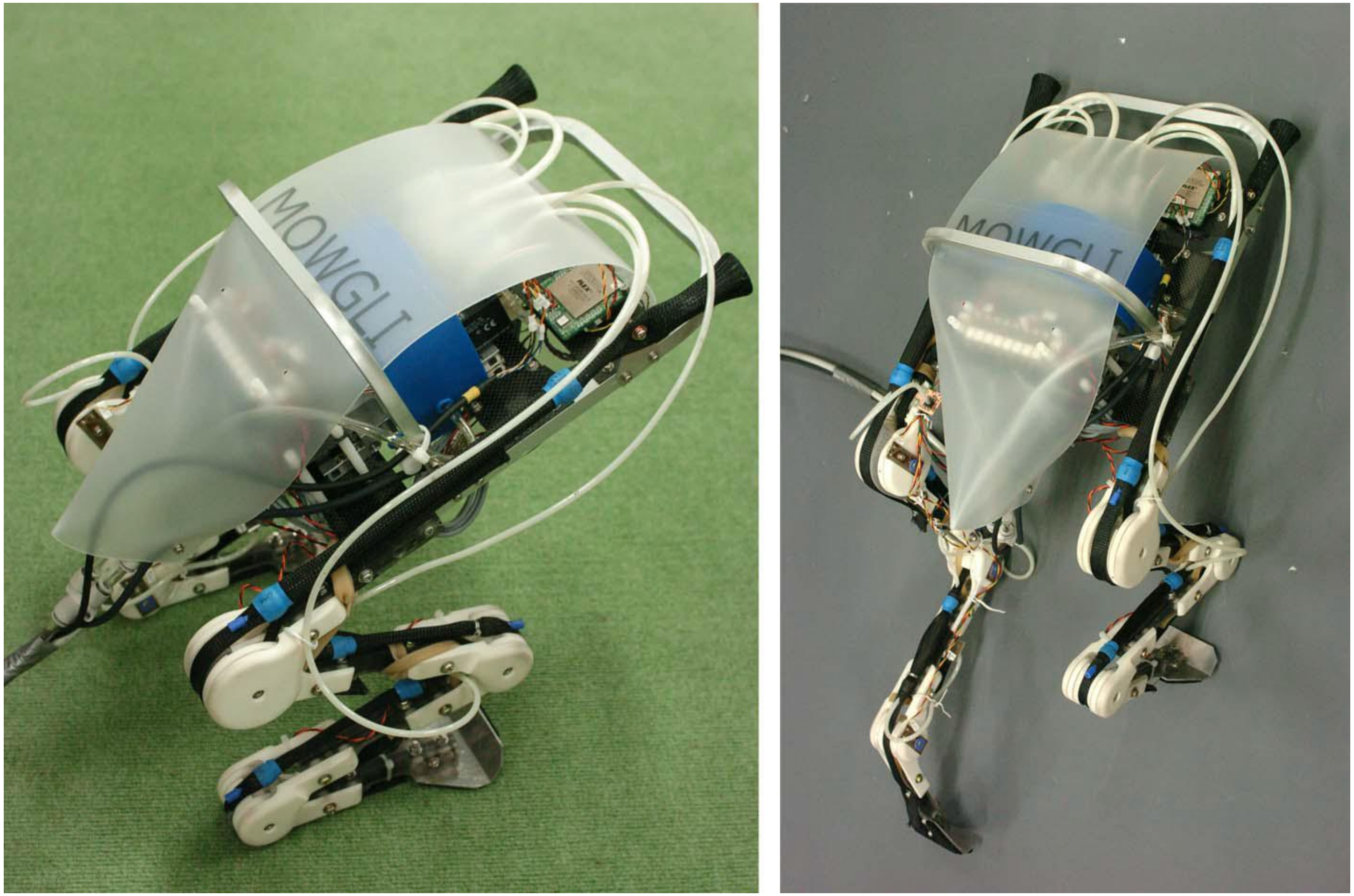


A MagLev can be called a glorified linear motor

One with the track extended as the rails of a train and the carriage transported being the train itself

Mowgli – pneumatic air muscles

- **Pneumatic artificial muscles** (PAMs) are contractile or extensional devices operated by pressurized air filling a pneumatic bladder



Mowgli

Shadow Hand

The shadow hand developed by CMU uses PAMs to mimic nearly all the degrees of freedom of a human hand using 40 muscle fibres and 80 valves to control the flow to them


Thank You!