Design Lab: Actuation

Corso Materiali intelligenti e Biomimetici
24/03/2020

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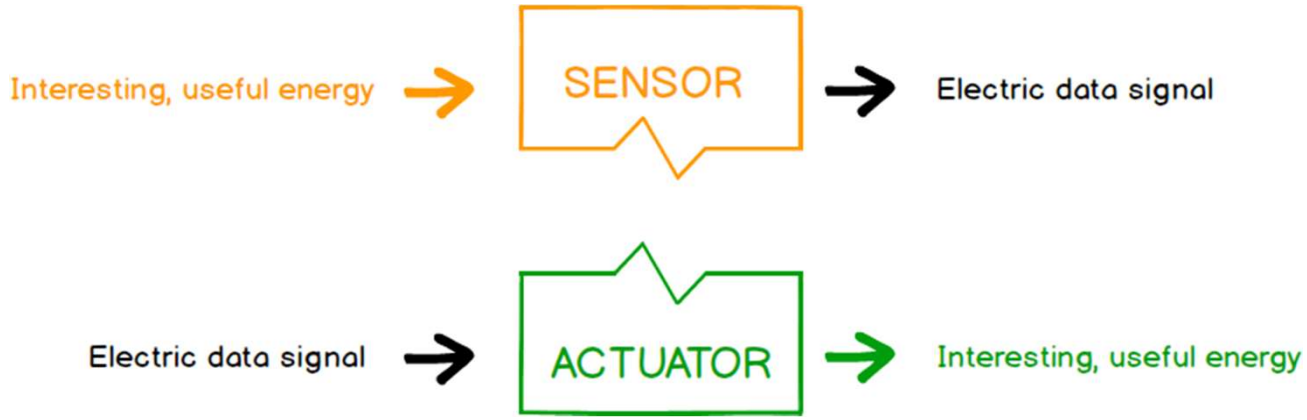
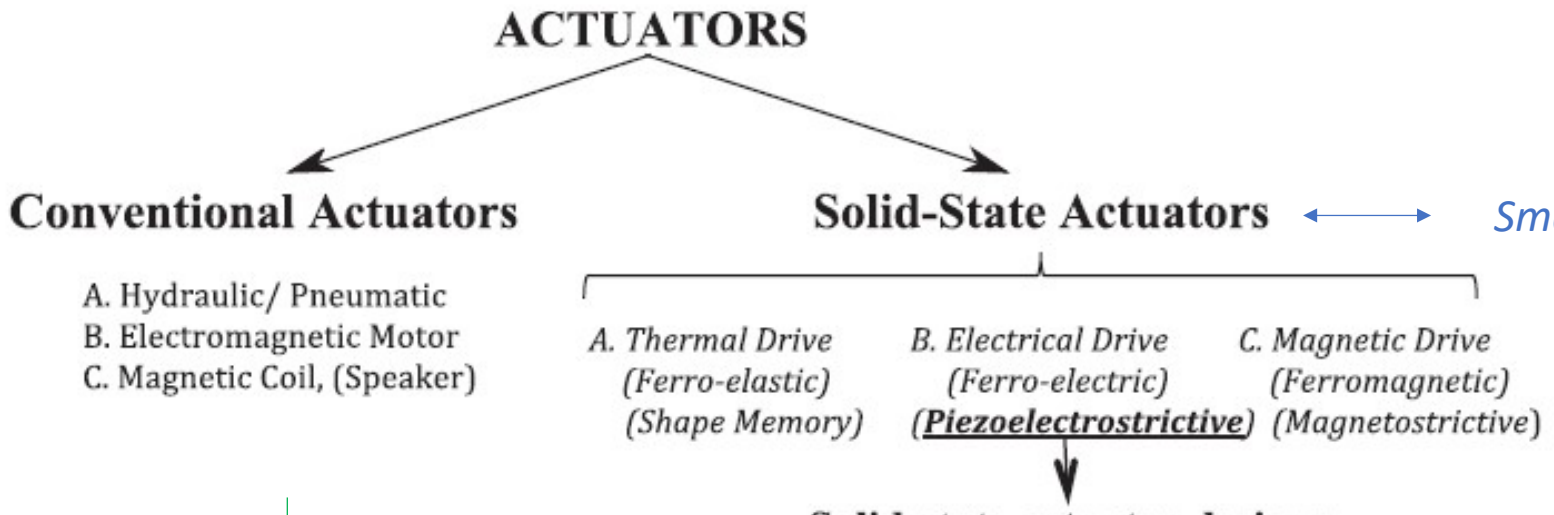
Sensors vs. Actuators



The word "**Transducer**" is the collective term used for both Sensors and Actuators.

Devices which perform an **"Input" function** are commonly called **Sensors** because they "*sense" a physical change* in some characteristic and covert that into an electrical signal.

Devices which perform an **"Output" function** are generally called **Actuators** and are used to *control some external device*, for example movement or sound.



Advantages:

- low cost
- high force and stroke
- easy commercial availability.

Advantages

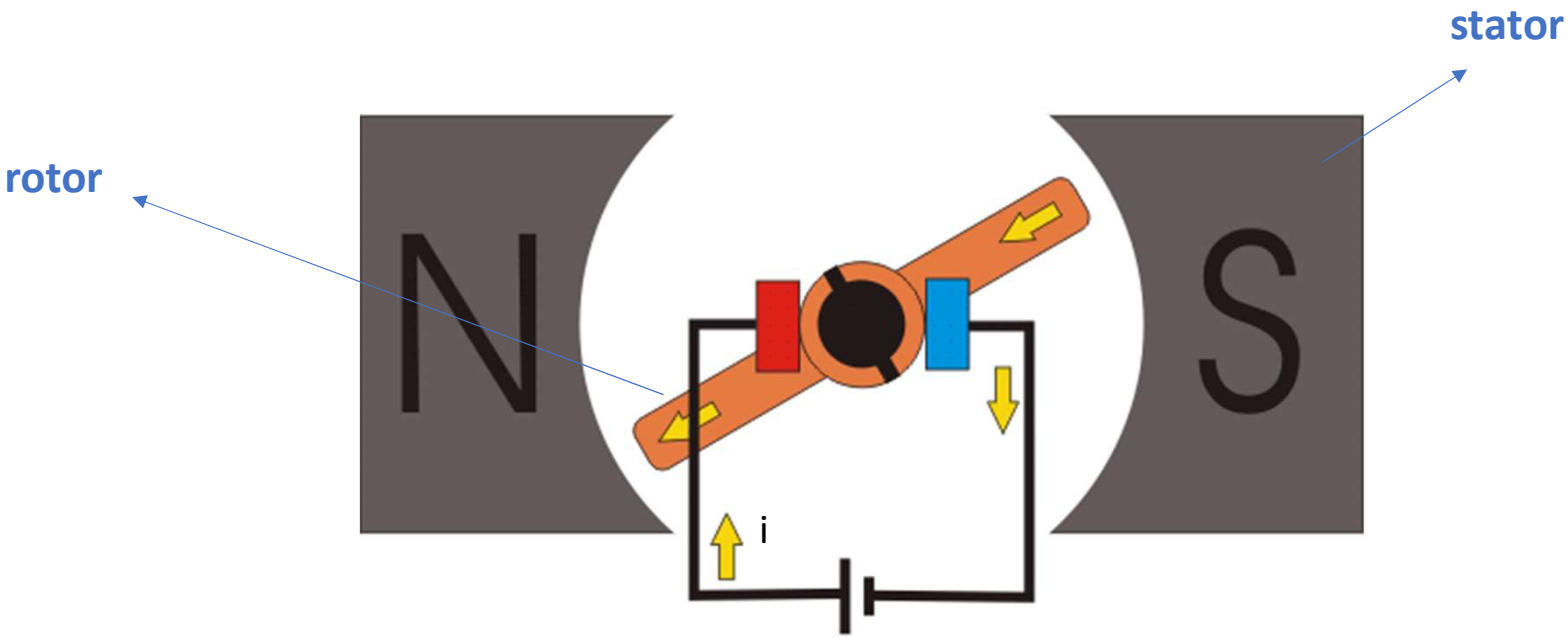
- Higher power density
- Smaller space requirements (size), weight

Actuation

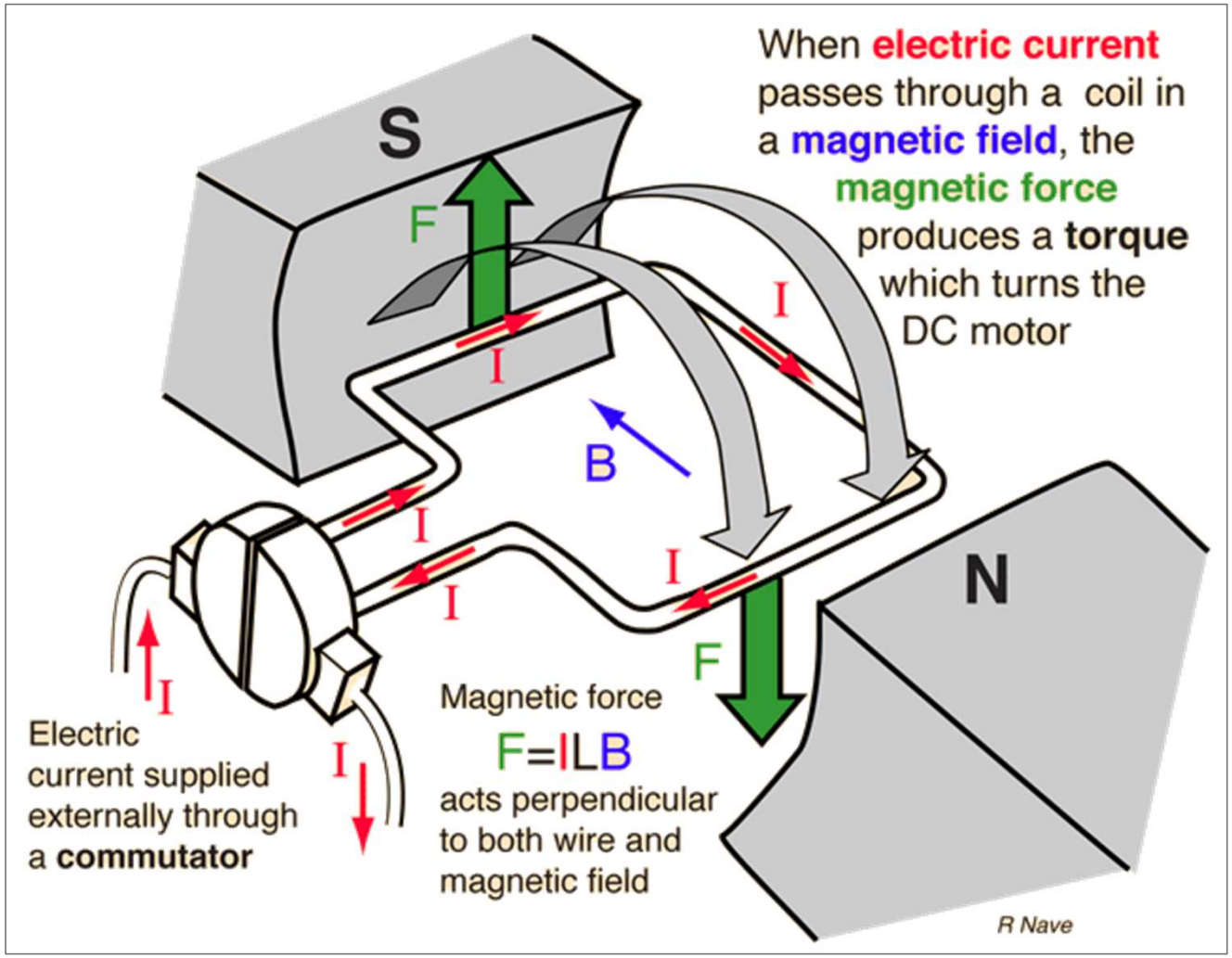
Conventional electromagnetic motors

A motor is an **electro-mechanical device** that **converts electrical energy to mechanical energy**.

Main components:

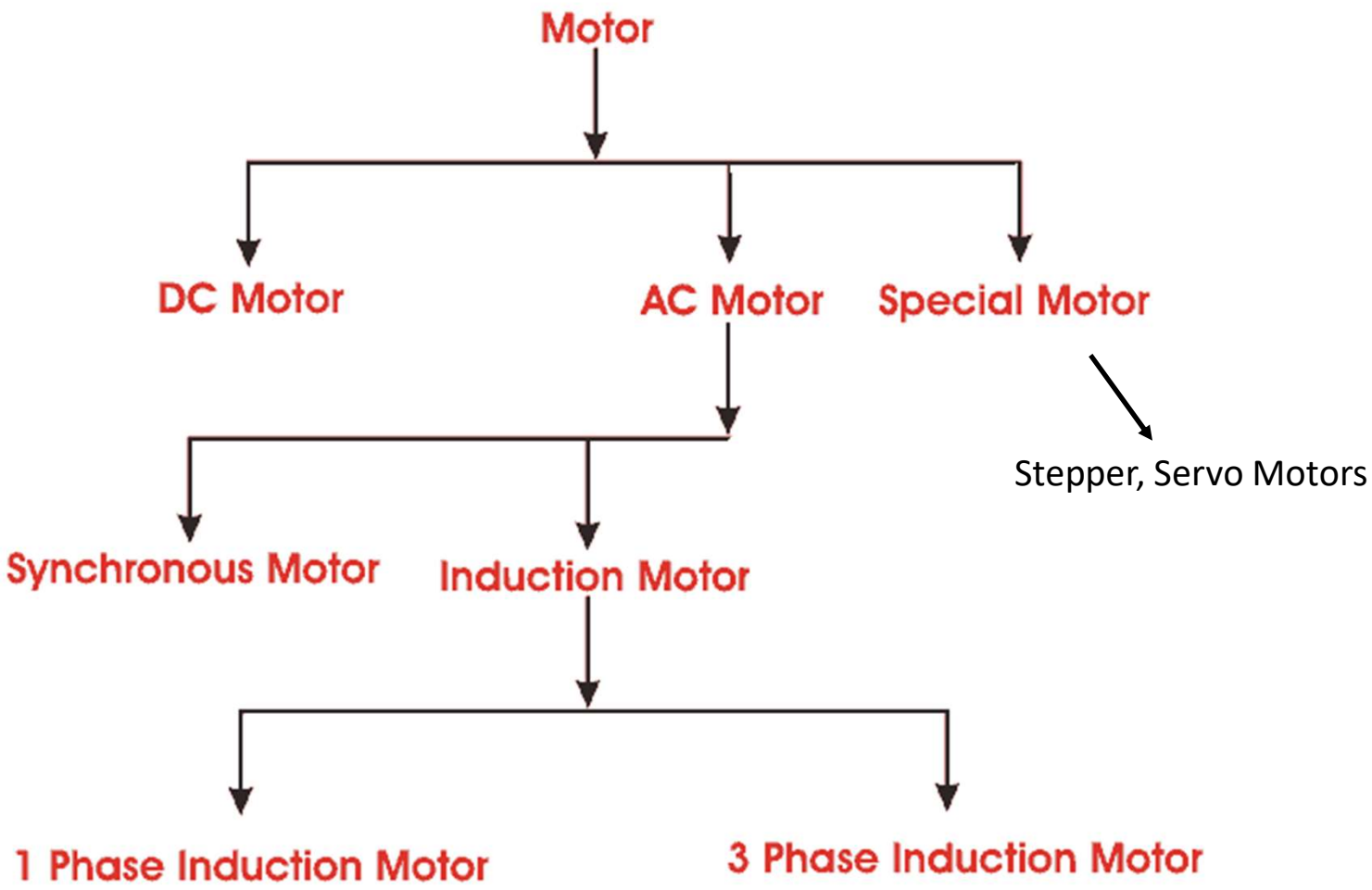


Actuation


When electric current passes through a coil in a magnetic field, the magnetic force produces a torque which turns the DC motor
S
N
F
I
B
Electric current supplied externally through a commutator
Magnetic force
F=ILB
acts perpendicular to both wire and magnetic field
R Nave

Actuation

Electromagnetic Motors



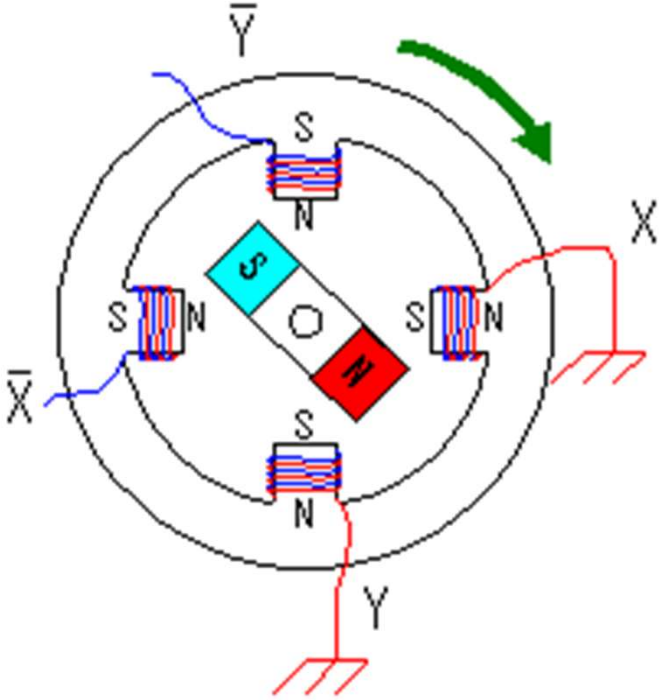
Actuation

Stepper

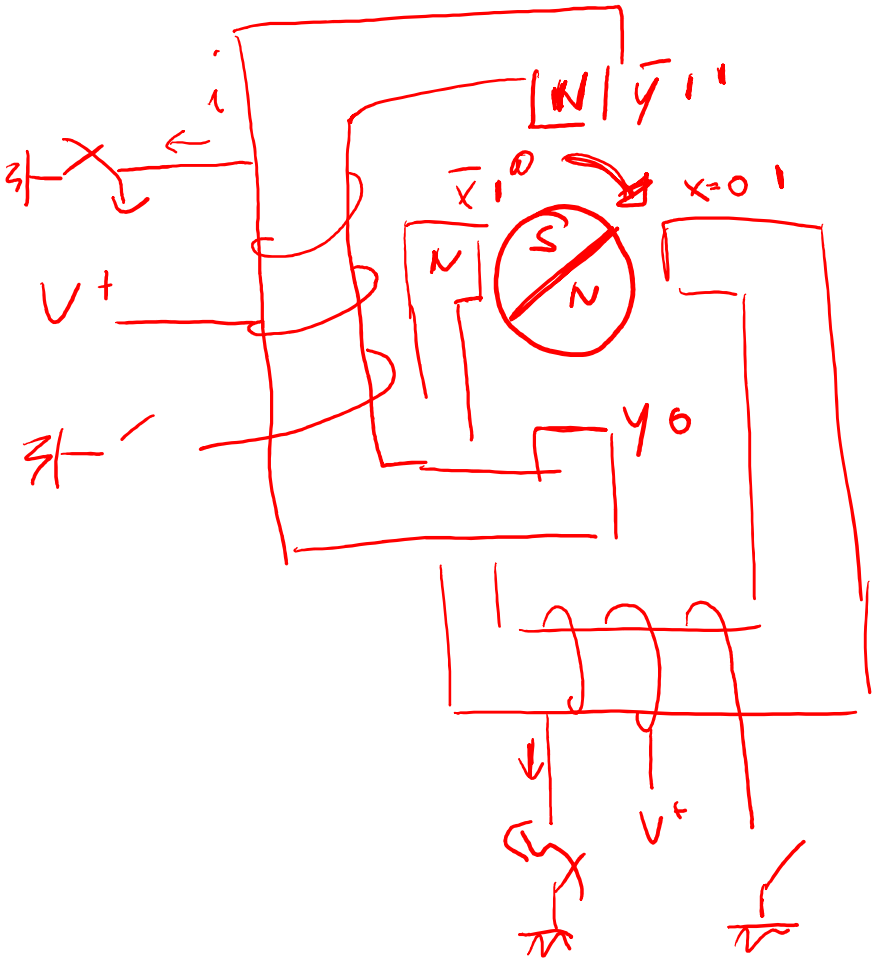
A stepper motor is a **type of DC motor that rotates in steps**.

Components: **rotor**-> *permanent magnet*.
stator -> *winding* (activated in sequence)

- The **speed of rotation** depends on the ***rate*** *at which the electrical signals are applied*;
- The **direction of rotation** is dependent on the ***pattern*** *of pulses* that is followed (normally a 4 step sequence is followed. When the sequence is followed from step 1 to 4, we get a *clock wise* rotation and when it is followed from step 4 to 1, we get a *counter clockwise rotation*).
- **Unipolar/Bipolar configuration**

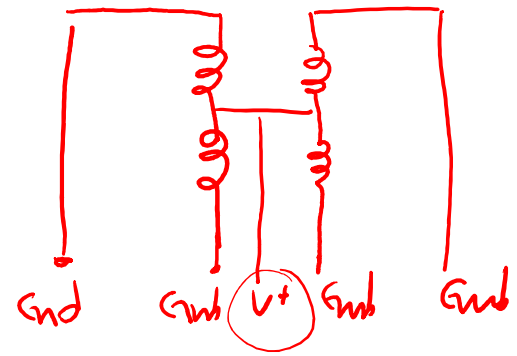


X	$\bar{X}$	Y	$\bar{Y}$
0	1	0	1
1	0	0	1
1	0	1	0
0	1	1	0

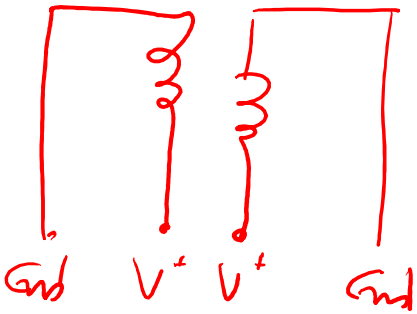


x	y	$\bar{x}$	$\bar{y}$
0	0	1	1
1	0	0	1

UNIPOLARE



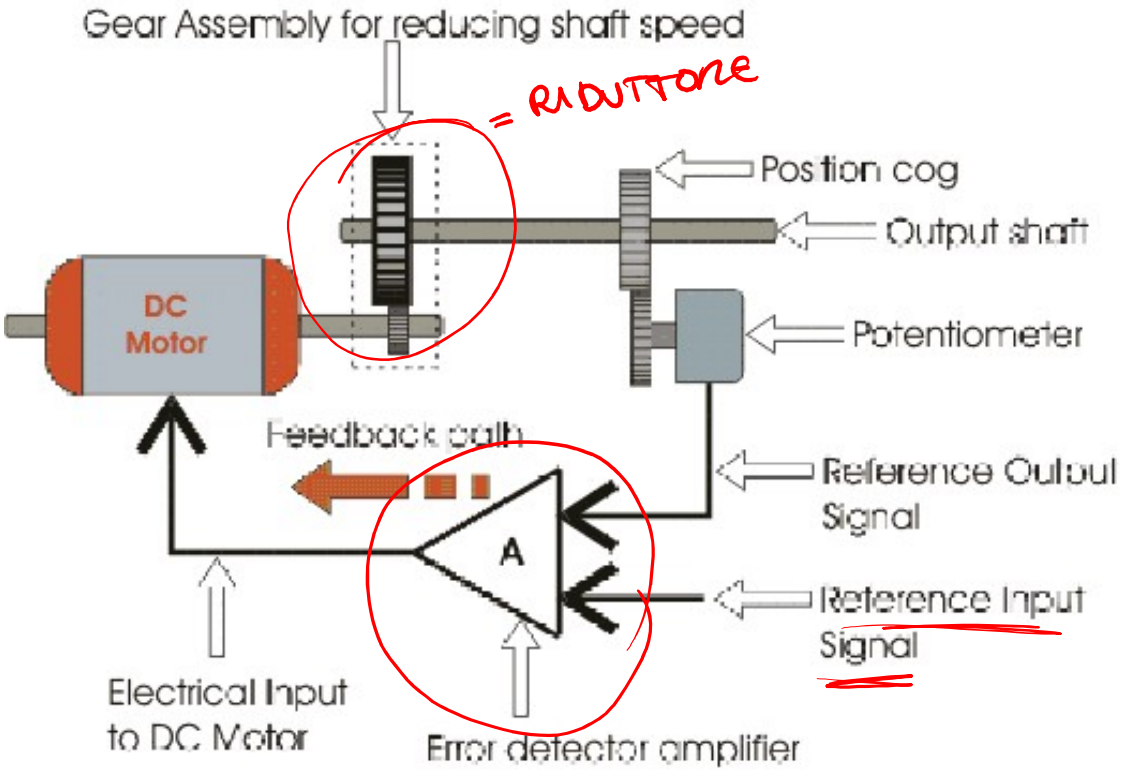
BIPOLARE



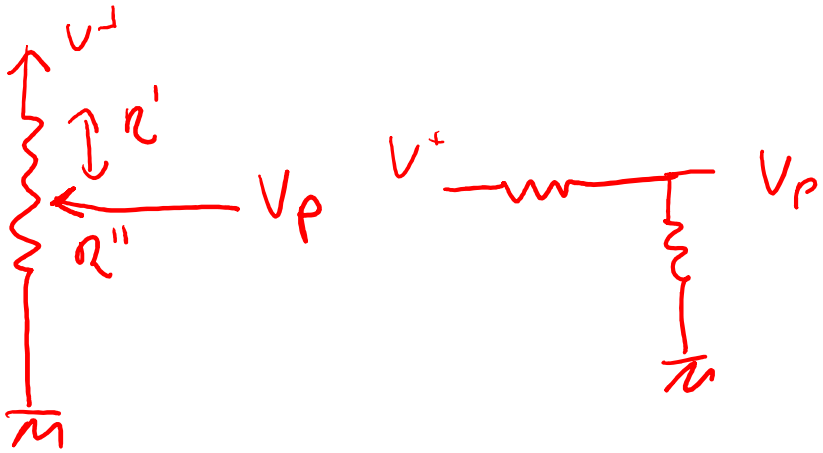
Actuation

Servo

A servo system mainly consists of a **small DC motor**, a **potentiometer**, **gear arrangement** and a **feedback system.**



- The device is controlled by a feedback signal generated by comparing output signal and reference input signal. Hence, the primary task of a servomechanism is to **maintain the output of a system at the desired value** in the presence of disturbances.
- *During rotation of the shaft, the knob of the potentiometer also rotates* and creates an **varying electrical potential that is taken to the error detector feedback amplifier** along with the input reference commands i.e. input signal voltage.
- The gear mechanism is used to **step down the high rpm of the motor shaft to low rpm at the output shaft** of the servo system (small DC motor will rotate with high speed but the torque generated by its rotation will not be enough to move even a light load).



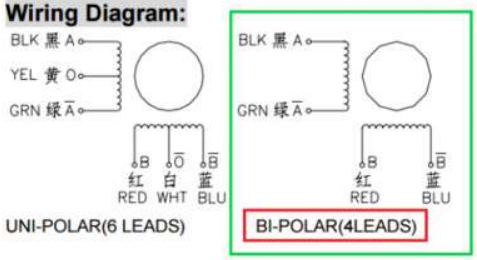
ΠΟΤΕΝΤΙΟΜΕΤΡΟ

Actuation

Esempio

17HS series-Size 42mm(1.8 degree)

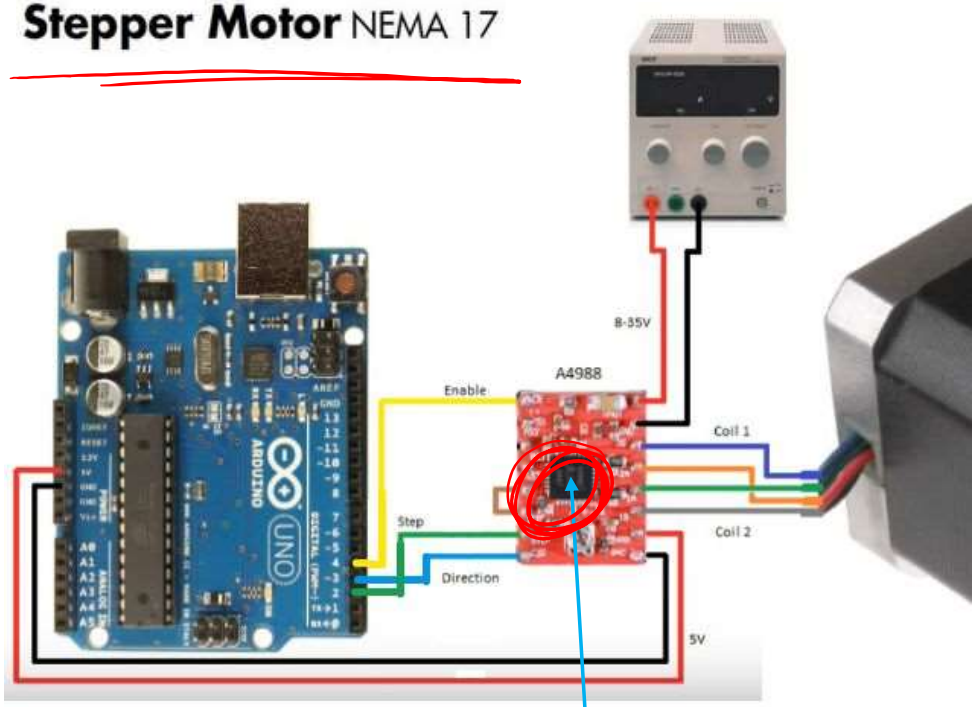
Wiring Diagram:



Electrical Specifications:

Series Model	Step Angle (deg)	Motor Length (mm)	Rated Current (A)	Phase Resistance (ohm)	Phase Inductance (mH)	Holding Torque (N.cm Min)	Detent Torque (N.cm Max)	Rotor Inertia (g.cm²)	Lead Wire (No.)	Motor Weight (g)
17HS2408	1.8	28	0.6	8	10	12	1.6	34	4	150
17HS3401	1.8	34	1.3	2.4	2.8	28	1.6	34	4	220
17HS3410	1.8	34	1.7	1.2	1.8	28	1.6	34	4	220
17HS3430	1.8	34	0.4	30	35	28	1.6	34	4	220
17HS3630	1.8	34	0.4	30	18	21	1.6	34	6	220
17HS3616	1.8	34	0.16	75	40	14	1.6	34	6	220
17HS4401	1.8	40	1.7	1.5	2.8	40	2.2	54	4	280
17HS4402	1.8	40	1.3	2.5	5.0	40	2.2	54	4	280
17HS4602	1.8	40	1.2	3.2	2.8	28	2.2	54	6	280
17HS4630	1.8	40	0.4	30	28	28	2.2	54	6	280
17HS8401	1.8	48	1.7	1.8	3.2	52	2.6	68	4	350
17HS8402	1.8	48	1.3	3.2	5.5	52	2.6	68	4	350
17HS8403	1.8	48	2.3	1.2	1.6	46	2.6	68	4	350
17HS8630	1.8	48	0.4	30	38	34	2.6	68	6	350

Stepper Motor NEMA 17



Allegro MicroSystems, LLC

A4988

Actuation

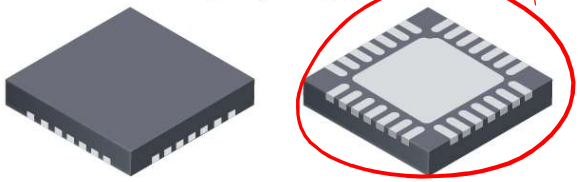
DMOS Microstepping Driver with Translator And Overcurrent Protection

Features and Benefits

- Low $R_{DS(ON)}$ outputs
- Automatic current decay mode detection/selection
- Mixed and Slow current decay modes
- Synchronous rectification for low power dissipation
- Internal UVLO
- Crossover-current protection
- 3.3 and 5 V compatible logic supply
- Thermal shutdown circuitry
- Short-to-ground protection
- Shorted load protection
- Five selectable step modes: full, $^1/_2$, $^1/_4$, $^1/_8$, and $^1/_{16}$

Package:

28-contact QFN
with exposed thermal pad
5 mm × 5 mm × 0.90 mm
(ET package)



Description

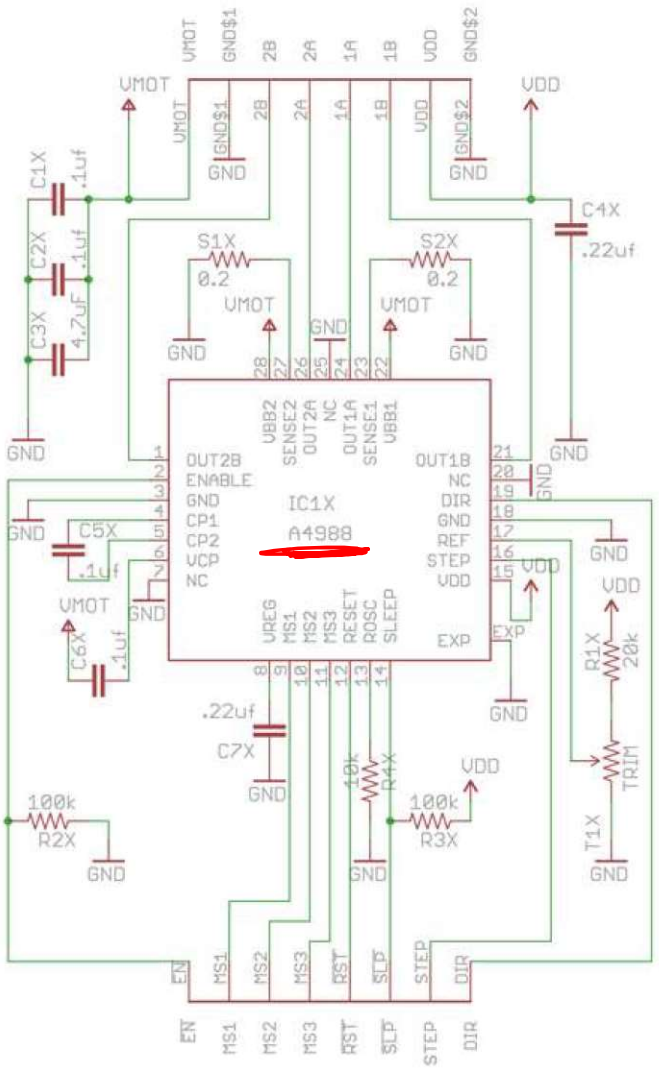
The A4988 is a complete microstepping motor driver with built-in translator for easy operation. It is designed to operate bipolar stepper motors in full-, half-, quarter-, eighth-, and sixteenth-step modes, with an output drive capacity of up to 35 V and ±2 A. The A4988 includes a fixed off-time current regulator which has the ability to operate in Slow or Mixed decay modes.

The translator is the key to the easy implementation of the A4988. Simply inputting one pulse on the STEP input drives the motor one microstep. There are no phase sequence tables, high frequency control lines, or complex interfaces to program. The A4988 interface is an ideal fit for applications where a complex microprocessor is unavailable or is overburdened.

During stepping operation, the chopping control in the A4988 automatically selects the current decay mode, Slow or Mixed. In Mixed decay mode, the device is set initially to a fast decay for a proportion of the fixed off-time, then to a slow decay for the remainder of the off-time. Mixed decay current control results in reduced audible motor noise, increased step accuracy, and reduced power dissipation.

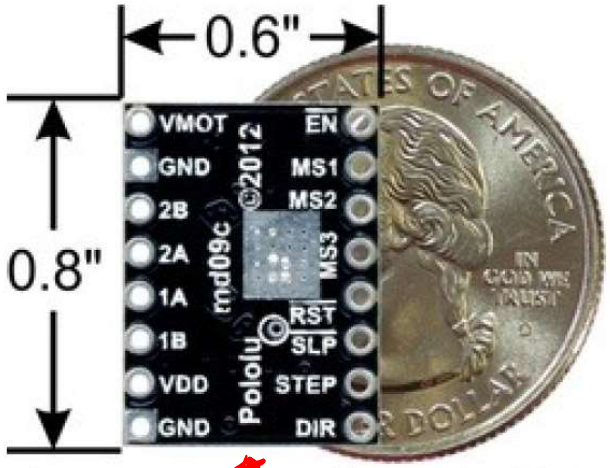
Actuation

SCHEMATIC



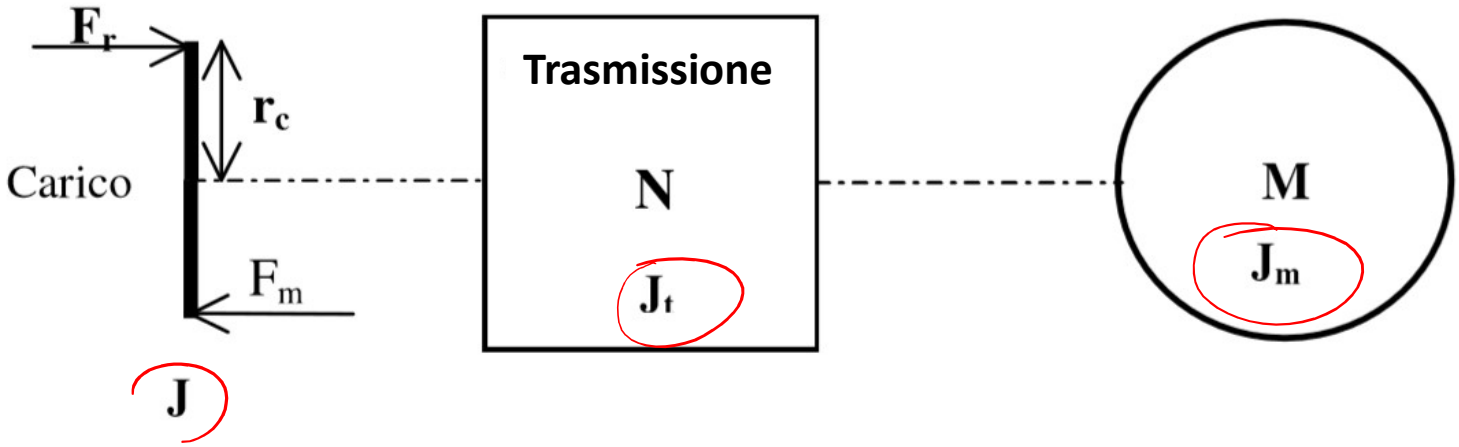
Pololu
Robotics & Electronics

A4988 Stepper Motor Driver Carrier, Black Edition



A4988 stepper motor driver carrier, Black Edition, bottom view with dimensions.

Catena Cinematica



Tutti I dispositivi interposti tra l'asse del motore (M) e l'oggetto movimentanto (carico), prendono il nome di **catena cinematica.**
J sono i relativi momenti di inerzia

$$T_{motrice\_tot} > \underbrace{T_{carico} + T_{inerzia} + T_{attrito}}_{\text{Coppie resistenti}}$$

$I = m \frac{d^2}{2}$ [kg m²]

INERZIA

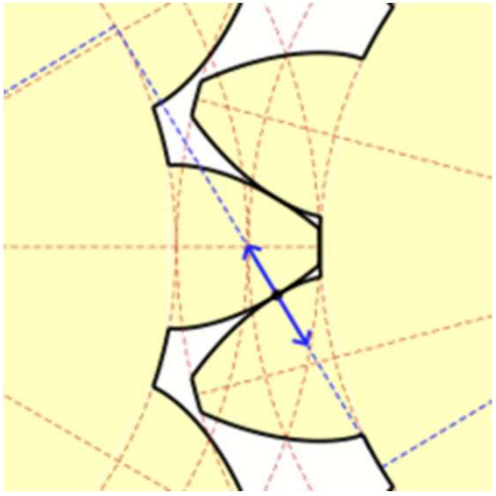
$J_{TOT} = J_c + J_T + J_m$

J_c — carico; J_T — trasmissione riduttore; J_m — motore

$T_{inerzia} = J_{TOT} \frac{d\omega}{dt}$ $\quad [Nm] = [Kgm^2] \left[\frac{1}{s^2}\right]$

$$T_m > T_c + T_i + T_a$$

Trasmissione



Un ingranaggio è un meccanismo utilizzato per trasmettere un momento meccanico da un oggetto a un altro.

Generalmente è costituito da due o più **ruote dentate**, che possono essere di uguale o diversa dimensione. La ruota più piccola è comunemente chiamata *pignone*, mentre la grande è chiamata *corona*.

Ruote di diversa dimensione sono spesso usate **in coppia** per *aumentare il momento meccanico riducendo nel contempo la velocità angolare, o viceversa* aumentare la velocità diminuendo il momento.

Rapporto di trasmissione $\tau = \frac{\omega_2}{\omega_1}$

Rendimento Meccanico $\eta = P_{out}/P_{in}$

$\tau = \frac{\omega_{out}}{\omega_{in}}$

↓

RAPPORTO TRASMISSIONE

RENDIMENTO

$\eta = \frac{P_{out}}{P_{in}} = \frac{\omega_{out}}{\omega_{in}} \frac{T_{out}}{T_{in}}$ (τ)

$\Rightarrow \quad \tau = \eta \frac{T_{in}}{T_{out}}$

$[\omega_{out}] = [\frac{1}{s}] [N_{in}]$ (I)

$$T_{in} = \frac{\tau T_{out}}{\eta}$$

$0 < \eta < 1$

Moto traslatorio

Meccanismi che consentono la conversione del **moto rotatorio (giri/min) in traslatorio (mm/min)**:

- Vite-madrevite
- Vite a circolazione di sfere
- fune-tamburo
- cinghia-puleggia
- Pignone-cremagliera

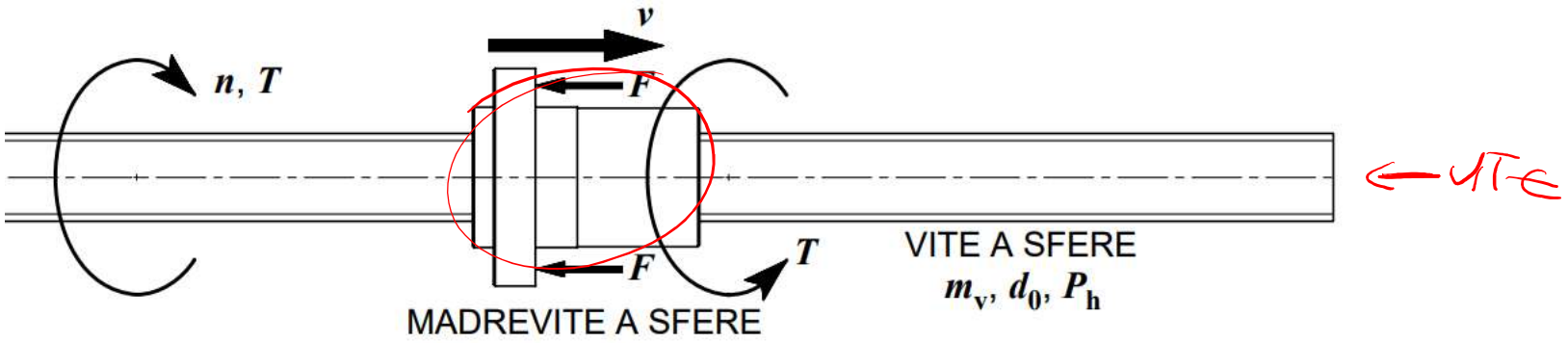
$V_t = 20\ mm/s$ ←

Passo vite = 1 mm

$$\frac{20\ \frac{mm}{s}}{1\ \frac{mm}{giro}} = 20\ \frac{giri}{s} \cdot 60 = 1200\ \frac{giri}{min}$$

Vite a ricircolo di sfere

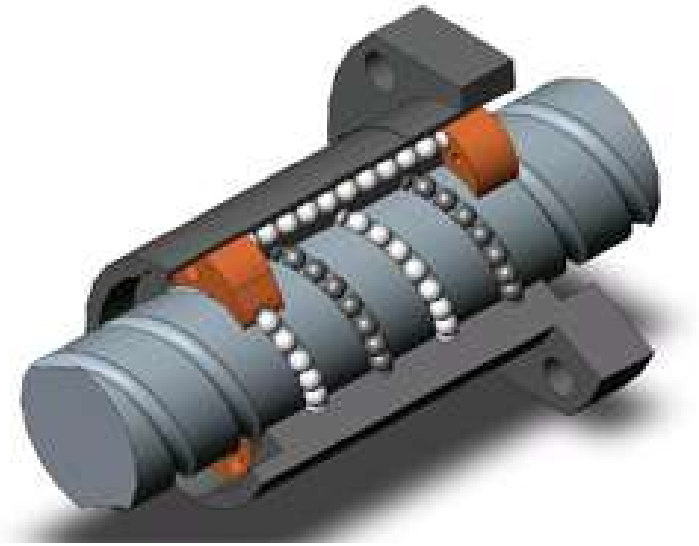
Vite: collegata all'albero del motore ruota
Madrevite trasla



$$T = \frac{F \times P_h}{2 \times \pi} \times \frac{1}{\eta}$$

Formula per dimensionare Coppia motrice

Vite a ricircolo di sfere



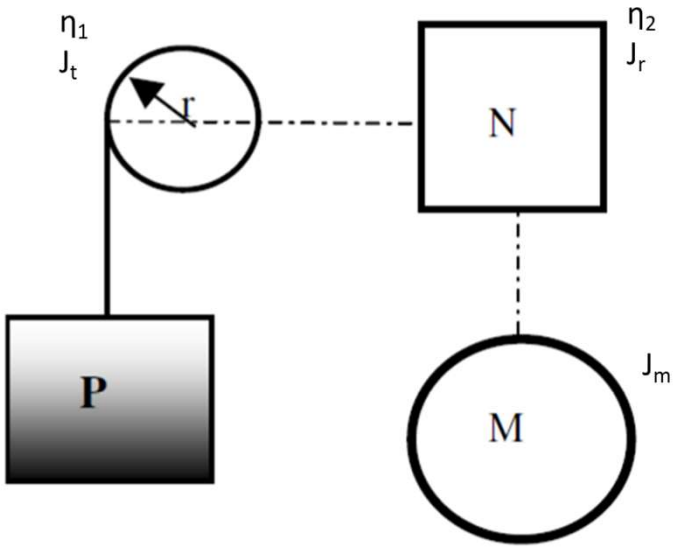
Una vite a ricircolo di sfere è un sistema a rotolamento composto da un albero con filetto a profilo e da una madrevite che, anch'essa filettata internamente secondo un profilo, contiene un numero determinato di sfere.

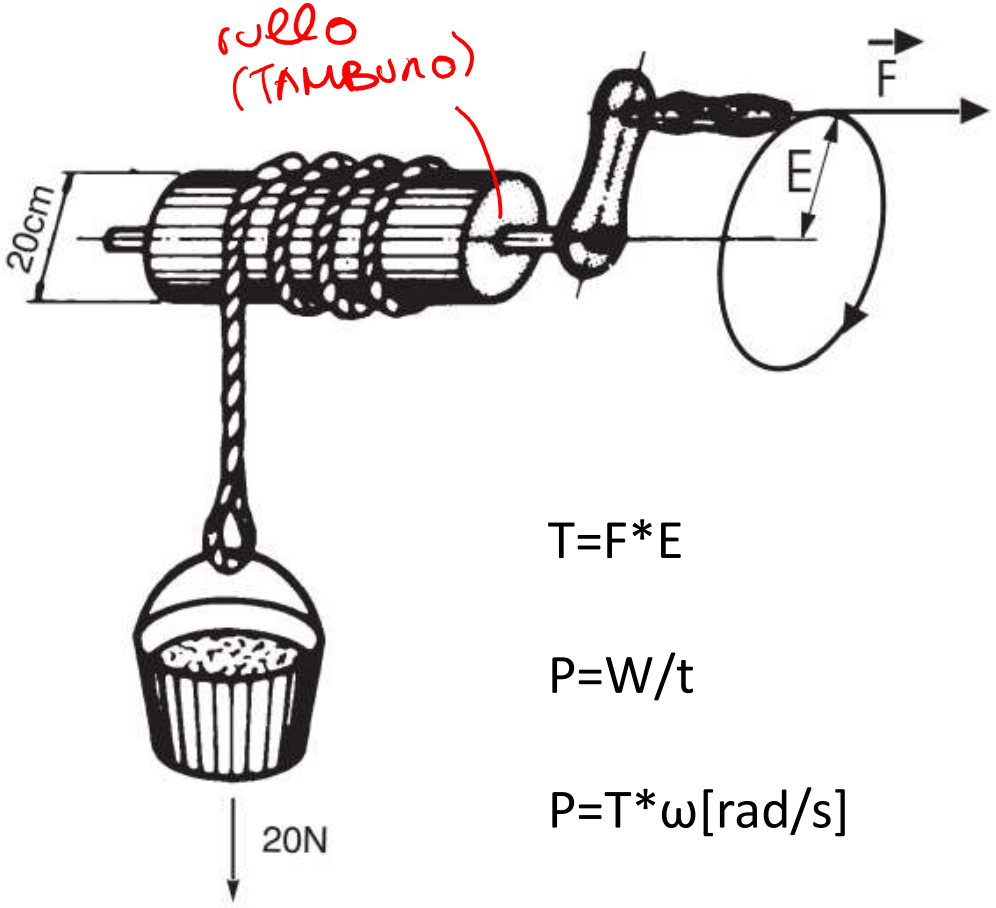
Il recupero delle sfere che durante il rotolamento effettuano un percorso all'interno della madrevite, è consentito da uno o più elementi meccanici denominati deflettori.

Il funzionamento delle viti a ricircolo di sfere si basa sull'azione di r**otolamento delle sfere interposte tra l'albero filettato e la madrevite**, che *trasforma il movimento rotatorio dell'albero in rettilineo (della madrevite),* **producendo un minor attrito** e *massimizzando l'efficacia* nelle applicazioni che richiedono elevati livelli di precisione.

Transmission

Fune-tamburo

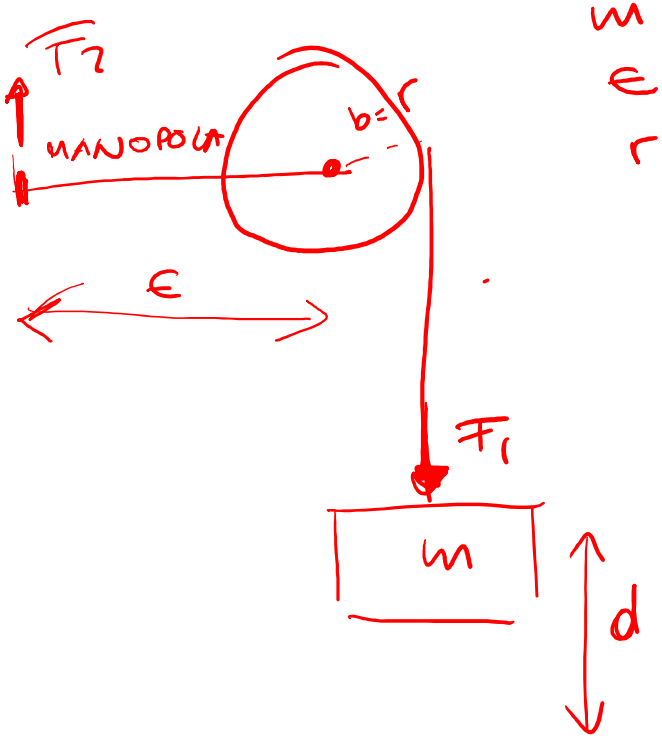




$T=F*E$

$P=W/t$

$P=T*\omega[rad/s]$



$m = 2\,kg$

$\epsilon = 20\,cm$

$r = 10\,cm$

$T_1 = F_1 r = 20N * 0.1m = 2\,Nm$

$T_2 = T_1$

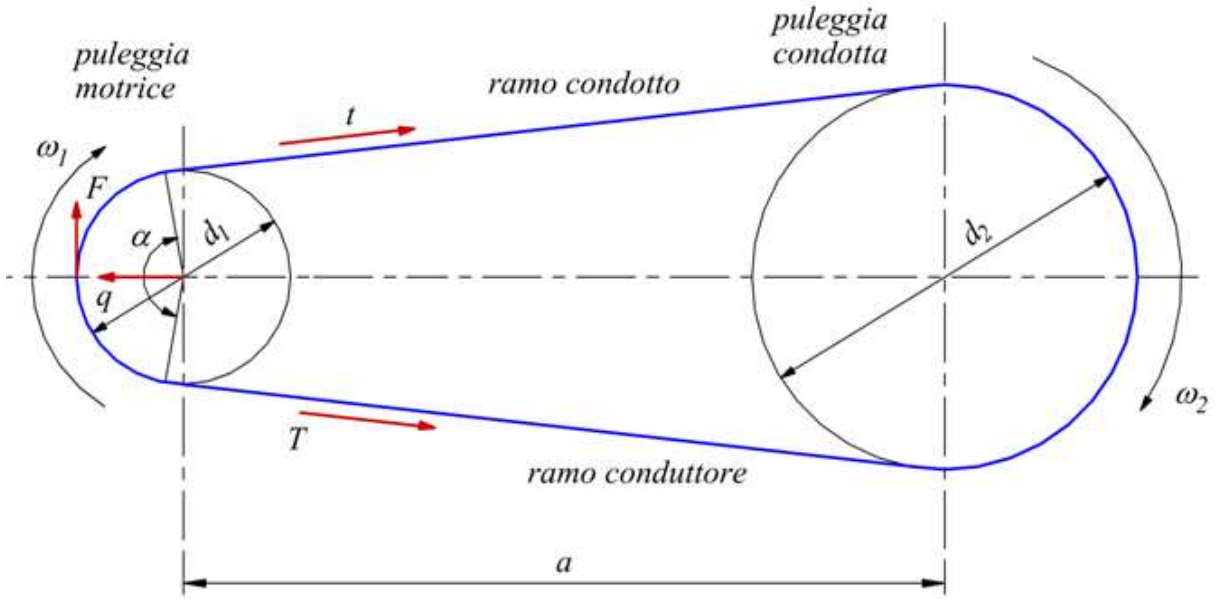
$T_2 = F_2 \epsilon$

$\Rightarrow F_2 = \frac{T_1}{\epsilon} = \frac{2\,Nm}{0.2m} = 10N$

$d = 25m \quad t = 2s$

$P = \frac{Fd}{t} = \frac{20N \cdot 25m}{2s} = 250\,W$

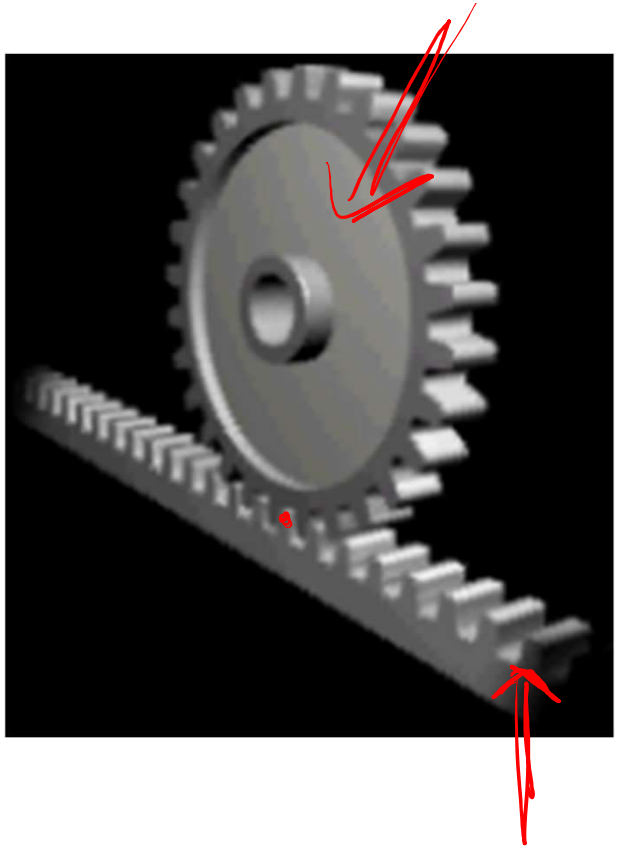
Cinghia-Puleggia



Rapporto di trasmissione

$$\tau = \frac{\omega_2}{\omega_1} = \eta \frac{d_1}{d_2}$$

Pignone-Cremagliera



La cremagliera è una **ruota cilindrica degenere** (raggio infinito), utilizzata in coppia con una **ruota non degenere** (pignone o rocchetto).

La **velocità di traslazione della cremagliera** è uguale a quella di un punto della primitiva della ruota dentata che la muove.

Esercitazione LAB2

- identificare attuatori adeguati per l'applicazione e riassumerne le proprietà rilevanti
- Aggiornare BOM
- Calcolare coppia motrice (se prevista trasmissione nell'applicazione)