



# Sensors and actuators



Last update: January 17, 2022

# Agenda

- Types of actuators
- Benefits of each type
- Sensors



# Actuators

## Definition

An actuator is the element of the robot that 'acts'! It is the part responsible for moving and controlling our robot. They have a control signal and a source of energy.



# Actuators

## Definition

An actuator is the element of the robot that 'acts'! It is the part responsible for moving and controlling our robot. They have a control signal and a source of energy.

Can you think of some examples of actuators?



# Actuators



What type of actuator? Control signal?

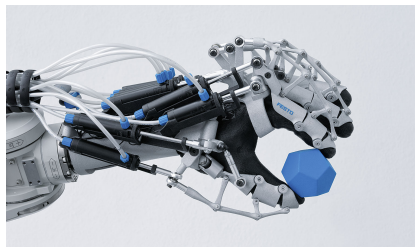
# Actuators



What type of actuator? Control signal?

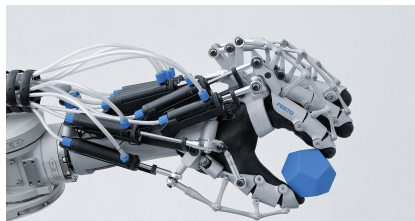


# Actuators



What type of actuator? Control signal?

# Actuators



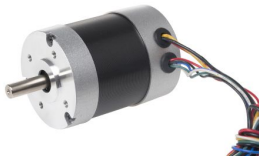
What type of actuator? Control signal?



# Motors

## Types of motors

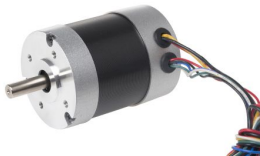
Different types of electric motors exist.



# Motors

## Types of motors

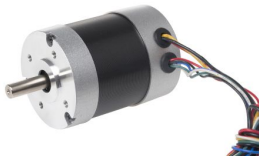
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# Motors

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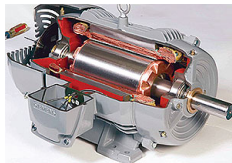
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# Motors

## Types of motors

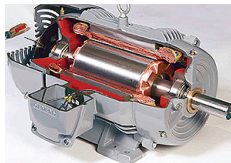
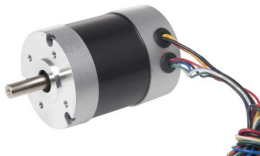
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# Motors

## Types of motors

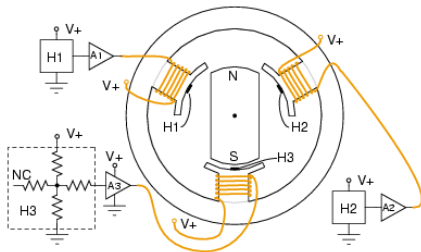
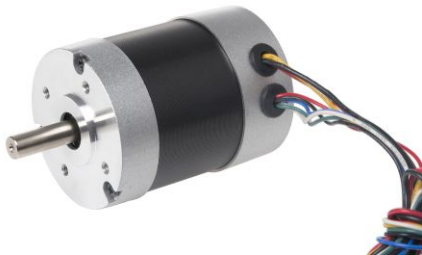
Different types of electric motors exist.



How does each one work?

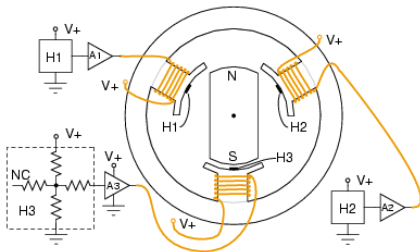
# Motors

## Brushless DC



# Motors

## Brushless DC

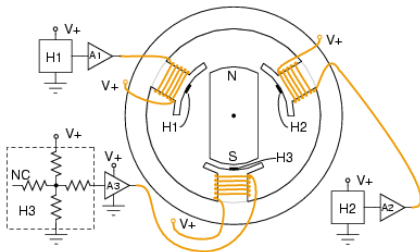
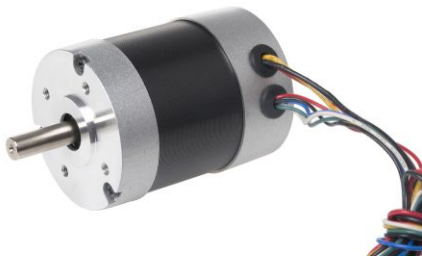


A permanent magnet as a rotor



# Motors

## Brushless DC



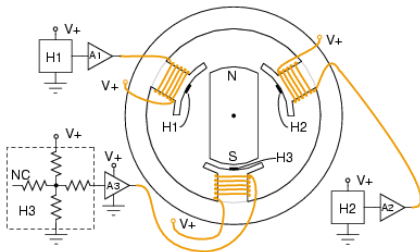
A permanent magnet as a rotor  
Coils at fixed intervals





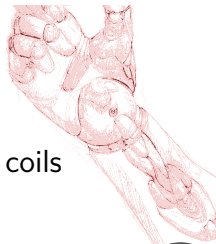
# Motors

## Brushless DC



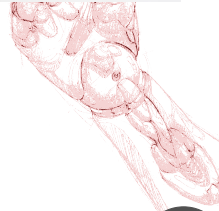
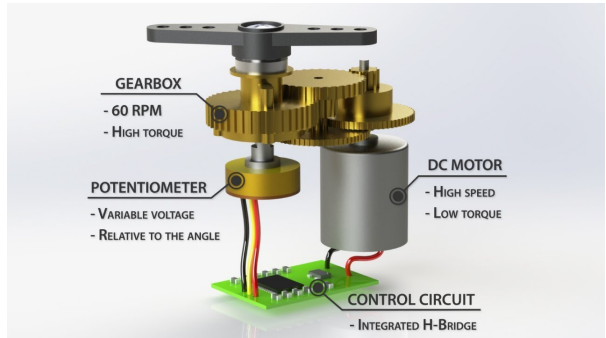
A permanent magnet as a rotor  
Coils at fixed intervals

We control the speed by changing the polarity of the coils



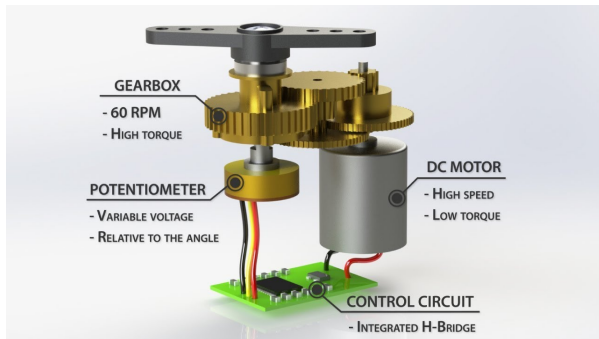
# Motors

## Servomotors

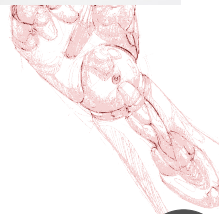


# Motors

## Servomotors

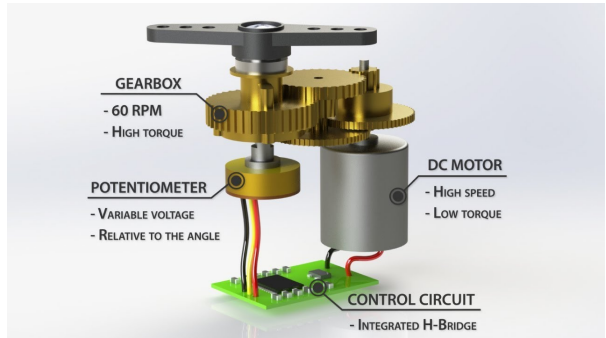


A suitable motor (brushed or brushless)



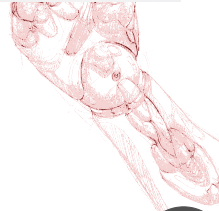
# Motors

## Servomotors



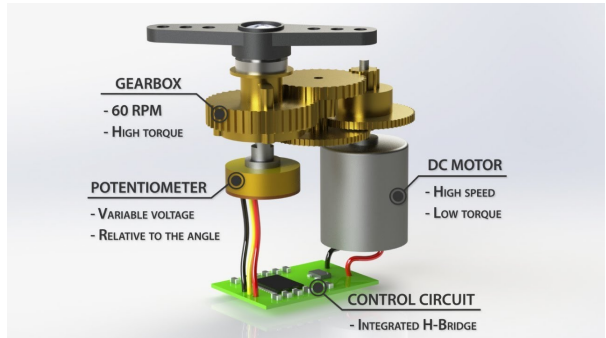
A suitable motor (brushed or brushless)

A gearbox



# Motors

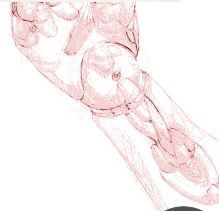
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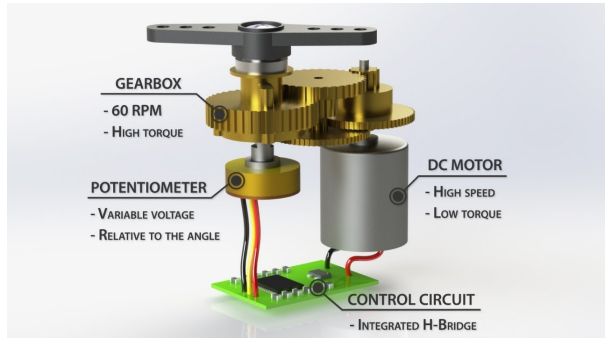
A gearbox

A feedback mechanism



# Motors

## Servomotors



A suitable motor (brushed or brushless)

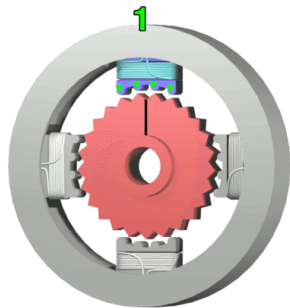
A gearbox

A feedback mechanism

A control circuit

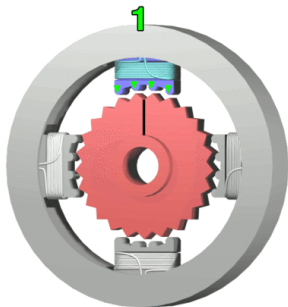
# Motors

## Steppers

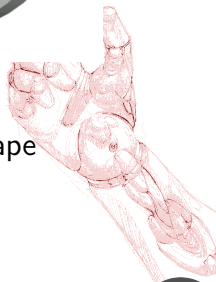


# Motors

## Steppers



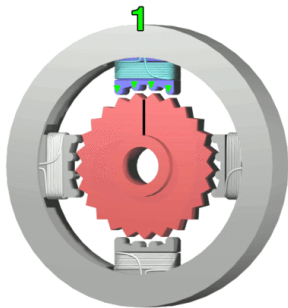
The rotor is a permanent magnet, with a toothed shape





# Motors

## Steppers

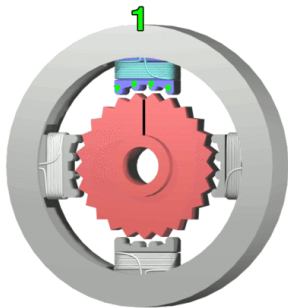


The rotor is a permanent magnet, with a toothed shape  
Multiple coils, with a similar shape as the rotor



# Motors

## Steppers

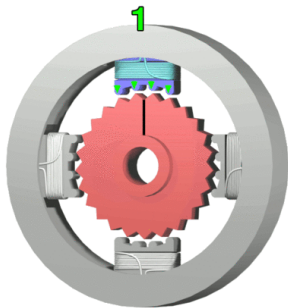


The rotor is a permanent magnet, with a toothed shape  
Multiple coils, with a similar shape as the rotor  
The offset between the teeth of the rotor and coils, is the step of rotation



# Motors

## Steppers



The rotor is a permanent magnet, with a toothed shape  
Multiple coils, with a similar shape as the rotor  
The offset between the teeth of the rotor and coils, is the step of rotation

A controller for the operation is necessary



# Motors

## Gearbox



# Motors

## Gearbox



Reduce the angular speed



# Motors

## Gearbox



Reduce the angular speed  
Increase the torque!



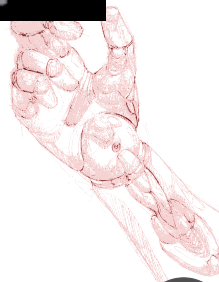
# Motors

## Gearbox



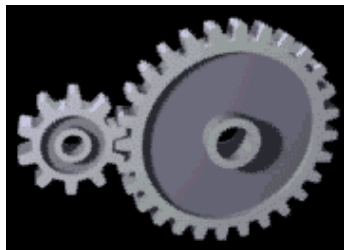
Reduce the angular speed  
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A gear is like a levering mechanism



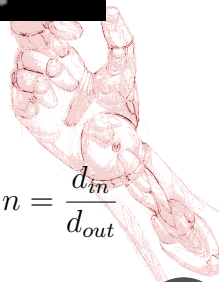
# Motors

## Gearbox



Reduce the angular speed  
Increase the torque!

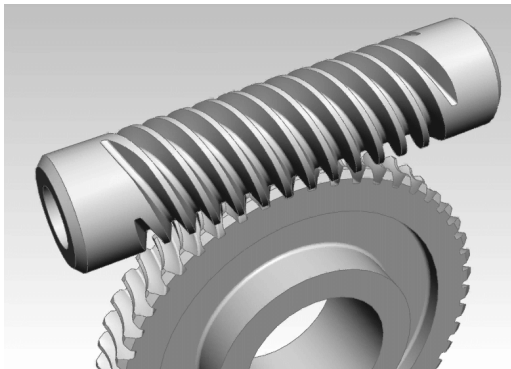
A gear is like a levering mechanism The gear ratio is  $n = \frac{d_{in}}{d_{out}}$





# Motors

## Gearbox

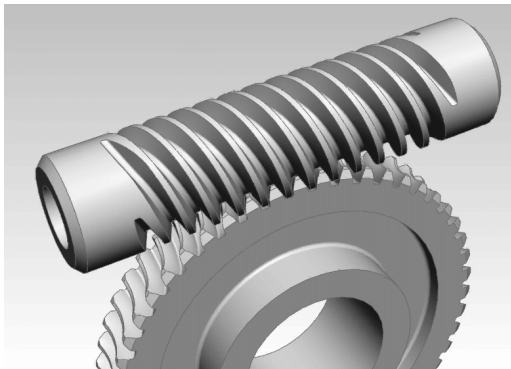


A worm-gear combination is used a lot in servomotors



# Motors

## Gearbox

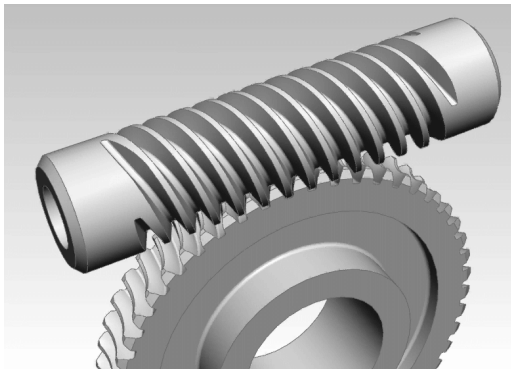


A worm-gear combination is used a lot in servomotors  
Very high gear ratio



# Motors

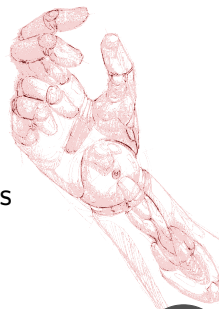
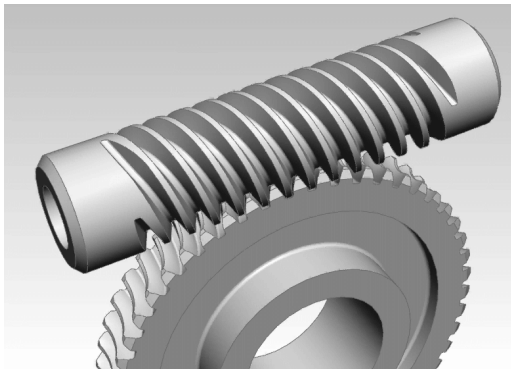
## Gearbox



A worm-gear combination is used a lot in servomotors  
Very high gear ratio  
Very small size

# Motors

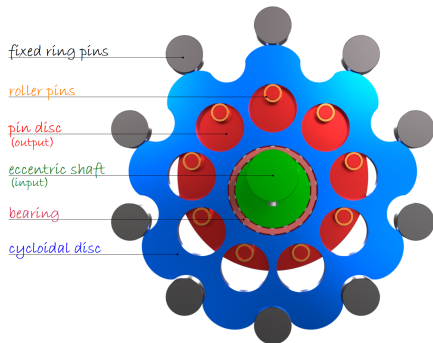
## Gearbox



A worm-gear combination is used a lot in servomotors  
Very high gear ratio  
Very small size  
Change of direction

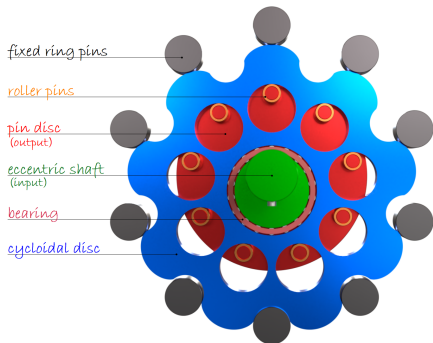
# Motors

## Cycloid gear



# Motors

## Cycloid gear

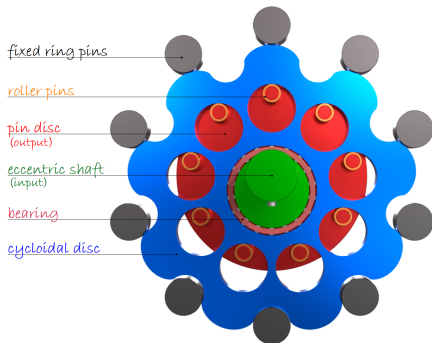


High reduction



# Motors

## Cycloid gear

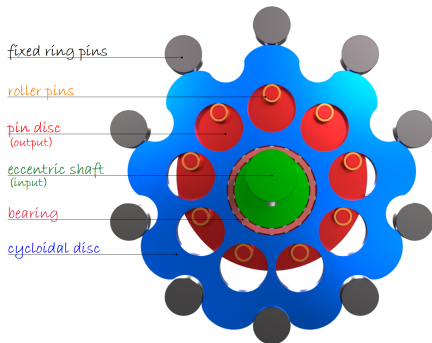


High reduction  
Very compact



# Motors

## Cycloid gear



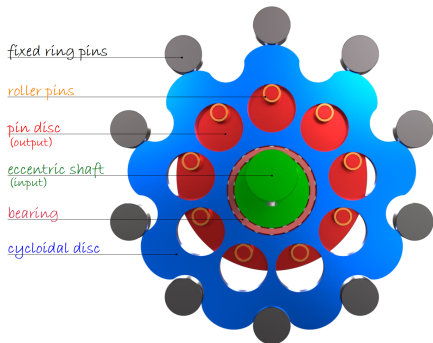
High reduction  
Very compact  
Very low backlash





# Motors

## Cycloid gear

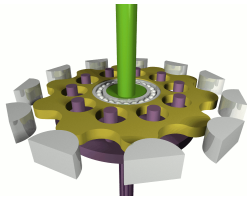
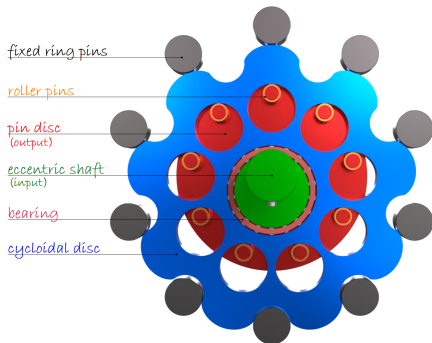


High reduction  
Very compact  
Very low backlash  
Vibrations



# Motors

## Cycloid gear



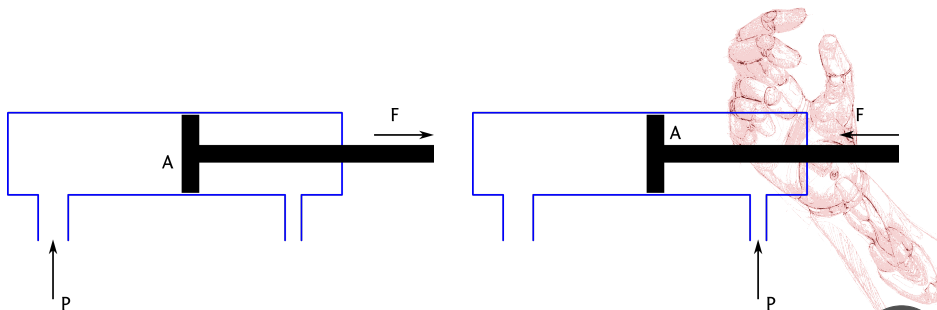
High reduction  
Very compact  
Very low backlash  
Vibrations



# Hydraulics & Pneumatics

## Principle of operation

The hydraulic and pneumatic actuators, are based on the simple equation of pressure:



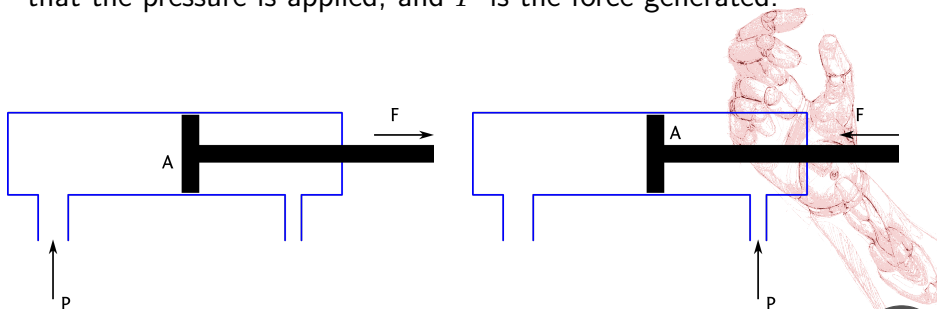
# Hydraulics & Pneumatics

## Principle of operation

The hydraulic and pneumatic actuators, are based on the simple equation of pressure:

$$F = PA$$

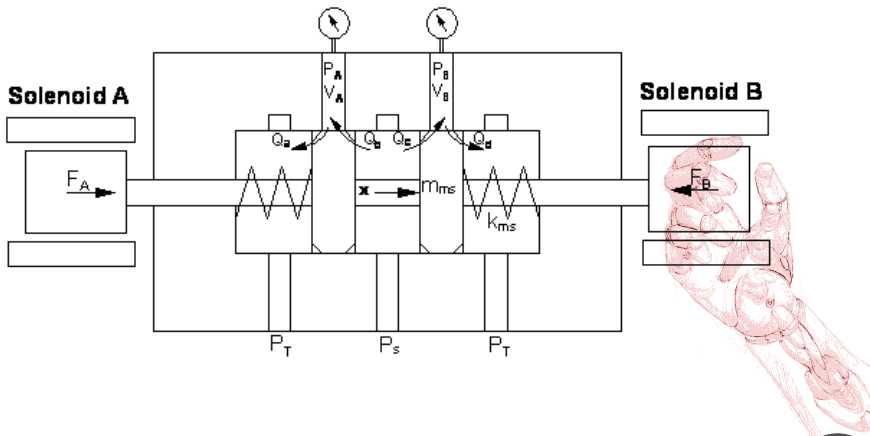
Where,  $P$  is the pressure of the fluid,  $A$  is the surface of the area that the pressure is applied, and  $F$  is the force generated.



# Hydraulics & Pneumatics

## Control systems

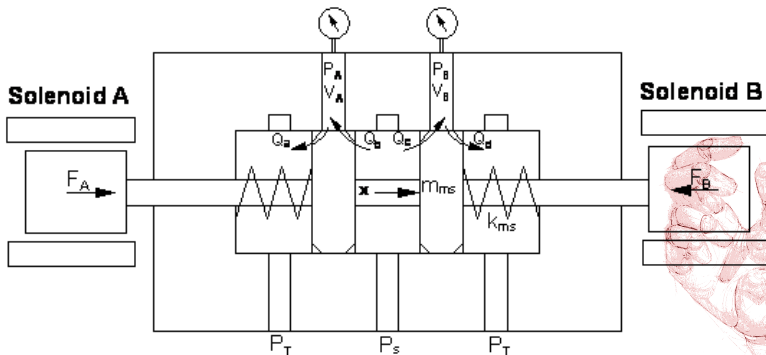
To be used in a robotic control system, we need a way to regulate the pressure, usually using a proportional valve



# Hydraulics & Pneumatics

## Control systems

To be used in a robotic control system, we need a way to regulate the pressure, usually using a proportional valve



The use of a feedback mechanism is often essential for control

# Comparison of actuation systems

-					
Control					
Force					
Position					
Speed					
Cost					
Weight					



# Comparison of actuation systems

-	DC				
Control					
Force					
Position					
Speed					
Cost					
Weight					





# Comparison of actuation systems

-	DC				
Control	Speed				
Force	Fair				
Position	Low				
Speed	Good				
Cost	Low				
Weight	Low				



# Comparison of actuation systems

-	DC	Servomotors			
Control	Speed				
Force	Fair				
Position	Low				
Speed	Good				
Cost	Low				
Weight	Low				



# Comparison of actuation systems

-	DC	Servomotors			
Control	Speed	Position			
Force	Fair	Good			
Position	Low	Good			
Speed	Good	Fair			
Cost	Low	Low			
Weight	Low	Low			



# Comparison of actuation systems

-	DC	Servomotors	Steppers		
Control	Speed	Position			
Force	Fair	Good			
Position	Low	Good			
Speed	Good	Fair			
Cost	Low	Low			
Weight	Low	Low			



# Comparison of actuation systems

-	DC	Servomotors	Steppers		
Control	Speed	Position	Position		
Force	Fair	Good	Low		
Position	Low	Good	Excellent		
Speed	Good	Fair	Good		
Cost	Low	Low	Medium		
Weight	Low	Low	Low		



# Comparison of actuation systems

-	DC	Servomotors	Steppers	Pneumatic	
Control	Speed	Position	Position		
Force	Fair	Good	Low		
Position	Low	Good	Excellent		
Speed	Good	Fair	Good		
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# Comparison of actuation systems

-	DC	Servomotors	Steppers	Pneumatic	
Control	Speed	Position	Position	Force	
Force	Fair	Good	Low	Low	
Position	Low	Good	Excellent	Poor	
Speed	Good	Fair	Good	Good	
Cost	Low	Low	Medium	High	
Weight	Low	Low	Low	Medium	



# Comparison of actuation systems

-	DC	Servomotors	Steppers	Pneumatic	Hydraulic
Control	Speed	Position	Position	Force	
Force	Fair	Good	Low	Low	
Position	Low	Good	Excellent	Poor	
Speed	Good	Fair	Good	Good	
Cost	Low	Low	Medium	High	
Weight	Low	Low	Low	Medium	





# Comparison of actuation systems

-	DC	Servomotors	Steppers	Pneumatic	Hydraulic
Control	Speed	Position	Position	Force	Force
Force	Fair	Good	Low	Low	Very High
Position	Low	Good	Excellent	Poor	Fair
Speed	Good	Fair	Good	Good	Poor
Cost	Low	Low	Medium	High	Very High
Weight	Low	Low	Low	Medium	Very High



# Actuators



What type of actuator? Why?

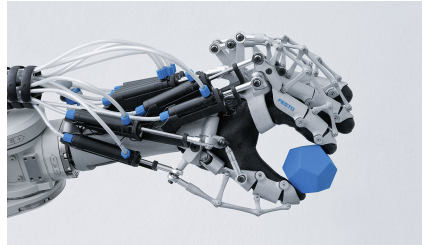
# Actuators



What type of actuator? Why?

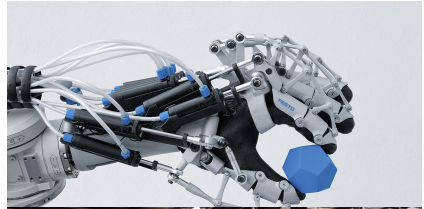


# Actuators



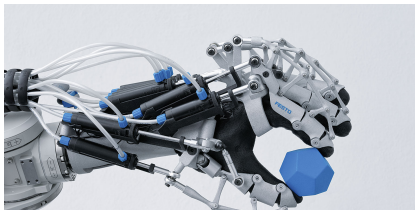
What type of actuator? Why?

# Actuators



What type of actuator? Why?

# Actuators



What type of actuator? Why?  
What type of gearbox? Why?

# Sensors

## What is a sensor

### Definition

A sensor is a device that detects events happening in the physical world and is transmitting it to another electronic device.



# Sensors

What is a sensor

## Definition

A sensor is a device that detects events happening in the physical world and is transmitting it to another electronic device.

There is a huge variety of sensors available, in different sizes and specifications. Here, we discuss the most common ones in robotic applications





# Sensors

## Encoders

One of the most common types of sensor that is used in robotics, are encoders. An encoder gives us information about the angle of rotation or the amount of translation between two parts.

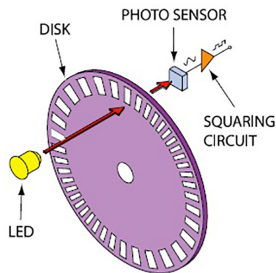


# Sensors

## Encoders

One of the most common types of sensor that is used in robotics, are encoders. An encoder gives us information about the angle of rotation or the amount of translation between two parts.

### Relative encoder

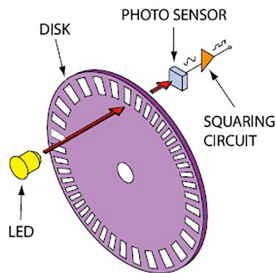


# Sensors

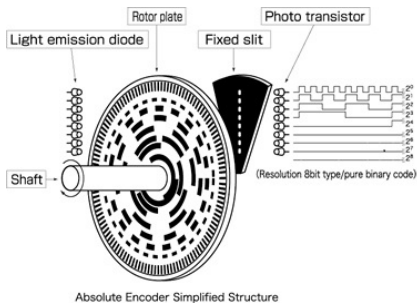
## Encoders

One of the most common types of sensor that is used in robotics, are encoders. An encoder gives us information about the angle of rotation or the amount of translation between two parts.

### Relative encoder



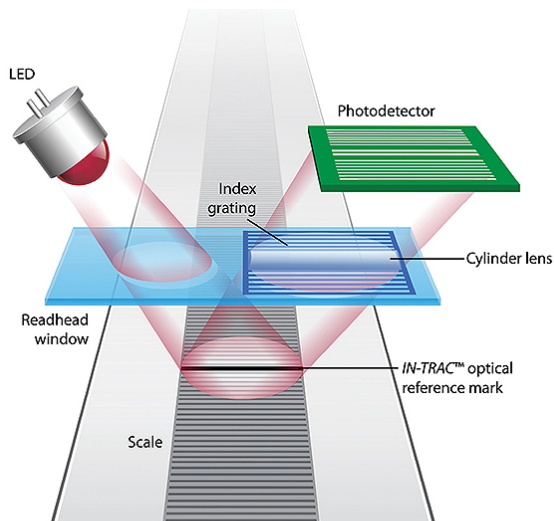
### Absolute encoder



# Sensors

## Encoders

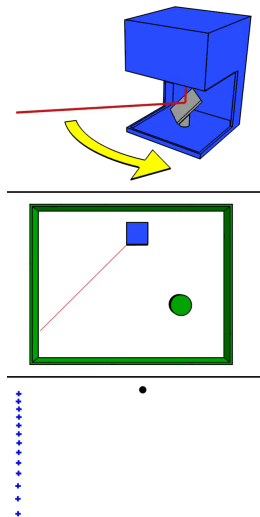
The same distinction between relative and absolute can be found for linear encoders as well



# Sensors

## LIDAR

Environment sensing sensor using the 'time of flight' principle



# Sensors

## LIDAR

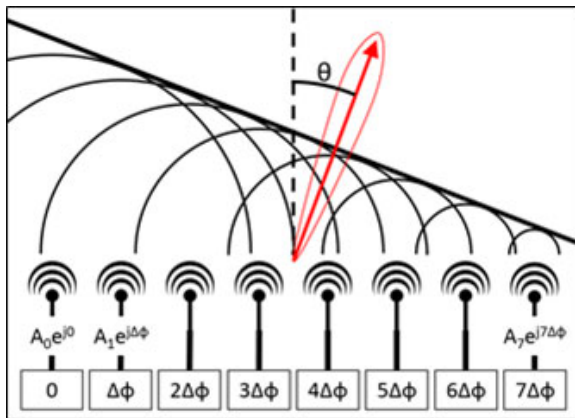
Often used with mobile robots for scanning the environment



# Sensors

## Solid State LIDAR

The problem with traditional LIDAR is that they rely on moving parts. Solid state LIDAR has no moving parts. They generate beams of light by smartly position emitting arrays



# Sensors

## Light sensor



A light sensor can detect light intensity. It can be useful to scan the area to find windows or doors. They usually translate light intensity into resistance

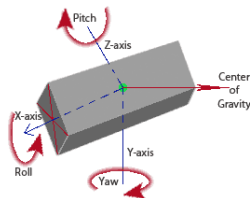




# Sensors

## IMUs

An IMU (Inertial Measurement Unit) combines information from different sensors (Accelerometers, Gyroscopes, Magnetometer etc.) to infer the orientation and speed of the unit. They can be useful when combined with relative encoders, to correct any possible errors in position



# Sensors

## Load cells

A load cell is a sensor that measures forces and torques applied on an object. This is done by measuring tiny deformations on the loadcell. By knowing the material properties of the loadcell, we can translate the deformation into force.



# Sensors

## Many many types

There is practically a huge amount of sensors used in robots, depending on the application



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# Sensors

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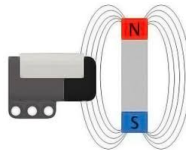
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# Sensors

## Many many types

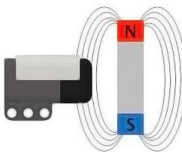
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# Sensors

Many many types

There is practically a huge amount of sensors used in robots, depending on the application



And many many more





# Questions?