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Robotics – Planning and Motion

Actuators & Sensors

COMP52815

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Lecture 2: Learning Objectives

We will introduce different types of actuators and sensors which are used in robotics. A brief introduction.

- **Objectives:**
  - Different Types of Actuators
  - Sensors

Actuators

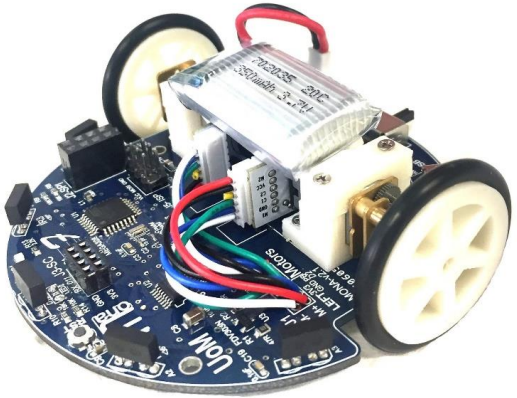
Three commonly used actuator types:

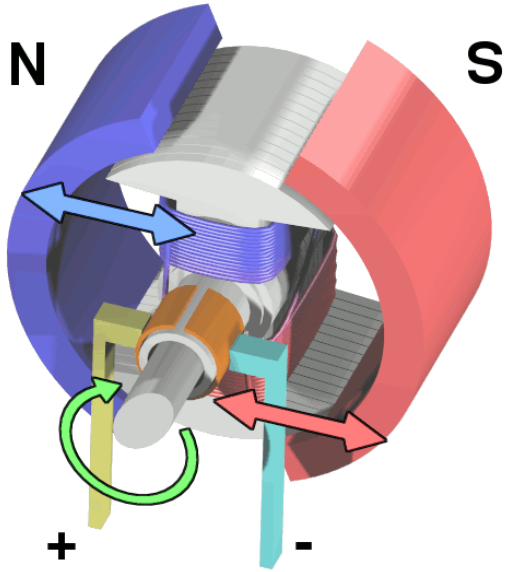
- Electromagnetic
  - *The most common types of actuators*
- Hydraulic
- Pneumatic

Electromagnetic Actuators

Brushed DC Motor

- Current flowing through armature generates a magnetic field and permanent magnets torque the armature
  - Advantages: provides variable speeds, low-cost
  - Disadvantages: Brush wear out, low precision





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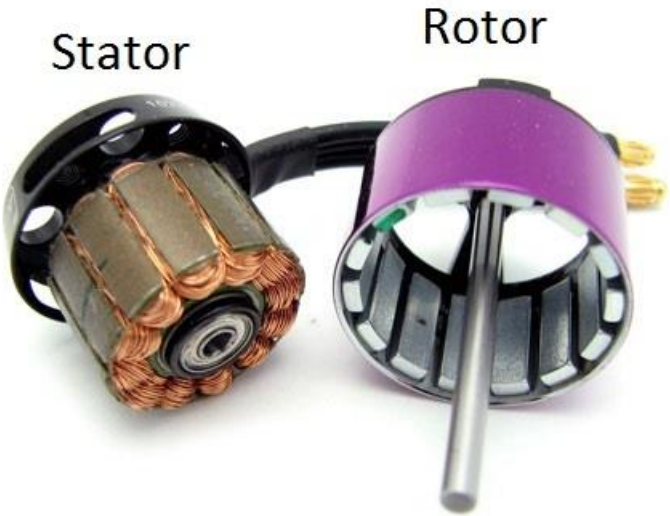
Electromagnetic Actuators

Brushless DC Motor

- Armature is fixed, and permanent magnets rotate
  - *Advantages*: Efficiency, Low noise, Cooling, Water-resistant
  - *Disadvantages*: low precision, costly



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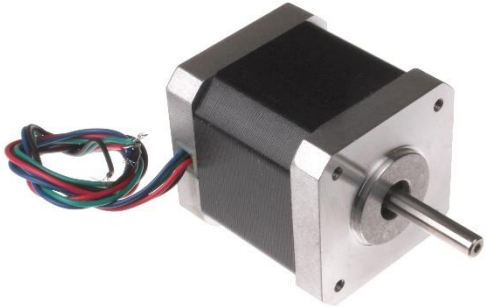
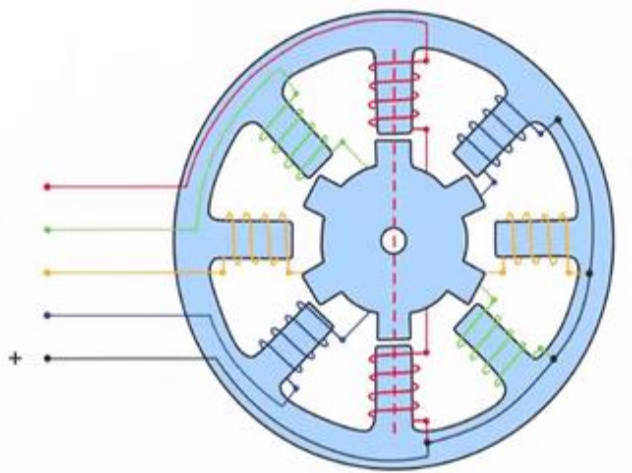
Electromagnetic Actuators

Stepper Motor



- Brushless, synchronous motor that moves in discrete steps
  - *Advantage*: Precise, quantized control without feedback
  - *Drawback*: Slow and moves in discrete steps, expensive



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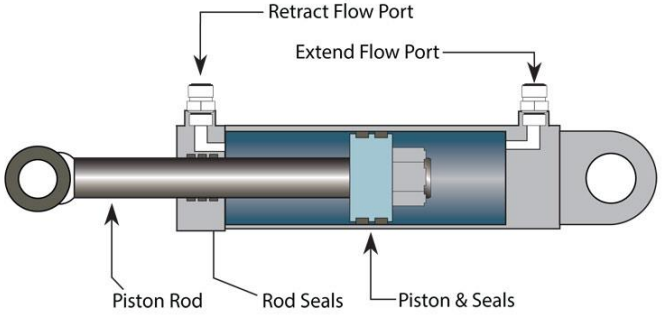
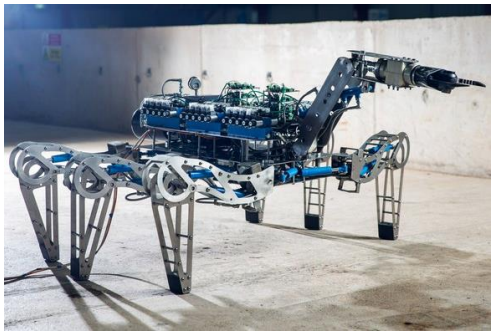
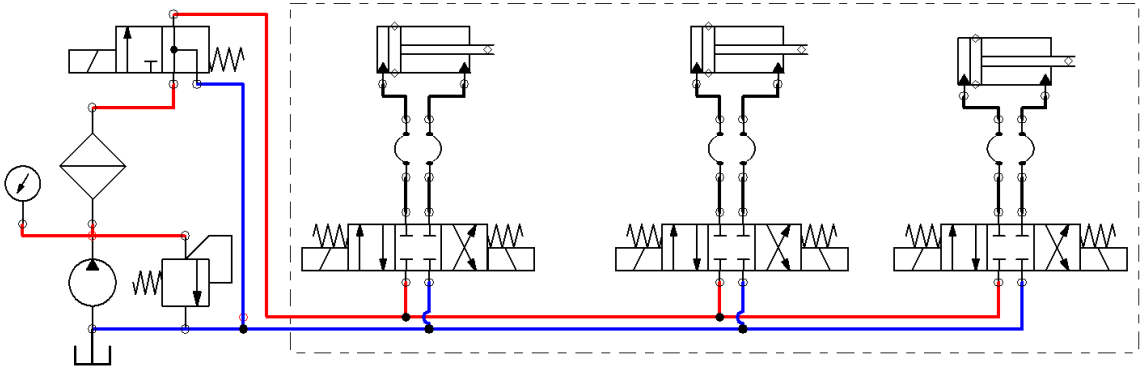
Hydraulic Actuators

Cylinders (linear actuators):

- Advantages:
  - Very powerful that offer very large force capability, but expensive
  - High power-to-weight ratio
- Drawbacks:
  - Their power supplies are bulky and heavy
  - Oil leakage







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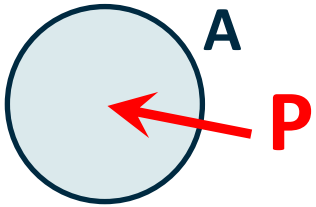
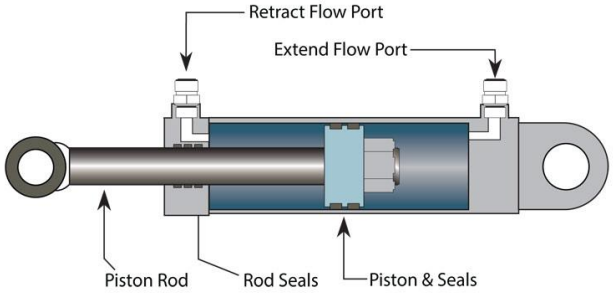
Hydraulic Actuators

Cylinders (linear actuators):

- Force, F, calculation extend & retract:
  - Cylinder bore diameter: 25 mm
  - Cylinder rod diameter: 16 mm
  - Max pressure, P= 21 MPa (210 bar)

$$F = P \,.\, A$$





Calculate force for extending the rod with max P:

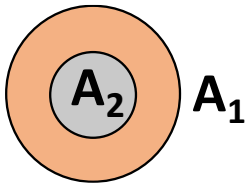
$A = \pi R^2 = 490.625 \text{ mm}^2$

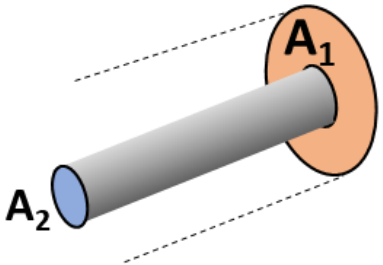
$F = 21 \text{ x } 490.625 = 10{,}303 \text{ N}$

Retract the rod:

$A = A_1 - A_2 = 289.665 \text{ mm}^2$

$F = 21 \text{ x } 289.665 = 6{,}083 \text{ N}$





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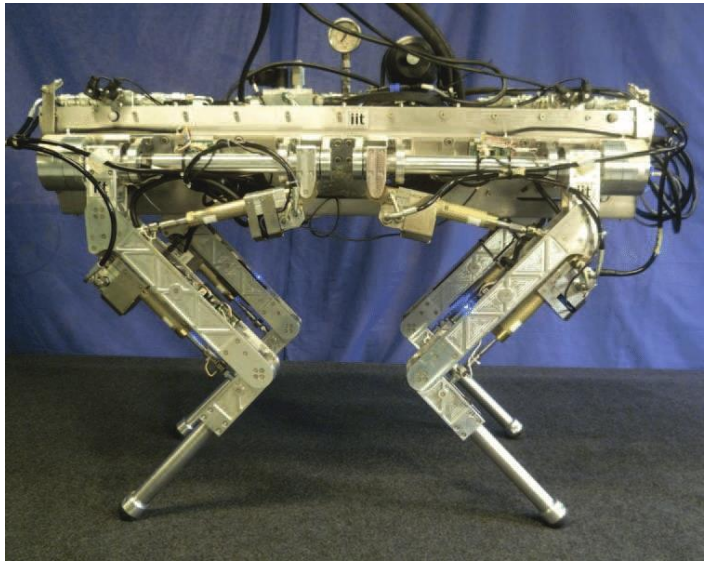
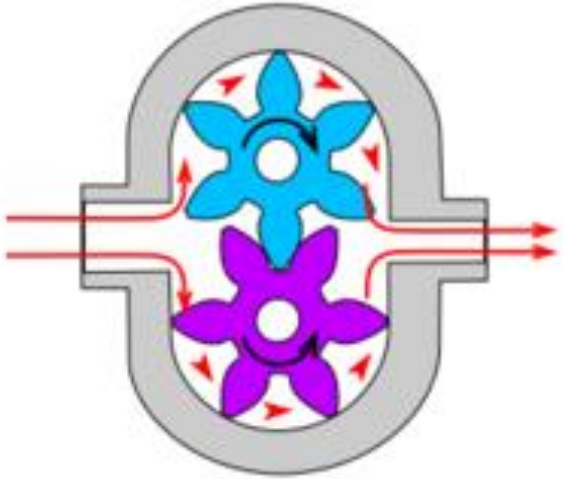
Hydraulic Actuators

Motors (rotary actuators):





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Integrated Smart Hydraulic Actuator

Usual hydraulic actuator-valve configuration:

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Pneumatic Actuators

- Cylinders (linear actuators)

- Motors (rotary actuators)

Sensors

- Motivation, why do robots need sensors?
- Robotic sensor classification
- Various sensors overview

Motivation

- A robot would be easily controlled if a complete model of the environment was available for the robot, and if its actuators could execute motion commands perfectly relative to this model.
- Sensors only measure a physical quantity

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Robotic sensor classification

- **Proprioceptive**
  - Internal state of the robot
  - Measures values e.g. wheels position, joint angle, battery level, etc
- **Exteroceptive**
  - External state of the system
  - Observing environment, detecting objects, etc.

- **Active**
  - Emits energy (e.g. radar)
- **Passive**
  - Receives energy, e.g. camera

Robotic sensor classification

Application	Sensors	PC/EC	A/P
Tactile sensors (physical contacts, distance estimation etc)	Bumpers, contact switches Optical barrier Proximity sensors	EC EC EC	P A A
Wheels and Motors sensors Detecting speeds and position	Brush encoders Potentiometers Optical, magnetic, inductive capacitive encoders	PC PC PC	P P A
Heading Sensors Orientation of robot and alignment	Compass Gyroscopes Inclinometer	EC PC EC	P P A/P
Ground based beacons (localisation)	GPS RF, ultrasonic, reflective beacons	EC EC	A A
Active ranging (reflectivity, time-of-flight, geometric triangulation)	Ultrasonic, laser, reflective sensors Optical triangulation (1D) Structured light (2D)	EC EC EC	A A A
Motion and speed sensors (relative to a fix or moving object)	Doppler radar Doppler sound	EC EC	A A
Vision-based sensors (visual ranging, segmentation, object detection etc)	CCD/CMOS cameras (ranging, tracking, etc packages)	EC	P

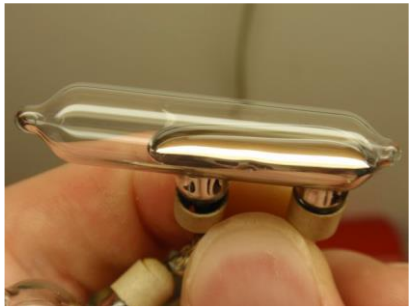
Robotic sensor classification

- **Real-world Characteristics of sensors**
  - **Sensitivity**: Ratio of output change to input change.
  - **Error/Accuracy**: Difference between the sensor's output and the true value.
    - **Systematic/Deterministic Error**: Caused by factors that can be modelled (in theory), e.g., calibration of a laser sensor.
    - **Random Error**: e.g., hue instability of camera, black level noise of camera.
  - **Reproducibility**: Reproducibility of sensor results.

Various sensors overview

- A simple On/Off switch

- Titl sensor (mercury titl)



- Dual axis inclinometer

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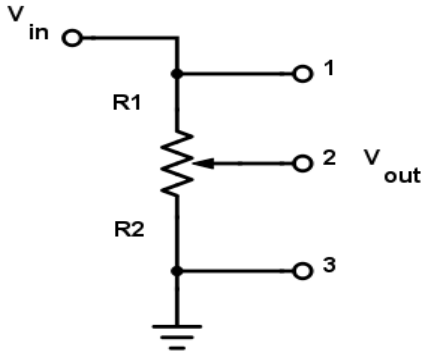
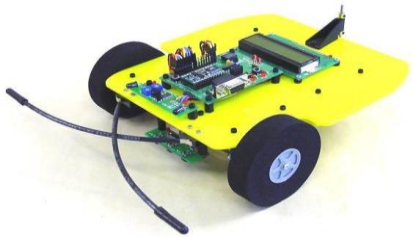
Various sensors overview

- Potentiometer



- Bumpers
  - Mechanical switches



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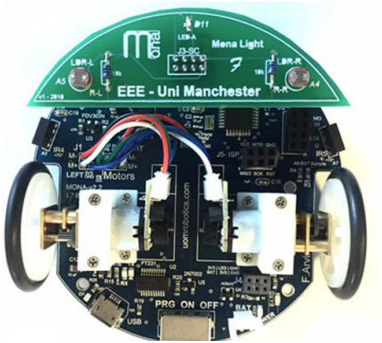
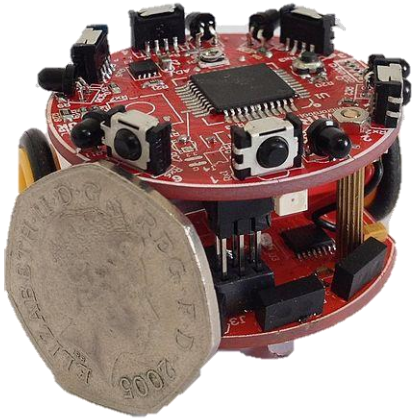
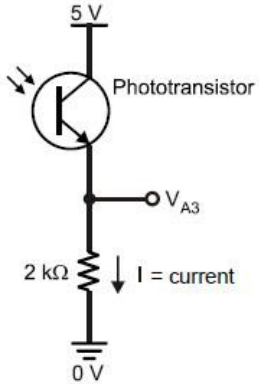
Various sensors overview



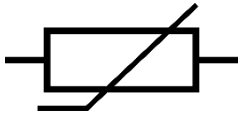
- **Light sensors**
- Photoresistors, *light dependent resistors (LDR)*
- Phototransistors





Various sensors overview

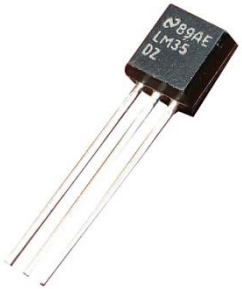
- **Thermal sensor**



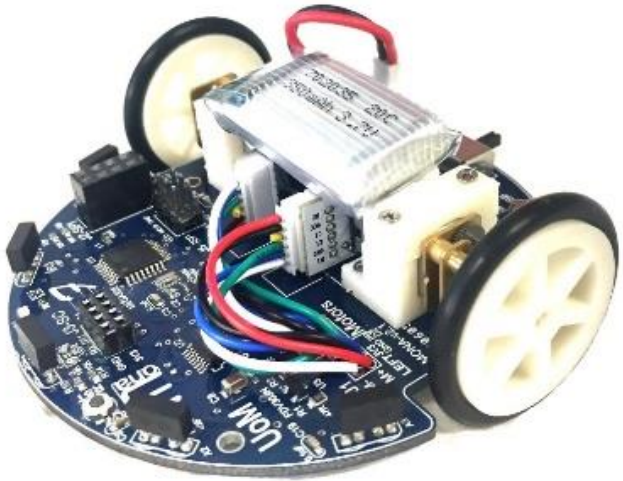
- Thermal resistor

- Temperature sensors
  - Analogue

  - Digital

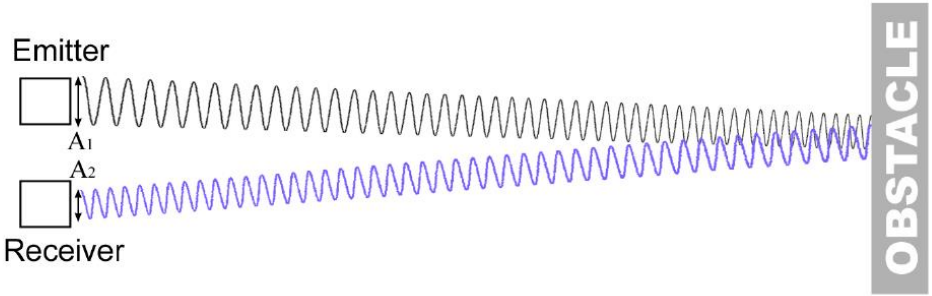


Various sensors overview



- **Proximity sensors**
- Non-contact
- Devices that can be used in areas that are near to an object to be sensed

- Different types of Proximity Sensors:
  - Infrared
  - Ultrasonic
  - Inductive
  - Capacitive



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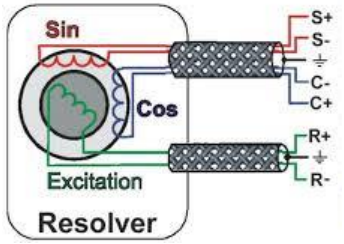
Various sensors overview

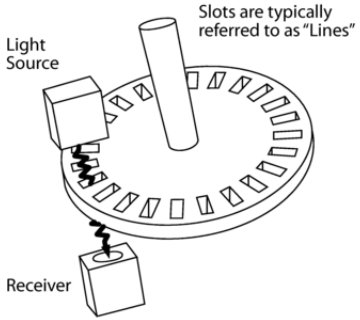
Position Sensors *(for angle)*

- Potentiometer

- Resolver



- Optical Encoders
  - Relative position
  - Absolute position



Measure position, speed, direction of revolution of the wheel.

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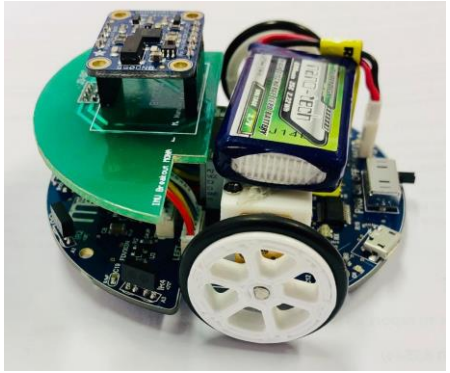
Various sensors overview



Heading sensors:

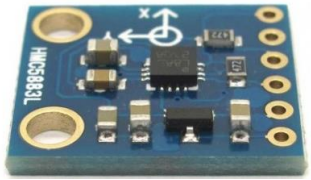
- Heading sensors can be proprioceptive (gyroscope, inclinometer) or exteroceptive (compass).
- Used to determine the robots orientation and inclination

Compass

- The magnetic compass was invented by Chinese (more than 2000 years ago), suspended a piece of natural magnetite from a silk thread and used it to guide a chariot over land.
- Absolute measure for orientation based on Earth magnetic field

- Mechanical magnetic compass
- Direct measure of the magnetic field, Hall-effect
- ***Drawbacks***:

Easily disturbed by magnetic objects or other sources



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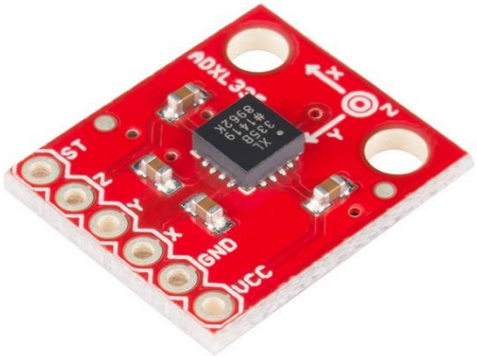
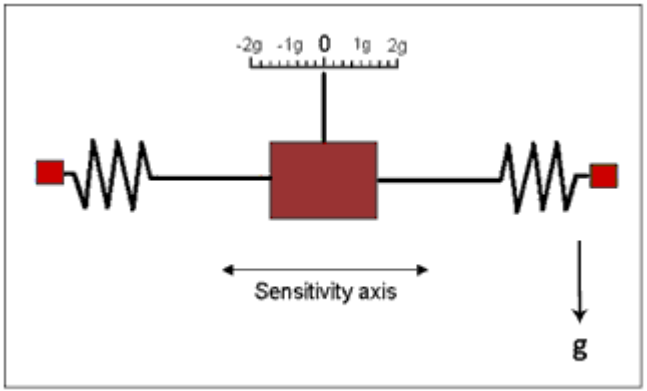
Various sensors overview

- **Accelerometer**

Acceleration is the change in velocity over time, based on Newton's 2nd law ($F = ma$) a sensor may be made to sense acceleration by simply measuring the force on a mass.





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Various sensors overview

Gyroscope

- Heading sensors for measuring and to keep the orientation to a fixed frame
- Two methods:
  - Mechanical (flywheel)
  - Electronic

Gyroscope was invented by Jean Bernard Léon Foucault, a French physicist, in 1852.

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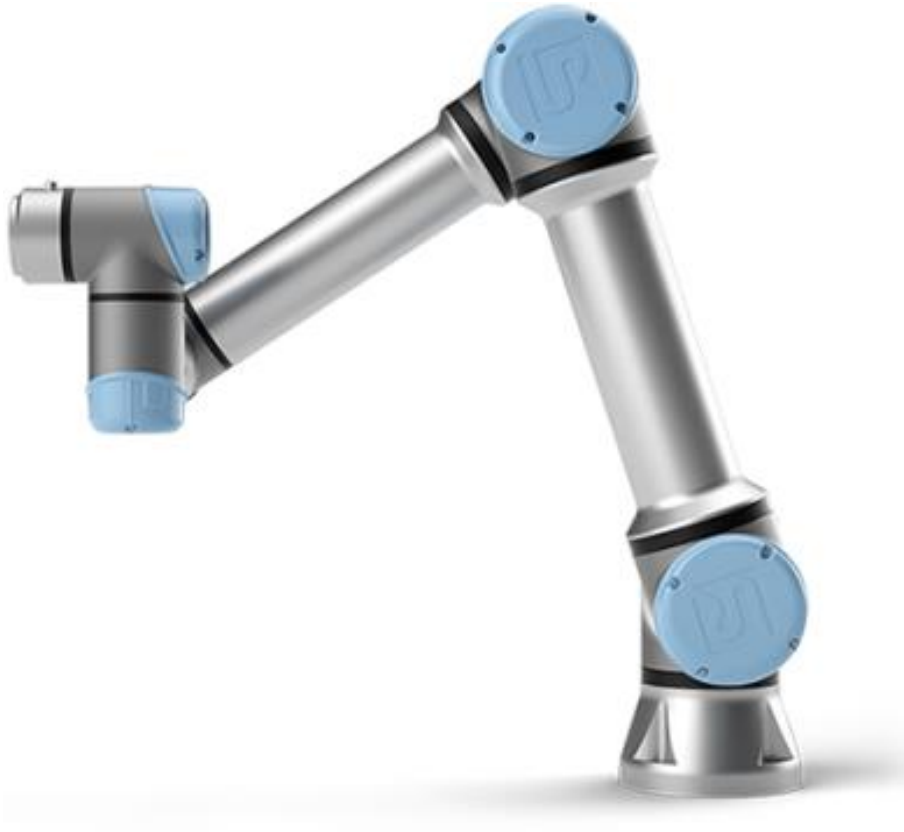
Components used for Manipulators

- **Components in a joint:**
  - Motors (electric or hydraulic)
  - Motor Encoders
    - Angle (joint angle)
    - Displacement sensor
  - Gearbox



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Lecture 2 Summary

- Discussed various types of actuators
- Introduced various types of sensors and their application is robotics
- Components used for manipulators