Design Lab: Introduction & Sensing

Corso Materiali intelligenti e Biomimetici
17/03/2020

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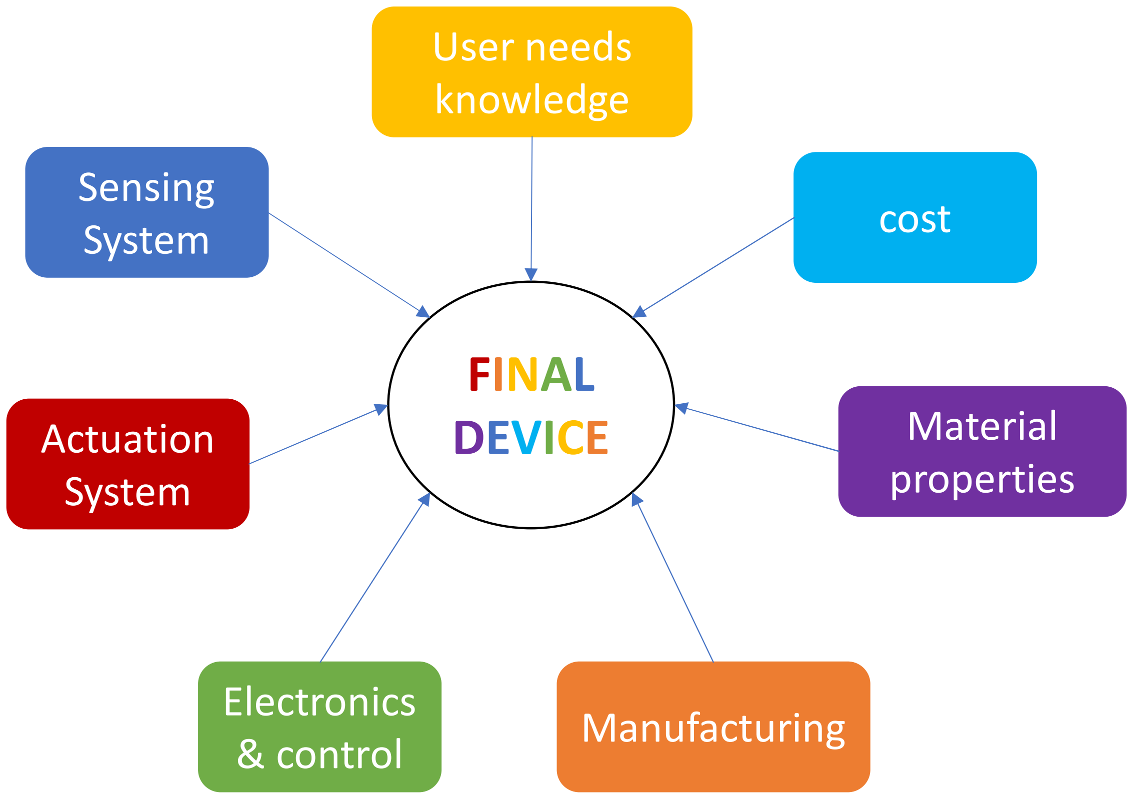
Design of intelligent systems

The importance of being a Biomedical Engineer



Martedì 17/03	Design LAB: Introduction & **Sensing** (ricerca sensore)/scelta applicazione
Martedì 24/03	Design LAB: **actuation&transmission** (dimensionamento e ricerca motore, trasmissione)
Martedì 31/03	Design LAB: Prototyping&Production (tecniche e materiali costruttivi)
Martedì 7/04	Design LAB: alternativa materiale intelligente per sensing/actuation (vantaggi/svantaggi)
Martedì 21/04	Design LAB: **eCAD&Control** (introduzione+scelta componenti)
Martedì 28/04	Design LAB: **eCAD** (esercitazione *fritzing*)
Martedì 5/05	Design LAB: **eCAD** (esercitazione *eagle)*
Martedì 12/05	Design LAB: progettazione circuito e script controllo arduino
Martedì 19/05	Design LAB: CAD design struttura/case elettronica
Martedì 26/05	Design LAB: varie

Design Lab: progettare una struttura intelligente basata su:

i) componenti classici;
ii) materiali intelligenti (differenze costi/prestazioni tra sistema classico e con smart materials)

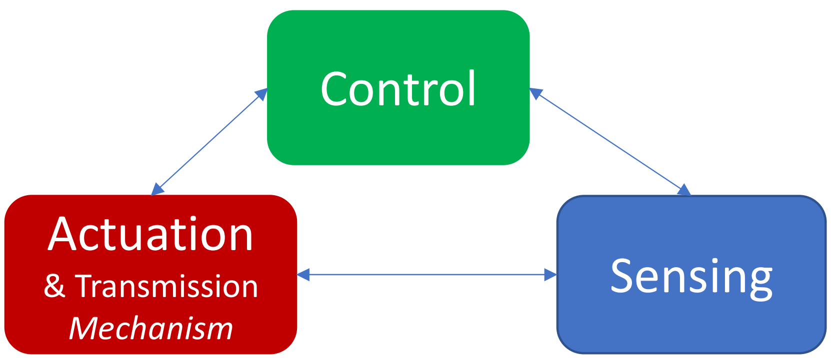
Dispositivo per test meccanici di tessuti biologici o altra struttura (con applicazione biomedica) a scelta dello studente

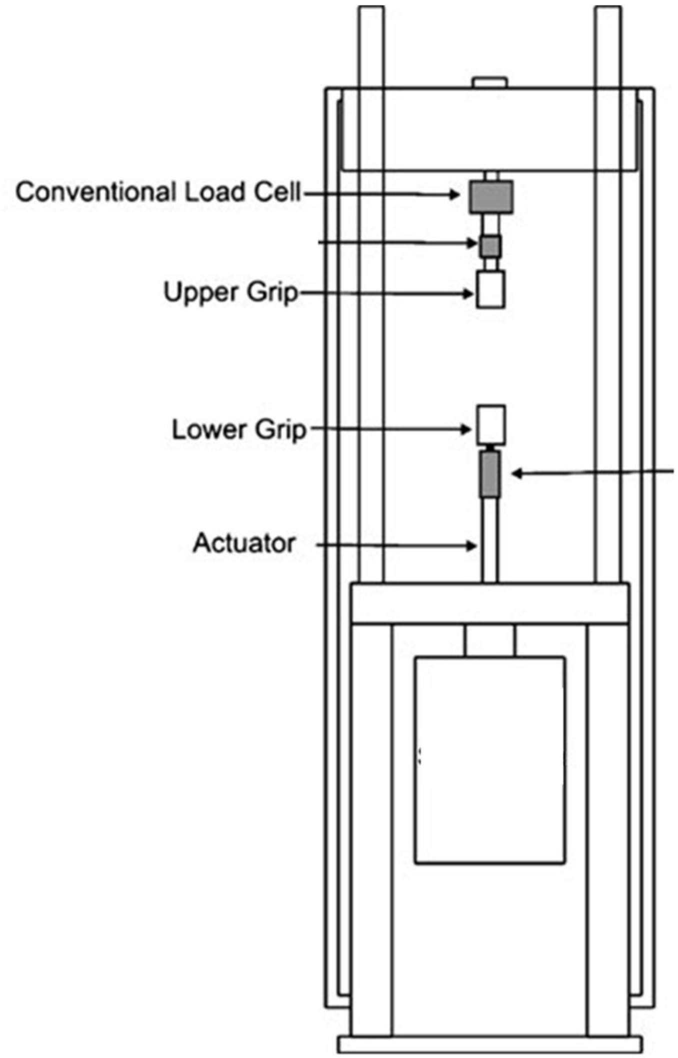
Google Classroom:
vqnjbs3

Universal Testing Machine

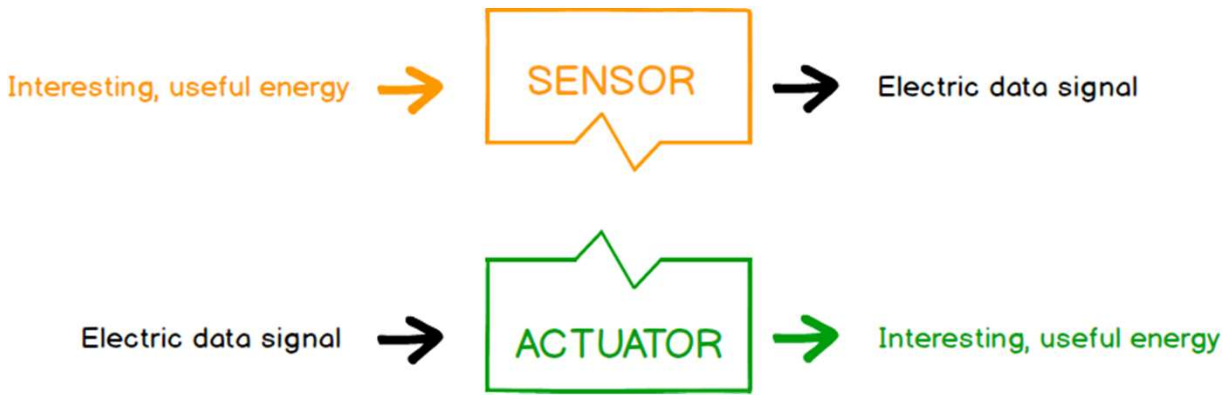
Main components:

- **Load cell** (different maximum loads)
- **Actuator**
- **Control system**
- Sample holding system





Sensors vs. Actuators



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

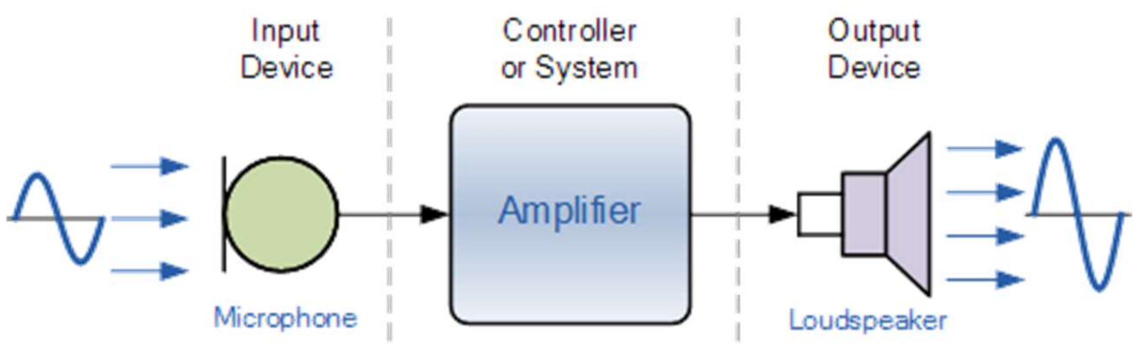
Devices which perform an **"Input" function** are commonly called **Sensors** because they *"sense" a physical change* in some characteristic and covert that into an electrical signal.

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

Transducers

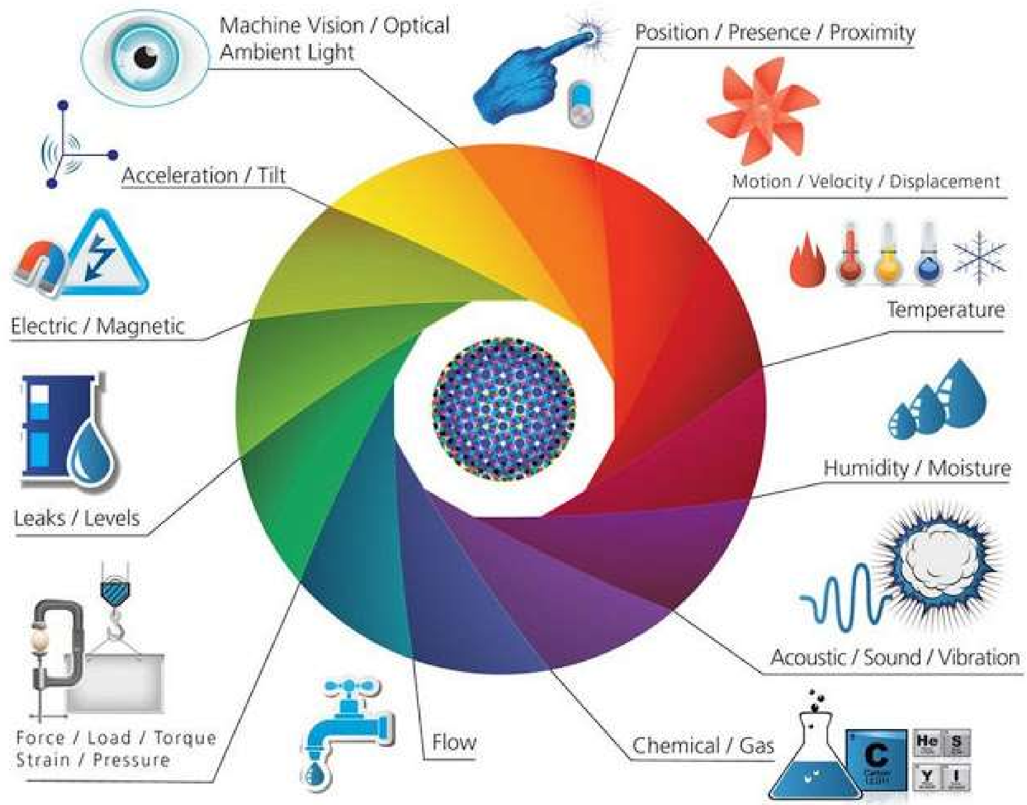
Electrical Transducers are used to **convert energy of one kind into energy of another kind.**

For example, *a microphone (input device) converts sound waves into electrical signals* for the amplifier, and *a loudspeaker (output device) converts these electrical signals* back into sound waves and an example of this type of simple Input/Output (I/O) system is given below



Transducer – types

Quantity being Measured	Input Device (Sensor)	Output Device (Actuator)
Light Level	Light Dependant Resistor (LDR) Photodiode Photo-transistor Solar Cell	Lights & Lamps LED's & Displays Fibre Optics
Temperature	Thermocouple Thermistor Thermostat Resistive Temperature Detectors	Heater Fan
Force/Pressure	Strain Gauge Pressure Switch Load Cells	Lifts & Jacks Electromagnet Vibration
Position	Potentiometer Encoders Reflective/Slotted Opto-switch LVDT	Motor Solenoid Panel Meters
Speed	Tacho-generator Reflective/Slotted Opto-coupler Doppler Effect Sensors	AC and DC Motors Stepper Motor Brake
Sound	Carbon Microphone Piezo-electric Crystal	Bell Buzzer Loudspeaker



Sensors

Input type transducers or sensors, produce a **voltage or signal output response, which is proportional to the change in the quantity that they are measuring** (the stimulus). The type or amount of the output signal depends upon the type of sensor being used.

- **active sensors** require an **external power supply to operate**, called an excitation signal which is used by the sensor to produce the output signal. Active sensors can also produce signal amplification. A good example of an active sensor is an LVDT sensor or a *strain gauge*. Strain gauges are pressure-sensitive resistive bridge networks that are external biased (excitation signal) in such a way as to produce an output voltage in proportion to the amount of force and/or strain being applied to the sensor.
  physical phenomena: meccanoresistive, termoresistive..etc

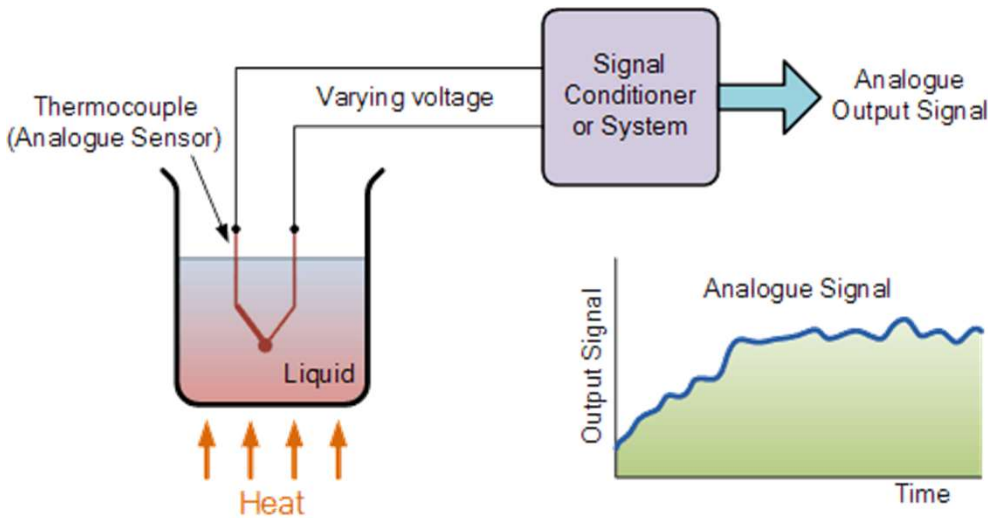
- A **passive sensor** does **not need any additional power source** or excitation voltage. Instead a passive sensor generates an output signal in response to some external stimulus. For example, a *thermocouple* which generates its own voltage output when exposed to heat.

physical phenomena: piezoelectric, thermoelectric..etc

Analogue Sensors

Analogue Sensors produce a **continuous output signal** or voltage which is generally *proportional to the quantity being measured*.

Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc are all analogue quantities as they tend to be continuous in nature. For example, the temperature of a liquid can be measured using a thermometer or thermocouple which continuously responds to temperature changes as the liquid is heated up or cooled down.

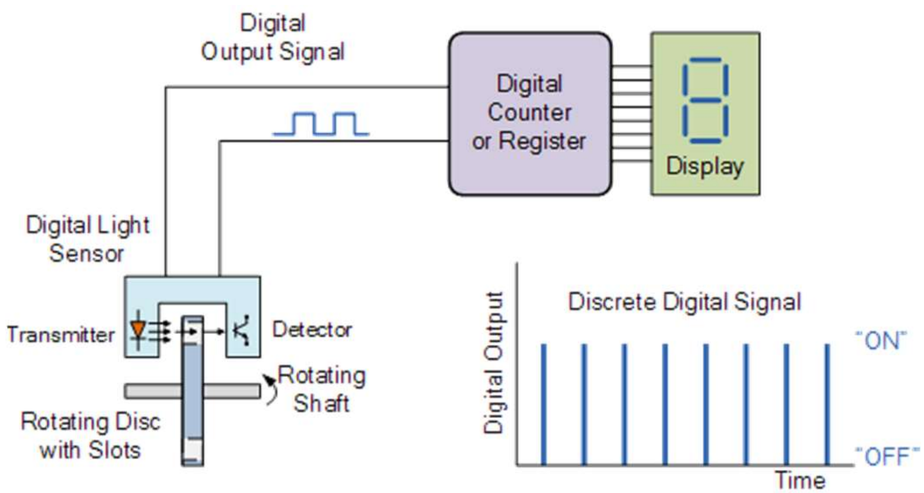


Also **analogue signals can be easily converted into digital type** signals for use in micro-controller systems by the use of **analogue-to-digital converters** (ADC).

Digital Sensors

Digital Sensors produce a **discrete digital output signals** or voltages that are a *digital representation of the quantity being measured*.

Digital sensors produce a **Binary output signal** in the form of a logic "1" or a logic "0", ("ON" or "OFF"). This means then that a digital signal *only produces discrete (non-continuous) values* which may be outputted as a single "bit", (serial transmission) or by combining the bits to produce a single "byte" output (parallel transmission).



For example, the speed of the rotating shaft can measured by using a digital LED/Opto-detector sensor.

The disc which is fixed to a rotating shaft has a number of transparent slots within its design. As the disc rotates with the speed of the shaft, each slot passes by the sensor in turn producing an output pulse representing a logic "1" or logic "0" level.

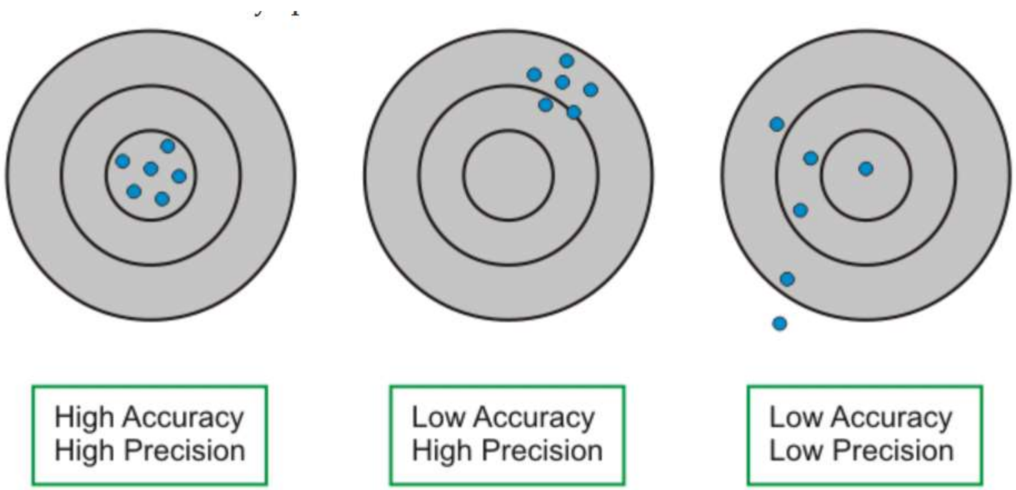
These pulses are sent to a register of counter and finally to an output display to show the speed or revolutions of the shaft. By increasing the number of slots or "windows" within the disc more output pulses can be produced for each revolution of the shaft

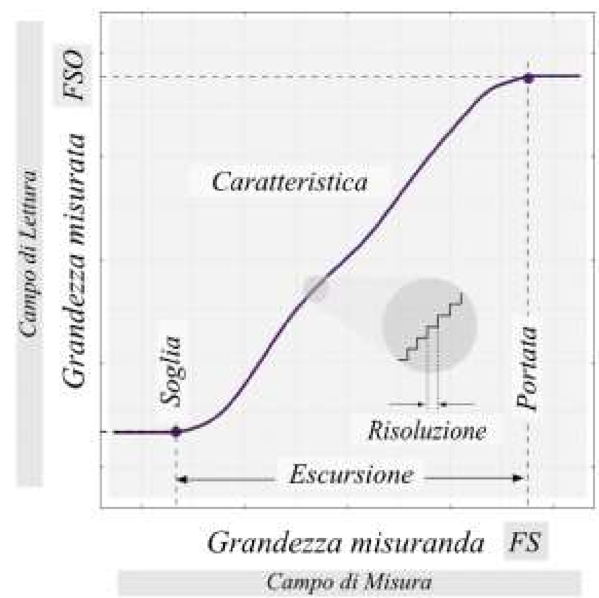
Sensor Characteristics

- **Range**: it is the minimum and maximum value of physical variable that the sensor can sense or measure
- **Sensitivity** is the ratio of change in output to change in input.
- **Resolution: i**t is the minimum change in input that can be sensed by the sensor.

$$S = \frac{dY}{dX} = \frac{\Delta Y}{\Delta X}$$

- **Accuracy:** It is defined as *the* difference between *measured value* and *true value*. It is defined in terms of % of full scale or % of reading.
- **Precision:** It is defined as the closeness among a set of repeated measurements



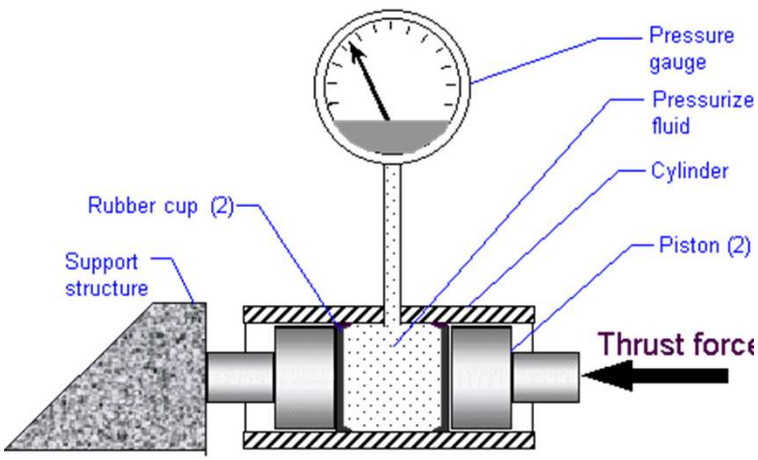


Example: Load cells

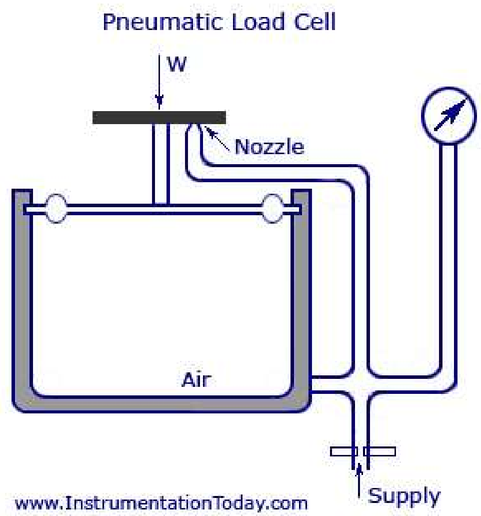
A load cell is a **transducer that tranforms pressure (force) into an electrical signal**.

Types:

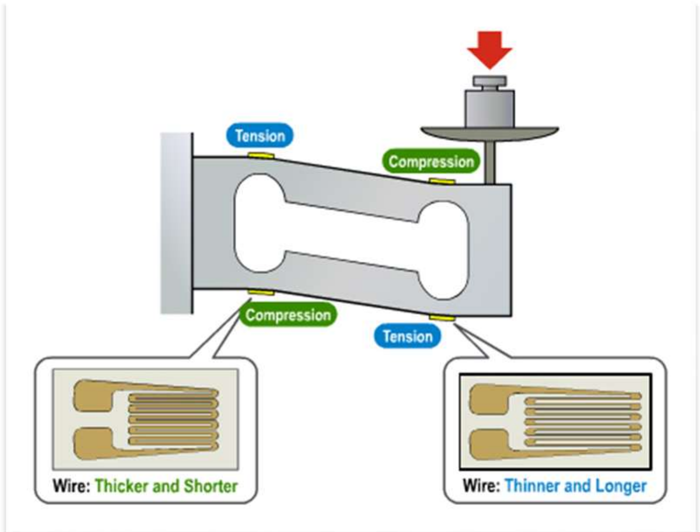
Hydraulic Load Cells



Pneumatic Load Cells



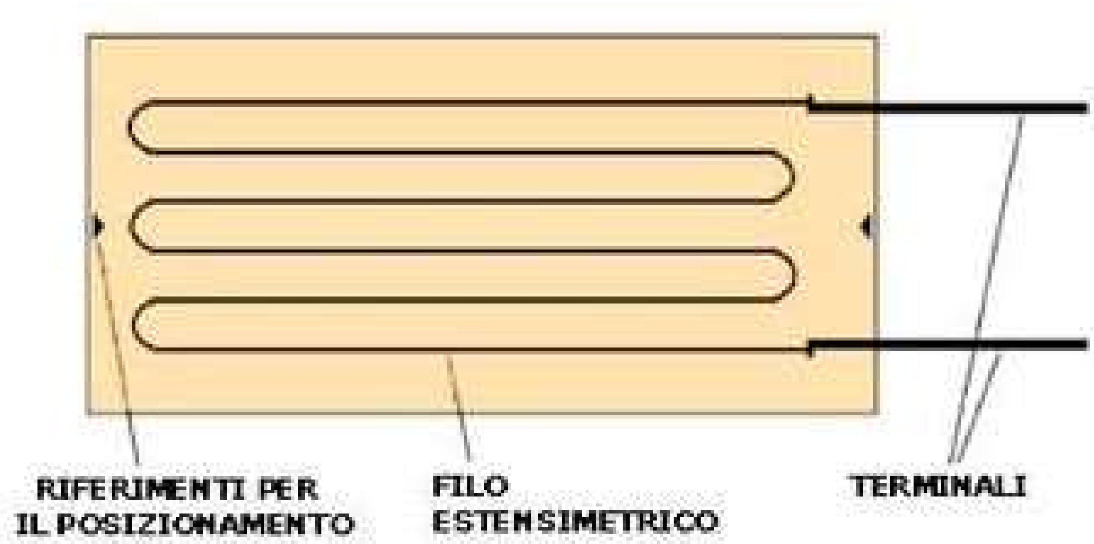
Strain Gauge Load Cells



Strain Gauge (1)

Sensing

A strain gauge is a device that measures electrical **resistance changes in response to strain** (indirectly pressure/force) applied to the device.



Strain Gauge (2)

Sensing

The sensitivity to strain is expressed quantitatively as the **gauge factor (GF)**, defined as the *ratio of fractional change in electrical resistance to the fractional change in strain.*

$$GF = \frac{\Delta R/R0}{\Delta\epsilon}$$

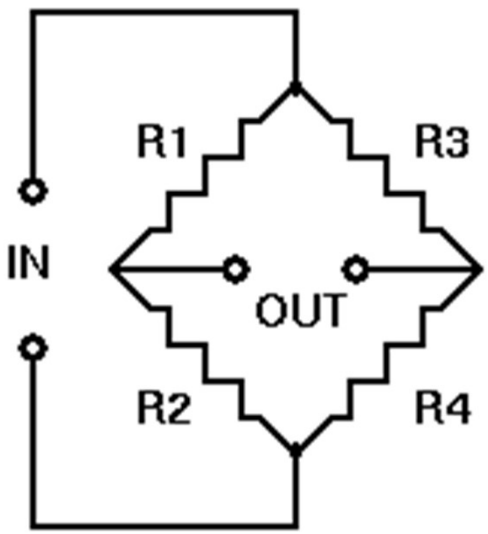
Example: GF=2, $\Delta\epsilon$=500°-6, R0= 120Ω → ΔR= R0*GF* $\Delta\epsilon$=0.12Ω

Typically ***resistance variation are very small*** (i.e. small electrical signal, difficult to detect), so we need to turn it into something that we can measure accurately.

Strain Gauge (3)

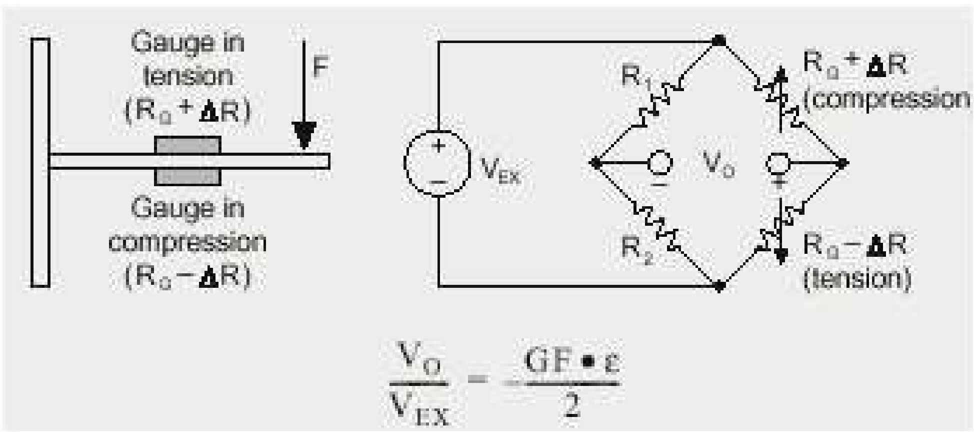
wheatstone bridge:

when $R1/R2 = R3/R4$ ➡ Vout=0



but if there is a change to the value of one of the resistors:

$$Vout = [(R3/(R3 + R4) - R2/(R1 + R2))] * Vin$$



FX1901
Compression Load Cell

SPECIFICATIONS

- High Reliability Design for OEM, Appliance and Medical Applications
- 10 – 200 lbf Ranges
- Compact Coin Cell Package
- Anti-Rotation Mounting Features
- CE Compliance

ORDERING INFORMATION

FX19	0	0	–	0001	–	0010	200	L

FX19 Model Name

Output
0=20mA

Plastic Shell & Cable
0=NO **1**=Yes

Description
0001=Standard **SXXX**=Special
XXXX=EWR Customize

Range
0010 0025 0050
0100 0200

Force Range
0010 0025 0050
0100 0200

Units
L=lbf

CODICE PRODUTTORE

PARAMETERS	TYP	UNITS
Recommended Excitation	5	V
Full Scale Output Span	20	mV/V

http://www.te.com/commerce/DocumentDelivery/DDEController?Action=srchrtrv&DocNm=FX19&DocType=DS&DocLang=English

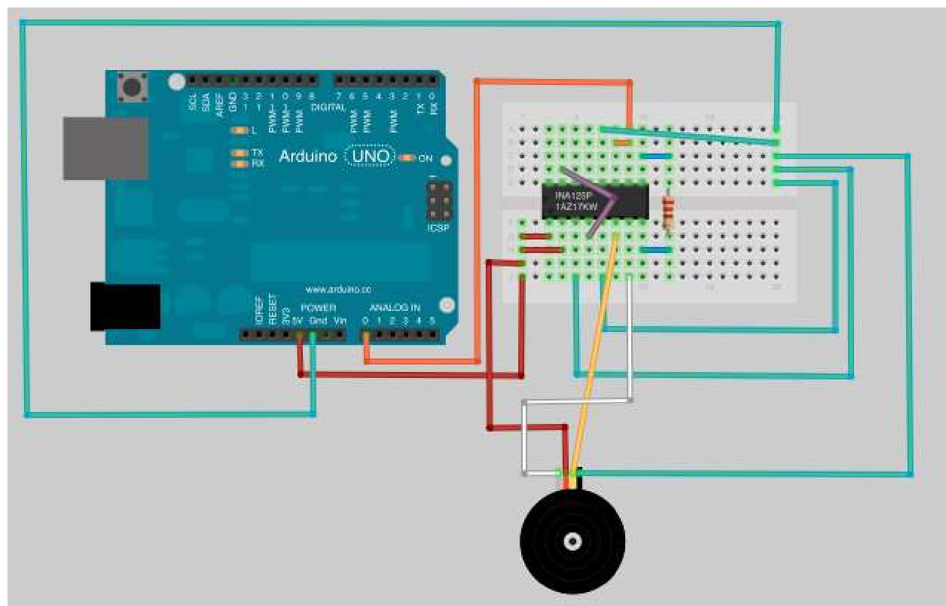
BURR - BROWN®

INA125

INSTRUMENTATION AMPLIFIER
With Precision Voltage Reference

$$V_O = (V_{IN}^{+} - V_{IN}^{-})\,G$$

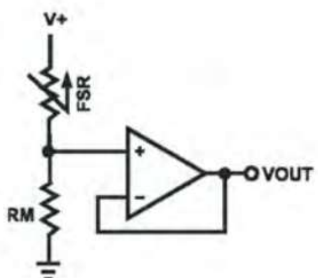
$$G = 4 + \frac{60k\Omega}{R_G}$$

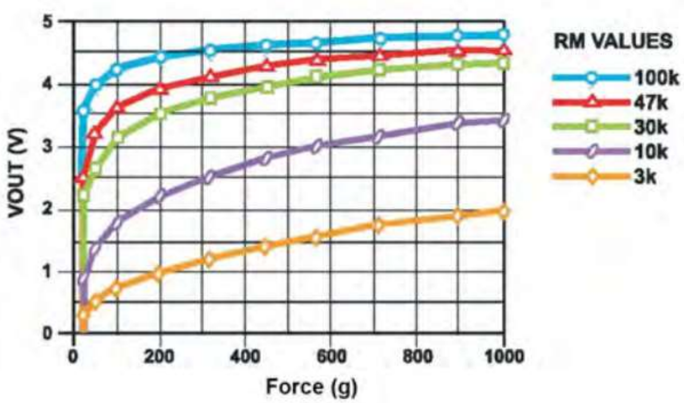


http://www.ti.com/lit/ds/symlink/ina125.pdf

FSR® 400

Force Range*	~0.2N – 20N
Force Resolution	Continuous (analog)





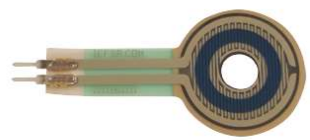
https://cdn2.hubspot.net/hubfs/3899023/Interlinkelectronics%20November2017/Docs/Datasheet_FSR.pdf

FSR® 400 Short
5mm Circle x 20mm

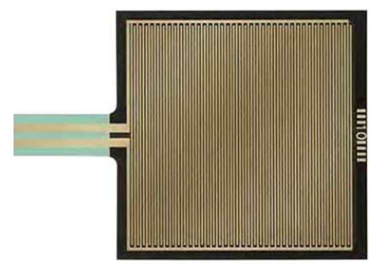
FSR® 400
5mm Circle x 38mm

FSR® 402 Short
13mm Circle x 25mm

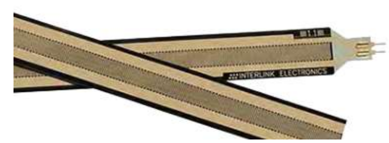
FSR® 402
13mm Circle x 56mm



FSR® 404
20mm Donut with 5.5mm hold



FSR® 406
38mm Square x 83mm



FSR® 408-xxx
10mm Wide x xxx mm strip
xxx = 50, 100, 200, 300, 400, 500mm

Sensing

Bill of Materials (BOM)

Tutti i prezzi sono in EUR.

Indice	Quantità	Immagine	Codice componente	Descrizione	Riferimento cliente	Quantità disponibile	Quantità in arretrato	Prezzo unitario	Prezzo totale
☒ 1	10		1027-1014-ND	SENSOR FORCE RES 0.04-4.5LBS		10 Immediatamente	0	7,01900	€ 70,19
☒ 2	1		INA125P-ND	IC OPAMP INSTR 150KHZ 16DIP		1 Immediatamente	0	5,58000	€ 5,58
☒ 3	1		223-1528-ND	SENSOR TENSE LOAD CELL		1 Immediatamente	0	24,92000	€ 24,92
								Totale parziale	**€ 100,69**
								Spedizione	**€ 0,00**
								Totale	**N/D**

Digikey, RS, and Mouser are the most popular suppliers of electronic components.

Esercitazione LAB1

- Identificare sensori almeno 3 sensori adeguati per l'applicazione e confrontarne le proprietà rilevanti (tabella)
- impostare BOM (*marca & modello, fornitore & codice fornitore, costo, disponibilità*) per il sensore scelto
- Se si sceglie un'applicazione diversa descriverla brevemente