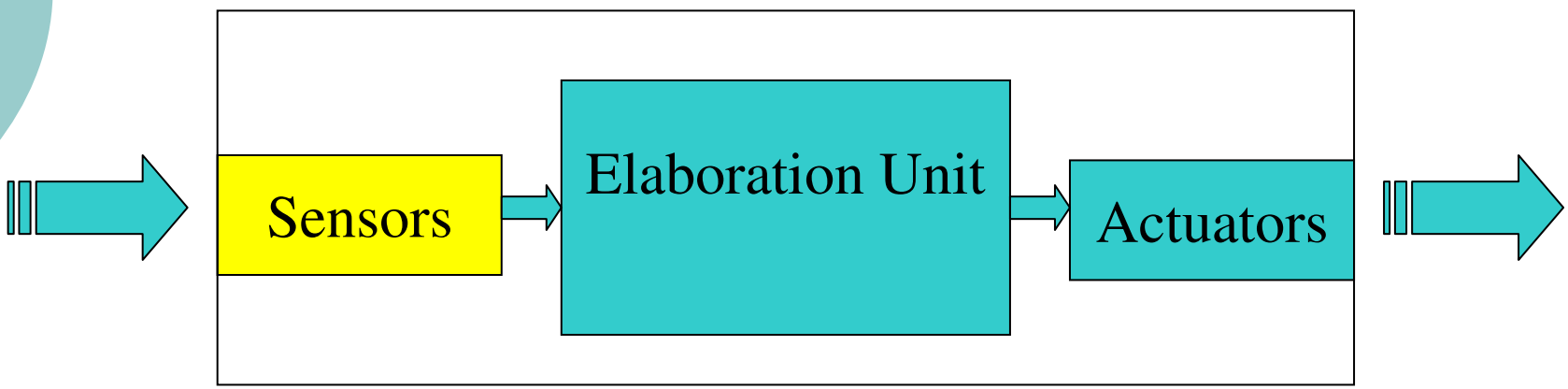
Sensori



Sensori – Unità di misura

	Dimension	
Unit	SI	IP
Primary		
Length	meter (m)	inch (in)
Mass	kilogram (kg)	pound-mass (lb_m)
Time	second (s)	second (s)
Temperature	kelvin (K)	rankine (°R)
Current	ampere (A)	ampere (A)
Substance	mole (mol)	mole (mol)
Light intensity	candela (cd)	candela (cd)
Derived		
Force	newton (N)	pound-force (lb)
Voltage	volt (V)	volt (V)
Resistance	ohm (Ω)	ohm (Ω)
Capacitance	farad (F)	farad (F)
Inductance	henry (H)	henry (H)
Stress, Pressure	pascal (Pa)	pound-force/inch^2 (psi)
Energy	joule (J)	British thermal unit (BTU)
Power	watt (W)	foot pound-force (ft-lb)

*SI dimensions and units are the international standards. IP units are presented for convenience.

Sensori – Electronic characteristics

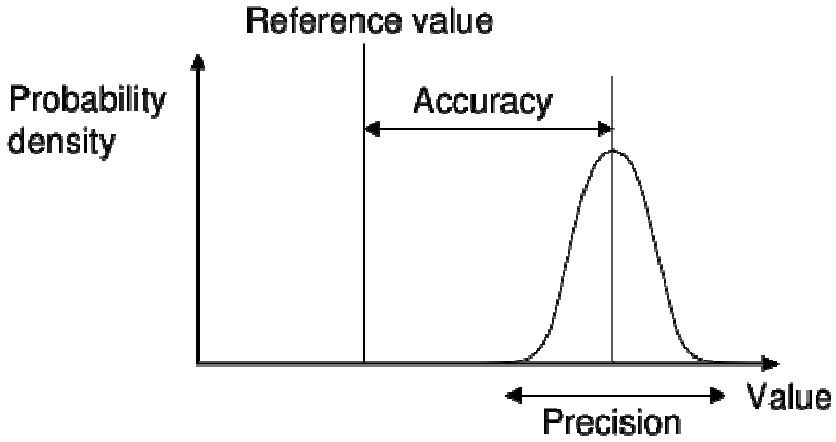
PROPERTY	SENSOR	ACTIVE/ PASSIVE	OUTPUT
Temperature	Thermocouple	Passive	Voltage
	Silicon	Active	Voltage/Current
	RTD	Active	Resistance
	Thermistor	Active	Resistance
Force / Pressure	Strain Gage	Active	Resistance
	Piezoelectric	Passive	Voltage
Acceleration	Accelerometer	Active	Capacitance
Position	LVDT	Active	AC Voltage
Light Intensity	Photodiode	Passive	Current

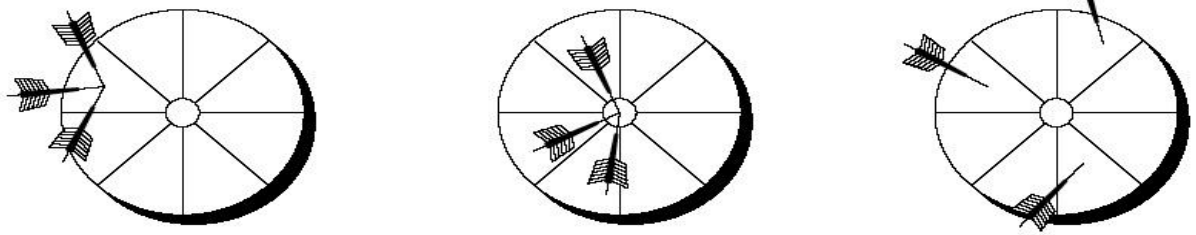
Reference: Analog Devices

Sensori – Caratteristiche

Accuratezza: rappresenta la vicinanza della misura (o della media di misure, per misure ripetute) al valore vero

Precisione: rappresenta l'ampiezza della distribuzione di valori in un gruppo di misure ripetute. Maggiore la precisione, minore l'ampiezza della distribuzione.





Preciso/non accurato **Preciso e accurato** **Non preciso/accurato**

Sensori – Caratteristiche

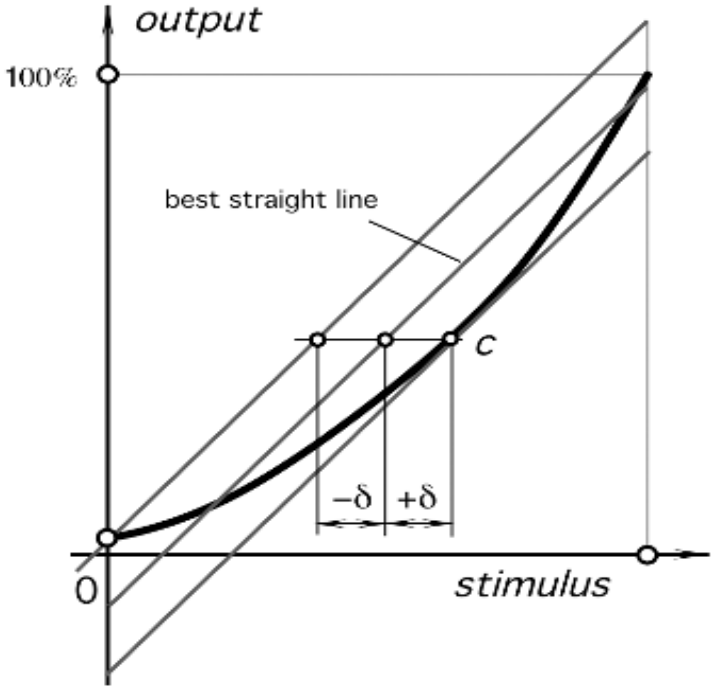
Sensibilità: La sensibilità e' la capacità di apprezzare piccole variazioni della grandezza in esame.

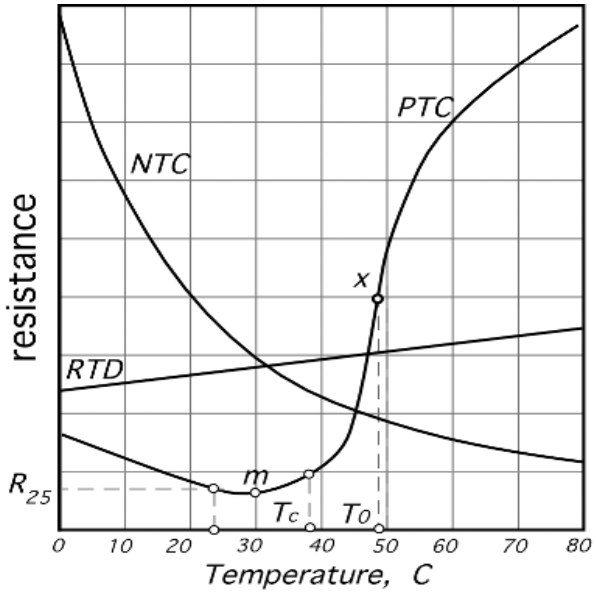
Risoluzione: La risoluzione rappresenta la minima variazione apprezzabile della grandezza in esame attraverso tutto il campo di misura: essa rappresenta il valore dell'ultima cifra significativa ottenibile.

Reference: Analog Devices

Sensori – Caratteristiche

Non Linearità: Scostamento massimo fra la retta ideale e la risposta del sensore.

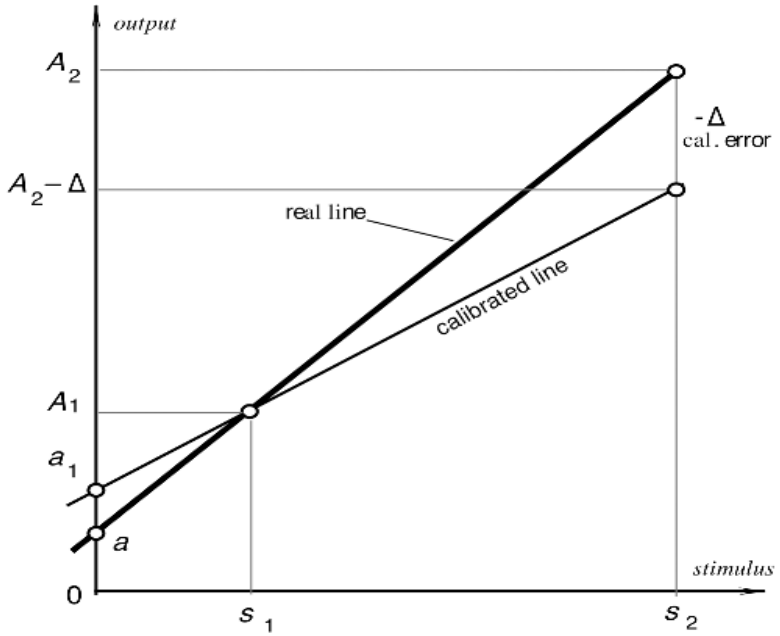




Reference: Analog Devices

Sensori – Caratteristiche

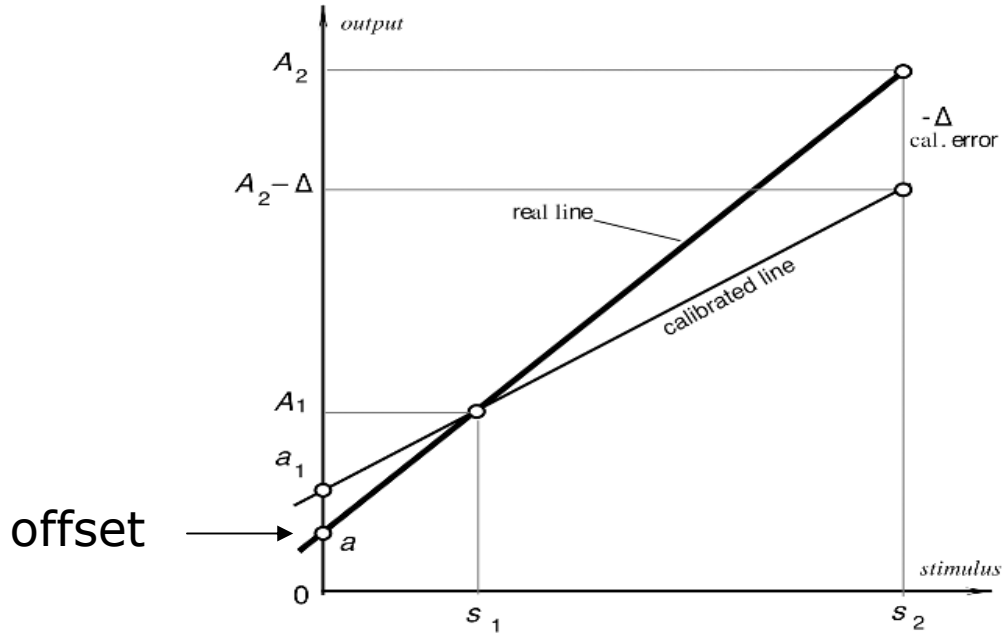
Errore di Calibrazione: Errore nel determinare il coefficiente della pendenza della retta di conversione



Reference: Analog Devices

Sensori – Caratteristiche

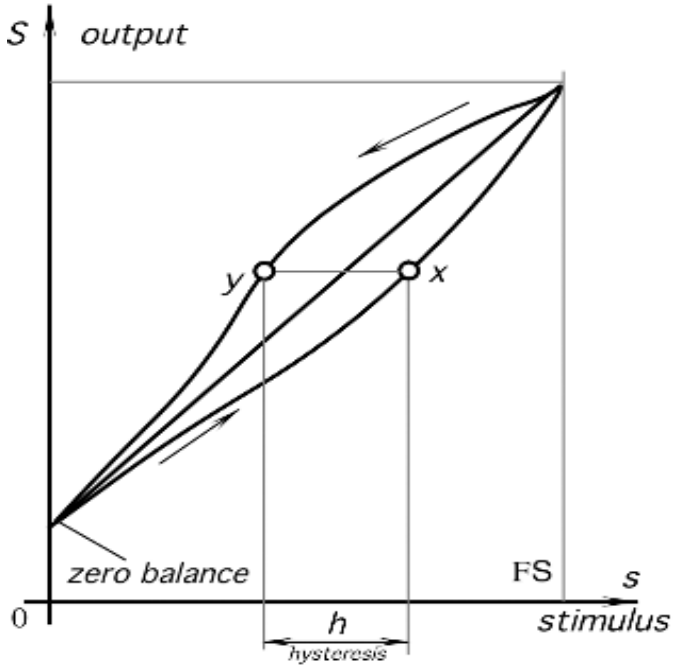
Offset: Valore dell'uscita in corrispondenza di un segnale di ingresso nullo



Reference: Analog Devices

Sensori – Caratteristiche

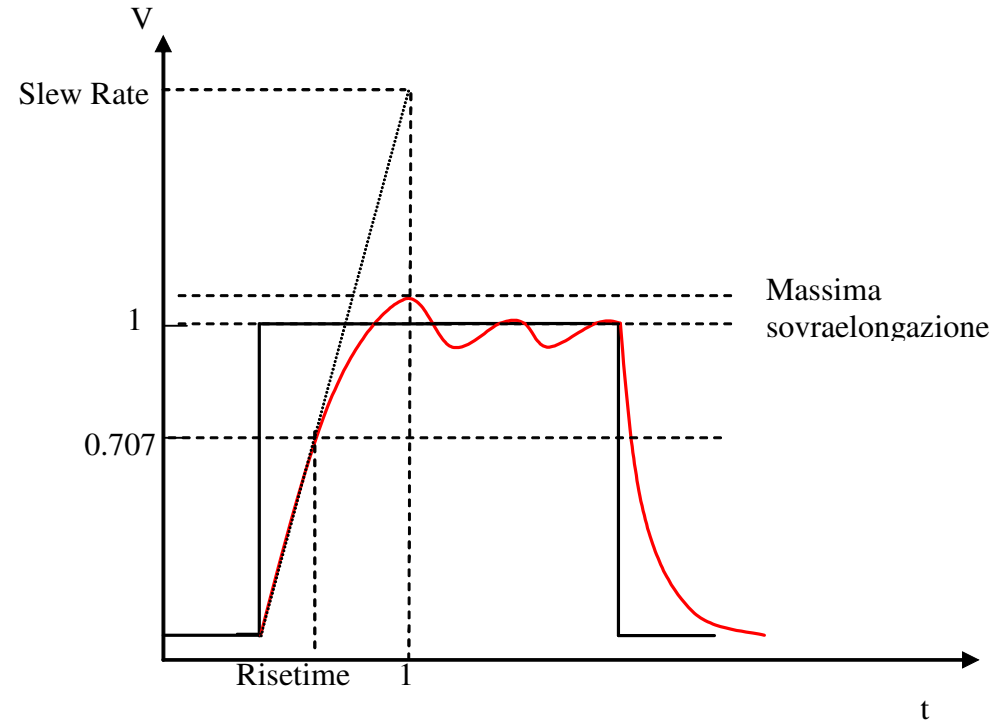
Isteresi: Variazione nella risposta del sensore in base a come viene variato il segnale da misurare



Reference: Analog Devices

Sensori – Caratteristiche

Risposta Dinamica: Capacità del sensore di risposte a variazioni del segnale di ingresso



Reference: Analog Devices

Temperature sensors

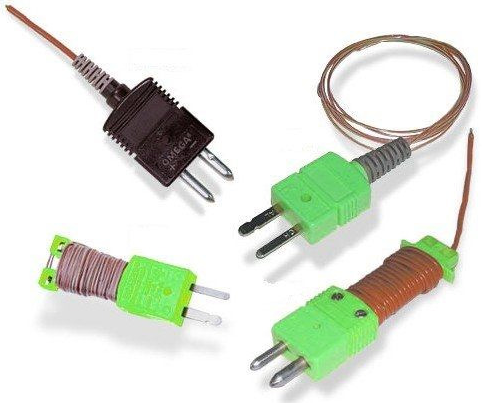
THERMOCOUPLE	RTD	THERMISTOR	SEMICONDUCTOR
Widest Range: –184°C to +2300°C	Range: –200°C to +850°C	Range: 0°C to +100°C	Range: –55°C to +150°C
High Accuracy and Repeatability	Fair Linearity	Poor Linearity	Linearity: 1°C Accuracy: 1°C
Needs Cold Junction Compensation	Requires Excitation	Requires Excitation	Requires Excitation
Low-Voltage Output	Low Cost	High Sensitivity	10mV/K, 20mV/K, or 1µA/K Typical Output

Thermocouple

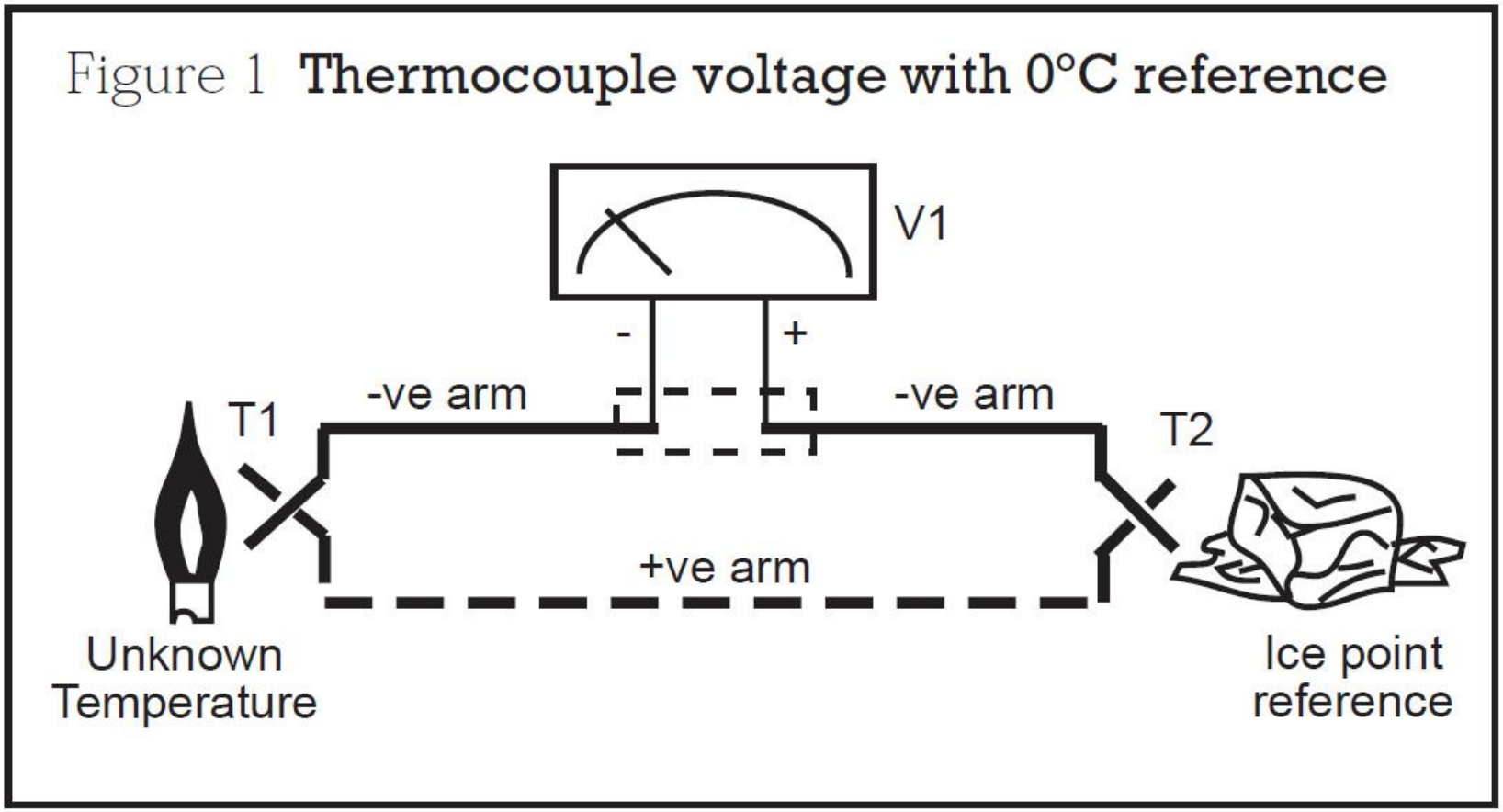
	Type J	Type K	Type N	Type T	Type R	Units
Minimum continuous temperature	-60	-200	-230	-200	-50	°C
Maximum continuous temperature	+850	+1100	+1300	+400	+1350	°C
Maximum spot reading	+1100	+1300	+1320	+500	+1400	°C

Tolerances (IEC 60584-3)

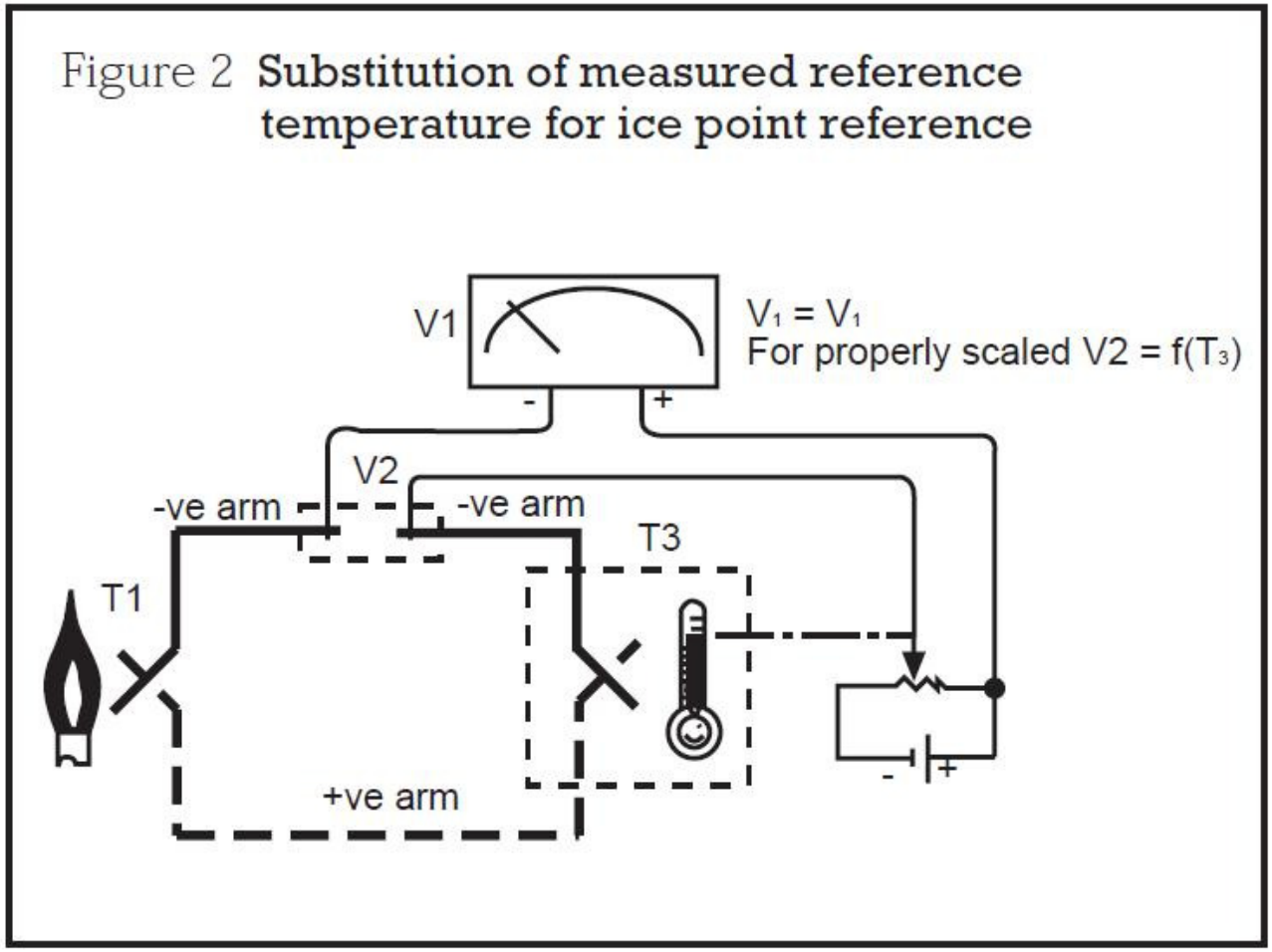
Accuracy - Class 2 (see note)	±2.5°C or 0.0075 x T	±2.5°C or 0.0075 x T	±2.5°C or 0.0075 x T	±1°C or 0.0075 x T	±1.5°C	°C
Temperature range - Class 2	-40 to +750	-40 to +1200	-40 to +1200	-40 to +350	-40 to +1600	°C



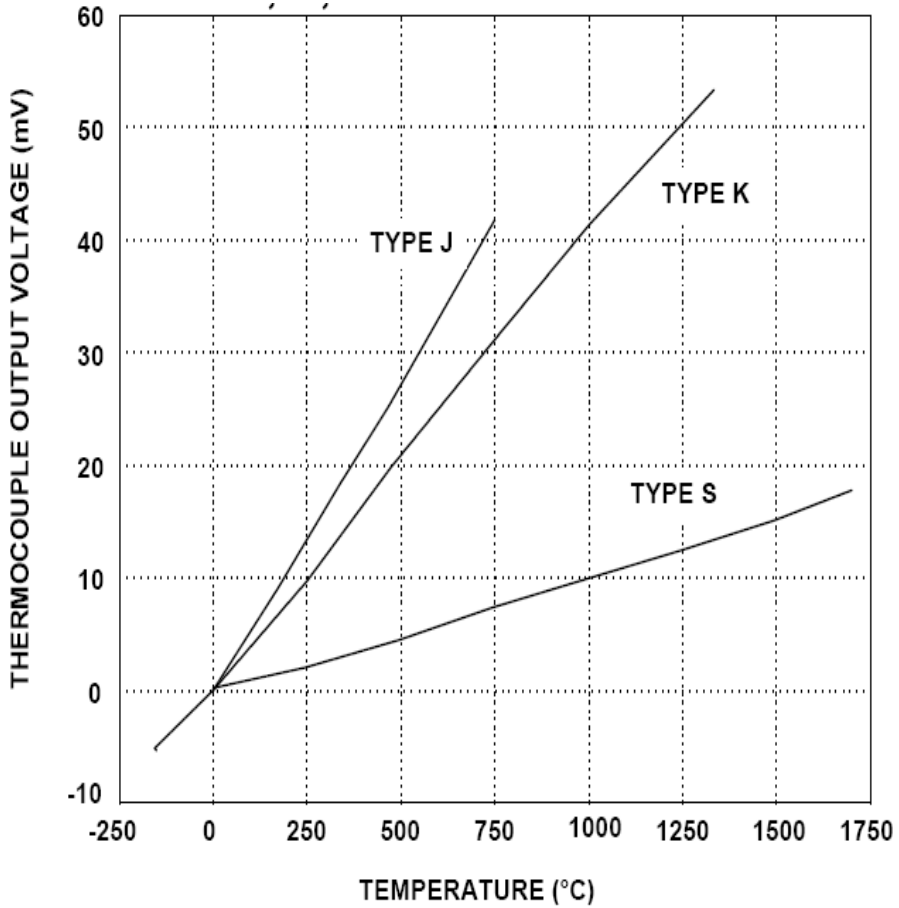
Thermocouple



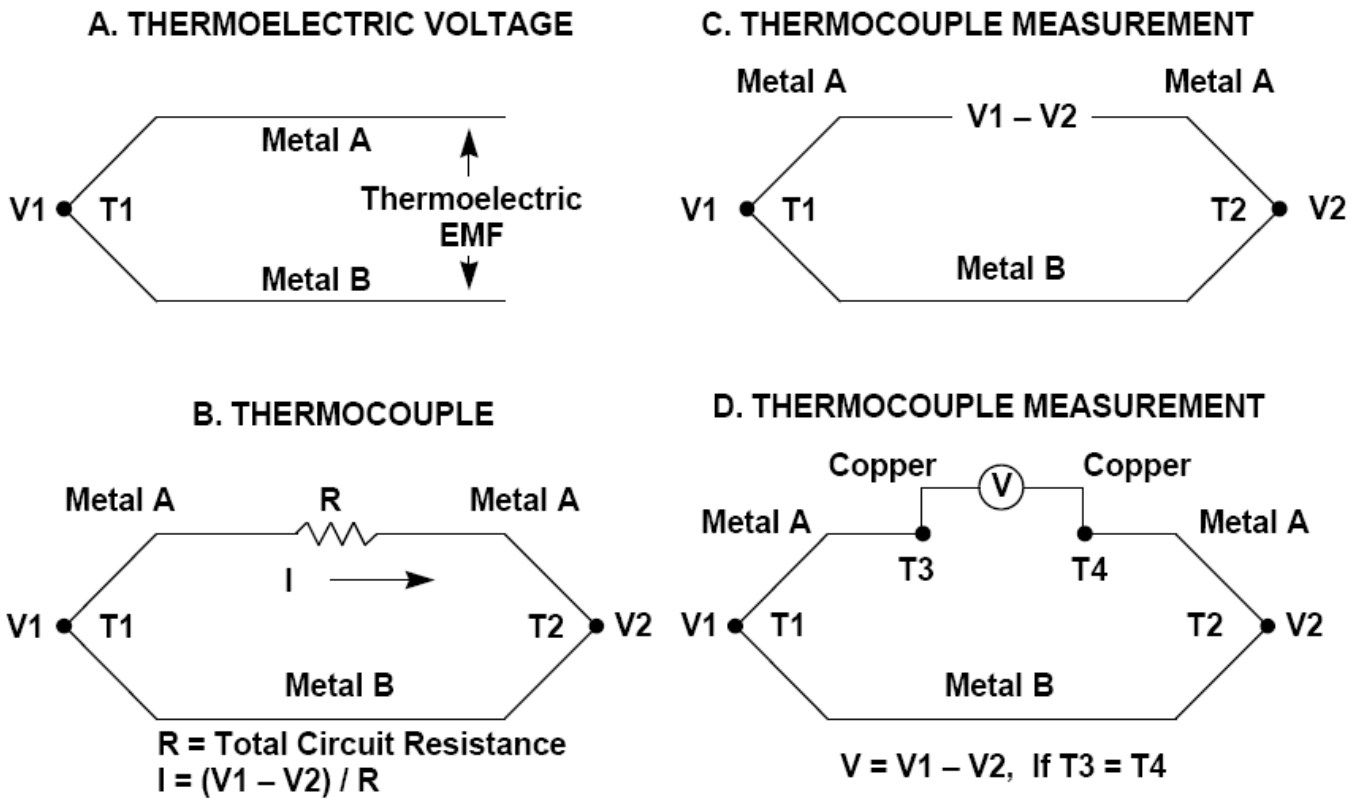
Thermocouple



Thermocouple Voltage vs. Temperature



Thermocouple - measurements



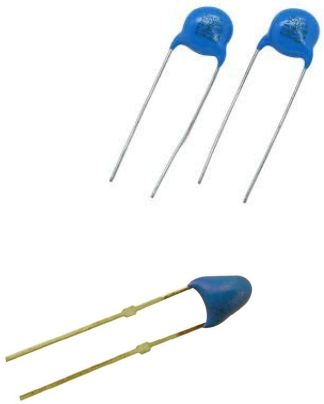
Thermistor – Resistance vs. Temperature

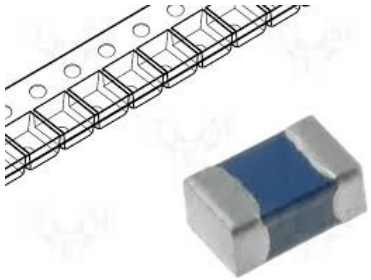
NTC

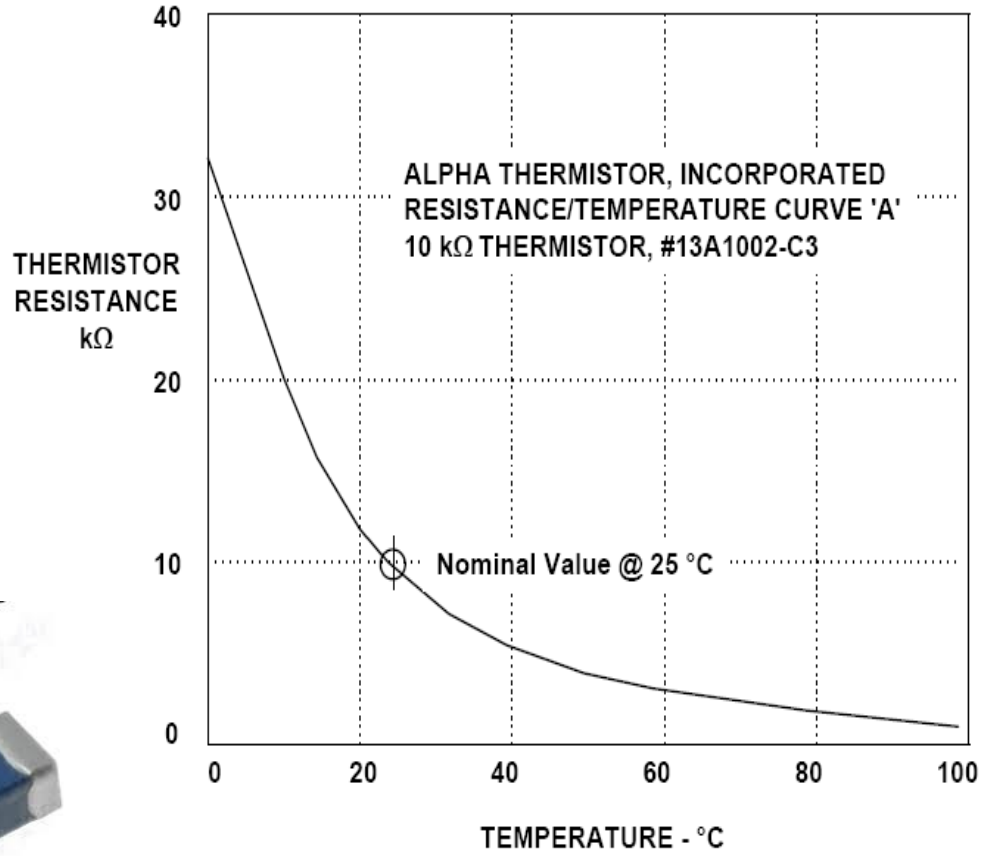
Negative temperature Coefficient

PTC

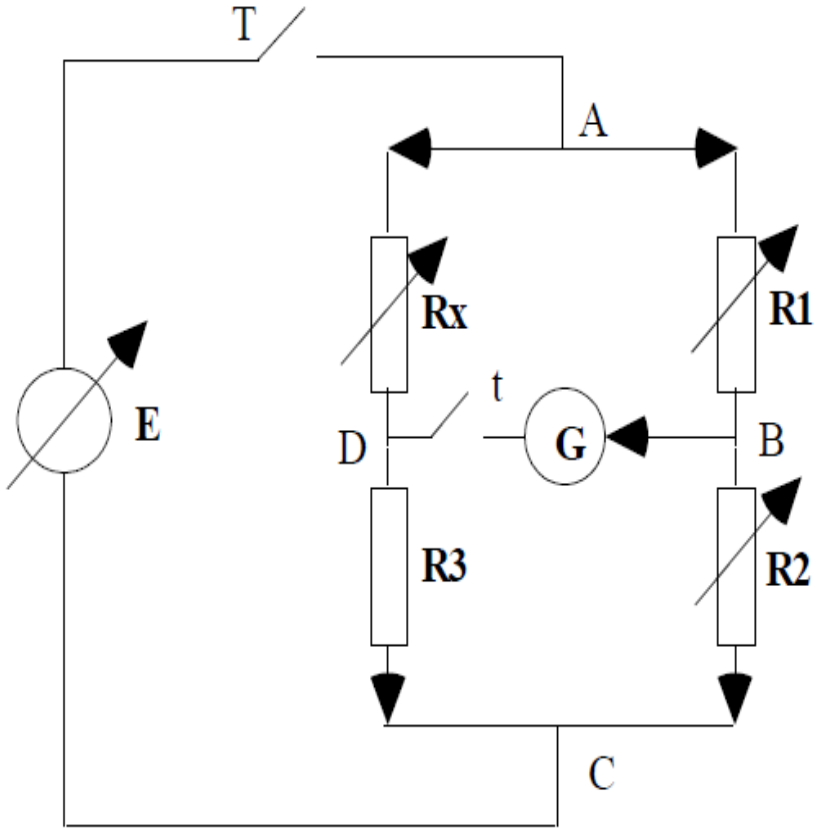
Positive temperature Coefficient





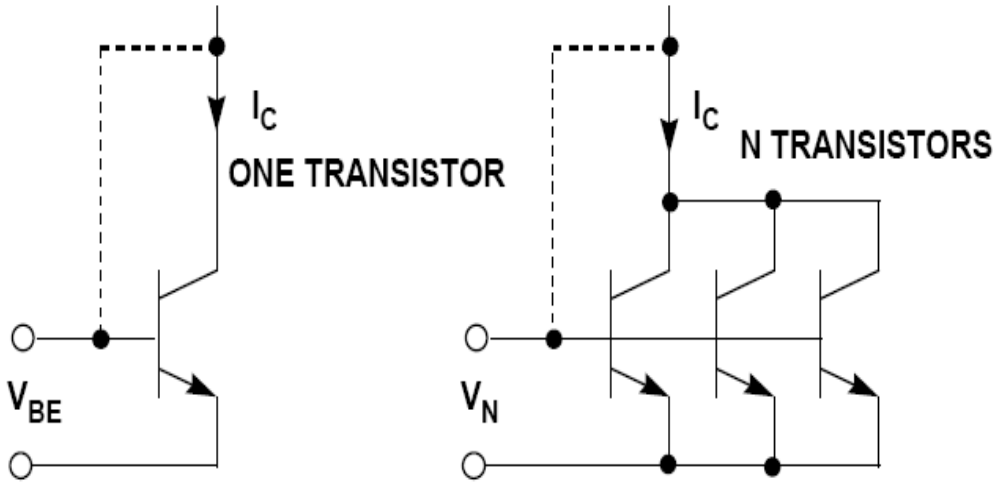


Ponte di Wheatstone



$$R_X = \frac{R_1}{R_2} \cdot R_3$$

Semiconductor temperature Sensors

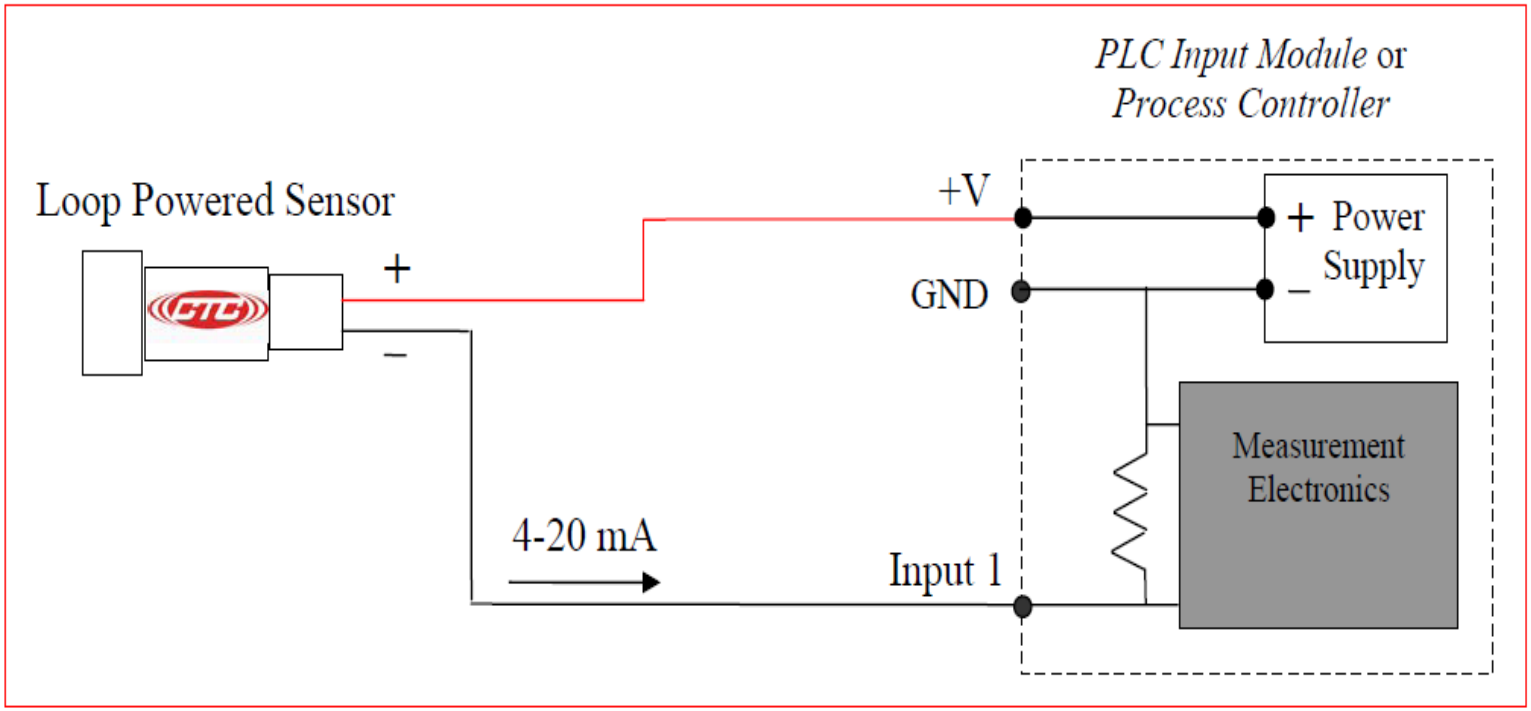


$$V_{BE} = \frac{kT}{q} \ln\left(\frac{I_C}{I_S}\right)$$

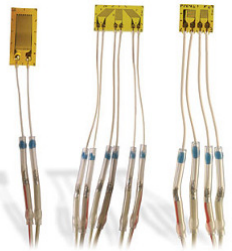
$$V_N = \frac{kT}{q} \ln\left(\frac{I_C}{N \cdot I_S}\right)$$

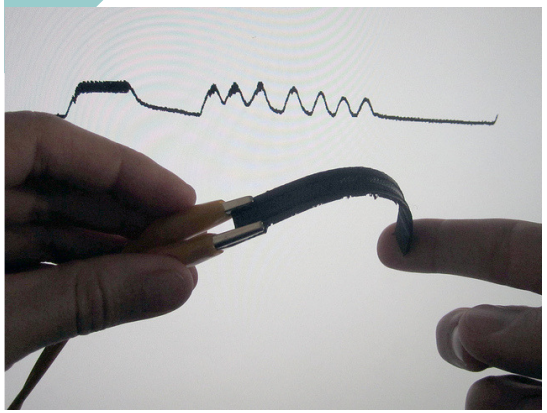
$$\Delta V_{BE} = V_{BE} - V_N = \frac{kT}{q} \ln(N)$$

4-20 ma output

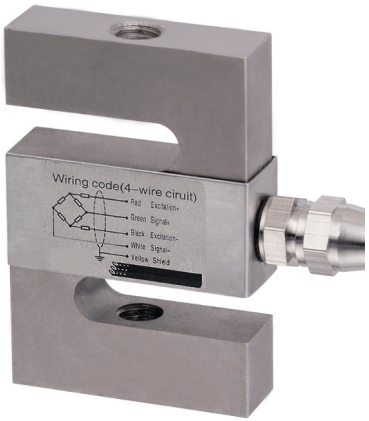


Sensori di deformazione

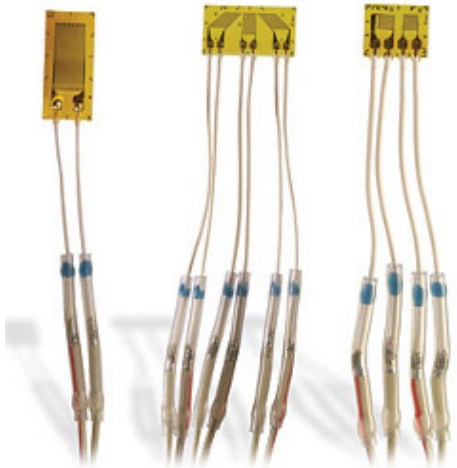


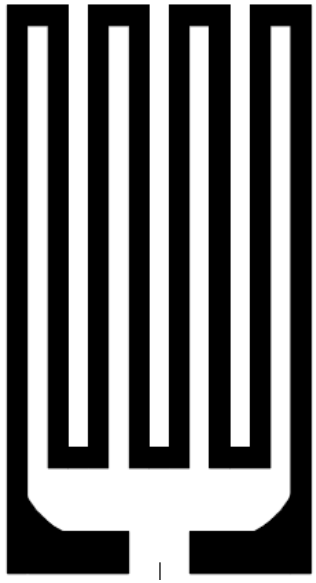


- **Strain:** Strain Gage, PiezoElectric Transducers
- **Force:** Load Cell
- **Pressure:** Diaphragm to Force to Strain Gage
- **Flow:** Differential Pressure Techniques



Strain Gage Sensor – Resistance variation with deformation



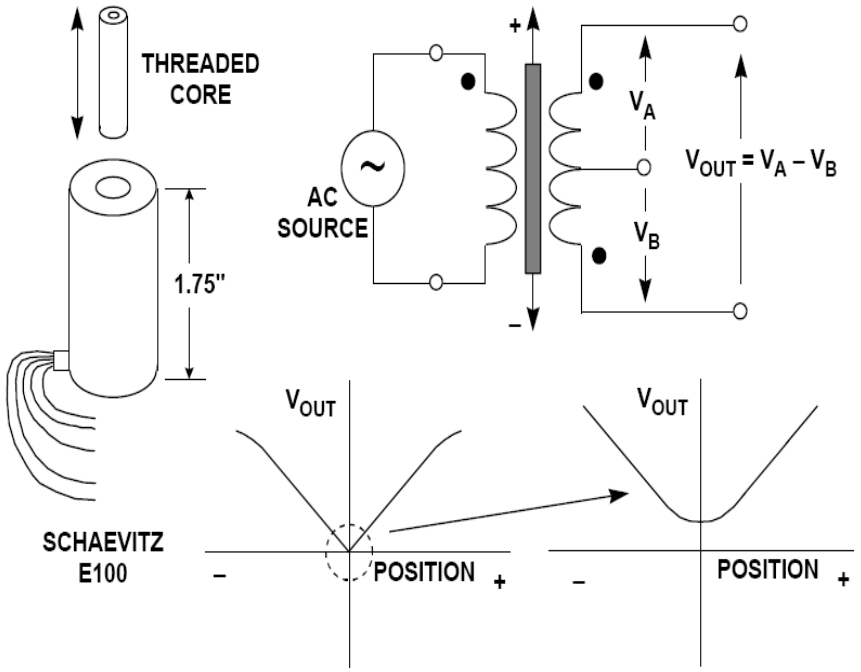


- PHOTO ETCHING TECHNIQUE
- LARGE AREA
- STABLE OVER TEMPERATURE
- THIN CROSS SECTION
- GOOD HEAT DISSIPATION

Position and Angular Sensors

- Linear Position: Linear Variable Differential Transformers (LVDT)
- Hall Effect Sensors
  - Proximity Detectors
  - Linear Output (Magnetic Field Strength)
- Rotational Position:
  - Rotary Variable Differential Transformers (RVDT)
  - Optical Rotational Encoders
  - Synchros and Resolvers
  - Inductosyns (Linear and Rotational Position)
  - Motor Control Applications
- Acceleration and Tilt: Accelerometers

Position Sensors - LVDT



Photodiode

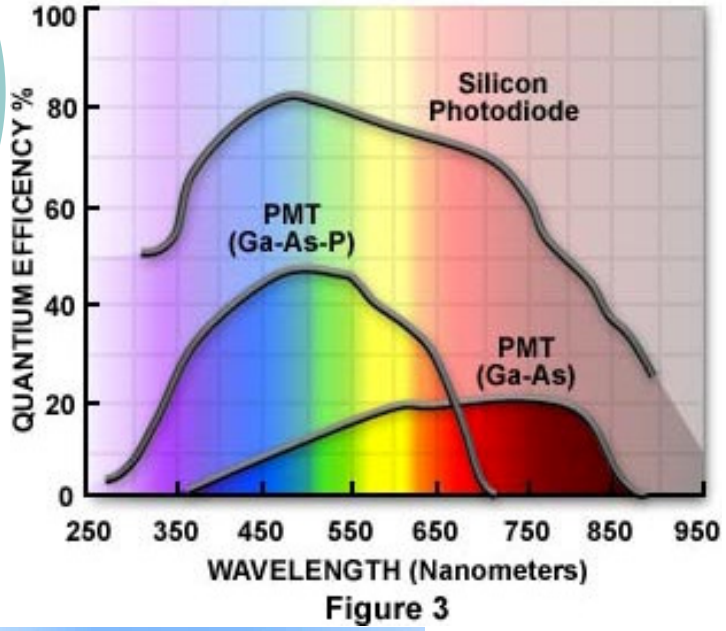
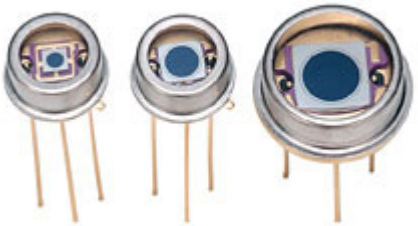
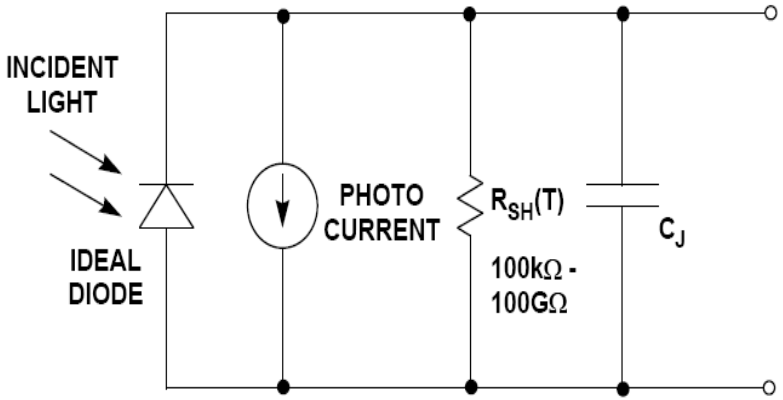
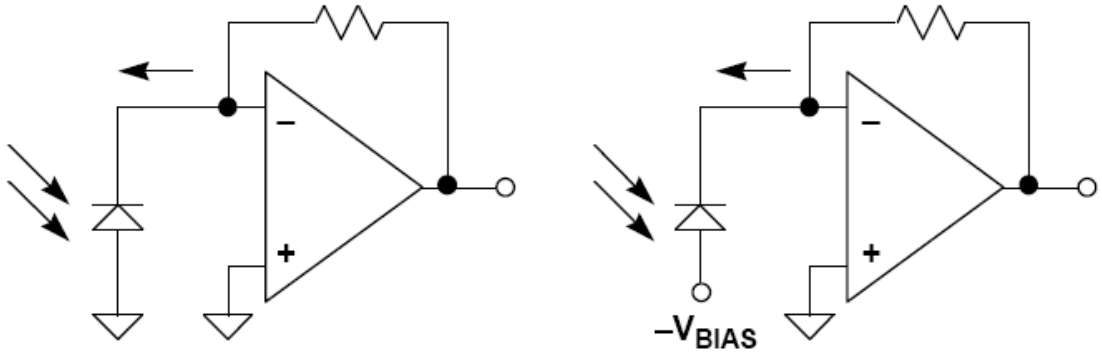


Figure 3





Photodiode – Signal conditioning



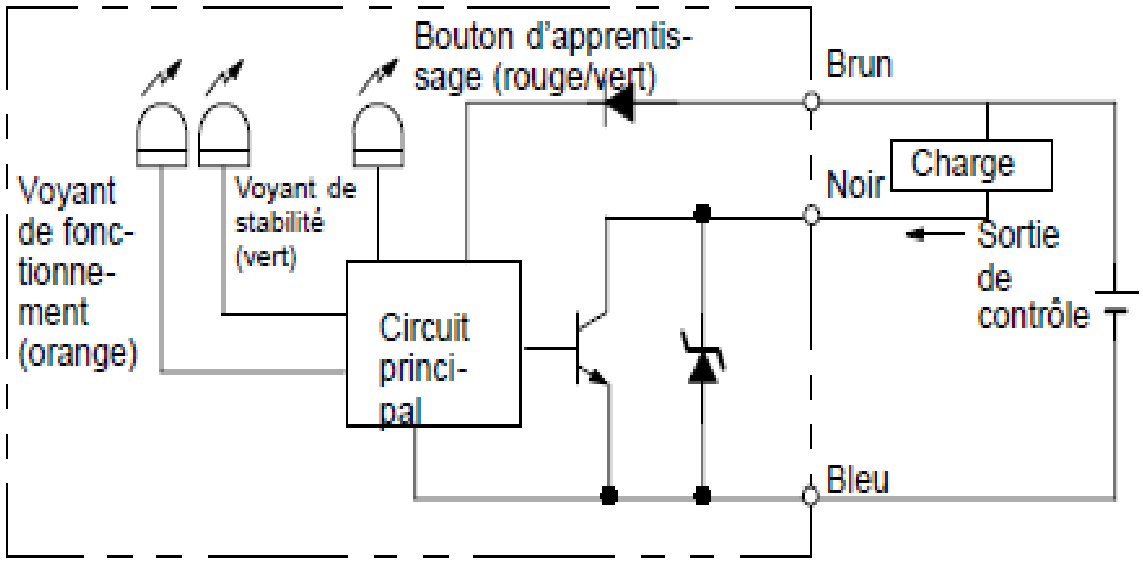
PHOTOVOLTAIC

- Zero Bias
- No "Dark" Current
- Linear
- Low Noise (Johnson)
- Precision Applications

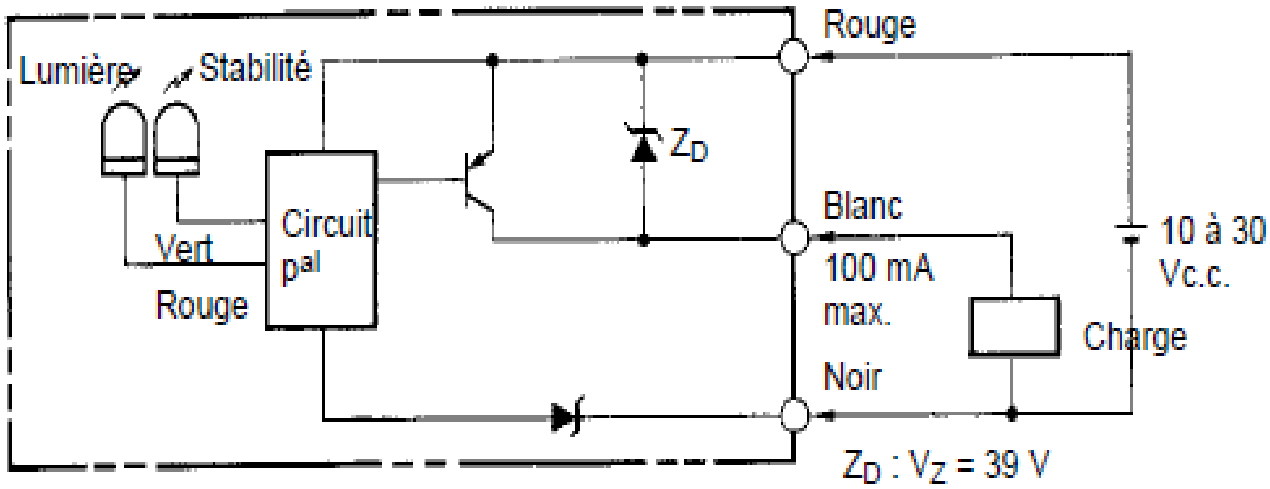
PHOTOCONDUCTIVE

- Reverse Bias
- Has "Dark" Current
- Nonlinear
- Higher Noise (Johnson + Shot)
- High Speed Applications

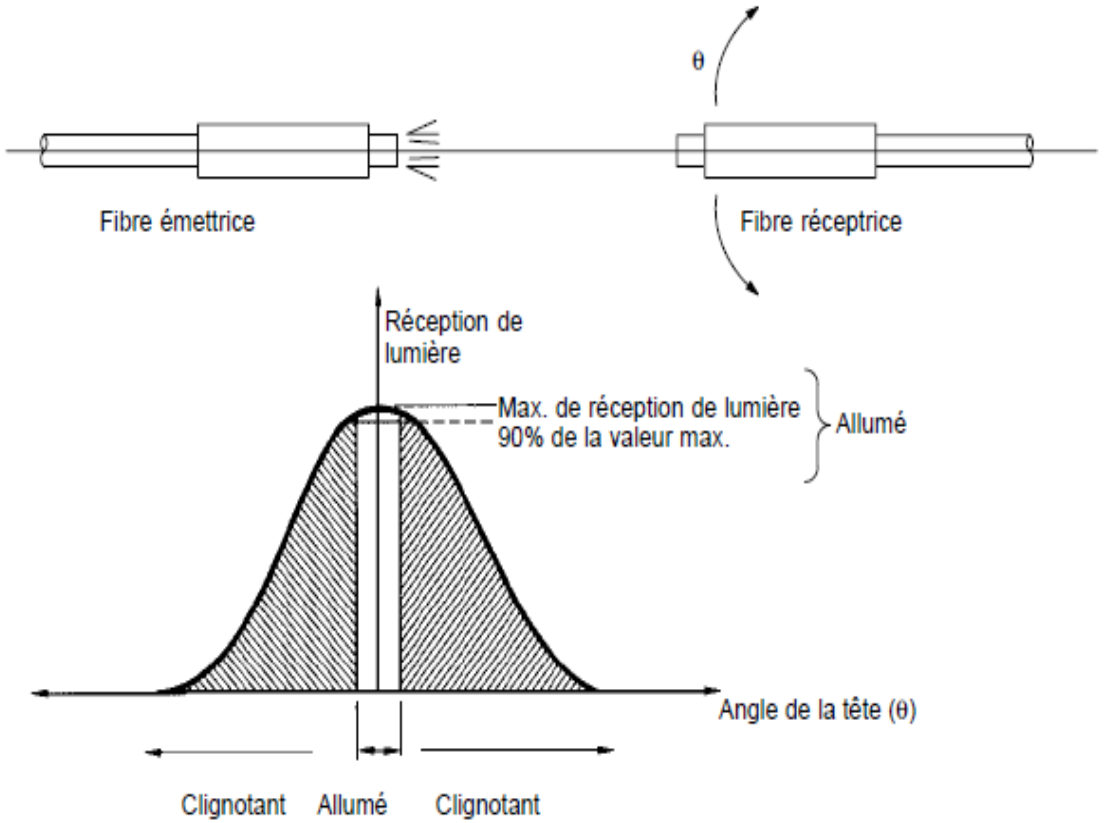
Sensori Riflessivi o Trasmissivi



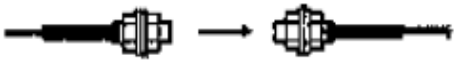
Sensori Riflessivi o Trasmissivi

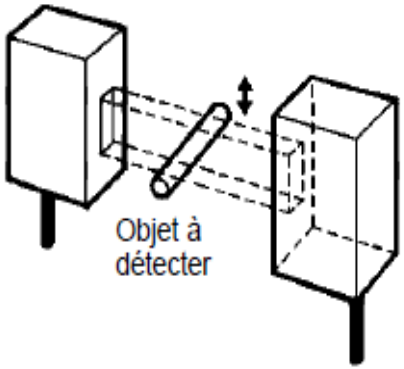


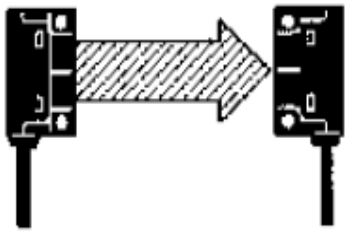
Sensori Fibra ottica



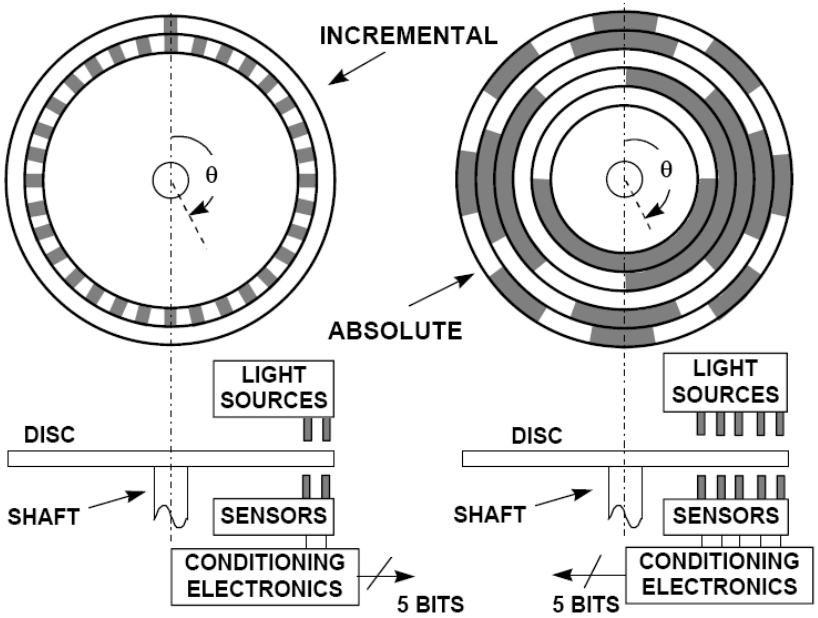
Sensori Fibra ottica

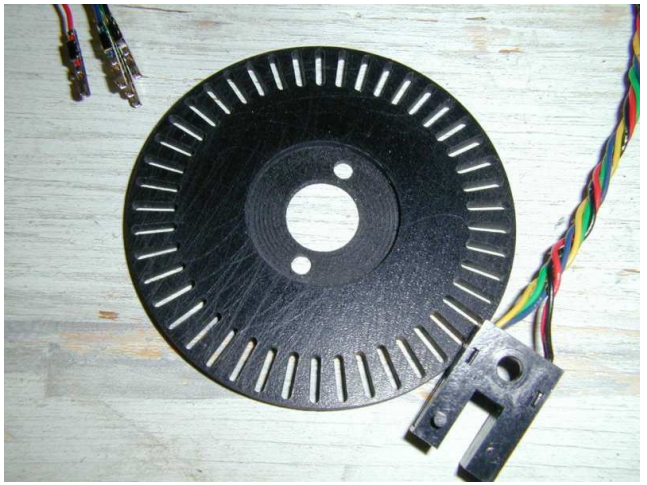


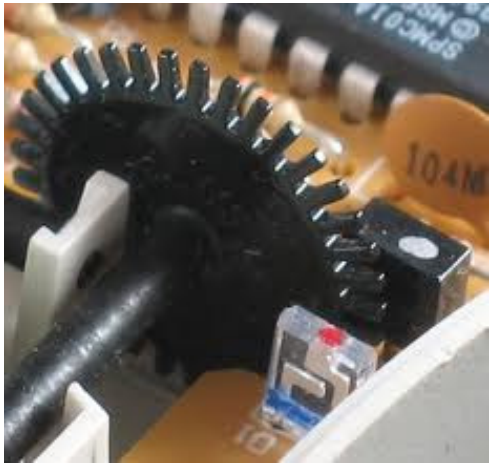




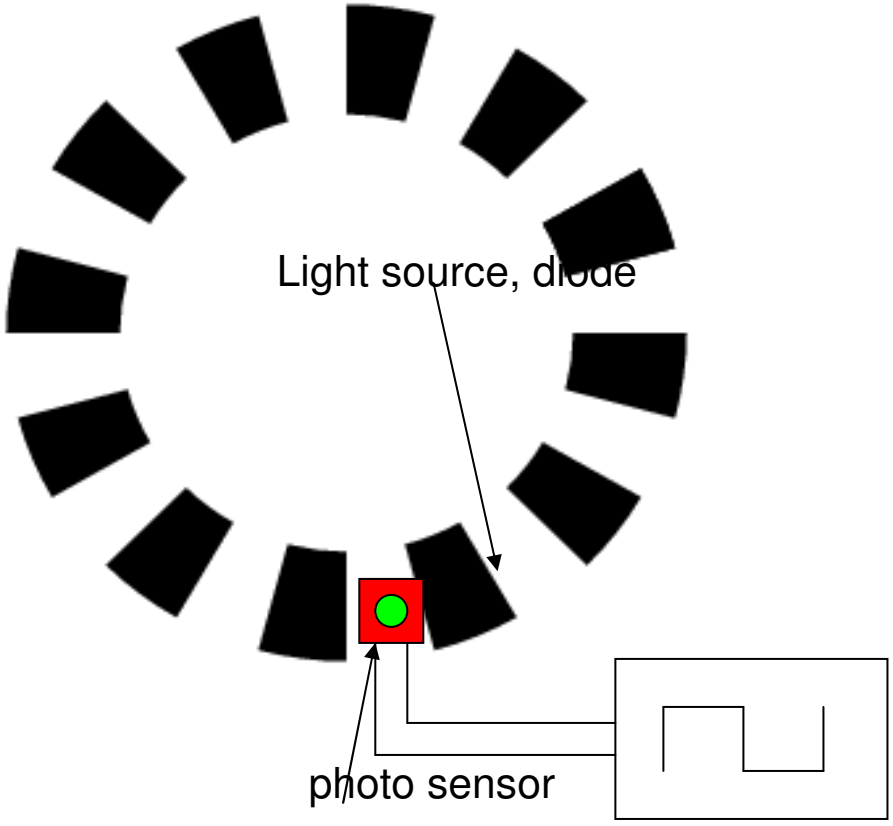
Angular Posistion Sensor - Encoders



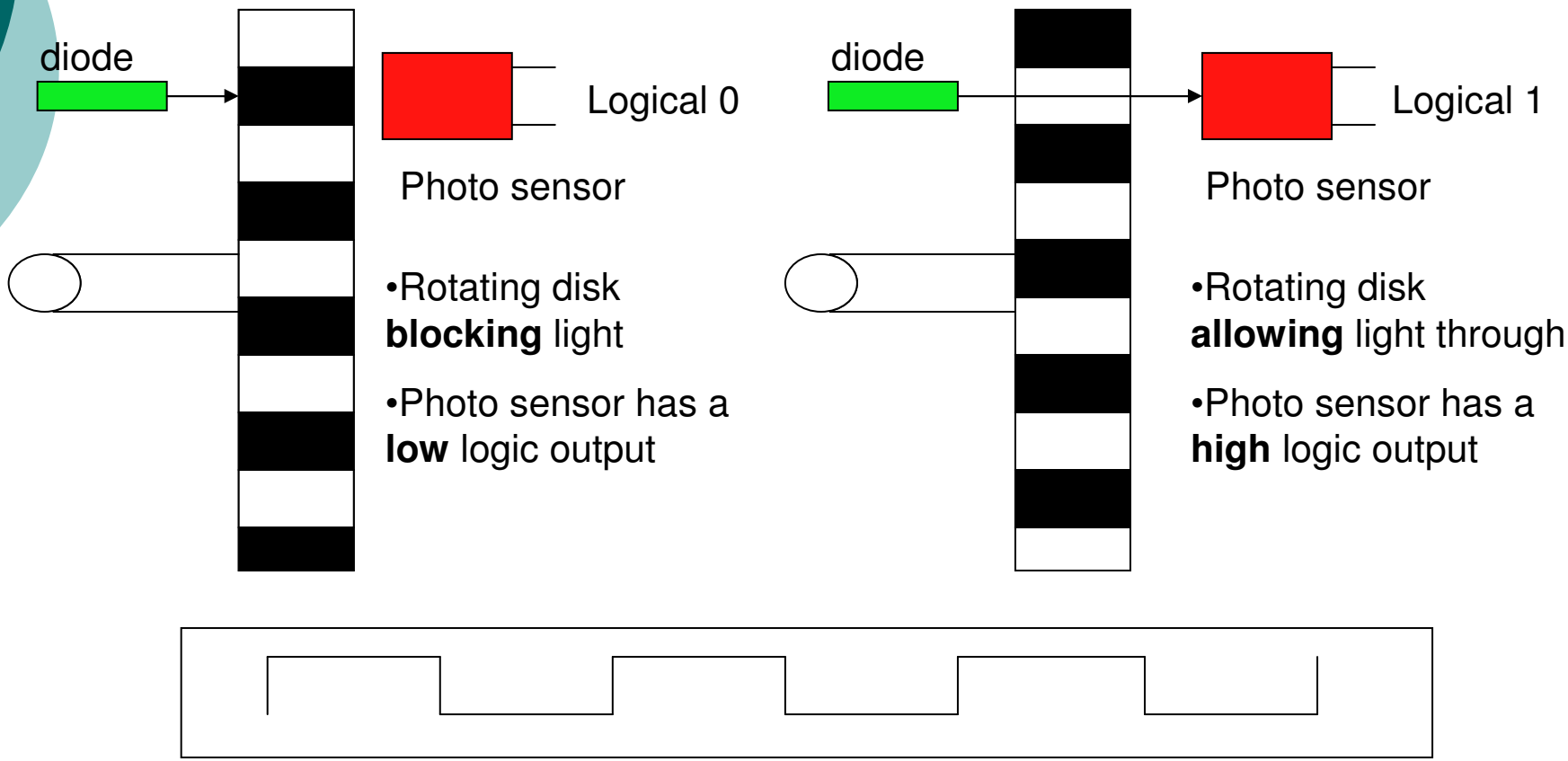




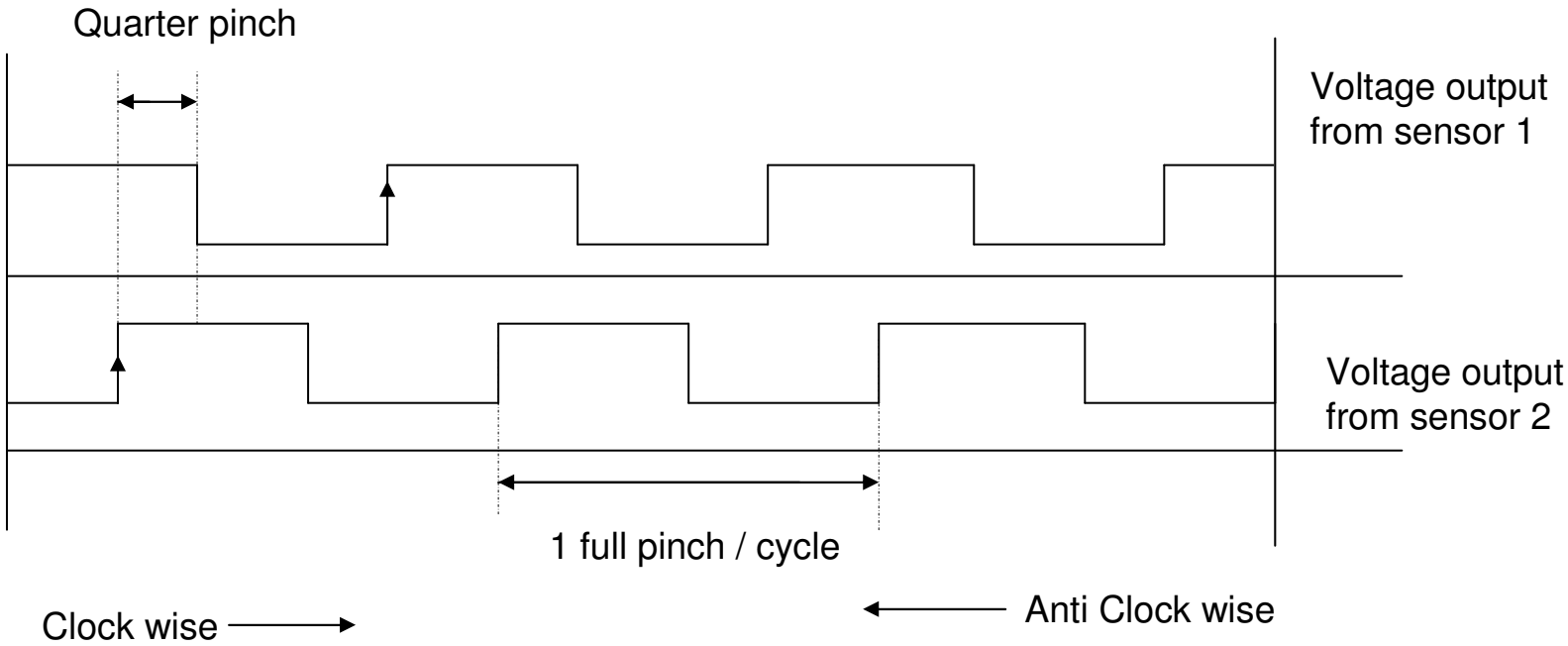
Angular Posistion Sensor - Encoders



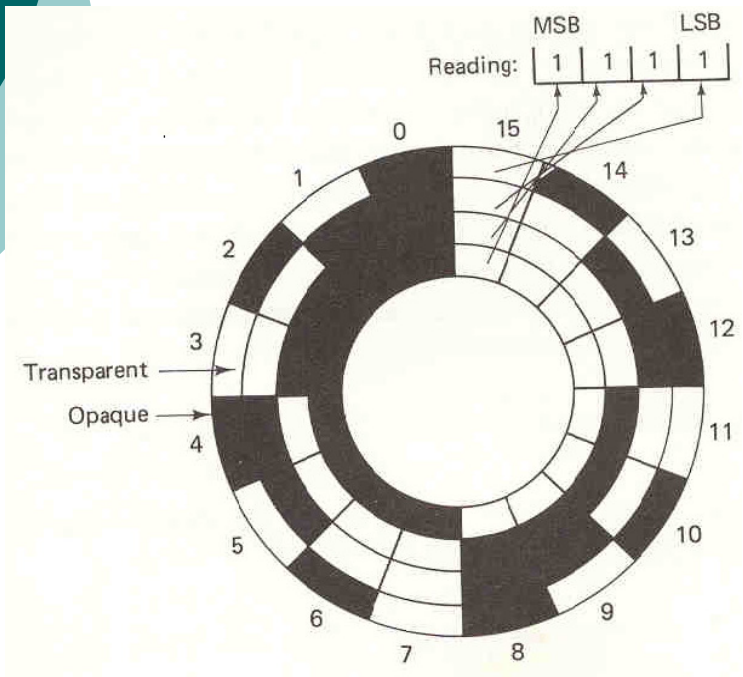
Angular Posistion Sensor – Encoders



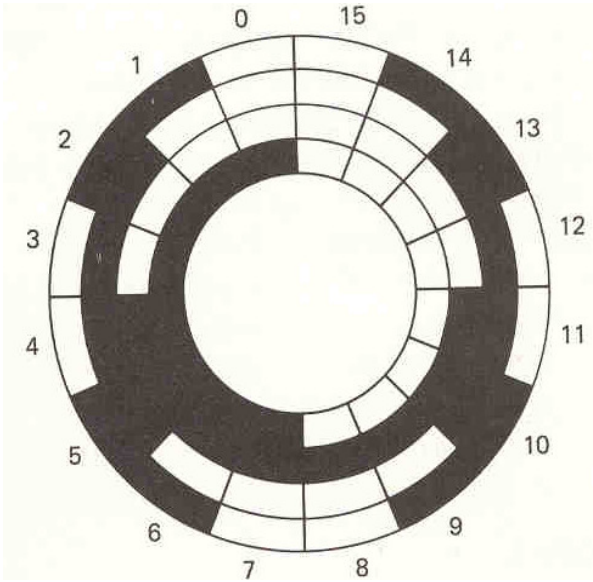
Angular Posistion Sensor – Encoders Incrementale



Angular Posistion Sensor – Encoders Assoluto



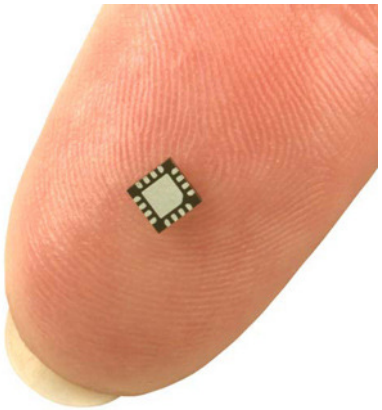
BCD

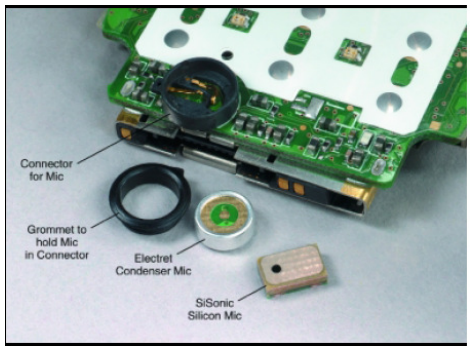


GRAY

Mems Sensors

- Accelerometer
- Gyroscope
- Magnetometer
- Pressure
- Microphone





Accelerometer

Measurement of gravity to determine orientation

- Tilt and inclination
- Position in 2 and 3 dimensional space
- Can only be done with accelerometers that have DC response

Inertial measurement of velocity and position

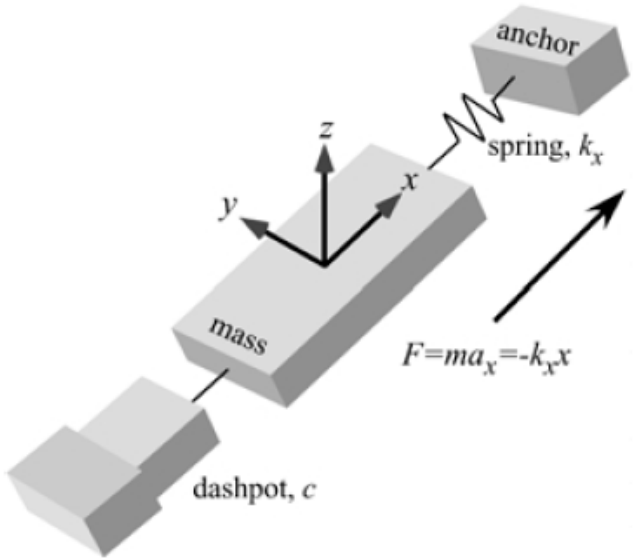
- Acceleration single integrated for velocity
- Acceleration double integrated for position

Vibration and shock measurement

- Measuring vibration for machine health
- Motion and shock detection

Accelerometer

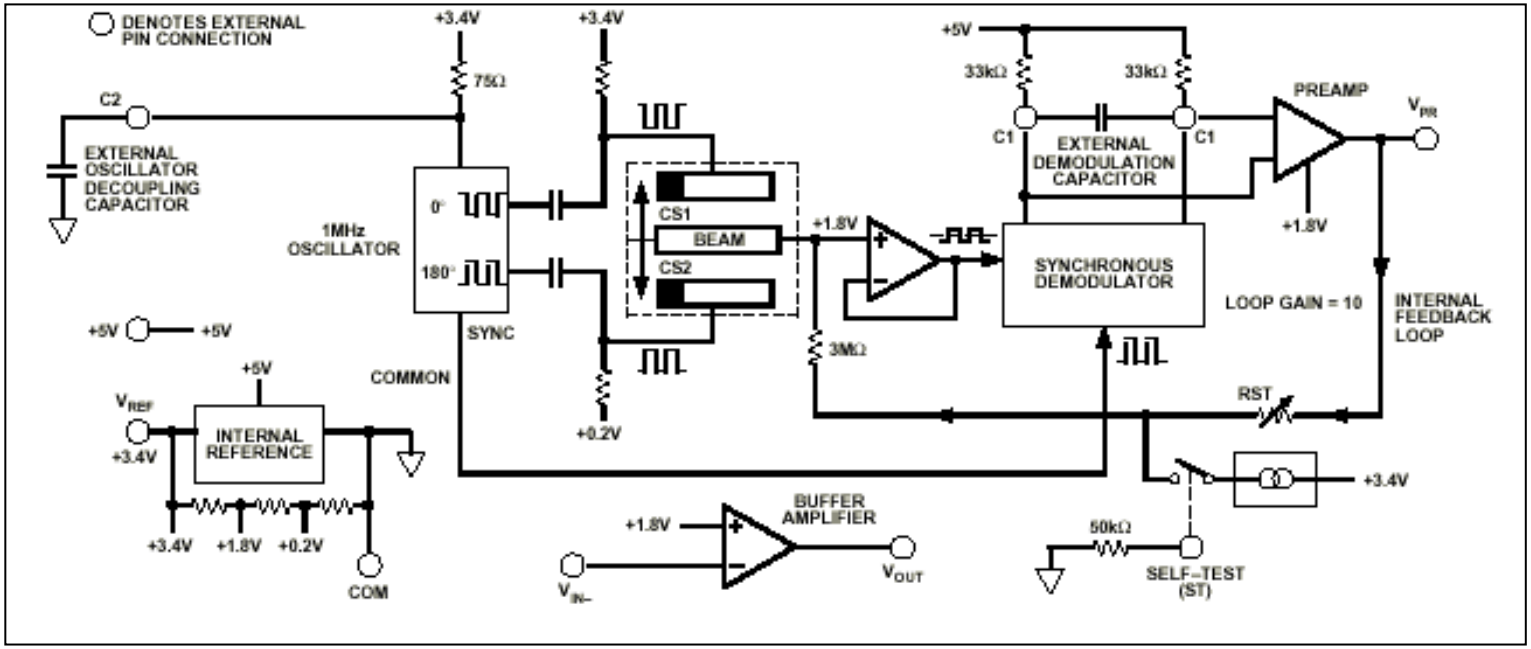
$$\mathbf{a} = \frac{d^2\mathbf{r}}{dt^2} = \frac{d\mathbf{v}}{dt}$$



$$\text{sensitivity} = \frac{\text{output (displacement)}}{\text{input (acceleration)}} = \frac{x}{a} = \frac{m}{k}$$

m proof mass (Kg)
a inertial acceleration (m/s2)
k elastic spring constant (N/m)
x displacement of the mass

Accelerometer **ADXL50**

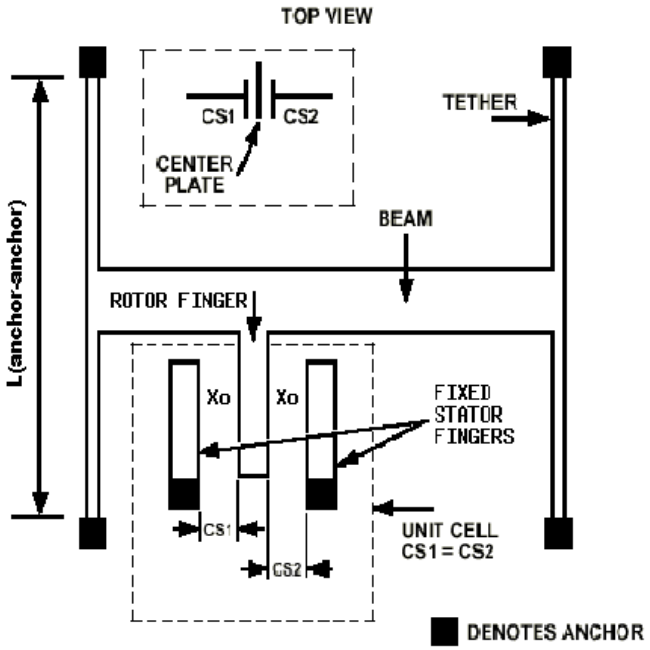


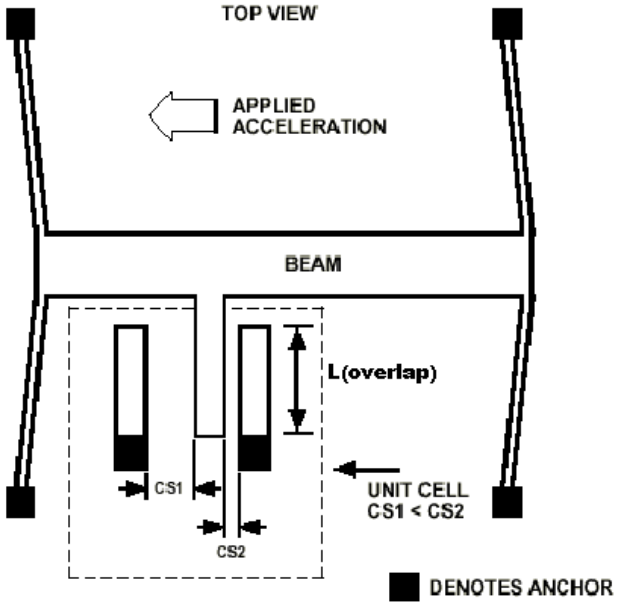
- Measurement range ± 50g
- Sensitivity 19 mV/g

- $F_{resonant}$ = 24 KHz
- C_o = 100 fF
- V_o = 1.8 V

Ref: Analog Devices ADXL50

Accelerometer

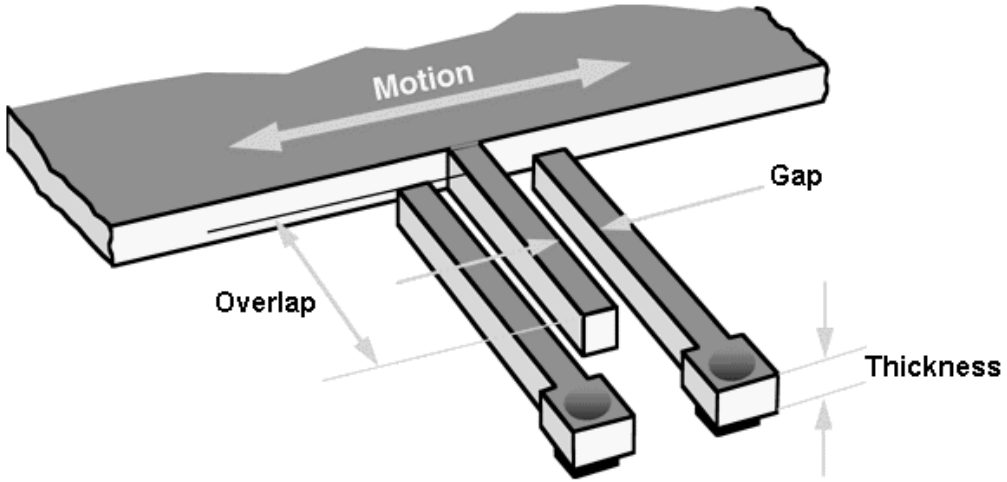




$$C_o = \frac{\varepsilon_o \times L_{overlap} \times thickness \times N}{X_o}$$

Ref: Analog Devices ADXL50

Accelerometer



- Gap Xo 2.25µm
- Thickness 0.3µm
- Overlap 282µm
- No. of fingers 300
- Area 580µm×920µm

Accelerometer

Interesting facts in MEMS

- **0.1µgrams Proof Mass**
- **0.1pF per Side for the Differential Capacitor**
- **20aF (10^{-18}f) Smallest Detectable Capacitance Change**
- **Total Capacitance Change for Full-scale is 10fF**
- **0.2Å Minimum Detectable Beam Deflection (one tenth of an Atomic diameter)**
- **10 to 22kHz Resonant Frequency of Beam**

Accelerometer - Characterization

Temperature Range

Bias drift with temperature

- **How does the zero g output change with temperature**
- **Can be trimmed out at system level by several methods**

Sensitivity drift with temperature

- **How does the output per g change with temperature**
- **Difficult to trim out at system level**

Bandwidth

Power consumption

- **Can power cycling be used to minimize power consumption**

Accelerometer

Figure 2. DEVICE BLOCK DIAGRAM

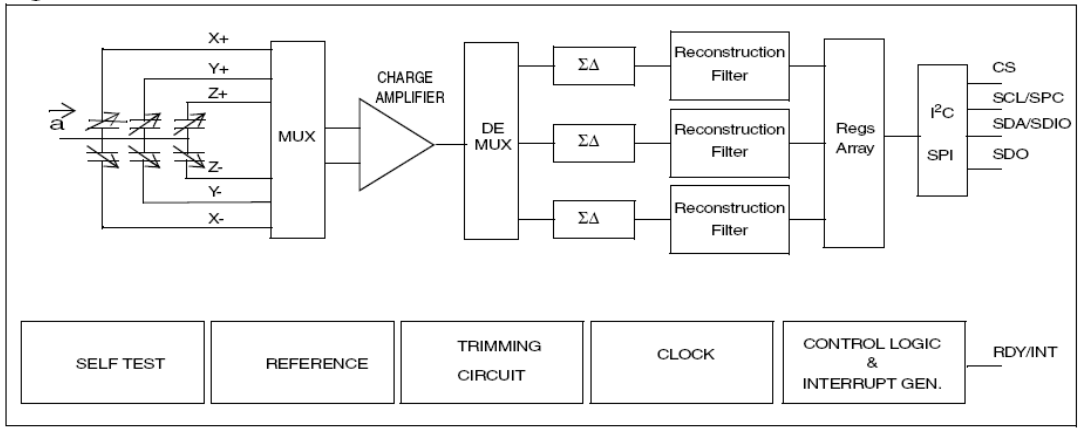
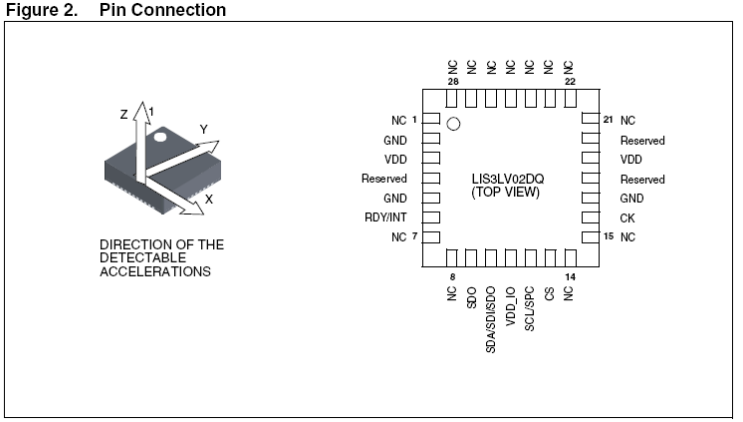


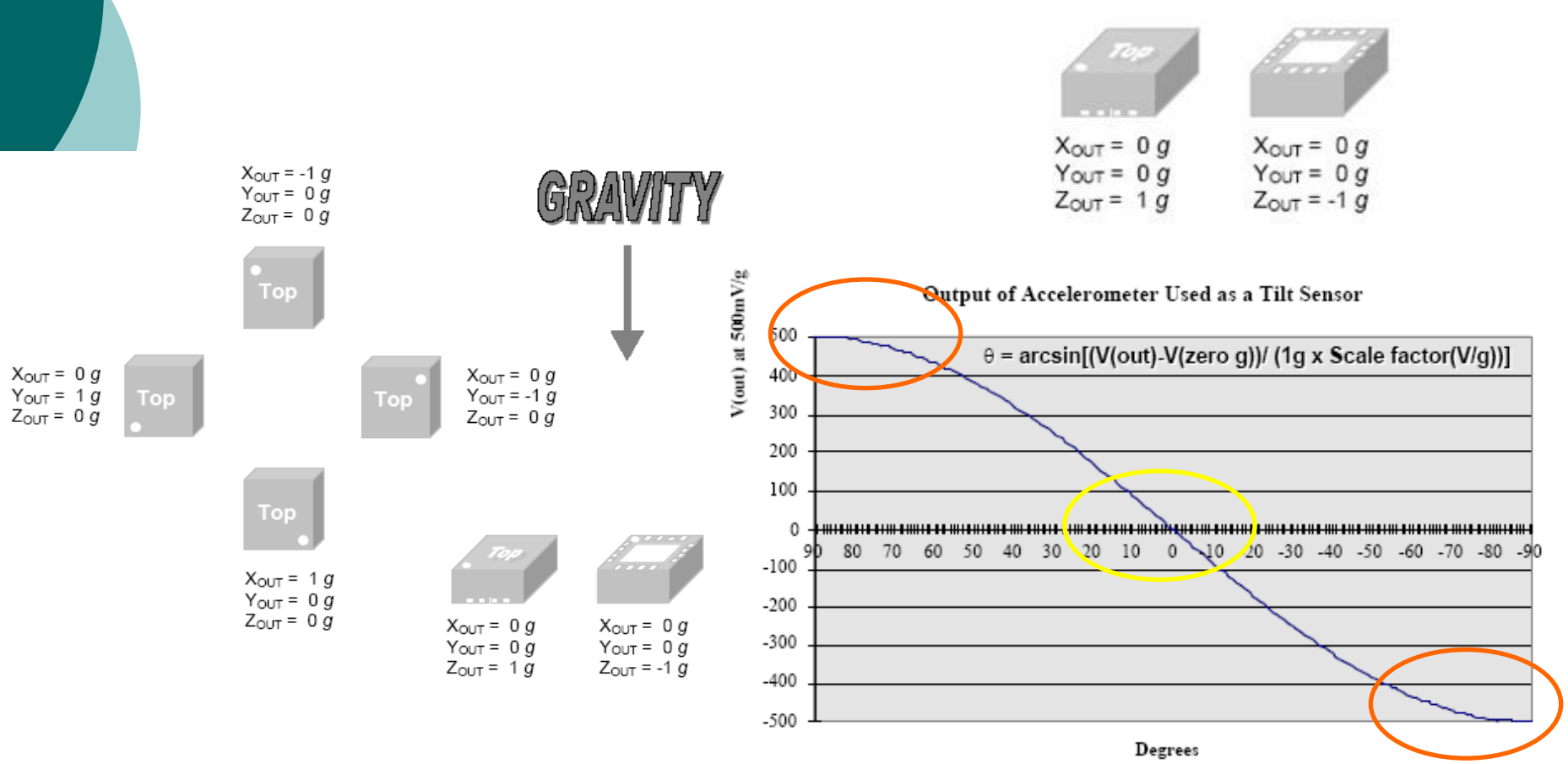
Table 5. Absolute maximum ratings

Symbol	Ratings	Maximum Value	Unit
Vdd	Supply voltage	-0.3 to 6	V
Vdd_IO	I/O pins Supply voltage	-0.3 to Vdd +0.1	V
Vin	Input voltage on any control pin (CS, SCL/SPC, SDA/SDI/SDO, CK)	-0.3 to Vdd_IO +0.3	V
A_{POW}	Acceleration (Any axis, Powered, Vdd=2.5V)	3000g for 0.5 ms	
		10000g for 0.1 ms	
A_{UNP}	Acceleration (Any axis, Unpowered)	3000g for 0.5 ms	
		10000g for 0.1 ms	
T_{OP}	Operating Temperature Range	-40 to +85	°C
T_{STG}	Storage Temperature Range	-40 to +125	°C
ESD	Electrostatic discharge protection	4.0 (HBM)	kV
		200 (MM)	V
		1.5 (CDM)	kV

Figure 2. Pin Connection

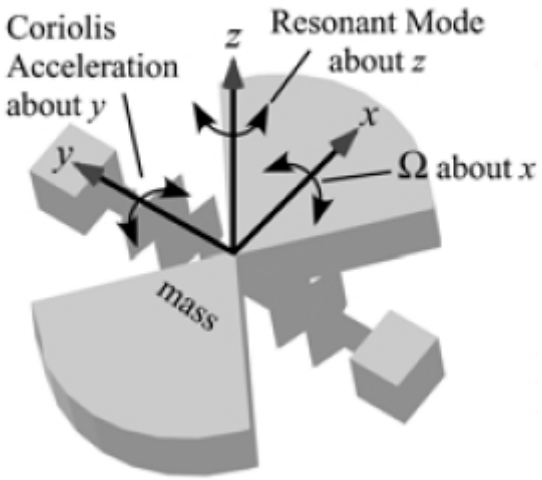


Accelerometer – Tilt and Inclination



Gyroscope

$$\omega = \frac{d\theta}{dt}$$



$$F_c = 2mv \times \Omega$$

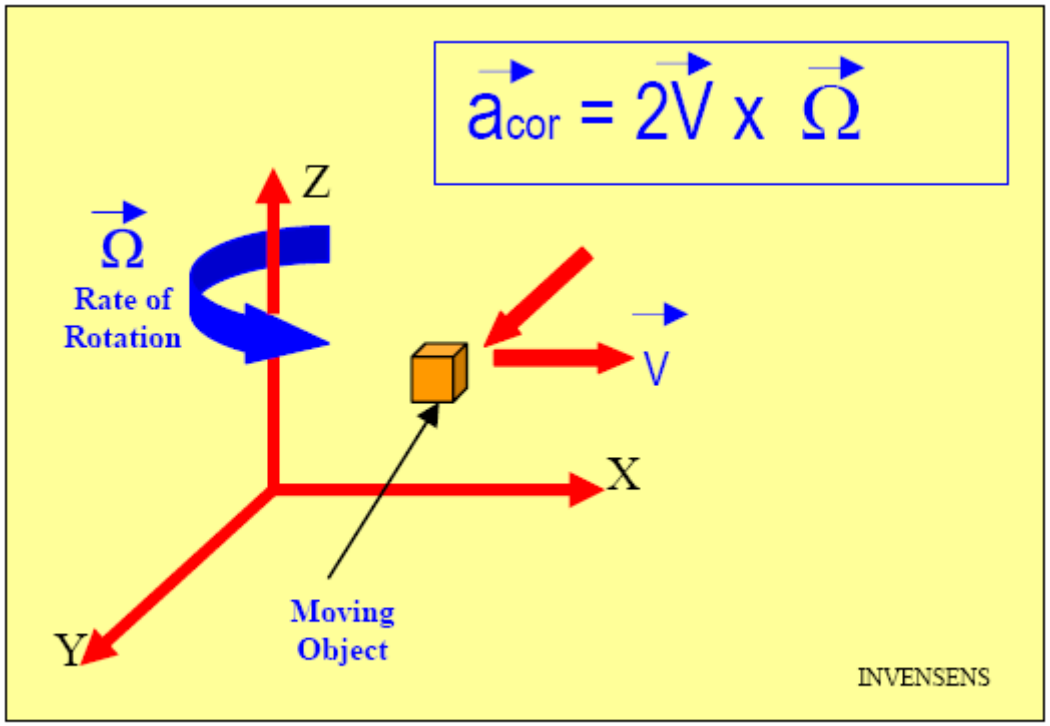
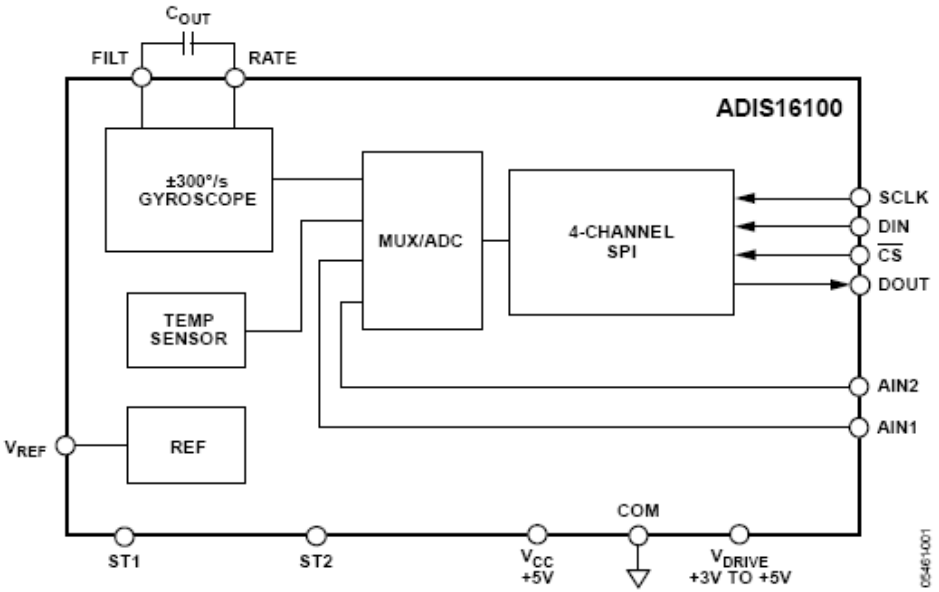


Figure1- Coriolis accelerometer concept

Gyroscope



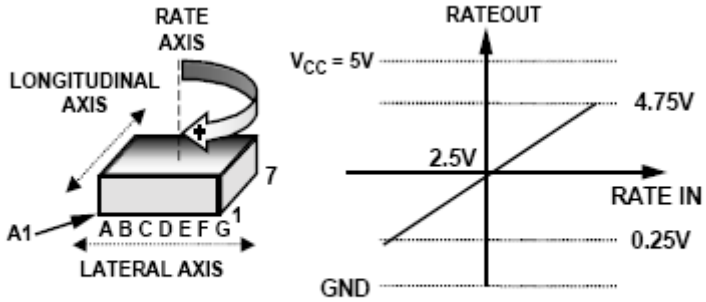
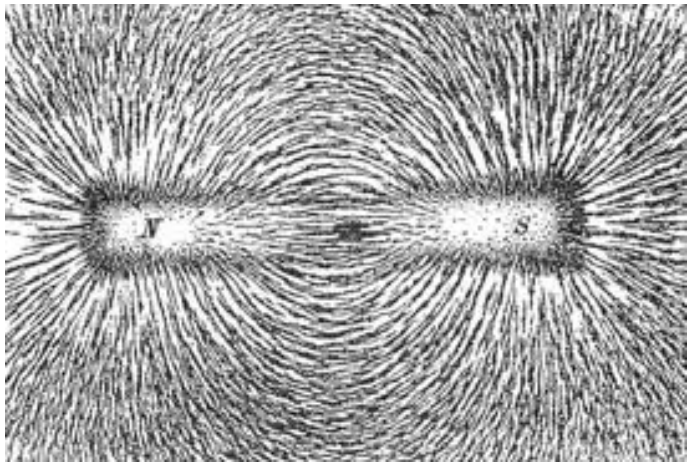
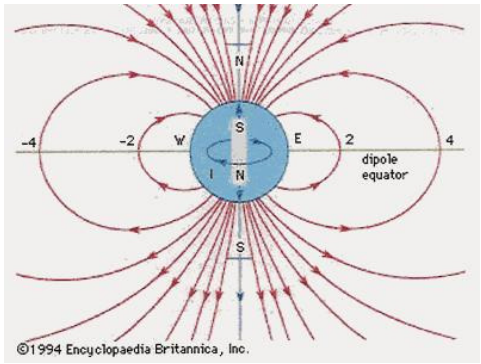
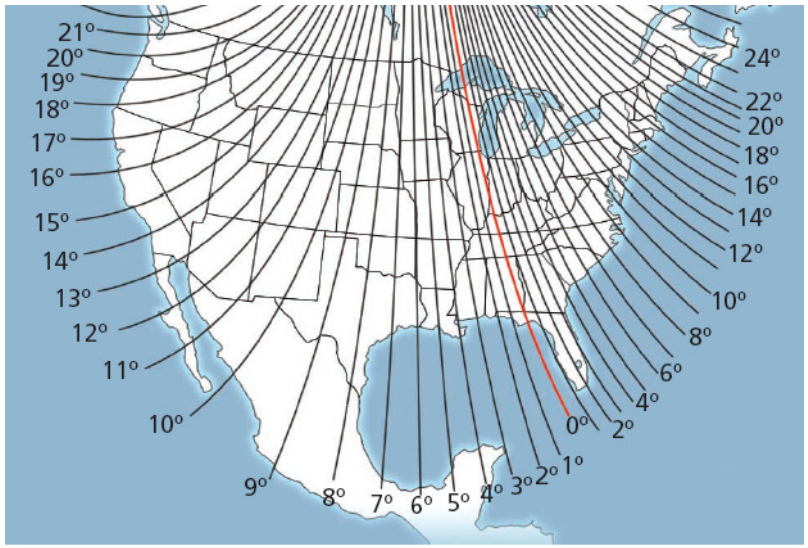


Figure 2. RATEOUT Signal Increases with Clockwise Rotation

Magnetic Sensor

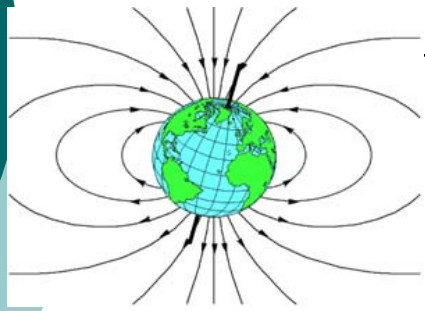




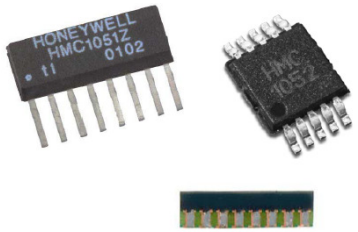


http://magnetic-declination.com/

Magnetic Sensor – Magneto resistivi



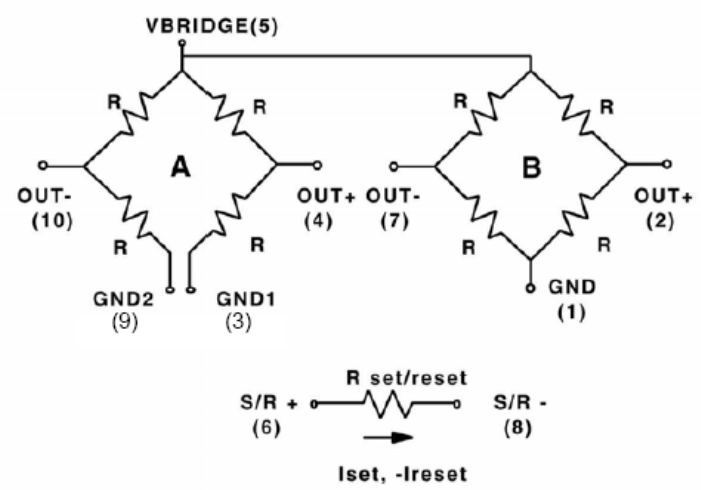
Unit Cost: 60 €



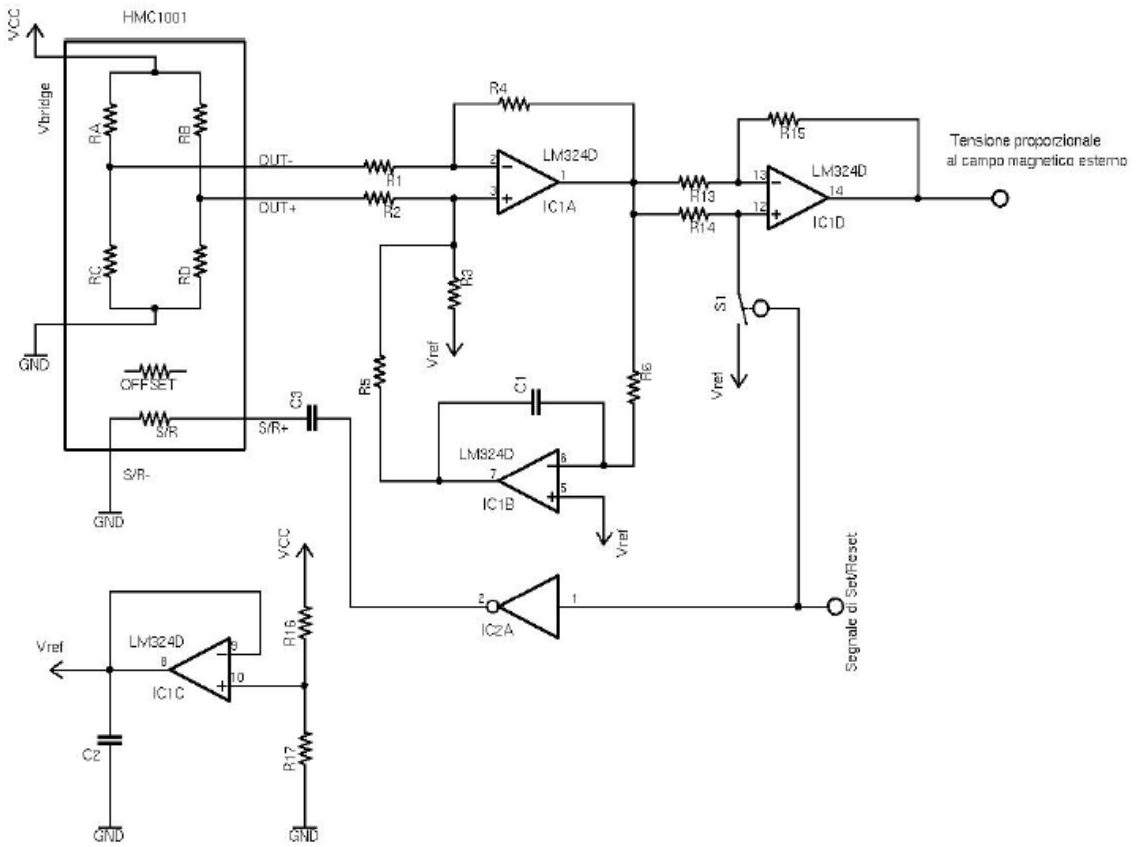
APPLICATIONS

- Compassing
- Navigation Systems
- Attitude Reference
- Traffic Detection
- Medical Devices
- Position Sensing

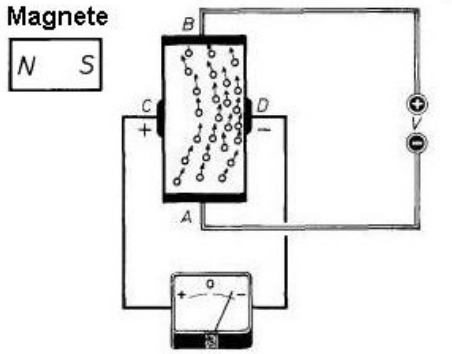
HMC1052 Circuit Diagram

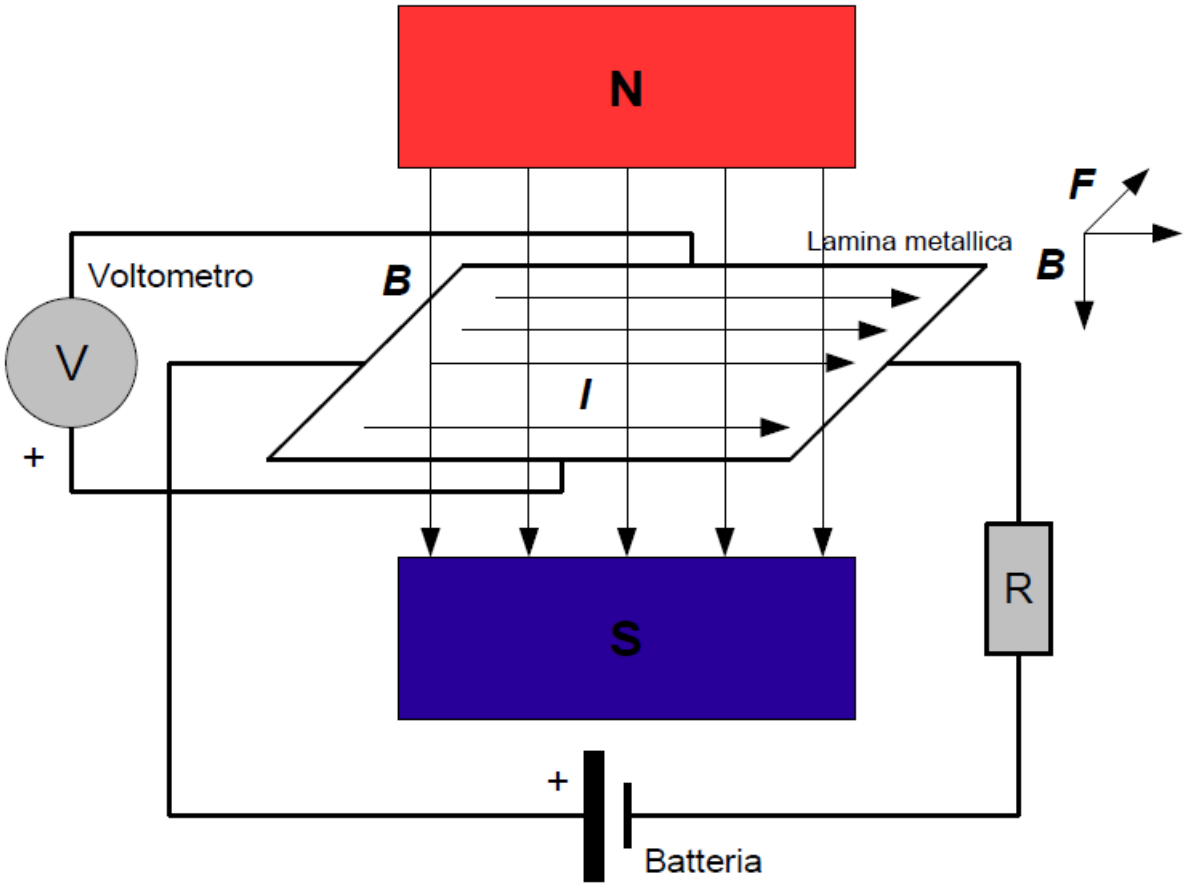


Magnetic Sensor – Magneto resistivi

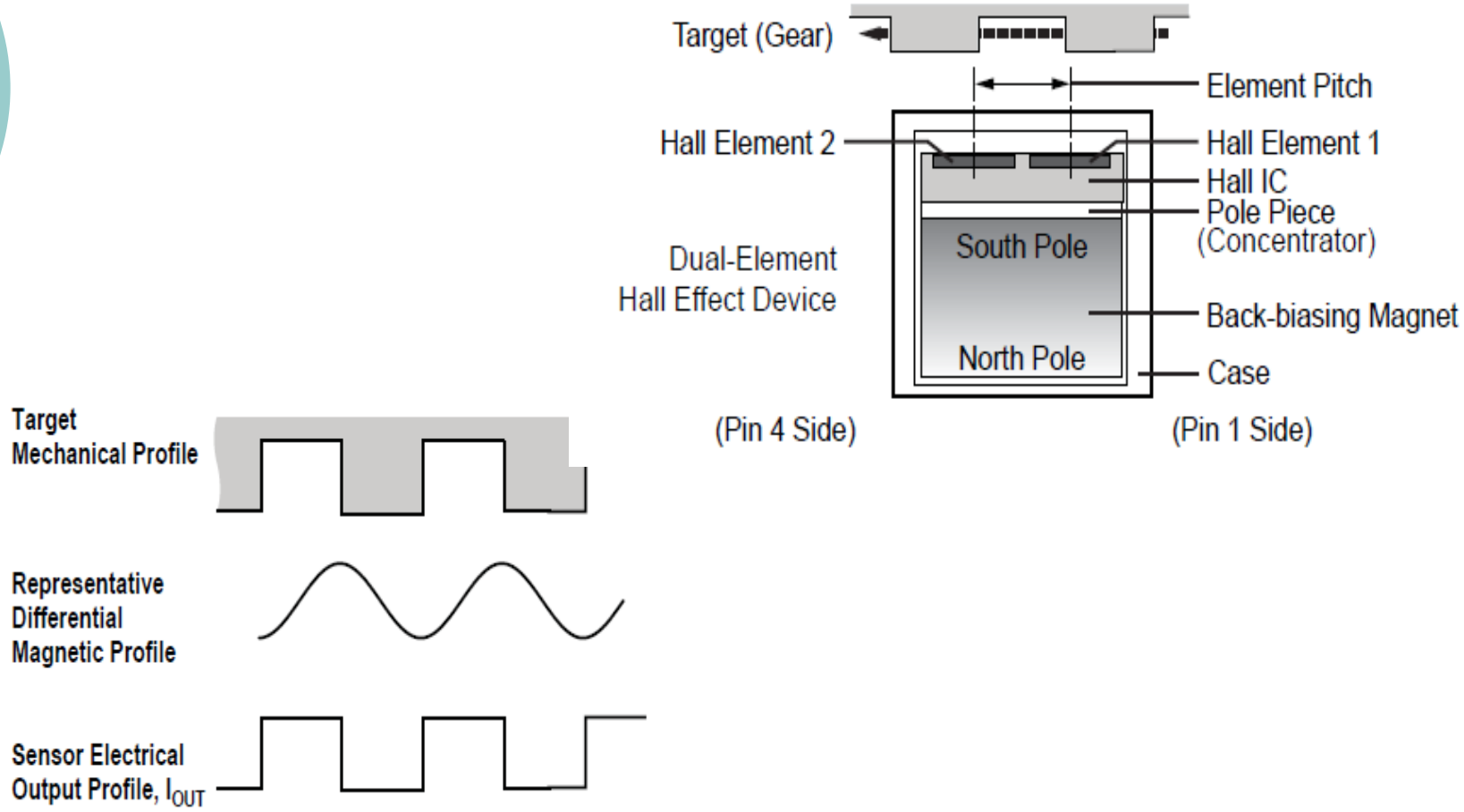


Magnetic Sensor – Effetto Hall





Magnetic Sensor



Magnetic Sensor