



Wrocław University of Science and Technology

# Industrial Sensors I & II




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## References

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**Introduction**

Conversion of a physical quantity  $G$  into a calibrated electrical signal

A humidity sensor as an example of how the measured value is obtained

\* Taken from [1]

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**Introduction**

Measurand	Sensor	Measurement range	Principle
Temperature	PTC metal	-200 ... +800°C	Positive temperature coefficient of the resistance of metals; e.g., platinum
	PTC thermistor	-50 ... +150°C	Positive temperature coefficient of the resistance of semiconductors; e.g., silicon
	NTC thermistor	-50 ... +150°C	Negative temperature coefficient of the resistance of metal-oxide ceramic
	Transistor	-50 ... +150°C	Negative temperature coefficient of the base-emitter voltage of a transistor
	Thermocouple	-200 ... +2,800°C	Thermo-electric voltage at contact of different metals
Crystal oscillator	-50 ... +300°C	Temperature coefficient of the resonant frequency of specially cut quartz crystals	

\* Taken from [1]

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**Introduction**

Measurand	Sensor	Measurement range	Principle
Temperature via heat radiation	Pyrometer	-100 ... +3,000°C	The spectral distribution of the luminance is temperature-dependent
	Pyroelement	-50 ... +2,200°C	The increase in temperature due to radiated heat generates a polarization voltage
Light intensity	Photodiode Phototransistor	$10^{-2} \dots 10^5$ lx	Current increases with light intensity due to optically released charge carriers
	Photoresistor	$10^{-2} \dots 10^5$ lx	Electrical resistance reduces as the illumination increases
	Photomultiplier	$10^{-6} \dots 10^3$ lx	Light releases electrons from a photocathode, which are multiplied by subsequent dynodes

\* Taken from [1]

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**Introduction**

Measurand	Sensor	Measurement range	Principle
Sound	Dynamic microphone		The induction of a voltage by movement of a coil within a magnetic field
	Condenser microphone		The voltage of a charged capacitor varies with the distance between the plates
Magnetic field	Crystal microphone		The piezoelectric effect generates a voltage
	Induction coil		Supplies voltage if the magnetic field changes or the coil moves within the field
	Hall-effect device	0.1 m ... 1 T	Produces a voltage across the semiconductor by deflection of electrons in the magnetic field
	Magnetoresistor	0.1 ... 1 T	Resistance increases in the semiconductor as a function of field strength

\* Taken from [1]

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**Introduction**

Measurand	Sensor	Measurement range	Principle
Force	Strain gauge	$10^{-2} \dots 10^3 \text{ N}$	Force causes elastic elongation of a thin-film resistor, thereby increasing its resistance
Pressure	Strain gauge	$10^{-3} \dots 10^3 \text{ bar}$	The bridge circuit of the strain gauge on the diaphragm is detuned by pressure
Acceleration	Strain gauge	1 ... 5,000 g	The strain-gauge bridge is detuned by acceleration force on weighted diaphragm
Linear displacement	Potentiometric displacement transducer	$\mu\text{m} \dots \text{m}$	The potentiometer tap is shifted
	Inductive displacement transducer	$\mu\text{m} \dots 10^{-1} \text{ m}$	The inductive bridge is unbalanced by displacement of a ferrite core
	Incremental displacement transducer, optical	$\mu\text{m} \dots \text{m}$	The reticle pattern is scanned. The number gives the displacement

\* Taken from [1]

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**Introduction**

Measurand	Sensor	Measurement range	Principle
Angle	Incremental angular displacement transducer, optical	1 ... 20,000 per revolution	The reticle pattern is scanned. The number gives the angle of rotation
	Incremental angular displacement transducer, magnetic	1 ... 1,000 per revolution	Magnetic scanning of a toothed-wheel sensor
	Incremental angular displacement transducer, capacitive	1 ... 1,000 per revolution	Capacitive scanning of a toothed-wheel sensor
Flow velocity	Windmill-type anemometer		The rotational speed increases with the flow speed
	Heated-wire anemometer		Cooling increases with the flow rate
	Ultrasound transceiver		The Doppler shift increases with the flow rate

\* Taken from [1]

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### Introduction

Measurand	Sensor	Measurement range	Principle
Gas concentration	Ceramic resistor		The resistance changes with the adsorption of the test substance
	MOSFET		Change in threshold voltage during adsorption of the test substance under the gate
Humidity	Absorption spectrum Capacitor	1 ... 100%	Absorption lines are characteristic for each gas The dielectric constant increases due to water absorption as the relative humidity rises
	Resistor	5 ... 95%	The resistance decreases due to water absorption as the relative humidity rises

\* Taken from [1]

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### Diodes and Transistors as Temperature Sensors

$$U(T) = m\phi_T(T) \ln\left(\frac{I_{D2}}{I_{D1}(T)}\right)$$

$$\phi_T(T) = \frac{kT}{q}$$

$$U_R = U_{D2} - U_{D1} = m\phi_T \ln\left(\frac{I_{D2}}{I_{D1}}\right)$$

$$\frac{dU_D}{dT} \approx -2mV / \text{deg\_for\_} I_D = 2mA$$

$$\frac{dU_R}{dT} = \frac{nk}{q} \ln\left(\frac{I_{D2}}{I_{D1}}\right)$$


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### Diodes and Transistors as Temperature Sensors

The use of the base-emitter voltage for temperature measurement

Base-emitter voltage as a function of temperature

\* Taken from [1]

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### Diodes and Transistors as Temperature Sensors

Use of a bandgap reference for temperature measurement (e. g. LT1019)

A supplementary circuit for implementing a Celsius zero point

\* Taken from [1]

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### Diodes and Transistors as Temperature Sensors

A temperature controlled current source using the bandgap principle (e. g. AD592)

A temperature controlled current source with a freely selectable output current (e. g. LM344)

\* Taken from [1]

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### Transistor Temperature Sensors example

**STLM20**  
Ultra-low current 2.4 V precision analog temperature sensor

**Features**

- Precision analog voltage output temperature sensor
- $\pm 1.5^\circ\text{C}$  temperature accuracy at  $25^\circ\text{C}$
- Ultra-low quiescent supply current:  $80\ \mu\text{A}$  (max)
- Operating voltage range: 2.4 V to 5.5 V
- Operating temperature range:  $-55^\circ\text{C}$  to  $150^\circ\text{C}$  (package -7)
- $-55^\circ\text{C}$  to  $85^\circ\text{C}$  (grade -9)
- SOT23-5 (SOT70-5) 5-lead package
- UDFN 4-lead package

**Applications**

- Third generation (3G) cell phones
- Multimedia PDA devices
- GPS devices
- Portable medical instruments
- Voltage-controlled crystal oscillator temperature monitors
- RF power transistor monitor

SOT23-5, SOT70-5 (WB)

UDFN 4-lead (DD)

\* Taken from „STLM20 – Ultra-low current 2.4V precision analog temperature sensor“, Technical Data Sheet, ST microelectronics, 2009 [8]

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### Transistor Temperature Sensors example

\* Taken from „STLM20 – Ultra-low current 2.4V precision analog temperature sensor“, Technical Data Sheet, ST microelectronics, 2009 [8]

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### Transistor Temperature Sensors example

STLM20  $V_{OUT}$  vs temperature

\* Taken from „STLM20 – Ultra-low current 2.4V precision analog temperature sensor“, Technical Data Sheet, ST microelectronics, 2009 [8]

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### Metals as PTC thermistors

Metals possess a positive temperature coefficient.

‘Pt...’ – platinum temperature detectors.  $R_0$  of the detector is specified at  $0^\circ C$  (Pt100, Pt200, ... Pt1000).

In the temperature range  $0^\circ C \leq \theta \leq 850^\circ C$

$$R_\theta = R_0 \left[ 1 + 3.90802 \cdot 10^{-3} \frac{\theta}{0^\circ C} - 0.58095 \cdot 10^{-6} \left( \frac{\theta}{0^\circ C} \right)^2 \right]$$


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**Metals as PTC thermistors**

In the temperature range  $-200^{\circ}C \leq \vartheta \leq 0^{\circ}C$

$$R_{\vartheta} = R_0 \left[ 1 + 3.90802 \cdot 10^{-3} \frac{\vartheta}{^{\circ}C} - 0.58095 \cdot 10^{-6} \left( \frac{\vartheta}{^{\circ}C} \right)^2 + 0.42735 \cdot 10^{-9} \left( \frac{\vartheta}{^{\circ}C} \right)^3 - 4.2735 \cdot 10^{-12} \left( \frac{\vartheta}{^{\circ}C} \right)^4 \right]$$

With nickel-iron temperature detectors  $R_0$  is specified at  $20^{\circ}C$ .  
For the temperature range  $-50^{\circ}C \leq \vartheta \leq 150^{\circ}C$

$$R_{\vartheta} = R_{20} \left[ 1 + 3.83 \cdot 10^{-3} \frac{\vartheta}{^{\circ}C} - 4.64 \cdot 10^{-6} \left( \frac{\vartheta}{^{\circ}C} \right)^2 \right]$$


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**Silicon-based PTC Thermistors**

Uniformly doped silicon possesses a positive temperature coefficient.

$$R_{\vartheta} = R_{25} \left[ 1 + 7.95 \cdot 10^{-3} \frac{\vartheta}{^{\circ}C} + 1.95 \cdot 10^{-5} \left( \frac{\vartheta}{^{\circ}C} \right)^2 \right]$$

Where  $R_{25}$  is a nominal resistance at  $25^{\circ}C$ .  
This equation is valid only for sensor of KTS-series from Infineon and Philips and is only approximate for other manufacturers.

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**Temperature coefficient**

Temperature coefficient:  $TC = \frac{1}{R} \cdot \frac{dR}{d\vartheta}$

A four-wire resistance measuring circuit that provides independence from lead resistance

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22 Taken from „Electronic circuits : handbook for design and application“ Tietze U., Schenk C. [1]

### Linearization of the PTC thermistors

Principle of linearized operation and the example of linearization, zero shift and gain for a silicon PTC sensors

\* Taken from [1]

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### Linearization of the PTC thermistors

Principle of linearized operation of Pt... Sensors, and implementation of a current source that has a negative output resistance

\* Taken from [1]

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<b>Temperature range</b>	- 50 °C to + 130 °C (Possible working temperatures using volume expansion aligned conductor board material: 150 °C)
<b>Temperature coefficient</b>	TCR = 3850 ppm/K
<b>Soldering connection</b>	end-termination galvanic tin plated with Ni-barrier
<b>Long term stability</b>	max. R <sub>0</sub> -drift 0.06 % after 1000 h at 130 °C
<b>Environmental conditions</b>	unhoused for dry environments only
<b>Insulation resistance</b>	> 100 MΩ at 20 °C; > 2 MΩ at 130 °C (glass covering)
<b>Measuring current</b>	100Ω: 0.3 to 1.0 mA 1000Ω: 0.1 to 0.3 mA (self heating has to be considered)
<b>Self heating</b>	0.4 K/mW at 0 °C
<b>Response time</b>	water current (v = 0.4 m/s): t <sub>0.5</sub> = 0.15 s; t <sub>0.9</sub> = 0.30 s air stream (v = 2 m/s): t <sub>0.5</sub> = 3.5 s; t <sub>0.9</sub> = 10 s

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Examples of Pt100/1000 packages

PT1000-SOT223

PT100-TO92

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Industrial thermometer housing

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Industrial thermometer housing

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**RTD**

TYPE	RESISTANCE
244050	10-250
TIP20C	10-250
239050	10-250

**RTD – Resistive Temperature Detector**

\* Taken from XTR105 4-20mA CURRENT TRANSMITTER with sensor excitation and linearization, Texas Instruments Application Note, 2004 [2]

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**NTC Thermistors**

NTC thermistors are temperature-dependent resistors with a very large, negative temperature coefficient. They are made of metal-oxide ceramic materials.

If the temperature of interest T is close to nominal temperature  $T_N$ :

$$R_T = R_N \exp \left[ B \left( \frac{1}{T} - \frac{1}{T_N} \right) \right] \quad T = 273 + \dots$$

Temperature in Kelvin

B is between 1500K and 7000K.

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**Linearization of the NTC thermistors**

$$V_{\phi} = I_{ref} \cdot R_{lin} \frac{R_{\phi}}{R_{\phi} + R_{lin}}$$

$$V_{\phi} = V_{ref} \frac{R_{\phi}}{R_{\phi} + R_{lin}}$$

Linearization of NTC thermistors characteristic using  $R_{lin}$ .

\* Taken from [1]

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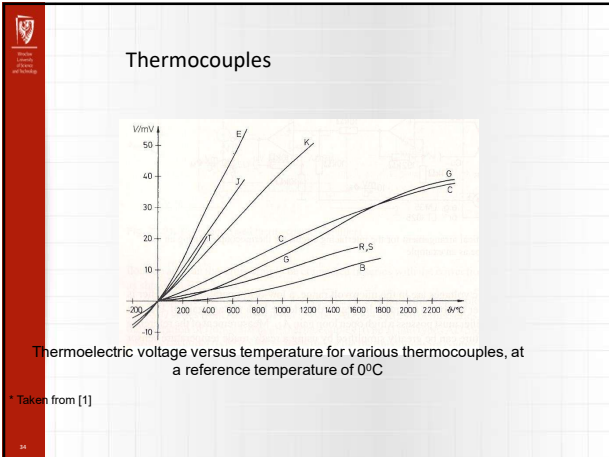
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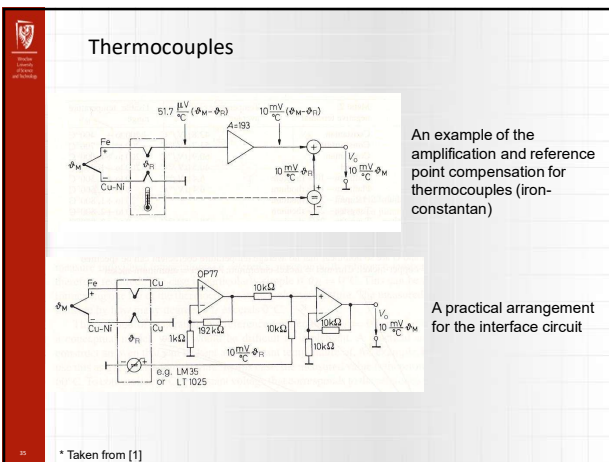
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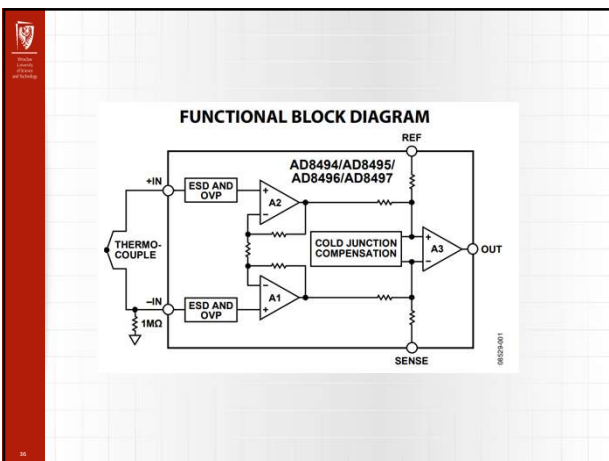
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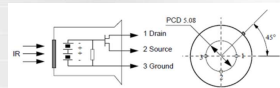
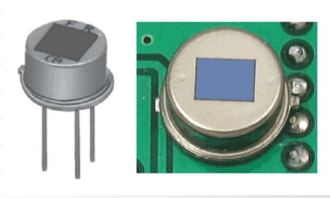
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pyroelectric sensor




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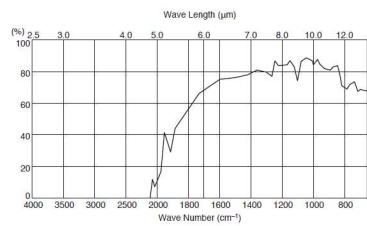
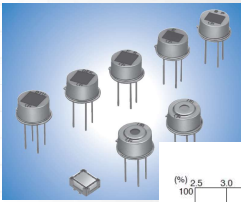
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pyroelectric sensor by muRata




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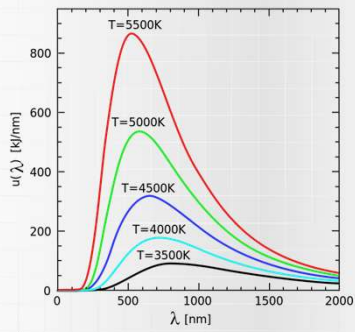
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### Temperature Sensors Summary (RTD)

Type	Manufacturer	Output signal nominal value	Temperature range
<b>Metal PTC thermistor</b>			
Pt 100...1000	Heraeus	100...1000 Ω	-50...+500°C
FK 100...2000	Heraeus	100...2000 Ω	-200...+500°C
1 Pt 100...1000	Omega	100...1000 Ω	-70...+500°C
Pt 100...1000	Murata	100...1000 Ω	-50...+600°C
Pt 100...1000	Sensycon	100...1000 Ω	-50...+600°C
<b>Silicon PTC thermistor</b>			
AD 22100 <sup>1</sup>	Analog D.	22 mV/K	-50...+150°C
KTY-Series	Infineon	1...2 kΩ	-50...+150°C
KTY-Series	Philips	1...2 kΩ	-50...+300°C
<b>Metal-ceramic NTC thermistors</b>			
M-Series	Infineon	1 k...100 kΩ	-50...+200°C
NTH-Series	Murata	100 Ω...100 kΩ	-50...+120°C
Thermistors	Philips	1 kΩ...1 MΩ	-50...+200°C

\* Taken from [1]

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### Temperature Sensors Summary (other)

Type	Manufacturer	Output signal nominal value	Temperature range
<b>Bridge sensors</b>			
AD 7818 <sup>2</sup>	Analog Dev.	4 LSB/K	-55...+125°C
TMP 04	Analog Dev.	PWM-Output	-40...+100°C
TMP 17	Analog Dev.	1 μA/K	-40...+105°C
TMP 36	Analog Dev.	10 mV/K	-40...+125°C
LT 1025 <sup>3</sup>	Lin. Tech.	10 mV/K	0...+60°C
MAX 6607	Maxim	10 mV/K	-20...+85°C
DS 18B 20 <sup>2</sup>	Maxim	20 LSB/K	-55...+125°C
LM 65	National	10 mV/K	-20...+100°C
LM 60	National	6 mV/K	-40...+125°C
LM 74 <sup>2</sup>	National	16 LSB/K	-55...+150°C
LM 134	National	0.1...10 μA/K	-40...+125°C
TMP 125	Texas Inst.	4 LSB/K	-40...+125°C
<b>Thermocouples</b>			
J, K, S, R, B	Heraeus	Fig. 21.26	Fig. 21.26
J, K, S, R, B, T, E, C, G	Omega	Fig. 21.26	Fig. 21.26
J, K, S	Philips	Fig. 21.26	Fig. 21.26
J, K, S, R, B	Sensycon	Fig. 21.26	Fig. 21.26
<b>Thermocouple amplifiers</b>			
AD 594	Analog Dev.	type J 10 mV/°C	-55°C...+125°C
AD 595	Analog Dev.	type K 10 mV/°C	-55°C...+125°C

- crystal oscillator
- pyrometer (bolometer, thermocouple...)
- -pyroelement

\* Taken from [1]

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### Strain gauges

If a strip of conductive metal is stretched, it will become skinnier and longer, both changes resulting in an increase of electrical resistance end-to-end. Conversely, if a strip of conductive metal is placed under compressive force (without buckling), it will broaden and shorten.

The diagram shows a bonded strain gauge on a substrate. Tension causes the gauge to stretch, increasing its length and decreasing its cross-sectional area, which results in an increase in resistance. Compression causes the gauge to shorten and broaden, decreasing its length and increasing its cross-sectional area, which results in a decrease in resistance. The gauge is noted as being insensitive to lateral forces.

$$R \uparrow = \rho \frac{l \uparrow}{s \downarrow}$$

$$U \uparrow = R \uparrow \cdot I$$

\* Taken from [1]

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### Strain gauges

Quarter-bridge strain gauge circuit

$$\frac{\Delta R_T}{R_T} = k\varepsilon$$

$$R_T = (30 - 3000)\Omega$$

$k$  – strain gauge constant  
 $\varepsilon$  - unit elongation

\* Taken from , Lessons In Electric Circuits, Volume I – DC, Kuphaldt T. R., Open Book Project, 2006 [4]

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### Strain gauges

Quarter-bridge strain gauge circuit with temperature compensation

strain gauge (unstressed)  
 strain gauge (stressed)

\* Taken from [4]

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### Strain gauges

Half-bridge strain gauge circuit

strain gauge (stressed)  
 strain gauge (stressed)

Strain gauge #1  
 Strain gauge #2  
 Bridge balanced

Strain gauge #1  
 Strain gauge #2  
 FORCE  
 Bridge unbalanced

\* Taken from [4]

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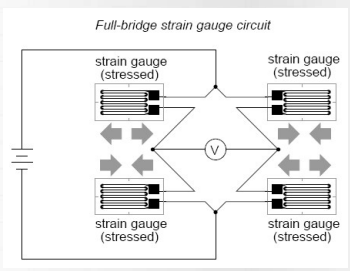
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Strain guages



\* Taken from [4]

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Strain guages

**Prime Strain Gage Selection Considerations**

- Gage Length
- Number of Gages in Gage Pattern
- Arrangement of Gages in Gage Pattern
- Grid Resistance
- Strain Sensitive Alloy
- Carrier Material
- Gage Width
- Solder Tab Type
- Configuration of Solder Tab
- Availability

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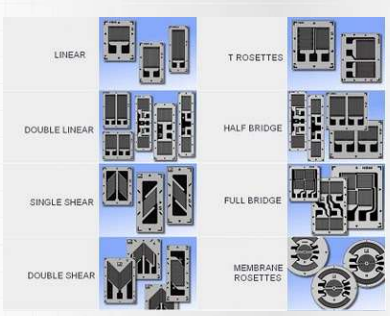
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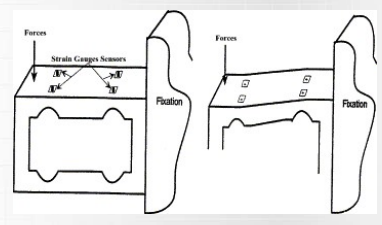
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### deformation of a mechanical transducer



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### Strain gauge – mechanical construction



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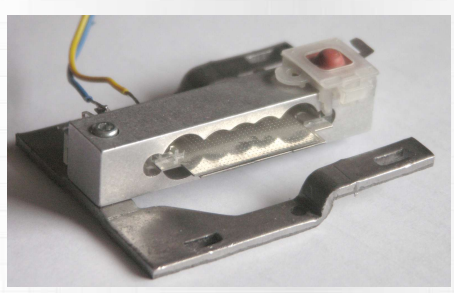
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### Strain gauge - capacitive



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### Pressure Measurement

Pressure range	Application
< 40 mbar	Water level in a washing machine, dishwasher
100 mbar	Vacuum cleaner, filtration monitoring, flow measurement
200 mbar	Blood pressure measurement
1 bar	Barometer, motor vehicle (correction for ignition and fuel injection)
2 bar	Motor vehicle (tire pressure)
10 bar	Espresso machinery
50 bar	Pneumatics, industrial robots
500 bar	Hydraulics, construction machinery
2000 bar	Car motor with fuel injection

Pressures that occur in practical applications

\* Taken from [1]

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### Pressure Measurement

**Definitions:**

$$1 \text{ Pascal} = \frac{1 \text{ Newton}}{1 \text{ Square meter}}$$

1 bar = 100 kPa      1 mbar = 1 hPa

1 cmH<sub>2</sub>O = 98.1 Pa = 0.981 mbar  
 1 mmHg = 133 Pa = 1.33 mbar

1 psi = pounds per square inch  
 1 psi = 6.98 kPa = 68.9 mbar

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### Pressure Measurement

A differential pressure sensor: Shows a cross-section of a sensor with two ports for pressure  $p_1$  and  $p_2$ , a central diaphragm, a casting, and an Si sensor.

An absolute pressure sensor: Shows a cross-section of a sensor with a single port for pressure  $p_1$ , a diaphragm, a casting, and a vacuum chamber where  $p_2 = 0$ .

Expansion and compression of the diaphragm of pressure sensors: A diagram showing a diaphragm being pushed up and down, with numbered points 1, 2, 3, and 4 indicating strain locations.

Arrangement of strain gauges on the diaphragm: A circular diagram showing four strain gauges (1, 2, 3, 4) arranged at 90-degree angles on a diaphragm.

\* Taken from „Electronic circuits : handbook for design and application“ Tietze U., Schenk C. [1]

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**Pressure Measurement**

Measuring bridge of a pressure sensor

$$\frac{V_D}{V_{ref}} = \frac{R + \Delta R}{2R} - \frac{R - \Delta R}{2R} = \frac{\Delta R}{R}$$

$$S = \frac{\Delta V_D}{\Delta p V_{ref}} = \frac{\Delta R}{\Delta p \cdot R}$$

\* Taken from „Electronic circuits : handbook for design and application“ Tietze U., Schenk C. [1]

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**Pressure Measurement**

An interfacing circuit for pressure sensor

$$U_{out} = 2 \underbrace{\left(1 + \frac{R_2}{R_1}\right)}_{GAIN} \underbrace{(U_1 - U_2)}_{U_D} + \underbrace{U_Z}_{U_0}$$

\* Taken from „Electronic circuits : handbook for design and application“ Tietze U., Schenk C. [1]

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**Pressure Measurement**

Resistance and sensitivity of silicon pressure sensors as a function of temperature

\* Taken from „Electronic circuits : handbook for design and application“ Tietze U., Schenk C. [1]

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### Pressure Measurement

Temperature compensation method for pressure sensors

An NTC thermistor - an example; SDX-series from SenSym

Approximately three diodes - an example; KP100A1 from Philips

A badgap temperature sensor - an example; LM335 from National

\* Taken from [1]

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### Pressure Measurement

**MPX2010  
MPXV2010G  
SERIES**

COMPENSATED PRESSURE SENSOR  
0 to 10 kPa @ 0 to 1.40 psia  
FULL SCALE SPAN: 20 mV

SMALL OUTLINE PACKAGE  
SENSING ELEMENT

PIN NUMBER			
1	GND	1	NC
2	V <sub>S</sub>	2	NC
3	V <sub>S</sub>	7	NC
4	OUT	8	NC

\* Taken from „MPX2010 10kPa on-chip temperature compensated & calibrated silicon pressure sensor“, Motorola Technica Data, 2002 [3]

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### Pressure Measurement

Unibody Package — Cross-Sectional Diagram (not to scale)

Output versus Pressure Differential

\* Taken from „MPX2010 10kPa on-chip temperature compensated & calibrated silicon pressure sensor“, Motorola Technica Data, 2002 [3]

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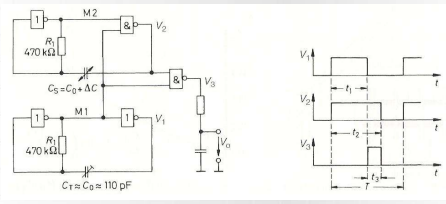
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# Humidity Sensors



Determining the increase in capacitance by measuring the increase in oscillation period (Gates: CMOS; for example CD4001)

Output signal resulting from the difference in switching times

Sensor example: SHT10, SHT11, SHT15 ([www.sensirion.com/humidity](http://www.sensirion.com/humidity))

\* Taken from [1]

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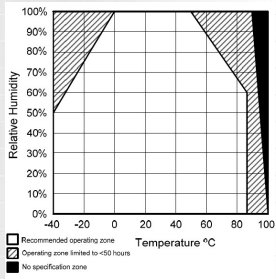
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# Honeywell humidity sensors




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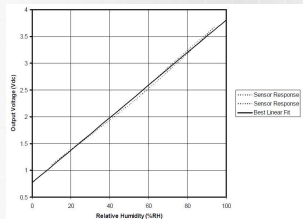
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# Honeywell humidity sensors




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Oxygen sensors

Water quality control – KDS25B.

\* Taken from „Product information – GS Yuasa Dissolved Oxygen Sensor KDS-25B“, Technical Data Sheet, Figaro Engineering Inc., 2007 [6]

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Oxygen sensors

Percent oxygen present in a particular atmosphere – KE25/50

*Features*

- \* Long life (KE-25 - 5 years / KE-50 - 10 years)
- \* Virtually no influence from CO<sub>2</sub>, CO, H<sub>2</sub>S, NO<sub>x</sub>, H<sub>2</sub>
- \* Low cost
- \* Operates in normal ambient temperatures
- \* Stable output signal
- \* No external power supply required for sensor operation
- \* No warm-up time is required

*Applications*

- \* Medical - Anesthetic instruments, respirators, oxygen-enrichers
- \* Biotechnology - Oxygen incubators
- \* Food industry - Refrigeration, greenhouses
- \* Safety - Air conditioners, oxygen detectors, fire detectors

\* Taken from „Technical information for GS Oxygen sensor KE series“, Technical Data Sheet, Figaro Engineering Inc., 2007 [7]

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Oxygen sensors

Theory of operation of the KE25/50 - the KE series sensor is a lead-oxygen battery which incorporates a lead anode, an oxygen cathode made of gold, and a weak acid electrolyte. Oxygen molecules enter the electrochemical cell through a non-porous fluorine resin membrane and are reduced at the gold electrode with the acid electrolyte. The current which flows between the electrodes is proportional to the oxygen concentration in the gas mixture being measured. The terminal voltages across the thermistor (for temperature compensation) and resistor are read as a signal, with the change in output voltages representing the change in oxygen concentration.

\* Taken from „Technical information for GS Oxygen sensor KE series“, Technical Data Sheet, Figaro Engineering Inc., 2007 [7]

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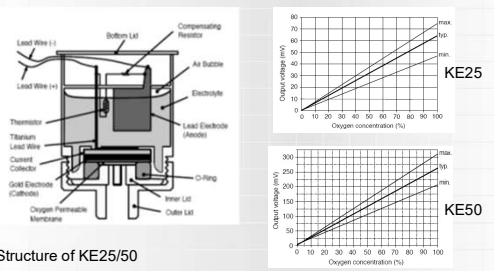
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### Oxygen sensors



\*Taken from „Technical information for GS Oxygen sensor KE series“, Technical Data Sheet, Figaro Engineering Inc., 2007 [7]

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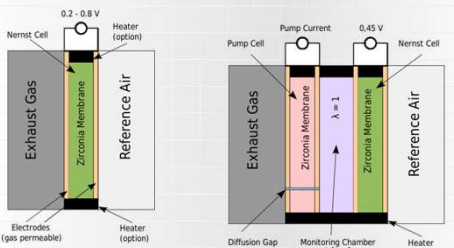
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### The zirconium dioxide lambda sensor



A planar zirconia sensor      A planar wideband zirconia sensor

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### Titania sensor

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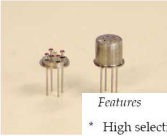
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## Air quality control sensor – TGS 2600

**Technical Information for Air Quality Control Sensors**

The Figaro 2600 series is a new type thick film metal oxide semiconductor, screen printed gas sensor which offers miniaturization and lower power consumption. The TGS2600 displays high selectivity and sensitivity to low concentrations of various air contaminants such as those found in cigarette smoke.



**Features**

- \* High selectivity to low gas concentrations
- \* Low power consumption
- \* Small size
- \* Long life

**Applications**

- \* Air cleaners for indoor air cleaners
- \* Air cleaners for vehicles
- \* Air quality monitors

\*Taken from „Technical information for air quality control sensor TGS 2600“, Technical Data Sheet, Figaro Engineering Inc., 2004, [9]

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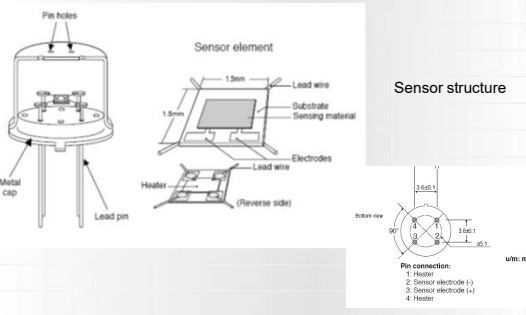
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## Air quality control sensor – TGS 2600



**Sensor structure**

\*Taken from „Technical information for air quality control sensor TGS 2600“, Technical Data Sheet, Figaro Engineering Inc., 2004, [9]

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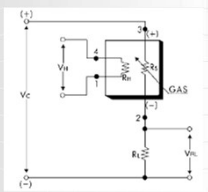
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## Air quality sensors

The structure of TGS2600. Using thick film techniques, the sensor material is printed on electrodes (noble metal) which have been printed onto an alumina substrate. The main sensing material of the sensor element is tin dioxide (SnO<sub>2</sub>). One electrode is connected to pin No.2 and the other is connected to pin No.3. An RuO<sub>2</sub> heater printed onto the reverse side of the substrate and connected to pins No.1 and No.4 heats the sensing material. Lead wires are Pt-W and connected to sensor pins which are made of Ni-plated Ni-Fe 50%. The sensor base is made of Ni-plated steel. The sensor cap is made of stainless steel and contains 6 pin holes on the sensor's top.



$$R_S = \frac{V_C - V_{out}}{V_{out}} R_L$$

\*Taken from „Technical information for air quality control sensor TGS 2600“, Technical Data Sheet, Figaro Engineering Inc., 2004, [9]

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### Air quality sensors

Item	Specification
Circuit voltage (Vc)	5.0V ± 0.2V DC
Heater voltage (Vh)	5.0V ± 0.2V DC/AC
Heater resistance (room temp.)	83Ω at room temp. (typical)
Load resistance (RL)	Variable (0.45kΩ min.)
Sensor power dissipation (Ps)	≤ 15mW
Operating & storage temperature	-10°C ~ +50°C
Optimal detection concentration	1-30ppm

Item	Specification
Sensor resistance (R0)	10kΩ ~ 90kΩ
Sensor resistance gradient (β)	0.3 ~ 0.6
$\beta = R_s(10\text{ppm hydrogen})/R_s(\text{air})$	
Heater current	42 ± 4mA
Heater power consumption	210mW (typical)

\*Taken from „Technical information for air quality control sensor TGS 2600“, Technical Data Sheet, Figaro Engineering Inc., 2004. [9]

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### Air quality sensors

Graph 1: R/R0 vs Gas concentration (ppm). Y-axis: 0.01 to 10. X-axis: 1 to 100 ppm. Gases: Air, Methane, CO, Iso-butane, Ethanol, Hydrogen.

Graph 2: R/R0 vs Number of cigarettes. Y-axis: 0.1 to 1.0. X-axis: 0 to 5 cigarettes. Data points: (1, ~0.7), (2, ~0.55), (3, ~0.45).

\*Taken from „Technical information for air quality control sensor TGS 2600“, Technical Data Sheet, Figaro Engineering Inc., 2004. [9]

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### Carbon monoxide sensor – TGS 2442

The Figaro TGS2442 sensor is a new type thick film metal oxide semiconductor, screen printed sensor which offers miniaturization and utilizes pulse heating for achieving low power consumption. The TGS2442 displays high selectivity to carbon monoxide together with improved humidity dependency and durability.

*Features*

- \* Miniature size and low power consumption
- \* High sensitivity/selectivity to carbon monoxide (CO)
- \* Low sensitivity to alcohol vapor
- \* Reduced influence by various interference gases
- \* Long life and low cost

*Applications*

- \* Residential and commercial CO detectors
- \* Air quality controllers
- \* Ventilation control for indoor parking garages

\*Taken from „Technical information for TGS2442“, Technical Data Sheet, Figaro Engineering Inc., 2007. [10]

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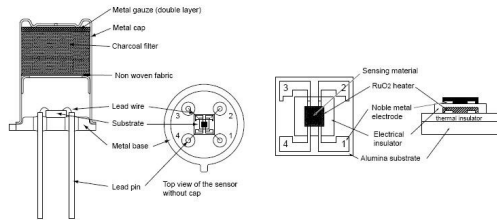
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### Carbon monoxide sensor – TGS 2442



\*Taken from „ Technical information for TGS2442“, Technical Data Sheet, Figaro Engineering Inc., 2007, [10]

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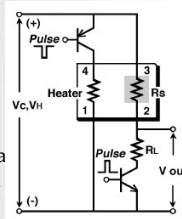
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### Carbon monoxide sensors

The structure of TGS2442. The sensor utilizes a multilayer structure. A glass layer for thermal insulation is printed between a ruthenium oxide (RuO<sub>2</sub>) heater and an alumina substrate. A pair of Au electrodes for the heater are formed on a thermal insulator. The gas sensing layer, which is formed of tin dioxide (SnO<sub>2</sub>), is printed on an electrical insulation layer which covers the heater. A pair of Pt electrodes for measuring sensor resistance is formed on the electrical insulator. An activated charcoal filter is used for the purpose of reducing the influence of noise gases.



\*Taken from „ Technical information for TGS2442“, Technical Data Sheet, Figaro Engineering Inc., 2007, [10]

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### Carbon monoxide sensors

Model number	TGS 2442	
Sensing element type	MF1	
Standard package	TO-5 metal can	
Target gases	Carbon monoxide	
Typical detection range	30 – 1000 ppm	
Standard circuit conditions	Heater voltage cycle	V <sub>in</sub> = 4.5V±0.2V DC, 14ms V <sub>in</sub> = 0.0, 950ms
	Circuit voltage cycle	V <sub>0</sub> = 5V for 995ms V <sub>0</sub> = 0.0V±0.2V DC for 5ms
	Load resistance	R <sub>L</sub> = variable (2.1KΩ)
Electrical characteristics under standard test conditions	Heater resistance	R <sub>H</sub> = 17 ± 2.5Ω at room temp.
	Heater current	I <sub>H</sub> = approx. 200mA (in case of V <sub>in</sub> )
	Heater power consumption	P <sub>H</sub> = approx. 14mW (ave.)
	Sensor resistance	R <sub>S</sub> = 13.9kΩ – 15.9kΩ in 100ppm of carbon monoxide
Standard test conditions	Sensitivity (change ratio of R <sub>S</sub> )	β = 0.13 – 0.31
	Test gas conditions	Carbon monoxide in air at 25±2°C, 65±5%RH
Standard test conditions	Circuit conditions	Same as Std. Circuit Condition (above)
	Conditioning period before test	2 days or more

$$R_S = \frac{V_C R_L}{V_{out}} - R_L$$

$$\beta = \frac{R_S(CO, 300 ppm)}{R_S(CO, 100 ppm)}$$

\*Taken from „ Technical information for TGS2442“, Technical Data Sheet, Figaro Engineering Inc., 2007, [10]

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### Carbon monoxide sensors

\*Taken from „Technical information for TGS2442“, Technical Data Sheet, Figaro Engineering Inc., 2007, [10]

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### Carbon monoxide sensors

\*Taken from „Technical information for TGS2442“, Technical Data Sheet, Figaro Engineering Inc., 2007, [10]

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### Carbon dioxide sensors

The Figaro TGS4161 is a new solid electrolyte type sensor which offers miniaturization, low power consumption, and long life. The TGS4161 displays high selectivity to carbon dioxide. Also, the TGS4161 displays good long term stability and shows excellent durability against the effects of high humidity through the application of innovative technology in the sensor's electrode design.

**Carbon Dioxide sensor – TGS 4161**

*Features*

- \* High selectivity to carbon dioxide
- \* Compact size
- \* Low dependency on humidity
- \* Low power consumption
- \* Long life and low cost

*Applications*

- \* Air quality control
- \* CO<sub>2</sub> monitors

\*Taken from „Technical information for Carbon Dioxide Sensor TGS4161“, Technical Data Sheet, Figaro Engineering Inc., 2006, [11]

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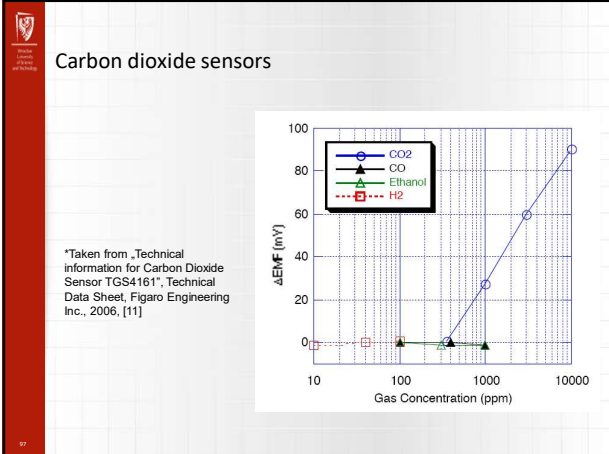
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- Summary – gas sensors
- selectivity – ability to distinguish different gases or to be sensitive to one substance
  - working conditions – temperature, acquisition time
  - sensitivity

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- Test questions (an example):
- Name 4 principles of temperature sensors.
  - What is the difference between sensitivity and selectivity of a sensor ?

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