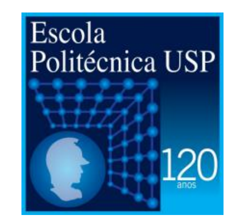
ESCOLA POLITÉCNICA DA
UNIVERSIDADE DE SÃO PAULO
Departamento de Engenharia de Sistemas Eletrônicos PSI - EPUSP




**PSI 2618**
**CIRCUITOS ELETRÔNICOS AUTOMOTIVOS**

# Sensores de Pressão

# *Strain Gauge*

**Tab. 7.3.1** Principles and features of pressure sensors

| *Principle* | *Piezoresistance* | | *Capacitance* | | *Piezoelectricity* |
|---|---|---|---|---|---|
| | *Silicon piezoresistance* | *Thin-film piezoresistance* | *Ceramic capacitance* | *Thin-film capacitance* | *Ceramic piezoelectricity* |
| Structure | IC<br>Gage strains | Thin-film(Poly-Si)<br>Metal | Ceramic substrate<br>Movable electrode<br>Fixed electrode | Upper electrode<br>Lower electrode | |
| Sensitivity | Middle<br>$\Delta R = 1/2 R \Delta\sigma\pi_{44}$<br>$\pi_{44}$= Piezoresistive coefficient | Low<br>$\pi_{44}$=One sixth of single-crystal silicon | High | High | Low |
| Integration | Easy | Difficult | Difficult | Easy | Difficult |
| LSI process | Easy | Difficult | Difficult | Easy | Difficult |

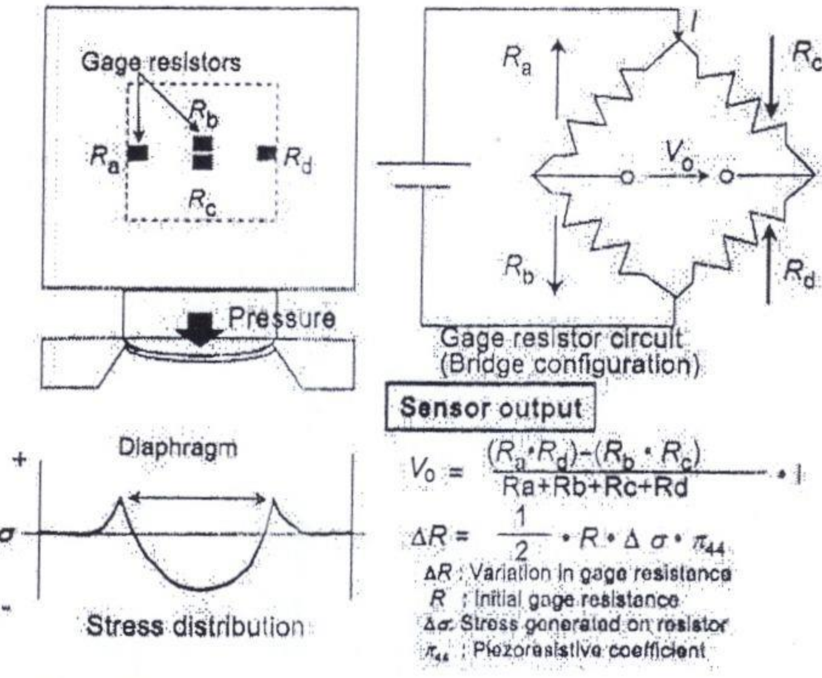



Fig. 7.3.1 Principle of piezoresistive sensor

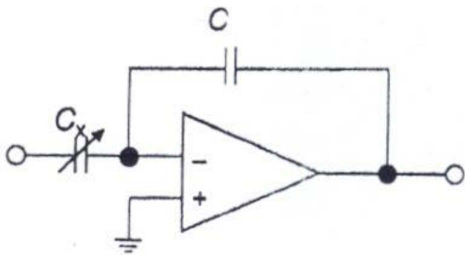



Fig. 7.3.2 Principle of capacitive sensor

$$\Delta C \propto \frac{W^4}{\Delta t^3} \times \Delta P$$

| | Low | Medium | High | | |
|---|---|---|---|---|---|
| ressure nge | 5 k Pa | 100 k Pa | 1~10 M Pa | 20 M Pa | 200 M P |
| | Gasoline vapor | Intake pressure | Air-conditioning Suspension | Fuel pressure | Common |
| Product | | | | | |

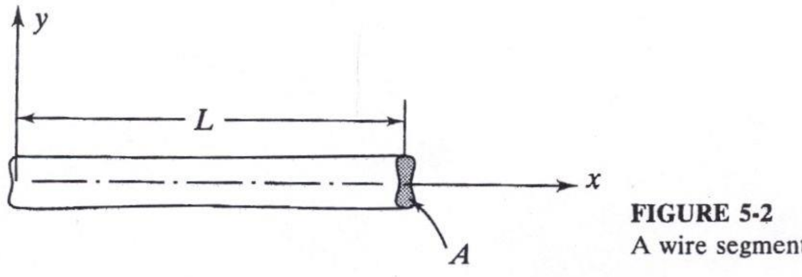
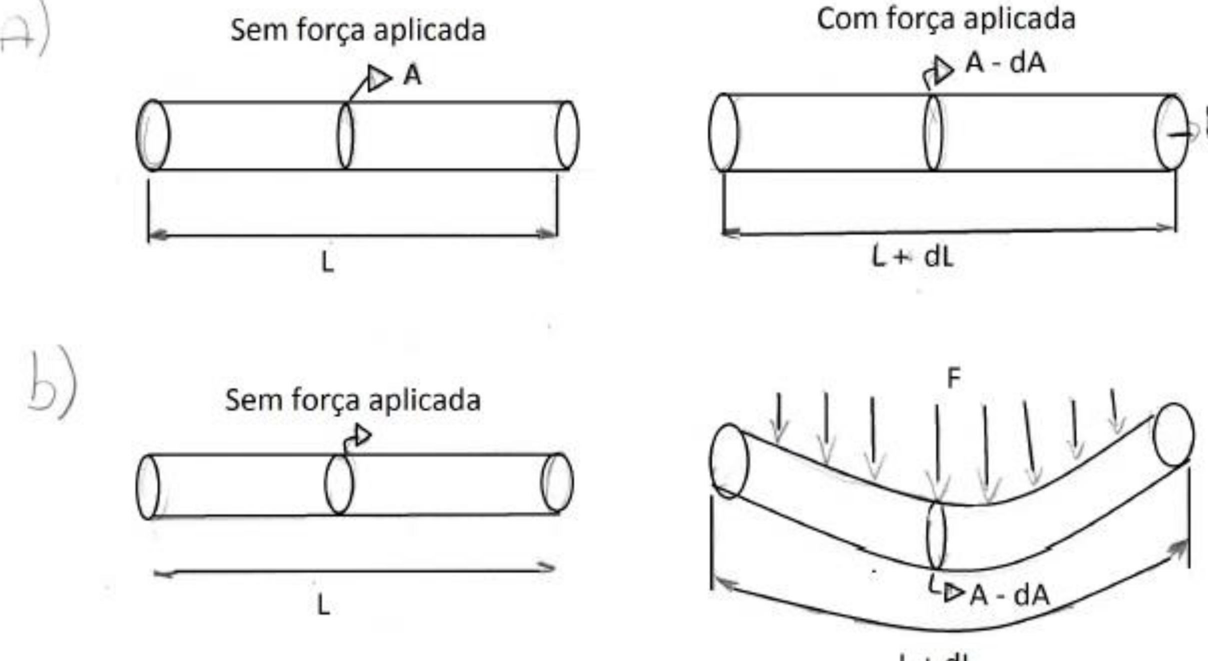
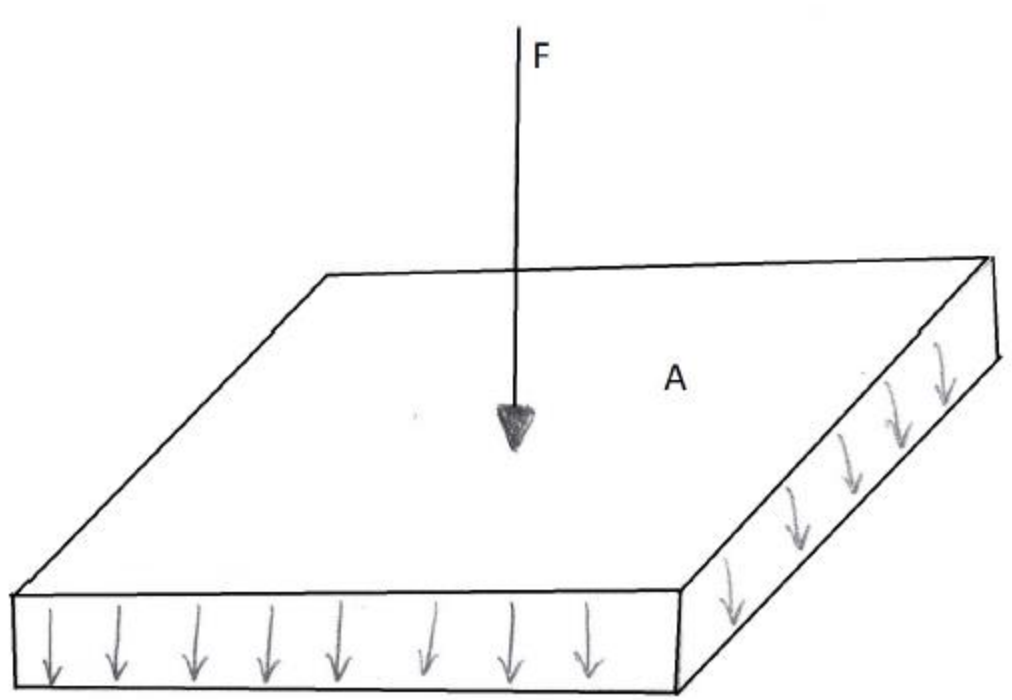
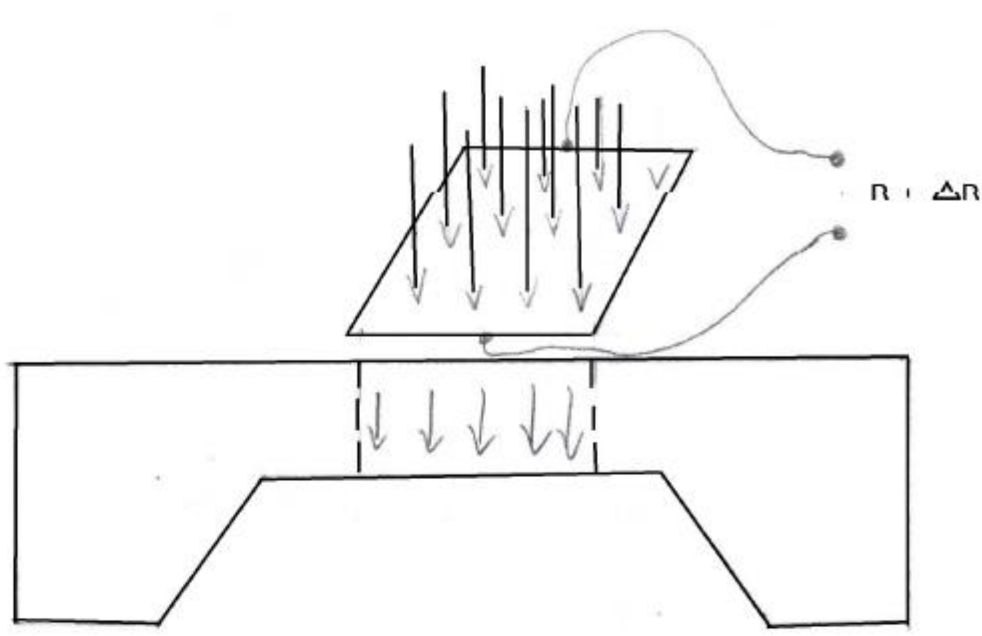



**FIGURE 5-2**
A wire segment.


a)
Sem força aplicada
A
L
Com força aplicada
A - dA
F
L + dL
b)
Sem força aplicada
L
F
A - dA
L + dL


F
A


R + ΔR

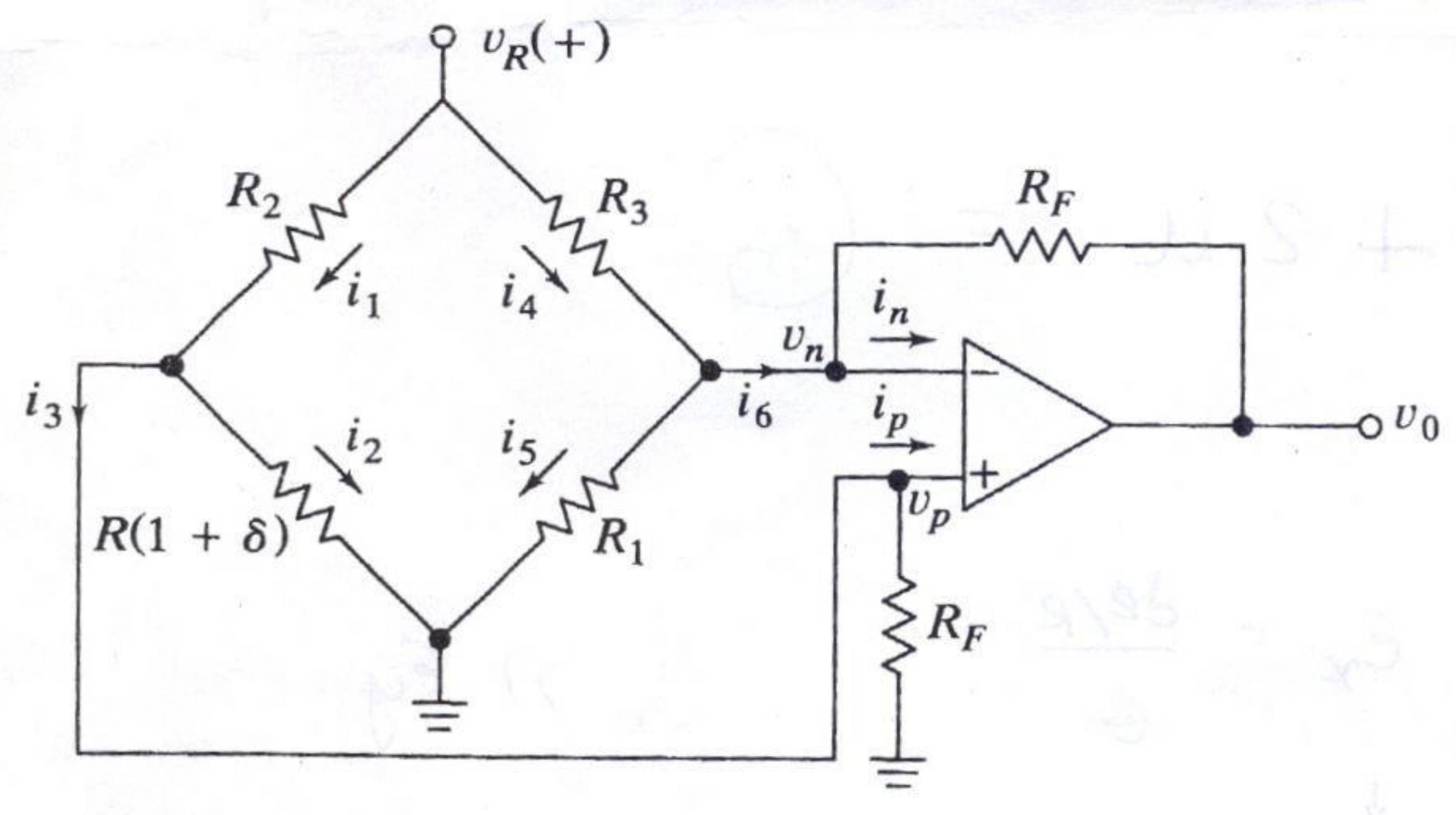



**FIGURE 5-3**
Strain gauge bridge circuit with differential amplifier.

$$i_1 = i_2 + i_3 \qquad \text{and} \qquad i_4 = i_5 + i_6$$

e of Ohm's law across each device, together with $i_n = 0$ and $i$
ally yields the equations

$$\frac{v_R - v_p}{R_2} = \frac{v_p - 0}{R(1+\delta)} + \frac{v_p - 0}{R_F}$$

$$\frac{v_R - v_n}{R_3} = \frac{v_n - 0}{R_1} + \frac{v_n - v_0}{R_F}$$

result in

$$v_p = \frac{v_R}{R_2} \frac{R(1+\delta)R_2R_F}{R_2R_F + R(1+\delta)(R_F + R_2)}$$

$$v_n = \left(\frac{v_R}{R_3} + \frac{v_0}{R_F}\right) \frac{R_1R_FR_3}{R_FR_3 + R_1R_3 + R_1R_F}$$

ing these two expressions yields $v_0$ in the form

$$v_0 = \frac{v_RR_F}{R_1R_3}\left[\frac{R(1+\delta)(R_FR_3 + R_1R_3 - R_1R_2) - R_1R_2R_F}{R_2R_F + R(1+\delta)(R_F + R_2)}\right]$$

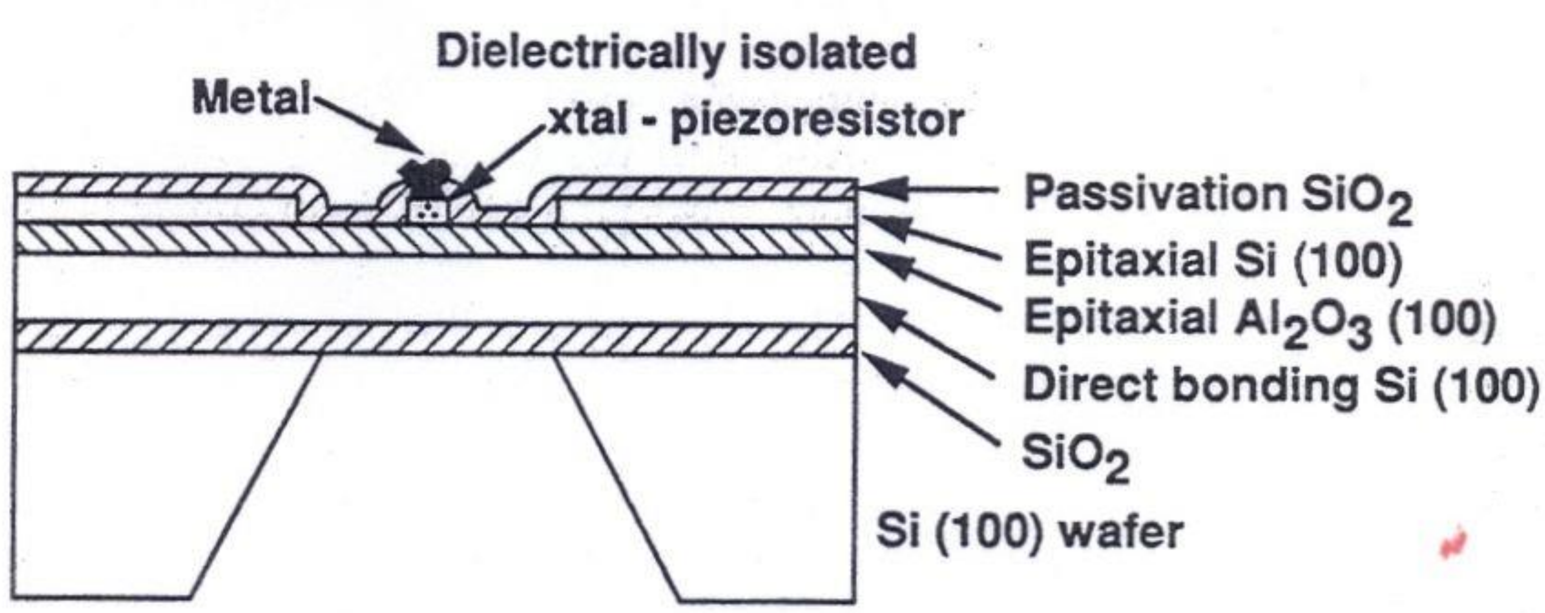
xpression simplifies considerably when two or more of the resistanc
n as equal. Thus a choice of $R_1 = R$ and $R_2 = R_3 = R_0$ yields

$$v_0 = \frac{v_RR_F}{R}\left[\frac{\delta}{\dfrac{R_0}{R} + (1+\delta)\left(1 + \dfrac{R_0}{R_F}\right)}\right]$$

$R_F \gg R_0$ and $\delta \ll 1$, the expression takes on the form

$$v_0 \approx \frac{v_RR_F}{R}\left[\frac{\delta}{\dfrac{R_0}{R} + 1}\right]$$

(a)




(b)

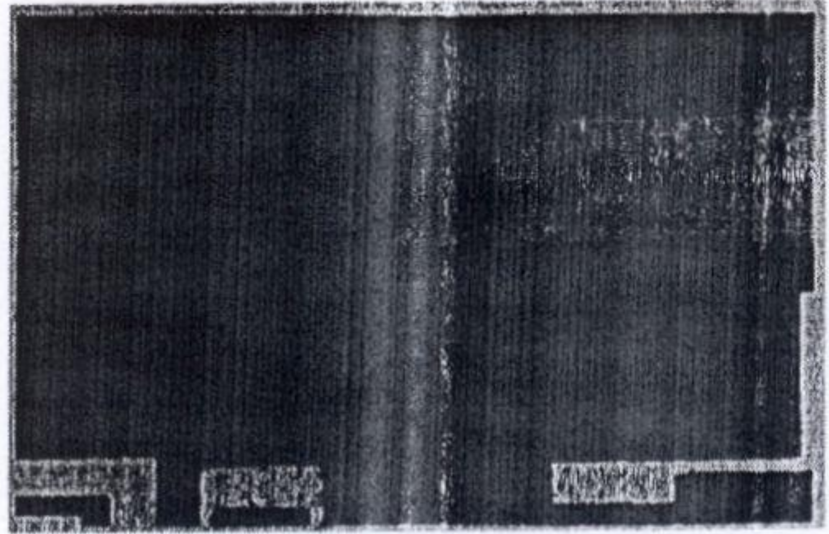
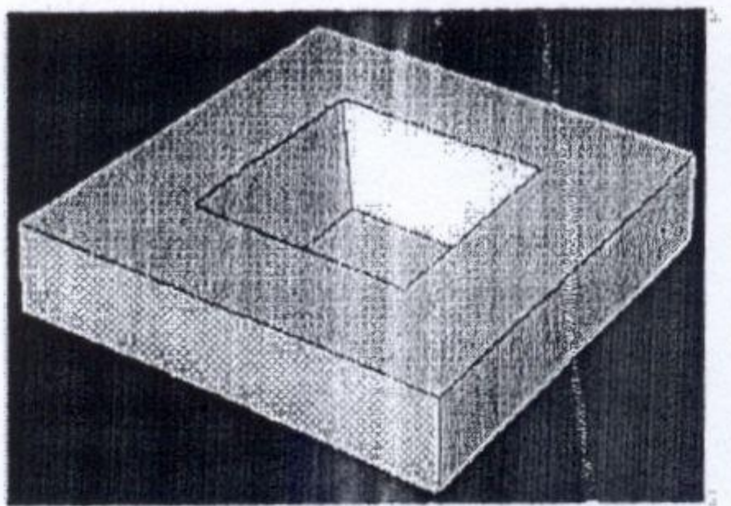


Fig. 7.3.6 Picture-frame photograph



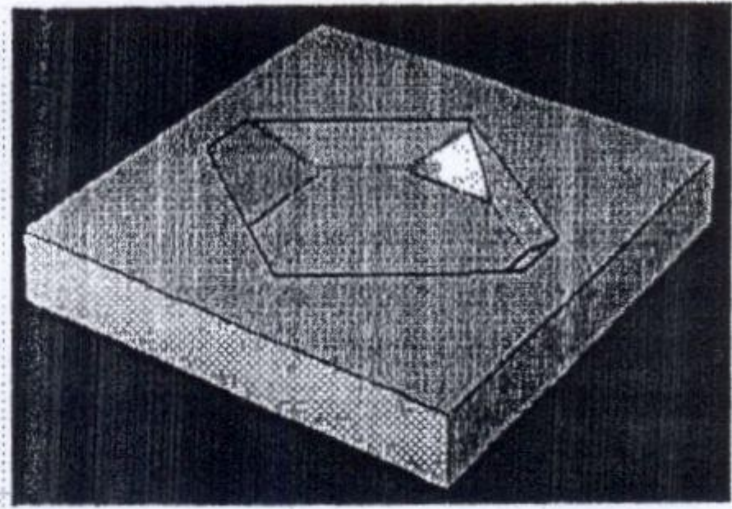
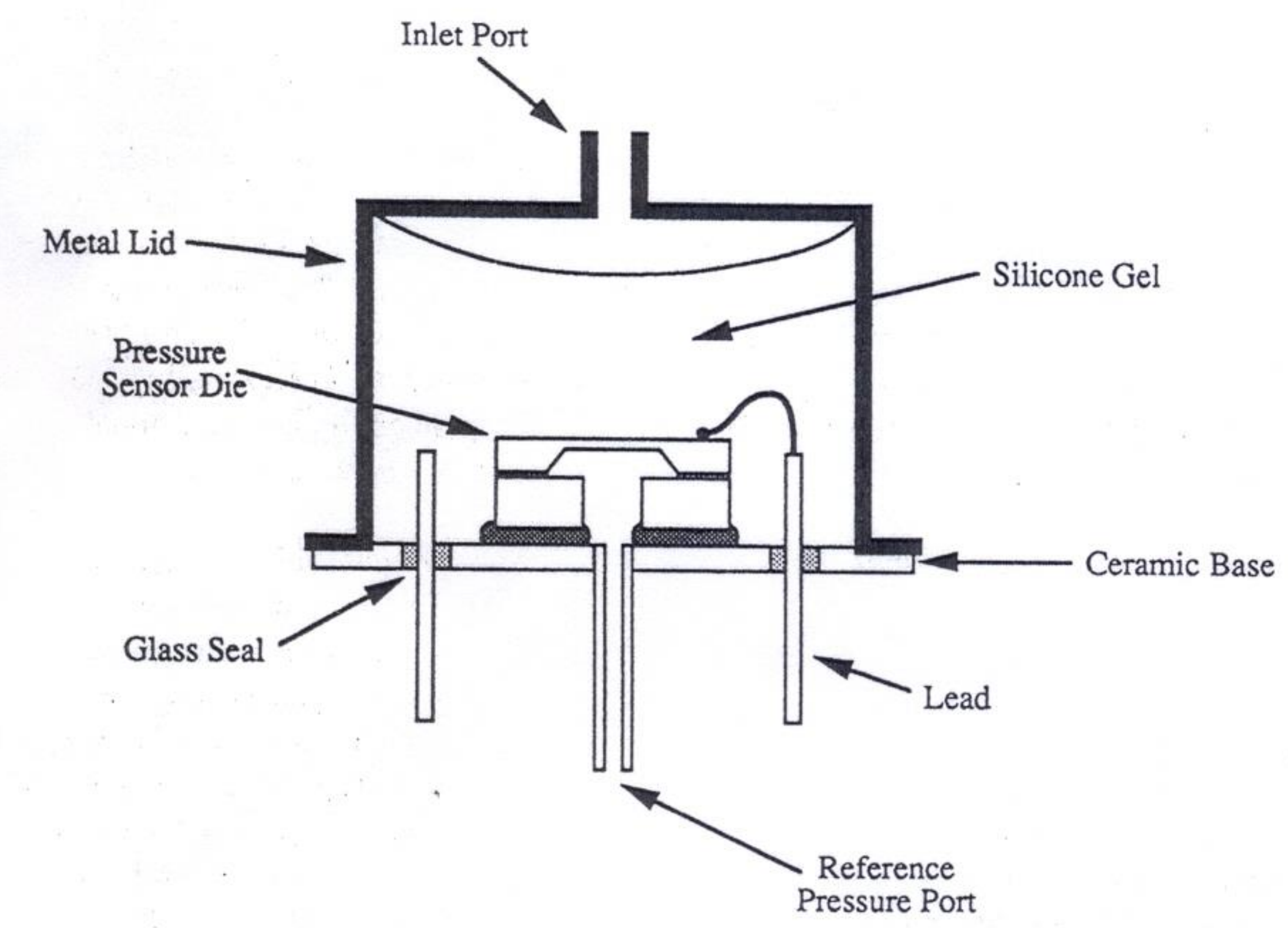
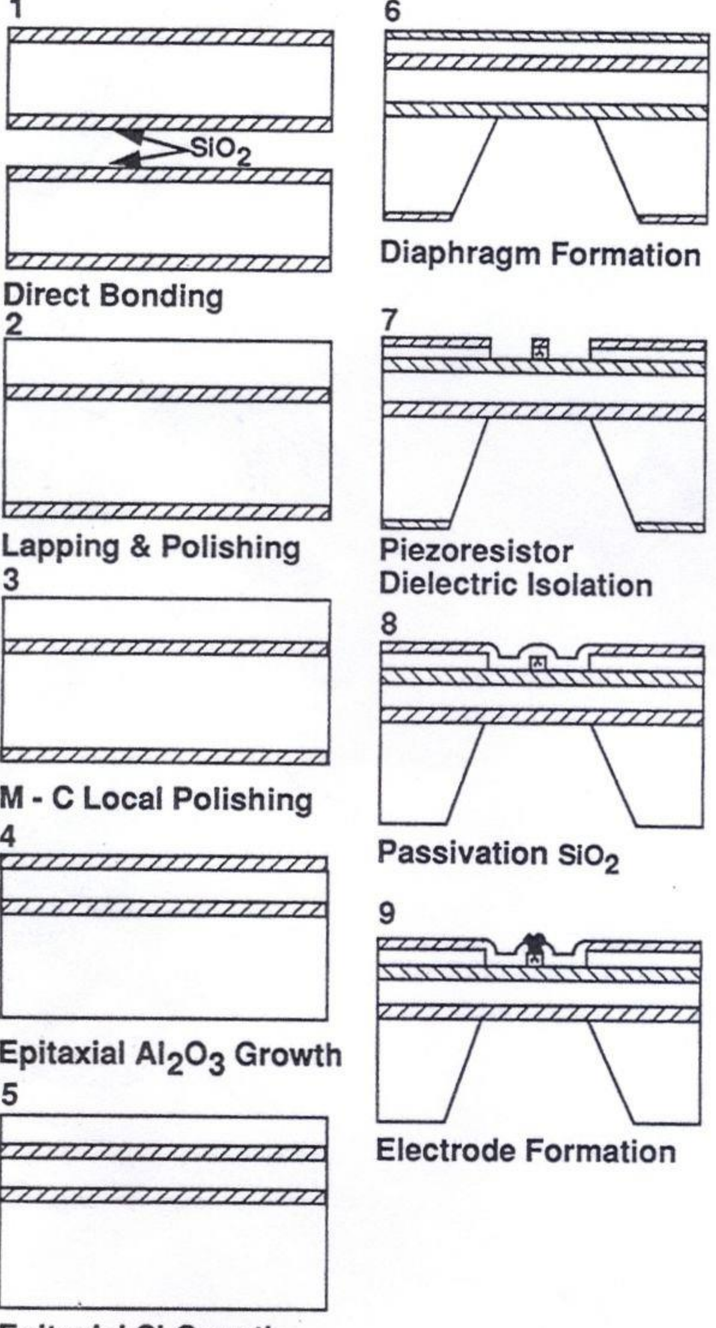
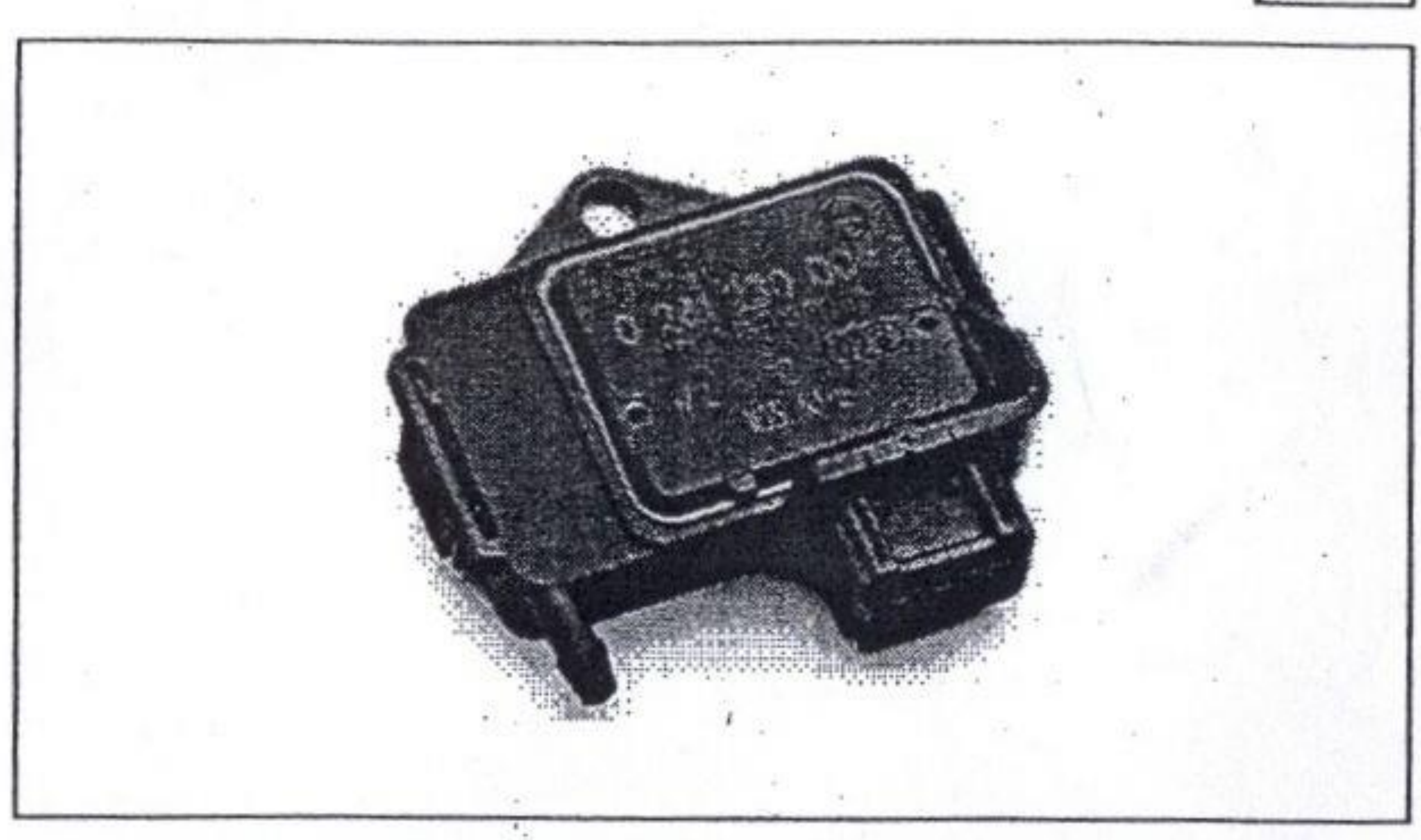


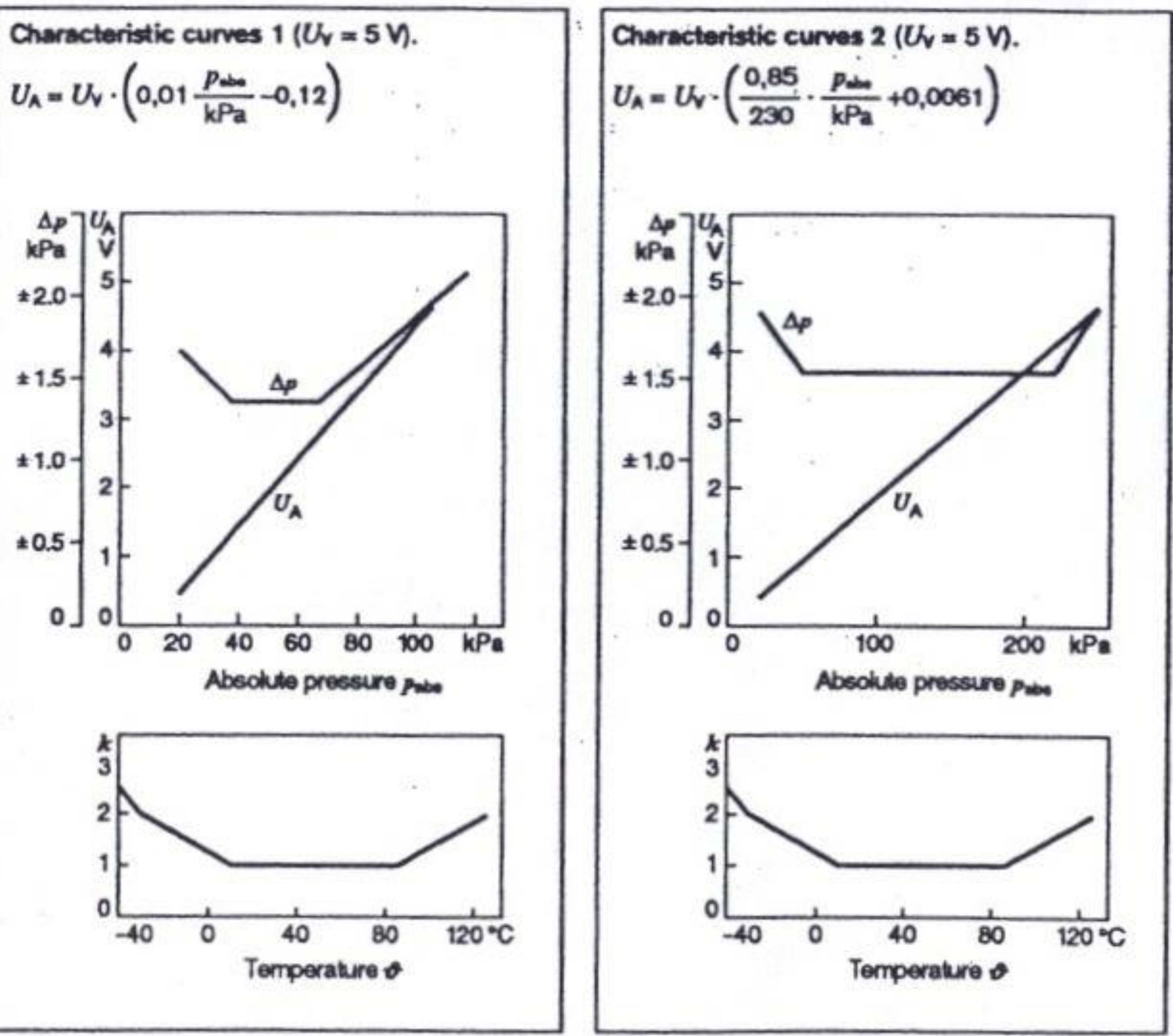
Fig. 7.3.7 Diaphragm geometries for silicon (100) and silicon (110)




(b)


1
SiO2
Direct Bonding
2
Lapping & Polishing
3
M - C Local Polishing
4
Epitaxial Al2O3 Growth
5
Epitaxial Si Growth
6
Diaphragm Formation
7
Piezoresistor
Dielectric Isolation
8
Passivation SiO2
9
Electrode Formation



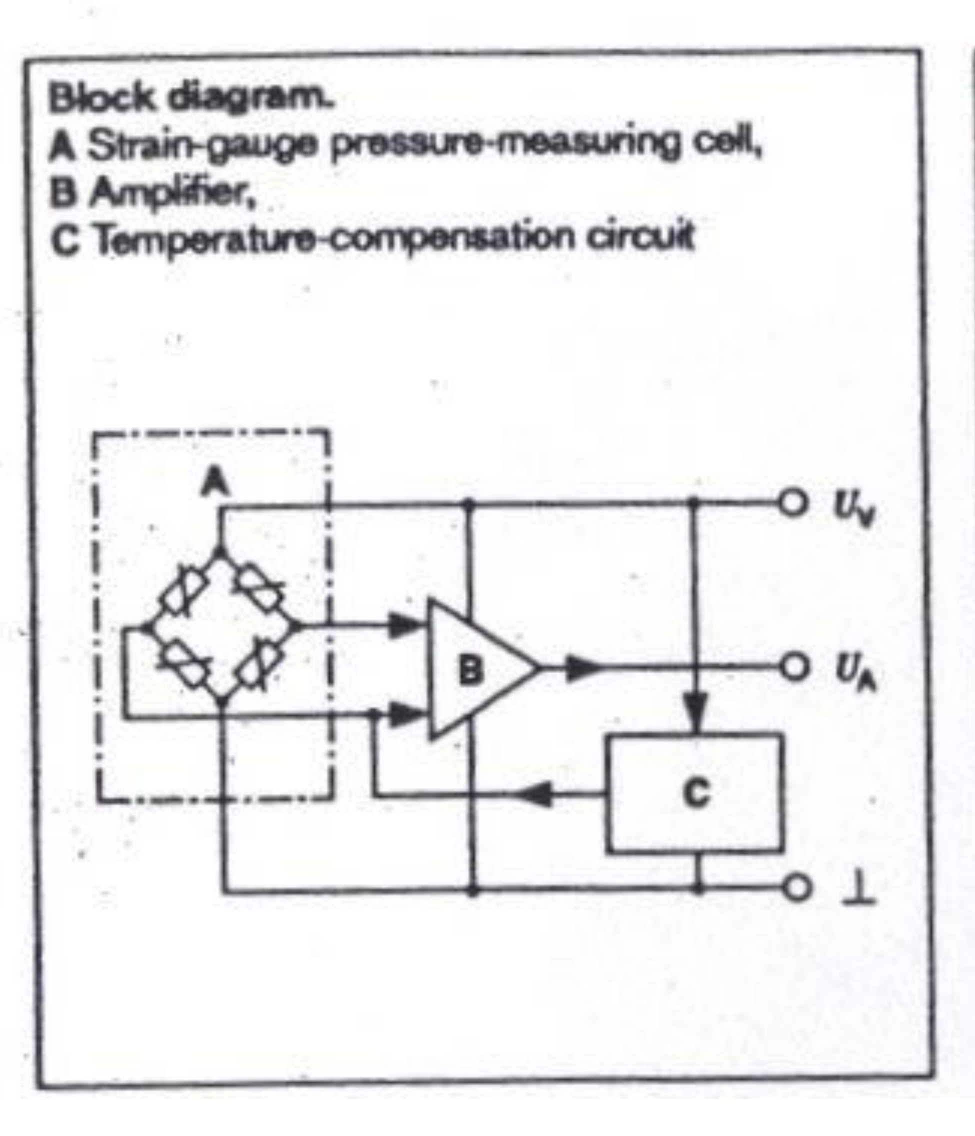



## Technical data / Range

| Part number | | 0 261 230 004 | 0 281 002 119 |
|---|---|---|---|
| Characteristic curve | | 1 | 2 |
| Measuring range | kPa | 20...105 | 20...250 |
| Max. pressure (1 s, 30 °C) | kPa | 600 | 500 |
| Pressure-change time | ms | ≤ 10 | ≤ 10 |
| Supply voltage $U_V$ | V | 4.75...5.25 | 4.75...5.25 |
| Max. supply voltage | V | 16 | 16 |
| Input current $I_V$ | mA | < 10 | < 10 |
| Load impedance $R_L$ | kΩ | > 50 | > 50 |
| Operating temperature range | °C | –40...+125 | –40...+120 |
| Degree of protection | | IP 54 A | – |

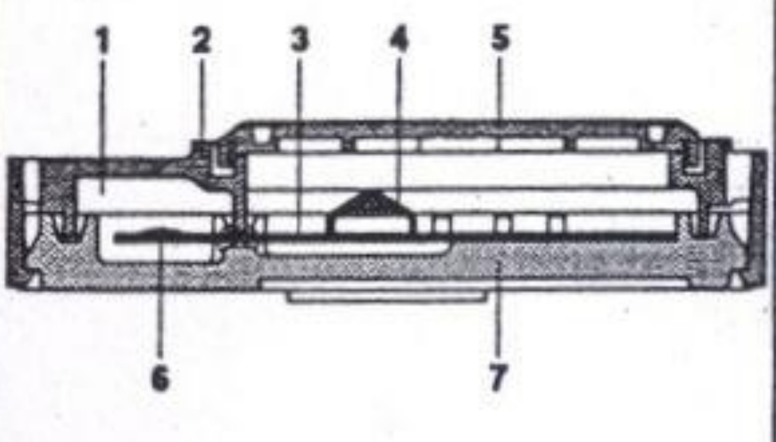
## Accessories

| Connector | 1 237 000 039 |
|---|---|



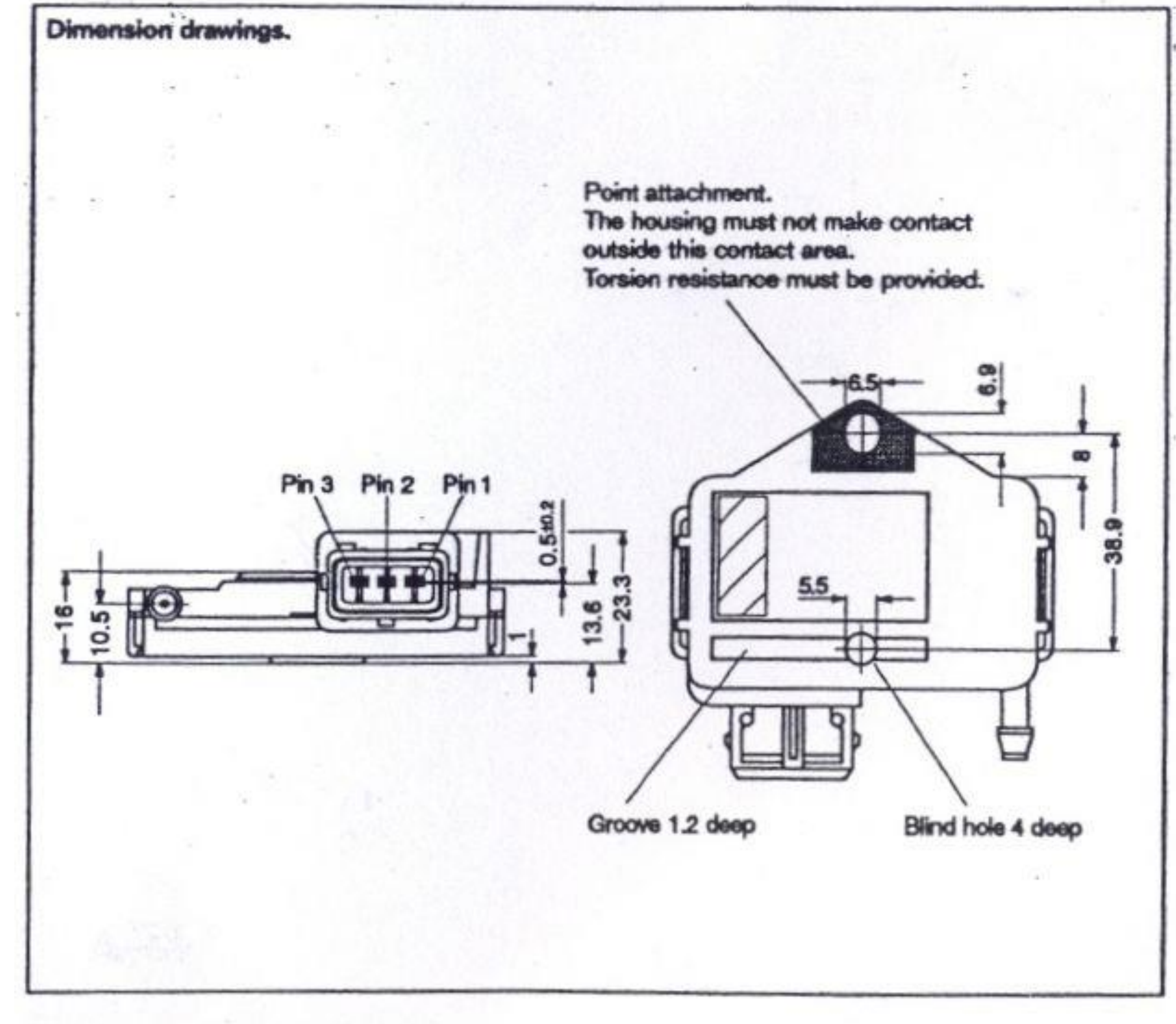

**Block diagram.**
**A** Strain-gauge pressure-measuring cell,
**B** Amplifier,
**C** Temperature-compensation circuit

**Design.**
1 Strain-gauge pressure-measuring cell, 2 Plastic housing, 3 Thick-film hybrid (sensor and evaluation circuit), 4 Operational amplifier, 5 Housing cover, 6 Thick-film sensor element (sensor bubble), 7 Aluminum base plate.




**Installation instructions**
A hose forms the connection between the sensor and the gas pressure to be measured. Upon installation, the sensor pressure connection should point downwards to prevent the ingress of moisture.
The angular position referred to the vertical must be +20°...–85°, preferably 0°.
Suggested fastening:
M6 screw with spring washer.

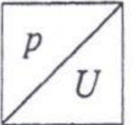
**Connector-pin assignment**
Terminal 1 $+U_V$
Terminal 2 Ground
Terminal 3 $U_A$



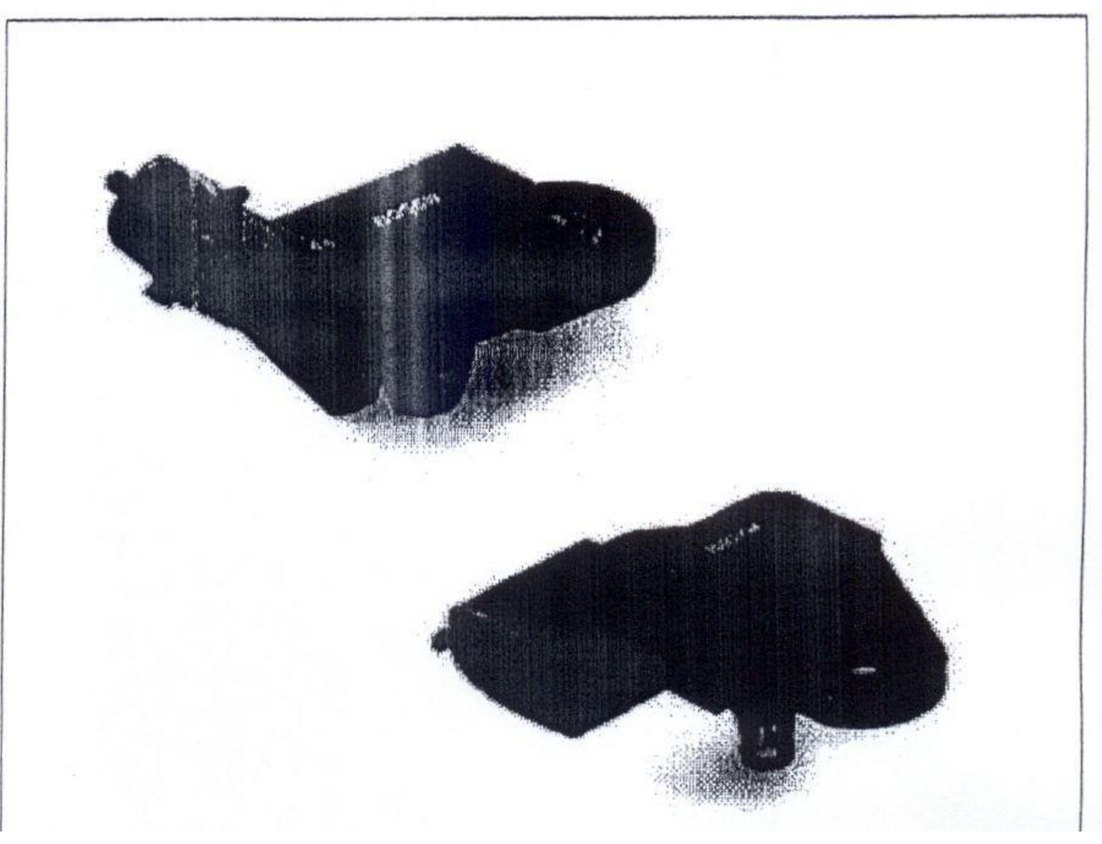
Dimension drawings.
Point attachment.
The housing must not make contact
outside this contact area.
Torsion resistance must be provided.
Pin 3
Pin 2
Pin 1
0.5±0.2
13.6
23.3
16
10.5
1
6.5
6.9
8
38.9
5.5
Groove 1.2 deep
Blind hole 4 deep

# Absolute-pressure sensors in micromechanical hybrid design

**Measurement of pressures in gases up to 400 kPa**




- High accuracy.
- EMC protection better than 100 V m$^{-1}$.
- Temperature-compensated.
- Version with additional integral temperature sensor.



| Pressure range kPa ($p_1 ... p_2$) | Characteristic curve[1] | Features | Dimension drawing[2] | Order No. |
|---|---|---|---|---|
| 10...115 | 1 | | 1 | **B 261 260 136**[3] |
| 10...115 | 1 | | 2 | **0 261 230 052** |
| 20...250 | 1 | | 1 | **0 281 002 487** |
| 10...115 | 1 | Integral temperature sensor | 3 | **0 261 230 030** |
| 20...250 | 1 | Integral temperature sensor | 3 | **0 261 230 042** |
| 20...300 | 1 | Integral temperature sensor | 3 | **0 281 002 437** |
| 50...350 | 2 | Integral temperature sensor | 3 | **0 281 002 456** |
| 50...400 | 2 | Integral temperature sensor | 3 | **B 261 260 508**[3] |

1) The characteristic-curve tolerance and the tolerance expansion factor apply for all versions, see Page 36

2) See Page 37

3) Provisional draft number, order number available upon enquiry. Available as from about the end of 2001

## Technical data

| | | | min. | typ. | max. |
|---|---|---|---|---|---|
| Operating temperature | $\vartheta_B$ | °C | –40 | – | +130 |
| Supply voltage | $U_V$ | V | 4.5 | 5.0 | 5.5 |
| Current consumption at $U_V = 5$ V | $I_V$ | mA | 6.0 | 9.0 | 12.5 |
| Load current at output | $I_L$ | mA | –1.0 | – | 0.5 |
| Load resistance to $U_V$ or ground | $R_{pull\text{-}up}$ | kΩ | 5 | 680 | – |
| | $R_{pull\text{-}down}$ | kΩ | 10.0 | 100 | – |
| Response time | $t_{10/90}$ | ms | – | 1.0 | – |
| Voltage limitation at $U_V = 5$ V | | | | | |
| Lower limit | $U_{A\,min}$ | V | 0.25 | 0.3 | 0.35 |
| Upper limit | $U_{A\,max}$ | V | 4.75 | 4.8 | 4.85 |

**Limit data**

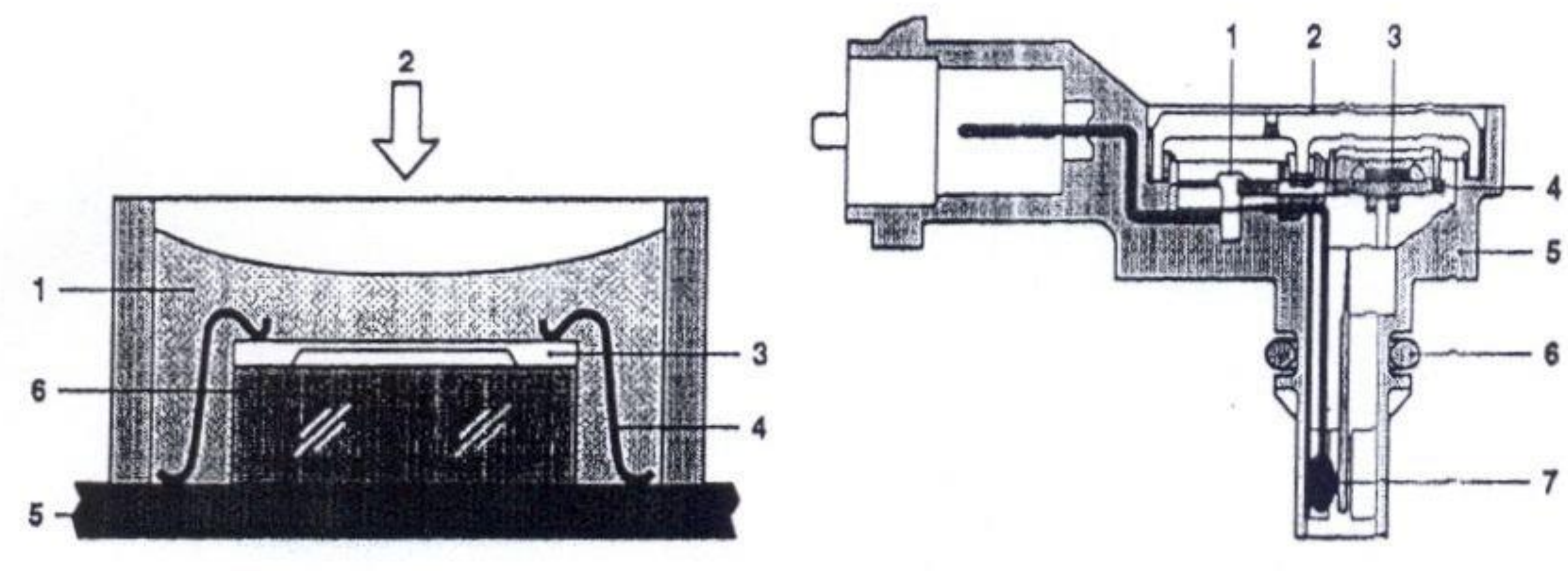
| | | | | | |
|---|---|---|---|---|---|
| Supply voltage | $U_{V\,max}$ | V | – | – | +16 |
| Storage temperature | $\vartheta_L$ | °C | –40 | – | +130 |

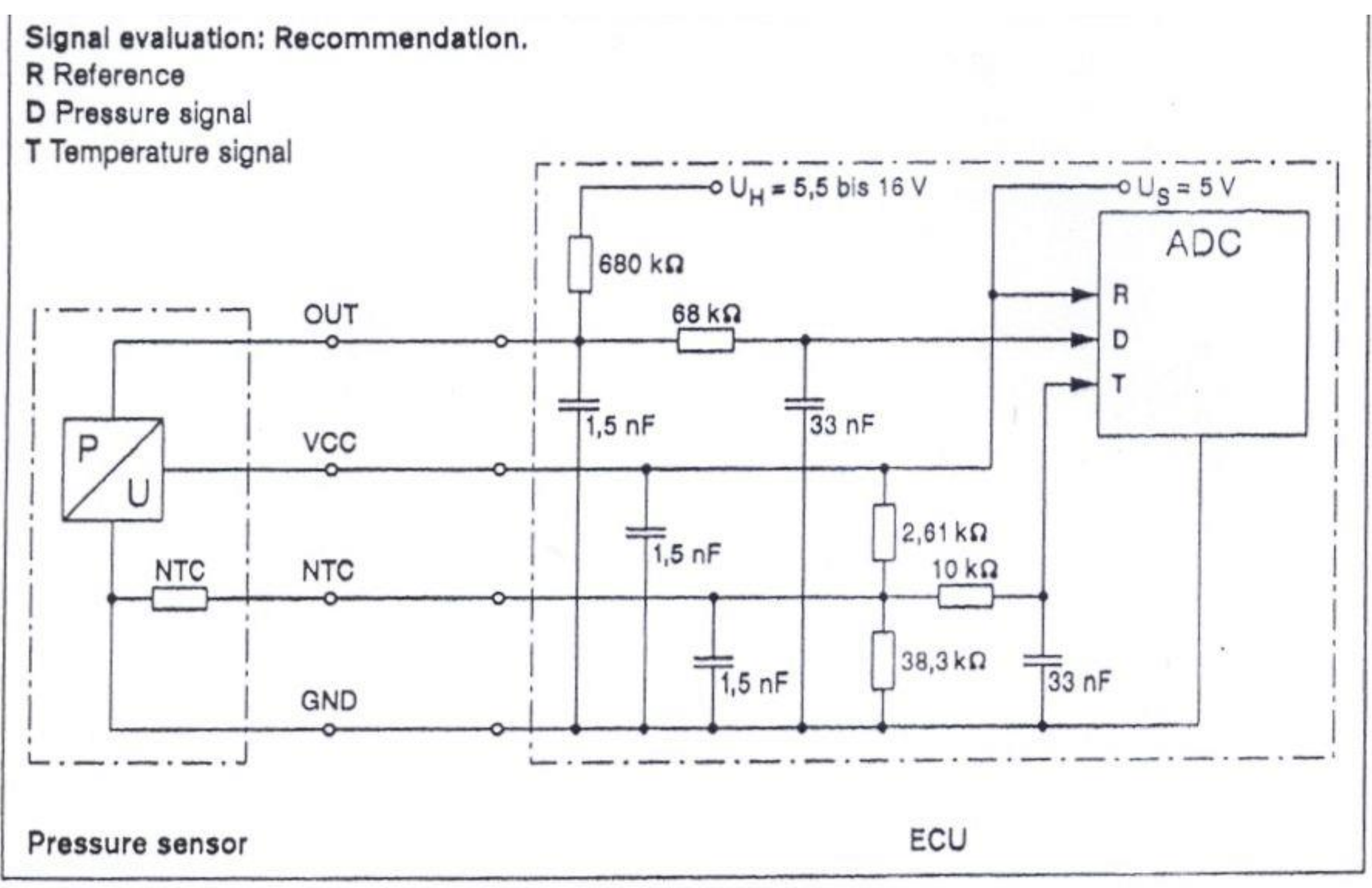
**Temperature sensor**

| | | | | | |
|---|---|---|---|---|---|
| Measuring range | $\vartheta_M$ | °C | –40 | – | +130 |
| Measured current | $I_M$ | mA | – | – | 1[1] |
| Nominal resistance at +20 °C | | kΩ | – | 2.5±5% | – |
| Thermal time constant | $t_{63}$ | s | – | – | 10[2] |

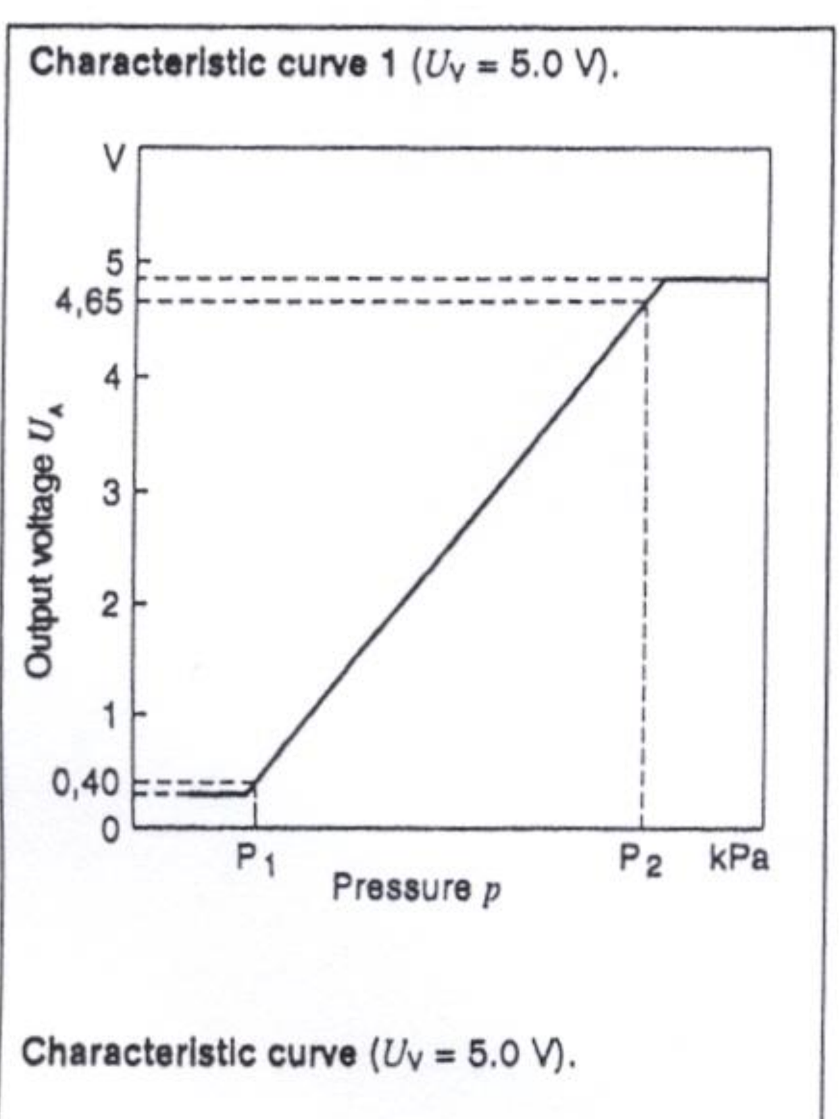
[1]) Operation at 5 V with 1 kΩ series resistor

[2]) In air with a flow rate of $6\ m \cdot s^{-1}$


Sectional view.
Section through the sensor cell
Section through the DS-S2 pressure sensor
2
1
3
6
4
5
1
2
3
4
5
6
7

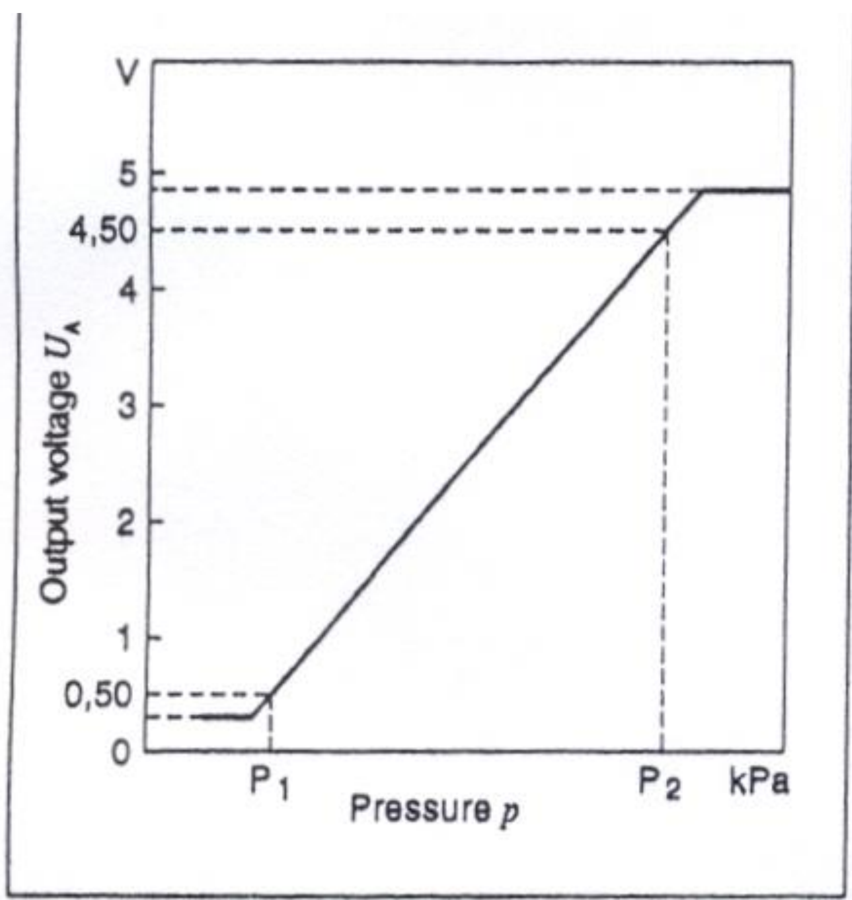


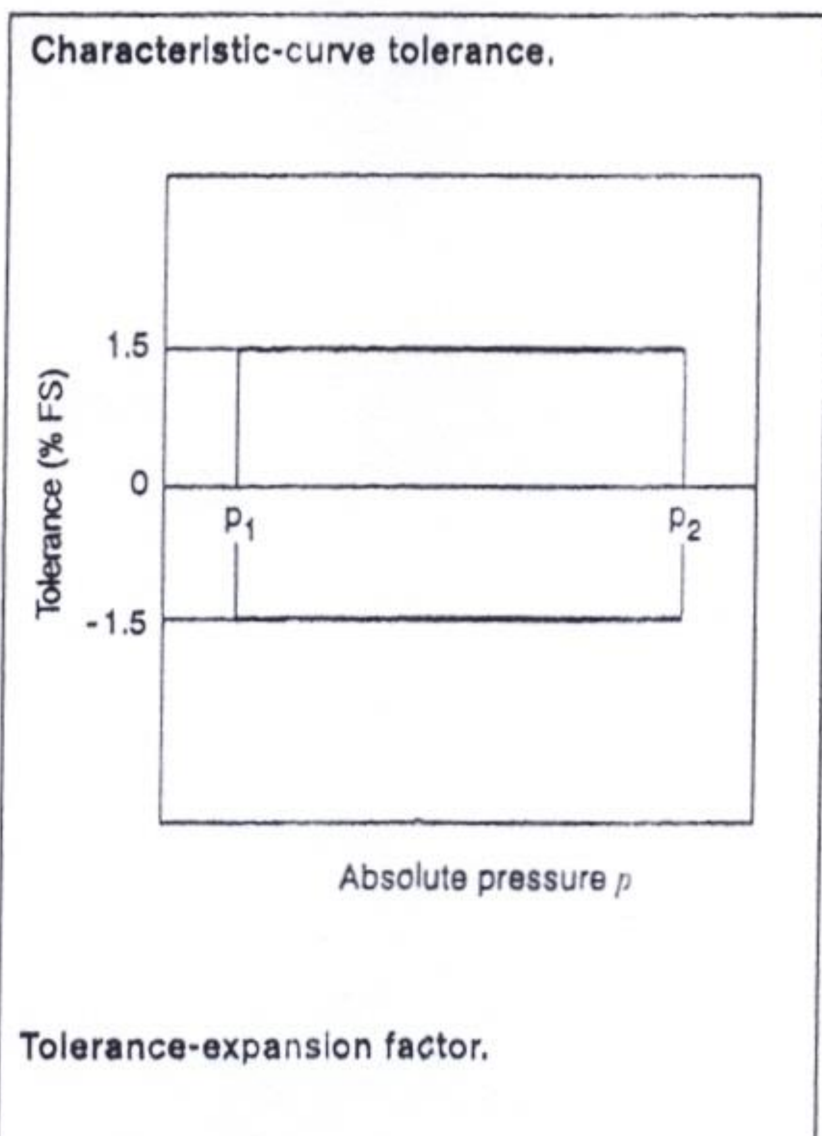
Signal evaluation: Recommendation.
R Reference
D Pressure signal
T Temperature signal
U_H = 5,5 bis 16 V
U_S = 5 V
ADC
680 kΩ
68 kΩ
R
D
T
OUT
1,5 nF
33 nF
P
U
VCC
1,5 nF
2,61 kΩ
NTC
NTC
10 kΩ
1,5 nF
38,3 kΩ
33 nF
GND
Pressure sensor
ECU




Characteristic curve 1 ($U_V$ = 5.0 V).

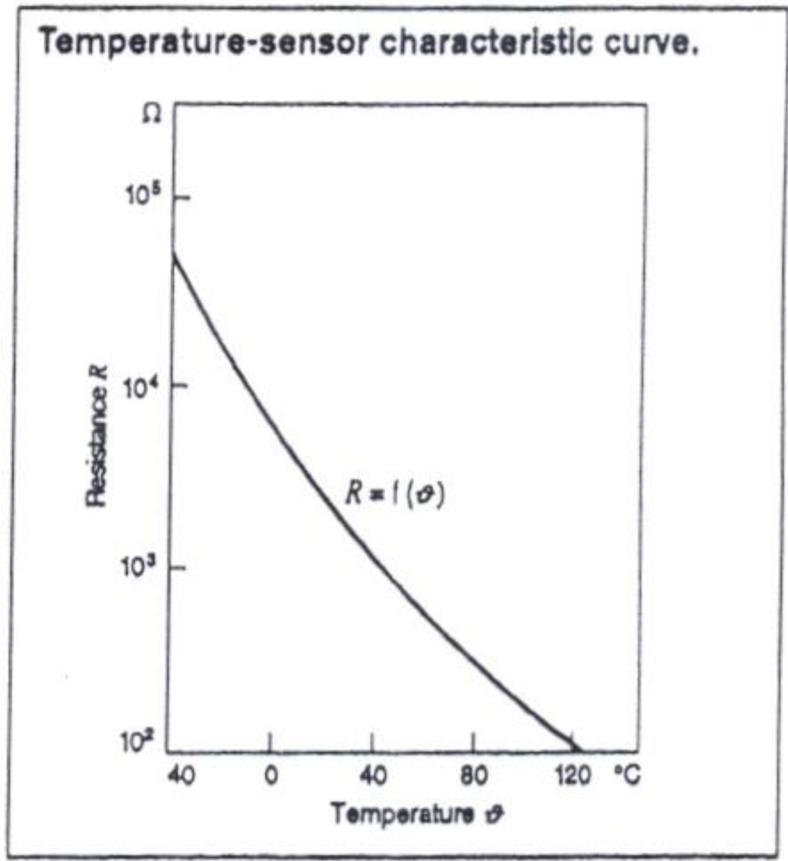
Characteristic curve ($U_V$ = 5.0 V).


V
5
4,50
4
3
2
1
0,50
0
Output voltage $U_A$
P 1
P 2
kPa
Pressure $p$




Characteristic-curve tolerance.

Tolerance-expansion factor.




Temperature-sensor characteristic curve.

**Explanation of symbols.**

$U_A$ Output voltage
$U_V$ Supply voltage
$k$ Tolerance multiplier
D After continuous operation
N As-new state