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Force and torque sensors

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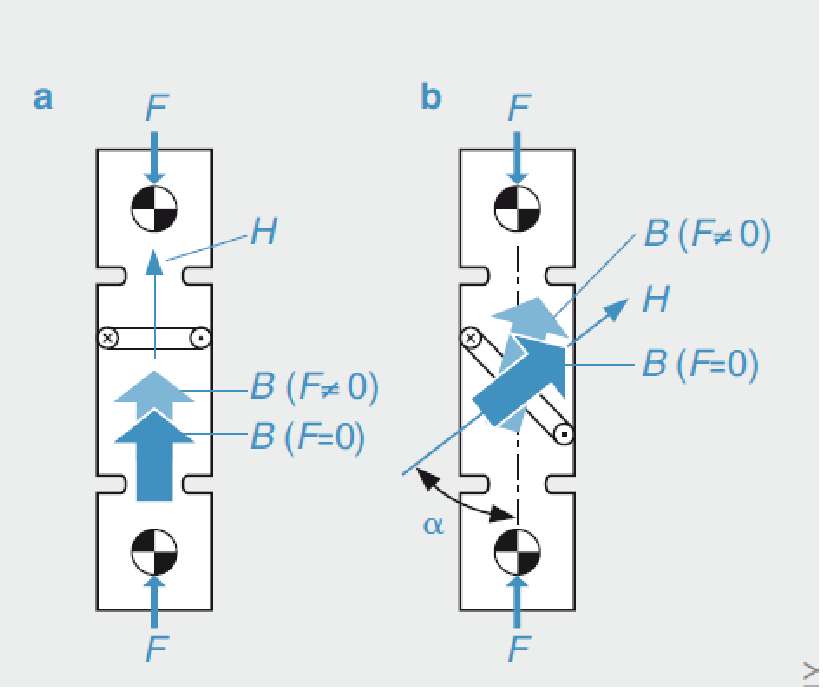
Introduction

- The following list underlines the wide variety of applications for force and torque sensors in automotive engineering:
- In the commercial-vehicle sector, coupling force between the tractor vehicle and its trailer or semitrailer for the closed-loop controlled application of the brakes, whereby neither push nor pull forces are active at the drawbar
- Damping force for use in electronic chassis and suspension control
- Axle load for electronically controlled braking-force distribution on commercial vehicles
- Pedal force on electronically-controlled brake systems
- Braking force on electrically actuated, electronically-controlled brake systems

Introduction

- Basically speaking, when considering force and torque measurement, a difference must be made between
- static and
- dynamic measuring principles,
- and between measuring principles based on
- displacement and
- mechanical strain.

Strain measuring force sensors
Magnetoelastic principle



Magnetoelastic anisotropic effect

a	With direction of force parallel to the direction of field
b	For different directions of field strength *H* and force *F*
B	Induction
α	Enclosed angle

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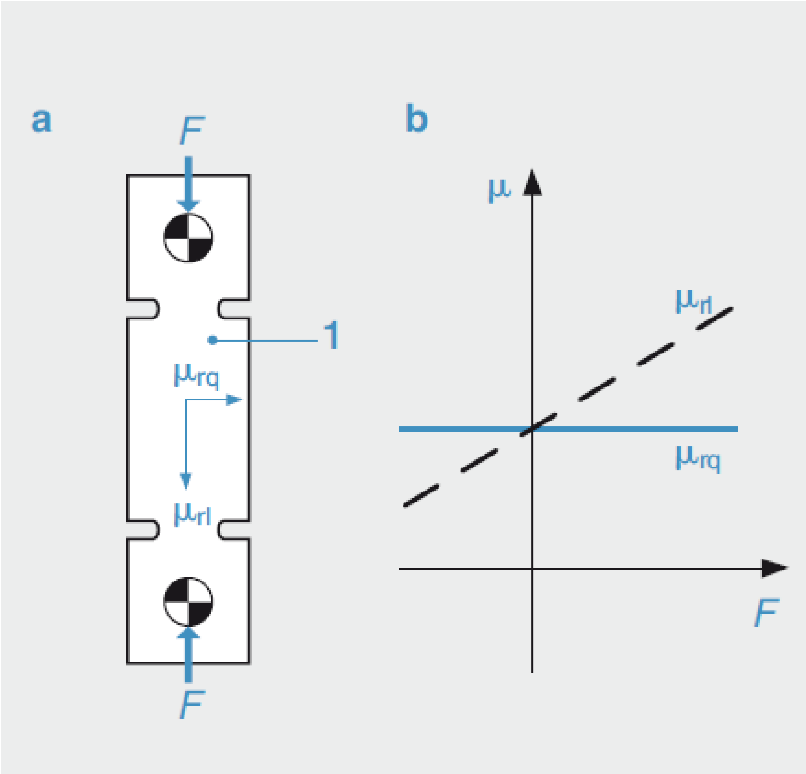
Measuring principles



Magnetoelastic anisotropic effect

a	*Magnetoelastic measurement structure*
b	*Measuring effect*
F	*Force*
μ_r	*Relative magnetic permeability*
μ_{rq}	*Transverse to the direction of force*
μ_{rl}	*In the direction of force*

Strain gage principle (piezoresistive)

Hooke's law:

$$\varepsilon = \Delta l / l = \sigma / E$$

K factor:

$$\Delta R / R = K\,\varepsilon$$

ε, mm/mm – elongation

Δl, mm – absolute elongation

l, mm – length

σ, MPa – mechanical strain

E, GPa – modulus of elasticity

K, – gage factor

ΔR, Ω –resistance change due resistor's elongation

R, Ω – resistance of resistor

ε, mm/mm – elongation

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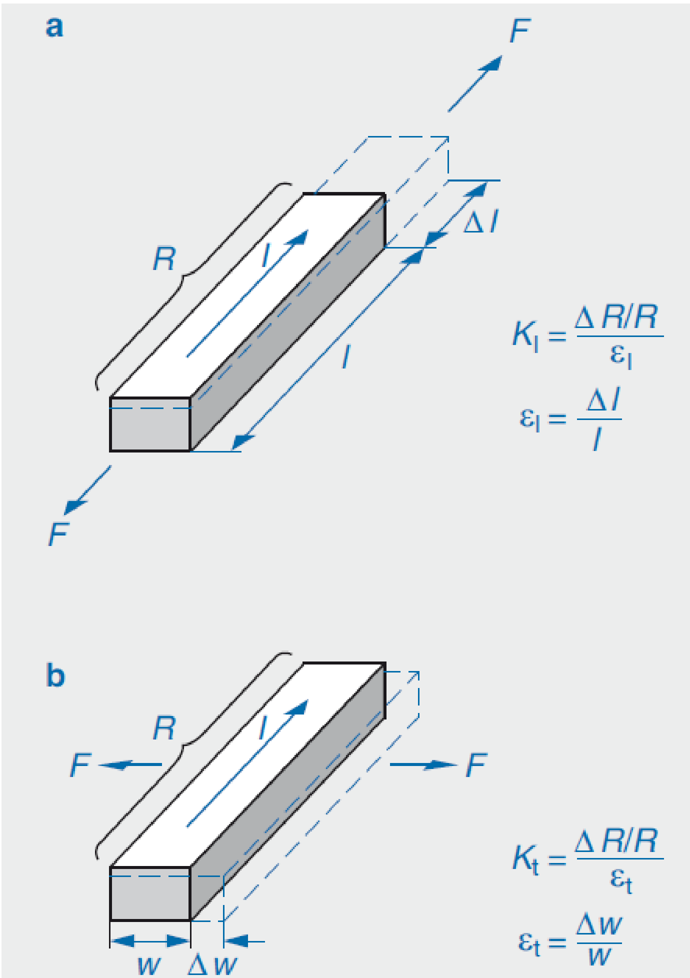
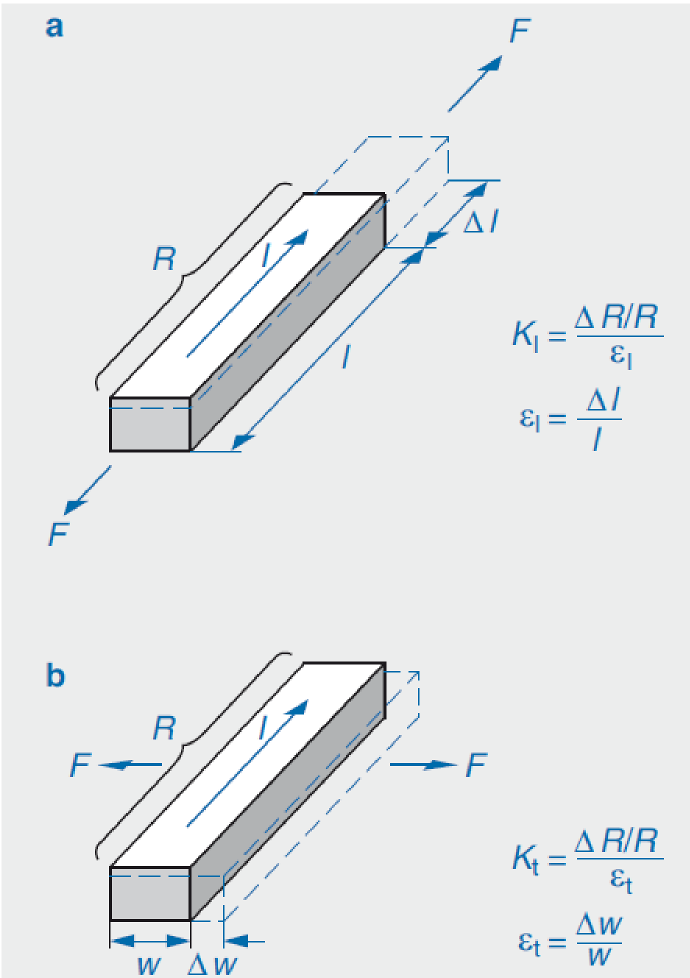
Measuring principles



Gage factor (K), physical quantities

a	*Longitudinal*
b	*Transverse*
F	*Force*
I	*Current*
R	*Resistance*
l	*Length*
K	*Gage factor*
ω	*Width*
ε	*Elongation*

Measuring principles



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Material	Gage factors (K)	
	longitudinal	transverse
Foil strain gage	1.6 to 2.0	≈ 0
Thick-film	12 to 15	12 to 15
Metal thin film	1.4 to 2.0	−0.5 to 0
Si thin film	25 to 40	−25 to −40
Si-monocrystalline	100 to 150	−100 to −150

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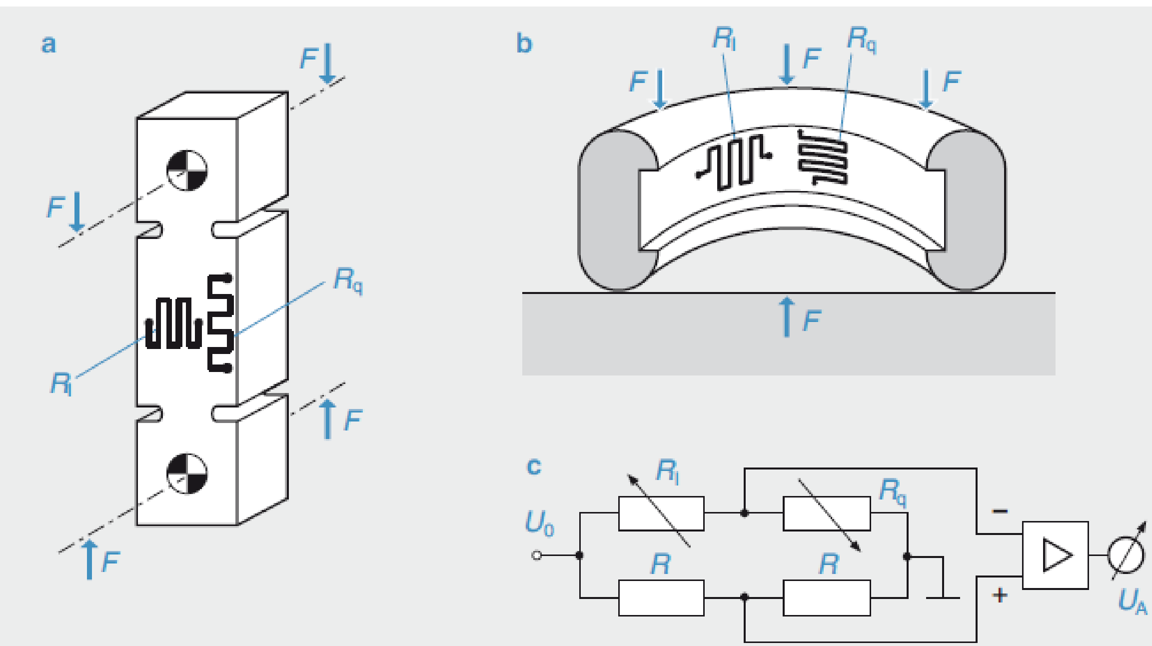
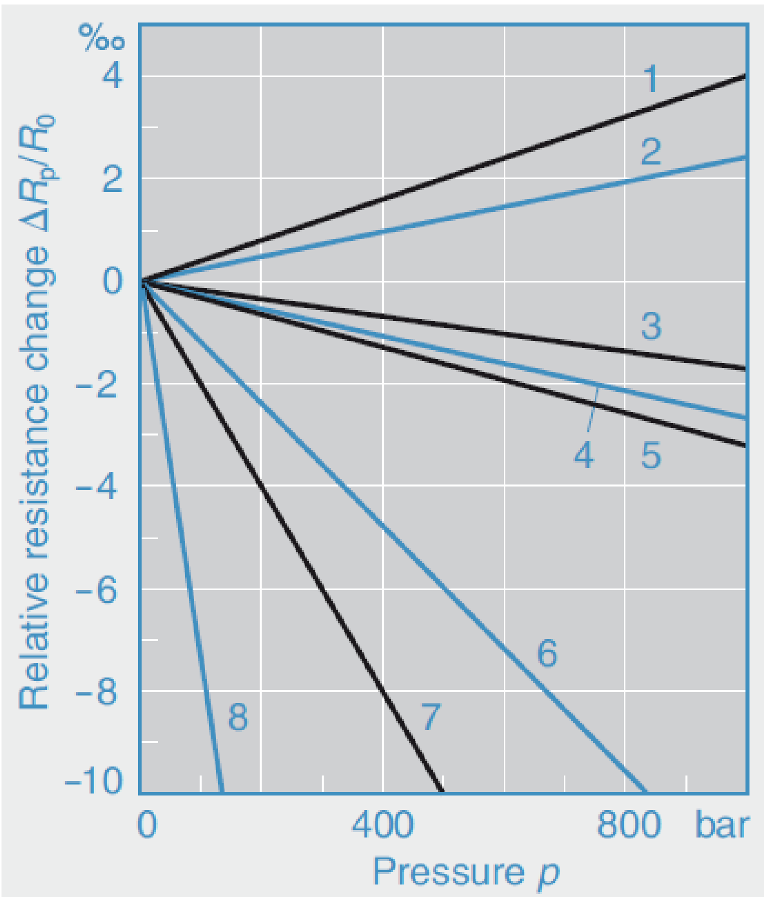
Strain gage principle (piezoresistive)



Strain-gage force sensors

a	*Rod-shaped*
b	*Toroidal-shaped*
c	*Electronic evaluation*
F	*Force*
$R_{l,q}$	*Metal-film resistors, lengthwise, crosswise*
R	*Auxiliary bridge Resistors*
U_o	*Supply voltage*
U_A	*Output voltage*

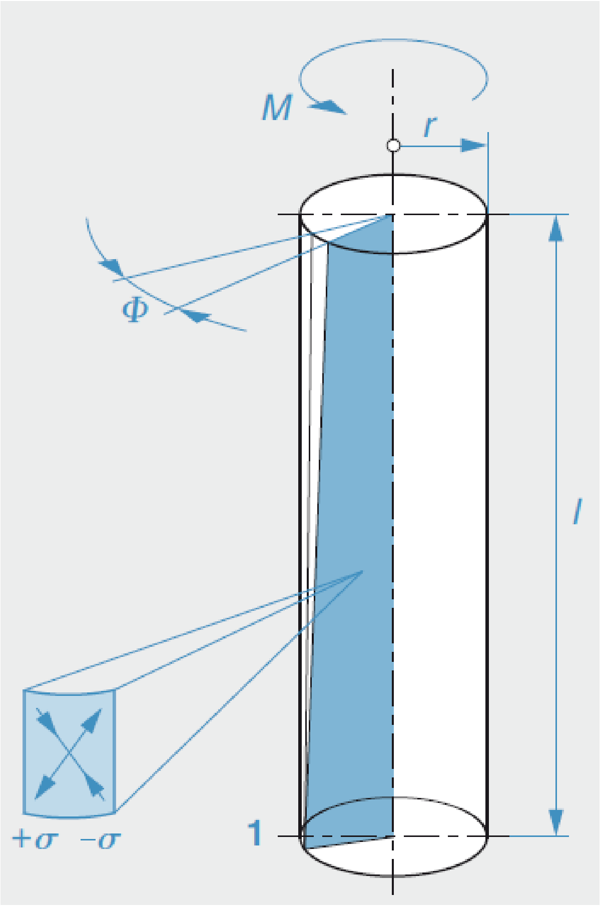
Strain gage principle (piezoresistive)



Piezoresistive behavior of various resistance materials when orthogonal compression is applied

1	*84.5 Ag 15.5 Mn*
2	*Manganin*
3	*Cu*
4	*Au*
5	*Ag*
6	*Carbon film/layer*
7	*Cermet*
8	*Conductive plastic*

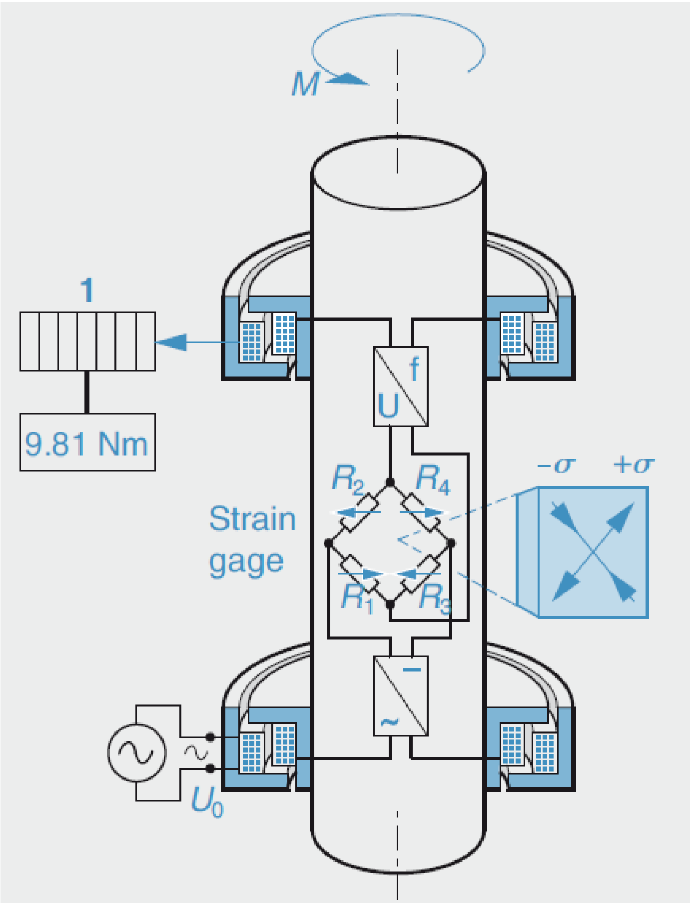
Torque sensors



Torque measurement: basic principle

1	*Torsion rod*
Φ	*Torsion angle*
σ	*Torsional stress*
M	*Torque*
r	*Radius*
l	*Rod length*

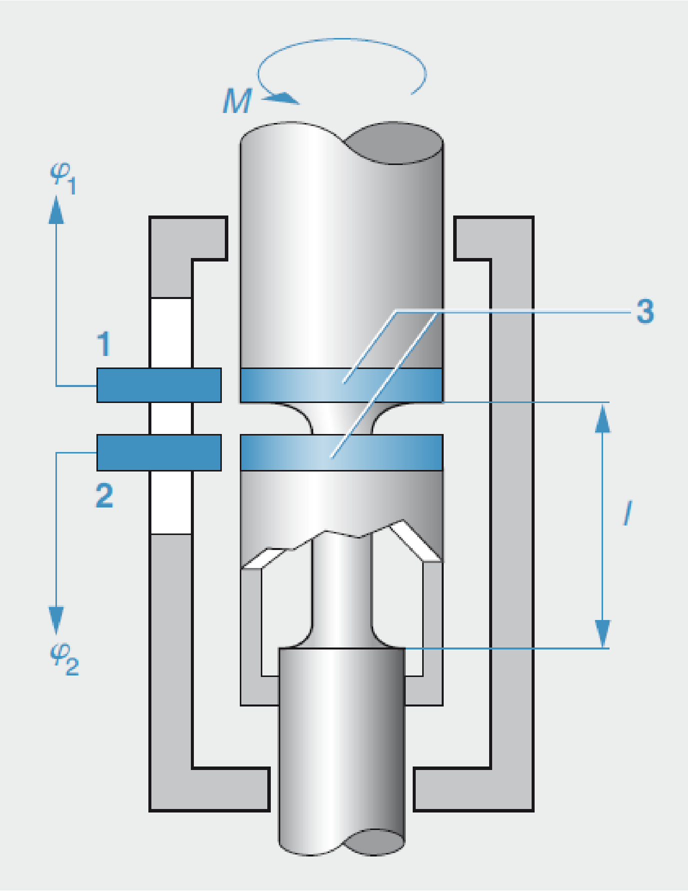
Strain-measuring torque sensors



Strain-gage torque sensor with non-contacting (proximity) transformer pick-off

1	*Torque indicator*
σ	*Torsional stress*
M	*Torque*
r	*Supply voltage*
R_1 to R_4	*Strain-gage measuring resistors*

Angle-measuring (torsion-measuring) sensors



Determining torque by measuring angular difference

$$M = \text{const} \cdot L \cdot (\varphi_2 - \varphi_1)$$

where *L* = length of the section subject to torsion

1, 2	*Angle/speed sensors*
3	*Angle markings*
M	*Torque to be measured*
l	*Torsionmeasurement section*
$\varphi_{1,2}$	*Angle signals*

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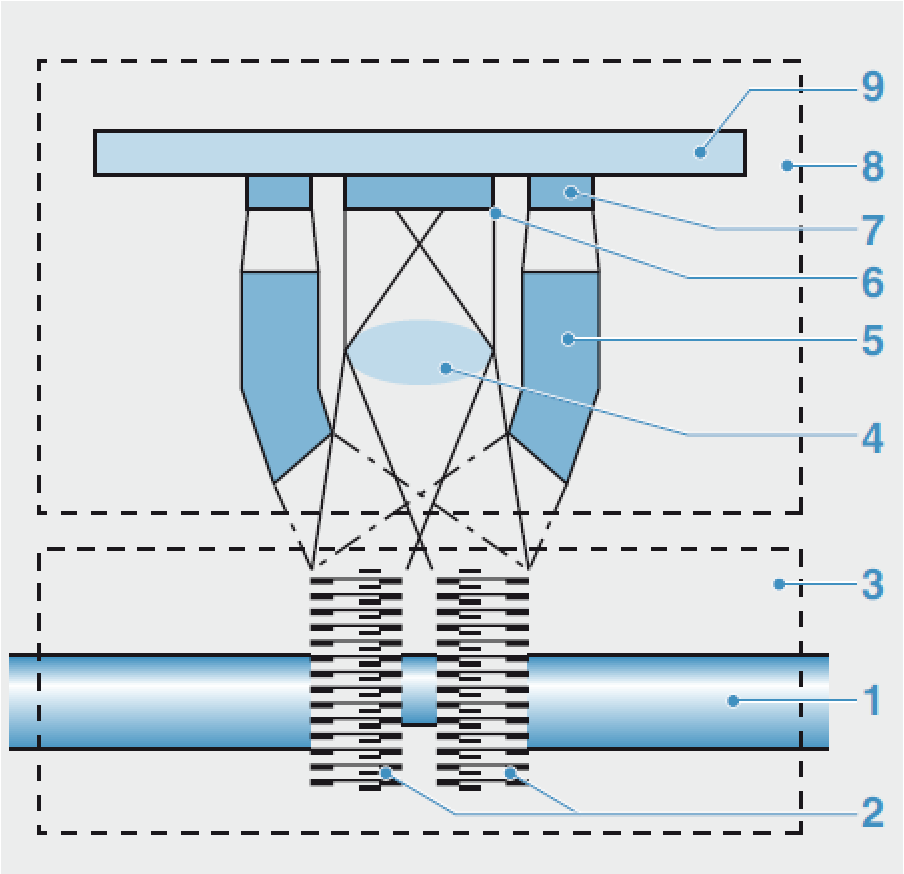
Angle-measuring (torsion-measuring) sensors

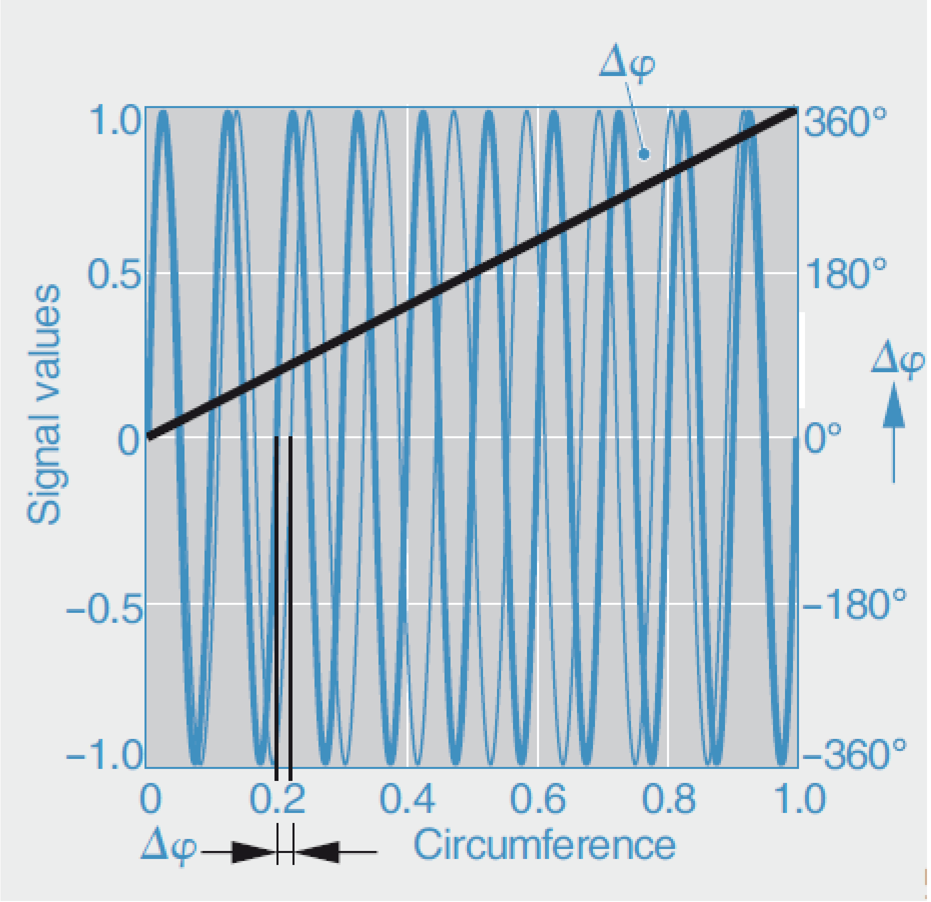


Optoelectronic angular difference steering torque sensor

Optical pick-off of the angle marking tracks

1	*Steering shaft with torsion rod*
2	*Code disks with bar code*
3	*Steering gear housing*
4	*Lens*
5	*Optical waveguides*
6	*Optical ASIC*
7	LED
8	Sensor module
9	PCB

Angle-measuring (torsion-measuring) sensors



Angle measurement using the vernier principle

$w = arctan\ (u_1/u_2)$

where $u_1 = u \cdot sin\ \varphi$ and

$u_2 = u \cdot cos\ \varphi$

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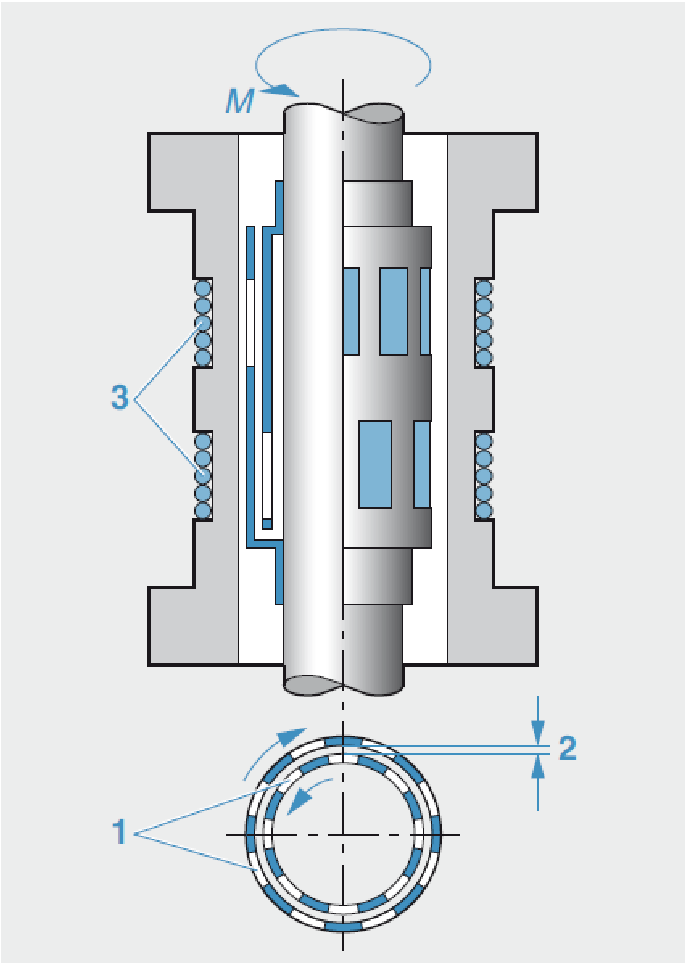
Eddy-current torque sensors



Eddy-current torque sensor

1	*Slotted sleeves*
2	*Air gap*
3	*High-frequency coils*
M	*Torque to be measured*