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5.1.1 Crank Shaft Angle and Engine Speed

5.1.2 Forces

5.1.3 Torque

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$$\omega = 2\pi n$$

ω angular velocity

n revolution speed
(take care: often given by minute)

$$\omega = \frac{d\varphi}{dt} \leftrightarrow \varphi = \int_0^t \omega \, d\tau + \varphi_0$$

φ crankshaft angle

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Angular Position and Speed Sensors

- Absolute Coders
- Incremental Coders (magnetic/optical)
- Resolvers/Synchros
- Tacho Generators
- (Potentiometers)

- Engine: ECU
- Engine: Ignition Frequency
- Engine: Generator

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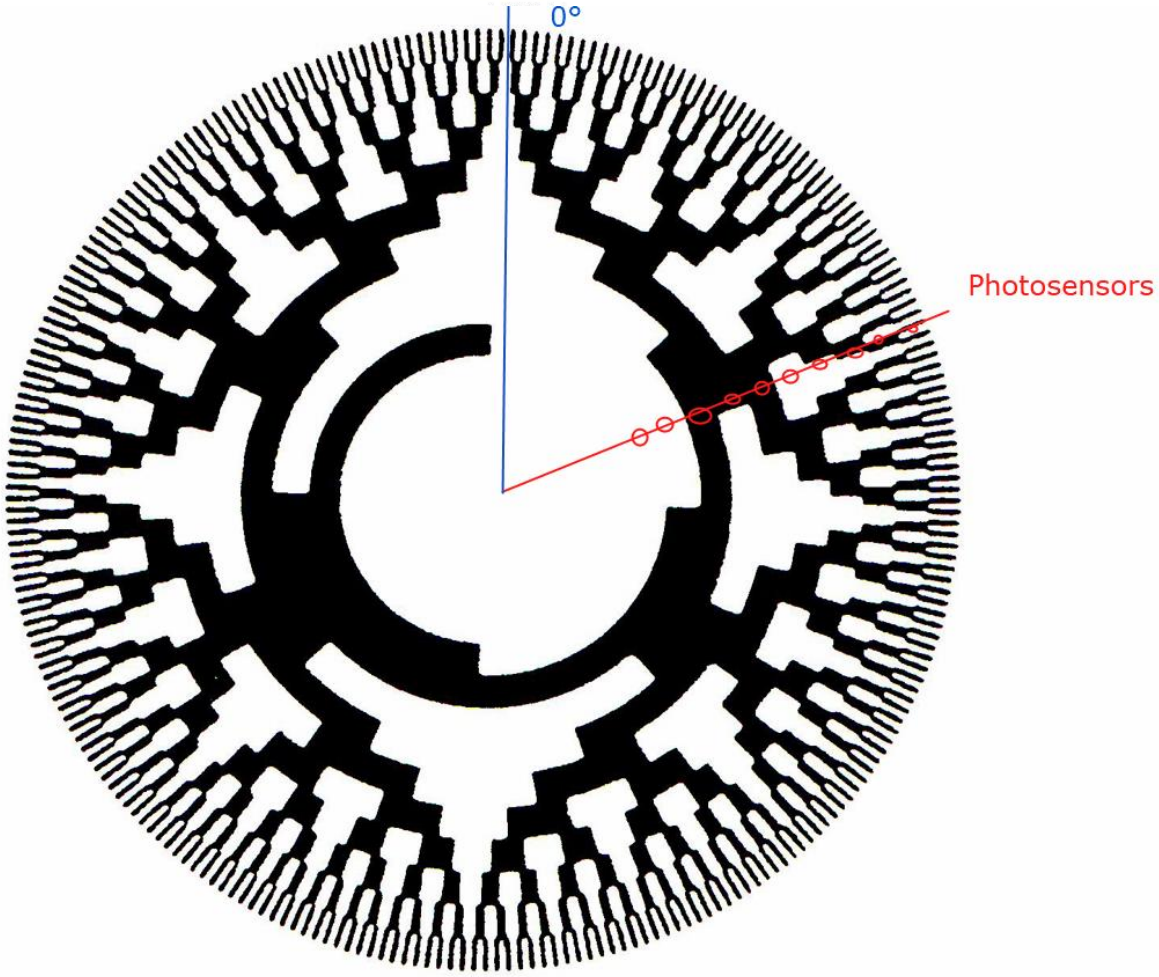
Angular Position and Speed Sensors
Absolute Coders

Binary Code 10 bit



Source:

UAS Hamburg
Prof. Zhang

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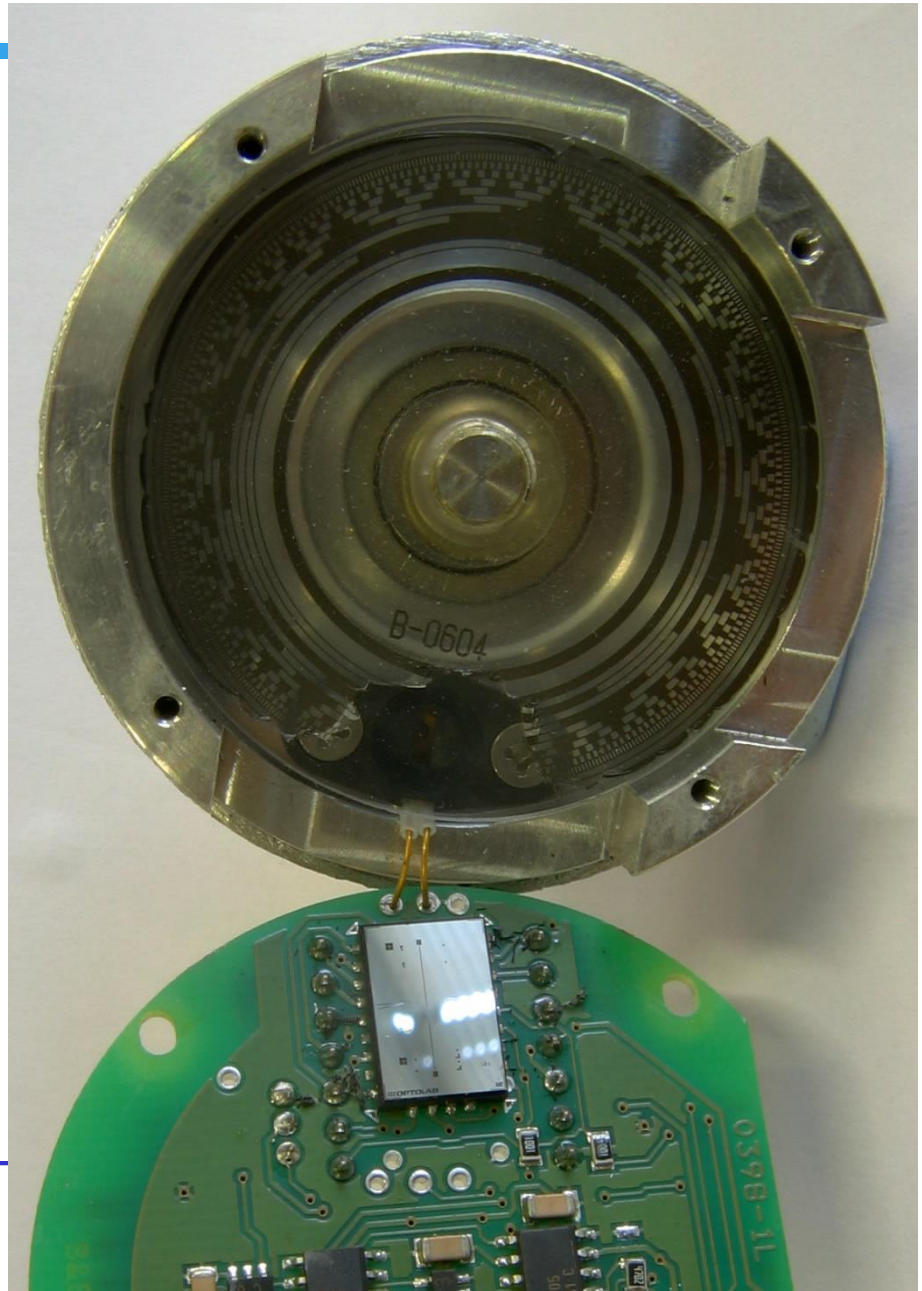
Angular Position and Speed Sensors
Absolute Coders

Optical Coder



Source:

Wikimedia Commons
User Mike1024

Absolute Coders

Binary Code	Gray Code
0000000001	0000000001
0000000010	0000000011
0000000011	0000000010
0000000100	0000000110
0000000101	0000000111
0000000110	0000000101
0000000111	0000000100
...	...

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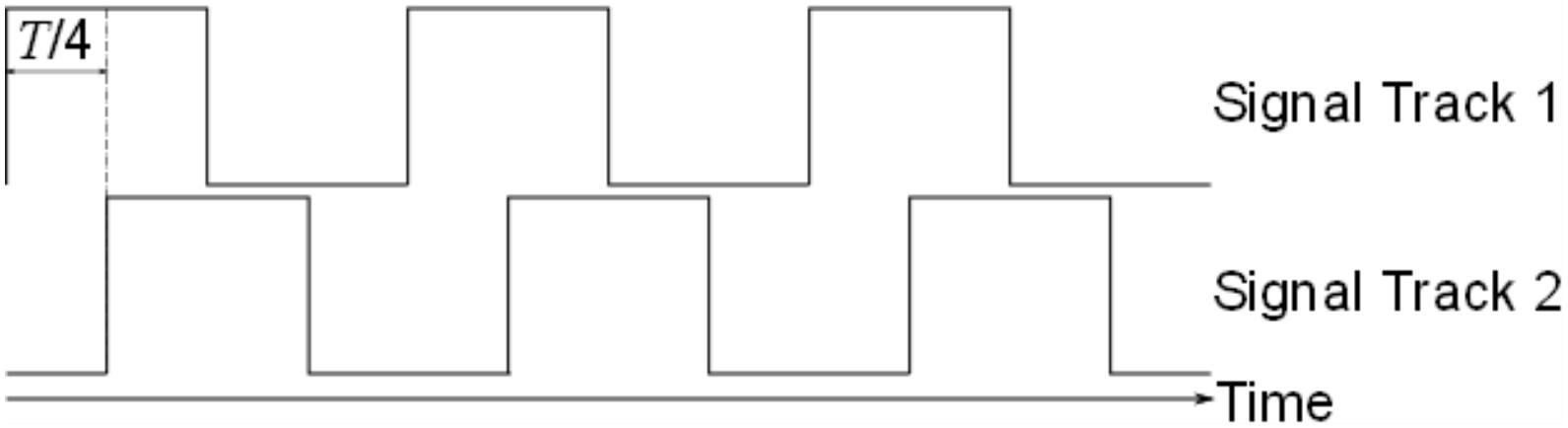
Angular Position and Speed Sensors
Incremental Coders



For absolute position reference mark necessary

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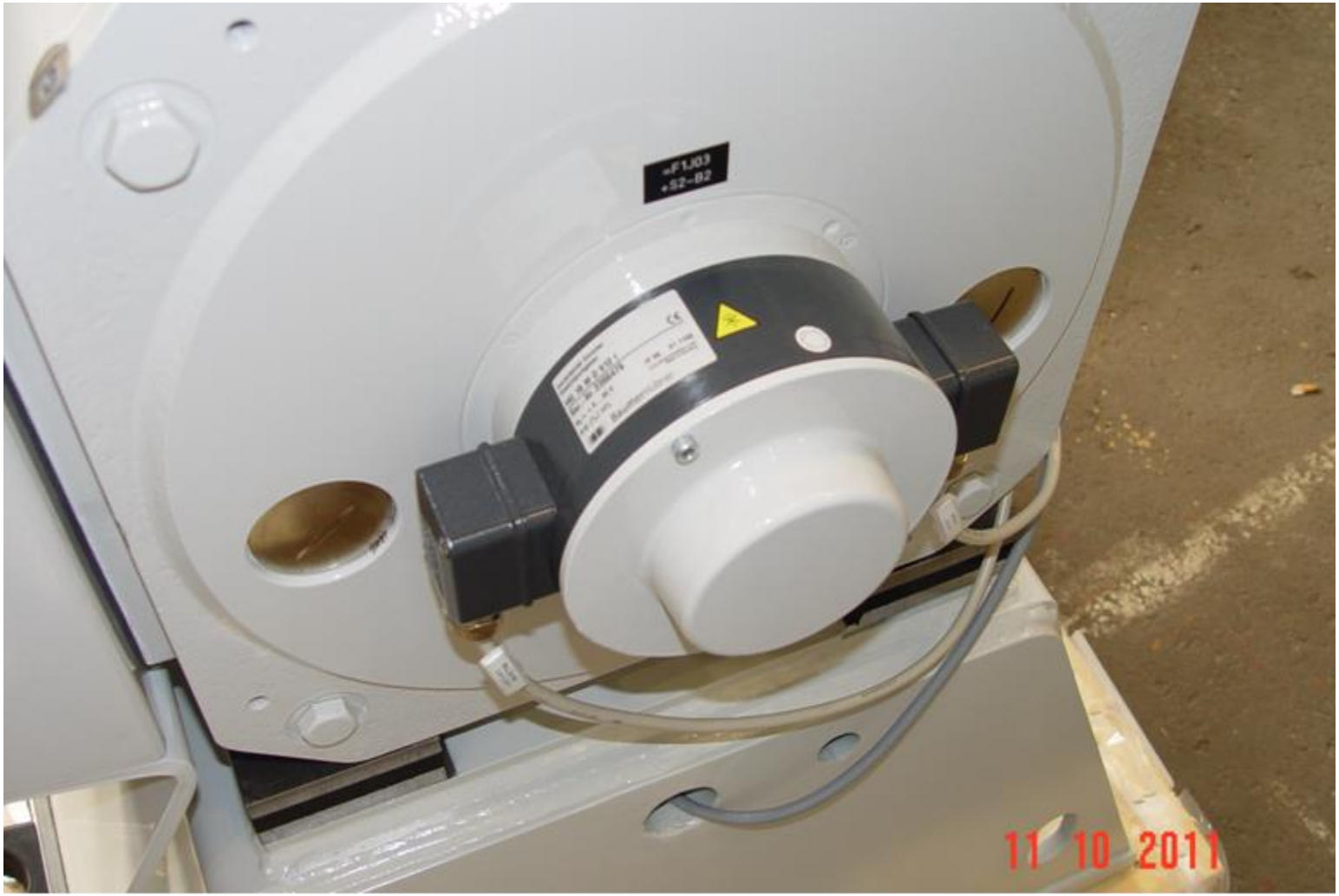
Angular Position and Speed Sensors
Incremental Coders



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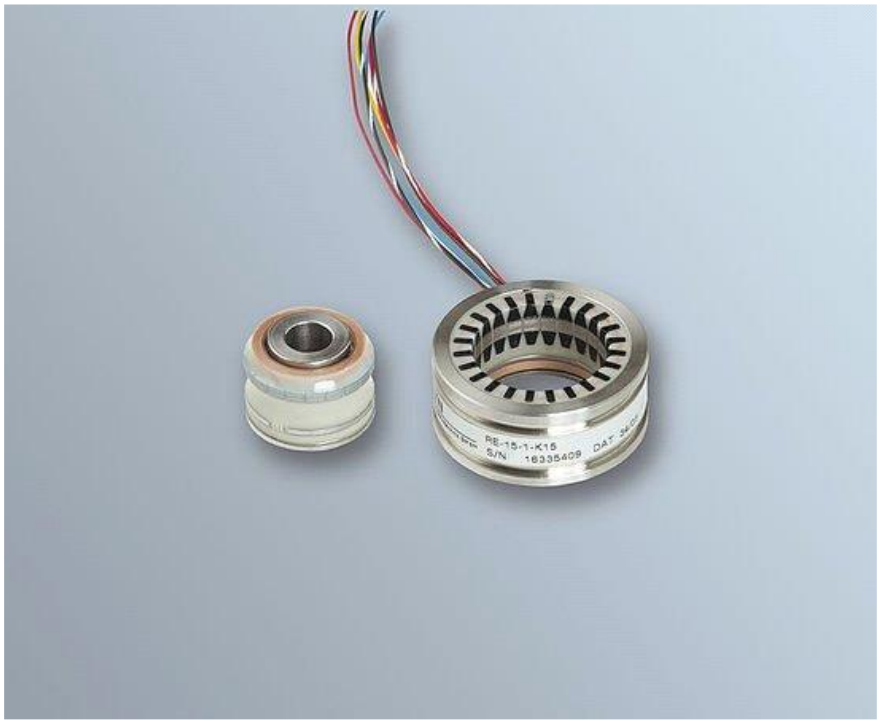
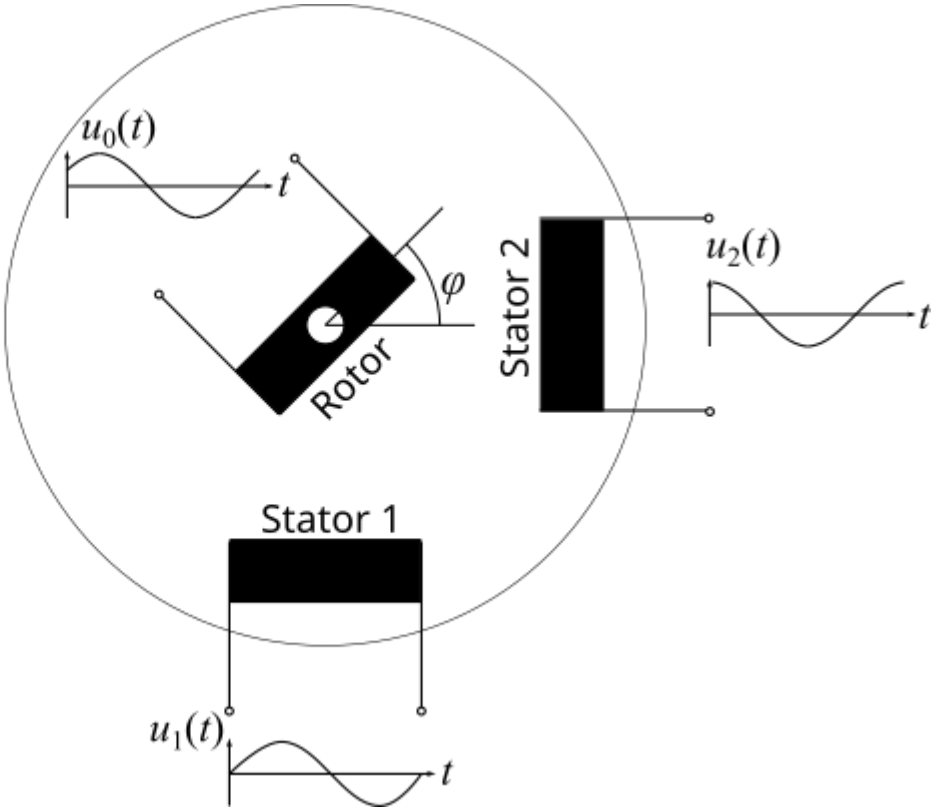
Angular Position and Speed Sensors
Resolvers





Source: Servotechnics

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5.1.1 Crank Shaft Angle and Engine Speed

5.1.2 Forces

5.1.3 Torque

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- **Piezoresistive Effect**
- Piezoelectric Effect
- Optical Strain Gauges (Bragg Interferometers)
- SAW (Surface Acoustic Wave) Sensors
- Piezomagnetic Effect
- Capacitive Gauges

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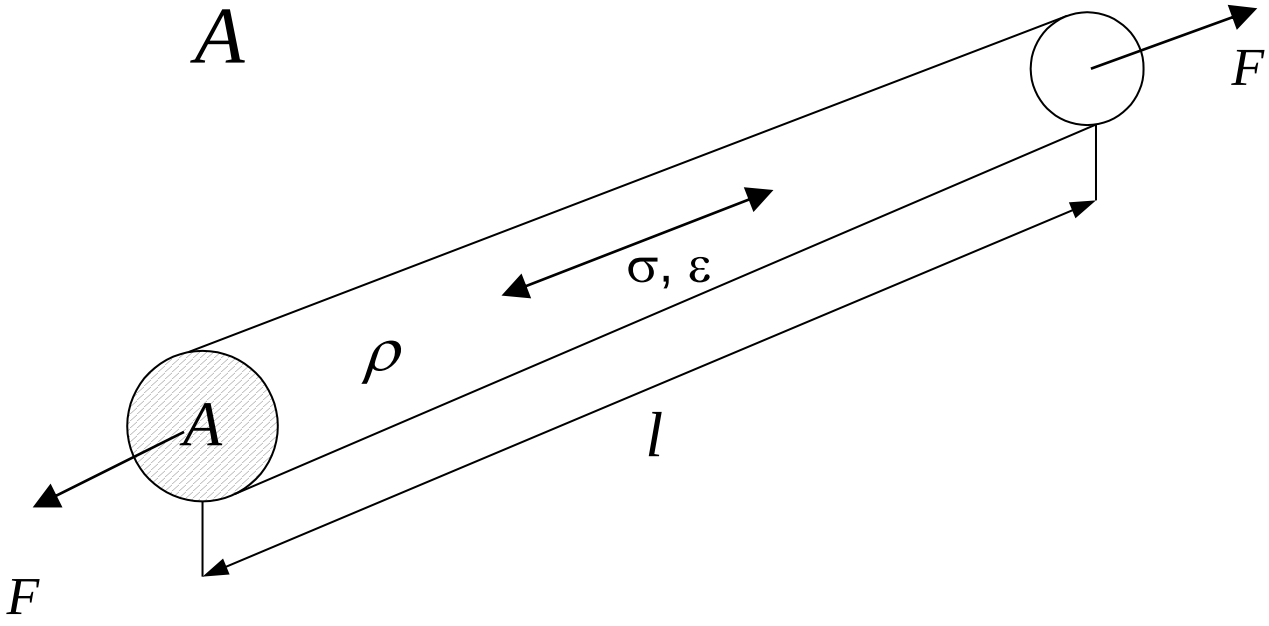
Piezoresistive Effect

$$R = \frac{\rho l}{A}$$



Definition 1: $\rho = f(\sigma)$

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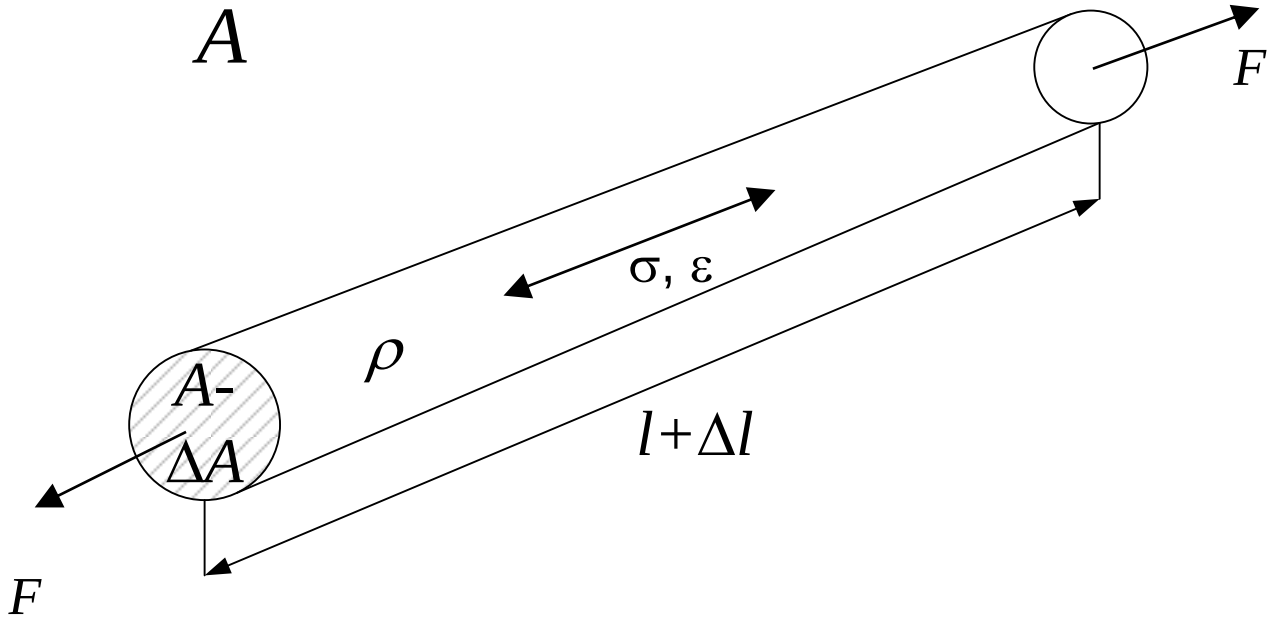
Piezoresistive Effect

$$R = \frac{\rho l}{A}$$



Definition 2: $R = f(\sigma)$

Combination of Piezoresistive Effect (1) and Volume Effect

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Piezoresistive Effect

Hooke's Law

$$\frac{F}{A} = \sigma = E\varepsilon$$

Relation between Longitudinal Strain ε
and Change of Diameter d

$$\frac{\Delta d}{d} = -\upsilon\varepsilon$$

υ Poisson's Ratio

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Piezoresistive Effect
k Value

$$R = \frac{\rho l}{A} = \frac{4\rho l}{\pi d^2}$$

Calculation of Strain Dependency by Total Differential:

$$\Delta R = f(\Delta\rho, \Delta l, \Delta d) = \ldots$$

Relative Change of Resistance:

$$\frac{\Delta R}{R} = \ldots$$

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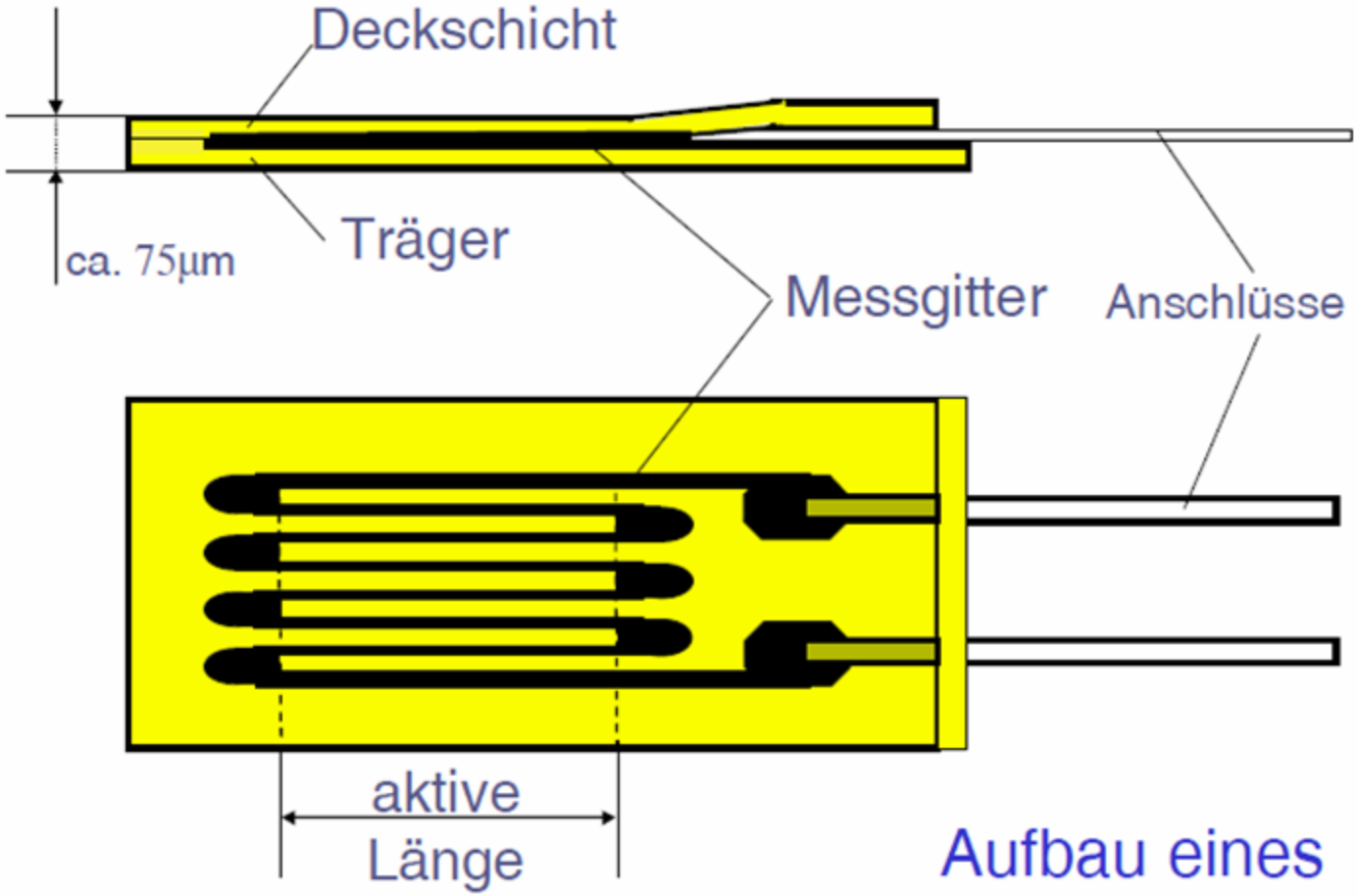
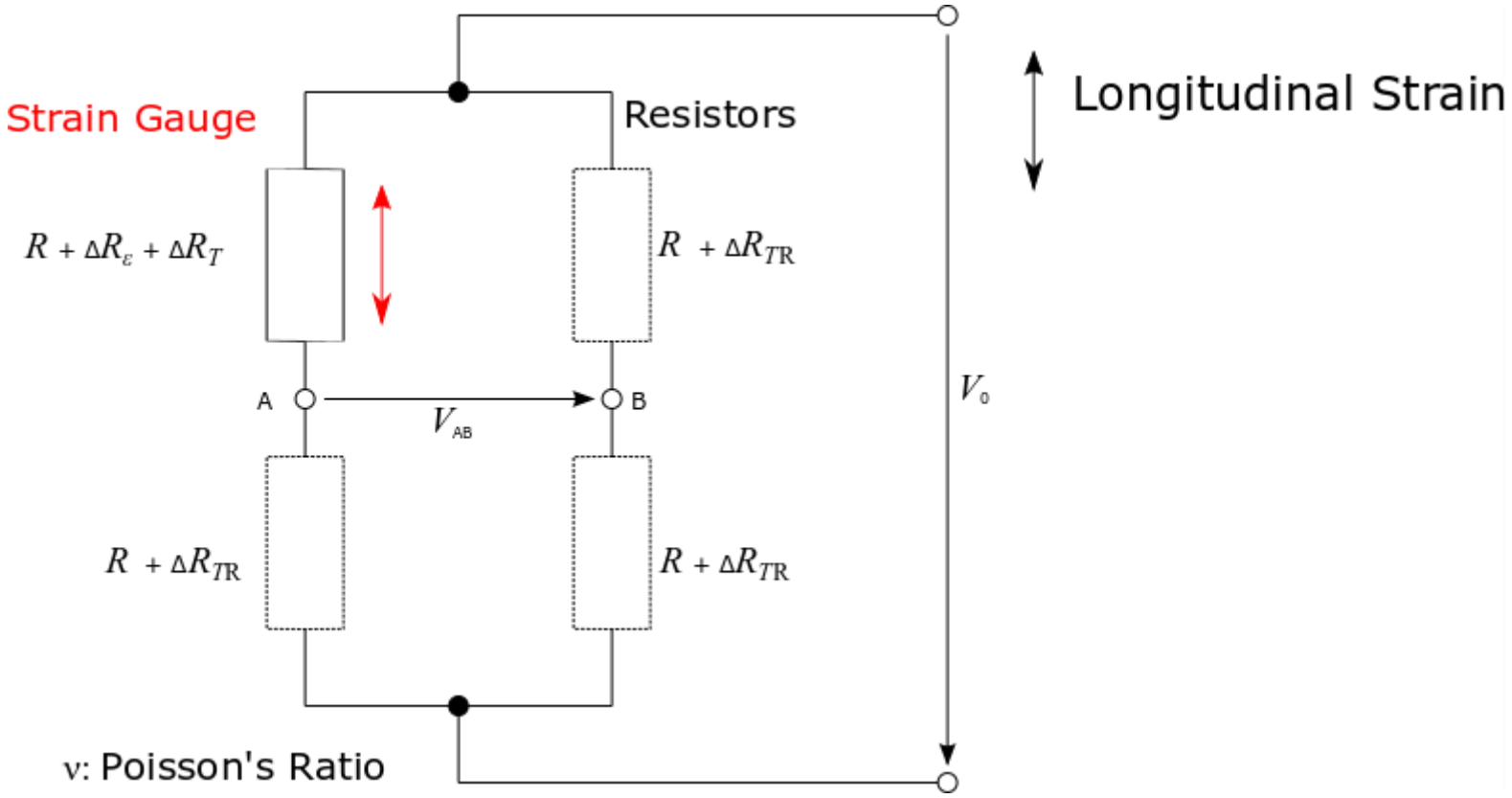


Aufbau eines
Metallfolie - DMS

Quarter Bridge



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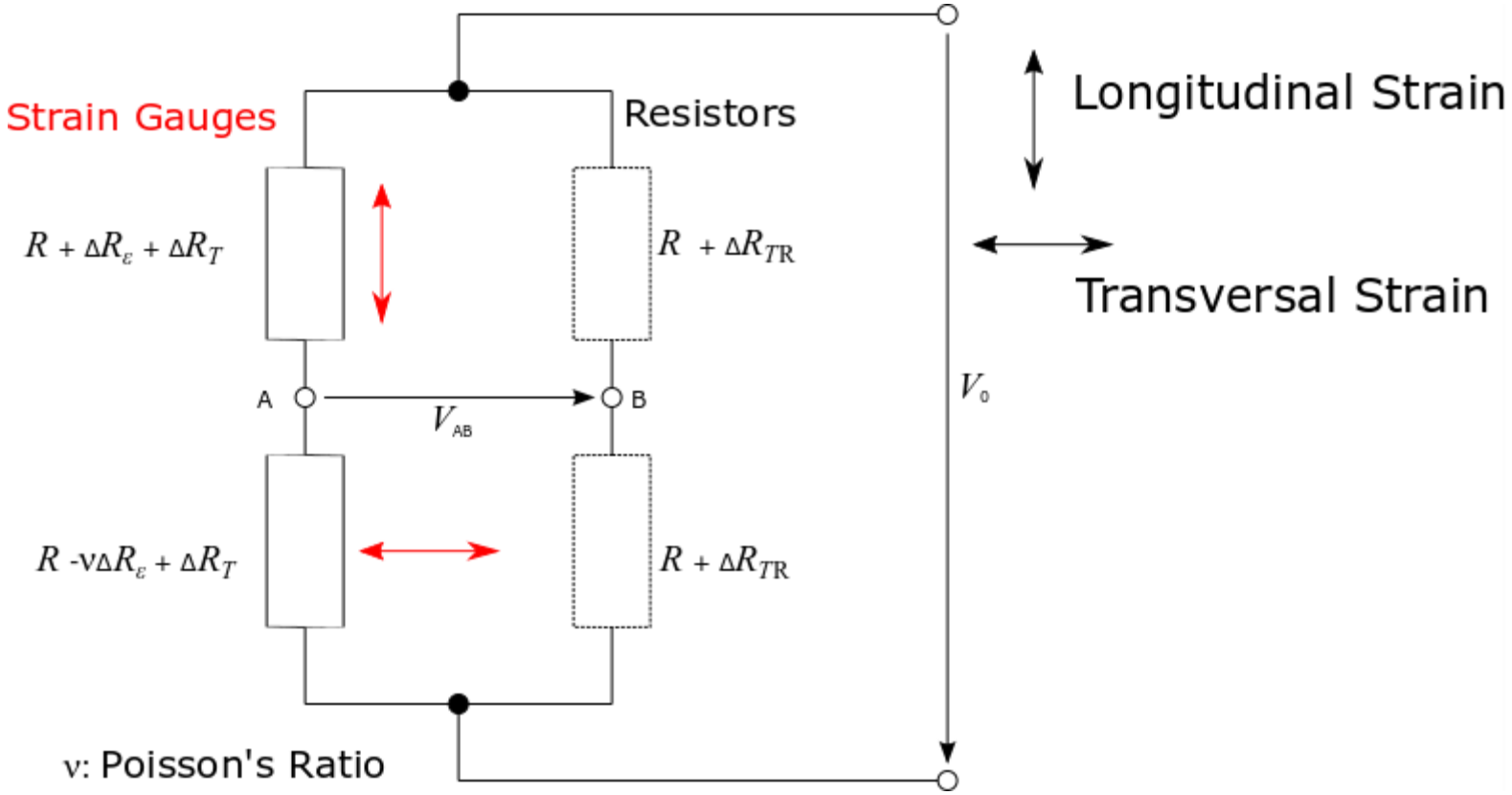
Half Bridge



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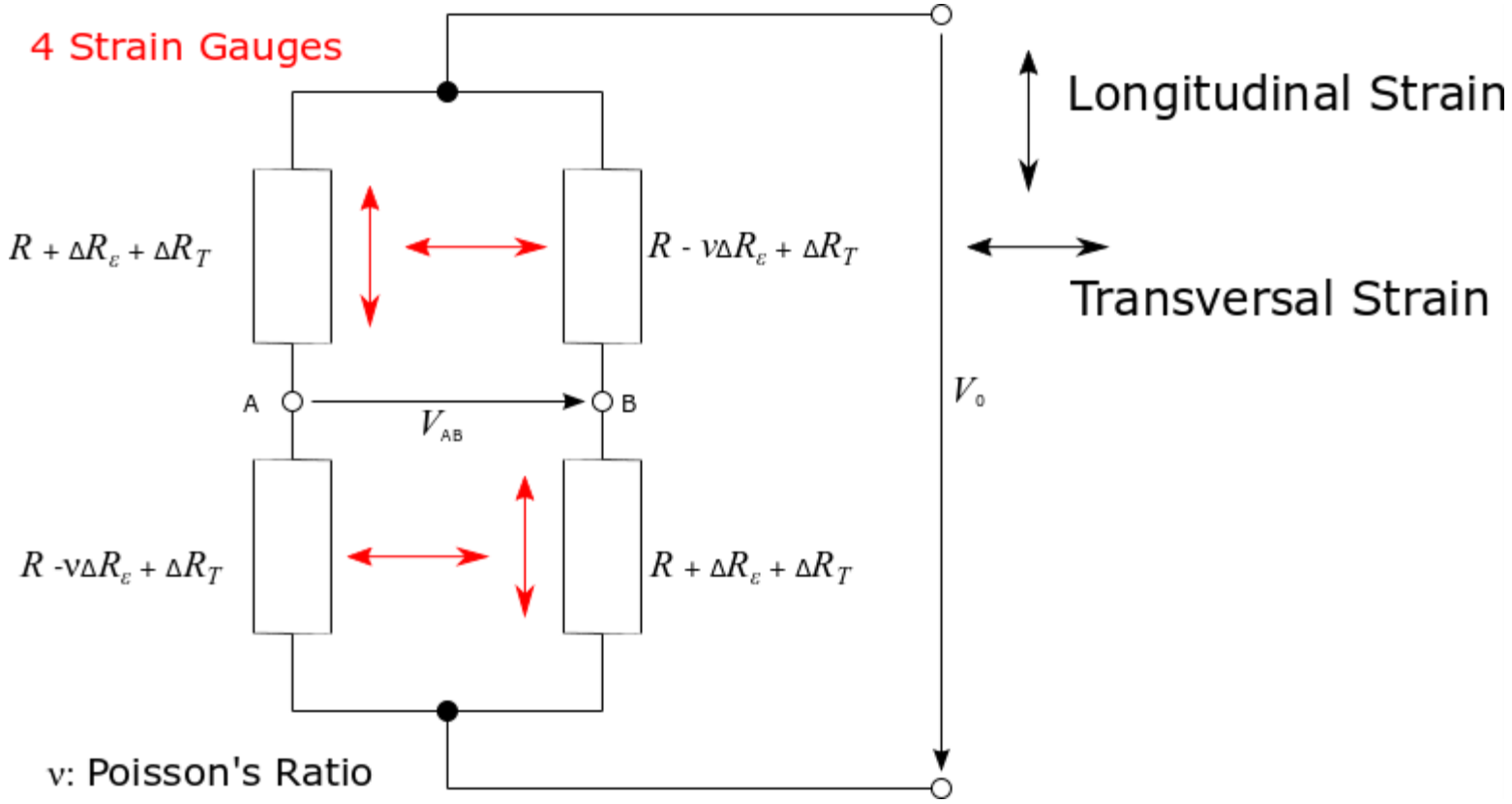
Full Bridge



$$V_{AB} = V_0 \frac{-(1+\nu)\Delta R_\varepsilon}{2R + (1-\nu)\Delta R_\varepsilon + 2\Delta R_T} \approx -V_0 \frac{(1+\nu)\Delta R_\varepsilon}{2R}$$

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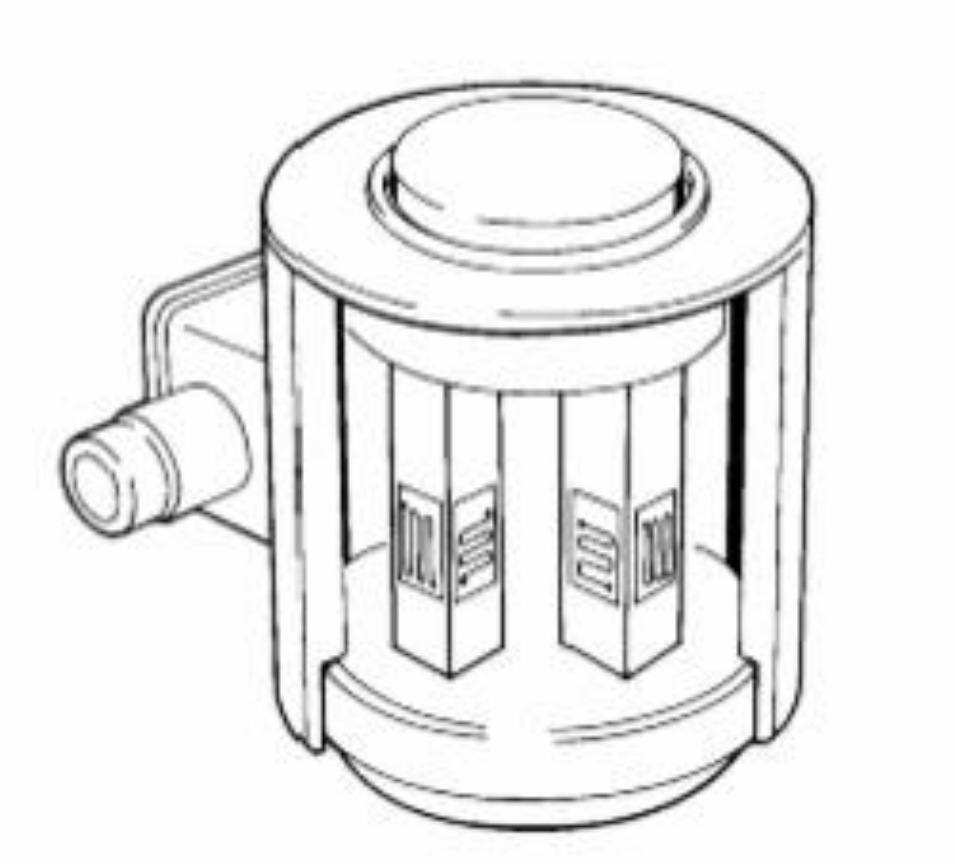
Load Cell

Source:
http://www.paari.de/de/informationen/technik/waegezellen/typen



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5.1.1 Crank Shaft Angle and Engine Speed

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Torque Measurement

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Torque Flange

→ Presentation HBM

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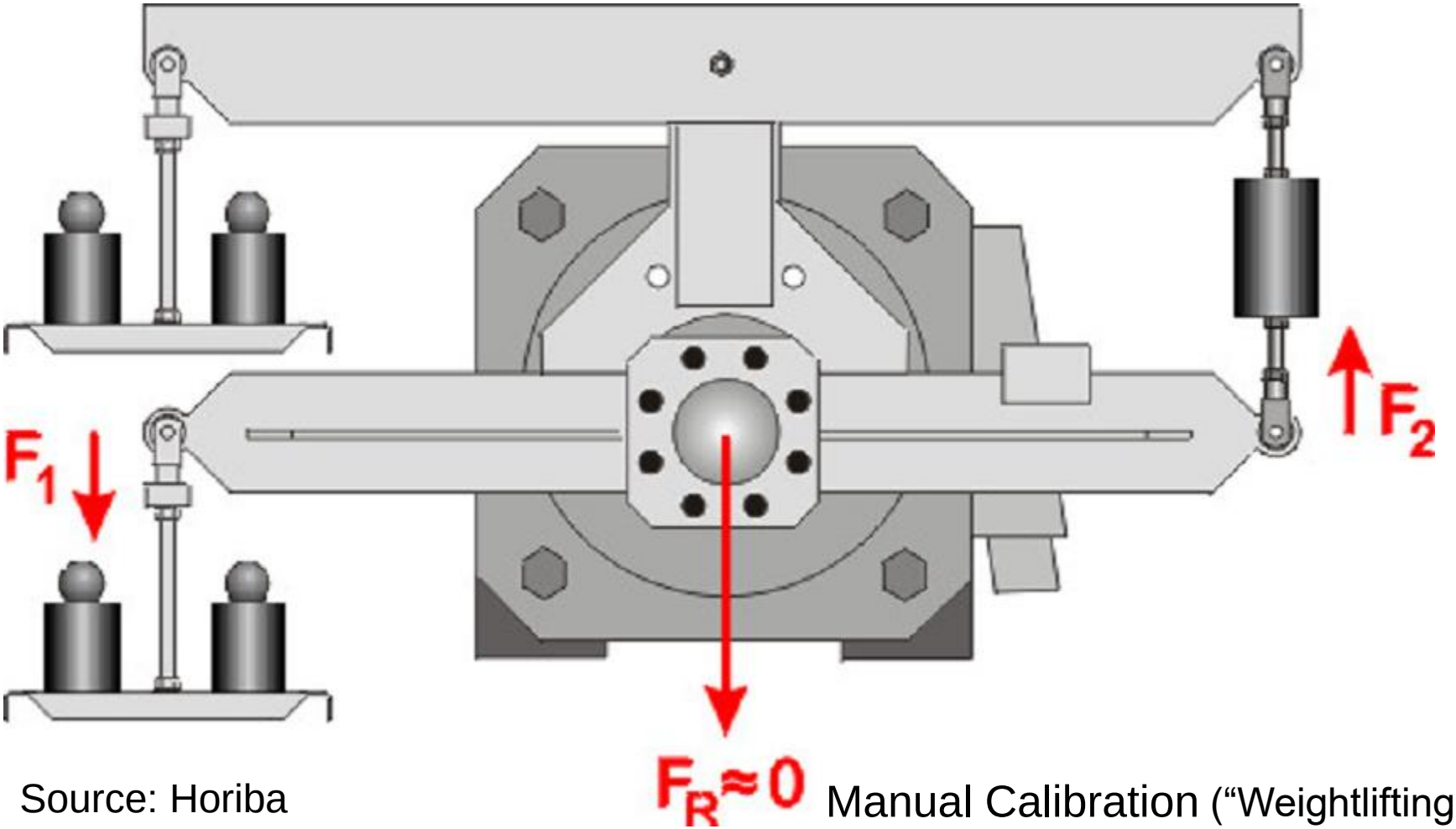
Torque Flange
Static Calibration



Source: Horiba

Manual Calibration (“Weightlifting”)

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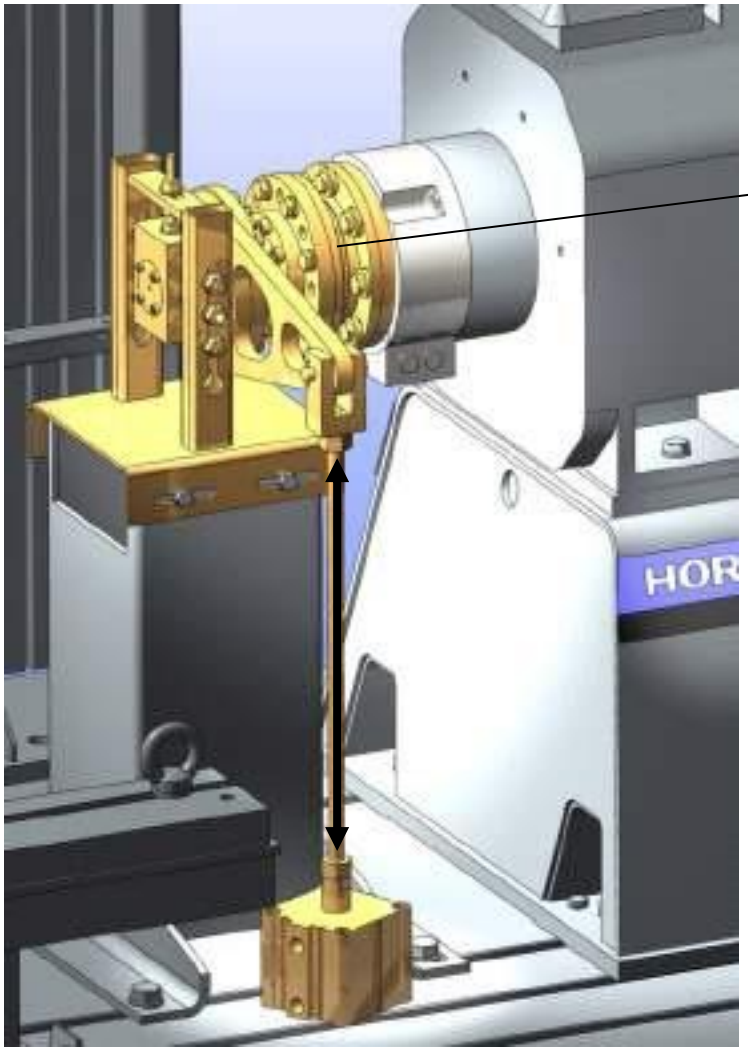
Torque Flange
Static Calibration



Source: Horiba

Calibration with Actor

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