Electronic Weighing Principles

Introduction

D Technology: Strain gauges
F Technology: Frequency-modulated force measurement
K Technology: Electromagnetic force compensation

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issue: May 91

Introduction

The market for electronic scales is today dominated by a very small number of well developed measurement principles.

In the weighing range between one ten millionth of a gram and several tonnes, since 1973 METTLER-TOLEDO has used exclusively electronic measurement principles in the construction of balances and scales. To meet the growing demands of our customers, our research, development and quality assurance departments are continuously working on the optimization of the familiar weighing technologies. Moreover, we are working in the front line to bring new, innovative ideas to marketability and to incorporate them in our products.

METTLER-TOLEDO uses the most important weighing principles and produces all weighing cells in its own production facilities. We are thus in a position to employ the appropriate scale with the right technology for every weighing application.

The present description provides an overview of the measurement principles used by METTLER-TOLEDO, their ranges of application, advantages and limitations.

Fundamental technical explanations have been intentionally avoided. Further details of the individual technologies can be found in various METTLER-TOLEDO brochures (e.g. Dictionary of Weighing Terms) or technology books.

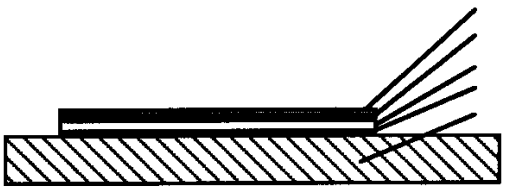
D Technology

Strain gauges

Operating principle

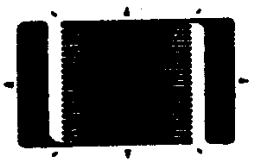
Strain gauge weighing cells comprise an elastically deformable body on which electrical resistive films (strain gauges) are mounted which change their resistance on deformation.
Suitable construction ensures that this resistance change is proportional to the acting deforming force.
Several strain gauges can be evaluated following the principle of the Wheatstone bridge circuit.

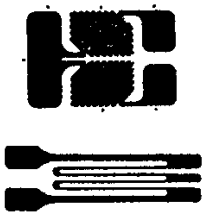
Structure of a strain gauge

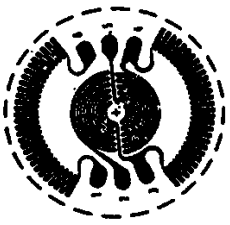


Cover film
Adhesive
Support & resistive film
Adhesive
Deforming body

Examples of designs



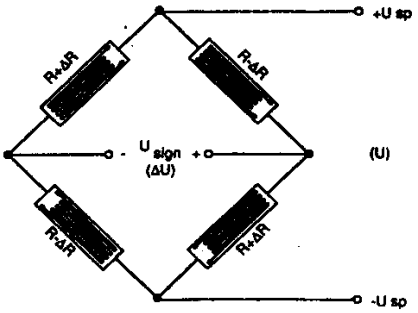




Wheatstone-bridge

higher resistance with stretching strain at strain gauge

lower resistance with compressive strain at strain gauge

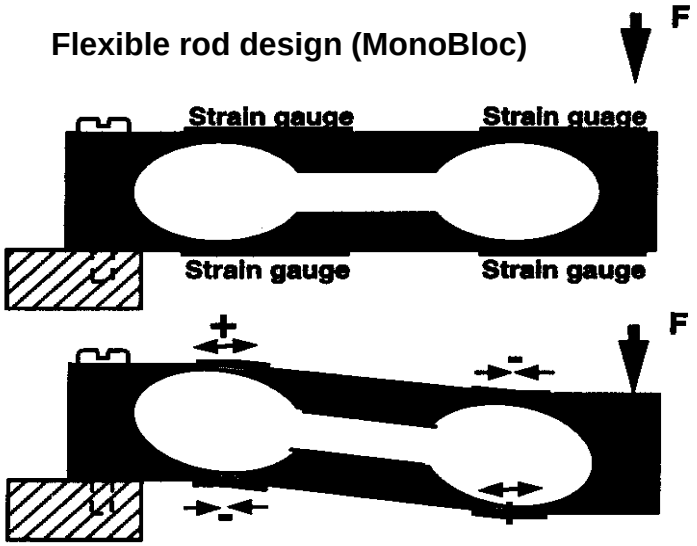


Designs

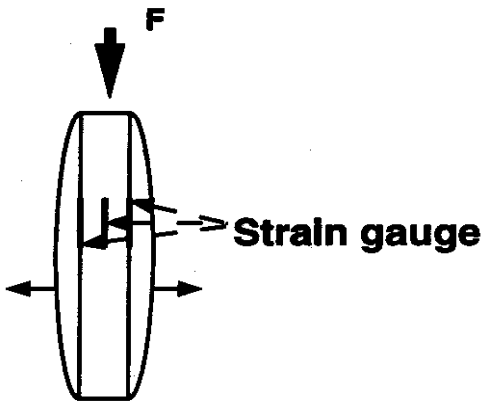
A great advantage of this technology lies in the different designs of the deforming body. A few examples are given below:

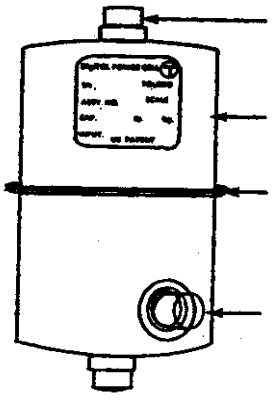
a) Flexible rod The load perpendicular is displaced with regard to the fastening point (used predominantly for relatively small nominal loads below 1000 kg)

Flexible rod design (MonoBloc)



b) Pin load cell For loads up to 50 tonnes, cells with a simple steel pin as a deformable body are used. The strain of the surface (bulging) is measured.





Steel pin (Pin)

Steel housing (filled with inert gas)

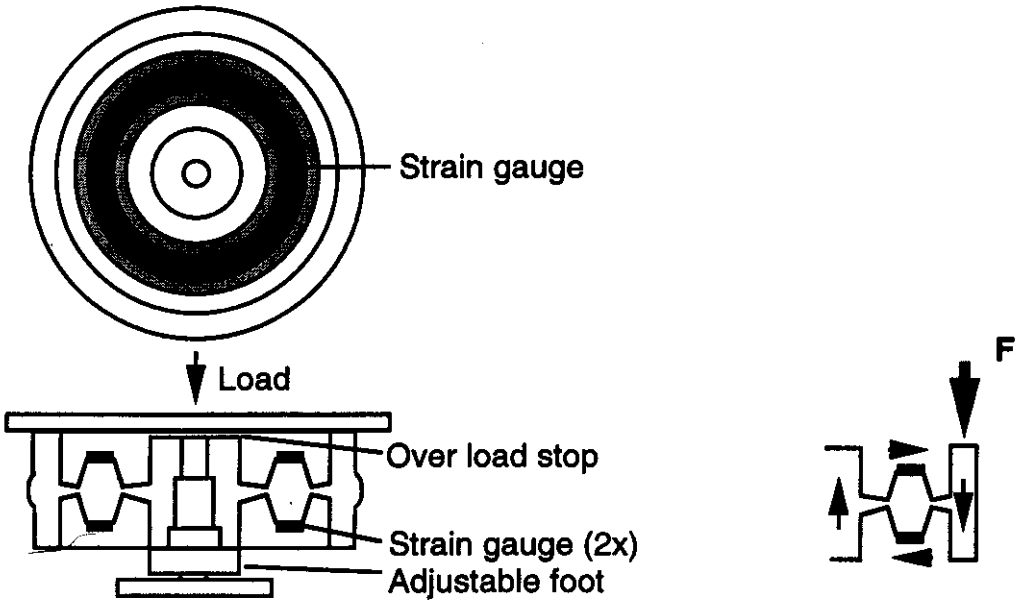
Welded joint

Connector (glass/metal connection)

Function:
Bulging on loading

c) Ring load cell

Rotationally symmetrical deformable body for nominal loads up to 3 tonnes. The impressive feature of this design is the extremely low height of 30 mm.



c) DigITOL®-weighing cells (digital METTLER-TOLEDO weighing cell)

Toledo has continued to develop and perfect its traditional technology. This technology makes use of state of the art microprocessors to digitalize the sensitive analog signals of a few millivolts (mV) as early as the load cell stage. Transmission of the weight values to the terminal is fully digital and hence free from interference. Disturbing influences such as temperature changes, unlinearity and material drift are detected immediately where they appear - in the cell - and compensated. Each DigiTOL load cell is fully adjusted and tested in production (linearity, temperature, cornerload, drift). The high degree of automation in production results in a high unvarying quality of the cells. The built-in fault diagnosis and self-test of the weighing cells increases the dependability and reduces the service work. In addition, if servicing is needed each cell can be replaced without additional adjustment work (e.g. soldering in of adjustment resistors, cornerload adjustment). With vehicle scales, the up to 32 load cells can be adjusted using the evaluation unit. The calibration data are stored in the appropriate cells.

The DigiTOL Technology solves numerous problems of analog load cells better. Faster, more stable products with improved fail-safe properties are the result.

Application range of strain gauge cells

Scales in the lower and medium nominal load range up to a few 100 kg. Leverless construction with only one (moment-independent) weighing cell results in extremely rugged bench, floor and shop scales.

- Low platform scales in the tonne range with several load cells

- Hopper scales (container, silos) with several load cells

- Scale construction with lever mechanism, strain gauge weighing cell at output of lever mechanism.

Advantages

- high nominal loads of the weighing cells (several kg up to approx. 50 tonnes)
- Leverless version with high nominal loads
- Very rugged design, no moving parts, high overload capacity
- Weighing platforms of low height (35 mm)
- Simple enclosure to protect against moisture and dust, corrosion- resistant owing to stainless steel construction.
- Easy to maintain (simple interchangeable parts)

Limitations

- Suitable for lower resolution range (3000 e). Higher resolutions lead to more complicated production (more extensive adjustment work, selection procedure with lower yield) and hence to appreciably higher costs.

Product line with D technology

MonoBloc: - METTLER-TOLEDO DT line up to 600 kg

Ring load cell: - Standard weighing cell of the METTLER-TOLEDO D line, used for pallet, platform and other scales above 600 kg nominal load

Simple flexible beam: - Used only in special models of the METTLER-TOLEDO D line

Pin cell: - METTLER-TOLEDO vehicle scales up to 100 tonnes

DigiTOL Technology: - METTLER-TOLEDO DT line up to 600 kg
- METTLER-TOLEDO vehicle scales up to 100 tonnes

F TECHNOLOGY

Frequency-modulated force measurement

Operating principles

METTLER-TOLED0 has combined two familiar elements of weighing technology and developed a new technology for the medium resolution range.

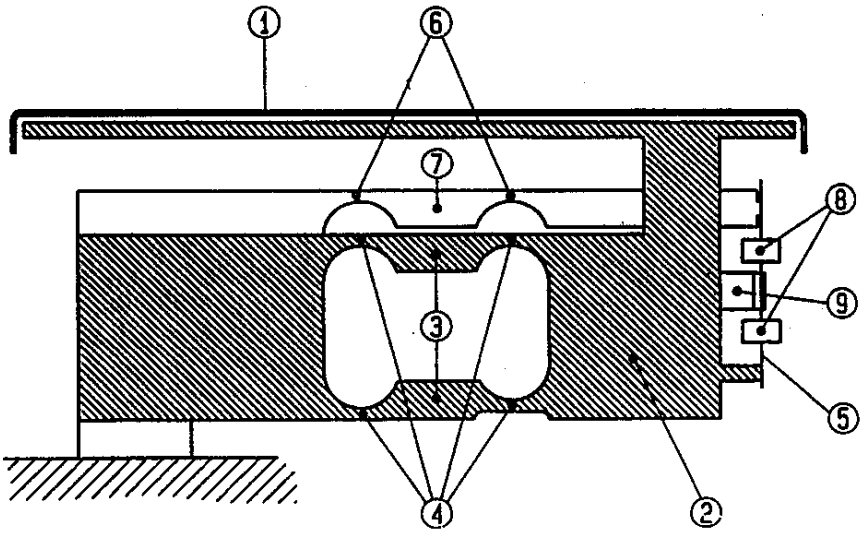
Mechanical part

All mechanical functions of flexible bearings, guides, link, reference springs and lever are integrated in a single block made of an aluminium alloy (special design of the familiar
MonoBloc). An important difference to the type of MonoBloc used with strain gauges involves the reference spring used.
Disturbing influences due to temperature and creep are virtually eliminated, automatically, by this technology.

Sensor

METTLER-TOLEDO has already used the principle of the vibrating string in various scale lines
(PS 1975, TE 1984). This principle has been further developed and optimized by METTLER-TOLEDO.
With the inherent high resolution, it is particularly suitable for use in F technology.
The force is stepped down in the MonoBloc and transferred to the string. The load-dependent frequency of vibration is measured and shown on the display

F weighing cell



1 Weighing pan
2 Hanger
3 Guide
4 Flexible bearings
5 String (sensor)
6 Flexible bending points
7 Reference string
8 Nodes
9 Permanent magnet

Application range of F Technology

- Standard industrial- and commercial scales in the medium resolution range MultiRange resolution 3 x 3000 e OIML class 111

Advantages of the F weighing cell

- Best technology in the resolution range 3 x 3000 e
- Digital signal/free from interference
- High weighing speed
- Rugged, simple construction extensive automatic production, few parts
- This measurement principle functions with low power (400 milliwatts), which allows more favorably priced construction solutions for the manufacture of mobile and increased-safety type scales.

Limitations

- Resolution range limited at present 3 x 3000 e
- In applications which requires extremely high ruggedness, the D technology is more suitable

Product line with F technology

F weighing cell:

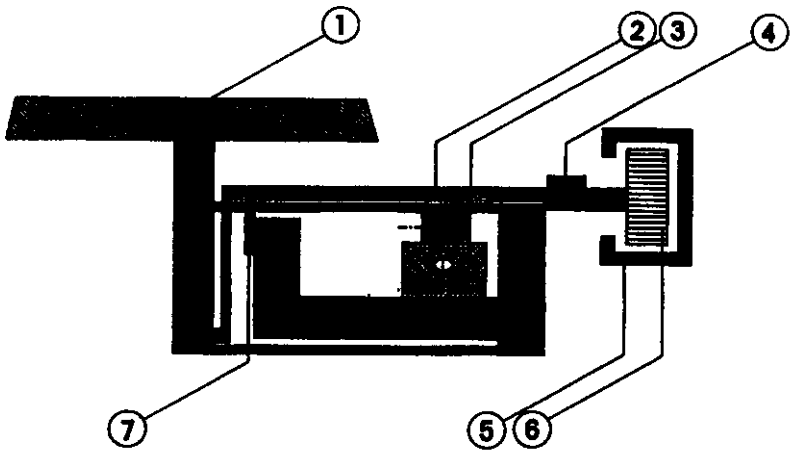
- Shop scales of the METTLER-TOLEDO U up to 15 kg.
- Industrial scales of the METTLER-TOLEDO MultiRange F line of weighing range 6 kg and greater

K TECHNOLOGY

Electromagnetic force compensation

Operating principle

The electromagnetic force compensation is a suitable measurement principle for electronic scales in the highest accuracy class.
With this principle, the loaded weight is compensated by an electro magnetically generated force. A compensation coil through which a permanent current flows is inserted in a permanent magnetic field. In the unloaded condition, current regulation ensures that the system is in the zero position. With the aid of an opt electronic position sensor, the coil position is controlled to an accuracy better than a thousandth of a millimeter. It records vertical positional changes when the scale is loaded. This information from the controller is used to generate a compensation current in the coil that returns the weighing system to zero. The current is directly proportional to the loaded weight. Its value is digitalized and sent to the display.



1. Weighing pan
2. Beam
3. Detection
4. Counterweight
5. Permanent-magnet
6. Coil
7. Flexible bearing

Application ranges of K technology

- Most widely used technology for microbalances, analytical and precision balances
- rugged Industrial scales of the highest accuracy through IP 67 sealing of themeasuring cell, overload-protection etc.

Advantages

- Suitable measurement principle for highest resolutions

KA32s industrial scale 32 000 e (OIML class 11)
AT400 analytical balance 405 000 e (OIML class 1)
MT5 Microbalance 5 100 000 d (not certified)

Limitations

- High production costs
- Complicated production procedure
-

Product lines with K technology

- **Microbalances:** M3, UM3, MT5 up to 5 g
- **Analytical balances:** AJ, AM, AE, AT up to 400 g
- **Precision balances / scales:** BB, PJ, PM up to 30 kg
- **Industrial scales:** MultiRange with K weighing platforms up to 6000 kg SM up to 15kg

ONLY SENSORS

METTLER TOLEDO
ELECTRONIC WEIGHING PRINCIPLES
(SENSOR COMPARISON)

	D TECHNOLOGY	**F TECHNOLOGY**	**K TECHNOLOGY**
Weighing Principle/technology	Strain gauges	Frequency-modulated force measurement	Electromagnetic force compensation
Resolution class Certification class	< 6000e class	3 x 3000e class III	32’000 e / 320’000 d class II (industrial scales) 500’000 e class I (analytical balances)
Stabilization time	ca. 1 sec.	ca. 1 sec.	< 2-3 sec.
Ruggedness	+++	++	++
Cell construction	Complete CrNi	Complete CrNi	Al housing powder-coated
IP degree of protection	IP 67	IP 67	IP 67
Method of construction/design	Very compact	Compact	Time-consuming
Power consumption (weighing cell only)	Approx. 0.4 watts	Approx. 0.4 watts	Approx. 2.5 watts