SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

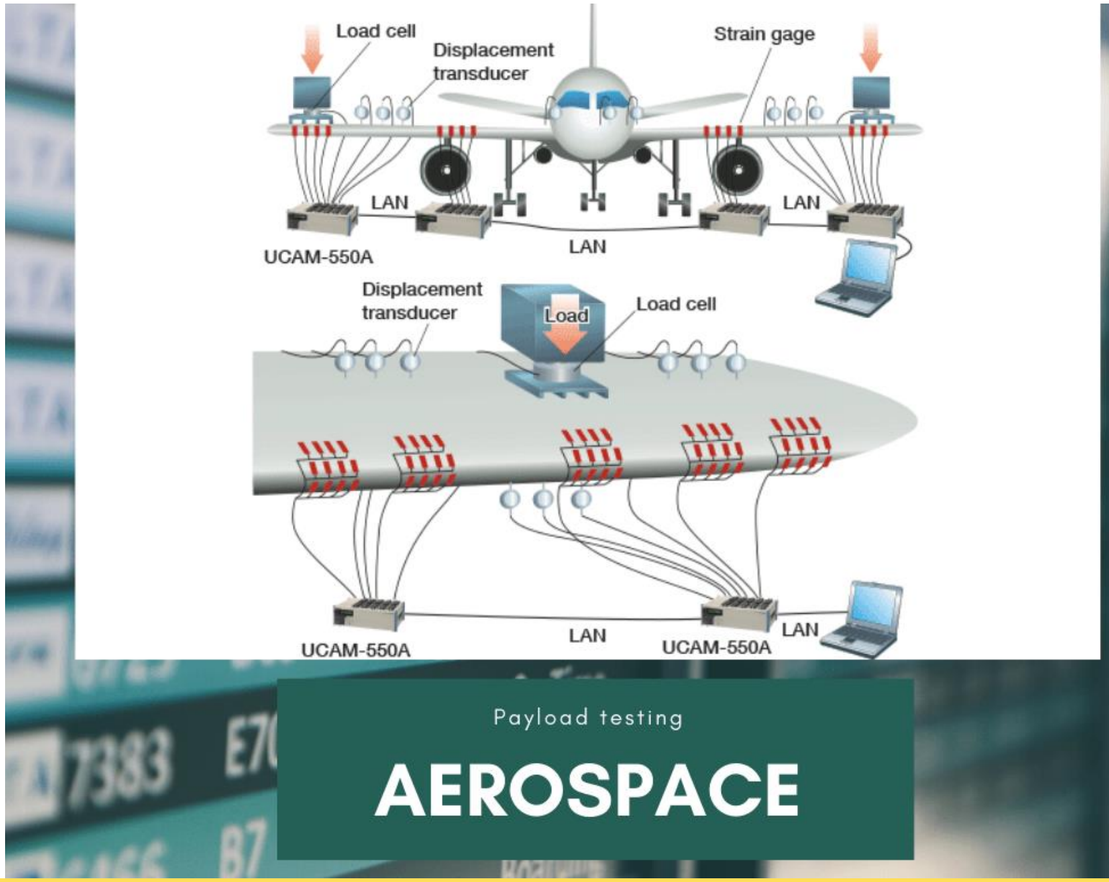
COURSE NAME : 23EET206 CONTROL SYSTEMS AND INSTRUMENTATION

II YEAR ECE /III SEMESTER

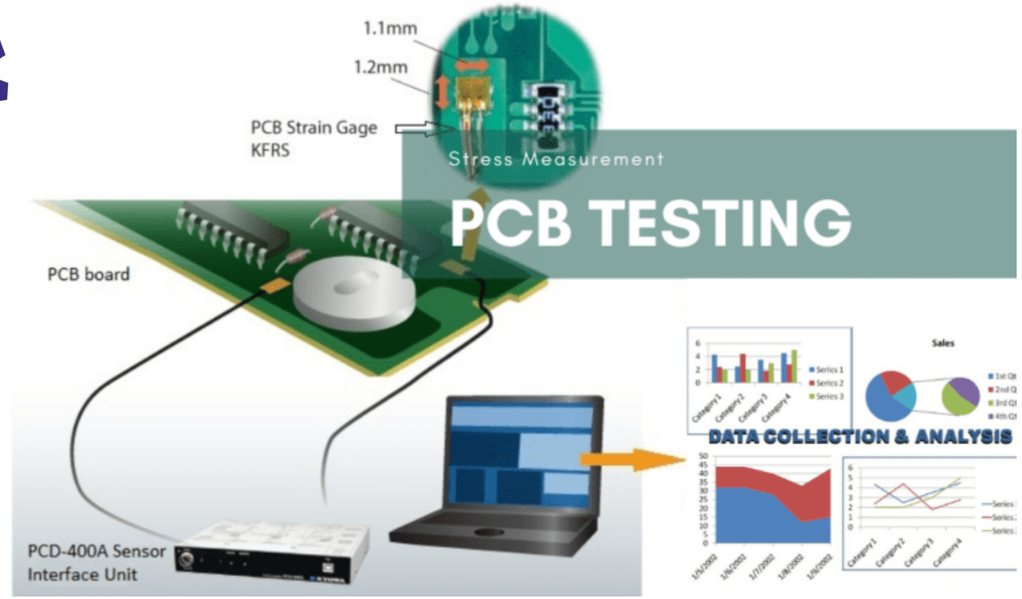
Unit 4- Electronic Instruments & Transducers

Topic 5 : Strain Gauges

STRAIN GAUGE

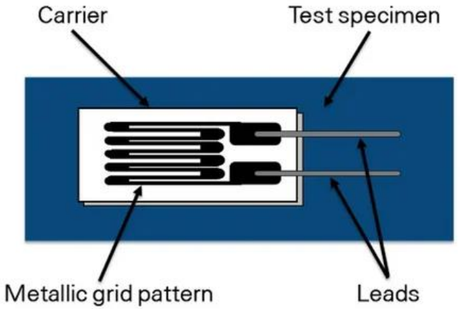


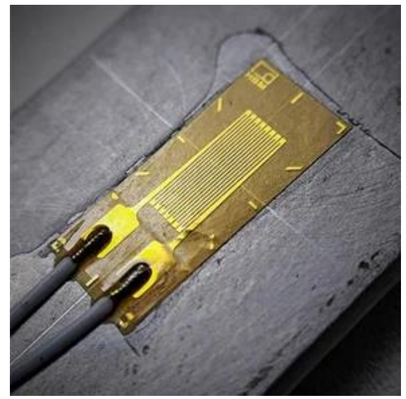
STRAIN GAUGE



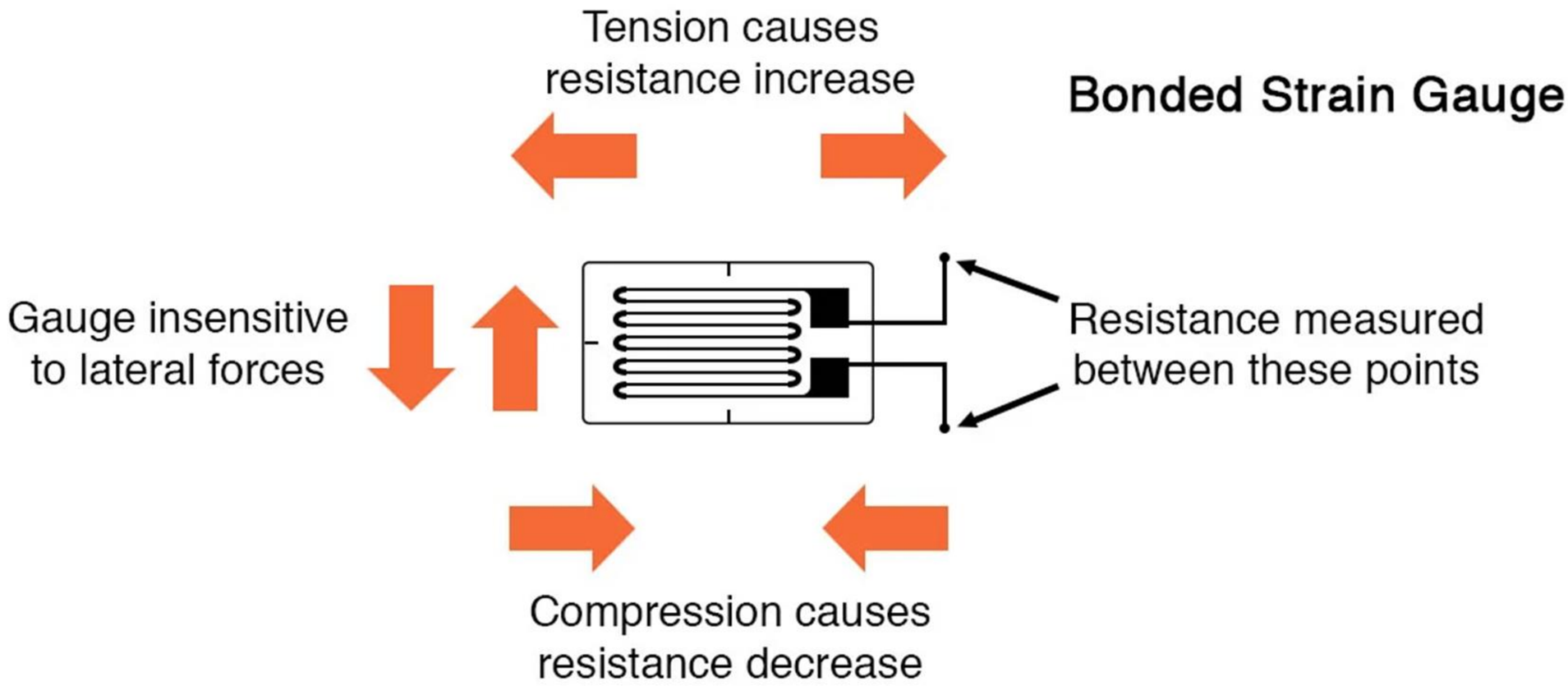
STRAIN GAUGE

- A strain gauge is a device that measures the deformation (strain) of an object when force is applied, through changes in electrical resistance.
- It is a passive transducer which converts a mechanical displacement(compression and elongation) into change of resistance.
- The strain gauge detects minute geometrical changes as resistance changes, which indicate the level of stress on the material.
- The strain gauge is part of a bridge circuit, where it helps detect imbalances in resistance that correspond to stress, measured by a central voltmeter.





STRAIN GAUGE



STRAIN GAUGE

- Each strain gauge is composed of a metal foil insulated by a flexible substrate.
- The two leads pass a current through the gauge, and as the surface of the object being measured stretches or contracts, the change in resistance is measured.
- This change in resistance is proportional to the change in length on the surface of the object being tested.
- Strain gauges work by measuring the change in electrical resistance across a thin conductive foil. The gauge factor (or “gage factor”) is the sensitivity of the strain gauge (usually 2). It converts the change in resistance to the change in length.

$$\frac{\triangle R}{R} = K \cdot \varepsilon$$

Resistance = R(Ω)
Changed resistance = △R(Ω)
Strain = ε
Gage factor = K

STRAIN GAUGE

- As a strain gauge experiences bending, stretching, or twisting, the change in resistance across the metal foil is measured by a Wheatstone bridge.
- The change in resistance that is measured is proportional to the strain experienced by the object. A user can determine the stress experienced by an object using Hooke's law by knowing the material's modulus of elasticity.

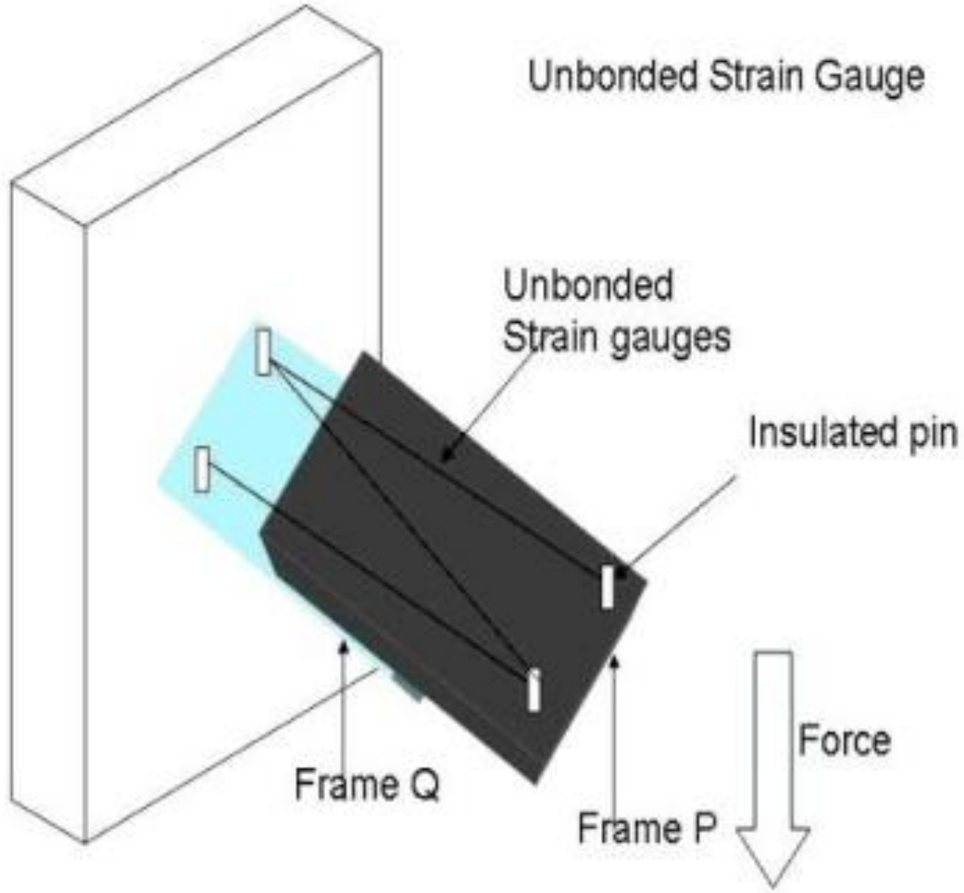
$$\sigma = E \cdot \varepsilon$$

UNBONDED STRAIN GAUGE

- It is a type of gauge in which a wire is stretched in an insulating medium in between two points. The insulating medium can be air. The wire can be made of alloys such as copper-nickel, chrome nickel, nickel-iron having a diameter of about 0.003 mm.
- The gauge factor for this category of the strain gauge is about 2 to 4 and capable to withstand a force of 2MN. These are almost exclusively used in transducer applications where preloaded resistance wires are connected in a Wheatstone bridge configuration.
- The arrangement of unbonded strain gauges consists of the following. Two frames P and Q carrying rigidly fixed insulated pins as shown in diagram. These two frames can move relative with respect to each other and they are held together by a spring loaded mechanism.
- A fine wire resistance strain gauge is stretched around the insulated pins. The strain gauge is connected to a wheat stone bridge.

UNBONDED STRAIN GAUGE

When a force is applied on the structure under study (frames P & Q), frames P moves relative to frame Q, and due to this strain gauge will change in length and cross section. That is, the strain gauge is strained. This strain changes the resistance of the strain gauge and this change in resistance of the strain gauge is measured using a wheat stone bridge. This change in resistance when calibrated becomes a measure of the applied force and change in dimensions of the structure under study.



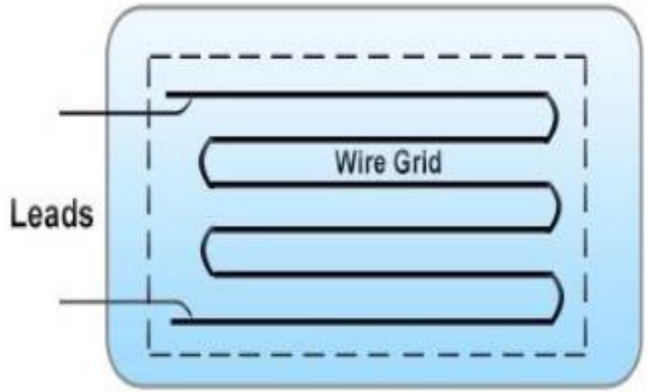
BONDED STRAIN GAUGE

These gauges are directly bonded (that is pasted) on the surface of the structure under study. Hence they are termed as bonded strain gauges. Along with the construction of transducers, a bonded metal wire strain gauge is used for stress analysis. A resistance wire strain gauge has a wire of diameter 0.25mm or less.

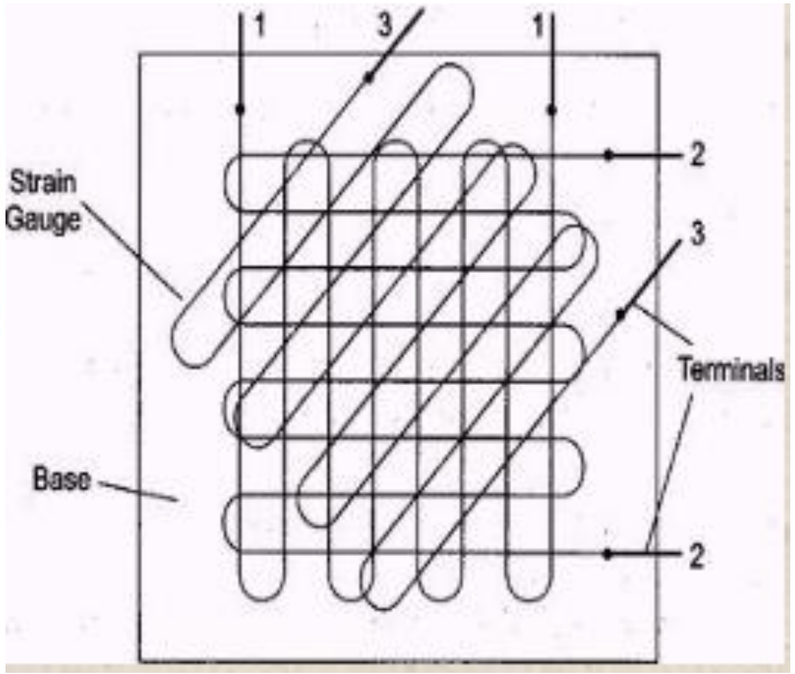
The grid of fine resistance wire is cemented to carrier. It can be a thin sheet of paper, Bakelite or a sheet of Teflon. To prevent the wire from any mechanical damage, it is covered on top with a thin sheet of material. The spreading of wire allows us to have a uniform distribution of stress over the grid. The carrier is bonded with an adhesive material. Due to this, a good transfer of strain from carrier to a grid of wires is achieved.

TYPES OF BONDED STRAIN GAUGE

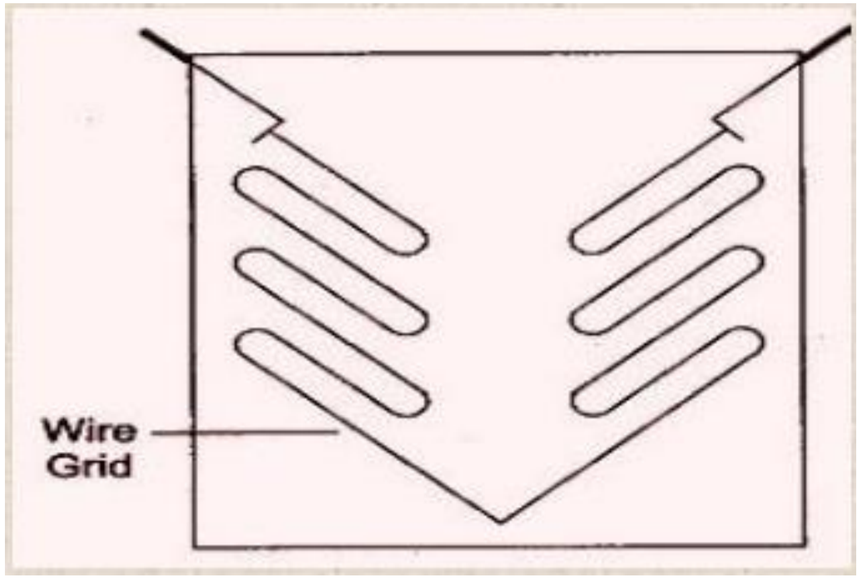
GRID TYPE STRAIN GAUGE



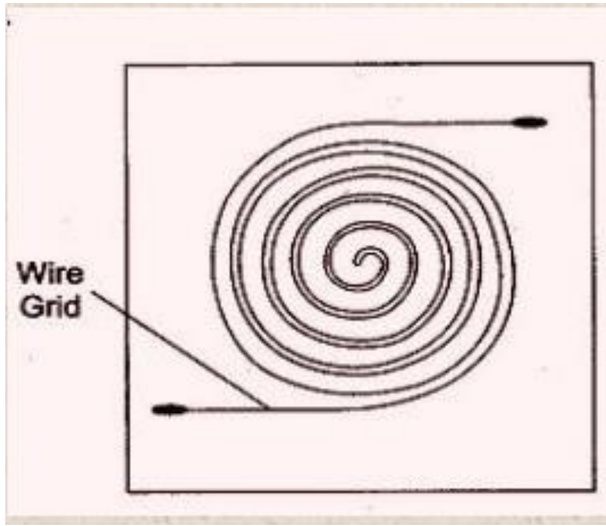
ROSSETTE TYPE STRAIN GAUGE



TORQUE TYPE STRAIN GAUGE

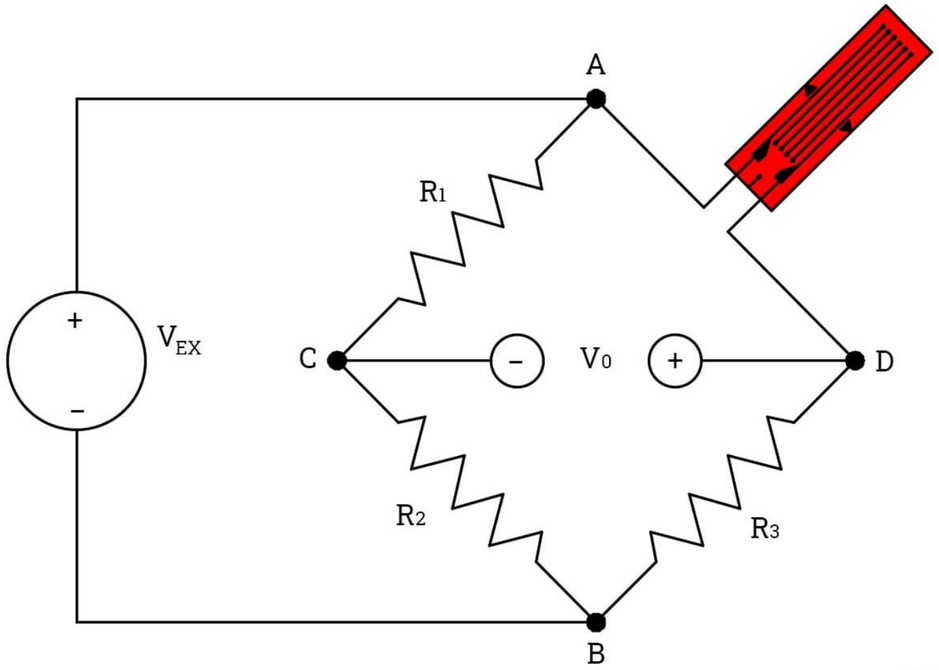


HELICAL TYPE STRAIN GAUGE



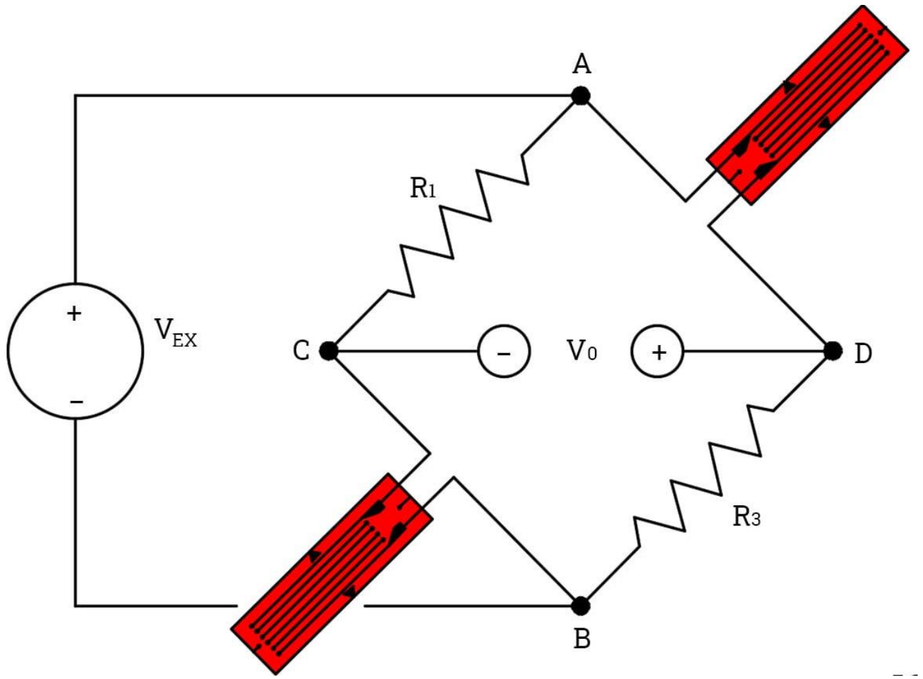
QUARTER BRIDGE STRAIN GAUGE

- This is the simplest among the strain gauge types in this category.
- It is composed of one active gauge and three completion resistors.
- The completion resistor paired with the strain gauge is called a dummy resistor.
- This type is the least sensitive and is prone to errors caused by temperature variations.



DOUBLE QUARTER BRIDGE OR DIAGONAL BRIDGE

- This configuration features two active strain gauges. One strain gauge is placed on one leg of the circuit, while the other is positioned on the second leg.
- These gauges are mounted on opposite sides of the elastic element or structure, oriented parallel to the direction of the applied load.



DOUBLE QUARTER BRIDGE OR DIAGONAL BRIDGE

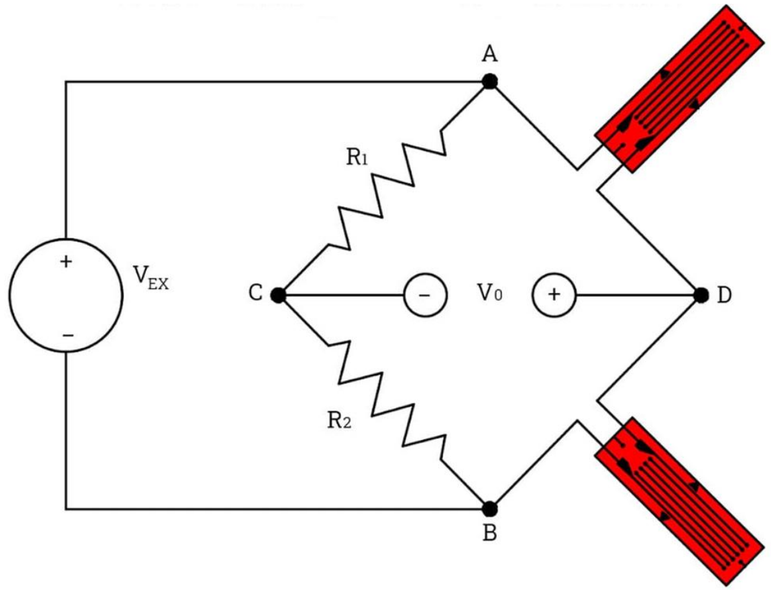
The diagonal bridge design offers two main advantages.

- Firstly, it provides increased sensitivity. Since both strain gauges in this configuration experience the same deformation, the output signal is roughly twice as large as that of a simple quarter-bridge circuit.
- Secondly, it effectively rejects bending strain. Diagonal bridge strain gauges are designed to measure only tensile and compressive strains. If the gauges detect strains in opposite directions, their effects cancel each other out, ensuring accurate measurements as long as the strains are aligned in the same direction.

However, this configuration also has a notable drawback: it is highly sensitive to temperature variations. This sensitivity can double the error introduced by temperature changes. To mitigate this issue, dummy gauges are used in conjunction with each active gauge to compensate for temperature-induced errors.

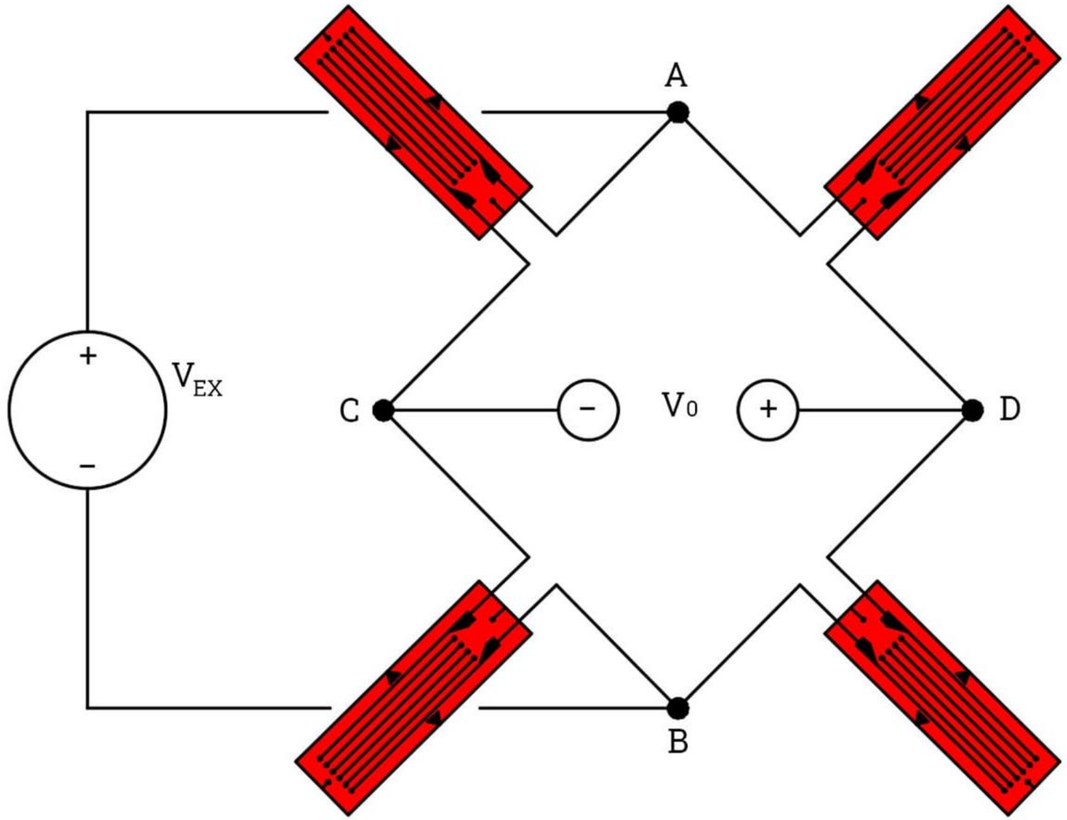
HALF BRIDGE

- Half-bridge circuits use two active strain gauges, making them more sensitive than quarter-bridge circuits due to the presence of two strain-measuring elements. There are two possible configurations for the strain gauges in a half-bridge circuit.
- **Half Bridge with Poisson Gauge**
- **Bending Half Bridge**



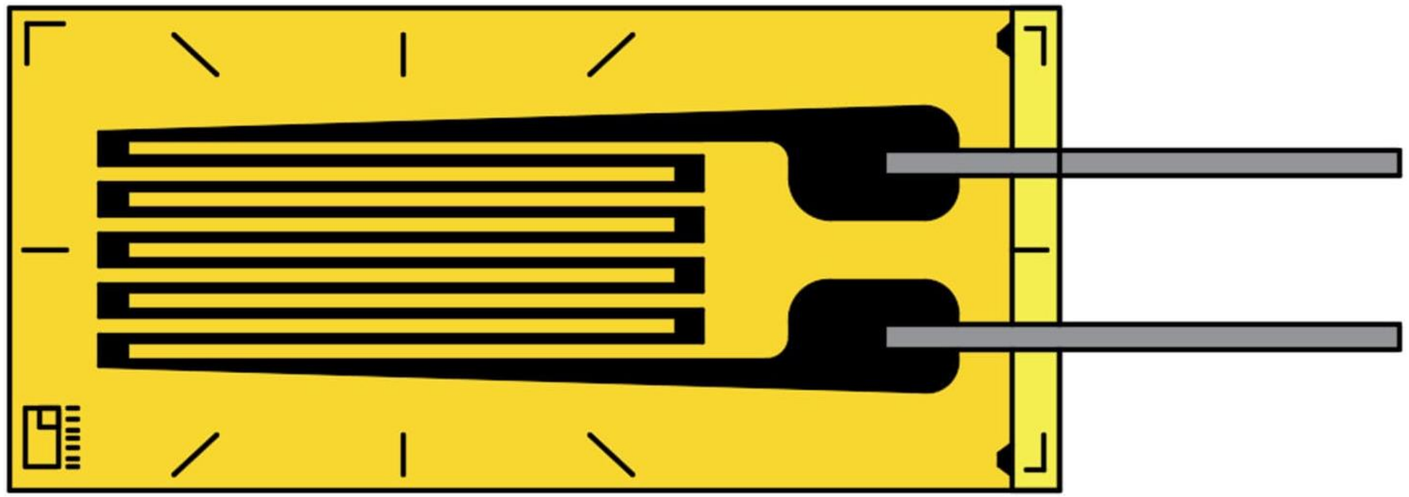
FULL BRIDGE

- A full-bridge circuit utilizes four active strain gauges in place of all resistors, offering high versatility due to the multiple configurations possible.
- Since all resistances are variable, temperature effects are effectively canceled out across the entire circuit, regardless of the specific configuration used.



LINEAR STRAIN GAUGE

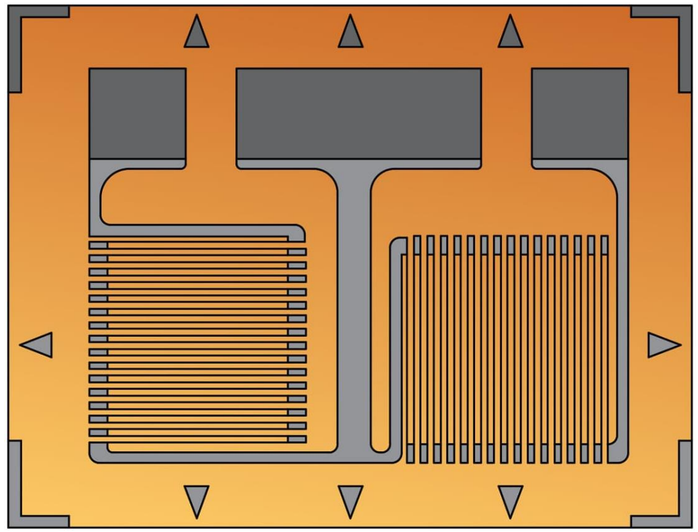
Linear strain gauges measure strain along a single direction. They are characterized by their simple construction and low cost, making them ideal for general applications such as load testing, fatigue testing, and structural integrity monitoring. Linear strain gauges can be used in quarter-bridge, diagonal bridge, or axial full-bridge circuits.



ROSETTE STRAIN GAUGE

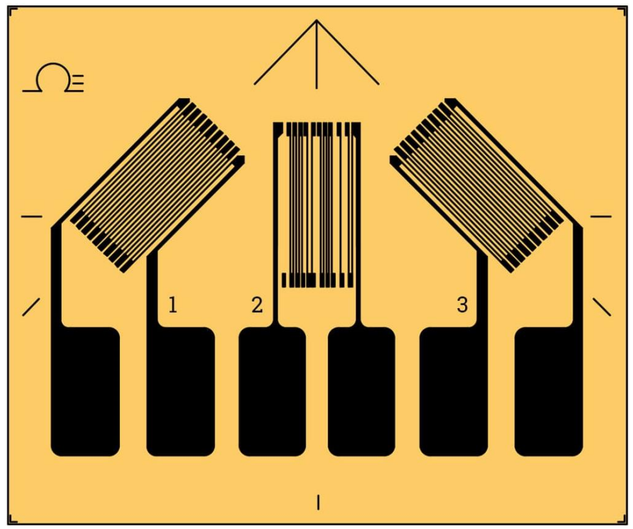
- Rosette strain gauges are made from multiple measuring elements bonded to a common carrier. As the name suggests, the arrangement of strain gauges resembles a rosette or circular pattern.
- They are oriented to have different measuring axes to measure strains generated by biaxial stress conditions.

Tee Rosette Strain Gauges: Sometimes referred to as 90° rosettes, these strain gauges are composed of two measuring elements oriented perpendicularly with each other. They are used in applications where the principal strain directions are known. One measuring element is aligned with the direction of a strain. 90° Rosette strain gauges can be configured into half bridge circuits. Full bridge circuits can also be created by using multiple rosettes.

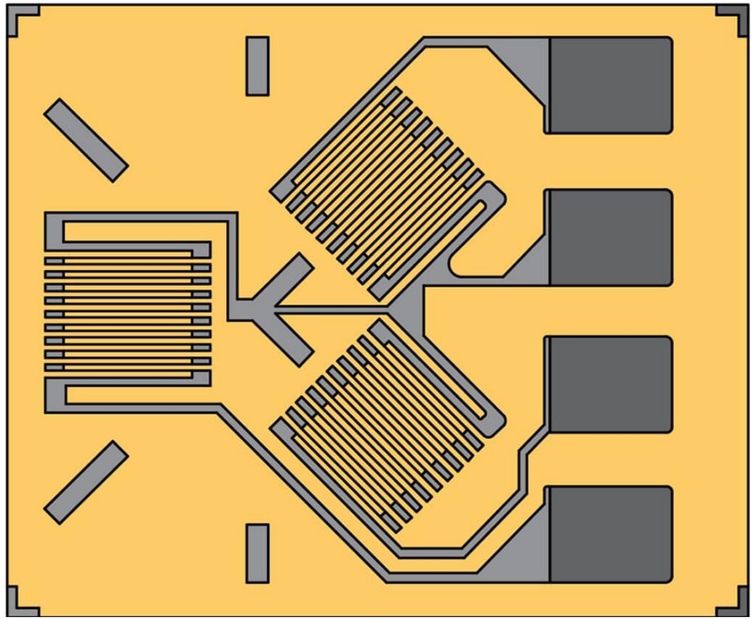


ROSETTE STRAIN GAUGE

Rectangular Rosette Strain Gauges: These rosette strain gauges have three measuring elements crossed at 0°/45°/90°. They are used when the principal strain directions are unknown.

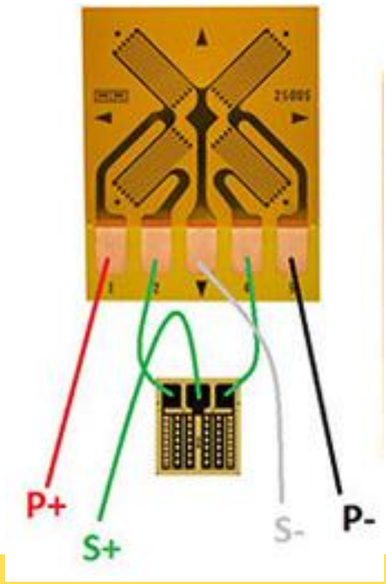


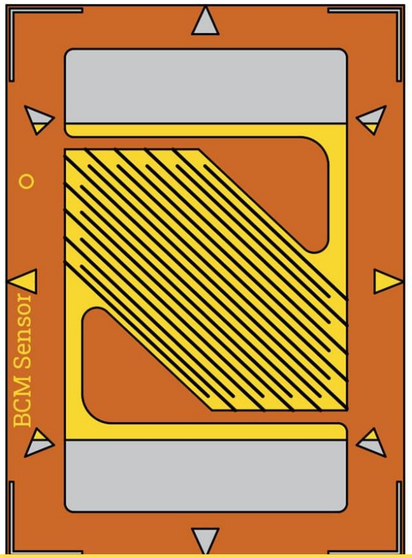
Delta Rosette Strain Gauges: Like rectangular strain gauges, they are also used when the principal strain directions are unknown. The measuring elements are aligned at 0°/60°/120°.

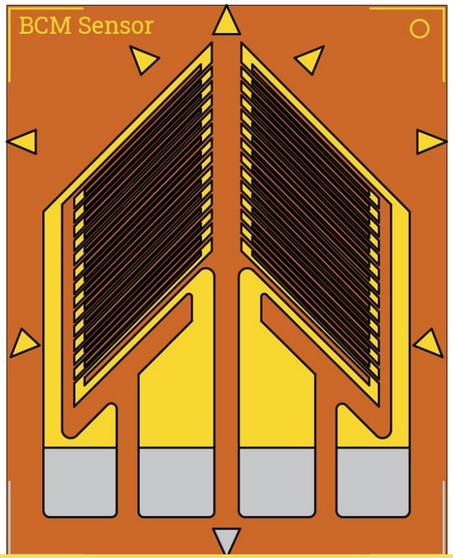


SHEAR STRAIN GAUGE

Shear strain gauges are designed to measure shear strain resulting from torque or torsional loading. They can feature either one or two measuring grids attached to a single carrier. In a single-grid configuration, the strain gauge element is oriented at a 45° angle relative to the shaft axis. A two-grid shear strain gauge, also known as a V Rosette, has measuring elements set at 45° and 135°. These gauges are commonly used in applications such as engine shafts and drivetrains, where they can be used to calculate shaft power based on strain measurements.

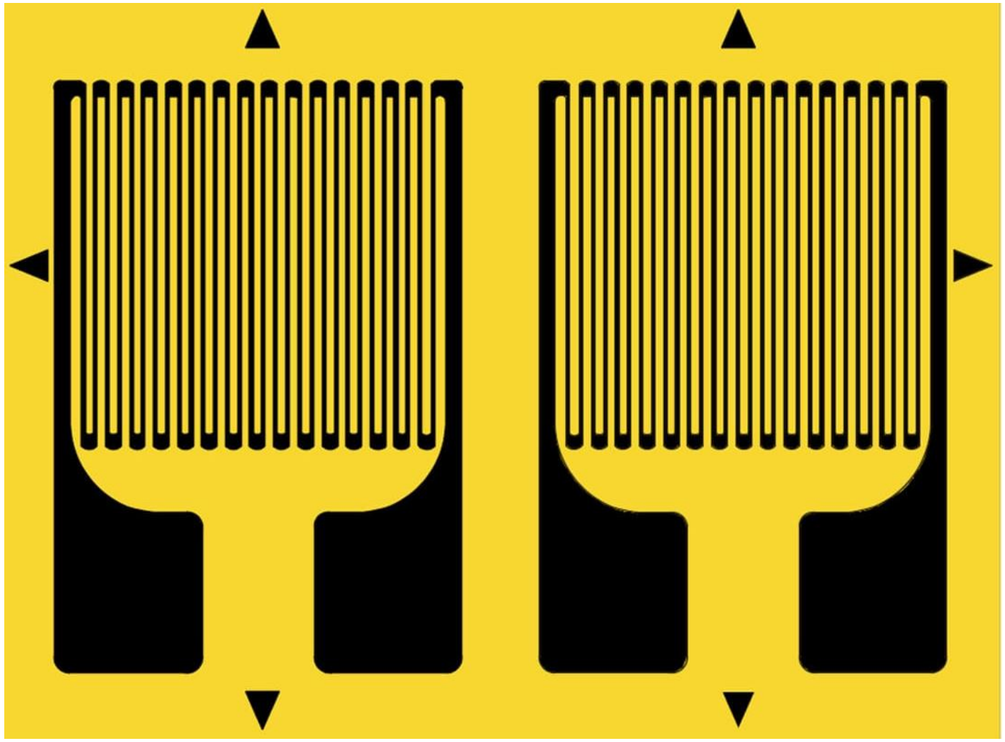






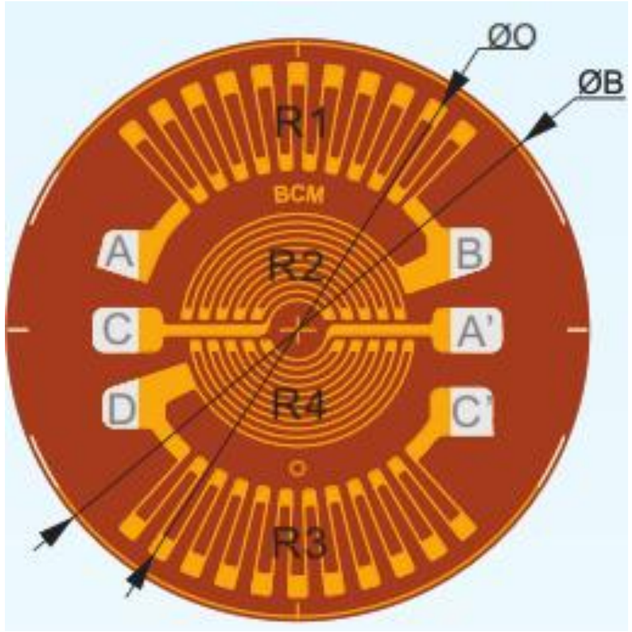
DOUBLE PARALLEL STRAIN GAUGE

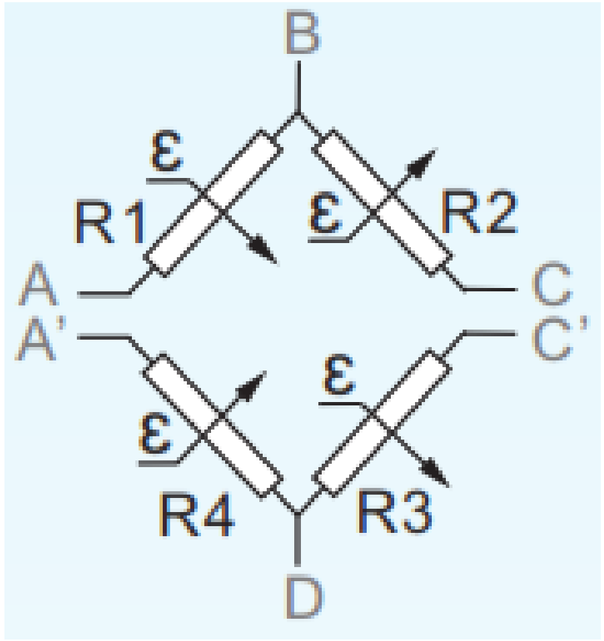
This type consists of two linear strain gauges arranged in parallel. They can be utilized with various bridge circuit configurations. A common example is the bending full-bridge circuit, where two parallel strain gauges are positioned on opposite sides of the structure.



DIAPHRAGM STRAIN GAUGE

Diaphragm strain gauges measure radial and tangential strains in structures such as columns, beams, or shafts. They are commonly arranged in a full-bridge circuit. The four measuring elements are typically configured in either circular or linear patterns. Tangential elements are placed near the periphery of the carrier, while radial elements are bonded closer to the center.





References

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Thank You