UNIT-2 MPHYEC-1F

TRANSDUCER

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Definition of Temperature Transducer

A Temperature Transducer is a device that converts the thermal quantity into any physical quantity such as mechanical energy, pressure and electrical signals. E.g. In Thermocouple the electrical potential difference is produced due to temperature difference across its terminals. So, thermocouple is a temperature transducer.

Main Features of Temperature Transducers

- The input to them are always the thermal quantities
- They generally converts the thermal quantity into electrical quantity
- They are usually used for the measurement of the temperature and heat flow

Basic Scheme of Temperature Transducers

The basic scheme of temperature transducers is given below in following steps:

Sensing Element

The sensing element in the **temperature transducers** is the element whose properties change with change in temperature. As the temperature changes the corresponding change occurs in certain property of the element. Example- In the Resistance Thermometers the sensing element is the Platinum metal.

Desirable Conditions for Choosing the Sensing Element are as

- Change per unit resistance of material per unit change in temperature should be large
- The material should have a high resistivity so that minimum volume of material is used for its construction

- The material should have continuous and stable relationship with temperature
- Transduction Element
  It is the element that transforms the output of the sensing element into electrical quantity. The change in the property of the of sensing element acts as the output for it. It measures the change in the property of sensing element. The output is of transduction element is then calibrated to give output which represents the change in the thermal quantity.

Example- In the thermocouple the potential difference produced across the two terminal is being measured by voltmeter and magnitude of voltage produced after calibration gives idea of change in temperature.

Types of Temperature Transducers

Contact Temperature Sensor Types

In these the sensing element is in direct contact with the thermal source. They use the conduction for transfer of thermal energy.

Non-contact Temperature Sensor Types

In these the sensing element is not in direct contact with the thermal source. They use principle of convection for heat flow. Various temperature transducers that are generally used are as:

Thermistor

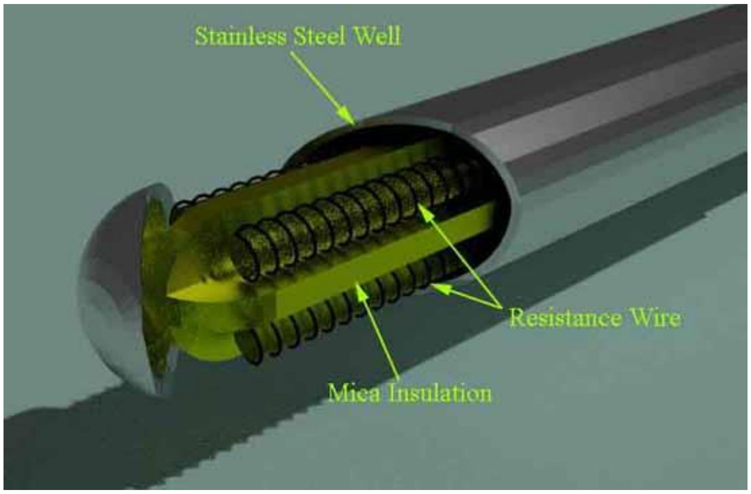
The word thermistor can be termed as Thermal Resistor. So as the name indicates it is a device whose resistance changes with the change of the temperature. Due to their high sensitivity they are widely used for the measurements of the temperature. They are usually called the ideal temperature transducer. Thermistors are generally composed of mixture of metallic oxides.

Properties of Thermistors: They have Negative Thermal Coefficient i.e. resistance of the thermistor decreases with increase in temperature

They are made up of the semiconductor materials
They are made sensitive than RTD (Resistance Thermometres) and Thermocouples
Their resistance lies between 0.5Ω to 0.75 MΩ
They are generally used in applications where measurement range of temperature is -60 ^{o}C to 15 • ^{o}C.

Resistance Thermometers

Another type of **temperature transducer** is the Resistance Temperature Detector or RTD. RTD's are precision temperature sensors made from high-purity conducting metals such as platinum, copper or nickel wound into a coil and whose electrical resistance changes as change of temperature, similar to that of the thermistor.



Their resistance changes with following relation as,

$$R = R_o(1 + \alpha\Delta T)$$

R = Resistance of element at given temperature
α = Thermal coefficient of element
R_o = Resistance of element at 0^{o}C

Main Features of RTD's

They are highly sensitive and very cheap as compared to thermistors and thermocouples. Moreover they can measure the temperature from -182.96 ^{o}C to 630.74 • ^{o}C

Thermocouples

Thermocouples are temperature transducers that are basically consists of two junctions of dissimilar metals, such as copper and constantan that are welded. One junction is kept at a constant temperature called the reference (Cold) junction, while the other the measuring (Hot) junction. When the two junctions are at different temperatures, a voltage is developed across the junction which is used to measure the temperature.

Principle of Thermocouple

When the junctions of two metals such as copper and constantan are connected together the potential difference is produced is produced between them. The phenomenon is called the Seebeck effect as a temperature gradient is generated along the conducting wires producing an emf. Then the output voltage from a thermocouple is a function of the temperature changes.

Main Features of Thermocouples

Extreme temperatures of range between -200^{o}C to over +2000^{o}C can be measured with thermocouples which is an advantage over both RTD and Thermistor

They are the Active Transducers so they don’t require any external source for measuring of temperature as like RTD’s and Thermistors.

They are the cheaper than both RTD’s and Thermistors.

These have small accuracy as compared to RTD’s and Thermistors so generally they are not used for high precision work.

Integrated Circuit Temperature Transducers

These are the temperature transducers which use the temperature sensing element with monolithic electronic circuits as a combination for the measurement of temperature.
They have following type

- LM 335 – it provides an output of 10 mV/^{o}K
- LM 34 – it provides an output of 10 mV/^{o}F
- AD 592 – it provides a current output of 1µA/^{o}K

Vacuum sensors

Vacuum sensors are used to measure vacuum or sub-atmospheric pressures. Vacuum means pressure below atmospheric. Since true vacuum is never attained, the measurement is in respect to a near absence of gas pressure. Vacuum can be measured using a conventional pressure sensor; however they typically do not resolve extremely low concentrations of gas due to poor signal- to-noise ratio. Vacuum sensors rely on physical properties of gaseous molecules that are related to the number of such molecules per volume of space.

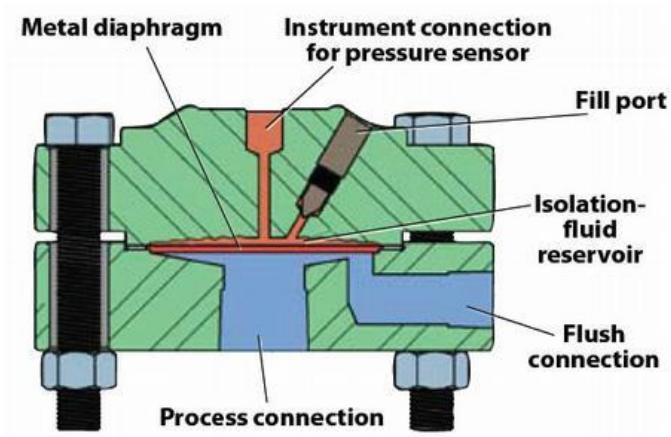
Vacuum Sensor Designs

Sensors that work in the vacuum range use some kind of physical displacement or material property change in order to make a measurement. Medium to high vacuum sensors use properties of the environment, such as thermal conductivity and ionization, to make a measurement.

Low Vacuums

Low vacuums can be measured using mechanical means such as those listed below.

Piston technology uses a sealed piston/Cylinder to measure changes in pressure. **Mechanical deflection** uses an elastic or flexible element to mechanically deflect with a change in pressure, for example a diaphragm, Bourdon tube, or bellows.



Piezoelectric pressure sensors measure dynamic and quasi-static pressures. The bi-directional transducers consist of metalized quartz or ceramic materials which have naturally occurring electrical properties. They are capable of converting stress into an electric potential and vice versa.

Micro Electro Mechanical systems (MEMS) are typically micro systems manufactured by silicon surface micromachining for use in very small industrial or biological systems.

Vibrating elements (silicon resonance) use a vibrating element technology, such as silicon resonance.

Variable capacitance pressure instruments use the capacitance change results from the movement of a diaphragm element to measure pressure. The device uses a thin diaphragm as one plate of a capacitor. The applied pressure causes the diaphragm to deflect and the capacitance to change. The deflection of the diaphragm causes a change in capacitance that is detected by a bridge circuit. Capacitive absolute pressure sensors with a vacuum between the plates are ideal for preventing error by keeping the dielectric constant of the material constant.

Strain gauges (strain-sensitive variable resistors) are bonded to parts of the structure that deform as the pressure changes. Strain gauges are rugged, accurate, and stable, they can operate in severe shock and vibration environments as well as in a variety of pressure media. Strain gauge pressure transducers come in several different varieties: the bonded strain gauge, the sputtered strain gauge, and the semiconductor strain gauge.

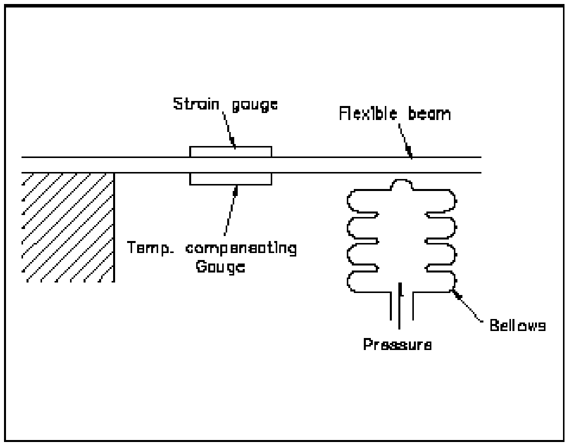


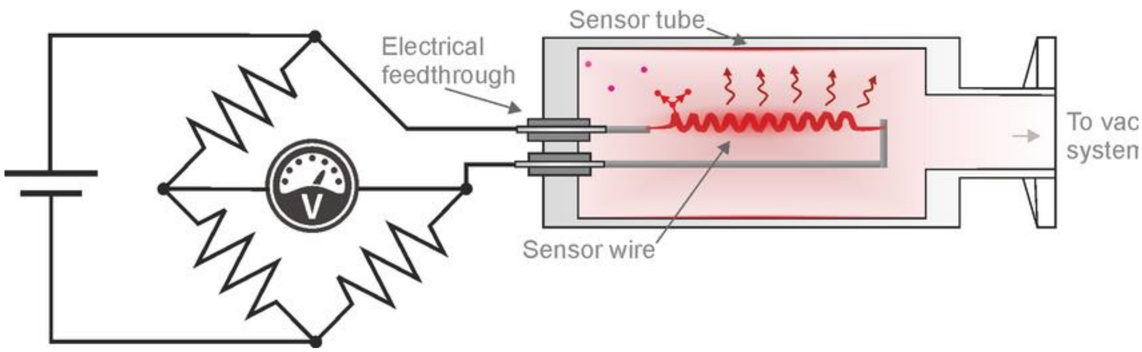
Figure 4 Strain Gauge Pressure Transducer

Semiconductor piezoresistive sensors are based on semiconductor technology. The change in resistance is not only because of a change in the length and width (as it is with strain gage) but because of a shift of electrical charges within the resistor. There are four piezoresistors within the diagram area on the sensor connected to an element bridge. When the diaphragm is deflected, two resistors are subjected to tangential stress and two to radial stress.

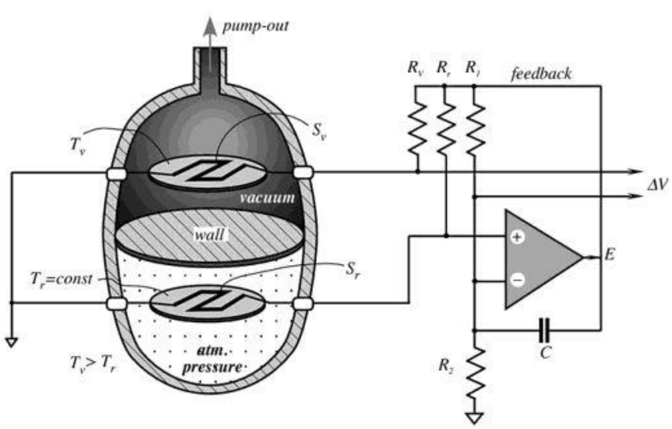
Medium-High Vacuums

At medium and high vacuums it is more accurate to measure vacuum with thermal and molecular devices.

Thermal conductivity - The thermal conductivity of gas is measured using a Pirani gauge.



It is a simple device that contains a heated plate and measures the amount of heat lost by the plate. The amount of heat lost depends on the gas pressure. There are several designs of the Pirani gauge. One design includes using two plates with different temperatures. The amount of power spent for heating is the measure of gas pressure. Another design uses a single plate to measure the thermal conductivity of gas by heat loss to the surrounding area. The gauge in the image below uses a thermal balance technique by dividing the sensing chamber into two sections and filling one with gas at a reference pressure and the other is connected to the vacuum that is being measured. Each of the chambers is the same size, shape, and construction and contains a single heated plate. The temperature measure is done with a thermocouple.



Ionization gauge Vacuum gauges which use ions are similar to vacuum tubes. The relationship between the ion current and the filament is a nearly linear function of molecular density (pressure). The operating principle is the same as a vacuum tube gauge. However, the plate is substituted by the wire surrounded by a grid, while the cathode filament is outside. There are two types available: hot cathode and cold cathode. The main difference between the two types is their method of electron production. Cold cathode devices draw the electrons from the electrode surface by a high potential field.

Additional Pressure Readings

Many vacuum sensors can perform additional pressure readings such as absolute, differential, gauge, compound, and sealed pressure.

- **Absolute pressure** is a pressure measurement relative to a perfect vacuum.
- **Differential pressure** is the difference between two input pressures.
- **Gauge pressure** is the pressure measured above the local atmospheric pressure. It is the most common pressure measurement.
- **Positive and negative** (vacuum) pressures can be measured using a compound vacuum sensor.
- **Sealed gauge pressure** is relative to one atmosphere at sea level (14.7 psi), regardless of local atmospheric pressure.

Operating temperature is another important element to consider when selecting a vacuum sensor. Operating temperature is the full-required range of ambient operating temperature. Temperature and pressure are directly related to each other. If the temperature of the operating environment increases the pressure in the system will increase. In order to prevent equipment damage, it is important to know the extreme temperature ranges of the area.

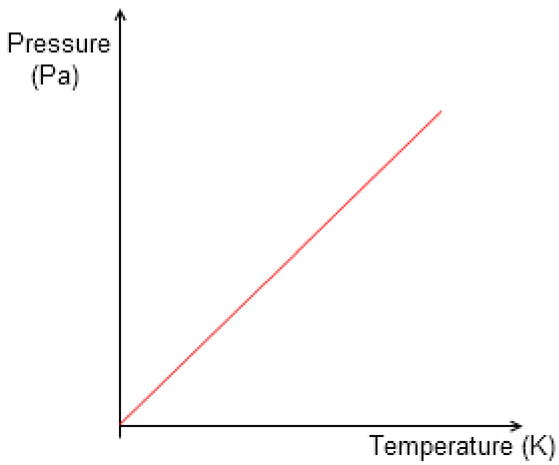


Fig: **Temperature and Pressure Relationship.**

Features

Vacuum sensors provide features such as:

- **TTL-compatible switches** are compatible with transistor-transistor logic.
- **Built-in audible or visual alarms** that signal when the switch or sensor has been turned on or off. This is important when the vacuum pressure of a system needs to be closely monitored.
- **Temperature measurement outputs** allow the user to observe the temperature of the system and adjust temperature and/or vacuum level as needed.
- **Temperature compensation** includes built-in factors that prevent pressure measurement errors due to temperature changes.
- **Negative pressure outputs** are available only with vacuum sensors that provide differential pressure measurements.

Applications

Applications for vacuum sensors include

- Chemical processing
- Freeze drying
- Helium leak
- Detection
- Sterilization
- Lamp, lighting, and laser products
- Cathode ray tubes (CRT)
- Electron microscopes
- High energy physics
- Optical, functional, and plasma-enhanced deposition
- Gas delivery manifolds Mechanical vacuum pumps
- Mass spectrometers
- Metallurgical processes