

A Field Guide to Understanding Pressure Transducers

Section I

Basic Theory of Pressure Transducers

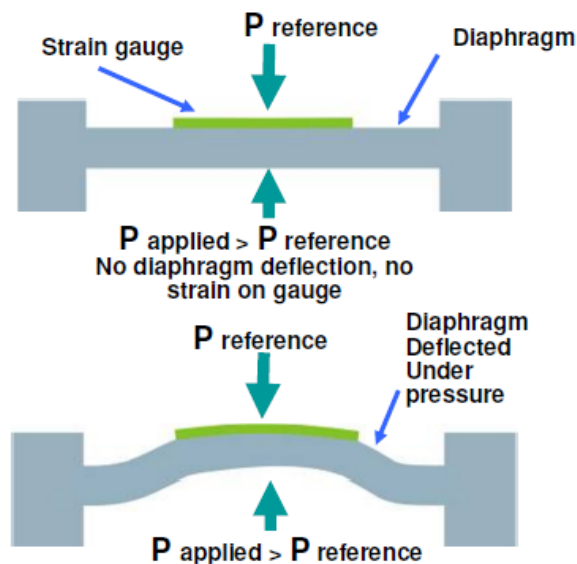
A pressure transducer is a device which converts an applied pressure into a measurable electrical signal which is linear and proportional to the applied pressure.

A pressure transducer consists of two main parts: an elastic material which will deform when exposed to a pressurized medium and an electrical device which detects the deformation and converts it into a usable electrical signal.

The elastic material can be formed into many different shapes and sizes depending on the sensing principle and range of pressures to be measured. This often involves a diaphragm combined with an electrical device that uses a *resistive, capacitive, or inductive* principle of operation.

Resistive Pressure Transducer (Strain Gauge)

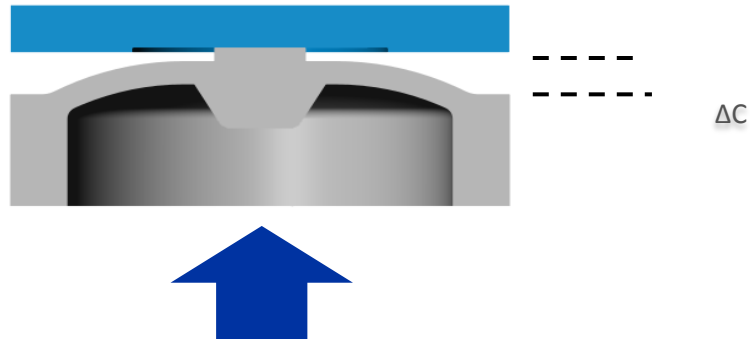
A resistive pressure transducer has strain gauges bonded to the surface of the non-media contacted side of the diaphragm so that any change in pressure will cause a momentary deformation of the elastic material resulting in a change of the resistance of the strain gauge that is converted into a useable electrical signal.



Capacitance Pressure Transducer

A variable capacitance pressure transducer has a capacitive plate (diaphragm) and another capacitive plate (Electrode) fixed to an unpressurized surface gapped a certain distance from the diaphragm (C_s - starting capacitance). A change in pressure will widen or narrow the gap

between the two plates which varies the capacitance (ΔC). This change in capacitance is then converted into a usable signal for the user.



Inductive Pressure Transducer

An inductive pressure transducer uses the principle of inductance to convert the flexing of a diaphragm into the linear movement of a ferromagnetic core. The movement of the core is used to vary the induced current generated by an AC powered primary coil on another secondary pick-up coil. This change in capacitance is then converted into a usable signal for the user.

Section II –

Standard Pressure Units and Measurement Types



Within the industry there are three major pressure datum's that you will need to understand for your given application; *absolute*, *differential*, and *gauge* pressure. Each area of the world uses a different unit of measure depending mostly on regionality as well as the magnitude of the measurement. The most common units of measure are Pounds Per Square Inch (PSI) and Bar (B)

for higher pressure ranges and Inches of Water Column (“WC) and Pascal (Pa) for lower pressure ranges (for a list of common units and conversions please go to [Setra Conversion Tool](#)).

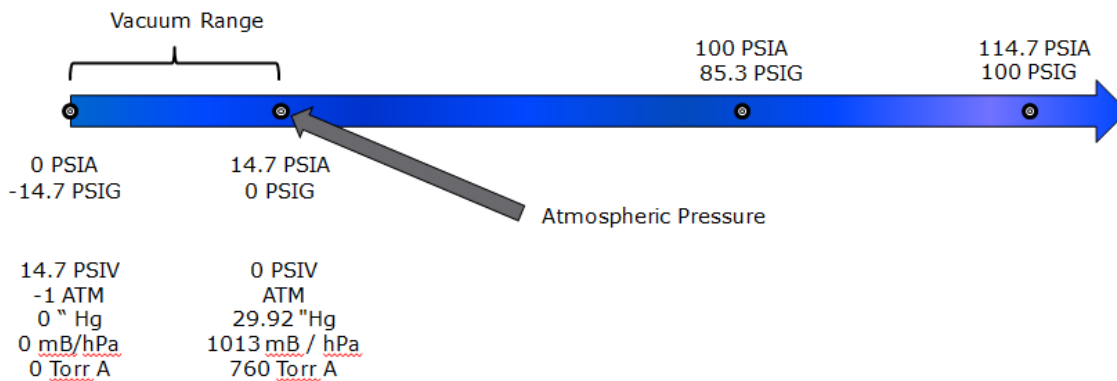
When the unit of measure and the pressure datum are combined it gives the user a more complete description of what is going on or what is needed in the application. The pressure datum is typically depicted as a suffix to the unit of measure.

Absolute pressure is measured relative to a perfect vacuum. A common unit of measure is pounds per square inch absolute (PSIA).

Differential pressure is the difference in pressure between two points of measurement (measured relative to a reference pressure). This is commonly measured in units of pounds per square inch differential (PSID).

Gauge pressure is measured relative to current atmospheric pressure. Common measurement units are pounds per square inch gauge (PSIG - also PSIC for compound or PSIV – Vacuum are also commonly used gauge measurements)

Understanding the difference between gauge and absolute pressure is critical for most applications. Remember that gauge pressure is measured relative to current atmospheric pressure (subject to change with changes in the barometric pressure) and that absolute pressure is measured relative to a perfect vacuum. Thus, your application will determine which of these approaches is required. For comparison so some common units of measure please see the pressure line below:



Also, with the pressure datum known as “gauge pressure” there are three main categories:

Vented to Atmosphere (PSIG)

Sealed (PSIS)

Vacuum (PSIV)

Sealed gauge pressure measurements are by definition still a gauge reference. The term sealed

refers to the fact that whatever the factories atmospheric pressure on the date of manufacture is sealed inside of the sensor body and used as the reference of the back side of the diaphragm. A sealed gauge sensor can provide additional protection from water/humidity ingress, but it does come with some drawbacks. The major drawback is the trapped volume of air is sealed in and becomes is sensitive to temperature changes; both ambient and pressure media. When sealing a volume of air in a chamber the “Ideal Gas Law” presents challenges that are unavoidable.

When talking about the ideal gas law as it pertains to a sealed gauge pressure transducer, the trapped volume of air expands or contracts with temperature changes and has a direct effect on the force applied on the backside of the diaphragm. The initial force on the back side of the diaphragm increases or decreases based on the direction of the temperature change. The lower the pressure range the greater the impact it has on the sensors overall accuracy. The higher the full scale pressure range is the less of an affect it will have accuracy, making it a viable solution to a humid or moist environment.

Vacuum gauge pressure measurements are also by definition still a gauge reference. The term vacuum refers to the fact that starting pressure for the analog output is at the current day’s atmospheric pressure and the application is pulling pressure below atmospheric pressure (i.e. a vacuum pump for a dental vacuum system that removes liquid from a patient’s mouth during a procedure). These vacuum ranges should not to be confused with absolute style sensors (refer back to the pressure line example above).

There are also Compound Pressure Sensors. Simply put, a compound gauge referenced sensor is a device that can sense both positive and negative (vacuum) pressures. These units still however have an atmospheric pressure reference. If your application is going to be subject to both positive and negative vacuum pressures, you may want a compound gauge pressure transducer so you are aware of the magnitude of those pressure ranges.

Now that you understand HOW pressure is measured – Absolute, Gauge (Sealed or Vacuum) and Differential – it is important to understand that many of today’s pressure transducers can handle a variety of applications by providing multiple measurement reference points.

For example, Setra’s Model 209 can handle pressure ranges from 1 to 10,000 psig in gauge, sealed gauge or vacuum pressures.

When evaluating sensors, knowing what type of pressure you are trying to measure is half the battle. Your specific application or product design will be directly affected by this early decision. If you have any questions, please feel free to contact your sensor manufacturer for understanding.

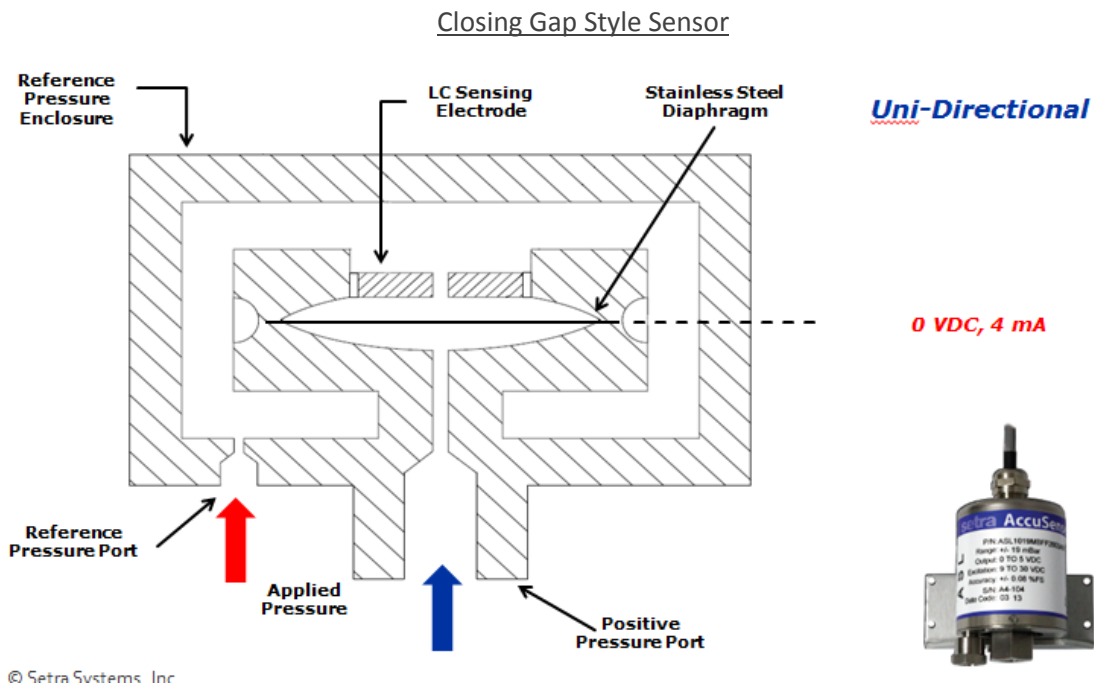
Section III

Capacitance versus Thin Film Strained Gauge

Not all sensors are created equal. As technology advances hit the sensor market, we've seen an increased use of what's called "Thin film strained gauge" sensors. Understanding the difference between a capacitance sensor and thin film strained gauge may be helpful during your evaluation process.

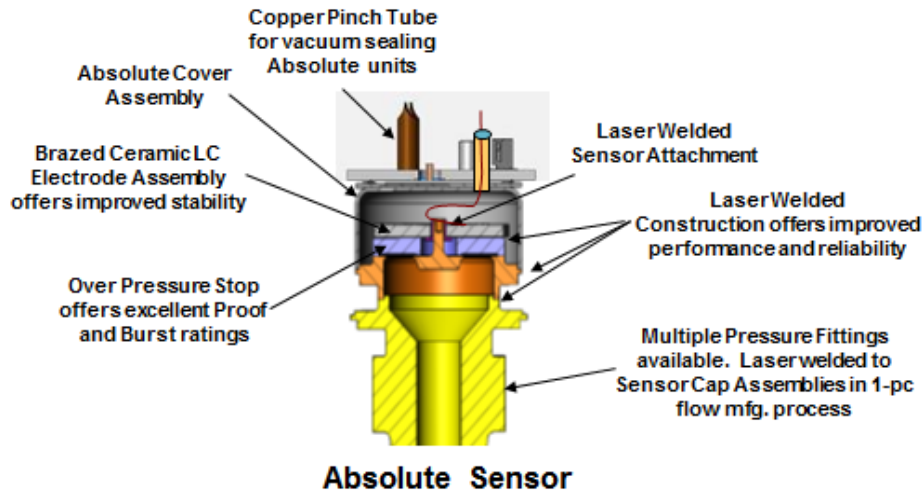
Capacitance

The capacitance changes as the diaphragm moves away or towards the sensing electrode:



Thus, a gap increase equals a capacitance change. In an analog sensor the sensor measures the change in capacitance (ΔC) and translates this into the relative change in pressure (ΔP) based on full scale range of the unit. In a digital sensor the change in capacitance is directly proportional to a change in frequency pulses that are proportional to that change in capacitance. This advance allows for some improved sensor performance and improved immunity to outside factors vs. earlier capacitance designs.

Opening Gap Style Sensor



With Variable Capacitance:

- Sensor housing contains two closely spaced, parallel, electrically-isolated metallic surfaces, one of which is a diaphragm capable of slight flexing under applied pressure
- Diaphragm is constructed of low hysteresis material (i.e. 17-4 pH SS), or proprietary compound of fused glass, conductor (i.e. Gold) and ceramic
- Plates are mounted so that a slight mechanical flexing of the assembly, caused by a change in applied pressure, alters gap between them; either opening or closing gap (creating a variable capacitor)

Advantages include:

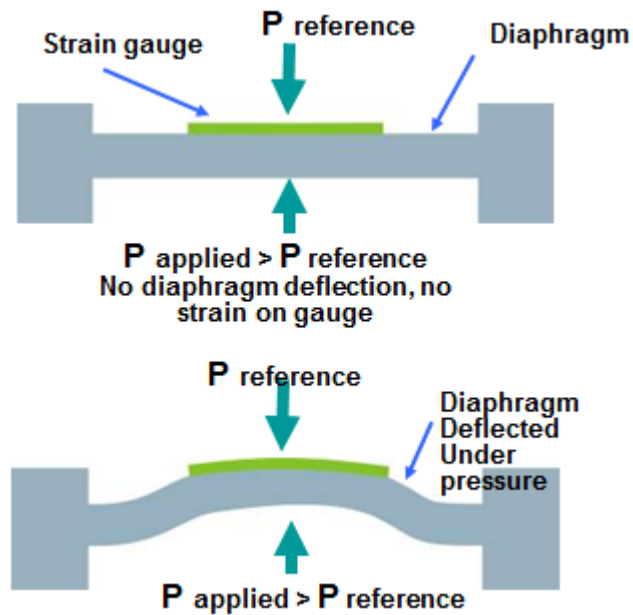
- Suitability for absolute, gauge, sealed gage, vacuum, and differential sensing applications
- Ideal for lower-pressure applications
- Performs well in applications that are susceptible to over-pressurization
- Very good hysteresis, linearity, stability, and repeatability, in addition to static pressure measurement capability

Disadvantages include:

- If misused in an application can be sensitive to particulate and humidity in the capacitive gap. This alters the di-electric area and can short out the capacitive gap if the humidity condenses or the particulate is too large.

Thin Film Strain Gauge

Strain gauge is built upon the backside of the pressure sensing diaphragm. It uses what's called a "sputtering" process to place an atomic-level bond onto the surface of the diaphragm. This produces a highly stable output.



With thin film:

- Sensing element is formed by machining the inside of a stainless-steel button until the remaining steel is very thin
- Strain gauge material is deposited onto steel diaphragm forming a Wheatstone-bridge resistor network
- Strain transfers to the resistors as pressure is applied to the back of the element unbalancing bridge and thus causing a resistance change that is multiplied to provide a high level output (volts, millivolts, or current)

The advantages of thin film strain gauge sensors include:

- Overpressure protection
- Better effective resolution
- Excellent resistance to shock, vibration, and dynamic pressure changes.

- Pressure sensor is usually welded to the pressure connection = hermetically sealed measurement cell that does not require any additional sealing materials

Disadvantages include:

- Properties of film dictate stability of the sensor output
- Sensor element materials have varying degrees of temperature/humidity stability

Media Isolated MEMS uses a similar fabrication process to thin film, but uses a silicon wafer rather than a steel diaphragm. The sensing element is isolated from media via an oil-filled chamber. This can make for most cost-effective sensors, but the oil-filled cavity can leak, which will create serious sensor instability and contamination of process.

Section IV –

Practical Applications

Absolute Measurements

Absolute measurements are generally used in applications where you need a repeatable reference pressure; i.e. in an experiment or in a barometric application. For example if you are looking to replicate a test that was originally completed by a colleague in Denver, CO and you are at a facility in Boston, Ma you may want to use an absolute sensor to minimize variables in your test. Other applications include weather stations, altimeter calibration equipment, and semiconductor fabs and many more. However, if you want to measure or control a pressure that is based on current conditions a gauge sensor may be best.

Gauge Measurements

Generally, if you want to measure or control a pressure that is influenced by changes in atmospheric pressure. This style sensor is used in any application where you want to overcome the atmospheric conditions to produce a task or pull a vacuum to accomplish another type of task. The applications for gauge pressure sensors are quite vast. Some examples are pump discharge pressure, fire hose discharge pressure, tank level, steam pressure in a commercial boiler and many more.

Compound Pressure Sensors

A sensor capable of compound pressure measurement is one that can measure both positive and negative (vacuum) pressures. Often compound pressure ranges are utilized in applications where different parts of a process may either be higher or lower than atmosphere. For example if you were a manufacturer of a collapsible water bottle, in one part of the process you may pressurize a mold to form the bottle, but then pull a vacuum to release the part. In this case you may be able to use only one sensor instead of two to accomplish the same task.

Differential Pressure Sensors

Remember that *Differential pressure* is the difference in pressure between two points of measurement. You can measure very low to high pressures in all kinds of different media including liquids, gases, water, refrigerants and air.

Thus, if you want to measure the difference in pressure across a filter (see below), you could use a differential pressure transducer like Setra's Model 269 to tell you when it was time to change the filter so you can maintain the Indoor Air Quality (IAQ) of your building. Differential applications can be quite varied, some examples are supply and return pressure in a chiller, air flow stations, leak detection systems, pressurized tank level, hospital isolation or protection rooms, and many more.

