First Sensor is now part of TE connectivity

LDE/LME/LMI series: Application advantages

Application note

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1. Measuring principle

The LDE/LME/LMI differential pressure sensors from First Sensor measure ultra-low air or gas pressures from 25 Pa (0.1 in H_2O) full scale. The sensors are based on a new and innovative MEMS technology which integrates a microflow channel within the silicon sensor chip.

At the same time the sensors use the proven principle of inferring differential pressure from a thermal mass flow measurement **(Figure 1)**. A heating element is located between two temperature sensitive resistors. A gas flow transfers heat from the upstream to the downstream resistor causing a temperature difference between them and as a result, a voltage signal proportional to mass flow is generated. Because the flow is caused by the pressure difference between the two sensor ports, the output signal is also a measure of the applied differential pressure.

Figure 2 shows the unamplified output of a basic LDE/LME/LMI sensing element as a function of differential pressure. The LDE/LME/LMI technology features high dynamic ranges and high sensitivities for low pressures especially around zero. The sensors offer digital signal conditioning for calibration, temperature compensation and amplification. They can be optimized to different application requirements depending on whether a high sensitivity, a high dynamic range or a linear output signal is needed.

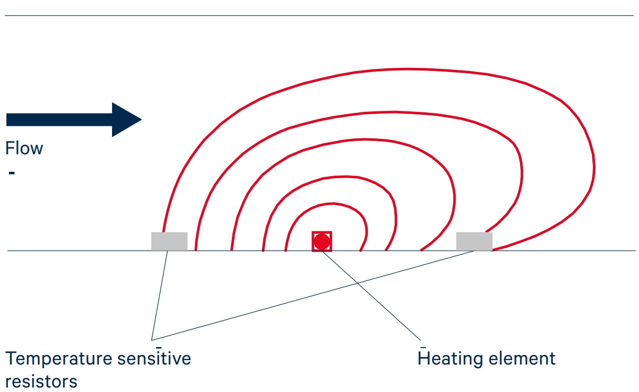

Figure 1 Principle of thermal mass flow measurement

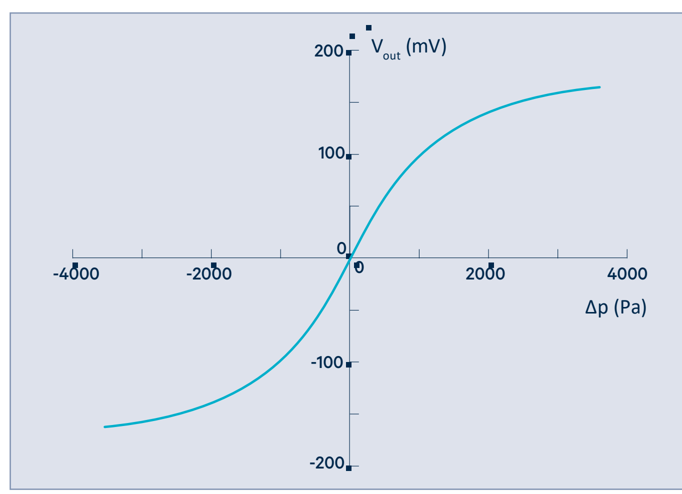

Figure 2 Characteristic curve of an unamplified basic LDE/LME/LMI sensor element

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2. Sensor construction

The LDE/LME/LMI sensors are based on a silicon sensor chip, only about 4 mm^2 (0.006 in^2) in size, which contains the micro-flow channel and the sensing element. By integrating the miniaturized flow channel on the sensor chip level **(Figure 3)**, the LDE/LME/LMI pressure sensors from First Sensor can achieve very high pneumatic impedances up to 200,000 Pa/(ml/s), which is up to 1000 times higher than comparable sensors. This reduces the gas flow through the sensor to an absolute minimum and offers unique application advantages in dusty and humid environments as well as when using long connection tubes or filters (detailed explanation in chapters 4 to 6).

In conventional flow-based differential pressure sensors the flow channel and gas flow through the sensor is determined by the geometry of the plastic housing. In contrast, the micro-flow channel of the LDE/LME/LMI devices is defined on the silicon chip level. This allows advantages in the construction of the sensor housing such as a high design flexibility, very small and stable packages as well as reduced manufacturing costs. Further, the semiconductor technology used for the silicon sensor chip enables extremely low production tolerances together with cost effective mass production.

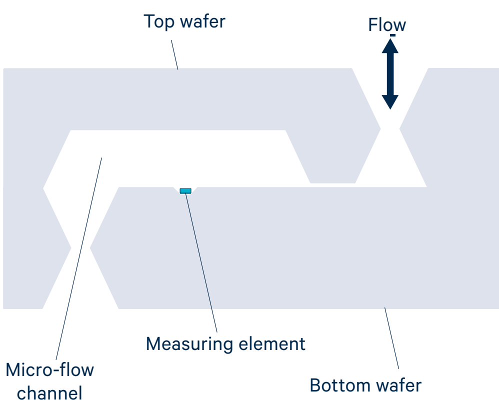

Figure 3 Principle construction of the LDE/LME/LMI differential pressure sensors (cross section)

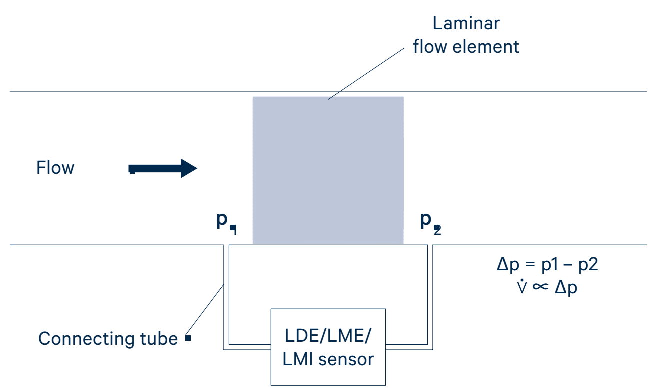

Figure 4 Typical volumetric flow measurement set-up with differential pressure sensor

3. Flow measurement with differential pressure sensors

Differential pressure sensors with very low pressure ranges of only a few millibar (a few inches of water column) are often used for volumetric flow measurement in tubes and pipes. Examples are respiration flow measurement in medical devices as well as air flow measurement or filter control in HVAC applications. An artificial flow restriction, e.g. by means of a baffle, orifice or laminar flow element induces a pressure drop to the flow which is a measure of the volumetric flow rate ($\dot{V}$) and can be detected with a differential pressure sensor **(Figure 4)**.

The flow-based LDE/LME/LMI sensors from First Sensor are calibrated to differential pressure and can detect the pressure drop across a flow element in a bypass configuration. Due to its very high pneumatic impedance the flow through the sensor is limited to max. 120-180 µl/min. This means that the LDE/LME/LMI sensor almost behaves like a membrane-based differential pressure sensor which does not allow any flow-through. However, it still shows the high measuring sensitivity for low pressures which is typical for the thermal mass flow sensing principle.

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4. Immunity to long connection tubes and input filters

To measure volumetric flow, the flow-based differential pressure sensor has to be connected to the main flow channel e.g. via tubes as shown in **Figure 4**. Sometimes, additional filters will be used in the bypass channel to protect the sensor against dust, humidity or bacterial contamination. However, any pneumatic element between the main flow channel and the bypass represents an additional flow resistance which leads to a pressure drop. The pressure sensor will therefore measure a differential pressure which is lower than the one caused by the flow restricting element in the main channel. The result is an inaccurate measurement of the volumetric flow rate in the main flow channel. The higher the flow impedance of the connecting tubes and additional filters compared to the sensor, the more dominant is this effect. Therefore, for conventional flow-based differential pressure sensors a maximum allowed tube length to the sensor is recommended or respectively a correction formula is given to compensate for the pressure drop in the bypass.

A tube of 1 m (40 in) length with an inner diameter of 1.6 mm (1/16 in) causes a pneumatic impedance of approx. 120 Pa/(ml/s). The LDE/LME/LMI sensors from First Sensor feature pneumatic impedances of up to 200,000 Pa/(ml/s). This means that the bypass flow is almost exclusively determined by the very high flow impedance of the LDE/LME/LMI device and influences of additional components with resistance to flow can be neglected. Therefore, LDE/LME/LMI differential pressure sensors can be used with long tubing, filters or other pneumatic elements without losing its calibration. Even if these elements change their resistance over time, such as a clogging filter, there will typically be no negative influence on the measurement accuracy.

5. Immunity to dust

If flow-based pressure sensors are used for volumetric flow measurement in dusty environments such as e.g. HVAC applications, there is the danger that dust particles reach the inside of the sensor and deposit on the walls of the inner flow channel. This would lead to an increase of the pneumatic impedance of the sensor and therefore to a decrease in the sensor output signal and a loss of calibration. In a worst case scenario the flow channel will be completely blocked which results in a total failure of the sensor. Further, dust can cover the sensitive measuring elements which also degrades the sensor signal.

The LDE/LME/LMI pressure sensors from First Sensor are highly immune to applications in dusty environments. Due to its very high pneumatic impedance, the air flow through the sensor is extremely small. This means that the total amount of dust-laden gas which streams through the bypass channel in a volumetric flow measurement set-up is reduced to an absolute minimum compared to conventional flow-based pressure sensors. Additionally, the flow velocity is greatly reduced so that the remaining dust quantity can normally settle out before it reaches the input of the sensor. In this way the LDE/LME/LMI flow-based pressure sensors prevent the ingress of dust into the sensor and ensure highly accurate measurements and very long sensor lifetimes.

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6. Immunity to humidity

In many medical devices such as respirators, spirometers, sleep diagnostic equipment and oxygen conservers the patient's breathing is controlled with the help of flow-based differential pressure sensors. Since the respiratory flow contains a considerable amount of humidity and is often also warmer than the environment this can lead to condensation inside the device. Water droplets can condense onto the tubing walls in the bypass line or in the sensor itself. If the droplets exceed a certain size or accumulate to larger droplets this can change the pneumatic characteristics of the connecting tubes and the sensor. This can result in an erroneous sensor output signal and a loss of sensor calibration. In a worst case scenario the flow channels will be completely blocked which leads to a total failure of the sensor.

The LDE/LME/LMI pressure sensors from First Sensor are highly immune to humid environments. Due to its very high pneumatic impedance, the air or gas flow through the sensor and its connecting tubes is extremely small. This means that the total amount of humid air which streams through the bypass channel in a volumetric flow measurement, and which can potentially condense, is reduced to an absolute minimum compared to conventional flow-based pressure sensors. Therefore, LDE/LME/LMI flow-based pressure sensors ensure highly accurate measurements and very long sensor lifetimes in typical applications with high humidity.