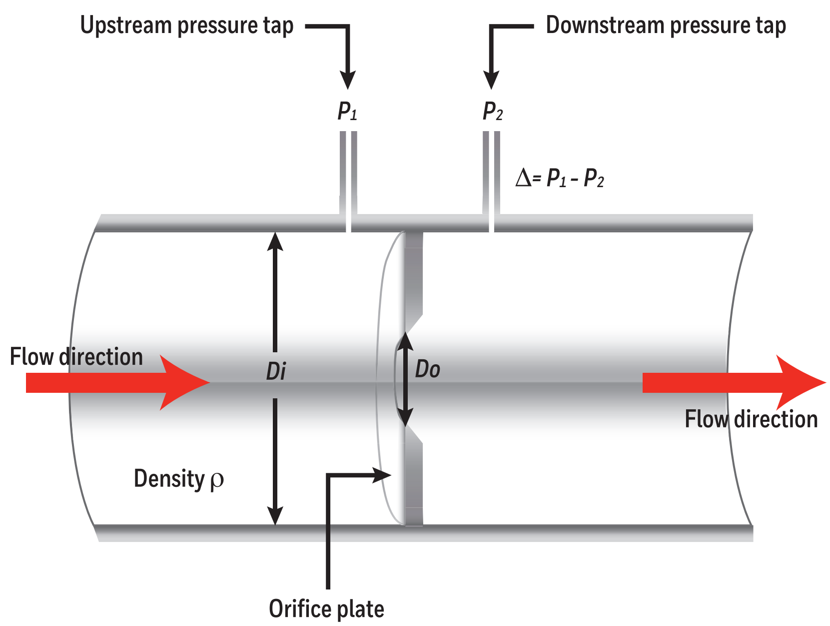
PRESSURE OR AIRFLOW SENSORS?

Technical Note

Both pressure and airflow sensors may be used to measure air flow rates. In many applications, either sensor type is used in conjunction with a flow restriction to create a pressure difference. Some 'airflow' sensors are sold as 'differential pressure' sensors based on the way they're calibrated, not on the internal technology. The purpose of this technical note is to clarify any confusion around these two sensor types, explain the differences between them, and provide guidance as to which type is better in an application.

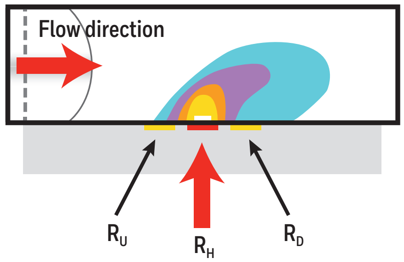
FIGURE 1. AIRFLOW SENSOR



WHAT IS AN AIRFLOW SENSOR?

At the simplest level, an airflow sensor, or more precisely a mass air flow sensor, is a device with two pressure ports where gas flows from one port to the other (see Figure 1). Inside the sensor, there's a sense element with a heated surface. As gas flows across the sense element, heat is transferred from upstream to downstream, as shown in Figure 2. This creates a thermal imbalance proportional to the mass of material flowing by which can be measured by an electronic circuit.

FIGURE 2. AIRFLOW SENSE ELEMENT



It's important to remember that the sensor is measuring the mass flow under standard conditions, not the actual volume of gas flowing through. While most sensors are compensated for the effects of temperature, changes in atmospheric pressure that affect the density of the gas will affect the output. Also, mass airflow sensors must be calibrated for a specific gas mix, as different gases have different thermal characteristics.

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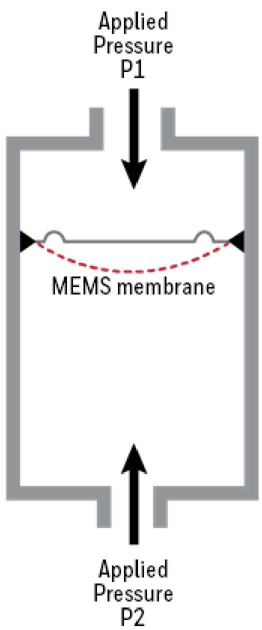
It's possible to calibrate a mass airflow sensor to provide an output that is proportional to the pressure drop between the two ports, as its this pressure drop that drives the flow through the sensor. This can lead to some confusion, as these sensors will often be sold as differential pressure sensors when the internal technology is really measuring flow.

WHAT IS A PRESSURE SENSOR?

A conventional differential pressure sensor also has two pressure ports; however, there is no gas flow between the two ports. Instead, there is a MEMS diaphragm (see Figure 3) between the ports that measures the pressure difference. The deflection of the diaphragm is measured by piezoresistors implanted in the silicon, and an electronic circuit converts this to an output signal.

FIGURE 3. DIFFERENTIAL PRESSURE SENSOR



MAJOR DIFFERENCES BETWEEN PRESSURE SENSORS AND MASS AIRFLOW SENSORS

FLOW PATH

The most obvious difference between pressure and mass airflow sensors is the presence or absence of a gas flow path. For a mass flow sensor to operate properly, gas must be able to flow through it. Any restriction in the flow path, such as dirt or liquid, will change the pneumatic resistance and therefore the output. In contrast, a pressure sensor is 'dead ended'. The only gas flow in its tubing system is the small amount caused by compression or expansion of gas under pressure. Dirt or liquid in the tubing system will only cause an output difference if the clog is sufficient to almost completely block the tubing. Contamination in the flow path that ends up on a mass airflow sensor's internal surfaces may also affect the heat transfer to the sense element, again affecting the output.

Example: A certain hospital infectious disease ward absolutely had to have a negative pressure compared to the outside world to prevent bacteria and viruses from escaping. When routine drywall maintenance was done, some of the fine particles from sanding made it through the system filters and ended up on the sense elements inside the airflow sensors. This caused erroneous readings and the system ended up controlling to a positive pressure, risking a disease outbreak!

Mass airflow sensors should only be used when the gas flowing through them is known to be free of contaminants.

STABILITY AND RESOLUTION

Because a mass airflow sensor is a thermal device, it's inherently more stable at zero flow (or zero pressure differential) than a stress-based pressure sensor. However, the failure modes described above will affect the slope of the sensor output. A pressure sensor's failure modes all tend to affect the zero-pressure offset of the device. It's very rare for a pressure sensor's slope to change.

Also, the sense element of a mass airflow sensor will have a higher output at low flows than at high flows. This means that a mass airflow sensor will have better resolution at very low flows than at higher flows, even if the output has been corrected to a linear signal. A pressure sensor's output is naturally almost linear over its working range, so resolution won't change (see Figures 4 and 5).

FIGURE 4. MASS AIRFLOW SENSOR OUTPUT VS FLOW

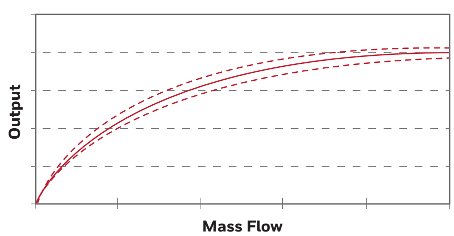
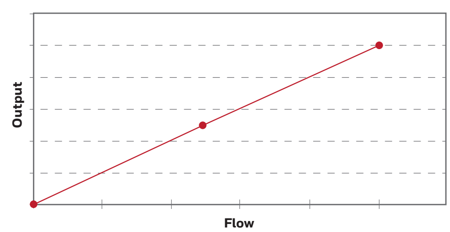


FIGURE 5. PRESSURE SENSOR OUTPUT VS FLOW



A mass airflow sensor has better resolution and stability at very low flows than an equivalent pressure sensor.

RESISTANCE TO CONTAMINATION

Contamination in the flow path can affect the output of a mass airflow sensor in several ways. Even a very thin film of liquid or dirt on the sense element itself will affect the thermal transfer and can lead to slope errors. Beyond this, if the sensor is being used in a bypass configuration as previously shown, anything that creates additional resistance to flow in the tubing path will affect the measurement. It takes additional pressure to force the same amount of flow through a clogged tube, and this will change the relationship between flow and pressure.

In contrast, there is almost no air movement in the tubing on a dead-ended pressure sensor. The only movement is the small amount of air that has to flow in or out to create a pressure change. A severely clogged tube might create frequency response problems in high frequency applications; however, the output of the sensor will be correct.

It's possible to create an almost fail-safe system by using both a pressure sensor and a mass airflow sensor in parallel to take the same measurement. As most of the failure modes in a pressure sensor will affect the offset, and most modes in a flow sensor affect the slope, the two devices are very unlikely to fail in the same way at the same time.

The slope of a pressure sensor will be more stable than the slope of a mass airflow sensor, and is unlikely to be affected by contamination.

AUTO-ZERO CALIBRATION TECHNIQUE

Auto-Zero is a calibration technique for pressure sensors based on sampling the output at a known reference condition to allow for additional external correction of output errors including offset error, thermal effect on offset (offset shift) and offset drift. Figures 5 and 6 show the output of a pressure sensor with a large offset before and after auto-zero calibration. If this technique can be done in an application, it's a simple way to obtain the advantages of a pressure sensor while avoiding the issues of a mass airflow sensor.

FIGURE 6. PRESSURE SENSOR WITH LARGE OFFSET SHIFT BEFORE AUTO-ZERO CORRECTION

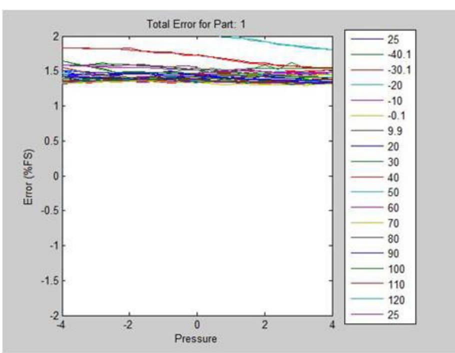
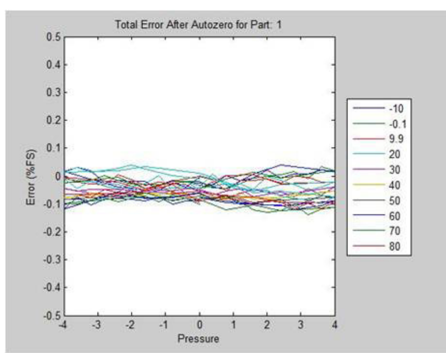


FIGURE 7. PRESSURE SENSOR WITH LARGE OFFSET SHIFT AFTER AUTO-ZERO CORRECTION



There are two different ways to apply this technique:

- The most straightforward way is to add a valve that disconnects one of the pressure ports from the outside system and connect it to the other port, thereby creating a zero pressure condition. This can be done at any convenient time in an application. The downside here is obviously the cost of the valve and associated plumbing.
- The other way is to 'turn off' the pressure on the system. For example, while a machine is starting up, if the fan that creates airflow is off, the sensor should be at zero pressure, and can be re-zeroed every time the system starts up.

POWER CONSUMPTION

The heater in a mass airflow sensor requires power to function properly and takes a small, but not insignificant amount of time, to warm up and stabilize. In contrast, the simple resistive Wheatstone bridge in most pressure sensors draws much less current and stabilizes very quickly. A typical airflow sensor may require 10 mA to 15 mA, while an otherwise equivalent pressure sensor would only need 2 mA. The output of a pressure sensor is usually stable within 2 ms or better, while an airflow sensor can take 35 ms. This makes power cycling strategies to conserve energy much less effective.

A pressure sensor is usually preferred in low power applications.

FREQUENCY RESPONSE

The sense element of a pressure sensor is a mechanical diaphragm, as previously shown in Figure 3. It typically has a maximum frequency response above 10 kHz. In a real-world application, sensor response is usually limited to around 1 kHz by electronics. In contrast, airflow sensors respond more slowly to rapid changes in flow and will tend to average out rapid changes – recall the difference in warm-up time. It's a little more difficult to exactly quantify the frequency response of a mass airflow sensor; however, in most cases, it's probably below 100 Hz. This difference can affect performance in applications.

Example: An airflow sensor was used to measure flow in a backpack positive-pressure safety mask system, and worked well. When a pressure sensor was tried as a replacement to reduce the chance of a contamination problem, the pressure sensor output was extremely noisy. The pressure sensor was picking up high frequency noise from the fan in the backpack to the point its output was almost unusable. The project team ended up staying with the airflow sensor because of the difficultly in filtering the output of the pressure sensor.

SUMMARY

Table 1 provides a summary of the major differences between pressure sensors and mass airflow sensors when used in an application.

TABLE 1. PRESSURE SENSORS VS MASS AIRFLOW SENSORS		
CHARACTERISTIC	**PRESSURE SENSOR**	**MASS AIRFLOW SENSOR**
Ability to handle restricted or contaminated gas in the flow path	✓	—
Better stability and resolution at lower flows	—	✓
Better resistance to contamination	✓	—
Low power applications	✓	—
Amenable to auto-zero calibration technique	✓	—
Faster frequency response	✓	—

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