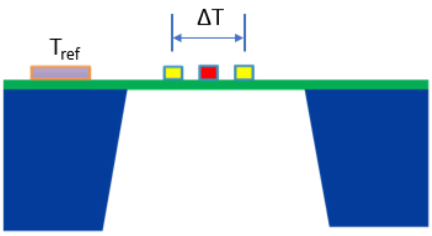
APSP TECHNICAL NOTE

Thermal time of flight sensing technology

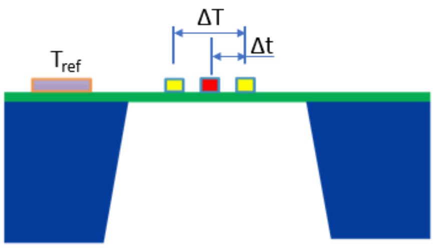
Major advantages of the technology

- ✓ Removes gas sensitivity with the same diffusivity
- ✓ Significantly improves the gas conversion linearity
- ✓ Improves measurement dynamic range with gas conversion
- ✓ Gas concentration measurement for binary gas mixtures

Micromachined or MEMS thermal mass flow sensor was first made in the early 1970s using thermal anemometry. However, the first commercially available MEMS thermal mass flow sensor was made with calorimetry. As of today, slightly over 10 companies in the world are offering a variety of MEMS mass flow sensing products, and almost all of these companies are making their MEMS mass flow sensors using the calorimetric sensing principle. These products are mostly applicable for clean and dry gas flow measurements for a flow speed within 20m/sec. Calorimetric sensing is more favorable for lower flow speed measurement as compared to anemometric sensing. One of the reasons for the choice is that the MEMS sensors are small in their footprints. Applications with low flow measurements are usually within a small flow channel. Consequently, it is easier to design the package for the MEMS flow sensors, and the position where the sensor is placed would be more relevant for the representation of the flow profile within a small flow channel. Most of the commercially available MEMS flow sensors have a very small footprint of less than 2x2mm, which makes it difficult even for proper sealing of the wire connections.



Traditional MEMS calorimetric sensing



New approach used in our products

While there are many successful applications of the MEMS flow sensors in automotive, medical, instrumentation, and automation applications, calorimetric sensing also has some drawbacks that haven't been solved. For example, the measurement of gas mass flow, q_m, is gas properties (specific heat Cp, end conduction loss L) dependent. i.e. the best metrological performance will require real gas calibration (ISO 14511: Measurement of fluid flow in closed conduits – thermal mass flow meters):

$$q_m = \frac{(P-L)\times f_{\mathrm{CTMF}}}{c_p\,(T_2-T_1)}$$

In the above formula, P is the constant input power, and f is the meter factor which further complicates the product-to-product variations. In the real manufacturing process, it is not practical to use real gas to calibrate as some gases can be expensive or even unavailable to purchase for safety reasons. Using air calibration and a theoretical gas conversion factor for application gas therefore would incur errors that could not be precisely controlled. Additional nonlinearity in the dynamic range is also a known issue.

Our products use a new data analytical algorithm by acquiring additional thermal transfer data in the time domain as shown in the above graph. With the additional data, it is then possible to process the data using the thermal transfer function:

$$\frac{\partial T}{\partial t} = \frac{k}{\rho c}\nabla^2 T + \frac{Q(t)}{\rho c} - V\nabla T$$

This allows the measurement to be independent of gas properties as long as the diffusivity of the gas is the same. For example, diffusivities for air, oxygen, nitrogen, and argon are the same within the measurement errors. Consequently, the measurement for these gases can all be calibrated with air. This is very helpful for applications with argon, such as welding process control.

Another example is the anesthesia applications. It has been a challenge for precise measurement of nitrous oxide using thermal mass flow meters. Calibration sometimes is done with carbon dioxide as it has a closer property using the traditional calorimetric approach. But still, it has pronounced nonlinearity in the dynamic range. This new algorithm hence effectively solved this issue and allowed a low-cost calibration with high precision.

Methane is a common gas for many applications. The traditional calorimetric flow measurement products would lose about 30% of the dynamic range if the measurements were converted from an air-calibrated product. With our thermal time of flight sensing technology, there will not be such a concern as the diffusivities between air and methane are only marginally different.

We are here for you. Addresses and Contacts.

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