Innovative Sensor Technology
physical. chemical. biological.

FS2T.0.1E.025

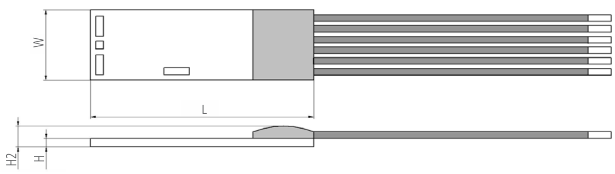
Thermal Mass Flow Sensor

Optimal for measuring gas flow and direction

Benefits & Characteristics

- Detection of flow direction
- Simple signal processing
- Outstanding sensitivity
- Stable platinum technology
- No moving mechanical parts
- Excellent long-term stability
- Simple calibration
- Bare sensor element resists up to +450 °C (customer specific)
- Excellent reproducibility

Illustration[1)]

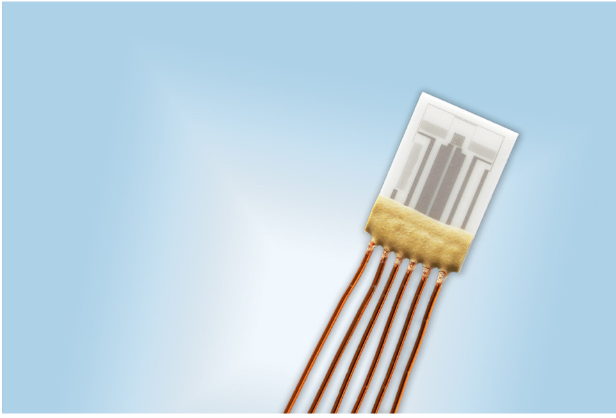


1) For actual size, see dimensions

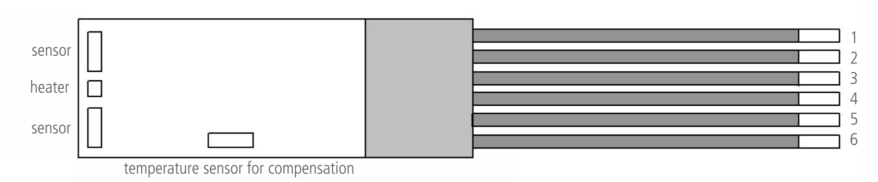
Technical Data

Dimensions (L x W x H / H2 in mm):	5.0 x 3.5 x 0.20 / 0.60
Operating measuring range:	0 ml/min to 50 ml/min (half bridge mode)
	0 m/s to 1 m/s (half bridge mode)
	0 m/s to 100 m/s (CTA mode)
	0 l/min to 5 l/min (CTA mode)
Minimum operating range:	0 ml/min to 2.5 ml/min
Response sensitivity:	0.001 m/s (50 µl/min)
Accuracy:	< 2 % of the measured value (dependent on the electronics and calibration)
Response time t_{63}:	< 0.5 s
Operating temperature range:	-20 °C to +150 °C
Temperature sensitivity:	< 0.1 %/K (dependent on the electronics)
Connection:	Cu-wire, enameled, Ø 0.2 mm, 25 mm long
Heater:*	R_H (25 °C) = 34 Ω ±10 %
Measuring element:	R_{S_i} (25 °C) = 425 Ω ±10 %
Reference element:	R_R (25 °C) = 710 Ω ±10 %
Voltage range (nominal):	2 V to 5 V (dependent on flow rate)

Product Photo



Pin Assignment



1	2	3	4	5	6
GND	temperature sensor 1	heater	heater	temperature sensor 2	temperature sensor for compensation

Order Information

Description:	Item number:	Former main reference:
FS2T.0.1E.025	103663	050.00130

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Application Note
Thermal Mass Flow Sensor
FS2

1. FS2

1.1 About the Sensor

The Innovative Sensor Technology IST AG thin film mass flow sensors were developed to offer solutions for a wide variety of flow applications with considerable advantages. Thermal mass flow modules and measuring systems are well-known devices that are offered in a wide range of applications by a handful of suppliers in the marketplace. Most of these designs are compact, ready to use systems with a channel and a passive or active output. These modules are sufficient for many general purpose applications where component price and size are less significant, but they are not well-suited for price-sensitive and space limited flow control solutions.

The FS2 flow sensor consists of four platinum thin film resistors, is based on a function of the flow speed and utilize heat transfer principles to determine the flow velocity. In no flow condition, two resistors are heated up equally. If flow appears, heat is carried from the sensors to the medium and one of them is cooled more than the other, depending on flow direction. If flow increases, so does the amount of heat that is transferred. By knowing the heat transfer, the flow rate can be determined from the amount of voltage compensation needed to maintain a constant temperature differential.

The Innovative Sensor Technology IST AG FS2 flow sensors are applicable in gas. They have a wide operating temperature range and flow measuring rate. Flow channels guarantee the best possible adaptation of the sensors to the requirements of your application, whether in terms of dynamic range, response time or ambient conditions. The FS2 flow sensors are optimal for limited space system integration and can be upgraded into finish developed systems. Furthermore, customer specific designs of the chip and housing/channels are possible as well as implementation in customer defined and supplied housings.

1.2. Benefits and Characteristics

The following list showcases the advantages FS2 flow sensor have. It is not a list of the sensor’s full range of capabilities and should not be seen as such.

- Detection of flow direction
- Simple signal processing
- Outstanding sensitivity
- Stable platinum technology
- Bare sensor element resists up to +450 °C (customer specific)
- Excellent long-term stability
- Simple calibration
- No moving mechanical parts
- Excellent reproducibility
- Customer specific sensor available upon request

1.3 Application Areas

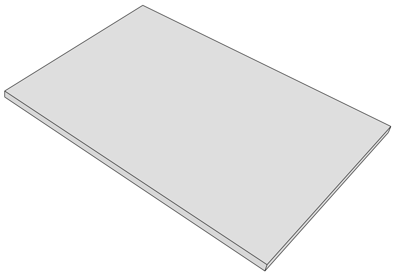
Among other, the FS2 flow sensor is suitable for, but not limited to, the following application areas:

- Compressed air billing
- HVAC - building automation
- Automotive
- Medical applications
- Device monitoring
- Coolant monitoring

1.4 Sensor Structure

The following paragraphs describes and elaborates the multiple steps of the sensor structure.

Substrate

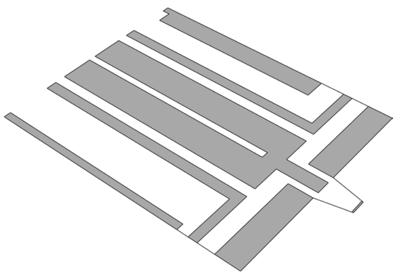


The base of the FS2 flow sensor chip is a special ceramic with low thermal conductivity.

The production of the FS2 flow sensor starts by deposition of high purity platinum thin film layers onto the ceramic substrate.

To ensure high quality sensors, wet chemical processes are performed on automated systems for chemical cleaning and etching processes.

Resistive structure

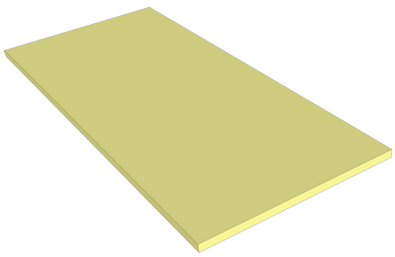


The resistive structure on the sensor, consists of four platinum resistors on one chip. The low ohmic resistance with a small area is used as heater. Two high ohmic resistors on the left and right hand side of the heater are used to detect the flow speed and flow direction. A further resistance allows the measurement of the gas temperature.

They are fabricated by multiple steps, hereunder spin coating of a photo-sensitive resist, illumination of the photo sensitive resist through a mask, developing the photo resist and etching the platinum, leaving only the sensor structure on the chip.

The sensor is individually laser trimmed to the customer specific resistance.

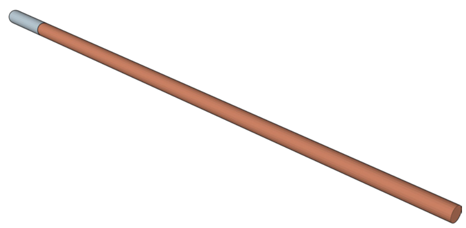
Passivation



The resistive structure is covered with a glass passivation using screen printing, which furthermore increases the robustness and strength.

Afterwards each substrate is diced on fully automated dicing machines and ready for wiring.

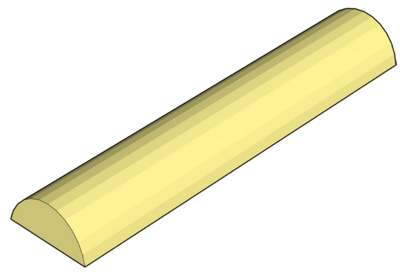
Wire connections



The FS2 sensor is equipped with wire connections welded on the chip on automated welding machines. For easy to use design-in the sensor can be ordered with various customer specific lengths, requirements and specifications.

The standard FS2 sensor is delivered with 25 mm enamelled Cu wire.

Wire fixation



The welding area is additionally covered by a polymide to increase robustness, resulting in a pull strength of 10N.

1.5 Measurement Principle

The Innovative Sensor Technology IST AG FS2 flow sensors are based on a variation of the heat transfer coefficient, which is a function of the flow speed. Thermal mass flow sensors utilize heat transfer principles to determine the flow velocity of a medium.

Flow speed changes the thermal energy loss by the heater: As a medium passes across the sensor, heat is carried from the sensor to the medium. As flow increases, so does the amount of heat that is transferred, meaning an increase in flow speed results in a higher cooling. This effect leads to a heat transfer coefficient change. Hence, cooling is a function of the mass flow.

The Flow Sens FS2 consists of four platinum thin film resistors. The low ohmic resistance with a small area is used as heater. Two high ohmic resistors on the left and right hand side of the heater are used to detect the flow speed and flow direction. A further resistance allows the measurement of the gas temperature.
The two resistors close to the heater can be connected in a bridge circuit. This leads in an output signal which is a function of flow speed and direction. In no flow condition, the two resistors are heated up equally. If flow appears, one of them is cooled more than the other, depending on flow direction. The temperature difference can be measured and depends on flow speed and direction. Response and heating up time of this flow sens is very short due to the small thermal mass. This kind of evaluation allows the measurement of very low flow speeds.

In order to detect higher flow velocities, the temperature sensor can be connected in a constant-temperature-anemometer.

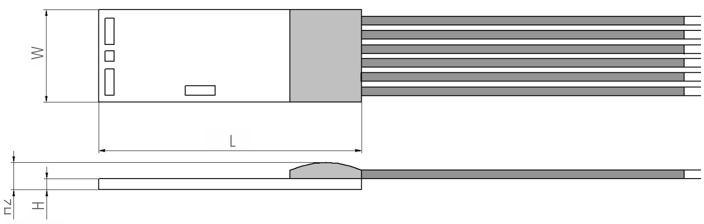
By adapting controllers, a constant temperature difference between the heater and the temperature sensor can be achieved. This measuring principle is called Constant Temperature Anemometer (CTA). The supplied electrical power, which controls the temperature difference, is a function of the flow speed. The power is converted into a voltage output signal with a bridge circuit and can be easily readout. Knowing the temperature of the medium, the flow rate can be determined from the amount of voltage compensation needed to maintain a constant temperature differential.

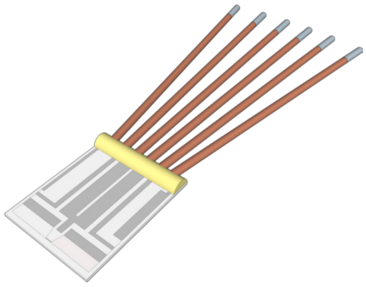
The range of flow measurements is very wide and can be adjusted to the specific application. Through an electronic circuit, it is possible to increase the temperature of the heater with respect to the temperature of the medium.

1.6 Dimensions and Housing

The following describes the dimension of the standard Innovative Sensor Technology IST AG FS2 flow sensor.

The standard FS2 measures 5 mm x 3.5 mm x 0.2 mm / 0.6 mm





Tolerances: outer dimension (chip): ± 0.2 mm; thickness (chip): ± 0.1 mm, height ± 0.3 mm

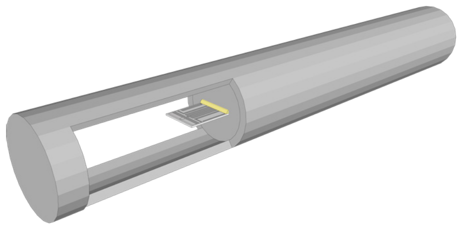
Other dimensions, customer specific housings and wire lengths available upon request.

1.7 Mounting

The following mounting possibilities serve as inspiration, only. If you have any questions regarding specific mounting possibilities, please contact us to find the best possible solution for your application.

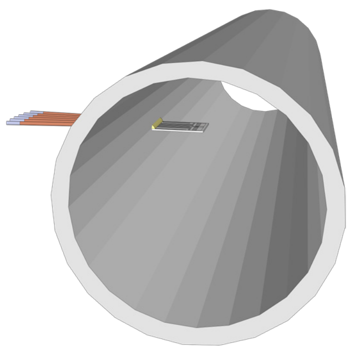
Duct mounting flow probe

Sensor mounted in a duct flow probe. The direction of the air flow must be across the sensor meaning an air flow flowing over the active sensor surface.



Customized channel / pipe with flow sensor

Sensor mounted in an air flow channel. The direction of the air flow must be across the sensor meaning an air flow flowing over the active sensor surface.



Connector

The standard Innovative Sensor Technology IST AG FS2 flow sensor is not supplied with a connector, but the sensor can be purchased with e.g. a JST connector. Please contact Innovative Sensor Technology IST AG for more information regarding the various connector possibilities.

1.8 Delivery and Content

The standard delivery time of the Innovative Sensor Technology IST AG FS2 sensor is 4-6 weeks after order receival.

The FS2 sensor is delivered without electronic parts or modules.

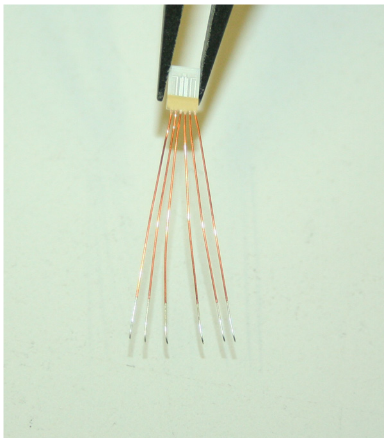
1.9 Handling

The FS2 sensor is delivered in a blister and must be handled as follows:

The FS2 sensor is delivered in a blister with label showing the exact sensor type and lot-number

Open the blister carefully with both hands

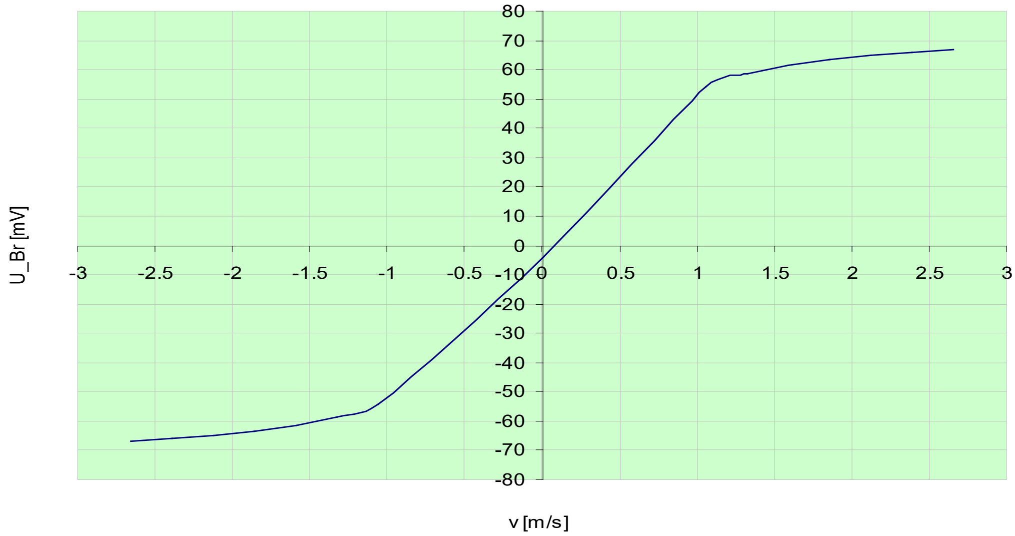
Remove the stripes of plastic covering the sensors



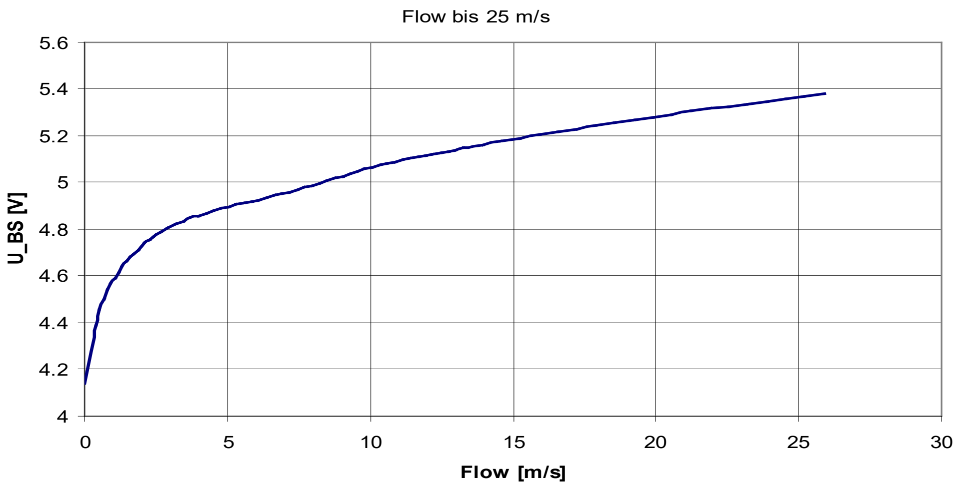
Handle the sensors with plastic tweezers only

1.10 Performance

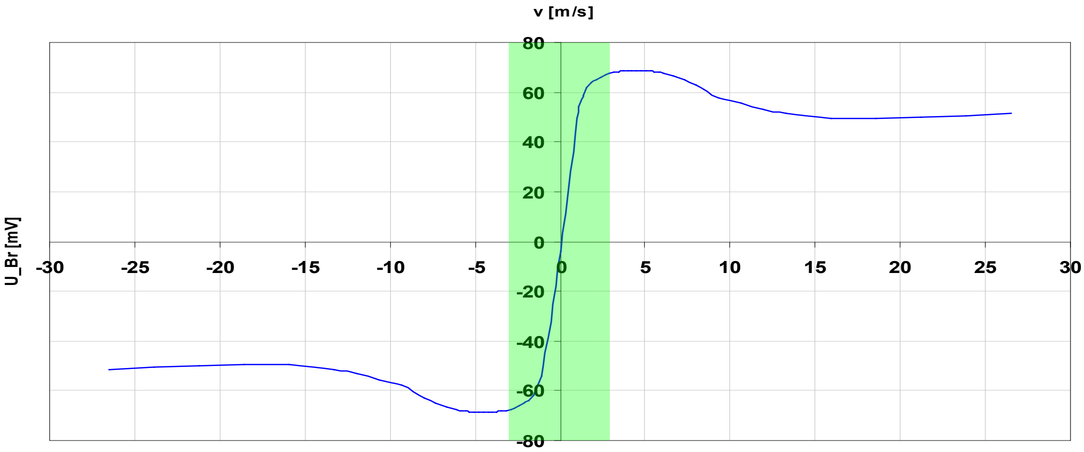
The following graphs showcases the performance of the IST AG FS2 sensor during application. Depending on the application and possible influences the measurements might vary.



Typical signal – curve between 0 m/s to 2.5 m/s



Example – Characteristic for high flow measurement with direction output



Bridge signal for direction detection

1.11 Influences

The following list showcases possible influences, however is strongly dependent upon the application. If you have any questions regarding specific applications and its possible influences, please contact IST AG to find the best possible solution for your application.

Contamination

The characteristics can be affected due to sensor contamination such as dust.

Alignment

The characteristics depend on sensor alignment/orientation. The sensor must be aligned so that the flow passes over the active sensor surface. The IST AG FS2 flow sensor is independent of flow direction.

Temperature (medium)

The characteristics depend on the medium temperature; therefore temperature compensation is necessary to achieve an accurate measurement.

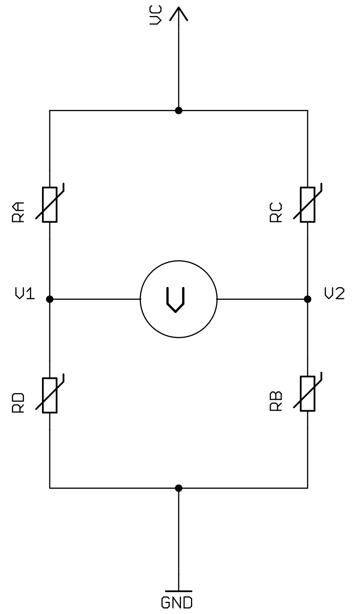
Temperature changes in the medium are already compensated by using the CTA electronics („first order“).

1.12 Electronic and Circuit Diagram

Wheatstone (Calorimetric)

The heater R_H is fed by a constant voltage or a constant temperature. As shown to the right, the two sensor-elements (RS left and RS right) can be connected in a bridge circuit.

With a corresponding supply V_{CC}, the bridge balance V_Br = V1-V2 is depending of the mass-flow. If the bridge balance is adjusted at flow = 0 to V_Br = 0, the sign gives the information about the direction of the flow. For this the resistor R1 has to be adjustable.



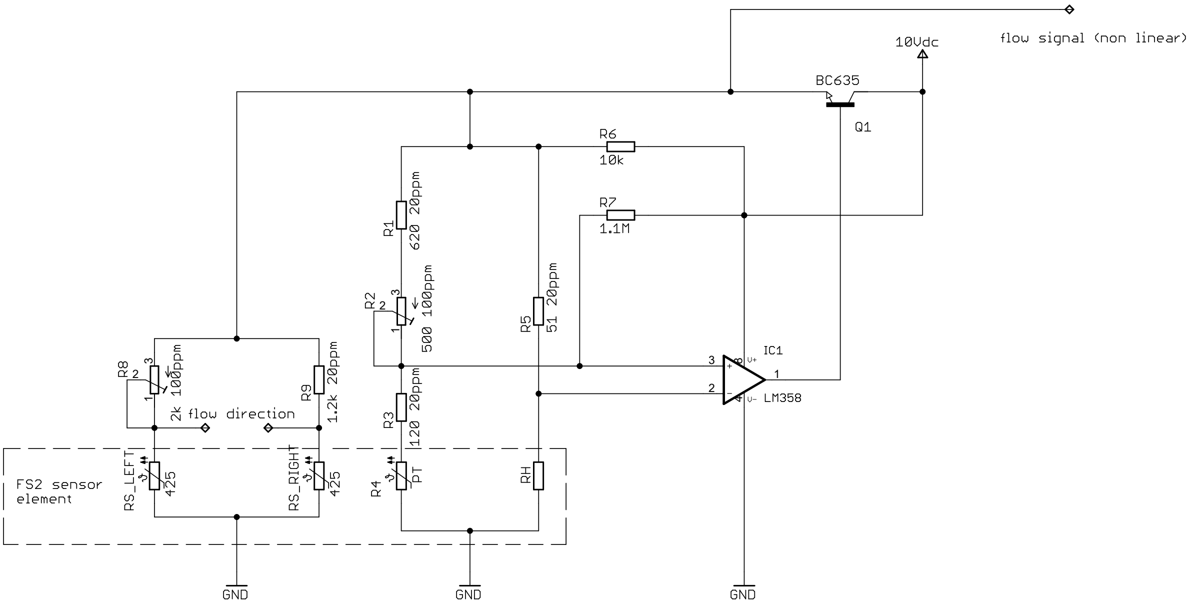
CTA (Constant Temperature Anemometer)

The CTA-mode (Constant Temperature Anemometer) consists of a simple feedback circuit for the temperature regulation of the heater on the flow sensor, as flow speed changes the thermal energy loss by the heater.

By adapting controllers, a constant temperature difference between the heater and the temperature sensor can be achieved. The supplied electrical power, which controls the temperature difference, is a function of the flow speed. The power is converted into a voltage output signal with a bridge circuit and can be easily readout. Knowing the temperature of the medium, the flow rate can be determined from the amount of voltage compensation needed to maintain a constant temperature differential.

The medium temperature variation is compensated by the temperature sensor on chip (Pt1200). The resistors R1 to R6 can be chosen as shown in the circuit below. The temperature difference (DT) between heater (R_H) and medium (RS) is set by resistor R1, e.g. DT=30 K for air. The resistor R2 should be adjustable within ±10 % for calibration. The R7 resistor is placed for stability of the anemometer circuit.

Depending on used operational amplifier, it should be valued from 1.1 MΩ to 3 MΩ.



Electronic circuit and curve progression are examples. Each application linked to the accuracy level requires an individual calibration of the system.

The CTA is described by King's law:

$$P_H = I_H^2 \cdot R_H = \left(A + B \cdot \vec{v}^{\,n}\right) \cdot \Delta T \qquad n = 0.3 \ldots 0.5$$

By convertion and simplification, the equation can be obtained in the following form:

$$U = U_0 \cdot \sqrt{1 + k \cdot \vec{v}^{\,n}}$$

U	= CTA-output	k	= Fluidic dependent constant
U_0	= Free convection offset	v	= Fluid velocity

U represents the flow depended output signal. U_0 represents the value of constant temperature difference (ΔT) between the heater and fluid at no flow speed, which results due to natural convection.
The controller of a CTA keeps the ΔT between heater and temperature sensor constant.

Maximum supply voltage

2 V to 5 V

Maximum heater voltage

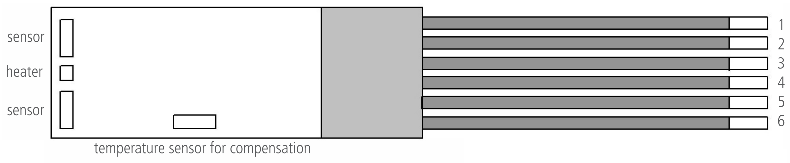
3 V (at 0 m/s)

Optimal resistance values (heater resistance)

RH (25 °C) = 34 Ohm ± 10 %

For gas applications, the temperature difference (resistor value) is recommended to 30 K.

Pin assignment



1	2	3	4	5	6
GND	Temperature sensor 1	Heater	Heater	Temperature sensor 2	Temperature sensor for compensation

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