



# FS5

## Thermal Mass Flow Sensor

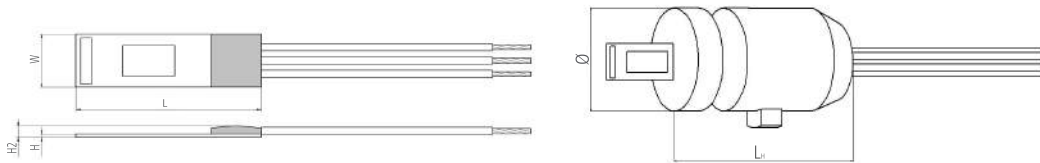
### For various gas flow applications



#### Benefits & Characteristics

- Easy adaptation in various applications and housings
- Simple signal processing
- Simple calibration
- No moving mechanical parts
- Excellent reproducibility
- Excellent long-term stability
- Bare sensor element resists up to +450 °C (customer specific)
- Stable platinum technology
- Customer specific sensor available upon request

#### Illustration<sup>1)</sup>



1) For actual size, see dimensions

#### Technical Data

Dimensions (L x W x H / H2 in mm):*	6.9 x 2.4 x 0.20 / 0.60 Ø 6.0, L <sub>H</sub> = 14 (complete dimensions in application note)
Operating measuring range:	0 m/s to 100 m/s
Response sensitivity:	0.01 m/s
Accuracy:	< 3 % of the measured value (dependent on the electronics and calibration)
Response time t <sub>63</sub> :	< 2 s
Operating temperature range:*	-20 °C to +150 °C
Temperature sensitivity:	< 0.1 %/K (dependent on the electronics)
Connection:*	3 pins, AWG 30/7, stranded wire, insulated with PTFE
Heater:*	R <sub>H</sub> (0 °C) = 45 Ω ± 1 %
Reference element:*	R <sub>S</sub> (0 °C) = 1200 Ω ± 1 %
Voltage range (nominal):*	2 V to 5 V (at Δ T = 30 K (0 m/s ≤ v <sub>gas</sub> ≤ 100 m/s)
Maximum heater voltage:*	3 V (at 0 m/s)
Alternative construction:*	Moulded plastic housing

\* Customer specific alternatives available



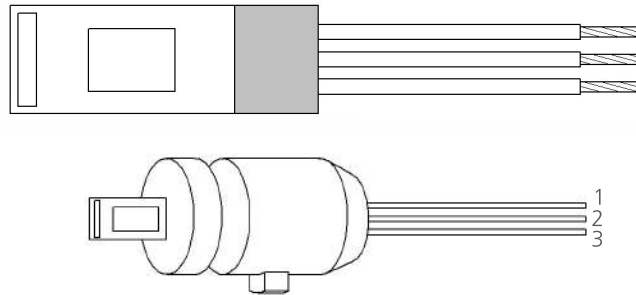
# FS5

## Thermal Mass Flow Sensor

### For various gas flow applications



#### Pin Assignment



1	2	3
heater	temperature sensor	GND

#### Order Information - 3 pins, stranded wire, AWG 30/7, PTFE insulated

Dimension (L x W x H in mm)	Without plastic housing	With plastic housing
6.9 x 2.4 x 0.20	FS5.0.1L.195	
Order code	050.00127	
Ø 6.0 (±0.1), L = 14 (±0.2)		FS5.A.1L.195
Order code		050.00128

#### Additional Electronics

Module:	Document name: DFFS5_FSL_Module_E
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#### Additional Documents

Application note:	Document name: AFFS5_E
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INNOVATIVE SENSOR TECHNOLOGY

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All mechanical dimensions are valid at 25 °C ambient temperature, if not differently indicated • All data except the mechanical dimensions only have information purposes and are not to be understood as assured characteristics • Technical changes without previous announcement as well as mistakes reserved • The information on this data sheet was examined carefully and will be accepted as correct; No liability in case of mistakes • Load with extreme values during a longer period can affect the reliability • The material contained herein may not be reproduced, adapted, merged, translated, stored, or used without the prior written consent of the copyright owner • Typing errors and mistakes reserved • Product specifications are subject to change without notice • All rights reserved



# FS5 Flowmodule

## Thermal Mass Flow Sensor

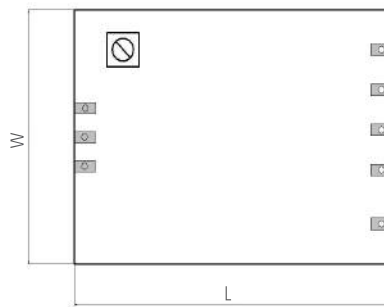
### For gas flow sensor evaluation



#### Benefits & Characteristics

- Easy to use plug & play module (not calibrated)
- Simple CTA (constant temperature anemometer)
- Simple gain adjustment
- No microprocessor or software influenced signal
- Customer specific sensor available upon request

#### Illustration<sup>1)</sup>



1) For actual size, see dimensions

#### Technical Data

Dimensions (L x W in mm):	45 x 25
Operating measuring range:	0 m/s to 50 m/s
Accuracy:	< 5 % of the measured value (dependent on calibration)
Operating temperature range:	-40 °C to +85 °C (module)
Temperature sensitivity:	< 0.5 %/K (dependent on calibration)
Connection:	solder pads on PCB
Heater <sup>2)</sup> : *	$R_H(0\text{ °C}) = 45\ \Omega \pm 1\ \%$
Reference element <sup>3)</sup> : *	$R_s(0\text{ °C}) = 1200\ \Omega \pm 1\ \%$
Voltage range (nominal): *	5 V DC $\pm 5\ \%$ (internal main voltage is 10 V)
Warm-up time:	< 30 s
Analog output, non linear <sup>4)</sup> :	0 V (2) to 10 V; (operating point at still air = 3.5 V)

2) Related to the FS5 sensor

3) Related to the FS5 sensor

4) Can be adjusted with potentiometer

\* Customer specific alternatives available



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# FS5 Flowmodule

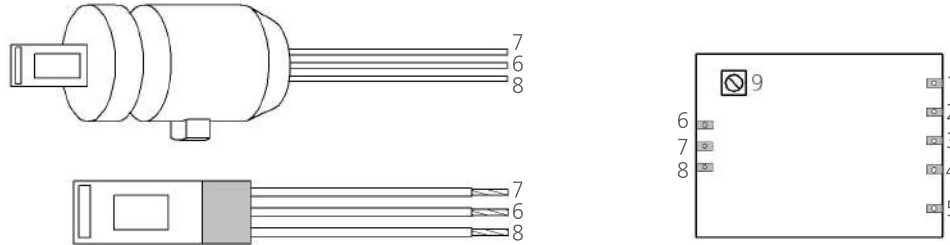
## Thermal Mass Flow Sensor

### For gas flow sensor evaluation



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#### Pin Assignment



1	2	3	4	5
flow output			GND	$U_{\text{supply}} +5 \text{ V}$
6	7	8	9	
temperature sensor	heater	GND	potentiometer	

#### Adjustment Procedure (if necessary)

1. Power up the module with  $5 \text{ V}_{\text{DC}}$  (min. 200 mA)
2. Connect multimeter to "flow output"
3. Adjust potentiometer for an output signal of about  $3.5 \text{ V}_{\text{DC}}$  at flow = 0
4. Produce a well-known flow e.g. 10 m/s (with reference, for example a mass flow controller)
5. Measure voltage at output (should be in the range of  $5 \text{ V}_{\text{DC}}$  to  $7 \text{ V}_{\text{DC}}$ )
6. Calculate the voltage difference between 0 m/s and 10 m/s (e.g.  $2.8 \text{ V}_{\text{DC}}$ )
7. The signal is the non linearised output signal  $> 0 \text{ m/s}$  to  $10 \text{ m/s} = 3.5 \text{ V}_{\text{DC}}$  to  $6.3 \text{ V}_{\text{DC}}$

The signal then can be offset adjusted and linearised with software on target system like a microcontroller, LabView, MatLab etc.

#### Order Information<sup>3)</sup>

Order code	FS5-Flowmodul 160.00001
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<sup>3)</sup> The module does not contain any sensor. The sensor should be ordered separately.



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# Application Note

## Thermal Mass Flow Sensor

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# Application Note

## Thermal Mass Flow Sensor

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#### 1. FS5

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##### 1.1 About the Sensor

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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 FS5 flow sensors are based on a function of the flow speed and utilize heat transfer principles to determine the flow velocity. As flow 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. 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 FS5 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 our sensors to the requirements of your application, whether in terms of dynamic range, response time or ambient conditions. The FS5 flow sensors are optimal for limited space system integration and can be upgraded into finish developed systems simply. 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

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- No moving mechanical parts
- Simple signal processing
- Simple calibration
- Easy adaptation in various applications and housings
- Bare sensor element resists up to 450 °C (customer specific)
- Excellent long-term stability
- Stable platinum technology
- Excellent reproducibility
- Customer specific sensor available upon request

##### 1.3 Application Areas

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Among other, the FS5 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

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



# Application Note

## Thermal Mass Flow Sensor

### FS5

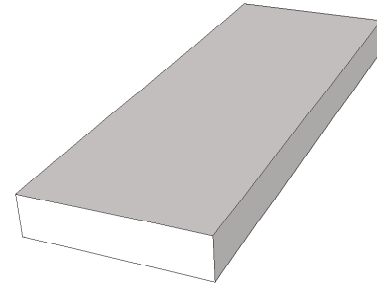


#### Substrate

The base of the FS5 flow sensor chip is a special ceramic with low thermal conductivity.

The production of the FS5 flow sensor starts by deposition of high purity platinum thin film layers onto the ceramic substrate.

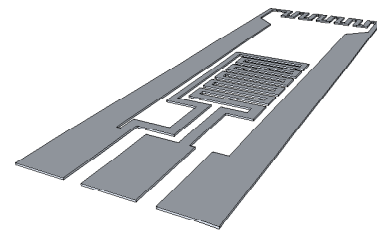
To ensure high quality sensors, wet chemical processes are performed on automated systems for chemical cleaning and etching processes.



#### Resistive structure

The resistive structure on the sensor, consists of two platinum resistors on one chip. The small resistor is used as heater and the high resistor as temperature sensor. 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.

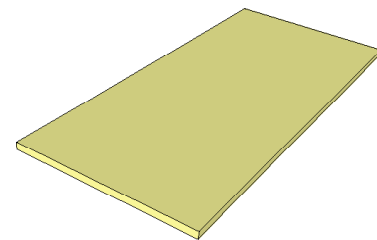
The sensor is individually laser trimmed to the customer specific resistance.



#### 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 FS5 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 FS5 sensor is delivered with 195 mm black PTFE insulated AWG 28/7 stranded wires suitable for crimping and attaching connectors.

The wires are stripped 5 mm.





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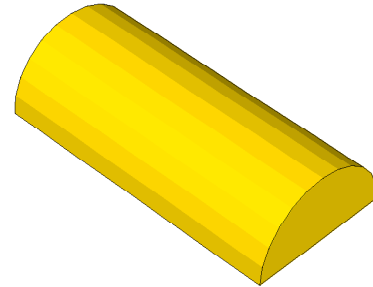
## Thermal Mass Flow Sensor

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#### Wire fixation

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



## 1.5 Measurement Principle

The Innovative Sensor Technology IST AG FS5 thermal mass 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.

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 dimensions of the two standard Innovative Sensor Technology IST AG FS5 thermal mass flow sensors - the FS5.0 without housing and the FS5.A with housing.

### 1.6.1 FS5.0

The standard FS5.0 measures 6.9 mm x 2.4 mm x 0.2 mm



Tolerances: outer dimension (chip):  $\pm 0.2$  mm; thickness (chip):  $\pm 0.1$  mm, height  $\pm 0.3$  mm

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





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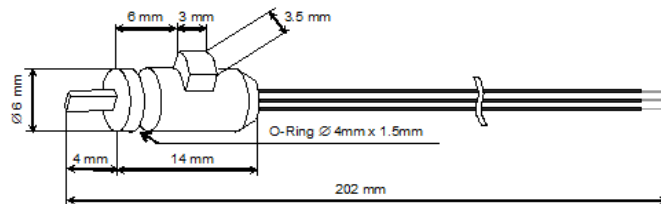
## Thermal Mass Flow Sensor

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#### 1.6.2 FS5.A

For an easy mounting in a channel, the FS5.A is offered with a standard housing.



The standard FS5.A measures  $\varnothing 6.0$ ,  $L = 14$ . PTFE wires measure 195 mm.

Tolerances:  $\pm 0.1$  mm

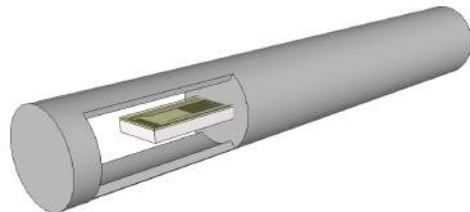
Other dimensions, customer specific housings and wire lengths available upon request.

## 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.

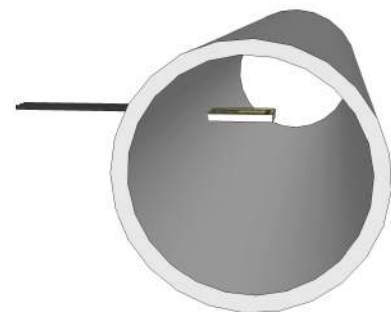
#### Duct mounting flow probe

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.



#### O-Ring

The size of the O-ring is 4 mm x 1.5 mm. The material is NBR with a shore hardness of 70.

Other materials and sizes upon request.



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# Application Note

## Thermal Mass Flow Sensor

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#### Connector

The standard Innovative Sensor Technology IST AG FS5 thermal mass 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

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The standard delivery time of the Innovative Sensor Technology IST AG FS5 sensor is 4-6 weeks after order receipt.

The FS5 sensor is delivered without electronic parts or modules. The FS5 test module must be purchased separately.

#### 1.9 Handling

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The FS5.0 sensor is delivered in a carton box and must be handled as follows:



The FS5.0 sensor is delivered in a box with label showing the exact sensor type and lot-number



Open the box carefully with both hands



Remove the stripes of plastic covering the sensors



Open the carton flaps to release the sensors



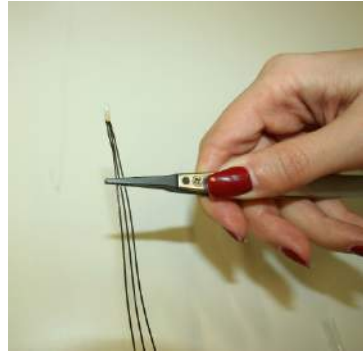
# Application Note

## Thermal Mass Flow Sensor

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Carefully remove the plastic spiral around the wires

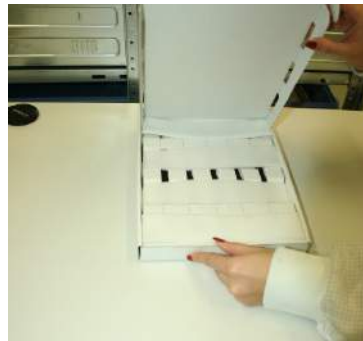


Handle the sensors with plastic tweezers only

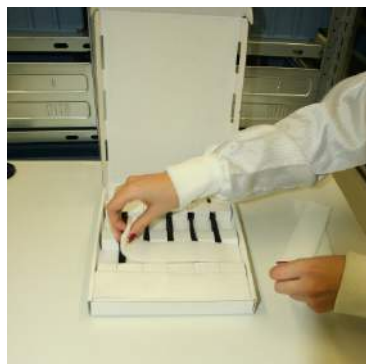
The FS5.A is delivered in a carton box and must be handled as follows:



The FS5.A sensor is delivered in a box with label showing the exact sensor type and lot-number



Open the box carefully with both hands



Remove the stripes of plastic covering the sensors



Open the carton flaps to release the sensors

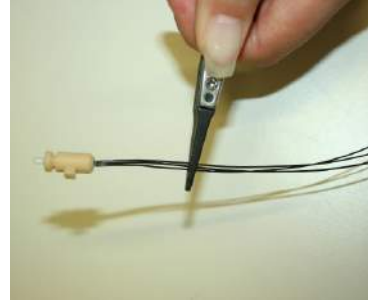
# Application Note

## Thermal Mass Flow Sensor

### FS5



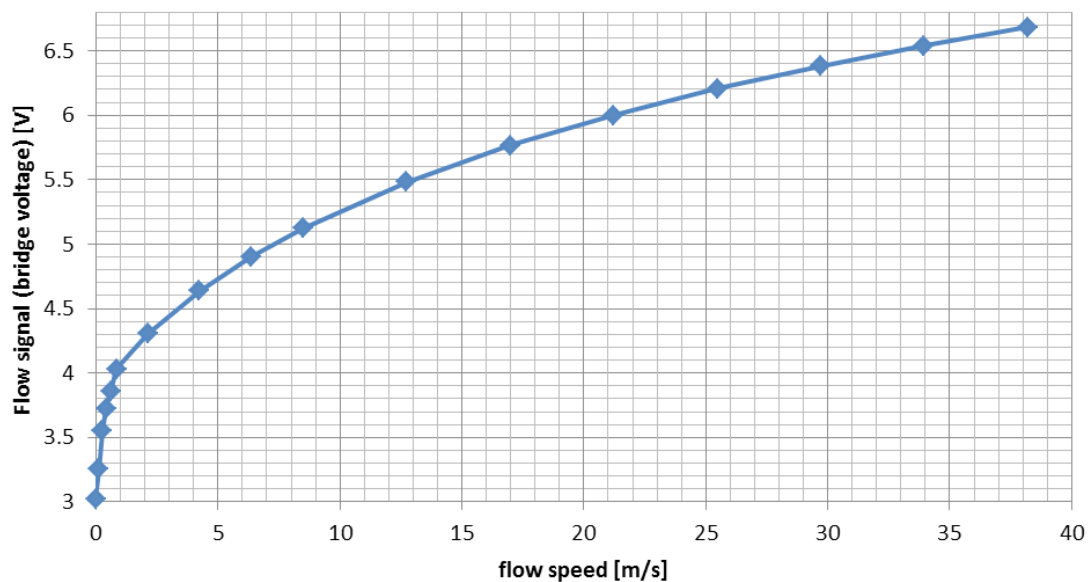
Carefully remove the plastic spiral around the wires



Handle the sensors with plastic tweezers only

#### 1.10 Performance

The following graph showcases the performance of the Innovative Sensor Technology IST AG FS5 sensor during application. Depending on the application and possible influences the measurements might vary.



The output signal is adjusted to 3.0 V at zero flow and corresponds to a temperature difference (heater temperature minus ambient) of approximately 30K. With the temperature difference an optimal overhead of the heating element is generated and hence a perfect performance exists. According to King's Law, which is declared in section 1.12, the sensor performance has the highest sensitivity at lower flow speeds.

The flow speed was measured with a CTA-circuit (see section 1.12) and with nitrogen at an ambient temperature of 25 °C. The sensor was mounted in a tube with an inner diameter of 5 mm.

#### 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 us to find the best possible solution for your situation.



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#### 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 the flow passes over the active sensor surface. The Innovative Sensor Technology IST AG FS5 is independent from 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

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. When 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.

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 (RH) and medium (RS) is set by resistor R1, e.g. DT=30 K for air. The resistor R2 should be adjustable within  $\pm 10\%$  for calibration. The R7 resistor is placed for stability of the anemometer circuit.

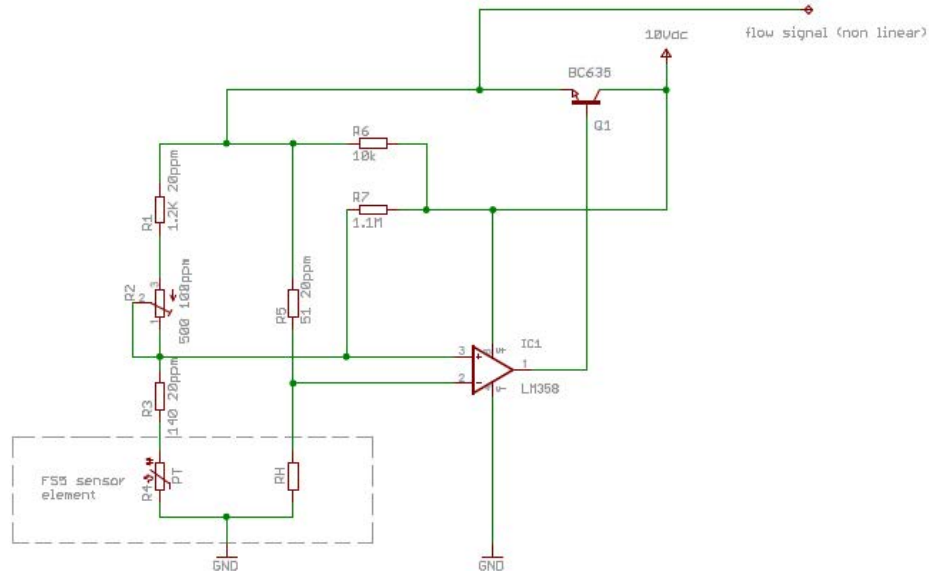
Depending on used operational amplifier, it should be valued from 1.1 M $\Omega$  to 3 M $\Omega$ .



# Application Note

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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:

$$P_H = I_H^2 \cdot R_H = (A + B \cdot \bar{v}^n) \cdot \Delta T \quad n = 0.3 \dots 0.5$$

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

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

$U$  = 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 ( $\Delta T$ ) between the heater and fluid at no flow speed, which results due to natural convection. The controller of a CTA keeps the  $\Delta T$  between heater and temperature sensor constant.

#### Maximum supply voltage

2 V to 5 V

#### Maximum heater voltage

3 V (at 0 m/s)



# Application Note

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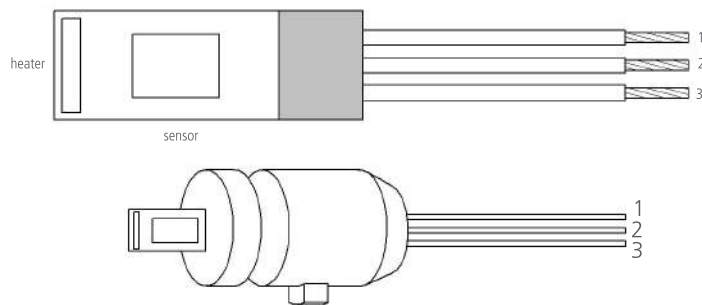


Optimal resistance values (heater resistance)

$R_H (0\text{ }^{\circ}\text{C}) = 45\text{ Ohm} \pm 1\%$

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

Pin assignment



1	2	3
heater	temperature sensor	GND

## 2. Additional Electronics

Module: DFFS5\_FSL\_Module\_E

## 3. Additional Documents

	Document name:
Data sheet:	DFFS5_E DFFS5_D



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