

Determination of the minimum detectable air velocity by thermal flow sensors

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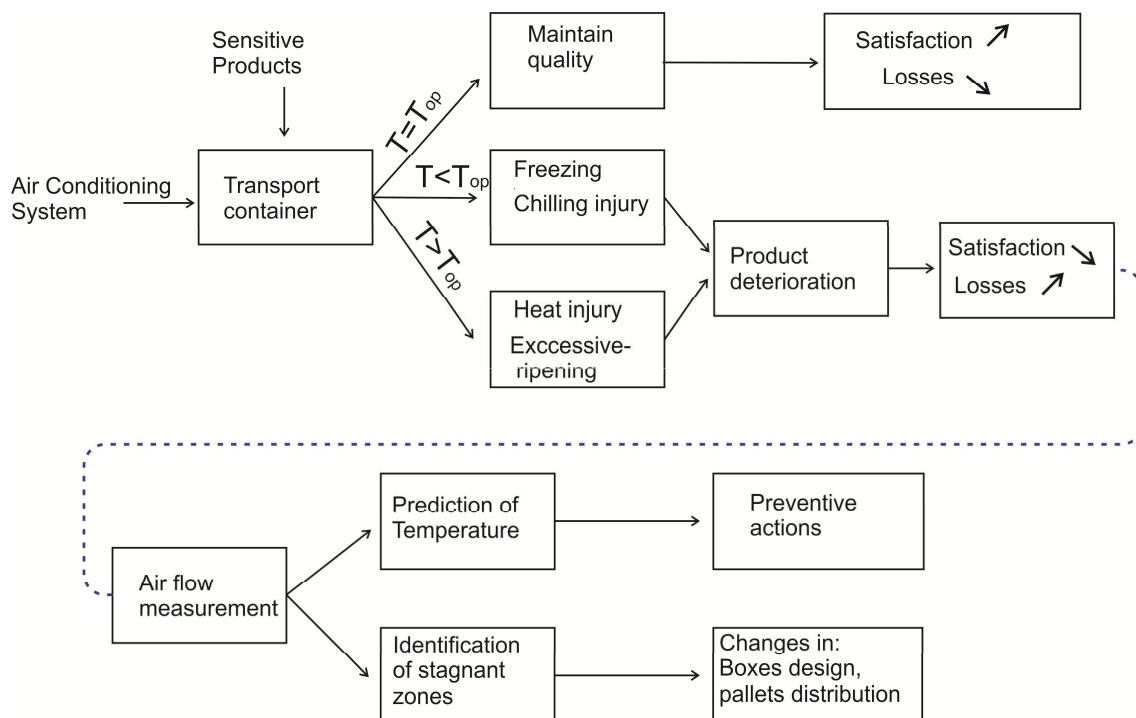
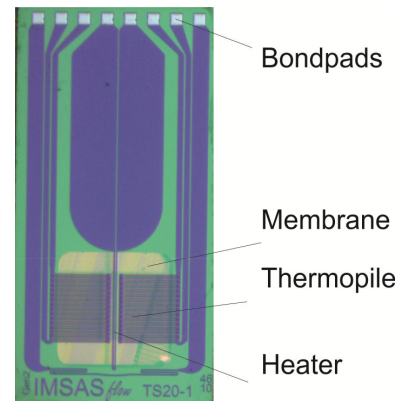
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Content:

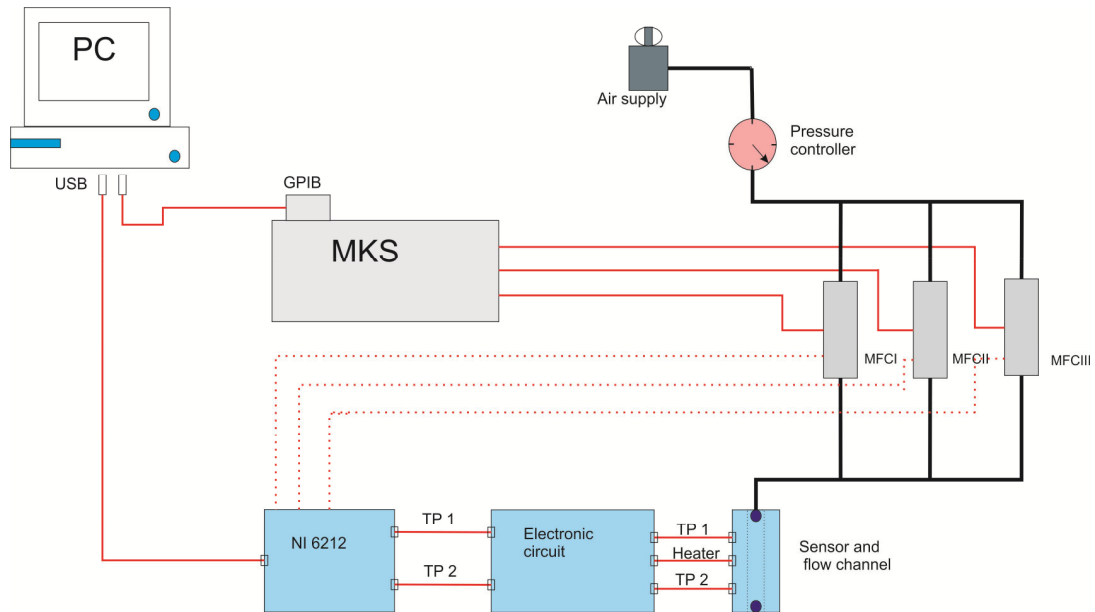
- Introduction
- Characterization of thermal flow sensors
 - Characteristic curves
 - Minimum detectable flow
- Conclusion

Thermal flow sensors

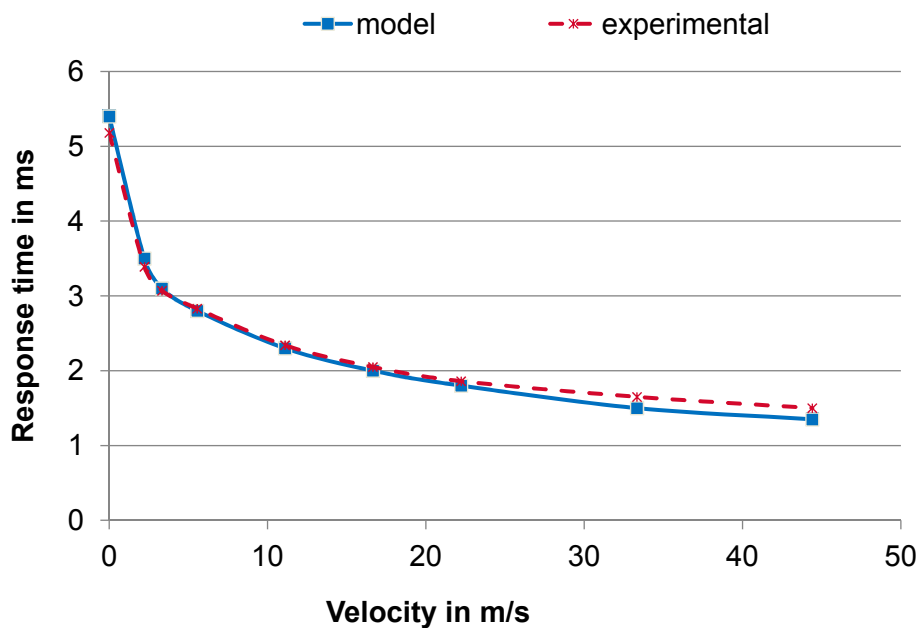
- Principle of sensing
- Sensitive for low flow rates
- Fast response time
- Adaptable for wireless network
- Applications: Medical, Automotive and airflow measurements



Measurement setup



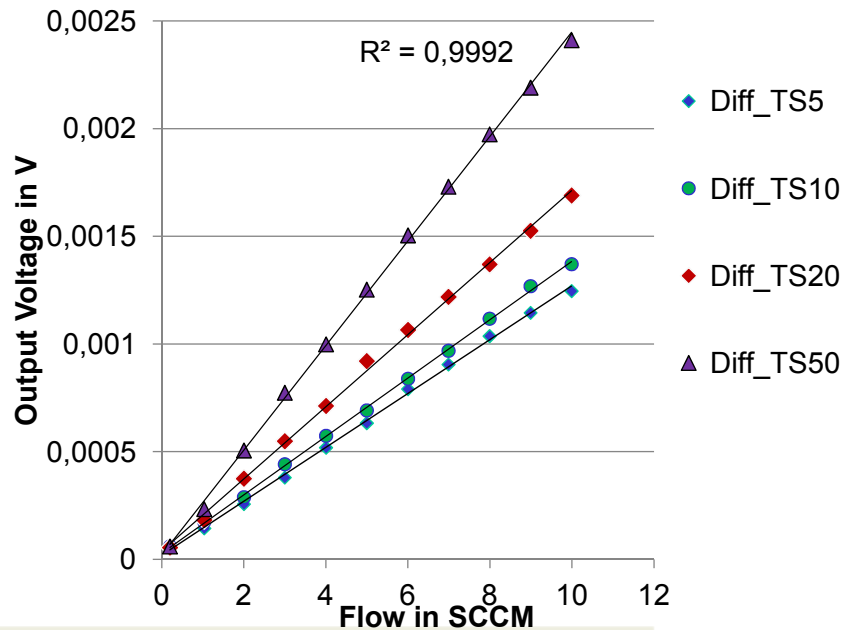
Response time



Characteristic curves (1)

Ultra-low flow:

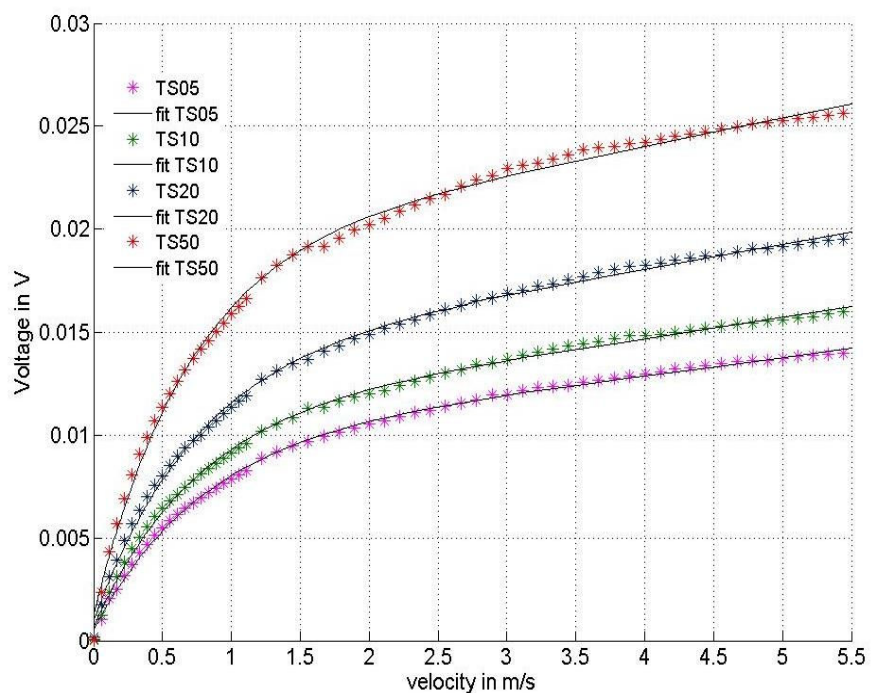
- Range: 0 – 10 SCCM
- Characteristic curve is linear
- R-squared values ≈ 1
- Sensitivity increases with “d”



Characteristic curves (2)

Low flow:

- Range:
0 – 1000 SCCM
 \Leftrightarrow 0 – 5,5 m/s
- Characteristic curve:
 $\Delta E = a e^{bu} + c e^{du}$
- R-squared values ≈ 1
- Sensitivity increases with “d”



Minimum detectable flow (1)

Noise resources:

- Natural convection
- Temperature noise
- Thermal noise (Johnson noise)

Noise level:

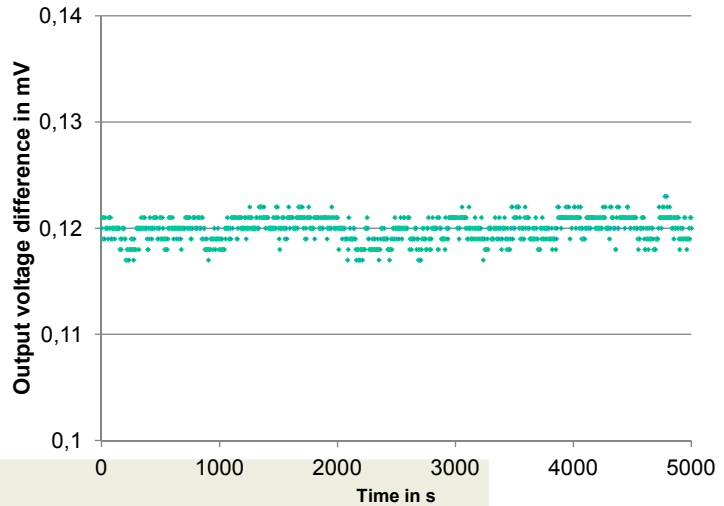
0,1198 mV ± 2,3 μV
(flow = 0)

⇒

Minimum detectable
velocity = U/S
≈ 0,05 mm/s

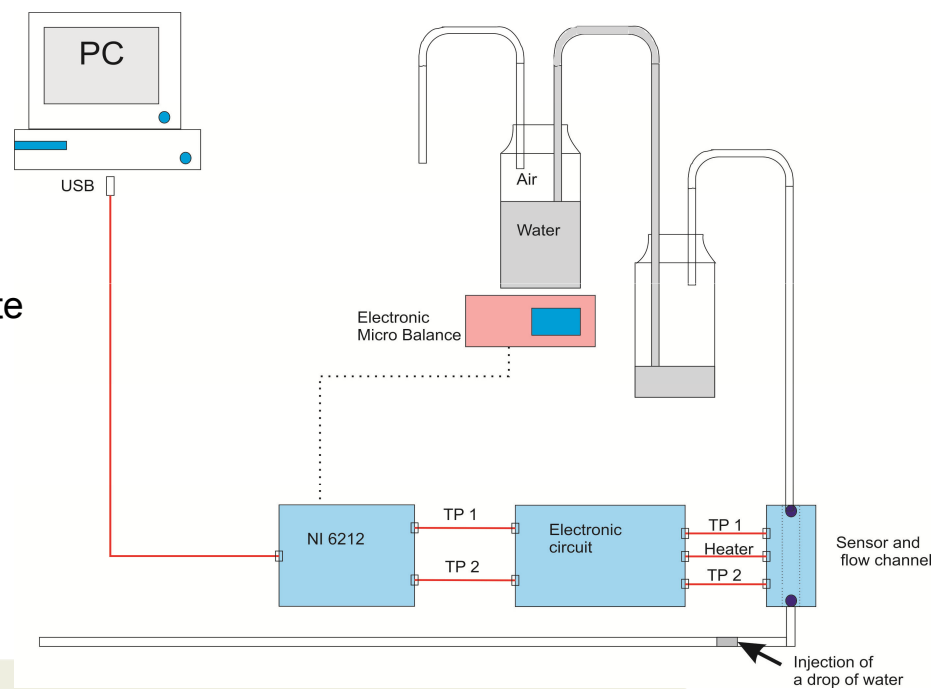
Sensitivity of the sensor:

$$S = \left. \frac{\partial V_{diff}}{\partial u} \right|_{u=0}$$



Minimum detectable flow (2)

Experimental
methods to generate
very low flow

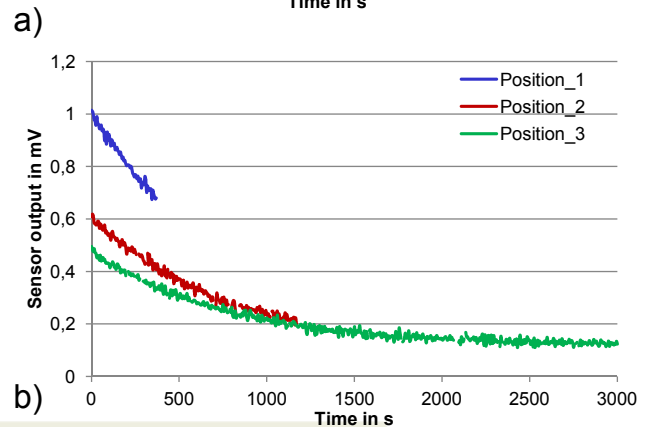
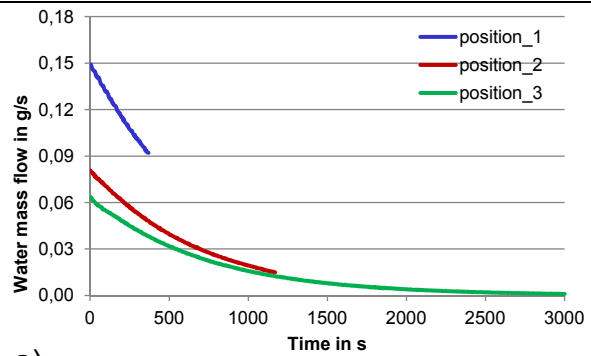


Minimum detectable flow (3)

3 different relative positions
for the two bottles

a) Balance readings
(g/s \Rightarrow mm/s)

b) Thermopiles output voltage
difference (mV)



Minimum detectable flow (4)

$$v = 21.1136 e^{-0.0014 \cdot t} - 0.0092 \quad (\text{in mm/s})$$

$$E = 0.3635 e^{-0.0014 \cdot t} + 0.1228 \quad (\text{in mV})$$

$$E = 0.01722 \cdot v + 0.12296 \quad \Rightarrow$$

$$\Delta E = 0.01722 \cdot \Delta v$$

Considering results and noise in zero flow \Rightarrow
Minimum detectable flow velocity = 0.3 mm/s

Conclusions

The studied thermal flow sensors have:

- Linear characteristic curves for ultra low flow
- Minimum detectable air velocity
 - Theoretically 0.05 mm/s
 - Experimentally 0.3 mm/s

Thank you for your attention