SMD pressure and flow sensor for compressed air in LTCC technology with integrated electronics

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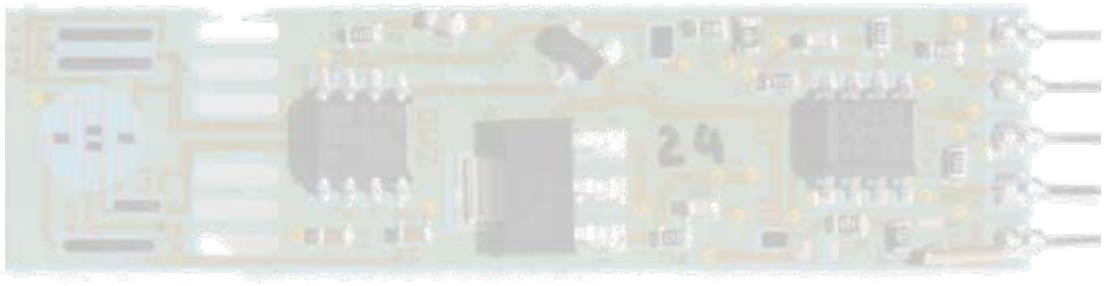
Flow Sensors session - Sept 9th, 10:30-12:00



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http://lpm.epfl.ch/tf

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STI-LPM, Station 17, 1015 Lausanne, Switzerland

What is it all about?

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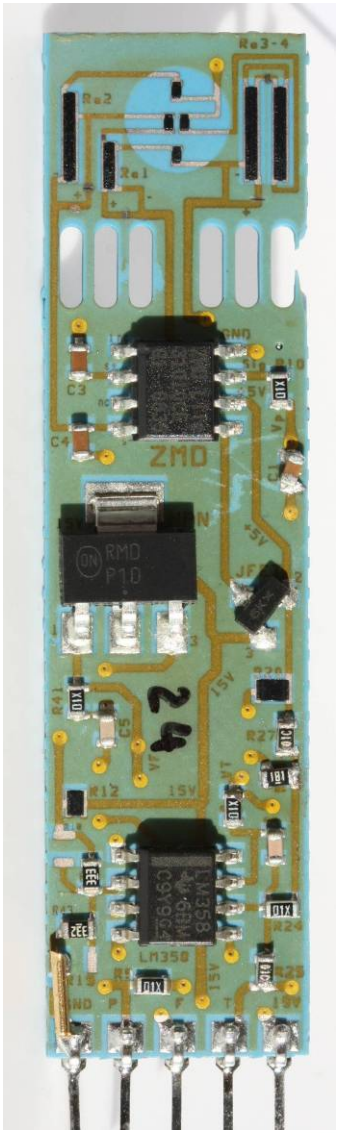
An integrated sensor:

- ...in **LTCC**, for the pneumatic industry
- ...**SMD** mountable by soldering
- ...with **integrated electronics**

For measuring:

- **air pressure** 0...6 bar
- **air flow** 0...100 NL/min
- **air temperature** 0...100 °C



Presentation outline

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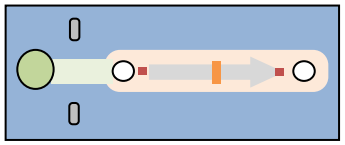
1. Introduction – the needs of the industry
2. Integrated sensor – manufacturing
3. Measurements – pressure, flow, temp.
4. Conclusions & outlook



1. Motivations

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Precise fluid measurement (p, flow, T): **OK**

- numerous methods already exist
- usually with specific CMOS chips

Still an issue for industrial devices:

- coarse measurements for diagnostics

safe & reliable

low-cost

easy to integrate → "total" SMD

1. Motivations

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Focussing on custom pneumatic circuits:

- actuator feedback: *has the piston moved?*
- monitoring: *what is the valve output pressure?*
- circuit diagnostics: *is the channel clogged / leaking?*

⇒ **Measurement of pressure, flow, and temperature**

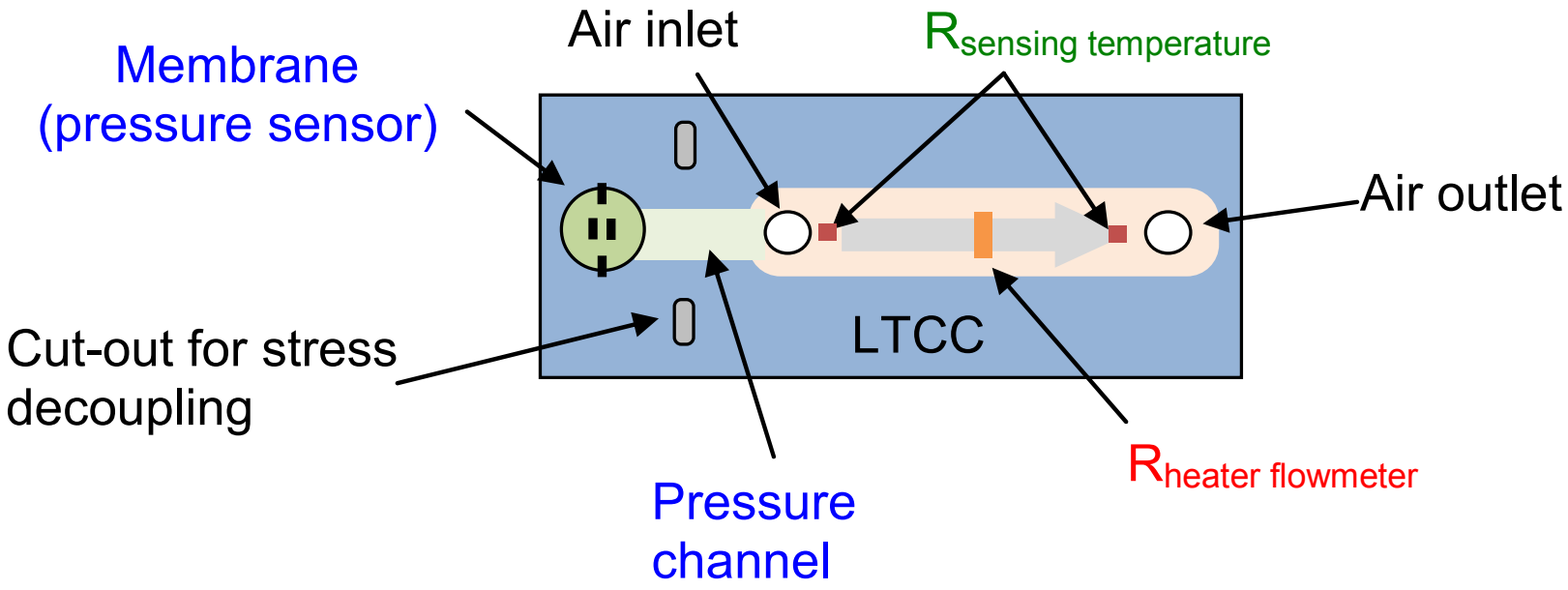
Sensors requirements:

- simple, cheap, robust, reliable
- **no need for precision**
- easily mountable (SMD for both electronics + fluidics)
- integrated electronics (no need for signal processing)

2. Integrated sensor

Proposal: an LTCC integrated sensor with electronics

- pressure
- flow
- temperature



2. Screen-printing, stacking

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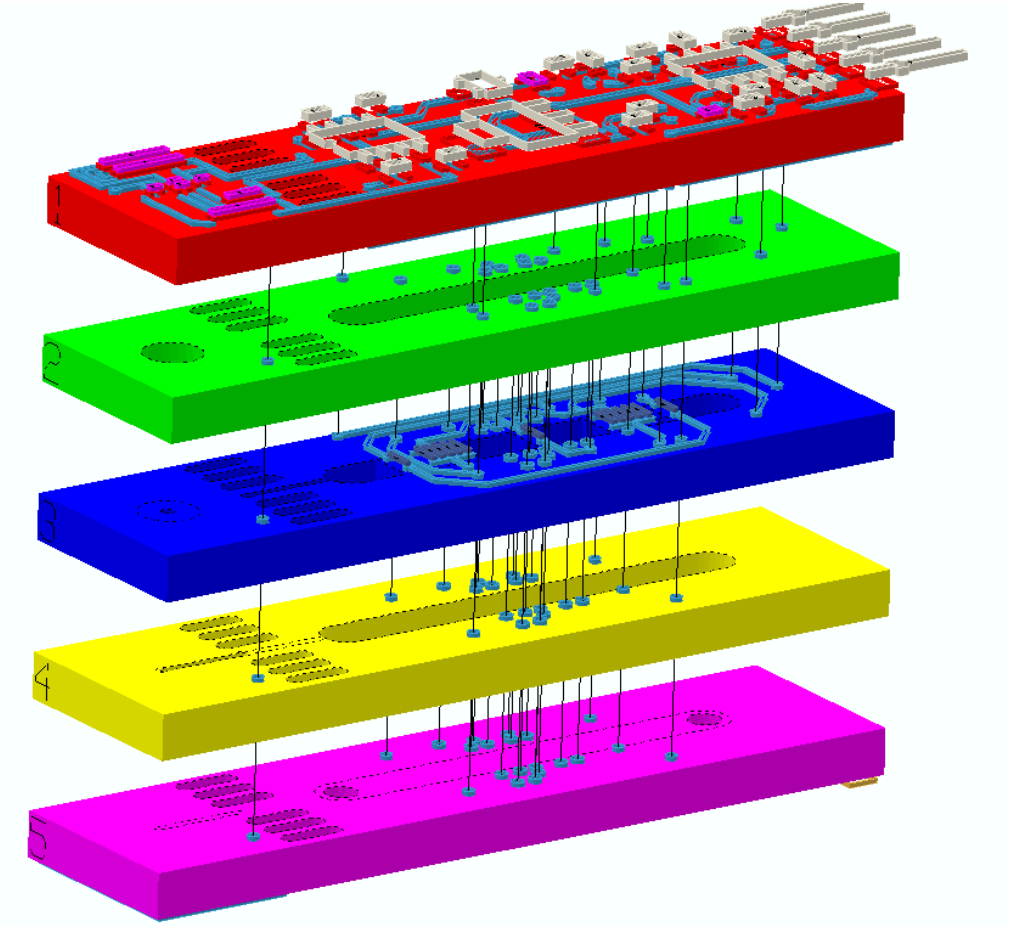
LTCC DuPont 951

- **Vias**
  Ag *DuPont 6141*
- **Conductor tracks**
  Ag:Pd *DuPont 6146*
  Ag *DuPont 6145*
- **Resistors**
  10 kΩ/□ *DuPont 2041*
  PTC *DuPont 5092D*



2. Lamination and firing

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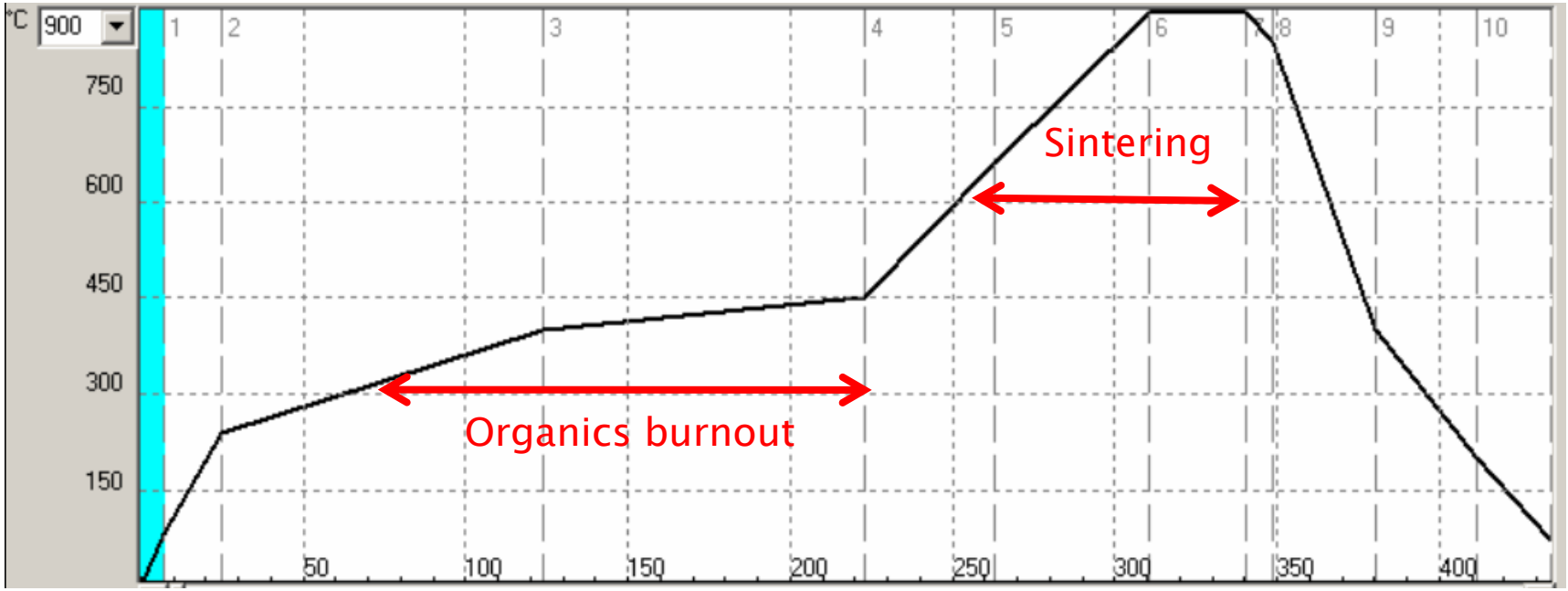
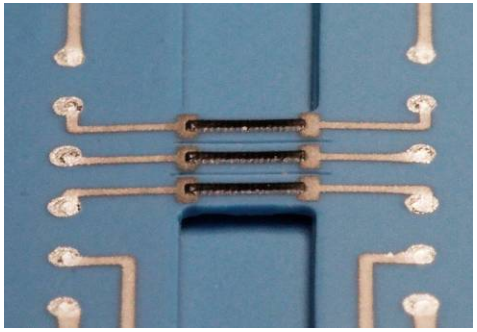
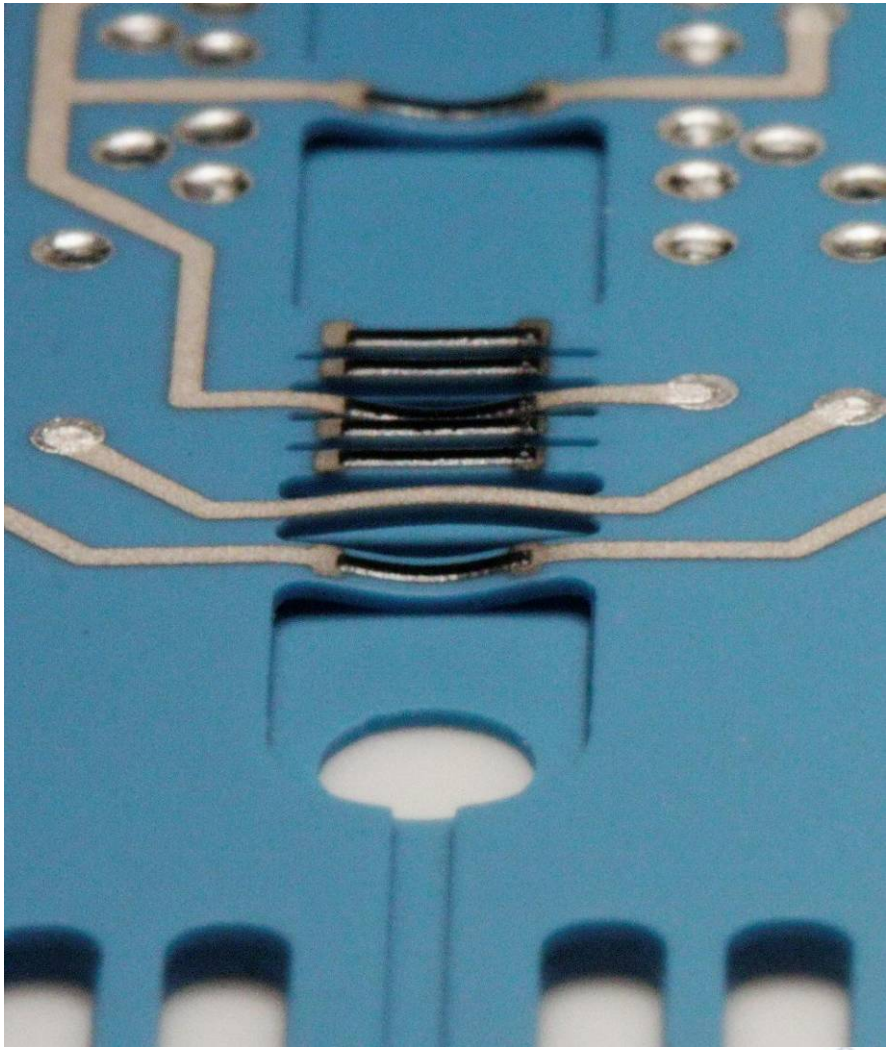
- Successive partial and total laminations:
  - **constrained rubber @ 90 bar, 46°C**, 10 min
  - **metal plates @ 80 bar, 25°C**, 10 min
- Firing in air, 875°C, heating ramp 5 K/min



2. Manufacturing issues





Differential sintering issues between LTCC and pastes
→ **deformations**

⇒ Need adapted layout or sacrificial layers

2. Assembly on test PCB

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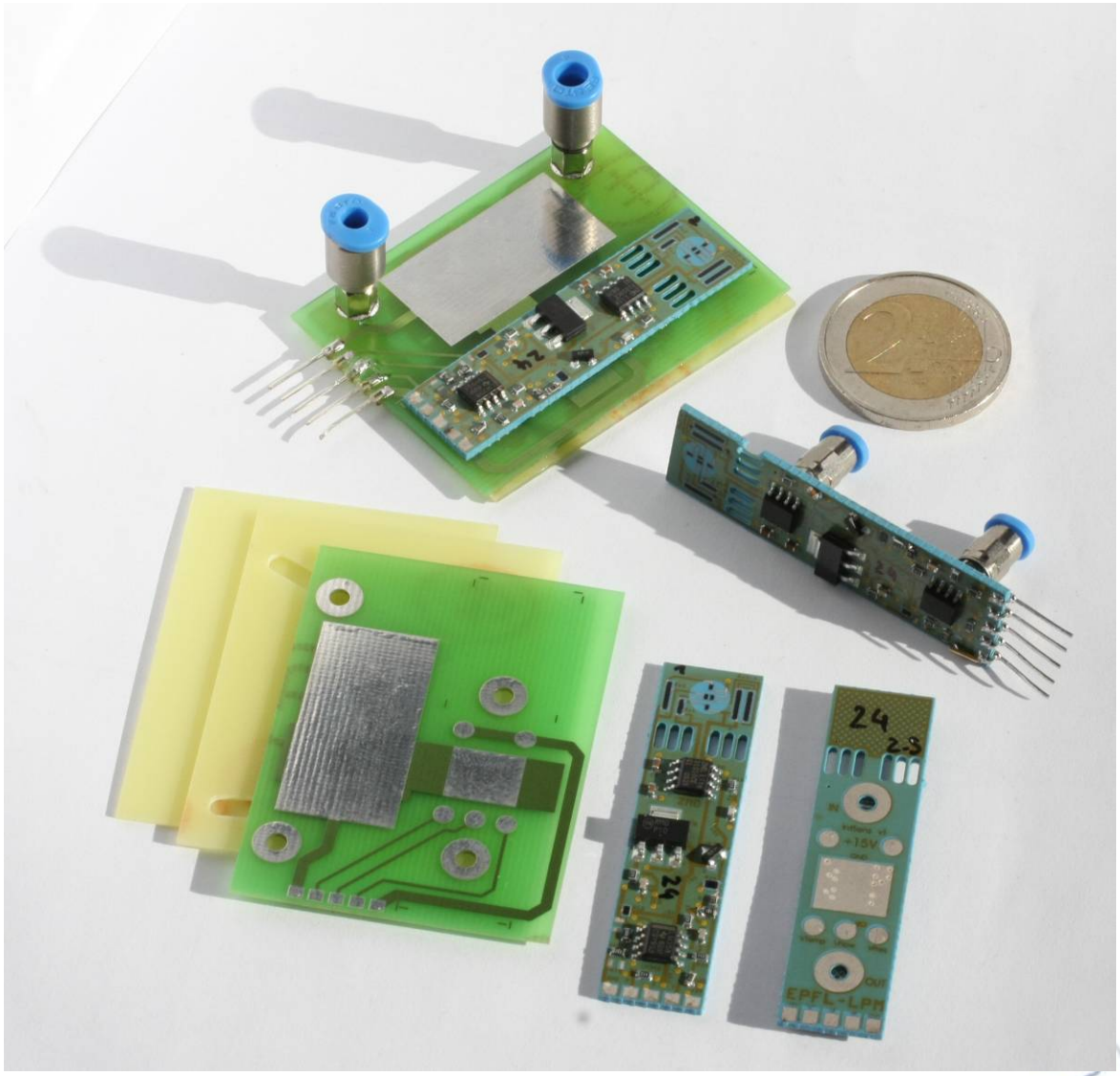
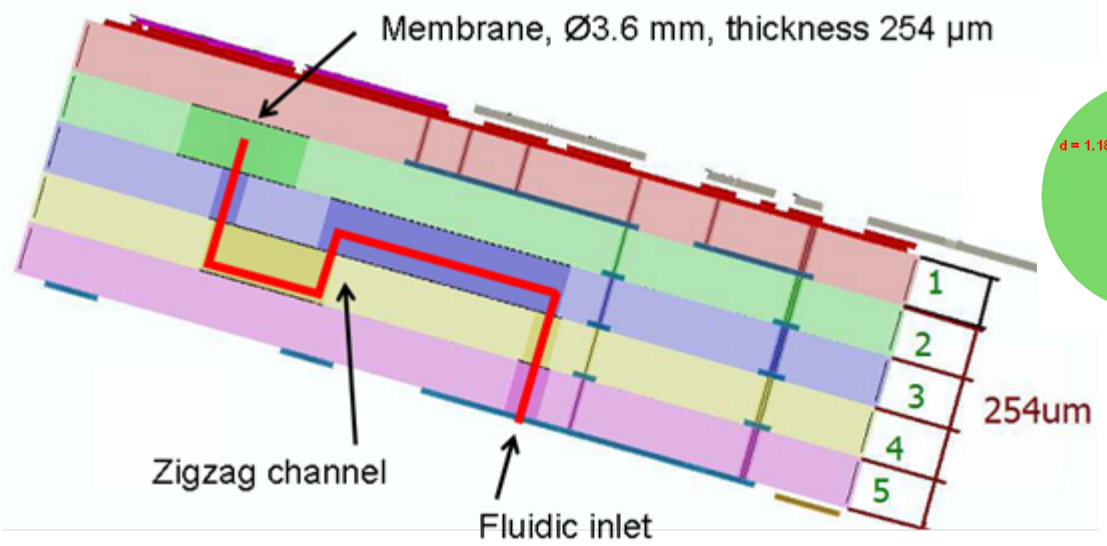
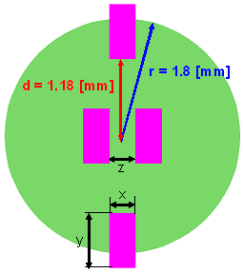
Test PCB

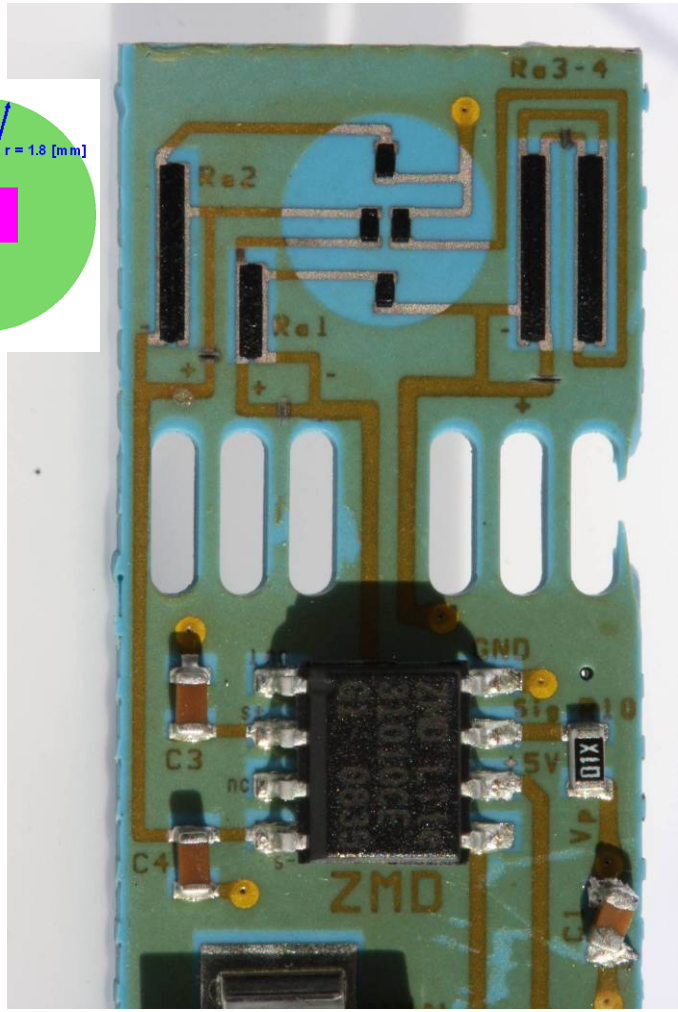
- Fluidic connections
- Electrical interconnects
- Large copper planes for future thermal studies



3. Pressure sensor







- Nominal pressure: **6 bar**
- **Piezoresistive bridge** on circular membrane
- Pressure path to avoid stress concentration on membrane

3. Pressure signal conditioning

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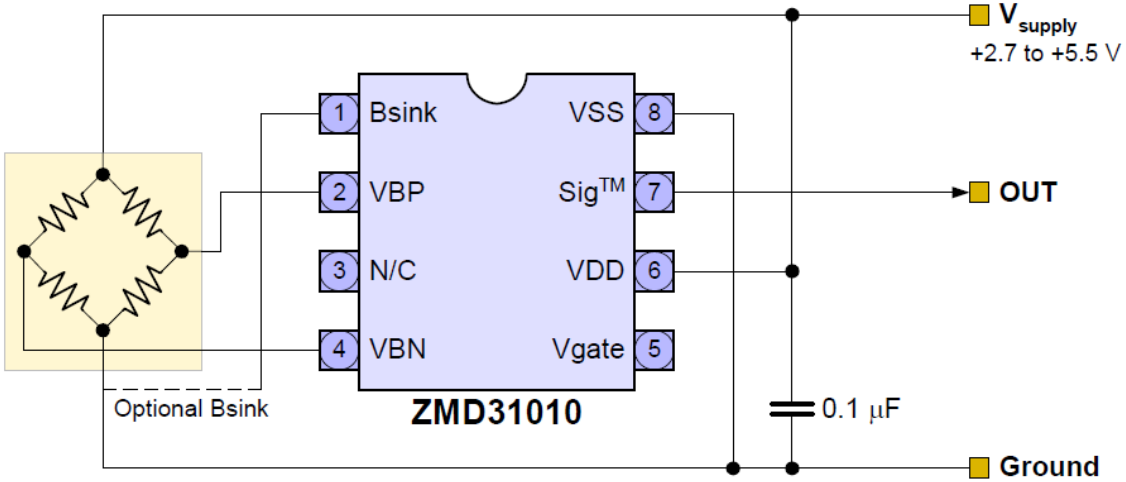
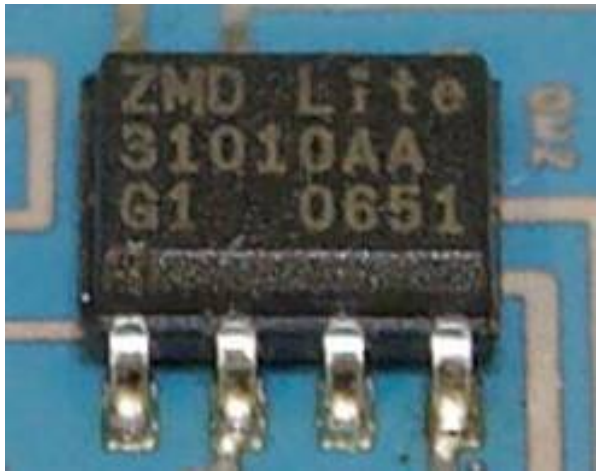
- Easy adjustment of gain/offset

⇒ Wheatstone bridge

⇒ **programmable integrated conditioner** (*ZMD 31010*)





3. Performance (pressure)

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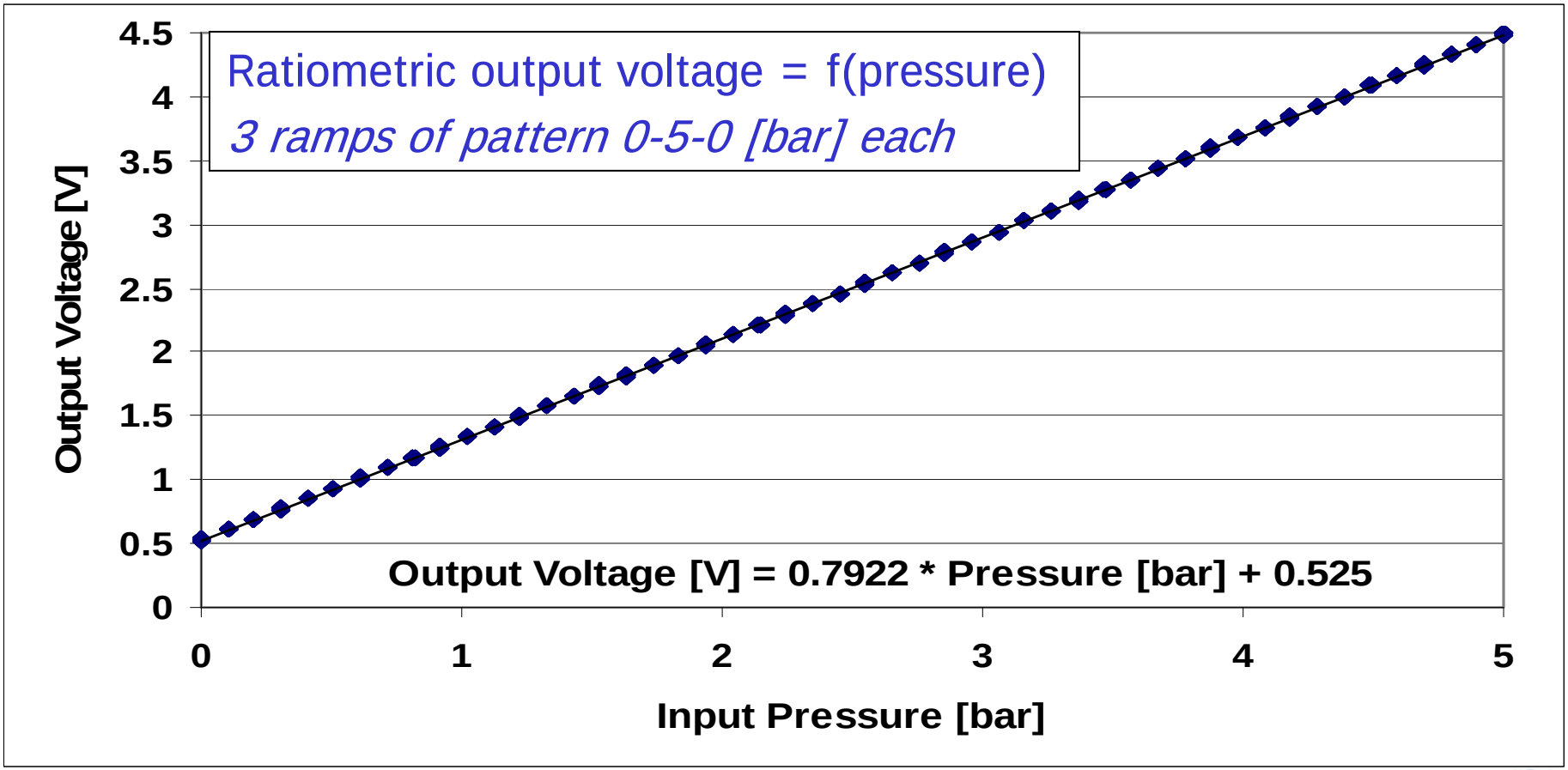
- Very good repeatability: <0.1% (former prototype)
- Precision = f (voltage reference) (~1-2 %)



3. Flow sensor

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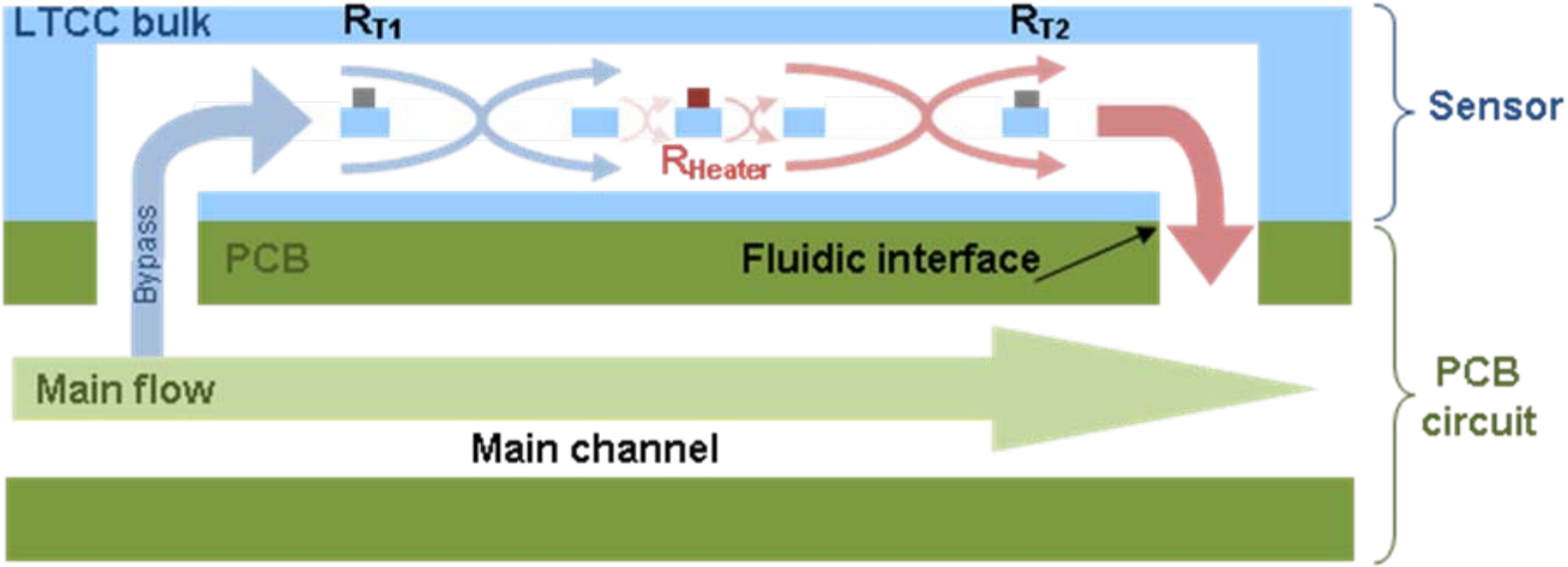
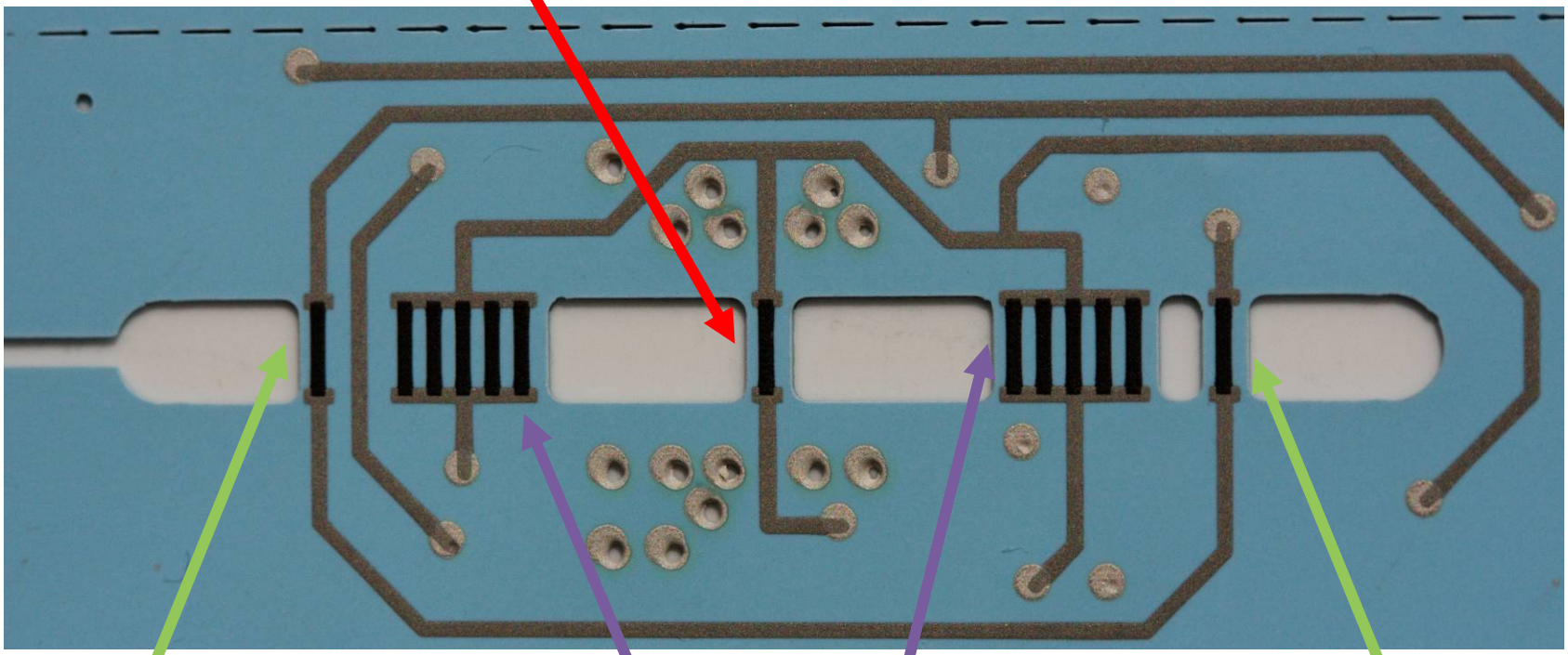
- Flow range: 0...20 NL/min (100 NL/min with bypass)
- Reaction time: <3 s
- Measuring principle: **anemometric, 1 central heater**



3. Resistors layout



3. Performance (flow)

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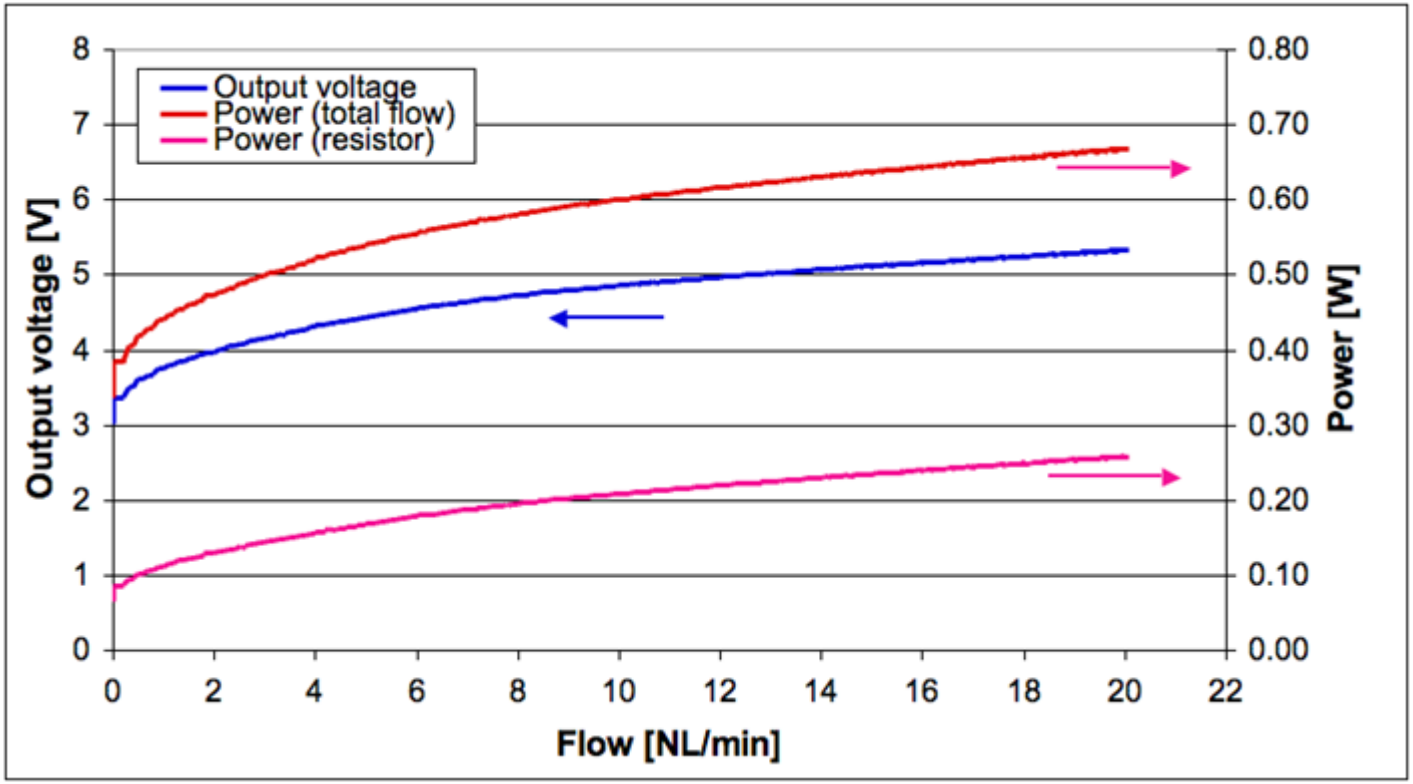
- Output voltage in function of flow (here w/o bypass)
- Output well correlated with dissipated power (square root with offset)
- High total dissipation due to linear regulation → **go to switching**



3. Temperature sensor

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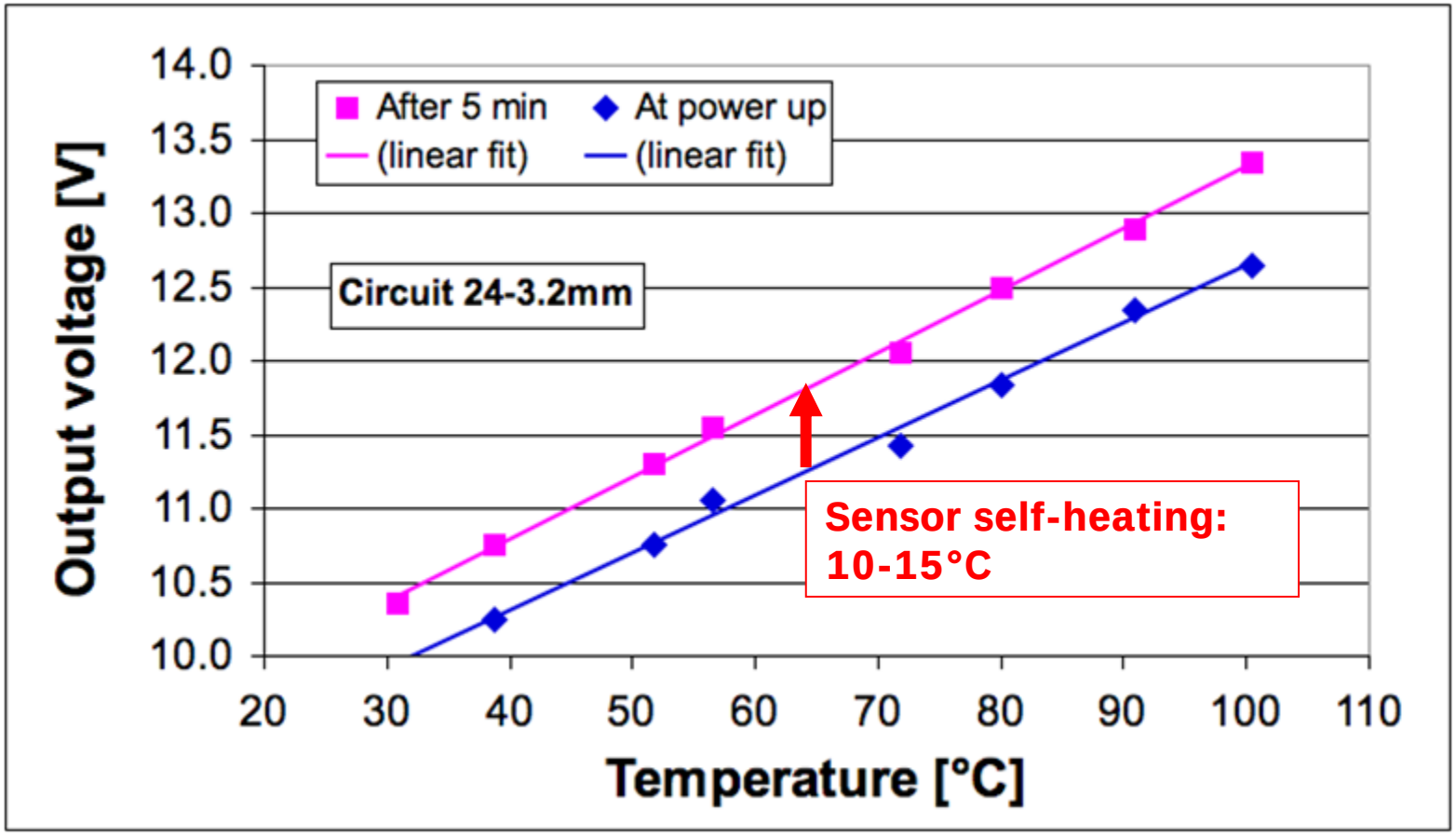
- Two PTC thermistors placed in channel near orifices



Measured under 12 V in air oven

Idle sensor current: ~32 mA

4. Conclusions & outlook

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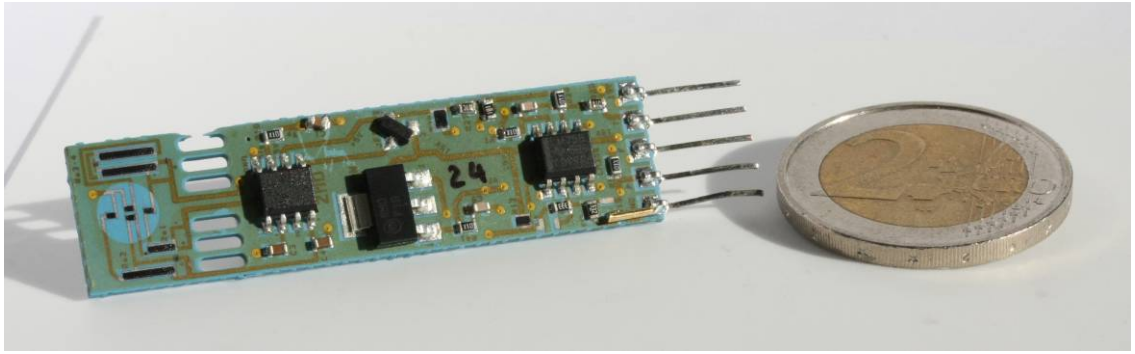
- **Simple & cheap LTCC compressed air diagnostics sensor**
- **Assembly by SMD**
- **Pressure:** 0...6 bar, piezoresistive
- **Flow:** 0...20 NL/min (higher with bypass), anemometric, constant temp.
- **Temperature:** 0...100°C coarse measurement



- **Thermal characterisation + optimisation**
- **Go to switching regulator for heater**

The end – questions?

Thank you for your attention…
…and enjoy Switzerland!

Feel free to contact us for a lab visit here at EPFL:
LPM (Laboratoire de Production Microtechnique)
in the BM (Bâtiment de Microtechnique)

Annexes

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Supplementary slides

2. Specs

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- Hybrid design: thick-film + SMD devices

- Assembly and connections by flip-chip

  ⇒ use of **different solder pastes**:
  - for electronics: lead-free Sn96.5-Ag3.0-Cu0.5, 220°C
  - for the whole sensor on PCB: SnBi, 138°C

- 5 pins: ground, signals (p, F, T) and power +15V

2. Pressure fluidics

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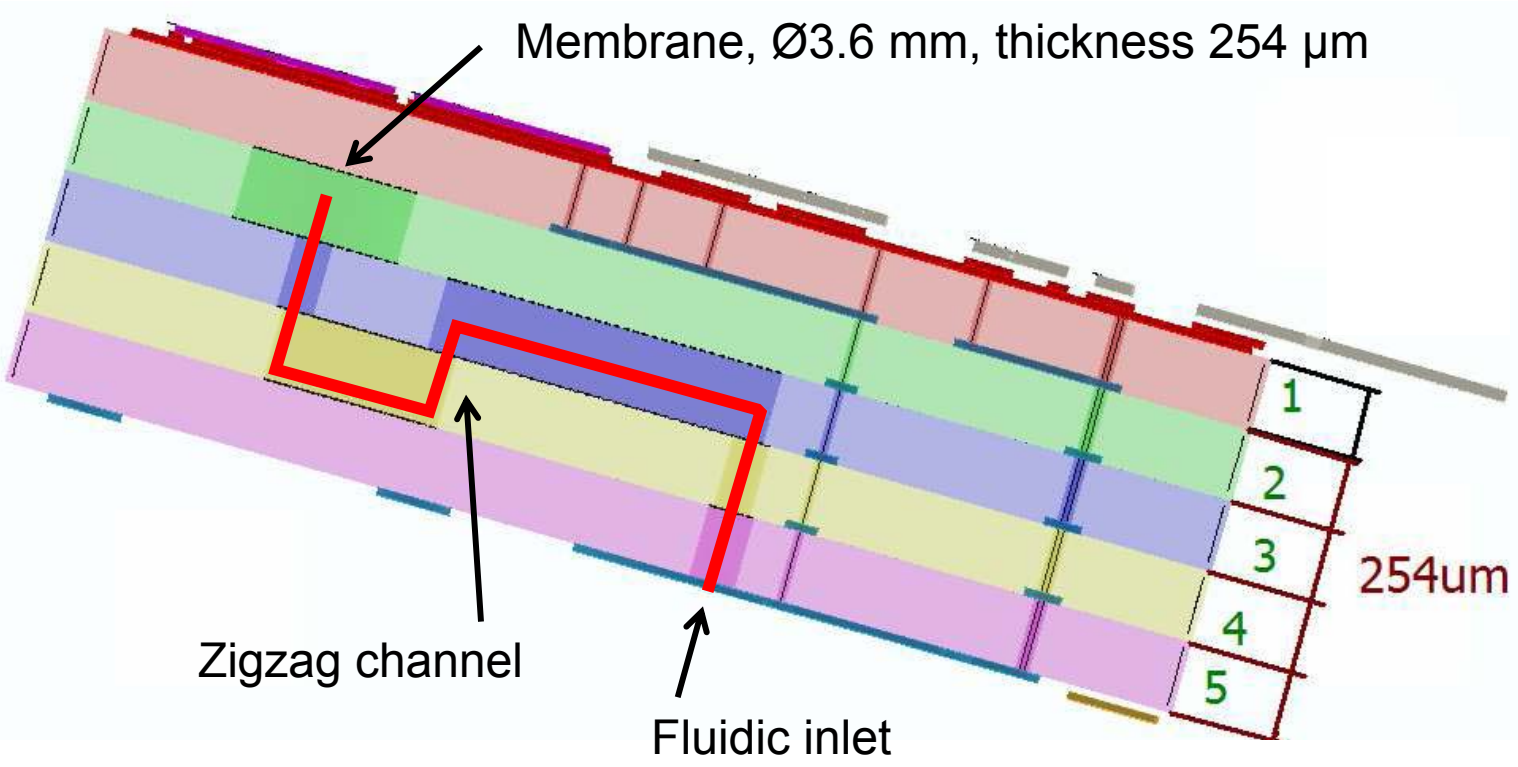
- 200-µm membrane decoupled from fluidic inlet (reduction of assembly stress influence)
- Channel in zigzag (issues with long channels)



3. Flow vs pressure

Pressure in channel increasing with flow