DfMM NoE PATENT

Information Society Technologies
European Commission

WP1: Test engineering and Design for Testability of Micro- and Nano-Systems

MEMS Testing through Bias Superposition

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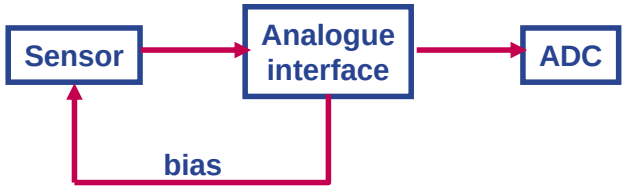
Background and Test Principle

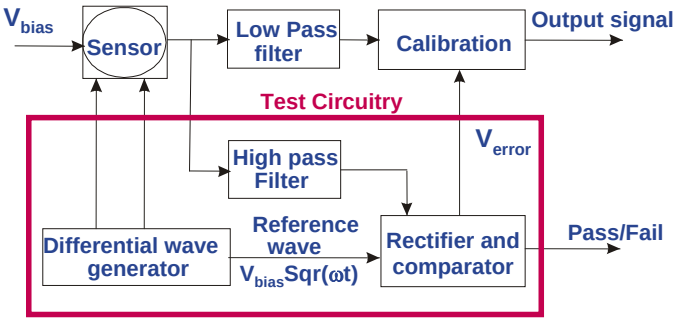
- Architecture of microsensors



- Solutions for cross-sensitivity compensation, auto-calibration and health monitoring:
  - Triple Modular Redundancy (TMR) ⇨ not competitive
  - Secondary sensor
  - Bias superposition
    - Only one sensor to perform both measurement of the physical parameter and to provide information regarding its transfer function
    - Alteration of the sensor bias outside its operating frequency band
      - Superposition of a signal test
      - Amplitude modulation of the bias to create a signal test

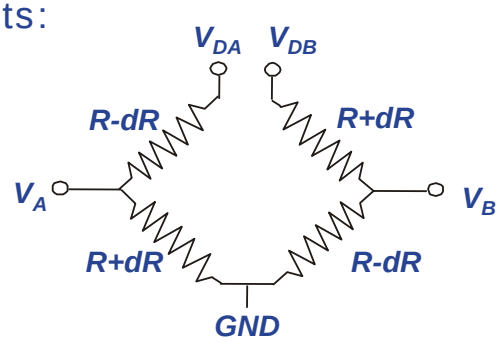
Piezoresistive Wheatstone Bridge

- Test principle and high level diagram of the system:



- V_{DD} is split into two differential inputs:

$V_{DA}=V_{bias}+V_{bias}Sqr(\omega t)$, $V_{DB}=V_{bias}-V_{bias}Sqr(\omega t)$



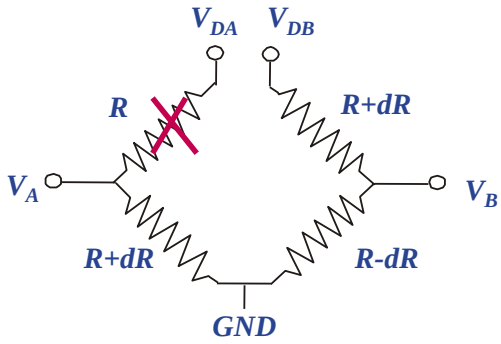
Fault-free sensor

$$V_{outDC} = V_{bias}\frac{dR}{R}$$

$$V_{outAC} = V_{bias}sqr(\omega t) \quad \Rightarrow \quad V_{error} = 0$$

Piezoresistive Wheatstone Bridge

- Response of a faulty device:



  - DC response

$$V_{outDC} = \left(\frac{3RdR+dR^2}{4R^2+2RdR}\right)V_{bias}$$

  - Amplitude of the AC response

$$V_{outAC} = \left(\frac{4R^2+RdR-dR^2}{4R^2+2RdR}\right)V_{bias}$$

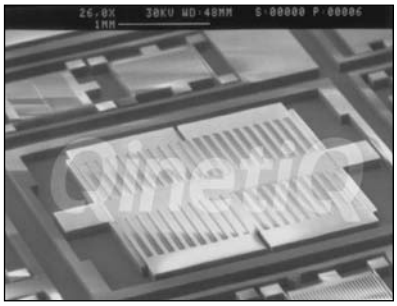
- Error signal: $V_{err} = \left(\frac{RdR+dR^2}{4R^2+2RdR}\right)V_{bias}$

Response of a fault-free device !

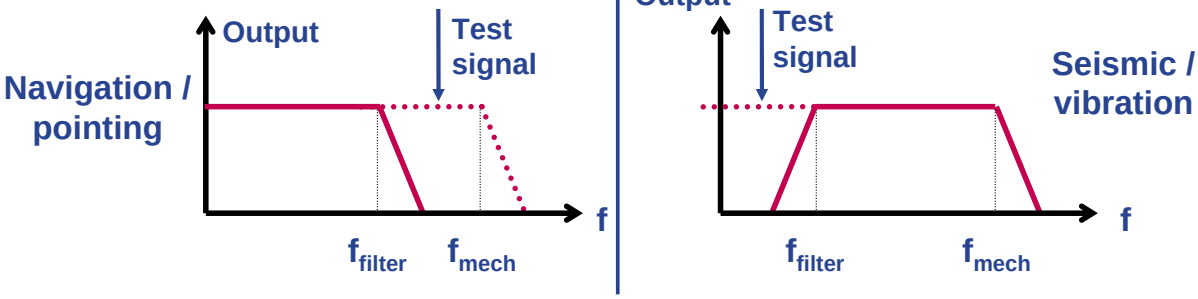
- Calibration: $V_{out} = V_{outDC} + V_{err} = \frac{dR}{R}V_{bias}$

Capacitive Accelerometer

- Potential demonstrator for bias superposition technique
  - Capacitive accelerometer of QinetiQ
  - Signal test below the mechanical cut-off frequency
- Bias superposition frequency depends on application
  - Navigation/pointing applications - requires DC output
  - Seismic/vibration applications - finite bandwidth

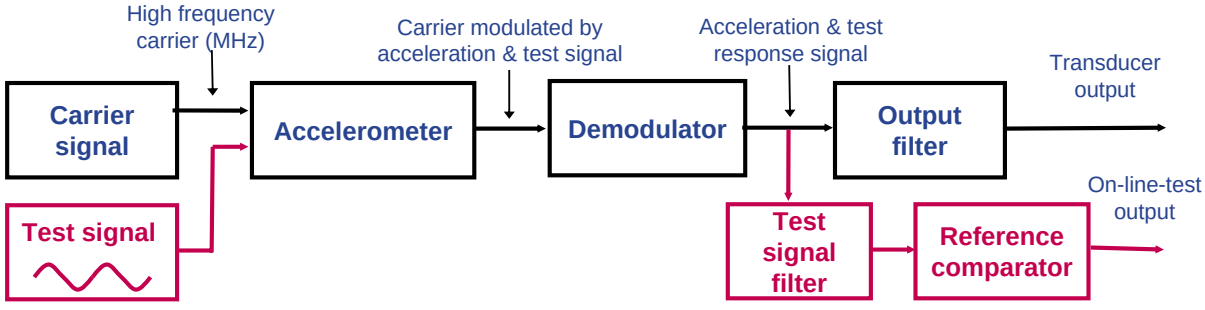


DRIE SOI (100µm thick) Accelerometer (2.6mm x 2.6mm)

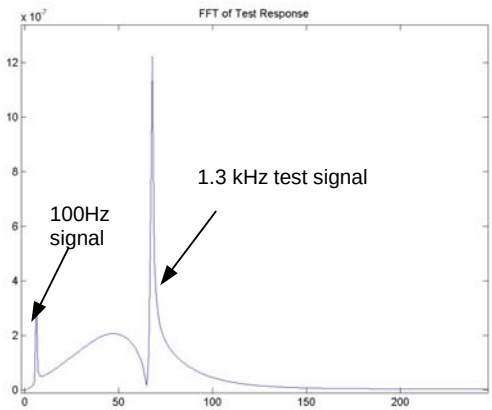


Capacitive Accelerometer: Proposed Test Implementation

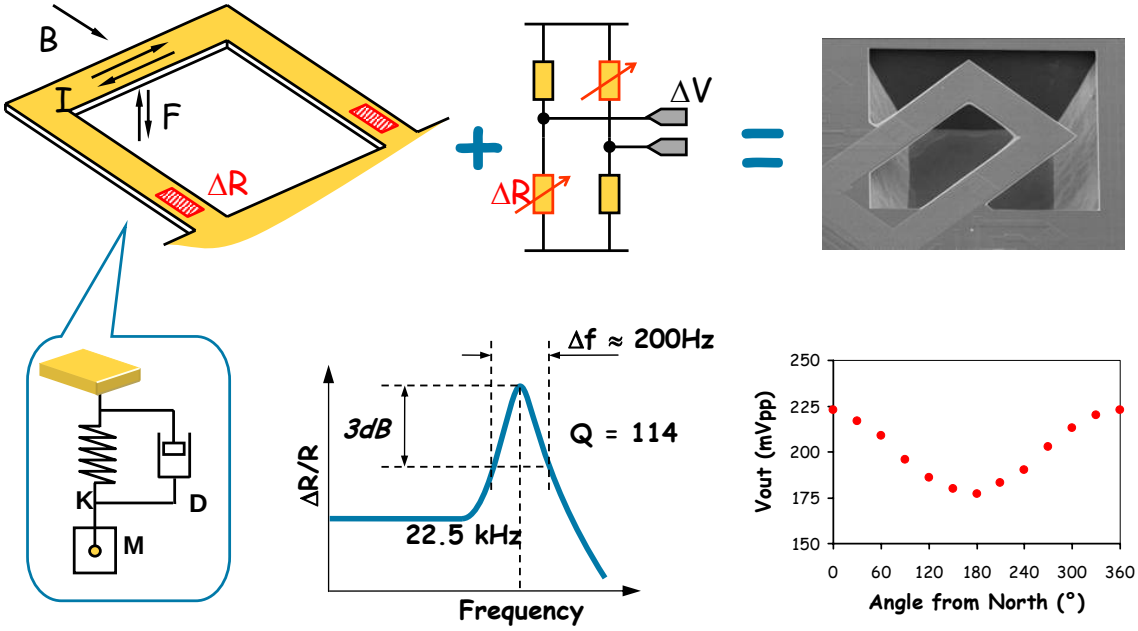
- High level diagram of the system + bias superposition



- Matlab simulations
  - Acceleration: 1mg, 100Hz
  - Test signal: 50mg, 1.3kHz

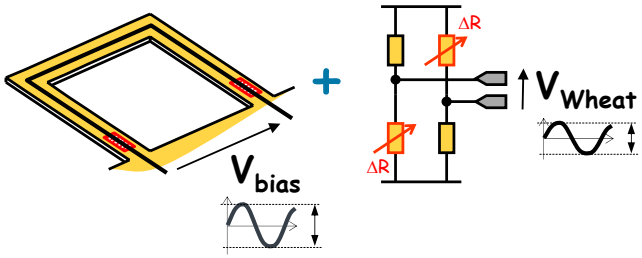


Magnetometer : Background

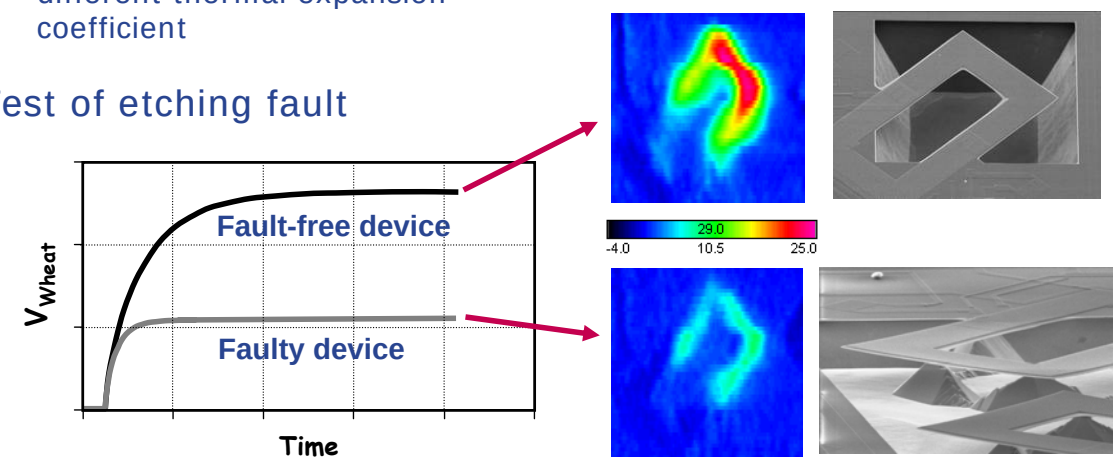


Thermal behavior

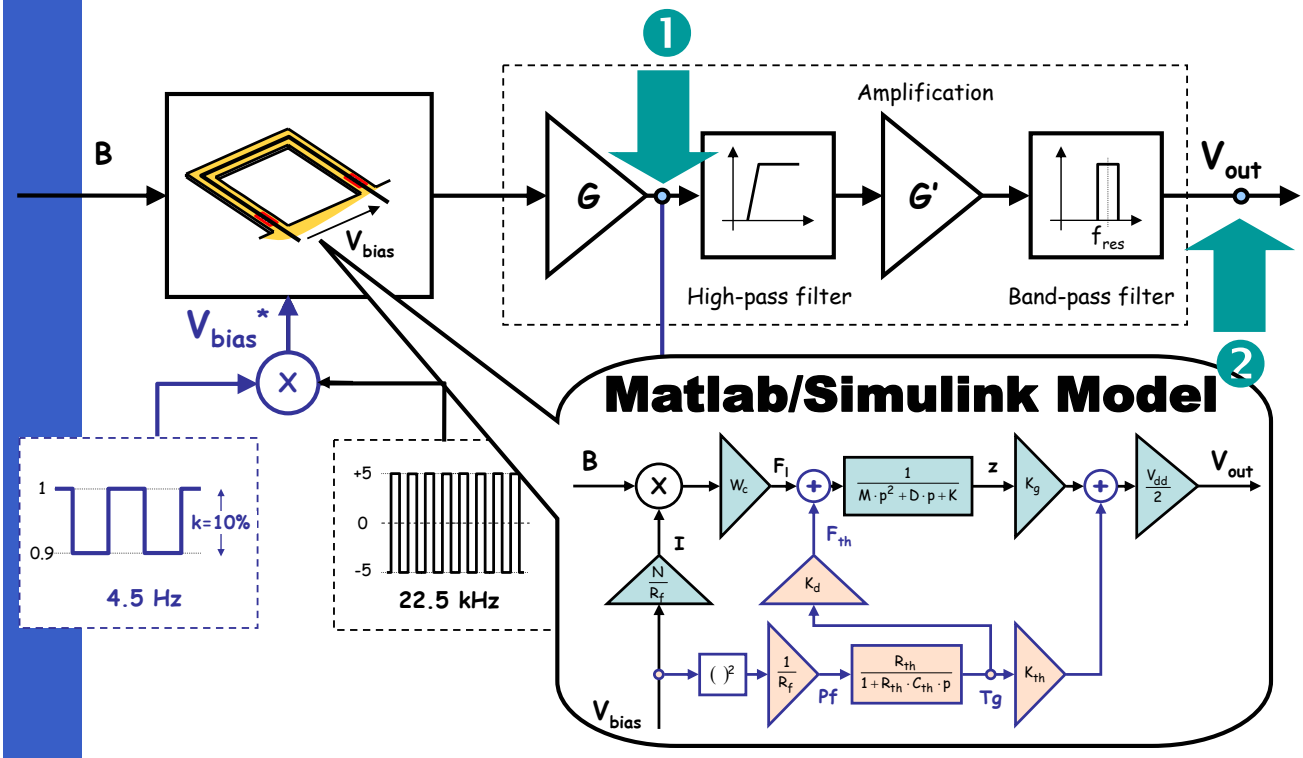
- 2 effects related to temperature
  - Temperature induced signal due to the thermal sensitivity of the gauges
  - Deformation of the mechanical frame due to different thermal expansion coefficient



- Test of etching fault



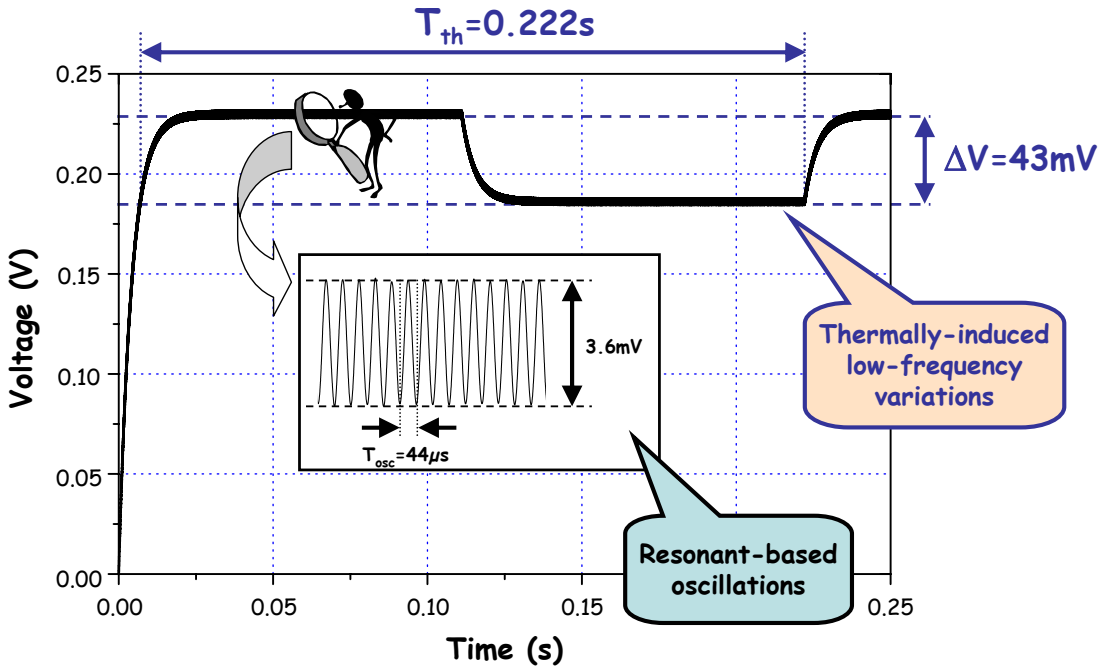
Electronic interface and Test Implementation



Sensor output

k=10%

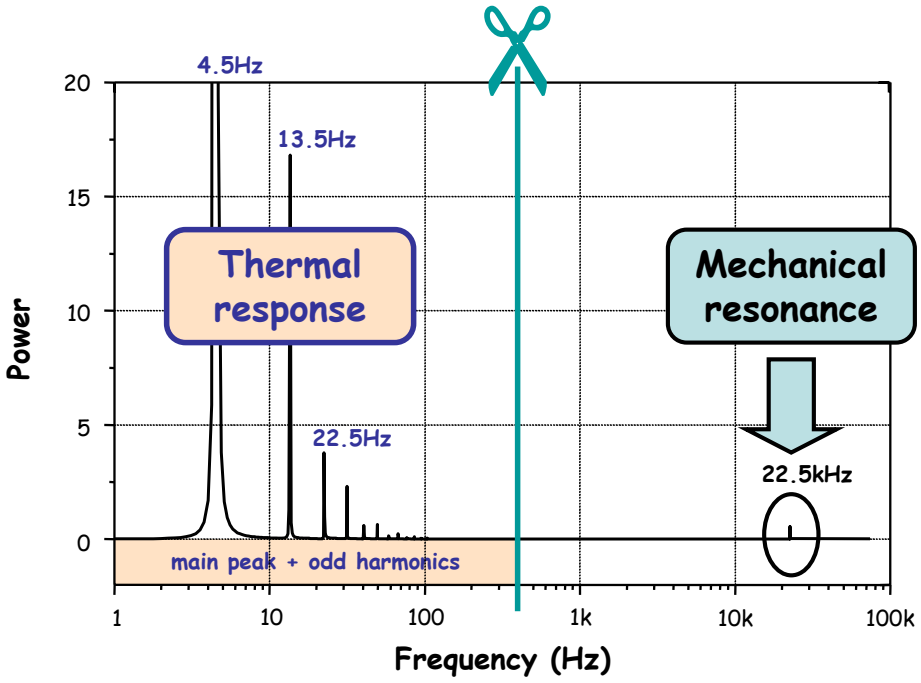
Transient response



Sensor output

k=10%

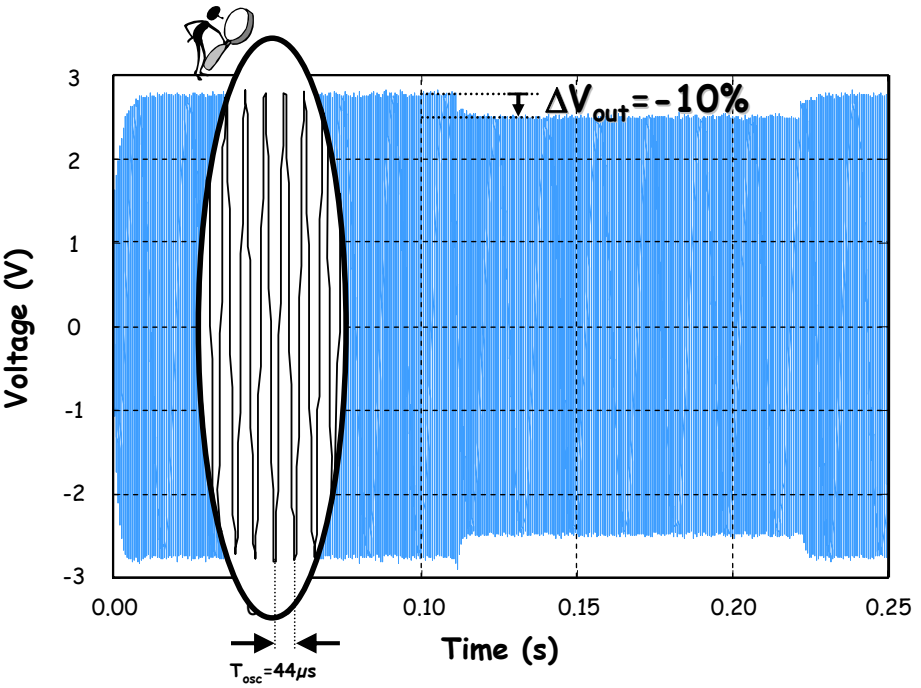
Frequency spectrum



Functional output

k=10%

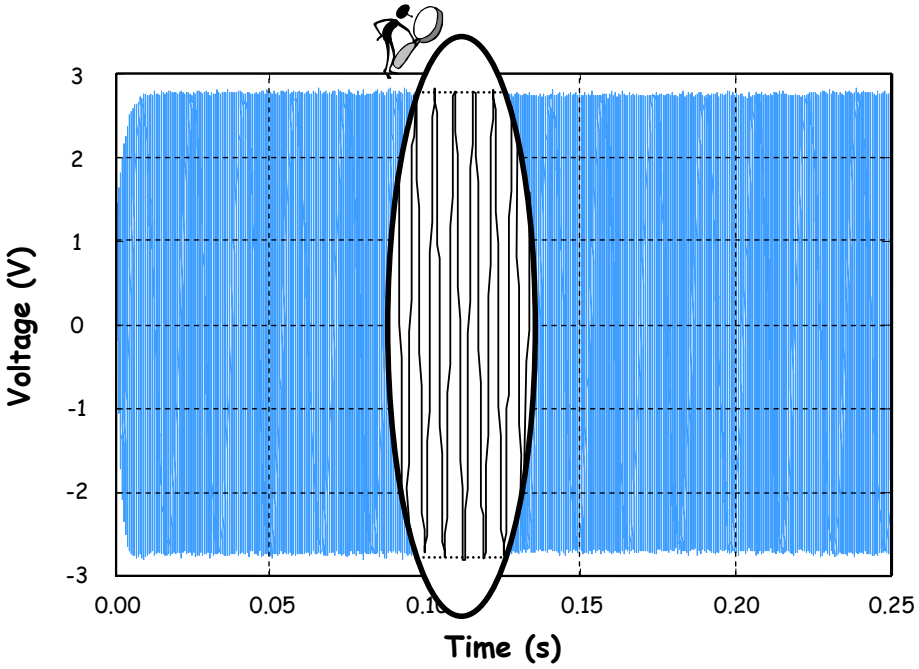
Transient response



Functional output

k=1%

Transient response



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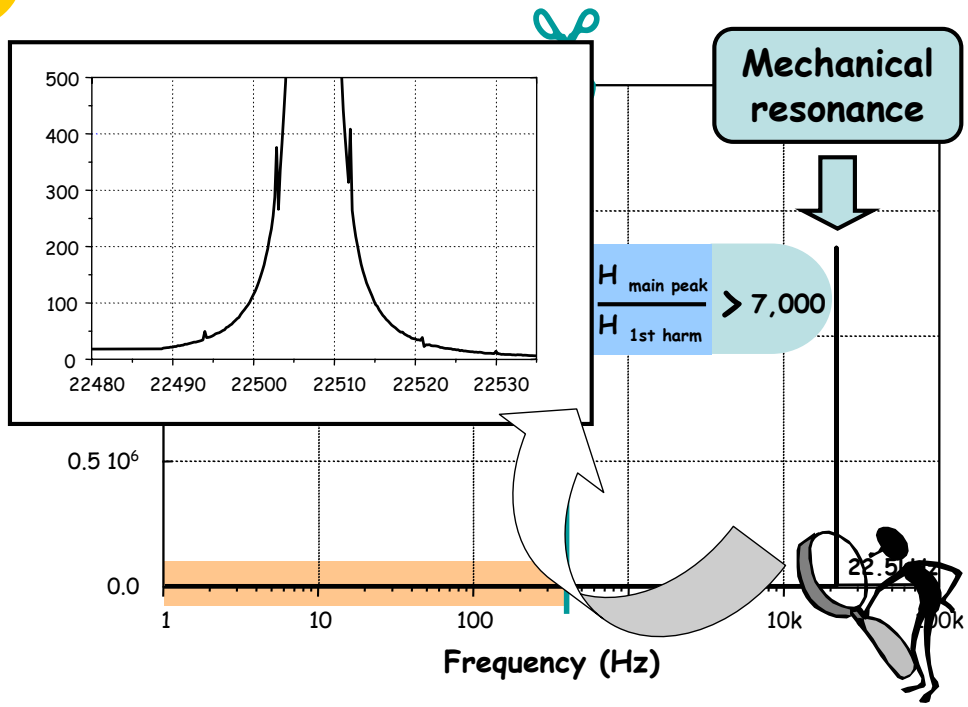
Functional output

k=1%

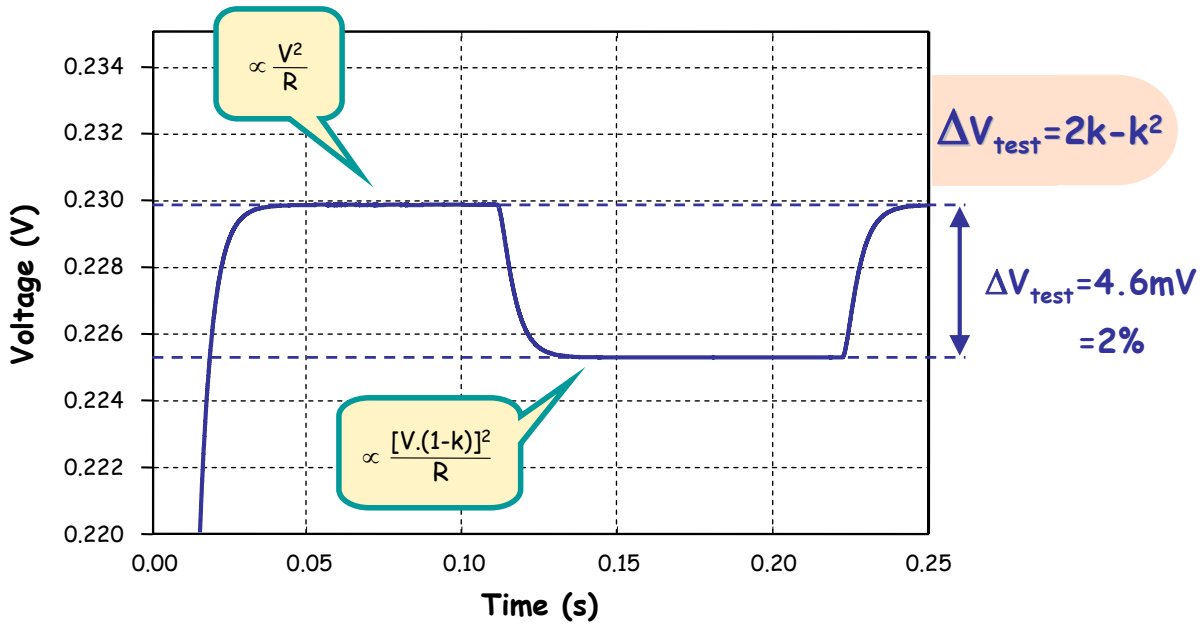
Frequency spectrum



Test output

k=1%

Transient response



Conclusions and perspectives

- Evaluation of bias superposition at the system level:
  - Different kind of sensors (capacitive, piezoresistive, …)
  - several architectures were studied with respect to test setup and response analysis
  - spectrum analysis was used to demonstrate on-line ability
- Extension of the project (2005):
  - Evaluation at the circuit (layout) level: silicon cost, DfT, …
  - Evaluation of the efficiency with fault modeling, fault coverage
  - Application of Bias superposition to different kind of MEMS