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NAVIGATION GRADE MEMS ACCELEROMETER

P. Zwahlen [1], A.-M. Nguyen [1], Y. Dong [1], F. Rudolf [1], M. Pastre [2], H. Schmid [3]

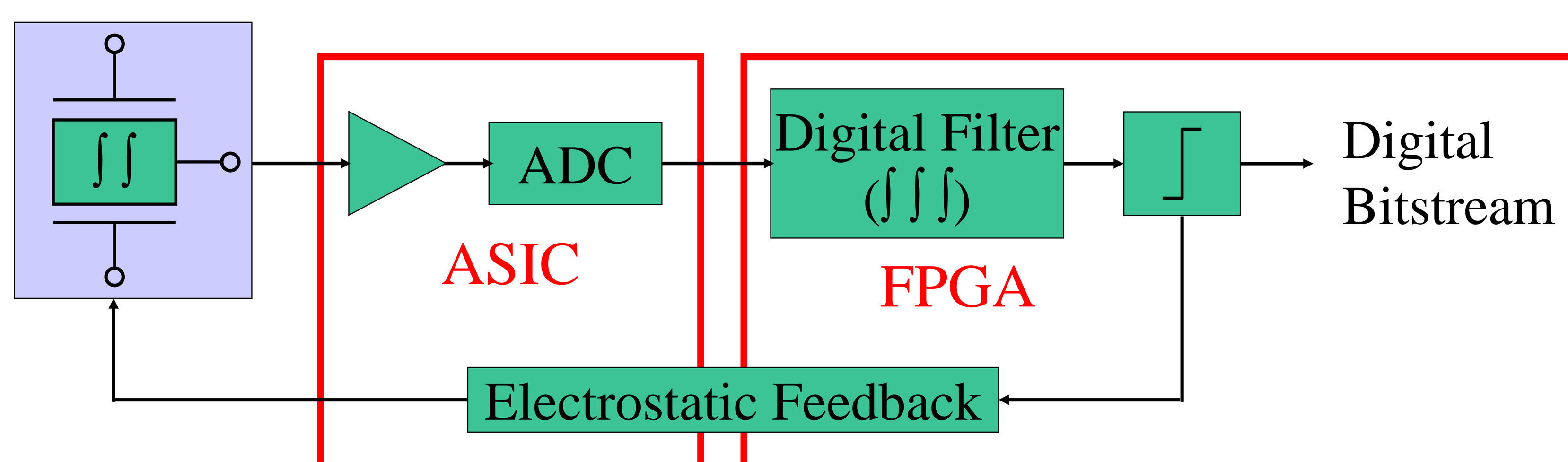
[1] COLIBRYS SA, Neuchâtel, Switzerland www.colibrys.com

[2] STI-IEL-ELab-EPFL, Swiss Federal Institute of Technology Lausanne, Switzerland

[3] IME-FHNW, University of Applied Sciences, Switzerland

Abstract: This paper reports on a high performance navigation grade MEMS servo accelerometer targeted at inertial applications. Reported results are for a bulk MEMS capacitive sensor with 11g full scale over a 300 Hz bandwidth interfaced with a highly optimized servo-loop 5th-order sigma-delta electronic. Measurements demonstrate a long-term bias stability of +/-0.1mg, a second order non-linearity K2 $<5\ \mu g/g^2$, and in-band noise floor of 1.5 µg/√Hz.

System Design



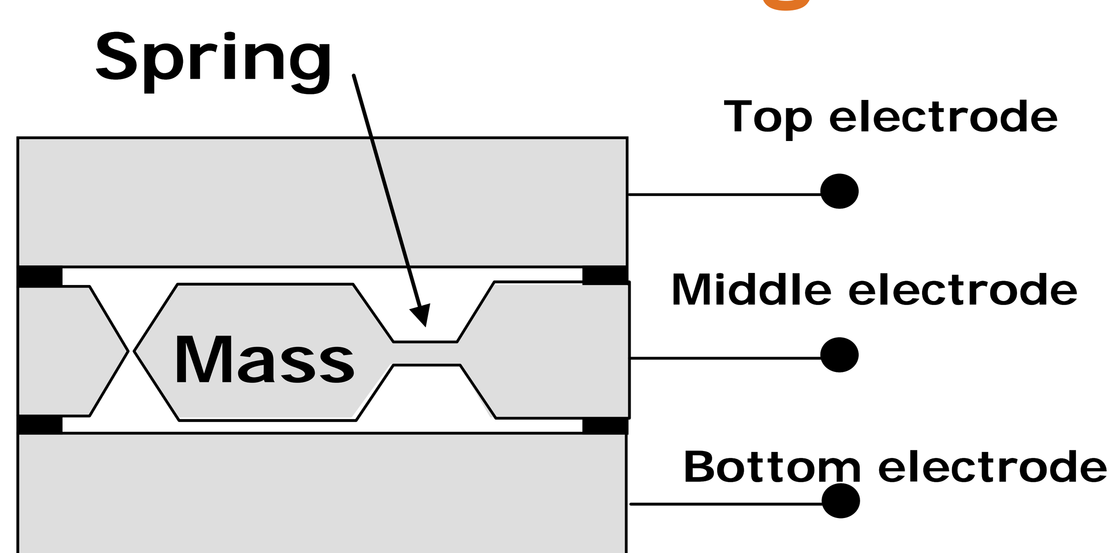
Key servo loop architecture choice:

- **Modulation type:** *Sigma-delta* pulse modulation resulting in excellent linearization of the electrostatic forces.
- **Position detector:** analog capacitive front-end amplifier followed by a low-resolution ADC
- **Loop filtering:** Performs noise shaping by rejecting noise in high frequency band. Implemented in digital domain
- **1-bit comparator:** Defines sign of the signal, which is the output bitstream and determines the direction of the actuation force

Strength of the architecture

- ***High resolution*** comes from the oversampling technique and the 5th order noise shaping implementation, thus relaxing the design constraints of the analog part
- ***System versatility*** thanks to the digital loop filtering, allowing final tuning based on the specific end application

MEMS Design

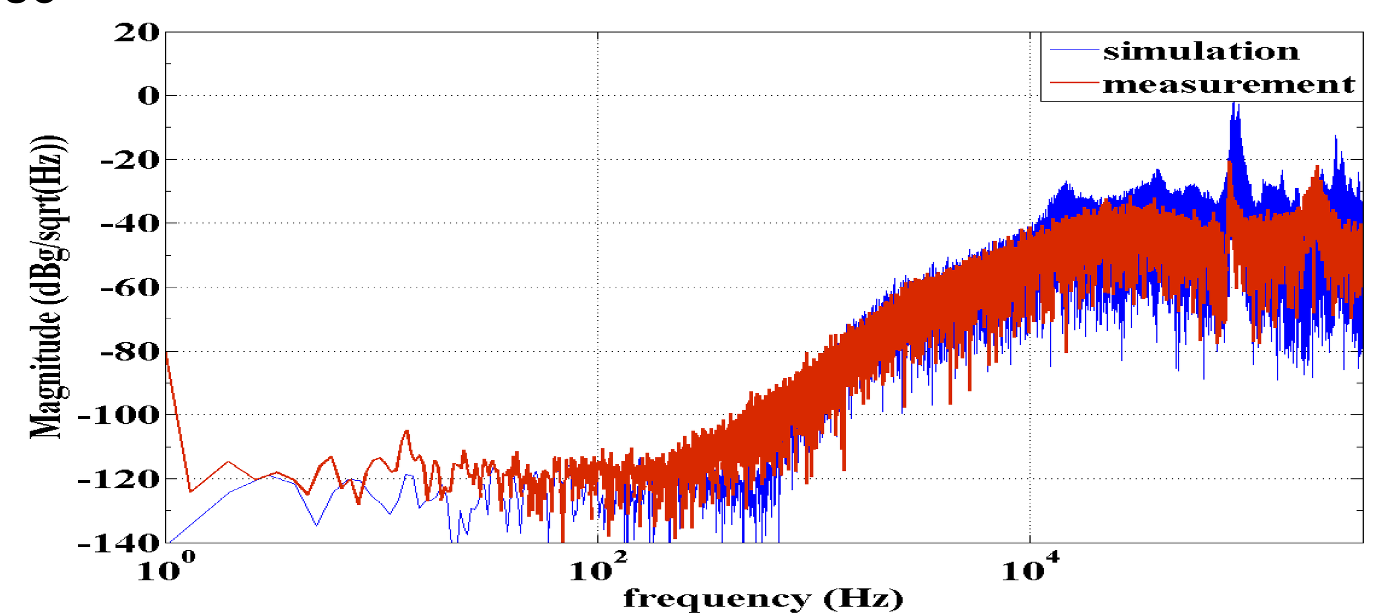


Key MEMS feature for inertial performance:

- **Out-of-plane capacitive structure:** Bulk through silicon wafer micromachining allows large mass, large capacitive area and an overall rigid structure essential in high stability applications like inertial navigation
- **High vacuum and high hermeticity:** Pressure down to 0.3 mbar is achieved through Silicon Fusion Bonding, resulting in an excellent hermeticity. High quality factors and low mechanical Brownian noise can thus be achieved, key factors for high resolution system performance.
- **Good manufacturing tolerance capability:** Achieved by DRIE etching of the seismic mass wafer. Tight control of this process allows to keep electronic input referred noise at low value
- **Robustness to shock:** small inter-electrode gap of 2 µm and excellent manufacturing control allows shock tolerance above 4000g

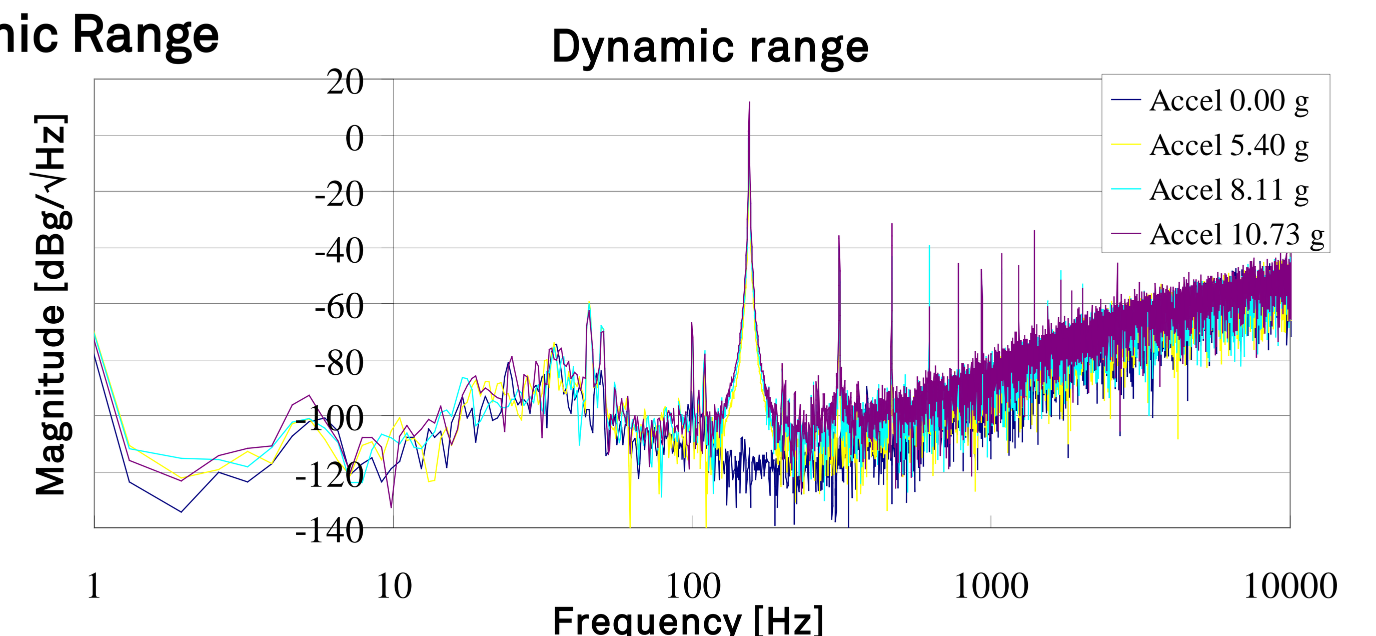
System Performance

1. Noise



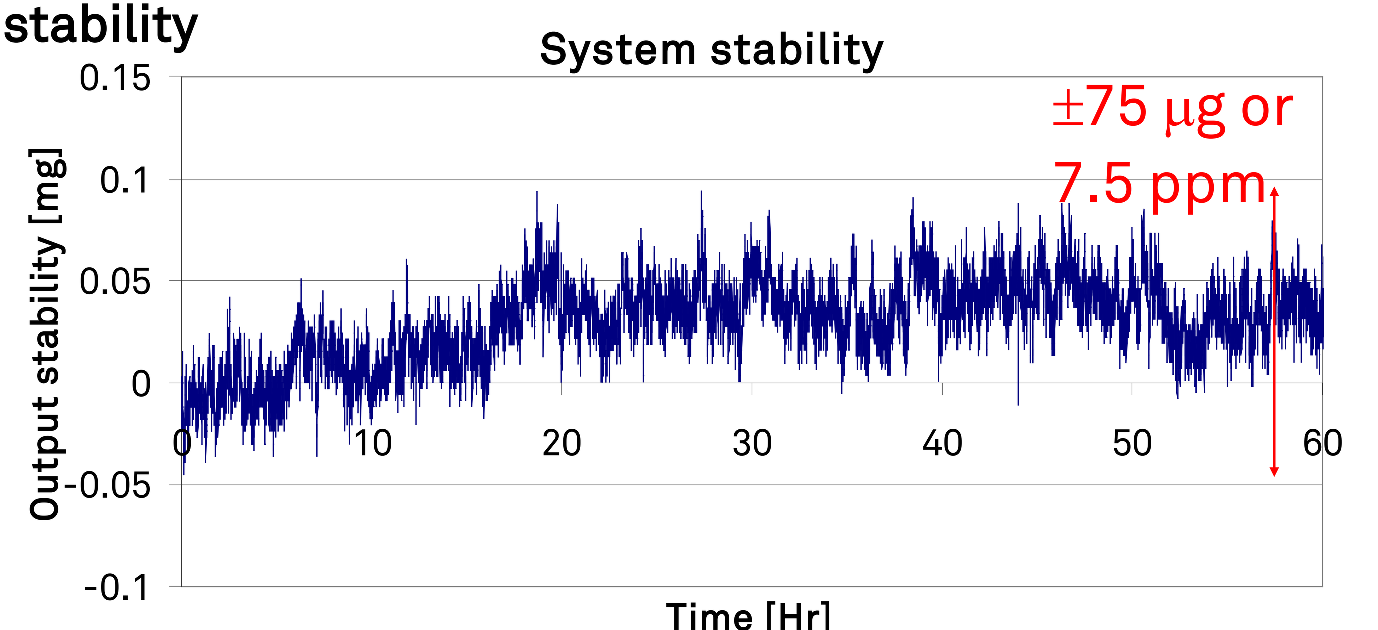
- Noise measurement performed in a quiet room

2. Dynamic Range



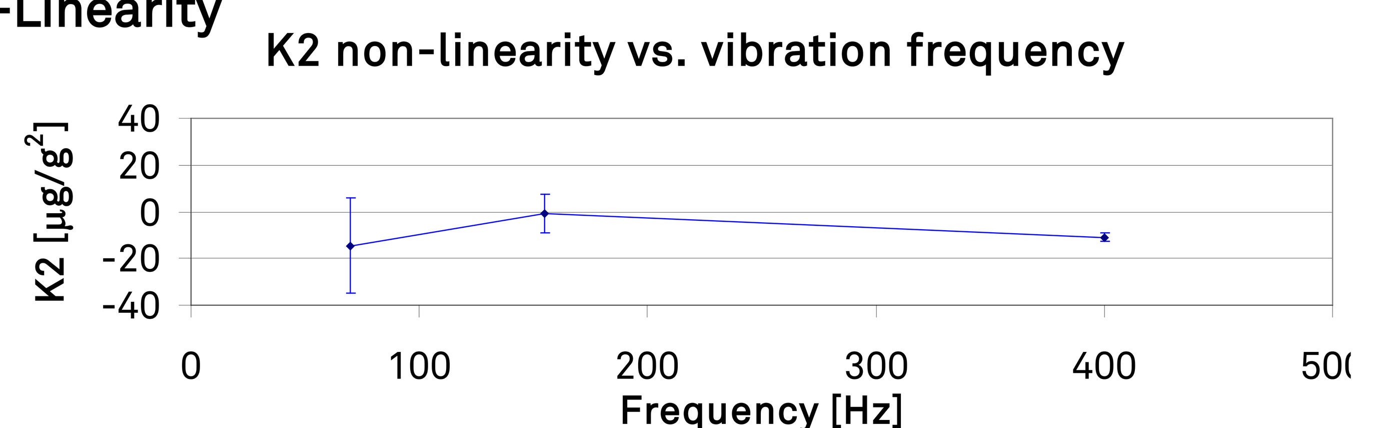
- Low frequency noise hump due to building noise
- Large harmonics amplitude are linked to shaker non-linearity

3. Bias stability



- Excellent stability thanks to the mechanics rigidity and highly stable voltage reference (50 ppm)

4. Non-Linearity



- Non-linearity measurement errors decrease with increasing frequency

5. Performance Summary

	Colibrys	QA 2030	Unit
Input Range	11.7	60	g
Noise	1.5	3	µg/√Hz
Dynamic Range (1 Hz BW)	136 (22 bits)	143	dB
Bias stability (24 hrs)	0.1	0.1	mg
Non-Linearity, K2	<10	<20	µg/g²
Bias Temperature coefficient	150	<30	µg/°C
Scale Factor Temp. coefficient	80	180	ppm/°C