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A combined modulated feedback and temperature compensation approach to improve bias drift of a closed-loop MEMS capacitive accelerometer

Key words: Bias drift, Closed-loop MEMS accelerometer, Modulated feedback approach, Temperature compensation

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Introduction

- The closed-loop MEMS capacitive accelerometer suffers from bias drift. According to Allan variance, the bias instability comes mainly from low-frequency noise, and the long term drift can be caused by some factors such as temperature variation.

- To minimize the low-frequency noise, we employ the modulated feedback approach (MFA). The low-frequency noise at the feedback path is filtered and the feedback function remain the same.

- To reduce the temperature coefficient, a reference signal is created for temperature compensation. The phase of the signal after demodulation in digital domain can reflect the temperature variation.

The modulated feedback approach (MFA)

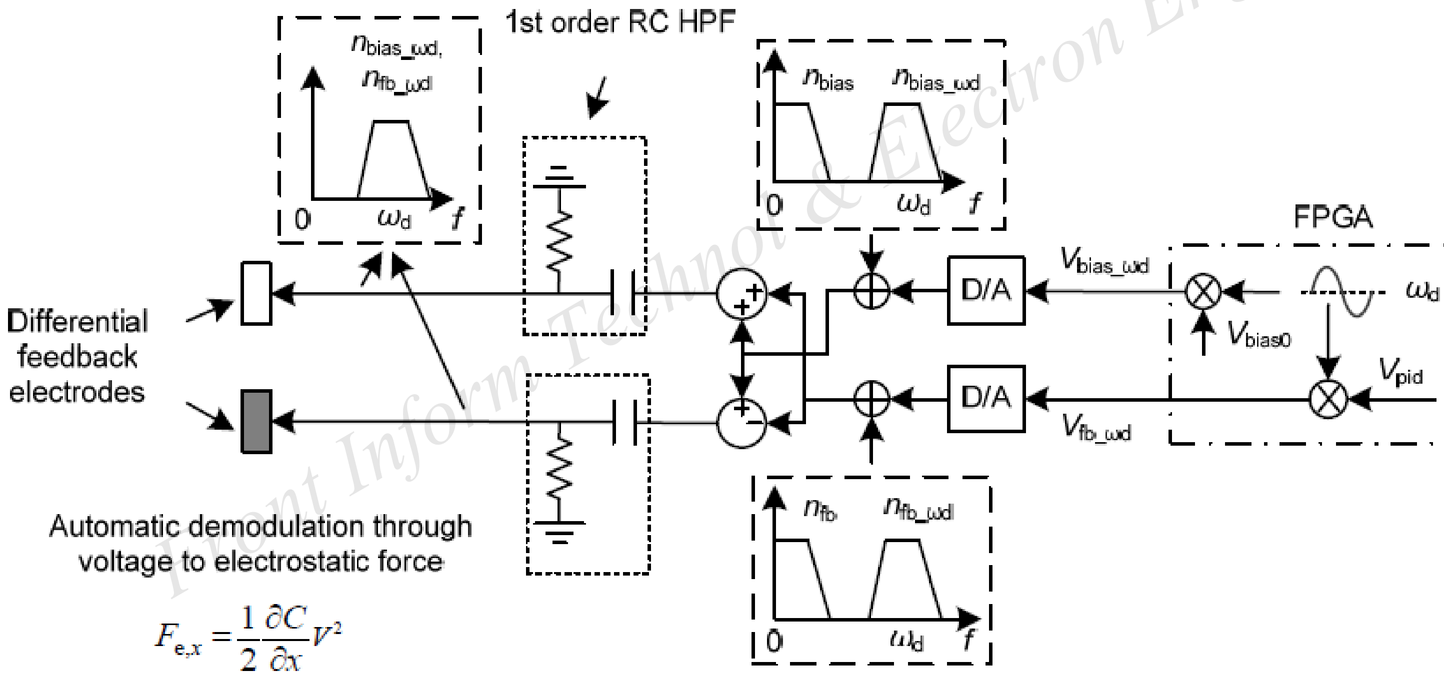

Fig. 4 Schematic of the noise spectrum in a modulated feedback approach and implementation of the modulated feedback approach

The novel temperature compensation

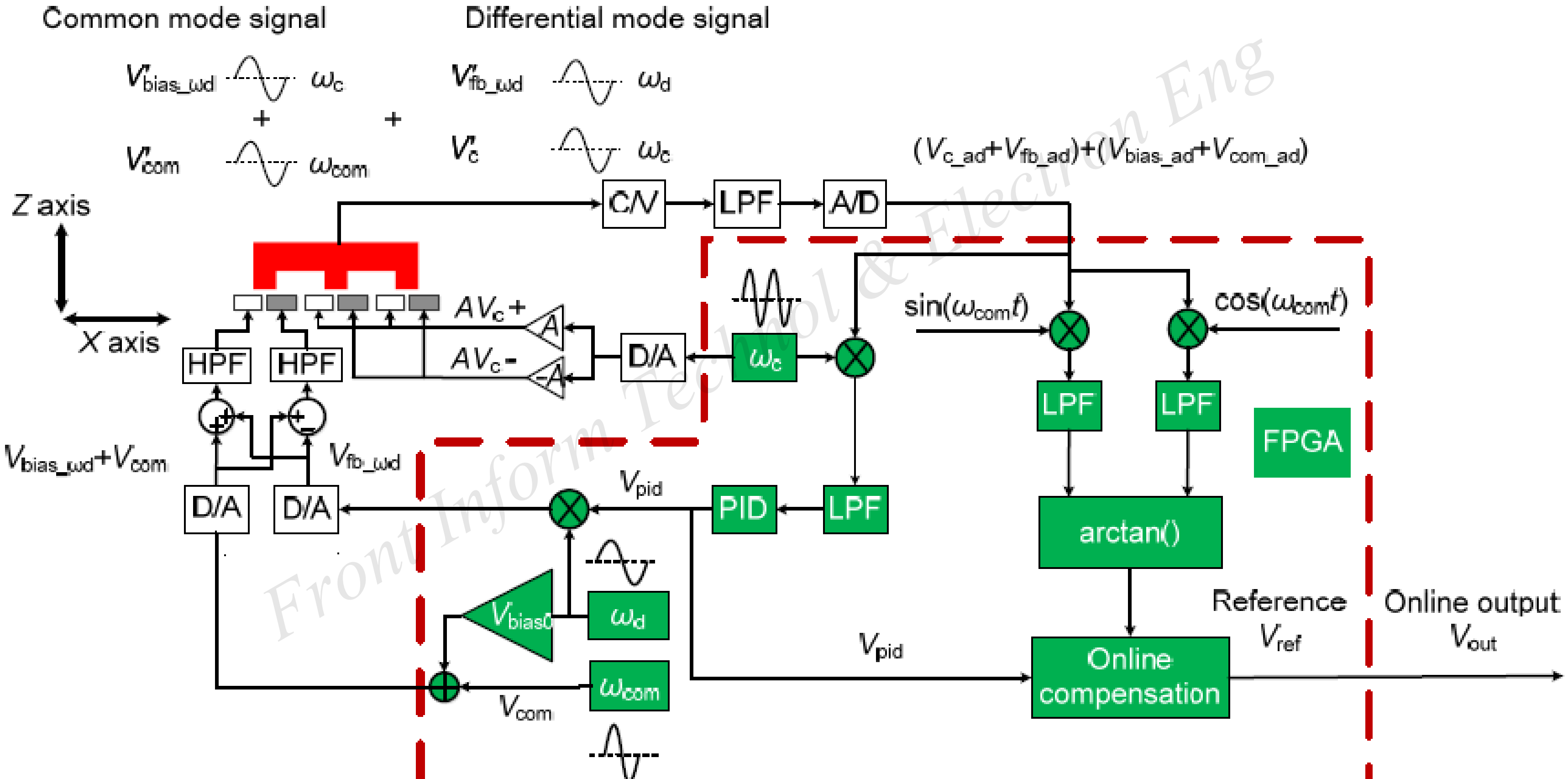

Fig. 5 Novel closed-loop diagram with a modulated feedback approach and temperature compensation

Measurement results: MFA v.s. DFA

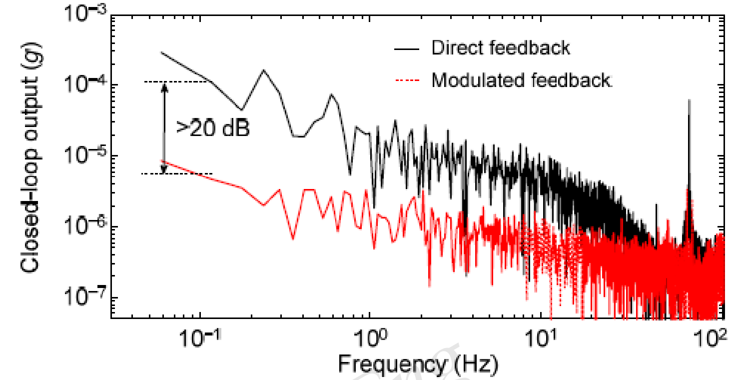

Fig. 11 Measured spectrums of direct and modulated feedback outputs

Both signals are sampled from the digital output of PID blocks

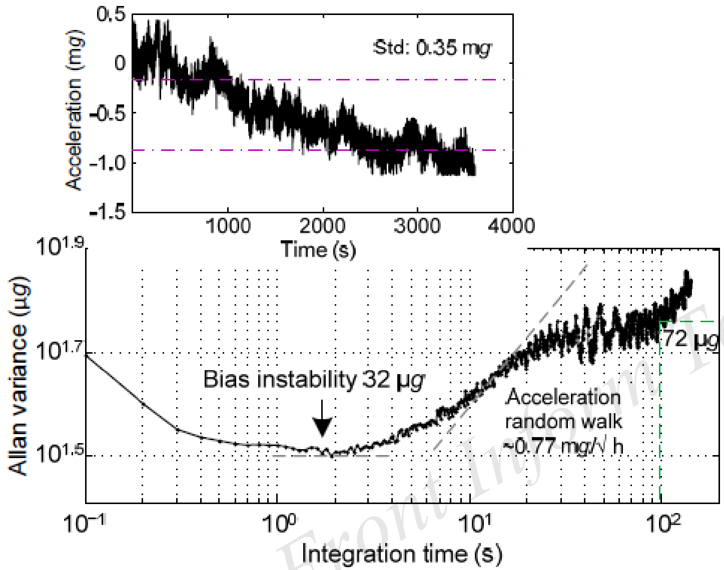

Fig. 13 One-hour stability test with zero acceleration input by applying a direct feedback approach

The large plot shows the Allan variance results and the inset is the time-domain trace

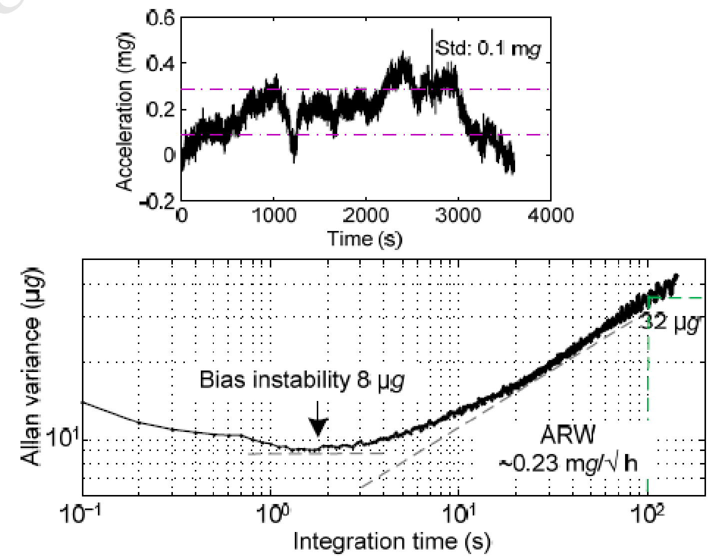

Fig. 14 One-hour stability test with zero acceleration input by applying a modulated feedback approach

The large plot shows the Allan variance results and the inset is the time-domain trace

Measurement results: temperature compensation

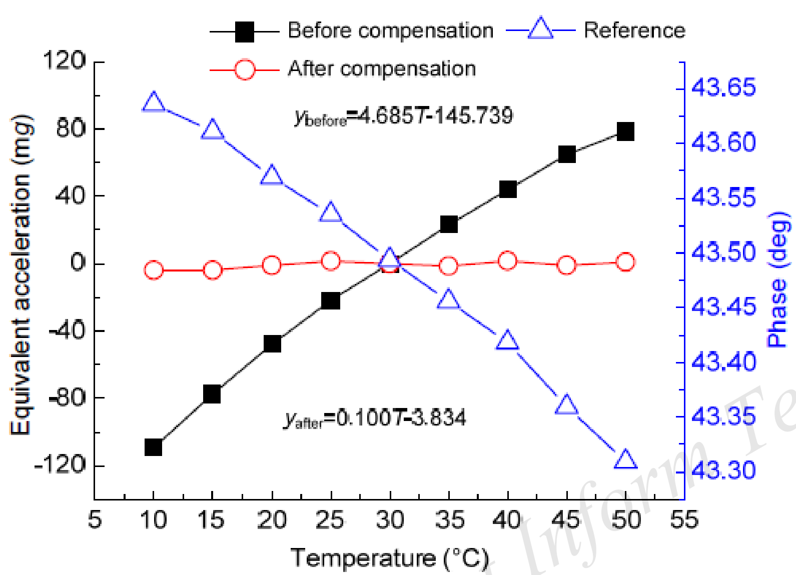

Fig. 16 Measured closed-loop output before and after compensation

The reference signal V_{ref} is also added. The closed-loop output and the reference signal both vary linearly with temperature, making the compensation easy to realize with the first-order compensation algorithm

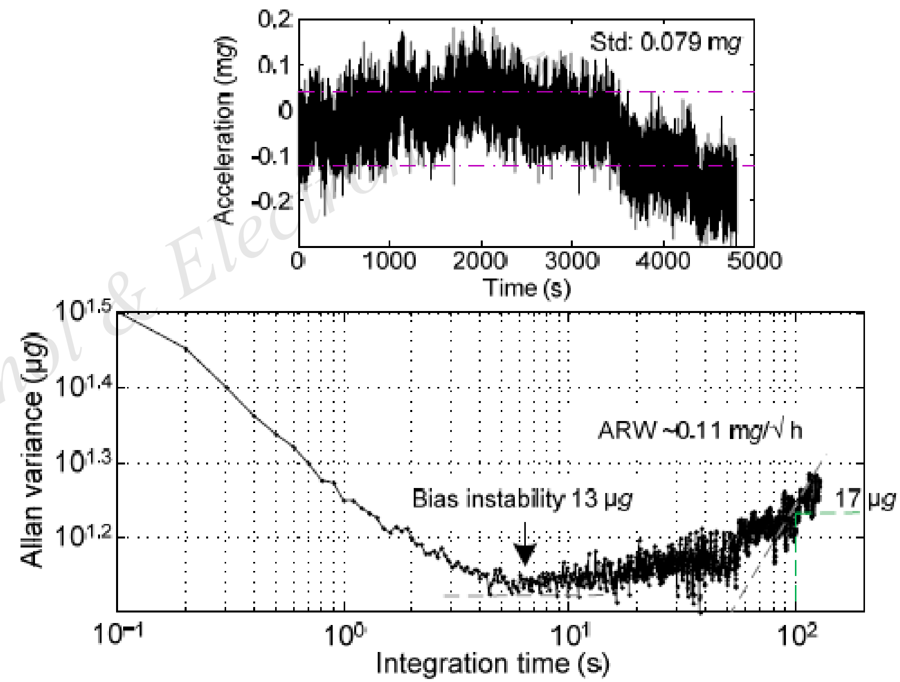

Fig. 19 Online compensation time-domain trace and the Allan variance results demonstrated by the black solid line in Fig. 17

Performance comparison

Table 3 Time-domain and Allan variance performance comparison

Mode	Time-domain trace Std (mg)	Bias instability (μg)	Drift at 100 s of integration time (μg)	Temperature coefficient (mg/°C)
Open loop	0.520	12	180	–
Direct feedback	0.350	32	72	>4.685
Modulated feedback	0.100	8	32	4.685
Modulated feedback with temperature compensation	0.079	<13	<17	0.100

Conclusions

- A combined modulated feedback and temperature compensation approach is demonstrated. The modulated feedback approach aims to minimize the low-frequency noise in the feedback path, and the temperature compensation reduces the temperature coefficient as for the long-term drift.
- The proposed approach improves the bias instability to around 13 μg, the temperature coefficient to 0.1 mg/°C, and the long-term drift to 17 μg at 100 s integration time.