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SILENT SENSORS FOR STELLAR ECHO'S AND SEISMIC SURVEYS

SENSEIS - THE ELECTRONICS

O. Can Akgun / ET

HISTORY OF SENSEIS

- Began in 2014.
- Collaboration between Nikhef, UT and Innoseis (Nikhef spin-off).
- From Nikhef, DRD and ET are involved.
- Scientific aim is to develop a **MEMS** (**M**icro **E**lectro **M**echanical **S**ystems) inertial sensor + custom microelectronic readout system for newtonian noise (NN) recording.
- R&D project, MEMS G7, ASIC G4

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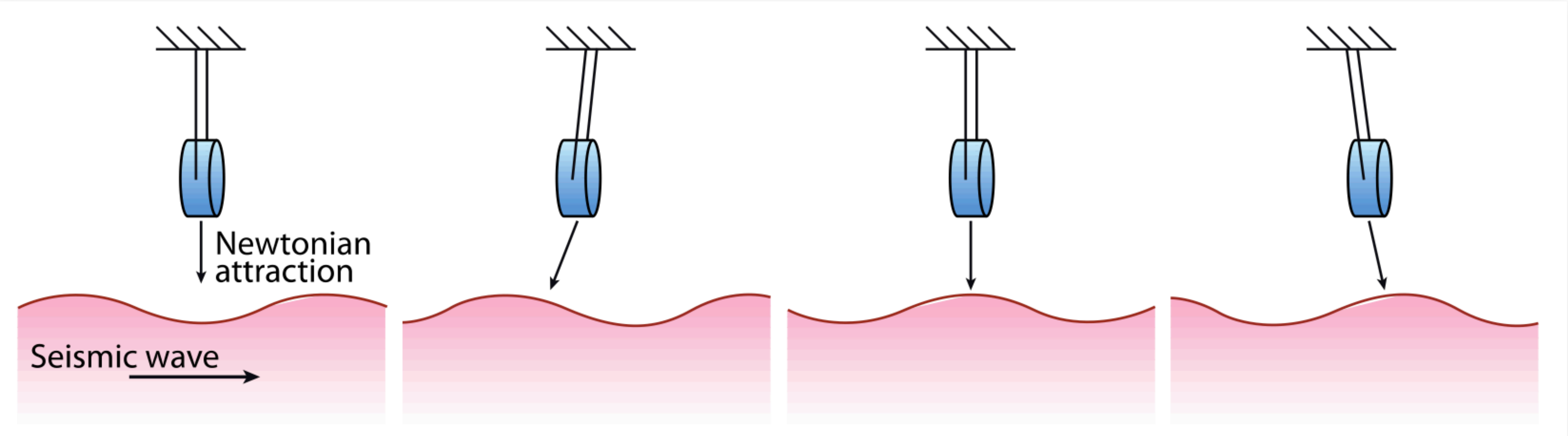
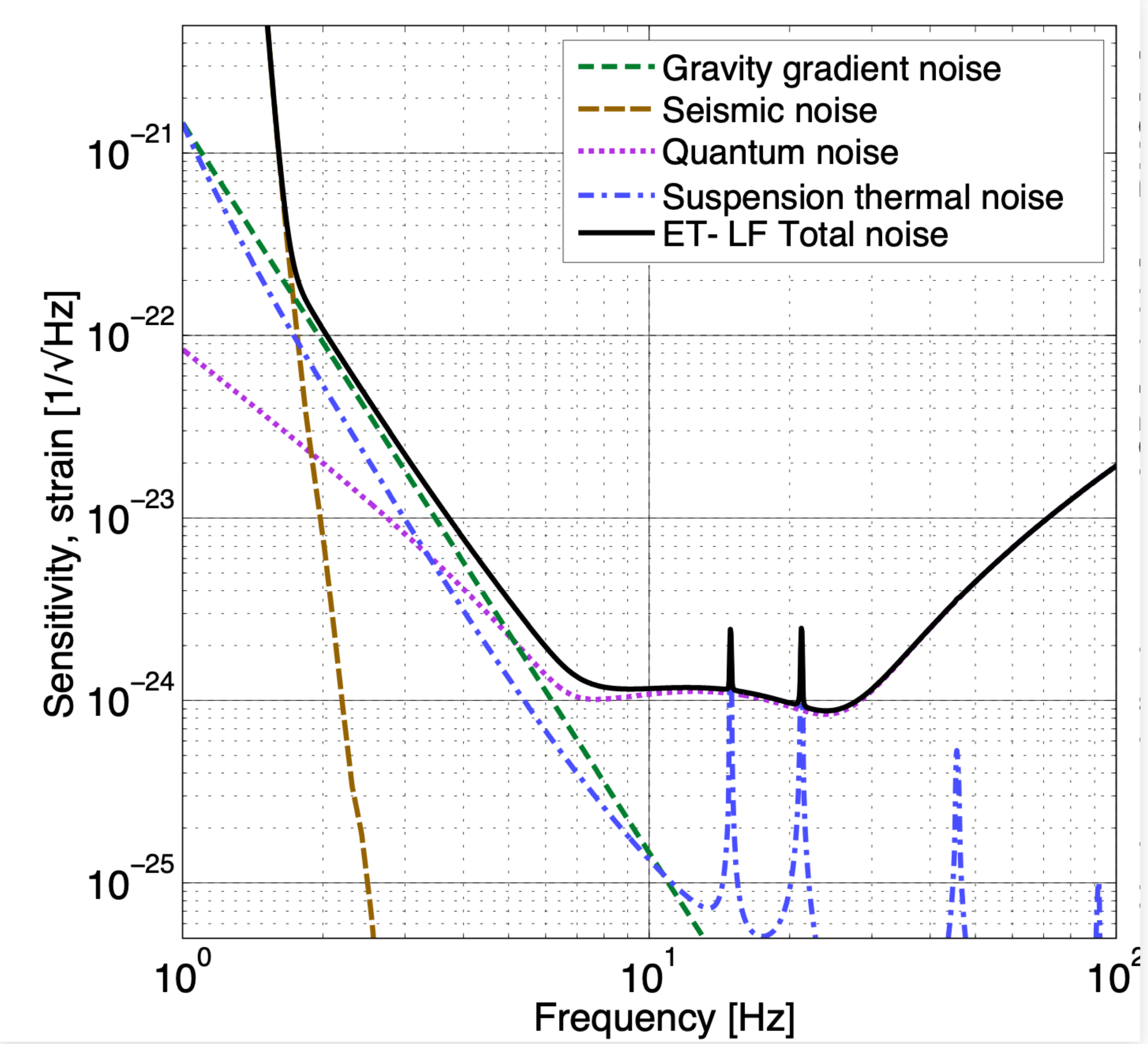
UNIVERSITY OF TWENTE.

INNOSEIS

SCIENTIFIC APPLICATION - NN MITIGATION

- NN is produced by the tiny fluctuations of air and soil density near test masses and couples via the law of universal gravitation.
- 3rd generation gravitational wave detectors will have to rely on large arrays of low noise seismic sensors for mitigating Newtonian noise.
- LF (below 6 Hz) measurements are limited by NN.





M G Beker 2012 J. Phys.

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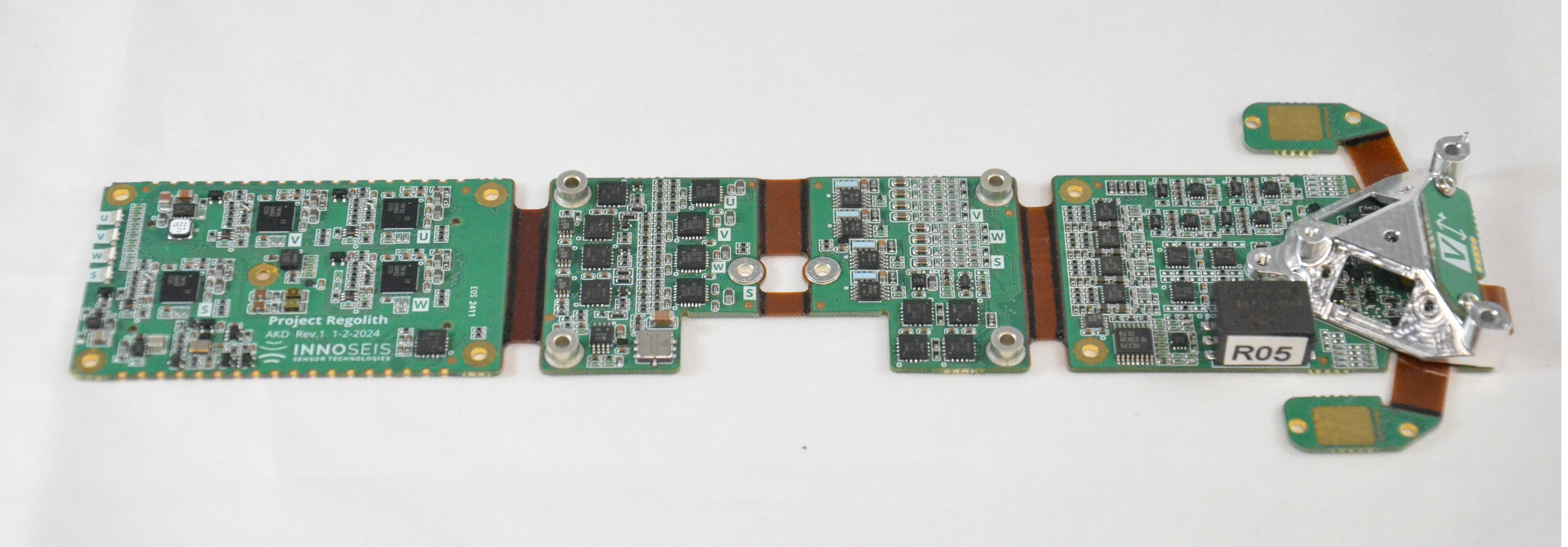
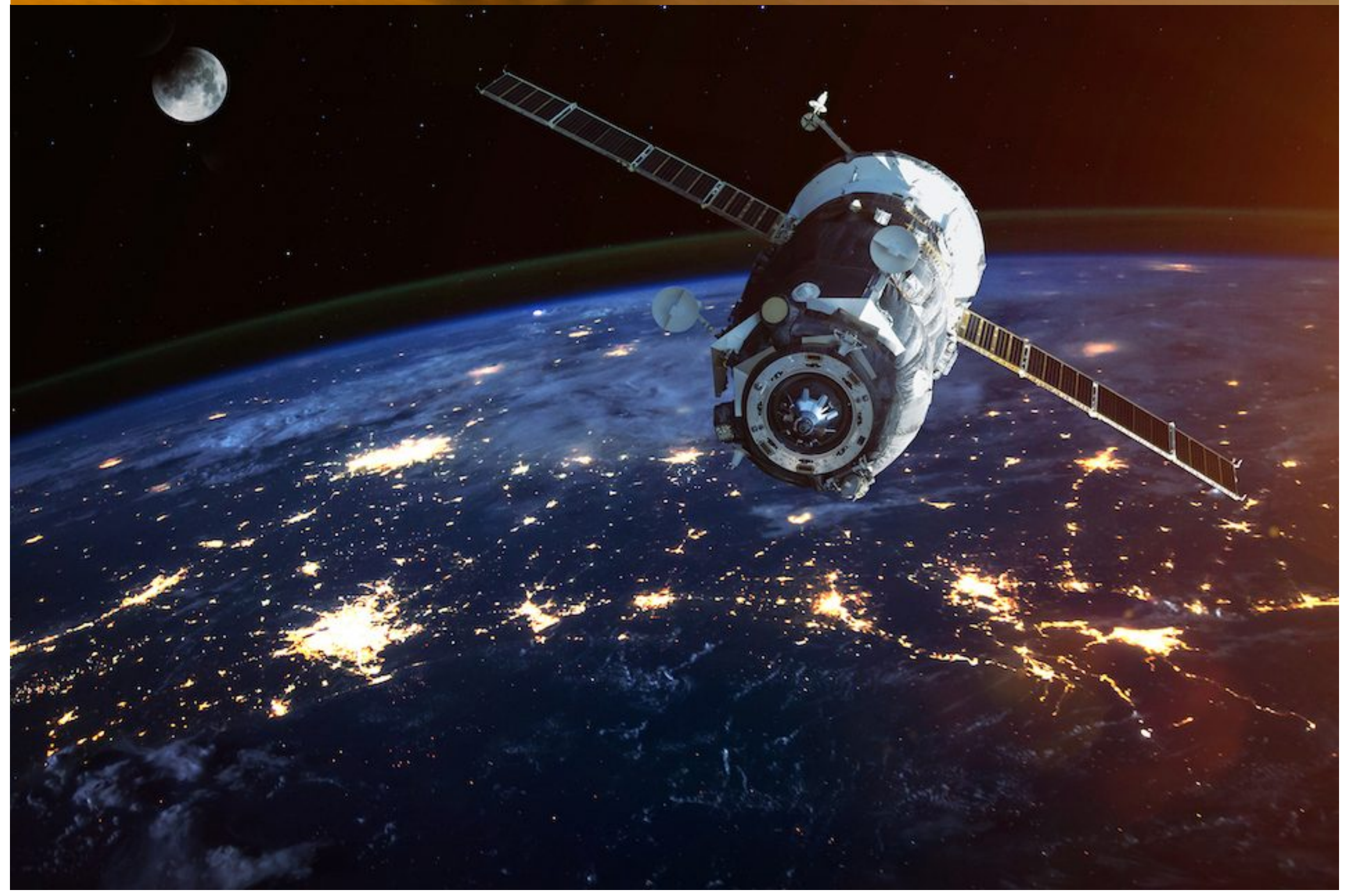
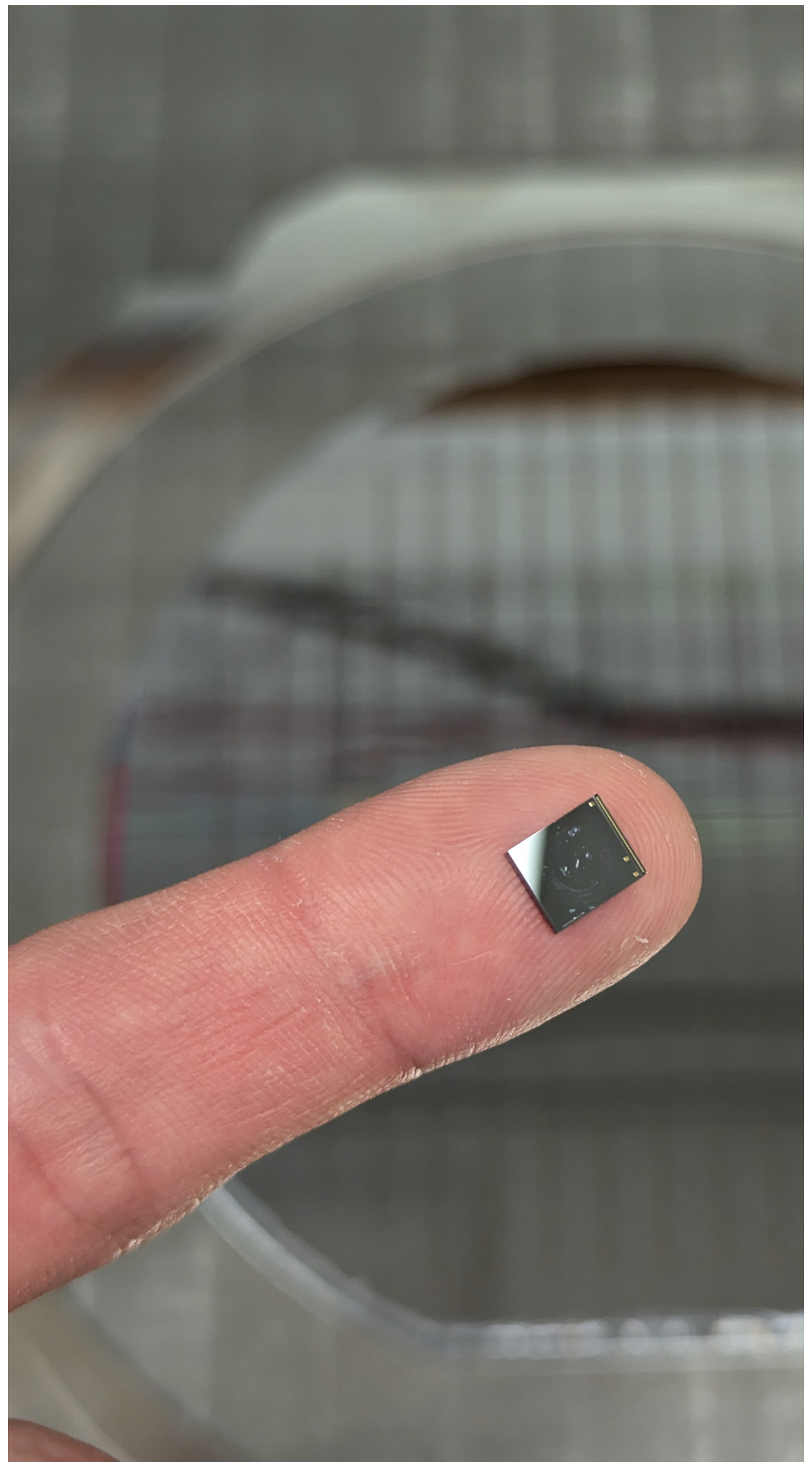
INDUSTRIAL APPLICATIONS

- Aerospace (positioning and guidance).
- Space (seismic data from moon).
- Infrastructure health monitoring.
- Seismic sensors for oil exploration.
- Earthquake monitoring.





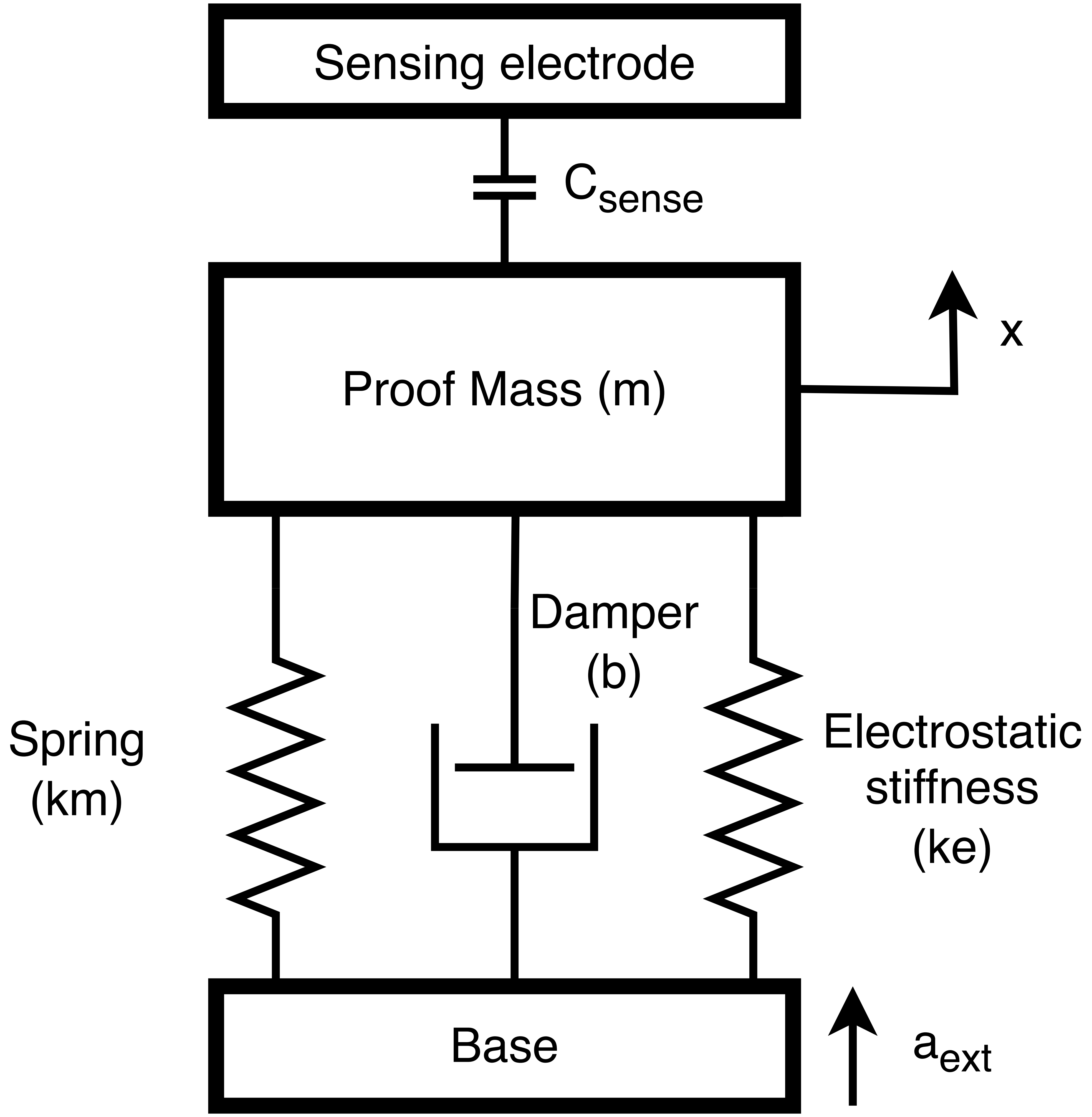


Innoseis

TARGET SPECIFICATIONS

	Scientific	Industrial
Clipping level (g)	0.1	**0.5**
System noise ($ng/Hz^{1/2}$)	**4**	20
Bandwidth (min-max) (Hz)	1 - 50	10m - 200
Dynamic range (dB)	**140**	128
Frontend Voltage	3.3	3.3

USING MEMS FOR INERTIAL SENSING



- Proof mass is suspended by silicon tethers with stiffness **km**.
- Viscous damping from gas (air) is **b.**
- Proof mass moves in the direction x with acceleration, changing C_{sense}.
- C_{sense} value is read by electronic readout. However this causes electrostatic stiffness **ke**.

$$H(s) = \frac{X(s)}{A(s)} = \frac{m}{ms^2 + bs + km + ke}$$

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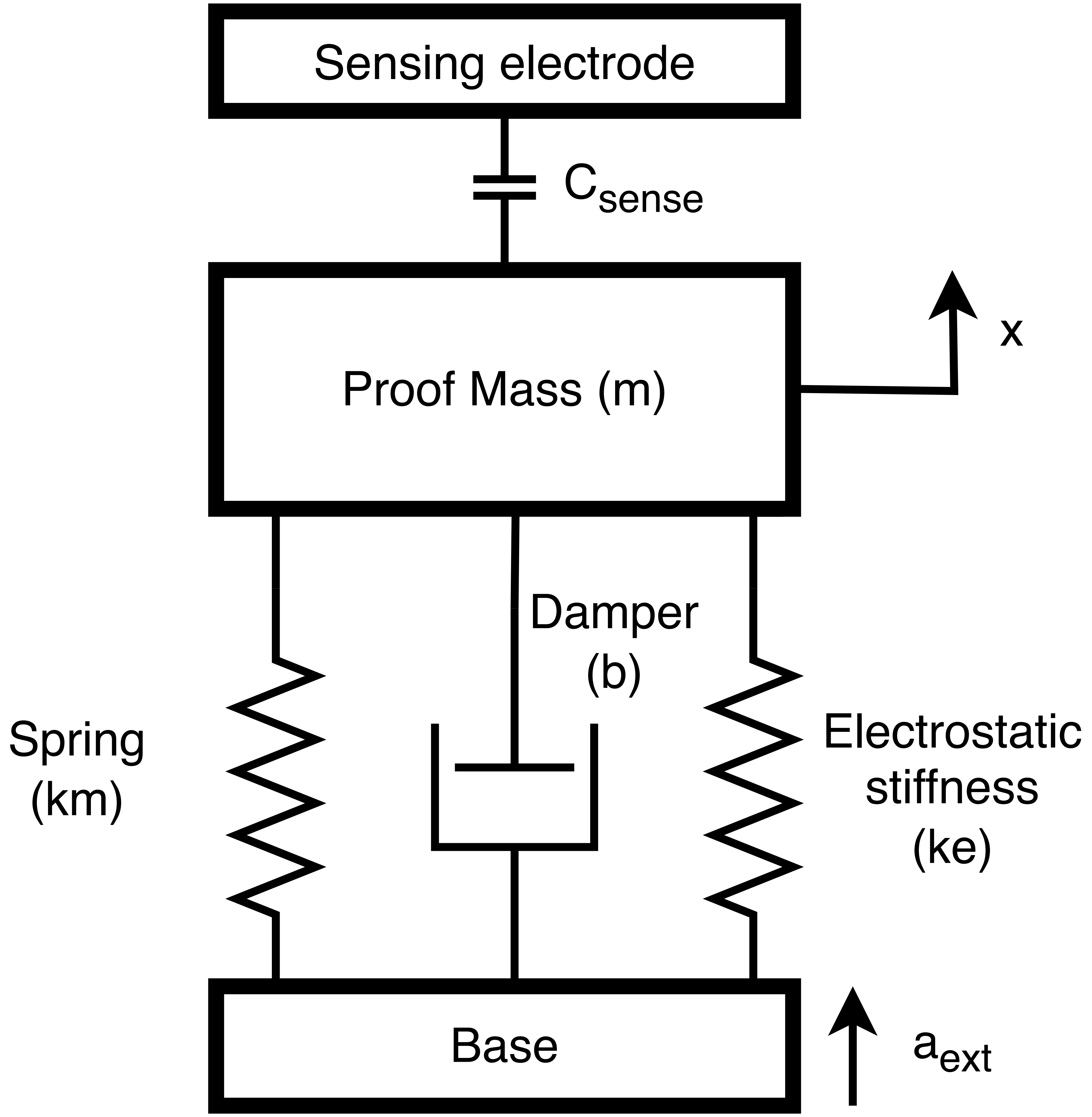
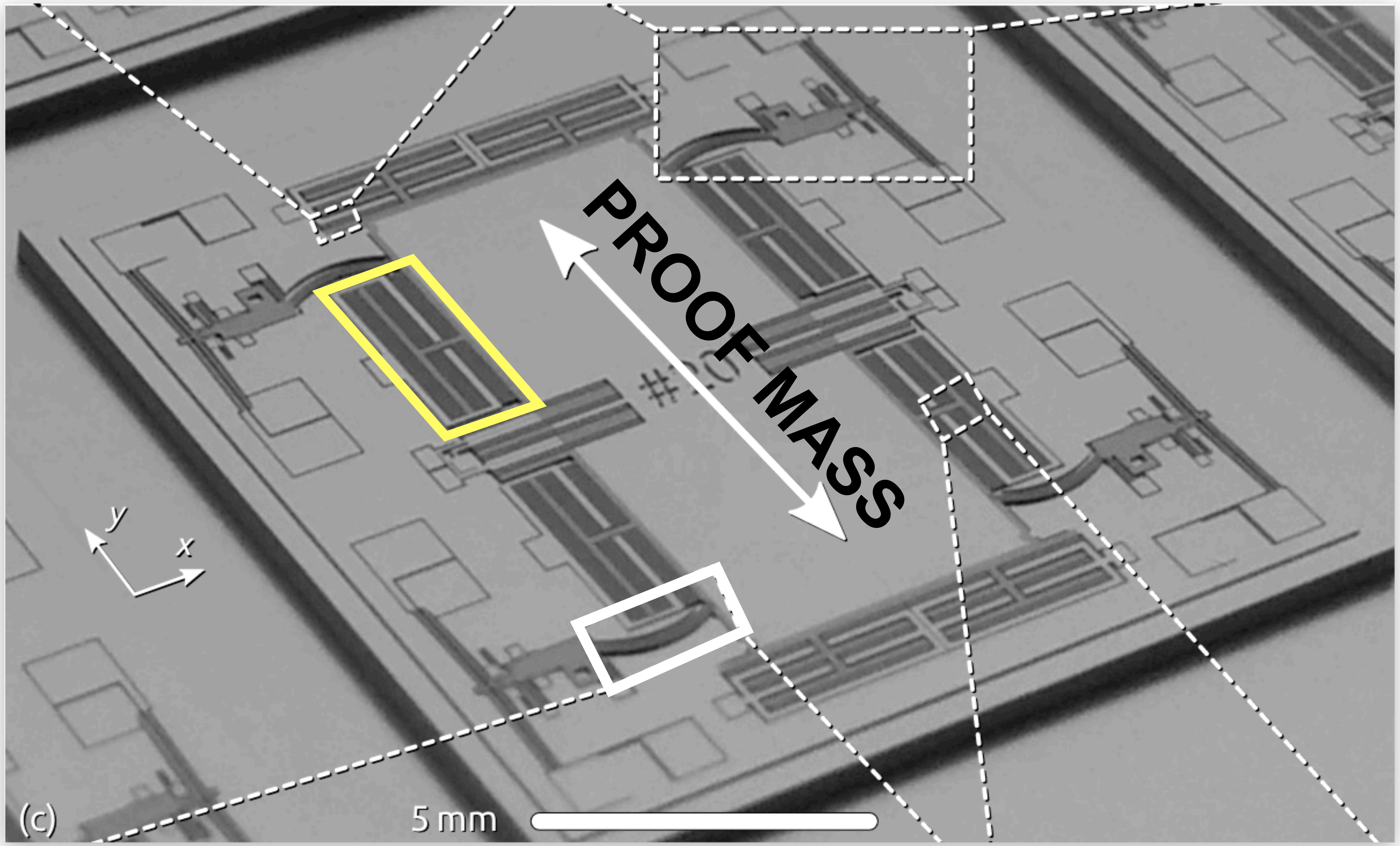
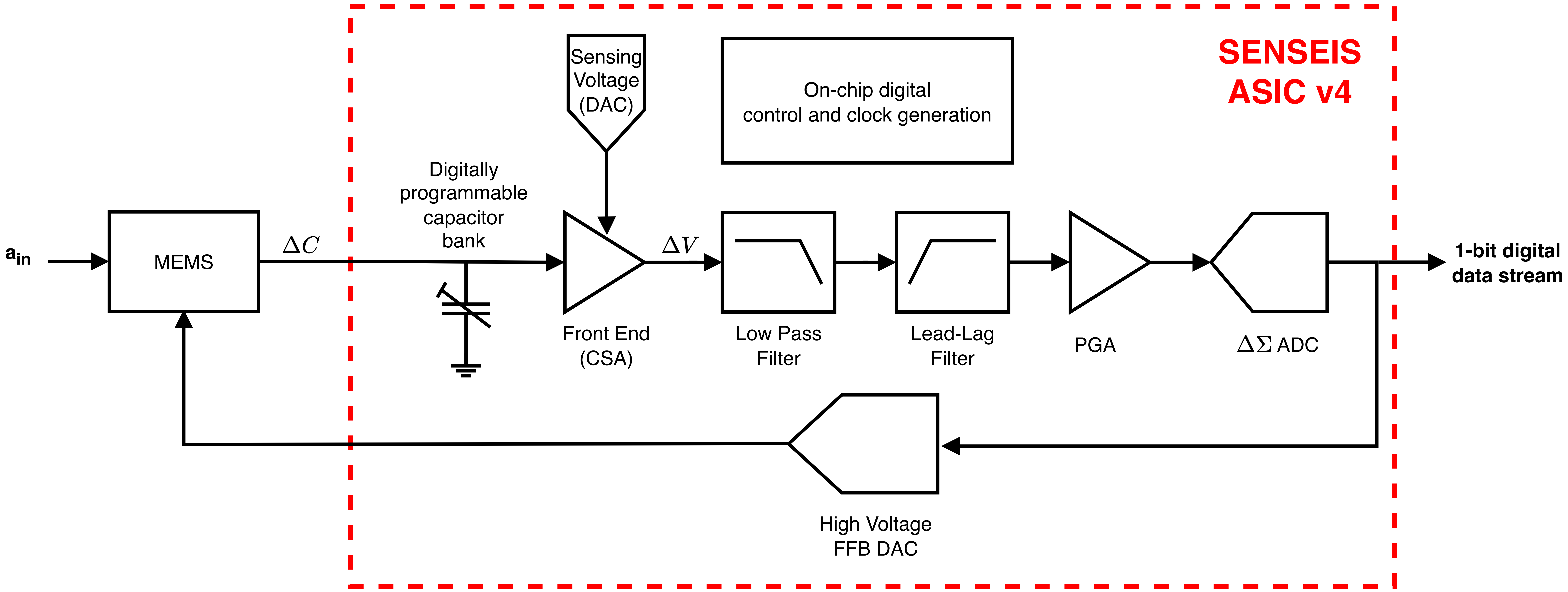
USING MEMS FOR INERTIAL SENSING





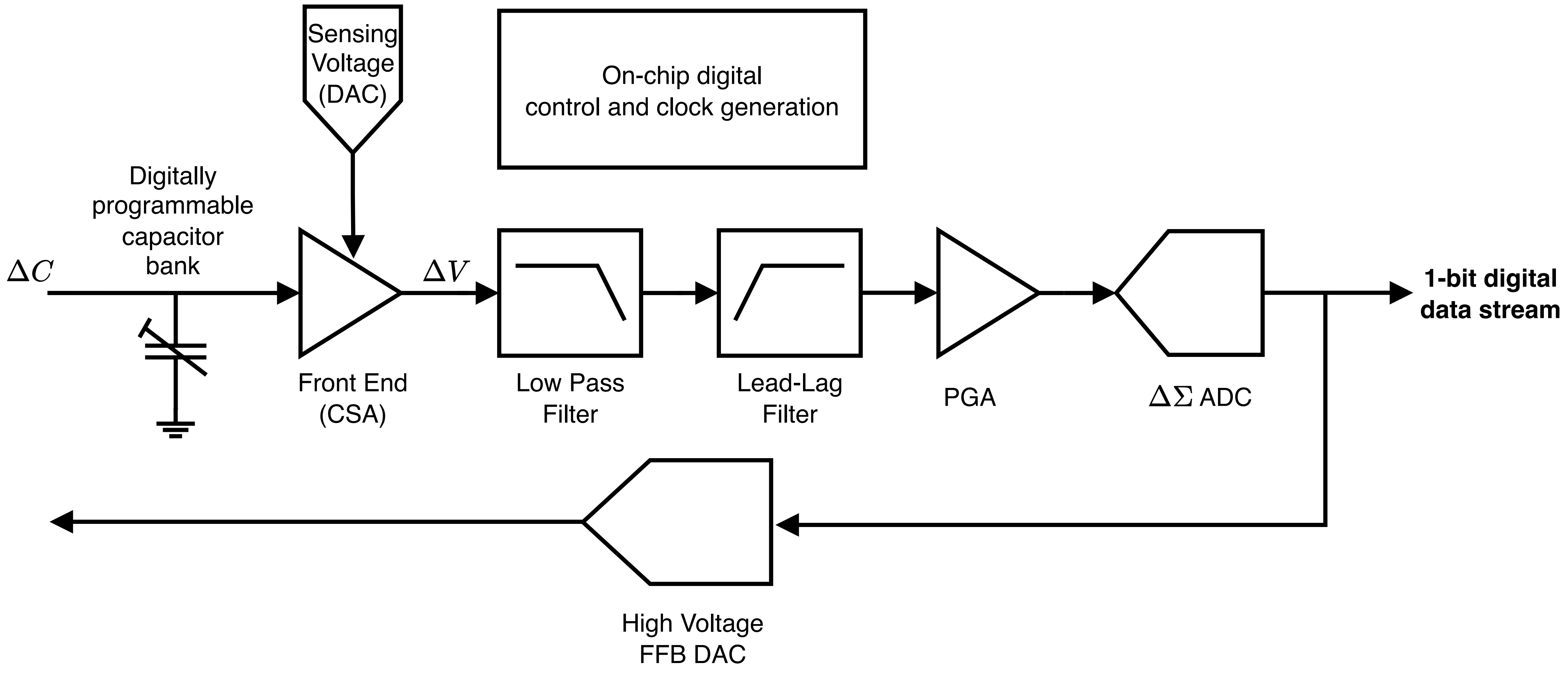
Boris Boom, dissertation: Acceleration Sensing at the Nano-g Level

SENSEIS READOUT CHIP ARCHITECTURE



NOVELTIES IN SYSTEM DESIGN

One of the design aims was to have a system with as much configurability as possible for robust operation under changing conditions.

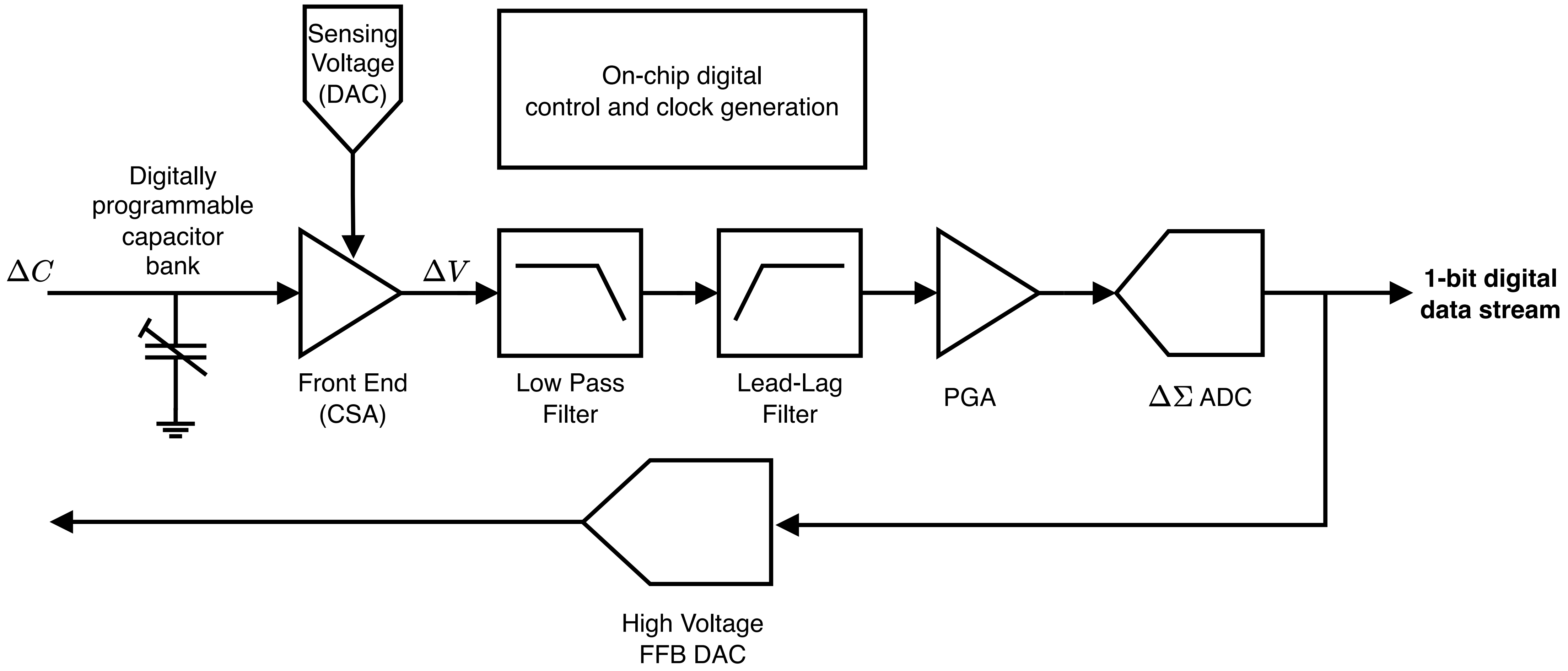


Programmable capacitors: Mitigating the tilt in the MEMS due to manufacturing process variations electrically.

Sensing Voltage DAC: For dynamically controlling the gain of the FE, dynamic input range and controlling **ke**.

NOVELTIES IN SYSTEM DESIGN

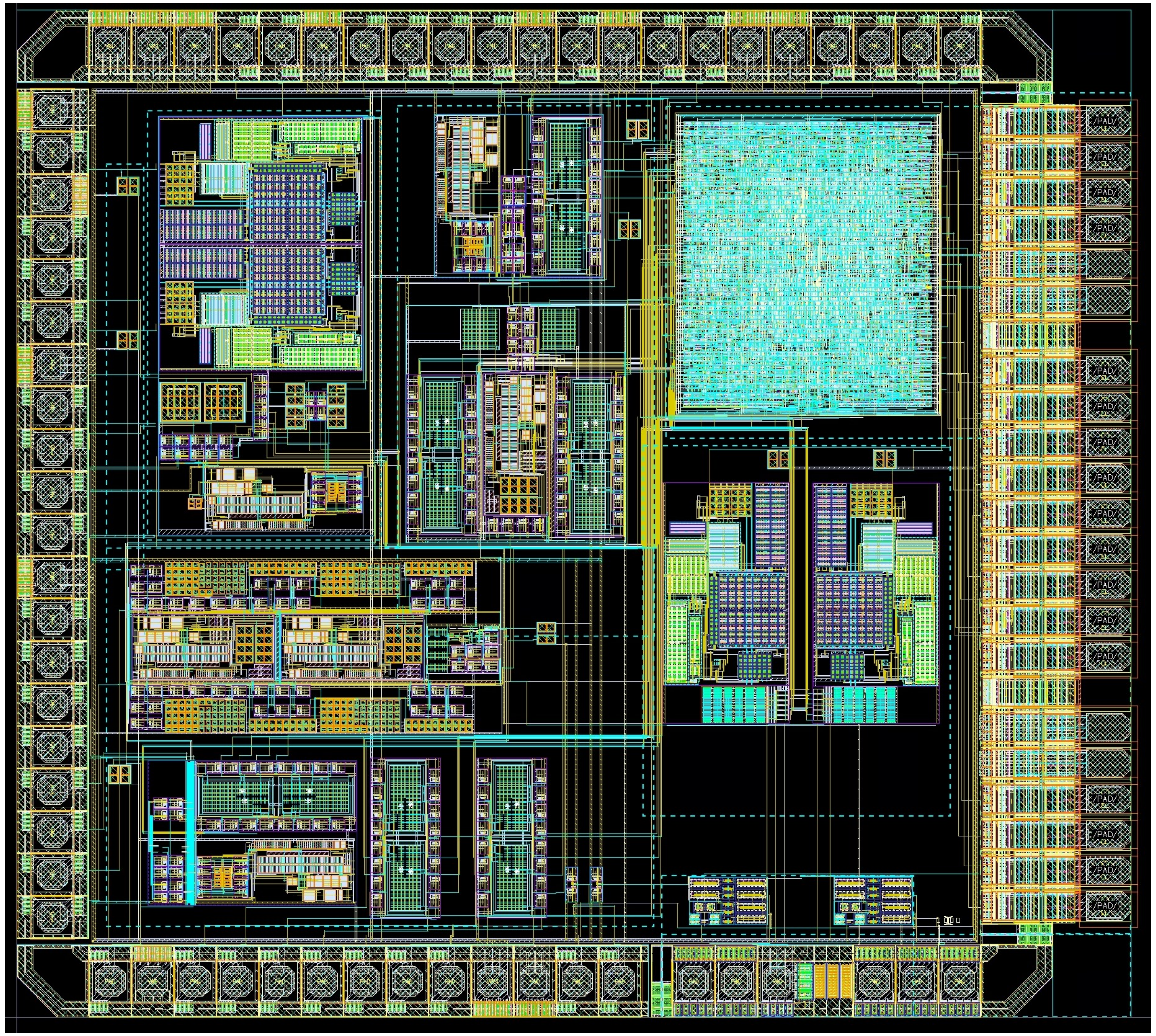
Programmable LPF and LLF: Reducing the in-band noise of the loop and controlling the stability (phase margin).



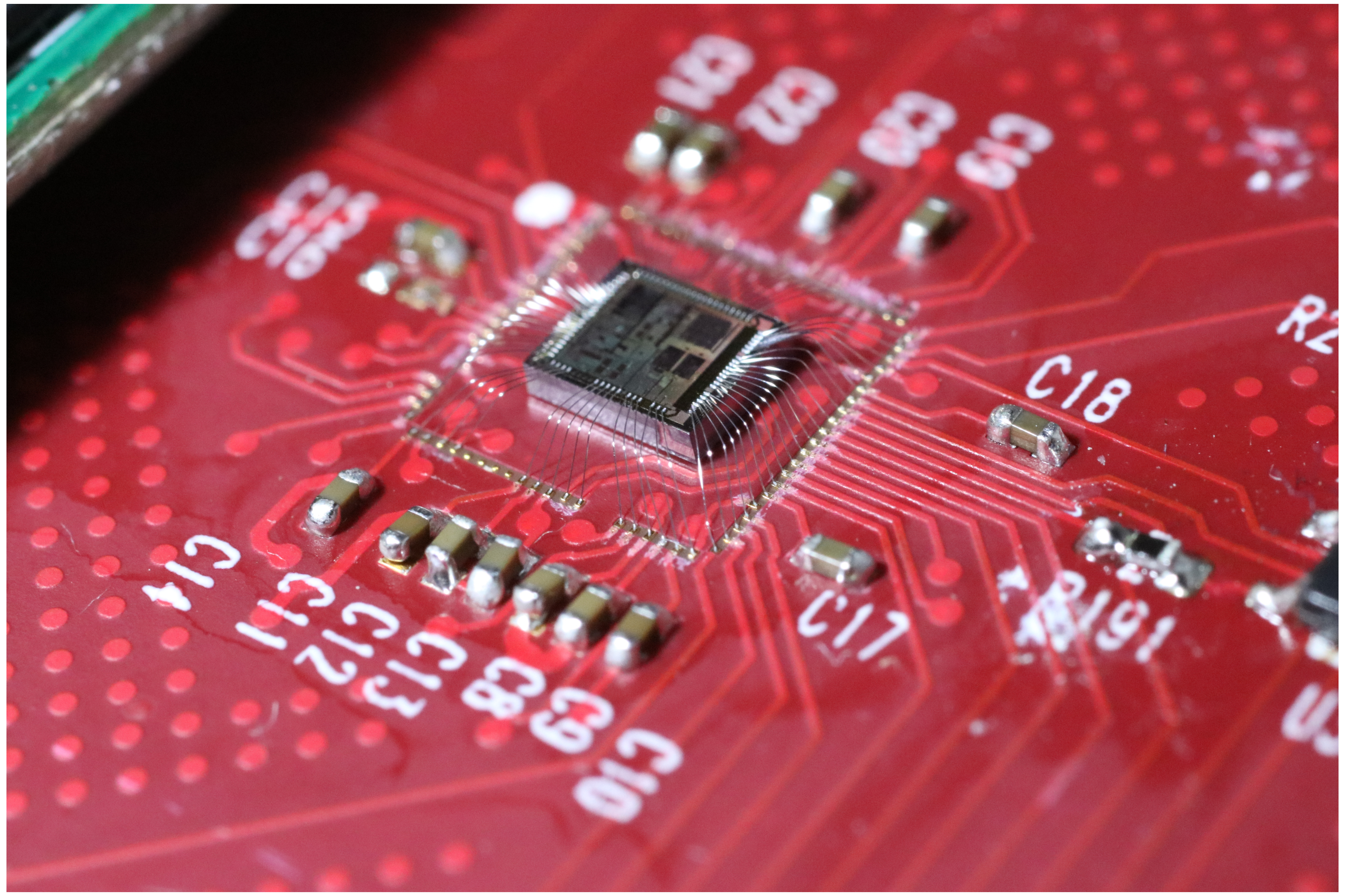
Programmable Gain Amplifier: Dynamically changing the gain of the loop for optimal operation under changing conditions.

Programmable HV FFB DAC: For dynamically controlling amount of force-feedback applied for stable operation.

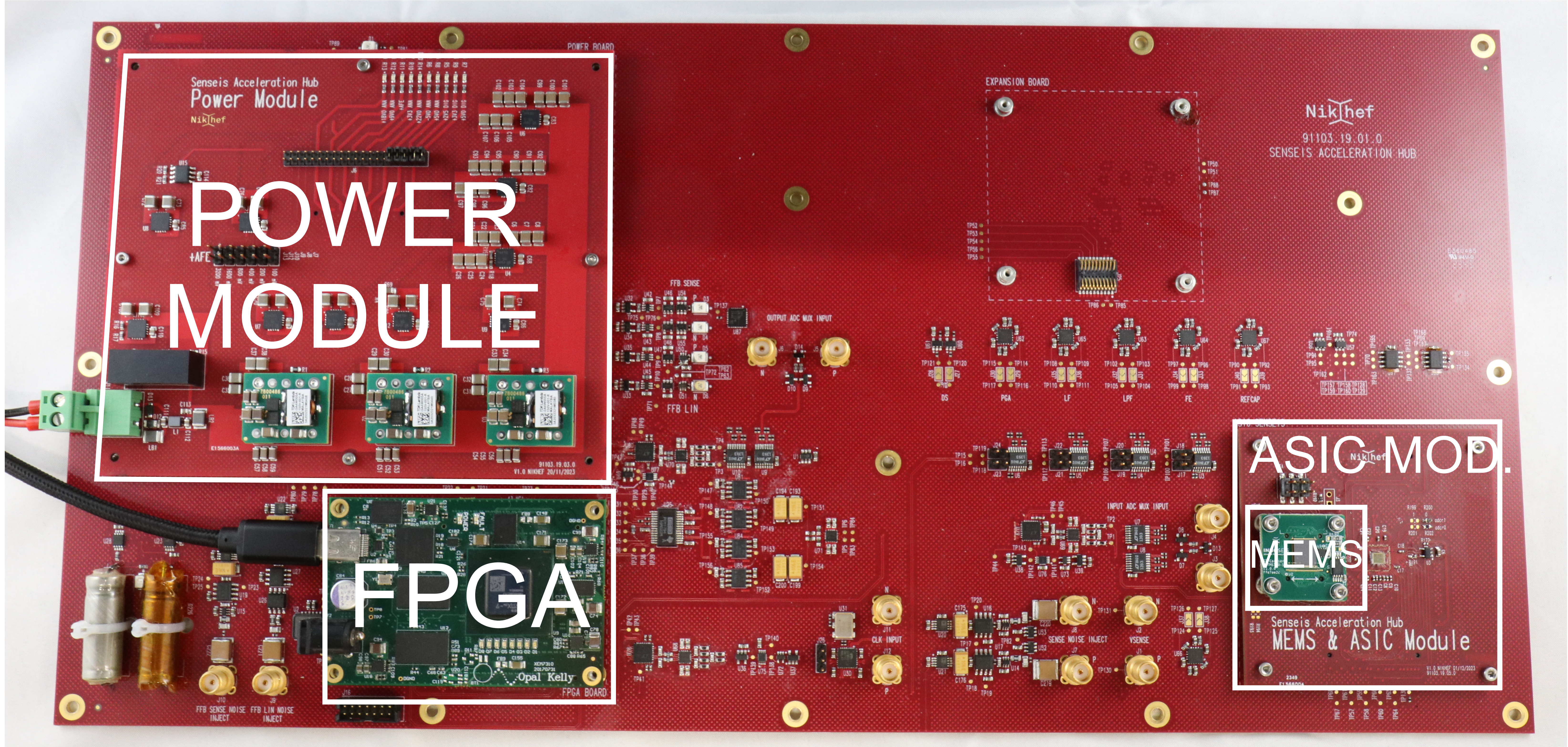
SENSEIS CHIP



- Chip was manufactured in XFAB 0.35um HV process.
- Chip area is 10mm^2.
- Power consumption is 87 mW.



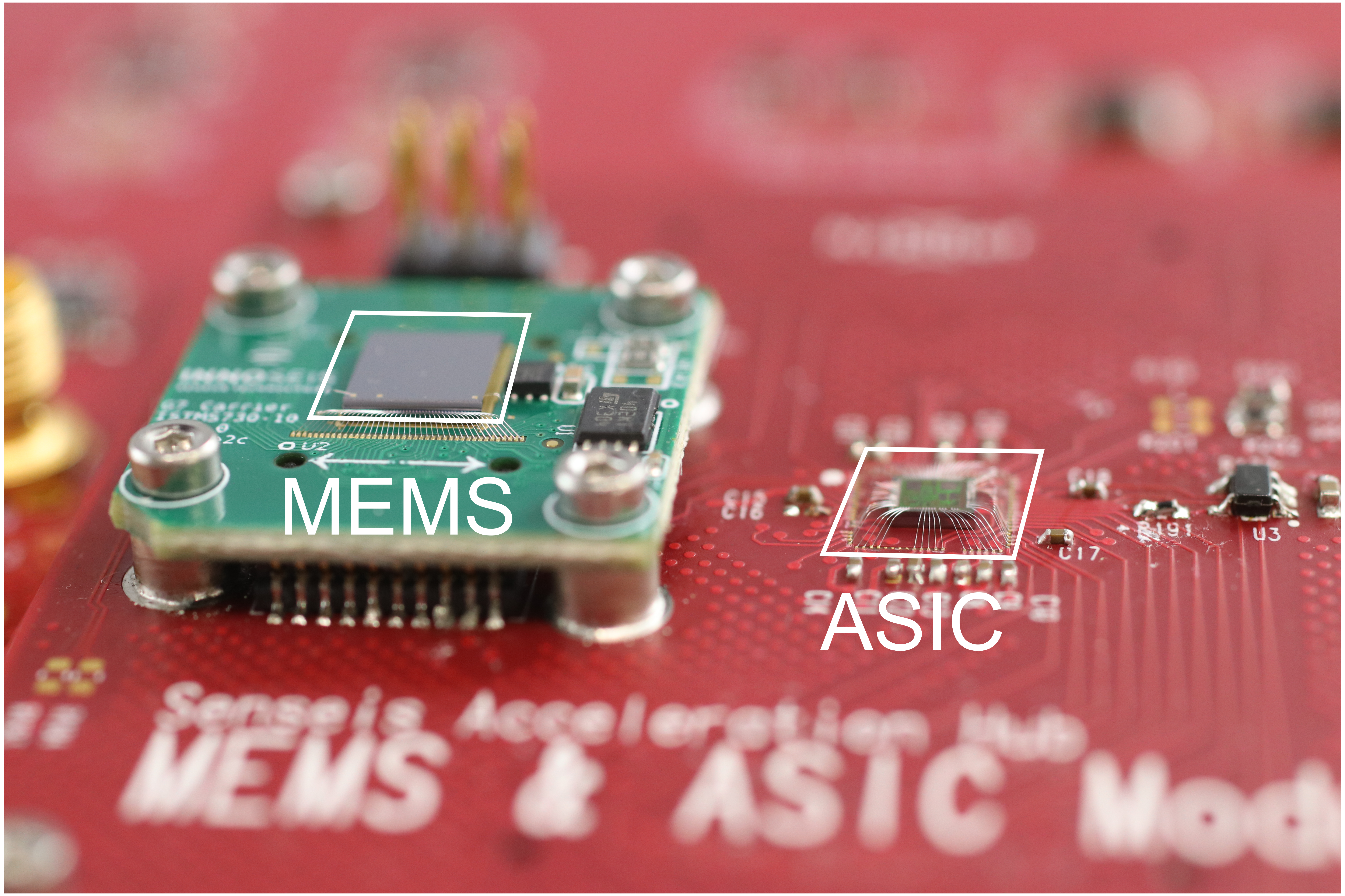
ELECTRICAL MEASUREMENT SETUP



- Similar to the ASIC, a lot of configurability on the PCB.
- Modular design.
- Design by Sander, implementation by Sander and Charles.

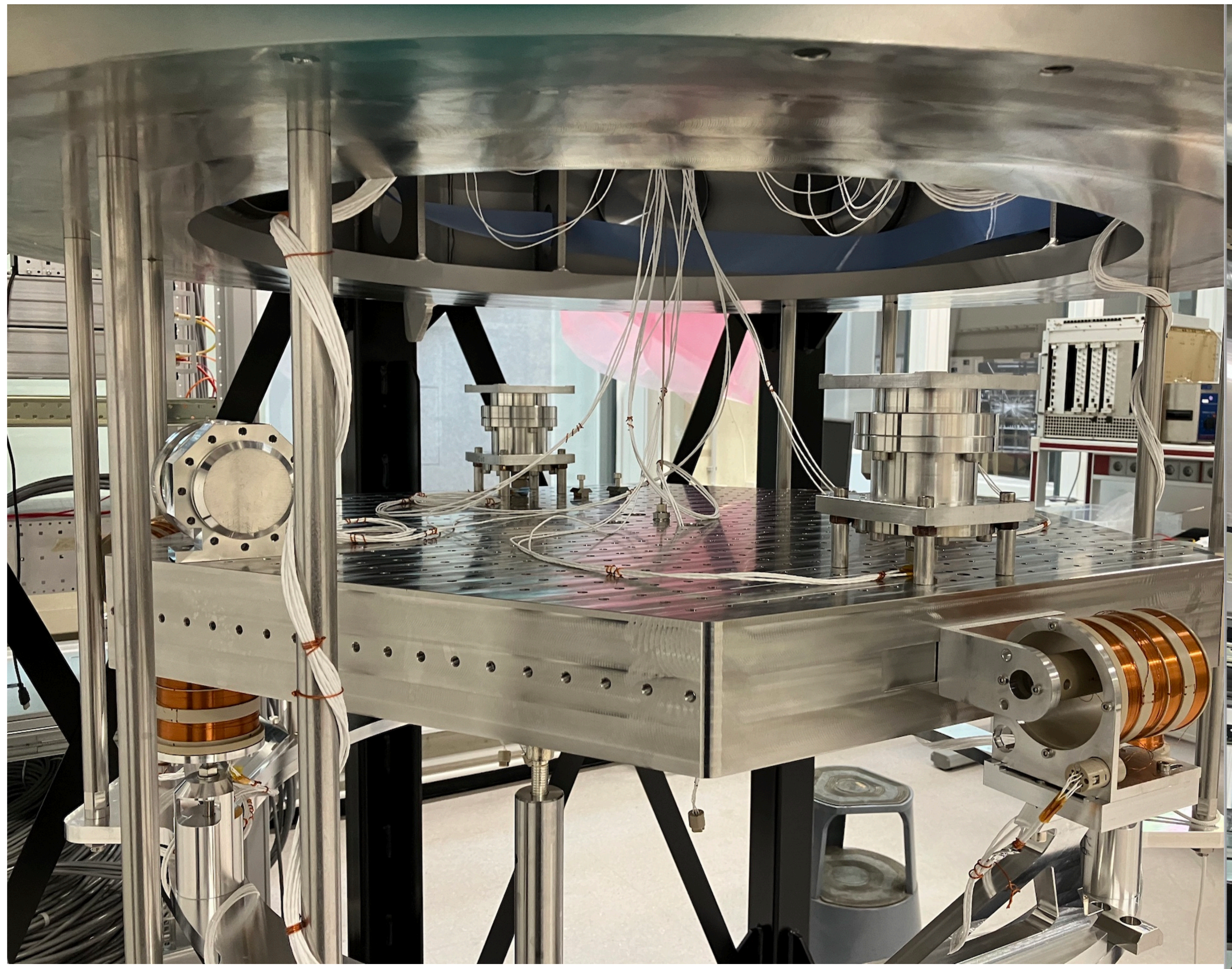
For robust operation and avoiding nasty surprises, all the blocks in the signal chain on the ASIC can be swapped with an equivalent block on the board.

ELECTRICAL MEASUREMENT SETUP



- ASIC is bonded directly to the PCB to avoid parasitics coming from the package.
- Bonding is done in-house by Dimitri (MT).
- MEMS module is on top of the ASIC module, easy to replace and test many.

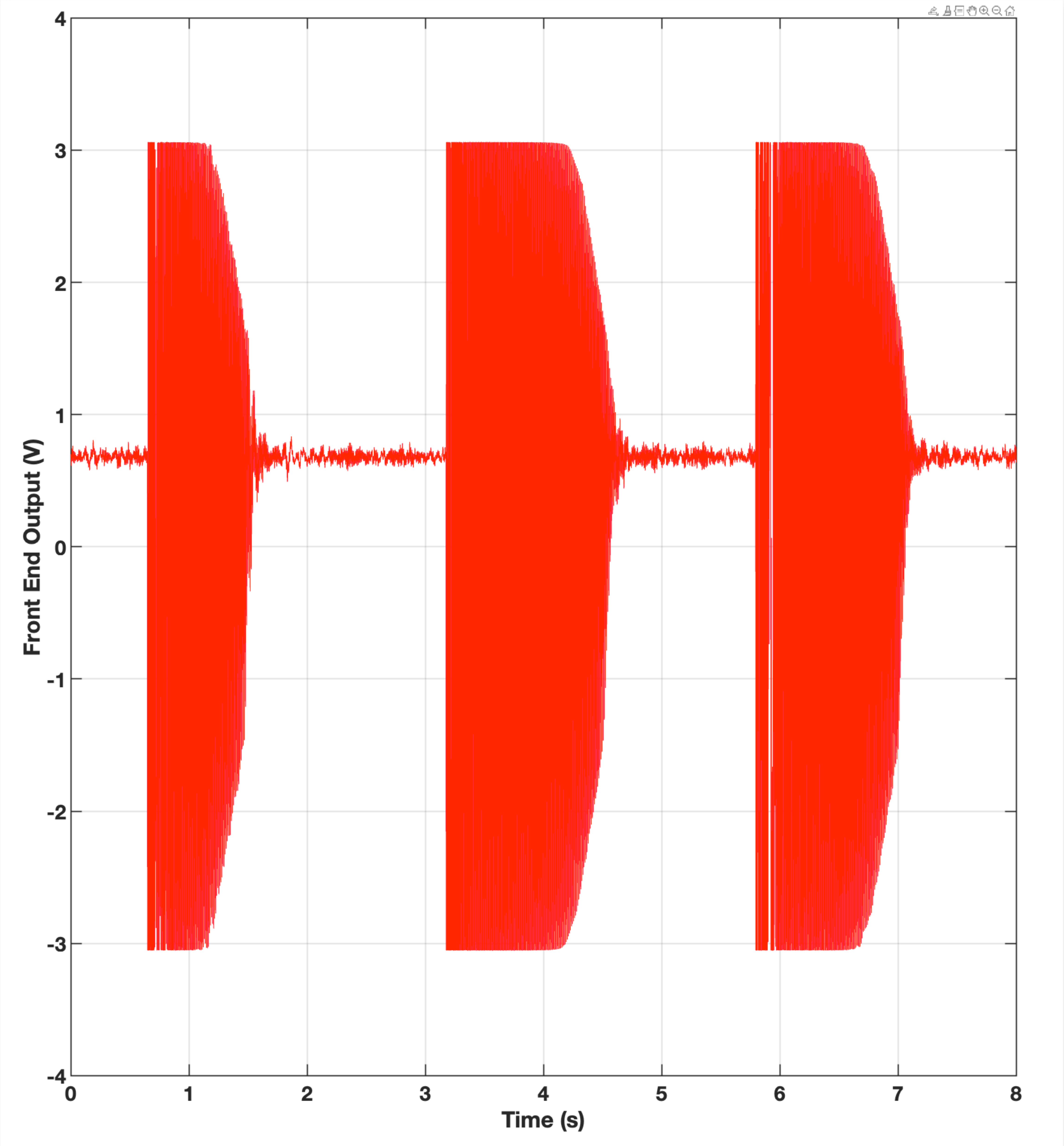
PHYSICAL MEASUREMENT SETUP



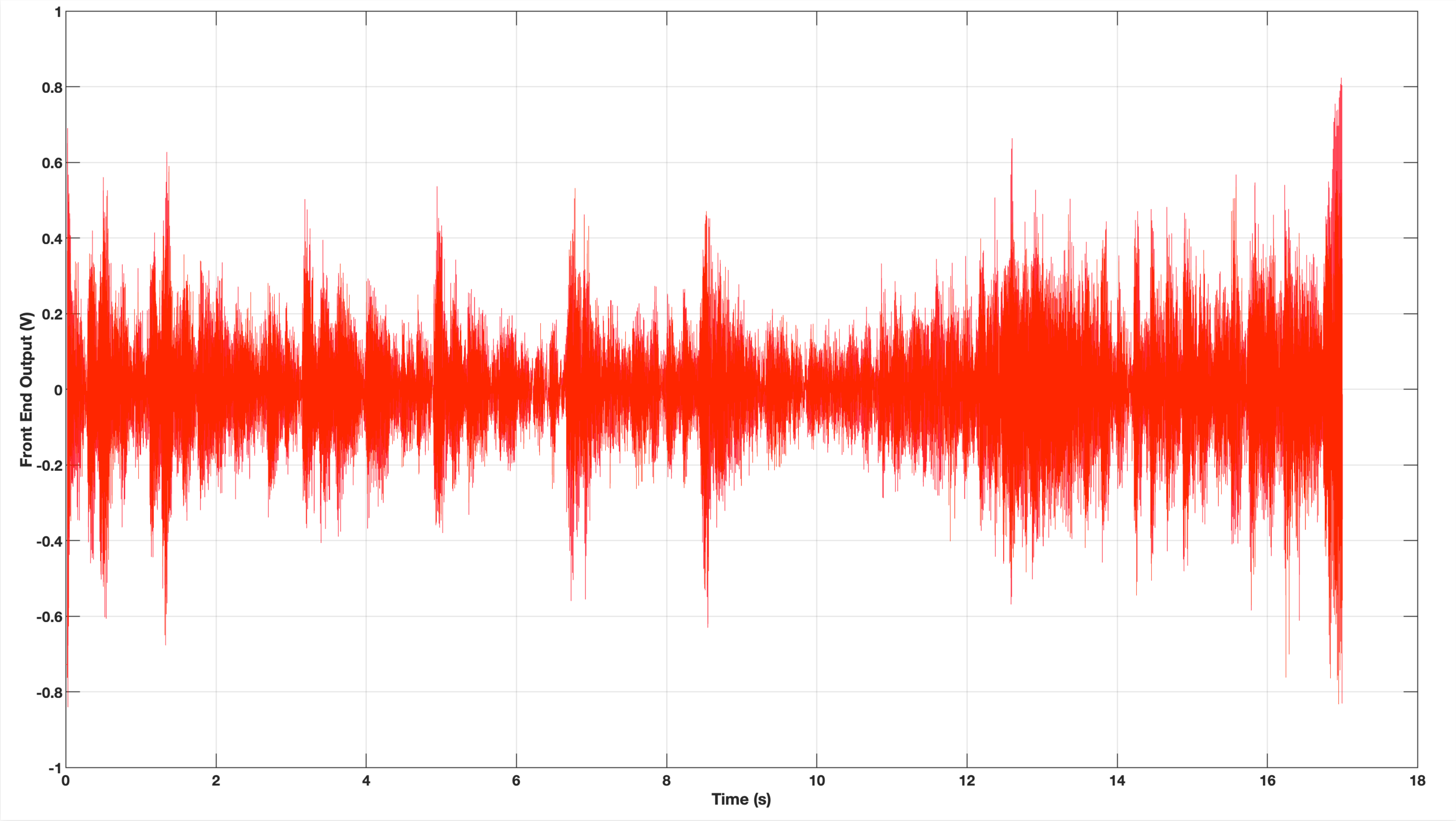
- Table-top measurement setup is good up to a point for electrical characterisation.
- For seismic noise measurements m-SAS is needed.
- M-SAS is almost operational.

RESULTS

- System is operational in close-loop, i.e., can sense vibrational events.
- Too much environmental noise to be able to characterise the acceleration noise capabilities.
- System is robust under high-g acceleration events (tapping the table).



ONE LAST TEST



CONCLUSIONS

- R&D project running since 2014.
- Collaboration between industry and the institute.
- MEMS G7, ASIC G4, both functional.
- Closed loop operation verified.
- Electrical measurements look OK.
- Looking forward to acceleration noise characterisation.

THANK YOU FOR YOUR ATTENTION.

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