Electronic Interfaces for MEMS

Overview

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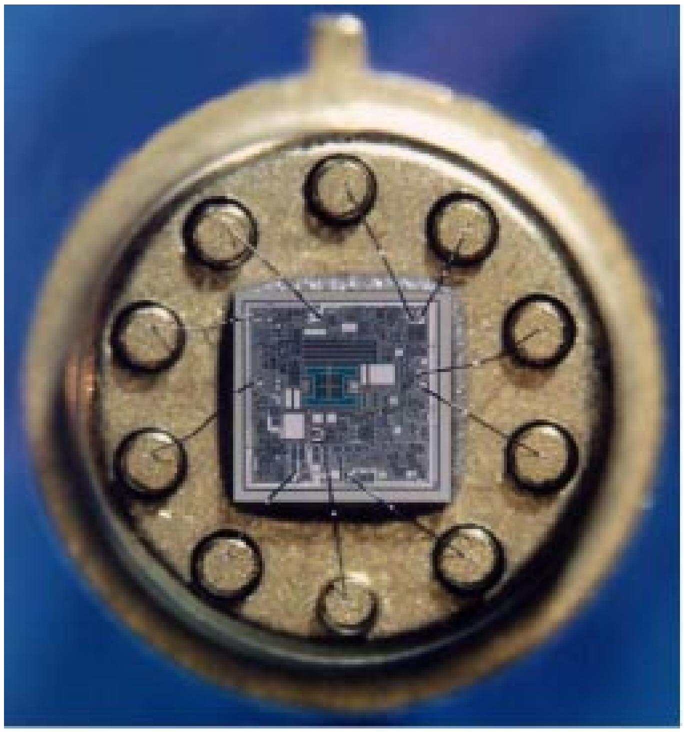
Typical MEMS



Ref: Analog Devices ADXL-50

- Micro-Electro-Mechanical System
- tight integration of sensor and electronics (monolithic or single package)
- blurring of functions between mechanics and electronics

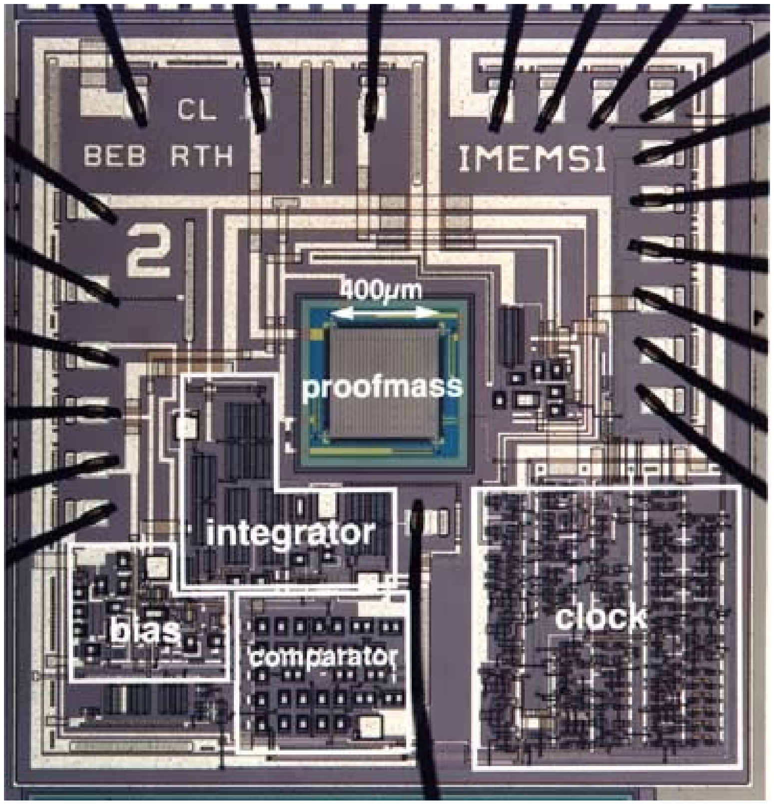
  e.g. electrostatic springs,
  electromechanical ADC

Role of Electronics in MEMS

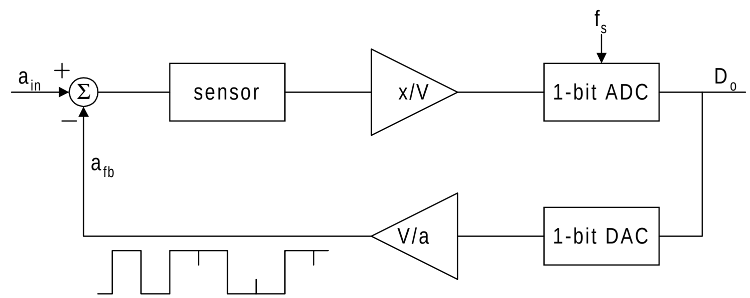
Examples:

- signal detection & conditioning
  (traditional role of electronics in sensors)
- electrostatic springs
- noise reduction
- self test
- increase precision beyond fabrication tolerance

Signal Detection & Conditioning

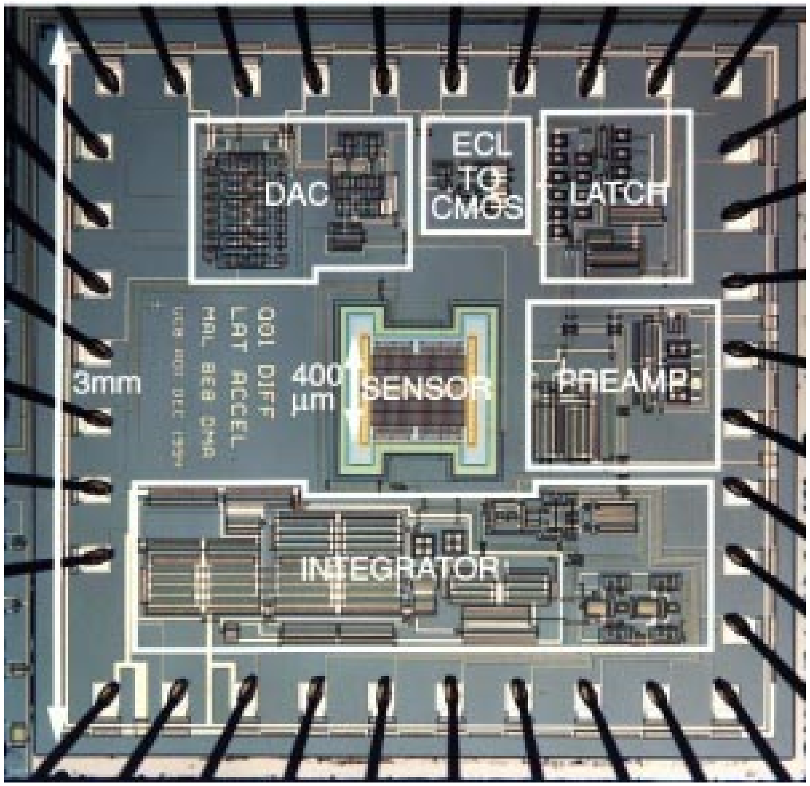


Ref.: C. Lu et al, "A surface micromachined accelerometer with digital output", J. Solid-State Circ., pp. 1367-1373, Dec. 1995.



electro-mechanical analog-to-digital converter for digital output

Noise Reduction



Ref.: M. Lemkin et al, “A fully differential lateral ΣΔ accelerometer with drift cancellation circuitry”, in digest IEEE Solid-State Sensor and Actuator Workshop, Hilton Head, pp. 90-93, June 1996.

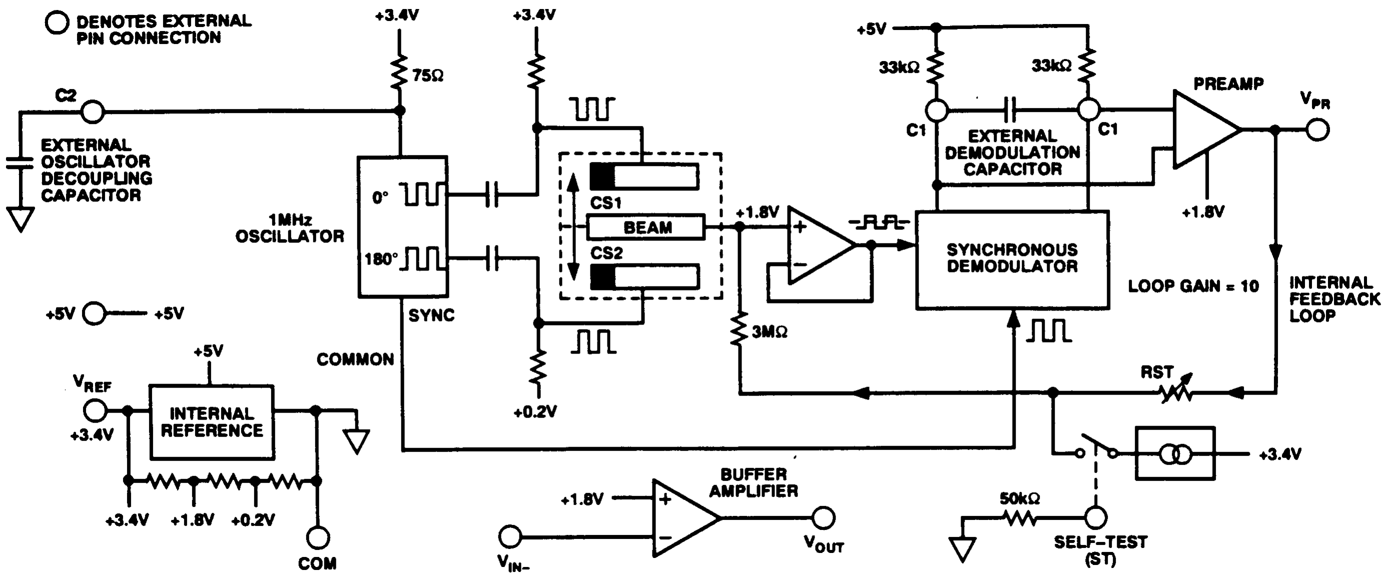
Brownian motion noise:

$$\sqrt{\frac{\overline{a_{noise}^2}}{\Delta f}} = \sqrt{\frac{4k_B T\omega_r}{mQ}}$$

Vacuum package for increased Q and reduced noise.

Electronic force-feedback dampens motion of high-Q system.

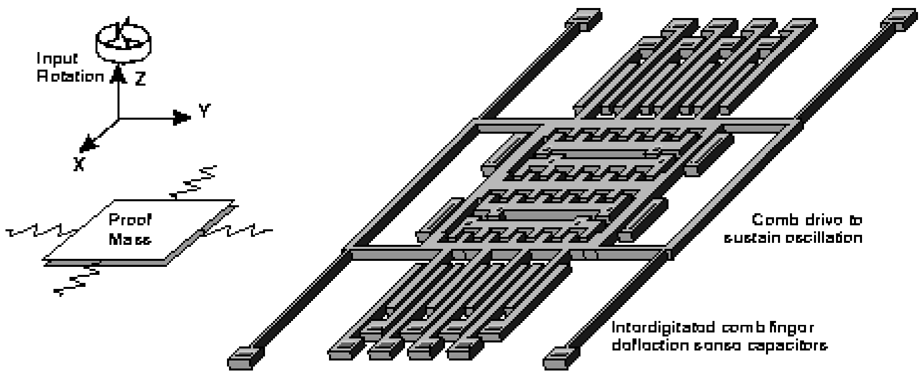
Self Test



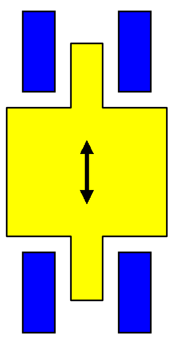
Ref.: ADXL-50 data sheet.

Self test based on electrostatic actuation of the proof-mass of the acceleration sensor.

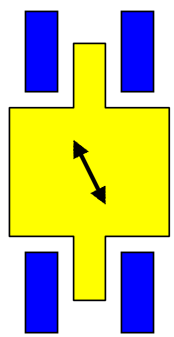
Precision Beyond Fabrication Tolerances



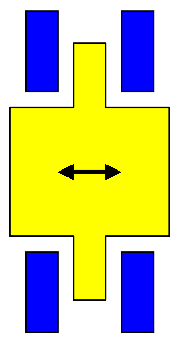
Ref.: W. Clark, "Surface Micromachined Z-Axis Vibratory Rate Gyroscope", Solid-State Sensor and Actuator Workshop, Hilton Head, pp. 283-287, June 1996.



desired drive signal



actual drive (mismatch)



coriolis signal

- mismatch (suspension, forcing capacitors) cause parasitic output signal
- *solution:* electrostatic compensation force

Elements of Sensor Electronics

- capacitive interface
  - signal detection
  - force actuation
- capacitor sense circuits
  - position sensor
  - extreme accuracy requirements: detect less than 10^{-18} F to sense less than 0.01Å displacement
- mechanical resonators
  - sustaining amplifier
- feedback
  - improves key characteristics of sensor, e.g. accuracy, linearity, drift, frequency response, …
  - adds little complexity to MEMS device