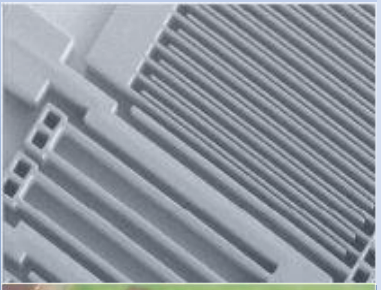
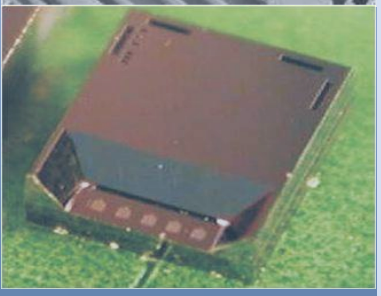
“MEMS Capacitive Accelerometers for Future Launchers”

SEPTEMBER 2010

> www.theon.com

OUTLINE





- Company
- Brief History
- Activity Description
- Development Approach
- Accelerometer Module Architecture
- Core Technology Presentation – MEMS + CMOS
- Next Steps

THEON SENSORS

Process technology

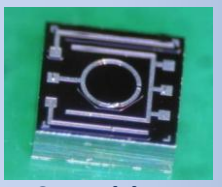
MEMS Surface Micromachining for Capacitive Inertial Sensors (XFAB)

MEMS Fusion Bonding for Capacitive Pressure Sensors (THEON-XFAB)

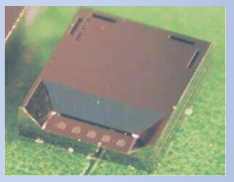
MEMS Bulk Micromachining for Resistive Flow Sensors (ISIT Fraunhofer)

0.18um Mixed-Signal CMOS (XFAB)

MEMS



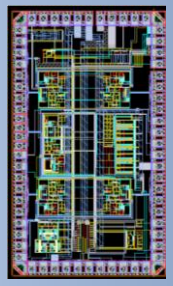
Capacitive Pressure Sensor



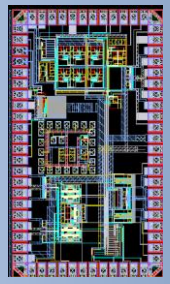
Capacitive Accelerometer

Flow

ASIC



Capacitive Interface



Resistive Interface

Peripherals

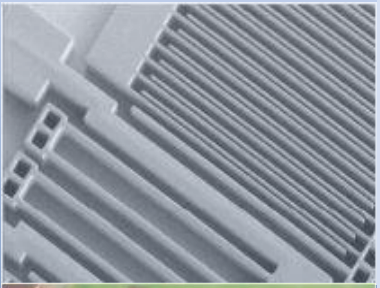
Digital Logic
(Processor for Calibration, Compensation, etc)

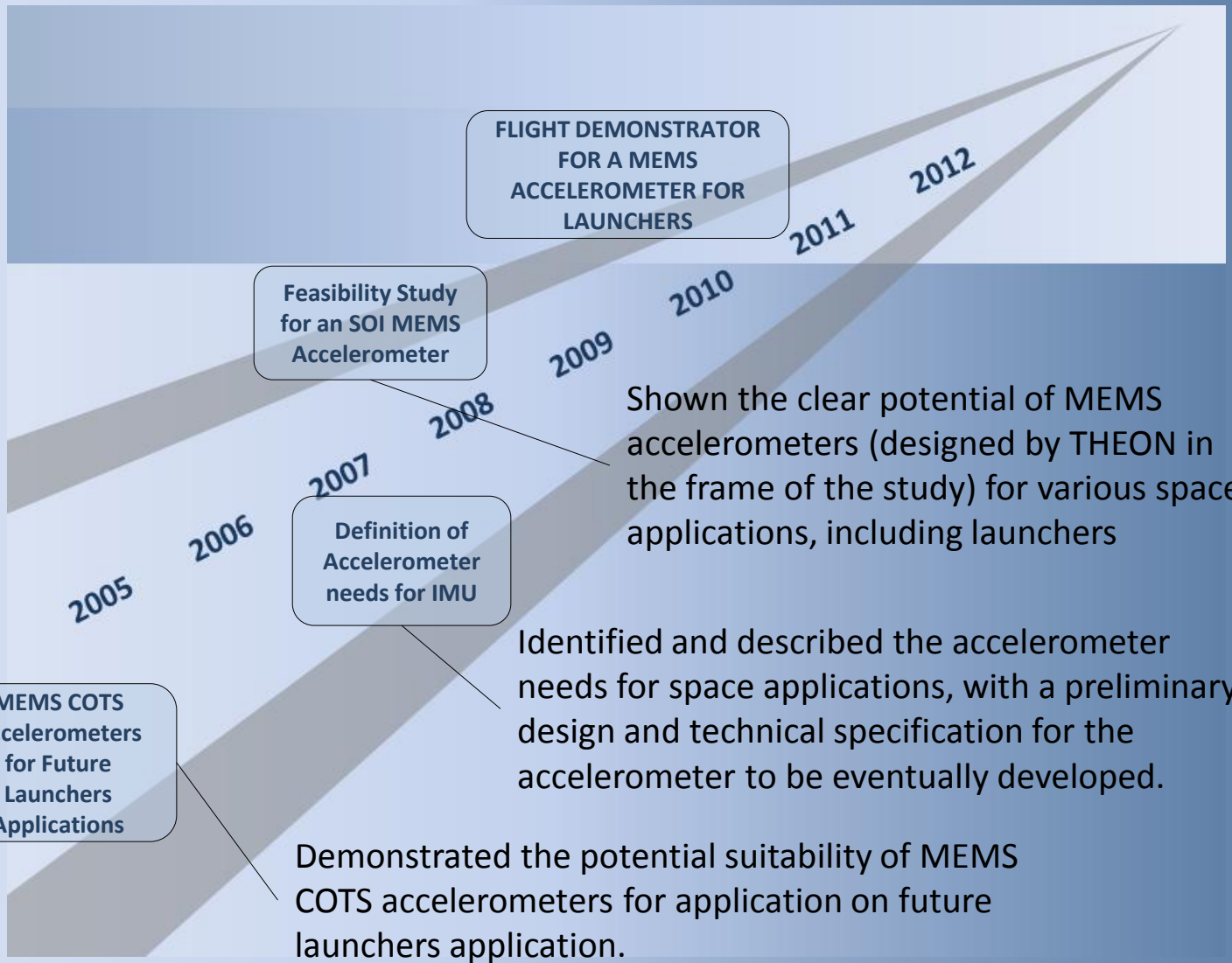
Power Supply
(DC-DC converters, Voltage regulators, etc)

COMMS
(SPI, I2C, custom)

Other
(Instrumentation Amplifiers, Balancers, Bandgaps, etc.)

Brief History - Status



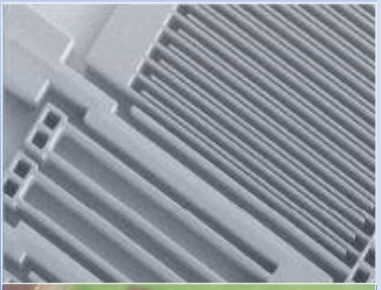


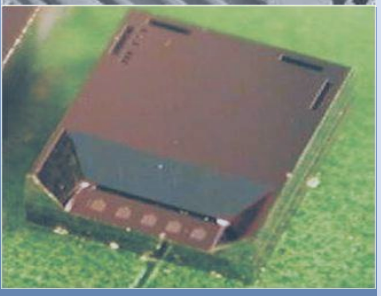
Shown the clear potential of MEMS accelerometers (designed by THEON in the frame of the study) for various space applications, including launchers

Identified and described the accelerometer needs for space applications, with a preliminary design and technical specification for the accelerometer to be eventually developed.

Demonstrated the potential suitability of MEMS COTS accelerometers for application on future launchers application.

Activity Description





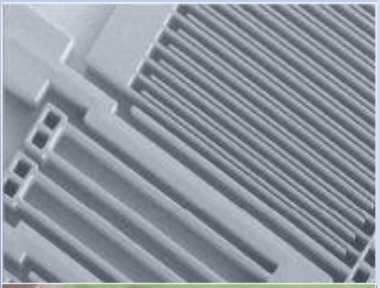
FLIGHT DEMONSTRATOR FOR A MEMS ACCELEROMETER FOR LAUNCHERS

- Started in NOV 2009, 38 months, 2 phases
- Industrial scheme: ASTRIUM ST Prime, THEON sub-contractor, ESA end-user
- Development of flight model for future ARIANE

MAIN ASSUMPTIONS

- Flight model, TRL= 8
- Be usable in any part of the launcher and at any phase during the flight mode including “upper stages” (low weight and small size objectives)
- Compliant with A5 launcher environments
- Compliant with all the mission requirements applied to the TM system
- Friendly adaptable to the current TM subsystem

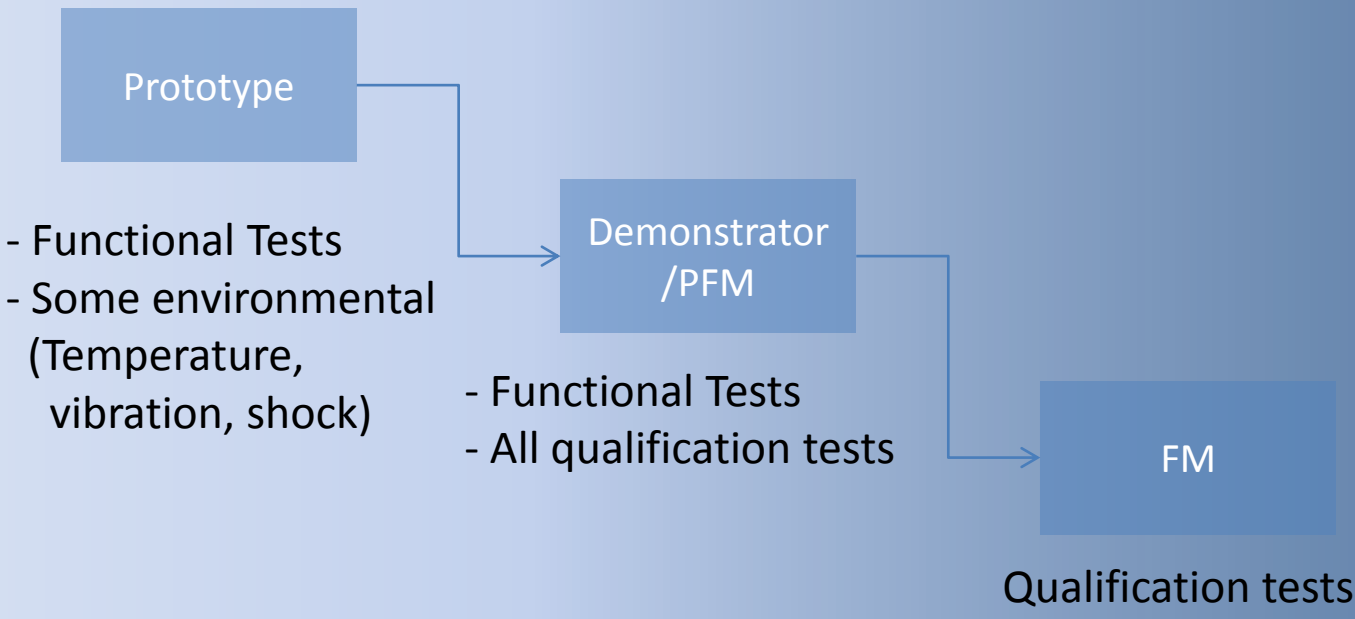
Work Logic/Approach



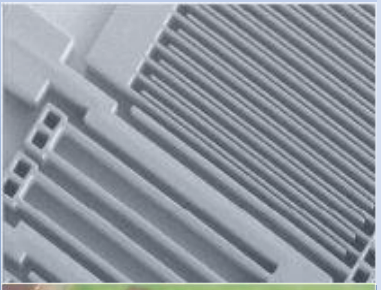
Introduction of two novel features, for the Ariane 5 sensors:

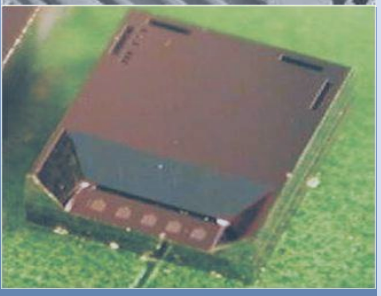
1. the MEMS technology
2. the digital interface

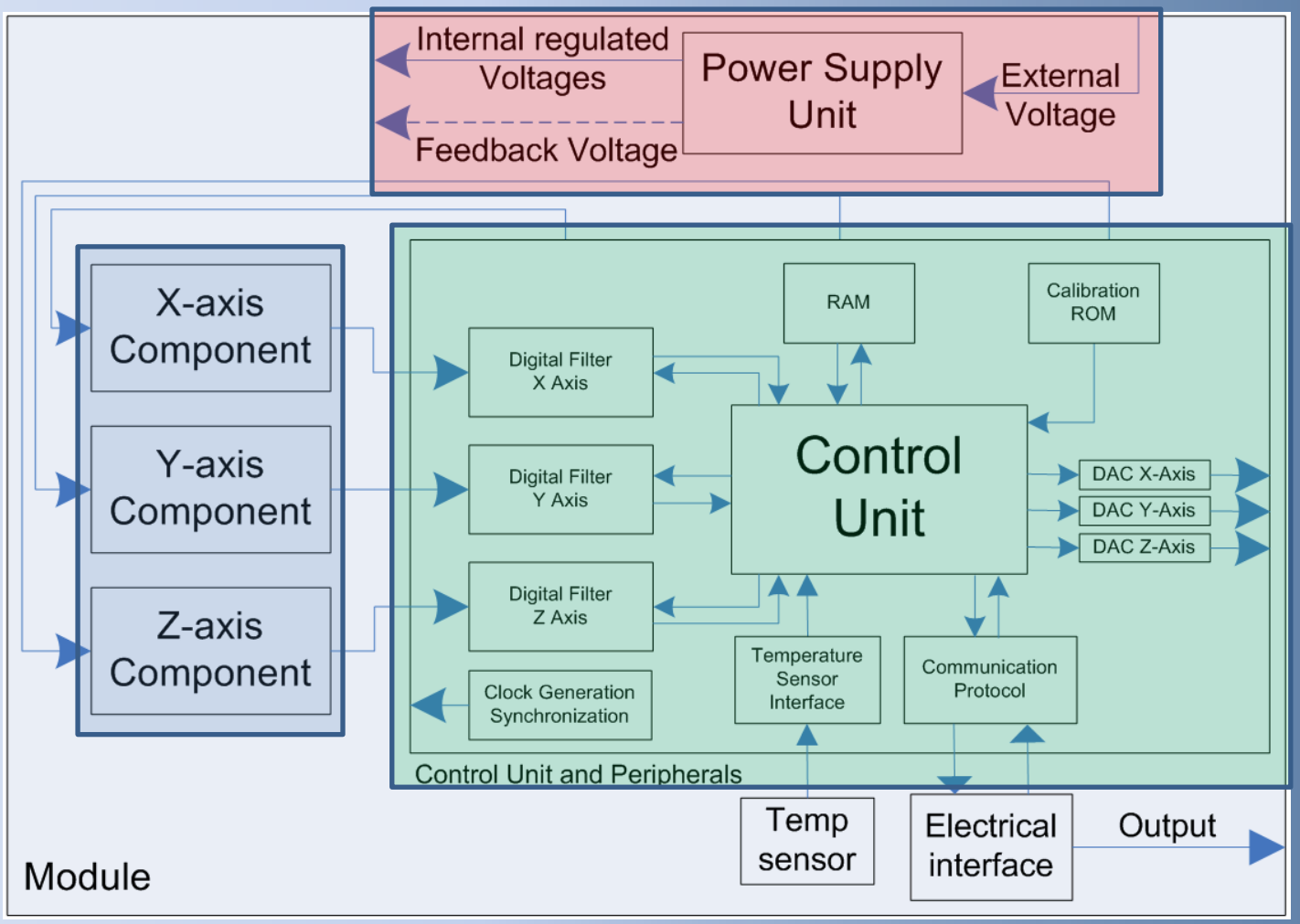
PROTO FLIGHT MODEL APPROACH



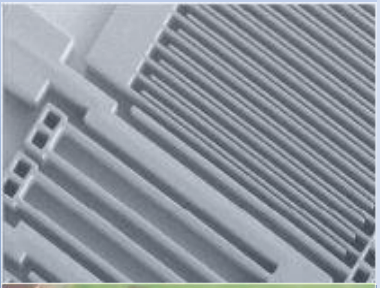
Module Architecture

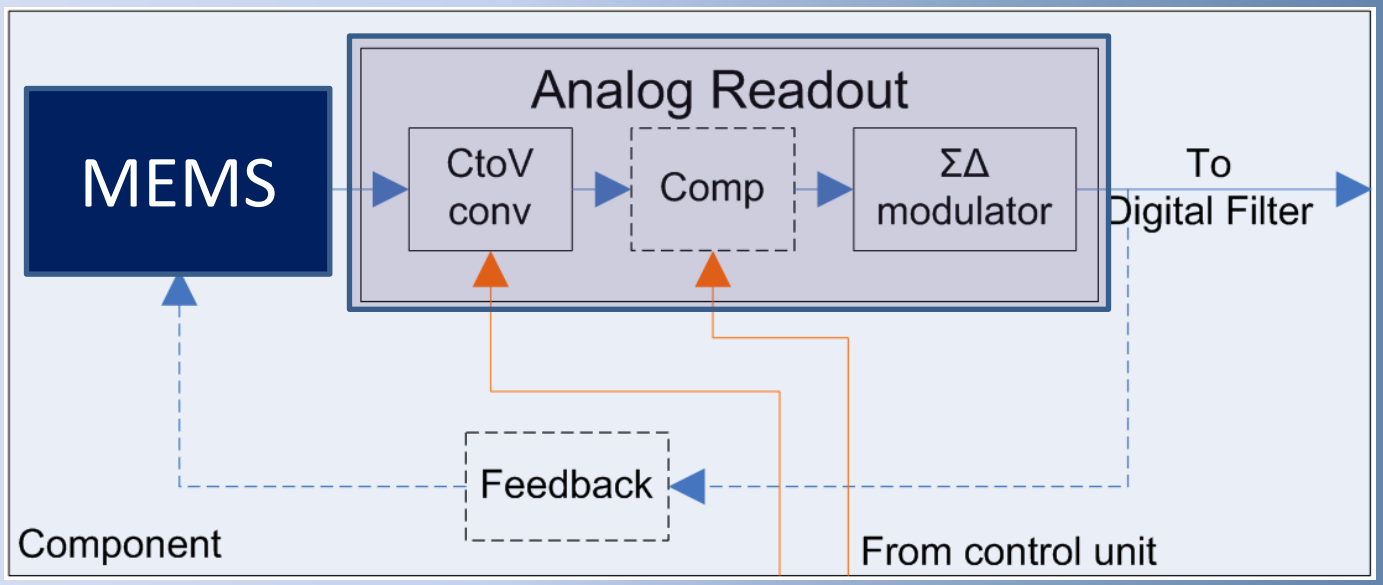




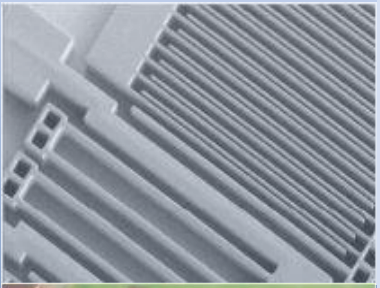


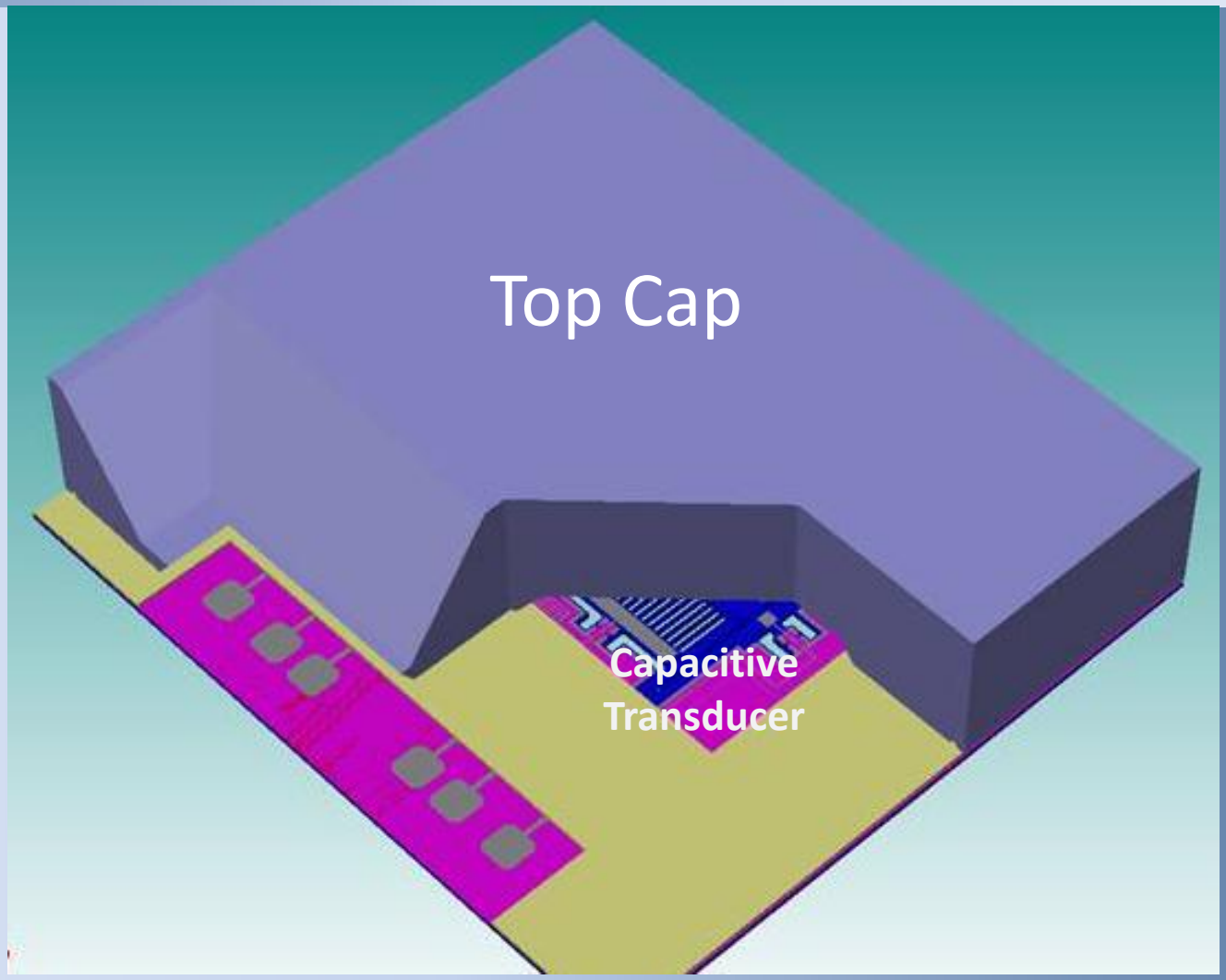
Accelerometer Component



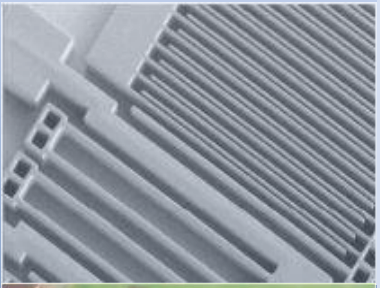


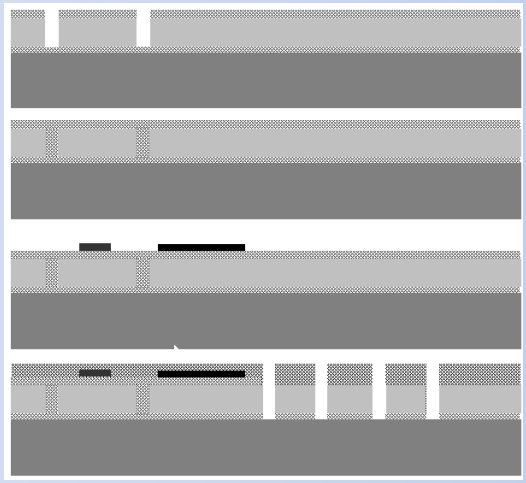
MEMS

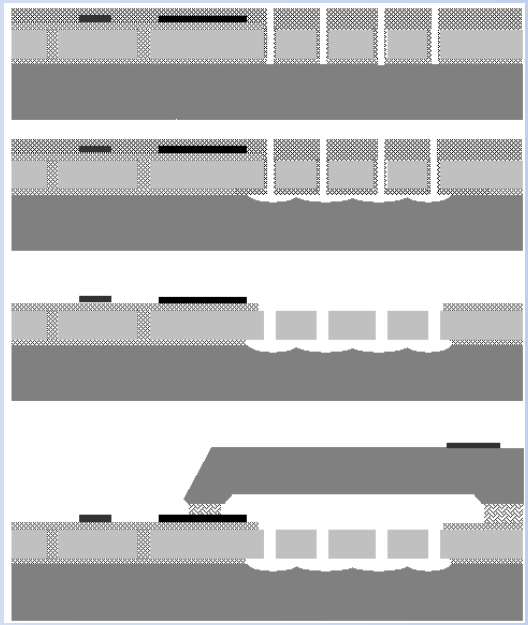




X-FAB Surface Micromachining Technology

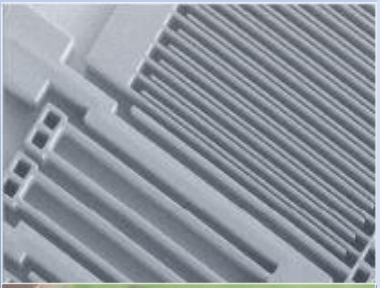






1. Etch isolation trenches
2. Fill isolation trenches, deposit intermediate isolator
3. Deposit and pattern metal layer
4. DRIE mechanical structure
5. Passivate sidewalls,
   then open bottom of trenches
6. Isotropic etch to release mechanical structure
   (structure width determines which parts are freed)
7. Strip etch mask, sidewall passivation and buried oxide
   leaving single-crystal mechanical structure
8. Cap sensor wafer by glass frit wafer bonding

X-FAB Surface Micromachining Technology



1. **Etch isolation trenches**
2. **Fill isolation trenches, planari**
3. **Deposit and pattern intermed isolator**
4. **Deposit and pattern metal**
5. **DRIE mechanical structure**
6. **Passivate sidewalls, then open bottom of trenches**
7. **Isotropic release etch**
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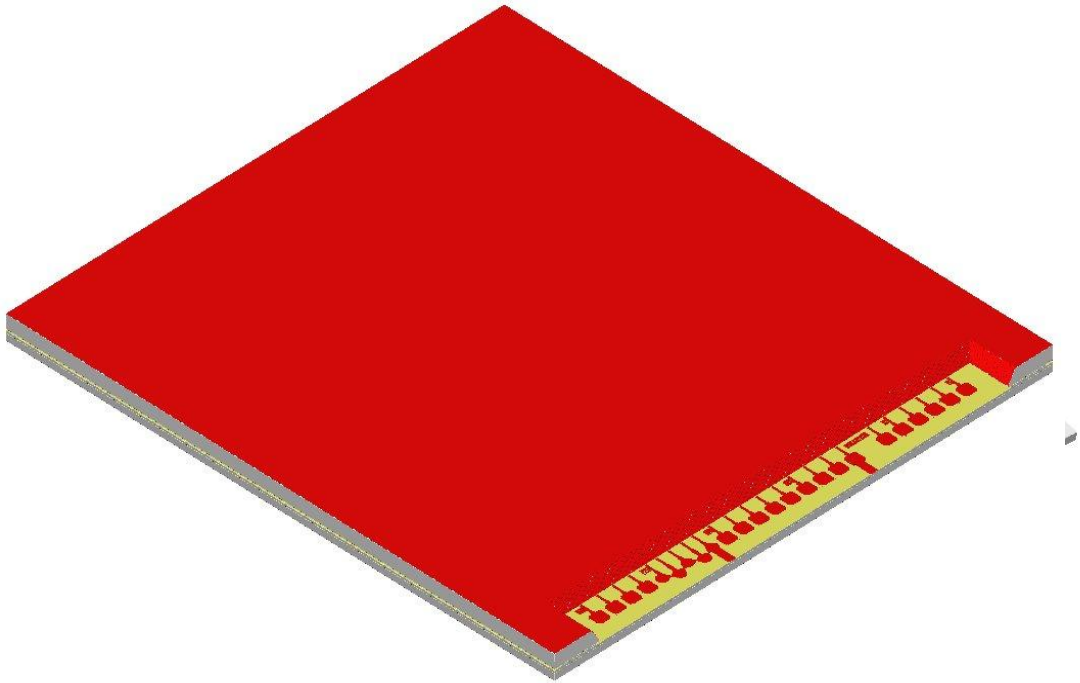
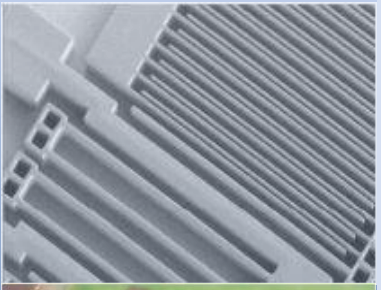
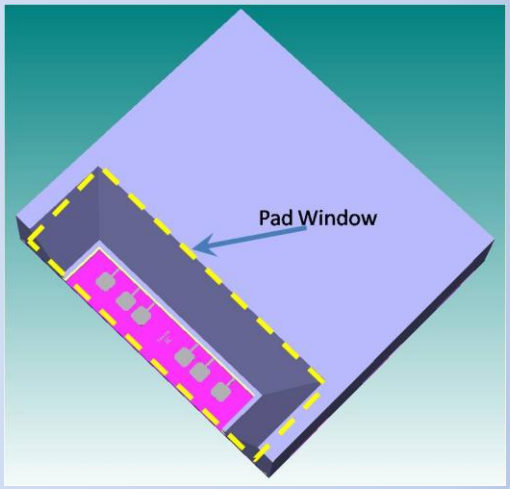
9. **Cap wafer by glass frit wafer bonding**

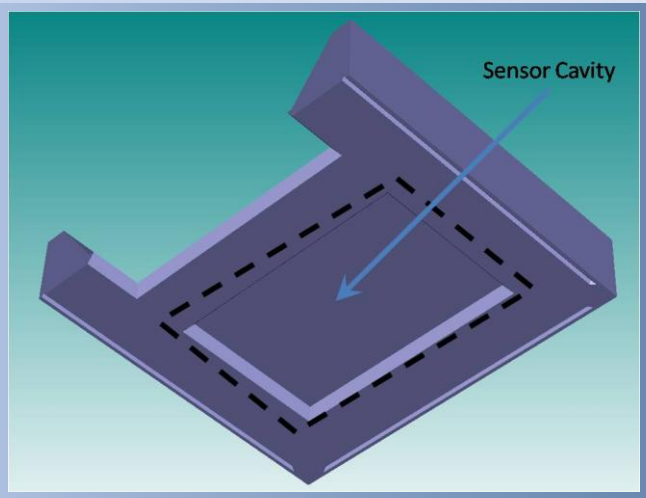


SEM picture of gyroscope chip with open cap wafer

Wafer Level Packaging

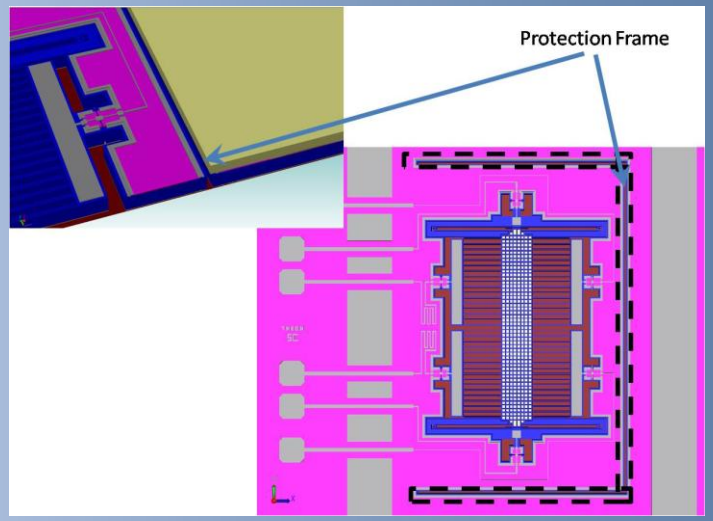




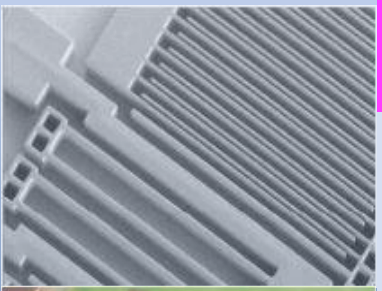


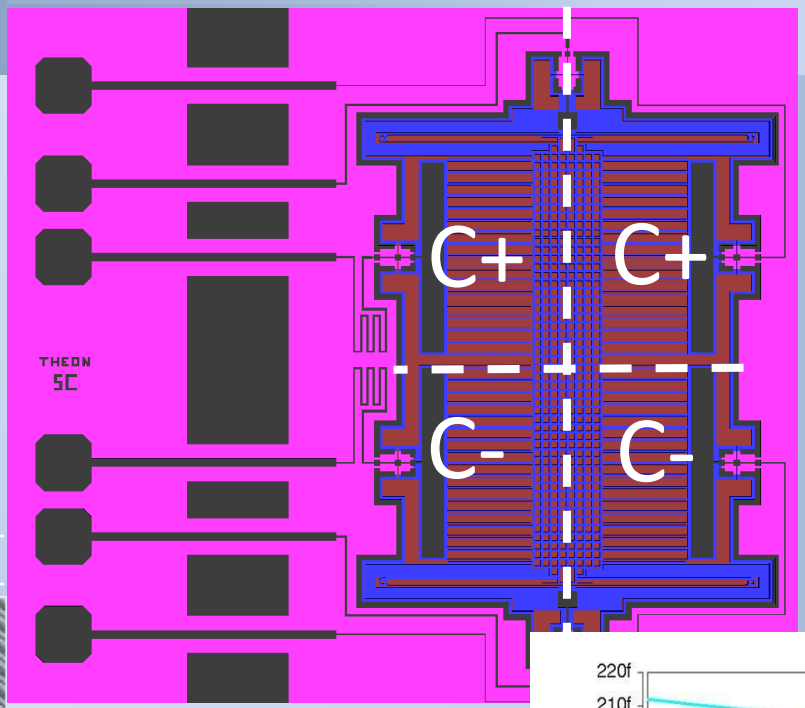
Wafer level encapsulation major steps

- The wafer cap preparation
- The frit glass bonding
  1. Deposition of the glass paste by screen printing
  2. Conditioning of the paste
  3. Actual bonding



Capacitive MEMS Accelerometer



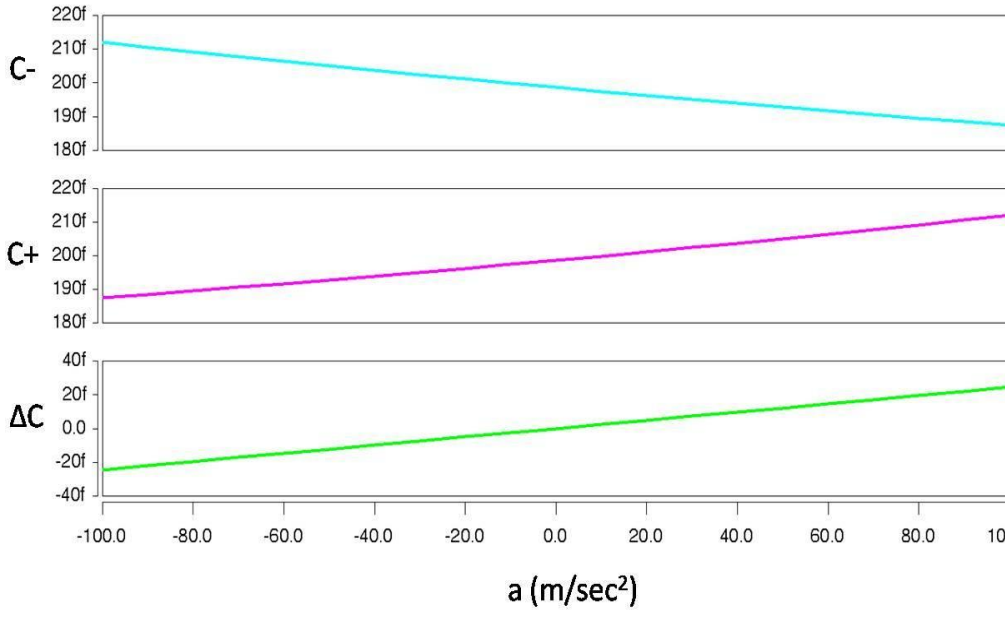


The structure has both a horizontal and vertical symmetry

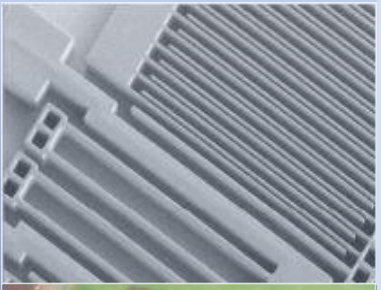
The symmetry guarantees that:

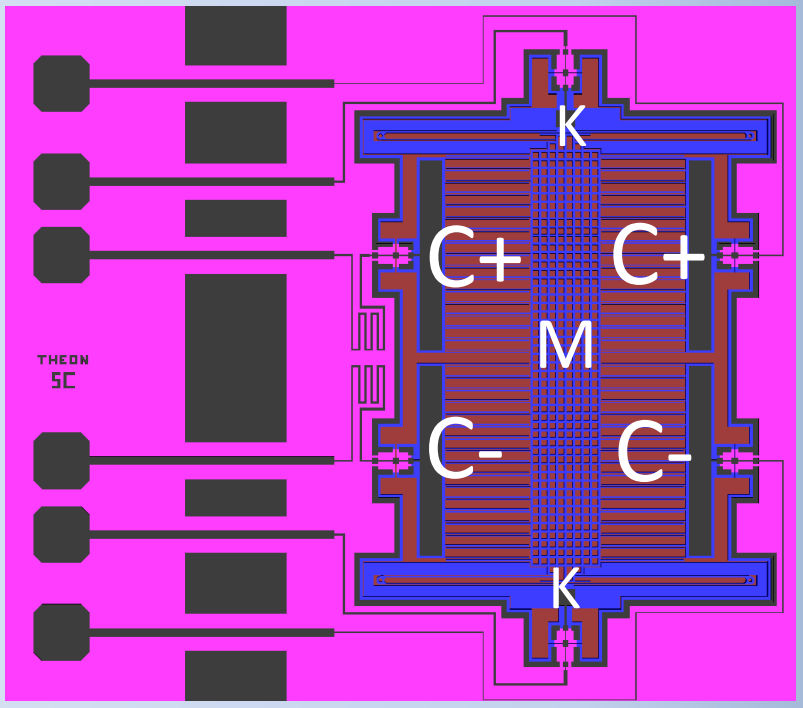
- The four sensing capacitors are perfectly matched and therefore the common mode effects will be suppressed
- The 2nd order non-linearity of the parallel plate capacitors will be eliminated
- The requirement for a fully differential design for the readout electronics is met

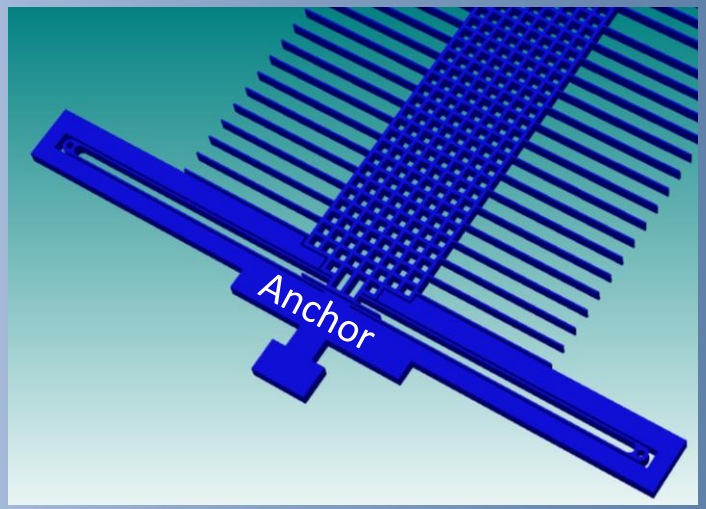
Four parallel plate capacitors are used for the electromechanical energy transduction. The input acceleration displaces the proof mass and the acquired kinetic energy is converted to electrical energy which is stored in the four sensing capacitors

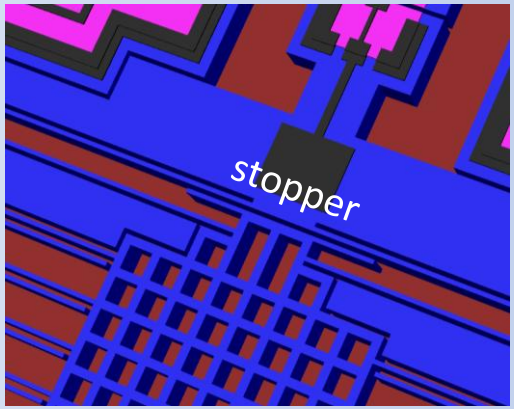


Capacitive MEMS Accelerometer







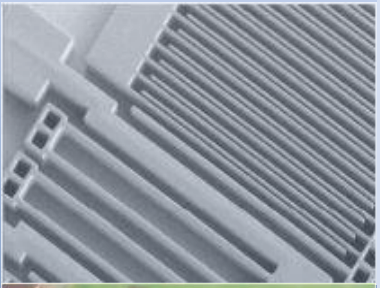


The motion of the proof mass is limited by mechanical stoppers

The stoppers guarantee that:

- The maximum in-plane displacement of the proof mass is always lower than the gap between the fingers of the parallel plate capacitors so as to avoid a catastrophic short-circuit (i.e in case pull-in instability occurs)
- The maximum in-plane motion is kept within specific limits so as to avoid fracture of the mechanical springs

Analog Readout Electronics



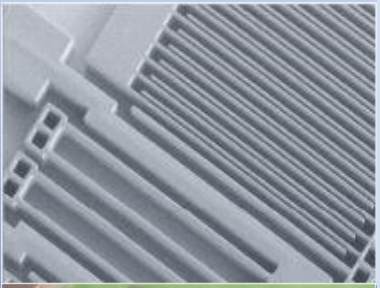
Technology (X-FAB 0.18 um mixed signal CMOS, XC018)

- Low cost CMOS technology
- Standard European CMOS technology (No subject to ITAR)
- Excelent “Analog” performance
- Compatibility/Future co-integration with MEMS

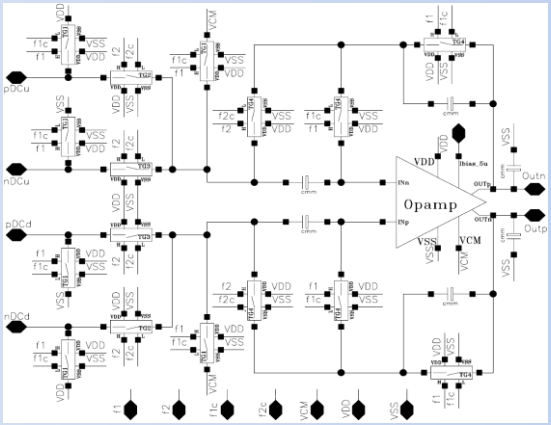
Analog Design Blocks

- Discrete-time (Switched Capacitor) configuration are used appropriate for applying noise reduction techniques
- Capacitance to Voltage Converter (sense transducer capacitance)
- ΣΔ modulator (Quantization of analog response)
- Compensator (to ensure stability in close loop designs)

Analog Readout Electronics

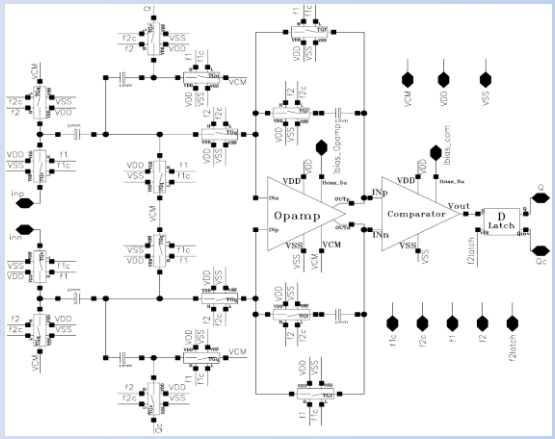


Capacitance to Voltage converter



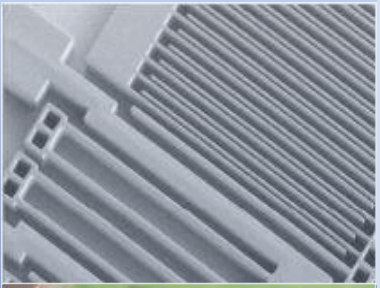
- The Capacitance of the Transducer is sensed
- Input Capacitance is translated into differential voltage
- Noise reduction techniques are applied

Sigma Delta (ΣΔ) modulator



- Input Voltage is quantized (1Bit ΣΔ are appropriate for low bandwidth application)
- 1st of 2nd order ΣΔ modulators could be used regarding the desired quantization noise level
- Noise reduction techniques are applied

Next Steps



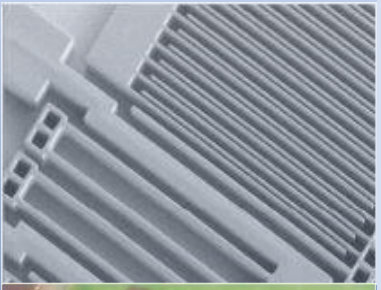
Short term

- Fabrication and functional verification of MEMS (Q1 2011)
- Fabrication and functional verification of ASIC (Q1 2011)

Mid term

- Fabrication and functional verification of the component (Q3 2011)

MEMS Business Unit



Thank you for your attention

Contact: Thanasis Kollias

Technical Director

MEMS Business Unit

THEON SENSORS

Email:kollias@theon.com

Tel.: +30 210 66 41 420