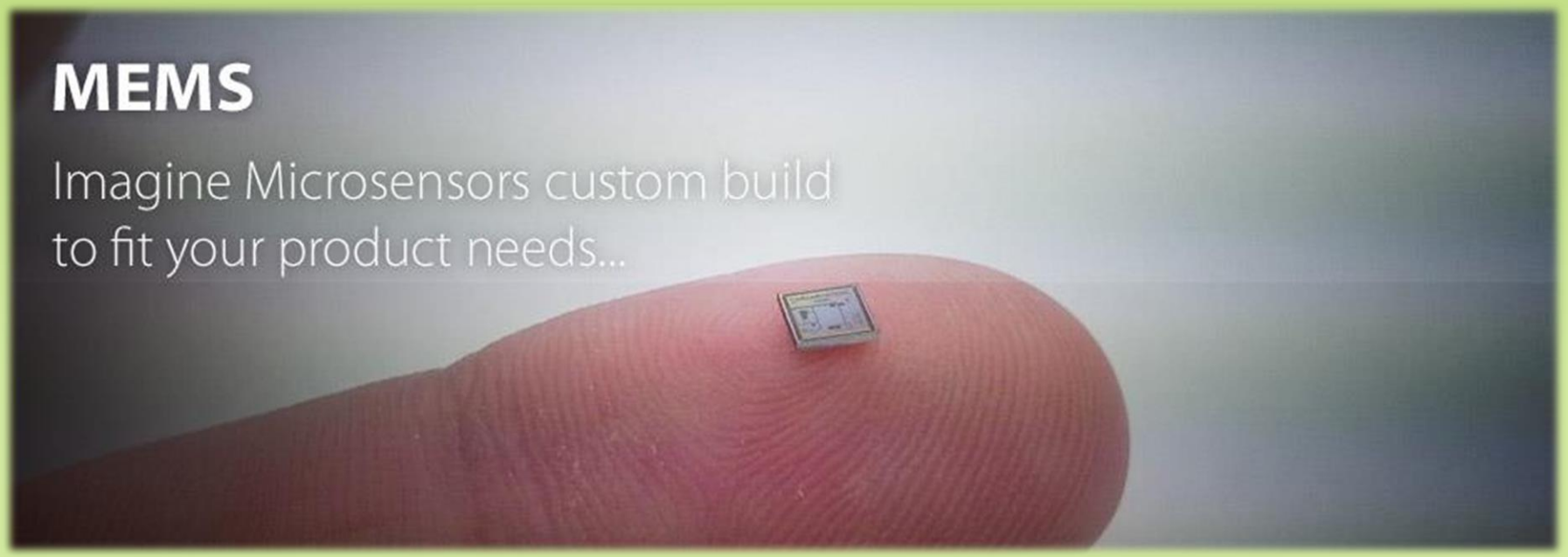


Advances in MEMS-based accelerometer component for space applications

MNT 2014, 12 June 2014

Presenter: Tasos Petropoulos

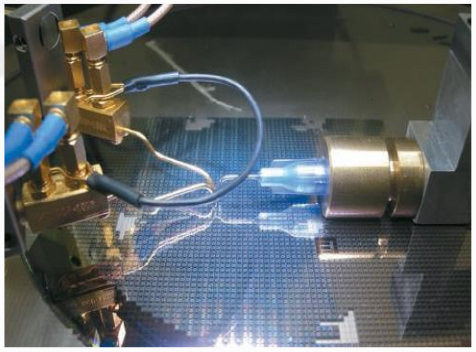
www.esenssys.com

Presentation Overview

- *Company overview*
  - ESS Activities
  - Overview of the company's space history
- *Single axis accelerometer component*
  - Background & Objective
  - System description
  - MEMS detector
  - ASIC
  - Package
  - Qualification procedure
- *Summary - conclusions*

Company profile

- A developer and manufacturer of high quality sensors based on *microelectromechanical systems (MEMS)*
- Spin-off from THEON Sensors in 2012
- A *high technology company* with advanced design capabilities, *flexibility* and *custom made approach*
- Our vision is to deliver *high quality products* customized to meet demanding requirements



Business model

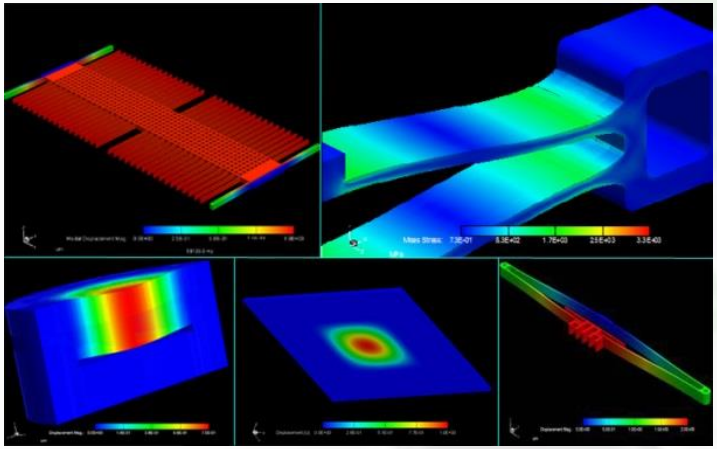
Designed internally by ESS
Fabrication is Outsourced

- **MEMS Sensors**
- **CMOS electronics**
- **PCB's**
- **Mechanical packages**
- **Calibration Algorithms**

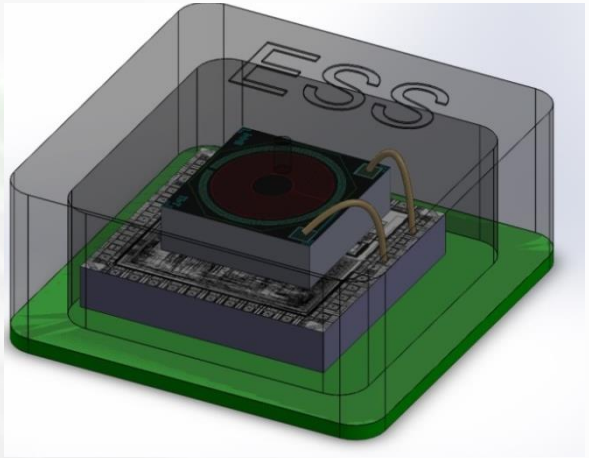
- ***Full control*** **and** ***ownership*** **of all aspects of our products**
- ***Fabless model*** **offers significant flexibility**
- **Since 100% of the design is implemented in house, ESS is** ***capable*** **to design, develop and fabricate** ***custom made sensing solutions***

Design activities

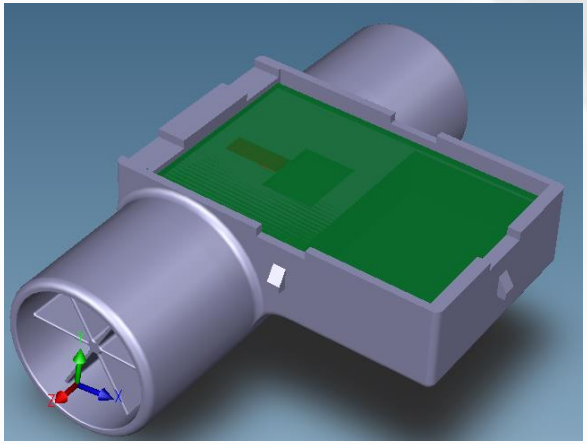
MEMS sensors



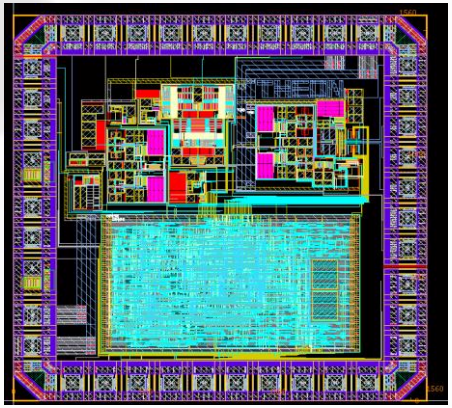
Packages



Mechanical Parts



Signal Conditioning Electronics



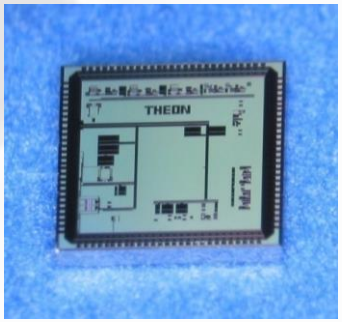
Product range

Pressure Sensors

Accelerometers

Flow Sensors

Signal Conditioning Electronics



ESS Space History

#	Activity title	Timeframe	
1	Feasibility Study for MEMS-SOI Capacitive Accelerometer	Sep07 - Nov08	ESA
2	Flight Demonstrator for a MEMS Accelerometer for Launchers	Sep09 - Dec10	ESA
3	Accelerometer Re-direction study	Nov11 - Nov13	ESA
4	Performance Demonstration of THEON's existing Pressure Modules for Space applications	Feb09 - Sep11	ESA
5	Space Qualified Family of MEMS Pressure Modules for Satellite Applications	Sep12 – on	ESA
6	Accelerometer Component to TRL5	Jan13 – on	ESA
7	SME-SAT	Feb13 – on	FP7
8	Connectivity and Packaging of Systems-of-Microsystems	Jan13 – on	ESA

Background and objectives

Accelerometer

Early accelerometer concepts (ESA activities 2007-11)
ITAR-free prototype accelerometer detector available to European industries

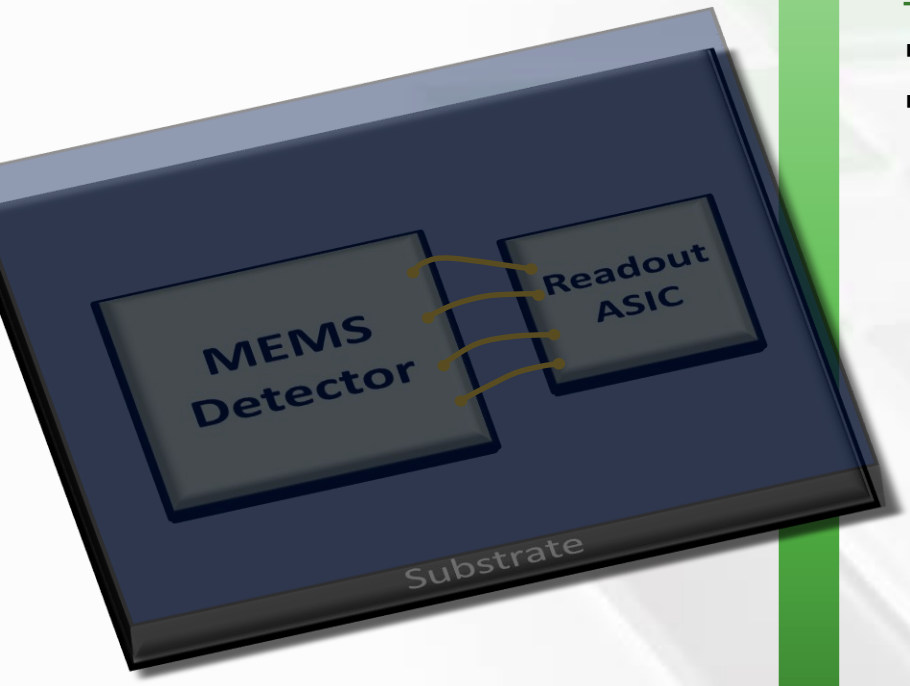
Redirection (2011-2013)

- A new accelerometer design concept adapted to updated requirements (Single axis, high performance, rad-hard)
- Detailed design, fabrication and measurement of MEMS detectors

Accelerometer component to TRL5 (2013-on)

- To make component suitable for incorporation into other equipment
- Performance, lifetime and environmental needs of future ESA exploration missions
- Radiation Hardened ASIC & MEMS
- Performance and suitability demonstrated by test

1-axis Accelerometer component



time

MEMS Detectors

- Acceleration detection through capacitance change
- Two distinct models (±1g & ±20g) in the component

Design, fabrication and early measurements in "***Redirection"*** activity

ASIC

- Capacitance to Voltage conversion
- Rad hard ASIC with 2-channel analog output

Design, fabrication and measurement in "***Accelerometer component to TRL5"***

Packaging

- Design and development of packaging scheme based in commercially available housing

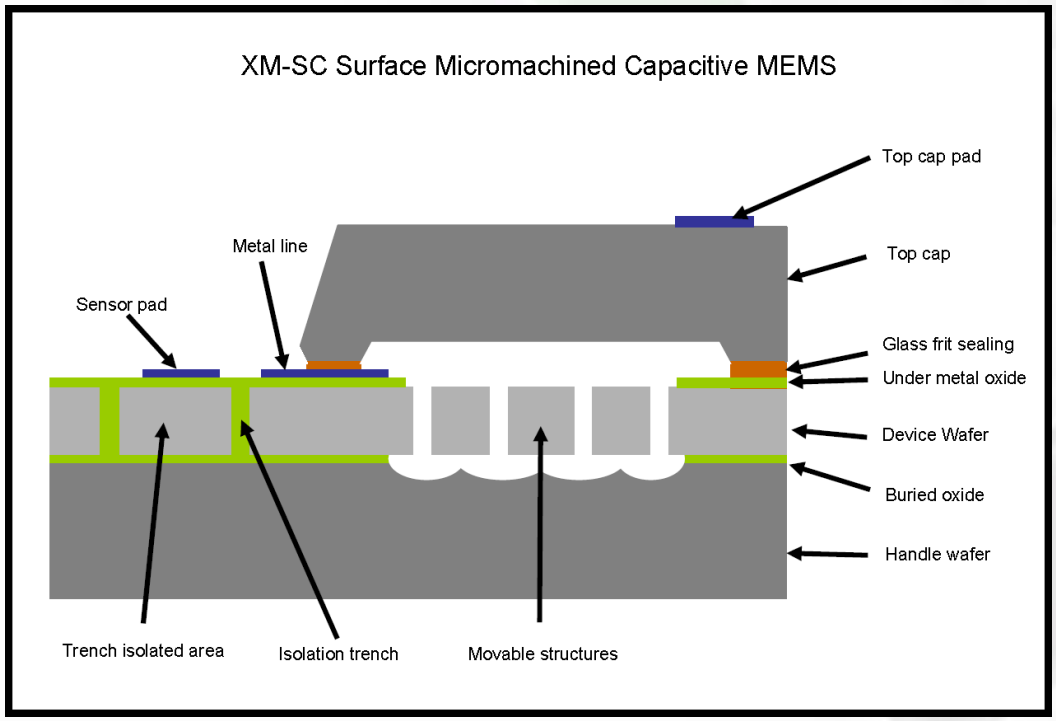
Fabrication commenced in "***Accelerometer component to TRL5"***

MEMS Fabrication Technology

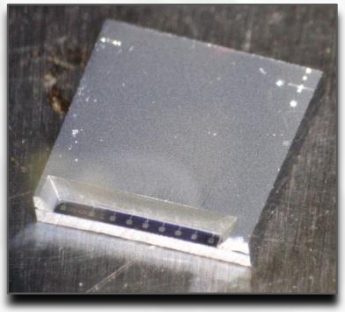
MEMS Fabrication Technology:

- Surface Micromachining of SOI wafers with 2µm minimum feature size and 15µm mass thickness

X-Fab's XMS10 Technology for Capacitive MEMS inertial Sensors

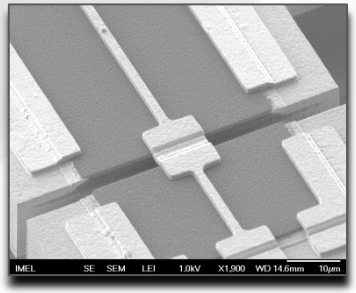


Wafer Level Encapsulation:



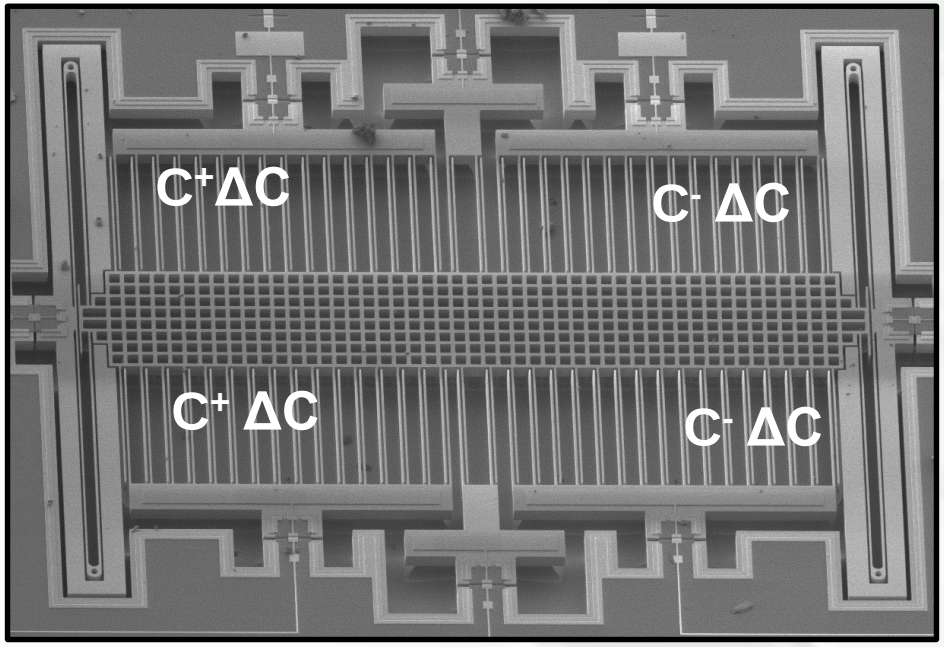
Built in pressure:
1Bar down to 0.1 Bar
Suppression of the thermo-mechanical (Brownian) noise

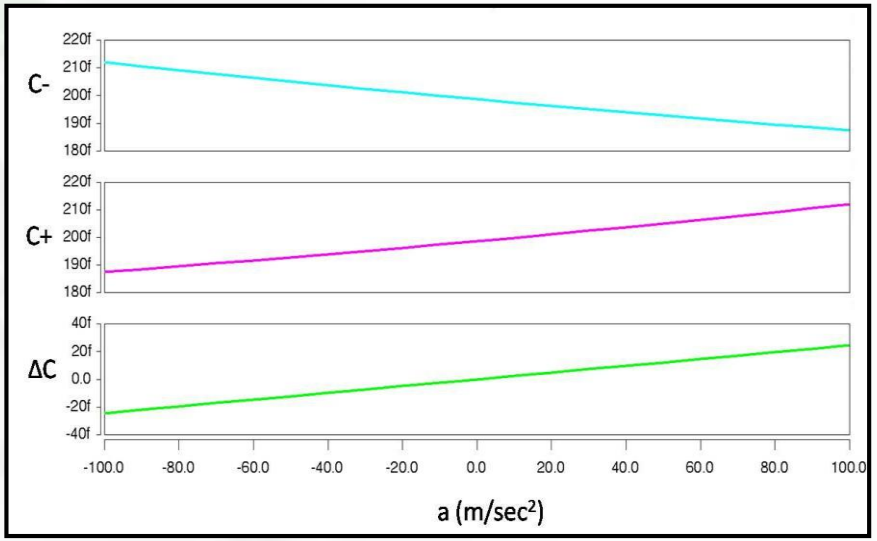
Isolation trenches:



Electrical isolation of designated parts of the device.
Allows the presence of multiple capacitors on chip.

MEMS Detector architecture

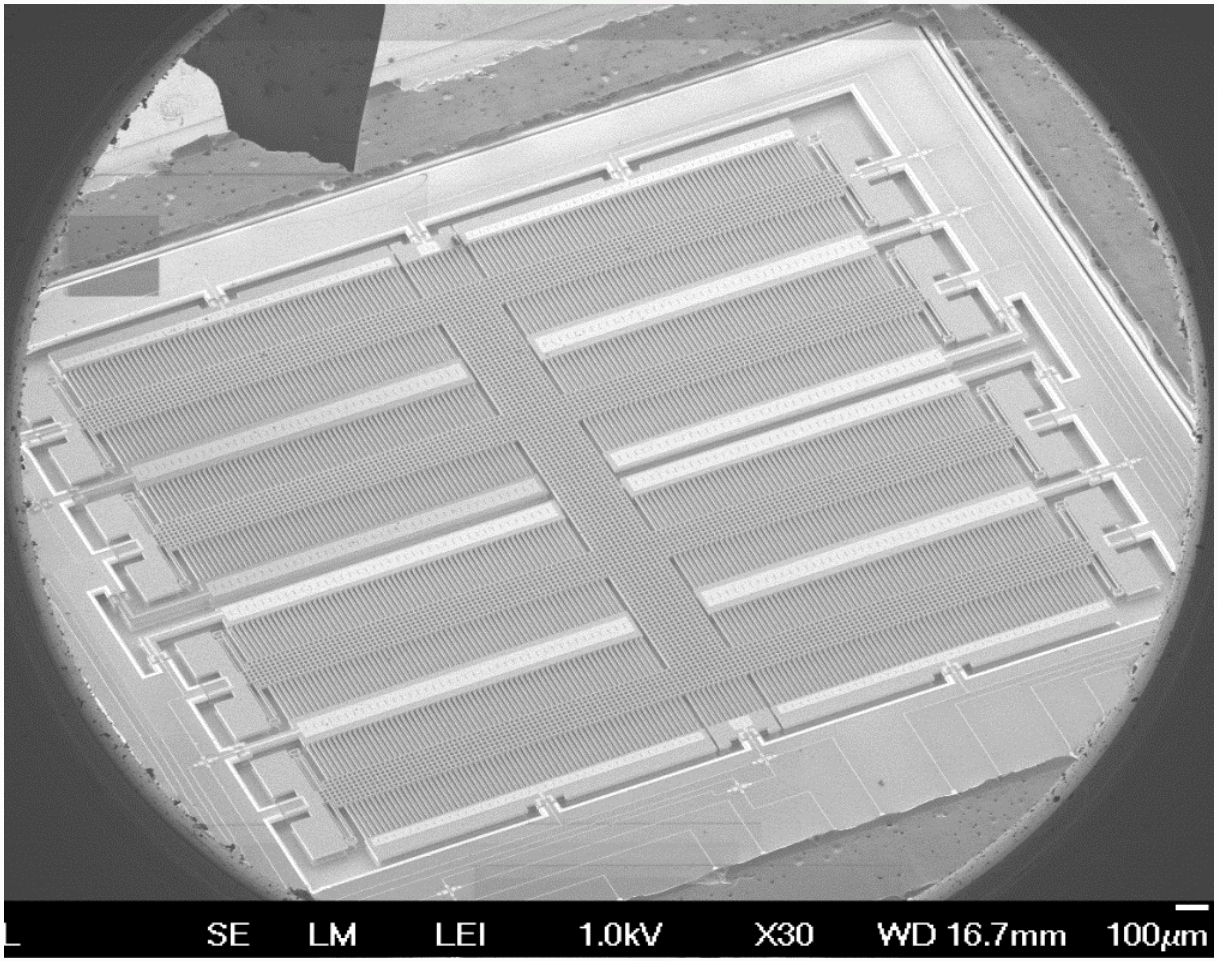




- Highly linear output due to minimization of 2nd order non-linearity terms
- The four sensing capacitors are closely matched and therefore common mode effects are suppressed
- Fully differential design as required by the ASIC

MEMS detector models

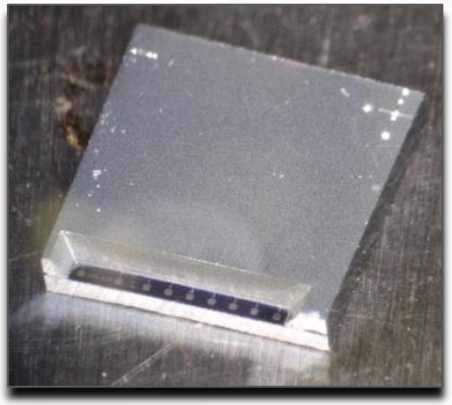
- Multiple MEMS detector models developed
- ±1g and ±20g to be used simultaneously in component



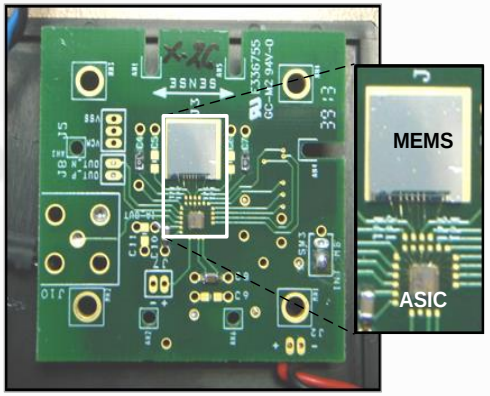
View of ±20g model

MEMS Detector Performance

Characteristic	ESXLM2-2c	ESXLM2-20c	Units
Measurement Range	±1	±20	g
Rest capacitance at each comb drive	23	10	pF
Scale Factor	180	22	fF/g
Noise	5	9	$\mu g/Hz^{0.5}$
Resonance	1.8	5.5	kHz
Non-Linearity (Non-Calibrated)	0.1	0.1	%FSO
Temperature Range	-40 - 125	-40 - 125	^{o}C



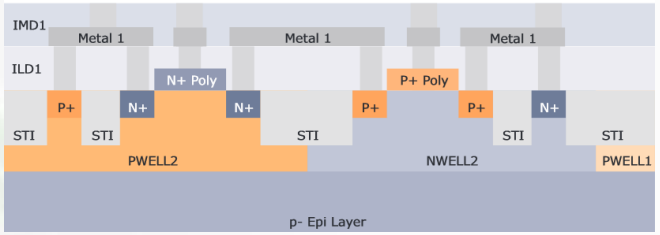
MEMS detector die



PCB with MEMS detector and ESS113 ASIC

ESS213 - Fabrication Technology

Fabrication Technology: XFAB XH018 (*0.18µm CMOS*)



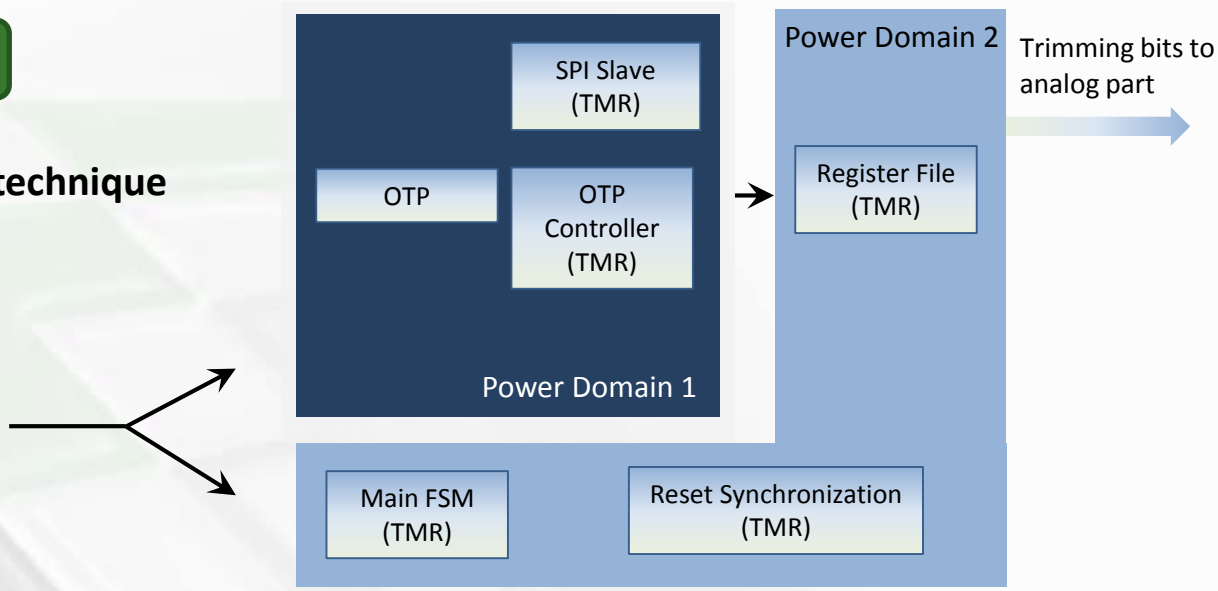
- ITAR free
- High performance characteristics
  Selected after performance evaluation of different technologies
- High Voltage devices
- Non-volatile memory options (OTP)
  Enables the use of One Time Programmable memory for storing the trimming configuration and coefficients
- Radiation hardening of circuits by design and layout techniques
  Rad hard technologies not commercially available or ITAR restricted

- ❑ Previous ESS chips have shown immunity up to 100Krad of TID
- ❑ The goal is to design a chip with tolerance to Single Event Effects

Radiation Hardening techniques

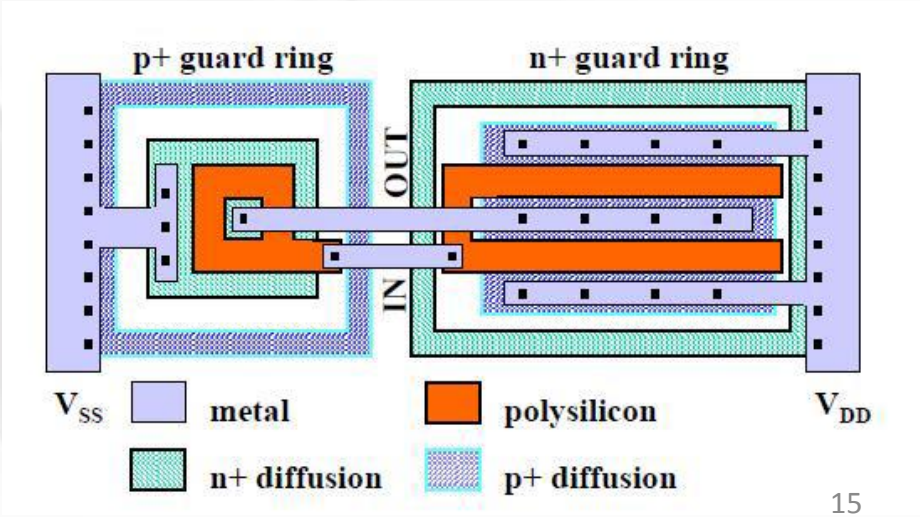
Digital Part (*design techniques*)

- **Triple Module Redundancy (TMR) technique**
- **Power Domain Separation**

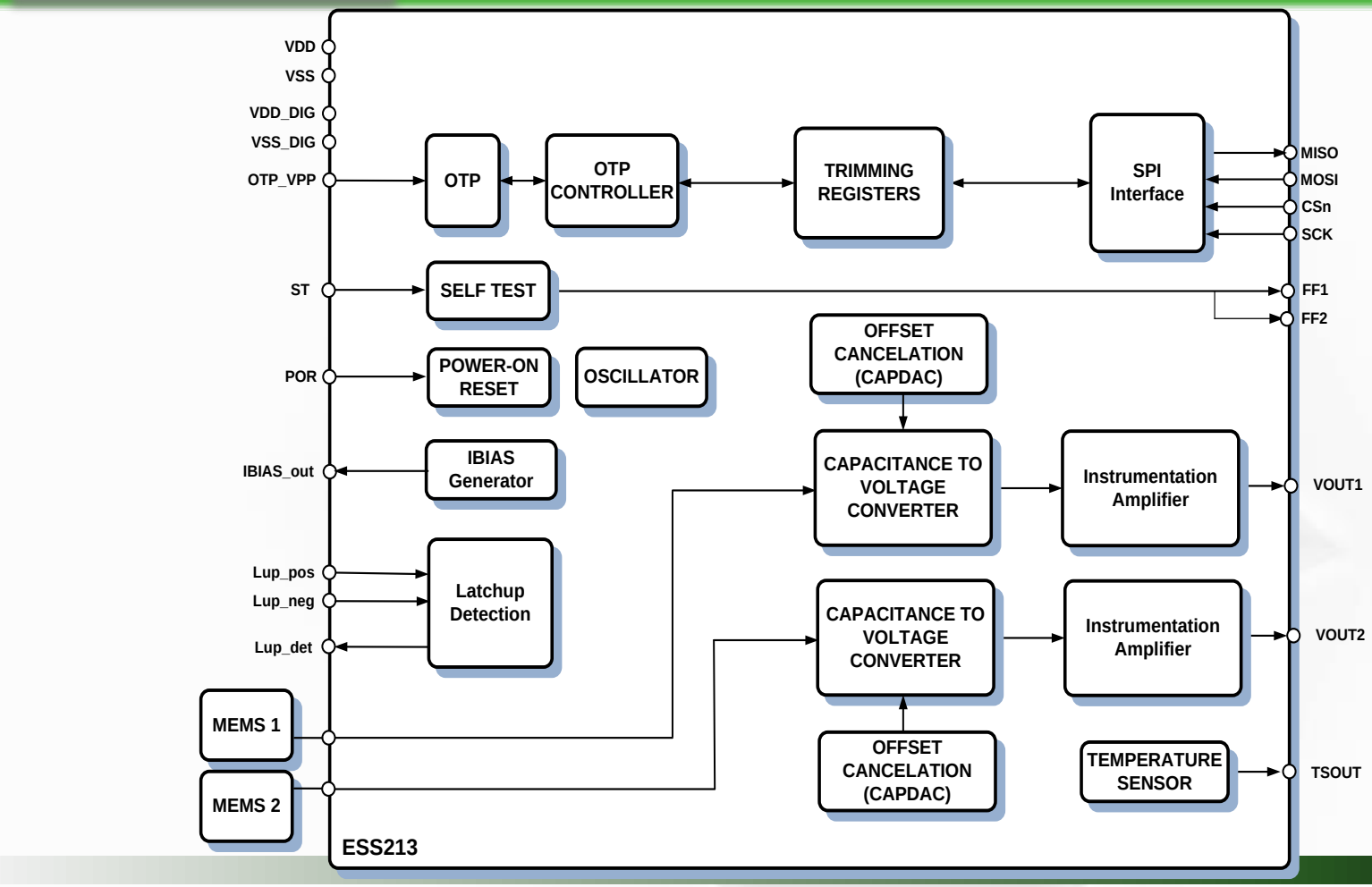


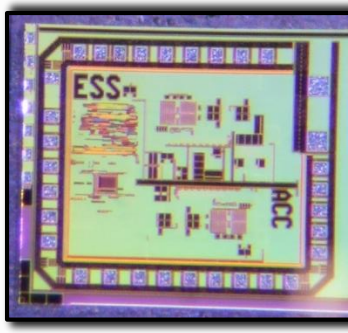
Analog Part (Layout techniques)

- **Implementation of NMOS devices in enclosed geometry**
- **P+ guard ring around NMOS devices**
- **N+ guard ring around PMOS devices**



ESS213 Architecture

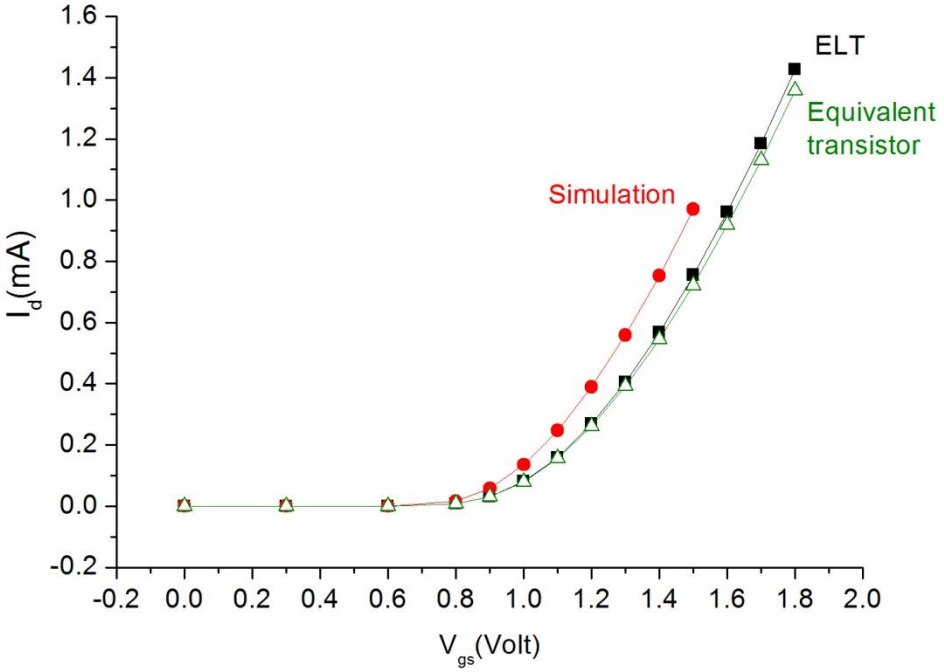




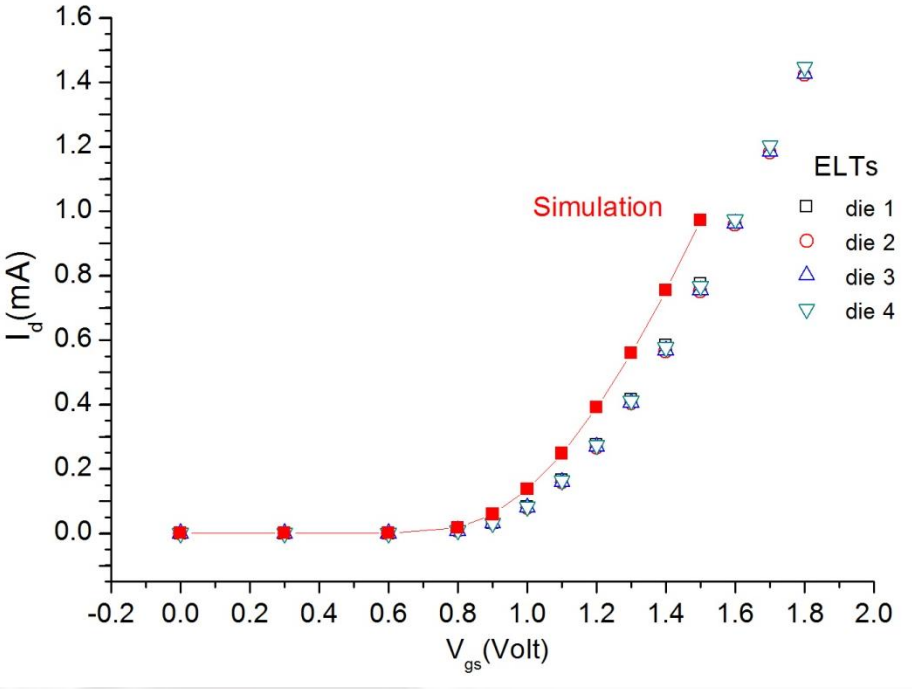
- 2 Capacitance-to-Voltage Conversion Channels
- Two Capacitance and One Temperature Single-Ended Analogue Outputs
- SPI Interface for Trimming Configuration Programming
- Radiation Hardened Design with Latchup Detection Circuit
- Internal Oscillator and Power-On Reset Circuit
- OTP Memory for Trimming Configuration Storage
- 3.3V Power Supply
- 1.3 mm × 1.5 mm × 0.3 mm
- Temperature Sensor
- Offset Cancelation Circuit
- Low noise output
- Fully Differential Architecture

Measurements: ELTs

ELT vs Equivalent transistors



ELT Reproducibility



- Specifically developed model for the simulation of enclosed transistors
- Measurement of enclosed transistor I-V and comparison with regular transistor. Highly satisfying correlation (worst case 15% difference between ELT – regular)
- Minimal effects due to process variations

Packaging

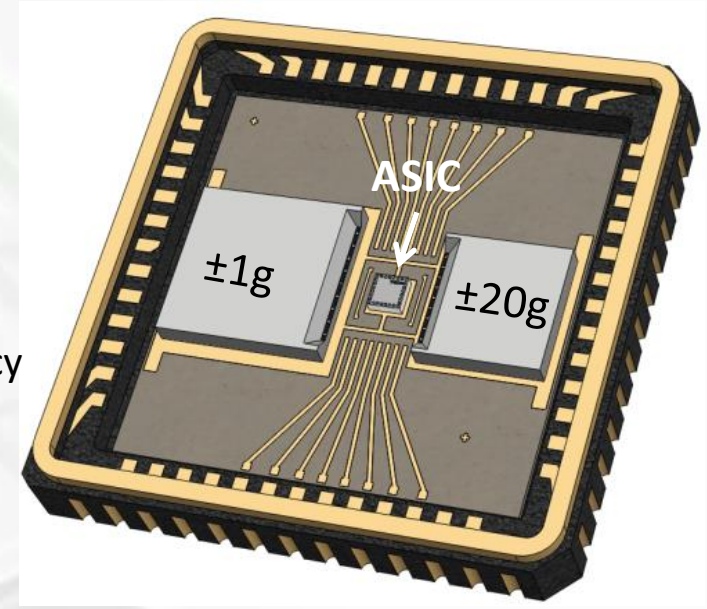
Component made of 2 MEMS detectors + 1 ASIC

- **52pin CLCC with Alumina or AlN ceramic tile**

- **Wire and die bond**
  - Wires separated to the maximum spacing possible
  - In-line die attach approach for maximum die placement accuracy
  - Adhesive: Applebond 84-1, ESA approved

- **Environmental conditions**
  - Parallel seam seal method with the aid of a Kovar ring to achieve hermeticity
  - Controlled moisture content of less than 5000ppm

- **Controls**
  - Wire pull, ball shear, die shear & x-ray.
  - Placement accuracy
  - Fine/gross leak test and RGA



20mm × 20mm × 3mm
Power <25mW

Further Development

Qualification procedure – Component level measurements

Large number of parameters to be measured

Performance tests (*sensitivity, linearity, noise, long term stability…*)

Thermal behavior (*thermal dependence, thermal shock, thermal cycling …*)

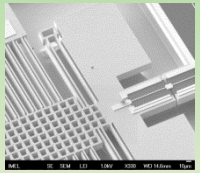
Destructive and EOL test (*ESD, mechanical shock…*)

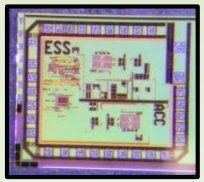
Radiation testing (*TID, Heavy Ions, SEE…*)

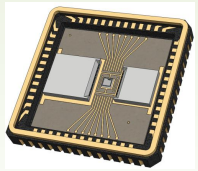
Outcome :

- Detailed device characterization
- Study the effectiveness of the implemented radiation hardening methods
- Locate component's weak points
- Status towards TRL5 and feedback for further development

Conclusions - Summary







- Presented the update of the effort towards a TRL5 1-axis accelerometer component
- MEMS detectors of ±1g and ±20g range with enhanced performance have been developed and characterized
- Rad-hard ASIC has been designed and fabricated. Initial measurements of ELT transistors revealed good correlation with simulation
- Package development already initiated
- Component qualification procedure about to commence

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