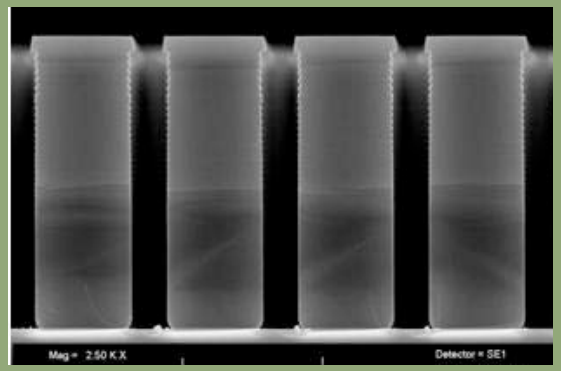
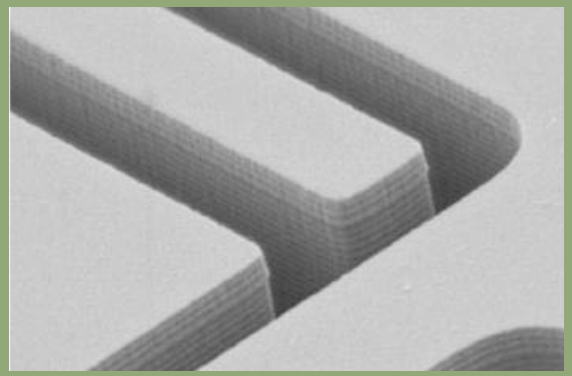
Low g Inertial Sensor based on High Aspect Ratio MEMS





Matthieu Rezé
Sensor & Analog Products Division
Freescale Semiconductor

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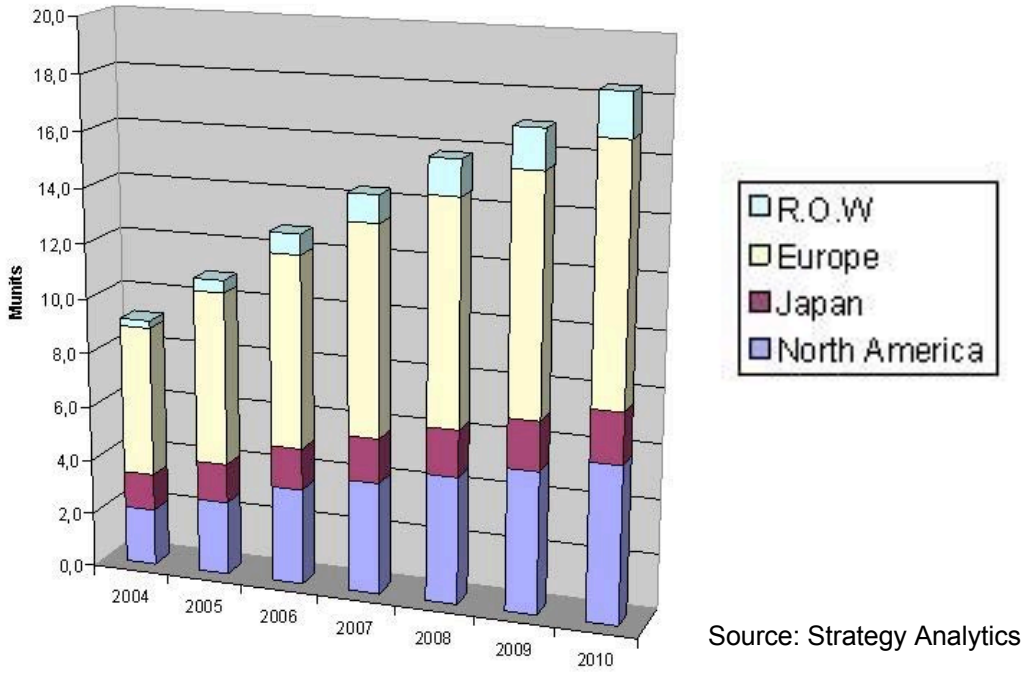
Outline

- Vehicle Stability Control (VSC) market overview
- VSC Component requirements
- Technology presentation
  - Sensing element: High Aspect Ratio MEMS (HARMEMS)
  - Mixed signal ASIC
  - Small plastic QFN Package
- Conclusion

VSC market demand is increasing

- **Vehicle Stability Control (VSC) systems like ESP are recognized to be a huge safety benefit for the driver**
- **Most car manufacturers in Europe & Japan and now in the US are fitting this equipment as standard in new vehicles**



Source: Strategy Analytics

VSC demand in 2008
More than 15 Mu (WW)
More than 50% in Europe

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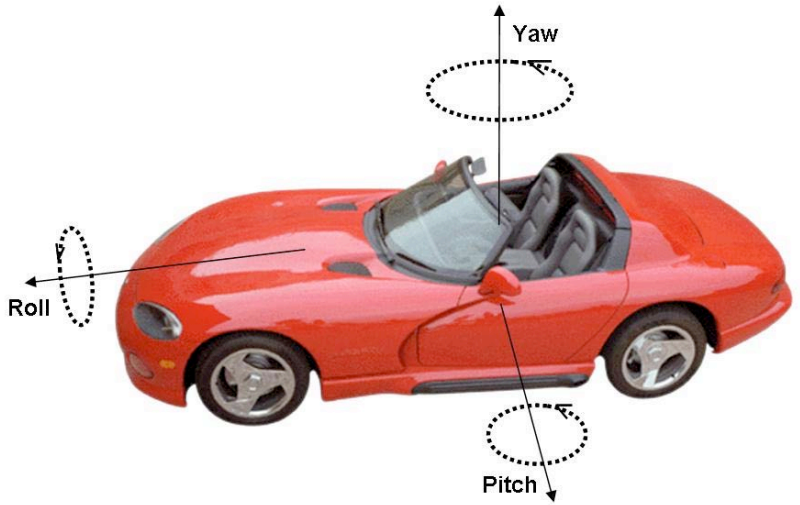
ESP components

Electronic Stability Program (ESP) is an additional improvement to the ABS system:

<u>It features</u>:

- Hydraulic Control unit
- Steering wheel angle sensor
- Wheel speed sensors
- Yaw rate sensor
- **Lateral acceleration sensor**
  - X axis low g or
  - XY axis low g
  - Need to have high sensitivity & accuracy

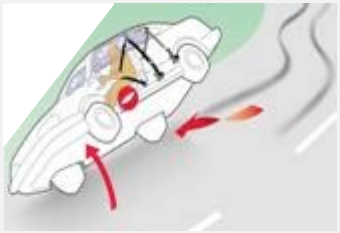


Freescale Inertial Sensor Applications

Low g

1 to 20g

ABS - ESP



Roll over

Electrical Parking Brake

Suspension Control

Medium g

40 to 100g

Crash detection

High g

100 to 250g

Side Crash detection

freescale semiconductor

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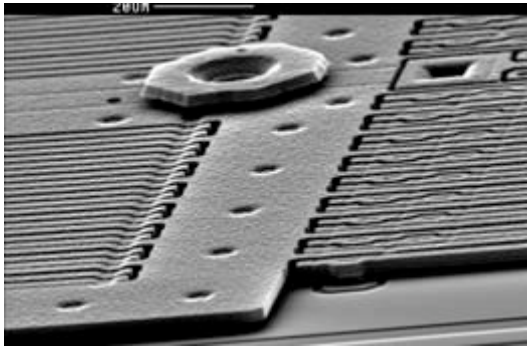
Next Generation of MEMS Accelerometers: HARMEMS

Today's finger cross section: no squeeze film damping

Today's Technology poly-Si MEMS

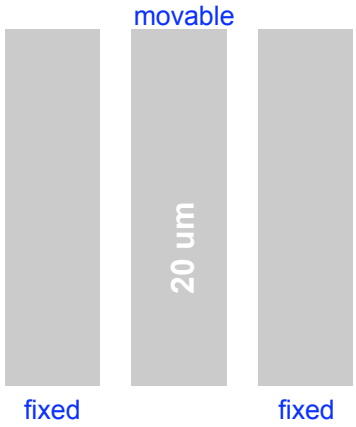
- Underdamped mechanical response
- Glass frit wafer bond sealing limits die shrink
- Low resistance to vertical stiction vs. sensitivity



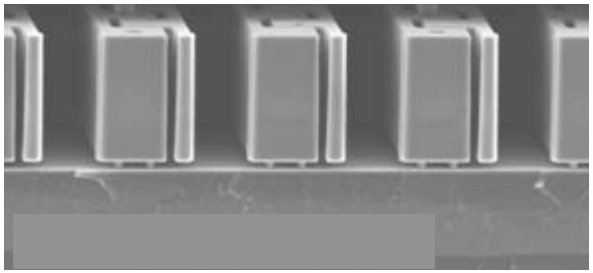
Poly-Si lateral transducer
(3 um poly-Si mechanical layer)

Next Generation Technology HARMEMS

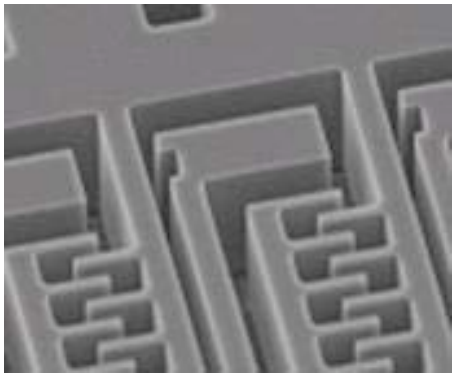
- Overdamped mechanical response (customer requirement)
- Improved resistance to vertical stiction vs sensitivity
- Better signal to noise for same gain and die size



HARMEMS finger cross section: squeeze film damping



HARMEMS cross section
(20 um single crystal-Si mechanical layer)



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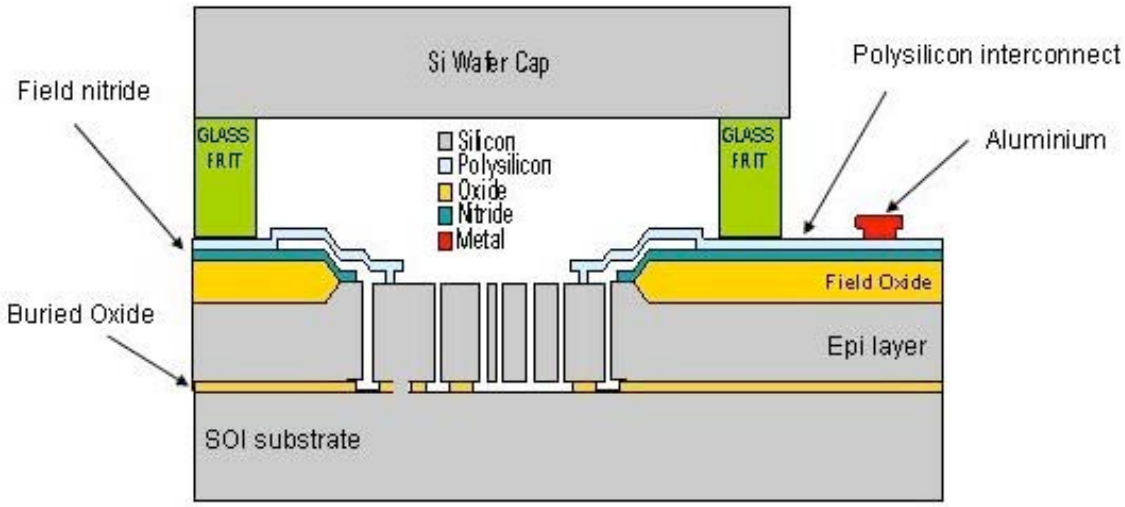
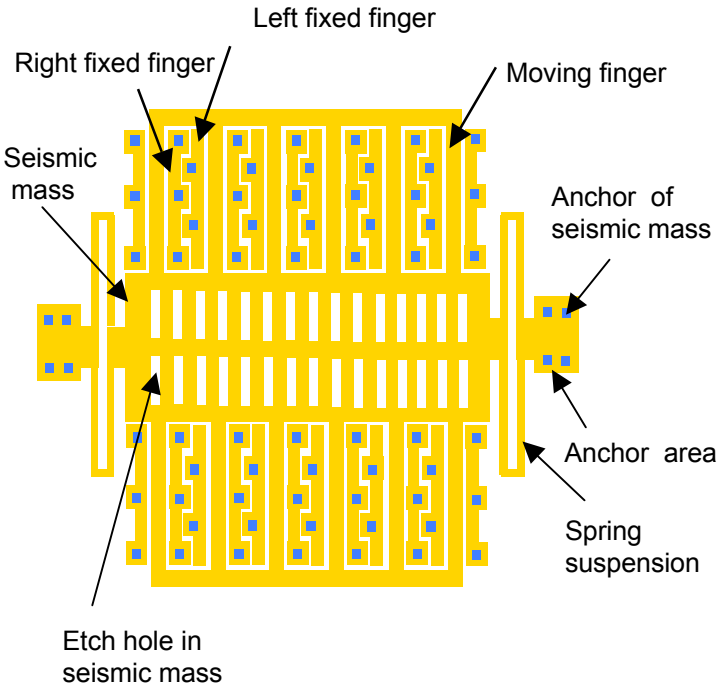
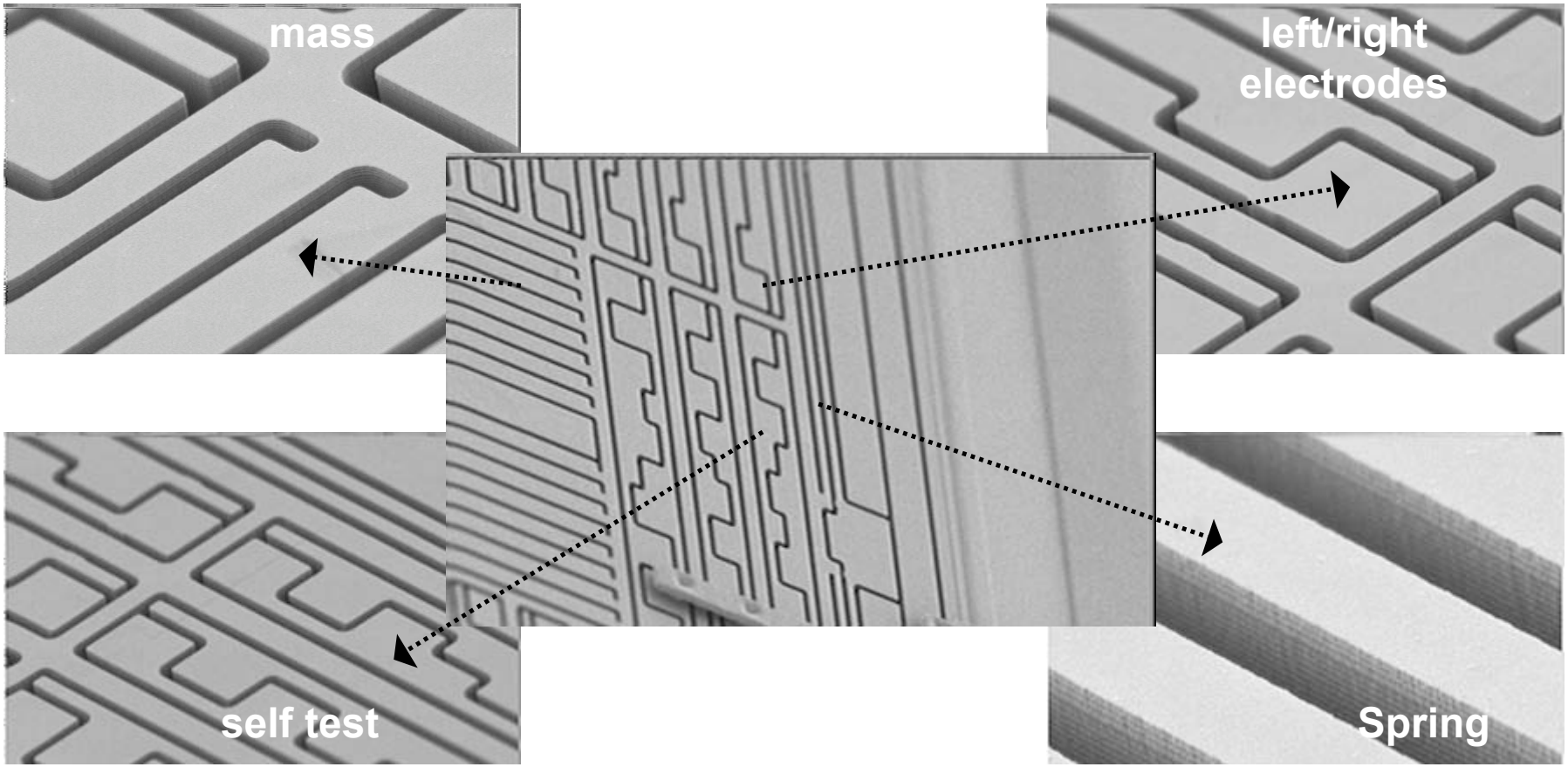
High Aspect Ratio Accelerometer with glass-frit bonded cap wafer





Top view

Freescale HARMEMS pictures



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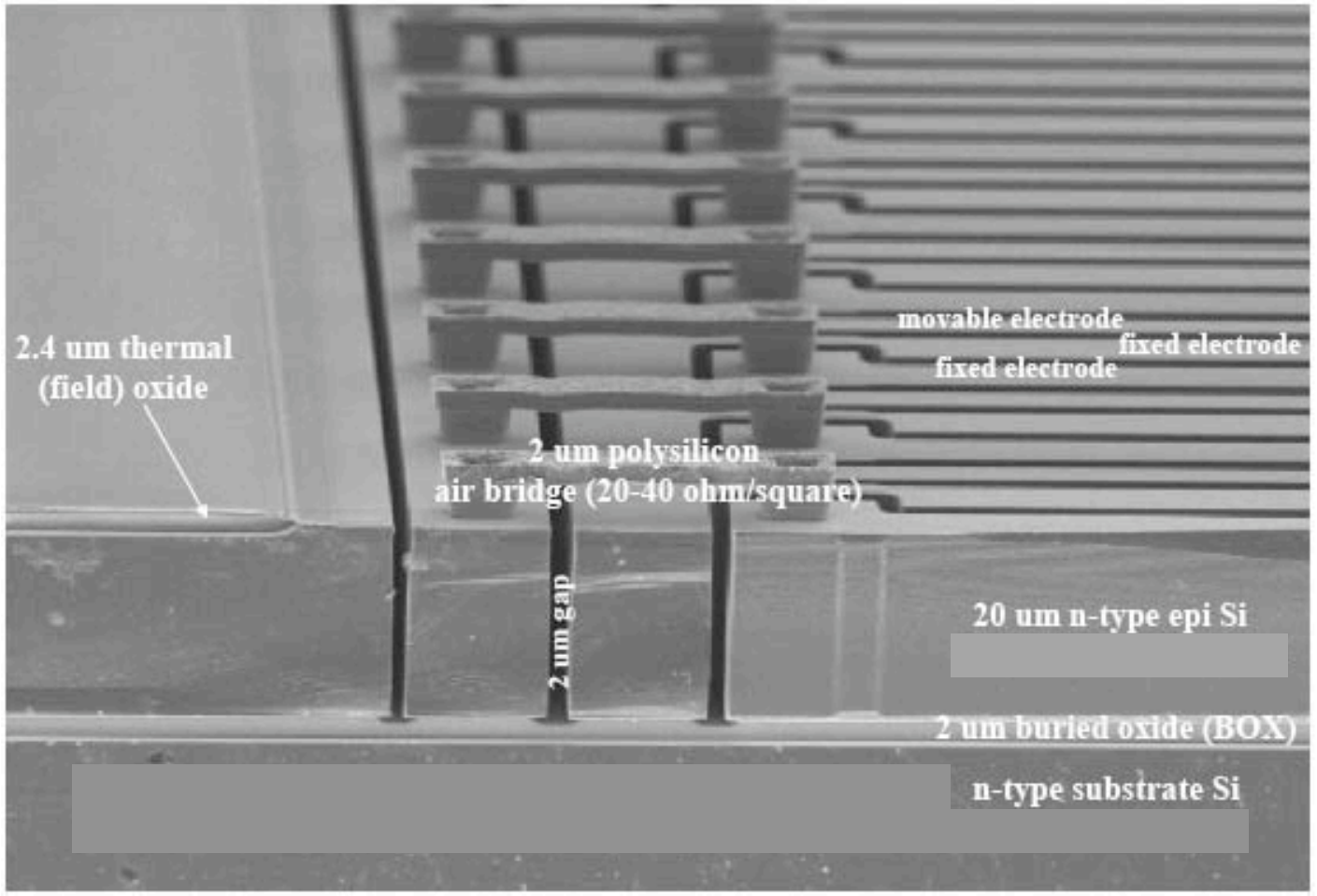
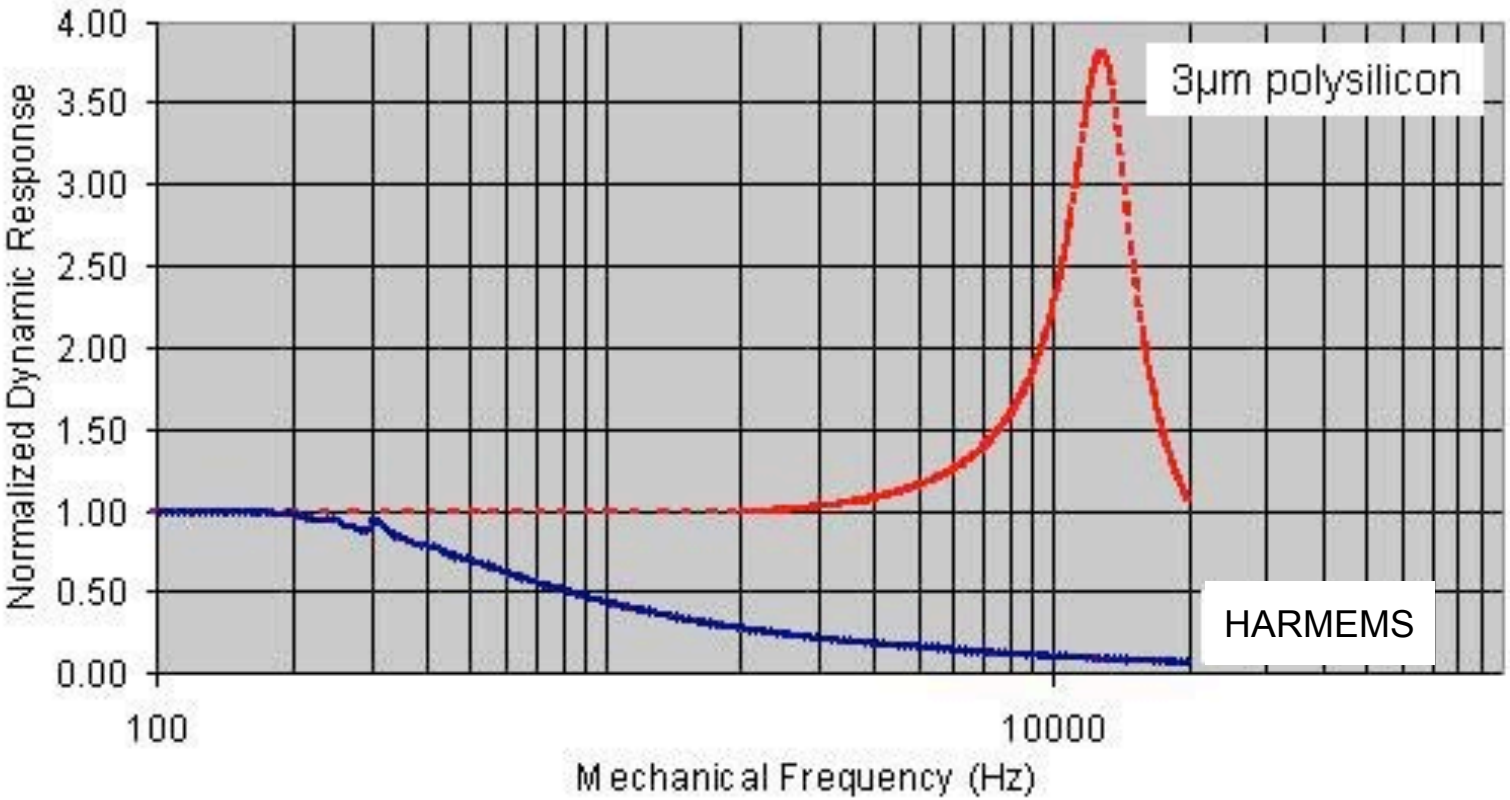
Freescale HARMEMS cross section



Mechanical frequency response



HARMEMS design offers an overdamped mechanical response. The device is immune to any high frequency shocks.

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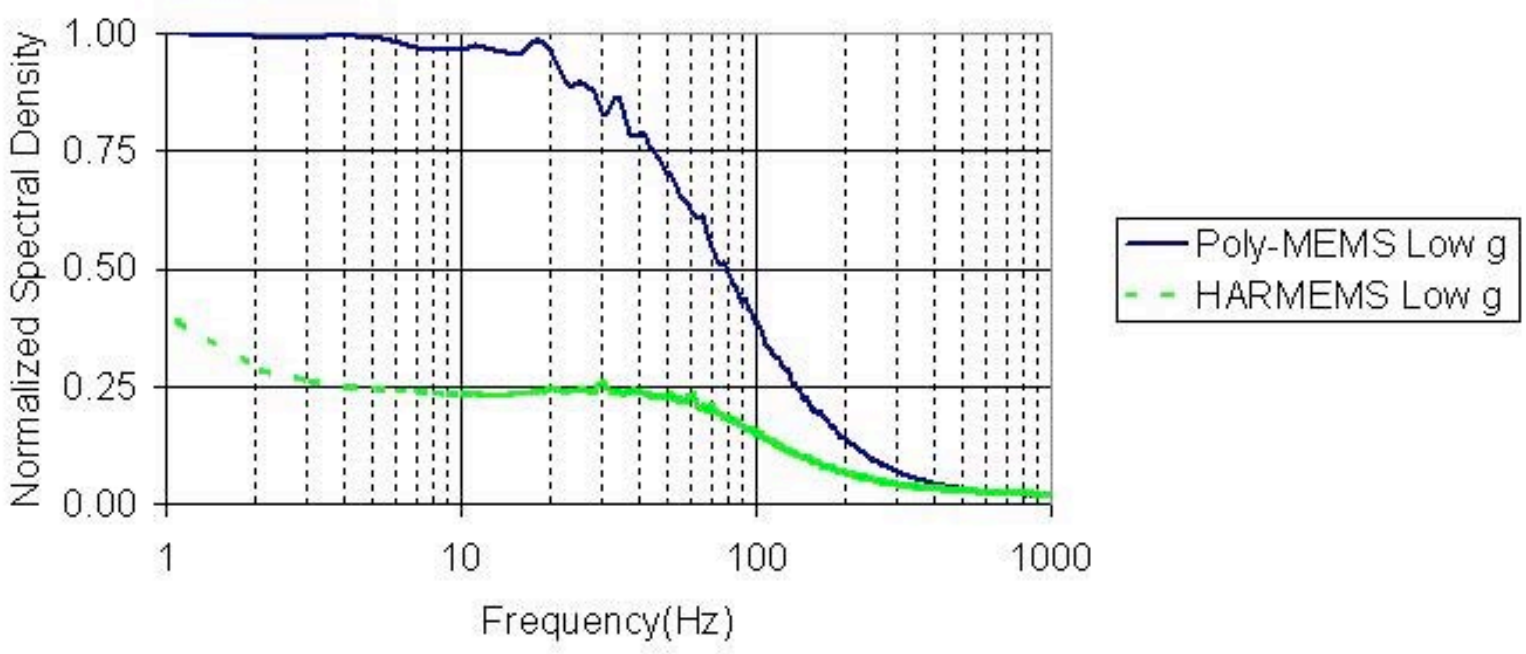
HARMEMS Spectral density



Thanks to a thicker capacitor layer, a 20 µm HARMEMS base capacitance increases by more than 10 times compared to a 3 µm polysilicon MEMS transducer

Using the same circuit, a HARMEMS accelerometer demonstrates better than 50% decrease in power spectral density.

ASIC: SmartMOS™ Product Capabilities

Analog to Digital Converter
8, 10 & 16 bit ✳✤

Oscillator
Crystal, internal - to 8MHz, 2%

9-Bit D-A
Guaranteed monotonic

Op Amps
Rail-to-Rail

Charge Pump
Internal ~ 200 µA, or external

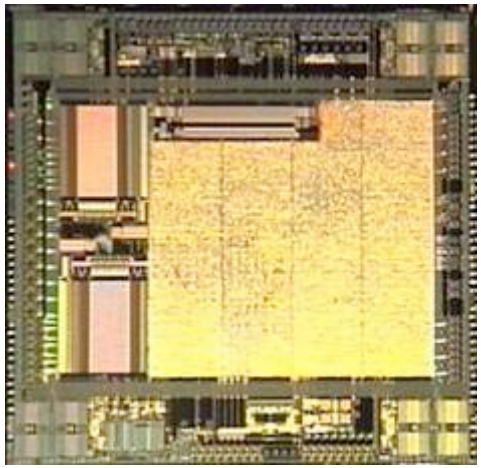
Comparators
5mV, or autozeroed

Switched Cap
Filters, Gain stages

Precision References
Bandgap - 1.2V, ±1% etc.

Voltage Regulators
DC/DC & Linear 5V, 3.3V, 2.6V etc.

High Speed CMOS
5AP: 1K's of gates, < **10MHz** state machines
5HV+: 10K's of gates, < **25MHz** state machines
8MV: 100K's of gates, < **200MHz**, 2,6V



SmartMOS™ World

8/16-bit CPU
HC08/HC12, 50MHz

Non-Volatile Memory
trim, ID, serial numbers

Analog MOS
20V or 60V or 105V

Power MOSFETs
5AP: to 65V, 5A, 50mΩ
5HV+:105V, 5A, 50mΩ

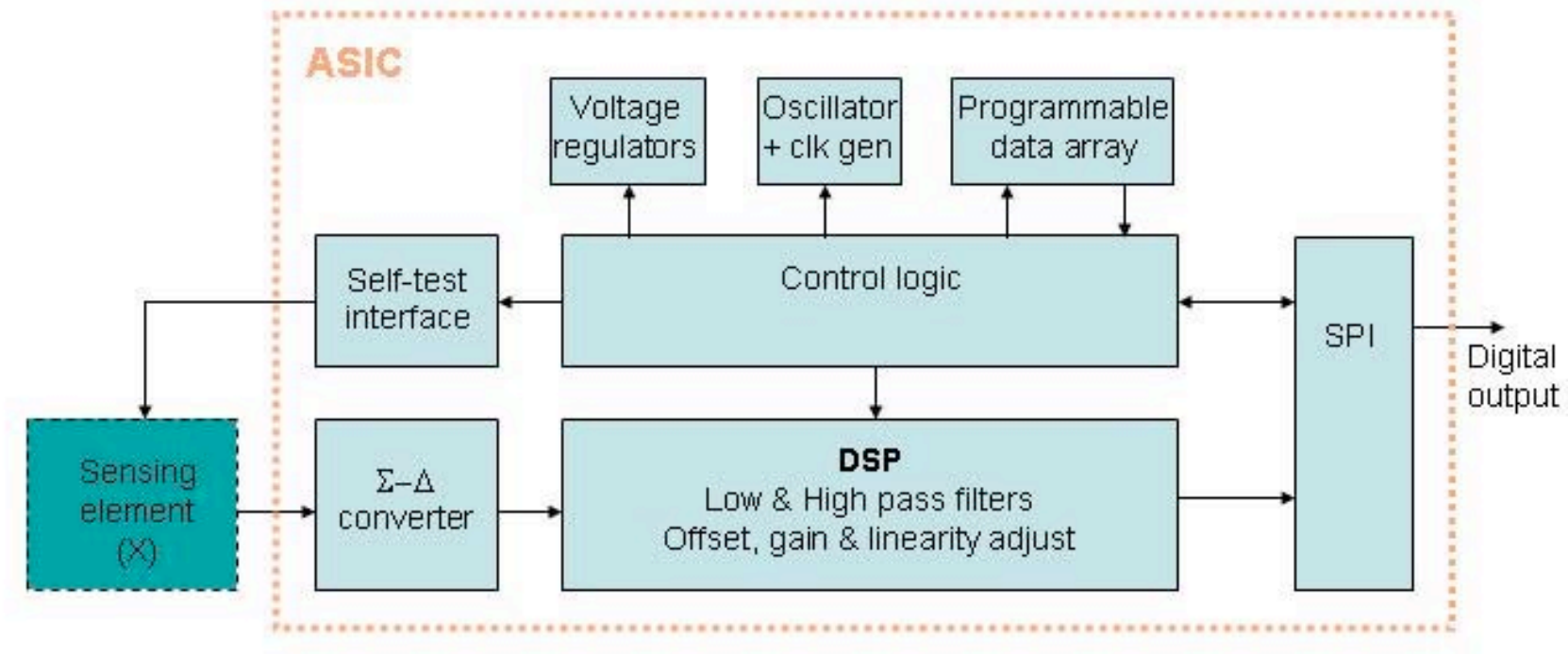
Inductive Energy Clamps
1J, 50 µs to 4ms

Independent Thermal Management
Shutdown at 165 ±15 °C

Load Sensing
Shorted Load
Open Load

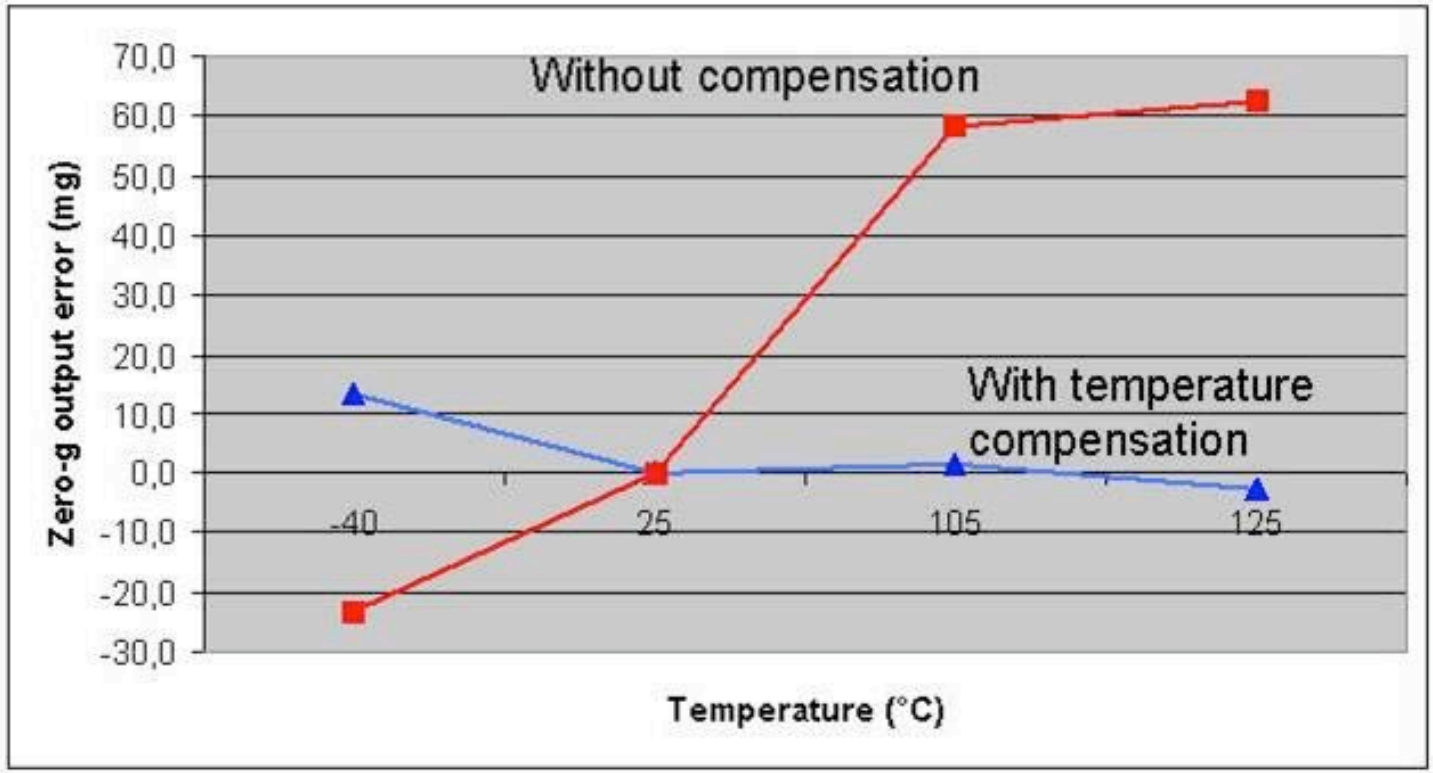
RF
900MHz Tx

ASIC architecture



Flexible design allows to implement more channels like XY or XYZ
Analog output can be provided by adding a DAC at the DSP output

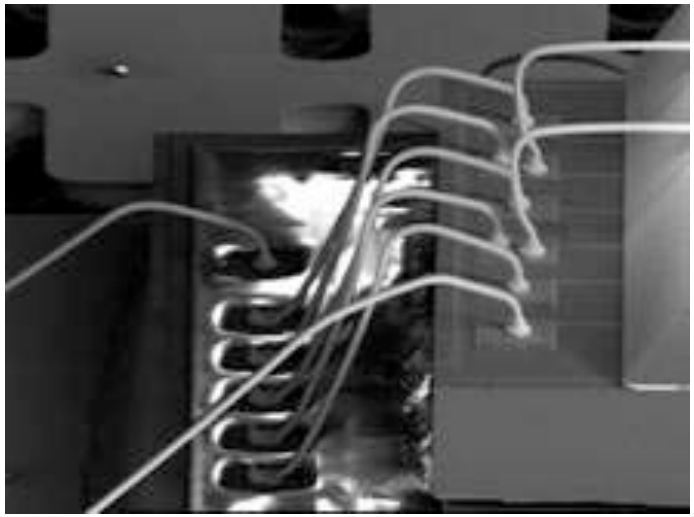
Zero-g output error of a QFN low-g device vs temperature (-40°C to 125°C)

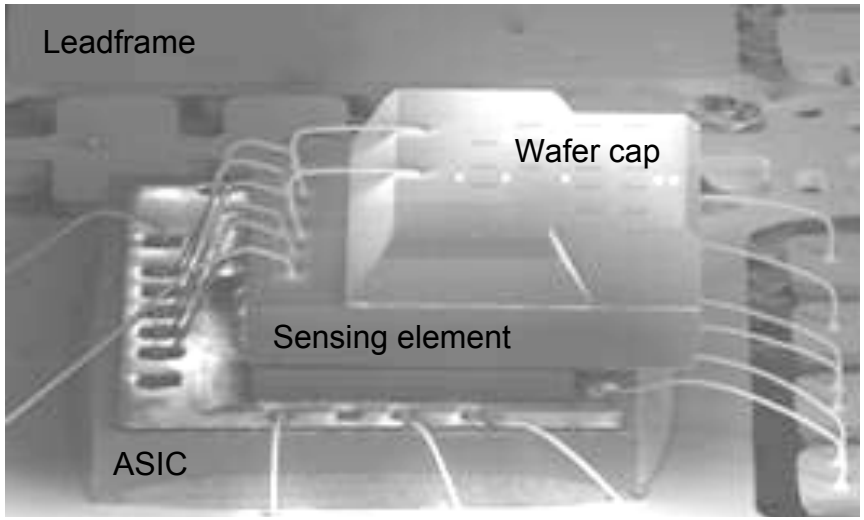


By adding on-chip temperature compensation, this variation can be reduced to 19 mV. Dividing by the device sensitivity of 1.2 V/g, this equates to 16 mg's.

Inertial QFN package

QFN 6x6 mm (thickness ≤ 1.98 mm)
Environmental friendly (Green) package
Low stress package design
PCB reliability –40 C to 125 C: **pass 2000 cycles**
MSL3 min at 260°C (MSL1 and 2 under evaluation).





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Conclusion

- A new low g accelerometer based on a High Aspect Ratio sensing element has been presented
- High signal to noise ratio and overdamped frequency response makes this device perfectly suited for Vehicle Dynamic Control application
- An ASIC contains a full digital signal conditioning path allowing the implementation of programmable parameters
- This multichip approach combined with high flexibility is ideal for the development of a full family of single, dual and tri axis low g axis sensors

Thank you !

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