

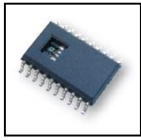
Test Strategies for MEMS Products for the Automotive Industry



Innovation Matters



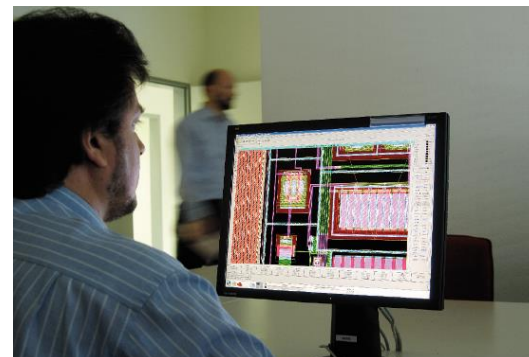
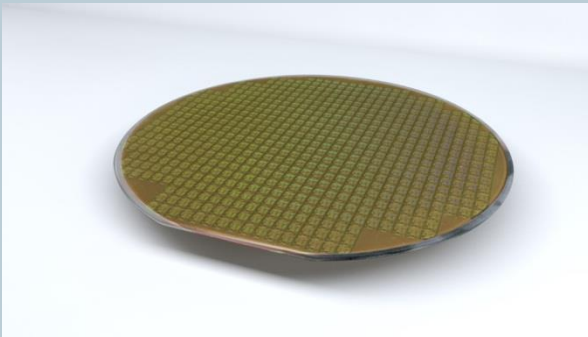
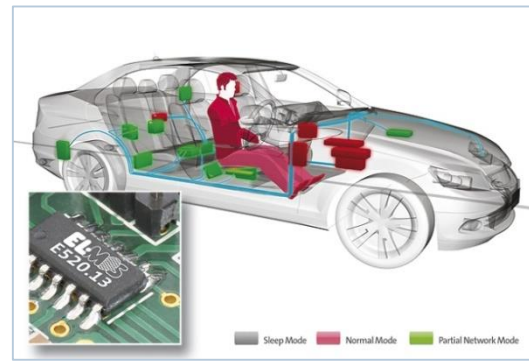
Salland – The futures of MEMS testing
Thomas Lehner / 06.06.2019



Company Overview



- Focus on **automotive** (>90%)
- Automotive **quality** (< 0.5ppm)
- Design resources with **30+ years of experience**
- Focused on Sensor ICs
- Supplies to automotive **safety applications** (ISO26262)
- Redundant supply by **own fabs** and #1 partners (**TSMC, Magna Chip**)
- Guaranteed **long term supply**
- **Stable** Shareholder Structure



Founded 1984

Automotive Focus

330 Mio USD revenues

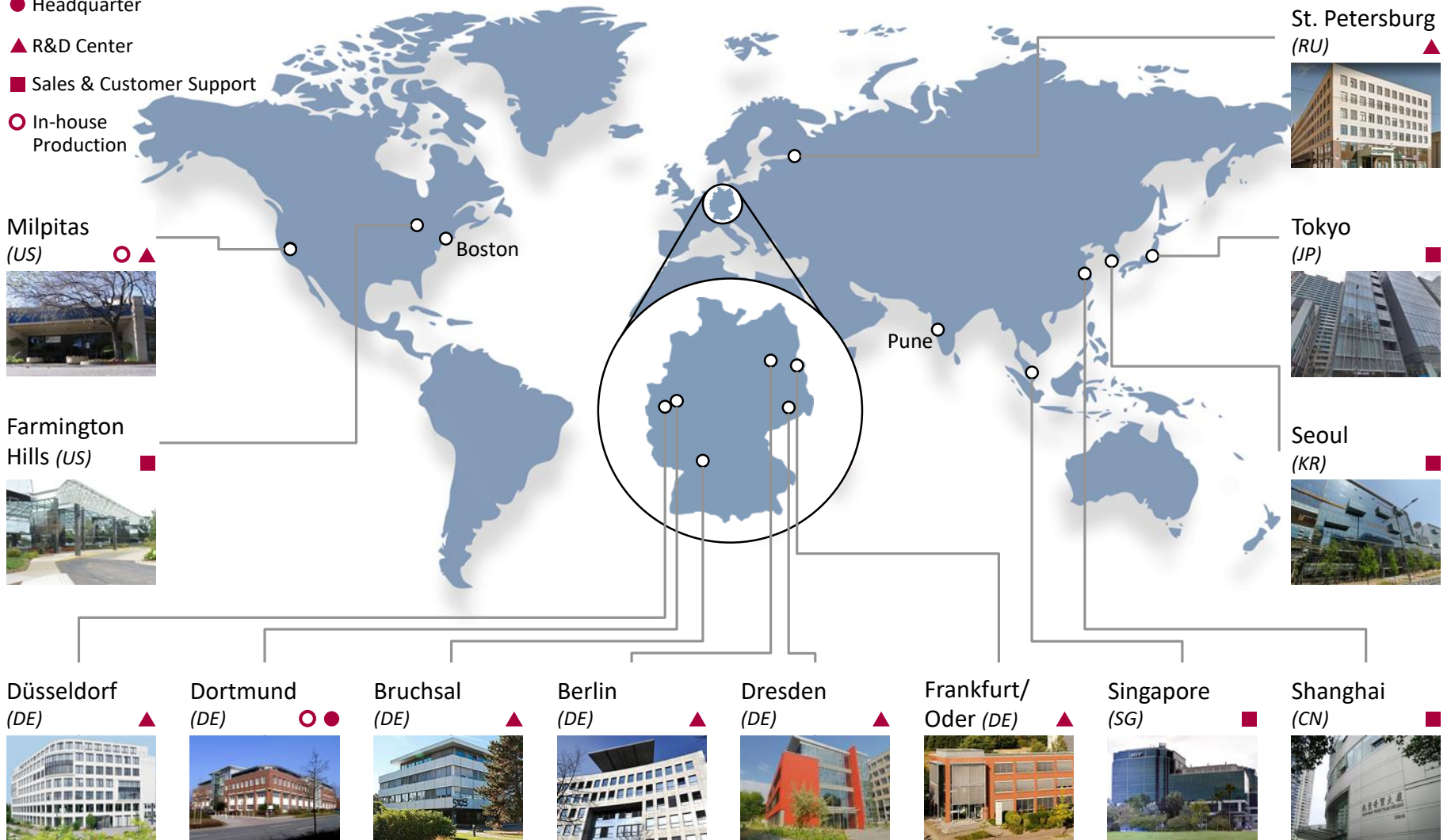
~1300 employees

400+ Mio ICs per year

Elmos global sites



- Headquarter
- ▲ R&D Center
- Sales & Customer Support
- In-house Production



Our product segment setup: focused on applications and expertise



Business Line 1 - Sensors

Ranging



Sensor ICs



Optical

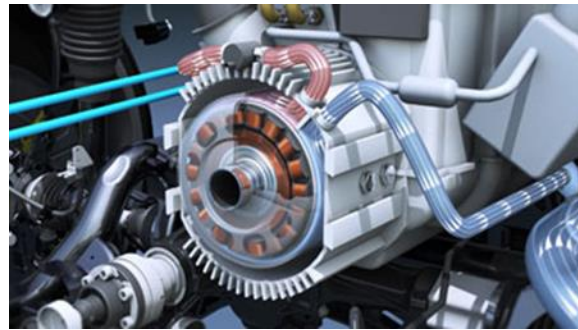


Business Line 2 – Smart Control

Lighting



Motor Control



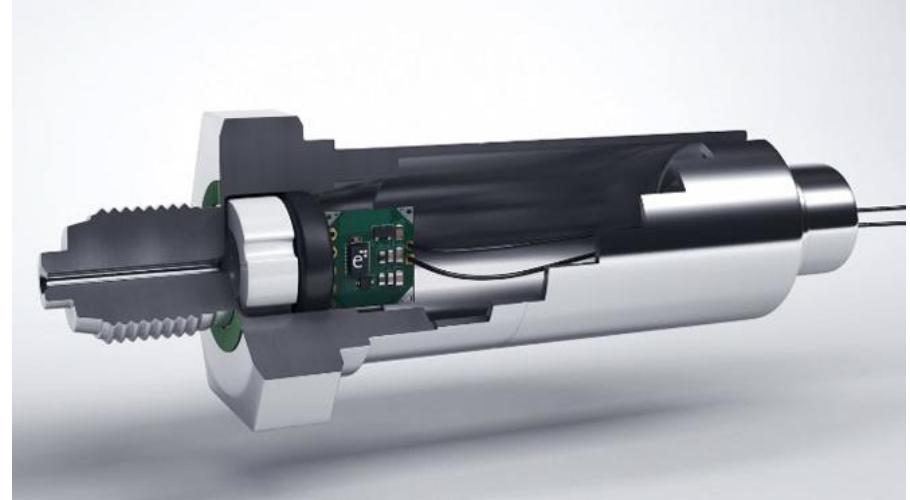
Business Line 3 - Smart Solutions

Safety, Power & Custom ICs

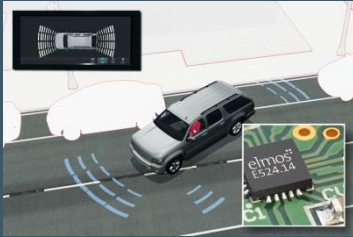


Bridging the physical world precisely to standard analog & digital interfaces

- >15 years experience in automotive and industrial **pressure sensing**
- Portfolio of **Sensor Signal Processors**
 - Supporting all standard sensor interfaces
 - Ready for safety applications
 - Lowest BOM cost at best performance
 - Unique features like integrated shunt resistors, power line communication and bridge current measurement
- Various IC solutions for sensing temperature, inductance, capacitance and magnetic field



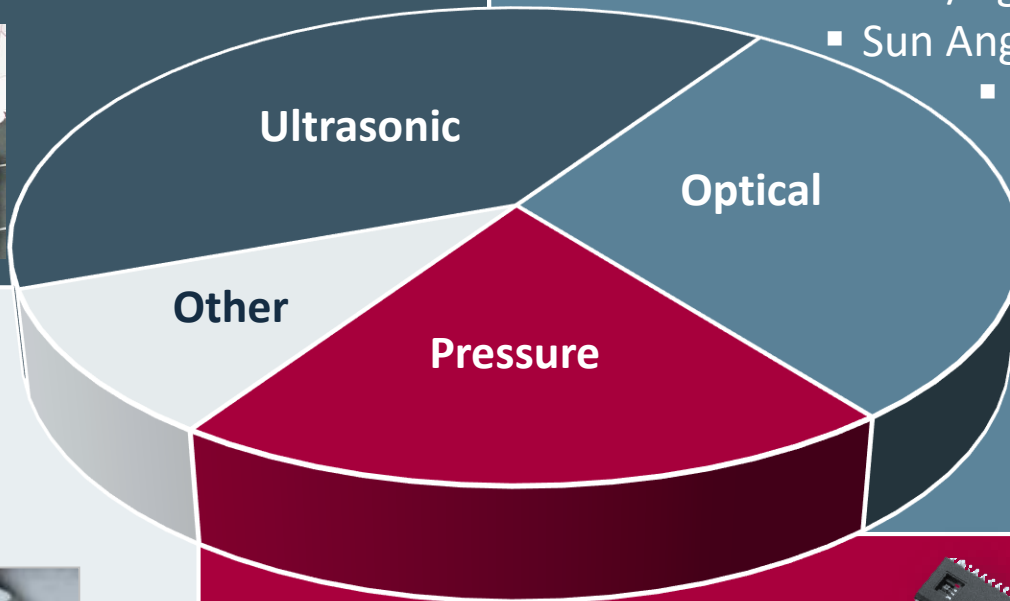
- Park Distance Control ASIC's
- Digital USPA
- Smart USPA
- Industrial US IC's



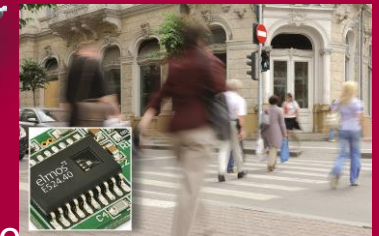
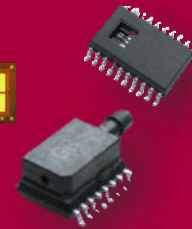
- Proximity Sensors
- Gesture Recognition
- IR Distance
- Rain/Light Sensors
- Sun Angle Sensors
 - Smoke/Dust Sensors
 - Passive IR Sensors
 - IR Temp Sensors



- Inductive Sensors
- Capacitive Sensors



- Safety Pressure Sensors
- Harsh Environment Sensors
- Low Pressure Sensors
- SSP's for Pressure, Strain, Force, Torque

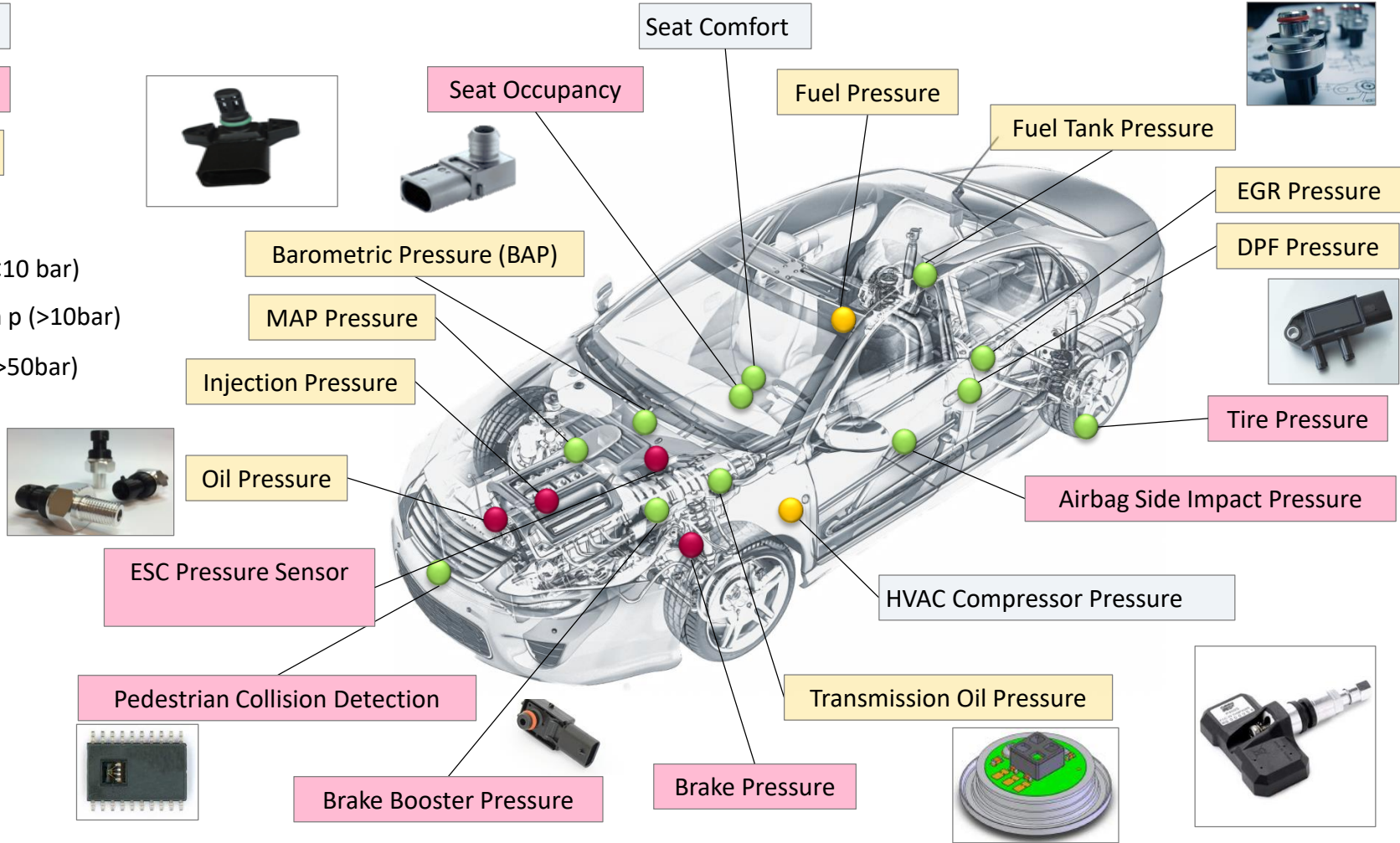


Automotive p-Sensor / SSP Applications



- Comfort
- Safety
- Powertrain

- Low p (<10 bar)
- Medium p (>10bar)
- High p (>50bar)











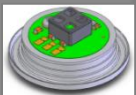



Trend

More and more Pressure Sensor applications guide to over proportional market growth

Modular Pressure Sensor Solutions

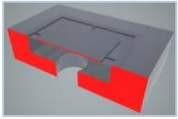


Value Chain	Sensor	SSP (Sensor Signal Processor)	Level I Integration (SIP System in Package) + Calibration	Level II Integration (Module)
Pressure Range				
● Low p (<10 bar)	<p>MEMS</p>  	<p>Bare Die</p> 	<p>Plastic</p>  	<p>Plastic</p> 
● Medium p (>10bar)				
● Ultra High p (>50bar)	 <p>Ceramic / Metal Film</p>	 <p>Package</p>	 <p>Metal / Hybrid / PCB</p>	 <p>Metal</p>



Test approach

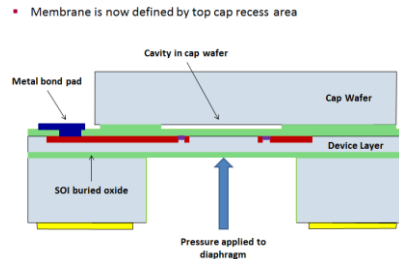
Test and Calibration of smart sensors in the package prior to module assembly



Backside Entry for Harsh Environment

Key Features SM98

- All silicon for improved TC matching
- DRIE on SOI etch stop
- Backside entry
- Temperature diode
- Extended Burst Pressure
- Pressure range: 15 to 750 PSI (1 to 50bar) absolute



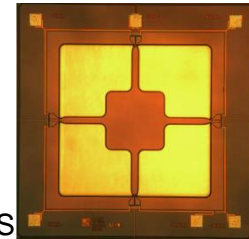
Applications

- Oil-Pressure, Transmission,.....

Ultra Low Pressure

Key Features SM95

- All silicon for improved TC matching
- DRIE on SOI etch stop
- High Sensitivity
- Pressure range: 0.3 PSI to 1.5 PSI (20 to 100 mbar)



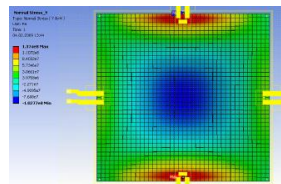
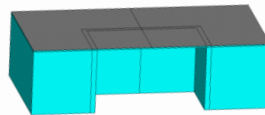
Applications

- HVAC, Respirator, Liquid Level, FTPS

High Accuracy Differential

Key Features SM30

- All silicon for improved TC matching
- DRIE on SOI etch stop
- Optimized Linearity and lowest drift
- Pressure range: 5 PSI to 300 PSI (0,3 to 20 bar)



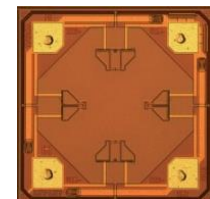
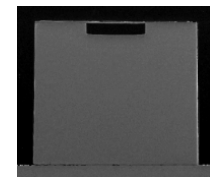
Applications

- Gauge/Differential, DPF, EGR, Vac Brake Booster,...

Ultra Small

Key Features SM68

- All silicon for improved TC matching
- Buried Cavity Technology
- 0.65 x 0.65 x 0.65 mm³ only
- Pressure range: 15 PSI to 150 PSI (1 to 10 bar)



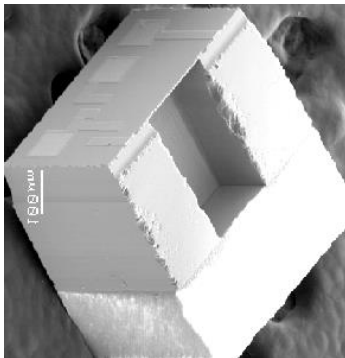
Applications

- TPMS, T-MAP, BAP,.....

Basic Questions concerning MEMS Test

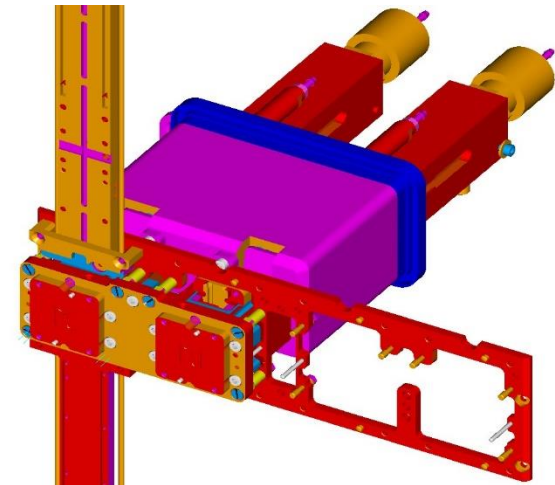
General / Technical

- Type of MEMS
- Type of package / type of carrier
- Kind of physical stimuli
- Requirements concerning precision / tolerance (electrical / physical / environmental)
- Restrictions for handling (e.g. acceleration)
- Integrated system or pure sensor
- Calibration / identification of units?
- Capabilities of ATE (e.g. limitation on site count)
- Overall process flow



Production

- Annual volume
- Required uph
- Requirements concerning automation
- Potential Process integration w/ assembly
- Required environmental conditions
- Test-HW concept for stability and maintainability
- COT!!!



- **Non standard packages**

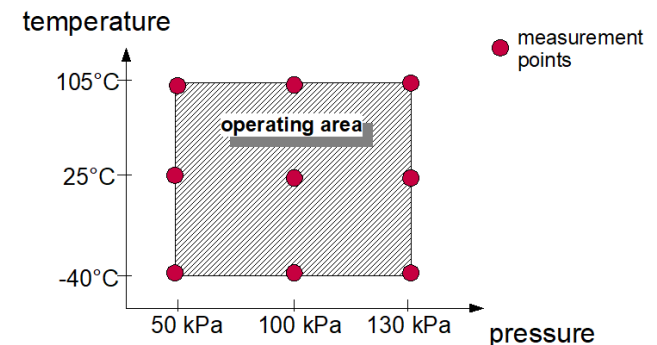
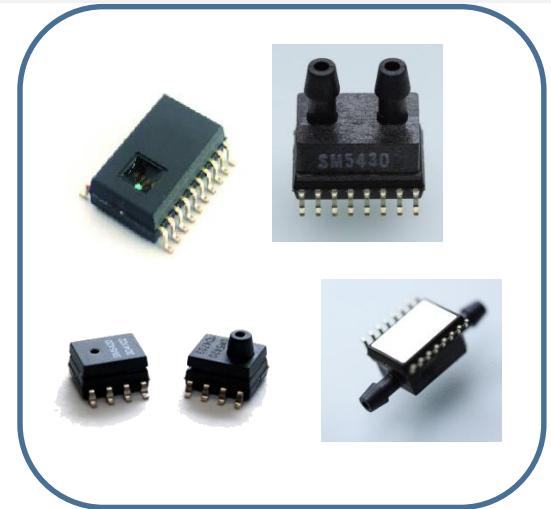
- no standard equipment available
- customized systems, or at least modification, needed

- **Physical Stimuli**

- no standard equipment available
- high effort for integration in existing systems
- Precision of stimuli

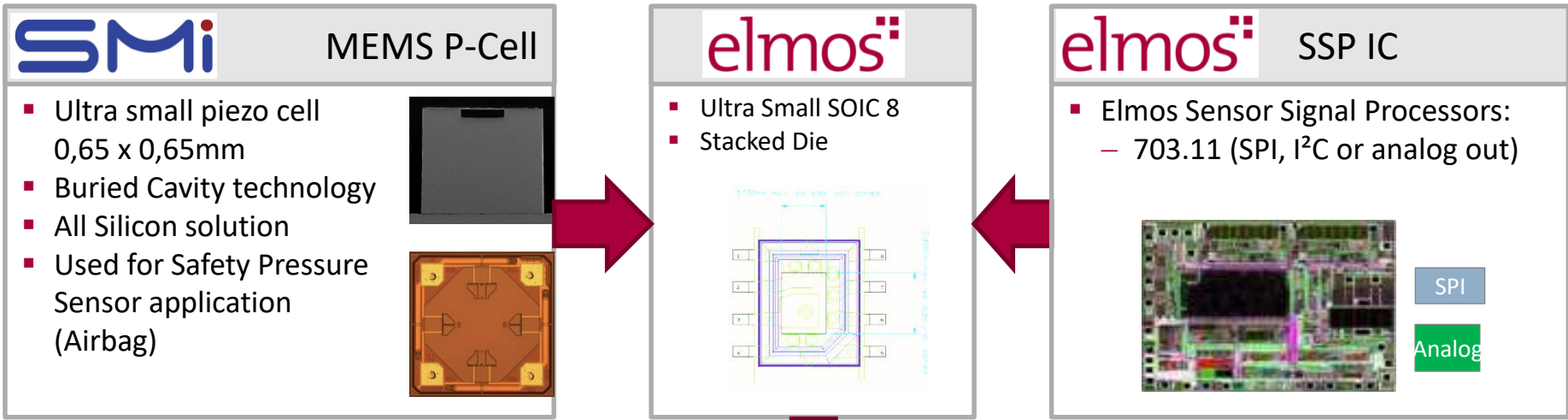
- **Temperature conditioning**

- Wide temperature range (~ -40 - +125°C)
- Temperature cycling time
- Side effects between physical stimuli and temperature

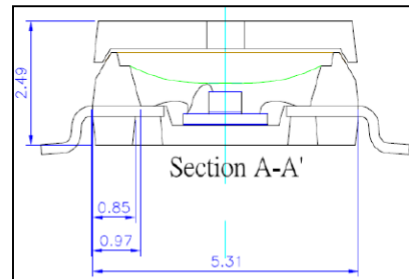


Standard IC test handling systems are most likely not suitable!

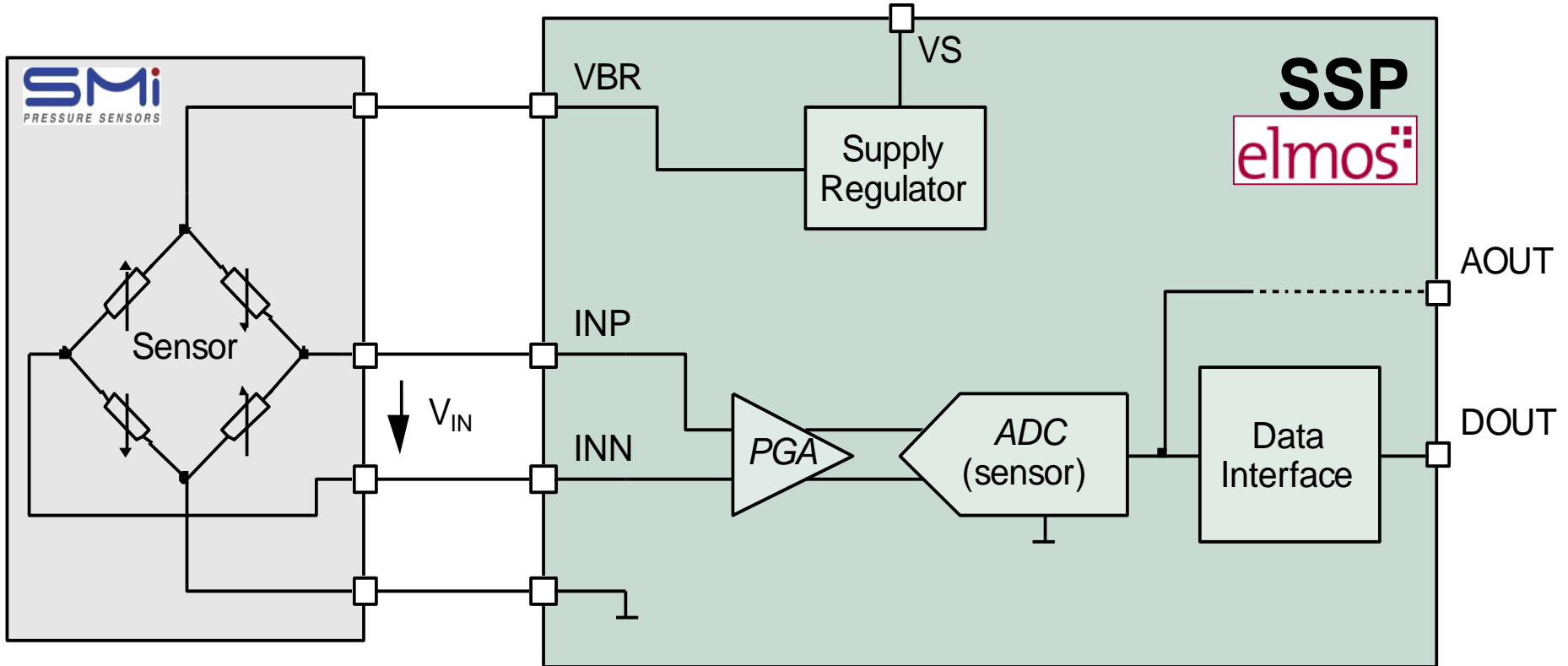
524.7X BAP (Barometric Pressure Sensor)



- Fully integrated pressure sensor system
- Communication via SPI / I²C / analog V
- Package size only 30mm² (50% of competing solutions)
- Multi temperature calibrated
- Low power consumption
- Applications: Powertrain BAP, Seat, industrial,...



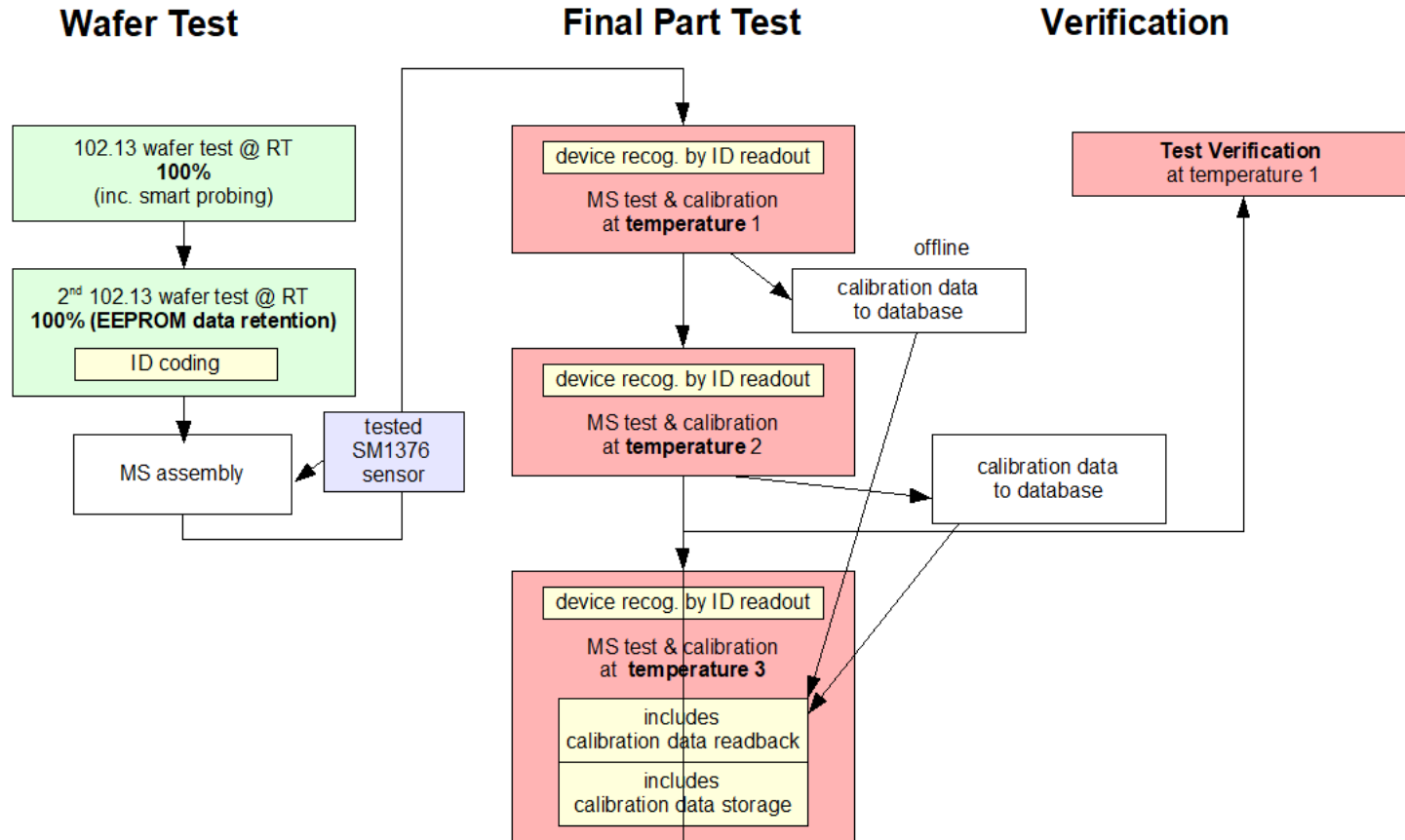
Example: Pressure Sensor



- **Electrical Test of all ASIC components**
 - Analog: Adj. amplifier, voltage reference, POR, ...
 - Digital: Calculation Engine, Error detection, SPI circuit
 - Mixed Signal: Sigma Delta ADC Loop
 - Memory: EEPROM, ROM, RAM
- **Physical Pressure Test**
 - Monitoring of Sensor Parameters (non-linearity, pressure hysteresis)
 - Calibration = Measurement and calculation of correction coefficients
 - Temperature coefficients for offset and span / hysteresis
- **General**
 - Multisite approach for high productivity
 - High test stability needed: R&R between sites, retest capabilities
 - Full traceability

Test and calibration over full temperature range mandatory!

Typical test flow for singulated MEMS



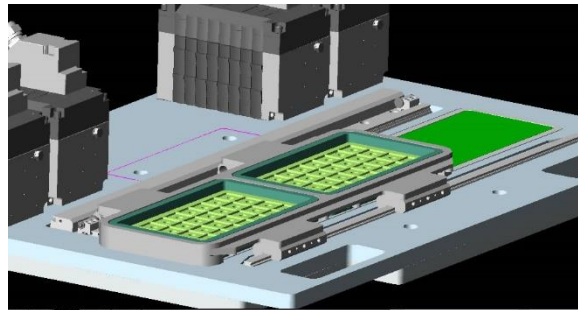
Singulated testing

- Use of gravity or PnP handling
- Up to 8 sites in parallel
- Settling time for physical stimulus is critical
- Fast cycle time
- Temperature setup per batch
- Automated handling



Batch testing

- Customized systems
- > 24 sites in parallel possible
- Settling time once per batch
- Long cycle times
- Temperature cycling during test
- Manual handling



InStrip testing

- Use of InStrip system
- > 24 sites in parallel possible
- Settling time for physical stimulus less critical
- Fast cycle time
- Temperature setup per batch
- High volume testing



Actual Projects at Elmos

MEMS / Sensor products:

- BAP / CAPS / MAP pressor sensors
- IntraSense
- Time-of-flight (3D camera)
- Hall-Sensors



Production setup:

- Modified standard gravity systems for absolute pressure sensors and magnetic test
- Modified standard P&P handling systems for optical devices
- Customized contactors and test chambers
- Sources for physical stimuli

Benefit through usage of standard systems!

Conclusions

- **Need of detailed analysis of MEMS project prior to decision for test setup**
 - Annual volume / required throughput per week
 - Technical feasibility study
 - Restrictions of the ATE and physical stimulus sources
 - Required accuracy and precision
- **Further more / last but not least:**
 - Maintainability of customized solutions / systems
 - Backup
 - Cost of Test calculation / prove of business case
 - Amortization of test equipment / potential reuse

Testing of MEMS products is rarely „as usual“ !

Innovation Matters



Thank you!