Activities in SINTEF on High Temperature Electronics

Ovidiu Vermesan

SINTEF, Norway

The Foundation for Scientific and Industrial Research
at the Norwegian Institute of Technology

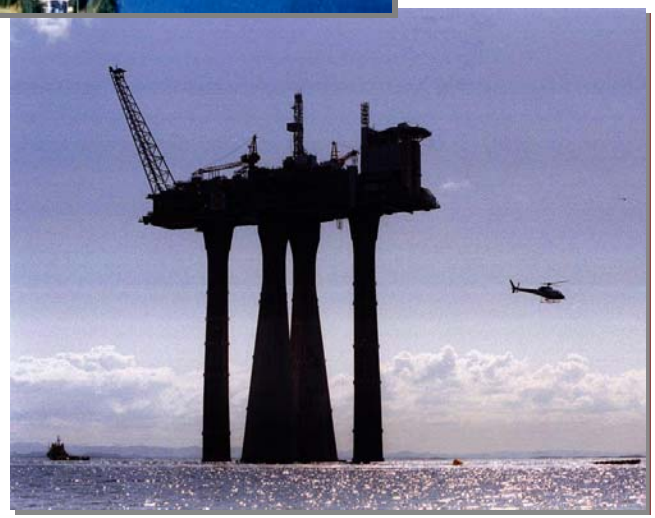
SINTEF

The vision:
Technology for a better society

Business concept:
SINTEF sell research-based knowledge and related services to Norwegian and international clients.

Social perspective:
SINTEF aims to contribute to the creation of value and to a society in healthy sustainable development.

Oil and Gas in One and the Same Pipeline



- The most important fundament to the OLGA computer program – a vital tool on the continental shelf

Multiphase transportation:

- Major savings in development projects
- Has made marginal fields profitable

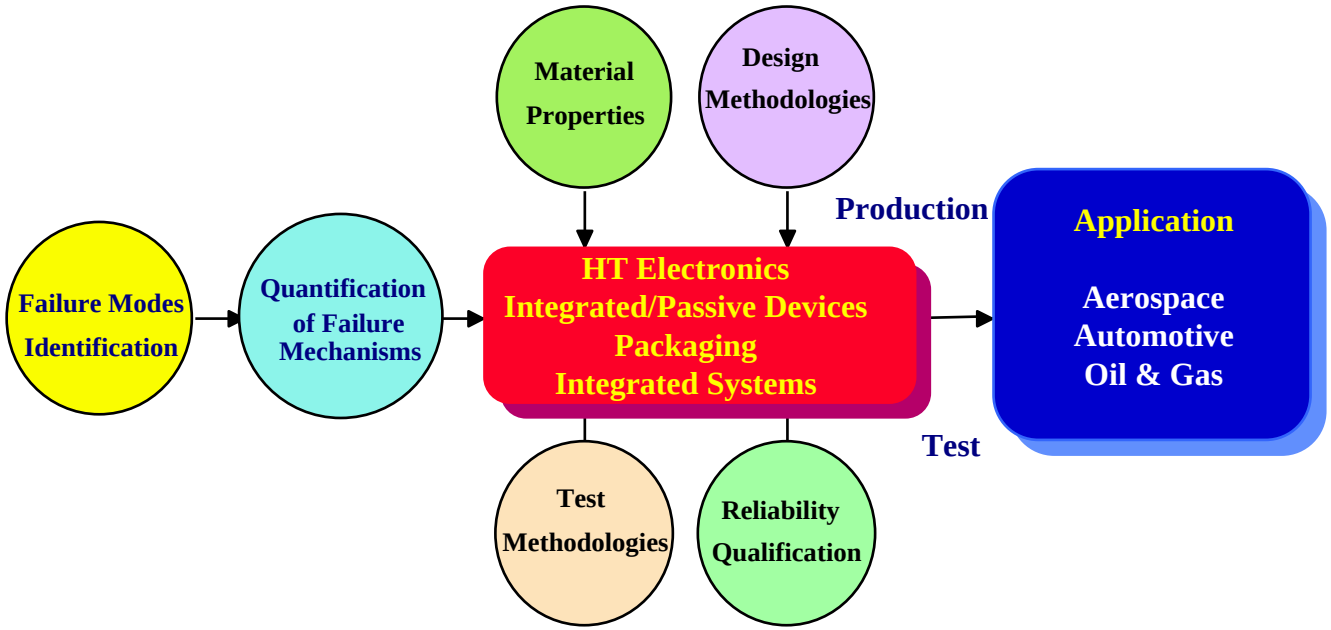
High Temperature Technical Areas

- Advanced Integrated Measurement Systems
- Microtechnology
- Advanced Control Systems

High Temperature Electronics

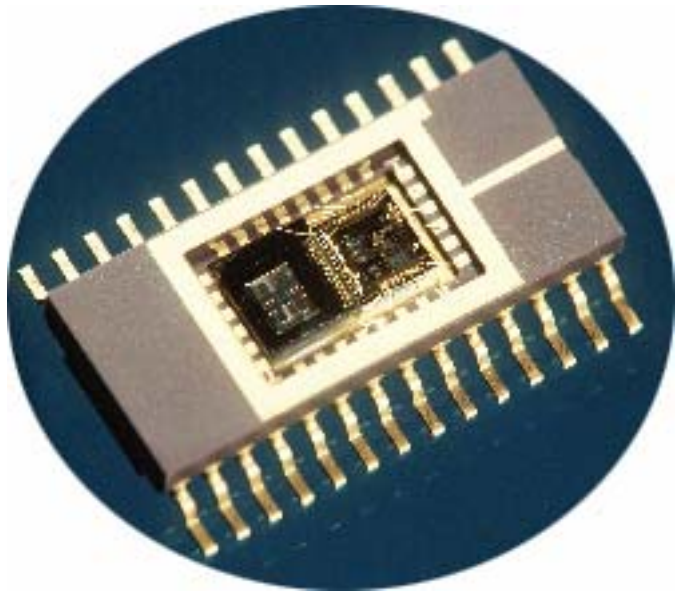
Advantages of Integrated HTE

- Improved accuracy
- Lighter, faster more responsive control
- Improved efficiency reducing losses and saving costs
- Improved reliability

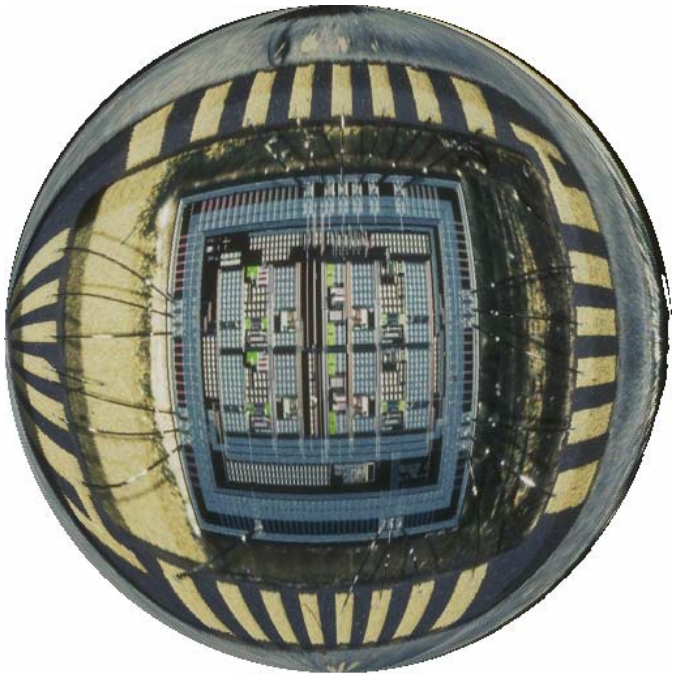


SINTEF High Temperature Technical Areas

- Intelligent Instrumentation Systems
- Integrated Circuits (HTASIC® HoTASIC®)
- MEMS/Sensors and Actuators for High Temperature Applications
- Silicon Process Technology
- Packaging
- MCM Integration
- Reliability



SINTEF High Temperature Electronics History

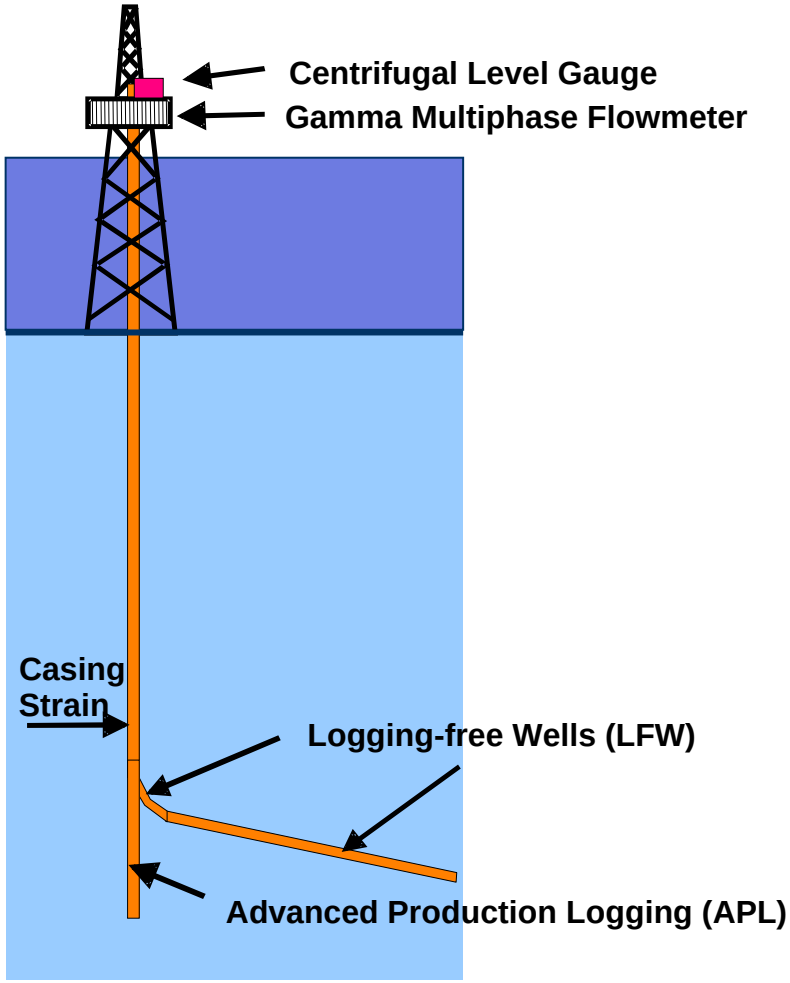


- 1984: Design of the first logging tool
- 1988: Characterised technology for HTE in CMOS/BiCMOS processes
- 1992: The first HTASIC®
- 1993: The first HTASIC® tested up to 275°C
- 2001: New technology developed HoTASIC®
- 2003: More than 300 circuits used in oil applications

Intelligent Oil Wells

The Intelligent Wells program combines state of the art instrumentation and simulation technologies with methodology for modern industrial process control to increase the inflow of oil into advanced wells and obtain optimal drainage of the reservoir.

Instrumentation Systems For Oil Production



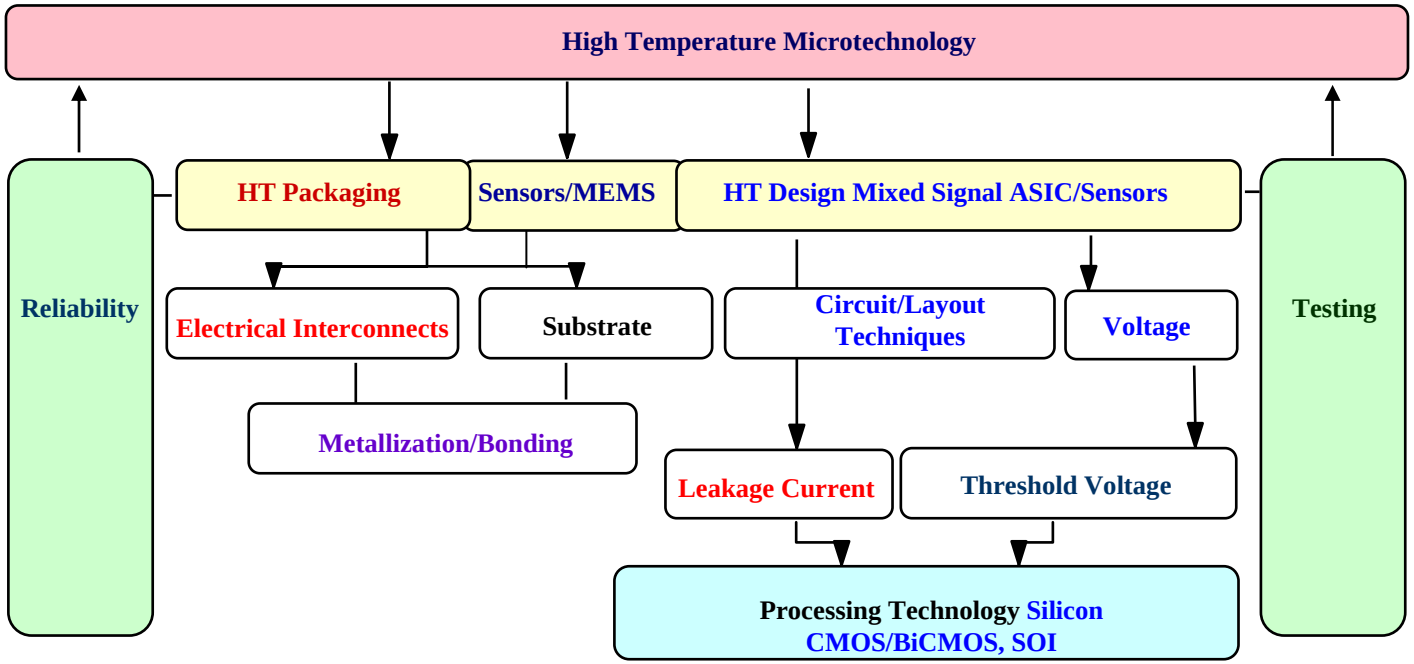
Successful Projects

- Logging-Free Wells
- Advanced Production Logging

Environmental characteristics:

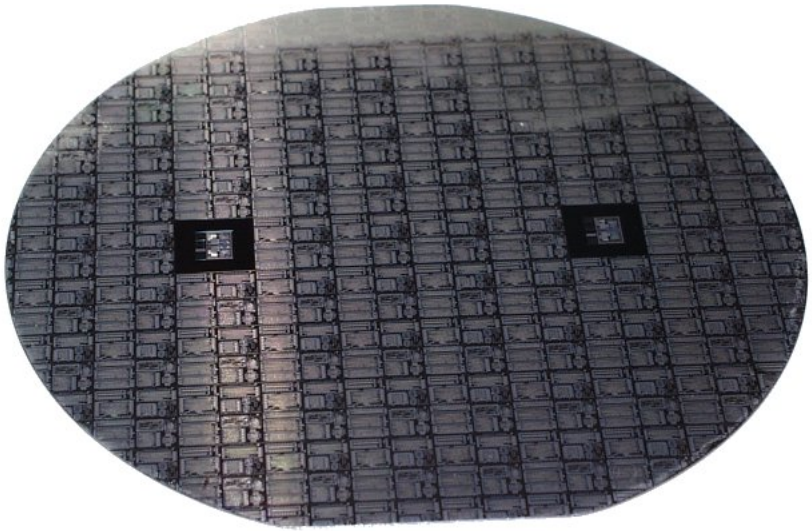
- Temperatures: 0 - 200ºC
- Pressure: 0 - 1000 bar
- Vibration, shock
- Aggressive liquids/gases
- Difficult/expensive to test

High Temperature Microtechnology



HTASIC® HoTASIC® Integrated Circuits Family

Leading implementation of high temperature integrated circuits



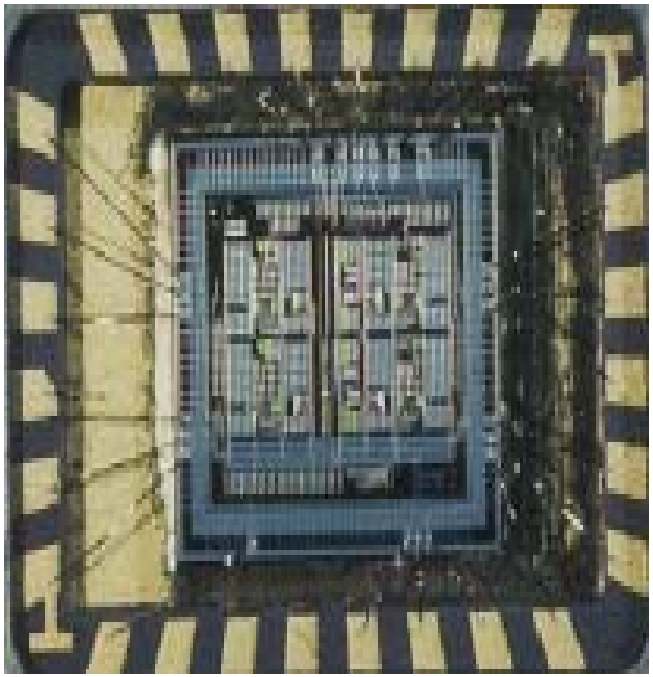
- Custom designed CMOS/BiCMOS circuits for operation up to 200°C

- Advantages CMOS/BiCMOS technology

- Power consumption
- Silicon area
- Circuit density
- Reliability

HTASIC® HoTASIC® Integration Solution for HTE

Advantages of integrating on chip for HTE

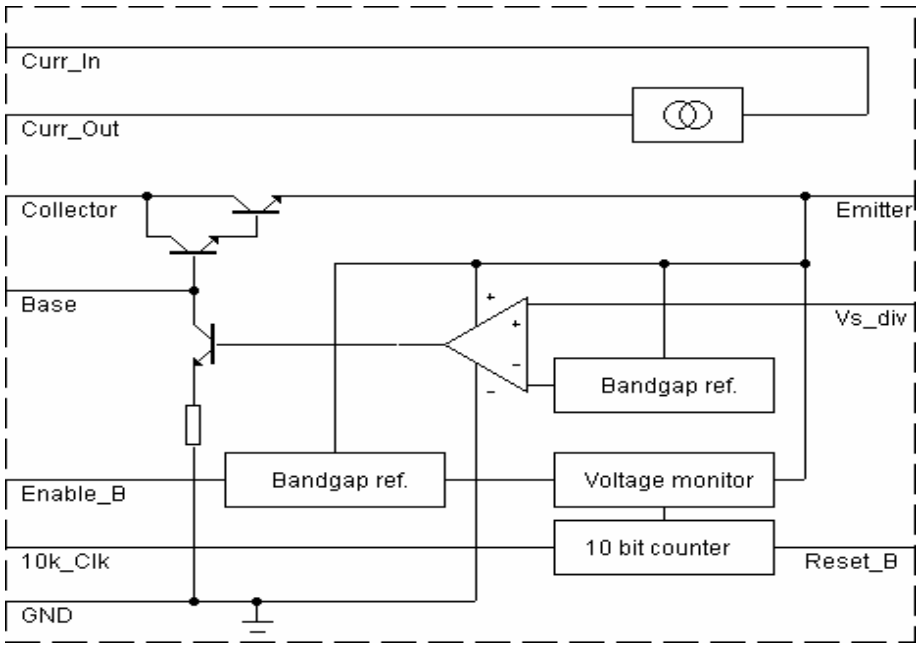


- **Small size**
- **Multi channel implementation**
- **Less parts components used for the system**
- **Increased reliability**
- **Simple package system**
- **Package system that can include multiple dies (MCMs)**
- **Easier to protect in harsh environments**
- **Less power consumption**
- **Lower price in medium and higher volumes**

HTASIC® HoTASIC® High Temperature Library

- HT Power - Linear Power Supply Regulator
- CMC - Capacitance Measurement Circuit
- TMM - Telemetry Master Module
- TTC - Tool Telemetry Chip
- TPELS - Temperature/Pressure Electronic System
- SDMS - Sigma Delta Measurement System
- VFC - Voltage Frequency Converter
- SAC - Spectrum Analyser Chip

HT Power - Linear Power Supply Regulator

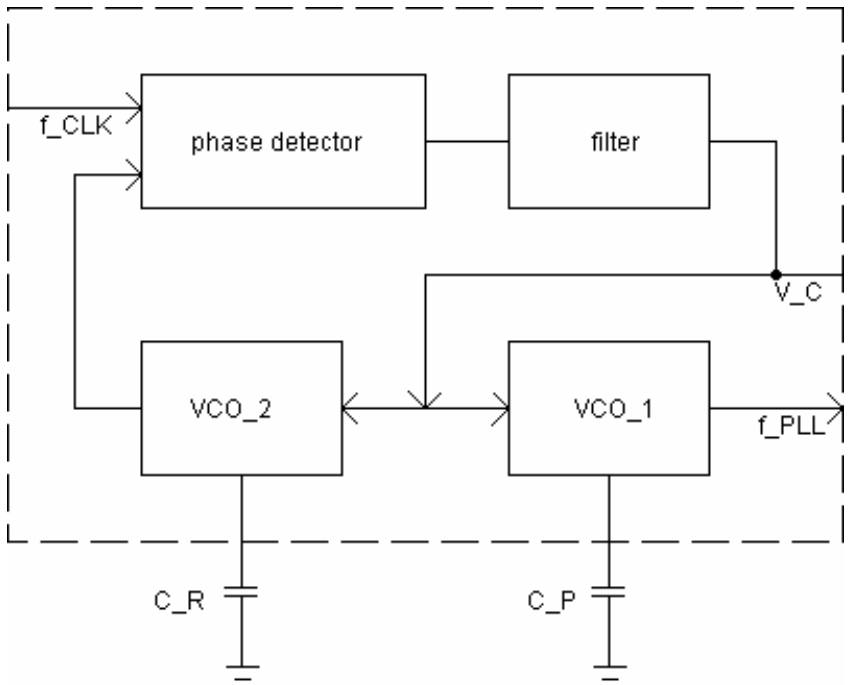


- 1.2 μm BiCMOS technology
- Die size: 5.2 mm^2
- Voltage Power Supply: 5V
- 2.7 mA quiescent current
- Output current up to 250 mA
- Adjustable output 5V-12V
- Operating temperature: 0°C to 200°C.
- CSOIC16-pins package

Applications:

- Downhole logging systems
- High temperature applications
- Electric power conversion

CMC - Capacitance Measurement Circuit

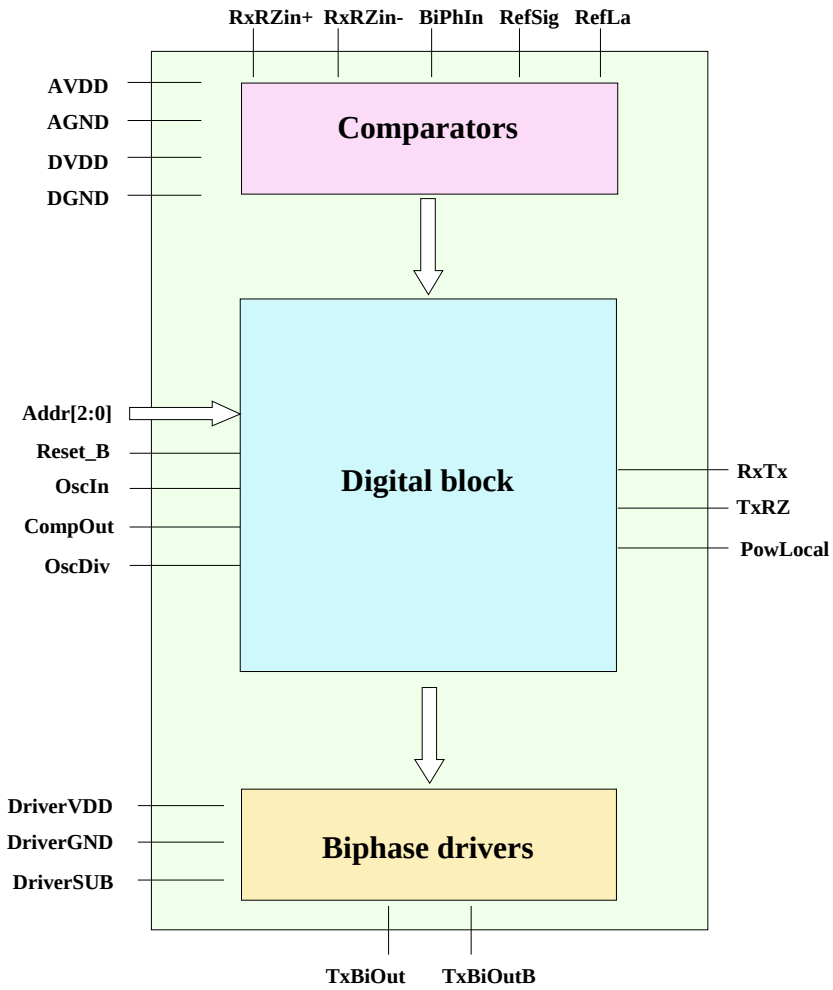


- 1.2 μm BiCMOS technology
- Die size: 4.5mm^2
- 700 μA quiescent current
- Operating temperature: 0°C to 200°C.
- CSOIC 16-pin package

Applications:

- Downhole logging systems
- High temperature applications
- Sensor applications

TMM - Telemetry Master Module

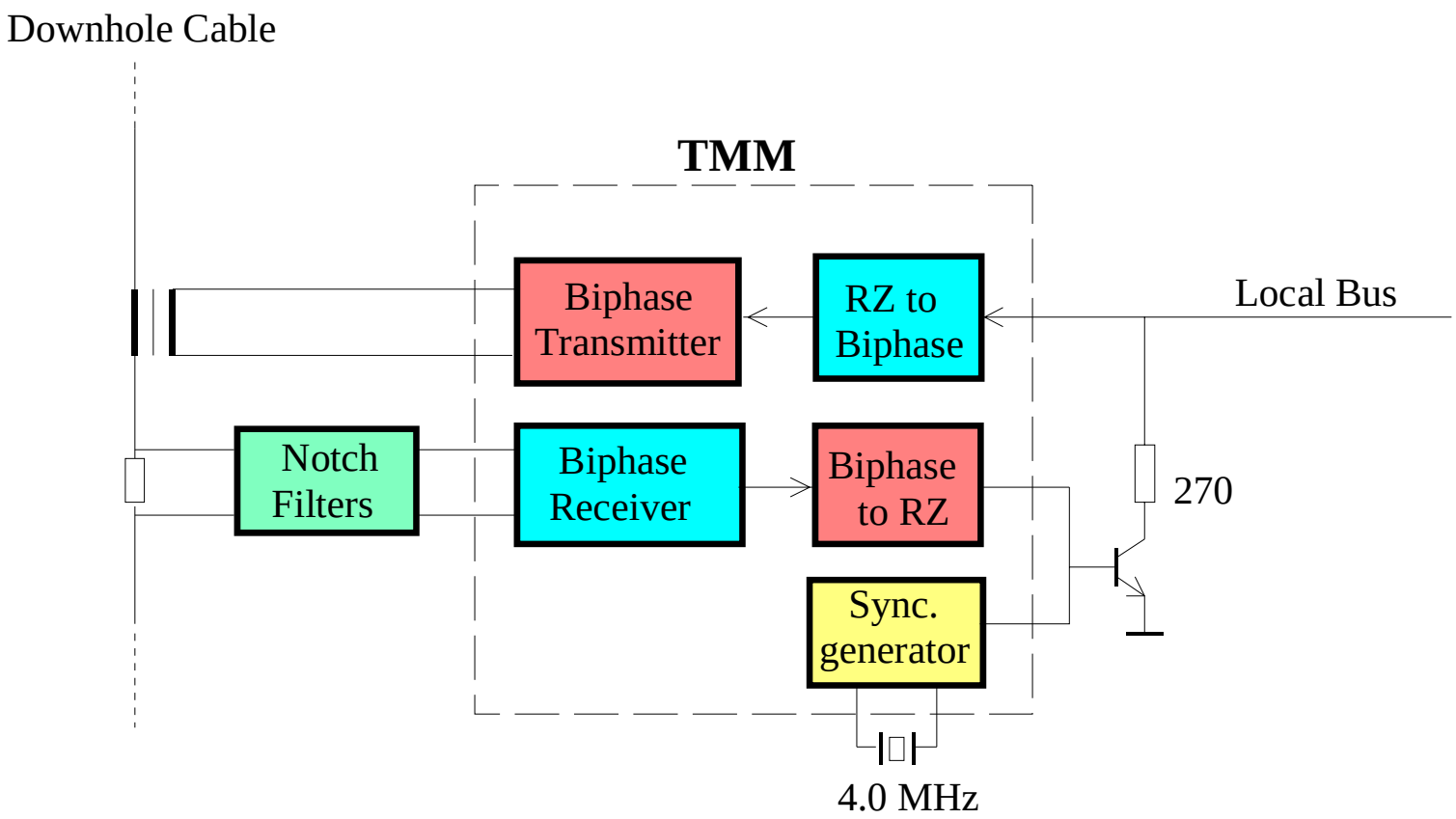


- 1.2 μm BiCMOS technology
- Die size: 13.6 μm^2
- Voltage Power Supply: 5V
- Operating temperature: 0°C to 200°C.
- CSOIC 28-pin package

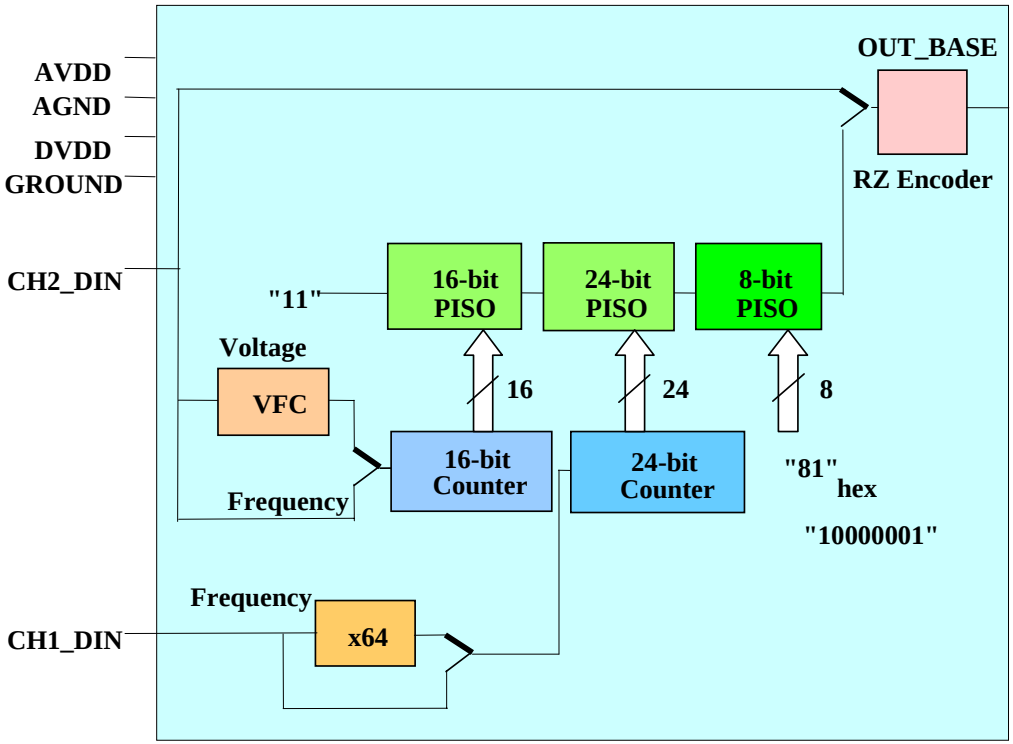
Applications:

- Downhole logging systems
- High temperature applications
- Telemetry systems

TMM - Telemetry Master Module



TTC - Telemetry Tool Circuit

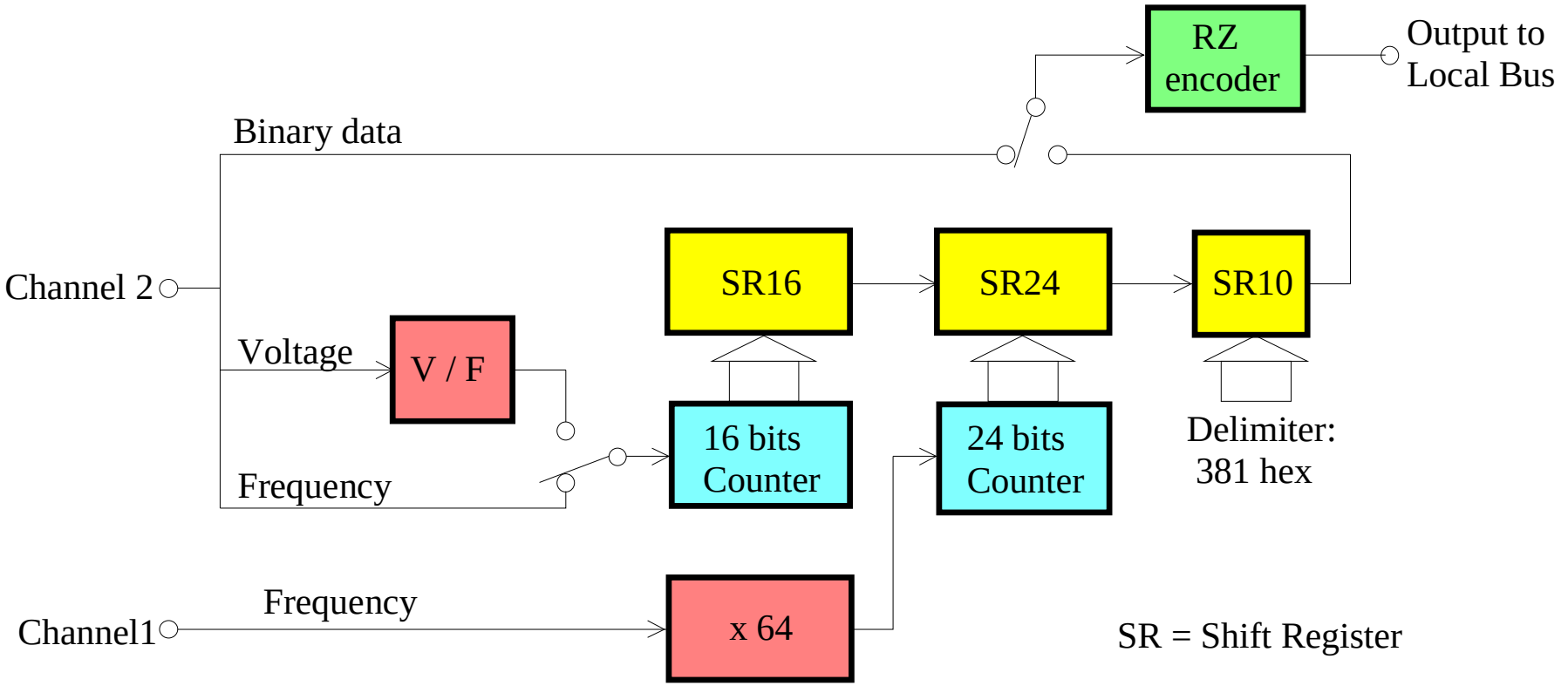


- 1.2 μm BiCMOS technology
- Die size: 17.5 μm^2
- Voltage Power Supply: 5V
- Operating temperature: 0°C to 200°C.
- CSOIC 28-pin package

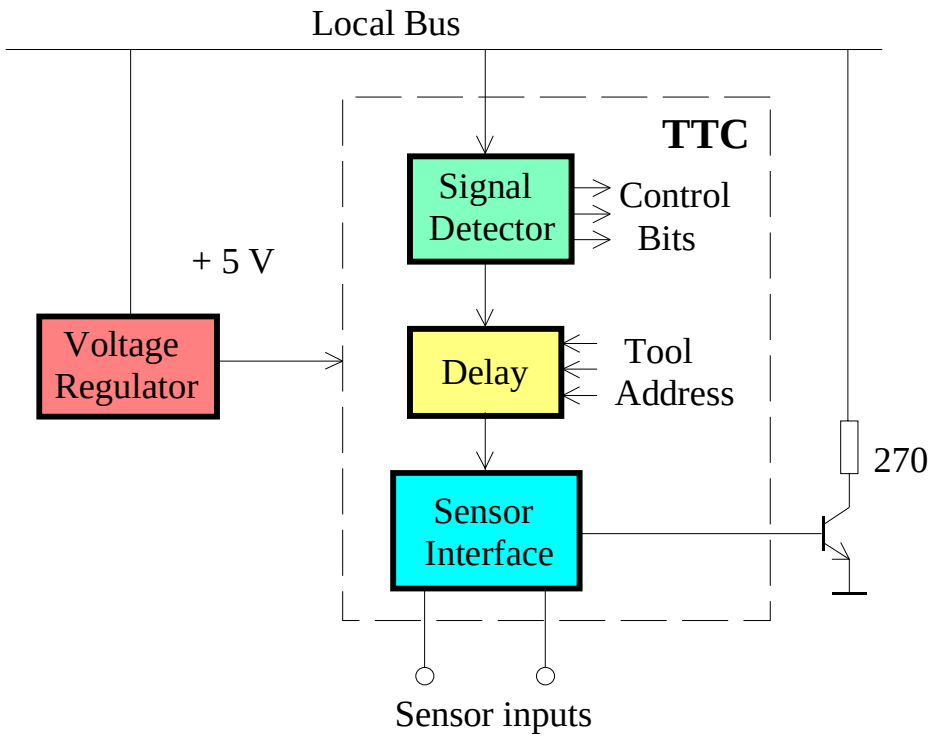
Applications:

- Downhole logging systems
- High temperature applications
- Telemetry systems

TTC - Telemetry Tool Circuit



TTC - Telemetry Tool Circuit

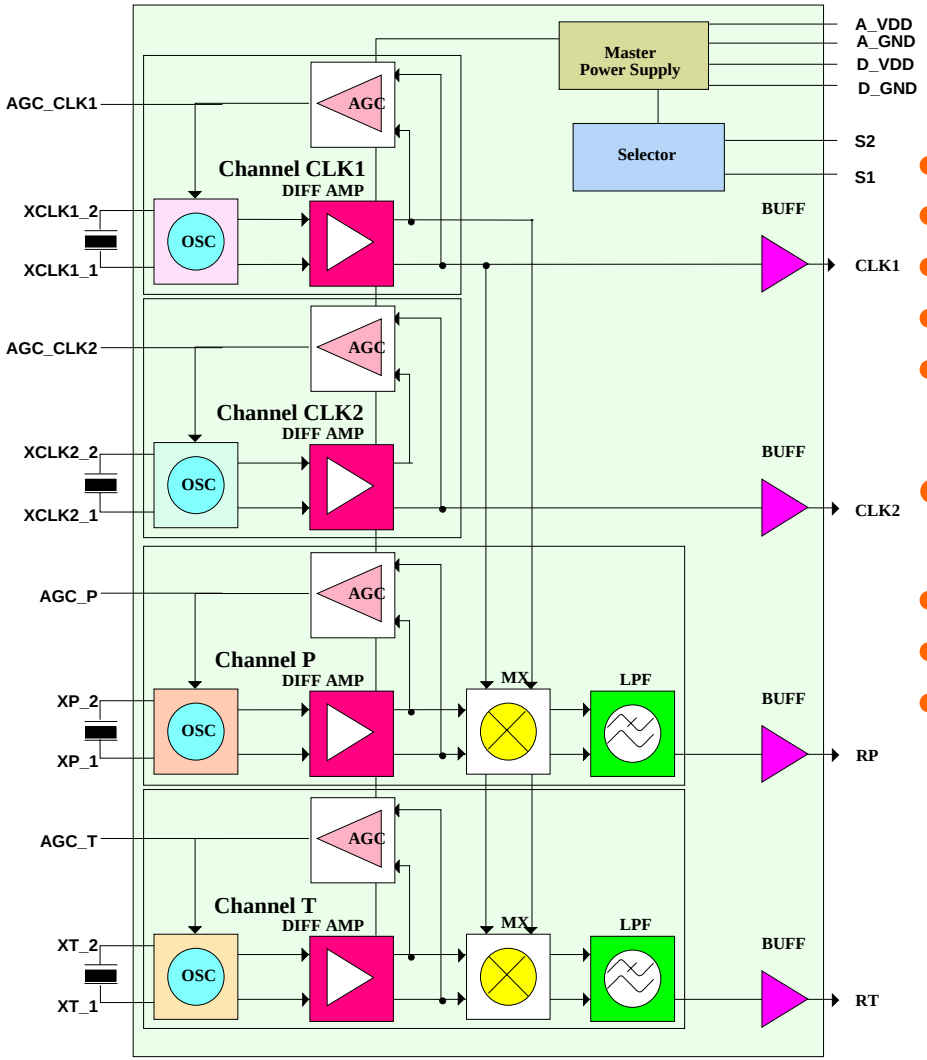


- VFC (Voltage to Frequency Converter) for sensor channel 2.
- 16 bit counter for sensor channel 2.
- x64 Frequency multiplier for sensor channel 1.
- 24 bit counter for sensor channel 1.
- 48 bit PISO

- Sensor output interpreted by the TTC:

- Analog voltage in the range 1-4 Volt.
- Frequency below 4MHz or an arbitrary binary data stream

TPELS - Temperature/Pressure Electronic System



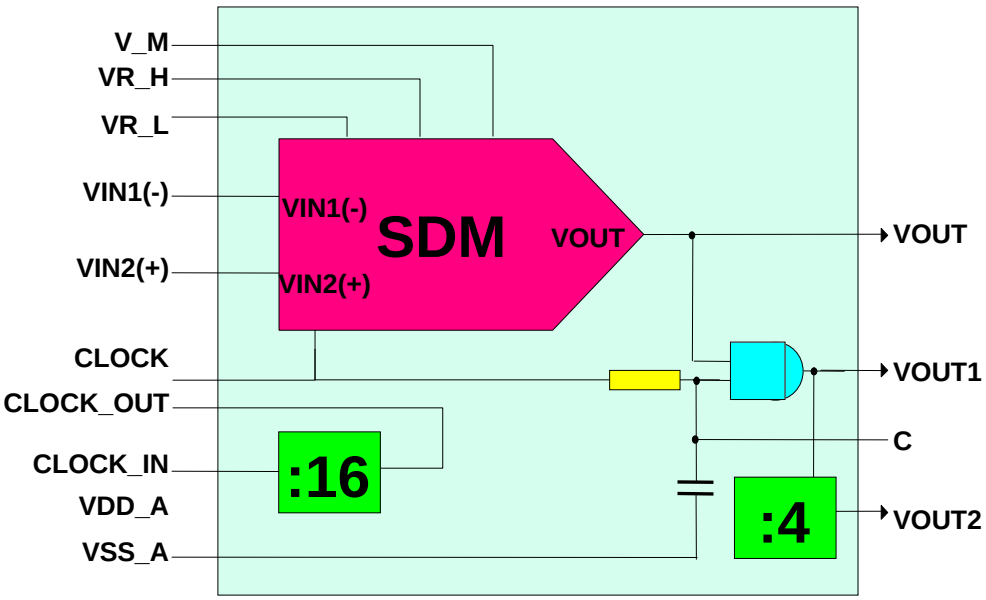
- *1.2 μm BiCMOS technology*
- *Die size: 15 mm²*
- *Voltage Power Supply: 5-3.5V*
- *Operating temperature: 0°C to 200°C*
- *CSOIC 28-pin package*

- **Applications:**

- *Pressure/Temperature measurements*
- *High temperature applications*
- *Downhole memory and wireline quartz gauge*

Reference Clock Channel CLK1
Clock Channel CLK2
Pressure Channel RP
Temperature Channel RT

SDMS - Sigma Delta Measurement System

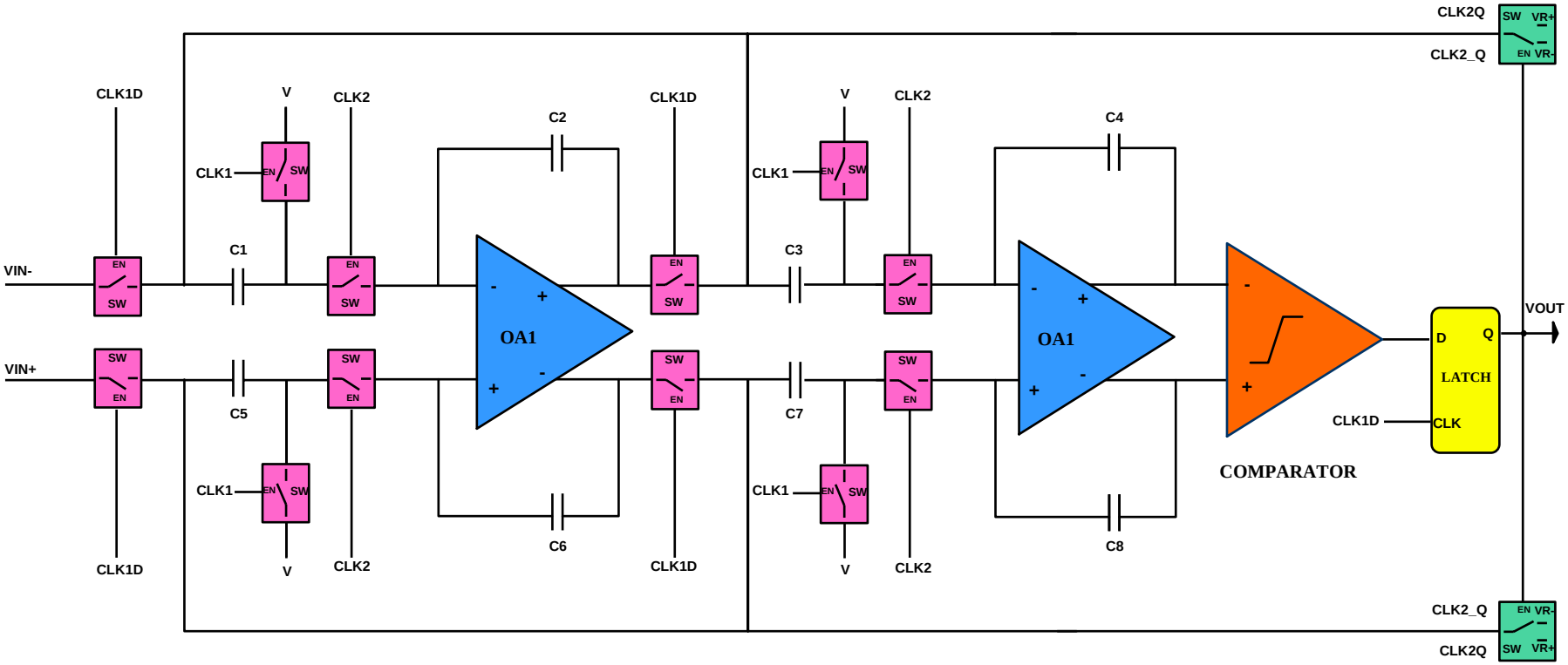


- 1.2 μm BiCMOS technology
- Die size: 4.89 μm^2
- Voltage Power Supply: 5V
- Operating temperature: 0°C to 200°C.
- CSOIC 16-pins package

Applications:

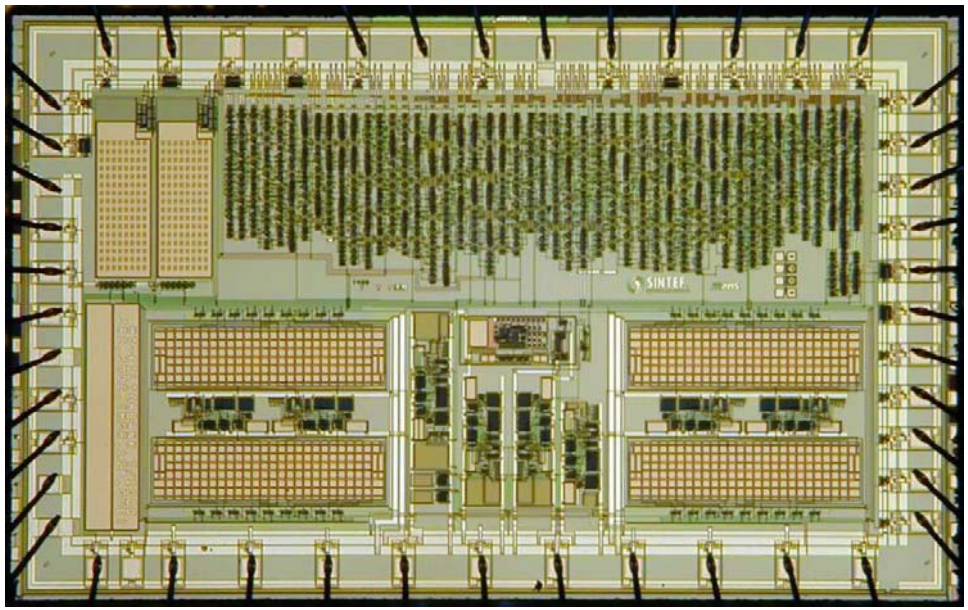
- Pressure/Temperature measurements
- Bridge measurement systems
- High temperature applications
- Downhole memory and wireline quartz gauge

SDMS - Sigma Delta Modulator



Two discrete time integrators
1-bit quantizer (ADC)
1-bit digital to analog converter (DAC)
Output digital decimator
Clock block

SAC - Spectrum Analyser Circuit

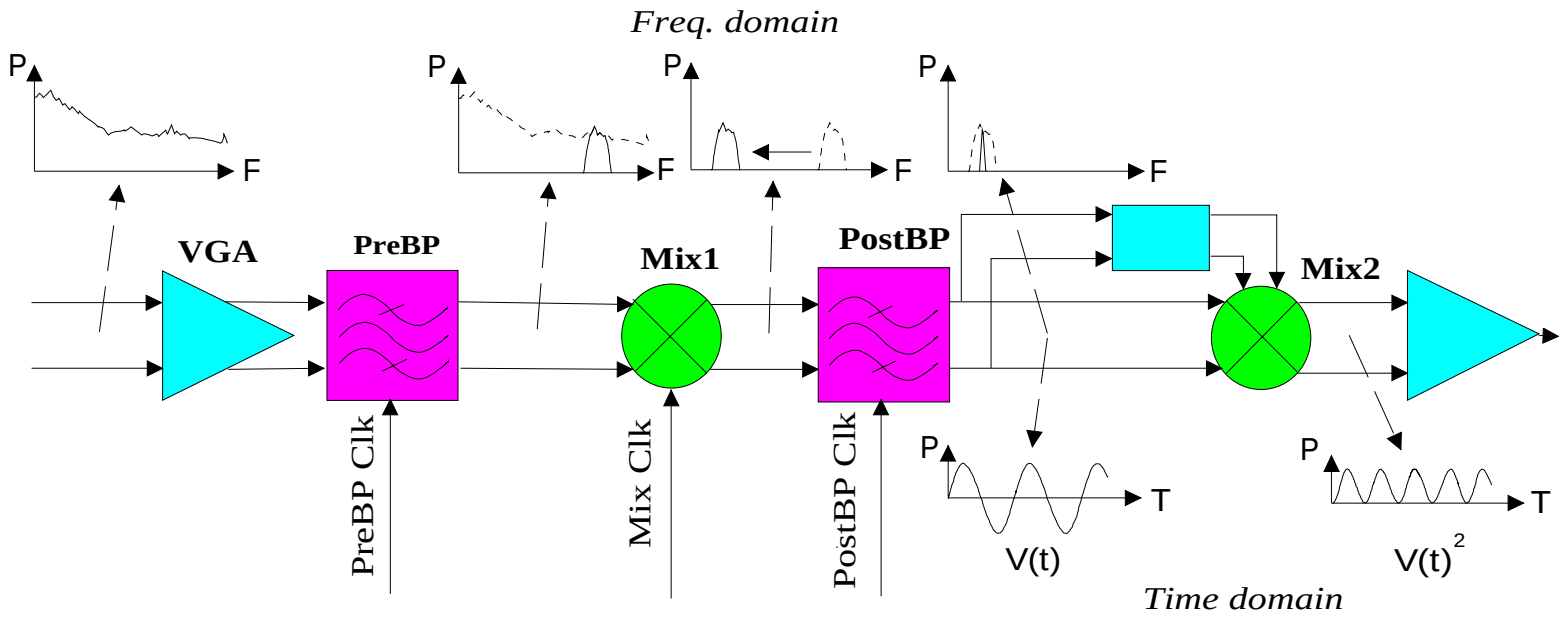


- 1.2 μm BiCMOS technology
- Voltage Power Supply: 5V
- Operating temperature: 0°C to 200°C.
- Frequency Range: 500Hz to 50,000Hz

Applications:

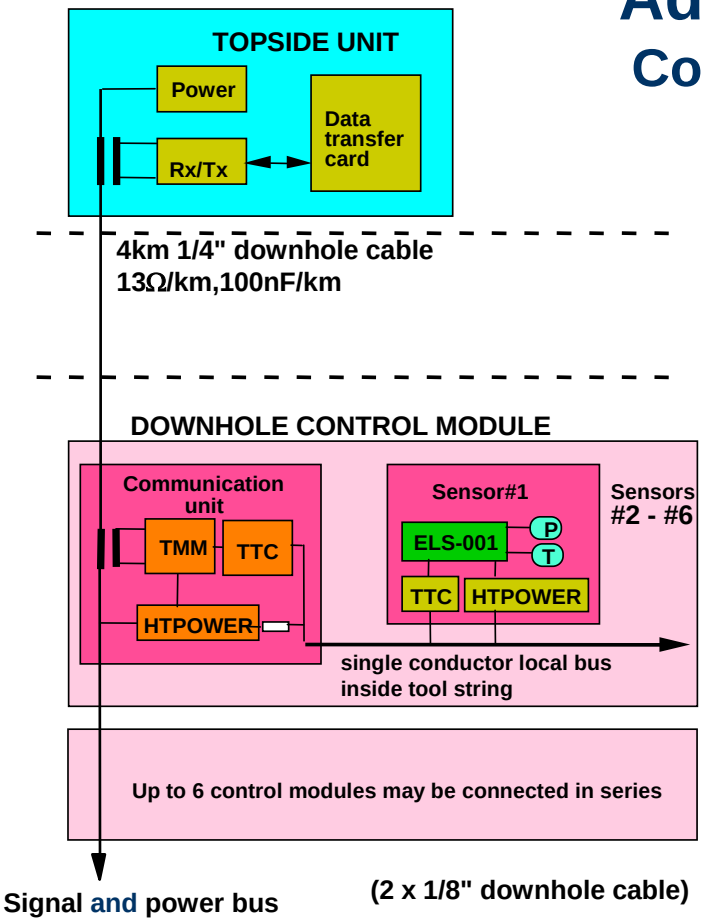
- Downhole logging systems
- High temperature applications

SAC - Spectrum Analyser Circuit



The Spectrum Analyser Circuit finds the power spectrum of an input signal by sweeping through the frequency range and measuring the power at each particular frequency.

Instrumentation Systems HTASIC® Technology



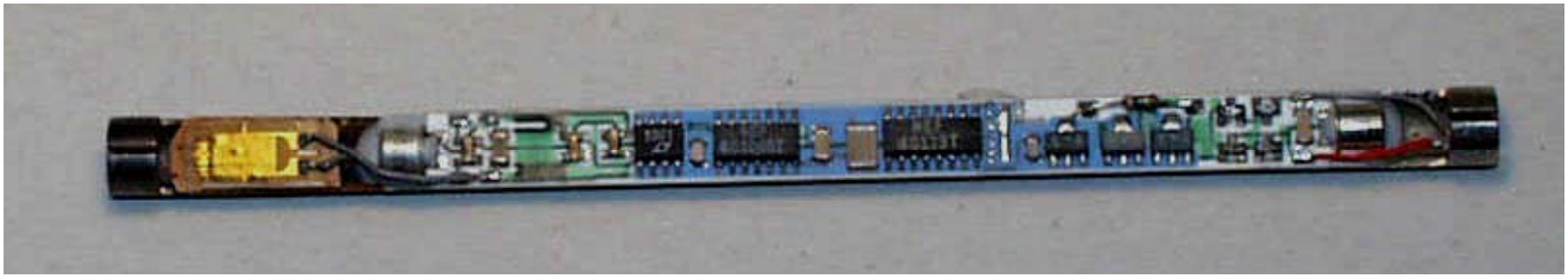
Advanced Production Logging (APL)

Complete system for remote measurements

- Well logging down to 10km
- Tool string with up to 30 tools
- Two-way communication and power on one "coax" cable
- 150 - 200 ºC operation
- Measurements:
  - Flow
  - Pressure
  - Gamma counts
  - Watercut
  - Temperature

Hybrid Systems HTASIC® Technology

Hybrid for Casing Strain 8x100 mm



- Ceramic hybrid fixed to steel vessel with silicon rubber
- Vibration / shock test: No sign of damage or malfunction
  - 20g, 40-2000 Hz, 3 axis
  - 125g, 4ms, 6 axis
  - 750g, 3ms, 6 axis
  - 1300g, 1ms, 6 axis

Instrumentation Systems HTASIC® Technology

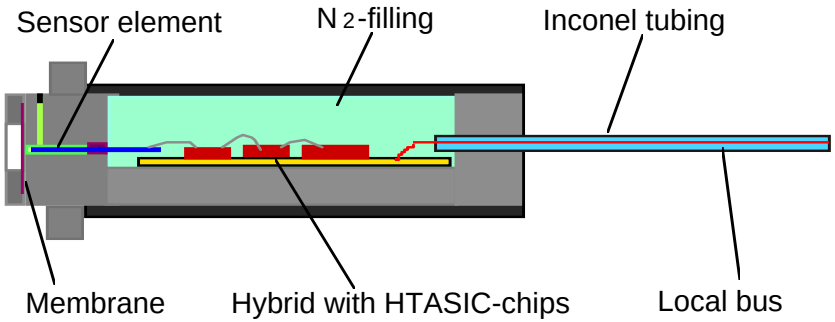
”Sensorfish”

Complete sensor measurement system

- Pressure: 0-1000 bar
- Diff.pressure: -0.6 -1 bar
- Temperature: 0-200ºC
- Diff. temperature: 0-2ºC
- Capacitance: 10-80 pF
- Hydrophone: 20 - 10000Hz

All electronics in housing of Zirconia and duplex steel with gold seal

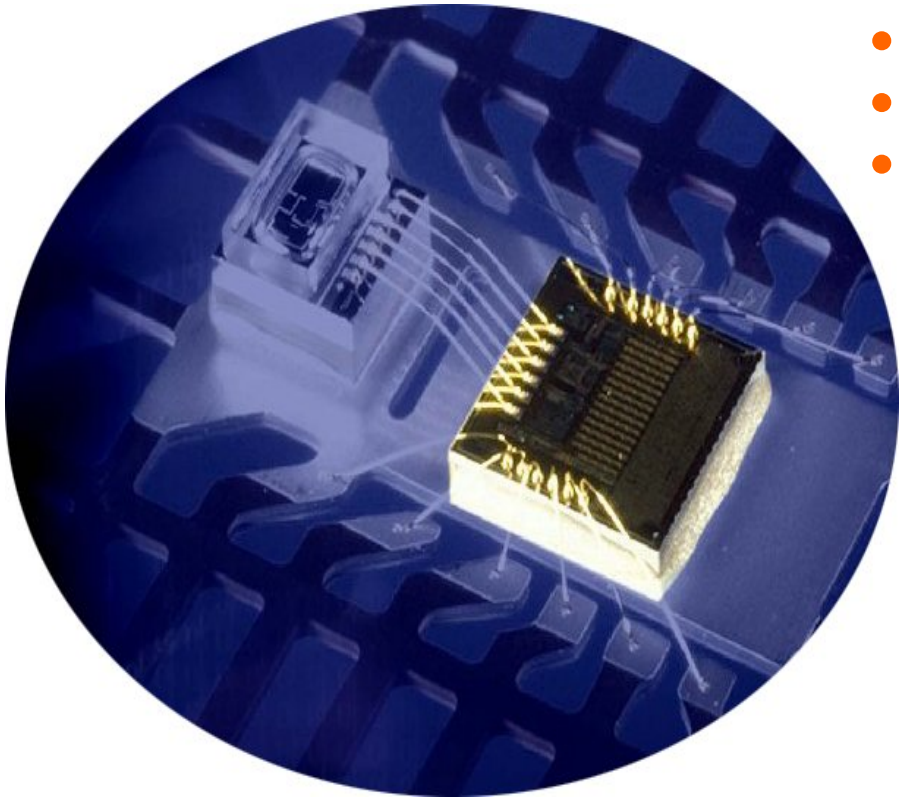
Presens - Pressure Sensor 1000 Bar



- Buried strain gauges
- Large signal: 1V FSO
- Range: 0-1000 bar
- Accuracy: 0.1% FSO
- Repeatability and hysteresis: 0,005% FSO
- Operating Temperature: -10 to 200ºC

PRESENS

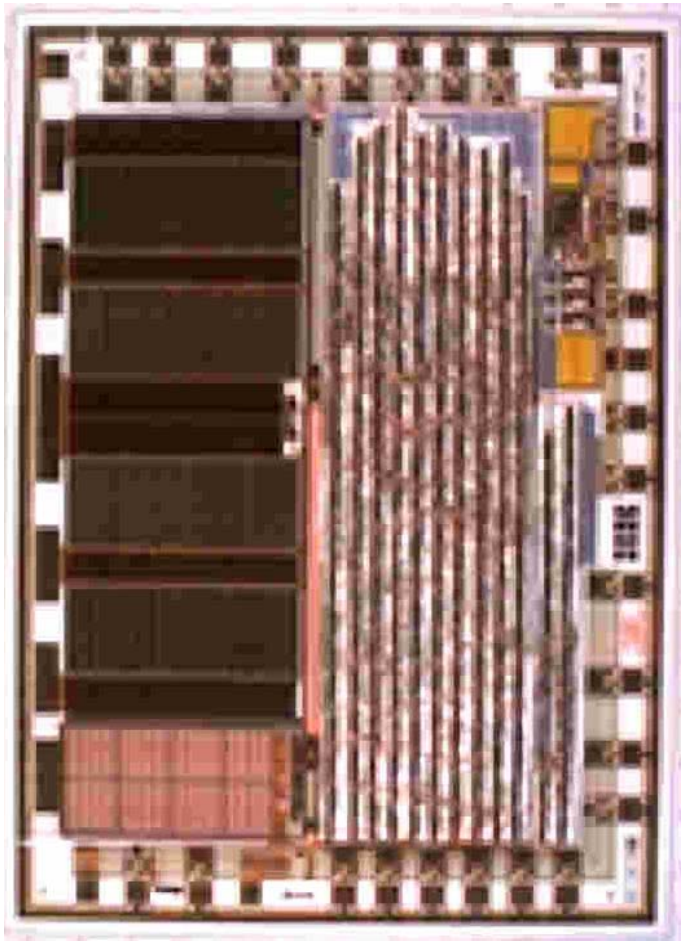
High Temperature Integrated Systems On Chip



- Integrated systems on common substrate
- Packaging
- Metallization

- Multi Chip Modules MCMs
- ASIC die
- Sensor die
- Passive Components

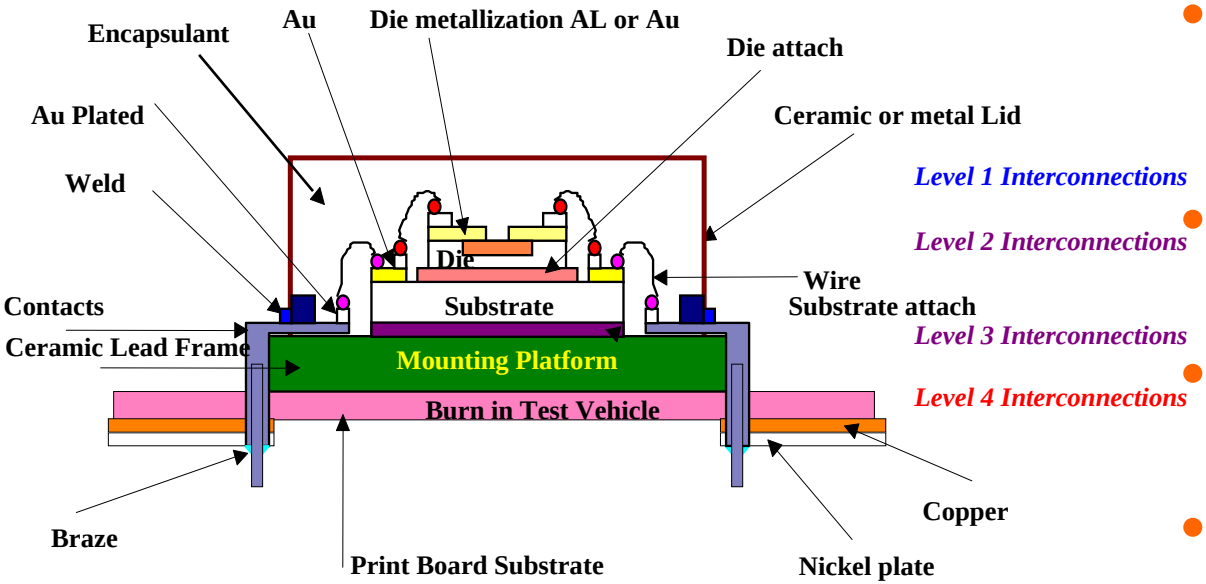
Reliability Tests HTASIC® Circuits



- Four chips tested at 230ºC in 4700 hours continuous operation:
  No failures on ASICs
- Using 0.7eV in exponential function gives estimated lifetime > 4 years at 175ºC

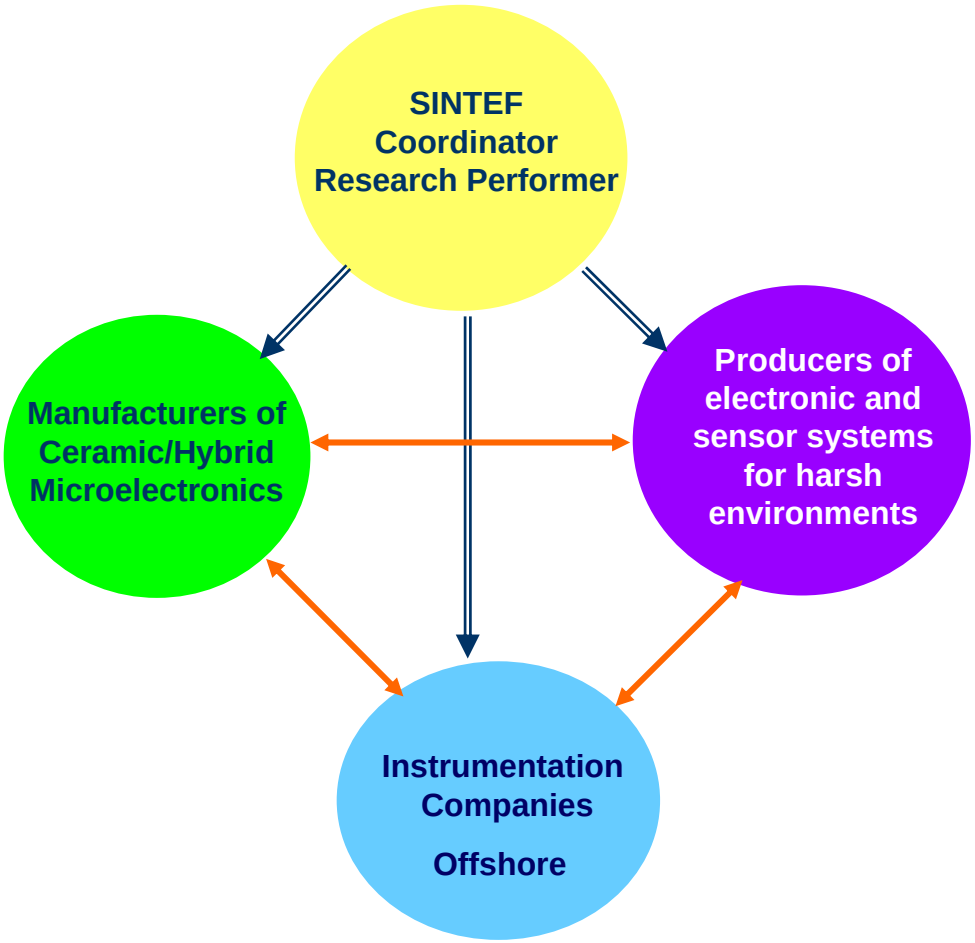
Low current density is one important design criterion

Reliability and Lifetime



- Level 1 Interconnections - Sensor/ASIC (Application Specific Integrated Circuit) level.
- Level 2 Interconnections - Sensor - Sensor or ASIC-ASIC level (MCM, Chip on Board).
- Level 3 Interconnections - Sensor-Package or ASIC-Package level.
- Level 4 Interconnections - Print Board level

Reliable Electronics For Harsh Environments



Objective:

- **Develop know-how for design, production, test and qualification of highly reliable microelectronic systems for high temperature and harsh environment applications.**
- **Develop generic processes for packaging of harsh environment electronics.**
- **Establish guidelines for reliability testing and qualification for such environments.**

Conclusions

- **Integrated solutions are the answer for the future high temperature electronics applications.**

SINTEF

- **Research activities in high temperature electronics driven by oil industry**

- **Leading implementation of high temperature integrated circuits (HTASIC® HoTASIC®) in CMOS/BiCMOS processes**