MARTIN COMPANY
Electronics Engineering and Manufacturing

ISTFA 2014 Panel Discussion
November 12, Houston, Texas

System to Component Level Failure Analysis in Space & Oil industries

John Martin

12 November, 2014

Downhole Electronics

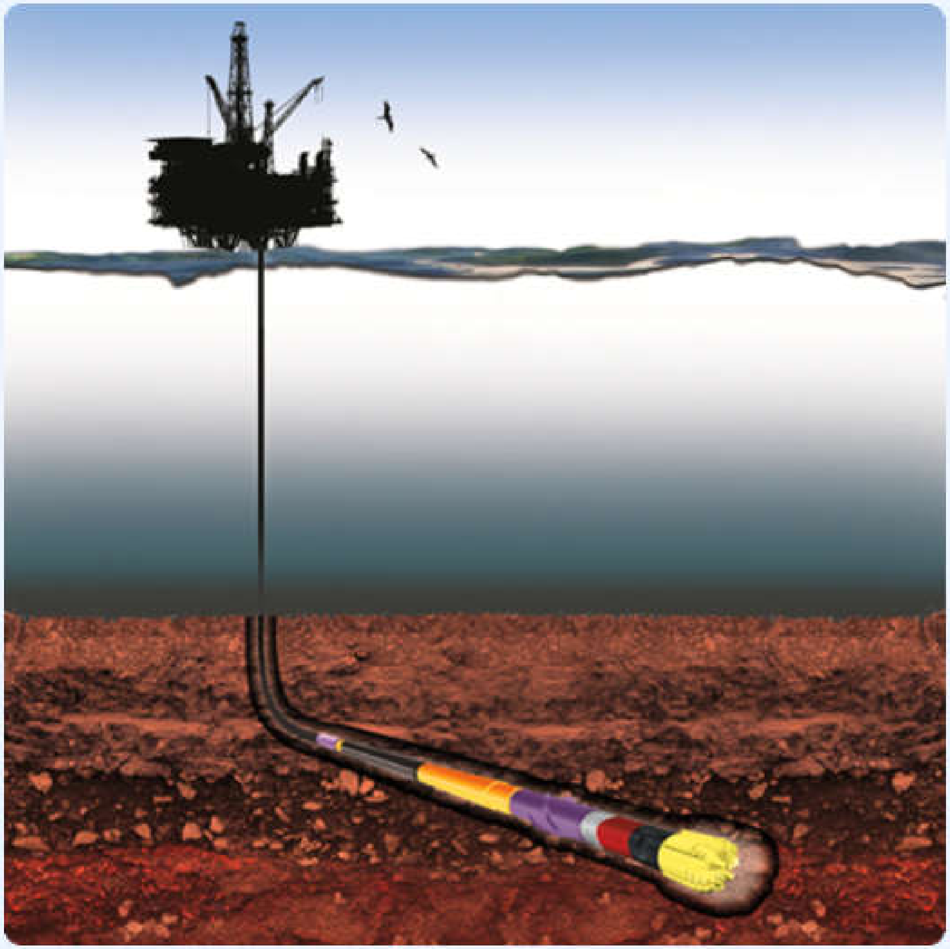

Figure 1. Downhole drilling operation.

Temperature Range:
150 ° C – 200 C
Increases 25 ° C/km
Pressure > 25 kpsi

Thanks to Analog Devices for the information in this slide.

Space & Oil Electronics

- Harris Semiconductor introduced radiation resistant analog and digital devices and PROMs for use in space and military applications and they were also found to work at high temperatures.
- RCA CMOS microprocessors were also found to work at high temperatures.
- Other companies have since introduced both monolithic and hybrid components for use or have discovered that their COTS parts worked at high temperatures.

Typical Downhole Instrumentation

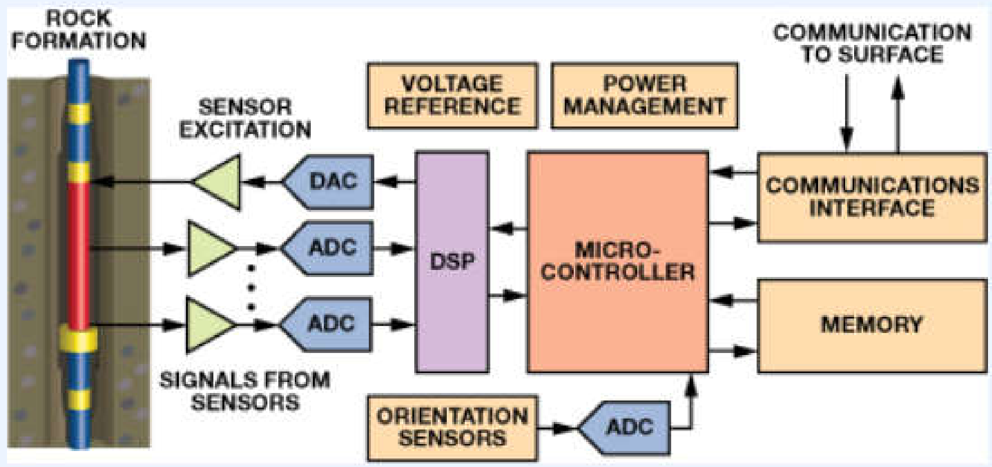

Figure 2. Simplified downhole logging instrumentation signal chain.

Downhole systems are similar to typical data acquisition systems except for harsh environment and narrow pcb form factor.

Thanks to Analog Devices for the information in this slide.

Leakage?

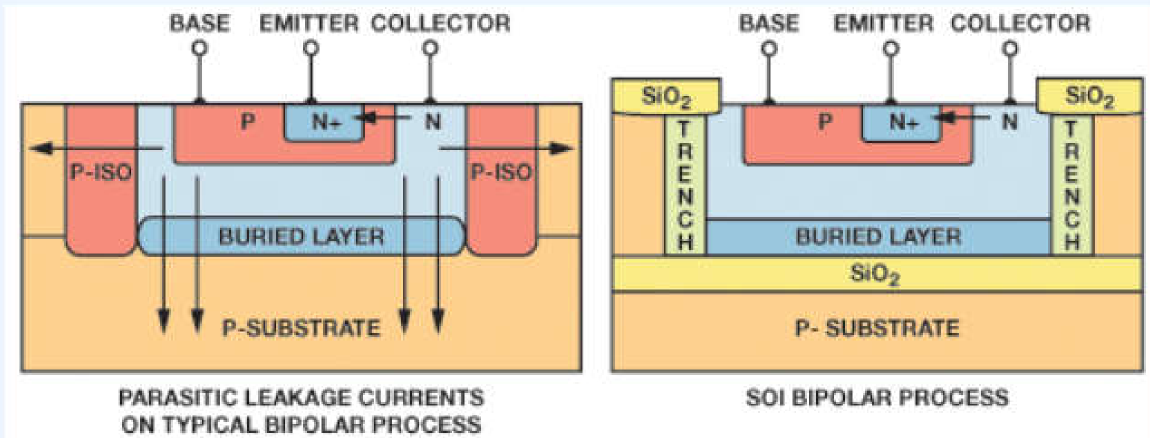

Figure 5. Junction leakage mechanisms in bulk silicon and SOI compared.

Thanks to Analog Devices for the information in this slide.

Leakage issues have been a major cause of failures at high temperature.

Bond Damage

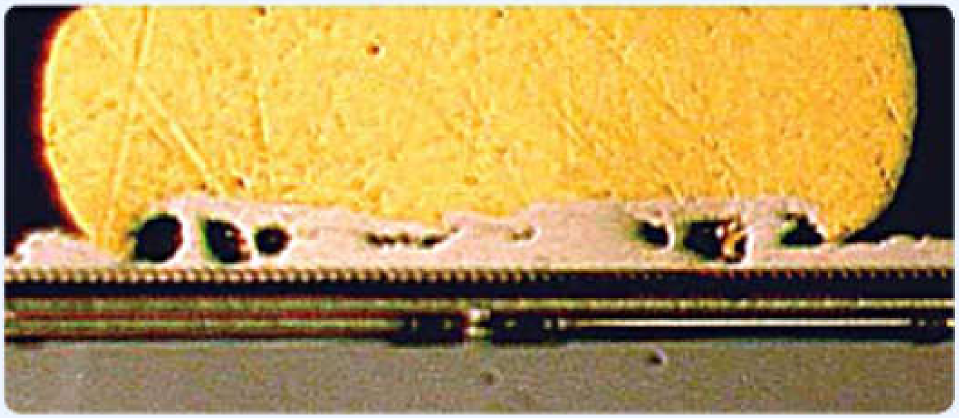

Figure 7. Au/Al bond after 500 hours at 195°C.

Thanks to Analog Devices for the information in this slide.

Packaging is often also a major factor in using COTS parts at high temperature.

Accelerated Testing

To accelerate testing of life and reliability, an accepted practice for electronic components is to perform the tests at an elevated temperature. This introduces an acceleration factor, α, defined by the Arrhenius equation:

$$\alpha = e^{\frac{E_a}{k}\left(\frac{1}{T_a}-\frac{1}{T_s}\right)}$$

where E_a is the activation energy,
k is the Boltzmann's constant,
T_a is the expected operating temperature during use,
T_s is the stress temperature.

Thanks to Analog Devices for the information in this slide.

Example of AD8229

To guarantee the lifetime reliability of high-temperature devices like the AD8229, the *high-temperature operating life* test (HTOL) was run at the maximum rated temperature of 210° C for 1000 hours (approximately six weeks). For lower temperatures, the expected lifetime can be predicted using the acceleration relationship shown in Figure 11.

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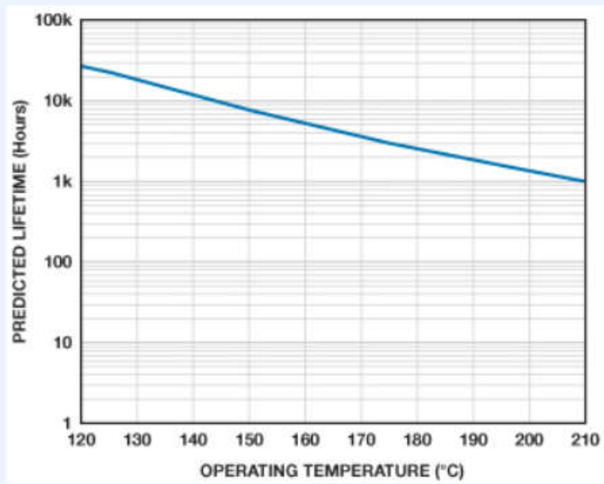

Figure 11. AD8229 lifetime vs. operating temperature, 1000 hours @ 210°C.[11]

Conclusions

- High temperature electronics is a growing market.
- Some existing lower temperature parts may be used at high temperature.
- Failure analysis plays an important role to determine which parts will work and to develop new components.
- Failure analysis of COTS components tested at high temperature (>150 ° C) may provide valuable information to the component manufacturer for use in lower temperature applications.