ADVANCED DATA LOGGING ELECTRONICS FOR HIGH PRESSURE AND TEMPERATURE SUBSURFACE ENVIRONMENTS

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Introduction
Problem
• Instruments in subsurface environments can encounter temperatures and pressures over 400°C and 150 bar
• Enhanced geothermal wells can be up to 3km deep, consisting of temperatures and pressures over 300°C and 150 bar. New wells will have to go deeper and hotter.

Solution
• Silicon Carbide Integrated Circuits provide the ability to operate at high temperatures (300 – 600°C) due to the material properties of SiC—such as a low intrinsic carrier concentration, a large band gap, and a high thermal conductivity.

Methods
A data acquisition platform that begins with high-temperature wireline logging (WL). Data acquisition and power (tan blocks) can be combined with data processing and advanced acquisition platforms (blue blocks) to enable in-situ analysis.

Evaluation and Characterization of Existing SiC Devices
• Characterize available SiC devices - in both HiTSiC® CMOS (Raytheon) and JFET-R (NASA Glenn Research Center) – for high temperature and pressure.

Sensor Development for High Temperature Environments
• Investigate aerosol jet printing as a manufacturing technique for platinum-based resistors, or RTDs.

Analog Electronic Design
• Design an optimized ADC in HiTSiC® and RS-485 in JFET-R, and verify performance using parasitic extracted simulations.

Results

Conclusions
• In SiC semiconductors at high temperature/pressure, the temperature effects dominate pressure effects.
• The RTD printed temperature sensors can be printed on alumina substrates. With optimized cure time, the resistance observed is extremely repeatable.
• Designed CMOS 16 channel 16 bit ADC can achieve up to samples/second at 470°C
• JFET RS-485 can achieve up to 25 kbaud transmission at 500°C

Future Work
• Evaluate chipset blocks
• Design and fabricate pressure and flow sensor modules

Products Developed
1. JFET-R RS-485
2. HiTSiC® SRAM
3. HiTSiC® 10 bit ADC
4. Integrated RTD Temperature Sensor
5. HiTSiC® UV Imager

RS-485 in JFET-R – designed awaiting arrival
10 bit ADC in HiTSiC® – designed
UV Imager in HiTSiC® – ready for evaluation (NASA)

SiC RS-485 Maximum Data Rate (kbaud) Simulation

<table>
<thead>
<tr>
<th>VDD</th>
<th>R0</th>
<th>R15</th>
<th>R30</th>
<th>R0</th>
<th>R15</th>
<th>R30</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°C</td>
<td>12.5</td>
<td>6.3</td>
<td>12.5</td>
<td>6.3</td>
<td>12.5</td>
<td>6.3</td>
</tr>
<tr>
<td>500°C</td>
<td>25.0</td>
<td>50.0</td>
<td>12.5</td>
<td>12.5</td>
<td>6.3</td>
<td>12.5</td>
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R® represents the radius from the center of a wafer in mm.

SiC JFET-R Ring Oscillator Frequency vs Pressure at 475°C
SiC HiTSiC® Ring Oscillator Frequency vs Pressure at 475°C

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In SiC semiconductors at high temperature/pressure, the temperature effects dominate pressure effects.

High temperature and pressure testing of a SiC ring oscillator (Courtesy Arkansas Center for Space and Planetary Science).