World Oil® HPHT
DRILLING, COMPLETIONS & PRODUCTION CONFERENCE
October 30–31, 2018
Norris Conference Centers – CityCentre, Houston, Texas
HPHTConference.com

Rapid Deployment of 200°C High Temperature Electronic Data Acquisition and Control Solutions

Jeff Watson

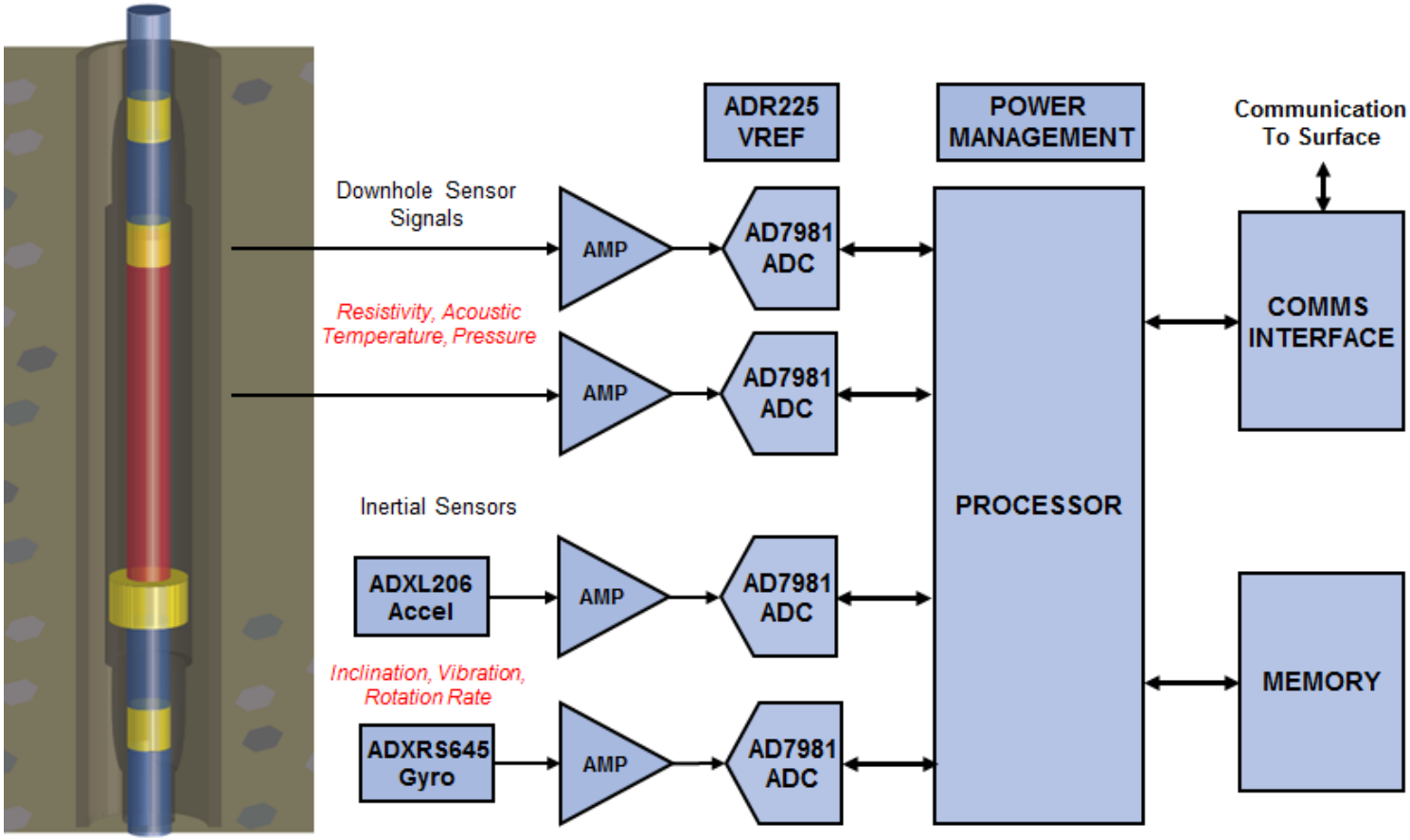
Marketing and Applications Manager

Analog Devices, Inc.

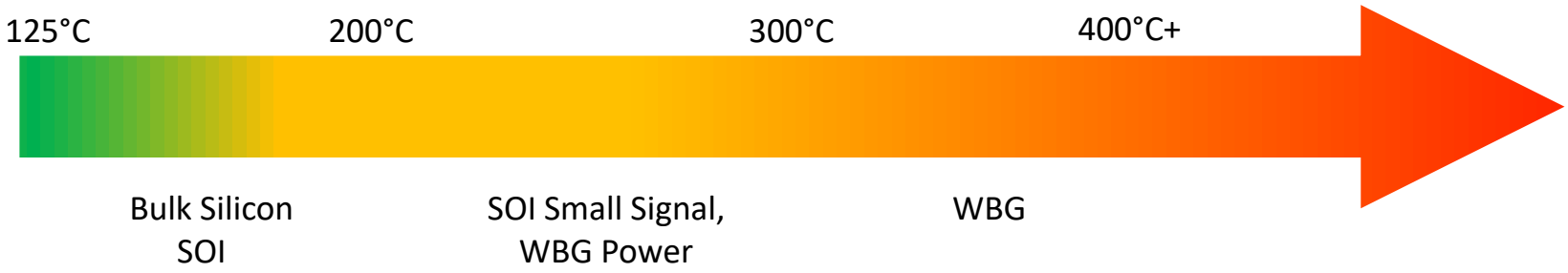
Agenda

- Background and Motivation
- Challenges in HT electronics
- Hardware Architecture Overview
- Software Overview
- High Temperature Construction
- Test Results
- Summary

Typical Down-Hole Tool



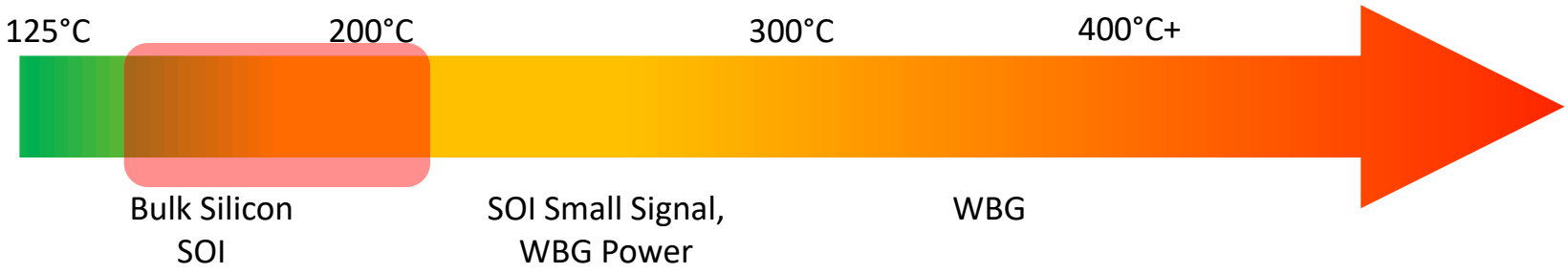
Semiconductor Technology Summary



Types of HT products commercially available today (~225 ° C max):

- Bulk Silicon, SOI:
  - Op Amps, Power Management, Simple Logic, Data Conversion, Microcontroller, DSP, Interface, MEMS sensors, Gate Drivers, etc
- SiC:
  - JFETs, BJTs, Diodes, etc

Semiconductor Technology Summary

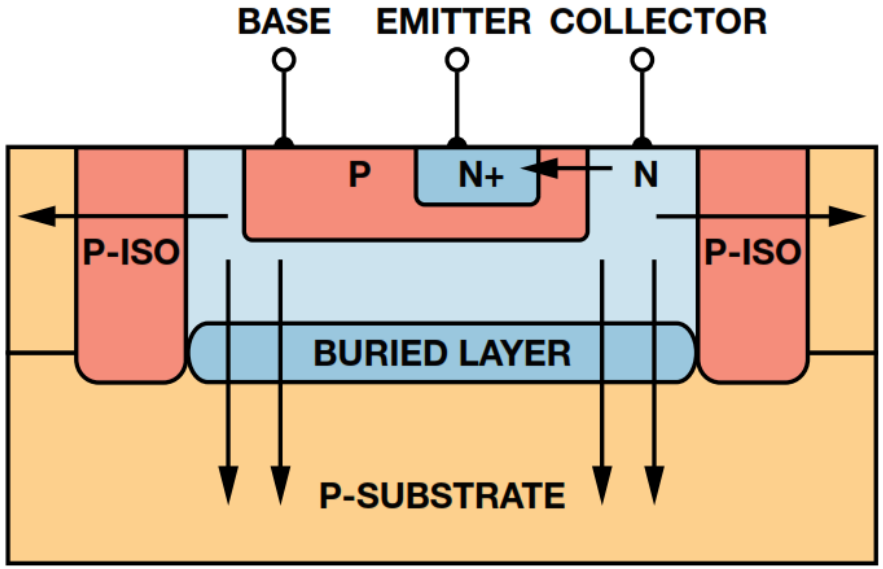


Types of HT products commercially available today (~225C max):

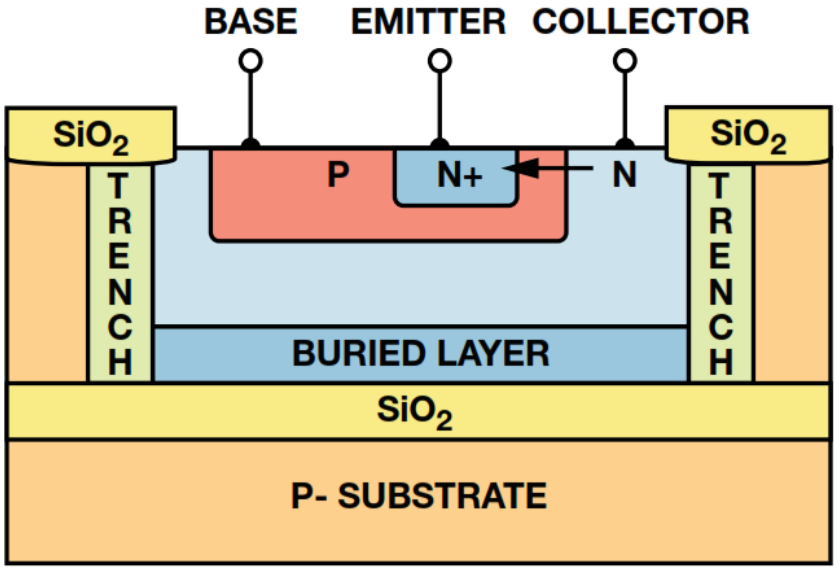
- Bulk Silicon, SOI:
  - Op Amps, Power Management, Simple Logic, Data Conversion, Microcontroller, DSP, Interface, MEMS sensors, Gate Drivers, etc
- SiC:
  - JFETs, BJTs, Diodes, etc

Silicon on Insulator Process

- High performance 36V analog complimentary bipolar process
- Very low leakage at elevated temperatures
- All supported devices modelled at high temperature (225C)

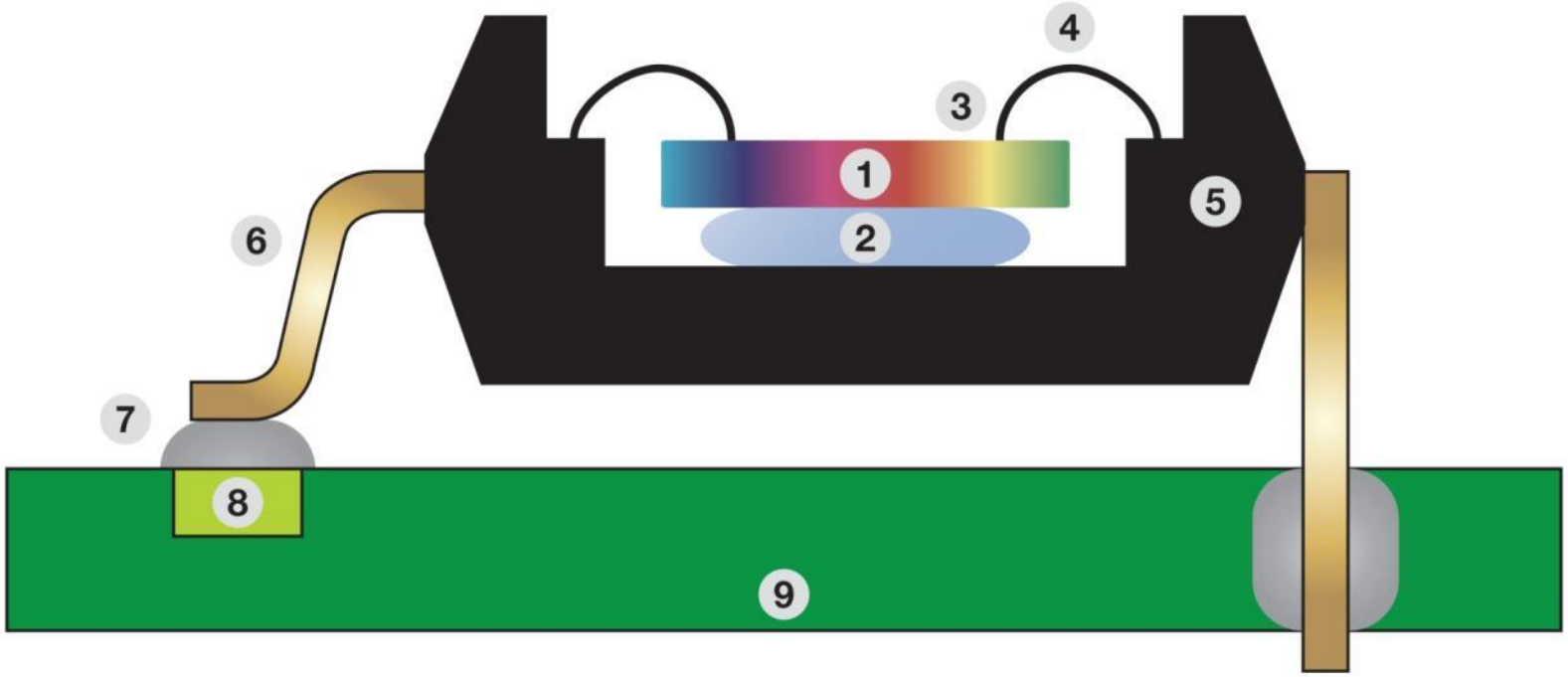


PARASITIC LEAKAGE CURRENTS
ON TYPICAL BIPOLAR PROCESS



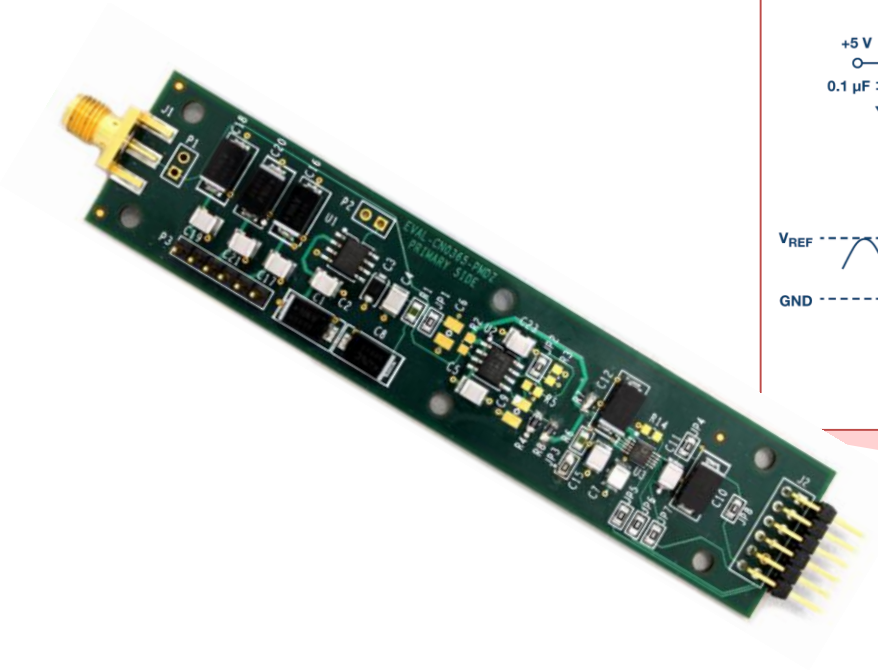
SOI BIPOLAR PROCESS

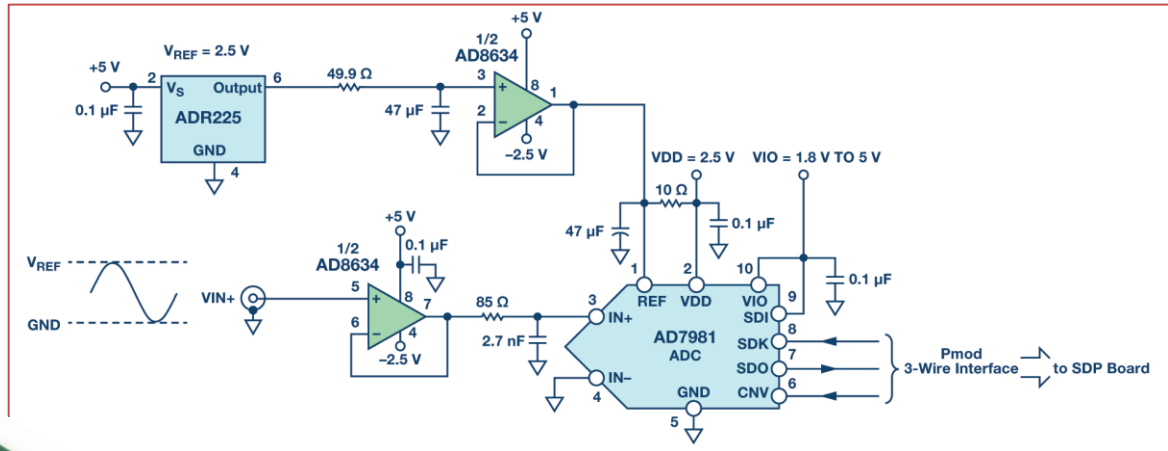
Critical Parts of a High Temp IC Construction

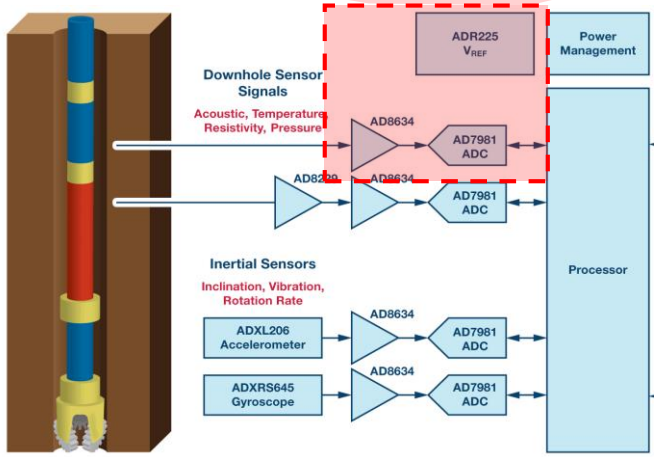


[1]SILICON
[2]DIE ATTACH
[3]BOND-PAD METALLIZATION
[4]BOND WIRES
[5]PACKAGE
[6]PINS
[7]PIN SOLDER INTEGRITY
[8]PCB TRACES
[9]PCB-THERMAL INTEGRITY

HT Data Acquisition Single Channel



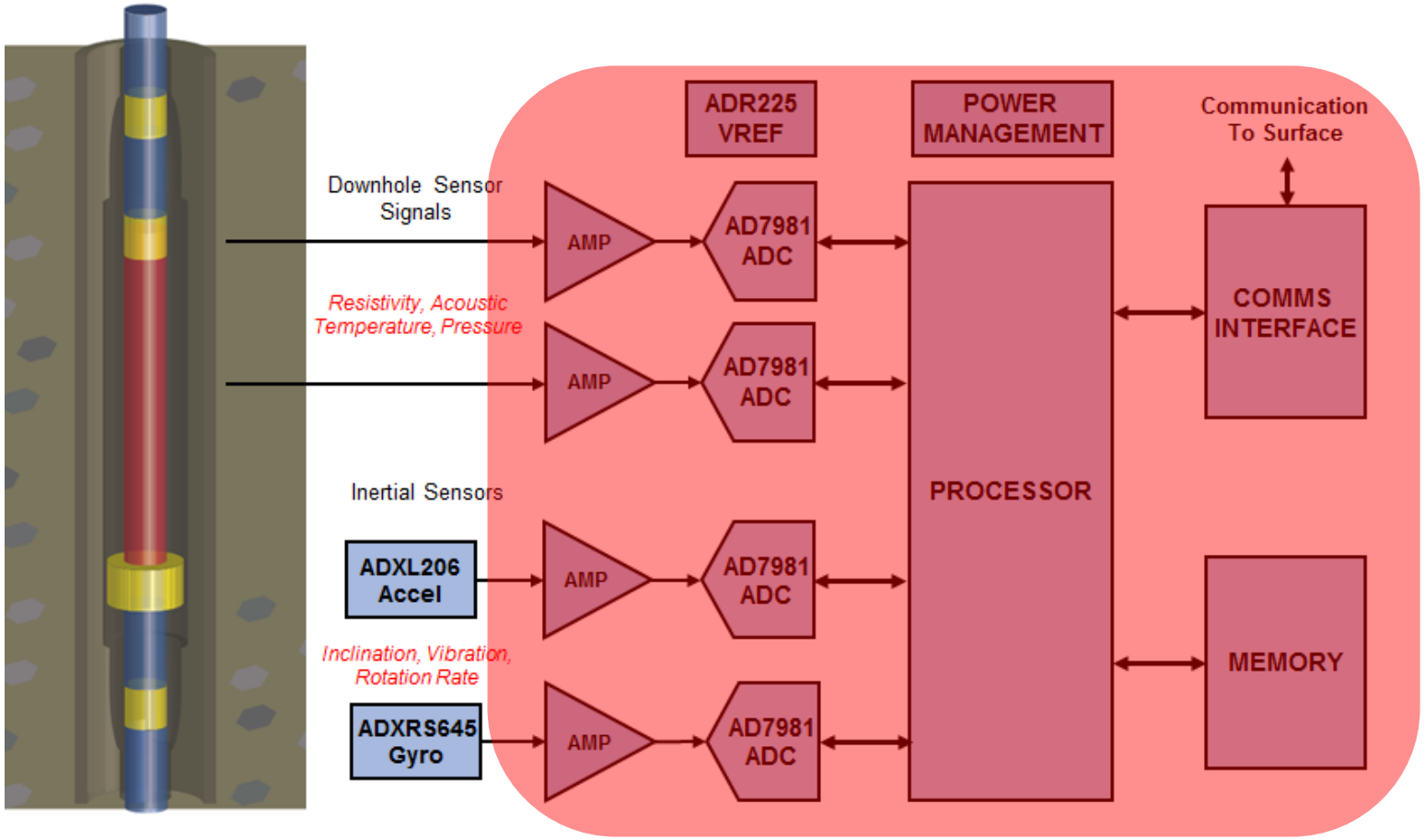




CN-0365: 16 b, 600 kSPS data acquisition system

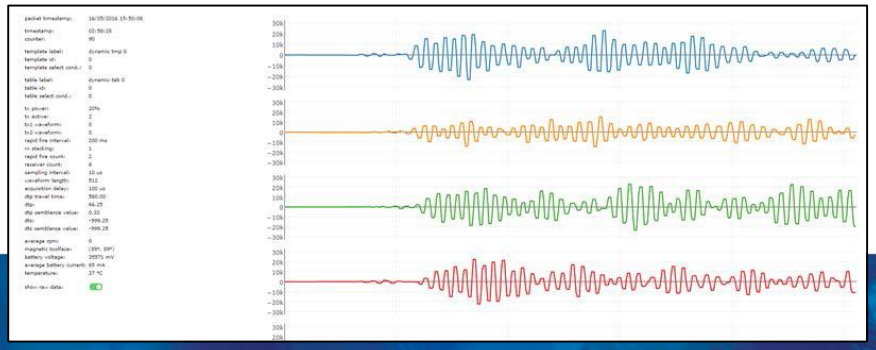
- ADI's first high temperature, 175°C characterized reference design
- Sensor-to-bits solution for oil and gas, avionics and heavy industrial applications
- Decreased customer design and evaluation time
- Demonstrates our commitment to robustness and competence in harsh environment applications

… But we really want all of this:



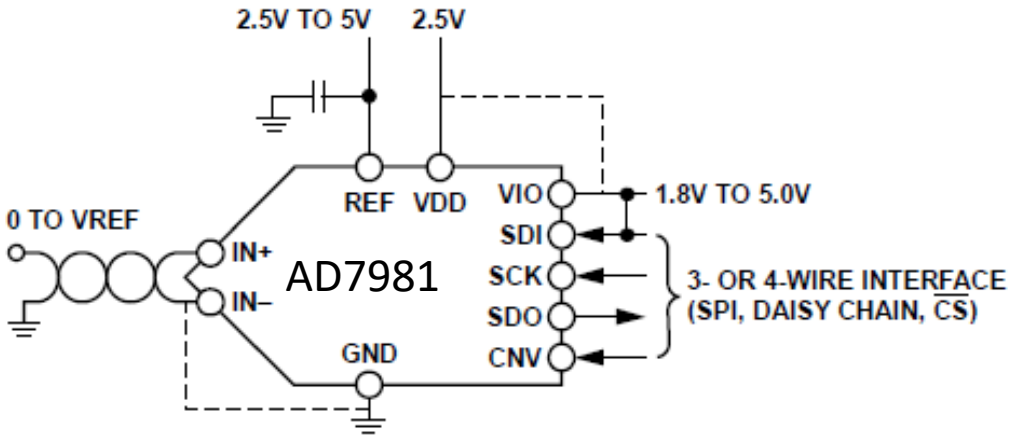
Reference Design Objectives

- Demonstrate a complete functional electronic system including 200°C hardware, firmware, PC software and design documentation, useful for applications in downhole Oil and Gas, aerospace and other harsh environment systems
- Provide a rapid development platform for prototyping and evaluation using the ADI signal processing hardware combined with partner HT components (ARM processor, flash memory, power management, etc)
- Reference design will be structured to take advantage of the AD7981 SAR ADC architecture
  - High Precision, 16b NMC, 91dB SNR @ 210°C, 600ksps
  - Focus on low power, scalable with throughput
  - Simplified power requirements (number of rails and sequencing)
  - Flexible sampling to suit variety of sensors, two fast channels and eight multiplexed channels
- Deliverables include tested circuit assembly, schematics, PCB design files, BOM, firmware project files, user guide, source code for PC software



AD7981: 16-Bit ADC, 600Ksps 175°C, 210°C

- Key Features
  - 16 Bit resolution with no missing codes
  - 600 ksps throughput
  - INL: ±2.0LSB Guaranteed (MSOP)
    ±2.5LSB Guaranteed (FLATPACK)
  - SINAD: 90.5dB typ @ 1kHz, 5V ref
  - THD: -102dB @ 1kHz
  - Single supply 2.5V operation with 1.8V/2.5V/3V/5V logic interface
  - High Temperature Packaging:
    - -40°C to +175°C, 10L MSOP, KGD
    - -40°C to +210°C, 10L Ceramic FLATPACK
- Applications
  - Downhole Drilling and Instrumentation
  - Avionics, Heavy Industrial Electronics
  - High Temperature Environments



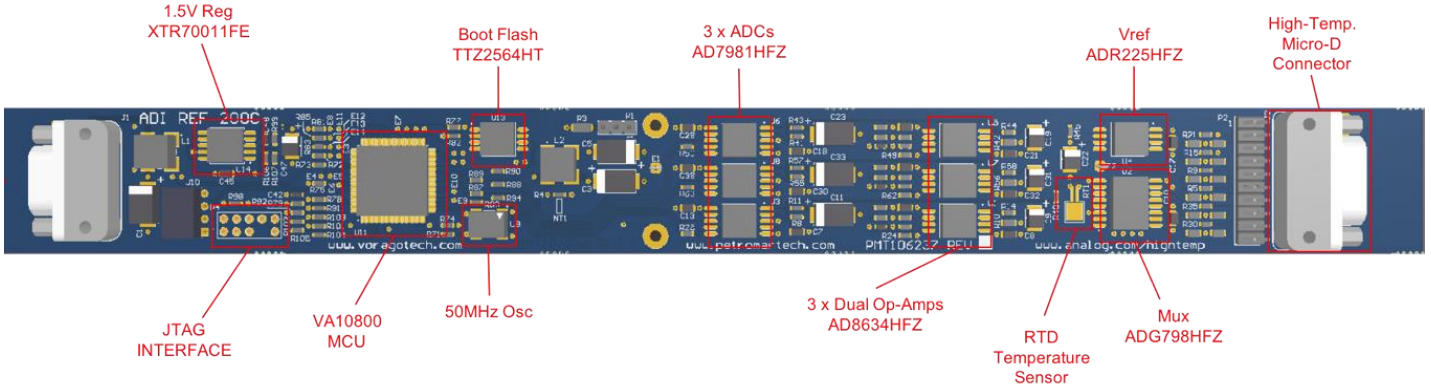
Advantages

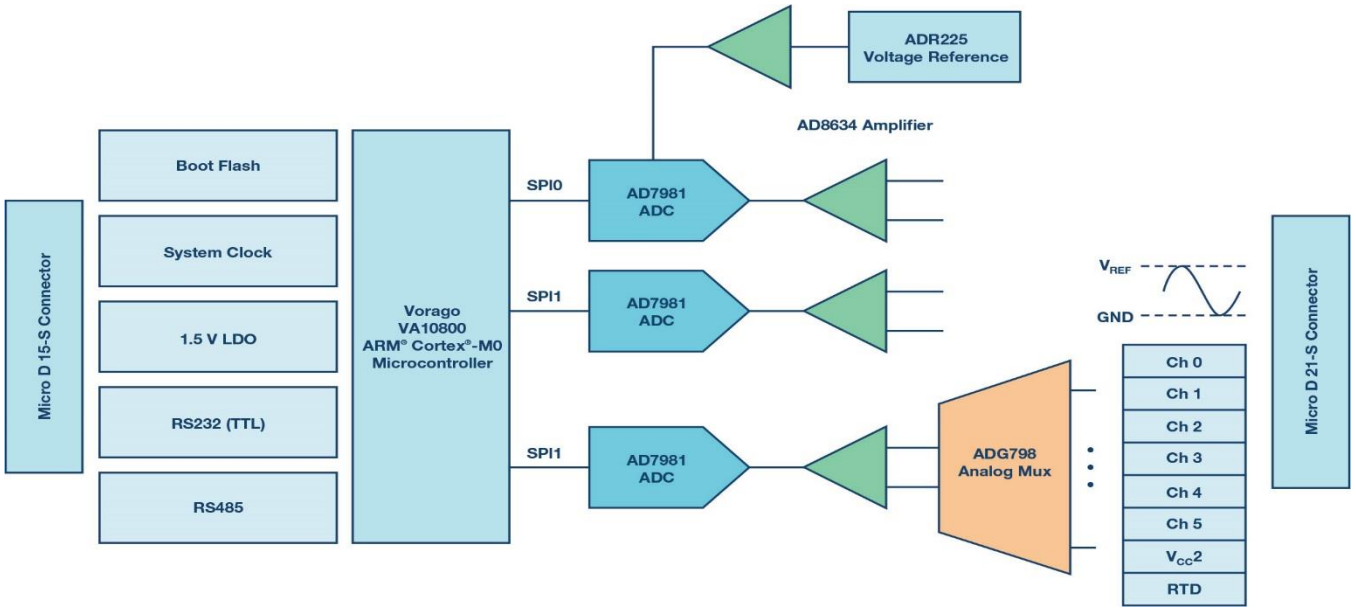
Offering accurate, fast analog to digital conversion at extreme temperatures, AD7981 is optimized for low power and space-constrained applications. Available in two small, surface mount packages.

Resolution	Power Supply	Power Dissipation	Interface	SNR	Temp
16 Bits	2.5V to 5V	5mW @ 600ksps 70µW @ 10ksps	SPI 1.8V/2.5V/3V/5V	91dB @ 1 kHz	MSOP: -40°C - 175°C Flatpack: -40°C - 210°C

World Oil® HPHT
DRILLING, COMPLETIONS & PRODUCTION CONFERENCE

EV-HT-200CDAQ1 Block Diagram





World Oil® HPHT
DRILLING, COMPLETIONS & PRODUCTION CONFERENCE

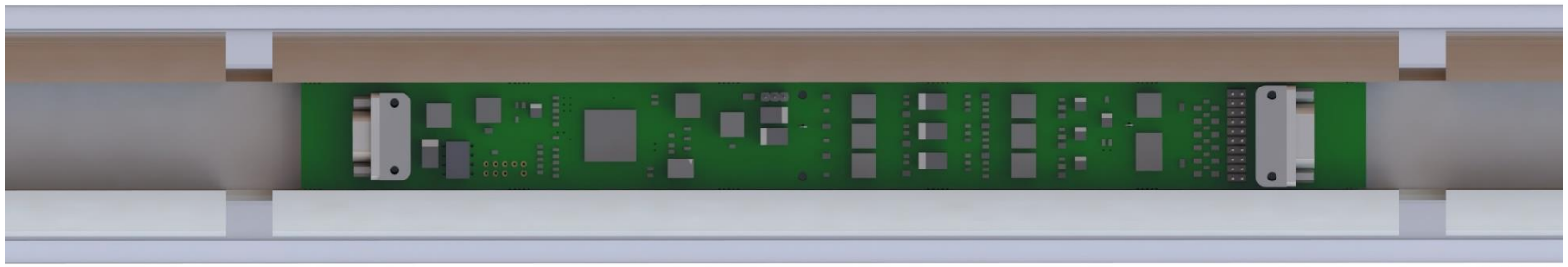
EV-HT-200CDAQ1 High Level Features

- All components and assembly materials rated for 200°C
  - 200 hour qualification
- Downhole friendly form factor – 1.1”x11.5”
- TTL UART, optional RS485 communications
- 10 channels of high precision ADC conversion
  - (2) direct channels 400ksps max
  - (8) multiplexed channels 16ksps (including temp sensor, Vcc)
- Multiple GPIO, option for external triggering
- Up to 16kB conversion result buffer
- JTAG debug connector for easy programming and debugging

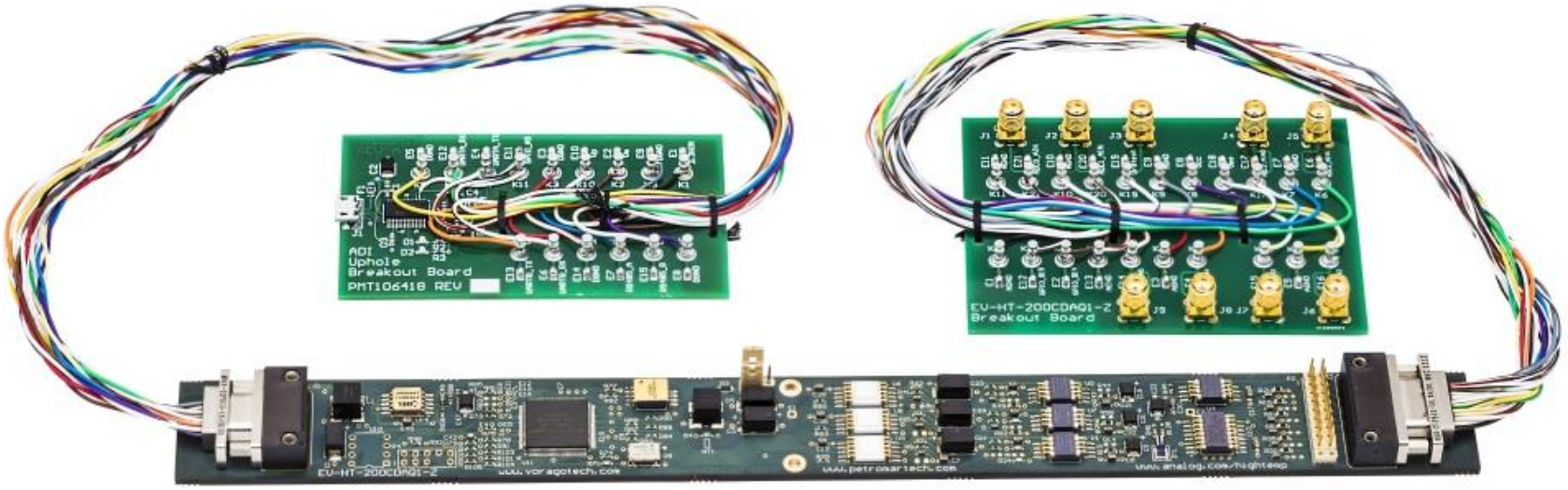
Flexible Power Domains

- Option to power the board with separate analog bipolar supplies for higher precision operation
- …OR single +3.3V supply with limitation on analog input range and performance
- Power mode set with a single high temp jumper on board

Hardware Form Factor



Hardware Form Factor



1.1”x11.5”

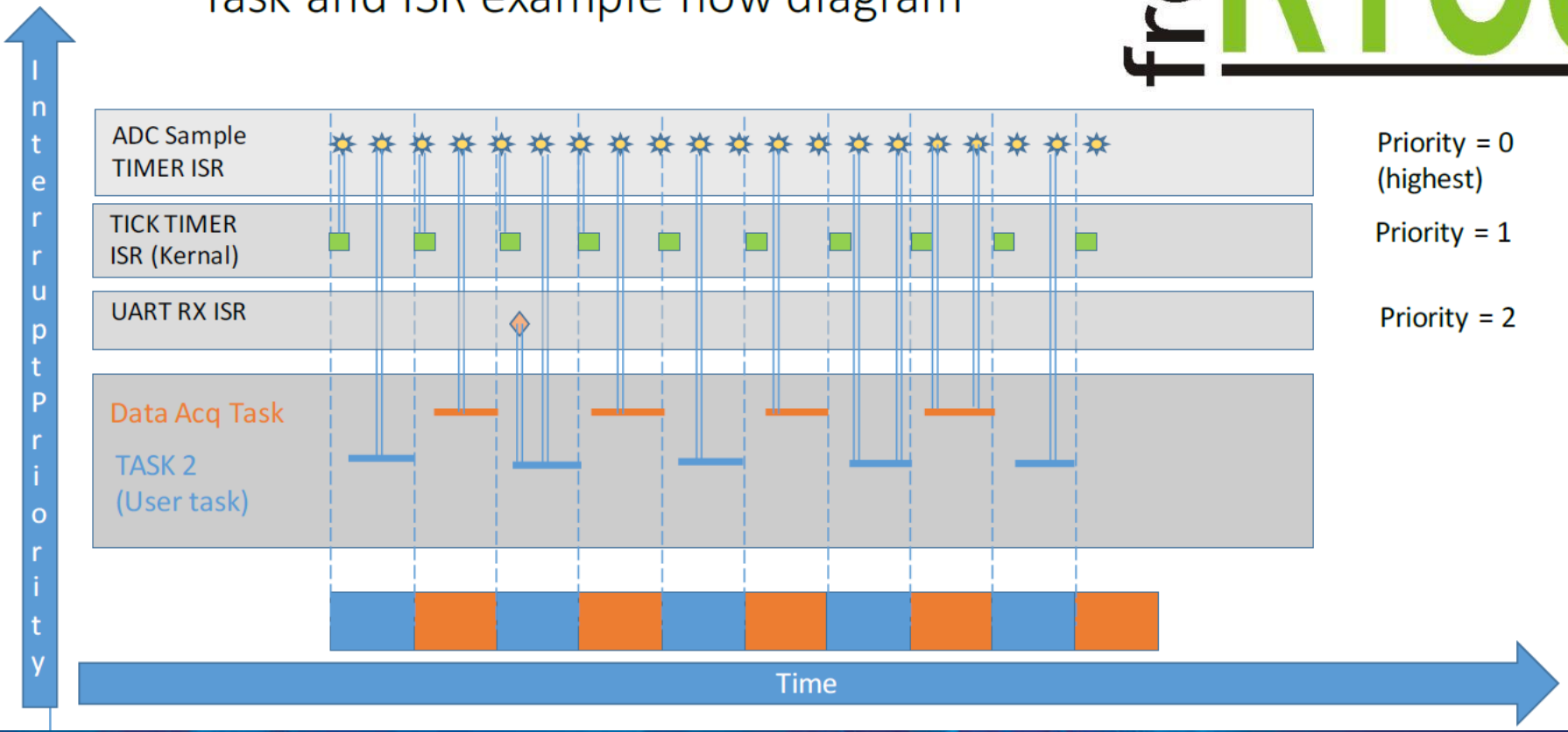
Software Overview

- Firmware and Desktop software design driven by a protocol definition, which enables flexible data acquisition optimized for resource constrained systems
- Bust Acquisition Mode: A fixed number of samples from selected channels is obtained in one shot and processed, optionally repeating at a fixed interval of time. Useful for frequency domain analysis and high throughput triggered measurements.
- Continuous Acquisition Mode: A sample from each selected channel is acquired at a fixed time interval and processed. Useful for time domain analysis and lower throughput continuous measurements.
- Streaming Operation: Both modes are setup for streaming out of the RS232 port for visualization and data capture on PC
- RTOS Integration (FreeRTOS)

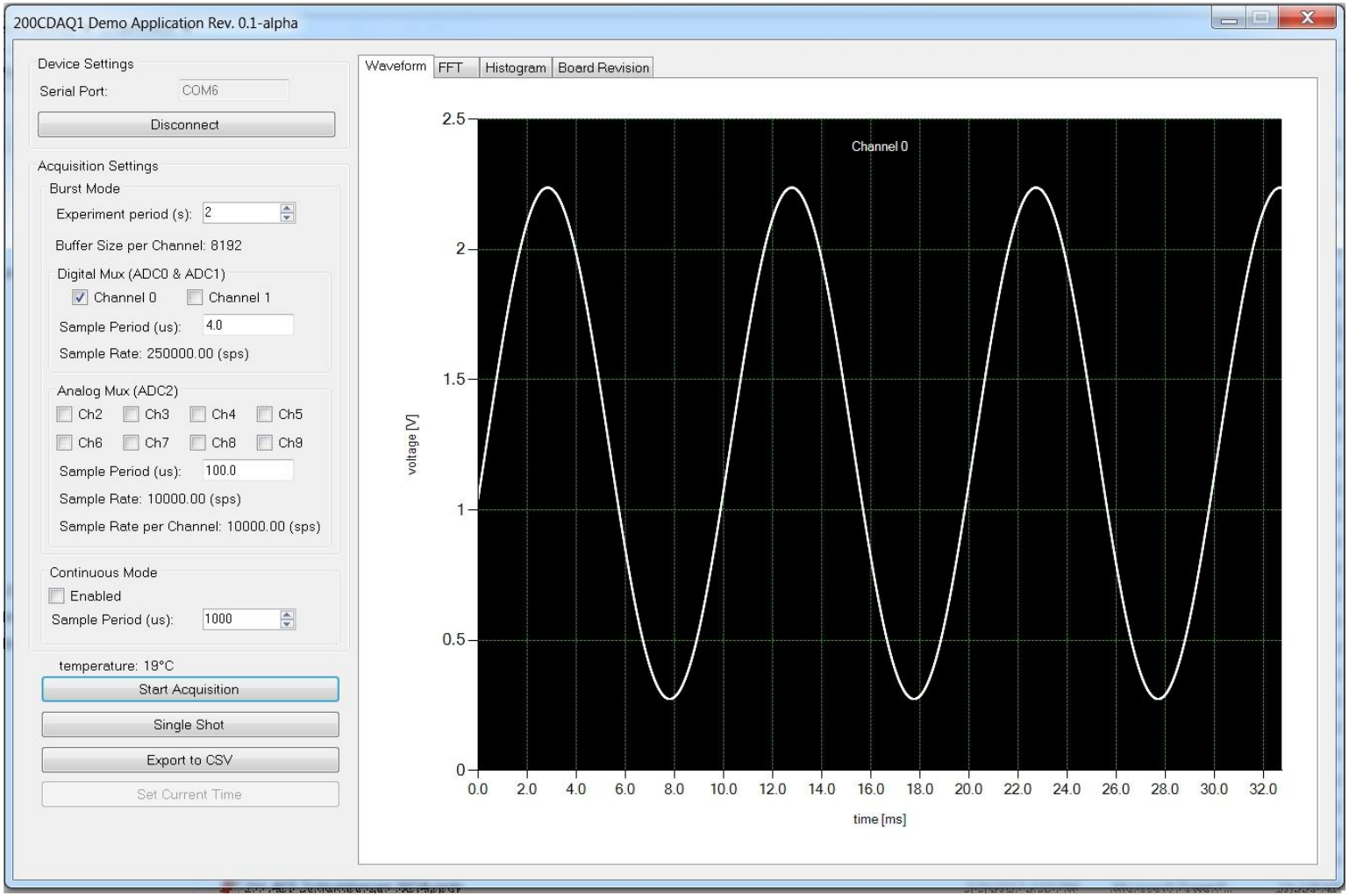
Firmware Architecture

freeRTOS

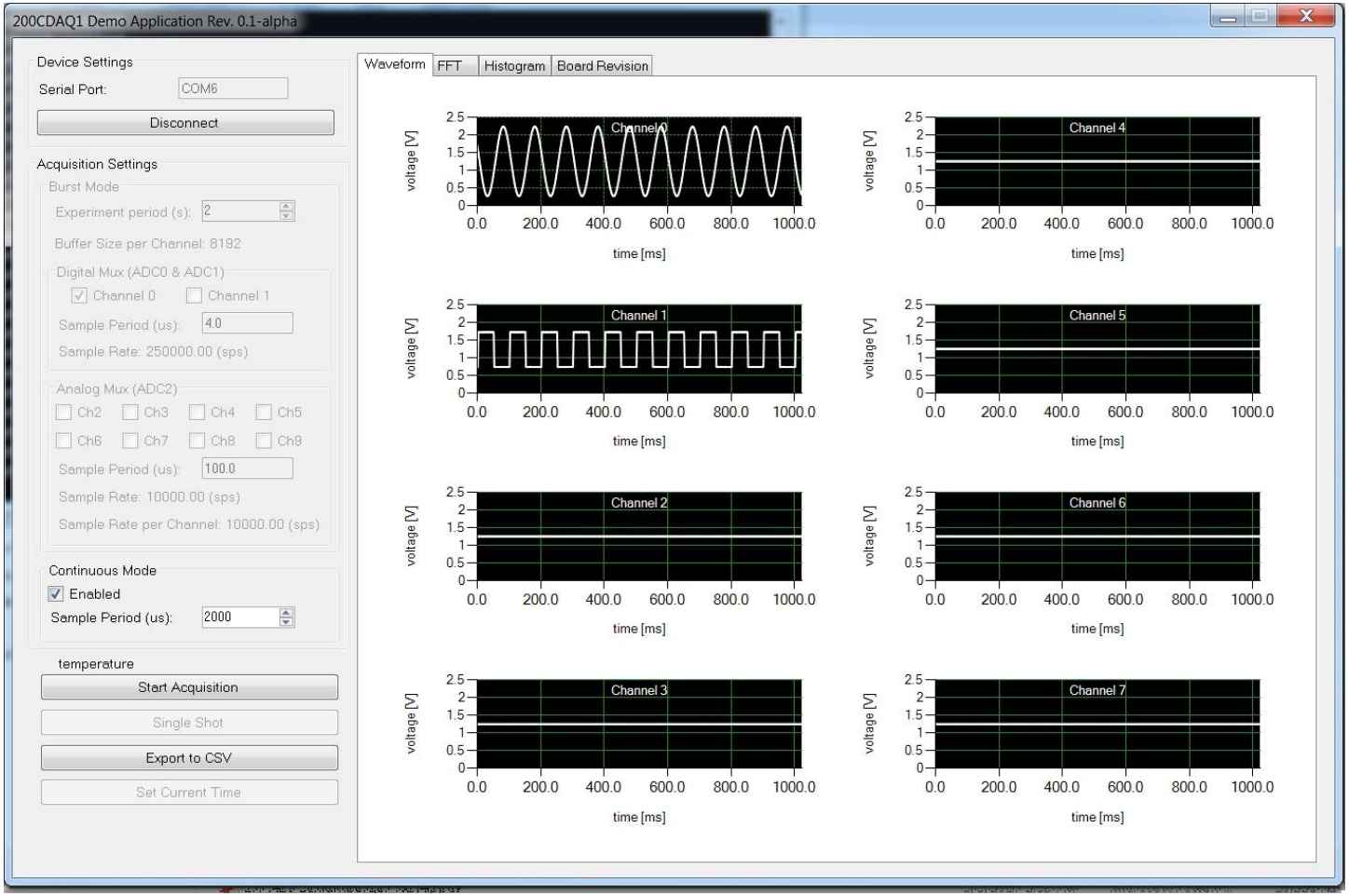
Task and ISR example flow diagram



PC Data View / Capture Software – Single Channel

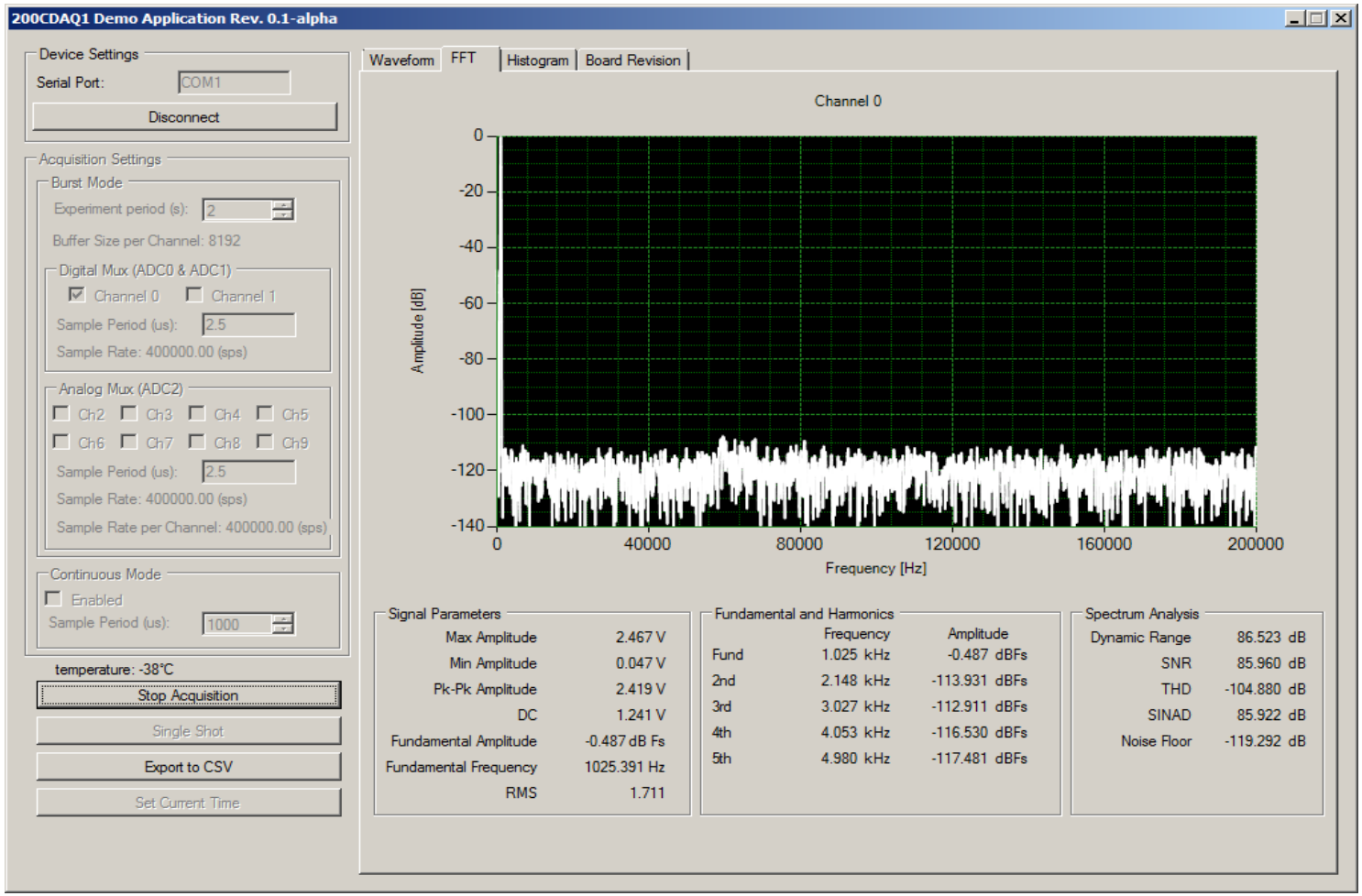


PC Data View / Capture Software – 8 Channel



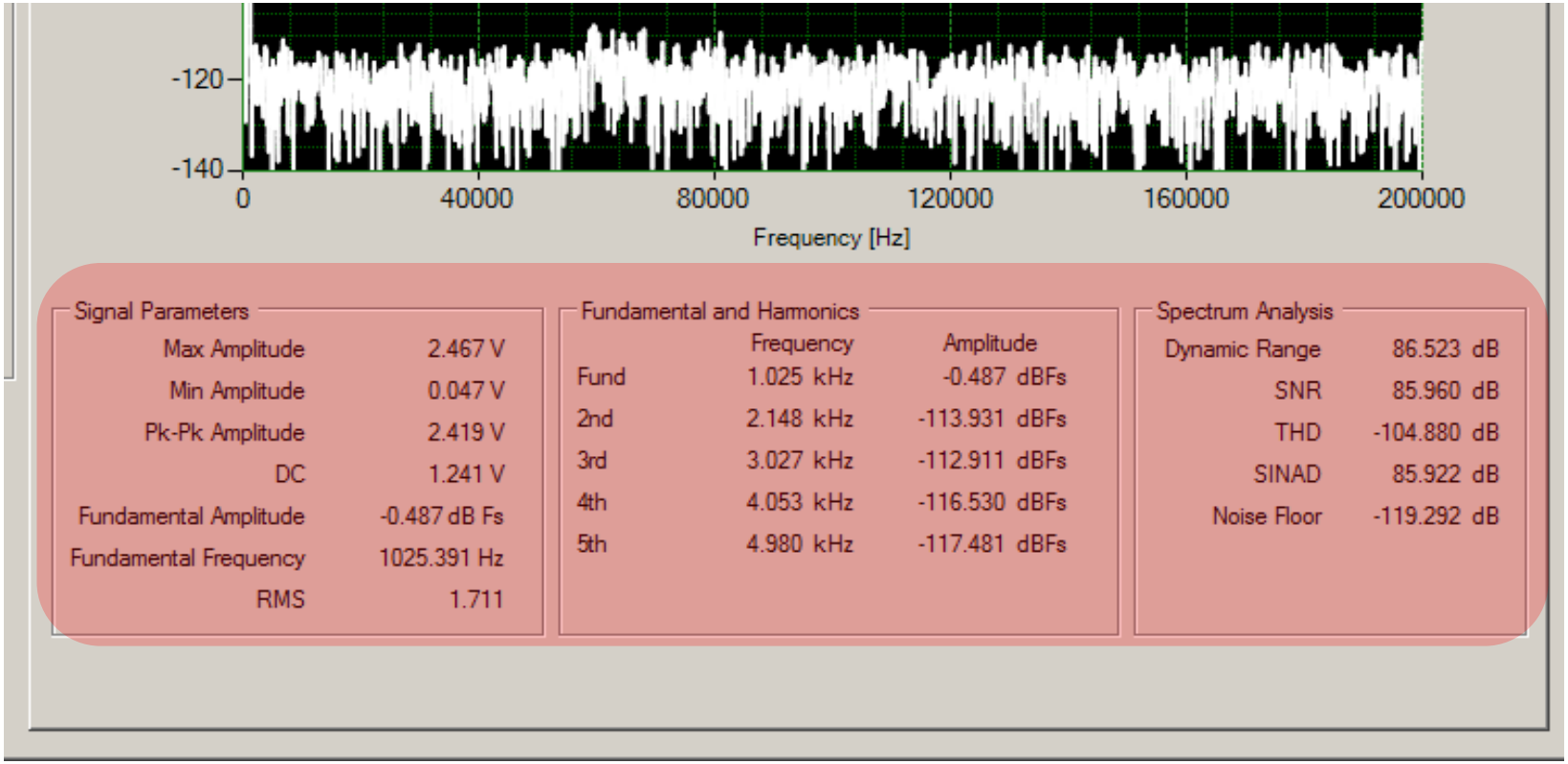
World Oil® HPHT
DRILLING, COMPLETIONS & PRODUCTION CONFERENCE

PC Data View / Capture Software - FFT



World Oil® HPHT
DRILLING, COMPLETIONS & PRODUCTION CONFERENCE

PC Data View / Capture – Spectrum Analysis



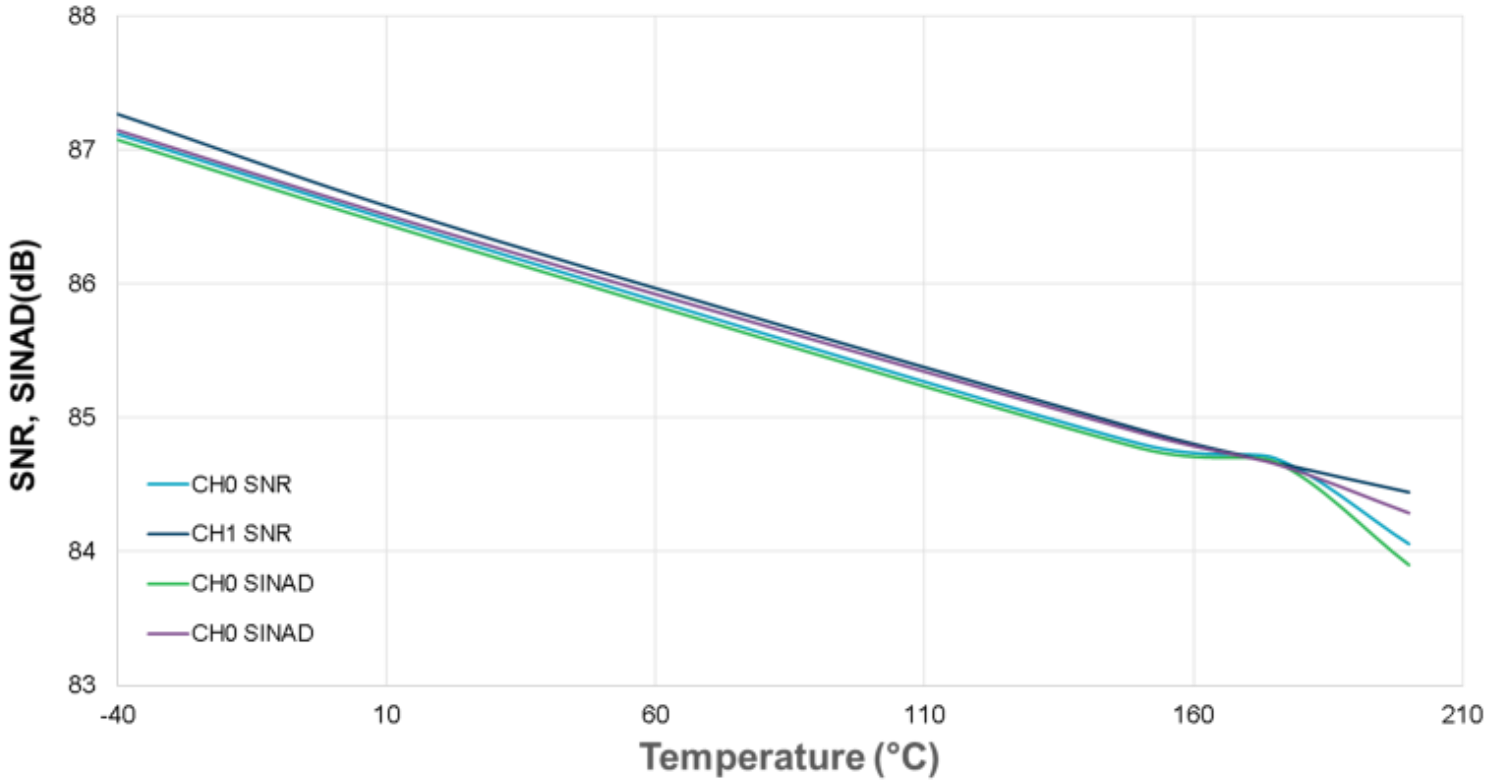
Software Overview – Source Code

- All source code, project files and documentation will be made freely available for embedded processor and desktop application
- Firmware includes Keil project files
- Desktop PC software is C# .NET based and includes project files as well

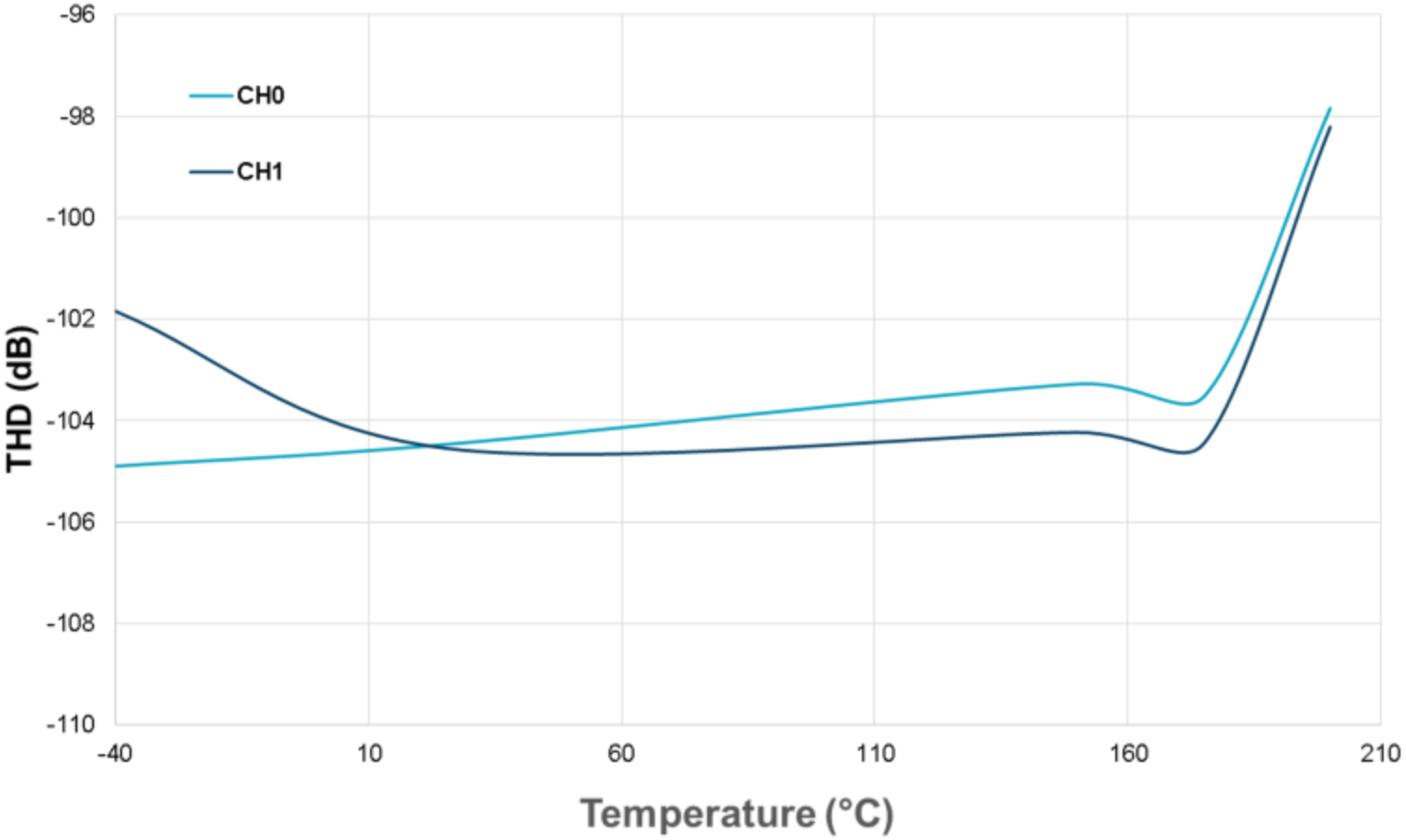
High Temperature Construction

- ICs, passives, connectors, etc high temp rated by vendor (with exception of some mechanical pieces, i.e. pins)
- Component layout, sizes, materials carefully selected for electrical and mechanical performance over temperature
- PCB laminate: Polyimide High Tg, Bromine Free (Arlon 85N)
- Surface Finish
- High Melting Point Solder (Lead Free Sn95Sb05)
- High Temp Passives, Connectors
- 200 hour min qualification
- Production test at high temperature

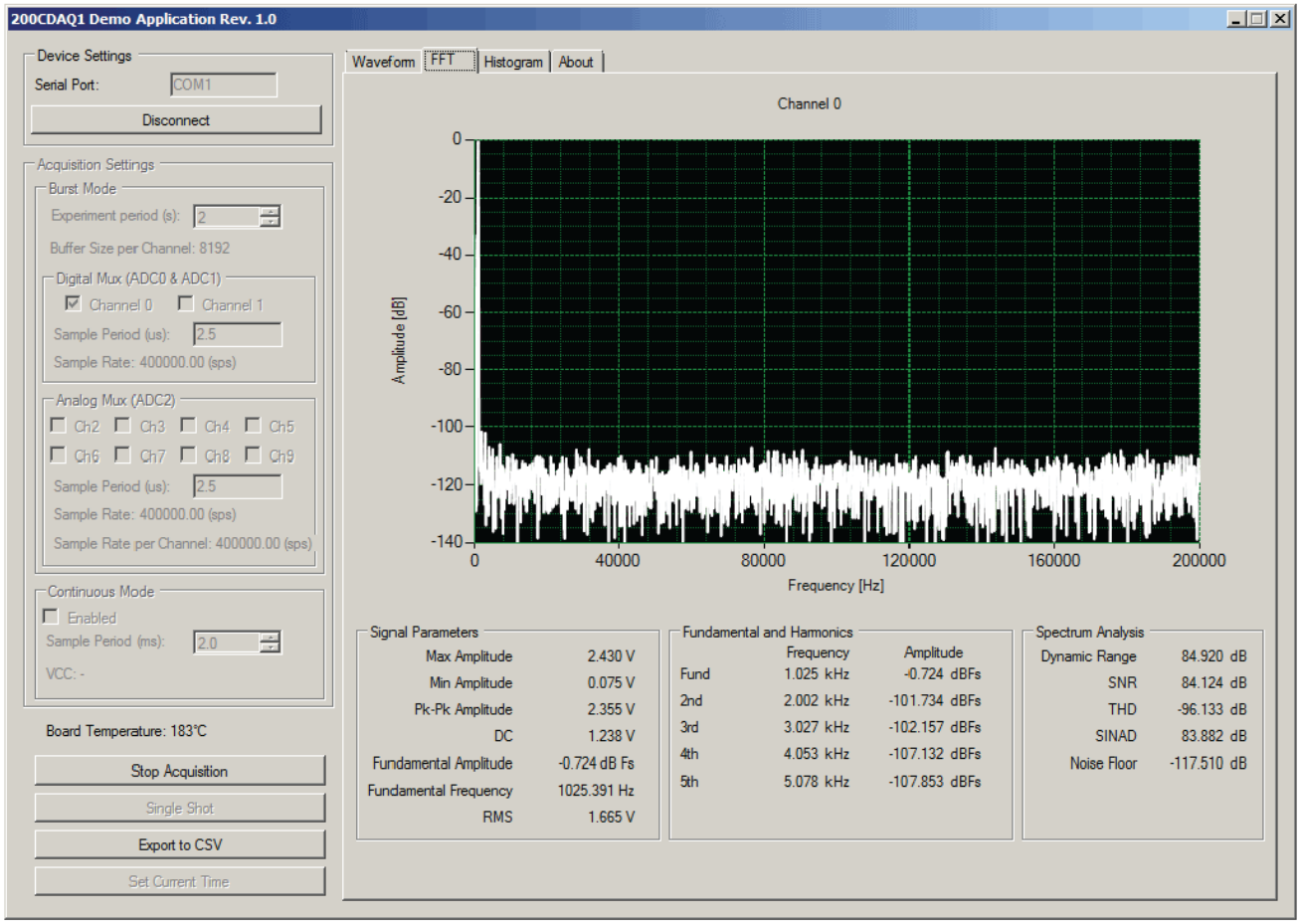
AC Characterization – SNR, SINAD



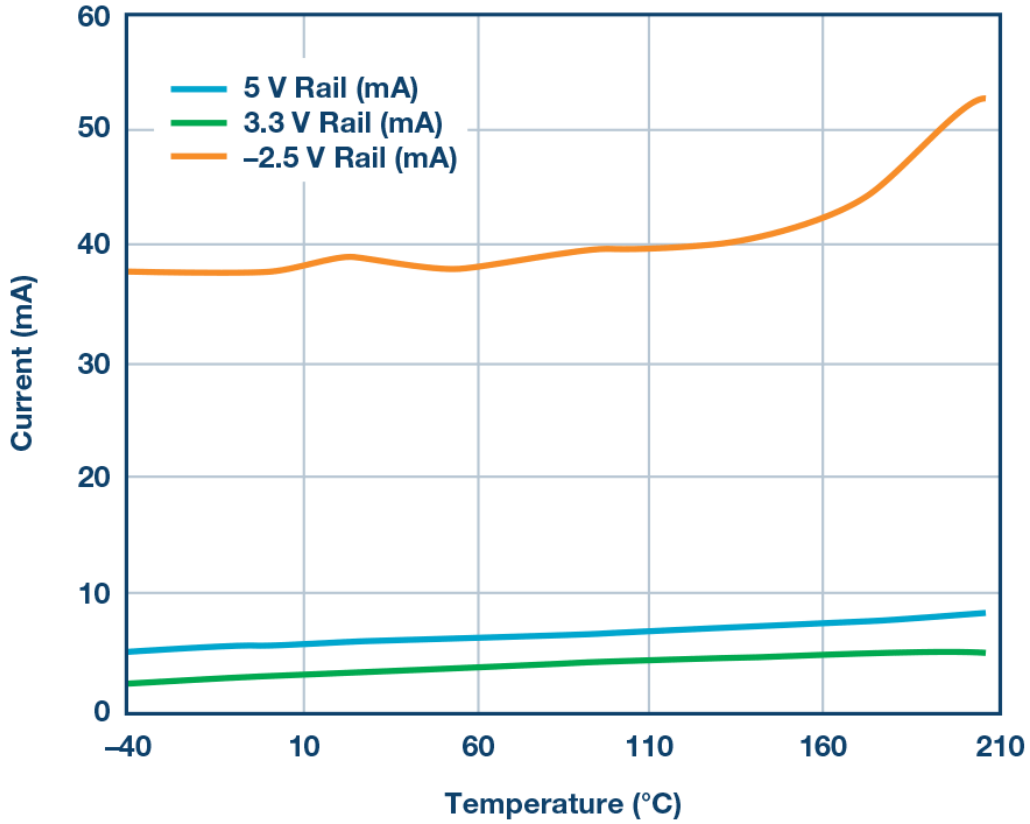
AC Characterization – THD



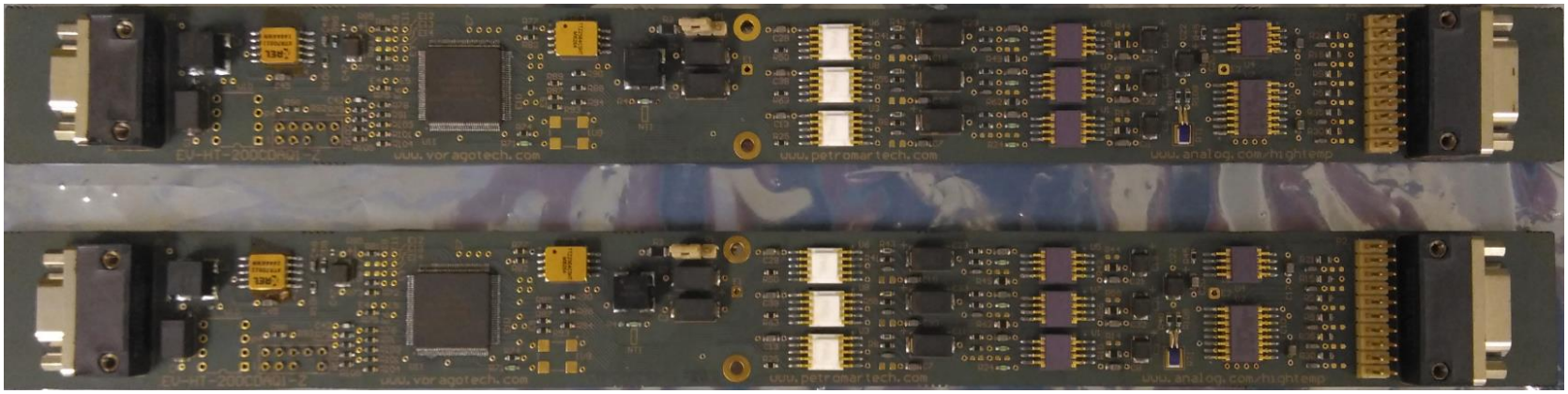
AC Characterization – Spectral Analysis @ 200°C



Power Consumption



200 hour, 200°C Temp Soak



Summary

- We presented a new, highly integrated data acquisition reference platform qualified and characterized for 200°C operation.
- Allows designers to use the latest state-of-the-art components for rapid prototyping and evaluation, minimizing development time and time to market
- Only high temperature qualified components have been selected and the board has been developed using best practices and materials so that it is ready to be operated under high temperature conditions off the shelf.
- In order to provide flexibility to designers who want to use this design as a reference, the design files, schematics and bill-of-materials are provided as is all source code and documentation for firmware and software.