SAND2011-7876 C

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Dewarless High-Temperature Seismic Tool for EGS

Geothermal Research Council Conference 2011

Presented By

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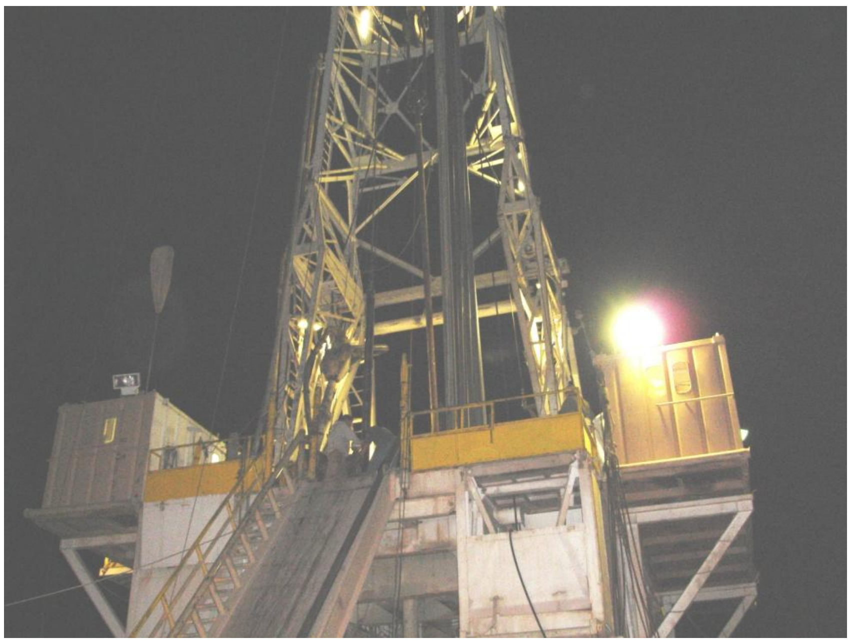

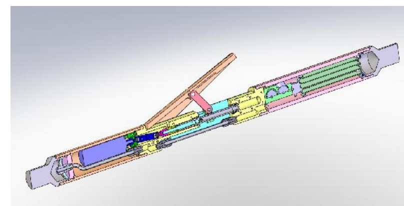

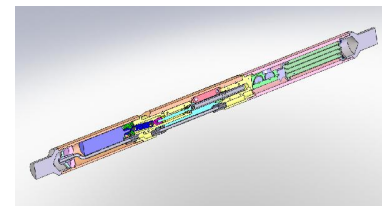

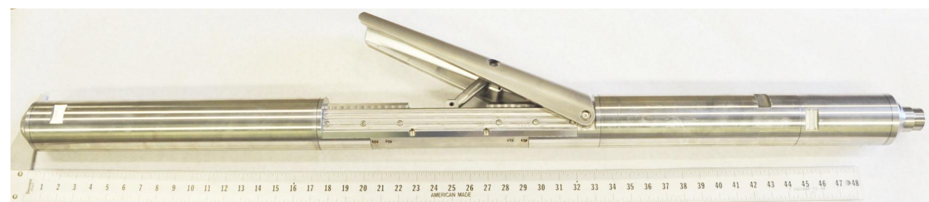

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Overview

- Program Objectives
- Hardware Design
- Electronics and Sensors
- Clamping Arm Drive Motor
- Field Testing
- Future Work
- Conclusions

Program Objectives

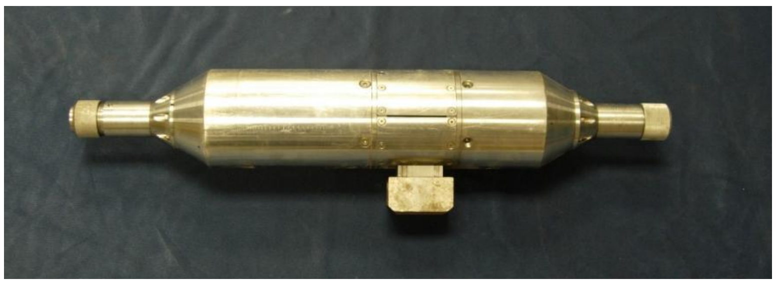
- Design, fabricate and field test a HT Seismic Tool in an EGS application.
  - Seismic tools enable real-time mapping of fractures during well stimulation.
- Work with commercial partner in the development of the tool
  - Pinnacle Technologies
  - Harvey Mudd College
- Develop two electronic designs:
  - 240°C SOI Tool (Continuous, 17000 hour life)
    - Three axis, 1 uG (based on electronics)/ 100 Hz seismic sensitivity (Honeywell 18 bit A/D converter)
  - 210°C Tool (Continuous, 1000 hour life)
    - Three axis, 1 uG (based on electronics)/ 1000 Hz seismic sensitivity (Texas Components, Texas Instruments 24 bit A/D converter)

Why a HT Seismic Tool?

- **EGS requires stimulation of drilled wells, most likely through hydraulic fracturing**
  - **Microseismic monitoring provides one method of real-time mapping of fractures**
    - **During creation of reservoir, monitoring helps to assess stimulation effectiveness and provides information necessary to properly create the reservoir**
    - **After reservoir is established, monitoring can provide information on reservoir performance and evolution over time**
- **No HT seismic tool exists that will operate continuously at well temperatures > 125 -150°C**

Hardware Design

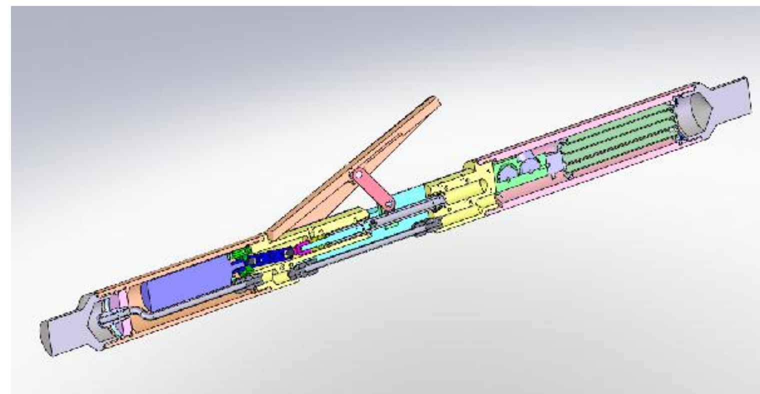
Low temperature Sandia-designed seismic tools

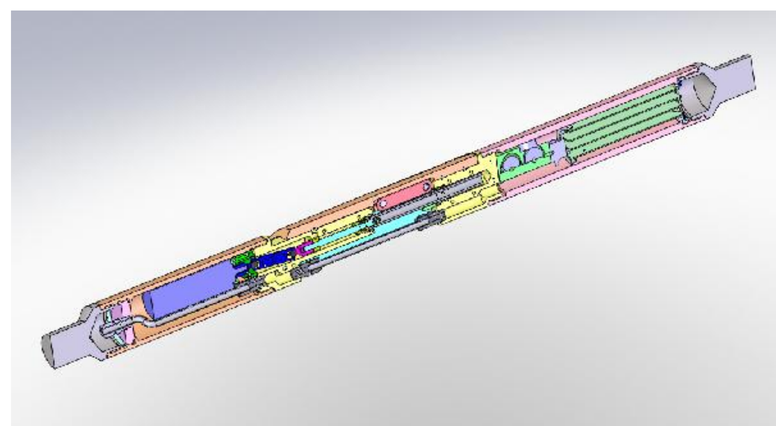


Prototype tool

Commercialized tool

High temperature Sandia-designed seismic tools

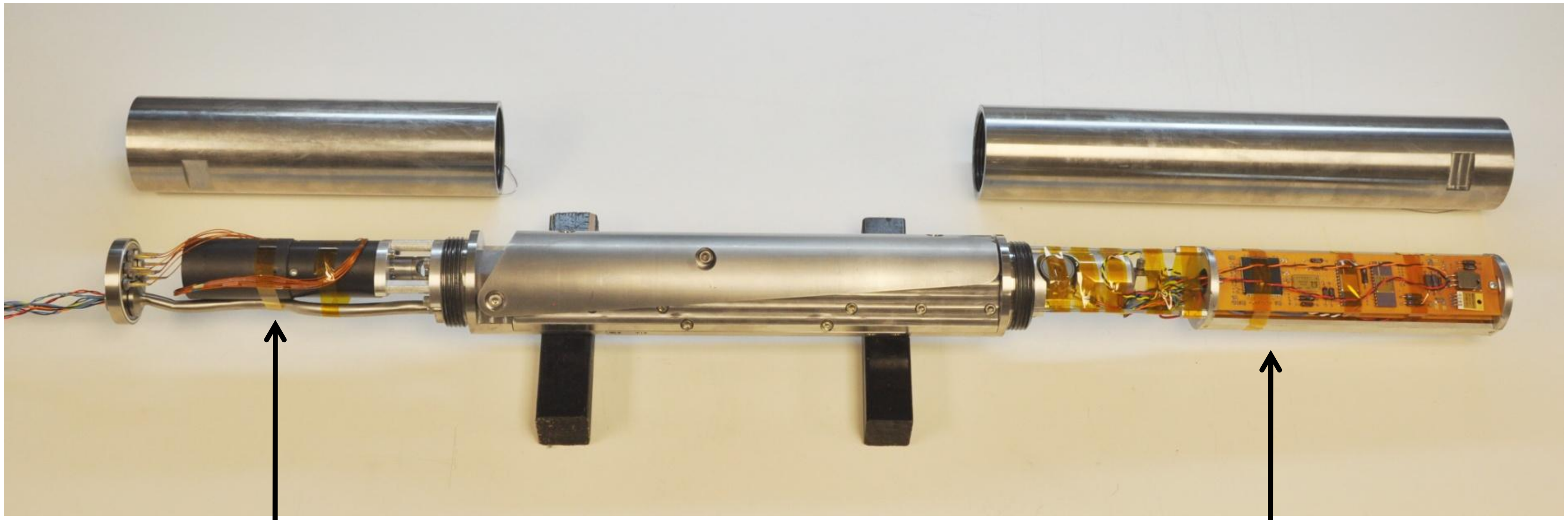




Hardware Design (Continued)

- **Design Highlights**
  - All metal seals
  - Shear pin for emergency extraction
  - Stepper motor drive for arm
  - Electronics design for 240°C operation; exception is the high resolution 24 bit A/D (210°C; 1000 hrs)

Tool Assembly

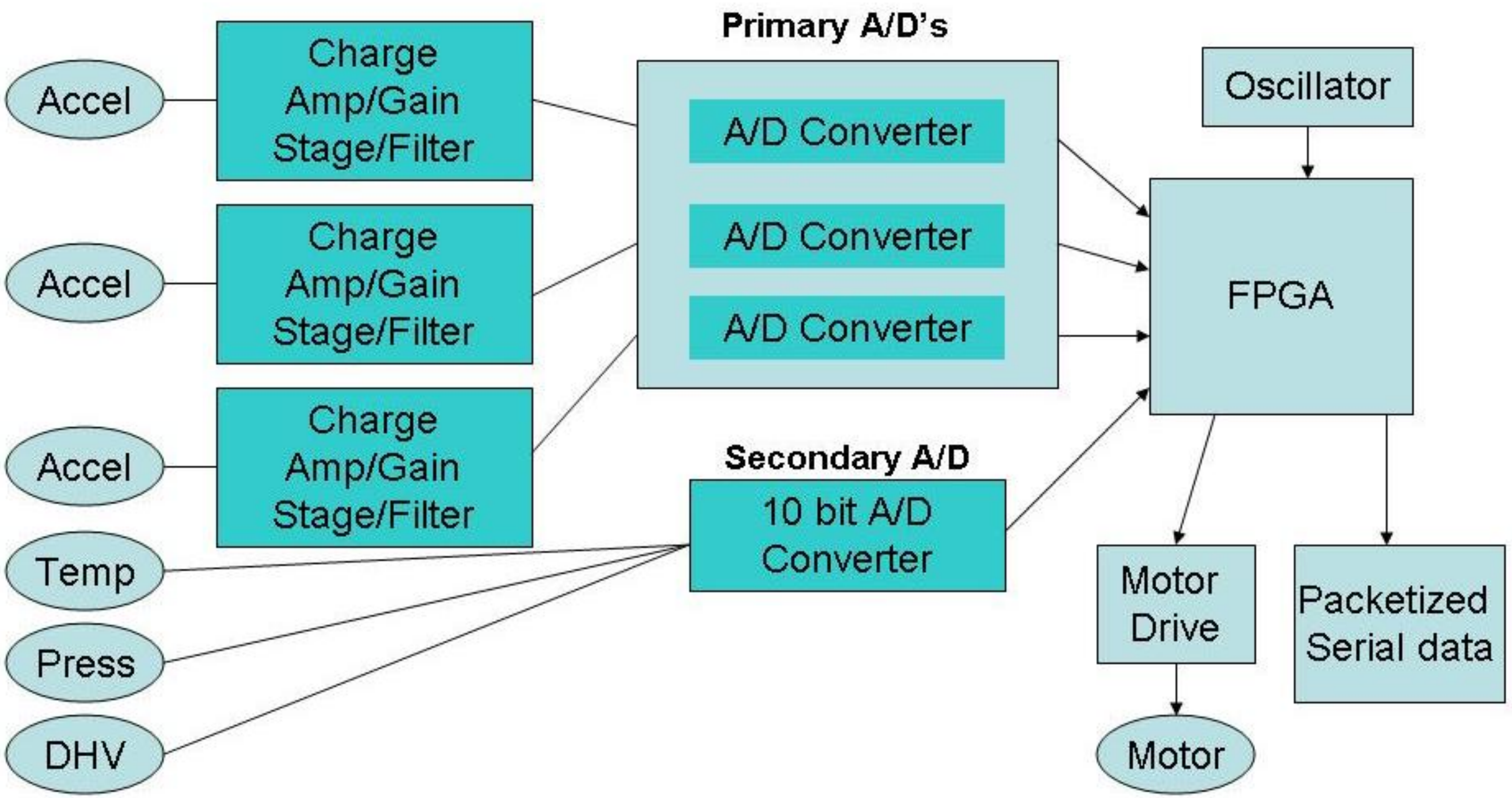


HT Stepper Motor

Electronics/Sensor Package

Electronics consists of four boards, two board sets are assembled and tested up to 200 – 240°C

Block Diagram of Electronics

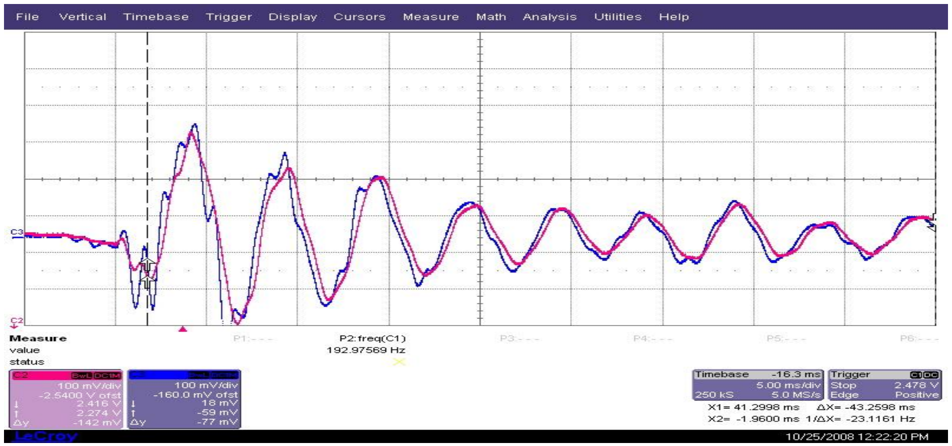


Two high resolution A/D converters have been evaluated with acceptable results. (Texas Components TX424 and the newly available Texas Instruments ADS1278)

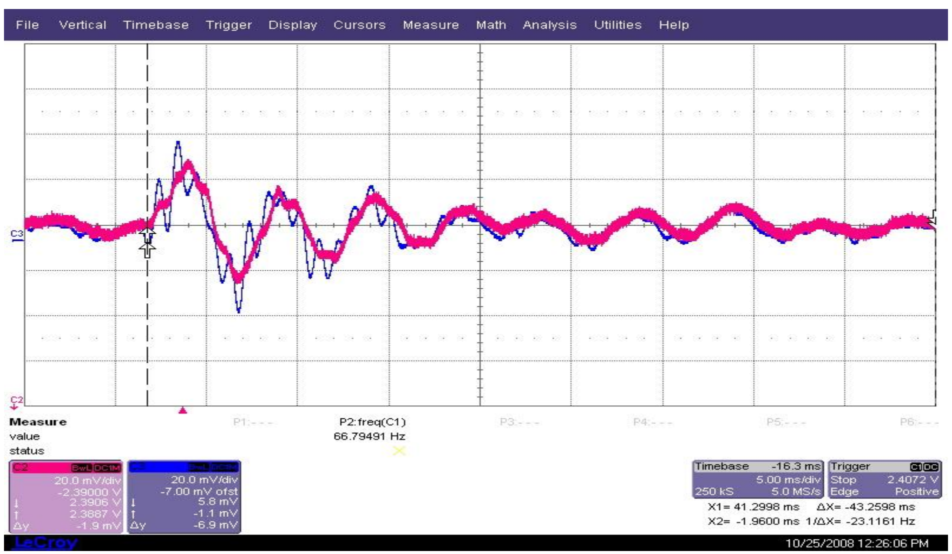
Seismic Sensor Selection

- **Seismic sensor desired specifications**
  - Resonant frequency > 3 KHz
  - Operational frequency range - DC to 2 KHz
  - Maximum operating temperature range > 240°C
  - Sensitivity > 50ug
  - Low cross-axis sensitivity
  - Shock survivability > 5000 g
- **Seismic sensor options**
  - Geophone
    - Best suited for detecting low frequency events (<100 Hz)
    - Prone to cross-axis sensitivity issues
    - Rated to 200°C with limited life
    - Shock limit approximately 500g
  - Accelerometer
    - Resonant frequency > 10kHz
    - Operational frequency range - 1Hz to 3 kHz respectively
    - Maximum operating temperature range – 260°C
    - Sensitivity – 1000 pC/g
    - Shock limit approximately 1000g

Vibration Response of LT and HT Sensors



50 mg vibration test



4mg vibration test

The graphs at the left compare the output of a low temperature seismic sensor to the HT seismic sensor with the HT signal conditioning circuits

Even in an open (unshielded) setup, it is evident that an acceleration level of less than 2mg can easily be detected. In a shielded setup, one would expect a factor of approximately 50 – 100 improvement in sensitivity.

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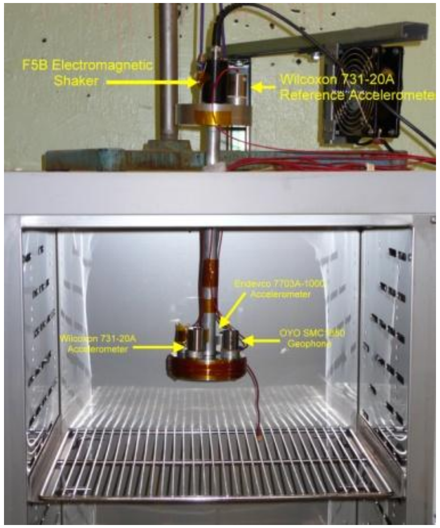
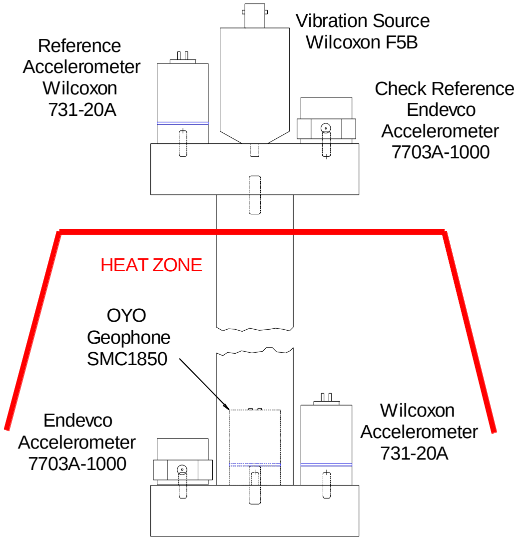
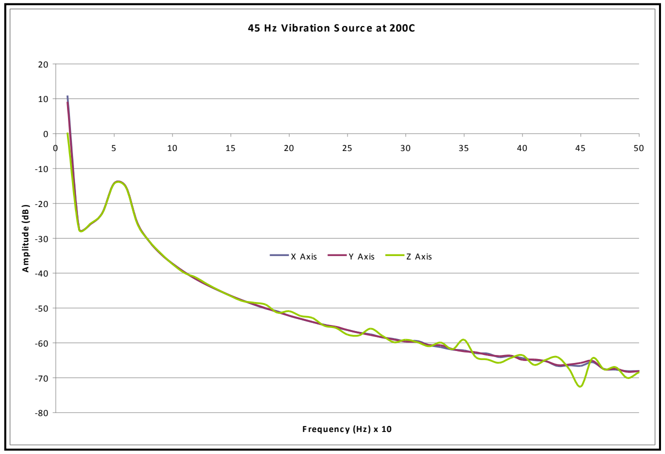
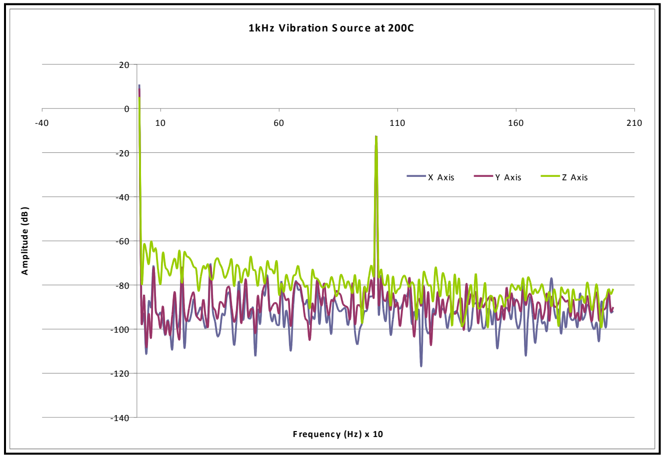
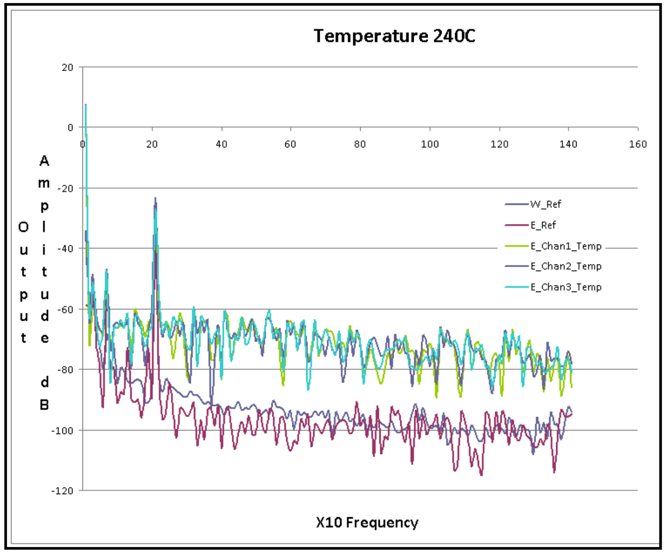
Vibration Response at 200°C and 240°C

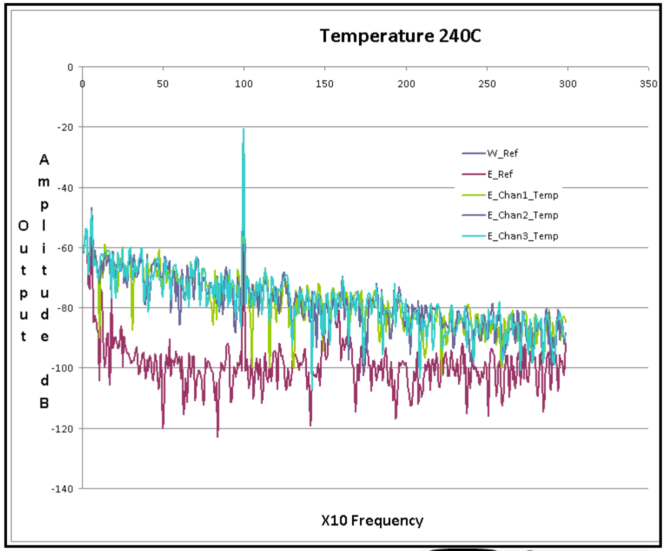












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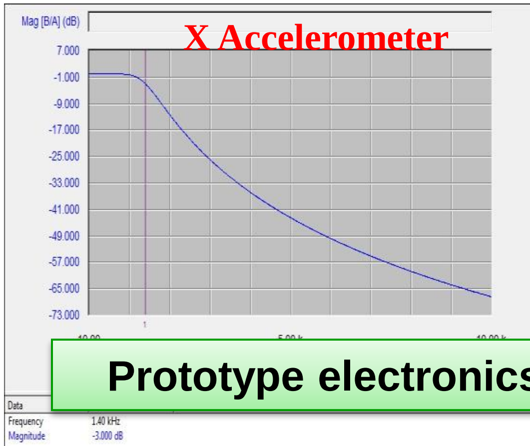
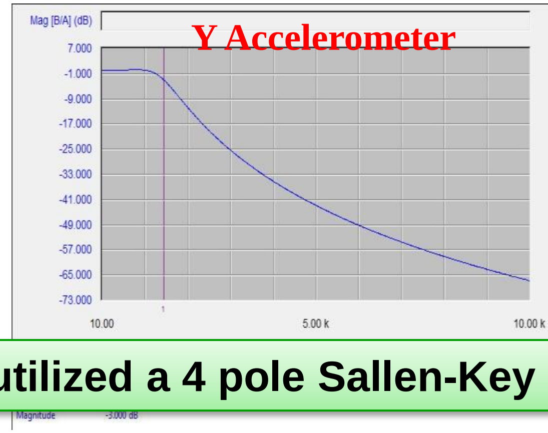
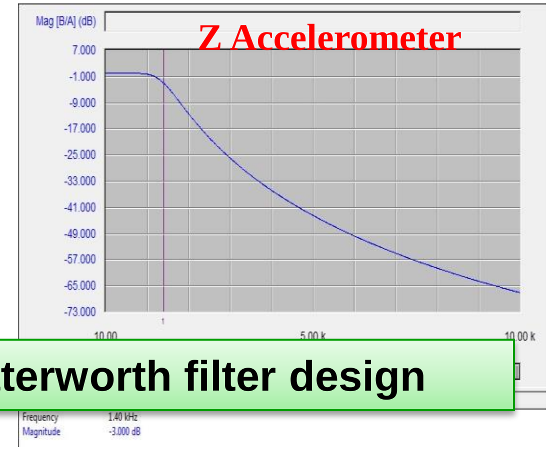
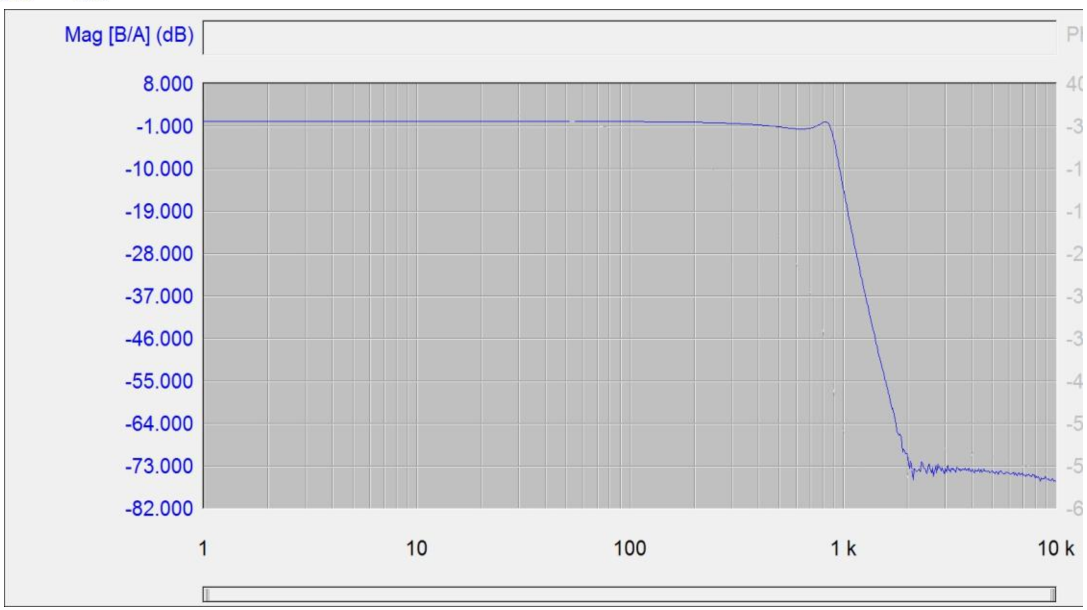
Filter Response







Prototype electronics utilized a 4 pole Sallen-Key Butterworth filter design



Final electronics design utilized a 8 pole Sallen-Key Chebyshev filter design

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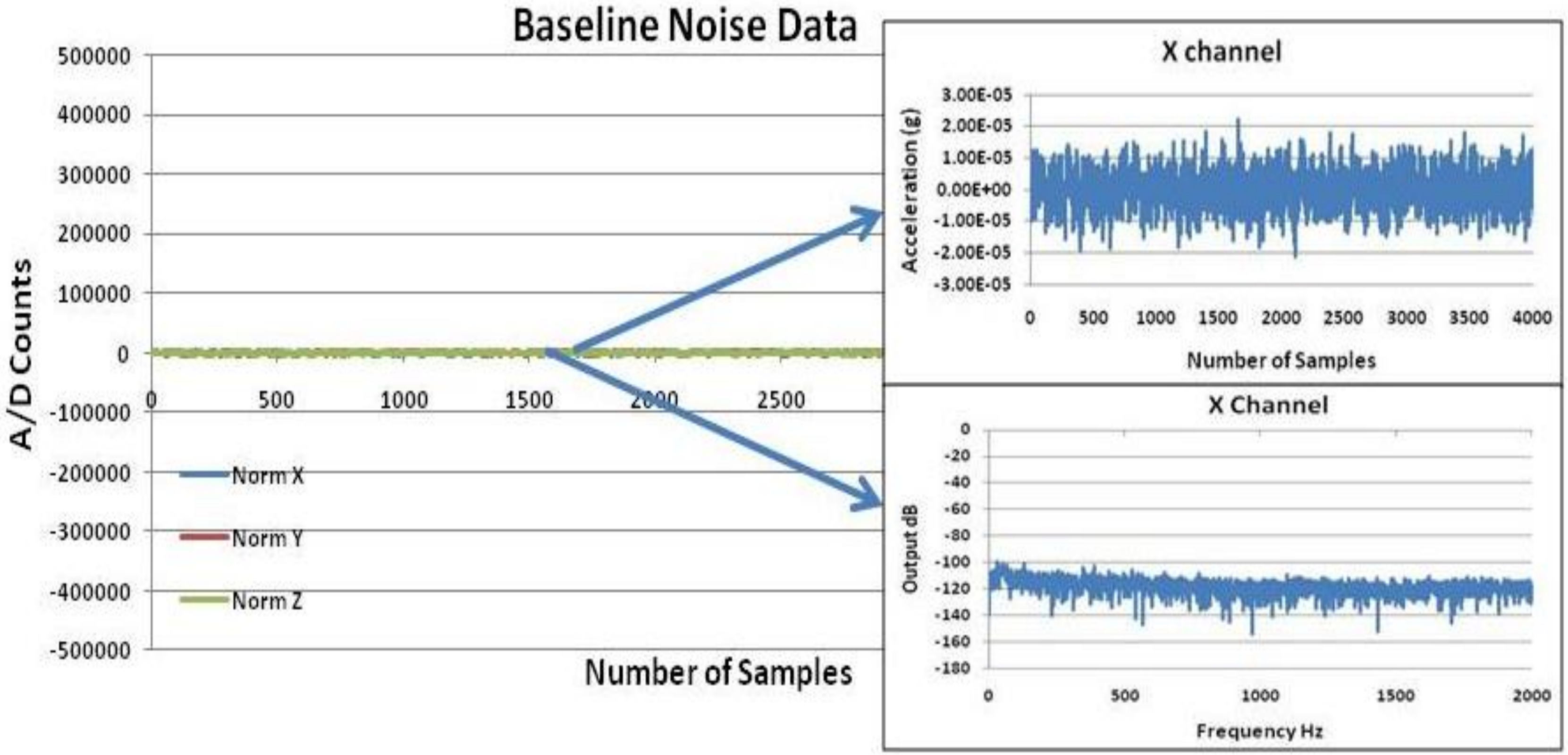
Electronics Noise Evaluation (Charge amp, Filter and A/D converter)

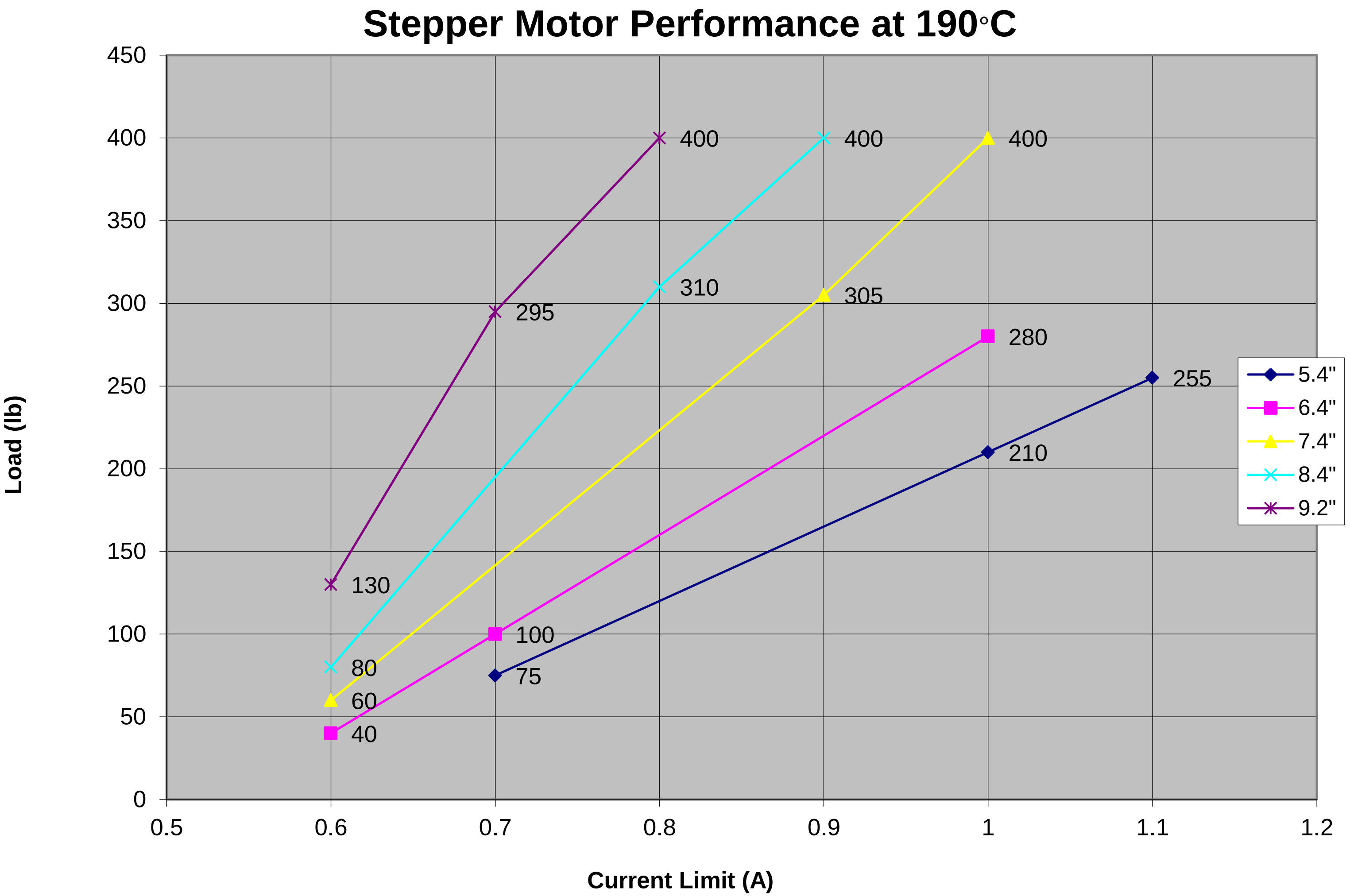


Arm Drive Motor Selection

- DC motor
  - Easy to use, and directly compatible with industry.
  - HT motor not currently available; Could be designed but was not within our timeframe and budget
- AC motor
  - Speed control more difficult than DC motor
  - Torque is limited (size restrictions)
  - HT motor not currently available; Could be designed
- Stepper motor
  - Control is difficult using HT components
  - Torque is adequate
  - Suitable for HT operation

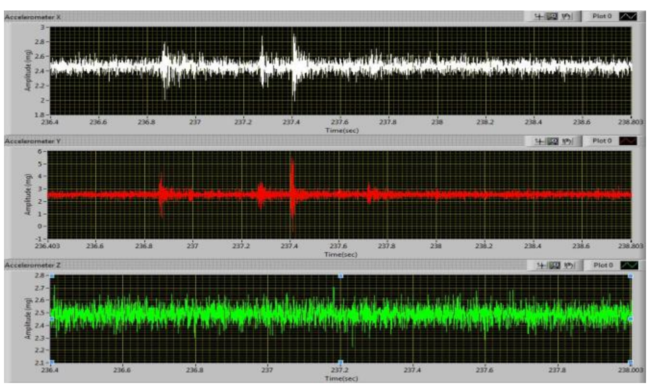
Load Testing

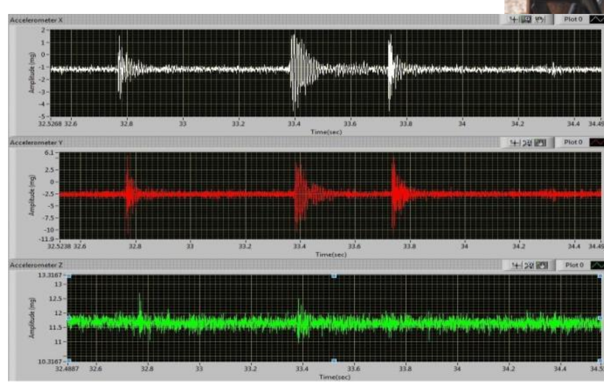
Load Testing (continued)



Field Tests

- **Deployed in test well to ensure proper operation of tool and arm deployment system**
  - **Use conventional 7 conductor wireline to send commands to operate arm, initiate test, etc**
  - **High speed data stored in tool**
- **With support from Ormat, deployed tool in Geothermal wells located at Brady and Desert Peak Nevada**
  - **Injection test at Desert Peak**
  - **HT test at Brady**





Future Plans

- Field test with industry
- Electronics modifications
  - Replace charge amplifier with analog Multi Chip Module (MCM)
  - Develop a high speed data link using HT components
    - Contract initiated with Harvey Mudd College to pursue data link options
  - Field using fiber optic data link
    - Optical modulator
      - Lithium niobate modulator
      - Silicon-based optical modulator
- Hardware modifications
  - Add pressure transducer to monitor fluid fluctuations during test
  - Fabricate hardware using PH17-4 and Nitronic 50 to enhance pressure capabilities of the tool
  - Laser-weld electrical feed throughs into bulkhead

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Conclusions

- HT seismic tool has been designed and lab tested
  - Individual boards
  - Complete assembly testing
  - Motor drive load evaluations
- Initial field deployments complete
- Upcoming HT field test with industry