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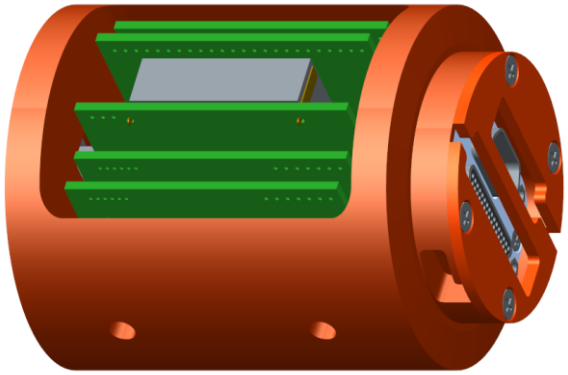

Shock-hardened Penetrator Data Recorder to Support Hard-Target Fuze Development

SAND2016-3004 C

59th Annual NDIA Fuze Conference, Charleston, SC

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Acknowledgements

- This work was sponsored by B61-12 nuclear safety testing.

Background / Problem Statement

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- Measure component-level impact environments for B61-12 Anomalous Environment (AE) nuclear safety sled track test
  - Four, identical modular recorders comprise entire package
  - 48 total analog channels (12 per module)
  - 24 discrete (on or off detect) channels (6 per module)
- Fit within defined envelope of B61-12…**but readily adaptable for most penetrator packages** (> 4” in diameter)
- Store energy to record post-impact without external power
- Survive impact and then hold data without power
- Accommodate use for other high-shock data acquisition tasks
- Low-pass filter to avoid aliasing recorded data

“AE Data Recorder”

Strong Pedigree

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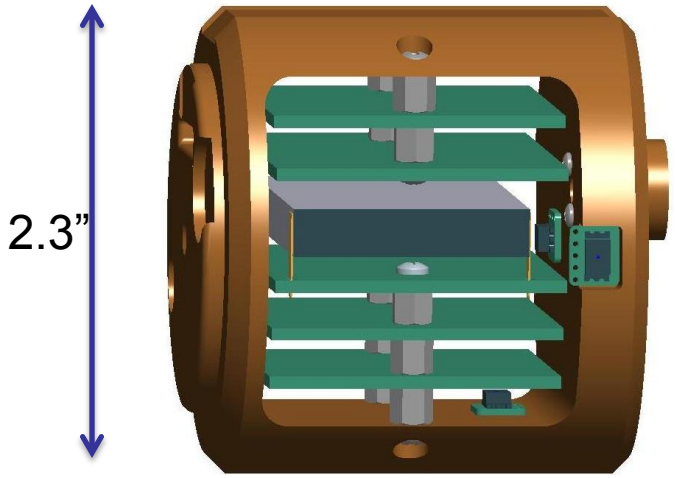
Sandia 3AMP

- Successfully recorded acceleration of hundreds of penetration events.
- Same packaging techniques employed

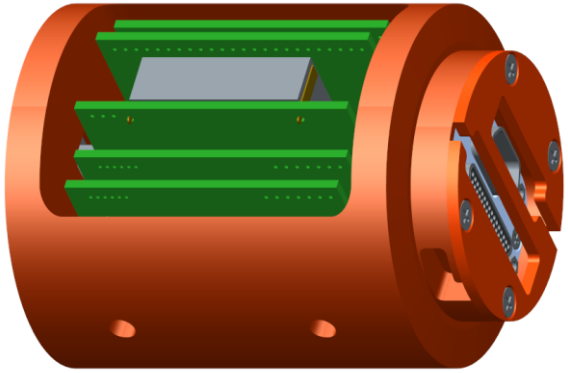
Sandia 3DDR-AM

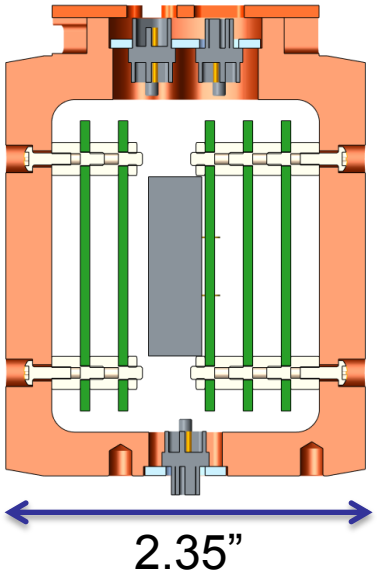
- Similar form factor and functional architecture
  - Multiple data channels
  - Similar sample rate
  - Anti-aliasing low-pass filter
  - Similar power requirements



AE Recorder Design Overview

- Stainless Steel Housing with Potting (not shown here)
- Five total Printed Circuit Boards (PCBs)
  - 3 Analog (identical)
  - 1 Power/Interface
  - 1 Digital
- Three MDM Connectors
  - Top: MDM-31P & MDM-15S
  - Bottom: MDM-15P
- Approximately 1.4 lbs





Before Encapsulation

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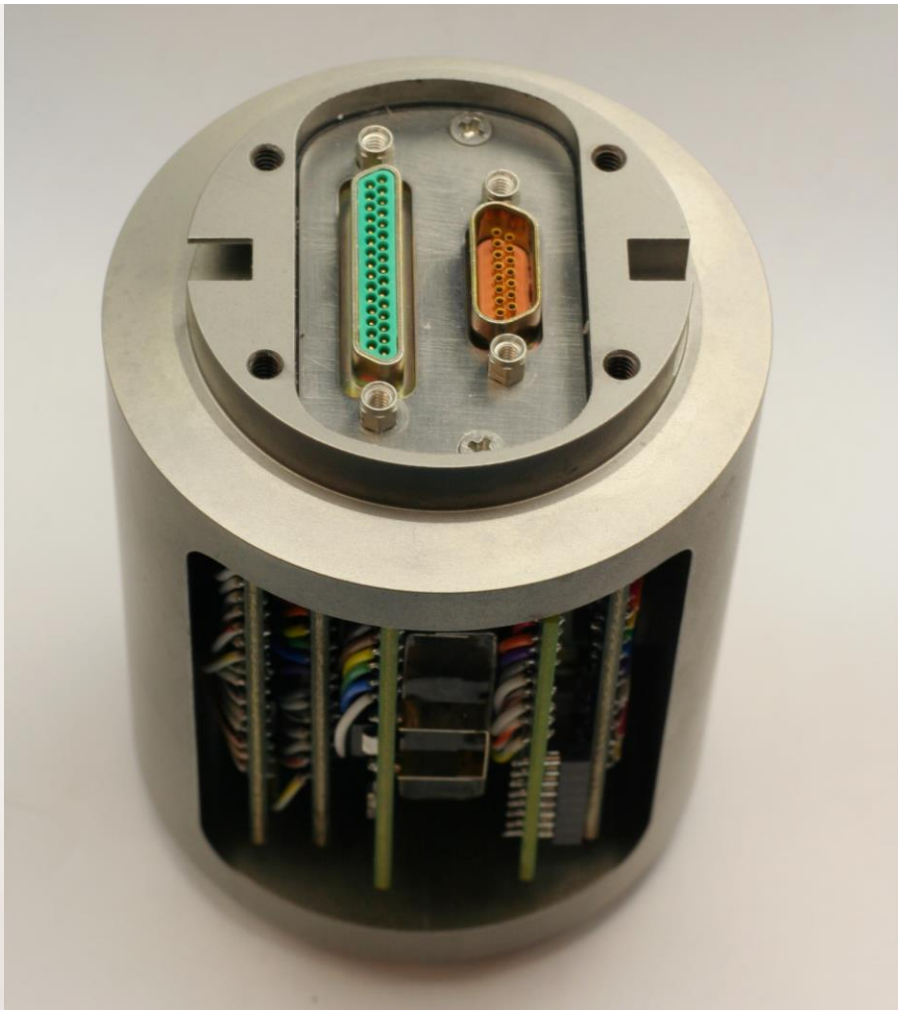

After Encapsulation

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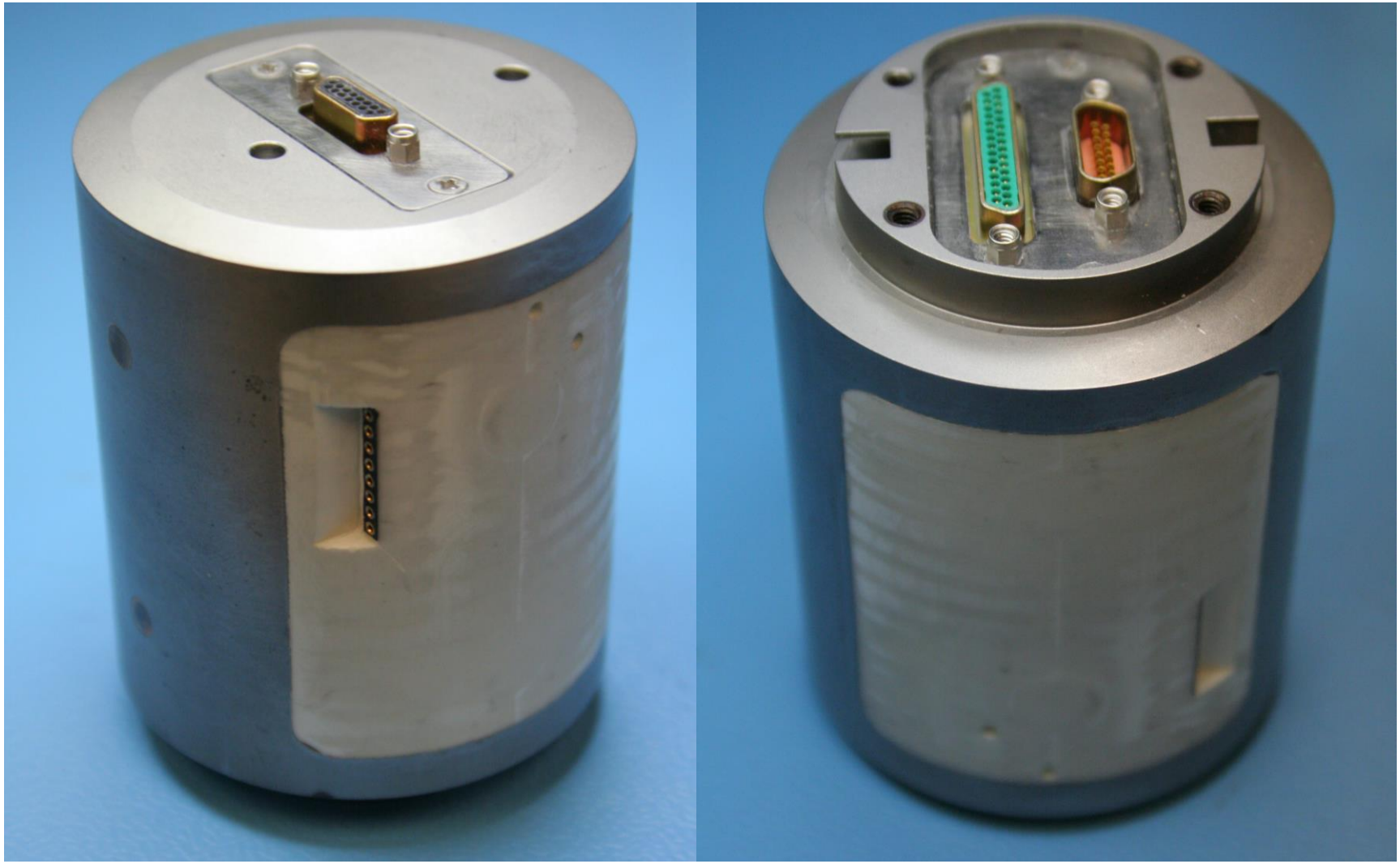


Mechanical Modeling & Simulation

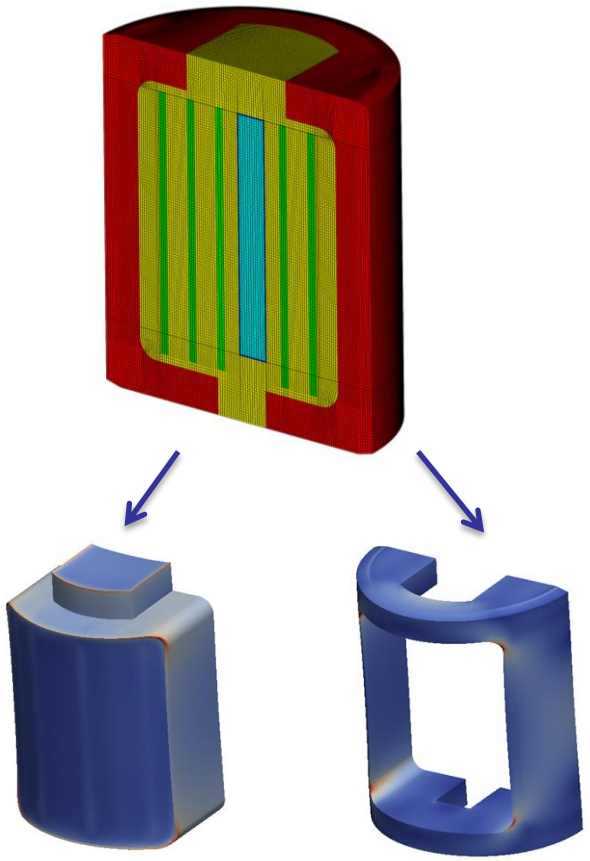
- **Goal is to increase likelihood that the design is robust**
- **Multi-Stage FEA Procedure Captures stress profile of components over entire life cycle**

Implicit Quasistatic, Sierra S/M: Adagio

1. Cool from Potting Cure Temperature to lowest operational temperature
2. Apply compressive preload to chamfers.

Explicit Dynamic, Sierra S/M: Presto

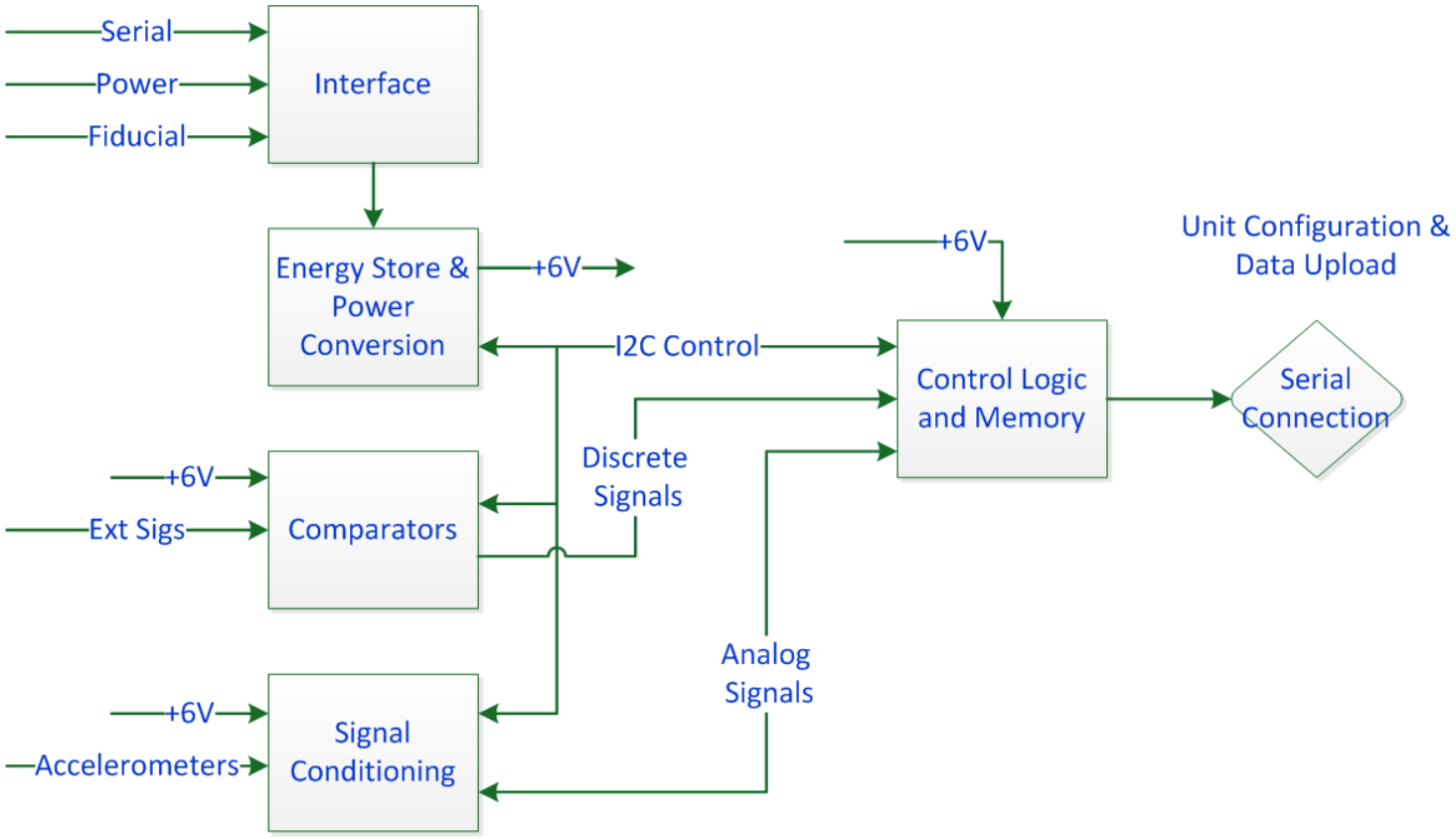
3. At lowest operational temperature, accelerate module at chamfered surfaces with defined acceleration.



Modeling reveals no flaws with design.

AE Recorder Block Diagram

- Design divided into functional sections:



Energy Storage & Power Conversion

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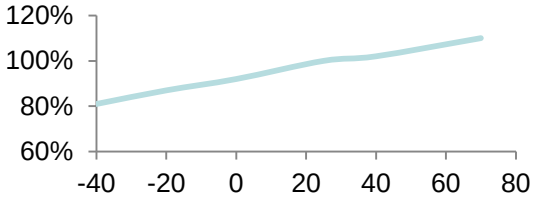
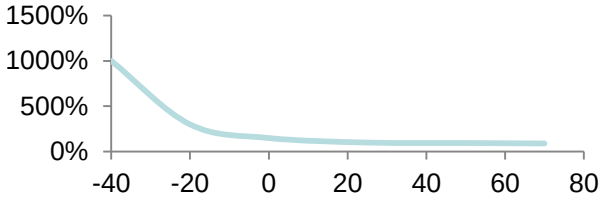
- Shock-tolerant capacitor powers recorder post impact
  - Battery is expected to fail at impact
  - Store sufficient energy to complete post-impact recording
  - Temperature affects properties: Capacitance, series resistance (ESR)

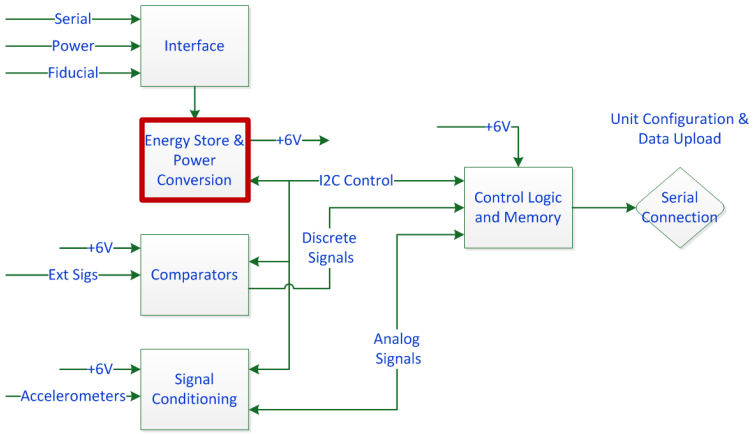
Relative Capacitance



Relative ESR

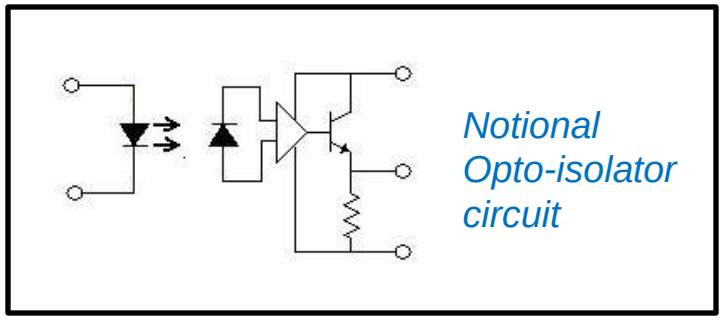


- Switch-Mode Power Converter improves energy efficiency
  - Efficiency 75%, compared to 37% for linear regulator
  - Reduces required energy storage

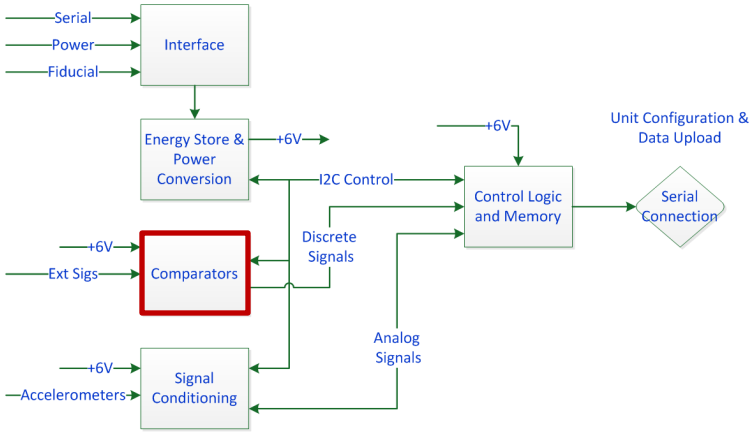


Comparators

- Bi-level inputs for additional data
  - Comparator with programmable voltage threshold
- Spare channels for test-specific purposes
  - Record & trigger (if configured) on spare channels for test scenario flexibility

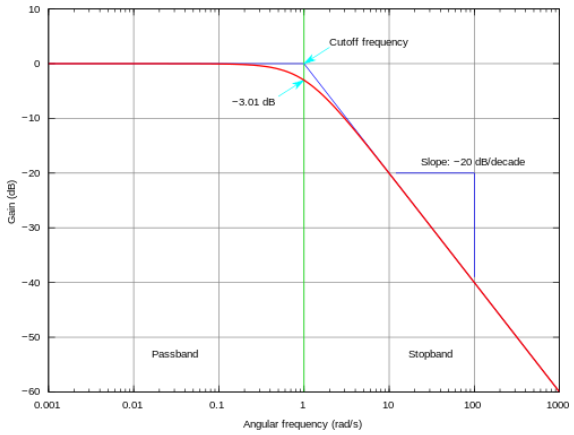


Notional Opto-isolator circuit



Signal Conditioning

- Low-pass filter excludes high frequency content
  - Accelerometers output high frequency signals that are not useful
  - Must be sufficiently attenuated at sampling frequency
  - Phase compensation avoids time correlation problems
- AE Recorder has programmable gain and balance
  - Adjustable gain to match accelerometer's wide sensitivity variation
  - Balance to compensate for offset
  - Allows replaceable accelerometers and test-specific changes



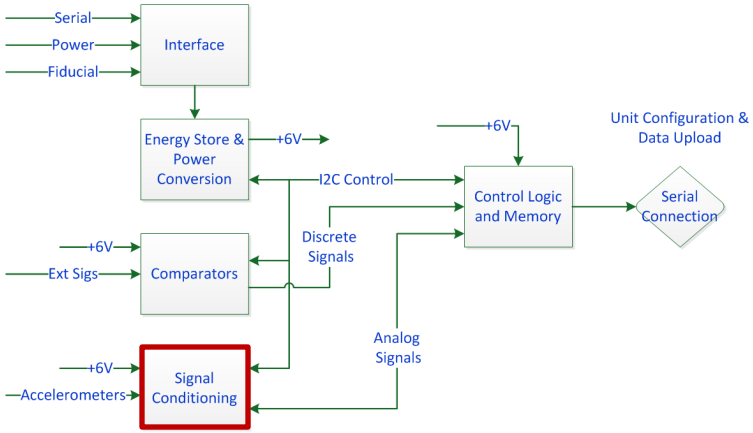


Image source: www.wikipedia.org

Sensor Excitation Voltage

- Using 5V accelerometer excitation voltage
  - Reduces power consumption over 10V operation
  - Calibration at 5V is routinely available
- Each Analog board has separate 5V regulator
  - Processing for four sensors per analog board
  - Employ current limit on excitation to mitigate shorted sensor
  - On/off control removes Analog & sensor power during sleep mode, conserving power

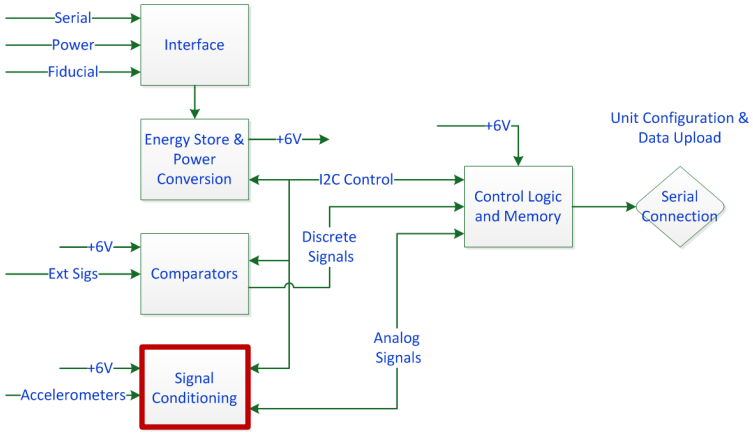
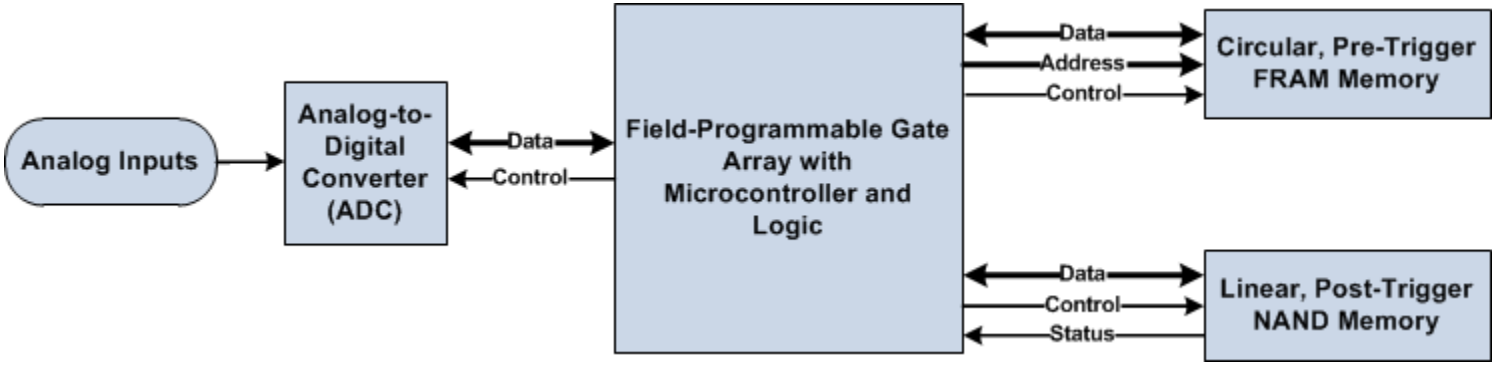


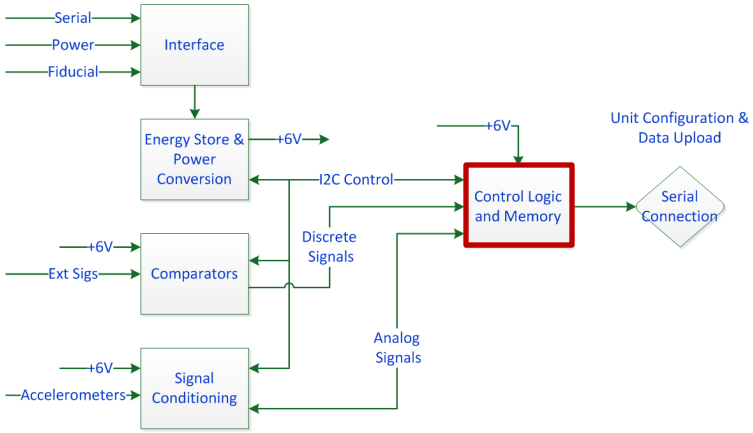
Image source: www.endevco.com

Microprocessor & Logic Combined



Combination reduces board area, complexity

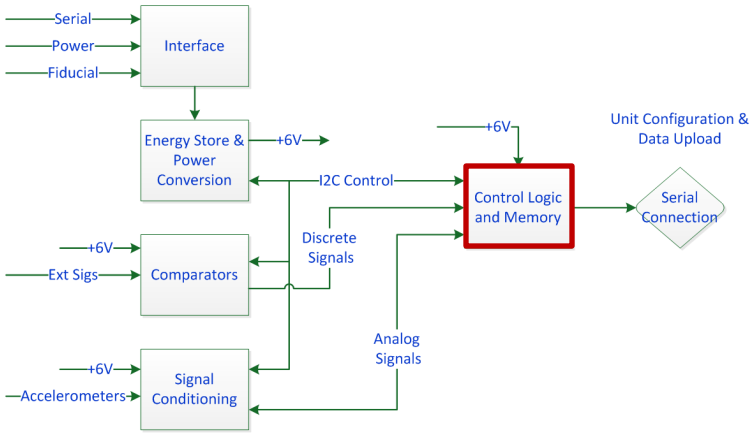
- Microprocessor implements high-level control and configuration
- Logic handles high-speed data movement from ADC to memory
- FIFO buffers acquisition during NAND Flash write cycle
- Serial interface provides external control and data extraction
- I^2C interface for inter-board control



Both Circular and Linear Memory

- Requirements: capture pre-trigger data plus post trigger (analogous to an oscilloscope)
- Pre-Trigger, Circular memory is rapidly written / overwritten
  - FRAM is excellent non-volatile choice, but limited recording capacity
- Post-Trigger, Linear memory handles continuous recording
  - NAND Flash memory for long recording, but limited rewrite cycles
  - Cannot erase / re-write quickly, so inadequate for pre-trigger

To acquire both a fairly long pre-trigger record in addition to a much longer post-trigger data record requires two different types of memory technology.



Summary and Conclusions

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- AE Recorder has many favorable design features:
  - Programmable gain and balance per channel
  - High sample rate
  - Long recording time
  - Multiple analog/discrete channels
- Strong High-G pedigree
  - 3AMP, 3DDR-AM, others
  - Design has been validated in sled track environment

AE Recorder is Sandia's most advanced/versatile high-G recorder.

Questions?

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    skcurti@sandia.gov

Back Up

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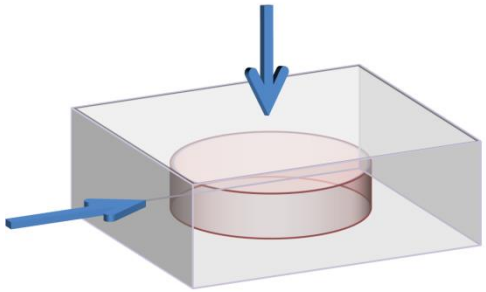
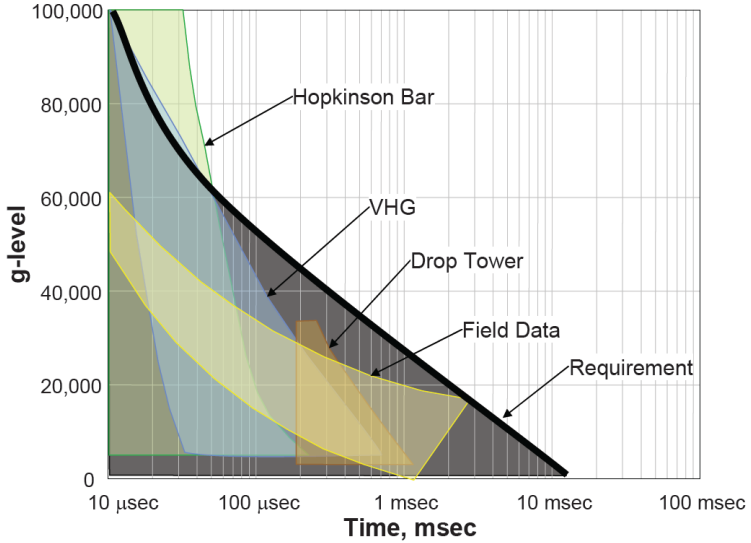
Component Evaluation for Shock

- Begin with electrical characterization under static loading
  - quasi-static compressive stress axially & laterally
- Drop table, Hopkinson bar and VHG impact testing for dynamic loads
  - Small test circuit built to fit on Hopkinson bar
  - Adapter fixture attaches same circuit for VHG testing





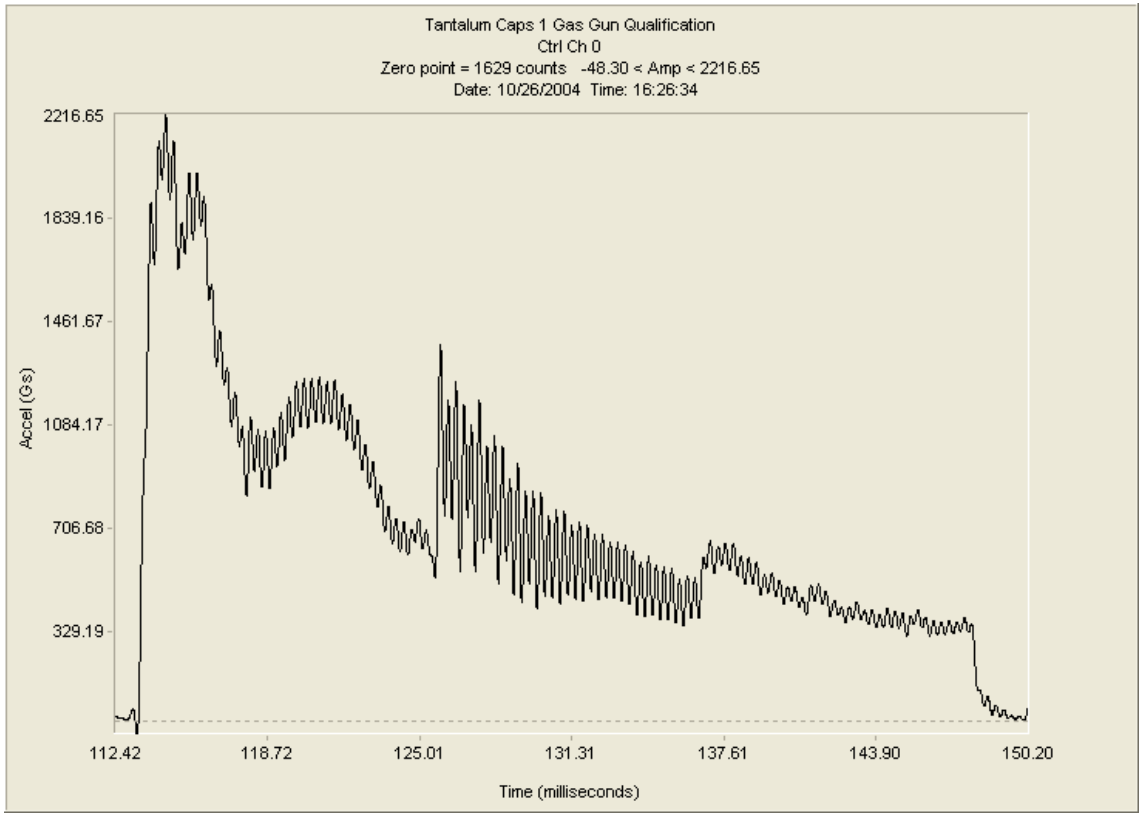
White, H.G., et al., *High-G Testing for Fuze Research*, in *74th Shock and Vibration Symposium*. 2003, SAVIAC: San Diego, CA.

Importance of Check Channels

- Example system, Measurement configuration:
  - Penetrator instrumentation with Bessel LP filter, switched-capacitor type

Gas Gun Launch Pulse

Integrates to correct velocity and displacement



Check Channel Reveals Problem

- A channel with resistor replacing accelerometer
  - Passes thru same filtering as normal channel
  - Piezoelectric components in signal conditioning create bogus signals

Correct response would have been a flat-line output