# Progress on a 60kG MEMS Sensor

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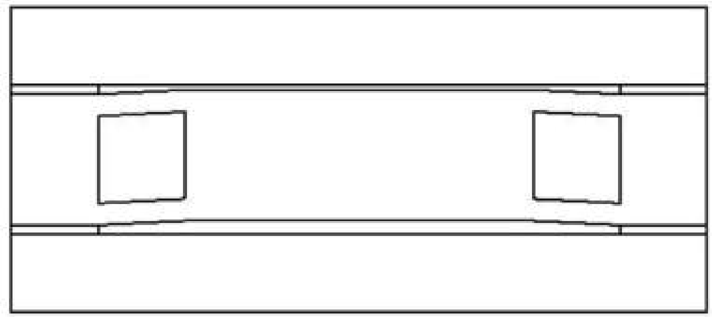
# Introduction

- Description of new 60kG sensor
- Frequency response
- Amplitude linearity
- Mechanical stops
- Electrical characteristics
- Thermal characteristics
- Results of pyrotechnic testing

# New 60KG Sensor Design



- Same body plan as proven 20kG sensor
  - Diced from a protective hermetic sandwich of three wafers
  - Air trapped in gap causes squeeze-film damping, reducing resonant amplification
  - Built-in mechanical stops prevent overrange failures
- Optimized features enhance survivability
  - Modified cantilevers for higher measurement range
  - Strain relief features reduce stress when stops are encountered
  - Improved ESD tolerance
  - (the last two features have also been applied to new 20kG)

# Sensor Comparison



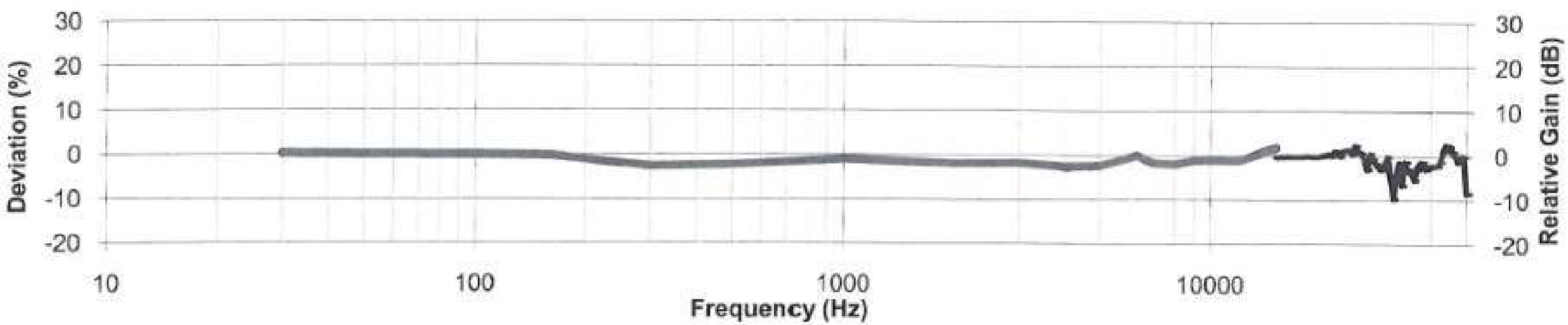
| | 20kG | 60kG |
|---|---|---|
| **Sensitivity** | 1uV/V/G | 0.3uV/V/G |
| **Full Scale (20mV/V)** | 20kG | 60kG |
| **Resonance** | ~65kHz | ~150kHz |
| **Mechanical stops** | +/- 35kG | +/- 100kG |
| **Resonant amplification "Q"** | ~10 | ~40 (estimated) |

the following parameters are the same for both versions

| | |
|---|---|
| **Input Resistance** | ~5000 Ω |
| **Bias (ZMO)** | 20%FS max (2% typical) |
| **Dimensions** | 0.098" x 0.067" x 0.039" (2.5mm x 1.7mm x 1.0 mm) |

# Frequency Response

•From similarity, the response should be at least as flat as the 20kG sensor response, which has a lower resonance, shown here. It is difficult to measure the frequency response of 60kG sensor with a shaker due to force limitations of shakers.




•Classic SDOF of 150kHz resonance: <5% deviation to 30kHz.

•It is possible to derive frequency response characteristics from shock data

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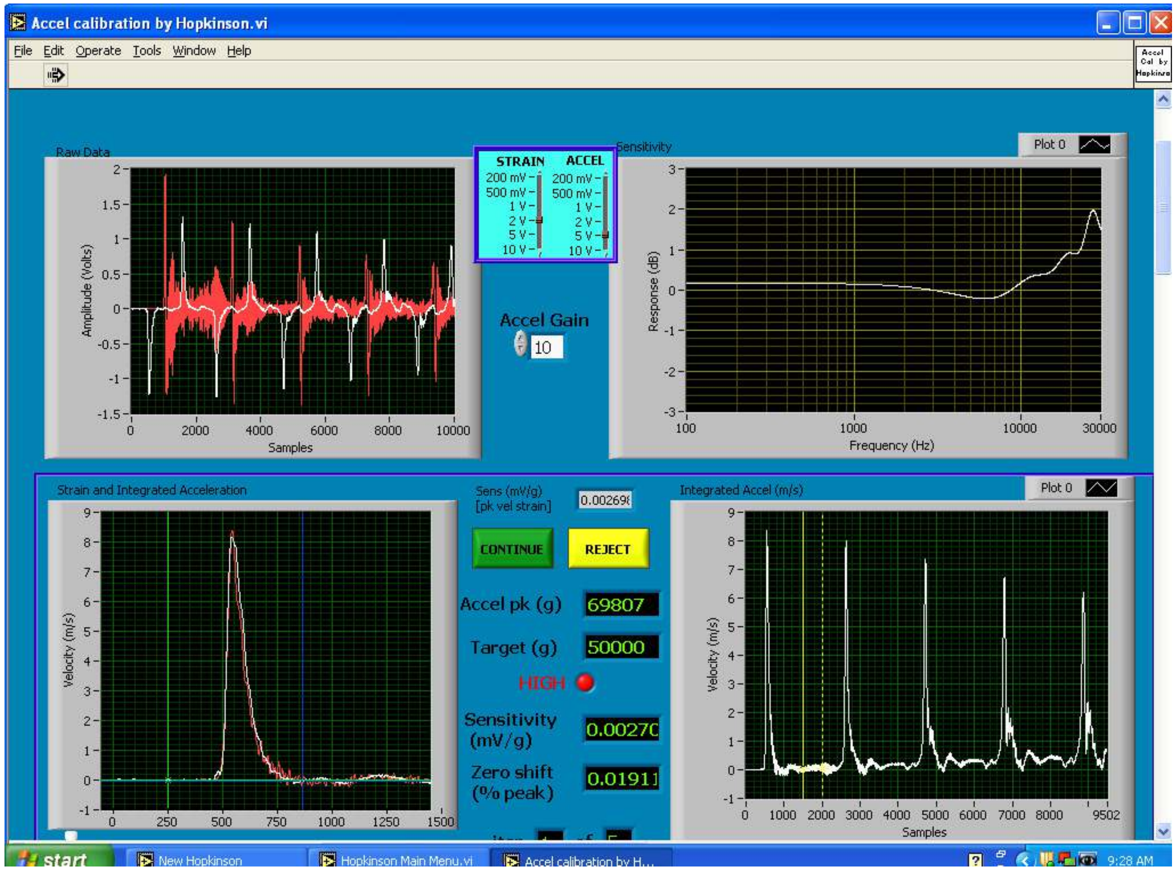
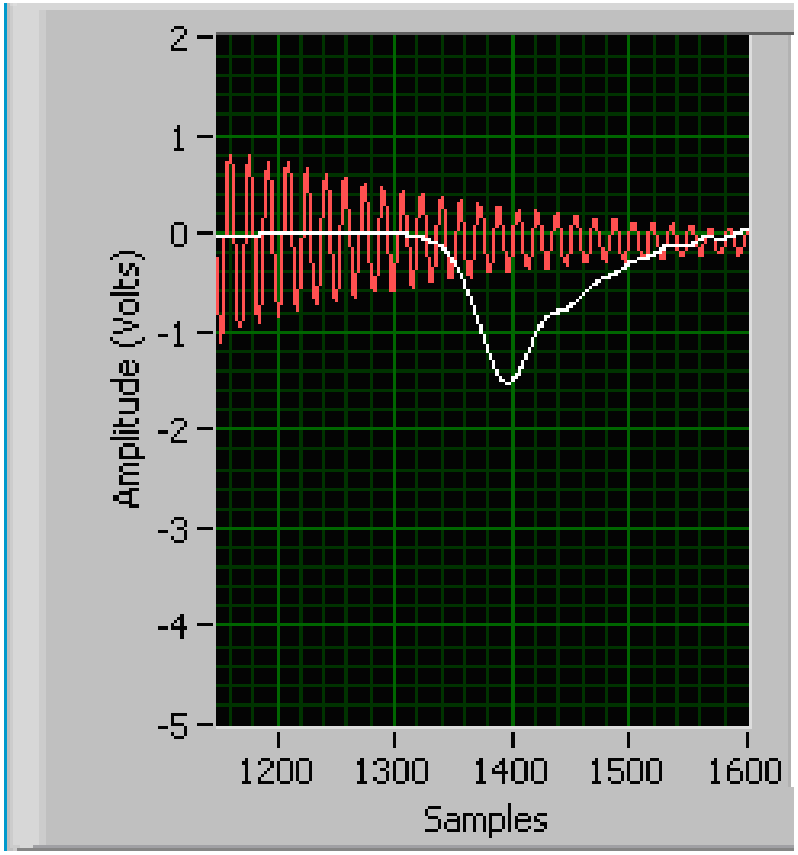
# Frequency Response (cont)



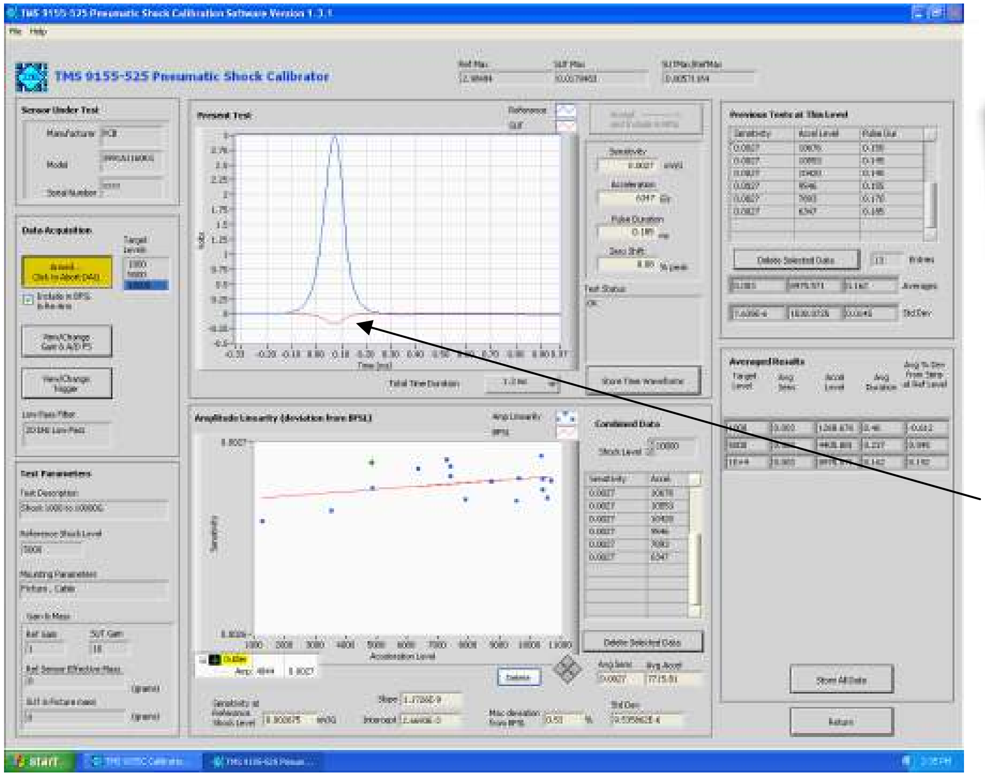

•Determined by this Hopkinson bar software, the frequency response on the upper right is <1dB to 20kHz. It is based on the ratio of FFT amplitudes of the integrated Unit-Under-Test to that of the velocity from the strain gages.

# Damping




•Logarithmic decrement calculation indicates 1.2% damping in the most recent wafer assembly.

# Amplitude Linearity





Negative-going output of unit-under-test when mounting upside down

- Sensitivity determined by comparison can only be done to ~10KG
- The package shown (but without welded cover) was mounted normally and upside down (don't try this at home)
- The lower plot is Sensitivity vs absolute G level, showing flat response in both positive and negative directions with deviations from BFSL of ~0.5%

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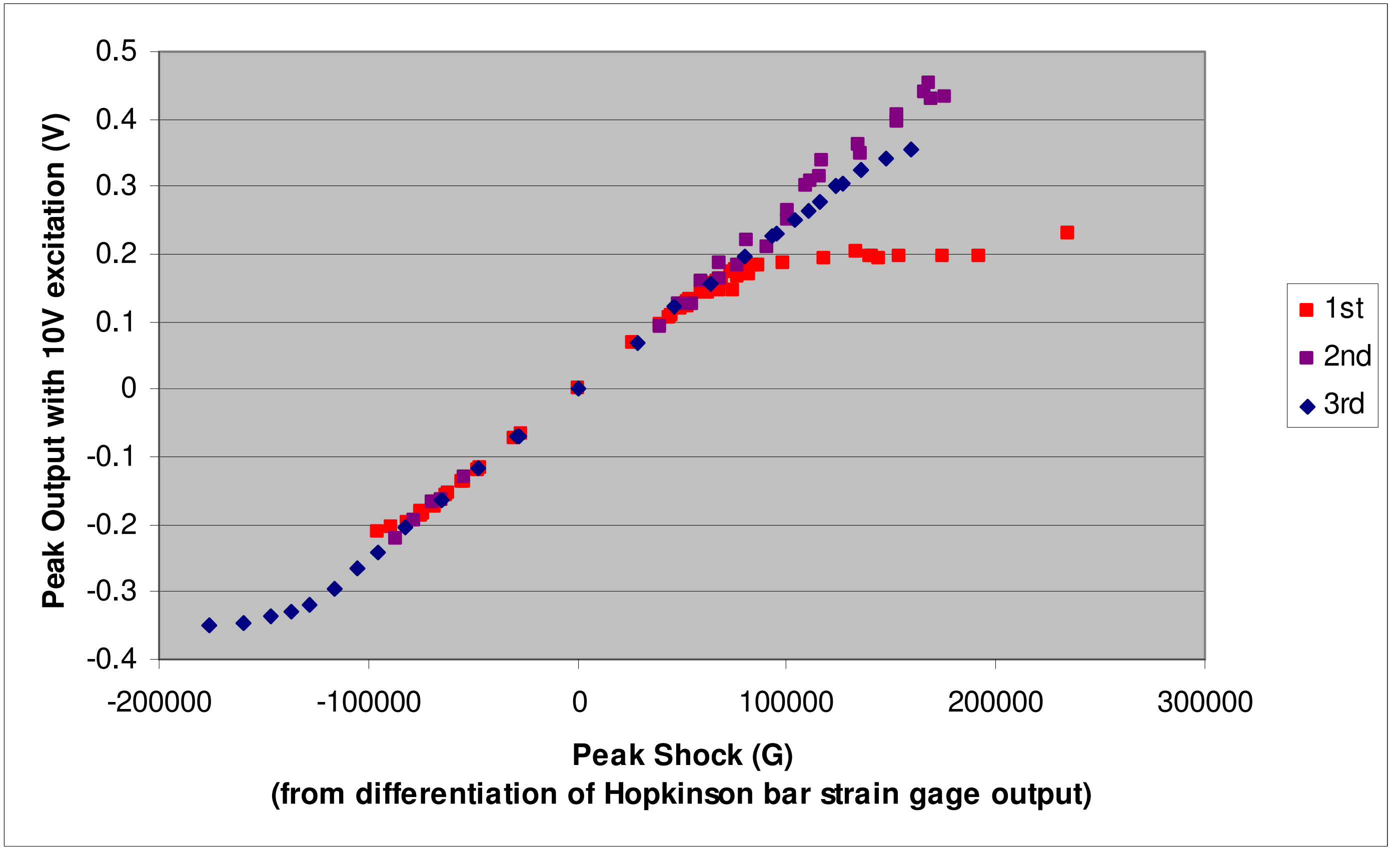
# Finding the Mechanical Stop Level




- Three 60kG wafer assemblies were made with three intentionally different stop levels (in search of Goldilocks level)
- Hopkinson bar was used in these tests of linearity, again using sensor package that could also be mounted upside down

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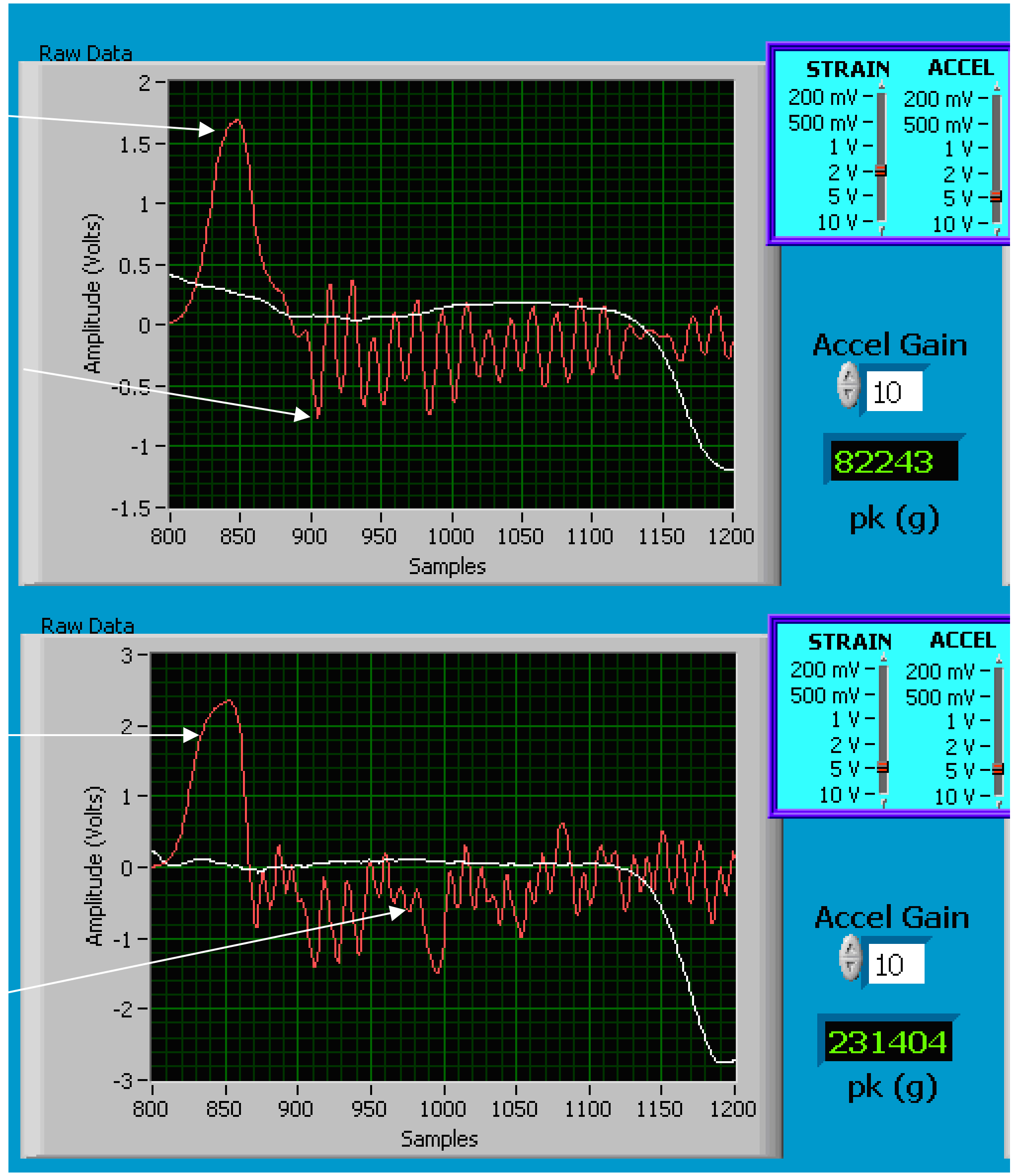
# Mechanical Stop Dynamics

- From the 1st wafer, output slope just begins to smoothly "roll over" at 80kG
- Low-Q 150kHz resonance
- Recovers within a few microseconds from 230kG overload
- Output continues to increase after hitting the stop, the cantilevers continue bending from their own inertia
- Higher 250kHz mode is visible

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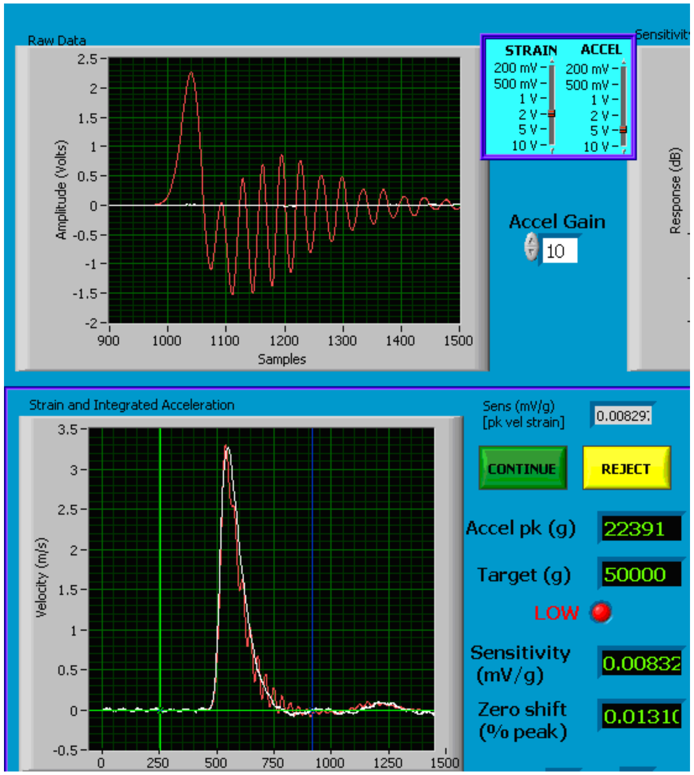
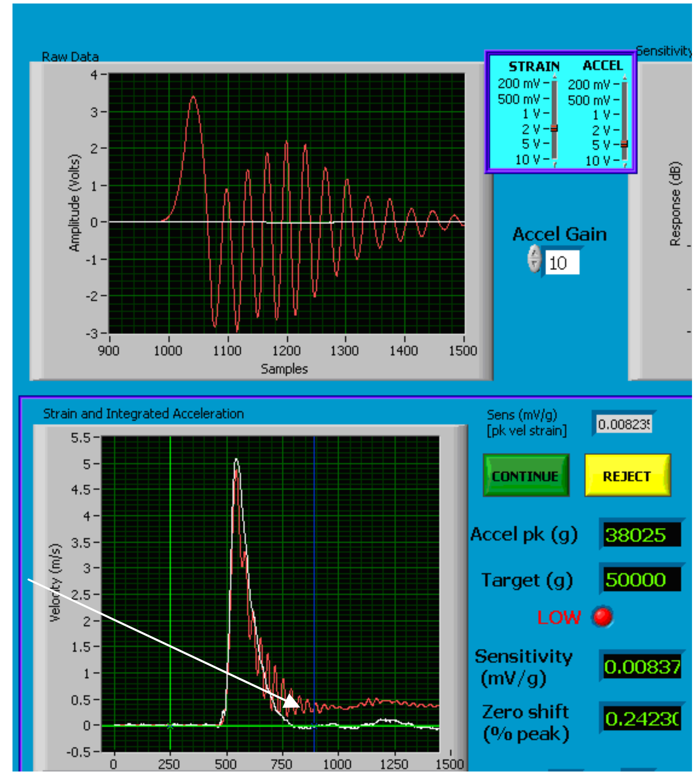
# Errors Caused by Hitting Stops




Integration error




- The lower graph in each test is the integrated accelerometer output overlaid on the Hopkinson bar strain gage output. On the left is a 22kG test of a 20KG sensor; on the right is 38kG, at which the positive stops just touch. A microsecond delay of output explains the integration error on the right. (<u>This is NOT zero shift</u>.)
- The 60KG sensor allows much larger dynamic range to avoid hitting stops.

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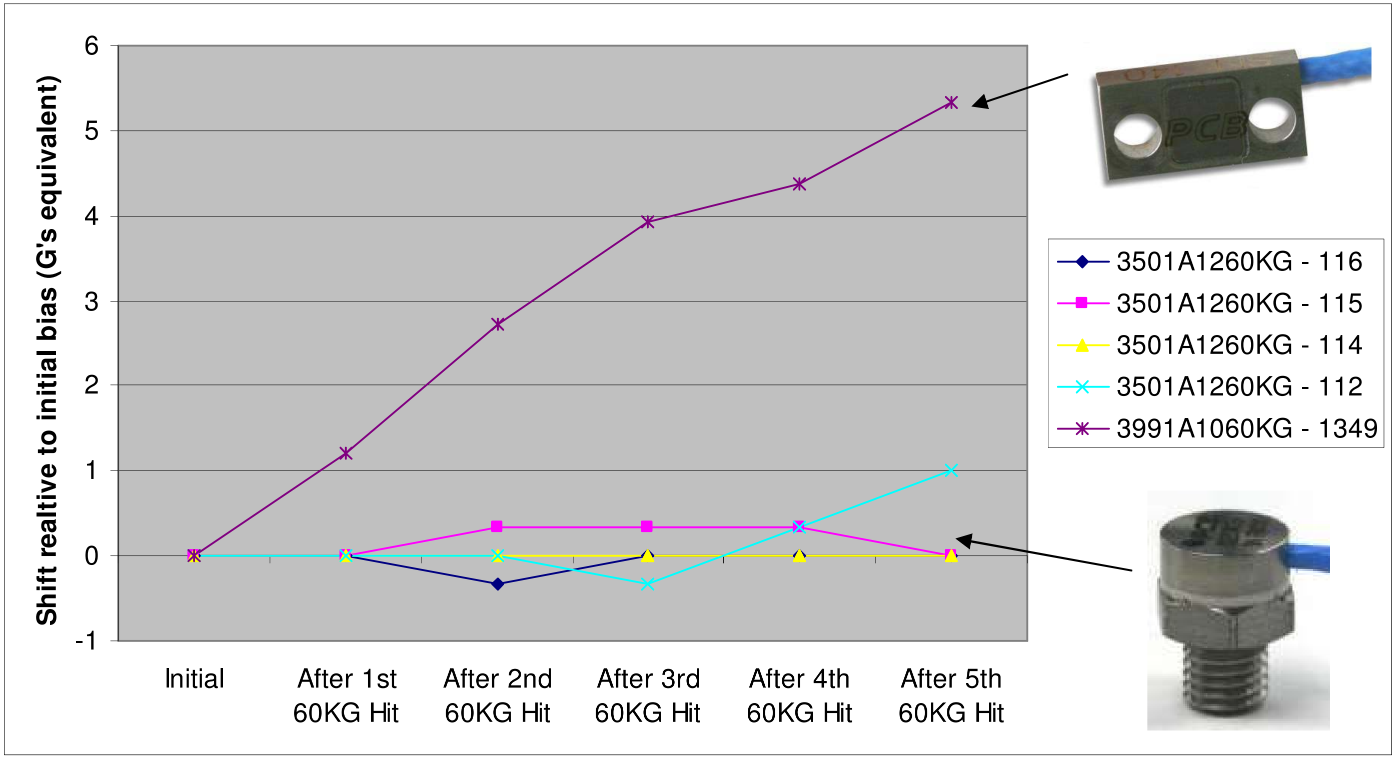
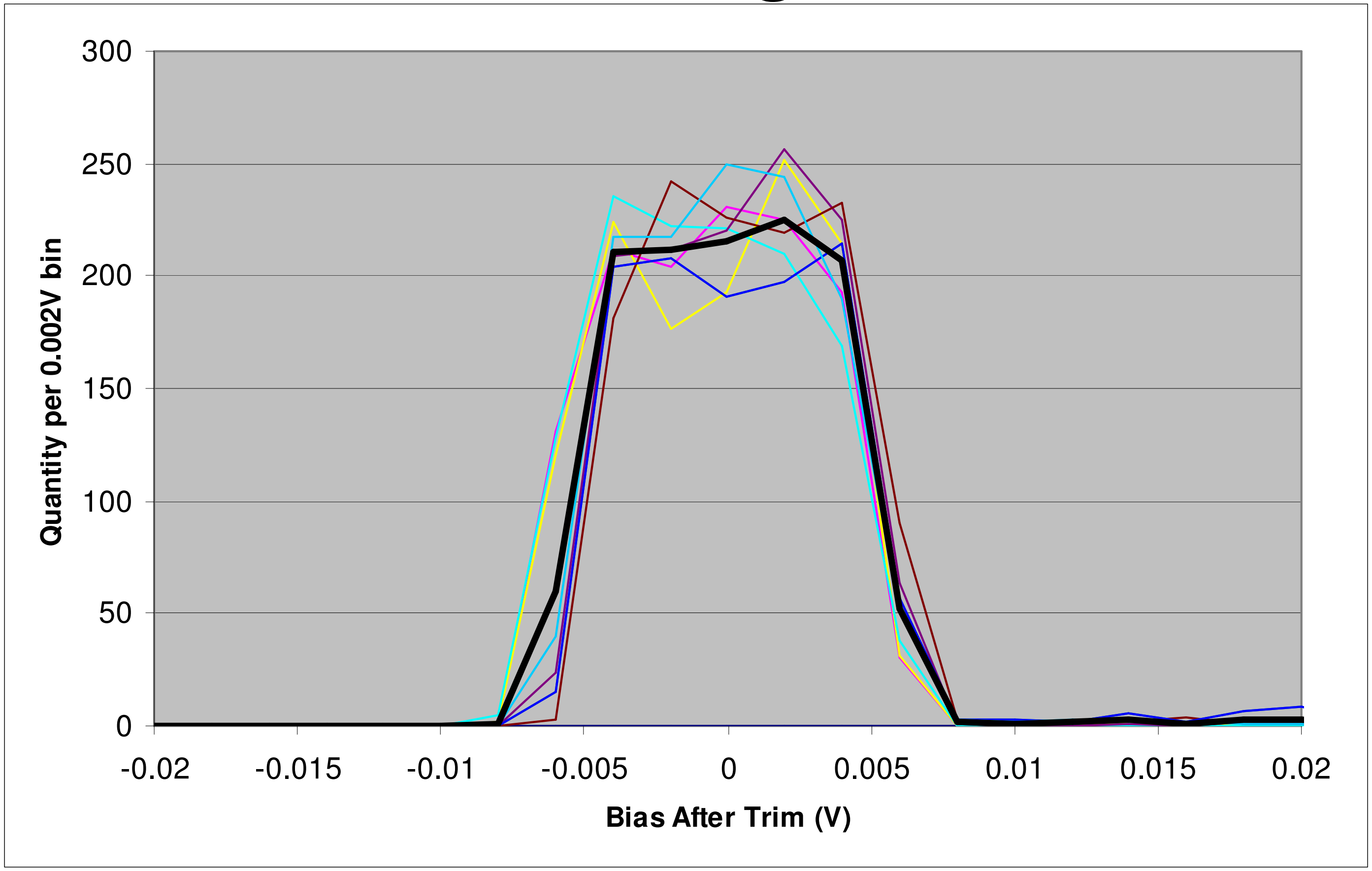
# Zero Shifts due to Shock




- These are shifts over a sequence of 5 Hopkinson bar hits at 60KG.
- The stud package has better base strain isolation than the flat package

# Bias Histograms




- The bias trim operation was performed on >10,000 sensors (each line represents a wafer, black line is the average)
- Typical bias after trim is 2% of Full Scale output (1 standard deviation = 1% Full Scale)

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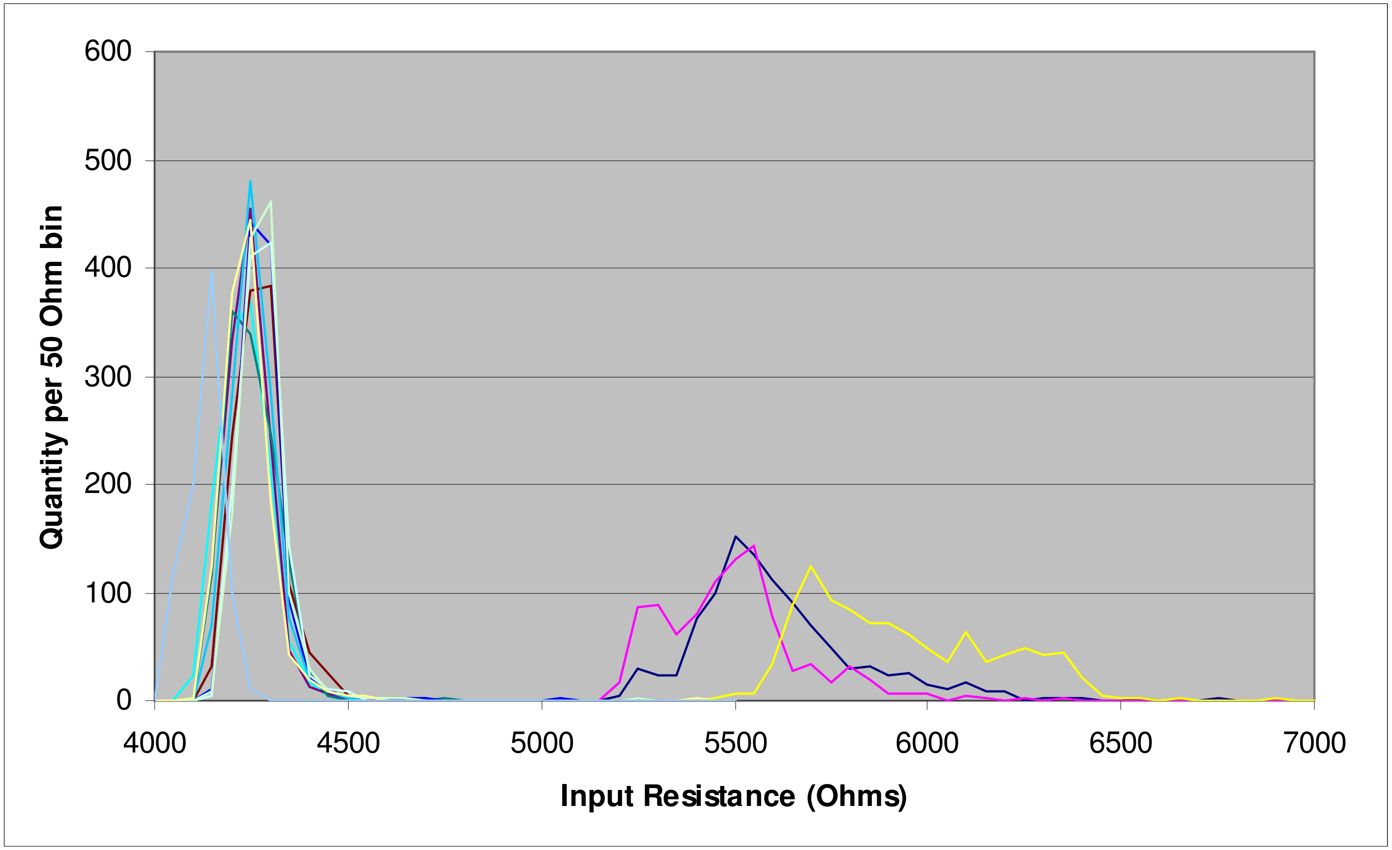
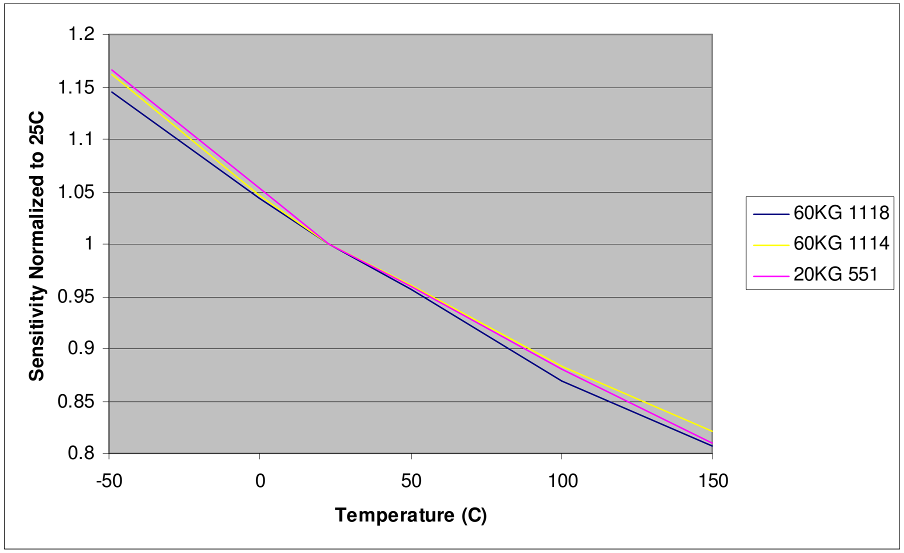
# Resistance Histograms



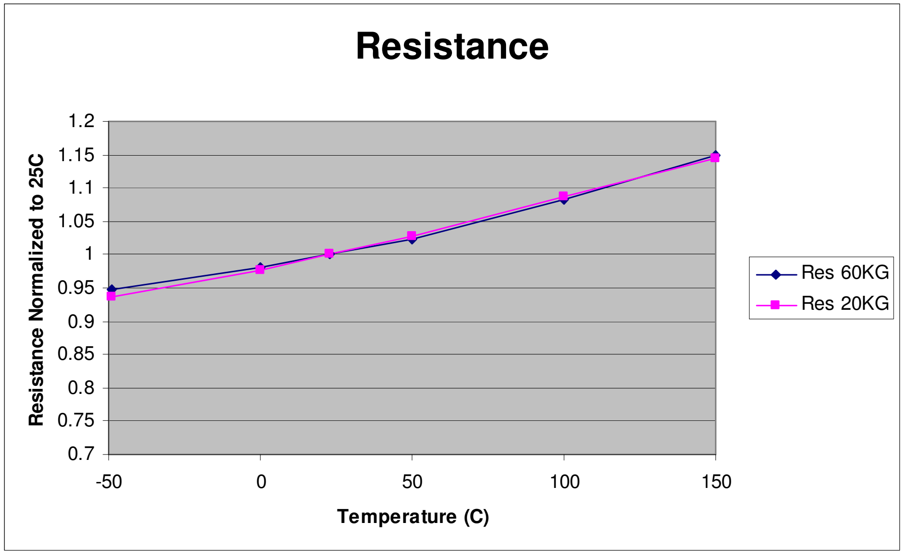

- Resistance on 10 production process wafers on left shows extremely tight spread (standard deviation of <1.5%)

# Thermal Characteristics

•Sensitivity: -17%/100C




•Resistance: +10%/100C

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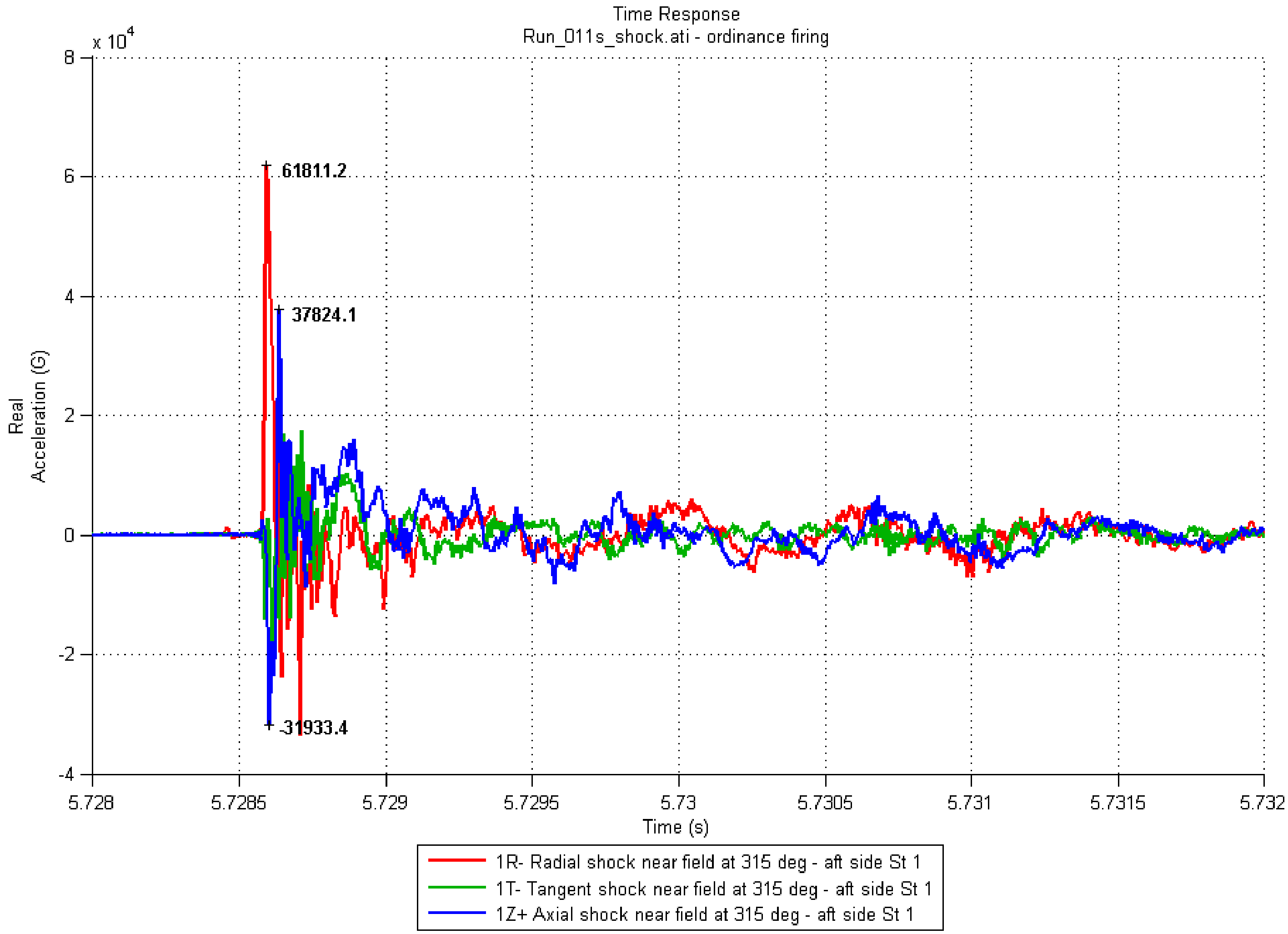
# Near-field Pyrotechnic Test




•Data courtesy Douglas Osterholt, ATA Engineering, Inc.

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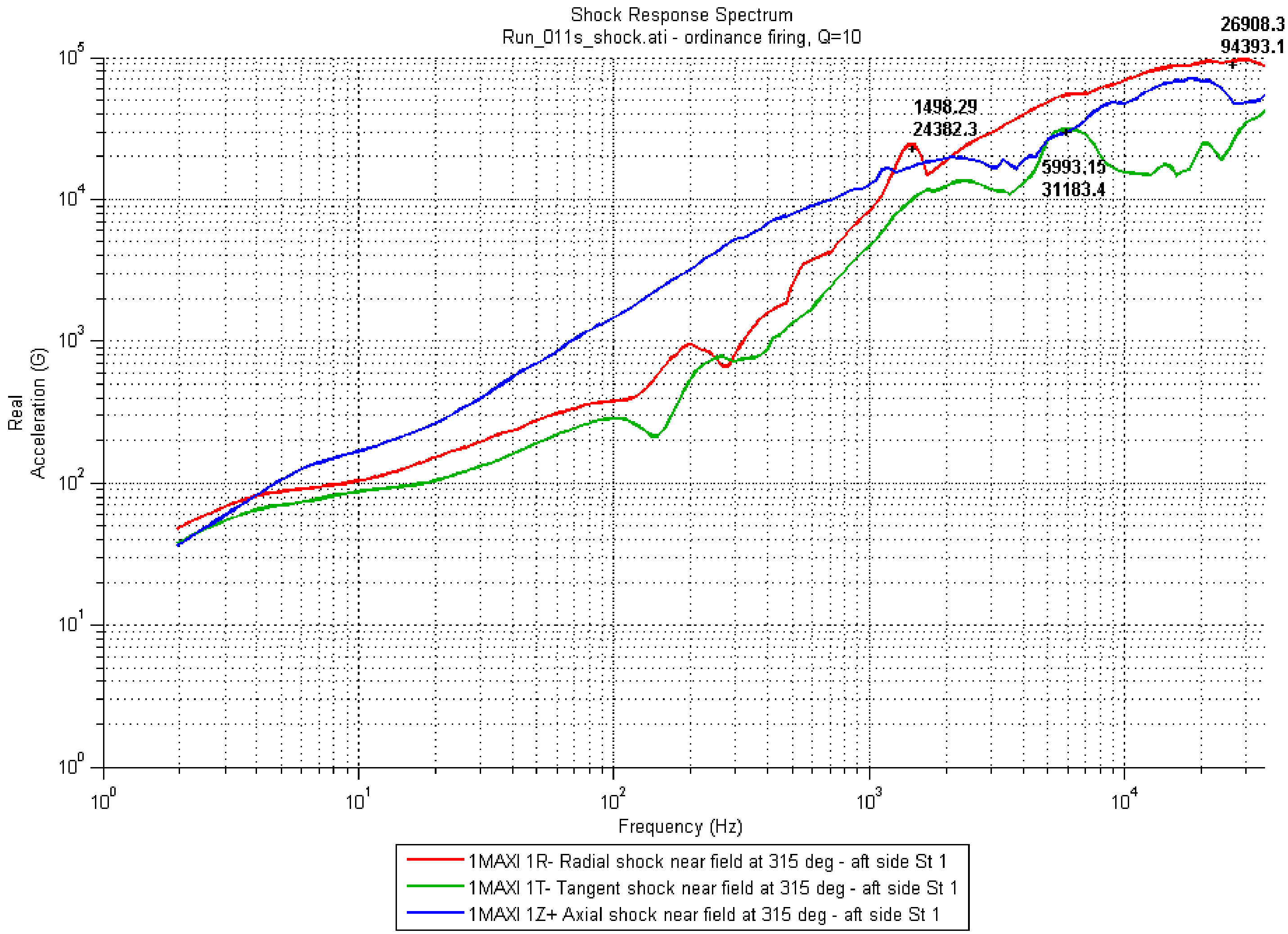


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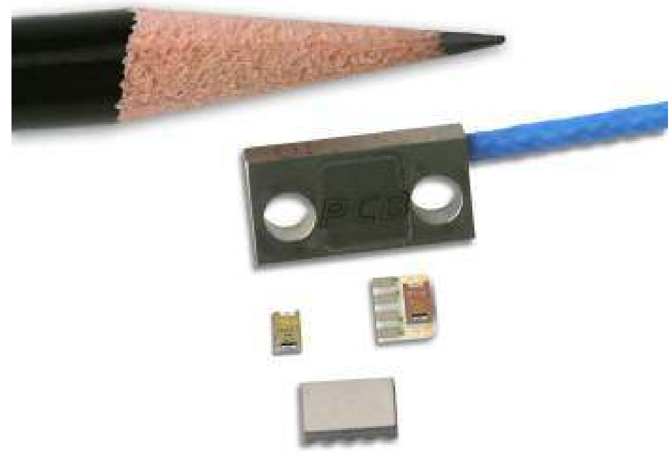
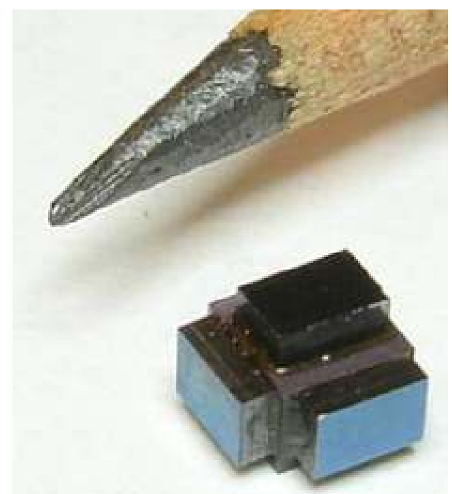
# Conclusions



- New 60KG sensor:
  - Extremely rugged
  - Wide frequency response
  - Large dynamic range
  - Trimmed to low bias value
  - Low bias shift
  - Stable, low drift
- Manufacturing process is mature for 20kG and 60kG
- Both sensors fit in a large variety of packages



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