60kG MEMS Sensor

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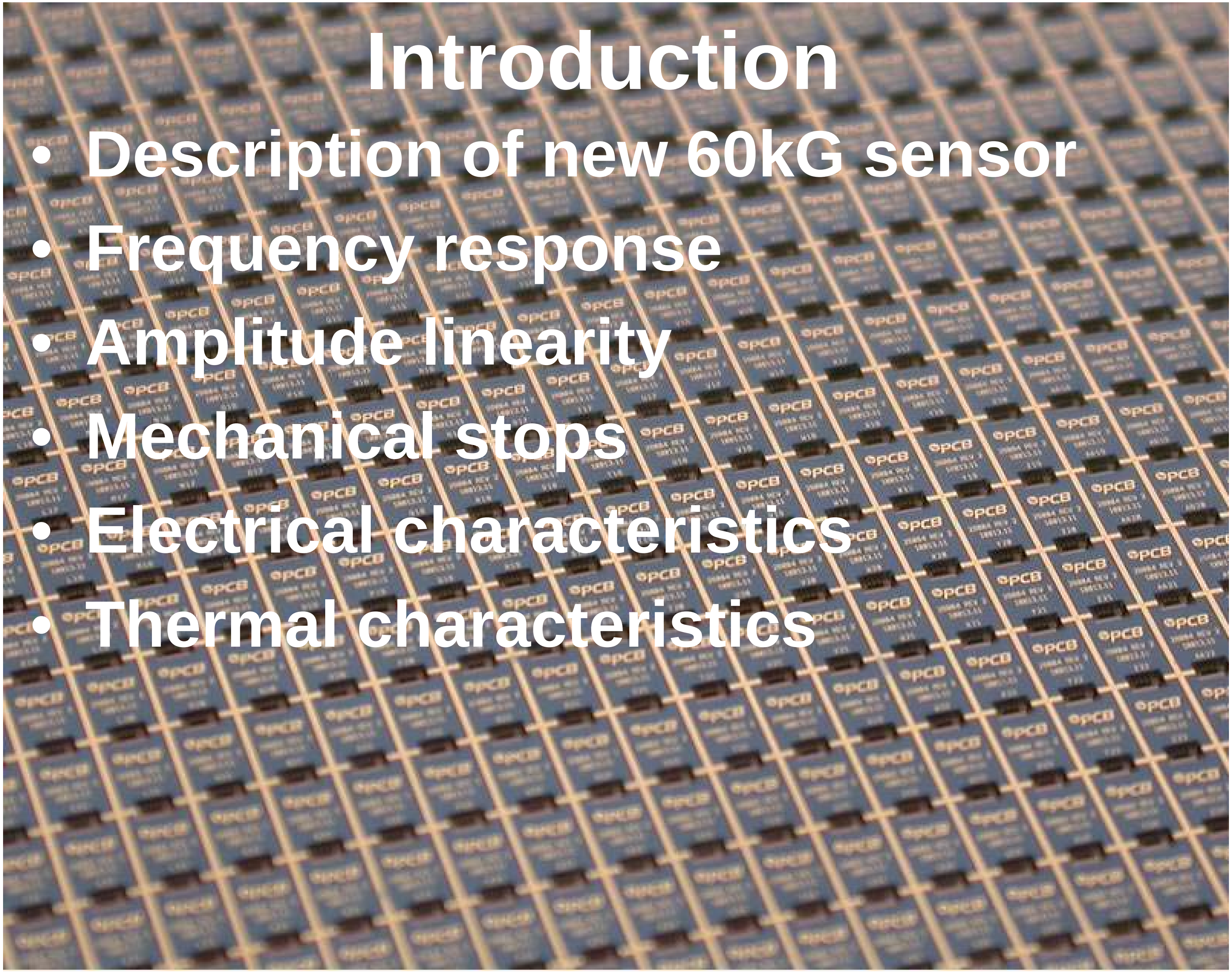
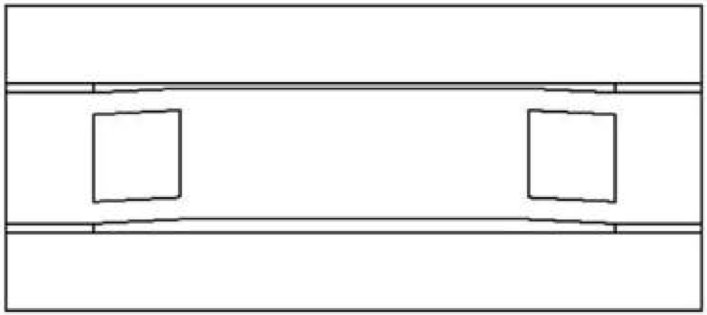
Introduction

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



Proven 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

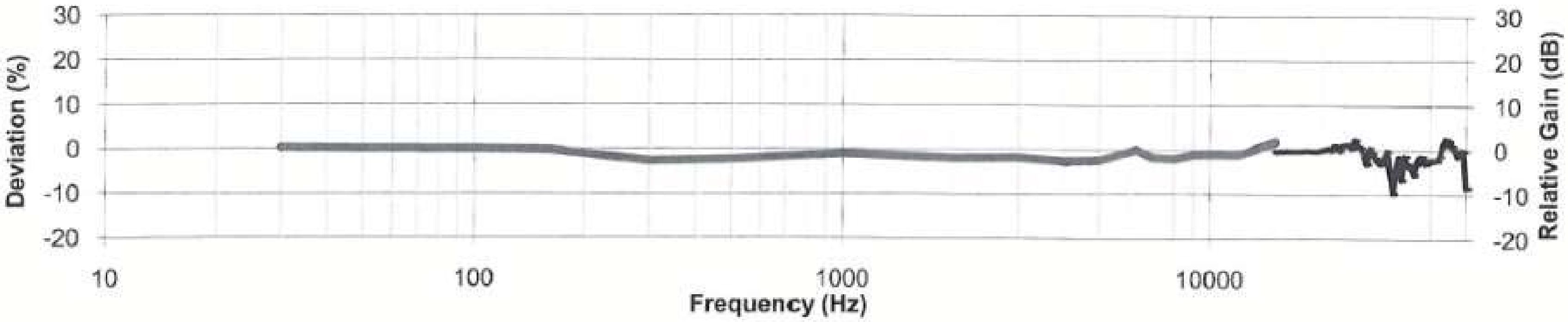
	20kG	60kG
Sensitivity	1uV/V/G	0.3uV/V/G
Full Scale (20mV/V)	20kG	60kG
Resonance	~65kHz	~150kHz
Mechanical stops	+/- 35kG	+/- 100kG
Resonant amplification "Q"	~10	~30 (estimated)

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

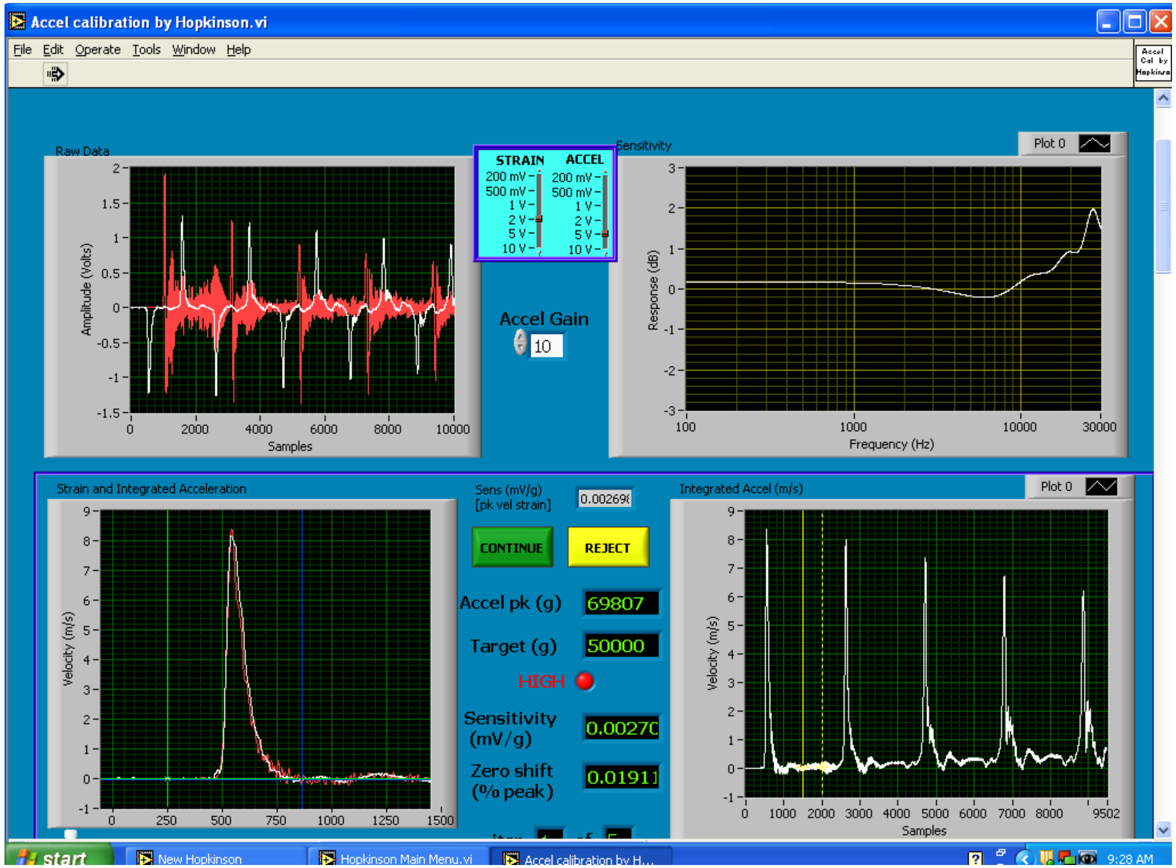
•From similarity, the response should be at least as flat as the 20kG sensor response, which has a lower resonance, shown here. It is difficult to measure the frequency response of 60kG sensor with a shaker due to force limitations of shakers.



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

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

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.

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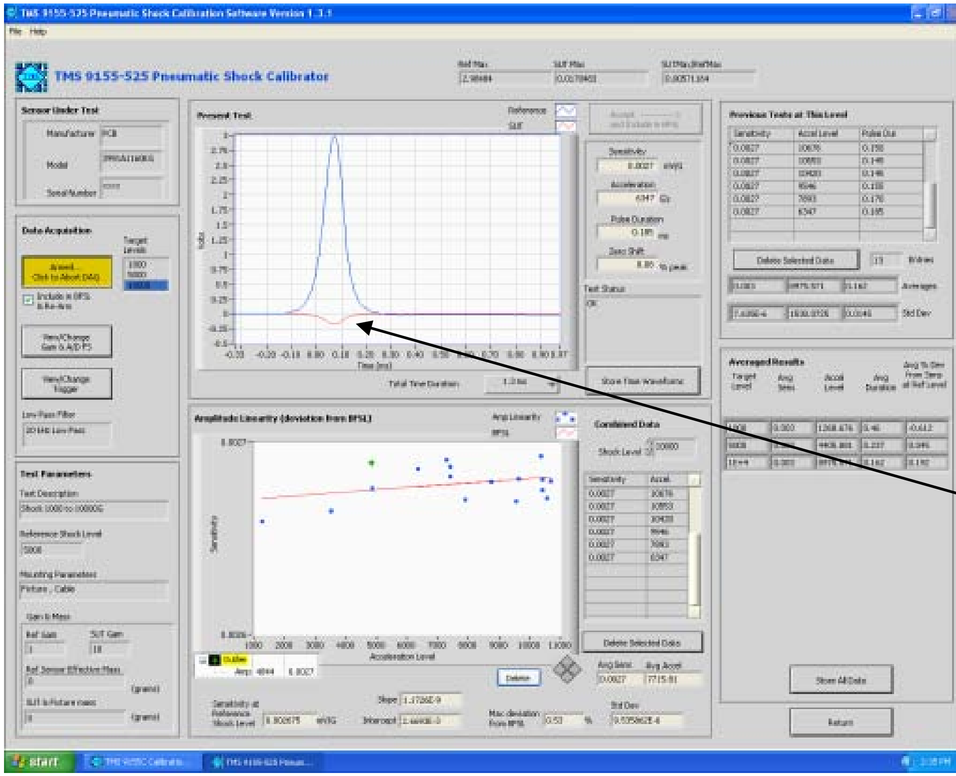
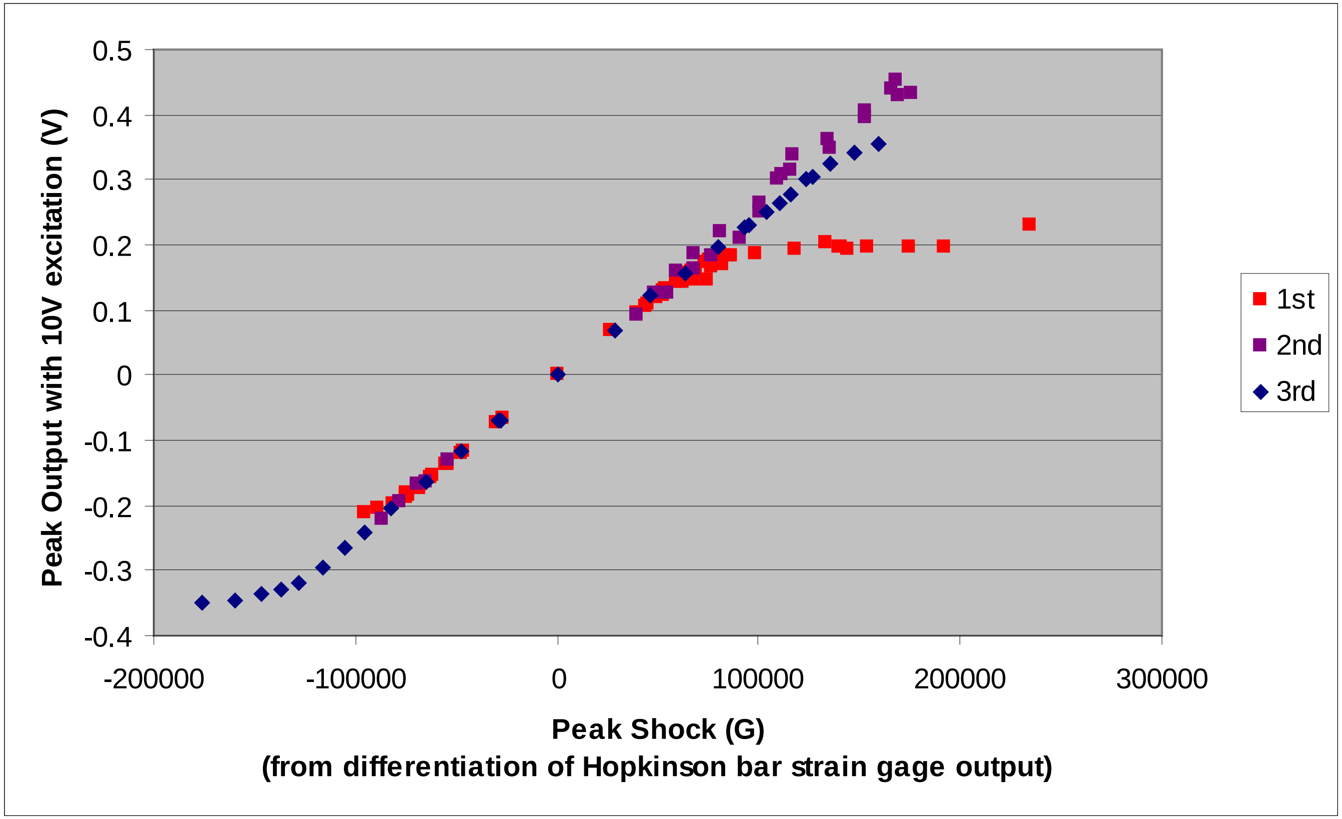
Amplitude Linearity



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%

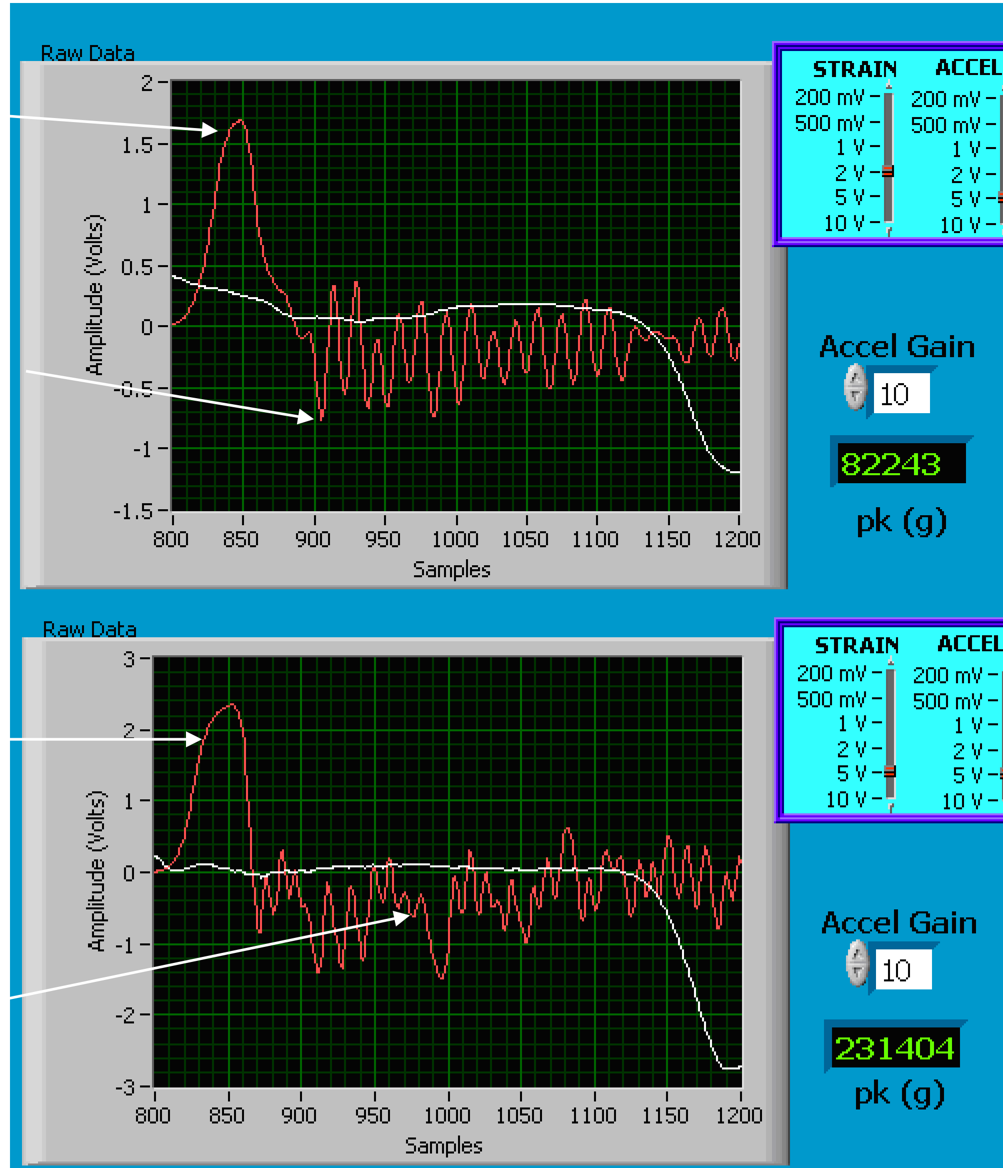
Finding the Mechanical Stop Level



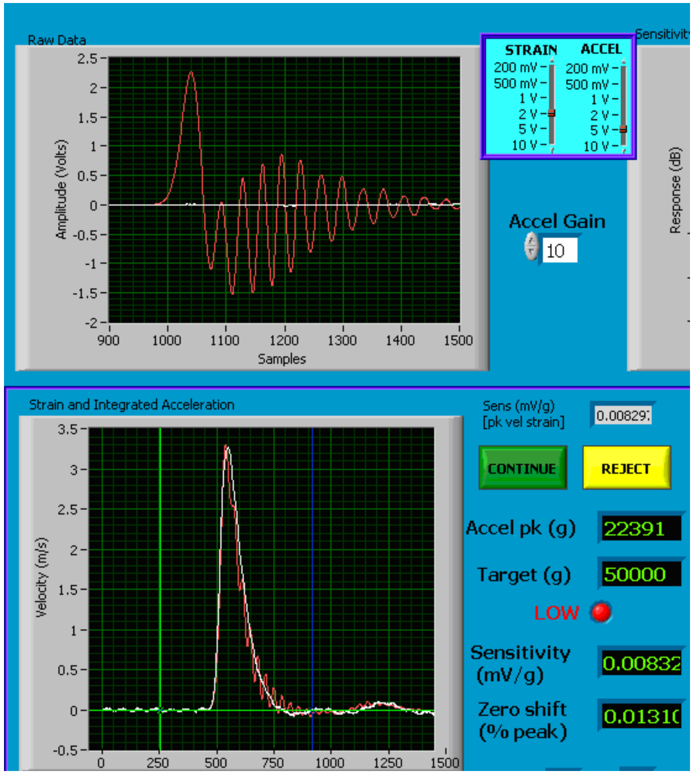
- Three 60kG wafer assemblies were made with three intentionally different stop levels (in search of Goldilocks level)
- Hopkinson bar was used in these tests of linearity, again using sensor package that could also be mounted upside down

Mechanical Stop Dynamics

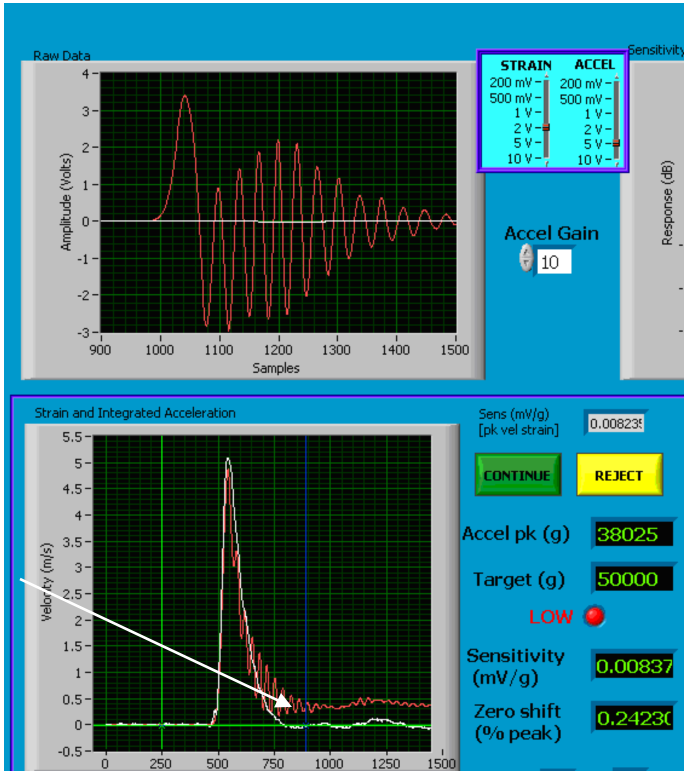
- From the 1st wafer, output slope just begins to smoothly "roll over" at 80kG
- Low-Q 150kHz resonance
- Recovers within a few microseconds from 230kG overload
- Output continues to increase after hitting the stop, the cantilevers continue bending from their own inertia
- Higher 250kHz mode is visible



Errors Caused by Hitting Stops

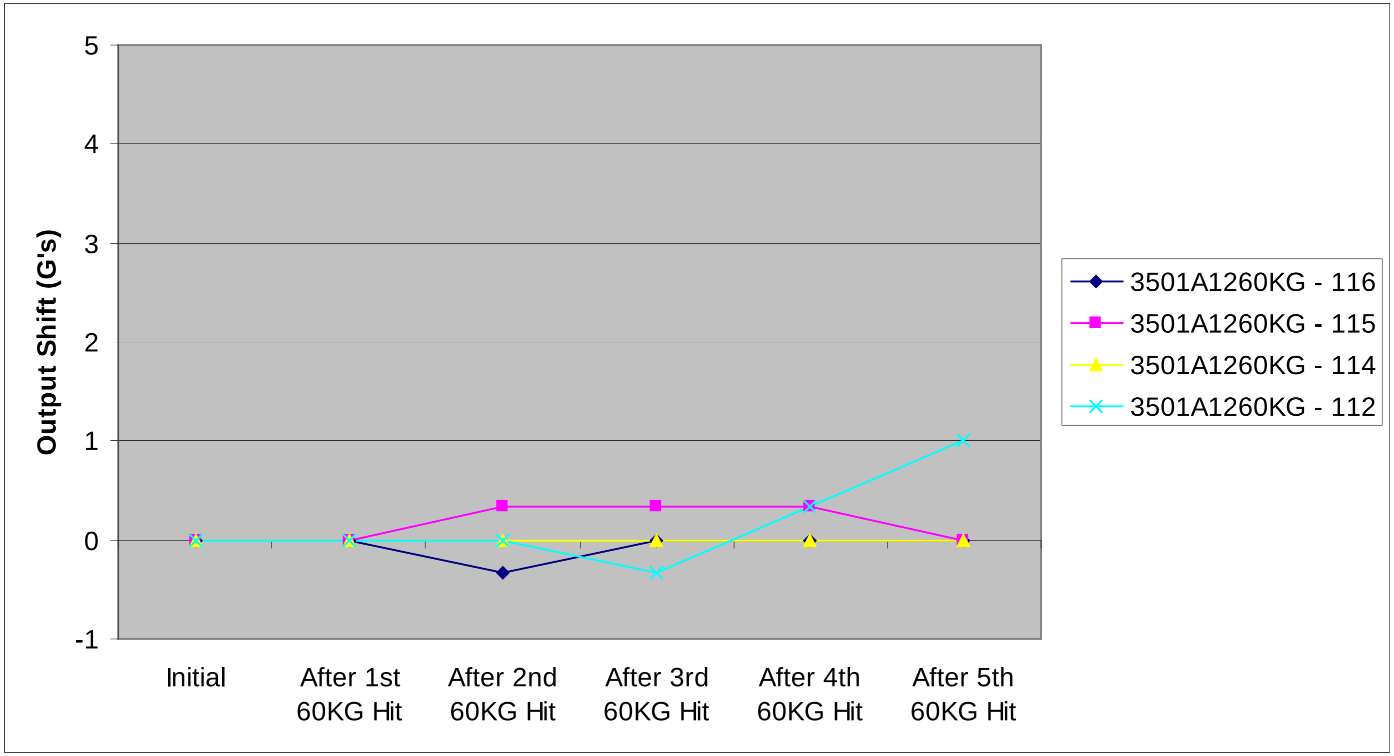


Integration error



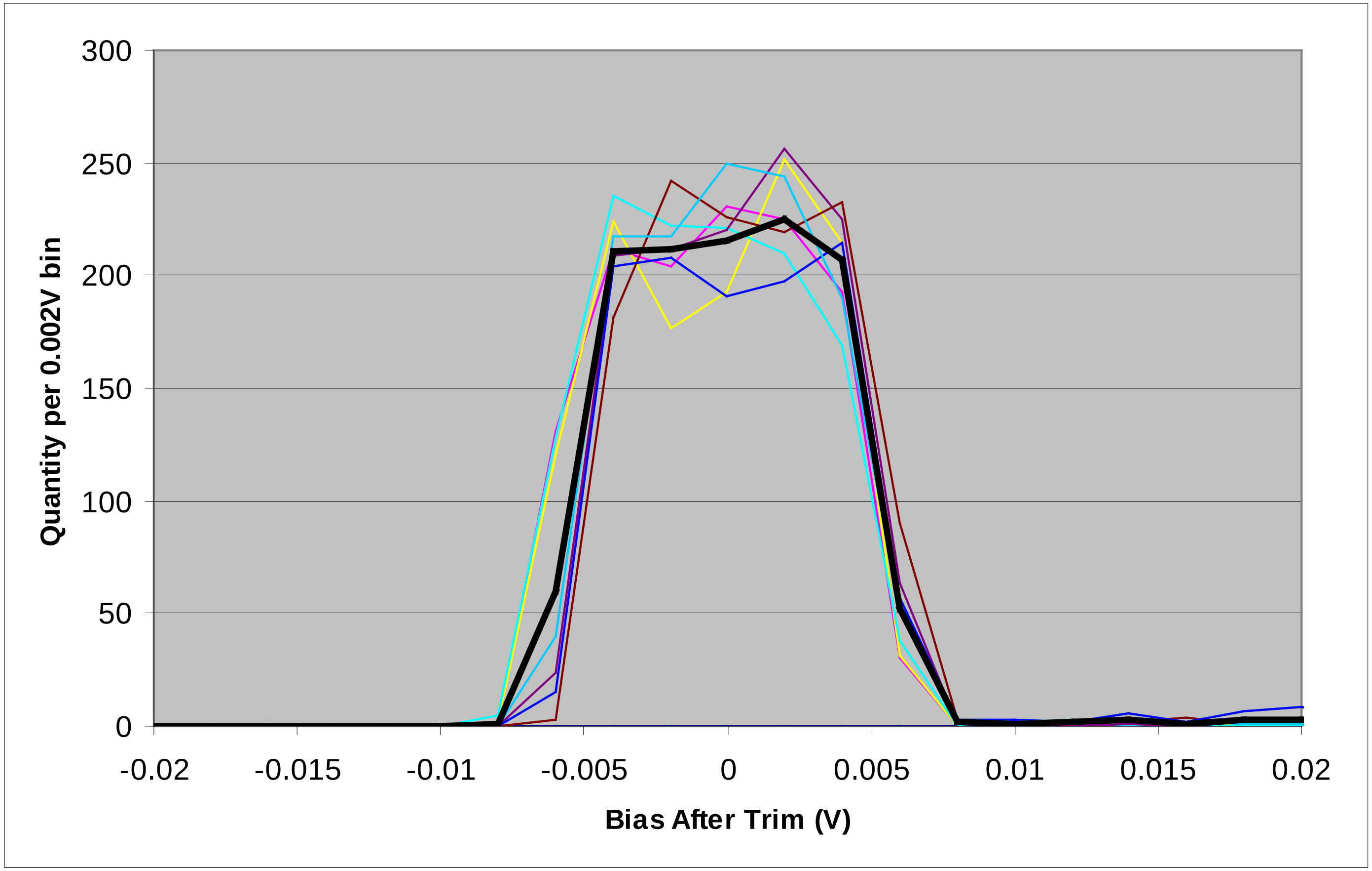
- The lower graph in each test is the integrated accelerometer output overlaid on the Hopkinson bar strain gage output. On the left is a 22kG test of a 20KG sensor; on the right is 38kG, at which the positive stops just touch. A microsecond delay of output explains the integration error on the right.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

Zero Shifts due to Shock



•These shifts represent a few microvolts total change in output over a sequence of 5 Hopkinson bar hits at 60KG on each of 4 sensors.

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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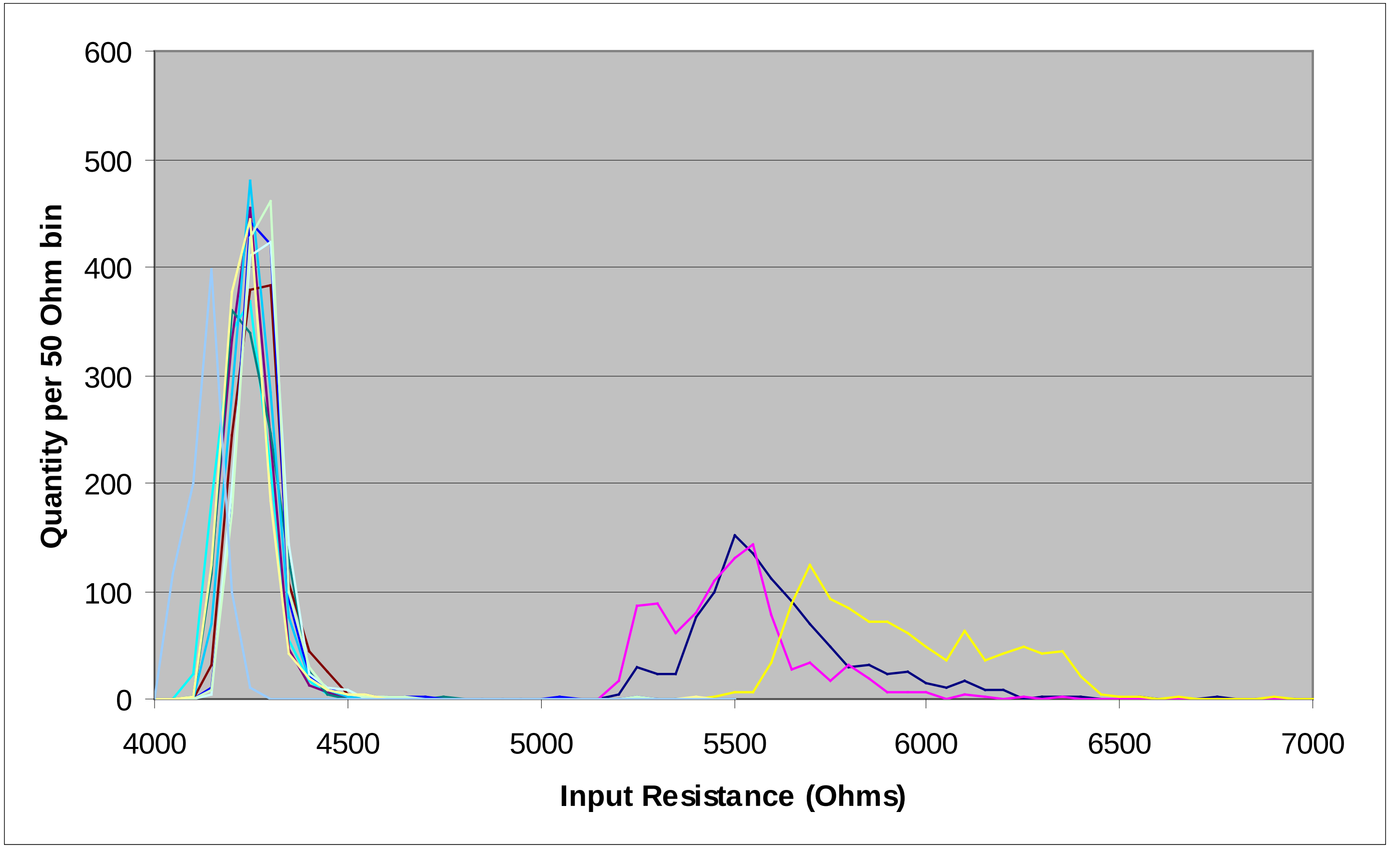
Resistance Histograms



- Resistance on 10 production process wafers on left shows extremely tight spread (standard deviation of <1.5%)
- This is an improvement over the 20KG prototype wafers on right, correlated with improved bias stability (see next graph)

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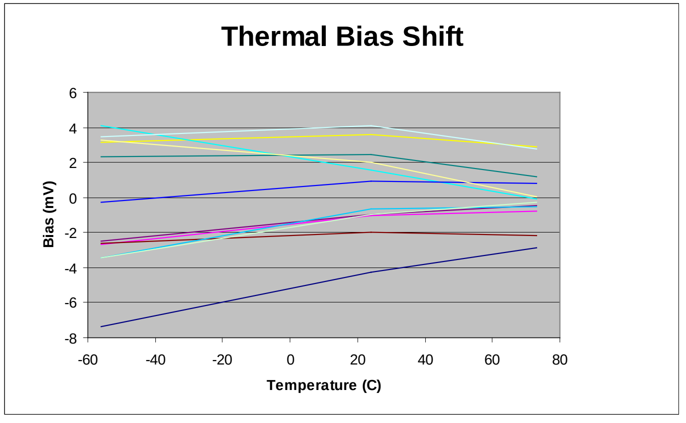
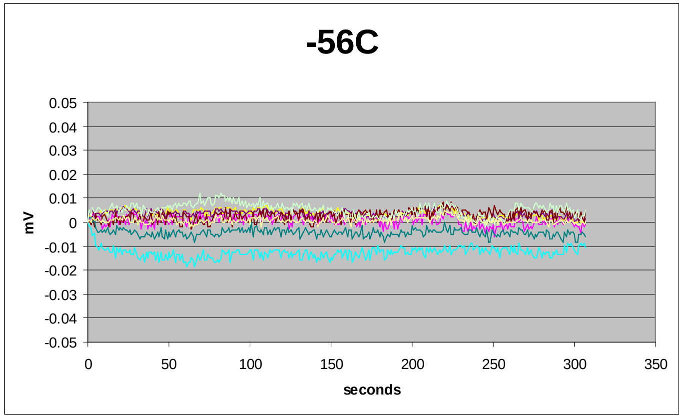
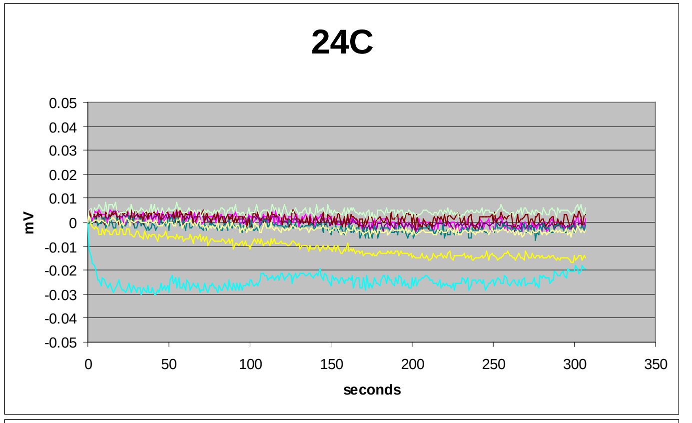
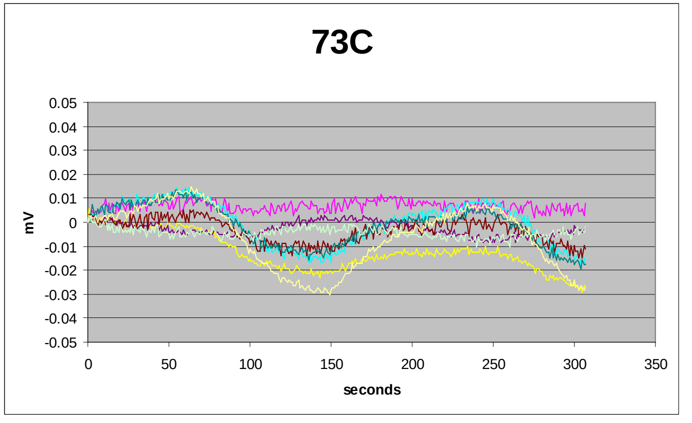
Power-on Warm-up Drift

- Excitation voltage is suddenly applied, then bias is monitored for 300 seconds. ~0.01% FS drift
- Self heating is minimal.
- Bias shift of <+/-4%FS/100C









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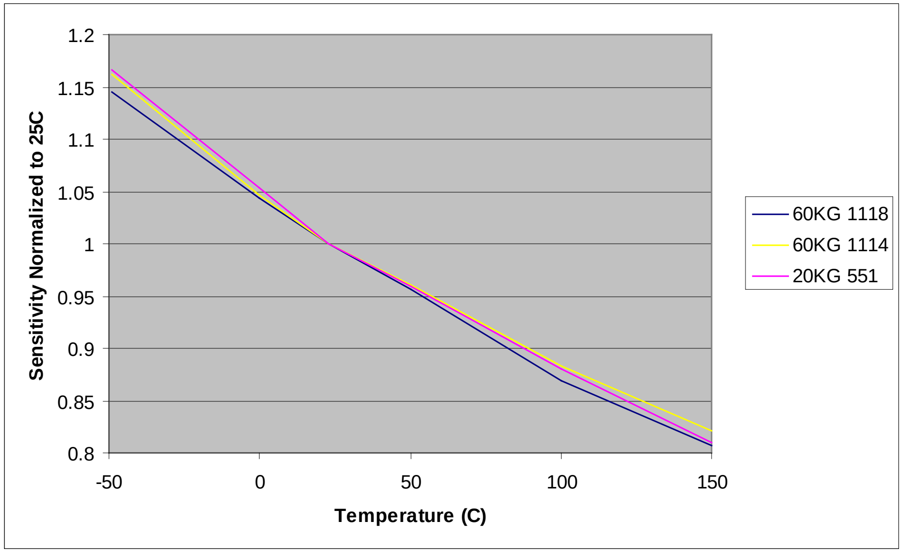
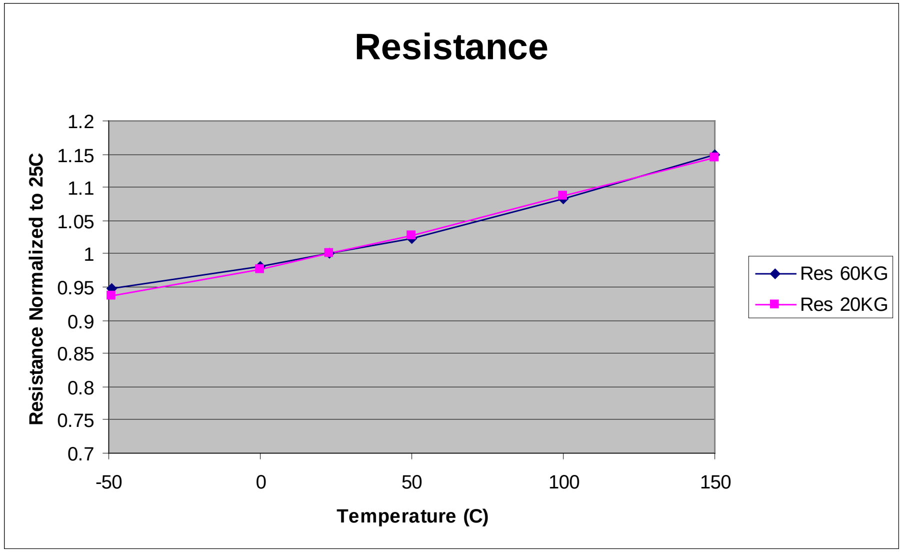
Thermal Characteristics

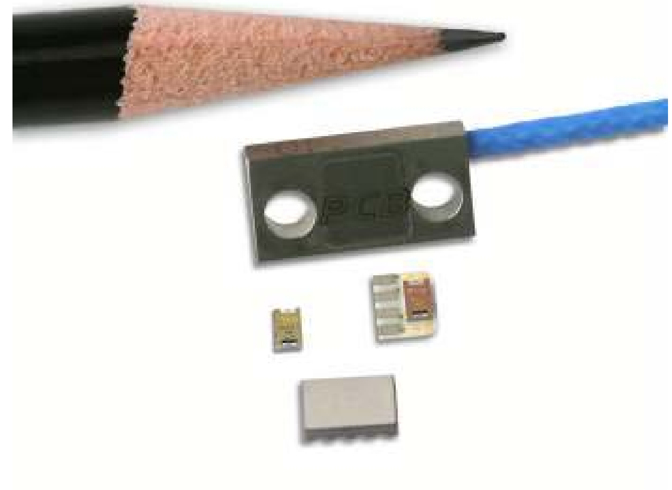
•Sensitivity: -17%/100C

•Resistance: +10%/100C





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