

DC Response from an ICP® Supply Using a 60kG PR MEMS Sensor

Robert D. Sill

Senior Scientist

PCB Piezotronics Inc.

951 Calle Negocio, Suite A

San Clemente CA, 92673

rsill@pcb.com (877) 679 0002 x2954

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The title should raise questions:

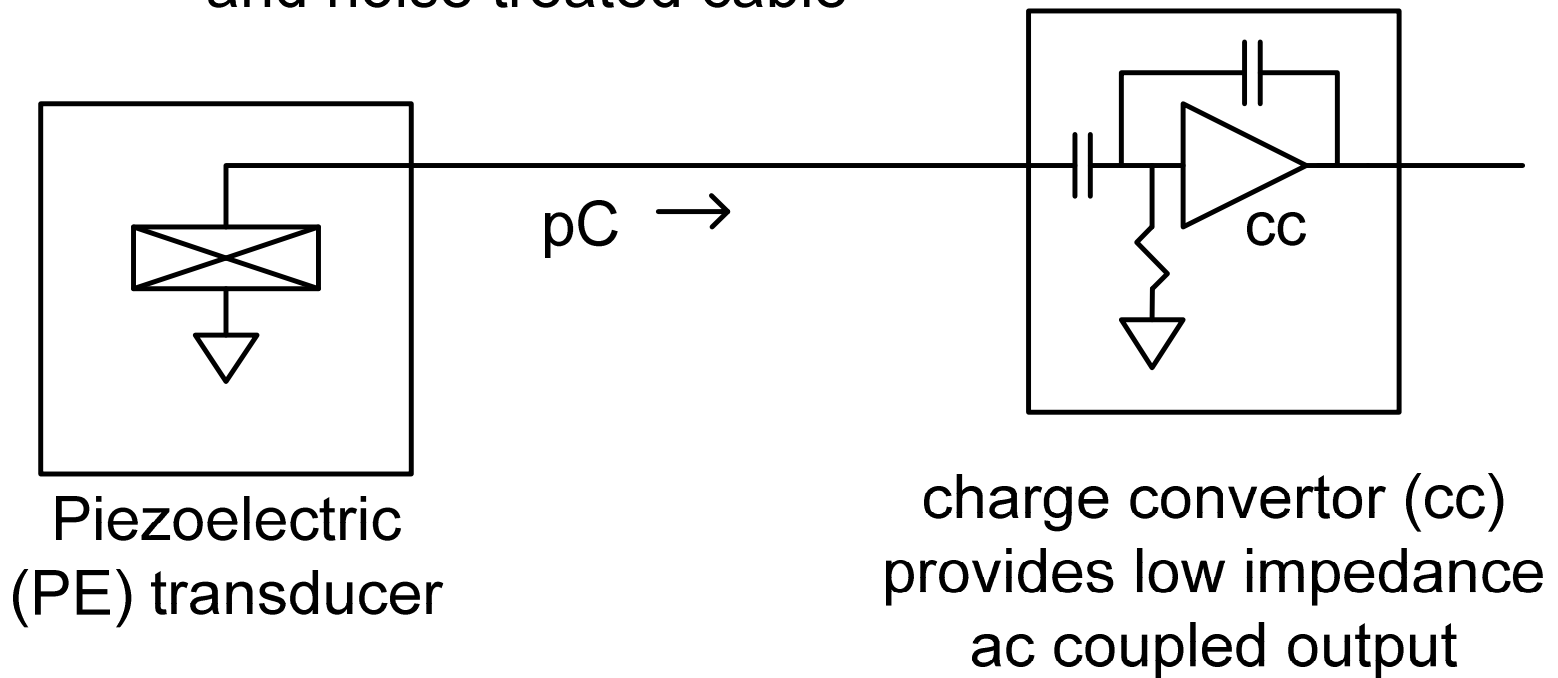
- How to get DC response from ICP® conditioning that is normally AC-coupled?
- Since ICP® is normally used with PE transducers, what does that have to do with *PiezoResistive* (PR) Micro-Electro-Mechanical Systems (MEMS) sensors?
- Why bother with DC-coupling at all?
- And why use a 60kG sensor?

Introduction

- Evolution of transducers and signal conditioning from PE to ICP® to PR to ICPR™
- Performance of new circuitry
- Performance of new 60kG sensor

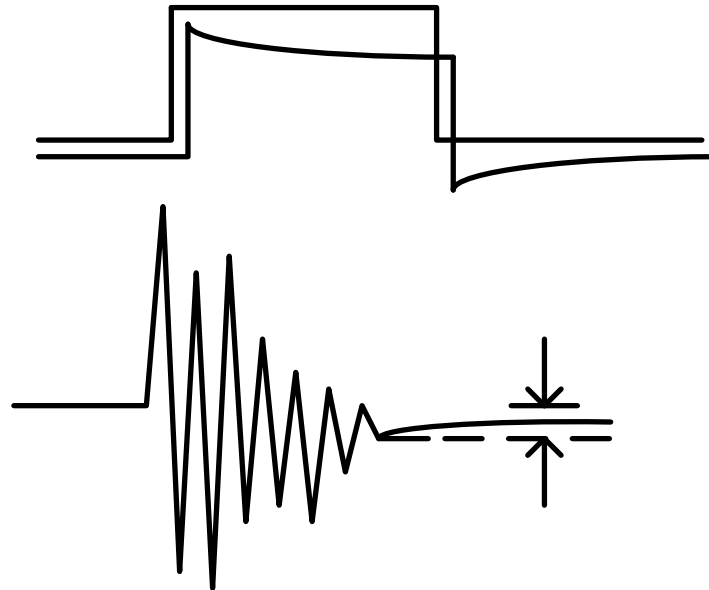
Piezoelectric

charge signals require extremely high impedance circuits, shielding and noise treated cable



Piezoelectric (cont)

ac coupling
distorts long
pulses



possible
zero shift

Advantages:

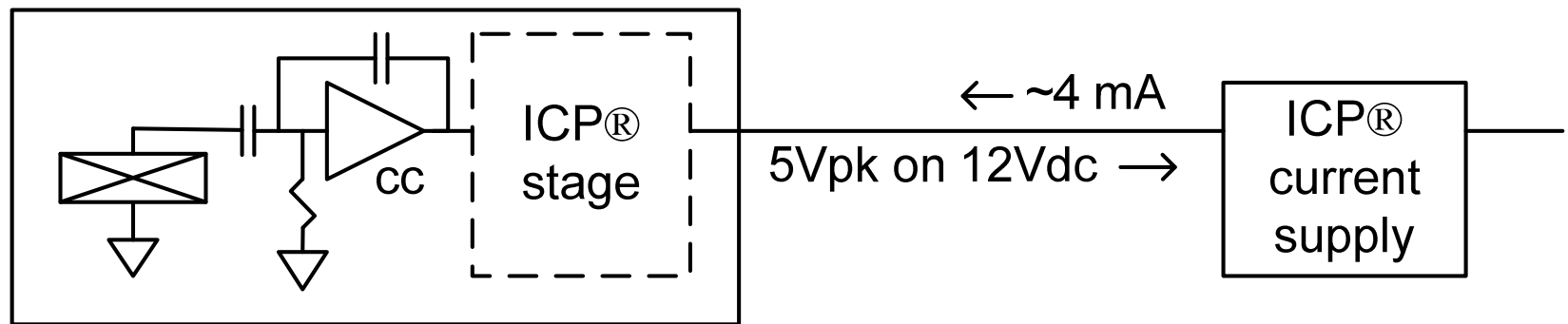
- tough
- thermal extremes

Disadvantages:

- noise treated cable
- ac coupling
- zero shifting

ICP®

internal circuit allows simple 2-wire cable

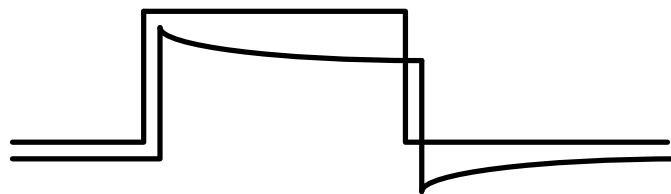


ICP® transducer

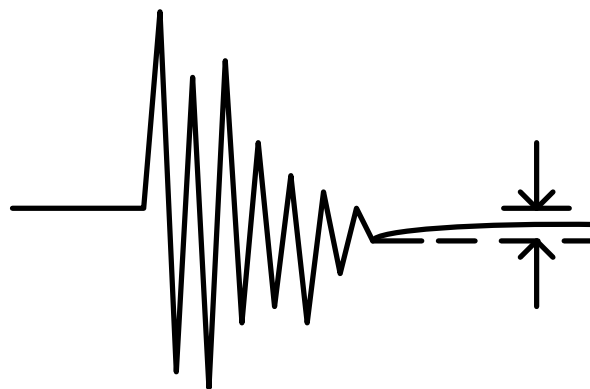
low impedance ICP®
stage adds ac coupled
signal onto dc bias

ICP® (cont)

ac coupling
distorts long
pulses



possible
zero shift



Advantages:

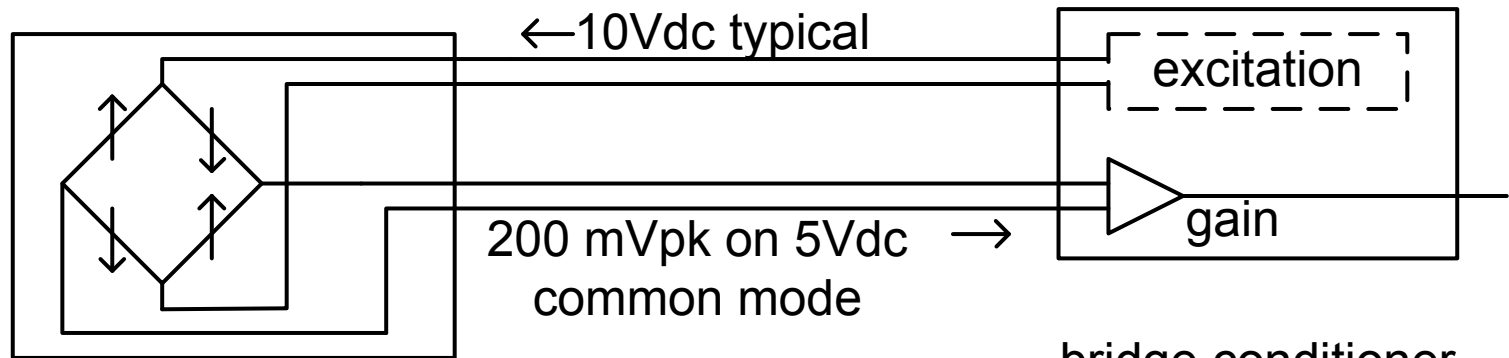
- Tough
- simple cable

Disadvantages:

- ac coupling
- zero shifting

Piezoresistive Bridge Conditioning

Differential output allows rejection of common mode noise, needs four wire cable (six wires for long leads and sensed excitation)



Piezoresistive (PR) transducer has moderate impedance, thermal sensitivity, can be fragile if undamped

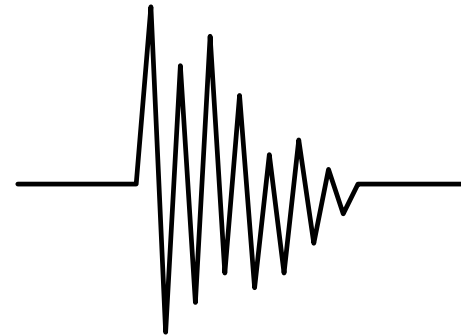
bridge conditioner provides excitation and dc coupled signal

PR Bridge Conditioning (cont)

dc coupled



Low probability
of zero shift



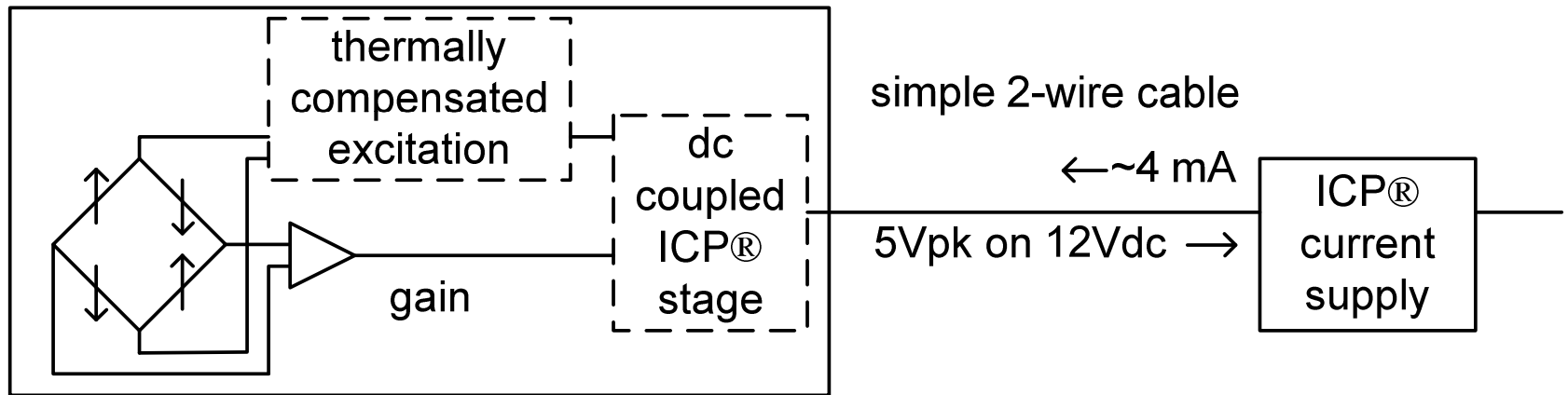
Advantages:

- dc coupling
- less zero shift

Disadvantages:

- can be brittle, high Q
- excitation and cabling
- temperature sensitive

ICPR™



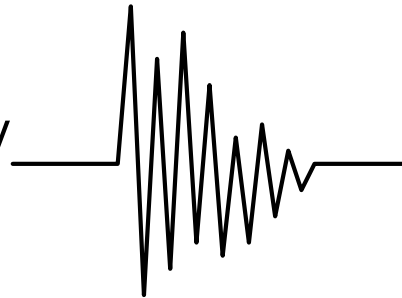
ICPR™ transducer has gain and thermally compensating excitation, moderately-damped piezoresistive (PR) transducer with over range stops, low impedance ICP® stage which adds dc coupled signal onto dc bias

ICPR™ (cont)

dc coupled



Low probability
of zero shift



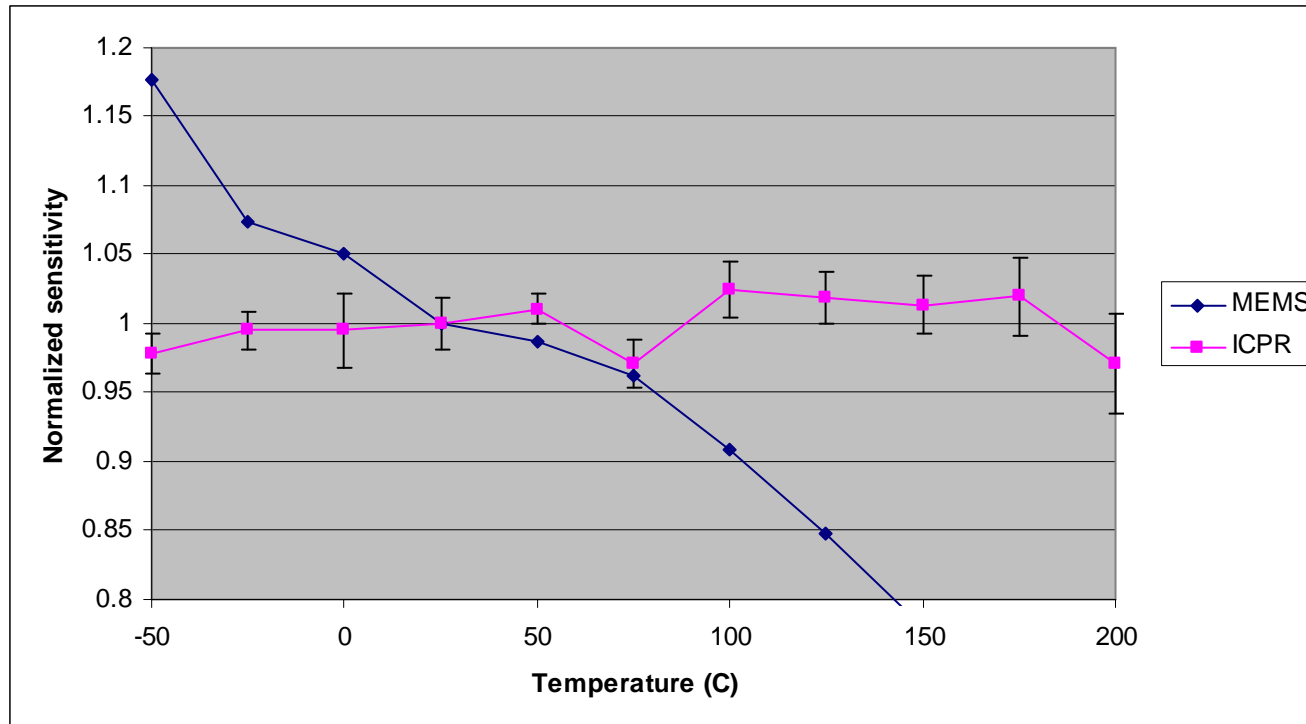
Advantages:

- dc coupling
- less zero shift
- simple cable
- damping, stops
- thermally compensated

Disadvantages:

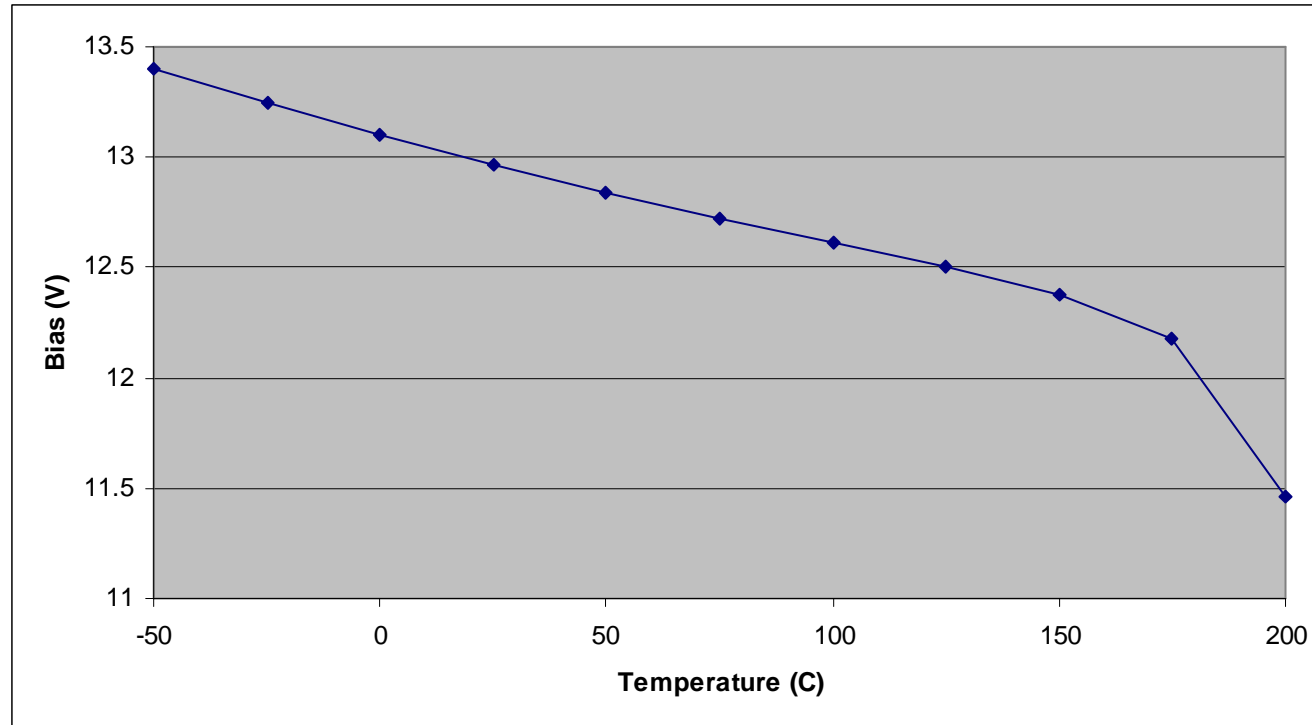
- gain stage adds noise
- base strain sensitivity is more apparent

Thermal Sensitivity Compensation



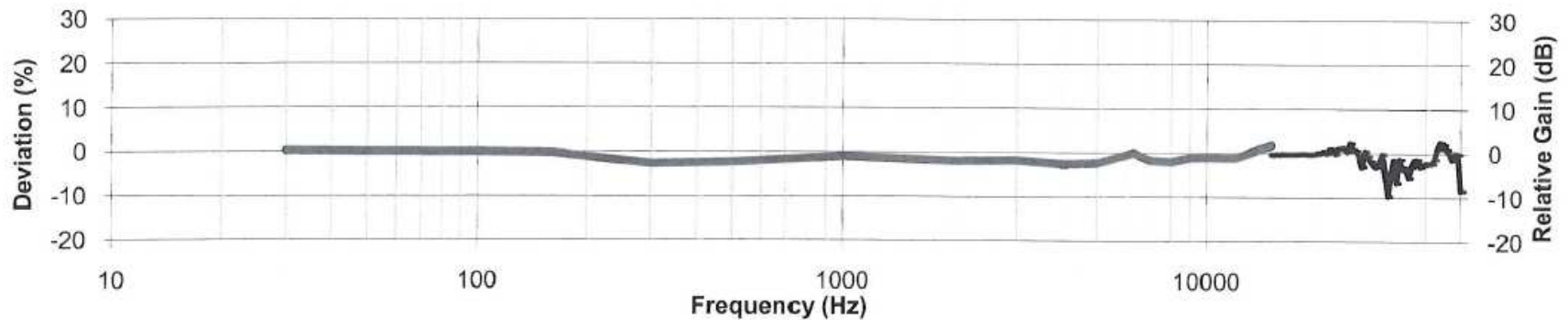
- MEMS sensitivity vs. temperature is nicely linear: $-20\%/100\text{C}$
- MEMS resistance vs. temperature is nicely linear: $+10\%/100\text{C}$
- ICPR™ system sensitivity was successfully compensated (with the supply described in the patent), well beyond normal temperatures (components detached at 200C when solder softened during this Hopkinson bar test)

Thermal characteristics



- ~1V/200C thermal bias shift (20%FS/200C = ~1%/10C)

Frequency Response of MEMS and Circuit



- Frequency response performed on air bearing shaker with aluminum armature and beryllium insert at 10G

(Dips in response at 30kHz are probably armature resonances, as they were seen on reference transducer as well)

- It is difficult to calibrate low sensitivity shock accelerometers at very low frequencies due to displacement limits on shakers ...

DC calibration (?)



Left: Sensor is oriented up, measuring +1G

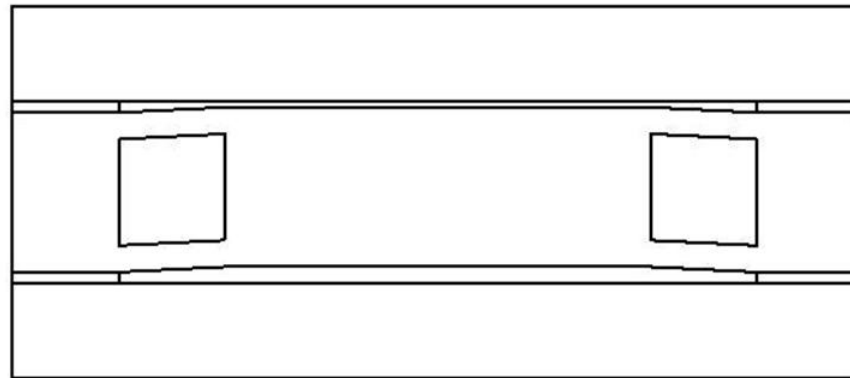
Right: Sensor is upside down, measuring -1G

Sensitivity is 0.5mV/G for this 10KG FS version, therefore the expected change of output is 0.001V, as shown

[“2G turnover” calibration is not normally done with 10KG shock sensors]

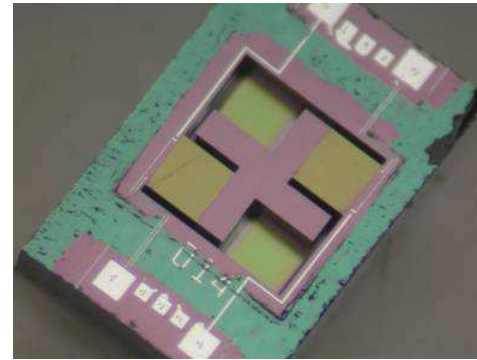
New Sensor Description

- Same format, diced from a sandwich of three wafers
 - Sensors are hermetically sealed
 - Thicker cantilevers for higher range
- Higher resonance than previous sensor: $\sim 150\text{kHz}$



- Relatively large displacements enables:
 - Squeeze-film damping, from air trapped in gap, to reduce resonant amplification
 - Over Range stops can be well controlled

Sensor Comparison

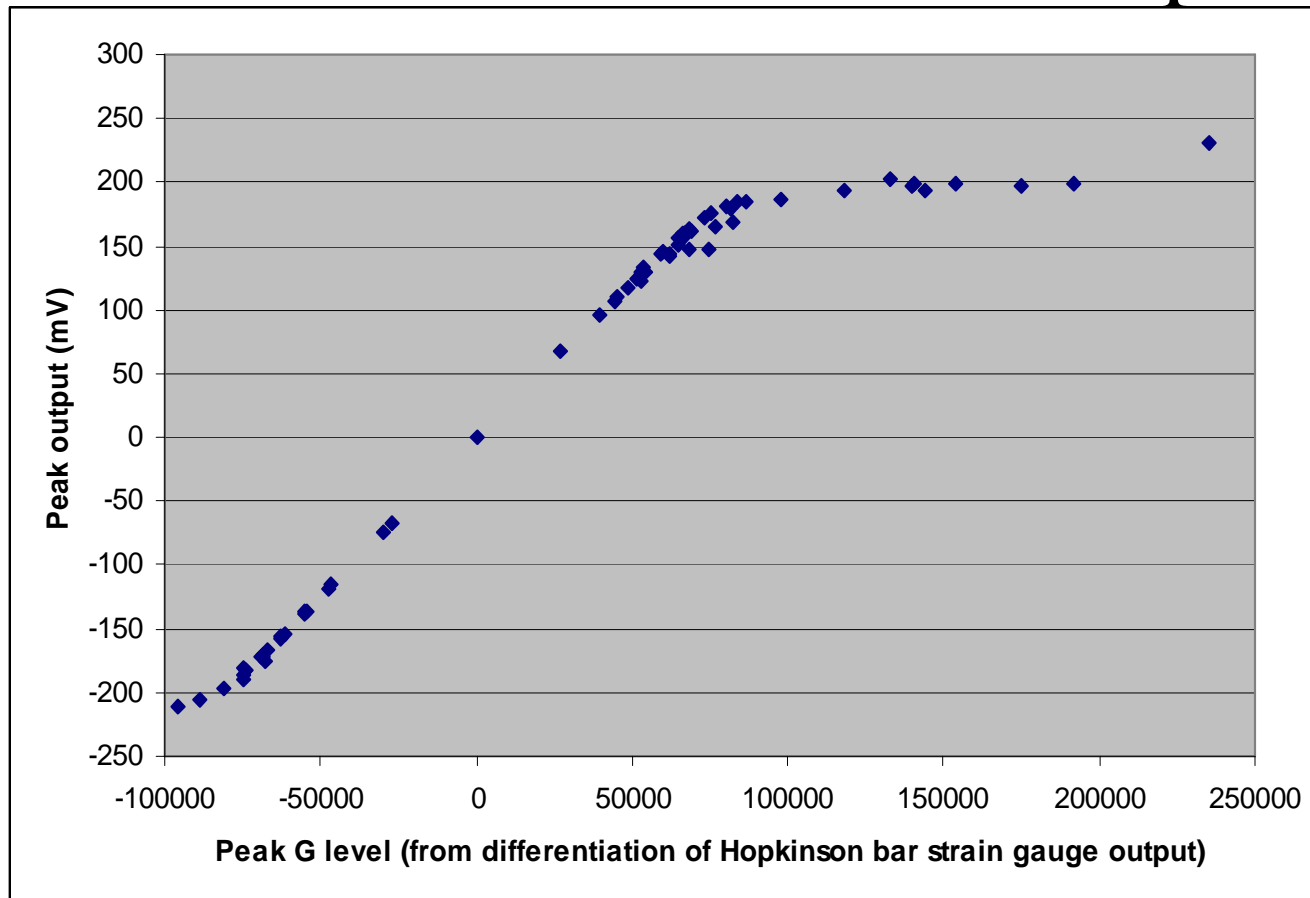


	20kG	60kG
Sensitivity	1uV/V/G	0.3uV/V/G
Full Scale (20mV/V)	20kG	60kG
Resonance	~65kHz	~150kHz
Mechanical stops	+/- 35kG	+/- 100kG
Resonant amplification "Q"	~10	~30

other parameters are the same for both versions

Input Resistance	~5000 Ω
ZMO	<20%FS (2% typical)
"Flip chip" capable?	yes
Dimensions	0.098" x 0.067" x 0.039" (2.5mm x 1.7mm x 1.0 mm)

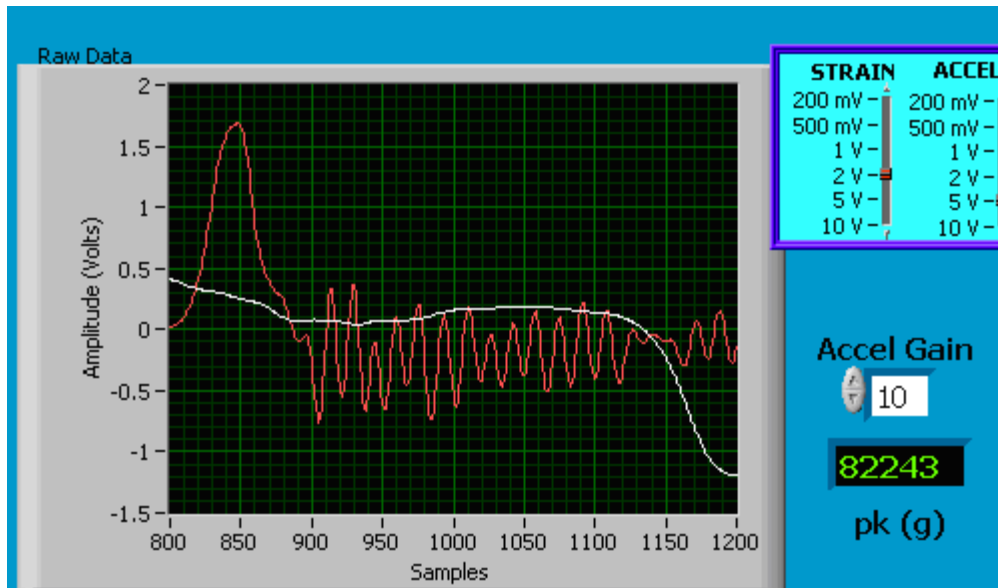
60KG sensor mechanical stops



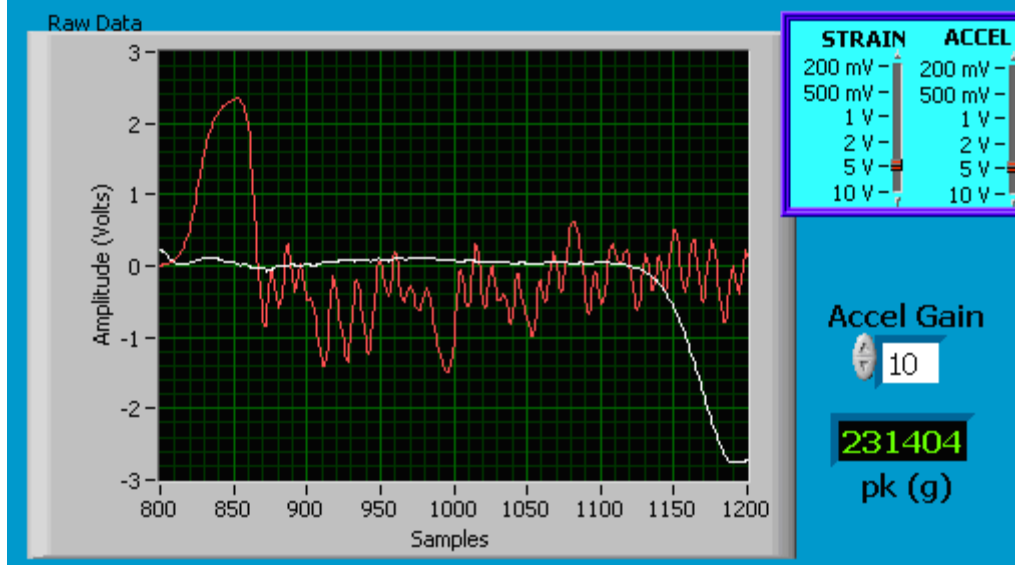
Peak output vs input of four 60KG sensors, hit 82 times

- All were also mounted upside down to find negative stops (not in ICPR housing)
- All survived with sensitivity and bias unchanged.

60KG mechanical stops (cont)



- Output slope just begins to smoothly “roll over” at 80kG
- Low-Q 150kHz resonance



- Recovers quickly from 230kG overload
- Not a hard stop, perhaps the cantilevers continue bending from their own inertia
- higher 250kHz mode is visible

Conclusions

- Patent pending ICPR™ combines PR with ICP® 2-wire cable
 - Allows more accurate integration of velocity and displacement with low shift PR and 0Hz (DC) data
 - Provides thermal compensation of PR sensitivity
 - High level (5V FS) output from PR sensor
 - Present ranges: 100KG, 50KG, 10KG, 5KG
- (External PR sensors can use in-line ICPR™ module
 - Provides fixed 5V excitation, not thermal compensation)
- 60KG sensor
 - Extremely rugged, survives ~4 times full scale without damage or bias shift