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SIXTY YEARS OF
TRUSTED
MEASUREMENTS

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smart engineering for
extreme environments

Advancements in Low Noise Accelerometers

- Challenges to Creating Lower Noise Devices
  - IEPE
  - PE
- Endevco Publications
  - IEEE Published Papers since 2000
- New Low Noise Products
  - Model 2771C
  - Model 86
  - Model 87

Challenges to Lower Noise - IEPE

- IE - FET Amplifiers (field effect transistors)
  - Noise dependant upon the source impedance
  - Channel thermal noise
    - Usually dominates at frequencies above 1Khz
  - Thermal noise of biasing resistor
    - Usually dominates at frequencies below 1kHz
  - FET design and selection critical to creating low noise devices
    - FET suppliers generally do not provide noise specifications
    - Sensor manufacturers most have the experience and capabilities to choose the best components
  - Optimization of circuit schematic

- PE - Electrical-Thermal
- PE - Mechanical-Thermal

Challenges to Lower Noise - PE

- Electrical-Thermal
  - PE Element
  - Determined by the loss factor of the PE Element
  - Frequently neglected in design and analysis
  - Directly related to the quality of the material
  - Generally dominant over M-T noise of PE devices up to 10kHz
- Mechanical-Thermal
  - Damped Harmonic Oscillator
  - Lower noise can be obtained through design
    - Increased mass reduces noise
      - Effectively decreases the resonant frequency of the device
    - Increased Q (quality factor) at resonance
  - Generally dominant over E-T noise of PE device above 10kHz

Endevco Publications

- IEEE Sensors Journal
  - Vol. 4, No. 1, Feb 2004 – “Fundamental Noise Limit of Piezoelectric Accelerometer”
  - Vol. 5, No. 6, Dec 2005 – “Noise of PE Accelerometer with Integral FET Amplifier”
- IEEE Transactions on Circuits and Systems
  - Vol. 47, No. 7, July 2000 – “Noise of the JFET Amplifier”
  - Vol. 54, No. 6, Dec 2005 – “Measurement of Low-Frequency Noise of Modern Low-Noise JFET”
- Upcoming Papers
  - “175ºC, 100 mV/G IEPE Miniature Triaxial Accelerometer”
  - “Ultra-Low Noise 10 V/g Compact Seismic Accelerometer”

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New Products

2771C – Lowest Noise Remote Charge Converter

Frequency response

	Lower cutoff frequency -3dB	Lower cutoff frequency ±5%	Upper cutoff frequency ±5%
-01	0.4 Hz	1.2 Hz	8 kHz
-1	0.4 Hz	1.2 Hz	30 kHz
-10	2 Hz	6 Hz	50 kHz

Electrical noise for -01, -1, -10
with Cs = 20 nF, for -10 with Cs = 2.8 nF
(Cs of model 7704A-50)

	-01	-1	-10	Competitive Products
Broadband noise (1 Hz-20 kHz), μVrms	5	30	50	200
Spectral noise, μV/ √Hz, 1 Hz	0.7	3.2	9	20
10 Hz	0.15	0.8	2	4
100 Hz	0.06	0.3	0.5	1.5
1 kHz	0.03	0.15	0.25	1.0
10 kHz	0.03	0.12	0.2	1.0

Two Wire, Single Ended

Microdot to BNC

al

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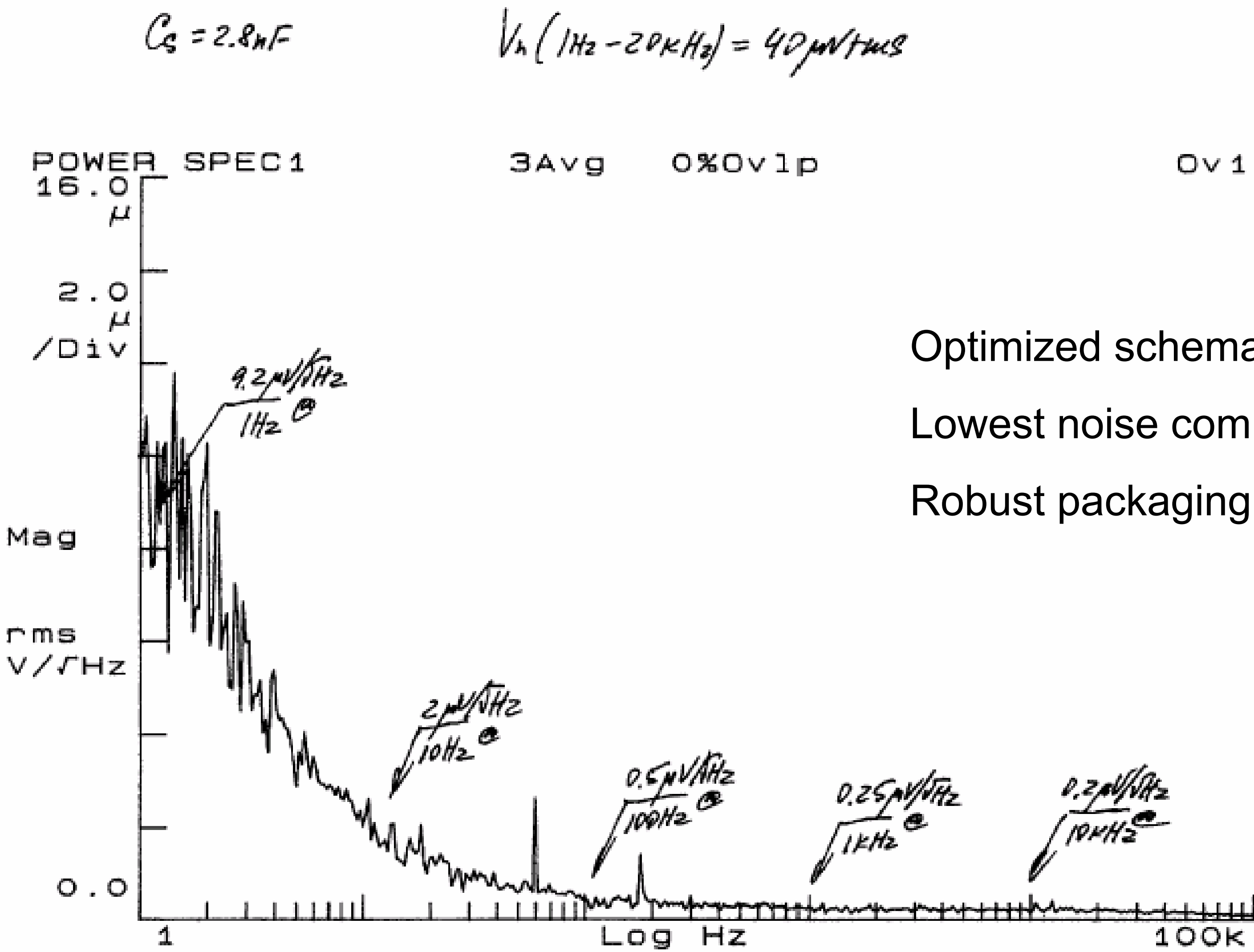
2771C Ultra Low Noise Charge Converter



Optimized schematic design

Lowest noise components

Robust packaging

Lowest Noise IEPE accelerometers

- Model 86 low noise performance verified by NIST on the world's quietest platform and used as feedback to make the world's most frequency stable laser for atomic clock measurements
  - http://www.nist.gov/public_affairs/releases/mercury_atomic_clock.htm
- Model 87 being used for vibration site surveys, perimeter monitoring, platform stabilization

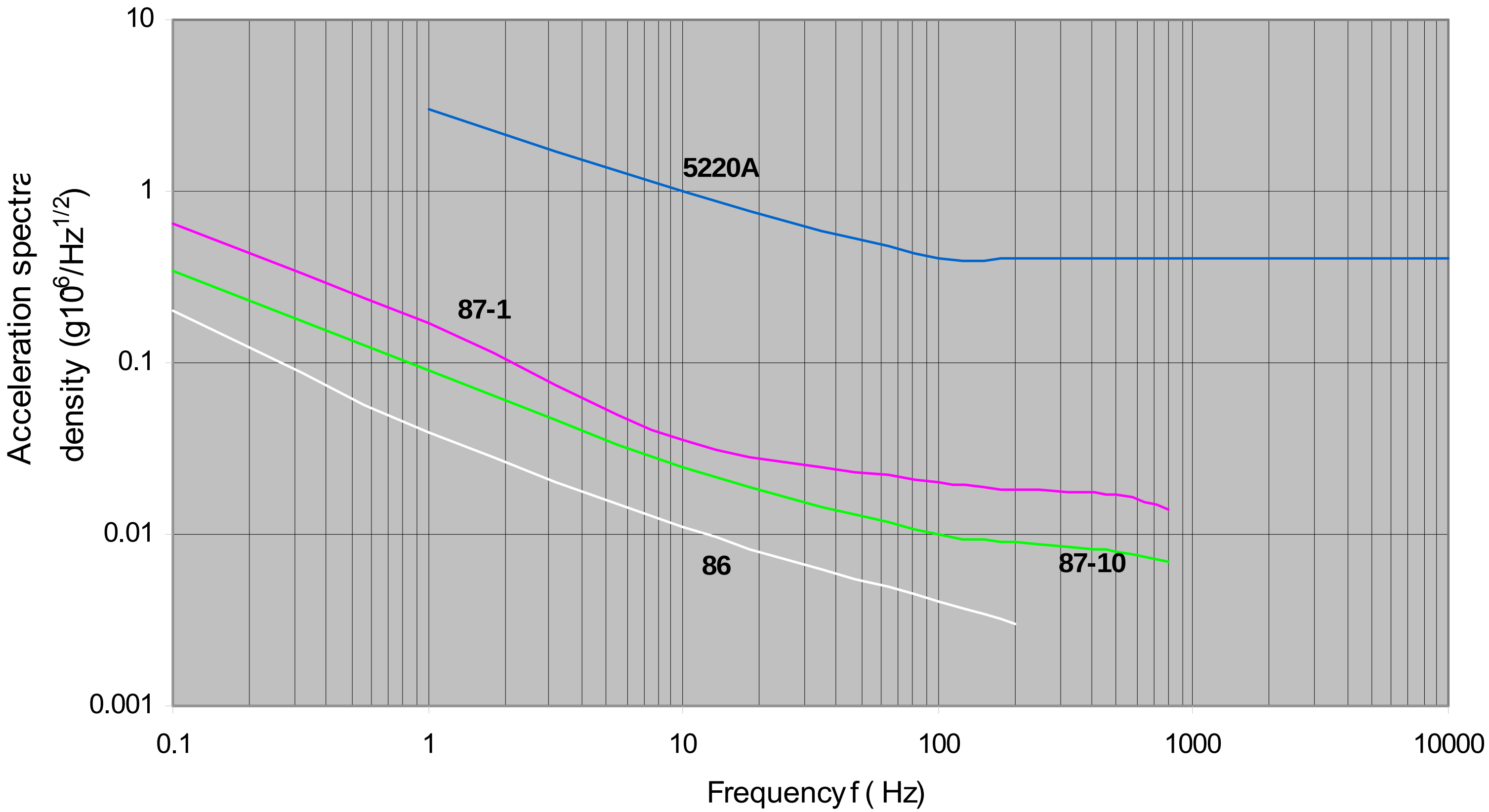
Model 86

Model 87

	86	87-1	87-10
Frequency Response +/- 1dB Hz	0.005 to 100	0.015 to 380	0.05 to 380
Sensitivity V/g	10	1	10
Residual Noise**			
Broadband 0.1 Hz to 1kHz typical equiv. ng rms	0.1	1000	340
Spectral – 0.5 Hz equiv. ng/√Hz	52		
Spectral – 1 Hz equiv. ng/√Hz	39	170	90
Spectral – 10 Hz equiv. ng/√Hz	11	36	25
Spectral – 100 Hz equiv. ng/√Hz	4	20	10
Resonant Frequency Hz	370	1220	
Operating Temperature Range (deg C)	-10 to 100	-20 to 100	
Shock Limit g	250	400	
Weight grams	771	165	

** Noise values shown above include the electronics circuit's noise and the PE transducer's noise which were determined based on the PE elements loss factor, which is constant over entire frequency range.

Noise Plot Comparison Between Low Noise Models 86, 87 and Industrial Standard Accelerometer



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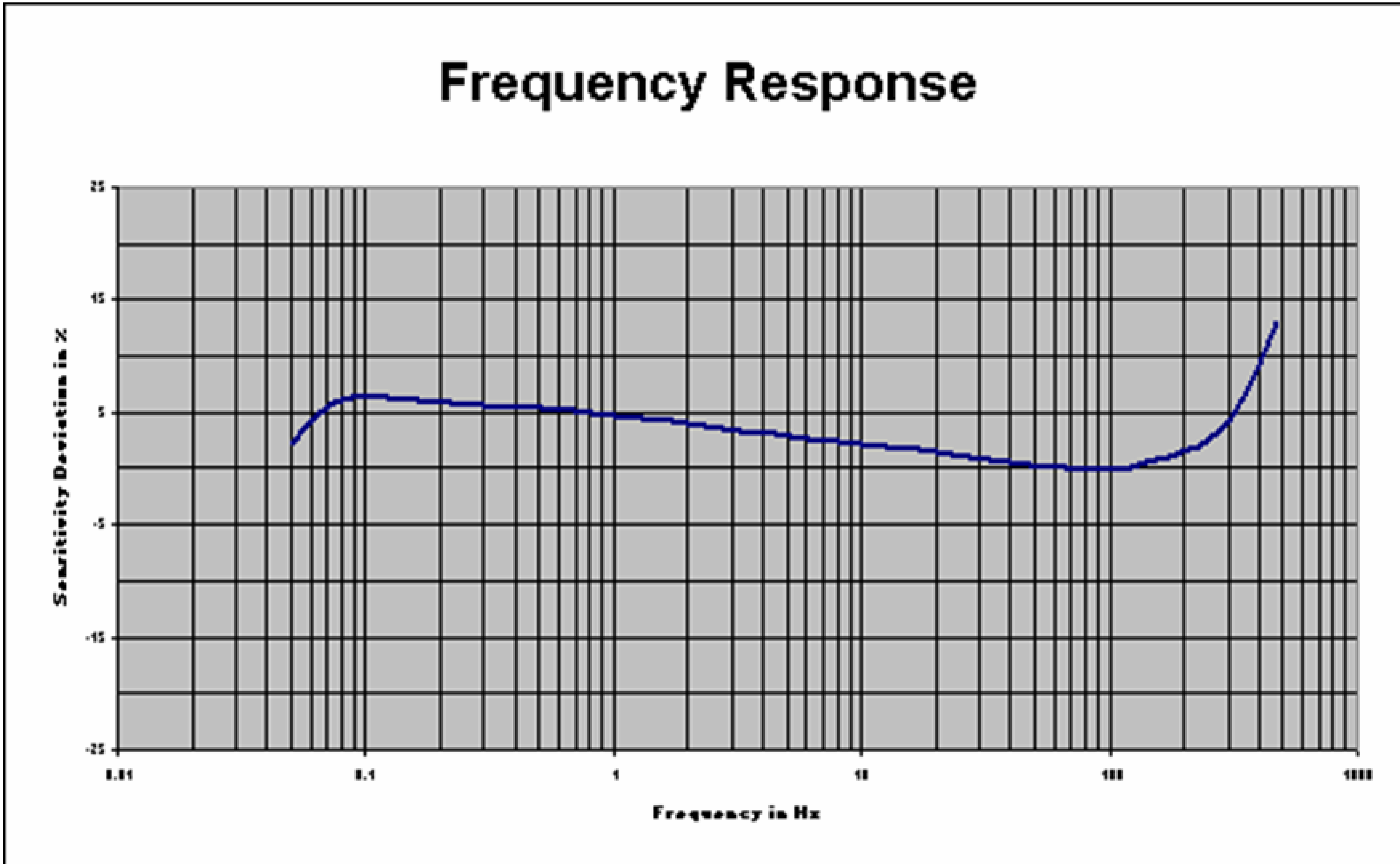
Model 87 – Low Noise Seismic Accelerometer



Final Thoughts

- Challenges to Creating Lower Noise Devices
  - The schematic solution is a critical foundation of low noise devices
  - Low noise FET's and other active components support effective design
  - Proper shielding, manufacturing and assembly needed to realize design intent
  - Improved mechanical designs and material quality
  - Endevco devices becoming quieter as our experience grows

- Applications which will benefit from lower noise devices
  - Platform stabilization, particularly in active isolation systems
  - Seismic or perimeter monitoring
  - Modal studies where small sensor outputs require even lower noise levels
  - Structural monitoring and structural design optimization for "quiet" vehicles

- It is critical that we continue to move performance to the extremes to enable future applications and fill in gaps in other technologies

Thank You!

Have a Great IMAC!

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