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THE INDUSTRY'S LOWEST NOISE 10 V/G COMPACT PIEZOELECTRIC SEISMIC ACCELEROMETER WITH INTEGRAL FET AMPLIFIER

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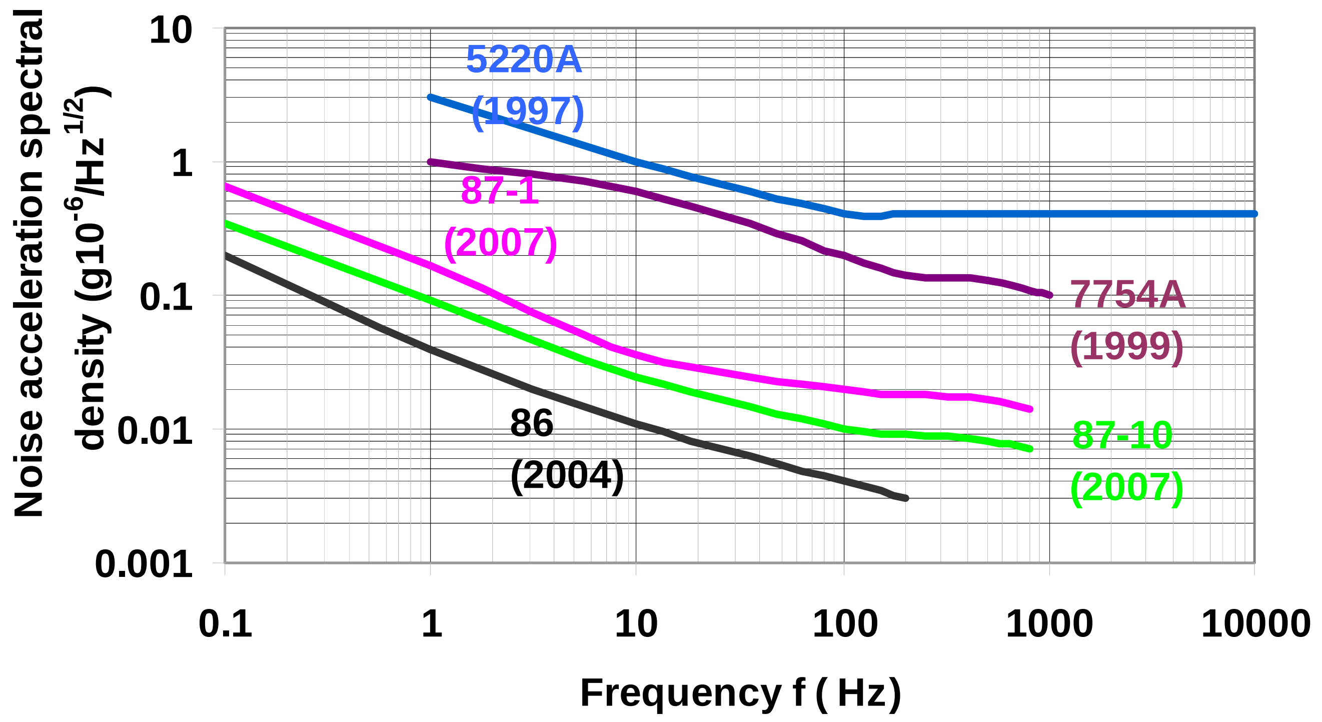
OUTLINE

- Low-noise IEPE accelerometers, their advantages and applications
- Configuration of the designed accelerometer
- Key factors providing ultra-low-noise operation
- Equivalent noise circuit of the IEPE accelerometer
- Parameters of designed accelerometer and measurement results
- Conclusions

Low-noise IEPE accelerometers and their applications

- Advantages: high sensitivity, wide dynamic, frequency, and temperature range, low-output impedance, and availability of compact design.
- Applications: Geological survey industry, structural health monitoring, developmental stabilization platforms, satellite systems, medical imaging technologies, and spectroscopy
- Progress in design of low-noise IEPE accelerometers for the past 10 years

Comparison of the IEPE accelerometers noise for the past 10 years



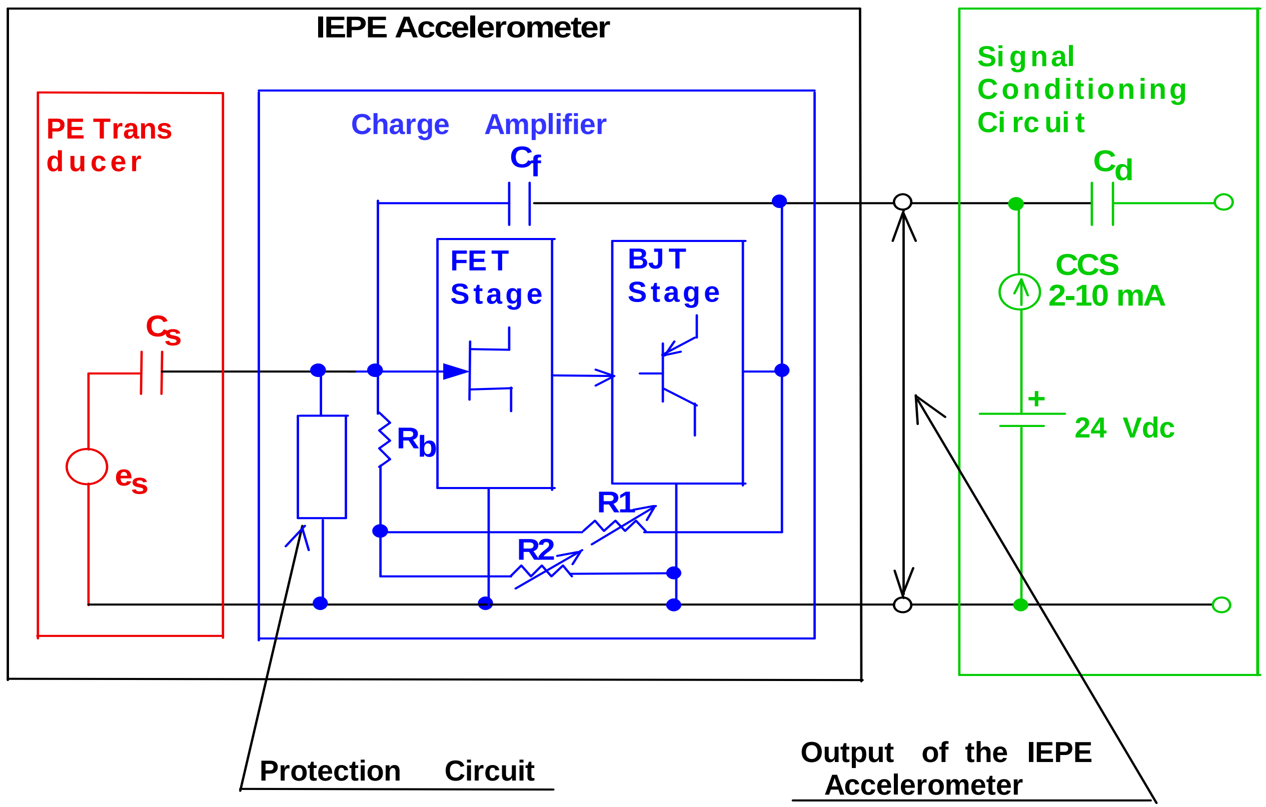
The industry's lowest noise models 86 and 87

- 86 : Sens. 10 V/g, F.R. (-3 dB) from 0.003 to 200 Hz ,
- 87-10: Sens. 10 V/g, F.R. (-3dB) from 0.04 to 800 Hz.

Noise acceleration spectral density, ng/$\sqrt{Hz}$

Frequency, Hz	0.1	1	10	100	200	800
86	200	39	11	4	3	
87-10	340	90	25	10	9	7
WR 731-207		400	90	30		

The industry's lowest noise models 86 and 87


IEPE Accelerometer
PE Trans ducer
Cs
es
Charge Amplifier
Cf
FET Stage
BJT Stage
Rb
R1
R2
Signal Conditioning Circuit
Cd
CCS 2-10 mA
+
24 Vdc
Protection Circuit
Output of the IEPE Accelerometer

Configuration of designed accelerometer

It is comprised of PE Transducer and ULN JFET–input amplifier, which is the core of the design.

PE Transducer :

$e_s = a_s \cdot V_s$,

$V_s = Q_s / C_s$,

- e_s is the EMF ,
- a_s is an input acceleration,
- V_s is voltage sensitivity,
- Cs is electrical capacitance.

V.S. from +24 to + 30 Vdc, I. S. =4 mA typical.

PE element made of PZT (ceramic),

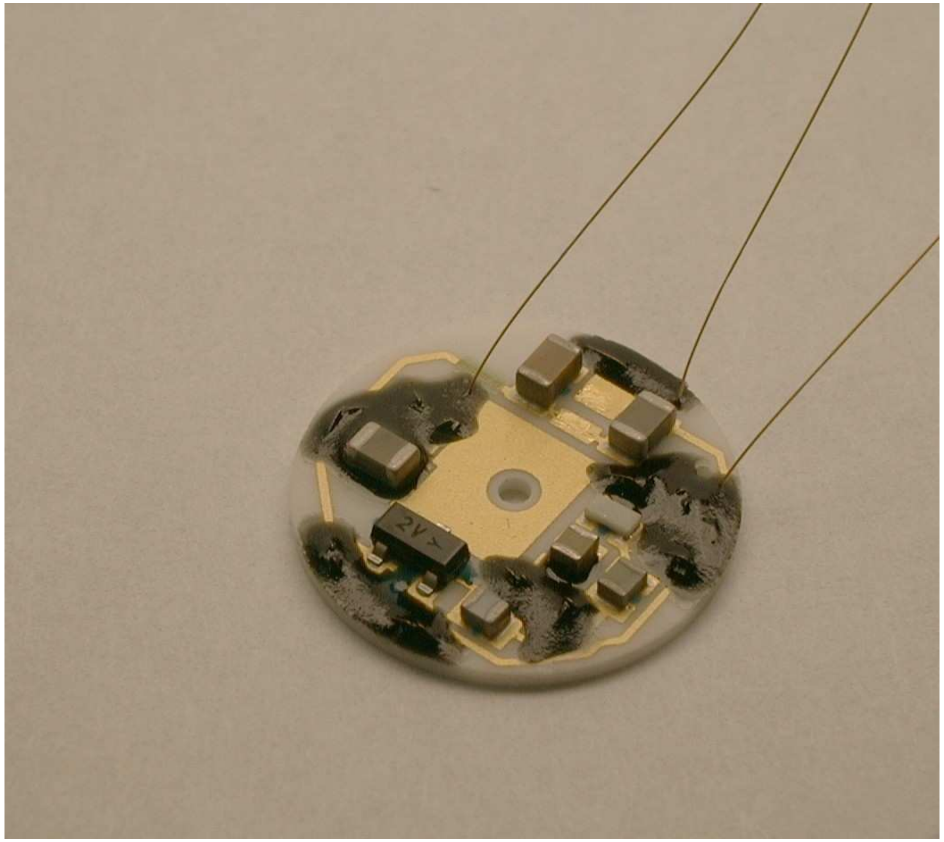
Operates in the circular bender bimorph mode.

Configuration of designed accelerometer

ULN Amplifier:

a) 2 stages: JFET and BJT,
b) V.S. from +24 to + 30 Vdc, I. S. =4 mA typical,
c) 2 wire output,
d) Protection circuit against transients (ESD, input shock impact),
e) F.R. (-3dB): 0.04 Hz – 100 kHz,
f) Max. output voltage : 5 Vpk,
g) Ouput bias: 9 -13 Vdc (room temp.), 8 -14 Vdc (over temp.),
h) Output impedance: $\leq 10\ \Omega$.

Photograph of the ULN amplifier hybrid substrate



Key Factors providing ULN operation

- Noise analysis of the system: PE Transducer – JFET amplifier
- Design of ULN JFET-input amplifier
- Design of PE transducer

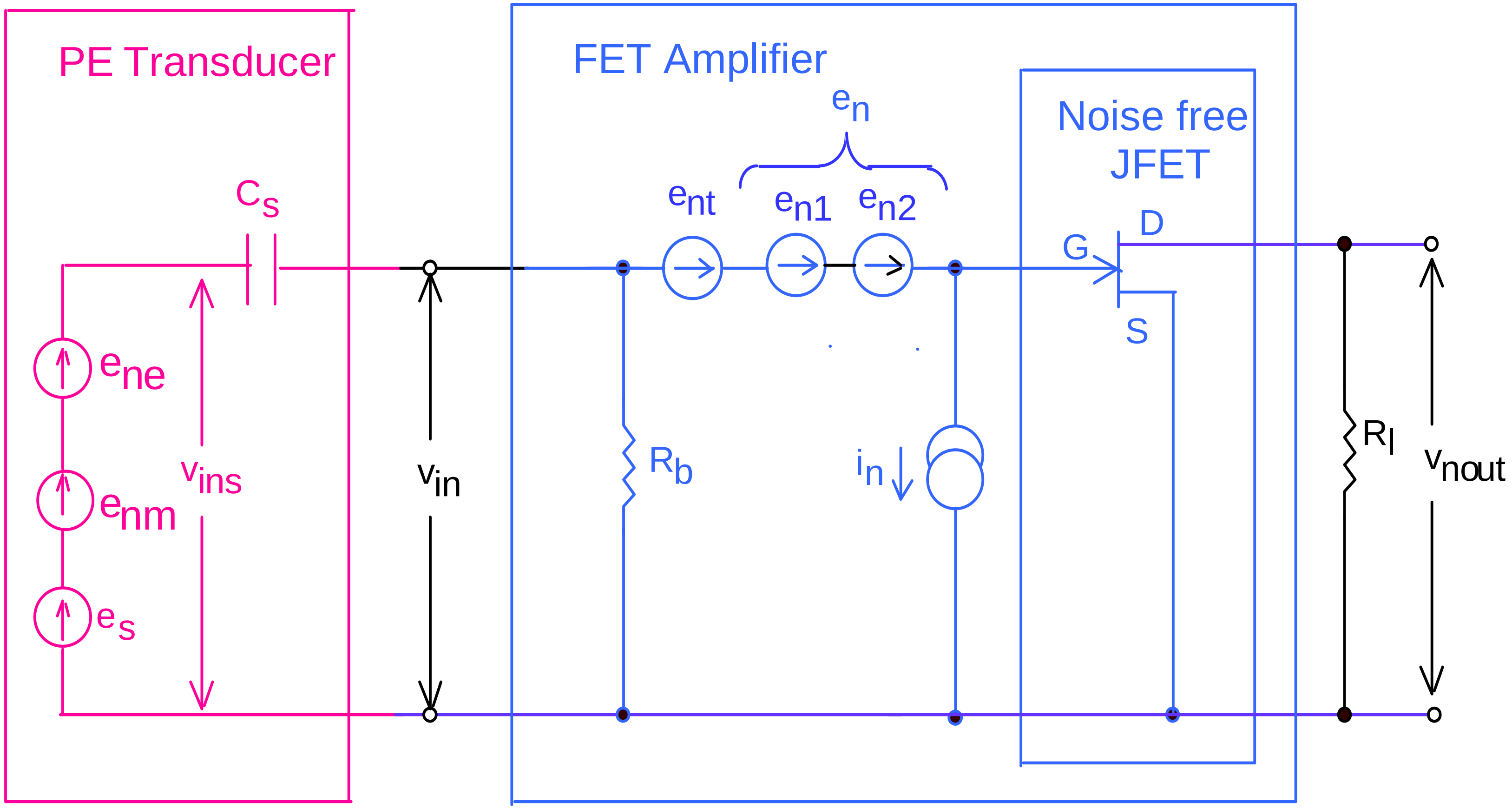
Key Factors providing ULN operation

Noise analysis of the system: PE Transducer – JFET amplifier

Equivalent noise circuit of this system includes:

- e_s is a signal source EMF,
- e_{nm} is a PE transducer's mechanical-thermal noise voltage,
- e_{ne} is a PE transducer's electrical-thermal noise voltage,
- e_{nt} is a thermal noise voltage of R_b,
- e_{n1} is a JFET channel thermal noise voltage,
- e_{n2} is a JFET 1/f noise voltage,
- i_n is a JFET noise current in the gate circuit.

Equivalent noise circuit



Noise analysis of the system: PE Transducer – JFET amplifier

$$\overline{a_n^2} = \overline{a_{ntr}^2} + \overline{a_{namp}^2} = 4k_B T \left\{ \frac{\omega_0}{mQ} + \frac{\eta}{\omega C_s V_s^2} + \frac{R_b C_f^2}{\left[1+\left(\omega R_b C_f\right)^2\right] Q_s^2} + \frac{A}{g_{fs} V_s^2} \right\} + \frac{\overline{e_{n2}^2}}{V_s^2}$$

$$+ \frac{2qI_{GSS}}{\left(\omega Q_s\right)^2}.$$

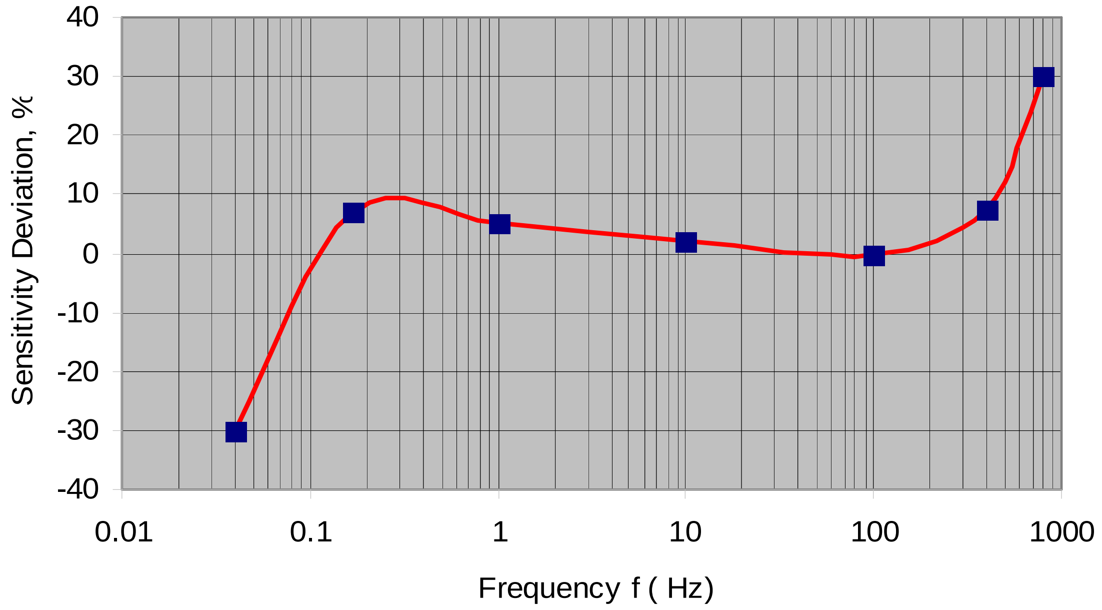
Formula for noise floor of the accelerometer includes:

- PE transducer’s mechanical-thermal noise voltage,
- PE transducer’s electrical-thermal noise voltage,
- Thermal noise voltage of R_b,
- JFET channel thermal noise voltage,
- JFET 1/f noise voltage,
- JFET noise current in the gate circuit.

Parameters of designed accelerometer and measurement results

- Sensitivity is 10 V/g, Range is 0.5 g pk
- F.R. (-3dB) is from 0.04 Hz to 800 Hz (see plot)
- Temp. range is from -20ºC to + 100ºC (see plot)
- Max. output signal is 5 V pk
- V. S. is from 24 to 30 Vdc
- C. S. is from 2 to 10 mA
- V_b = 9 -13 Vdc (room temp.) and 8 -14 Vdc (over temp. range)
- Start-up time is 20 sec
- Output impedance is $\leq 10\ \Omega$

Frequency Response



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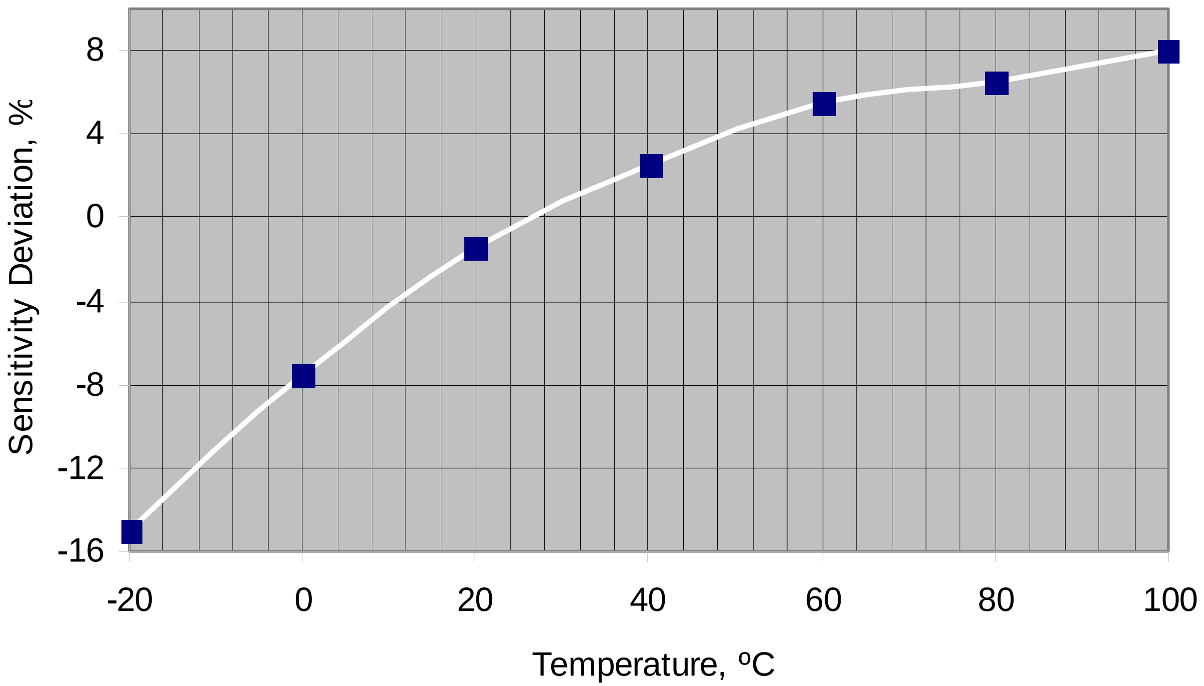
Temperature response



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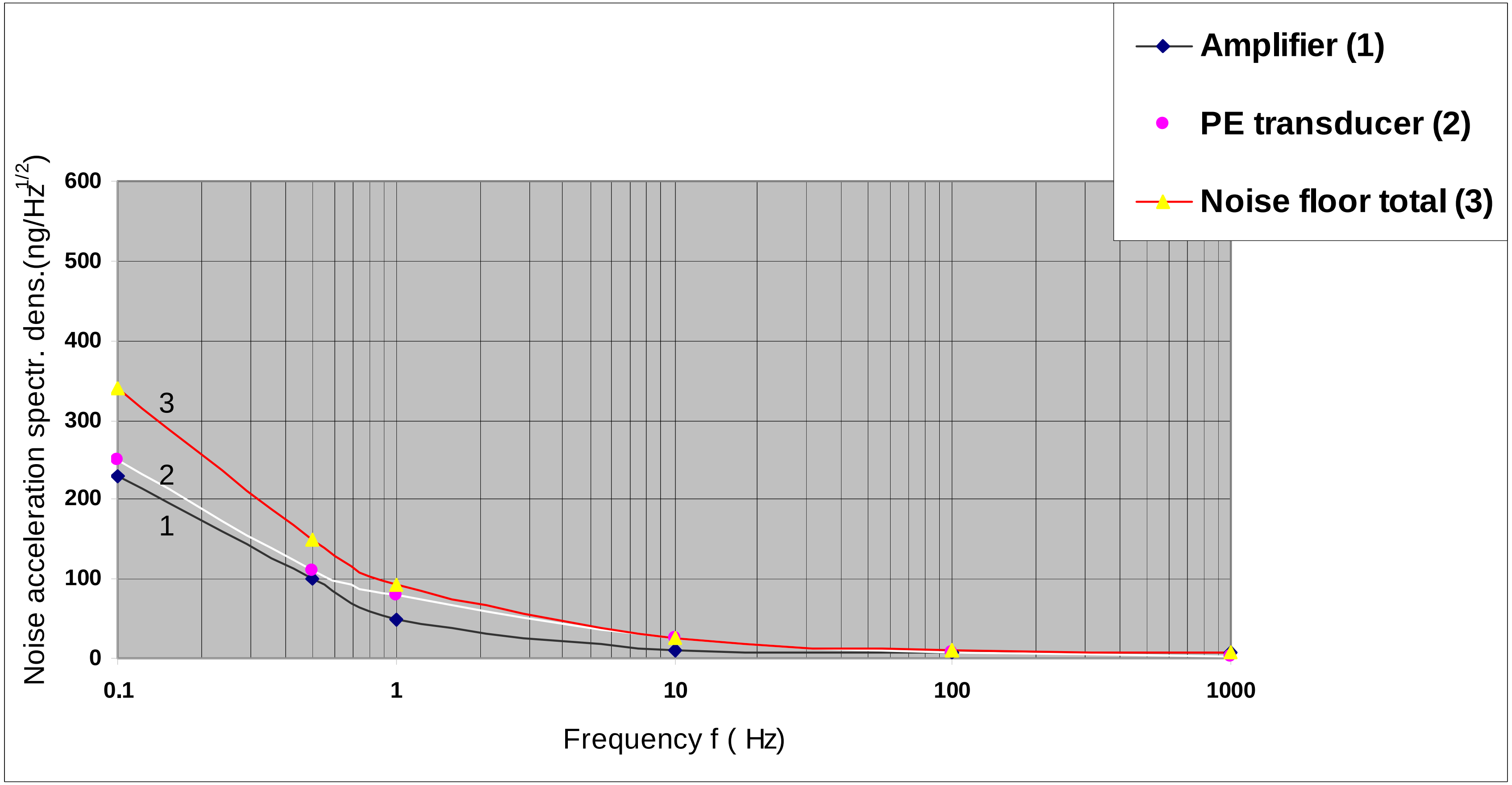
Contribution of PE Transducer noise a_{ntr} and JFET Amplifier noise a_{namp} into the total accelerometer noise



Contribution of different noise sources into the total accelerometer noise

- At $f \le 100$ Hz, a_{ntr} and a_{namp} have comparable values
- At $f > 100$ Hz, a_{namp} is predominates over a_{ntr}
- Among the JFET amplifier noise sources:

a) at $f \le 1$ Hz, noise of R_b and 1/f noise prevails over other noise sources,

b) at $f \ge 10$ Hz, JFET channel noise is main noise source,

c) at 1 Hz $\le f \le$ 10 Hz both those noise sources should be taken into account.

Conclusions

- The industry's lowest noise 10 V/g compact seismic IEPE accelerometer has been designed, fabricated, and tested
- The accelerometer has a 2-pin connector and cylindrical shape with a diameter of about 28.6 mm and a height of about 56 mm
- The F. R. (-3 dB) is from about 0.04 Hz to 800 Hz
- Noise floor is about 340, 90, 25, and 10 ng/√Hz at f = 0.1, 1, 10, and 100 Hz respectively
- Output impedance ≤ 10 Ω
- 400 g pk shock limit
- Two wires output availability
- Operating temperature range is from -20º C to + 100º C


MODEL 87-10
ISOTRON
ACCELEROMETER
S/N10006