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Understanding and Interpreting Datasheet Noise Specifications of IEPE Accelerometers

(A User's Perspective)

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An Example Accelerometer Datasheet Noise Specification

Resolution (typical):

Broadband (2 Hz to 25 kHz) .... 600 μg rms

Spectral 10 Hz .... 8 μg/√Hz

100 Hz .... 5 μg/√Hz

1000 Hz .... 5 μg/√Hz

What kind of noise are we talking about?

INTRINSIC noise: generated by the accelerometer's electrical, electronic and mechanical components themselves

NOT EXTRINSIC noise: originating from external sources to the accelerometer, such as:

60 Hz interference

Ground loops

EMI/RFI

Understanding intrinsic noise specifications will assist you in selecting the right accelerometer for your application, but you must still observe Best Practices in installing and using the sensor during your test.

What is the nature of this noise?

Random and unpredictable

Frequency content is very broadband

Varies over the frequency range of the accelerometer

There is nothing the user can do to reduce it

You can only manage it

An Example Accelerometer Datasheet Noise Specification

Resolution (typical):

Broadband (2 Hz to 25 kHz) .... 600 μg rms

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Noise is specified in two parts: Broadband and Spectral

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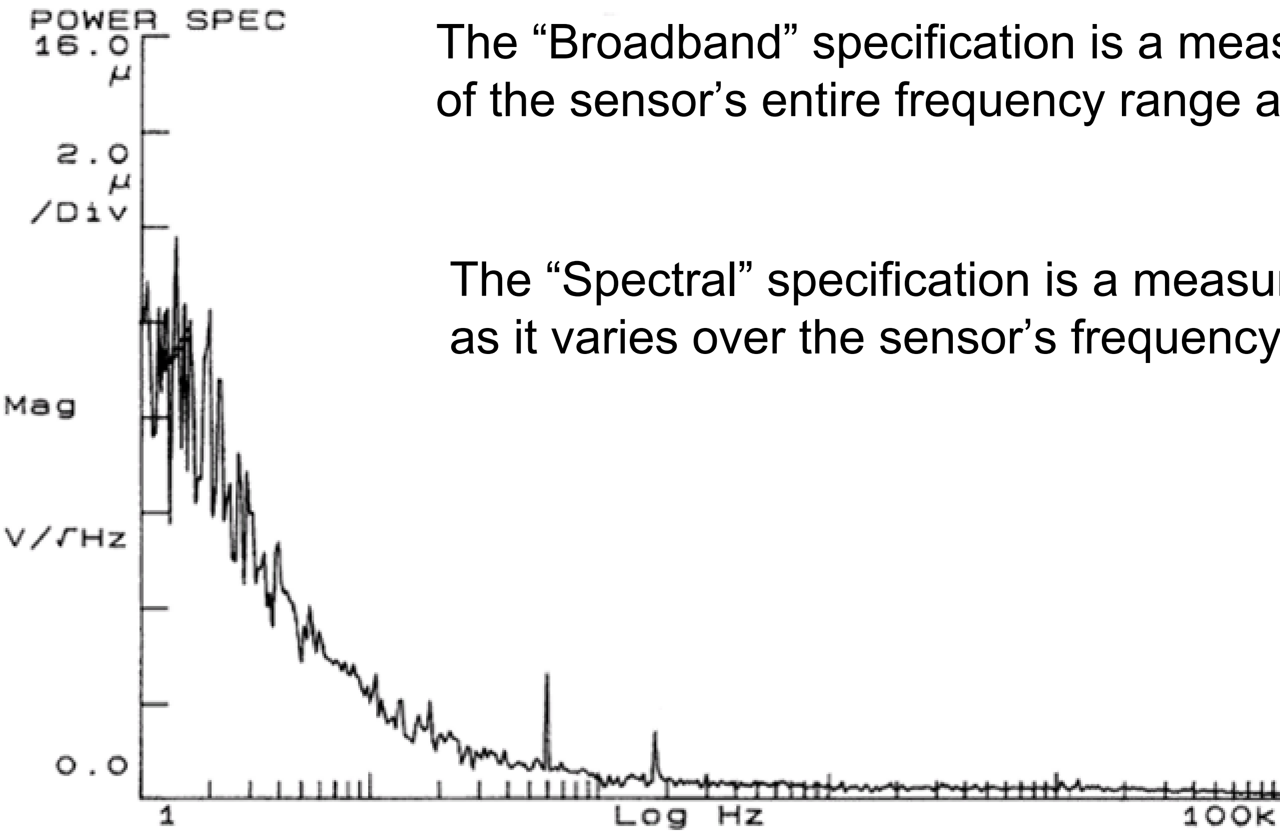
Noise Over Frequency



Frequency

The “Broadband” specification is a measure of noise of the sensor’s entire frequency range as a whole

The “Spectral” specification is a measure of noise as it varies over the sensor’s frequency range

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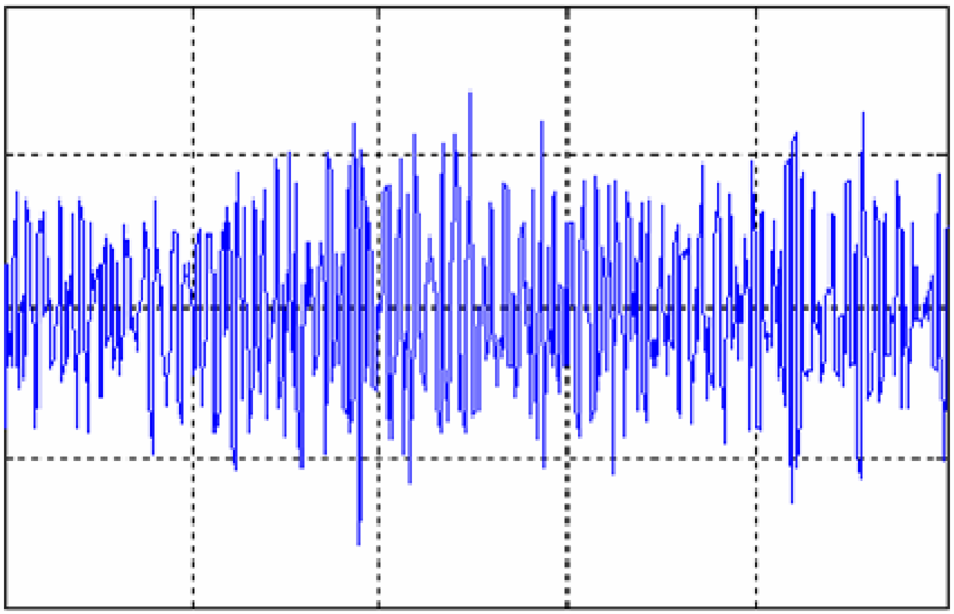
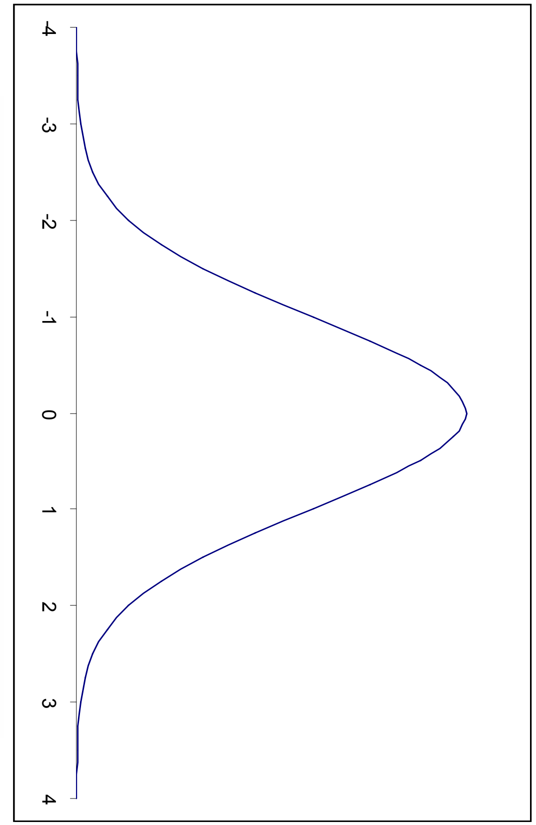
How do we analyze this noise?



Noise waveform (time based)



Statistical probability distribution

How do we analyze this noise (cont.)?

Since noise is random and unpredictable, we can employ statistical methods

By sampling a noise waveform, it can be shown to follow a statistical probability distribution (with the average value being zero)

It can also be shown that the first standard deviation from the average of this distribution is equivalent to the RMS value of the waveform

We now have some tools to estimate how much confidence we have in the measurements we make with our “noisy” accelerometers.

Recall the example accelerometer noise specification…

Resolution (typical):

Broadband (2 Hz to 25 kHz) ……………. 600 μg rms

Spectral 10 Hz ……………. 8 μg/√Hz

100 Hz ……………. 5 μg/√Hz

1000 Hz ……………. 5 μg/√Hz

So, for a broadband (unfiltered) measurement, how close to the broadband noise floor can we get?

The answer lies in statistics…

Using statistical methods, we can calculate the probability a measurement is true, useful signal and not noise.

Or, looked at in reverse, we can determine how close we want to get to the noise floor with the desired amount of confidence we need.

For our example:

600 µg rms is the first standard deviation from the average noise

Recall from statistics that with a Gaussian distribution, the number of standard deviations away from the average determines the probability an event will happen:

Standard Deviation	Probability of Event	Probability an event won't occur
$\pm 1\sigma$	68.26%	31.74%
$\pm 2\sigma$	95.44%	4.56%
$\pm 3\sigma$	99.74%	0.26%
$\pm 4\sigma$	99.994%	0.006%

With our example accelerometer…

Making a measurement as low as 600 µg (1σ) would mean there is a 31.74% chance of what you measured is strictly noise

Making a measurement as low as 1200 µg (2σ) would mean there is a 4.56% chance of what you measured is strictly noise

Making a measurement as low as 1800 µg (3σ) would mean there is a 0.26% chance of what you measured is strictly noise

Making a measurement as low as 2400 µg (4σ) would mean there is a 0.006% chance of what you measured is strictly noise

Rule of Thumb

Clearly, staying at least 3 times above the noise floor affords a more comfortable confidence margin in the measurement you are making

But what about the spectral noise?

Spectral Noise

Resolution (typical):

Broadband (2 Hz to 25 kHz) .... 600 µg rms

Spectral 10 Hz .... 8 µg/√Hz

100 Hz .... 5 µg/√Hz

1000 Hz .... 5 µg/√Hz

How did we come to use units of g/√Hz?

Spectral Noise

Scientists speak of electronic noise in terms of power, with units of watts (W)

As we have seen, noise varies with frequency. So we can construct a power spectral density plot, with units of W per Hz

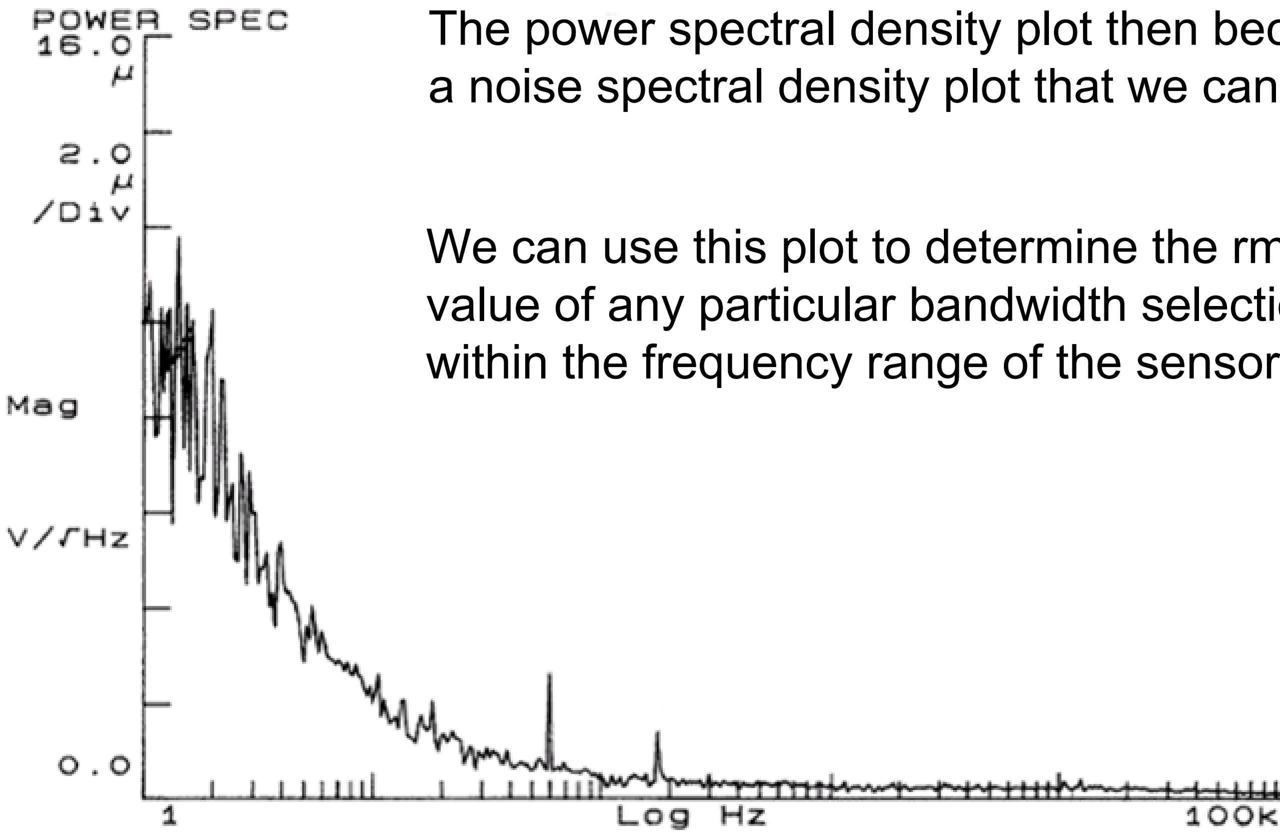
Voltage is more conveniently measured, and since watts are related to the square of volts, we can change W per Hz to V^2 per Hz or $V/\sqrt{Hz}$

Since we are working with accelerometers, we want to convert volts to gs, using the sensitivity of the sensor, thus:

$$\frac{W}{Hz} \Rightarrow \frac{V^2}{Hz} \Rightarrow \frac{V}{\sqrt{Hz}} \Rightarrow \frac{g}{\sqrt{Hz}}$$

$\mu g/\sqrt{Hz}$

Spectral Noise



Frequency

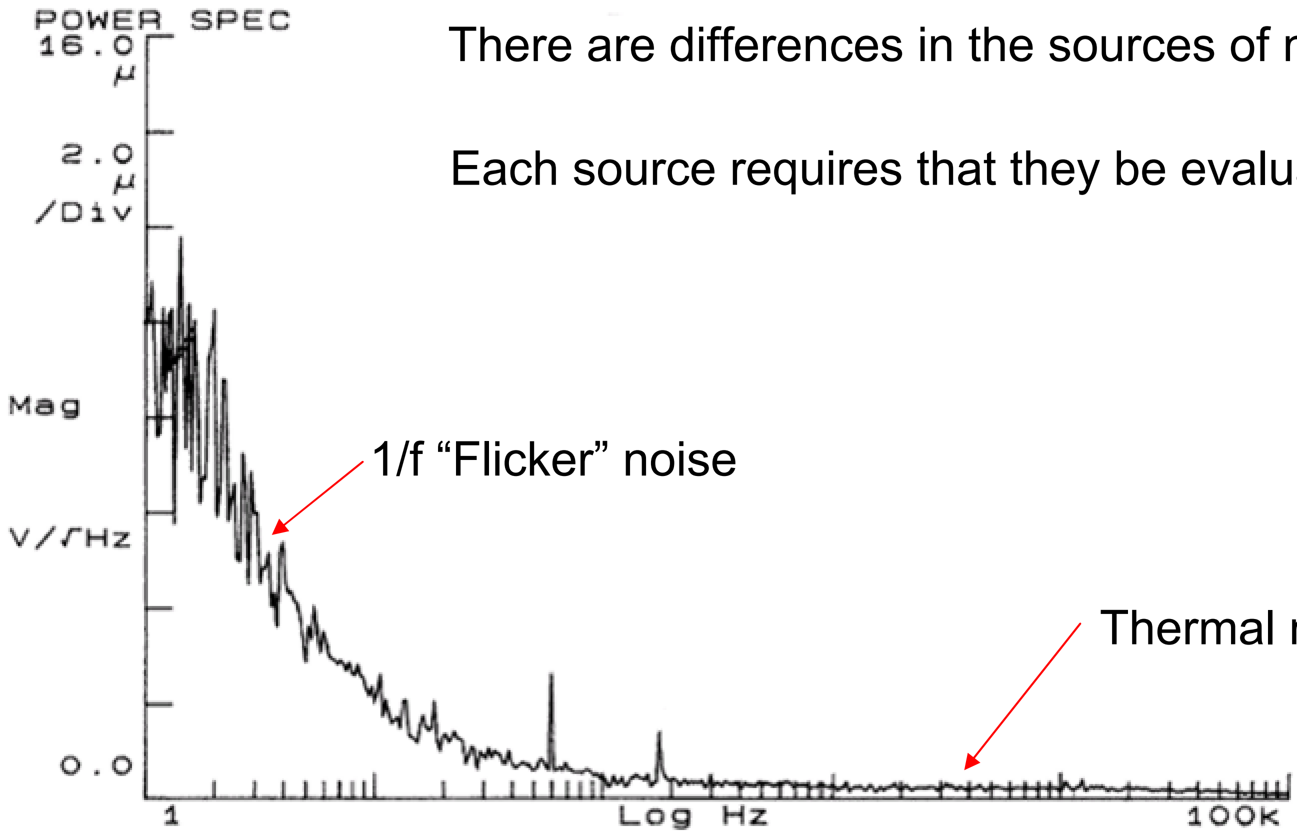
The power spectral density plot then becomes a noise spectral density plot that we can use

We can use this plot to determine the rms noise value of any particular bandwidth selection we want within the frequency range of the sensor

Noise Differences

There are differences in the sources of noise

Each source requires that they be evaluated differently



Spectral Noise

To determine rms noise within bandwidth f_L to f_H :

Thermal noise region:

$$g_n = g_s \sqrt{(f_H - f_L)} \quad \text{, units of g rms}$$

where g_s is the specified spectral noise in the thermal noise region

Also assumes a “brick wall” filter

Spectral Noise

To determine rms noise within bandwidth f_L to f_H :

Flicker noise region:

$g_n = g_1\sqrt{\ln(f_H/f_L)}$, units of g rms

where g_1 is the spectral noise at 1 Hz

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