Kurtosis and Kurtosion®

A Short History and Implementation of Kurtosis

in Vibration Testing and VibrationVIEW

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Vibration Research Corporation

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VR Core Focus

To make the world's most innovative sound and vibration technology tools, enabling our customers to make reliable decisions and trustworthy products

Company Values

Strong & Driven Work Ethic

We do the Right Thing

Capable & Competent

Accountable & Responsible

Collaboration

Innovation

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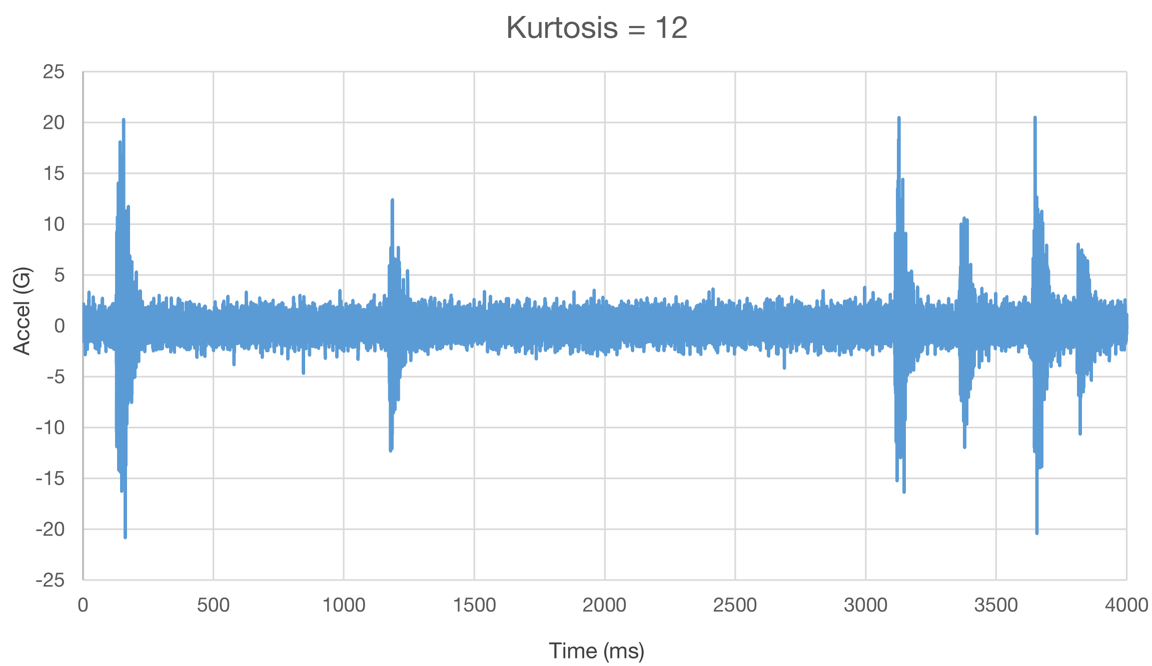
Introduction

- What is Kurtosis?
- Brief History of Kurtosis in Vibration Testing
- Kurtosis control methods
- Validating your kurtosis control method

What is Kurtosis?

- Kurtosis is a way to measure the “peakiness” of a response signal

- High Kurtosis = High Peaks
- Low Kurtosis = Low Peaks

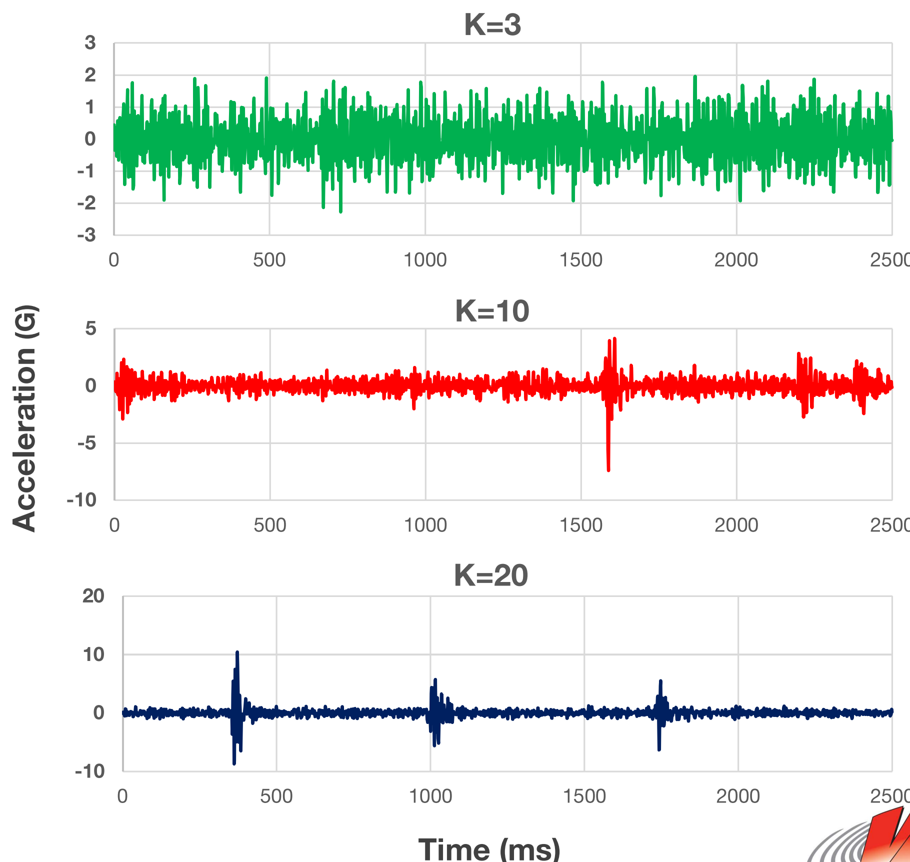


Crest Factor and Kurtosis

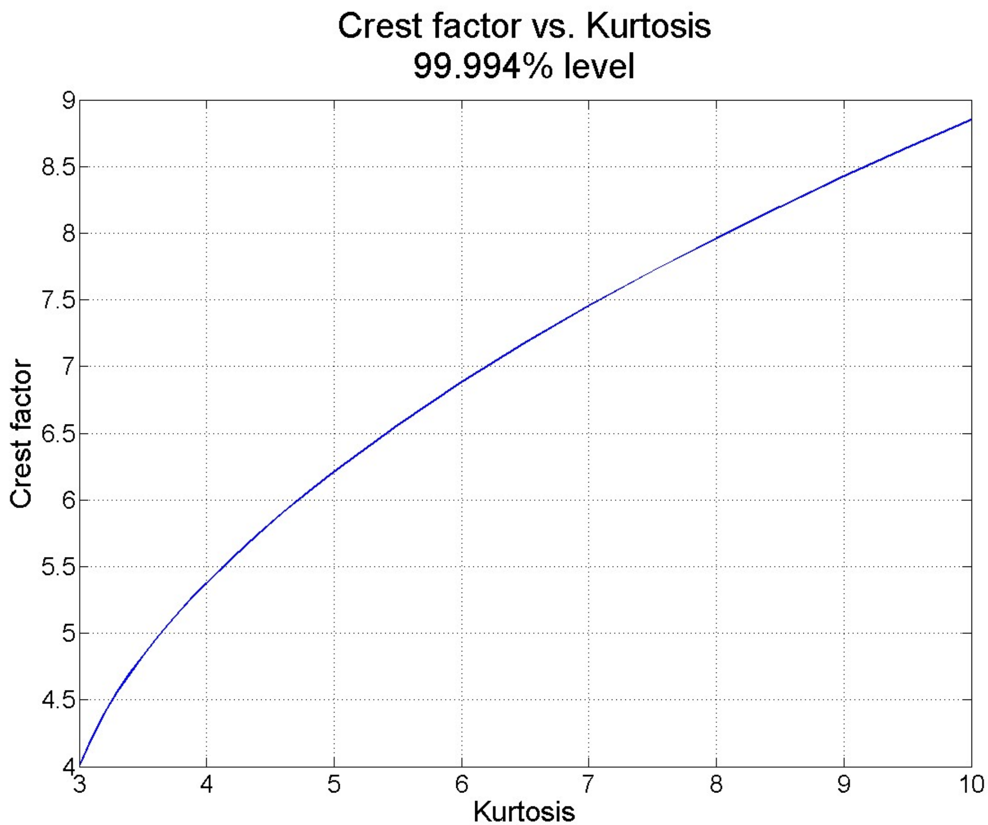
- What is crest factor and what does it tell me?
  - Crest Factor $(\mathrm{cf}) = \frac{peak}{rms}$
  - Crest factor is one method of comparing the data from a shaker test to real world data
- How can I modify a random test so that the cf more closely matches the real world?
  - Kurtosis
- What tools are available to add kurtosis to a random test?
  - Kurtosion® from Vibration Research

Kurtosis and Acceleration

- Along with higher peaks in acceleration, the high kurtosis signal will also appear more spread out and erratic across time
- The lower kurtosis signal will appear more constant, staying around the same values
- Increasing kurtosis inherently increases the crest factor

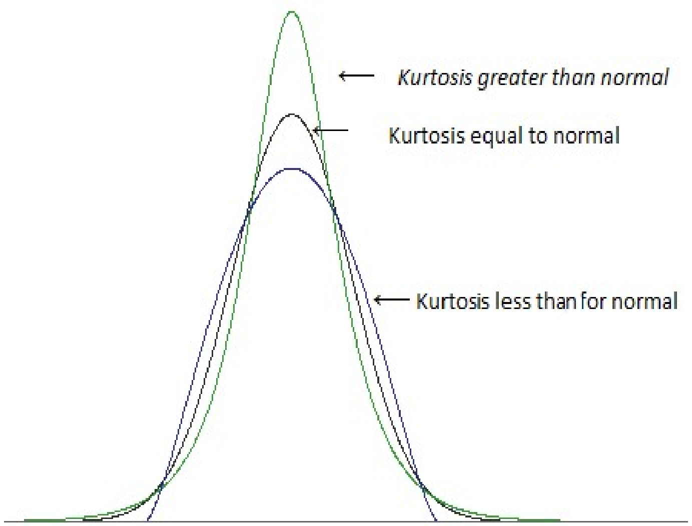


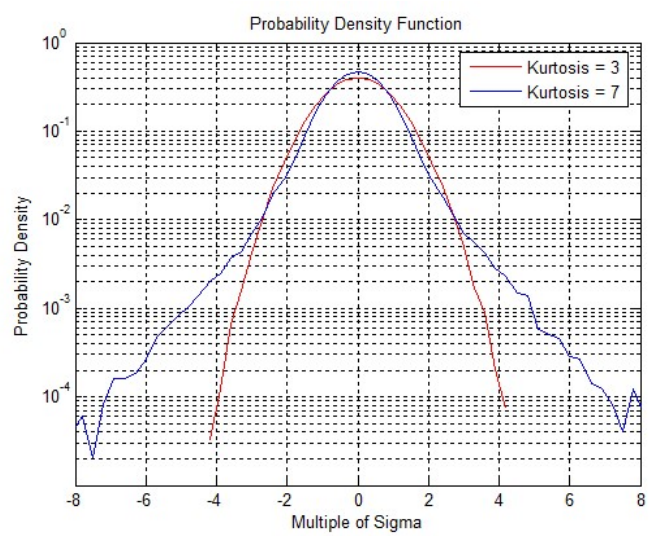
Crest factor and Kurtosis



Probability Density Function

- A kurtosis value of 3 is the same as saying the response is Gaussian
- This means the probability density function fits a normal distribution
- As the kurtosis value rises, the probability density function will begin to sharpen and grow "tails" at the ends





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Calculating Kurtosis

- A “moment” is statistics is a way to describe the shape of a set of data

- 1^{st} moment = mean
- 2^{nd} moment = variance
- 3^{rd} moment = skewness
- 4^{th} moment = kurtosis

If you know or can find the mean and variance of a data set, you can find the kurtosis using this formula:

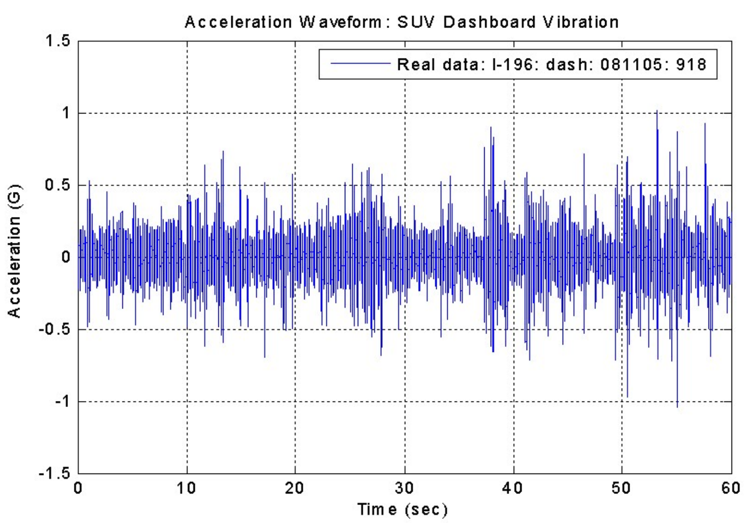
$$\mathrm{K} = n\frac{\sum_{i=1}^{n}\left(X_i - X_{avg}\right)^4}{\left(\sum_{i=1}^{n}(X_i - x_{avg})^2\right)^2}$$

Why add Kurtosis?

Adding kurtosis makes the data appear more random and sporadic.

Wouldn't we want the data to be regular and easy to follow if we were running tests?

Real-world Data



- Real-world data is often not Gaussian, meaning the kurtosis value is greater than 3
- So when real-world data is brought in, you will see those random, high-peak accelerations
- Adding kurtosis will give a more accurate test than running a straight Gaussian test

Test Acceleration

- Increasing the kurtosis value past 3 will cause the test energy to concentrate into the peak accelerations
- This ultimately causes more damage to the product across all frequencies
- More damage will ensure a quicker failure
- The total energy of the test stays the same, but the energy available is used more efficiently with added kurtosis

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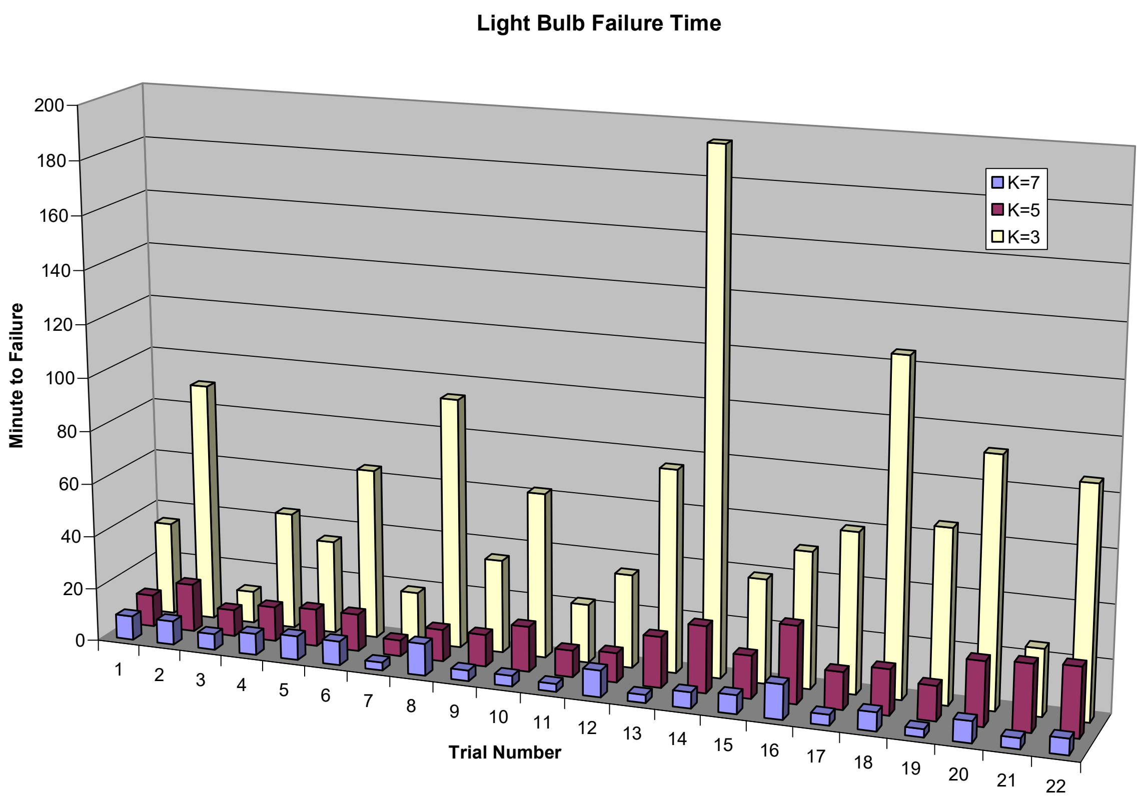
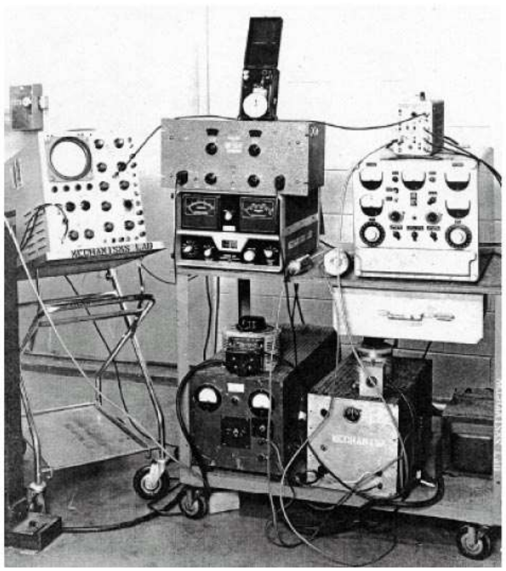
Light Bulb Case Study



Time to failure decreased as the kurtosis value was raised

History of Kurtosis



- When originally investigated, engineers found a major flaw with kurtosis control methods!
  - The kurtosis could be injected and measured at the input of the system (shaker armature/head)
  - When the vibration passed through a resonance, it would be damped.
  - Input kurtosis = 6, output resonance = 3
  - The kurtosis, although visible on the input, had 0 effect on the output/resonance of the product rendering it pointless.

<u>Is your kurtosis control method effective or effectively worthless?</u>

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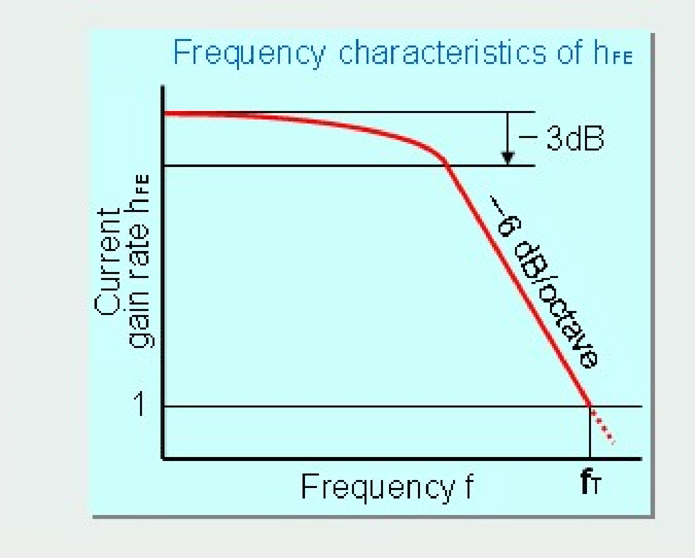
The Issue

Why did the output show k = 3 when k = 6 was put into the test?

Transition Frequency

Transition Frequency

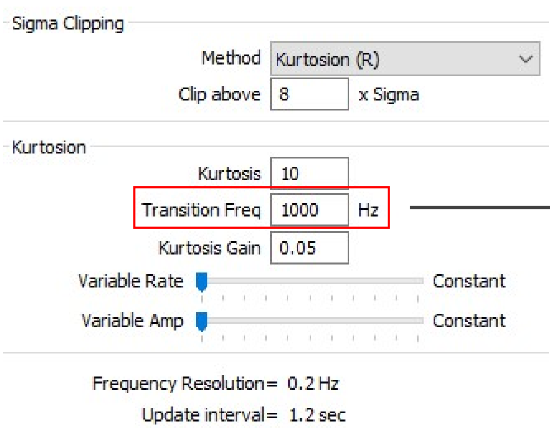


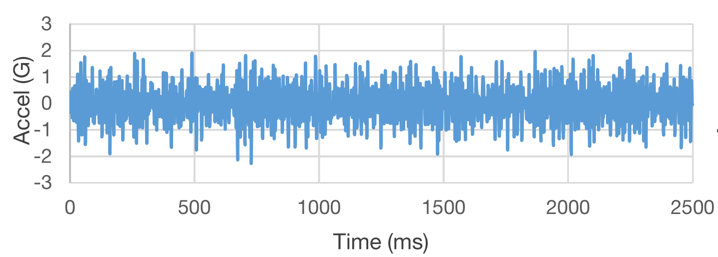
- What is the transition frequency?
- Frequency where the gain = 1
- Tells us how close together or far apart the high accelerations will occur
- High transition frequency (100 – 10,000) = close together
- Lower transition frequency = farther apart

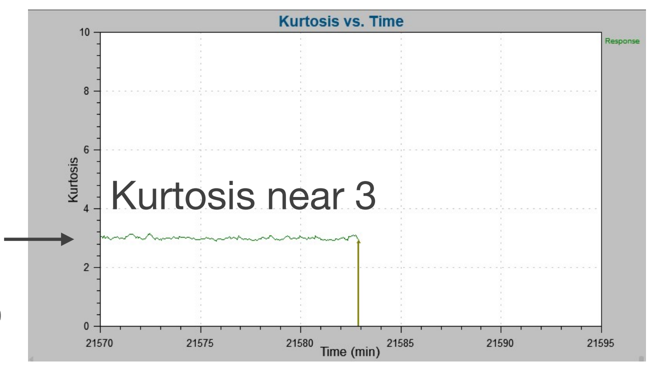
Improper Use

High transition frequency

- High acceleration real-world signal cancels out
- Kurtosis unable to effect the signal
- Leads to the Gaussian signal on the output







Proper Use

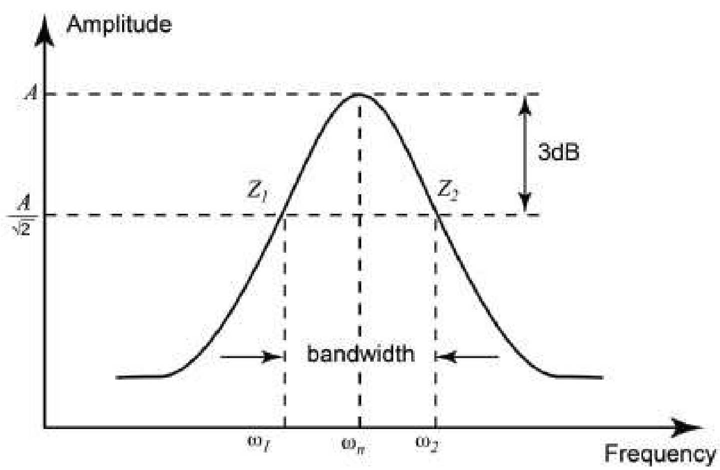
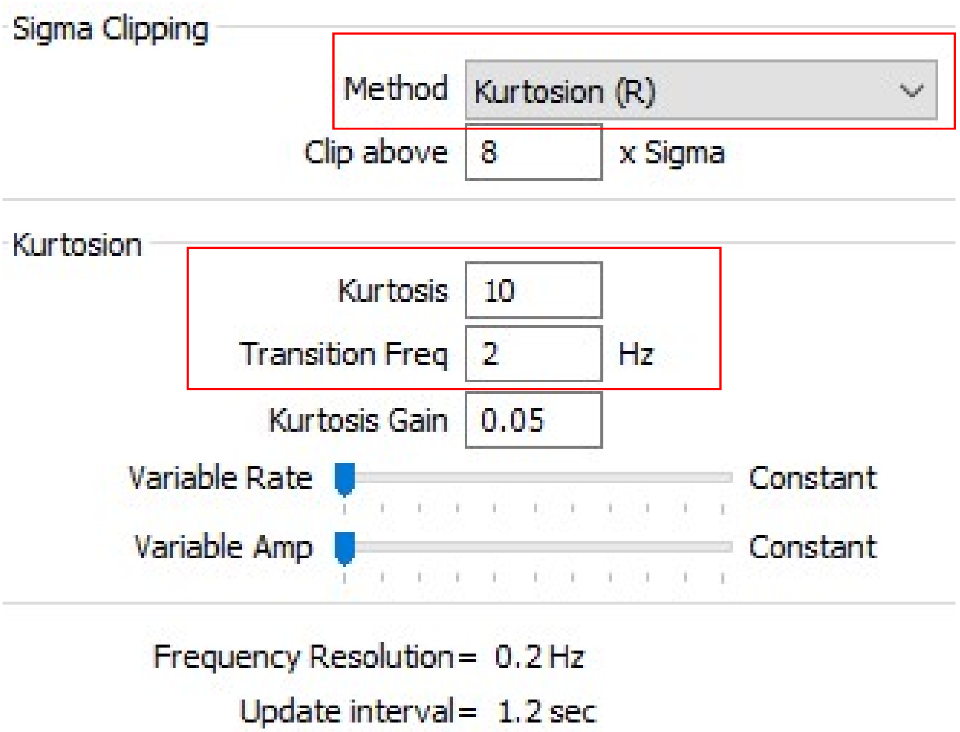


Figure 1. Half-power band method.

- Kurtosis most effective in the resonances
- Need to know the half-power bandwidth of the resonance
- Make transition frequency less than the half-power bandwidth
- Kurtosis will get into the resonances

Kurtosion®



Kurtosion® uses the method just described:

- Change the transition frequency of the kurtosis input to ensure a kurtosis signal on the output
- Located in the 'Parameters' tab of a test profile

Is there a simple test we can perform to check for a kurtosis output signal?

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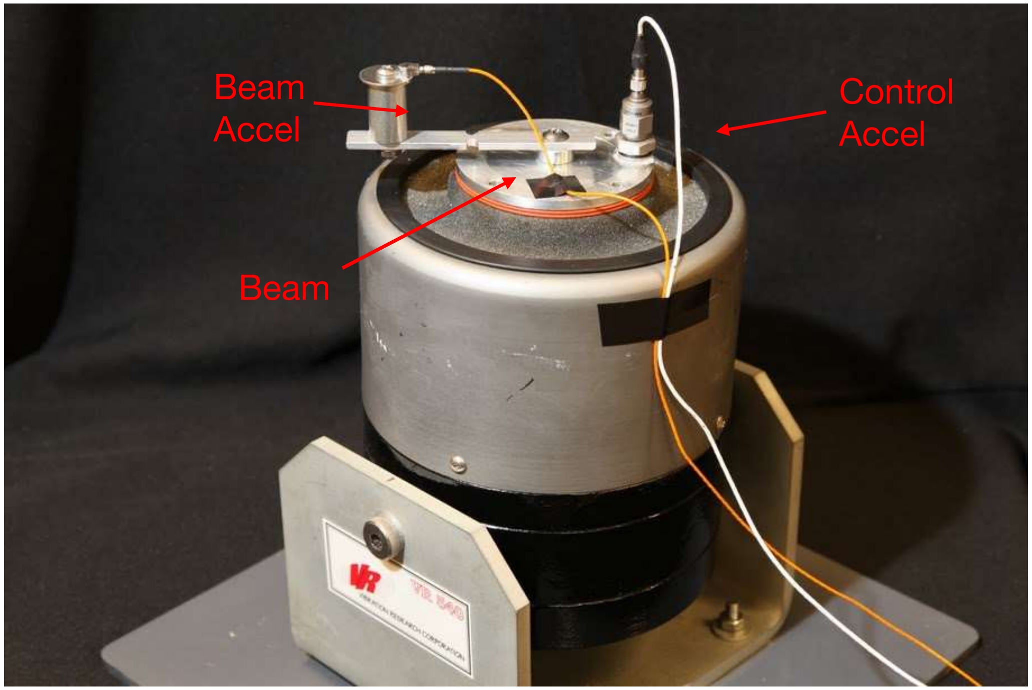
Kurtosis on the Output



Experiment Setup:

- Cantilever beam on shaker with accelerometers mounted as shown
- Accelerometer on shaker is the control
- One at the end of beam is the response

Test Setup

Steps:

- Find the beam's resonance with a sine test
- Find the half-power bandwidth of the resonance
- Input a kurtosis greater than 3 (non-Gaussian)
- Make transition frequency greater than half-power bandwidth

Run the Test and create a new graph for kurtosis to watch what happens

Getting a Response

- Stop the test
- Change the transition frequency to an appropriate number lower than the half-power bandwidth of the resonance
- Run the revised test
- Watch the response accelerometer give a kurtosis signal near to the input kurtosis value
- You have successfully gotten a kurtosis signal on the output of the test

Any Questions?

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Thank You!

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