# IEC 60068-2-64

Edition 2.0 2019-10

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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AMENDMENT 1
AMENDEMENT 1

## Environmental testing –
## Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance

## Essais d'environnement –
## Partie 2-64: Essais – Essai Fh: Vibrations aléatoires à large bande et guide



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# FOREWORD

This amendment has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.

The text of this amendment is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 104/848/FDIS | 104/855/RVD |

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.



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## INTRODUCTION

*Add, after the fourth paragraph, the following new paragraph:*

The traditional general purpose broad-band random vibration test utilizes waveforms with a Gaussian distribution of amplitudes. However, when so specified, this test procedure can also be utilized with random vibration tests with a non-Gaussian distribution of amplitudes. Such tests are sometimes alternatively known as high kurtosis tests.

*Add, after the last paragraph, the following new paragraph:*

Annex C is an informative annex giving information on non-Gaussian distribution/high kurtosis tests.

## 3 Definitions

*Add the following new terminological entries:*

**3.39**
**kurtosis**
4th statistical moment, which provides a measure of the shape of an amplitude distribution

Note 1 to entry: Typically a waveform with Gaussian distribution will have a kurtosis of 3, if considered over an infinite period.

Note 2 to entry: Kurtosis is given by:

$$kurtosis = \frac{1}{N}\sum_{i=1}^{N}\left(x_i - \overline{x}\right)^4 \cdot \frac{1}{\sigma^4}$$

where:

$\sigma$ is the standard deviation of the $N$ values which describe the waveform;

$x_i$ are individual values representing the waveform described by $N$ such values;

$\bar{x}$ is the mean value of the $N$ values which describe the waveform.

**3.40**
**skewness**
3rd statistical moment, which provides a measure of non-symmetry of an amplitude distribution



Note 1 to entry: Typically a waveform with Gaussian distribution will have a skewness of 0, if considered over an infinite period.



Note 2 to entry: Skewness is given by:

$$skewness = \frac{1}{N}\sum_{i=1}^{N}\left(x_i - \overline{x}\right)^3 \cdot \frac{1}{\sigma^3}$$

where:

$\sigma$ is the standard deviation of the $N$ values which describe the waveform;

$x_i$ are individual values representing the waveform described by $N$ such values;

$\bar{x}$ is the mean value of the $N$ values which describe the waveform.

**3.41**
**beta distribution**
family of continuous probability distributions defined on the interval [0, 1] parametrized by two positive shape parameters, denoted by $\alpha$ and $\beta$, that appear as exponents of the random variable and control the shape of the distribution

SEE: Figure 4.

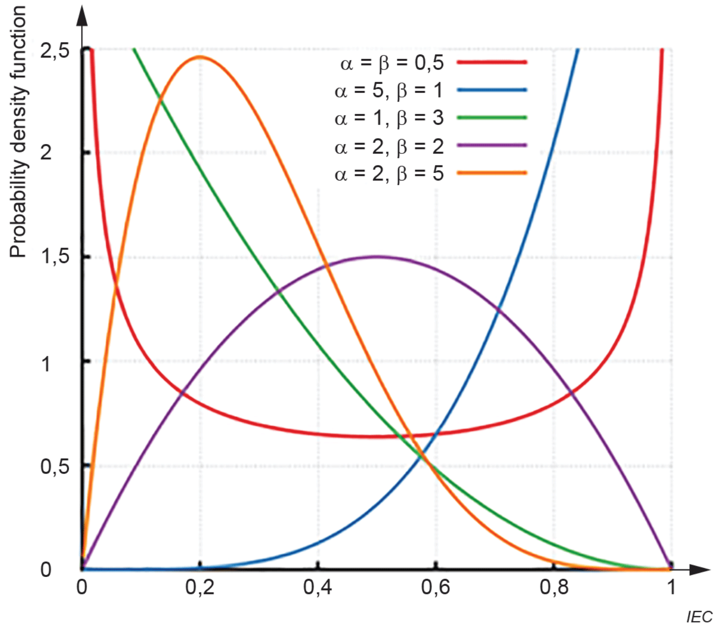



**Figure 4 – Examples of the beta distribution with different *α* and *β* values**

## 4 Requirements for test apparatus



### 4.1 General

*Add, at the end of 4.1, the following new paragraph:*



For non-Gaussian testing, the test apparatus shall be able to produce a signal with a specified probability distribution and crest factor. Generally, non-Gaussian random vibration testing requires shaker and amplifier systems that are designed for Gaussian random vibrations but with increased crest factor capabilities.

### 4.6.2 Distribution

*Add, after Figure 2, the following new paragraph:*

For non-Gaussian tests, the time history shall be recorded and the statistical characteristics of crest factor, skewness, kurtosis and amplitude probability distribution established, see Clause C.3. If required by the test specification, additional analysis of the time history shall be undertaken. The measurement time for kurtosis, skewness and amplitude probability distribution should be long enough to obtain statistically acceptable results.

## 5 Severities

*Replace, in the second paragraph, the first two sentences with the following:*

Each parameter shall be specified by the relevant specification. They shall be:

*Add, at the end of the second paragraph, after list item d), the following new text:*

For non-Gaussian vibration testing the test severity is determined by the same parameters as for broad-band Gaussian vibration testing but with the addition of:

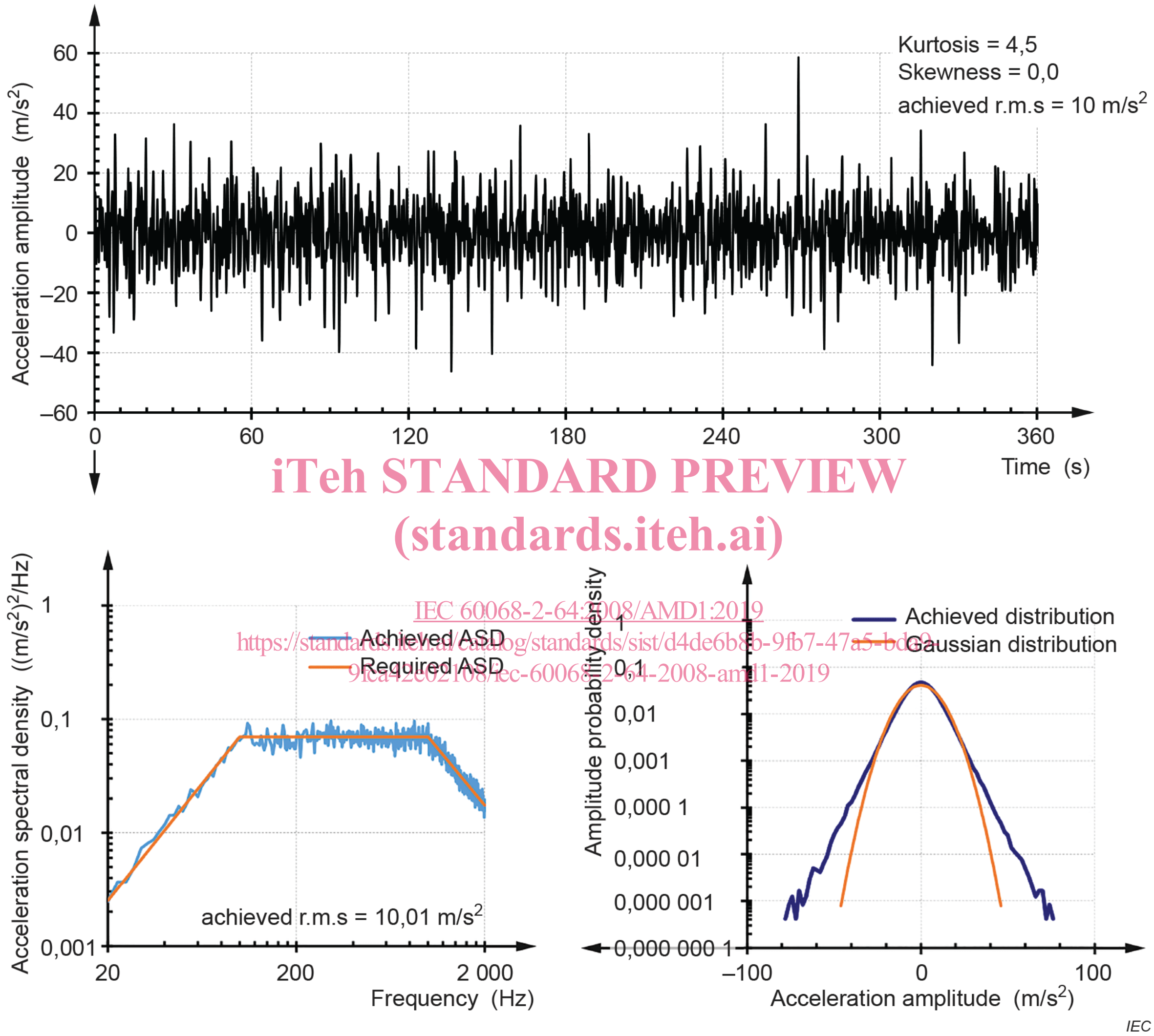
– the type of non-Gaussian testing to be undertaken (see Annex C),
– the required probability distribution or kurtosis (and skewness if applicable),

– the required crest factor.

### 8.4.1 General

*Add, at the end of 8.4.1, the following new text and Figure 5:*

For non-Gaussian vibration testing, the time history shall be recorded and the kurtosis, skewness (if applicable) and amplitude probability density shall be established as required by the relevant specification (see also Figure 5).






**Key**

Kurtosis = 4,5 (see 3.39)

Skewness = 0 (see 3.40)

**Figure 5 – Time history of non-Gaussian excitation –
Probability density function compared with Gaussian (normal) distribution**

## 11 Information to be given in the relevant specification

*Replace the existing list item h) with the following new list item h):*

h) Crest factor* / amplitude distribution, kurtosis and skewness (if applicable)/drive signal clipping amplitude

*Replace, in list item h) the clause number with "4.6.2 and 5.3"*

*Add, at the end of Annex B, the following new Annex C:*

# Annex C
(informative)

# Guidance on non-Gaussian distribution/high kurtosis tests

## C.1 Non-Gaussian random vibration

Random vibration testing has traditionally utilized a nominally Gaussian distribution of amplitudes, but with the crest factor of the waveform set so as to truncate the amplitude distribution at around three standard deviations. In recent years, several different techniques have become available, which allow the required acceleration spectral density to be achieved, but with a waveform distribution typically modified to permit higher amplitudes to occur with a greater probability. This commonly results in a distribution with a $4^{th}$ moment of statistics (kurtosis), which is greater than that of a normal or Gaussian distribution. Hence, the approach is sometimes referred to as high kurtosis or non-Gaussian vibration testing. With some available techniques it may also be possible to use a waveform with a kurtosis less than that of a Gaussian distribution and/or with a non-zero skewness.

High kurtosis or non-Gaussian vibration testing can be advantageous in a number of circumstances. A typical application arises when both vibration and shock conditions occur together. Such conditions commonly occur when equipment is transported on or installed in land vehicles. In such cases it may be required to incorporate moderately higher amplitude components to the waveform either randomly or pseudo-periodically. High kurtosis or non-Gaussian vibration testing may also be used to replicate the effects of repeated impacts of moderate amplitude such as occurs when equipment is loose or experiences “rattling”. In this case a waveform with a high kurtosis and non-zero skewness could be used.



The traditional general purpose broad-band random vibration test procedure of this document can also be used with high kurtosis or non-Gaussian vibration testing with only minor modifications.



High kurtosis or non-Gaussian vibration testing should not be used in place of a traditional broad-band Gaussian vibration test, except were explicitly specified in the relevant specification.

## C.2 Methods to generate non-Gaussian random vibration

### C.2.1 General

High kurtosis or non-Gaussian vibration testing mostly utilizes the same control strategy as used with traditional broad-band Gaussian vibration tests. Moreover, the underlying techniques used by vibration controllers to establish a non-Gaussian waveform, are essentially the same as for Gaussian vibration testing, but typically with an additional step.

Currently, there are several different available techniques used to modify a Gaussian waveform into a non-Gaussian one. The different techniques may produce distinctly different waveforms, simply specifying the acceleration spectral density, skewness, and kurtosis is not sufficient to produce a waveform with identical characteristics. As a consequence, the techniques are not necessarily interchangeable and different failure modes may be stimulated, by the different techniques, even if the test severity is identical. Therefore, it is essential to record and to interpret the time history characteristics during the test.

Set out below is information on three methods for modifying a Gaussian waveform into a non-Gaussian one. It should be emphasized that these three different methods are only included here as guidance for the specifier who may have no prior knowledge. Available approaches are not limited to those described and indeed many other methods and variants exist which can also be used to effectively implement the non-Gaussian vibration test of this document.

The three methods described in this annex are:

– amplitude modulation technique,
– phase modification technique,
– non-uniform phase technique.

The selection of the most appropriate techniques for generating a non-Gaussian waveform will depend upon the application and characteristics of the waveform required. This document makes no recommendations as to the most appropriate technique for a particular application. Any choice to be made is left to the relevant specification.

### C.2.2 Amplitude modulation technique

Commonly, general purpose broad-band Gaussian digital random vibration test controllers generate the required waveform by randomizing the phase components of a frequency spectrum, using a uniformly distributed random variable. This frequency spectrum is converted to a waveform by means of an inverse Fourier transform. The random waveform is typically multiplied by a window function, overlapped and then added together to form a nearly stationary input to the vibration excitation system. The multiplication by the window function accomplishes two objectives: the spectral lines are spread and the window limits the leakage into nearby frequencies. If the window and overlap are chosen appropriately, the result can be truly stationary. If the overlap is not sufficient for a given window, the data can be slightly non-stationary, with a period equal to the overlap duration.



The amplitude modulation approach to generate a non-Gaussian waveform is similar to the one described above, except the amplitude of the window is a random variable. The distribution of this random variable can arise from any distribution, although if a beta distribution is used, it effectively limits the kurtosis.



The amplitude modulation technique:

a) Produces waveforms with a well-defined spectrum.
b) Produces waveforms with zero skewness.
c) Produces waveforms which have relatively long “bursts” of high amplitudes. Hence, long realizations need to be generated to accurately estimate the kurtosis. The kurtosis of short segments will vary considerably.
d) The kurtosis of the waveform can be controlled using a defined distribution such as with the parameters of a beta distribution. Increasing the standard deviation of the beta distribution monotonically increases the kurtosis. This makes an iterative procedure to pick the parameters for a specified kurtosis relatively straightforward.

### C.2.3 Phase modification technique

Another way to generate non-Gaussian vibrations is to initially set the phase of the frequency spectrum from a uniform distribution, as in the previous technique. However, the phase is subsequently modified using an optimization procedure to vary the phase in an attempt to minimize the difference between the target kurtosis and skewness with that of the generated waveform.

The phase modification technique:

a) can produce waveforms with kurtosis both less than 3 and greater than 3;
b) can produce waveforms with a skewness other than zero;
c) is computationally intensive.

### C.2.4 Non-uniform phase technique

If the values chosen for the frequency spectrum are selected from a distribution other than a non-uniform one, the resultant waveform will have non-Gaussian kurtosis and skewness statistics.

If, for example, the phase values are selected from a beta distribution, the span of values will be in the range 0 to 2π and the mean will have a value of π. If the two parameters of the beta distribution ($\alpha$ and $\beta$) are equal and positive, the distribution will be symmetrical about the mean. If, $\alpha = \beta = 1$, a uniform distribution results. As the values of $\alpha$ and $\beta$ become large, the distribution starts to approximate to a Gaussian distribution whose variance decreases as the values of $\alpha$ and $\beta$ increase.

When all the phase angles of the frequency spectrum are 0, the peak amplitude of the waveform will be the maximum possible. If the phase distribution moves from uniformly distributed random toward an impulse at π, a waveform with an increasing peak amplitude and hence an increasing kurtosis, will be produced. This can be achieved using a beta distribution with a decreasing variance (an increasing $\alpha$ and $\beta$).

It is even possible to make the beta parameters ($\alpha = \beta$) a function of frequency and hence the kurtosis will be a function of frequency. This can for example be used to generate a waveform which is approximately Gaussian at low frequencies but has a large kurtosis at higher frequencies.

Variation to the technique can be achieved by modifying the way that the resultant waveforms are windowed, overlapped and added together. These can be used to control where in the extended waveform the peaks occur. In this way the peaks can occur randomly or pseudo-periodically.



The non-uniform phase technique:

a) Can only generate waveforms with a values of kurtosis greater than or equal to 3.
b) Can only generate waveforms with negative and positive skewness.
c) Produces waveforms with many short duration excursions greater than would be expected from a Gaussian distribution. The frequency of these excursions can be controlled in either a random or quasi-periodic manner.
d) Is computationally efficient.

## C.3 Additional analysis

The relevant specification may specify, when undertaking non-Gaussian or high kurtosis testing, that additional parameters of the waveform are derived. These additional parameters are not used to control the test waveform, but rather to establish additional characteristics of the waveform which can be used for comparison with perceived damage criterion. Different additional waveform parameters may be used, depending upon the perceived damage criterion of concern. Several or all of the following parameters may be considered.

a) cycle counting,
b) Rainflow cycle fatigue counting,
c) level crossing counts,
d) maximum response spectrum (MRS),
e) fatigue damage spectrum (FDS),
f) temporal moments.