# Random Vibration Control System

# K2+

# Soft-Clipping Option

## Instruction Manual

IMV CORPORATION

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|---|---|
| Type of Document | : Instruction Manual |
| System Applied | : K2+ |
| | Software <RANDOM> Later than Version 20.0.0 |

*To activate this optional functionality, the license below is equired:Soft-Clipping Option

English Edition

| Version | Date | Contents |
| --- | --- | --- |
| 1.0.0 | 2020.10.16 | First edition |

# CONTENS

# Chapter 1 Theory

## 1.1 Soft-Clipping Option

This optional functionality is for limiting the peak voltage of the drive signal which is an output voltage signal of the K2+/RANDOM to be input to the power amplifier of the vibration system.

While the clipping functionality itself has been provided as ‘Clipping’ since the first release of the application, this new functionality is called ‘Soft-Clipping’ in contrast to the existing one which is based on a simple hard clipping process. Now a much sophisticated technique of ‘Soft-Clipping’ makes it possible to provide better performance.

## 1.2 Gaussian random signal

When a drive signal output by a random vibration controller is analyzed in the aspect of amplitude distribution, it will be found that its probability density function (PDF) has the shape of the ‘Normal distribution’. Such a signal is called Gaussian random noise signal.

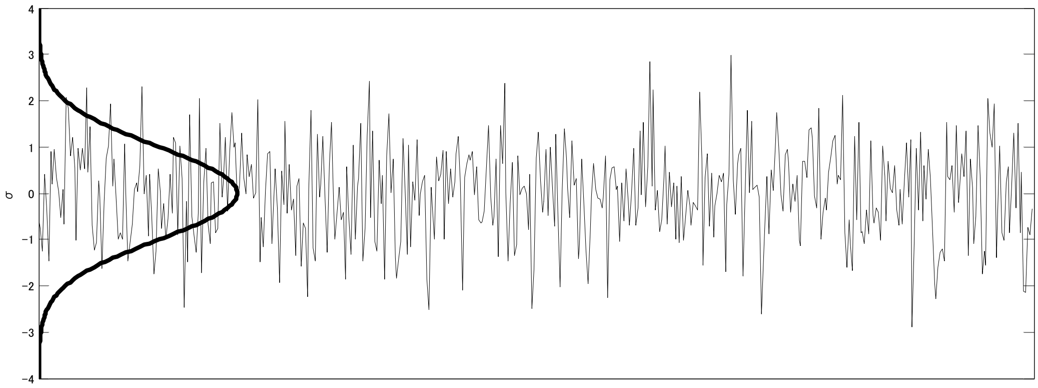


Fig. 1

Fig.1 shows a typical Gaussian random noise signal, and the overlaid bell-shaped curve on the signal is the PDF of the signal obtained after long time observation, which is showing the shape of the Normal distribution.

Normal distribution (also called as Gaussian distribution) is expressed in the following mathematical form:

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left( -\frac{(x-\mu)^2}{2o^2} \right) \qquad ①$$

As seen in this example, when random noise signals are analyzed, many of the PDFs of the signals can be almost exactly expressed by this formula. This fact is simply expressed that enormous proportion of the random noises are Gaussian. Mathematicians may state that it is a result of the Central Limit Theorem which guarantees that arbitrary random signals independent of each other will get close to Gaussian when they are superimposed and averaged. Mathematical statement sounds rather complicated, but it is very usual and general situation found in the world we live. Signals always tend to lose particular information underlying in them and get more disordered, and finally they result to be Gaussian.

The statistical nature of the Gaussian random signal is characterized by the two parameters; the average μ and the standard deviation σ. In addition, it is usual that the random signal is observed as an AC signal of μ=0 with the DC component is neglected or separated. In this case, the standard deviation σ of the signal is equal to the root mean square (RMS) of the signal. Therefore the position of the scale '1' in the Fig.1 is showing the level of the RMS value of this signal.

To express a level of a random signal it is convenient to express the level measured by the RMS value (= σ) as a unit, because when the level is expressed in the unit of σ the event occurrence probability of the signal of the level is possible to be immediately estimated assuming that the signal is Gaussian.

For this reason, a quantity called 'Crest Factor' is often used to express the peak value $A_p$ of the signal in the unit of RMS value $A_{rms}$（=σ）. The crest factor, when denoted 'CF', is defined as follows:

$$CF = \frac{A_p}{A_{rms}} = \frac{A_p}{\sigma} \qquad ②$$

## 1.3 Necessity for clipping

K2+/RANDOM outputs a Gaussian drive voltage signal, and so there comes high level voltage peak of 4~5 σ at a low probability obeying to the Gaussian distribution.

When the excitation level is low compared to the rating of the shaker system, there is no problem caused by such high CF peak. But when the testing is carried out at around the system rating, as the power amplifier would be also operating at around the rating, an over-specification stop of the amplifier could occur when such a high CF peak signal is input to the amplifier. Then, testing would be aborted. Also, there is a possibility that a high peak excitation force generated by the armature table corresponding to the high CF drive signal and the specimen will be exposed to an effect caused by the too high peak force which is not expected for the testing.

## 1.4 Hard-Clipping

To avoid such an undesired case to happen, a functionality of ‘Hard-Clipping specified by crest factor’ has been provided in this system. This is a voltage limiting functionality to clip the voltage signal at a pre-defined limitation as shown in the Fig.2

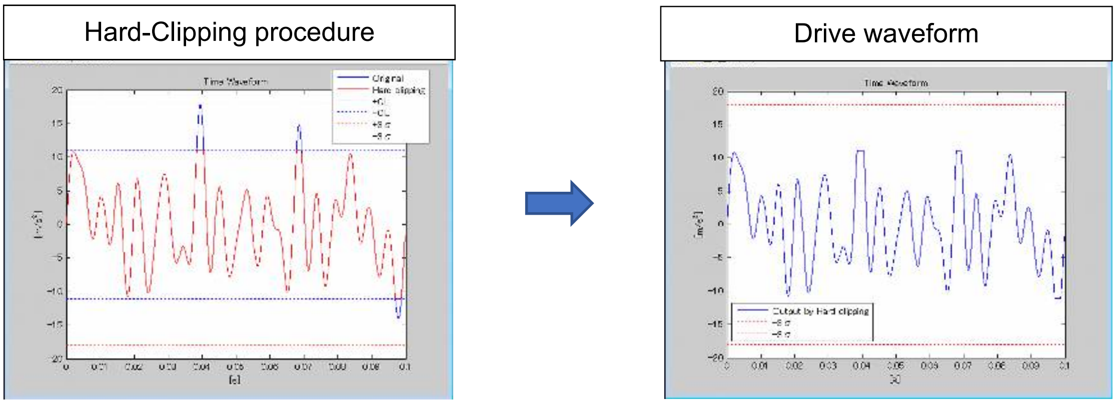


Fig. 2

All the voltage values at the points of the signal exceeding the limit voltage determined by the specified CF value and the RMS value（=σ）at the moment are replaced with the limit value. This procedure is simple and clear, but the spectrum (PSD) is more or less modified according to the clipping amount. In addition to this, analogue distortion is added after the D/A conversion by the transient response events that occur in the analogue parts when the clipped signal passes the circuit and the signal would show some overshooting. As a result, actual peak voltage would exceed the planned limitation value, and also the spectrum of the response signal would be more or less different from the plan.

## 1.5 Soft-Clipping

Some smart solution to avoid the disadvantages of the Hard-Clipping, which is a non-Gaussian random vibration control technique, is applied that makes it possible peak values of the whole signal not exceed the limit value without giving any modification of the PSD of the drive signal. This technique is named as 'Soft-Clipping' and implemented in this optional functionality.

The procedure is exemplified in the Fig.3. The original signal is the same as the one in Fig.2, but the produced final drive signal has no such flattened parts seen in the Fig.2. To keep the peaks not exceed the limit with keeping the PSD unmodified, other parts of the waveform of the clipped peak parts are all modified slightly in the time-domain.

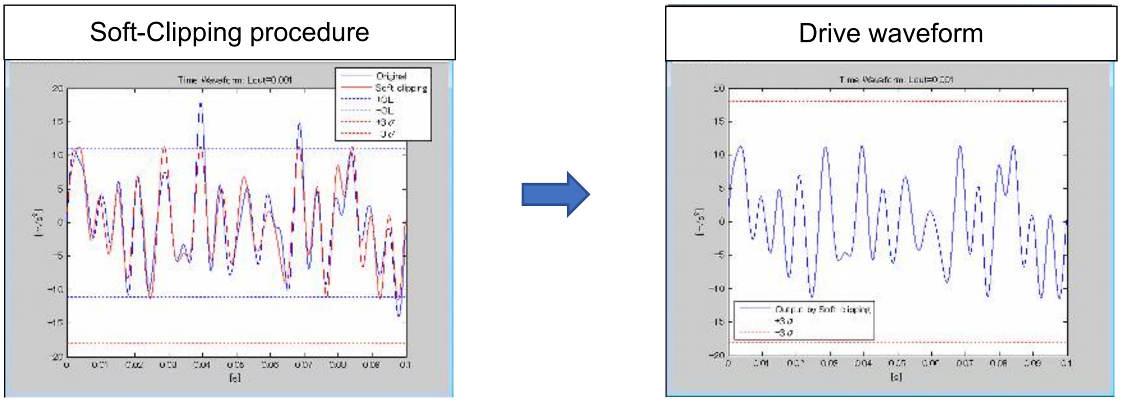


Fig. 3

And in case of Hard-Clipping, the clipping level voltage is determined by the product of the specified CF value and the drive RMS value at the moment, so even when the excitation level is lower than 0dB the drive waveform output by the controller has been always treated clipping.

In contrast, in the case of Soft-Clipping, the voltage limit value is determined by the product of the specified CF value and the drive RMS value at 0dB excitation level of the reference spectrum, so when the excitation level is small still compared to the 0dB level, the drive signal clipping does not occur. When the excitation level gets near to 0dB and there appears a peak that could exceed the limit value, then the Soft-Clipping works to keep the drive signal not exceed the limit, that is, Soft-Clipping does not occur when the excitation level is small.

# Chapter 2 Operation

## 2.1 Specifying the Soft-Clipping

In the Test Definition mode, double-click the [Excitation system setting] title in the Test Definition list. Then, the setting window for Excitation system setting appears:

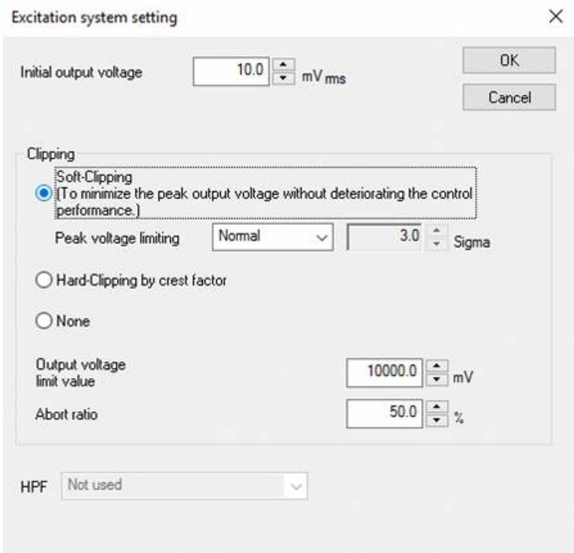


Fig. 4

To specify the Soft-Clipping, set the radio button of the selection item ‘Soft-Clipping’ active among the method selection of ‘Clipping’.

The default setting of the Peak voltage limiting is set ‘Normal’. Selection is provided among below items (see Fig.5):

- Normal : The drive peak limit voltage is set to the value corresponds to 3σ. (Excepting the case the value is set larger than ‘3.0’ enforced by the system according to the control conditions.)
- Loose : The drive peak limit voltage is set to the value 0.2σ larger than that in ‘Normal’
- Severe : The drive peak limit voltage is set to the possible smallest value determined by the system according to the control condition of ‘fmax’ and spectral resolution setting of ‘Line’
- Specify : Arbitrary value possible within the selectable range of the setting value is to be specified（Fig.6）.

Restriction of HPF usage

When ‘Soft-Clipping’ is selected, the selection of HPF usage is restricted disable and selection is fixed to ‘Not used’.

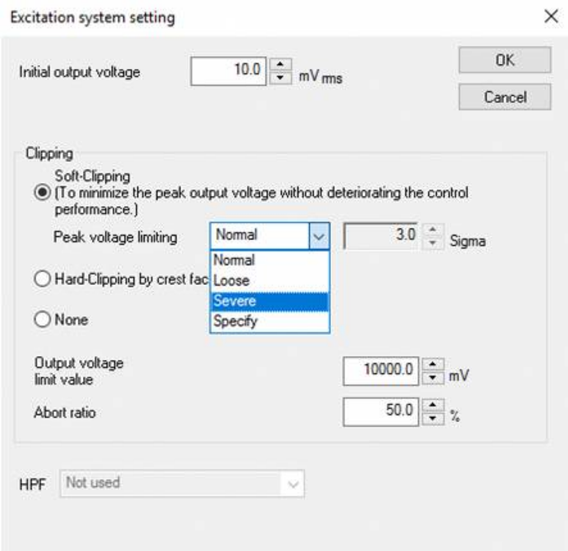


Fig. 5

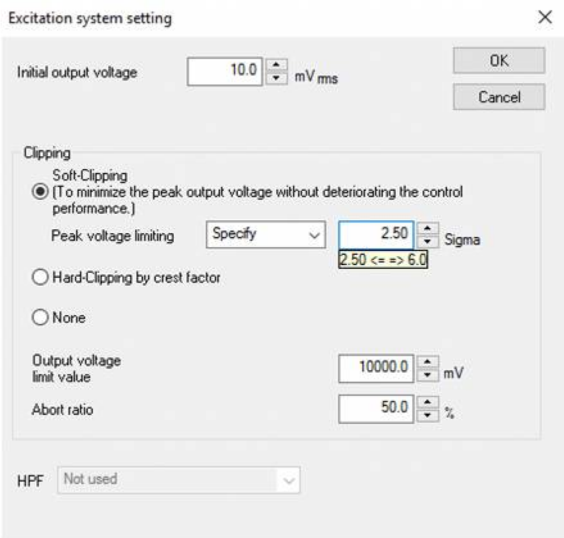


Fig.6

## 2.2 Setting of the PDF analysis

Amplitude probability density function (PDF) real-time analysis is provided by this optional functionality.

The real-time analysis of the PDF consumes some computational power. So, if PDF monitoring is not necessary in your testing, PDF analysis setting may better not to be done.

Setting of the PDF analysis is possible to be done for the input channels only that are specified as ‘Control channel’.

The drive voltage output waveform signal can also be PDF analyzed and the graph of it can be displayed with those of the response signals. But in case of the tests of ROR/SOR in which the drive spectrum can be quickly varied from time to time along with the narrowband sweeping, the PDF graph displaying of the drive signal is suppressed. PDF analysis is provided basically for stationary signals.

**＜Setting procedure＞**

(1) [Amplitude probability] in the [Test Definition] is double-clicked to open the setting window for the PDF analysis:

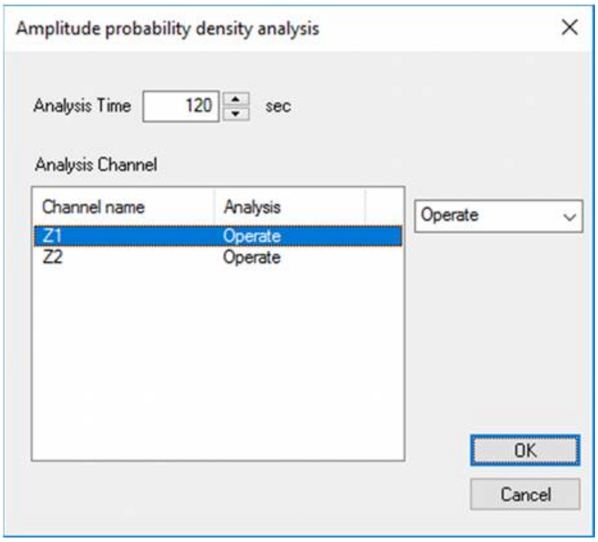


Fig.7

(2) In the setting window, all of the names of the control channels are listed (in this example, ‘Z1’ and ‘Z2’). And to operate or not to operate of the analysis is to be specified in the ‘Analysis’ column.

The default setting is ‘Operate’. If there is no need to operate analysis for some of the control channels, the setting of the channel should be changed to ‘Not operate’ (Fig.8).

‘Analysis Time’ specifies the duration of the time waveform subject to the PDF analysis.

The default setting is ‘120s’ and the analysis result of the recent 120s of the signal is displayed as a graph.

On the other hand, in the case of ROR/SOR in which non-stationary signals can be input for analysis, the default value setting is changed to ‘5s’. The setting can be changed to a longer value on necessity.

(3) When the setting is finished, press the [OK] button.

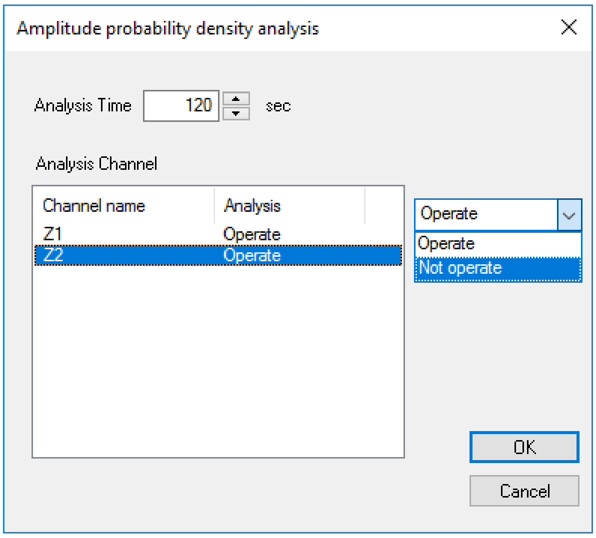


Fig.8

Then, as shown in below, the content of the [Test Definition Information] is updated.

And the icon in the left-side column changes as seen in the figure.

When the PDF analysis setting is desired to be returned to the undefined state, press this icon to reset the definition.

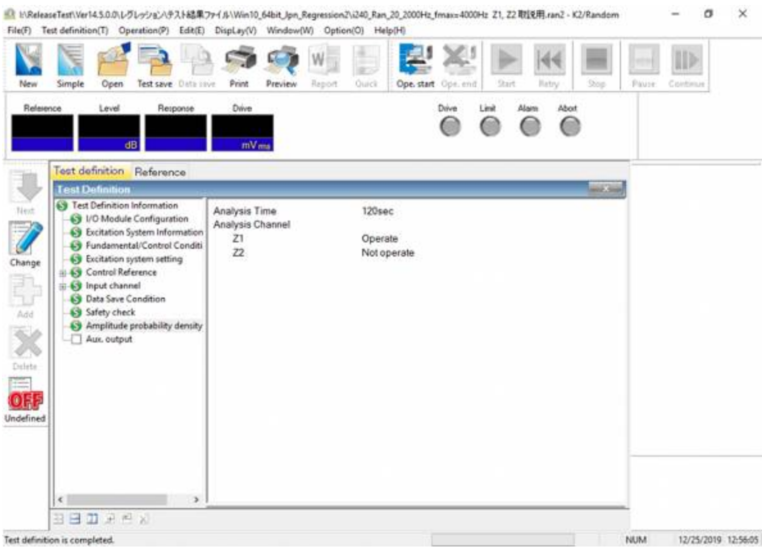


Fig.9

## 2.3 Special instruction：Recommended setting of the ‘fmax’

Let us notify the frequency band of the reference spectrum defined by an expression as [f1, f2] here, where f1 denotes the lowest frequency and f2 the highest frequency.

As stated in the section 1.4, the actually measured crest factor value CF gets to be a little bit larger than the set value in the specified value CF_s in the ‘Clipping’ setting in [Excitation system setting], and this tendency becomes prominent when the frequency f2 gets nearer to the control frequency rage fmax.

When you wish to make the actual CF value as small as possible, that is as near as possible to the specified value CF_s, set the control condition as the fmax value is about twice of the highest frequency f2. (To set fmax as f2 ≒fmax/2 is a good setting for better accuracy of CF control, which is known experimentally.)

## 2.4 Operation of test execution

The operation of test execution is basically the same as the usual operation of the K2+/RANDOM. When the setting of the Clipping is over, press [Ope. Start] to enter in the operation mode.

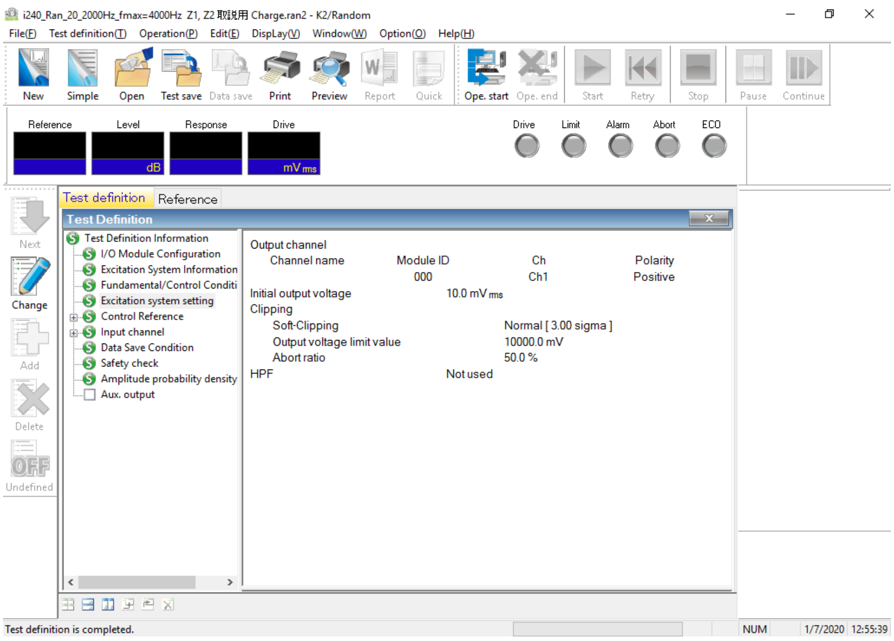


Fig.10

Then, the system starts to move into the operation mode. Below is a screenshot of a system with ISM-EM, the energy-saving option, is equipped.

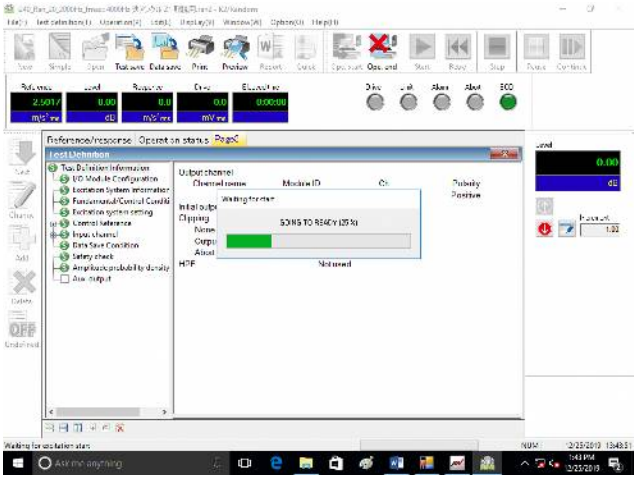

Fig.11

When the transition to the operation mode is completed, the [Start] button become available to start the excitation:

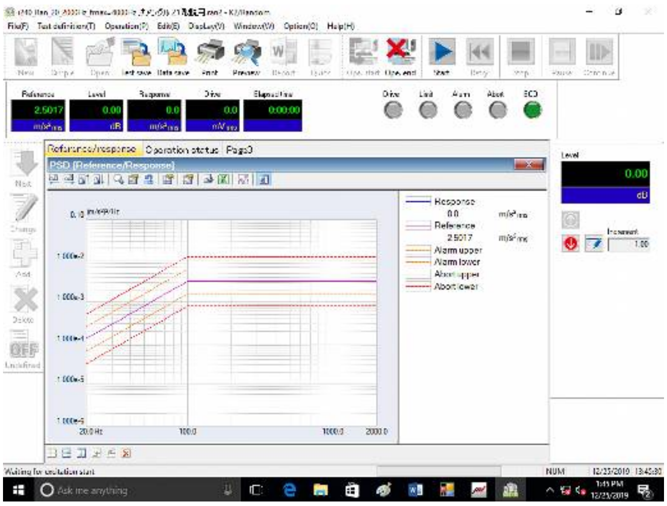

Fig.12

When the [Start] button is pressed, the drive signal outputting is started and the initial equalization to make the response acceleration PSD to be equal to the reference PSD is carried out. When the PSD control is established stable, then the random vibration testing is started.

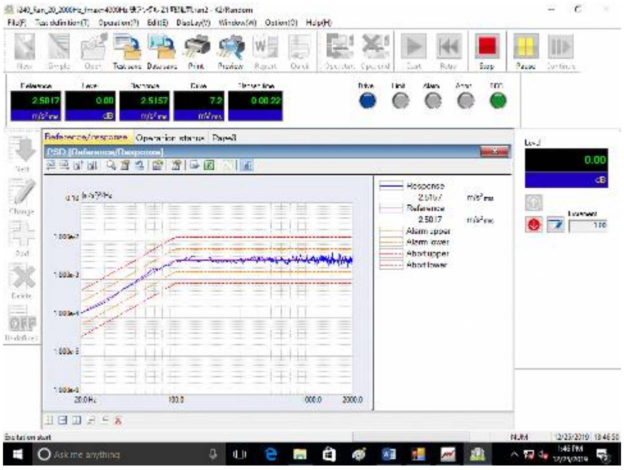

Fig.13

## 2.5 Displaying the PDF graphs

Real-time histogram analysis of the specified input channel signals under the specified condition is started when the testing is started and the analysis results are displayed as PDF graphs.

To activate the PDF graph displaying, move to a page on which you wish to display the graph. And press the [Window] button in the top-side ribbon on the screen and select the [Graph] button, then the Graph type selection window appears as below. Select 'Amplitude probability density', and specify the graph displaying specifications:

In the setting window,

Input channel signal name to be displayed is specified.

And below graph display specifications are selected:

☐ Display the Normal distribution

☐ Normalize the horizontal axis by RMS

☐ Display the drive PDF

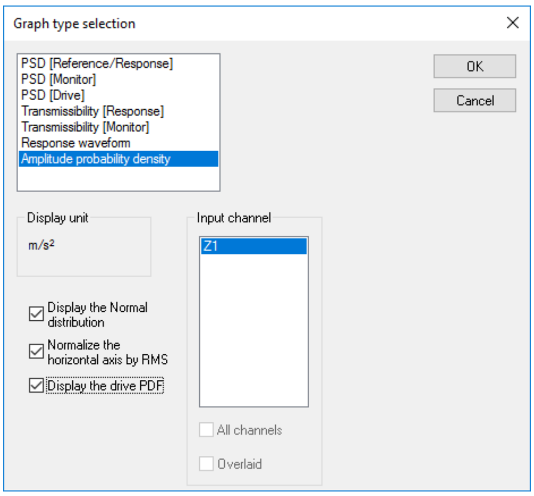


Fig.14

When the setting is completed, press [OK] to make the graph displayed on the screen:

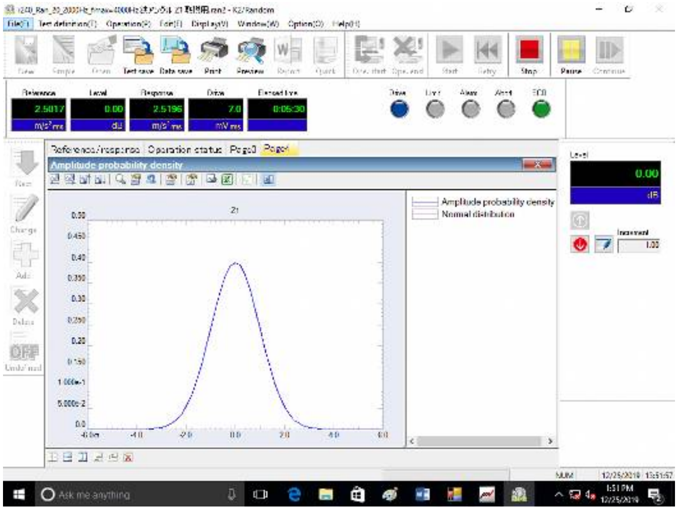


Fig.15

To check the detail of the part at where CF value takes large values, it is convenient to use the logarithm scale for the horizontal axis. To do this 'Log' setting, press the [Scale] button among the graph display specification setting buttons.

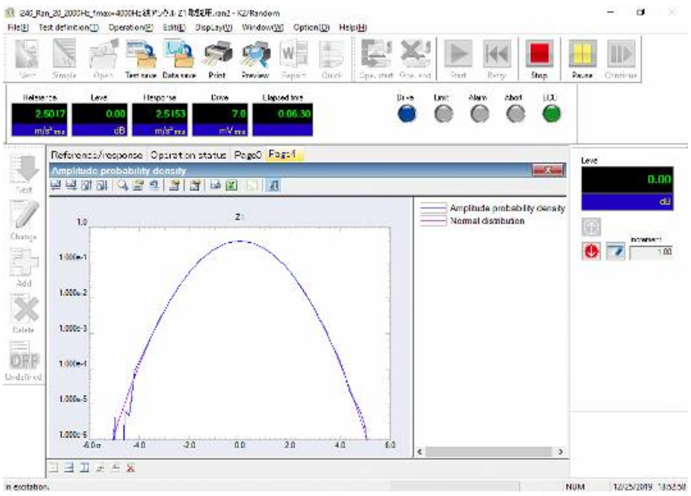


Fig.16

## 2.6 Operation status

In the [Operation status], there displayed RMS values of all the channels and crest factor CF of the channels of which signal's PDF analysis has been specified to be operated.

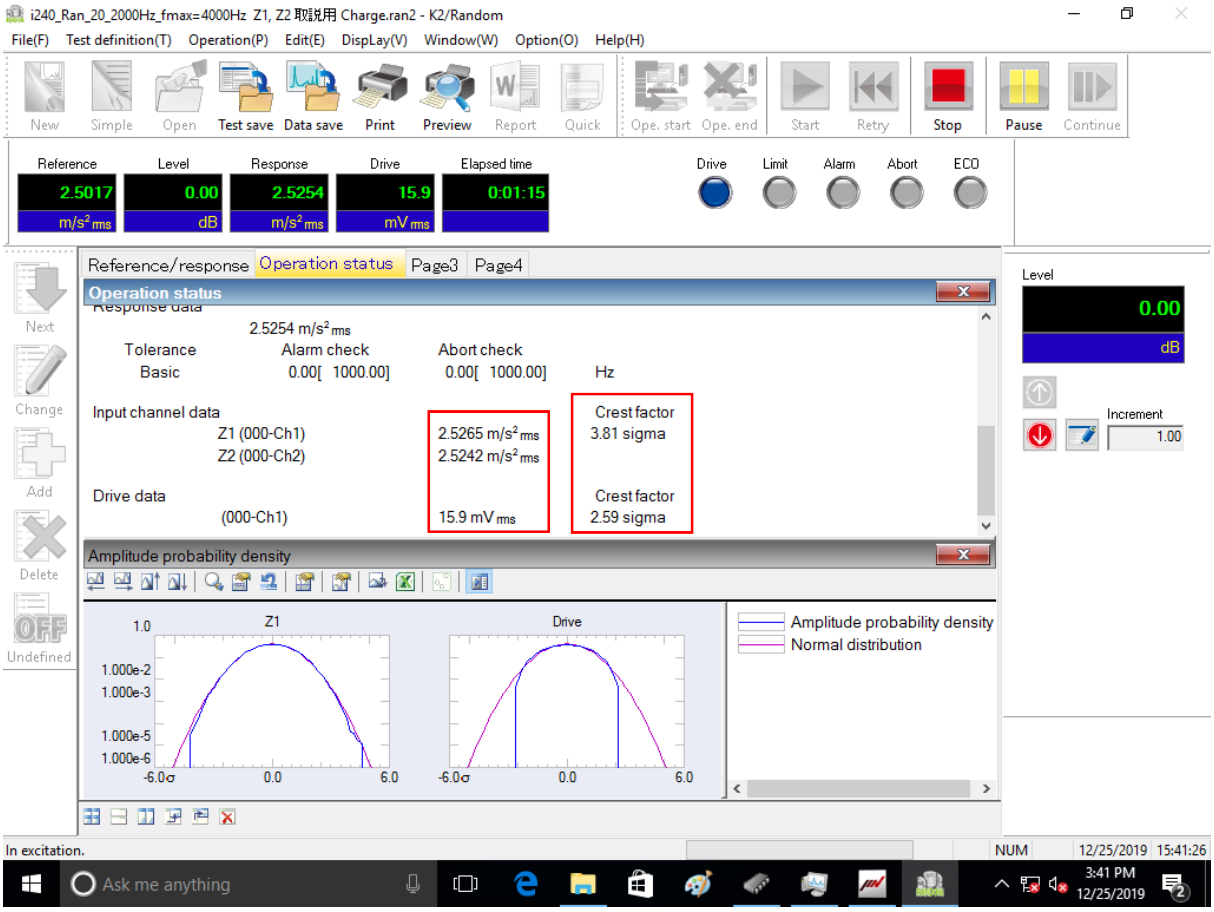


Fig.17

It should be noted that these values displayed in [Operation status] are all 'theoretical values' obtained in the digital signal processing by the controller. When the actually output analogue voltage signals are measured, it is usual that the measured value of CF is slightly larger than the displayed values on the screen. This is caused by the transient response occurs in the analogue circuit noticed in the section 1.4. And, it is experimentally confirmed that the divergence amount of measured value from theoretical one is smaller in case of the Soft-Clipping than that in Hard-Clipping.

(Fig.17 shows an example of 2 issues (Operation status and PDF graphs) displaying on the same single page.)

<u>Note on the automatic PDF graph resetting</u>

In case of the Energy-saving system with ISM-EM equipped, the field coil current optimization is carried out just after the random vibration testing started and the scale of the drive signal varies in accordance with the change of the field current. This change requires the PDF analysis horizontal axis to be adjusted once again. For this purpose, the data and the graphs of the PDF display is automatically reset once the ISM optimization is completed.

## 2.7 Countermeasure to CPU overload error

This optional functionality of Soft-Clipping is for to keep the drive peak voltage within the limit value that is determined by the 0dB reference level (RMS) and by the specified CF value, and to implement this functionality a technique of 'Non-Gaussian random signal generation' is applied. Smaller the required CF value, heavier the computational power for the functionality to work in real-time manner. More exactly, the computational load to the CPU also depends on the control condition (fmax, L) and characteristics of the controlled system. Of course, the CPU clock and memory condition have much influence on the performance.

Affected by such many factors, CPU overload error of the application can occur. When the error event occurs, the system automatically stops the vibration control procedure safely with publishing the error message as seen in below. The drive voltage output is quickly squeezed to zero in a stably controlled manner never to make any damage to the equipment and specimen.

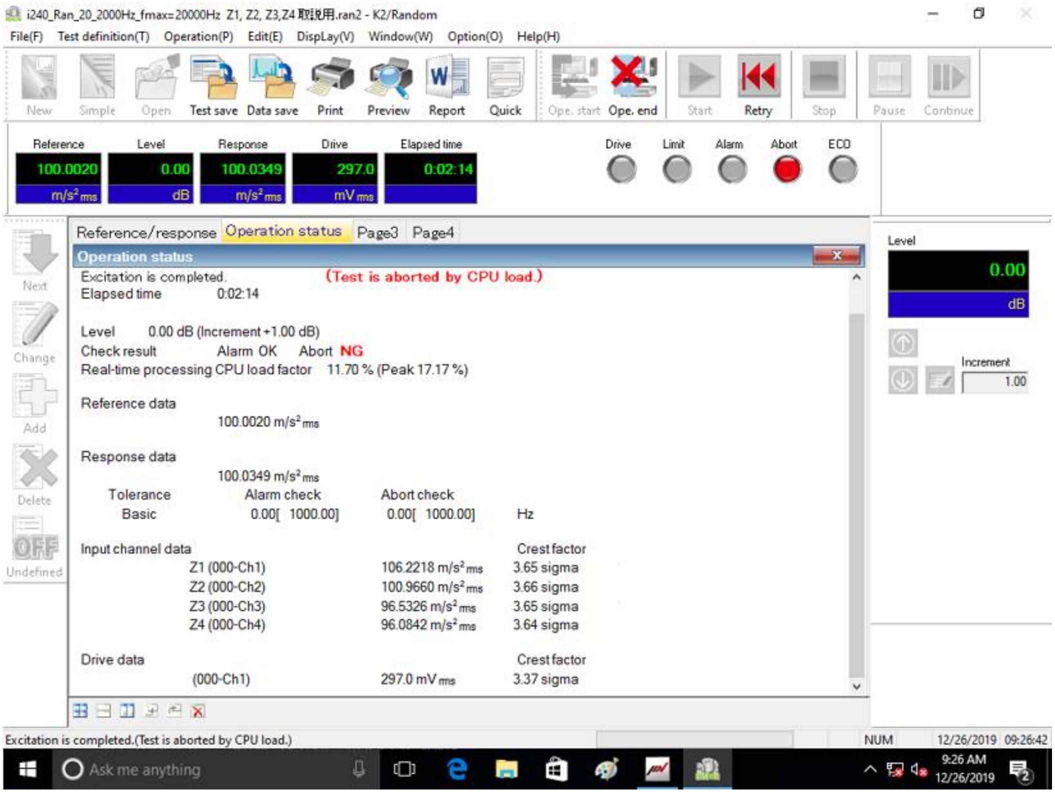


Fig.18

When such an error event occurred, please return to the Test Definition stage and double-click [Excitation system setting] to open the setting window for 'Clipping', and loosen the CF setting than before. Then try the operation once more. (When the setting was at 'Normal', then try 'Loose'. When 'Specify' was used, loosen the CF value for 0.1 or so.)

Even the value CF is fixed, computational load gets heavier when the control line number L is set larger. So, if possible, reducing the line number L will contribute to reduce the CPU load.