Shock Vibration Control System

K2+

SHOCK
Instruction Manual

IMV CORPORATION

Type of Document :	Instruction Manual	
System Applied :	K2+	
	Software <SHOCK>	later than Version 20.1.0

Japanese Edition

Version	Date	Contents
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1.1.0	2021.02.01	Additional description of ‘Clear history at operation start’ and ‘Set the data file name automatically’ of ‘Set up’.

English Edition

Version	Date	Contents
1.0.0	2020.10.16	First edition
1.1.0	2021.02.01	Additional description of ‘Clear history at operation start’ and ‘Set the data file name automatically’ of ‘Set up’.

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Chapter 1　Outline of the System

1.1 Specification

1.1.1 SHOCK

(1) Control Method :　Finite-length waveform control based on feed-forward method

(2) Control frequency Range fmax : Maximum 20 kHz (However, it may be limited by conditions.)

(3) Number of Control Lines L :　Maximum 25,600 line

(4) Sampling Frequency fs :　2.56・fmax

(5) Control Dynamic Range :　More than 84 dB

(6) Reference Waveform Maximum Length : 16K points (standard specification)
200K points (with LONG WAVEFORM Option)
5000K points (with MEGA POINT Option)
(However, it may be limited by conditions.)

(7) Input Channel

1) Number of Channels :　Maximum 64ch. (Control channel is limited to 1.)
(However, it may be limited by conditions.)

2) Type of Channel :　Control Channel / Monitor Channel

(8) Output Channel

1) Number of Drive Channel :　1

2) Other Output Channel :　1 (Timing output is available.)

(9) Reference Waveform Type

- Classical Shock Waveform (Half-sine, Haversine, Saw-tooth, Triangle, Trapezoid)
- Sine Beat / Sine Burst
- Measured Waveform

Usable waveform format for loadingg :　CSV, TSW (standard format for F2 control system of IMV), UFF(dataset58), MTS(RPCIII))

- Defined Waveform (Symmetric Compensation)
- Damped Sine(Compensated Exponentially Decaying Sinusoid(CEDS), Zero Residual Displacement Decaying Sinusoid(ZERD), Wavelet(WAVSYN))

(10) Analysis・Display Data

1) Reference, Control Response Waveform and the spectrum

2) Response Waveform of each Input channel and the spectrum

3) Drive Waveform and the spectrum

4) Transmissibility :　・Controlled System Transfer Function, Coherence
・Transmissibility between Input Channels (amplitude, phase)
・Transfer Function between the reference and the response waveform

(11) Data Save :　Saving various type of data

(12) Option　:　SRS, LONG WAVEFORM, MEGA POINT

1.1.2 SRS (Option)

(1) Function : When this option is added, the system is applicable for SRS Shock Testing in which the requirement and judgment of the testing is done based on SRS (Shock Response Spectrum) not by the waveform itself. SRS analysis for acceleration waveform data of each control response or monitor response obtained after the excitation in an ordinary shock testing is operated just after the acquisition. And the result is displayed as SRS Analysis Result besides the excitation result as response waveform.

(2) Number of SDOF Filters : Maximum 256

(3) Analysis Type : Absolute Acceleration, Relative Displacement

(4) Analysis・Display Data : Reference Analysis
Control Response Analysis
Monitor Analysis

1.1.3 LONG WAVEFORM (Option)

(1) Function : Maximum 16K points of Reference Waveform can be used in standard SHOCK. However, much longer waveform data is usable as a reference waveform when this option is added.

(2) Max. Length of Reference Waveform : 200K points

1.1.4 MEGA POINT (Option)

(1) Function : Maximum 200K points of Reference Waveform can be used in SHOCK with LONG WAVEFORM option. However, much longer data is usable as a reference waveform when this option is added.
LONG WAVEFORM option is required to be added before adding the MEGA POINT option.

(2) Max. Length of Reference Waveform : 5000K points

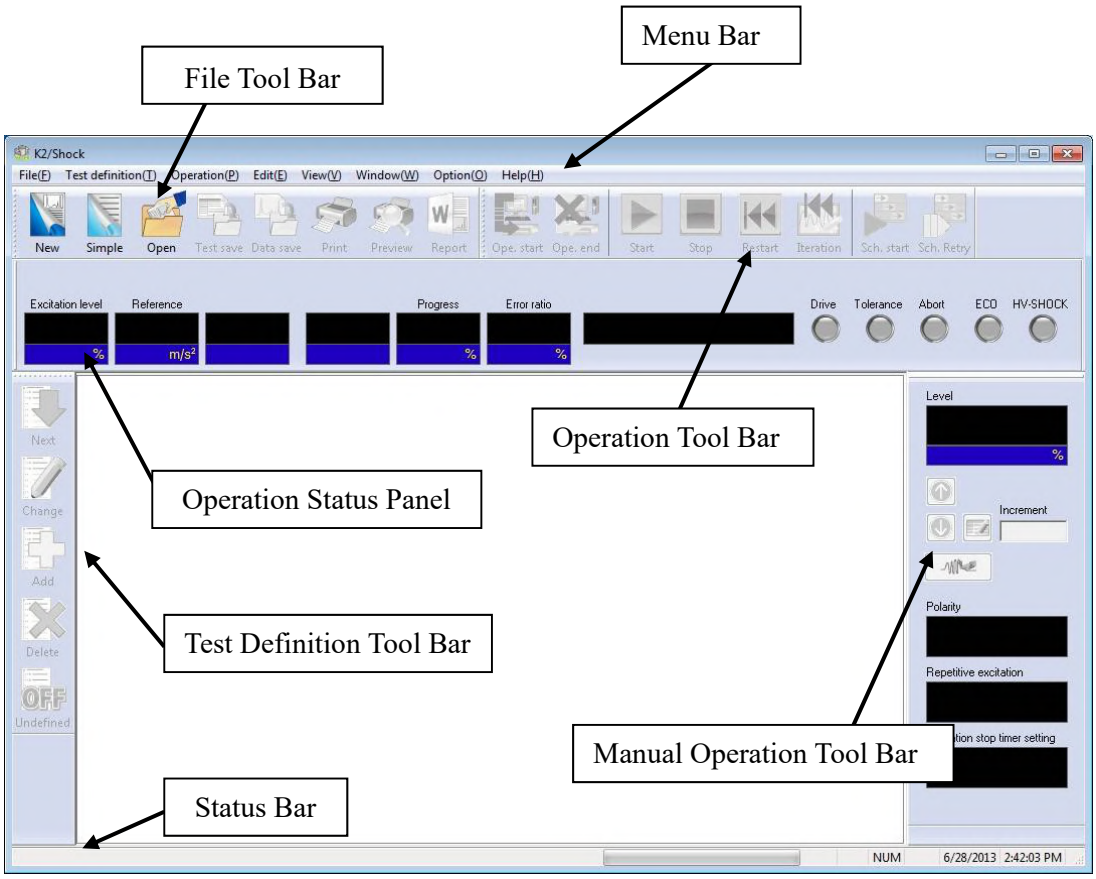
Chapter 2　Operation System of K2+ Application

2.1 Outline

In K2+ application, operation after booting up is executed by using a keyboard and a mouse. When this application is started, a window shown as below appears.

All the names of menu in this application are displayed in Menu Bar. Each menu is to be opened by clicking on its name and available commands appears as a list.

The commands used frequently are displayed as buttons in each Tool Bar. A command is executed or a dialog box corresponding to the command is opened when the button is clicked. Operation status of K2+ Controller is displayed in Status Bar. The state during the excitation operation is displayed in Operation status panel.



K2+ Application Window

2.2 Test File

In K2+ application, necessary information to operate a test is saved in a specified file called ‘Test File’. Following kinds of Test File are available in this system.

Necessary Test Files for test operation

・Test Definition File : The file created in Ver.20.0.0.0 or later
K2+/SHOCK（*.sho2, *.srs2）
The file created in Ver.10.0.0.0 or later
K2/SHOCK（*.sho2, *.srs2）
The file created before Ver.10.0.0.0
K2/SHOCK（*.sho, *.srs）

・Graph Data File : The file created in Ver.10.0.0.0 or later（*.vdf2）
The file created before Ver.10.0.0.0（*.vdf）

・Environment setting File
(I/O Module Configuration Information, Excitation System Information, Input channel Information) : SystemInfo.Dat2

Note 1) Saved in ‘\IMV\K2_Plus’ on System Drive. Deleting inhibited

2.3 Test Type

Following types of tests are available in K2+/SHOCK.

(1) Shock test for replicating the finite arbitrary reference waveform given in a digital format by using it as the control reference value

Example) Classical Shock Waveform
Sine Beat
Replicating test of Measured Waveform

(2) SRS Shock Test **(SRS option is necessary)**

Shock test for replicatiing the excitation of the generated reference waveform data having a given Reference SRS. And the result is judged by SRS analysis.

(3) Endurance test by repeating the excitation as stated above

Chapter 3 Basic Operation

3.1 SHOCK Test

< Example >

An example of Shock Test is described as below ;

[Reference Waveform]

- Type of Waveform : Half-sine
- Peak amplitude Value : 200m/s^2
- Pulse width : 11 ms
- Tolerance : IEC(JIS C) 60068-2-27
- (Auto-set of sampling frequency and data length)

[Control Condition]

- Control frequency lines : 400 lines
- Initial level : 30 %
- XFR Function [Output level at XFR measurement] : Auto

[Information of sensors to be used]

Two acceleration pickups of piezoelectric : one is used for control and another for monitor.

Ch.1 : for control, sensitivity 3pC/(m/s^2)

Ch.2 : for monitor, sensitivity 3pC/(m/s^2)

However, these channels must be registered in Input Channel Information (in this example, 'Input01').

Also, the rating information of Excitation System has already been registered in Excitation System Information (in this example, 'Exc01').

[Information of specimen]

Specimen mass : 10[kg]

[Excitation Procedures]

(1) Excitation is operated at the Excitation Level = 30 %.

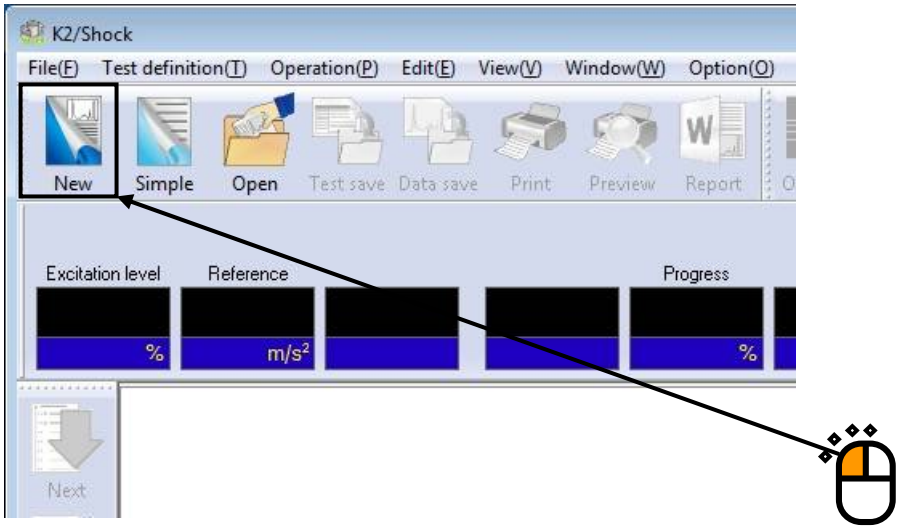
(2) Iteration is executed.

(3) Excitation is operated at the Excitation Level = 100 %.

< Procedures >

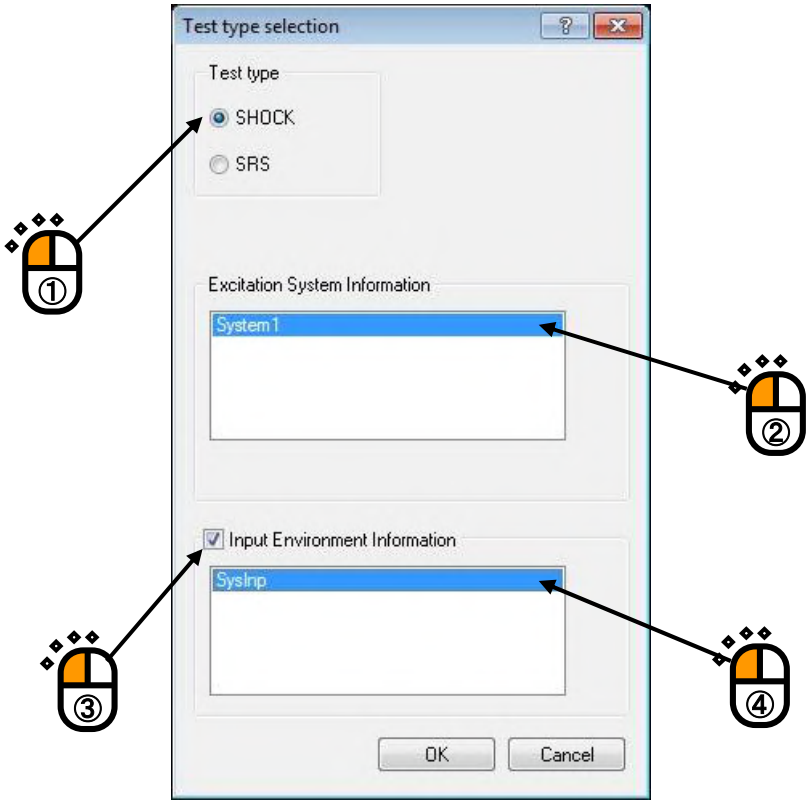
< Step 1 >

Press the [New] button to start ‘New Definition’.



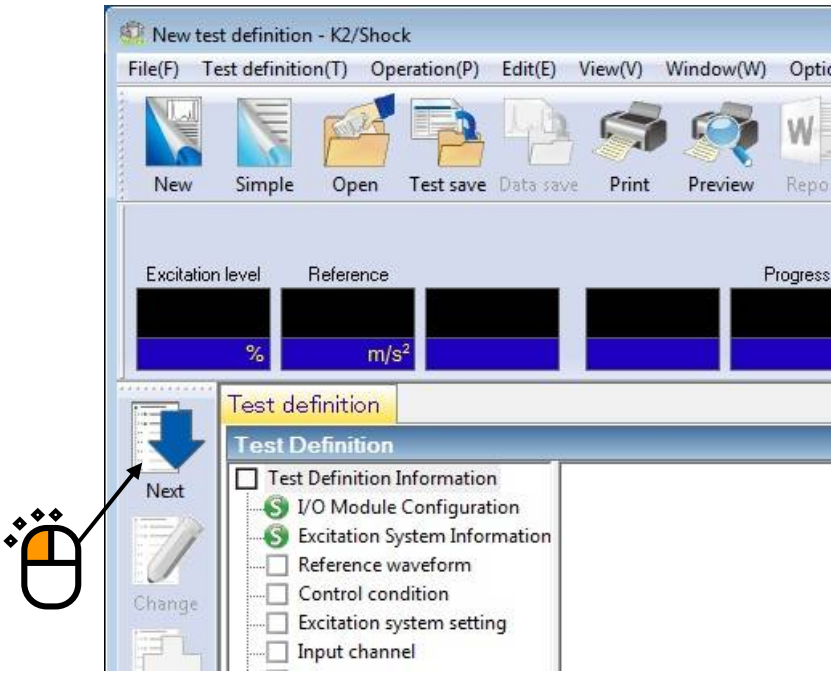
< Step 2 >

Select ‘Shock’ in Test Types. And, select appropriate item each from the list of ‘Excitation System Information’ and ‘Input Channel Information’.



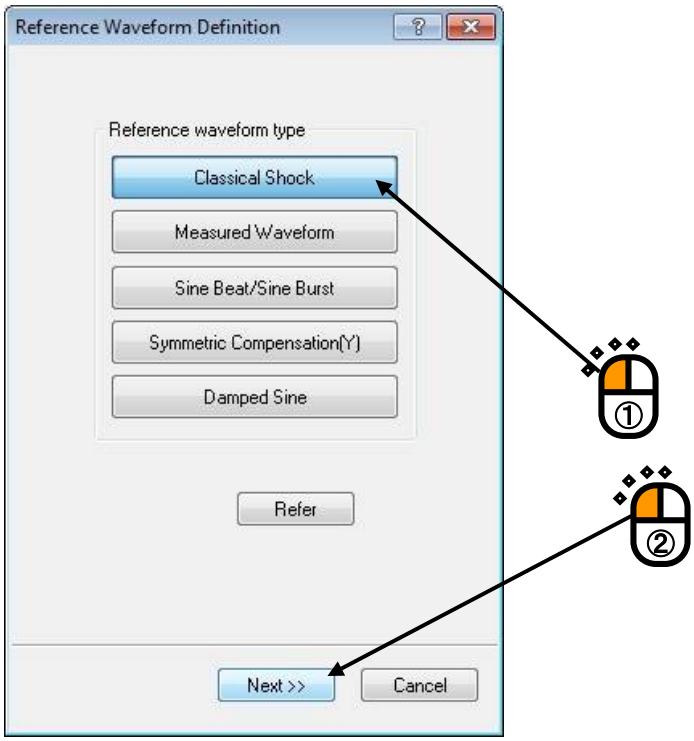
< Step 3 >

Press the [Next] button.



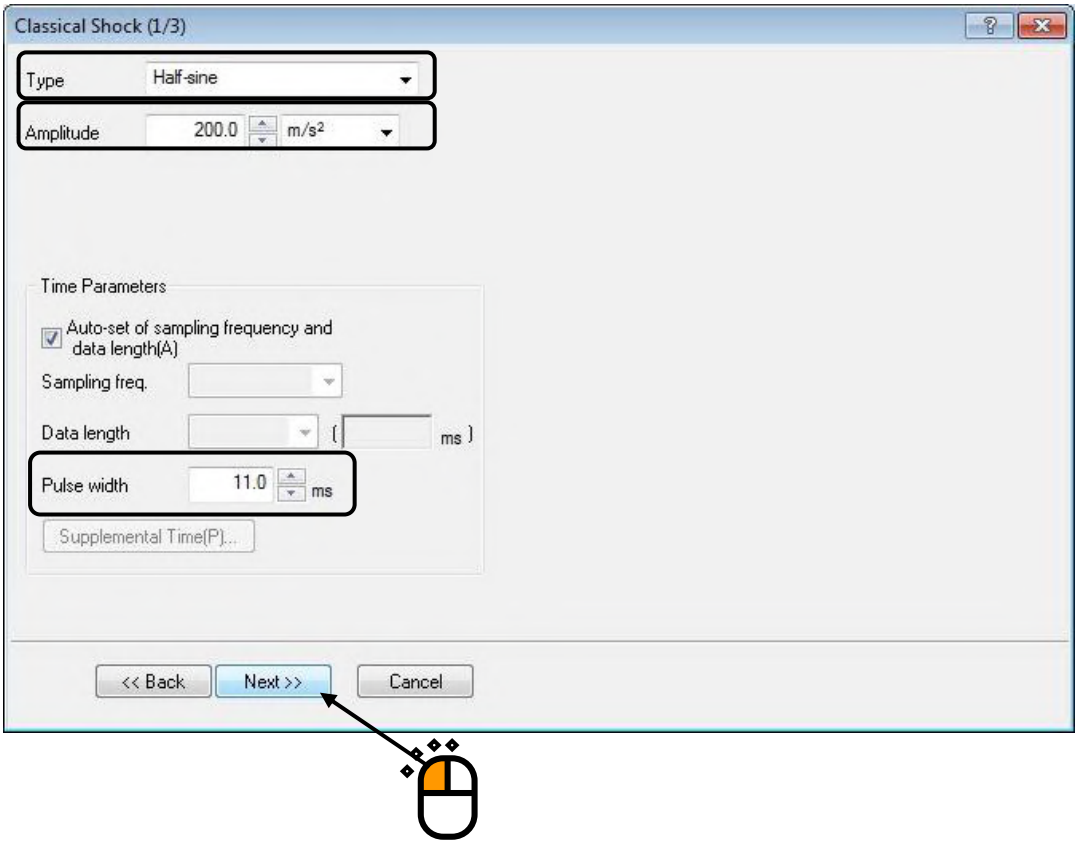
< Step 4 >

Select [Classical Shock] and press the [Next] button.



< Step 5 >

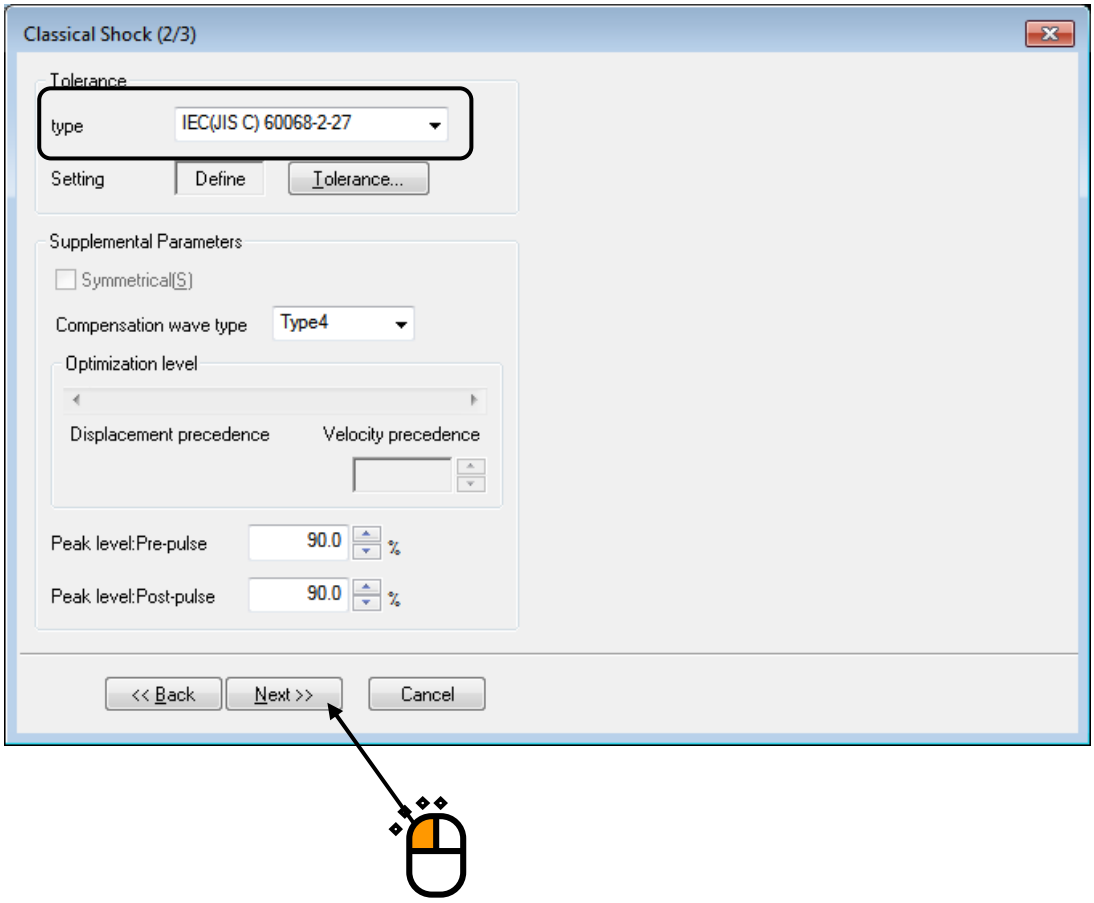
In the first definition dialog, input the values to ‘Waveform type (Type)’, ‘Amplitude’ and ‘Pulse width’. Press [Next] when all the items are filled.



< Step 6 >

In the next Reference Waveform Definition dialog, select a type of Tolerance.

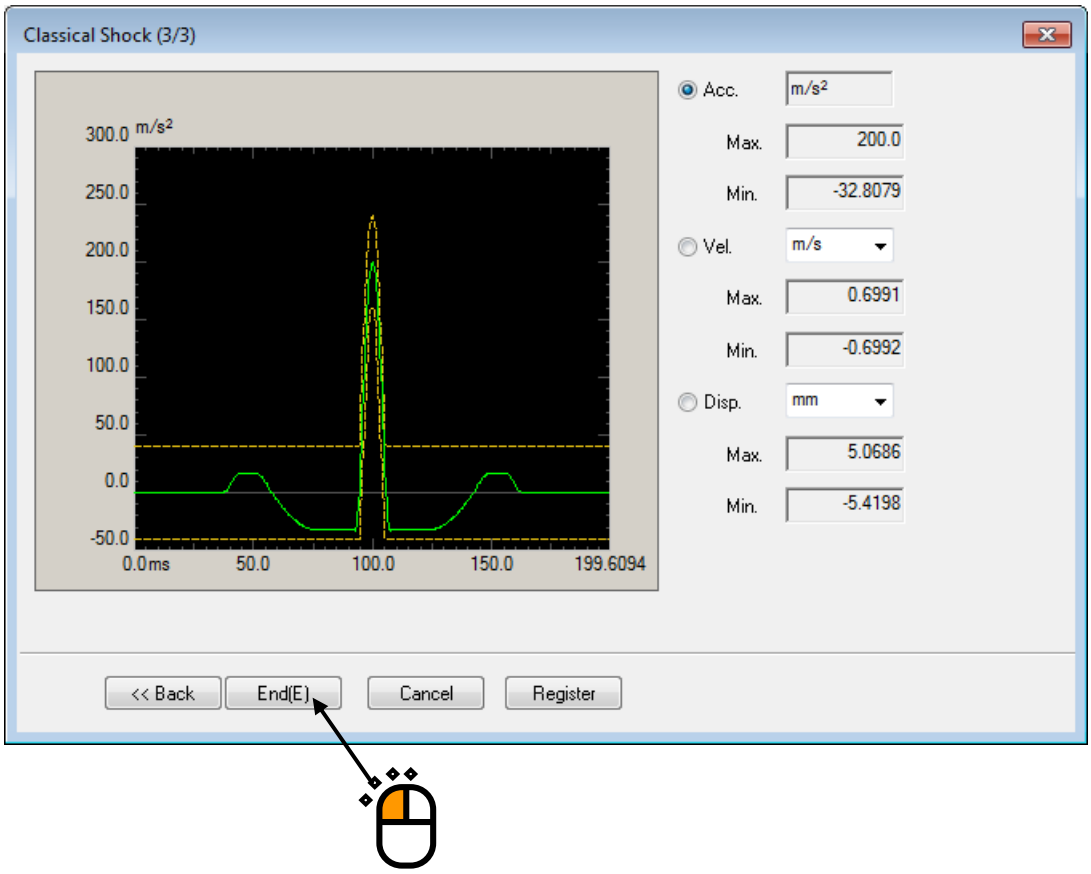
Press [Next] when all the items are filled.



< Step 7 >

Now, the definition of Reference Waveform is completed.

The generated Reference Waveform is displayed as below. Press the [End] button.



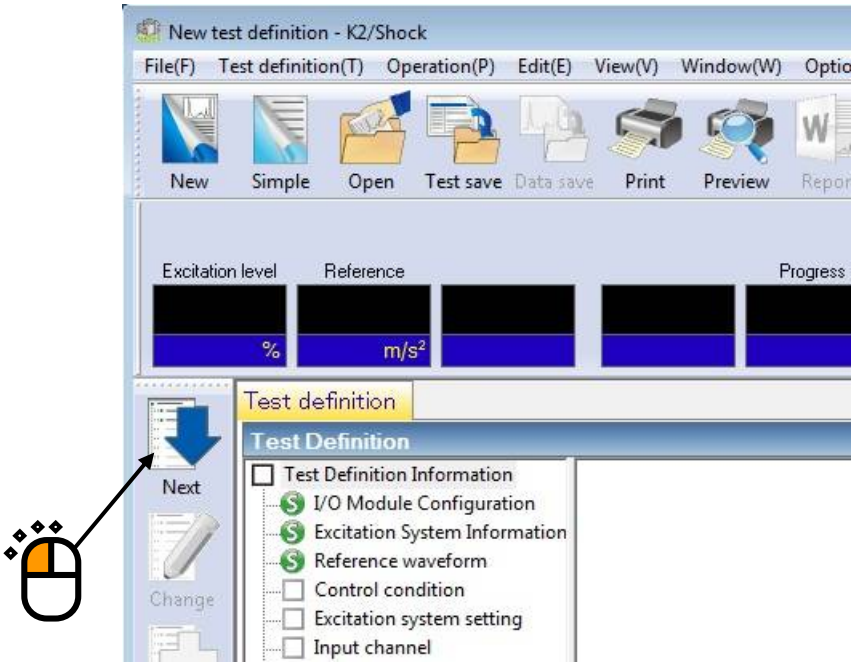
(In case of not convergent)

When the generated Reference waveform doesn't converge, that is, the reference waveform data exceeds over the Tolerance, return to the display of < Step 2 > (page 1/3) and check off "Auto-set of sampling frequency and data length" and specify arbitrary values of Sampling frequency and Data length.

Convergence of the generated Reference waveform relies on the condition of Reference waveform.

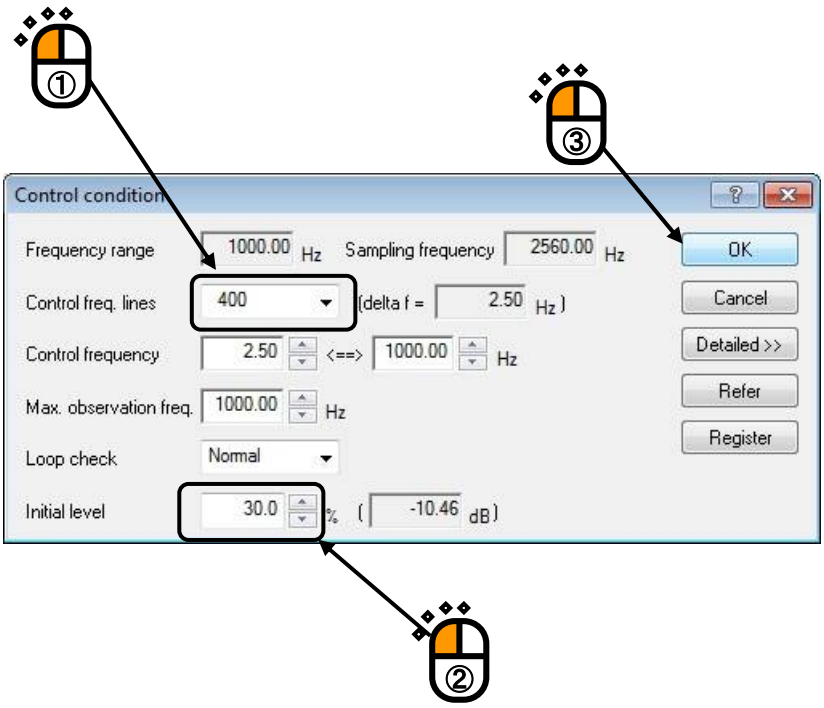
< Step 8 >

Press the [Next] button.



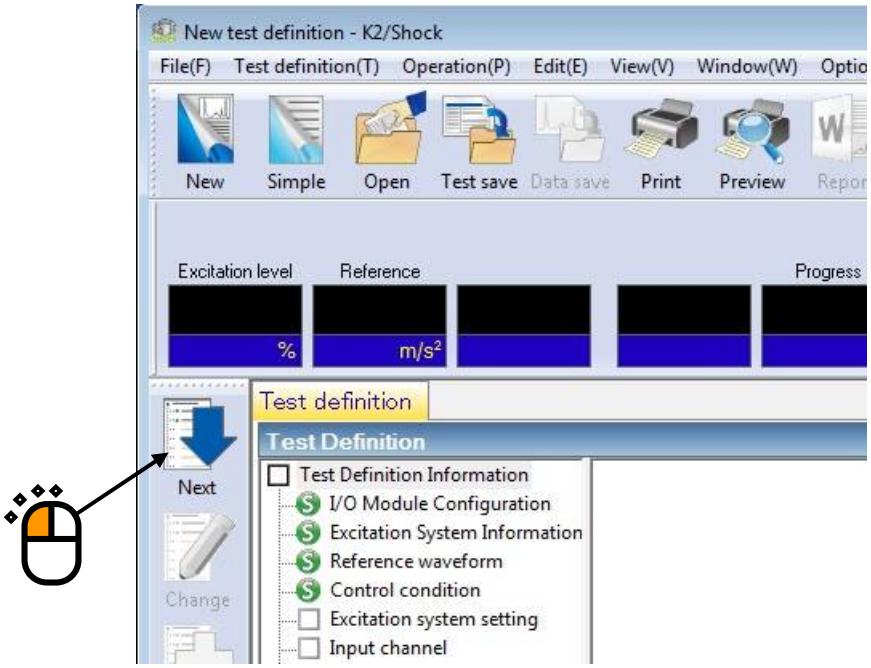
< Step 9 >

Set the Control frequency lines to ‘400’ and the Initial level to ‘30 %’. And, press [OK] button.



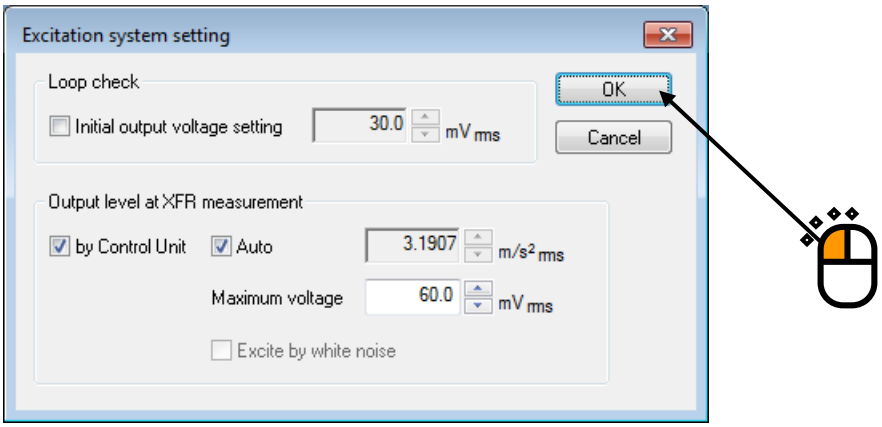
< Step 10 >

Press the [Next] button.



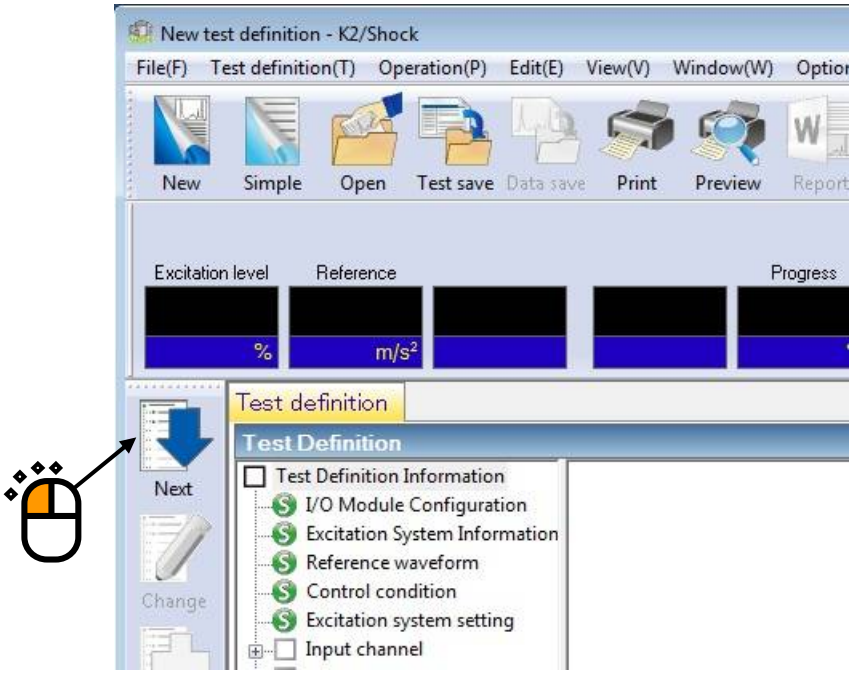
< Step 11 >

Press [OK] button.



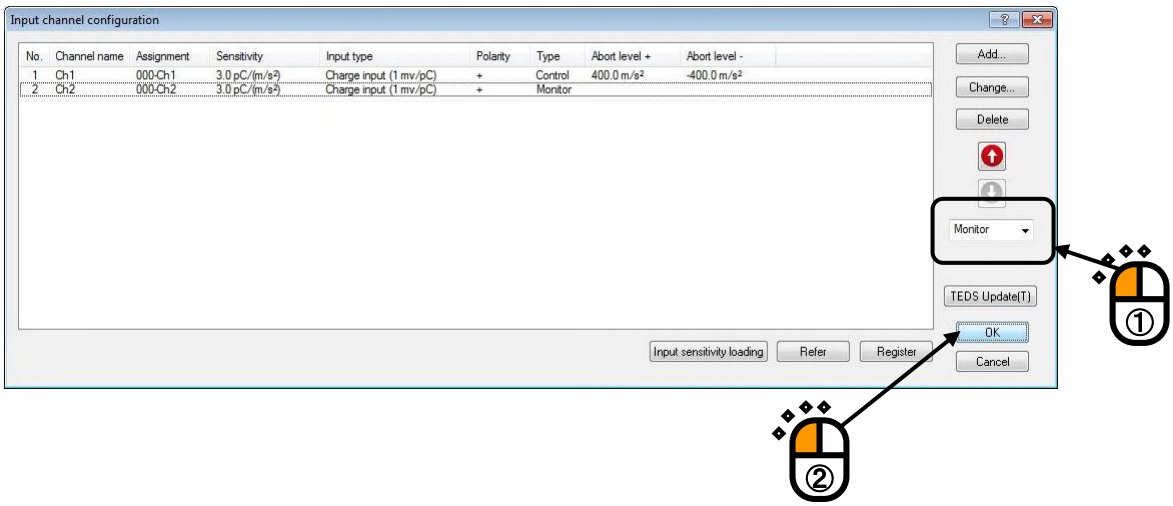
< Step 12 >

Press the [Next] button.



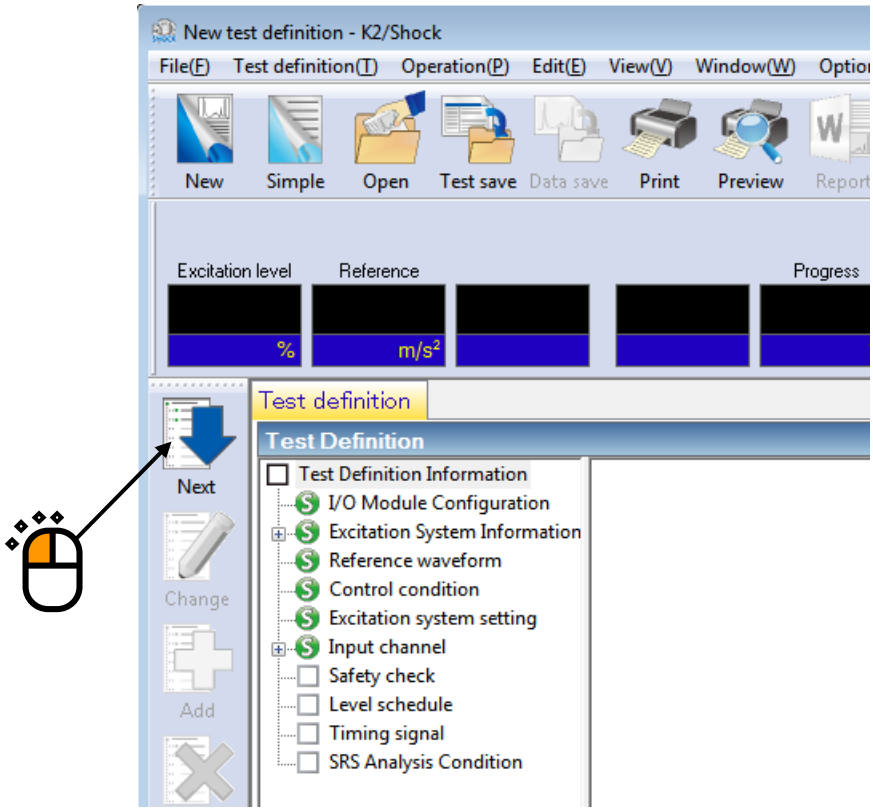
< Step 13 >

Select ‘Ch.1’ and set as ‘Control’. Also, select ‘Ch.2’ and set as ‘Monitor’. Then, press [OK] button.



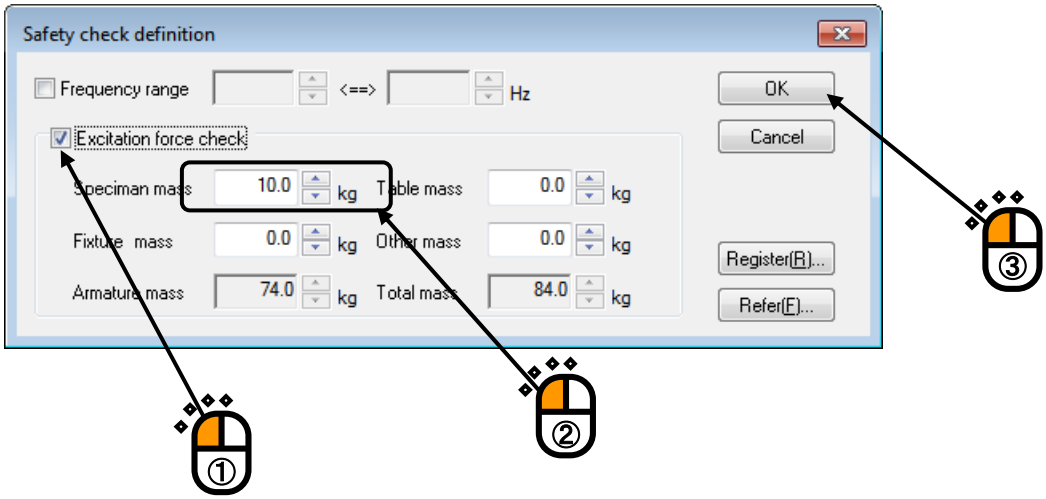
< Step 14 >

Press the [Next] button.



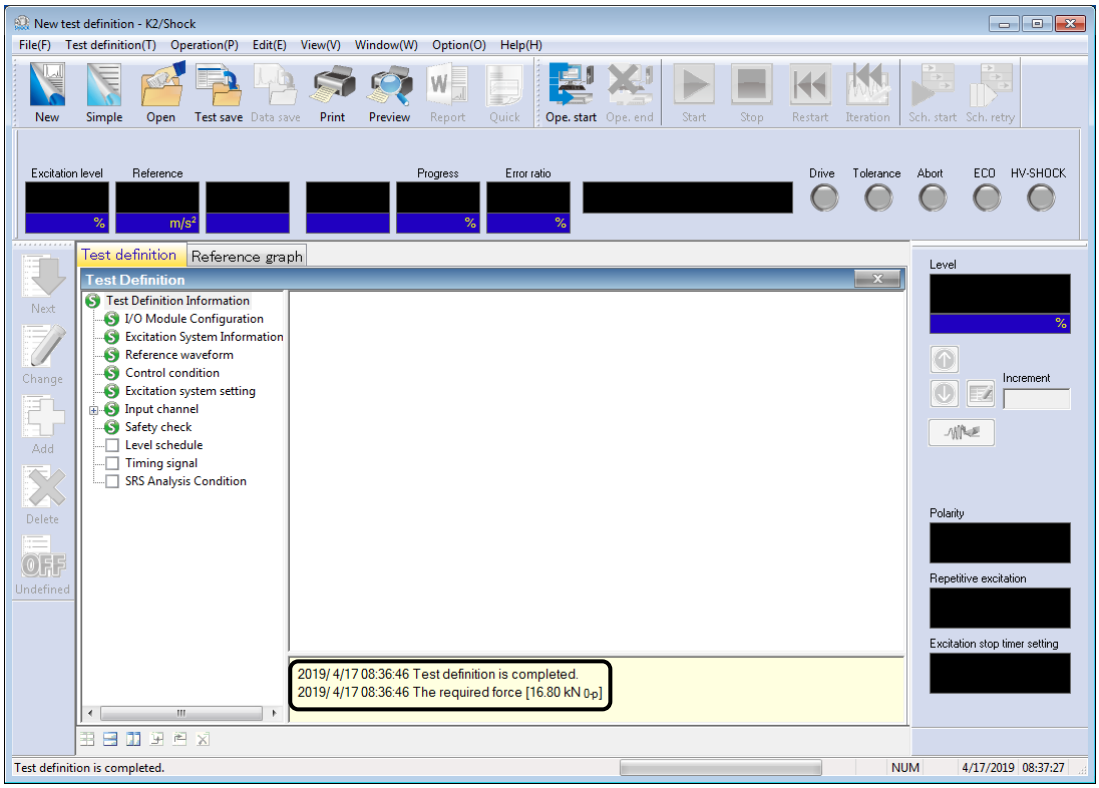
< Step15 >

Select ‘Excitation force check’ and input the value as ‘Specimen mass : 10 [kg]. And press the button of [OK].



＜Step16＞

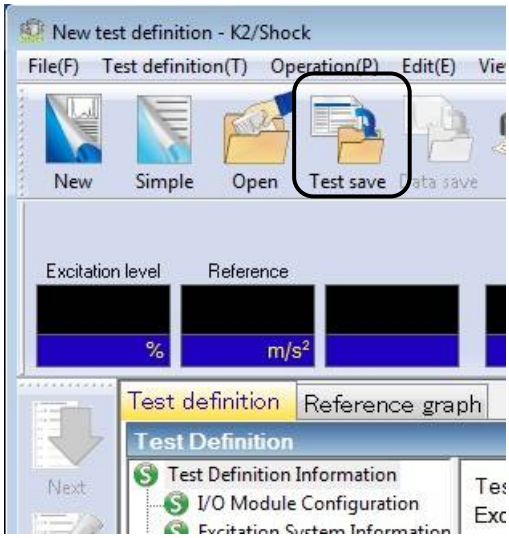
Now, the definition is completed.



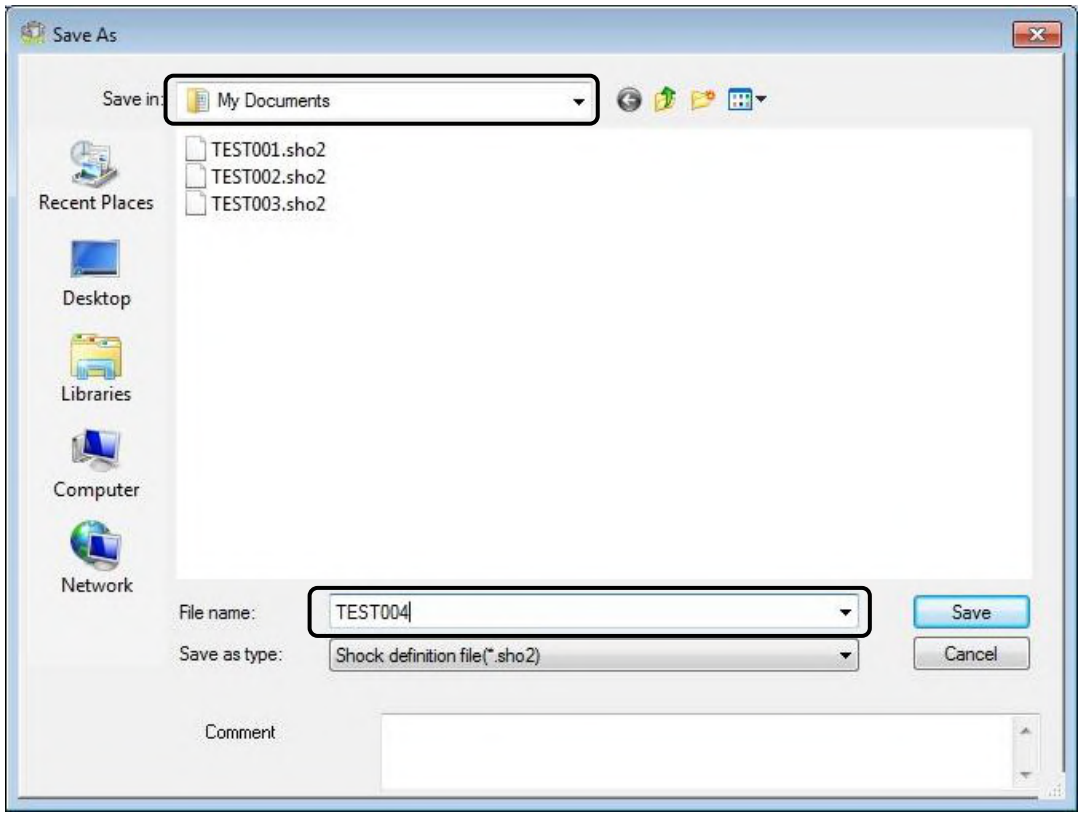
< Step 17 >

Save the defined test information to a test file.

Click the [Save] button.



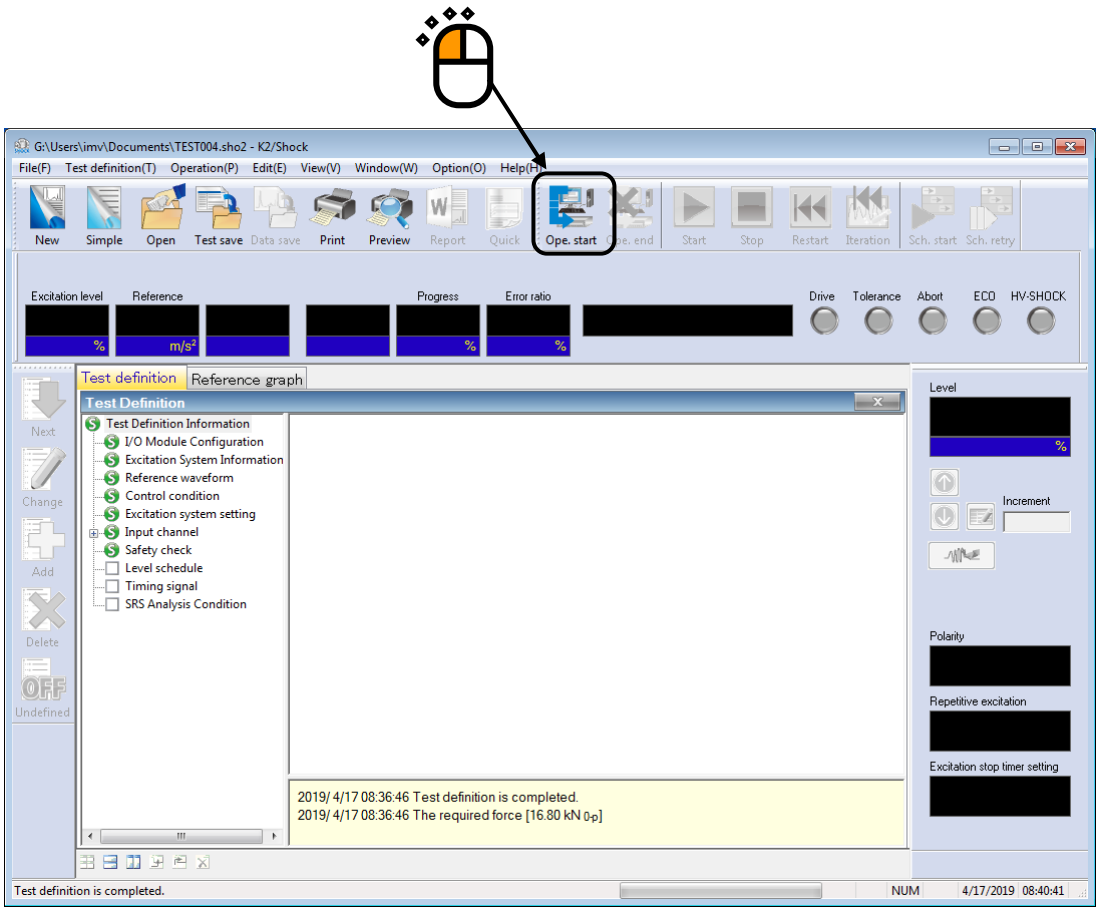
The dialog box as below appears. Specify an arbitrary directory in ‘Save in’ and input a name to ‘File name’.



< Operation of Test >

< Step 1 >

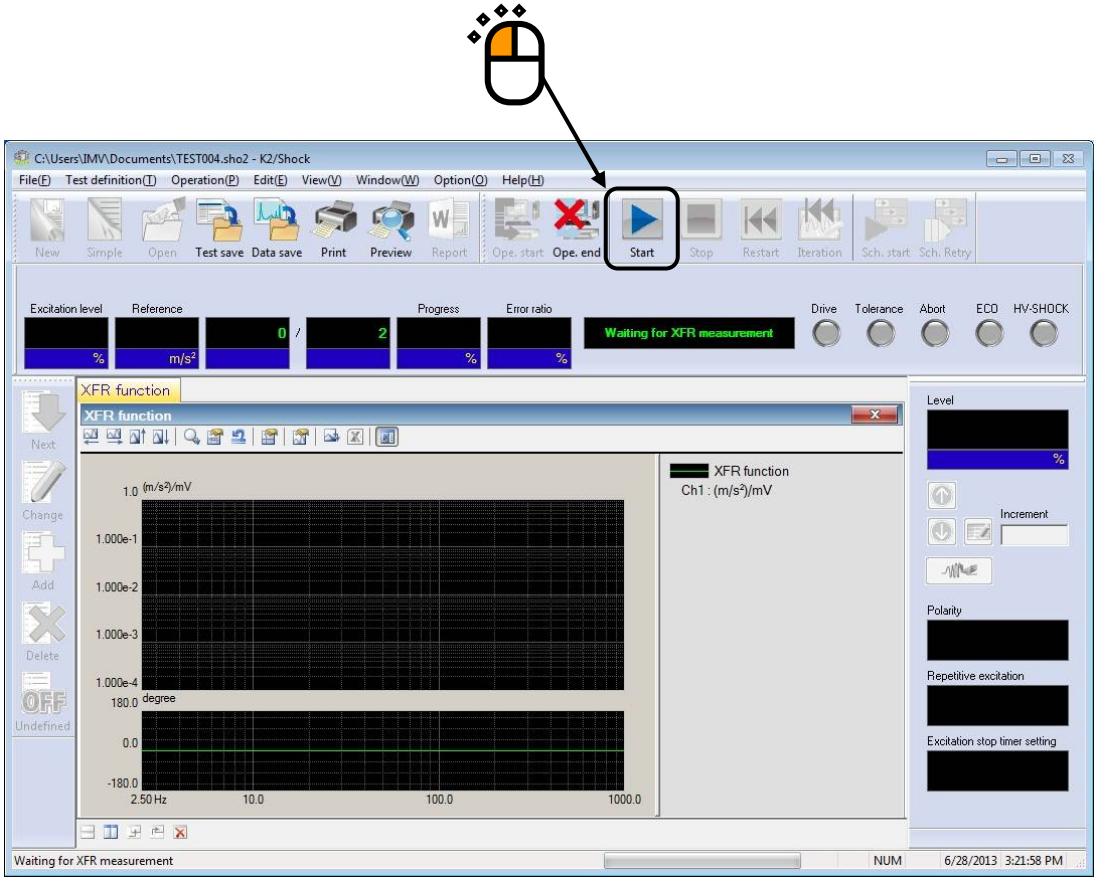
Press the [Operation start] button for ‘Operation Start’.



< Step 2 >

Transfer Function of the controlled system is measured.

Press the [XFR measurement start] button to execute.

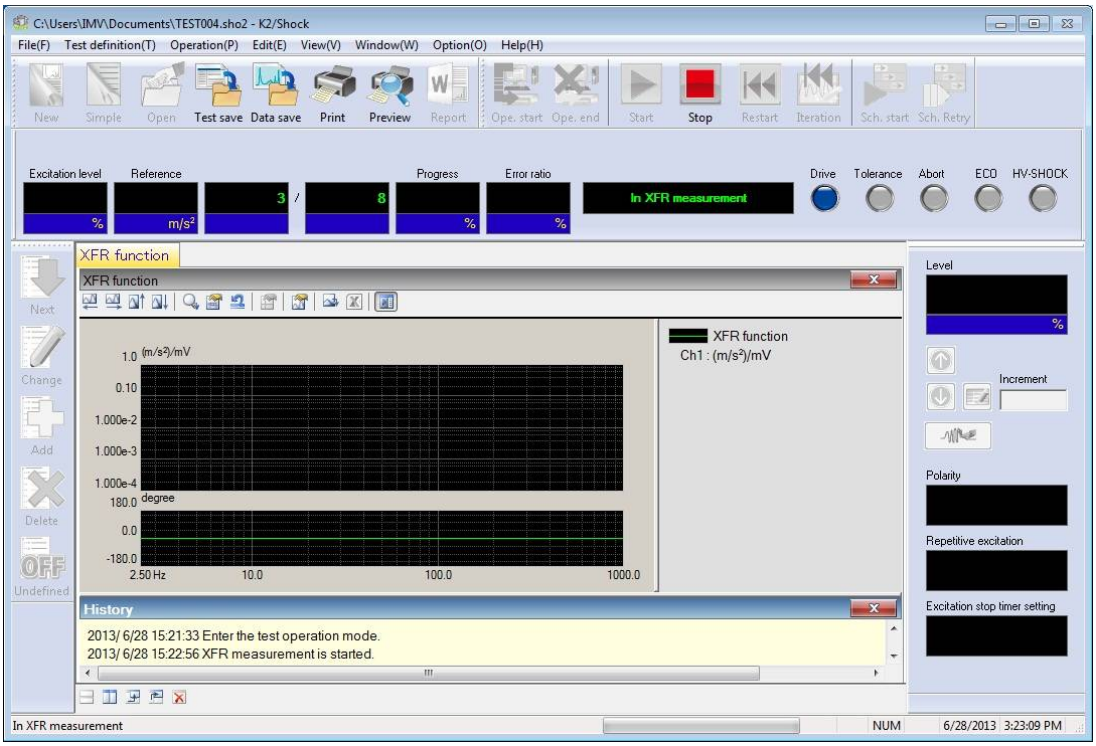


< Step 3 >

Loop Check and the XFR Measurement are operated.

The system is automatically set to the state of waiting for the Drive Generation when the XFR Measurement is completed.

If the XFR Measurement is needed to be stopped in the middle of the operation, press the [Stop] button.

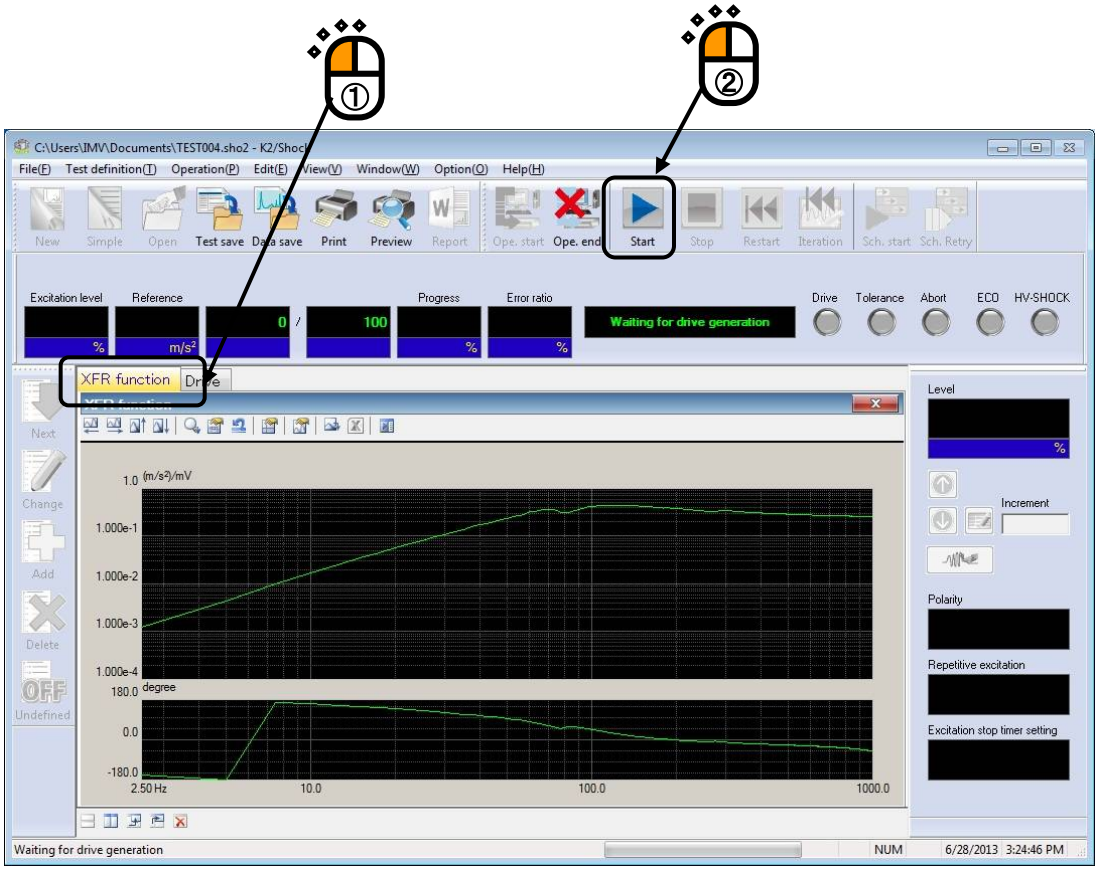


< Step 4 >

When the XFR Measurement is completed, the graph of the XFR Measurement appears.

Drive voltage is to be generated after checking the obtained XFR function normal.

Press the [Drive generation] button.



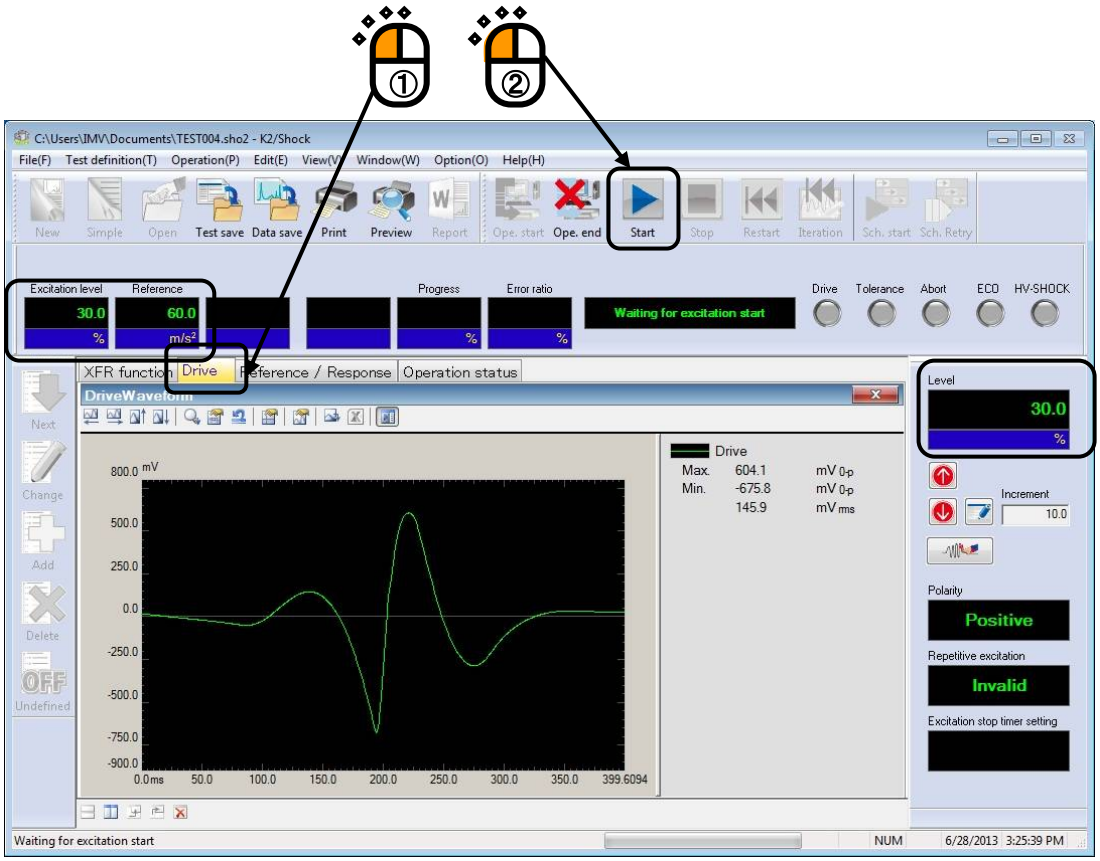
< Step 5 >

The system is set to the state for Excitation Start when the drive generation is completed.

In Operation Status Panel, Excitation Level and Peak level of Reference Waveform are displayed.

Excitation is operated at 30 % in this example at first. The setting of this value is not necessary to be corrected because the Initial level has been set to 30 %.

Check the display of the Drive Waveform and the Excitation Level. Then, press [Excitation. start] button to start the excitation operation.



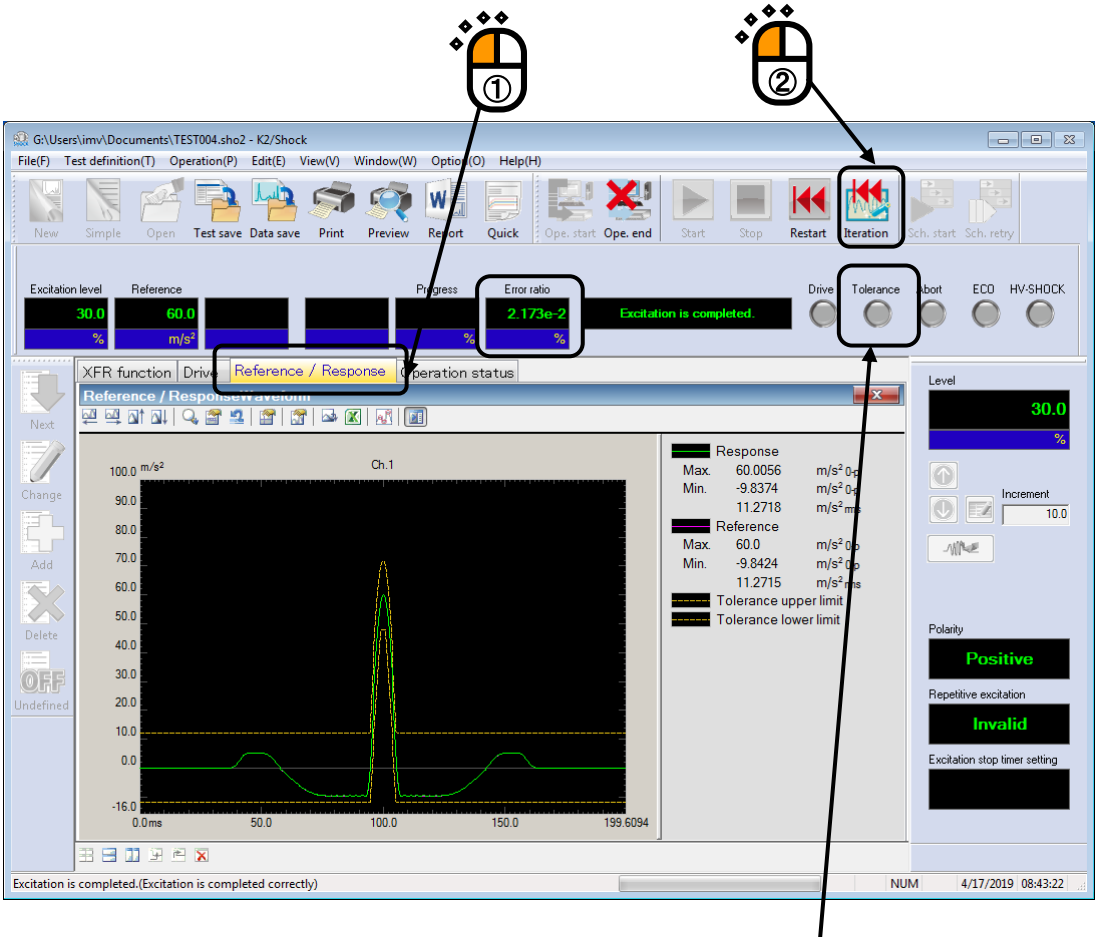
< Step 6 >

The system is set to the state of ‘Excitation completed’ when the excitation operation is ended.

In Operation Status Panel, the results of Control Error and Tolerance Check are displayed.

If the Response Waveform passes the check without any abnormal phenomenon, the correction of drive voltage is executed according to the excitation result.

Press the [Iteration] button.

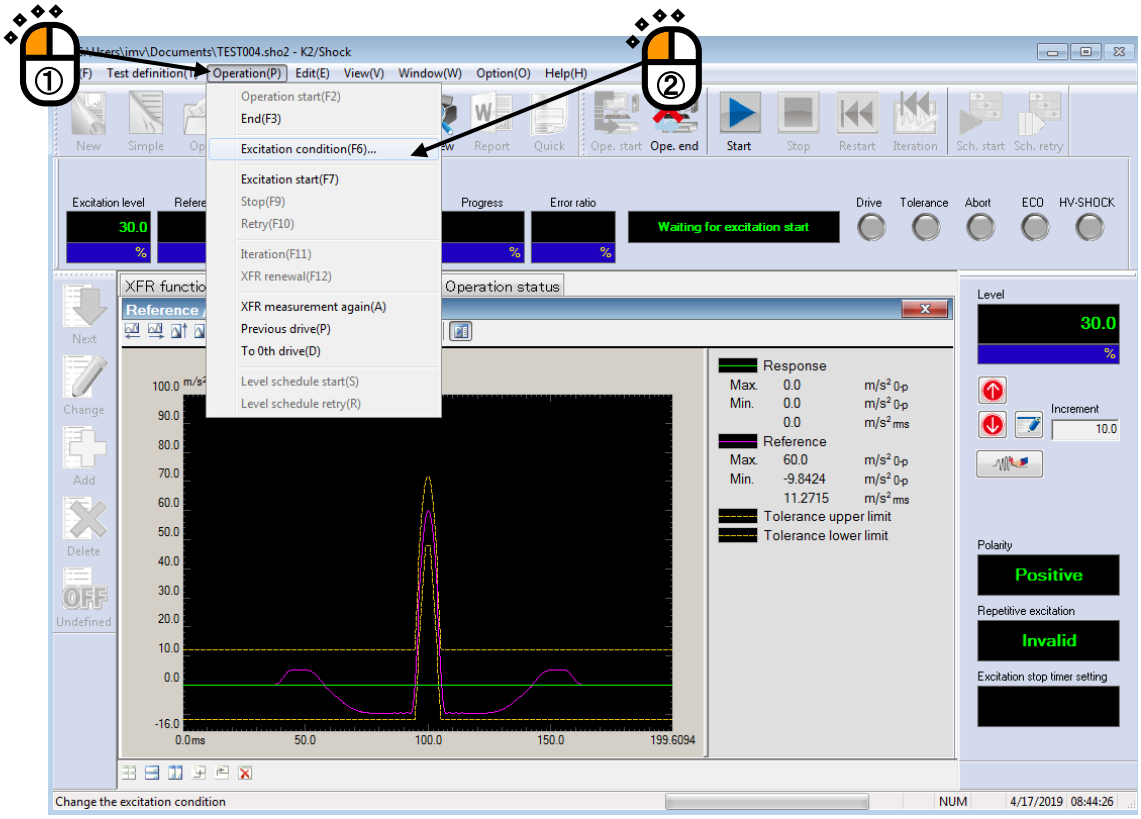


When the Tolerance Check results in NG, the yellow mark is lit as in this display.

< Step 7 >

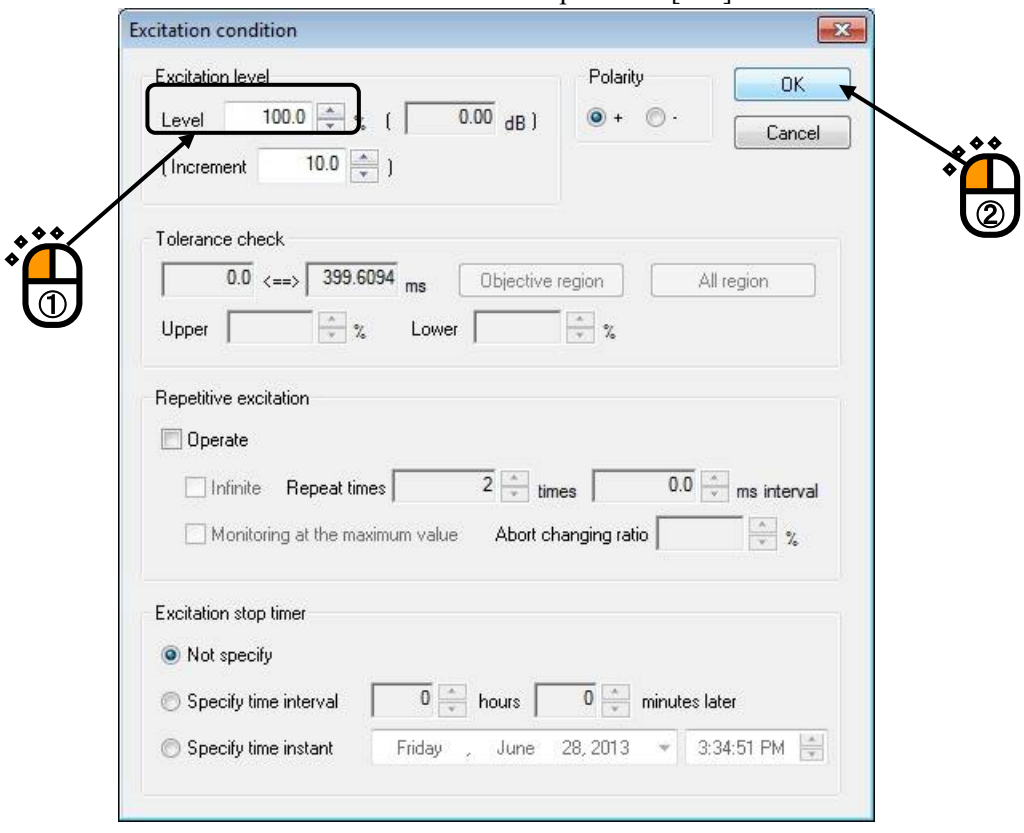
Check the Drive Waveform and correct the Excitation Level to 100 %.

Select [Operation] → [Excitation condition] in Menu bar.



< Step 8 >

Set the value of Excitation Level to 100 % and press the [OK] button.

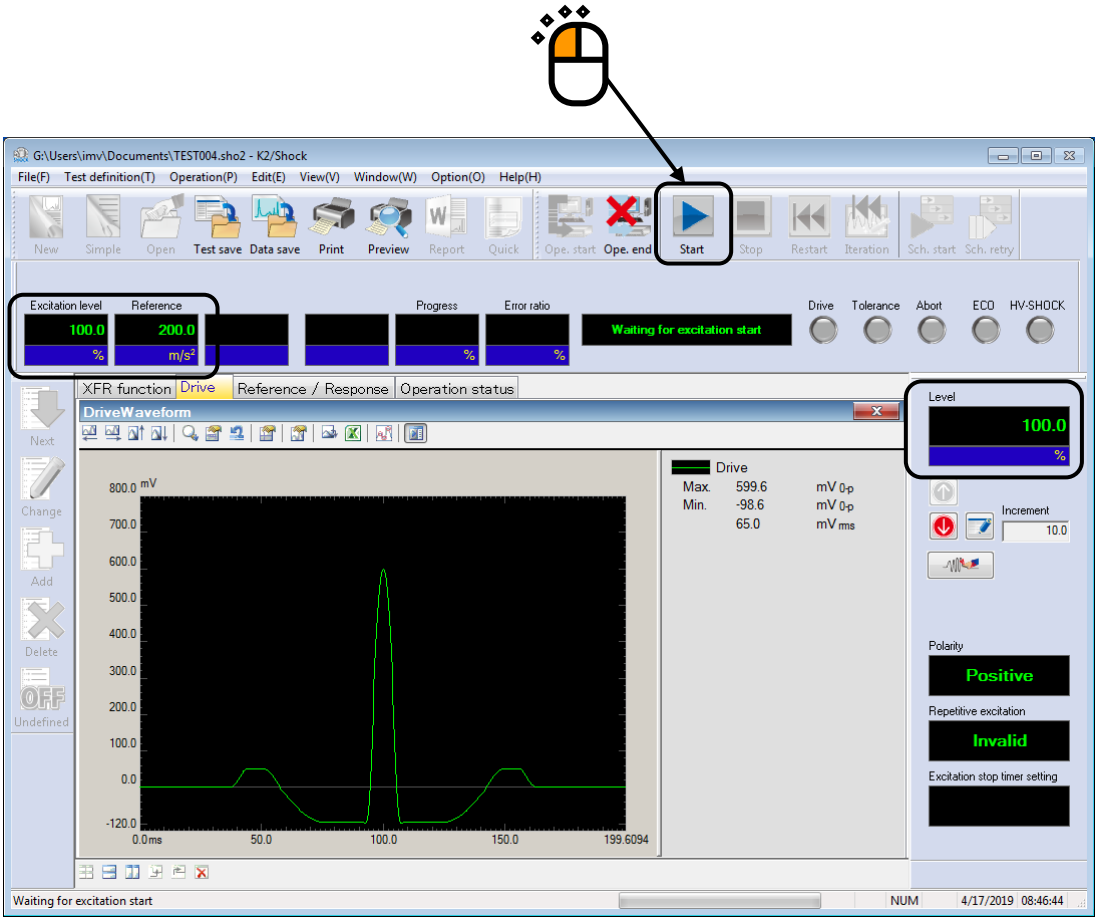


< Step 9 >

When the Excitation Level is corrected, the value of Excitation Level and the Peak level of reference waveform are renewed in the Operation Status Panel.

The Drive Waveform is proportionally adjusted according to the level.

When the checks of the Drive Waveform and the Excitation Level are done, press [Excitation. start] to start the excitation operation.

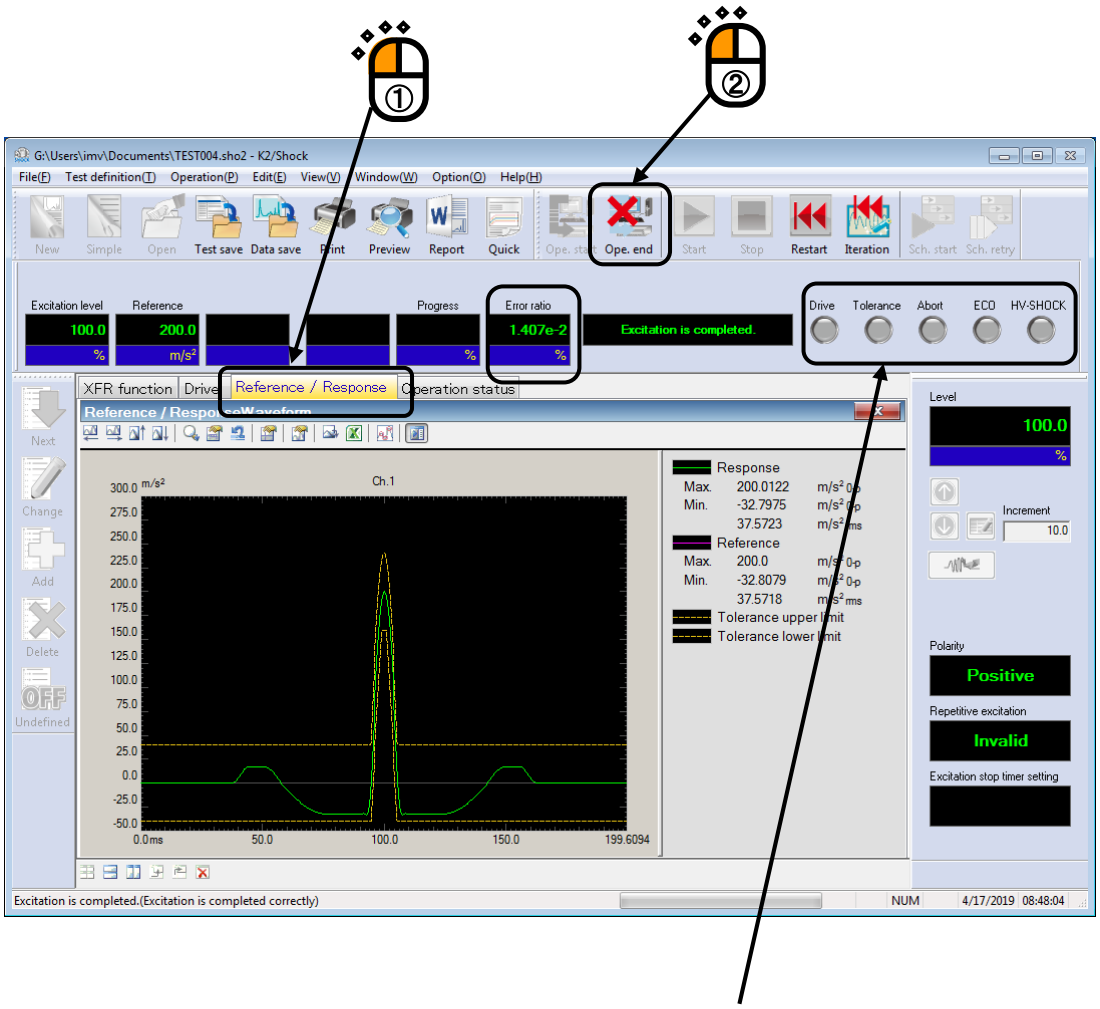


< Step 10 >

When the excitation is done, test operation is completed.

In Operation Status Panel, the results of Control Error and Tolerance Check are displayed.

Press the [End] button to return the test definition mode.



When the Tolerance Check results in OK, Nothing lights up.

3.2 Simplified Definition

This definition mode is for defining a Classical-shock test in a simple way.

< Example >

An example of Shock test of described as below ;

[Reference waveform]

- Waveform type Half-sine
- Peak amplitude value 200m/s^2
- Pulse width 11ms
- Tolerance IEC(JIS C) 60068-2-27
- (Auto-set of sampling frequency and data length)

[Control condition]

- Control frequency lines 400 lines
- Initial excitation level : 30 %
- XFR measurement Auto-set

[Information of sensor to be used]

One accelerometer of piezo-electric

Input terminal of K2+ Hardware to be used : Ch.1 of Module ID 0

Channel name : Ch.1 (Sensitivity :3 pC/(m/s^2)

Also, the rating information of excitation system has already been registered in Excitation System Information (in this example, 'System1').

[Information of specimen]

Specimen mass : 10[kg]

[Excitation procedure]

(1) Excitation is operated at the Excitation level = 30 %.

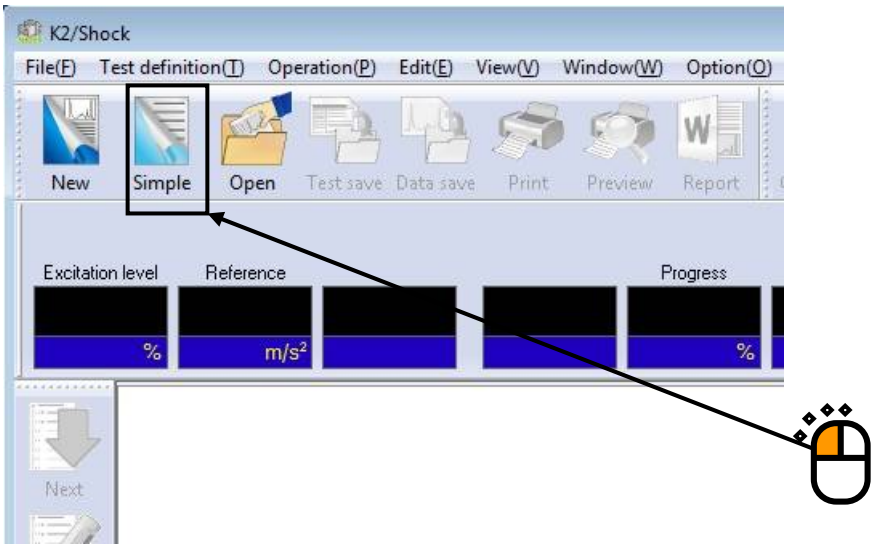
(2) Iteration is executed.

(3) Excitation is operated at the Excitation level = 100%.

< Operation procedures >

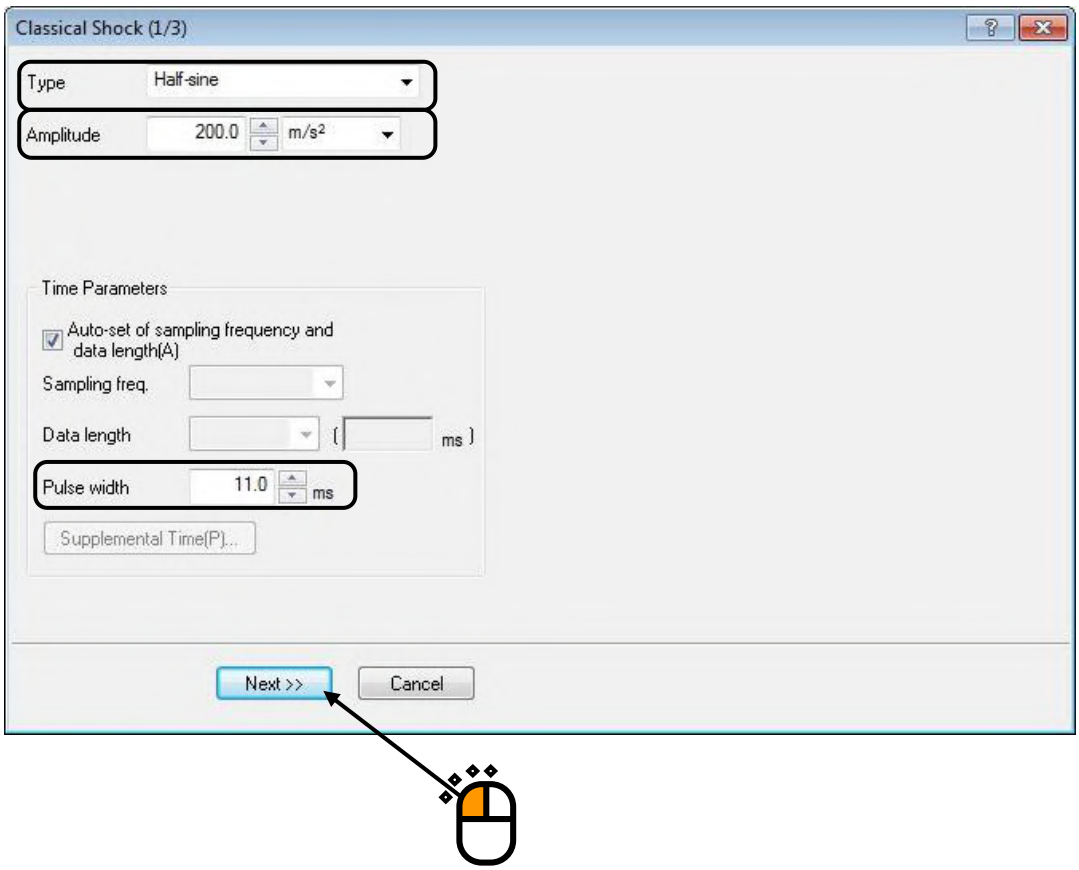
< Step 1 >

Press the button of [Simplified] to start the ‘Simplified Definition’.



< Step 2 >

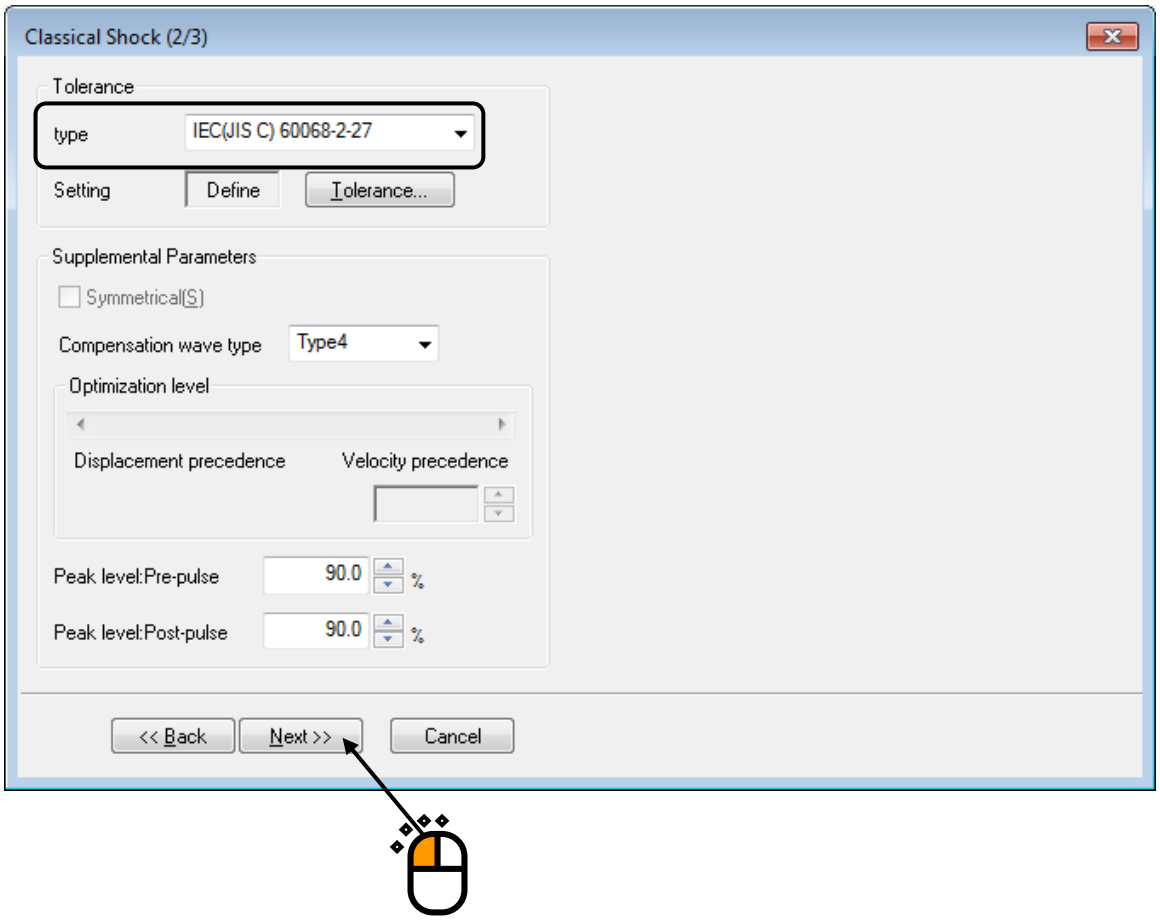
In the first definition dialog, input the values to ‘Waveform type’, ‘Peak amplitude’ and ‘Pulse width’. Press the [Next] after filling all of the items.



< Step 3 >

In the next reference waveform definition dialog, Tolerance is defined.

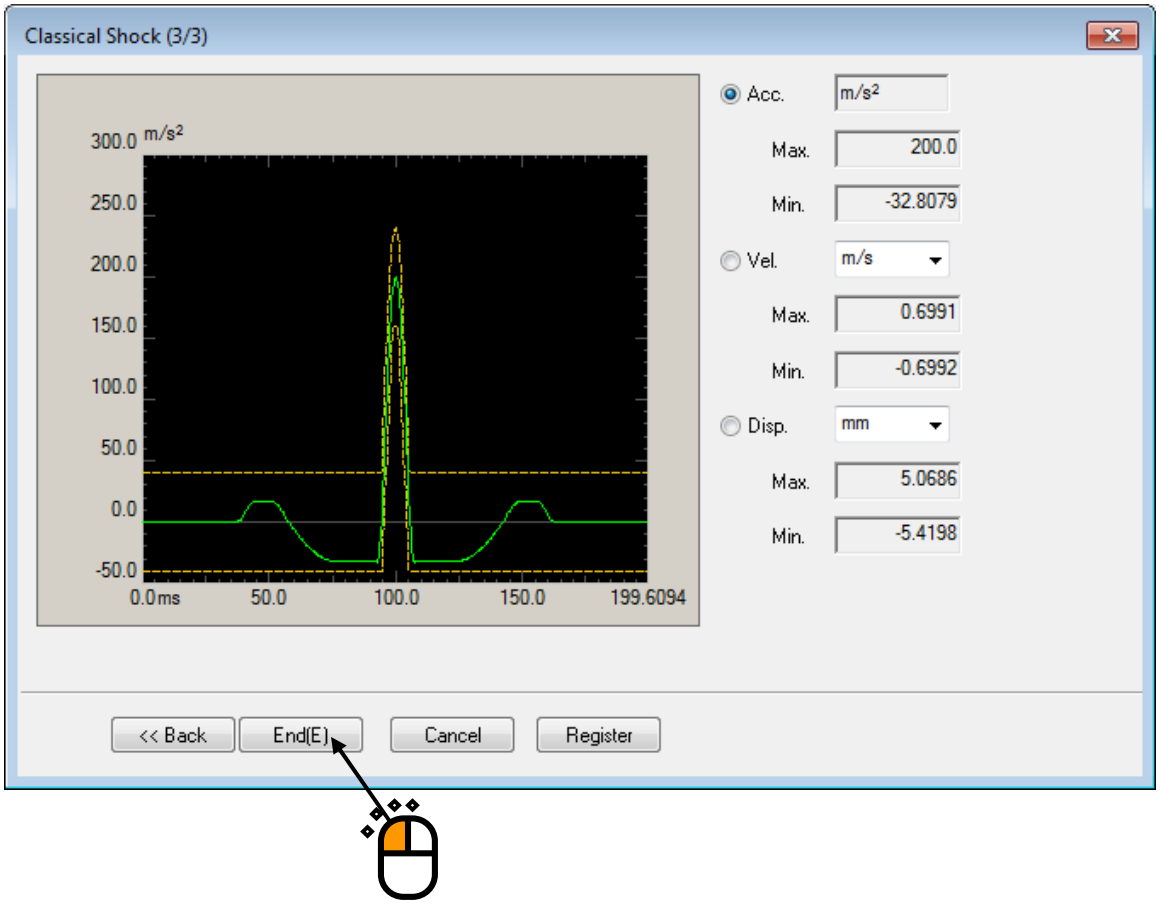
Press the [Next] button after inputting all the setting items of Tolerance.



< Step 4 >

The definition of Reference waveform is completed.

The generated reference waveform is displayed as below. Press the [End] button.



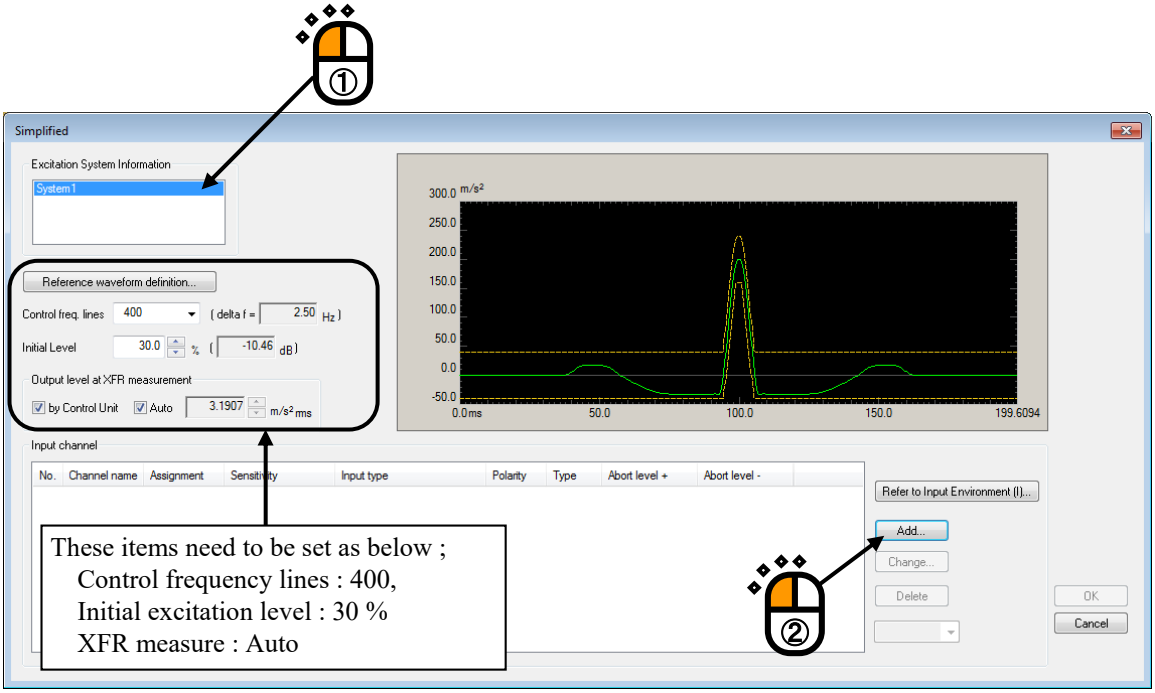
(In case of not convergent)

When the generated Reference waveform doesn't converge, that is, the reference waveform data exceeds over the Tolerance, return to the display of < Step 2 > (page 1/3) and check off "Auto-set of sampling frequency and data length" and specify arbitrary values of Sampling frequency and Data length.

Convergence of the generated Reference waveform relies on the condition of Reference waveform.

< Step 5 >

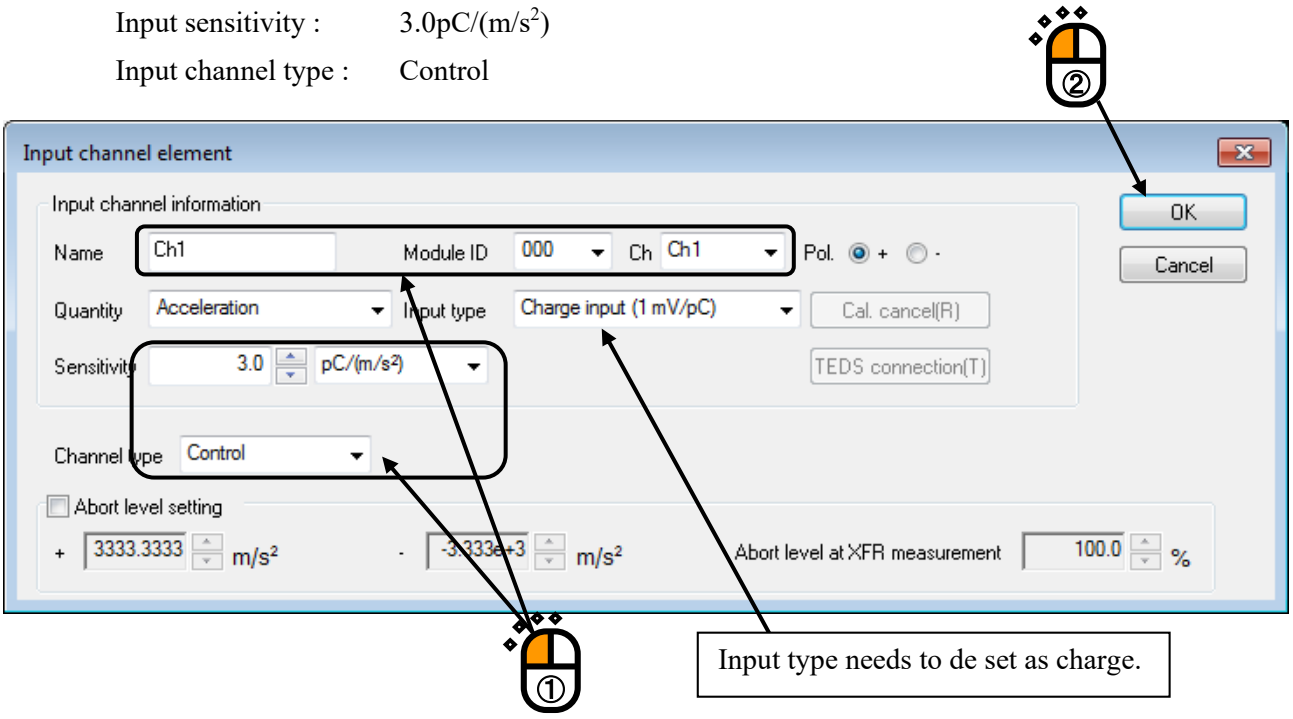
Select ‘System1’ among the items of Excitation System Information. And press the button of [Add].



< Step 6 >

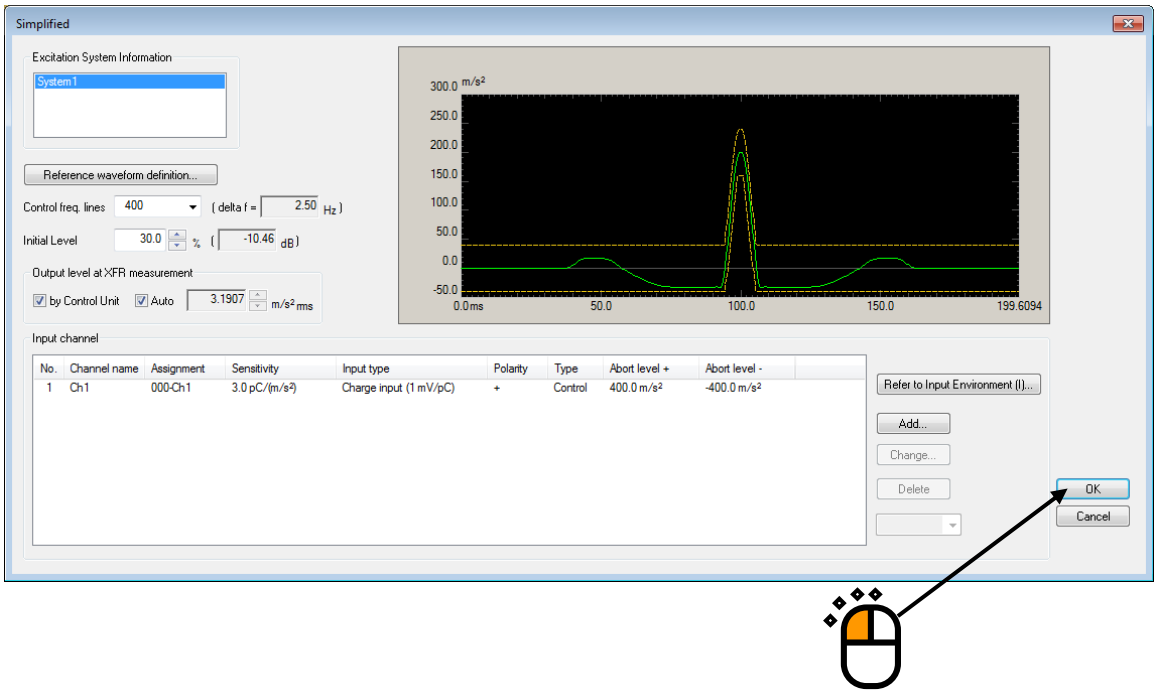
Set the Input channel element as below, and press the [OK] button ;

Channel name :	Ch.1
Module ID :	000
Ch :	Ch.1
Input sensitivity :	3.0pC/(m/s^2)
Input channel type :	Control



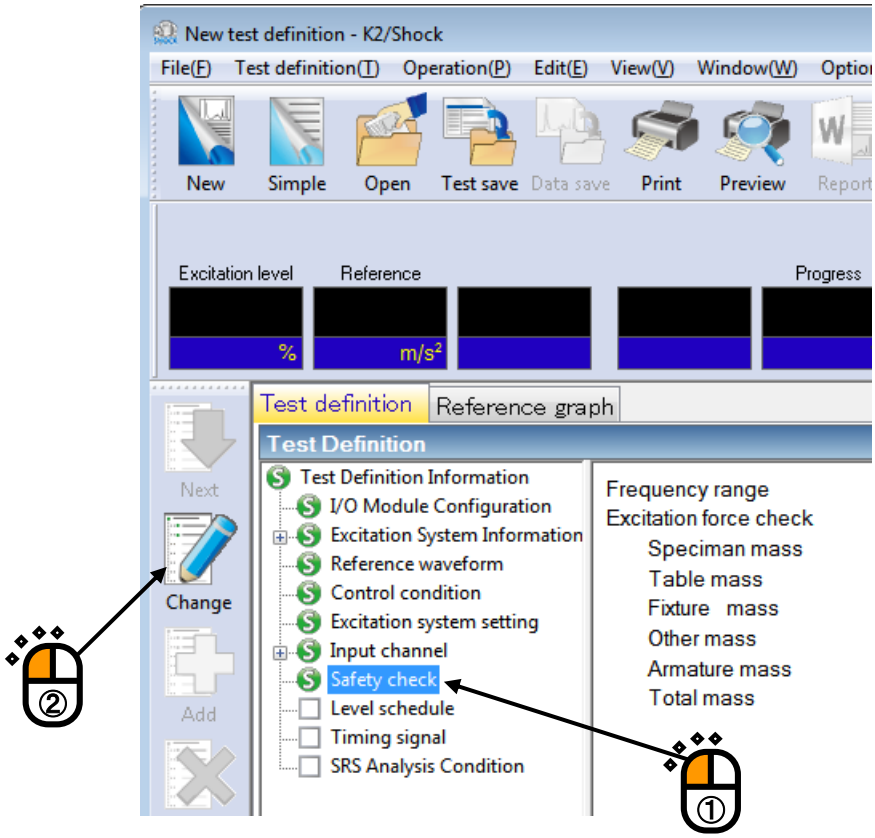
< Step 7 >

Press the [OK] button.



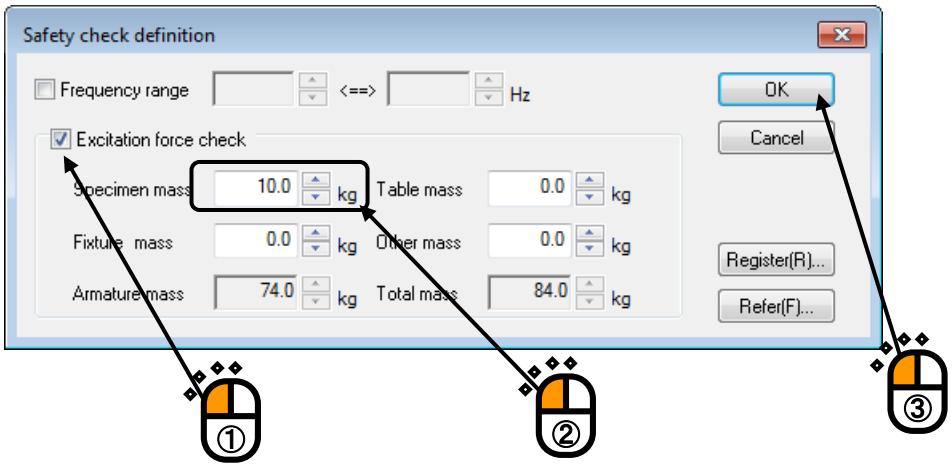
＜Step8＞

Select ‘Safety check’ and press the button of [Change].



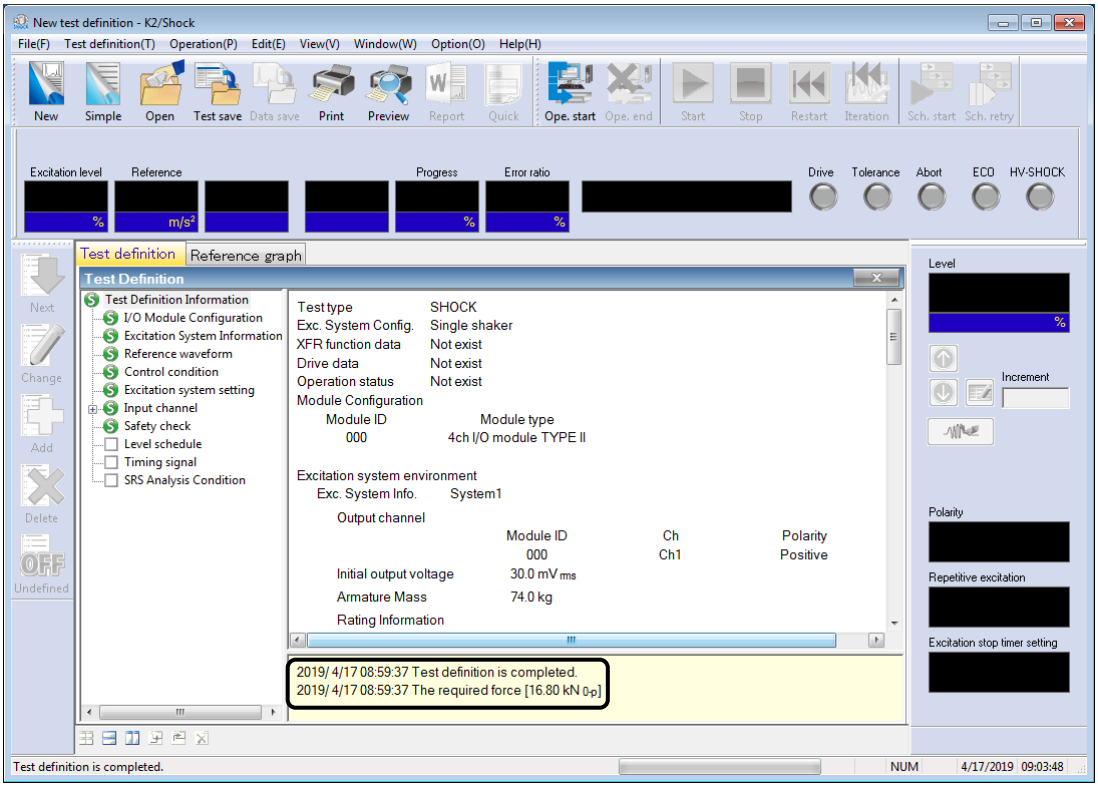
< Step9 >

Select ‘Excitation force check’ and input the value as ‘Specimen mass : 10 [kg]. And press the button of [OK].



＜Step10＞

Now, the definition is completed.

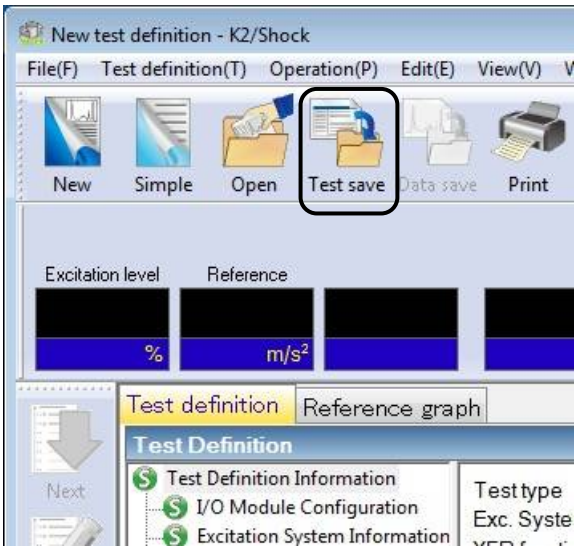


<Save of a test >

< Step 1 >

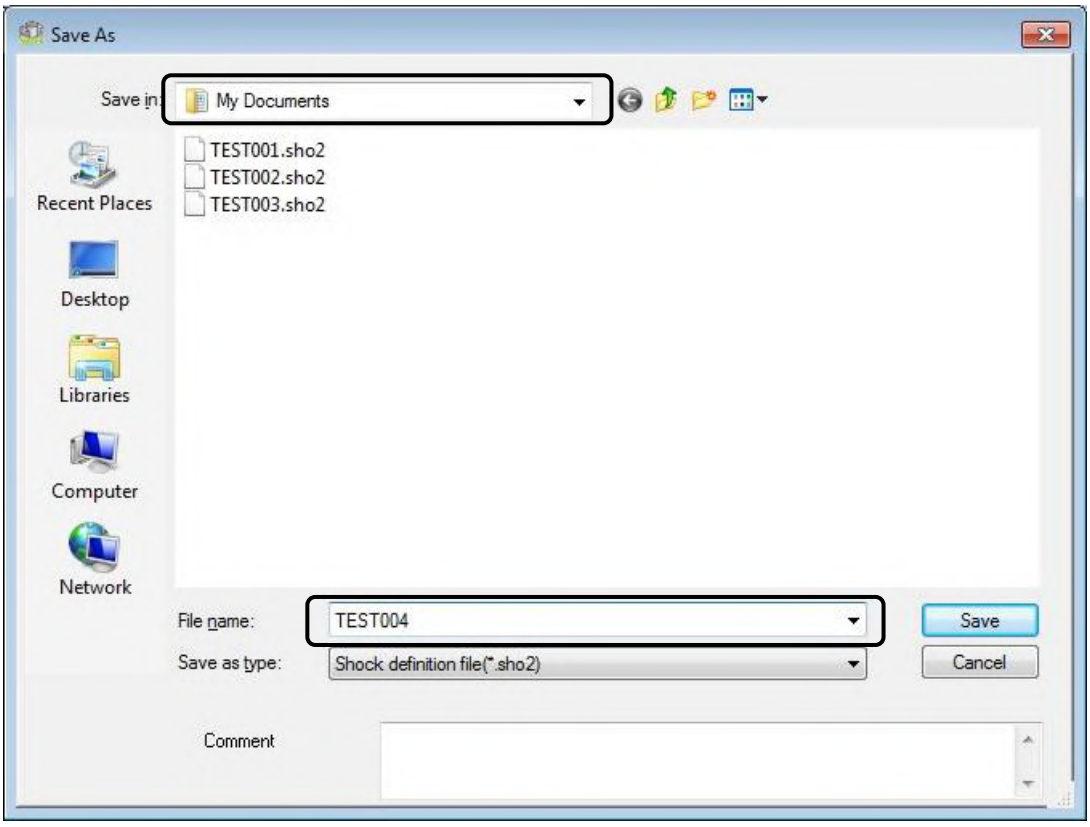
Save the defined test to a file.

Press the button of [Save].



< Step 2 >

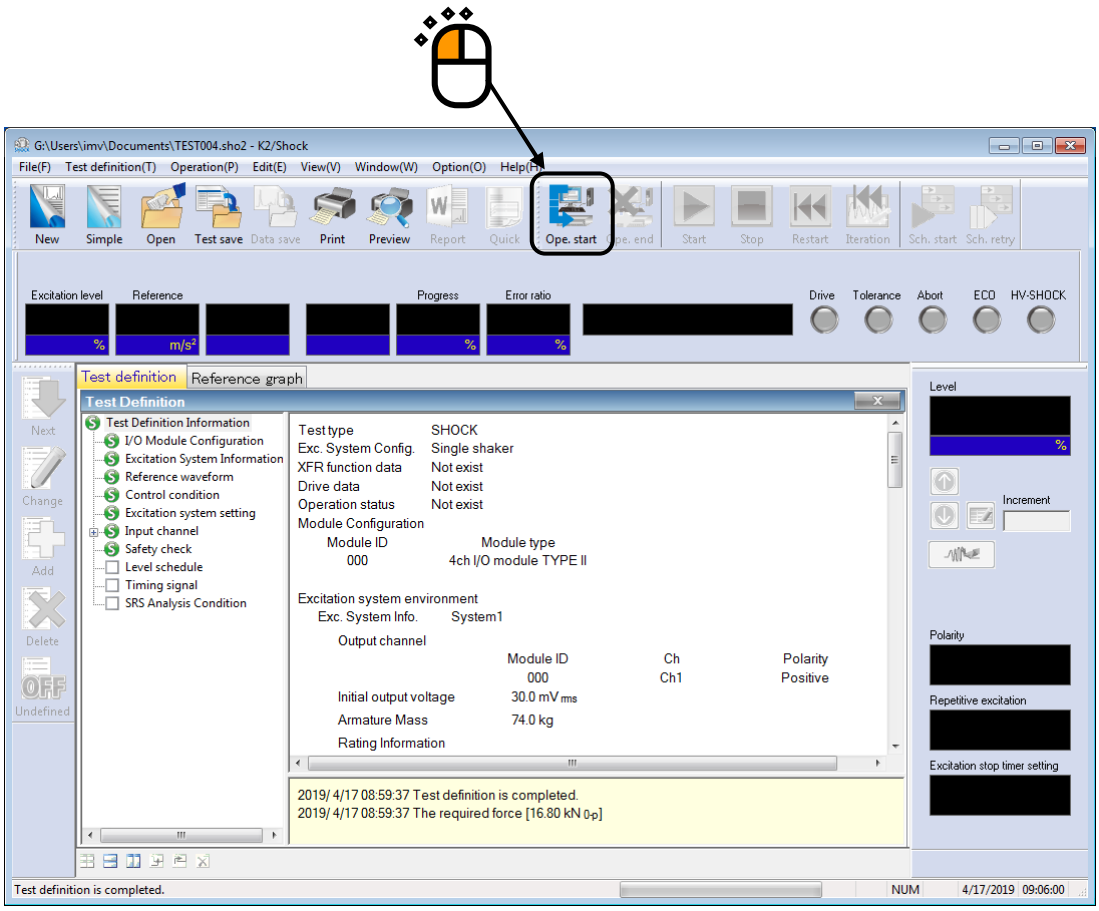
The dialog as below appears. Specify an arbitrary direction in a ‘Folder’ and input a name to ‘File name’.



< Operation of test >

< Step 1 >

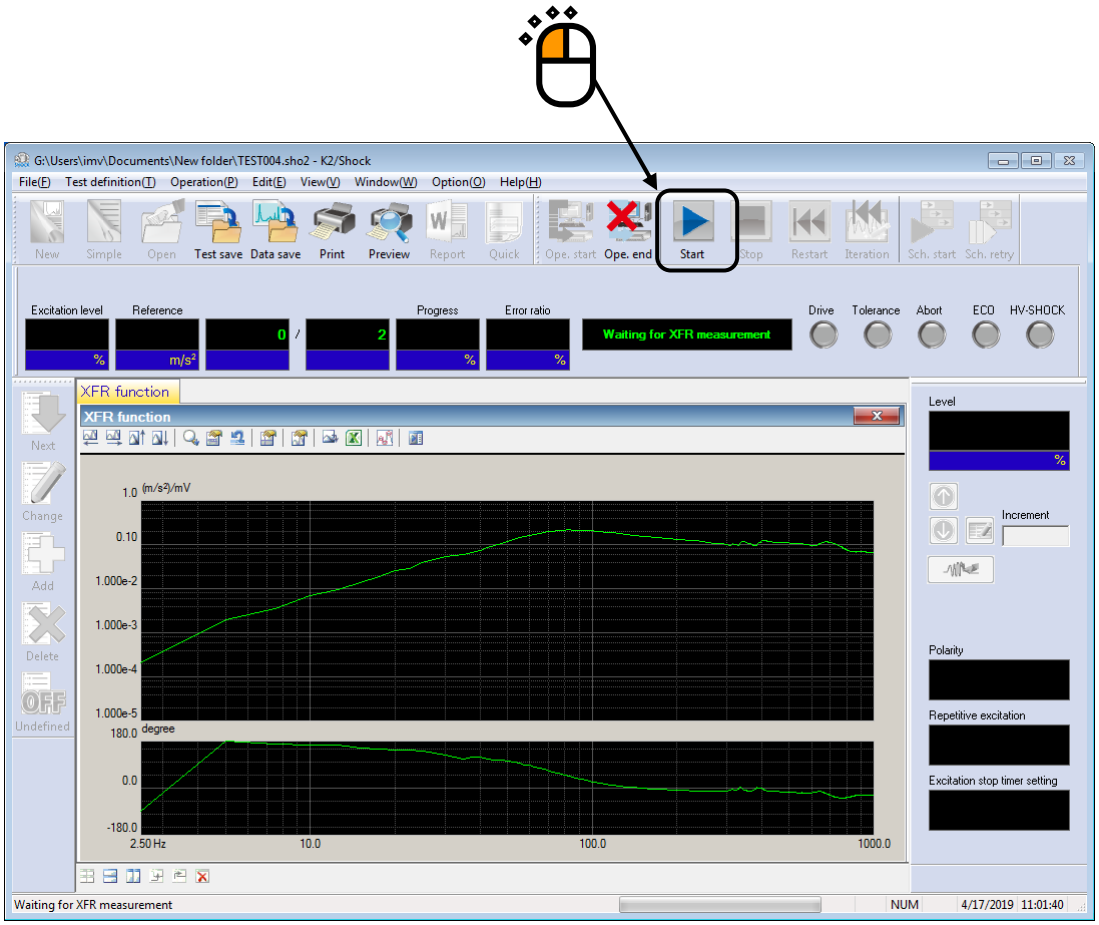
Press the button of [Operation]



< Step 2 >

Transfer function of the controlled system is measured.

Press the [XFR measurement start] button to execute.

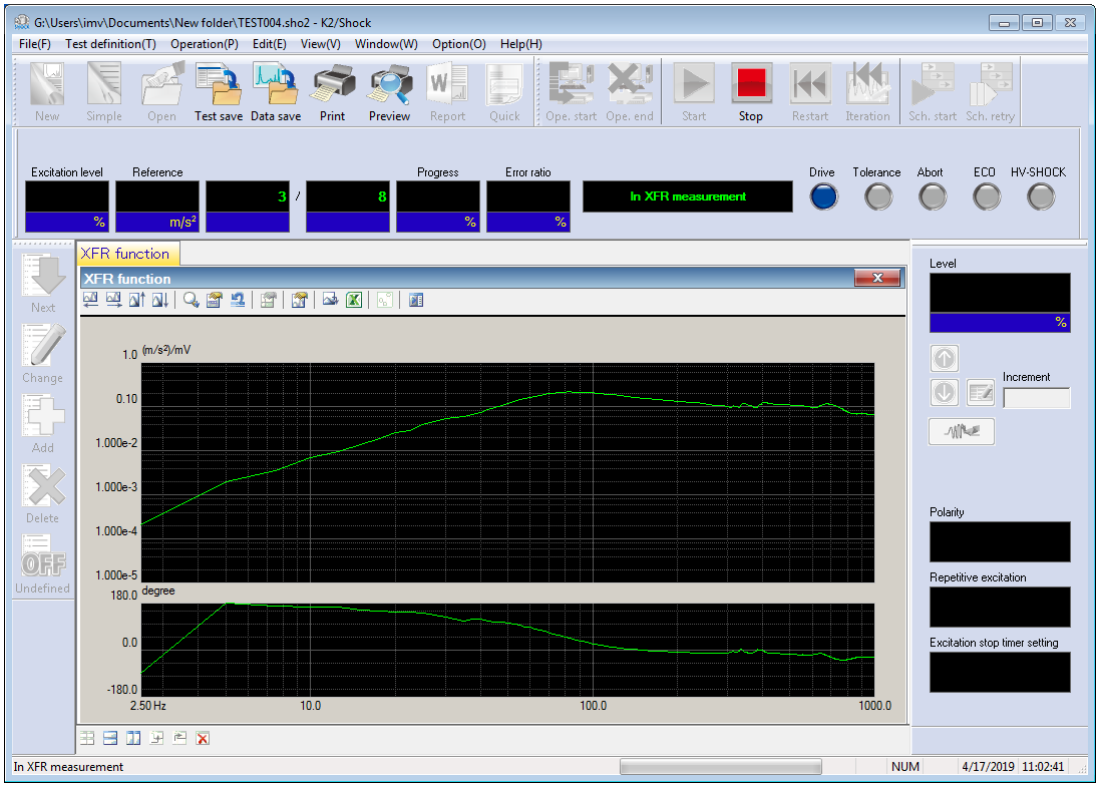


< Step 3 >

Loop check and XFR measurement are operated.

The system is automatically set to the state of waiting for drive generation when the XFR measurement is completed.

Press the [Stop] button when the XFR measurement needs to be aborted.

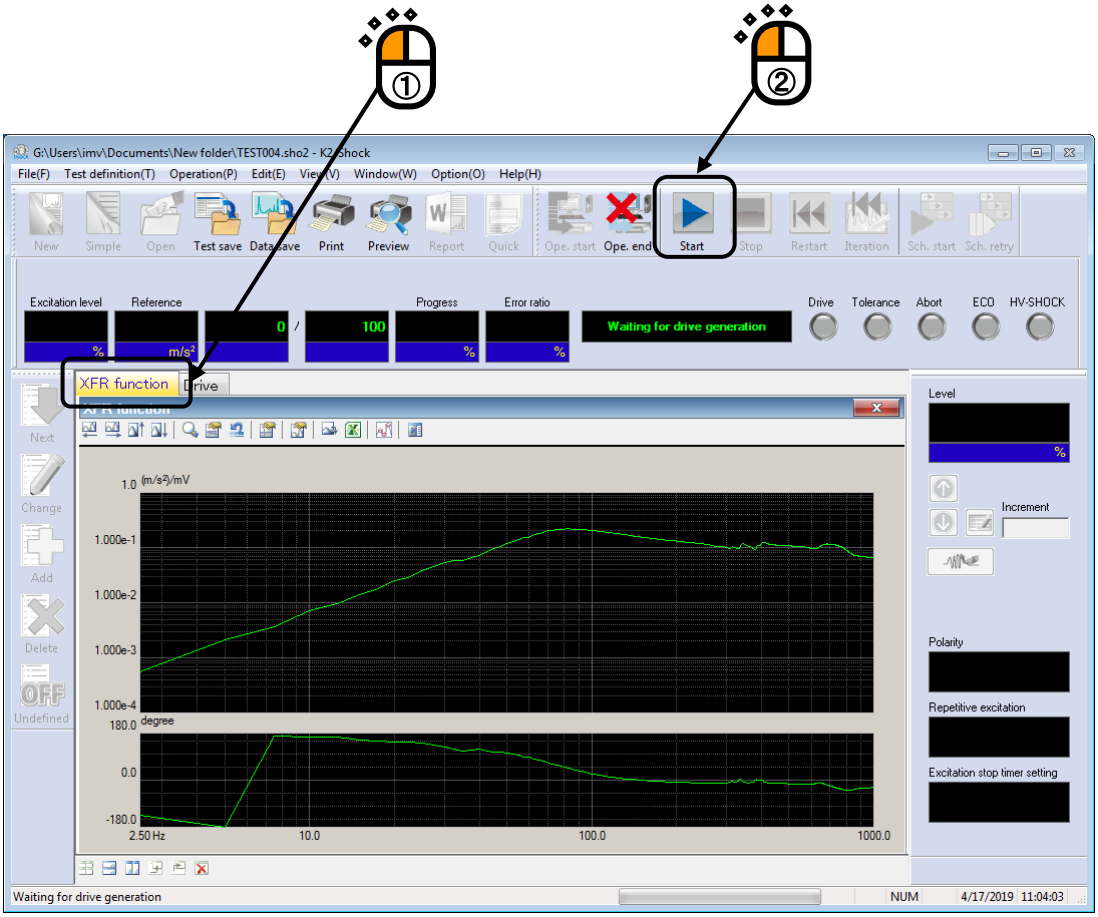


< Step 4 >

When the XFR measurement is finished, the graph of XFR function appears in the display.

The drive voltage is to be generated after checking the obtained transfer function normal.

Press the button of [Drive generation].



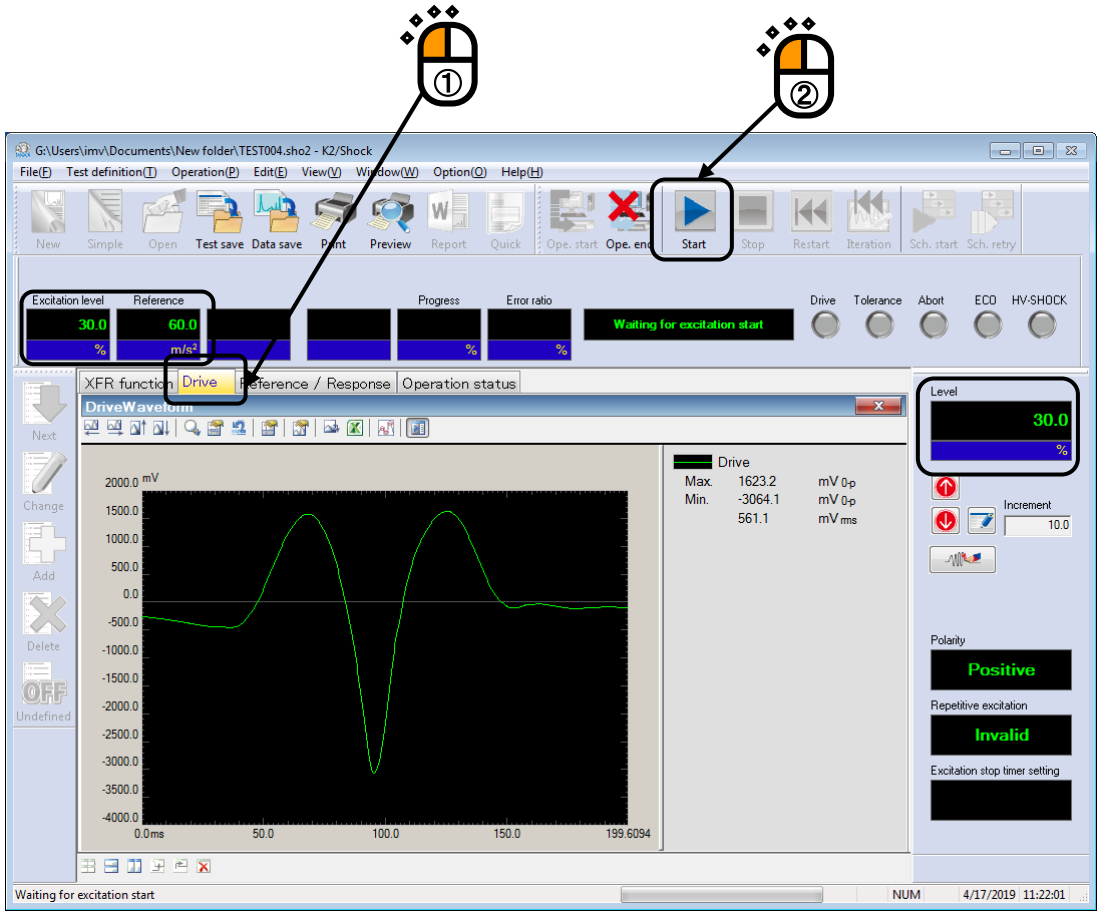
< Step 5 >

The system is set to the state for Excitation start when the drive generation is completed.

In Operation status panel, Excitation level and Peak level of reference waveform are displayed.

Excitation is operated at 30 % in this example at first. The setting of this value is not necessary to correct because the Initial level has been set to 30 %.

Check the display of the drive waveform and the Excitation level. Then, press the [Exc. start] button to start the excitation operation.



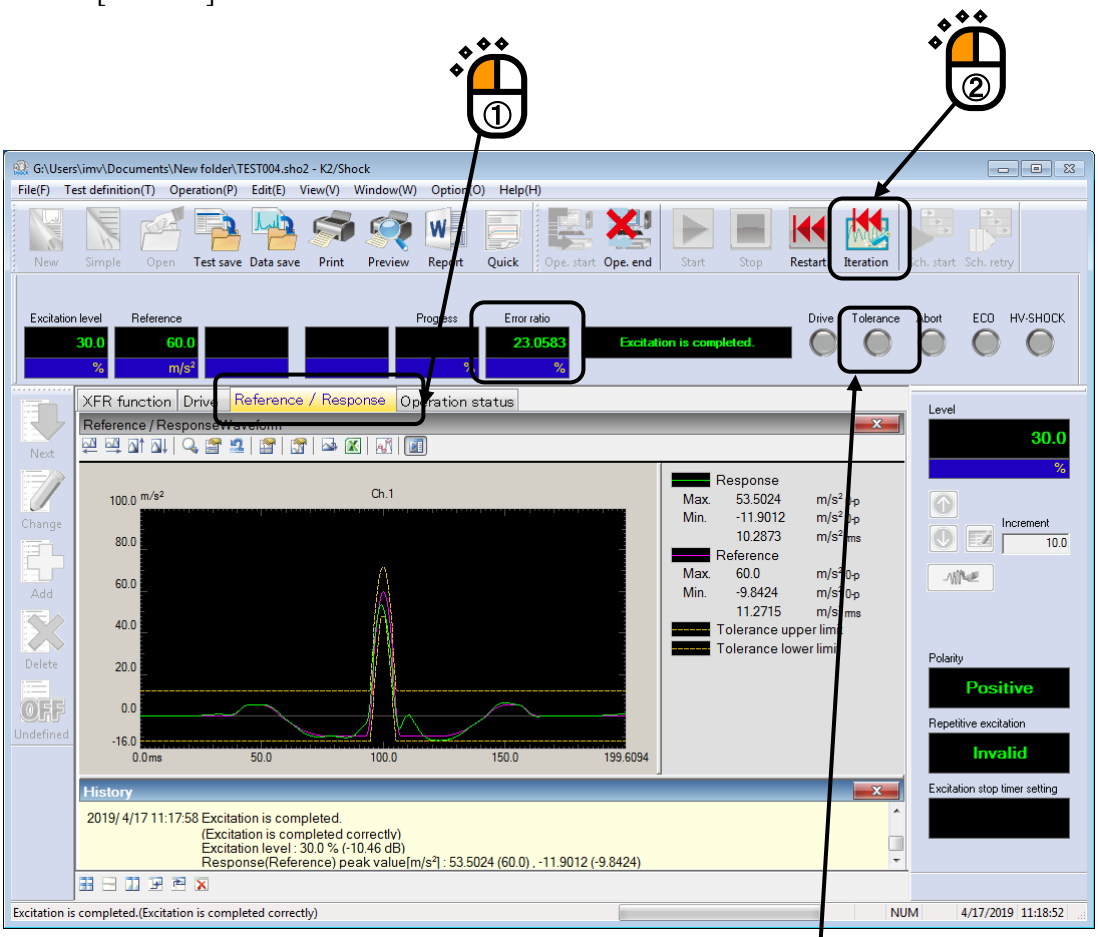
< Step 6 >

The system is set to the state of ‘Excitation completed’ when the excitation operation is ended.

In Operation status panel, the results of Control error and Tolerance check are displayed.

If the response waveform passes the check without any abnormal phenomenon, the correction of drive voltage is executed according to the excitation result.

Press the [Iteration] button.

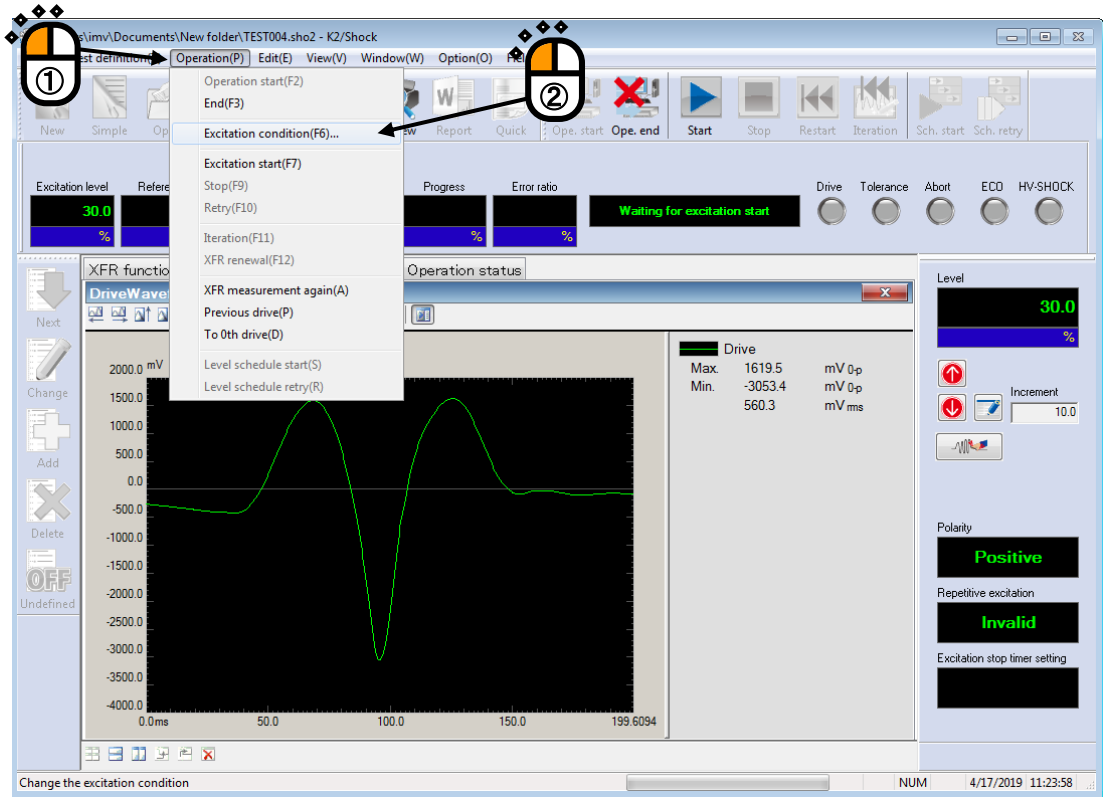


When the Tolerance Check results in NG, the yellow mark is lit as in this display.

< Step 7 >

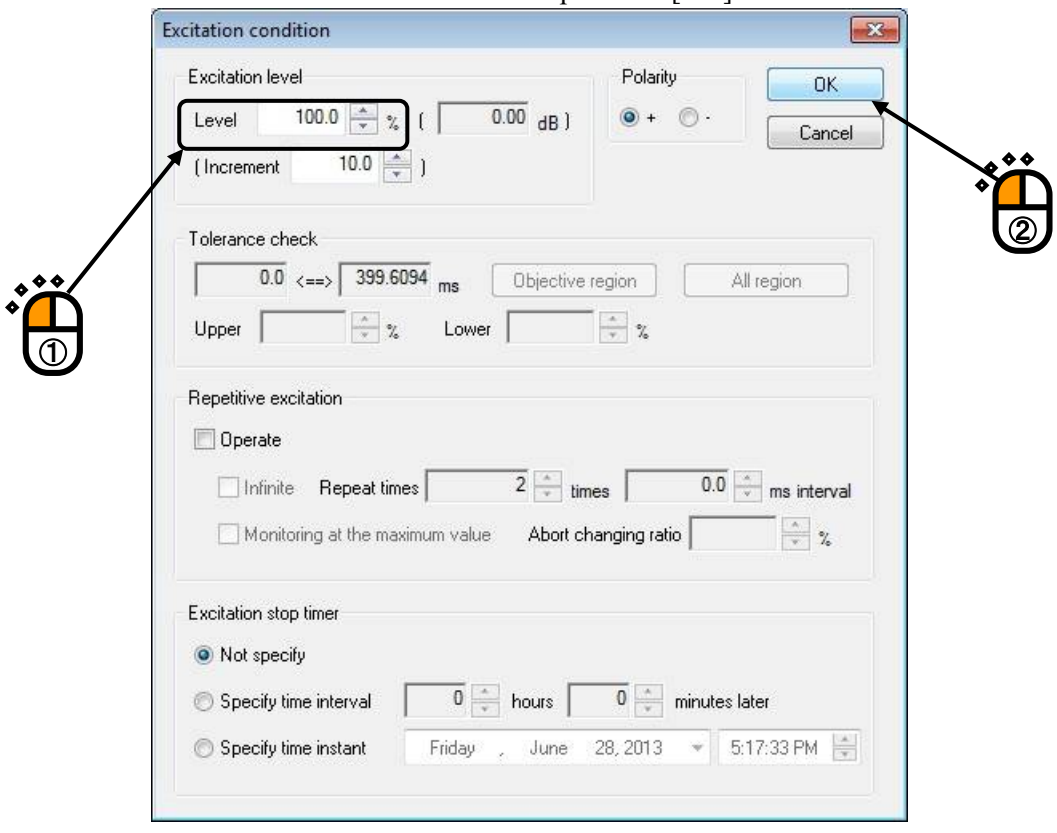
Check the Drive Waveform and correct the Excitation Level to 100 %.

Select [Operation] → [Excitation condition] in Menu bar.



< Step 8 >

Set the value of Excitation Level to 100 % and press the [OK] button.

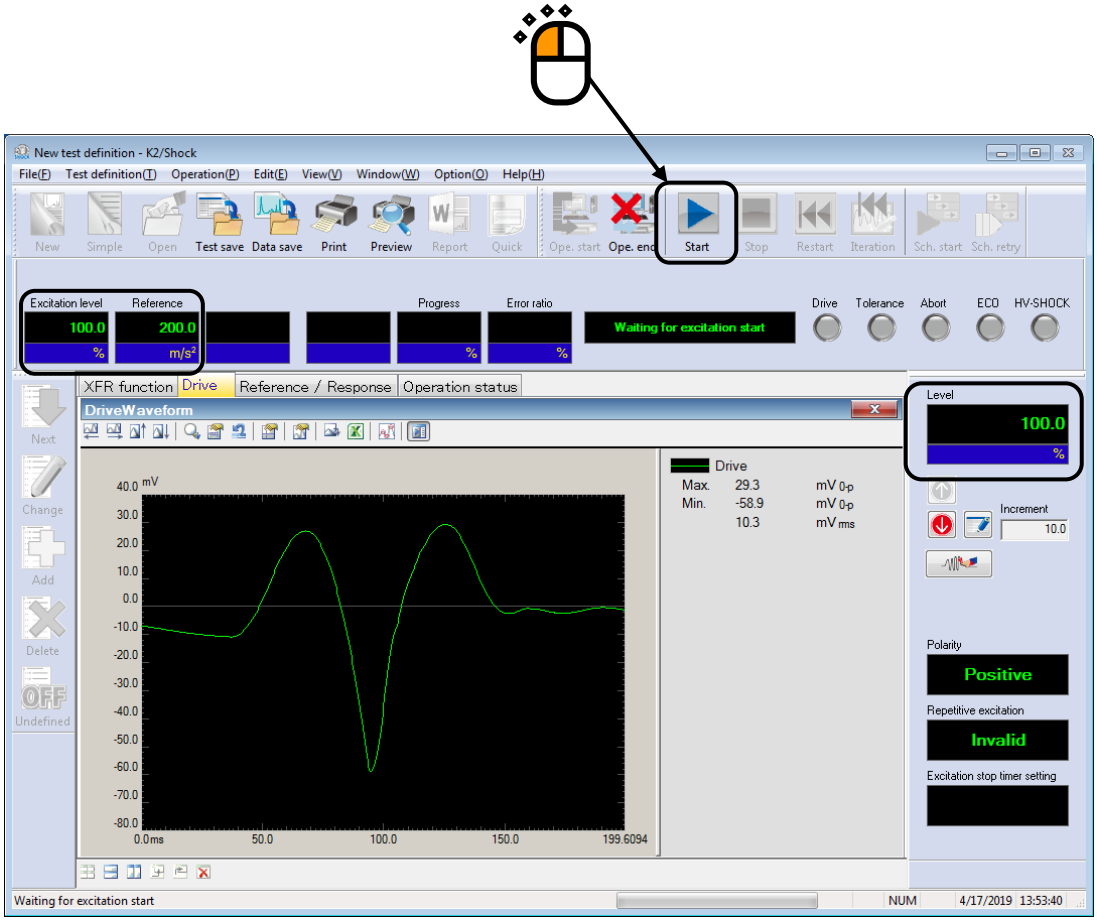


< Step 9 >

When the Excitation Level is corrected, the value of Excitation Level and the Peak level of reference waveform are renewed in the Operation Status Panel.

The Drive Waveform is proportionally adjusted according to the level.

When the checks of the Drive Waveform and the Excitation Level are done, press [Excitation. start] to start the excitation operation.

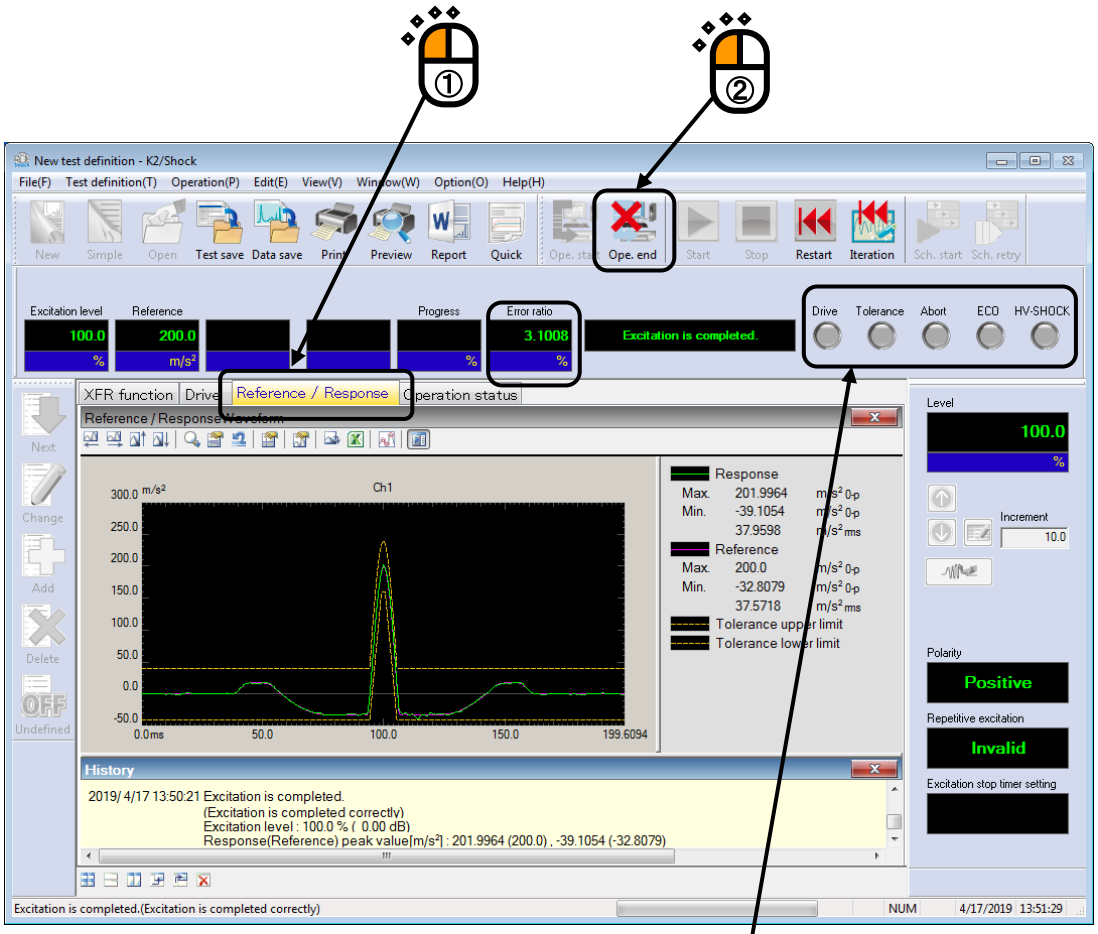


< Step 10 >

When the excitation is done, test operation is completed.

In Operation Status Panel, the results of Control Error and Tolerance Check are displayed.

Press the [End] button to return the test definition mode.



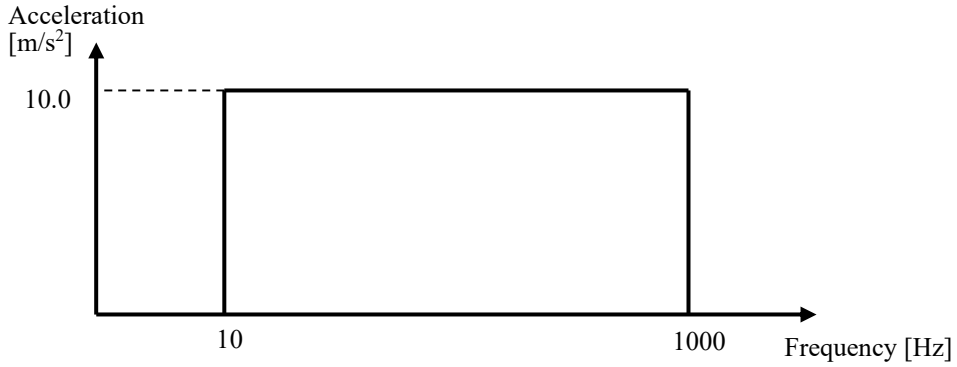
When the Tolerance Check results in OK, Nothing lights up.

3.3 SRS SHOCK Test

< Example >

An example of SRS SHOCK test is described as below ;

［Reference SRS］



[SRS Analysis Condition]

・Sampling Frequency : 8192 Hz

・Data Length : 4096 points

Sampling Frequency is set to a value on the higher side so that the SRS Analysis is operated correctly.

[Waveform Synthesis Condition]

・Synthesized Waveform Type : WAVSYN (Wavelet)

[Control Condition]

・Control Frequency Line : 800

[Information of sensors to be used]

Two accelerometers of piezo-electric : One is used for control and another for monitor

Ch.1 : for control, sensitivity 3pC/(m/s^2)

Ch.2 : for monitor, sensitivity 3pC/(m/s^2)

However, these channels must be registered in Input Channel Information (‘Input01’ in this example).

Also, the rating information of Excitation System has already been registered in Excitation System Information (‘Exc01’ in this example).

[Information of specimen]

Specimen mass : 10[kg]

[Excitation procedures]

(1) Excitation is operated at the Excitation level = 30 %

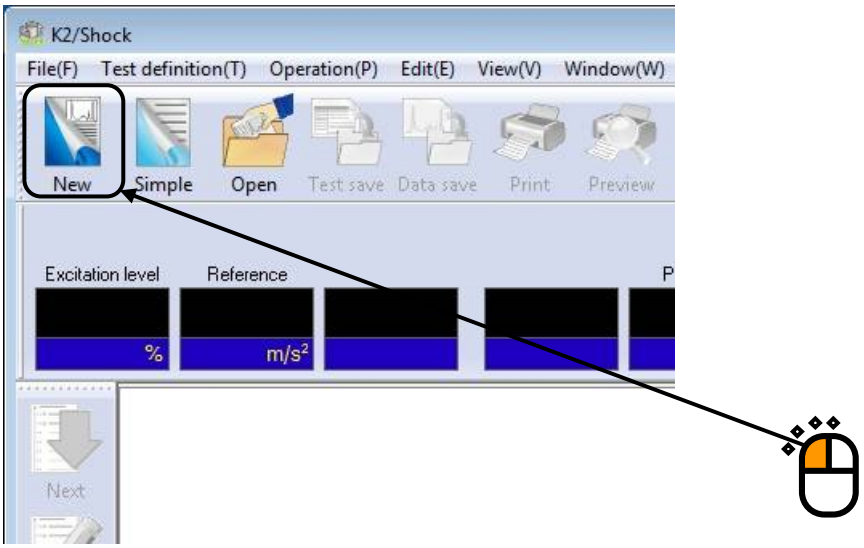
(2) Iteration is executed.

(3) Excitation is operated at the Excitation Level =100 %

< Procedures >

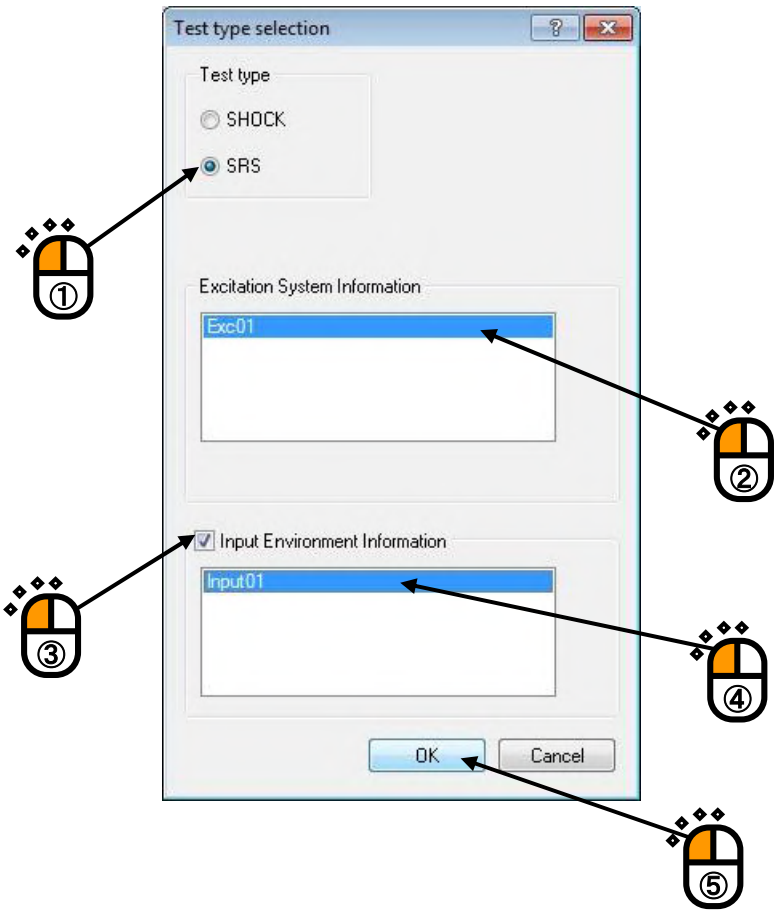
< Step 1 >

Press the [New] button to start ‘New Definition’.



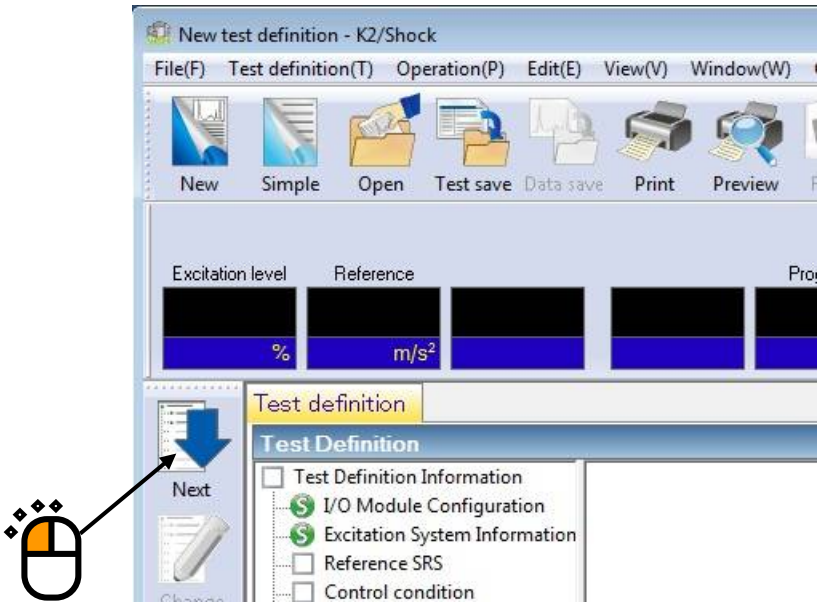
< Step 2 >

Set the Test type to ‘SRS’ and select each one item on Excitation System Information and Input Channel Information.



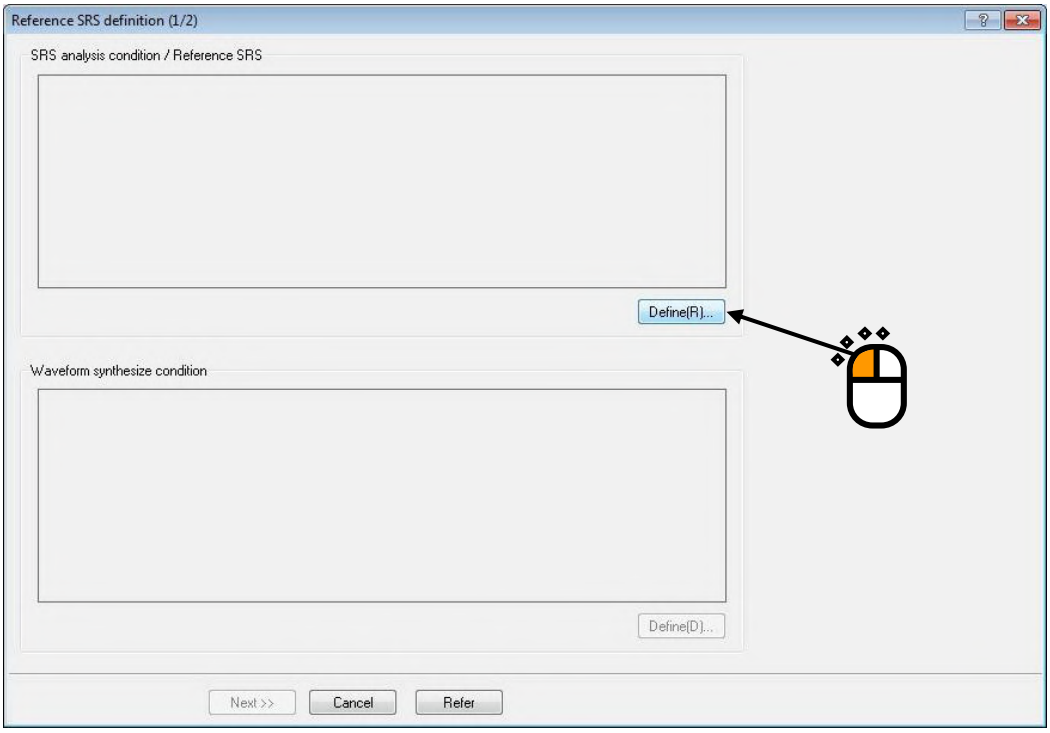
< Step 3 >

Press the button to go to the next definition item.



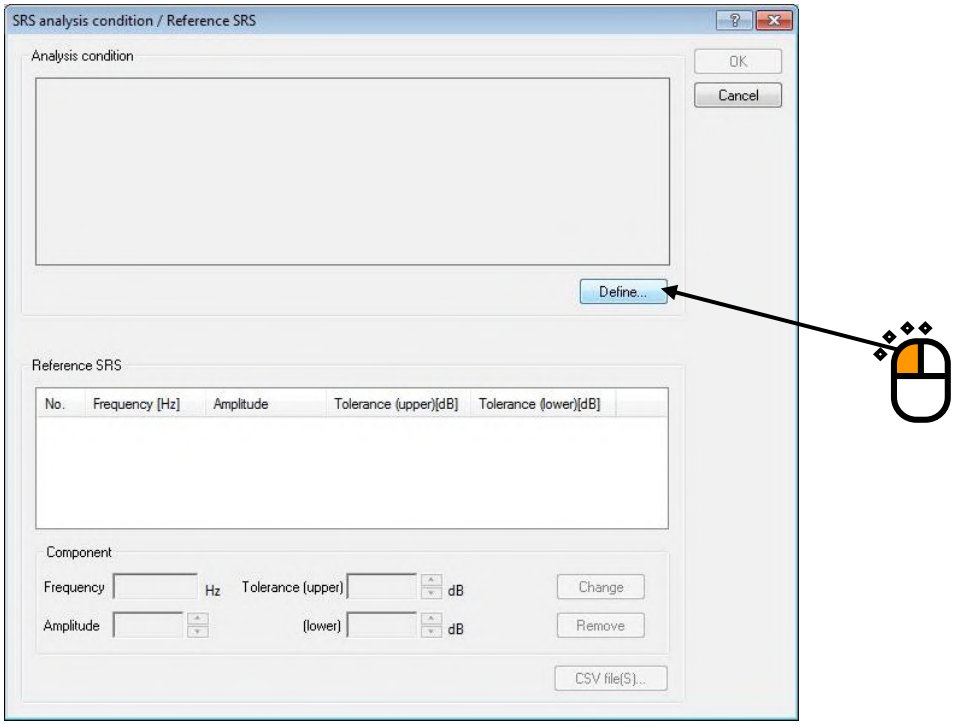
< Step 4 >

Press the [Define] button.



< Step 5 >

Press the [Define] button.

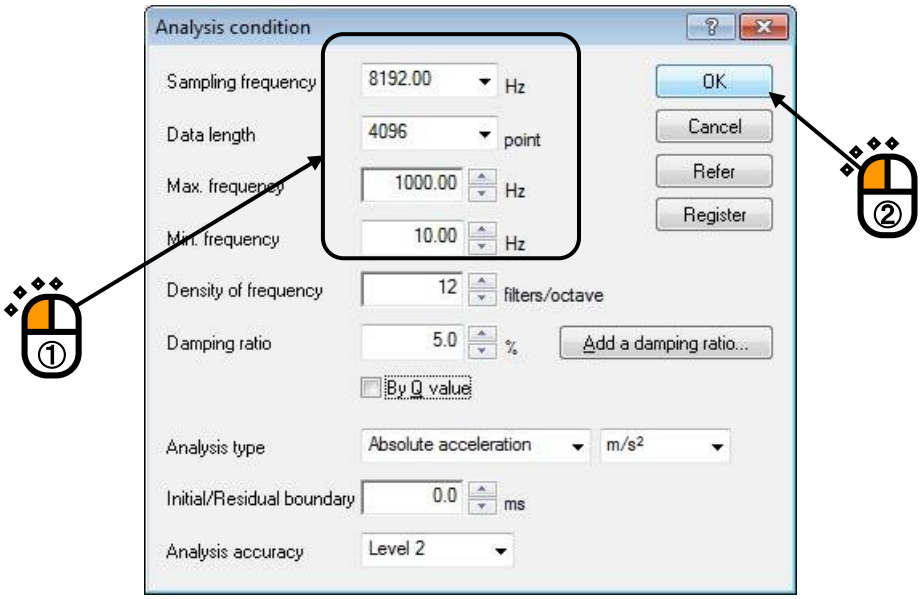


< Step 6 >

This item is for setting of SRS Analysis Condition.

Press the [OK] button after setting of the conditions as below.

- Sampling Frequency : 8192Hz
- Data Length : 4096
- Max. Frequency of Analysis : 1000Hz
- Min. Frequency of Analysis : 10Hz

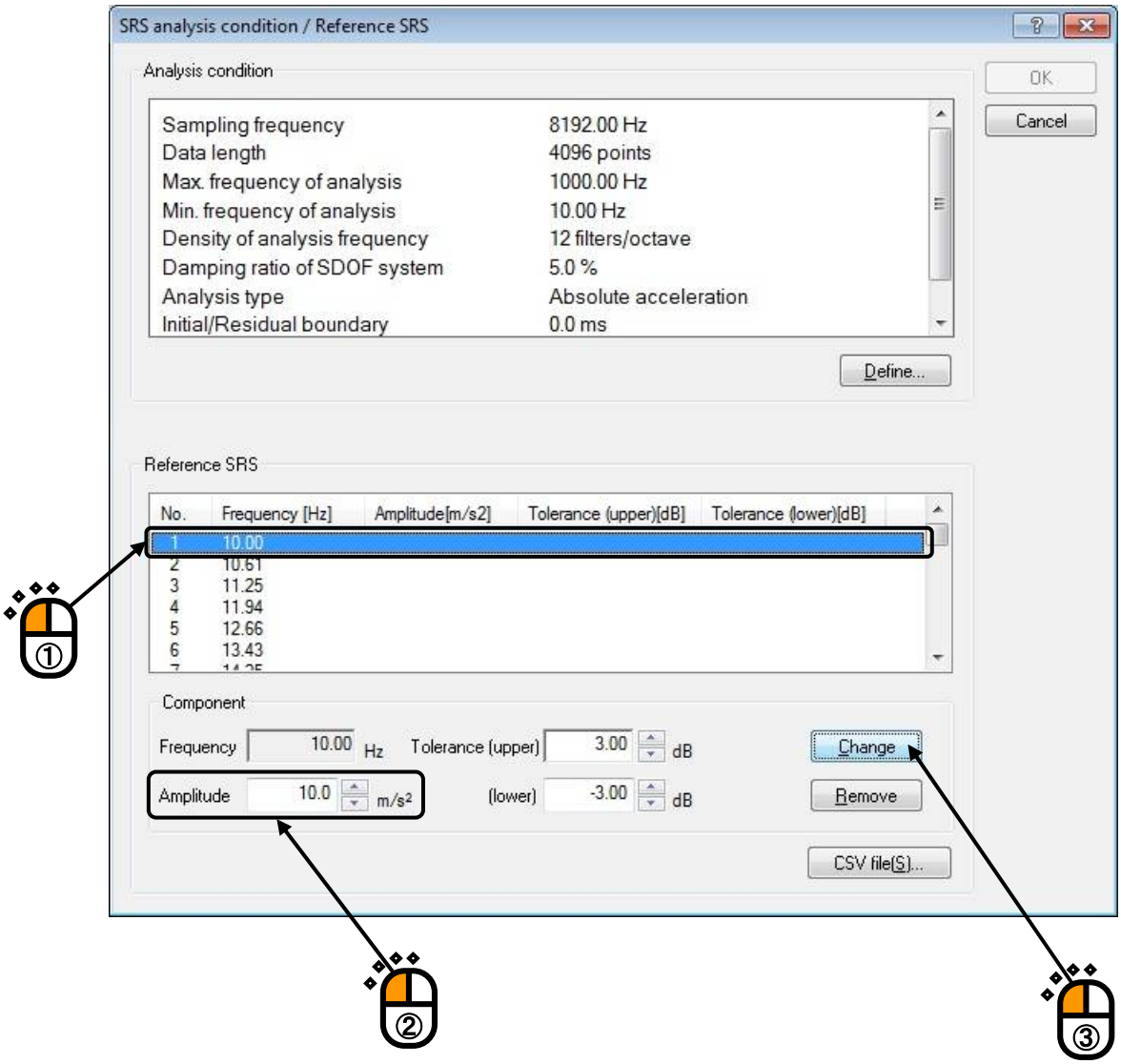


< Step 7 >

This item is for setting of Reference SRS.

The first break point is to be set.

Select ’10 Hz’ among the values in frequency list and input ’10 m/s^2’ in amplitude. Then, press the [Change] button.

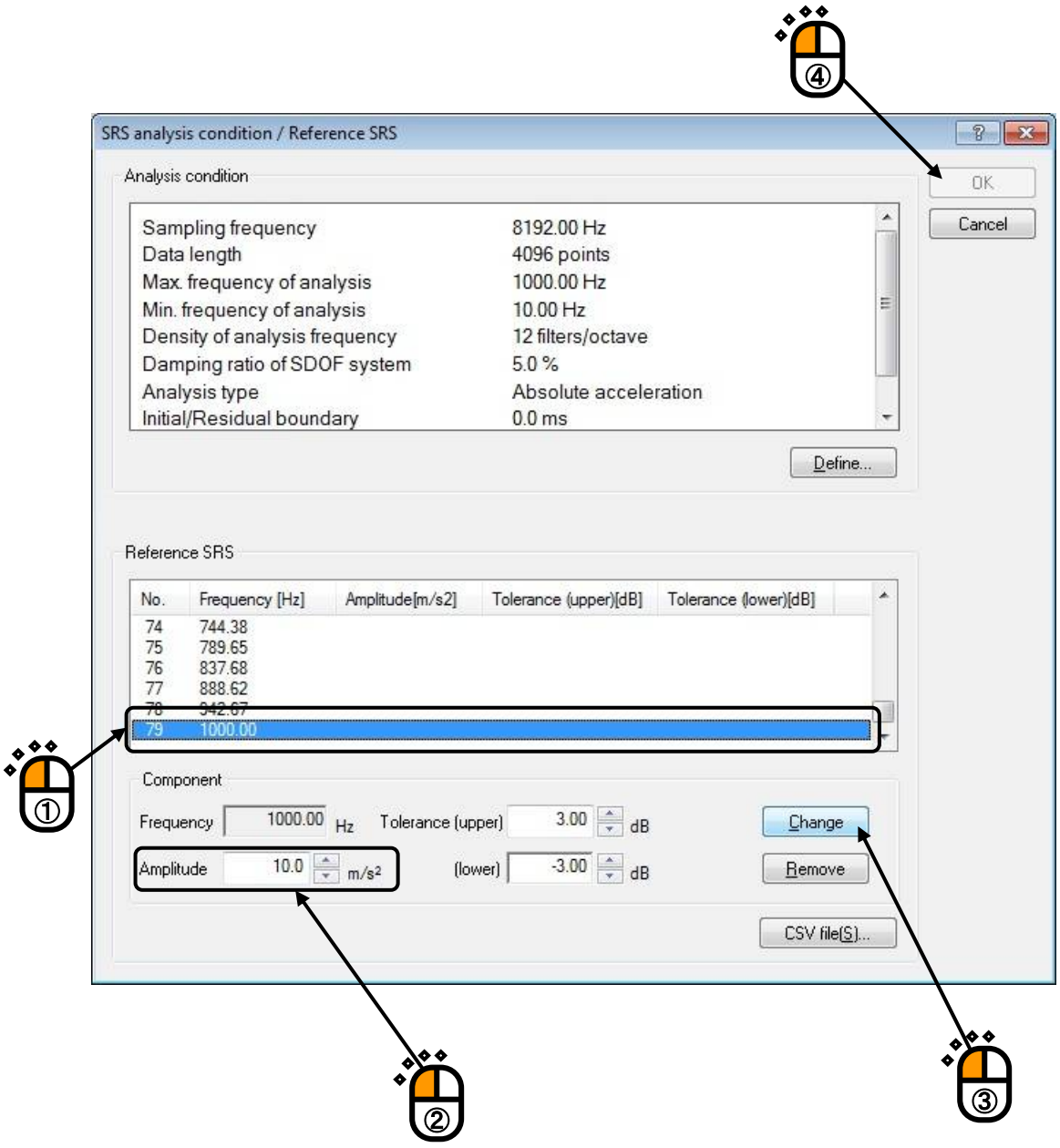


< Step 8 >

The second break point is to be set.

Select ’1000 Hz’ among the values in frequency list and input ’10 m/s^2’ in amplitude. Then, press the [Change] button.

After completing of the break points setting, press the [OK] button.

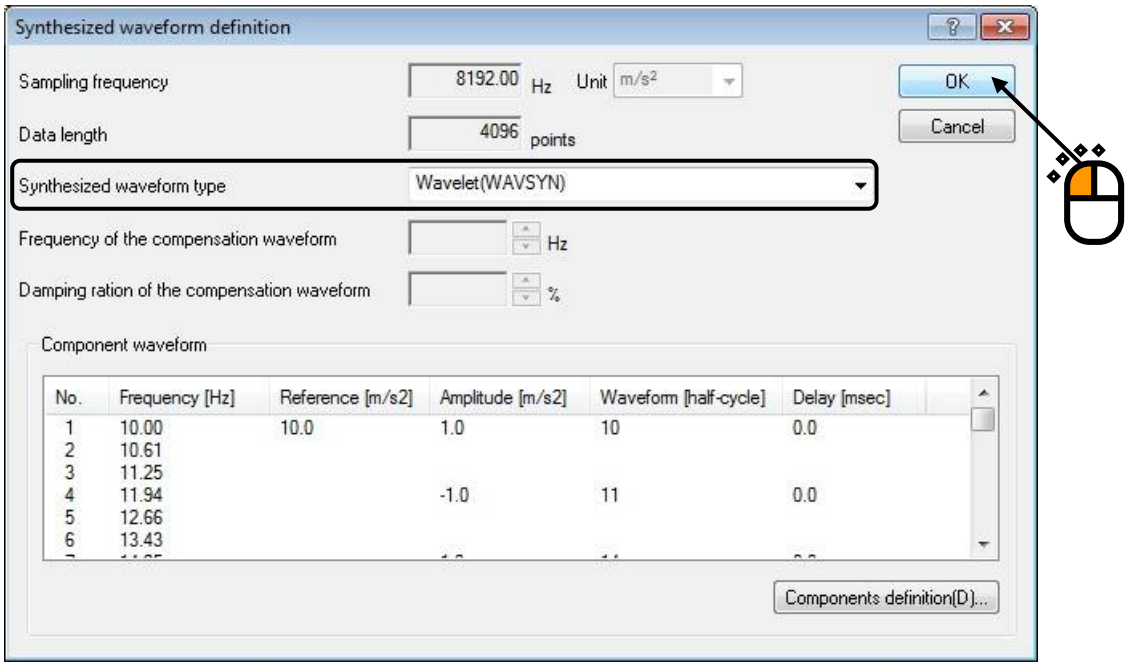


< Step 9 >

This item is for setting of Waveform Synthesis Condition.

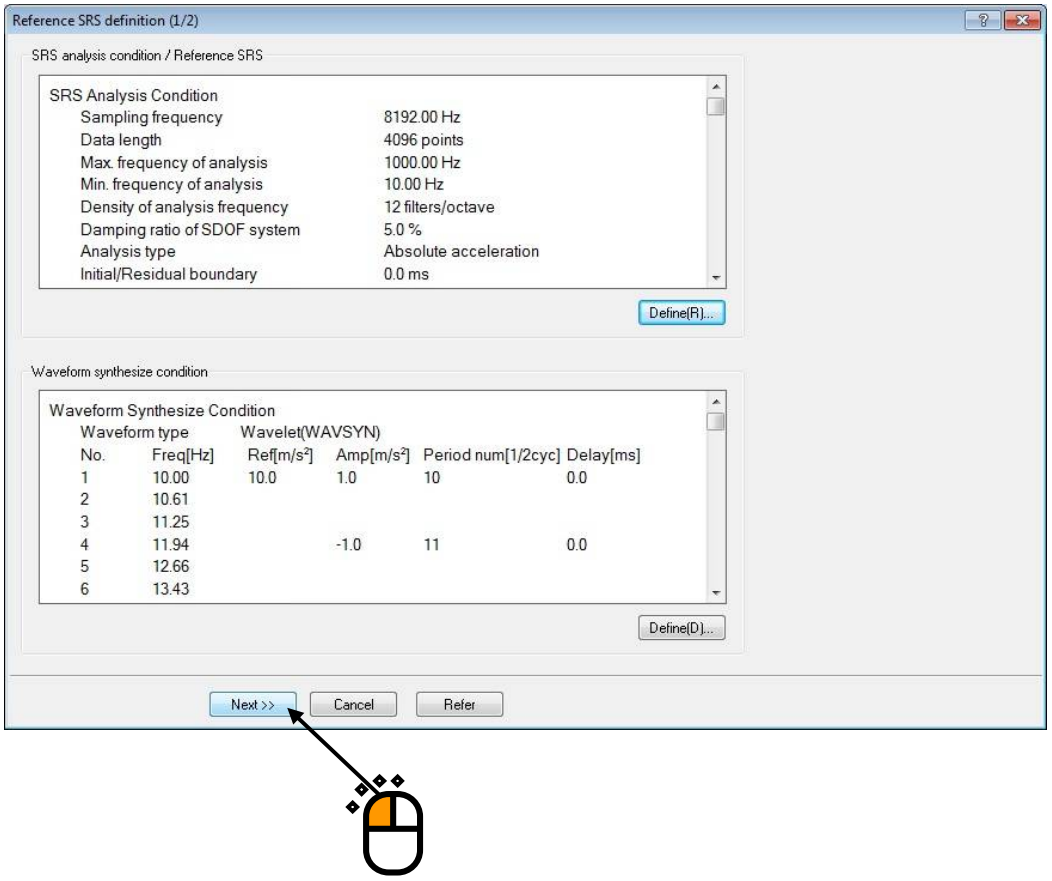
Make sure that Synthesized Waveform Type is set to Wavelet (WAVSYN).

Then, press the [OK] button.



< Step 10 >

Press the [Next] button.



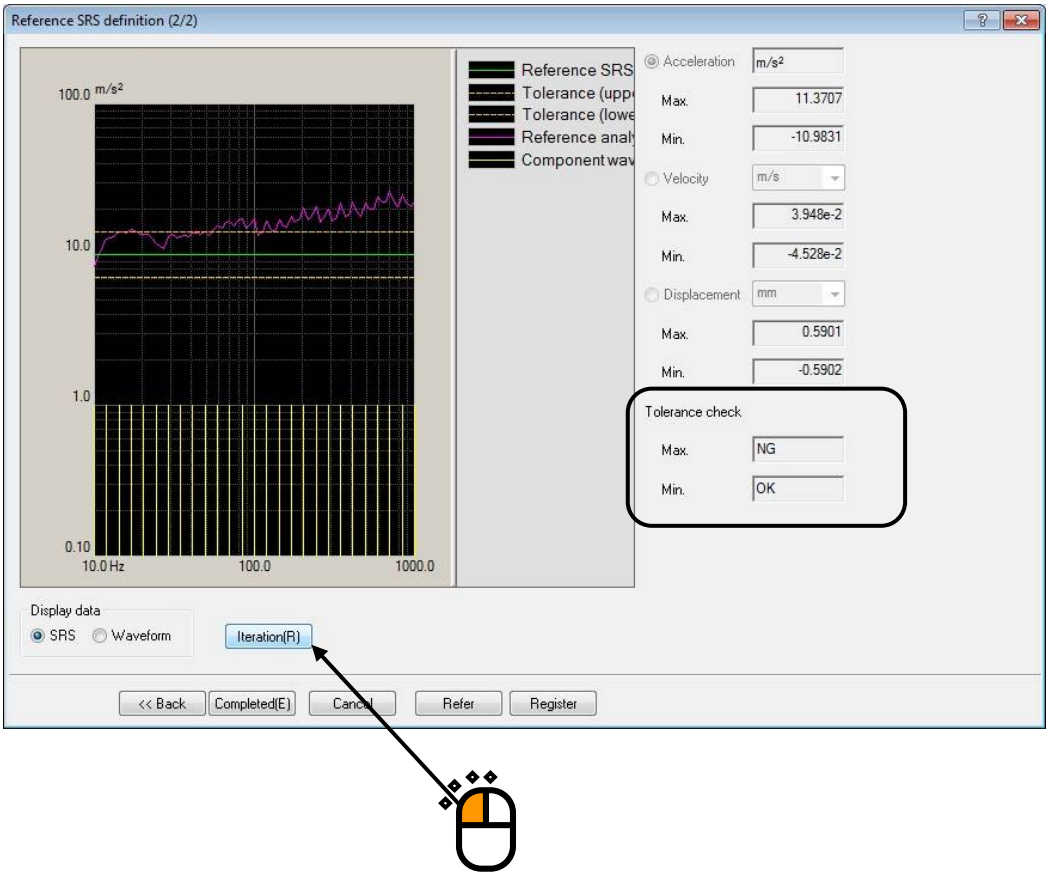
< Step 11 >

The definition of Reference SRS is completed.

However, Reference Analysis SRS obtained by SRS Analysis of generated Reference waveform exceeds over the specified Tolerance. Tolerance check is resulted in NG.

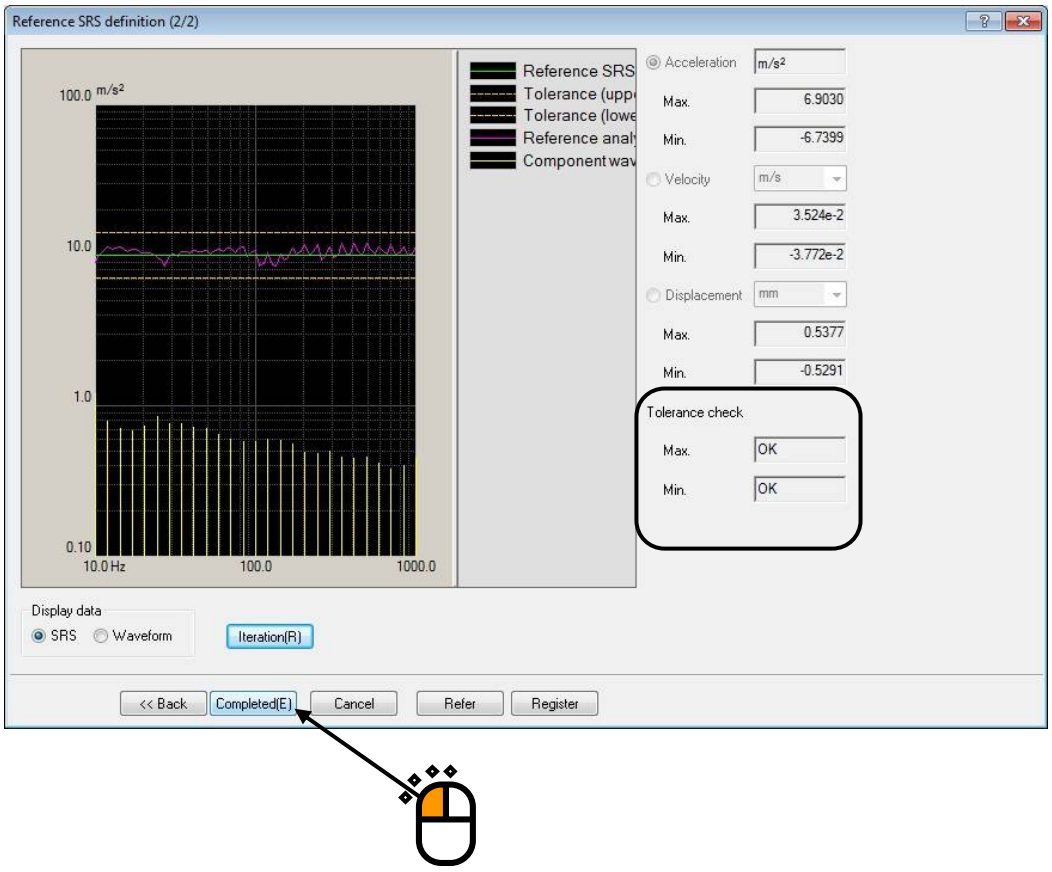
Here, SRS Fitting calculation is operated to set the Reference Analysis SRS within the Tolerance by Iteration process.

Iteration is operated by pressing the [Iteration] button.



< Step 12 >

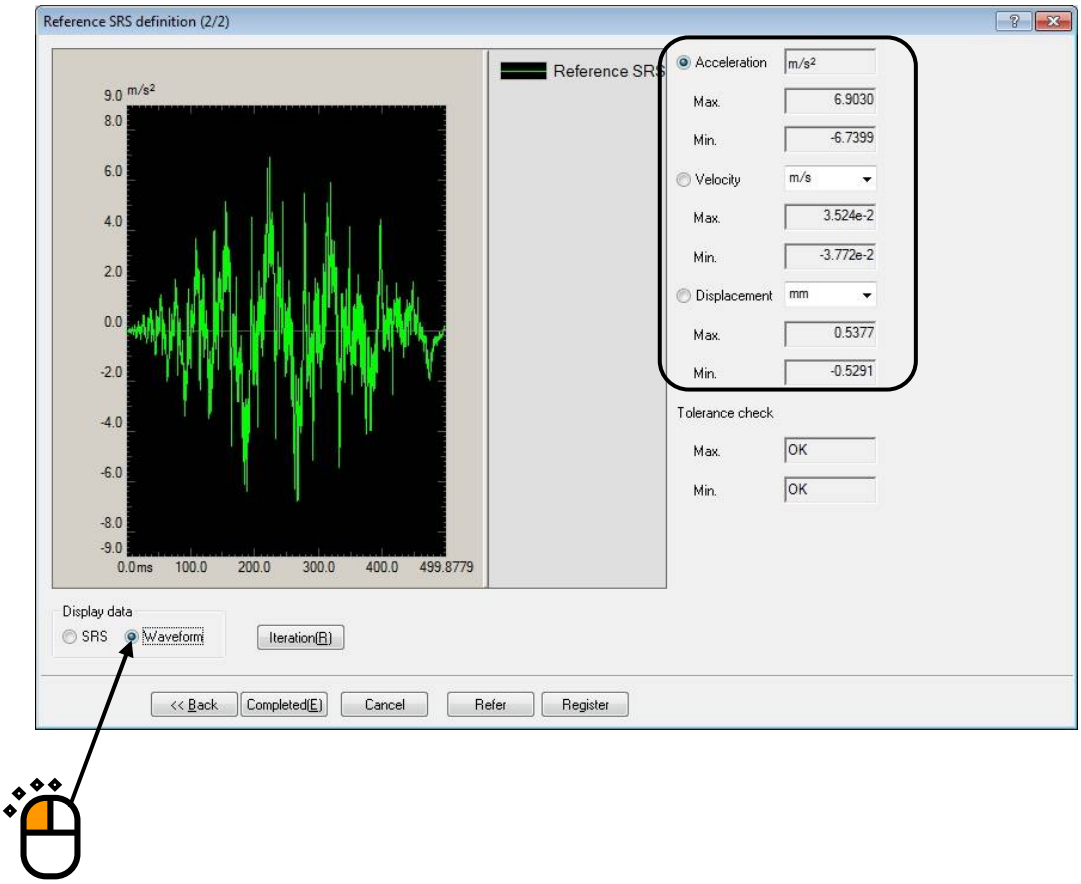
The result of Tolerance check is obtained as OK when the Reference Analysis SRS is converged within the Tolerance. Press the [OK] button to complete the definition of Reference SRS.



(Supplementary explanation)

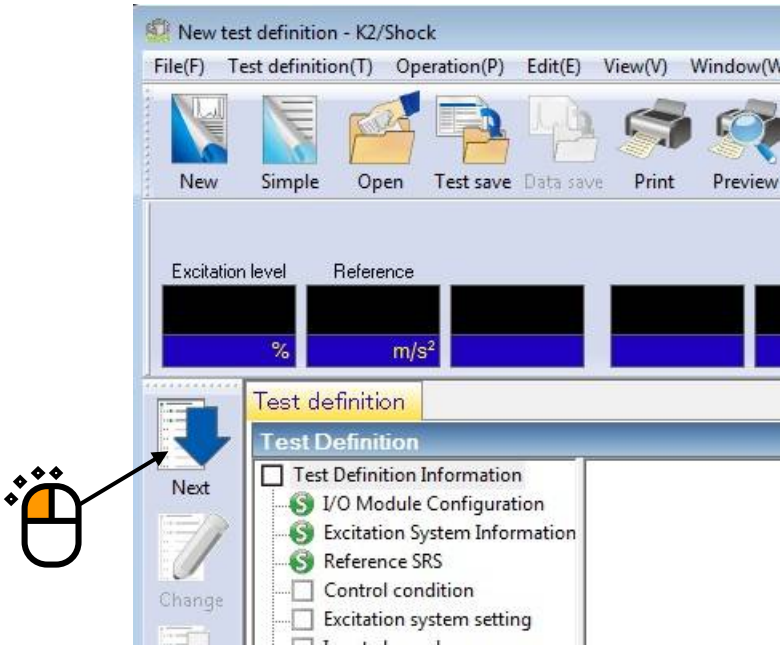
The max. and the min. values of Acceleration / Velocity / Displacement of reference waveform are displayed in the definition display of Reference SRS.

When the data to be displayed is specified to ‘Waveform’, the reference waveform is displayed in the window.



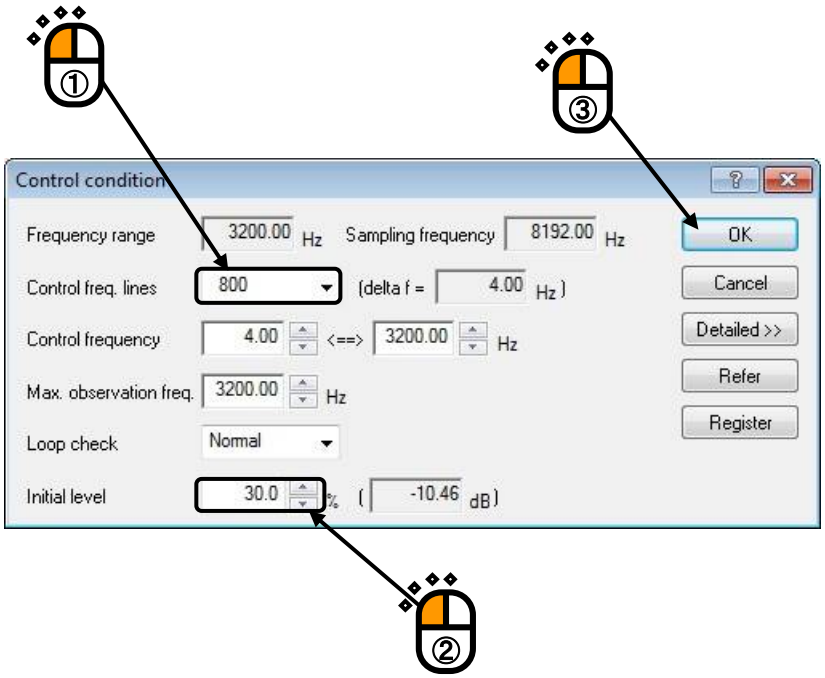
< Step 13 >

Press the button to go to the next definition item.



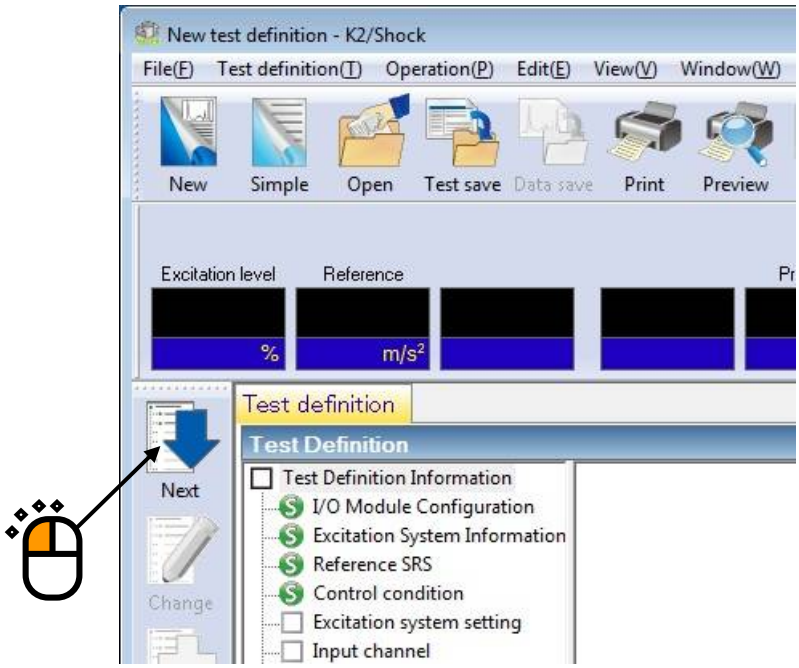
< Step 14 >

Set the Control frequency lines to ‘800’ and the Initial level to ’30 %’. And press the [OK] button.



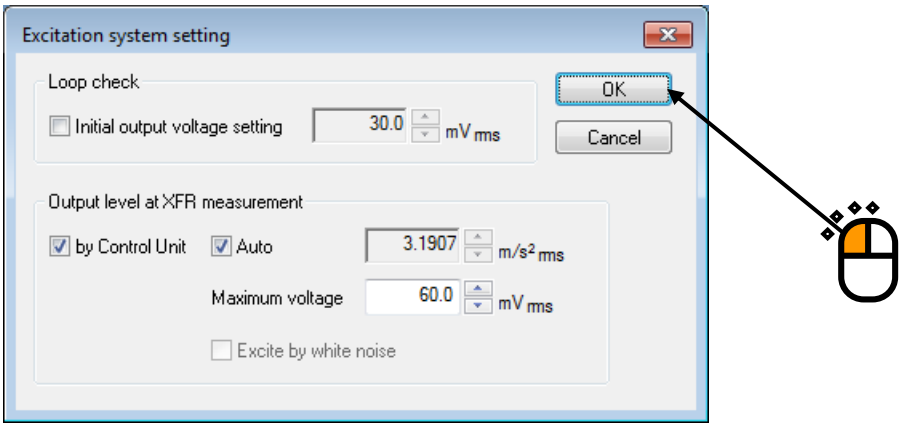
< Step 15 >

Press the button to go to the next definition item.



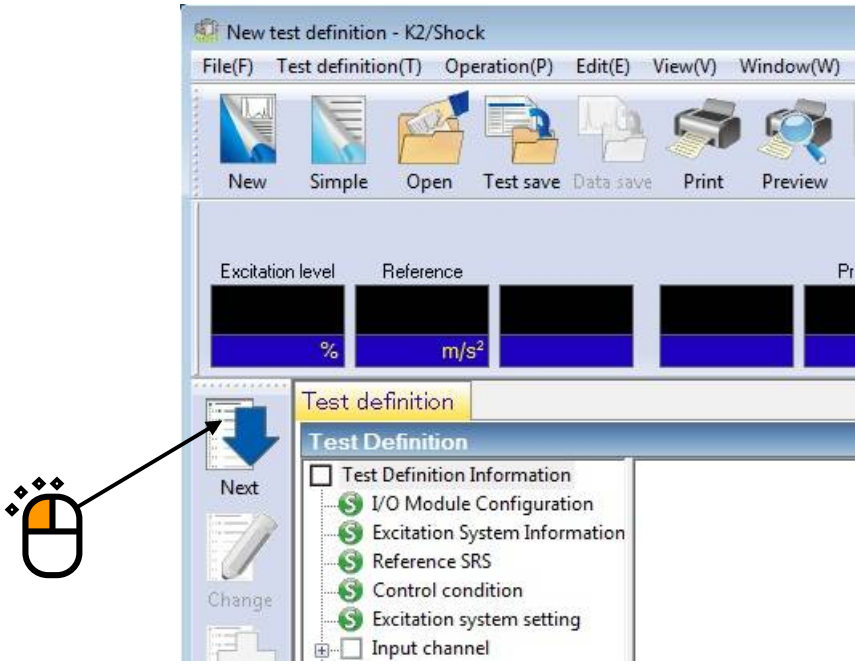
< Step 16 >

Press the [OK] button.



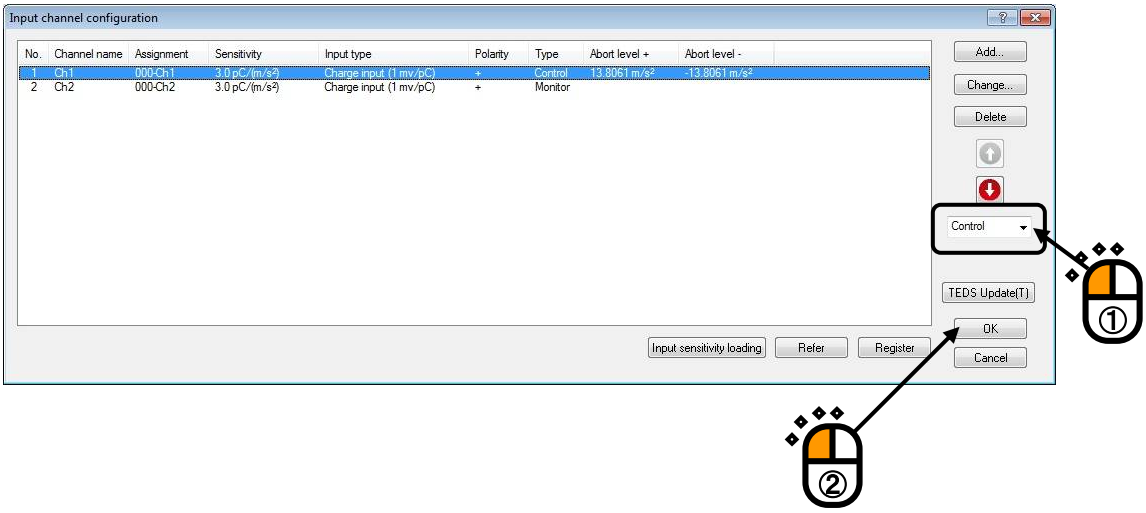
< Step 17 >

Press the button to go to the next definition item.



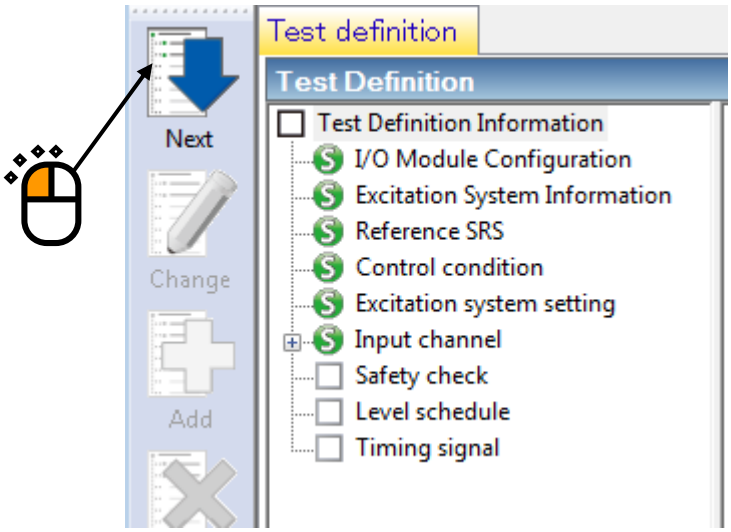
< Step 18 >

Select ‘Ch.1’ and set as ‘Control’. Also, select ‘Ch.2’ and set as ‘Monitor’. Then, press [OK] button.



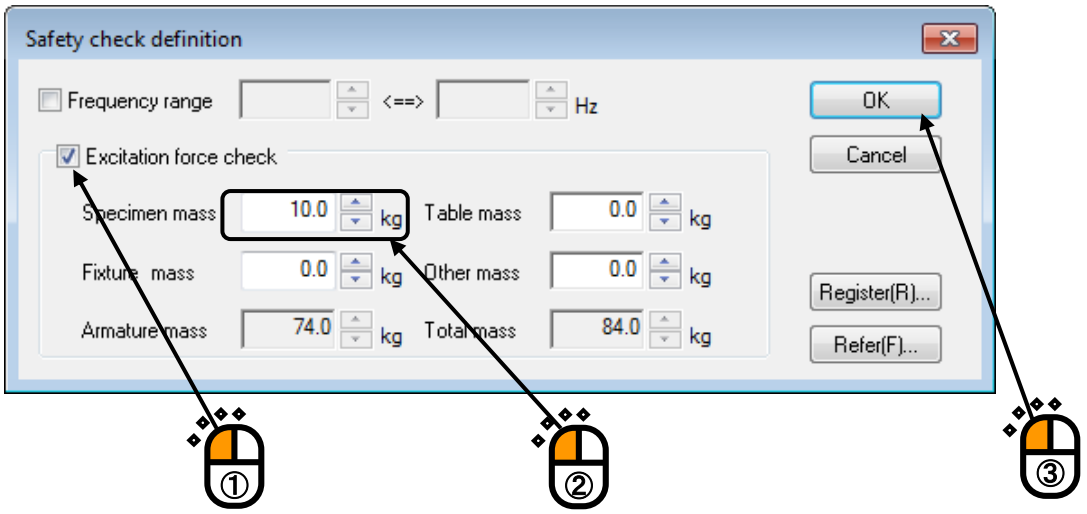
< Step 19 >

Press the button of [Next].



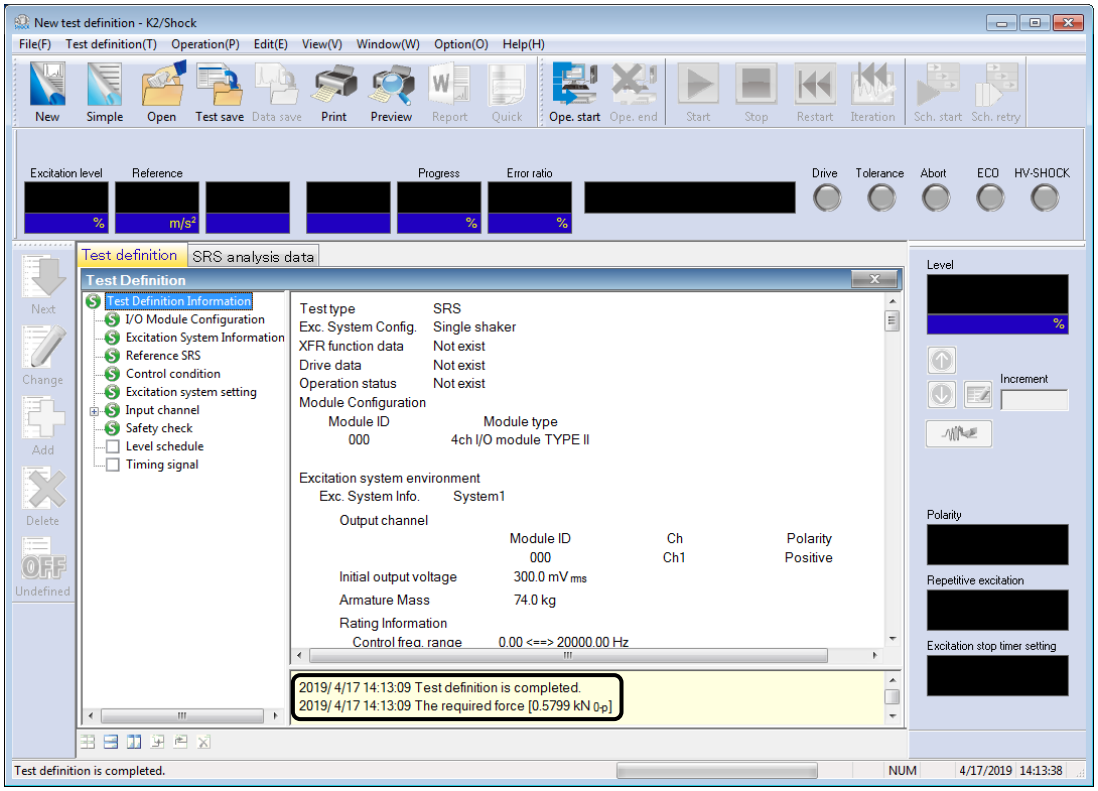
< Step20>

Select ‘Excitation force check’ and input the value as ‘Specimen mass : 10 [kg]. And press the button of [OK].



< Step21 >

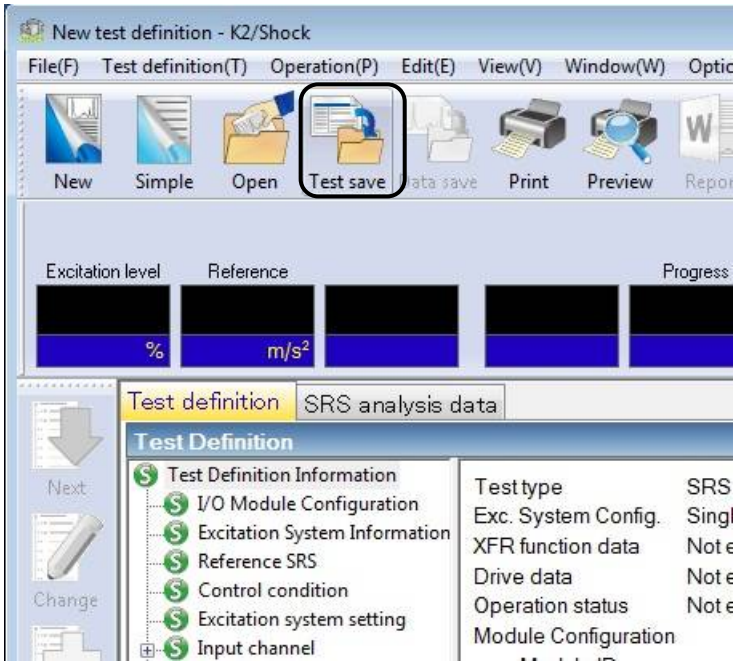
The definition is completed.



< Save of test >

< Step 1 >

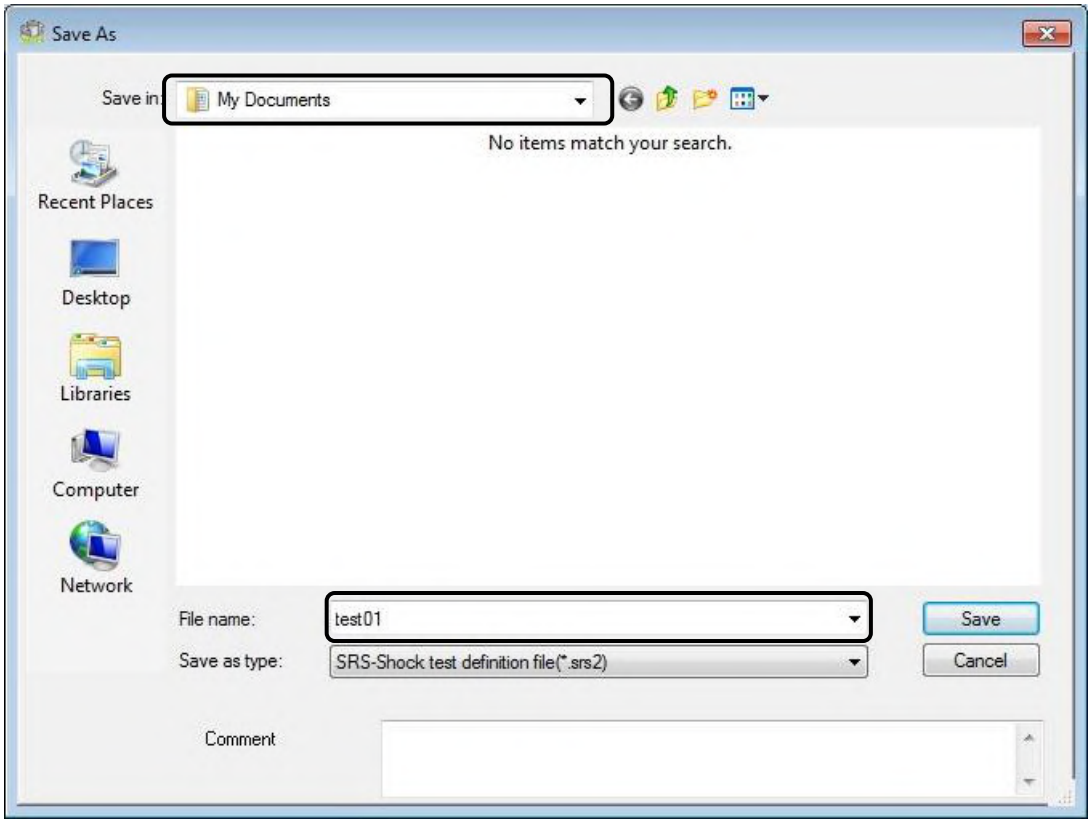
Save the defined test information as a test file.



< Step 2 >

Press the [Save] button of a test.

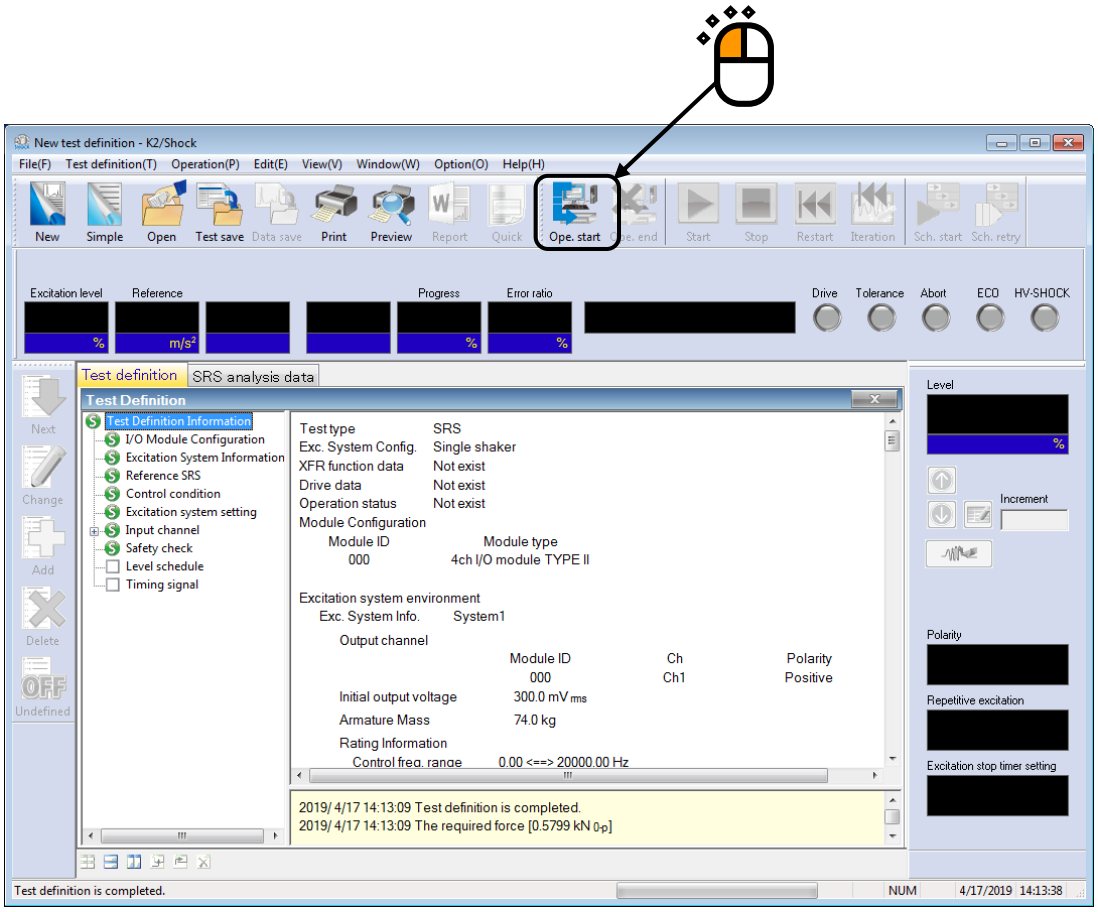
The dialog box as below appears. Specify an arbitrary directory in ‘Folder’ and input a name to ‘File name’.



< Operation of test >

< Step 1 >

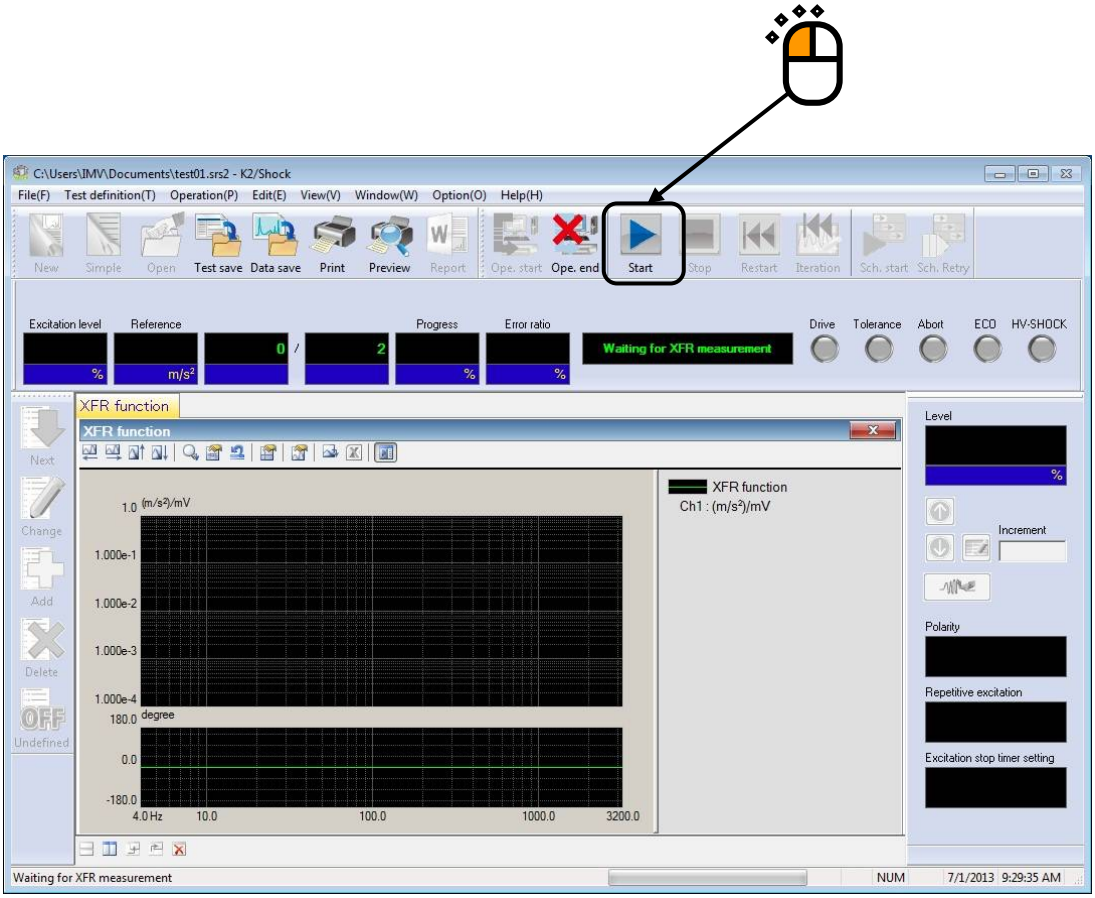
Press the button of [Operation start].



< Step 2 >

The transfer function of controlled system is to be measured.

Press the button of [XFR Measure].

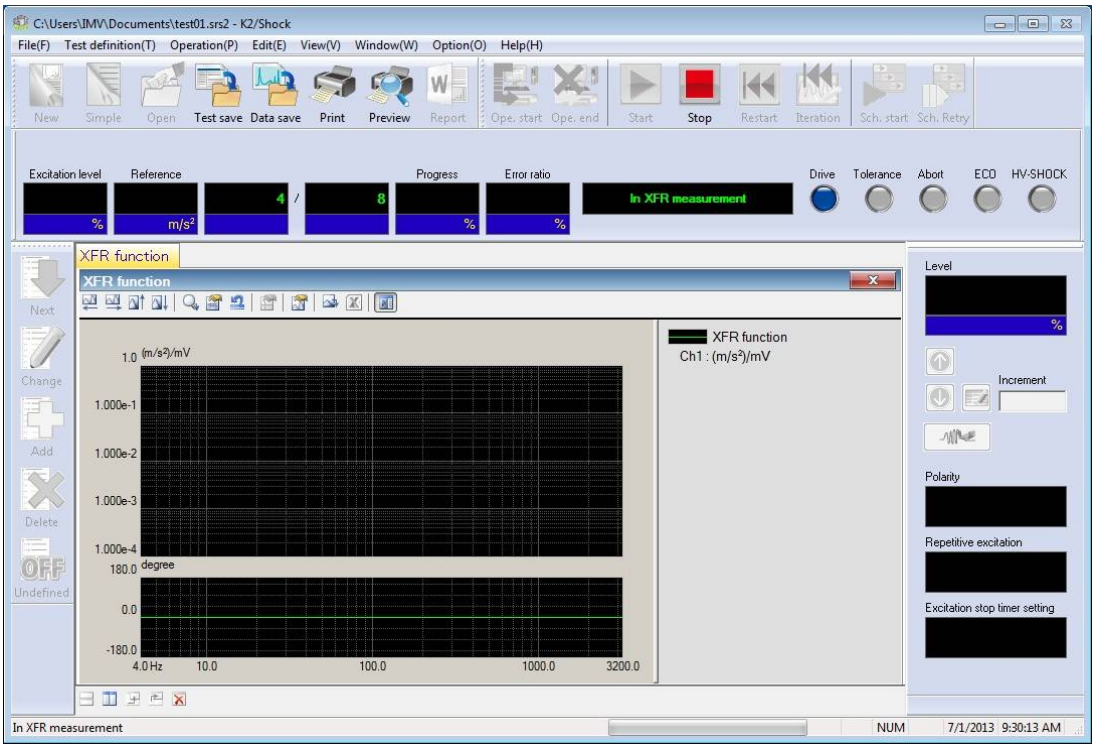


< Step 3 >

Loop check and XFR measurement is operated.

The system is automatically set to the state of waiting for the drive generation when the XFR measurement is completed.

Press the [Stop] button when the operation needs to be aborted during the XFR measurement.

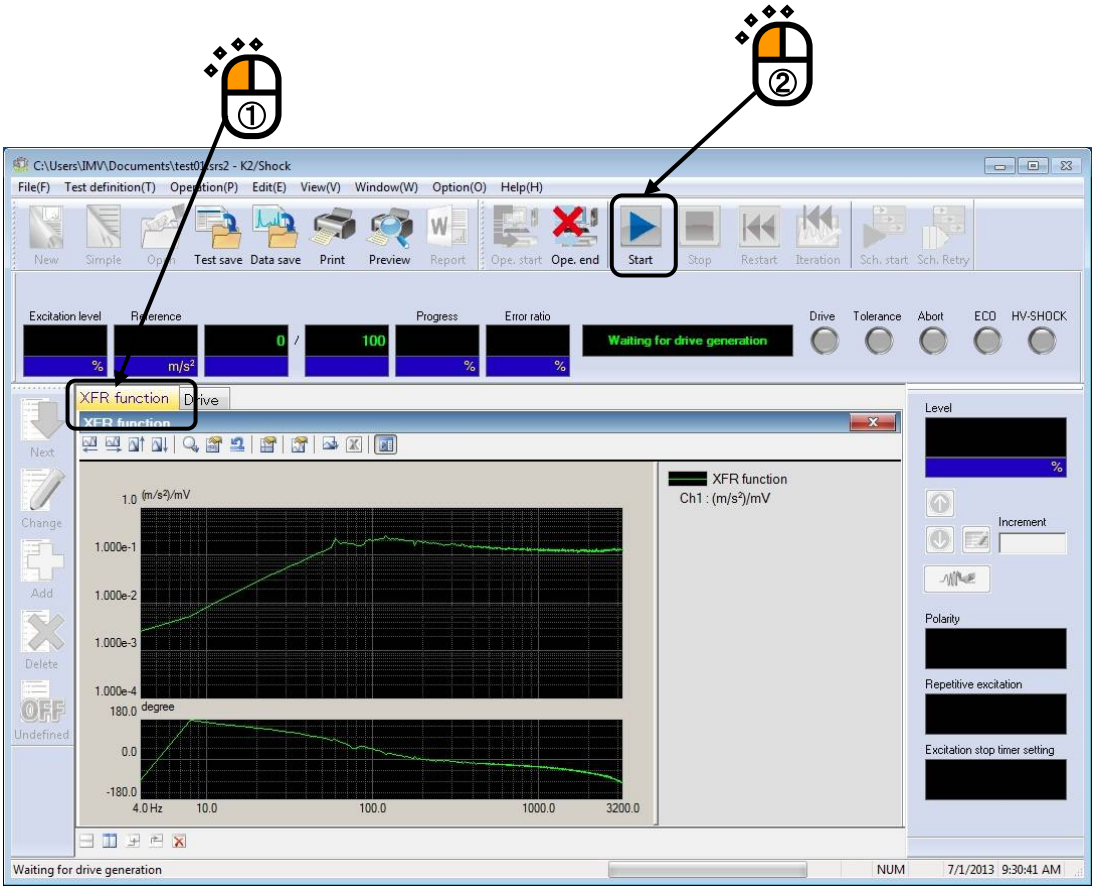


< Step 4 >

When the XFR measurement is completed, the graph of the XFR measurement appears.

Drive waveform is to be generated after checking the obtained transfer function normal.

Press the button of [Drive generation].



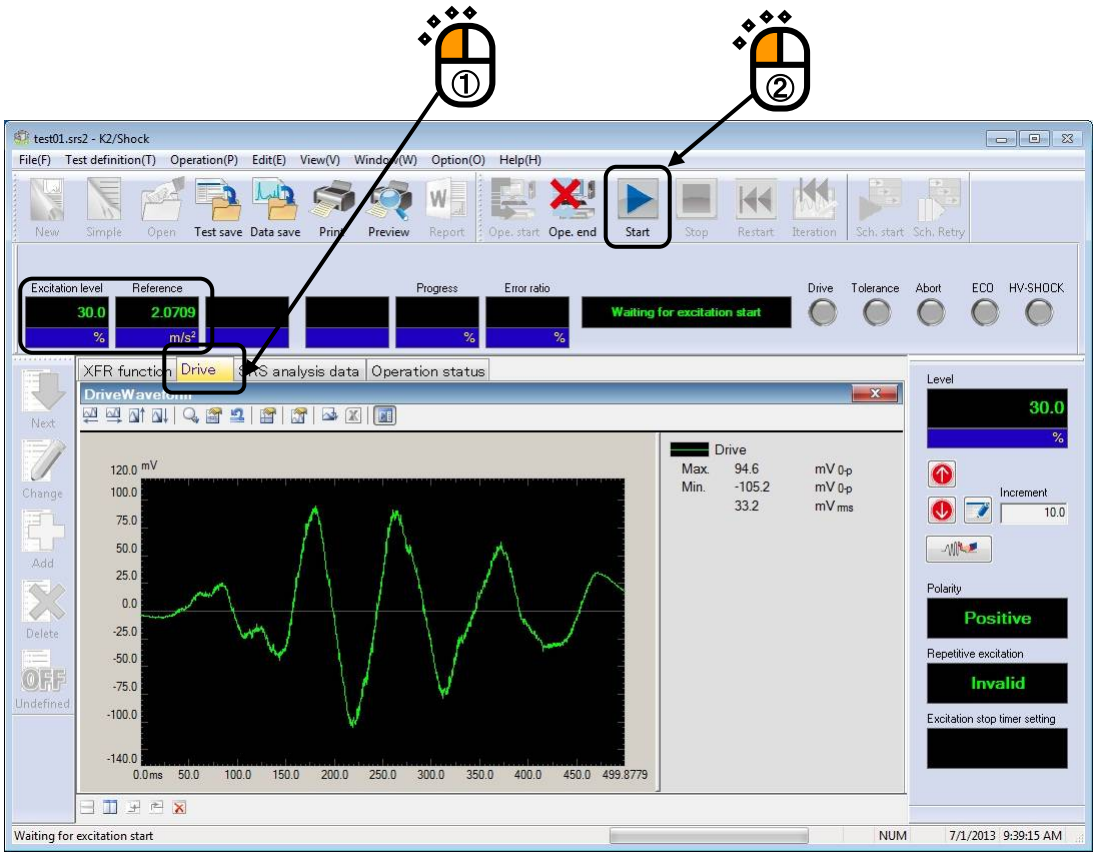
＜Step5＞

The system is set to the state for Excitation Start when the drive generation is completed.

In the operation status panel, Excitation level and Peak level of reference waveform are displayed.

In this example, the excitation is operated at 30 % at first. The setting of this level is not necessary to be corrected because the initial level has been set to 30 %.

Check the Drive waveform and the Excitation level in the display. Press the button of [Exc. Start] to start the excitation operation.

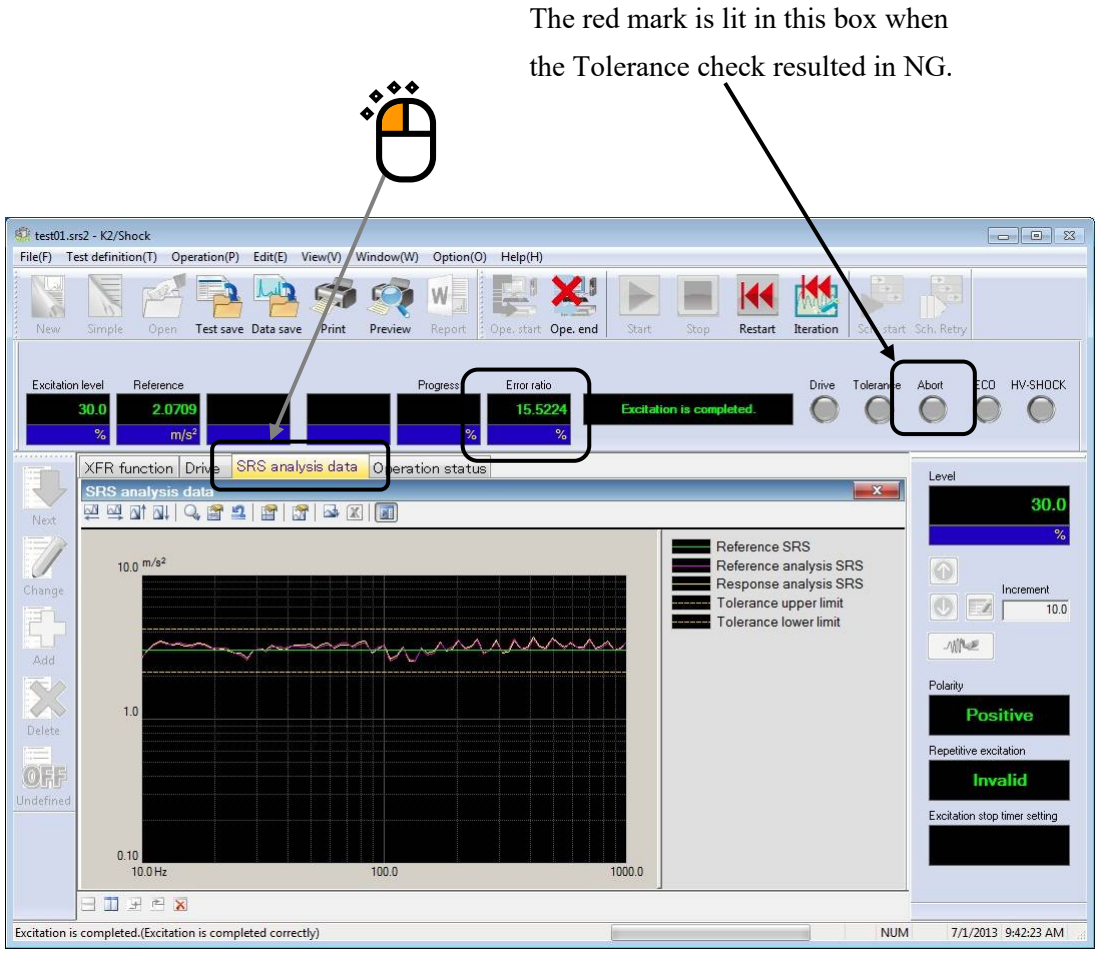


< Step 6 >

The system is set to the state of Excitation completed when the excitation operation is ended.

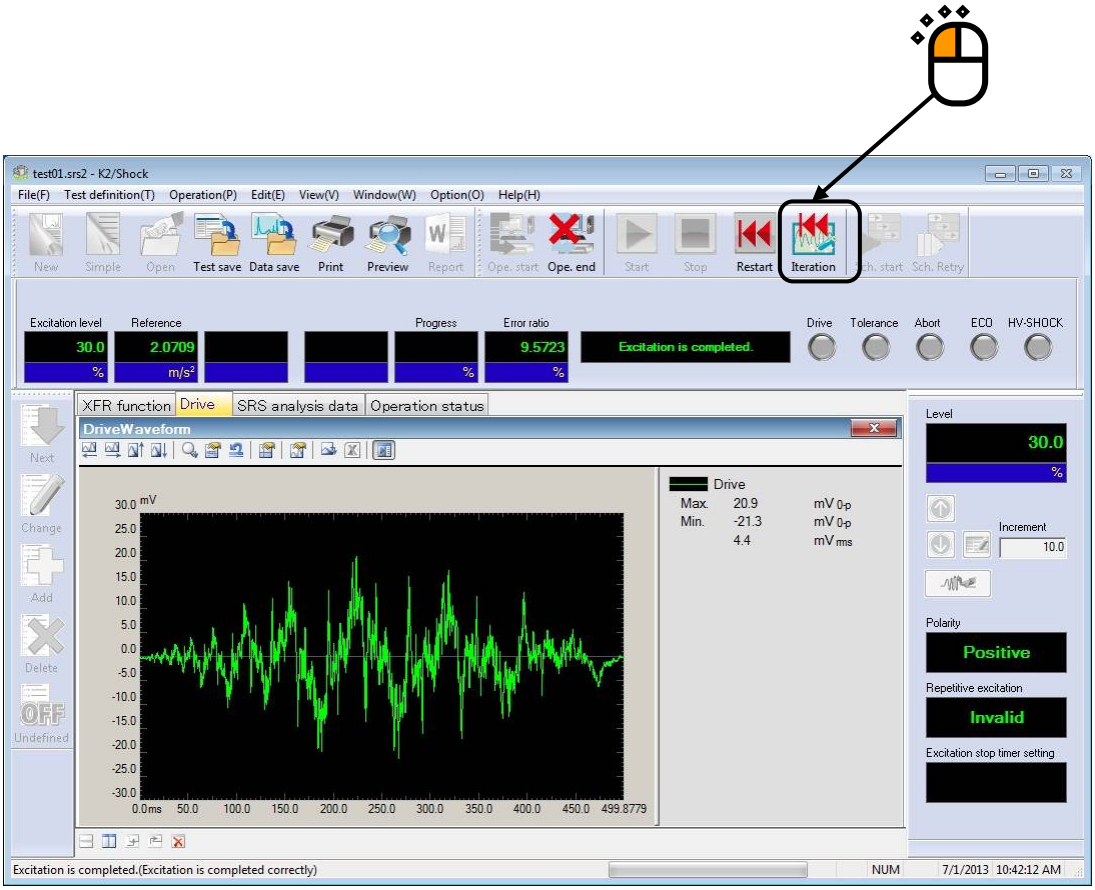
In Operation status panel, the result of Control error rms and Tolerance check are displayed.

In SRS SHOCK test, the Tolerance check is judged according to the response analysis SRS (the result obtained from the control response waveform analyzed by SRS).



When the obtained response analysis SRS passes the check without any abnormal phenomenon, the correction of drive voltage is executed according to the excitation result.

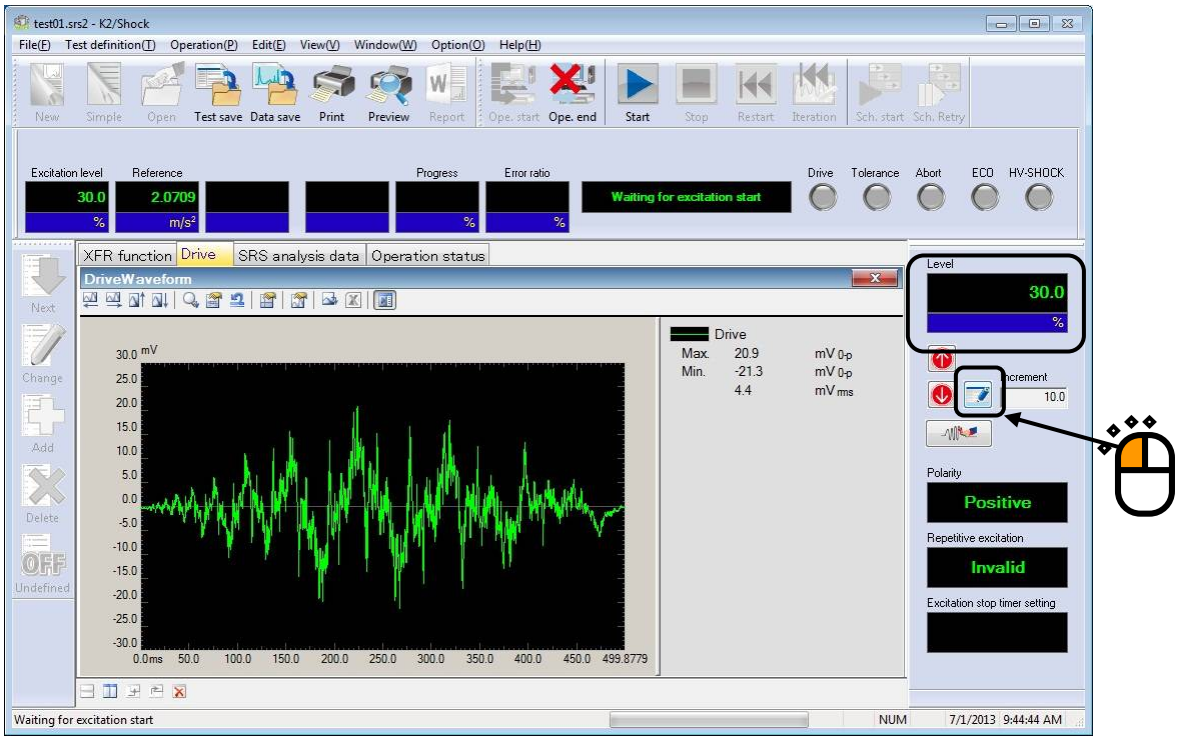
Press the [Iteration] button.



< Step 7 >

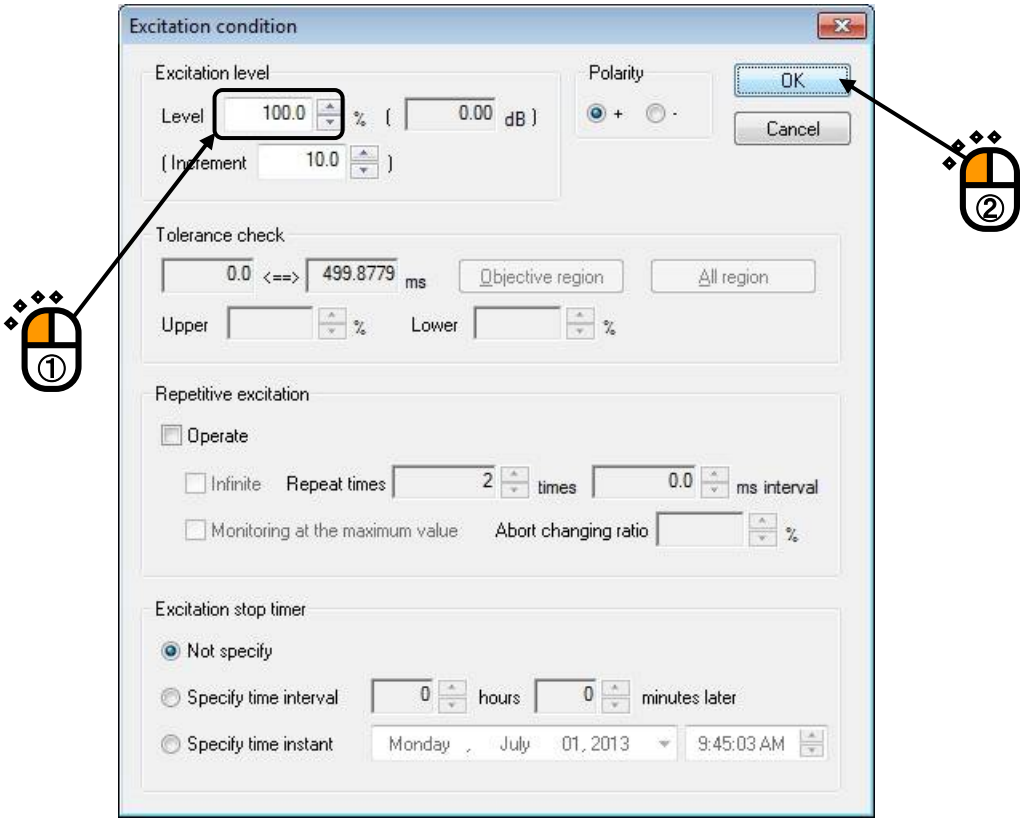
Check the drive waveform and change the Excitation level to 100 %.

Press the button of [Exc. Condition].



< Step 8 >

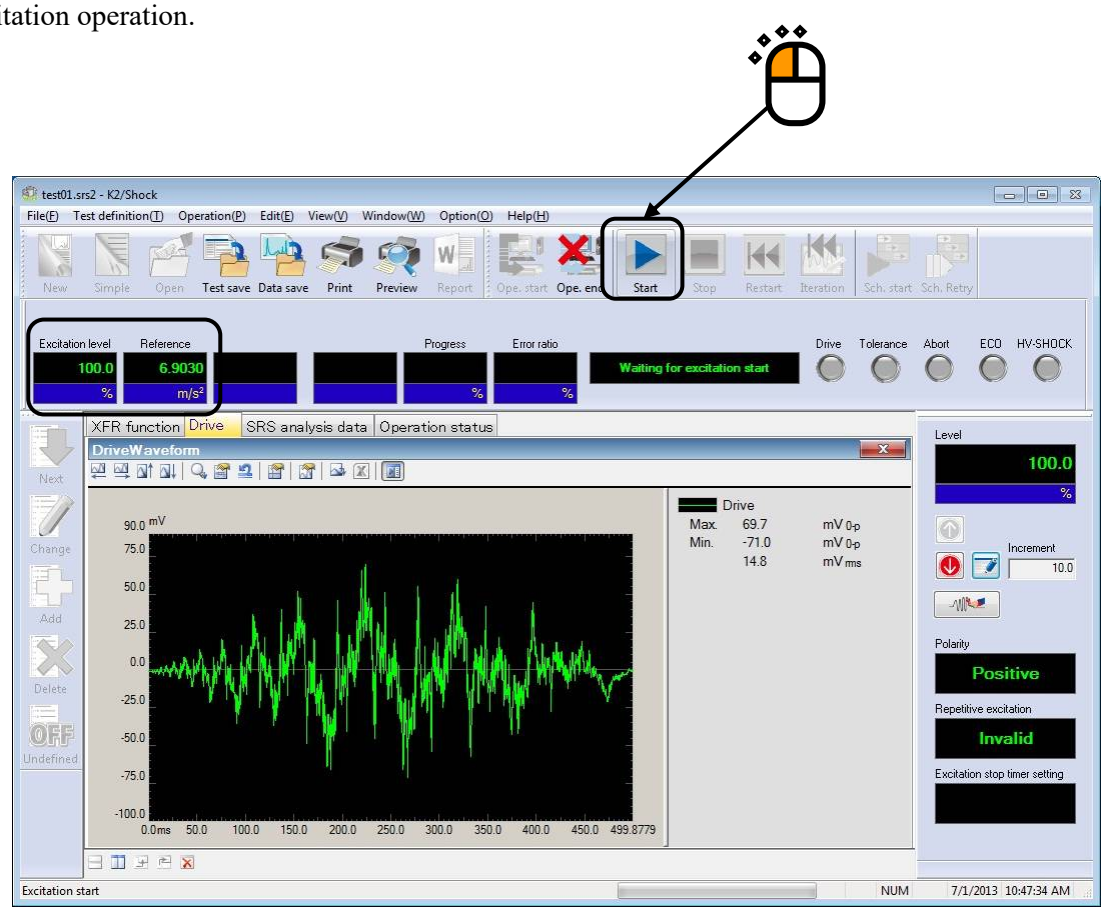
Set the Excitation level to 100 % and press the [OK] button.



＜Step9＞

When the Excitation level is changed, the value of Excitation level and the peak level of reference waveform are renewed in the operation panel. The drove waveform os proportionally adjusted according to the level.

When the checks of the drive waveform and the Excitation level are done, press [Exc. start] to start the excitation operation.

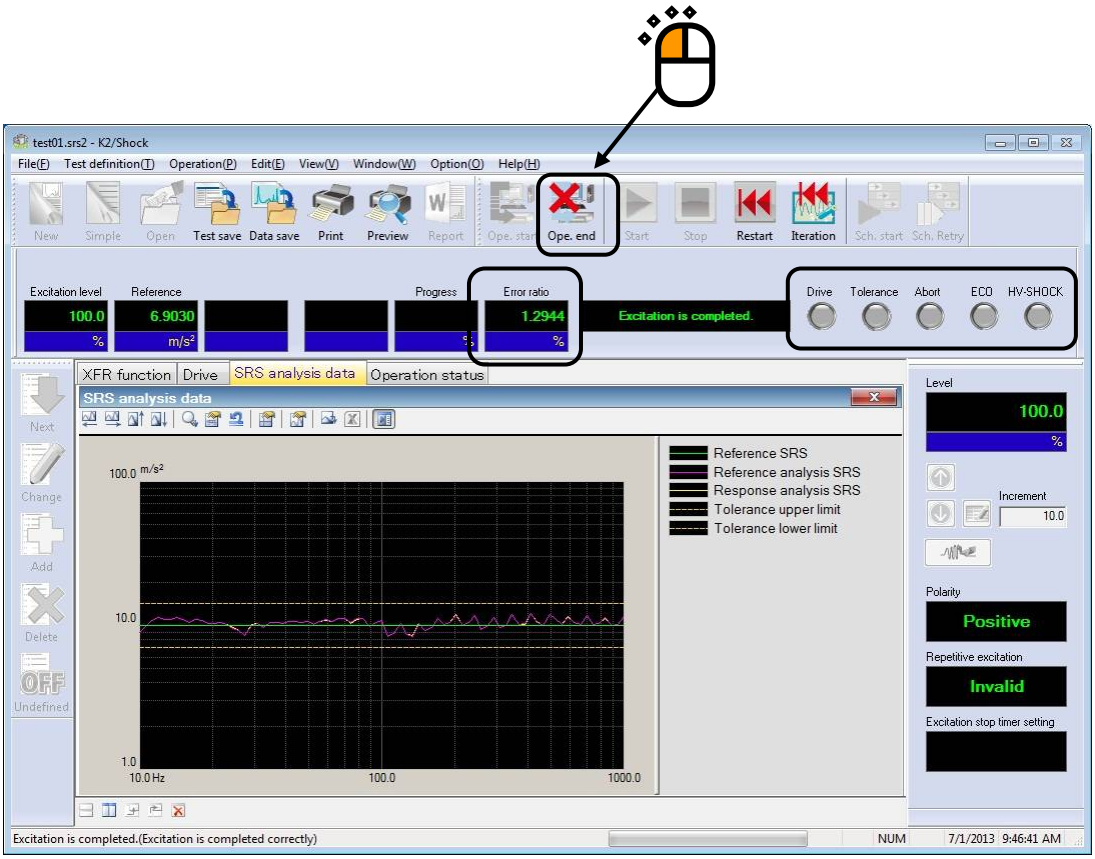


< Step 10 >

When the excitation is completed, the system is set to the state of Excitation completion.

In operation status panel, the results of Control error rms and Tolerance check are displayed.

Press the button of [Exit] to end the operation. The system set to the test definition mode again.



Chapter 4 Test Definition

4.1 Outline

In this system, a complete set of information needed for test operation is called ‘Test’.

To perform a test, Test must be defined first of all.

This chapter describes the procedure to define the Test.

Test is defined by the setting of the information in Table 4-1 in order for each Test types.

Table.4-1 Definition Information

Setting Information	
(1) I/O Module Configuration	○
(2) Excitation System Information	○
(3) Reference Waveform	○
(4) Control Condition	○
(5) Excitation System setting	○
(6) Input Channel	○
(7) Safety check	○
(8) Level Schedule	△
(9) Timing Signal	△
(10) SRS Analysis Condition*	△

○ : Information that must be defined

△ : Information that is defined if necessary

Note) * SRS is an optional function.

Information of Test completely defined is to be saved in a file as a specified format of ‘Test File’.

Test operation can be executed by loading a file in which the information of Test defined beforehand is saved as a Test File.

4.2 Reference Waveform

Reference Waveform is defined.

This definition determines the waveform to be generated on the shaker table.

Refer to ‘Chapter 5 Reference Waveform Definition’ about the details.

4.3 Control Condition

The parameters concerning to the control is defined.

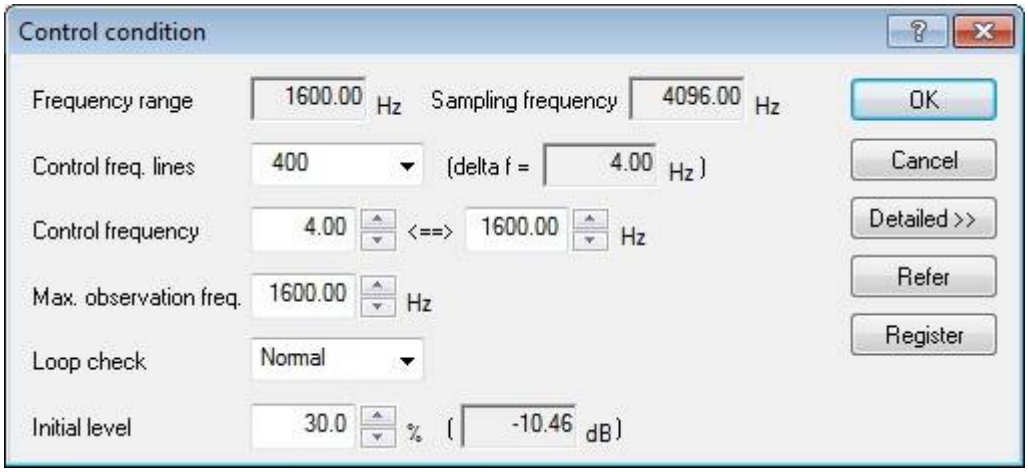
Sampling frequency fs is one of the important parameters that defined in Reference Waveform. So, it is not needed to be defined in Control Condition.

The maximum controllable Frequency range fmax is related to the Sampling frequency fs as below ;

fmax = fs / 2.56

Therefore, the Frequency range is determined automatically when the Sampling frequency is specified.

And it is also not needed to be defined in Control Condition.



4.3.1 Control frequency lines (Control freq. lines)

(1) Meaning

Complex Spectrum data for N/2 lines is obtained in the Frequency range by FFT for the waveform data of one frame length (for N points). Control frequency lines is for specifying the number of data line (from the lower frequency) that is treated as the valid data of control operation.

The relation between Control frequency lines L and the number of points N for FFT is expressed as below ;

$$L = N / 2.56$$

Frequency resolution which means the closeness of control on the frequency axis Δf is determined when the Control frequency lines is specified.

The relation between Δf and the Control frequency lines is described as below ;

$$\Delta f = fmax / L \ (= fs / N)$$

And, the Frame Time T (the time of Waveform Data for N points) has the following relation with the Control frequency lines Δf :

$$T = 1 / \Delta f \quad [sec]$$

< Selection guide for Control frequency lines L >

The line number is selected based on the transfer characteristic of the controlled system. To succeed in control, almost all impulses response of the controlled system must be within the set control frame.

If unsuccessful, select a larger line number stepwise. It is better to do it this way rather than set an excessively large number.

In Loop check or XFR Measurement, the excitation for at least one frame time has to be operated. So, the closer the Frequency resolution is specified, the more it takes time.

When the use of Transfer Function File or Drive Data File is specified in the definition of the fundamental condition, the correction of this item is prohibited because consistency must be maintained with those data.

4.3.2 Control frequency

(1) Meaning

Control processing of this system is performed in the frequency domain. This is a special item which defines a function to give a certain restriction as needed in order to achieve better control when control is done in the frequency region. The function is indispensable in some cases, so please take the time to understand it.

Generally, the frequency band in which the control is operated is denoted as [Δf, fmax] ([0, fmax] in DC Control). It is better to control this frequency band to obtain a good result.

For example, most frequency components of the reference waveform dominate in the frequency band which is much lower than fmax. When it is sufficient to control components up to some fmax/2 in order to meet the requirements for waveform reproduction, it is better to exclude components in a higher frequency band from the controlled components. In particular, the drive correction algorithm of this system is very sensitive to non-linear response (frequency components originally excluded from the reference waveform appear in the response waveform), so it is sharp but sensitive to noise. Therefore, it is better to exclude a negligible band from the controlled band.

Likewise, when Δf is too small, it is better to exclude the much lower frequency band from the controlled band depending on the characteristics of the pickup used. An observation in the lower frequency band may affect control and generate a large displacement, so it is important to set this item properly.

In this item, as a controlled frequency band, a maximum and a minimum frequency value are set. If we denote a minimum frequency f1, and a maximum frequency f2, the relation with the Control frequency range fmax must be as follows ;

$$0 \leqq f1 < f2 \leqq fmax$$

In actuality, the data of the frequency band is only in Control frequency lines, so the corresponding line number is determined by rounding up 0.5 and above and cutting away the rest when the defined values of f1, f2, divided by Δf are not whole numbers.

When an ordinary piezoelectric pickup is used, f1 must be set to about 1 ~ 2 Hz.

4.3.3 Max. observation Frequency (Max. observation freq.)

(1) Meaning

This item is for the setting of the Cut-off frequency of LPF (Low Pass Filter) operated to the acquired waveform.

Usually the setting value is met with a setting value of Control frequency Range fmax. But it is possible to set a smaller one if necessary.

To exactly process a signal in the frequency band within the defined Control frequency Range fmax, corresponding to the nature of the input signal, the band must be restricted using LPF and a digital filter.

In this case, it is reasonable to set the Cut-off frequency fc corresponding to fmax. However, for example, when frequency components of reference waveform data are much lower than those of fmax, and higher components than those frequency components must be cut from the beginning in observation of response data, the function of this item is very useful.

Denoting the observation frequency by fobs, the possible setting range of fobs is as follows ;

$$f2 \leqq fobs \leqq fmax$$

where fs = maximum Control frequency defined in the previous clause.

Filtering is processed in digital.

4.3.4 Loop check

(1) Meaning

This item is for specifying the strictness of the criteria for monitoring the control loop correctly connected.

For the Loop check in transfer function measurement, the vibration generator is given white-noise output signal of the level defined as Initial Output Voltage before the measurement. Loop check is for checking the voltage level to find an abnormal control loop.

In this item, an abnormal detection criteria for Loop check must be selected from the following ;

1. Severe : The severest criterion for a specimen with a good linearity.
2. Normal : The criterion allows an ordinary level of non-linearity.
3. Loose : The criterion allows a larger non-linearity. Use this criterion when the Loop check is failed in the 'Normal' setting.

4.3.5 Initial level

(1) Meaning

Before testing on the basis of the defined reference waveform, a trial run of the specimen or excitation system may be needed : reproduce the waveform analogous to the reference waveform at a lower excitation level.

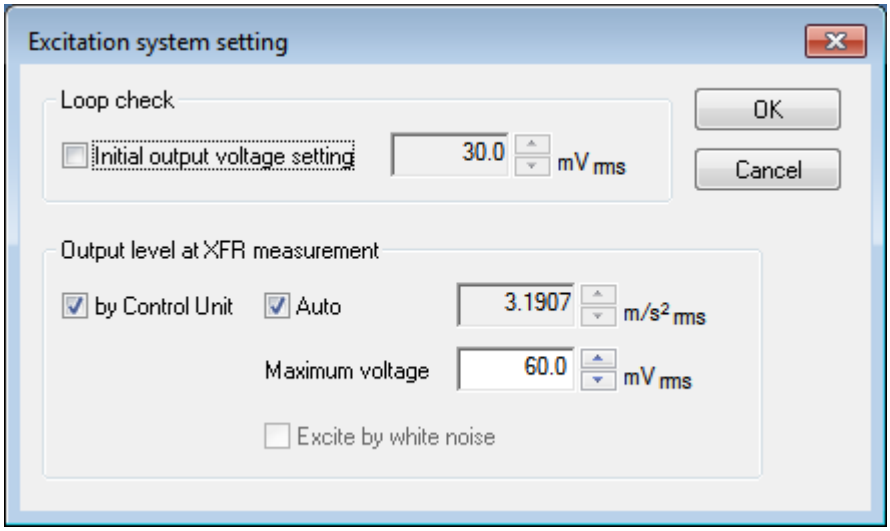
The lower excitation level, which is the reference to reproduce the initial waveform, is called the Initial level.

This item defines the Initial level, which is defined in the form of a percentage having the reference level (100 % [0 dB]) as the standard.

The setting of excitation level can be changed (less than 100 %) any time during the testing of actual excitation, but it is easy to make the mistake of doing excitation at 0 dB from the beginning. This can be avoided by first setting the required value. This item helps you to avoid making this mistake.

4.4 Excitation System setting

In this dialog, the items concerning with the excitation and the output system of control are defined.



4.4.1 Initial output voltage setting

(1) Meaning

Initial Output Voltage is the voltage which is given at first to a vibration generator for the initial Loop check.

The set value is specified by the unit of [mV] for the voltage in RMS.

When this item is not defined, the value of Initial output voltage (mVrms) defined in Excitation System Information is used automatically.

Note) The value of Initial output voltage should be set properly for the shaker to be used.

4.4.2 Output level at XFR measurement

(1) Meaning

Following two types of methods are available to specify the Excitation Level at measurement of XFR Function ;

1.Specify by Output Voltage

2.Specify by Control Unit

When this item is specified by Output Voltage, the voltage level (RMS) of drive signal given to a generator is defined to make excitation for the transfer function measurement.

When this item is specified by Control Unit, the Excitation Level (RMS) is defined for the transfer function measurement.

When the excitation for transfer function measurement is controlled, the random drive signal is outputted after the response frequency component (the average of more than one component) is equalized to have almost flat characteristics

This item defines the level of the drive voltage waveform.

When this item is specified by Control Unit, the level of Output Voltage is calculated by the system gain obtained in Loop check and the response level specified. However, the output voltage level will be limited to the maximum voltage. The initial-value setting for the maximum voltage is double the initial output voltage.

In the case of specifying by Control Unit, the Excitation Level can be specified automatically.

When the check box of 'Auto' is selected, the system defines the Excitation Level as a function of Reference Peak Value automatically.

The theory of Excitation Level definition is based on the guideline that operating the transfer function measurement by using the required level as lower as possible. Concretely, the Excitation Level (RMS) is defined as –20 ~ -40 dB of Reference Peak Value as below ;

Reference Peak Value	Excitation Level (RMS) of XFR Measurement
1m/s^2	0.1 m/s^2
10m/s^2	0.46 m/s^2
50m/s^2	1.36 m/s^2
100m/s^2	2.15 m/s^2
500m/s^2	6.3m/s^2
1000m/s^2	10m/s^2

When you use the drive having flat frequency characteristics not the drive that makes the response frequency characteristics flat, check 'Excite by white noise'.This setting is valid when Output level at XFR measurement is specified by Output Voltage (when 'by Control Unit' is not checked).

4.5 Input Channel

4.5.1 Outline

In this system, there are two types of response input channel ;

Control channel

Monitor channel

In this system, all of the used input channels are defined as Monitor channels.

Therefore, an input channel specified as Control channel also has the function as Monitor.

Control channel is the most important one of which response signals are controlled to meet with the control reference. And, only one Control channel is available to be specified.

Physical quantity controlled by the control channel must have the same dimension.

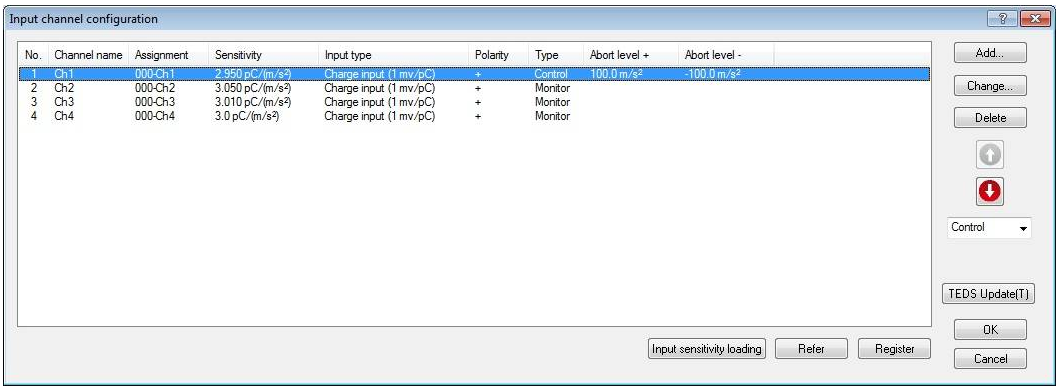
4.5.2 Input Channel

The input channels to be used are set in the definition dialog of Input Channel.

Two setting methods of input channel are available in this system ;

Set the input channels for each Test Definition

Set the input channels by referring to the Input Channel Information



[Add] : The use of a new input channel is declared.

[Change] : The definition of declared input channel is changed.

[Delete] : The declared input channel is deleted.

[Up] [Down] : The registered order of an input channels is corrected.
The registered order has mot much meaning than the order of graph display.

[Not used] : The channel is not used.

[Control] : The channel is used as a control channel.

[Monitor] : The channel is used as a monitor channel.

[TEDS Update] : The input sensitivity is set from the connected TEDS corresponding IEPE sensor automatically. The function is enabled with the TYPEII hardware.

[Refer] : The registered definition contents of input channel configuration is loaded and used.

[Register] : The defined contents of input channel configuration is saved and registered as a file.

4.5.3 Input sensitivity loading

The [Input sensitivity loading] button is for loading the sensitivity data directly from the sensitivity data file of CSV format in the dialog of Input Channel Configuration.

File format : the file format to be loaded is displayed as ;

1st line : comments

2nd line and below : sensitivity data

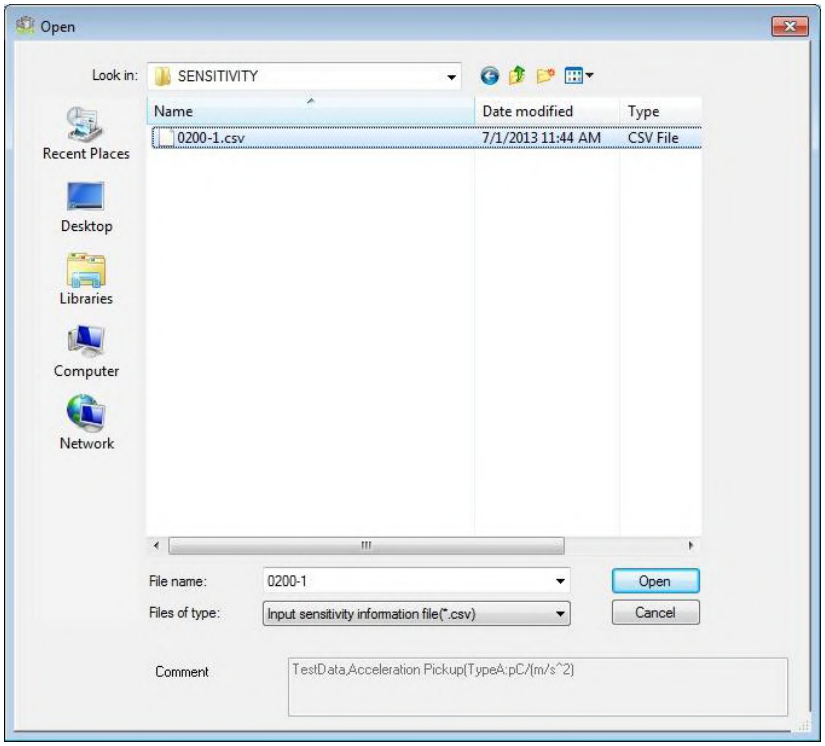
For example, the data of “n line, 1st column” is described as below ;

Sensitivity File.csv

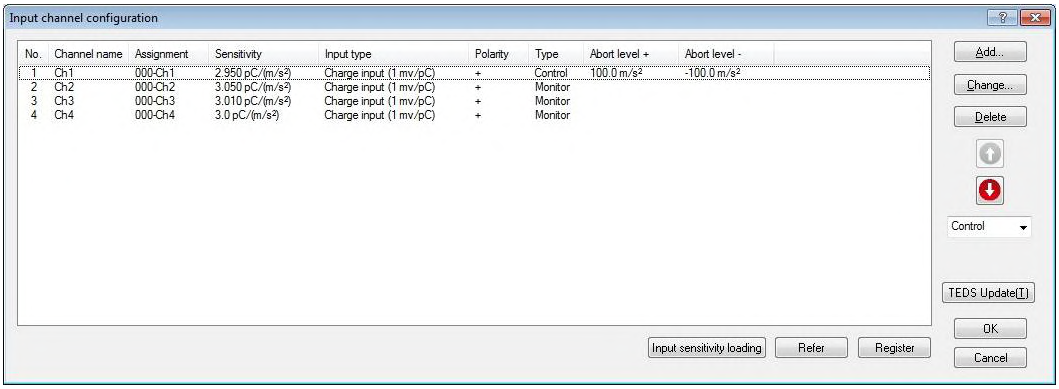
	A	B	C	D	E
1	TestData,Acceleration Pickup(TypeA:pC/(m/s^2)				
2	2.95				
3	3.05				
4	3.01				
5	3				
6					

The operation method of sensitivity data loading is ;

The dialog appears when the [Input sensitivity loading] button is pressed in Input Channel Configuration.



Select a file and press [Open] to load the input sensitivity data.



Note) The loaded input sensitivity data is automatically allocated to the channels in order. Therefore, the sensitivity data will not be allocated for the rest of channels when the number of channels is more than the number of sensitivity data. And the reverse case, the sensitivity data allocating is stopped when all the data is loaded for all the channels.

Input sensitivity data file needs to be closed when it is loaded. Loading operation is impossible to execute while the file is opened.

4.6 SRS Analysis Condition (SRS Option)

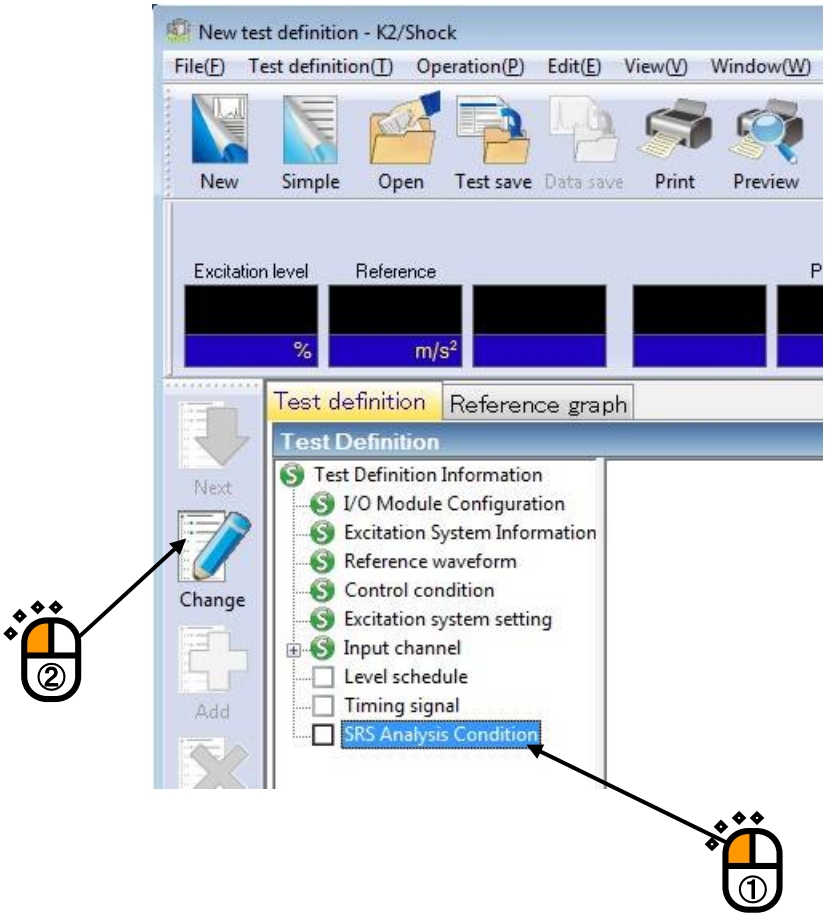
In a test other than SRS_SHOCK, the analysis condition is defined for SRS Analysis of the monitor response.

On the other hand, in a test of SRS_SHOCK, the SRS Analysis for Monitor Response is always available to operate and the analysis condition is as the same as that defined in Reference SRS.

< Procedures >

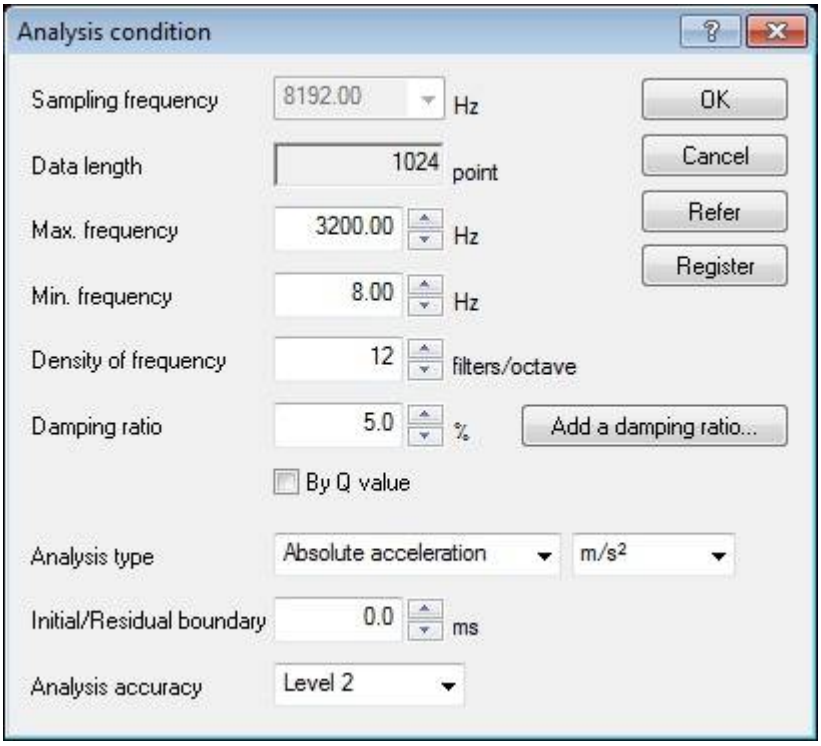
<Step 1>

Select 'SRS Analysis' and press the [Change] button.



<Step 2>

Define the items in SRS Analysis Condition.



The values of Sampling Frequency and Data Length have already defined in Reference Waveform. These values are not to be defined in SRS Analysis Condition.

4.6.1 Max. Frequency of Analysis (Max. Frequency)

(1) Meaning

This item is for specifying the maximum value of frequency range at SRS Analysis. SRS is obtained by calculating the response of each SDOF system configured for each Density of Analysis within the segment between Min. Frequency of Analysis specified in the following item and Max. Frequency of Analysis specified in this item.

4.6.2 Min. Frequency of Analysis (Min. Frequency)

(1) Meaning

This item is for specifying the minimum value of frequency range at SRS Analysis. SRS is obtained by calculating the response of each SDOF system configured for each Density of Analysis Frequency within the segment between Min. Frequency of Analysis specified in this item and Max. Frequency of Analysis specified in the above item.

4.6.3 Density of Analysis Frequency (Density of Frequency)

(1) Meaning

This item is for specifying the density of SDOF system filters prepared to operate SRS Analysis.

That is, in this item, the number of SDOF system to be set for each 1 octave is set. (filters/octave)

Total number of SDOF filters to be composed is defined by the specified value of this item and the specified values of Min./Max. Frequency Analysis. Maximum of total number is **256** in this system.

4.6.4 Damping Ratio of SDOF System (Damping Ratio)

(1) Meaning

This item is for specifying the common value to all the filters as damping ration of SDOF system filters prepared to operate the SRS Analysis as below ;

$$\zeta = \frac{C}{C_C}$$

Where, C_c is the criteria damping factor of SDOF system ;

$$Cc = 2\sqrt{mk}$$

Generally, the value Q and the damping ratio ζ is related as below ;

$$Q = \frac{1}{2\zeta}$$

4.6.5 Analysis Type

(1) Meaning

This item is for specifying the type of output waveform data to be calculated, that is, the type of SDOF System to be defined.

One of the following types of output waveform can be selected ;

a. Absolute Acceleration Output Waveform
b. Relative Displacement Output Waveform

4.6.6 Initial / Residual Boundary

(1) Meaning

This item is for setting of a data which denotes an effective completion time of input waveform and is used as the base for calculating the initial response SRS (+I, -I, absI) and the residual response SRS (+R, -R, absR) in the process of SRS Analysis operation (which defines the boundary of 'Initial' and 'Residual').

The setting of this item influences the SRS data to be obtained largely **but does not influence the maximax SRS**.

4.6.7 Analysis Accuracy

(1) Meaning

This item is for selecting the accuracy of simulation calculation operation to obtain the output waveform from SDOF system.

Analysis Accuracy can be selected among the 5 levels from ‘Level 1’ to ‘Level 5’.

When a larger number of level is set, the calculation becomes more accuracy and the calculation takes more time (increasing almost exponential functionally).

The schedule of operating the interpolation is automatically dedicated according to the resonance frequency of each SDOF system.

In ordinal cases with Damping Ratio < 10 %, enough accuracy can be obtained by the setting of ‘Level 2’.

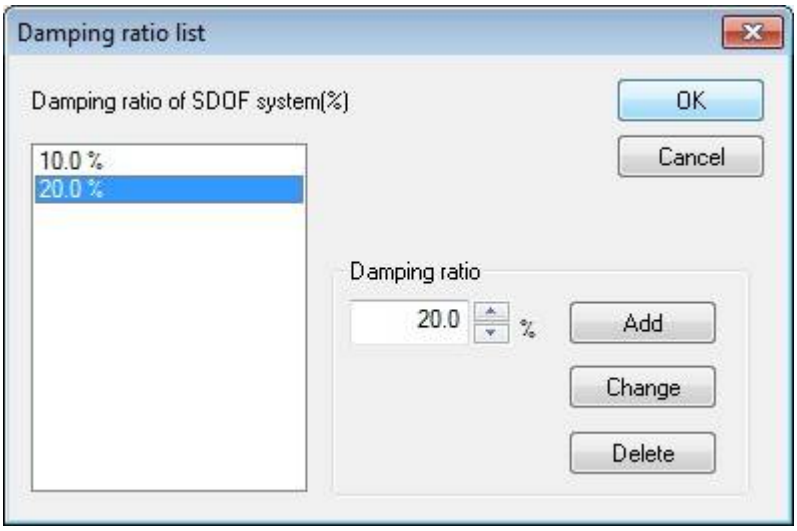
4.6.8 Multiple Damping Ratio

(1) Meaning

In addition to the Damping Ratio specified in 4.6.4 Damping Ratio of SDOF System, SRS Analysis by multiple Damping Ratios is simultaneously operated. However, in SRS Analysis by multiple Damping Ratio, only the **maximax SRS** is analyzed.

Press [Multiple Damping Ratio] button when multiple Damping Ratios of SDOF System is needed to be specified. The dialog box as below appears by pressing of [Multiple Damping Ratio].

Press [Add] and input the value of SDOF Damping Ratio.



4.7 Level Schedule

This function is for operating the test by scheduled excitation level.

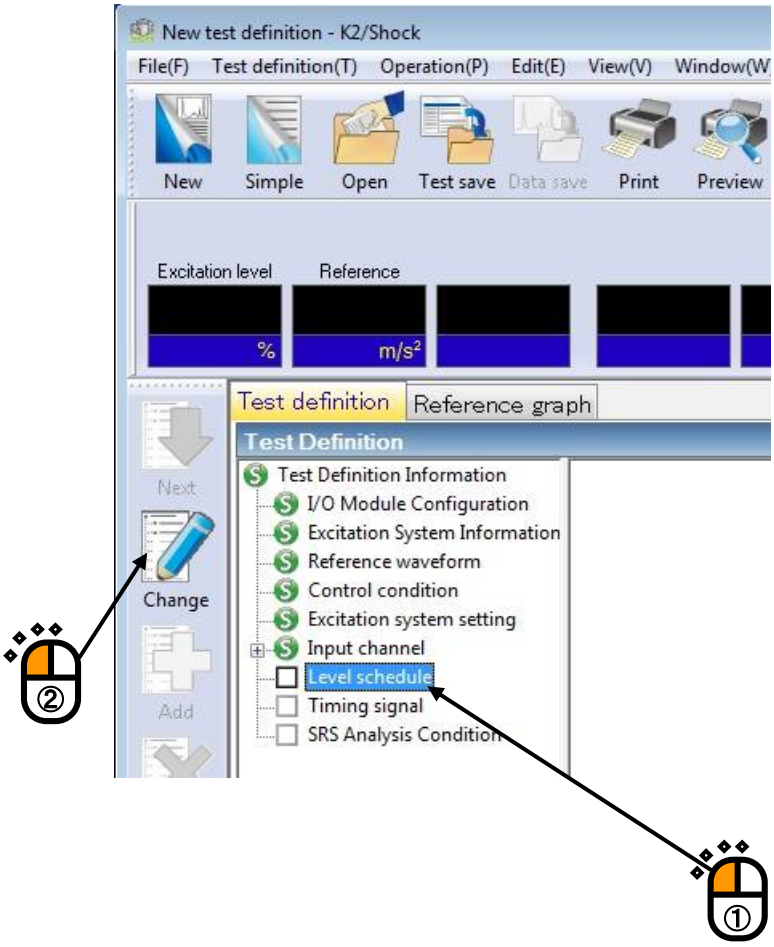
The schedule condition of Excitation level, Excitation count and Iteration are specified in each item of Level Schedule.

The excitation operation is selectable between by a normal operation or by a level scheduled operation at the excitation start even if the Level Schedule has been defined.

< Operation procedures (definition) >

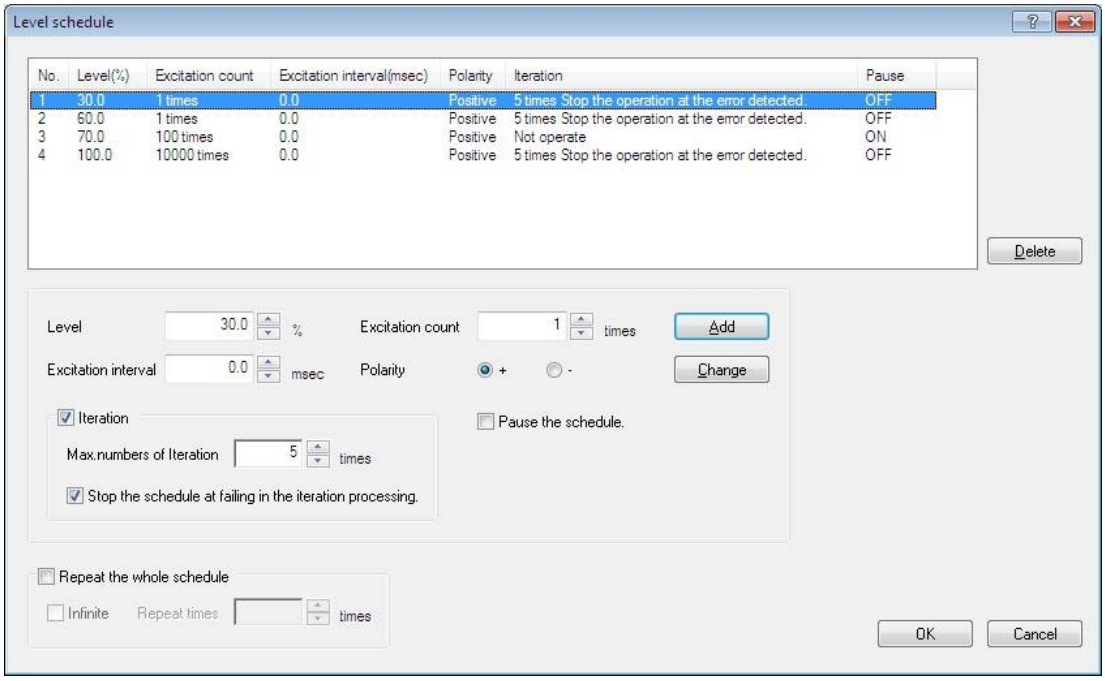
< Step 1 >

Select the item of Level Schedule and press the button of [Define].



< Step 2 >

Define the ‘Level Schedule’.



The following buttons are used for setting and registering of each schedule item.

[Add] : This button is for registering a new schedule item
After inputting the values to Level and Time, press this button to register and display the current schedule in the list.

[Change] : This button is for changing the values of a registered schedule.
Selecting a schedule by a mouse, input the values to be changed and press this button.

[Delete] : This button is for deleting the registered schedule.
Selecting a schedule to be deleted by a mouse, press this button to delete it.

4.7.1 Level

(1) Meaning

This item is for setting of the excitation level.

4.7.2 Excitation count

(1) Meaning

This item is for setting of the excitation count (times of repetitive excitation).

When the schedule is operated, the excitation operation is repeated for the specified times of this item.

The excitation count of Iteration process is not included in this excitation count.

4.7.3 Excitation interval(Time interval)

(1) Meaning

This item is for setting of the time interval of repetitive excitation.

4.7.4 Polarity

(1) Meaning

This item is for setting of the excitation polarity (excitation direction).

4.7.5 Iteration

(1) Meaning

Tolerance check and Iteration process are to be scheduled to operate by setting of this item before the repetitive excitation is operated for the times specified in Excitation count.

When this item is activated, Tolerance check is operated before the repetitive excitation operation. And Iteration process is also operated when the Tolerance check results in NG.

Phase of Iteration is stopped and the repetitive excitation is started to operate when the system passes the Tolerance check as OK.

4.7.5.1 Max. Numbers of Iteration

(1) Meaning

The maximum times of Iteration processing is specified when Iteration is to be operated.

4.7.5.2 Stop the schedule at failing in the iteration processing

(1) Meaning

This item is for setting the schedule stop when the tolerance check results in NG even though the Iteration times are set to the maximum (at failing in the iteration processing).

When this item is set to activate, the system stops the schedule and shifts to the state of excitation completion at failing in the iteration processing.

On the other hand, when this item is not set, the system continues to proceed to the phase of repetitive excitation without stopping the schedule at failing in the iteration processing.

4.7.6 Pause the schedule

(1) Meaning

When this function is not set, the system proceeds to the next scheduled item automatically at completing of the excitation (repetitive excitation) of the current schedule.

When this function is set, the system pause the schedule and set the state of waiting for the operator’s command at completing of the excitation (repetitive excitation) of the current schedule.

4.8 Timing Signal

4.8.1 Outline

When you measure using an external instrument synchronizing with excitation, some signal from this system may be required as a Timing Signal.

When this item is used, a constant DC voltage is outputted for the specified timing synchronizing with the drive signal for control (reference signal).

The output channel for Timing Signal is available to specify for one among arbitrary output channels except the output channel specified for control.

4.8.2 Basic Operation

< Example >

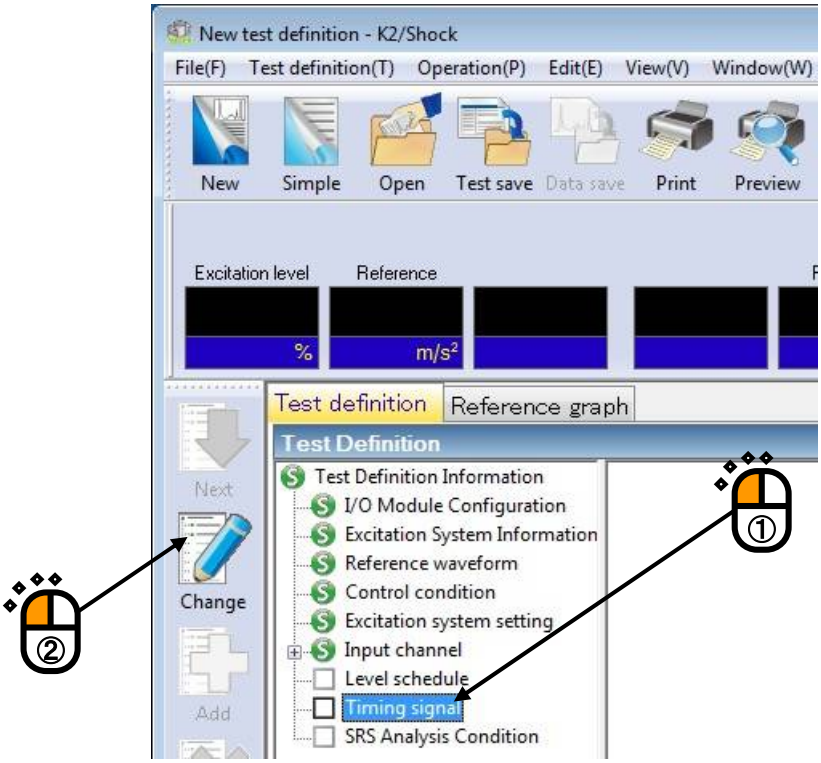
Timing signal of 5V is outputted for 100ms ~200ms synchronizing with Reference.

In this case, Ch.2 is used as the output channel for Timing Signal.

< Procedures >

<Step 1>

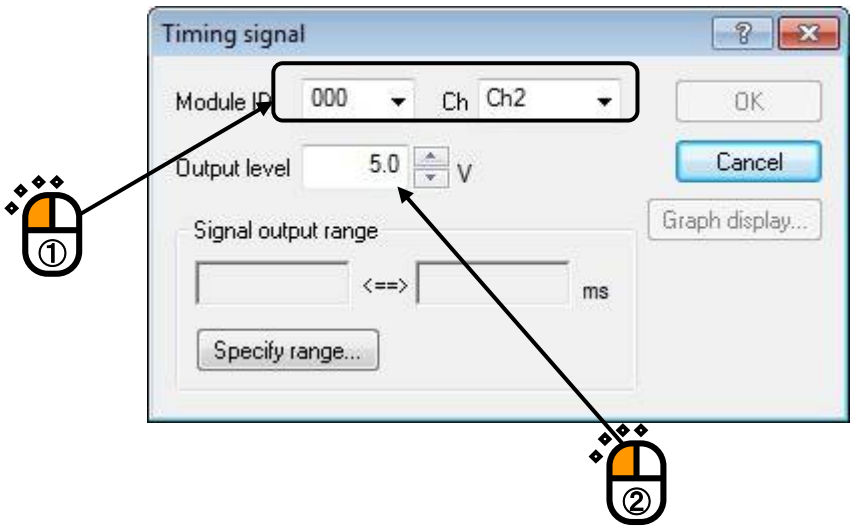
Select 'Timing Signal' and press the [Define] button.



< Step 2>

Specify the ‘Module ID’ and the output channel ‘Ch.’ as Ch2.

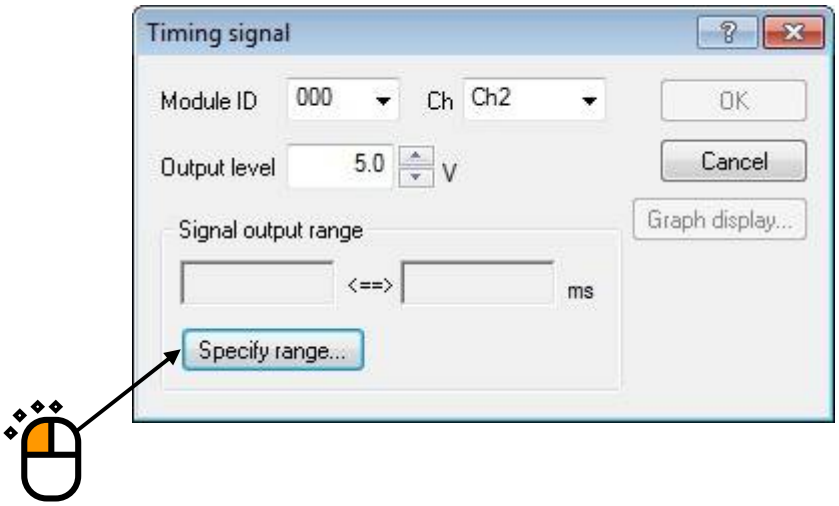
Input ‘5V’ to ‘Output Level’.



<Step 3>

Press the [Specify range] button in Signal Output Range.

The dialog of Signal Output Range setting appears by pressing of [Specify range].



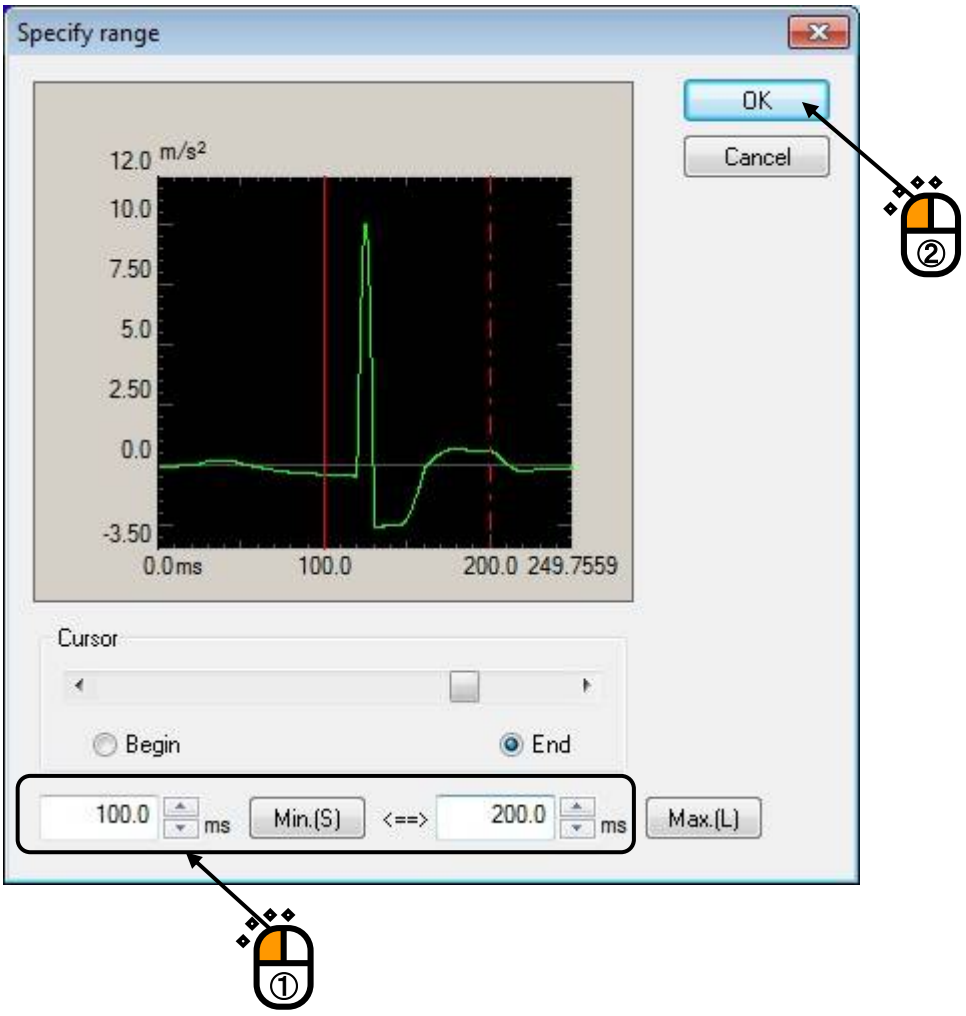
<Step 4>

Input ‘100ms’ as the value of ‘Begin’ and ‘200ms’ as the value of ‘End’.

Then, Press [OK].

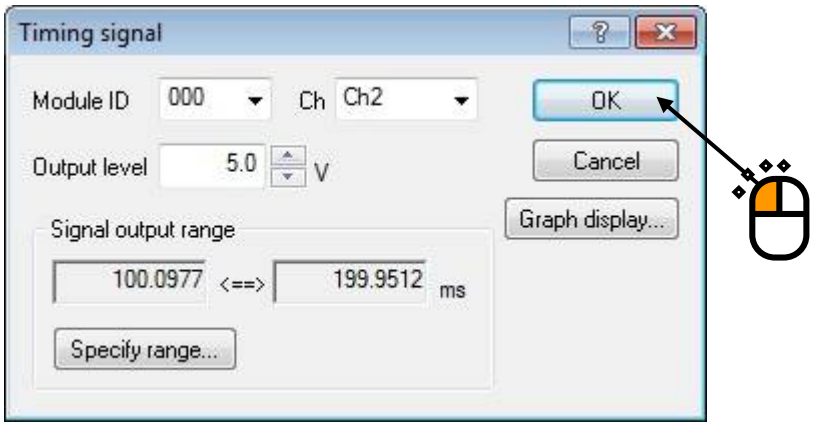
However, the specified value in these items are rounded off the nearest actual output time because the time interval of actual signal output is determined by Sampling Frequency.

Press [OK] to return to the definition display of Timing Signal.

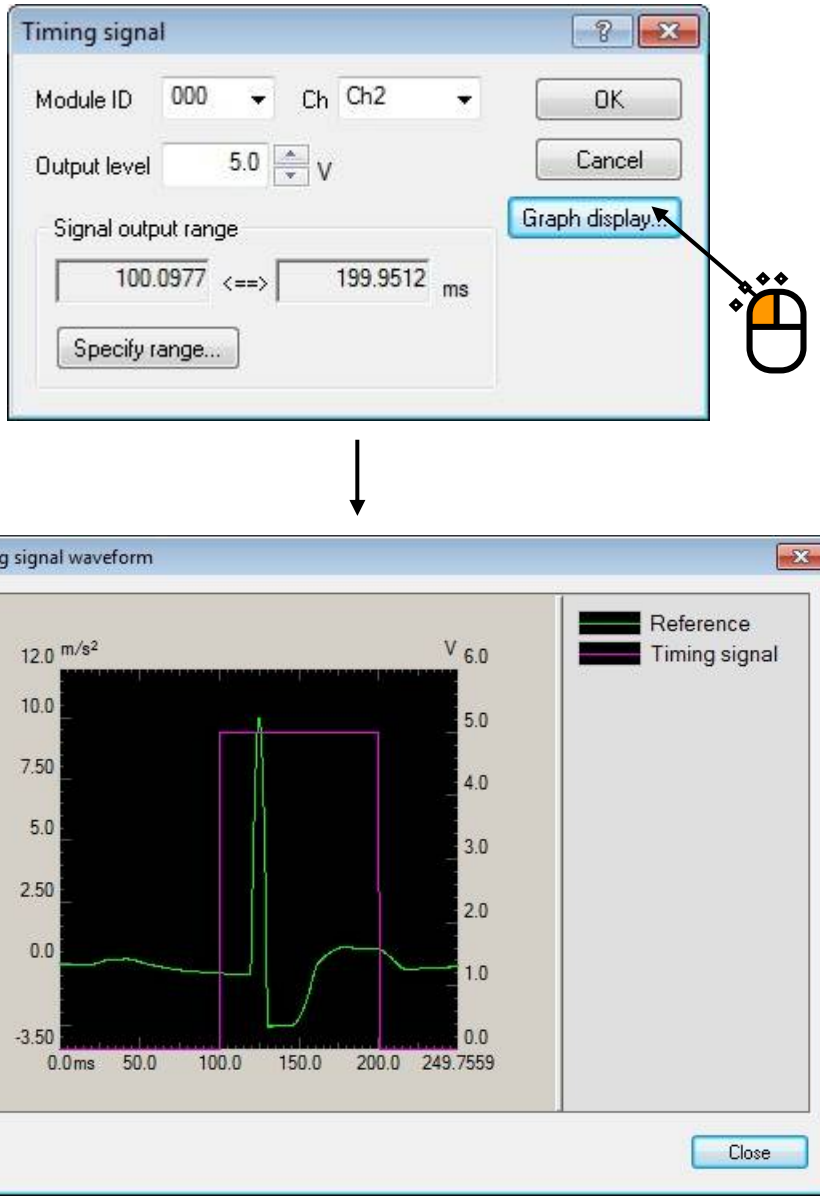


<Step 5>

Press [OK].



Where, the defined Timing Signal and Reference Waveform are displayed by pressing the [Graph] button.



4.9 Iteration (Correction of Drive data)

4.9.1 Outline

Iteration is one of methods for control accuracy improvement.

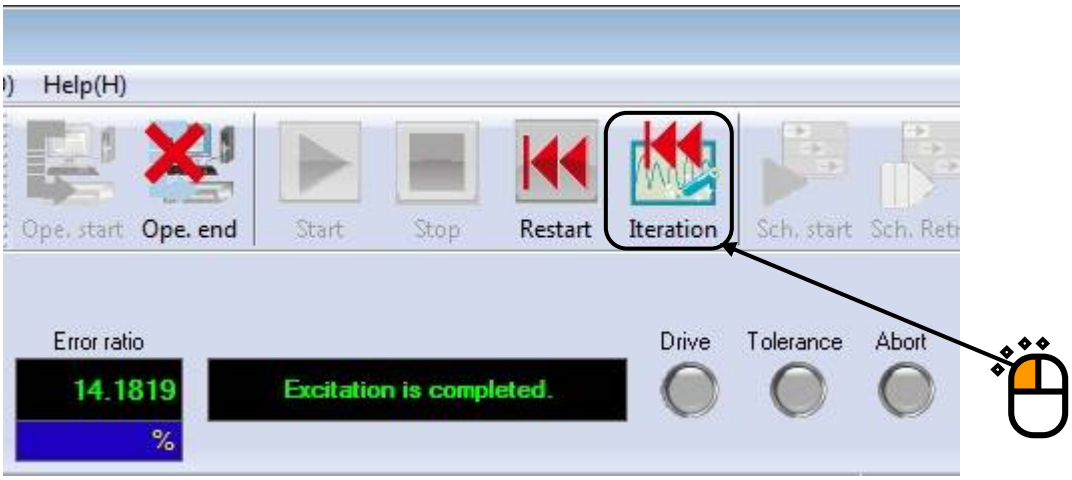
The control error data can be gotten from reference data and control response data.

And drive data is corrected for control error data to reduce.

4.9.2 Basic Operation

<Procedures>

Press the [Iteration] button in the state of 'Excitation completed'.



4.10 XFR renewal(Correction of XFR)

4.10.1 Outline

XFR renewal is one of methods for control accuracy improvement.

XFR function of the controlled system can be gotten from excitation result.

XFR function is renewed by using drive data and control response data.

The drive data has the following options.

・Case to replicate the drive data.

The new drive data is replicated by using the renewed XFR function and the reference data.

The system state proceeds to ‘Waiting for excitation start’.’ from ‘Excitation completed’.

・Case not to replicate the drive data.

XFR function is renewed and the current drive data is used.

Then the system is set to the state of ‘Excitation completed’.

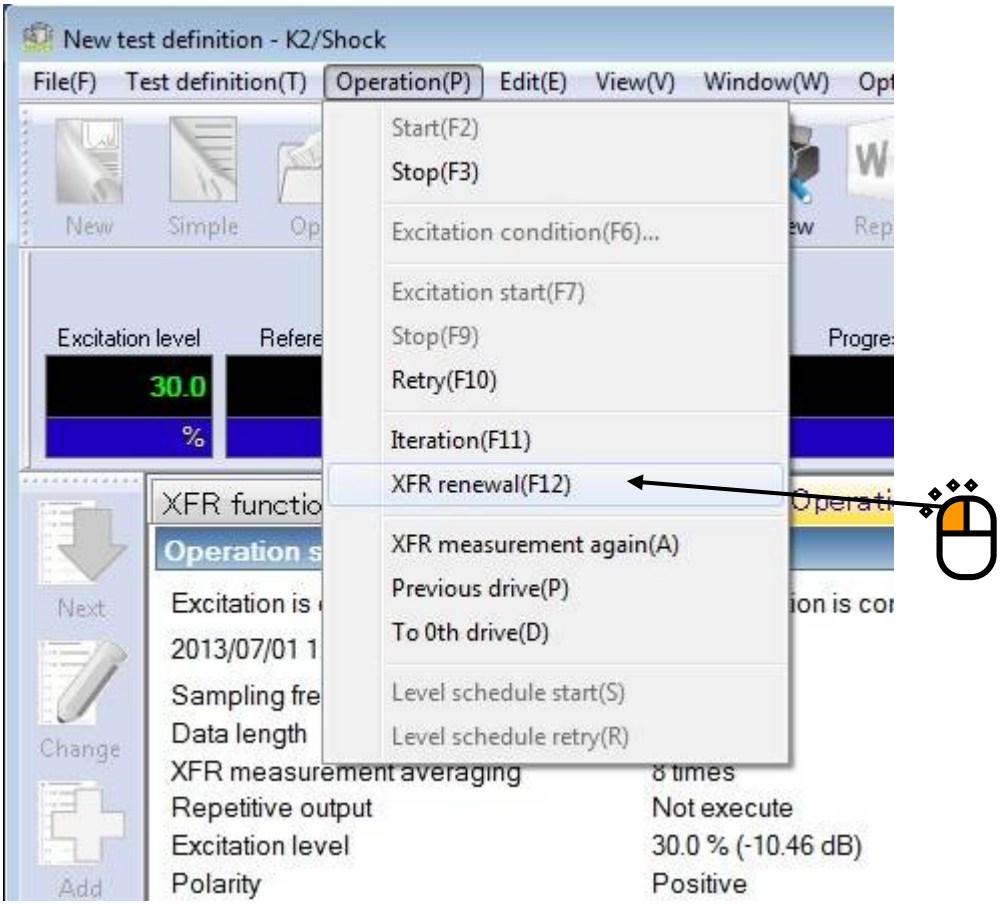
When ‘Iteration’(refer to ‘4.9 Iteration’) is executed in this state, the current drive data is corrected by using the renewed XFR function.

4.10.2 Basic Operation

<Procedures>

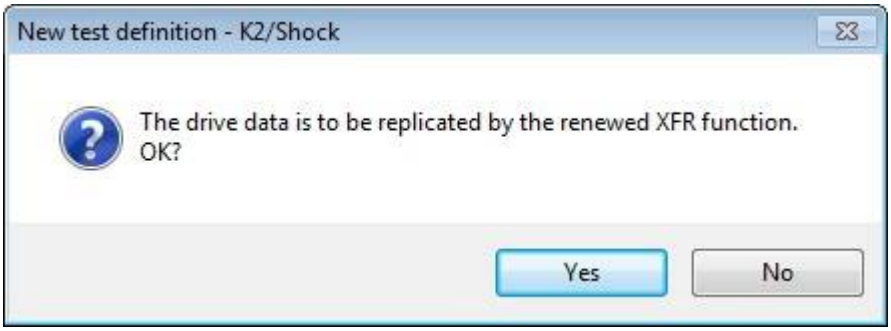
＜Step1＞

Select [Operation] → [XFR renewal] in Menu bar in the state of ‘Excitation completed’.



＜Step2＞

Select whether to replicate the drive data by using the renewed XFR function.



・Case to replicate the drive data

The current drive data is discarded and the new drive data is replicated by using the renewed XFR function.

Then the system is set to the state of ‘Waiting for excitation start’.

・Case not to replicate the drive data

XFR function is renewed and the current drive data is used.

Then the system is set to the state of ‘Excitation completed’.

Refer to ‘4.9 Iteration’ about the following operation.

4.11 Drive data edit

CAUTION

This is the function to edit directly the drive signal that drives excitation system.
The improper edit may result in property damage or injury.
Please pay attention to this operation.

4.11.1 Outline

This function is for editing the current drive waveform by changing the level of drive spectrum.
Drive data edit has 2 methods.

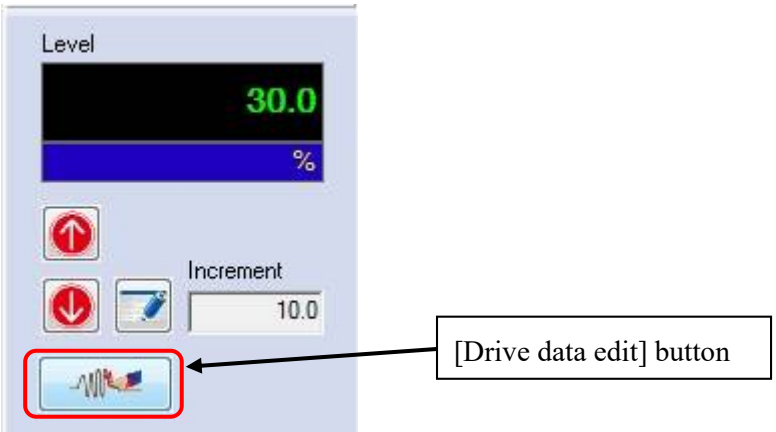
- Specify the pattern of weighting factor(selection range:0～1) in arbitrary frequency range and filtering drive waveform using this weighting factor.
  It is possible to specify objective region of this editing in time domain.
- Specify PSD level at arbitrary frequency and generate drive waveform.

This function is valid in the state of 'Waiting for excitation start'.

＊1) The level in frequency domain cannot be set exceeding level of original data.
＊2) The time domain that this editing is executed might be different from the definition because of using FFT.

4.11.2 Specify frequency weighting factor

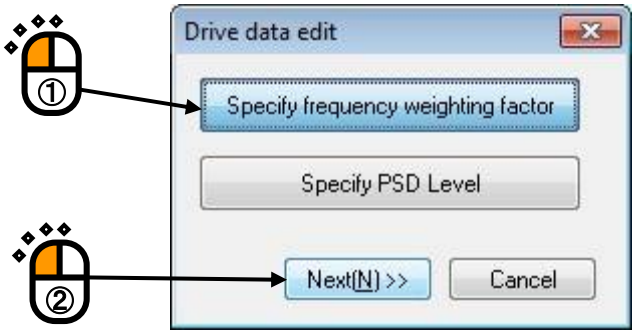
<Procedures>
<Step1>
Press [Drive data edit] button in Manual operation bar.



＜Step2＞

The dialog box as below appears.

Select 'Specify frequency weighting factor' and press [Next] button.



＜Step3＞

The drive data edit dialog box as below appears.

This procedure is as follows.

(1) Select the data name of drive waveform to be edited.

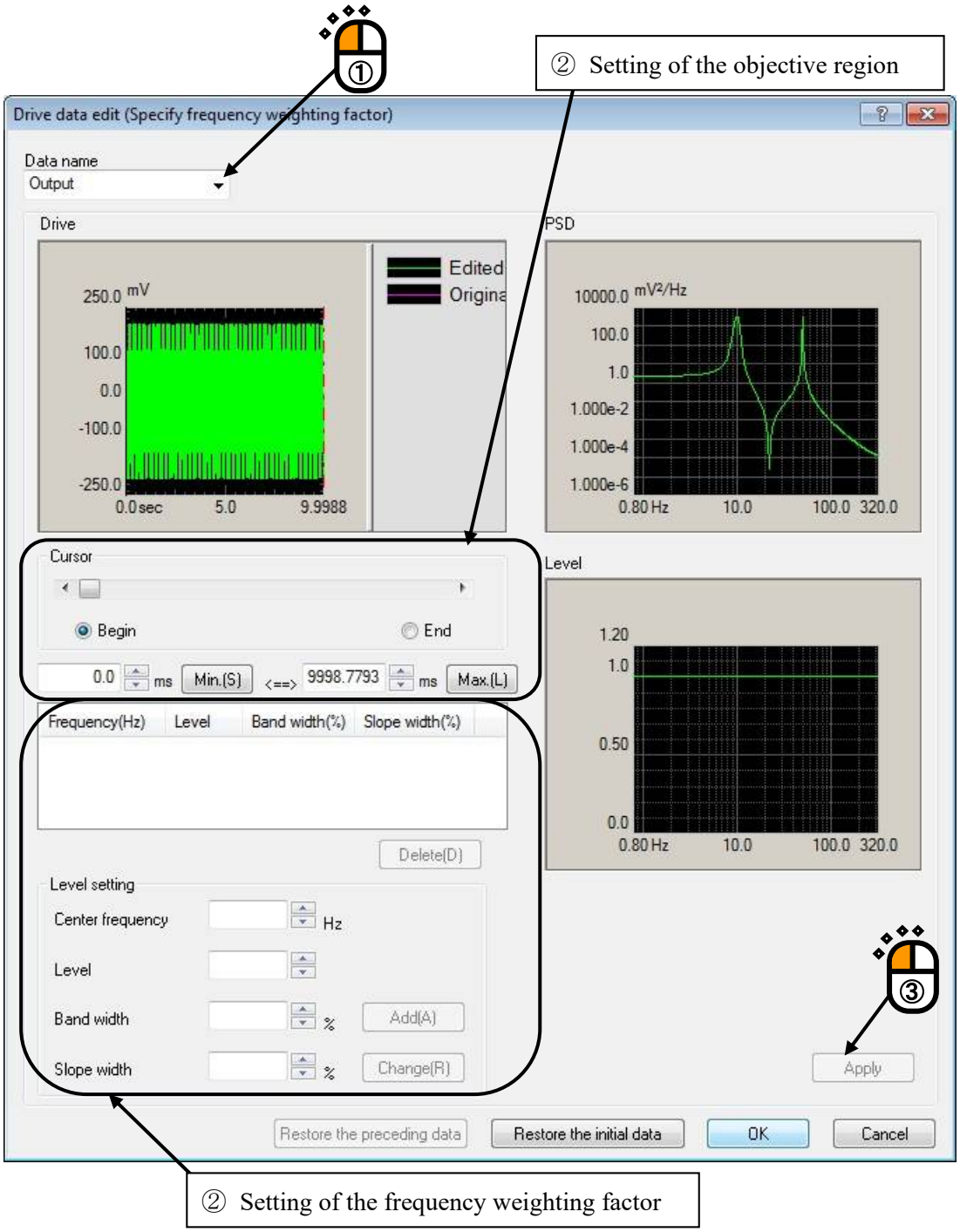
(2) Set the frequency weighting factor and the objective region.

・The frequency weighting factor is specified by Center frequency , Level, Band width and Slope width in Level setting.

・The objective region specified by begin and end point.

(3) Press [Apply] button.

（Repeat the operation of (2) ~ (3) as necessary.）



＜Step4＞

An example is described as below.

Drive signal is synthesized from sine wave of 10Hz and 50Hz and Data name is 'OUtput'.

Remove sine wave of 10Hz from this drive signal and the objective region of this editing is from 3sec to 7 sec.

(1) Specify the objective region.

Set 'Begin' to 3000[ms] and set 'End' to 7000[ms].

(2) Specify the frequency weighting factor in Level setting.

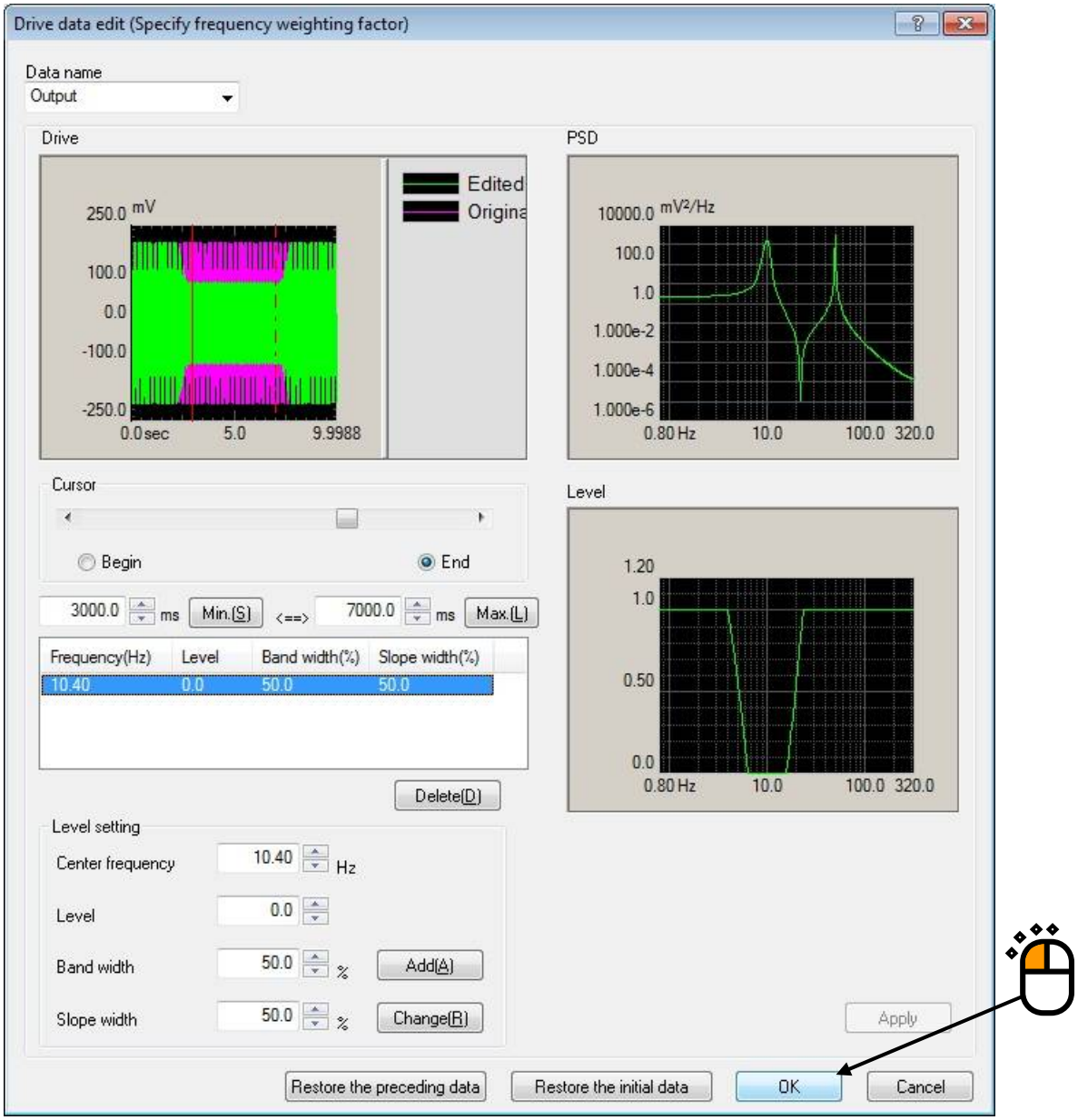
Center frequency : 10[Hz], Level : 0, Band width : 50[%], Slope width: 50[%]

(3) Press [Apply] button.

Editing of drive waveform is executed according to this setting.

The edited drive waveform and PSD are displayed.

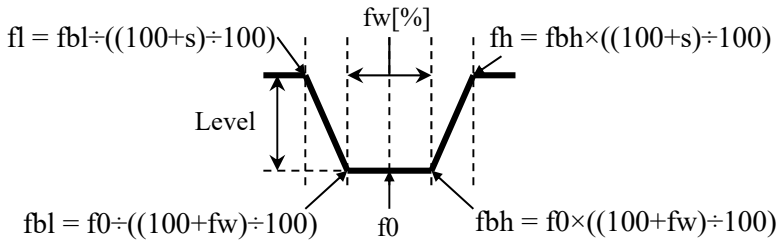
If the displayed data is proper, press [OK] button.



(Supplementation with setting of frequency weighting factor)

The method of specifying the frequency weight factor is as shown in the figure below.

Center frequency:f0[Hz], Band width:fw[%], Slope width: s[%]



These values in this example are as follows.

f0 = 10Hz

fbh = 10×((100+50)÷100) = 15Hz

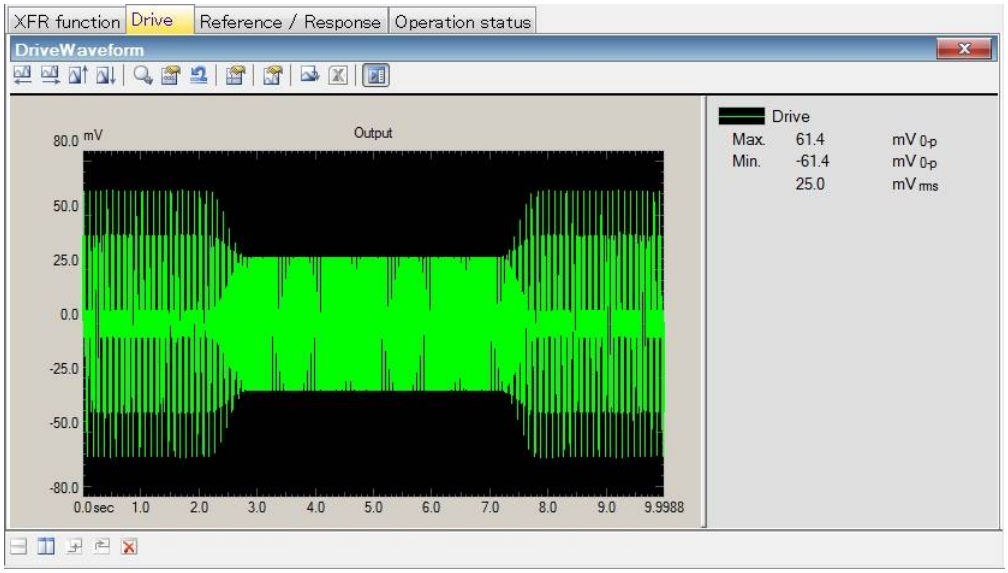
fbl = 10÷((100+50)÷100) = about 6.7Hz

fh = 15×((10+50)÷100) = 22.5Hz

fl = 6.7÷((10+50)÷100) = about 4.4Hz

＜Step5＞

When editing is executed in the state of ‘Waiting for excitation start’ The edited waveform is set as the drive waveform.



4.11.3 Specify PSD level

<Procedures>

<Step1>

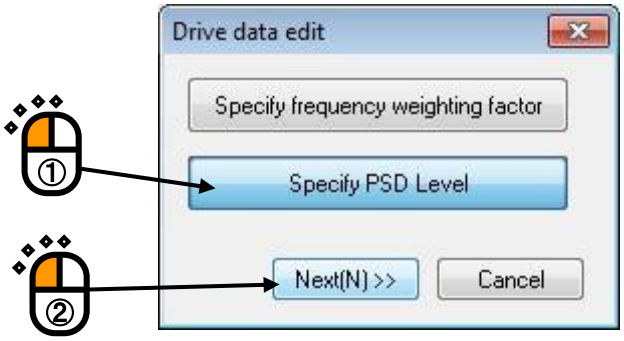
This function is valid in the state of 'Waiting for excitation start'. This is same as 'Specify frequency weighting factor' of the previous section.

＜Step2＞

Press [Drive data edit] button in Manual operation bar.

The dialog box as below appears.

Select 'Specify PSD level' and press [Next] button.

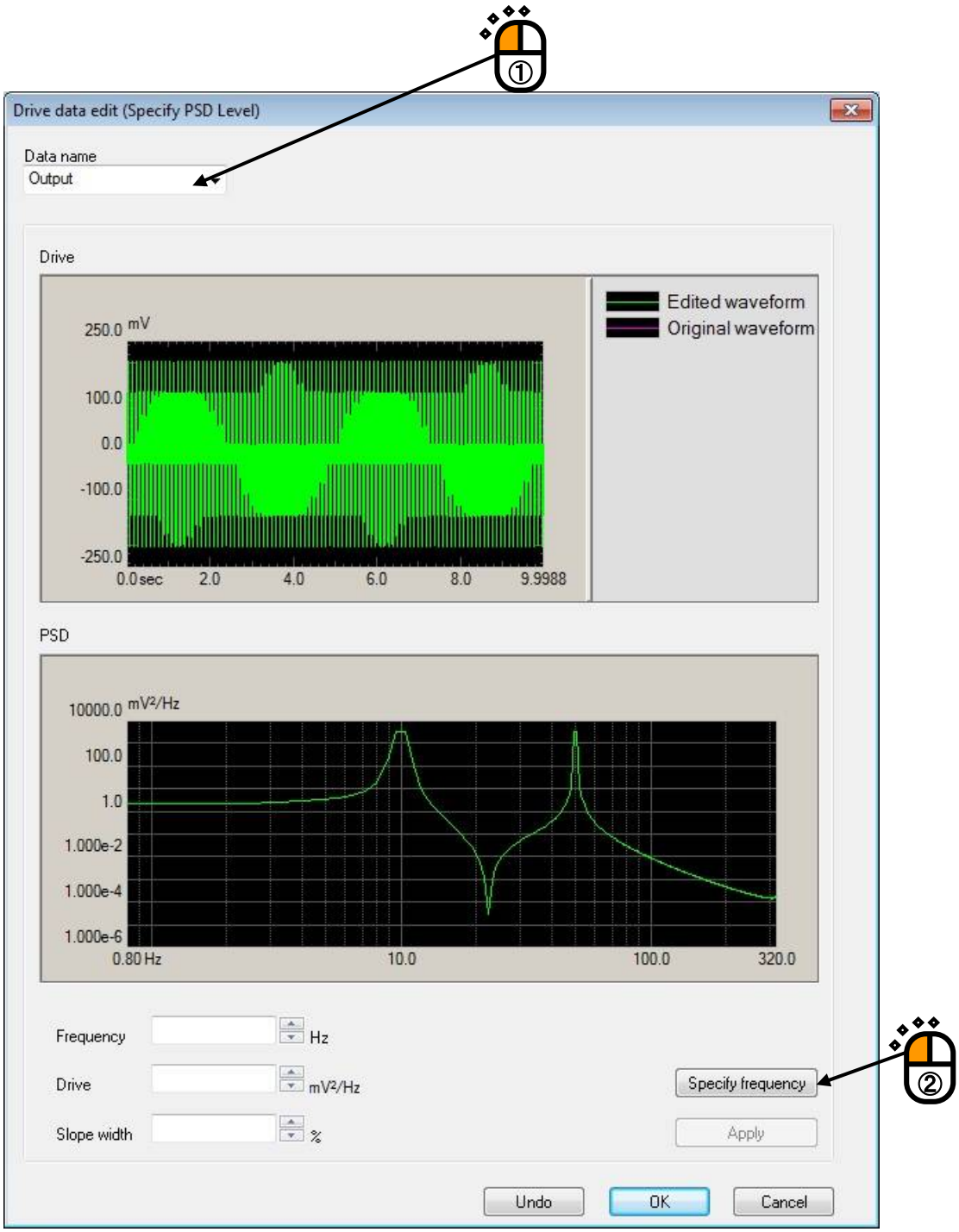


＜Step3＞

The drive data edit dialog box as below appears.

(1) Select the data name of drive waveform to be edited.

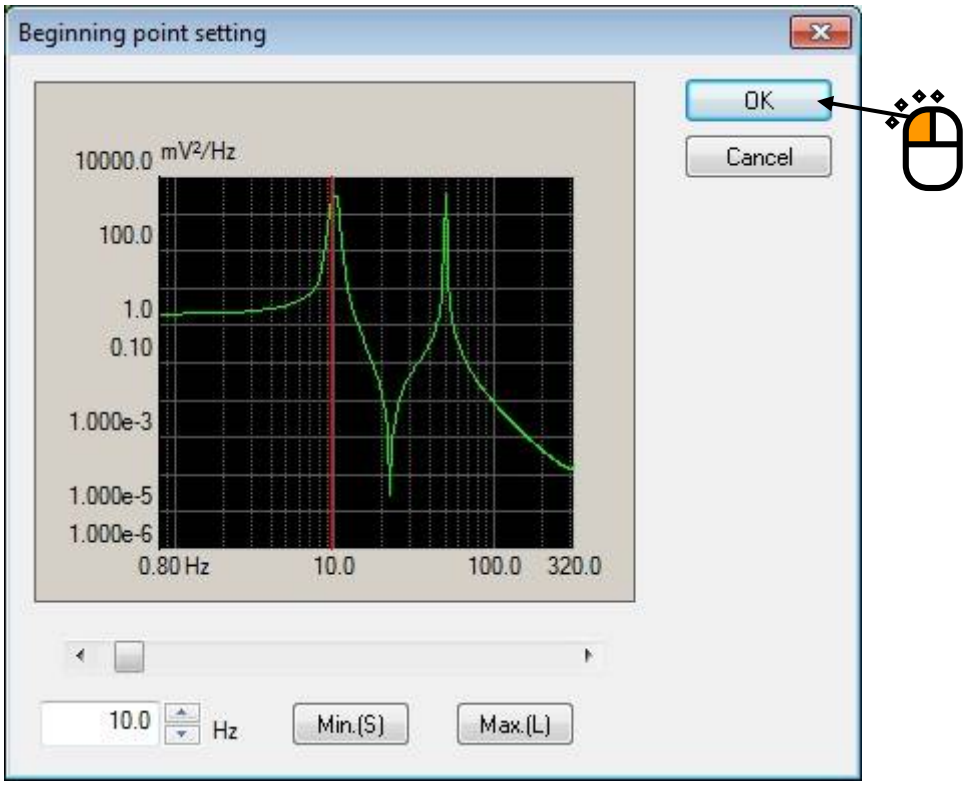
(2) Press [Specify frequency] button.



＜Step4＞

Set frequency by moving the cursor and press [OK] button.

Set frequency to 10[Hz] in this example.



＜Step5＞

The current PSD value at 10[Hz] is displayed in Drive.

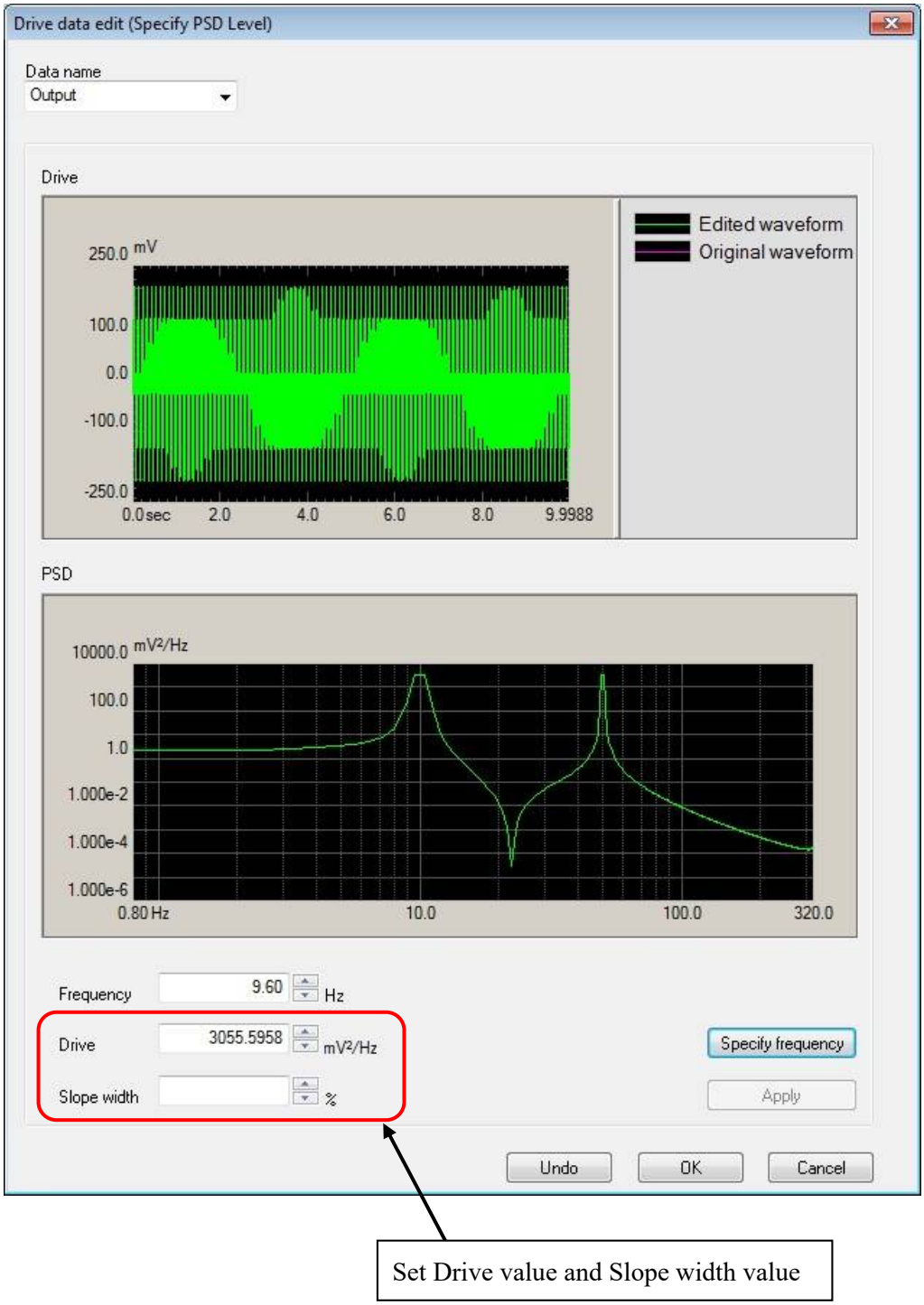
Set Drive to smaller value than this value.

When Slope is set to larger value than 0[%], PSD level is changed having the specified slope.

When Slope is set to 0[%], PSD level only at the specified frequency is changed.

*) The edited result becomes not same as setting value in Drive because of operation algorithm.

When slope is set to large value, the edited result becomes closer to setting value.

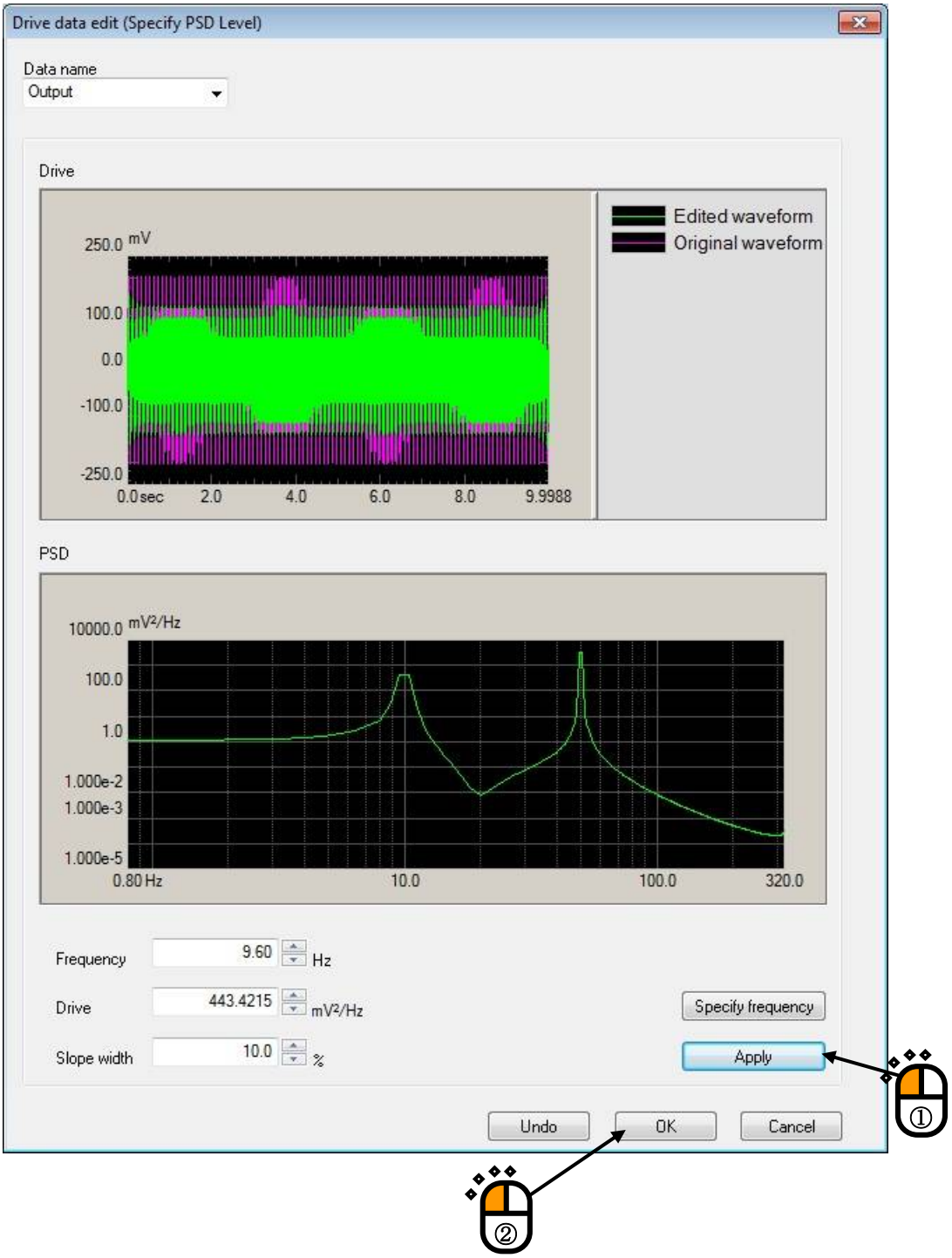


Set Drive value and Slope width value

＜Step6＞

After setting the drive value and the slope width, press the [Apply] button to display the waveform having the changed PSD level.

Press [OK] if it is proper.

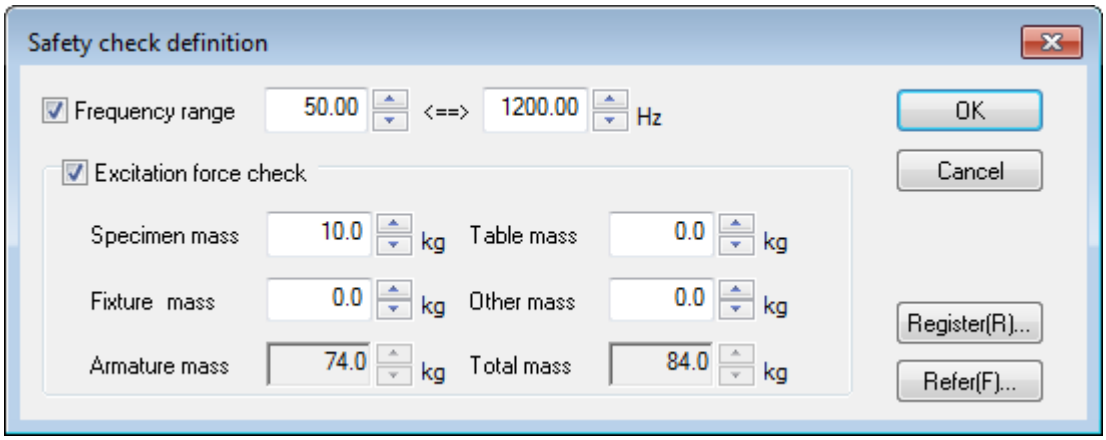


＜Step7＞

The edited waveform is set as the drive waveform.

4.12 Safety check

4.12.1 Outline



The system has the feature of Rating check*[1] to evaluate whether the defined test can be performed on the excitation system as a protective feature. The safety check expands this protective feature and makes it possible to use the excitation system more safely.

(1) Excitation force check

This check is made to evaluate whether the excitation force required for the test is held within the excitation system rating.

The excitation force F required for the test is calculated with the formula shown below.

$F = M a$

a: peak value of reference acceleration

M: Total mass

The total mass M is the sum of “Specimen mass, Table mass, Fixture mass and Other mass” entered in this dialog box and the “Armature mass” specified in the system rating information.

The excitation force check is effective only if the controlled variable was the acceleration.

(2) Frequency range check

This check is made to evaluate whether the control frequency is within the usable frequency range.

Although there is a similar protective feature of “control frequency range” setting in the excitation system information, this is a feature to perform this check for each test.

While the usable frequency range for the excitation system is defined, it may be limited depending on the characteristics of specimen and fixture etc.. Use this feature in such cases.

[Refer] : The registered definition contents of Safety check is loaded and used.

[Register] : The defined contents of Safety check is saved and registered as a file.

*1 Feature of standard rating check

1) This check is made to evaluate whether the reference level is held within the excitation system rating. If the controlled variable was the acceleration, the velocity and displacement will also be checked.
   Refer to ‘6.7 System Rating Check’ about the details.
2) If a “control frequency range” was specified in the excitation system information, a check is made to evaluate whether the control frequency is within the “control frequency range.”

Note)

When specimen and/or fixture is attached to the armature, it may occur that the required acceleration level can not be reproduced within the usable frequency range because of resonance or anti-resonance of the attached specimen and / or fixture.

Chapter 5 Reference Waveform Definition

5.1 Reference Waveform

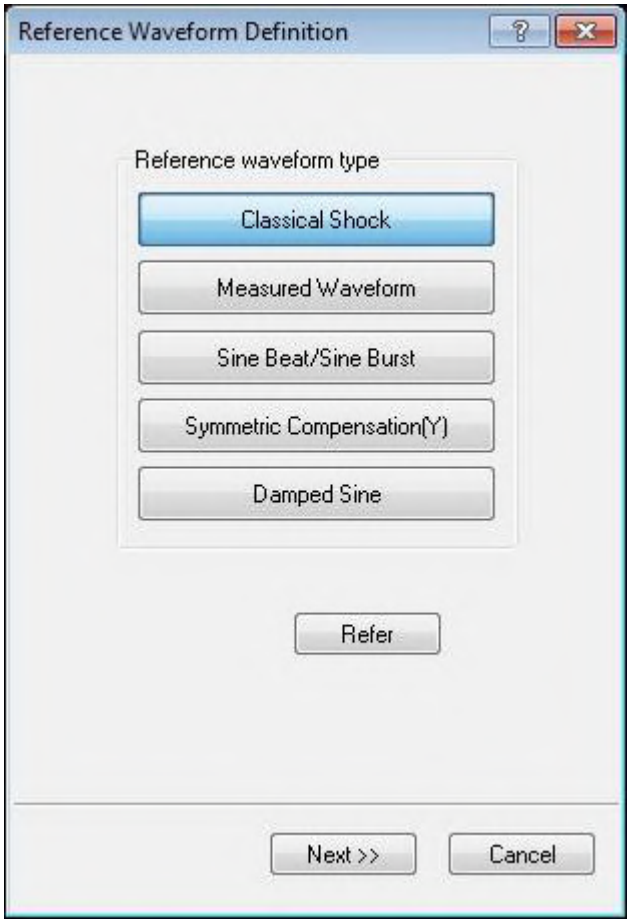
Reference Waveform is generated.

The reference specified in definition decides the waveform to be generated on the shaker table.

Available Reference Waveform types to be defined in this system are as below ;

- Classical Shock
- Measured Waveform
- Sine Burst / Sine Beat
- Defined Waveform (Symmetric Compensation)

Select one among the available Reference Waveform types displayed in the dialog box of Reference Waveform Definition as below. And press the [Next] button to define each Reference Waveform selected.



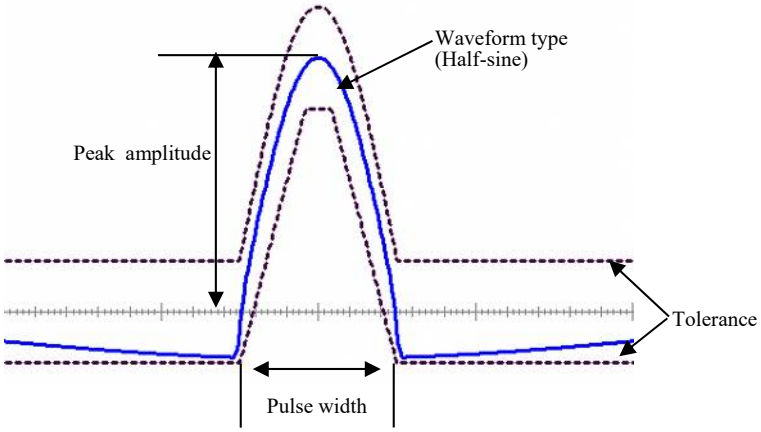
5.2 Classical Shock

Acceleration waveform data based on the requirement defined by each Shock Testing Specification is generated.

This item is available only when the dimension of controlled variable is specified as ‘Acceleration’.

Classical Shock waveform is expressed as an acceleration waveform as below and the shape of this waveform is specified by the following items ;

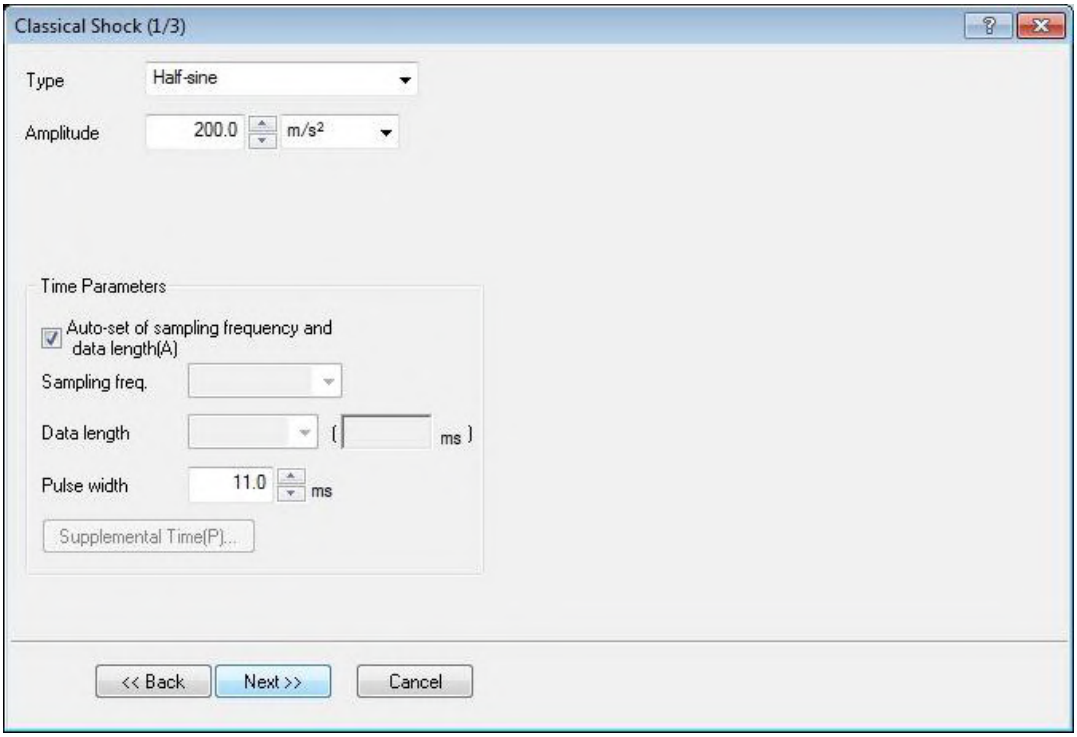
- Waveform type (Half-sine, Saw-tooth, Trapezoid)
- Peak amplitude (Peak Acceleration)
- Pulse width
- Tolerance [Test Specification] (IEC-68-2-27, MIL-STD-810C)



Classical Shock waveform is composed by the definition of two definition displays.

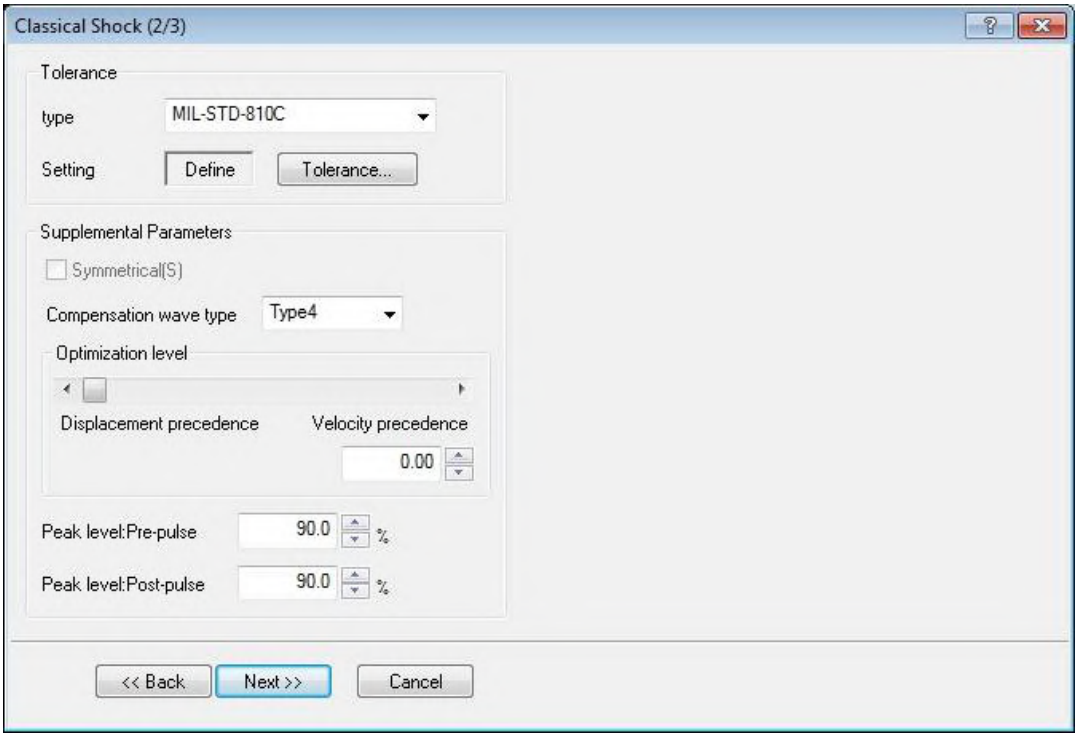
When [Classical Shock] is selected, the definition dialog of Classical Shock (1/3) to specify the following items appears;

- Waveform type
- Peak amplitude
- Pulse width etc. in Time Parameter



Press [Next] when these items are defined.

When the definition in the dialog of Classical Shock (1/3) is completed, the definition dialog of Classical Shock (2/3) to define Tolerance appears;



The definition of Classical Shock is completed when the Tolerance is determined.

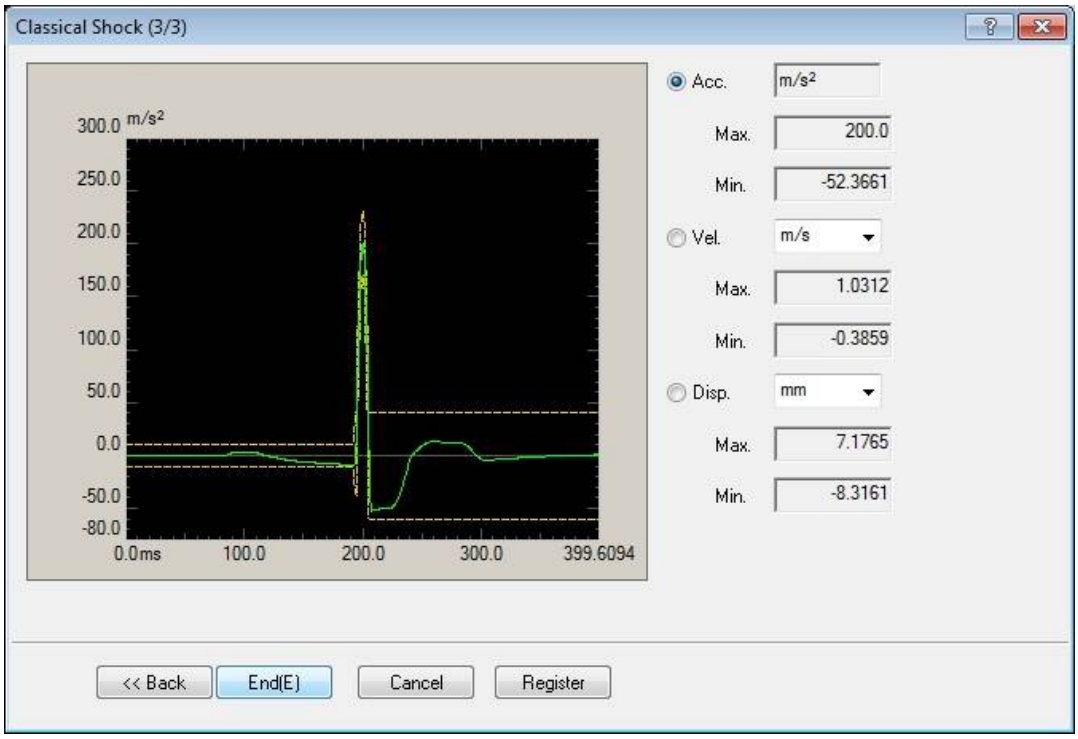
The generated acceleration waveform is displayed by pressing [Next].

The system returns to the definition dialog of Classical Shock (1/3) by pressing [Back].

When the definition in the dialog box of Classical Shock (2/3) is completed, the definition dialog of Classical Shock (3/3) appears. In this dialog of Classical Shock (3/3), the generated acceleration waveform is displayed.

The system returns to the definition dialog of Classical Shock (2/3) by pressing [Back].

The definition of Reference Waveform is completed by pressing [End].



5.2.1 Waveform type (Type)

(1) Meaning

This item is for specifying the type of waveform data to be generated.

1. Half-sine
2. Saw-tooth
3. Trapezoid
4. Triangle
5. Synthesize (Generalized Trapezoid)
6. Haversine

'Rise time' and 'Fall time' are specified in the following clause only when 'Synthesize' is selected as Waveform type.

5.2.2 Peak Amplitude (Amplitude)

(1) Meaning

Level of nominal waveform data to be generated is specified by peak value (0-p).

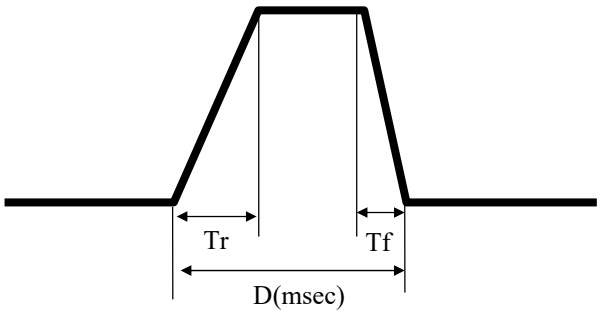
The value of this item should be set at the smaller value than maximum rating of excitation system to be used.

5.2.3 Rise time / Fall time

(1) Meaning

Rise time and Fall time are specified in the following clause only when 'Synthesize' is selected as Waveform type.

The set values of Rise time Tr and Fall time Tf are specified as percentage to 'Pulse width' D of nominal waveform data specified later.



5.2.4 Time Parameter

This item is for setting the parameters concerning to time for defining a waveform data.

<Remarks for Definition>

When Reference Waveform specified in Test Specification cannot be defined, Sampling frequency and Data length are needed to be corrected properly.

5.2.4.1 Auto-set of sampling frequency and data length

(1) Meaning

This item is for setting a proper sampling frequency and data length automatically among the specified pulse width. The values of sampling frequency and data length are selected automatically when the check box of "Auto-set of sampling frequency and data length" is checked.

5.2.4.2 Sampling frequency (Sampling freq.)

(1) Meaning

This item is for setting of Sampling frequency fs that is used at the conversion of analog data to digital data.

Frequency range fmax that specifies the upper limit of frequency of the measurement control is related with Sampling frequency fs as below ;

$$fmax = fs / 2.56$$

Sampling frequency should be set at the proper value to measure the required frequency.

For example, when the observation up to 2000 [Hz] is required by Test Specification, the value of fmax should be set to more than 2000 [Hz] at least.

Also, the available Pulse width is limited by Sampling frequency.

The value of Sampling frequency fs is selected to make more than about 30 points of Data

length within the Pulse width. However, it varies depending on the Waveform type and other conditions.

Data length within the Pulse width is obtained by the following expression. Denoting Data length within the Pulse width as Nd and Pulse width as D [ms] ;

$$Nd = D \times fs / 1000$$

5.2.4.3 Data length

(1) Meaning

This item is for specifying Data length (Na) of Acceleration Waveform to be generated.

The time length Ta [sec] of Reference Waveform data is obtained from Sampling frequency fs and Data length Na as below ;

$$Ta = Na / fs$$

The available Pulse width is limited by the time length Ta of Reference Waveform data.

The value of Data length is selected to make the time length of Reference Waveform more than about 20 times of Pulse width. However, it varies depending on the Waveform type and other conditions.

5.2.4.4 Pulse width

(1) Meaning

This item is for setting of Pulse width (duration) Dw for a half period of the nominal waveform to be generated by a value having the unit of [ms].

< Note for available range of set value >

The setting of this item is directly influenced by the length of set time length Ta of Reference Waveform data. The set value of this item is closely related to the set value of Sampling frequency and Data length. ($\because$ $Ta = Na / fs$)

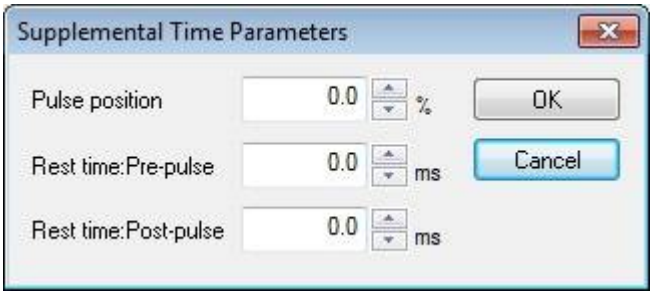
The set values of Sampling frequency and Data length are needed to be corrected when the set value of this item cannot be defined in the available range obtained by the current setting.

5.2.4.5 Supplemental Time Parameter

Supplemental Time Parameter is provided for the special cases. Usually, the default values are acceptable.

Note that the setting of Supplemental Time Parameter cannot be corrected when 'Auto' is set.

The definition dialog of Supplemental Time Parameter as below appears by pressing [Supplemental Time Parameter].



5.2.4.5.1 Pulse position

(1) Meaning

The position for setting of nominal waveform is specified.

Normally, this item is set to the default value ('0 %' : denoting the center).

Actual definition method is as below ;

Corresponding position used for setting of the center point of nominal waveform within the length of reference waveform as a whole (frame time) is specified by percentage to Frame Time Length Tl [ms] having its center position as a base point of Reference Waveform.

For example, when this item is set to 10 %, the center position of nominal waveform is set at the point of 0.6 Tl [ms] having the beginning point of Reference Waveform as a base point. When –10 % is set, the center position is set at 0.4 Tl [ms].

5.2.4.5.2 Rest time

(1) Meaning

In this system, the function that ensures the region of 'acceleration zero' in front and rear of the nominal waveform pulse is available. The parameter that specifies the region of the acceleration zero to ensure compulsorily is called as 'Rest time'.

Rest time can be specified independently on each side (front and rear) of the nominal waveform, and it is distinguished by 'Pre-pulse' and 'Post-pulse'.

The setting of Rest time makes the required displacement quantity increased.

As long as there is not necessity, set both Rest time : Pre-pulse and Post-pulse to the default value 0 [ms].

5.2.5 Tolerance

5.2.5.1 Tolerance Type

(1) Meaning

Each Test Specification has a fixed allowance range of equivalency to the Reference Waveform of response and it is called as 'Tolerance'.

In this item, type of Tolerance to be set is selected.

< Tolerance Type >

This system has the function to set the defined Tolerance automatically for some representative Test Specifications.

① Half-sine

'MIL-STD-810C', MIL-STD-810B', 'MIL-STD-202F', 'IEC 68-2-27 (JIS C 60068-2-27)', 'DIN 40 046', ' User definition' , 'Specify'

② Saw-tooth

'MIL-STD-810C/D/E', 'MIL-STD-810B', 'MIL－STD-202F', 'IEC 68-2-27 (JIS C 60068-2-27)', 'DIN 40 046', 'User definition' , Specify'

③ Trapezoid

'MIL-STD-810D/E', 'IEC 68-2-27(JIS C 60068-2-27)', 'DIN 40 046', 'User definition' , 'Specify'

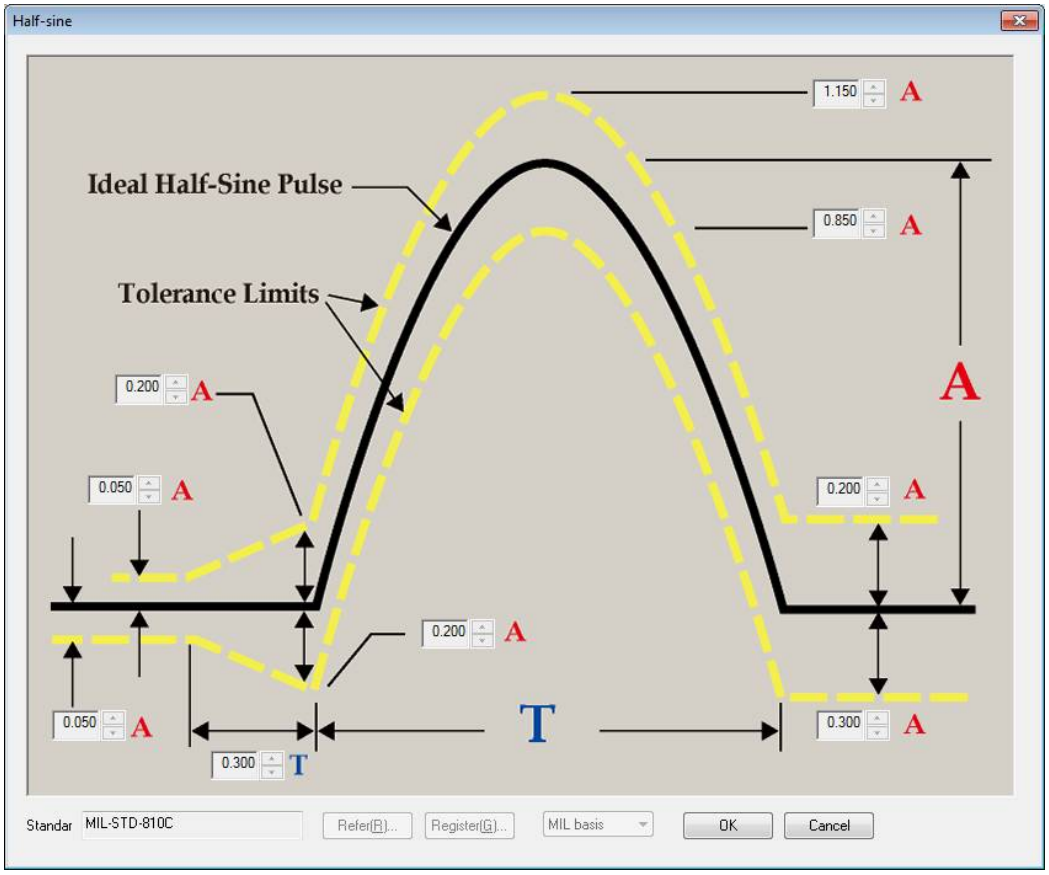
④ Triangle, Synthesize or Haversine

'User definition' only

< Standard Test >

If ‘MIL-STD-810C’ or other standard tests which have been prepared in advance are selected, the tolerances stipulated by the standards will be automatically set.

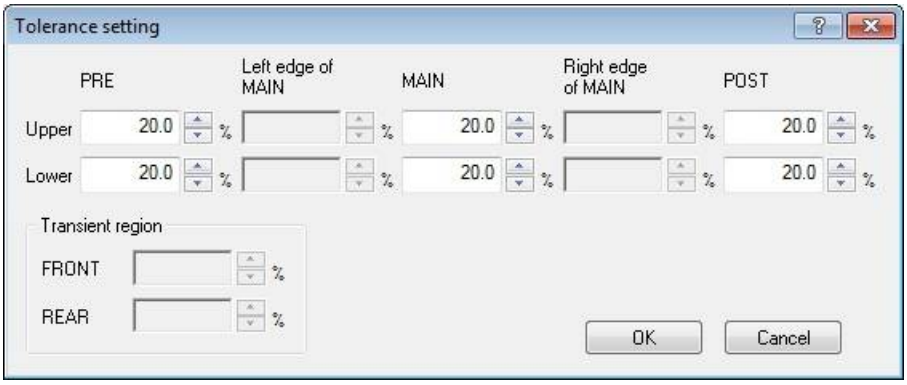
Press the ‘Tolerance Setting’ button to display the window with which the tolerance forms and parameters for the selected standard test can be checked.



< ‘User definition’ mode >

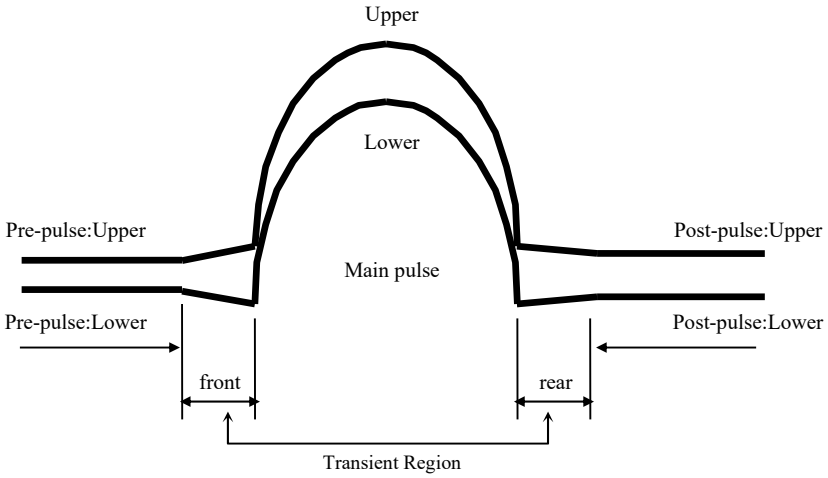
The original Tolerance can be defined by selecting ‘User definition’.

Set the tolerance type to ‘User definition’ and press the ‘Tolerance setting’ button to open the dialog box below:



In ‘User definition’ mode, Tolerance is divided into three portions ; ‘Main Pulse’ which is the portion having the nominal waveform, ‘Pre-pulse’ which is the front portion of Main pulse and ‘Post-pulse’ which is the rear portion of Main pulse. Tolerance is defined by setting of the upper and lower values for each portion with using percentage to Peak amplitude of the nominal waveform.

Also, if it is necessary, the length between Main pulse and Pre/Post-pulse is specified by percentage to the Pulse width of nominal waveform, and upper/lower limit values of the connection point between Transient Region and Main pulse are specified.

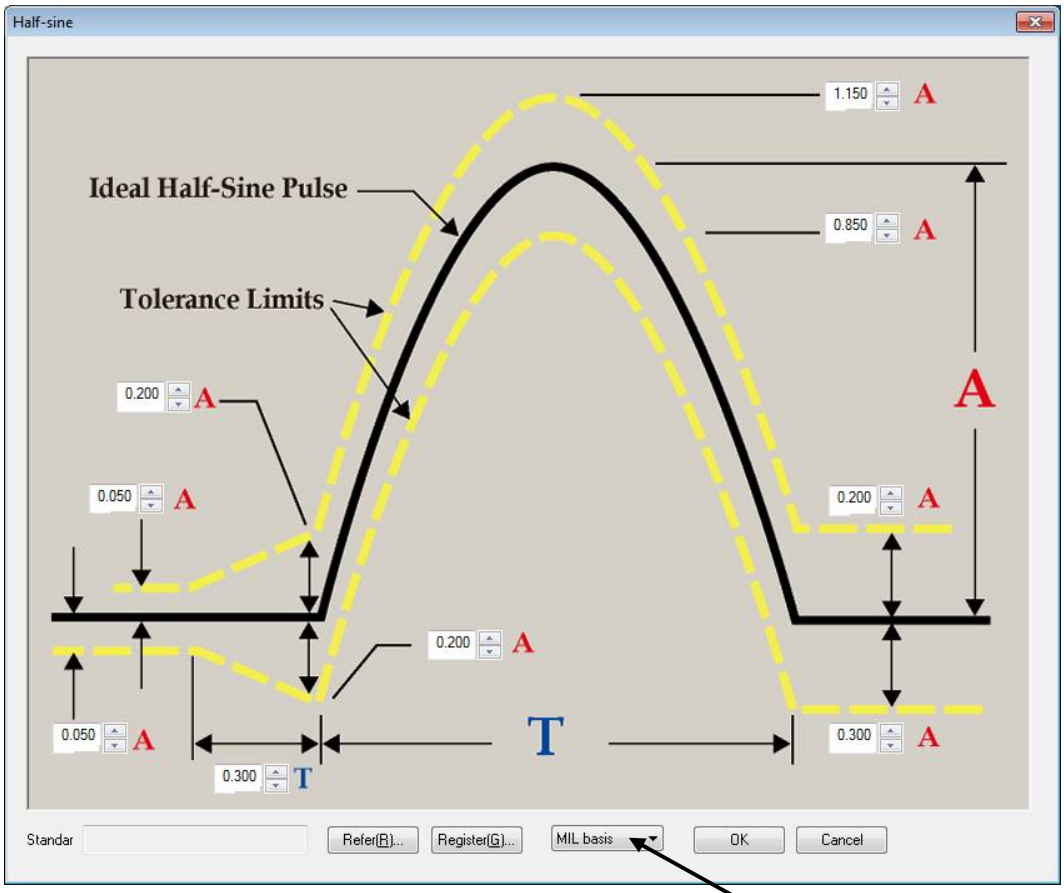


However, <u>Transient Region can be defined only when the set value of Pre(Post)-pulse by percentage is smaller than that of Main pulse.</u> That is, the Transient Region cannot be defined when this condition is not satisfied. (If the condition is not satisfied at the both side, both sides of Transient Region can not be defined.)

< ‘Specify’ mode >

If the tolerance type is set to ‘Specify’, you can arbitrarily set the parameters for the tolerance defined under the test standard.

Set the tolerance type to ‘Specify’ and press the ‘Tolerance setting’ button to open the definition window below:



＜Operating procedure＞

＜Step 1＞

Select the using test standard as the base.

Tolerance forms vary depending on the test standard selected.

＜Step 2＞

Modify the tolerance parameters.

＜Step 3＞

Press the ‘Register’ button, and then name and register the set tolerance.

＜Step 4＞

Press the ‘OK’ button to define the tolerance.

To reuse the registered tolerance, press the ‘Refer’ button and select the tolerance condition file.

5.2.6 Compensation wave parameters

This item is for defining of the condition to add the Compensation wave to nominal waveform for generating the Reference Waveform to realize the shock testing under the conditions set in each item described in the above.

This item is constructed by some small items to specify the following conditions ;

① Symmetrical Compensation wave is specified.

② Shape of Compensation wave is specified.

③ Optimization level is specified when the compensation wave type is set to 'Type 4'.

④ Upper / Lower limit value of Compensation wave is specified.

5.2.6.1 Symmetry of Compensation wave

(1) Meaning

Specify the symmetry of the Compensation wave to be added from the selection window.

Select the setting method according to the following cases.

In case that the shape of Pre-pulse and Post-pulse of Tolerance are the same ;

Set 'Symmetrical'.

In other cases ;

Set 'Asymmetrical'.

More precisely, the judgment of symmetry in this small item is done only on the magnitude of Tolerance in the vertical direction.

When the Peak levels of Tolerance in the Pre and Post-pulse are equal, the judgment should be 'Symmetrical'.

Therefore, even if the symmetrical Tolerance shifted the pulse position of the nominal pulse from the center of Frame Time, the case is judged symmetric still. (Though the Tolerance is obviously asymmetric by looking a the center point of Frame Time is the axis of symmetry. We are watching just only the Peak levels of Pre/Post-pulse.)

If 'Symmetrical' is set internationally to a symmetrical Tolerance, the following operation is executed ;

Compensation wave is added symmetrically with the smaller one (Pre/Post) of asymmetrical Tolerance. As a result, the displacement requirement to the excitation system of the reference waveform to be produced becomes larger certainly compared with the 'Asymmetrical' case.

Compensation wave is added symmetrically by checking the check box of 'Symmetrical'.

5.2.6.2 Compensation wave type

(1) Meaning

The type of Compensation wave which is used at the operation for adding the Compensation wave is specified.

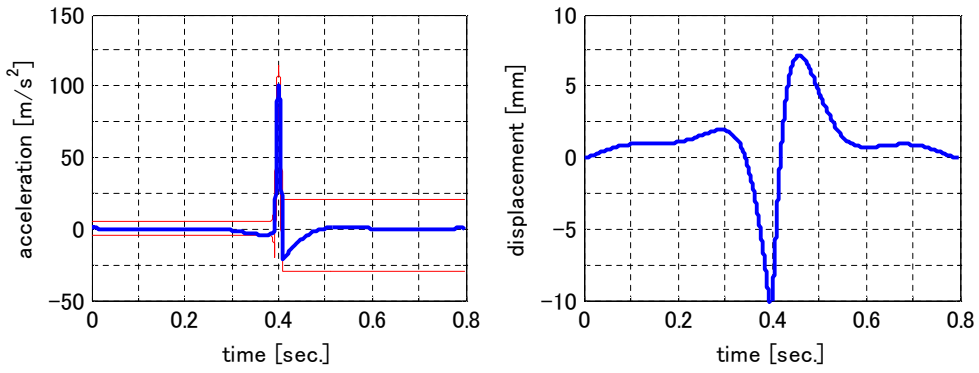
Following three types of Compensation wave are available ;

Type 1 : The most smooth type of Compensation is added. The necessary displacement becomes the largest among three.

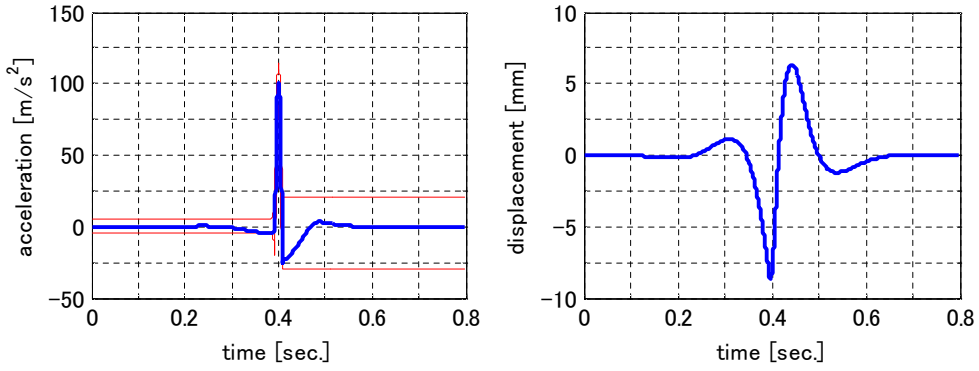
Type 2 : The good balanced Compensation wave that has both the smooth shapes and the reduction ratio of necessary displacement is added. Select Type 2 for compensation wave type when Type 4 is unusable.

Type 3 : Compensation wave that the necessary displacement becomes smaller than Type2 is added. Instead, the shape of Compensation wave is not so graceful.

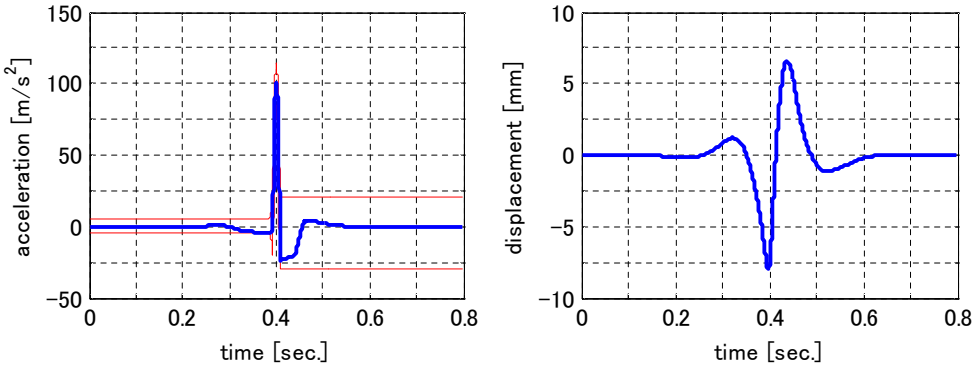
Type 4 : Compensation wave is add with setting to take the smaller precedence between displacement and velocity. When the displacement takes precedence, Compensation wave that the necessary displacement becomes the smallest is added. Type 4 is recommended for general use. However, it is unusable when Tolerance type is set to “User definition”.



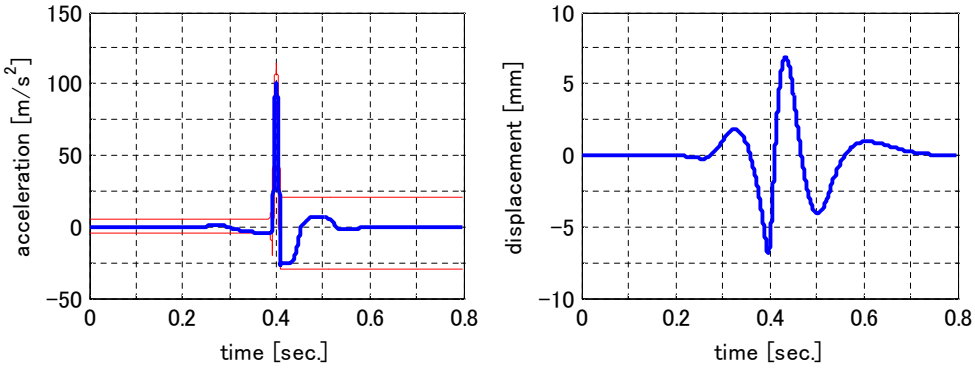
Compensation wave (Type 1)



Compensation wave (Type 2)



Compensation wave (Type 3)



Compensation wave (Type 4)

There is the following relation between the type and the necessary displacement ;

As much as Compensation wave gathers close the Main Pulse, the necessary displacement becomes smaller.

The reference waveform shows the acceleration waveform which will be produced at the table of the excitation system. Because the type of the displacement waveform is made by integrating twice by time, roughly speaking, the non-zero component of acceleration waveform has the contribution in displacement proportional to the square of time. Even if the same velocity change is produced, the displacement values which produced between the adding large acceleration at a short time and the adding small acceleration at a long time are different.

The former can be less that the latter. That is, the secret of saving of the displacement is ‘not to give the table a time to move’.

Though it is better that there is no Compensation wave, this one is to be obliged to add. In case that the maximum displacement rating of the excitation system is larger enough, the type like ‘Type 1’ of which region is long and has a small acceleration level is more close to ideal.

On the other hand, when the necessary displacement of the testing to be defined is too large and there is no room on the maximum displacement rating, even if ‘the grace’ is sacrificed, the given freedom of Tolerance can make the displacement minimum. In such a case, the characteristics of ‘legal’ Type 4 may be the great help.

The larger the number is selected, the smaller the necessary displacement can be set.
Normally, ‘Type4’ is recommended which is set as the default level.

5.2.6.3 Optimization level

(1) Meaning

This item is available to use when Type 4 is selected for Compensation wave type.

Generally, the necessary displacement becomes smaller while the necessary velocity becomes lager, or otherwise.

Optimization level is for specifying the smallest necessary displacement or velocity by the level 0 to 1. The value closer to 0 set to take the smaller necessary displacement precedence. The value closer to 1 set to take the smaller necessary velocity precedence in generating the compensation wave.

Normally, ‘0 (displacement precedence)’ is recommended which is set as the default level.

The setting of velocity precedence is useful when the necessary velocity is large enough and the maximum displacement rating has a margin of value.

5.2.6.4 Peak level of Compensation wave

(1) Meaning

The maximum and the minimum level of Compensation wave to be produced are specified in a percentage value based on Tolerance.

The setting is operated for each pulse (Pre/Post).

The purpose of this setting are as follows ;

A : Compensation wave should be made within the Tolerance for the control error.

B : ‘Compensation by Pre/Post-pulse only’ is set.

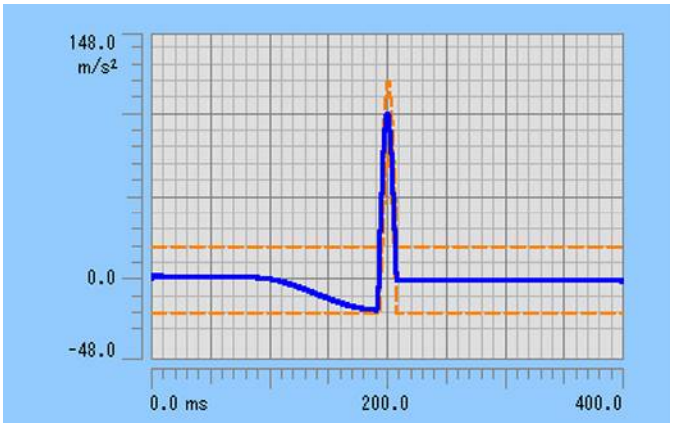
For the purpose of A, the value of this item is set ‘90%’ as the default value. Normally, this value is recommended.

In the following, the above B is explained ;

The meaning of ‘Compensation by Pre-pulse only’ is that ‘there is no Compensation wave in Post-pulse region’. As in the same way, the meaning of ‘Compensation by Post-pulse only’ is that ‘there is no Compensation wave in Pre-pulse region’;

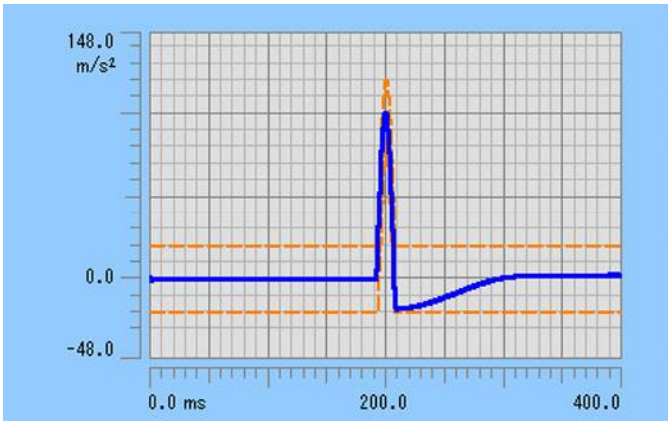
‘Compensation wave : Peak level (Pre-pulse)’

Set ‘0%’ to the set value of ‘Post-pulse’.



‘Compensation wave : Peak level (Post-pulse)’

Set ‘0 %’ to set value of ‘Pre-pulse’.



However, note that in the followings ;

As the Reference Waveform is actually produced after the setting, the waveform data at the concerning portion to be produced is not accurately zero. The value about 0.5% of the Peak amplitude remains.

It is caused by the phenomenon to be produced I the optimization routine.

5.3 Measured Waveform

The waveform data stored as a digital data is used as Reference Waveform.

Usable waveform data file formats are ; CSV, TSW (standard format for F2 control system of IMV), UFF (dataset58), MTS (RPCIII).

・CSV File

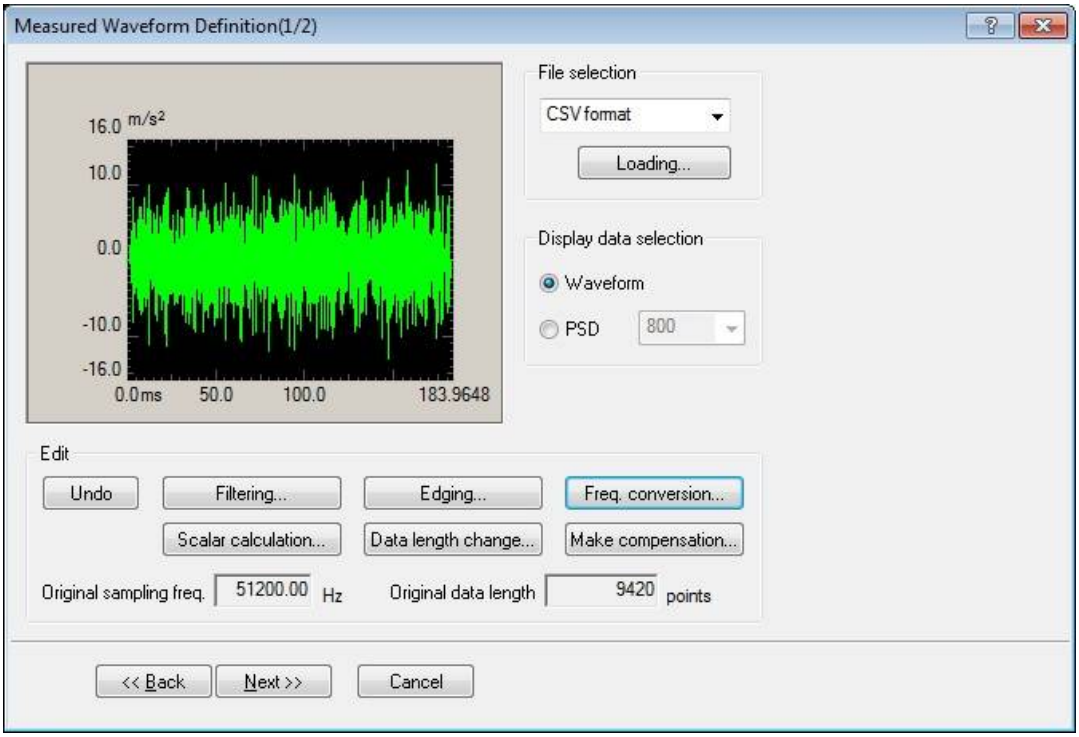
The waveform data should be described in CSV data file format specified by K2+ system.

The maximum Data Length of available waveform data varies depending on the kind of options.
In standard specification, the maximum Data Length is specified as **16384** points.

When [Measured Waveform] is selected, the definition dialog (1/2) appears to define the items as below ;

・File Selection

・Edit Function



When these items are defined, press [Next]. Then, the generated acceleration waveform is displayed.

(Note). The [Next] button becomes available when the conditions as below are satisfied ; **'Sampling frequency should be usable in K2+.' and 'Not to exceeds over the maximum Data Length usable as waveform data.'**

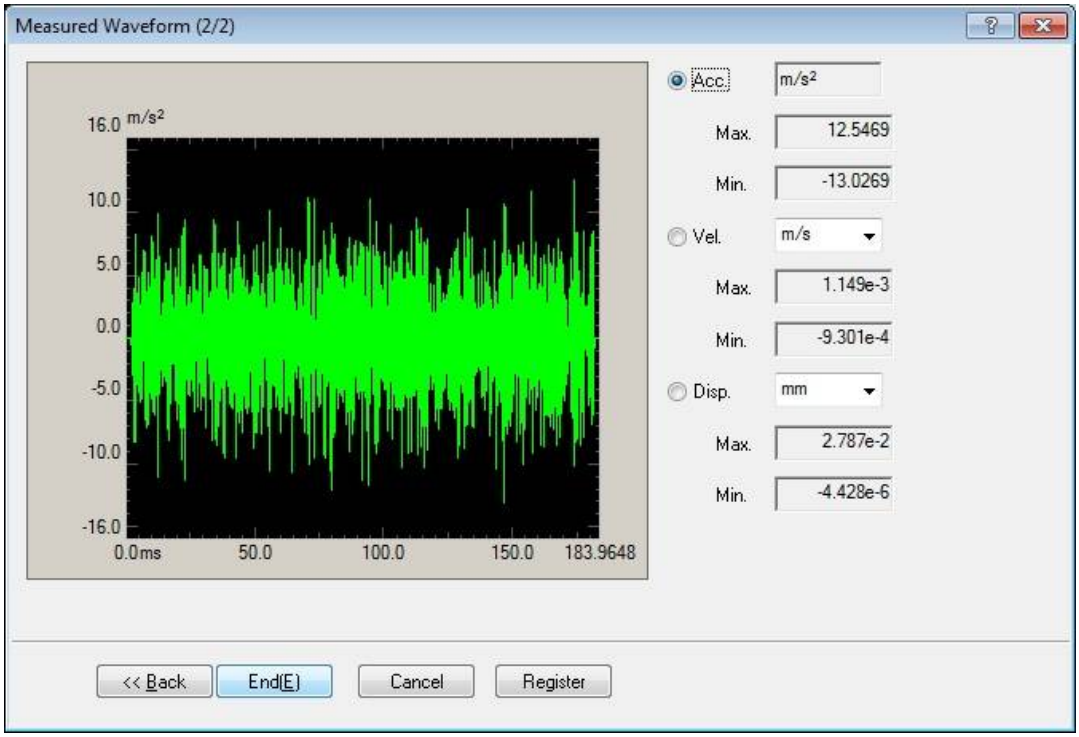
Editing of [Freq. conversion] or [Data length change] should be operated to satisfy the conditions in the above.

When an error occurred in Sampling frequency, the mark as '***' is displayed on the present Sampling frequency. Also, when an error occurred in Data Length, the mark as '***' is displayed on the present Data Length.

Then the definition dialog (1/2) is completed, the definition dialog (2/2) appears. In this dialog, the generated acceleration waveform is displayed.

Press [Back] to return to the definition dialog (1/2).

Press [End] to finish the definition of Reference Waveform.



5.3.1 Data File Format

5.3.1.1 CSV File

(1) File Format

Text File (MS-DOS format)

(2) Data

Sampling frequency data at each time is described as below in order of time passing.

	1st column	2nd column	3rd column		
1st line	*Time (ms)*	Data Name 1,	Data Name 2,	Data Name 3,	……
2nd line	0.0,	***.***,	***.**,	***.**,	……
3rd line	Δt	***.***,	***.**,	***.**,	……
	2Δt	***.***,	***.**,	***.**,	……
	.	.	.	.	.
	T,	***.***,	***.***,	***.**,	……

・It is not necessary to specify the data in a 1st line.

・The order of data (column) are not specified specially.

・Time data is not necessary to me specified.

(3) Unit of Data

Unit of data to be described is determined by selecting a Data File.

(4) Sampling frequency

Sampling frequency of data to be described is specified after selecting the data file.

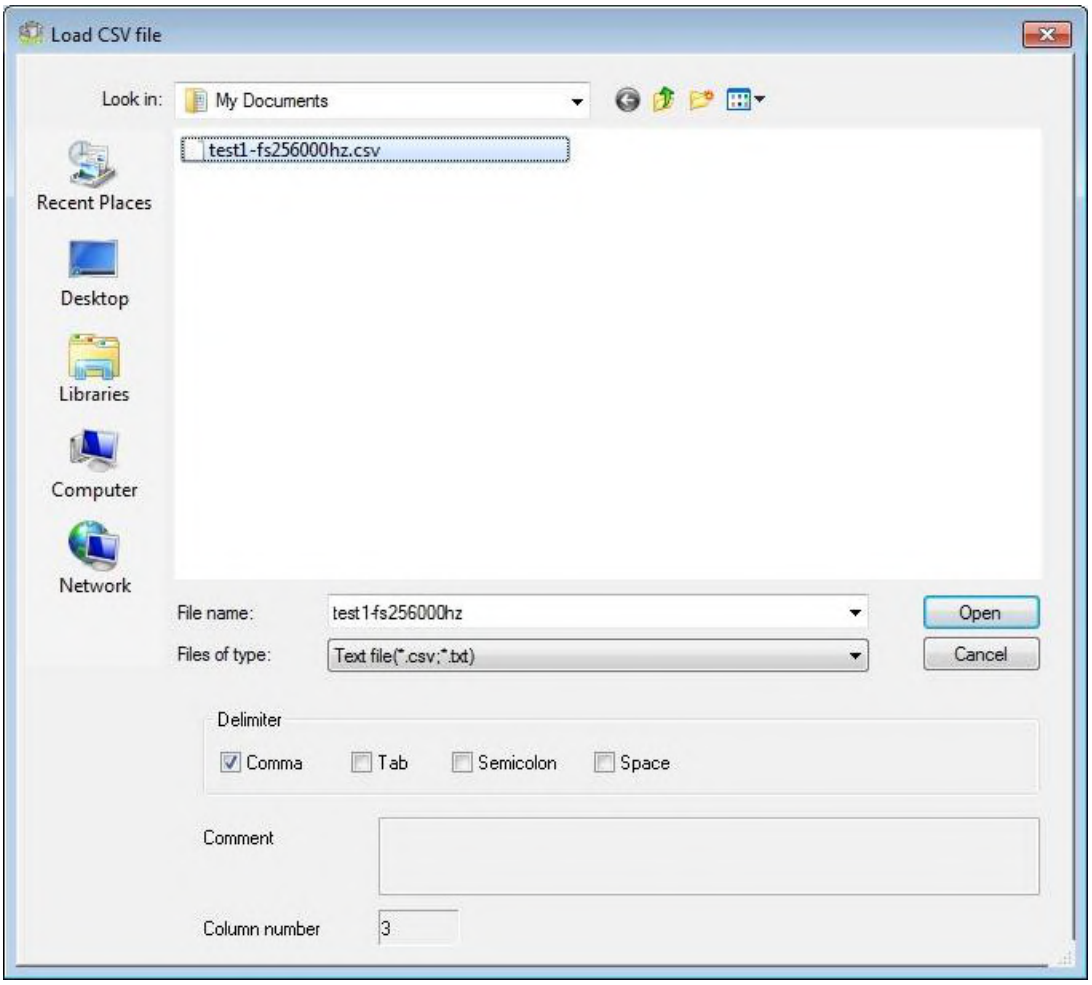
Sampling frequency can be calculated automatically from time data when time data exists.

5.3.2 Data Loading

5.3.2.1 Data File Selection

When [Loading…] is pressed in the definition dialog (1/2), the selection display as below appears.

Select an objective data file.

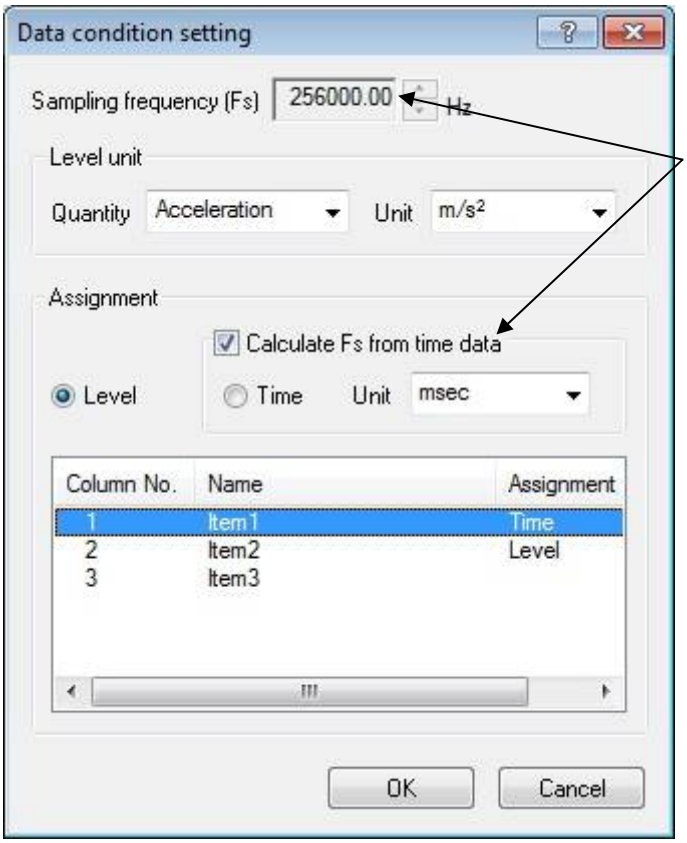


5.3.2.2 Data Unit and Sampling frequency

When the objective data file is selected, the dialog as below appears.

Where, the data of specified condition is loaded by setting of Data Unit and Sampling frequency.

<CSV File>



When Time Data is defined in Data File, Sampling Frequency is available to be calculated from the Time Data.
Or, Sampling Frequency can be set directly by canceling the check of 'Calculate the Fs from Time Data'.

5.3.3 Data Edit

This item is for editing the data, such as, ‘Cut-off the unnecessary Frequency range’ and ‘Convert the Sampling frequency to the value usable in K2+’, etc.

Processes of Data Edit as below are available ;

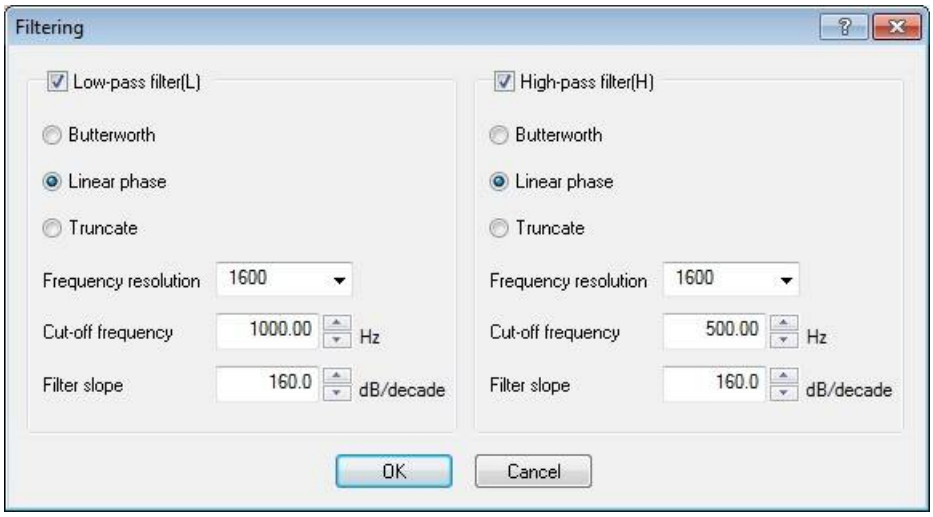
- Filtering
- Edging
- Frequency conversion
- Scalar calculation
- Data length change
- Make compensation

The operation of Data Edit is canceled by pressing [Undo].

5.3.3.1 Filtering

This item is for operating of Filtering to the waveform data loaded.

The definition dialog of Filtering as below appears by pressing [Filtering] button in the definition dialog (1/2).



5.3.3.1.1 Type of Filter

(1) Meaning

Type of Filter is selected.

- Low-pass filter

  In this type, the low frequency component of waveform data is passed.

- High-pass filter

  In this type, the high frequency component of waveform data is passed.

5.3.3.1.2 Filter Characteristics

(1) Meaning

Filter Characteristic is selected. Generally, the default setting of 'Linear Phase' is used.

・Butterworth

Nth-order Butterworth Filter.

How to specify the order N is described after the next clause.

・Linear phase

The Linear Filter cuts the components without giving any non-linear phase change to the input signal.

This system adopts the specifications that the slope at the attenuation band can be defined without changing the phase in all the frequency elements at all.

・Truncate

The characteristics of the Frequency range which is the object for the filter processing is truncated to zero bounded by the specified cut-off frequency fc.

The phase characteristics are the same as the 'Linear Phase' in the previous clause.

5.3.3.1.3 Frequency resolution

(1) Meaning

The frequency resolution is specified to carry out Fourier Transform and Inverse Fourier Transform by FFT technique for the filter processing of the waveform data.

Therefore, the input lower Cut-off frequency fc is determined when frequency resolution is specified.

5.3.3.1.4 Cut-off frequency

(1) Meaning

This item specifies the Cut-off frequency for Filtering.

The possible lower value fc_min is determined by the Sampling frequency fs of the objective waveform data of the Filtering process and the frequency resolution L as follows.

fc_min = Δ f [Hz] $\Delta f = fmax/L$, $fmax = fs/2.56$

5.3.3.1.5 Filter order

(1) Meaning

This item is defined only when 'Butterworth' is specified for Filter Characteristics.

The order N is inputted that specifies the Cut-off Characteristics of the Filter.

5.3.3.1.6 Filter slope

(1) Meaning

This item is defined only when Filter Characteristic is 'Linear Phase'. The Slope of the attenuation transient band characteristics S[dB/decade] that is correspondent to the order of the Filter is specified.

When this item is defined, Filtering process according to the following formula is executed within the objective range.

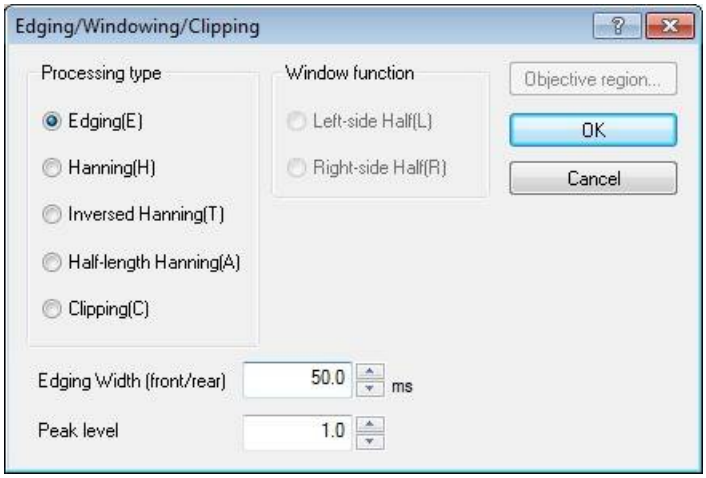
$$A'(f)\begin{cases} = A(f) & \Delta f \le f < fc \\ = A(f)/(f/fc)^{S/20} & fc \le f \le f\,\max \end{cases}$$

A(f) Amplitude value

5.3.3.2 Edging

This item is for operating the edging process that achieves to smooth the loaded waveform data at the beginning/ending edge to zero. Half-length Hanning Windowing is used in this process.

When [Edging] button is pressed in the definition dialog (1/2), the definition dialog of Edging appears as below.



5.3.3.2.1 Edging Width

(1) Meaning

This item is for specifying of the time for edging Te.

Windowing by Half-length Hanning is operated to time data from the beginning to the ending edge.

5.3.3.2.2 Peak level

(1) Meaning

This item is for specifying the Peak level of Half-length Hanning to be used. The default value of this item is '1'.

5.3.3.3 Frequency conversion(Freq. Conversion)

The process of Frequency conversion is operated to the waveform data loaded.

There are two functions as below ;

① Signal frequency conversion

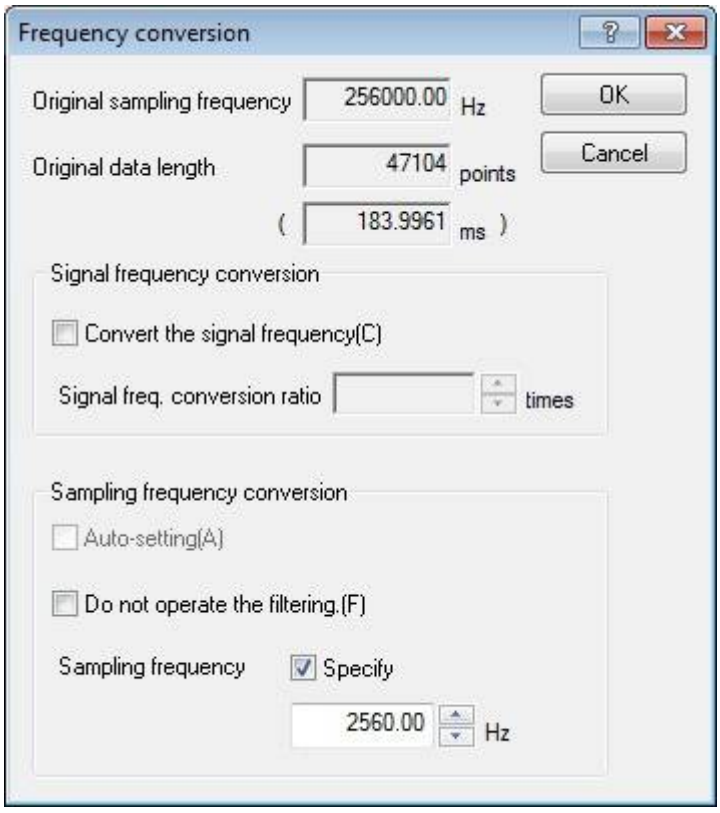
When in such a case that vibration test is simulated with a model, the signal frequency of a measured waveform data has to be converted as the original measured data is not suitable for the use. This function is for such need.

② Sampling frequency conversion

As the measurement condition of the waveform data does not meet that of the K2+ Application, a new data is made adding some changes to the waveform data.

Sampling frequency of waveform data should be 'the one usable in K2+'. When this condition is not satisfied, the value of Sampling frequency is needed to be corrected by operating the process ②.

When [Freq. conversion] is pressed in the definition dialog (1/2), the definition dialog of Frequency conversion as below is displayed.



5.3.3.3.1 Signal frequency conversion

This item is for converting the Signal Frequency of the waveform data itself.

In general, it is necessary to convert the Sampling frequency in this case, too.

To execute this function, select the check box [Convert the signal frequency].

5.3.3.3.1.1 Signal frequency conversion ratio(Signal freq. conversion ratio)

(1) Meaning

This item is for specifying the signal frequency conversion ratio of the waveform data. When the signal frequency is converted, the Sampling frequency is also needed to be converted, in general. The operation is described later.

5.3.3.3.2 Sampling frequency conversion

This item is for converting the Sampling frequency of the waveform data. (Process ②)

5.3.3.3.2.1 Auto-setting

(1) Meaning

This item is defined only when the signal frequency is converted.

As mentioned above, when the signal frequency of the waveform data is converted, it is also necessary to convert Sampling frequency. However, in this case, Sampling frequency is automatically set to meet the set value of the signal frequency. Sampling frequency us determined according to the following rules ;

① Calculate a provisional Sampling frequency fs' from the signal frequency ratio.

$fs' = b \cdot fs$ b : Signal frequency conversion ratio

② Determine a Sampling frequency fs' which is closest to fs' and can be used in the K2+ Application over fs'.

5.3.3.3.2.2 Do not operate the filtering

(1) Meaning

When Sampling frequency conversion is carried out, this system executes a sequence of digital processing by the necessary combination of Decimation / Interpolation that is mentioned in the next clauses. At this time, the Low-pass Filter processing is achieved at each stage during the process, according to the general rule of Decimation / Interpolation.

This Low-pass Filtering process is very legitimate when using the waveform data made by capturing an existing analog signal rationally.

On the other hand, in such a case when the waveform data is generated or defined in completely digital manner neglecting the Nyquist's Theorem, the usage of the LPF in the process may not suitable to fit the 'requirement'.

This item is provided for such a case. When it is defined, frequency conversion is achieved by a simple linear interpolation without using the rational Decimation / Interpolation method.

However, when carrying out this item (Do not operate the filtering), Signal frequency conversion cannot be operated.

5.3.3.3.2.3 Sampling frequency

(1) Meaning

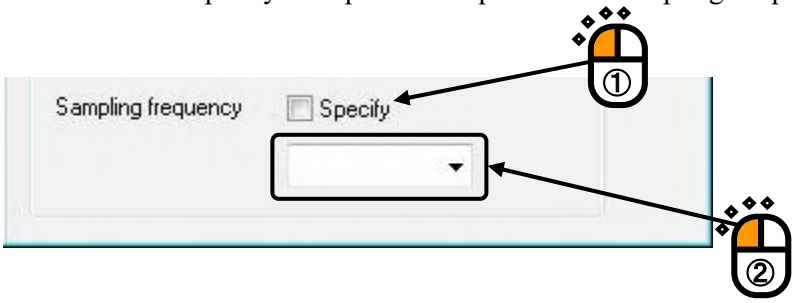
This item defines a new Sampling frequency fs'.

Sampling frequency available in K2+ is selected by the procedures as below ;

<Procedures>

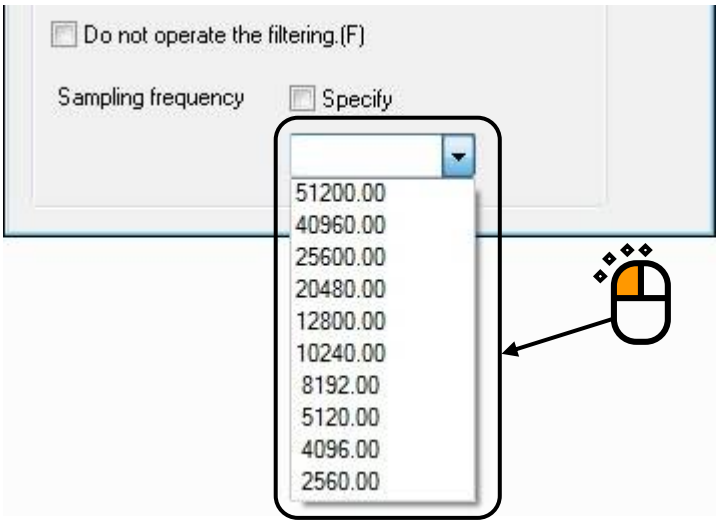
<Step 1>

Uncheck check box of 'Specify' and press the input area of Sampling frequency.



<Step 2>

Sampling frequencies available in K2+ are listed. Select a proper value for Sampling frequency from the list.



In this item, the waveform data in which Sampling frequency is changed from fs to fs' is produced keeping the frame time (T = R/fs) unchanged (the data length R is subject to the same change as fs).

The sampling time interval Δt increases or decreases in inverse proportion to the change in fs as follows ;

$$\Delta t' = 1 / fs'$$

Example : Conversion by the factor 1/2 ;

Sampling frequency is halved so the time interval Δt is doubled. A new data itself will be produced to give a coarser sampling of the same time length of the waveform.

In order words, in every two contiguous data, only one data is left, and other

sampling points of the old data are useless and discarded. But if this simple method is done straightforwardly, some unexpected distortion will be produced.

In this system, through the digital processing by a Decimator, a new waveform data item consisting of only the frequency components less than fmax (fmax = fs'/2.56) : the new fmax has no frequency components included in the old fmax frequency band.

Example : Conversion by the factor2 ;

Sampling frequency is doubled, so the time interval Δt is halved. A new data item will be produced to give a more finely-grained sampling of the same time length of the waveform.

In other words, a sampling point is added between each pair of sampling points, which creates new data.

In this system, through digital processing by an Interpolator, a new waveform data consisting of frequency components less than the old fmax is produced using the new Sampling frequency fs'. So some frequency components are not added to the new fmax frequency band from the old fmax.

In contrast, in an easier way, for example, when an intermediate data is produced by linear interpolation from two data points, the high-frequency components that are never observed in the original measurement may be added to the new fmax frequency band unnoticed.

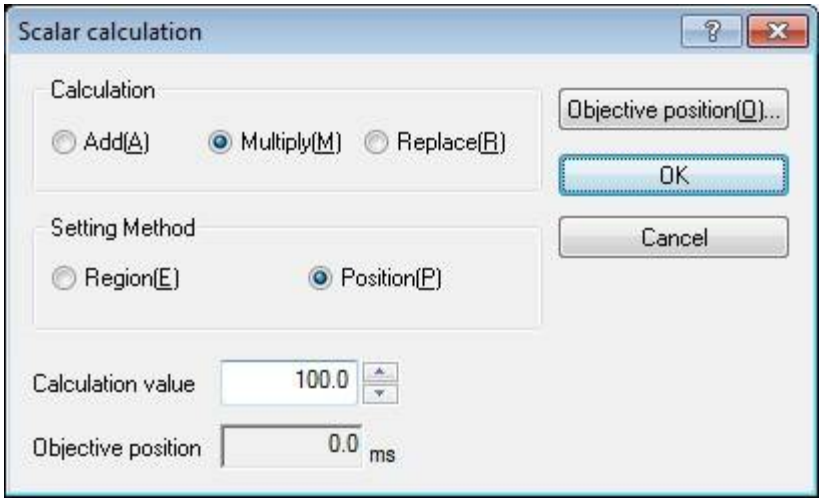
This clause is about the process when the previous item is not set to 'Do not operate the filtering', and for the case of setting to 'Do not operate the filtering', Frequency conversion is executed according to the logic of the simple linear interpolation.

When the converted Data Length R' exceeds over the maximum Data Length usable in K2+, Data Length should be edited by Data length change.

5.3.3.4 Scalar calculation

This item is for setting of the calculation between numeral values of the waveform data loaded.

When [Scalar calculation] is pressed in the definition dialog (1/2), the definition dialog of Scalar calculation appears as below ;



5.3.3.4.1 Calculation

(1) Meaning

This item defines the calculation type between the waveform data and numeric value.

- Add

  The defined quantity is uniformly added to the current waveform data.

- Multiply

  The waveform data is transformed in proportion to the defined multiplier.

- Replace

  The current waveform data is replaced by the defined value.

5.3.3.4.2 Calculation value

(1) Meaning

This item defines the value to be calculated.

When the calculation type is specified to ‘Multiply’, this item is set to the untitled value. When the type is specified to ‘Add’ or ‘Replace’, the unit must be the same as that of the current waveform data.

5.3.3.4.3 Setting Method

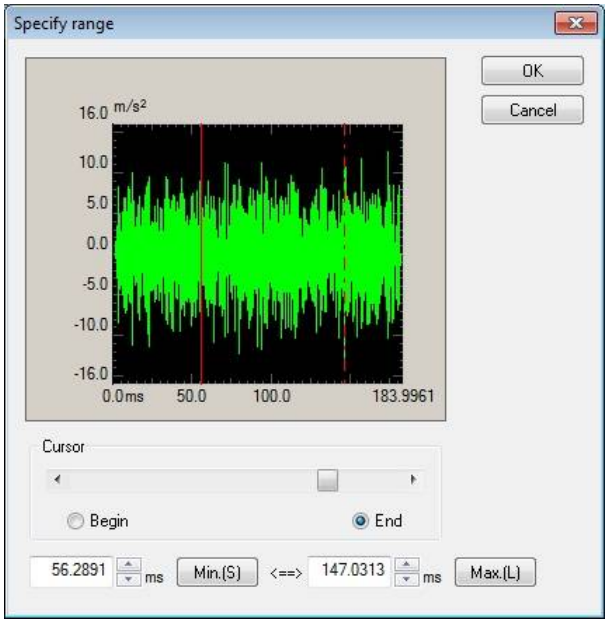
(1) Meaning

This item defines the objective range to be calculated.

・Region

To specify the objective region of the calculation by defining the beginning point and ending point.

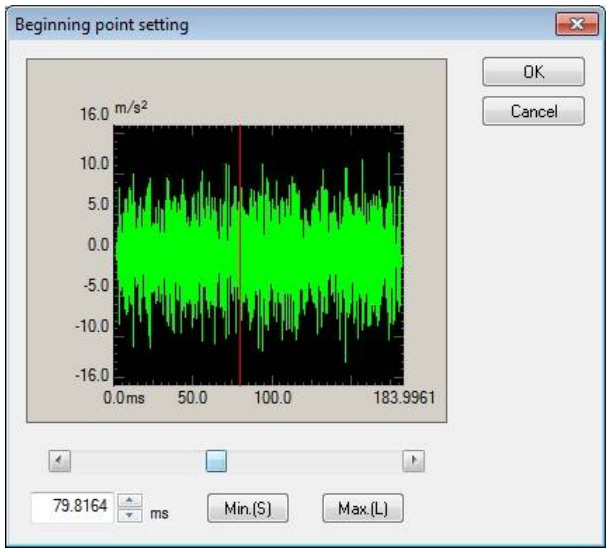
Select [Objective region] to display the dialog as below. And define the beginning and the ending points that become the objects for calculation.



・Position

Only the data of the specified time position is the objective data of the calculation. Namely, only the data for one point on the specified time axis is processed by the calculation.

When [Objective position] is selected, the dialog as below appears. And define the position of the objects for calculation.

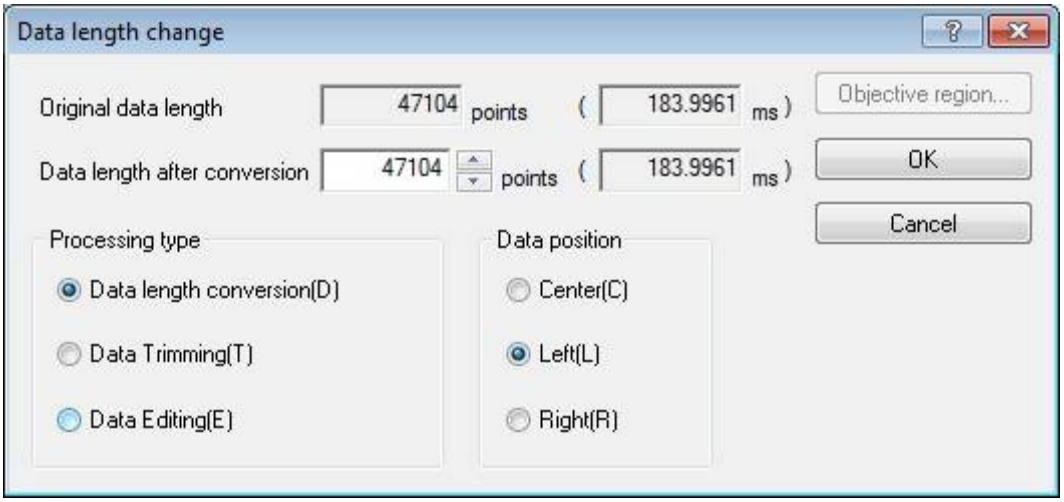


5.3.3.5 Data length change

This item is for changing the waveform data length.

Data Length of the waveform data should not exceed over the maximum Data Length usable in K2+. When this condition is not satisfied, the data is needed to be edited by cutting off unnecessary part of data and reducing the Data Length.

Select [Data length change] in the definition dialog (1/2). The definition dialog of Data length change as below appears.



5.3.3.5.1 Processing type

(1) Meaning

When Data Length of waveform data is converted, the following methods are available ;

・Data length conversion

The desired Data length which will be converted from the current data length is specified. Data Length can be increased or decreased from the current data length.

・Data trimming

The data in the specified region is trimmed from the objective waveform data and the rest is used as a new waveform data.

Data Length is decreased from the current data length.

・Data editing

The data in the specified region is trimmed from the objective waveform data and the trimmed part is used as a new waveform data.

Data Length is decreased from the current data length.

5.3.3.5.2 Data Length

(1) Meaning

This item is specified only when Processing type is specified as Data length conversion and is defined a new Data Length R'.

In this item, the waveform data of a new Data Length is generated, while Sampling frequency fs is kept unchanged.

In other words, the Frame Time T increases or decreases in proportion to the Data Length as follows ;

T = R' / fs [s] R' : A new Data Length

・The old Data Length R > The new Data Length R' ;

Part of the old data is discarded in proportion to the decrease of the Frame Time T (the discarded area depends on the defined data position stated later).

・The old Data Length R < The new Data Length R' ;

Zero data is added to the old data in proportion to the increase of the Frame Time T (the added area depends on the defined data position stated later).

5.3.3.5.3 Data Position

(1) Meaning

This item should be inputted only when the Processing type is 'Data length conversion' and this item defines the reference position for changing the waveform data, led by changing the data length.

・Center

The data is increased or decreased with keeping the center of the old data as a base. The data is added or discarded uniformly on the right and the left.

・Left

The data is increased or decreased with keeping the left end of the old data fixed. The data is added or discarded from its right end.

・Right

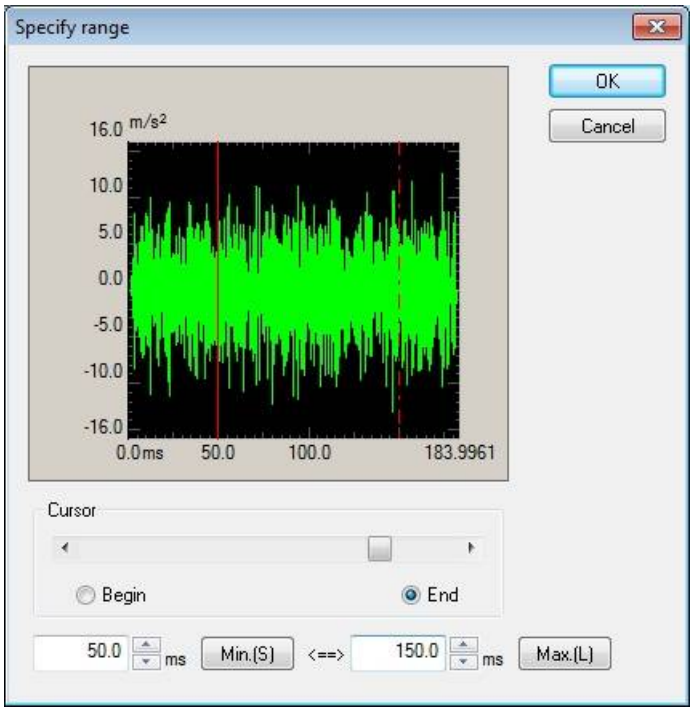
The data is increased or decreased with keeping the right end of the old data fixed. The data is added or discarded from its left end.

5.3.3.5.4 Objective Region

(1) Meaning

This item is valid only when 'Data trimming' or 'Data editing' is set in Processing type.

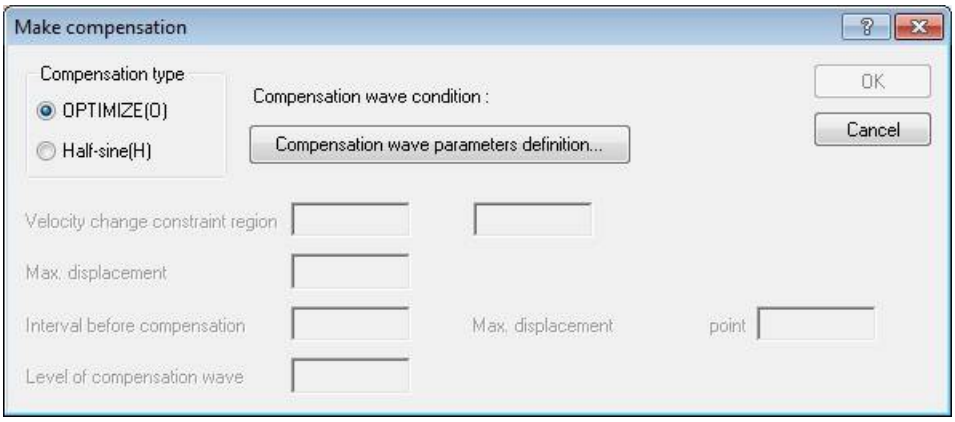
When [Objective Region] is pressed, the dialog box for setting of objective region appears.



5.3.3.6 Make compensation

In this item, Compensation Wave can be added to the loaded waveform data if it is necessary. **However, to do the Compensation Wave adding, the dimension of the physical quantity of the waveform data must be acceleration.**

When [Make compensation] button is pressed in the definition dialog (1/2), the definition dialog of Compensation Waveform adding as below appears.



5.3.3.6.1 Compensation type

(1) Meaning

This system supports the following two modes for adding a Compensation Wave ;

・Half-sine

This item specifies to add Half-sine Compensation Wave, which enables the final velocity to terminate at zero, to the read-in waveform data based on the defined parameters. Final Displacement has non-zero value generally.

・OPTIMIZE

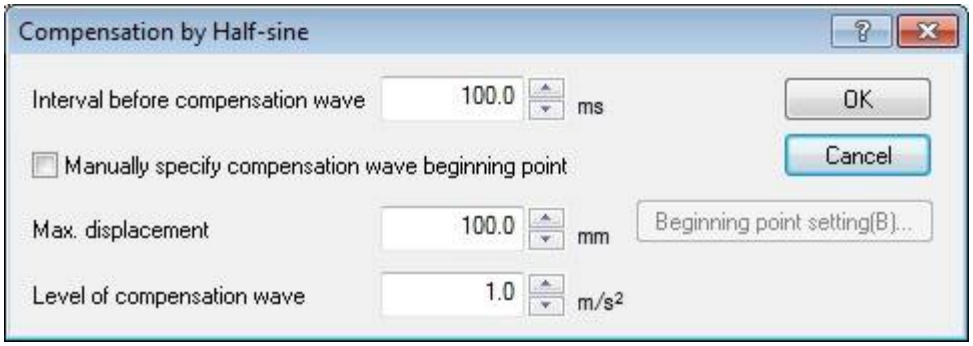
This item specifies to give automatically the optimized Compensation Wave (zero final velocity, zero final displacement and minimum required displacement) under some constraints and adds it.

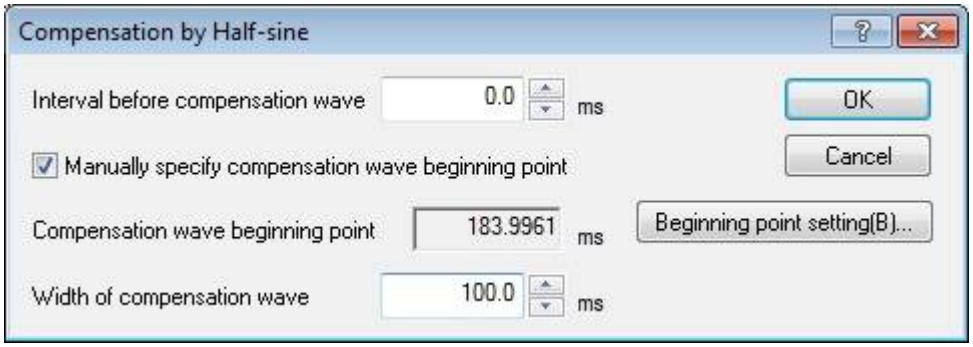
However, the Data Length available to operate Compensation by OPTIMIZE is limited up to **16384** points.

5.3.3.6.2 Compensation by Half-sine

In the definition dialog of Make compensation, select the check box of 'Half-sine' of Compensation type.

When [Compensation wave parameters definition] is pressed, the definition dialog of Compensation by Half-sine appears as below.





5.3.3.6.2.1 Interval before compensation wave

(1) Meaning

This item specifies a data interval (zeroes) between the waveform data and Compensation Wave data.

5.3.3.6.2.2 Manually specify compensation wave beginning point

(1) Meaning

There are two Compensation Methods ; AUTO and MANUAL. In the event of Manual, the beginning point of Compensation Wave is specified.

Auto : The check box of 'Manually specify compensation wave beginning point' is not checked.

Manual : The check box of 'Manually specify compensation wave beginning point' is checked.

Depending on which method is selected AUTO or MANUAL, the succeeding items are different as follows ;

・AUTO

Max. displacement

Level of compensation wave

・MANUAL

Compensation wave beginning point

Width of compensation wave

5.3.3.6.2.3 Max. displacement

(1) Meaning

This item is valid only when AUTO is selected.

Based on the set value of this item, the maximum displacement of Reference Waveform with Compensation Wave to be generated is determined.

The set value of this item should be less than that of the shaker to be used.

5.3.3.6.2.4 Level of compensation wave

(1) Meaning

This item is valid only when AUTO is selected.

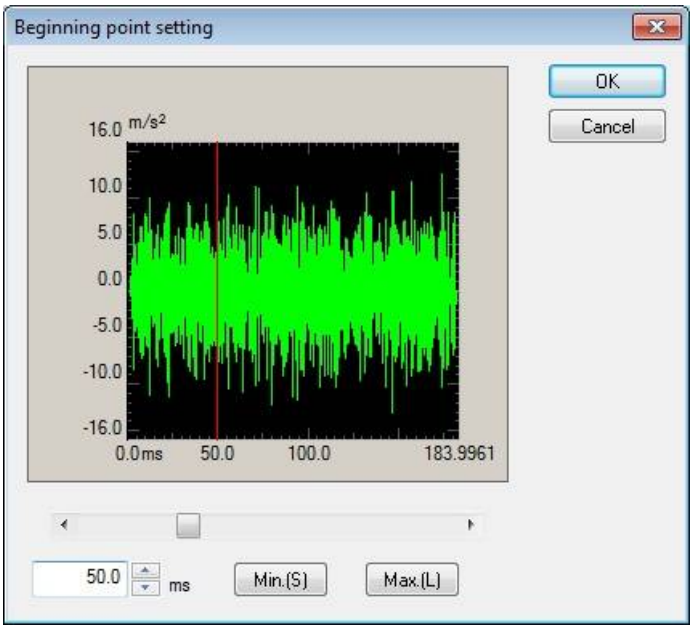
Peak Level of compensation wave (Half-sine) to be added is specified (0-p).

5.3.3.6.2.5 Compensation wave beginning point

(1) Meaning

This item is valid only when MANUAL is selected.

In the definition dialog of Compensation by Half-sine, the dialog box for specifying the beginning point as below appears by pressing [Beginning point setting].



The set value affects the maximum required displacement of the waveform data, so set a proper value.

5.3.3.6.2.6 Width of compensation wave

(1) Meaning

This item is valid only when MANUAL is selected.

Compensation Wave width equivalent to a half period sinusoid (half-sine wave) is inputted.

The set value affects the maximum required displacement of the waveform data, so set a proper value.

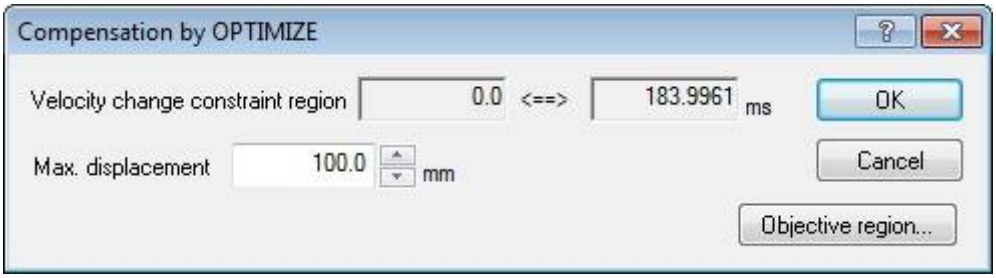
5.3.3.6.3 Compensation by OPTIMIZE

In the ‘OPTOMIZE’ method, an optimization processing called ‘Displacement Optimize Routine’ is applied to generate a suitable Compensation Wave.

This method is developed especially for ‘Classical Shock’ waveform compensation originally, and gives the best solution having minimum displacement value. However, this process applies the method to a Measured Waveform data.

(Tolerance that is a strict constraint condition in Classical Shock waveform is not considered in Measured Waveform.)

In the definition dialog of Make compensation, select the check box of ‘OPTIMIZE’ of Compensation type. Then, the definition dialog of Compensation by OPTIMIZE appears by pressing [Compensation wave parameters definition].



However, Data Length of the waveform data that is possible to be generated by Compensation Wave by OPTIMIZE is limited up to **16384** points as the total length.

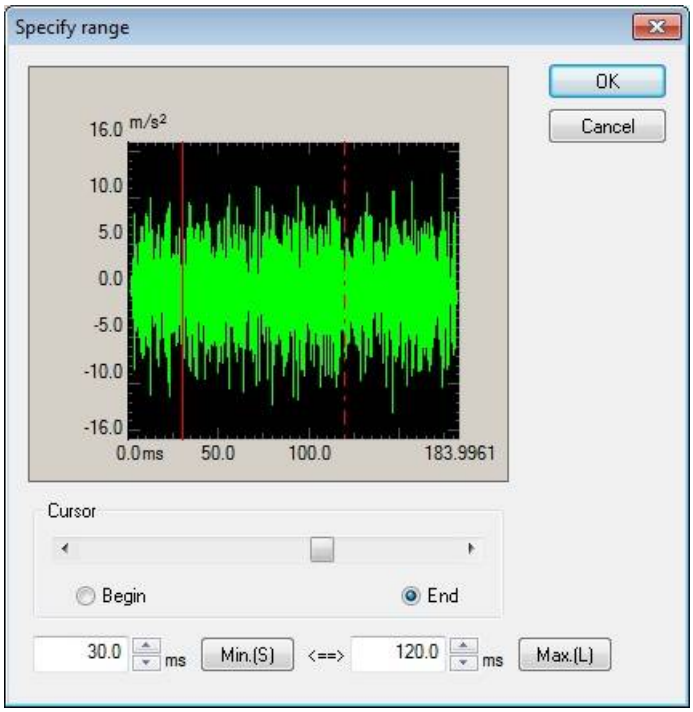
5.3.3.6.3.1 Velocity change constraint region

(1) Meaning

Velocity change value in the specified time region is held to be equal to that of the original waveform (the original waveform suffers some modification in shape anyhow corresponding to the depth of optimization).

Specify the region inside where the original shape should be held to have little change from the original (velocity change is held exactly the same to the original).

Press [Objective region] in the definition dialog of Compensation by OPTIMIZE. The dialog box as below appears. Specify the beginning and the ending point of Velocity change constraint region.



5.3.3.6.3.2 Max. displacement

(1) Meaning

This value gives the allowable maximum displacement value in the optimization processing as a constant.

The smaller the value is set, the smaller the displacement is required. In return, the modification of the waveform shape becomes larger.

The value should be smaller that the rating displacement value of the excitation system to be used.

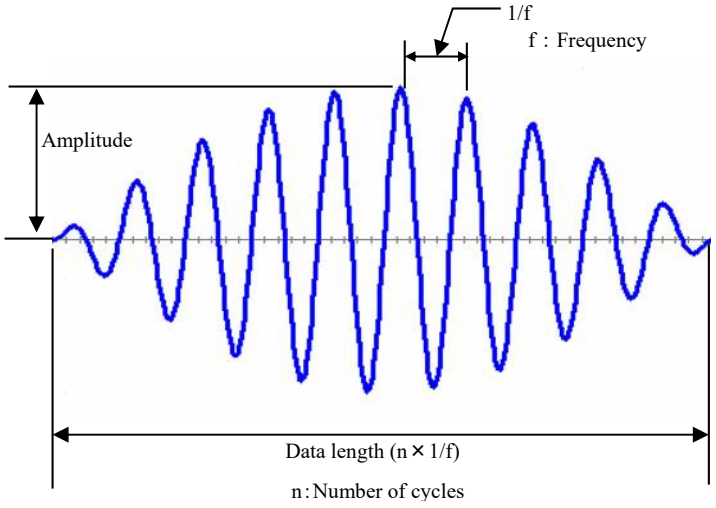
5.4 Sine Beat / Sine Burst

Acceleration waveform data of Sine Beat / Sine Burst is generated.

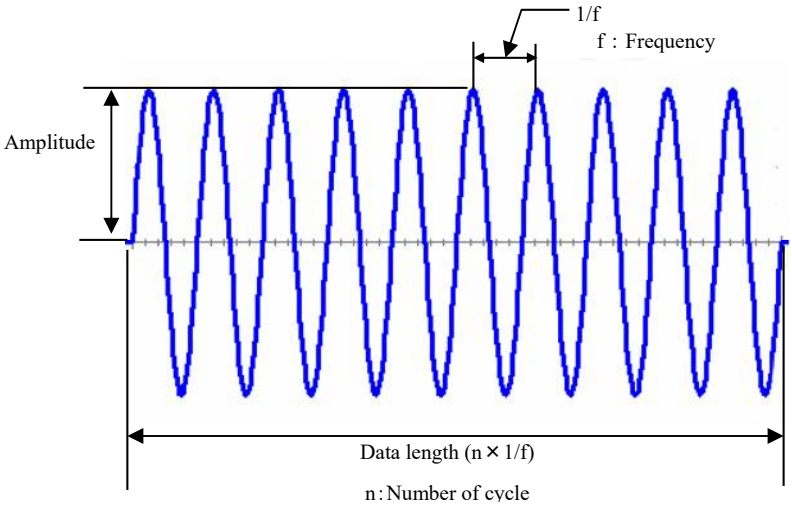
The dimension of Controlled Variable is limited to ‘acceleration’.

Sine Beat / Sine Burst have the shapes of acceleration waveform as below. And, the shapes of waveform are defined by the following items ;

- Amplitude
- Frequency of sinusoid to be generated
- Data length (number of cycles) of data to be generated



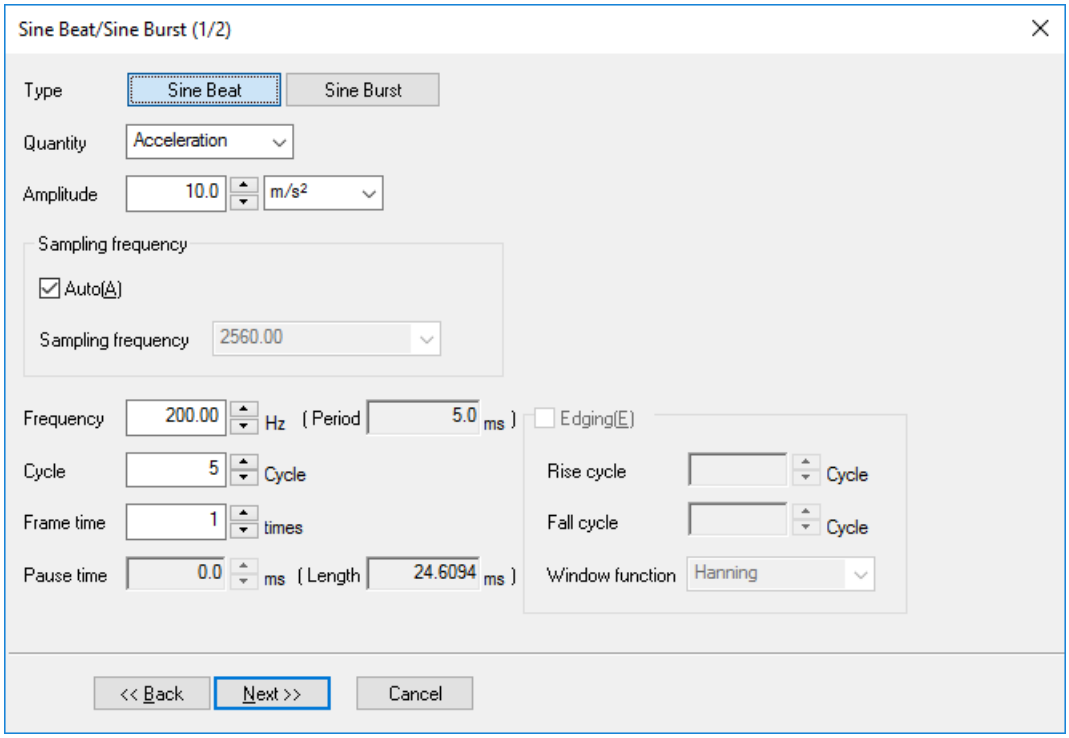
Sine Beat



Sine Burst

When [Sine Beat / Sine Burst] is selected in Reference Waveform Definition, the definition dialog (1/2) for specifying the items as below which define the shape of waveform appears.

- Waveform type
- Amplitude
- Frequency of sinusoid to be generated
- Data length (number of cycles) to be generated

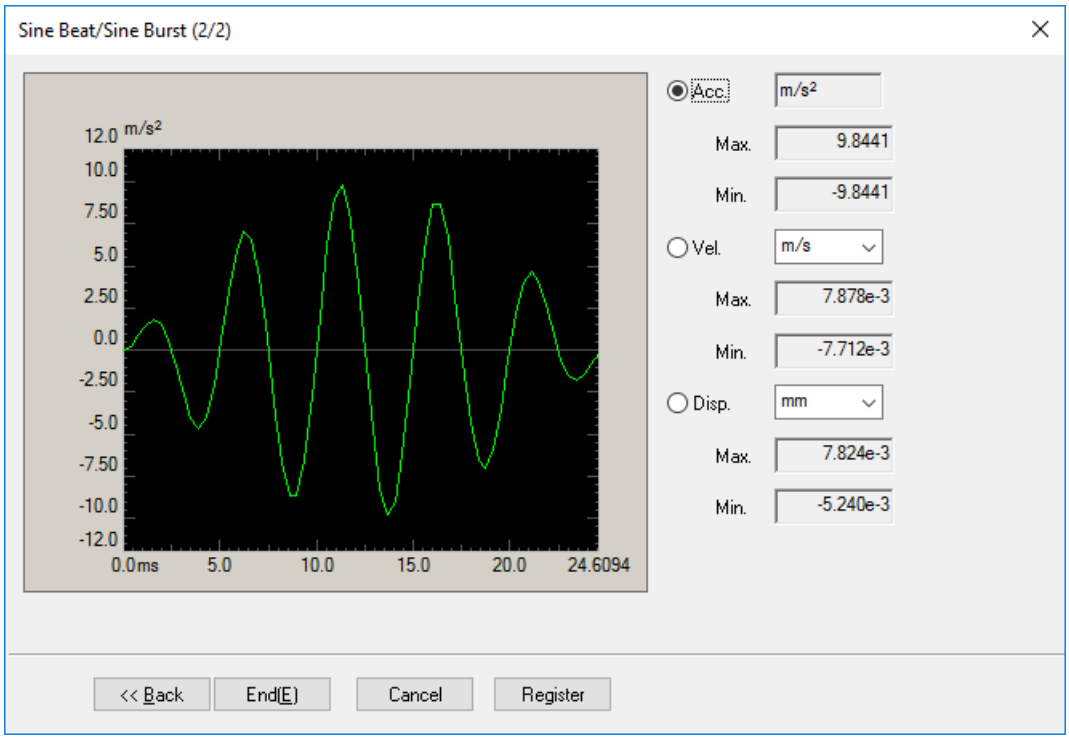


Press [Next] when the definition of these items is completed.

The generated acceleration waveform appears by pressing of [Next].

When the definition of the dialog (1/2) is completed, the definition display (2/2) appears and the generated acceleration waveform appears.

Press [End] to complete the definition of Reference Waveform.



5.4.1 Waveform type (Type)

(1) Meaning

This item is for specifying the type of sinusoidal pulses.

1. Sine Beat

The parameters which specify Sine Beat are Peak amplitude A, Frequency f and Cycle n.

In this system, Sine Beat can be expressed by the following equation ;

$$A1(t) = A \cdot \sin(2\pi ft) \cdot \sin(2\pi ft/p)$$

p : The ratio defined by frequency f and modulating frequency fm.

p = 2n is adopted in this system.

As exceptional, this waveform has a characteristic of Reference Waveform only as a nominal waveform itself. That is, the velocity waveform and the displacement waveform which are the integral value of this nominal waveform satisfies the final condition without Compensation Wave.

2. Sine Burst

This pulse is equivalent to the length for integer number of period of sinusoid.

The parameters which specify Sine Burst are Peak amplitude A, Frequency f and Cycle n.

5.4.2 Physical quantity (Quantity)

(1) Meaning

This item is for selecting the physical quantity of waveform data to be generated among 'Acceleration', 'Velocity', 'Displacement' and 'Force'.

5.4.3 Peak Amplitude (Amplitude)

(1) Meaning

This item is for setting of the amplitude of waveform data to be generated by peak value (0-p).

The value of this item should be set to the lower value than the maximum rating of the excitation system to be used.

5.4.4 Sampling frequency / Auto-set of Sampling frequency(Auto)

(1) Meaning

This item is for setting of Sampling frequency fs that is used at the conversion of analog data to digital data.

Frequency range fmax that specifies the upper limit of frequency of the measurement control is related with Sampling frequency fs as below ;

$$fmax = fs / 2.56$$

Sampling frequency should be set at the proper value to measure the required frequency.

For example, when the observation up to 2000 [Hz] is required by Test Specification, the value of fmax should be set to more than 2000 [Hz] at least.

Also, the available frequency of sine is limited by Sampling frequency.

The value of Sampling frequency fs is selected to be more than about 15 times of the frequency of sine to be generated. However, it varies depending on other conditions.

When the check box of 'Auto-set of Sampling frequency' is checked, an applicable Sampling frequency is selected within the specified frequency of sine automatically.

5.4.5 Frequency

(1) Meaning

This item is for inputting the frequency of sinusoid to be generated.

5.4.6 Cycle

(1) Meaning

This item is for specifying the number of sinusoidal pulse, that is, the number of periods of the waveform cycle to be generated for the specified frequency.

5.4.7 Frame time

(1) Meaning

Frame specifies the number of Sine Beat / Sine Burst generated by the frequency and the waveform cycles.

Where, this item is for setting of the times for repeating Sine Beat / Sine Burst generated by the specified frequency and waveform cycles.

5.4.8 Pause time

(1) Meaning

When the multiple frame are specified. This item is for setting of pause time between the frames.

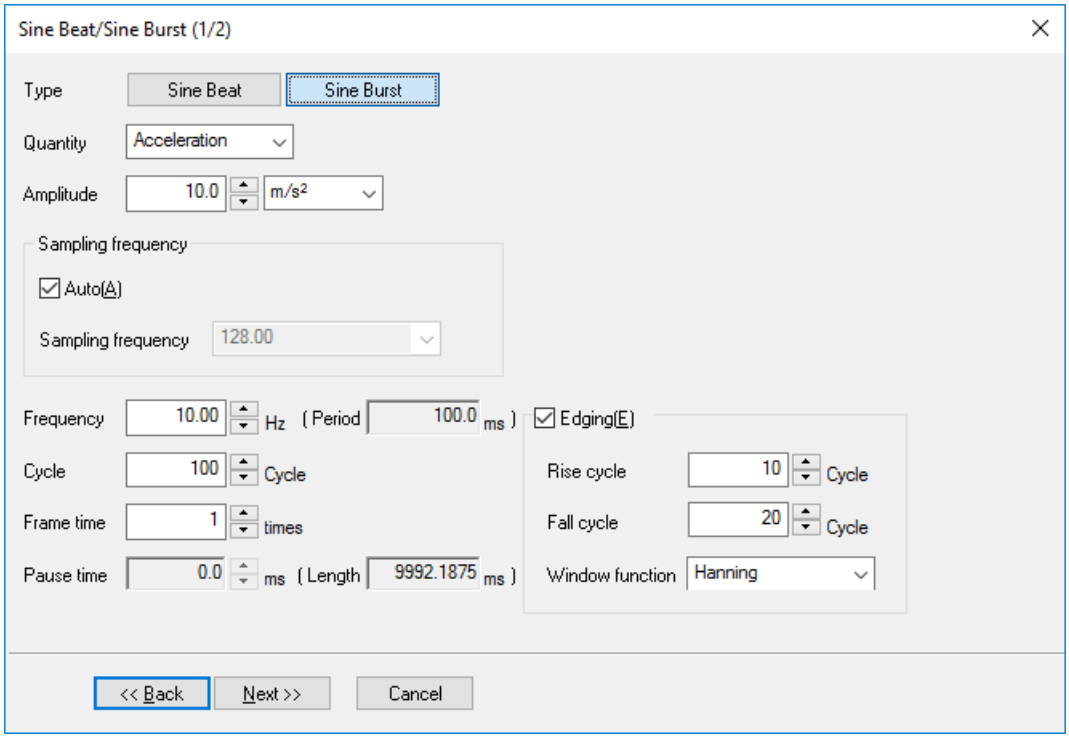
The zero reference for the specified time in this item is put between each frame.

5.4.9 Edging

(1) Meaning

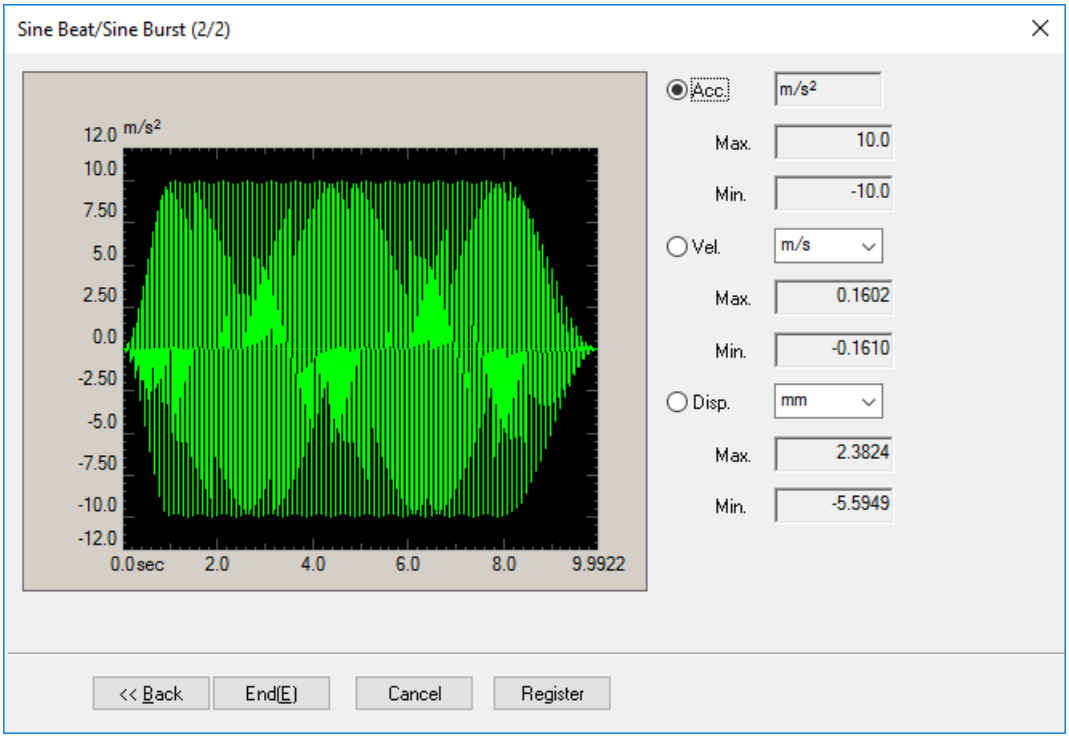
This feature is effective only for the Sine Burst.

The edging is applied for a sine burst waveform to bring the rising and falling edges to zero smoothly. For the window function, either 'Hanning' or 'Ramp' function may be selected.



Select [Sine Burst], check 'Edging' and then set:

- Rise cycle,
- Fall cycle, and
- Window function.



5.4.9.1 Rise cycle

(1) Meaning

Specifies the number of cycles (time) for applying the rising edge process.

Setting this to '0' will nullify the rising edge process.

The sum of 'Rise cycle' and 'Fall cycle' cannot exceed the overall 'Cycle'.

5.4.9.2 Fall cycle

(1) Meaning

Specifies the number of cycles (time) for applying the falling edge process.

Setting this to '0' will nullify the falling edge process.

The sum of 'Rise cycle' and 'Fall cycle' cannot exceed the overall 'Cycle'.

5.4.9.3 Window function

(1) Meaning

This setting selects the window function used for edging.

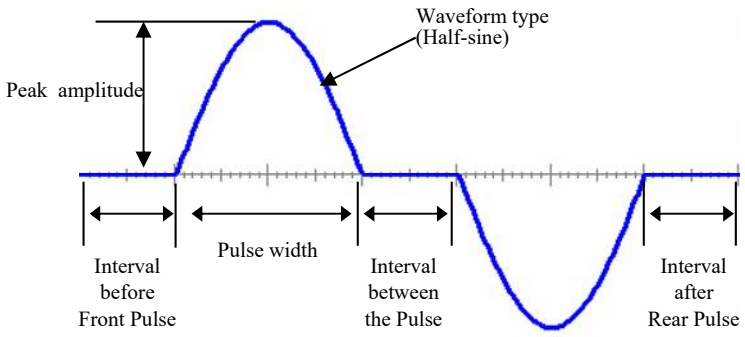
5.5 Symmetric Compensation (Defined Waveform)

The function is this item is for generating a waveform data by using each type of pulse and the same pulse to the specified one having the inverse polarity.

The dimension of Controlled Variable is limited to ‘acceleration.

Symmetric Compensation (Defined Waveform) has the shape of the acceleration waveform as below. And the items that defines the shape of waveform are listed as below ;

- Waveform type
- Peak amplitude
- Pulse width
- Interval before front pulse
- Interval between the Pulse
- Interval after rear pulse



<Compensation Wave>

Compensation of this Waveform type is used to make the final velocity zero.
The result of the final displacement depends on the method of Compensation Wave adding.

(When Compensation Wave is added after the Main pulse ;)

This is a popular method.

In this case, Compensation Wave having the same Pulse width, the same Amplitude and the inverse Polarity as those of Main Pulse is added to the waveform after the Main Pulse.

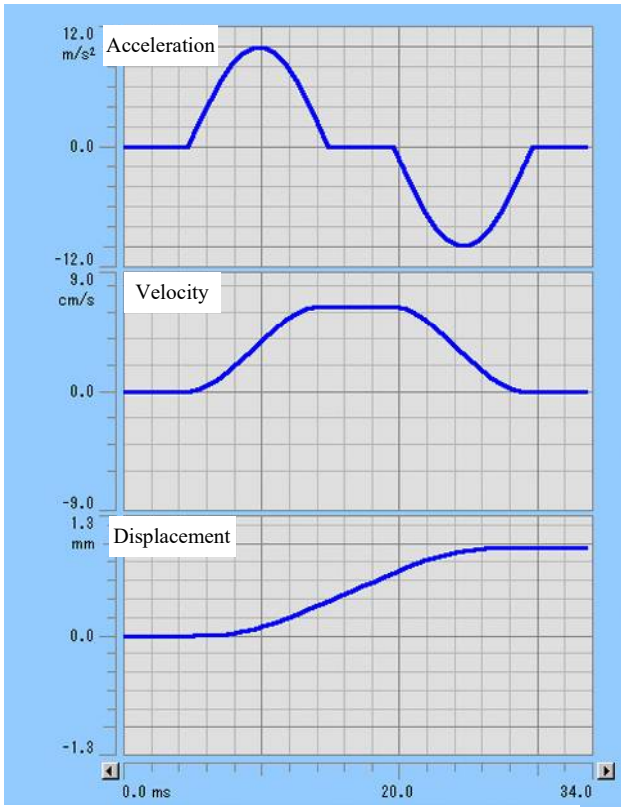
The final displacement zero is not obtained.

(When Compensation Wave is added to front and rear of the Main Pulse ;)

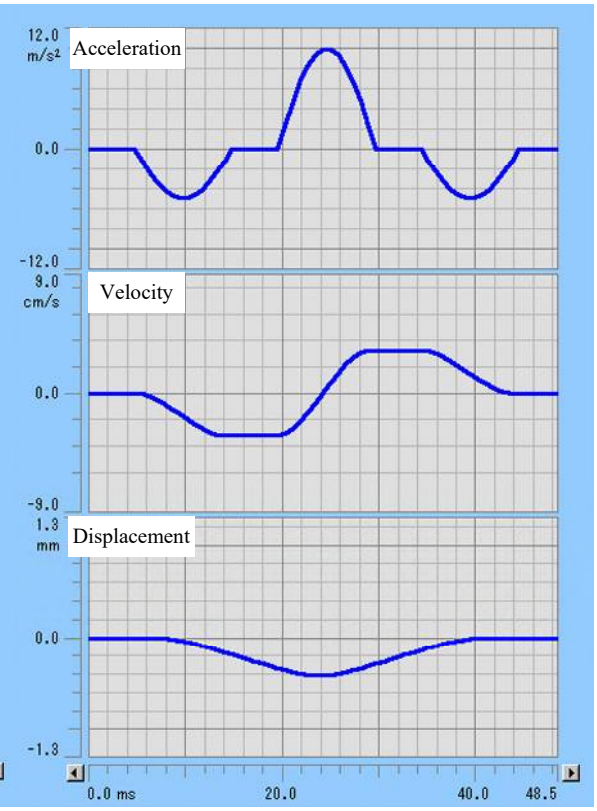
In this case, Compensation Wave having the same Pulse width, 1/2 of the Amplitude and the inverse Polarity as those of Main Pulse is added to the front and rear of waveform.

The final displacement zero is obtained.

Compensation Wave added after the Main Pulse (Normal)

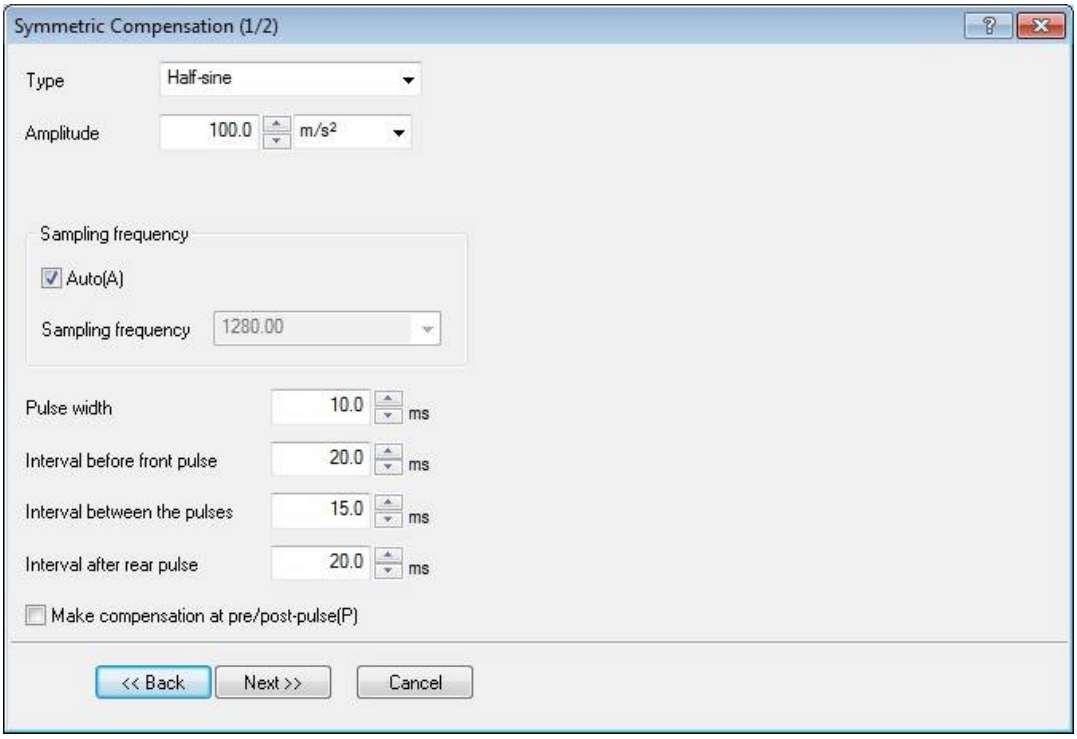


Compensation Wave added to front and rear of the Main Pulse



When [Symmetric Compensation] is selected, the definition dialog (1/2) for setting of the items which defines the shape of waveform appears.

- Waveform type
- Peak amplitude
- Pulse width
- Interval before front pulse
- Interval between the pulses
- Interval after rear pulse



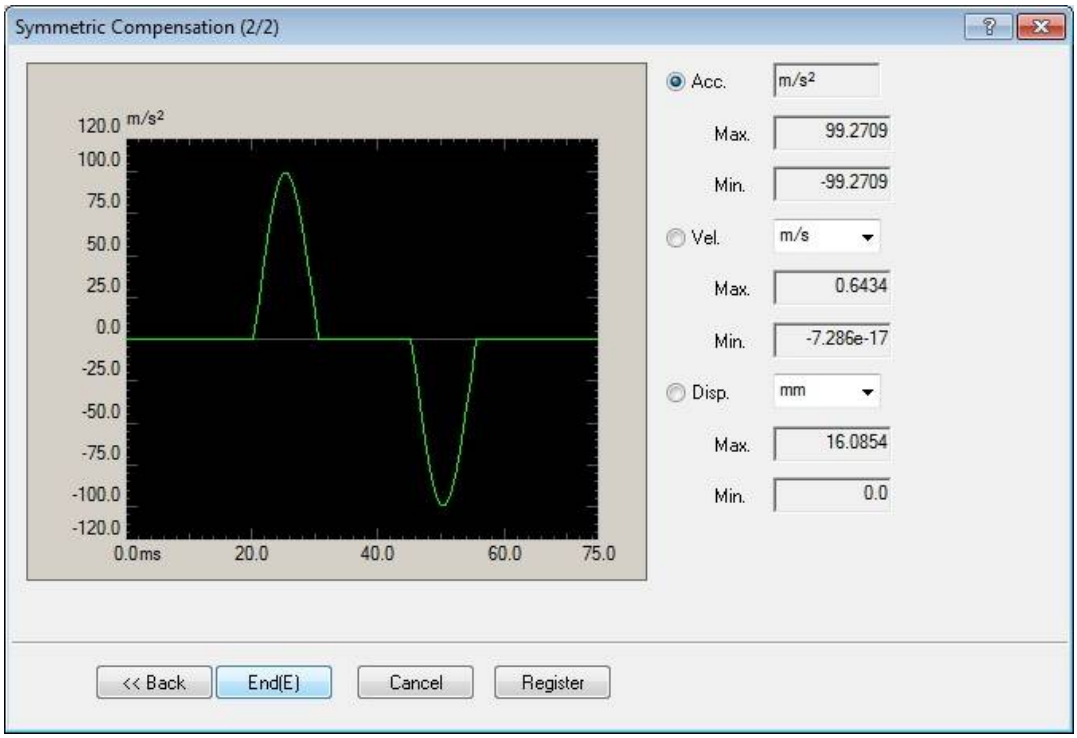
Press [Next] when the setting of these items is completed.

The generated acceleration waveform appears by pressing of [Next].

When the setting of definition dialog (1/2) is completed, the definition dialog (2/2) appears and the generated acceleration is displayed.

Press [Back] to return to the definition dialog (1/2).

Press [End] to complete the definition of Reference Waveform.



5.5.1 Waveform type (Type)

(1) Meaning

This item is for specifying of the type of waveform data to be generated.

・Half-sine

Pulse waveform for a half period of sinusoid

・Haversine

Pulse waveform for one period of waveform cycle expressed by Hanning function

・Triangle

Pulse waveform for a half period of triangle waveform

Actually, a type of pulses specified in this item and the equivalent pulse to the specified one having the inverse polarity are generated as a pair (the pulse having the inverse polarity is used as Compensation Wave).

5.5.2 Peak Amplitude (Amplitude)

(1) Meaning

This item is for setting of the level of waveform data to be generated by peak value (0-p).

The value of this item should be set to the lower value than the maximum rating of the excitation system to be used.

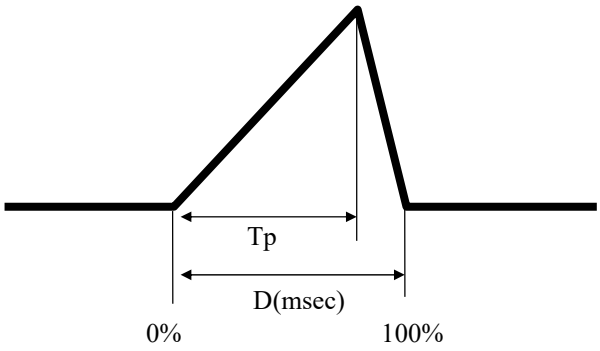
5.5.3 Peak position

(1) Meaning

This item is set only when 'Triangle' is selected as Waveform type.

Peak position is specified by the percentage to Pulse width D (defined later).

The center of pulse is positioned at 50 %.



5.5.4 Sampling frequency / Auto-set of Sampling frequency(Auto)

(1) Meaning

This item is for setting of Sampling frequency fs that is used at the conversion of analog data to digital data.

Frequency range fmax that specifies the upper limit of frequency of the measurement control is related with Sampling frequency fs as below ;

$$fmax = fs / 2.56$$

Sampling frequency should be set at the proper value to measure the required frequency.

For example, when the observation up to 2000 [Hz] is required by Test Specification, the value of fmax should be set to more than 2000 [Hz] at least.

Also, the available Pulse width is limited by Sampling frequency.

The value of Sampling frequency fs is selected to make around 15 points of Data Length within the Pulse width. However, it varies depending on the Waveform type and other conditions.

Data Length within the Pulse width is obtained by the following expression. Denoting Data Length within the Pulse width as Nd and Pulse width as D [ms] ;

$$Nd = D \times fs / 1000$$

When the check box of 'Auto-set of Sampling frequency' is checked, an applicable Sampling frequency is selected within the specified Pulse width automatically.

5.5.5 Pulse width

(1) Meaning

This item is for inputting the Pulse width for a half-period of waveform data to be generated.

5.5.6 Interval before front pulse

(1) Meaning

This item is for specifying the length of zero data when it is added before the Main Pulse.

This item is set to 0[ms] as an initial value.

5.5.7 Interval between the pulses

(1) Meaning

This item is for specifying the length if zero data when it is added between the Main Pulse and Compensation Wave having the inverse polarity.

This item is set to 0 [ms] as an initial value.

When this item is set to 0 [ms], a half-period of pulse having the inverse polarity succeeds the Main Pulse without interval, that is, a waveform data for one period is generated.

Note that the required displacement is sure to be increased when the interval of this item is set.

5.5.8 Interval after rear pulse

(1) Meaning

This item is for specifying the length of zero data when it is added after a half-period of pulse having the inverse polarity. This item is set to 0 [ms] as an initial value.

5.5.9 Make compensation at pre/post-pulse

(1) Meaning

Generally, Compensation Wave (a half-period of pulse having the inverse polarity) is added after the Main Pulse. However in this item, it is added before and after the Main Pulse.

Compensation Wave added before and after the Main Pulse has the same Pulse width as that of the Main Pulse and 1/2 of Amplitude as that of the Main Pulse. In this case, both the final velocity and the final displacement are set to zero.

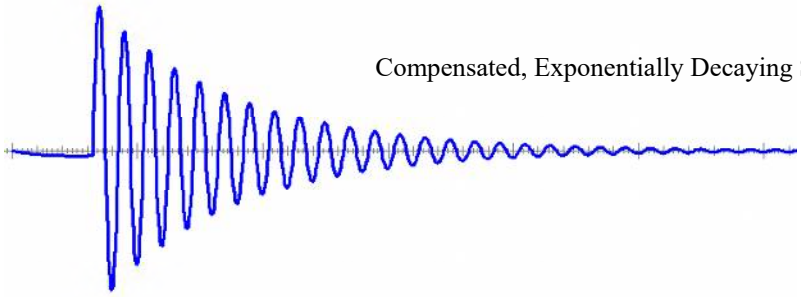
5.6 Damped Sine

Acceleration waveform data of Damped Sine is generated.

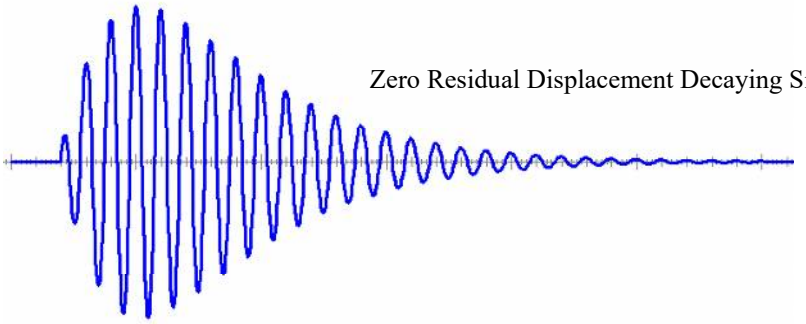
The dimension of Controlled Variable is limited to ‘acceleration’.

Damped Sine has the shape of the acceleration waveform as below. And the items that defines the shape of waveform are listed as below ;

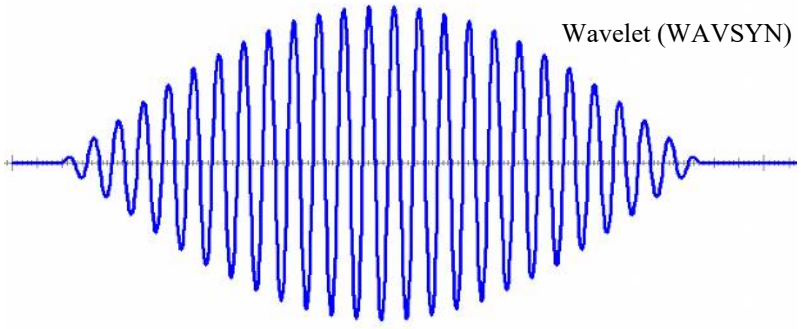
- Waveform Type of Damped Sine (Synthesized Waveform Type)
- Peak Amplitude of Damped Sine
- Frequency of Damped Sine
- Damping Ratio of Damped Sine
- Sampling Frequency
- Data Length (Number of Data Points)



Compensated, Exponentially Decaying Sinusoid (CEDS)



Zero Residual Displacement Decaying Sinusoid (ZERD)



Wavelet (WAVSYN)

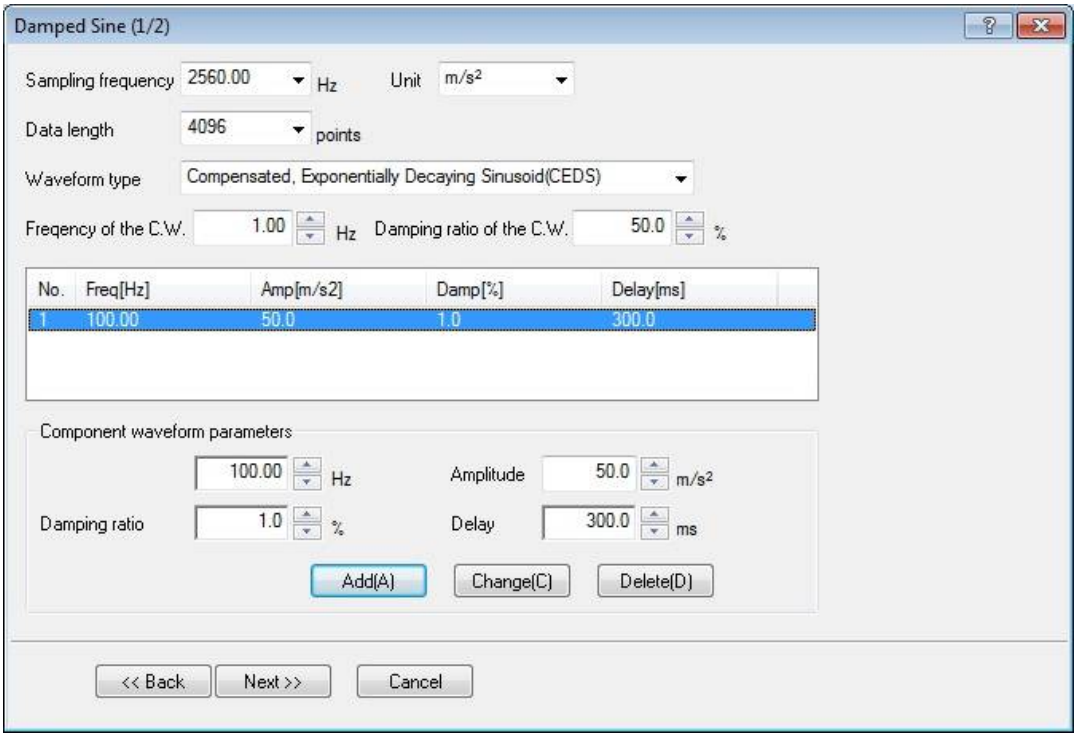
Also, more complex waveform can be generated by superposing these waveforms of Damped Sine.
Damped Sine generated in this system satisfies the conditions as below ;

Initial Velocity = Final Velocity = 0

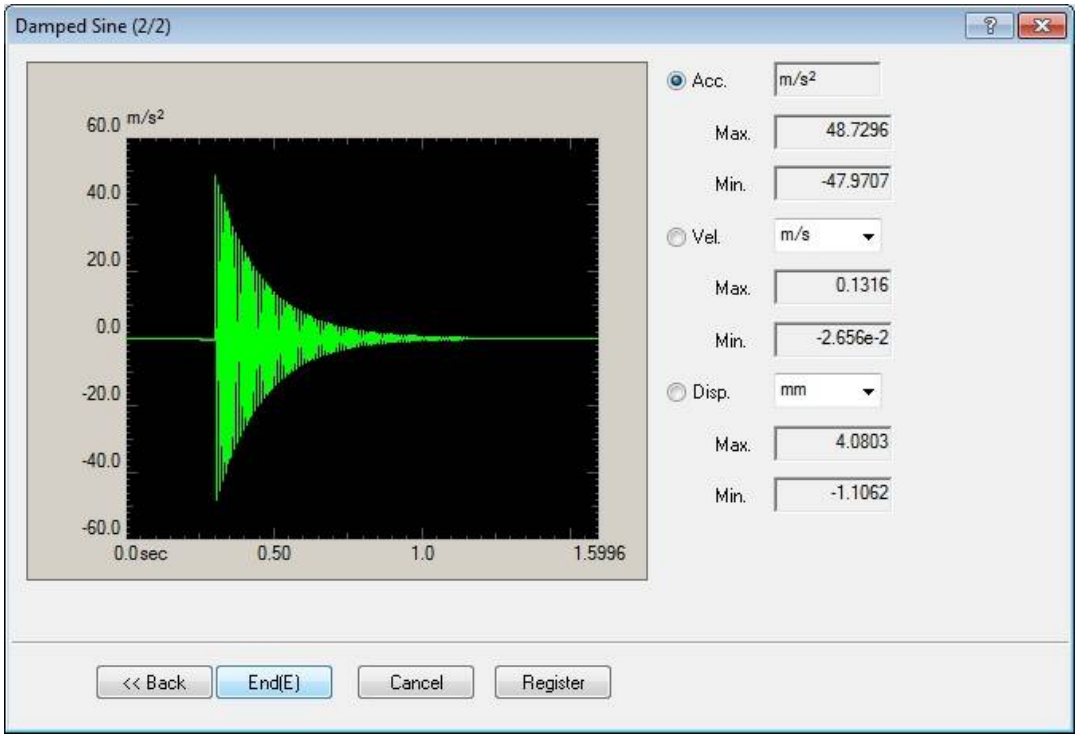
Initial Displacement = Final Displacement = 0

When [Damped Sine] is selected, the definition dialog of Synthesized Waveform for setting of the items that define the shape of waveform appears.

- Synthesized Waveform Type
- Amplitude of each Component Waveform (Damped Sine)
- Frequency of each Component Waveform (Damped Sine)
- Damping Ratio of each Component Waveform (Damped Sine)
- Sampling Frequency
- Data Length



Press [Next] when the setting of these items is completed.



When the setting of definition dialog of Synthesized Waveform is completed, the display of Damped Sine (2/2) appears and the generated acceleration waveform is displayed.

Press [Damped Sine (1/2)] to return to the definition dialog of Synthesized Waveform.

Press [OK] to complete the definition of Reference Waveform.

5.6.1 Synthesized Waveform Type

(1) Meaning

This item is for specifying of the type of waveform data to be generated.

① Compensated, Exponentially Decaying Sinusoid (CEDS)

CEDS (Compensated, Exponentially Decaying Sinusoid) was originated by D.O.Smallwood*[1].

Waveform $\ddot{x}(t)$ is generated by superposing Exponentially Decaying Sinusoids as element waves ;

$$\ddot{x}(t)=\sum_{i=1}^{n} U(t-\tau_i)A_i \exp\{-\zeta_i\omega_i(t-\tau_i)\}\sin\omega_i(t-\tau_i) \tag{5-6-1}$$

Compensation wave hasn't been added to this form yet. So, another additional Exponentially Decaying Sinusoid ω_m is added,

$$\begin{aligned}\ddot{x}(t)=\sum_{i} U(t-\tau_i)A_i \exp\{-\zeta_i\omega_i(t-\tau_i)\}\sin\omega_i(t-\tau_i) \\ +U(t+\tau_m)A_m \exp\{-\zeta_m\omega_m(t+\tau_m)\}\sin\omega_m(t+\tau_m)\end{aligned} \tag{5-6-2}$$

and this form of synthesized waveform is produced. U(t) in this expression indicates the Heaviside's step function.

The problem is how to decide the Compensation wave item. Smallwood calculates the

velocity and displacement expression of (5-6-2) by using Laplace transform, then decides Am and τ m as a function of ω_m, τ_m. That is, Frequency and decaying rate of Compensation wave is given as user defining quantity, and calculate A_m and τ_m are decided using these quantities (A_i, ζ_i, ω_i, τ_i).

The method of this system is the method of Smallwood in the above as it is. Therefore, only in this case, Compensation wave parameters as ω_m and τ_m are needed to be specified in addition to the Component waveform parameters (A_I, ζ_i, ω_i, τ_i).

For some combination of ω_i and ζ_i, enough decaying won't be damped in the defined Frame Time (N/fs). In such a case, it is impossible for the waveform to converge in the Frame Time. To avoid such situation, this program controls the available input value range of ζ_i :At first ω_i is to be specified. And minimum possible ζ_i for the decaying Sinusoid to converge near to zero within the Frame Time is calculated and used as the minimum input range value for ζ_i. To be more exact, the time length which is gotten as the resultant of subtraction of Delay Time which is stated below from the Frame Time is used instead of 'Frame Time' in above statement.

The Time Origin is set to the beginning point of the Frame Time. When Delay Time is set to non-zero value, the corresponding time distance is maintained for delay, and the CEDS waveform is generated accompanied by preceding Compensation Wave according to the above stated procedure.

In some cases, the program may change the Specified Delay Time to a longer one.

*1) Reference : D.O.Smallwood

"Matching Shock Spectra with Sums of Decaying Sinusoids Compensated for Shaker Velocity and Displacement Limitation."

Shock and Vibration Bulletin. 44(3) : 43～56

② Zero Residual Displacement (ZERD) Decaying Sinusoid

D.K.Fisher and M.R.Posehn took another approach to make a compensated decaying sinusoid than CEDS *[2].

The waveform was named as 'ZERD' (Zero Residual Displacement) and has a property of self-compensation by itself.

The definition of ZERO is :

$$\ddot{x}(t) = A\exp(1)\zeta\exp(-\zeta\omega t)[\sin\omega t - \omega t\cos(\omega t+\psi)], t \geq 0$$

$$\psi = \tan^{-1}\left(\frac{-2\zeta}{\zeta^2 - 1}\right) \qquad (5\text{-}6\text{-}3)$$

Quantities to be specified in this expression are A, ω and ζ. Also Delay Time τ can be specified in this program.

Same as in the case of CEDS, minimum possible value of ζ, maximum value is 99%, is determined for giving ω to satisfy the convergence condition by the program.

This waveform has a distinctive envelope of ZERD wave.

*2) Reference : Christian Lalanne

"Mechanical Vibration & Shock Mechanical Shock Volume II" : 253～258

Hermes Penton Science

③ Wavelet (WAVSYN)

The following expression defines a kind of a wave pocket (Wavelet)*[3].

And the Wavelet is designed to have the self-compensation nature like as ZERD, and called 'WAVSYN'.

$$\ddot{x}(t) = A \sin(kt) \sin(\omega t) \qquad 0 \leqq t \leqq T$$

$$0 \qquad \text{other t}$$

$$k = \omega / m$$

$$T = m\pi / \omega$$

$$m = 3,5,7,9, \cdots \qquad (5\text{-}6\text{-}4)$$

Where m is a number of half-period wave and called ''Number of Peaks'. 'Number of Peaks' m must be an odd integer number larger than 3 for WAVSYN to have the self-compensated property. 'Number of period' m corresponds to Damping Ratio ζ in other waveform above. But the properties are reciprocal : large value of m corresponds to a small value of ζ.

Quantities to be specified for defining a WAVSYN are A, ω, m and Delay Time τ. Possible value range for m corresponding to the given value of ω is controlled by the program. In case your requirement is not accepted by the program, try follows ;

- Set Data Length N larger.
- Set Frequency (denoted ω is above) larger, if it is acceptable for the testing.

*3) Reference : R.C.Yang

"Safeguard BMD System - Development of a Waveform Synthesis Technique"

SAF-64 (New York : Ralph M Parsons Co, Aug. 28, 1970)

5.6.2 Sampling Frequency

(1) Meaning

This item is for specifying the Sampling Frequency of waveform data to be generated.

By the setting of this item, 'Frequency Range fmax' that is defined when this data is used in the waveform control program is determined.

Frequency Range fmax is related to Sampling Frequency fs by the equation as below ;

fmax = fs / 2.56 [Hz]

5.6.3 Data Length

(1) Meaning

This item is for specifying the number of data points sampled by Sampling Frequency in the above clause for expressing the waveform data.

The whole length T[s] of waveform data is determined by the equation as below ;

T = N / fs [s] N : Number of Data Points

5.6.4 Frequency of the Compensation Wave

(1) Meaning

This item is defined when CEDS is selected as Synthesized Waveform Type.

This item is for specifying the frequency of Compensation Wave (Exponentially Decaying Sinusoid) to operated the compensation to the superposed acceleration waveform of specified Exponentially Decaying Sinusoids in order to obtain 'Final Velocity zero, Final Displacement zero'. Ordinary, a smaller value than the minimum frequency of the other component waveform is set.

5.6.5 Damping Ratio of the Compensation Wave

(1) Meaning

This item is for specifying the damping ratio given to CEDS in the previous clause.

Ordinary, this item is set to '100 %'.

5.6.6 Component Waveform Parameters (Damped Sine)

The definition of Synthesized Waveform is executed by using the buttons as below ;

[Add] : Damped Sine is registered.

[Change] : Components of the registered Damped Sine is corrected.
Select the number of waveform to be corrected by the mouse and press this button. Then, the parameter of the objective waveform appears.

[Delete] : The registered Damped Sine is deleted.
Select the number of waveform to be deleted by the mouse and press this button.

5.6.6.1 Frequency

(1) Meaning

This definition item is common to each special waveform, CEDS, ZERD and WAVSYN.

This item is for specifying the frequency given to each component.

5.6.6.2 Amplitude

(1) Meaning

This definition item is common to each special waveform, CEDS, ZERD and WAVSYN.

This item is for specifying the initial amplitude Ai given to each component.

The dimension of Controlled Variable for the special waveform data generated by this system is limited to 'acceleration'.

5.6.6.3 Damping Ratio

(1) Meaning

This definition item is common to CEDS and ZERD. This item is for specifying the Damping Ratio ζi given to each component.

<Minimum value>

The minimum value of this item is defined as below ;

Damping Ratio ζi by which the amplitude of component waveform is damped lower that 1/100 of Initial Amplitude Ai at the ending edge of frame time is used as lower limit value.

That is, the lower limit value is defined as the condition assuring the sufficient damping for each waveform within the set data length (specified by fs and N).

When the lower limit value is too large, try follows ;

- Set Data Length N larger.
- Set Delay Time smaller.

<Maximum value>

CEDS : 999.99 %

ZERD : 99 %

5.6.6.4 Number of Periods (WAVSYN)

(1) Meaning

This item is defined when WAVSYN is selected as Synthesized Waveform Type.

The meaning of Number of Periods corresponds to Damping Ratio in CEDS and ZERD. Note that the large Number of Periods corresponds to the small Damping Ratio.

<Minimum value>

Minimum number of Periods is specified to 3 in WAVSYN.

<Maximum>

The program sets that the defined waveform specifies the maximum number of periods converged within the defined data length.

5.6.6.5 Delay

(1) Meaning

This definition item is common to each special waveform, CEDS, ZERD and WAVSYN.

This item is for specifying the delay time τ i given to each component.

That is, the set value of this item defines the time origin of Synthesized Waveform.

For example, when τ i = 10ms is defined, the waveform is generated as the wave that begins at 10 ms passed from the data generation start.

Chapter 6　Supplementary Explanation for Operation

6.1 Tolerance Check in Shock Test other than in Classical Shock

The setting of Tolerance in Shock test is included in the definition items of Reference Waveform in Classical Shock. However, in other types of Reference Waveform, the definition of Tolerance is independent of the definition items in Reference Waveform (Test Definition).

Tolerance is a criterion of judgment for control result and doesn't give any influence to the control ability.

Tolerance of Reference Waveform other than in Classical Shock is not included in the definition file of each Test File. It is defined at each time of testing operation. Tolerance is defined by the item as below ;

- Upper Limit/Lower Limit of Tolerance
  (Set by the percentage to Peak Value of Reference Waveform)

The initial value of Upper Limit/Lower Limit of Tolerance is set at [Set up].

Refer to "6.5.1 Tolerance" about the details.

6.2 Excitation Level Change

Excitation Level is changed by the procedures as below in Excitation Condition.

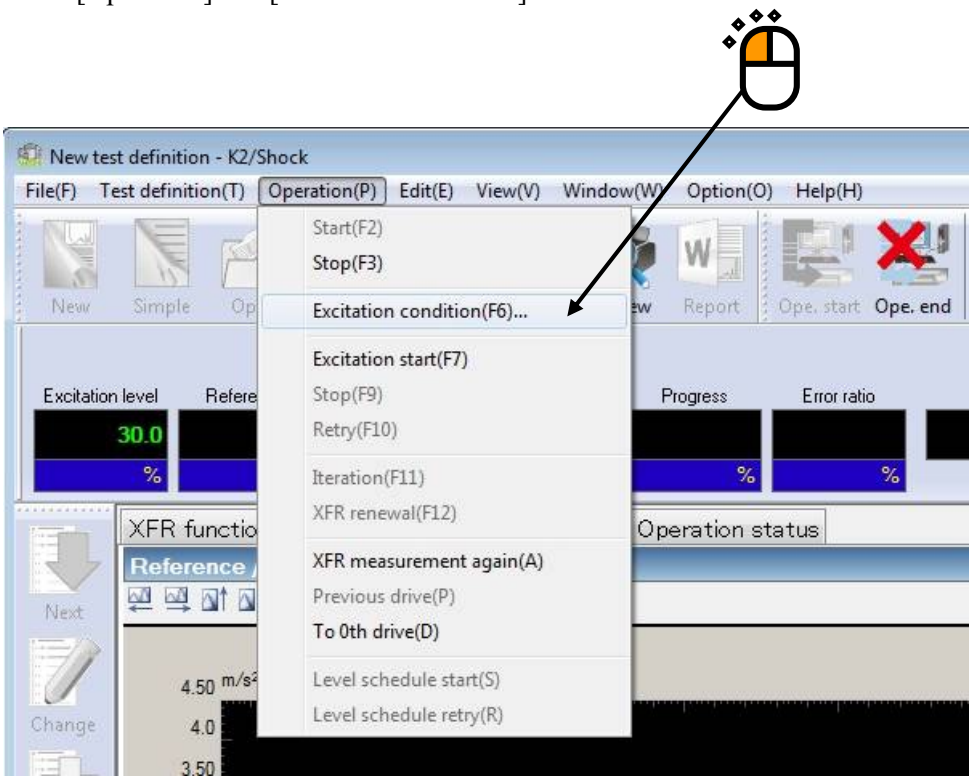
The contents of Excitation Condition can be changed in the state of waiting for Excitation start.

The initial value of Excitation Level is defined in Initial level of Control Condition Definition.

<Procedures>

<Step 1>

Select [Operation] → [Excitation condition] in Menu bar.

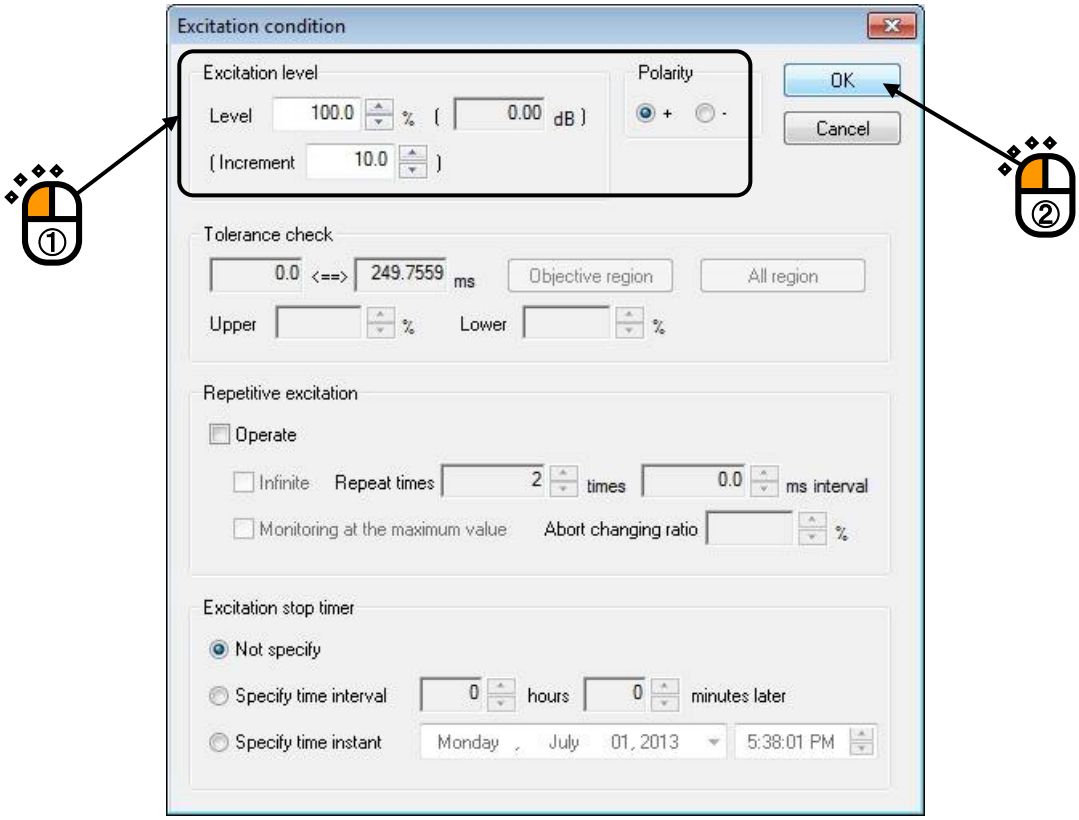


<Step 2>

Excitation Level is specified in this item.

The initial value is set to the value specified in Initial level of Control Condition.

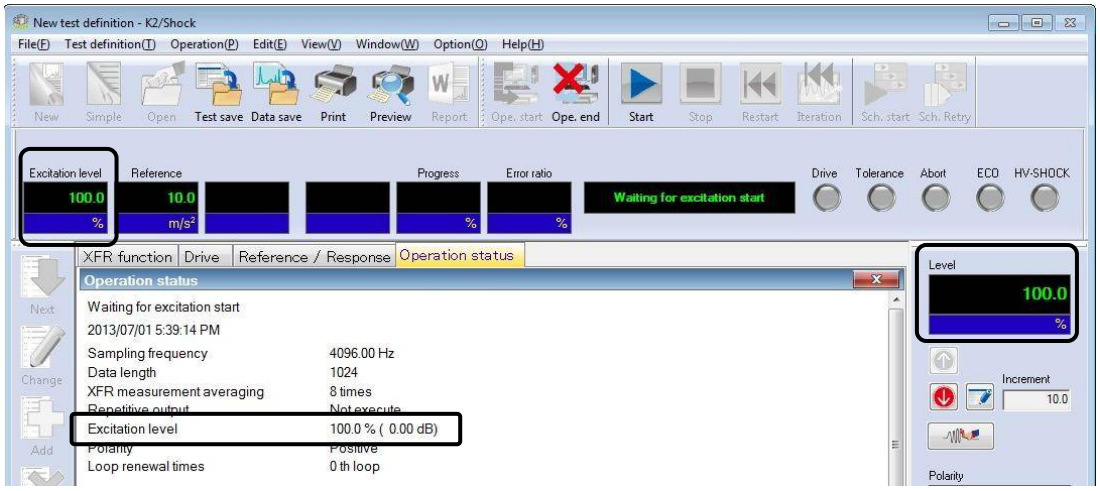
In the dialog as below, Excitation Level is specified to '100 %' as an example.



<Step 3>

Excitation Level is corrected to the specified value in the above.

The excitation is started at the specified Excitation Level by pressing of [Excitation start].



6.3 Polarity Change of Reference Waveform

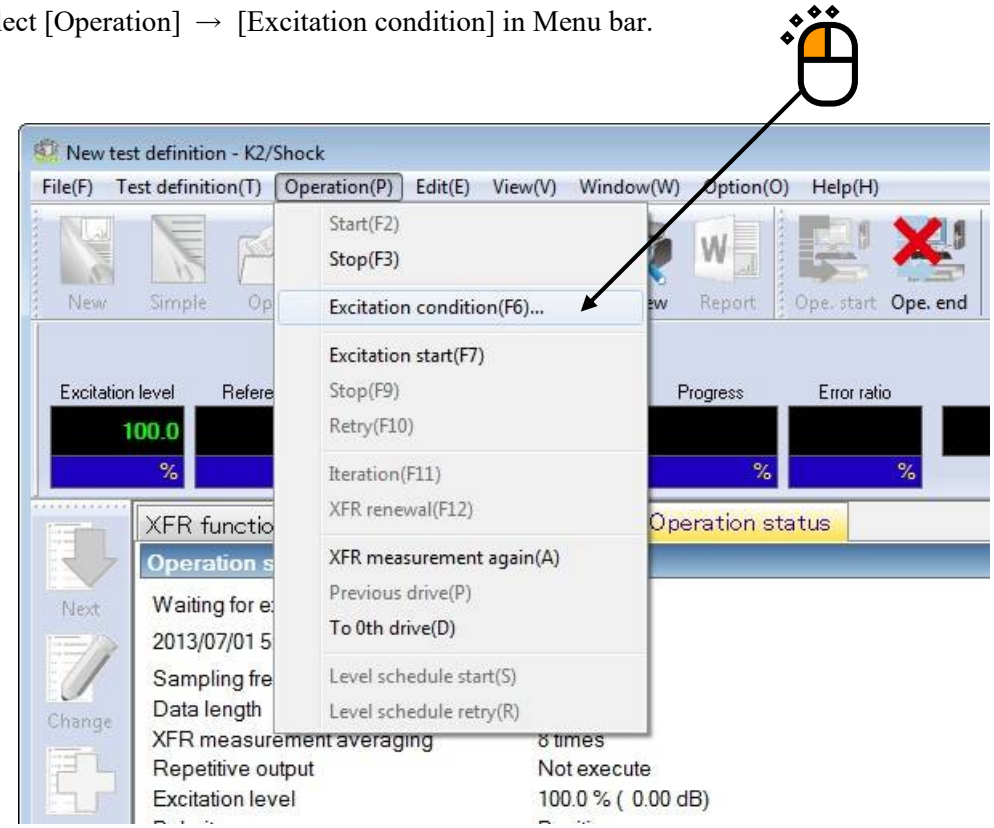
Polarity of Reference Waveform is changed by the procedures as below in Excitation Condition.
The contents of Excitation Condition can be changed in the state of waiting for Excitation start.

The initial value of Polarity of Reference Waveform is specified in Polarity of Control Condition Definition (Detailed Definition).

<Procedures>

<Step 1>

Select [Operation] → [Excitation condition] in Menu bar.

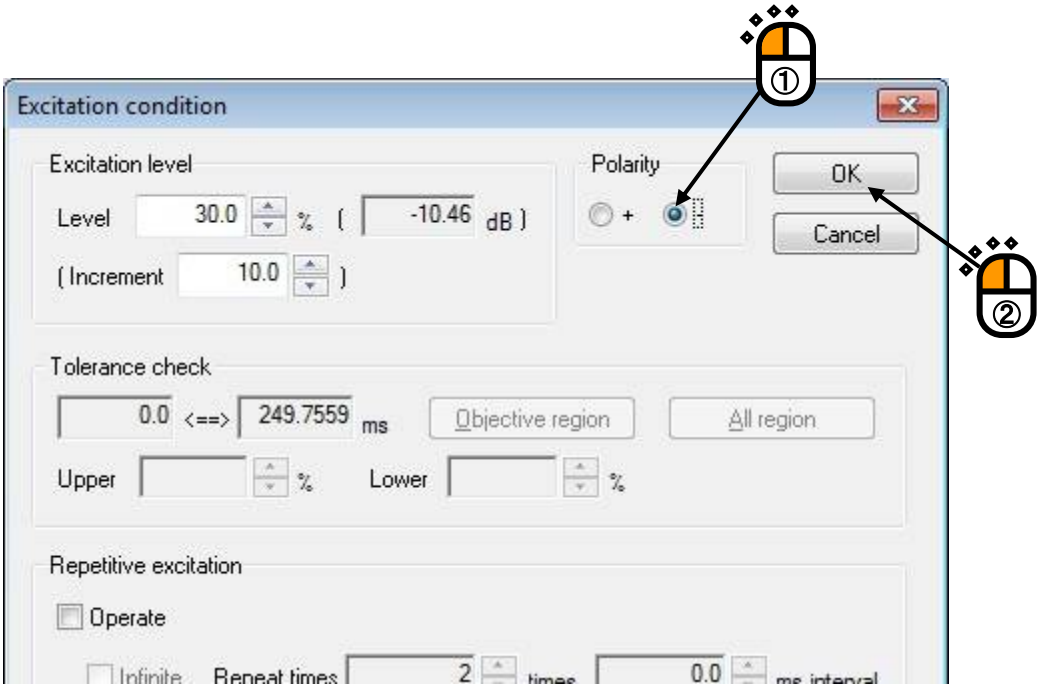


<Step 2>

Select the type of Polarity.

The initial value is specified to the value defined in Polarity of Control Condition.

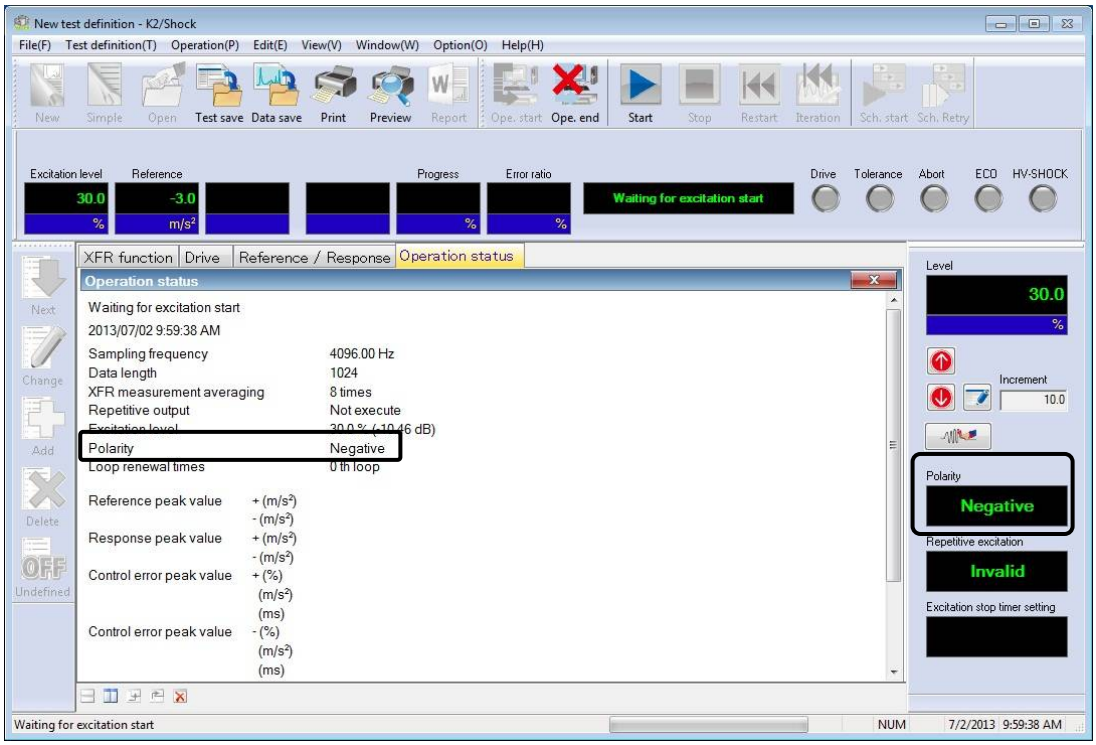
In the dialog as below, Polarity is specified to '－(minus)' as an example.



<Step 3>

Polarity is corrected to the specified value in the above.

The excitation is started in the specified Polarity by pressing of [Excitation start]



6.4 Repetitive Excitation

6.4.1 The operation of Repetitive Excitation

The operation of Repetitive Excitation is set by the procedures as below in Excitation Condition. The contents of Excitation Condition can be changed in the state of waiting for Excitation start.

The condition of Repetitive Excitation is specified by two items as below ;

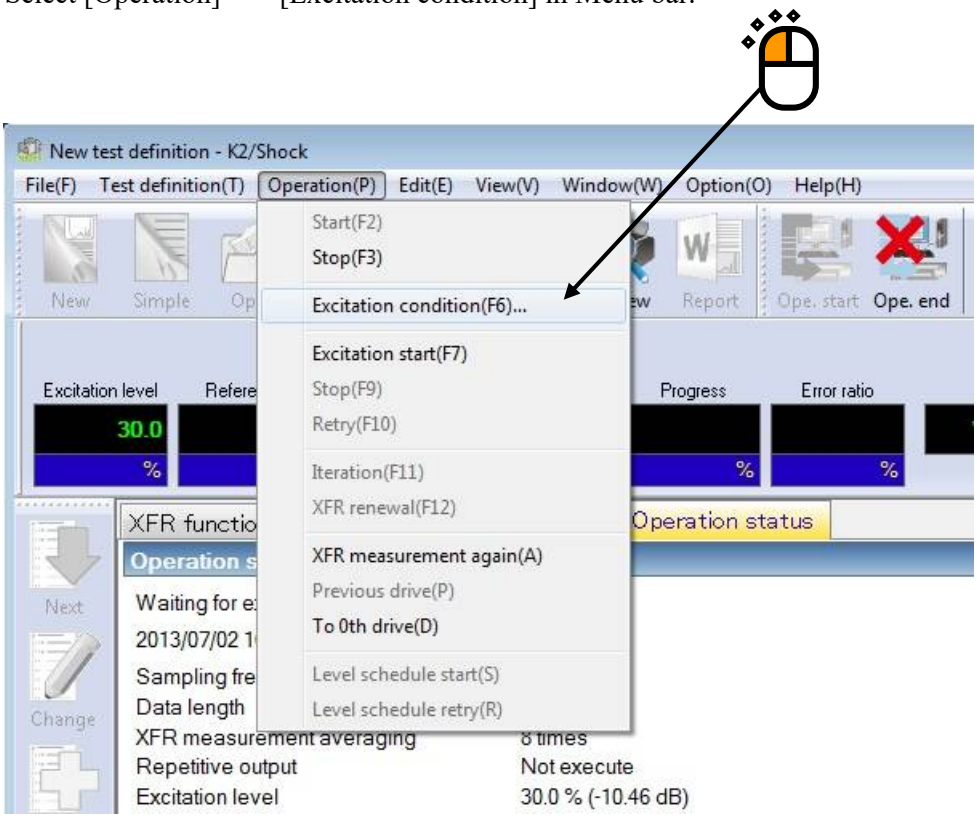
- Repeat times
- Interval

The initial value of Repetitive Excitation is specified in Repetitive Excitation of Control Condition Definition (Detailed Definition).

<Procedures>

<Step 1>

Select [Operation] → [Excitation condition] in Menu bar.



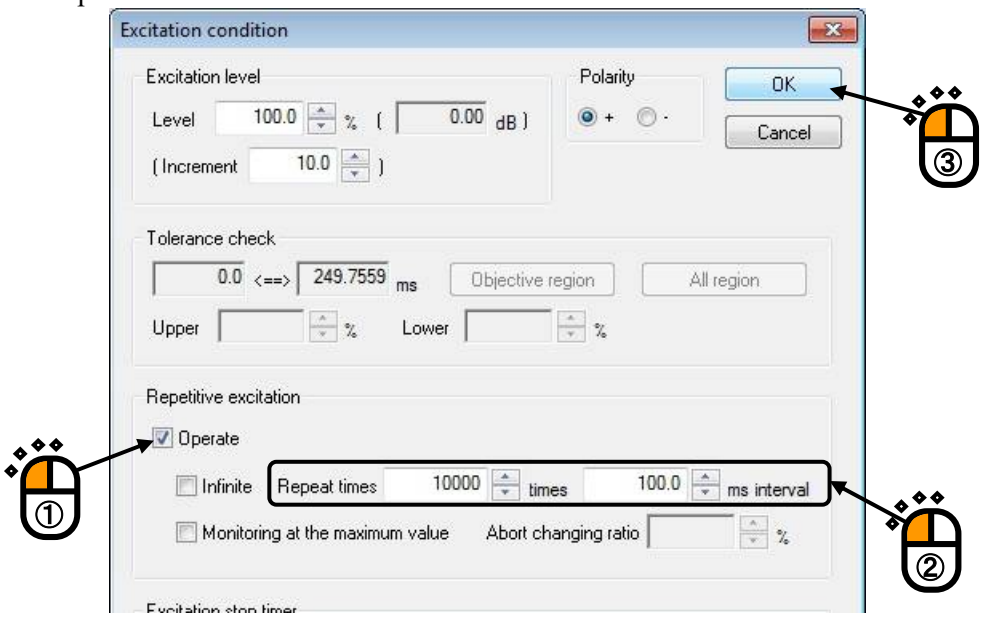
<Step 2>

Check the check box of ‘Operate’ in the items of Repetitive Excitation.

Check the check box of ‘Infinite’ when the times of repeat are not specified. On the other hand, the times of repeat can be specified by inputting the times in Repeat Time and specifying the interval of repeat after canceling the check of ‘Infinite’.

The initial value is set by the condition defined in Repetitive Excitation of Control Condition Definition.

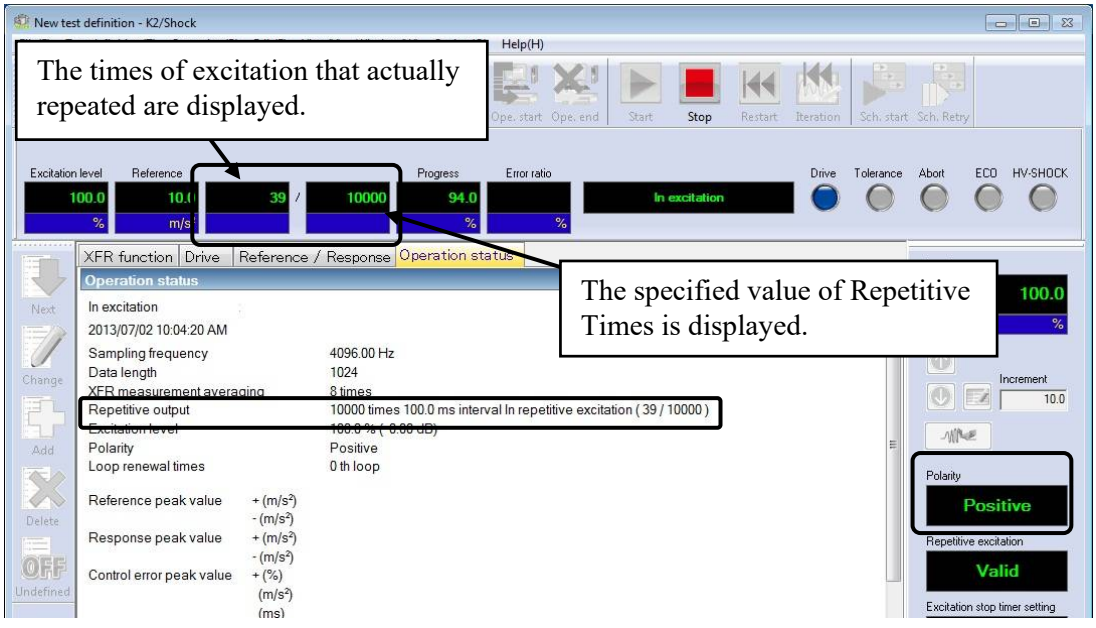
In the dialog as below, Repeat Times is specified to 10000 times and Interval is specified to 100 ms as an example.



<Step 3>

Repetitive Excitation is corrected to the specified value in the above.

The excitation is started in the specified condition of Repetitive Excitation by pressing of [Excitation start].



6.4.2 Monitoring at the maximum value

This function is for monitoring response during repetitive excitation.

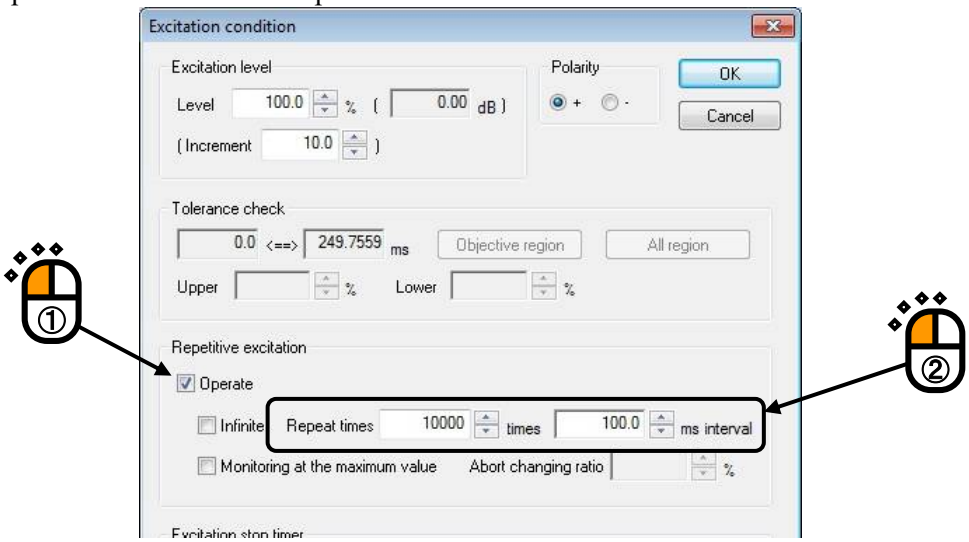
By using this function, for example when excitation system or sensor system becomes abnormal and response is changed, the excitation can be stopped.

The peak value of response at current excitation is compared to the peak value at first excitation during repetitive excitation. And when the change ratio is larger than the specified ratio (Abort changing ratio), the excitation is stopped.

<Procedures>

<Step 1>

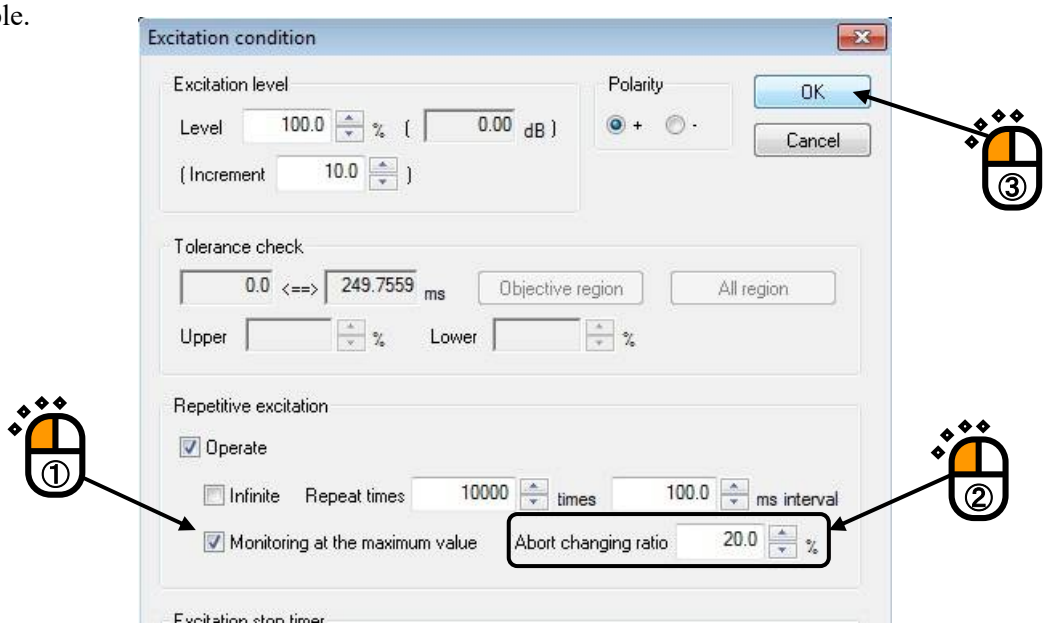
Set 'Repetitive Excitation' of the previous section.



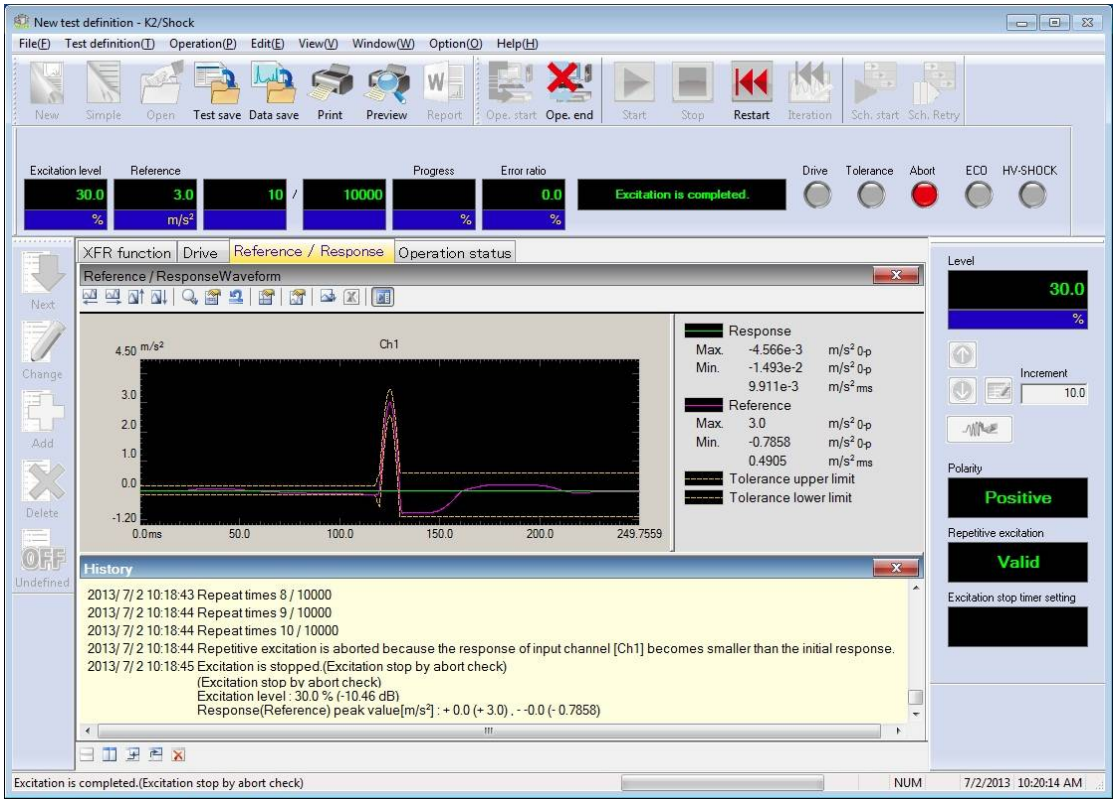
＜Step2＞

Check the check box of ‘Monitoring at the maximum value’.

Specify Abort changing ratio. In the dialog as below, Abort changing ratio is specified to 20% as an example.



The example that response becomes small during repetitive excitation is shown below.

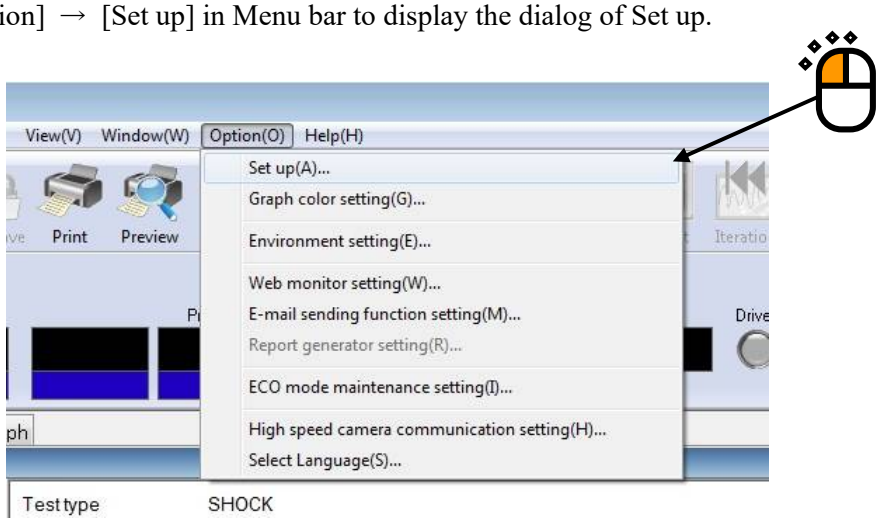


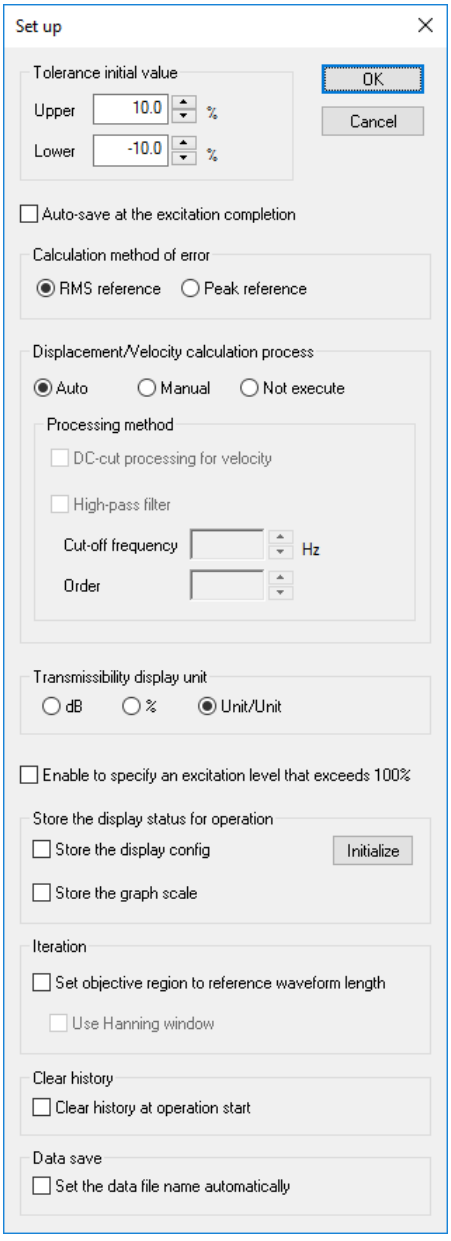
When response becomes smaller during repetitive excitation than Abort changing ratio, the excitation is stopped and the abort message is displayed in History window.

6.5 Set Up

The function of Set up is described in this clause.

Select [Option] → [Set up] in Menu bar to display the dialog of Set up.





6.5.1 Tolerance

Select the tag of Tolerance. The initial value of Upper Limit/Lower Limit of Tolerance is specified for Excitation Condition.

Upper Limit/Lower Limit of Tolerance is specified by the percentage to Peak Value of Reference Waveform.

6.5.2 Displacement/Velocity Calculation Process

Select the tag of Displacement/Velocity Calculation Process. This item is for specifying the method of Displacement/Velocity Calculation Process. This item is valid only when the Controlled Variable is set to 'Acceleration'.

Based on the reliability of definite integral characteristics and acceleration data in the lower frequency range, when the check of system rating is operated by the displacement/velocity waveform simply integrated, the test operation itself cannot be executed because of the error that too much displacement/velocity of Reference is obtained. This function is for operating the adjust process to get a proper displacement/velocity waveform with avoiding the phenomenon in the above. However, carefully use of this function is required because too much displacement/velocity is real in some cases.

Note that the displacement/velocity waveform calculated from acceleration waveform must be treated as a reference. Use displacement sensor when accurate response displacement waveform is needed to be obtained.

<Auto>

- In case the reference waveform type is 'Measured waveform" or "Sine burst waveform"
  - Velocity DC cutting : ON
  - High-pass filter processing : ON

    Cutoff frequency : max [2 Δ f, control lower limit frequency], Degree : 1
- Other cases
  - Velocity DC cutting : OFF
  - High-pass filter processing : OFF

<Manual>

Adjusting process is operated as below ;

- DC-cut processing for Velocity

  DC component is cut off at calculating the velocity waveform.
- HPF

  High-pass Filtering (Butterworth Filter) is operated to the displacement waveform to adjust it. When this item is selected, the values of 'Cut-off frequency' and 'Order' are specified. The larger the value of Cut-off frequency is specified, the smaller the displacement is calculated. And, the larger the value of Order is specified, the steeper the slope of Filter is obtained.

  The signals in the lower frequency range exceeding over the usable frequency band of Accelerometer should be cut-off. The signal component in the lower frequency range is needed to be removed beforehand because it is amplified by processing of integral.

6.5.3 Transmissibility display unit

This item is for specifying the display unit of Transmissibility between the data having the same dimension each other.

The display unit of Transmissibility between the data having different dimensions is described as 'Unit/Unit' in all cases.

6.5.4 Auto-save at the excitation completion

This item is for saving the data file automatically at the excitation completion.

The file name of data to be generated is as below.

Test file name XXX.vdf

XXX : The sequential serial number is obtained at each time when the excitation is completed. In repetitive excitation operation, only the latest excitation data is saved.

6.5.5 Enable to specify an excitation level that exceed 100%

This function allows to set higher excitation level than 100%. The upper limit is 200%.

Use this function after fully understanding the dangerousness. Wrong use may damage the system. To perform higher than 100% of excitation, we strongly recommend raising the reference waveform level itself without using this function.

Rating check is held at 100% during definition. It cannot therefore be seen whether higher than 100% of excitation is available or not at the end of definition. Since rating is checked before every excitation, however, such a safety function as 'higher than the rated excitation is unavailable' works.

6.5.6 Store the display status for operation

・'Store the display config' check box

Check 'Store the display config' to store the display configuration during testing. Display configuration is stored for each test type. If the display configuration is stored, graphs and others based on the same settings as those for the previous testing will be displayed during next testing. Uncheck 'Store the display config' not to store the display configuration modified thereafter.

・‘Store the graph scale’ check box

Check ‘Store the graph scale’ to store the scale of the displayed graphs during testing. The graph scale is stored for each test type. If the graph scale is stored, graphs based on the same scale as those for the previous testing will be displayed during next testing. Uncheck ‘Store the graph scale’ not to store the graph scale modified thereafter.

・‘Initialize’ check box

Select ‘Initialize’ to format the display configuration and the graph scale.

6.5.7 Calculation method of error

The calculation method of error is selectable between ‘RMS reference’ and ‘Peak reference’ in the dialog box of Set up.

RMS reference :

Calculating the percentage of error ratio by comparing RMS of error waveform to reference waveform.

Error ratio[%] ＝ RMS of error waveform / RMS of reference waveform × 100

Peak reference

Calculating the percentage of error ratio by comparing Peak of error waveform to ‘Peak to Peak’ of reference waveform.

Error ratio[%] ＝ Peak of error waveform / p-p of reference waveform × 100

6.5.8 Iteration (Correction of Drive data)

By iteration, an unwanted response may occur outside the reference waveform region. If this happens, use this function.

・ ‘Set objective region to reference waveform length’ check box

This eliminates any effect of errors outside the reference waveform region from the iteration processing. However, because errors outside the reference waveform region will be removed forcibly, the use of this function may cause unwanted components in the drive waveform immediately before and after the reference waveform region. For this reason, the “use Hanning window” check box described below should be selected in most cases.

・ ‘Use Hanning window’ check box

Errors outside the reference waveform region will be disregarded in consideration of continuity of the error waveform in the iteration processing. However, the error convergence of response waveform in regions at the beginning and end of the reference waveform will be poor.

6.5.9 Clear history

・‘Clear history at operation start’ check box

Check ‘Clear history at operation start’ to clear the history of earlier times at operation start automatically.

6.5.10 Data save

・‘Set the data file name automatically’ check box

Check ‘Set the data file name automatically’ to set the destination folder and the file name automatically. If this item is checked, a dialog of [Save as] doesn’t appear even if [Data save] is selected from the menu or the tool bar. The data file name is set to the name of the test definition file plus a 3-digit sequence number, and is saved in the same folder as the test definition file.

Example) When the test definition file is “C:/K2Data/ShockTest.sho2”,
the data file is saved with the name “C:/K2Data/ShockTest001.vdf2”.
If the same name exists, it is saved with the name increased by one sequence number.

If this item is unchecked, a dialog of [Save as] appears and it is possible to select the folder and the file name as desired.

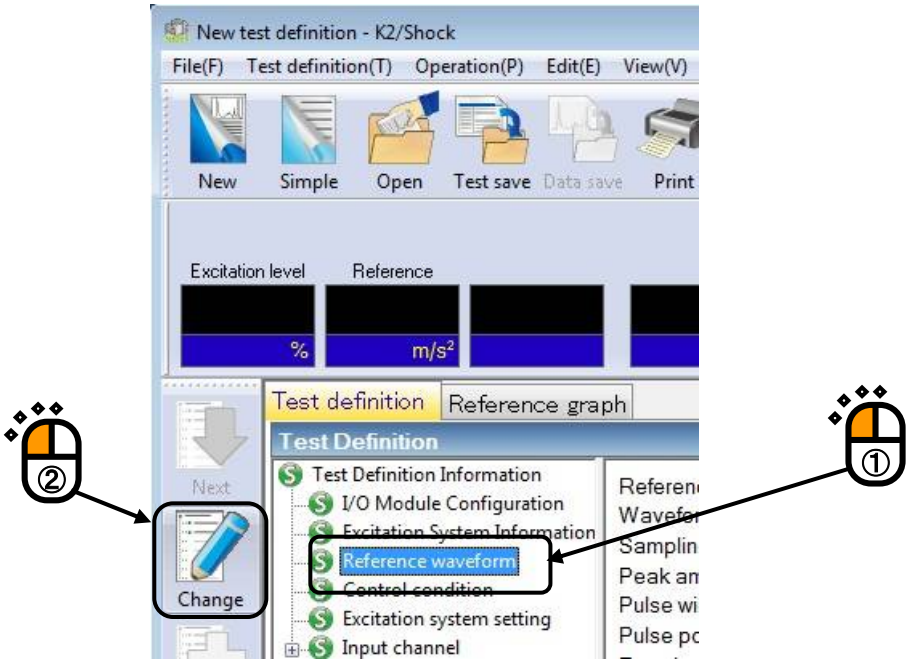
6.6 Reference Waveform Type Change

The procedures of correcting the defined Reference Waveform Type are described.

<Procedures>

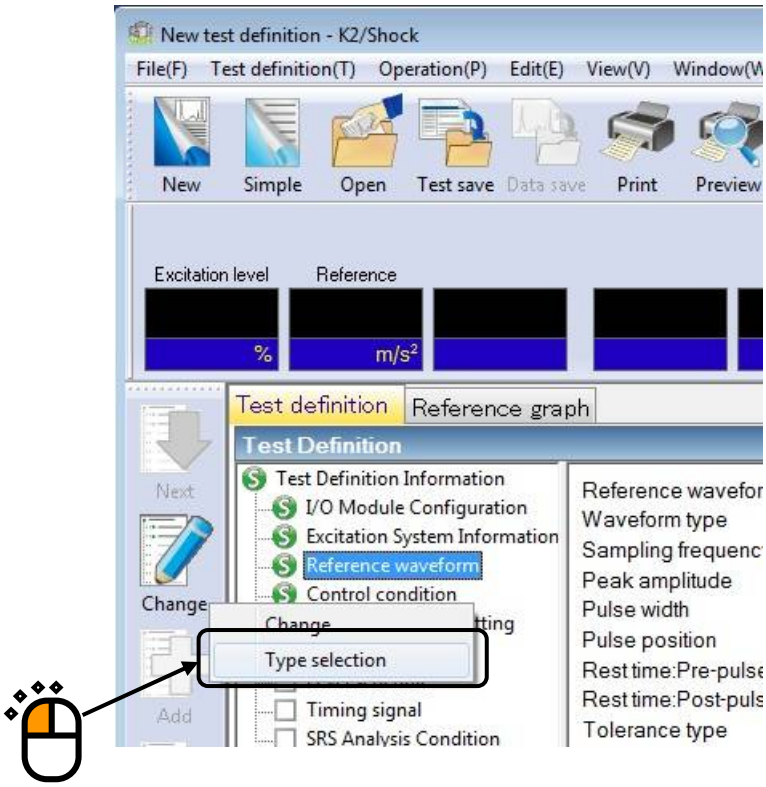
<Step 1>

Select ‘Reference’ in Test Definition items and press [Definition Change] button.



<Step 2>

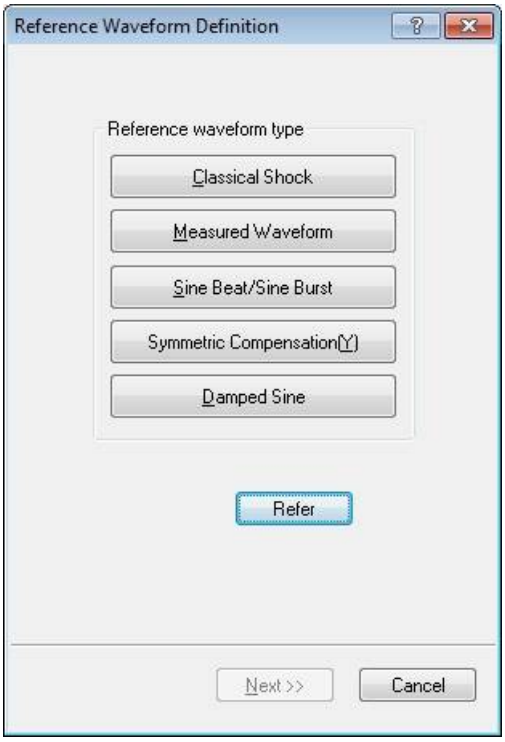
Select ‘Type selection’ in menu items.



<Step 3>

Select one of the Reference Waveform Type to be defined in the dialog of Reference Waveform Definition. Then, press [Next].

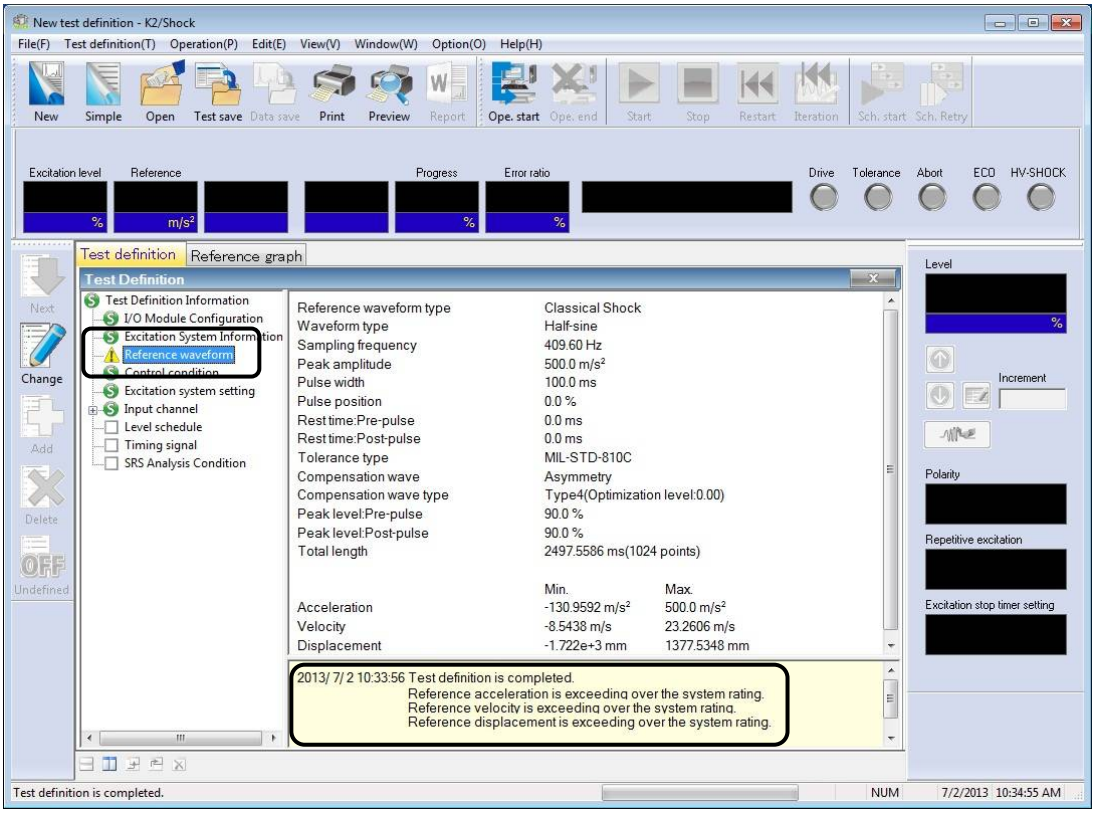
The definition dialog of each waveform type appears. Refer to Reference Waveform Definition in Chapter 5 about the details of each type.



6.7 System Rating Check

As one of the safety functions, the displacement and velocity waveform of the Reference Waveform is calculated and checked by comparing with the value of System Rating when the Reference Waveform is specified as acceleration.

If the values exceed over the System Rating, the error or the warning messages are displayed.



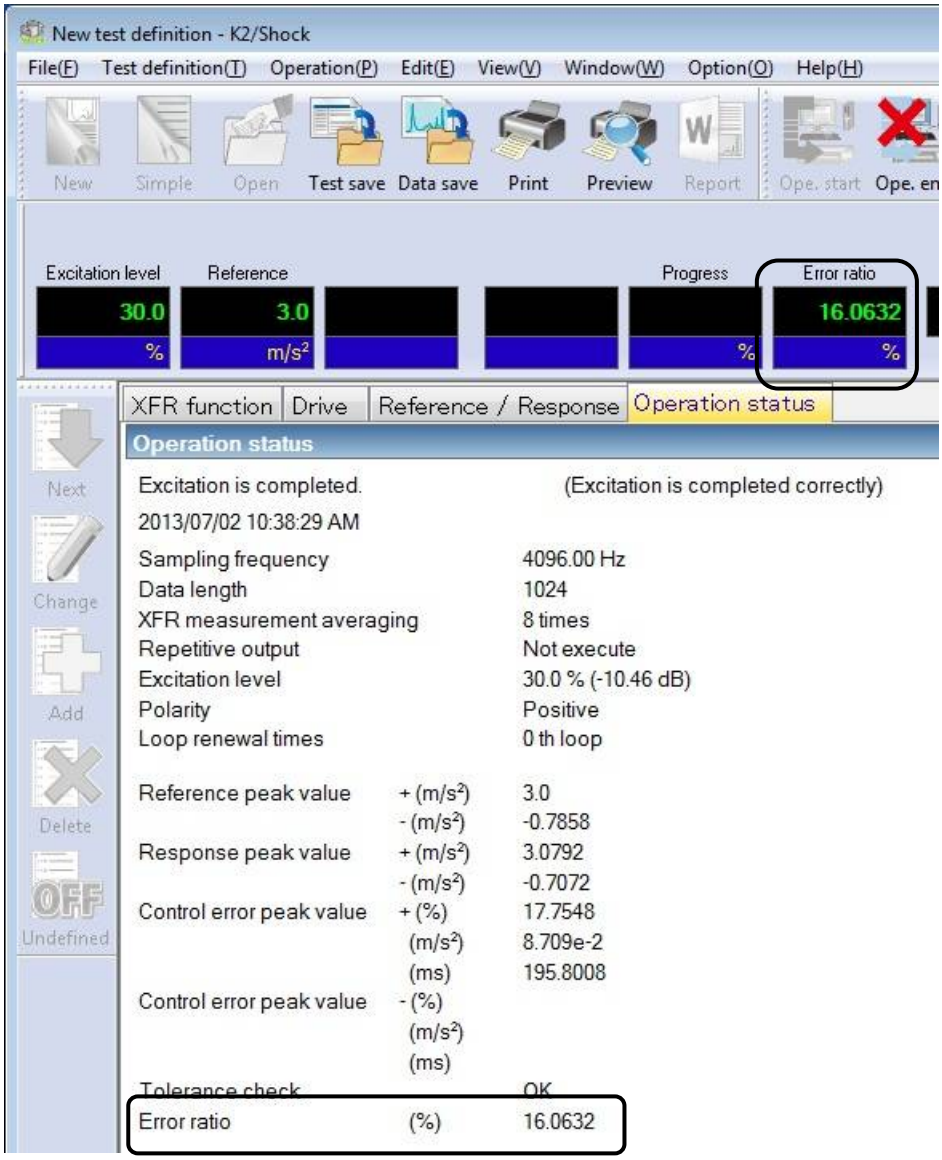
Refer to “6.5.2 Displacement/Velocity Calculation Process” about the calculation of Displacement and Velocity waveforms.

Refer to “4.12 Safety check” about the System Rating Check by excitation force.

6.8 Error ratio

When the excitation is completed, the results of excitation, such as the result of Tolerance Check and Error ratio, are displayed.

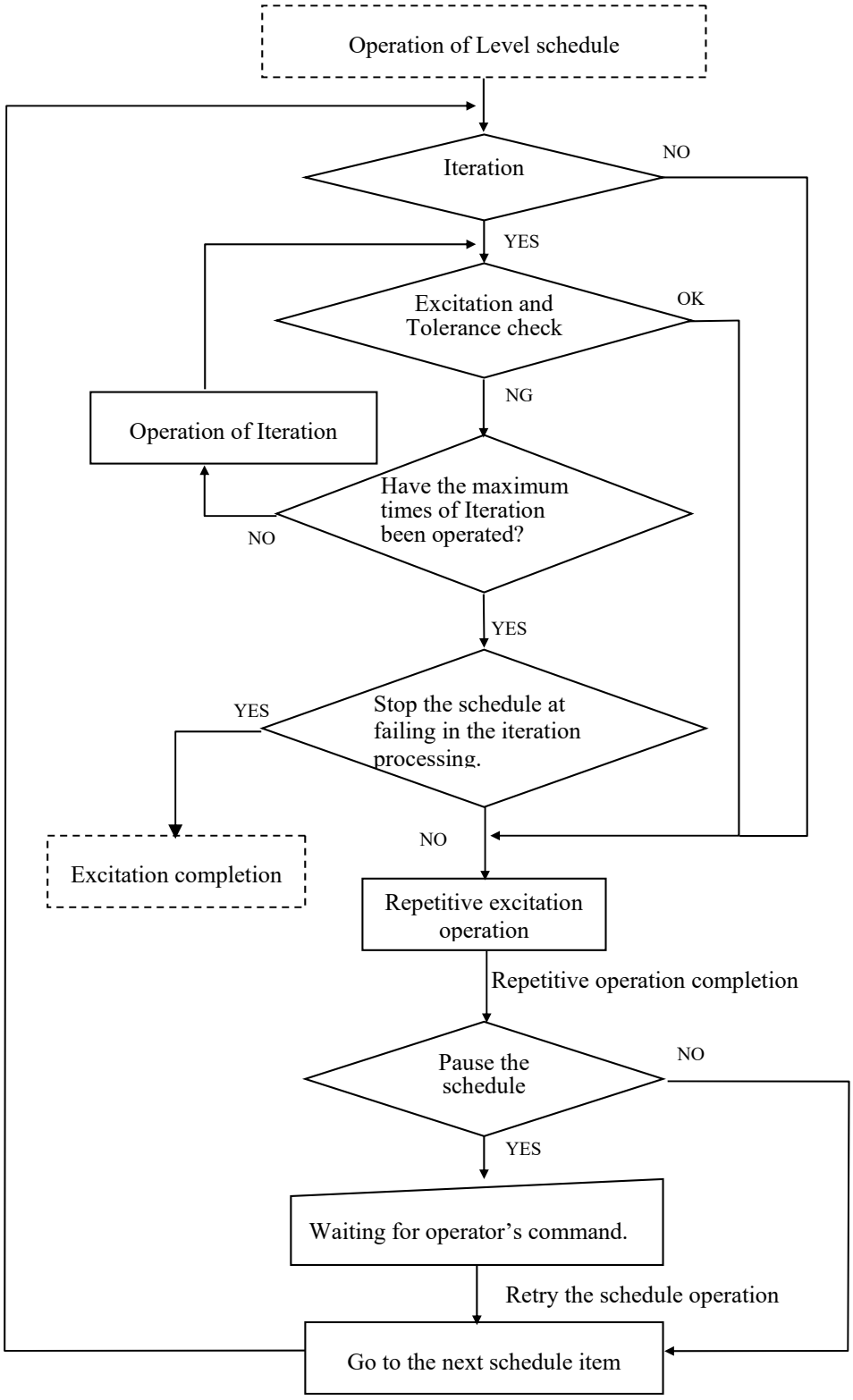
The Error ratio is calculated according to the method in “6.5.7 Calculation method of error”.



6.9 Operation of Level Schedule

Level schedule operation is available when the level schedule is defined.

The outline of Level scheduling process is described as below ;



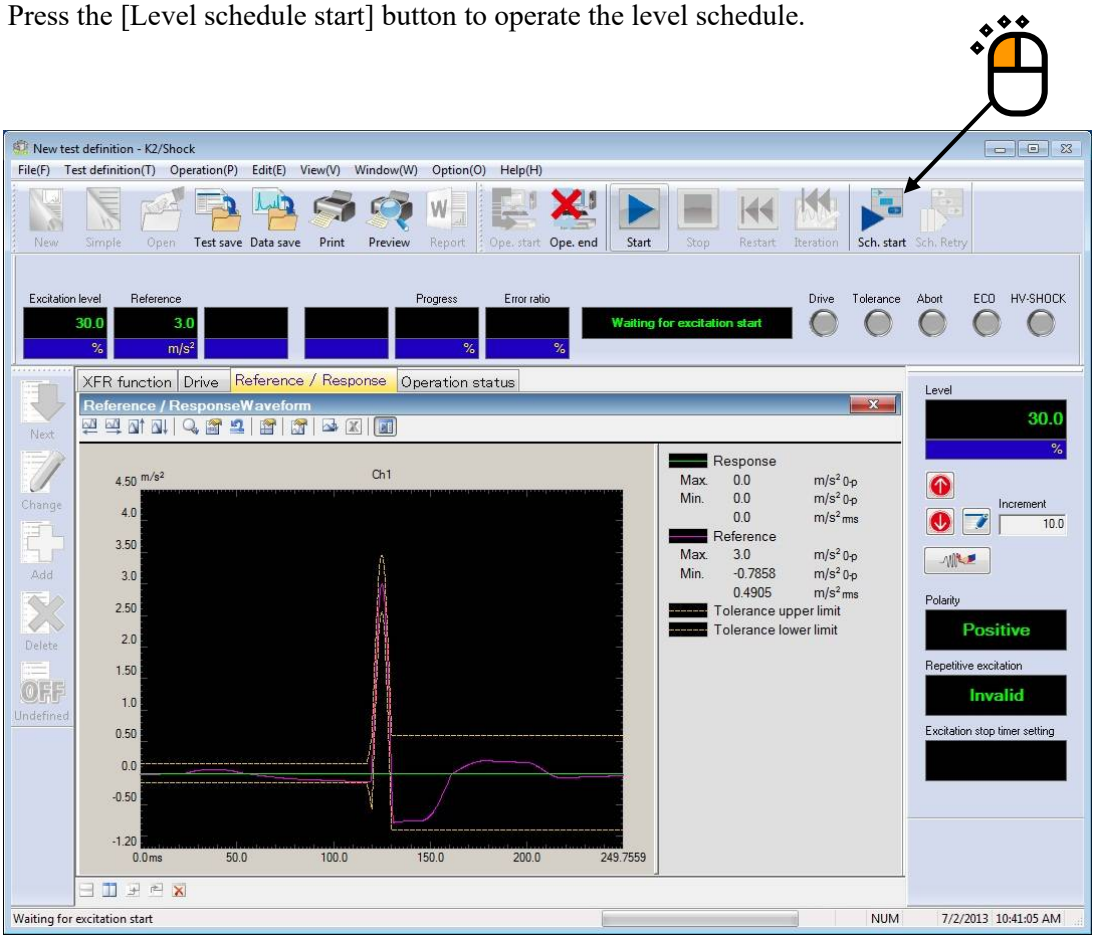
Operation of Level Schedule is executed along the following procedures.

< Procedures >

< Step 1 >

When a test file with its Level schedule defined is selected, the button of [Level schedule] is activated in the state of waiting for the excitation start.

Press the [Level schedule start] button to operate the level schedule.



On the other hand, when the general excitation operation needs to be operated, press the button of [Exc.start].

< Step 2 >

(1) In case that ‘Iteration’ is defined in Level schedule

Iteration is operated when the Tolerance check is resulted in NG before executing the repetitive operation.

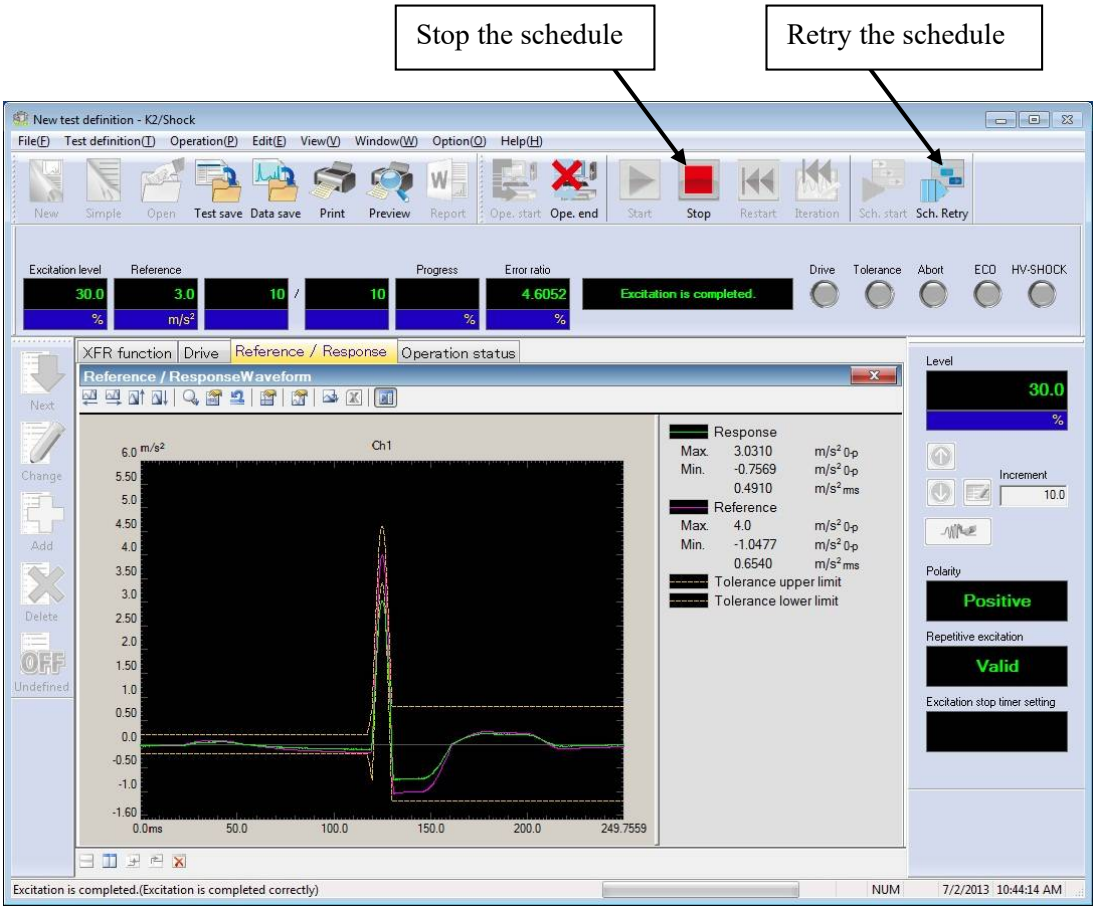
When ‘Stop the schedule at failing in the iteration processing’ is set, the system abort the testing operation and proceeds to the state of excitation completion in case that it is resulted in NG in Tolerance check after the maximum times of Iteration.

(2) In case that ‘Pause the schedule’ is defined in Level schedule

The system is set to the state of waiting for operator’s command when the schedule is paused after the excitation completion according to the current schedule items.

Press the button of [Level schedule retry] to restart the schedule.

Press the [Stop] button to stop the schedule operation.



(3) In case that ‘Continue’ is defined in Level schedule

The system operates the next schedule item automatically after the excitation completion of the current schedule items.

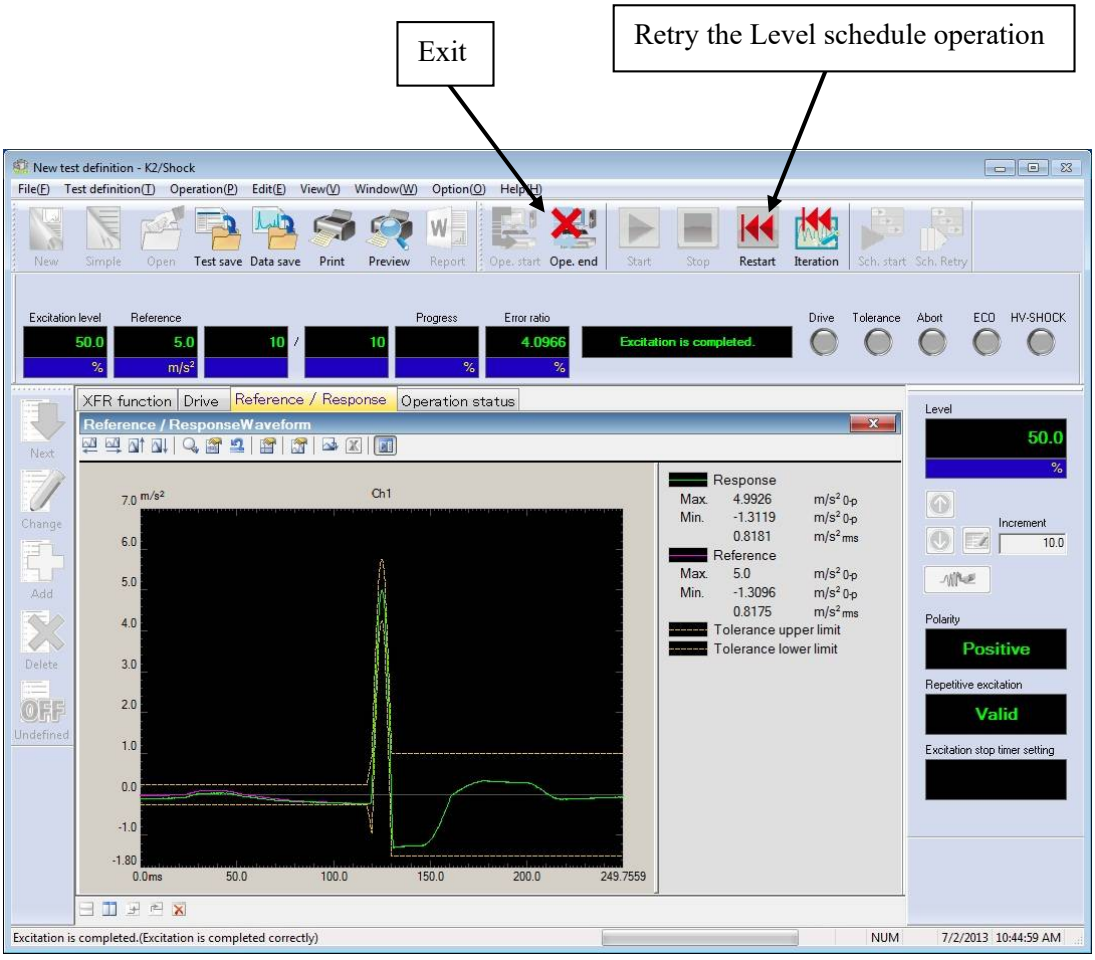
< Step 3 >

When the Level schedule is completed, the system is set to the state of Excitation completion.

The Level schedule can be operated again by pressing the [Retry] button.

When the [Retry] button is pressed, the system returns to the state of waiting for the excitation start as < Step 1 >.

Press the [Exit] button to finish the testing operation.



6.10 Using / Deleting of Live Data in Operation

The data (necessary for test operation) obtained at test abort (end) can be used by saving that of Test Definition File in the condition of Excitation Stop.

The saved data is called as Live Data in Operation.

The types of Live Data in Operation are as below ;

- XFR Function
- Drive

When Live Data in Operation is saved in Test Definition File, the merits and demerits as below exist ;

[Merit]

<Using of XFR Function>

Transfer Function obtained in a test operation can be used in the next test. (XFR Measurement can be skipped.)

However, pay attention to the danger when the system configuration and the condition of sensors and specimens are different. In such a case, XFR Function is needed to be measured again as the same as in an ordinary test.

<Using of Drive Waveform>

Drive waveform obtained in a test operation can be used in the next test. The test operated previously can be replicated to have the same control accuracy.

However, pay attention to the danger when the system configuration and the condition of sensors and specimens are different. In such a case, XFR Function is needed to be measured in a new environment and Drive is generated newly.

[Demerit]

A part of Test Definition contents cannot be corrected until the used Live Data in Operation is deleted.

6.10.1 Using of Live Data in Operation

Live Data in Operation can be used when the excitation operation is finished.

6.10.1.1 Add the live data in operation at finishing the operation

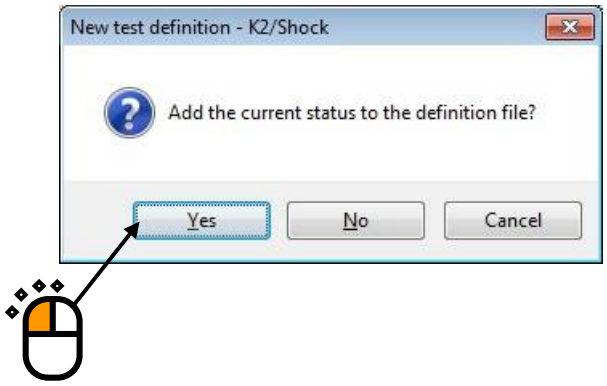
<Procedures>

<Step 1>

Save the test file.

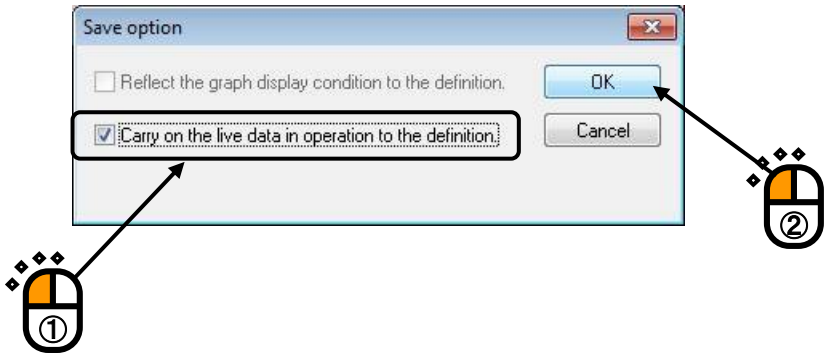
The confirmation message as below appears at saving the file.

Select [Yes] in this dialog box.



<Step 2>

The dialog box of “Save option” is displayed. Select “Carry on the live data in operation to the definition” and select [OK].



・ XFR function

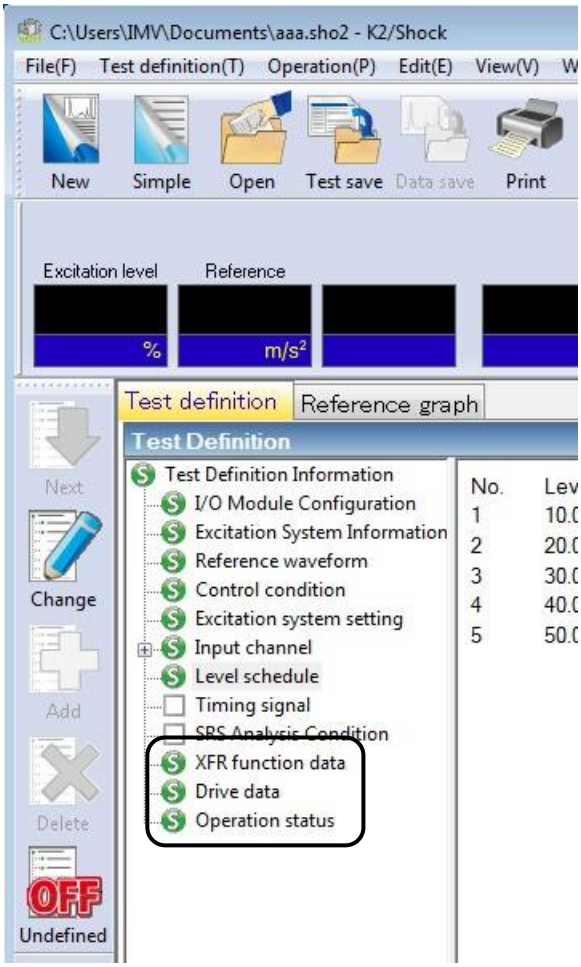
Available to correlate with the definition after XFR measurement.

・Drive waveform

Available to correlate with the definition after Drive generation.

<Step 3>

The names of data related to the definition are added in the display of Test Definition.



6.10.1.2 Add the live data in operation in Test definition mode

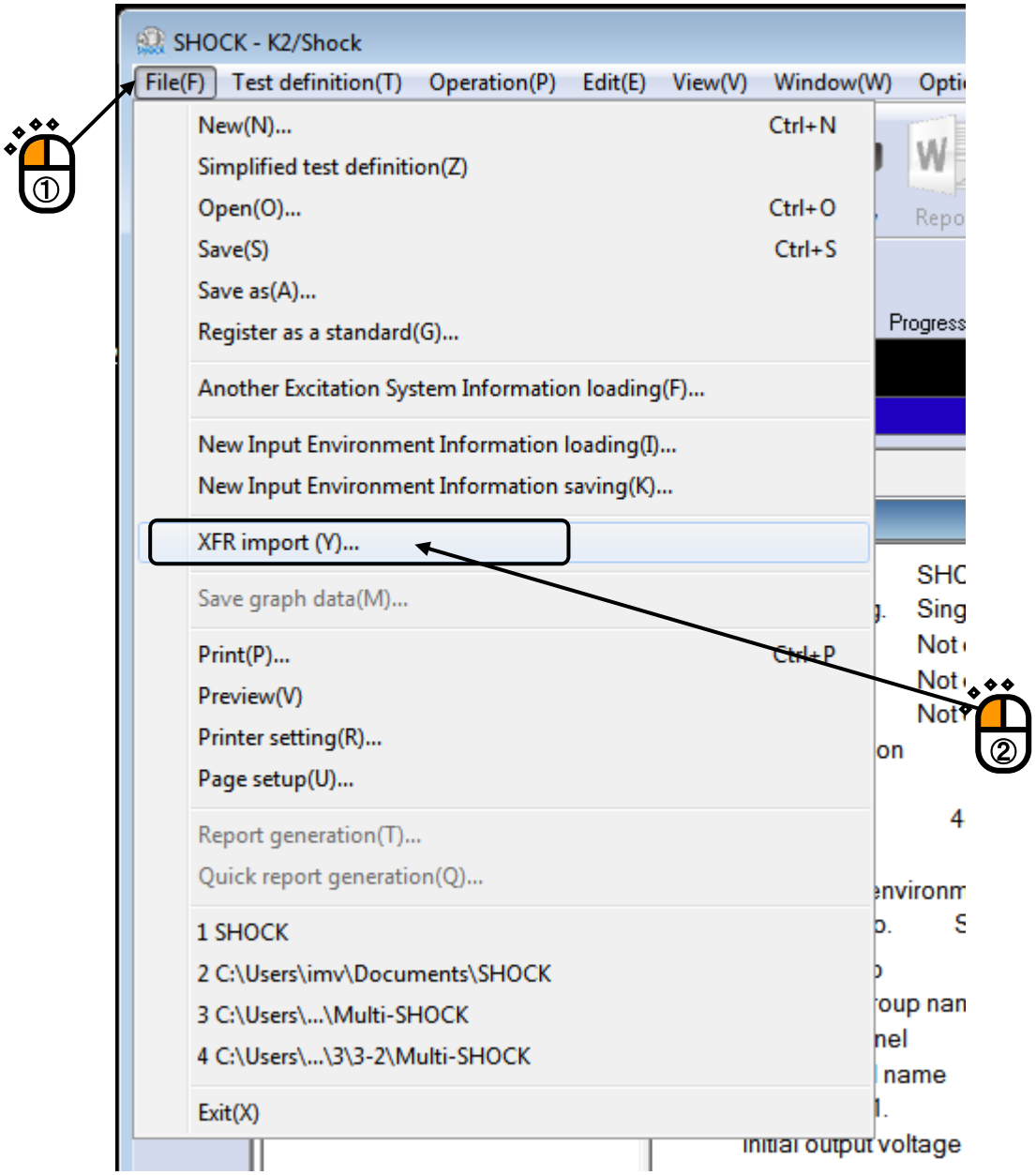
<Procedures>

<Step 1>

In Test definition mode, the XFR function data can be imported from data files by the operation below.

The data available to import is the XFR function.

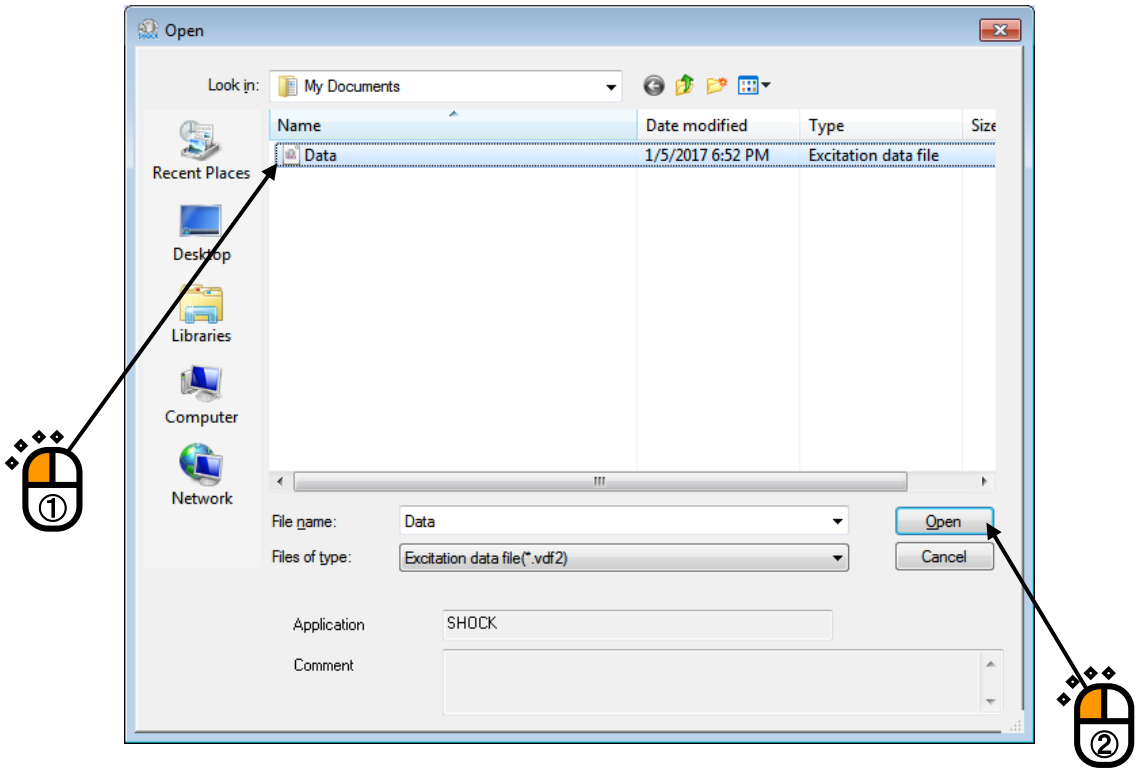
Select [File] → [XFR import] in Menu bar.



<Step2>

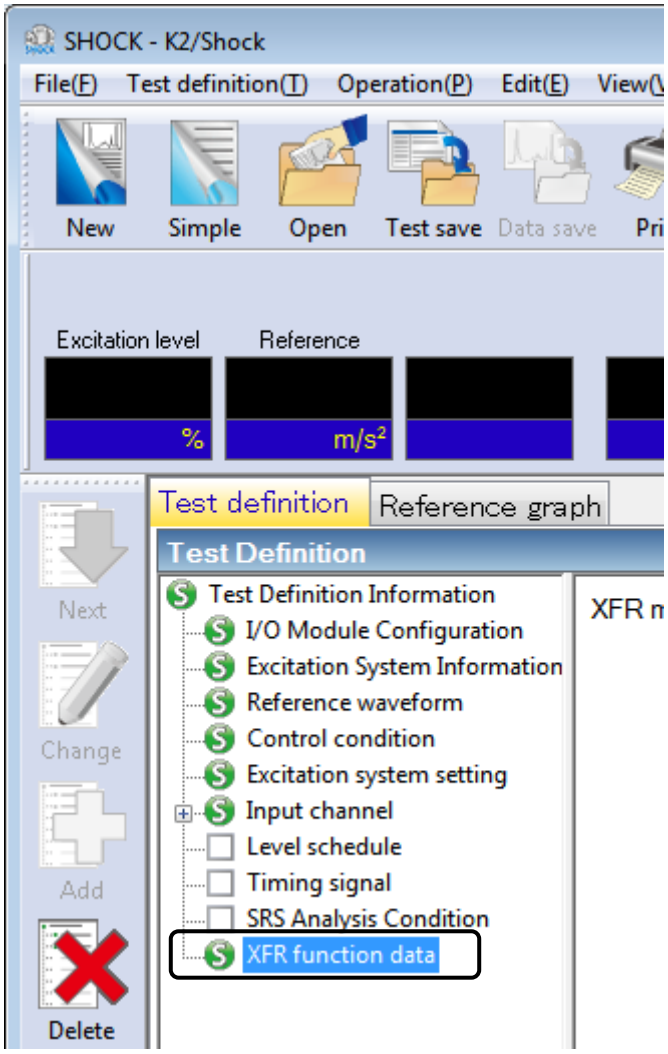
Select a file to import (the XFR function) and press [Open].

These items are available only when the selected test data file has consistent condition having the same sampling frequency other parameters with the Test definition.



<Step3>

The imported data is added and displayed in the Test definition information as a related data.



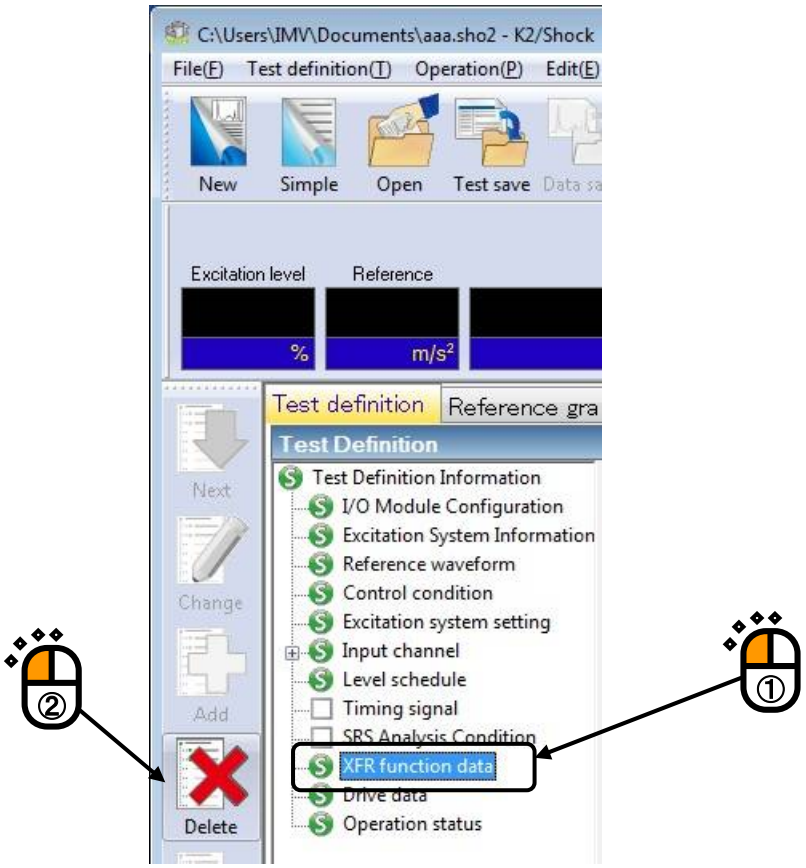
6.10.2 Deleting of Live Data in Operation

The added Live Data in Operation can be deleted by the procedures as below ;

<Procedures>

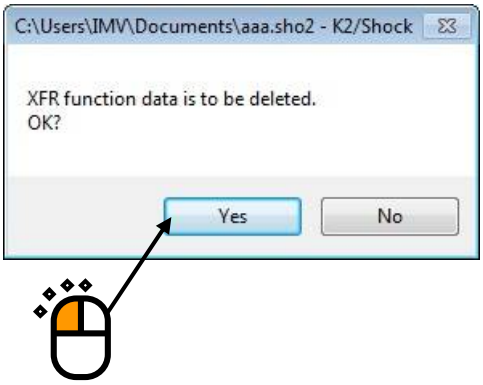
<Step 1>

Select the Live Data in Operation to be deleted. Press the [Delete] button.



<Step 1>

The confirmation message appears as below. Select [Yes].



6.11 Skipping of XFR Measurement (Use the XFR Function of Live Data in Operation)

In a Test File having the XFR Function of Live Data in Operation, the related XFR Function can be used and XFR Measurement can be skipped in test operation.

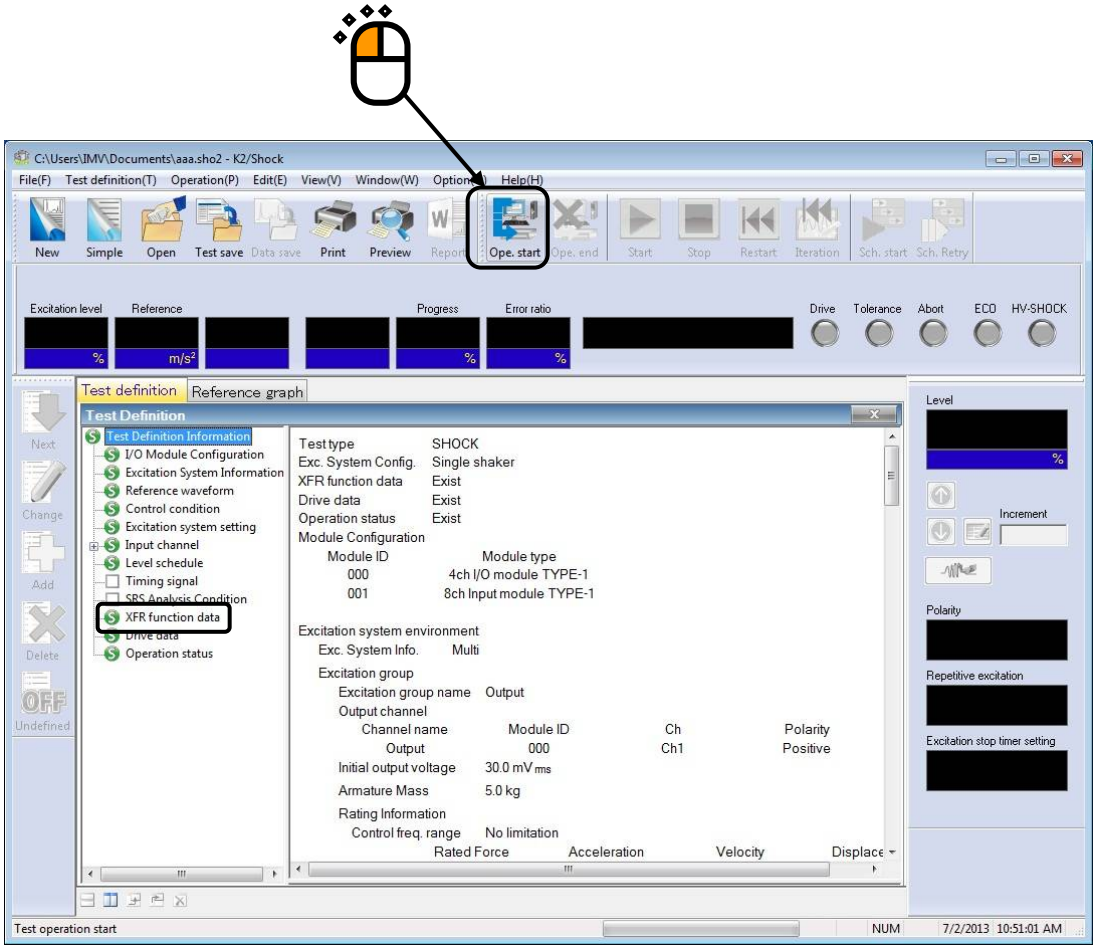
However, pay attention to the danger when the system configuration and the condition of sensors and specimens are different. In such a case, XFR Function is needed to be measured again as the same as in an ordinary test.

Refer to Using / Deleting of Live Data in Operation about the details of using XFR Function.

<Procedures>

<Step 1>

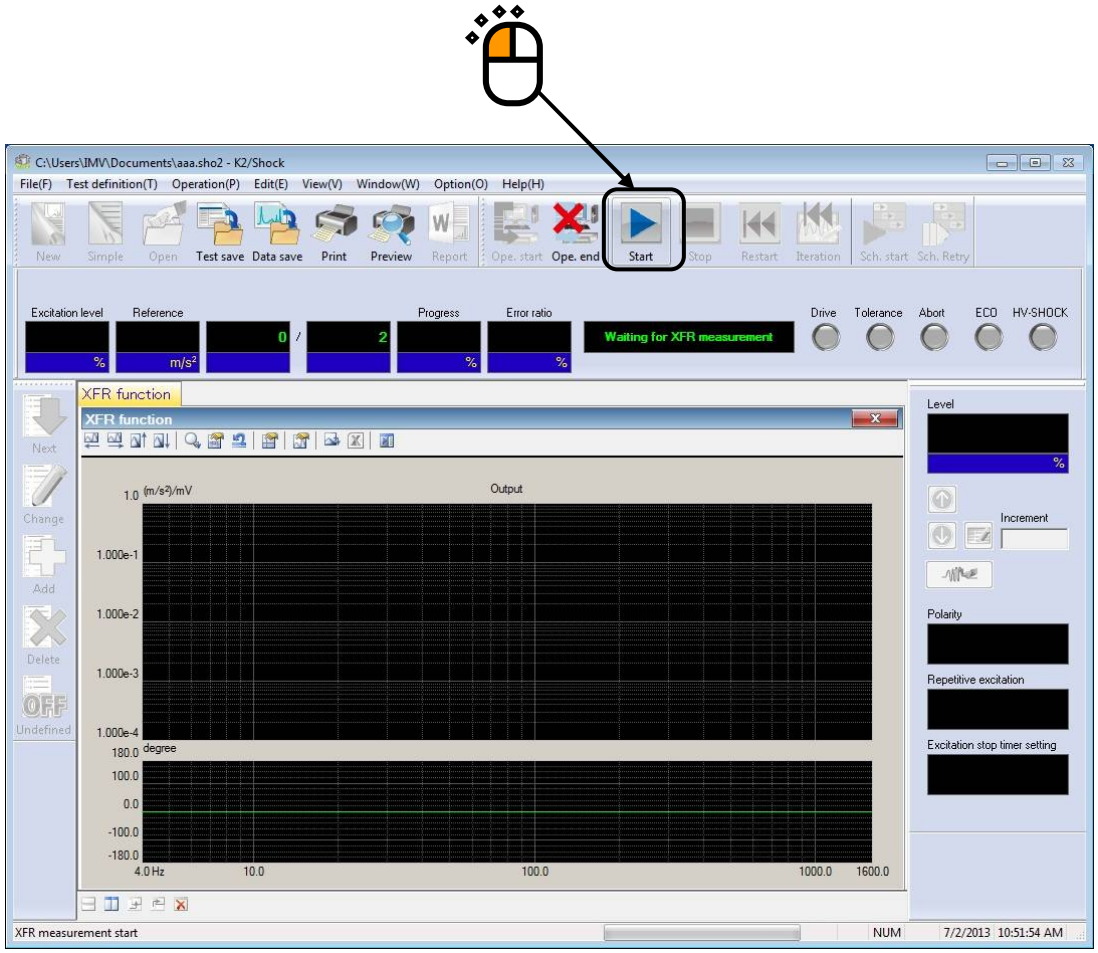
Load the Test File using the XFR Function of Live Data in Operation and press [Operation start] button.



<Step 2>

XFR Measurement of the controlled system is executed.

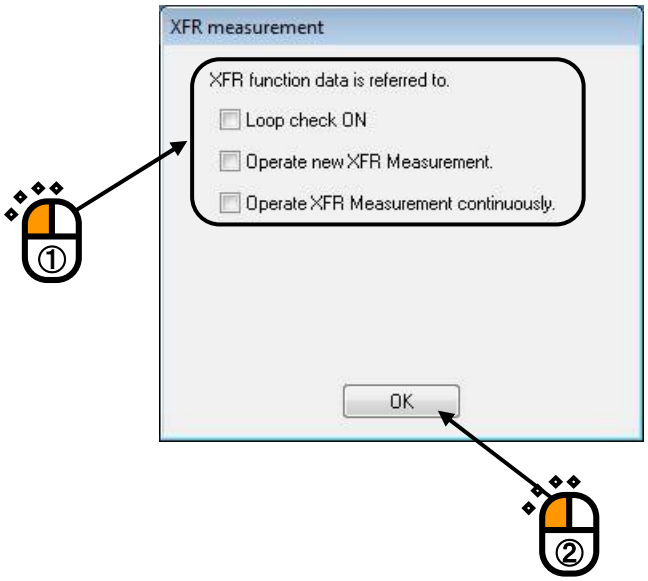
Press [XFR measurement start] button.



<Step 3>

The dialog for selecting operations concerning with XFR Measurement appears when XFR Function of Live Data in Operation is used in the test.

When both Loop Check and XFR Measurement are needed to be skipped, cancel the checks in all of the check boxes and press [OK]. After [OK] button is pressed, XFR Function of Live Data in Operation is loaded and the system proceeds to the state of 'to 0th Drive'.



The phases of XFR Measurement is composed by Loop Check and XFR Measurement. Loop Check is needed to be executed for operating XFR Measurement.

Four selections are provided in this item ;

1) Skip both of Loop Check and XFR Measurement (the contents as in the above).
2) Operate Loop Check and skip XFR Measurement only (the check for cables and control system connection).
3) Operate new XFR Measurement. Loop Check is operated automatically before the XFR Measurement.
4) Operate XFR Measurement continuously (See the next clause). Execute XFR Measurement and add the measured data to the current XFR function (to increase the average times of XFR function). Loop Check is not operated.

6.12 Continuous XFR Measurement

This item is for operating XFR measurement continuously and adding the measured data to the current XFR function.

It is usable when the averaging times of XFR function need to be increased after operating XFR Measurement.

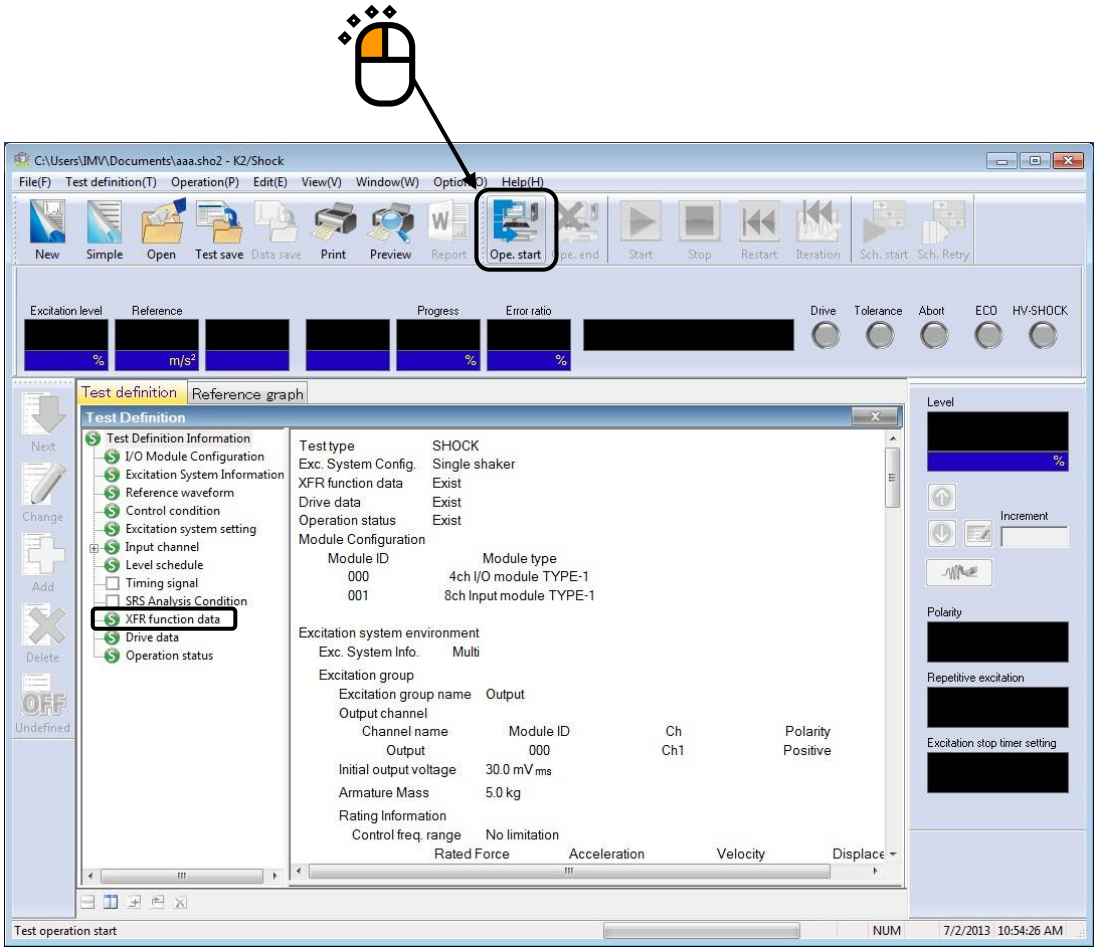
The condition of continuous XFR Measurement is described as below;

- Loop Check is not operated.
- Drive waveform at XFR Measurement is calculated according to the XFR function to be added. So, the drive waveform is obtained as random waveform that equalized to have the flat characteristics in frequency component of control response

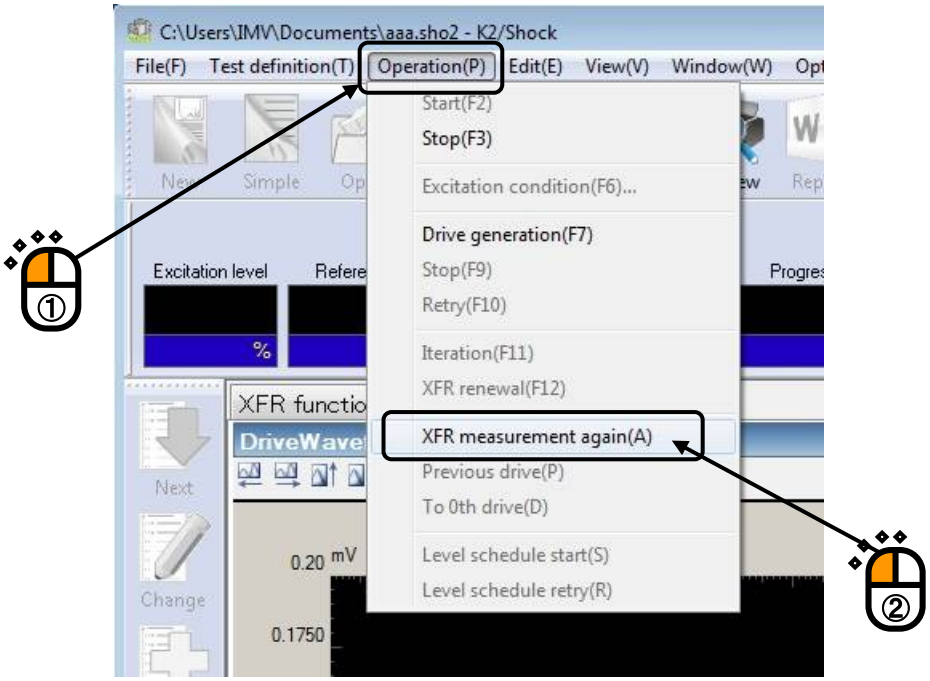
<Procedures>

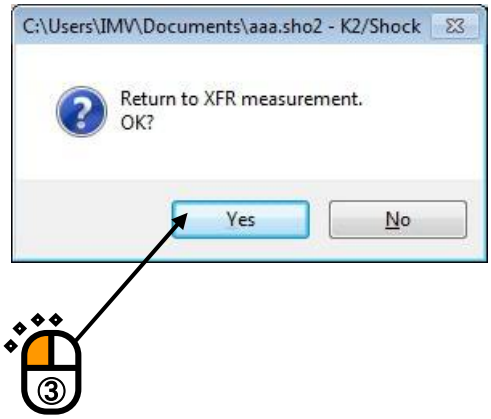
<Step 1>

Load the Test File using the XFR Function of Live Data in Operation and press [Operation start] button.



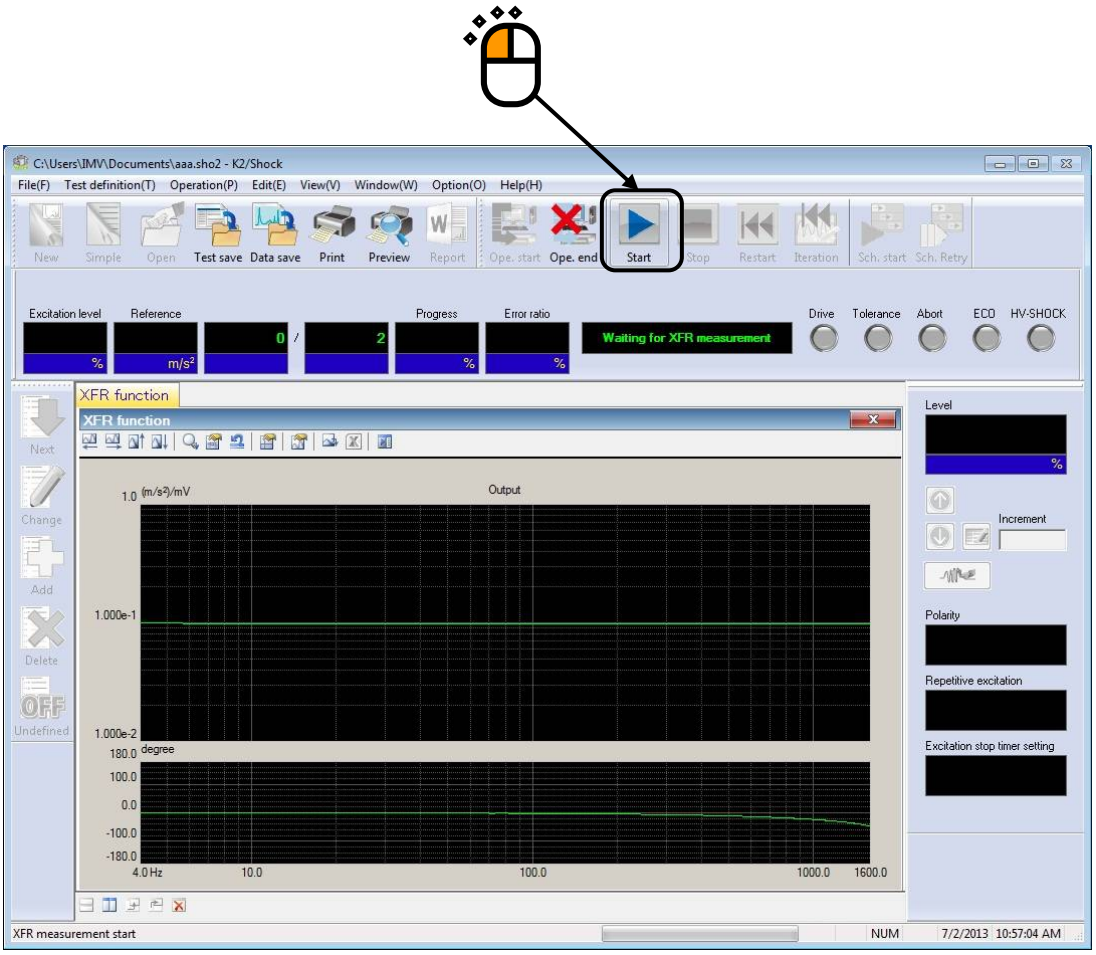
Or otherwise, select [Operation] in the menu bar after completing the XFR Measurement.
Select [XFR measurement again] Then, the confirmation message appears.
Select [Yes] in this dialog.





<Step 2>

Press [XFR measurement start] button.



＜Step3＞

The dialog for specifying the measurement method of XFR function is displayed.

Check the check box of “Operate XFR Measurement continuously” and press [OK] after setting the required usage below. Then, the continuous measurement of XFR function is executed.

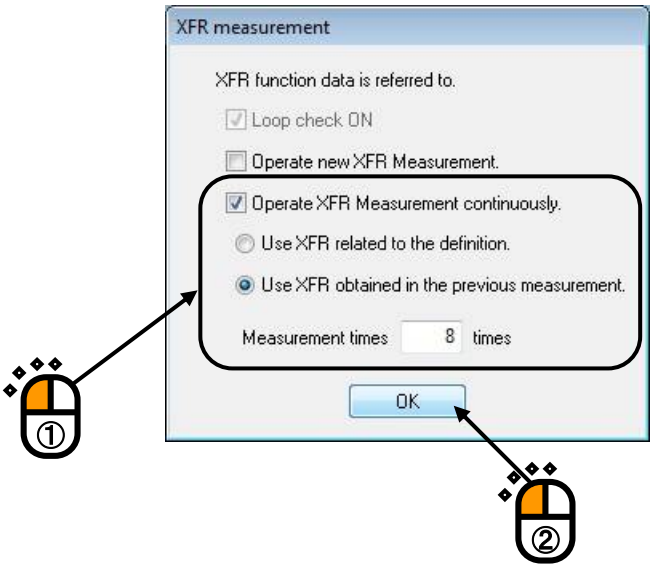
- Specify the objective XFR function to be added

  When the XFR function loaded in a test file needs to be used, select “Use the transfer function related to the definition”.

  When the current XFR function needs to be used, select “Use the transfer function obtained in the previous measurement”.

- Specify the averaging times

  Input the required times of continuous measurement in “Measurement times”.



6.13 Using Drive of Live Data in Operation

In a Test File having the Drive of Live Data in Operation, the related Drive can be used and Drive Generation can be skipped in test operation.

Drive waveform generated in a test operation can be used in the next test. The test operated previously can be replicated to have the same control accuracy.

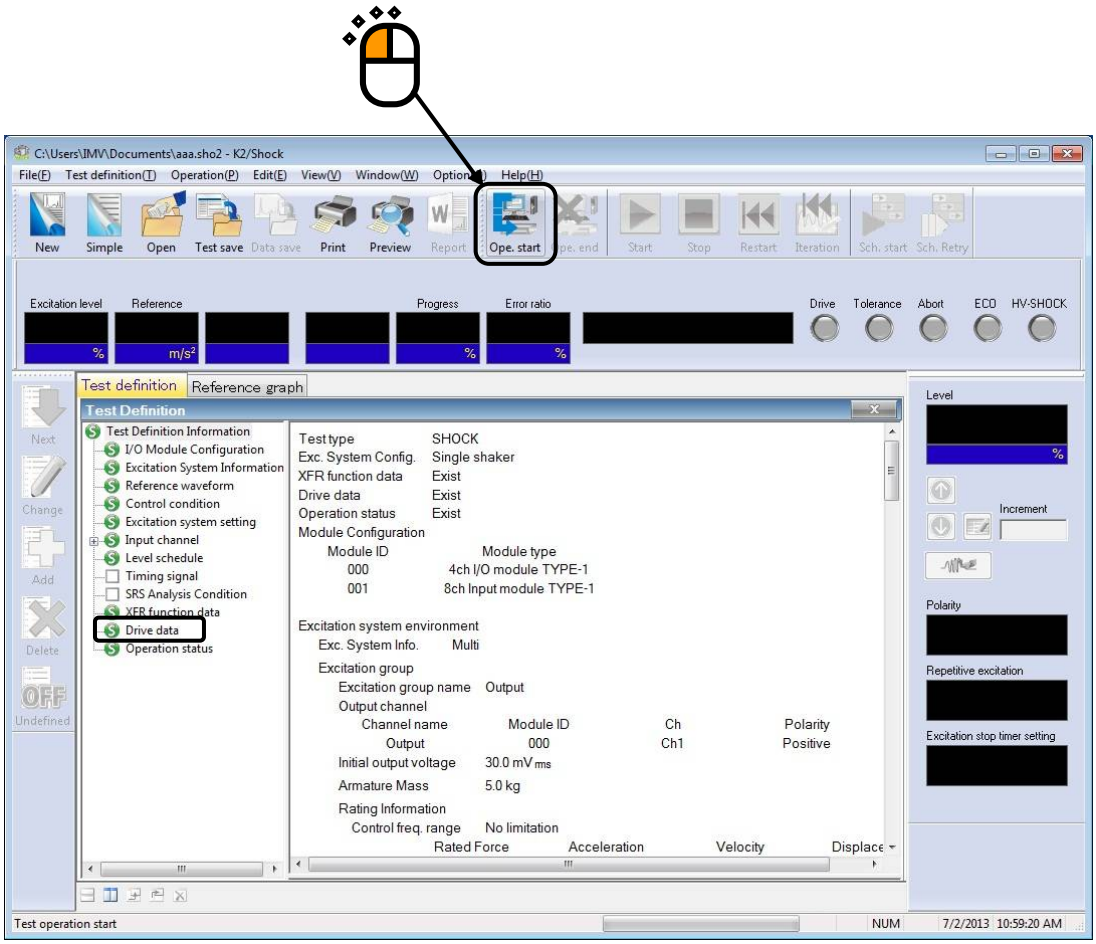
However, pay attention to the danger when the system configuration and the condition of sensors and specimens are different. In such a case, XFR Function is needed to be measured in a new environment and Drive is generated newly.

Refer to Using / Deleting of Live Data in Operation about the details of using Drive.

<Procedures>

<Step 1>

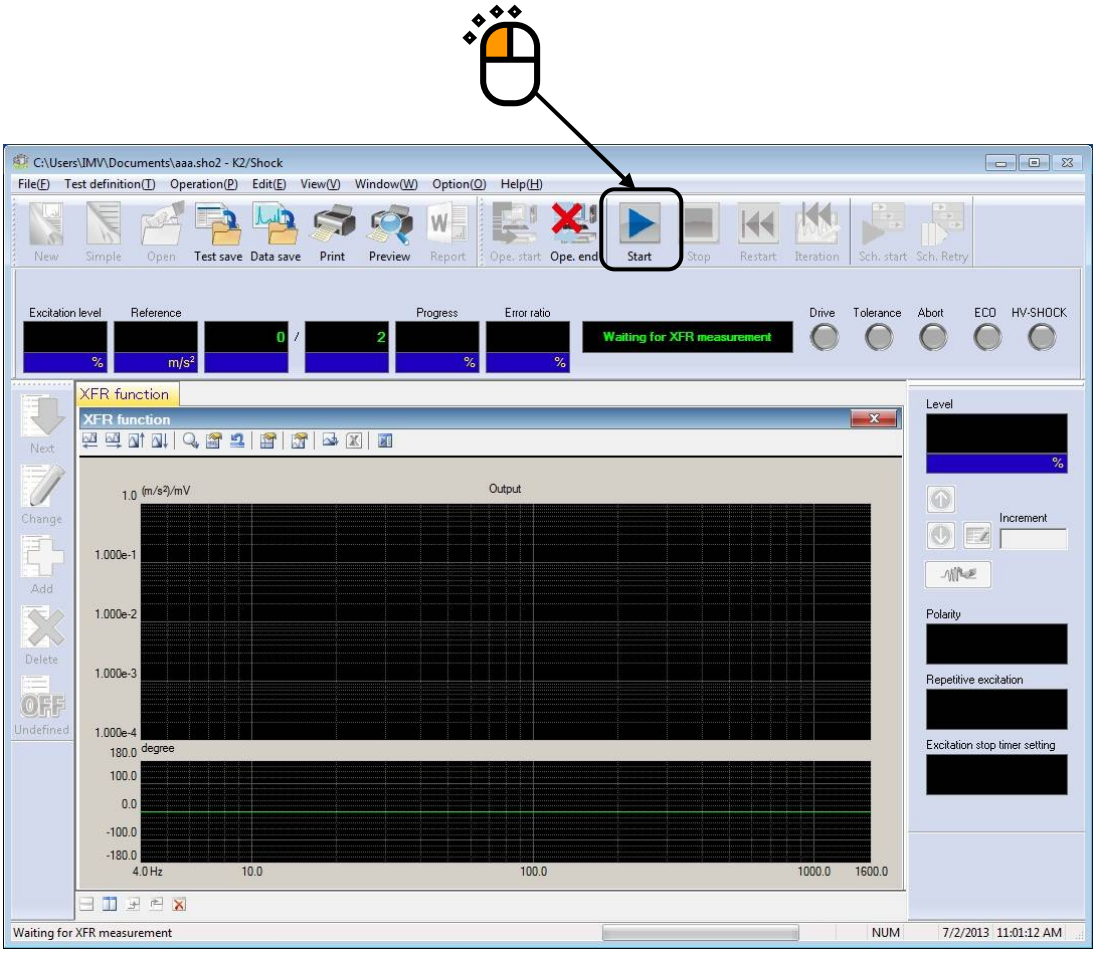
Load the Test File using the Drive of Live Data in Operation and press [Operation start] button.



<Step 2>

XFR Measurement of the controlled system is executed.

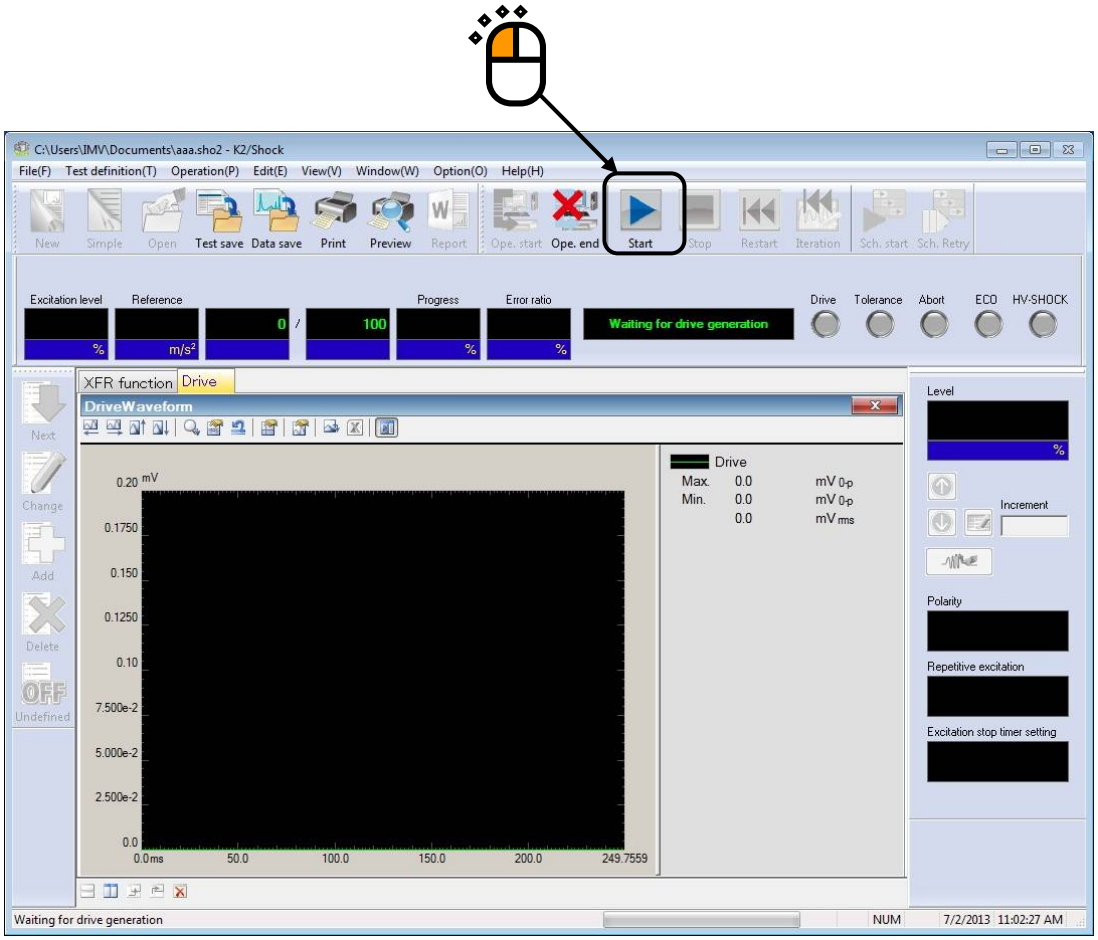
Press [XFR measurement start] button.



<Step 3>

When the XFR Measurement is completed, the system proceeds to the state of 'waiting for drive generation' automatically.

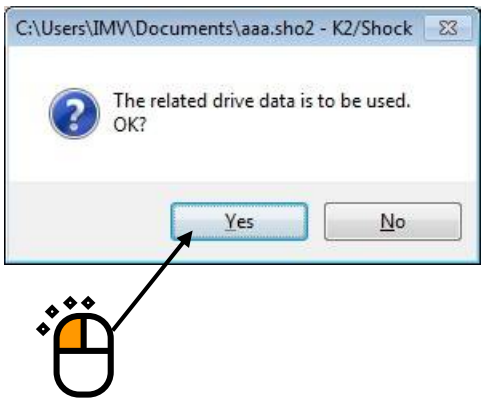
Press [Drive generation] button.



<Step 4>

The dialog for assuring the operations that Drive Generation is skipped and the related Drive of Live Data in Operation is used appears when Drive of Live Data in Operation is used in the test.

Press [Yes] to use the Drive of Live Data in Operation. When [Yes] button is pressed, the Drive of Live Data in Operation is loaded and the system proceeds to the state of waiting for Excitation Start.



When [No] button is pressed, the Drive is generated newly from the Reference Waveform and the XFR Function as the same as in an ordinal test.

6.14 Tolerance Check of SRS SHOCK

Tolerance Check in Shock test, such as Classical Shock, is operated for Control Response Waveform. On the other hand, in SRS SHOCK test, it is operated for Response Analysis SRS (the result of SRS Analysis of Control Response Waveform).

The same waveform control is operated both in Shock test and SRS SHOCK test. So, note that the Tolerance Check of excitation results in NG even if the control is completed perfectly when the Tolerance Check of Reference Analysis SRS (the result of SRS Analysis of Reference Waveform) results in NG.

RMS error of SRS SHOCK test is calculated from the RMS value of the error waveform and that of Reference Waveform as the same method as in Shock test.

6.15 (This section is left blank intentionally.)

6.16 (This section is left blank intentionally.)

6.17 (This section is left blank intentionally.)

6.18 Excitation stop timer

6.18.1 Outline

This function is for stopping the excitation at the specified time.

Excitation stop timer is set in Excitation condition.

Setting of Excitation stop timer is valid in the state of 'Waiting for excitation start'.

Excitation stop timer has 2 setting methods.

- Specify time interval

  The excitation is stopped when the specified excitation time has passed.

- Specify time instant:

  The excitation is stopped stop at the specified time.

When the specified stop condition of this function is satisfied, the excitation is stopped immediately. And the current excitation is not counted of repeat times when repetitive excitation is operated.

This operation is same as when the excitation is stopped by command of operator.

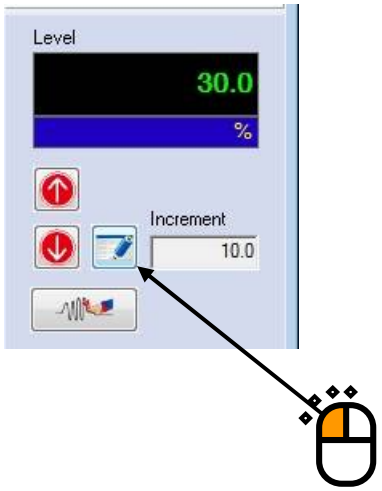
6.18.2 Specify time interval

<Procedures>

<Step 1>

Select [Operation] → [Excitation condition] in Menu bar or press [Excitation condition] button in Manual operation bar as shown in the figure below.

Then the dialog of Excitation condition is displayed.



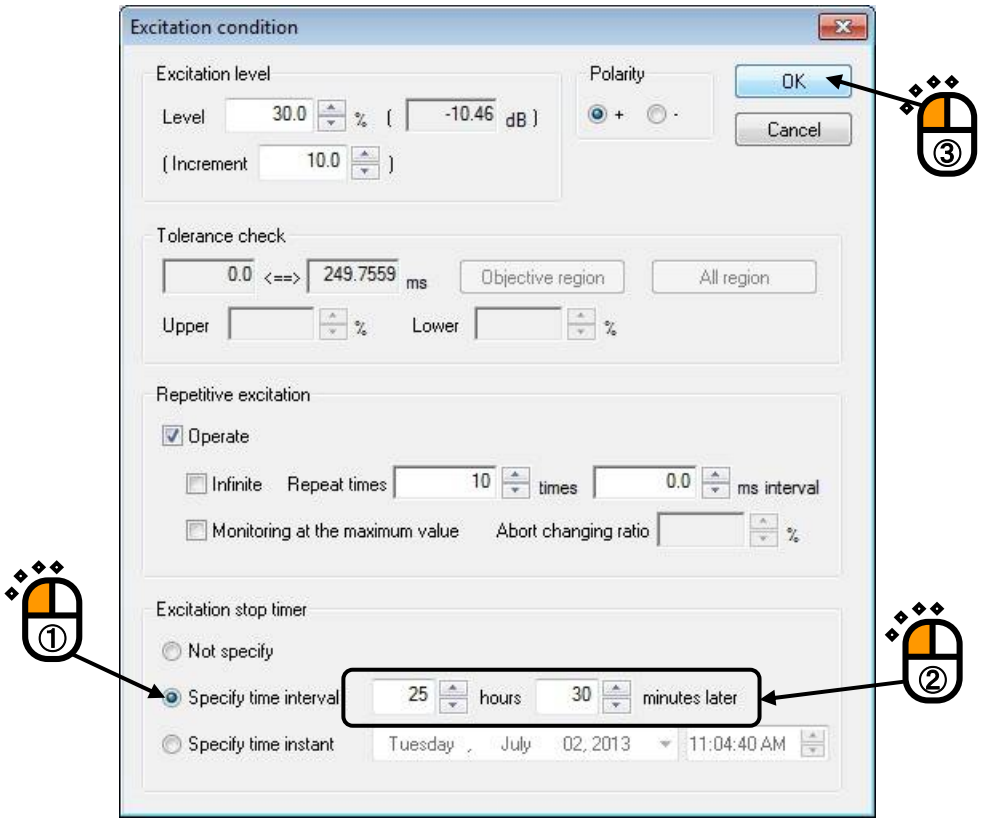
<Step 2>

Select ‘Specify time interval’ and specify time interval of excitation.

Time interval is specified by ‘hours’ and ‘minutes’.

The example of setting of this item is shown below. In this case, the excitation is stopped 25 hours and 30 minutes later from excitation start.

Specify time interval and press [OK] button.

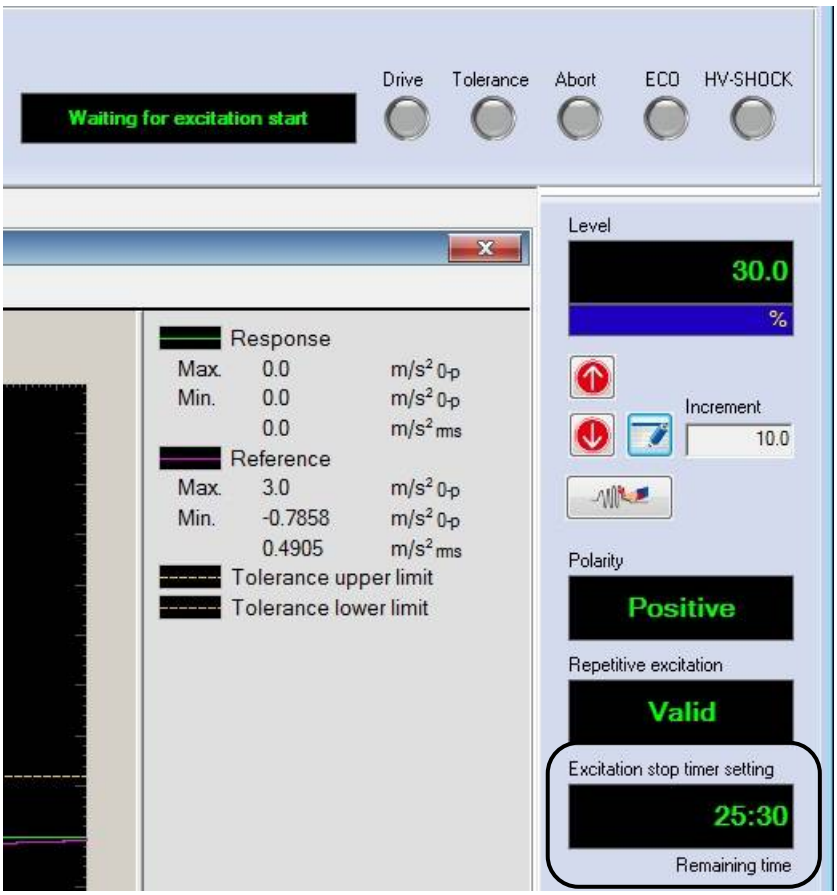


The upper limit of ‘hours’ is 999 and the upper limit of ‘minutes’ is 59.

<Step 3>

When setting of this item is completed, the remaining time is displayed in Excitation stop timer setting position in Manual operation bar.

As shown in the following figure, the specified time is displayed when the excitation is not started.



<Step 4>

When the excitation is started, the timer is started and the remaining time is decreased

When the excitation is stopped by command of operator etc, the remaining time and the setting of time interval are initialized.

6.18.3 Specify time instant

<Procedures>

<Step 1>

Select [Operation] → [Excitation condition] in Menu bar or press [Excitation condition] button in Manual operation bar same as 'Specify time interval'.

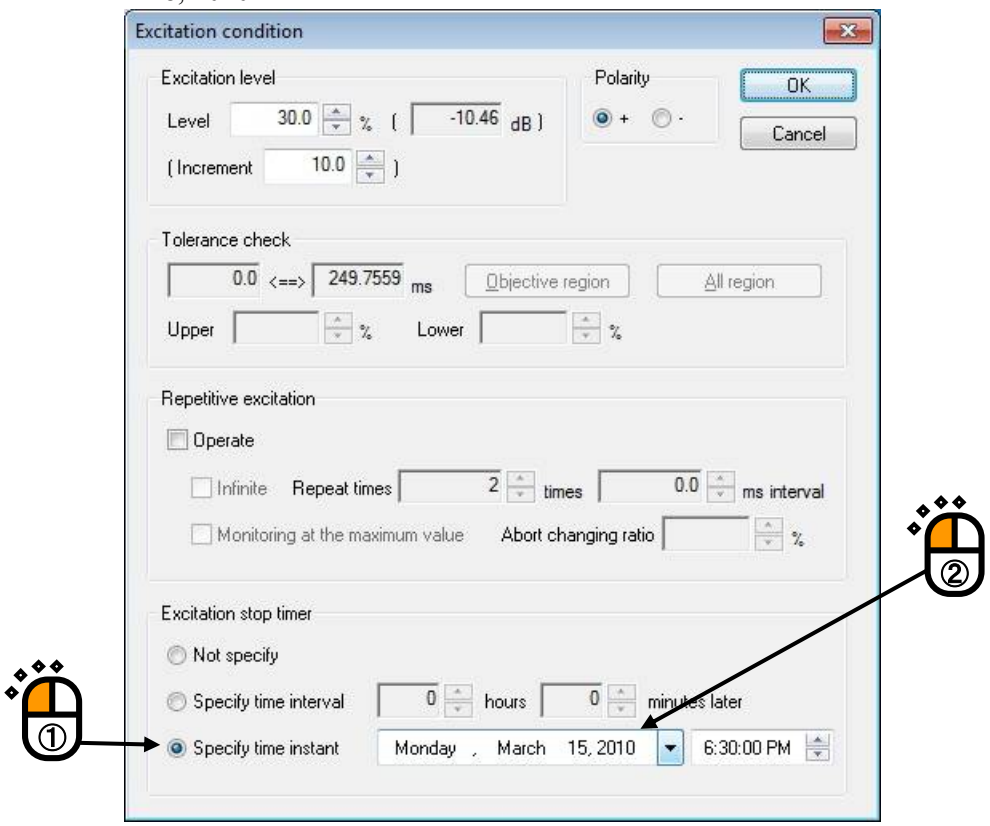
Then the dialog of Excitation condition is displayed.

<Step 2>

Select 'Specify time instant' and specify time instant to be stopped the excitation.

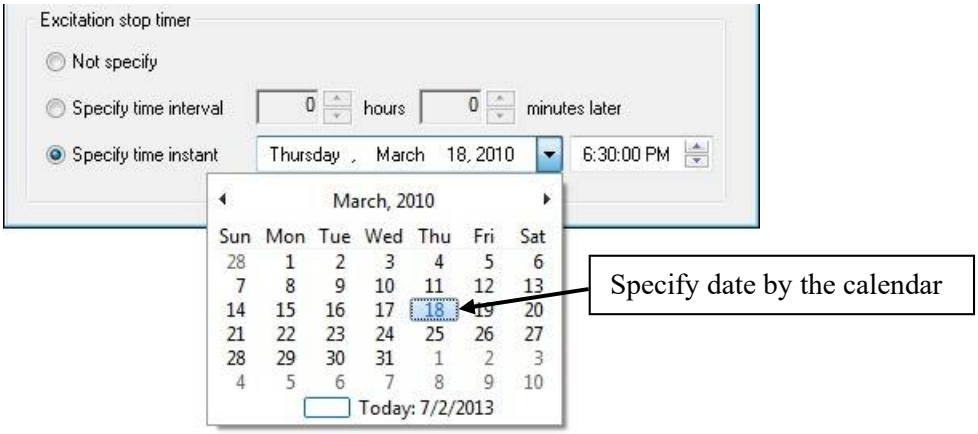
Time interval is specified by 'date' and 'time instant'.

The example of setting of this item is shown below. In this case, the excitation is stopped at 6:30 PM March 18, 2010



Press [▼] button to be specified 'date' as shown in the dialogue above. The calendar is displayed.

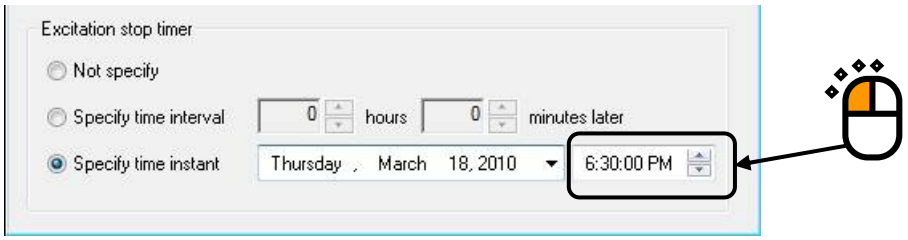
Specify 'date' to be stopped the excitation. In this case, specify 'March 18, 2010'.



<Step 3>

Specify ‘time instant’ to be stopped the excitation. In this case, specify ‘6:30 PM’.

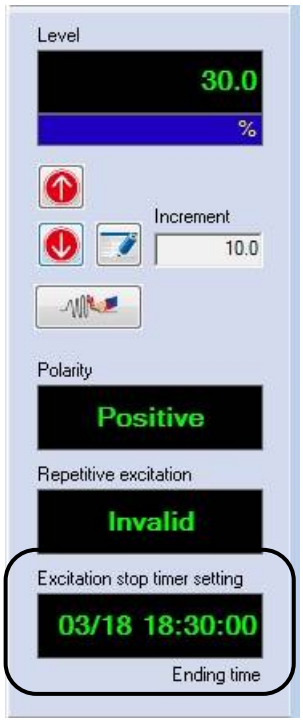
Press [OK] button.



<Step 4>

When setting of this item is completed, Ending time is displayed in Excitation stop timer setting position in Manual operation bar.

The excitation is stopped when time becomes at the specified time constant.



When the excitation is stopped by command of operator etc, the remaining time and the setting of time instant are initialized.

This is same as ‘Specify time interval’.

And when the specified time constant has been passed, the remaining time and the setting of time instant are initialized.

Chapter 7 Theory of SRS SHOCK (Option)

7.1 Shock Response Spectrum (SRS)

7.1.1 Description of SRS

The concept of Shock Response Spectrum was established by M.A.Biot in 1930s.

Biot proposed the concept of SRS in the view that **the Effect** to be given by earthquake waveform should be considered rather than the earthquake waveform itself when the problem of earthquake-proof building was treated.

Suppose an input signal expressed as a waveform is given to a series of Single Degree-Of Freedom (SDOF) system (for abstracting the resonance characteristics of buildings and constructing the constant definition). The peak of this waveform obtained by calculating the response output waveform of each SDOF system is treated as the maximum response of this resonance system. Such maximum response value are calculated as a function of resonance frequency of SDOF system in order and plotted as spectrum. This spectrum is called as SRS of input waveform to be considered.

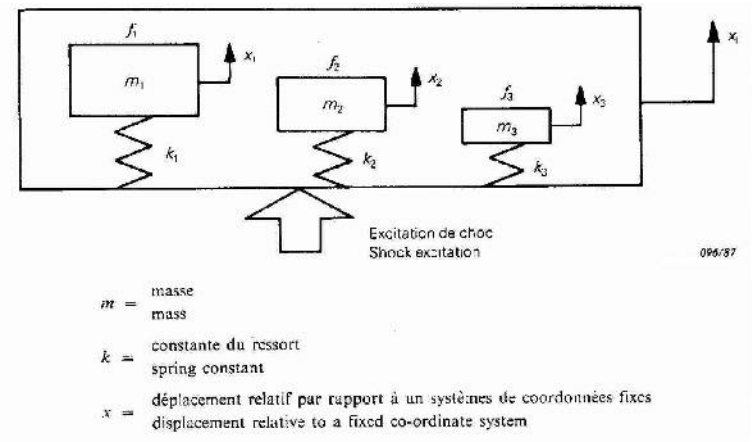
In the problem of the earthquake-proof, it is important finally to know **the maximum value** of response (for example, a design for strengthen construction can not be executed when relative displacement to be generated at maximum between the ground and buildings is not known). The operation of 'extracting the maximum value' that is especially peculiar in the concept of SRS is based on such a necessity.

As stated, **the Effect** of input waveform can be expressed by the quantity of SRS. However the characteristics of actual constructions are different each other, it can be said that SRS makes 'the effect of each waveform' possible to be grasped as the concept corresponding to the waveform itself by converting its characteristics to 'a series of infinite SDOF system formed in order of resonance frequency closely' which is a unified concept of every building. Here, note that the relation between waveform and SRS is not as one to one. SRS corresponding to a specified waveform is decided as one, but waveforms corresponding to a specified SRS can exist for plural numbers (not unique). (It is explained by the complex algorithm of SRS calculation as below ; especially, all other waveform information are abandoned by the operation of 'extracting the maximum value only'.)

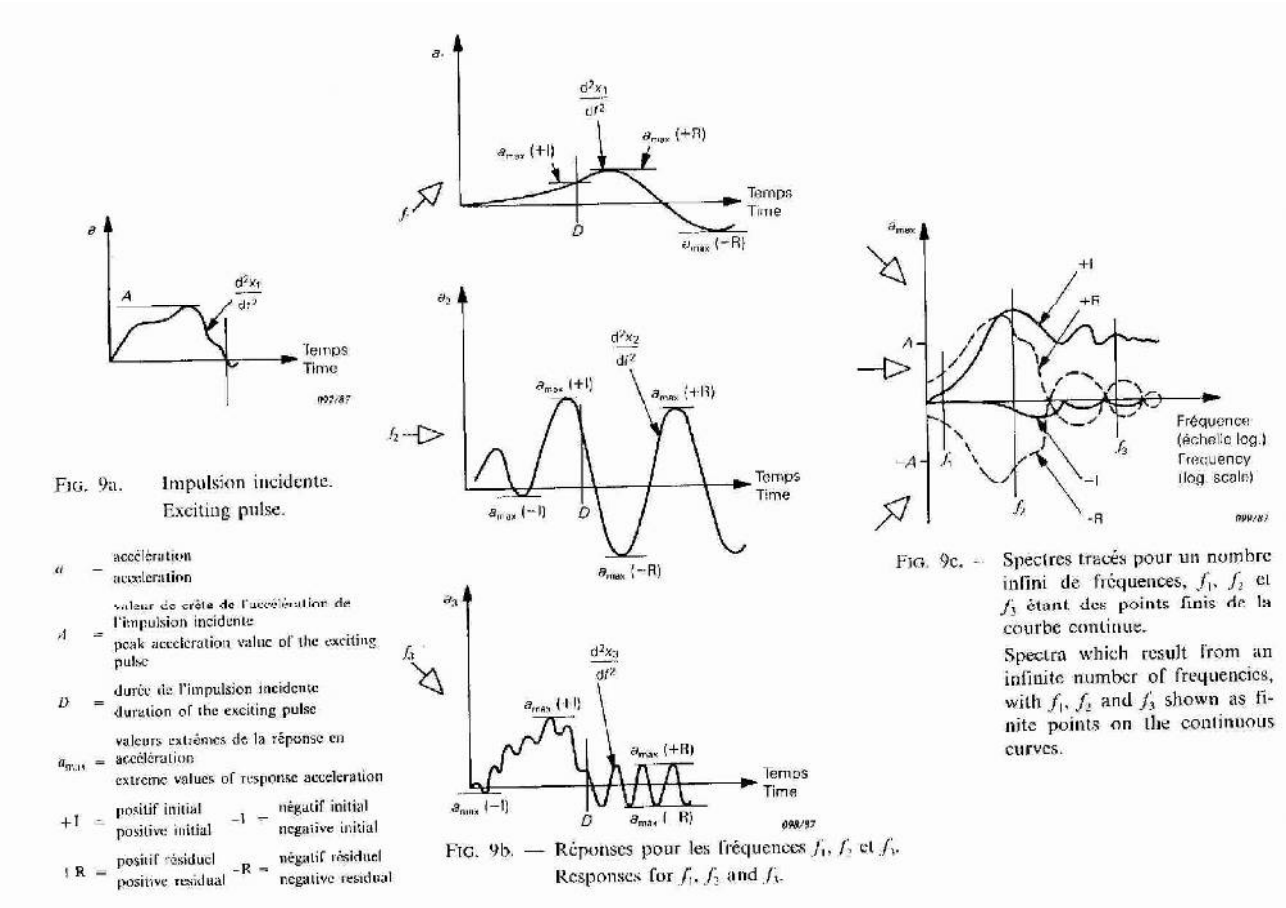
However, the concept of SRS was produced from the problem of earthquake-proof, its utility is applied not only in the field of earthquake but in others. Generally, the concept of SRS must be useful in the field where the response to a relatively short signal is considered. Our shock testing is not an exceptional.

Shock testing is operated by some abstracted waveform such as Half-sine for a long time (that is, 'Classical Shock Waveform', which has the advantage of easy defining for specifications but is not realistic). According to the progress of controller techniques, the importance of testing by 'measured waveform' is gradually recognized. Recently, specification and operation of the testing from the view of 'damages given by the shock' is to be required. The importance of SRS concept becomes to increase.

7.1.2 Terms of SRS



Model of SDOF System (no-damping case)



Input Acceleration Waveform Output Waveform of each Resonance System SRS Analysis Result

SRS is the spectrum plotted with the value as a function of system resonance frequency by selecting the peak value of output waveform of each resonance system.

Fig.7-1-1 Concept of SRS

(Refer to IEC Pub. 68-2-27)

(1) Definition of SDOF System

As stated in the above, SRS is defined through the medium of 'infinite SDOF System'. However 'infinite system' is needed to be replaced with 'finite system' at calculation of SDOF system on the computer. This calculation can be done by defining of the following quantities ;

1) Max. Frequency for Analysis fmax

2) Min. Frequency for Analysis fmin

3) Density of Analysis Frequency

SRS is obtained by calculating the response from each SDOF system configured at the density specified between [fmin, fmax]. It is rational that the density of frequency is specified in logarithmically and the method that specifies the density by the configuration number for octave is commonly used. This system also follows this method, and the number of SDOF system to be configured and resonance frequency of each system are defined.

4) Damping ration of SDOF System

When obeying to the specification of IEC in Fig.7-1-1, SDOF system is treated as not-damped system. Damping Ratio ζ is specified by generalizing SDOF system as a damped system. However, ζ should be the value common to all the SDOF system.

(2) Type of SRS

5) Initial / Residual Boundary

As shown in Fig.7-1-1, SRS has Initial Response SRS and Residual Response SRS. These SRS can be expressed as +I, -I, +R, -R distinguished by positive and negative. Initial Response is the response obtained before the input waveform decreases to zero. And Residual Response is the SDOF system output obtained after the input waveform is completed.

The boundary where the input waveform finishes at zero can be specified easily in the case of, for example, Half-sine. But it can not be specified in the case of general waveform ; it is not assured that the input waveform finishes at zero in this generally case. Therefore, in the case of general waveform, this software has the specification that Initial / Residual Boundary is defined by the operator because the boundary should be defined by the operator of the calculation for the above reason.

SRS is divided into some types, such as '+I', '-R', and these 'I' and 'R' is influenced naturally by the setting if the boundary. However, to avoid the complexity of the setting, 'maximax SRS' defined as 'the maximum value of +I, -I +R, -R' is used ordinary. 'maximax SRS' means that maximum value of SRS which is basically the gathering of maximum values. 'I' and 'R' changes by the setting of the boundary, but 'maximax' does not.

In addition to the above items, this software has the specification that absI which is the maximum of the absolute value of '+I' and '-I', 'absR' which is the maximum of the absolute value of '+R' and '-R' are displayed.

The following SRS are displayed in this software ;

+I : positive maximum values among the initial responses

-I : negative maximum values among the initial responses (as absolute value)

absI : maximum value as absolute values among the initial responses

+R : positive maximum values among the residual responses.

-R : negative maximum values among the residual responses (as absolute value)

absR : maximum values as absolute value among the residual responses

maximax : maximum values as absolute value among all of the responses

(3) Absolute Acceleration SRS and Relative Displacement SRS

Input to the SDOF system is done by Acceleration waveform. As the output of this system, two cases that using the Acceleration waveform and using the Displacement waveform are available.

In the view of the displacement, relative displacement between the base ground and SDOF system is needed to be known. So SRS is calculated by using the maximum value of the relative displacement.

On the other hand, in the view of the acceleration, the destruction caused by acceleration is influenced by the acceleration that the SDOF system has referring to the inertial system, not by the relative acceleration between the base ground and SDOF system. (This acceleration is usually called as 'absolute acceleration' with stress.) SRS is calculated by using the maximum value of the absolute acceleration to be obtained.

The concrete calculation methods of these values in the above are described in the following clause.

7.2 Construction of SDOF System Digital Filter

7.2.1 Outline

As stated in the above clause, the core of SRS Analysis is constructed by the calculation of SDOF system output waveform for a given input waveform. This calculation (simulation of waveform passing through a SDOF system) is executed by configuring of IIR Type Digital Filter in this software. In this clause, the method of this calculation is described.

And Interpolation and Decimation procedures which are required for ensuring the analysis accuracy of this simulation are also described later.

In this system, SRS is obtained by direct calculation of waveform data using the digital filter method. However, an analytical method and its result for some classical waveform appears in Reference (3) listed at the end of this chapter and this article provides an excellent description about the basic concept of SRS.

7.2.2 Description of SDOF System and Construction of SDOF System Digital Filter

Our SDOF system is shown as Fig.7-2-1. In this system, the input to the system is the acceleration waveform of the base denoted as $\ddot{x}(t)$, the output of the system is denoted as $\ddot{y}(t)$ when the absolute acceleration SRS is calculated and as *z(t)* when the relative displacement SRS is calculated.

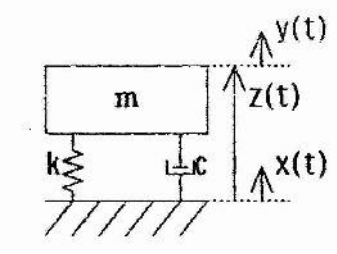


Fig.7-2-1

The equation of motion expressing this system is as below ;

$$m\ddot{y} + c\dot{y} + ky = c\dot{x} + kx \qquad (7\text{-}1)$$

At first, the transfer function of this system is calculated for constructing the digital filter for simulating this dynamical system. (7-1) can be described as follows by using the Laplace transform method ;

$$(s^2 + 2\zeta\omega_n s + \omega_n^2)\,Y(s) = (2\zeta\omega_n s + \omega_n^2)\,X(s) \qquad (7\text{-}2)$$

$$\omega n = \sqrt{k/m}$$

$$\zeta = c/Cc$$

$$Cc = 2\sqrt{mk}$$

Here, the critical attenuation coefficient of this system is denoted as C_C.

According to (7-2), the transfer function of the absolute acceleration is calculated as follows ;

$$H_{acc}(s) = \frac{s^2 Y(s)}{s^2 X(s)} = \frac{2\zeta\omega_n s + \omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \qquad (7\text{-}3)$$

On the other hand, the transfer function $H_{rd}(s)$ corresponding to the relative displacement is calculated by this equation ;

$$H_{rd}(s) = \frac{Z(s)}{s^2 X(s)} \qquad (7\text{-}4)$$

With noticing the following condition,

$$z(t) = y(t) - x(t) \qquad (7\text{-}5)$$

(7-1) can be expressed by x(t) and z(t) as below ;

$$m\ddot{z}(t) + c\dot{z}(t) + kz(t) = -m\ddot{x}(t) \qquad (7\text{-}6)$$

So, the equation is obtained as follow ;

$$(s^2 + 2\zeta\omega_n s + \omega_n^2)\,Z(s) = -s^2\,X(s) \qquad (7\text{-}7)$$

And, (7-4) is obtained as below ;

$$H_{rd}(s) = \frac{-1}{s^2 + 2\zeta\omega_n s + \omega_n^2} \qquad (7\text{-}8)$$

According to the above, the transfer functions of this system treated are obtained. Then, IIR Type Digital Filters having the transfer function as in the above are designed. The method of this filter design is not described in this manual. Refer to Reference (2) if you interested in it.

Coefficients of IIR Type Filter is obtained by replacing (7-3) and (7-8) with *z* transfer in the form of (7-9) as follows ;

$$H(z) = \frac{a_0 + a_1 z^{-1}}{1 - b_1 z^{-1} - b_2 z^{-2}} \qquad (7\text{-}9)$$

In case of the absolute acceleration ;

$$a_0 = 2\zeta\omega_n / fs$$

$$a_1 = a_0 \exp(-\zeta\omega_n / fs)\left[\frac{1-2\zeta^2}{2\zeta\sqrt{1-\zeta^2}}\sin(\sqrt{1-\zeta^2}\,\omega_n / fs) - \cos(\zeta\sqrt{1-\zeta^2}\,\omega_n / fs)\right] \quad (7\text{-}10)$$

$$b_1 = 2\exp(-\zeta\omega_n / fs)\cos(\sqrt{1-\zeta^2}\,\omega_n / fs)$$

$$b_2 = -\exp(-2\zeta\omega_n / fs)$$

In case of the relative displacement ;

$$a_0 = 0$$

$$a_1 = \frac{-\exp(\zeta\omega_n / fs)}{\sqrt{1-\zeta^2}\,\omega_n}\sin(\sqrt{1-\zeta^2}\,\omega_n / fs) / fs \quad (7\text{-}11)$$

$b_1 =$ }
$b_2 =$ } Same as in the case of the absolute acceleration of the above

7.2.3 Interpolation and Decimation

<Necessity of Interpolation>

Output waveform of an arbitrary SDOF system can be calculated by passing the input waveform data through the IIR Type Filter in the above. However, unpredictable calculation error may occur when this calculation is executed without any protection.

Example of this calculation error is shown in Fig.7-2-2. SRS (maximax) in Fig.7-2-2 was obtained by passing a Half-sine waveform of 11 ms, 1 m/s^2 sampled at fs = 8192 Hz through SDOF system in the above without any protection. As displayed in this graph, the calculation error occurred apparently in higher range (comparing with the graph of Fig.7-2-3 which shows the correct result by calculating rightly).

How does this calculation error occur? Main pulse of Half-sine for 11 ms sampled at 8192 Hz is expressed by 90 (= 8192 Hz × 0.011 s) of the data points. Such an input data is inputted to SDOF system and its output is calculated by this system. However, when the resonance frequency of SDOF system rises higher, the number of data points expressing the output waveform which corresponds to the resonance frequency become insufficient. For example, in the resonance system of 1000 Hz, the output waveform has the dominant components for 1000 Hz. However in this case, only 8 (= 8192 Hz × 1/1000 Hz) of data points expressing the components of 1000 Hz for one period are obtained.

As this result, action of the digital filter for output waveform data calculation becomes abnormal and its calculation results in unreliable. SRS is the collected peaks of SDOF system output waveform. However, in such a condition, it is not assured that the peak values are correctly acquired by calculation. That is, for obtaining the correct SRS, the filtering calculation should be executed under the condition in which number of data points for one period is assured to be sufficient to acquire the correct peak values.

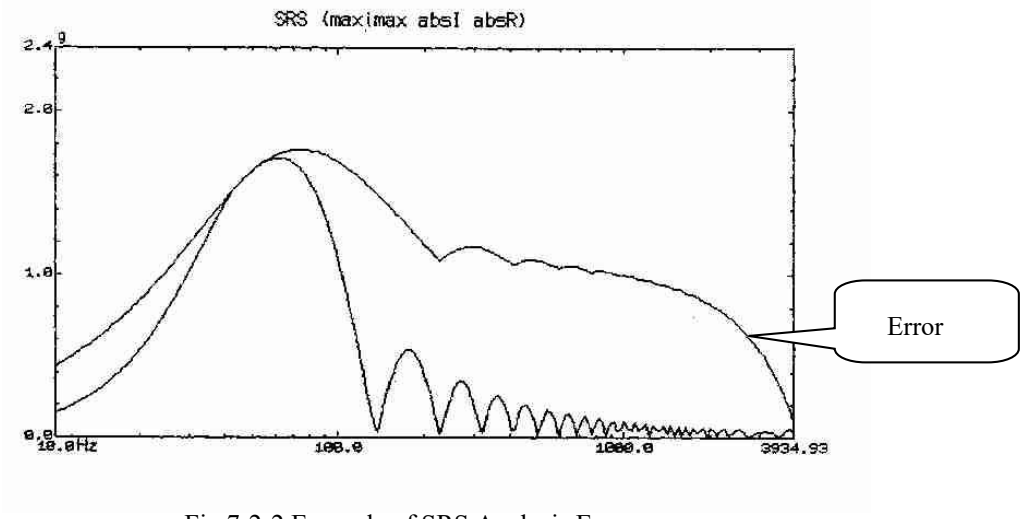


Fig.7-2-2 Example of SRS Analysis Error

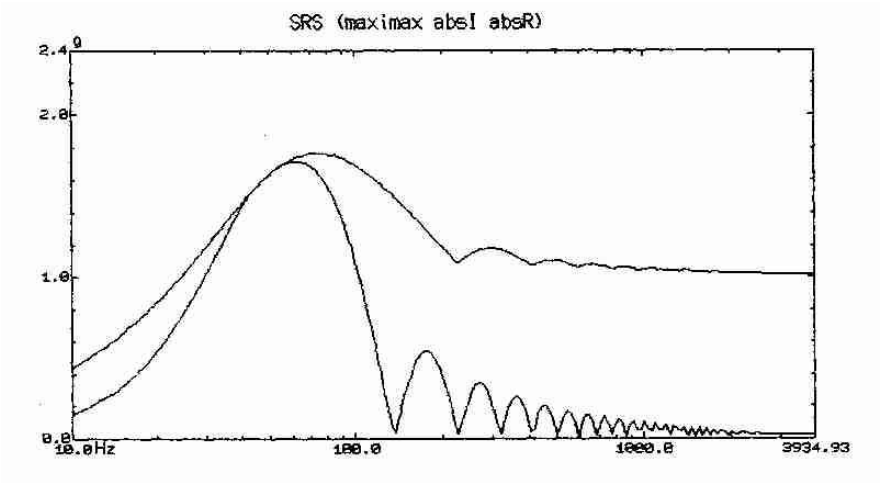


Fig.7-2-3 Correct Analysis Result

<Interpolation>

To prevent such calculation error in the above, the method of Interpolation is generally used. In the above example, 8192 Hz of Sampling Frequency is too small to treat the phenomenon produced at 1000 Hz. So that, the Sampling Frequency is raised effectively based on the given data by the method of Interpolation. Of course, Interpolation is executed providently. Interpolation is a sophisticated method that enables us to obtain the data looks like the sampled data at the higher frequency than actually used one without adding any components that are not included in the original data. (This method is due to the use of FIR Type Filter that does not generate any phase distortion theoretically. Refer to Reference (5) about the method of Interpolation.)

The data in Fig.7-2-3 is calculated by this process in the condition that the correct peak detection is assured. In this system, at the same time with proceeding of analysis band to the high frequency range, SRS Analysis is executed by using the calculation algorithm which enables us to obtain a correct result with Interpolation operation for each time.

<Difficulty to operate Interpolation>

However, as you can imagine, Interpolation is very extravagant process. When Sampling Frequency is raised as twice higher, the number of data points also becomes as twice larger. In some cases, the waveform for one period is needed to be expressed by 256 of data points to assure the correct result. The original data expresses the waveform for one period by only 2 of data points, at the theoretically possible maximum analysis frequency (Nyquist frequency). (In this case of fs = 8192 Hz, Nyquist frequency = 4096 Hz.) In this case, the Sampling Frequency is needed to be multiplied by 128 times (=256/2) and the quantity of data is also multiplied by 128 times as this result. When the original data is 4 Kpoint, the data is obtained as 512 Kpoint by Interpolation.

In both cases, the correct SRS can be calculated by using out new algorithm for Interpolation. Actually, as stated later, when 'Level 5' is specified for calculation, the SRS Analysis is executed with keeping the number of data points for one period as over 256 points. However, it is not avoidable that the calculation quantity increases when Interpolation time increases and it takes a longer time to obtain the result.

<Decimation>

As the opposite operation with Interpolation, Decimation is the process to reduce the number of data points with lowering the Sampling Frequency effectively. In Decimation, the method of FIR Filtering is used and a kind of 'magic' is executed.

As opposed to Interpolation, Decimation is usable when the number of data points is too large in the lower frequency range and IIR Filter becomes unstable (feed-back process is included in this calculation). Stability of the numerical filter depends on the word length for data calculation. In this software, though the problem of such instability is almost solved by executing the filtering calculation itself with double-precision, Decimation process is executed in the meaning of making the analysis accuracy equal at each band.

<Necessity of Interpolation in SDOF System having a large Damping Ratio>

The problem of instability of filter occurs when SDOF system with large damping ratio is set. By this reason, the value of ζ is often limited about 10% at most. However, in this software, the correct SRS analysis can be executed even at ζ = 90% by calculating in 'Level 5' mode.

<Setting of Analysis Accuracy>

As stated in the above, analysis accuracy can be raised by increasing the times of Interpolation. But it takes a longer time for analysis in this method.

Therefore, the function for setting of Analysis Accuracy is available in this software and this function can be used depending on the purposes.

Level 1 : Minimum number of waveform data for one period is specified as 16.

Level 2 : Minimum number of waveform data for one period is specified as 32.
This one would be the standard. When ζ <10 %, sufficient accuracy is obtained.

Level 3 : Minimum number of waveform data for one period is specified as64.

Level 4 : Minimum number of waveform data for one period is specified as 128.

Level 5 : Minimum number of waveform data for one period is specified as 256.

Maximum number of waveform data for one period is quantity which specifies the Decimation operation and set as 512 for each Level commonly.

<Operation in Calculation of Output Waveform through SDOF System>

In Calculation of Output Waveform through SDOF system that simulates waveform passing through a specified SDOF Filter and displays the output waveform itself, Interpolation is also executed (otherwise, the result can not be obtained correctly). However, in this case, all the points are calculated in this operation but data extraction is operated for graph display because the number of data points to be displayed as a graph is limited.

The examples are shown in Fig.7-2-4 and Fig.7-2-5. The reason why Interpolation is needed to be executed is clearly shown.

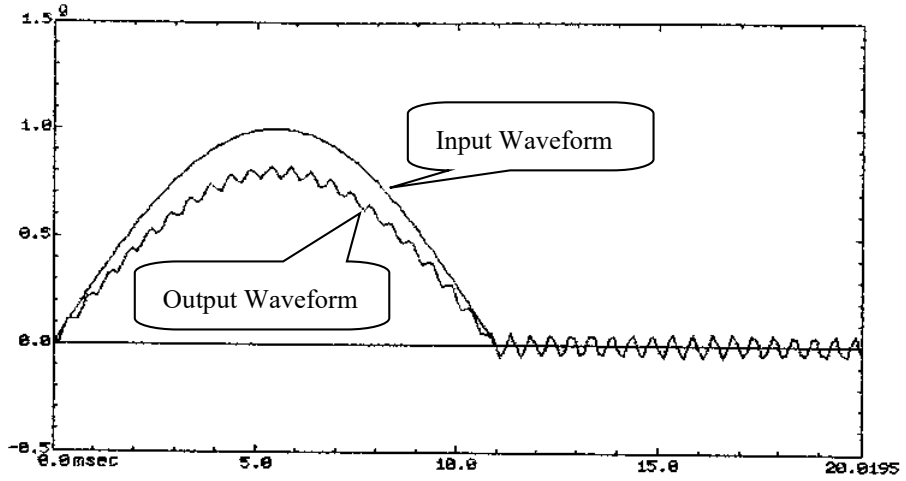


Fig.7-2-4 Calculation Example of SDOF System Input/Output Waveform with insufficient Interpolation

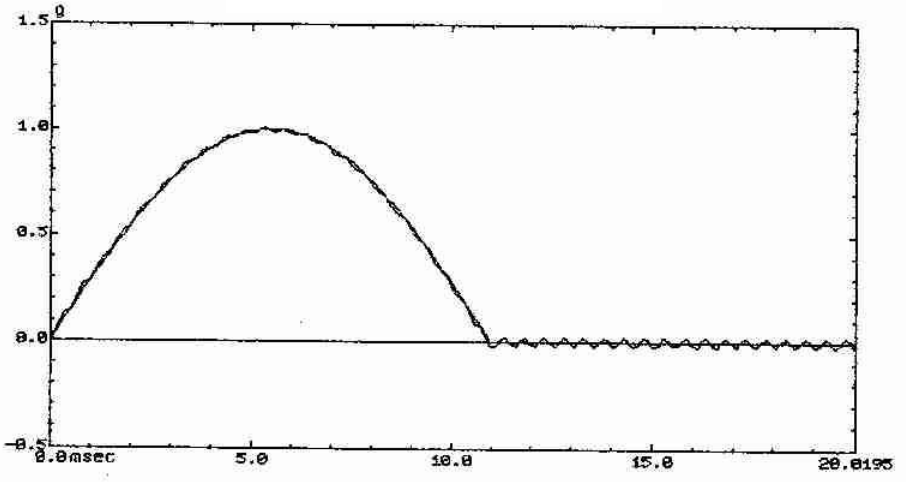


Fig.7-2-5 Example of Correct Calculation

7.2.4 Configuration of SDOF System Filters

In SRS Analysis, a series of SDOF system filters is configured based on the specified SRS Analysis Condition. The operation that how this filter configuration is executed is described in this clause.

The components to define the filter configuration are Max. Frequency of Analysis (fmax), Min. Frequency of Analysis (fmin) and Density of Analysis Frequency.

(1) Converting 'octave' → 'decade'

Density of Analysis Frequency is usually defined by the number of filters for each octave (filters/decade).

On the other hand, it is to be desired that the frequency values for configuring the filters actually include a good number to leave off (such as 100 [Hz] or 1000 [Hz]). Actually, the filtering frequency used for 1/3 octave analysis in the field of acoustics in set to such numbers. However, this filtering frequency cannot be realized by using the octave definition only as it is.

In this software, the filtering frequency is defined as in the following method ;

The value *m'* [filters/decade] which is obtained by converting the specified Density of Analysis Frequency *m* [filters/octave] to the decade band unit. According to this value, the actual filtering frequency is decided for each decade. (That is, the filtering frequency definition is actually executed as the decade band.)

However, the conversion of $m \rightarrow m'$ is executed by calculating the integer number *m'* from the integer number *m*. So the frequency which is different from the frequency calculated by octave band method is selected for the error of rounding. (As a result of this, a good number to leave off is selected ; for example, when 1 [Hz] is used as a basis, 1000 [Hz] is selected instead of 1024 [Hz].)

(2) Maximum / Minimum Frequency

In case that the values of specified fmax and fmin are not equivalent to the filter frequency calculated as in the above unfortunately, the frequency of composed filters fn is set as the value between the lower and the upper limit. That is, SDOF system filters having the sequence series of fn which satisfies the following condition is configured ;

$$\mathrm{fmin} \leqq \mathrm{fn} \leqq \mathrm{fmax}$$

7.3 Synthesizing of Waveform having the Reference SRS

7.3.1 Outline

In this clause, the method of 'SRS Filtering', that is, method of synthesizing a waveform having the Reference SRS is described.

The process of SRS Filtering is composed by the following three stages ;

First stage : Definition of Reference SRS

Second stage: Setting of initial value of component waveform for synthesizing

Third stage : Operation of SRS Filtering Calculation

Main concept of these stages is described in the clauses as below.

7.3.2 Reference SRS

Reference SRS is the reference used in the operation of the SRS Fitting, that is, the reference to which the SRS of synthesized waveform should be equivalent equal.

(1) One of the analysis types can be specified for Reference SRS between Absolute Acceleration and Relative Displacement.

(2) In both cases, Tolerance is defined for Reference SRS (unit : dB).

(3) Reference SRS is defined by one of the following two methods ;

A. Define by Break points

B. Refer to SRS File

The points for Reference SRS definition are as in the above. Reference SRS has the basic role to decide 'the stage' for SRS Fitting itself by its specified contents. That is, the process of SRS Fitting executed after setting of Reference SRS is operated based on the setting based on all the set parameters of Reference SRS (Max./Min. Frequency of Analysis, Density of Analysis Frequency, etc.). Component waveforms are specified as the waveforms having frequencies that are contained in the SDOF System Filter Resonance Frequency defined by Reference SRS (this is used basically just for convenience). Then, SRS analysis for the synthesized waveform by using these component waveforms of the above is operated in the same condition as that of Reference SRS (the analysis should be operated in such a condition).

7.3.3 Importance of Initial Value of Component Waveform for Synthesizing

The synthesized waveform to be used for SRS Fitting can be selected among three types in this system.

The role of SRS Fitting is described as follows ;

Initial value is given to the parameter of each component waveform according to the type of synthesized waveform to be selected. According to this initial value, a waveform is generated and operated by SRS Analysis to compare with Reference SRS. Then, a synthesized waveform having the SRS that is controlled to be closer to the Reference SRS as possible is calculated by iterative

manner with correcting the parameters of component waveforms to make the SRS equivalent equal to the Reference SRS.

However, note that the iterative process of the above does not always result in success. It could be occur that the SRS of synthesized waveform cannot be controlled to be closer to the Reference SRS by the iterative process for any times.

This case can be classified into two cases. One is the case that the SRS of synthesized waveform can be controlled to be closer to the Reference SRS as possible by some method. And another is the case that the SRS of synthesized waveform cannot be controlled by any method.

In the former case of the above, the values given to the component waveforms for synthesizing initially are of great importance (initial value).

It seems so hard to treat the condition of convergence to the reference generally in such a complicated process like as SRS Fitting. However, it can be said that the convergence of SRS can be realized in the cases of which component waveforms for synthesizing are given with proper initial values (the number of such cases is uncertain).

The available methods to give the proper initial values for realizing the convergence are as follows ;

A. Manual (all the setting is done by the operator)

B. Auto

As far as we know, it is difficult to set the initial value by the operator in the function ‘A’. This method requires a lot of skills and a preliminary examination to operate the control successfully.

On the other hand, the function ‘B’ is provided to solve this difficulty automatically. As stated in the above, the process of SRS Fitting is complicated, so this function cannot assure the convergence. However, in the most cases, it can be said that the function ‘B’ is much more effective that the function ‘A’.

The importance of initial value is described with emphasis in the above. The most important item in the initial value setting is the frequency selected among the available frequency given to the component waveforms. When the frequency of initial value setting is not selected properly, the SRS cannot be controlled to be closer to the Reference SRS.

7.3.4 SRS Fitting Calculation

The algorithm adopted in this system for executing the iteration of SRS Fitting is very simple.

Denoting the amplitude of component waveform corresponding to i-th frequency component (SDOF System Filter Resonance Frequency) as amp [i], the next amplitude of component waveform is decided by the following equation ;

$$amp[i] = amp[i]\frac{refsrs[i]}{synsrs[i]} \qquad (7\text{-}12)$$

Here, refsrs [i] is i-th component of Reference SRS and synsrs [i] is i-th component of synthesized waveform SRS. The characteristics of this method are described as follows ;

(1) synsrs [i] is decided not only by amp [i] but also by contribution from the components other than i-th component which are certainly existing. So it cannot be assured that the SRS is controlled (as synsrs [i] = refsrs [i]) by the equation (7-12). However, this equation is used because there is no other good simple method.

(2) In this software, other parameters of component waveform are not controlled. A good result may be obtained by controlling other parameters but such an operation requires the calculation processor faster that some ten times of PC to execute the control in actual time.

<Reference>

(1) J.S.Bendat / A.G.Piersol

RANDOM DATA : Analysis and Measurement Procedures

John Wiley & Sons Inc. (1971)

(2) G.Strang

Linear Algebra and Its Applications

Academic Press (1976)

(3) R.S.Ayre

Transient Response to Step and Pulse Functions

Shock and Vibration Handbook 2nd Edition Chapter. 8, McGraw-Hill

(4) Oppenheim / Schafer

DIGITAL SIGNAL PROCESSING

Prentice-Hall, Inc.

(5) R.E.Crochiere / L.R.Rabiner

Optimum FIR Digital Filter Implementations for Decimation, Interpolation, and Narrow-Band Filtering

IEEE Transactions, Vol:ASSP-23 No.5:444～456

Chapter 8 Test Definition of SRS SHOCK (Option)

8.1 Outline of SRS SHOCK Test Definition

Test definition of SRS SHOCK is almost the same as that of normal SHOCK test but has a different method of Reference definition.

SRS SHOCK test is defined by the setting of the information in Table 8-1 in order for each Test types.

Table 8-1 Definition Information

Setting Information	
(1) I/O Module Configuration	○
(2) Excitation System Information	○
(3) Reference SRS	○
(4) Control Condition	○
(5) Excitation System setting	○
(6) Input Channel	○
(7) Safety check	○
(8) Level Schedule	△
(9) Timing Signal	△

○ : Information that must be defined

△ : Information that is defined if necessary

Information of Test completely defined is to be saved in a file as a specified format of 'Test File'.

Test operation can be executed by loading a file in which the information of Test defined beforehand is saved as a Test File.

SRS Analysis Condition of Monitor waveform is the condition of analysis defined in Reference SRS.

The Definition of Reference SRS is described in the following clauses.

Other items of test definition are the same as those in normal SHOCK test. Refer to "Chapter 4 Test Definition" about the details.

8.2 Reference SRS

In SRS SHOCK test, Reference SRS is used as reference by the operator when the waveform control is operated. Also, the judgment of the control result is operated by SRS.

The dimension of Controlled Variable is limited to ‘acceleration’.

Reference SRS is determined by setting the information as below in order.

(1) SRS Analysis Condition

The items that defines SRS Analysis Condition are listed as below ;

- Sampling Frequency
- Data Length (Number of Data Points) of Reference Waveform
- Frequency Range and Resonance (series of SDOF Resonance Frequency) of SRS Analysis
- Damping Ratio of SRS Analysis
- SRS Analysis Type

(2) Reference SRS Condition

In Reference SRS Condition, Frequency / Amplitude / Tolerance are defied as a break point.

Series of frequencies has already defined in SRS Analysis Condition. So, Amplitude / Tolerance are specified at the objective Frequency to be selected in this operation.

(3) Waveform Synthesizing Condition

The condition of Synthesized Waveform satisfying the Reference SRS Condition is defined.

Synthesized Waveform is generated by composing the multiple component waveforms. Component waveforms are defined in Damped Sine. Refer to 5.6 Damped Sine about the details of Damped Sine.

The items that defines waveform synthesizing are listed as below ;

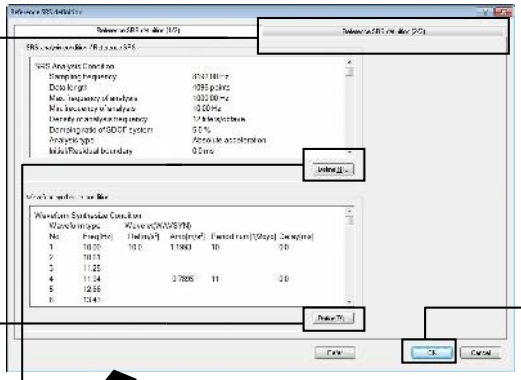
- Synthesized Waveform Type
- Auto /Manual setting of component waveform
- The condition of Frequency Range and spacing of component waveform in Auto
- Frequency and Amplitude of each component waveform in Manual

(4) Operation of SRS Fitting

The synthesized waveform generated in Waveform Synthesizing Condition is used as Reference Waveform. This synthesized waveform is generated to satisfy Reference SRS Condition. However, generally, it is difficult to satisfy Reference SRS Condition in the initial setting of synthesized waveform.

So, each components of synthesized waveform is needed to be corrected so that the SRS Analysis (Reference Analysis SRS) of Reference Waveform (Synthesized Waveform) converges within the Tolerance specified in Reference SRS Condition.

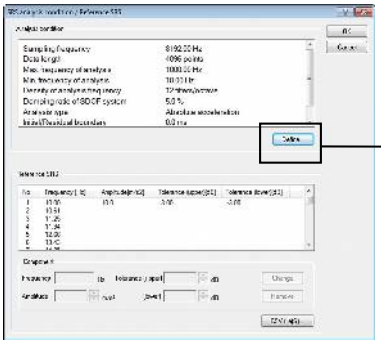
① Reference SRS



Reference SRS Definition is completed.

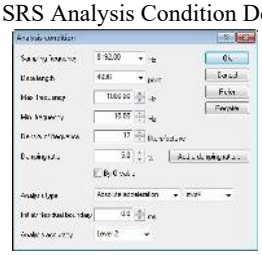
(2) Setting of Reference SRS Condition

② SRS Analysis Condition
Reference SRS Definition



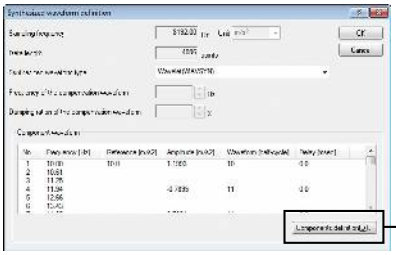
(1) Setting of SRS Analysis Condition

③ SRS Analysis Condition Definition

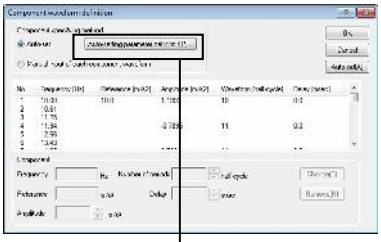


(3) Setting of Waveform Synthesizing Condition

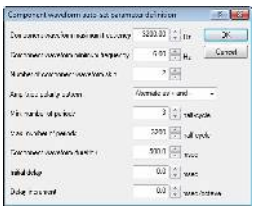
④ Synthesized Waveform Definition



⑤ Component Wave Definition

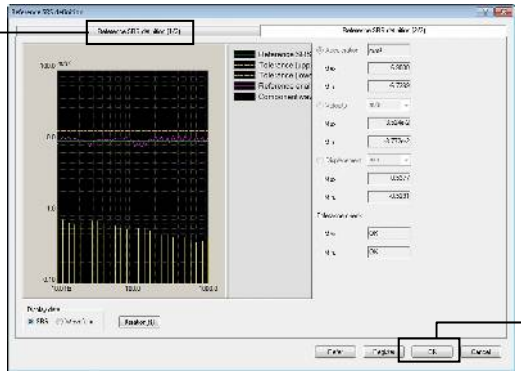


⑥ Component Wave Auto-set Parameters



(4) Operation of SRS Fitting

⑦ Display of Reference SRS



Reference SRS Definition is completed.

Chart and the relations of information for defining the Reference SRS are described in the above page.

However, the definition displays as below appears in order of the information to be defined when a test is newly defined.

③ SRS Analysis Condition Definition : (1) SRS Analysis Condition Definition

↓

② SRS Analysis Condition
Reference SRS Definition : (2)Reference SRS Condition Definition

↓

④ Synthesized Waveform Definition : (3) Waveform Synthesize Condition Definition

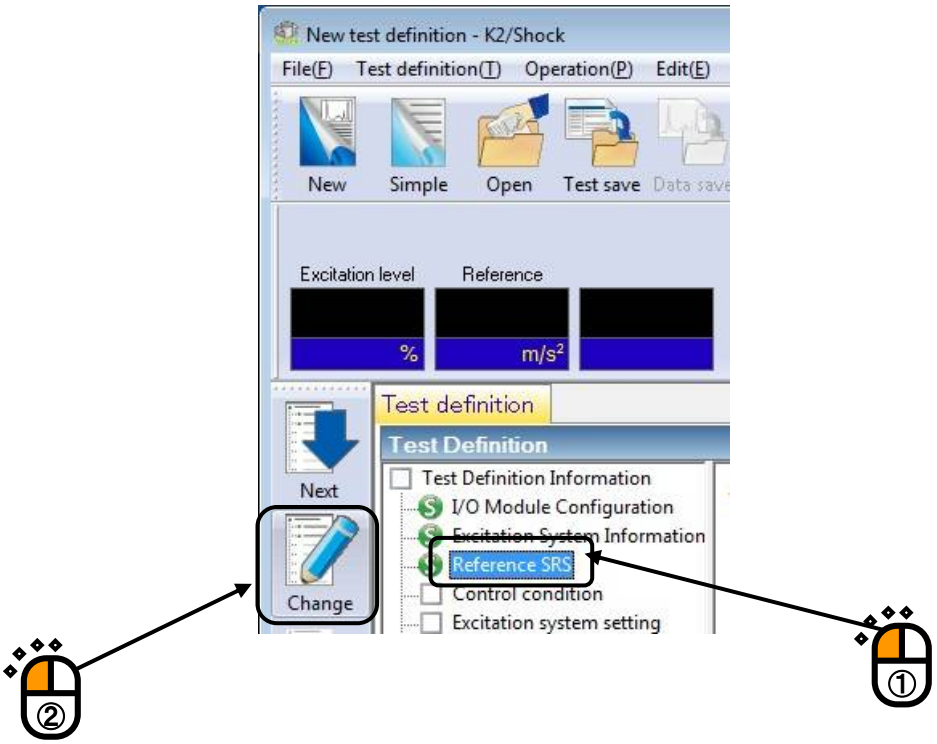
↓

① Reference SRS Definition

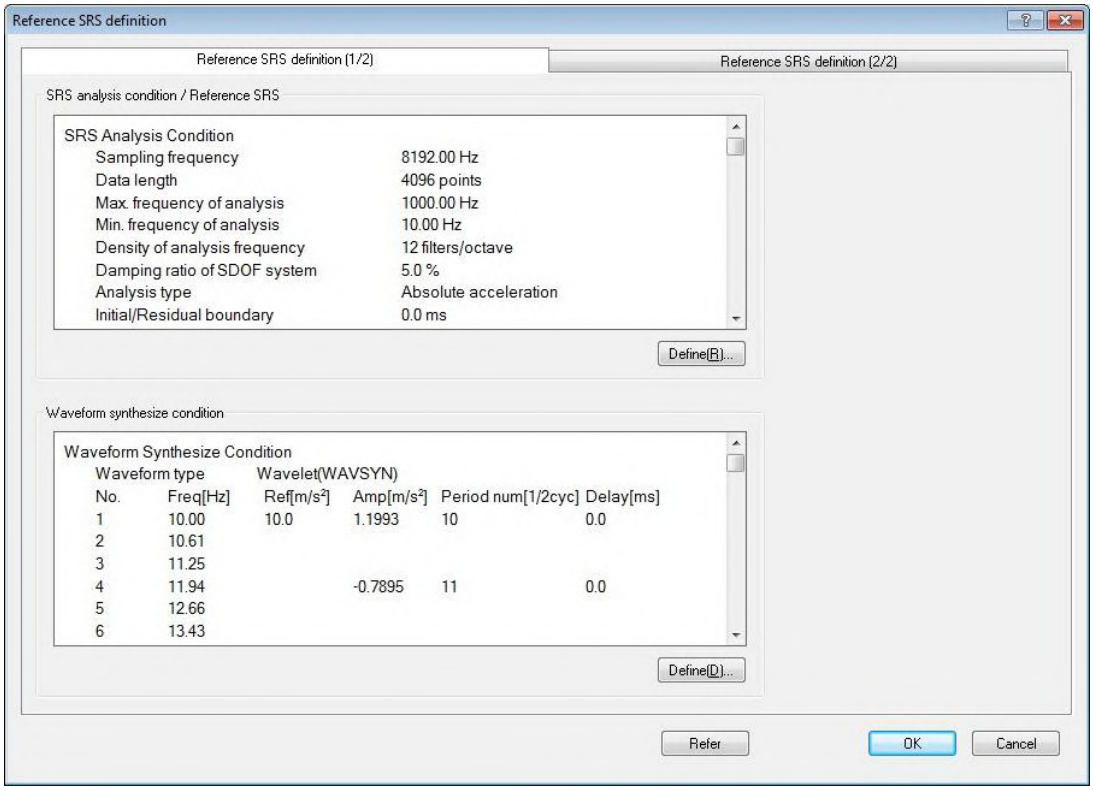
↓

⑦ Display of Reference SRS : (4) Operation of SRS Fitting

Select ‘Reference SRS’ in Test Definition and press the [Correct] icon when Reference SRS of the defined test is needed to be corrected.



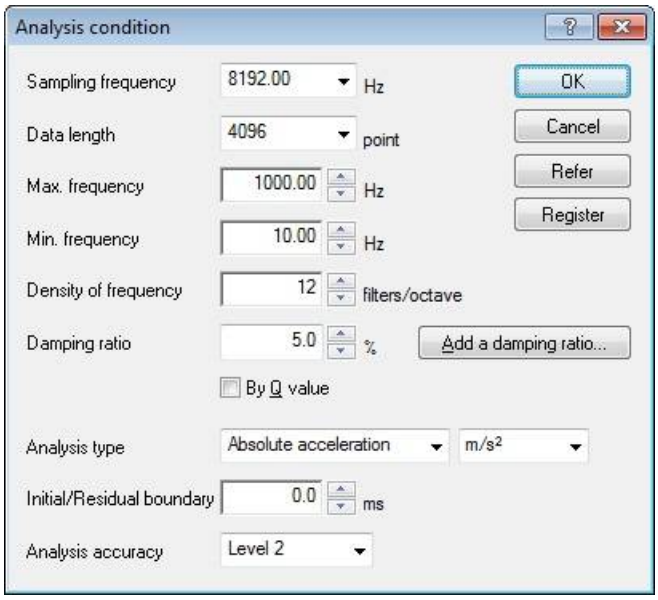
A dialog of Reference SRS Definition is displayed when the [correct] icon is pressed.



8.2.1 SRS Analysis Condition

In the dialog of Analysis Condition Definition, the condition of SRS Analysis is defined.

The display of SRS Analysis Condition / Reference SRS Definition appears by pressing the [OK] button in Analysis Condition Definition when the setting of each parameters are completed.



8.2.1.1 Sampling Frequency

(1) Meaning

This item is for selecting the Sampling Frequency fs of the waveform data to be generated.

Frequency Range fmax used when the waveform control program operates this data is specified by the setting of this item.

Frequency Range fmax is related to Sampling Frequency fs by the equation as below ;

$$Fmax = fs / 2.56 \text{ [Hz]}$$

8.2.1.2 Data Length

(1) Meaning

This item is for specifying the number of data points to express the waveform data that sampled by Sampling Frequency in the above clause.

The whole length T [s] of waveform data is defined by the equation as below ;

$T = N / fs$ [s] N : Number of data points

8.2.1.3 Max. Frequency of Analysis

(1) Meaning

This item is for specifying the maximum value of frequency range at SRS Analysis. SRS is obtained by calculating the response of each SDOF system configured for each Density of Analysis within the segment between Min. Frequency of Analysis specified in the following item and Max. Frequency of Analysis specified in this item.

8.2.1.4 Min. Frequency of Analysis

(1) Meaning

This item is for specifying the minimum value of frequency range at SRS Analysis. SRS is obtained by calculating the response of each SDOF system configured for each Density of Analysis Frequency within the segment between Min. Frequency of Analysis specified in this item and Max. Frequency of Analysis specified in the above item.

8.2.1.5 Density of Analysis Frequency

(1) Meaning

This item is for specifying the density of SDOF system filters prepared to operate SRS Analysis.

That is, in this item, the number of SDOF system to be set for each 1 octave is set. (filters/octave)

Total number of SDOF filters to be composed is defined by the specified value of this item and the specified values of Min./Max. Frequency Analysis. Maximum of total number is **256** in this system.

8.2.1.6 Damping Ratio of SDOF System

(1) Meaning

This item is for specifying the common value to all the filters as damping ration of SDOF system filters prepared to operate the SRS Analysis as below ;

$$\zeta = \frac{C}{C_C}$$

Where, C_c is the criteria damping factor of SDOF system ;

$$Cc = 2\sqrt{mk}$$

Generally, the value Q and the damping ratio ζ is related as below ;

$$Q = \frac{1}{2\zeta}$$

8.2.1.7 Analysis Type

(1) Meaning

This item is for specifying the type of output waveform data to be calculated, that is, the type of SDOF System to be defined. One of the following types of output waveform can be selected ;

a. Absolute Acceleration Output Waveform

b. Relative Displacement Output Waveform

8.2.1.8 Initial / Residual Boundary

(1) Meaning

This item is for setting of a data which denotes an effective completion time of input waveform and is used as the base for calculating the initial response SRS (+I, -I, absI) and the residual response SRS (+R, -R, absR) in the process of SRS Analysis operation (which defines the boundary of 'Initial' and 'Residual').

The setting of this item influences the SRS data to be obtained largely **but does not influence the maximax SRS**.

8.2.1.9 Analysis Accuracy

(1) Meaning

This item is for selecting the accuracy of simulation calculation operation to obtain the output waveform from SDOF system.

Analysis Accuracy can be selected among the 5 levels from 'Level 1' to 'Level 5'.

When a larger number of levels is set, the calculation becomes more accuracy and the calculation takes more time (increasing almost exponential functionally).

The schedule of operating the interpolation is automatically dedicated according to the resonance frequency of each SDOF system.

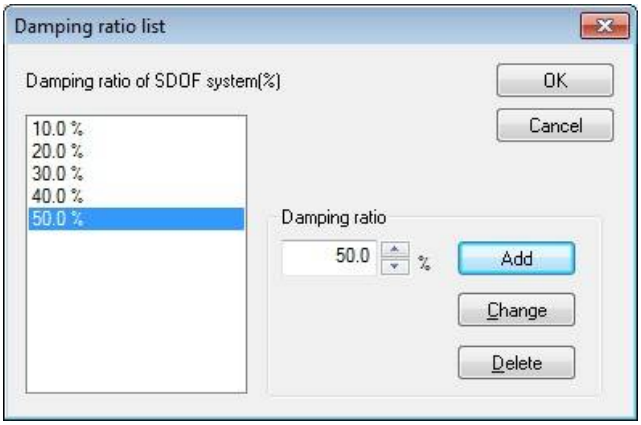
In ordinal cases with Damping Ratio < 10 %, enough accuracy can be obtained by the setting of 'Level 2'.

8.2.1.10 Add a Damping Ratio

(1) Meaning

In addition to the Damping Ratio specified in 8.2.1.6 Damping Ratio of SDOF System, SRS Analysis by multiple Damping Ratios is simultaneously operated. However, in SRS Analysis by multiple Damping Ratio, only the **maximax SRS** is analyzed.

Press [Add a Damping Ratio] button when multiple Damping Ratios of SDOF System is needed to be specified. The dialog box as below appears by pressing of [Add a Damping Ratio]. Press [Add] and input the value of SDOF Damping Ratio.

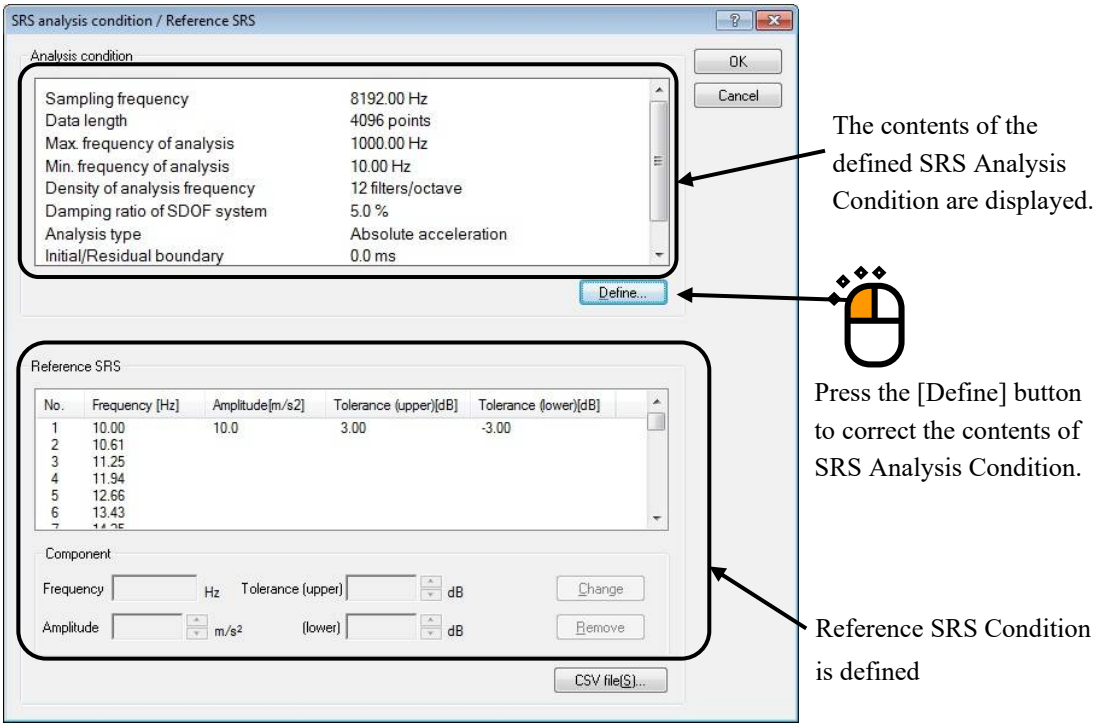


8.2.2 Reference SRS Condition

In the dialog of SRS Analysis Condition / Reference SRS Definition, the condition of Reference SRS is defined.

When the setting of each parameter is completed, the dialogs as below appear by pressing the [OK] button.

- In 'New Definition' : The dialog of Synthesized Waveform Definition is displayed
- In 'Correction Definition : The dialog of Reference SRS Definition is displayed.



SRS Analysis Condition used as the Reference of SRS Fitting is defined (SRS of the synthesized waveform should be equal to this reference).

(1) One of the analysis types can be specified for Reference SRS between Absolute Acceleration and Relative Displacement.
However, this setting has already specified in 'Analysis Type' of 8.2.1 SRS Analysis Condition.

(2) Reference SRS is defined by the method of 'Define by Break Points'.
However, this frequency series of break points has already defined in 'Max. Frequency of Analysis', 'Min. Frequency of Analysis' and 'Density of Analysis Frequency' of 8.2.1 SRS Analysis Condition as same as the frequency series of SRS Analysis. Only the amplitude is defined.

(3) Tolerance of Reference SRS is defined.

Definition contents completed to be defined in SRS Analysis Condition is displayed as in the above. SRS Analysis Condition can be corrected by pressing the [Define] button in Analysis Condition.

8.2.2.1 Setting of Break Points

(1) Meaning

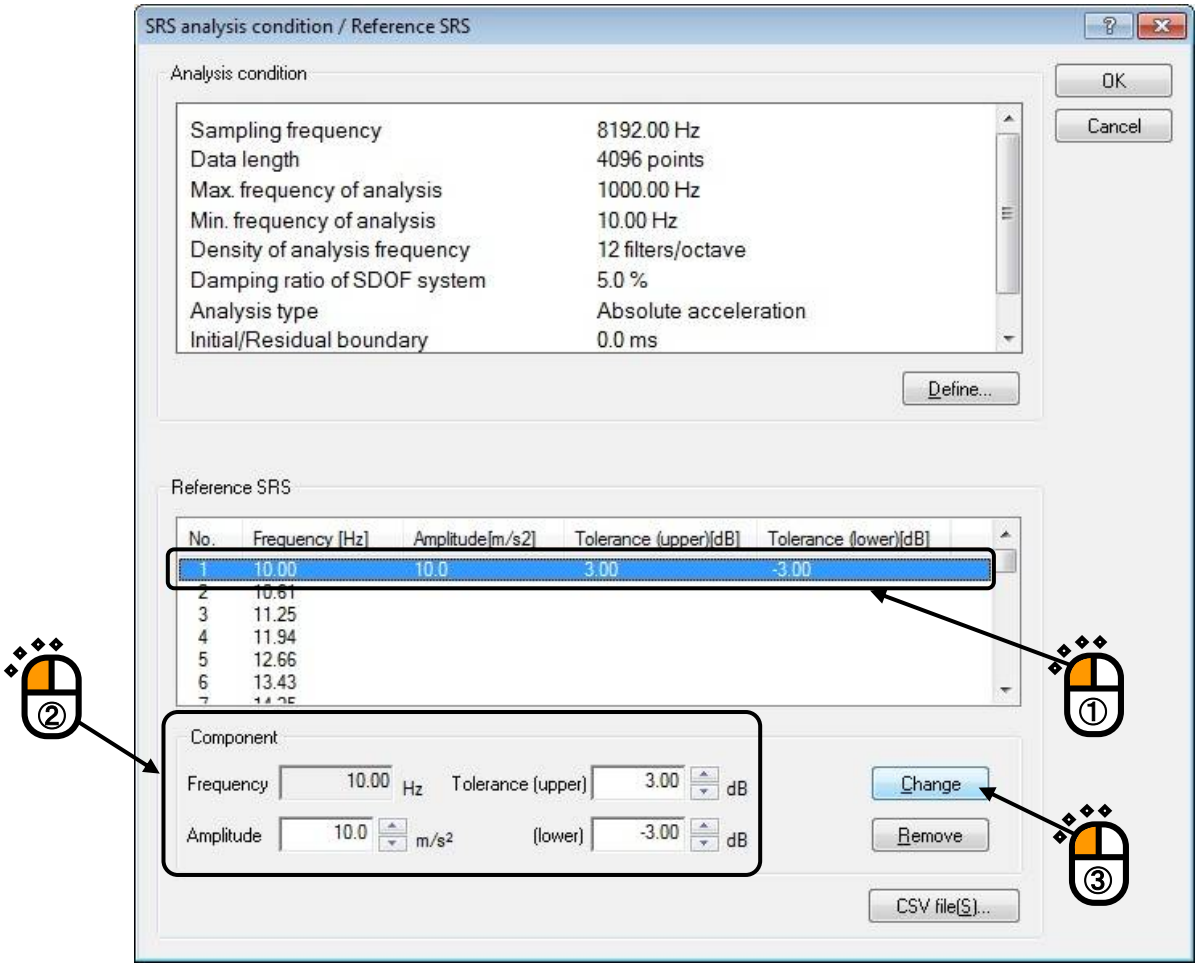
Break Points are defined by the procedures as below ;

① Select a Frequency that is used for setting of a break point among the frequency list.

② Input the values of Amplitude and Tolerance.

③ Press the [Change] button.

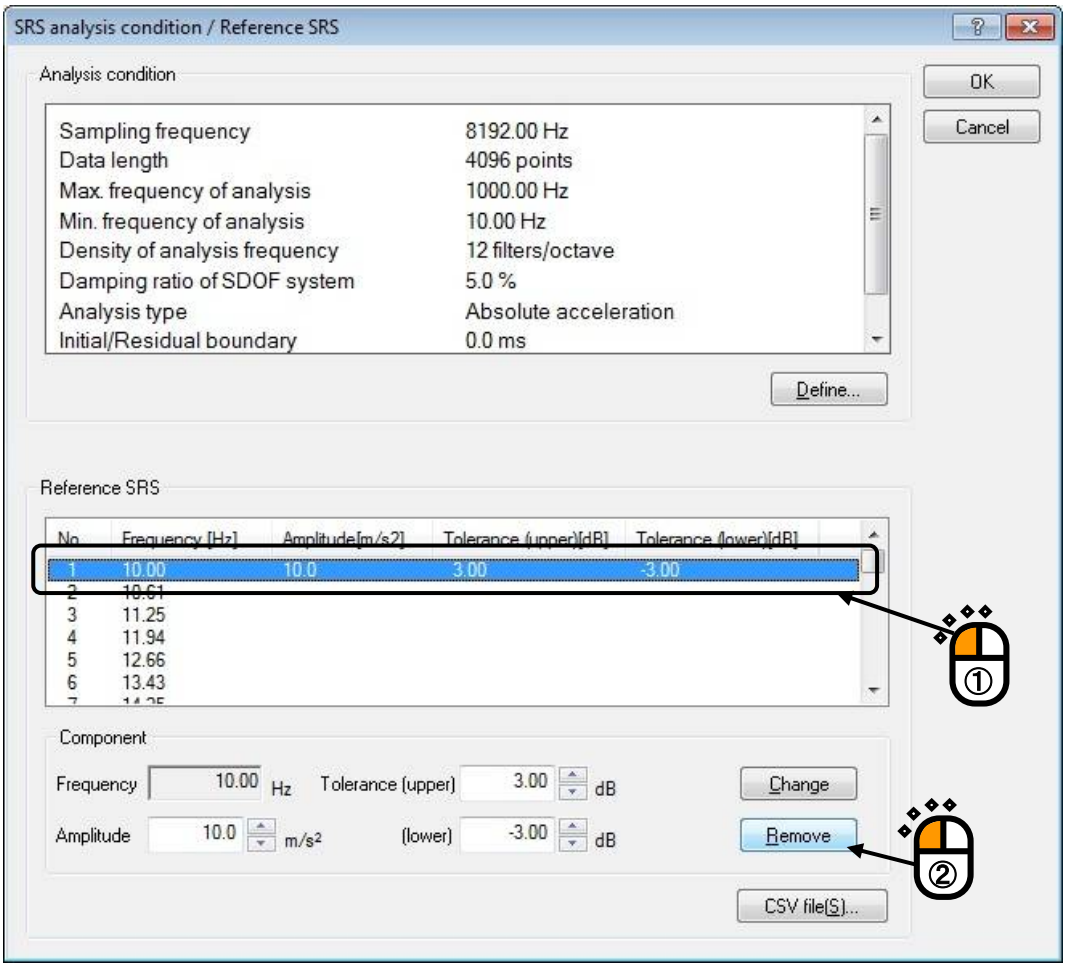
Break Point can be set to the frequency that you need to be defined.



The defined break point can be deleted by the procedures as below ;

① Select a frequency that is used to set a component wave among the frequency list.

② ② Press the [Remove] button.



The frequencies that have no amplitudes defined in this item are set by the system according to the following condition.

When the amplitudes of f2 and f5 are set by the operator among the frequency data of f1, f2, f3, f4, f5, f6, f7 ;

f3, f4 : The amplitudes calculated from the amplitude of f2, f5 are given.

f1, f6, f7 : The amplitudes are set to zero.

8.2.2.2 To set the Break Point by CSV File

'Frequency-Amplitude Tolerance' saved in a specified file can be used as a break point data to be loaded by pressing the [CSV File] button.

The formats as below are available to be loaded ;

(1) CSV File

A CSV format file that is written as the values divided from each other by a comma as below ;

Frequency [Hz], Amplitude, Tolerance:Upper [dB], Tolerance:Lower [dB]

Unit of the Amplitude is not specified in CSV File. The unit specified in Analysis Condition is used as the Amplitude unit.

The setting of Tolerance can be submitted. The default value of set when it is submitted.

Description example of CSV File is shown as below (from the left, Frequency [Hz], Amplitude, Tolerance:Upper [dB], Tolerance:Lower [dB]).

```
5.689, 10, 6, -6 CR
8.612, 20, 6, -6 CR
11.56, 20, 6, -6 CR
```

(CR : Carriage Return)

(Substitution for approximate value of Frequency at referring to a file)

This system substitutes the frequency sequence described in a file which is referred to approximate value of Frequency automatically when the values are different from the Frequency sequence in Analysis Condition.

An example of loading a CSV File and substituting the values for approximate frequencies are shown in Fig.8-2-1, Fig.8-2-2 and Fig.8-2-3.

The frequency 4.2 Hz in Fig.8-2-2 is not found in the frequency sequence of Analysis Condition in Fig.8-2-1. However, in Fig.8-2-3, this system substitutes the value for an approximate value as 4.12 Hz at loading the data.

No.	Freq.[Hz]	Amp.[m/s2]
1	4.12	
2	4.38	
3	4.64	
4	4.92	
5	5.22	
6	5.54	
7	5.88	
8	6.24	
9	6.61	
10	7.02	
11	7.44	

Fig.8-2-1 Frequency sequence of Analysis Condition

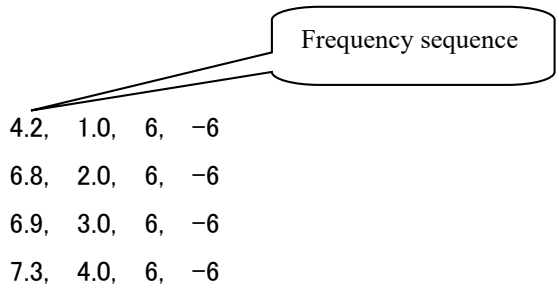


Fig.8-2-2 CSV File to be loaded

No.	Freq.[Hz]	Amp.[m/s2]
1	4.12	1.0
2	4.38	
3	4.64	
4	4.92	
5	5.22	
6	5.54	
7	5.88	
8	6.24	
9	6.61	2.0
10	7.02	3.0
11	7.44	4.0

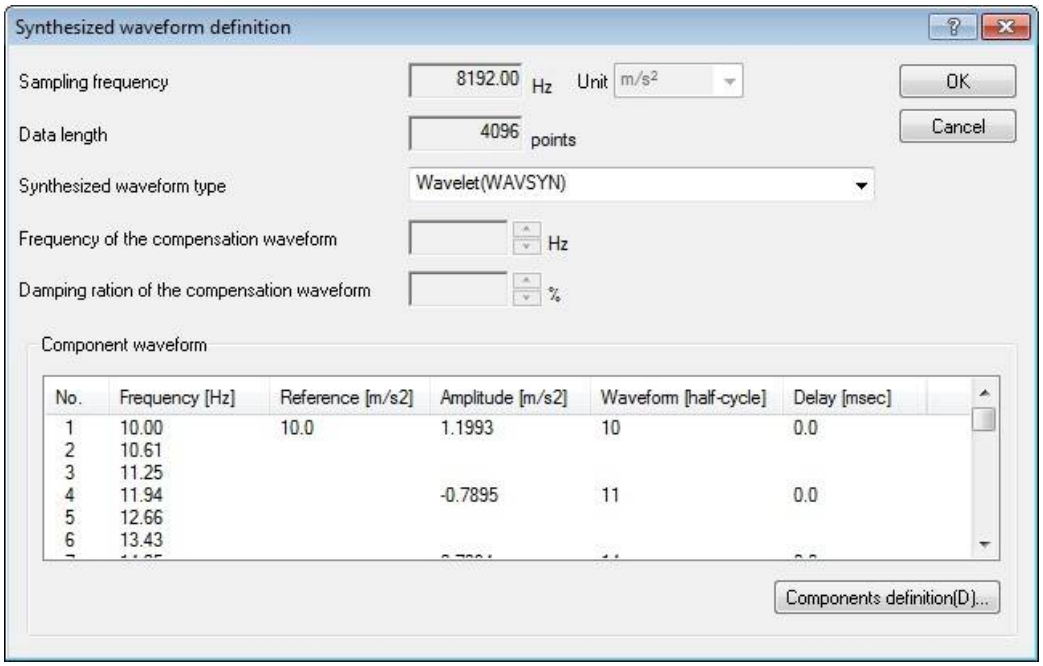
Fig.8-2-3 After loading the CSV File in the above

8.2.3 Waveform Synthesize Condition

8.2.3.1 Outline

In this dialog, the generation condition of synthesized waveform is defined.

The dialog of Reference SRS Definition appears by pressing the [OK] button when the setting of each parameter is completed.



Initial value is given to the component waveform parameters for synthesizing used at SRS Fitting. Setting of component waveform parameters for synthesizing, that is, setting of initial value for waveform synthesizing can be done by one of the following two methods ;

a. Auto-set

b. Manual input of each Component Waveform

(1) In either cases of a, b, only the component given as initial value having the amplitude which is not zero is treated as the objective for controlling by SRS Fitting calculation. That is the component which is not given as the initial value is obtained as zero by any times of iteration operation. So the necessary component for fitting operation is needed to be given as initial value.

(2) Although frequencies are not necessary to be selected among these frequencies decided by the SRS Analysis, this function is for simplifying the operation by providing the frequency data from the system side.

8.2.3.2 Sampling Frequency fs

(1) Meaning

This item is for indicating the Sampling Frequency of synthesized waveform.

The value of this item has been defined in Max. Control Frequency fmax of Time Parameters. It cannot be changed in this display.

8.2.3.3 Data Length N

(1) Meaning

This item is for specifying the length of synthesized waveform.

As same as Sampling Frequency, the value of this item has also been defined in Number of Control Frequency Lines L of Time Parameters. It cannot be changed in this display.

Whole length of synthesized waveform T [s] is defined by the following equation ;

$$T = L / fmax \ [s]$$

L : Number of Control Frequency

fmax : Max. Control Frequency

8.2.3.4 Control Unit

(1) Meaning

This item is for specifying the control unit.

The dimension of the control unit is specified to the 'acceleration'.

Control unit can be selected when the Analysis Type of SRS Analysis Condition is specified to 'Correlation Displacement'.

The unit of Analysis Type of SRS Analysis Condition has defined and cannot be changed when the Analysis Type of SRS Analysis Condition is specified to 'Absolute Acceleration'.

8.2.3.5 Synthesized Waveform Type

(1) Meaning

This item is for specifying the waveform type generated as synthesized waveform.

In this system, the following three types are available ;

1. Compensated, Exponentially Decaying Sinusoid (CEDS)
2. Zero Residual Displacement Decaying Sinusoid (ZERD)
3. Wavelet (WAVSYN)

Refer to "5.6 Damped Sine in Chapter 5" about the details of these waveform in the above.

8.2.3.6 Frequency of the Compensation Wave

(1) Meaning

This item is defined when CEDS is selected as Synthesized Waveform Type. This item is for specifying the frequency of Compensation Wave (Exponentially Decaying Sinusoid) to operated the compensation to the superposed acceleration waveforms of specified Exponentially Decaying Sinusoids in order to obtain 'final velocity zero, final displacement zero'.

Ordinary, a smaller value than minimum frequency of the other component waveform is set.

8.2.3.7 Damping Ratio of the Compensation Wave

(1) Meaning

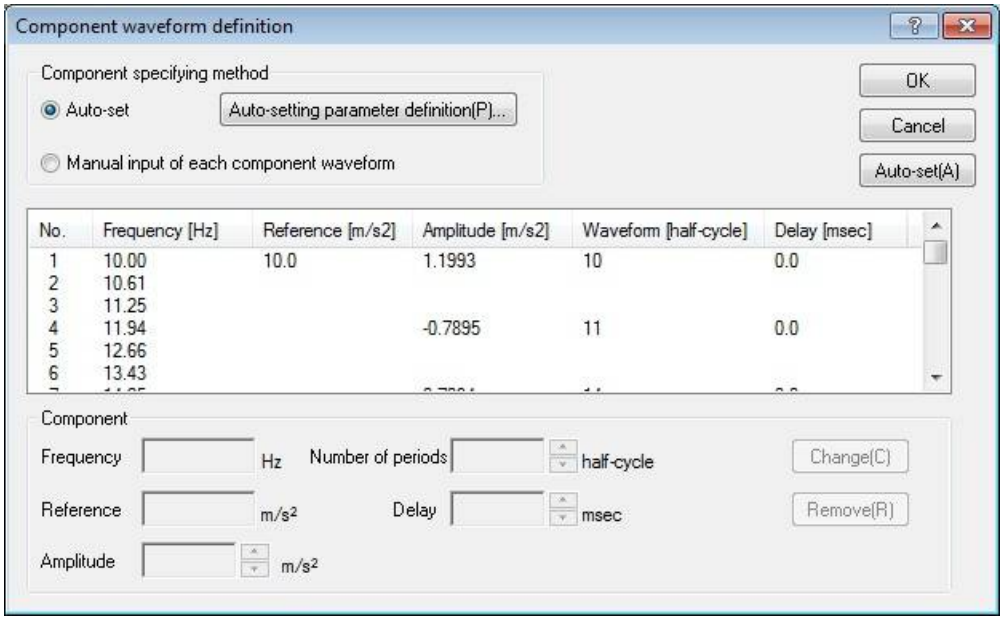
This item is for specifying the damping ratio given to CEDS in the previous clause. Ordinary, this item is set about [100 %].

8.2.3.8 Components Definition

Each component wave parameter used in waveform synthesizing is defined.

The dialog of Component Wave Definition appears for defining each item when the [Components Definition] button is pressed in the display of Synthesized Waveform Definition.

The definition contents of Component Wave are determined by pressing the [OK] button in the dialog of Component Wave Definition. Then, the system returns to the Synthesized Waveform Definition display.



8.2.3.8.1 Components Specifying Method

(1) Meaning

In this system, the following two methods for specifying the initial values given to synthesized component waveforms available ;

A. Manual input of each Component Waveform

B. Auto-set

However, it is difficult to set the initial values by the operator in the function ‘A’. This method requires a lot of skills and a preliminary study to operate the calculation successfully. To avoid this difficulty, the function ‘B’ is provided to solve this problem automatically. As stated in the above, the process of SRS Fitting is completed, so this function cannot assure the convergence. However, in most cases, it can be said that the

function ‘B’ is much more effective than the function ‘A’.

When ‘Auto-set’ is selected, press [Parameter Auto-setting Definition]. Then, each kind of parameters for auto-setting is set in the dialog box.

On the other hand, when ‘Manual input of each Component Waveform’ is selected, the parameter in the frequency tables of Component Waveform Definition is defined by selecting the frequency for setting of the initial value.

8.2.3.8.2 Auto-set of Component Waveform

Component Waveform is automatically defined by the procedures as below ;

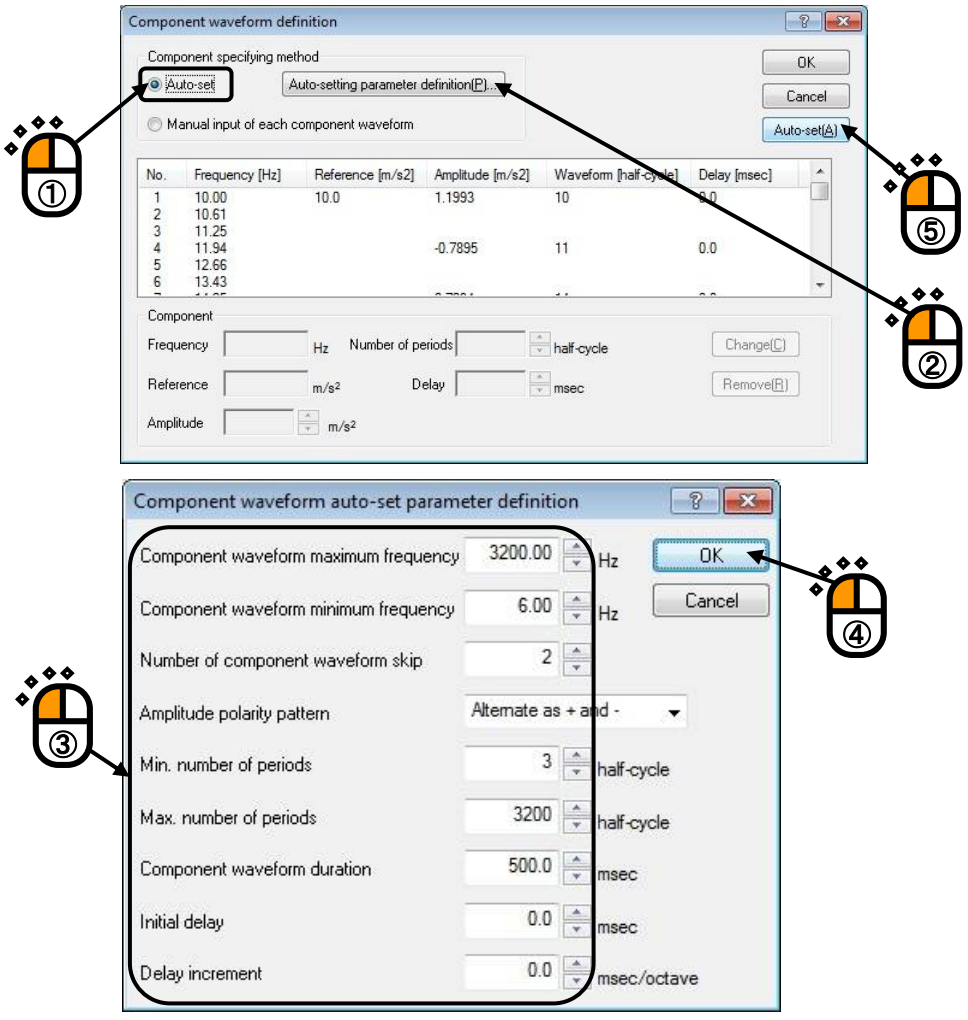
① Select the item of ‘Auto-set’ in the dialog of Component Waveform Definition.

② Press the [Parameter Auto-setting Definition] button.

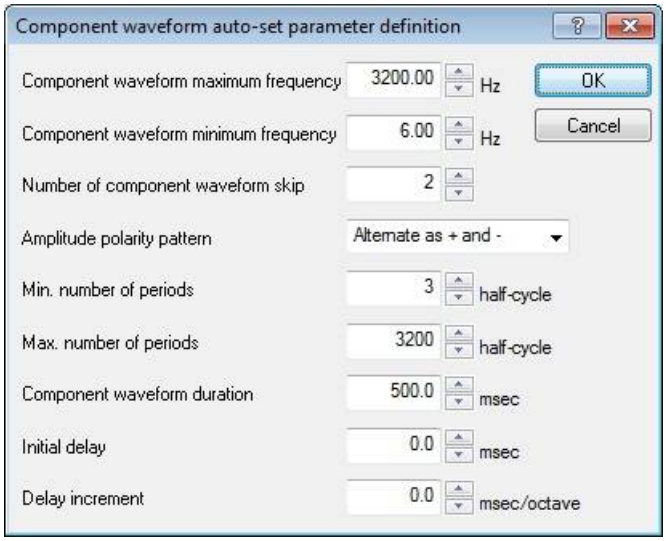
③ The necessary parameter is defined in the dialog of Component Waveform Parameter Auto-setting Definition.

④ Press the [OK] button in the dialog of Component Waveform Parameter Auto-setting Definition.

⑤ Press the [Auto-set] button to return to the dialog of Component Waveform Definition. The Component Waveform parameter is set according to the Auto-set Parameters.



8.2.3.8.2.1 Component Waveform Auto-set Parameter Definition



8.2.3.8.2.1.1 Component Waveform Max. Frequency

(1) Meaning

This item is inputted only when 'Auto-set' is selected as Components Specifying Method. When the initial values of waveform synthesizing are automatically set in this method, this item is for defining the maximum value of frequency for auto-setting. When the frequency data larger than the specified value exists in the table of SDOF Filter frequency series, auto-setting of the initial value cannot be done. Ordinary, the maximum value within the input range is inputted.

8.2.3.8.2.1.2 Component Waveform Min. Frequency

(1) Meaning

When the initial values of waveform synthesizing are automatically set in this method, this item is for defining the minimum value of frequency for auto-setting. When the frequency data smaller than the specified value exists in the table of SDOF Filter frequency series, auto-setting of the initial value cannot be done. Ordinary, the minimum value within the input range is inputted.

8.2.3.8.2.1.3 Number of Component Waveform Skips

(1) Meaning

It may be inconvenient for the purpose of SRS Fitting of the component waveforms are given to all the frequencies having Reference SRS at Component Waveform Auto-setting. In such a case, the convergence can be disturbed by interference between each SRS corresponding to the component waveform. So, it is valid for good convergence to specify the setting of component waveform as 'Skip', that is, the component wave is set after each constant interval.

This item is for specifying the number of Skips described in the above. For example, when the number of Skips is specified as 1, Component Waveform setting is done every other series of SDOF Filter Frequency. The default setting to set one component waveform for each 1/2 octave.

8.2.3.8.2.1.4 Amplitude Polarity Pattern

(1) Meaning

It may be inconvenient that too large peak value is obtained as the result of superposing of the Component Waveforms when all the polarity of amplitudes are set equally at the setting of amplitude value A_i in Component Waveform auto-setting. (Especially, in the case that all of the delay are set to zero.) In this case, it may be valid that the polarity is set by switching + and – alternately. In this item, the pattern of switching polarity is specified.

8.2.3.8.2.1.5 Min./Max Damping Ratio

(1) Meaning

This item is inputted only when 'CEDS' or 'ZERD' is selected as Synthesized Waveform Type. The range of Damping Ratio ζ_i given to each Component Waveform is specified by setting of the minimum and the maximum values for auto-setting of this system.

Basically, minimum value of Damping Ratio is specified as follows ;

The Damping Ratio ζ_i by which the amplitude of Component Waveform is damped lower than 1/100 of initial Amplitude A_i at the ending edge of frame time is used as the lower limit value. That is, the lower limit value is defined as the condition assuring the sufficient damping for each waveform within the set data length (specified by fs and N).

However, it is actually considered that superposing of multiple Component Waveforms occurs inevitably for Damping Ratio of each Component Waveform at the ending edge of frame time. The ζ_i given to each Component Waveform is calculated by the method prepared in this system and set automatically at auto-setting of Component Waveform. When the

calculated ζ_i exceeds over the set value of lower / upper limit of this item, ζ_i is changed to the specified value of this item (Clipping). That is, the limit ζ_i is set between the value of the minimum and the maximum specified by this system. Such a proper process as in the above is definitely important to be operated for realizing the convergence to Reference SRS.

The standard value which is proper for the set value of this item is as follows when the number of Component Waveform Skip is specified as the default value ;

CEDS : minimum 20 %, maximum 40 %

ZERD : minimum 30 %, maximum 60 %

8.2.3.8.2.1.6 Min. / Max. Number of Periods

(1) Meaning

This item is inputted only when 'WAVSYN' is selected as Synthesized Waveform Type. The range of Number of Periods given to each Component Waveform is specified by setting of the minimum and the maximum values for auto-setting of this item. The meaning of Number of Periods corresponds to Damping Ratio in 'CEDS' and 'ZERD'. Note that the large number of periods corresponds to the small Damping Ratio. This item has an important meaning for the convergence of SRS because it is also gives the effect of Clipping at auto-setting as same as that described in the above.

8.2.3.8.2.1.7 Component Waveform Duration

(1) Meaning

The time before the sufficient damping executed by each Component Waveform, that is, the valid length of Component Waveform in the meaning of actual effect is called as Component Waveform Duration.

This item is for setting of a common duration to each Component Waveform at auto-setting of Component Waveform. According to the set value in this item, Damping Ratio (CEDS, ZERD) or Number of Periods (WAVSYN) to realize the setting of this item is automatically set corresponding to the frequency of each Component Waveform by this system.

8.2.3.8.2.1.8 Initial Delay

(1) Meaning

This item is for setting of a common delay time given to all the Component Waveforms. The setting value of this item has the function that shifts the time origin of Synthesized Waveform (from the beginning edge of frame time).

8.2.3.8.2.1.9 Delay Increment

(1) Meaning

This system has the function of giving the delay time as the function of frequency which is set to each Component Waveform. And this item is for setting of increment as a coefficient of the function. The unit of this item is [ms/octave] including the increment of delay for 1 octave of frequency ratio.

The setting range of this item is influenced by the set value if Initial Delay in the above. For example, when the value other than zero is given as Initial Delay, the value of this item can be specified as a negative value (the delay decreasing according to the logarithm of frequency).

The meaning of setting the other value than zero to this item can be found when some actual process is simulated (such as a platform having a construction in which the response is generated from the lower frequency range) or when the interference between the Component Waveform as stated in 8.2.3.8.2.1.4 is needed to be avoided (for example, when the acceleration of excitation system is limited).

8.2.3.8.3 Manual input of each Component Waveform

Component Waveform is defined in manual by the procedures as below ;

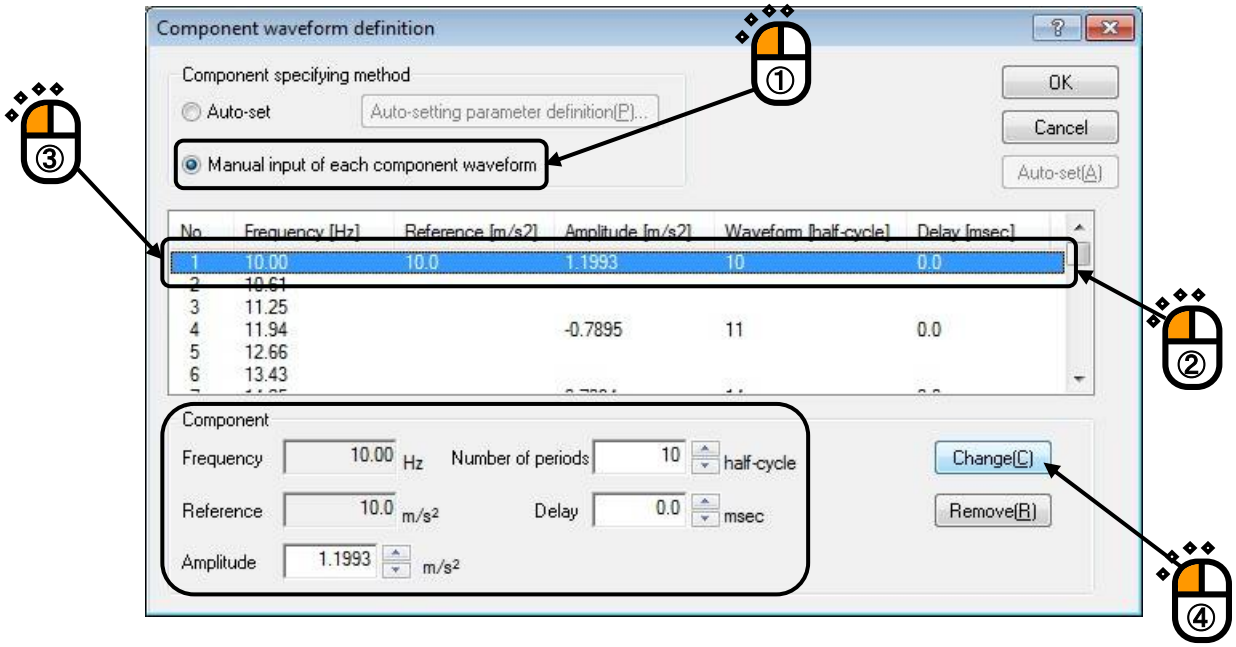
① Select the item of 'Manual input of each Component Waveform' in the dialog of Component Waveform Definition.

② Select a frequency to be set for Component Waveform among the frequency list.

③ Input the value of Amplitude and Damping Ratio that required to set the Component Waveform.

④ Press the [Change] button.

The setting of components is needed to be set for each frequency required.

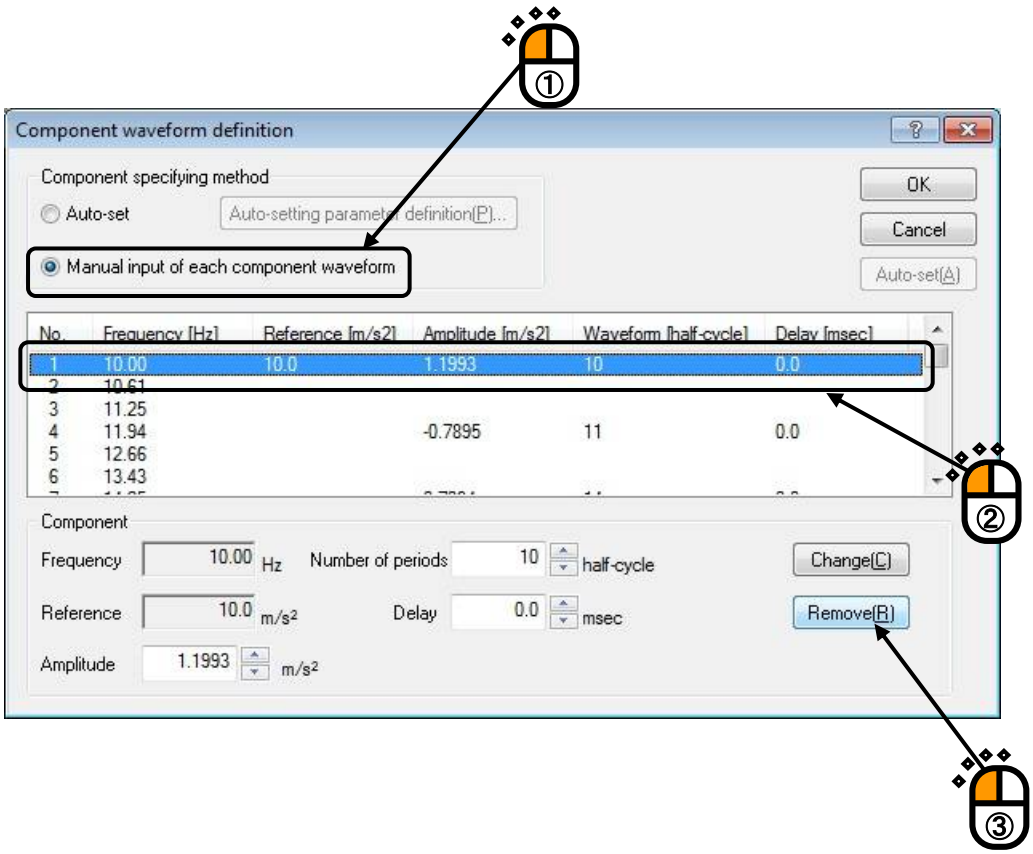


The defined components can be deleted by the procedures as below ;

① Select the item of 'Manual input of each Component Waveform' in the dialog of Component Waveform Definition.

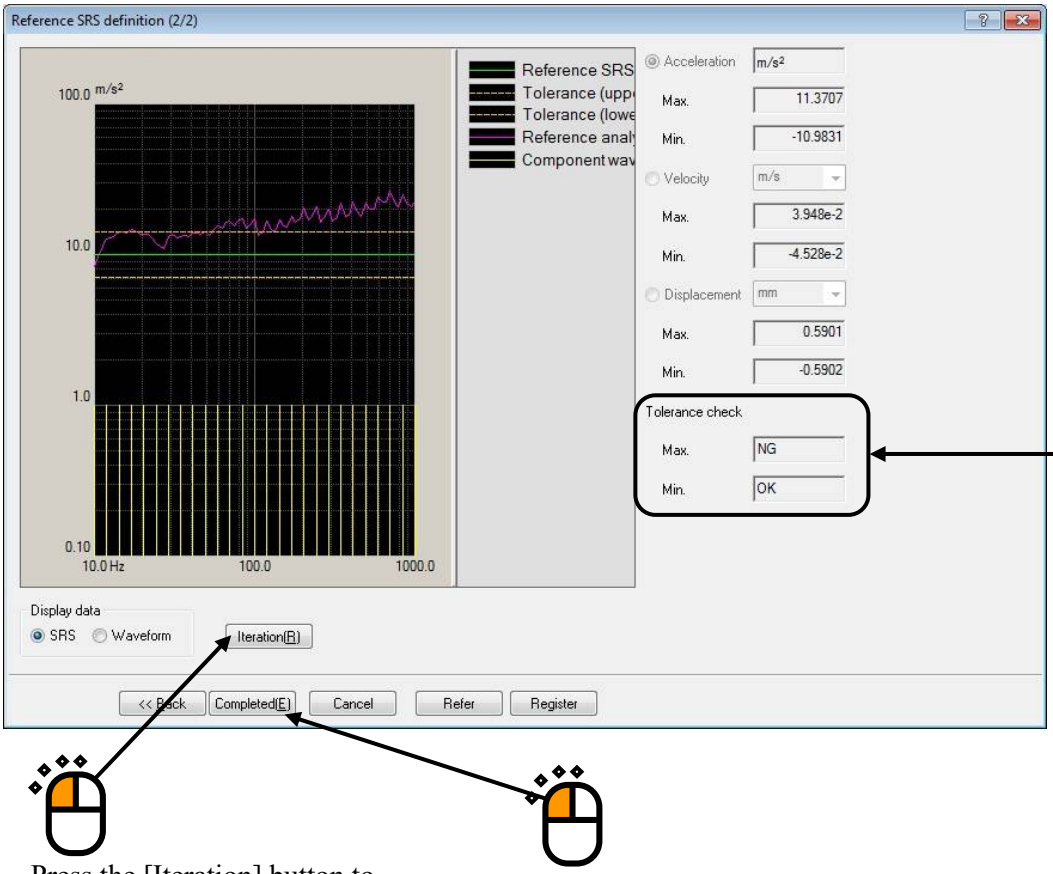
② Select a frequency to be set for Component Waveform among the frequency list.

③ Press the [Remove] button.



8.2.4 Operation of SRS Fitting Calculation

After completing the definitions of SRS Analysis, Reference SRS Condition and Waveform Synthesizing Condition, the assuring display of Reference SRS appears by pressing the [Reference SRS definition 2/2] tab. In this display, the matching of the result of SRS calculation from the specified parameter is shown.



Press the [Iteration] button to execute the repetitive operation of SRS Fitting Calculation.

The definition of Reference SRS is completed by pressing the

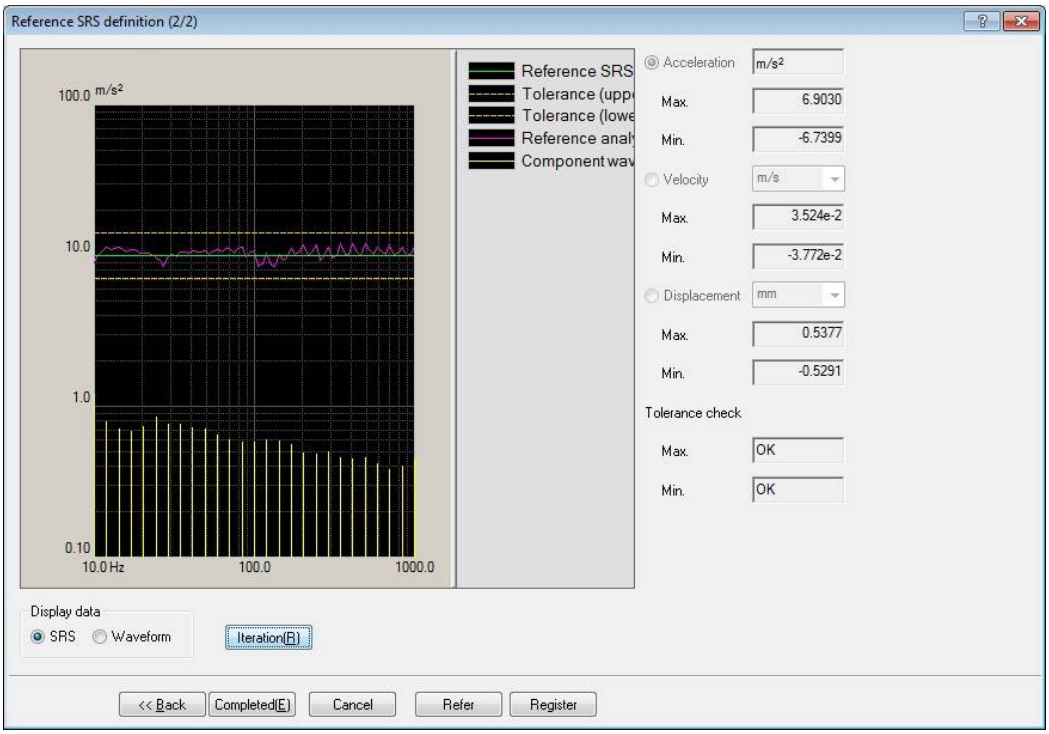
The result of the Tolerance Check for Reference Analysis SRS is displayed.

This graph is a result of the first processing. In this example, the synthesized waveform SRS is exceeding over the Tolerance band in the lower frequency range specially.

In this state, the calculation of Iteration process is executed.

When Iteration is to be executed, press the [Iteration] button in the assuring display of Reference SRS.

In the graph as below, the result if Iteration executed for some times is shown. In this example, the synthesized waveform SRS exists within the Tolerance in all ranges.



It cannot be assured that convergence will be realized in all the cases. However, Iteration Process in very effective for 1 ~ 2 times of operation.

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