

Portable FFT Analyzer Model CF-7200

Damping factor measurement to use the Hilbert transform

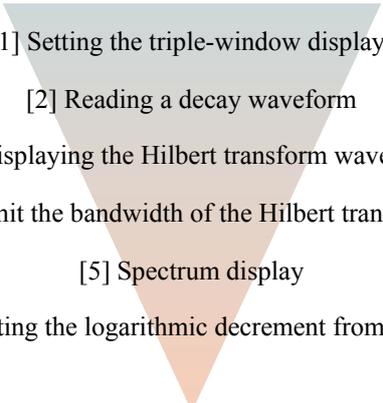
You can obtain the damping factor (ζ) of a system using the Hilbert transform. This document describes the operating procedure using the case of obtaining the damping factor from a free decay waveform recorded, as an example.

If you are to use the decay waveform that has been just measured, proceed to Step 3 of the operating procedure with the attenuation waveform displayed on the screen.

Here, the measurement procedure to obtain a decay waveform as well as how to apply an exponential window when the decay time is long is not described in this document.

[] stands for software key operation, and “ ” stands for button operation on the operation panel.. In the sentences, "Key" is a soft key, and "Button" is the button on the operation panel. Note that the operation to press the 'OK' or 'CLOSE' button after setting some parameter is omitted here.

■ Operation Flow

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- [1] Setting the triple-window display.
 - [2] Reading a decay waveform
 - [3] Displaying the Hilbert transform waveform
 - [4] Setting to limit the bandwidth of the Hilbert transform waveform
 - [5] Spectrum display
 - [6] Manually calculating the logarithmic decrement from the decay waveform

■ Operation Procedure

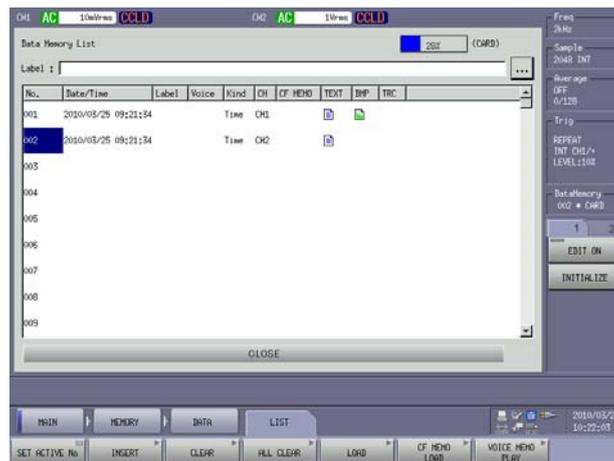
1. Setting the triple-window display.

Select in the order below: [MAIN]> [DISPLAY]>[FORMAT]>[TYPE]>[TRIPLE] to turn it on.
The triple window display will be shown.

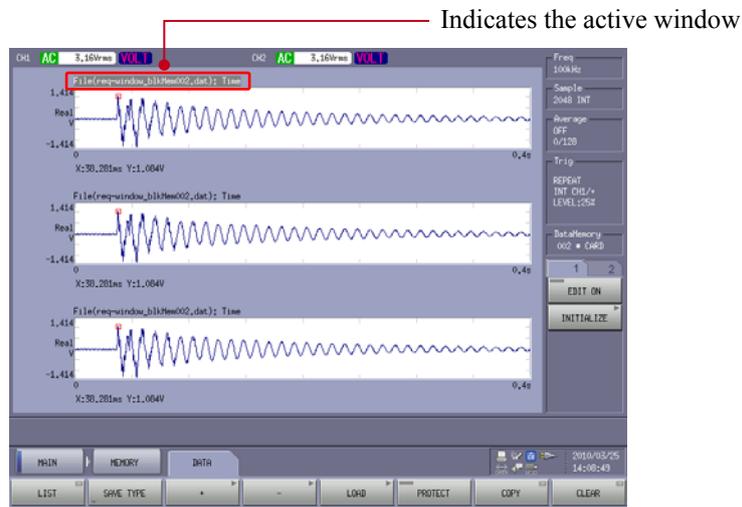


2. Reading a decay waveform

- 1. Select in the order below: [MAIN]>[MEMORY]>[DATA]>[LIST]. The list of data records appears.
- 2. Select the decay waveform to be used from the list and press the [LOAD] key. The decay waveform selected will be reproduced on the active window.



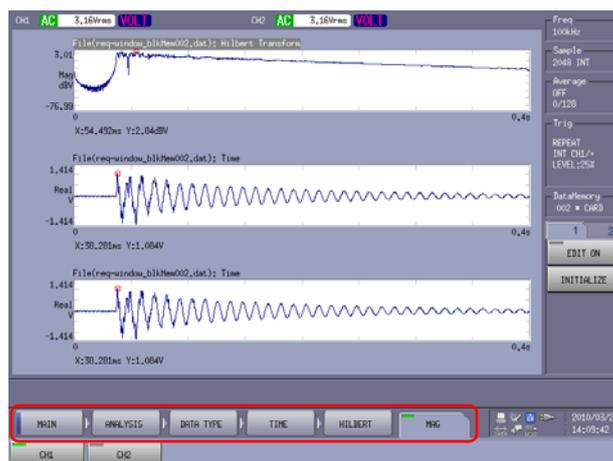
- 3. Switch the active window one by one to display the same decay waveform on all of the three windows. Touching inside the window area makes the window active to show the title in white characters against black background.



3. Displaying the Hilbert transform waveform

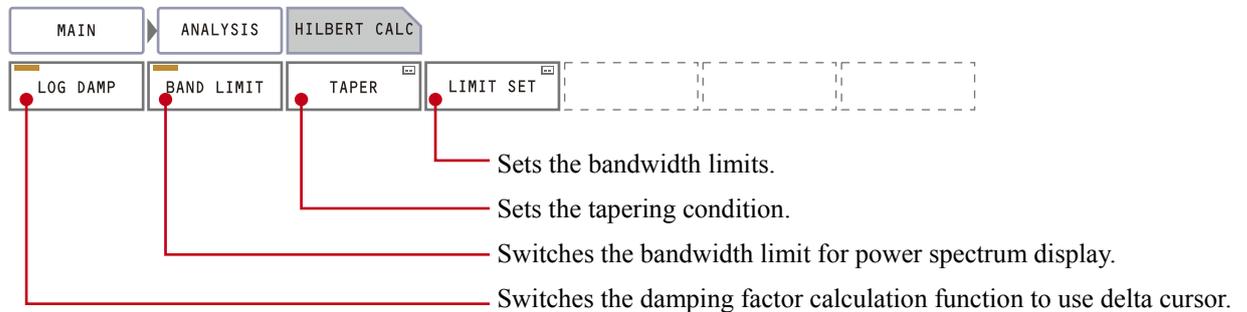
- 1. Touch inside the top window to make it active.
- 2. Select in the order below: [MAIN]>[ANALYSIS]>[DATA TYPE]>[TIME]>[HILBERT]>[MAG]. The Hilbert waveform will appear.

Note that the [CH 1] and [CH 2] keys will appear in the bottom of the screen. However, be careful not to press these keys because pressing the key will display the CH 1 or CH 2 input data.



4. Setting to limit the bandwidth of the Hilbert transform waveform

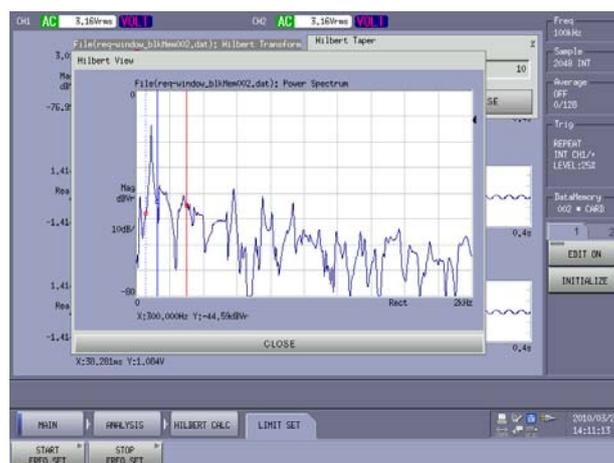
You can limit the frequency bandwidth of the Hilbert transform waveform. For this, the following keys are used:



- 1. Select in the order below: [MAIN]>[ANALYSIS]>[HILBERT CALC]>[LIMIT SET]. The "Hilbert View" window will open.
- 2. Set the upper and lower limit frequencies. Determine and set the upper and lower limit frequencies to include the peak frequency of interest (i.e., resonance frequency) in the selected frequency band, by viewing the spectrum in the "Hilbert View" window.

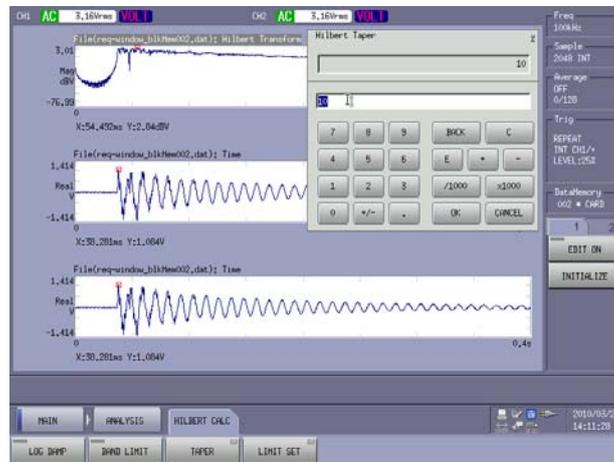
First, set the cursor on the lower limit frequency and press the [START FREQ] key to fix the position. A blue dotted line will appear. Next, set the cursor on the upper limit frequency and press the [STOP FREQ] key to fix the position. A blue solid line will appear. As the blue line will be overlapped with the red search line, click on a different position to shift the red search line to check it.

In Step 5 below, the Hilbert waveform of which bandwidth is limited by the upper and lower limit frequencies will be displayed. By viewing the waveform, the upper and lower limit frequencies are to be adjusted to make the Hilbert waveform as straight line as possible.



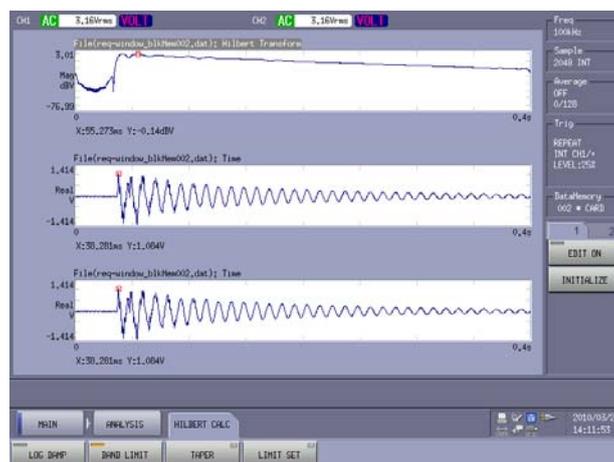
- 3. Close the "Hilbert View" window.

- 4. Set the tapering of the bandwidth limiting characteristic. Select in the order below: [MAIN]>[ANALYSIS]>[HILBERT CALC]>[TAPER]. In the "Hilbert Taper" dialog box displayed, use the keypad to enter 10% as a guideline for the tapering.



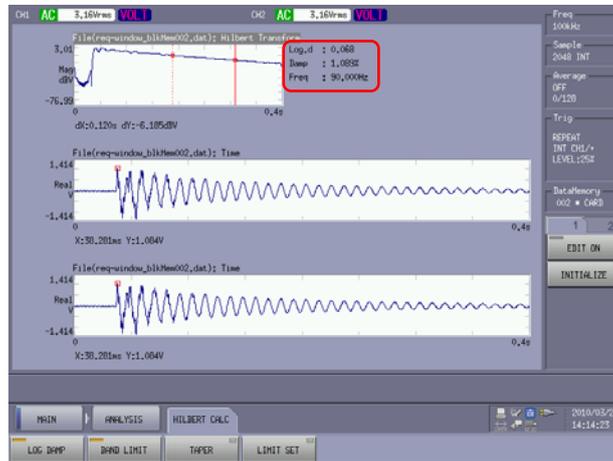
The tapering is used to gradually cut-off the frequency response from the upper and lower limit frequencies, instead of cutting off sharply. The greater the tapering value (%), the more gradual the slope. Adjust the tapering value to make the Hilbert waveform as straight as possible.

- 5. To enable the band limiting function, select in the order below: [MAIN]>[ANALYSIS]>[HILBERT CALC]>[BAND LIMIT]. This operation enables the band limiting function, and the Hilbert waveform will be displayed in the bandwidth limited form. When the [BAND LIMIT] key is turned on, any parameter change made in the above Step 3 or Step 4 will immediately be reflected to the Hilbert waveform. Pressing the [BAND LIMIT] key again will turn it off, and the bandwidth limitation will be removed.

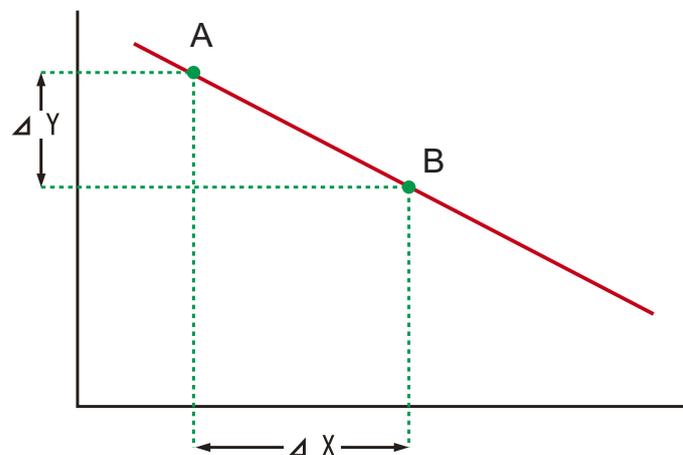


- 6. To obtain the damping factor, place two points A and B on the Hilbert waveform by referring to the supplement "How to calculate logarithmic decrement" shown below. Turn on the 'SEARCH' button, place the cursor at a freely selected Point A, and press the 'ΔSET' button. The point will be shown by a dotted red line. Then, only place the cursor on Point B, and do not press the 'ΔSET' button. The dotted red line is at Point A, and the solid red line at Point B. Select the points A and B such that the section between points A and B is as straight line as possible. If the positions are to be changed, repeat the above steps.

- 7. To calculate the damping factor, select in the order below: [MAIN]>[ANALYSIS]>[HILBERT CALC]>[LOG DAMP]. The calculation results (i.e., the damping factor, ζ (Damp) and resonant frequency (Freq)) will be shown on the right side of the window. If the points A and/or B are changed in the previous Step 6, the damping factor will be recalculated and displayed. Pressing the [LOG DAMP] key again disables the damping factor calculation function.



(Supplement) How to calculate logarithmic decrement



$$\text{Logarithmic decrement (log.D): } \delta = \left| \frac{\Delta Y(\text{dB})}{\Delta X} \right| * \frac{\ln 10}{20} * \frac{1}{f_n} = 0.1151 * \left| \frac{\Delta Y}{\Delta X} \right| * \frac{1}{f_n}$$

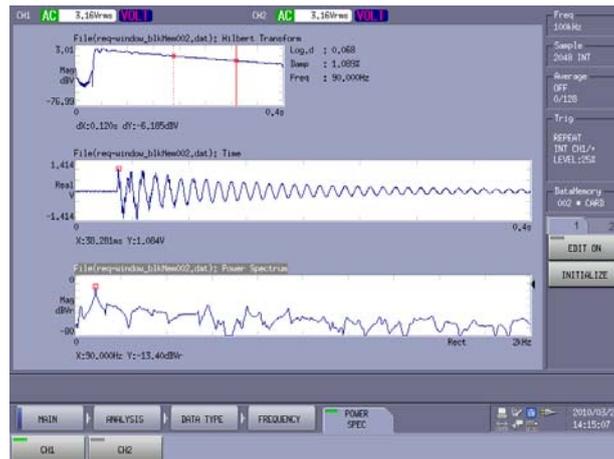
$$\text{Damping factor (Damp): } \zeta = \frac{\delta}{2\pi} = 0.01832 * \left| \frac{\Delta Y}{\Delta X} \right| * \frac{1}{f_n}$$

Here, f_n : Resonant frequency, ΔX , ΔY : XY coordinates of the two points set by the delta cursor.

5. Spectrum display

- 1. Touch inside the bottom window to make it active.
- 2. Select in the order below: [MAIN]>[ANALYSIS]>[DATA TYPE]>[FREQUENCY]>[POWER SPECT]. The window now shows the spectrum.

Note that the [CH 1] and [CH 2] keys will appear in the bottom of the screen. However, be careful not to press these keys because pressing the key will display the CH 1 or CH 2 input data.

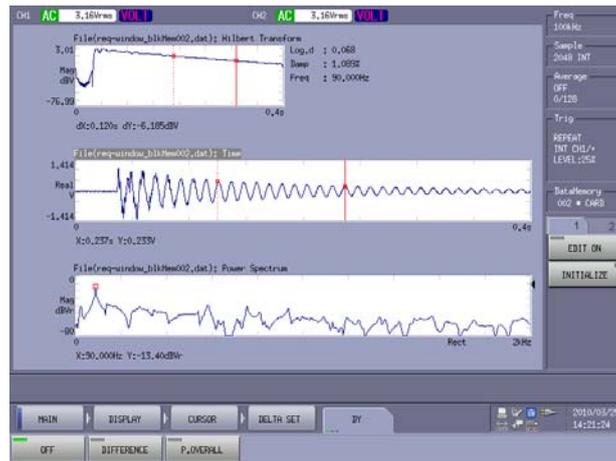


6. Manually calculating the logarithmic decrement from the decay waveform

- 1. Select in the order below: [MAIN]>[DISPLAY]>[CURSOR]>[ALL SET] to turn off the [ALL SET] key. This operation enables independent operation of the cursors between the top, center, and bottom windows. When the [ALL SET] key is turned on, it returns to the linked cursor operation.
- 2. Touch inside the middle window to make it active.
- 3. Press the 'SEARCH' button to turn it off, and then turn it on again to change the mode from the delta cursor mode to the search cursor mode. Move the cursor to a freely selected peak point, and read the value Y1.
- 4. Move the cursor to the 10th peak to the right from the position selected in Step 3, and read the value Y2. For the number of peaks shifted m (in this case, m = 10), the logarithmic decrement δ can be calculated from the equation below.

For example, if the values read are Y1= 0.456, Y2=0.233, and m = 10, the resulting damping factor is 0.067, which is nearly equal to the value calculated using the Hilbert transform function.

$$\delta = \frac{1}{m} * \ln \frac{Y_1}{Y_2} = \frac{1}{10} * \ln \frac{0.456}{0.233} = 0.067$$



If the Hilbert waveform does not properly form a straight line, the resulting values will be different depending on the positions A and B on the waveform. You should carefully perform the measurement as hitting the target object very hard can produce distortion in the decay waveform, and the amplitude of the decay waveform can change during the decay period.

While the definition of the logarithmic decrement is for the purpose of explanation in Step 6, you should place the positions A and B properly in such a way that the section between these points is fairly linear.

-End-
(2015/04/20)