HIOKI

4

ANALYSIS SUPPLEMENT

8860
8861
MEMORY HiCORDER

Using analysis functions to analyze measurement data

HIOKI E. E. CORPORATION

Contents

Introduction

In this manual, “the instrument” means the Model 8860 or 8861 Memory HiCorder. The following documents are provided with this instrument. Refer to them as appropriate for your application.

Document	Description
1 **Quick Start Manual**	**Read this first.** It describes preparations for use, basic operating procedures and usage methods.
2 **Input Module Guide**	**To connect input modules and measurement cables, and when making input channel settings;** this Guide describes the optional input modules, related cable connection procedures, and their settings and specifications.
3 **Instruction Manual**	**To obtain setting details;** this Manual describes details of the functions and operations of the instrument, and its specifications.
4 **Analysis Supplement** (This document)	**The supplement describes usage of the calculation functions to analyze measurement data.**

Before Use

Be sure to read the safety precautions in the *Quick Start Manual.*
Also read the precautions regarding input modules and connection cables in the chapter about connections in the *Input Module Guide*.

Registered trademarks
Windows is a registered trademark of Microsoft Corporation in the United States and/or other countries.

Symbols and Indicators in This Manual

The following symbols in this manual indicate the relative importance of cautions and warnings.

NOTE	Indicates advisory items related to performance or correct operation of the instrument.

Other Indicators

(⇒ p.)	Indicates the location of reference information.
*****	Indicates that descriptive information is provided below.
A→B	Indicates an operation sequence.
[ ]	Screen labels such as menu items, page titles, setting items, dialog titles and buttons are indicated by square brackets [ ].
CURSOR (Bold characters)	Bold characters within the text indicate operating key labels.

Accuracy

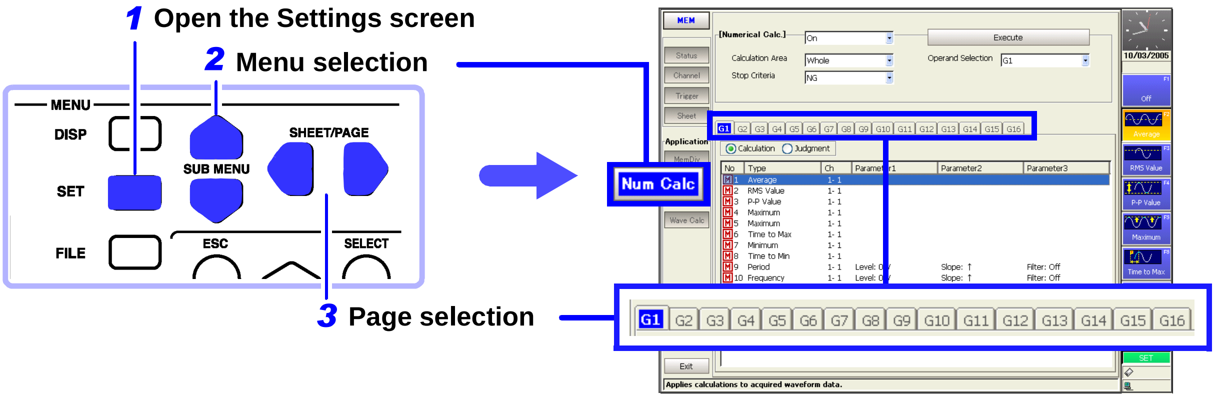
We define measurement tolerances in terms of f.s. (full scale) values, with the following meanings:
f.s. : maximum display value or scale length

In this instrument, the maximum displayable value is the range (V/div) times the number of divisions (20) on the vertical axis.
Example: For the 1 V/div range, f.s. = 20 V

Numerical Calculation Functions

Chapter 1

Numerical calculations can only be used with the Memory function.
Results calculated from the acquired waveform are displayed as numerical values on the Waveform screen.
Judgments can also be made based on calculation results.
Numerical calculation settings are made on the Numerical Calculations Setting screen (Num Calc).



Numerical Calculation Function Capabilities (Numerical Calculation Screen)

Numerical Calculations

- Average value
- RMS value
- Peak-to-Peak (p-p) value
- Maximum value
- Time to maximum value
- Minimum value
- Time to minimum value
- Period
- Frequency
- Rise time
- Fall time
- Standard Deviation
- Area value
- X-Y Area value
- Time to specified level
- Pulse width
- Duty (%)
- Pulse count
- Numerical results of four standard arithmetic operators

(Total 19 types)

- Specified calculation between A/B cursors

Numerical calculations are available in the range specified by A/B cursors

Details of calculation expressions: "1.6 Numerical Value Calculation Expressions" (⇒ p. 19)

Judgments based on Numerical Calculation (⇒ p. 11)

Results of numerical calculations can be compared with a specified range for GO/NG judgments.

Saving and Printing Numerical Calculation Results

- Automatic saving of numerical calculation results
- Manual saving of existing numerical calculation results

See "1.4 Saving Numerical Calculation Results" (⇒ p. 14) in this manual, "Chapter 10 Saving/Loading Data & Managing Files" in the *Instruction Manual*

- Automatic printing
- Manual printing

See "Chapter 11 Printing" in the *Instruction Manual*

Of the nineteen types of numerical calculation available, sixteen types can be applied at the same time.
Up to sixteen groups composed of multiple calculation types (operations) can be defined, with up to sixteen types of calculation per group. By setting up such groups of multiple calculations beforehand, they can be readily selected at calculation time.

See "1.6 Numerical Value Calculation Expressions" (⇒ p. 19)

When Scaling is enabled, numerical calculations are performed on scaled values.
Numerical calculation is also available when Memory Division is enabled.

1.1 Numerical Value Calculation Workflow

Before Setting

When specifying a waveform range for calculation: [A-B]

Before executing a calculation, specify the calculation range using the A/B cursors (Vertical or Trace cursors) on the Waveform screen. Set the calculation range on the Num Calc Settings screen to [A-B].

- Horizontal cursors cannot be used to specify the range.
- When one cursor is used, the calculation range is from the cursor to the end of the data.

See "8.7 Specifying a Waveform Range" in the *Instruction Manual*
"1.2 Settings for Numerical Value Calculation" (⇒ p. 6)

To change calculation settings and recalculate

You can make changes to calculation settings and resume calculations from the Waveform screen.

See "To recalculate after changing calculation type settings" (⇒ p. 9)

The following two calculation methods are available:

- Calculate while measuring
  Requires making numerical calculation settings beforehand.
- Apply calculations to existing data
  Calculations can be applied to data after waveforms are acquired, or after data has been saved to storage media.

Calculating While Measuring

Make Calculation Settings ↓

Make calculation settings on the Numerical Calculation Settings screen (⇒ p. 6).
When judging based on calculation results: (⇒ p. 11)
To automatically print or save calculation results: make printing and saving settings before measuring.

- Printing calculation results automatically
  ([Printer] page on the Print Settings screen: Calculation Results [On])

See "11.3 Making Auto Print Settings" in the *Instruction Manual*

- Saving calculation results automatically
  ([Auto Save] page on the Save Settings screen: Auto Save [On], Calculation Results [On])

See "1.4.1 Automatically Saving Numerical Calculation Results" (⇒ p. 14)

Start Measurement ↓

Acquire Data ↓

The instrument acquires data when the trigger criteria are met.
(If triggering is not enabled, the instrument acquires data when you press the **START** key.)

Calculate ↓

“Calculating” appears on the screen’s status bar.
Calculations are performed sequentially from No. 1 to No. 16.
(To interrupt calculations, press the **STOP** key to abort)

Display Calculation Results ↓

Results are displayed on the Waveform screen (⇒ p. 9).

(Calculation Judgments) ↓

(only if judgments are enabled)

(Print or Save) ↓

(if auto printing or auto saving are enabled)
Calculation results are automatically printed or saved.

Stop Measurement

Applying Calculations to Existing Data

(Load the Data) ↓

(To load measurement data from storage media for calculation)
See "10.4 Loading Data" in the *Instruction Manual*

Make Calculation Settings ↓

Make calculation settings on the Numerical Calculation Settings screen (⇒ p. 6).
When judging based on calculation results: (⇒ p. 11)

Execute Calculation ↓

Press the [Execute] button to execute calculations.
(To interrupt calculations, press the **STOP** key)

Display Calculation Results ↓

Results are displayed on the Waveform screen (⇒ p. 9).

(Calculation Judgments) ↓

(only if judgments are enabled)

(Print or Save)

Print or save calculation results as occasion demands.

- Print: **PRINT** key
- Save: **SAVE** key

See "11.4 Making Manual Print (PRINT Key Output) Settings" in the *Instruction Manual*
"1.4.2 Optionally Selecting Numerical Calculation Results & Saving (SAVE Key)" (⇒ p. 15)

1.2 Settings for Numerical Value Calculation

Numerical Calculations

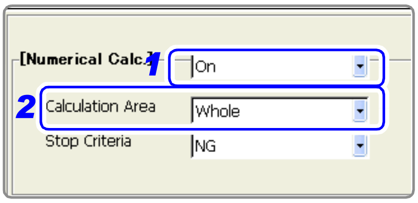
MEM

To open the screen: Press the **SET** key → Select **Num Calc** with the **SUB MENU** keys →Num Calc Settings screen

Operating Key	Procedure

1 Enable the Numerical Calculation function.

CURSOR	Move the cursor to the [Numerical Calc.] item.
F2	Select [On].



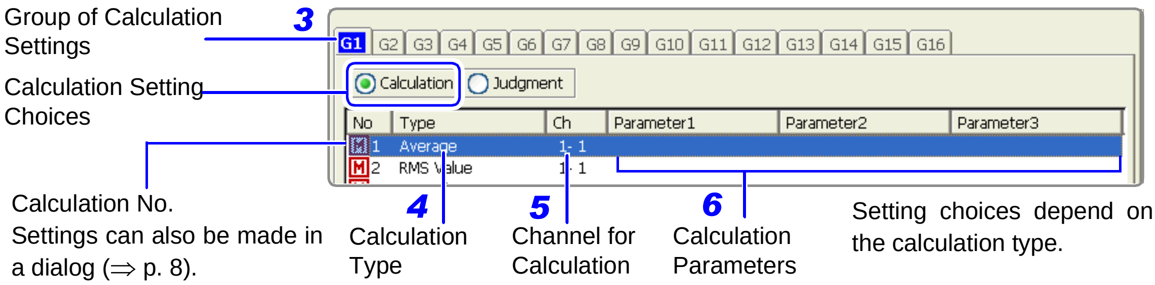
2 Specify the numerical calculation range.

CURSOR	Move the cursor to the [Calculation Area] item.
F1 to F8	Select either choice.

Whole	Applies calculations to the whole waveform. (default setting)
A-B	Applies calculations to the data between A/B cursors.

When selecting [A-B], specify the calculation range using the A/B cursors on the Waveform screen.
If no measurement data has been acquired by the instrument, first measure once so that the range can be specified for calculations to be applied to subsequent measurements.

3 Perform calculation settings.



SHEET/PAGE	Select the group for which to set calculations. (G1 to G16)
CURSOR **F1**	Move the cursor to your setting choice, and select [Calculation].

Also select [Judgment] if you require judgment of calculation results. (⇒ p. 11)

4 Select the Calculation type.

CURSOR	Move the cursor to the [Type] column of the No. row of the calculation to set.
F1 to F8 **(Switch Display: F8)**	Select the calculation type.

Off	No calculation. (default setting)
Average	Average value of waveform data
RMS Value	RMS value of waveform data
P-P Value	Peak-to-peak value of waveform data
Maximum	Maximum value of waveform data
Time to Max	Time from trigger to maximum value
Minimum	Minimum value of waveform data
Time to Min	Time from trigger to minimum value
Period	Period of signal waveform
Frequency	Frequency of signal waveform

Operating Key	Procedure	
F1 to F8 (Switch Display: F8)	**Rise Time**	Rise time of waveform data
	Fall Time	Fall time of waveform data
	Std Deviation	Standard deviation of waveform data
	Area	Area enclosed by zero position and signal waveform
	X-Y Area	Area of X-Y composite waveform
	Time to Level*	Time from trigger to specified level
	Pulse Width*	Pulse width of waveform data
	Duty*	Duty of waveform data
	Pulse Count*	Pulse count of waveform data
	4 Operations	Four arithmetic operations on numerical calculation results

* Applicable to logic channels

5 **Select the channel for calculations.**

CURSOR Move the cursor to the [Ch] item.

F1 to F8 Select a channel for calculations.
The waveform calculations (Zn) can be selected.

6 **Set parameters.**

(not required for some calculation types)

CURSOR Move the cursor to the [Parameter] item.

F1 to F8 Make appropriate parameter settings.
About setting choices (⇒ p. 19)
See "3.3.3 Entering Text and Numbers" in the *Instruction Manual*

7 **Select a calculation group.**

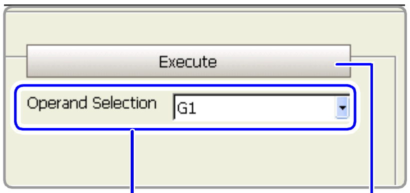
CURSOR Move the cursor to the [Operand Selection] item.

F1 to F8 Select a calculation group.

Execute the calculations.
(when judging calculations (⇒ p. 12))

To print or save calculation results while measuring
Before measuring, enable Auto Save (⇒ p. 14) or Auto Print. Enable [Calc Results] on the Save Settings or Print Settings screen.
See "10.3.4 Setting Auto Save",
"11.3 Making Auto Print Settings"
in the *Instruction Manual*

To print or save existing data
Press the PRINT or SAVE key (⇒ p. 15).
Manual Print Settings
Manual Save Settings
See "11.4 Making Manual Print (PRINT Key Output) Settings",
"10.3.5 Setting Manual Save (SAVE Key Output)" in the *Instruction Manual*



7 [Execute] button

Execute calculation of the displayed group.

Changes made to calculation settings while measuring do not take effect until measurement has been stopped and restarted.

Applying Calculations to Existing Data

CURSOR Move the cursor to the [Execute] button.

F1 Select [Execute].

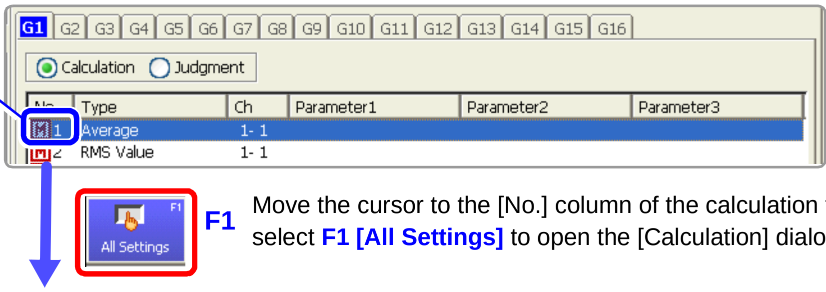
When calculating automatically after measurement

START Starts measurement.

Making settings in the [Calculation] dialog

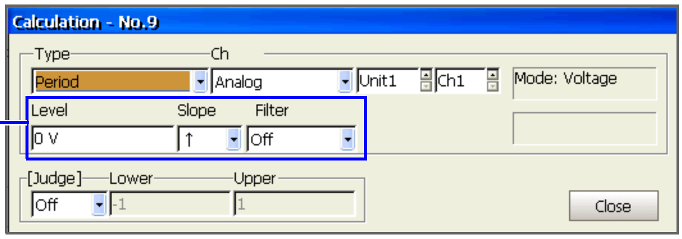
Calculation Marker
Markers are displayed next to the calculation No. of enabled calculations.

To copy settings between calculation Nos.:
Select F2 [Copy]. (⇒ p. 10)



F1 Move the cursor to the [No.] column of the calculation to set, and select **F1 [All Settings]** to open the [Calculation] dialog.

Parameter Settings
(Displayed as required for the selected calculation type)



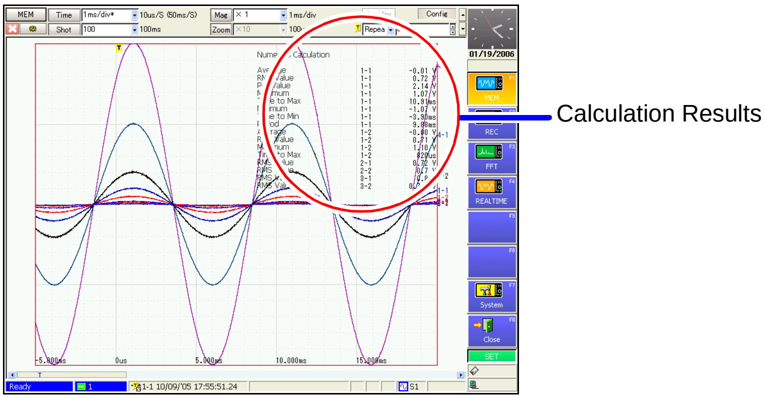
Move the cursor to each item, and make the setting.

See Parameter setting: "1.6 Numerical Value Calculation Expressions" (⇒ p. 19)

After making the appropriate settings, press the **ENTER** key or move the cursor to the **[Close]** button and press the **F1 [Close]** key to accept your settings.

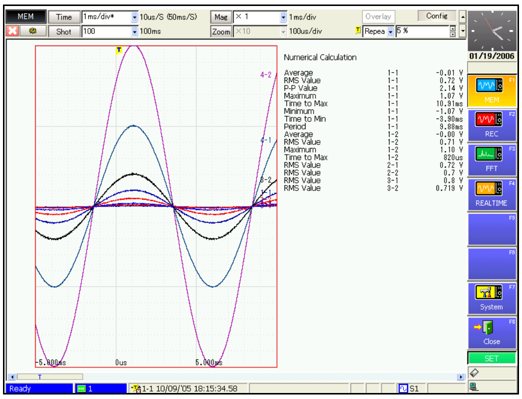
Numerical Calculation Results

Numerical calculation results are displayed on the Waveform screen.



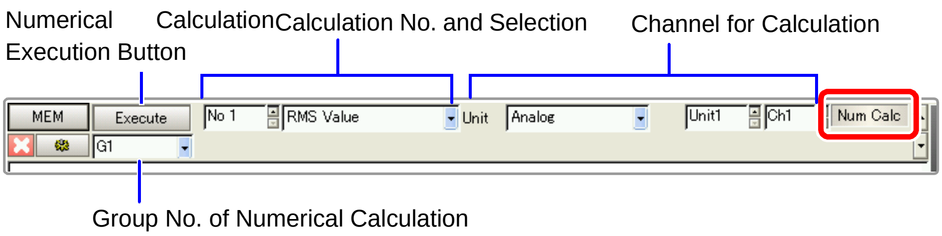
If the display is hard to view because of overlapping numerical values and waveforms

Press the **DISP** key.
Numerical values and waveforms are displayed separately.



To recalculate after changing calculation type settings

Select your choices for the calculation setting items on the Waveform screen, and execute calculation.
Press the **SUB MENU** keys to switch to the [Num Calc] settings.



Select a Group No. for calculation or change your choices, and select the **[Execute]** button.
All calculations specified for the selected Group No. are performed.

To save or print calculation results after measuring

When Selection Save (default setting) is enabled, press the **SAVE** key and select [Calc Results] for the Save Type.
When Selection Print (default setting) is enabled, press the **PRINT** key and select **F6 [Calc Results]**.

Copying Settings Between Calculation Nos. MEM

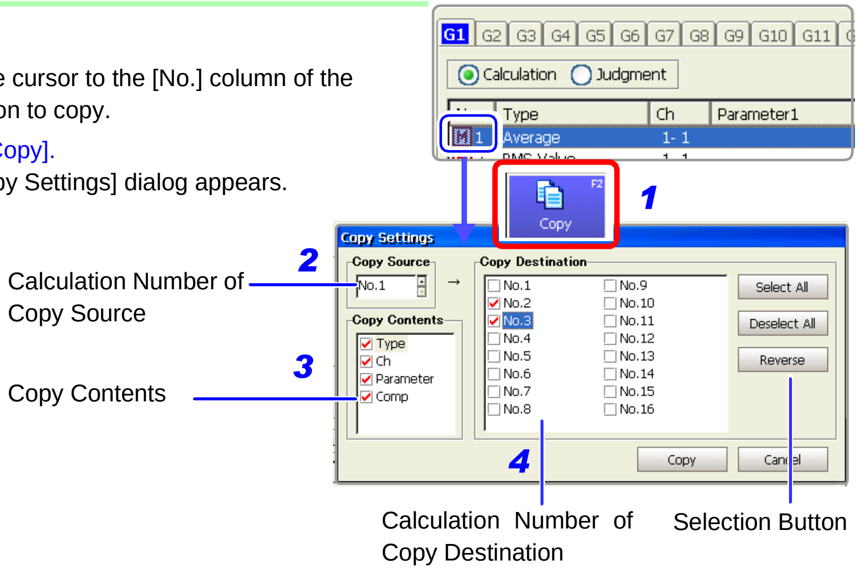
To open the screen: Press the **SET** key → Select **Num Calc** with the **SUB MENU** keys →Num Calc Settings screen

Operating Key Procedure

1 Open the dialog.

CURSOR Move the cursor to the [No.] column of the calculation to copy.

F2 Select [Copy].
The [Copy Settings] dialog appears.



2 Select the copy source.

CURSOR Move the cursor to the [Copy Source] item.

F1 to F8 Select the Calculation Number of the copy source.

3 Select the contents to copy.

CURSOR Move the cursor to the [Copy Contents] item.

F1 to F8 Select the contents to copy.

4 Select the copy destination.

CURSOR Move the cursor to the [Copy Destination] item.

F1 to F8 Select the Calculation Number of the copy destination.

5 Execute copy.

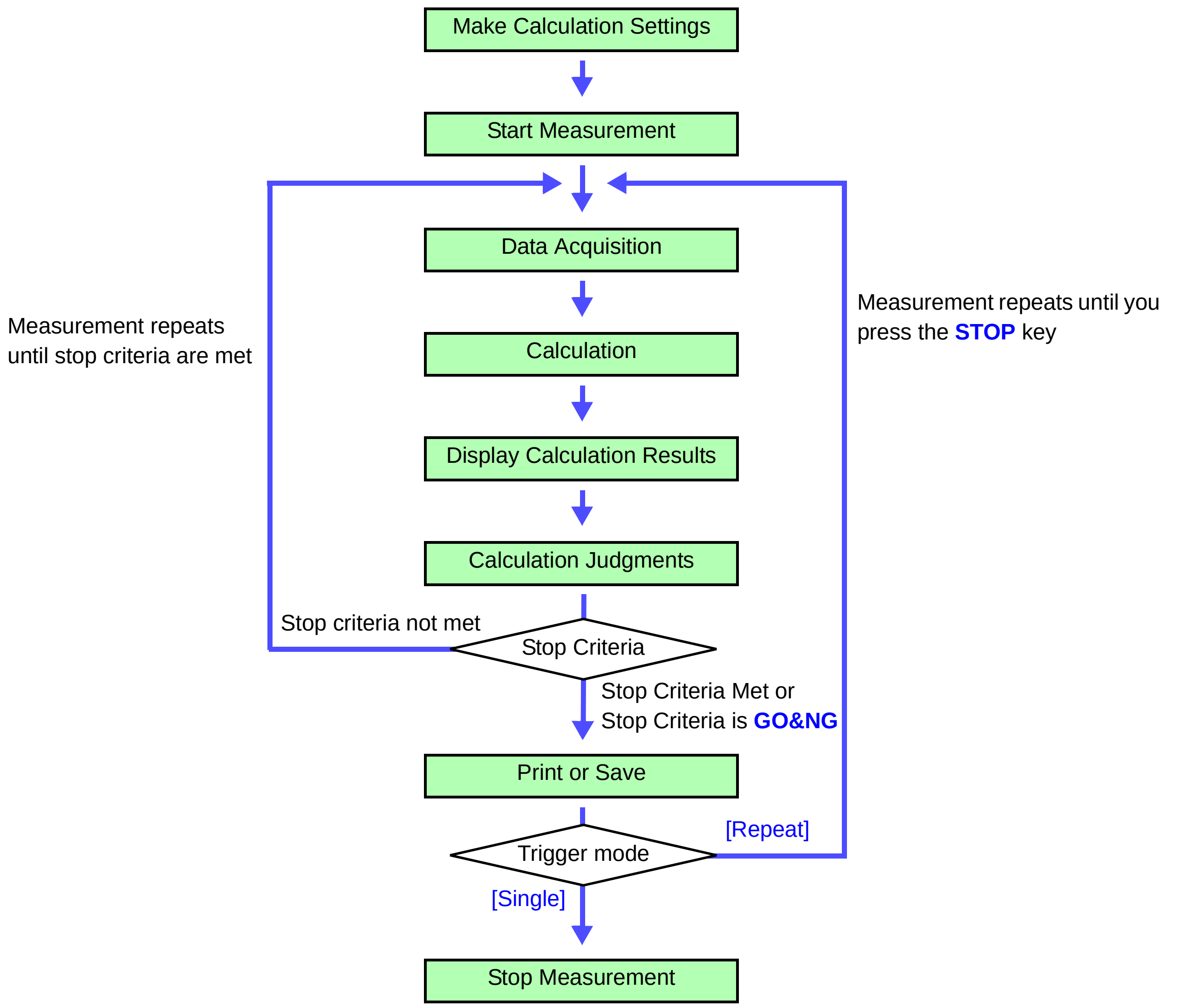
F7 Select [Copy].
The selected contents are copied.

Selections can be made using the buttons in the dialog.
Move the cursor to a button, and press the F1 key.

- Select All
  Selects all copy destinations.
- Deselect All
  Deselects all copy destinations.
- Reverse
  Reverses selected and deselected settings.
- Copy
  Executes the copy process.
- Cancel
  Cancels the copy process.

1.3 Judging Calculation Results

Set the judgment criteria (upper and lower threshold values) by which to judge numerical calculation results. Judgment criteria can be set for every numerical calculation.
Waveform acquisition processing depends on the trigger mode setting (Single or Repeat) and the criteria specified to stop measuring upon judgment (GO, NG or GO & NG).



NOTE

Judgment when memory division is enabled

When memory division is enabled, waveform data is retained in the measured block only when stop criteria are met.
When stop criteria are not met, measurement continues to repeat within the same block.

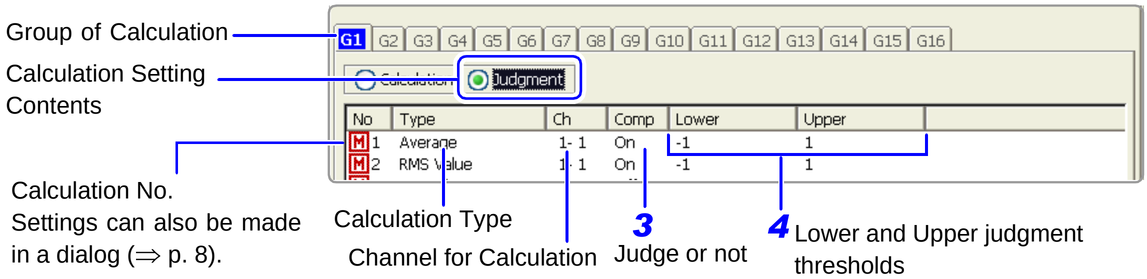
Judging Numerical Value Calculation Results **MEM**

To open the screen: Press the **SET** key → Select **Num Calc** with the **SUB MENU** keys →Num Calc Settings screen

Operating Key	Procedure

1 **Make settings for calculation (⇒ p. 6).**

2 **Select the appropriate calculation judgment settings.**



SHEET/PAGE	Select the group for which to set calculation judgment. (G1 to G16)
CURSOR **F2**	Move the cursor to your setting choice, and select [Judgment].

3 **Enable the judgment function.**

CURSOR	Move the cursor to the [Comp] setting for Calculation No. to judge
F2	Select [On].

4 **Specify the judgment thresholds.**

CURSOR	Set the [Lower] and [Upper].
F1 to F8	Select an entry method and enter the threshold values. Input range: –9.9999E+29 to 9.9999E+29

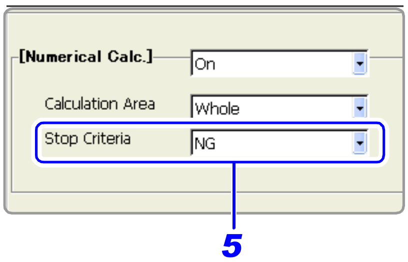
The upper threshold of the period range cannot be set below the lower threshold, and vice-versa.

See "3.3.3 Entering Text and Numbers" in the *Instruction Manual*

5 **Select the Stop Criteria upon judgment.**

CURSOR	Move the cursor to the [Stop Criteria] item.
F1 to F8	Select either choice.

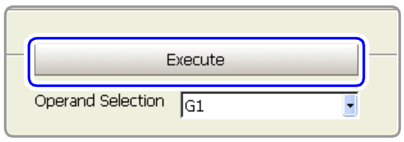
GO	Continue to the next process when within the threshold range (PASS judgment)
NG	Continue to the next process when outside of the threshold range (FAIL judgment)
GO & NG	Continue to the next process regardless of judgment result.



Execute calculation.

Judging Existing Data

CURSOR	Move the cursor to the [Execute] button.
F1	Select [Execute].



When judging automatically after measurement

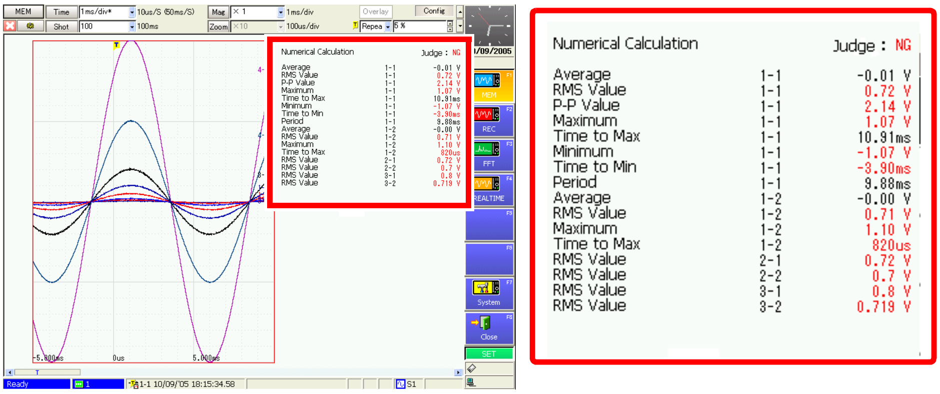
START	Starts measurement.

Processing depends on the Trigger Mode setting.
If calculating while acquiring waveforms, measurement is repeated until the Stop Criteria are met.

Description

About judgment results

Judgment results of numerical calculations are displayed on the Waveform screen.
Within the judgment threshold range: GO judgment
Out of the judgment threshold range: NG judgment (displayed in red)



When printing, judgment results for each parameter are also printed.

When performing external control

When the external I/O terminals are enabled, the signal is output from the next sampling period.

See "14.2.5 GO/ NG Evaluation Output (GO/EXT OUT1)/ (NG/EXT OUT2)" in the *Instruction Manual*

When the judgment result is GO

- The GO signal is output at the GO/EXT OUT1 external I/O terminal.

When the judgment result is NG

- The NG signal is output at the NG/EXT OUT2 external I/O terminal. The NG judgment is asserted when any channel is judged as NG.
- Channels judged as NG are indicated by an “×” in printouts.
- When the beeper is enabled, a beep sounds when a result is out of the threshold range.

1.4 Saving Numerical Calculation Results

1.4.1 Automatically Saving Numerical Calculation Results

Calculate and automatically save during data acquisition.
Before measurement begins, the calculation settings need to be set.

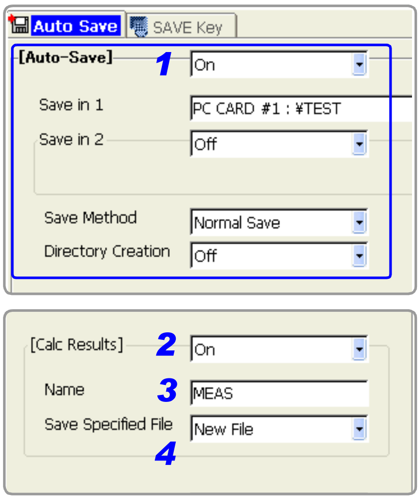
⚠CAUTION

When using auto save during measurement, do not remove the storage media specified as the save destination until the measurement operation is completely finished. Doing so may damage data on the storage media.

Automatically Saving Numerical Calculation Results **MEM**

To open the screen: Press the **SET** key → Select **Save** with the **SUB MENU** keys →Save Settings screen

[Auto Save] Page



Operating Key — Procedure

1 **Set auto save .**

Set the save destination.

See "10.3.4 Setting Auto Save" in the *Instruction Manual*

2 **Enable the saving of numerical calculation results.**

CURSOR — Move the cursor to the [Calc Results] item.
F2 — Select [On]. (Default setting: Off)

3 **Enter a save name (if you want to use a different name).**

CURSOR — Move the cursor to the [Name] item.
F1 to F8 — Enter the save name. (Default setting: MEAS)

See "3.3.3 Entering Text and Numbers" in the *Instruction Manual*

4 **Select the file creation method.**

CURSOR — Move the cursor to the [Save Specified File] item.
F1 to F8 — Select either choice.

New File	Creates a new file for each measurement.
Existing File	Adds calculation results to one file.

Confirm the measurement configuration and numerical calculation result settings, then start measurement (START key).

After the data is acquired and the numerical calculation process completes, the numerical calculation results (text) are saved automatically to the specified storage media.

Save Name

Up to 40 characters (single byte and double byte) can be used for the save name. A sequential number starting from 0001 is added after save names (if [New File] is selected).

Note that a PC will not be able to handle the following characters if they are used.

- ASCII:
  + = [ ] \ / | : * ? " < > ; ,
- White space characters

Some saved characters may differ from those used on the instrument. (⇒ p. 16)

1.4.2 Optionally Selecting Numerical Calculation Results & Saving (SAVE Key)

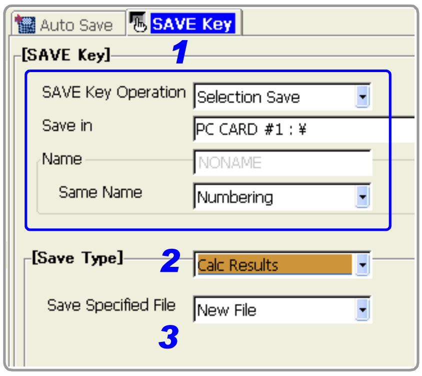
Perform calculations on data saved to storage media and internal memory and save the calculation results by pressing the **SAVE** key.
Before calculation results can be saved, the calculation settings needs to be set and the calculations need to be performed.

Manually Saving Numerical Calculation Results MEM

To open the screen: Press the **SET** key → Select **Save** with the **SUB MENU** keys →Save Settings screen

Operating Key Procedure

[SAVE Key] Page



1 Set manual save.

See "10.3.5 Setting Manual Save (SAVE Key Output)" in the *Instruction Manual*

For [Selection Save], press the **SAVE** key after setting the calculation settings and performing the calculations.
(The [Save] dialog box appears.)
Set the save destination.

2 Select the save type.

CURSOR Move the cursor to the [Save Type] item.
F4 Select [Calc Results].

3 Select the file creation method.

CURSOR Move the cursor to the [Save Specified File] of the numerical calculation result settings field.
F1 to F8 Select either choice.

New File	Creates a new file each time measurement starts (start operation).
Existing File	Adds calculation results to one file.

Some saved characters may differ from those used on the instrument (⇒ p. 16).

For [Quick Save]:

Press the SAVE key

The calculation results (text) are saved to the specified storage media upon pressing the key.

For [Selection Save]:

Select the [OK] button.

The calculation results (text) are saved to the specified storage media upon selecting the button.

1.4.3 Example of Saving Numerical Calculation Results

NOTE

If you save numerical calculation results or data in text format, characters or display items used on the instrument are converted as shown below.
(Characters used on the instrument → Saved characters)
^{2} → ^2, ^{3} → ^3 , ^{n} → ^n, µ→ ~u, Ω→ ~o, ε → ~e, ° → ~c ,
±→ ~+, µε (display only) → uE, °C (display only)→ C

Calculation No. 1: Maximum value of analog channel 1-1
Calculation No. 2: Minimum value of analog channel 1-1
Calculation No. 3: Maximum value of analog channel 1-2
Calculation No. 4: Minimum value of analog channel 1-2

```
"Trig Time","No1 Maximum A1_1","No2 Minimum A1_1","No3 Maximum A1_2","No4 Minimum A1_2"
"","V","V","V","V"
"'04-12-14 11:29:12.530",143,-143,0.0038124997,-0.0038124997
"'04-12-14 11:29:15.570",143,-143,0.0038124997,-0.0038124997
"'04-12-14 11:29:18.790",143,-142.75,0.0038749997,-0.0038124997
"'04-12-14 11:29:21.940",143.25,-143.25,0.0038124997,-0.0038124997
```

Line 1: Calculation Settings
Line 2: Calculation Result Unit
From Line 3: Calculation Results

Recorded in the order of the calculation settings of line 1.

1.5 Reading Numerical Calculation Results on a PC

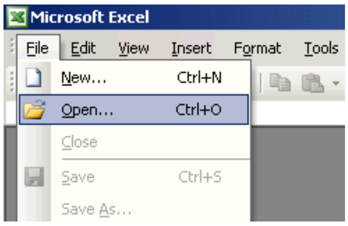
The following explains how to import data into Excel on Windows.

The capacity of Excel to import data from a text file is limited to 256 columns and 65,536 rows.

Text files containing data that exceeds these limits cannot be imported into Excel. To avoid exceeding these limits when saving text data, select [Displayed Ch] as the channels to save, or specify the saving range as that between A/B cursors.

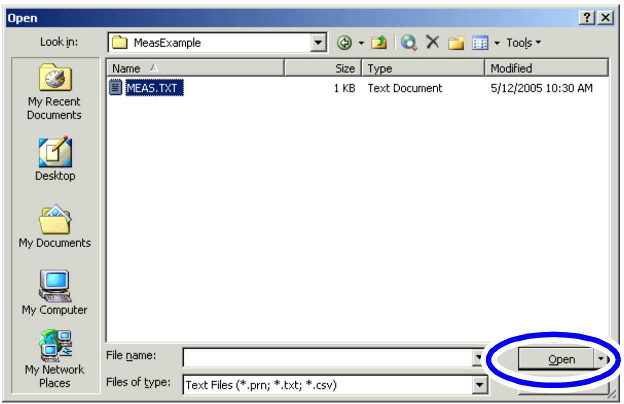
1 Start Excel and click [Open] from the [File] menu.

The [Open] dialog box appears.



2 Select the file to import.

Select the file and click [Open].



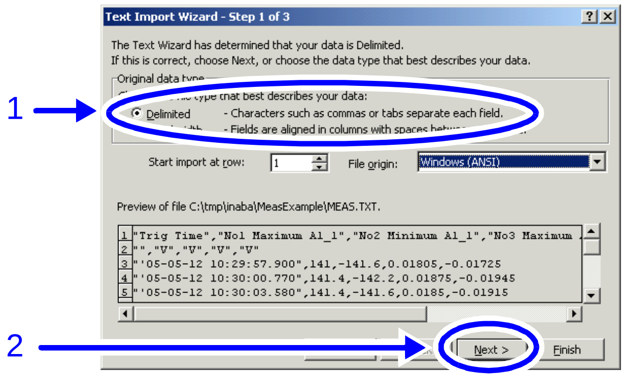
The Text Import Wizard appears.

3 Select the text processing method.

[Text Import Wizard Step 1 of 3]

1. Select [Characters such as commas or tabs separate each field].

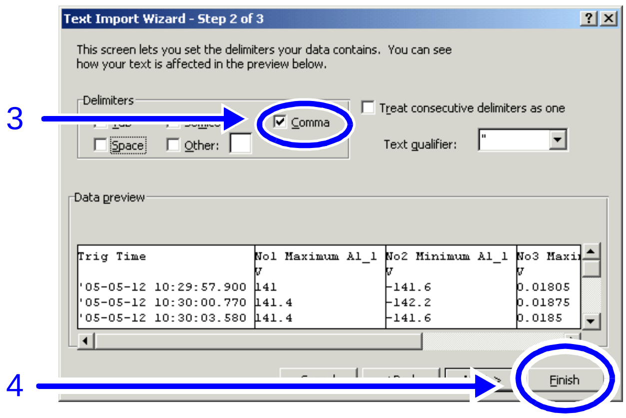
2. Click [Next].



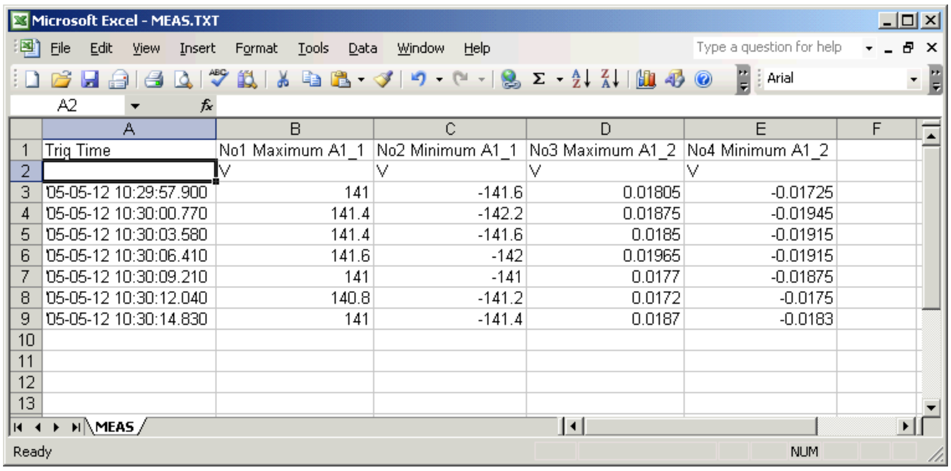
[Text Import Wizard Step 2 of 3]

3. Select [Comma] only for the delimiters.

4. Click [Finish].

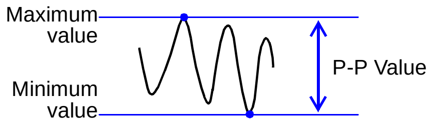
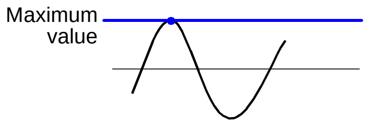
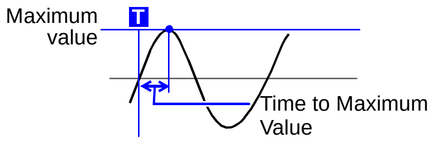
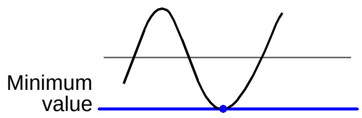
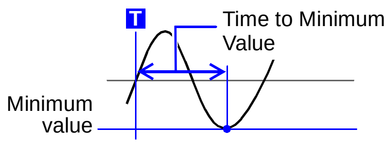
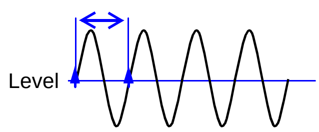


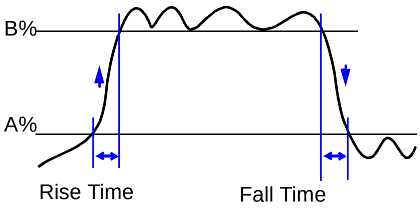
Numerical Calculation Results Data Imported into Excel

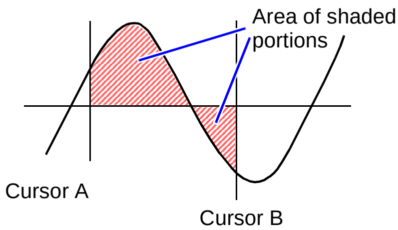


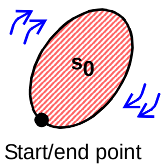
	A	B	C	D	E	F
1	Trig Time	No1 Maximum A1_1	No2 Minimum A1_1	No3 Maximum A1_2	No4 Minimum A1_2	
2		V	V	V	V	
3	'05-05-12 10:29:57.900	141	-141.6	0.01805	-0.01725	
4	'05-05-12 10:30:00.770	141.4	-142.2	0.01875	-0.01945	
5	'05-05-12 10:30:03.580	141.4	-141.6	0.0185	-0.01915	
6	'05-05-12 10:30:06.410	141.6	-142	0.01965	-0.01915	
7	'05-05-12 10:30:09.210	141	-141	0.0177	-0.01875	
8	'05-05-12 10:30:12.040	140.8	-141.2	0.0172	-0.0175	
9	'05-05-12 10:30:14.830	141	-141.4	0.0187	-0.0183	
10						
11						
12						
13						

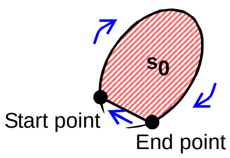
1.6 Numerical Value Calculation Expressions

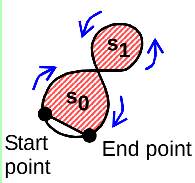
Numerical Calculation Type	Description
Average	Obtains the average value of waveform data. $Avg = \frac{1}{n}\sum_{i=1}^{n} di$ Avg: Average value n: Data count di: Data on channel number i
RMS (Root-Mean-Square) value	Obtains the RMS value of waveform data. If Scaling is enabled, calculations are applied to the waveform after scaling. $RMS = \sqrt{\frac{1}{n}\sum_{i=1}^{n} di^2}$ RMS: RMS value n: Data count di: Data on channel number i
Peak-to-Peak (P-P) value	Obtains the value of the difference (peak-to-peak value) between maximum and minimum values of waveform data. 
Maximum Value	Obtains the maximum value of waveform data. 
Time to Maximum Value (Time to Max)	Obtains the time (in seconds) from the last trigger point to the maximum value. If the maximum value occurs in two or more instances, the first instance is treated as the maximum value. 
Minimum Value	Obtains the minimum value of waveform data. 
Time to Minimum Value (Time to Min)	Obtains the time (in seconds) from the last trigger point to the minimum value. If the minimum value occurs in two or more instances, the first instance is treated as the minimum value. 
Period and Frequency	Displays the period (in seconds) and frequency (Hz) of the signal waveform. The calculation is based on the interval between two sequential points where the waveform crosses the same level (amplitude) in the same direction (slope). Setting Choices: Level, Slope (↑ or ↓) and Filter 

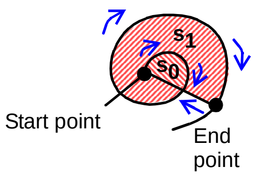
<table>
<tr><th>Numerical Calculation Type</th><th>Description</th></tr>
<tr><td>Rise Time and Fall Time</td><td>
The rise time of the acquired waveform from A% to B% (or fall time from B% to A%) is obtained by calculation using a histogram (frequency distribution) of the 0 and 100% levels of the acquired waveform.
As waveform data is acquired, the rise time (or fall time) is obtained from the first rising (or falling) edge.
When calculation of the range specified by the A/B cursors is selected, the obtained rise time (or fall time) is the first rising (or falling) edge between the cursors.


A: 5 to 30%
B: 95 to 70%
Setting Choices: Numerical percentage (%) of rise time (A% → B%) or fall time (B% → A%)
</td></tr>
<tr><td>Standard Deviation (Std Deviation)</td><td>
Obtains the standard deviation of the waveform data.
$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(di - Avg)^2}$$
σ: Standard Deviation
Avg: Average
n: Data count
di: Data on channel number i
</td></tr>
<tr><td>Area</td><td>
Obtains the area value (V•s) enclosed by the zero position (point of zero potential) and the signal waveform.
When calculation of the range specified by the A/B cursors is selected, the calculated area is constrained to the waveform between the cursors.


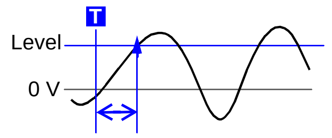
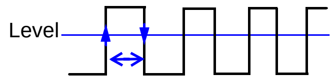
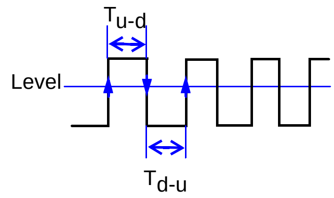
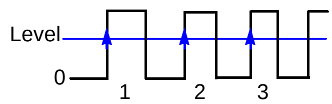
$$S = \sum_{i=1}^{n} |di| \bullet h$$
S: Area
n: Data count
di: Data on channel number i
h=Δt: Sampling period
</td></tr>
<tr><td>X-Y Area</td><td>
Obtains the area (V^2) of an X-Y composite waveform. In the following figures, the areas within the lines are calculated. The calculation is available even if the X-Y composite waveform is not intended for display.
To enable area calculation, specify the calculation range using the A/B cursors (Vertical or Trace) on the waveform of each channel for X-Y composition. (The area cannot be specified directly by A/B cursors on the X-Y waveform.)
See About A/B cursors: "8.8 Cursor Values" in the Instruction Manual
When the trace consists of multiple loops


$S = n \times s_0$
S: Area
n: Number of loops
When the trace is an open curve


$S = s_0$
S: Area
(Area enclosed by the curve and line connecting start and end points)
When the trace is a figure-8


$S = | s_0 - s_1 |$
S: Area
When the trace is a spiral


$S = s_0 \times 2 + s_1$
S: Area
(The number of overlapping regions increases with the number of loops)
Setting Choices: Set the X- and Y-axis channels.
When measuring with Timebase 1 and 2, be sure to select both X- and Y-axis channels from the same Timebase (either Timebase 1 or Timebase 2).
The X-Y area value cannot be calculated if the channels are not on the same Timebase.
</td></tr>
</table>

Numerical Calculation Type	Description
Time to Level	Finds the point where the signal crosses a specified level from the start of the calculation range, and obtains the time elapsed from the last trigger event. Setting Choices: Level, Slope (↑ or ↓) and Filter 
Pulse Width	Obtains pulse width as the time difference between one rising or falling intersection of the waveform through a specified level to the next intersection (with opposite slope). Setting Choices: Level, Slope (↑ or ↓) and Filter 
Duty (%)	Obtains the duty percentage based upon the ratio of the time from a rising intersection to the next falling intersection at a specified level, to the time from the same falling intersection to the next rising intersection at the same level.  Duty (%) = $\frac{Tu\text{-}d}{Tu\text{-}d + Td\text{-}u}$ X *100 (%)* $T_{u\text{-}d}$: Time (seconds) after rising intersection to falling intersection $T_{d\text{-}u}$: Time (seconds) after falling intersection to the next rising intersection Setting Choices: Level, Filter
Pulse Count	Obtains the count of pulses from the number of rising or falling intersections with a specified level. One pulse is counted when the signal falls back below the specified level after rising through it (or vice versa) Setting Choices: Level, Slope (↑ or ↓) and Filter 
Four Arithmetic Operations (4 Operations)	Performs arithmetic operations (+, –, ×,÷) upon arbitrarily selected results of numerical calculations. Setting Choices: Numerical Calculation No., arithmetic operator

NOTE

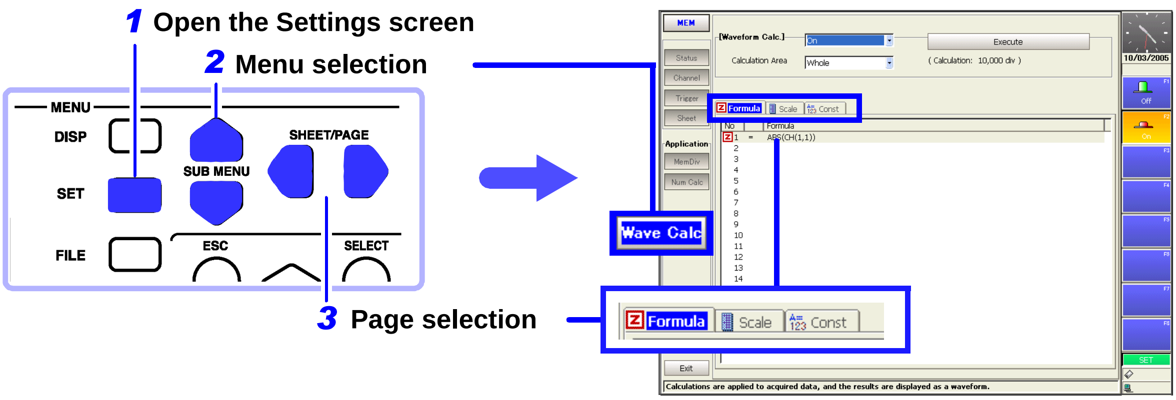
- Depending on the signal waveform for parameters of period, frequency, rise time and fall time, calculated values may not be displayed.
- When Scaling is enabled, calculations are performed after waveform data has been scaled. Also, the units of parameter values should match the scaling units.

See About Scaling:
"5.4 Converting Input Values (Scaling Function)" in the *Instruction Manual*

Waveform Calculation Functions

Chapter 2

Waveform calculations can only be used with the Memory function.
A pre-specified calculation equation is applied to acquired waveform data, and the calculation results are displayed as a waveform on the Waveform screen.
Waveform calculation settings are made on the Waveform Calculations Setting screen (Wave Calc).



Waveform Calculation Function Capabilities (Waveform Calculation Screen)

Numerical Calculations

- Four Arithmetic Operators (+, -, *, /)
- Absolute Value (ABS)
- Exponent (EXP)
- Common Logarithm (LOG)
- Square Root (SQR)
- Moving Average (MOV)
- Slide along the time axis

- Differential Calculus: 1st derivative (DIF), 2nd derivative (DIF2)
- Integral Calculus: 1st integral (INT), 2nd integral (INT2)
- Trigonometric functions (SIN, COS TAN)
- Inverse Trigonometric functions (ASIN, ACOS ATAN)

(Total 11 types)

- Specified calculation between A/B cursors

Waveform calculations can be limited to data within the range specified by A/B cursors.

Calculation operator details:
"2.4 Waveform Processing Calculation Operators and Results" (⇒ p. 34)

Of the eleven types of waveform calculation available, sixteen types can be applied at the same time.

When Scaling is enabled, numerical calculations are performed on scaled values.

2.1 Waveform Calculation Workflow

Before Setting

When specifying a waveform range for calculation: [A-B]

Before executing a calculation, specify the calculation range using the A/B cursors (Vertical or Trace cursors) on the Waveform screen. Set the calculation range on the Wave Calc Settings screen to [A-B].

- Horizontal cursors cannot be used to specify the range.
- When one cursor is used, the calculation range is from the cursor to the end of the data.

See "8.7 Specifying a Waveform Range" in the *Instruction Manual*
"2.2 Settings for Waveform Calculation" (⇒ p. 26) in this manual

Changing calculation settings while measuring

Changes made to calculation settings while measuring are applied after measurement is finished.

To change calculation settings and recalculate

Make changes to calculation contents on the Waveform Calculation Settings screen, and execute the calculation.

See "2.2 Settings for Waveform Calculation" (⇒ p. 26)

To not display a calculation waveform, or to display only the desired waveform

The displayed sheet and calculation waveform to be displayed can be selected on the Sheet Settings screen.

See "2.3 Calculation Waveform Display" (⇒ p. 33)

NOTE

- Maximum recording length available for waveform calculations

Installed Memory (Word)		Maximum recording length (Divisions)
8860	8861	
32M	64M	2,500
128M	256M	10,000
512M	1G	40,000
1G	2G	80,000

  If the recording length is set longer than the above maximum, waveform calculation is not performed.
  In this case, reset the recording length so that it is below the maximum, or after performing a partial or divided save, reload a portion of the data into the instrument and apply the calculation.
- Waveform calculation is not available when using Roll Mode and Memory Division.
- When Memory Division is disabled, up to 16 past waveforms can be used for reference. However, waveforms other than the currently referring block (that which includes data for calculation) are deleted when waveform calculation executes.
- If a waveform calculation is interrupted when loading data, the incomplete calculation result is displayed. To repeat the calculation, select the [Execute] button on the Waveform Calculation Settings screen.

The following two calculation methods are available:

- Calculate while measuring
  Requires making waveform calculation settings beforehand.
- Apply calculations to existing data
  Calculations can be applied to data after waveforms are acquired, or after data has been saved to storage media.

Calculating While Measuring

[Make Calculation Settings]

Make calculation settings on the Waveform Calculation Settings screen (⇒ p. 26).

Make display settings for waveform calculation results on the Sheet Settings screen. (⇒ p. 33)

To automatically print or save calculation results: make printing and saving settings before measuring.

- Printing calculation results automatically
  ([Printer] page on the Print Settings screen: Auto Print [On])

See "11.3 Making Auto Print Settings" in the *Instruction Manual*

- Saving calculation results automatically
  ([Auto Save] page on the Save Settings screen: Auto Save [On])

See "10.3.7 Automatically Saving Waveforms" in the *Instruction Manual*

↓

[Start Measurement]

↓

[Acquire Data]

The instrument acquires data when the trigger criteria are met.

(If triggering is not enabled, the instrument acquires data when you press the **START** key.)

↓

[Calculate]

"Calculating" appears on the screen's status bar.

Calculations are performed sequentially from No. 1 to No. 16.

(To interrupt calculations, press the **STOP** key to abort)

↓

[Display Calculation Results]

Results are displayed on the Waveform screen (⇒ p. 27).

↓

[(Print or Save)]

(if auto printing or auto saving are enabled)

Calculation results are automatically printed or saved.

↓

[Stop Measurement]

Applying Calculations to Existing Data

[(Load the Data)]

(To load measurement data from storage media for calculation)

See "10.4 Loading Data" in the *Instruction Manual*

↓

[Make Calculation Settings]

Make calculation settings on the Waveform Calculation Settings screen (⇒ p. 26).

↓

[Execute Calculation]

Press the [Execute] button to execute calculations.

(To interrupt calculations, press the **STOP** key)

↓

[Display Calculation Results]

Results are displayed on the Waveform screen (⇒ p. 27).

↓

[(Print or Save)]

Print or save calculation results as occasion demands.

- Print: **PRINT** key
- Save: **SAVE** key

2.2 Settings for Waveform Calculation

Waveform Calculations

MEM

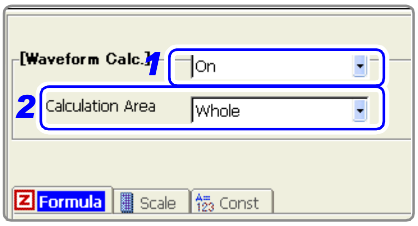
To open the screen: Press the **SET** key → Select **Wave Calc** with the **SUB MENU** keys →Wave Calc Settings screen

Operating Key Procedure

1 Enable the Waveform Calculation function.

CURSOR Move the cursor to the [Waveform Calc.] item.

F2 Select [On].



2 Specify the waveform calculation range.

CURSOR Move the cursor to the [Calculation Area] item.

F1 to F8 Select either choice.

Whole	Applies calculations to the whole waveform. (default setting)
A-B	Applies calculations to the data between A/B cursors.

When selecting [A-B], specify the calculation range using the A/B cursors on the Waveform screen.
If no measurement data has been acquired by the instrument, first measure once so that the range can be specified for calculations to be applied to subsequent measurements.

3 Perform calculation settings.

CURSOR Move the cursor to your setting choice on the [Formula] page.

F1 Select [Set].
A dialog is displayed for entering a calculation equation.

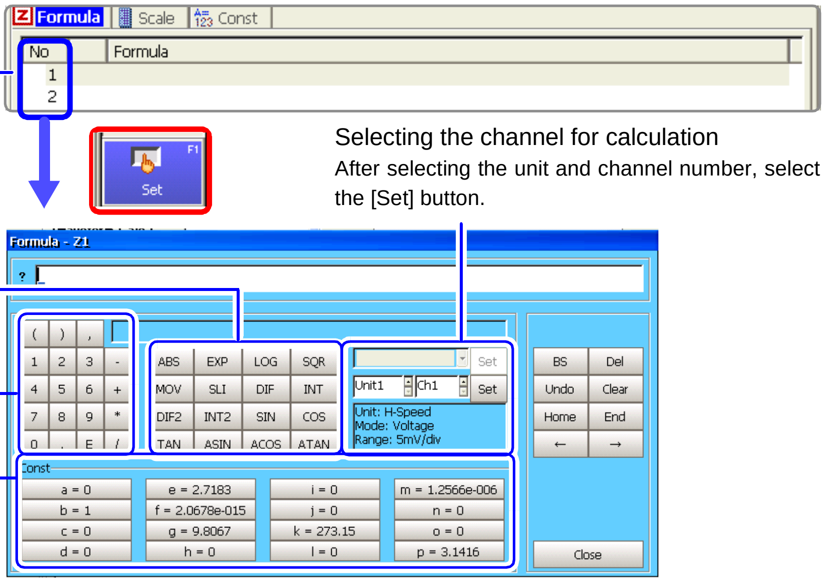
Calculation No.

Selecting the channel for calculation
After selecting the unit and channel number, select the [Set] button.

Enter calculation operators

Enter numerical values and symbols

Enter constants
Constants must have been previously entered on the [Const] page. (⇒ p. 29)



CURSOR Select a calculation equation.
F1 to F8 Example of calculation equation entry:(⇒ p. 32)

F7 When finished entry, select [OK].
The entered equation is displayed in the [Formula] field.

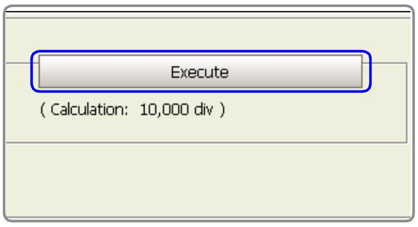
The default setting for calculation results display is [Auto].
To change the display, make settings on the [Scale] page.

See "Calculation Waveform Display Settings" (⇒ p. 30)

If "=" is displayed
The entered calculation equation is syntactically correct.
If "?" is displayed
The equation has a syntax error.
The cursor is placed at the location of the error to facilitate correction.

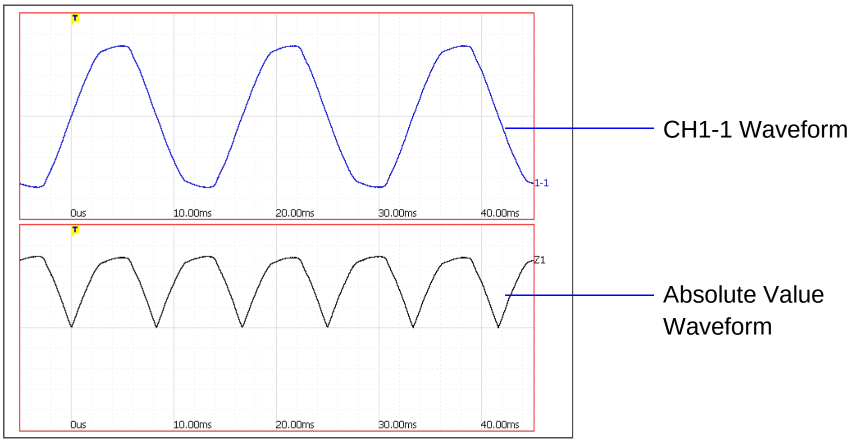
- Are parentheses correctly matched?
- Has a multiplication operator "*" been omitted?

Operating Key	Procedure
4	**(As occasion demands)** **Make display settings for waveform calculation results on the Sheet Settings screen (⇒ p. 33)** **Set auto saving and auto printing as needed (*Instruction Manual*)**
5	**Execute the calculations.**
Applying Calculations to Existing Data	
CURSOR	Move the cursor to the [Execute] button.
F1	Select [Execute].
To calculate while measuring	
START	Starts measurement. Calculation waveforms are displayed after loading waveforms.



Waveform Calculation Results

Example: Waveform of the calculated absolute value of the waveform of CH1-1. Calculation equation = ABS(CH(1,1))



To copy settings from one calculation to another

The method is the same as for copying numerical value calculations.

See "Copying Settings Between Calculation Nos." (⇒ p. 10)

To distribute calculation results onto sheets, or to display in separate Graphs

Display/non-display of calculation waveforms and graph division can be set on the Sheet Settings screen.

See "2.3 Calculation Waveform Display" (⇒ p. 33)

Description

About calculation equations

Operators:

Operator	Name	Operator	Name
ABS	Absolute Value	DIF2	2^{nd} Derivative
EXP	Exponent	INT2	2^{nd} Integral
LOG	Common Logarithm	SIN	Sine
SQR	Square Root	COS	Cosine
MOV	Moving Average	TAN	Tangent
SLI	Movement parallel to the time axis	ASIN	Inverse Sine
DIF	1^{st} Derivative	ACOS	Inverse Cosine
INT	1^{st} Integral	ATAN	Inverse Tangent

See "2.4 Waveform Processing Calculation Operators and Results" (⇒ p. 34)

Entering Calculation Equations

- Each entered calculation equation may contain up to 80 characters.
- Each constant in a calculation equation may contain up to 30 digits.
- The multiplication operation (*) must always be explicitly entered.
- Each calculation expression may contain up to eight instances of the four arithmetic operators.
  Multiplication and division or addition and subtraction of channels within parentheses [e.g., (CH(1,1)*CH(1,2)) or (CH(1,1)+CH(1,2))] each count as one operation.

ABS(CH(1,1))+CH(1,2)*CH(2,1)–(CH(2,2)+CH(3,2))*ABS(CH(4,1))/DIF(CH(1,1),1)

1 2 3 4 5

- Division by zero, such as 1/0 (1 ÷ 0), results in overflow output.
- Channel data is specified in the form CH(u,n), where u = the Unit (input module) number, and n = the number of the channel within input module u.
  (Example: To specify the data on Channel 2 of Unit 1, enter “CH(1,2)”.)
- The result of calculation Z_i can be used in other calculation equations. However, the nth equation can only refer to the results of equations up to Z_{n-1}.
  (Example: Equation Z4 can include the results of equations Z1 through Z3.)

Using the MOV, SLI, DIF and DIF2 operators in an equation

The number # after a comma within parenthesis (_,#) for each operation is set to the calculation operator.

Operator	Setting Choice	Setting Examples
MOV (Moving Average) SLI (Parallel Movement)	Set the number of points to move. Setting Range MOV (Moving Average): 1 to 5000 SLI: -5000 to 5000	Calculate the 10-point moving average of CH1-1: MOV(CH(1,1),10)
DIF (Derivative) DIF2 (2nd Derivative)	Specify the sampling interval for differentiation. "1" is normally acceptable, but this should be set larger to capture fluctuation values of slowly changing waveforms. DIF and DIF2 Setting Range: 1 to 5000	Differentiate CH1-2 using a 20-point sampling interval: DIF(CH(1,2),20)

When calculation results overflow (OVER)

- The displayed A/B cursor values (and those printed when the printer recording type is set to [Numeric]) are incorrect.
- When [Scale] is set to [Auto], waveforms appear at the top or bottom edge of the screen. This makes calculation result overflow obvious.

Waveform calculations with Timebase 2 (measurements using sampling rate 2)

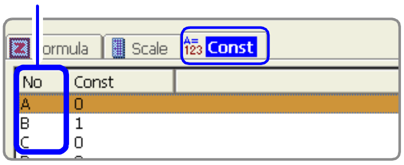
- Calculation equations Z1 to Z8 apply only to Timebase 1, and Z9 to Z16 apply only to Timebase 2.
- Channel data set to use Sampling Rate 1 can only be used in equations Z1 to Z8, and channel data set to use Sampling Rate 2 can only be used in equations Z9 to Z16.
- Inclusion of the results of one calculation (Zn) in another is also limited to only those calculations which apply to the same timebase.
(Example: equation Z8 can include only the results of Z1 to Z7, and Z16 can include only the results of Z9 to Z15.)

Defining Constants MEM

To open the screen: Press the **SET** key → Select **Wave Calc** with the **SUB MENU** keys →Wave Calc Settings screen

Operating Key	Procedure
SHEET/PAGE	Select the [Const] page.
CURSOR	Move the cursor to the Constant No. to be defined.
F1 to F8	Select an entry method, and enter the constant. Setting range: -9.9999E+29 to +9.9999E+29 **See** "3.3.3 Entering Text and Numbers" in the *Instruction Manual*

Constant No.

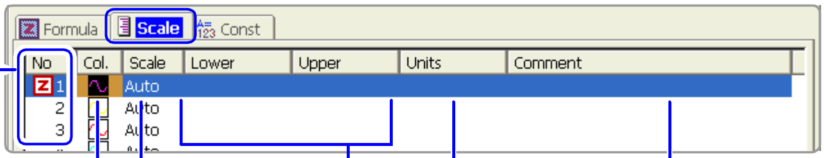


Defined constants are shown in the constant display of the calculation equation setting dialog.

Calculation Waveform Display Settings **MEM**

To open the screen: Press the **SET** key → Select **Wave Calc** with the **SUB MENU** keys →Wave Calc Settings screen

Operating Key	Procedure
1 **SHEET/PAGE**	Select the [Scale] page.



To copy settings between Calculation Nos.:
Select F2 [Copy].

2 Enable waveform display, and display color

CURSOR Move the cursor to the [Color] column.

F1 to F8 Select whether to display the waveform, and its color (when On)

Off	The waveform is hidden.
On	The waveform is displayed. (default setting)

3 Select a method to set scaling

CURSOR Move the cursor to the [Scale] column for the Calculation No. to be set.

F1 to F8 Set the display range for the calculation waveform.

Auto	Automatically sets the display range of the vertical axis. (After calculation, the upper and lower limits are obtained from the results, and set automatically.)
Manual	Upper and lower limits of the vertical axis display range are entered manually.

> Depending on calculation results, automatic scaling settings may be unsatisfactory, in which case the limits must be entered manually.

4 Set the upper and lower limits of the display range (when [Manual] is selected)

CURSOR Select [Lower] and [Upper].

F1 to F8 Select an entry method and enter the limit values.
Entry range: -9.9999E+29 to +9.9999E+29

> **See** "3.3.3 Entering Text and Numbers" in the *Instruction Manual*

5 Specify the physical units

CURSOR Move the cursor to the [Units] column.

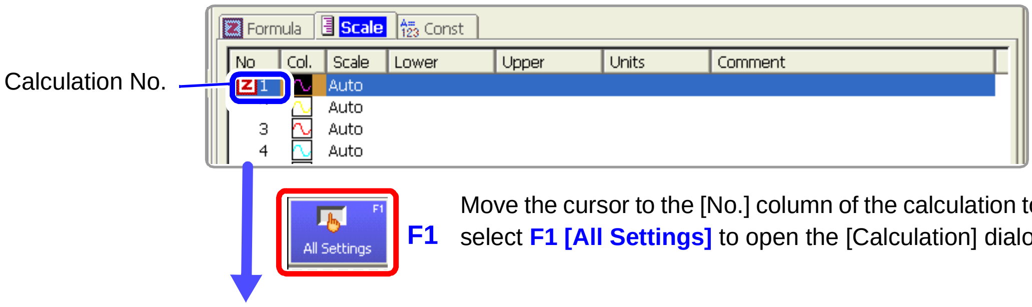
F1 to F8 Select an entry method and enter the physical units.

6 Enter a comment (as occasion demands)

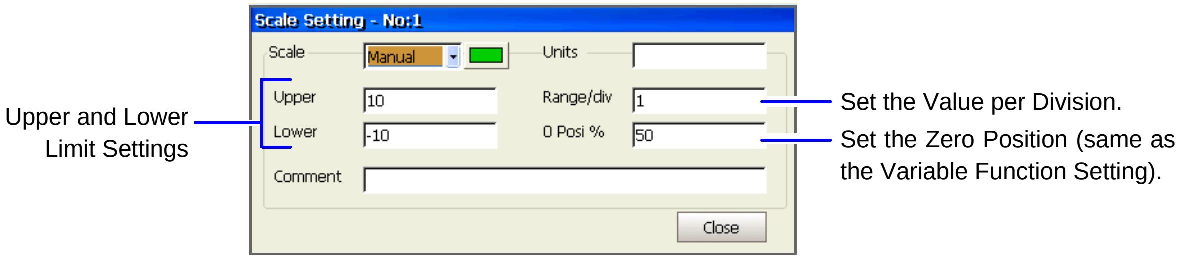
CURSOR Move the cursor to the [Comment] column.

F1 to F8 Enter your comment.

Making settings in the [Calculation] dialog



Move the cursor to the [No.] column of the calculation to set, and select **F1 [All Settings]** to open the [Calculation] dialog.

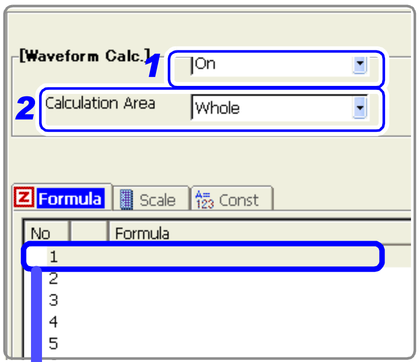


Waveform Calculation Example

Calculate the RMS waveform from the instantaneous waveform

The RMS values of the waveform input on Unit 1 Channel 1 are calculated and displayed. This example describes the calculation of waveform data measured for one cycle over two divisions.

Operating Key	Procedure
1	**Enable the Waveform Calculation function.**
CURSOR	Move the cursor to the [Waveform Calc.] item.
F2	Select [On].
2	**Specify the waveform calculation range.**
CURSOR	Move the cursor to the [Calculation Area] item.
F1	Select [Whole].
3	**Perform calculation settings.**
CURSOR	Move the cursor to No. 1 on the [Formula] page.
F1	Select [Set]. A dialog is displayed for entering a calculation equation.



After selecting the unit and channel number, select the [Set] button.

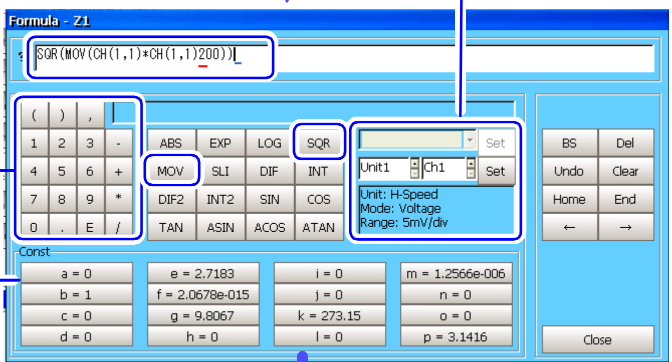
Entering the calculation equation

SQR(MOV(CH(1,1)*CH(1,1),200))

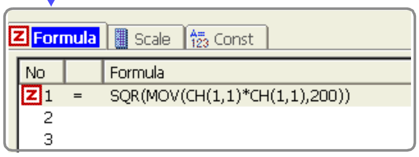
The number of samples per cycle (1 division = 100 samples) Here, one cycle is two divisions (200 samples)

Enter numerical values and symbols

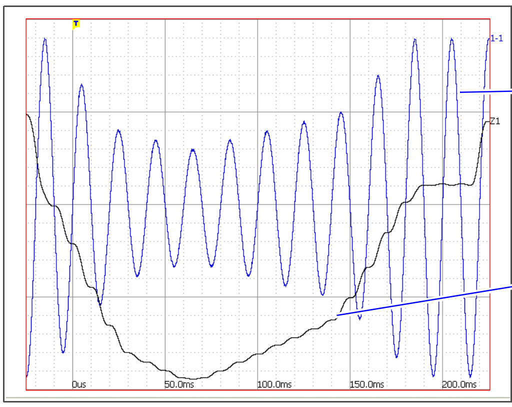
It is convenient to set constants beforehand on the [Const] page. (⇒ p. 29)



When finished entry, select **F7** [OK].
The entered equation is displayed in the [Formula] field.



4	**Execute the calculations.**
START	Starts measurement. The calculation waveform is displayed after acquiring the input waveform.



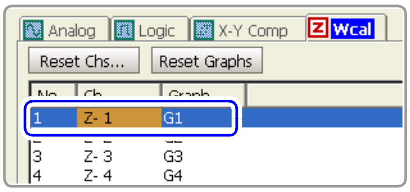
To view the waveform calculated from the acquired data, press the [Execute] button on the Waveform Calculation Settings screen.

2.3 Calculation Waveform Display

Assignment of calculation results and split-screen graph display arrangement can be set.
These settings are effective when Waveform Calculation is enabled.

Waveform Calculation Display Settings **MEM**

To open the screen: Press the **SET** key → Select **Sheet** with the **SUB MENU** keys →Sheet Settings screen



Operating Key | Procedure

1 **SHEET/PAGE** Select the [Wcal] page.

2 **Select whether to display calculation waveforms.**

CURSOR Move the cursor to the [Unit-Ch] column for the Calculation No. to be displayed.

F1 to F8 Select the desired calculation equation for display.

Off	The calculation waveform is not displayed.
Z1 to Z16	Displays the selected calculation waveform.

Z1 to Z16
correspond to the calculation equations defined on the Waveform Calculation Setting (Wave Calc) screen.

3 **Select a Graph for display.**
(when [Split-Screen] is set to [2 Graphs] or more, or the [Display Type] is set to [Wave+X-Y])

CURSOR Move the cursor to [Graph].
F1 to F8 Select the Graph number to be displayed.
Graph number samples (G1, G2, ...) are displayed at the left side of the screen.

4 **Verify the calculation waveform on the Waveform screen.**

DISP The Waveform screen appears.

2.4 Waveform Processing Calculation Operators and Results

b_i: ith member of calculation result data, d_i: ith member of source channel data

Waveform Calculation Type	Description
Four Arithmetic Operators (+, −, *, /)	Executes the corresponding arithmetic operation.
Absolute Value (ABS)	$b_i = \lvert d_i \rvert$ (i = 1, 2, ... n)
Exponent (EXP)	$b_i = exp(d_i)$ (i = 1, 2, ... n)
Common Logarithm (LOG)	When $d_i > 0$, $b_i = log_{10}\, d_i$ When $d_i = 0$, $b_i = -\infty$ (overflow value output) When $d_i < 0$, $b_i = log_{10} \lvert d_i \rvert$ (i = 1, 2, ... n) Note: Use the following equation to convert to natural logarithm calculations. $LnX = log_e X = log_{10} X / log_{10} e$ $1 / log_{10} e \approx 2.30$
Square Root (SQR)	When $d_i \geq 0$, $b_i = \sqrt{d_i}$ When $d_i < 0$, $b_i = -\sqrt{\lvert d_i \rvert}$ (i = 1, 2, ... n)
Moving Average (MOV)	When k is odd number: $bi = \frac{1}{k} \sum_{t=i-\frac{k}{2}}^{i+\frac{k}{2}} dt$ (i = 1, 2, ... n) When k is even number: $bi = \frac{1}{k} \sum_{t=i-\frac{k}{2}+1}^{i+\frac{k}{2}} dt$ (i = 1, 2, ... n) dt: t^{th} member of source channel data k : number of points to move (1 to 5000) 1 div = 100 points. k is specified after a comma. (Ex.) To make Z1 the moving average of 100 points: MOV(Z1,100)
Slides waveform data along the time axis (SLI)	Moves along the time axis by the specified distance. $b_i = d_i - k$ (i = 1, 2, ... n) k : number of points to move (-5000 to 5000) k is specified after a comma. (Ex.) To slide Z1 by 100 points along the time axis: SLI(Z1,100) Note: When sliding a waveform, if there is no data at the beginning or end of the calculation result, the voltage value becomes zero. 1 div = 100 points.
Sine (SIN)	$b_i = sin(d_i)$ (i = 1, 2, ... n) Trigonometric functions employ radian (rad) units.
Cosine (COS)	$b_i = cos(d_i)$ (i = 1, 2, ... n) Trigonometric functions employ radian (rad) units.
Tangent (TAN)	$b_i = tan(d_i)$ (i = 1, 2, ... n) where $-10 \leq b_i \leq 10$ Trigonometric functions employ radian (rad) units.
Arcsine (ASIN)	When $d_i > 1$, $b_i = \pi / 2$ When $-1 \leq d_i \leq 1$, $b_i = asin(d_i)$ When $d_i < 1$, $b_i = -\pi / 2$ Trigonometric functions employ radian (rad) units.

b_i: ith member of calculation result data, d_i: ith member of source channel data

Waveform Calculation Type	Description
Arccosine (ACOS)	When $d_i > 1$, $b_i = 0$ When $-1 \le d_i \le 1$, $b_i = acos(d_i)$ When $d_i < -1$, $b_i = \pi$ (i = 1, 2, ... n) Trigonometric functions employ radian (rad) units.
Arctangent (ATAN)	$b_i = atan(d_i)$ (i = 1, 2, ... n) Trigonometric functions employ radian (rad) units.
First derivative (DIF) **Second derivative (DIF2)**	The first and second derivative calculations use a fifth-order Lagrange interpolation polynomial to obtain a point data value from five sequential points. d_1 to d_n are the derivatives calculated for sample times t_1 to t_n. Note: Scattering of calculation results increases as input voltage level decreases. If scattering is excessive, apply the moving average (MOV). Calculation formulas for the first derivative Point t_1 $b_1 = (-25d_1 + 48d_2 - 36d_3 + 16d_4 - 3d_5)/ 12h$ Point t_2 $b_2 = (-3d_1 - 10d_2 + 18d_3 - 6d_4 + d_5)/ 12h$ Point t_3 $b_3 = (d_1 - 8d_2 + 8d_4 - d_5)/ 12h$ ↓ Point t_i $b_i = (d_{i-2} - 8d_{i-1} + 8d_{i+1} - d_{i+2})/ 12h$ ↓ Point t_{n-2} $b_{n-2} = (d_{n-4} - 8d_{n-3} + 8d_{n-1} - d_n)/12h$ Point t_{n-1} $b_{n-1} = (-d_{n-4} + 6d_{n-3} - 18d_{n-2} + 10d_{n-1} + 3d_n)/12h$ Point t_n $b_n = (3d_{n-4} - 16d_{n-3} + 36d_{n-2} - 48d_{n-1} + 25d_n)/12h$ b_1 to b_n: calculation results $h = \Delta t$: Sampling Period Calculation formulas for the second derivative Point t_1 $b_1 = (35d_1 - 104d_2 + 114d_3 - 56d_4 + 11d_5)/12h^2$ Point t_2 $b_2 = (11d_1 - 20d_2 + 6d_3 + 4d_4 - d_5)/12h^2$ Point t_3 $b_3 = (-d_1 + 16d_2 -30d_3 + 16d_4 - d_5)/12h^2$ ↓ Point t_i $b_i = (-d_{i-2} + 16d_{i-1} - 30d_i + 16d_{i+1} - d_{i+2})/12h^2$ ↓ Point t_{n-2} $b_{n-2} = (-d_{n-4} + 16d_{n-3} - 30d_{n-2} + 16d_{n-1} - d_n)/12h^2$ Point t_{n-1} $b_{n-1} = (-d_{n-4} + 4d_{n-3} + 6d_{n-2} - 20d_{n-1} + 11d_n)/12h^2$ Point t_n $b_n = (11d_{n-4} -56d_{n-3} + 114d_{n-2} - 104d_{n-1} + 35d_n)/12h^2$

b_i: ith member of calculation result data, d_i: ith member of source channel data

Waveform Calculation Type	Description
First integral (INT) **Second integral (INT2)**	First and second integrals are calculated using the trapezoidal rule. d_1 to d_n are the integrals calculated for sample times t_1 to t_n. Calculation formulas for the first integral Point t_1 $I_1 = 0$ Point t_2 $I_2 = (d_1 + d_2)h/2$ Point t_3 $I_3 = (d_1 + d_2)h/2 + (d_2 + d_3)h/2 = I_2 + (d_2 + d_3)h/2$ ↓ Point t_n $I_n = I_{n-1} + (d_{n-1} + d_n)h/2$ I_1 to I_n: calculation results $h = \Delta t$: Sampling Period Calculation formulas for the second integral Point t_1 $II_1 = 0$ Point t_2 $II_2 = (I_1 + I_2)h/2$ Point t_3 $II_3 = (I_1 + I_2)h/2 + (I_2 + I_3)h/2 = II_2 + (I_2 + I_3)h/2$ ↓ Point t_n $II_n = II_{n-1} + (I_{n-1} + I_n)h/2$ II_1 to II_n: calculation results

FFT Function Chapter 3

3.1 Overview and Features

FFT analysis can only be used with the FFT function.
The FFT (Fast-Fourier Transform) functions provide frequency analysis of input signal data.
Use these functions for frequency analysis of rotating objects, vibrations, sounds and etc.
For details, refer to "3.11 FFT Definitions" (⇒ p. 103).

Analysis can be performed on data as it is being measured, on pre-existing analog waveform data previously acquired with the Memory function, and on data output from waveform calculations.
However, FFT analysis cannot be applied to data acquired with the Model 8958 16-Ch Scanner Unit. Also, FFT analysis cannot be applied to pre-existing waveform data acquired from channels that used Timebase 2 for sampling.
When using an input module equipped with an anti-aliasing filter, the cut-off frequency can be automatically set by linking with the frequency range setting.
(Model 8938 FFT Analog Unit, 8947 Chargh Unit, 8957 High Resolution Unit, 8960 Strain Unit)

Major Features

- FFT analysis frequency range: 133 mHz to 8 MHz
- Frequency resolution: 1/400th, 1/800th, 1/2000th or 1/4000th of the frequency range
- FFT Analysis Modes (16 types)
  - Storage Waveform
  - RMS Spectrum
  - Power Spectrum Density*
  - Auto-correlation Function
  - Transfer Function
  - Impulse Response
  - 1/1 Octave Analysis*
  - Phase Spectrum
  - Linear Spectrum
  - Power Spectrum
  - Cross-power Spectrum
  - Histogram
  - Cross-correlation Function
  - Coherence Function
  - 1/3 Octave Analysis*
  - Power Spectrum Density (LPC)*

* Not available when using external sampling.

For phase spectra, only the required phase information is highlighted and displayed.

See "3.4.7 Emphasizing Analysis Results (phase spectra only)" (⇒ p. 61)

Also, when performing FFT analysis with the instrument connected to a sound level or vibration meter, scaling by dB can be set from the Channel Settings screen if you want to read values directly in calibrated units of measurement.

See "Scaling" (⇒ p. 71)

NOTE

To suppress the effects of aliasing distortion

We recommend using input modules that are equipped with anti-aliasing filtering to suppress the effects of aliasing distortion when sampling.

See Aliasing Distortion and Anti-Aliasing Filters
"3.11 FFT Definitions" (⇒ p. 103)

Refer to the *Instruction Manual* for FFT function specifications.

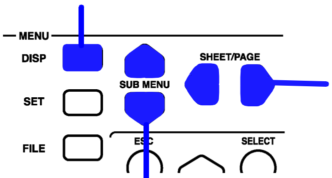
3.2 Screen Organization (FFT Function)

Measurement-related settings for FFT analysis are made on the Settings screens (Status, Channel, Trigger and Sheet); saving and printing settings are made on the Save Settings and Print Settings screens; and measurement data display settings are made on the Waveform screen. The Channel Settings, Trigger Settings, Save Settings and Print Settings screens are nearly the same as for the other operating functions.

3.2.1 Waveform Screen

To open the Waveform screen

1 **Press the DISP key**
(The Waveform screen appears)



Press the SHEET/PAGE keys
(To change sheets)
This is valid only when measurement data has been assigned to multiple sheets.

Press the SUB MENU keys
(To change choices of setting items)

Data acquired by the instrument can be displayed as any of the following types. The display type can be selected for each Sheet.

Display type:
- FFT
- Nyquist
- FFT+Nyquist
- Wave+FFT
- Wave+Nyquist

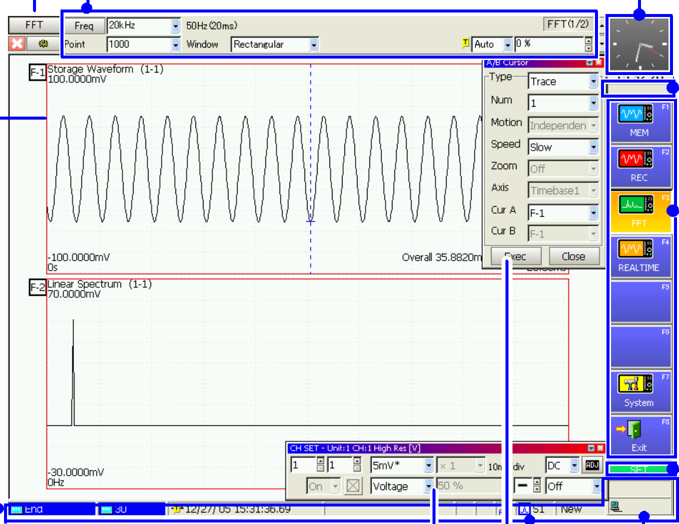
See "3.6 Setting the Screen Layout of the Waveform Screen" (⇒ p. 72)

Function Menu
Select a function before measuring.

Setting Items and Choices (⇒ p. 39)
Calculation configuration and trigger criteria settings can be changed. These can be changed while measuring. Press the **SUB MENU** keys to select the items to change.

Clock
Shows the current time. You can change the display appearance.

On-screen changes can be made by clicking the mouse.



Recorded Data
Shows data acquired with this instrument.

"Key Lock" appears when the key-lock state is enabled.

Setting Choices
The cursor indicates the current setting choice.
Select with F keys (F1 to F8).
Press the **FUNCTION MODE** key to change the F key functions.

F-Key Function Status
Shows the current F key status.

Status Bar
This bar indicates the current states of data acquisition, internal processing, settings and display information.

Input Channel Settings Dialog
Input channel settings can be changed.
(Appears when you press the **UNIT** or **CH** keys, or press or turn the **RANGE** knob)

Internal and External Connection Status

A/B Cursor Settings Dialog
Select the type of cursors.
(Appears when you press the **TYPE** key or knob **A**)

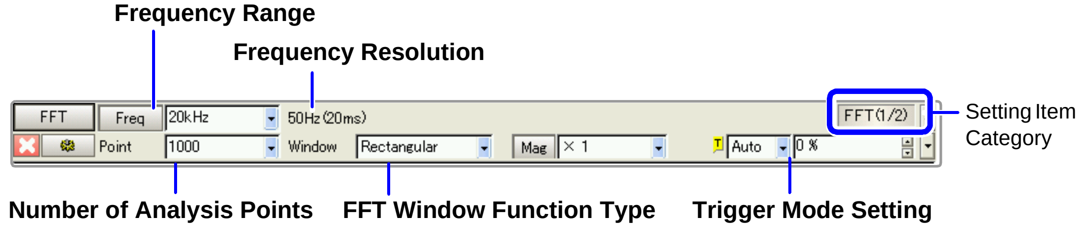
Sheet No.

Press the ESC key to remove the dialog.

Setting Items and Choices

FFT Function Settings [FFT(1/2)]

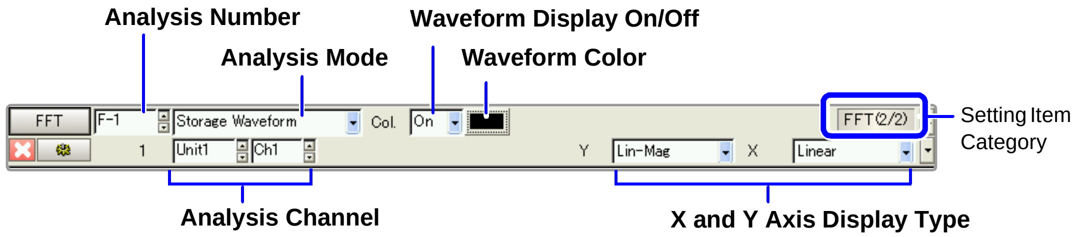
See "3.4.10 Setting and Changing Analysis Conditions on the Waveform Screen" (⇒ p. 67)



Switch with the **SUB MENU** keys

FFT Function Settings [FFT(2/2)]

See "3.4.10 Setting and Changing Analysis Conditions on the Waveform Screen" (⇒ p. 67)



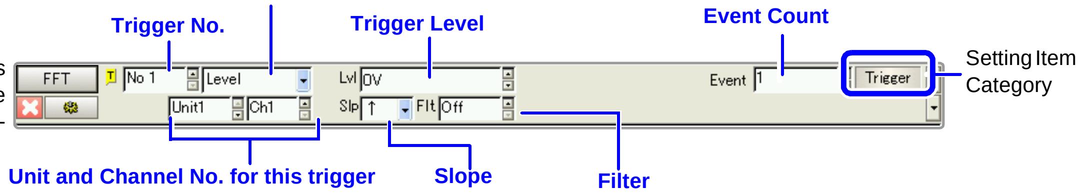
Switch with the **SUB MENU** keys

Analog Trigger Settings [Trigger]

See "6.7 Triggering by Analog Signals" in the *Instruction Manual*

(When using Level Triggering) **Type of Analog Trigger**

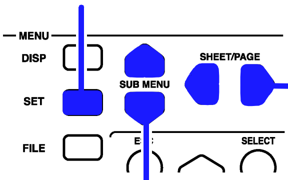
The display differs according to the type of analog triggering.



3.2.2 Settings Screen

To open the Settings screen

1 **Press the SET key.** (The Settings screen appears.)



3 **Press the SHEET/PAGE keys to select a page.**

2 **Press the SUB MENU keys to select from the Settings menu.**

Status **Status Settings Screen**

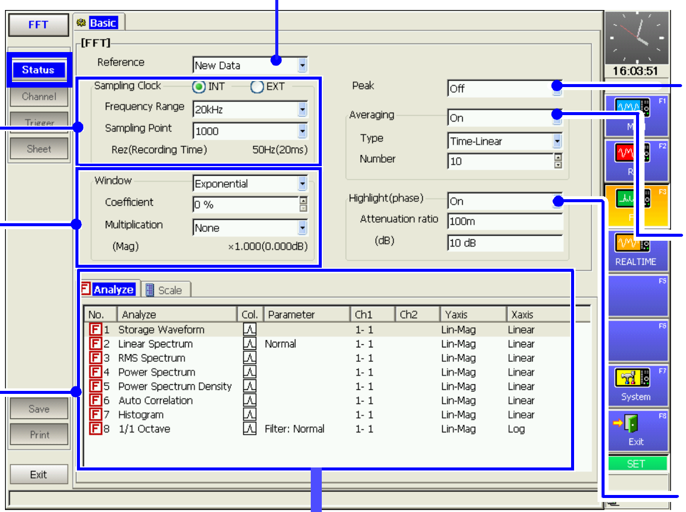
Make settings here for FFT analysis.

Input Data Selection (⇒ p. 52)
Select whether FFT analysis is to be applied to newly acquired data, or to a pre-existing waveform (Memory waveform).

Frequency Range and Number of Calculation Points (⇒ p. 53)
More calculation points provide greater frequency resolution.

Window Function Settings (⇒ p. 56)
Selects a window function and correction for acquiring input signals.

FFT Analysis Settings (⇒ p. 62)

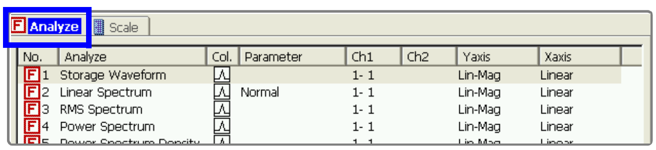


Peak Value Display Setting (⇒ p. 57)
Selects whether to display the peaks (maximal or maximum) of analysis results.

Averaging Settings (⇒ p. 58)
Noisy or unstable values can be averaged to clarify the waveform display.
When averaging is enabled, select the method and count for averaging.

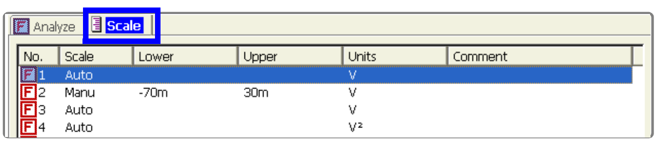
Phase Spectra Highlighting
For the maximum value of a power spectrum or cross-power spectrum, data exceeding the specified ratio can be displayed with emphasis (highlighted).

[Analyze] Page



Selects the analysis mode, analysis channels, x and y axes and display parameters. (⇒ p. 62)

[Scale] Page



Sets the display scale of the vertical (y) axis. (⇒ p. 66)

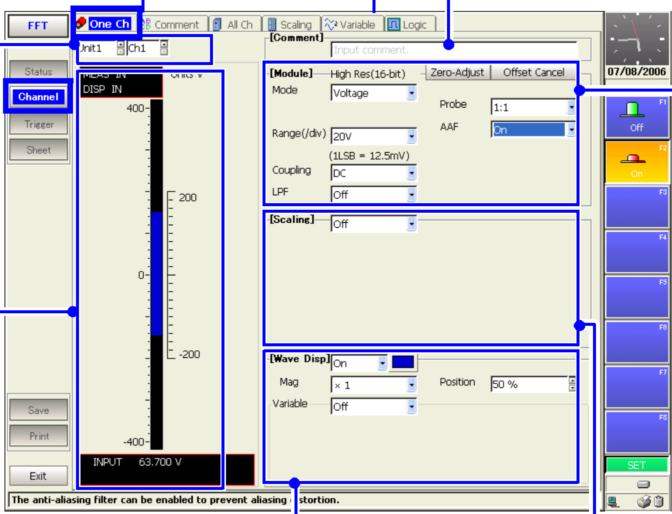
Channel — Channel Settings Screen

Set analog channels.

Comment Setting
Make this setting to enter channel-specific comments. This setting is also available on the [Comment] page. Comments can be displayed on the Waveform screen.

All Channel Settings List
(The Logic page is not accessible)

Setting Unit (Module) and Channel Nos.



Input Module Settings
Set the input channels for the installed input modules.
See "Chapter 3 Input Channel Settings" in the *Input Module Guide*.
These settings are also available on the [All Ch] page.

Level Monitor
Indicates the value and range of input relative to the area displayed on the waveform screen for verification.

Input Waveform Settings
Set the waveform display color, zero position, vertical axis magnification and display area. These settings are also available on the [All Ch] page.

Scaling Settings (⇒ p. 71)
Make these settings to convert measurement units for display as physical values when using a clamp or external sensor. These settings are also available on the [Scaling] page.

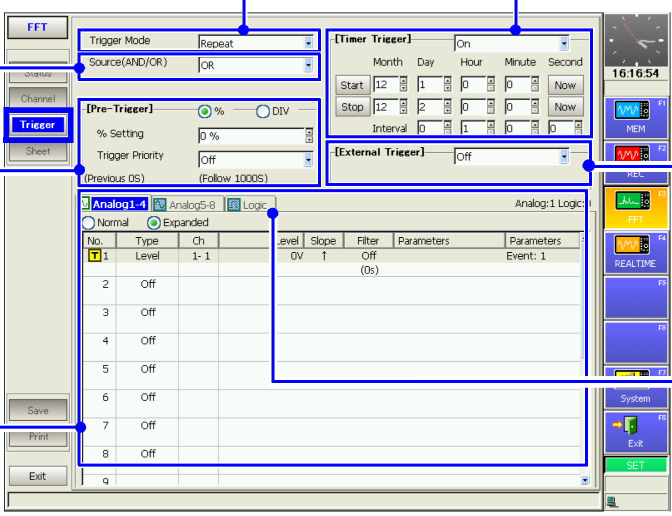
Trigger — Trigger Settings Screen

Set trigger criteria.

Trigger Mode Setting
Sets trigger activation criteria.

Timer Trigger Settings
Set recording start and end times, and set timing when desired to apply a trigger within a specified period.

Combining Method (AND/OR) for Multiple Trigger Sources



External Trigger Settings
Set this to accept triggering from a signal input on the External Trigger terminal.

Pre-Trigger Settings
Make these settings to record prior to triggering. When Trigger Priority is On, triggering is allowed during the Pre-Trig Wait.

Logic Trigger Settings

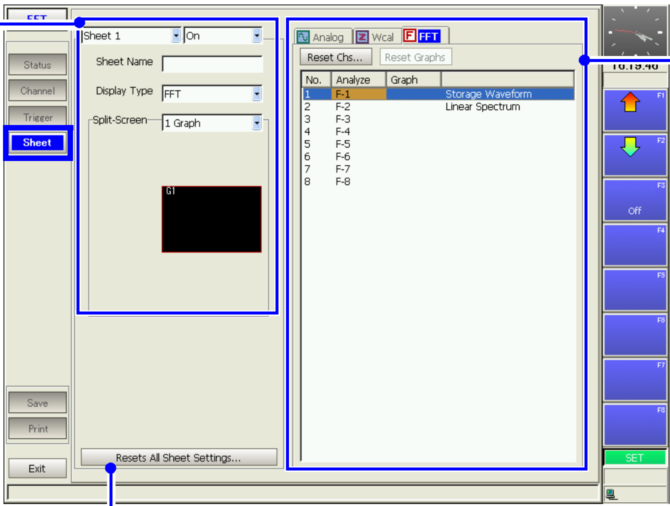
Analog Trigger Settings

Settings on the [Analog] and [Wcal] pages are the same as for the Memory function.

Sheet — Sheet Settings Screen

Set the display method for the Waveform screen.

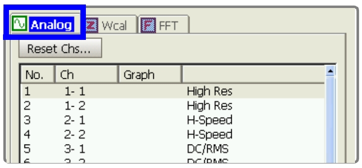
Screen Layout Setting
(⇒ p. 72)
Set the data type and display arrangement for each sheet to be displayed.
- Sheet Name setting
- Display type
- Split screen



Assigning Channels to Sheets
Assigns the channel, calculation results and waveform display position for each display sheet.

Resets all sheet settings

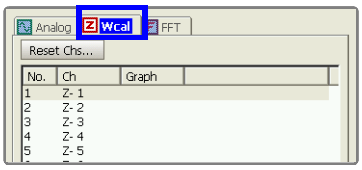
[Analog] Page



Assign analog channels.

See "7.2.6 Assigning Display Channels to Graphs (Analog Channels)" in the *Instruction Manual*

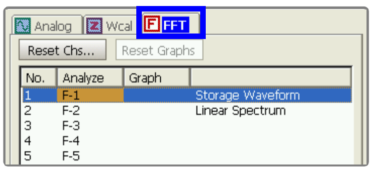
[Wcal] Page



Arrange waveform calculation results.

See "2.3 Calculation Waveform Display" (⇒ p. 33)

[FFT] Page



Assigns FFT analysis results and sets graph arrangement for split-screen display.

Setting procedures on the Save Settings screen are the same for all functions.
See "Chapter 10 Saving/Loading Data & Managing Files" in the *Instruction Manual* for details.

Save — Save Settings Screen [Auto Save] Page

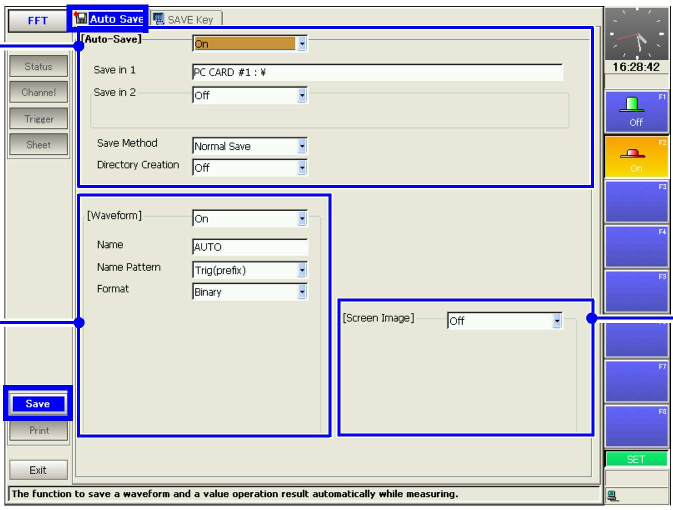
Make these settings to specify automatic saving.
The factory default setting for auto save is [Off].

Auto-Save Settings

Select the action to take when the save destination or storage media becomes full during automatic saving, such as whether to create new directories. (Default setting: [Off])

Settings for Saving Waveform Data

Select the saving format, area to save and related settings for automatic saving.



Settings for Saving Screen Images

Make these setting to automatically save Waveform screens.

Save — Save Settings Screen [SAVE Key] Page

These settings determine the operation of the **SAVE** key.

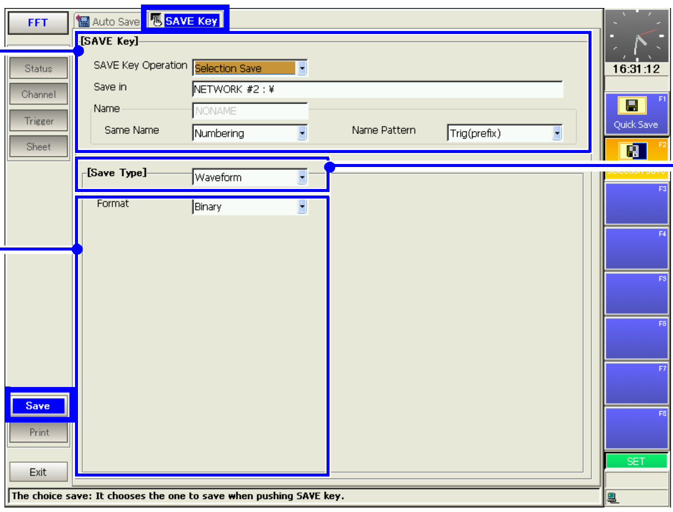
Manual Save Settings (Saving by SAVE key)

Set the save destination, file name and related settings for saving with the **SAVE** key.

Settings for Saving Waveform Data

Select the saving format, area to save and related settings for waveform saving.

Save settings are also available for saving settings data and display images.



Save Type Settings

Select what to save with the **SAVE** key.
Display contents depend on the selections.

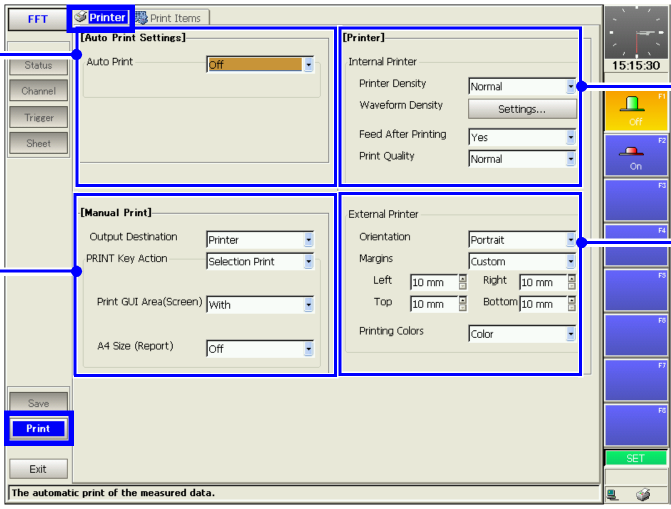
Setting procedures on the Print Settings screen are the same for all functions.
See "Chapter 11 Printing" in the *Instruction Manual* for details.

Print Print Settings Screen [Printer] Page

Select the printing method and printer for automatic or manual printing.
The factory default setting for auto print is [Off].

Auto Print Settings
Make these setting to print automatically.

Manual Print Settings
Set the printing method (Quick or Selection Print) and items you want to print when pressing the **PRINT** key.



Internal Printer Settings
Set the printer's print density and quality.

External Printer Settings
Set the paper orientation and margins.

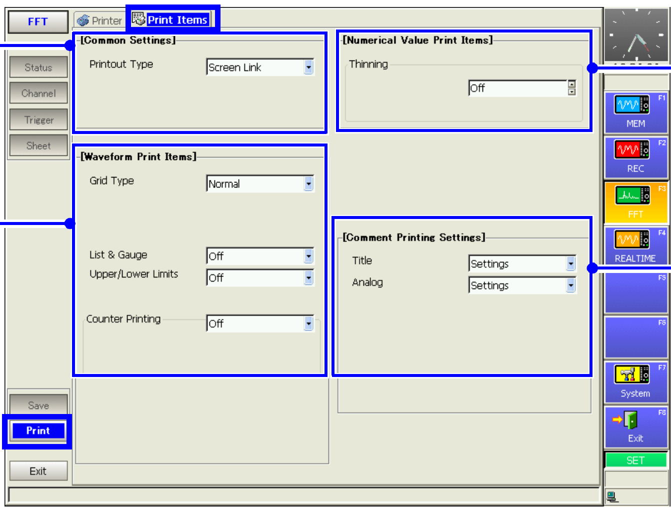
Print Print Settings Screen [Print Items] Page

Select the items to be printed (printout contents).

Print Item Common Settings
Select the printout type, print area and horizontal axis display value.

Waveform Printing Settings
Select the items to print when printing waveforms.

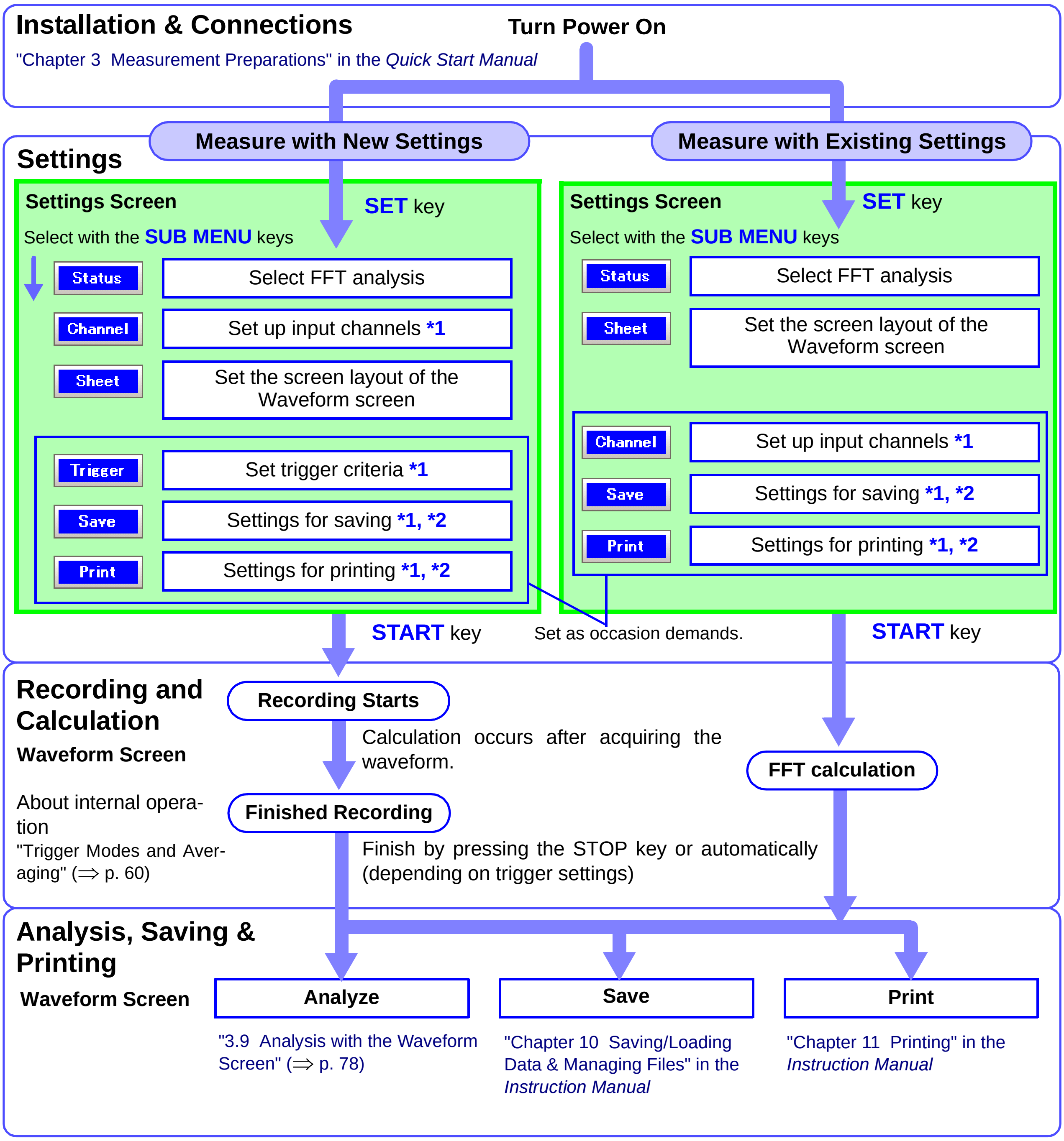
- Grid Type
- List & Gauge
- Print Upper and Lower Limits
- Print Counter



Numerical Printing Settings
Select the thinning method for numerical data.

Printing Settings for Comments, Title and Settings Data

3.3 Operation Workflow



*1. Settings are the same as for the Memory and Recorder functions. Refer to the *Instruction Manual* for details about each setting.

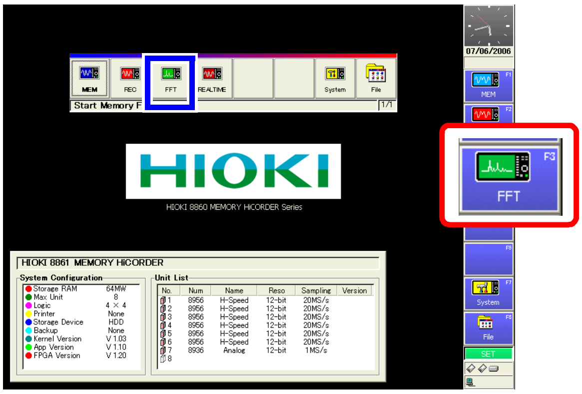
*2. When saving or printing manually, settings can be changed after calculation.

Settings Procedure for FFT Analysis

Function Selection

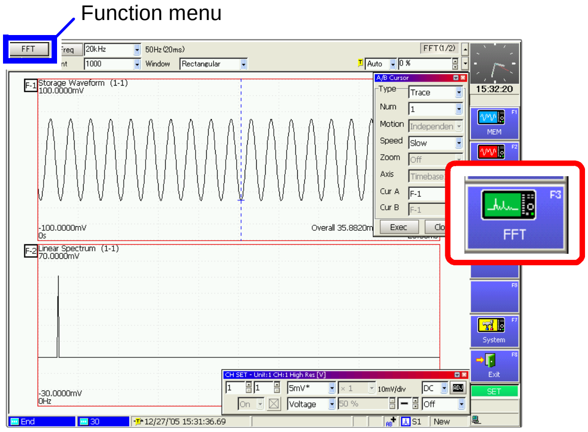
Select the FFT function (⇒ p. 51).

Opening screen:
Press the F3 [FFT] key.



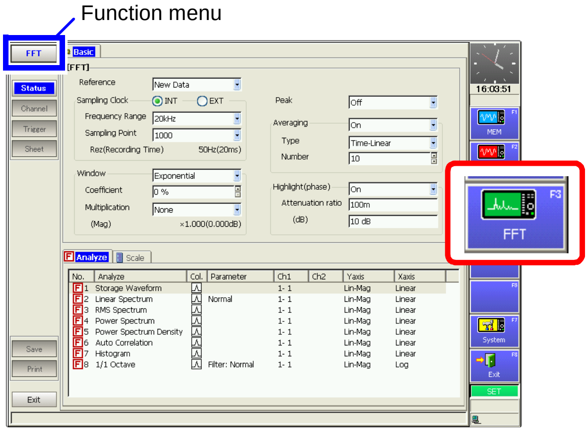
Waveform screen or Settings screen:
Using the CURSOR keys, move the cursor to the Function menu, and press the F3 [FFT] key.

Function menu



Waveform screen

Function menu

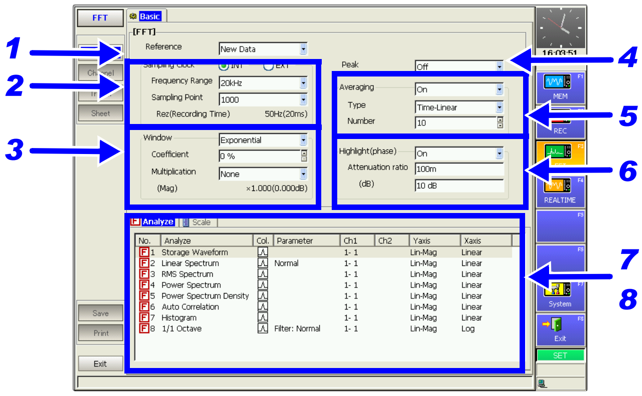


Settings screen

Measurement Configuration Settings

Press the SET key to open the Settings screen
Press the SUB MENU keys to select the Status menu

Make settings on the Status Settings screen.



See "3.4 Setting FFT Analysis Conditions" (⇒ p. 51)

1 Select the input data
Select whether to analyze newly acquired data, or existing data.

2 Select the frequency range and number of points for FFT analysis

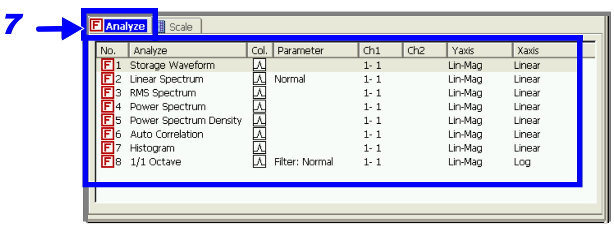
3 Select the desired window function
Set the window function to be applied to the input signal.

4 Select the peak value display
Select whether to display local or global maximum result values (maximal/ maximum).

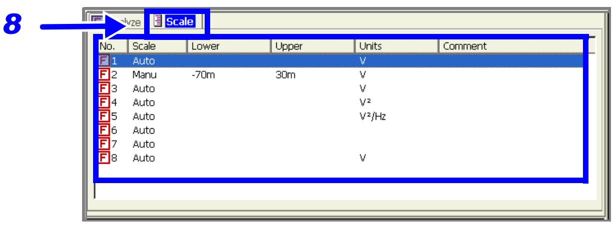
5 Set averaging
If averaging is desired, select the method and count for averaging.

6 Set highlighting (attenuation correction rate, for phase spectrum analysis only)
Select whether a spectrum is to be displayed with highlighting. If highlighting, sets the attenuation correction ratio to the maximum value of the power spectrum (or cross-power spectrum).

7 Select the analysis type
Select the analysis type, x axis, y axis, waveform color and channels to be analyzed (up to eight).



8 Set scaling
Set the display scale of the vertical (y) axis.



Input Channel Settings

Press the SUB MENU keys to select the **Channel** menu
Press the SHEET/PAGE keys to select the [One Ch] page

9 **Select the Unit (module) and Channel**

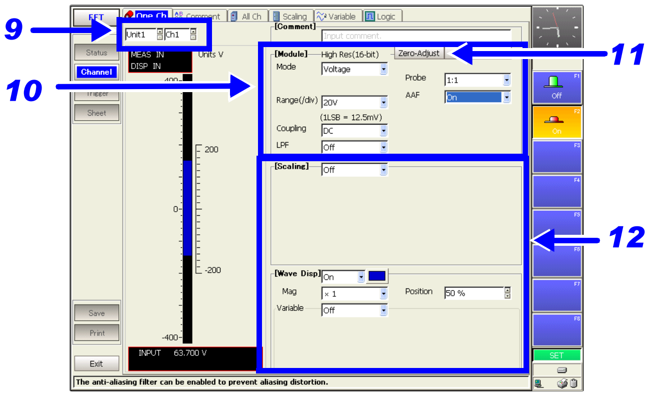
10 **Select the measurement range (vertical axis)**
Make input-module-related settings

11 **Perform zero adjustment**

(after warm-up)

12 (As occasion demands)
Set the scaling

Make settings on the Channel Settings screen.



See "3.5 Selecting Channels" (⇒ p. 69)

Trigger Settings

Press the SUB MENU keys to select the **Trigger** menu

13 **Set the trigger mode**

Default setting: [Auto]

14 **Set the trigger criteria (AND/OR)**

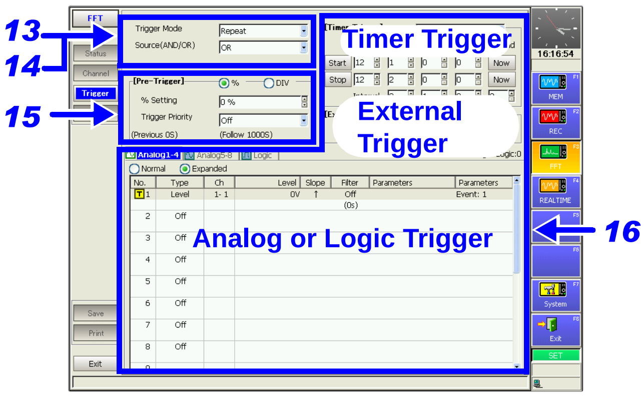
Default setting: [OR]

15 (As occasion demands) Set pre-trigger

16 **Set each trigger source**

Default setting: All [Off]

(If you want to record a specific waveform, such as an anomaly)
Set on the Trigger Settings screen.



Settings are the same as for the Memory function.
See "Chapter 6 Trigger Settings" in the *Instruction Manual*

Display Sheet Settings

Press the SUB MENU keys to select the Sheet menu

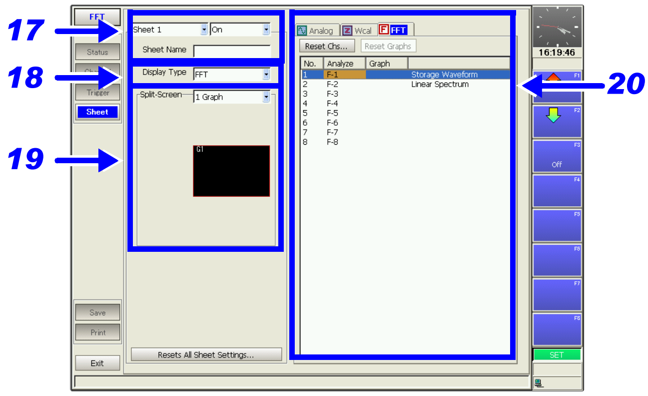
(Configure the Waveform screen display layout)
Set on the Sheet Settings screen.

17 **Select the Sheet No. on which to display FFT analysis results**
(Enter a Sheet name as needed)

18 **Select the Display Type**

19 **Select the split-screen number for the graph**

20 **Select the Analysis No. (F1 to F8) to be displayed**
Select the Analysis No. to display on each Sheet.



See "3.6 Setting the Screen Layout of the Waveform

Saving Settings

Press the SUB MENUs key to select the Save menu

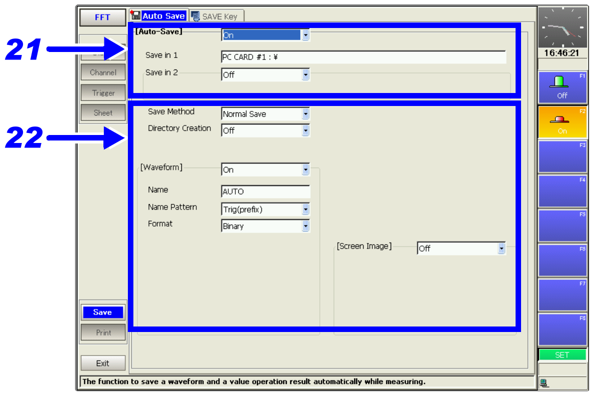
(If you want to save data)
Set on the Save Settings screen.

21 **Select automatic or manual saving**
Specify the saving destination

Verify that storage media has been inserted.
When saving manually, settings can be changed after measurement.

Default setting:
Auto Save [Off],
Manual Save [Selection Save]

22 **Select what to save**



(Example: Auto Save)

See "Chapter 10 Saving/Loading Data & Managing Files" in the *Instruction Manual*

Printing Settings

Press the SUB MENU keys to select the Print menu
Press the SHEET/PAGE keys to select the [Printer] page

23 Select automatic or manual printing

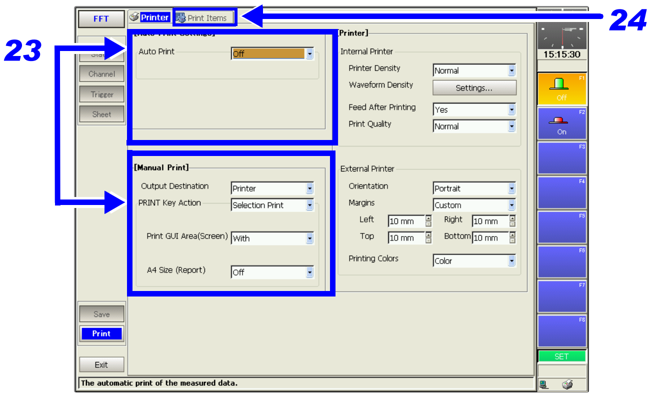
Verify that the paper is loaded correctly.
When printing manually, settings can be made after measurement.

Default setting:
Auto Print [Off]
Manual Print [Selection Print]

Press the SHEET/PAGE keys to select the [Print Items] page

24 Select what you want to print

(If you want to print data)
Set on the Print Settings screen.

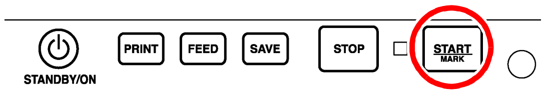


See "Chapter 11 Printing" in the *Instruction Manual*

Start of Measurement

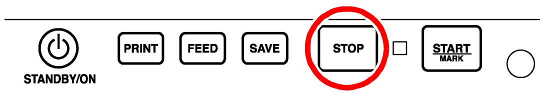
Data acquisition
Save & Print (when Auto enabled)

Press the START key. (the green LED lights)



End of Measurement

Press the STOP key.
Recording stops after acquiring the specified length (the green LED goes off).



Press twice to stop immediately.
If [Single] trigger is selected, recording stops automatically after acquiring the specified data length.

Data Analysis

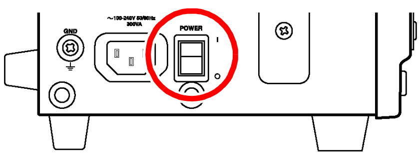
Analysis on the waveform screen.
See "3.9 Analysis with the Waveform Screen" (⇒ p. 78)

Optionally Save and Print

Press the SAVE key to save. (Manual saving)
Press the PRINT key to print. (Manual printing)

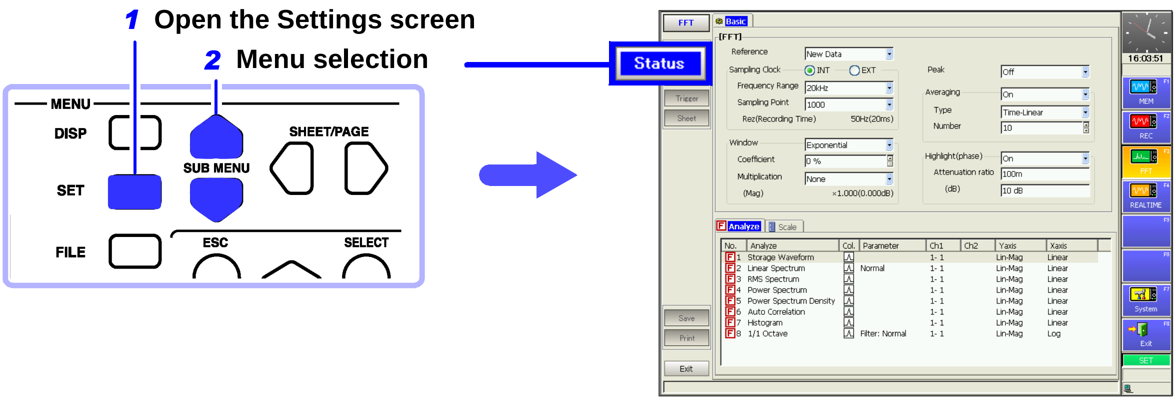
Power OFF

Remove the cables from the measurement object, and turn the power off.



3.4 Setting FFT Analysis Conditions

Basic measurement configuration settings are performed on the Status Settings screen. Measurement configuration can be performed from the Waveform screen (⇒ p. 67).



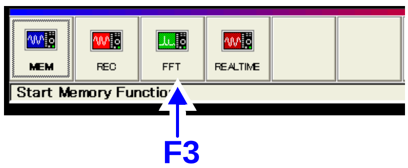
3.4.1 Selecting the FFT Function

The FFT function can be selected from the Opening, Waveform or Settings screen.

Function Selection: From the Opening Screen

	Operating Key	Procedure
1	**CURSOR**	Move to the desired function.
2	**F1 to F8**	Select the appropriate function.

Opening Screen



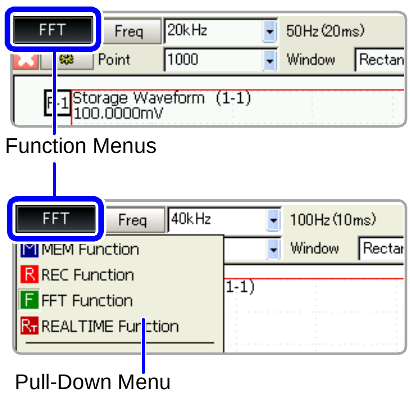
Function Selection: From the Waveform or Settings Screen

	Operating Key	Procedure
1	**CURSOR**	Move to the function menu (at the top left).
2	**F3**	Select the FFT function.

(Select from the pull-down menu)

SELECT	The pull-down menu appears.
CURSOR	Select the appropriate function.
ENTER	Accepts the setting.

Waveform Screen



3.4.2 Selecting the Data Source for Analysis

Select the data to be used for FFT analysis.
Analysis can be applied either to new data as it is measured, or to existing data (previously recorded to memory).

Selecting Input Data

FFT

To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40), To set from the Waveform screen (⇒ p. 67)

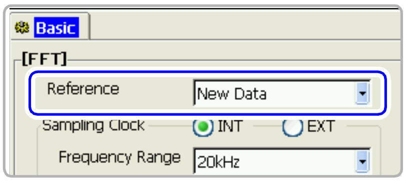
Operating Key Procedure

1 **Select the input data source.**

CURSOR Move the cursor to the [Reference] item.

F1 to F8 Selects the data to be analyzed.

New Data	Acquire a new waveform for analysis.
From Mem	Analyze a waveform recorded in memory.



2 **When finished making settings, press the START key**

For the [New Data] case

Measurement starts to acquire data for the number of analysis points specified as the [Sampling Point], and FFT analysis is performed.

For the [From Mem] case

Analysis is performed on the number of specified points from data previously recorded in memory (Memory function data).
The analysis starting point can also be specified.

See "3.9.3 Analyzing after Specifying an Analysis Starting Point" (⇒ p. 80)

The frequency range is selected automatically.

See "Relationship Between Frequency Range, Resolution and Number of Analysis Points" (⇒ p. 55)

When the trigger mode is [Repeat] or [Auto], and the input data [Reference] is [From Mem]

Analysis is performed until the specified number of FFT analysis points have been processed, then the data is shifted by that amount and analysis repeats until all of the previously acquired data has been processed. (If the amount of data is less than the specified number of FFT analysis points, no analysis occurs.)

See "Trigger Modes and Averaging" (⇒ p. 60)

When no trace is displayed after pressing the START key

Analysis is impossible if [From Mem] is selected as the input data source and no recorded data exists in the instrument's memory.
Either select [New Data] as the input data source, or load the data to be analyzed before pressing the START key again.

3.4.3 Setting the Frequency Range and Number of Analysis Points

About the frequency range and number of analysis points

The settings for the frequency range and number of analysis points determine the input signal acquisition time and frequency resolution.
The frequency range setting for the FFT function corresponds to the timebase (time/division) setting of the Memory function. Changing the frequency range also changes the data sampling period.

See "Relationship Between Frequency Range, Resolution and Number of Analysis Points" (⇒ p. 55)

The cut-off frequency of the anti-aliasing filter is the same as the frequency range setting.

The set number of analysis points specifies the amount of data to be analyzed with each measurement. Increasing the number of analysis points increases the frequency resolution, but also increases the time required for calculations.

See "Number of Analysis Points" (⇒ p. 105)

When using the external sampling to calculate:

Set the Sampling Clock to [EXT] (External sampling).
In this case, octave analysis, power spectrum density and LPC power spectrum density are not available.

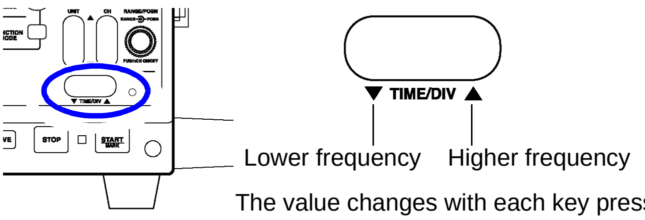
The following two methods are available for setting the frequency range:

- Using the operating keys
- Using the **TIME/DIV** key (settable regardless of cursor position)

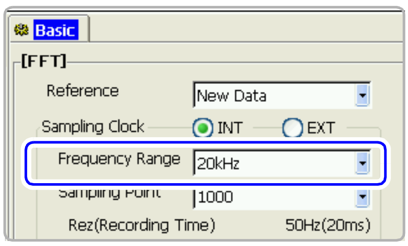
Frequency Range Setting: Using the TIME/DIV Key FFT

To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40), To set from the Waveform screen (⇒ p. 67)



The value changes with each key press.



Frequency Range and No. of Analysis Points Settings: Using the Operating Keys

FFT

To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40), To set from the Waveform screen (⇒ p. 67)

Operating Key Procedure

1 Select the sampling clock.

Operating Key	Procedure
CURSOR	Move the cursor to the [Sampling Clock] item.
F1	Select [INT] (Internal). (default setting)

2 Select the frequency range.

Operating Key	Procedure
CURSOR	Move the cursor to the [Frequency Range] item.
F1 to F8 (Switch Display: F8)	Select the frequency range.

8 (default setting), 4, 2 MHz
800, 400, 200, 80, 40, 20, 8, 4, 2 kHz
800, 400, 200, 80, 40, 20, 8, 4, 1.33 Hz
800, 667, 400, 333, 133 mHz

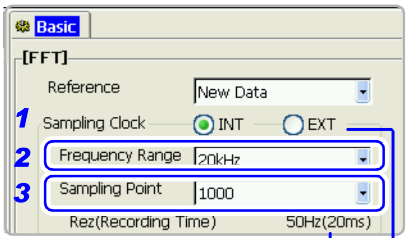
See "Relationship Between Frequency Range, Resolution and Number of Analysis Points" (⇒ p. 55)

3 Set the number of FFT analysis points.

Operating Key	Procedure
CURSOR	Move the cursor to [Sampling Point]
F1 to F8 (Switch Display: F8)	Select the number of points for analysis.

1000(default setting), 2000, 5000, 10000

See "Number of Analysis Points" (⇒ p. 105)



Frequency Resolution (during acquisition)
The resolution is affected by settings of frequency range and the number of analysis points. Not displayed for external sampling.

Normally, select [INT].

To control sampling by an external signal, select [EXT]
In this case, set only the number of analysis points.

When [From Mem] is selected as the input data source
The frequency range is set automatically when analysis is started.

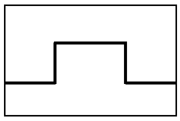
Relationship Between Frequency Range, Resolution and Number of Analysis Points

Range [Hz]	Sampling frequency [Hz]	Timebase [/div] (MEM)	Sampling period	Number of FFT Analysis Points							
				1,000		2,000		5,000		10,000	
				Resolution [Hz]	Acquisition interval	Resolution [Hz]	Acquisition interval	Resolution [Hz]	Acquisition interval	Resolution [Hz]	Acquisition interval
8 M *1	20 M	5 µs	50 ns	20 k	50 µs	10 k	100 µs	4 k	250 µs	2 k	500 µs
4 M *1	10 M	10 µs	100 ns	10 k	100 µs	5 k	200 µs	2 k	500 µs	1 k	1 ms
2 M *1	5 M	20 µs	200 ns	5 k	200 µs	2.5 k	400 µs	1 k	1 ms	500	2 ms
800 k *1	2 M	50 µs	500 ns	2 k	500 µs	1 k	1 ms	400	2.5 ms	200	5 ms
400 k *1	1 M	100 µs	1 µs	1 k	1 ms	500	2 ms	200	5 ms	100	10 ms
200 k *1	500 k	200 µs	2 µs	500	2 ms	250	4 ms	100	10 ms	50	20 ms
80 k *1	200 k	500 µs	5 µs	200	5 ms	100	10 ms	40	25 ms	20	50 ms
40 k	100 k	1 ms	10 µs	100	10 ms	50	20 ms	20	50 ms	10	100 ms
20 k	50 k	2 ms	20 µs	50	20 ms	25	50 ms	10	100 ms	5	200 ms
8 k	20 k	5 ms	50 µs	20	50 ms	10	100 ms	4	250 ms	2	500 ms
4 k	10 k	10 ms	100 µs	10	100 ms	5	200 ms	2	500 ms	1	1 s
2 k	5 k	20 ms	200 µs	5	200 ms	2.5	400 ms	1	250 ms	500 m	2 s
800	2 k	50 ms	500 µs	2	500 ms	1	1 s	400 m	2.5 s	200 m	5 s
400	1 k	100 ms	1 ms	1	1 s	500 m	2 s	200 m	5 s	100 m	10 s
200	500	200 ms	2 ms	500 m	2 s	250 m	4 s	100 m	10 s	50 m	20 s
80	200	500 ms	5 ms	200 m	5 s	100 m	10 s	40 m	25 s	20 m	50 s
40	100	1 s	10 ms	100 m	10 s	50 m	20 s	20 m	50 s	10 m	100 s
20	50	2 s	20 ms	50 m	20 s	25 m	40 s	10 m	100 s	5 m	200 s
8 *2	20	5 s	50 ms	20 m	50 s	10 m	100 s	4 m	250 s	2 m	500 s
4 *2	10	10 s	100 ms	10 m	100 s	5 m	200 s	2 m	500 s	1 m	1 ks
1.33 *2	3.33	30 s	300 ms	3.33 m	300 s	1.66 m	600 s	666 µ	1.5 ks	333 µ	3 ks
800 m *2	2	50 s	500 ms	2 m	500 s	1 m	1 ks	400 µ	2.5 ks	200 µ	5 ks
667 m *2	1.67	60 s	600 ms	1.66 m	600 s	833 µ	1.2 ks	333 µ	3 ks	166 µ	6 ks
400 m *2	1	100 s	1 s	1 m	1 ks	500 µ	2 ks	200 µ	5 ks	100 µ	10 ks
333 m *2	833 m	120 s	1.2 s	833 µ	1.2 ks	416 µ	2.4 ks	166 µ	6 ks	83.3 µ	12 ks
133 m *2	333 m	300 s	3 s	333 µ	3 ks	166 µ	6 ks	66.6 µ	15 ks	33.3 µ	30 ks

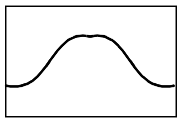
The cut-off frequency of the anti-aliasing filter is the same as the frequency range.
*1. The anti-aliasing filter is turned off.
*2. Cut-off frequency is 20 Hz.

3.4.4 Setting the Window Function

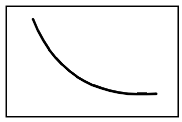
The window function defines the segment of the input signal to be analyzed. Use the window function to minimize leakage errors. There are three general types of window functions:



- Rectangular window



- Hann window
- Hamming window
- Blackman window
- Blackman-Harris window
- Flat top window



- Exponential window

The non-rectangular window functions generally produce lower-level analysis results. By applying attenuation correction, the attenuation introduced by the non-rectangular window functions can be corrected to bring analysis results back to similar levels.

Selecting the Window Function and Correction FFT

To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40), To set from the Waveform screen (⇒ p. 67)

Operating Key Procedure

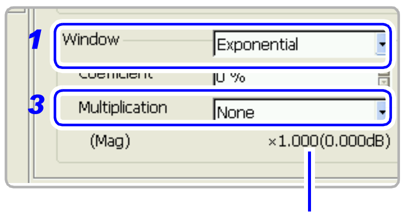
1 Select the window function.

CURSOR Move the cursor to the [Window] item.

F1 to F8 Select the appropriate window function type.

Rectangular (default setting), Hanning, Exponential, Hamming, Blackman, BlackmanHarris, FlatTop

See "Window Function" (⇒ p. 110)



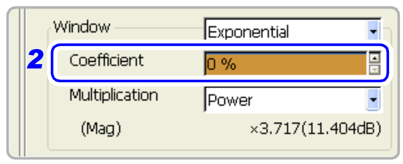
Correction value

2 If [Exponential] is the selected type

Set the attenuation coefficient (percentage).

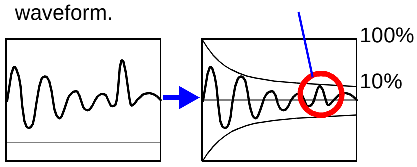
CURSOR Move the cursor to the [Coefficient] item.

F1 to F8 Set the attenuation coefficient as a percentage. Setting the attenuation coefficient to 0% results in the same processing as a setting of 0.1%.



For the exponential window function

Noise is suppressed in the attenuated waveform.



When the attenuation rate is 10%

3 Set attenuation correction.

CURSOR Move the cursor to the [Multiplication] item.

F1 to F8 Select the correction method.

None	Attenuated window function values are not corrected. (default setting)
Power	The window function multiplies the power levels of the time-domain waveform so that output levels are comparable to those of a rectangular window.
Average	The window function multiplies the average value of the time-domain waveform so that output levels are comparable to those of a rectangular window.

For the rectangular window function:
The correction value is always 1 (0 dB).
For the exponential window function:
The correction value depends on the attenuation coefficient.

Power correction	$\sqrt{\dfrac{2\ln(x/100)}{(x/100)^2-1}}$
Average correction	$\dfrac{\ln(x/100)}{(x/100)-1}$

x: Attenuation coefficient (%)

3.4.5 Setting Peak Values of Analysis Results

Either local or global maxima ([maximal]/ [maximum]) of the input signal and analysis results can be displayed on the Waveform screen. However, if Nyquist display is selected on the Sheet Settings screen, no peak values are displayed.

Selecting Displayed Values **FFT**

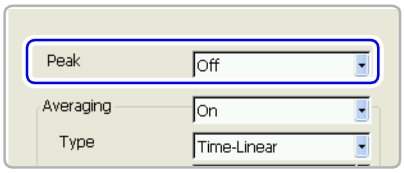
To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40)

Operating Key	Procedure

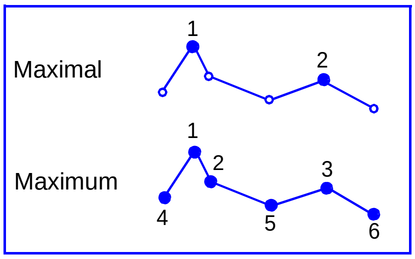
Selecting peak value display.

CURSOR Move the cursor to the [Peak] item.



F1 to F8 Select the type of numerical value to be displayed.

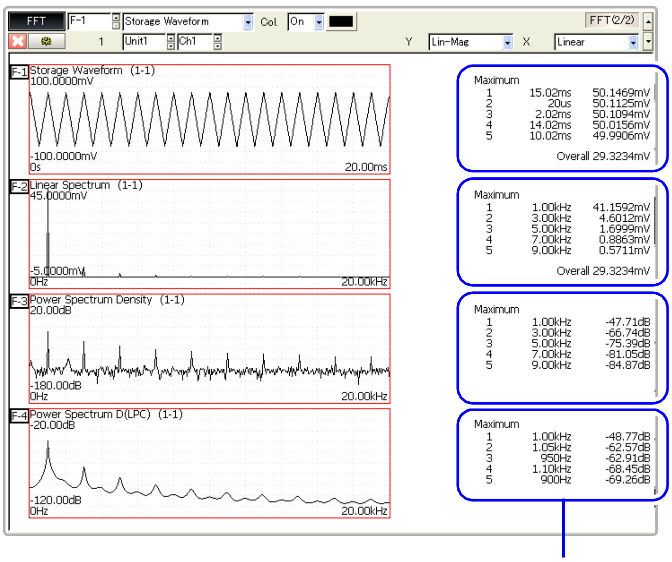
Off	Not displayed.(default setting)
Maximal	(local maxima) When the value of data at a point is greater than that of the adjacent points, that data is considered a local maxima. The ten largest local maxima are displayed.
Maximum	(global maxima) Among all data values, the ten points with the greatest values are displayed.



NOTE

- Peak values on the Waveform screen can be displayed and printed, but cannot be saved as peak values in text files.
- Depending on split-screen settings, there may be insufficient space to display all ten maxima. In this case, only the number of maxima that can be displayed are shown, from the largest.

Example: 4-Section Split-Screen



Peak value display
From 1 to 5

3.4.6 Averaging Waveforms

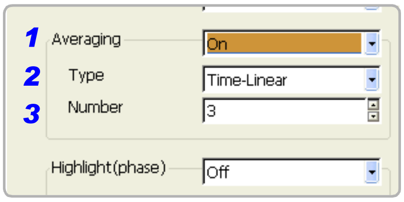
The averaging function calculates the average of the values obtained from multiple measurements of a periodic waveform. This can reduce noise and other non-periodic signal components. Averaging can be applied to a time-domain waveform or to a spectrum.

Averaging Settings

FFT

To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40)



Operating Key	Procedure

1 **Enable averaging.**

CURSOR Move the cursor to the [Averaging] item.

F1 to F8 Select whether to enable or disable averaging.

Off	Averaging is disabled (default setting)
On	Averaging is enabled.

2 **Select the type of averaging.**

CURSOR Move the cursor to the [Type] item.

F1 to F8 Select from the following types:

Time-Linear	Perform simple (linear) averaging of time-domain waveform values.
Time-Exponential	Perform exponential averaging of time-domain waveform values.
Freq-Linear	Perform simple (linear) linear averaging of (frequency-domain) spectrum values.
Freq-Exponential	Perform exponential averaging of (frequency-domain) spectrum values.
Freq-Peak Hold	Retain the maximum value of (frequency-domain) spectrum values.

About averaging calculation formulas

See "Averaging" (⇒ p. 109)

When averaging and auto saving or auto printing are enabled at the same time

Data is saved or printed after the specified count of values have been averaged.

After calculating the average, changing the analysis channel does not cause recalculation.

3 **Select the count for averaging.**

CURSOR Move the cursor to the [Number] item.

F1 to F8 Select the number of measurements to be averaged.
Setting range: 2 to 10,000

NOTE

- After measuring with averaging enabled, display is not available when the channel is changed. Also, when the analysis mode is changed, the analysis modes that can be displayed are limited.
- When averaging is performed with the analysis mode disabled (Off), no trace is displayed when the analysis mode is changed after measurement.

Description

See "Trigger Modes and Averaging" (⇒ p. 60)

When averaging time-domain waveform values

Waveforms are acquired and averaged within the time domain. After averaging, FFT calculation is performed.
When the trigger mode is [Auto]: Data is acquired when the START key is pressed, even if trigger criteria are not met after a certain interval. So if averaging is applied to an asynchronous signal, the resulting data is meaningless.
Synchronous signals have better SNR (signal-to-noise ratio) and are more suitable for analysis.

When averaging spectrum values

Acquired data is first subject to FFT analysis. After analysis, averaging is performed within the frequency range, and the result is displayed. This differs from time-domain averaging in that averaging can be performed without trigger synchronization. However, if the characteristics of the input waveform allow triggering, using the trigger for synchronization is recommended.

Spectrum peak hold

After performing FFT calculations on the acquired waveform, peak values are retained (held) and displayed within the frequency range.

FFT Analysis Modes and Averaging

●: Settable, ×: Unsettable, O: Partially settable

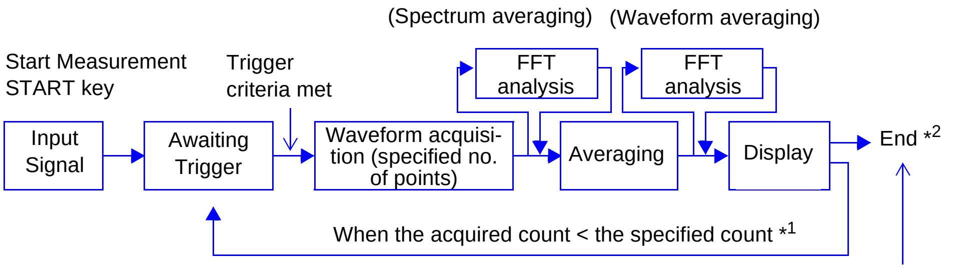
Analysis Mode	Averaging				
	Waveform Averaging		Spectrum Averaging		
	Simple	Exponential	Simple	Exponential	Peak Hold
OFF	×	×	×	×	×
Storage Waveform	●	●	×	×	×
Linear Spectrum	●	●	O *2	O *2	O *2
RMS Spectrum	●	●	O *2	O *2	O *2
Power Spectrum	●	●	●	●	●
Power Spectrum Density *1	●	●	●	●	●
Auto-correlation Function	●	●	●	●	●
Histogram	●	●	×	×	×
1/1 Octave Analysis *1	●	●	●	●	●
1/3 Octave Analysis *1	●	●	●	●	●
Transfer Function	●	●	O *2	O *2	O *2
Cross Power Spectrum	●	●	O *2	O *2	O *2
Cross-correlation Function	●	●	●	●	●
Impulse Response	●	●	●	●	●
Coherence Function	×	×	●	●	×
Phase Spectrum	●	●	×	×	×
Power Spectrum Density (LPC) *1	●	●	×	×	×

*1. Not available for external sampling
*2. Not available when the y axis is real (linear) or imaginary (linear), or for Nyquist plots

Trigger Modes and Averaging

When the trigger mode is [Single]

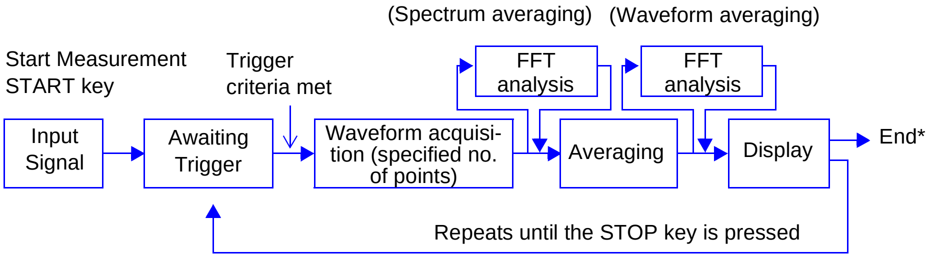
Measurements continue until the specified number of averaging points is acquired.



*1. Awaiting trigger continues until the specified count is reached.
*2. Measurement stops automatically when the specified count is reached. If measurement was interrupted by the STOP key, the averaging result up to that point is displayed.

When the trigger mode is [Repeat]

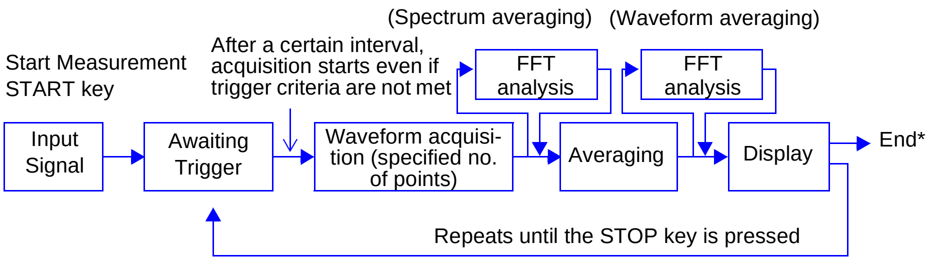
Measurement continues after the specified averaging count has been acquired.
When the specified averaging count is exceeded, averaging is repeated and measurement continues until the STOP key is pressed.



* When stopped before the specified count, the average up to that point is displayed.

When the trigger mode is [Auto]

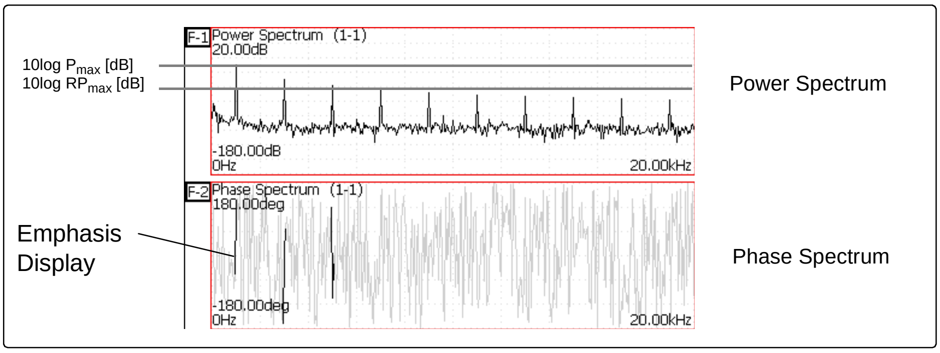
- For time-domain waveforms:
  Data is acquired when the START key is pressed, even if trigger criteria are not met after a certain interval. So if averaging is applied to an asynchronous signal, the resulting data is meaningless.
- For spectrum values:
  When the START key is pressed, measurement starts. Even if the trigger criteria are not met, the specified amount of data is acquired, and after FFT analysis, the results are averaged.
  When the specified averaging count is exceeded, averaging is repeated and measurement continues until the STOP key is pressed.



* When stopped before the specified count, the average up to that point is displayed.

3.4.7 Emphasizing Analysis Results (phase spectra only)

By specifying a setting factor (rate) to be applied to the input signal, the display of data exceeding the resulting threshold can be emphasized. This feature is useful for viewing waveforms that may otherwise be obscured by noise.
The reliability of phase spectrum values is poor when discrete Fourier transform values are extremely small. For example, in the case of a pure sine wave, almost all phase values at frequencies other than the input frequency result from calculation errors. By treating the maximum value of the power (or cross-power) spectrum of the input signal, P_{max}, as a reference value, data that exceeds that value multiplied by rate R can be displayed with emphasis.



Setting Phase Spectrum Highlighting **FFT**

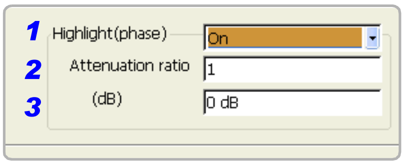
To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen
See Screen Layout (⇒ p. 40)

Operating Key | Procedure

1 **Enable the highlighting function.**

Operating Key	Procedure
CURSOR	Move the cursor to the [Highlight (phase)] item.
F1 to F8	Select whether to enable or disable the highlighting function.

Off	Emphasis display disabled.(default setting)
On	Emphasis display enabled.



2 **Set the attenuation rate or attenuation value.**

To set an attenuation rate

Operating Key	Procedure
CURSOR	Move the cursor to the [Attenuation ratio] item.
F1 to F8	Enter the attenuation rate.

To set an attenuation value [dB]

Operating Key	Procedure
CURSOR	Move the cursor to the [(dB)] item.
F1 to F8	Enter the attenuation value.

Attenuation Rate and Value
Attenuation value: A [dB]
Attenuation rate: R

$-A = 10\log_{10}R$
$1 \times 10^{-6} \leq R \leq 1$
$0 \leq A \leq 60$

3.4.8 Analysis Mode Settings

Select the type of FFT analysis, channel(s), waveform display color and x and y axes.

Analysis Content Settings

FFT

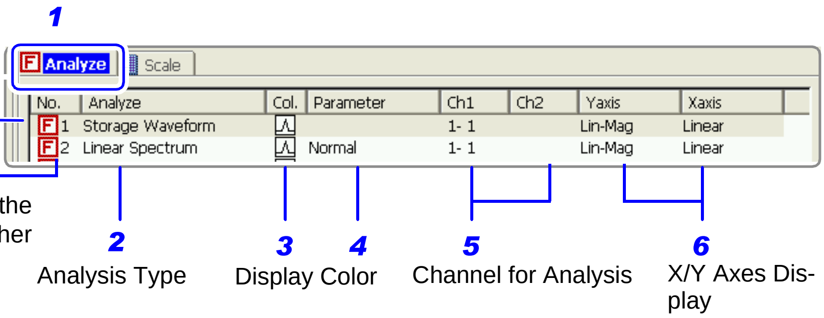
To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40), To set from the Waveform screen (⇒ p. 67)

Operating Key Procedure

1 Open the [Analyze] page.

SHEET/PAGE Select the [Analyze] page.



Analysis Setting Contents

Analysis No.
Settings can be made from the dialogs, or copied from another Analysis No. (⇒ p. 65)

2 Select the FFT analysis mode.

CURSOR Move the cursor to the [Analyze] column of the Analysis No. to set.

F1 to F8 (Switch Display: F8) Select the analysis mode.

OFF	No analysis. (default setting)	**1/1 Octave***	Example (⇒ p. 91)
		1/3 Octave*	Example (⇒ p. 91)
Storage Waveform	Example (⇒ p. 85)	**Phase Spectrum**	Example (⇒ p. 95)
Linear Spectrum	Example (⇒ p. 86)	**Transfer Function**	Example (⇒ p. 96)
RMS Spectrum	Example (⇒ p. 87)	**Cross Power Spectrum**	Example (⇒ p. 97)
Power Spectrum	Example (⇒ p. 88)		
Pow.Spectrum Density*	(Power spectrum density) Example (⇒ p. 89)	**Cross Correlation**	Example (⇒ p. 98)
		Impulse Response	Example (⇒ p. 99)
Auto Correlation	Example (⇒ p. 90)	**Coherence**	Example (⇒ p. 100)
Histogram	Example (⇒ p. 90)	**Pow.Spectrum Density (LPC)***	(Power spectrum density LPC) Example (⇒ p. 101)

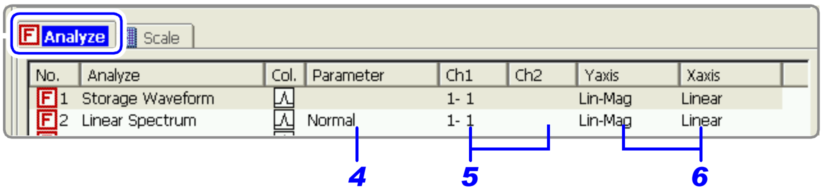
* Not available with external sampling enabled.

See "3.10.2 Analysis Mode Functions" (⇒ p. 102)

3 Select whether to display the waveform, and its color.

CURSOR Move the cursor to the [Col.] column.

F1 to F8 Select whether the waveform is to be displayed (On) or not, and its color if displayed.



Operating Key Procedure

4 When [Parameter] setting contents are displayed

Set the parameter.

CURSOR Move the cursor to the [Parameter] column of the Analysis No. to set.

F1 to F8 Select the desired type of analysis or display.

Analyze mode	Parameter	Setting Contents
Linear Spectrum, Transfer Function, Cross Power Spectrum	**Normal**	Analysis results are displayed as amplitude vs. frequency.
	Nyquist	Analysis results are displayed as imaginary vs. real components.
1/1 Octave, 1/3 Octave	**Filter: Normal**	Enables the octave filter.
	Filter: Sharp	See "Octave Filter Setting" (⇒ p. 64)
Phase Spectrum	**1ch FFT**	Calculates the phase of [Channel 1].
	2ch FFT	Calculates the phase difference between [Channel 1] and [Channel 2].
Pow.Spectrum Density (LPC)	**Order:2 to 64**	Larger numerical values make finer spectrum components visible.

5 Select the channel for analysis.

CURSOR Move the cursor to the [Ch1] item.

F1 to F8 Select which channel number to use.

6 Set the x and y axes for display of analysis results.

CURSOR Move the cursor to the [X axis] or [Y axis] item.

F1 to F8 Select the analysis result components to display on the x and y axes.
(Selectable display components depend on the analysis mode)
See "Analysis Modes and X/Y Axis Display" (⇒ p. 64)

Y-axis display

Lin-Mag	Analysis results are displayed as amplitude values.
Log-Mag	Analysis results are displayed as dB values.
Lin-Real	The real-number component of analysis results are displayed.
Lin-Imag	The imaginary component of analysis results are displayed.

X-axis display

Linear	Frequency is displayed linearly.
Log	Frequency is displayed logarithmically. This is convenient when the data of interest is at the lower end of the frequency range, such as for sound and vibration.

Analysis channel setting

For any of the following analysis modes, set both channels 1 and 2.

Transfer Function, Impulse Response, Cross-correlation Function, Cross Power Spectrum, Coherence Function, Phase Spectrum (2ch FFT)

To analyze without the influence of aliasing distortion

The following input modules are recommended for channels to be subject to FFT analysis:

- Model 8938 FFT Analog Unit
- Model 8947 Chargh Unit
- Model 8957 High Resolution Unit
- Model 8960 Strain Unit

To analyze using external sampling

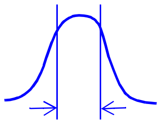
The x axis displays the number of data points.

For Nyquist display

When the [Nyquist Display] parameter settings is selected, x- and y-axis display settings are not available.

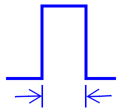
Octave Filter Setting

Filter characteristics comply with tolerance standards for IEC61260 filters.



Normal

Filter characteristics approximate those of an analog filter.



Sharp

Only those spectral component within the octave band are used for analysis. Spectral components outside of the octave band are totally ignored.

After determining the entire power spectrum, the instrument performs octave analysis on the spectral bands defined by the above filter characteristics. Analog filtering is not used for analysis.

See "Octave Filter Characteristics" (⇒ p. 114)

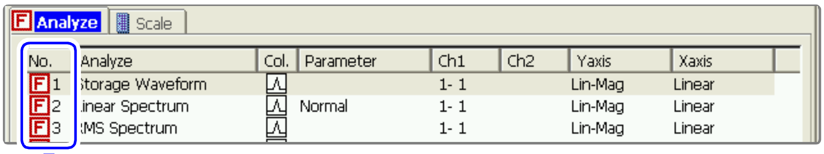
Analysis Modes and X/Y Axis Display

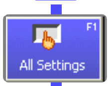
O: Selectable, ×: Unselectable

Analysis Mode	X axis		Y axis				Nyquist display
	Linear	Log	Lin-Mag	Log-Mag	Lin-Real	Lin-Imag	
OFF	×	×	×	×	×	×	×
Storage Waveform	O	×	O	×	×	×	×
Linear Spectrum	O	O	O	O	O	O	O
RMS Spectrum	O	O	O	O	O	O	×
Power Spectrum	O	O	O	O	×	×	×
Power Spectrum Density	O	O	O	O	×	×	×
Auto-correlation Function	O	×	O	×	×	×	×
Histogram	O	×	O	×	×	×	×
1/1 Octave	O	O	O	O	×	×	×
1/3 Octave	O	O	O	O	×	×	×
Transfer Function	O	O	O	O	O	O	O
Cross Power Spectrum	O	O	O	O	O	O	O
Cross-correlation Function	O	×	O	×	×	×	×
Impulse Response	O	×	O	×	×	×	×
Coherence Function	O	O	O	×	×	×	×
Phase Spectrum	O	O	O	×	×	×	×
Power Spectrum Density (LPC)	O	O	O	O	×	×	×

The x/y axes cannot be set when Nyquist Display is selected.

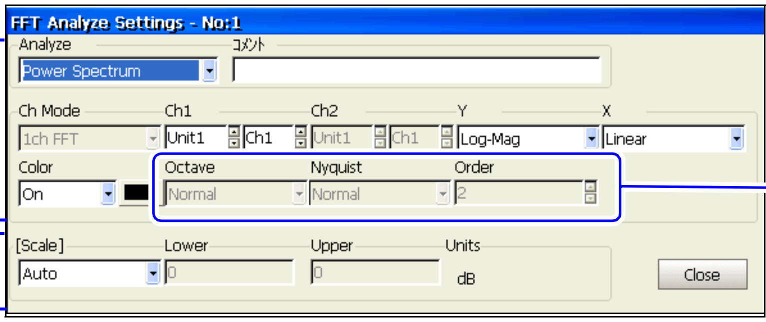
To Set from a Dialog





Move the cursor to the [No.] column of the Analysis to set, and press F1 [All Settings].

A dialog box appears. Items that cannot be set for the particular analysis mode are grayed out.
Move the cursor to each item, and select with the F1 to F8 keys.

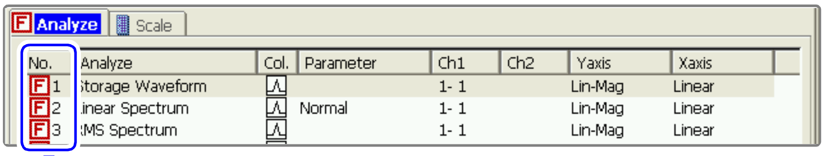


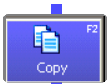
These are the same as the setting contents on the [Analyze] page.

These are the same as the setting contents on the [Scale] page.

Parameter Settings

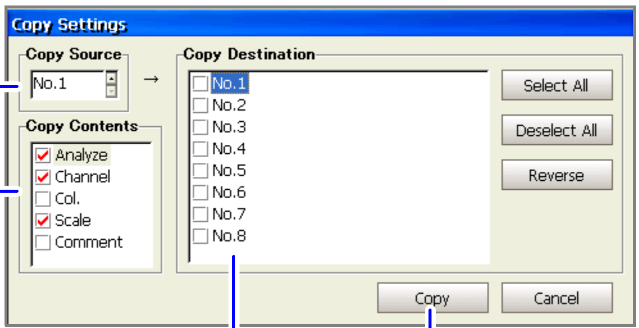
To copy settings between Calculation Nos.





Move the cursor to the [No.] column of the Analysis to copy, and press F2 [Copy].

A dialog box appears.
Make settings in the dialog with the F keys or dialog buttons.



1 Select the Analysis No. of the copy source.

2 Select the contents to copy.

3 Select the Analysis No. of the copy destination.

4 Make the desired settings, and click Copy (or F7 [Copy]).

3.4.9 Setting the Display Range of the Vertical Axis (Scaling)

The display range of the vertical (y) axis can be set to automatically suit analysis results, and can be freely expanded and compressed.

Vertical Axis (Scaling) Setting

FFT

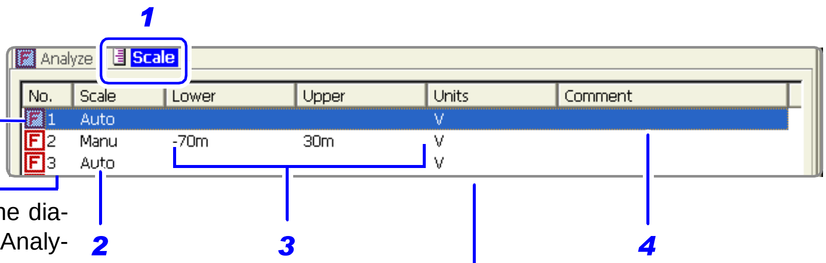
To open the screen: Press the **SET** key → Select **Status** with the **SUB MENU** keys →Status Settings screen

See Screen Layout (⇒ p. 40)

Operating Key | Procedure

1 Open the [Scale] page.

SHEET/PAGE Select the [Scale] page.



Analysis Setting Contents

Calculation No.
Settings can be made from the dialogs, or copied from another Analysis No. (⇒ p. 65)

2 Select automatic or manual scaling of the y-axis display.

CURSOR Move the cursor to the [Scale] column of the Analysis No. to set.

F1 to F8 Select the scaling display type.

Auto	Scaling of the vertical (y) axis is automatically set according to analysis results. (default setting)
Manu (manual)	Scaling of the vertical (y) axis can be set as desired, to suit the purpose of the measurement. This is useful for magnifying or reducing the displayed amplitude, and for shifting the displayed waveform up or down.

About displayed units (y axis)

The selected units for the scaled channel are displayed. When scaling is disabled [Off], the measurement range units are displayed.
To convert to other units, set the scaling units on the Channel Settings screen.

See "5.4 Converting Input Values (Scaling Function)" in the *Instruction Manual*

Input values can be converted to dB.

See "Scaling" (⇒ p. 71)

3 When [Manu] is selected

Set the upper and lower limits to display.

CURSOR Move the cursor to the [Lower] or [Upper] item.

F1 to F8 Set the upper and lower limits to display the analysis results.
Setting range: -9.9999E+29 to +9.9999E+29
(with exponent from E-29 to E+29)

4 To enter a comment for an analysis result

CURSOR Move the cursor to the [Comment] item.

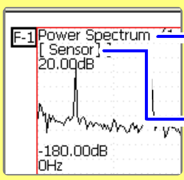
F1 Enter your comment.
The entry method is the same as for channel comments.

See "5.2.2 Adding Channel Comments";"Comment Entry Example" in the *Instruction Manual*

To display comments on the Waveform screen

Enable the [Comment] setting on the System Settings screen.

When comments are entered on both the Channel Settings screen and the [Analyze] page, both comments are displayed. When no channel comment has been entered, unit (module) and channel number are displayed.



Channel Comment (when not set)

[Scale] Page Comment

3.4.10 Setting and Changing Analysis Conditions on the Waveform Screen

The following settings can be made on the Waveform screen.
Press the **SUB MENU** keys to switch the displayed measurement items.
Changes to the displayed analysis results become effective when the settings are changed.

- **[FFT(1/2)]**
  Available settings are frequency range, number of analysis points, type of window function, trigger mode and pre-triggering
- **[FFT(2/2)]**
  Available settings are analysis number, analysis mode, waveform color, analysis channel and x/y axis display type
- **[Trigger]**
  Available settings are trigger number and analog trigger settings

To change the analysis number to be displayed on the current Sheet, press the F5 [Channel Set] key in the FN mode, and make settings in the dialog (⇒ p. 68).

Changes can be made to frequency range, number of analysis points, type of window function, trigger mode and pre-triggering

1 **Press the SUB MENU key to display [FFT(1/2)].**

2 **Use the CURSOR keys to move the cursor to each setting item, and select your choice with the F keys.**

Frequency Range (⇒ p. 53)
Select whether to sample from an internal (input module) or external (External Control terminal) source.

Select the frequency range (133 mHz to 8 MHz).

Frequency Resolution (during acquisition)

FFT Window Function Type (⇒ p. 56)

Number of Analysis Points (⇒ p. 53)
(1000, 2000, 5000, 10000)

Trigger mode and Pre-trigger
Select the trigger mode and pre-triggering (same as for the Memory function).
Trigger Mode: Single, Repeat, Auto
Pre-trigger: -100 to 100% (1% or 1div step)
See "6.3 Setting the Trigger Mode" and "6.5 Pre-Trigger Settings" in the *Instruction Manual*

Changing analysis number, analysis mode, waveform color, analysis channel and x/y axis display type

1 Press the **SUB MENU** key to display **[FFT(2/2)]**.

2 Use the **CURSOR** keys to move the cursor to each setting item, and select your choice with the F keys.

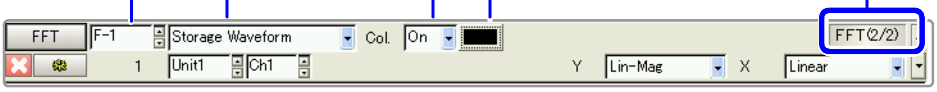
Analysis Number (⇒ p. 62)

This is linked to the setting on the [Analyze] page of the Status Settings screen.

Analysis Mode

Waveform Display On/Off

Waveform Color



Analysis Channel

X and Y Axis Display Type

Changing Analog Trigger Settings

See "6.12 Making Trigger Settings on the Waveform Screen" in the *Instruction Manual*

1 Press the **SUB MENU** key to display **[Trigger]**.

2 Use the **CURSOR** keys to move the cursor to each setting item, and select your choice with the F keys.

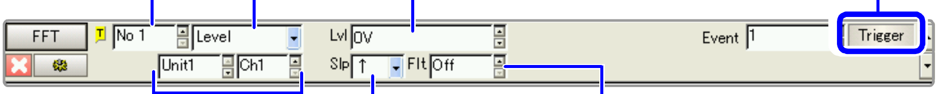
(When using Level Triggering)

Type of Analog Trigger

Trigger No.

Trigger Level

The display differs according to the type of analog triggering.



Unit and Channel No. for this trigger

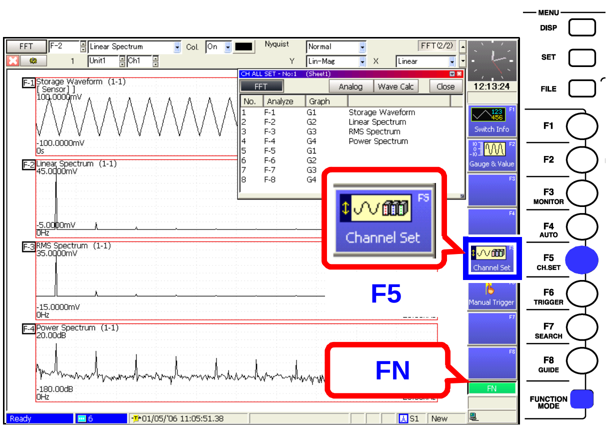
Slope

Filter

Changing the Analysis No. for Display

This setting is the same as that on the Display page of the Sheet Settings screen.

See "3.6 Setting the Screen Layout of the Waveform Screen" (⇒ p. 72)

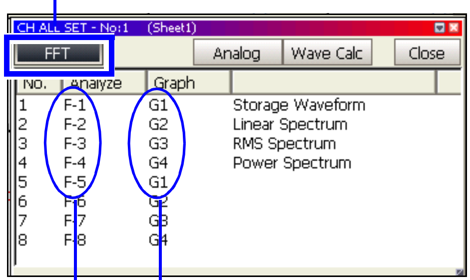


1

2

(FN: FUNCTION MODE)

3 Select [FFT].



4 Select the Analysis Nos. for display

5 Select the graph(s) for display.

3.5 Selecting Channels

Channel selection is the same for all functions. The setting examples here describe operation with the Model 8957 High Resolution Unit.

Channel Settings

MEM REC FFT

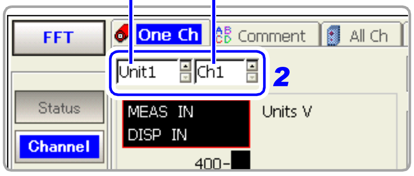
To open the screen: Press the **SET** key → Select **Channel** with the **SUB MENU** keys →Channel Settings screen

See Screen Layout (⇒ p. 41)

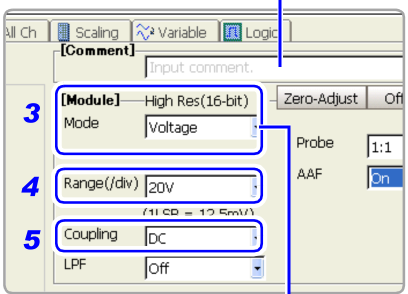
	Operating Key	Procedure
1	**SHEET/PAGE**	Select the [One Ch] page.
2	**Select the module (Unit) and channel number to be set.**	
	CURSOR	Move the cursor to each [Unit (no.)] and [Ch (no.)].
	F1 to F8	Select the module (Unit) number (Unit 1, 2, ...) and channel. (The type of the selected module is indicated beside the [Unit].)
3	**Verify the module type and measurement mode to be set.**	
		Verify that the [Mode] is set to [Voltage].
4	**Set the measurement range.**	
	CURSOR	Move the cursor to the [Range (/div)] item.
	F1 to F8	Set the vertical axis (voltage axis range).
		5 m, 10 m, 20 m, 50 m, 100 m, 200 m, 500 mV/div, 1, 2, 5, 10, 20 V/div
		The setting is the amplitude per division on the vertical axis. This setting can also be made with the **RANGE/POSN** knobs.
5	**Select the input signal coupling method (as occasion demands).**	
	CURSOR	Move the cursor to the [Coupling] item.
	F1 to F8	Select either choice.

DC	DC Coupling Select this to acquire both DC and AC components of an input signal.
AC	Select this to eliminate any DC component from an input signal. Use this to measure only the ripple component superimposed on pulsating current.
GND	The input signal is disconnected. Zero position can be confirmed.

Module (Unit) No. Channel No.



Comments can be entered for each channel.



Measurement Mode

When using an input module that can provide multiple types of measurement, select the type of measurement to be performed.

See "3.10.2 Setting Input Coupling" in the *Input Module Guide*

Operating Key	Procedure

6 Set low-pass filtering (as occasion demands).

CURSOR Move the cursor to the [LPF] item.

F1 to F8 Set the low-pass filter in the input module.

(For Model 8957) OFF, 5Hz, 50Hz, 500Hz, 5kHz, 50Hz

7 Select the probe attenuation.

CURSOR Move the cursor to the [Probe] item.

F1 to F8 Select according to the connection cables being used.

1:1	Select when measuring using Model 9197, 9198 or 9217 Connection Cords.
10:1	Select when measuring using the Model 9665 10:1 Probe.
100:1	Select when measuring using the Model 9666 100:1 Probe.
1000:1	Select when measuring using the Model 9322 Differential Probe.

8 Set the anti-aliasing filter.

CURSOR Move the cursor to the [AAF] item.

F1 to F8 Select either choice.

Off	The anti-aliasing filter is disabled. (default setting)
On	The anti-aliasing filter is enabled. (When the external sampling is used, the anti-aliasing filter (AAF) is not available.)

9 Perform zero adjustment (after warm-up).

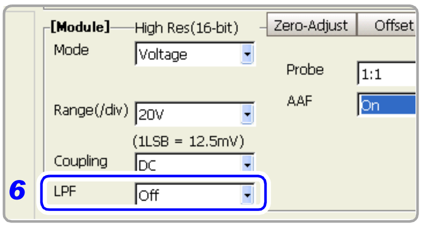
CURSOR Move the cursor to the [Zero-Adjust] button.

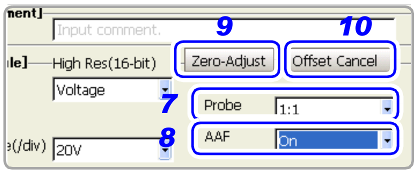
F1 Select [Execute].
When executed, all channels are zero adjusted. (Except in the Model 8958 16-Ch Scanner Unit)

10 Perform Offset Cancel (as occasion demands).

CURSOR Move the cursor to the [Offset Cancel] button.

F1 Select [Execute].
When executed, only the selected channel is corrected.





About low-pass filtering
See "3.10.3 Low-Pass Filter (LPF) Settings" in the *Input Module Guide*

About probe attenuation
Matching the probe attenuation setting to that of the input channel's probe enables automatic conversion of voltage axis range measurements for direct reading of numerical values.
See "3.10.15 Probe Attenuation Selection" in the *Input Module Guide*

Anti-Aliasing Filter
Enable to prevent aliasing distortion.
See "Anti-Aliasing Filters" (⇒ p. 107)

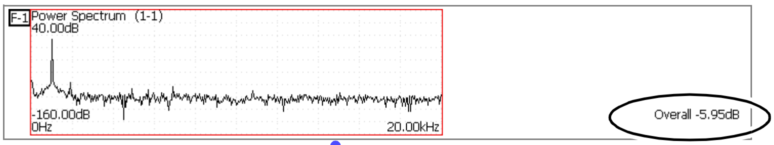
About zero adjustment
Adjusts the zero position of an input module. Warm-up time depends on the type of input module.
See "3.10.17 Executing Zero Adjustment" in the *Input Module Guide*

About offset canceling
Executing Offset Cancel when using a sensor corrects for external signal bias.
See "3.10.18 Executing Offset Cancellation" in the *Input Module Guide*

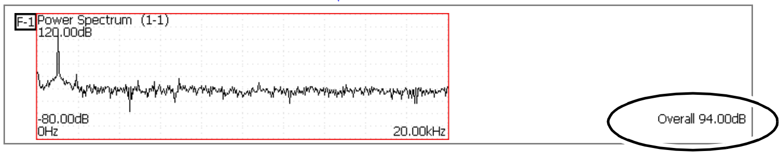
Scaling

The scaling setting allows values displayed on this instrument to match the actual values read directly on a sound level meter or vibration meter.

Without Scaling

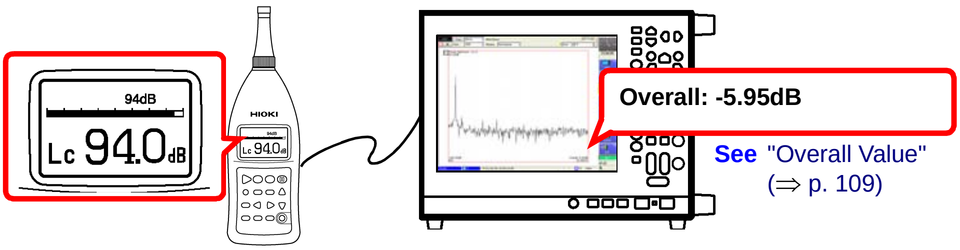


With Scaling



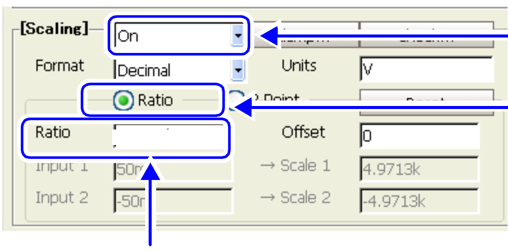
Setting example: To display measurement data on this instrument so that it corresponds to that on a sound level meter.

In a case where a sound level meter displays 94 dB and the overall value displayed on the Waveform screen of this instrument is -5.95 dB.



See "Overall Value" (⇒ p. 109)

Sound Level Meter

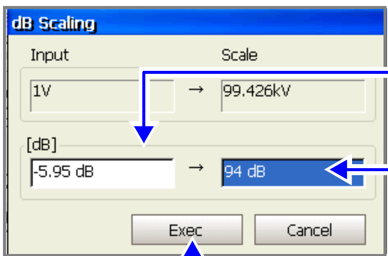


1 **Select [On].**

2 **Select [Ratio].**

3 **Move the cursor to [Ratio], and press the F7 [dB] key.**

The dB Scaling dialog appears.



4 **Enter the (overall) value “-5.95” displayed on the instrument.**

5 **Enter the value "94" (from the sound level meter) that you want to read directly.**

6 **Activate scaling.**

Scaling is performed automatically, and the corresponding values appear in the conversion ratio fields.

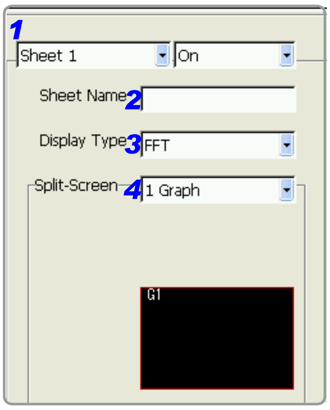
3.6 Setting the Screen Layout of the Waveform Screen

Measurement data can be split and displayed on up to 16 sheets on the Waveform screen.

Assigning the Results of FFT Analysis to a Sheet FFT

To open the screen: Press the **SET** key → Select **Sheet** with the **SUB MENU** keys →Sheet Settings screen

See Screen Layout (⇒ p. 42)



Operating Key	Procedure
1	**Sheet Assignment.**
CURSOR	Move the cursor to the [Sheet 1] item.
F1 to F8	Select the number of the Sheet to set.
CURSOR	Move the cursor to the [On] or [Off] item.
F1 to F8	Select whether to display the selected sheet on the Waveform screen.

Off	The selected sheet is not displayed.
On	The selected sheet is displayed.

2 **Enter a Sheet Name (if you want to change it).**

CURSOR	Move the cursor to the [Sheet Name] item.
F1 to F8	Enter a name. (up to 8 characters) (When you enter a sheet name other than the default, it is displayed to the right of the waveform.)

3 **Select the Display Type.**

CURSOR	Move the cursor to the [Display Type] item.
F1 to F8	Select the type of data to be displayed. The display type depends on the input data selected for analysis.

FFT	Displays a plot of FFT analysis results.
Nyquist	(When the analysis mode is Linear Spectrum, Transfer Function or Cross-Power Spectrum) The real-number part is displayed on the x axis, and the imaginary part on the y axis.
FFT+Nyquist	Analysis results and the Nyquist plot are displayed at the same time.
Wave+FFT *	A memory waveform and FFT analysis results are displayed.
Wave+Nyquist *	The Memory waveform and Nyquist plot are displayed at the same time.

* Input data source [Reference]: selectable only when [From Mem] is selected.

To use an existing memory waveform for analysis

Select [From Mem] as the input data source [Reference].

See "3.4.2 Selecting the Data Source for Analysis" (⇒ p. 52)

To specify the analysis starting point

Specify the starting point on the memory waveform.

See "3.9.3 Analyzing after Specifying an Analysis Starting Point" (⇒ p. 80)

4 **Select split-screen display (as occasion demands).**

The number of possible screen partitions depends on the selected display type.

See "Display Types and Split-Screen Settings" (⇒ p. 74)

Operating Key | Procedure

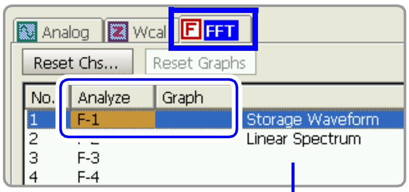
5 **Select the data to display on the Sheet.**

Operating Key	Procedure
SHEET/PAGE	Select the [FFT] page.
CURSOR	Move the cursor to the [Analyze] column.
F1 to F8	Select the desired calculation number for display. (This becomes the Analysis No. setting on the Status Settings screen.)

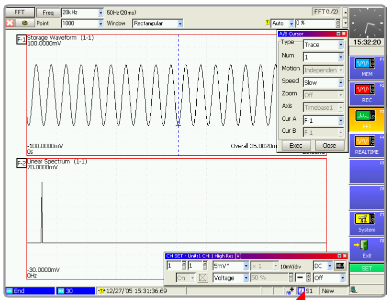
(When using split-screen display)

Operating Key	Procedure
CURSOR	Move the cursor to the [Graph] column.
F1 to F8	Select the Graph number to be displayed.

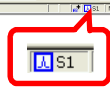
5



The analysis mode is displayed.



Waveform screen



The sheet number is displayed.

Press the DISP key to display the Waveform screen.

The displayed sheet changes each time you press the SHEET/PAGE keys.

When "Drawing failed"

- **NG: Nyquist Display¶**
  There is a mismatch between the display type setting on the Sheet Settings screen and a parameter setting on the Status Settings screen.
  The normal display and Nyquist display cannot be combined. To display both, set the display type to [FFT+Nyquist].

- **NG: X-Axis Setting**
  Increase the number of split screen sections, or change the x-axis display.
  Linear x-axis and logarithmic displays cannot be combined in the same graph.

- **NG: Analysis Mode Error**
  Octave analysis (1/1 or 1/3) cannot be overlaid with another analysis. Increase the number of split screen sections, or set display on another sheet.

Display Types and Split-Screen Settings

Fourteen display arrangements are available.

	1 Graph	2 Graphs	4 Graphs	4 (Print 8)
FFT	G1	G1 G2	G1 G2 G3 G4	G1 G2 G3 G4
Nyquist	G1	G1 G2	G1 G2 G3 G4	G1 G2 G3 G4
FFT+Nyquist	FFT Nyquist G1	FFT Nyquist Nyquist G1 G2	———	———
Wave+FFT *	ANALOG FFT G1	ANALOG FFT G1 FFT G2	———	———
Wave+Nyquist*	ANALOG Nyquist G1	ANALOG Nyquist Nyquist G1 G2	———	———

* Selectable only when the [Reference] setting on the Status Settings screen is [From Mem].

3.7 Saving Analysis Results

The saving procedure is the same as for the Memory and Recorder functions.

See "Chapter 10 Saving/Loading Data & Managing Files" in the *Instruction Manual*

The size of saved files depends on the file format.

See "Appendix 2.2 Waveform File Sizes" in the *Instruction Manual*

When FFT Analysis Results are Saved as Text

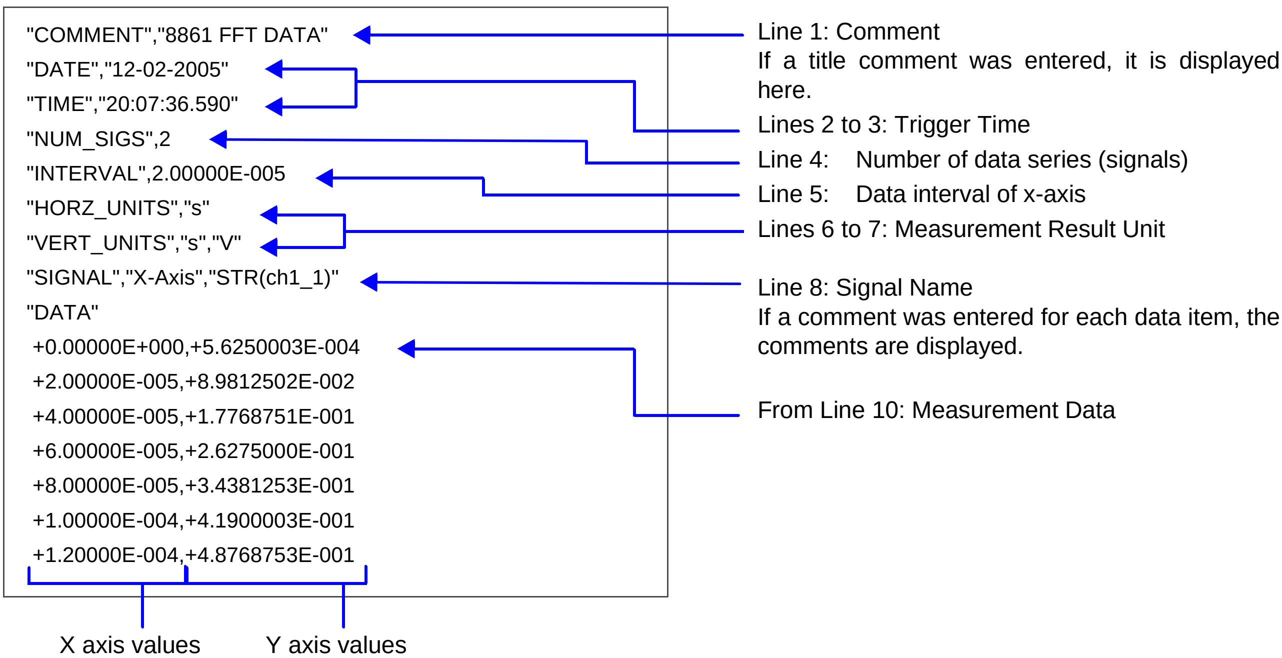
A file is created for each analysis mode. One of the following text strings is appended to the file name.

Example: When the Name Pattern setting is [Trig (prefix)] and the save name is "TEST"

150000_051201_TEST_LIN.TXT
(15:00:00, Dec. 1, 2005, "TEST" Linear Spectrum text data)

Analysis Mode	Save Name	Analysis Mode	Save Name
Storage Waveform	STR	Cross Power Spectrum	CSP
Linear Spectrum	LIN	Cross-correlation Function	CCR
RMS Spectrum	RMS	Impulse Response	IMP
Power Spectrum	PSP	Coherence Function	COH
Power Spectrum Density	PSD	Phase Spectrum (1ch / 2ch)	PHASE
Auto-correlation Function	ACR	Power Spectrum (LPC)	LPC
Histogram	HIS	1/1 Octave	1_1_OCT
Transfer Function	TRF	1/3 Octave	1_3_OCT

Text Saving Example

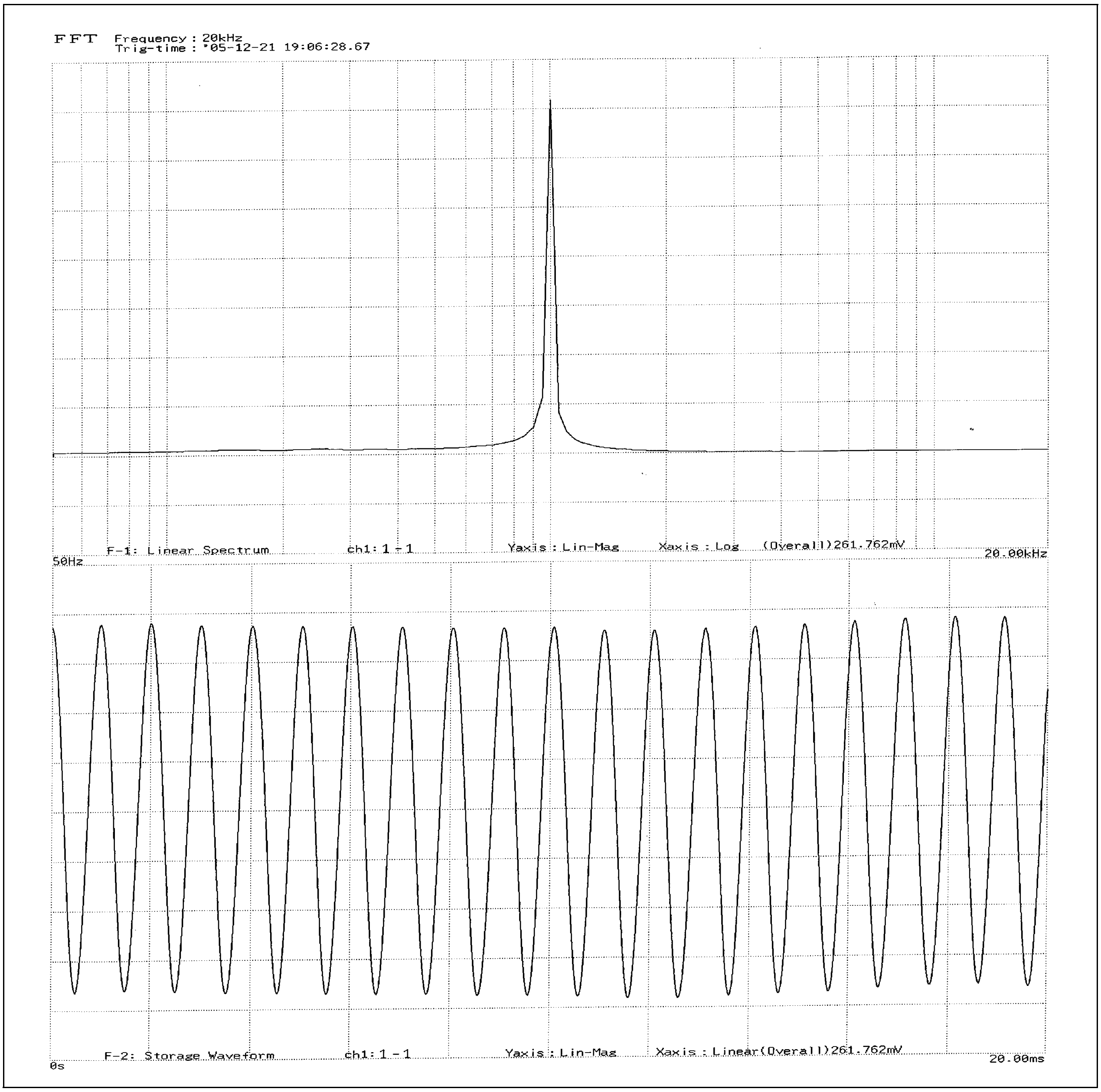


3.8 Printing Analysis Results

The printing procedure is the same as for the Memory and Recorder functions.

See "Chapter 11 Printing" in the *Instruction Manual*

Example of Waveform Printout



Example of Numerical Value Printout

FFT '05-12-21 19:06:28.67

F-1 Linear Spectrum w1:1-1 Yaxis:Lin-Mag Xaxis:Log (Overall)261.762mV

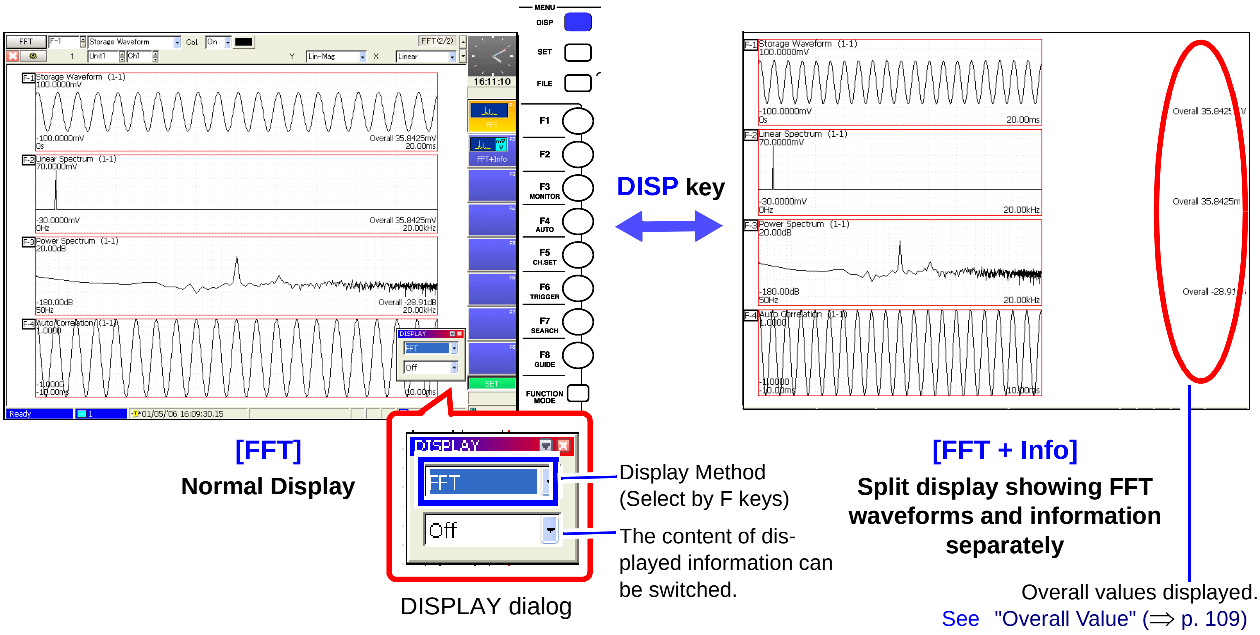
0Hz	0.553mV	50Hz	4.317mV	100Hz	4.851mV	150Hz	5.760mV	200Hz	5.247mV	250Hz	6.366mV	300Hz	5.270mV	350Hz	5.736mV
400Hz	5.585mV	450Hz	6.029mV	500Hz	6.080mV	550Hz	6.698mV	600Hz	7.217mV	650Hz	8.203mV	700Hz	9.355mV	750Hz	11.066mV
800Hz	13.587mV	850Hz	18.098mV	900Hz	27.135mV	950Hz	57.346mV	1.00kHz	358.934mV	1.05kHz	42.153mV	1.10kHz	22.056mV	1.15kHz	14.742mV
1.20kHz	11.054mV	1.25kHz	8.785mV	1.30kHz	7.251mV	1.35kHz	6.153mV	1.40kHz	5.435mV	1.45kHz	4.764mV	1.50kHz	4.282mV	1.55kHz	3.821mV
1.60kHz	3.470mV	1.65kHz	3.110mV	1.70kHz	2.870mV	1.75kHz	2.749mV	1.80kHz	2.442mV	1.85kHz	2.365mV	1.90kHz	2.168mV	1.95kHz	2.055mV
2.00kHz	1.948mV	2.05kHz	1.836mV	2.10kHz	1.761mV	2.15kHz	1.665mV	2.20kHz	1.632mV	2.25kHz	1.545mV	2.30kHz	1.471mV	2.35kHz	1.404mV
2.40kHz	1.325mV	2.45kHz	1.292mV	2.50kHz	1.261mV	2.55kHz	1.205mV	2.60kHz	1.131mV	2.65kHz	1.074mV	2.70kHz	1.206mV	2.75kHz	1.083mV
2.80kHz	1.041mV	2.85kHz	1.043mV	2.90kHz	0.967mV	2.95kHz	0.940mV	3.00kHz	0.933mV	3.05kHz	0.904mV	3.10kHz	0.884mV	3.15kHz	0.885mV
3.20kHz	0.836mV	3.25kHz	0.825mV	3.30kHz	0.791mV	3.35kHz	0.734mV	3.40kHz	0.740mV	3.45kHz	0.760mV	3.50kHz	0.707mV	3.55kHz	0.702mV
3.60kHz	0.670mV	3.65kHz	0.685mV	3.70kHz	0.680mV	3.75kHz	0.647mV	3.80kHz	0.617mV	3.85kHz	0.621mV	3.90kHz	0.586mV	3.95kHz	0.620mV
4.00kHz	0.636mV	4.05kHz	0.567mV	4.10kHz	0.557mV	4.15kHz	0.571mV	4.20kHz	0.586mV	4.25kHz	0.552mV	4.30kHz	0.518mV	4.35kHz	0.538mV
4.40kHz	0.546mV	4.45kHz	0.538mV	4.50kHz	0.543mV	4.55kHz	0.521mV	4.60kHz	0.486mV	4.65kHz	0.505mV	4.70kHz	0.489mV	4.75kHz	0.461mV
4.80kHz	0.460mV	4.85kHz	0.472mV	4.90kHz	0.479mV	4.95kHz	0.447mV	5.00kHz	0.448mV	5.05kHz	0.443mV	5.10kHz	0.439mV	5.15kHz	0.460mV
5.20kHz	0.411mV	5.25kHz	0.425mV	5.30kHz	0.437mV	5.35kHz	0.405mV	5.40kHz	0.421mV	5.45kHz	0.403mV	5.50kHz	0.384mV	5.55kHz	0.413mV
5.60kHz	0.426mV	5.65kHz	0.382mV	5.70kHz	0.370mV	5.75kHz	0.400mV	5.80kHz	0.384mV	5.85kHz	0.358mV	5.90kHz	0.374mV	5.95kHz	0.379mV
6.00kHz	0.382mV	6.05kHz	0.353mV	6.10kHz	0.349mV	6.15kHz	0.352mV	6.20kHz	0.346mV	6.25kHz	0.320mV	6.30kHz	0.356mV	6.35kHz	0.343mV
6.40kHz	0.283mV	6.45kHz	0.362mV	6.50kHz	0.359mV	6.55kHz	0.285mV	6.60kHz	0.359mV	6.65kHz	0.344mV	6.70kHz	0.267mV	6.75kHz	0.332mV
6.80kHz	0.334mV	6.85kHz	0.311mV	6.90kHz	0.371mV	6.95kHz	0.277mV	7.00kHz	0.313mV	7.05kHz	0.362mV	7.10kHz	0.260mV	7.15kHz	0.310mV
7.20kHz	0.298mV	7.25kHz	0.278mV	7.30kHz	0.352mV	7.35kHz	0.282mV	7.40kHz	0.265mV	7.45kHz	0.319mV	7.50kHz	0.287mV	7.55kHz	0.288mV
7.60kHz	0.308mV	7.65kHz	0.281mV	7.70kHz	0.275mV	7.75kHz	0.257mV	7.80kHz	0.330mV	7.85kHz	0.293mV	7.90kHz	0.219mV	7.95kHz	0.274mV
8.00kHz	0.276mV	8.05kHz	0.245mV	8.10kHz	0.244mV	8.15kHz	0.240mV	8.20kHz	0.301mV	8.25kHz	0.281mV	8.30kHz	0.226mV	8.35kHz	0.269mV
8.40kHz	0.254mV	8.45kHz	0.245mV	8.50kHz	0.253mV	8.55kHz	0.313mV	8.60kHz	0.266mV	8.65kHz	0.202mV	8.70kHz	0.235mV	8.75kHz	0.286mV
8.80kHz	0.277mV	8.85kHz	0.213mV	8.90kHz	0.264mV	8.95kHz	0.265mV	9.00kHz	0.250mV	9.05kHz	0.220mV	9.10kHz	0.216mV	9.15kHz	0.294mV
9.20kHz	0.289mV	9.25kHz	0.224mV	9.30kHz	0.226mV	9.35kHz	0.199mV	9.40kHz	0.281mV	9.45kHz	0.270mV	9.50kHz	0.188mV	9.55kHz	0.269mV
9.60kHz	0.136mV	9.65kHz	0.167mV	9.70kHz	0.248mV	9.75kHz	0.213mV	9.80kHz	0.235mV	9.85kHz	0.206mV	9.90kHz	0.133mV	9.95kHz	0.161mV
10.00kHz	0.210mV	10.05kHz	0.224mV	10.10kHz	0.214mV	10.15kHz	0.160mV	10.20kHz	0.115mV	10.25kHz	0.183mV	10.30kHz	0.224mV	10.35kHz	0.189mV
10.40kHz	0.211mV	10.45kHz	0.179mV	10.50kHz	0.173mV	10.55kHz	0.213mV	10.60kHz	0.192mV	10.65kHz	0.178mV	10.70kHz	0.188mV	10.75kHz	0.184mV
10.80kHz	0.175mV	10.85kHz	0.171mV	10.90kHz	0.189mV	10.95kHz	0.157mV	11.00kHz	0.143mV	11.05kHz	0.186mV	11.10kHz	0.173mV	11.15kHz	0.176mV
11.20kHz	0.179mV	11.25kHz	0.168mV	11.30kHz	0.196mV	11.35kHz	0.226mV	11.40kHz	0.182mV	11.45kHz	0.131mV	11.50kHz	0.196mV	11.55kHz	0.235mV
11.60kHz	0.188mV	11.65kHz	0.219mV	11.70kHz	0.186mV	11.75kHz	0.133mV	11.80kHz	0.204mV	11.85kHz	0.198mV	11.90kHz	0.203mV	11.95kHz	0.178mV
12.00kHz	0.159mV	12.05kHz	0.182mV	12.10kHz	0.154mV	12.15kHz	0.183mV	12.20kHz	0.227mV	12.25kHz	0.222mV	12.30kHz	0.185mV	12.35kHz	0.159mV
12.40kHz	0.196mV	12.45kHz	0.181mV	12.50kHz	0.195mV	12.55kHz	0.210mV	12.60kHz	0.134mV	12.65kHz	0.165mV	12.70kHz	0.186mV	12.75kHz	0.150mV
12.80kHz	0.186mV	12.85kHz	0.190mV	12.90kHz	0.126mV	12.95kHz	0.158mV	13.00kHz	0.196mV	13.05kHz	0.182mV	13.10kHz	0.134mV	13.15kHz	0.164mV
13.20kHz	0.148mV	13.25kHz	0.140mV	13.30kHz	0.197mV	13.35kHz	0.181mV	13.40kHz	0.166mV	13.45kHz	0.147mV	13.50kHz	0.160mV	13.55kHz	0.182mV
13.60kHz	0.209mV	13.65kHz	0.169mV	13.70kHz	0.148mV	13.75kHz	0.162mV	13.80kHz	0.165mV	13.85kHz	0.180mV	13.90kHz	0.176mV	13.95kHz	0.127mV
14.00kHz	0.131mV	14.05kHz	0.170mV	14.10kHz	0.155mV	14.15kHz	0.174mV	14.20kHz	0.143mV	14.25kHz	0.154mV	14.30kHz	0.145mV	14.35kHz	0.149mV
14.40kHz	0.201mV	14.45kHz	0.150mV	14.50kHz	0.110mV	14.55kHz	0.169mV	14.60kHz	0.170mV	14.65kHz	0.155mV	14.70kHz	0.142mV	14.75kHz	0.145mV
14.80kHz	0.169mV	14.85kHz	0.164mV	14.90kHz	0.149mV	14.95kHz	0.130mV	15.00kHz	0.164mV	15.05kHz	0.176mV	15.10kHz	0.161mV	15.15kHz	0.139mV
15.20kHz	0.137mV	15.25kHz	0.186mV	15.30kHz	0.165mV	15.35kHz	0.114mV	15.40kHz	0.132mV	15.45kHz	0.193mV	15.50kHz	0.139mV	15.55kHz	0.152mV
15.60kHz	0.171mV	15.65kHz	0.120mV	15.70kHz	0.159mV	15.75kHz	0.183mV	15.80kHz	0.112mV	15.85kHz	0.141mV	15.90kHz	0.170mV	15.95kHz	0.174mV
16.00kHz	0.178mV	16.05kHz	0.092mV	16.10kHz	0.188mV	16.15kHz	0.200mV	16.20kHz	0.097mV	16.25kHz	0.175mV	16.30kHz	0.177mV	16.35kHz	0.097mV
16.40kHz	0.159mV	16.45kHz	0.137mV	16.50kHz	0.141mV	16.55kHz	0.163mV	16.60kHz	0.104mV	16.65kHz	0.167mV	16.70kHz	0.175mV	16.75kHz	0.091mV
16.80kHz	0.146mV	16.85kHz	0.180mV	16.90kHz	0.170mV	16.95kHz	0.135mV	17.00kHz	0.168mV	17.05kHz	0.156mV	17.10kHz	0.138mV	17.15kHz	0.162mV
17.20kHz	0.138mV	17.25kHz	0.165mV	17.30kHz	0.183mV	17.35kHz	0.142mV	17.40kHz	0.129mV	17.45kHz	0.174mV	17.50kHz	0.160mV	17.55kHz	0.120mV
17.60kHz	0.152mV	17.65kHz	0.157mV	17.70kHz	0.128mV	17.75kHz	0.142mV	17.80kHz	0.124mV	17.85kHz	0.159mV	17.90kHz	0.159mV	17.95kHz	0.094mV
18.00kHz	0.149mV	18.05kHz	0.156mV	18.10kHz	0.120mV	18.15kHz	0.140mV	18.20kHz	0.102mV	18.25kHz	0.163mV	18.30kHz	0.199mV	18.35kHz	0.091mV
18.40kHz	0.134mV	18.45kHz	0.189mV	18.50kHz	0.138mV	18.55kHz	0.124mV	18.60kHz	0.145mV	18.65kHz	0.115mV	18.70kHz	0.104mV	18.75kHz	0.172mV
18.80kHz	0.166mV	18.85kHz	0.103mV	18.90kHz	0.150mV	18.95kHz	0.130mV	19.00kHz	0.133mV	19.05kHz	0.155mV	19.10kHz	0.122mV	19.15kHz	0.146mV
19.20kHz	0.129mV	19.25kHz	0.133mV	19.30kHz	0.127mV	19.35kHz	0.087mV	19.40kHz	0.163mV	19.45kHz	0.140mV	19.50kHz	0.117mV	19.55kHz	0.164mV
19.60kHz	0.077mV	19.65kHz	0.138mV	19.70kHz	0.183mV	19.75kHz	0.120mV	19.80kHz	0.125mV	19.85kHz	0.091mV	19.90kHz	0.131mV	19.95kHz	0.122mV
20.00kHz	0.127mV														

3.9 Analysis with the Waveform Screen

3.9.1 Selecting the Display Method

The display of FFT analysis data can be switched between waveform and numerical views.

Press the **DISP** key repeatedly to change the display method.
Pressing the **DISP** key opens the Display dialog in which to select a display method. Selections in this dialog are available using the F keys.
Press the **ESC** key or an F key to close the dialog.



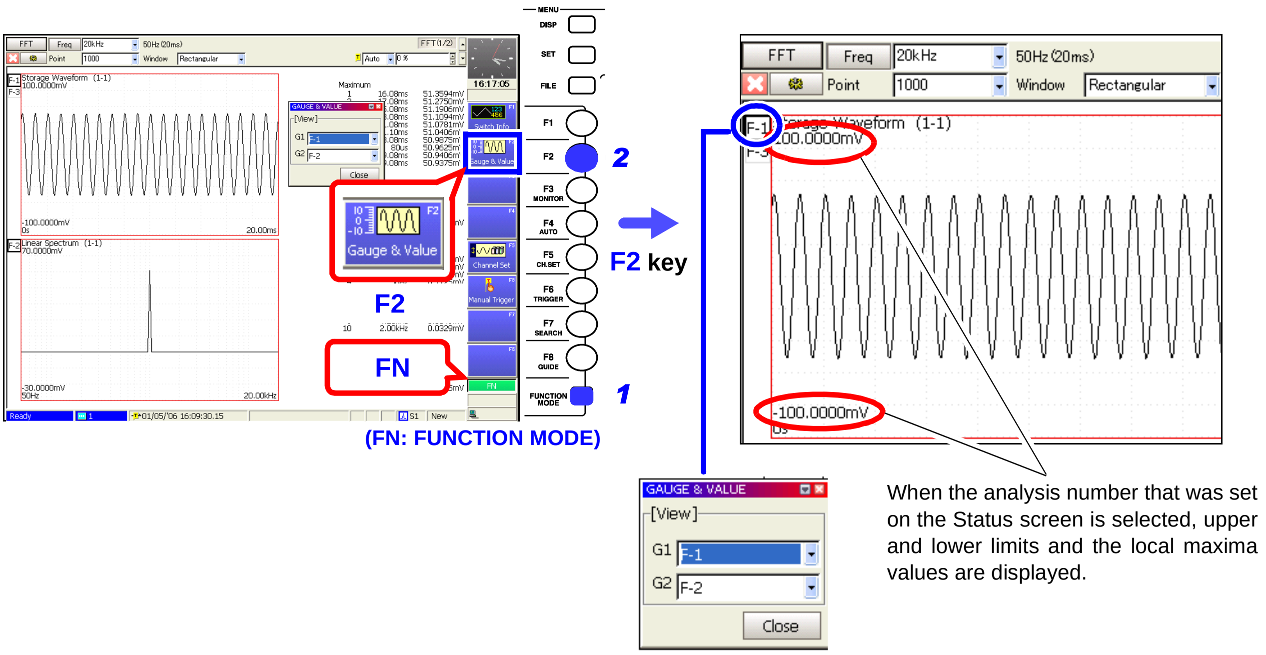
See "Overall Value" (⇒ p. 109)

NOTE When the display type on the Sheet Settings screen is [Nyquist], [FFT+Nyquist] or [Wave+Nyquist], the display cannot be switched.

3.9.2 Selecting Gauges and Values

Display of upper and lower limits and peak values [maximal/ maximum] can be selected by analysis number. However, selection is not possible when Nyquist display is enabled.

Press the **FUNCTION MODE** key to enable the FN mode, then press **F2** [Gauge & Value].
The Gauge dialog appears.
Select an analysis number as occasion demands to display gauge and measurement values.
Press the **ESC** key or the **F8** [Close] key to close the dialog.



GAUGE&VALUE dialog
Using the CURSOR keys, move the cursor into the dialog and select the channels for which to display a gauge.

3.9.3 Analyzing after Specifying an Analysis Starting Point

A starting point for FFT analysis can be specified on an existing memory waveform before analyzing.

The procedure depends on the Trigger Mode setting.
See "Trigger Modes and Averaging" (⇒ p. 60)

- When the Trigger Mode is [Single]
  Analysis is performed once on the specified number of analysis points beginning with the specified starting point, and analysis results are displayed.
  This is convenient for analyzing only a specific range. However, if averaging is enabled, analysis repeats for the specified averaging count.
- When the Trigger Mode is [Auto] or [Repeat]
  Analysis is performed repeatedly on the specified number of analysis points beginning with the specified starting point and ending with end of waveform data, and final analysis results are displayed (because analysis is only performed on the specified number of analysis points, final analysis results may be determined and become available before the end of the waveform data).

The starting point can be specified by one of the following methods:

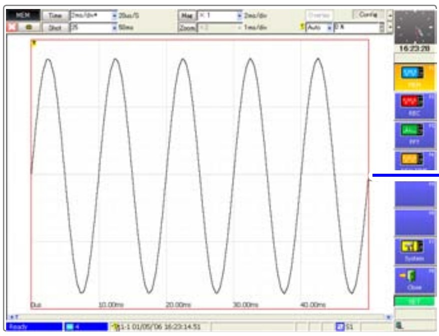
(1) Verifying the analysis starting point while viewing analysis data (⇒ p. 81)

The memory waveform and analysis results are displayed at the same time on the Waveform screen (Sheet Settings screen: Display type [Wave+FFT] or [Wave+Nyquist]) and the analysis starting point is specified on the memory waveform.

(2) Performing FFT analysis after specifying a starting point on an existing memory waveform using the A/B cursors (⇒ p. 83)

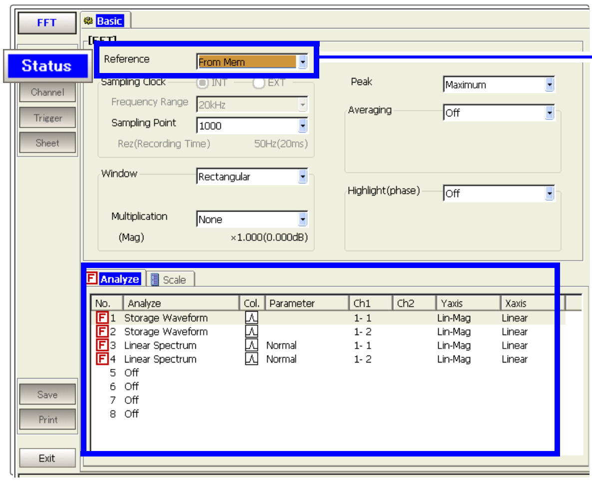
The analysis starting point is specified using the A/B cursors with the Memory function. If the cursors are not displayed, analysis begins at the start of the data.
The starting position cannot be verified while the FFT function is enabled.

Procedure 1. Verifying the analysis starting point while viewing analysis data



1 **Display the waveform to be analyzed.**

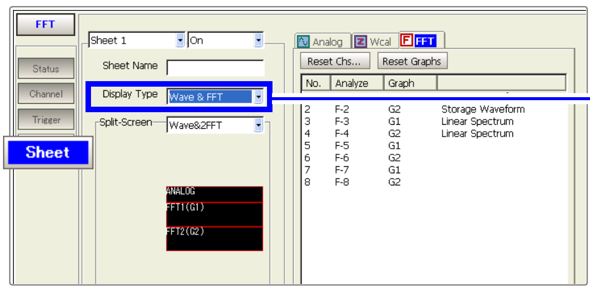
2 **Select the FFT function (F3 [FFT]) to display the Status Settings screen.**



3 **Set the analysis input data source to [From Mem].**

Set analysis conditions such as the analysis mode and number of analysis points (these can also be set on the Waveform screen).

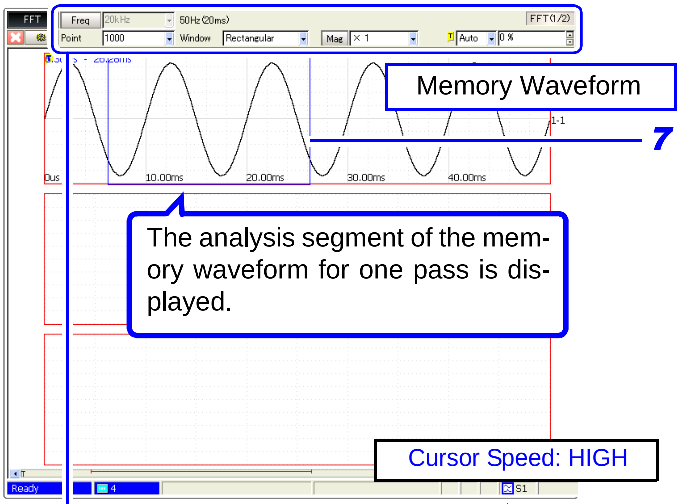
4 **Press the SUB MENU keys to display the Sheet Settings screen.**



5 **Set the display type to [Wave+FFT] or [Wave+Nyquist].**

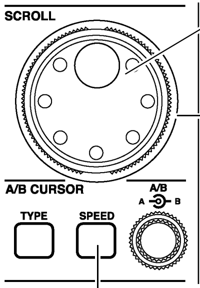
To use split-screen display, set graph assignments on the [FFT] page.

6 **Press the DISP key to display the Waveform screen.**



Analysis segment for one pass (the number of analysis points)

7 **Specify the location of the analysis input data using the jog and shuttle controls.**

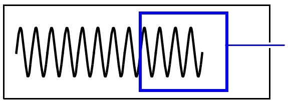


Jog
Moves the analysis starting point.

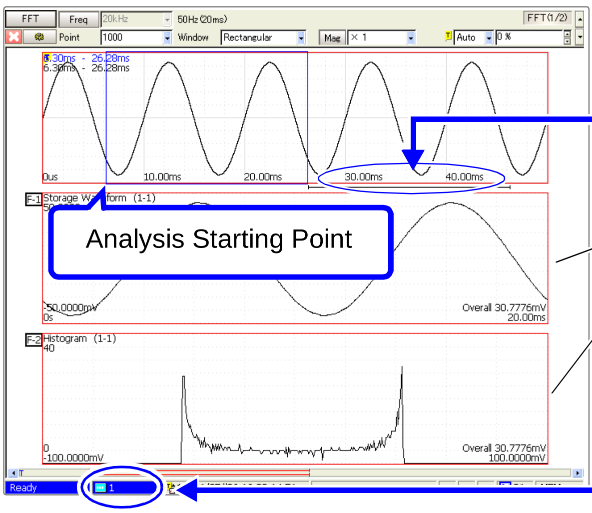
Shuttle
Scrolls the Memory waveform.

Press the **SPEED** key to adjust the movement and scrolling speed.

8 **Select analysis conditions as occasion demands.**

To change the number of analysis points	The setting can be changed at the top of the Waveform screen. The range is determined by the number of analysis points. If the analysis range (number of points) is larger than the memory waveform as shown below, analysis is not performed.  Analysis Segment Display
To analyze only a certain portion	At the top of the Waveform screen, set the trigger mode to [Single], so that only the currently displayed analysis segment will be analyzed. When the trigger mode is other than [Single], analysis continues for the specified number of analysis points, or to the end of data. To interrupt analysis in progress, press the **STOP** key.
To change analysis conditions	Press the **SUB MENU** keys to select [FFT (1/2)] or [FFT (2/2)], and change the settings.

9 **Press the START key to begin analyzing.**



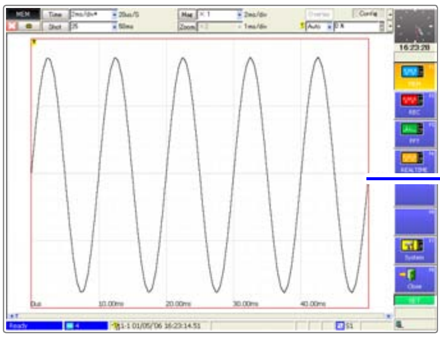
Shows the last analysis segment.

Analysis results are displayed on the lower graphs.

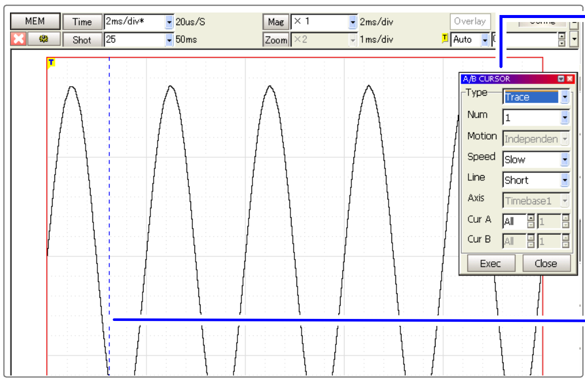
When the trigger mode is [Auto] or [Repeat], the number of analysis points up to the end of the waveform data is analyzed, and the last data is displayed.

Shows the number of times analysis was performed.

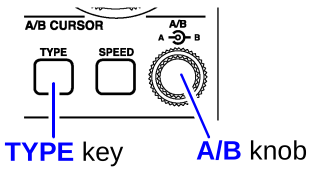
Procedure 2. Performing FFT analysis after specifying a starting point on an existing memory waveform using the A/B cursors



1 **Display the waveform with the Memory function.**



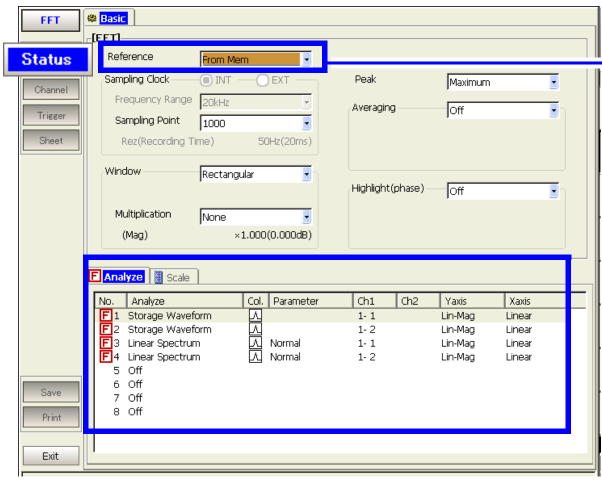
2 **Press the TYPE key and select [Vertical] or [Trace].**



3 **Specify the analysis starting point with the A/B knobs.**

When both A/B cursors are enabled, the analysis starting point is determined by the earliest (leftmost) cursor. <u>The length of the waveform segment for FFT analysis cannot be specified using the cursors.</u>

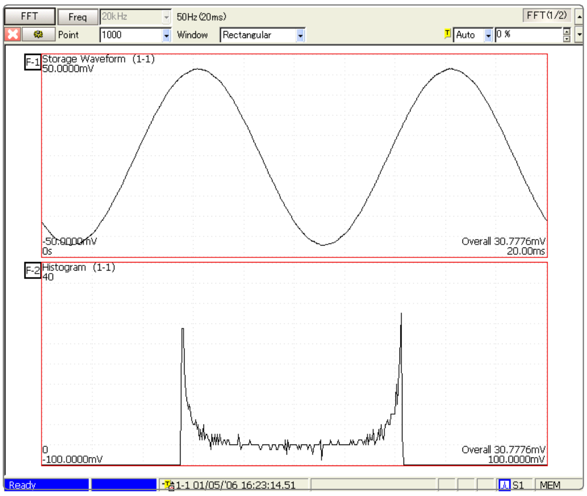
4 **Select the FFT function (F3 [FFT]) to display the Status Settings screen.**



5 **Set the analysis input data source to [From Mem].**

Set analysis conditions such as the analysis mode and number of analysis points (these can also be set on the Waveform screen).

6 **Press the DISP key to display the Waveform screen.**



7 **Make other settings as occasion demands, then press the START key to begin analyzing.**

3.10 FFT Analysis Modes

3.10.1 Analysis Modes and Display Examples

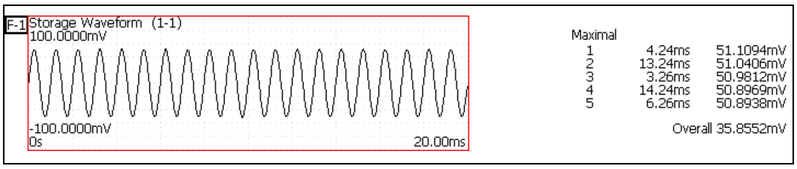
For the functions of each analysis mode, see "3.10.2 Analysis Mode Functions" (⇒ p. 102).

Storage STR

Displays the time axis waveform of the input signal.
When the window function setting is other than rectangular, the window function is applied to the waveform and displayed.

Axis	Display Type	Description
X axis	**Linear**	Time-domain display Displays the value of the time-domain waveform corresponding to the set frequency range. **See** "Relationship Between Frequency Range, Resolution and Number of Analysis Points" (⇒ p. 55)
Y axis	**Lin-Mag**	Displays the input module waveform.

Waveform Example



Window: Rectangular
X axis: Linear
Y axis: Lin-Mag

Linear Spectrum LIN

The linear spectrum plots the input signal frequency. It can be displayed as a Nyquist plot.

Main uses:

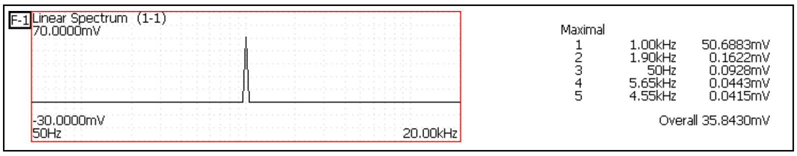
- To inspect the peak frequency contents of a waveform
- To inspect signal amplitudes at each frequency

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

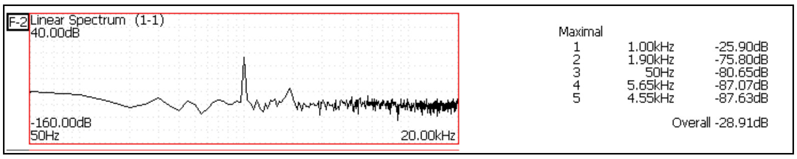
Axis	Display Type	Description
X axis	**Linear**	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
	Nyquist display	The real-number component of analysis values are displayed linearly.
Y axis	**Lin-Mag**	Analysis values are displayed linearly.
	Log-Mag	Analysis values are displayed as dB values. (0 dB reference value: 1eu)*
	Lin-Real	The real-number component of analysis values are displayed.
	Lin-Imag	The imaginary component of analysis values are displayed.
	Nyquist display	The imaginary component of analysis values are displayed.

* eu: engineering units that are currently set are the standard (e.g., when the unit settings is volts, 0 dB = 1 V)

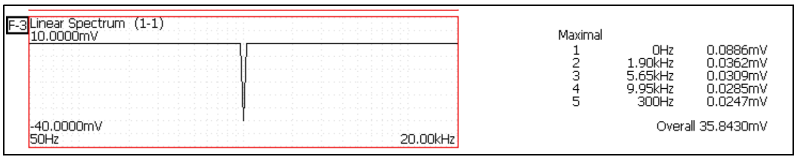
Waveform Example



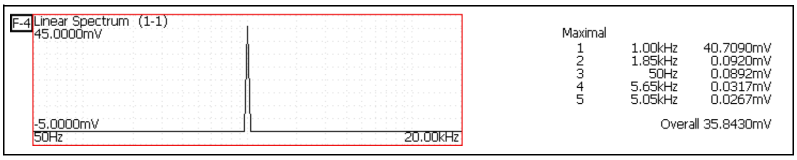
Normal display
X axis: Log
Y axis: Lin-Mag



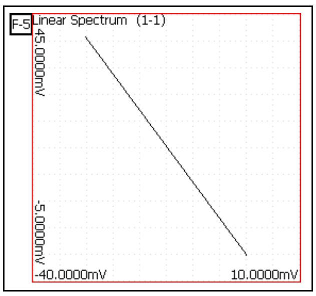
Normal display
X axis: Log
Y axis: Log-Mag



Normal display
X axis: Log
Y axis: Lin-Real



Normal display
X axis: Log
Y axis: Lin-Imag



Nyquist display

RMS Spectrum RMS

Amplitudes (RMS values) are calculated along the frequency axis from the input signal waveform. RMS and power spectra displays use the same analysis results displayed logarithmically (amplitude in dB).

Main uses:

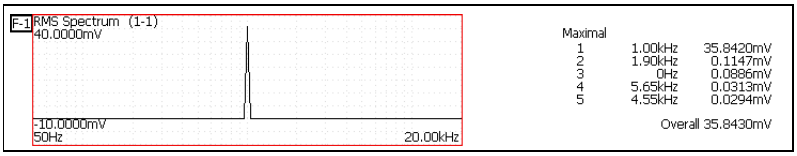
- To inspect the peak frequency contents of a waveform
- To inspect the RMS value at each frequency

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

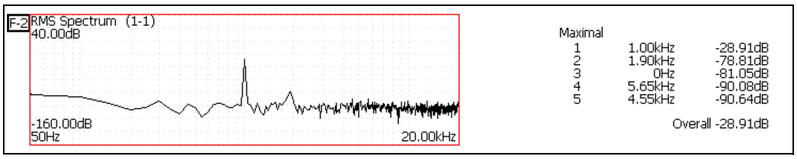
Axis	Display Type	Description
X axis	**Linear**	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
Y axis	**Lin-Mag**	Analysis values are displayed linearly.
	Log-Mag	Analysis values are displayed as dB values. (0 dB reference value: 1eu)*
	Lin-Real	The real-number component of analysis values are displayed.
	Lin-Imag	The imaginary component of analysis values are displayed.

* eu: engineering units that are currently set are the standard (e.g., when the unit settings is volts, 0 dB = 1 V)

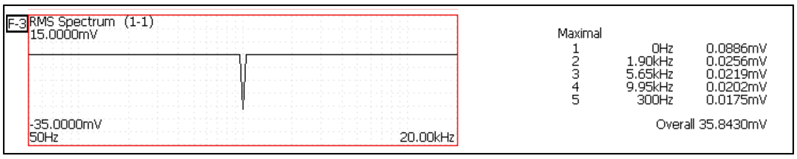
Waveform Example



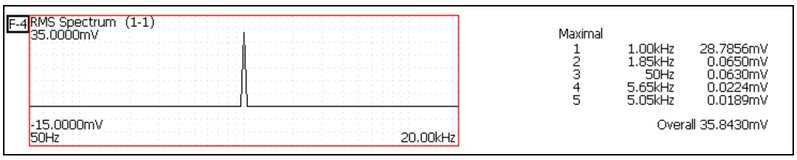
Normal display
X axis: Log
Y axis: Lin-Mag



Normal display
X axis: Log
Y axis: Log-Mag



Normal display
X axis: Log
Y axis: Lin-Real



Normal display
X axis: Log
Y axis: Lin-Imag

Power Spectrum PSP

Displays input signal power as the amplitude component.

Main uses:

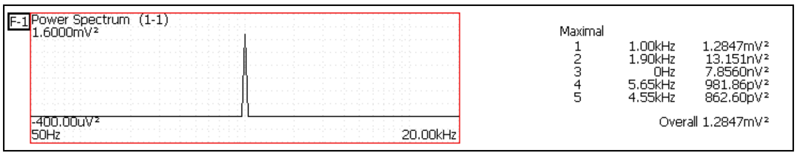
- To inspect the peak frequency contents of a waveform
- To inspect the power level at each frequency

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

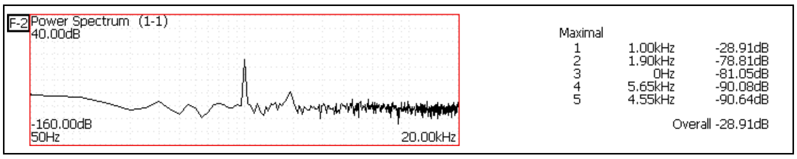
Axis	Display Type	Description
X axis	**Linear**	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
Y axis	**Lin-Mag**	Analysis data is displayed linearly as squared values. Indicates the power component.
	Log-Mag (logarithm)	Analysis values are displayed as dB values. (0 dB reference value: 1eu^2)*

* eu: engineering units that are currently set are the standard (e.g., when the unit settings is volts, 0 dB = 1 V^2)

Waveform Example



Normal display
X axis: Log
Y axis: Lin-Mag



Normal display
X axis: Log
Y axis: Log-Mag

Power Spectrum Density PSD

Indicates the power spectrum density of the input signal with only the amplitude component included. This is the power spectrum divided by the frequency resolution.

Not available with external sampling enabled.

Main uses:

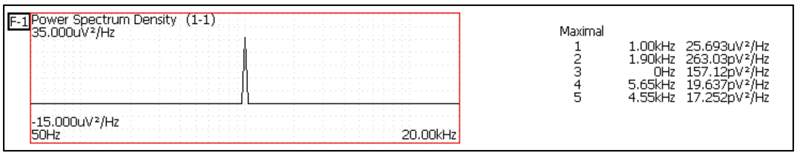
To acquire a power spectrum with 1-Hz resolution for highly irregular waveforms such as white noise

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

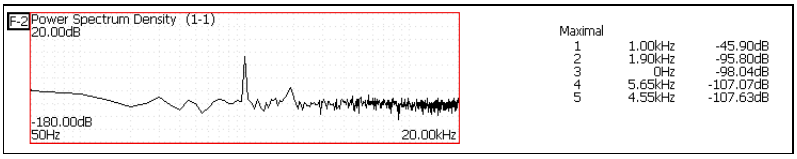
Axis	Display Type	Description
X axis	**Linear**	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
Y axis	**Lin-Mag**	Analysis values are displayed linearly.
	Log-Mag (logarithm)	Analysis values are displayed as dB values. (0 dB reference value: $1eu^2$/Hz)*

* eu: engineering units that are currently set are the standard (e.g., when the unit settings is volts, 0 dB = 1 V^2/Hz)

Waveform Example



Normal display
X axis: Log
Y axis: Lin-Mag



Normal display
X axis: Log
Y axis: Log-Mag

Auto Correlation Function ACR

Shows the correlation of two points on the input signal at time differential *t*.

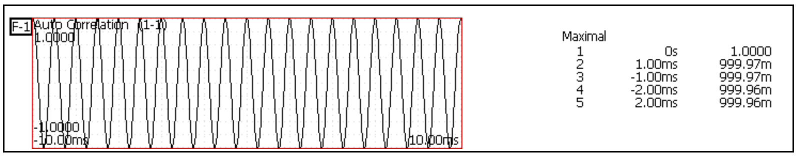
Main uses:

- To detect periodicy in irregular signals (improving and detecting SNR)
- To inspect periodic components in a noisy waveform.

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

Axis	Display Type	Description
X axis	**Linear**	Time display The center (t = 0) is the reference. To the right is lag time (+t), and to the left is lead time (-t)
Y axis	**Lin-Mag**	+1 to -1 (dimensionless units) The closest correlation at time differential t is +1, and the least correlation is 0. -1 indicates completely reversed polarity. Because of the characteristics of the function, t = 0 becomes +1.

Waveform Example



X axis: Linear
Y axis: Lin-Mag

This instrument provides a circular auto-correlation function.
Analysis results are normalized to the maximum value.

Histogram HIS

Acquires the amplitude distribution of the input signal.

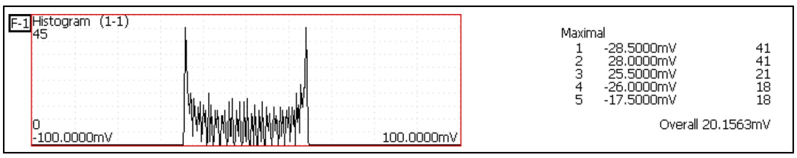
Main uses:

- To inspect deviations in the amplitude range of a waveform
- With analysis point distribution, to ascertain whether a waveform is artificial or natural (natural forms exhibiting regular distribution)

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

Axis	Display Type	Description
X axis	**Linear**	Displays input level of the input signal.
Y axis	**Lin-Mag**	Displays analysis data distribution.

Waveform Example



Normal display
X axis: Log
Y axis: Lin-Mag

1/1 and 1/3 Octave Analysis OCT

The sound pressure level of the spectrum of a signal such as noise is displayed through a fixed-width one- or one-third octave band-pass filter.

Not available with external sampling enabled.

Main uses:

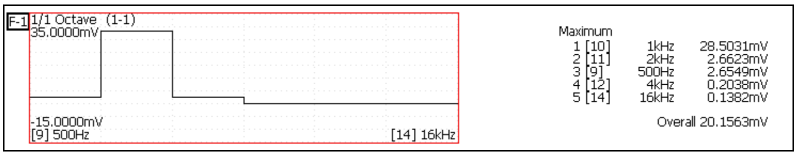
To analyze frequency components of noise

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102), "Octave Filter Characteristics" (⇒ p. 114)

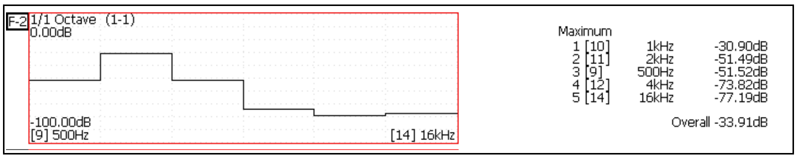
Axis	Display Type	Description
X axis	**Log**	Displays the center frequency of each band.
Y axis	**Lin-Mag**	Octave analysis values are displayed linearly.
	Log-Mag (logarithm)	Octave analysis values are displayed as dB values. (0 dB reference value: 1eu)*

* eu: engineering units that are currently set are the standard (e.g., when the unit settings is volts, 0 dB = 1 V)

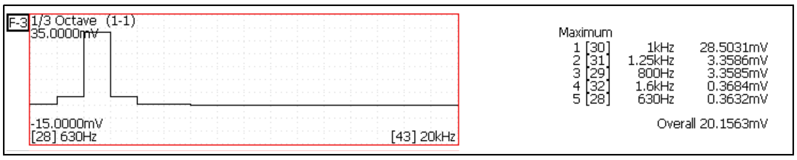
Waveform Example



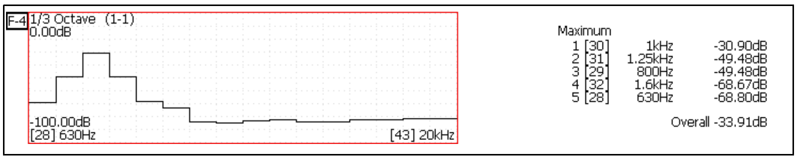
1/1 Octave
X axis: Log
Y axis: Lin-Mag
Filter: Normal



1/1 Octave
X axis: Log
Y axis: Log-Mag
Filter: Normal



1/3 Octave
X axis: Log
Y axis: Lin-Mag
Filter: Normal



1/3 Octave
X axis: Log
Y axis: Log-Mag
Filter: Normal

Octave Analysis

Octave analysis consists of frequency analysis of the signal passed through a constant-width band-pass filter. The power spectrum displays the power level in each subband after dividing the spectrum into fixed-width segments (subbands), while octave analysis scales the spectrum logarithmically and displays each octave (subband) as a bar graph.

The center frequency of the octave bands and filter characteristics are determined according to IEC61260 standards. With this instrument, 1/1- and 1/3-octave analyses are calculated using power spectrum Analysis results.

1/1 Octave Analysis: 6 subbands
1/3 Octave Analysis: 16 subbands

Measurable Ranges with Octave Analysis

(●: 1/1 OCT, ○: 1/3 OCT)

Timebase			5μ	10μ	20μ	50μ	100μ	200μ	500μ	1m	2m	5m	10m	20m	50m	100m	200m	500m	1	2	5	10	30	50	60	100	120	300
Period [s]			50n	100n	200n	500n	1μ	2μ	5μ	10μ	20μ	50μ	100μ	200μ	500μ	1m	2m	5m	10m	20m	50m	100m	300m	500m	600m	1	1.2	3
Sampling frequency [Hz]			20M	10M	5M	2M	1M	500k	200k	100k	50k	20k	10k	5k	2k	1k	500	200	100	50	20	10	3.33	2	1.66	1	833m	333m
Frequency range [Hz]			8M	4M	2M	800k	400k	200k	80k	40k	20k	8k	4k	2k	800	400	200	80	40	20	8	4	1.33	800m	667m	400m	333m	133m
1/1 OCT	1/3 OCT	Center frequency [Hz]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-8	-24	4m																										●
	-23	5m																										○
-7	-22	6.3m																										○
	-21	8m																									●	●○
	-20	10m																									○	○
-6	-19	12.5m																								○	○	○
	-18	16m																							●	●○	●○	●○
	-17	20m																							○	○	○	○
-5	-16	25m																						○	○	○	○	○
	-15	31.5m																					●	●○	●○	●○	●○	●○
	-14	40m																					○	○	○	○	○	○
-4	-13	50m																					○	○	○	○	○	○
	-12	63m																					●○	●○	●○	●○	●○	●○
	-11	80m																					○	○	○	○	○	○
-3	-10	100m																					○	○	○	○	○	○
	-9	125m																				●○	●○	●○	●○	●○	●○	●○
	-8	160m																				○	○	○	○	○	○	○
-2	-7	200m																				○	○	○	○	○	○	
	-6	250m																			●○	●○	●○	●○	●○	●○	●○	
	-5	315m																			○	○	○	○	○	○	○	
-1	-4	400m																			○	○	○	○	○	○		
	-3	500m																		●	●○	●○	●○	●○	●○	●○		
	-2	630m																		○	○	○	○	○	○			
0	-1	800m																		○	○	○	○	○				
	0	1																	●	●○	●○	●○	●○	●				
	1	1.25																	○	○	○	○	○					
1	2	1.6																	○	○	○	○						
	3	2																●	●○	●○	●○	●○						
	4	2.5																○	○	○	○	○						
2	5	3.15																○	○	○	○	○						
	6	4																●○	●○	●○	●○	●○						
	7	5																○	○	○	○							
3	8	6.3															○	○	○	○	○							
	9	8															●○	●○	●○	●○	●○							
	10	10															○	○	○	○								
4	11	12.5														○	○	○	○	○								
	12	16														●○	●○	●○	●○	●○								
	13	20														○	○	○	○	○								
5	14	25													○	○	○	○	○									
	15	31.5													●○	●○	●○	●○	●○									
	16	40													○	○	○	○	○									
6	17	50													○	○	○	○										
	18	63												●○	●○	●○	●○	●○										
	19	80												○	○	○	○	○										

(●: 1/1 OCT, ○: 1/3 OCT)

Timebase			5μ	10μ	20μ	50μ	100μ	200μ	500μ	1m	2m	5m	10m	20m	50m	100m	200m	500m	1	2	5	10	30	50	60	100	120	300
Period [s]			50n	100n	200n	500n	1μ	2μ	5μ	10μ	20μ	50μ	100μ	200μ	500μ	1m	2m	5m	10m	20m	50m	100m	300m	500m	600m	1	1.2	3
Sampling frequency [Hz]			20M	10M	5M	2M	1M	500k	200k	100k	50k	20k	10k	5k	2k	1k	500	200	100	50	20	10	3.33	2	1.66	1	833m	333m
Frequency range [Hz]			8M	4M	2M	800k	400k	200k	80k	40k	20k	8k	4k	2k	800	400	200	80	40	20	8	4	1.33	800m	667m	400m	333m	133m
1/1 OCT	1/3 OCT	Center frequency [Hz]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
7	20	100												○	○	○	○											
	21	125											● ○	● ○	● ○	● ○	● ○											
	22	160											○	○	○	○	○											
8	23	200											○	○	○	○	○											
	24	250										● ○	● ○	● ○	● ○	● ○	●											
	25	315										○	○	○	○	○												
9	26	400										○	○	○	○	○												
	27	500									●	● ○	● ○	● ○	● ○	●												
	28	630									○	○	○	○	○													
10	29	800									○	○	○	○	○													
	30	1k								●	● ○	● ○	● ○	● ○	●													
	31	1.25k								○	○	○	○	○														
11	32	1.6k								○	○	○	○	○														
	33	2k							●	● ○	● ○	● ○	● ○	● ○														
	34	2.5k							○	○	○	○	○															
12	35	3.15k							○	○	○	○	○															
	36	4k							● ○	● ○	● ○	● ○	● ○															
	37	5k							○	○	○	○																
13	38	6.3k						○	○	○	○	○																
	39	8k						● ○	● ○	● ○	● ○	● ○																
	40	10k						○	○	○	○																	
14	41	12.5k					○	○	○	○	○																	
	42	16k					● ○	● ○	● ○	● ○	● ○																	
	43	20k					○	○	○	○	○																	
15	44	25k				○	○	○	○	○																		
	45	31.5k				● ○	● ○	● ○	● ○	● ○																		
	46	40k				○	○	○	○	○																		
16	47	50k				○	○	○	○																			
	48	63k			● ○	● ○	● ○	● ○	● ○																			
	49	80k			○	○	○	○	○																			
17	50	100k			○	○	○	○																				
	51	125k		● ○	● ○	● ○	● ○	● ○																				
	52	160k		○	○	○	○	○																				
18	53	200k		○	○	○	○	○																				
	54	250k	● ○	● ○	● ○	● ○	● ○	●																				
	55	315k	○	○	○	○	○																					
19	56	400k	○	○	○	○	○																					
	57	500k	● ○	● ○	● ○	● ○	●																					
	58	630k	○	○	○	○																						
20	59	800k	○	○	○	○																						
	60	1M	● ○	● ○	● ○	●																						
	61	1.25M	○	○	○																							
21	62	1.6M	○	○	○																							
	63	2M	● ○	● ○	● ○																							
	64	2.5M	○	○																								

(●: 1/1 OCT, ○: 1/3 OCT)

Timebase			5μ	10μ	20μ	50μ	100μ	200μ	500μ	1m	2m	5m	10m	20m	50m	100m	200m	500m	1	2	5	10	30	50	60	100	120	300
Period [s]			50n	100n	200n	500n	1μ	2μ	5μ	10μ	20μ	50μ	100μ	200μ	500μ	1m	2m	5m	10m	20m	50m	100m	300m	500m	600m	1	1.2	3
Sampling frequency [Hz]			20M	10M	5M	2M	1M	500k	200k	100k	50k	20k	10k	5k	2k	1k	500	200	100	50	20	10	3.33	2	1.66	1	833m	333m
Frequency range [Hz]			8M	4M	2M	800k	400k	200k	80k	40k	20k	8k	4k	2k	800	400	200	80	40	20	8	4	1.33	800m	667m	400m	333m	133m
1/1 OCT	1/3 OCT	Center frequency [Hz]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
22	65	3.15M	○	○																								
	66	4M	● ○	● ○																								
	67	5M	○																									
23	68	6.3M	○																									
	69	8M	● ○																									
	70	10M																										
24	71	12.5M																										

Phase Spectrum PHA

Shows the phase characteristics of the input signal.

Main uses:

- To inspect the phase spectrum of channel 1. Displays the phase of a cosine waveform as a reference (0º).
- To inspect the phase difference between channels 1 and 2.

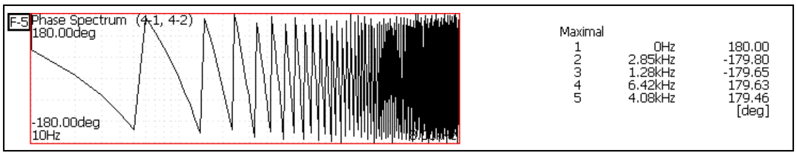
See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

1 Ch FFT: Displays the phase of the signal on channel 1. Displays the phase of a cosine waveform as a reference (0º). Unless the waveform is synchronous, phase values are unstable.

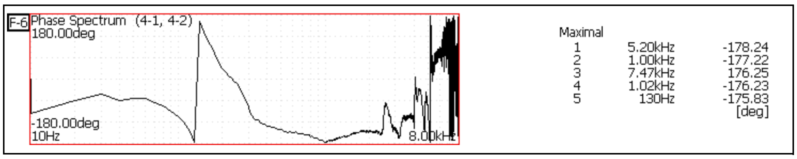
2 Ch FFT: Displays the phase difference between channels 1 and 2. Positive values indicate that the phase of channel 2 is leading.

Axis	Display Type	Description
X axis	**Linear**	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
Y axis	**Lin-Mag**	Analysis values are displayed linearly.

Waveform Example



1chFFT
X axis: Log
Y axis: Lin-Mag



2chFFT
X axis: Log
Y axis: Log-Mag

Emphasizing only a Specific Portion (Highlighted Display)

A specific portion of a phase spectrum can be emphasized and displayed.

See "3.4.7 Emphasizing Analysis Results (phase spectra only)" (⇒ p. 61)

Transfer Function TRF

From the input and output signals, the transfer function (frequency characteristic) of a measurement system can be obtained. It can also be displayed as a Nyquist plot.

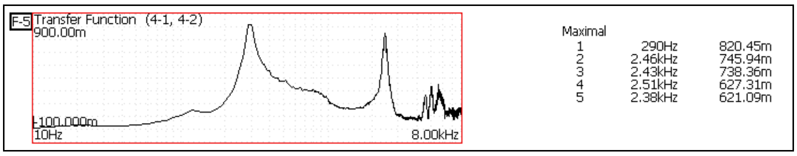
Main uses:

- To inspect a filter’s frequency characteristic
- To inspect the stability of a feedback control system (using the Nyquist plot)
- To inspect the resonance characteristic of an object using an impulse hammer and pick-up sensor

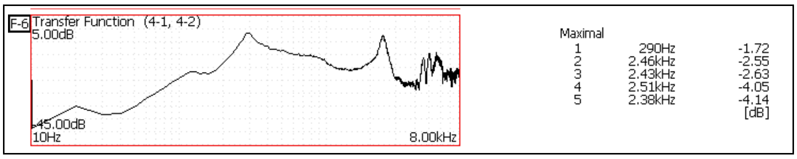
See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102), "Linear Time-Invariant Systems" (⇒ p. 104)

Axis	Display Type	Description
X axis	**Linear**	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
	Nyquist display	Displays the real-number component of the input-output ratio.
Y axis	**Lin-Mag**	Displays the input-output ratio linearly (dimensionless units).
	Log-Mag (logarithm)	Displays the input-output ratio as dB values.
	Lin-Real	Displays the real-number component of the input-output ratio (dimensionless units).
	Lin-Imag	Displays the imaginary component of the input-output ratio (dimensionless units).
	Nyquist display	Displays the imaginary component of the input-output ratio.

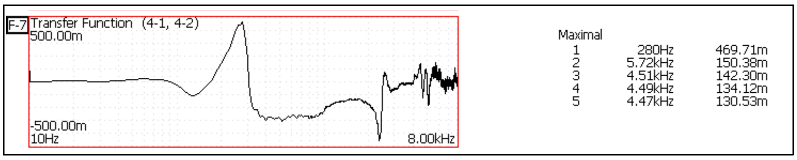
Waveform Example



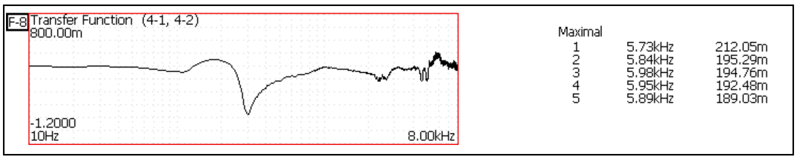
Normal display
X axis: Log
Y axis: Lin-Mag



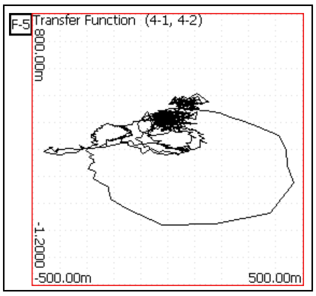
Normal display
X axis: Log
Y axis: Log-Mag



Normal display
X axis: Log
Y axis: Lin-Real



Normal display
X axis: Log
Y axis: Lin-Imag



Nyquist display

Cross Power Spectrum CSP

The product of the spectra of two input signals can be obtained. The common frequency components of two signals can be obtained.
Using the voltage and current waveforms as input signals, active power, reactive power and apparent power can be obtained at each frequency.

Main uses:

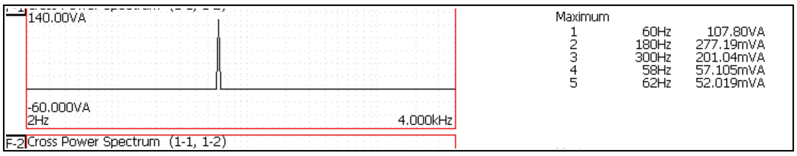
To inspect common frequency components of two signals

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

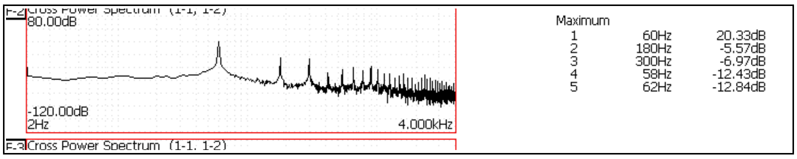
Axis	Display Type	Description
X axis	**Linear**	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
	Nyquist display	Displays the real-number component of the input-output ratio linearly.
Y axis	**Lin-Mag**	Displays the squared value of amplitude contents of analysis data linearly.
	Log-Mag (logarithm)	Displays the amplitude contents of analysis data as dB values. (0 dB reference value: 1eu^2)*
	Lin-Real	Displays the squared values of the real component of analysis data linearly.
	Lin-Imag	Displays the squared values of the imaginary component of analysis data linearly.
	Nyquist display	Displays the imaginary component of analysis data linearly.

* eu: engineering units that are currently set are the standard (e.g., when the unit settings is volts, 0 dB = 1 V^2)

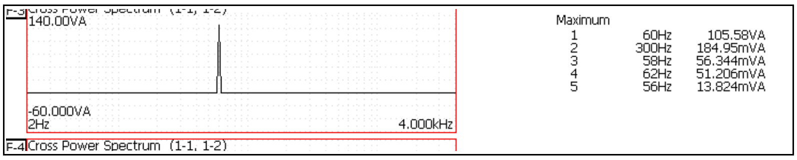
Waveform Example



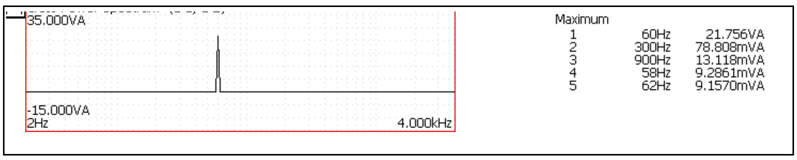
Normal display
X axis: Log
Y axis: Lin-Mag



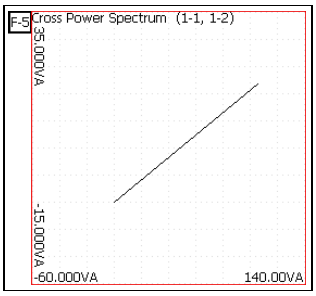
Normal display
X axis: Log
Y axis: Log-Mag



Normal display
X axis: Log
Y axis: Lin-Real



Normal display
X axis: Log
Y axis: Lin-Imag



Nyquist display

Cross-Correlation Function CCR

Using two input signals, shows the correlation of two points on the input signal at time differential *t*. Output is displayed as a function of differential time *t*.

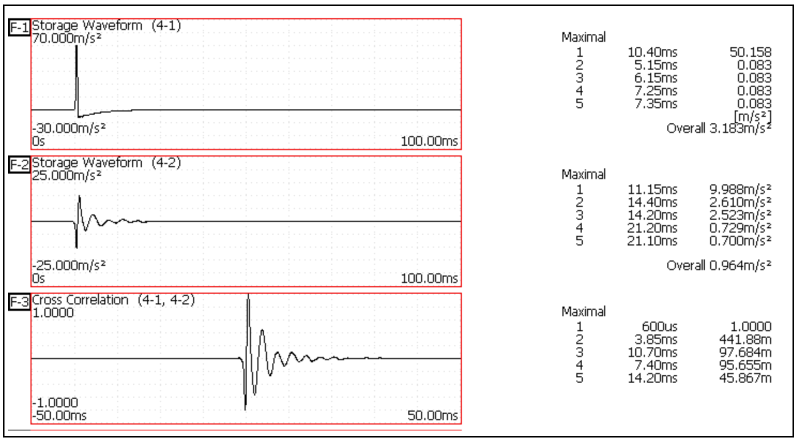
Main uses:

- To determine the phase shift of two signals per unit of time
- To determine the speed and distance of time lag between two signals

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

Axis	Display Type	Description
X axis	**Linear**	Time display The center (*t* = 0) is the reference. To the right is lag time (+*t*), and to the left is lead time (-*t*)
Y axis	**Lin-Mag**	+1 to -1 is displayed in dimensionless units. At time differential *t*, this value is +1 when the correlation of input and output signals is the closest, and 0 when correlation is the least. -1 indicates completely reversed polarity.

Waveform Example



X axis: Linear
Y axis: Lin-Mag

CH1 (Input 1)

CH2 (Input 2)

CCR (Output)

This instrument provides a circular cross-correlation function.
Analysis results are normalized to the maximum value.

Impulse Response IMP

The transfer characteristic of a system is obtained as a time-domain waveform.
Utilizing both output and input signals of the measurement system, a unit impulse is applied to the system and the corresponding response waveform is obtained.

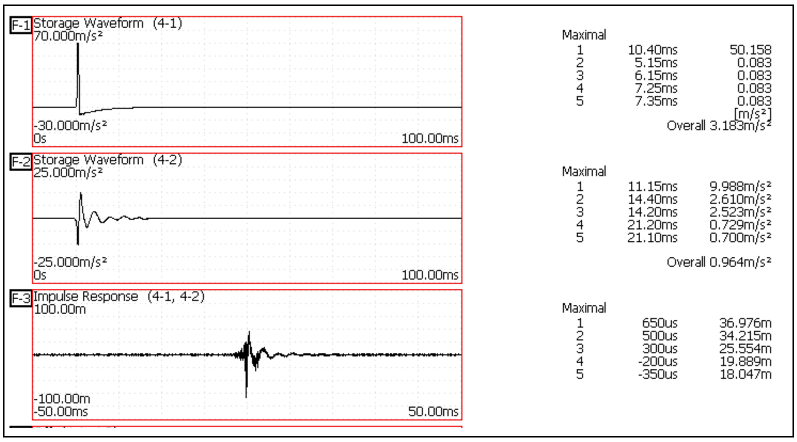
Main uses:

To inspect circuit time constants

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102), "Linear Time-Invariant Systems" (⇒ p. 104)

Axis	Display Type	Description
X axis	**Linear**	Time display The center (t = 0) is the reference. To the right is lag time (+t), and to the left is lead time (-t)
Y axis	**Lin-Mag**	This value is the transfer function provided by inverse Fourier transformation.

Waveform Example



Normal display
X axis: Linear
Y axis: Lin-Mag

CH1

CH2

IMP

Coherence Function COH

This function gives a measure of the correlation (coherence) between input and output signals. Values obtained are between 0 and 1.
With a single measurement, the coherence function gives a value of one for all frequencies. Spectrum (frequency-domain) averaging should always be performed before measurement (analysis is not available with time-domain averaging).

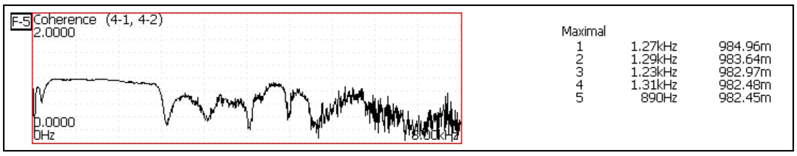
Main uses:

- To evaluate transfer functions
- In a system with multiple inputs, to inspect the effect of each input on the output

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

Axis	Display Type	Description
X axis	Linear	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
Y axis	Lin-Mag	Displays the causal relationship and degree of relationship between two input signals, as a value between 0 and 1 (dimensionless units).

Waveform Example



Normal display
X axis: Log
Y axis: Lin-Mag

The coherence function has two general definition formulas. For the definition formulas, see "3.10.2 Analysis Mode Functions" (⇒ p. 102)

Power Spectrum Density (Linear Predictive Coding) LPC

When the spectrum shape is complex and hard to comprehend with either linear or power spectra, a rough spectrum structure can be obtained.

Not available with external sampling enabled.

Main uses:

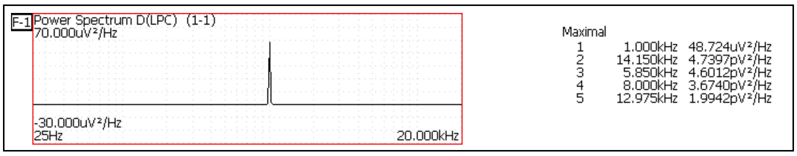
To obtain a spectral envelope using statistical methods

See About the Functions "3.10.2 Analysis Mode Functions" (⇒ p. 102)

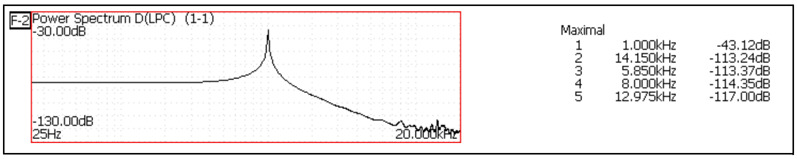
Axis	Display Type	Description
X axis	Linear	Frequency is displayed with equal spacing Display Range: DC to the top of the frequency range
	Log	Frequency is displayed logarithmically Display Range: 1/400th to 1/4000th (depending on the number of analysis points) to the top of the frequency range
Y axis	Lin-Mag	Analysis values are displayed linearly.
	Log-Mag (logarithm)	Analysis values are displayed as dB values. (0 dB reference value: 1eu^2/Hz)*

* eu: engineering units that are currently set are the standard (e.g., when the unit settings is volts, 0 dB = 1 V^2/Hz)

Waveform Example



X axis: Log
Y axis: Lin-Mag



X axis: Log
Y axis: Log-Mag

NOTE

- Always specify the order (from 2 to 64). Higher orders can expose finer spectral details.
- Amplitude values provided by LPC are not always the same as the power spectrum density.
- If an error occurs during analysis, no waveform is displayed.
- Noise-like phenomena can strongly affect the spectrum shape.

3.10.2 Analysis Mode Functions

Analysis Mode	Internal analysis formula (linear, real, imag [imaginary], log [logarithm])
No Analysis	No analysis.
Storage Waveform	A waveform obtained by applying the window function to a time-domain waveform.
Linear Spectrum (LIN)	$X(k)=\sum_{n=0}^{N-1}x(n)W^{kn}$ $F(k)=CX(k)$ $C=\begin{cases}1/N(DC)\\2/N(AC)\end{cases}$ $linear=\lvert F(k)\rvert$ $real=\mathrm{Re}\{F(k)\}$ $imag=\mathrm{Im}\{F(k)\}$ $\log=20\log\lvert F(k)\rvert$
RMS Spectrum (RMS)	$F'(k)=C'F(k)$ $C'=\begin{cases}1\quad(DC)\\1/\sqrt{2}(AC)\end{cases}$ $linear=\lvert F'(k)\rvert$ $real=\mathrm{Re}\{F'(k)\}$ $imag=\mathrm{Im}\{F'(k)\}$ $\log=20\log\lvert F'(k)\rvert$
Power Spectrum (PSP)	$P(k)=a\lvert F(k)\rvert^2$ $a=\begin{cases}1\quad(DC)\\1/2(AC)\end{cases}$ $linear=P(k)$ $\log=10\log\lvert P(k)\rvert$
Power Spectrum Density (PSD)	$P'(k)=P(k)/\delta f$ δf: Frequency resolution $linear=P'(k)$ $\log=10\log\lvert P'(k)\rvert$
Auto-correlation Function (ACR)	$R_{xx}(n)=\frac{1}{N}\sum_{k=0}^{N-1}\lvert X(k)\rvert^2W^{-kn}$ (recursive convolution)
Histogram (HIS)	Counts amplitude data.
Transfer Function (TRF)	$H(k)=Y(k)/X(k)$ $linear=\lvert H(k)\rvert$ $real=\mathrm{Re}\{H(k)\}$ $imag=\mathrm{Im}\{H(k)\}$ $\log=20\log\lvert H(k)\rvert$
Cross Power Spectrum (CSP)	$S_{yx}(k)=X^*(k)Y(k)$: Cross Spectrum $X_{power}(k)=AS_{yx}(k)$ $A=\begin{cases}1/N^2\\2/N^2\end{cases}$ $linear=\lvert X_{power}(k)\rvert$ $real=\mathrm{Re}\{X_{power}(k)\}$ $mag=\mathrm{Im}\{X_{power}(k)\}$ $\log=10\log\lvert X_{power}(k)\rvert$
Cross-correlation Function (CCR)	$R_{yx}(n)=\frac{1}{N}\sum_{k=0}^{N-1}S_{yx}(k)W^{-kn}$ (recursive convolution)
Impulse Response (IMP)	$h(n)=\frac{1}{N}\sum_{k=0}^{N-1}\frac{Y(k)}{X(k)}W^{-kn}$
Coherence Function (COH)	$coh(k)=\sqrt{\frac{S_{yx}(k)S_{yx}^*(k)}{S_{xx}(k)S_{yy}(k)}}$
Phase Spectrum (1ch / 2ch) (PHA)	$\theta(k)=180/\pi\times\tan^{-1}(\mathrm{Im}(F'(k))/\mathrm{Re}(F'(k))$ $\theta(k)=180/\pi\times\tan^{-1}(\mathrm{Im}(S_{yx}(k))/\mathrm{Re}(S_{yx}(k))$
Power Spectrum (LPC)	(Abbr.) Spectrum approximation from Linear Predictive Coding. See "Linear Predictive Coding (LPC)" (⇒ p. 115)

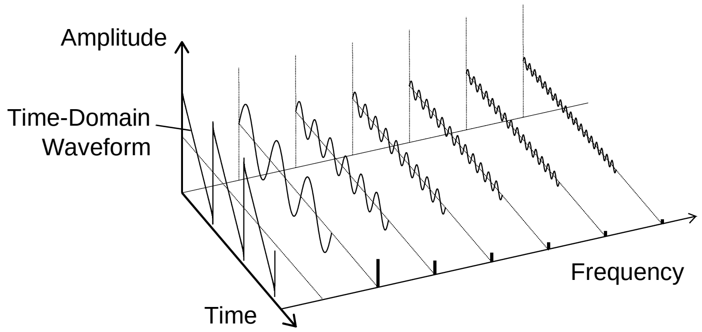
3.11 FFT Definitions

What is FFT?

FFT is the abbreviation for Fast Fourier Transform, an efficient method to calculate the DFT (Discrete Fourier Transform) from a time-domain waveform. Also, the reverse process of transforming frequency data obtained by the FFT back into its original time-domain waveform is called the IFFT (Inverse FFT). The FFT functions perform various types of analysis using FFT and IFFT.

Time and Frequency Domain Considerations

All signals are input to the instrument as a function of the time domain. This function can be considered as a combination of sine waves at various frequencies, such as in the following diagram. The characteristics of a signal that may be difficult to analyze when viewed only as a waveform in the time domain can be easier to understand by transforming it into a spectrum (the frequency domain).



Discrete Fourier Transforms and Inverse FFT

For a discrete signal $x(n)$, the DFT is $X(k)$ and the number of Analysis points is N, which relate as follows:

$$X(k) = DFT\{x(n)\} = \sum_{n=0}^{N-1} x(n) W_N^{kn} \quad \text{(1)}$$

$$x(n) = IDFT\{X(k)\} = \frac{1}{N} \sum_{n=0}^{N-1} X(k) W_N^{-kn} \quad \text{(2)}$$

$$W_N = \exp\left(-j\frac{2\pi}{N}\right) \quad \text{(3)}$$

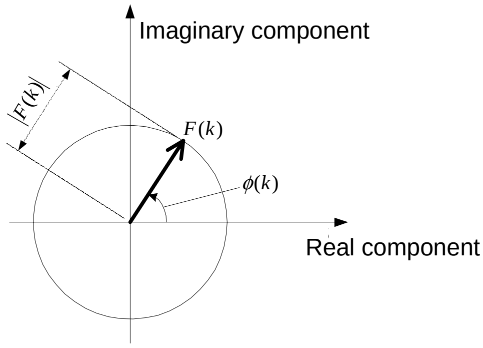
$X(k)$ is typically a complex number, so expression (1) can be transformed again and written as follows:

$$F(k) = |F(k)| \exp\{j\phi(k)\} = |F(k)| \angle \phi(k) \quad \text{(4)}$$

$$\phi(k) = \tan^{-1} \frac{\mathrm{Im}\{X(k)\}}{\mathrm{Re}\{X(k)\}} \quad \text{(5)}$$

$|F(k)|$: Amplitude spectrum, $\phi(k)$: Phase spectrum

Representing the above relationship on a complex flat surface produces the following figure.



Linear Time-Invariant Systems

Consider a linear time-invariant (LTI) system $y(n)$ that is a response to discrete time-domain signal $x(n)$.

In such an LTI system, the following expression applies to any integer A_i when the response to $x_i(n)$ is $y_i(n) = L[x_i(n)]$.

$$L[A_1 x_1(n) + A_2 x_2(n)] = A_1 y_1(n) + A_2 y_2(n) \quad (6)$$

If the system function of an LTI system is $h(n)$, the input/output relationship can be obtained by the next expression.

$$y(n) = \sum_{m=0}^{\infty} h(n)x(n-m) = \sum_{m=-\infty}^{\infty} h(n-m)x(m) \quad (7)$$

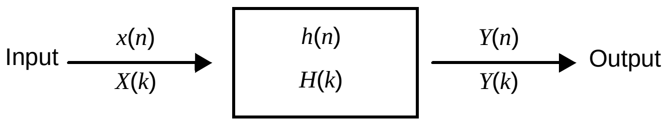
Therefore, when a unit impulse $\delta(n)$ (which is 1 when $n = 0$, and 0 when $n \neq 0$) is applied to $x(n)$, the input/output relationship is:

$$y(n) = h(n) \quad (8)$$

This means that when the input signal is given as a unit impulse, the output is the LTI system characteristic itself.
The response waveform of a system to a unit impulse is called the **impulse response**.
On the other hand, when the discrete Fourier transforms of $x(n)$, $y(n)$ and $h(n)$ are $X(k)$, $Y(k)$ and $H(k)$, respectively, expression (7) gives the following:

$$Y(k) = X(k)H(k) \quad (9)$$

$H(k)$ is also called the transfer function, calculated from $X(k)$ and $Y(k)$. Also, the inverse discrete Fourier transform function of $H(k)$ is the unit impulse response $h(n)$ of the LTI system. The impulse response and transfer function of this instrument are calculated using the relationships of expression (9).



Number of Analysis Points

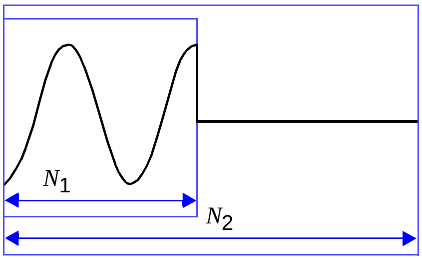
The FFT functions of this instrument can perform frequency analysis of time-domain waveforms consisting of 1000, 2000, 5000 or 10,000 points. However, when the following conditions are satisfied, previously analyzed data can be reanalyzed with a different number of analysis points.

A. When measurements are made with the averaging function disabled (Off)
B. When measurements are made with the averaging function enabled for time-domain averaging (simple or exponential).

When the number of analysis points at measurement time is N_1 and the number of analysis points is changed to N_2 after measurement, the instrument performs as follows.

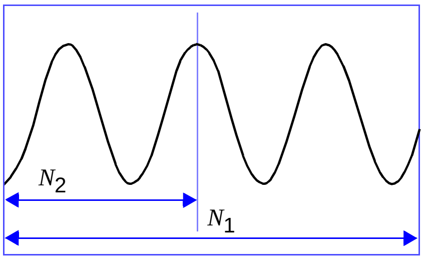
(1) When $N_1 < N_2$

- Because not enough data has been collected, zero is inserted for time after the end of the measured waveform.
- The window function applies only to the N_1 segment.
- Frequency resolution is increased. For example, if N_1 = 1000 and N_2 = 2000, frequency resolution is doubled.
- The average energy of the time-domain waveform is reduced, so the amplitude of the linear spectrum is also reduced.



(2) When $N_1 > N_2$

- The specified (N_2) segment is extracted from the head of the (N_1) data.
- The window function applies only to the N_2 segment.
- Frequency resolution is decreased. For example, if N_1 = 2000 and N_2 = 1000, frequency resolution is halved.
- The average energy of the time-domain waveform is unchanged, so the amplitude of the linear spectrum is not significantly affected.



Aliasing

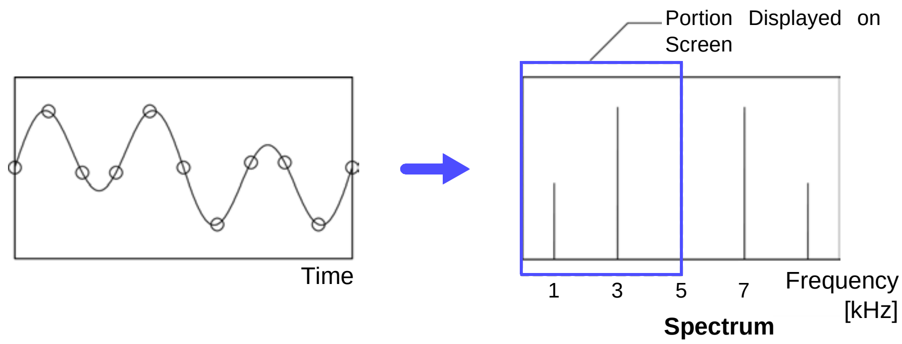
When the frequency of a signal to be measured is higher than the sampling rate, the observed frequency is lower than that of the actual signal, with certain frequency limitations. This phenomena occurs when sampling occurs at a lower frequency than that defined by the Nyquist-Shannon sampling theorem, and is called **aliasing**.
If the highest frequency component of the input signal is f_{max} and the sampling frequency is f_S, the following expression must be satisfied:

$$f_s = 2 f_{max} \quad (10)$$

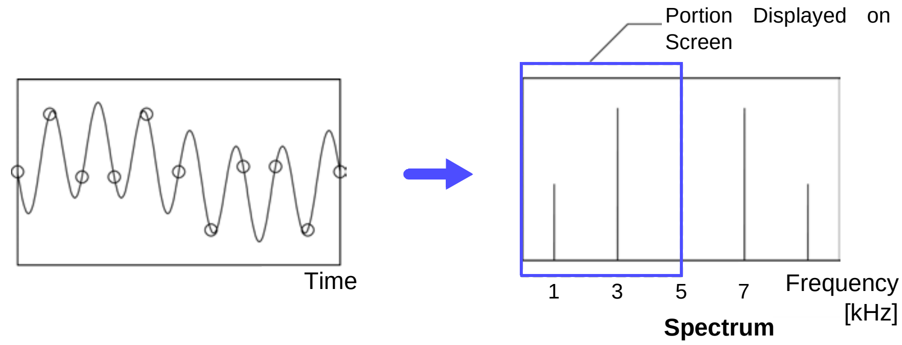
Therefore, if the input includes a frequency component higher than $f_S/2$, it is observed as a lower frequency (alias) that does not really exist.

The following diagrams show the results of spectrum analysis of composite waveforms having components of 1 kHz and 3 kHz, and of 1 kHz and 7 kHz.
If sampling frequency f_S is 10 kHz, the spectral component of an input frequency above 5 kHz (in this case, 7 kHz) is observed as an alias at 5 kHz or below.
In this example the difference between the 3 and 7 kHz components is indiscernible.

Composite waveform of 1 kHz and 3 kHz components sampled at 10 kHz



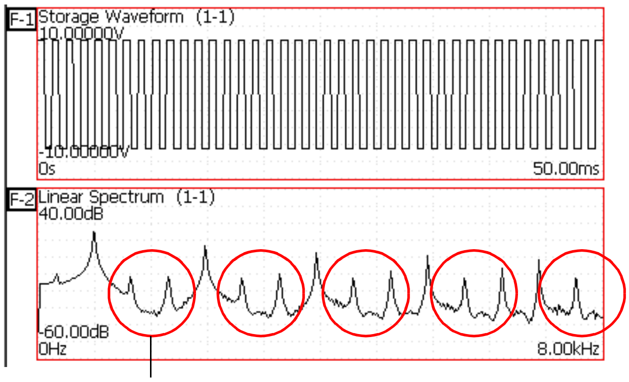
Composite waveform of 1 kHz and 7 kHz components sampled at 10 kHz



Anti-Aliasing Filters

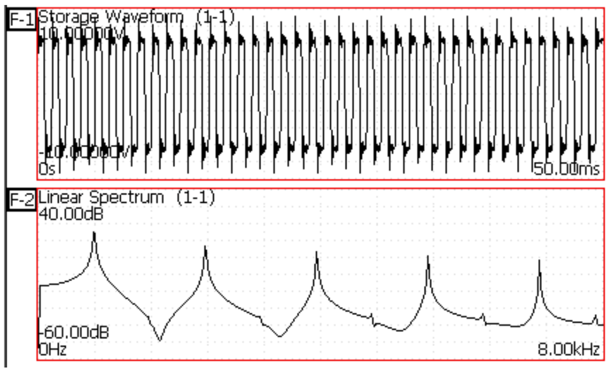
When the maximum frequency component of the input signal is higher than one-half of the sampling frequency, aliasing distortion occurs. To eliminate aliasing distortion, a low-pass filter can be used that cuts frequencies higher than one-half of the sampling frequency. Such a low-pass filter is called an anti-aliasing filter.
The following figures show the effect of application of an anti-aliasing filter on a square wave input waveform.

Without an anti-aliasing filter



Non-existent frequency components are observed.

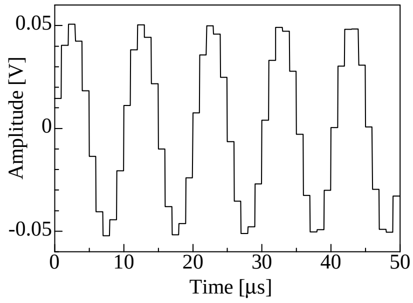
With an anti-aliasing filter



Imaging

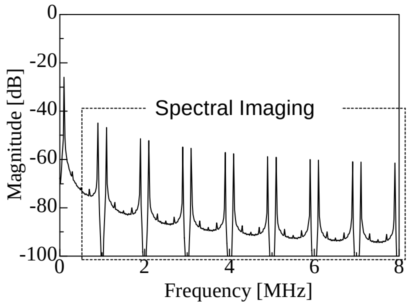
When the instrument is set to a measurement frequency range that requires a higher sampling rate than the maximum capability of the input module, intermediate data points are interpolated between successive data samples. In this case, the time-domain waveform exhibits a stair-step shape. When FFT analysis is performed in this situation, non-existent high frequency spectral components appear. This phenomena is called zero-order hold characteristic **imaging**.

The following figures show the time-domain waveform and spectrum of a sine wave applied to the Model 8959 DC/RMS Unit.



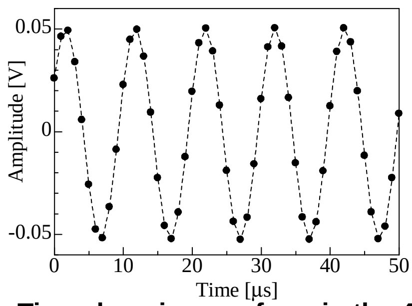
Time-domain waveform in the 8 MHz frequency range (sampling frequency = 20 MHz)

The highest sampling frequency of the Model 8959 is 1 MHz, so the same input data value is used for each block of 20 samples, resulting in a stair-step waveform.



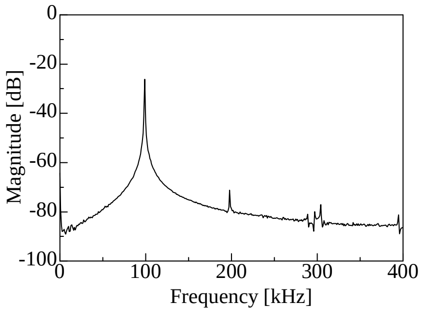
Spectrum

When FFT processing is performed on a stair-step waveform, the resulting spectrum shows non-existent components.
In this case, the spectral components above 1 MHz / 2 = 500 kHz are theoretically meaningless.



Time-domain waveform in the 400 kHz frequency range (sampling frequency = 1 MHz)

Here, the frequency range matches the sampling frequency of the Model 8959, so no interpolation is performed on the time-domain data.



Spectrum

To avoid imaging phenomena when analyzing waveforms with the FFT function, verify the maximum sampling frequency of the input module before measuring.

Averaging

With the FFT function, averaging is performed according to the following analytical expressions. Averaging in the time domain produces meaningless data if performed with inconsistent trigger criteria.

1. Simple Averaging (Time and Frequency Domains)

Sequences of acquired data are summed and divided by the number of acquisitions.

$$A_n = \frac{(n-1)A_{n-1} + Z_n}{n} \quad (11)$$

n: count of measurements to average
A_n: averaging results of n counts
Z_n: measurement data of n counts

2. Exponential Averaging (Time and Frequency Domains)

Before averaging, newer data is given exponentially greater significance than older data.

$$A_n = \frac{(N-1)A_{n-1} + Z_n}{N} \quad (12)$$

N: Specified number of counts to average
n: count of measurements to average
A_n: averaging results of n counts
Z_n: measurement data of n counts

Overall Value

The overall value is the sum of the power spectrum at each frequency. This value is equal to the positive sum of the squares of the (RMS) input signals, except when frequency averaging is performed. The FFT function of this instrument calculates and displays the RMS values for stored waveforms and the overall value from the sum of the power spectrum for the frequency domain.

$$(Over\ all) = \sum_{i=0} P_i \quad (13)$$

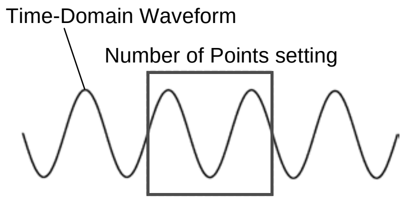
P_i: power spectrum of value i

Window Function

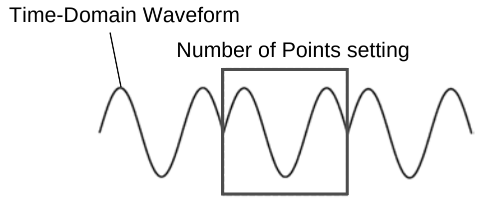
The Fourier transform of a continuous system is defined by the integral Calculus in expression (14) for the time range from minus infinity to plus infinity.

$$X(f) = \int_{-\infty}^{\infty} x(t)\varepsilon^{-2\pi ft}dt \quad \text{(14)}$$

However, because expression (14) cannot be calculated with actual measurements, the Analysis is performed on a segment between finite limits. Processing the waveform segment within these limits is called window processing. For FFT analysis, the waveform segment within these limits is assumed to repeat periodically (as shown below).



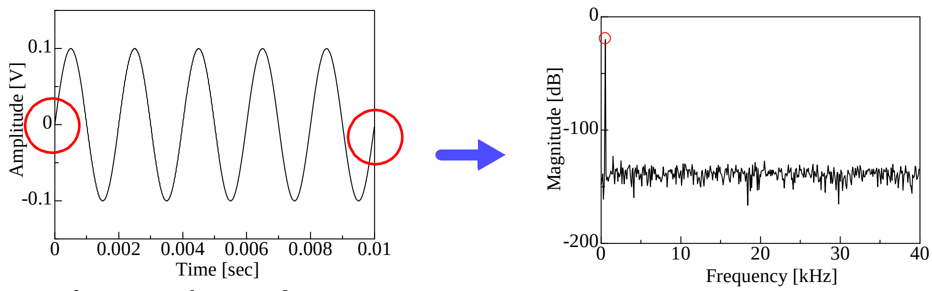
Original Time-Domain Waveform



Waveform to be assumed with FFT

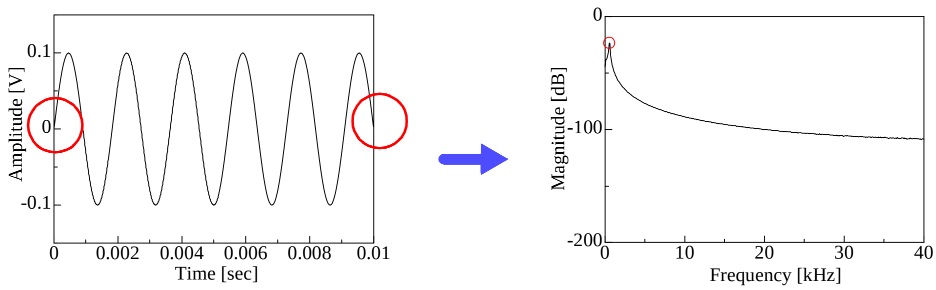
When the number of points for FFT analysis is an integer multiple of the input signal frequency, a single-line spectrum is obtained. However, if it is not an integer multiple of the frequency (when the waveform assumed with FFT includes discontinuous points), the spectrum is scattered, and a line spectrum cannot be obtained. This phenomena is called leakage error (as shown below).

Time-domain waveform when the number of analysis points is an integer multiple of the input frequency



Time-Domain Waveform **Spectrum**

Time-domain waveform when the number of analysis points is not an integer multiple of the input frequency

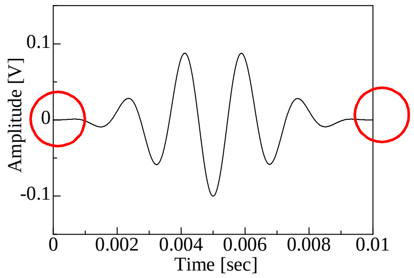


Time-Domain Waveform **Spectrum**

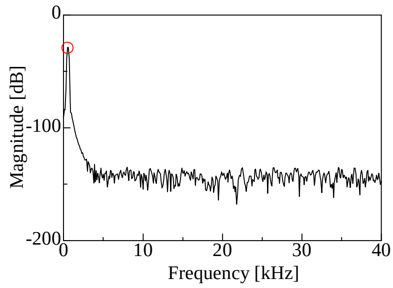
The window function was created to suppress such leakage errors. The window function smoothly connects each end of the time-domain waveform where it is cut off.

The following figure presents an example of spectral analysis by applying a window function to a time-domain waveform.
Using the window function, discontinuous points on the time-domain waveform are eliminated, so the wave shape approaches a line spectrum.

When a Blackman-Harris window function is applied to a time-domain waveform (⇒ p. 110) in which the number of analysis points is not an integer multiple of the input frequency



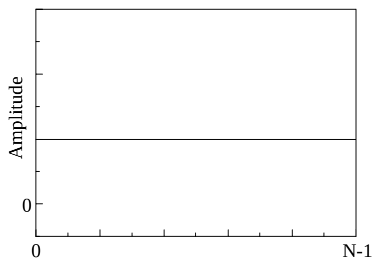
Time-Domain Waveform



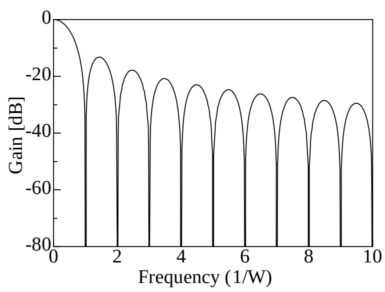
Spectrum

The following figure shows the time-domain waveform of the window function and its spectrum.
Each spectrum shows a large peak at a low frequency, and many smaller peaks at higher frequencies. The largest peak is called the **main lobe**, and the smaller peaks are the **side lobes**.
The most accurate results of the FFT function are obtained when the width of the main lobe and the amplitude of the side lobes are minimized, although both conditions cannot be satisfied at the same time.
Therefore, a window function having a wide main lobe is used when amplitude values are important, while a window function having a small main lobe is used to observe fine spectral details, and a window function having small side lobe amplitudes is used to exclude the effects of the surrounding spectrum.
However, because the main lobe width is proportional to the width (1/W) of the window, increasing the number of analysis points increases the frequency resolution.

Rectangular window

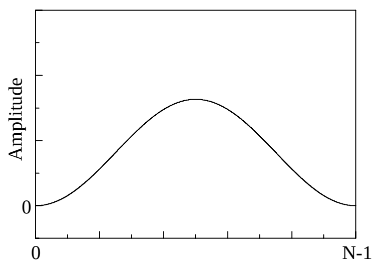


Time-Domain Waveform

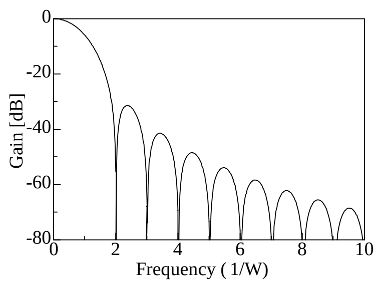


Spectrum

Hann window

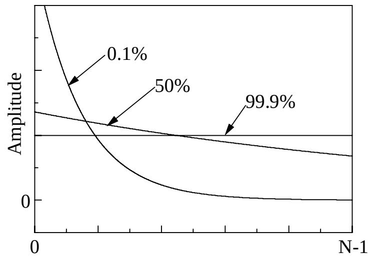


Time-Domain Waveform

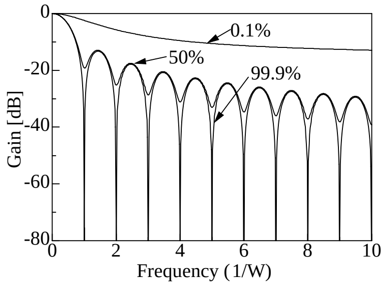


Spectrum

Exponential window

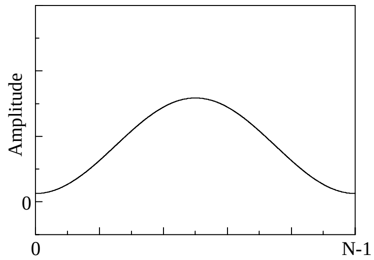


Time-Domain Waveform

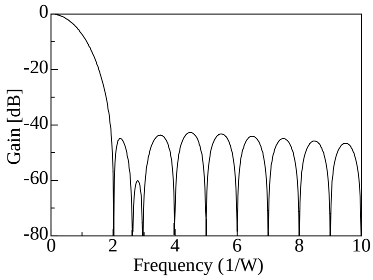


Spectrum

Hamming window

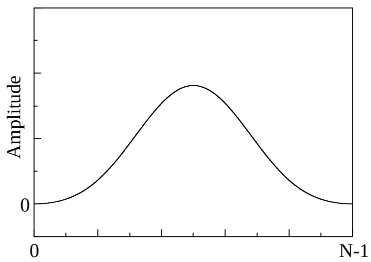


Time-Domain Waveform

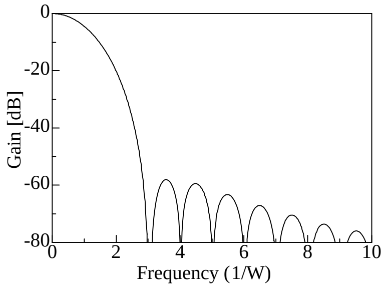


Spectrum

Blackman window

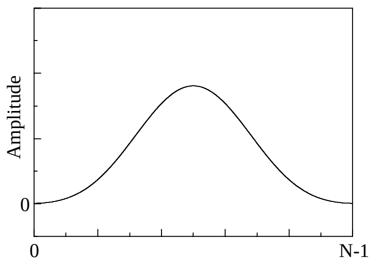


Time-Domain Waveform

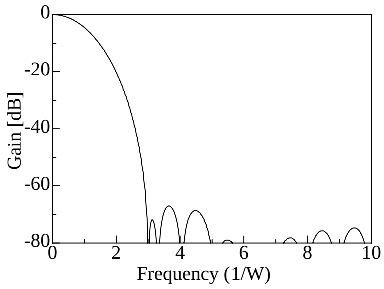


Spectrum

Blackman-Harris window

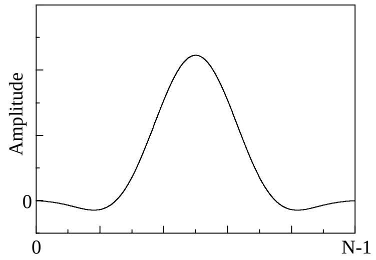


Time-Domain Waveform

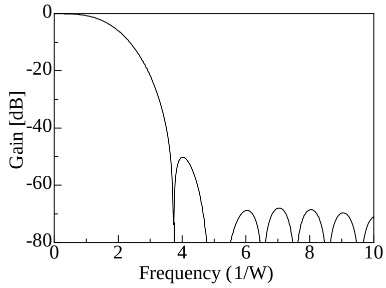


Spectrum

Flat top window

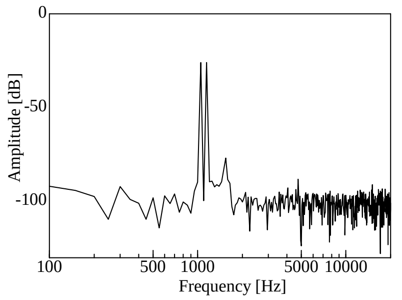


Time-Domain Waveform

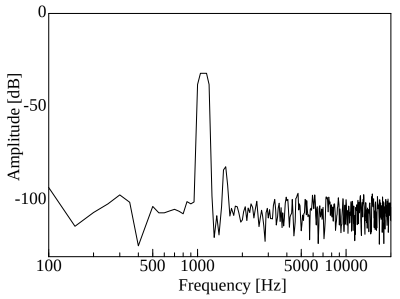


Spectrum

The following example shows input sine waves of 1050 and 1150 Hz analyzed with different window functions. Because the frequencies in this example are close to one another, a rectangular window with a narrow main lobe is able to separate and display both frequencies, but a Hann window with a wide main lobe displays the two as a single spectral component.



Analysis Using a Rectangular Window

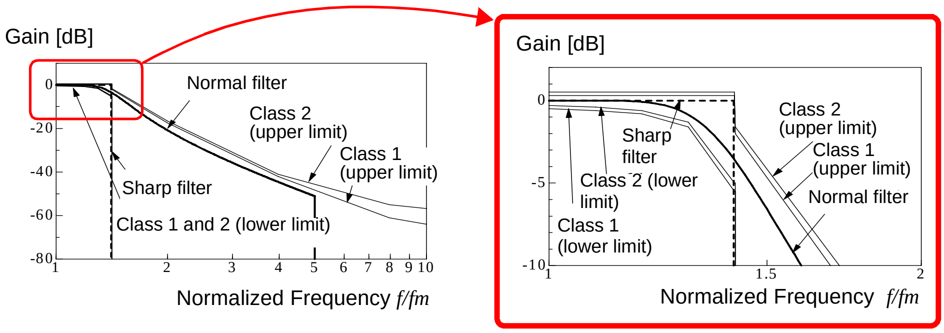


Analysis Using a Hann Window

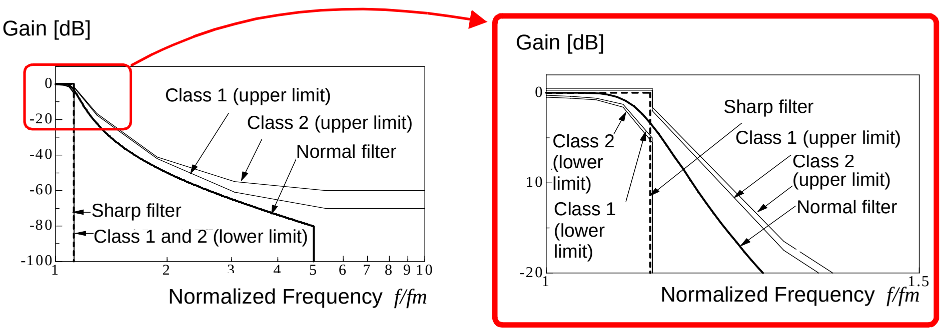
Octave Filter Characteristics

Octave filter characteristics are determined according to IEC61260 standards. The figures below show these standards and the filter characteristics of this instrument.

1/1 Octave Filter Characteristic

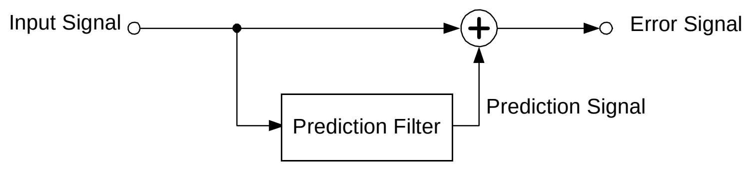


1/3 Octave Filter Characteristic



Linear Predictive Coding (LPC)

In the following figure, linear predictive coding is implemented by passing a sample of the input signal through the prediction filter while altering the filter so as to minimize errors in the original signal.



Given a time-discrete signal $\{x_t\}$ (t is an integer) where the input signal is sampled at interval ΔT, LPC analysis presumes the following relationship between current sample value x_t and the value of previous sample p.

$$x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \cdots + \alpha_p x_{t-p} = \varepsilon_t \quad (15)$$

However, $\{\varepsilon_t\}$ is an uncorrelated random variable with average value 0 and the dispersion σ^2.
Expression (15) shows how current sample value x_t can be "linearly predicted" from previous sample values. If the predicted value of x_t is actually $\hat{x}_t$, expression (15) can be transformed as follows.

$$x_t = \hat{x}_t + \varepsilon_t = -\sum_{i=1}^{p} \alpha_i x_{t-i} + \varepsilon_t \quad (16)$$

Here, α_i is called the **linear predictor coefficient**.
For LPC analysis, this coefficient is calculated using the Levinson-Durbin algorithm, and a spectrum is obtained. In this instrument, the order of the coefficient can be set from 2 to 64. Larger orders reveal fine spectral components, while small orders reveal the overall spectrum shape.

Index

A

B

C

D

E

F

G

H

I

L

Index

X

Y

Z

Index

HIOKI 8860/8861 MEMORY HiCORDER
Analysis Supplement

Publication date: July 2006 Revised edition 1

Edited and published by HIOKI E.E. CORPORATION
Technical Support Section

All inquiries to International Sales and Marketing Department
81 Koizumi, Ueda, Nagano, 386-1192, Japan
TEL: +81-268-28-0562 / FAX: +81-268-28-0568
E-mail: os-com@hioki.co.jp
URL http://www.hioki.co.jp/

Printed in Japan 8860A987-01

HIOKI

HIOKI E. E. CORPORATION

HEAD OFFICE
81 Koizumi, Ueda, Nagano 386-1192, Japan
TEL +81-268-28-0562 / FAX +81-268-28-0568
E-mail: os-com@hioki.co.jp / URL http://www.hioki.co.jp/

HIOKI USA CORPORATION
6 Corporate Drive, Cranbury, NJ 08512, USA
TEL +1-609-409-9109 / FAX +1-609-409-9108

8860A987-01 06-07H

Printed on recycled paper