NF

IMPEDANCE/GAIN-PHASE ANALYZER

ZGA5920

INSTRUCTION MANUAL

NF Corporation

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───── Preface ─────

Thank you for purchasing the "ZGA5920 IMPEDANCE/GAIN-PHASE ANALYZER". Please read, first of all, "**Safety Precautions**" on the next page, so that you can use the instrument in the correct and safe manner.

● Notes on marks, symbols and terminology used in this Manual
The marks shown below are used in this Manual to indicate Warning and Caution instructions. Please carefully follow the instructions that are indicated by these marks, so that users or operators are safe in using the instrument and that the instrument will not be damaged during operation.

⚠ WARNING　Instructions are given to avoid such potential hazardous situations that instrument operators would be involved in a risk of facing death and/or personal serious injury.

⚠ CAUTION　Instructions are given to avoid possible personal injury or instrument damages due to incorrect use/operation of the instrument.

● This Instruction Manual comprises the following Chapters.
Please read the Manual from the very beginning, i.e., from Chapter 1, if you use this type of instrument for the first time. Meanwhile, please be advised that the instructions for the USB interface are included in a separate manual.

1. **Introduction**
This Chapter involves such information as overview, features, applications, functions and operational principles of the instrument.
2. **Preparations before use**
Information is given in this Chapter on what should be done by users and other people concerned before you use the instrument.
3. **Description on panels and basic operations**
Descriptions are given in this Chapter on functions and basic operations of the indicators and connectors located on panels. Please also read this Chapter while you operate the instrument.
4. **Measurement operation (Basic)**
Descriptions are given in this Chapter on operations of impedance measurement and gain-phase measurement.
5. **Measurement operation (Samples)**
Descriptions are given in this Chapter on operations of measurement functions for each application.
6. **Files**
Descriptions are given for file formats.
7. **Troubleshooting**
Error messages and their implications are described.
8. **Maintenance**
Procedures of performance testing of the instrument are described. Information on storage, re-packaging and transportation is also provided.
9. **Specifications**
Instrument specifications are provided in regard to functions and performance.

─── Safety Precautions ───

To ensure safe use, be sure to observe the following warnings and cautions.

NF Corporation shall not be held liable for damages that arise from a failure to observe these warnings and cautions.

This product is a Class I product (with protective conductor terminal) that conforms to the JIS and IEC insulation standards.

- **Observe all the instructions of this Instruction Manual by all means.**

  This Instruction Manual contains those instructions which are to be observed by users so that users and/or operators prepare and operate the instrument in safety.

  Read the Manual by all means as your first duty before you use the instrument.

  All the Warnings described in this Manual are provided for you to avoid any serious accidents to occur from using the instrument. Therefore, your observation of the instructions in the Manual is essential to use the instrument.

- **Ground the instrument at all times.**

  To avoid risk of electric shock, be sure to connect securely to ground through less than 100 Ω. This instrument is so designed that the instrument will be grounded by connecting its three-pole power supply plug with a three-pole electric power source outlet with a proper grounding connection.

- **Check the power supply voltage.**

  This instrument operates at the power source voltage as described in "2.3 Grounding and power supply connection" in this Instruction Manual.

  Inspect and confirm that the outlet voltage conforms to the rated supply voltage of the instrument, before connecting the power supply of the instrument to the power source.

- **React promptly if you notice anything wrong with the instrument.**

  Promptly stop operating the instrument by disconnecting the power supply cable plug from the power source outlet, if any amount of smoke or strange smell or sound comes out from the instrument, for example.

  Immediately contact NF Corporation or your dealer, if you have a problem as described above. Keep the instrument unoperated and take measures so that no one could operate it until the instrument will have been repaired.

- **Do not operate the instrument in the gaseous environment.**

  Operation of the instrument in any gaseous environment could cause an explosion.

- **Do not remove the housing (cover) from the instrument.**

  This product has high-voltage portions inside. Never remove the housing (cover) from the instrument by any means.

  No one except the service technicians certified by NF Corporation are allowed to check or touch the inside of this instrument. Do not touch the inside by yourself in any case.

● **Do not modify the instrument.**

Never modify or try to modify the instrument. Your modification of the instrument could cause unexpected accidents or failures. NF Corporation has the right to refuse providing services for any instruments modified by unauthorized persons.

● **Marks and codes to indicate safety information and/or instructions:**

General definitions for marks and codes to indicate safety information and/or instructions in this Manual as well as at the instrument itself are the following:

⚠ **Instructions Manual reference mark**

This mark indicates that users should pay attention to potential failures, damages or injury and that they are requested to refer to the appropriate section in the Reference Manual.

⚡ **Mark to indicate risks of electric shocks**

This mark is used at locations where one can receive an electric shock under certain conditions.

⚠ WARNING **Warning mark**

Instructions are given to avoid such potential hazardous situations that instrument operators would be involved in a risk of facing death and/or personal serious injury.

⚠ CAUTION **Caution mark**

Instructions are given to avoid possible personal injury or instrument damages due to incorrect use/operation of the instrument.

● **Other marks and codes**

| This mark indicates the "ON" position of the power switch.
○ This mark indicates the "OFF" position of the power switch.
⏚ This mark indicates a connection with the instrument housing.

⏚ This mark indicates that the outer conductor of the connector is connected with the signal ground.

● **Request about disposal**

For environmental protection, please note the following guidelines for disposal of this device.

1. This device is equipped with a lithium battery. Ask an industrial waste disposal contractor to dispose of such batteries.
2. Ask an industrial waste disposal contractor to dispose of the entire device.

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1. Introduction

1.1 Features

The "**ZGA5920 IMPEDANCE/GAIN-PHASE ANALYZER**" can measure the impedance characteristics of electronic components, dielectric materials, and magnetic materials, the gain-phase characteristics of electronic circuits, and the servo characteristics of negative feedback loop. In addition to the measurement, it can perform the measurement data analysis, the feature extraction, the simulation, and the report generation on one unit. It can be widely used for the material research, circuit analysis, or other purpose.

■ Various measurement functions
It can measure the impedance characteristics of the target sample and the gain-phase characteristics of the target circuit by sweeping them in the wide frequency range between 0.1 mHz and 15 MHz. In addition to the frequency, it can sweep the measurement amplitude, the DC bias, and the time (zero span), which enables the nonlinearity and time variability measurements of the sample.

■ Advanced analysis functions for various measurement applications
It provides the advanced analysis functions for many applications, such as piezoelectric parameter extraction, characteristics simulation, and drive circuit design support as analysis functions for the piezoelectric material.

    (Examples of the supported application and analysis functions)
    Piezoelectric material: Piezoelectric parameter display, simulation, etc.
    Dielectric material, magnetic material: Derivation of dielectric permittivity and magnetic permeability, etc.
    Electronic components (inductor, capacitor, and resistor): Equivalent circuit estimation and simulation, etc.
    Electronic component (transformer): Mutual inductance, coupling coefficient, turns ratio, etc.
    Servo characteristics: Phase margin/gain margin, open- and closed-loop conversion, transfer function generation, etc.
    Amplifier circuit: Transfer function generation, CMRR, PSRR, Differential gain/differential phase, group delay, saturation characteristics, etc.
    Filter: passband ripple, attenuation, cutoff frequency, group delay, transfer function generation, etc.

■ Excellent operability
This instrument is operated by using a keyboard and trackball. The results of measurement, analysis, and simulation are displayed on the high resolution large-sized screen monitor with a high level of visibility (external). They can also be printed by the printer or copied to a USB memory as a file to be reused on a PC.

■ Management functions for measurement conditions and measurement result data
Measurement conditions can be saved as measurement recipes, and measurement conditions that vary with the sample can be managed as the measurement conditions for each sample unit.
Recipes and measurement result data can easily be verified on the instrument operation screen. Even if the number of recipes or measurement data increases, you can easily find the target recipe or measurement result by selecting what to be displayed.

■ Automatic measurement function
The measurement can be automatically repeated, such as the measurement due to change of DC bias voltage.

■ Measurement support
The operation screen shows how to connect the sample to this instrument and to operate this instrument, and provides the support information to help you determine measurement conditions. When this instrument is connected to the Internet, you can obtain the information useful for measurement, and inquire about measurement methods while operating this instrument.

■ Ability to work with external devices
This instrument has a control I/O function to control external devices in concert with measurements on the instrument or control measurements on this instrument according to external control signals.

■ Data logging function for analog signals
This function allows you to log signal states during measurement.
This instrument can be used as a drive source to measure (drive) DUTs while logging data.

■ Ability to work with user systems
Connecting this instrument to LAN allows you to easily build a measurement system on PC that remotely controls measurement operations from PC and accesses the application data stored in this instrument, such as measurement recipes and measurement result data.
A software developer kit provided with this instrument can be used to build a system on PC by programming in the general PC software development environment.

■ NF FRA compatible remote control functions
This instrument has the FRA compatible remote control functions so that you can use this instrument as our FRA5097. The FRA compatible remote control functions can be used like the FRA5097 via USB connection.

■ Various installation types supported
The horizontal and vertical installations are supported.

1.2 Applications

- Research and evaluation of materials and electronic components such as piezoelectric material, capacitor, and inductor.
- Evaluation of response characteristics of electronic circuits such as filter and amplifier.
- Evaluation of negative feedback characteristics of switching power supply, inverter, etc.
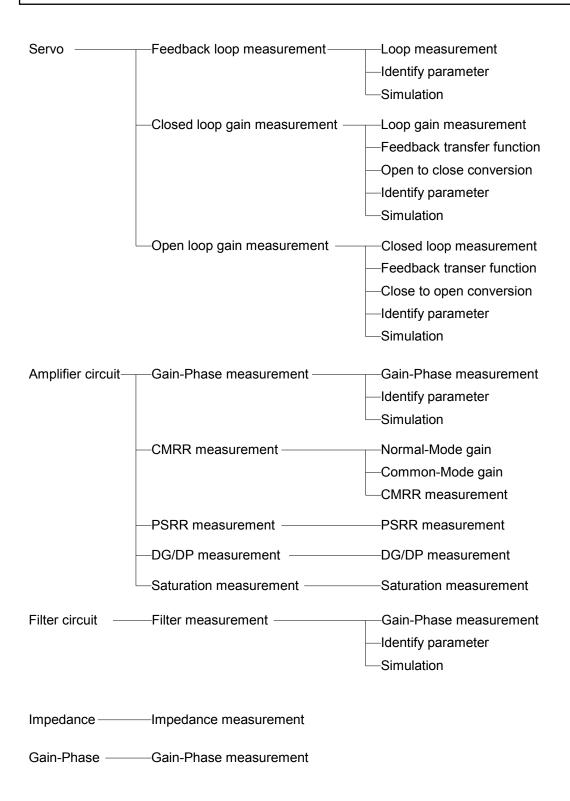
1.3 List of functions

The followings show a list of important functions (measurement types) of the ZGA5920 and the function tree of them.

Measurement type name	General descriptions
Piezoelectric measurement	Resonance characteristics measurement and piezoelectric parameter extraction of piezoelectric material
Dielectric measurement	Complex dielectric permittivity measurement and analysis
Magnetic measurement	Complex magnetic permeability measurement and analysis
Inductor measurement	Characteristics measurement and equivalent circuit estimation of inductor
Capacitor measurement	Characteristics measurement and equivalent circuit estimation of capacitor
Resister measurement	Characteristics measurement and equivalent circuit estimation of resistor
Transformer	
Leakage inductance measurement	Leakage inductance measurement of transformer
Mutual inductance measurement	Mutual inductance measurement of transformer
Coupling coefficient measurement	Coupling coefficient measurement of transformer
Turns ratio measurement	Primary/secondary turns ratio measurement of transformer
Varactor diode measurement	CV characteristics measurement, tuning characteristics simulation
Servo	
Feedback loop measurement	Loop characteristics measurement, model identification, simulation
Closed loop gain measurement	Open to closed loop conversion, model identification, simulation
Open loop gain measurement	Closed to open loop conversion, model identification, simulation
Amplifier circuit	
Gain-Phase measurement	Frequency characteristics measurement, model identification, simulation
CMRR measurement	Common-mode or normal-mode gain measurement, CMRR calculation
PSRR measurement	PSRR measurement
DG/DP measurement	DG/DP measurement
Saturation measurement	1 dB compression level measurement
Filter measurement	Calculation of passband ripple and cutoff frequency, transfer function identification
Impedance measurement	Impedance measurement
Gain-Phase measurement	Gain-phase measurement

Piezoelectric material —— Piezoelectric measurement —— Piezoelectric material measurement
— Display parameter
— Simulation

Dielectric material —— Dielectric measurement —— Dielectric material measurement
— Analyze parameter

Magnetic material —— Magnetic measurement —— Magnetic material measurement
— Analyze parameter

Inductor —— Inductor measurement —— Measurement
— Equivalent circuit estimation
— Simulation

Capacitor —— Capacitor measurement —— Measurement
— Equivalent circuit estimation
— Simulation

Resistor —— Resister measurement —— Measurement
— Equivalent circuit estimation
— Simulation

Transformer —— Leakage inductance measurement —— Leakage inductance measurement
— Mutual inductance measurement —— Aid connection measurement
— oppose connection measurement
— Mutual inductance measurement
— Coupling coefficient measurment —— Short secondary measurement
— Open secondary measurement
— Coupling coefficient measurement
— Turns ratio measurement —— Turns ratio measurement

Diode —— Varactor diode measurement —— CV measurement
— Simulation

Servo ——— Feedback loop measurement ——— Loop measurement
              └ Identify parameter
              └ Simulation

    ── Closed loop gain measurement ——— Loop gain measurement
              └ Feedback transfer function
              └ Open to close conversion
              └ Identify parameter
              └ Simulation

    └ Open loop gain measurement ——— Closed loop measurement
              └ Feedback transer function
              └ Close to open conversion
              └ Identify parameter
              └ Simulation

Amplifier circuit ── Gain-Phase measurement ——— Gain-Phase measurement
              └ Identify parameter
              └ Simulation

    ── CMRR measurement ——— Normal-Mode gain
              └ Common-Mode gain
              └ CMRR measurement

    ── PSRR measurement ——— PSRR measurement
    ── DG/DP measurement ——— DG/DP measurement
    └ Saturation measurement ——— Saturation measurement

Filter circuit ——— Filter measurement ——— Gain-Phase measurement
              └ Identify parameter
              └ Simulation

Impedance ——— Impedance measurement

Gain-Phase ——— Gain-Phase measurement

1.4 Principle of operation

1.4.1 Basic principle

ZGA5920 measures the I/O transfer characteristics of a system under test and the impedance of a target sample. ZGA5920 is equipped with the oscillator output section with the sine wave oscillator and the two-channel measurement signal input section (CH1 and CH2), and calculates vector quantity (amplitude and phase) of each measurement frequency component from the Fourier coefficient obtained through the discrete Fourier transform of the input signal. It can obtain the gain and the phase at the measurement frequency f by measuring the input and output signals of the system under test from each of the measurement signal inputs (CH1 and CH2) and calculating the vector ratio (CH1/CH2).

For impedance measurement, it can measure the impedance as ratio of CH1 (voltage) and CH2 (current), taking the voltage of sample from CH1 and the voltage signal proportional to the current from CH2.
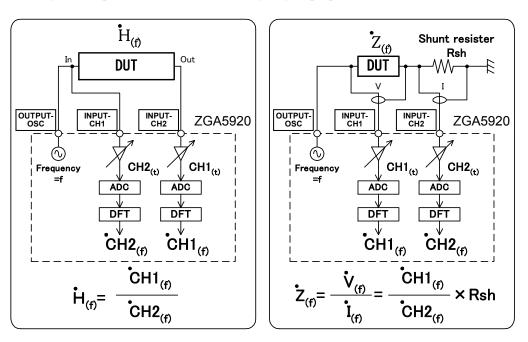
Figure 1-1 Transfer characteristics/impedance characteristics measurement

At one time of measurement, the gain and the phase at the measurement frequency f, which is the oscillator output frequency, will be measured. The frequency characteristics like the Bode diagram will be obtained by sweeping the measurement frequency and thus accumulating the values of the amplitude and the phase of CH1 and CH2 at individual frequencies. In addition to the frequency, the sweep can also be applied to the amplitude, the DC bias, and the time (zero span). At each measurement, the gain of the measurement signal input section will be readjusted to be most appropriate for the coming measurement. Therefore, the measurement will be performed with a wide dynamic measurement range and optimum signal-to-noise ratio, adding the gain variation range of the preamplifier before A/D conversion in the measurement signal input section to the A/D converter dynamic range.

In addition, the discrete Fourier transform used for the measurement has the following features:
- The discrete Fourier transform itself has a steep band-pass characteristic, which reduces the effect of noise and harmonics.
- Measurement can be made within the time period corresponding to the measurement frequency, that is, only about one second is needed to measure the amplitude and phase for 1 Hz.
- The freedom of setting measurement frequencies (frequency sweep density) is large, which allows you to select linear or logarithmic sweep and set the number of measurement points per sweep.

1.4.2 Block diagram
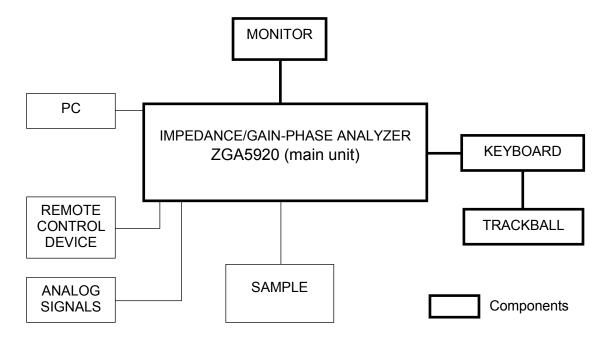
Figure 1-2 System block diagram

A monitor, keyboard, and trackball (pointing device) are required to operate ZGA5920. If you use ones other than the included items, they might not work correctly.
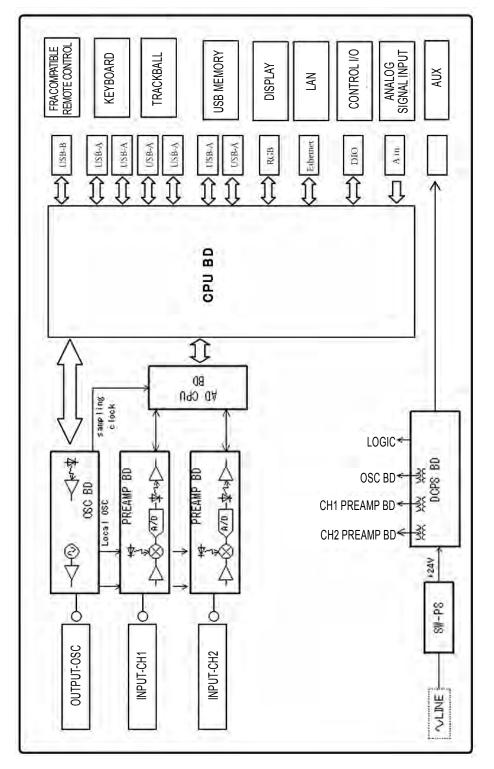
Figure 1-3 Block diagram (main unit)

This section describes the configuration of the ZGA5920 (see "Figure 1-3 Block diagram (main unit)").

a) OSC BD

This is an oscillator that generates timing signals for the ZGA5920.
The OSC BD generates the three following types of signals: sampling clock signal for A/D conversion, local frequency signal for heterodyne, and oscillator output.
This oscillator has a setting resolution of 0.1 mHz for the frequency range of 0.1 mHz to 15 MHz, based on the direct digital frequency synthesizer technology using dedicated LSIs. It has other features, such as instantaneous frequency change with phase continuity.

b) PREAMP BD

This is the measurement signal input section composed of an amplifier with variable gain and an A/D converter.
The input signal will have its DC component removed and be amplified or attenuated to an appropriate level to be A/D-converted to a 16-bit signal. If the analysis frequency is below 3 kHz, the signal will be directly A/D-converted. If the analysis frequency is 3 kHz or higher, the signal will be converted to the intermediate frequency of approx. 55 Hz through the frequency conversion circuit before the A/D conversion.

c) AD CPU BD

In the AD CPU BD, the digital data signal that has been A/D-converted through the PREAMP BD will be Fourier-integrated and stored as measurement data. The AD CPU BD contains a 16-bit CPU and controls the Fourier integration, the auto-range of PREAMP BD, or other functions.

d) CPU BD

The MAIN CPU BD reads measured data from the AD CPU BD, performs calculations such as coordinate transform and error compensation, and displays the outcome on the external monitor.

e) DCPS BD

The DCPS BD supplies isolated electric power with high impedance to the measurement signal input section (CH1 and CH2) and the oscillator output section.

2. Preparation before Use

2.1 Inspection before use

■ Ensuring safety

To ensure the safety, refer to "**Safety Precautions**" described in the beginning of this Instruction Manual before using the ZGA5920.

In addition, read "2.3 Grounding and power supply connection" in this Instruction Manual to sufficiently ensure the safety before connecting the instrument to the power source.

■ Check upon Unpacking

At first, check that there is no damage caused by an accident or other reason during transportation. After unpacking, refer to "Table 2-1 Content list" to check the contents.

Table 2-1 Content list

ZGA5920 (main unit) 1
Monitor (19-inch, 1280 × 1024 dot).. 1
Keyboard 1
Trackball.. 1
Accessories
CD-ROM provided with the ZGA5920 1
ZGA5920 Instruction Manual.. 1
Signal cable (BNC-BNC 50 Ω 1 m, 250 Vrms) 3
T-branch (250 Vrms) 1
Ferrite core (clamp type) 1
Power code set (2m, with 3-prong plug) 1

■ Monitor, keyboard, and trackball

A monitor, keyboard, and trackball (pointing device) are required to operate this instrument.

Use the items provided with this instrument. If you use ones other than the items provided or items not specified by us, they might not work correctly.

■ Ferrite core

Attach a ferrite core to the connecting cable of the trackball to prevent noise.

■ **Accompanying CD-ROM**

The CD-ROM contains a utility software and a software developer kit (SDK) that can be used on a PC.
You can use the utility software to easily obtain measurement result data.

You can use this SDK to develop programs in a general PC programming environment for controlling measurement by this instrument and accessing information on measurement conditions, and measurement result data on it.

To use the utility software and the software developer kit, you need to connect this instrument to PC via LAN.

[Utility software]

Operating environment (OS)	Windows XP, Vista, 7
	.NET Framework 3.5 needs to be installed in your environment.

[SDK]

Operating environment (OS)	Windows XP, Vista, 7
	.NET Framework 3.5 needs to be installed in your environment.
PC programming environment	Microsoft Visual Studio 2008
Programming languages	Languages supporting .NET Framework 3.5 like C#, Visual Basic

In addition, the CD-ROM contains the Instruction Manual of FRA compatible remote control that provides the same remote control functions as our FRA5097 in electronic data form.

■ **Remote interface cable**

A remote interface cable is required when you want to remotely control this instrument from a PC or other device. A remote interface cable is not provided. Please purchase separately commercial cables according to each remote interface, which is used for different purpose. The cable specifications are:

[ZGA remote control communications]

To control measurement by this instrument, or access measurement recipes and measurement result data on it

LAN cable	RJ-45, category 5 or higher 2-pair or 4-pair UTP cable

In addition to the above cable, a HUB will be required to connect this instrument to a PC via LAN.

[FRA compatible remote control]

To use the FRA compatible functions

USB cable	USB 1.1, USB 2.0 compliant cable

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■ **Peripherals**

For specific targets, the peripherals and related products listed in the table below are available (sold separately). For details of restrictions other than ones described in the table below, see the specification for each peripheral.

Target	Peripherals/related products	Features
Piezoelectric material Dielectric material Magnetic material Inductor Capacitor Resistor Transformer Varactor diode	Impedance Measuring Adapter PA-001-0368	Directly connected, 4 terminal configuration ~200 kHz
	Kelvin clip for Impedance Measuring Adapter PC-007-1490	(for replacement)
	High Power Impedance Measuring Adapter PA-001-1840 (Max. input current 1 Arms) PA-001-1841 (Max. input current 0.1 Arms)	Measures impedance at actual operating voltage by using a bipolar amplifier together
	Test Fixture Adapter PA-001-1838 (built-in shunt resistor 1 Ω) PA-001-1839 (built-in shunt resistor 100 Ω)	Can be used to connect various test fixtures for LCR meters
	Shunt Resistor PA-001-0370	For current-voltage conversion 1 V/1 A, 1 Arms rated
	High Speed Bipolar Amplifier HVA/HSA/BA/BP series	For drive signal amplification Maximum 50 MHz, 10 kV, 20 A
Servo loop	Loop Gain Measuring Adapter PA-001-0369	Directly connected, withstand voltage 42 V DC
	Clip cable for Loop Gain Measuring Adapter PC-007-1922	(for replacement)
	Signal Injector Probe 5055	Low stray capacitance, maximum 100 kHz
Others (Cables and others)	High Withstand Voltage Alligator Clip Cable Set (3 per set) PA-001-0420 (small) PA-001-0421 (large)	Maximum 250 Vrms
	High Withstand Voltage Clip Set (3 per set) PC-001-0419	Rated 250 Vrms
	High Withstand Voltage BNC Cable PC-002-3347 (*1)	Rated 250 Vrms
	High Withstand Voltage BNC Adapter (T-branch) PC-001-4503 (*1)	Rated 250 Vrms
	Alligator Clip Cable Set (3 per set) PC-001-0422	Rated 30 Vrms

(*1) The same one as provided with the main unit.

⚠ **WARNING**

High voltages appear inside of the instrument. Do not remove the cover.

No one except the trained service technicians who are thoroughly experienced in the hazard prevention is allowed to check or touch the inside of this instrument. Do not touch the inside by yourself in any case.

2.2 Mounting and installation

2.2.1 General precautions on installation

● Install the instrument with all the four foot-stands on the bottom or side of the instrument on the level plane, e.g., on an appropriate desk surface, so that the instrument will be stationed stable. The ZGA5920 can be placed horizontally or vertically (the power switch is on the top and the BNC connector is on the bottom).

● The ZGA5920 uses a forced air cooling system with a fan. If you notice the fan stopped, remove immediately the power supply and report to NF Corporation or NF's agent/dealer.
If you continue to use the instrument with the fan stopped, there is a risk of expansion of damages and hence difficulty/impossibility of repair.

● Air intake and exhaust ports are located on the bottom and rear surfaces of the ZGA5920 (when placed horizontally). Therefore, it is requested to install the instrument with its bottom and rear surfaces 10 cm apart from the wall at minimum.

2.2.2 Installation location conditions

a) Use the instrument under the following range of temperature and humidity environment: Note that the pollution condition is degree 2.
Operation   +5 to +35 °C, 30 to 80% RH (no condensation)
Storage   -10 to +50 °C, 30 to 80% RH (no condensation)

b) Do not install the instrument at locations as follows:
  ● Environment with flammable gas
   If the instrument is placed in environment with flammable gas, there will be a high risk of explosion. Never install, use or operate the instrument in such environment.
  ● Places with direct sunshine or near fire or near fire or heat source
   If the instrument is installed or operated at a place with direct sunshine or near fire or heat sources, it may not meet the performance specifications or instrument failures may be induced.
  ● Environment with corrosive gas, moisture or dust, or with high humidity
   If the instrument is installed in such environment, it could be corroded or instrument failures could be caused.
  ● Places near high voltage equipment, power cables or high electromagnetic field sources
   Operating the instrument at such a place could cause malfunctions and/or measurement errors.
  ● Environment with vibration
   Operating the instrument in such environment could cause malfunctions and/or failures.

In addition, signal cables for measurement shall be so routed that they will be immune from interference/induction with noise or electric power by separating them from power cables of the ZGA5920 or otherwise. If signal and power supply cables are routed close to each other, there could be malfunctions and/or measurement errors.
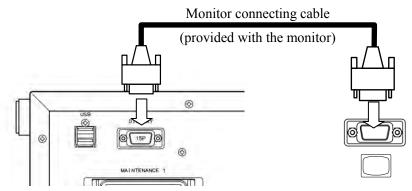
2.2.3 Peripherals connection

Connect the monitor, keyboard, and trackball to the instrument in the following order. Use the recommended items described in **"2.1 Inspection before use"** for these peripherals. Other items may not work correctly. For inquiry about failure of a peripheral, contact us or our agents, instead of its manufacturer.

■ Monitor

Use the monitor cable provided with the monitor to connect the DISPLAY connector on the rear of the ZGA5920 main unit with the analog RGB connector (mini D-Sub 15-pin) on the monitor.
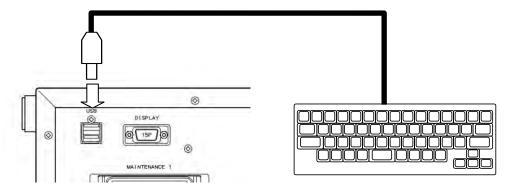
Rear of ZGA5920 main unit   Rear of monitor

■ Keyboard

Connect the keyboard USB connector (plug) to the USB connector on the rear of the ZGA5920 main unit.
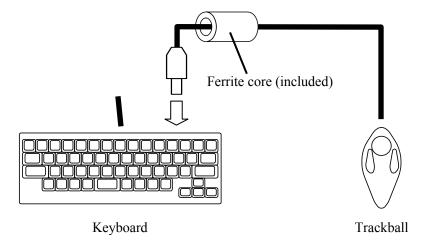
Rear of ZGA5920 main unit   Keyboard

■ Trackball

The keyboard is equipped with two ports of USB hub. Connect the trackball to the USB hub on the keyboard instead of the USB port on the ZGA5920 main unit.

Ferrite core (included)

Keyboard   Trackball

Please install the ferrite core (included) near the keyboard. It can reduce interference of the high-frequency electromagnetic field radiated from surrounding objects, and also reduce interference to surrounding objects.

2.3 Grounding and power supply connection

■ Grounding

| ⚠ WARNING | This product uses a line filter, **which may cause electric shock if the product is not grounded**.
Be sure to connect the protective grounding terminal to an earth ground before connecting measurement cables.
The protective grounding terminals of the ZGA5920 main unit and monitor are ground pins for three-pole power supply cables. Be sure to insert the power supply plug into the three-pole power supply outlet with a protective grounding contact. |

■ Power source

| ⚠ CAUTION | Confirm that the voltage of the power supply outlet is within the range of the power supply voltage specifications before connecting the power supply. Otherwise, the ZGA5920 may be damaged. |

■ Power supply conditions of ZGA5920
- Voltage range: AC 90 V~132 V/180 V~250 V
- Frequency range: 50 Hz/60 Hz
- Power consumption: 150 VA or lower (ZGA5920 main unit), 45 W (monitor)
- Overvoltage category: II

■ The following procedure shall be taken to connect the power supply:
1) Confirm that the commercial power supply voltage is within the allowable voltage range of the ZGA5920.
2) Connect the power supply cable female-plug into the power supply connector located on the rear of the ZGA5920 main unit.
3) Connect the power supply cable female-plug into the power supply connector located on the rear of the monitor.
4) Insert the power supply cable plugs for the monitor and main unit into three-pole power supply outlets.

After turning off the power, wait for at least 5 seconds before turning on the power again.

> ⚠ **WARNING**   This device contains high-voltage parts. Do not remove the cover.

2.4 Compliant standards

The ZGA5920 complies with the following standards.

Safety standard: EN 61010-1:2010
EN 61010-2-30:2010

EMC: EN 61326-1:2006 (Group 1, Class A)
EN 61000-3-2:2006
EN 61000-3-3:2008

The following cables and peripherals are used during the EN 61326-1:2006 test.

- Monitor: S1901-BST (Eizo Nanao Corporation)
  The monitor accessories are used for the power cord and monitor cable.
- Keyboard: PD-DB200B/U (PFU LIMITED)
- Trackball: TM-150 (Logitech International S.A.), Ferrite core (included)
- Printer: H470 (Hewlett-Packard Development Company, L.P.)
  The printer accessories are used for the AC adapter, power cord, and USB cable.

(Cables and others)

- Power cord: Accessory
- Signal cable: Accessory
- T-branch: Accessory
- USB cable: USB 2.0 compliant cable, 1 m (Sanwa Supply, Inc., KU20-1)
  (for external PC control)

2.5 Quick function checking

This section introduces quick operation checking methods for this instrument to be used for quickly checking important functions of the instrument after delivery or prolonged storage.
Refer to "8. Maintenance" for more detail on instrument check-out.

2.5.1 Checking functions and indications at power "ON"

First, turn on the monitor. When you turn on the ZGA5920 main unit, all lamps on the front panel of the ZGA5920 main unit will be lit on. Make sure there are no unlit lamps.

- **For more detail on lamp indications at the time of power supply "ON", refer to "3.2 Display at power "ON" and initial settings".**
- **For more detail on error messages, refer to "7.1 Error messages".**

⚠ WARNING
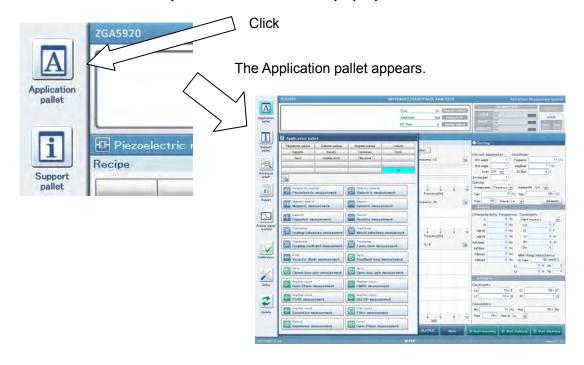
Smoke, odor, strange sound
In such event, immediately disconnect the power cable from the outlet and do not use the equipment until repairs are completed.
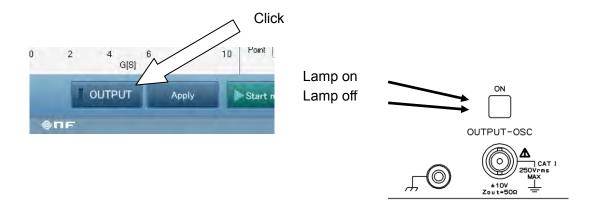
2.5.2 Checking responses for key actions

Check and ensure that main keys and the trackball function properly.

Click

The Application pallet appears.
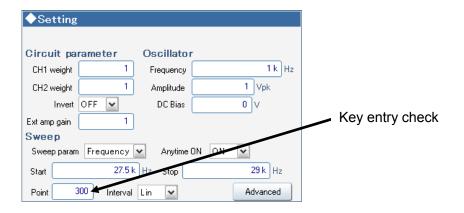
Click the OUTPUT button on the bottom of the screen by using the left button of the trackball.
Check that the OUTPUT-OSC ON lamp (above the oscillator output connector) on the front panel of the
ZGA5920 main unit is turned on. Similarly, check that the ON lamp is turned off when clicking the
OUTPUT button again on the bottom of the monitor screen.

Click the measurement condition setting area and then click the setting field of number of measurement
points ([Point]). Enter a numeric value from the keyboard to check that key entries work correctly.

2.5.3 Precautions at power "OFF"

When turning off the power, press the power switch on the ZGA5920 main unit to turn it off. This
automatically shuts down the power and turns off the power lamp.
Do not disconnect the power supply cable from the outlet or shut down the commercial power source
supplying to the ZGA5920 main unit by an external breaker. It may cause the internal data and program to
be damaged, and thus the ZGA5920 may not start up at the next power-on. Never shut down the
commercial power source.
If it has been one minute without power-off since you started the power shutdown process, internal
processing may be delayed. You can press and hold down the power switch for 5 seconds or longer to turn
off the power.
After turning off the power, wait for at least 5 seconds before turning on the power again.

2.6 Calibration

Although somewhat contingent on the usage environment and how often the ZGA5920 is used, conduct the performance tests of Section 8.5 at least once a year.
The performance tests are also recommended immediately before using the equipment for important measurements or testing.
Refer the performance tests to technicians possessing experience in operating measuring equipment and have a good general knowledge of instrumentation.

3. Descriptions on Panels and Basic Operations

3.1 Panel descriptions

This section describes names and operations of various parts of the main unit front and rear panels and the monitor display of the ZGA5920.

3.1.1 Main unit front panel

USB peripherals
They are connected by an USB memory, keyboard,, etc.

STATUS lamp
ERROR: It is lit on when an error occurs.
MEASURE: It is lit on during measurement.
CALIBRATION: It is lit on during self-calibration.

Power switch and lamp
The lamp is on while the power is on.

Analog signal input terminal (ANALOG SIGNAL INPUT)
Data logging signal is input.

Measurement signal input (INPUT-CH1, CH2)
Measurement signal is input.

Oscillator output (OUTPUT-OSC)
Measurement signal is output.

Control I/O terminal (CONTROL I/O INPUT/OUTPUT)
Digital I/O control signals are input and output.

Measurement ground terminal
It is connected to the enclosure.

Figure 3-1 Main unit front panel

3.1.2 Main unit rear panel

USB peripherals
They are connected by an USB memory, keyboard, etc.

USB connector
It is used for communication with an external PC.

Monitor connecting connector

Air outlet

COA*1 label

LAN connector

Certification label

USB

DISPLAY
15P

LAN

USB

MAINTENANCE 1
50P

AUX
14P

MAINTENANCE 2
24P

⚠ WARNING
FOR PROTECTION FROM
ELECTRICAL SHOCK,
POWER CORD GROUND MUST
NOT BE DELETED.

⚠ WARNING
DO NOT REMOVE COVERS.
NO OPERATOR SERVICEABLE
PARTS INSIDE.
REFER SERVICING TO
QUALIFIED PERSONNEL.

MODEL
SERIAL NO.
NF Corporation MADE IN JAPAN

~LINE
100V...230V
50Hz/60Hz 150VA MAX

Maintenance connector
Do not connect anything.

AUX connector
Connector for a signal injector probe 5055 (sold separately)

Nomenclature plate

Power inlet

*1: COA (Microsoft Certificate of Authenticity)

Figure 3-2 Main unit rear panel

3.2 Display at power "ON" and initial settings

3.2.1 Displays and indications at power "ON"

Take necessary steps before instrument usage/operation according to "2. Preparation before Use". When the power switch is turned on, all of the lamps on the main unit front panel of the ZGA5920 are lit on and then the system starts up.

The system starts up after approximately one minute, and then all the lamps on the front panel other than the "POWER" lamp are lit off.

Figure 3-3 Screen at power "ON"

When you start the ZGA5920 for the first time or under factory default conditions, the setup screen appears, allowing you to specify a language and time zone. When you click the OK button, the system restarts.
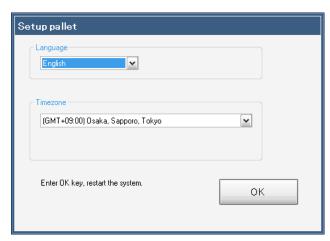
Figure 3-4 Setup screen

When the startup process is complete, the display changes "Figure 3-5 Measurement screen" to be operational.
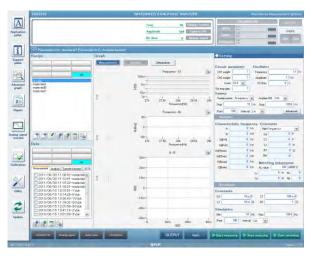
Figure 3-5 Measurement screen

3.2.2 Initial settings

The measurement condition setting area on the measurement screen of the ZGA5920 is initially populated with the default measurement conditions (Measurement Recipe) as the factory default. The initialization values and setting ranges of the default measurement conditions are shown in "Table 3-1 List of initialization values (measurement condition setting area)" and "Table 3-2 List of initialization values (measurement condition setting pallet)".

Table 3-1 List of initialization values (measurement condition setting area)

Setting items	Initialization value	Setting range	Setting resolution	Unit
Circuit				
CH1 weight	1.0000.000E+00	0.0000~1.0000E+06	5 digits|1E-11	
CH2 weight	1.0000.000E+00	0.0000~1.0000E+06	5 digits|1E-11	
Phase invert	OFF	OFF|ON		
Ext amp gain[*1]	+1.00	±(0.01~999)	3 digits|0.01	
Oscillator				
Frequency	1,000.0000	0.0001~15,000,000.0000	0.0001	Hz
Amplitude[*1]	1.00	0.00~9999	3 digits|0.0001	Vpk[*2]
DC Bias[*1]	0.0000	-9990~+9999	3 digits|0.0001	V[*2]
Sweep				
Sweep param[*3]	Frequency|Amplitude|DC bias|Zero span			
Min (Frequency)	10.0000[*4]	0.0001~15,000,000.0000	0.0001	Hz
Max (Frequency)	1,000,000.0000[*4]	0.0001~15,000,000.0000	0.0001	Hz
Min (Amplitude)	0.00	0.00~9999	3 digits|0.0001	Vpk[*2]
Max (Amplitude)	10.0	0.00~9999	3 digits|0.0001	Vpk[*2]
Min (DC bias)	0.00	-9990~9999	3 digits|0.0001	V[*2]
Max (DC bias)	5.00	-9990~9999	3 digits|0.0001	V[*2]
Sweep Time (Zero span)	30.00	0.03~999999.99	0.01	s
Point	101[*5]	4~20000	1	
Interval	Log[*6]	Log|Lin		
Anytime ON	OFF	OFF|ON		

*1: The following restrictions are applied to the setting range of External amplifier gain, Amplitude, and DC Bias:

   (Amplitude setting value + DC Bias setting value) ≤ (External amplifier gain × 10)

*2: When the measurement application is "Magnetic measurement" or "Inductor measurement", the unit is current [Apk] or [A] instead of voltage.

*3: The available sweep parameters vary depending on the measurement type. Refer to "Table 3-3 List of available sweep parameters".

*4: When the measurement application is "Piezoelectric measurement", the Min is 10 kHz and the Max is 100 kHz.

*5: When the measurement application is "Piezoelectric measurement", this is 11.

*6: When the measurement application is "Piezoelectric measurement", "DG/DP measurement", or "Saturation measurement", this is Lin.

Table 3-2 List of initialization values (measurement condition setting pallet)

Setting items	Initialization value	Setting range	Setting resolution	Unit
Input over				
CH1	250	0~250	1	Vrms
CH2	250	0~250	1	Vrms
Action	None	None|Stop sweep|Output OFF		
Integration				
Type	Cycle	Cycle|Time		
Cycle	1	1~9999	1	Cycle
Time	0.01	0.01~9999	4 digits|0.01	s
Delay				
Type	Cycle	Cycle|Time		
Cycle	0	0~9999	1	Cycle
Time	0.00	0.00~9999	4 digits|0.01	s
Slow sweep[*1]				
Item	OFF	OFF|LogR|R|θ|A|B		
CH	CH1	1|2		
Variation (LogR)	1.00	0.00~1000	3 digits|0.01	dB
Variation (R)	1.00	0.00~1.00G	3 digits|1μ	Vrms
Variation (θ)	1.00	0.00~180	3 digits|0.01	deg
Variation (A, B)	1.00	0.00~1.00G	3 digits|1μ	Vrms
Amplitude compression				
Compression mode	OFF	OFF|CH1|CH2		
Amplitude [Vrms]	1	1m~250	3 digits|10μ	Vrms
Limit [Vpk]	1	1m~10.0	3 digits|10μ	Vpk
Error [%]	10	0~100	1	%
Retry	10	1~9999	1	
Correction [%]	100	0~100	1	%

*1: The slow sweep works only when the sweep parameter is Frequency.

Setting values of Amplitude and DC Bias are External amplifier output equivalents.
(The value of Amplitude or DC Bias divided by External amplifier gain is output for the oscillator output of the ZGA5920.)

    Example) When External amplifier gain = -100 and DC Bias = 10.0 V, the result of 10.0 V / (-100) = -0.1 V is output on the ZGA5920 front panel.

Table 3-3 List of available sweep parameters

Measurement application	Sweep parameter			
	Frequency	Amplitude	DC Bias	Zero span
Piezoelectric measurement	○	×	×	○
Dielectric measurement	○	×	○	○
Magnetic measurement	○	×	○	○
Inductor measurement	○	○	○	○
Capacitor measurement	○	○	○	○
Resister measurement	○	○	○	○
Transformer				
—Leakage inductance measurement	○	×	×	○
—Mutual inductance measurement	○	×	×	×
—Coupling coefficient measurement	○	×	×	×
—Turns ratio measurement	○	×	×	○
Varactor diode measurement	○	×	○	○
Servo - Feedback loop measurement	○	×	×	×
Servo - Closed loop gain measurement	○	×	×	×
Servo - Open loop gain measurement	○	×	×	×
Amplifier circuit - Gain-Phase measurement	○	×	×	○
Amplifier circuit - CMRR measurement	○	×	×	×
Amplifier circuit - PSRR measurement	○	×	×	×
Amplifier circuit - DG/DP measurement	×	×	○	×
Amplifier circuit - Saturation measurement	×	○	×	×
Filter measurement	○	×	×	×
Impedance measurement	○	×	×	×
Gain-Phase measurement	○	×	×	×

The following tables show the setting items for each measurement application screen and the initial values for the analysis setting area and simulation condition setting area.

Table 3-4 List of initialization values for piezoelectric measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Constants display				
Cd mode	High Frequency	High Frequency|Gmax|Bmax_Bmin		
AL value	100.0	0.001~9999	4 digits|0.001	nH/N^2
Constants				
Cd	10.0000E-12	±(1E-18~999.999E+15)	6 digits|1E-18	F
C1	100.000E-09	±(1E-18~999.999E+15)	6 digits|1E-18	F
L1	10.0000E-03	±(1E-18~999.999E+15)	6 digits|1E-18	H
R1	1.00000E+00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data) Lin	Log|Lin		

Table 3-5 List of initialization values for dielectric measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Parameter				
Electrode area S	1	0.001~99990	4 digits|0.001	mm^2
Electrode distance t	1	0.001~9999	4 digits|0.001	mm
Simulation				
None				

Table 3-6 List of initialization values for magnetic measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Parameter				
Core area S	1	0.001~99990	4 digits|0.001	mm^2
Core magnetic path length l	1	0.001~9999	4 digits|0.001	mm
Coil turns N	1	1~9999	1	
Winding diameter d	0.080	0.001~9999	4 digits|0.001	mm
Winding around length len	1	0.001~9999	4 digits|0.001	mm
Electrical resistivity ρ	16.80n	1.0E-11~1.000	4 digits|10p	Ωm
Simulation				
None				

Table 3-7 List of initialization values for inductor measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
Equivalent circuit	A:Inductor(lossy core)	A:Inductor(lossy core)	B:Inductor or resistor	C:Resistor(high resistance)	D:Capacitor	E:Resonator		
Equivalent circuit simulation				
Equivalent circuit	A:Inductor(lossy core)	A:Inductor(lossy core)	B:Inductor or resistor	C:Resistor(high resistance)	D:Capacitor	E:Resonator		
C0	0.00000E-12	±(1E-18~999.999E+15)	6 digits|1E-18	F
C1	1.00000E-09	±(1E-18~999.999E+15)	6 digits|1E-18	F
L1	10.0000E-03	±(1E-18~999.999E+15)	6 digits|1E-18	H
R1	1.00000E+00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

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Table 3-8 List of initialization values for capacitor measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
Equivalent circuit	D:Capacitor	A:Inductor(lossy core) | B:Inductor or resistor | C:Resistor(high resistance) | D:Capacitor | E:Resonator		
Equivalent circuit simulation				
Equivalent circuit	D:Capacitor	A:Inductor(lossy core) | B:Inductor or resistor | C:Resistor(high resistance) | D:Capacitor | E:Resonator		
C0	0.00000E-12	±(1E-18~999.999E+15)	6 digits|1E-18	F
C1	1.00000E-07	±(1E-18~999.999E+15)	6 digits|1E-18	F
L1	1.00000E-02	±(1E-18~999.999E+15)	6 digits|1E-18	H
R1	1.00000E+00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

Table 3-9 List of initialization values for resistor measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
Equivalent circuit	B:Inductor or resistor	A:Inductor(lossy core) | B:Inductor or resistor | C:Resistor(high resistance) | D:Capacitor | E:Resonator		
Equivalent circuit simulation				
Equivalent circuit	B:Inductor or resistor	A:Inductor(lossy core) | B:Inductor or resistor | C:Resistor(high resistance) | D:Capacitor | E:Resonator		
C0	0.00000E-12	±(1E-18~999.999E+15)	6 digits|1E-18	F
C1	1.00000E-07	±(1E-18~999.999E+15)	6 digits|1E-18	F
L1	1.00000E-02	±(1E-18~999.999E+15)	6 digits|1E-18	H
R1	1.00000E+00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

Table 3-10 List of initialization values for transformer leakage inductance measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-11 List of initialization values for transformer mutual inductance measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-12 List of initialization values for transformer coupling coefficient measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-13 List of initialization values for transformer turns ratio measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-14 List of initialization values for varactor diode measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Tuning characteristics simulation				
C0	1.00000E-12	±(1E-18~999.999E+15)	6 digits|1E-18	F
C1	1.00000E-09	±(1E-18~999.999E+15)	6 digits|1E-18	F
L1	1.00000E-03	±(1E-18~999.999E+15)	6 digits|1E-18	H
Simulation				
None				

Table 3-15 List of initialization values for servo - feedback loop measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Circuit model generation				
Algorithm	A	A|B		
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Order	5	5~20	1	
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

Table 3-16 List of initialization values for servo - closed loop gain measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Calculation mode				
Feedback parameter	Measurement	Measurement|Constant		
Circuit model generation				
Algorithm	A	A|B		
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Order	5	5~20	1	
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

Table 3-17 List of initialization values for servo - open loop gain measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Calculation mode				
Feedback parameter	Measurement	Measurement|Constant		
Circuit model generation				
Algorithm	A	A|B		
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Order	5	5~20	1	
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

Table 3-18 List of initialization values for amplifier circuit gain-phase measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Phase range				
Phase range	±180deg	-180~+180 | -360~0 | 0~+360 | UNWRAP		
Group delay				
Aperture	(Number of data × 0.05)	2 to (Number of data - 1)	1	
Transfer function generation				
Algorithm	A	A|B		
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Order	5	5~20	1	
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

Table 3-19 List of initialization values for amplifier circuit CMRR measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Normal-Mode gain selection				
Normal-Mode gain	Measurement	Measurement|Constant		
Constant	0.000	-99.999~+99.999	0.001	dB
Simulation				
None				

Table 3-20 List of initialization values for amplifier circuit PSRR measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-21 List of initialization values for amplifier circuit DG/DP measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-22 List of initialization values for amplifier circuit saturation measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-23 List of initialization values for filter measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Phase range				
Phase range	±180deg	-180~+180 | -360~0 | 0~+360 | UNWRAP		
Aperture	(Number of data × 0.05)	2 to (Number of data - 1)	1	
Filter				
Filter Type	LPF	LPF|HPF|BPF|BEF		
Fc mode	-3dB	-3dB|GRipple		
Transfer function generation				
Algorithm	A	A|B		
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Order	5	5~20	1	
Simulation				
Min	(Minimum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Max	(Maximum frequency of measurement data)	0.0001~15,000,000.0000	0.0001	Hz
Point	(Number of measurement points of measurement data)	3~20000	1	
Interval	(Measurement interval of measurement data)	Log|Lin		

Table 3-24 List of initialization values for impedance measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

Table 3-25 List of initialization values for gain-phase measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Analysis				
None				
Simulation				
None				

3.2.3 Warm-up
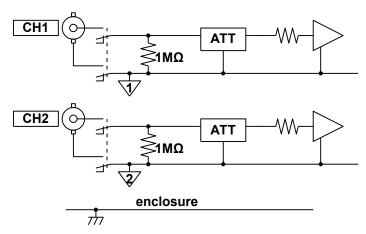
It takes at least 30 minutes after the power supply switching-on for the internal temperature of the ZGA5920 to reach stable.

Perform measurement right after calibration is made, which shall be made after sufficient time of warm-up has been made. Note that the measurement accuracy specification is met under the condition immediately after calibration.

Conduct re-calibration when environment temperature has been changed.

3.3 Input and output terminals

■ INPUT-CH1, INPUT-CH2

Each of the measurement signal inputs (CH1 and CH2) of the ZGA5920 is electrically insulated from the enclosure, the oscillator output, and the other measurement signal input. The minimum breakdown voltage is 250 Vrms between any two of the enclosure, CH1, CH2, and the oscillator output when using the accompanying insulated coaxial cable. Restriction of 30 Vrms applies when a cable other than the accompanying cable is used. Note that accidents due to electric shocks could occur, if voltages exceeding the minimum breakdown voltage are applied between the above mentioned insulated parts, leading to dielectric breakdown. Refer to "3.4 Insulation breakdown voltages of input and output terminals" by all means, when you make a measurement with a higher voltage applied between any two of the enclosure, CH1, CH2, and the oscillator output.

⚠ **WARNING**

- Do not use for measurement of the main power supply circuit.
- Do not connect to any measurement target with transient overvoltages that exceed 1,500 Vrms.
- Do NOT connect to any measurement target that exceeds 250 Vrms.
  Doing so may result in insulation breakdown, imposing electric shock.
- You could be suffered from electric shocks when you measure high voltage circuit signals. Use accessory coaxial cables of the insulation type by all means, so that you cannot directly touch metallic portions of the BNC connectors at the measurement signal input terminals.

The measurement signal input terminals have the input impedance of 1 MΩ (parallel capacitance of 25 pF±5 pF) and the maximum allowable input voltage of ±350 V for AC+DC. Never apply any voltages exceeding the maximum allowable voltage, since the inside of the instrument will be damaged by application of voltages exceeding the minimum allowable voltage.
The ZGA5920 has the capability of measuring the amplitude and the phase of input signals up to 15 MHz. Use the same type and the same length of signal cables to be connected to individual measurement signal inputs so that the phase can be measured with high accuracy at high frequencies.
The connection between the input connector and the internal circuits is cut off when the power supply is off.
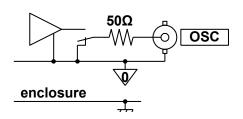
■ Oscillator output terminal (OUTPUT-OSC)

The oscillator output is electrically insulated from both the enclosure and the measurement signal inputs (CH1 and CH2). The minimum breakdown voltage between the oscillator and either the enclosure or the measurement signal inputs is 250 Vrms when using the accompanying insulated coaxial cable. Restriction of 30 Vrms applies when a cable other than the accompanying cable is used.

Note that accidents due to electric shocks could occur, if voltages exceeding the minimum breakdown voltage are applied between the above mentioned insulated parts, leading to dielectric breakdown.

Refer to "3.4 Insulation breakdown voltages of input and output terminals" by all means, when you make a measurement with a higher voltage applied between any two of the enclosure, CH1, CH2, and the oscillator output.

⚠ **WARNING**

- Do not use for measurement of the main power supply circuit.
- Do NOT connect to any measurement target with transient overvoltages that exceed 1,500 Vrms.
- Do NOT connect to any measurement target that exceeds 250 Vrms
  Doing so may result in insulation breakdown, imposing electric shock.
- You could be suffered from electric shocks when you measure high voltage circuit signals. Use accessory coaxial cables of the insulation type by all means, so that you cannot directly touch metallic portions of the BNC connectors at the oscillator output terminal.

The output impedance is always 50 Ω whether or not the output is **"ON"**.

The maximum allowable output voltage is ±10 V (for no load condition) for AC+DC, and the maximum allowable output current is ±100 mA.

The load resistance to be connected at the maximum output shall be no less than 50 Ω.

The maximum output voltage to be set is ±10 V (peak value) for AC+DC when a 50 Ω load is connected, where ±5 V is applied for the 50 Ω load.

Set the output voltage with a condition of no load connected.

⚠ **CAUTION**   The internal circuit will be damaged if you apply external signal voltages to the output terminal. Never apply signal voltages to the output terminal.

[Notes]

- A signal transmitted on a 50 Ω series coaxial cable and the accompanying BNC cable (e.g., RG-58A/u, 3D-2V, etc.) gets approx. 5 ns per meter of time delay. This can be converted to the phase of 1.8 deg. per meter for 1 MHz.
- A 50 Ω series coaxial cable has approx. 100 pF per meter of electrostatic capacitance. If a signal is driven with a signal source resistance of 50 Ω, the signal will be affected so that it changes about -0.0043 dB in amplitude and -1.8 deg. in phase at 1 MHz.
- Pay attention to the cleanliness of the contact of the connector. Dirt/stains at the connector contact can cause approx. 0.03 dB of measurement errors depending upon measurement conditions.

■ ±24 V power supply output (AUX)

This is an electrical power supply outlet for supplying electrical power to the Signal Injector Probe 5055 (sold separately), which is used for servo measurement. Connect to the outlet (AUX) the cable that is attached to the Signal Injector Probe 5055.

The figure below shows an example of connection of the Signal Injector Probe 5055 to the instrument.

For further information on operational methods of the 5055, refer to the 5055 Instruction Manual.
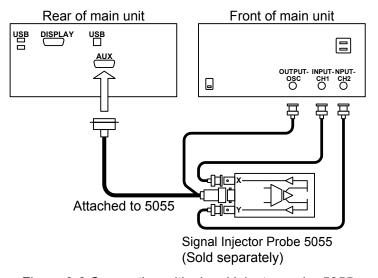
Figure 3-6 Connection with signal injector probe 5055

3.4 Insulation breakdown voltages of input and output terminals

The oscillator output terminal (OUTPUT-OSC) and the analyzer input terminals (INPUT-CH1 and INPUT-CH2) individually are electrically insulated from the enclosure. The minimum dielectric breakdown voltage between the enclosure and the above mentioned parts of the ZGA5920 is 250 Vrms when the accompanying BNC cable is used, and 30 Vrms when another cable is used. Be careful not to apply voltages exceeding 250 Vrms between the enclosure and the individual polarities (i.e., signals and ground) of OUTPUT-OSC, INPUT-CH1 and INPUT-CH2 terminals.
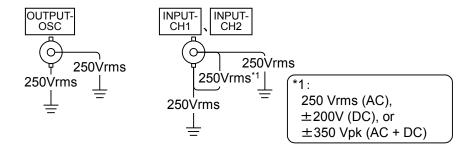
Figure 3-7 Specifications for isolation withstand voltage (with supplied BNC cable used)
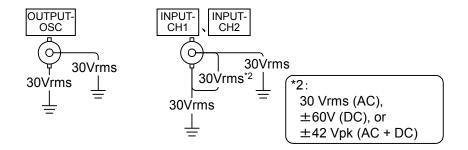
Figure 3-8 Specifications for isolation withstand voltage (with other cable used)

OUTPUT-OSC, INPUT-CH1 and INPUT-CH2 are electrically insulated to each other. The minimum insulation breakdown voltage between the signal and the ground polarities for OUTPUT-OSC, INPUT-CH1 and INPUT-CH2, individually, is 250 Vrms when the accompanying BNC cable is used, and 30 Vrms when another cable is used. The same minimum insulation breakdown voltage of 250 Vrms applies between signal polarities of OUTPUT-OSC, INPUT-CH1 and INPUT-CH2.
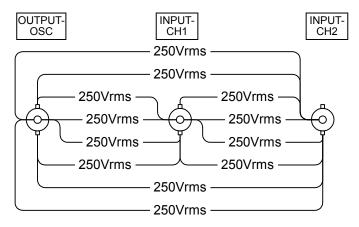
Figure 3-9 Specifications for isolation withstand voltage between oscillator and analysis input
(with supplied BNC cable used)
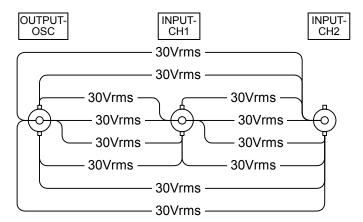
Figure 3-10 Specifications for isolation withstand voltage between oscillator and analysis input
(with other cable used)

⚠ WARNING

- Do not apply excessive voltages between insulated signal terminals. You could be suffered from electric shocks, if excessive voltages are applied between these terminals leading to dielectric breakdown.
- You could be suffered from electric shocks when you measure high voltage circuit signals. Use accessory coaxial cables of the insulation type by all means, so that you cannot directly touch metallic portions of the BNC connectors at the analyzer input and output terminals.

3.5 Basic operation

The ZGA5920 is operated by clicking buttons on the monitor and entering numeric values with the pointing device (trackball) and the keyboard.

The followings describe the typical operations of the ZGA5920.

■ Button operations and pallet screen display

With the ZGA5920, the button operation for opening screens basically involves the toggle operation of clicking a button to open the screen and clicking the button again to close the screen.

The operation may differ for some processes with operational restrictions.
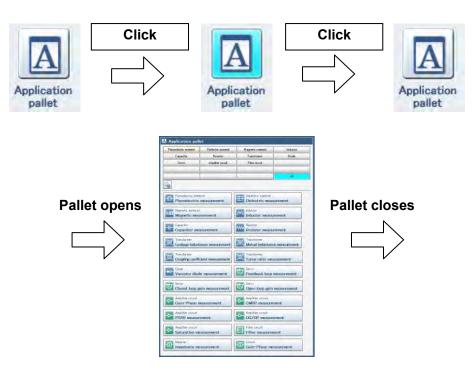
Figure 3-11 Button operations

■ Search refine setting

Search refine setting is a function for specifying a keyword to display only certain data in a list.

This function allows you to refine a search for each of measurement application on the Application pallet, measurement recipe, and measurement result data.

The registered keywords are displayed on the buttons, and clicking a keyword button displays a list of data that corresponds to that keyword.
Also, multiple keywords can be selected at the same time.
Clicking All cancels the search refine setting.
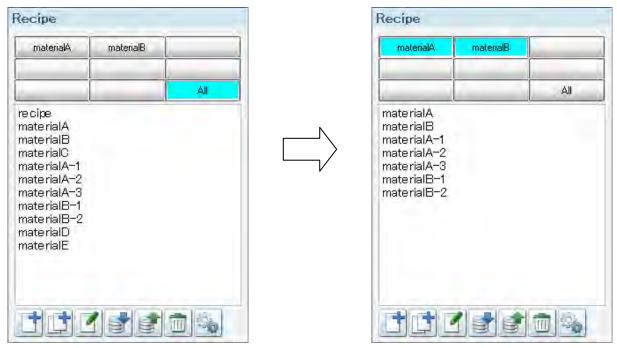
Figure 3-12 Refining search by selecting multiple keywords

You can also register a keyword by clicking the button shown in "Figure 3-13 Search refine setting button", entering a string for the keyword, and registering the keyword.
You can also select a partial match from the names in the list.

Figure 3-13 Search refine setting button

3.5.1 Descriptions on screens

This section describes the basic screen configuration of the ZGA5920.
The screen is split into four areas as shown in the figure below.
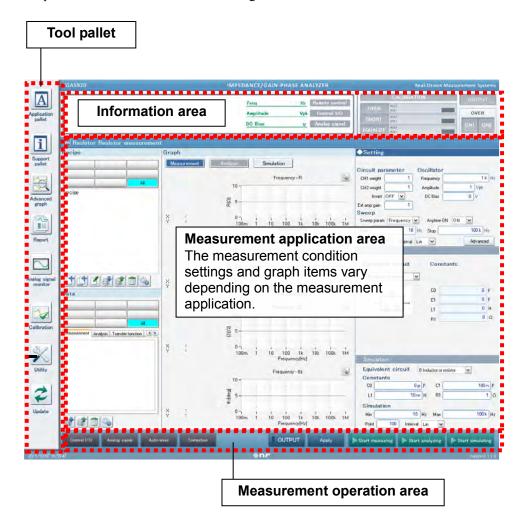
Figure 3-14 Basic screen configuration

■ Information area

This area displays the operating status and operational guidance for the ZGA5920.

During measurement, it displays the estimated time until the measurement is completed to represent the progress of measurement.

The contents of the information area are organized as shown in the following figure.
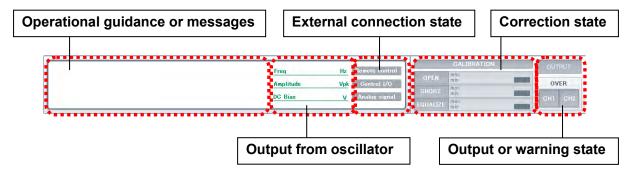
Figure 3-15 Information area configuration

The following figure shows an example of display indicating the state during measurement.
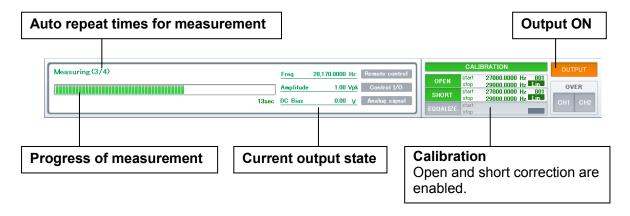
Figure 3-16 Example of display indicating the state during measurement

■ Tool pallet

This pallet includes the button for the Utility of the ZGA5920 and the function buttons commonly used for all measurement applications. Clicking a button on the Tool pallet displays the pallet screen of the corresponding function to enable you to set and operate the function.

Application pallet	Opens the Application pallet for switching the measurement application.
Support pallet	Shows the support information provided for each measurement application, such as how to connect the ZGA5920 and measurement target. The support information will be improved through, for example, software updates. The information on the Topics and Communication will also be improved in the same way.
Advanced graph	Displays the Advanced graph pallet for displaying all of the types of graph that can be displayed for each measurement application.
Report	Displays the Report pallet for printing the reports of measurement applications.
Analog signal monitor	Displays the pallet of the analog signal input for data logging.
Calibration	Displays the Calibration pallet for self correction of the ZGA5920.
Utility	Opens the Utility pallet to enable you to configure various system settings of the ZGA5920.
Update	Opens the screen for updating the software of the ZGA5920.

Figure 3-17 Tool pallet buttons

To close the displayed pallet, click the button again you clicked to open the pallet.

■ Measurement application area

You can set different measurement conditions, analysis or simulation conditions for each measurement application, and display graph.

You also can select or view the measurement recipe that enables measurement conditions, correction data, auto repeat measurement setting values, and other data to be handled as a measurement template, and perform measurement result data.
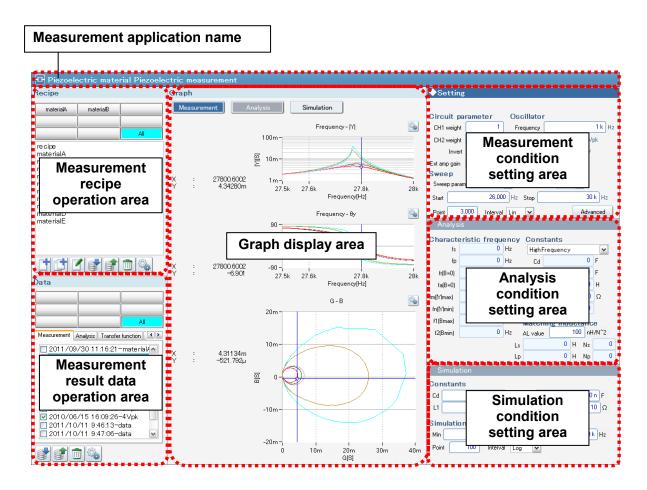
Figure 3-18 Measurement application area

(Measurement recipe operation area)
You can handle measurement and other conditions and correction and other data as a single measurement recipe, and create a list of measurement recipes suitable for samples.
Selecting a measurement recipe from the list instantly applies all of the measurement conditions, analysis and simulation conditions, correction data, etc.
Clicking each corresponding icon in the area enables you to create, save, edit, import, export, or delete a measurement recipe, or refine your search.
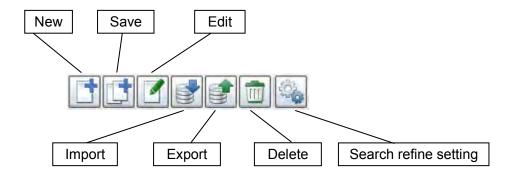
Figure 3-19 Operation icons

New	Creates a new recipe with default measurement conditions.
	A single recipe is added.
Save	Saves the changed settings (the current settings configuration) to the recipe.
	A single recipe is added.
Edit	Allows you to edit the current content of the recipe, or rename the recipe.
Import/Export	Allows a recipe to be added to or exported from the root directory of USB memory.
	An exported recipe can be edited on a PC in accordance with "6.2 Measurement recipe and measurement result data formats".
Delete	Deletes a recipe.
	The deletion pallet appears when you click this. Select the recipe you want to delete in this pallet, and click the Delete button.
Search refine setting	Allows you to refine the search as described in "Search refine setting" of "3.5 Basic operation".

The names of recipes created by clicking the New or Save icon are assigned automatically. To rename a recipe, click the Edit icon while the recipe you want to edit is selected.

(Measurement result data operation area)

When a measurement operation is performed, the measurement results are automatically recorded.

Non-measurement data such as analysis and simulation data is also recorded.

To display measurement results, analysis, simulation, or other data, click the corresponding place for the data type to display a list.

Clicking measurement result data from the measurement result list displays a graph of the measurement result data, measurement conditions, and other information.

Also, selecting the checkboxes on the left in the list overlays graphs so that the differences in the samples and measurement conditions can be viewed even while measurement is not being performed.

The measurement result data operation area also has the Import, Export, Delete, and Search refine setting icons as with the measurement recipe operation area.

In the same way as with measurement recipes, operation can be performed in each of the measurement data, analysis result, transfer function, simulation result, and analog input tabs.

The measurement results, analysis results, simulation results, and other results are displayed in lists like the one shown in the following figure.

Clicking data in the list reads its data and then displays it as a graph.
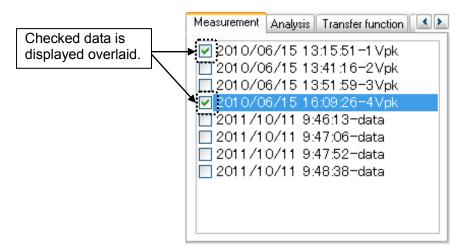
Figure 3-20 Specifying overlaying

If data is clicked after other data has been read, the displayed data is cleared and the newly specified data is read.

If you want to overlay data, select the checkboxes on the left side after data has been read.

By default, the data name "data" is assigned to the measurement result. If you want to rename the data, click the data to be renamed and then press the F2 key. The field for renaming the data will appear.
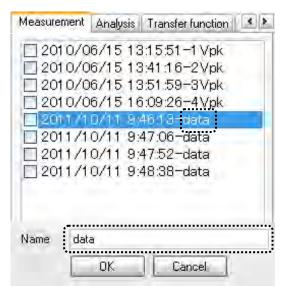
Figure 3-21 Renaming data

(Measurement condition setting area)
You can set measurement conditions for the ZGA5920.

When setting a numeric value for a measurement condition, you can set it in combination with the auxiliary unit.

Use the trackball or the Tab key on the keyboard to select a setting item and then left click or press the Enter key to enter the numeric value input state.

Enter a numeric value and then use the trackball to click one of the icons for auxiliary unit or press the ◄ or ► cursor key to change the auxiliary unit.

If the auxiliary unit is changed before a numeric value is entered, the auxiliary unit will change but the numeric value will become 0. In this case, be sure to enter an appropriate numeric value.
The following shows the example of changing a frequency setting parameter from 10 Hz to 1 kHz.
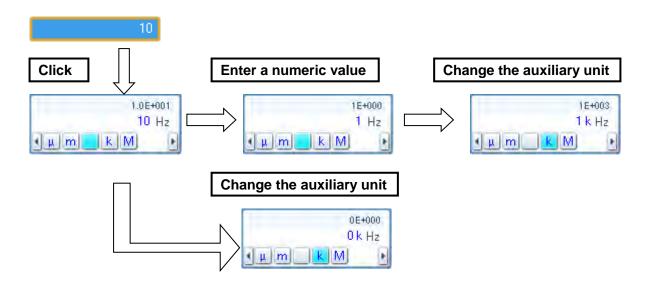
Figure 3-22 Numeric value input example

If the combination of the entered numeric value and auxiliary unit result in a value that is outside the range of that setting parameter, the parameter will be restored to the original numeric value setting.
Specified auxiliary units can be saved to the recipe for each setting item.
With some numeric value input parameters, auxiliary units cannot be used due to setting range limits.

(Analysis condition setting area)
You can set analysis conditions for each measurement application.

(Simulation condition setting area)
You can set simulation conditions for each measurement application.

■ Measurement operation area

This area is for performing operations during measurement.

After the measurement conditions are determined, the basic measurement operations can be performed using the buttons in this area.
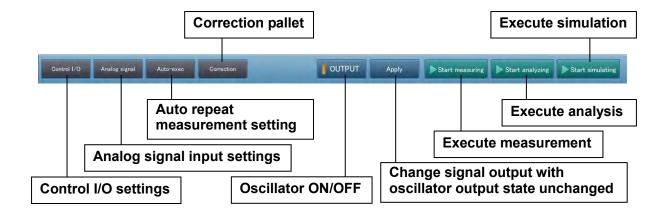
Figure 3-23 Measurement operation area

3.5.2 Measurement application selection

You can select a measurement application from the Application pallet.
Click the button for the measurement application from the list you want to select.

To switch to measurement operation, click the Application pallet on the Tool pallet again.
The Application pallet closes and operations can be performed in the measurement screen.
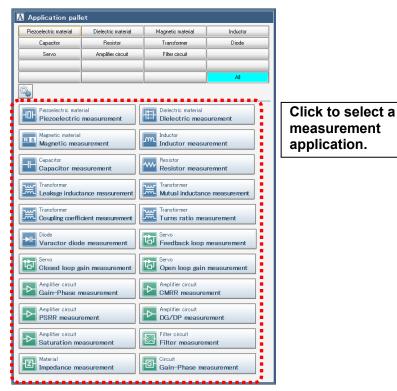
Figure 3-24 Application pallet

The Assist tab of the Support pallet displays information, such as connection examples between the sample and the ZGA5920 according to the application selected in the Application pallet.
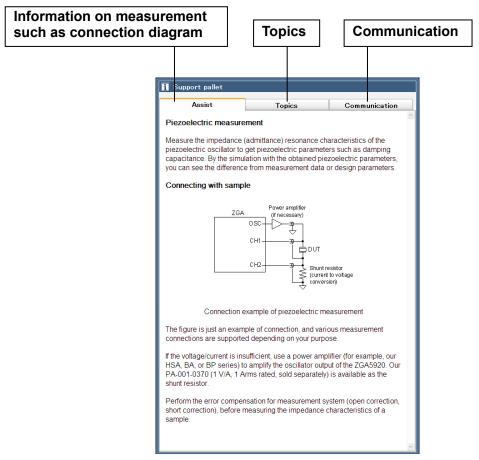
Figure 3-25 Support pallet

3.5.3 Operations from measurement through analysis up to simulation

This section shows the procedure of operations from the start of measurement through analysis up to simulation, taking the piezoelectric measurement as an example. Analysis or simulation may not be possible in some cases depending on the measurement application.

For how to connect the sample, click the Support pallet on the Tool pallet and then access the Assist tab on the Support pallet, or see "5. Measurement Operation (Samples)".

To close the Support pallet, click the Support pallet.

■ Starting the piezoelectric measurement application

Open the piezoelectric measurement screen. The following describes the operations of (1) to (9) in order.
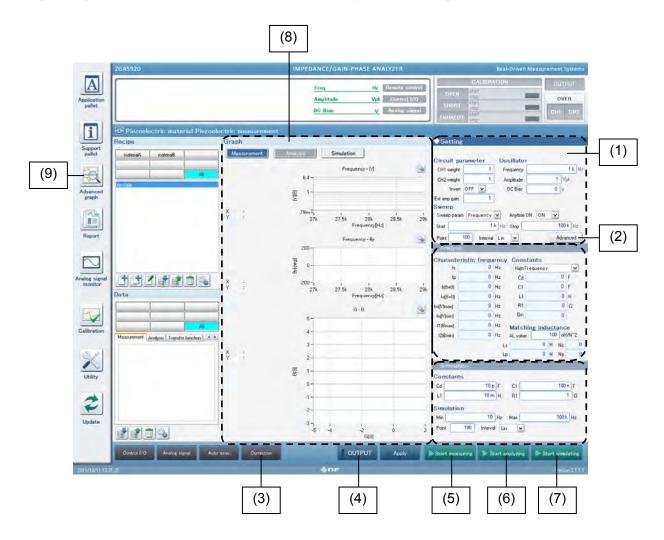
Figure 3-26 Piezoelectric measurement screen

■ Setting the measurement conditions

Set the required measurement conditions in the measurement condition setting area.

If necessary, click Advanced and set the advanced measurement conditions on the Advanced setting pallet.
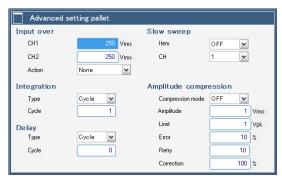
Figure 3-27 Advanced setting pallet

When measuring a sample like piezoelectric material where sharp changes occur around specific frequencies, accurate measurement is possible using "Slow sweep". For details, see "4.3.3 Slow sweep". When the settings are finished, click Advanced to close the Advanced setting pallet.

■ Correction

Next, perform open correction and short correction to reduce errors in the measurement system (cables, etc.).

Click Correction in the measurement operation area to display the Correction pallet.
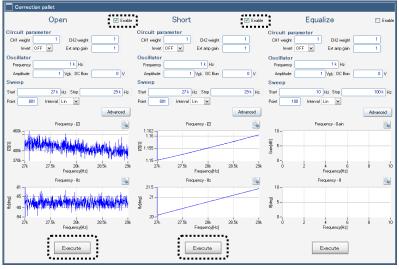
Figure 3-28 Correction pallet

Click Execute for open correction on the Correction pallet to perform open correction.

When the correction is finished, click Execute for short correction to execute short correction.

Select the Enable checkboxes for open correction and short correction so that the correction results will be used to measure.

When the settings are finished, click Correction to close the Correction pallet.

For details on open correction and short correction, see "4.1.3 Open correction and short correction".

■ Starting measurement

When the preparation for measurement is finished, execute measurement. To start measurement, click OUTPUT in the measurement operation area to turn output on.

Check the output state in "OUTPUT" of the information area and then click Start measuring to start measurement.

The progress is displayed in the information area during measurement.

When measurement is finished, a graph of the measurement results is displayed in the graph display area and the measurement results are displayed on the Measurement tab in the measurement result data operation area.
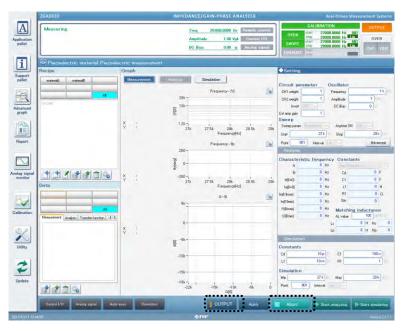
Figure 3-29 Display during measurement
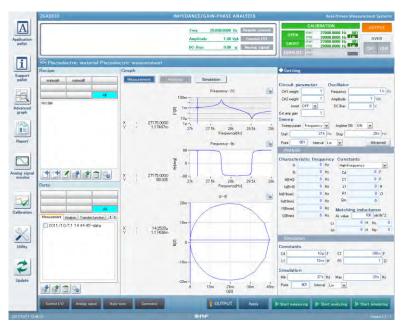
Figure 3-30 Measurement results

■ Executing analysis

When the measurement is finished, execute analysis.

Set the conditions in the analysis condition setting area and then click Start analyzing in the measurement operation area.

When analysis is finished, the analysis results are displayed in the analysis condition setting area and on the Analysis tab in the measurement result data operation area.

Figure 3-31 Analysis results

■ Executing simulation

Set the conditions in the simulation condition setting area and then click Start simulating in the measurement operation area.

When simulation is finished, the results are displayed in the graph display area and on the Simulation tab in the measurement result data operation area.
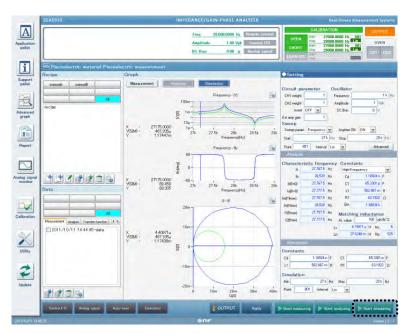
Figure 3-32 Simulation results

It is possible to show a magnified view of, for example, a location where there are sharp changes in the graph displaying measurement results or simulation results. For the detailed operations, see "3.5.7 Graph display".
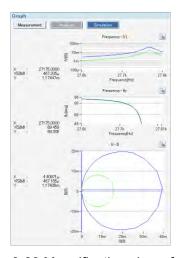
Figure 3-33 Magnification view of graph

■ Advanced graph display

Click $\boxed{\text{Advanced graph}}$ in the Tool pallet to display the Advanced graph pallet. Using the Advanced graph pallet, you can select and display graph formats that cannot be displayed in the graph display area.
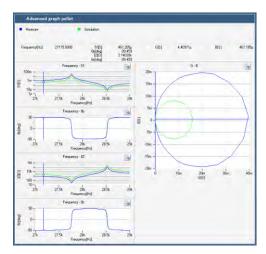
Figure 3-34 Advanced graph display

3.5.4 Report output

The measurement conditions of the ZGA5920 and a screen capture image can be output as a report in PDF format.

Lists the PDF templates used for report output.

Previews the output report.

Outputs reports using the template selected in the template list.

Lists the output reports.
Click a report in the list to preview it.

Lists the screen capture images.
Click an image in the list to preview it.

Outputs the data being previewed to the printer connected to the ZGA5920 via USB.

Captures the screen of the ZGA5920.

Figure 3-35 Report pallet

You can change the output layout by preparing a PDF template file (using Adobe Acrobat or other software) that contains the report output layout and any changes, and then importing the file to the ZGA5920.

The name of the report layout file is assigned automatically when the image file is created. To rename the file, press the F2 key while the file you want to edit is selected. The field for renaming the file will appear.

3.5.5 Correction process

● Calibration (self-calibration)

This is a self-calibration performed using an internal reference signal source of the ZGA5920. The calibration results are stored in the internal memory and will be used as calibration data for measurements.

With the ZGA5920, calibration is not performed at power-on.

If you need calibration, click Execute in the Calibration pallet.
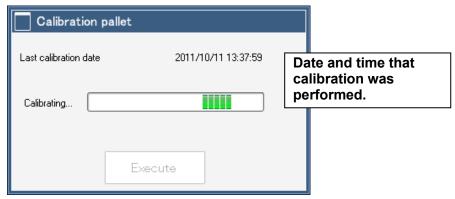
Figure 3-36 Calibration pallet

At the time of calibration, the BNC connectors of the oscillator output, CH1, and CH2 on the front panel are separated from the internal circuit by turning off the internal relays. Although calibration can be performed with the signal cable connected, it becomes susceptible to disturbance noise. Therefore, perform calibration with the signal cable (BNC cable on the front panel) disconnected preferably.
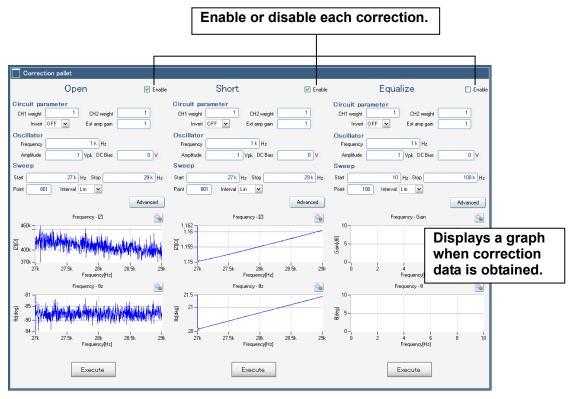
While the oscillator output is on, calibration cannot be performed. Turn off the oscillator output for calibration.

Note that the measurement accuracy specification of the ZGA5920 is met under the condition immediately after calibration. It is recommended that calibration is performed when sufficient heat run time has elapsed (approximately 30 minutes) since power-on, immediately before conducting important measurements, or when environment temperature and humidity have been changed.

● Open correction, short correction, and equalization

As correction functions, the open correction and short correction are effective (significant) at the time of impedance measurement and the equalization is effective at the time of gain-phase measurement.

These correction functions also cover the measurement system including cables and probes connected to ZGA5920.

Figure 3-37 Calibration pallet

The open correction is effective for higher impedance measurements (roughly 10 kΩ or more) and the short correction for lower impedance measurements (roughly 10 Ω or less).

The correction functions including equalization require preliminary correction data to be created before starting measurement. For each correction function to be applied, click Execute and wait until the correction data has been obtained.

After the data has been acquired, the function for which the Enable checkbox was selected is enabled. The enabled correction function is reflected in the correction state display section in the information area. (See "Figure 3-16 Example of display indicating the state during measurement".)

For details of usage, see "4. Measurement Operation (Basic)".

3.5.6 Measurement conditions

● Setting the measurement conditions
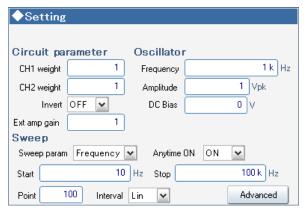
Figure 3-38 Measurement condition settings

(Circuit parameter)

■ CH1 weight, CH2 weight

Weighting factor of the measurement signal inputs. The input values multiplied by these numeric values are used for measurement processing.

■ Invert

Turned on for the measurement circuit in which the phase of voltage or current detection is inverted, for example when the PA-001-0368 Impedance Measurement Adapter (sold separately) is used.

It must normally be left OFF.

■ Ext amp gain

Enter the amplifier gain to amplify the oscillator output signal. It must be left 1.0 when the amplifier is not used.

(Oscillator)

■ Frequency

Set the output frequency. After the frequency sweep measurement, the last swept frequency is output.

■ Amplitude

Set the measurement signal amplitude (external amplifier output equivalent). After amplitude sweep measurement, the last swept amplitude is output.

■ DC Bias

Set the DC bias (external amplifier output equivalent).

After DC bias sweep measurement, the last swept DC bias is output.

(Sweep)

■ Sweep param

Select Frequency, Amplitude, DC Bias, or Zero span (time).

■ Start, Stop (Sweep time (Zero span))

Set the sweep range. There is no minimum value setting for the zero span sweep.

The Direction is determined by the values of sweep start and sweep stop.

■ Point

The number of measurement points to acquire between the values of sweep start and sweep stop.

■ Interval

Select Lin (linear scale) or Log (logarithmic scale).

■ Anytime ON   Set the ON/OFF state of the oscillator output after a measurement.

Even if the AC amplitude or DC bias setting is changed, the signal output from the BNC connector (oscillator output) on the front panel will not change unless OUTPUT button or Apply button is clicked.

⚠ **CAUTION**   Even if the output voltage setting is changed, the output voltage will not change unless the output is turned OFF and then the OUTPUT button is clicked.

(Advanced)
Click Advanced to further refine the measurement settings.
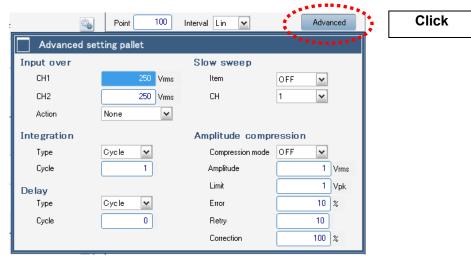
Figure 3-39 Advanced measurement condition settings

(Input over)
■ CH1   Set the voltage to detect as an overload input for CH1.
■ CH2   Set the voltage to detect as an overload input for CH2.
■ Action   Select whether to continue, abort sweep, or stop oscillator output when overload input is detected.

(Integration)
■ Type   Select the setting unit of integration (averaging). Select [Cycle] or [Time].
■ Cycle/Time   Set integration. Regardless of the integration time setting, integration is always performed for one cycle of the measurement frequency.

(Delay)

■ Type	Select the delay setting unit. Select [Cycle] or [Time].
■ Cycle/Time	Set the delay.

(Slow sweep)

Enabled only when the sweep parameter is Frequency.

■ Item	Select the parameter for monitoring an abrupt change. Select [OFF] (function off), LogR (ratio dB unit), R (ratio), θ (phase), A (real part), or B (imaginary part).
■ CH	Select the input for monitoring an abrupt change. Select [CH1] or [CH2].

(Amplitude compression <pseudo constant current measurement>)

■ Compression mode	CH1, CH2, or OFF	
■ Amplitude	Detection range of target voltage level	1 m to 250 Vrms
■ Limit	Limit range of output voltage	1 mV to 10 Vpk
■ Error	Tolerance range of target level	0 to 100%
■ Retry	Maximum level control counts	1 to 9,999
■ Correction	Level correction control rate	0 to 100%

Constant current measurement can be performed for the samples. The constant current measurement can be performed by converting the current applied to the sample into a voltage using a shunt resistor, detecting it at the monitored measurement signal input, and controlling the oscillator output level. In consideration of the characteristics of the sample, you need to select the shunt resistor and the amplifier which can properly detect the voltage from the target current value at the monitored measurement signal input, and set them as appropriate.

○ Zero span sweep

When you set the sweep parameter to Zero span, measurements are repeated for the same oscillator output frequency, AC amplitude, and DC bias to obtain data where the X axis represents time. It is a function to observe time variation of the gain, impedance, or other parameter of the target.

For zero span sweep measurement, it takes approximately 2 seconds for each measurement point. If the time of ("Point" × 2 seconds) set in the measurement value input tab exceeds the "Sweep Time", the time required for the zero span sweep is calculated by ("Point" × 2 seconds).

3.5.7 Graph display

Some measurement applications have more than one graph format (combination of X and Y axes). When you click a desired graph format, the graph is displayed in the selected format. The graph format varies depending on the selected measurement application.
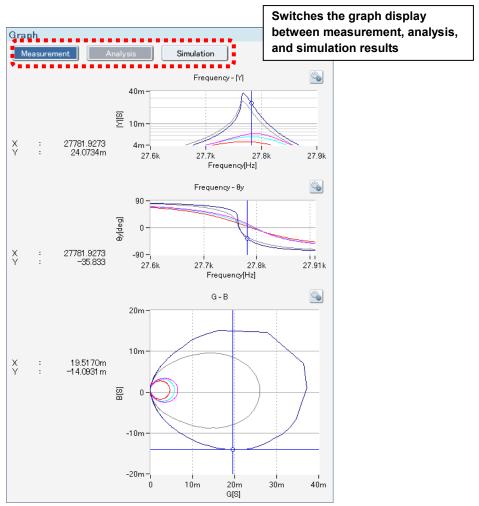
Figure 3-40 Graph display area

For details, see **"4. Measurement Operation (Basic)"** and **"5. Measurement Operation (Samples)"**.

■ Marker

For measurement data or simulation data, you can use the marker to read the numeric value of a data item on the graph. The read numeric value is displayed.

Immediately after a sweep measurement, the marker is at the left or right end of the graph. When you hover the pointer over the marker by the trackball, the pointer changes. The ○ mark is displayed on the intersection of the plotted data and the marker.

Normal pointer

When the pointer is on the marker

When the pointer is on the intersection of data and marker

For Nyquist diagram or other graph, the marker is displayed on the X and Y axes
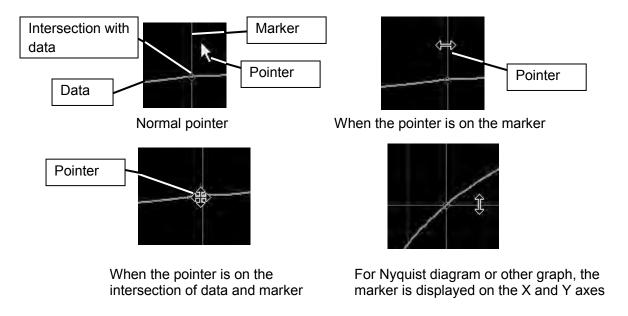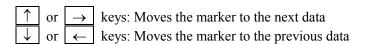
Figure 3-41 Marker pointer

The marker displays a numeric value based on the sweep parameter. When plural data items are displayed, for example the measurement data and the simulation data, the values with the same frequency are displayed. Even in a graph that does not have a sweep parameter on the X axis, for example the Nyquist diagram, the marker moves along the sweep parameter.

You can move the marker by dragging the pointer (while holding down the left button of the trackball) as well as using the cursor keys on the keyboard.

| ↑ | or | → | keys: Moves the marker to the next data
| ↓ | or | ← | keys: Moves the marker to the previous data

■ Graph operation

$\boxed{\text{SHIFT}}$ + left button click　　: Zoom in
$\boxed{\text{SHIFT}}$ + right button click　: Zoom out
$\boxed{\text{SHIFT}}$ + drag　　　　　　　: Zoom in to the selected range
$\boxed{\text{SHIFT}}$ + $\boxed{\text{ALT}}$ + drag　　　: Zoom in, keeping the aspect ratio
$\boxed{\text{CTRL}}$ + drag　　　　　　　: Pan
$\boxed{\text{SHIFT}}$ + $\boxed{\text{BackSpace}}$　　: Cancel the pan or zoom (return to auto scale)
$\boxed{\text{CTRL}}$ + $\boxed{\text{BackSpace}}$　　: (same as above)

* "Drag" is an operation to move the pointer by rolling the ball while holding down the left button of the trackball.

You can set the display ranges and titles of the X and Y axes for graphs.
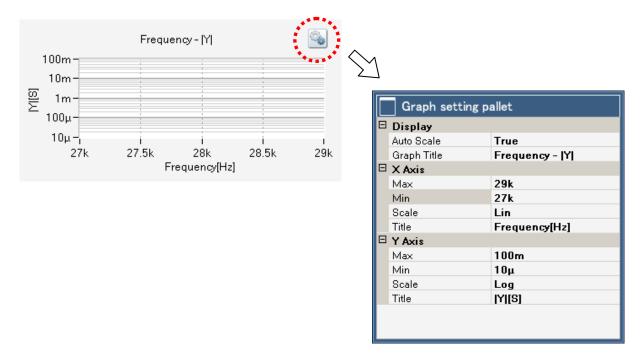
Figure 3-42 Graph scale setting

For [Auto Scale], you can select [True] or [False].

        True: Automatically sets the axis ranges so that all data can fit into the graph.

        False: Applies the manually set values to the axes.

When you open the Graph setting pallet while [Auto Scale] is set to [True], the values of the currently displayed graphs are entered in [Min] and [Max] of the X and Y axes.

For [Scale] of the X or Y axis, the axis scale type is set.

        Lin: Axis with a linear scale

        -Lin: Axis with a linear scale and the vertical (X axis) or horizontal (Y axis) scale in the reverse direction

        Log: Axis with a logarithmic scale

        -Log: Axis with a logarithmic scale for negative data

When zero or less value is included in the [Log] axis data or zero or more value is included in the [-Log] axis data, the graphs cannot be displayed correctly. Set the axis scale to [Lin] for data including both negative and positive values.

3.5.8 OUTPUT ON, OFF

In the output on state, the "OUTPUT" lamp of the oscillator output connector is lit on and the signal is being output.
The ON/OFF state of oscillator output after measurement differs depending on the [Anytime ON] setting in the measurement condition settings.

- When [Anytime ON] is set to [ON]: The ON state continues after a measurement.
  The oscillator output keeps the last state (Frequency, Amplitude, and DC Bias) of the sweep.

- When [Anytime ON] is set to [OFF]: The output is turned OFF after a measurement.
  Next time the oscillator output is turned on, Frequency, Amplitude, and DC Bias set in [Oscillator] of the measurement condition setting area are used for output.

3.5.9 Measurement control

Use the Start measuring button to start a sweep measurement. When the measurement signal output is OFF, you cannot start a measurement.
Use the Abort button to interrupt the measurement. The data measured by the time of interruption is displayed in the graph. Note that in case of interruption, the start and stop sweep values setting do not apply to the data range.

3.5.10 Control I/O

You can control the external device and operate it in conjunction with the ZGA5920 using the control I/O. The control I/O is set on the Control I/O setting pallet, which opens by clicking Control I/O in the measurement operation area.

To control the ZGA5920 with input via the control I/O, select the [Enable] checkbox.
It is possible to control the starting and aborting of measurement and ON/OFF of output.

Output from the control I/O includes the pulse output of elapsed time since the start of measurement (set 0 to 999 seconds) in addition to the pulse outputs of start measuring and complete measuring, Output ON/OFF, and the output of measurement state.
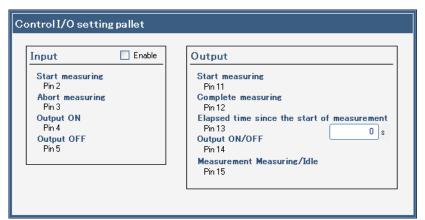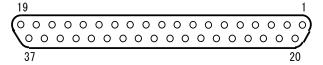
Figure 3-43 Control I/O screen

(D-Sub connector, view from panel side)

Figure 3-44 Control I/O connector

Table 3-26 Control I/O connector

Pin No.	Signal name	Type	Description
1	Reserved	Input	Reserved
2	Start measuring	Input	When a negative logic pulse is input, measurement is started.
3	Abort measuring	Input	When a negative logic pulse is input, measurement is aborted.
4	Output ON	Input	When a negative logic pulse is input, output is turned ON.
5	Output OFF	Input	When a negative logic pulse is input, output is turned OFF.
6	Reserved	Input	Reserved
7	Reserved	Input	Reserved
8	Reserved	Input	Reserved
9	Reserved		Reserved
10	Reserved		Reserved
11	Start measuring	Output	When measurement is started, a positive pulse is output.
12	Complete measuring	Output	When measurement is completed, a positive pulse is output.
13	Elapsed time	Output	Output varies in accordance with the [Elapsed time since the start of measurement] setting.
14	Output	Output	1: Output ON, 0: Output OFF
15	Measurement	Output	1: Measuring, 0: Idle
16	Reserved	Output	Reserved
17	Reserved	Output	Reserved
18	Reserved		Reserved
19	Reserved		Reserved
20	GND	GND	
:	:	:	
37	GND	GND	

3.5.11 Analog signal input

The ZGA5920 is equipped with an analog signal input with an input range of ±10 V.
You can log temperature, humidity, and other data in accordance with the measurement that is performed.
Data logging starts when measurement is started and completed or when output is turned ON and OFF. The delay time can also be set.

The analog signal input is set on the Analog condition pallet, which opens by clicking Analog signal in the measurement operation area.

When the [Enable] checkbox is selected, logging is performed in accordance with the [Start logging] and [Stop logging] settings.

    Sampling rate   1 to 25000 S/s

    Start logging   [Start measuring] or [Output ON]
                Delay time can be set from 0 to 999 seconds.

    Stop logging   [Complete measuring], [Abort measuring], [Output OFF], or [Logging time]
                Logging time can be set from 0 to 28800 seconds (8 hours).
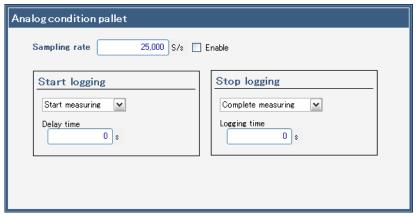
Figure 3-45 Analog signal input screen

Clicking Analog signal monitor on the Tool pallet opens the analog input signal monitor to enable you to see the input signal during logging.
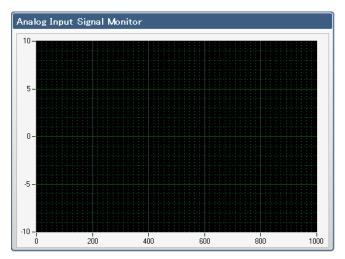
Figure 3-46 Analog signal monitor

You can also export the logged data to USB memory.
Select the logged data in the Analog signal tab of the data list display section in the measurement result data operation area, and then export it.

3.5.12 Automatic measurement

You can automate repeated measurement operations.
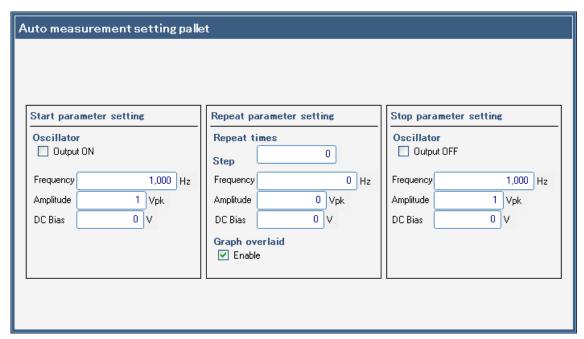
Figure 3-47 Auto measurement setting pallet

(Start parameter setting)

■ Oscillator   When [Output ON] is selected and the measurement signal output is turned
                      off, the measurement signal output will be turned on before the measurement
                      is started automatically.
                      This setting is enabled when the [Repeat times] setting is set to at least one
                      time.

■ Frequency   Set the output frequency for when the sweep for automatic measurement
                      starts.
                      This setting is enabled when the [Repeat times] setting is set to at least one
                      time.

■ Amplitude   Set the amplitude (external amplifier output equivalent) for when the sweep
                      for automatic measurement starts.
                      This setting is enabled when the [Repeat times] setting is set to at least one
                      time.

■ DC Bias   Set the DC bias (external amplifier output equivalent) for when the sweep
                      for automatic measurement starts. This setting is enabled when the [Repeat
                      times] setting is set to at least one time.

(Repeat parameter setting)

■ Repeat times   Set the number of times to repeat the measurement. The actual number of measurements will be the [Repeat times] setting +1. When 0 is set, one measurement will be performed.

■ Step (Frequency, Amplitude, DC Bias)
                        Set the incremental increase in the measurement signal output for each successive sweep measurement.

■ Graph overlaid   When [Enable] is selected, the results of the repeated measurements will be overlaid in a graph. Up to 16 data sets can be overlaid. If measurements are repeated more than 16 times, the newest 16 data sets will be overlaid.

(Stop parameter setting)

■ Oscillator   When [Output OFF] is selected, the measurement signal output will be turned off when all measurements are complete.
                        This setting is enabled when the [Repeat times] setting is set to at least one time.

■ Frequency   Set the output frequency for when automatic measurement completes.
                        This setting is enabled when the [Repeat times] setting is set to at least one time.

■ Amplitude   Set the amplitude (external amplifier output equivalent) for when automatic measurement completes.
                        This setting is enabled when the [Repeat times] setting is set to at least one time.

■ DC Bias   Set the DC bias (external amplifier output equivalent) for when automatic measurement completes.
                        This setting is enabled when the [Repeat times] setting is set to at least one time.

3.5.13 Excessive input indicators

The maximum measurement voltage of the ZGA5920 is 250 Vrms. When a signal exceeding 250 Vrms is input to a measurement signal input terminal, the "OVER" lamp on the main unit front panel and the excessive input indicator at the top right of the monitor screen are lit on. When these lamps are lit on, turn OFF the oscillator output or remove the signal cable to avoid an excessive input to the ZGA5920.

⚠ **WARNING**

- Do not use for measurement of the main power supply circuit.
- Do NOT connect to any measurement target with transient overvoltages that exceed 1,500 Vrms.
- Do NOT connect to any measurement target that exceeds 250 Vrms.
  Doing so may result in insulation breakdown, imposing electric shock.
- You could be suffered from electric shocks when you measure high voltage circuit signals. Use accessory coaxial cables of the insulation type by all means, so that you cannot directly touch metallic portions of the BNC connectors at the measurement signal input terminals.

For details of specifications and precautions of the input connectors, see "3.3 Input and output terminals" and "3.4 Insulation breakdown voltages of input and output terminals".

3.5.14 Utility

When you click the Utility button in the Tool pallet, the Utility pallet is displayed.
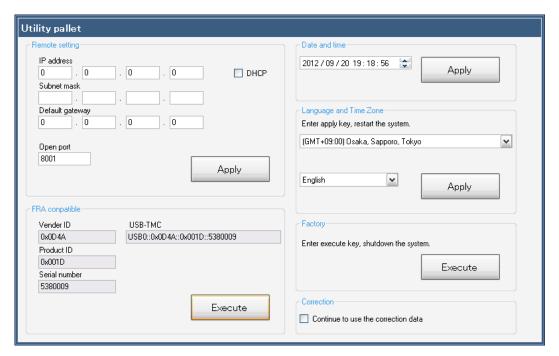
Figure 3-48 Utility pallet

■ LAN

Specifies the IP address used to connect the ZGA5920 to your PC via LAN and perform measurement control from your PC.

The default value 8001 for the Open port can be changed.

However, when using the NFRemote component in the Software Developer Kit for LAN connection (contained in the accompanying CD-ROM) or the ZGA5920 Utility Software, you need to use the same port number. See also the instructions contained in the accompanying CD-ROM.

You can use the Utility Software to easily obtain measurement recipes or measurement result data via LAN.

■ FRA compatible remote control

When you connect the ZGA5920 to an external PC or other controller via FRA5097-compatible USB connection, the switching operation is required. Click Execute to enable or disable FRA compatible remote control. When you want to perform the remote control, use a commercial USB cable to connect the USB-B connector on the rear of the ZGA5920 main unit with the PC. For details on remote control commands, see "ZGA5920 FRA Compatible Remote Control Instruction Manual".

The displayed values are numbers for the PC to identify the ZGA5920. From the top:
    0x0D4A: USB Vendor ID of NF Corporation.
    0x001D: Product ID, the number representing the model number ZGA5920.
    xxxxxxx: 7-digit manufacturing number (serial number). This is unique to each product.

Note that measurement operations are disabled on the ZGA5920 under remote control.

■ Data and Time

This tab is used to set the built-in calendar and clock of the ZGA5920.

■ Language and Time zone

Switches time zones and the Japanese/English display setting.
Click the Apply button to restart the system.

■ Factory

Restores the ZGA5920 to the factory default.
All saved data is deleted at this time.

■ Correction

When [Continue to use the correction data] is selected, you can continue to use the same correction data, even after changing recipes or applications.
When you load data while this check box is selected, the correction data from during the measurement will not be loaded.

3.5.15 Update

This pallet is used to upgrade the ZGA5920 software. For a specific operation, see update information provided by us.
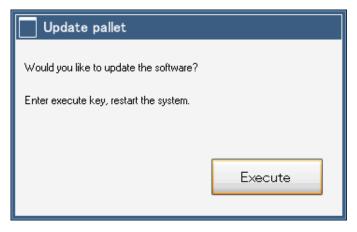
Figure 3-49 Update pallet

3.6 High frequency measurement

At frequencies above approx. 100 kHz, measurement error increases with greater frequency. This section describes main considerations for measurement at high frequencies.

a) Effect of isolation

The oscillator output has 250 pF and each of CH1 and CH2 has 200 pF of against-enclosure electrostatic capacitance (isolation capacitance). The reactance (impedance) with 250 pF of electrostatic capacitance can reduce to approx. 6.4 kΩ at 100 kHz and approx. 640 Ω at 1 MHz. For a measurement circuit using isolation, it must be considered that the impedance of isolation is finite and can reduce in proportion to frequency.

For measurement at high frequency, a measurement circuit with the shield side of three measurement terminals (OSC, CH1, and CH2) grounded to the enclosure can get better results.

b) Auto ranging

The internal measuring range of the ZGA5920 automatically corresponds to the signal size. Since calibration error increases at high frequency, the measurement graph may show small bumps before and after range selection.

c) Use correct probe

At high frequency, line-to-line electrostatic capacitance of the cable may give load to the system under test (SUT) and thus greatly affect the measurement result and the action of SUT. In addition, with a longer cable (than approximately a few percent of the measurement signal wave), the signal reflection can increase measurement error due to impedance mismatch. In these situations, the use of a suitable probe is recommended to reduce measurement error.

For example, a 10:1 oscilloscope probe can be used. Select a probe with an oscilloscope matching impedance within the allowable range of 20-30 pF or more at 1 MΩ. Before measurement, adjust the probe trimmer for flat frequency response. While using the probe to measure the oscillator output signal, adjust the trimmer so that the gain at 100 kHz is equal to the one at 10 Hz. According to the probe type and trimmer initial setting, a lower reference frequency is desirable.

By using a 10:1 probe, the signal is attenuated 1/10. This can be largely compensated by setting the CH1 or CH2 weighting factor to 10 in the measurement condition setting area.

> **For details of the CH1 and CH2 weights, see "4.3 Overview of measurement and processing".**

The ZGA5920 equalizer function can be used to correct the probe error accurately.

> **For details of the equalize function, See "4.2.3 Equalize".**

By applying a feed through type 50 Ω terminator to the ZGA5920 measurement signal input terminal, a 500 Ω input impedance high frequency 10:1 probe can also be used.

d)　Connecting cable length and routing

The signal line and the enclosure of the ZGA5920 are isolated. However, at high frequency, current can easily flow between the cable outer conductor (shield) and ground due to stray capacitance.

If the connecting cable is long, oscillation can occur due to such properties as cable inductance and isolation capacitance, disturbing frequency response and possibly preventing measurement. In this type of case, such measures as shortening the cable or inserting a common mode choke in the cable can provide improvement. For example, a clamp type ferrite core, such as used for correcting noise, can be attached to the cable.

Cable routing and coupling between cables can change the impedance to ground and thus appear like a variation in characteristics. In this type of case, minimizing cable induction and securing the cable location can improve measurement consistency.

4. Measurement Operation (Basic)

4.1 Impedance measurement

"**Impedance measurement**" is a general-purpose impedance measurement function which is not limited to particular measurement purposes. To open the measurement screen, select [Impedance measurement] from the Application pallet.
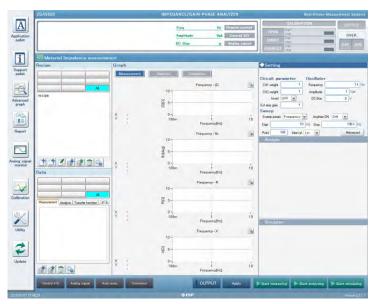
Figure 4-1 Impedance measurement screen

The ZGA5920 performs impedance measurement by the following calculations.

$|Z|$ = (CH1 voltage amplitude) / (CH2 voltage amplitude)

θ = (CH1 phase) - (CH2 phase)

The impedance of a sample can be measured by adding the oscillator output signal to the sample, then inputting the voltage between both ends of the sample to CH1 and the voltage converted from the current flowing through the sample to CH2.
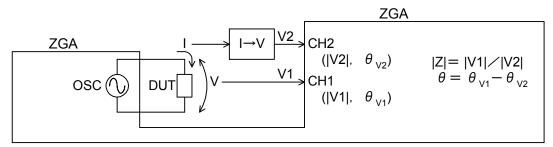
Figure 4-2 Principle of impedance measurement

4.1.1 Connecting with sample

The ZGA5920 supports various measurement connections depending on the impedance magnitude and the measurement conditions of the target sample. Select the appropriate measurement circuit (connection) by referring to "Figure 4-3 Measurement connection selection procedure". Note that the frequency or impedance magnitude given as the selection range is just a guide for you.
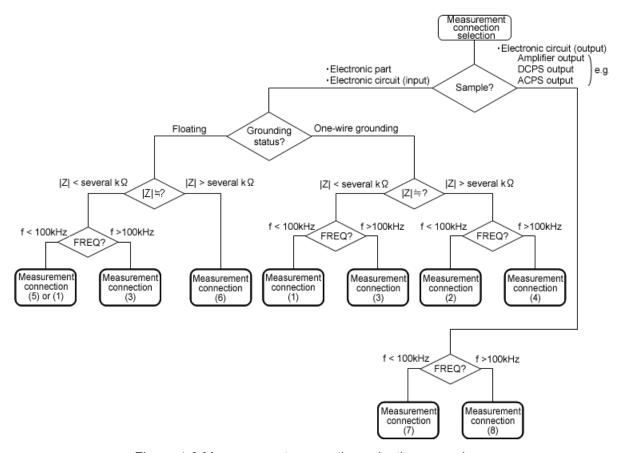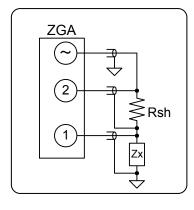
Figure 4-3 Measurement connection selection procedure

The measurement connections (x) are explained in the following pages.

In the figures below, $\sim$, ①, and ② indicate the oscillator output, CH1, and CH2, respectively. Rsh indicates the shunt resistor for current-to-voltage conversion. Our PA-001-0370 (1 V/A, 1 Arms rated, sold separately) is available as the shunt resistor. Use a shunt resistor with appropriate current value and current-voltage conversion ratio for on your purpose.

○ Measurement connection (1)　　　Low-Z, Low-f, grounded sample measurement
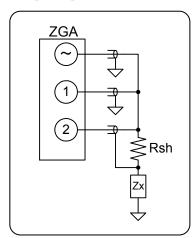
This 4-terminal configuration is impervious to the measurement cable contact resistance and thus is suited to measure low-impedance samples. The appropriate shunt resistor Rsh is approx. 1 Ω or less.
With a larger sample impedance, the ZGA5920 CH1 input impedance or the cable capacitance would be an error factor. With a higher frequency, the CH2 floating capacitance would adversely affect the measurement accuracy.
For the Rsh (CH2) and the DUT (CH1), place whichever is lower in impedance (smaller voltage drop) on the ground side (see also the measurement connection (5)).

○ Measurement connection (2)　　　High-Z, Low-f, grounded sample measurement
　Input impedance of electronic circuit, high-impedance sample, and so on
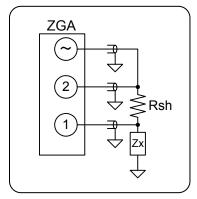
This connection is effective when the sample impedance is high and the ZGA5920 CH1 input impedance (1 MΩ) is not ignorable. A higher frequency would reduce the measurement accuracy due to effect of the CH2 floating capacitance.
Making the Rsh as large as several tens to a hundred ohms improves the signal-to-noise ratio at high impedance measurement.

○ Measurement connection (3)　　　Low-Z, High-f, grounded sample measurement
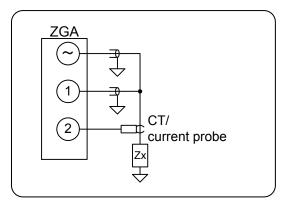
This connection is impervious to the ZGA5920 CH1 and CH2 floating capacitances, and thus can stably measure up to high frequencies. However, the measurement error increases for a larger sample impedance. The appropriate Rsh is approx. 1 Ω or less.
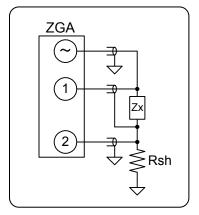
○ Measurement connection (4)　　　High-Z, High-f, grounded sample measurement

This connection is suitable for measurement at high frequencies when the CT (current transformer) and current probe band widths are wide. However, the signal-to-noise ratio is disadvantageous (due to a larger noise particularly for DC-CT).

○ Measurement connection (5)　　　Low-Z, Low-f, both-end floating sample measurement
Electric double layer capacitor (EDLC), and so on
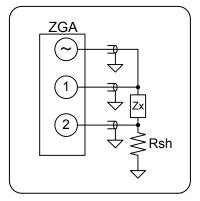
This 4-terminal configuration is impervious to the measurement cable contact resistance. The appropriate Rsh is approx. 1 Ω or less.
For the Rsh and the sample, place whichever is lower in impedance (smaller voltage drop) on the ground side. See also the measurement connection (1).
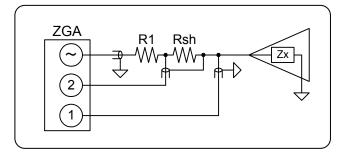
○ Measurement connection (6)　　　High-Z, High-f, both-end floating sample measurement

This connection is impervious to the **ZGA5920** CH1 and CH2 floating capacitances, and thus can stably measure up to high frequencies. Making the Rsh as large as several tens to a hundred ohms improves the signal-to-noise ratio at high impedance sample measurement.

○ Measurement connection (7)　　　Low-Z, Low-f, grounded sample measurement
　　Output impedance of electronic circuit (e.g., amplifier, power supply circuit) , and so on
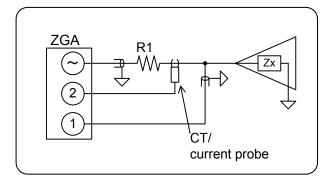
The R1 (protective resistance) limits the current reversely injected to the oscillator output by the output voltage of the sample (amplifier or power supply circuit). Decide the resistance value to limit the current to tens of milliamperes or less.
A higher frequency would reduce the measurement accuracy due to effect of the CH2 floating capacitance.

○ Measurement connection (8)　　　Low-Z, High-f, grounded sample connection
　　Output impedance of electronic circuit (e.g., amplifier, power supply circuit) , and so on

The R1 (protective resistance) limits the current reversely injected to the oscillator output by the output voltage of the sample (amplifier or power supply circuit). Decide the resistance value to limit the current to tens of milliamperes or less.
By using a CT (current transformer) or current probe for current detection, the connection is more impervious to the **ZGA5920** floating capacitance and thus stabilizes measurements at high frequencies.

Though the ZGA5920 oscillator output has ±10 V output at maximum, a larger signal can be used for measurement by connecting a power amplifier. We offer a variety of power amplifiers, including High Speed Bipolar Amplifier HSA/BA series, BP series, and 4500 series, for various voltage, current, and bandwidth requirements. In combination with any of these power amplifiers, you can perform measurements at actual signal levels used by the sample.

The maximum input voltage of the ZGA5920 measurement signal input terminals is 250 Vrms. However, the voltage measurement range can be expanded by externally connecting an attenuator, high pressure probe, or differential probe.

4.1.2 Setting impedance measurement

Set the followings according to the circuit connected with the sample.
(Circuit parameter)
• CH1 weight
• CH2 weight
• Invert
• Ext amp gain

For the CH1 weight, set the inverse number of the gain for the probe or preamplifier connected to the CH1. For the CH2 weight, set the inverse number of the gain for the shunt resistor or CT (current-voltage conversion) connected to the CH2. These weight settings allow you to perform measurement as a value at the sample end, instead of at the ZGA5920 input terminal. Setting examples of the external amplifier gain, CH1 weight, and CH2 weight are shown in the "Figure 4-4 Connection diagram for impedance measurement - Setting example".
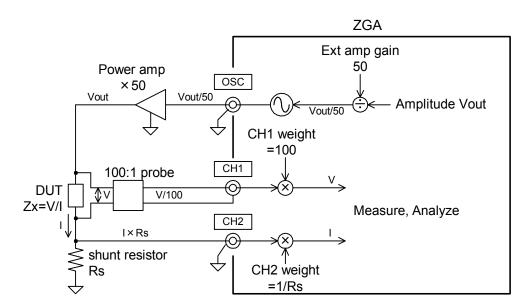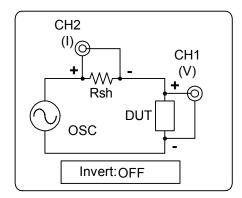
Figure 4-4 Connection diagram for impedance measurement - Setting example

Set [Invert] to [ON] to perform measurement with the phase inverted (+180°). This can be effective for inverting voltage and current phase when measuring impedance. When using the **Impedance Measuring Adapter PA-001-0368** (sold separately), set [Invert] to [ON].
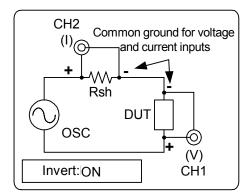
Figure 4-5 Phase invert function

Set other items, according to the measurement.
(Oscillator)

• Frequency:	Immediately after the setting, this is the frequency of a signal actually output from the current oscillator output regardless of the start and stop sweep values. When a frequency sweep finishes, the last measured frequency in the sweep is output regardless of this setting.	
• Amplitude, DC Bias:	The signal to be actually output from the oscillator output connector on the ZGA5920 main unit is (This value)/(External amplifier gain).	

(Sweep)
- Sweep param: Fixed to Frequency in the impedance measurement.
- Anytime ON: Selects whether to turn off (OFF) or leave on (ON) the oscillator output after a sweep measurement.
- Start, Stop: Sweep measurement range.
- Point: The number of measurement points between the start and stop sweep values.
- Interval: [Lin] (linear) or [Log] (logarithmic) of the measurement frequency sweep, which is independent from Lin or Log of the graph display.

(Integration): Set when the noise is large. See **"4.3.1 Integration"**.

(Delay): Needs to be set when measuring a sample that shows sharp resonance characteristics. See **"4.3.2 Delay"**.

(Slow sweep): This function automatically increases the sweep density in the portion where the characteristics are greatly changed. See **"4.3.3 Slow sweep"**.

Each gain (attenuation) for the shunt resistor and probe set in the CH1 and CH2 weights is a certain value regardless of the frequency. The effect of phase shift cannot be corrected. For more accurate measurements by correcting the residual impedance and admittance of cables for each measurement frequency, perform the open or short correction (see "4.1.3 Open correction and short correction").

4.1.3 Open correction and short correction

This function measures in advance the measurement system errors (residual impedance and admittance) generated from the connection with a sample, stores them in the ZGA5920 main unit, and uses them for correcting the impedance measurement result to reduce measurement system error effects. The open correction is effective for higher impedance measurements (roughly 10 kΩ or more) and the short correction for lower impedance measurements (roughly 10 Ω or less). Of course, it is also effective to perform both the open and short corrections.

These corrections are performed by the following procedure.

1) Set the sweep parameter to Frequency. Make any other necessary settings such as start sweep value, stop sweep value, and AC amplitude. See "4.1.2 Setting impedance measurement".

2) Open the Correction pallet. See "Figure 4-6 Correction pallet".

Figure 4-6 Correction pallet

(To perform the open correction)

3-1) Open the measurement terminal (that is, an infinite-ohm sample is connected). When the oscillator output signal is amplified using a constant-current power amplifier, prevent overcurrents by inserting a bleeder resistance in the power amplifier output or by any other mean.
Make as much distance between measurement terminals as at the sample measurement, in order to keep the terminal-to-terminal electrostatic capacitance equivalent to the one when the sample is connected.

3-2) Set the measurement conditions for open correction. When you click the fromMeas or fromShort button, the measurement condition parameters or the short correction measurement condition parameters will be copied respectively.

3-3) Click the Execute button in the Correction pallet, and then wait until the sweep measurement finishes.

3-4) When finished obtaining correction data, a graph is displayed in the Correction pallet.
You can obtain correction data as many times as you want.

(To perform the short correction)

4-1) Short the measurement terminals using a material with the impedance low enough such as a metal plate (that is, a zero-ohm sample is connected). When the oscillator output signal is amplified using a power amplifier, temporarily lower the oscillator output level to avoid the shunt resistor from being burnt by overcurrents.

4-2) Set the measurement conditions for short correction. When you click the fromMeas or fromOpen button, the measurement condition parameters or the open correction measurement condition parameters will be copied respectively. Click the Execute button in the Correction pallet, and then wait until the sweep measurement finishes.

4-3) When finished obtaining correction data, a graph is displayed in the Correction pallet.
You can obtain correction data as many times as you want.

5) When you performed the open correction measurement, check the [Enable] checkbox for the open correction. When you performed the short correction measurement, check the [Enable] checkbox for the short correction. When you performed both the measurements, check the [Enable] checkbox for each of the open and short corrections.

6) When you actually perform measurement, the correction data is logged in the measurement result data. When you obtain a correction data while editing a measurement recipe, the data can also be logged in the measurement recipe.

⚠ **CAUTION**   When the measurement terminal is shorted or opened, the shunt resistor may burn by overcurrent or overvoltage depending on the connection. Be careful not to generate overcurrent (overvoltage), for example, by temporarily lowering the oscillator output level.

Each correction data is stored in the ZGA5920 even when the [Enable] checkbox is deselected. Re-select [Enable] to activate the correction again.

The open correction data and short correction data are logged in the measurement result data when you perform measurement with correction enabled, and in the measurement recipe when you obtain the correction data while editing a measurement recipe.

Perform the correction measurement again after a change of the measurement connection, or before an accurate measurement.

(Description)

The open and short corrections perform the correction calculation based on the following model.

Measurement terminals

Zs

I

Zx

Zp (=1/Yp)

V

$Z = \dfrac{V}{I}$

Zx:Sample impedance
Yp:Residual admittance
Zs:Residual impedance
Z:Measured impedance

Sample | Measurement connection including cables | ZGA
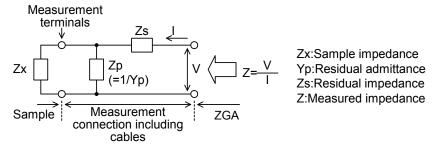
Figure 4-7 Measurement system error model

Zp is obtained by a measurement with the sample Zx opened (open correction measurement). Zs can be ignored, as it is far smaller than Zp.

Measurement terminals

(Open)

Zs

Ip

Zp (=1/Yp)

Vp

$Zp = \dfrac{Vp}{Ip} - Zs \fallingdotseq Zp$

(Because Zs<<Zp)

Measurement connection including cables | ZGA
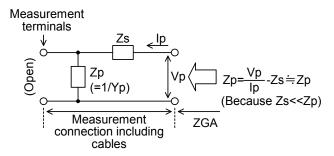
Figure 4-8 Open correction measurement

Zs is obtained by a measurement with the sample Zx shorted (short correction measurement).

Measurement terminals

(Short)

Zs

Is

Zp (=1/Yp)

Vs

$Zs = \dfrac{Vs}{Is}$

Measurement correction including cables | ZGA
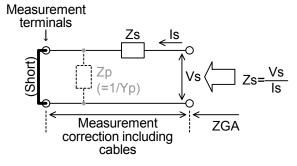
Figure 4-9 Short correction measurement

ZGA5920

Each of the open correction and short correction can be set to Enable or Disable independently. The sample impedance Zx is obtained through the correction calculations in the table below, according to the combinations of these Enable/Disable.

Table 4-1 Open and short correction formulas

Open correction	Short correction	Correction formula
Disable	Enable	$Zx = Z - Zs$
Enable	Disable	$Zx = Zp \times Z/(Zp - Z)$
Enable	Enable	$Zx = Zp \times (Z - Zs)/(Zp - (Z - Zs))$

After any of the following cases, perform the open and/or short correction measurement again.

- After power-on

  The open correction data and short correction data are cleared at power-off.

  However, you can set them using the correction data logged in the measurement recipe or the measurement result data.

- After the measurement connection is changed

  The residual impedance and admittance have changed.

- After the sweep range (start or stop sweep value) is changed

  A wider sweep range makes a frequency area with no correction data, which disables the corrections.

  With a narrower sweep range, the frequency is interpolated for the open or short correction. The correction is effective. However, another correction measurement is recommended because it has different frequency measurement points.

- After the measurement interval is changed

  Even when Lin/Log of the sweep is changed, the correction is effective through frequency interpolation unless there is no change to the sweep range. However, another correction measurement is recommended because it has different frequency measurement points.

4.1.4 Measuring sample impedance

Click the ⌷Start measuring⌷ button to start a sweep measurement. When the sweep finishes, the data are displayed in graphs.
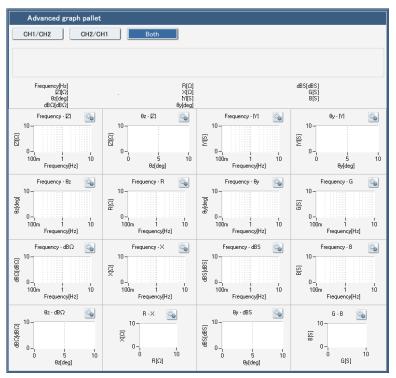
Figure 4-10 Impedance measurement graphs

Displayed graph varies depending on the analysis mode setting. In analysis mode, "CH1" indicates measurement input terminal 1, and "CH2" indicates measurement input terminal 2. When the analysis mode is set to "CH1/CH2", the impedance-related graphs can be displayed. When it is set to "CH2/CH1", the admittance-related graphs can be displayed. The types of graph that can be displayed are shown in "Table 4-2 Graph types in Basic mode (impedance measurement)".

Table 4-2 Graph types in Basic mode (impedance measurement)

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency —θz	Frequency [Hz]	Impedance phase [deg]	○	—	—	
Frequency —dBΩ	Frequency [Hz]	Impedance [dBΩ]	○	—	—	
θz—dBΩ	Impedance phase [deg]	Impedance [dBΩ]	○	—	—	
θz—|Z|	Impedance phase [deg]	Impedance [Ω]	○	—	—	
Frequency —R	Frequency [Hz]	Resistance [Ω]	○	—	—	
Frequency —X	Frequency [Hz]	Reactance [Ω]	○	—	—	
R—X	Resistance [Ω]	Reactance [Ω]	○	—	—	
Frequency —|Y|	Frequency [Hz]	Admittance [S]	○	—	—	
Frequency —θy	Frequency [Hz]	Admittance phase [deg]	○	—	—	
Frequency —dBS	Frequency [Hz]	Admittance [dBS]	○	—	—	
θy—dBS	Admittance phase [deg]	Admittance [dBS]	○	—	—	
θy—|Y|	Admittance phase [deg]	Admittance [S]	○	—	—	
Frequency —G	Frequency [Hz]	Conductance [S]	○	—	—	
Frequency —B	Frequency [Hz]	Susceptance [S]	○	—	—	
G—B	Conductance [S]	Susceptance [S]	○	—	—	

- The polarities of the phase are opposite for the analysis modes CH1/CH2 and CH2/CH1.
  (impedance phase in CH1/CH2 and admittance phase in CH2/CH1)
- "dBΩ" is the calculated result of $20 \times \text{Log}_{10}(|Z|)$. Its unit is [dBΩ].
- "dBS" is the calculated result of $20 \times \text{Log}_{10}(|Y|)$. Its unit is [dBS].
- Each parameter is determined through the following conversions using the complex impedance
  (Z=R+jX) measured in the CH1/CH2 analysis mode.

  (Analysis mode = CH1/CH2)

  $$|Z| = \sqrt{R^2 + X^2} \ , \ \ \theta = \tan^{-1}\frac{X}{R}$$

  (Analysis mode = CH2/CH1)

  $$G = \frac{R}{R^2 + X^2} \ , \ \ B = \frac{-X}{R^2 + X^2} \ , \ \ |Y| = \frac{1}{\sqrt{R^2 + X^2}} \ , \ \ \theta = -\tan^{-1}\frac{X}{R}$$

The markers in the table below are displayed according to the analysis mode, regardless of the selected graph format. Each indicates the parameter at the marker frequency.

Table 4-3 Marker display in impedance measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
|Z|	Ω	Absolute value of impedance	
R	Ω	Resistance	
X	Ω	Reactance	
θz	deg	Phase of impedance	
dBΩ	dBΩ	Impedance (dB unit)	
|Y|	S	Absolute value of admittance	
G	S	Conductance	
B	S	Susceptance	
θy	deg	Phase of admittance	
dBS	dBS	Admittance (dB unit)	

4.2 Gain-phase measurement

"Gain-Phase measurement" is a general-purpose gain-phase measurement function which is not limited to particular measurement purposes.

For each measurement application, the same explanation applies to the gain-phase measurement.

Figure 4-11 Gain-phase measurement screen

The ZGA5920 performs gain-phase measurement by the following calculations.

Gain = (CH1 voltage amplitude) / (CH2 voltage amplitude)

θ = (CH1 phase) - (CH2 phase)

The gain-phase (transfer characteristics) of the target circuit can be measured by applying the oscillator output signal to the target circuit and inputting the target circuit output and input to CH1 and CH2 respectively.
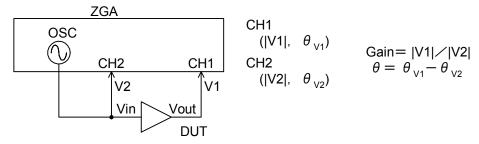
Figure 4-12 Principle of gain-phase measurement

"Figure 4-12 Principle of gain-phase measurement" measures the transmission characteristics between the input and the output of an amplifier or filter. The servo-feedback loop measurement (switching power supply loop characteristics and other automatic control loop) uses the principle shown in the figure below (loop gain characteristics measurement).
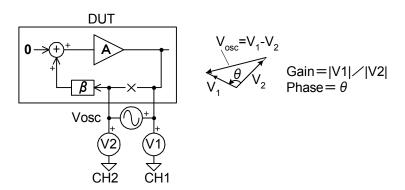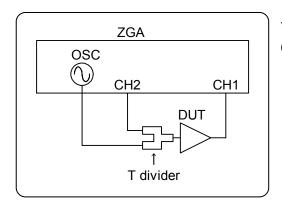
Figure 4-13 Principle of servo measurement
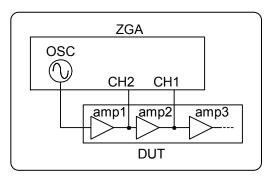
4.2.1 Connecting with target circuit

●Measurement connection with amplifier circuit, filter, and so on (1)
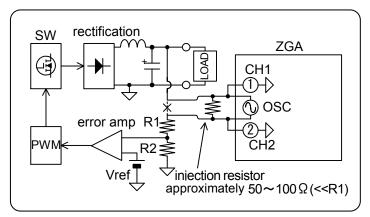
This connection measures the input/output characteristics (transfer characteristics) of the target circuit.

●Measurement connection with amplifier circuit, filter, and so on (2)

When CH1 and CH2 are connected at some midpoints in the circuit as shown in the left figure, the input/output transfer characteristics (gain-phase characteristics) can be measured only for the amp2 portion.

●Servo-feedback loop measurement   Connection for switching supply loop characteristics measurement

The injection resistor prevents the target loop from becoming open if the connection is disconnected from the ZGA5920. Make this resistance value much smaller than R1 to avoid effects on the output voltage.
This connection is applicable to a switching supply with up to 200Vdc (ZGA5920 floating breakdown voltage) output.

4.2.2 Setting gain-phase measurement

Set the followings according to the circuit connected with the target circuit.
(Circuit parameter)
*   CH1 weight
*   CH2 weight
*   Ext amp gain

For the CH1 and CH2 weights, set the reciprocal number of the gain for the probe or preamplifier connected to CH1 and CH2, respectively. These weight settings allow you to perform measurement as a value at the target circuit, instead of at the ZGA5920 input terminal. Setting examples of the external amplifier gain, CH1 weight, and CH2 weight are shown in the "Figure 4-14 Gain-phase measurement connection - Setting example".
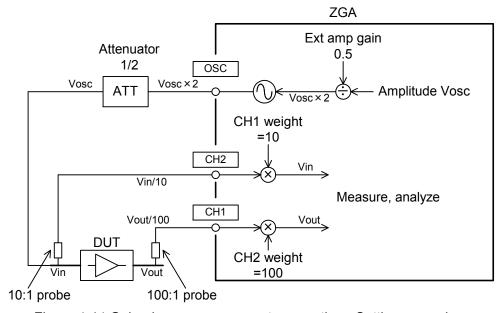
Figure 4-14 Gain-phase measurement connection - Setting example

Set other items, according to the measurement.

(Oscillator)

- Frequency: Immediately after the setting, this is the frequency of a signal actually output from the current oscillator output regardless of the start and stop sweep values. When a frequency sweep finishes, the last measured frequency in the sweep is output regardless of this setting.

- Amplitude, DC Bias: The signal to be actually output from the oscillator output connector on the ZGA5920 main unit is (This value)/(External amplifier gain).

(Sweep)

- Sweep param: Fixed to Frequency in the gain-phase measurement.
- Anytime ON: Selects whether to turn off (OFF) or leave on (ON) the oscillator output after a sweep measurement.
- Start, Stop: Sweep measurement range.
- Point: The number of measurement points between the minimum and maximum sweep values.
- Interval: [Lin] (linear) or [Log] (logarithmic) of the measurement frequency sweep, which is independent from Lin or Log of the graph display.

(Integration): Set when the noise is large. See "4.3.1 Integration".

(Delay): Needs to be set when measuring a circuit with a large attenuation slope. See "4.3.2 Delay".

(Slow sweep): This function automatically increases the sweep density in the portion where the characteristics are greatly changed. See "4.3.3 Slow sweep".

Each gain (attenuation) for the preamplifier and probe set in the CH1 and CH2 weights is a certain value regardless of the frequency. The effect of phase shift cannot be corrected. For more accurate measurements by correcting the frequency characteristics (gain and phase) of probes, perform the equalization (see "4.2.3 Equalize").

4.2.3 Equalize

This function measures in advance the measurement system errors generated by cables or probes used for connection with the target circuit, stores them in the ZGA5920 main unit, and uses them for correcting the gain-phase measurement result to reduce measurement system error effects. Measurement error occurs even if the connection is made using only the coaxial cables that come with the product, without using a probe (a cable itself is an error factor).

The equalization is performed by the following procedure.

1) Set the sweep parameter to Frequency. Make any other necessary settings such as start sweep value, stop sweep value, and AC amplitude. See "4.2.2 Setting gain-phase measurement".

2) Open the Correction pallet. See "Figure 4-6 Correction pallet".

3) Remove the target circuit and directly connect the input to the output (that is, the transfer gain is 0dB and 0deg).

4) Set the measurement conditions for equalization. You can copy the measurement condition parameters by clicking the fromMeas button.

5) Click the Execute button for the equalization, and then wait until the sweep measurement finishes.

6) When finished obtaining correction data, a graph is displayed in the Correction pallet.
   You can obtain correction data as many times as you want.

7) Select the [Enable] checkbox for the equalization.

8) When you actually perform measurement, the correction data is logged in the measurement result data. When you obtain a correction data while editing a measurement recipe, the data can also be logged in the measurement recipe.

The equalization does not work when [Enable] is not selected even if the equalization measurement is made. Be careful about it.

The equalization data is stored in the ZGA5920 even when the [Enable] checkbox is deselected. Re-select [Enable] to activate the equalization again.
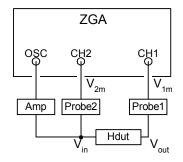
The equalization data is logged in the measurement result data when you perform measurement with correction enabled, and in the measurement recipe when you obtain the correction data while editing a measurement recipe.
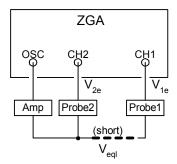
Perform the correction measurement again after a change of the measurement connection, or before an accurate measurement.

(Description)

The equalization is done through two steps: a) to measure the measurement system errors and b) to correct the measurement data that includes the measurement target (i.e., to equalize). The equalization operation procedure is shown with **"Figure 4-15 Principle of equalization"** as an example.

This example assumes that you want to have the correct characteristics of the target circuit (for which transfer function is Hdut) through canceling errors caused/brought by "Amp", "Probe1" and "Probe2".

a) Measurement connection involving DUT   b) Connection for measuring measurement system errors

Figure 4-15 Principle of equalization

First, perform a sweep measurement with the connection b) in **"Figure 4-15 Principle of equalization"**. Suppose the Amp output is V_{eql}, then the CH1 and CH2 input voltages (V_{1e} and V_{2e}, respectively) are:

$$V_{1e} = V_{eql} \times Probe1$$
$$V_{2e} = V_{eql} \times Probe2$$

Record/store the above measurement data in the equalizing memory of the **ZGA5920** main unit as the equalization data. The equalizing memory records (CH1/CH2). Therefore, the content of the equalizing memory (EQL) will be:

$$EQL = \frac{V_{1e}}{V_{2e}} = \frac{V_{eql} \times Probe1}{V_{eql} \times Probe2} = \frac{Probe1}{Probe2}$$

Connect as shown in a) in **"Figure 4-15 Principle of equalization"** and measure the overall system under test. Suppose the Amp output voltage is V_{in} and the target circuit's output voltage V_{out}, then the data measured by the **ZGA5920** (MEAS) is:

$$MEAS = \frac{V_{1m}}{V_{2m}} = \frac{V_{out} \times Probe1}{V_{in} \times Probe2} = \frac{V_{in} \times Hdut \times Probe1}{V_{in} \times Probe2} = \frac{Probe1}{Probe2} \times Hdut$$

Equalize the above measurement data MEAS by the EQL value. The equalization process is an operation to divide (normalize) the measurement data MEAS by EQL. The equalized measurement data MEAS' is given by:

$$MEAS' = \frac{MEAS}{EQL} = \frac{\dfrac{Probe1}{Probe2} \times Hdut}{\dfrac{Probe1}{Probe2}} = Hdut$$

This cancels the Probe1 and Probe2 effects and provides the target circuit's transfer characteristics Hdut.

After any of the following cases, perform the equalization measurement again.

• After power "ON"

The equalization data is cleared at power-on.

• After the measurement connection is changed

The probe gain and phase characteristics of CH1 and CH2 have changed.

• After the sweep range (start or stop sweep value) is changed

A wider sweep range makes a frequency area with no correction data, which disables the corrections.

With a narrower sweep range, the frequency is interpolated for the equalization. The correction is effective. However, another correction measurement is recommended because it has different frequency measurement points.

• After the measurement interval is changed

Even when Lin/Log of the sweep is changed, the correction is effective through frequency interpolation unless there is no change to the sweep range. However, another correction measurement is recommended because it has different frequency measurement points.

4.2.4 Measuring gain-phase characteristics of target circuit

Click the Start measuring button to start a sweep measurement. When the sweep finishes, the data are displayed in graphs.
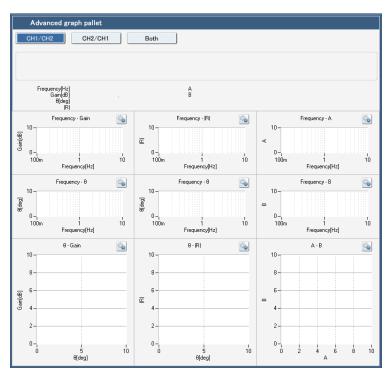
Figure 4-16 Graph display of gain-phase measurement

In analysis mode, "CH1" indicates measurement input terminal 1, and "CH2" indicates measurement input terminal 2. Normally, the analysis mode is set to "CH1/CH2". Measurements and analyses in "5. Measurement Operation (Samples)" also assume the gain and phase in the analysis mode "CH1/CH2" (the analysis mode is always "CH1/CH2" in the advanced mode). When the analysis mode is set to "CH2/CH1", the gain is indicated as an inverse number (sign inverted in the dB display) and the phase indicated with the sign inverted.

Available graph types are shown in "Table 4-4 Graph types in gain-phase measurement".

Table 4-4 Graph types in gain-phase measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Analysis mode: CH1/CH2						
Frequency —Gain	Frequency [Hz]	Gain [dB]	○	—	—	
Frequency —θ	Frequency [Hz]	Phase [deg]	○	—	—	
Frequency —|R|	Frequency [Hz]	Gain	○	—	—	
θ—|R|	Phase [deg]	Gain	○	—	—	
θ—Gain	Phase [deg]	Gain [dB]	○	—	—	
Frequency —A	Frequency [Hz]	Real part of gain	○	—	—	
Frequency —B	Frequency [Hz]	Imaginary part of gain	○	—	—	
A—B	Real part of gain	Imaginary part of gain	○	—	—	
Analysis mode: CH2/CH1						
Frequency —InvGain	Frequency [Hz]	Inverse number of gain [dB]	○	—	—	
Frequency —Invθ	Frequency [Hz]	Phase of inverse number of gain [deg]	○	—	—	
Frequency —inv|R|	Frequency [Hz]	Inverse number of gain	○	—	—	
invθ— inv|R|	Phase of inverse number of gain [deg]	Inverse number of gain	○	—	—	
Invθ— InvGain	Phase of inverse number of gain [deg]	Inverse number of gain [dB]	○	—	—	
Frequency —invA	Frequency [Hz]	Real part of inverse number of gain	○	—	—	
Frequency —invB	Frequency [Hz]	Imaginary part of inverse number of gain	○	—	—	
invA—invB	Real part of inverse number of gain	Imaginary part of inverse number of gain	○	—	—	

- "Gain (dB)" is the calculated result of $20 \times \mathrm{Log}_{10}(|R|)$. Its unit is [dB].
- Each parameter is obtained by the following formulas from the complex gain (R=A+jB) measured in the analysis mode "CH1/CH2".

    (Analysis mode: CH1/CH2)

$$|R| = \sqrt{A^2 + B^2} , \quad \theta = \tan^{-1}\frac{B}{A}$$

    (Analysis mode: CH2/CH1) A', B', |R|', θ' are values in the analysis mode "CH2/CH1"

$$A' = \frac{A}{A^2 + B^2} , \quad B' = \frac{-B}{A^2 + B^2} , \quad |R|' = \frac{1}{\sqrt{A^2 + B^2}} , \quad \theta' = -\tan^{-1}\frac{B}{A}$$

The graph display area shows the following markers. Each indicates the parameter at the marker frequency.

Table 4-5 Marker indication in gain-phase measurement

Display parameter	Unit	Description	Notes
Analysis mode: CH1/CH2			
Frequency	Hz	Frequency	
Gain	dB	Absolute value of gain	
θ	deg	Phase	
A	(No unit)	Real part of gain	
B	(No unit)	Imaginary part of gain	
|R|	(No unit)	Gain	
Analysis mode: CH2/CH1			
invGain	dB	Inverse number of gain	
invθ	deg	Phase of inverse number of gain	
invA	(No unit)	Real part of inverse number of gain	
invB	(No unit)	Imaginary part of inverse number of gain	
inv|R|	(No unit)	Inverse number of gain	

4.3 Overview of measurement and processing

This section describes the flow of data processing in the ZGA5920 (see "Figure 4-17 Measurement processing overview"). The same processing applies to both the impedance and gain-phase measurements.
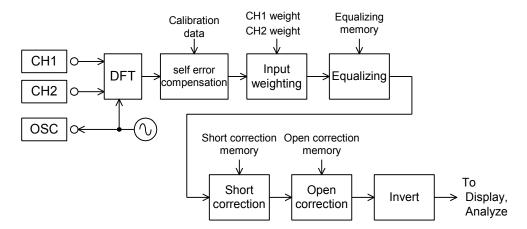
Figure 4-17 Measurement processing overview

● DFT: The measurement frequency component contained in the input signals are detected by DFT (discrete Fourier transform) to obtain the magnitude ratio and phase difference between the two signals as a complex number consisting of the real and imaginary parts.
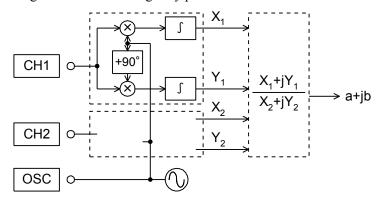
Figure 4-18 DFT overview

● Self error compensation: Self error compensation is made through the use of data obtained by calibration. Calibration can be performed by using the Calibration pallet.

● Weighting operation: The CH1 and CH2 weight values are reflected by multiplying (CH1 weight)/(CH2 weight).

● Equalize: The measurement data is divided by the data registered in the equalizing memory. This function corrects the frequency characteristics of peripherals connected to the measurement input terminals (such as probes and amplifiers) and is effective for gain-phase measurement.

- Short correction: The data registered in the short correction memory is subtracted from the measurement data. This function corrects the residual impedance due to test fixtures or contact resistances and is effective for impedance measurement.

- Open correction: The reciprocal numbers of the data registered in the open correction memory is subtracted from the reciprocal numbers of the measurement data. This function corrects the residual admittance due to test fixtures or cables and is effective for impedance measurement.

- Invert: This function is used when the phase is inverted by an external wiring such as the PA-001-0368 Impedance Measuring Adapter (sold separately).
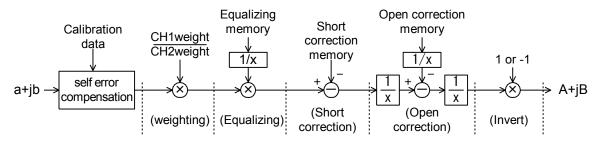
Figure 4-19 Error correction overview

4.3.1 Integration

The ZGA5920 performs analysis processing through discrete Fourier transform (DFT) with one period of the measured waveform as the unit. This eliminates noises and harmonics depending on the DFT's nature. However, a number of times of integrations enables measurement with a higher accuracy when the measurement amplitude is smaller than the noise or when a highly accurate measurement is necessary. The Fourier integral operation by its nature attenuates harmonics component by more than 60 dB, irrespective of the integration period. White noise component is suppressed by Fourier integration by the amount approximately proportional to the integration period. Noise components outside of analysis frequencies are also suppressed by increasing the integration period. Therefore, the more the integration period, the higher the accuracy of measurement. The time required for measurement is, needless to say, proportional to the number of times of Fourier integrations.
When the sweep target is Frequency, the time needed for one integration period varies depending on the analysis frequency f, which is roughly:

- $f \leq$ approx. 54 Hz: 1/f (period of f)
- approx. 54 Hz $\leq f \leq$ 3 kHz: 18 ms to 55 ms
- 3 kHz $\leq f$:   approx. 18 ms

"Figure 4-20 Effect of integration" illustrates an example of effect of the number of times of integrations by comparing the numbers 100 versus 1. The figure shows that the noise suppression effect is approximately 10 times (20 dB), which is the square root of the integration period ratio 100.
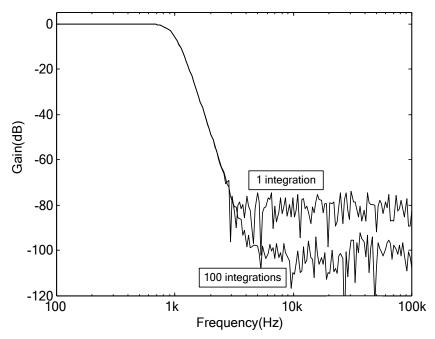
Figure 4-20 Effect of integration

4.3.2 Delay

When the measurement signal frequency or amplitude is changed, its transient response causes an error in the measurement data if the system under test includes a response delay element. The delay setting has a function to delay the measurement start in order to minimize this error. You can set the delay time period according to the time constant of the system under test. Note that the delay setting does not work for the zero-span sweep.
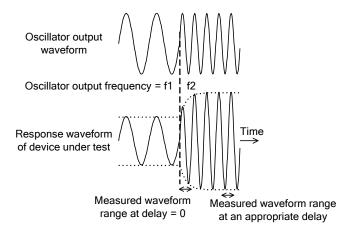
Figure 4-21 Response waveform requiring delay

A larger delay time is necessary for devices that have a resonance circuit with a high Q (quality factor), such as steep filters and piezoelectric vibrators. Figure 4-22 shows an example of the resonance characteristics of the quarts crystal (32.768kHz). Normal characteristics cannot be obtained without an appropriate delay time. Start the measurement with 0 second delay. Then, increase the delay time appropriately to find the optimum (necessary) delay time where the measurement data does not show a large difference.
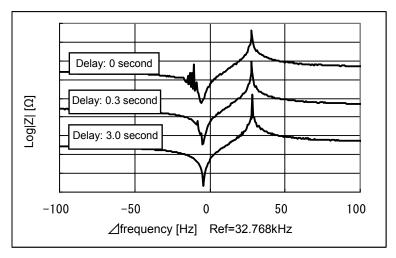
Figure 4-22 Example of resonance characteristics by delay

4.3.3 Slow sweep

This function automatically fine-measure the sweep density only before and after an abrupt change in the measurement data when the data substantially changes. This gives highly accurate data in a short time when measuring a sample like piezoelectric vibrator that has mixed characteristics of less change and sudden change around the resonance point. The slow sweep (automatic high density sweep) function works only when the sweep parameter is Frequency (and does not work for Amplitude, DC Bias, and Zero span). The slow sweep is configured in the Advanced setting pallet.

- Item: Select "LogR" (ratio dB), "R" (ratio), "θ" (phase), "A" (real part of ratio), "B" (imaginary part of ratio), or "OFF" (function off).
- CH: This is used to select the channel in which to monitor if there is any abrupt change in the measurement data.
- Variation: Enter the value regarded as an abrupt change.

When the difference between the measured values at the previous frequency and this frequency exceeds [Variation], the sweep density is automatically increased until the difference becomes equal to or lower than the value set in the [Variation]. The original sweep density is restored when the data change becomes equal to or lower than [Variation].

If the value set in [Variation] is too low, the sweep density becomes extremely high and the sweep operation could stop on the way due to the memory capacity being full. Note that the ZGA5920 has the maximum number of frequency point measurement capacity of 20,000 due to the memory capacity available. Do not decrease the [Variation] setting needlessly.

When measuring the resonance characteristics (impedance characteristics) of a piezoelectric vibrator, set the monitoring parameter to "θ" (phase) for better results. This is because the phase change is steepest at frequencies around the (anti) resonance point peak or bottom. Either the monitoring channel CH1 or CH2 has the same result because the phase change is monitored. First, perform a measurement by setting the number of sampling points to a lower value such as 100 and the slow sweep variation to around 10 (deg). Then, adjust these parameters as you check the measurement time and data fineness (frequency density fineness).

"Figure 4-23 Slow sweep example" shows an example of the resonance characteristics of a piezoelectric vibrator. Each dot "●" means a measured data point. These figures indicate that abrupt phase changes are measured at high density.
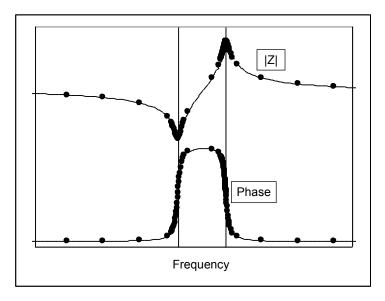
Figure 4-23 Slow sweep example

5. Measurement Operation (Samples)

5.1 Overview of measurement for each specific sample

With the ZGA5920, each specific sample has a corresponding measurement application.
Each measurement application includes the measurement method, data format, graph format, analysis method, and simulation method in accordance with its measurement purpose. For a selected measurement type, you can perform a series of operations from measurement to simulation, without having to switch measurement types (move to another measurement type).

The measurement type can be selected in the Application pallet of the ZGA5920. To switch to another measurement type, click the button for the target measurement application in the Application pallet.

The measurement process of each measurement application includes the analysis of the data obtained by the impedance measurement of a sample or the gain-phase measurement/servo measurement of a target circuit, and in some cases, the simulation. For details on how to connect a sample (or a target circuit) to the ZGA5920, see "4.1.1 Connecting with sample" (for impedance measurement), or "4.2.1 Connecting with target circuit" (for gain-phase measurement).

5.2 Piezoelectric measurement

Measure the impedance (admittance) resonance characteristics of the piezoelectric oscillator to get piezoelectric parameters such as damping capacitance. By the simulation with the obtained piezoelectric parameters, you can see the difference from measurement data or design parameters.

5.2.1 Connecting with sample
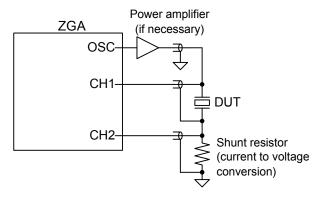
Figure 5-1 Connection example of piezoelectric measurement

"Figure 5-2-1 Connection example of piezoelectric measurement" shows an example of connecting with a sample. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample". If the voltage/current is insufficient, use a power amplifier (for example, our HSA, BA, or BP series) to amplify the oscillator output of the ZGA5920. Our PA-001-0370 (1 V/A, 1 Arms rated, sold separately) is available as the shunt resistor.
Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

5.2.2 Piezoelectric measurement setting

For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring piezoelectric material characteristics.

(Sweep)
• Sweep param:	Select Frequency or Zero span (time). The piezoelectric parameter extraction and the simulation are performed for the data of frequency sweep.
(Delay):	Needs to be set when measuring a oscillator with steep frequency characteristics. See "4.3.2 Delay".
(Slow sweep):	Effective when measuring a oscillator with steep frequency characteristics. See "4.3.3 Slow sweep".

5.2.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-1 Graph types of piezoelectric measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —|Y|	Frequency [Hz]	Admittance [S]	○	—	○	
Frequency —θy	Frequency [Hz]	Phase (of admittance) [deg]	○	—	○	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	○	
Frequency —θz	Frequency [Hz]	Phase (of impedance) [deg]	○	—	○	
G—B	Conductance [S]	Susceptance [S]	○	—	○	
Time—|Y|	Time [s]	Admittance [S]	○	—	—	
Time—θy	Time [s]	Phase (of admittance) [deg]	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase (of impedance) [deg]	○	—	—	
G—B	Conductance [S]	Susceptance [S]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-2 Marker indication in piezoelectric measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency	* Select sweep
Time	s	When the sweep parameter is Zero span	* Select sweep
|Y|	S	Admittance	
|Y|(Sim)	S	Admittance (Simulation data)	
θy	deg	Phase of admittance	
θy(Sim)	deg	Phase of admittance (Simulation data)	
G	S	Conductance	
G(Sim)	S	Conductance (Simulation data)	
B	S	Susceptance	
B(Sim)	S	Susceptance (Simulation data)	
|Z|	Ω	Impedance	
|Z|(Sim)	Ω	Impedance (Simulation data)	
θz	deg	Phase of impedance	
θz(Sim)	deg	Phase of impedance (Simulation data)	

5.2.4 Measure

Turn on the oscillator output, click the |Start measuring| button to start measurement. When the measurement is finished, the data are displayed in graphs. The graph of simulation data is displayed when simulation is performed.

Each parameter displayed in the graph is determined through the following conversions using the complex impedance (Z=R+jX) obtained from the measurement.

$$| Y |= \frac{1}{\sqrt{R^2 + X^2}} , \quad \theta y = -\tan^{-1}\frac{X}{R}, \quad G = \frac{R}{R^2 + X^2} , \quad B = \frac{-X}{R^2 + X^2}$$

You can use "G—B" for extracting piezoelectric parameters.

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target. The marker of simulation data is displayed when simulation is performed.

In the calculation of piezoelectric constants described in the next chapter, the measurement data including different resonance characteristics cannot be analyzed successfully. Adjust the sweep frequency range so that there is only one resonance characteristic as shown in **"Figure 5-2 Analyzable characteristics"**. The analysis is also difficult when the width of the resonance characteristic is too narrow.

| Appropriate | Inappropriate (too narrow and unclear resonance characteristic) | Impossible (more than one resonance characteristics) |
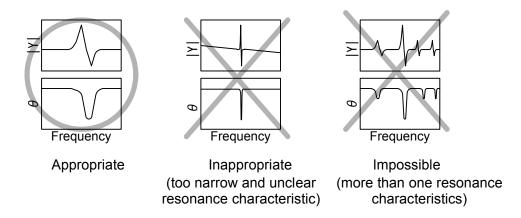
Figure 5-2 Analyzable characteristics

5.2.5 Calculation of piezoelectric constants

After the sweep measurement (or reading from measurement result data) is finished, click the Start analyzing button to get the piezoelectric constants. Note that the piezoelectric constants calculation and the simulation can be performed only for the frequency sweep data.
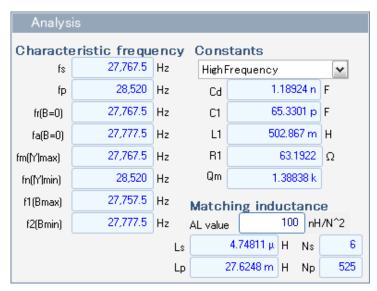
Figure 5-3 Piezoelectric parameter display screen

■ Characteristic frequency extraction

The frequency information is automatically searched from the measurement data to calculate the piezoelectric constants. They are determined automatically.

- **fs**: Mechanical series resonance frequency (Frequency at which the conductance G is maximum)

  ... Usually, this is the frequency for driving the piezoelectric oscillator.

- **fp**: Mechanical parallel resonance frequency (Frequency at which the phase is same as that of fs)

- **fr(B=0)**: Resonance frequency (Frequency at which the susceptance B is 0, fr < fa)

- **fa(B=0)**: Antiresonant frequency (Frequency at which the susceptance B is 0, fr < fa)

- **fm(|Y|max)**: Maximum admittance point (Frequency at which the admittance |Y| is maximum)

- **fn(|Y|min)**: Minimum admittance point (Frequency at which the admittance |Y| is minimum)

- **f1(Bmax)**: Susceptance maximum point (Frequency at which the susceptance B is maximum)

- **f2(Bmin)**: Susceptance minimum point (Frequency at which the susceptance B is minimum)
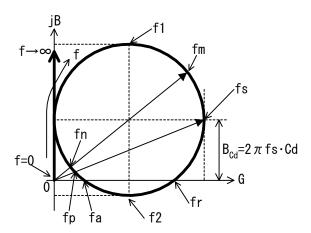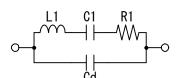
Figure 5-4 Admittance circle of piezoelectric oscillator

Each characteristic frequency is obtained from the actually measured frequency data. For this reason, a lower sweep frequency density of the measurement data causes a larger error. Be sure to perform the measurement with a high enough sweep density.

If the frequency range is appropriate for analysis (the resonance can be recognized clearly), the admittance locus has an approximately circular shape. If it is shown as an irregular circle or polygonal shape, the sweep density is too low. In this case, perform the measurement again with an increased number of measurement points, or use the slow sweep function to get data with a high enough density.

■ Calculation of piezoelectric constants

The LCR constants (piezoelectric constants) shown in **"Figure 5-5 Equivalent circuit of piezoelectric oscillator"** are calculated from a characteristic frequency searched from the measurement data.

- Cd: Damping capacitance
- C1: Equivalent electrostatic capacitance of piezoelectric mechanical vibration
- L1: Equivalent inductance of piezoelectric mechanical vibration
- R1: Equivalent resistor of mechanical vibration loss
- (• Qm: Mechanical quality factor)

Figure 5-5 Equivalent circuit of piezoelectric oscillator

The admittance locus of the circuit shown in **Figure 5-5** will describe a true circle that is offset by $+B_{Cd}$ (= $2\pi fsCd$) in the Y-axis (susceptance) direction, like the circle shown in **"Figure 5-4 Admittance circle of piezoelectric oscillator"**. First, you need to get the offset value in the Y-axis direction, B_{Cd}. There are three methods for getting B_{Cd}, which can be selected from the pull-down menu for the Cd mode.

- **High Frequency**: As B_{Cd}, this method obtains the susceptance for the maximum frequency from the measurement data.
- **Gmax**: As B_{Cd}, this method obtains the susceptance for the maximum conductance (at fs) from the measurement data.
- **Bmax_Bmin**: As B_{Cd}, this method uses the average of the maximum (at f1) and minimum (at f2) susceptances obtained from the measurement data.
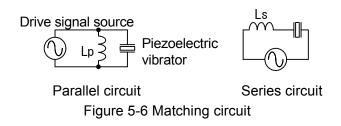
If the obtained characteristic data is ideal, any of these methods produces the same result. However, for the real data, these methods produce different results due to various reasons, such as measurement error, finite frequency sweep density, existence of noise, difference in their equivalent circuits, and so on. So you also need to check the result of the simulation described in **"5.2.6 Simulation"**, and then select the method that produces the result closest to the actual measurement data.

After getting the offset value in the Y-axis direction, B_{Cd}, the values of Cd, C1, L1, R1, and Qm are automatically calculated using a characteristic frequency.

■ Matching inductance design support

A piezoelectric oscillator can most effectively convert electrical energy into mechanical oscillation at the mechanical series resonance frequency, fs. fs is usually used to drive a oscillator. However, the impedance at fs of a piezoelectric oscillator includes a reactance component in addition to a resistance component (component converted into mechanical vibration). Due to a reactance component, all of the electrical energy output from the driving amplifier is not converted into the mechanical vibration, and some of the energy returns to the driving amplifier. This may cause abnormal heat generation or damage on the driving amplifier, so a driving amplifier with an unnecessarily large capacity is required. If there is only a pure resistance component, not a reactance component, then the required output of the driving amplifier can be minimum.

The impedance at fs of a piezoelectric oscillator is capacitive. The inductor that is used to compensate the capacitance at fs so that the driving amplifier recognizes only a pure resistance, is called "matching inductance". The ZGA5920 can display design parameters of this inductance. There are two types of matching circuit, parallel and series. The series circuit has a smaller inductance.

Figure 5-6 Matching circuit

Ls and Lp are the inductances that are necessary to compensate the reactance at the mechanical series resonance frequency (fs) to zero.

Ns and Np are the numbers of coil turns that are necessary to get the inductances, Ls and Lp, respectively. Input the AL value (unit: $nH/turn^2$) of a magnetic core you want to use to display Ns and Np.

5.2.6 Simulation

After obtaining the piezoelectric constants on the parameter display screen, perform the parameter simulation to see how well the simulated data matches the actual measured data.

(Constants)
- Cd, C1, L1, R1:   Input the constants for the piezoelectric material equivalent circuit (piezoelectric constants).

(Simulation)
- Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
- Point: The number of frequency points to be used for simulation.
- Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Start simulating button: Click to calculate the admittance characteristics with the simulation conditions that you have set, and display it on a graph.

If there is a large difference between the measurement and simulation data, recalculate the piezoelectric constants (change Cd mode) or modify the piezoelectric constants manually. When you modify the piezoelectric parameters or the simulation conditions and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be displayed for the simulation data as well as the measurement result. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequencies of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

5.3 Dielectric measurement

Derive the complex relative dielectric permittivity by measuring the capacitance of a sample (dielectric material) which is fitted with electrodes to make up a capacitor. You can use the frequency sweep to measure the frequency dependence of the dielectric permittivity, the DC bias voltage sweep to measure the nonlinearity of the dielectric permittivity, and the zero span sweep to measure a time variability.

5.3.1 Connecting with sample
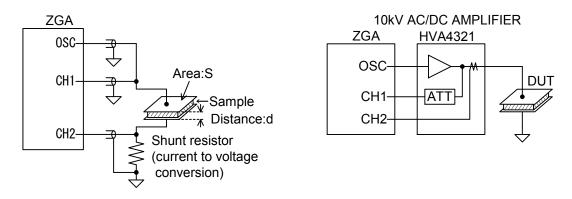
Figure 5-7 Connection example of dielectric measurement

"Figure 5-7 Connection example of dielectric measurement" shows an example of connecting with a sample. Make up a capacitor by attaching electrodes on both sides of the dielectric material to measure the electrostatic capacitance.

You can use our 10kV AC/DC Amplifier HVA4321 as a power amplifier to amplify up to ±10 kV for measurement. As it is equipped with voltage and current monitor terminals, the ZGA5920 never touches a high voltage section, which enables safer measurement. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".

Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction". As the impedance of a sample is usually large, only the open correction can achieve enough accuracy.

5.3.2 Setting

For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring dielectric material characteristics.

(Sweep)
• Sweep param: Select Frequency, DC Bias (bias voltage), or Zero span (time).

(Oscillator)
• Frequency: The output frequency when the sweep parameter is DC Bias or Zero span (time).
• DC Bias (voltage):   The DC bias voltage when the sweep parameter is Frequency or Zero span (time).

5.3.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-3 Graph types of dielectric measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —Cp	Frequency [Hz]	Parallel capacitance [F]	○	—	—	
Frequency —Rp	Frequency [Hz]	Parallel resistance [Ω]	○	—	—	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency —θz	Frequency [Hz]	Phase (of impedance) [deg]	○	—	—	
Frequency —εs	Frequency [Hz]	Relative dielectric permittivity	—	○	—	
Frequency —tanδ	Frequency [Hz]	Dissipation factor	—	○	—	
Frequency —εs'	Frequency [Hz]	Real part of relative dielectric permittivity	—	○	—	
Frequency —εs"	Frequency [Hz]	Imaginary part of relative dielectric permittivity	—	○	—	

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
DC Bias—Cp	DC bias [V]	Parallel capacitance [F]	○	—	—	
DC Bias—Rp	DC bias [V]	Parallel resistance [Ω]	○	—	—	
DC Bias—|Z|	DC bias [V]	Impedance [Ω]	○	—	—	
DC Bias—θz	DC bias [V]	Phase (of impedance) [deg]	○	—	—	
DC Bias—εs	DC bias [V]	Relative dielectric permittivity	—	○	—	
DC Bias—tanδ	DC bias [V]	Dissipation factor	—	○	—	
DC Bias—εs'	DC bias [V]	Real part of relative dielectric permittivity	—	○	—	
DC Bias—εs"	DC bias [V]	Imaginary part of relative dielectric permittivity	—	○	—	
Time—Cp	Time [s]	Parallel capacitance [F]	○	—	—	
Time—Rp	Time [s]	Parallel resistance [Ω]	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase (of impedance) [deg]	○	—	—	
Time—εs	Time [s]	Relative dielectric permittivity	—	○	—	
Time—tanδ	Time [s]	Dissipation factor	—	○	—	
Time—εs'	Time [s]	Real part of relative dielectric permittivity	—	○	—	
Time—εs"	Time [s]	Imaginary part of relative dielectric permittivity	—	○	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-4 Marker indication in dielectric measurement (dielectric material characteristics)

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency.	* Select sweep
DC Bias	V	When the sweep parameter is DC bias.	* Select sweep
Time	s	When the sweep parameter is Zero span.	* Select sweep
Cp	F	Parallel capacitance	
Rp	Ω	Parallel resistance	
|Z|	Ω	Impedance	
θz	deg	Phase of impedance	
εs	—	Relative dielectric permittivity	
tanδ	—	Dissipation factor	
εs'	—	Real part of complex relative dielectric permittivity	
εs"	—	Imaginary part of complex relative dielectric permittivity	

5.3.4 Measure

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the data are displayed in graphs. The graph of analysis data is displayed when dielectric permittivity derivation is performed.

The measurement result graph plots Cp (parallel capacitance) and Rp (parallel resistance). Cp[F] and Rp[Ω] are determined through the following conversions using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$R_p = \frac{R^2 + X^2}{R}, \quad C_p = -\frac{X}{2\pi f(R^2 + X^2)}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target. The marker of analysis data is displayed when dielectric permittivity derivation is performed.

5.3.5 Dielectric permittivity derivation

The ZGA5920 derives the relative dielectric permittivity to the dielectric permittivity ε_0 in vacuum. The information necessary for derivation can be set in the analysis condition setting area.

- Electrode area S:　　　　　Input the electrode area of the sample in mm^2.
- Electrode distance t:　　　Input the distance between electrodes in mm.
- Start analyzing button:　　Click to convert the measurement data to a complex relative dielectric permittivity using the values of [Electrode area S] and [Electrode distance t] that you have input, and display the result in graphs.

Each parameter is determined through the following conversions using the values of Cp and Rp obtained from the measurement. f is the measurement frequency [Hz].

$$\varepsilon s' = \frac{Cp}{C_0}, \quad \varepsilon s'' = \frac{1}{2\pi f C_0 Rp}, \quad \varepsilon s = \sqrt{\varepsilon s'^2 + \varepsilon s''^2}, \quad \tan\delta = \frac{\varepsilon s''}{\varepsilon s'}$$

C_0[F] is the electrostatic capacitance in a virtual and ideal vacuum for the electrode area S (mm^2) and the distance between electrodes t (mm).

$$C_0[F] = \frac{S\varepsilon_0}{1000t}$$

$$\varepsilon_0 = \frac{1}{\mu_0 c^2} \fallingdotseq 8.854187816... \times 10^{-12} \text{ [F/m]} \qquad \text{permittivity of vacuum}$$

$$c \fallingdotseq 2.99792458... \times 10^{8} \text{ [m/s]} \qquad \text{speed of light in vacuum}$$

$$\mu_0 = 4\pi \times 10^{-7} \fallingdotseq 1.2566370614... \times 10^{-6} \qquad \text{permeability of vacuum}$$

The dielectric constant is calculated on the assumption that all lines of electric force pass through the sample (dielectric material) located between electrodes. Note that the error becomes larger if there is a gap between the electrodes and the sample, or if the electrode area is small in proportion to the distance between the electrodes (more lines of electric force pass through space).
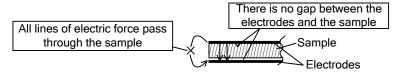
Figure 5-8 Preconditions of dielectric permittivity derivation

5.4 Magnetic measurement

Derive the complex relative magnetic permeability by measuring the inductance characteristics of a magnetic sample with windings applied to make up a coil. You can use the frequency sweep to measure the frequency dependence of the magnetic permeability, the DC bias current sweep to measure the nonlinear characteristics, and the zero span sweep to measure a time variability of the magnetic permeability.

5.4.1 Connecting with sample

Figure 5-9 Connection example of magnetic measurement

"Figure 5-9 Connection example of magnetic measurement" shows an example of connecting with a sample. Wind a conductor wire around the sample to make up a coil, and measure the inductance characteristics of the coil.

You can use our Bipolar DC Power Supply BP4620 as a power amplifier to amplify the sample current up to 20 A for measurement. As it is equipped with voltage and current monitor terminals, you can easily connect it to the ZGA5920. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".

Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

5.4.2 Setting

For details on basic settings, see **"4.1.2 Setting impedance measurement"**. This section describes only points to be considered when measuring magnetic material characteristics.

(Circuit parameter)
*   Ext amp gain: Set the voltage-current conversion gain of the current-output amplifier (CC amplifier). In the magnetic measurement, a CC amplifier is assumed as the external amplifier.

(Oscillator)
*   Frequency: The output frequency when the sweep target is DC or Zero span (time).
*   Amplitude (current): Set the AC current amplitude to be measured.
*   DC Bias (current):   The DC bias current when the sweep parameter is Frequency or Zero span (time).

(Sweep)
*   Sweep param: Select Frequency, DC Bias (bias current), or Zero span (time).

If a constant voltage amplifier (CV amplifier) is used as the external amplifier, set the gain (voltage amplification factor) of the CV amplifier for the external amplifier gain. The values of Amplitude and DC Bias correspond to the output voltage of the external amplifier. A large current may flow to the sample due to the DC offset voltage of the external amplifier. Prevent an excessive current, for example, by connecting a current-limiting resistor in series.
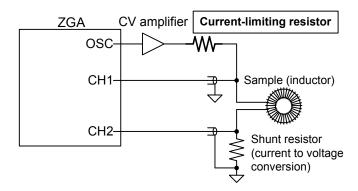
Figure 5-10 Notes on using CV amplifier

5.4.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-5 Graph types of magnetic measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—Ls	Frequency [Hz]	Series inductance [H]	○	—	—	
Frequency—Rs	Frequency [Hz]	Series resistance [Ω]	○	—	—	
Frequency—|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency—θz	Frequency [Hz]	Phase (of impedance) [deg]	○	—	—	
Frequency—μs	Frequency [Hz]	Relative magnetic permeability	—	○	—	
Frequency—tanδ	Frequency [Hz]	Dissipation factor	—	○	—	
Frequency—μs'	Frequency [Hz]	Real part of relative magnetic permeability	—	○	—	
Frequency—μs"	Frequency [Hz]	Imaginary part of relative magnetic permeability	—	○	—	
DC Bias—Ls	DC bias [A]	Series inductance [H]	○	—	—	
DC Bias—Rs	DC bias [A]	Series resistance [Ω]	○	—	—	
DC Bias—|Z|	DC bias [A]	Impedance [Ω]	○	—	—	
DC Bias—θz	DC bias [A]	Phase (of impedance) [deg]	○	—	—	
DC Bias—μs	DC bias [A]	Relative magnetic permeability	—	○	—	
DC Bias—tanδ	DC bias [A]	Dissipation factor	—	○	—	
DC Bias—μs'	DC bias [A]	Real part of relative magnetic permeability	—	○	—	
DC Bias—μs"	DC bias [A]	Imaginary part of relative magnetic permeability	—	○	—	
Time—Ls	Time [s]	Series inductance [H]	○	—	—	
Time—Rs	Time [s]	Series resistance [Ω]	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase (of impedance) [deg]	○	—	—	
Time—μs	Time [s]	Relative magnetic permeability	—	○	—	
Time—tanδ	Time [s]	Dissipation factor	—	○	—	
Time—μs'	Time [s]	Real part of relative magnetic permeability	—	○	—	
Time—μs"	Time [s]	Imaginary part of relative magnetic permeability	—	○	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-6 Marker indication in magnetic measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency.	* Select sweep
DC Bias	V	When the sweep parameter is DC Bias.	* Select sweep
Time	s	When the sweep parameter is Zero span.	* Select sweep
Ls	H	Series inductance	
Rs	Ω	Series resistance	
|Z|	Ω	Impedance	
θz	deg	Phase of impedance	
μs	—	Relative magnetic permeability	
tanδ	—	Dissipation factor	
μs'	—	Real part of complex relative magnetic permeability	
μs"	—	Imaginary part of complex relative magnetic permeability	

5.4.4 Measure

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the data are displayed in graphs. The graph of analysis data is displayed when magnetic permeability derivation is performed.

The measurement result graph plots Ls (series inductance) and Rs (series resistance). Ls[H] and Rs[Ω] are determined through the following conversions using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$Rs=R, \ Ls=\frac{X}{2\pi f}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target. The marker of analysis data is displayed when magnetic permeability derivation is performed.

5.4.5 Magnetic permeability derivation

The ZGA5920 derives the relative magnetic permeability to the magnetic permeability μ_0 in vacuum. The information necessary for derivation can be set in the analysis condition setting area.

- Core area S: Input the effective cross-section area of the sample (core) in mm^2.
- Core magnetic path length l: Input the effective magnetic flux path length of the sample (core) in mm.
- Coil turns N: Input the number of turns of a coil (integer equal or greater than one).
- Winding diameter d: Input the diameter of conductive part of winding (wire) in mm.
- Winding around length len: Input the length of winding per turn in mm.
- Electrical resistivity ρ: The resistivity of winding. The initial value is the copper resistivity, 1.68×10^{-8} [Ωm]. If it is necessary to change it, input the value in [Ωm]. This value is used for calculation of the winding resistance.
- Start analyzing button: Click to convert the measurement data to a complex relative magnetic permeability using the parameter values that you have input, and display the result in graphs.

Each parameter is determined through the following conversions using the values of Ls and Rs obtained from the measurement. f is the measurement frequency [Hz].

$$\mu s' = \frac{Ls}{L_0}, \quad \mu s'' = \frac{Rs - Rw}{2\pi f L_0}, \quad \mu s = \sqrt{\mu s'^2 + \mu s''^2}, \quad \tan\delta = \frac{\mu s''}{\mu s'}$$

L_0[H] is the inductance of a toroidal coil in a virtual and ideal vacuum for the effective cross-section area S [mm^2], the effective magnetic flux path length l [mm], and the coil turns N.

$$L_0 = \frac{S \times N^2 \times \mu_0}{1000 \times l}$$
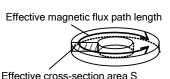
$\mu_0 = 4\pi \times 10^{-7} \fallingdotseq 1.2566370614... \times 10^{-6}$ [H/m]   permeability of vacuum

Rw[Ω] is the resistance value of winding.

$$Rw = \frac{N \rho \, len}{\pi d^2} \times 4000$$

The magnetic permeability is calculated on the assumption that the sample has no leakage magnetic flux like an ideal toroidal core. Note that the error becomes larger if the sample has a large leakage magnetic flux, as in the case of a core with a gap or a solenoidal coil.

Effective magnetic flux path length

Effective cross-section area S

5.5 Inductor measurement

Measure the impedance characteristics of a inductor to show the inductance characteristics, ESR (equivalent series resistance), Q (quality factor), and so on. By the equivalent circuit estimation, you can also get ESR and the winding capacitance (stray capacitance). In addition to the frequency sweep, you can use the DC bias current sweep to measure DC superposition, AC current amplitude sweep to measure the nonlinearity of the inductance, and the zero span sweep to measure a time variability.

5.5.1 Connecting with sample
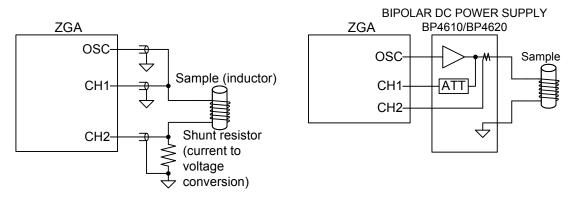


Figure 5-11 Connection example of inductor measurement

"Figure 5-11 Connection example of inductor measurement" shows an example of connecting with a sample. You can use our Bipolar DC Power Supply BP4620 as a power amplifier to amplify the sample current up to 20 A for measurement. As it is equipped with voltage and current monitor terminals, you can easily connect it to the ZGA5920. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".

Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

5.5.2 Setting

For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring inductor characteristics.

(Circuit parameter)
- Ext amp gain: Set the voltage-current conversion gain of the current-output amplifier (CC amplifier). In the inductor measurement, a CC amplifier is assumed as the external amplifier.

(Oscillator)
- Frequency: The output frequency when the sweep target is Amplitude, DC Bias, or Zero span (time).

- Amplitude (current): The AC current amplitude when the sweep parameter is Frequency, DC Bias, or Zero span (time).

- DC Bias (current):   The DC bias current when the sweep parameter is Frequency, Amplitude, or Zero span (time).

(Sweep)
- Sweep param: Select Frequency, Amplitude (AC current amplitude), DC Bias (DC bias current), or Zero span (time).

If a constant voltage amplifier (CV amplifier) is used as the external amplifier, set the gain (voltage amplification factor) of the CV amplifier for the external amplifier gain. The values of Amplitude and DC Bias correspond to the output voltage of the external amplifier. A large current may flow to the sample due to the DC offset voltage of the external amplifier. Prevent an excessive current, for example, by connecting a current-limiting resistor in series.
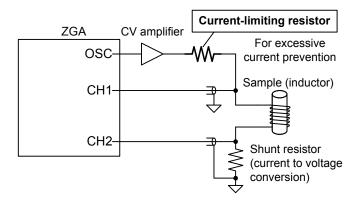
Figure 5-12 Notes on using CV amplifier

5.5.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-7 Graph types of inductor measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —Ls	Frequency [Hz]	Series inductance [H]	○	—	○	
Frequency —Rs	Frequency [Hz]	Series resistance (ESR) [Ω]	○	—	○	
Frequency —θs	Frequency [Hz]	Phase (of series equivalent circuit) [deg]	○	—	○	
Frequency —Q	Frequency [Hz]	Quality factor	○	—	○	
Frequency —Lp	Frequency [Hz]	Parallel inductance [H]	○	—	○	
Frequency —Rp	Frequency [Hz]	Parallel resistance [Ω]	○	—	○	
Frequency —θp	Frequency [Hz]	Phase (of parallel equivalent circuit) [deg]	○	—	○	
Frequency —D	Frequency [Hz]	Dissipation factor	○	—	○	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	○	
Frequency —θz	Frequency [Hz]	Phase (of impedance) [deg]	○	—	○	
Amplitude —Ls	AC current [Apk]	Series inductance [H]	○	—	—	
Amplitude —Rs	AC current [Apk]	Series resistance (ESR) [Ω]	○	—	—	
Amplitude —θs	AC current [Apk]	Phase (of series equivalent circuit) [deg]	○	—	—	
Amplitude —Q	AC current [Apk]	Quality factor	○	—	—	
Amplitude —Lp	AC current [Apk]	Parallel inductance [H]	○	—	—	
Amplitude —Rp	AC current [Apk]	Parallel resistance [Ω]	○	—	—	
Amplitude —θp	AC current [Apk]	Phase (of parallel equivalent circuit) [deg]	○	—	—	
Amplitude —D	AC current [Apk]	Dissipation factor	○	—	—	
Amplitude —|Z|	AC current [Apk]	Impedance [Ω]	○	—	—	
Amplitude —θz	AC current [Apk]	Phase (of impedance) [deg]	○	—	—	

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
DC Bias—Ls	DC bias [A]	Series inductance [H]	○	—	—	
DC Bias—Rs	DC bias [A]	Series resistance (ESR) [Ω]	○	—	—	
DC Bias—θs	DC bias [A]	Phase (of series equivalent circuit) [deg]	○	—	—	
DC Bias—Q	DC bias [A]	Quality factor	○	—	—	
DC Bias—Lp	DC bias [A]	Parallel inductance [H]	○	—	—	
DC Bias—Rp	DC bias [A]	Parallel resistance [Ω]	○	—	—	
DC Bias—θp	DC bias [A]	Phase (of parallel equivalent circuit) [deg]	○	—	—	
DC Bias—D	DC bias [A]	Dissipation factor	○	—	—	
DC Bias—|Z|	DC bias [A]	Impedance [Ω]	○	—	—	
DC Bias—θz	DC bias [A]	Phase (of impedance) [deg]	○	—	—	
Time—Ls	Time [s]	Series inductance [H]	○	—	—	
Time—Rs	Time [s]	Series resistance (ESR) [Ω]	○	—	—	
Time—θs	Time [s]	Phase (of series equivalent circuit) [deg]	○	—	—	
Time—Q	Time [s]	Quality factor	○	—	—	
Time—Lp	Time [s]	Parallel inductance [H]	○	—	—	
Time—Rp	Time [s]	Parallel resistance [Ω]	○	—	—	
Time—θp	Time [s]	Phase (of parallel equivalent circuit) [deg]	○	—	—	
Time—D	Time [s]	Dissipation factor	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase (of impedance) [deg]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-8 Marker indication in inductor measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency.	* Select sweep
Amplitude	Apk	When the sweep parameter is Amplitude.	* Select sweep
DC Bias	A	When the sweep parameter is DC Bias.	* Select sweep
Time	s	When the sweep parameter is Zero span.	* Select sweep
Ls	H	Series inductance	
Ls(Sim)	H	Series inductance (Simulation data)	
Rs	Ω	Series resistance	

Display parameter	Unit	Description	Notes
Rs(Sim)	Ω	Series resistance (Simulation data)	
θs	deg	Phase in series equivalent circuit	
θs(Sim)	deg	Phase in series equivalent circuit (Simulation data)	
Lp	H	Parallel inductance	
Lp(Sim)	H	Parallel inductance (Simulation data)	
Rp	Ω	Parallel resistance	
Rp(Sim)	Ω	Parallel resistance (Simulation data)	
θp	deg	Phase in parallel equivalent circuit	
θp(Sim)	deg	Phase in parallel equivalent circuit (Simulation data)	
Q	—	Quality factor	
Q(Sim)	—	Quality factor (Simulation data)	
D	—	Dissipation factor	
D(Sim)	—	Dissipation factor (Simulation data)	
|Z|	Ω	Impedance	
|Z|(Sim)	Ω	Impedance (Simulation data)	
θz	deg	Phase of impedance	
θz(Sim)	deg	Phase of impedance (Simulation data)	

5.5.4 Measure

Turn on the oscillator output, click the Start measuring button to start measurement. When the measurement is finished, the data are displayed in graphs. The graph of simulation data is displayed when equivalent circuit simulation is performed.

Each parameter is determined through the following conversions using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$Ls = \frac{X}{2\pi f}, \; Rs = R, \; \theta s = \tan^{-1}\frac{X}{R}, \; Q = \frac{X}{R},$$

$$Lp = \frac{R^2 + X^2}{2\pi f X}, \; Rp = \frac{R^2 + X^2}{R}, \; \theta p = \tan^{-1}\frac{-X}{R}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target. The marker of simulation data is displayed when equivalent circuit simulation is performed.

5.5.5 Equivalent circuit estimation
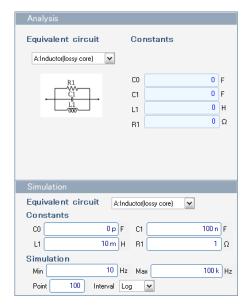
Figure 5-13 Equivalent circuit estimation screen

■ Equivalent circuit

Select the equivalent circuit type to calculate the equivalent circuit constants that well-agree with the measurement data. For the inductor measurement, select either A or B for the equivalent circuit type.

<div>

A:Inductor(lossy core):   When the effect of ESR is small

B:Inductor or resistor: When the effect of ESR is relatively large

</div>

To select an equivalent circuit type, click the corresponding checkbox with the trackball.

You can also select C, D or E for the equivalent circuit type, but the equivalent circuit constants cannot be calculated correctly. Of the two equivalent circuit types A and B, which type can accurately calculate the device constants may depend on the measurement data. Check simulation results to select an appropriate equivalent circuit type.

After selecting the equivalent circuit type, click the Start analyzing button to calculate the circuit constants.

■ Constants

The circuit parameters for the selected equivalent circuit type. C0 is a value calculated only for the equivalent circuit type E. This section only displays the results of estimation calculation, and the values cannot be changed directly.

5.5.6 Equivalent circuit simulation

After obtaining the circuit constants on the equivalent circuit estimation screen, perform the equivalent circuit simulation to see how well the simulated data matches the actual measured data.

(Equivalent circuit)
- Circuit type, R1, C1, L1, C0:

  Select the equivalent circuit type and input the parameters.

(Simulation)
- Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
- Point: The number of frequency points to be used for simulation.
- Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Start simulating button: Click to calculate the inductance characteristics with the simulation conditions that you have set, and display it on a graph.

If there is a large difference between the measurement and simulation data, an appropriate circuit type is not selected, or the circuit parameters estimation is not performed properly. Try the following methods to get the equivalent circuit parameters that agree with (match) the measurement data as well as possible.

1) Adjust the values of R1, C1, or L1.
2) Change the circuit type.
3) Change the measurement conditions, and then perform the measurement again.

If the measurement data contains a large noise, the estimation cannot be performed successfully. Especially, a higher frequency tends to make the measurement data unstable. Set an appropriate sweep frequency range.

When you modify these simulation conditions and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be displayed for the simulation data as well as the measurement result. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequency points.

5.6 Capacitor measurement

Measure the impedance characteristics of a capacitor to display the capacitance characteristics, ESR (equivalent series resistance), ESL (equivalent series inductance), D (dissipation factor), and so on. By the equivalent circuit estimation, you can also get ESR and ESL. In addition to the frequency sweep, you can use the DC bias voltage sweep to measure DC superimposition, AC amplitude sweep to measure the nonlinearity of the electrostatic capacitance, and the zero span sweep to measure a time variability of the electrostatic capacitance.

5.6.1 Connecting with sample
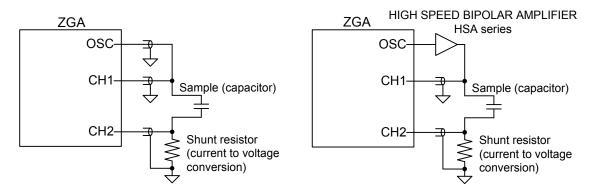
Figure 5-14 Connection example of capacitor measurement

"Figure 5-14 Connection example of capacitor measurement" shows an example of connecting with a sample. You can use our High Speed Bipolar Amplifier HSA series as a power amplifier to amplify the signal up to 300 Vp-p for measurement. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".
Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

5.6.2 Setting

For details on basic settings, see **"4.1.2 Setting impedance measurement"**. This section describes only points to be considered when measuring capacitor characteristics.

(Circuit parameter)
*   Ext amp gain: Set the gain of the external amplifier.

(Oscillator)
*   Frequency: The output frequency when the sweep parameter is Amplitude, DC Bias, or Zero span (time).

*   Amplitude: The AC amplitude when the sweep parameter is Frequency, DC Bias, or Zero span (time).

*   DC Bias: The DC bias voltage when the sweep parameter is Frequency, Amplitude, or Zero span (time).

(Sweep)
*   Sweep param: Select Frequency, Amplitude (AC amplitude), DC Bias (DC bias voltage), or Zero span (time).

5.6.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-9 Graph types of capacitor measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —Cs	Frequency [Hz]	Series capacitance [F]	○	—	○	
Frequency —Rs	Frequency [Hz]	Series resistance [Ω]	○	—	○	
Frequency —θs	Frequency [Hz]	Phase in series equivalent circuit [deg]	○	—	○	
Frequency —Q	Frequency [Hz]	Quality factor	○	—	○	
Frequency —Cp	Frequency [Hz]	Parallel capacitance [F]	○	—	○	
Frequency —Rp	Frequency [Hz]	Parallel resistance [Ω]	○	—	○	
Frequency —θp	Frequency [Hz]	Phase in parallel equivalent circuit [deg]	○	—	○	
Frequency —D	Frequency [Hz]	Dissipation factor	○	—	○	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	○	
Frequency —θz	Frequency [Hz]	Phase (of impedance) [deg]	○	—	○	

5.6 Capacitor measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Amplitude —Cs	AC voltage [Vpk]	Series capacitance [F]	○	—	—	
Amplitude —Rs	AC voltage [Vpk]	Series resistance [Ω]	○	—	—	
Amplitude —θs	AC voltage [Vpk]	Phase in series equivalent circuit [deg]	○	—	—	
Amplitude —Q	AC voltage [Vpk]	Quality factor	○	—	—	
Amplitude —Cp	AC voltage [Vpk]	Parallel capacitance [F]	○	—	—	
Amplitude —Rp	AC voltage [Vpk]	Parallel resistance [Ω]	○	—	—	
Amplitude —θp	AC voltage [Vpk]	Phase in parallel equivalent circuit [deg]	○	—	—	
Amplitude —D	AC voltage [Vpk]	Dissipation factor	○	—	—	
Amplitude —|Z|	AC voltage [Vpk]	Impedance [Ω]	○	—	—	
Amplitude —θz	AC voltage [Vpk]	Phase (of impedance) [deg]	○	—	—	
DC Bias— Cs	DC bias [V]	Series capacitance [F]	○	—	—	
DC Bias— Rs	DC bias [V]	Series resistance [Ω]	○	—	—	
DC Bias— θs	DC bias [V]	Phase in series equivalent circuit [deg]	○	—	—	
DC Bias— Q	DC bias [V]	Quality factor	○	—	—	
DC Bias— Cp	DC bias [V]	Parallel capacitance [F]	○	—	—	
DC Bias— Rp	DC bias [V]	Parallel resistance [Ω]	○	—	—	
DC Bias— θp	DC bias [V]	Phase in parallel equivalent circuit [deg]	○	—	—	
DC Bias— D	DC bias [V]	Dissipation factor	○	—	—	
DC Bias— |Z|	DC bias [V]	Impedance [Ω]	○	—	—	
DC Bias— θz	DC bias [V]	Phase (of impedance) [deg]	○	—	—	

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Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Time—Cs	Time [s]	Series capacitance [F]	○	—	—	
Time—Rs	Time [s]	Series resistance [Ω]	○	—	—	
Time—θs	Time [s]	Phase in series equivalent circuit [deg]	○	—	—	
Time—Q	Time [s]	Quality factor	○	—	—	
Time—Cp	Time [s]	Parallel capacitance [F]	○	—	—	
Time—Rp	Time [s]	Parallel resistance [Ω]	○	—	—	
Time—θp	Time [s]	Phase in parallel equivalent circuit [deg]	○	—	—	
Time—D	Time [s]	Dissipation factor	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase (of impedance) [deg]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-10 Marker indication in capacitor measurement (capacitor characteristics)

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency.	* Select sweep
Amplitude	Vpk	When the sweep parameter is Amplitude.	* Select sweep
DC Bias	V	When the sweep parameter is DC Bias.	* Select sweep
Time	s	When the sweep parameter is Zero span.	* Select sweep
Cs	F	Series electrostatic capacitance	
Cs(Sim)	F	Series electrostatic capacitance (Simulation data)	
Rs	Ω	Series resistance	
Rs(Sim)	Ω	Series resistance (Simulation data)	
θs	deg	Phase in series equivalent circuit	
θs(Sim)	deg	Phase in series equivalent circuit (Simulation data)	
Cp	F	Parallel electrostatic capacitance	
Cp(Sim)	F	Parallel electrostatic capacitance (Simulation data)	
Rp	Ω	Parallel resistance	
Rp(Sim)	Ω	Parallel resistance (Simulation data)	
θp	deg	Phase in parallel equivalent circuit	
θp(Sim)	deg	Phase in parallel equivalent circuit (Simulation data)	
Q	—	Quality factor	
Q(Sim)	—	Quality factor (Simulation data)	
D	—	Dissipation factor	
D(Sim)	—	Dissipation factor (Simulation data)	
|Z|	Ω	Impedance	
|Z|(Sim)	Ω	Impedance (Simulation data)	
θz	deg	Phase of impedance	
θz(Sim)	deg	Phase of impedance (Simulation data)	

5.6.4 Measure

Turn on the oscillator output, click the Start measuring button to start measurement. When the measurement is finished, the data are displayed in graphs. The graph of simulation data is displayed when equivalent circuit simulation is performed.

Each parameter is determined through the following conversions using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$Cs = \frac{-1}{2\pi f X} , \ Rs = R, \ \theta s = \tan^{-1}\frac{X}{R} , \ Q = -\frac{X}{R} , \ D = -\frac{R}{X} ,$$

$$Cp = \frac{-X}{2\pi f (R^2 + X^2)} , \ \ Rp = \frac{R^2 + X^2}{R} , \ \theta p = \tan^{-1}\frac{-X}{R}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target. The marker of simulation data is displayed when equivalent circuit simulation is performed.

5.6.5 Equivalent circuit estimation
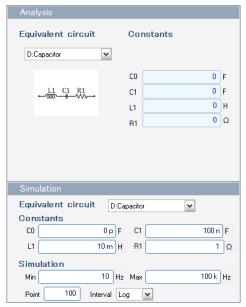
Figure 5-15 Equivalent circuit estimation screen

■ Equivalent circuit

Select the equivalent circuit type to calculate the equivalent circuit constants that well-agree with the measurement data. For the capacitor measurement, select either C or D for the equivalent circuit type.

        C:Resistor(high resistance): When the effect of leakage resistance is large

        D:Capacitor: General capacitor circuit type including ESR and ESL

To select an equivalent circuit type, click the corresponding checkbox with the trackball.

You can also select A, B or E for the equivalent circuit type, but the equivalent circuit constants cannot be calculated correctly. Of the two equivalent circuit types C and D, which type can accurately calculate the device constants may depend on the measurement data. Check simulation results to select an appropriate equivalent circuit type.

After selecting the equivalent circuit type, click the ⌞Start analyzing⌟ button to calculate the circuit constants.

■ Constants

The circuit parameters for the selected equivalent circuit type. C0 is a value calculated only for the equivalent circuit type E. This section only displays the results of estimation calculation, and the values cannot be changed directly.

5.6.6 Equivalent circuit simulation

After obtaining the circuit constants on the equivalent circuit estimation screen, perform the equivalent circuit simulation to see how well the simulated data matches the actual measured data.

(Equivalent circuit)
*   Circuit type, R1, C1, L1, C0:

    Select the equivalent circuit type and input the parameters.

(Simulation)
*   Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
*   Point: The number of frequency points to be used for simulation.
*   Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
*   Start simulating button: Click to calculate the capacitance characteristics with the simulation conditions that you have set, and display it on a graph.

If there is a large difference between the measurement and simulation data, an appropriate circuit type is not selected, or the circuit parameters estimation is not performed properly. Try the following methods to get the equivalent circuit parameters that agree with (match) the measurement data as well as possible.
1) Adjust the values of R1, C1, or L1.
2) Change the circuit type.
3) Change the measurement conditions, and then perform the measurement again.

If the measurement data contains a large noise, the estimation cannot be performed successfully. Especially, a higher frequency tends to make the measurement data unstable. Set an appropriate sweep frequency range.
When you modify these simulation conditions and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be displayed for the simulation data as well as the measurement result. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

5.7 Resistor measurement

Measure the impedance characteristics of a resistor to display the resistance and reactance components. By the equivalent circuit estimation, you can also get the stray capacitance and stray inductance. In addition to the frequency sweep, you can use the DC bias/AC amplitude sweep to measure the nonlinear characteristics, and the zero span sweep to measure a time variability of the impedance characteristics.
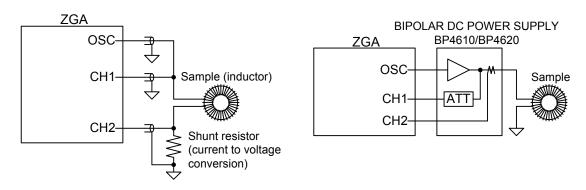
5.7.1 Connecting with sample
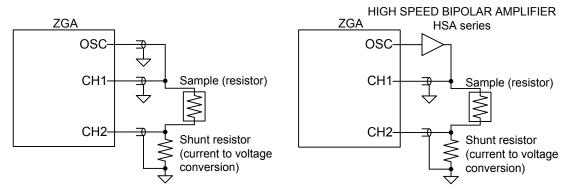
Figure 5-16 Connection example of resistor measurement

"Figure 5-16 Connection example of resistor measurement" shows an example of connecting with a sample. You can use our High Speed Bipolar Amplifier HSA series as a power amplifier to amplify the signal up to 300 Vp-p for measurement. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".

Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

5.7.2 Setting

For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring resistor characteristics.

(Circuit parameter)
- Ext amp gain: Set the gain of the external amplifier.

(Oscillator)
- Frequency: The output frequency when the sweep parameter is Amplitude, DC Bias, or Zero span (time).

- Amplitude: The AC amplitude when the sweep parameter is Frequency, DC Bias, or Zero span (time).

- DC Bias: The DC bias voltage when the sweep parameter is Frequency, Amplitude, or Zero span (time).

(Sweep)
- Sweep param: Select Frequency, Amplitude (AC amplitude), DC Bias (DC bias voltage), or Zero span (time).

5.7.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-11 Graph types of resistor measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —R	Frequency [Hz]	Resistance [Ω]	○	—	○	
Frequency —X	Frequency [Hz]	Reactance [Ω]	○	—	○	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	○	
Frequency —θz	Frequency [Hz]	Phase [deg]	○	—	○	
Amplitude —R	AC voltage [Vpk]	Resistance [Ω]	○	—	—	
Amplitude —X	AC voltage [Vpk]	Reactance [Ω]	○	—	—	
Amplitude —|Z|	AC voltage [Vpk]	Impedance [Ω]	○	—	—	
Amplitude —θz	AC voltage [Vpk]	Phase [deg]	○	—	—	
DC Bias— R	DC bias [V]	Resistance [Ω]	○	—	—	
DC Bias— X	DC bias [V]	Reactance [Ω]	○	—	—	

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
DC Bias—|Z|	DC bias [V]	Impedance [Ω]	○	—	—	
DC Bias—θz	DC bias [V]	Phase [deg]	○	—	—	
Time—R	Time [s]	Resistance [Ω]	○	—	—	
Time—X	Time [s]	Reactance [Ω]	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase [deg]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-12 Marker indication in resistor measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency.	* Select sweep
Amplitude	Vpk	When the sweep parameter is Amplitude.	* Select sweep
DC Bias	V	When the sweep parameter is DC Bias.	* Select sweep
Time	s	When the sweep parameter is Zero span.	* Select sweep
|Z|	Ω	Impedance	
|Z|(Sim)	Ω	Impedance (Simulation data)	
θz	deg	Phase of impedance	
θz(Sim)	deg	Phase of impedance (Simulation data)	
R	Ω	Resistance	
R(Sim)	Ω	Resistance (Simulation data)	
X	Ω	Reactance	
X(Sim)	Ω	Reactance (Simulation data)	

5.7.4 Measure

Turn on the oscillator output, click the ⌷Start measuring⌷ button to start measurement. When the measurement is finished, the data are displayed in graphs. The graph of simulation data is displayed when equivalent circuit simulation is performed.

Each parameter is determined through the following conversions using the complex impedance (Z=R+jX) obtained from the measurement.

$$|Z| = \sqrt{R^2 + X^2} \ , \ \theta = \tan^{-1} \frac{X}{R}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target. The marker of simulation data is displayed when equivalent circuit simulation is performed.

5.7.5 Equivalent circuit estimation

Figure 5-17 Equivalent circuit estimation screen

■ Equivalent circuit

Select the equivalent circuit type to calculate the equivalent circuit constants that well-agree with the measurement data. For the resistor measurement, select either B or C for the equivalent circuit type.

> B:Inductor or resistor:　　When the resistance value is low and the effect of inductance is large

> C:Resistor(high resistance):　When the resistance value is high and the effect of stray capacitance is large

To select an equivalent circuit type, click the corresponding checkbox with the trackball.

You can also select A, D or E for the equivalent circuit type, but the equivalent circuit constants cannot be calculated correctly. Of the two equivalent circuit types B and C, which type can accurately calculate the device constants may depend on the measurement data. Check simulation results to select an appropriate equivalent circuit type.

After selecting the equivalent circuit type, click the Start analyzing button to calculate the circuit constants.

■ Constants

The circuit parameters for the selected equivalent circuit type. C0 is a value calculated only for the equivalent circuit type E. This section only displays the results of estimation calculation, and the values cannot be changed directly.

5.7.6 Equivalent circuit simulation

After obtaining the circuit constants on the equivalent circuit estimation screen, perform the equivalent circuit simulation to see how well the simulated data matches the actual measured data.

(Equivalent circuit)
*   Circuit type, R1, C1, L1, C0:

    Select the equivalent circuit type and input the parameters.

(Simulation)
*   Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
*   Point: The number of frequency points to be used for simulation.
*   Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
*   Start simulating button:Click to calculate the admittance characteristics with the simulation conditions that you have set, and display it on a graph.

If there is a large difference between the measurement and simulation data, an appropriate circuit type is not selected, or the circuit parameters estimation is not performed properly. Try the following methods to get the equivalent circuit parameters that agree with (match) the measurement data as well as possible.
1)   Adjust the values of R1, C1, or L1.
2)   Change the circuit type.
3)   Change the measurement conditions, and then perform the measurement again.

If the measurement data contains a large noise, the estimation cannot be performed successfully. Especially, a higher frequency tends to make the measurement data unstable. Set an appropriate sweep frequency range.
When you modify these simulation conditions and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be effective for the simulation data as well as the measurement result. The marker is displayed not only for the measurement data but for the simulation data. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

5.8 Leakage inductance measurement (transformer)

Short the secondary winding of a transformer, and measure the inductance of the primary winding. This enables you to measure the frequency characteristics of the leakage inductance of a leakage transformer or a resonant transformer. You can use a power amplifier to perform the measurement under driving conditions (voltage and current testing) similar to actual ones with a sample connected.

In addition to the frequency characteristics, you can also use the zero span sweep, which enables the measurement of a time variability of the leakage inductance.

5.8.1 Connecting with sample
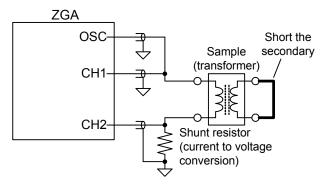
Figure 5-18 Connection example of transformer (leakage inductance) measurement

"Figure 5-8-1 Connection example of transformer (leakage inductance) measurement" shows an example of connecting a sample. You can use a power amplifier (such as the High Speed Bipolar Amplifier HSA series) to amplify the oscillator output signal up to 300 Vp-p for measurement. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".

Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

5.8.2 Setting

For details on basic settings, see **"4.1.2 Setting impedance measurement"**. This section describes only points to be considered when measuring resistor characteristics.

(Oscillator)
*   Frequency: The output frequency when the sweep parameter is Zero span (time).
*   DC Bias: Usually, set to 0 V.
(Sweep)
*   Sweep param: Select Frequency or Zero span (time).

5.8.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-13 Graph types of transformer-leakage inductance measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —Lleak	Frequency [Hz]	Leakage inductance [H]	○	—	—	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency —θz	Frequency [Hz]	Phase [deg]	○	—	—	
Time—Lleak	Time [s]	Leakage inductance [H]	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase [deg]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-14 Marker indication in transformer-leakage inductance measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency	* Select sweep
Time	s	When the sweep parameter is Zero span	* Select sweep
Lleak	H	Leakage inductance	
|Z|	Ω	Impedance	
θz	deg	Phase of impedance	

5.8.4 Measure

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the graph of leakage inductance is displayed.

The leakage inductance is determined through the following conversion using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$L_{leak} = \frac{X}{2\pi f}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target.

5.9 Mutual inductance measurement (transformer)

Measure the frequency characteristics of the mutual inductance between the primary and secondary windings of a transformer. Perform the measurement twice with different transformer connections, and then calculate the mutual inductance from these two sets of the inductance characteristics.

5.9.1 Connecting with sample
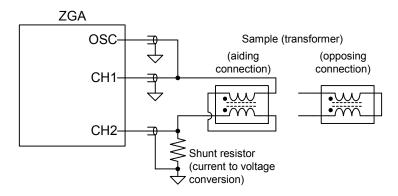
Figure 5-19 Connection example of transformer (mutual inductance) measurement

"Figure 5-19 Connection example of transformer (mutual inductance) measurement" shows an example of connecting a sample. You can use a power amplifier (such as the High Speed Bipolar Amplifier HSA series) to amplify the oscillator output signal up to 300 Vp-p for measurement. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".
Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

In the mutual inductance measurement, the inductance measurement is performed twice with different sample connections.
- Aiding connection: The magnetic fluxes in the magnetic core strengthen each other
- Opposing connection: The magnetic fluxes in the magnetic core counteract each other
In general, the aiding connection has a larger inductance.

5.9.2 Setting

For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring mutual inductance characteristics.

(Oscillator)
*   DC Bias: Usually, set to 0 V.
(Sweep)
*   Sweep param: Only Frequency can be selected.

5.9.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-15 Graph types of mutual inductance measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —La	Frequency [Hz]	Inductance of aiding connection characteristics [H]	○	—	—	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency —θz	Frequency [Hz]	Phase [deg]	○	—	—	
Frequency —Lo	Frequency [Hz]	Inductance of opposing connection characteristics [H]	○	—	—	
Frequency —|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency —θz	Frequency [Hz]	Phase [deg]	○	—	—	
M	Frequency [Hz]	Mutual inductance [H]	—	○	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-16 Marker indication in mutual inductance measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
La	H	Inductance of aiding connection characteristics	
|Z|	Ω	Impedance of aiding connection characteristics	
θz	deg	Phase of impedance of aiding connection characteristics	
Lo	H	Inductance of opposing connection characteristics	
|Z|	Ω	Impedance of opposing connection characteristics	
θz	deg	Phase of impedance of opposing connection characteristics	
M	H	Mutual inductance	

5.9.4 Aiding connection characteristics measurement

Connect the transformer in the aiding connection (see "Figure 5-19 Connection example of transformer (mutual inductance) measurement"), turn on the oscillator output, and click the Start measuring button to start measurement. When the measurement is finished, the inductance characteristics are displayed in graphs.

The inductance is determined through the following conversion using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$La = \frac{X}{2\pi f}$$

A marker is displayed in the graph of the measurement results. The parameter is indicated at the marker frequency.

5.9.5 Opposing connection characteristics measurement

Connect the transformer in the opposing connection (see **"Figure 5-19 Connection example of transformer (mutual inductance) measurement"**), turn on the oscillator output, and click the $\boxed{\text{Start}}$ $\boxed{\text{measuring}}$ button to start measurement. When the measurement is finished, the inductance characteristics are displayed in graphs.

Do not change the sweep condition settings (start sweep, stop sweep, number of measurement points, measurement interval) from ones of the aiding connection characteristics measurement. When you want to load a measurement data, be sure to use a data that has the same sweep conditions.

The inductance is determined through the following conversion using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$Lo = \frac{X}{2\pi f}$$

A marker is displayed in the graph of the measurement results. The parameter is indicated at the marker frequency.

5.9.6 Mutual inductance calculation

The mutual inductance is calculated using the inductance characteristics obtained from the aiding and opposing connections.

The mutual inductance M[H] is calculated from the inductance La[H] obtained for the aiding connection and the inductance Lo[H] obtained for the opposing connection, using the following formula.

$$M = \frac{La - Lo}{4}$$

A marker is displayed in the graph of the measurement results. The parameter is indicated at the marker frequency.

(Notes)

The mutual inductance can be measured directly as shown in **"Figure 5-20 Mutual inductance measurement method"**, instead of using the method described above.
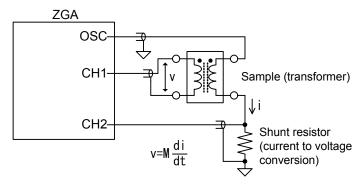
Figure 5-20 Mutual inductance measurement method

In this method, the mutual inductance can be calculated using the formula: $M = X/2\pi f$, where X is the reactance component of the complex impedance obtained by the measurement. The result does not necessarily match a value obtained by the measurement method described in this chapter, because the load condition of a transformer varies, and the measurement is affected by the isolation capacitance of the ZGA5920. However, this method requires no change in the connection and can perform the measurement with only one sweep.

5.10 Coupling coefficient measurement (transformer)

Measure the primary-secondary coupling coefficient of a transformer (by a method compliant with JIS C5321). You can use the frequency sweep to measure the frequency dependence of the coupling coefficient within the available bandwidth of the transformer.

5.10.1 Connecting with sample
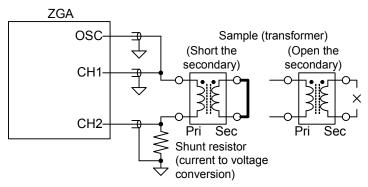
Figure 5-21 Connection example of transformer (coupling coefficient) measurement

"Figure 5-21 Connection example of transformer (coupling coefficient) measurement" shows an example of connecting with a sample. You can use a power amplifier (such as the High Speed Bipolar Amplifier HSA series) to amplify the oscillator output signal up to 300 Vp-p for measurement. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.1.1 Connecting with sample".
Perform the error compensation for measurement system (open correction, short correction), before measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

In the coupling coefficient measurement, the inductance measurement is performed twice with different sample connections.
• Short the secondary, and measure the primary inductance
• Open the secondary, and measure the primary inductance
In general, the open secondary has a larger inductance.

5.10.2 Setting

For details on basic settings, see **"4.1.2 Setting impedance measurement"**. This section describes only points to be considered when measuring coupling coefficient.

(Oscillator)
- DC Bias: Usually, set to 0 V.

(Sweep)
- Sweep param: Only Frequency can be selected.

5.10.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-17 Graph types of coupling coefficient measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—Ls	Frequency [Hz]	Inductance with the short secondary [H]	○	—	—	
Frequency—|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency—θz	Frequency [Hz]	Phase [deg]	○	—	—	
Frequency—Lo	Frequency [Hz]	Inductance with the open secondary [H]	○	—	—	
Frequency—|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency—θz	Frequency [Hz]	Phase [deg]	○	—	—	
k	Frequency [Hz]	Coupling coefficient	—	○	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-18 Marker indication in coupling coefficient measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
Ls	H	Inductance with the short secondary	
|Z|	Ω	Impedance with the short secondary	
θz	deg	Phase of impedance with short secondary	
Lo	H	Inductance with the open secondary	
|Z|	Ω	Impedance with the open secondary	
θz	deg	Phase of impedance with open secondary	
k	—	Coupling coefficient (no unit)	

5.10.4 Short secondary measurement

Short the secondary of the transformer (see "Figure 5-21 Connection example of transformer (coupling coefficient) measurement"), turn on the oscillator output, and click the Start measuring button to start measurement. When the measurement is finished, the inductance characteristics are displayed in graphs.

The short secondary inductance Ls[H] is determined through the following conversion using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$Ls = \frac{X}{2\pi f}$$

A marker is displayed in the graph of the measurement results. The parameter is indicated at the marker frequency.

5.10.5 Open secondary measurement

Open the secondary of the transformer (see "Figure 5-21 Connection example of transformer (coupling coefficient) measurement"), turn on the oscillator output, and click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the inductance characteristics are displayed in graphs.

Do not change the sweep condition settings (start sweep, stop sweep, number of measurement points, measurement interval) from ones of the short secondary characteristics measurement.

The open secondary inductance Lo[H] is determined through the following conversion using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$\text{Lo} = \frac{X}{2\pi f}$$

A marker is displayed in the graph of the measurement results. The parameter is indicated at the marker frequency.

5.10.6 Coupling coefficient calculation

Calculate the coupling coefficient using the inductance characteristics obtained from the short and open secondaries.

The coupling coefficient k [no units] is calculated from the inductance Ls obtained for the short secondary and the inductance Lo obtained for the open secondary, by using the following formula.

$$k = \sqrt{1 - \frac{Ls}{Lo}}$$

The coupling coefficient k should be a numerical value between 0 and 1.0. However, when it is calculated from actually measured characteristics including self resonance, it may be the square root of a negative value (that is, k is an imaginary). If an obtained data yields an imaginary value as k, the ZGA5920 shows the coupling coefficient k at that frequency as "-1.0" (in all of the graph, marker, and file output).

A marker is displayed in the graph of the analysis results. The parameter is indicated at the marker frequency.

(Notes)
In principle, whether being measured from the primary or the secondary of a transformer, the coupling coefficient is the same. However, in actual, you can get a more accurate result by using which has the larger inductance.

5.11 Turns ratio measurement (transformer)

Measure the voltage transfer ratio (step-up/step-down ratio) between the primary and secondary of a transformer, and convert it to the turns ratio. You can use the frequency sweep to measure the frequency dependence of the turns ratio. The zero span sweep is also available, which allows you to measure a time variability of the turns ratio (voltage transfer ratio).

5.11.1 Connecting with sample

Measure the transfer characteristics (gain-phase measurement), instead of the impedance.
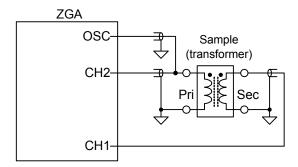
Figure 5-22 Connection example of transformer (turns ratio) measurement

"Figure 5-22 Connection example of transformer (turns ratio) measurement" shows an example of connecting with a sample. You can use a power amplifier (such as the High Speed Bipolar Amplifier HSA series) to amplify the oscillator output signal up to 300 Vp-p for measurement. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.2.1 Connecting with target circuit".
Perform the error compensation for measurement system (equalization), before measuring the transfer characteristics of a sample. See "4.2.3 Equalize".

5.11.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring turns ratio.

(Oscillator)
• DC Bias: Usually, set to 0 V.
(Sweep)
• Sweep param: Select Frequency or Zero span (time).

5.11.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-19 Graph types of turns ratio measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—N	Frequency [Hz]	Turns ratio	○	—	—	
Frequency—Gain	Frequency [Hz]	Gain [dB]	○	—	—	
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	
Time—N	Time [s]	Turns ratio	○	—	—	
Time—Gain	Time [s]	Gain [dB]	○	—	—	
Time—θ	Time [s]	Phase [deg]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-20 Marker indication in turns ratio measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency	* Select sweep
Time	s	When the sweep parameter is Zero span	* Select sweep
N	—	Turns ratio	
Gain	dB	Gain	
θ	deg	Phase	

5.11.4 Measure

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the turns ratio characteristics are displayed in graphs.

The turns ratio N is determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$N = \sqrt{A^2 + B^2}$$

A marker is displayed in the graph of the measurement results. The parameter is indicated at the marker frequency.

(Notes)
The displayed turns ratio is calculated using the absolute value of the transfer gain between the primary and secondary on the assumption that the transformer has no leakage magnetic flux (coupling coefficient k = 1.0). When the coupling coefficient k is not 1.0 (less than 1.0), there is the following relationship:

Turns ratio = Transfer gain / Coupling coefficient

When the coupling coefficient is less than 1, the error from the actual turns ratio becomes larger.

The transfer characteristics of a transformer are affected by the load impedance of the secondary side (as a result, the turns ratio is affected). In the ZGA5920, the input impedance of the measurement signal input terminals or the interline capacitance of cables can be a load impedance of the transformer's secondary side. If necessary, take a measure such as using a high input impedance probe (for oscilloscope), in order to reduce the effect of load impedance.

5.12 Varactor diode measurement

Measure the DC bias dependence (CV characteristics) of the electrostatic capacitance of a
variable-capacitance diode (varicap or varactor diode), and simulate the tuning characteristics.
In addition to the DC bias sweep (CV characteristics measurement), the frequency sweep and the zero
span sweep are also available.

5.12.1 Connecting with sample
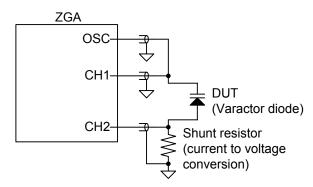
Figure 5-23 Connection example of varactor diode measurement

"Figure 5-23 Connection example of varactor diode measurement" shows an example of connecting
with a sample. The ZGA5920 by itself can output a DC bias of ±10 V. You can use the High Speed
Bipolar Amplifier HSA series (sold separately) to amplify the oscillator output signal up to ±71 V for bias
sweep measurement. The figure is just an example of connection, and various measurement connections
are supported depending on your purpose. See also "4.1.1 Connecting with sample".
Perform the error compensation for measurement system (open correction, short correction), before
measuring the impedance characteristics of a sample. See "4.1.3 Open correction and short correction".

5.12.2 Setting

For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes
only points to be considered when measuring diode characteristics.

(Oscillator)
* Frequency: The output frequency when the sweep parameter is DC bias or Zero span
                      (time).
* DC Bias: The DC bias value when the sweep parameter is Frequency or Zero span
                      (time).
(Sweep)
* Sweep param: Select Frequency, DC Bias (DC bias), or Zero span (time).
                      For the DC bias sweep range, both the plus and minus ranges can be set.

5.12.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-21 Graph types of varactor diode measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—Cp	Frequency [Hz]	Parallel capacitance [F]	○	—	—	
Frequency—Q	Frequency [Hz]	Quality factor	○	—	—	
Frequency—|Z|	Frequency [Hz]	Impedance [Ω]	○	—	—	
Frequency—θz	Frequency [Hz]	Phase [deg]	○	—	—	
DC Bias—Cp	DC bias [V]	Parallel capacitance [F]	○	—	—	
DC Bias—Q	DC bias [V]	Quality factor	○	—	—	
DC Bias—|Z|	DC bias [V]	Impedance [Ω]	○	—	—	
DC Bias—θz	DC bias [V]	Phase [deg]	○	—	—	
DC Bias— Freq_res	DC bias [V]	Tuning frequency [Hz]	—	—	○	
Time—Cp	Time [s]	Parallel capacitance [F]	○	—	—	
Time—Q	Time [s]	Quality factor	○	—	—	
Time—|Z|	Time [s]	Impedance [Ω]	○	—	—	
Time—θz	Time [s]	Phase [deg]	○	—	—	
Time—Freq_res	Time [s]	Tuning frequency [Hz]	—	—	○	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-22 Marker indication in varactor diode measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency.	* Select sweep
DC Bias	V	When the sweep parameter is DC Bias.	* Select sweep
Time	s	When the sweep parameter is Zero span.	* Select sweep
Cp	F	Parallel capacitance	
Q	—	Quality factor	
|Z|	Ω	Impedance	
θz	deg	Phase of impedance	
Freq_res	Hz	Tuning frequency	

5.12.4 Measure

Turn on the oscillator output, click the ⌗Start measuring⌗ button to start measurement. When the measurement is finished, a graph of the parallel capacitance Cp and Quality factor Q is displayed. The X axis is the sweep target (frequency, DC bias, or time). The graph of simulation data is displayed when tuning characteristics simulation is performed.

The display parameters Cp[F] and Q are determined using the complex impedance (Z=R+jX) obtained from the measurement. f is the measurement frequency [Hz].

$$Cp = \frac{-X}{2\pi f(R^2 + X^2)}, \quad Q = \frac{-X}{R}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target. The marker of simulation data is displayed when tuning characteristics simulation is performed.

5.12.5 Tuning characteristics simulation

The tuning characteristics can be simulated by inputting the constants of a resonance circuit obtained from the measured CV characteristics (DC bias—capacitance Cp).
The tuning characteristics simulation requires data from the DC bias sweep.

(Tuning circuit)
- C0, C1, L: Input the constants of the tuning circuit.
- Start simulating button: Click to calculate the resonance frequency using the measured CV
                            characteristics and the above tuning circuit constants (C0, C1, and L) and
                            display a result graph.

A marker is displayed in the graph of the tuning characteristics simulation results.

The tuning frequency is calculated on the assumption that the tuning circuit consists of the measured varicap (varactor) diode combined with C0, C1, and L shown in "Figure 5-24 Tuning circuit".

Figure 5-24 Tuning circuit
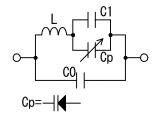
$$\text{Tuning frequency} \ = \frac{1}{2\pi\sqrt{L \cdot C}}, \qquad C = \frac{(Cp + C1)C0}{Cp + C1 + C0}$$

5.13 Feedback loop measurement (servo)

Measure the frequency response of the loop gain characteristics of a negative feedback loop (servo loop) to display indices of the loop stability such as phase margin and gain margin. You can also generate a circuit model (system identification from the frequency domain transfer characteristics) and save it in a text file. The model obtained by the actual measurement of a control target can be used for the control system design based on modern control theories.

5.13.1 Connecting with target circuit
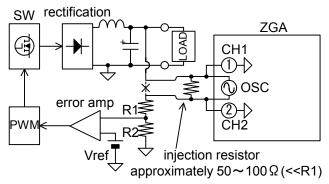
Figure 5-25 Connection example of servo-feedback loop measurement

"Figure 5-25 Connection example of servo-feedback loop measurement" shows an example of connecting with a target circuit. This is a connection example of the switching supply loop characteristics measurement. For a power supply circuit of up to DC 200 V, you can use the connection shown in Figure 5-25 for measurement. The injection resistor has another purpose to prevent the target circuit loop from being opened even when the target circuit is accidentally disconnected with the ZGA5920. Connect it to the target circuit by soldering so that it will not come off easily. See also "4.2.1 Connecting with target circuit".

5.13.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring servo-feedback loop characteristics.

(Oscillator)
* Amplitude: Set to about 5% of the voltage in the circuit, and then adjust it while checking results.
* DC Bias: Usually, set to 0 V. This setting is independent of the voltage of the target circuit.

(Sweep)
* Sweep param: Frequency only.
* Interval: Generally, set to [Log], because the measurement should be performed for a broad range of frequency.

(Integration):   Set to 1 cycle at first, and then adjust it while checking results.

5.13.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-23 Graph types of loop characteristics measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency —Gain	Frequency [Hz]	Gain [dB]	○	—	○	Bode diagram
Frequency —θ	Frequency [Hz]	Phase [deg]	○	—	○	Bode diagram
Re(Gain)— Im(Gain)	A (Real part of gain)	B (Imaginary part of gain)	○	—	○	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	○	—	○	Nichol's diagram

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-24 Marker indication in loop characteristics measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Simulated frequency	
Loop Gain	dB	Loop gain	
Loop Gain(Sim)	dB	Loop gain (Simulation data)	
θ	deg	Phase of loop gain	
θ(Sim)	deg	Phase of loop gain (Simulation data)	
Re(Gain)	—	Real part of gain	
Re(Gain)(Sim)	—	Real part of gain (Simulation data)	
Im(Gain)	—	Imaginary part of gain	
Im(Gain)(Sim)	—	Imaginary part of gain (Simulation data)	

5.13.4 Measure

Turn on the oscillator output, click the Start measuring button to start measurement. When the measurement is finished, the loop gain characteristics (bode diagram) are displayed in graphs. The graph of simulation data is displayed when circuit model simulation is performed.

If the AC amplitude is too large, the circuit saturates and the characteristics cannot be measured correctly. Perform the measurement while changing the AC amplitude accordingly, and set as large an AC amplitude as possible that does not cause a difference in the characteristics (does not cause saturation).

If the AC amplitude is small, the noise increases relatively. On the contrary, if you increase the AC amplitude carelessly, saturation occurs as mentioned above, and the reliability of measurement results is lost. If the AC amplitude does not cause saturation but the noise is large, increase the number of integrations (see "4.3.1 Integration").

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \ , \ \theta \ = \tan^{-1}\frac{B}{A}$$

The search result and marker are displayed in the graph of the measurement results.
- Phase margin: Phase at the frequency where the gain crosses 0 dB
- Bandwidth: Frequency for which the phase margin is searched
- Gain margin: Gain at the frequency where the phase crosses 0 deg

Both phase margin and gain margin are indices of the control loop stability. A phase margin closer to 0 deg means less stable (a larger margin means more stable). A gain margin closer to 0 dB means less stable, too.

The phase margin refers to the value closer to 0 dB of the two values before and after the measurement data crosses 0 dB. The gain margin is defined likewise. The search starts from the beginning of the sweep data, and shows the first position that matches the search conditions. However, the displayed search result may not indicate the correct position, for example due to noise. In such case, click the search again buttons ◀ ▶ to search again and display the next (previous) position that matched the search conditions.

You can use the marker to read the value at an arbitrary frequency, independently of these search results.

○ Notes on Nyquist diagram

When you select [Re(Gain)—Im(Gain)] for the graph display format, you can display a Nyquist diagram. In the Nyquist diagram, you can check the stability using the Nyquist's stability determination method, but need to pay attention to the following point.

As usually described in literatures on the automatic control, the Nyquist diagram is created using the vector locus of A × β (excluding the subtraction section of input). However, in the ZGA5920, the actual loop gain measurement gives A × β × -1 (including the subtraction section of input) as the measurement data.
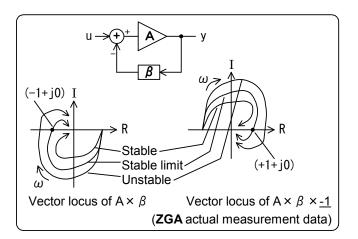
Figure 5-26 Nyquist diagram obtained by actual measurement

As the sign of the subtraction section of input is reversed, the measured data is symmetrical about the origin, compared to general Nyquist diagrams described in literatures. The singular point (-1 + j0) to determine the stability also moves to (+1 + j0). Therefore, the way of determining the stability is the same as that of general Nyquist diagrams. Note that the singular point moves to (+1 + j0).

○ About phase margin/gain margin

The smaller the phase margin or gain margin (closer to 0 deg or 0 dB), the lower the stability. If the phase margin is 0 deg (or the gain margin is 0 dB), the loop is certainly unstable (oscillating state). However, a negative value (the phase margin < 0 deg, or the gain margin < 0 dB) does not necessarily mean instability. In such case, use the Nyquist diagram together to determine the stability. For details, refer to specialized books on the automatic control. **"Figure 5-25 Example of stable vector locus with negative phase/gain margin"** shows an example of vector locus that is not unstable even when the phase margin < 0 deg or the gain margin < 0 dB.
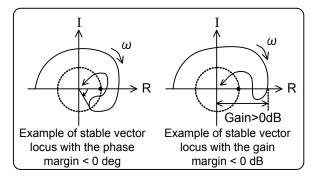
Figure 5-27 Example of stable vector locus with negative phase/gain margin

5.13.5 Circuit model generation

- Algorithm: Select [A] or [B]. [A] is less accurate but less divergent (noise-tolerant), while [B] is highly accurate but more divergent (not noise-tolerant).

(Identification condition)

- Min, Max: In the servo measurement, the noise tends to increase in lower and higher frequency regions. This function excludes such noisy data from the calculation when generating a circuit model. Usually, set values according to the sweep measurement range.

- Order: An order to be used for the calculation. It tends to generate a more accurate model to set a larger value than the actual order.

- Start analyzing button: Click to calculate the model with the conditions specified above. Save the calculated transfer function in a file. For details, see **"6.3 Transfer function file format"**.

5.13.6 Circuit model simulation

When the circuit model generation is finished, you can perform the circuit model simulation to see how well the simulated data matches the actual measured data.

(Simulation)
- Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
- Point: The number of frequency points to be used for simulation.
- Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To specify a transfer function file, select the transfer function in the measurement result data list at the input location for the transfer function.
- Start simulating button: Click to calculate the loop gain characteristics with the simulation conditions that you have set, and display it on a graph.

If there is a large difference between the measurement and simulation data, change the model generation conditions such as the order. After you generate a circuit model again, click the Start simulating button to perform the re-calculation.

The search result and marker are displayed in the graph of the measurement results.
- Phase margin: Phase at the frequency where the gain crosses 0 dB
- Bandwidth: Frequency for which the phase margin is searched
- Gain margin: Gain at the frequency where the phase crosses 0 deg

The result of searching the simulation data is displayed, instead of the measured data.

After the simulation is complete, the marker will be effective for the simulation data as well as the measurement result. The marker is displayed not only for the measurement data but for the simulation data. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

(Notes) About circuit model

The circuit model generation feature generates a transfer function from the frequency-complex gain characteristics measured by the ZGA5920, using the system identification algorithm of the frequency domain. The transfer function is output in the three format types: polynomial, pole-zero, and state space.

○ Polynomial format

$$H_{(s)} = \frac{num_n s^n + num_{n-1} s^{n-1} + num_{n-2} s^{n-2} + \cdots + num_1 s + num_0}{den_n s^n + den_{n-1} s^{n-1} + den_{n-2} s^{n-2} + \cdots + den_1 s + den_0}$$

○ Pole-zero format

$$H_{(s)} = K \frac{(s - z_{n-1})(s - z_{n-2})(s - z_{n-3}) \cdots (s - z_1)(s - z_0)}{(s - p_{n-1})(s - p_{n-2})(s - p_{n-3}) \cdots (s - p_1)(s - p_0)}$$

○ State space format

$$\begin{cases} \dot{X} = AX + Bu \\ y = CX + Du \end{cases}$$

The internal algorithm calculates the function in the polynomial format at first. Then, it converts the function to the pole-zero and state space formats and outputs the results.
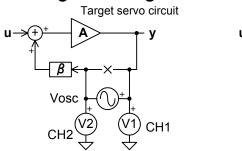
The circuit model generation screen displays the same contents as the transfer function file. For details, see "6.3 Transfer function file format".

5.14 Closed loop gain measurement (servo)

Measure the loop gain characteristics and feedback transfer characteristics of a negative feedback loop (servo loop) to display the phase margin and gain margin. From these measured characteristics, calculate the closed loop characteristics (performance characteristics) and the amplification section characteristics. You can generate a circuit model (transfer function) using the calculated closed loop characteristics and amplification section characteristics, and save the generated model in a text file. The model (system identification) obtained by the actual measurement of a control target can be used for the control system design based on modern control theories.

5.14.1 Connecting with target circuit

Connection example of loop gain measurement

Connection example of feedback transfer characteristics measurement

Figure 5-28 Connection example of closed loop gain measurement

"Figure 5-28 Connection example of closed loop gain measurement" shows an example of connecting with a target circuit. You need measure the loop gain characteristics and the feedback transfer characteristics (β) using a different connection for each of them.
See also "4.2.1 Connecting with target circuit".

5.14.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring servo-feedback loop characteristics.

(Oscillator)
- Amplitude: Set to about 5% of the voltage in the circuit, and then adjust it while checking results.
- DC Bias: Usually, set to 0 V. This setting is independent of the voltage of the target circuit.

(Sweep)
- Sweep param: Frequency only.
(Integration):   Set to 1 cycle at first, and then adjust it while checking results.

5.14.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-25 Graph types of closed loop gain measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Loop gain measurement						
Frequency—Gain	Frequency [Hz]	Gain [dB]	○	—	—	Bode diagram
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	Bode diagram
Re(Gain)—Im(Gain)	A (Real part of gain)	B (Imaginary part of gain)	○	—	—	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	○	—	—	Nichol's diagram
Feedback transfer function measurement						
Frequency—Gain	Frequency [Hz]	Gain [dB]	○	—	—	Bode diagram
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	Bode diagram
Re(Gain)—Im(Gain)	A (Real part of gain)	B (Imaginary part of gain)	○	—	—	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	○	—	—	Nichol's diagram
Open to closed loop conversion and circuit model simulation						
Frequency—Gain	Frequency [Hz]	Gain [dB]	—	○	○	Bode diagram
Frequency—θ	Frequency [Hz]	Phase [deg]	—	○	○	Bode diagram
Re(Gain)—Im(Gain)	A (Real part of gain)	B (Imaginary part of gain)	—	○	○	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	—	○	○	Nichol's diagram

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-26 Marker indication in closed loop gain measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
Gain	dB	Feedback gain	
θ	deg	Phase of feedback gain	
Re(Gain)		Real part of feedback gain	
Im(Gain)		Imaginary part of feedback gain	
Gain	dB	Gain	
θ	deg	Phase of gain	
Re(Gain)		Real part of gain	
Im(Gain)		Imaginary part of gain	
Gain	dB	Gain (Analysis data)	
Gain(Sim)	dB	Gain (Simulation data)	
θ	deg	Phase (Analysis data)	
θ(Sim)	deg	Phase (Simulation data)	
Re(Gain)	—	Real part of gain (Analysis data)	
Re(Gain)(Sim)	—	Real part of gain (Simulation data)	
Im(Gain)	—	Imaginary part of gain (Analysis data)	
Im(Gain)(Sim)	—	Imaginary part of gain (Simulation data)	

5.14.4 Loop gain measurement

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the loop gain characteristics (bode diagram) are displayed in graphs.
To obtain good data without saturation and with good signal-to-noise ratio, the AC amplitude and the number of integrations should be adjusted. See **"5.13.4 Measure"**.

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \ , \ \ \theta = \tan^{-1}\frac{B}{A}$$

The search result and marker are displayed in the graph of the measurement results.
* Phase margin: Phase at the frequency where the gain crosses 0 dB
* Bandwidth: Frequency for which the phase margin is searched
* Gain margin: Gain at the frequency where the phase crosses 0 deg
For details on how to check the phase/gain margin and determine the stability, see **"5.13.4 Measure"**.

You can use the marker to read the value at an arbitrary frequency, independently of these search results.

5.14.5 Feedback transfer function measurement

For the feedback transfer characteristics measurement, change the connection with the target circuit.
(See **"Figure 5-28 Connection example of closed loop gain measurement"**.)
Leave the settings the same as the loop gain measurement except the integration-related settings.
You can perform the closed loop conversion calculation, giving a fixed value as the feedback transfer function without an actual measurement. This method is useful when the feedback section of the target circuit only consists of a resistance and the phase delay of the feedback transfer characteristics can be ignored. If you do not measure the feedback transfer function, go to **"5.14.6 Open to closed loop conversion"**.

Turn on the oscillator output, click the ⬚Start measuring button to start measurement. When the measurement is finished, the feedback transfer characteristics are displayed in graphs.

The valued read by the marker is displayed just like on the loop gain measurement screen. The search result of phase/gain margin is not displayed.

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \ , \ \theta \ = \tan^{-1}\frac{B}{A} \ , \ \text{Re(Gain)=A, Im(Gain)=B}$$

5.14.6 Open to closed loop conversion

Calculate the closed loop characteristics (or amplification section characteristics) from the loop gain characteristics and the feedback transfer function.

- Feedback parameter

    Measurement: Perform the open to closed loop conversion using measurement data (or loaded from a file).

    Constant: Perform the open to closed loop conversion using a constant value as the negative feedback transfer function.

- Output
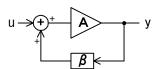
    Closed loop gain: Calculates the closed loop characteristics.

    Amplifier gain: Calculates the amplification section characteristics.

- Constant: Input the β section gain in dB. Effective only when the [Feedback parameter] is set to [Constant].

The closed loop gain and open loop gain are defined as follows:

- Loop gain = Aβ
- Feedback transfer function = β
- Closed loop gain (performance characteristics) = y/u = A/(1 - Aβ)
- Open loop gain (amplification section characteristics) = A

Using the complex gain G1 (= Aβ) of the loop gain and the complex gain G2 (= β) of the feedback transfer function β, the following conversion is performed:

$$\text{Open loop gain} = \frac{G1}{G2}, \text{ Closed loop gain} = \frac{G1}{G2(1-G1)}$$

When the conversion is finished, the conversion result is displayed in graphs.

5.14.7 Circuit model generation

When the open to closed loop conversion is finished, set the model generation conditions for generating a circuit model.

(Identification parameter)
- Algorithm   Select [A] or [B]. [A] is less accurate but less divergent (noise-tolerant), while [B] is highly accurate but more divergent (not noise-tolerant).

(Identification condition)
- Min, Max: In the servo measurement, the noise tends to increase in lower and higher frequency regions. This function excludes such noisy data from the calculation when generating a circuit model. Usually, set values according to the sweep measurement range.
- Order: An order to be used for the calculation. It tends to generate a more accurate model to set a larger value than the actual order.
- Start analyzing button: Click to calculate the model with the conditions specified above. Save the calculated transfer function in a file. For details, see "6.3 Transfer function file format".

The circuit model generation is performed for the characteristics that you have specified in the open to close conversion screen (open loop characteristics or closed loop characteristics). A model with the characteristics displayed on the open to close conversion screen is generated.

5.14.8 Circuit model simulation

When the circuit model generation is finished, you can perform the circuit model simulation to see how well the simulated data matches the actual measured data.

(Simulation)
- Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
- Point: The number of frequency points to be used for simulation.
- Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To specify a transfer function file, select the transfer function in the measurement result data list at the input location for the transfer function.
- Start simulating button: Click to calculate the open loop or closed loop characteristics with the simulation conditions that you have set, and display it on a graph.

If there is a large difference between the measurement and simulation data, change the parameters such as the order. When you generate a circuit model again and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be effective for the simulation data as well as the measurement result. The marker is displayed not only for the measurement data but for the simulation data. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

5.15 Open loop gain measurement (servo)

Measure the input/output characteristics (closed loop gain) and feedback transfer function of a negative feedback circuit (servo loop), and calculate the loop gain characteristics and the amplification section characteristics. You can generate a circuit model (transfer function) using the calculated closed loop characteristics and amplification section characteristics, and save the generated model in a text file. The model (system identification) obtained by the actual measurement of a control target can be used for the control system design based on modern control theories.

5.15.1 Connecting with target circuit

Connection example of closed loop gain measurement

Connection example of feedback transfer characteristics measurement

Figure 5-29 Connection example of open loop gain measurement

"Figure 5-29 Connection example of open loop gain measurement" shows an example of connecting with a target circuit. You need measure the closed loop characteristics and the feedback transfer characteristics (β) using a different connection for each of them.
See also "4.2.1 Connecting with target circuit".

5.15.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring closed loop characteristics.

(Oscillator)
- Amplitude: For the closed loop gain measurement, set to a value equal to or less than the amplitude that the circuit can handle. For the feedback transfer measurement, set to about 5% of the voltage in the circuit.
- DC Bias: For the closed loop gain measurement, set according to the target circuit' needs. For the feedback transfer measurement, usually set to 0 V.

(Sweep)
- Sweep param: Frequency only.
(Integration):   Set to 1 cycle at first, and then adjust it while checking results.

5.15.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-27 Graph types of open loop gain measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Closed loop gain measurement						
Frequency—Gain	Frequency [Hz]	Gain [dB]	○	—	—	Bode diagram
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	Bode diagram
Re(Gain)—Im(Gain)	A (Real part of gain)	B (Imaginary part of gain)	○	—	—	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	○	—	—	Nichol's diagram
Feedback transfer function measurement						
Frequency—Gain	Frequency [Hz]	Gain [dB]	○	—	—	Bode diagram
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	Bode diagram
Re(Gain)—Im(Gain)	A (Real part of gain)	B (Imaginary part of gain)	○	—	—	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	○	—	—	Nichol's diagram
Closed to open loop conversion and circuit model simulation						
Frequency—Gain	Frequency [Hz]	Gain [dB]	—	○	○	Bode diagram
Frequency—θ	Frequency [Hz]	Phase [deg]	—	○	○	Bode diagram
Re(Gain)—Im(Gain)	A (Real part of gain)	B (Imaginary part of gain)	—	○	○	Nyquist diagram
θ—Gain	Phase [deg]	Gain	—	○	○	Nichol's diagram

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-28 Marker indication in open loop gain measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
Close Gain	dB	Closed loop gain	
θ	deg	Phase of closed loop gain	
Re(Gain)		Real part of closed loop gain	
Im(Gain)		Imaginary part of closed loop gain	
Gain	dB	Feedback gain	
θ	deg	Phase of feedback gain	
Re(Gain)		Real part of feedback gain	
Im(Gain)		Imaginary part of feedback gain	
Gain	dB	Gain (Analysis data)	
Gain(Sim)	dB	Gain (Simulation data)	
θ	deg	Phase (Analysis data)	
θ(Sim)	deg	Phase (Simulation data)	
Re(Gain)	—	Real part of gain (Analysis data)	
Re(Gain)(Sim)	—	Real part of gain (Simulation data)	
Im(Gain)	—	Imaginary part of gain (Analysis data)	
Im(Gain)(Sim)	—	Imaginary part of gain (Simulation data)	

5.15.4 Closed loop gain measurement

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the loop gain characteristics (bode diagram) are displayed in graphs.

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \text{ , Gain} = \sqrt{A^2 + B^2} \text{ , } \theta = \tan^{-1}\frac{B}{A}$$

A marker is displayed in the graph of the measurement results. You can read a value at an arbitrary frequency.

5.15.5 Feedback transfer function measurement

For the feedback transfer characteristics measurement, change the connection with the target circuit. (See "Figure 5-29 Connection example of open loop gain measurement".)

Leave the sweep-related settings (for example, minimum value, maximum value, and number of points) the same as those of the closed-loop measurement. You may change the DC bias and AC amplitude. Typically, set the DC bias to 0 V and the AC amplitude to a value less than about 5% of the voltage in the circuit.

You can perform the closed loop conversion calculation, giving a fixed value as the feedback transfer function without an actual measurement. This method is useful when the feedback section of the target circuit only consists of a resistance and the phase delay of the feedback transfer characteristics can be ignored. If you do not measure the feedback transfer function, go to "5.15.6 Closed to open loop conversion".

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the feedback transfer characteristics are displayed in graphs.

The valued read by the marker is displayed just like on the closed loop gain measurement screen. The search result of phase/gain margin is not displayed.

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \ , \ \theta \ = \tan^{-1}\frac{B}{A} \ , \ \text{Re(Gain)=A, Im(Gain)=B}$$

5.15.6 Closed to open loop conversion

Calculate the loop gain characteristics (or amplification section characteristics) from the closed loop characteristics and the feedback transfer function.

- Feedback parameter
  - Measurement: Perform the open to closed loop conversion using the feedback transfer function measurement data (or loaded from a file).
  - Constant: Perform the closed to open loop conversion using a constant value as the negative feedback transfer function.
- Output
  - Amplifier gain: Calculates the amplification section characteristics.
  - Loop gain: Calculate the loop gain characteristics (corresponding to Aβ).
- Constant: Input the β section gain in dB. Effective only when the [Feedback parameter] is set to [Constant].
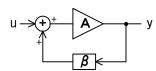
The loop gain and open loop gain are defined as follows:

- Closed loop gain (performance characteristics) = y/u
- Feedback transfer function = β
- Loop gain = Aβ
- Open loop gain (amplification section characteristics) = A

Using the complex gain G1(= y/u) of the closed loop gain and the complex gain G2 (= β) of the feedback transfer function β, the following conversion is performed:

$$\text{Loop gain (A}\beta) = \frac{G1 \cdot G2}{(1+G1 \cdot G2)}, \text{Open loop gain (A)} = \frac{G1}{(1+G1 \cdot G2)}$$

When the conversion is finished, the conversion result is displayed in graphs, and the marker read values are also displayed.

5.15.7 Circuit model generation

When the open to closed loop conversion is finished, set the model generation conditions for generating a circuit model.

(Identification parameter)
- Algorithm: Select [A] or [B]. [A] is less accurate but less divergent (noise-tolerant), while [B] is highly accurate but not noise-tolerant (more divergent).

(Identification condition)
- Min, Max: In the servo measurement, the noise tends to increase in lower and higher frequency regions. This function excludes such noisy data from the calculation when generating a circuit model. Usually, set values according to the sweep measurement range.
- Order: An order to be used for the calculation. It tends to generate a more accurate model to set a larger value than the actual order.
- Start analyzing button: Click to calculate the model with the conditions specified above. When the calculation is finished, the factors of the transfer function are displayed on the right of the screen (not editable).
  Save the calculated transfer function in a file. For details, see "6.3 Transfer function file format".

The circuit model generation is performed for the characteristics that you have specified in the open to close conversion screen (open loop characteristics or loop gain characteristics). A model with the characteristics displayed on the open to close conversion screen is generated.

5.15.8 Circuit model simulation

When the circuit model generation is finished, you can perform the circuit model simulation to see how well the simulated data matches the actual measured data.

(Simulation)
- Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
- Point: The number of frequency points to be used for simulation.
- Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To specify a transfer function file, select the transfer function in the measurement result data list at the input location for the transfer function.
- Start simulating button: Click to calculate the loop gain or open loop characteristics with the simulation conditions that you have set, and display it on a graph.

If there is a large difference between the measurement and simulation data, change the parameters such as the order. When you generate a circuit model again and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be effective for the simulation data as well as the measurement result. The marker is displayed not only for the measurement data but for the simulation data. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

5.16 Gain-phase measurement (amplifier circuit)

Measure the frequency response of the I/O transfer characteristics of an amplifier circuit (amplifier) to display the gain, phase, and group delay. You can also generate a transfer function (system identification from the frequency domain transfer characteristics) and save it in a text file. You can use it to model automatic control loop components and compare with a designed transfer function.
In addition to the frequency sweep measurement, you can use the zero span sweep to measure a time variability of the gain-phase characteristics.

5.16.1 Connecting with target circuit
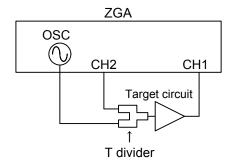
Figure 5-30 Connection example of gain-phase measurement

"Figure 5-30 Connection example of gain-phase measurement" shows an example of connecting with a target circuit. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.2.1 Connecting with target circuit".
Perform the error compensation for measurement system (equalization), before measuring the transfer characteristics of a target circuit. See "4.2.3 Equalize".

5.16.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring gain-phase characteristics.

(Sweep)
• Sweep param: Select Frequency or Zero span (time).

5.16.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-29 Graph types of gain-phase measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—Gain	Frequency [Hz]	Gain [dB]	○	○	○	
Frequency—θ	Frequency [Hz]	Phase [deg]	○	○	○	
Frequency—GD	Frequency [Hz]	Group delay [s]	○	○	○	
Time—Gain	Time [s]	Gain [dB]	○	—	—	
Time—θ	Time [s]	Phase [deg]	○	—	—	
Time—GD	Time [s]	Group delay [s]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-30 Marker indication in gain-phase measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	When the sweep parameter is Frequency.	* Select sweep
Time	s	When the sweep parameter is Zero span.	* Select sweep
Gain	dB	Gain	* Select sweep
Gain(Sim)	dB	Gain (Simulation data)	
θ	deg	Phase	
θ(Sim)	deg	Phase (Simulation data)	
GD	s	Group delay	
GD(Sim)	s	Group delay (Simulation data)	

5.16.4 Measure

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the gain-phase characteristics are displayed in graphs. The graphs of analysis data and simulation data are displayed when analysis and simulation are performed.

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2}\ ,\quad \theta = \tan^{-1}\frac{B}{A},\quad GD = \frac{\partial\theta_{[\text{rad}]}}{\partial\omega_{[\text{rad/s}]}}$$

The settings related to the phase range and group delay are included.
- Phase range: Select the display range of phase from the following four types:
  -180< θ ≤+180 deg: Displays the phase in the range of -180 to +180 deg.
  -360< θ ≤0 deg: Displays the phase in the range of -360 to 0 deg.
  0< θ ≤+360 deg: Displays the phase in the range of 0 to +360 deg.
  UNWRAP: Displays the unwrapped phase.

- Phase shift: Effective when the phase range is set to UNWRAP.
  $\boxed{\blacktriangleleft}$:   Subtracts 360 deg from the current phase.
  $\boxed{\blacktriangleright}$:   Adds 360 deg to the current phase.
- Aperture   The average movement distance (on the frequency axis) of the phase characteristic when measuring the group delay. This value is set by a number of measurement points.
  A larger aperture setting makes the group delay characteristic smoother, but will lose steep changes (on the frequency axis).

5.16.5 Transfer function generation

The transfer function can be generated only for the data obtained by the frequency sweep measurement. It cannot be generated for the data obtained by the zero span sweep measurement.

Set the conditions of model generation.
- Identification parameter

    Algorithm: Select [A] or [B]. [A] is less accurate but less divergent (noise-tolerant), while [B] is highly accurate but more divergent (not noise-tolerant).

- Identification condition

    Min, Max: If the noise increases in lower and higher frequency regions, this function excludes such noisy data from the calculation. Usually, set values according to the sweep measurement range.

    Order: An order to be used for the calculation. It tends to generate a more accurate model to set a larger value than the actual order.

- Start analyzing button: Click to calculate the transfer function with the conditions specified above. When the calculation is finished, the factors of the transfer function are displayed on the right of the screen (not editable). Save the calculated transfer function in a file. For details, see "6.3 Transfer function file format".

5.16.6 Simulation

When the transfer function generation is finished, you can perform the transfer function simulation to see how well the simulated data matches the actual measured data.

(Simulation)

- Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
- Point: The number of frequency points to be used for simulation.
- Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To specify a transfer function file, select the transfer function in the measurement result data list at the input location for the transfer function.
- Start simulating button: Click to calculate the loop gain characteristics with the simulation conditions that you have set, and display it on a graph.

(Phase range / Group delay)

- Phase range: Select the display range of phase from the following four types: This setting affects both the measurement data and the simulation data.
  - $-180 < \theta \leq +180$ deg: Displays the phase in the range of -180 to +180 deg.
  - $-360 < \theta \leq 0$ deg: Displays the phase in the range of -360 to 0 deg.
  - $0 < \theta \leq +360$ deg: Displays the phase in the range of 0 to +360 deg.
  - UNWRAP: Displays the unwrapped phase.
- Phase shift: Effective when the phase range is set to UNWRAP. This setting affects only the simulation data.
  - ◀ : Subtracts 360 deg from the current phase.
  - ▶ : Adds 360 deg to the current phase.
- Aperture The average movement distance (on the frequency axis) of the phase characteristic when measuring the group delay. This value is set by a number of measurement points.

If there is a large difference between the measurement and simulation data, change the parameters such as the order. When you generate a circuit model again and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be effective for the simulation data as well as the measurement result. The marker is displayed not only for the measurement data but for the simulation data. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

5.17 CMRR measurement (amplifier circuit)

Measure the CMRR (Common Mode Rejection Ratio), an important performance characteristic of a differential amplifier. The ZGA5920 has a large dynamic range of 140 dB, so you can measure a CMRR exceeding 100 dB.

5.17.1 Connecting with target circuit

Connection for normal-mode gain measurement

Connection for common-mode gain measurement

Figure 5-31 Connection example of CMRR measurement

"Figure 5-31 Connection example of CMRR measurement" shows an example of connecting with a target circuit. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.2.1 Connecting with target circuit".

Perform the error compensation for measurement system (equalization), before measuring the transfer characteristics of a sample. See "4.2.3 Equalize".

5.17.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring CMRR characteristics.

(Oscillator)
- Amplitude: You may set different amplitudes between the normal-mode gain and common-mode gain measurements. When measuring the common-mode gain, a large amplitude within the tolerance range of the common-mode input voltage of the target differential amplifier can decrease the noise in the result.

(Sweep)
- Sweep param: Frequency only.
(Integration):   For the common-mode gain measurement, set a relatively large value in order to measure very low input signals.

5.17.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-31 Graph types of CMRR measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—GainNORM	Frequency [Hz]	Normal-mode gain [dB]	○	—	—	
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	
Frequency—GainCOM	Frequency [Hz]	Common-mode gain [dB]	○	—	—	
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	
Frequency—CMRR	Frequency [Hz]	CMRR [dB]	—	○	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-32 Marker indication in CMRR measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
GainNORM	dB	Normal-mode gain	
θ	deg	Normal-mode gain phase	
GainCOM	dB	Common-mode gain	
θ	deg	Common-mode gain phase	
CMRR	dB	CMRR	

5.17.4 Normal-mode gain measurement

You can use a fixed normal-mode gain value instead of a measured one, and measure only the common-mode gain to display the CMRR. If you do so, go to **"5.17.5 Common-mode gain measurement"**.

Connect the ZGA5920 with the target differential amplifier for the normal-mode gain measurement (see **"Figure 5-31 Connection example of CMRR measurement"**).
Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the normal-mode gain characteristics (gain [dB], phase [deg]) are displayed in graphs.

The normal-mode gain characteristics are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{GainNorm} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \, , \, \theta = \tan^{-1}\frac{B}{A}$$

5.17.5 Common-mode gain measurement

Make the sweep-related settings (start value, stop value, measurement interval) the same as those of the normal-mode gain measurement. You may change the AC amplitude and DC bias of the oscillator output according to the input voltage range of the target differential amplifier. As the gain is much smaller compared to that obtained by the normal-mode gain measurement (the output level of the differential amplifier is near zero), you might have to increase the number of integrations. Change the settings appropriately according to measurement results.

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the common-mode gain characteristics are displayed in graphs.

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{GainCOM} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \, , \, \theta = \tan^{-1}\frac{B}{A}$$

5.17.6 CMRR display

When the normal-mode and common-mode gain measurements are finished, calculate the CMRR from the characteristics of both the gains.
Set the conditions of CMRR characteristics calculation.

- Normal-Mode gain
  - Measurement: Calculate the CMRR using the data measured.
  - Constant: Calculate the CMRR using a fixed value, which is input in [Constant] described below.
- Constant: Input a value (in dB) when you want to use a fixed normal-mode gain value.

When the CMRR calculation is finished, a graph is displayed, where the X axis represents the frequency [Hz] and the Y axis represents the CMRR [dB]. The marker read values are displayed.

The CMRR is calculated from the normal-mode gain GainNORM [dB] and the common-mode gain GainCOMM [dB], using the following formula:
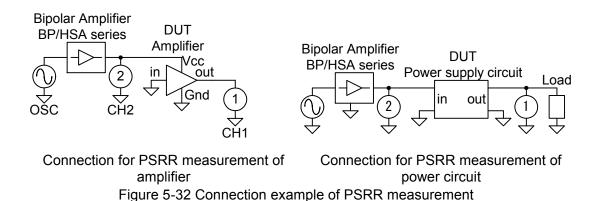
CMRR [dB]=GainNORM [dB] — GainCOMM [dB]

The larger (positive) the value of the CMRR, the higher ability of common-mode component rejection the differential amplifier has.

5.18 PSRR measurement (amplifier circuit)

Measure the effect of a power fluctuation of an amplifier circuit (amplifier) on the output signal (Power Supply Rejection Ratio). The target includes power circuits (for example, a DC-DC converter, an analog series regulator), as well as amplifiers. For power circuits, the performance corresponding to the line regulation or ripple rejection ratio can be measured and evaluated for arbitrary frequencies or disturbance conditions.

5.18.1 Connecting with target circuit

Connection for PSRR measurement of amplifier

Connection for PSRR measurement of power circuit

Figure 5-32 Connection example of PSRR measurement

"Figure 5-32 Connection example of PSRR measurement" shows an example of connecting with a target circuit. In many cases, the oscillator output of the ZGA5920 cannot provide a sufficient power supply (voltage, current) to the target circuit by itself. You can use our Bipolar Amplifier HSA/BP series together.

The above figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.2.1 Connecting with target circuit".

Perform the error compensation for measurement system (equalization), before measuring the transfer characteristics of a sample. See "4.2.3 Equalize".

5.18.2 Setting

For details on basic settings, see **"4.2.2 Setting gain-phase measurement"**. This section describes only points to be considered when measuring PSRR characteristics.

(Oscillator)
- Amplitude: In consideration of the power supply voltage (DC bias) of the target circuit, do not set the amplitude too large.
- DC Bias: Set the power supply voltage supplied to the target circuit.
  If you want to add another DC bias from an external amplifier, set the DC bias setting of the ZGA5920 to 0 V.

(Sweep)
- Sweep param: Frequency only.

5.18.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-33 Graph types of PSRR measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—PSRR	Frequency [Hz]	PSRR [dB]	○	—	—	
Frequency—θ	Frequency [Hz]	Phase [deg]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-34 Marker indication in PSRR measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
PSRR	dB	PSRR	
θ	deg	Phase	

5.18.4 Measure

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the PSRR characteristics are displayed in graphs.

The PSRR is determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{PSRR [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2}$$

The marker is displayed, and you can read the value at an arbitrary frequency.

5.19 Differential gain-differential phase measurement (amplifier circuit)

Measure the DC bias dependence of the gain and phase of a target amplifier circuit (amplifier). In origin, this is an evaluation item related to a composite video signal. This feature generalizes it as the DC bias dependence of the gain and phase of a target circuit.

5.19.1 Connecting with target circuit
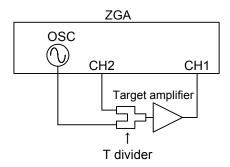
Figure 5-33 Connection example of differential gain/differential phase measurement

"Figure 5-33 Connection example of differential gain/differential phase measurement" shows an example of connecting with a target circuit. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.2.1 Connecting with target circuit".
Before measuring the transfer characteristics of the target circuit, perform the error compensation for measurement system (equalization) by a frequency sweep including the measurement frequency. See "4.2.3 Equalize".

5.19.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring gain-phase characteristics.

(Oscillator)
- Frequency: Set the measurement frequency.
- Amplitude: Set an amplitude that is not too large compared to the DC bias to be swept.

(Sweep)
- Sweep param: DC Bias only.

5.19.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-35 Graph types of differential gain/differential phase measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
DC Bias—DG	DC bias [V]	Differential gain [dB]	○	—	—	
DC Bias—DP	DC bias [V]	Differential phase [deg]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-36 Marker indication in differential gain/differential phase measurement

Display parameter	Unit	Description	Notes
DC Bias	V	DC bias	
DG	dB	Differential gain	
DP	deg	Differential phase	

5.19.4 Measure

Turn on the oscillator output, click the $\boxed{\text{Start measuring}}$ button to start measurement. When the measurement is finished, the differential gain/differential phase characteristics are displayed in graphs, where the X axis represents the DC bias.

The top graph shows DC bias [V]—gain [dB], and the bottom graph shows DC bias [V]—phase [deg]. The gain and phase are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \,, \quad \theta = \tan^{-1}\frac{B}{A}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep parameter (DC bias).

5.20 Saturation measurement

Measure and display the AC amplitude dependence of the gain of a target amplifier circuit (amplifier). The AC amplitude is swept to display the input signal level at which the gain is suppressed by 1 dB, and the I/O gain at that level.

5.20.1 Connecting with target circuit
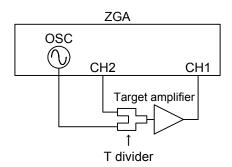
Figure 5-34 Connection example of saturation measurement

"Figure 5-34 Connection example of saturation measurement" shows an example of connecting with a target circuit. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.2.1 Connecting with target circuit".
Before measuring the transfer characteristics of the target circuit, perform the error compensation for measurement system (equalization) by a frequency sweep including the measurement frequency. See "4.2.3 Equalize".

5.20.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring saturation characteristics.

(Oscillator)
*   Frequency: Set the measurement frequency.
*   DC Bias: Set according to the target circuit.
(Sweep)
*   Sweep param: Amplitude only.

5.20.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-37 Graph types of saturation measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Amplitude—Gain	AC voltage [Vpk]	Gain [dB]	○	—	—	
Amplitude—θ	AC voltage [Vpk]	Phase [deg]	○	—	—	
Amplitude—ΔGain	AC voltage [Vpk]	Deviation from maximum gain [dB]	○	—	—	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-38 Marker indication in saturation measurement

Display parameter	Unit	Description	Notes
Amplitude	Vpk	AC amplitude	
Gain	dB	Gain	
θ	deg	Phase	
ΔGain	dB	Deviation from maximum gain	

5.20.4 Measure

Turn on the oscillator output, click the Start measuring button to start measurement. When the measurement is finished, the Δ gain characteristics with AC amplitude on the X axis are displayed in graphs. The Δ gain is a gain characteristic that is normalized with the maximum gain in the sweep measurement range as 0 dB.

The Δ gain is determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\Delta \text{ gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \text{ —(Maximum gain [dB])}$$

The following parameters searched from the measurement data are displayed.

- P1dB [Vpk]: Input amplitude of the target circuit when the gain falls by 1 dB from the maximum gain
- GainP1dB [dB]: I/O gain when the gain falls by 1 dB from the maximum gain

A marker is displayed in the graph of the measurement results. The marker moves along the sweep parameter (AC amplitude).

5.21 Filter measurement

Measure the frequency response of the I/O transfer characteristics of various filter circuits such as lowpass filter circuit, to display the gain, phase, and group delay. From the measurement data, the cutoff frequency and in-band ripple can be searched and displayed. You can also generate a transfer function (system identification from the frequency domain transfer characteristics) and save it in a text file. The generated transfer function can be compared to the designed transfer function.

5.21.1 Connecting with target circuit
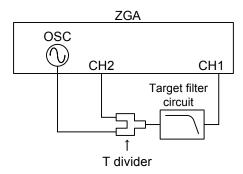
Figure 5-35 Connection example of filter circuit

"Figure 5-35 Connection example of filter circuit" shows an example of connecting with a target filter circuit. The figure is just an example of connection, and various measurement connections are supported depending on your purpose. See also "4.2.1 Connecting with target circuit".
Perform the error compensation for measurement system (equalization), before measuring the transfer characteristics of a target circuit. See "4.2.3 Equalize".

5.21.2 Setting

For details on basic settings, see "4.2.2 Setting gain-phase measurement". This section describes only points to be considered when measuring gain-phase characteristics.

(Sweep)
• Sweep param: Frequency only.
(Slow sweep):   Effective for the measurement of a steep filter. See "4.3.3 Slow sweep".

5.21.3 Graph and marker display

The graphs in the table below are displayed.

Table 5-39 Graph types of filter measurement

Graph type	X axis	Y axis	Measurement	Analysis	Simulation	Notes
Frequency—Gain	Frequency [Hz]	Gain [dB]	○	○	○	
Frequency—θ	Frequency [Hz]	Phase [deg]	○	○	○	
Frequency—GD	Frequency [Hz]	Group delay [s]	○	○	○	

The markers in the table below are displayed in graphs. The marker moves along the sweep target.

Table 5-40 Marker indication in filter measurement

Display parameter	Unit	Description	Notes
Frequency	Hz	Frequency	
Gain	dB	Gain	
Gain(Sim)	dB	Gain (Simulation data)	
θ	deg	Phase	
θ(Sim)	deg	Phase (Simulation data)	
GD	s	Group delay	
GD(Sim)	s	Group delay (Simulation data)	

5.21.4 Filter measurement

Turn on the oscillator output, click the Start measuring button to start measurement. When the measurement is finished, the gain-phase characteristics are displayed in graphs.

The parameters are determined through the following conversion using the complex gain (R=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2}, \quad \theta = \tan^{-1}\frac{B}{A}, \quad GD = \frac{\partial\theta_{[\text{rad}]}}{\partial\omega_{[\text{rad/s}]}}$$

A marker is displayed in the graph of the measurement results. The marker moves along the sweep target (Frequency).

The search results by filter type are also displayed.
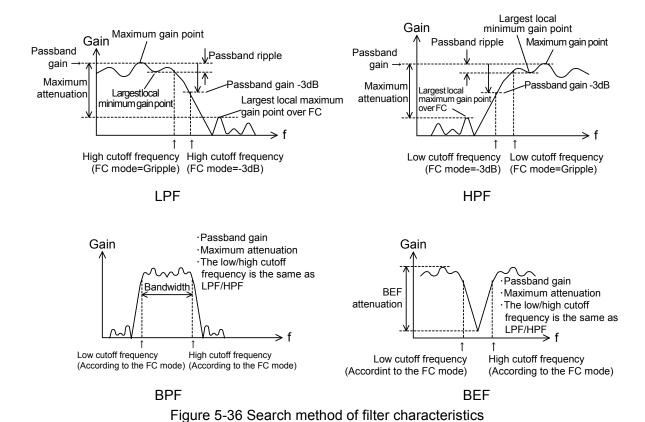
Table 5-41 Search display items by filter type

Displayed item	Filter type setting			
	LPF	HPF	BPF	BEF
FcLow (Low cutoff frequency [Hz])	×	○	○	○
FcHigh (High cutoff frequency [Hz])	○	×	○	○
GPath (Passband gain [dB])	○	○	○	○
GATT (Maximum attenuation [dB])	○	○	○	×
GRipple (Passband ripple [dB])	○	○	○	×
GBEF (BEF attenuation [dB])	×	×	×	○
Bandwidth [Hz]	×	×	○	×

There are two methods to search for the low cutoff frequency and high cutoff frequency. The following different frequencies are searched and displayed, according to the Fc mode setting.

Fc mode = -3dB: Frequency at which the gain is 3 dB lower than the passband gain

= GRipple:Frequency at which the attenuation exceeds the passband ripple

Figure 5-36 Search method of filter characteristics

These search start from the beginning of the sweep data, and show the first position that matches the search conditions. However, the displayed search result may not indicate the correct position, for example due to noise. In such case, click the search again buttons [◄] [►] next to each display item to search again and display the next (previous) position matching that matches the search conditions.

- Phase range: Select the display range of phase from the following four types:
    -180< θ ≤+180 deg: Displays the phase in the range of -180 to +180 deg.
    -360< θ ≤0 deg: Displays the phase in the range of -360 to 0 deg.
    0< θ ≤+360 deg: Displays the phase in the range of 0 to +360 deg.
    UNWRAP: Displays the unwrapped phase.
- Phase shift: Effective when the phase range is set to UNWRAP.
    [◄] :   Subtracts 360 deg from the current phase.
    [►] :   Adds 360 deg to the current phase.
- Aperture   The average movement distance (on the frequency axis) of the phase characteristic when measuring the group delay. This value is set by a number of measurement points.
                                 A larger aperture setting makes the group delay display smoother, but will lose steep changes (on the frequency axis).

5.21.5 Transfer function generation

To generate the transfer function of the gain/phase characteristics that is measured (or loaded from a file), set the conditions of model generation.

(Identification parameter)
- Algorithm: Select [A] or [B]. [A] is less accurate but less divergent (noise-tolerant), while [B] is highly accurate but more divergent (not noise-tolerant).

(Identification condition)
- Min, Max: If the noise increases in lower and higher frequency regions, this function excludes such noisy data from the calculation. Usually, set values according to the sweep measurement range.
- Order: An order to be used for the calculation. It tends to generate a more accurate model to set a larger value than the actual order.
- Start analyzing button: Click to calculate the transfer function with the conditions specified above. Save the calculated transfer function in a file.
  For details, see "6.3 Transfer function file format".

5.21.6 Simulation

When the transfer function generation is finished, you can perform the transfer function simulation to see how well the simulated data matches the actual measured data.

(Simulation)
- Min, Max: The frequency range to be used for simulation. They are automatically populated with the frequency range obtained from the measurement data, but you can change them arbitrarily.
- Point: The number of frequency points to be used for simulation.
- Interval: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To specify a transfer function file, select the transfer function in the measurement result data list at the input location for the transfer function.
- Start simulating button: Click to calculate the loop gain characteristics with the simulation conditions that you have set, and display it on a graph.

(Phase range / Group delay)
- Phase range: Select the display range of phase from the following four types: This setting affects both the measurement data and the simulation data.
  - $-180< \theta \leq +180$ deg: Displays the phase in the range of -180 to +180 deg.
  - $-360< \theta \leq 0$ deg: Displays the phase in the range of -360 to 0 deg.
  - $0< \theta \leq +360$ deg: Displays the phase in the range of 0 to +360 deg.
  - UNWRAP: Displays the unwrapped phase.
- Phase shift: Effective when the phase range is set to UNWRAP. This setting affects only the simulation data.
  - ◄ :   Subtracts 360 deg from the current phase.
  - ► :   Adds 360 deg to the current phase.
- Aperture: The average movement distance (on the frequency axis) of the phase characteristic when measuring the group delay. This value is set by a number of measurement points. This setting affects both the measurement data and the simulation data.

If there is a large difference between the measurement and simulation data, change the parameters such as the order. When you generate a circuit model again and click the Start simulating button, the recalculation will be performed to update the graph.

After the simulation is complete, the marker will be effective for the simulation data as well as the measurement result. The marker is displayed not only for the measurement data but for the simulation data. Note that the marker is displayed for the frequencies at which this simulation is performed. If the frequency points of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

In addition to the marker, the data search result is displayed. The result of searching the simulation data is displayed, instead of the measured data. For details on display items and settings, see "5.21.4 Filter measurement".

6. Files

6.1 Overview

In the ZGA5920, you can store the measurement data in the internal storage and read it later for analysis. You can also store the data in an external memory (USB memory) for use on a personal computer (e.g., by spreadsheet software). The ZGA5920 can export following file types.

- Measurement recipe   XML format   Measurement condition, and so on
- Measurement data file   XML format   Measurement result data, measurement condition, and so on
- Transfer function file   TXT format   Transfer function coefficients, and so on
- Report file   PDF format   Report output file
- Screen capture file   BMP format   Measurement screen capture image (including graph output)
- Analog signal input file   WDB format   Data logger data

This section describes each file format.

6.2 Measurement recipe and measurement result data formats

Description:

These files contain measurement conditions, correction data, and auto repeat measurement settings for each measurement application.

Format: XML

The XML file's tag structure is shown below.

● Common tags

Tag name			Description	Type	Notes
Header			Header	-	
	Version		File version information	String	x.x.x.x
	Application		Measurement application name	String	Name of each measurement application
	Type		File type	String	Recipe/Measure/Analysis/Simulation
	Name		File name	String	Any string
	Time		Measurement date/time	String	YYYY-MM-DDThh:mm:ss
Common			Common parameters for all measurement applications	-	
	ControlIOParameter		Control I/O setting	-	
		Input	Control I/O input signal acceptance	String	Enable/Disable
		ElapsedTime	Elapsed time since the start of measurement [s]	Integer	
	AnalogParameter		Analog signal input setting	-	
		Logging	Data logging enable/disable	String	Checkbox
		SamplingRate	Sampling rate	Integer	
		Start	Start logging (Start measuring/Output ON)	String	Start measuring/Output ON
		DelayTime	Delay time [s]	Integer	
		Stop	Stop logging (Complete measuring/Abort measuring/Output OFF/Logging time)	String	Complete measuring/Abort measuring/Output OFF/Logging time
		LoggingTime	Logging time [s]	Integer	
	Sequence1Parameter		Auto measurement condition 1	-	
		Start	Start parameter setting	-	
		OutputON	Oscillator output ON	String	Enable/Disable
		Frequency	Frequency at starting measurement	Real number	
		Amplitude	AC amplitude	Real number	
		DcBias	DC bias	Real number	
		Repeat	Repeat parameter setting	-	
		Cycle	Repeat times	Integer	
		Frequency	Frequency	Real number	
		Amplitude	AC amplitude	Real number	
		DcBias	DC bias	Real number	
		Graph	Graph overlaid	String	Enable/Disable
		Stop	Stop parameter setting	-	
		OutputOFF	Oscillator output OFF at completing measurement	String	Enable/Disable
		Frequency	Frequency	Real number	

Tag name				Description	Type	Notes
		Amplitude		AC amplitude	Real number	
		DcBias		DC bias	Real number	
	Sequence2Parameter			Auto measurement condition 2	-	
		Start		Start parameter setting	-	
			OutputON	Oscillator output ON	String	Enable/Disable
			Frequency	Frequency	Real number	
			Amplitude	AC amplitude	Real number	
			DcBias	DC bias	Real number	
		Repeat		Repeat parameter setting	-	
			Cycle	Repeat times	Integer	
			Frequency	Frequency	Real number	
			Amplitude	AC amplitude	Real number	
			DcBias	DC bias	Real number	
			Graph	Graph overlaid	String	Enable/Disable
		Stop		Stop parameter setting	-	
			OutputOFF	Oscillator output OFF	String	Enable/Disable
			Frequency	Frequency	Real number	
			Amplitude	AC amplitude	Real number	
			DcBias	DC bias	Real number	
	CorrectParameter			Correction condition	-	
		Open		Open correction	String	Enable/Disable
		Short		Short correction	String	Enable/Disable
		Equalize		Equalization	String	Enable/Disable
	OpenParameter			Open correction measurement setting condition	-	Same as "Measure1Parameter" of the measurement condition tag
	ShortParameter			Short correction measurement setting condition	-	Same as "Measure1Parameter" of the measurement condition tag
	EqualizeParameter			Equalization measurement setting parameter	-	Same as "Measure1Parameter" of the measurement condition tag
	OpenData			Open correction data	-	
		Data		Data point	-	Up to 20,000 data points
			Frequency	Frequency	Real number	
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
	ShortData			Short correction data	-	
		Data		Data point	-	Up to 20,000 data points
			Frequency	Frequency	Real number	
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
	EqualizeData			Equalization data	-	
		Data		Data point	-	Up to 20,000 data points
			Frequency	Frequency	Real number	
			A	Real part of complex gain	Real number	
			B	Imaginary part of complex gain	Real number	
	GraphSetting			Graph setting	-	
		GraphN		n^{th} graph setting	-	n = 1 to 6
			Data	Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
				YAxis	Y axis setting	-	

Tag name				Description	Type	Notes
			Max	Maximum value	Real number	
			Min	Minimum value	Real number	
			Scale	Scale	String	Lin/Log/-Lin/-Log
			Title	Axis title	String	Any string
	NumericSetting			Numeric input setting	-	
		Measure		Numeric input setting for measurement	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 14
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		MeasureAd		Numeric input setting for advanced setting	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 16
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		Open		Numeric input setting for open correction	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 14
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		OpenAd		Numeric input setting for advanced open correction setting	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 16
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		Short		Numeric input setting for short correction	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 14
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		ShortAd		Numeric input setting for advanced short correction setting	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 16
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		Equalize		Numeric input setting for equalization	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 14
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		EqualizeAd		Numeric input setting for advanced equalization setting	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 16
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		ControlIO		Control I/O setting pallet	-	
			ParameterN	n^{th} numeric input	-	n = 1
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		Analog		Analog setting pallet	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 3
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
		Sequence		Auto-exec setting pallet	-	
			ParameterN	n^{th} numeric input	-	n = 1 to 10
			Data	Setting data	-	
			UnitIndex	Index of auxiliary unit for display	Integer	
Application				Dependent on measurement application	-	See the tag description for each measurement application.

● Measurement condition tags

Tag name	Description	Type	Notes
Measure1Parameter	Measurement condition 1	-	
SweParam	Sweep parameter	String	Frequency/Amplitude/DCBias/ZeroSpan
Fstart	Starting frequency	Real number	
Fstop	Stopping frequency	Real number	
Astart	Starting AC amplitude	Real number	
Astop	Stopping AC amplitude	Real number	
Dstart	Starting DC bias	Real number	
Dstop	Stopping DC bias	Real number	
Zstop	Zero span measurement time	Real number	
Point	Number of measurement points	Integer	
Interval	Measurement interval	String	Lin/Log
SlowItem	monitoring item for slow sweep	String	LogR/R/θ/A/B/OFF
SlowCh	Monitored measurement signal input	String	CH1/CH2
SlowVarLogR	Variation (LogR)	Real number	
SlowVarR	Variation (R)	Real number	
SlowVarTheta	Variation (θ)	Real number	
SlowVarA	Variation (A)	Real number	
SlowVarB	Variation (B)	Real number	
IntegParam	Integration type	String	Cycle/Time
IntegCycle	Integration cycle	Integer	
IntegTime	Integration time	Real number	
DelayParam	Delay type	String	Cycle/Time
DelayCycle	Delay cycle	Integer	
DelayTime	Delay time	Real number	
Ch1Factor	CH1 weight	Real number	
Ch2Factor	CH2 weight	Real number	
Invert	Phase invert	String	OFF/ON
ExtAmpGain	External amplifier gain	Real number	
Freq	Frequency	Real number	
Ampl	AC amplitude	Real number	
Dc	DC bias	Real number	
AnytimeOn	Output after measurement	String	OFF/ON
CompressionMode	Monitored measurement signal input	String	OFF/CH1/CH2
CompressionAmplitude	Target level	Real number	
CompressionLimit	Max output voltage	Real number	
CompressionError	Measurement tolerance	Integer	
CompressionRetry	Max repeat times	Integer	
CompressionCorrection	Correction voltage coefficient	Integer	
Ch1Over	Measurement signal input CH1	Integer	
Ch2Over	Measurement signal input CH2	Integer	
OverMode	Action upon detection	String	None/Stop sweep/Output OFF

6.2 Measurement recipe and measurement result data formats

Tag name	Description	Type	Notes
Measure2Parameter	Measurement condition 2	-	
SweParam	Sweep parameter	String	Frequency/Amplitude/DCBias/Zero Span
Fstart	Starting frequency	Real number	
Fstop	Stopping frequency	Real number	
Astart	Starting AC amplitude	Real number	
Astop	Stopping AC amplitude	Real number	
Dstart	Starting DC bias	Real number	
Dstop	Stopping DC bias	Real number	
Zstop	Zero span measurement time	Real number	
Point	Number of measurement points	Integer	
Interval	Measurement interval	String	Lin/Log
SlowItem	monitoring item for slow sweep	String	LogR/R/θ/A/B/OFF
SlowCh	Monitored measurement signal input	String	CH1/CH2
SlowVarLogR	Variation (LogR)	Real number	
SlowVarR	Variation (R)	Real number	
SlowVarTheta	Variation (θ)	Real number	
SlowVarA	Variation (A)	Real number	
SlowVarB	Variation (B)	Real number	
IntegParam	Integration type	String	Cycle/Time
IntegCycle	Integration cycle	Integer	
IntegTime	Integration time	Real number	
DelayParam	Delay type	String	Cycle/Time
DelayCycle	Delay cycle	Integer	
DelayTime	Delay time	Real number	
Ch1Factor	CH1 weight	Real number	
Ch2Factor	CH2 weight	Real number	
Invert	Phase invert	String	OFF/ON
ExtAmpGain	External amplifier gain	Real number	
Freq	Frequency	Real number	
Ampl	AC amplitude	Real number	
Dc	DC bias	Real number	
AnytimeOn	Output after measurement	String	OFF/ON
CompressionMode	Monitored measurement signal input	String	OFF/CH1/CH2
CompressionAmplitude	Target level	Real number	
CompressionLimit	Max output voltage	Real number	
CompressionError	Measurement tolerance	Integer	
CompressionRetry	Max repeat times	Integer	
CompressionCorrection	Correction voltage coefficient	Integer	
Ch1Over	Measurement signal input CH1	Integer	
Ch2Over	Measurement signal input CH2	Integer	
OverMode	Action upon detection	String	None/Stop sweep/Output OFF

● Piezoelectric measurement tags

Tag name	Description	Type	Notes
Application	Measurement application-specific information	-	
Measure1Parameter	Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
AnalysisParameter	Analysis condition	-	
CdMode	Cd mode	String	HighFrequency/Gmax/Bmax_min
AL	AL value	Real number	
SimulationParameter	Simulation condition	-	
Cd	Damping capacitance	Real number	
C1	Equivalent electrostatic capacitance of piezoelectric mechanical vibration	Real number	
L1	Equivalent inductance of piezoelectric mechanical vibration	Real number	
R1	Equivalent resistance of mechanical vibration loss	Real number	
Fmin	Minimum value of simulation frequency range	Real number	
Fmax	Maximum value of simulation frequency range	Real number	
Point	Number of sampling points	Integer	
Interval	Interval of sampling points	String	Lin/Log
Measure1Data	Measurement data	-	
SweParam	Sweep parameter	String	Frequency/ZeroSpan
Data	Measurement data	-	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
A	Real part of complex impedance	Real number	
B	Imaginary part of complex impedance	Real number	
Z	Absolute value of impedance	Real number	
Y	Absolute value of admittance	Real number	
Pz	Phase of impedance	Real number	
Py	Phase of admittance	Real number	
Gc	Conductance	Real number	
Bc	Susceptance	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name				Description	Type	Notes
AnalysisData				Analysis data	-	
	fs			Mechanical series resonance frequency	Real number	
	fp			Mechanical parallel resonance frequency	Real number	
	fr			Resonance frequency	Real number	
	fa			Antiresonant frequency	Real number	
	fm			Maximum admittance point	Real number	
	fn			Minimum admittance point	Real number	
	f1			Maximum susceptance point	Real number	
	f2			Minimum susceptance point	Real number	
	Cd			Damping capacitance	Real number	
	C1			Equivalent electrostatic capacitance of piezoelectric mechanical vibration	Real number	
	L1			Equivalent inductance of piezoelectric mechanical vibration	Real number	
	R1			Equivalent resistance of mechanical vibration loss	Real number	
	Qm			Mechanical quality factor	Real number	
	Ls			Series matching inductance	Real number	
	Lp			Parallel matching inductance	Real number	
	Ns			Number of coil turns for deriving series matching inductance	Integer	
	Np			Number of coil turns for deriving parallel matching inductance	Integer	
SimulationData				Simulation data	-	
	SweParam			Sweep parameter	String	Frequency
	Data			Simulation data	-	Up to 20,000 data points
		Frequency		Oscillator frequency	Real number	
		Amplitude		Oscillator AC amplitude	Real number	
		DcBias		Oscillator DC bias	Real number	
		Time		Time	String	YYYY/MM/DD hh:mm:ss
		A		Real part of complex impedance	Real number	
		B		Imaginary part of complex impedance	Real number	
		Z		Absolute value of impedance	Real number	
		Y		Absolute value of admittance	Real number	
		Pz		Phase of impedance	Real number	
		Py		Phase of admittance	Real number	
		Gc		Conductance	Real number	
		Bc		Susceptance	Real number	
GraphSetting				Graph setting	-	
	GraphN			nth graph setting	-	n = 1 to 3
		Data		Setting data	-	
			AutoScale	Auto scale	String	Enable/Disable
			Title	Graph title	String	Any string
			XAxis	X axis setting	-	
			Max	Maximum value	Real number	
			Min	Minimum value	Real number	
			Scale	Scale	String	Lin/Log/-Lin/-Log
			Title	Axis title	String	Any string
			YAxis	Y axis setting	-	
			Max	Maximum value	Real number	
			Min	Minimum value	Real number	
			Scale	Scale	String	Lin/Log/-Lin/-Log
			Title	Axis title	String	Any string

6.2 Measurement recipe and measurement result data formats

Tag name					Description	Type	Notes
	AGraphN				nth advanced graph setting	-	n = 1 to 5
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
NumericSetting					Numeric input setting	-	
	Analysis				Numeric input setting for analysis	-	
		ParameterN			nth numeric input	-	n = 1
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	
	Simulation				Numeric input setting for simulation	-	
		ParameterN			nth numeric input	-	n = 1 to 7
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	

● Dielectric measurement tags

Tag name				Description	Type	Notes
Application				Measurement application-specific information	-	
	Measure1Parameter			Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter			Analysis condition	-	
		S		Electrode area	Real number	
		t		Electrode distance	Real number	
	Measure1Data			Measurement data	-	
		SweParam		Sweep parameter	String	Frequency/ZeroSpan/DCBias
		Data		Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			Cp	Parallel capacitance	Real number	
			Rp	Parallel resistance	Real number	
			Es	Relative dielectric permittivity	Real number	
			TD	Dissipation factor	Real number	
			EsR	Real part of complex relative dielectric permittivity	Real number	
			EsI	Imaginary part of complex relative dielectric permittivity	Real number	
	AnalysisData			Analysis data	-	
		SweParam		Sweep parameter	String	Frequency/ZeroSpan/DCBias
		Data		Dielectric permittivity derivation data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			Cp	Parallel capacitance	Real number	
			Rp	Parallel resistance	Real number	
			Es	Relative dielectric permittivity	Real number	
			TD	Dissipation factor	Real number	
			EsR	Real part of complex relative dielectric permittivity	Real number	
			EsI	Imaginary part of complex relative dielectric permittivity	Real number	

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	n^{th} graph setting	-	n = 1 to 8
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	n^{th} advanced graph setting	-	n = 1 to 8
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
NumericSetting	Numeric input setting	-	
Analysis	Numeric input setting for analysis	-	
ParameterN	n^{th} numeric input	-	n = 1 to 2
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	

● Magnetic measurement tags

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter		Analysis condition	-	
		S	Core area	Real number	
		l	Core magnetic path length	Real number	
		N	Number of coil turns	Integer	
		d	Winding diameter	Real number	
		len	Winding around length	Real number	
		rho	Winding resistivity	Real number	
	Measure1Data		Measurement data	-	
		SweParam	Sweep parameter	String	Frequency/ZeroSpan/DCBias
		Data	Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			Ls	Series inductance	Real number	
			Rs	Series resistance	Real number	
			Us	Relative magnetic permeability	Real number	
			TD	Dissipation factor	Real number	
			UsR	Real part of complex relative magnetic permeability	Real number	
			UsI	Imaginary part of complex relative magnetic permeability	Real number	
	AnalysisData		Analysis data	-	
		SweParam	Sweep parameter	String	Frequency/ZeroSpan/DCBias
		Data	Magnetic permeability derivation data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			Ls	Series inductance	Real number	
			Rs	Series resistance	Real number	
			Us	Relative magnetic permeability	Real number	
			TD	Dissipation factor	Real number	
			UsR	Real part of complex relative magnetic permeability	Real number	
			UsI	Imaginary part of complex relative magnetic permeability	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	nth graph setting	-	n = 1 to 8
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	nth advanced graph setting	-	n = 1 to 8
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
NumericSetting	Numeric input setting	-	
Analysis	Numeric input setting for analysis	-	
ParameterN	nth numeric input	-	n = 1 to 6
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	

● Inductor measurement

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter		Analysis condition		
		Circuit	Equivalent circuit type	String	Inductor(lossy core)/Inductor or resistor/Resistor(high resistance)/ Capacitor/Resonator
	SimulationParameter		Simulation condition	-	
		Circuit	Equivalent circuit type	String	Inductor(lossy core)/Inductor or resistor/Resistor(high resistance)/ Capacitor/Resonator
		C0	Equivalent electrostatic capacitance C0	Real number	
		C1	Equivalent electrostatic capacitance C1	Real number	
		L1	Equivalent inductance L1	Real number	
		R1	Equivalent resistance R1	Real number	
		Fmin	Minimum value of simulation frequency range	Real number	
		Fmax	Maximum value of simulation frequency range	Real number	
		Point	Number of sampling points	Integer	
		Interval	Interval of sampling points	String	Lin/Log
	Measure1Data		Measurement data	-	
		SweParam	Sweep parameter	String	Frequency/ZeroSpan/DCBias/ Amplitude
		Data	Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			Ls	Series inductance	Real number	
			Rs	Series resistance	Real number	
			Ps	Phase in series equivalent circuit	Real number	
			Q	Quality factor	Real number	
			Lp	Parallel inductance	Real number	
			Rp	Parallel resistance	Real number	
			Pp	Phase in parallel equivalent circuit	Real number	
			D	Dissipation factor	Real number	
	AnalysisData		Analysis result	-	
		C0	Equivalent electrostatic capacitance C0	Real number	
		C1	Equivalent electrostatic capacitance C1	Real number	
		L1	Equivalent inductance L1	Real number	
		R1	Equivalent resistance R1	Real number	

Tag name					Description	Type	Notes
SimulationData					Simulation data	-	
	SweParam				Sweep parameter	String	Frequency
	Data				Simulation data	-	Up to 20,000 data points
		Frequency			Oscillator frequency	Real number	
		Amplitude			Oscillator AC amplitude	Real number	
		DcBias			Oscillator DC bias	Real number	
		Time			Time	String	YYYY/MM/DD hh:mm:ss
		A			Real part of complex impedance	Real number	
		B			Imaginary part of complex impedance	Real number	
		Z			Absolute value of impedance	Real number	
		Pz			Phase of impedance	Real number	
		Ls			Series inductance	Real number	
		Rs			Series resistance	Real number	
		Ps			Phase in series equivalent circuit	Real number	
		Q			Quality factor	Real number	
		Lp			Parallel inductance	Real number	
		Rp			Parallel resistance	Real number	
		Pp			Phase in parallel equivalent circuit	Real number	
		D			Dissipation factor	Real number	
GraphSetting					Graph setting	-	
	GraphN				n^{th} graph setting	-	n = 1 to 4
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
	AGraphN				n^{th} advanced graph setting	-	n = 1 to 10
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
NumericSetting					Numeric input setting	-	
	Simulation				Numeric input setting for simulation	-	
		ParameterN			n^{th} numeric input	-	n = 1 to 7
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	

● Capacitor measurement tags

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter		Analysis condition		
		Circuit	Equivalent circuit type	String	Inductor(lossy core)/Inductor or resistor/Resistor(high resistance)/ Capacitor/Resonator
	SimulationParameter		Simulation condition	-	
		Circuit	Equivalent circuit type	String	Inductor(lossy core)/Inductor or resistor/Resistor(high resistance)/ Capacitor/Resonator
		C0	Equivalent electrostatic capacitance C0	Real number	
		C1	Equivalent electrostatic capacitance C1	Real number	
		L1	Equivalent inductance L1	Real number	
		R1	Equivalent resistance R1	Real number	
		Fmin	Minimum value of simulation frequency range	Real number	
		Fmax	Maximum value of simulation frequency range	Real number	
		Point	Number of sampling points	Integer	
		Interval	Interval of sampling points	String	Lin/Log
	Measure1Data		Measurement data	-	
		SweParam	Sweep parameter	String	Frequency/ZeroSpan/DCBias/ Amplitude
		Data	Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			Cs	Series electrostatic capacitance	Real number	
			Rs	Series resistance	Real number	
			Ps	Phase in series equivalent circuit	Real number	
			Q	Quality factor	Real number	
			Cp	Parallel electrostatic capacitance	Real number	
			Rp	Parallel resistance	Real number	
			Pp	Phase in parallel equivalent circuit	Real number	
			D	Dissipation factor	Real number	
	AnalysisData		Analysis result	-	
		C0	Equivalent electrostatic capacitance C0	Real number	
		C1	Equivalent electrostatic capacitance C1	Real number	
		L1	Equivalent inductance L1	Real number	
		R1	Equivalent resistance R1	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name					Description	Type	Notes
SimulationData					Simulation data	-	
	SweParam				Sweep parameter	String	Frequency
	Data				Simulation data	-	Up to 20,000 data points
		Frequency			Oscillator frequency	Real number	
		Amplitude			Oscillator AC amplitude	Real number	
		DcBias			Oscillator DC bias	Real number	
		Time			Time	String	YYYY/MM/DD hh:mm:ss
		A			Real part of complex impedance	Real number	
		B			Imaginary part of complex impedance	Real number	
		Z			Absolute value of impedance	Real number	
		Pz			Phase of impedance	Real number	
		Cs			Series electrostatic capacitance	Real number	
		Rs			Series resistance	Real number	
		Ps			Phase in series equivalent circuit	Real number	
		Q			Quality factor	Real number	
		Cp			Parallel electrostatic capacitance	Real number	
		Rp			Parallel resistance	Real number	
		Pp			Phase in parallel equivalent circuit	Real number	
		D			Dissipation factor	Real number	
GraphSetting					Graph setting	-	
	GraphN				n^{th} graph setting	-	n = 1 to 4
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
	AGraphN				n^{th} advanced graph setting	-	n = 1 to 10
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
NumericSetting					Numeric input setting	-	
	Simulation				Numeric input setting for simulation	-	
		ParameterN			n^{th} numeric input	-	n = 1 to 7
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	

● Resistor measurement tags

Tag name				Description	Type	Notes
Application				Measurement application-specific information	-	
	Measure1Parameter			Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter			Analysis condition	-	
		Circuit		Equivalent circuit type	String	Inductor(lossy core)/Inductor or resistor/Resistor(high resistance)/ Capacitor/Resonator
	SimulationParameter			Simulation condition	-	
		Circuit		Equivalent circuit type	String	Inductor(lossy core)/Inductor or resistor/Resistor(high resistance)/ Capacitor/Resonator
		C0		Equivalent electrostatic capacitance C0	Real number	
		C1		Equivalent electrostatic capacitance C1	Real number	
		L1		Equivalent inductance L1	Real number	
		R1		Equivalent resistance R1	Real number	
		Fmin		Minimum value of simulation frequency range	Real number	
		Fmax		Maximum value of simulation frequency range	Real number	
		Point		Number of sampling points	Integer	
		Interval		Interval of sampling points	String	Lin/Log
	Measure1Data			Measurement data	-	
		SweParam		Sweep parameter	String	Frequency/ZeroSpan/DCBias/ Amplitude
		Data		Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			R	Resistance	Real number	
			X	Reactance	Real number	
	AnalysisData			Analysis result	-	
		C0		Equivalent electrostatic capacitance C0	Real number	
		C1		Equivalent electrostatic capacitance C1	Real number	
		L1		Equivalent inductance L1	Real number	
		R1		Equivalent resistance R1	Real number	
	SimulationData			Simulation data	-	
		SweParam		Sweep parameter	String	Frequency
		Data		Simulation data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of complex impedance	Real number	
			B	Imaginary part of complex impedance	Real number	
			Z	Absolute value of impedance	Real number	
			Pz	Phase of impedance	Real number	
			R	Resistance	Real number	
			X	Reactance	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	nth graph setting	-	n = 1 to 4
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	nth advanced graph setting	-	n = 1 to 4
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
NumericSetting	Numeric input setting	-	
Simulation	Numeric input setting for simulation	-	
ParameterN	nth numeric input	-	n = 1 to 7
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	

● Transformer leakage inductance measurement tags

Tag name	Description	Type	Notes
Application	Measurement application-specific information	-	
Measure1Parameter	Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
Measure1Data	Measurement data	-	
SweParam	Sweep parameter	String	Frequency/ZeroSpan
Data	Measurement data	-	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
A	Real part of complex impedance	Real number	
B	Imaginary part of complex impedance	Real number	
Lleak	Leakage inductance	Real number	
Z	Absolute value of impedance	Real number	
Pz	Phase of impedance	Real number	
GraphSetting	Graph setting	-	
GraphN	n^{th} graph setting	-	n = 1 to 3
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	n^{th} advanced graph setting	-	n = 1 to 3
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string

● Transformer mutual inductance measurement tags

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Aiding connection characteristics measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure2Parameter		Opposing connection characteristics measurement condition	-	Same as "Measure2Parameter" of the measurement condition tag
	Measure1Data		Aiding connection characteristics measurement data	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Aiding connection characteristics measurement data	-	Up to 20,000 data points
		Frequency	Oscillator frequency	Real number	
		Amplitude	Oscillator AC amplitude	Real number	
		DcBias	Oscillator DC bias	Real number	
		Time	Time	String	YYYY/MM/DD hh:mm:ss
		A	Real part of complex impedance	Real number	
		B	Imaginary part of complex impedance	Real number	
		La	Inductance of aiding connection characteristics	Real number	
		Z	Absolute value of impedance	Real number	
		Pz	Phase of impedance	Real number	
	Measure2Data		Opposing connection characteristics measurement data	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Opposing connection characteristics measurement data	-	Up to 20,000 data points
		Frequency	Oscillator frequency	Real number	
		Amplitude	Oscillator AC amplitude	Real number	
		DcBias	Oscillator DC bias	Real number	
		Time	Time	String	YYYY/MM/DD hh:mm:ss
		A	Real part of complex impedance	Real number	
		B	Imaginary part of complex impedance	Real number	
		Lo	Inductance of opposing connection characteristics	Real number	
		Z	Absolute value of impedance	Real number	
		Pz	Phase of impedance	Real number	
	AnalysisData		Analysis data	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Mutual inductance calculation data	-	Up to 20,000 data points
		Frequency	Oscillator frequency	Real number	
		Amplitude	Oscillator AC amplitude	Real number	
		DcBias	Oscillator DC bias	Real number	
		Time	Time	String	YYYY/MM/DD hh:mm:ss
		M	Mutual inductance	Real number	

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	n[th] graph setting	-	n = 1 to 7
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	n[th] advanced graph setting	-	n = 1 to 7
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string

● Transformer coupling inductance measurement tags

Tag name	Description	Type	Notes
Application	Measurement application-specific information	-	
Measure1Parameter	Short secondary measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
Measure2Parameter	Open secondary measurement condition	-	Same as "Measure2Parameter" of the measurement condition tag
Measure1Data	Short secondary measurement data	-	
SweParam	Sweep parameter	String	Frequency
Data	Short secondary measurement data	-	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
A	Real part of complex impedance	Real number	
B	Imaginary part of complex impedance	Real number	
Ls	Inductance with the short secondary	Real number	
Z	Absolute value of impedance	Real number	
Pz	Phase of impedance	Real number	
Measure2Data	Open secondary measurement data	-	
SweParam	Sweep parameter	String	Frequency
Data	Open secondary measurement data	-	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
A	Real part of complex impedance	Real number	
B	Imaginary part of complex impedance	Real number	
Lo	Inductance with the open secondary	Real number	
Z	Absolute value of impedance	Real number	
Pz	Phase of impedance	Real number	
AnalysisData	Analysis data	-	
SweParam	Sweep parameter	String	Frequency
Data	Coupling coefficient calculation data	-	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
k	Coupling coefficient	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name						Description	Type	Notes
GraphSetting						Graph setting	-	
	GraphN					n^{th} graph setting	-	n = 1 to 7
		Data				Setting data	-	
			AutoScale			Auto scale	String	Enable/Disable
			Title			Graph title	String	Any string
			XAxis			X axis setting	-	
				Max		Maximum value	Real number	
				Min		Minimum value	Real number	
				Scale		Scale	String	Lin/Log/-Lin/-Log
				Title		Axis title	String	Any string
			YAxis			Y axis setting	-	
				Max		Maximum value	Real number	
				Min		Minimum value	Real number	
				Scale		Scale	String	Lin/Log/-Lin/-Log
				Title		Axis title	String	Any string
	AGraphN					n^{th} advanced graph setting	-	n = 1 to 7
		Data				Setting data	-	
			AutoScale			Auto scale	String	Enable/Disable
			Title			Graph title	String	Any string
			XAxis			X axis setting	-	
				Max		Maximum value	Real number	
				Min		Minimum value	Real number	
				Scale		Scale	String	Lin/Log/-Lin/-Log
				Title		Axis title	String	Any string
			YAxis			Y axis setting	-	
				Max		Maximum value	Real number	
				Min		Minimum value	Real number	
				Scale		Scale	String	Lin/Log/-Lin/-Log
				Title		Axis title	String	Any string

● Transformer turns ratio measurement tags

Tag name					Description	Type	Notes
Application					Measurement application-specific information	-	
	Measure1Parameter				Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure1Data				Measurement data	-	
		SweParam			Sweep parameter	String	Frequency/ZeroSpan
		Data			Measurement data	-	Up to 20,000 data points
			Frequency		Oscillator frequency	Real number	
			Amplitude		Oscillator AC amplitude	Real number	
			DcBias		Oscillator DC bias	Real number	
			Time		Time	String	YYYY/MM/DD hh:mm:ss
			A		Real part of complex gain	Real number	
			B		Imaginary part of complex gain	Real number	
			N		Turns ratio	Real number	
			Gain		Transfer gain	Real number	
			P		Phase	Real number	
	GraphSetting				Graph setting	-	
		GraphN			n^{th} graph setting	-	n = 1 to 3
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
		AGraphN			n^{th} advanced graph setting	-	n = 1 to 3
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string

● Varactor diode measurement tags

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	SimulationParameter		Simulation condition	-	
		C0	Tuning circuit capacitance C0	Real number	
		C1	Tuning circuit capacitance C1	Real number	
		L	Tuning circuit inductance L	Real number	
	Measure1Data		Measurement data	-	
		SweParam	Sweep parameter	String	Frequency/ZeroSpan/DCBias
		Data	Measurement data	-	Up to 20,000 data points
		Frequency	Oscillator frequency	Real number	
		Amplitude	Oscillator AC amplitude	Real number	
		DcBias	Oscillator DC bias	Real number	
		Time	Time	String	YYYY/MM/DD hh:mm:ss
		A	Real part of complex impedance	Real number	
		B	Imaginary part of complex impedance	Real number	
		Cp	Parallel capacitance	Real number	
		Q	Quality factor	Real number	
		Z	Absolute value of impedance	Real number	
		Pz	Phase of impedance	Real number	
		Freq_res	Tuning frequency	Real number	
	SimulationData		Simulation data	-	
		SweParam	Sweep parameter	String	ZeroSpan/DCBias
		Data	Tuning characteristics simulation data	-	Up to 20,000 data points
		Frequency	Oscillator frequency	Real number	
		Amplitude	Oscillator AC amplitude	Real number	
		DcBias	Oscillator DC bias	Real number	
		Time	Time	String	YYYY/MM/DD hh:mm:ss
		A	Real part of complex impedance	Real number	
		B	Imaginary part of complex impedance	Real number	
		Cp	Parallel capacitance	Real number	
		Q	Quality factor	Real number	
		Z	Absolute value of impedance	Real number	
		Pz	Phase of impedance	Real number	
		Freq_res	Tuning frequency	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name					Description	Type	Notes
GraphSetting					Graph setting	-	
	GraphN				nth graph setting	-	n = 1 to 5
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
	AGraphN				nth advanced graph setting	-	n = 1 to 5
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
NumericSetting					Numeric input setting	-	
	Simulation				Numeric input setting for simulation	-	
		ParameterN			nth numeric input	-	n = 1 to 3
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	

● Servo feedback loop measurement tags

Tag name				Description	Type	Notes
Application				Measurement application-specific information	-	
	Measure1Parameter			Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter			Analysis condition	-	
		Algorithm		Generation algorithm	String	Algorithm A/Algorithm B
		Order		Order	Integer	
		Fmin		Minimum frequency for model generation conditions	Real number	
		Fmax		Maximum frequency for model generation conditions	Real number	
	SimulationParameter			Simulation condition	-	
		Name		Transfer function file name	String	YYYYMMDDhhmmss
		Num		Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den		Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		Fmin		Minimum value of simulation frequency range	Real number	
		Fmax		Maximum value of simulation frequency range	Real number	
		Point		Number of sampling points	Integer	
		Interval		Interval of sampling points	String	Lin/Log
	Measure1Data			Measurement data	-	
		SweParam		Sweep parameter	String	Frequency
		Data		Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	
	AnalysisData			Analysis data	-	
		Num		Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den		Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
	SimulationData			Simulation data	-	
		SweParam		Sweep parameter	String	Frequency
		Data		Simulation data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	

Tag name					Description	Type	Notes
GraphSetting					Graph setting	-	
	GraphN				n^{th} graph setting	-	n = 1 to 3
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
	AGraphN				n^{th} advanced graph setting	-	n = 1 to 4
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
NumericSetting					Numeric input setting	-	
	Analysis				Numeric input setting for analysis	-	
		ParameterN			n^{th} numeric input	-	n = 1 to 3
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	
	Simulation				Numeric input setting for simulation	-	
		ParameterN			n^{th} numeric input	-	n = 1 to 3
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	

● Servo closed loop gain measurement tags

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Loop gain measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure2Parameter		Feedback transfer function measurement condition	-	Same as "Measure2Parameter" of the measurement condition tag
	AnalysisParameter		Analysis condition	-	
		FeedBackGain	Feedback transfer function type	String	Measurement/Const
		Constant	Feedback transfer function constant value	Real number	
		OutputData	Output	String	Close loop gain/Open loop gain
		Algorithm	Generation algorithm	String	Algorithm A/Algorithm B
		Order	Order	Integer	
		Fmin	Minimum frequency for model generation conditions	Real number	
		Fmax	Maximum frequency for model generation conditions	Real number	
	SimulationParameter		Simulation condition		
		Name	Transfer function file name	String	YYYYMMDDhhmmss
		Num	Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den	Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		Fmin	Minimum value of simulation frequency range	Real number	
		Fmax	Maximum value of simulation frequency range	Real number	
		Point	Number of sampling points	Integer	
		Interval	Interval of sampling points	String	Lin/Log
	Measure1Data		Loop gain measurement data	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Loop gain measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	
	Measure2Data		Feedback transfer function measurement condition	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Feedback transfer function measurement condition	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name			Description	Type	Notes
	AnalysisData		Analysis data	-	
		Num	Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den	Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		k	Gain coefficient for transfer function in pole-zero format	Real number	
		Zr	Zero real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zr": 5 to 20
		Zi	Zero imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zi": 5 to 20
		Pr	Pole real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pr": 5 to 20
		Pi	Pole imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pi": 5 to 20
		Sa	Row of matrix A for transfer function in state space format	Real number	Number of elements in the real array "Sa": 25 to 400
		Sb	Column vector B for transfer function in state space format	Real number	Number of elements in the real array "Sb": 5 to 20
		Sc	Row vector C for transfer function in state space format	Real number	Number of elements in the real array "Sc": 5 to 20
		Sd	Scalar D for transfer function in state space format	Real number	
		SweParam	Sweep parameter	String	Frequency
		Data	Conversion data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	
	SimulationData		Simulation result	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Simulation result of conversion data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	n^{th} graph setting	-	n = 1 to 12
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	n^{th} advanced graph setting	-	n = 1 to 12
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
NumericSetting	Numeric input setting	-	
Analysis	Numeric input setting for analysis	-	
ParameterN	n^{th} numeric input	-	n = 1 to 4
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	
Simulation	Numeric input setting for simulation	-	
ParameterN	n^{th} numeric input	-	n = 1 to 3
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	

● Servo open loop gain measurement tags

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Closed loop gain measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure2Parameter		Feedback transfer function measurement condition	-	Same as "Measure2Parameter" of the measurement condition tag
	AnalysisParameter		Analysis condition	-	
		FeedBackGain	Feedback transfer function type	String	Measurement/Const
		Constant	Feedback transfer function constant value	Real number	
		OutputData	Output	String	Open loop gain/Loop gain
		Algorithm	Generation algorithm	String	Algorithm A/Algorithm B
		Order	Order	Integer	
		Fmin	Minimum frequency for model generation conditions	Real number	
		Fmax	Maximum frequency for model generation conditions	Real number	
	SimulationParameter		Simulation condition	-	
		Name	Transfer function file name	String	YYYYMMDDhhmmss
		Num	Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den	Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		Fmin	Minimum value of simulation frequency range	Real number	
		Fmax	Maximum value of simulation frequency range	Real number	
		Point	Number of sampling points	Integer	
		Interval	Interval of sampling points	String	Lin/Log
	Measure1Data		Closed loop gain measurement data	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Closed loop gain measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	
	Measure2Data		Feedback transfer function measurement condition	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Feedback transfer function measurement condition		Up to 20,000 data points
			Frequency	Oscillator frequency		
			Amplitude	Oscillator AC amplitude		
			DcBias	Oscillator DC bias		
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name			Description	Type	Notes
AnalysisData			Analysis data	-	
	Num		Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
	Den		Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
	k		Gain coefficient for transfer function in pole-zero format	Real number	
	Zr		Zero real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zr": 5 to 20
	Zi		Zero imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zi": 5 to 20
	Pr		Pole real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pr": 5 to 20
	Pi		Pole imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pi": 5 to 20
	Sa		Row of matrix A for transfer function in state space format	Real number	Number of elements in the real array "Sa": 25 to 400
	Sb		Column vector B for transfer function in state space format	Real number	Number of elements in the real array "Sb": 5 to 20
	Sc		Row vector C for transfer function in state space format	Real number	Number of elements in the real array "Sc": 5 to 20
	Sd		Scalar D for transfer function in state space format	Real number	
	SweParam		Sweep parameter	String	Frequency
	Data		Conversion data	-	Up to 20,000 data points
		Frequency	Oscillator frequency	Real number	
		Amplitude	Oscillator AC amplitude	Real number	
		DcBias	Oscillator DC bias	Real number	
		Time	Time	String	YYYY/MM/DD hh:mm:ss
		A	Real part of gain	Real number	
		B	Imaginary part of gain	Real number	
		Gain	Gain	Real number	
		P	Phase	Real number	
SimulationData			Simulation result	-	
	SweParam		Sweep parameter	String	Frequency
	Data		Simulation result of conversion data	-	Up to 20,000 data points
		Frequency	Oscillator frequency	Real number	
		Amplitude	Oscillator AC amplitude	Real number	
		DcBias	Oscillator DC bias	Real number	
		Time	Time	String	YYYY/MM/DD hh:mm:ss
		A	Real part of gain	Real number	
		B	Imaginary part of gain	Real number	
		Gain	Gain	Real number	
		P	Phase	Real number	

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	n^{th} graph setting	-	n = 1 to 12
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	n^{th} advanced graph setting	-	n = 1 to 12
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
NumericSetting	Numeric input setting	-	
Analysis	Numeric input setting for analysis	-	
ParameterN	n^{th} numeric input	-	n = 1 to 4
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	
Simulation	Numeric input setting for simulation	-	
ParameterN	n^{th} numeric input	-	n = 1 to 3
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	

● Amplifier circuit gain-phase measurement tags

Tag name			Description	Type	Notes
Application			Measurement application-specific information	-	
	Measure1Parameter		Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter		Analysis condition	-	
		Aparture	Aperture	Integer	
		Algorithm	Generation algorithm	String	Algorithm A/Algorithm B
		Order	Order	Integer	
		Fmin	Minimum frequency for model generation conditions	Real number	
		Fmax	Maximum frequency for model generation conditions	Real number	
	SimulationParameter		Simulation condition	-	
		Aparture	Aperture	Integer	
		Name	Transfer function file name	String	YYYYMMDDhhmmss
		Num	Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den	Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		Fmin	Minimum value of simulation frequency range	Real number	
		Fmax	Maximum value of simulation frequency range	Real number	
		Point	Number of sampling points	Integer	
		Interval	Interval of sampling points	String	Lin/Log
	Measure1Data		Measurement data	-	
		SweParam	Sweep parameter	String	Frequency/ZeroSpan
		Data	Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	
			Pu	Phase continuity (UNWRAP)	Real number	
			GD	Group delay	Real number	
	AnalysisData		Analysis data	-	
		Num	Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den	Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		k	Gain coefficient for transfer function in pole-zero format	Real number	
		Zr	Zero real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zr": 5 to 20
		Zi	Zero imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zi": 5 to 20
		Pr	Pole real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pr": 5 to 20
		Pi	Pole imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pi": 5 to 20
		Sa	Row of matrix A for transfer function in state space format	Real number	Number of elements in the real array "Sa": 25 to 400
		Sb	Column vector B for transfer function in state space format	Real number	Number of elements in the real array "Sb": 5 to 20
		Sc	Row vector C for transfer function in state space format	Real number	Number of elements in the real array "Sc": 5 to 20
		Sd	Scalar D for transfer function in state space format	Real number	

Tag name					Description	Type	Notes
SimulationData					Simulation data	-	
	SweParam				Sweep parameter	String	Frequency
	Data				Simulation data	-	Up to 20,000 data points
		Frequency			Oscillator frequency	Real number	
		Amplitude			Oscillator AC amplitude	Real number	
		DcBias			Oscillator DC bias	Real number	
		Time			Time	String	YYYY/MM/DD hh:mm:ss
		A			Real part of gain	Real number	
		B			Imaginary part of gain	Real number	
		Gain			Gain	Real number	
		P			Phase	Real number	
		Pu			Phase continuity (UNWRAP)	Real number	
		GD			Group delay	Real number	
GraphSetting					Graph setting	-	
	GraphN				nth graph setting	-	n = 1 to 3
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
	AGraphN				nth advanced graph setting	-	n = 1 to 3
		Data			Setting data	-	
			AutoScale		Auto scale	String	Enable/Disable
			Title		Graph title	String	Any string
			XAxis		X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
			YAxis		Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
NumericSetting					Numeric input setting	-	
	Analysis				Numeric input setting for analysis	-	
		ParameterN			nth numeric input	-	n = 1 to 4
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	
	Simulation				Numeric input setting for simulation	-	
		ParameterN			nth numeric input	-	n = 1 to 4
			Data		Setting data	-	
				UnitIndex	Index of auxiliary unit for display	Integer	

● Amplifier circuit CMRR measurement tags

Tag name	Description	Type	Notes
Application	Measurement application-specific information	-	
Measure1Parameter	Normal-mode gain measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
Measure2Parameter	Common-mode gain measurement condition	-	Same as "Measure2Parameter" of the measurement condition tag
AnalysisParameter	CMRR display condition	-	
NormalModeGain	Select normal-mode gain	String	Measurement/Const
Constant	Normal-mode gain constant	Real number	
Measure1Data	Normal-mode gain measurement data	-	
SweParam	Sweep parameter	String	Frequency
Data	Normal-mode gain measurement data	-	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
A	Real part of gain	Real number	
B	Imaginary part of gain	Real number	
GainNORM	Normal-mode gain	Real number	
P	Phase	Real number	
Measure2Data	Common-mode gain measurement data	-	
SweParam	Sweep parameter	String	Frequency
Data	Common-mode gain measurement data	Real number	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
A	Real part of gain	Real number	
B	Imaginary part of gain	Real number	
GainCOM	Common-mode gain	Real number	
P	Phase	Real number	
AnalysisData	CMRR display data	-	
SweParam	Sweep parameter	String	Frequency
Data	CMRR display data	-	Up to 20,000 data points
Frequency	Oscillator frequency	Real number	
Amplitude	Oscillator AC amplitude	Real number	
DcBias	Oscillator DC bias	Real number	
Time	Time	String	YYYY/MM/DD hh:mm:ss
CMRR	CMMR value	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	n^{th} graph setting	-	n = 1 to 5
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	n^{th} advanced graph setting	-	n = 1 to 5
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
NumericSetting	Numeric input setting	-	
Analysis	Numeric input setting for analysis	-	
ParameterN	n^{th} numeric input	-	n = 1
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	

● Amplifier circuit PSRR measurement tags

Tag name						Description	Type	Notes
Application						Measurement application-specific information	-	
	Measure1Parameter					Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure1Data					Measurement data	-	
		SweParam				Sweep parameter	String	Frequency
		Data				Measurement data	-	Up to 20,000 data points
			Frequency			Oscillator frequency	Real number	
			Amplitude			Oscillator AC amplitude	Real number	
			DcBias			Oscillator DC bias	Real number	
			Time			Time	String	YYYY/MM/DD hh:mm:ss
			A			Real part of gain	Real number	
			B			Imaginary part of gain	Real number	
			PSRR			PSRR value	Real number	
			P			Phase	Real number	
	GraphSetting					Graph setting	-	
		GraphN				nth graph setting	-	n = 1 to 2
			Data			Setting data	-	
				AutoScale		Auto scale	String	Enable/Disable
				Title		Graph title	String	Any string
				XAxis		X axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
				YAxis		Y axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
		AGraphN				nth advanced graph setting	-	n = 1 to 2
			Data			Setting data	-	
				AutoScale		Auto scale	String	Enable/Disable
				Title		Graph title	String	Any string
				XAxis		X axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
				YAxis		Y axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string

● Amplifier circuit DG/DP measurement tags

Tag name						Description	Type	Notes
Application						Measurement application-specific information	-	
	Measure1Parameter					Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure1Data					Measurement data	-	
		SweParam				Sweep parameter	String	DCBias
		Data				Measurement data	-	Up to 20,000 data points
			Frequency			Oscillator frequency	Real number	
			Amplitude			Oscillator AC amplitude	Real number	
			DcBias			Oscillator DC bias	Real number	
			Time			Time	String	YYYY/MM/DD hh:mm:ss
			A			Real part of gain	Real number	
			B			Imaginary part of gain	Real number	
			DG			Differential gain	Real number	
			DP			Differential phase	Real number	
	GraphSetting					Graph setting	-	
		GraphN				nth graph setting	-	n = 1 to 2
			Data			Setting data	-	
				AutoScale		Auto scale	String	Enable/Disable
				Title		Graph title	String	Any string
				XAxis		X axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
				YAxis		Y axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
		AGraphN				nth advanced graph setting	-	n = 1 to 2
			Data			Setting data	-	
				AutoScale		Auto scale	String	Enable/Disable
				Title		Graph title	String	Any string
				XAxis		X axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
				YAxis		Y axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string

● Amplifier circuit saturation measurement tags

Tag name					Description	Type	Notes
Application					Measurement application-specific information	-	
	Measure1Parameter				Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure1Data				Measurement data	-	
		SweParam			Sweep parameter	String	Amplitude
		P1dB			Input amplitude of the target circuit when the gain falls by 1 dB from the maximum gain	Real number	
		GP1dB			I/O gain when the gain falls by 1 dB from the maximum gain	Real number	
		Data			Measurement data	-	Up to 20,000 data points
			Frequency		Oscillator frequency	Real number	
			Amplitude		Oscillator AC amplitude	Real number	
			DcBias		Oscillator DC bias	Real number	
			Time		Time	String	YYYY/MM/DD hh:mm:ss
			A		Real part of gain	Real number	
			B		Imaginary part of gain	Real number	
			Gain		Gain	Real number	
			P		Phase	Real number	
			DG		Δ gain (deviation from maximum gain)	Real number	
	GraphSetting				Graph setting	-	
		GraphN			n^{th} graph setting	-	n = 1 to 3
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
		AGraphN			n^{th} advanced graph setting	-	n = 1 to 3
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string

● Filter measurement tags

Tag name				Description	Type	Notes
Application				Measurement application-specific information	-	
	Measure1Parameter			Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	AnalysisParameter			Transfer function generation condition	-	
		Filter		Filter type	String	LPF/HPF/BPF/BEF
		FcMode		FC Mode	String	-3dB/GRipple
		Aparture		Aperture	Integer	
		Algorithm		Generation algorithm	String	Algorithm A/Algorithm B
		Order		Order	Integer	
		Fmin		Minimum frequency for model generation conditions	Real number	
		Fmax		Maximum frequency for model generation conditions	Real number	
	SimulationParameter			Simulation condition	-	
		Filter		Filter type	String	LPF/HPF/BPF/BEF
		FcMode		FC Mode	String	-3dB/GRipple
		Aparture		Aperture	Integer	
		Name		Transfer function file name	String	YYYYMMDDhhmmss
		Num		Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den		Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		Fmin		Minimum value of simulation frequency range	Real number	
		Fmax		Maximum value of simulation frequency range	Real number	
		Point		Number of sampling points	Integer	
		Interval		Interval of sampling points	String	Lin/Log
	Measure1Data			Measurement condition	-	
		SweParam		Sweep parameter	String	Frequency
		Data		Measurement data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	
			Pu	Phase continuity (UNWRAP)	Real number	
			GD	Group delay	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name			Description	Type	Notes
	AnalysisData		Transfer function generation data	-	
		Num	Numerator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Num": 6 to 21
		Den	Denominator coefficient for transfer function in polynomial format	Real number	Number of elements in the real array "Den": 6 to 21
		k	Gain coefficient for transfer function in pole-zero format	Real number	
		Zr	Zero real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zr": 5 to 20
		Zi	Zero imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Zi": 5 to 20
		Pr	Pole real part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pr": 5 to 20
		Pi	Pole imaginary part of transfer function in pole-zero format	Real number	Number of elements in the real array "Pi": 5 to 20
		Sa	Row of matrix A for transfer function in state space format	Real number	Number of elements in the real array "Sa": 25 to 400
		Sb	Column vector B for transfer function in state space format	Real number	Number of elements in the real array "Sb": 5 to 20
		Sc	Row vector C for transfer function in state space format	Real number	Number of elements in the real array "Sc": 5 to 20
		Sd	Scalar D for transfer function in state space format	Real number	
	SimulationData		Simulation data	-	
		SweParam	Sweep parameter	String	Frequency
		Data	Simulation data	-	Up to 20,000 data points
			Frequency	Oscillator frequency	Real number	
			Amplitude	Oscillator AC amplitude	Real number	
			DcBias	Oscillator DC bias	Real number	
			Time	Time	String	YYYY/MM/DD hh:mm:ss
			A	Real part of gain	Real number	
			B	Imaginary part of gain	Real number	
			Gain	Gain	Real number	
			P	Phase	Real number	
			Pu	Phase continuity (UNWRAP)	Real number	
			GD	Group delay	Real number	

6.2 Measurement recipe and measurement result data formats

Tag name	Description	Type	Notes
GraphSetting	Graph setting	-	
GraphN	nth graph setting	-	n = 1 to 3
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
AGraphN	nth advanced graph setting	-	n = 1 to 3
Data	Setting data	-	
AutoScale	Auto scale	String	Enable/Disable
Title	Graph title	String	Any string
XAxis	X axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
YAxis	Y axis setting	-	
Max	Maximum value	Real number	
Min	Minimum value	Real number	
Scale	Scale	String	Lin/Log/-Lin/-Log
Title	Axis title	String	Any string
NumericSetting	Numeric input setting	-	
Analysis	Numeric input setting for analysis	-	
ParameterN	nth numeric input	-	n = 1 to 4
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	
Simulation	Numeric input setting for simulation	-	
ParameterN	nth numeric input	-	n = 1 to 4
Data	Setting data	-	
UnitIndex	Index of auxiliary unit for display	Integer	

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● Impedance measurement tags

Tag name					Description	Type	Notes
Application					Measurement application-specific information	-	
	Measure1Parameter				Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure1Data				Measurement data	-	
		SweParam			Sweep parameter	String	Frequency
		Data			Measurement data	-	Up to 20,000 data points
			Frequency		Oscillator frequency	Real number	
			Amplitude		Oscillator AC amplitude	Real number	
			DcBias		Oscillator DC bias	Real number	
			Time		Time	String	YYYY/MM/DD hh:mm:ss
			A		Real part of complex impedance	Real number	
			B		Imaginary part of complex impedance	Real number	
			Z		Absolute value of impedance	Real number	
			Pz		Phase of impedance	Real number	
			DBZ		Decibel value of impedance	Real number	
			Gc		Conductance	Real number	
			Bc		Susceptance	Real number	
			Y		Absolute value of admittance	Real number	
			Py		Phase of admittance	Real number	
			DBY		Decibel value of admittance	Real number	
	GraphSetting				Graph setting	-	
		GraphN			n^{th} graph setting	-	n = 1 to 4
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
		AGraphN			n^{th} advanced graph setting	-	n = 1 to 34
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
					Max	Maximum value	Real number	
					Min	Minimum value	Real number	
					Scale	Scale	String	Lin/Log/-Lin/-Log
					Title	Axis title	String	Any string

● Gain-phase measurement tags

Tag name					Description	Type	Notes
Application					Measurement application-specific information	-	
	Measure1Parameter				Measurement condition	-	Same as "Measure1Parameter" of the measurement condition tag
	Measure1Data				Measurement data	-	
		SweParam			Sweep parameter	String	Frequency
		Data			Measurement data	-	Up to 20,000 data points
			Frequency		Oscillator frequency	Real number	
			Amplitude		Oscillator AC amplitude	Real number	
			DcBias		Oscillator DC bias	Real number	
			Time		Time	String	YYYY/MM/DD hh:mm:ss
			A		Real part of complex gain measured on CH1/CH2	Real number	
			B		Imaginary part of complex gain measured on CH1/CH2	Real number	
			Gain		Gain measured on CH1/CH2 (dB)	Real number	
			P		Phase measured on CH1/CH2	Real number	
			R		Gain measured on CH1/CH2 (dB)	Real number	
			InvA		Real part of complex gain measured on CH2/CH1	Real number	
			InvB		Imaginary part of complex gain measured on CH2/CH1	Real number	
			InvGain		Gain measured on CH2/CH1 (dB)	Real number	
			InvP		Phase measured on CH2/CH1	Real number	
			InvR		Gain measured on CH2/CH1 (dB)	Real number	
	GraphSetting				Graph setting	-	
		GraphN			n^{th} graph setting	-	n = 1 to 4
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
		AGraphN			n^{th} advanced graph setting	-	n = 1 to 34
			Data		Setting data	-	
				AutoScale	Auto scale	String	Enable/Disable
				Title	Graph title	String	Any string
				XAxis	X axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string
				YAxis	Y axis setting	-	
				Max	Maximum value	Real number	
				Min	Minimum value	Real number	
				Scale	Scale	String	Lin/Log/-Lin/-Log
				Title	Axis title	String	Any string

6.3 Transfer function file format

The transfer function file is in the TXT format (text format). This file is used to read a transfer function modeled in the ZGA5920 with MATLAB or other numerical software for design and simulation of the control system.
The transfer function is output to a file in the three expression types: polynomial, pole-zero, and state space. A line that starts with "%" is a comment line.

Top of file	Measurement date
	Transfer function part (polynomial format)
	Transfer function part (pole-zero format)
End of file	Transfer function part (state space format)

Figure 6-2 Structure of transfer function file

The size of a transfer function file (number of coefficients) is determined by the order (= n) specified at the model generation. Coefficients in a line are space-separated to be output.

Values are output in the floating-point format:
$\pm$(mantissa, 15 digits)E$\pm$(exponent, 3 digits).
However, the pole (p_i) and zero (z_i) are a complex number:
$\pm$(real part)$\pm$j(imaginary part),
where "j" is the imaginary unit.

The transfer function is output in the following three formats:
○ Polynomial format

$$H_{(s)} = \frac{num_n s^n + num_{n-1} s^{n-1} + num_{n-2} s^{n-2} + \cdots + num_1 s + num_0}{den_n s^n + den_{n-1} s^{n-1} + den_{n-2} s^{n-2} + \cdots + den_1 s + den_0}$$

○ Pole-zero format

$$H_{(s)} = K \frac{(s-z_{n-1})(s-z_{n-2})(s-z_{n-3})\cdots(s-z_1)(s-z_0)}{(s-p_{n-1})(s-p_{n-2})(s-p_{n-3})\cdots(s-p_1)(s-p_0)}$$

○ State space format

$$\begin{cases} \dot{X} = AX + Bu \\ y = CX + Du \end{cases}$$

The transfer function file format is shown in "Table 6-1 Transfer function file format".

Table 6-1 Transfer function file format

Row	Content	Description
1	%2010/0101 12:34:56.78	(Date and time when the original data for transfer function derivation were measured)
2	%TF	(Start of transfer function in polynomial format)
3	%numerator	(Numerator coefficient)
4	(num_n) $(num_{n-1})\cdots(num_1)$ (num_0)	Numerator coefficients from the highest order
5	%denominator	(Denominator coefficient)
6	(den_n) $(den_{n-1})\cdots(den_1)$ (den_0)	Denominator coefficients from the highest order
7		(Blank line)
8	%ZP	(Start of transfer function in pole-zero format)
9	%K	(Gain coefficient)
10	(K)	Gain of transfer function in pole-zero format
11	%zero	(Zero point)
12	(z_{n-1}) $(z_{n-2})\cdots(z_1)$ (z_0)	Zero points in complex number format
13	%pole	(Pole)
14	(p_{n-1}) $(p_{n-2})\cdots(p_1)$ (p_0)	Poles in complex number format
15		(Blank line)
16	%SS	(Start of transfer function in state space format)
17	%A	(Matrix A)
18	(A_{11}) $(A_{12})\cdots(A_{1n})$	1st row of the matrix A
19	(A_{21}) $(A_{22})\cdots(A_{2n})$	2nd row of the matrix A
20	:	:
17+n	(A_{n1}) $(A_{n2})\cdots(A_{nn})$	n^{th} row of the matrix A
18+n	%B	(column vector B)
19+n	(B_1)	
20+n	(B_2)	
:	:	
18+2n	(B_n)	
19+2n	%C	(row vector C)
20+2n	(C_1) $(C_2)\cdots(C_n)$	
21+2n	%D	(scalar D)
22+2n	(D)	

6.4 Report file format

This report format file contains measurement result graphs as well as measurement records (e.g., measurer), measurement conditions, and remarks column.

The report file has the following format:

File size	About 200 kB or larger (depending on the content)
File format	portable document format (file name extension is ".PDF")

With the ZGA5920, you can design the report output layout by specifying the following field names in the PDF template file. PDF template files can be created using a PDF creation program such as Adobe Acrobat.

● Common fields for all measurement applications

Field name	Description	Display examples
AppTitle	Measurement application name	Piezoelectric measurement
Meas1Circuit	Label name, value, unit of circuit parameter of measurement condition 1	CH1 weight: 1.0000E+00, CH2 weight: 1.0000E+00 Invert: OFF, Ext amp gain: 1.00
Meas1Osc	Label name, value, unit of oscillator parameter of measurement condition 1	Frequency: 1,000.0000 Hz, Amplitude: 1.00 Vpk, DC Bias: 0.00 V
Meas1Sweep	Label name, value, unit of sweep parameter of measurement condition 1	Sweep param: Frequency, Anytime ON: ON Start: 10.0000 Hz, Stop: 100,000.0000 Hz Point:100, Interval: Lin
Meas1Slow	Label name, value, unit of slow sweep parameter of measurement condition 1	Item: LogR, CH: CH1, Variation(LogR): 1.00
Meas1Integral	Label name, value, unit of integration parameter of measurement condition 1	Type: Cycle, Cycle : 1
Meas1Delay	Label name, value, unit of delay parameter of measurement condition 1	Type: Cycle, Cycle: 1
Meas1Compression	Label name, value, unit of amplitude compression parameter of measurement condition 1	Compression mode: OFF, Amplitude: 1.00 Vrms, Limit: 1.00 Vpk Error: 10%, Retry: 10, Correction: 100%
Meas1Input	Label name, value, unit of input over parameter of measurement condition 1	CH1: 250 Vrms, CH2: 250 Vrms Action: Output OFF
Meas2Circuit	Label name, value, unit of circuit parameter of measurement condition 2	CH1 weight: 1.0000E+00, CH2 weight: 1.0000E+00 Invert: OFF, Ext amp gain: 1.00
Meas2Osc	Label name, value, unit of oscillator parameter of measurement condition 2	Frequency: 1,000.0000 Hz, Amplitude: 1.00 Vpk, DC Bias: 0.00 V
Meas2Sweep	Label name, value, unit of sweep parameter of measurement condition 2	Sweep param: Frequency, Anytime ON: ON Start: 10.0000 Hz, Stop: 100,000.0000 Hz Point:100, Interval: Lin
Meas2Slow	Label name, value, unit of slow sweep parameter of measurement condition 2	Item: LogR, CH: CH1, Variation(LogR): 1.00
Meas2Integral	Label name, value, unit of integration parameter of measurement condition 2	Type: Cycle, Cycle : 1
Meas2Delay	Label name, value, unit of delay parameter of measurement condition 2	Type: Cycle, Cycle: 1
Meas2Compression	Label name, value, unit of amplitude compression parameter of measurement condition 2	Compression mode: OFF, Amplitude: 1.00 Vrms, Limit: 1.00 Vpk Error: 10%, Retry: 10, Correction: 100%
Meas2Input	Label name, value, unit of input over parameter of measurement condition 2	CH1: 250 Vrms, CH2: 250 Vrms Action: Output OFF
Figure	ZGA screen image	<Captured image is displayed.>

6.4 Report file format

Field name	Description	Display examples
Date	Date and time of measurement (Header-Time tag of measurement result file)	2011/01/02 12:34:56
DateNow	Current date and time	2011/01/02 12:34:56
Comment1	Text entered for Comment1	<enter up to 255 character>
Comment2	Text entered for Comment2	<enter up to 255 character>
Comment3	Text entered for Comment3	<enter up to 255 character>
Comment4	Text entered for Comment4	<enter up to 255 character>

● Fields for piezoelectric measurement

Field name	Description	Display examples
AnaCdMode	Cd calculation method (HighFrequency|Gmax|Bmax_min)	HighFrequency
AnaAl	AL value	100nH/N^2
SimCd	Damping capacitance	1.00000E-011F
SimC1	Equivalent electrostatic capacitance of piezoelectric mechanical vibration	1.00000E-007F
SimL1	Equivalent inductance of piezoelectric mechanical vibration	1.00000E-002H
SimR1	Equivalent resistance of mechanical vibration loss	1.00000E+000 Ω
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100,000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points (Lin|Log)	Lin
Fs	Mechanical series resonance frequency	100,000.0000 Hz
Fp	Mechanical parallel resonance frequency	100,000.0000 Hz
Fr	Resonance frequency	100,000.0000 Hz
Fa	Antiresonant frequency	100,000.0000 Hz
Fm	Maximum admittance point	100,000.0000 Hz
Fn	Minimum admittance point	100,000.0000 Hz
F1	Maximum susceptance point	100,000.0000 Hz
F2	Minimum susceptance point	100,000.0000 Hz
Cd	Damping capacitance	1.00000E-011F
C1	Equivalent electrostatic capacitance of piezoelectric mechanical vibration	1.00000E-007F
L1	Equivalent inductance of piezoelectric mechanical vibration	1.00000E-002H
R1	Equivalent resistance of mechanical vibration loss	1.00000E+000 Ω
Qm	Mechanical quality factor	0.00000E+000
Ls	Series circuit inductance	1.00000E-002H
Lp	Parallel circuit inductance	1.00000E-002H
Ns	Number of coil turns for series circuit	100
Np	Number of coil turns for parallel circuit	100

● Fields for dielectric measurement

Field name	Description	Display examples
AnaS	Electrode area	1.000 mm^2
AnaT	Electrode distance	1.000 mm

● Fields for magnetic measurement

Field name	Description	Display examples
AnaS	Core area	1.000 mm^2
AnaL	Core magnetic path length	1.000 mm
AnaN	Number of coil turns	1
AnaD	Winding diameter	0.080 mm
AnaLen	Winding around length	1.000 mm
AnaRho	Winding resistivity	1.680E-009 Ωm

● Fields for inductor measurement

Field name	Description	Display examples
AnaCircuit	Circuit type	A
SimCircuit	Circuit type	A
SimC0	Equivalent circuit inductance	0.00000E+000F
SimC1	Equivalent circuit capacitance	1.00000E-007F
SimL1	Equivalent circuit inductance	1.00000E-002H
SimR1	Equivalent circuit resistance	1.00000E+000 Ω
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin
C0	Equivalent circuit inductance	0.00000E+000F
C1	Equivalent circuit capacitance	1.00000E-007F
L1	Equivalent circuit inductance	1.00000E-002H
R1	Equivalent circuit resistance	1.00000E+000 Ω

● Fields for capacitor measurement

Field name	Description	Display examples
AnaCircuit	Circuit type	D
SimCircuit	Circuit type	D
SimC0	Equivalent circuit inductance	0.00000E+000F
SimC1	Equivalent circuit capacitance	1.00000E-007F
SimL1	Equivalent circuit inductance	1.00000E-002H
SimR1	Equivalent circuit resistance	1.00000E+000 Ω
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin
C0	Equivalent circuit inductance	0.00000E+000F
C1	Equivalent circuit capacitance	1.00000E-007F
L1	Equivalent circuit inductance	1.00000E-002H
R1	Equivalent circuit resistance	1.00000E+000 Ω

- Fields for resistor measurement

Field name	Description	Display examples
AnaCircuit	Circuit type	B
SimCircuit	Circuit type	B
SimC0	Equivalent circuit inductance	0.00000E+000F
SimC1	Equivalent circuit capacitance	1.00000E-007F
SimL1	Equivalent circuit inductance	1.00000E-002H
SimR1	Equivalent circuit resistance	1.00000E+000 Ω
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin
C0	Equivalent circuit inductance	0.00000E+000F
C1	Equivalent circuit capacitance	1.00000E-007F
L1	Equivalent circuit inductance	1.00000E-002H
R1	Equivalent circuit resistance	1.00000E+000 Ω

- Fields for leakage inductance measurement (transformer)
  No fields need to be set for this application.

- Fields for mutual inductance measurement (transformer)
  No fields need to be set for this application.

- Fields for coupling coefficient measurement (transformer)
  No fields need to be set for this application.

- Fields for turns ratio measurement (transformer)
  No fields need to be set for this application.

- Fields for varactor diode measurement

Field name	Description	Display examples
SimC0	Capacitance	1.00000E-012F
SimC1	Capacitance	1.00000E-009F
SimL	Inductance	1.00000E-003H

● Fields for feedback loop measurement (servo)

Field name	Description	Display examples
AnaAlgorithm	Generation algorithm	A
AnaOrder	Order	5
AnaFmin	Minimum frequency	10.0000 Hz
AnaFmax	Maximum frequency	100000.0000 Hz
SimName	Transfer function file name	20110520152637
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin

● Fields for closed loop gain measurement (servo)

Field name	Description	Display examples
AnaFeedBackGain	Feedback transfer function type	Measure
AnaConstant	Feedback transfer function constant value	0.000 dB
AnaOutputData	Conversion type	CloseLoop
AnaAlgorithm	Generation algorithm	A
AnaOrder	Order	5
AnaFmin	Minimum frequency	10.0000 Hz
AnaFmax	Maximum frequency	100000.0000 Hz
SimName	Transfer function file name	20110520152637
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin

● Fields for open loop gain measurement (servo)

Field name	Description	Display examples
AnaFeedBackGain	Feedback transfer function type	Measure
AnaConstant	Feedback transfer function constant value	0.000 dB
AnaOutputData	Conversion type	Loop
AnaAlgorithm	Generation algorithm	A
AnaOrder	Order	5
AnaFmin	Minimum frequency	10.0000 Hz
AnaFmax	Maximum frequency	100000.0000 Hz
SimName	Transfer function file name	20110520152637
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin

● Fields for gain-phase measurement (amplifier circuit)

Field name	Description	Display examples
AnaAparture	Aperture	5
AnaAlgorithm	Generation algorithm	A
AnaOrder	Order	5
AnaFmin	Minimum frequency	10.0000 Hz
AnaFmax	Maximum frequency	100000.0000 Hz
SimAparture	Aperture	5
SimName	Transfer function file name	20110520152637
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin

● Fields for CMRR measurement (amplifier circuit)

Field name	Description	Display examples
AnaNormalModeGain	Normal-mode gain	Measure
AnaConstant	Normal-mode gain constant value	0.000 dB

● Fields for PSRR measurement (amplifier circuit)

No fields need to be set for this application.

● Fields for DG/DP measurement (amplifier circuit)

No fields need to be set for this application.

● Fields for saturation measurement

Field name	Description	Display examples
P1dB	Input amplitude of the target circuit when the gain falls by 1 dB from the maximum gain	1.00000E+000 Vpk
GainP1dB	I/O gain when the gain falls by 1 dB from the maximum gain	15.465 dB

- Fields for filter measurement

Field name	Description	Display examples
AnaFilter	Filter type	LPF
AnaFcMode	FcMode	-3 dB
AnaAparture	Aperture	5
AnaAlgorithm	Generation algorithm	A
AnaOrder	Order	5
AnaFmin	Minimum frequency	10.0000 Hz
AnaFmax	Maximum frequency	100000.0000 Hz
SimFilter	Filter type	LPF
SimFcMode	FcMode	-3 dB
SimAparture	Aperture	5
SimName	Transfer function file name	20110520152637
SimFmin	Minimum frequency	10.0000 Hz
SimFmax	Maximum frequency	100000.0000 Hz
SimPoint	Number of sampling points	100
SimInterval	Interval of sampling points	Lin
AnaGpath	Passband gain	-0.007 dB
AnaGripple	Passband ripple	-0.007 dB
AnaGatt	Maximum attenuation	-82.983 dB
AnaGbef	BEF attenuation	-82.983 dB
AnaFcLow	Low cutoff frequency	83215.8538 Hz
AnaFcHigh	High cutoff frequency	104712.8548 Hz
AnaBW	Bandwidth	21497.0010 Hz
SimGpath	Passband gain	-0.007 dB
SimGripple	Passband ripple	-0.007 dB
SimGatt	Maximum attenuation	-82.983 dB
SimGbef	BEF attenuation	-82.983 dB
SimFcLow	Low cutoff frequency	83215.8538 Hz
SimFcHigh	High cutoff frequency	104712.8548 Hz
SimBW	Bandwidth	21497.0010 Hz

- Fields for impedance measurement

  No fields need to be set for this application.

- Fields for gain-phase measurement

  No fields need to be set for this application.

6.5 Screen capture format

This file contains a simple image copy of an on-screen graph area.

The graph output file has the following format:

File size	About 3.75 MB
File format	Windows Bitmap (file name extension is ".BMP")
Number of colors	24-bit true color (16.7 million colors)
Number of pixels	1280×1024 dot

6.6 Analog signal input data format

A proprietary binary file format is used. (file extension is "WDB")

Item		Type	Size (in byte)	Description	Notes
Header part	Identifier	Char	3	Identifier (3 bytes, fixed)	_WD
	Version	Char	5	File version number (5 bytes, fixed)	01.10
	Sampling rate	Integer	8	Sampling rate (8 bytes, fixed)	
	Header size	Numeric	3	Header size in byte (3 bytes, fixed)	19 bytes + title string size
	Title	String	Variable	Title (variable)	(Data Title)
Data part	Recorded data	Binary	Variable	Analog data (binary data)	(data) (data)…

7. Troubleshooting

7.1 Error messages

This section lists the error messages that are output by the ZGA5920, their causes, and required actions.
If a repair is needed, contact us or our agent.
When you request a repair of the ZGA5920, please provide us with the details of any error messages. Any undocumented error message may be displayed due to malfunction caused by a strong external noise or other reason.

Table 7-1 Error message list

Error message	Description
An internal processing error occurred. Please restart the system.	This error occurs when the analysis section failed in connection during communication processing.
An internal processing error occurred. Please restart the system	This error occurs when there is a communication error in the analysis section during communication processing.
An internal processing error occurred. Please restart the system	This error occurs when there is a communication error while obtaining measurement results.
An internal processing error occurred. Please restart the system	This error occurs when there is a timeout during calibration or correction.

Errors that occur during the FRA compatible remote control (USBTMC) are not displayed on the monitor. They can be read using remote commands. Please see "ZGA5920 FRA Compatible Remote Control Instruction Manual".

7.2 Quick diagnosis

If you find anything wrong with operations of the instrument, try the following quick diagnoses and measures. If the operations cannot be recovered after the measures taken, contact NF Corporation or one of its representatives.

Symptom	Possible cause	Quick measure
Power supply cannot be "on".	The power supply is out of the rated range.	Use the power supply within the specified ratings.
	The operation is not normal due to external noise, etc.	Reinstall the instrumentation at a location with less noise/ good environment.
No key operations are accepted.	Under remote control.	In the Utility window, exit the external control.
	Keys and/or connectors have been deteriorated.	Contact NF Corporation to ask repair.
External control through USB cannot be done.	Wrong Product ID, Vendor ID, or Serial number	Create the program with the correct ID and serial number.
	Not in the external control state.	In the Utility window, enter the external control.
Calibration errors occur.	Measurement accuracy has been degraded due to external noise.	Disconnect the signal cables (oscillator output and measurement signal input) and calibrate again. Install the instrument in quiet environment far from noise sources.

8. Maintenance

8.1 Introduction

Maintenance is essential for you to use the instrument under the good working condition as below:

- Operation inspection   Check to see if the equipment is operating correctly.
- Performance test   Check to see if the equipment satisfies the ratings.
- Adjustment and calibration   If any rating is not satisfied, we will perform adjustment or calibration to recover the performance.
- Troubleshooting   Should no improvement result, we will investigate into the cause and failed portion to repair it.

This Instruction Manual describes the performance testing method that can be easily performed.

For advanced inspections, adjustments, calibrations, and troubleshooting, contact us or our agent.

8.2 Daily maintenance

Install and use the ZGA5920 in a place that satisfies the installation conditions.

For installation conditions, see "2.2.2 Installation location conditions".

When you find the surface of the instrument panel or the enclosure to be dirty, wipe it with a soft cloth. When it is extremely dirty, wipe it using a cloth firmly wrung out of a neutral detergent. Never wipe using organic solvents as thinner or benzine or chemically treated towels, since the surface treatment might be altered and/or its painting might be damaged.

8.3 Storage, re-packaging, and transportation

a) Storage for a long period of time (when you do not plan to use the instrument for a long time in future)

- Remove the power supply cable from both the instrument connector and the power source outlet.
- Store the instrument at a dirt-free location such as on a safe shelf or in an equipment rack, where nothing could drop down from higher place to hit the instrument.
  If the instrument is subject to dirt, cover the instrument with a proper sheet.
- Maintain the temperature and humidity of the storage location within the following range:
  Temperature: -10 to +50 °C
  Humidity: 30 to 80% RH (no condensation is allowed)
- The instrument storage location shall not be such a place as having direct sunlight, near the fire or heat source, or having wide ranges of temperature variation during storage period. The instrument could be deformed or damages could be induced due to such environment.
- The instrument shall not be stored being exposed to corrosive gas, moisture, dust or dirt. The high humidity shall also be avoided for the instrument storage.
  The instrument could be corroded or damages could be induced due to such environment.

b) Re-packaging for transportation

Observe the following when you re-pack the instrument for transportation, etc.:

- Enclose the whole enclosure involving the instrument so that the surface is protected against potential damages and that thin dust does not get into the inside of the instrument.
- Use a box with appropriate strength and also with appropriate size margin.
- Use buffer materials for packaging so that all the six external faces of the instrument body can be protected.
- Notify by all means to the shipping agent that the instrument inside is a precision machine, when you order shipping.

8.4 Identification of version number

The version number is always visible in the bottom right of the screen.

Figure 8-1 Identification of version number

Note that the version number might not always be the same even if the instrument bears the identical type number.

Since different version numbers can mean different operations or functions, inform the agent of the version number together with the failure symptom, when you find anomalies and request repair.

8.5 Performance test

This section describes, among principal test items, those items which can be tested without using special/elaborate jigs or measurement equipment. Adjustment and/or repair is needed when you have any test results that do not meet the specifications.
Ask NF Corporation for more detailed tests, calibrations and/or repairs.

8.5.1 Test equipment

The following test equipments and cables are required for performance tests:
- Frequency counter: Accuracy: 1×10^{-6} or better
- Multi-meter (the following measurement shall be possible):
    - AC voltage: Accuracy: ±0.1%, 100 mV to 10 V, 100 Hz to 10 kHz
    - DC voltage: Accuracy: ±0.1%, 100 mV to 10 V
- Wideband multi-meter (the following measurement shall be possible):
    - AC voltage: Accuracy: ±0.5%, 100 mV to 10 V, 100 kHz to 200 kHz
        Accuracy: ±1%, 100 mV to 10 V, 200 kHz to 1 MHz
        Accuracy: ±5%, 100 mV to 10 V, 1 MHz to 15 MHz
- Distortion meter: 0.1% or better for full-scale
- Others: BNC-BNC coaxial cable, T-branch, and so on

8.5.2 Pretest preparations

a) Confirmation of test environment

Perform the test under the following conditions:
- Ambient temperature: +18 to +28 °C
- Ambient humidity: 25 to 75% RH
- Power supply voltage: 90 to 132 V AC or 180 to 250 V AC

b) Confirmation of functions/operations

Check and confirm important functions, before the test, in an abbreviated manner according to **"2.5 Quick function checking"**.

c) Warm-up

Leave the instrument for at least one (1) hour after turning the power on so that the internal temperature becomes stabilized.
Perform/execute calibration by all means before the test. The performance of the ZGA5920 is specified on the basis of the status right after calibration.

8.5.3 Oscillator output frequency accuracy

This section explains the testing on the oscillator output for output frequency accuracy.

a) Setting

ZGA5920		Frequency counter	
Output voltage		Gate time:	10 sec
AC:	1 Vpk		
DC Bias:	0 V		
Anytime ON status			
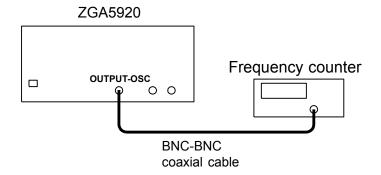
b) Connection

ZGA5920

OUTPUT-OSC

Frequency counter

BNC-BNC
coaxial cable

c) Procedure

Set the oscillator output frequency at the following and read the indication of the frequency counter:
Oscillator output frequency: 100 kHz

d) Judgment

Oscillator output frequency	Frequency counter	Tolerance
100 kHz	_____ kHz	99.9990 to 100.0010 kHz

8.5.4 Oscillator output amplitude accuracy

This section explains the testing on the oscillator output for amplitude and frequency response.
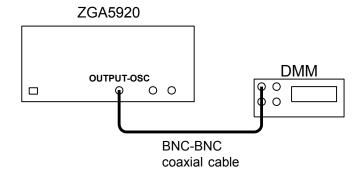
a) Setting

ZGA5920	Multi-meter
Output voltage	Measurement mode: AC voltage (True RMS)

Output voltage
    AC: 10 Vpk
    DC Bias: 0 V
    Anytime ON status

Measurement mode: AC voltage (True RMS)

b) Connection

c) Procedure

Set the oscillator output frequency as follows and read the multi-meter indications. Use a wideband multi-meter for frequencies above 100 kHz.

    Oscillator output frequency: 1 kHz, 100 kHz, 1 MHz, 15 MHz

Derive the amplitude from the multi-meter indication by the following formula.

    Amplitude accuracy [dB] = $20 \times \log_{10}$ [multi-meter indication (Vrms)] - 16.9897

d) Judgment

Oscillator output frequency	Multi-meter	Amplitude accuracy	Tolerance
1 kHz	_____ Vrms	_____ dB	-0.30 to +0.30 dB
100 kHz	_____ Vrms	_____ dB	-0.30 to +0.30 dB
1 MHz	_____ Vrms	_____ dB	-1.00 to +1.00 dB
15 MHz	_____ Vrms	_____ dB	-3.00 to +3.00 dB
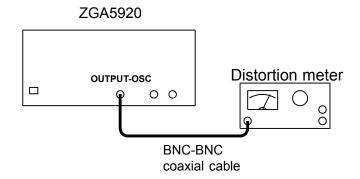
8.5.5 Oscillator distortion

This section explains the testing on the oscillator output for sine wave distortion rate.

a) Setting

ZGA5920	Distortion meter
Output wave voltage	Noise distortion (THD) measuring mode

    AC: 10 Vpk

    DC Bias: 0 V

    Anytime ON status

b) Connection

ZGA5920

OUTPUT-OSC

Distortion meter

BNC-BNC
coaxial cable

c) Procedure

Set the oscillator output frequency as follows and read the distortion meter indications. Set the distortion meter lowpass filter (LPF) to 100 kHz.

    Oscillator output frequency: 10 kHz

d) Judgment

Oscillator output frequency	Distortion (THD)	Tolerance
10 kHz	_____ %	< 0.2%

THD: Total Harmonic Distortion

8.5.6 Oscillator output DC bias accuracy
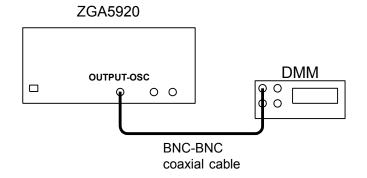
This section explains the testing on the oscillator output for output DC bias accuracy.

a) Setting

ZGA5920	Multi-meter
Output voltage	Measurement mode: DC voltage
AC: 0 Vpk	
Anytime ON status	

b) Connection

ZGA5920

c) Procedure

Set the oscillator output DC bias as follows and read the multi-meter indications.

Oscillator output DC bias: -10 V, 0 V, +10 V

d) Judgment

Oscillator output DC bias	Multi-meter	Tolerance
-10 V	_____ V	-10.130 to -9.870 V
0 V	_____ V	-30.0 to +30.0 mV
+10 V	_____ V	+9.870 to +10.130 V

8.5.7 Analyzer IMRR

This section explains the testing on IMRR at 60 Hz.

a) **Setting**

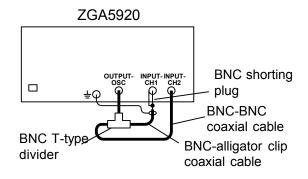| ZGA5920	
Measurement type:	Gain-phase measurement
Measurement setting	
Number of integrations:	100 cycles
Sweep setting:	Zero span, 100 points, 600 s
Oscillator output section	
Frequency:	60 Hz
Output voltage:	AC: 10 Vpk, DC Bias: 0 V
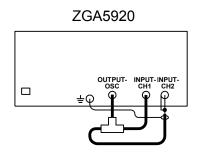
b) **Connection**

IMRR measurement on CH1   IMRR measurement on CH2

c) **Procedure**

Set the Analysis mode as follows, then perform the zero span sweep measurement with the ZGA5920.

In the measurement result, use the marker to read the minimum gain [dB] on the monitor screen.

    Analysis mode for the IMRR measurement on CH1: CH2/CH1

    Analysis mode for the IMRR measurement on CH2: CH1/CH2

d) **Judgment**

Connection	Measured value	Tolerance
CH1 (Analysis mode: CH2/CH1)	Gain = _____ dB	More than 120 dB
CH2 (Analysis mode: CH1/CH2)	Gain = _____ dB	More than 120 dB

8.5.8 Analyzer dynamic range

This section explains the testing on the dynamic range.

a) Setting

<u>ZGA5920</u>

Measurement type:	Gain-phase measurement
Measurement setting	
Number of integrations:	2,000 cycles
Sweep setting:	10 Hz to 1 MHz/1 MHz to 15 MHz,
	100 points/sweep, Log sweep
Oscillator output section	
Output voltage:	AC: 10 Vpk, DC Bias: 0 V

b) Connection

Dynamic range measurement on CH1   Dynamic range measurement on CH2

c) Procedure

Set the Analysis mode as follows, then perform the frequency sweep measurement with the ZGA5920.

In the measurement result, use the marker to read the minimum gain [dB] on the monitor screen.

    Analysis mode for the dynamic range measurement on CH1: CH2/CH1

    Analysis mode for the dynamic range measurement on CH2: CH1/CH2

d) Judgment

Connection	Minimum measured value	Tolerance
CH1 (10 Hz to 1 MHz)	Gain = _____ dB	140 dB typ
CH2 (10 Hz to 1 MHz)	Gain = _____ dB	140 dB typ
CH1 (1 MHz to 15 MHz)	Gain = _____ dB	80 dB typ
CH2 (1 MHz to 15 MHz)	Gain = _____ dB	80 dB typ

8.5.9 Analyzer measuring error frequency response

This section explains the testing on the frequency dependence of CH1/CH2 measured values at 100 mVpk output.

a) Setting

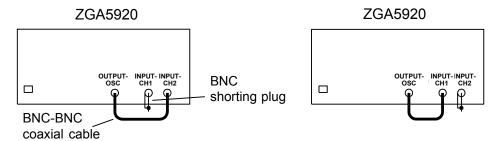| ZGA5920	
Measurement type:	Gain-phase measurement
Measurement setting	
Number of integrations:	50 cycles
Sweep setting:	10 Hz to 15 MHz, 100 points/sweep, Log sweep
Oscillator output section	
Output voltage:	AC: 100 mVpk, DC Bias: 0 V
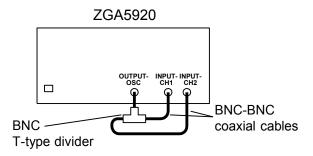
b) Connection

c) Procedure

Use the ZGA5920 for sweep measurement.

In the measurement result, use the marker to read the maximum absolute values of gain [dB] and phase at each of the frequency ranges of up to 20 kHz, up to 500 kHz, up to 2.2 MHz, and up to 15 MHz, on the monitor screen.

d) Judgment

Frequency range	Measured value	Tolerance
10 Hz to 20 kHz	_____ dB	-0.05 to +0.05 dB
	_____ deg	-0.3 to +0.3 deg
20 kHz to 500 kHz	_____ dB	-0.1 to +0.1 dB
	_____ deg	-0.5 to +0.5 deg
500 kHz to 2.2 MHz	_____ dB	-1.0 to +1.0 dB
	_____ deg	-2.0 to +2.0 deg
2.2 MHz to 15 MHz	_____ dB	-2.0 to +2.0 dB
	_____ deg	-5.0 to +5.0 deg

9. Specifications

Accuracy (range) denotes guaranteed performance unless otherwise specified.

Other values are typical values

9.1 Analysis processing

(Measurement and analysis functions for each application)

- ● Piezoelectric material analysis function

Admittance characteristics measurement/display	Graphically displays the admittance and phase.
Piezoelectric parameter extraction	Displays the characteristic frequency and piezoelectric parameter.
Matching support	Displays the matching inductance.
Simulation	Displays the admittance characteristics calculated from piezoelectric parameters.

- ● Dielectric material analysis function

Capacitance characteristics measurement/display	Graphically displays the capacitance and resistance component.
Dielectric permittivity derivation	Derives and graphically displays the complex dielectric permittivity and tanδ (dissipation factor).

- ● Magnetic material analysis function

Inductor characteristics measurement/display	Graphically displays the self-inductance and resistance component.
Magnetic permeability derivation	Derives and graphically displays the complex magnetic permeability and tanδ (dissipation factor).

- ● Inductor analysis function

Inductor characteristics measurement/display	Graphically displays the self-inductance, phase, and Q (quality factor).
Equivalent circuit estimation	Calculates the equivalent circuit parameter.
Equivalent circuit simulation	Simulates the inductor characteristics from the estimated equivalent circuit result.

- ● Capacitor analysis function

Capacitance characteristics measurement/display	Graphically displays the capacitance, phase, D (dissipation factor), and Q (quality factor).
Equivalent circuit estimation	Calculates the equivalent circuit parameter.
Equivalent circuit simulation	Simulates the capacitor characteristics from the estimated equivalent circuit result.

- ● Resistance analysis function

Resistance characteristics measurement/display	Graphically displays the complex impedance and phase.
Equivalent circuit estimation	Calculates the equivalent circuit parameter.
Equivalent circuit simulation	Simulates the resistance characteristics from the estimated equivalent circuit result.

● Transformer analysis function
    Leakage inductance measurement/display   Graphically displays the leakage inductance characteristics.

    Mutual inductance measurement/display   Graphically displays the mutual inductance characteristics.

    Coupling coefficient measurement/display   Displays the coupling coefficient characteristics.

    Turns ratio measurement/display   Displays the frequency characteristics of the primary-to-secondary turns ratio equivalent.

● (Varactor) Diode analysis function
    CV characteristics measurement/display   Displays the DC bias dependence of the capacitance and Q (quality factor).

    Tuning characteristics simulation   Displays the DC bias-resonance frequency characteristics.

● Servo analysis function
    Loop gain measurement/display   Displays the Bode diagram.
    Parameter extraction   Extracts the phase margin, gain margin, and loop bandwidth.

    Open to closed loop conversion   Calculates the closed loop characteristics from the loop gain characteristics.

    Closed to open loop conversion   Calculates the open loop characteristics from the closed loop characteristics.

    Circuit model identification   Identifies the transfer function (polynomial format, pole-zero format, and state space format).

    Circuit model simulation   Calculates the gain characteristics from the identified transfer function.

● Amplifier circuit analysis function
    Gain-Phase measurement/display   Displays the gain, phase, and group delay characteristics.

    Transfer function identification   Identifies the transfer function (polynomial format and state space format).

    Transfer function simulation   Calculates the amplifier circuit characteristics from the identified transfer function.

    CMRR characteristics measurement/display   Measures and displays the common mode rejection ratio (CMRR) characteristics.

    PSRR characteristics measurement/display   Measures and displays the power supply rejection ratio (PSRR) characteristics.

    Differential gain/phase measurement/display   Measures and displays the differential gain (DG) and differential phase (DP) characteristics.

    Saturation characteristics measurement/display   Measures and displays the 1 dB compression level.

- Filter circuit analysis function
  Filter frequency characteristics measurement/display

	Displays the passband gain, phase, and group delay characteristics.
Parameter extraction	Extracts the cutoff frequency, passband gain, passband ripple, maximum attenuation, BEF attenuation, and BPF bandwidth.
Transfer function identification	Identifies the transfer function (polynomial format and state space format).
Transfer function simulation	Calculates the filter characteristics from the identified transfer function.

- Impedance measurement function
  Impedance characteristics measurement/display

	Displays the complex impedance and phase characteristics of a sample.
Graph format	Bode diagram, Nyquist diagram, Cole Cole plot
Measurement item	$|Z|$ (impedance), $|Y|$ (admittance), θ (phase), R (resistance), X (reactance), G (conductance), B (susceptance)
Open correction, short correction	Measurement system error correction function at the impedance measurement

- Gain-phase measurement function
  Gain-phase characteristics measurement/display

	Displays the complex gain and phase characteristics of a target circuit.
Graph format	Bode diagram, Nyquist diagram, Cole Cole plot, Nichol's diagram
Measurement item	$|R|$ (gain), θ (phase), A (real part of gain), B (imaginary part of gain)
Equalize	Measurement system error correction function at the gain-phase measurement

9.2 Measurement accuracy

Measurement accuracy = basic accuracy + measurement system accuracy

● Basic accuracy
The accuracy of main unit alone, without signal cables and shunt resistors.
(Conditions)
- Immediately after calibration
- CH1/CH2 or CH2/CH1
- Measurement signal input voltages are from 100 mVpk to 10 Vpk
  (up to 2 Vpk over 2.2 MHz)

(Impedance) Basic accuracy (Za), Unit: %

Measured frequency			
≤ 20 kHz	≤ 500 kHz	≤ 2.2 MHz	> 2.2 MHz
0.5	1.0	10.0	25.0

(Gain) Basic accuracy (Ga), Unit: dB

Measured frequency			
≤ 20 kHz	≤ 500 kHz	≤ 2.2 MHz	> 2.2 MHz
0.05	0.1	1.0	2.0

(Phase) Basic accuracy (θa), Unit: deg

Measured frequency			
≤ 20 kHz	≤ 500 kHz	≤ 2.2 MHz	> 2.2 MHz
0.3	0.5	2.0	5.0

● Measurement system accuracy

Additional errors resulted from shunt resistor errors or stray components of the measurement cables when measuring impedance.

The measurement system accuracy varies depending on impedance measurement circuits or connection methods. The following is an example of measurement system accuracy when measuring impedances using "Shunt Resistor PA-001-0370" or "Test Fixture Adapter (100 Ω) PA-001-1839". Note that each value in the shaded area is the guaranteed performance, and others are typical values.
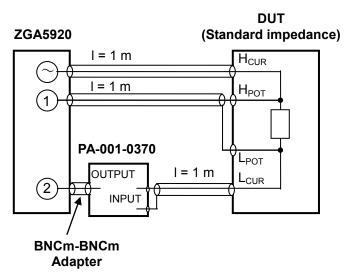
• When using Shunt Resistor PA-001-0370

(Impedance) Measurement system accuracy (Zb), Unit: %

DUT \ Frequency	≤ 100 Hz	≤ 1 kHz	≤ 10 kHz	≤ 100 kHz	≤ 1 MHz
1 Ω ≤ DUT < 10 Ω	1.0	1.0			1.5
10 Ω ≤ DUT ≤ 100 Ω					1.2

(Phase) Measurement system accuracy (θb), Unit: deg

DUT \ Frequency	≤ 100 Hz	≤ 1 kHz	≤ 10 kHz	≤ 100 kHz	≤ 1 MHz
1 Ω ≤ DUT < 10 Ω	0.1	0.1			0.5
10 Ω ≤ DUT ≤ 100 Ω	0.0	0.0			0.1

Connection diagram
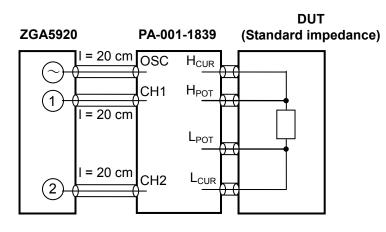
- When using Test Fixture Adapter (100 Ω) PA-001-1839

(Impedance) Measurement system accuracy (Zb), Unit: %

DUT \ Frequency	≤ 100 Hz	≤ 1 kHz	≤ 10 kHz	≤ 100 kHz	≤ 1 MHz
10 Ω ≤ DUT < 100 Ω	1.5				
100 Ω ≤ DUT < 1 kΩ	1.2				
1 kΩ ≤ DUT ≤ 100 kΩ	1.0	1.0			1.0
100 kΩ < DUT ≤ 1 MΩ	1.2				
1 MΩ < DUT ≤ 10 MΩ	4.0				

(Phase) Measurement system accuracy (θb), Unit: deg

DUT \ Frequency	≤ 100 Hz	≤ 1 kHz	≤ 10 kHz	≤ 100 kHz	≤ 1 MHz
10 Ω ≤ DUT < 100 Ω	1.0			1.0	5.0
100 Ω ≤ DUT < 1 kΩ	0.5				
1 kΩ ≤ DUT ≤ 100 kΩ	0.0	0.0		0.5	
100 kΩ < DUT ≤ 1 MΩ	0.5			1.0	
1 MΩ < DUT ≤ 10 MΩ	2.0				

Connection diagram

● Measurement accuracy

Impedance measurement accuracy Zacc and phase measurement accuracy θacc are obtained as shown below.

$$Zacc = Za + Zb$$
$$\theta acc = \theta a + \theta b$$

Parameters with a subscript x are obtained from actual measurements.

θx: Phase obtained from a measurement (phase converted to a value ranging from -180 to +180 deg)

$\tan\delta x$: $\tan\delta$ (dissipation factor) obtained from a measurement

Qx: Q (quality factor) obtained from a measurement

kx: k (transformer coupling coefficient) obtained from a measurement

○ Piezoelectric measurement accuracy

- Admittance |Y|[S]
- Conductance   G[S]   (when $|\theta x| \leq 5$ deg)
- Susceptance   B[S]   (when $|\theta x| \geq 85$ deg)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

  Measurement accuracy: ±Zacc %

- Conductance   G[S]   (when $|\theta x| > 5$ deg)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

  Measurement accuracy: $\pm\dfrac{Zacc}{\cos\theta x}$ %

- Susceptance   B[S]   (when $|\theta x| < 85$ deg)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

  Measurement accuracy: $\pm\dfrac{Zacc}{\sin\theta x}$ %

- Phase   θ [deg]

  Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution

  Measurement accuracy: $\pm\theta$ acc   deg

○ Dielectric measurement accuracy
- Parallel capacitance   Cp[F]   (when $|\theta x| \geq 85$ deg)
- Parallel resistance   Rp[Ω]   (when $|\theta x| \leq 5$ deg)
- Relative dielectric permittivity εs
- Real part of relative dielectric permittivity $\varepsilon s'$ (when $|\tan \delta x| \leq 0.1$)
- Imaginary part of relative dielectric permittivity $\varepsilon s''$ (when $|\tan \delta x| \geq 10$)
    Display range: $\pm$(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm$Zacc %

- Parallel capacitance   Cp[F]   (when $|\theta x| < 85$ deg)
- Real part of relative dielectric permittivity $\varepsilon s'$ (when $|\tan \delta x| > 0.1$)
    Display range: $\pm$(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm \dfrac{Zacc}{\sin \theta x}$ %

- Parallel resistance   Rp[Ω]   (when $|\theta x| > 5$ deg)
- Imaginary part of relative dielectric permittivity $\varepsilon s''$ (when $|\tan \delta x| < 10$)
    Display range: $\pm$(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm \dfrac{Zacc}{\cos \theta x}$ %

- Dissipation factor of relative dielectric permittivity $\tan \delta$ (when $|\tan \delta x| < 0.1$)
    Display range: $\pm$(0.000001 to 99,999.9) and 0, up to 6 digits
    Measurement accuracy: $\pm \dfrac{Zacc}{100}$

    * Accuracy of the value itself, not the percent (%).

○ Magnetic measurement accuracy
- Series inductance   Ls[H]   (when $|\theta x| \geq 85$ deg)
- Series resistance   Rs[Ω]   (when $|\theta x| \leq 5$ deg)
- Relative magnetic permeability μs
- Real part of relative magnetic permeability μs'   (when $|\tan\delta x| \leq 0.1$)
- Imaginary part of relative magnetic permeability μs"   (when $|\tan\delta x| \geq 10$)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: ±Zacc %

- Series inductance   Ls[H]   (when $|\theta x| < 85$ deg)
- Real part of relative magnetic permeability μs'   (when $|\tan\delta x| > 0.1$)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{Zacc}{\sin \theta x}$ %

- Series resistance   Rs[Ω]   (when $|\theta x| > 5$ deg)
- Imaginary part of relative magnetic permeability μs"   (when $|\tan\delta x| < 10$)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{Zacc}{\cos \theta x}$ %

- Dissipation factor of relative magnetic permeability   tanδ (when $|\tan\delta x| < 0.1$)
    Display range: ±(0.000001 to 99,999.9) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{Zacc}{100}$

    * Accuracy of the value itself, not the percent (%).

○ Inductor measurement accuracy
- Series inductance　Ls[H], parallel inductance　Lp[H]　　　(when |θx| ≥ 85 deg)
- Series resistance　Rs[Ω], parallel resistance　Rp[Ω]　　　(when |θx| ≤ 5 deg)
  - Display range:　　　　　　　±(1E-18 to 999.999E+15) and 0, up to 6 digits
  - Measurement accuracy:　　±Zacc %

- Series inductance　Ls[H], parallel inductance　Lp[H]　　　(when |θx| < 85 deg)
  - Display range:　　　　　　　±(1E-18 to 999.999E+15) and 0, up to 6 digits
  - Measurement accuracy:　　$\pm\dfrac{Zacc}{\sin\theta\,x}$ %

- Series resistance　Rs[Ω], parallel resistance　Rp[Ω]　　　(when |θx| > 5 deg)
  - Display range:　　　　　　　±(1E-18 to 999.999E+15) and 0, up to 6 digits
  - Measurement accuracy:　　$\pm\dfrac{Zacc}{\cos\theta\,x}$ %

- Phase　θ [deg]
  - Display range:　　　　　　　-9,999.999 to +9,999.999 deg with 0.001 deg resolution
  - Measurement accuracy:　　± θ acc deg

- Quality factor　Q
  - Display range:　　　　　　　±(0.000001 to 99,999.9) and 0, up to 6 digits
  - Measurement accuracy:　　$\pm\dfrac{\sin\theta\,acc\cdot Qx^{2}}{1-\sin\theta\,acc\cdot Qx}$

  * Accuracy of the value itself, not the percent (%).

○ Capacitor measurement accuracy
- Series capacitance   Cs[F], parallel capacitance   Cp[F]   (when $|\theta x| \geq 85$ deg)
- Series resistance   Rs[Ω], parallel resistance   Rp[Ω]   (when $|\theta x| \leq 5$ deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: ±Zacc %

- Series capacitance   Cs[F], parallel capacitance   Cp[F]   (when $|\theta x| < 85$ deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{\text{Zacc}}{\sin \theta \text{ x}}$ %

- Series resistance   Rs[Ω], parallel resistance   Rp[Ω]   (when $|\theta x| > 5$ deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{\text{Zacc}}{\cos \theta \text{ x}}$ %

- Phase   θ [deg]
    Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution
    Measurement accuracy: $\pm \theta$ acc deg

- Quality factor   Q
    Display range: ±(0.000001 to 99,999.9) and 0, up to 6 digits

    Measurement accuracy: $\pm\dfrac{\sin \theta \text{ acc}\cdot \text{Qx}^2}{1 - \sin \theta \text{ acc}\cdot \text{Qx}}$

    * Accuracy of the value itself, not the percent (%).

- Dissipation factor   D   (when $|\tan\delta x| < 0.1$)
    Display range: ±(0.000001 to 99,999.9) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{\text{Zacc}}{100}$

    * Accuracy of the value itself, not the percent (%).

○ Resistor measurement accuracy
  - Impedance |Z|[Ω]
  - Resistance   R[Ω]   (when |θx| ≤ 5 deg)
  - Reactance   X[Ω]   (when |θx| ≥ 85 deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: ±Zacc %

  - Resistance   R[Ω]   (when |θx| > 5 deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: $\pm\dfrac{Zacc}{\cos\theta\,x}$ %

  - Reactance   X[Ω]   (when |θx| < 85 deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: $\pm\dfrac{Zacc}{\sin\theta\,x}$ %

  - Phase   θ [deg]
      Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution
      Measurement accuracy: $\pm\theta$ acc deg

○ Transformer leakage inductance measurement accuracy
  - Leakage inductance   Lleak[H]   (when |θx| ≥ 85 deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: ±Zacc %

  - Leakage inductance   Lleak[H]   (when |θx| < 85 deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: $\pm\dfrac{Zacc}{\sin\theta\,x}$ %

○ Transformer mutual inductance measurement accuracy
   • Inductance at aiding/opposing connection   Inductance[H]   (when $|\theta x| \geq 85$ deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: ±Zacc %

   • Inductance at aiding/opposing connection   Inductance[H]   (when $|\theta x| < 85$ deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: $\pm\dfrac{Zacc}{\sin \theta \, x}$ %

   • Mutual inductance   M[H]
      When (Inductance at aiding connection) > (inductance at opposing connection × 10)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: $\pm\dfrac{Zacc}{\sin \theta \, x}$ %

○ Transformer coupling coefficient measurement accuracy
   • Inductance when secondary side is shorted/opened   Inductance[H]   (when $|\theta x| \geq 85$ deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: ±Zacc %

   • Inductance when secondary side is shorted/opened   Inductance[H]   (when $|\theta x| < 85$ deg)
      Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
      Measurement accuracy: $\pm\dfrac{Zacc}{\sin \theta \, x}$ %

   • Coupling coefficient   k
      Display range: 0.000 to 1.000 with 0.001 resolution
      Measurement accuracy: $\pm\dfrac{Zacc}{50}$ (1 - kx)

      * Accuracy of the value itself, not the percent (%).

○ Transformer turns ratio measurement accuracy

      Display range: 0.0001 to 9,999, up to 4 digits

      Measurement accuracy: $\pm Za$ %

○ (Varactor) Diode measurement accuracy

- Parallel capacitance $Cp[F]$ (when $Qx \geq 10$)

      Display range: $\pm$(1E-18 to 999.999E+15) and 0, up to 6 digits

      Measurement accuracy: $\pm Zacc$ %

- Parallel capacitance $Cp[F]$ (when $Qx < 10$)

      Display range: $\pm$(1E-18 to 999.999E+15) and 0, up to 6 digits

      Measurement accuracy: $\pm \dfrac{Zacc}{\sin \theta x}$ %

- Quality factor Q

      Display range: $\pm$(0.000001 to 99,999.9) and 0, up to 6 digits

      Measurement accuracy: $\pm \dfrac{\sin \theta \, acc \cdot Qx^2}{1 - \sin \theta \, acc \cdot Qx}$

      * Accuracy of the value itself, not the percent (%).

○ Servo characteristics measurement accuracy
- Loop gain   Gloop[dB]
- Feedback gain   Gfbk[dB]
- Closed loop gain   Gclose[dB]
    Display range: -999.999 to +999.999 dB with 0.001 dB resolution
    Measurement accuracy: ±Ga dB

- Real part of loop gain   Real(Gloop)   (when $|\theta x| \leq 5$ deg or 175 deg $\leq |\theta x|$)
- Imaginary part of loop gain   Imag(Gloop)   (when 85 deg $\leq |\theta x| \leq 95$ deg)
- Real part of feedback gain   Real(Gfbk)   (when $|\theta x| \leq 5$ deg or 175 deg $\leq |\theta x|$)
- Imaginary part of feedback gain   Imag(Gfbk)   (when 85 deg $\leq |\theta x| \leq 95$ deg)
- Real part of closed loop gain   Real(Gclose)   (when $|\theta x| \leq 5$ deg or 175 deg $\leq |\theta x|$)
- Imaginary part of closed loop gain   Imag(Gclose)   (when 85 deg $\leq |\theta x| \leq 95$ deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: ±Za %

- Real part of loop gain   Real(Gloop)   (when 5 deg $< |\theta x| < 175$ deg)
- Real part of feedback gain   Real(Gfbk)   (when 5 deg $< |\theta x| < 175$ deg)
- Real part of closed loop gain   Real(Gclose)   (when 5 deg $< |\theta x| < 175$ deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{Za}{\cos\theta x}$ %

- Imaginary part of loop gain   Imag(Gloop)   (when $|\theta x| < 85$ deg or 95 deg $< |\theta x|$)
- Imaginary part of feedback gain   Imag(Gfbk)   (when $|\theta x| < 85$ deg or 95 deg $< |\theta x|$)
- Imaginary part of closed loop gain   Imag(Gclose)   (when $|\theta x| < 85$ deg or 95 deg $< |\theta x|$)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{Za}{\sin\theta x}$ %

- Phase   θ [deg]
    Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution
    Measurement accuracy: $\pm\theta a$ deg

○ Amplifier circuit gain-phase characteristics measurement accuracy
- Gain   Gain[dB]
    Display range: -999.999 to +999.999 dB with 0.001 dB resolution
    Measurement accuracy: ±Ga dB

- Phase   θ [deg]
    Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution
    Measurement accuracy: ± θ a deg

- Group delay   GD[s]
    Display range: ±(1E-15 to 9.99999E+03) s and 0 s, up to 6 digits

    Measurement accuracy: $\pm\dfrac{\theta\,a}{360\times APT}$ s

    * APT: Aperture setting (Δf[Hz])

○ Amplifier circuit CMRR characteristics measurement accuracy
- Common-mode gain   GainCOM[dB], Normal-mode gain   GainNORM[dB]
    Display range: -999.999 to +999.999 dB with 0.001 dB resolution
    Measurement accuracy: ±Ga dB

- Phase   θ [deg]
    Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution
    Measurement accuracy: ± θ a deg

- CMRR[dB]   (When normal-mode gain are measured)
    Display range: -999.999 to +999.999 dB with 0.001 dB resolution
    Measurement accuracy: ±2Ga dB

- CMRR[dB]   (When normal-mode gain are setting constant)
    Display range: -999.999 to +999.999 dB with 0.001 dB resolution
    Measurement accuracy: ±Ga dB

○ Amplifier circuit PSRR characteristics measurement accuracy

      Display range: -999.999 to +999.999 dB with 0.001 dB resolution

      Measurement accuracy: $\pm Ga$ dB

○ Amplifier circuit differential gain/phase characteristics measurement accuracy

  • Differential gain   DG[dB]

      Display range: -999.999 to +999.999 dB with 0.001 dB resolution

      Measurement accuracy: $\pm Ga$ dB

  • Differential phase   DP[deg]

      Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution

      Measurement accuracy: $\pm \theta a$ deg

○ Amplifier circuit saturation characteristics measurement accuracy

      Display range: -999.999 to +999.999 dB with 0.001 dB resolution

      Measurement accuracy: $\pm 2Ga$ dB

○ Filter circuit measurement accuracy

  • Gain   Gain[dB]

      Display range: -999.999 to +999.999 dB with 0.001 dB resolution

      Measurement accuracy: $\pm Ga$ dB

  • Phase θ [deg]

      Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution

      Measurement accuracy: $\pm \theta a$ deg

  • Group delay   GD[s]

      Display range: $\pm$(1E-15 to 9.99999E+03) s and 0 s, up to 6 digits

      Measurement accuracy: $\pm \dfrac{\theta a}{360 \times APT}$ s

  * APT: Aperture setting (Δf[Hz])

○ Impedance measurement accuracy
- Impedance |Z|[Ω]
- Resistance   R[Ω]   (when |θx| ≤ 5 deg)
- Reactance   X[Ω]   (when |θx| ≥ 85 deg)
- Conductance   G[S]   (when |θx| ≤ 5 deg)
- Susceptance   B[S]   (when |θx| ≥ 85 deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: ±Zacc %

- Resistance   R[Ω]   (when |θx| > 5 deg)
- Conductance   G[S]   (when |θx| > 5 deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{Zacc}{\cos\theta x}$ %

- Reactance   X[Ω]   (when |θx| < 85 deg)
- Susceptance   B[S]   (when |θx| < 85 deg)
    Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
    Measurement accuracy: $\pm\dfrac{Zacc}{\sin\theta x}$ %

- Phase   θ [deg]
    Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution
    Measurement accuracy: ± θ acc deg

○ Gain-phase measurement accuracy
- Gain [dB]
  Display range: -999.999 to +999.999 dB with 0.001 dB resolution
  Measurement accuracy: ±Ga dB

- Real part of gain   A   (when $|\theta x| \leq 5$ deg or 175 deg $\leq |\theta x|$)
- Imaginary part of gain   B   (when 85 deg $\leq |\theta x| \leq 95$ deg)
  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
  Measurement accuracy: ±Za %

- Real part of gain   A   (when 5 deg $< |\theta x| < 175$ deg)
  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
  Measurement accuracy: $\pm\dfrac{Za}{\cos \theta x}$ %

- Imaginary part of gain   B   (when $|\theta x| < 85$ deg or 95 deg $< |\theta x|$)
  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits
  Measurement accuracy: $\pm\dfrac{Za}{\sin \theta x}$ %

- Phase θ [deg]
  Display range: -9,999.999 to +9,999.999 deg with 0.001 deg resolution
  Measurement accuracy: $\pm \theta a$ deg

9.3 Measurement processing

● Auto ranging

This function allows an input range to switch in response to input signal level.

● Delay

This function is to delay measurement start time after frequency change.

A delayed amount is specified by time or cycle count.

Process of "frequency setting → delay → measurement" is to be repeated during frequency sweep.

    Setting by time

        Range   0 to 9,999 sec

        Set resolution   10 ms

    Setting by cycle count

        Range   0 to 9,999 cycles

        Set resolution   1 cycle

● Integration

This function is to integrate data for measurement with noise reduced.

A measuring cycle is specified by cycle count or time.

    Setting by cycle count

        Range   1 to 9,999 cycles

        Set resolution   1 cycle

    Setting by time

        Range   0 to 9,999 sec

                              (The integral of one cycle must be evaluated regardless of settings.)

        Set resolution   10 ms

● Frequency axis high-density sweep (automatic slow high-density sweep)

This function is to perform accurate measurement through automatic increase in sweep density between the relevant frequencies in response to substantial changes in measurement data.

    Reference channel   CH1 or CH2

    Variation width

      a, b, R

        Setting range   0 to 1 GVrms

        Set resolution   3 digits or 1 μV, either of whichever are greater

      dBR

        Setting range   0 to 1000 dB

        Set resolution   3 digits or 0.01 dB, either of whichever are greater

      Phase

        Setting range   0 to 180 deg

        Set resolution   3 digits or 0.01 deg, either of whichever are greater

- Pseudo constant current output measurement (amplitude compression)
  Constant current measurement can be performed for the samples.
  The constant current measurement can be performed by converting the current applied to the sample into a voltage using a shunt resistor, detecting it at the monitored measurement signal input, and controlling the oscillator output level.
  In consideration of the characteristics of the sample, you need to select the shunt resistor and the amplifier which can properly detect the voltage from the target current value at the monitored measurement signal input, and set them as appropriate.

Compression mode	CH 1, CH 2 or OFF
Detection range of target voltage level	1 m to 250 Vrms
Tolerance range of target level	0 to 100%
Maximum level control counts	1 to 9,999
Level correction control rate	0 to 100%
Limit range of output voltage	1 mV to 10 Vpk

- Overload input detection

CH1	0 to 250 Vrms
CH2	0 to 250 Vrms
Action upon detection	Continue, abort sweep, or turn output OFF

- Equalization
  The equalization function is to be utilized with frequency response of the measuring system (sensor, cable) pre-investigated. This function is to sort only characteristic of the intended measuring system from errors upon actual measurement.

- Open/short correction
  This function is to measure in advance the frequency characteristics of the residual impedance and admittance of the measurement system such as a shunt resistor and cable, and remove these measurement system residuals to get the impedance characteristics of a target sample itself in a production measurement. It is used at the impedance measurement.

- Calibration
  This function is to perform the self error compensation.

  With this instrument, calibration is not automatically performed at power-on.
  Perform calibration by all means before measurement.
  Otherwise, a measurement error could be caused.

  Measurements cannot be performed during calibration.

9.4 Analyzer input

- Number of input channels   2 channels

  The impedance measurement assumes the CH1 as voltage and the CH2 as a value converted from current to voltage.

- Connector   Insulated BNC connector
- Input impedance   1 MΩ ±2%, 25 pF ±5 pF (parallel)
- IMRR (isolation mode rejection ratio)

  Max. 120 dB (DC to 60 Hz)

  Applicable if a signal source impedance is smaller than 1 Ω

- Isolation

  Withstand voltage   250 Vrms continuous (between signal/ground and cabinet)

  250 Vrms continuous (between signal/ground and oscillator, between analysis input channels)

  A voltage when a supplied BNC cable is used

  30 Vrms continuous if other cable is used

  Capacitance against enclosure   Max 200 pF

- Maximum transient overvoltage   1,500 Vrms
- Frequency range   0.1 mHz to 15 MHz
- Max. input voltage   250 Vrms (AC), ±200 V (DC), or ±350 Vpeak (AC+DC)

  A voltage when a supplied BNC cable is used

  30 Vrms (AC), ±60 V (DC), or ±42 Vpeak (AC+DC) if other cable is used

- Max. measured voltage   250 Vrms

  A voltage when a supplied BNC cable is used

  30 Vrms if other cable is used

- Harmonics and noise rejection ratio

  Normal mode DC   Min. 60 dB

  Wideband white noise   Min. 50 dB (noise bandwidth: 500 kHz, integration: 1,000 cycles)

  Harmonics (Max. order 10)   Min. 60 dB (analysis frequency: Max. 100 kHz)

  Min. 40 dB (analysis frequency: Min. 100 kHz)

- Dynamic range   140 dB typ (10 Hz to 1 MHz)

  80 dB typ (Min. 1 MHz, Max. 15 MHz)

  (Larger channel input: Min. 10 Vpeak, integration: 4,000 cycles)

- Input weighting   0 to 1.0E+6 (resolution: 5 digits or 0.01E-9)

  Phase invert is possible.

Specifications for isolation withstand voltage between the oscillator (OUTPUT-OSC) or analysis input (INPUT-CH1 and INPUT-CH2) and the cabinet with the supplied BNC cable used are presented below (Figure 9-1).
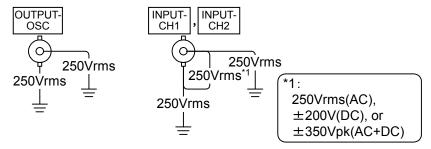
Figure 9-1 Specifications for isolation withstand voltage (with supplied BNC cable used)

Figure 9-2 shows isolation withstand voltage specifications when other cable is used.
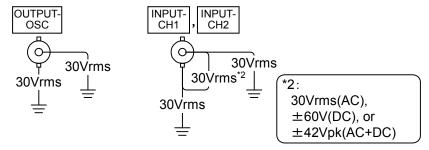
Figure 9-2 Specifications for isolation withstand voltage (with other cable used)

Specifications for isolation withstand voltage between the oscillator (OUTPUT-OSC) and analysis input (INPUT-CH1 and INPUT-CH2) with the supplied BNC cable used are presented in Figure 9-3).
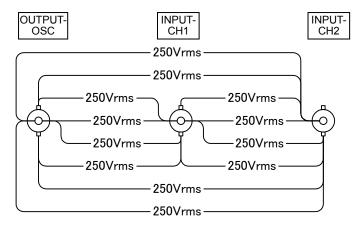

Figure 9-3 Specifications for isolation withstand voltage between oscillator and analysis input
(with supplied BNC cable used)

Figure 9-4 shows isolation withstand voltage specifications between the oscillator (OUTPUT-OSC) and analysis input (INPUT-CH1 and INPUT-CH2) when other cable is used.
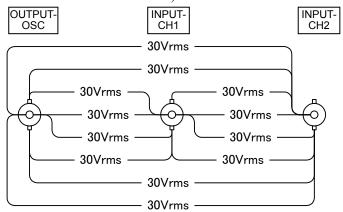

Figure 9-4 Specifications for isolation withstand voltage between oscillator and analysis input
(with other cable used)

9.5 Oscillator

- Number of output channels   1 channel
- Connector   Insulated BNC connector
- Output waveform   Sinusoidal
- Frequency
  Range   0.1 mHz to 15 MHz
  Set resolution   0.1 mHz
  Accuracy   ±10 ppm
- AC amplitude
  Range   0 V to 10 Vpk (at no load)
  Set resolution   3 digits or 0.01 mVpk, either of whichever are greater
  Accuracy (sine wave)   Within ±0.3 dB (for no more than 100 kHz)
      Within ±1 dB (for no more than 1 MHz)
      Within ±3 dB (for no more than 15 MHz)
      (A value obtained immediately after calibration with it being set at 100 mVpeak to 10 Vpk, at no load)
  Distortion (sine wave)   Max. 0.2% (Max. 100 kHz, BW500 kHz at 10 Vpk output)
- DC bias
  Range   -10 V to 10 V (at no load)
  Resolution   10 mV
  Accuracy   ±(1% of DC bias setting + 2% of AC amplitude setting + 30 mV)
      (A value obtained immediately after calibration, at no load)
- Output impedance   50 Ω ±2% (at 1 kHz), unbalanced (BNC junction)
- Max. output (AC+DC)
  Voltage   ±10 V (at no load)
  Current   ±100 mA
- Sweep
  Sweep item   Any of Frequency, Amplitude, DC Bias, and Zero span (time)
- Frequency sweep
  Range   0.1 mHz to 15 MHz
  Points
     Log sweep   4 to 20,000 points
     Linear sweep   4 to 20,000 points

- Amplitude sweep
  - Range   0.01 mVpk to 10 Vpk
  - Points
    - Log sweep   4 to 20,000 points
    - Linear sweep   4 to 20,000 points
- DC bias sweep
  - Range   -10 V to +10 V
  - Points
    - Log sweep   4 to 20,000 points
    - Linear sweep   4 to 20,000 points
- Zero span sweep
  - Range   1.00 s to 999,999.99 s (approximately 12 days)
  - Resolution   0.01 s
  - Points
    - Log sweep   4 to 20,000 points
    - Linear sweep   4 to 20,000 points
- Isolation
  - Withstand voltage   250 Vrms continuous (between signal/ground and cabinet)
    - 250 Vrms continuous (between signal/ground and analysis input)
    - A voltage when a supplied BNC cable is used
    - 30 Vrms continuous if other cable is used
  - Capacitance against enclosure   Max. 250 pF
- Maximum transient overvoltage   1,500 Vrms

9.6 Display

- Monitor   1,280 × 1,024 dots, 19 inches
- Status display   LED lamp on the front panel

  Lamps that indicate states of this instrument.

  Displayed item

MEASURING	It is lit on during measurement.
CALIBRATING	It is lit on during calibration.
ERROR	It is lit on when an error occurs.
POWER	It is lit on during power-on.
ON OUTPUT-OSC	It is lit on during oscillator output.
OVER INPUT-CH1	It is lit on while an excess voltage is inputting to the INPUT-CH1.
OVER INPUT-CH2	It is lit on while an excess voltage is inputting to the INPUT-CH2.

- Measurement result data display (marker)

  Measurement and simulation data can be read by the marker.

  Gain

Linear	1E-18 to 999.999E+15 and 0, up to 6 digits
Logarithmic	±999.999 dB with 0.001 dB resolution
Phase	-9,999.999 to +9,999.999 deg with 0.001 deg resolution
|Z|, |Y|, R, X, G, B, L, C, R	±(1E-18 to 999.999E+15) and 0, up to 6 digits
D, Q	±(0.00001 to 99,999.9) and 0, up to 6 digits
ε, μ	±(1E-18 to 999.999E+15) and 0, up to 6 digits
k (Coupling coefficient)	0.000 to 1.000 with 0.001 resolution
N (transformer turns ratio)	0.0001 to 9,999, up to 4 digits
GD (Group delay)	±(1E-15 to 9.99999E+03) s and 0 s, up to 6 digits
tanδ (dissipation factor)	±(0.000001 to 99,999.9) and 0 s, up to 6 digits

9.7 Internal storage

The internal storage (memory) of this instrument stores data, setting information, and so on.

- Measurement recipe   Measurement conditions, correction data, and control I/O settings for each application
  300 or more recipes can be stored for each application.
  They are not lost at power-off.
- Measurement result data   Data obtained from a measurement or simulation
  300 or more sets of data can be stored for each application.
  They are not lost at power-off.
- Setting information   Various setting information of this instrument
  At power-on, this instrument returns to the setting at which it was last operated.
  It cannot be saved or read by user operations.
  Only one set can be stored.
- Correction data   Data for correcting measurement system errors
  This data is stored when performing correction.

  Equalizing memory   Stores the frequency characteristics of a probe and so on at gain-phase measurement.

  Open correction memory   Stores the residual admittance frequency characteristics at impedance measurement.

  Short correction memory   Stores the residual impedance frequency characteristics at impedance measurement.
- Data logger data   Data recorded from analog signal input

9.8 External storage

- External memory   USB 1.1 or USB 2.0 compliant USB memory
- Connector   Front panel, USB-A connector
- File system   FAT32
- Maximum capacity   32 GB
- File type
  - Report output

File format	PDF format
Measurement result	Graph, marker reading, parameter extraction result, and so on
Measurement conditions	Measurement date and time, instrument settings, and so on
Measurement record	Measurer, location, temperature, humidity, atmospheric pressure, list of used instruments (entered by user)

  - Graph output (hardcopy of graph area)

File format	BMP format

  - Measurement recipe

File format	XML format

  - Measurement result data

File format	XML format

  - Transfer function

File format	TXT format

  - Data logger

File format	WDB format (a proprietary binary file format)

9.9 Peripheral input/output functions

- USB (host)
  This port is used to connect with a keyboard, trackball, USB memory (sold separately).

Standard	USB 2.0
Number of ports	6 (2 on the front panel, 4 on the rear panel)
Connector	USB-A connector

- USB (function)
  This port is used to connect with an external PC when using this instrument as an FRA compatible unit.

Standard	USB 1.1
Number of ports	1
Connector	Rear panel, USB-B connector
Device class	USB-TMC

There are following functional restrictions in the FRA compatible remote control:
- The functions in "9.1 Analysis processing" are not available.
  Measurement is limited to the basic gain-phase and impedance characteristics.
  (Impedance is handled as the magnitude ratio and phase difference between CH1 (voltage) and CH2 (current-to-voltage conversion result).)
- The "● Amplitude sweep", "● DC bias sweep", and "● Zero span sweep" in "9.5 Oscillator" are not available. Limited only to the frequency sweep.
- Only the gain and phase can be read in "● Measurement result data display" in "9.6 Display".

● LAN (Ethernet)

This port is used to connect to LAN when this instrument is controlled through an external PC.

When connected, the Auto Negotiation function automatically detects the transfer rate.

The AUTO-MDIX, which automatically detects the required cable connection type (straight-through or crossover), is not supported.

Interface standard	IEEE 802.3ab compliant (for 1000 BASE-T)
	IEEE 802.3u compliant (for 100 BASE-T)
	IEEE 802.3 compliant (for 10 BASE-T)
Transfer rate (logical value)	1,000 Mbps (for 1000 BASE-T)
	100 Mbps (for 100 BASE-T)
	10 Mbps (for 10 BASE-T)
Number of ports	1
Connector	Rear panel: RJ-45 type, 8-pin modular jack
	Category 5e cables are recommended for connection.
	The desired transfer rate may not be reached with cables in a category lower than 5e.

A proprietary protocol for ZGA5920 is used for controlling measurement, or importing or exporting files from a PC. To enable easy communication from a PC, use the Utility Software and the Software Developer Kit (NFRemote component) contained in the accompanying CD-ROM.

● VGA

Standard	Analog RGB
Number of ports	1
Connector	Rear panel, DIPSLAY connector (mini D-Sub 15-pin, female)

● DC power output

Power output connected to our Signal Injector Probe 5055 (sold separately)

Connector	Rear panel, AUX connector

● Maintenance connector

This connector is for maintenance of the ZGA5920 main unit. Do not connect anything.

Connector	Rear panel, MAINTENANCE1 and MAINTENANCE2

● Control I/O
This connector is used to control external devices and operate them in conjunction with this instrument.
Connect the external device to the control I/O connector via the appropriate relay drive circuit to drive external relay.

Signal input section
Channels	8 channels
Input voltage	TTL
Input impedance	10 kΩ pull-up
High Voltage	2.1 V (Min)/5.5 V (Max)
Low Voltage	-0.5 V (Min)/0.5 V (Max)
Minimum detectable pulse width	300 μs
Input logic polarity	Negative logic
Input terminal	Control I/O D-Sub 37-pin connector
Input signals	Start measuring (2)/Abort measuring (3)/Output ON (4)/Output OFF (5)

Figures in brackets ( ) are pin numbers. (6) to (9) Reserved.
Maximum delay time from signal input until measurement starts is possible is 250 ms or less.

Signal output section
Channels	8 channels
Output format	TTL
High Voltage	3.8 V (Min)
Low Voltage	0.44 V (Max)
Maximum output current	5 mA
Output logic polarity	Positive logic
Output terminal	Control I/O D-Sub 37-pin connector
Output signals	Pulse output	Start measuring (11)/Complete measuring (12)/Elapsed time since the start of measurement (13)
	State output	Output: ON/OFF (14) Measurement: Measuring/Idle (15)

Figures in brackets ( ) are pin numbers. (16) to (18) Reserved.
Maximum delay time from change in internal state to signal output is 250 ms or less.

● Analog signal input
This connector is used to perform data logging in concert with measurements on this instrument.

Input section
Channels	1 channel
Input range	±10 V
Input impedance	1 MΩ
Input coupler	DC
A/D converter resolution	16-bit
Input error	Input range FS ±0.5%, DC (typical value)
Frequency characteristics	DC to 10 kHz, ±3 dB (typical value)
Input terminal	BNC

Logging function
Storage	Internal storage, up to 20 GB
Sampling rate	1 to 25 k S/s
Maximum logging time	Approximately 8 hours/log
	You can store multiple logs within the limit of 20 GB.
Start logging	Start measuring/Output ON/Specified logging time from starting logging
	Data will not be logged if logging is completed before the specified logging time elapses.
	Maximum delay time until logging starts is 250 ms or less.
Stop logging	Complete measuring/Abort measuring/Output OFF/Specified logging time from starting logging
	Note that logging will stop when the maximum logging time is reached.
	Maximum delay time until logging stops is 250 ms or less.

9.10 Miscellaneous specifications

(System common specifications)

- Power input   Check for the power input specification when you order this instrument.

      Voltage   AC 90 V to 132 V/180 V to 250 V

      Frequency   50 Hz/60 Hz ±2 Hz

      Overvoltage category   II

- Environmental conditions

      Ambient temperature/humidity range

         Performance guaranteed   +5 to +35 °C, 30 to 80% RH (no condensation)

         Storage conditions   -10 to +50 °C, 30 to 80% RH (no condensation)

         Pollution degree   2

- Safety standard[1]   EN 61010-1:2010

                               EN 61010-2-30:2010

- EMC[1]   EN 61326-1:2006 (Group 1, Class A)

                               EN 61000-3-2:2006

                               EN 61000-3-3:2008

*1: Compliant only on ZGA5920 units with the CE marking.

(ZGA5920 main unit specifications)

- Power consumption   Maximum 150 VA
- Machine cooling   Forced air cooling, rear discharge type
- Installation posture   Level or upright (within 10°)
- Insulation resistance   No less than 20 MΩ (at 500 V DC, between power inputs altogether and the enclosure)
- Withstand voltage   1,500 V AC (between power inputs altogether and the enclosure)
- External dimensions   430 (W) × 173 (H) × 438 (D) mm (without protrusions)
- Weight   About 12.5 kg

(Monitor unit specifications)   External view and specifications are subject to change without prior notice. Please check when placing your order.

- Power consumption   Maximum 45 W
- External dimensions   405 (W) × 416 (H) × 205 (D) mm
- Weight   About 6 kg

(Keyboard unit specifications)   External view and specifications are subject to change without prior notice. Please check when placing your order.

- Interface standard   USB 1.1 HID compliant, 106/109 compatible keyboard (Japanese) or 101/104 compatible keyboard (US)
- Power source   Supplied from the ZGA5920 main unit USB port
- External dimensions   338 (W) × 37 (H) × 251 (D) mm
- Weight   About 610 g

(Trackball unit specifications) External view and specifications are subject to change without prior notice. Please check when placing your order.

- Interface standard USB 1.1 HID compliant mouse
- Power source Supplied from the keyboard USB port
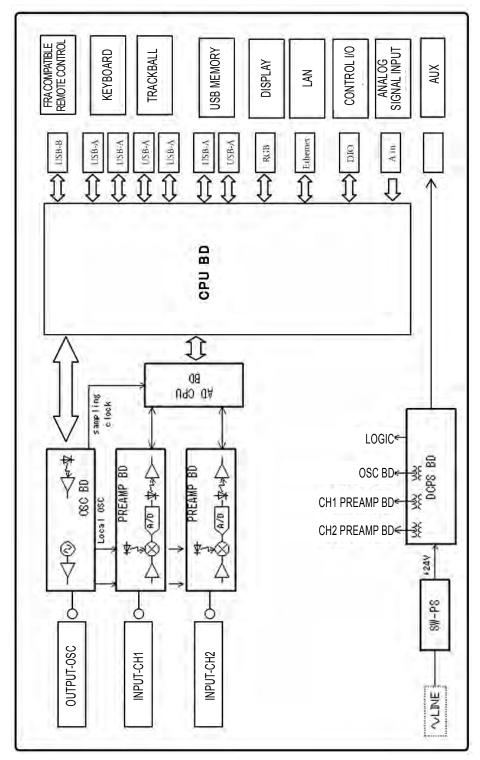- External dimensions 87 (W) × 43 (H) × 166 (D) mm
- Weight About 200 g
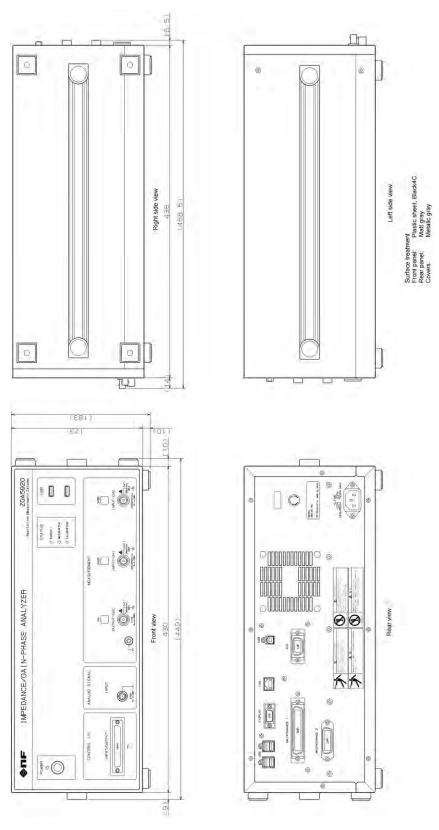
Figure 9-5 Block diagram (main unit)

Languages on the labels may vary depending on users area.

Figure 9-6 Outline drawing (main unit)

── WARRANTY ──

NF Corporation certifies that this product was thoroughly tested and inspected and found to meet its published specifications when it was shipped from our factory.

All **NF** products are warranted against defects in materials and workmanship for a period of one year from the date of shipment. During the warranty period, **NF** will repair the defective product without any charge for the parts and labor. For repair service under warranty, the product must be returned to either **NF** or an agent designated by **NF**. Purchaser shall prepay all shipping charge, duties and taxes for the product to either **NF** or the agent from another country, and shipping charge for the return of the product to purchaser shall be paid by **NF** side.

This warranty shall not apply to any defect, failure or damage caused by a) improper use; b) improper or inadequate maintenance and care; or c) modification by purchaser or personnel other than **NF** representatives.

NF Corporation

If there are any misplaced or missing pages, we will replace the manual. Contact the sales representative.

NOTES

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- The contents of this manual may be revised without notice.
- Information provided in this manual is intended to be accurate and reliable. However, we assume no responsibility for any damage regarding the contents of this manual.
- We assume no responsibility for influences resulting from the operations in this manual.

ZGA5920   Instruction Manual

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