IMPEDANCE/GAIN-PHASE ANALYZER

ZGA5905

INSTRUCTION MANUAL

NF Corporation

DA00028610-002

IMPEDANCE/GAIN-PHASE ANALYZER

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INSTRUCTION MANUAL

Preface

Thank you for purchasing "the ZGA5905 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 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. **Operations in Basic Mode**
   Descriptions are given in this Chapter on operations of impedance measurement and gain-phase measurement.
5. **Operations in Advanced Mode**
   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 warnigns and cautions.
NF Corporation shall not be held liable for damages that arise from a failure to observe these warinings 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 100Ω.
  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 Section 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.

Table of Contents

Figures

Tables

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H. Notes. The following applies to the VLP (Volume License Program):

(1.) Program Requirements. You shall designate a separate Software Administrator for each Site and shall promptly notify NI in writing of any changes to the Software Administrator(s). In order to participate in the VLP, the VLP Licenses that you maintain during the VLP Term must at all times include a minimum of five (5) copies (in the aggregate) of versions of the SOFTWARE, which are considered by NI to be development versions of the SOFTWARE. NI will deliver the master installation disks for the SOFTWARE and, if provided for in the applicable written quotation from NI, make available the NI VLM to the Software Administrator(s). You are responsible for ensuring that an Approved Volume License Manager, together with the most current license file provided by NI that controls end-user access to the SOFTWARE, is in use at all times with the SOFTWARE licensed under the VLP (during the term of the VLP and thereafter). If the Approved Volume License Manager is the NI VLM or if NI makes documentation available for the applicable Approved Volume License Manager, such Approved Volume License Manager shall be installed and used in accordance with the documentation provided by NI. If you have existing individual, computer based or named user licenses for the SOFTWARE that are to be covered by the VLP, (i) you shall notify NI in writing of the product, platform, and serial number information for each such license; (ii) each such license shall (as of the VLP Effective Date) no longer be in effect and shall be superseded by the VLP; (iii) all individual serial numbers for each such license shall be cancelled and replaced by a single, common serial number assigned to the VLP and the corresponding VLP Licenses; and (iv) should you later desire to obtain individual serial numbers for any of the VLP Licenses, you will be required to pay NI its then current fee for a conversion from a VLP License to an individual named user license, computer based license, or debug license having an individual serial number. Regarding Software Service, NI reserves the right to restrict Software Service to the then most current version of the SOFTWARE that is commercially available. You understand that NI may not make available Software Service for all SOFTWARE available under the VLP.

(2.) Activity Compliance Logs. In addition to the submission requirement in sub-section (4.) below, you are required to provide an Activity Compliance Log for each Site to NI promptly (but in no event later than fifteen (15) days) following (i) the annual anniversary of the VLP Effective Date during the VLP Term and (ii) the VLP Termination Date. NI may, upon notice to you, inspect the Site(s) and applicable records in order to verify the accuracy of the Activity Compliance Logs. You shall pay any verified underpayments to NI within thirty (30) days of receipt of a written notice of such underpayments. Further, if you have underpaid, NI may require you to pay for any reasonable out-of-pocket costs actually incurred by NI in verifying the underpayment.

(3.) Purchase Orders; Invoices. You shall submit purchase orders to NI as follows:

a. in the amount of the Activation Fee within the time-frame specified in the quote provided by NI to you for the VLP;

b. in the amount of the Additional VLP Fees prior to the end of the then current VLP Term as set forth below; and

c. in the amount of the VLP Renewal Fees prior to the end of the then current VLP Term as set forth below if you desire to renew the VLP.

You are required to obtain and maintain Software Services for each VLP License for which Software Services are made available by NI. The Software Services are charged on an annual basis and, for VLP Licenses added during the VLP Term, will only be pro-rated on a quarterly basis (based on the quarter of the VLP Term in which the SOFTWARE under such VLP License was first used), or such shorter basis as NI may designate, if a purchase order is submitted to NI prior to the date the SOFTWARE for the Additional VLP License is installed or otherwise used. All invoices shall be paid within thirty (30) days of the date you receive them.

(4.) VLP Term. The initial Term of the VLP will start on the VLP Effective Date and continue for a period of one (1) year (the "Initial VLP Term"). You may renew the VLP for additional one (1) year periods (the Initial VLP Term and each such renewal term, each herein referred to herein as a "VLP Term"). Should you desire to renew the VLP for an additional one (1) year period, you must provide a current Activity Compliance Log to NI at least sixty (60) days before the end of the then current VLP Term so that the number of VLP Licenses for the SOFTWARE may be determined. NI will then provide you with a quote for Software Services, any Additional VLP Fees that are applicable, and any new VLP Licenses that you request for the renewal VLP Term (the "VLP Renewal Fee"). The VLP will be renewed for an additional one (1) year period each time you issue to NI a purchase order for the VLP Renewal Fees prior to the end of the then current VLP Term. You shall promptly notify NI if the information in the Activity Compliance Log regarding the number of VLP Licenses changes following your submission, and NI reserves the right to revise the VLP Renewal Fee (as applicable) to reflect Additional VLP Licenses used and not reflected in the applicable Activity Compliance Log that you provided to NI at the time you desired to renew. **IF, PRIOR TO THE END OF THE THEN CURRENT VLP TERM, YOU DO NOT ISSUE A PURCHASE ORDER FOR THE SOFTWARE SERVICES AND ANY ADDITIONAL VLP FEES THAT ARE DUE (I) THE VLP WILL AUTOMATICALLY TERMINATE AT THE END OF THE CURRENT VLP TERM; (II) ALL SOFTWARE SERVICES FOR THE VLP WILL AUTOMATICALLY AND IMMEDIATELY TERMINATE AT THE END OF THE THEN CURRENT VLP TERM; AND (III) YOU MAY NOT, IN ANY EVENT, EXCEED THE NUMBER OF VLP LICENSES FOR WHICH YOU HAVE PAID THE REQUIRED FEES TO NI. UPON TERMINATION OF THE VLP, NI WILL ATTEMPT TO PROVIDE YOU WITH AN UPDATED LICENSE FILE AND YOU MAY CONTINUE TO USE THE VLP LICENSES IN EFFECT (AND FOR WHICH YOU HAVE PAID THE REQUIRED FEES TO NI) PRIOR TO THE DATE OF TERMINATION (THE "SURVIVING VLP LICENSES"); PROVIDED THAT ALL SUCH USE IS CONDUCTED WITH AN APPROVED VOLUME LICENSE MANAGER (USING THE LICENSE FILE PROVIDED BY NI FOLLOWING THE TERMINATION OF THE VLP) AND IS CONDUCTED PURSUANT TO THE TERMS AND CONDITIONS OF THIS AGREEMENT (INCLUDING, BUT NOT LIMITED TO, THE PROHIBITIONS ON TRANSFER AS SET FORTH IN SECTION 5 BELOW). IN NO EVENT MAY YOU INCREASE THE NUMBER OF THE SURVIVING VLP LICENSES FOLLOWING THE TERMINATION OF THE VLP. IT IS YOUR RESPONSIBILITY TO OBTAIN SUCH LICENSE FILE FROM NI AND TO INSTALL AND USE THE LICENSE FILE AS SOON AS POSSIBLE AFTER DELIVERY OF SUCH LICENSE FILE FROM NI, BUT IN NO EVENT LATER THAN SIXTY (60) DAYS AFTER THE TERMINATION OF THE VLP. THE SOFTWARE AND THE APPROVED VOLUME LICENSE MANAGERS MAY CONTAIN CODE THAT WILL, FOLLOWING TERMINATION OF THE VLP, DEACTIVATE YOUR ABILITY TO USE THE SOFTWARE UNDER THE VLP. ALTHOUGH THE NI VLM MIGHT ATTEMPT TO WARN YOU OF THE TIME-FRAME IN WHICH YOUR ABILITY TO ACCESS AND USE THE SOFTWARE WILL BE DISABLED, YOU ACKNOWLEDGE AND AGREE THAT THE SOFTWARE MAY BE AUTOMATICALLY DEACTIVATED OR RENDERED UNUSABLE WITH OR WITHOUT WARNING UPON THE TERMINATION OF THE VLP. ANY REACTIVATION OF THE VLP FOLLOWING ITS TERMINATION SHALL BE AT THE SOLE DISCRETION OF NI AND MAY BE SUBJECT TO THE PAYMENT OF APPLICABLE REACTIVATION FEES AS DETERMINED BY NI. SHOULD YOU AT ANY TIME DESIRE TO OBTAIN INDIVIDUAL SERIAL NUMBERS FOR ANY OF THE VLP LICENSES OR SURVIVING VLP LICENSES, YOU WILL BE REQUIRED TO PAY NI ITS THEN CURRENT FEE FOR A CONVERSION FROM A VLP LICENSE OR A VLP SURVIVING LICENSE (AS APPLICABLE) TO (AS APPLICABLE) AN INDIVIDUAL NAMED USER LICENSE, COMPUTER BASED LICENSE, OR DEBUG LICENSE HAVING AN INDIVIDUAL SERIAL NUMBER. SHOULD YOU LATER DESIRE TO OBTAIN UPGRADES FOR THE SOFTWARE OR PURCHASE AVAILABLE SOFTWARE SERVICES FOR THE SOFTWARE, YOU WILL BE REQUIRED TO PAY NI AN APPLICABLE FEE FOR EACH SUCH SURVIVING VLP LICENSE.**

(5.) Additional Definitions. For purposes of the VLP, the following capitalized terms have the following meanings:

"Activation Fee" means the amount specified in the applicable written quotation from NI that permits you to replace the existing individual named user, computer based, or debug licenses for the SOFTWARE used at the Site that you designate with a VLP License and/or acquire a VLP License at the Site for the number of named user (i.e., initial Named Users), computer based, or debug licenses listed in the written quotation from NI. The Activation Fee consists of a one-time license fee for each VLP License in effect at the start of the VLP Effective Date and an initial annual user fee for Software Services. Documentation is provided in electronic form only and comes with the master installation disk for the SOFTWARE. You may, however, purchase from NI sets of applicable written documentation and additional master installation disks at NI's then prevailing rates.

"Activity Compliance Logs" are the reports and other applicable information generated by the NI VLM. If the Approved Volume License Manager is not the NI VLM, then you are responsible for obtaining the form of report, which will be accepted by NI and which might require manual completion and delivery to NI by you.

"Additional VLP Fees" means the fees (i.e., one-time license and initial annual fees for Software

Services) for each Additional VLP License installed (i.e., in use) during the applicable VLP Term beyond the number of initial VLP Licenses.

"Additional VLP License" means each computer based license, named user license, or debug license you add, in accordance with the terms and conditions set forth herein, during the applicable VLP Term.

"Approved Volume License Manager" is the NI VLM or FLEXnet or FLEXlm software or any other third party computer software approved in writing by NI for controlling end-user access to the SOFTWARE.

"NI VLM" is NI′s computer software for controlling end-user access to the SOFTWARE and that generates applicable usage compliance information, including the Activity Compliance Logs.

"Site(s)" is/are the physical location of the Software Administrator unless otherwise specified in the VLP Documentation.

"Software Administrator(s)" are the individuals at each Site who are responsible for administering the VLP. Each Software Administrator is responsible for distributing and overseeing the installation and use of the master installation disks for the SOFTWARE and the Approved Volume License Manager.

"Surviving VLP License" has the meaning set forth in Section 2.H.(4.) above.

"VLP Documentation" means the quote(s) that you obtain from NI regarding the VLP and the VLP Welcome Kit you obtain from NI.

"VLP Effective Date" means the date that the VLP Welcome Kit is sent to you; provided, however, that if the VLP is terminated and then reactivated, as permitted in sub-section (4.) above, then the VLP Effective Date means the date the VLP is reactivated by NI.

"VLP License" means each individual named user license, computer based license, concurrent use license, and/or debug license to the SOFTWARE used by you under the VLP during the term of the VLP.

"VLP Renewal Fees" has the meaning set forth in Section 2.H.(4.) above.

"VLP Term" has the meaning set forth in Section 2.H.(4.) above.

"VLP Termination Date" means the date that the VLP terminates in accordance with the provisions above.

I. Third Party Contractors. If you have acquired one of the licenses set forth in Section 2.A., B., C., D., E., or G. above, then third party contractors that you have engaged may (if you desire) access and use the SOFTWARE solely for your benefit; provided: (i) the contractor (or, if applicable, its employee) shall be considered, as applicable, the Named User or Authorized User for purposes of the applicable license type, and all use by such contractor shall be in accordance with the terms and conditions of this Agreement, (ii) before accessing the SOFTWARE, the contractor agrees in writing that (a) the SOFTWARE shall be used solely in accordance with the terms of this Agreement and solely for your benefit and (b) the contractor shall be liable to NI for any breach by it of this Agreement, and (iii) you hereby agree and acknowledge that you will be liable for any and all actions or omissions of the contractor with respect to the use of the SOFTWARE, as if such actions or omissions were your own.

3. License Term. This Agreement shall continue until the earlier of (a) termination by NI or you as provided in this Agreement; or (b) such time as there is no SOFTWARE being licensed to you hereunder.

   A. Term Licenses. You hereby acknowledge and agree that each Term license will expire automatically at the end of the Term, unless you continue your license by remitting the then-current Term license fee. You hereby acknowledge and agree that the SOFTWARE may stop working and become unusable unless you pay the license fee and, if applicable, are provided with new authorization codes. Any use of the SOFTWARE after the license Term expires will violate the terms of this Agreement.

   B. Perpetual Licenses. Pursuant to a perpetual license, you have the right to use the SOFTWARE indefinitely, subject to the Termination provisions in this Agreement. If you have purchased Software Service, you understand and agree that the support for the SOFTWARE will only continue for the amount of time specified in your purchase order for Software Service. After such time, you may continue to purchase Software Service at NI′s then current price, provided that Software Service is offered.

4. Restrictions. You may not: (i) reverse engineer, decompile, or disassemble the SOFTWARE (except to the extent such foregoing restriction is expressly prohibited by applicable law); (ii) use the SOFTWARE to gain access to unencrypted data in a manner that defeats the digital content protection provided in the SOFTWARE; (iii) sub-license, lease, or rent the SOFTWARE; (iv) (other than as expressly permitted under this Agreement) distribute in whole or part, modify, or create derivatives of the SOFTWARE or distribute applications created with the SOFTWARE; and (v) directly or indirectly, export, re-export, download, or ship the SOFTWARE in violation of the laws and regulations of the U.S.A. and the laws and regulations of the

applicable jurisdiction in which you use or are downloading the SOFTWARE. Further, all uses of the SOFTWARE shall be in accordance with the applicable documentation that accompanies the SOFTWARE and not in any manner intended to (or that) circumvents such documentation or the intent of this Agreement. Except as expressly permitted in Section 2, under no circumstance is "floating," shared, or concurrent use permitted under this Agreement. Further, if you have acquired a computer based NI TestStand Development System License or NI TestStand Custom Sequence Editor License, you may not remotely access the SOFTWARE. If you have acquired a named user NI TestStand Development System License or NI TestStand Custom Sequence Editor License, only the then current Named User may remotely access the SOFTWARE. Nothing in this Agreement, however, is intended to prevent you from creating your own driver interface software for use with NI SOFTWARE and third party hardware; provided, however, that in doing so you do not modify, supplement, or use (in whole or part) any of the driver interface SOFTWARE. Except as otherwise expressly permitted by NI in writing, if the SOFTWARE is the NI LabVIEW FPGA Module, you (a) may only use the intermediate code representations (e.g., VHDL code and netlists) or object or bit files generated by the SOFTWARE for the purpose of customization of the FPGA functionality of applicable NI hardware and (b) may not modify or distribute any of the intermediate code representations (e.g. VHDL code and netlists) generated by the SOFTWARE.

Additionally, the use of the SOFTWARE is intended only for use with content owned by the user, public domain content or properly licensed content. You may require a patent, copyright, or other license from a third party to create, copy, download, record or save content files for use with this SOFTWARE or to serve or distribute such files to be used with the SOFTWARE. You agree that you shall only use the SOFTWARE and documentation in a manner that complies with all applicable laws in the jurisdictions in which you use the SOFTWARE and documentation, including, but not limited to, applicable restrictions concerning copyright and other intellectual property rights. You may not use the SOFTWARE in an attempt to, or in conjunction with, any device, program or service designed to, circumvent technological measures employed to control access to, or the rights in, a content file or other work protected by the copyright laws of any jurisdiction.

5. Transfer. If you have a named user license, computer based license, debug license, or if the SOFTWARE is Multiple Access Software, you may transfer the SOFTWARE to a third party provided that you notify NI in writing of such transfer (including the name and location of such third party), such third party accepts the terms and conditions of this Agreement, and after such transfer, you do not retain any copies of the SOFTWARE (including all Upgrades that you may have received) nor retain any of the written materials accompanying the SOFTWARE. NI may, in its discretion, charge you a fee for the transfer of the SOFTWARE. If you have a VLP License, a Surviving VLP License, a concurrent use license, an academic license (including without limitation a student edition license), or a debug license, the license is non-transferable and you may not, without the prior written consent of NI or its affiliates, distribute or otherwise provide the SOFTWARE to any third party or (with respect to a VLP License or a Surviving VLP License) to any of your Sites or facilities not expressly identified in the applicable documents from NI.

6. Upgrades; Additional Licenses for Prior Versions. If the SOFTWARE is an Upgrade, you may only use the SOFTWARE if: (i) you have (at the time you receive the Upgrade) a valid license to use the pre-existing SOFTWARE (the "Pre-existing License") and (ii) the Upgrade was provided to you in accordance with the Limited Warranty noted below in Section 14 or provided to you as part of the Software Service for which you have paid applicable fees. The license agreement accompanying the Upgrade (the "Upgrade License") applies to your use of the Upgrade; provided, however, (i) you may only install and use the Upgrade on those computers on which you are authorized to use the pre-existing SOFTWARE pursuant to the Pre-existing License and (ii) in no event may you run both the Upgrade and the pre-existing SOFTWARE concurrently. Further and with respect to any SOFTWARE delivered and licensed under this Agreement ("Delivered SOFTWARE"), you may elect to install and use a pre-existing version of the applicable SOFTWARE (rather than the Delivered SOFTWARE); provided, (i) you have an authorized copy of the pre-existing version of the Delivered SOFTWARE, (ii) all use will be pursuant to and in accordance with this Agreement (including the license type acquired for the Delivered SOFTWARE), and (iii) that notwithstanding anything in this Agreement to the contrary, in no event shall NI be required to support any versions of the SOFTWARE (including providing applicable software key codes or hardware keys) other than the then most current version of the Delivered SOFTWARE.

7. Home Usage Exception. Notwithstanding anything in this Agreement to the contrary, if you are a business or other entity, the designated Named User for the applicable license (or in the case of computer based license, the single individual who is the primary user of the single computer on which the SOFTWARE is installed and used) may also install and use the SOFTWARE on one (1) computer located in such user′s home, provided that (i) the use of the SOFTWARE is pursuant to one of the licenses enumerated in Section 2 above (other than a debug license, concurrent use license, or academic research license); and (ii) the use of the SOFTWARE on such home computer is limited to work performed in the scope of such person′s employment with you and complies with all terms and conditions of this Agreement other than as expressly set forth in this Section 7. The SOFTWARE must be promptly uninstalled from the individual's home computer upon the termination of the designated individual's employment with you, the transfer of the SOFTWARE to another Named User or change to another computer as permitted under Section 2 above, or the termination of this Agreement (whichever is earlier). Notwithstanding the foregoing, if you have a debug license, concurrent use

license, or academic research license, this Home Usage Exception does not apply to you.

8. Modifications of Driver Interface Software. Driver interface SOFTWARE may not be amended, modified, or supplemented with any additional code except for the purpose of further configuring the driver interface SOFTWARE for use with hardware of National Instruments Corporation.

9. Multiple Versions (CD-ROM/DVD-ROM Media). If the SOFTWARE is distributed on a CD-ROM or DVD-ROM containing multiple versions of the SOFTWARE for use with different operating systems, you may only use one version of the SOFTWARE. The foregoing limitation does not apply to Multiple Access Software.

10. Software/Hardware Key. If the SOFTWARE requires a software key code or a hardware key, you acknowledge that the SOFTWARE will not function without a certain, unique software key code or hardware key. This software key code or hardware key will be furnished to you by NI and you agree that such software key code and hardware key is to be used solely with the SOFTWARE for which it is provided. While NI may (in its sole discretion) provide you with the applicable key prior to receipt from you of the applicable license fees, you will remain obligated to pay such fees to NI.

11. Copyright; No Other Licenses. The SOFTWARE is owned by NI or its suppliers and is protected by applicable copyright laws and international treaty provisions. Therefore, you must treat the SOFTWARE like any other copyrighted material. You may, however, (i) make a reasonable number of copies of the SOFTWARE solely for backup or archival purposes and (ii) make a reasonable number of copies of the documentation that accompanies the SOFTWARE solely for your internal use in connection with your use of the SOFTWARE. All rights not expressly granted to you in this Agreement are reserved to NI. Further, and without limiting the foregoing, no license or any right of any kind (whether by express license, implied license, the doctrine of exhaustion, or otherwise) is granted under any NI patents (whether identified herein or not) or other intellectual property right of NI with respect to any other product(s) of NI or of any third party, including without limitation, the right to use any of these other products.

12. Patent and Trademark Notice. For patents covering National Instruments products, refer to the appropriate location: **Help»Patents** in the SOFTWARE, the patents.txt file on the CD-ROM, DVD-ROM, or ni.com/patents. National Instruments, NI, ni.com, and LabVIEW are trademarks of National Instruments Corporation. Refer to ni.com/trademarks for more information about National Instruments trademarks. Further, all other product and company names used herein are (or may be) trademarks or trade names of their respective companies.

13. Application Deployment. You may distribute or otherwise make available Authorized Applications (including applicable runtime engines for the SOFTWARE and applicable driver interface SOFTWARE that you may include as part of or together with your Authorized Applications), provided that you comply with each of the requirements set forth in sub-sections (A) and (B) below:

    A. Distribution Requirements.

        (1.) You include the following copyright notice "Copyright © [insert year] National Instruments Corporation. All Rights Reserved." in (a) the Authorized Application′s About Box (if applicable) and (b)(i) any applicable written documentation or, (ii) if no such documentation exists, in a "read me" or other .txt file distributed with each copy of the Authorized Application (you may include your own copyright notice with the notice(s) required above);

        (2.) You do not use NI′s name, logo, or trademarks to market your Authorized Application without NI′s express prior written permission;

        (3.) You shall indemnify, hold harmless, and defend NI from and against any claims or lawsuits, including attorneys′ fees, that arise or result from the use or distribution of your application**, AND EVEN IF DUE IN PART TO NI′S CONCURRENT NEGLIGENCE OR OTHER FAULT OR STRICT LIABILITY WITHOUT REGARD TO FAULT; PROVIDED, HOWEVER, THAT YOUR CONTRACTUAL OBLIGATION OF INDEMNIFICATION SHALL NOT EXTEND TO THE PERCENTAGE OF THE CLAIMANT′S DAMAGES OR INJURIES OR THE SETTLEMENT AMOUNT ATTRIBUTABLE TO NI′S NEGLIGENCE OR OTHER FAULT OR TO STRICT LIABILITY IMPOSED UPON NI AS A MATTER OF LAW;** and

        (4.) You conform to the requirements described in the SDKLIC.TXT or the other applicable files if you are using Microsoft SDK files or other third party files.

        (5.) If you distribute a run-time engine for the SOFTWARE or driver interface SOFTWARE with your Authorized Application, you must pass through to your end users either this Agreement, or your own license agreement, which is substantially in accordance with this Agreement, with restrictions against allowing your end users to (i) reverse engineer, decompile, or disassemble the SOFTWARE (except to the extent such foregoing restriction is expressly prohibited by applicable law); (ii) sub-license, lease, or rent the SOFTWARE; (iii) distribute in part, modify, or create derivatives of the SOFTWARE; (iv) amend, modify, or supplement driver interface SOFTWARE with any additional code except for the purpose of further configuring the driver interface SOFTWARE for use with hardware of National Instruments Corporation or its affiliates; and (v) directly or indirectly, export, re-export, download, or ship the SOFTWARE in violation of the laws and regulations of the U.S.A.

(6.) If you distribute a bit file generated by the NI LabVIEW FPGA Module, you must pass through to your end users either this Agreement or your own license agreement, which is substantially in accordance with this Agreement, with restrictions against allowing your end users to (i) reverse engineer, decompile, or disassemble such bit file (except to the extent such foregoing restriction is expressly prohibited by applicable law); (ii) sub-license, lease, or rent such bit file; (iii) distribute in part, modify, or create derivatives of such bit file; (iv) use such bit file except for the purpose of customization of the FPGA functionality of applicable NI hardware; and (v) directly or indirectly, export, re-export, download, or ship such bit file in violation of the laws and regulations of the U.S.A.

B. Fees. Generally, you may distribute or otherwise make available Authorized Applications without paying additional fees to NI. If, however, the Authorized Application was created utilizing any of the following SOFTWARE: LabVIEW Real-Time Module, LabWindows/CVI Real-Time Module, LabVIEW Remote Panels, LabVIEW Datalogging and Supervisory Control Module, National Instruments Sound and Vibration Toolkit, National Instruments Modulation Toolkit, National Instruments Sound and Vibration Measurement Suite, LabVIEW Mobile Module, National Instruments Vision Development Module, National Instruments Vision Acquisition Software, National Instruments Vision Builder for Automated Inspection, National Instruments Switch Executive, National Instruments TestStand, National Instruments Test Executive, National Instruments Lookout, NI-Device, NI GPS Toolkit, or such other SOFTWARE as NI may from time to time designate, then you must (before distributing or otherwise making available the Authorized Application and applicable runtime engines for the SOFTWARE for use on any other computer) either: (i) verify that the recipient has a valid license to run the applicable Authorized Application on (or has a valid license for such SOFTWARE for) each computer on which the Authorized Application will be used; or (ii) obtain written distribution authorization from NI and (if required by NI) pay to NI a per copy distribution/development fee for each Authorized Application distributed. If the Authorized Application utilizes, calls, or otherwise accesses any driver interface SOFTWARE, then you must (before distributing the Authorized Application and applicable driver interface SOFTWARE) either: (i) verify that the recipient has a valid license to such driver interface SOFTWARE for each computer on which the Authorized Application will be used; or (ii) obtain written distribution authorization from NI and (if required by NI) pay to NI a per copy distribution/development fee for each Authorized Application distributed. Contact NI or, if applicable, the NI subsidiary serving your country, for the amount of the applicable per copy distribution/development fee.

14. Limited Warranty. Except for SOFTWARE provided under an evaluation license which SOFTWARE is provided without warranty, NI warrants, for your benefit alone, that for a period of ninety (90) days from the date the SOFTWARE is shipped to you (i) the SOFTWARE will perform substantially in accordance with the accompanying written materials, and (ii) the medium on which the SOFTWARE is recorded will be free from defects in materials and workmanship under normal use and service ("Limited Warranty"). Any replacement SOFTWARE will be warranted for the remainder of the original warranty period or thirty (30) days, whichever is longer. Some states/jurisdictions do not allow limitations on duration of an express or implied warranty, so the above or any other limitation provided herein may not apply to you. In such event, such warranties are limited to the minimum warranty period allowed by applicable law. You must obtain a Return Material Authorization number from NI before returning the SOFTWARE under warranty to NI and you agree to pay expenses for shipment to and from NI. The Limited Warranty is void if failure of the SOFTWARE has resulted from accident, abuse, misapplication, improper calibration by you, third party products (i.e., hardware or software) used by you which are not intended by NI for use with the SOFTWARE, utilization of an improper hardware or software key (if applicable), or unauthorized maintenance of the SOFTWARE.

15. Customer Remedies. NI′s sole obligation (and your sole remedy) with respect to the foregoing Limited Warranty shall be to, at NI′s option, return the fees paid by you to NI or repair/replace the SOFTWARE, provided that NI receives written notice of applicable defects during the warranty period. You may not bring an action to enforce your remedies under the foregoing Limited Warranty more than one (1) year after the accrual of such cause of action.

16. **No Other Warranties. EXCEPT AS EXPRESSLY SET FORTH ABOVE, NO OTHER WARRANTIES, EITHER EXPRESS OR IMPLIED ARE MADE WITH RESPECT TO THE SOFTWARE OR SOFTWARE SERVICES, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT. THERE ARE NO OTHER WARRANTIES THAT MAY ARISE FROM USAGE OF TRADE OR COURSE OF DEALING. NI DOES NOT WARRANT, GUARANTEE, OR MAKE ANY REPRESENTATIONS REGARDING THE USE OF OR THE RESULTS OF THE USE OF THE SOFTWARE OR SOFTWARE SERVICES IN TERMS OF CORRECTNESS, ACCURACY, RELIABILITY, OR OTHERWISE AND DOES NOT WARRANT THAT THE OPERATION OF THE SOFTWARE OR SOFTWARE SERVICES WILL BE UNINTERRUPTED OR ERROR FREE.**

17. Intellectual Property Liability. NI shall, at its own expense, defend any claim resulting from your use of the SOFTWARE as authorized by your license, to the extent that such claim alleges that the SOFTWARE infringes any patent, copyright, or trademark protected by the laws of the U.S.A., Canada, Mexico, Japan, Australia, Switzerland, Norway, or the European Union, provided that such claim does not arise from your

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370406M-01

March 2009

1. Introduction

1.1 Features

The "**ZGA5905 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 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 extraction, 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, turn 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.
- Various installation types supported
  In addition to the typical horizontal (desktop) installation, the vertical installation and rack-mount are supported. The vertical installation can save the working space.

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 ZGA5905 and the function tree of them. The functions are divided into two modes: Advanced mode and Basic mode. The advanced mode specializes in objects to be measured and the basic mode directly operates the basic part of the instrument.

Measurement type name	General descriptions
Advanced mode	
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 turn 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
Basic mode	
Impedance measurement	Impedance measurement
Gain-Phase measurement	Gain-phase measurement

(Function tree in the advanced mode)

- 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
    - Close 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

(Function tree in the basic mode)

- Impedance
  - Impedance measurement
- Gain-Phase
  - Gain-Phase measurement

1.4 Principle of operation

1.4.1 Basic principle

ZGA5905 measures the I/O transfer characteristics of a system under test and the impedance of a target sample. ZGA5905 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 ($\dot{\mathrm{C}}\mathrm{H1}/\dot{\mathrm{C}}\mathrm{H2}$).

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.

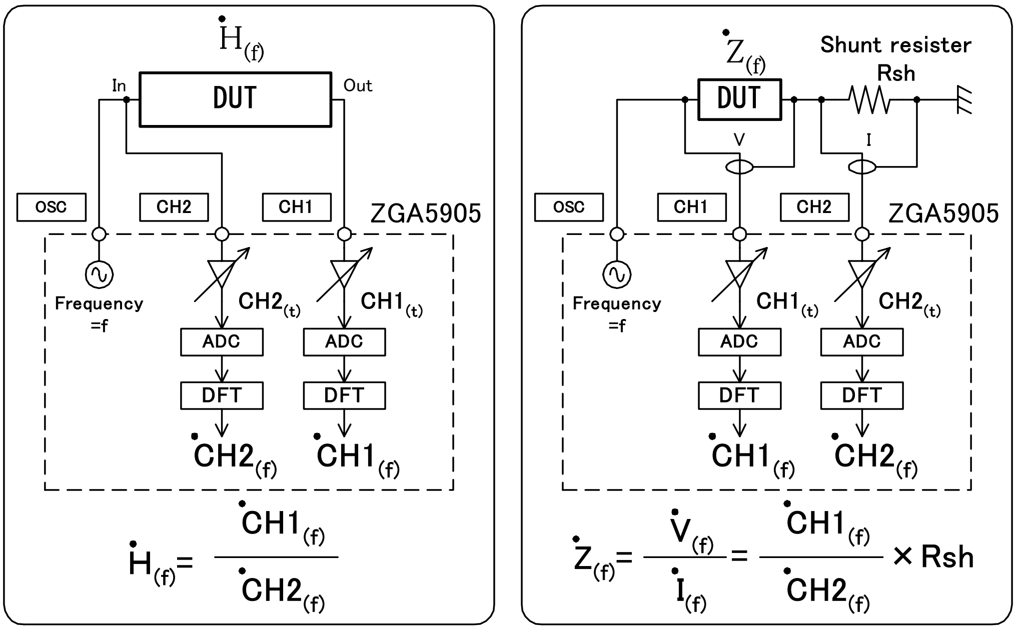


Figure 1-1 Transfer characteristics/impedance characteristics measurement

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

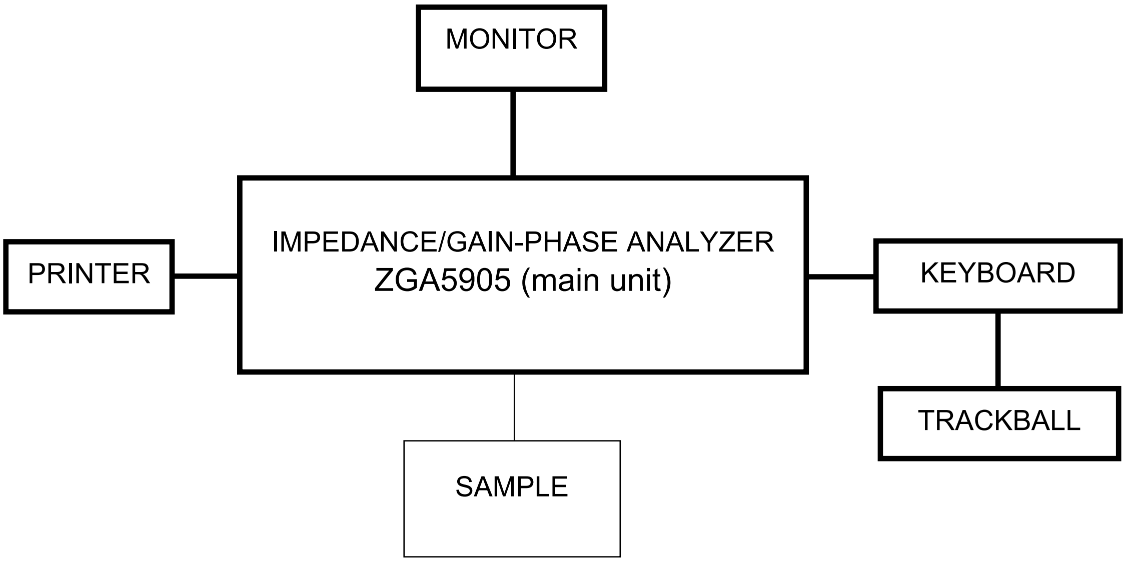


Figure 1-2 System block diagram

A monitor, printer, keyboard, and trackball (pointing device) are required to operate ZGA5905. If you use ones other than the included items, they might not work correctly.

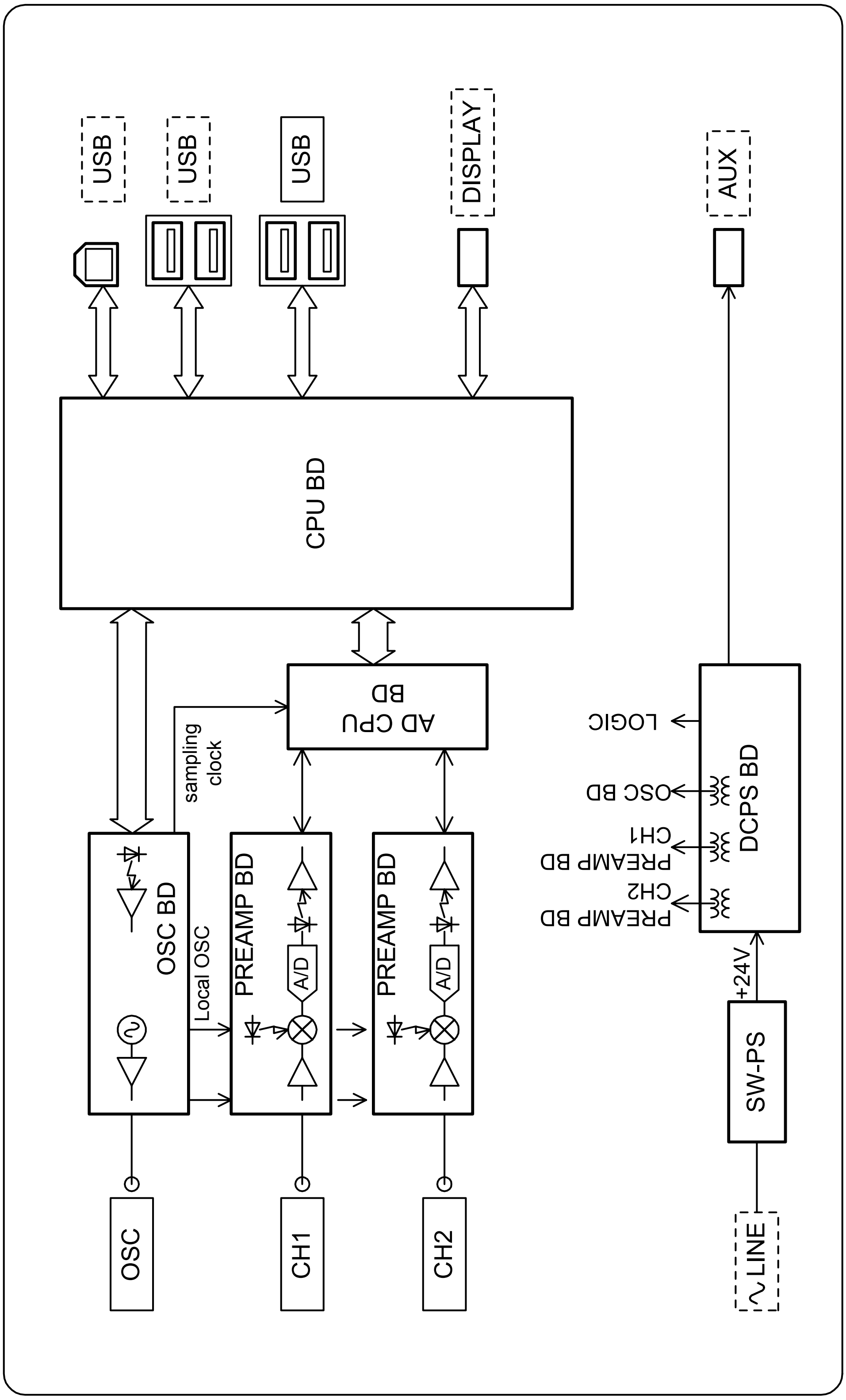


Figure 1-3 Block diagram (main unit)

This section describes the configuration of the ZGA5905 (see “Figure 1-3 Block diagram (main unit)”).

a) OSC BD

This is an oscillator that generates timing signals for the ZGA5905.
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 ZGA5905.
In addition, read Section 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 Composition list" to check the contents.

Table 2-1 Composition list

ZGA5905 (main unit)	1
Monitor (19-inch, 1280 x 1024 dot)	1
Printer (ink-jet, A4 plain paper)	1
Keyboard	1
Trackball	1
Accessories	
ZGA5905 Instruction manual	1
ZGA5905 Remote control Instruction manual	1
Signal cable (BNC-BNC 50 Ω 1 m, 250 Vrms CAT I)	3
T-shaped divider (250 Vrms CAT I)	1
Ferrite core (clamp type)	1
Power code set (2m, with 3-prong plug)	1

■ Monitor, printer, keyboard, and trackball

A monitor, printer, keyboard, and trackball (pointing device) are required to operate this instrument.
If you use ones other than the included items, they might not work correctly.

■ Ferrite core

Ferrite core (included), please use the trackball cable attached. It can reduce interference of the high-frequency electromagnetic field radiated from surrounding objects, and also reduce interference to surrounding objects. For more information, "2.2.4 Peripherals connection" please.

■ Remote interface cable

A remote interface cable is required when you want to control the ZGA5905 externally by using a PC.
A remote interface cable is not provided. A commercial cable must be purchased separately, if necessary. The cable specifications are:

USB cable	USB 1.1, USB 2.0 compliant cable

⚠ 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 ZGA5905 can be placed horizontally or vertically (the power switch is on the top and the BNC connector is on the bottom).
- The ZGA5905 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 ZGA5905 (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. (except for a printer)
Operation +5 to +35 °C, 30 to 80% RH (no condensation)
Storage -10 to +50 °C, 30 to 80% RH (no condensation)
The printer environmental condition is described below. If you use a printer, you must use the main unit, monitor, keyboard, and trackball in the following environment as well.
Operation +15 to +30 °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 ZGA5905 or otherwise. If signal and power supply cables are routed close to each other, there could be malfunctions and/or measurement errors.

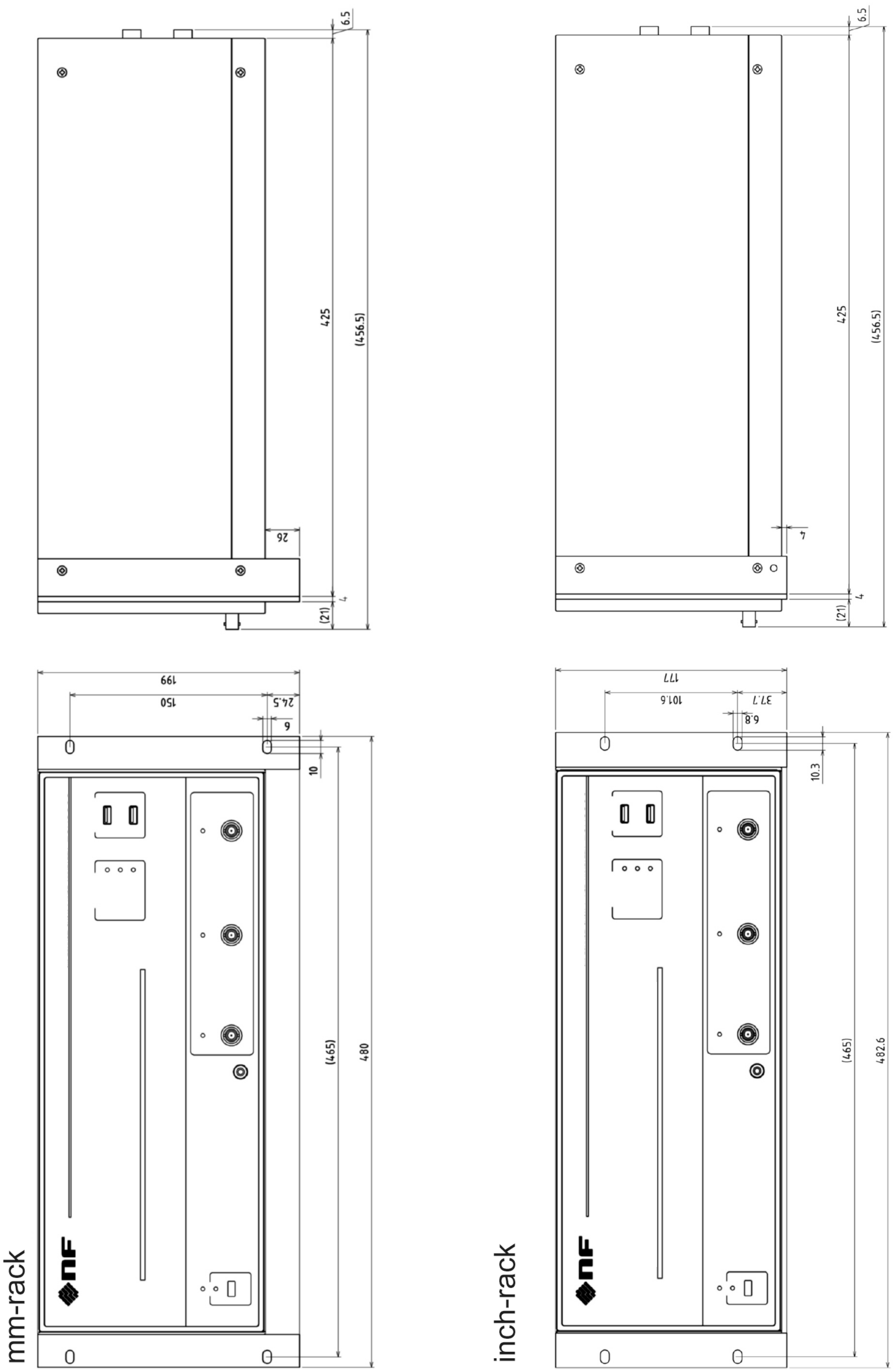
2.2.3 Rack mounting

The ZGA5905 can be mounted on the 19-inch IEC rack, EIA or JIS standard rack by the use of a rack-mount adapter (sold separately). The rack-mount adapter is provided for a mm rack and an inch rack. Mount the rack-mount adapter on the instrument as shown in "Figure 2-2 mm-rack mount assembly drawing" or "Figure 2-3 inch-rack mount assembly drawing", and then mount the instrument on the rack.

Following attention should be drawn when you mount the instrument on the rack:

- Support the ZGA5905 by all means by installing some supports such as rails on the rack.

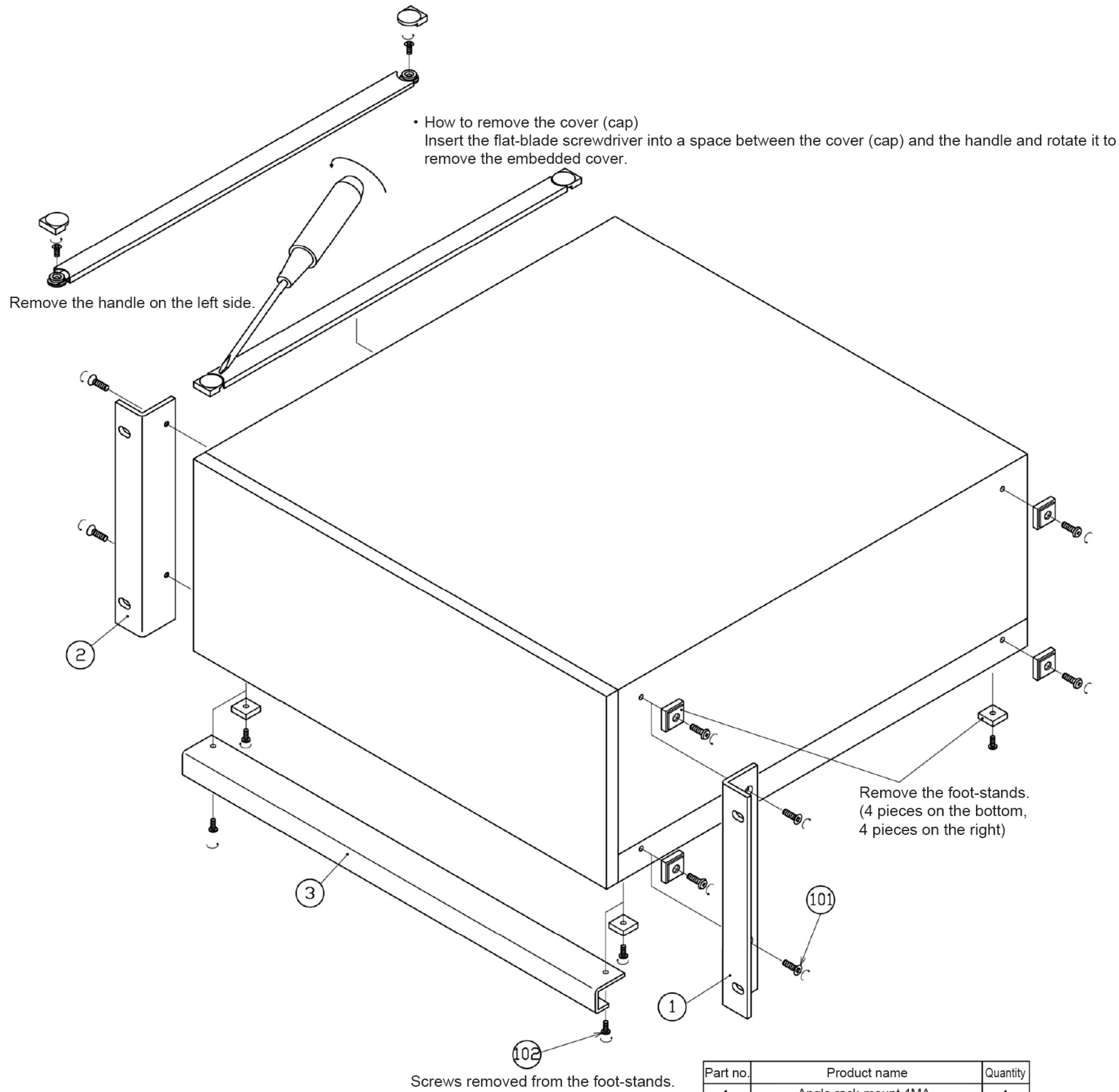
- Do not mount the ZGA5905 on an enclosed rack; otherwise, internal temperature rises high enough to induce operational failures.
  Prepare ventilation openings on the rack, or install an air flow system in the rack by using a fan.
  If you install other equipment above and/or below the ZGA5905 in the rack, secure the space of 40 mm at minimum between the lower equipment for ventilation purposes.



⚠ Caution

Do not just use the rack-mounting flanges when housing in the rack.
Provide a shelf or L liftings to hold the main unit on the rack.

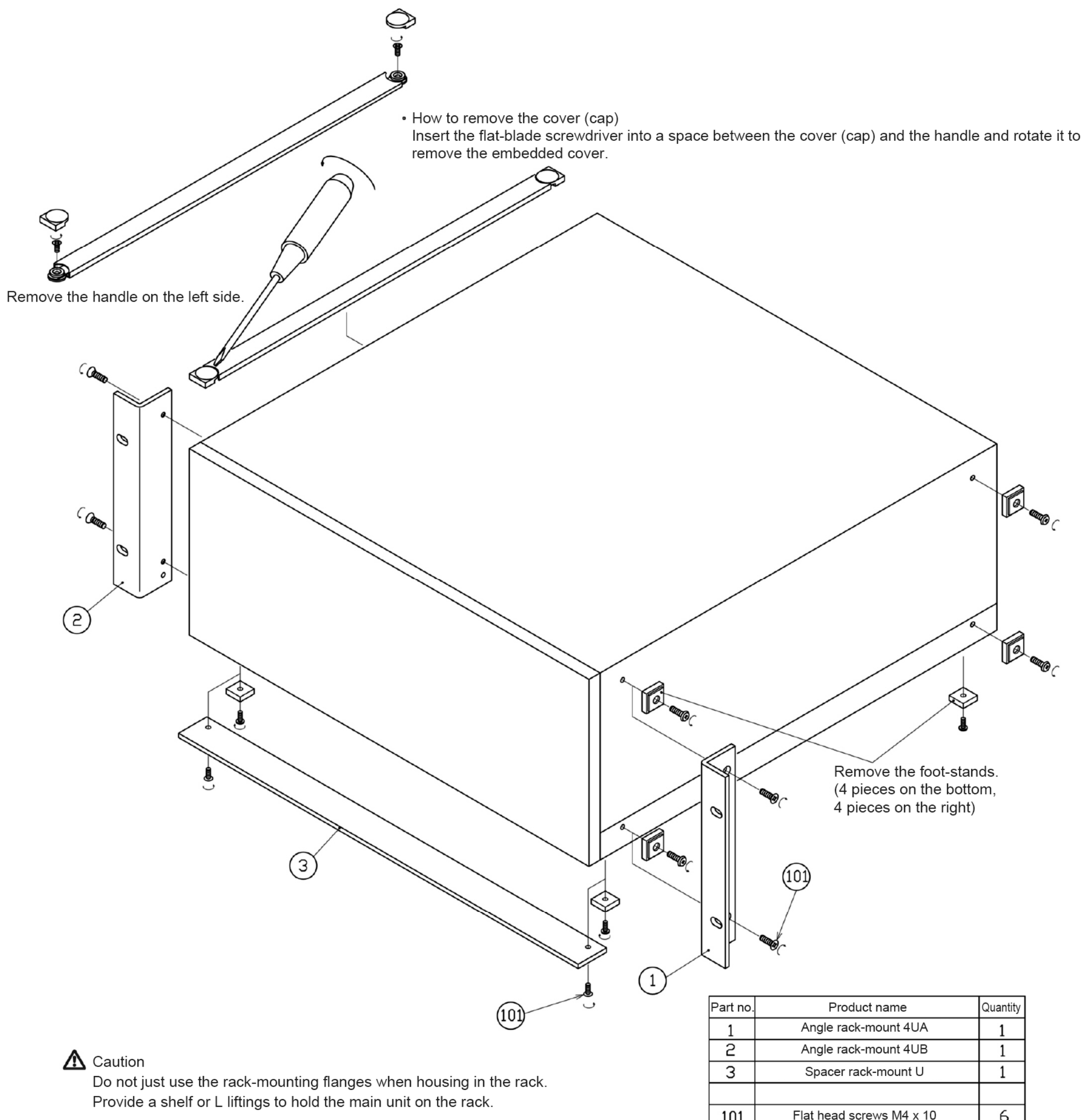
Figure 2-1 Size and dimensions of ZGA5905 rack mount



Part no.	Product name	Quantity
1	Angle rack-mount 4MA	1
2	Angle rack-mount 4MB	1
3	Spacer rack-mount M	1
101	Flat head screws M4 x 10	4
102	Pan head washer screws M4×10	2

⚠ Caution
Do not just use the rack-mounting flanges when housing in the rack.
Provide a shelf or L liftings to hold the main unit on the rack.

Figure 2-2 mm-rack mount assembly drawing



Part no.	Product name	Quantity
1	Angle rack-mount 4UA	1
2	Angle rack-mount 4UB	1
3	Spacer rack-mount U	1
101	Flat head screws M4 x 10	6

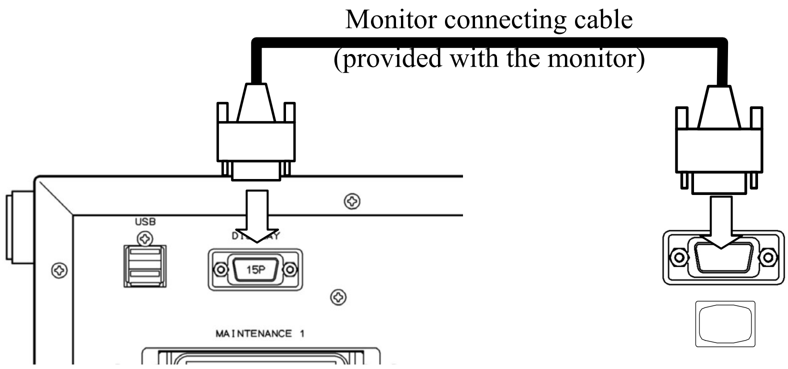
Figure 2-3 inch-rack mount assembly drawing

2.2.4 Peripherals connection

Connect the monitor, keyboard, trackball, and printer to the instrument in the following order. Use the recommended items described in Section 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 agent that you purchased it from, instead of its manufacturer.

■ Monitor

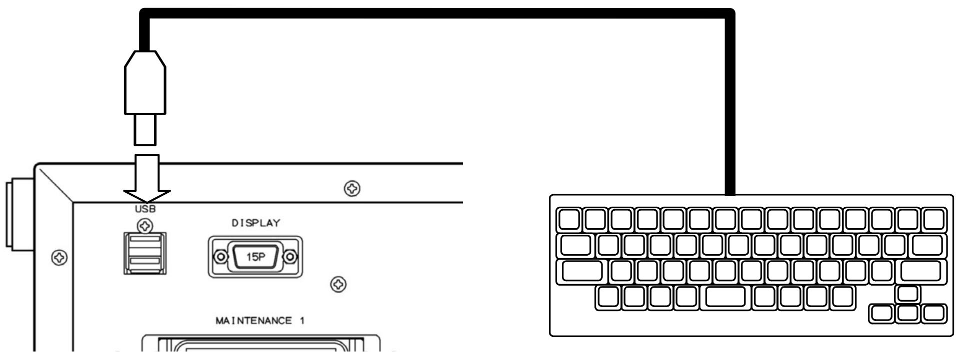
Use the monitor cable provided with the monitor to connect the DISPLAY connector on the rear of the ZGA5905 main unit with the analog RGB connector (mini D-sub 15-pin) on the monitor.



Rear of ZGA5905 main unit　　　　Rear of monitor

■ Keyboard

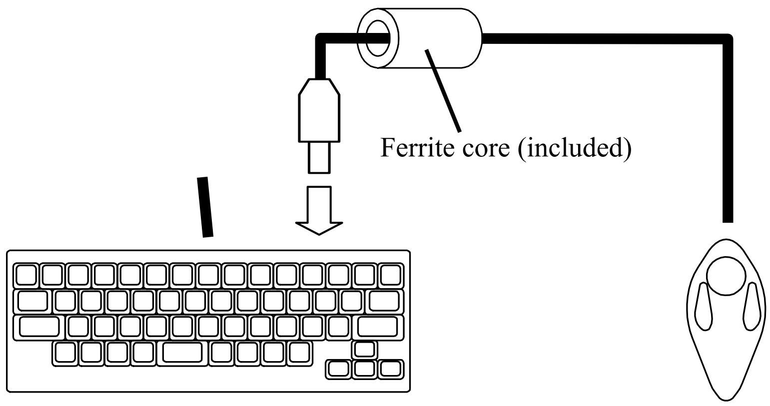
Connect the keyboard USB connector (plug) to the USB connector on the rear of the ZGA5905 main unit.



Rear of ZGA5905 main unit　　　　Keyboard

■ Trackball

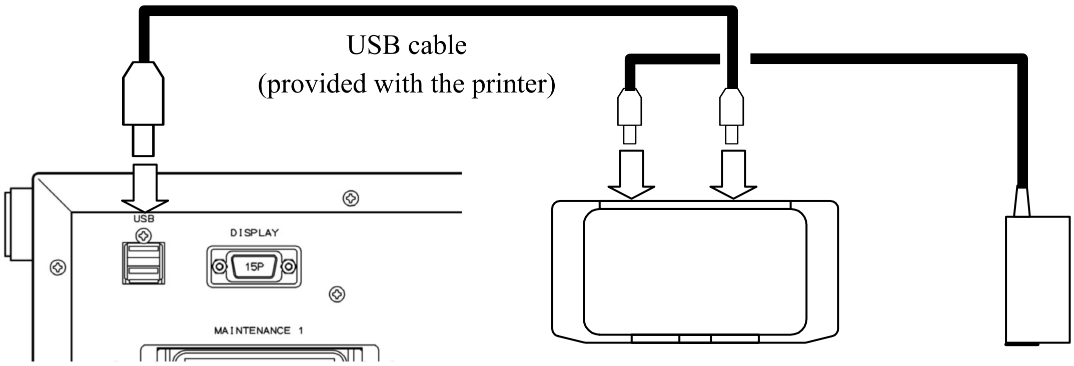
The keyboard is equipped with two ports of USB hub. Connect the trackball to the USB hub on the keyboard instead of the USB port on the ZGA5905 main unit.



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

■ Printer

Use the USB cable to connect the USB port on the rear of the ZGA5905 main unit with the printer. The USB cable is provided with the printer. Connect the AC adapter (provided with the printer) to the printer.



For information about how to operate the printer and maintain it (ink replacement, etc.), refer to the instruction manual of the printer.

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 ZGA5905 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.
The protective grounding terminal of the printer is the grounding conductor (green) of the power supply plug. Be sure to connect it to an earth terminal near the outlet.

■ 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 ZGA5905 may be damaged.

■ Power supply conditions of ZGA5905

- Voltage range: AC 90V~132V/180V~250V
- Frequency range: 50 Hz/60 Hz ±2Hz
- Power consumption: 150 VA or lower (ZGA5905 main unit), 45 W (monitor), 40 W (printer)
- 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 ZGA5905.
2) Connect the power supply cable into the AC adapter power supply connector for the printer.
3) Connect the power supply cable female-plug into the power supply connector located on the rear of the ZGA5905 main unit.
4) Connect the power supply cable female-plug into the power supply connector located on the rear of the monitor.
5) Connect the grounding conductor of the AC adapter power supply plug for the printer to an earth terminal near the outlet.
6) Insert the AC adapter power supply plug for the printer into a power supply outlet.
7) 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.

⚠ CAUTION The accessory power supply cable set is a conforming appliance to the Electrical Appliances and Material Safety Act and for use in Japan only. If you want to use the product with a power supply voltage exceeding AC 125 V or outside Japan, please contact the NF representatives.

2.4 Compliant standards

The ZGA5905 complies with the following standards.

Safety standard:	EN 61010-1:2001
EMC:	EN 61326-1:2006
	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 Japan, Ltd.)
  The printer accessories are used for the AC adapter, AC adapter power cord, and USB cable.
  (Cables and others)
- Power cord: Accessory
- Signal cable: Accessory
- T-shaped divider: Accessory
- USB cable: USB 2.0 standard compliant cable, 1 m (SANWA SUPPLY INC., KU20-1)
  (Used 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. Then, when you turn on the ZGA5905 main unit, power lamp on the front panel of the ZGA5905 main unit will be lit on. A message is also displayed on the monitor screen indicating that "Calibration (self-measurement to correct for any errors) is running". If the calibration has been successfully completed, this display automatically disappears and changes to the start-up menu screen display to be operational.

- **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”.**

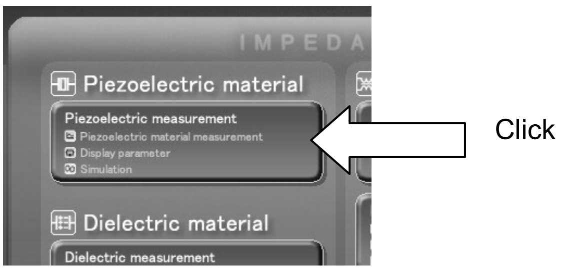
⚠ WARNING

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.

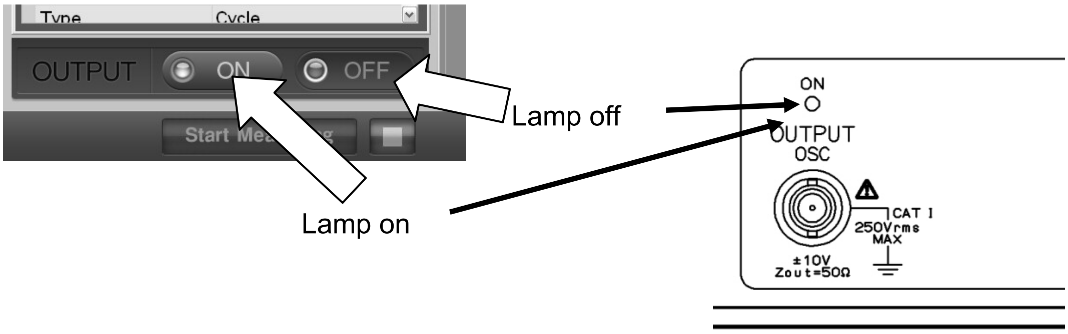
2.5.2 Checking responses for key actions

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

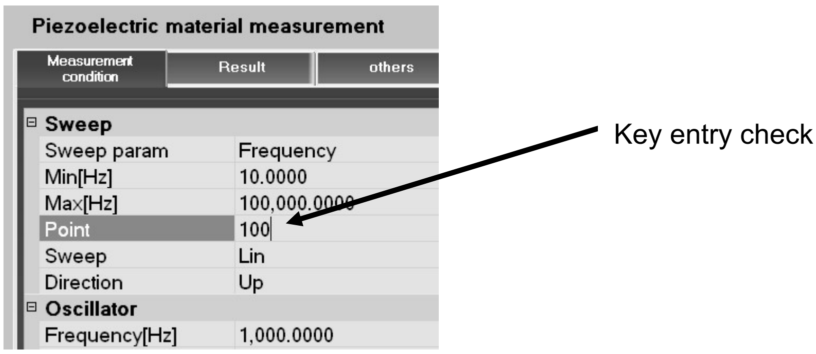
In the menu screen displayed after start-up, click the [Piezoelectric measurement] button to display the Piezoelectric measurement screen.



Click the [OUTPUT] ON button on the bottom left of the Piezoelectric measurement screen by using the left button of the trackball. Check that the OUTPUT "ON" lamp (above the oscillator output connector) on the front panel of the ZGA5905 main unit is turned on. Similarly, check that the OUTPUT "ON" lamp is turned off when clicking the [OUTPUT] OFF button on the bottom left of the monitor screen.



Click the [Measurement condition] tab 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, be sure to click [File] — [Exit] in the menu. Do not press the power switch on the ZGA5905 main unit to turn off the power. Do not disconnect the power supply cable from the outlet or shut down the commercial power source supplying to the ZGA5905 main unit by an external breaker. It may cause the internal data and program to be damaged, and thus the ZGA5905 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 selected [Exit] in the menu, 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 confirming that the lamp indicating "ACCESS" is off.
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 ZGA5905 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

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 ZGA5905.

3.1.1 Main unit front panel

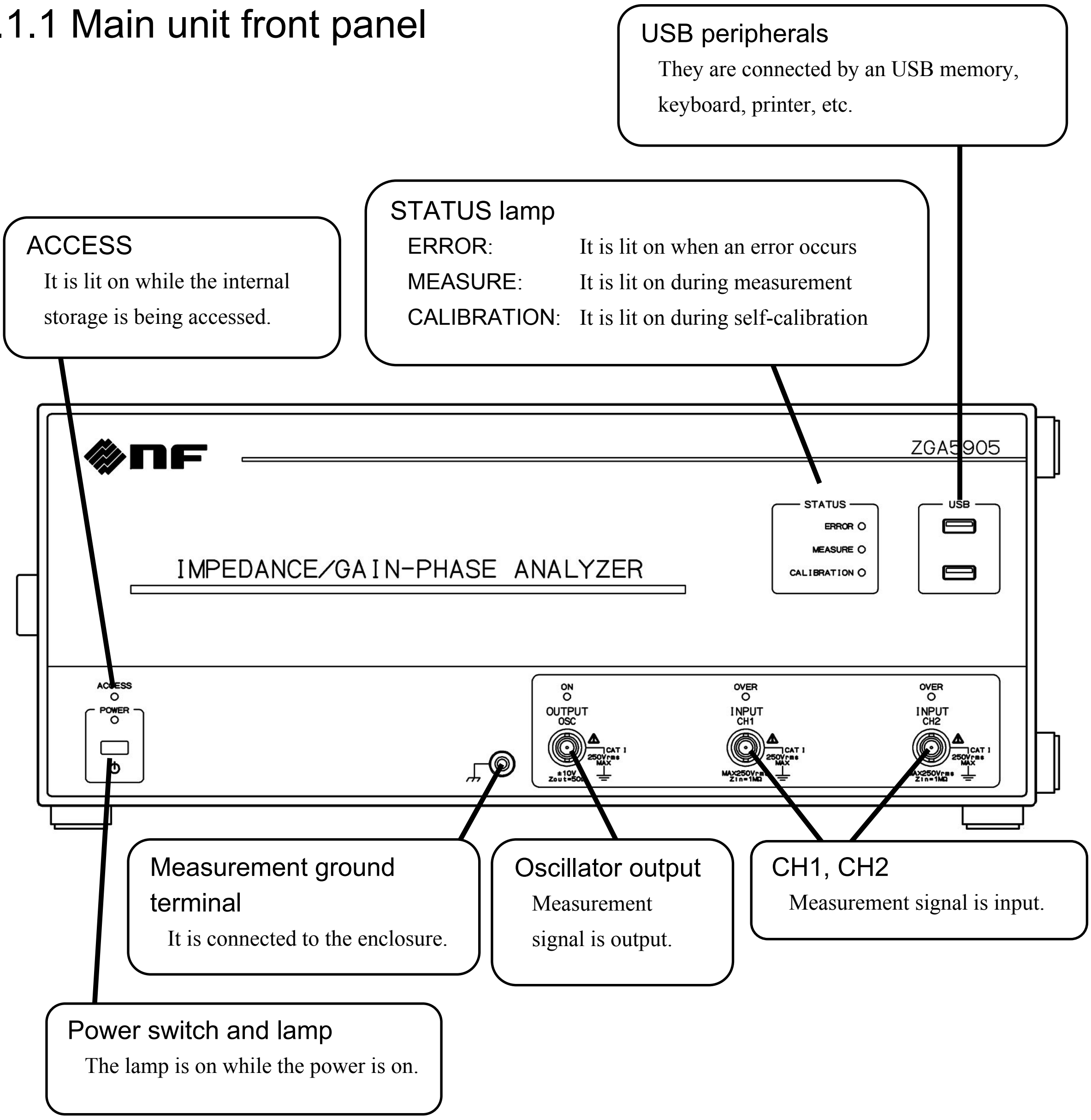
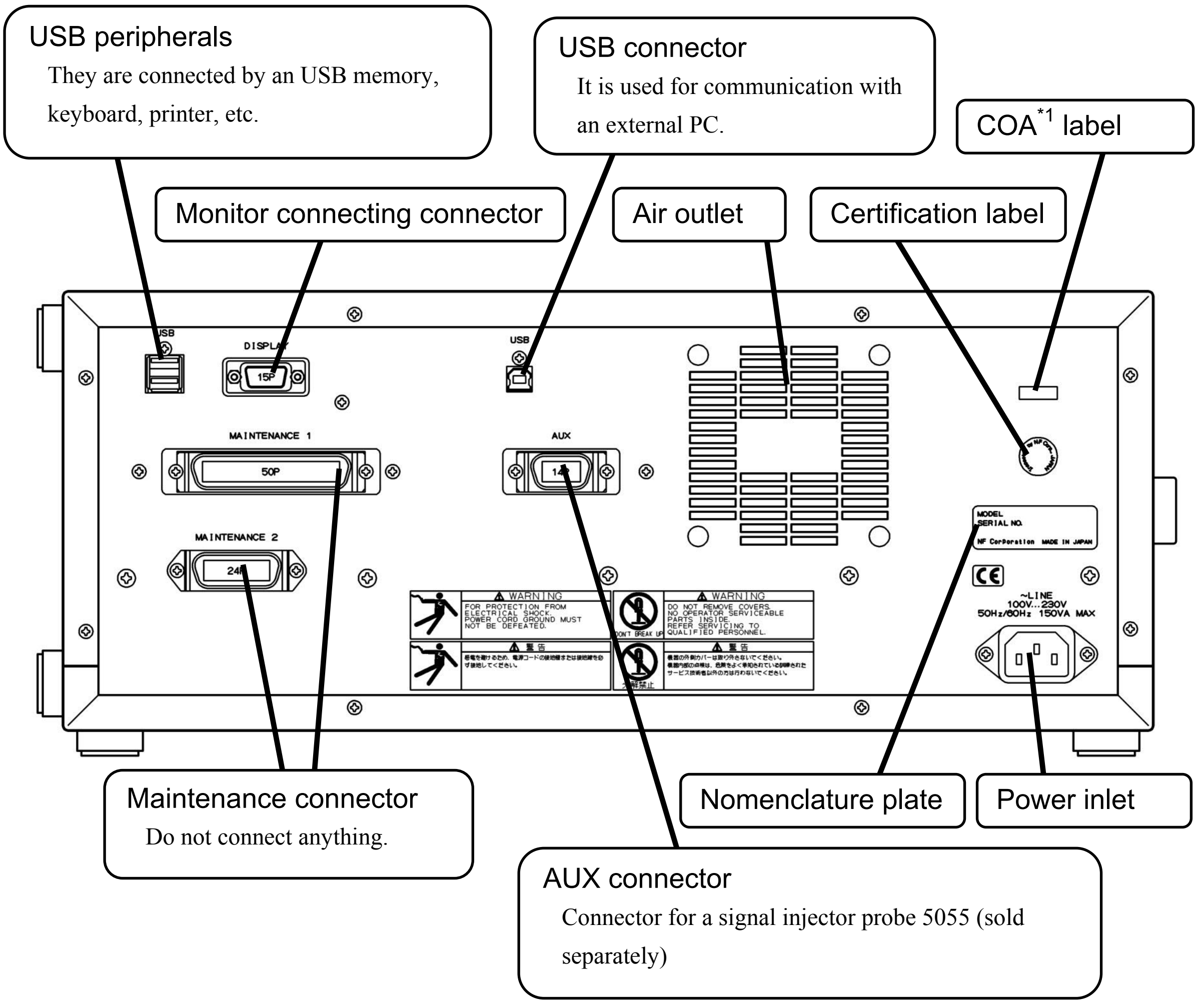


Figure 3-1 Main unit front panel

3.1.2 Main unit rear panel



*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. Preparations before Use”.
When the power switch is turned on, the power lamp on the main unit front panel of the ZGA5905 are lit on and then software starts up.
The software starts up after approximately one minute, the lamps on the front panel other than "POWER", "ACCESS" (flashing), and "CALIBRATION" lamps are lit off. Then the ZGA5905 starts the system-check and calibration (function check and self-measurement to correct for any errors). During the system-check and calibration, "Figure 3-3 Screen at power “ON”" is displayed on the monitor. It takes approximately five minutes to complete these checks.

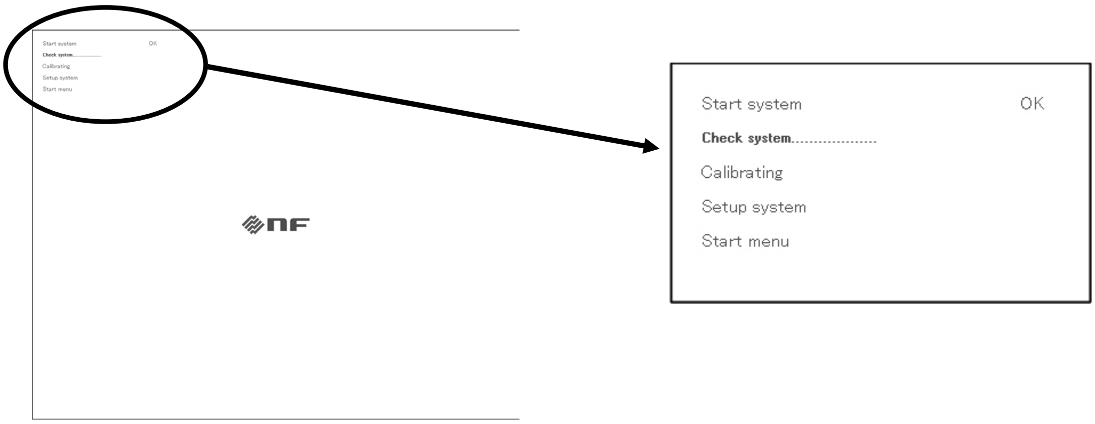


Figure 3-3 Screen at power “ON”

If an error is detected in the calibration, "Figure 3-4 Screen of calibration error at power “ON”" is displayed and the ZGA5905 does not work.

Figure 3-4 Screen of calibration error at power “ON”

Possible reasons that may cause a calibration error include:

- Effect of external noise

  During calibration processes, self-measurement is made by connecting the oscillator output and the CH1 and/or CH2 internally. A measurement error could be caused if a high level of external noise comes in at any time during the self-measurement. If the measurement error exceeds a certain predetermined range (threshold), an error message will be displayed and the instrument will be put in an inoperable status, since the measurement accuracy cannot be maintained.

  (Actions/measures to be taken)

  - Use the instrument in a low noise environment.
  - Switch on the power supply again after disconnecting a signal cable with BNC connectors from the oscillator output and the CH1 and/or CH2. This can isolate the noise source if noise has been induced on the signal cable.

- Failure of ZGA5905

  If a calibration error is indicated even after the above measures, malfunction of the ZGA5905 is suspected. Contact us or our representative to arrange for repair.

If the calibration has been successfully completed, the display changes to "Figure 3-5 Start-up menu screen" to be operational.

Figure 3-5 Start-up menu screen

The start-up menu screen is used to change screens based on the measurement purposes (measurement types). When you click the button for an intended measurement (by the left button of the trackball), the screen changes to the one for the measurement type.

"Fig 3-6 Initial screen of piezoelectric measurement" shows the screen when the [Piezoelectric measurement] button is selected as the measurement type.

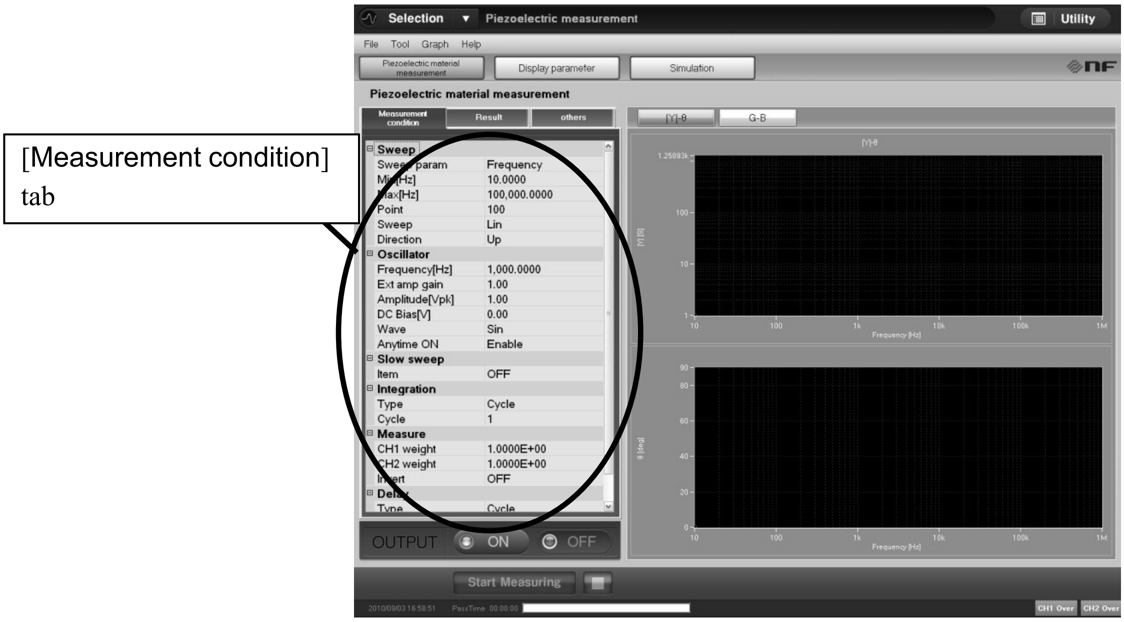


Figure 3-6 Initial screen of piezoelectric measurement

The oscillator output level and other settings are specified in the Measurement condition tab on the left side of the screen.

3.2.2 Initial settings

The settings in the [Measurement condition] tab on the left side of the monitor screen of the ZGA5905 are initialized at power-on. The oscillator output is initially set to “OFF”. The other initialization values and setting ranges are shown in “Table 3-1 List of initialization values”.

Table 3-1 List of initialization values ([Measurement condition] tab)

<table>
<tr><th>Setting item</th><th>Initialization value</th><th>Setting range</th><th>Setting resolution</th><th>Unit</th></tr>
<tr><td colspan="5">Sweep</td></tr>
<tr><td>Sweep param[*1]</td><td colspan="3">Frequency|Amplitude|DC bias|Zero span</td><td></td></tr>
<tr><td>Min (Frequency)</td><td>10.0000</td><td>0.0001~15,000,000.0000</td><td>0.0001</td><td>Hz</td></tr>
<tr><td>Max (Frequency)</td><td>100,000.0000</td><td>0.0001~15,000,000.0000</td><td>0.0001</td><td>Hz</td></tr>
<tr><td>Min (Amplitude)</td><td>0.00</td><td>0.00~9990</td><td>3 digits|0.0001</td><td>Vpk[*2]</td></tr>
<tr><td>Max (Amplitude)</td><td>10.0</td><td>0.00~9990</td><td>3 digits|0.0001</td><td>Vpk[*2]</td></tr>
<tr><td>Min (DC bias)</td><td>0.00</td><td>-9990~9990</td><td>3 digits|0.0001</td><td>V[*2]</td></tr>
<tr><td>Max (DC bias)</td><td>5.00</td><td>-9990~9990</td><td>3 digits|0.0001</td><td>V[*2]</td></tr>
<tr><td>Sweep Time (Zero span)</td><td>30.00</td><td>0.03~999999.99</td><td>0.01</td><td>s</td></tr>
<tr><td>Point</td><td>100</td><td>4~20000</td><td>1</td><td>1</td></tr>
<tr><td>Sweep</td><td>Log[*3]</td><td>Log|Lin</td><td></td><td></td></tr>
<tr><td>Direction</td><td>Up[*4]</td><td>Up|Down</td><td></td><td></td></tr>
<tr><td colspan="5">Oscillator</td></tr>
<tr><td>Frequency</td><td>1,000.0000</td><td>0.0001~15,000,000.0000</td><td>0.0001</td><td>Hz</td></tr>
<tr><td>Ext amp gain[*6]</td><td>+1.00</td><td>±(0.01~999)</td><td>3 digits|0.01</td><td></td></tr>
<tr><td>Amplitude[*6]</td><td>1.00</td><td>0.00~9999</td><td>3 digits|0.0001</td><td>Vpk</td></tr>
<tr><td>DC Bias[*6]</td><td>0.0000</td><td>-9990~+9990</td><td>3 digits|0.0001</td><td>V</td></tr>
<tr><td>Wave</td><td>Sin</td><td>Sin</td><td></td><td></td></tr>
<tr><td>Anytime ON</td><td>Disable</td><td>Disable|Enable</td><td></td><td></td></tr>
<tr><td colspan="5">Slow sweep[*5]</td></tr>
<tr><td>Item</td><td>OFF</td><td>OFF|LogR|R|θ|A|B</td><td></td><td></td></tr>
<tr><td>CH</td><td>1</td><td>1|2</td><td></td><td></td></tr>
<tr><td>Variation (LogR)</td><td>1.00</td><td>0.00~1000</td><td>3 digits|0.01</td><td>dB</td></tr>
<tr><td>Variation (R)</td><td>1.00</td><td>0.00~1.00G</td><td>3 digits|1μ</td><td>Vrms</td></tr>
<tr><td>Variation (θ)</td><td>1.00</td><td>0.00~180</td><td>3 digits|0.01</td><td>deg</td></tr>
<tr><td>Variation (A, B)</td><td>1.00</td><td>0.00~1.00G</td><td>3 digits|1μ</td><td>Vrms</td></tr>
<tr><td colspan="5">Integration</td></tr>
<tr><td>Type</td><td>Cycle</td><td>Cycle|Time</td><td></td><td></td></tr>
<tr><td>Cycle</td><td>1</td><td>1~9999</td><td>1</td><td>Cycle</td></tr>
<tr><td>Time</td><td>0.00</td><td>0.01~9999</td><td>4 digits|0.01</td><td>s</td></tr>
<tr><td colspan="5">Measure</td></tr>
<tr><td>CH1 weight</td><td>1.0000E+00</td><td>0.0000~1.0000E+06</td><td>5 digits|1E-11</td><td></td></tr>
<tr><td>CH2 weight</td><td>1.0000E+00</td><td>0.0000~1.0000E+06</td><td>5 digits|1E-11</td><td></td></tr>
<tr><td>Invert</td><td>OFF</td><td>OFF|ON</td><td></td><td></td></tr>
</table>

Table 3-1 List of initialization values ([Measurement condition] tab) (continued)

Setting item	Initialization value	Setting range	Setting resolution	Unit
Delay				
Type	Cycle	Cycle|Time		
Cycle	0	0~9999	1	Cycle
Time	0.00	0.00~9999	4 digits|0.01	s

*1: The available sweep parameters vary depending on the measurement type. Refer to "Table 3-2 List of available sweep parameters".

*2: When the measurement type is "magnetic measurement" or "inductor measurement", the unit is current [Apk] or [A] instead of voltage.

*3: This is Log when the sweep parameter is Frequency, and Lin otherwise.

*4: This is always Up when the sweep parameter is Zero span (time).

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

*6: 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 x 10)

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 ZGA5905.)

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 ZGA5905 front panel.

Table 3-2 List of available sweep parameters

Measurement type	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 initial values for various measurement type screens, excluding the [Measurement condition] tab.

Table 3-3 List of initialization values for piezoelectric measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Display parameter				
Cd mode	High Frequency	High Frequency|Gmax| Bmax_Bmin		
AL value	100.0	0.001~9999	4 digits|0.001	nH/N^2
(others Tab)				
Simulation				
Parameter				
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	10.0000E-00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
Simulation condition				
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-4 List of initialization values for inductor measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Simulation				
Type	A(Inductor)	A(Inductor) | B(Indoctor or resistor) | C(Resistor) | D(Capacitor) | E(Resonator)		
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
R1	100.000E+00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-5 List of initialization values for capacitor measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Simulation				
Type	A(Inductor)	A(Inductor) | B(Indoctor or resistor) | C(Resistor) | D(Capacitor) | E(Resonator)		
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
R1	100.000E+00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-6 List of initialization values for resistor measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
Simulation				
Type	A(Inductor)	A(Inductor) | B(Indoctor or resistor) | C(Resistor) | D(Capacitor) | E(Resonator)		
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
R1	100.000E+00	±(1E-18~999.999E+15)	6 digits|1E-18	Ω
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-7 List of initialization values for varactor diode measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
(others Tab)				
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

Table 3-8 List of initialization values for servo - feedback loop measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
(others Tab)				
Identify parameter				
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-9 List of initialization values for servo - closed loop gain measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
(others Tab)				
Open to close conversion				
select feedback gain	Measurement	Measurement|Const		
select output data	Closed loop gain	Closed loop gain |Amplifier gain		
Constant	0.000	-999.999 ~ +999.999	0.001	dB
Identify parameter				
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-10 List of initialization values for servo - open loop gain measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
(others Tab)				
Close to open conversion				
select feedback gain	Measurement	Measurement|Const		
select output data	Amplifier gain	Amplifier gain|Loop gain		
Constant	0.000	-999.999 ~ +999.999	0.001	dB
Identify parameter				
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-11 List of initialization values for amplifier circuit gain-phase measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
(others Tab)				
Gain-Phase measurement				
Phase range	±180deg	-180~+180deg|-360~0deg|0~+360deg|UNWRAP		
Aparture	(Number of data x 0.05)	2 to (Number of data - 1)	1	
Identify parameter				
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

Table 3-12 List of initialization values for amplifier circuit CMRR measurement

Setting item	Initialization value	Setting range	Setting resolution	Unit
(others Tab)				
CMRR measurement				
Select Normal-Mode gain	Measurement	Measurement|Const		
Constant	0.000	-99.999~+99.999	0.001	dB

Table 3-13 List of initialization values for filter measurement

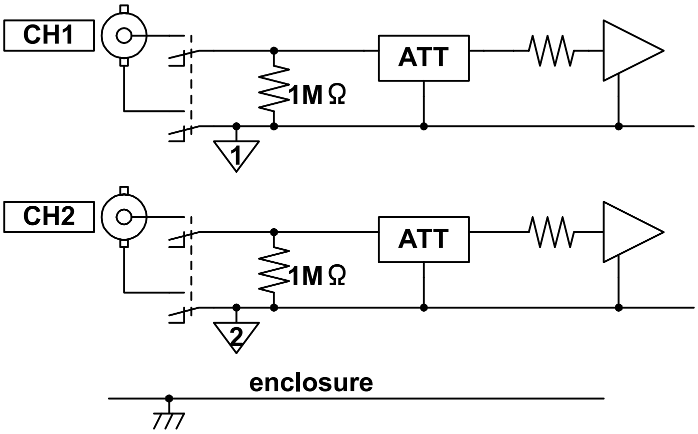
Setting item	Initialization value	Setting range	Setting resolution	Unit
(others Tab)				
Gain-Phase measurement				
Phase range	±180deg	-180~+180deg|-360~0deg|0~+360deg|UNWRAP		
Aparture	(Number of data x 0.05)	2 to (Number of data - 1)	1	
Filter Type	LPF	LPF|HPF|BPF|BEF		
Fc mode	-3dB	-3dB|GRipple		
Identify parameter				
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	
Lin/Log	(Measurement interval of measurement data)	Log|Lin		

3.2.3 Warm-up

It takes at least 30 minutes after the power supply switching-on for the internal temperature of the ZGA5905 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

■ CH1, CH2



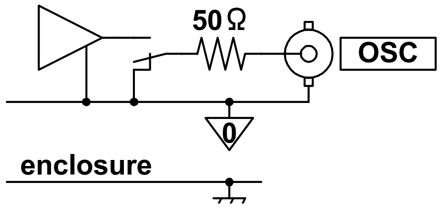
Each of the measurement signal inputs (CH1 and CH2) of the ZGA5905 is electrically insulated from the enclosure, the oscillator output, and the other measurement signal input. The minimum breakdown voltage is 250 Vrms (CAT I) between any two of the enclosure, CH1, CH2, and the oscillator output when 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 connect to any measurement target that exceeds 250 Vrms of CAT I. 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 ZGA5905 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



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 (CAT I) 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 connect to any measurement target that exceeds 250 Vrms of CAT I. 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.

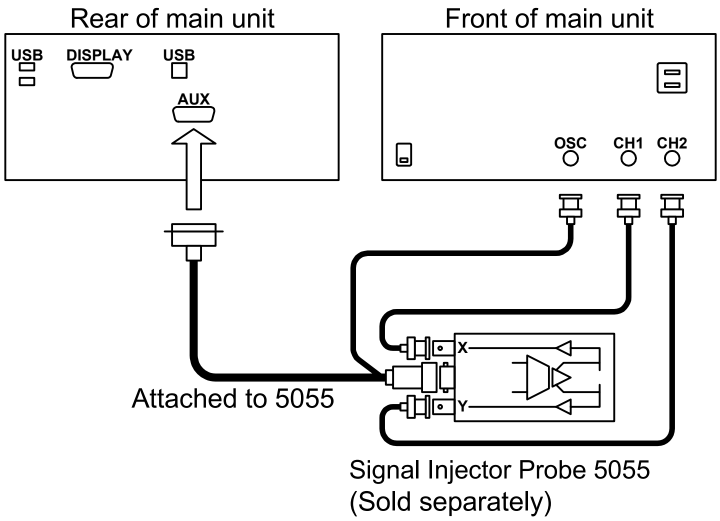


Figure 3-7 Connection with signal injector probe 5055

3.4 Insulation breakdown voltages of input and output terminals

The oscillator output terminal (OSC) and the analyzer input terminals (CH1 and CH2) individually are electrically insulated from the enclosure. The minimum dielectric breakdown voltage between the enclosure and the above mentioned parts of the ZGA5905 is 250 Vrms. (CAT I) 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 OSC, CH1 and CH2 terminals.

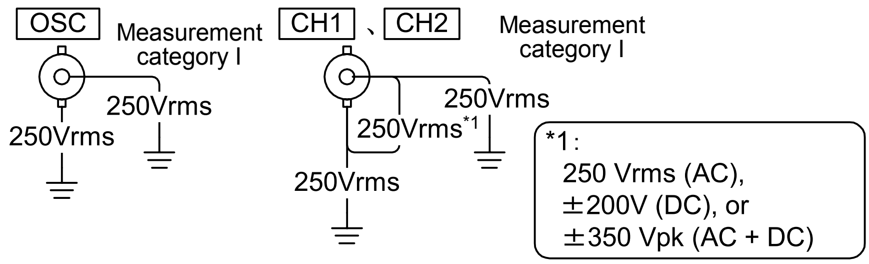


Figure 3-8 From-enclosure isolation voltage specifications (when accompanying BNC cable is used)

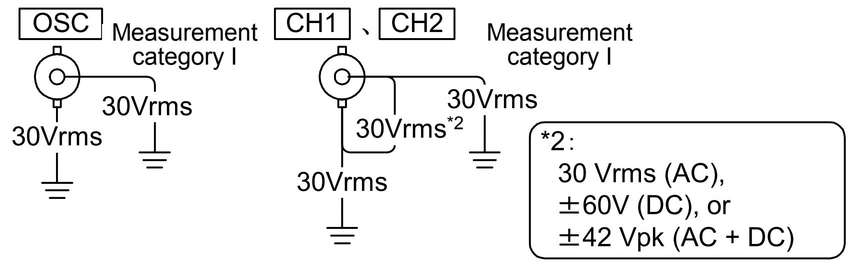


Figure 3-9 From-enclosure isolation voltage specifications (when a cable other than the accompanying cable is used)

OSC, CH1 and CH2 are electrically insulated to each other. The minimum insulation breakdown voltage between the signal and the ground polarities for OSC, CH1 and CH2, individually, is 250 Vrms. (CAT I) 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 OSC, CH1 and CH2.

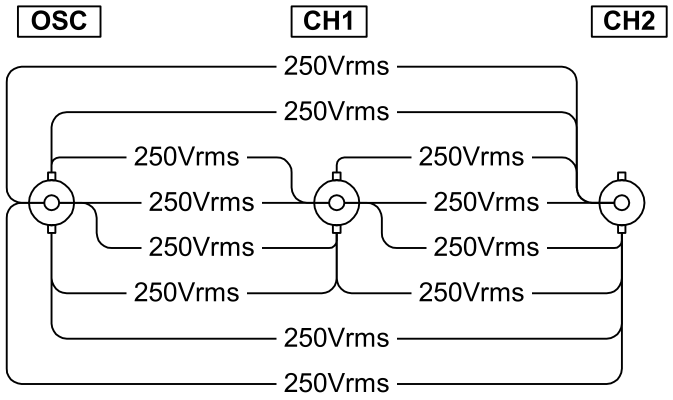


Figure 3-10 Oscillation section-analysis section inputs isolation voltage specifications (when accompanying BNC cable is used)

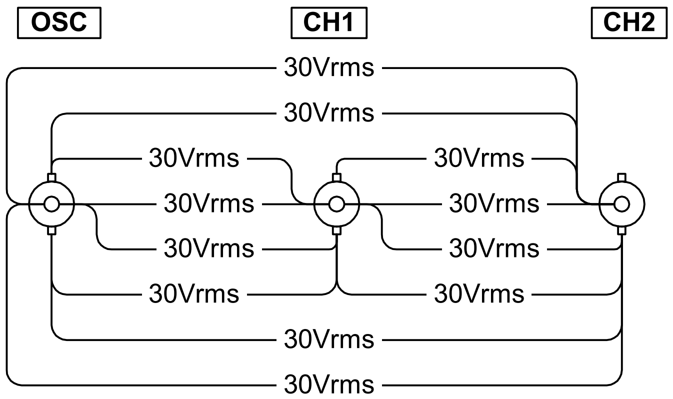


Figure 3-11 Oscillation section-analysis section inputs isolation voltage specifications (when a cable other than the accompanying cable is used)

⚠ 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 terminals.

3.5 Basic operation

As with PC application software, the ZGA5905 is operated by clicking buttons on the monitor and entering numeric values with the pointing device (trackball) and the keyboard.
When the calibration is successfully completed after turning on the power of the ZGA5905 main unit, the start-up menu screen appears as shown in the figure below.

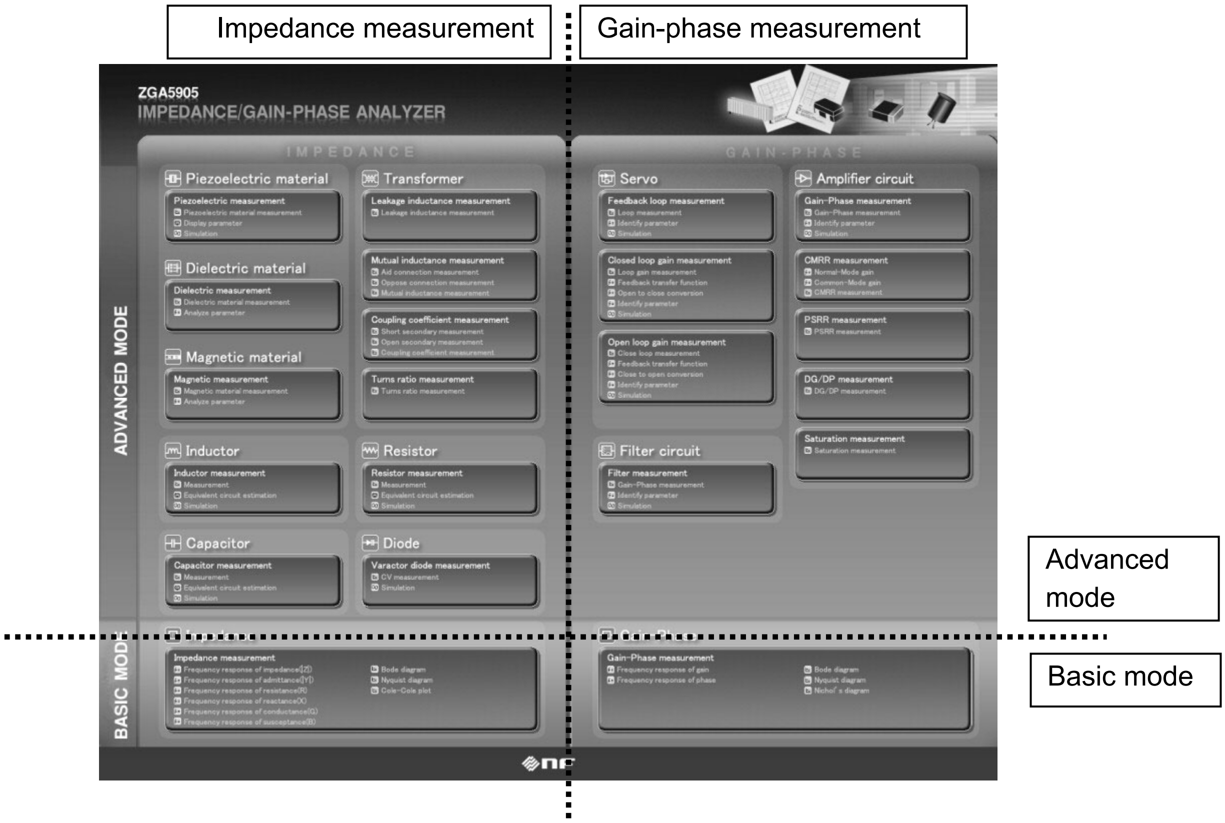


Figure 3-12 Start-up menu screen

The start-up menu screen displays a list of the ZGA5905 functions. These functions are categorized into two modes: advanced mode and basic mode. The advanced mode has various analysis functions for specific purposes (measurement types) and the basic mode performs basic measurements only. They can also be categorized into two types of measurement function: impedance measurement and gain-phase measurement.
When you click the button for a measurement type you want to use, the screen for the measurement type appears.

"Figure 3-13 Screen immediately after measurement type selection (example of piezoelectric measurement)" shows an initial screen before measurement, which appears immediately after clicking the Piezoelectric measurement button on the top left corner of the start-up menu screen.

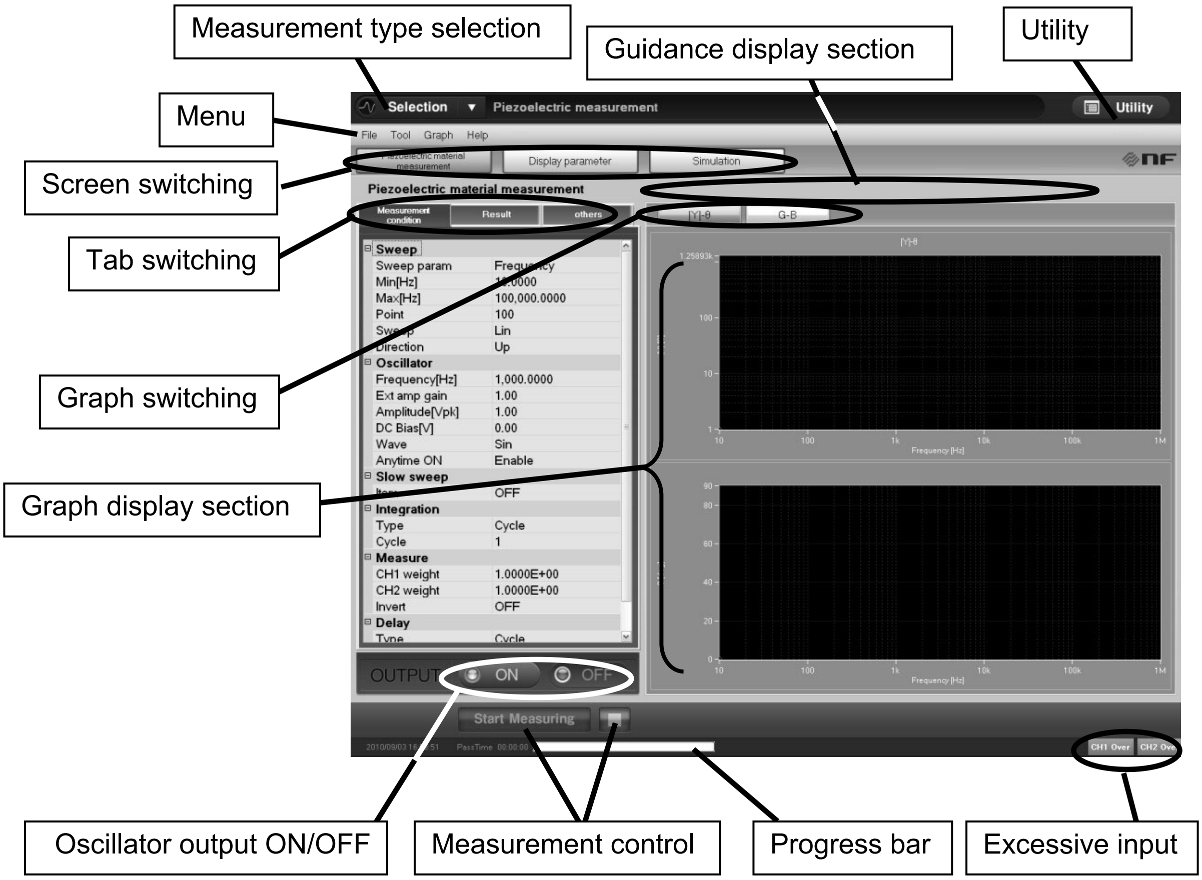


Figure 3-13 Screen immediately after measurement type selection (example of piezoelectric measurement)

The following sections describe various parts on the screen, taking "Figure 3-13 Screen immediately after measurement type selection (example of piezoelectric measurement)" as an example.

3.5.1 Measurement type selection

When you want to select another measurement type, click the ▼ button at the right of [Selection] on the top left corner of the screen to display a list, and then click a desired measurement type name.

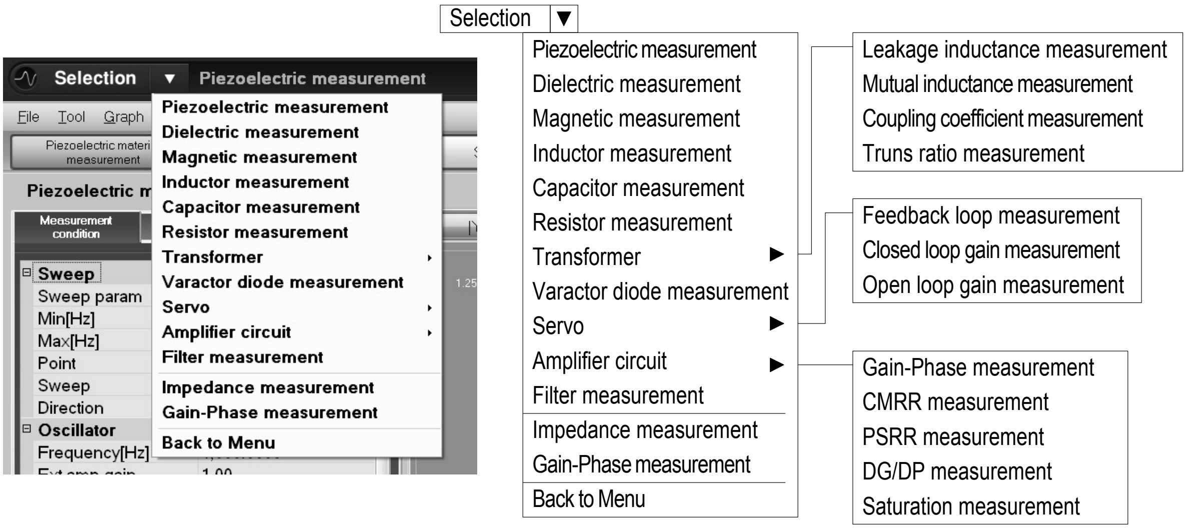


Figure 3-14 Measurement type selection

For details of each measurement type, see "4. Operations in Basic Mode" and "5. Operations in Advanced Mode"

Click “Back to Menu” in the Selector list to return to "Figure 3-12 Start-up menu screen".

3.5.2 Menu operation

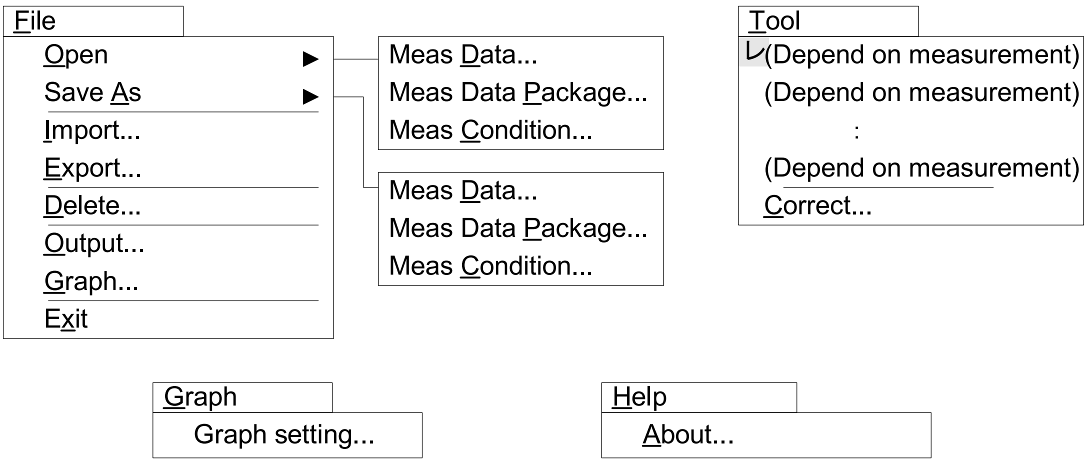


Figure 3-15 Menu tree

Table 3-14 Menu functionality

Menu	Optional		Function
File (Alt+F)	Open	Meas Data...	Loads a measurement data file.
		Meas Data Package...	Loads a multiple measurement data file.(*1)
		Meas Condition...	Loads a measurement condition file.
	Save As	Meas Data...	Saves the measurement data in a file.
		Meas Data Package...	Saves the multiple measurement data file. (*1)
		Meas Condition...	Saves the measurement condition in a file.
	Import...		Copies a file in a USB memory to the storage on the main unit.
	Export...		Copies a file in the storage on the main unit to a USB memory.
	Delete		Deletes the specified file.
	Output...		Creates, prints, and saves a report.
	Graph...		Creates, prints, and saves the hardcopy of a graph.
	Exit...		Turns off the power of the ZGA5905 main unit.
Tool (Alt+T)	(Depend on measurement)		Switches screens. It is the same action as clicking a screen switching button on the screen. The check mark is attached to the left of the currently displayed screen.
	:		
	(Depend on measurement)		
	Correct..		Corrects the measurement section such as calibration.
Graph (Alt+G)	Graph setting...		Sets the axis scale (Lin, Log) and axis range.
Help (Alt+H)	About...		Displays the version number, etc.

(*1) : This function is valid at the measurement type and the screen that practicable multiple data display.

■ Measurement data and measurement condition

Both the data and the measurement condition (such as sweep frequency range at measurement) are saved in a file (with .csv extension) together. The file format is common. The following actions are performed by the menu operation:

- [Open]—[Meas Data]: Loads only the data section in the selected file. The measurement condition is kept unchanged as the screen settings.
- [Open]—[Meas Data Package]: Loads only the multiple data section in the selected file. The measurement condition is kept unchanged as the screen settings.
- [Open]—[Meas Condition]: Loads only the measurement condition section in the selected file. The currently displayed data is not changed.
- [Save As]—[Meas Data]: Saves the currently displayed data on the screen and the measurement condition for the data in a file. The measurement condition at the time of the data measurement is saved in a file even if the measurement condition was changed after the data measurement.
- [Save As]—[Meas Data Package]: Save the currently displayed multiple data on the screen and the each measurement condition for the data in a file. The measurement condition at the time of the data measurement is saved in a file even if the measurement condition was changed after the data measurement.
- [Save As]—[Meas Condition]: Saves the current measurement condition in a file. The measurement data is empty.

For details of the file format, see "6. Files".

■ Storage on the main unit

A storage (**S**olid**S**tate**D**rive, SSD) is built in the ZGA5905 main unit to temporarily save the measurement data. The measurement data, the measurement condition, reports, and graph hardcopies are read from/saved in this storage (fixed to D:\, the root folder of the drive D). Note that the drive C (C:\) cannot be used.
When you want to use a USB memory to move files between the storage and an external PC, use [File] - [Import] or [File] - [Export] in the menu to copy the target files between the USB memory and the storage. While you can specify any folder as the source folder, the destination folder is fixed (D:\ of the ZGA5905 main unit at import or the root folder of the USB memory at export).
You can specify more than one file to be import, export, or deleted at a time. By clicking to select a file with the trackball button while holding down the SHIFT key, you can select all the files between the currently and previously selected files. By clicking to select a file with the trackball button while holding down the CTRL key, you can additionally select the file.

■ Report output

When you click [File] - [Output] in the menu, "Figure 3-16 Reporting window" is displayed.
When you enter necessary information from the keyboard and then click the Create button, "Figure 3-17 Report window" is displayed.When you click the OK button, the entered information is stored in the storage, and the [Reporting] window is closed. The entered information is displayed as is when the [Reporting] window is opened next time.When you click the Cancel button, the entered information is discarded, and the [Reporting] window is closed.
The content of a report varies depending on the measurement type. For details , see "6. Files".

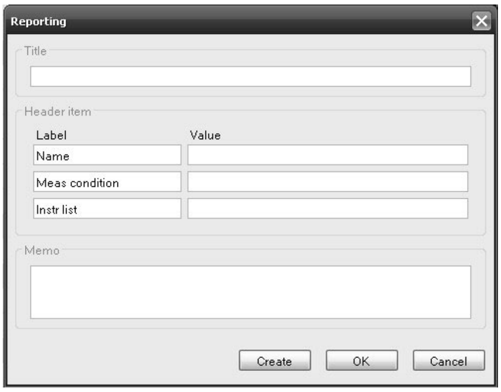


Figure 3-16 Reporting window

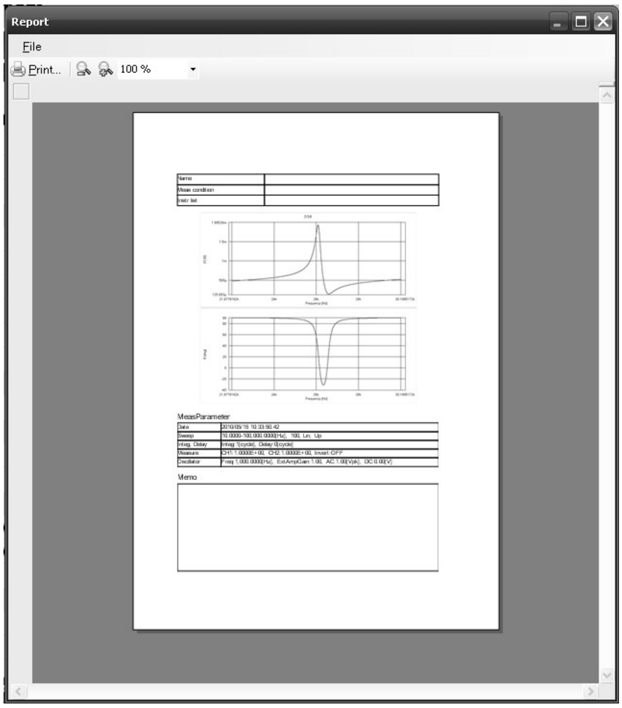


Figure 3-17 Report window

The report output destination can be selected by the menu on the [Report] window.

File
- Print
- Export...
- Close Ctrl+W

Figure 3-18 Report window menu tree

Table 3-15 Report window menu functions

Menu	Optional	Function
File	Print	Prints a report on a printer.
	Export	Saves a report in the storage in the pdf file format.
	Close	Closes the [Report] window.

For details of how to use a printer, see "3.7 Printer".

■ Graph output

When you click [File] - [Graph] in the menu, "Figure 3-19 Graph window" is displayed.

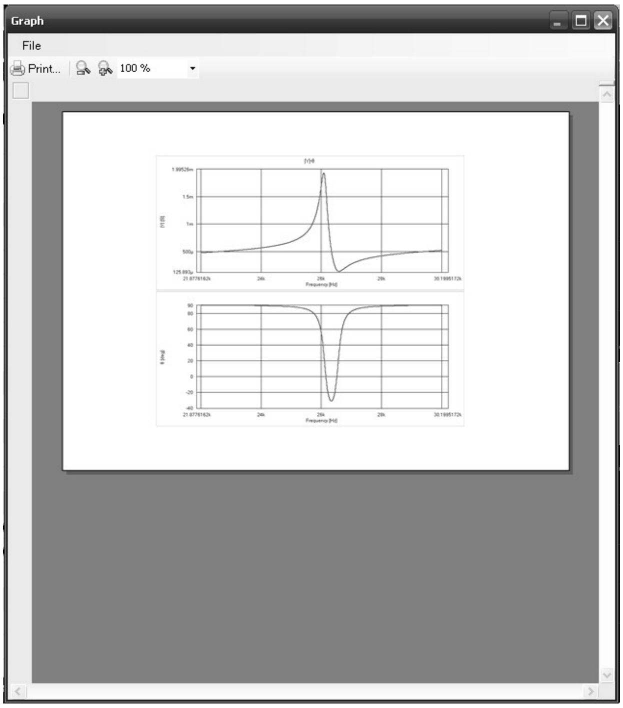


Figure 3-19 Graph window

The report output destination can be selected by the menu on the [Graph] window.

File
- Print
- Export...
- Close Ctrl+W

Figure 3-20 Graph window menu tree

Table 3-16 Graph window menu functions

Menu	Optional	Function
File	Print	Prints a graph hardcopy on a printer.
	Export	Saves a graph hardcopy in the storage in the bmp file format.
	Close	Closes the [Graph] window.

For details of how to use a printer, see "3.7 Printer".

■ Correction

When you click [Tool] - [Correct] in the menu, the [Correction] window is opened, where you can correct the error of the measurement system including the ZGA5905.

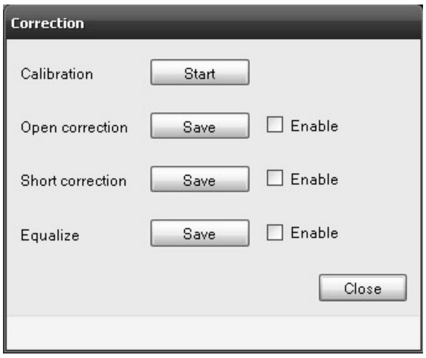


Figure 3-21 Correction window

● Calibration

This is a self-calibration performed using an internal reference signal source of the ZGA5905. The calibration results are stored in the internal memory and will be used as calibration data for measurements. It is the same function as the calibration performed at power-on.
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.
Calibration can be started by clicking the Start button. During calibration, the message "Calibrating..." is displayed in the bottom of the [Correction] window, indicating that the calibration is ongoing. When the calibration has been successfully completed, the [Correction] window returns to the initial state..

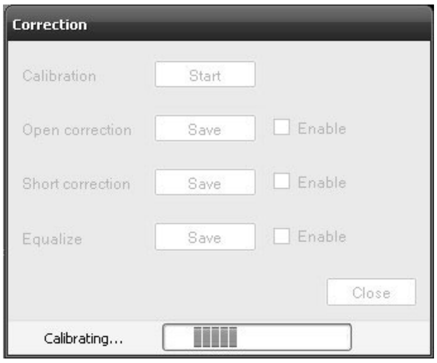


Figure 3-22 Correction window during calibration

While the oscillator output is on, the Start button on the "Figure 3-21 Correction window" is disabled and calibration cannot be performed. Turn off the oscillator output for calibration.

Note that the measurement accuracy specification of the ZGA5905 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 ZGA5905.

To enable a correction, use the ZGA5905 to measure data used for the correction, click the Save button, and select the [Enable] check box. When you want to disable the correction temporarily, clear the check box. When you want to enable the correction again, select the check box.

Note that data loaded from a data file (previously measured data) cannot be used as correction data. When no measurement has been performed since power-on, the Save buttons of the open correction, short correction, and equalization are disabled because there is no measurement data (even if a graph is displayed with a measurement data file opened). See "Figure 3-23 Correction window immediately after start-up".

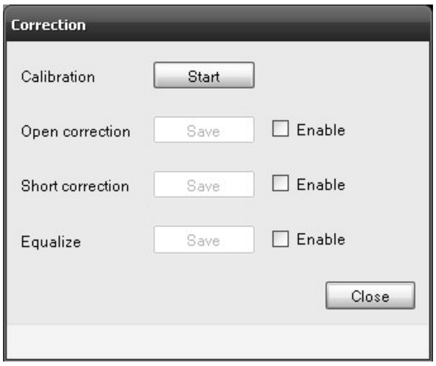
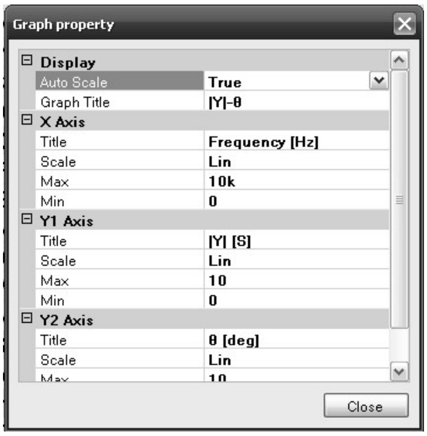


Figure 3-23 Correction window immediately after start-up

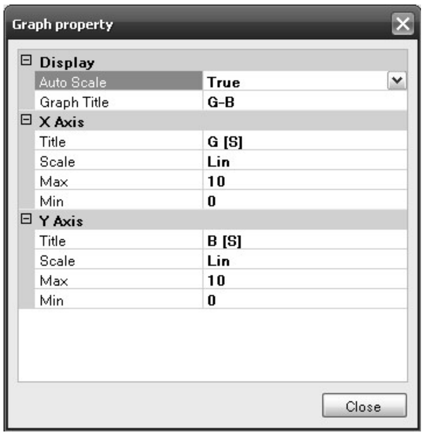
For details of usage, see "4. Operations in Basic Mode".

● Graph setting

You can set the display ranges and titles of the X and Y axes for graphs. When you click [Graph] - [Graph setting] in the menu, "Figure 3-24 Graph property window" is displayed.



When two graphs are displayed



When one graph is displayed

Figure 3-24 Graph property window

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 property] window with [Auto Scale] as [True], the values of the currently displayed graphs are entered in [Min] and [Max] of X, Y1, and Y2 axes.

For the Bode diagram or other graph that has two graphs on the top and bottom, the vertical axes of the upper and lower graphs are called the "Y1 Axis" and "Y2 Axis" respectively. The horizontal axis is called "X Axis" and common to Y1 and Y2 axes. For the Nyquist diagram or other graph that has only one graph, the only vertical axis is called the "Y Axis".

For [Scale] of the X, Y1, Y2, 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 (Y1 and Y2 axes) 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.

● Version information

When you click [Help] - [About], the version information of the ZGA5905 software is displayed.

3.5.3 Screen switching

The screen varies depending on the selected measurement type. For details, see "4. Operations in Basic Mode" and "5. Operations in Advanced Mode".
As the main flow of the measurement operations, you display and operate screens by clicking buttons in the order of left to right. Except for some measurement types, the main flow is as follows:

Data measurement (or measurement data file loading)
↓
Analysis, model generation, etc.
↓
Simulation (verification of analysis result or generated model)

A screen switching button to the left of the current screen can be used to display the screen. Subsequent screens (analysis or simulation) may not be displayed if no data measurement is performed. In that case, a message appears in the guidance display section. For details, see "3.5.12 Guidance display".

3.5.4 Tab switching

There are the following three tabs, which can be switched as needed:

- Measurement condition: Sets measurement conditions such as measurement frequency and amplitude.
- Result: Displays marker read values, various search results, etc.
- others: Enters simulation conditions, etc.

Figure 3-25 Tab switching

In the [Measurement condition] tab, the following settings required for measurement are performed:

(Sweep)

- Sweep param — Select [Frequency], [Amplitude], [DC Bias], or [ZeroSpan] (time).
- Min,Max — Set the sweep range. There is no minimum value setting for the zero span sweep.
- Point — The number of measurement points between the minimum and maximum sweep values.
- Sweep — Select [Lin] (linear scale) or [Log] (logarithmic scale).
- Direction — Select [Up] (minimum to maximum) or [Down] (maximum to minimum).

(Oscillator)

- Frequencuy — Set the output frequency. Note that, after the frequency sweep ends, the last swept frequency is output regardless of this setting.
- 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.
- Amplitude — Set the measurement signal amplitude (external amplifier output equivalent). Note that, after the amplitude sweep ends, the last swept amplitude is output regardless of this setting.
- DC Bias — Set the DC bias (external amplifier output equivalent). Note that, after the DC bias sweep ends, the last swept DC bias is output regardless of this setting.
- Wave — Fixed to [Sin] (sine wave).
- Anytime ON — Select whether to turn OFF or leave ON the oscillator output after a measurement. [Disable] turns the output off after a measurement. [Enable] leaves the output on after a measurement.

(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.
- Variation — Threshold of variation to be considered as an abrupt change. The unit varies depending on the monitored parameter.

(Integration)

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

(Measure)

- CH1,CH2 weight — Weighting factor of the measurement signal inputs. The input values multiplied by these numeric values are used for the 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.

(Delay)

- Type — Select the delay setting unit. Select [Cycle] or [Time].
- Cycle/Time — Delay setting.

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

⚠ **CAUTION** Even if the output voltage setting is changed, the output voltage will not change unless the [OUTPUT] ON button is clicked.

○ Zero span sweep

When you set the sweep parameter to ZeroSpan, 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 + integration cycle / measured frequency) seconds for each measurement point. If the number of measurement points [Point] x (2 + integration cycle / measured frequency) exceeds the [Sweep Time] in the [Measurement condition] tab, the time required for zero span sweep is calculated by [Point] x (2 + integration cycle / measured frequency).

In [Result] tab, the measurement results are displayed as numeric values (marker display). For details, see "4. Operations in Basic Mode" and "5. Operations in Advanced Mode".

In the [Others] tab, the simulation-related setting or multiple data display operation is performed. For simulation setting, see "4. Operations in Basic Mode" and "5. Operations in Advanced Mode".

(Multiple data display operation)

On the screens listed in "Table 3-17 Screens capable of multiple data display", up to 16 data can be displayed on the same graph.

Table 3-17 Screens capable of multiple data display

Measurement type	Screen
Piezoelectric measurement	Pezoelectric material measurement
Dielectric measurement	Dielectric material measurement
Magnetic measurement	Magnetic material measurement
Inductor measurement	Measurement
Capacitor measurement	Measurement
Resister measurement	Measurement
Transformer	
Leakage inductance measurement	Leakage inductance measurement
Turns ratio measurement	Turns ratio measurement
Varactor diode measurement	CV measurement
Servo	
Feedback loop measurment	Loop measurement
Amplifier circuit	
PSRR measurement	PSRR measurement
DG/DP measurement	DG/DP measurement
Saturation measurement	Saturation measurement

It is useful for comparing different measurement results with different measurement conditions.

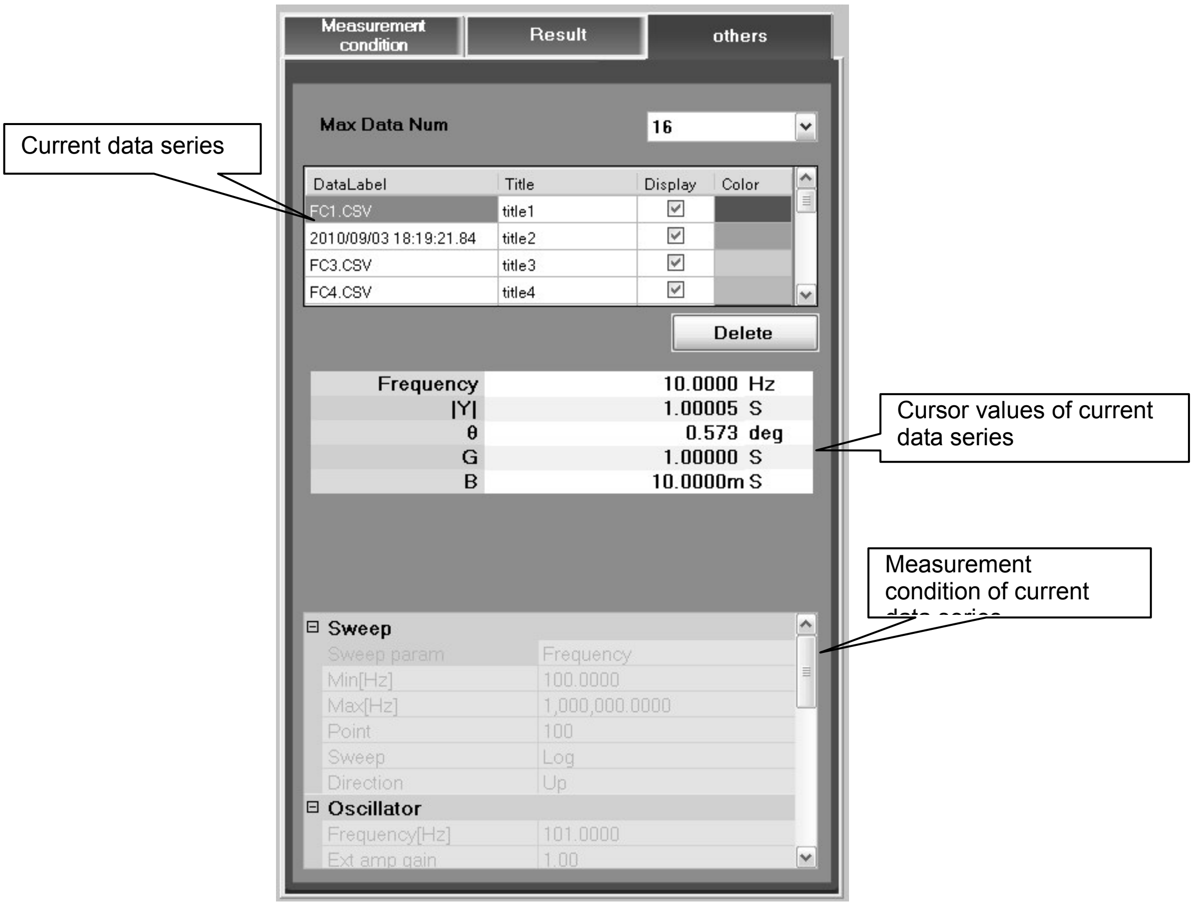


Figure 3-26 Multiple data display control

Up to 16 data can be displayed on the graph at a time. A sweep measurement or file data loading adds another data series.

- Max data Num: Set a value within the range of 1 – 16.
- DataLabel: For sweep measurement data, the measurement date will be displayed. For data loaded from a file, the file name is displayed. It cannot be edited.
- Title: You can specify any title.
- Display: Clear a check box to hide the series.

When reach the number of data to [Max data Num], and further measure (or load from file), the new measurement data (or load data from file) are replacing to the oldest data. Other data, color and Title will not change.

You can select a data series by clicking it with the trackball button. The following operations work on the selected data series:

- Marker display data (in the [Result] tab)
- Data deleted by the Delete button
- Data saved by the [File] - [Save As] - [Meas Data] menu

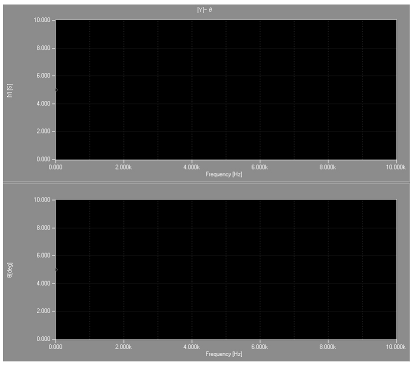
In the lower half of the [others] tab, the cursor values and measurement condition are displayed. It is the measurement condition that was used for the currently selected data series, and not the one set in the [Measurement condition] tab.

3.5.5 Graph switching

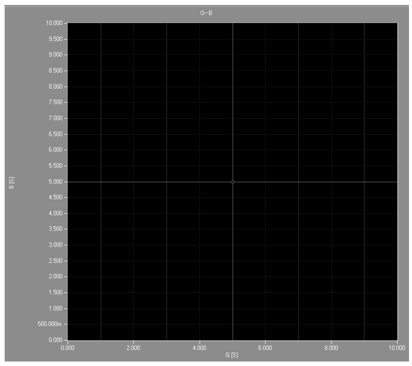
Some measurement types have more than one graph format (combination of X and Y axes). When you click a desired graph format, the graph is displayed in the selected format. The graph format varies depending on the selected measurement type. For details, see "4. Operations in Basic Mode" and "5. Operations in Advanced Mode".

3.5.6 Graph display section

Depending on the selected display format, two graphs (X-Y1-Y2 axes) may be displayed on the top and bottom or one large graph (X-Y axes) may be displayed. Depending on the measurement type, a screen may be displayed to specify the analysis result and analysis method, instead of graphs.
Most of two-graph displays have a sweep parameter (frequency, DC bias, AC amplitude, or time) on the X axis. One-graph display is mainly used for the Nyquist diagram and the Cole cole plot.



Example of two-graph display



Example of one-graph display

Figure 3-27 Graph display section

■ Marker

For measurement data or simulation data, you can use the marker to read the numeric value of a data item on the graph. It is displayed in the [Result] tab on the left half of the screen.
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.

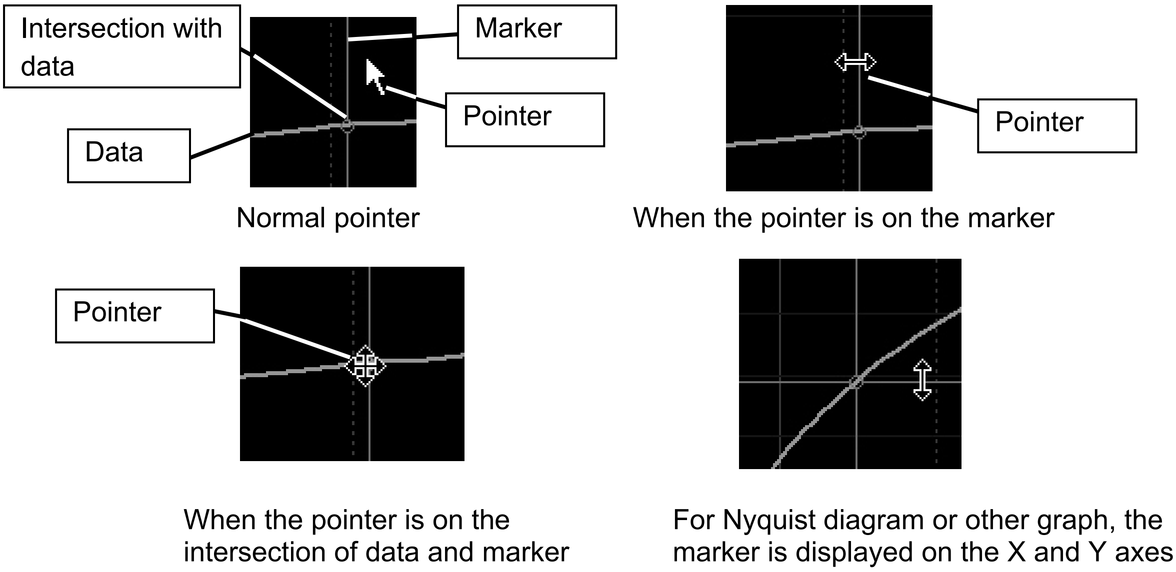


Figure 3-28 Marker pointer

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 in the [Result] tab. 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

You can operate the display range of a graph by selecting [Graph] - [Graph setting] menu as well as using the keyboard or trackball.

SHIFT + left button click	: Zoom in
SHIFT + right button click	: Zoom out
SHIFT + drag	: Zoom in to the selected range
SHIFT + ALT + drag	: Zoom in, keeping the aspect ratio
CTRL + drag	: Pan
SHIFT + BackSpace	: Cancel the pan or zoom (return to auto scale)
CTRL + 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.

3.5.7 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 the oscillator output after a measurement depends on the [Anytime ON] setting in the [Measurement condition] tab.

- When [Anytime ON] is set to [Enable]: 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 [Disable]: 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] tab are used for output.

3.5.8 Measurement control

Use the Measure button to start a sweep measurement. When the oscillator output is OFF, you cannot start a measurement.
Use the ■ (interruption) 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 minimum and maximum sweep values setting do not apply to the data range.

3.5.9 Progress bar

This represents the progress of a ZGA5905 sweep measurement. It indicates the progress percentage of the expected total measurement time value, instead of the number of measurement points (the number of measured points/the number of total measurement points). The actual measurement time varies depending on the auto-range processing (re-measurement due to range change) and the internal calculation processing of the ZGA5905.

3.5.10 Excessive input indicators

The maximum measurement voltage of the ZGA5905 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 bottom 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 ZGA5905.

⚠ WARNING

- Do NOT connect to any measurement target that exceeds 250 Vrms of CAT I. 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.

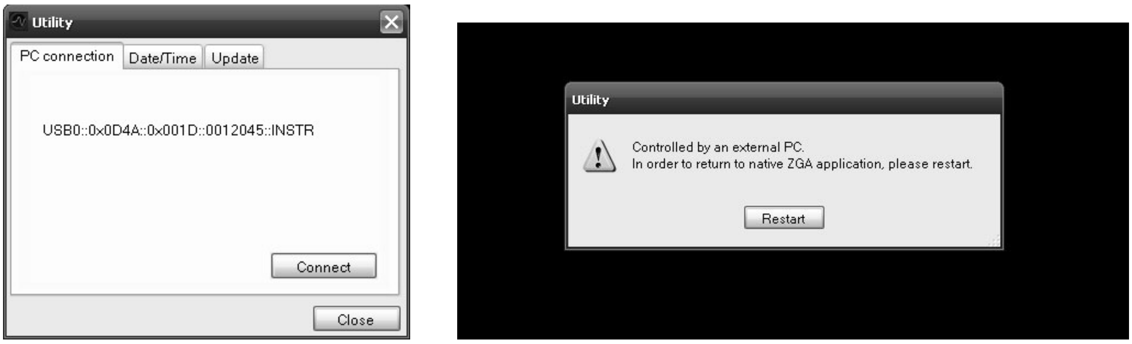
For details of specifications and precautions of the input connectors, see "3.3 Input and output terminals" and "3.4 Insulation breakdown voltages of input and output terminals".

3.5.11 Utility

When you click the Utility button on the top right of the monitor screen, the Utility window is displayed.

■ PC connection

This tab is used to use an external PC or other controller (external control) to control the ZGA5905.
You can connect with an external PC by clicking the Connect buttons, respectively. When you want to perform the external control, use a commercial USB cable to connect the USB-B connector on the rear of the ZGA5905 main unit with the PC. For details of external control commands, see "ZGA5905 Remote Control Instruction Manual".



Operated from the keyboard   Under external control

Figure 3-29 External control switching

The displayed values are numbers for the PC to identify the ZGA5905. From the top:

0x0D4A: USB Vendor ID of NF Corporation.
0x001D: Product ID, the number representing the model number ZGA5905.
0012045: 7-digit manufacturing number (serial number). This is unique to each product.

Note that operations other than Restart are disabled under external control.

To operate it in the ZGA5905 main unit, you must reboot the ZGA5905. Measurement data and condition data that are not saved will be lost. Please save the data you need.

The ZGA5905 will exit the external control by power-off. Therefore, when you want to control the ZGA5905 by using an external PC, open the Utility window to set the external PC connection after every power-on.

■ Data/Time

This tab is used to set the built-in calendar and clock of the ZGA5905.

■ Update

This tab is used to upgrade the ZGA5905 software. For a specific operation, see update information provided by us.

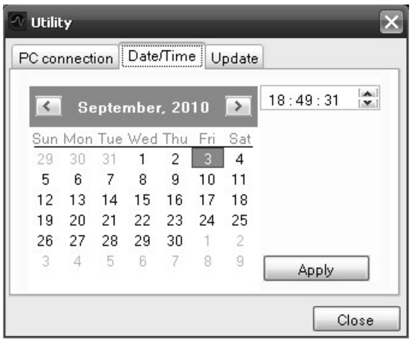


Figure 3-30 Data/Time

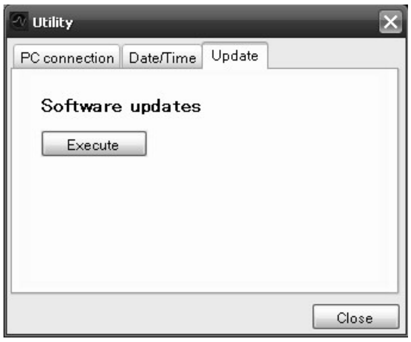


Figure 3-31 System update

3.5.12 Guidance display

In the ZGA5905 basic operation, you click the screen switching buttons from left to right to switch screen displays to perform measurement, analysis, and simulation. When you cannot switch screens before measurement (or before loading measurement data file) because there is no analysis data, an appropriate message is displayed on the guidance display section.

A guidance display appears when you cannot switch screens and also tabs (for example, when you try to open the [Result] tab with no data).

The content of a guidance display varies depending on the measurement type and is mainly categorized into the following two types:

(1) Please ***

Displayed when you tried to switch screens (or tabs), but could not do so. This informs you of a method (solution) to perform the operation.

Example) "Please measure"

This is displayed when you selected the [Result] tab (marker display) with no data. This message will not be displayed after you perform a measurement or load a measurement data file to display the data in a graph.

(2) Invalid control ***

Displayed when the operation itself is invalid.

Example) "Invalid control for this function"

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 ZGA5905 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 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] tab.

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

The ZGA5905 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 ZGA5905 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 ZGA5905 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.

3.7 Printer

When you print to a printer from the [Report] or [Graph] screen, "Figure 3-32 Print screen" is displayed.

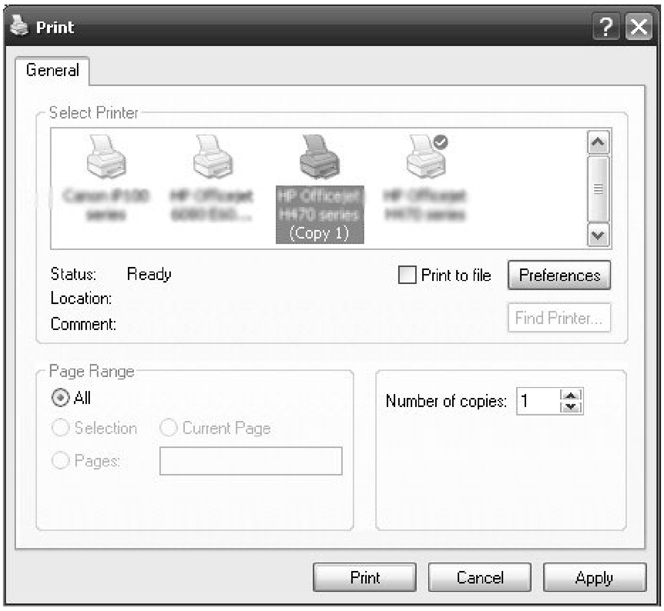


Figure 3-32 Print screen

The list of the printers supported by the ZGA5905 is displayed in [Select printer]. If a printer is available, its icon is highlighted. In addition, "(copy 1)" is appended to the printer name. A printer with a dimmed icon cannot be selected even if the printer model is the same as an available one.

You can click the [Preferences] button to set the print settings. The default settings are:

Paper size:	A4
Both side printing:	One-sided (Two-sided printing off)
Page orientation:	Portrait
Color printing	

You can click the [Print] button to start printing. For details of how to feed paper, replace ink cartridges, align printheads after ink replacement, or clean printheads, see the instruction manual provided with the printer.

For inquiry about a repair of printer or how to use a printer, contact us or our agent instead of its manufacturer.

4. Operations in Basic Mode

4.1 Impedance measurement

The "Impedance measurement (Basic mode)", which can be selected from the start-up menu screen or [Selection], is a general-purpose impedance measurement function which is not limited to particular measurement purposes.
In the advanced mode, the same explanation applies to the impedance measurement.

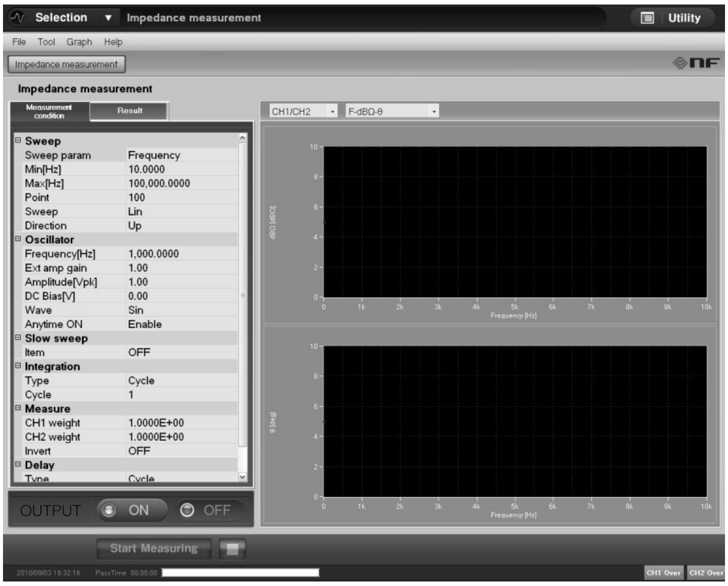


Figure 4-1 Impedance measurement screen

The ZGA5905 performs impedance measurement by the following calculations.

$|Z| = (\text{CH1 voltage amplitude}) / (\text{CH2 voltage amplitude})$

$\theta = (\text{CH1 phase}) - (\text{CH2 phase})$

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.

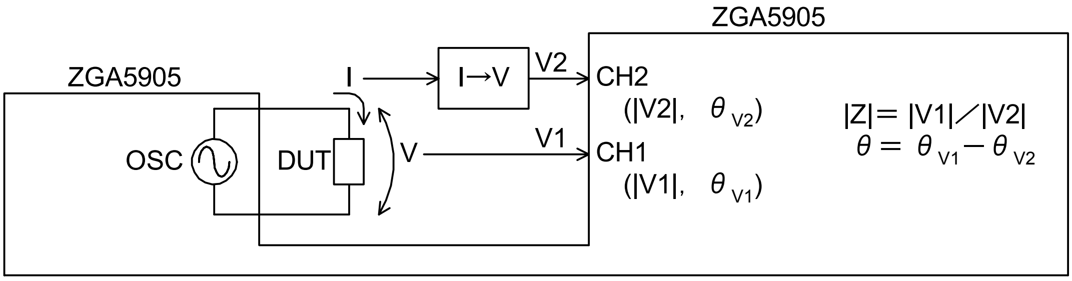


Figure 4-2 Principle of impedance measurement

4.1.1 Connecting with sample

The ZGA5905 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.

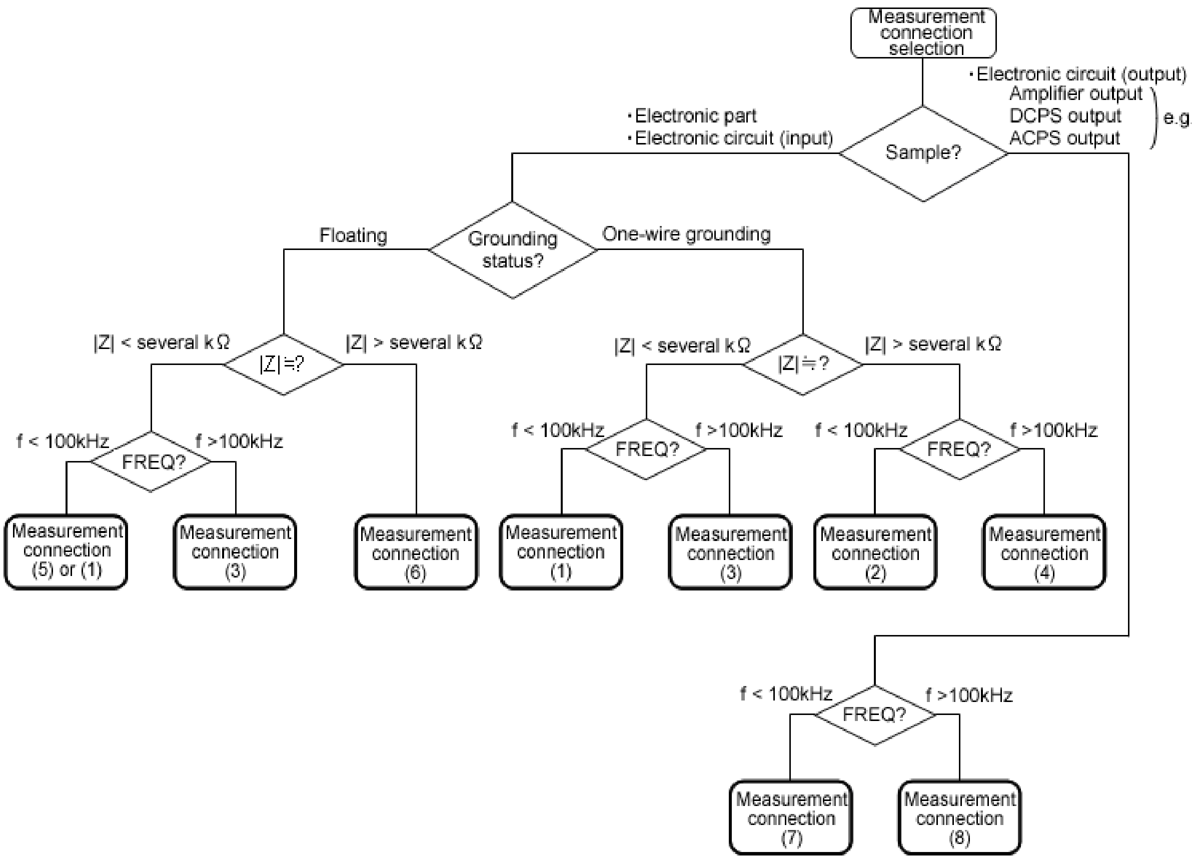
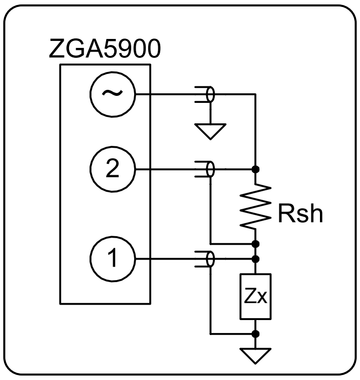


Figure 4-3 Measurement connection selection procedure

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

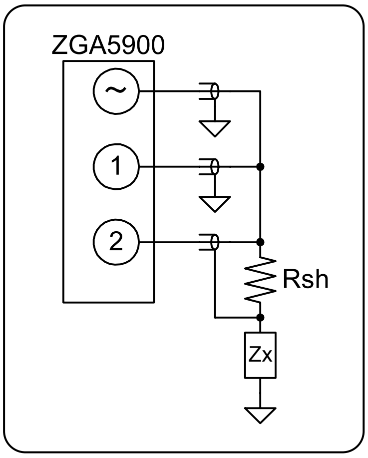
In the figures below, (~), ①, and ② indicate the oscillator output, CH1, and CH2, respectively. Rsh indicates the shunt resistor for current-to-voltage conversion. Our PA-001-0370 (1 V/A, 1 Arms rated, sold separately) is available as the shunt resistor. Use a shunt resistor with appropriate current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

○ Measurement connection (1)   Low-Z, Low-f, grounded sample measurement



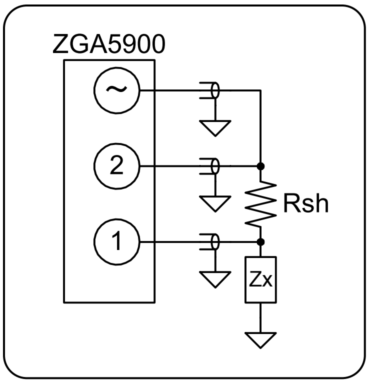
This 4-terminal configuration is impervious to the measurement cable contact resistance and thus is suited to measure low-impedance samples. The appropriate shunt resistor Rsh is approx. 1 Ω or less.
With a larger sample impedance, the ZGA5905 CH1 input impedance or the cable capacitance would be an 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



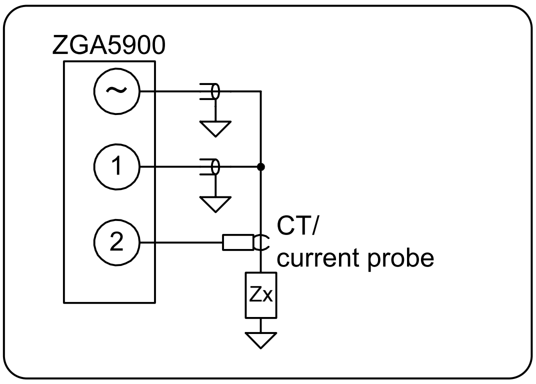
This connection is effective when the sample impedance is high and the ZGA5905 CH1 input impedance (1MΩ) is not ignorable. A higher frequency would reduce the measurement accuracy due to effect of the CH2 floating capacitance.
Making the Rsh as large as several tens to a hundred ohms improves the signal-to-noise ratio at high impedance measurement.

○ Measurement connection (3)　　　Low-Z, High-f, grounded sample measurement



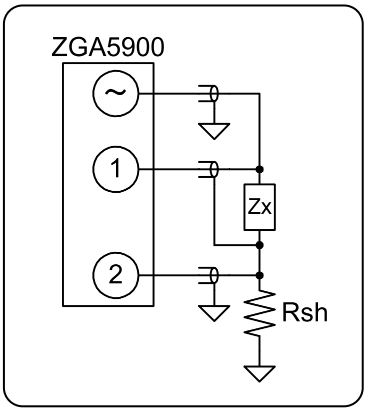
This connection is impervious to the ZGA5905 CH1 and CH2 floating capacitances, and thus can stably measure up to high frequencies. However, the measurement error increases for a larger sample impedance. The appropriate Rsh is approx. 1 Ω or less.

○ Measurement connection (4)　　　High-Z, High-f, grounded sample measurement



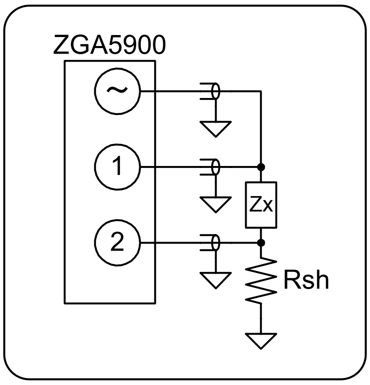
This connection is suitable for measurement at high frequencies when the CT (current transformer) and current probe band widths are wide. However, the signal-to-noise ratio is disadvantageous (due to a larger noise particularly for DC-CT).

○ Measurement connection (5)　　　Low-Z, Low-f, both-end floating sample measurement
Electric double layer capacitor (EDLC), and so on



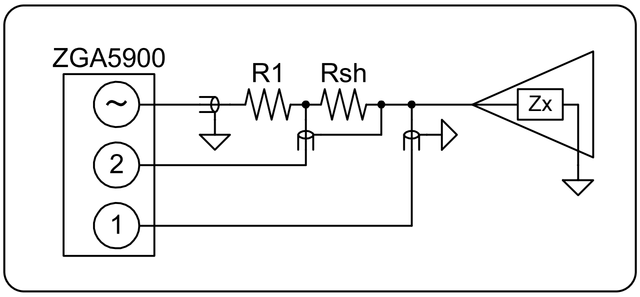
This 4-terminal configuration is impervious to the measurement cable contact resistance. The appropriate Rsh is approx. 1 Ω or less.
For the Rsh and the sample, place whichever is lower in impedance (smaller voltage drop) on the ground side. See also the measurement connection (1).

○ Measurement connection (6) High-Z, High-f, both-end floating sample measurement



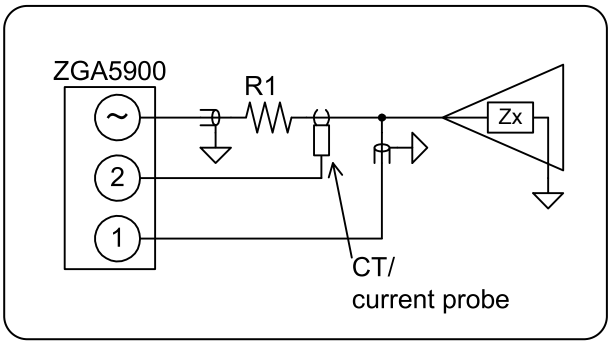
This connection is impervious to the ZGA5905 CH1 and CH2 floating capacitances, and thus can stably measure up to high frequencies. Making the Rsh as large as several tens to a hundred ohms improves the signal-to-noise ratio at high impedance sample measurement.

○ 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 ZGA5905 floating capacitance and thus stabilizes measurements at high frequencies.

Though the ZGA5905 oscillator output has ±10V 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 ZGA5905 measurement signal input terminals is 250Vrms. 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 (in the [Measurement condition] tab).

(Measure)

- CH1 weight
- CH2 weight
- Invert

(Oscillator output)

- External 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 ZGA5905 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."

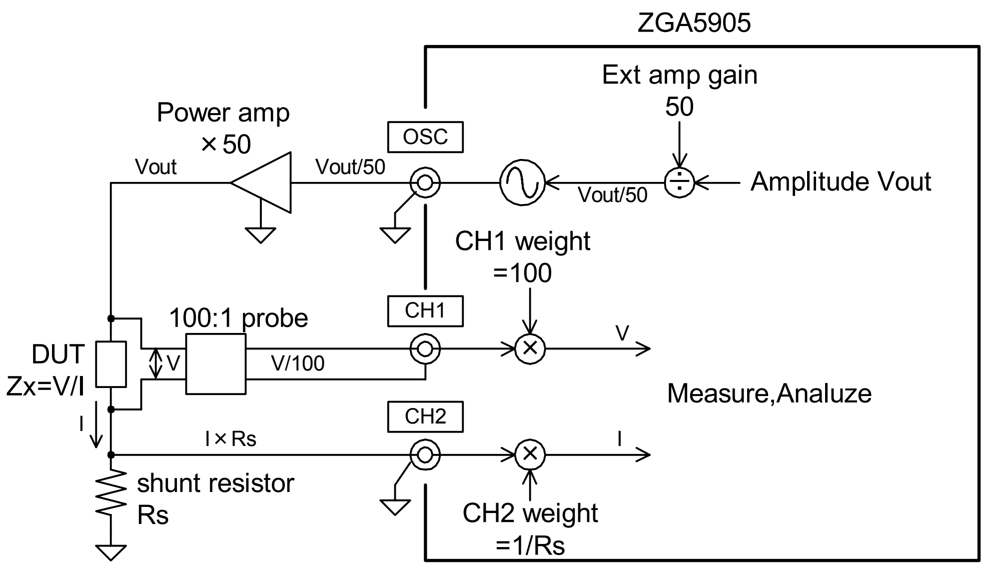


Figure 4-4 Connection diagram for impedance measurement - Setting example

Set [Invert] to [Enable] 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 [Enable].

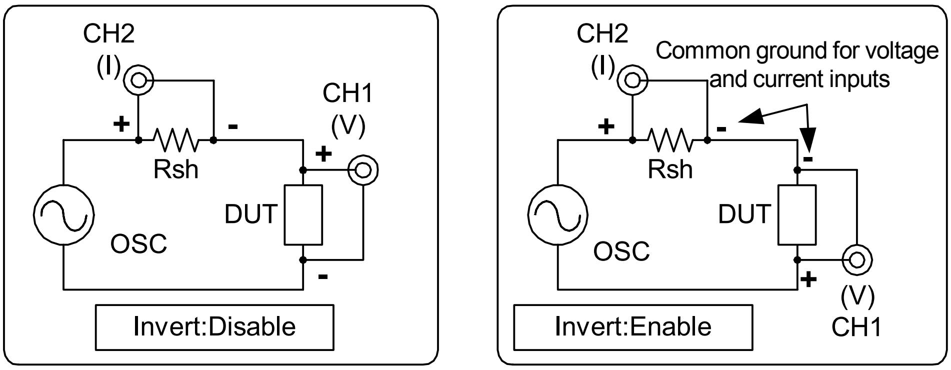


Figure 4-5 Phase invert function

Set other items, according to the measurement.

(Sweep)

- Sweep param : Fixed to Frequency in the impedance measurement.
- Min,Max : Sweep measurement range.
- Point : The number of measurement points between the minimum and maximum sweep values.
- Sweep : [Lin] (linear) or [Log] (logarithmic) of the measurement frequency sweep, which is independent from Lin or Log of the graph display.
- Direction : [Up] makes a sweep measurement from minimum to maximum, and [Down] from maximum to minimum.

(Oscillator)

- Frequency : Immediately after the setting, this is the frequency of a signal actually output from the current oscillator output regardless of the minimum and maximum 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 ZGA5905 main unit is (This value)/(External amplifier gain).
- Wave : Fixed to [Sin] (sine wave).
- Anytime ON : Selects whether to turn off (Disable) or leave on (Enable) the oscillator output after a sweep measurement.

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

(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."

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 ZGA5905 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 minimum sweep value, maximum sweep value, and AC amplitude. See "4.1.2 Setting impedance measurement."
2) From the menu, select [Tool] - [Correct...] to open the Correction window. See "Figure 4-6 Correction window."

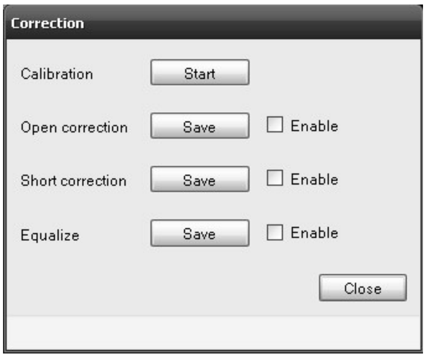


Figure 4-6 Correction window

3) In the Correction window, not checked the [Enable] check box for each of [Open correction], [Short correction], and [Equalize]. Then, click the Close button to close the Correction window.

(To perform the open correction)

4) 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.
5) Turn on the oscillator output, click the Start Measuring button, then wait until the sweep measurement finishes.
6) From the menu, select [Tool] - [Correct...] to open the Correction window. Click the Save button of the open correction, then click the Close button to close the window.

(To perform the short correction)

7) 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.
8) Turn ON the oscillator output, click the Start Measuring button, then wait until the sweep measurement finishes.
9) From the menu, select [Tool] - [Correct...] to open the Correction window. Click the Save button of the short correction, then click the Close button to close the Correction window.

10) From the menu, select [Tool] - [Correct...] to open the Correction window. When you performed the open correction measurement, check the [Enable] check box for the open correction. When you performed the short correction measurement, check the [Enable] check box for the short correction. When you performed both the measurements, check the [Enable] check box for each of the open and short corrections.

⚠ **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 ZGA5905 even when the [Enable] check box is deselected. Re-select [Enable] to activate the correction again.
The open correction data and short correction data are cleared at power-off. Perform the correction measurement again immediately after power-on, after a change of the measurement connection, or before an accurate measurement.

Data saved by click the SAVE button are the latest measurement data. You cannot use the data which loaded from a file for open correction data and short correction data.

(Description)

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

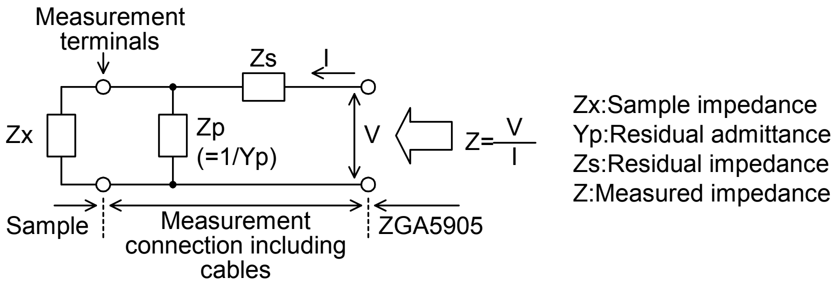


Figure 4-7 Measurement system error model

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.

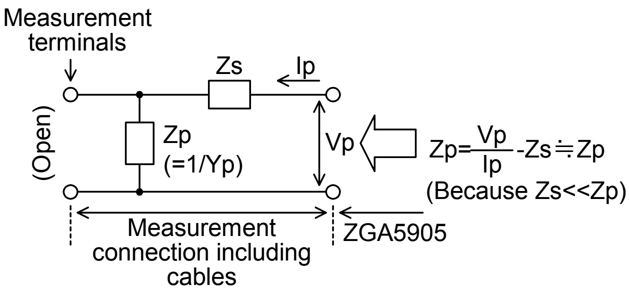


Figure 4-8 Open correction measurement

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

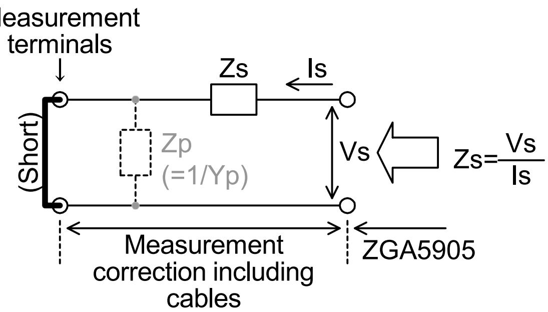


Figure 4-9 Open correction measurement

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×Z/(Zp—Z)
Enable	Enable	Zx=Zp×(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.
- After the measurement connection is changed

  The residual impedance and admittance have changed.
- After the sweep range (minimum or maximum 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.

A change of the sweep measurement direction (Up/Down) does not need another correction measurement.

4.1.4 Measuring sample impedance

Click the Measure button to start a sweep measurement. When the sweep finishes, the data are displayed in a graph. You can change the graph format as you need. In the basic mode, the graph format is selected through a pull-down menu above the graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You can display or analyze it completely the same way as you actually measured on a sample.

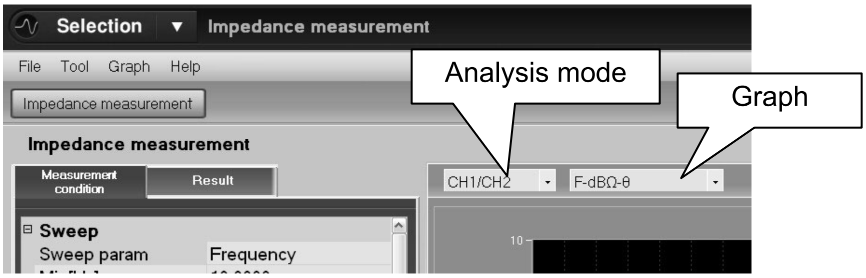


Figure 4-10 Graph selection in Basic mode (impedance measurement)

Available graphs varies depending on the analysis mode setting. When the analysis mode is set to "CH1/CH2", the impedance-related graphs become available. When it is set to "CH2/CH1", the admittance-related graphs become available. Available graph types are shown in "Table 4-2 Graph type in Basic mode (impedance measurement)."

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

Analysis mode	Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
CH1/CH2	F-dBΩ-θ	Frequency	Impedance	Phase
	F-|Z|-θ	Frequency	Impedance	Phase
	F-R-X	Frequency	Resistance	Reactance
	θ-dBΩ	Phase	Impedance	—
	θ-|Z|	Phase	Impedance	—
	R-X	Resistance	Reactance	—
CH2/CH1	F-dBS-θ	Frequency	Admittance	Phase
	F-|Y|-θ	Frequency	Admittance	Phase
	F-G-B	Frequency	Conductance	Susceptance
	θ-dBS	Phase	Admittance	—
	θ-|Y|	Phase	Admittance	—
	G-B	Conductance	Susceptance	—

- 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 x $Log_{10}(|Z|)$. Its unit is [dBΩ].
- "dBS" is the calculated result of 20 x $Log_{10}(|Y|)$. 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)

$$|Z|[\Omega] = \sqrt{R^2 + X^2}\ ,\ \ \theta[\mathrm{deg}] = \tan^{-1}\frac{X}{R}$$

(Analysis mode = CH2/CH1)

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

The [Result] tab shows the following markers 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 Basic mode (impedance measurement)

Analysis mode	Display parameter	Unit
CH1/CH2	Frequency	Hz
	dBΩ	dBΩ
	|Z|	Ω
	R	Ω
	X	Ω
	θ	deg
CH2/CH1	Frequency	Hz
	dBS	dBS
	|Y|	S
	G	S
	B	S
	θ	deg

4.2 Gain-phase measurement

The "Gain-Phase measurement (Basic mode)", which can be selected from the start-up menu screen or [Selector], is a general-purpose gain-phase measurement function which is not limited to particular measurement purposes.
In the advanced mode, the same explanation applies to the gain-phase measurement.

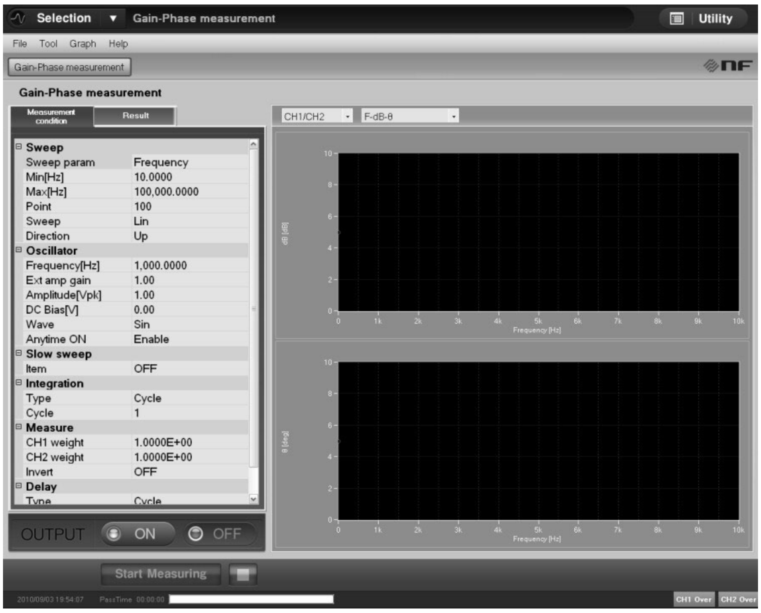


Figure 4-11 Gain-phase measurement screen

The ZGA5905 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.

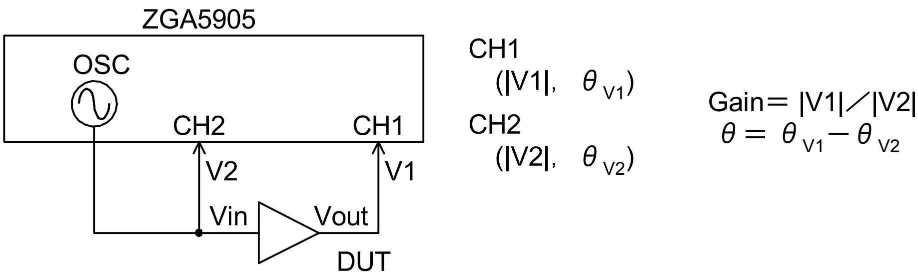


Figure 4-12 Principle of gain-phase measurement

"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).

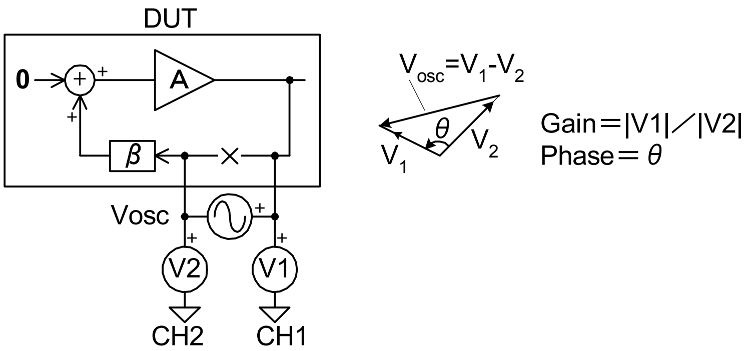
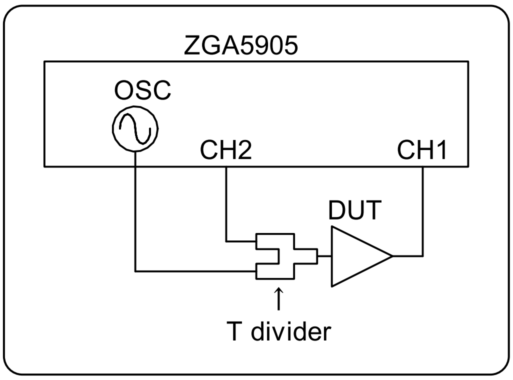


Figure 4-13 Principle of servo measurement

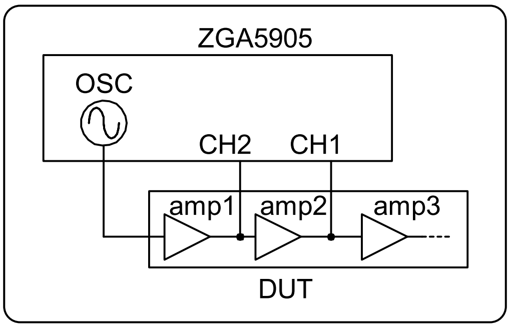
4.2.1 Connecting with target circuit

●Measurement connection with amplifier circuit, filter, and so on (1)



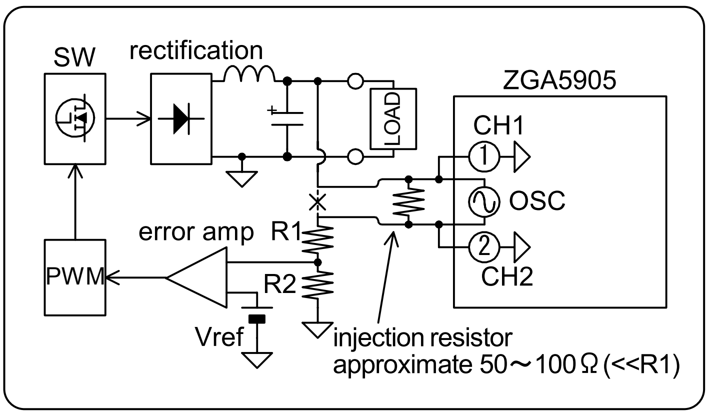
This connection measures the input/output characteristics (transfer characteristics) of the target circuit.

●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 ZGA5905. 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 (ZGA5905 floating breakdown voltage) output.

4.2.2 Setting gain-phase measurement

Set the followings according to the circuit connected with the target circuit.(in the [Measurement condition] tab)

(Measure)

- CH1 weight
- CH2 weight

(Oscillator)

- External 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 ZGA5905 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."

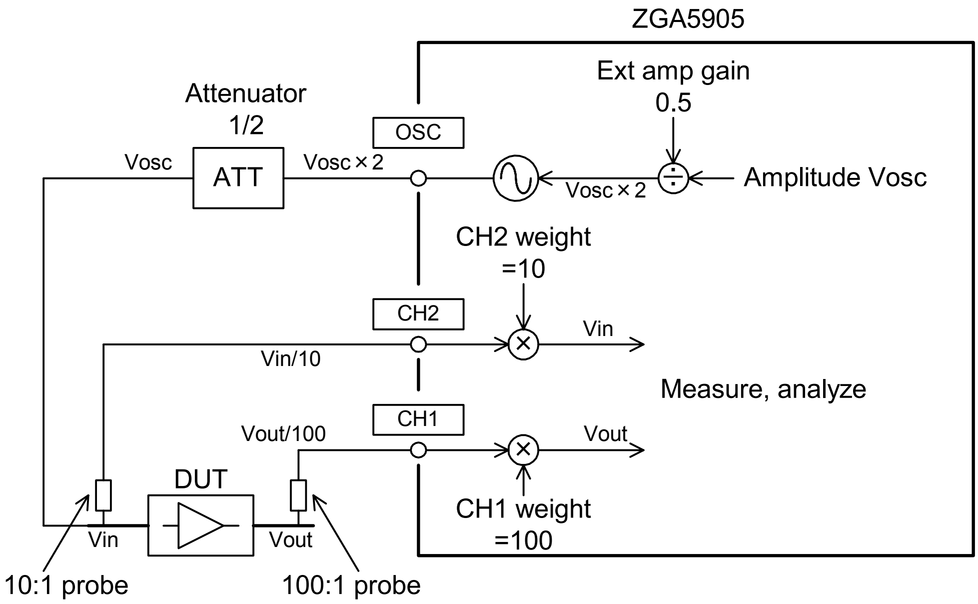


Figure 4-14 Gain-phase measurement connection - Setting example

Set other items, according to the measurement.

(Sweep)

- Sweep param : Fixed to Frequency in the gain-phase measurement.
- Max, Min : Sweep measurement range.
- Point : The number of measurement points between the minimum and maximum sweep values.
- Sweep : [Lin] (linear) or [Log] (logarithmic) of the measurement frequency sweep, which is independent from Lin or Log of the graph display.
- Direction : [Up] makes a sweep measurement from minimum to maximum, and [Down] from maximum to minimum.

(Oscillator)

- Frequency : Immediately after the setting, this is the frequency of a signal actually output from the current oscillator output regardless of the minimum and maximum 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 ZGA5905 main unit is (This value)/(External amplifier gain).
- Wave : Fixed to [Sin] (sine wave).
- Anytime ON : Selects whether to turn off (Disable) or leave on (Enable) the oscillator output after a sweep measurement.

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

(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."

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 ZGA5905 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 minimum sweep value, maximum sweep value, and AC amplitude. See "4.2.2 Setting gain-phase measurement."
2) From the menu, select [Tool] - [Correct...] to open the Correction window. See "Figure 4-6 Correction window."
3) In the Correction window, deselect the [Enable] check box for each of [Open correction], [Short correction], and [Equalize]. Then, click the Close button to close the Correction window.
4) Remove the target circuit and directly connect the input to the output (that is, the transfer gain is 0dB and 0deg).
5) Turn on the oscillator output, click the Measure button, then wait until the sweep measurement finishes.
6) From the menu, select [Tool] - [Correct...]. Click the Save button and check the [Enable] check box for the equalization.
7) Click the Close button to close the Correction window.

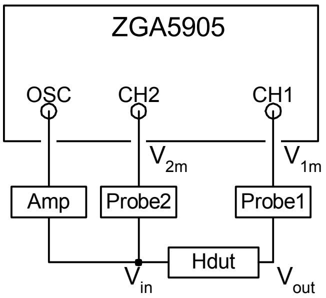
The equalization does not work when [Enable] is not selected even if the equalization measurement is made. Be careful about it.

The equalization data is stored in the ZGA5905 even when the [Enable] check box is deselected. Re-select [Enable] to activate the equalization again.

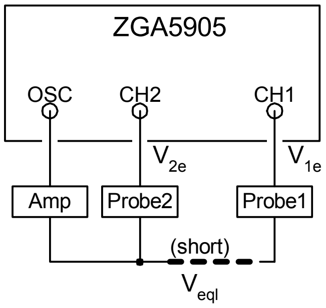
The equalization data is cleared at power-off. Perform the equalization measurement (measurement system error measurement) again after power-on or before an accurate measurement.

Data saved by click the SAVE button are the latest measurement data. You cannot use the data which loaded from a file for equalization data.

(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:

$V_{1e} = V_{eql} \times \text{Probe1}$

$V_{2e} = V_{eql} \times \text{Probe2}$

Record/store the above measurement data in the equalizing memory of the ZGA5905 main unit as the equalization data. The equalizing memory records (CH1/CH2). Therefore, the content of the equalizing memory (EQL) will be:

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

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 ZGA5905 (MEAS) is:

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

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:

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

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 (minimum or maximum 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.

A change of the sweep measurement direction (Up/Down) does not need another correction measurement.

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 a graph. You can change the graph format as you need. In the basic mode, the graph format is selected through a pull-down menu above the graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a target circuit. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.

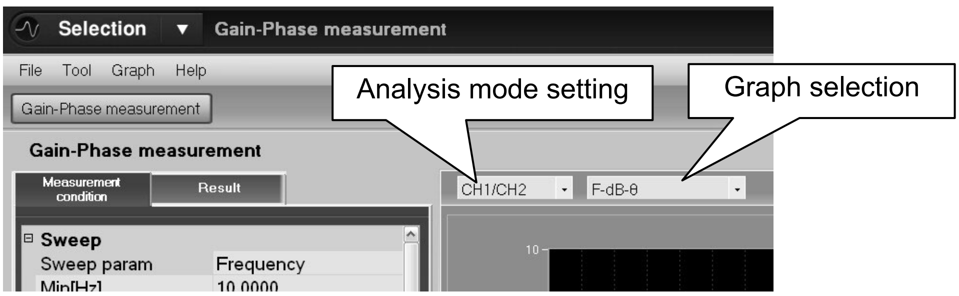


Figure 4-16 Graph selection in Basic mode (gain-phase measurement)

Normally, the analysis mode is set to "CH1/CH2". Measurements and analyses in "5. Operations in Advanced Mode" 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 Basic mode (gain-phase measurement)."

Table 4-4 Graph types in Basic mode (gain-phase measurement)

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter	Notes
F-dB-θ	Frequency	Gain (dB)	Phase	Bode diagram
F-|R|-θ	Frequency	Gain	Phase	
F-A-B	Frequency	Real part of gain	Imaginary part of gain	
θ-dB	Phase	Gain (dB)	—	Nichol's diagram
θ-|R|	Phase	Gain	—	
A-B	Real part of gain	Imaginary part of gain	—	Nyquist diagram

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

(Analysis mode: CH1/CH2)

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

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

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

The [Result] tab shows the following markers, regardless of the selected graph format. Each indicates the parameter at the marker frequency.

Table 4-5 Marker indication in Basic mode (gain-phase measurement)

Display parameter	Unit
Frequency	Hz
dBR	dB
|R|	(No unit)
A	(No unit)
B	(No unit)
θ	deg

4.3 Overview of measurement and processing

This section describes the flow of data processing in the ZGA5905 (see "Figure 4-17 Measurement processing overview"). The same processing applies to both the impedance and gain-phase measurements.

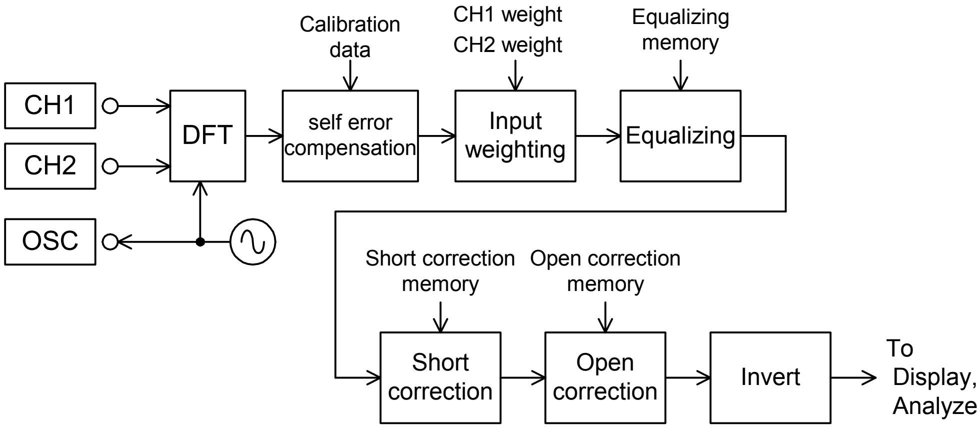


Figure 4-17 Measurement processing overview

- 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.

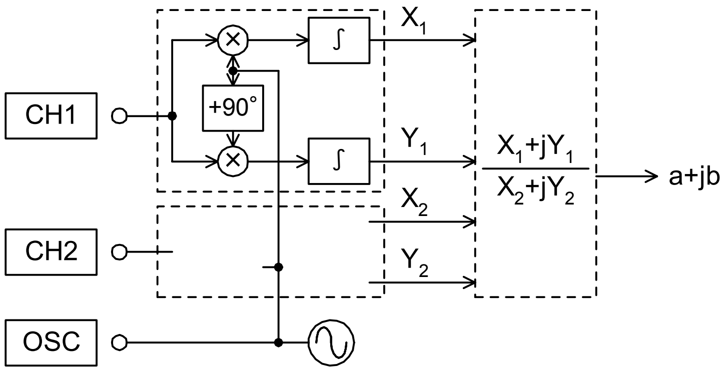


Figure 4-18 DFT overview

- Self error compensation: Self error compensation is made through the use of data obtained by calibration. Calibration can be done either by power-on, or through the menu [Tool] - [Correct...].
- Weighting operation: The CH1 and CH2 weight values in the [Measurement condition] tab 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).

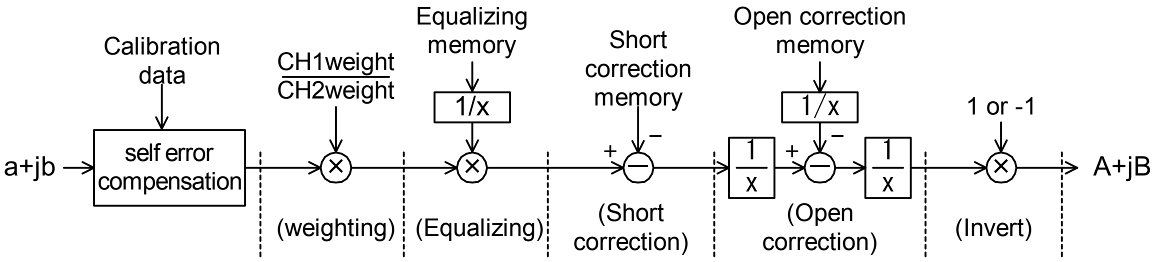


Figure 4-19 Error correction overview

4.3.1 Integration

The ZGA5905 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 ≤ approx. 54 Hz : 1/f (period of f)
- approx. 54 Hz ≤ f ≤ 3 kHz : 18 ms to 55 ms
- 3 kHz≤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.

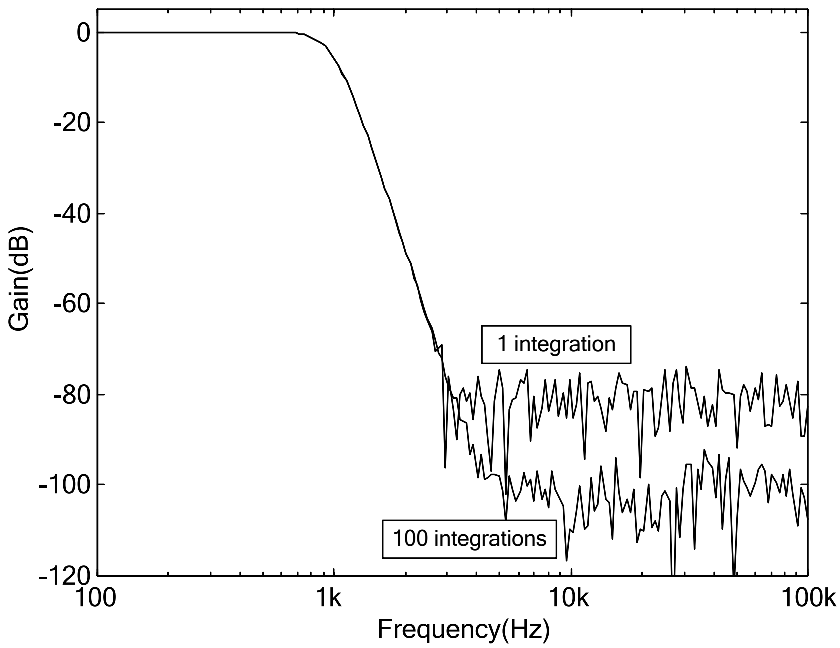


Figure 4-20 Effect of integration

4.3.2 Delay

When the drive 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.

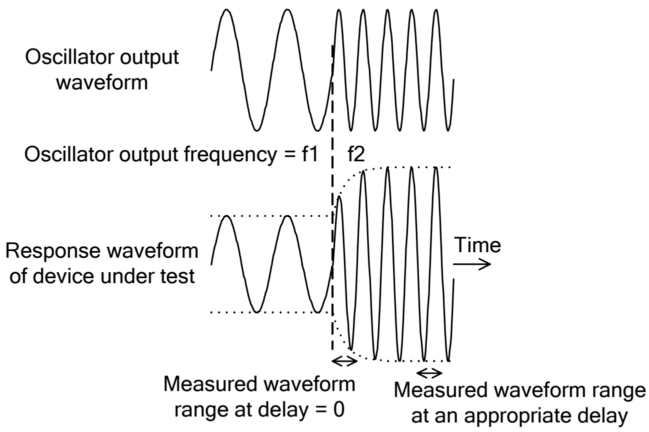


Figure 4-21 Response waveform requiring delay

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.

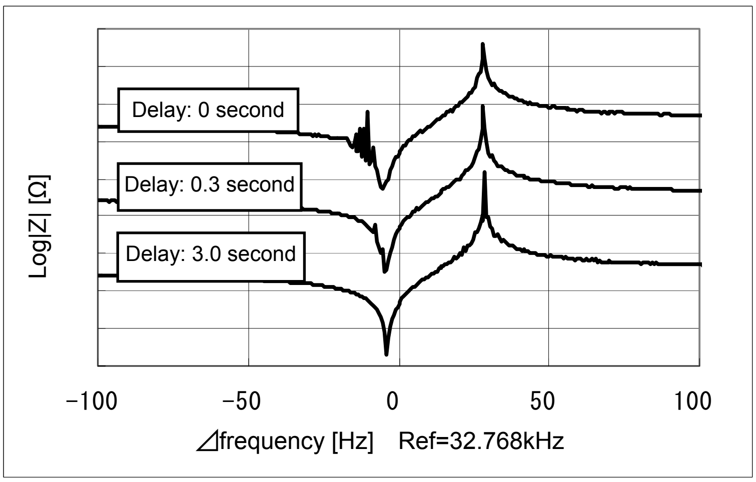


Figure 4-22 Example of resonance characteristics by delay

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 Time sweep).
The slow sweep is configured in the [Measurement condition] tab.

- 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 ZGA5905 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.

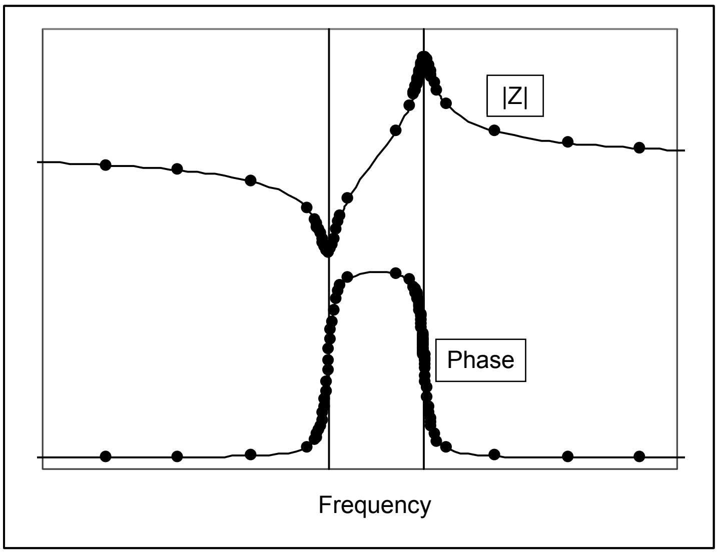


Figure 4-23 Slow sweep example

5. Operations in Advanced Mode

5.1 Overview of Advanced Mode

Each measurement type of the advanced mode 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 on the start-up menu screen immediately after the ZGA5905 power-on. To switch to another measurement type, select the desired type from the pull-down menu that is displayed by clicking the ▼ button to the right to [Selection] on the top left corner of the screen.

(See "3.2.1 Display at power-on" and "3.5.1 Measurement type selection".)

The measurement process in the advanced mode 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 ZGA5905, 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

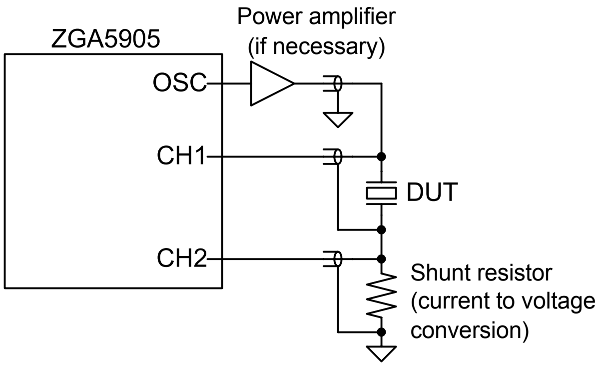


Figure 5-2-1 Connection example of piezoelectric measurement

"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 ZGA5905. 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

To measure the impedance characteristics of the sample, click the Piezoelectric material measurement screen switching button on the top of the screen.

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.

(Slow sweep): Effective when measuring a oscillator with steep frequency characteristics. See "4.3.3 Slow sweep".

(Delay): Needs to be set when measuring a oscillator with steep frequency characteristics. See "4.3.2 Delay".

5.2.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the data are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

The two types of graph format shown below can be selected using the graph switching buttons. You can use "|Y|-θ" for checking the resonance frequency, and "G-B" for extracting piezoelectric parameters.

Table 5-2-1 Graph types of piezoelectric measurement (Piezoelectric material measurement)

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
|Y|-θ	Sweep parameters • Frequency [Hz] • Zero span	Admittance [S]	Phase [deg]
G-B	Conductance [S]	Susceptance [S]	—

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

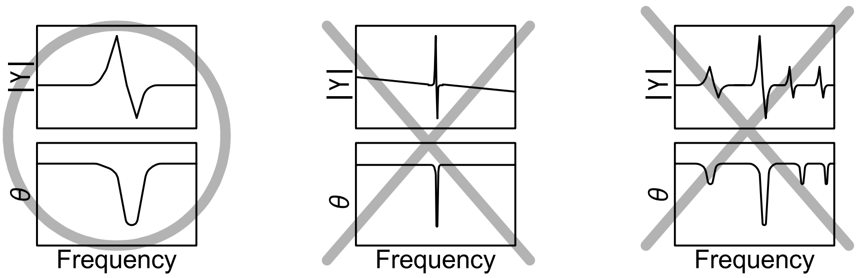
$$|\mathrm{Y}|[\mathrm{S}] = \frac{1}{\sqrt{\mathrm{R}^2+\mathrm{X}^2}},\ \theta[\mathrm{deg}] = -\tan^{-1}\frac{\mathrm{X}}{\mathrm{R}},\ \mathrm{G}[\mathrm{S}] = \frac{\mathrm{R}}{\mathrm{R}^2+\mathrm{X}^2},\ \mathrm{B}[\mathrm{S}] = \frac{-\mathrm{X}}{\mathrm{R}^2+\mathrm{X}^2}$$

The [Result] tab shows the following markers, regardless of the selected graph format. The marker moves along the sweep parameter.

Table 5-2-2 Marker indication in piezoelectric measurement (Piezoelectric material measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
Time	s	When the sweep parameter is Zero span (time)
|Y|	S	Admittance
θ	deg	Phase (of admittance)
G	S	Conductance
B	S	Susceptance

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 5-2-2 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 5-2-2 Analyzable characteristics

5.2.4 Calculation of piezoelectric constants

After the sweep measurement (or file loading) is finished, click the Display parameter screen switching button on the top of the screen to get the piezoelectric constants. Note that the piezoelectric constants calculation and the simulation can be performed only for the frequency sweep data.

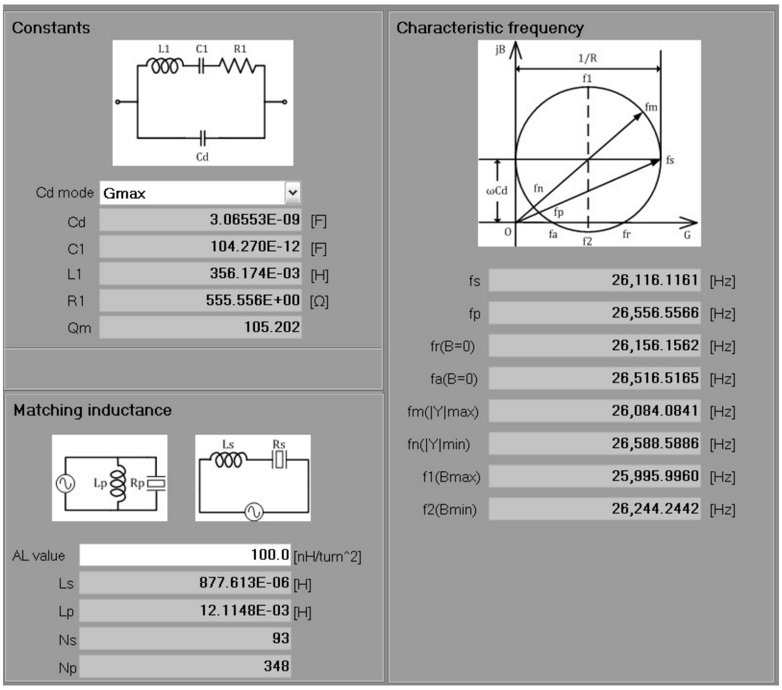


Figure 5-2-3 Piezoelectric parameter display screen

■ Characteristic frequency extraction

The frequency information is automatically searched from the measurement data to calculate the piezoelectric constants. There is no need for you to change the setting.

- 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)

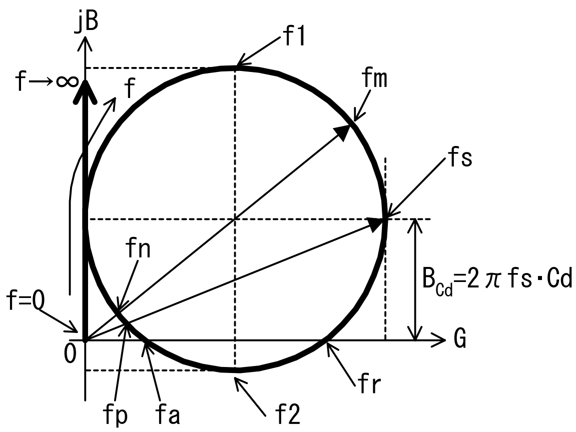


Figure 5-2-4 Admittance circle of piezoelectric oscillator

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 5-2-5 Equivalent circuit of piezoelectric oscillator" are calculated from a characteristic frequency searched from the measurement data.

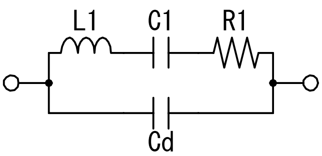


Figure 5-2-5 Equivalent circuit of piezoelectric oscillator

- 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)

The admittance locus of the circuit shown in Figure 5-2-5 will describe a true circle that is offset by $+B_{Cd}$(=2πfsCd) in the Y-axis (susceptance) direction, like the circle shown in "Figure 5-2-4 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 of [Cd Mode].

- HighFrequency: 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_min: 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 the section 5.2.5, 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 ZGA5905 can display design parameters of this inductance. There are two types of matching circuit, parallel and series. The series circuit has a smaller inductance.

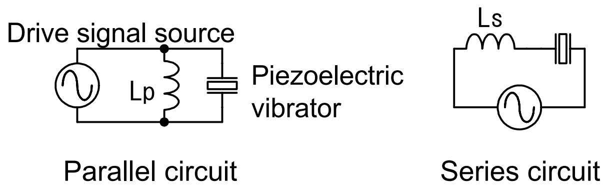


Figure 5-2-6 Matching circuit

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 an magnetic core you want to use to display Ns and Np.

5.2.5 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.
Click the Simulation screen display button.
The simulation conditions can be set in the [others] tab on the left of the screen.
(Parameter)

- Cd, C1, L1, R1: Input the constants for the piezoelectric material equivalent circuit (piezoelectric parameters).
- Initialize button: Click to reset the Cd, C1, L1, and R1 values to the piezoelectric constants obtained on the parameter display screen. You usually click this button first to copy the constants obtained by analysis after you display this screen.

(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Simulation button: Click to calculate the admittance characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
If there is a large difference between the measurement and simulation data, return to the Display parameter screen to recalculate the piezoelectric constants (change Cd mode) or modify the piezoelectric parameters manually. When you modify the piezoelectric parameters or the simulation conditions and click the Simulation 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. When you display the [Result] tab, 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 frequencies of measurement data do not match those of the simulation data, interpolation is executed using data at neighbor frequencies.

Table 5-2-3 Marker indication in piezoelectric measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
|Y|	S	Admittance (Measurement data)
|Y|(Sim)	S	〃 (Simulation data)
θ	deg	Phase (Measurement data)
θ(Sim)	deg	〃 (Simulation data)
G	S	Conductance (Measurement data)
G(Sim)	S	〃 (Simulation data)
B	S	Susceptance (Measurement data)
B(Sim)	S	〃 (Simulation data)

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

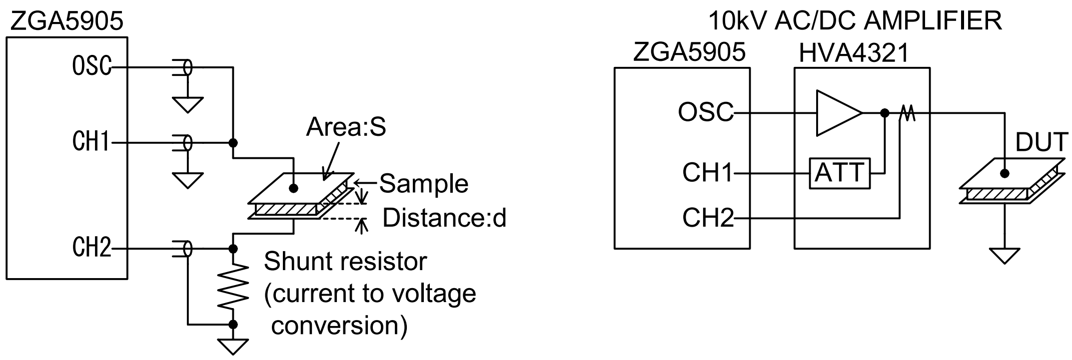


Figure 5-3-1 Connection example of dielectric measurement"

"Figure 5-3-1 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 ±10kV for measurement. As it is equipped with voltage and current monitor terminals, the ZGA5905 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

To measure the impedance characteristics of the sample, click the Dielectric material measurement screen switching button on the top of the screen.

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, Bias voltage (DC bias), or Zero span (time).

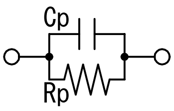
(Oscillator)
- Frequency: The output frequency when the sweep parameter is DC or Zero span.
- DC Bias (voltage): The DC bias voltage when the sweep parameter is Frequency or Time.

5.3.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the data are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

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].



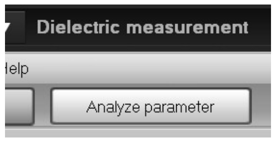
$$R_p[\Omega] = \frac{R^2 + X^2}{R}, C_p[F] = -\frac{X}{2\pi f(R^2 + X^2)}$$

The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-3-1 Marker indication in dielectric measurement (Dielectric material measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
DC Bias	V	When the sweep parameter is DC
Time	—	When the sweep parameter is Zero span
Cp	F	Parallel capacitance
Rp	Ω	Parallel resistance

5.3.4 Dielectric permittivity derivation



After the sweep measurement (or file loading) is finished, click the Analyze parameter screen switching button on the top of the screen to get the dielectric permittivity.

The ZGA5905 derives the relative dielectric permittivity to the dielectric permittivity ε_0 in vacuum. The information necessary can be set in the [others] tab on the left of the screen.

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

On the [Analyze parameter] screen, the following two types of graph format can be selected.

Table 5-3-2 Graph types of dielectric measurement (dielectric constant derivation)

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
εs—tanδ	Sweep parameters • Frequency [Hz] • DC Bias [V] • Time	Relative dielectric permittivity	Dissipation factor
εs'—εs"		Real part of relative dielectric permittivity	Imaginary part of relative dielectric permittivity

The [Result] tab shows marker read values of the dielectric permittivity characteristics.

Table 5-3-3 Marker indication in dielectric measurement (Analyze parameter)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
DC Bias	V	When the sweep parameter is DC
Time	—	When the sweep parameter is Zero span (time)
εs	—	Relative dielectric permittivity
tanδ	—	Dissipation factor
εs'	—	Real part of complex relative dielectric permittivity
εs"	—	Imaginary part of complex relative dielectric permittivity

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].

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

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].

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

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

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

$$\mu_0 = 4\pi \times 10^{-7} \cong 1.2566370614... \times 10^{-6}\ [H/m]$$ 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).

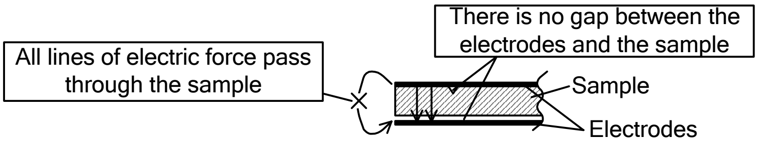


Figure 5-3-2 Preconditions of dielectric permittivity derivation

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

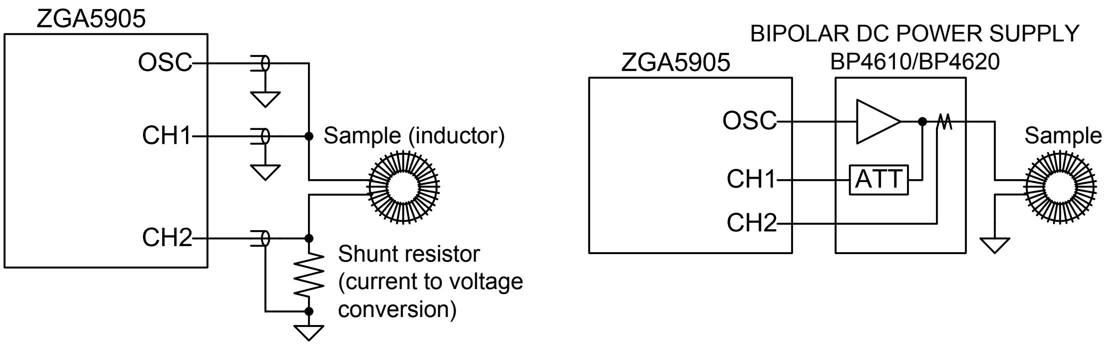


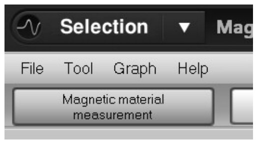
Figure 5-4-1 Connection example of magnetic measurement"

"Figure 5-4-1 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 power supply BP4620 as a power amplifier to amplify the sample current up to 20A for measurement. As it is equipped with voltage and current monitor terminals, you can easily connect it to the ZGA5905. 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



To measure the impedance characteristics of the sample, click the Magnetic material measurement screen switching button on the top of the screen.

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.

(Sweep)

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

(Oscillator)

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

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.

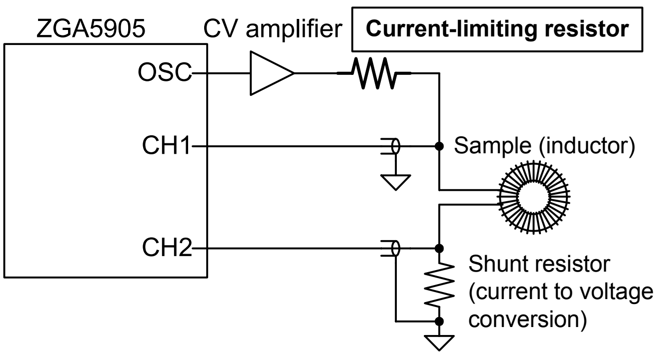


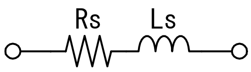
Figure 5-4-2 Notes on using CV amplifier

5.4.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the data are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

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].



$$Rs[\Omega]=R,\ Ls[H]=\frac{X}{2\pi f}$$

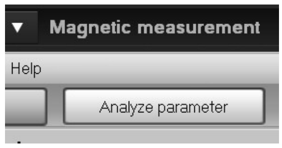
The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-4-1 Marker indication in magnetic measurement (Magnetic material measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
DC Bias	V	When the sweep parameter is DC
Time	—	When the sweep parameter is Zero span (time)
Ls	H	Series inductance
Rs	Ω	Series resistance

5.4.4 Magnetic permeability derivation

After the sweep measurement (or file loading) is finished, click the Analyze parameter screen switching button on the top of the screen to get the magnetic permeability.



The ZGA5905 derives the relative magnetic permeability to the magnetic permeability μ_0 in vacuum. The information necessary can be set in the [others] tab on the left of the screen.

- 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 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.
- Winding around length len: Input the length of winding per turn in mm.
- Calculation 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 a graph.

On the [Analyze parameter] screen, the following two types of graph format can be selected.

Table 5-4-2 Graph types of magnetic measurement (Analyze parameter)

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
μs—tanδ	Sweep parameters • Frequency [Hz] • DC Bias [A] • Time	Relative magnetic permeability	Dissipation factor
μs'—μs"		Real part of relative magnetic permeability	Imaginary part of relative magnetic permeability

The [Result] tab shows marker read values of the magnetic permeability characteristics.

Table 5-4-3 Marker indication in magnetic measurement (Analyze parameter)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
DC Bias	A	When the sweep parameter is DC
Time	—	When the sweep parameter is Zero span (time)
μ	—	Relative magnetic permeability
tanδ	—	Dissipation factor
μs'	—	Real part of complex relative magnetic permeability
μs"	—	Imaginary part of complex relative magnetic permeability

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.

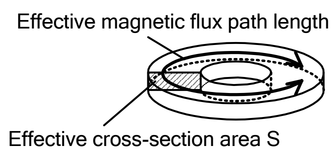
$$L_0[H] = \frac{S \times N^2 \times \mu_0}{1000 \times l}$$

$\mu_0 = 4\pi \times 10^{-7} \cong 1.2566370614... \times 10^{-6}$ [H/m] permeability of vacuum

Rw[Ω] is the resistance value of winding.

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

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.



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

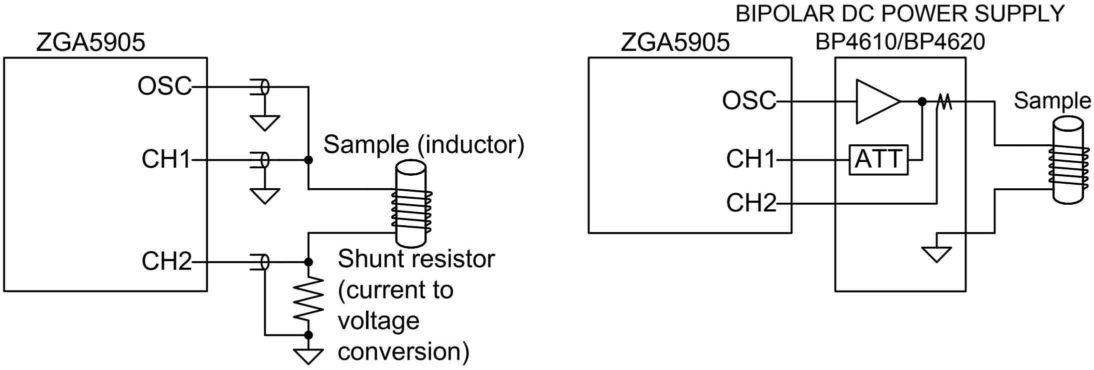
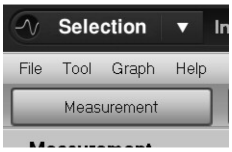


Figure 5-5-1 Connection example of inductor measurement"

"Figure 5-5-1 Connection example of inductor measurement" shows an example of connecting with a sample. You can use our bipolar power supply BP4620 as a power amplifier to amplify the sample current up to 20A for measurement. As it is equipped with voltage and current monitor terminals, you can easily connect it to the ZGA5905. 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



To measure the impedance characteristics of the sample, click the Measurement screen switching button on the top of the screen.
For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring inductor characteristics.

(Sweep)

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

(Oscillator)

- Frequency: The output frequency when the sweep target is AC amplitude, DC bias, or Zero span (time).
- 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.
- 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, AC amplitude, 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.

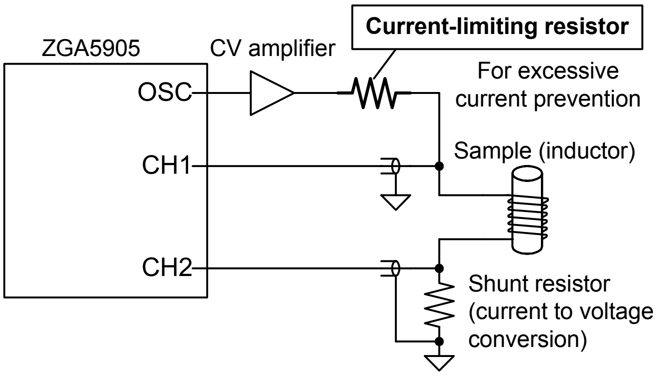


Figure 5-5-2 Notes on using CV amplifier

5.5.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the data are displayed in a graph.

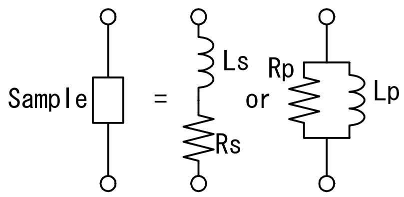
Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

The graph format can be changed by using the graph selection buttons on the top of the graph. The graph types that can be selected for the inductor measurement are shown in "Table 5-5-1 Graph types of inductor measurement".

Table 5-5-1 Graph types of inductor measurement

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
Ls-Rs	Sweep parameters • Frequency [Hz] • AC current [Apk] • DC Bias [A] • Zero span	Series inductance [H]	Series resistance (ESR) [Ω]
Ls-θs			Phase (of series equivalent circuit) [deg]
Ls-Q			Quality factor
Lp-Rp		Parallel inductance [H]	Parallel resistance [Ω]
Lp-θp			Phase (of parallel equivalent circuit) [deg]
Lp-Q			Quality factor

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].



$$Ls[H]=\frac{X}{2\pi f},\ Rs[\Omega]=R,\ \theta s[deg]=\tan^{-1}\frac{X}{R},\ Q=\frac{X}{R},$$

$$Lp[H]=\frac{R^2+X^2}{2\pi f X},\quad Rp[\Omega]=\frac{R^2+X^2}{R},\ \theta p[deg]=\tan^{-1}\frac{-X}{R}$$

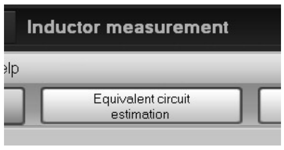
The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-5-2 Marker indication in inductor measurement (Measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
Amplitude	A	When the sweep parameter is AC
DC Bias	A	When the sweep parameter is DC
Time	—	When the sweep parameter is Zero span (time)
Ls	H	Series inductance
Rs	Ω	Series resistance
θs	deg	Phase in series equivalent circuit
Lp	H	Parallel inductance
Rp	Ω	Parallel resistance
θp	deg	Phase in parallel equivalent circuit
Q	—	Quality factor

5.5.4 Equivalent circuit estimation

After the sweep measurement (or file loading) is finished, click the Equivalent circuit estimation screen switching button on the top of the screen to perform the equivalent circuit estimation. Note that the equivalent circuit estimation and the simulation can be performed only for the frequency sweep data.



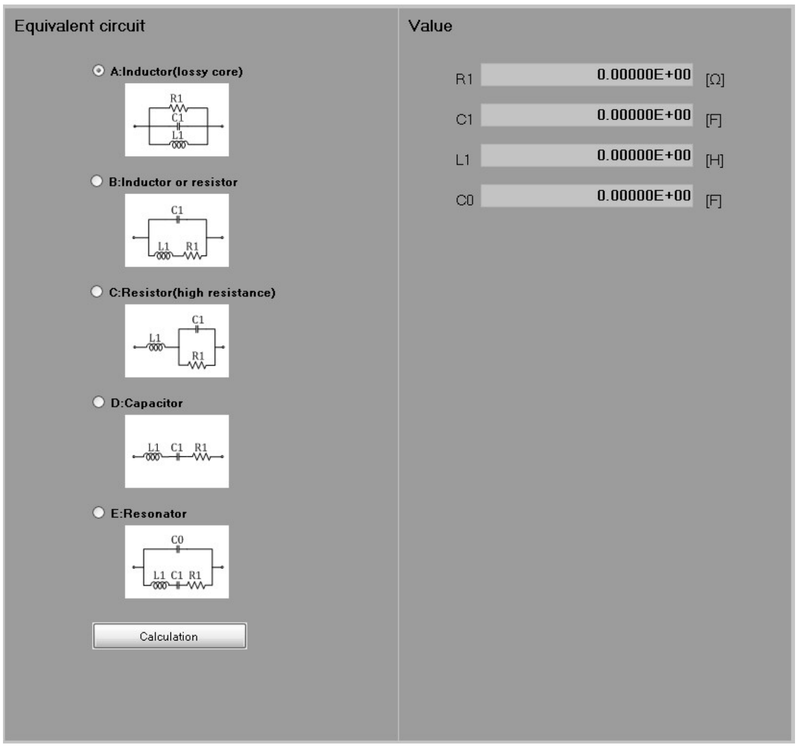


Figure 5-5-3 Equivalent circuit estimation screen

■ 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.

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

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

To select an equivalent circuit type, click the corresponding radio button with the mouse.

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 Calculation button to calculate the circuit constants.

■ Circuit parameter

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.

5.5.5 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.
Click the Simulation screen switching button.
The simulation conditions can be set in the [others] tab on the left of the screen.
(Equivalent circuit)

- Type, R1, C1, L1, C0: Select the equivalent circuit type and input the parameters.
- Initialize button: Click to reset the circuit type and the R1, C1, L1, and C0 values to those obtained on the equivalent circuit estimation screen. You usually click this button first to copy the circuit parameters obtained by the equivalent circuit estimation.

(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Simulation button: Click to calculate the inductance characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
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) Return to the Equivalent circuit estimation screen to change the circuit type.
3) Return to the Measurement screen to 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. Take a measure such as changing the sweep frequency range.
When you modify these simulation conditions and click the Simulation 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. When you display the [Result] tab, 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 frequency points.

Table 5-5-3 Marker indication in inductor measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
Ls	H	Series inductance (Measurement data)
Ls(Sim)	H	〃 (Simulation data)
Rs	Ω	Series resistance (Measurement data)
Rs(Sim)	Ω	〃 (Simulation data)
θs	deg	Phase in series equivalent circuit (measurement data)
θs(Sim)	deg	〃 (Simulation data)
Lp	H	Parallel inductance (Measurement data)
Lp(Sim)	H	〃 (Simulation data)
Rp	Ω	Parallel resistance (Measurement data)
Rp(Sim)	Ω	〃 (Simulation data)
θp	deg	Phase in parallel equivalent circuit (measurement data)
θp(Sim)	deg	〃 (Simulation data)
Q	—	Quality factor

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

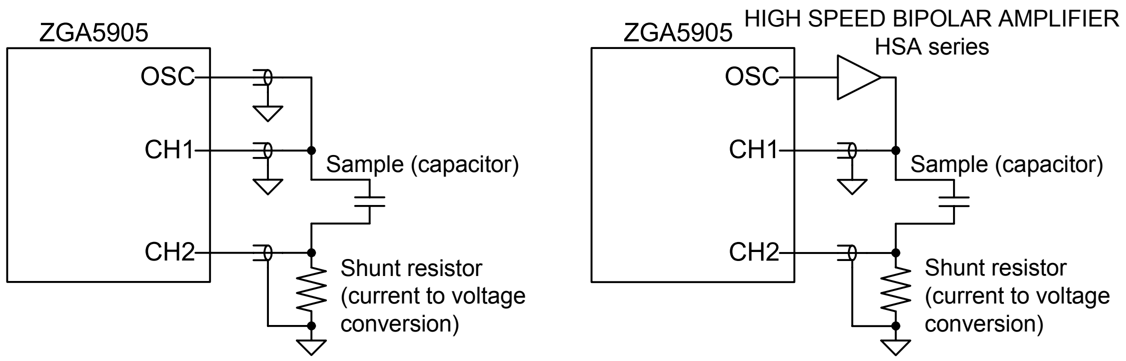
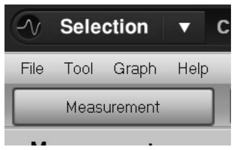


Figure 5-6-1 Connection example of capacitor measurement

"Figure 5-6-1 Connection example of capacitor measurement" shows an example of connecting with a sample. You can use our high-speed bipolar power supply HSA series as a power amplifier to amplify the signal up to 300Vp-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



To measure the impedance characteristics of the sample, click the Measurement screen switching button on the top of the screen.
For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring capacitor characteristics.

(Sweep)

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

(Oscillator)

- Frequency: The output frequency when the sweep parameter is AC amplitude, DC bias, or Zero span (time).
- Ext amp gain: Set the gain of the external amplifier.
- 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, AC amplitude, or Zero span (time).

5.6.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the data are displayed in a graph.

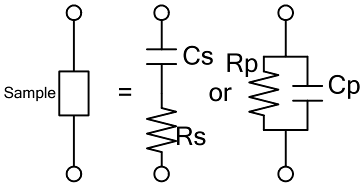
Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

The graph format can be changed by using the graph selection buttons on the top of the graph. The graph types that can be selected for the capacitor measurement are shown in "Table 5-6-1 Graph types of capacitor measurement".

Table 5-6-1 Graph types of capacitor measurement

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
Cs-Rs	Sweep parameters • Frequency [Hz] • Amplitude [Vpk] • DC Bias [V] • Zero span	Series capacitance [F]	Series resistance (ESR) [Ω]
Cs-θs			Phase (of series equivalent circuit) [deg]
Cs-Q			Quality coefficient
Cs-D			Dissipation factor
Cp-Rp		Parallel capacitance [F]	Parallel resistance [Ω]
Cp-θp			Phase (of parallel equivalent circuit) [deg]
Cp-Q			Quality coefficient
Cp-D			Dissipation factor

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].



$$Cs[F] = \frac{-1}{2\pi f X},\ Rs[\Omega]=R,\ \theta s[deg] = \tan^{-1}\frac{X}{R},$$

$$Q = -\frac{X}{R},\ D = -\frac{R}{X},\ Cp[F] = \frac{-X}{2\pi f (R^2+X^2)},\ Rp[\Omega] = \frac{R^2+X^2}{R},$$

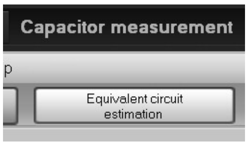
$$\theta p[deg] = \tan^{-1}\frac{-X}{R}$$

The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-6-2 Marker indication in capacitor measurement (Measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
Amplitude	V	When the sweep parameter is AC
DC Bias	V	When the sweep parameter is DC
Time	—	When the sweep parameter is Zero span (time)
Cs	F	Series electrostatic capacitance
Rs	Ω	Series resistance
θs	deg	Phase in series equivalent circuit
Cp	F	Parallel electrostatic capacitance
Rp	Ω	Parallel resistance
θp	deg	Phase in parallel equivalent circuit
Q	—	Quality factor
D	—	Dissipation factor

5.6.4 Equivalent circuit estimation



After the sweep measurement (or file loading) is finished, click the Equivalent circuit estimation screen switching button on the top of the screen to perform the equivalent circuit estimation. Note that the equivalent circuit estimation and the simulation can be performed only for the frequency sweep data.

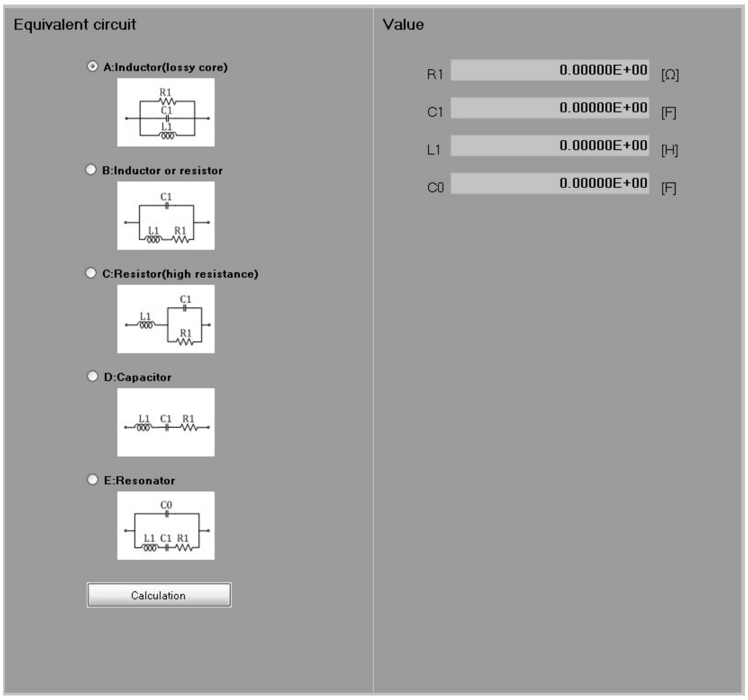


Figure 5-6-2 Equivalent circuit estimation screen

■ 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 (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 check box with the mouse.

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 Calculation button to calculate the circuit constants.

■ Circuit parameter

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.

5.6.5 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.
Click the Simulation screen switching button.
The simulation conditions can be set in the [others] tab on the left of the screen.
(Equivalent circuit)

- Type, R1, C1, L1, C0: Select the equivalent circuit type and input the parameters.
- Initialize button: Click to reset the circuit type and the R1, C1, L1, and C0 values to those obtained on the equivalent circuit estimation screen. You usually click this button first to copy the circuit parameters obtained by the equivalent circuit estimation.

(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Simulation button: Click to calculate the capacitance characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
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) Return to the Equivalent circuit estimation screen to change the circuit type.
3) Return to the Measurement screen to 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. Take a measure such as changing the sweep frequency range.
When you modify these simulation conditions and click the Simulation 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. When you display the [Result] tab, 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.

Table 5-6-3 Marker indication in capacitor measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
Cs	F	Series electrostatic capacitance (Measurement data)
Cs(Sim)	F	〃 (Simulation data)
Rs	Ω	Series resistance (Measurement data)
Rs(Sim)	Ω	〃 (Simulation data)
θs	deg	Phase in series equivalent circuit (measurement data)
θs(Sim)	deg	〃 (Simulation data)
Cp	F	Parallel electrostatic capacitance (Measurement data)
Cp(Sim)	F	〃 (Simulation data)
Rp	Ω	Parallel resistance (Measurement data)
Rp(Sim)	Ω	〃 (Simulation data)
θp	deg	Phase in parallel equivalent circuit (measurement data)
θp(Sim)	deg	〃 (Simulation data)
Q	—	Quality factor (Measurement data)
Q(Sim)	—	〃 (Simulation data)
D	—	Dissipation factor (Measurement data)
D(Sim)	—	〃 (Simulation data)

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

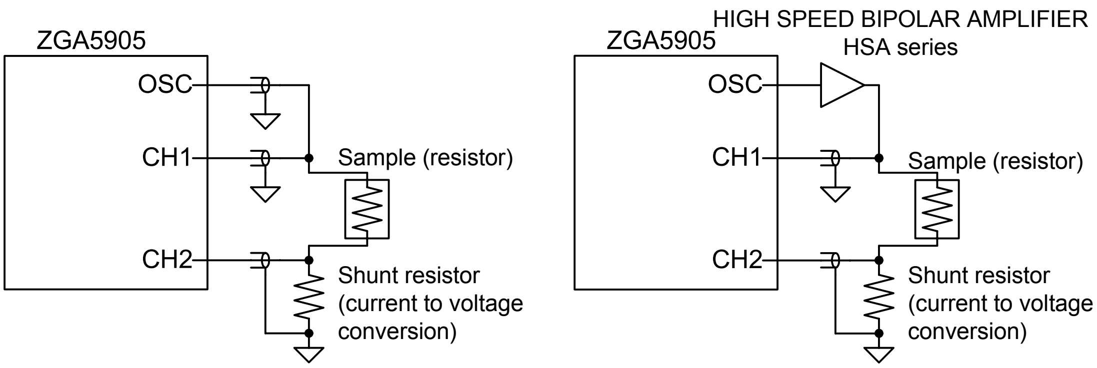
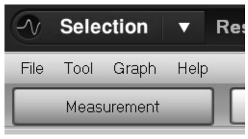


Figure 5-7-1 Connection example of resistor measurement"

"Figure 5-7-1 Connection example of resistor measurement" shows an example of connecting with a sample. You can use our high-speed bipolar power supply HSA series as a power amplifier to amplify the signal up to 300Vp-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



To measure the impedance characteristics of the sample, click the Measurement screen switching button on the top of the screen.
For details on basic settings, see "4.1.2 Setting impedance measurement".
This section describes only points to be considered when measuring resistor characteristics.

(Sweep)

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

(Oscillator)

- Frequency: The output frequency when the sweep parameter is AC amplitude, DC bias, or Zero span (time).
- Ext amp gain: Set the gain of the external amplifier.
- 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, AC amplitude, or Zero span (time).

5.7.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the data are displayed in a graph.

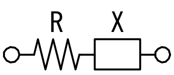
Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

The graph format can be changed by using the graph selection buttons on the top of the graph. The graph types that can be selected for the resistor measurement are shown in "Table 5-7-1 Graph types of resistor measurement".

Table 5-7-1 Graph types of resistor measurement

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
|Z|-θ	Sweep parameters • Frequency [Hz] • Amplitude [Vpk] • DC Bias [V] • Zero span (time)	Impedance [Ω]	Phase [deg]
R-X		Resistance [Ω]	Reactance [Ω]

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



$$|Z|[\Omega] = \sqrt{R^2 + X^2}, \ \theta[\mathrm{deg}] = \tan^{-1}\frac{X}{R}$$

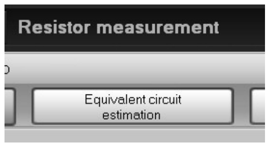
The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-7-2 Marker indication in resistor measurement (Measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
Amplitude	V	When the sweep parameter is AC
DC Bias	V	When the sweep parameter is DC
Time	—	When the sweep parameter is Zero span (time)
|Z|	Ω	Impedance (absolute value)
θ	deg	Phase
R	Ω	Resistance
X	Ω	Reactance

5.7.4 Equivalent circuit estimation

After the sweep measurement (or file loading) is finished, click the Equivalent circuit estimation screen switching button on the top of the screen to perform the equivalent circuit estimation. Note that the equivalent circuit estimation and the simulation can be performed only for the frequency sweep data.



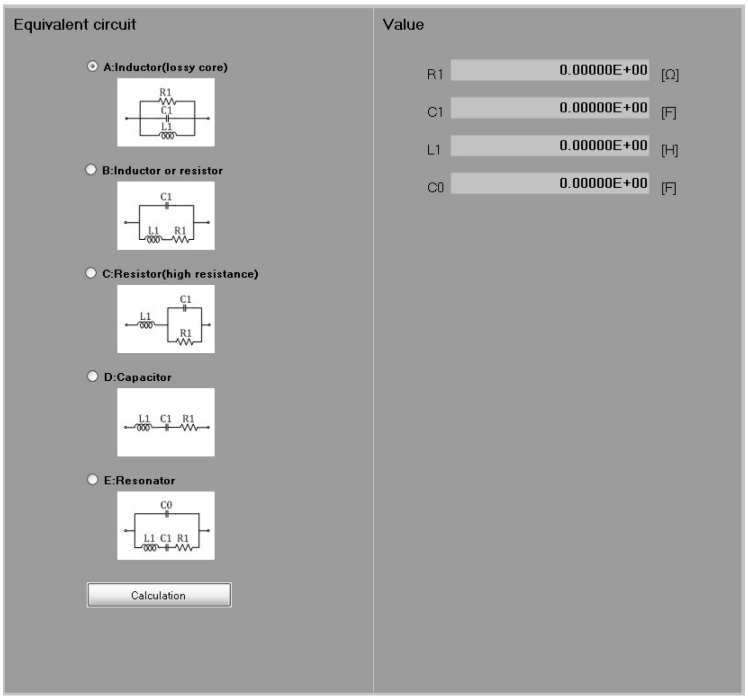


Figure 5-7-2 Equivalent circuit estimation screen

■ 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 and resistor): When the resistance value is low and the effect of inductance is large

C (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 check box with the mouse.

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 Calculation button to calculate the circuit constants.

■ Circuit parameter

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.

5.7.5 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.

Click the Simulation screen switching button.

The simulation conditions can be set in the [ohers] tab on the left of the screen.

(Equivalent circuit)

- Type, R1, C1, L1, C0: Select the equivalent circuit type and input the parameters.
- Initialize button: Click to reset the circuit type and the R1, C1, L1, and C0 values to those obtained on the equivalent circuit estimation screen. You usually click this button first to copy the circuit parameters obtained by the equivalent circuit estimation.

(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Simulation button: Click to calculate the admittance characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.

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) Return to the Equivalent circuit estimation screen to change the circuit type.
3) Return to the Measurement screen to 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. Take a measure such as changing the sweep frequency range.
When you modify these simulation conditions and click the Simulation 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. When you display the [Result] tab, 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.

Table 5-7-3 Marker indication in resistor measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
|Z|	Ω	Impedance (measurement data)
|Z|(Sim)	Ω	〃 (Simulation data)
θ	deg	Phase (Measurement data)
θ(Sim)	deg	〃 (Simulation data)
R	Ω	Resistance (Measurement data)
R(Sim)	Ω	〃 (Simulation data)
X	Ω	Reactance (Measurement data)
X(Sim)	Ω	〃 (Simulation data)

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, current) 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

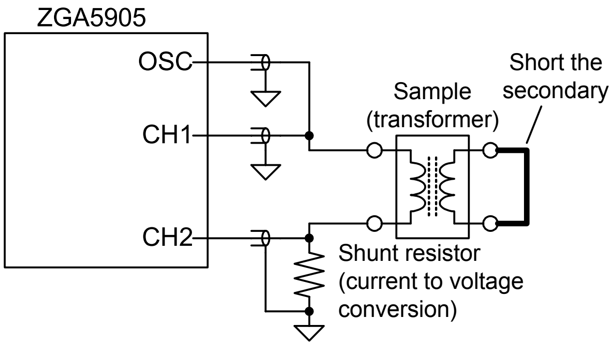
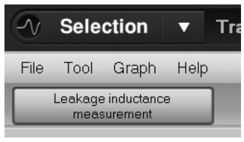


Figure 5-8-1 Connection example of transformer (leakage inductance) measurement

"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 power supply HSA series) to amplify the oscillator output signal up to 300Vp-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

To measure the impedance characteristics of the sample, click the Leakage inductance measurement screen switching button on the top of the screen.



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

(Sweep)

- Sweep param: Select Frequency or Zero span (time).

(Oscillator)

- Frequency: The output frequency when the sweep parameter is Zero span (time).
- DC Bias: Usually, set to 0 V.

5.8.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the graph of leakage inductance is displayed. The X axis is the sweep target (Frequency or Time).

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

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].

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

The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-8-1 Marker indication in transformer - leakage inductance measurement

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
Time	—	When the sweep parameter is Zero span (time)
Lleak	H	Leakage inductance

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 sweep 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

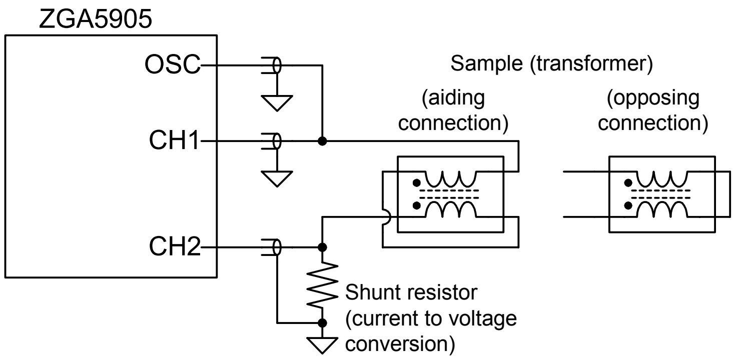


Figure 5-9-1 Connection example of transformer (mutual inductance) measurement

"Figure 5-9-1 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 power supply HSA series) to amplify the oscillator output signal up to 300Vp-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

First, measure the inductance characteristics for the in-phase connection.
Click the Aid connection measurement screen switching button on the top of the screen.
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.

(Sweep)

- Sweep param: Only Frequency can be selected.

(Oscillator)

- DC Bias: Usually, set to 0 V.

5.9.3 Aiding connection characteristics measurement

Connect the transformer in the aiding connection (see "Figure 5-9-1 Connection example of transformer (mutual inductance) measurement"), turn on the oscillator output, and click the Start Measuring button to start a sweep measurement. When the sweep finishes, the inductance characteristics are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

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].

$$La[H] = \frac{X}{2\pi f}$$

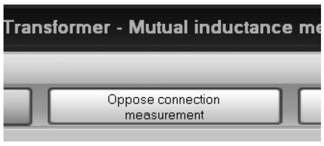
The [Result] tab displays the marker shown in the table below. Each indicates the parameter at the marker frequency.

Table 5-9-1 Marker indication in mutual inductance measurement (Aiding connection measurement)

Display parameter	Unit	
Frequency	Hz	Frequency
Inductance	H	Inductance of aiding connection characteristics

5.9.4 Opposing connection characteristics measurement

To measure the inductance characteristics for the opposing connection of the transformer, click the Oppose connection measurement screen switching button on the top of the screen.



Connect the transformer in the opposing connection (see "Figure 5-9-1 Connection example of transformer (mutual inductance) measurement"), turn on the oscillator output, and click the Start Measuring button to start a sweep measurement. When the sweep finishes, the inductance characteristics are displayed in a graph.

Do not change the sweep condition settings (Min, Max, Points, Sweep(Lin/Log), and Direction) from ones of the aiding connection characteristics measurement. When you want to load a measurement data file, be sure to use a data file 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].

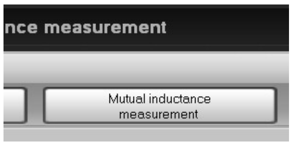
$$Lo[H] = \frac{X}{2\pi f}$$

The [Result] tab displays the marker shown in the table below. Each indicates the parameter at the marker frequency.

Table 5-9-2 Marker indication in mutual inductance measurement (Opposing connection measurement)

Display parameter	Unit	
Frequency	Hz	Frequency
Inductance	H	Inductance of opposing connection characteristics

5.9.5 Mutual inductance calculation



The mutual inductance is calculated using the inductance characteristics obtained from the aiding and opposing connections. Click the Mutual inductance measurement screen switching button on the top of the screen to display a graph of the mutual inductance characteristics.
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.

$$M[H] = \frac{La - Lo}{4}$$

The [Result] tab displays the marker shown in the table below. Each indicates the parameter at the marker frequency.

Table 5-9-3 Marker indication in mutual inductance measurement (Mutual inductance measurement)

Display parameter	Unit	
Frequency	Hz	Frequency
M	H	Mutual inductance

(Notes)
The mutual inductance can be measured directly as shown in "Figure 5-9-2 Mutual inductance measurement method", instead of using the method described above.

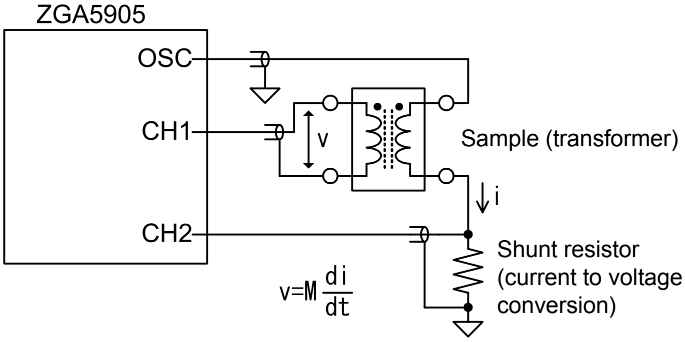
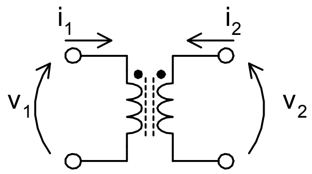


Figure 5-9-2 Mutual inductance measurement method

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 ZGA5905. However, this method requires no change in the connection and can perform the measurement with only one sweep.

The ZGA5905 measures and displays the mutual inductance that is referred to as "M" in "Figure 5-9-3 Definition of mutual inductance".



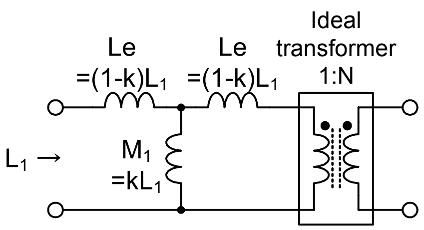
$$\begin{cases} v_1 = L_1 \dfrac{di_1}{dt} + M \dfrac{di_2}{dt} \\ v_2 = M \dfrac{di_1}{dt} + L_2 \dfrac{di_2}{dt} \end{cases} \qquad M = k\sqrt{L_1 L_2}$$

L_1: Primary inductance, L_2: Secondary inductance, M: Mutual inductance

k: Coupling coefficient

Figure 5-9-3 Definition of mutual inductance

Note that this inductance differs from the mutual inductance M_1 (for the primary side) shown in "Figure 5-9-4 Transformer equivalent circuit example", which is a general equivalent circuit of a transformer.



$$M_1 = \frac{M}{N}$$

L_1: Primary inductance, Le: Leakage inductance, k: Coupling coefficient

M_1: Primary mutual inductance

Figure 5-9-4 Transformer equivalent circuit example

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

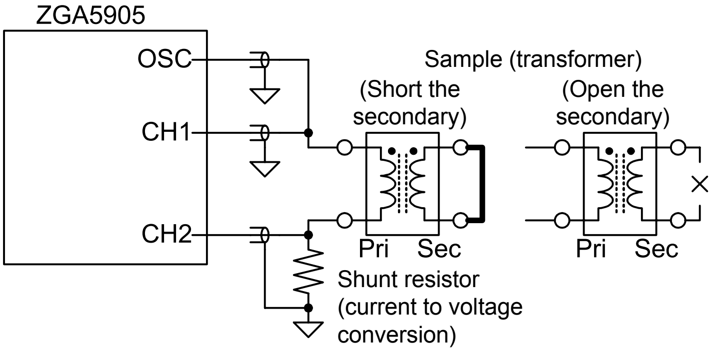


Figure 5-10-1 Connection example of transformer (coupling coefficient) measurement

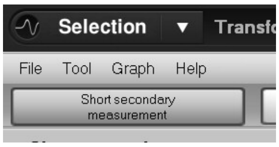
"Figure 5-10-1 Connection example of transformer (coupling coefficient) measurement" shows an example of connecting with a sample. You can use a power amplifier (such as the High-Speed Bipolar Amplifier HSA series) to amplify the oscillator output signal up to 300Vp-p for measurement. The figure is just 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



First, measure the inductance characteristics for the short secondary.
Click the Short secondary measurement screen switching button on the top of the screen.
For details on basic settings, see "4.1.2 Setting impedance measurement".
This section describes only points to be considered when measuring coupling coefficient.

(Sweep)

- Sweep param: Only Frequency can be selected.

(Oscillator)

- DC Bias: Usually, set to 0 V.

5.10.3 Short secondary measurement

Short the secondary of the transformer (see "Figure 5-10-1 Connection example of transformer (coupling coefficient) measurement"), turn on the oscillator output, and click the Start Measuring button to start a sweep measurement. When the sweep finishes, the inductance characteristics are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

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].

$$Ls[H] = \frac{X}{2\pi f}$$

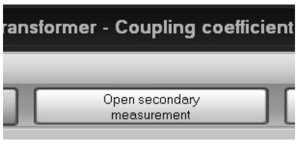
The [Result] tab displays the marker shown in the table below. Each indicates the parameter at the marker frequency.

Table 5-10-1 Marker indication in coupling coefficient measurement (Short secondary measurement)

Display parameter	Unit	
Frequency	Hz	Frequency
Inductance	H	Inductance with the short secondary

5.10.4 Open secondary measurement

To measure the inductance characteristics for the open secondary, click the Open secondary measurement screen switching button on the top of the screen.



Open the secondary of the transformer (see "Figure 5-10-1 Connection example of transformer (coupling coefficient) measurement"), turn on the oscillator output, and click the Start Measuring button to start a sweep measurement. When the sweep finishes, the inductance characteristics are displayed in a graph.

Do not change the sweep condition settings (minimum sweep, maximum sweep, number of measurement points, measurement interval, and direction of sweep measurement) from ones of the short secondary characteristics measurement. When you want to load a measurement data file, be sure to use a data file that has the same sweep conditions.

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].

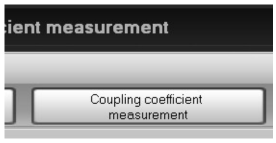
$$\mathrm{Lo[H]} = \frac{X}{2\pi f}$$

The [Result] tab displays the marker shown in the table below. Each indicates the parameter at the marker frequency.

Table 5-10-2 Marker indication in coupling coefficient measurement (Open secondary measurement)

Display parameter	Unit	
Frequency	Hz	Frequency
Inductance	H	Inductance with the open secondary

5.10.5 Coupling coefficient calculation



Calculate the coupling coefficient using the inductance characteristics obtained from the short and open secondaries. Click the Coupling coefficient measurement screen switching button on the top of the screen to display a frequency characteristics graph of the coupling coefficient.
The coupling coefficient k [no units] is calculated from the inductance Ls obtained for the short secondary and the inductance Ls 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 ZGA5905 shows the coupling coefficient k at that frequency as "-1.0" (in all of the graph, marker, and file output).

The [Result] tab displays the marker shown in the table below. Each indicates the parameter at the marker frequency.

Table 5-10-3 Marker indication in coupling coefficient measurement (Coupling coefficient measurement)

Display parameter	Unit	
Frequency	Hz	Frequency
k	—	Coupling coefficient (no unit)

(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 Turn 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 turn ratio. You can use the frequency sweep to measure the frequency dependence of the turn ratio. The zero span sweep is also available, which allows you to measure a time variability of the turn ratio (voltage transfer ratio).

5.11.1 Connecting with sample

Measure the transfer characteristics (gain-phase measurement), instead of the impedance.

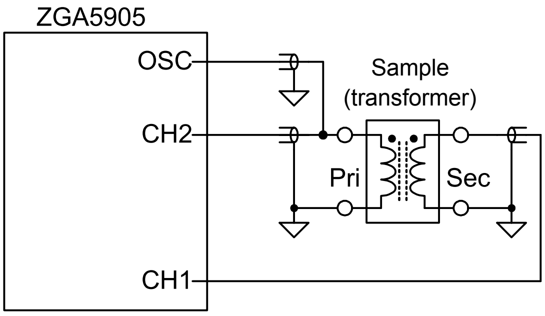


Figure 5-11-1 Connection example of transformer (turn ratio) measurement

"Figure 5-11-1 Connection example of transformer (turn 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 300Vp-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 turn ratio.

(Sweep)

- Sweep param: Select Frequency or Zero span(time).

(Oscillator)

- DC Bias: Usually, set to 0 V.

5.11.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the turn ratio characteristics are displayed in a graph.
Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

The turn ratio N is determined through the following conversion using the complex gain (G=A+jB) obtained from the measurement.

$$N = \sqrt{A^2 + B^2}$$

The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-11-1 Marker indication of transformer turn ratio

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
Time	—	When the sweep parameter is Zero span (time)
Turns Ratio	—	Turn ratio

(Notes)
The displayed turn 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:

Turn ratio = Transfer gain / Coupling coefficient

When the coupling coefficient is less than 1, the error from the actual turn ratio becomes larger.

The transfer characteristics of a transformer are affected by the load impedance of the secondary side (as a result, the turn ratio is affected). In the ZGA5905, 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 time sweep (zero span sweep) are also available.

5.12.1 Connecting with sample

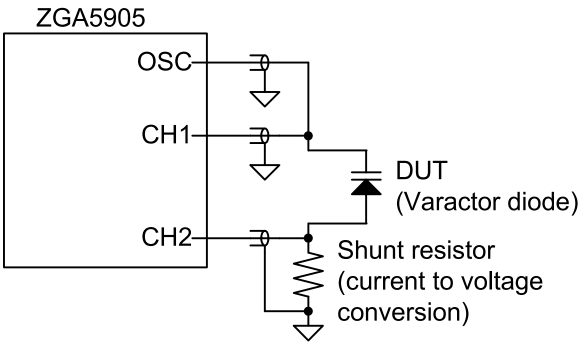
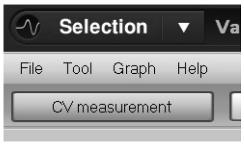


Figure 5-12-1 Connection example of varactor diode measurement

"Figure 5-12-1 Connection example of varactor diode measurement" shows an example of connecting with a sample. The ZGA5905 by itself can output a DC bias of ±10V. 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



To measure the characteristics of the sample, click the CV measurement screen switching button on the top of the screen. For details on basic settings, see "4.1.2 Setting impedance measurement". This section describes only points to be considered when measuring resistor characteristics.

(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.

(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).

5.12.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, 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).

Alternatively, you can read a saved measurement data file instead of actually measuring on a sample. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a sample.

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].

$$Cp[F] = \frac{-X}{2\pi f(R^2 + X^2)}, \quad Q = \frac{-X}{R}$$

The [Result] tab displays the marker shown in the table below. The marker moves along the sweep target.

Table 5-12-1 Marker indication in Varactor diode measurement (CV measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
DC Bias	V	When the sweep parameter is DC bias
Time	—	When the sweep parameter is Zero span (time)
Cp	F	Parallel capacitance
Q	—	Quality factor

5.12.4 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).
Click the Simulation screen switching button. The tuning characteristics simulation requires data from the DC bias sweep.

The simulation conditions can be set in the [others] tab on the left of the screen.

- C0, C1, L: Input the constants of the tuning circuit.
- Simulation 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.

Simulation condition (sweep range, etc) are same as measurement condition.

The result graph of the tuning characteristics simulation in the [Result] tab displays the marker shown in the table below.

Table 5-12-2 Marker indication in Varactor diode measurement (Simulation)

Display parameter	Unit	
DC Bias	V	DC Bias
Freq_res	Hz	Tuning frequency

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 5-12-2 Tuning circuit.

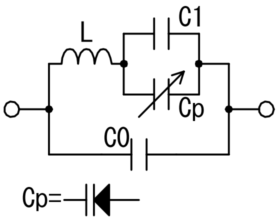


Figure 5-12-2 Tuning circuit

Tuning frequency [Hz] $= \dfrac{1}{2\pi\sqrt{\mathrm{L}\cdot\mathrm{C}}}$, $\quad \mathrm{C[F]} = \dfrac{(\mathrm{Cp}+\mathrm{C1})\mathrm{C0}}{\mathrm{Cp}+\mathrm{C1}+\mathrm{C0}}$

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

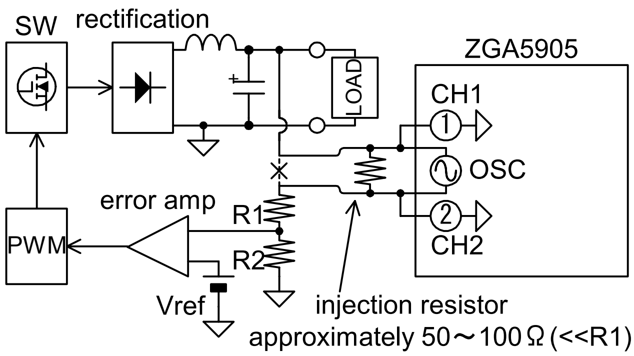
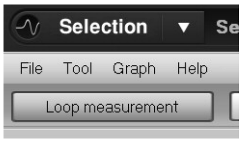


Figure 5-13-1 Connection example of servo-feedback loop measurement

"Figure 5-13-1 Connection example of servo 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 200V, you can use the connection shown in Figure 5-13-1 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 ZGA5905 and . 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



To measure the loop gain characteristics, click the Loop measurement screen switching button on the top of the screen.
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.

(Sweep)

- Sweep param: Frequency only.
- Sweep: Generally, set to [Log], because the measurement should be performed for a broad range of frequency.

(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.

(Integration): Set to 1 cycle at first, and then adjust it while checking results.

5.13.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the loop gain characteristics (bode diagram) are displayed in a graph.
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").

Alternatively, you can read a saved measurement data file instead of actually measuring on a target circuit. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.

The three types of graph format shown below can be selected using the graph switching buttons.

Table 5-13-1 Graph types of servo measurement (Loop measurement)

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter	Notes
Gain—θ	Frequency [Hz]	Gain [dB]	Phase [deg]	Bode diagram
Real(Gain) —Imag(Gain)	A (Real part of gain)	B (Imaginary part of gain)	—	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	—	Nichol's diagram

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2}\ ,\ \theta[\text{deg}] = \tan^{-1}\frac{B}{A}$$

The [Result] tab shows the measurement data search result and the marker.

- P_Margin: Phase at the frequency where the gain crosses 0 dB (phase margin)
- BW: Frequency for which the phase margin is searched
- G_Margin: Gain at the frequency where the phase crosses 0 deg (gain margin)

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.

Table 5-13-2 Marker indication in feedback loop measurement (Loop measurement)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Loop Gain	dB	Loop gain
θ	deg	Phase
Real(Gain)		Real part of gain
Imag(Gain)		Imaginary part of gain

○ Notes on Nyquist diagram

When you select [Real(Gain)-Imag(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 x β (excluding the subtraction section of input). However, in the ZGA5905, the actual loop gain measurement gives A x β x -1 (including the subtraction section of input) as the measurement data.

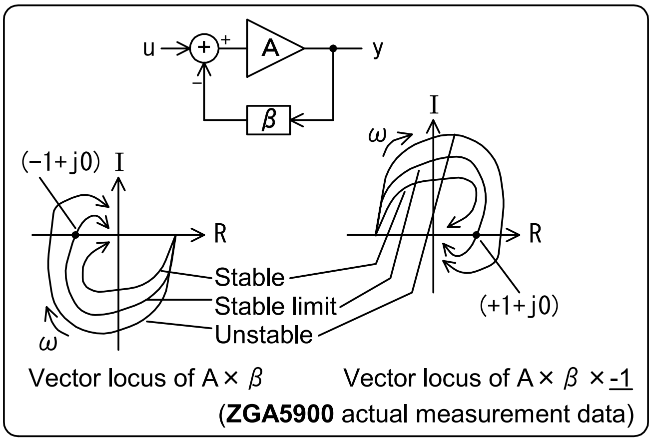


Figure 5-13-2 Nyquist diagram obtained by actual measurement

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 5-13-3 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.

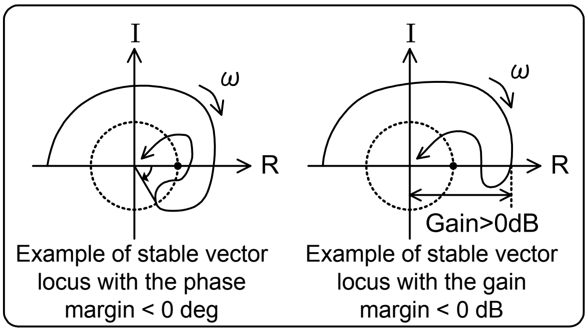
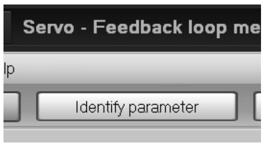


Figure 5-13-3 Example of stable vector locus with negative phase/gain margin

5.13.4 Circuit model generation



After the sweep measurement (or file loading) is finished, click the Identify parameter screen switching button on the top of the screen to generate a circuit model.

Set the conditions of model generation in the [others] tab on the left of the screen.

(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.
- Identify 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 button: Click to save the calculated transfer function in a file. For details, see "6.3 Transfer function file format".

5.13.5 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.
Click the Simulation screen switching button.
The simulation conditions can be set in the [others] tab on the left of the screen.
(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Open transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To load a transfer function file, click ... and specify the file.
- Simulation button: Click to calculate the loop gain characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
If there is a large difference between the measurement and simulation data, return to the Identification parameter screen and change the model generation conditions such as the order. After you generate a circuit model again, click the Simulation button to perform the re-calculation.

The [Result] tab shows the measurement data search result and the marker.

- P_Margin: Phase at the frequency where the gain crosses 0 dB (phase margin)
- BW: Frequency for which the phase margin is searched
- G_Margin: Gain at the frequency where the phase crosses 0 deg (gain margin)

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. When you display the [Result] tab, 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.

Table 5-13-3 Marker indication in loop gain measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
Loop Gain	dB	Loop gain (Measurement data)
Loop Gain(Sim)	dB	〃 (Simulation data)
θ	deg	Phase (Measurement data)
θ(Sim)	deg	〃 (Simulation data)
Real(Gain)	—	Real part of gain (Measurement data)
Real(Gain)(Sim)	—	〃 (Simulation data)
Imag(Gain)	—	Imaginary part of gain (Measurement data)
Imag(Gain)(Sim)	—	〃 (Simulation data)

(Notes) About circuit model

The circuit model generation feature generates a transfer function from the frequency-complex gain characteristics measured by the ZGA5905, 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

$$\begin{cases} \dot{X} = AX + Bu \\ y = CX + Du \end{cases}$$

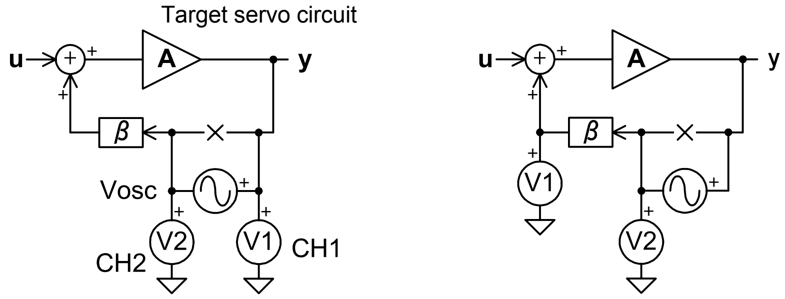
The internal algorithm calculates the function in the polynomial format at first. Then, it converts the function to the pole-zero and state space formats and outputs the results.

The [Identify parameter] 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 5-14-1 Connection example of closed loop gain measurement

"Figure 5-14-1 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

To measure the loop gain characteristics, click the Loop gain measurement screen switching button on the top of the screen.
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.

(Sweep)

- Sweep param: Frequency only.

(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.

(Integration): Set to 1 cycle at first, and then adjust it while checking results.

5.14.3 Loop gain measurement

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the loop gain characteristics (bode diagram) are displayed in a graph.
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 "5.13.3 Measure".

Alternatively, you can read a saved measurement data file instead of actually measuring on a target circuit. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.
The three types of graph format shown below can be selected using the graph switching buttons.

Table 5-14-1 Graph types of closed loop gain measurement

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter	Notes
Gain—θ	Frequency [Hz]	Gain [dB]	Phase [deg]	Bode diagram
Real(Gain) —Imag(Gain)	A (Real part of gain)	B (Imaginary part of gain)	—	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	—	Nichol's diagram

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2+B^2}\ ,\ \text{Gain} = \sqrt{A^2+B^2}\ ,\ \ \theta[\text{deg}] = \tan^{-1}\frac{B}{A}$$

The [Result] tab shows the measurement data search result and the marker.

- P_Margin: Phase at the frequency where the gain crosses 0 dB (phase margin)
- BW: Frequency for which the phase margin is searched
- G_Margin: Gain at the frequency where the phase crosses 0 deg (gain margin)

For details on how to check the phase/gain margin and determine the stability, see "5.13.3 Measure".

You can use the marker to read the value at an arbitrary frequency, independently of these search results.

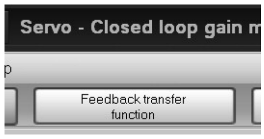
Table 5-14-2 Marker indication in closed loop gain measurement (Loop gain measurement)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Loop Gain	dB	Loop gain
θ	deg	Phase
Real(Gain)		Real part of loop gain
Imag(Gain)		Imaginary part of loop gain

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{Loop Gain[dB]} = 20\text{Log}_{10}\sqrt{A^2+B^2}\ ,\ \theta[\text{deg}]\ = \tan^{-1}\frac{B}{A},\ \text{Real(Gain)=A, Imag(Gain)=B}$$

5.14.4 Feedback transfer function measurement



For the feedback transfer characteristics measurement, change the connection with the target circuit. (See "Figure 5-14-1 Connection example of closed loop gain measurement".)
Click the Feedback transfer function screen switching button on the top of the screen.
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 "5.14.5 Open to closed loop conversion".

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the feedback transfer characteristics are displayed in a graph. The graph format can be selected from three types just like the loop gain measurement (see "Table 5-14-1 Graph types of closed loop gain measurement").

The [Result] tab shows the values read by the marker just like on the loop gain measurement screen. The search result of phase/gain margin is not displayed.

Table 5-14-3 Marker indication in closed loop gain measurement (Feedback transfer function)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Gain	dB	Feedback gain
θ	deg	Phase
Real(Gain)		Real part of feedback gain
Imag(Gain)		Imaginary part of feedback gain

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

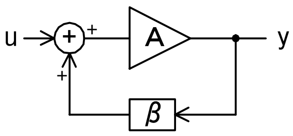
$$\text{Gain[dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2}\ ,\ \theta[\text{deg}] = \tan^{-1}\frac{B}{A}\ ,\ \text{Real(Gain)=A, Imag(Gain)=B}$$

5.14.5 Open to closed loop conversion

Calculate the closed loop characteristics (or amplification section characteristics) from the loop gain characteristics and the feedback transfer function. Click the [Open to close conversion] screen switching button on the top of the screen.
Set the conditions of open to closed loop conversion in the [others] tab on the left of the screen.

- Select feedback gain
  - Measurement: Perform the open to closed loop conversion using the data measured on the [Feedback transfer function] screen (or loaded from a file).
  - Const: Perform the open to closed loop conversion using a constant value as the negative feedback transfer function.
- Select output data
  - 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 [Select feedback gain] is set to [Const].
- [Open to close conversion] button: Click to start the open to closed loop conversion calculation.

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:

$$\text{Open loop gain} = \frac{G1}{G2}, \quad \text{Closed loop gain} = \frac{G1}{G2(1-G1)}$$

When the conversion is finished, the conversion result is displayed in a graph. The graph format can be selected from three types just like the loop gain measurement (see "Table 5-14-1 Graph types of closed loop gain measurement").
The [Result] tab shows marker read values of the characteristics. The gain and phase are the characteristics specified using the [Select output data] pull-down menu in the [others] tab.

Table 5-14-4 Marker indication in closed loop gain measurement (Open to close conversion)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Gain	dB	Gain
θ	deg	Phase
Real(Gain)		Real part of gain
Imag(Gain)		Imaginary part of gain

5.14.6 Circuit model generation

When the open to closed loop conversion is finished, click the Identify parameter screen switching button on the top of the screen to generate a circuit model.
Set the conditions of model generation in the [others] tab on the left of the screen.

(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.
- Identify 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 button: — Click to 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.

5.14.7 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.
Click the Simulation screen switching button.
The simulation conditions can be set in the [others] tab on the left of the screen.

(Simulation conditions)

- 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.
- Lin/Log: — The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Open transfer function: — If a date is displayed, the simulation is performed using the circuit model that you have just generated. To load a transfer function file, click ... and specify the file.
- Simulation button: — Click to calculate the open loop or closed loop characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
If there is a large difference between the measurement and simulation data, return to the Identifify parameter screen and change the parameters such as the order. When you generate a circuit model again and click the Simulation button, the recalculation will be performed to update the graph.

The [Result] tab shows the marker.
After the simulation is complete, the marker will be effective for the simulation data as well as the measurement result. When you display the [Result] tab, 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.

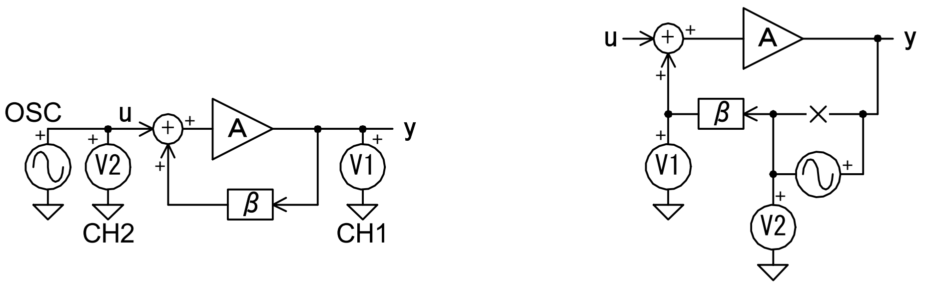
Table 5-14-5 Marker indication in closed loop gain measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
Gain	dB	Gain (Measurement data)
Gain(Sim)	dB	〃 (Simulation data)
θ	deg	Phase (Measurement data)
θ(Sim)	deg	〃 (Simulation data)
Real(Gain)	—	Real part of gain (Measurement data)
Real(Gain)(Sim)	—	〃 (Simulation data)
Imag(Gain)	—	Imaginary part of gain (Measurement data)
Imag(Gain)(Sim)	—	〃 (Simulation data)

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

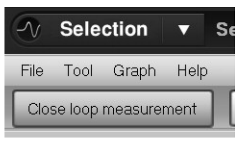
Connection example of feedback transfer characteristics measurement

Figure 5-15-1 Connection example of open loop gain measurement

"Figure 5-15-1 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

To measure the loop gain characteristics, click the Close loop measurement screen switching button on the top of the screen.
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.



(Sweep)

- Sweep param: Frequency only.

(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.

(Integration): Set to 1 cycle at first, and then adjust it while checking results.

5.15.3 Closed loop gain measurement

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the loop gain characteristics (bode diagram) are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a target circuit. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.
The three types of graph format shown below can be selected using the graph switching buttons.

Table 5-15-1 Graph types of open loop gain measurement

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter	Notes
Gain—θ	Frequency [Hz]	Gain [dB]	Phase [deg]	Bode diagram
Real(Gain)—Imag(Gain)	A (Real part of gain)	B (Imaginary part of gain)	—	Nyquist diagram
θ—Gain	Phase [deg]	Gain [dB]	—	Nichol's diagram

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2+B^2}\ ,\ \text{Gain} = \sqrt{A^2+B^2}\ ,\ \theta[\text{deg}] = \tan^{-1}\frac{B}{A}$$

The [Result] tab displays the marker. You can read a value at an arbitrary frequency.

Table 5-15-2 Marker indication in open loop gain measurement (Close loop measurement)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Close Gain	dB	Closed loop gain
θ	deg	Phase
Real(Gain)		Real part of closed loop gain
Imag(Gain)		Imaginary part of closed loop gain

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{Close Gain[dB]} = 20\text{Log}_{10}\sqrt{A^2+B^2}\ ,\ \theta[\text{deg}] = \tan^{-1}\frac{B}{A},\ \text{Real(Gain)=A, Imag(Gain)=B}$$

5.15.4 Feedback transfer function measurement

For the feedback transfer characteristics measurement, change the connection with the target circuit. (See "Figure 5-15-1 Connection example of open loop gain measurement".)
Click the Feedback transfer function screen switching button on the top of the screen.
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 "5.15.5 Closed to open loop conversion".

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the feedback transfer characteristics are displayed in a graph. The graph format can be selected from three types just like the loop gain measurement (see "Table 5-15-1 Graph types of open loop gain measurement").

The [Result] tab shows the values read by the marker just like on the closed loop gain measurement screen. The search result of phase/gain margin is not displayed.

Table 5-15-3 Marker indication in open loop gain measurement (Feedback transfer function)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Gain	dB	Feedback gain
θ	deg	Phase
Real(Gain)		Real part of feedback gain
Imag(Gain)		Imaginary part of feedback gain

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

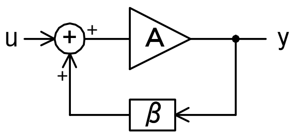
$$\mathrm{Gain[dB]} = 20\mathrm{Log}_{10}\sqrt{A^2+B^2}\ ,\ \theta[\mathrm{deg}] = \tan^{-1}\frac{B}{A}\ ,\ \mathrm{Real(Gain)=A,\ Imag(Gain)=B}$$

5.15.5 Closed to open loop conversion

Calculate the loop gain characteristics (or amplification section characteristics) from the closed loop characteristics and the feedback transfer function. Click the Close to open conversion screen switching button on the top of the screen. Set the conditions of closed to open loop conversion in the [others] tab on the left of the screen.

- Select feedback gain
  - Measurement: Perform the open to closed loop conversion using the data measured on the [Feedback transfer function] screen (or loaded from a file).
  - Const: Perform the closed to open loop conversion using a constant value as the negative feedback transfer function.
- Select outpu data
  - 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 [select feedback gain] is set to [Const].
- Close to open conversion button: Click to start the closed to open loop conversion calculation.

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 a graph. The graph format can be selected from three types just like the loop gain measurement (see "Table 5-15-1 Graph types of open loop gain measurement").

The [Result] tab shows marker read values of the characteristics. The gain and phase are the characteristics specified using the [select output data] pull-down menu in the [others] tab.

Table 5-15-4 Marker indication in open loop gain measurement (Close to open conversion)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Gain	dB	Gain
θ	deg	Phase
Real(Gain)		Real part of gain
Imag(Gain)		Imaginary part of gain

5.15.6 Circuit model generation

When the open to closed loop conversion is finished, click the Identify parameter screen switching button on the top of the screen to generate a circuit model.
Set the conditions of model generation in the [others] tab on the left of the screen.

(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.
- Identify 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 button: Click to 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.

5.15.7 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.
Click the Simulation screen switching button.
The simulation conditions can be set in the [others] tab on the left of the screen.

(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Open transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To load a transfer function file, click ... and specify the file.
- Simulation button: Click to calculate the loop gain or open loop characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
If there is a large difference between the measurement and simulation data, return to the Identify parameter screen and change the parameters such as the order. When you generate a circuit model again and click the Simulation 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. When you display the [Result] tab, 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.

Table 5-15-5 Marker indication in open loop gain measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
Gain	dB	Gain (Measurement data)
Gain(Sim)	dB	〃 (Simulation data)
θ	deg	Phase (Measurement data)
θ(Sim)	deg	〃 (Simulation data)
Real(Gain)	—	Real part of gain (Measurement data)
Real(Gain)(Sim)	—	〃 (Simulation data)
Imag(Gain)	—	Imaginary part of gain (Measurement data)
Imag(Gain)(Sim)	—	〃 (Simulation data)

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

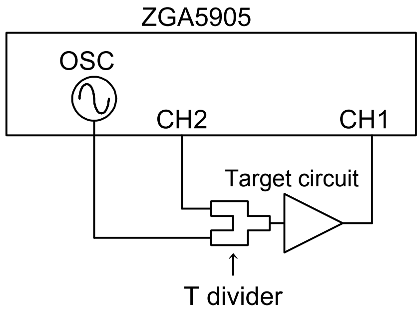
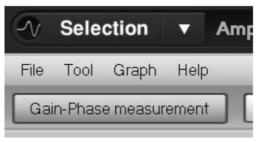


Figure 5-16-1 Connection example of gain-phase measurement

"Figure 5-16-1 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

To measure the gain-phase characteristics, click the Gain-Phase measurement screen switching button on the top of the screen.
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 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the gain-phase characteristics are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a target circuit. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.

The two types of graph format shown below can be selected using the graph switching buttons.

Table 5-16-1 Graph types of gain-phase measurement

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
Gain—θ	Sweep parameters • Frequency [Hz] • Zero span (time)	Gain [dB]	Phase [deg]
Gain—GD		Gain [dB]	Group delay [s]

The parameters are determined through the following conversion using the complex gain (G=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2+B^2}\ , \quad \theta[\text{deg}] = \tan^{-1}\frac{B}{A}\ , \quad \text{GD[s]} = \frac{\partial\theta_{[\text{rad}]}}{\partial\omega_{[\text{rad/s}]}}$$

The [Result] tab shows the following markers, regardless of the selected graph format. The marker moves along the sweep target.

Table 5-16-2 Marker indication in gain-phase measurement (Gain-Phase measurement)

Display parameter	Unit	
Frequency	Hz	When the sweep parameter is Frequency
Time	—	When the sweep parameter is Zero span (time)
Gain	dB	Gain
θ	deg	Phase
GD	s	Group delay

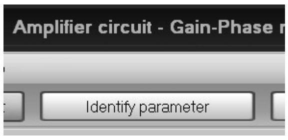
The [others] tab contains the settings related to the phase range and group delay.

- Phase range: Select the display range of phase from the following four types:
  - -180<θ≤+180deg: Displays the phase in the range of -180 to +180 deg.
  - -360<θ≤0deg: Displays the phase in the range of -360 to 0 deg.
  - 0<θ≤+360deg: 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.
- Aparture 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 aparture setting makes the group delay characteristic smoother, but will lose steep changes (on the frequency axis).

5.16.4 Transfer function generation

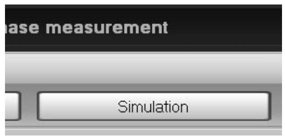


To generate the transfer function of the gain/phase characteristics that is measured (or loaded from a file), click the [Identify parameter] screen switching button.
The transfer function can be generated only for the data obtained by the frequency sweep measurement. It cannot be generated for the data obtained by the zero span sweep measurement.

Set the conditions of model generation in the [others] tab on the left of the screen.

- 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: 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.
- [Identify] 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] button: Click to save the calculated transfer function in a file. For details, see "6.3 Transfer function file format".

5.16.5 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.
Click the [Simulation] screen switching button.
The simulation conditions and the settings related to the phase range and group delay can be set in the [others] tab on the left of the screen.

- 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<θ≤+180deg: Displays the phase in the range of -180 to +180 deg.
  - -360<θ≤0deg: Displays the phase in the range of -360 to 0 deg.
  - 0<θ≤+360deg: 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.
- Aparture 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.

(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Open transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To load a transfer function file, click [...] and specify the file.
- [Simulation] button: Click to calculate the transfer characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
If there is a large difference between the measurement and simulation data, return to the [Identify parameter] screen and change the parameters such as the order. When you generate a circuit model again and click the [Simulation] 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. When you display the [Result] tab, 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.

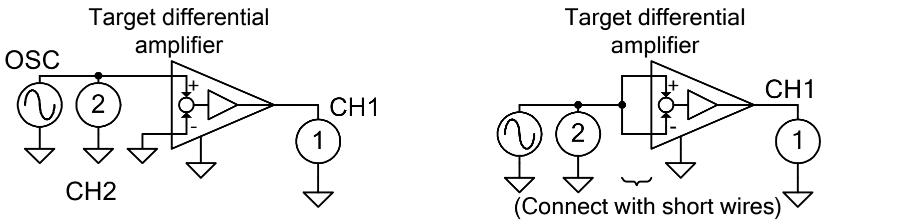
Table 5-16-3 Marker indication in loop gain measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated frequency
Gain	dB	Gain (Measurement data)
Gain(Sim)	dB	〃 (Simulation data)
θ	deg	Phase (Measurement data)
θ(Sim)	deg	〃 (Simulation data)
GD	s	Group delay (Measurement data)
GD(Sim)	—	〃 (Simulation data)

5.17 CMRR measurement (amplifier circuit)

Measure the CMRR (Common Mode Rejection Ratio), an important performance characteristic of a differential amplifier. The ZGA5905 has a large dynamic range of 140 dB, so you can measure a CMRR exceeding 100dB.

5.17.1 Connecting with target circuit



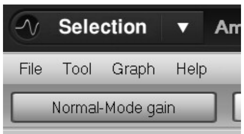
Connection for normal-mode gain measurement

Connection for common-mode gain measurement

Figure 5-17-1 Connection example of CMRR measurement"

"Figure 5-17-1 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



To measure the normal-mode gain, click the Normal-Mode gain screen switching button on the top of screen.
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.

(Sweep)

- Sweep param: Frequency only.

(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.

(Integration): For the common-mode gain measurement, set a relatively large value in order to measure very low input signals.

5.17.3 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 "5.17.4 Common-mode gain measurement".

Connect the ZGA5905 with the target differential amplifier for the normal-mode gain measurement (see "Figure 5-17-1 Connection example of CMRR measurement").
Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the normal-mode gain characteristics (gain [dB], phase [deg]) are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring the common-mode gain. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.

The normal-mode gain characteristics are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \text{ , } \theta\text{[deg]} = \tan^{-1}\frac{B}{A}$$

The [Result] tab displays the marker. You can read a value at an arbitrary frequency.

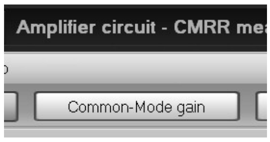
Table 5-17-1 Marker indication in CMRR measurement (Normal-Mode gain)

Display parameter	Unit	
Frequency	Hz	Measured frequency
GainNORM	dB	Normal-mode gain
θ	deg	Phase

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{GainNorm[dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} \text{ , } \theta\text{[deg]} = \tan^{-1}\frac{B}{A}$$

5.17.4 Common-mode gain measurement



To measure the common-mode gain, click the Common-Mode gain screen switching button on the top of screen.
Make the sweep-related settings (minimum value, maximum value, measurement interval, and sweep direction) 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 Start Measuring button to start a sweep measurement. When the sweep finishes, the common-mode gain characteristics are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring the normal-mode gain. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.

The [Result] tab displays the marker. You can read a value at an arbitrary frequency.

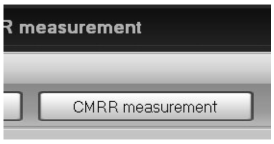
Table 5-17-2 Marker indication in CMRR measurement (Common-Mode gain)

Display parameter	Unit	
Frequency	Hz	Measured frequency
GainCOM	dB	Common-mode gain
θ	deg	Phase

The parameters are determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\text{GainCOM[dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2}\ ,\ \theta[\text{deg}] = \tan^{-1}\frac{B}{A}$$

5.17.5 CMRR display



When the normal-mode and common-mode gain measurements are finished, calculate the CMRR from the characteristics of both the gains. Click the CMRR measurement screen switching button on the top of the screen.
Set the conditions of CMRR characteristics calculation in the [others] tab on the left of the screen.

- Select Normal-Mode gain
  - Measurement: Calculate the CMRR using the data measured on the Normal-Mode gain screen
  - Const: 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.
- Calculation button: Click to calculate the CMRR characteristics based on the conditions specified above and display the result in a graph.

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 [Result] tab shows marker read values of the characteristics.

Table 5-17-3 Marker indication in CMRR measurement

Display parameter	Unit	
Frequency	Hz	Measured frequency
CMRR	dB	CMRR

The CMRR is calculated from the normal-mode gain GainNORM[dB] and the common-mode gain GainCOMM[dB], using the following formula:

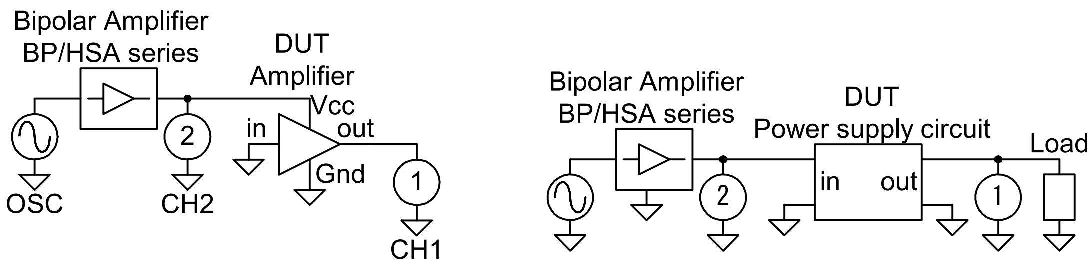
CMRR[dB]=GainNORM[dB] — GainCOMM[dB]

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 5-18-1 Connection example of PSRR measurement"

"Figure 5-18-1 Connection example of PSRR measurement" shows an example of connecting with a target circuit. In many cases, the oscillator output of the ZGA5905 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.

(Sweep)

- Sweep param: Frequency only.

(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 ZGA5905 to 0 V.

5.18.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the PSRR characteristics are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a target circuit. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.

The PSRR is determined through the following conversion using the complex gain (Gain=A+jB) obtained from the measurement.

$$\mathrm{PSRR[dB]} = 20\mathrm{Log}_{10}\sqrt{\mathrm{A}^2 + \mathrm{B}^2}$$

The [Result] tab displays the marker. You can read a value at an arbitrary frequency.

Table 5-18-1 Marker indication in PSRR measurement

Display parameter	Unit	
Frequency	Hz	Measured frequency
PSRR	dB	PSRR

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

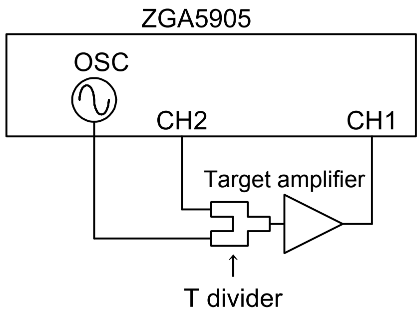


Figure 5-19-1 Connection example of differential gain/differential phase measurement

"Figure 5-19-1 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".
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.

(Sweep)

- Sweep param: DC bias only.

(Oscillator)

- Frequency: Set the measurement frequency.
- Amplitude: Set an amplitude that is not too large compared to the DC bias to be swept.

5.19.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, 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 (G=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2}\ ,\quad \theta[\text{deg}] = \tan^{-1}\frac{B}{A}$$

The [Result] tab displays the marker shown in the table below. The marker moves along the sweep parameter (DC bias).

Table 5-19-1 Marker indication in differential gain/differential phase measurement

Display parameter	Unit	
DC Bias	V	DC Bias
DG	dB	Differential gain
DP	deg	Differential phase

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

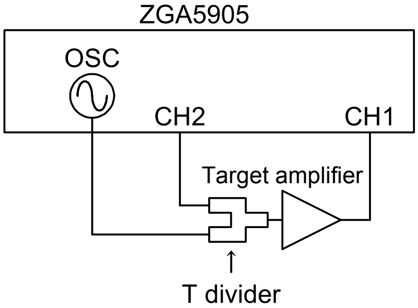


Figure 5-20-1 Connection example of saturation measurement

"Figure 5-20-1 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.
(Sweep)
- Sweep param: Amplitude only.

(Oscillator)
- Frequency: Set the measurement frequency.
- DC Bias: Set according to the target circuit.

5.20.3 Measure

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the Δ gain characteristics with AC amplitude on the X axis are displayed in a graph. 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 (G=A+jB) obtained from the measurement.

$$\Delta \text{ gain [dB]} = 20\text{Log}_{10}\sqrt{A^2 + B^2} - (\text{Maximum gain [dB]})$$

The [Result] tab shows the following parameters searched from the measurement data.

- P1dB: Input amplitude of the target circuit when the gain falls by 1 dB from the maximum gain
- GainP1dB: I/O gain when the gain falls by 1 dB from the maximum gain

It also displays the marker shown in the table below. The marker moves along the sweep parameter (AC amplitude).

Table 5-20-1 Marker indication in Saturation measurement

Display parameter	Unit	
Amplitude	Vpk	Amplitude
ΔGain	dB	Deviation from maximum gain

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

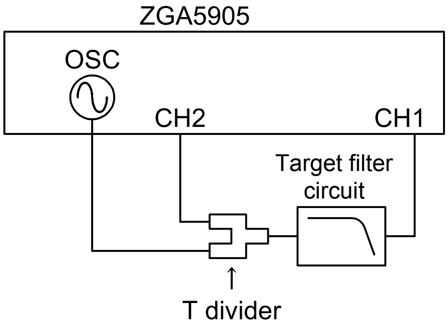
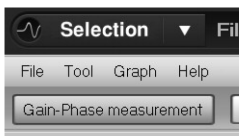


Figure 5-21-1 Connection example of filter circuit

"Figure 5-21-1 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



To measure the gain-phase characteristics, click the Gain-Phase measurement screen switching button on the top of the screen.
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 Filter measurement

Turn on the oscillator output, click the Start Measuring button to start a sweep measurement. When the sweep finishes, the gain-phase characteristics are displayed in a graph.

Alternatively, you can read a saved measurement data file instead of actually measuring on a target circuit. From the [File] menu, select [Open] - [Meas Data...] to read a measurement data file (in the CSV format). You may display or analyze it completely the same way as you actually measured on a target circuit.

The two types of graph format shown below can be selected using the graph switching buttons.

Table 5-21-1 Graph types of filter measurement

Graph type	X-axis parameter	Y1-axis parameter	Y2-axis parameter
Gain—θ	Frequency [Hz]	Gain [dB]	Phase [deg]
Gain—GD		Gain [dB]	Group delay [s]

The parameters are determined through the following conversion using the complex gain (G=A+jB) obtained from the measurement.

$$\text{Gain [dB]} = 20\text{Log}_{10}\sqrt{A^2+B^2}\ ,\ \theta\text{[deg]} = \tan^{-1}\frac{B}{A},\quad \text{GD[s]} = \frac{\partial\theta_{[rad]}}{\partial\omega_{[rad/s]}}$$

The [Result] tab shows the following markers, regardless of the selected graph format. The marker moves along the sweep target (Frequency).

Table 5-21-2 Marker indication in filter measurement (Gain-Phase measurement)

Display parameter	Unit	
Frequency	Hz	Measured frequency
Gain	dB	Gain
θ	deg	Phase
GD	s	Group delay

The [Result] tab also shows the measurement data search result. The displayed search result varies depending on the Filter Type selected in the [others] tab.

Table 5-21-3 Search display items by filter type

Displayed item	Filter type setting LPF	HPF	BPF	BEF	
FcLow	×	○	○	○	Low cutoff frequency
FcHigh	○	×	○	○	High cutoff frequency
GPath	○	○	○	○	Passband gain
GATT	○	○	○	×	Maximum attenuation
GRipple	○	○	○	×	Passband ripple
GBEF	×	×	×	○	BEF attenuation
BW	×	×	○	×	Bandwidth

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 in the [others] tab.

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

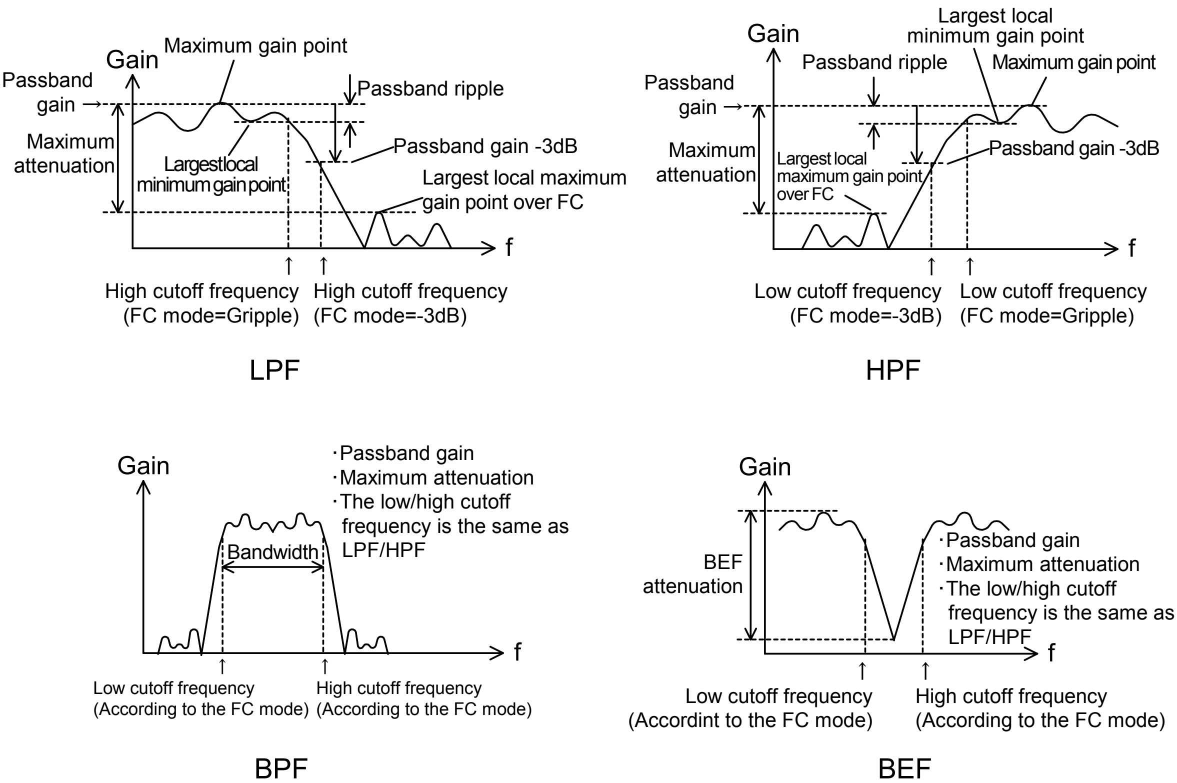


Figure 5-21-2 Search method of filter characteristics

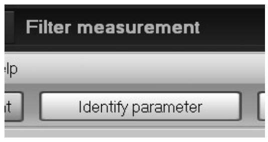
These search start from the beginning of the sweep data, and show the first position that matches the search conditions. However, the displayed search result may not indicate the correct position, for example due to noise. In such case, click the search again buttons ◀ ▶ next to each display item to search again and display the next (previous) position matching that matches the search conditions.

The settings related to phase and group delay are located on the [others] tab.

- Phase range: Select the display range of phase from the following four types:
  - -180<θ≤+180deg: Displays the phase in the range of -180 to +180 deg.
  - -360<θ≤0deg: Displays the phase in the range of -360 to 0 deg.
  - 0<θ≤+360deg: 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.
- Aparture: 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 aparture setting makes the group delay display smoother, but will lose steep changes (on the frequency axis).

5.21.4 Transfer function generation



To generate the transfer function of the gain-phase characteristics that is measured (or loaded from a file), click the Identify parameter screen switching button.
Set the conditions of model generation in the [others] tab on the left of the screen.

(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: 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.
- Identify 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 button: Click to save the calculated transfer function in a file. For details, see "6.3 Transfer function file format".

5.21.5 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.
Click the [Simulation] screen switching button.
The simulation conditions and the settings related to the phase range and group delay can be set in the [others] tab on the left of the screen.

- 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<θ≤+180deg: Displays the phase in the range of -180 to +180 deg.
  - -360<θ≤0deg: Displays the phase in the range of -360 to 0 deg.
  - 0<θ≤+360deg: 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.
- Aparture: 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.
- Filter Type: The type of filter [LPF]/[HPF]/[BPF]/[BEF] to choose from .
- Fc mode: Choose how to determine the cutoff frequency.
  - -3dB: Frequency at which the gain is 3 dB lower than the passband gain.
  - GRipple: Frequency at which the attenuation exceeds the passband ripple.

(Simulation conditions)

- 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.
- Lin/Log: The frequency interval to be used for simulation. Select [Lin] (equal interval) or [Log] (equal ratio interval).
- Open transfer function: If a date is displayed, the simulation is performed using the circuit model that you have just generated. To load a transfer function file, click [...] and specify the file.
- [Simulation] button: Click to calculate the filter characteristics with the simulation conditions that you have set, and plot the result on a graph.

The measurement data is plotted in pale blue, and the simulation data in green.
If there is a large difference between the measurement and simulation data, return to the [Identify parameter] screen and change the parameters such as the order. When you generate a circuit model again and click the [Simulation] 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. When you display the [Result] tab, 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.

Table 5-21-4 Marker indication in filter measurement (Simulation)

Display parameter	Unit	
Frequency	Hz	Simulated measurement frequency
Gain	dB	Gain (Measurement data)
Gain(Sim)	dB	〃 (Simulation data)
θ	deg	Phase (Measurement data)
θ(Sim)	deg	〃 (Simulation data)
GD	s	Group delay (Measurement data)
GD(Sim)	s	〃 (Simulation data)

In addition to the marker, the data search result is displayed as in the [Result] tab of the screen. The result of searching the simulation data is displayed, instead of the measured data. For details on display items and settings, see "5.21.3 Filter measurement".

6. Files

6.1 Overview

In the ZGA5905, 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 ZGA5905 can output following file types.

- Measurement data file — CSV format — measurement data, measurement condition, and so on
- Transfer function file — TXT format — transfer function coefficients, and so on
- Report file — PDF format — report output file (for printing)
- Graph file — BMP format — graph output file

You can only read measurement data files in the ZGA5905. Other file types are output (saved) only and cannot be read.
This section describes each file format.

6.2 Measurement data file format

The measurement data file is in the CSV format (text format). It can be displayed and edited with MS Excel or other spreadsheet software, or a text editor.
The file consists of three parts - application information, measurement condition, and data in this order. When you store multiple data at a time, the measurement data file will consist of one application information part, and the same number of measurement condition parts and data parts as the data.

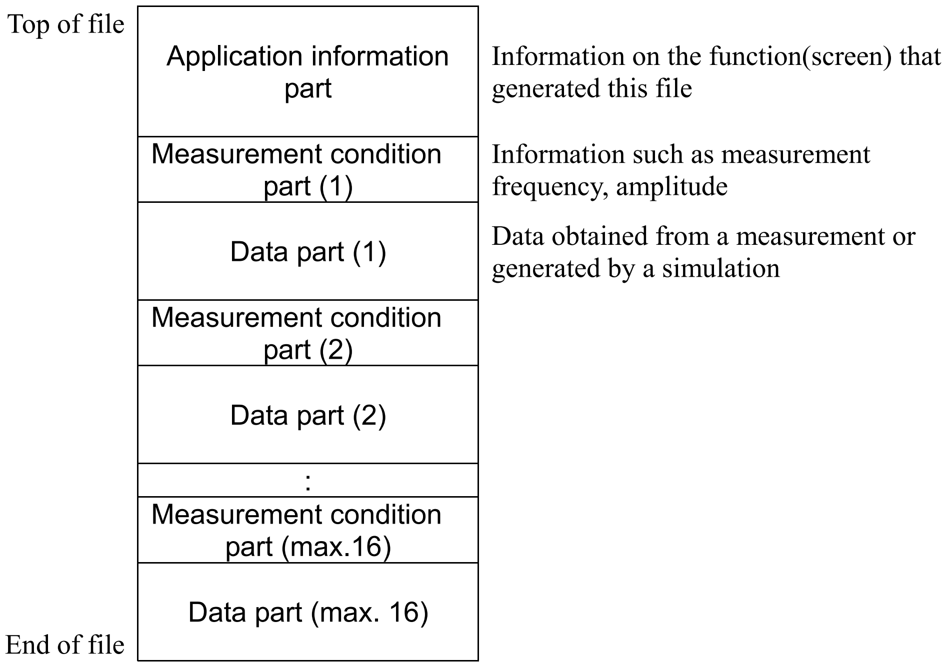


Figure 6-1 Structure of measurement data file

The following tables show the formats of these parts.

Table 6-1 Measurement data file format - Application information part

Content	Description
[Information]	Indicates the application information part.
ID,Item,Value	Header for indicating the column contents.
0,Target,"(Common|Specific|Package)"	File type Common: Reusable as measurement data Specific: Not reusable as measurement data Package: Reusable as multiple measurement data
1,Domain,"(measurement type name)"	Measurement type name for this file to be created.
2,Function,"(screen name)"	Function (screen) name for this file to be created.
3,DataMax,(maximum number of data series) *1	Sets the maximum number of display data. From 1 to 16
4,DataCount,(number of data) *1	Number of data displayed on a graph From 1 to (DataMax)
5,DataLabel,"Label1","Label2",... *1	Data label, (DataCount)
6,Title,"Title1","Title2",... *1	Data title, (DataCount)
7,Display,(0|1),(0|1),... *1	Sets whether or not to display the corresponding data: display (1), no display (0). (DataCount)
8,Color,(color1),(color2),... *1	Color of the corresponding data specified by the following strings. Crimson, DarkOrange, Gold, LawnGree, ForestGree, Turquoise, DodgerBlue, royalBlue, SlateBlue, BlueViolet, Fuchsia, DeepPink, LightPink, LighCoral, CadetBlue, LightSlateGray
(9|3),FileFormatVersion,"1.10" *2	File format version. The third digit indicates the version number.

*1: This items is exist at the measurement type which multiple data display is possible.
*2: At the measurement type which multiple data display is impossible, ID is 3.

The following table shows the list of measurement type names and screen names. For example, when you save a file with the measurement type "Inductor measurement" and the screen "Simulation", the fourth and fifth lines read as follows:

(Line 4) 1,Domain,"Inductor measurement"
(Line 5) 2,Function,"Simulation"

Table 6-2 List of measurement type and screen names

Measurement type name	Screen name
Piezoelectric measurement	Piezoelectric material measurement
	Simulation
Dielectric measurement	Dielectric material measurement
	Analyze parameter
Magnetic measurement	Magnetic material measurement
	Analyze parameter
Inductor measurement	Measurement
	Simulation
Capacitor measurement	Measurement
	Simulation
Resister measurement	Measurement
	Simulation
Transformer - Leakage inductance measurement	Leakage inductance measurement
Transformer - Mutual inductance measurement	Aid connection measurement
	Oppose connection measurement
	Mutual inductance measurement
Transformer - Coupling coefficient measurement	Short secondary measurement
	Open secondary measurement
	Coupling coefficient measurement
Transformer - Turns ratio measurement	Turns ratio measurement
Varactor diode measurement	CV measurement
	Simulation

Table 6-2 List of measurement type and screen names (continued)

Measurement type name	Screen name
Servo - Feedback loop measurement	Loop measurement
	Simulation
Servo - Closed loop gain measurement	Loop gain measurement
	Feedback transfer function
	Open to close conversion
	Simulation
Servo - Open loop gain measurement	Close loop measurement
	Feedback transfer function
	Close to open conversion
	Simulation
Amplifier circuit - Gain-Phase measurement	Gain-Phase measurement
	Simulation
Amplifier circuit - CMRR measurement	Normal-mode gain
	Common-mode gain
	CMRR measurement
Amplifier circuit - PSRR measurement	PSRR measurement
Amplifier circuit - DG/DP measurement	DG/DP measurement
Amplifier circuit - Saturation measurement	Saturation measurement
Filter measurement	Gain-Phase measurement
	Simulation
Impedance measurement	Impedance measurement
Gain-Phase measurement	Gain-Phase measurement

The following table shows the format of the setting condition part.

Table 6-3 Measurement data file format - Setting condition part

Content	Description
[Parameter]	Indicates the measurement condition part.
ID,Item,Value	Header for indicating the column contents.
0,SweParam,(sweep item)	Sweep item is one of the followings: Frequency: Frequency sweep Amplitude: Amplitude sweep DCBias: DC bias sweep ZeroSpan: Zero span sweep
1,Fmin,(minimum frequency)	Frequency sweep minimum value (Hz) with 0.1 mHz resolution Range 0.0001 to 15000000.0000
2,Fmax,(maximum frequency)	Frequency sweep maximum value (Hz) with 0.1 mHz resolution Range 0.0001 to 15000000.0000
3,Amin,(minimum amplitude)	Amplitude sweep minimum value (Vp) Resolution 3 digits or 0.0001 Vp Range 0.000 to 9990
4,Amax,(maximum amplitude)	Amplitude sweep maximum value (Vp) Resolution 3 digits or 0.0001 Vp Range 0.000 to 9990
5,Dmin,(minimum DC bias)	DC bias sweep minimum value (V) Resolution 3 digits or 0.0001 V Range -9990 to +9990
6,Dmax,(maximum DC bias)	DC bias sweep maximum value (V) Resolution 3 digits or 0.0001 V Range -9990 to +9990
7,Zmax,(zero span time width)	Zero span sweep time width (second) with 10 ms resolution Range 0.03 to 999999.99
8,Point,(number of sweep points)	Sweep point with a resolution of 1 Range 3 to 20000
9,Interval,(Lin|Log)	Sweep type Linear sweep (Lin) / Logarithmic sweep (Log)
10,Direction,(Up|Down)	Sweep direction Up sweep (Up), Down sweep (Down)

Table 6-3 Measurement data file format - Setting condition part (continued)

Content	Description
11,SlowItem,(OFF|LogR|R|Theta|A|B)	Monitoring parameter for automatic high density sweep OFF: Turns off the automatic high density sweep function LogR: Monitors changes in gain (dB) R: Monitors changes in absolute value of amplitude (Vrms) Theta: Monitors changes in phase (deg) A: Monitors changes in real part of amplitude (Vrms) B: Monitors changes in imaginary part of amplitude (Vrms)
12,SlowCh,(CH1|CH2)	Monitoring channel for automatic high density sweep
13,SlowVarLogR,(LogR change)	Target change in LogR (dB) for automatic high density sweep Resolution 3 digits or 0.01 dB Range 0.00 to 1000
14,SlowVarR,(R change)	Target change in R (Vrms) for automatic high density sweep Resolution 3 digits or 1 uV Range 0.00E-6 to 1.00E+9
15,SlowVarTheta,(phase change)	Target change in phase (deg) for automatic high density sweep Resolution 3 digits or 0.01 deg Range 0.00 to 180
16,SlowVarA,(A change)	Target change in A (Vrms) for automatic high density sweep Resolution 3 digits or 1 uV Range 0.00E-6 to 1.00E+9
17,SlowVarB,(B change)	Target change in B (Vrms) for automatic high density sweep Resolution 3 digits or 1 uV Range 0.00E-6 to 1.00E+9
18,IntegParam,(Cycle|Time)	Integration method selection Cycle (number of times) or Time
19,IntegCycle,(number of integrations)	Integration count setting with a resolution of 1 Range 1 to 9999
20,IntegTime,(integration time)	Integration time setting (s) with 10 ms resolution Range 0.00 to 9999.00
21,DelayParam,(Cycle|Time)	Delay method selection Cycle (number of times) or Time
22,DelayCycle,(delay cycle)	Delay cycle setting with a resolution of 1 Range 0 to 9999
23,DelayTime,(delay time)	Delay time setting (s) with 10 ms resolution Range 0.00 to 9999.00

Table 6-3 Measurement data file format - Setting condition part (continued)

Content	Description
24,Ch1Factor,(CH1 factor)	Weighting factor of CH1 Resolution 5 digits or 0.01E-9 Range 0.0000 to 1.0000E+6
25,CH2Factor,(CH2 factor)	Weighting factor of CH2 Resolution 5 digits or 0.01E-9 Range 0.0000 to 1.0000E+6
26,Invert,(OFF|ON)	Enable/disable the phase inversion function
27,Freq,(oscillator frequency)	Oscillator output frequency (Hz) with 0.1 mHz resolution Range 0.0001 to 15000000.0000
28,ExtAmpGain,(external amplifier gain)	External amplifier gain (no unit) Resolution 3 digits or 0.01 Range ±(0.01 to 999)
29,Ampl,(oscillator AC amplitude)	Oscillator output amplitude converted to external amplifier output (Vp) Resolution 3 digits or 0.0001 Vp Range 0.000 to 9990
30,Dc,(oscillator DC bias)	DC bias converted to external amplifier output (V) Resolution 3 digits or 0.0001 V Range -9990 to +9990
31,Wave,Sin	Oscillator output waveform in sine wave
32,AnytimeOn,(Disable|Enable)	Oscillator output Anytime ON (Enable), Only at measurement (Disable)
33,Date,(yyyy/mm/dd hh:mm:ss.ss)	Measurement start date and time with 0.01 second resolution

The following table shows the format of the data part. The same format applies to data obtained from actual sample measurements and to simulated or calculated data.

Table 6-4 Measurement data file format - Data part

Content	Description
[Data]	Indicates the data part.
Header for indicating the output data types Column 1: Sweep item Column 2 to 11: Up to 10 items according to the displayed graph	
(Measurement data corresponding to the header)	

Actual data starts from Line 45. One line represents the data of a single point. The number of data points is stored in [Parameter] No.8 Point in the measurement condition part.

Line 44 Column 1 is a header for indicating the sweep item. See the following table for sweep items.

Table 6-5 Measurement data file format - Sweep item

Header text	Sweep item
Frequency[Hz]	Frequency sweep
Amplitude[Vpk]	Voltage amplitude sweep
DC Bias[V]	DC bias voltage sweep
Amplitude[Apk]	Current amplitude sweep
DC Bias[A]	DC bias current sweep
Time	Zero span (time) sweep

Line 44 Columns 2 to 11 (up to 10 items) are headers for indicating output parameter types. See "Table 6-6 Measurement data file format - Parameter list" for header texts for various parameter types.

Table 6-6 Measurement data file format - Parameter list

Header text	Parameter content
a	Real part (gain or impedance)
b	Imaginary part (gain or impedance)
B[S]	Susceptance
Close Gain[dB]	Closed loop gain
CMRR[dB]	Common mode rejection ratio
Cp[F]	Parallel capacitance
Cs[F]	Series capacitance
D	Dissipation factor
DG[dB]	Differential gain
DP[deg]	Differential phase
Rreq_res[Hz]	Resonant (tuning) frequency
G[S]	Conductance
Gain[dB]	Gain
GainCOM[dB]	Common-mode gain
GainNORM[dB]	Differential-mode gain
GD[s]	Group delay time
Imag(Gain)	Imaginary part of gain
Inductance[H]	Inductance
k	Coupling coefficient
Lleak[H]	Leakage inductance
Loop Gain[dB]	Loop gain
Lp[H]	Parallel inductance

Header text	Parameter content
Ls[H]	Series inductance
M[H]	Mutual inductance
PSRR[dB]	Power supply rejection ratio
Q	Quality factor
R[Ω]	Resistance
Real(Gain)	Real part of gain
Rp[Ω]	Parallel resistance
Rs[Ω]	Series resistance
tanδ	Dissipation factor
Turns Ratio	Turn ratio
X[Ω]	Reactance
εs	Relative dielectric permittivity
εs'	Real part of complex relative dielectric permittivity
εs"	Imaginary part of complex relative dielectric permittivity
θ[deg]	Phase
θp[deg]	Phase (parallel equivalent circuit)
θs[deg]	Phase (series equivalent circuit)
μs	Relative magnetic permeability
μs'	Real part of complex relative magnetic permeability
μs"	Imaginary part of complex relative magnetic permeability
|Y|[S]	Admittance
|Z|[Ω]	Impedance
ΔGain[dB]	Δ gain

Which parameters are output to the file are determined by the screen being displayed when the data was saved. The system outputs all the parameters of all the graphs available in this screen. "Table 6-7 Measurement data file format - Output item list" lists the headers for various combinations of the measurement type and the screen. Note that any shaded item is output in a format that cannot be reused (loaded) as measurement data. See Line 3, Target in "Table 6-1 Measurement data file format - Application information part".

Table 6-7 Measurement data file format - Output item list

Measurement type name Screen name	Column 1	Column 2 ...
Piezoelectric measurement		
Piezoelectric material measurement	Frequency[Hz]	a,b,|Y|[S],θ[deg],G[S],B[S]
	Time	a,b,|Y|[S],θ[deg]
Simulation	Frequency[Hz]	a,b,|Y|[S],θ[deg],G[S],B[S]
Dielectric measurement		
Dielectric materal measurement	Frequency[Hz]	a,b,Cp[F],Rp[Ω]
	DC Bias[V]	
	Time	
Analyze parameter	Frequency[Hz]	εs,tanδ,εs',εs''
	DC bias[V]	
	Time	
Magnetic measurement		
Magnetic material measurement	Frequency[Hz]	a,b,Ls[H],Rs[Ω]
	DC Bias[A]	
	Time	
Analyze parameter	Frequency[Hz]	μs,tanδ,μs',μs''
	DC Bias[A]	
	Time	
Inductor measurement		
Measurement	Frequency[Hz]	a,b,Ls[H],Rs[Ω],θs[deg], Lp[H],Rp[Ω],θp[deg],Q
	DC Bias[A]	
	Amplitude[Apk]	
	Time	
Simulation	Frequency[Hz]	

Table 6-7 Measurement data file format - Output item list (continued)

Measurement type Screen name	Column 1	Column 2 ...
Capacitor measurement		
Measurement	Frequency[Hz]	a,b,Cs[F],Rs[Ω],θs[deg], Cp[F],Rp[Ω],θp[deg],Q,D
	DC Bias[V]	
	Amplitude[Vpk]	
	Time	
Simulation	Frequency[Hz]	
Resistor measurement		
Measurement	Frequency[Hz]	a,b,|Z|[Ω],θs[deg], R[Ω],X[Ω]
	DC bias[V]	
	Amplitude[Vpk]	
	Time	
Simulation	Frequency[Hz]	
Transformer-Leakage inductance measurement		
Leakage inductance measurement	Frequency[Hz]	a,b,Lleak[H]
	Time	
Transformer-Mutual inductance measurement		
Aid connection measurement	Frequency[Hz]	a,b,Inductance[H]
Oppose connection measurement	Frequency[Hz]	
Mutual inductance measurement	Frequency[Hz]	M[H]
Transformer-Coupling coefficient measurement		
Short secondary measurement	Frequency[Hz]	a,b,Inductance[H]
Open secondary measurement	Frequency[Hz]	
Coupling coefficient measurement	Frequency[Hz]	k
Transformer-Turns ratio measurement		
Truns ratio measurement	Frequency[Hz]	a,b,Turns Ratio
	Time	
Varactor diode measurement		
CV measurement	Frequency[Hz]	a,b,Cp[F],Q
	DC bias[V]	
	Time	
Simulation	DC bias[V]	Freq_res[Hz]
	Time	

Table 6-7 Measurement data file format - Output item list (continued)

Measurement type, Screen name	Column 1	Column 2 ...
Servo-Feedback loop measurement		
Loop measurement	Frequency[Hz]	a,b,Loop Gain[dB],θ[deg], Real(Gain),Imag(Gain)
Simulation	Frequency[Hz]	
Servo-Closed loop gain measurement		
Loop gain measurement	Frequency[Hz]	a,b,Loop Gain[dB],θ[deg], Real(Gain),Imag(Gain)
Feedback transfer function	Frequency[Hz]	a,b,Gain[dB],θ[deg], Real(Gain),Imag(Gain)
Open to close conversion	Frequency[Hz]	
Simulation	Frequency[Hz]	
Servo-Open loop gain measurement		
Close loop measurement	Frequency[Hz]	a,b,Close Gain[dB],θ[deg], Real(Gain),Imag(Gain)
Feedback transfer function	Frequency[Hz]	a,b,Gain[dB],θ[deg], Real(Gain),Imag(Gain)
Close to open conversion	Frequency[Hz]	
Simulation	Frequency[Hz]	
Amplifier circit-Gain-Phase measurement		
Gain-Phase measurement	Frequency[Hz]	a,b,Gain[dB],θ[deg],GD[s]
	Time[s]	a,b,Gain[dB],θ[deg]
Simulation	Frequency[Hz]	a,b,Gain[dB],θ[deg],GD[s]
Amplifier circuit-CMRR measurement		
Normal-Mode gain	Frequency[Hz]	a,b,GainNORM[dB],θ[deg]
Common-Mode gain	Frequency[Hz]	a,b,GainCOM[dB],θ[deg]
CMRR measurement	Frequency[Hz]	CMRR[dB]
Amplifier circuit-PSRR measurement		
PSRR measurement	Frequency[Hz]	a,b,PSRR[dB]
Amplifier circuit-DG/DP measurement		
DG/DP measurement	DC Bias[V]	a,b,DG[dB],DP[deg]
Amplifier circuit-Saturation measurement		
Saturation measurement	Amplitude[Vpk]	a,b,Delta Gain[dB]
Filter measurement		
Gain-Phase measurement	Frequency[Hz]	a,b,Gain[dB],θ[deg],GD[s]
Simulation	Frequency[Hz]	
Impedance measurement		
Impedance measurement	Frequency[Hz]	a,b
Gain-Phase measurement		
Gain-Phase measurement	Frequency[Hz]	a,b

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 ZGA5905 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.

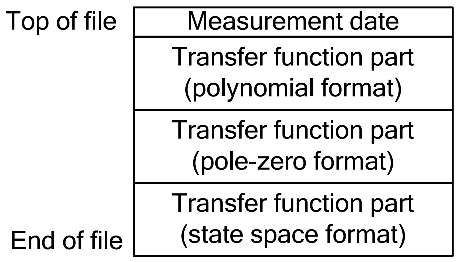


Figure 6-2 Structure of transfer function file

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:
±(mantissa, 15 digits)E±(exponent, 3 digits).
However, the pole (p_i) and zero (z_i) are a complex number:
±(real part)±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 6-8 Transfer function file format".

Table 6-8 Transfer function file format

Content	Description
%2010/0101 12:34:56.78	(Date and time when the original data for transfer function derivation were measured)
%TF	(Start of transfer function in polynomial format)
%numerator	(Numerator coefficient)
(num_n) (num_{n-1}) ･･･ (num_1) (num_0)	Numerator coefficients from the highest order
%denominator	(Denominator coefficient)
(den_n) (den_{n-1}) ･･･ (den_1) (den_0)	Denominator coefficients from the highest order
	(Blank line)
%ZP	(Start of transfer function in pole-zero format)
%K	(Gain coefficient)
(K)	Gain of transfer function in pole-zero format
%zero	(Zero point)
(z_{n-1}) (z_{n-2})･･･(z_1) (z_0)	Zero points in complex number format
%pole	(Pole)
(p_{n-1}) (p_{n-2})･･･(p_1) (p_0)	Poles in complex number format
	(Blank line)
%SS	(Start of transfer function in state space format)
%A	(Matrix A)
(A_{11}) (A_{12})･･･(A_{1n})	1st row of the matrix A
(A_{21}) (A_{22})･･･(A_{2n})	2nd row of the matrix A
:	:
(A_{n1}) (A_{n2})･･･(A_{nn})	nth row of the matrix A
%B	(column vector B)
(B_1)	
(B_2)	
:	
(B_n)	
%C	(row vector C)
(C_1) (C_2)･･･(C_n)	
%D	(scalar D)
(D)	

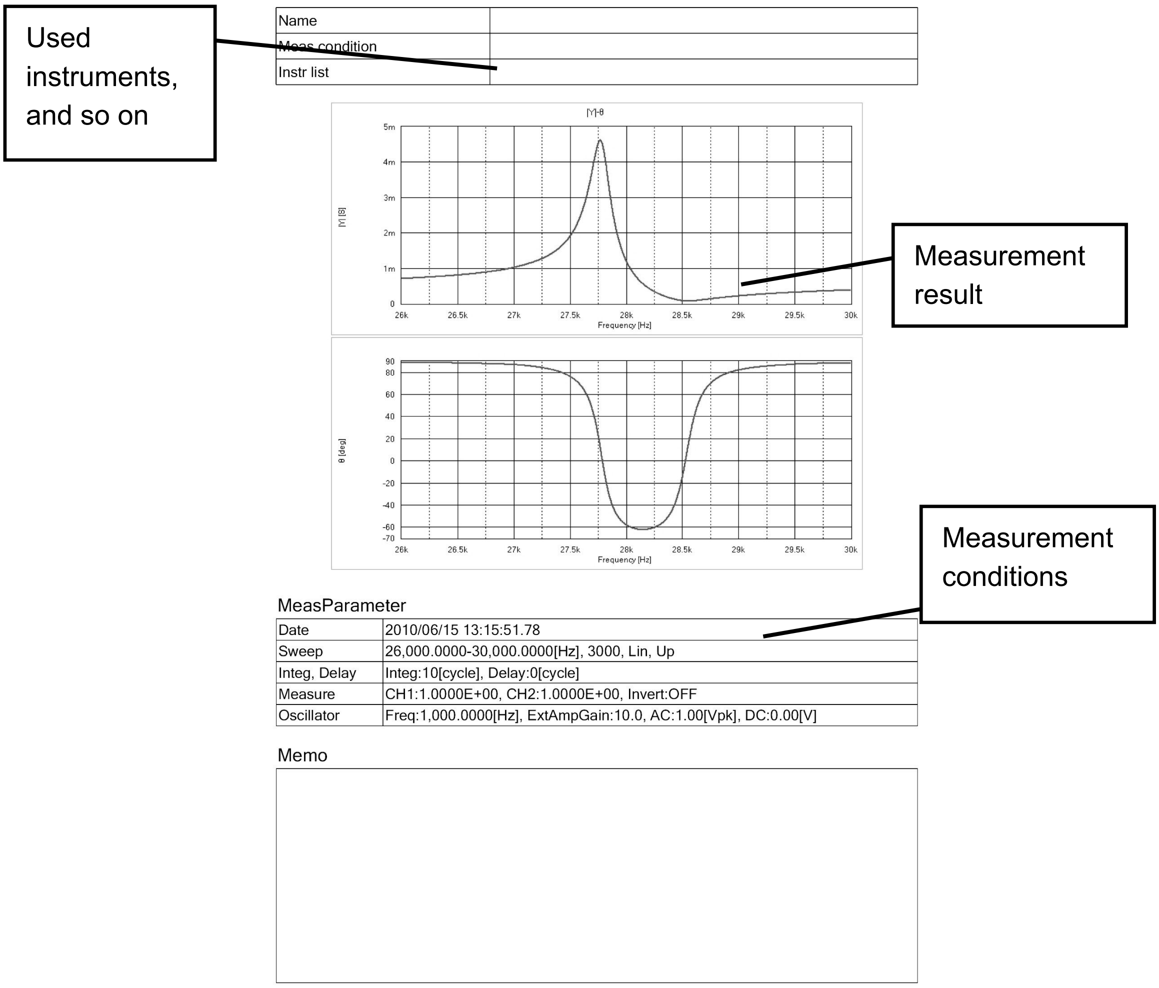
6.4 Report file format

This report format file contains measurement result graphs as well as measurement records (e.g., measurer), measurement conditions, and remarks column. Its content is the same as the report output which can be printed on a printer.

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")

An output example is shown below:



Name	
Meas condition	
Instr list	

MeasParameter

Date	2010/06/15 13:15:51.78
Sweep	26,000.0000-30,000.0000[Hz], 3000, Lin, Up
Integ, Delay	Integ:10[cycle], Delay:0[cycle]
Measure	CH1:1.0000E+00, CH2:1.0000E+00, Invert:OFF
Oscillator	Freq:1,000.0000[Hz], ExtAmpGain:10.0, AC:1.00[Vpk], DC:0.00[V]

Memo

Figure 6-3 Report file example

6.5 Graph file format

This file contains a simple image copy of an on-screen graph area. However, the marker is not included. Its content is the same as the graph output which can be printed on a printer.

The graph output file has the following format:

File size	About 2.2 MB
File format	Windows Bitmap (file name extension is ".BMP")
Number of colors	24-bit true color (16.7 million colors)
Number of pixels	814×715 dot

An output example is shown below:

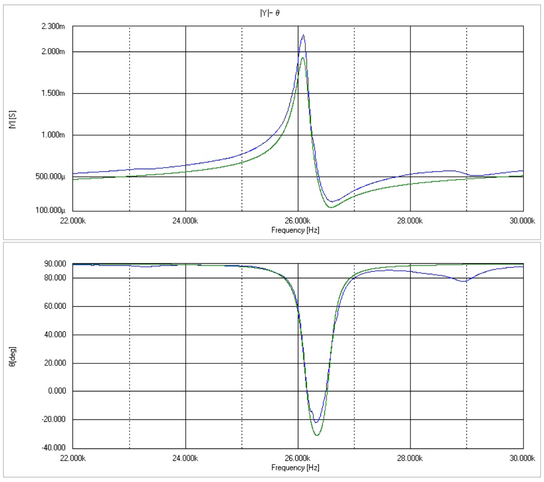


Figure 6-4 Graph output example (1)

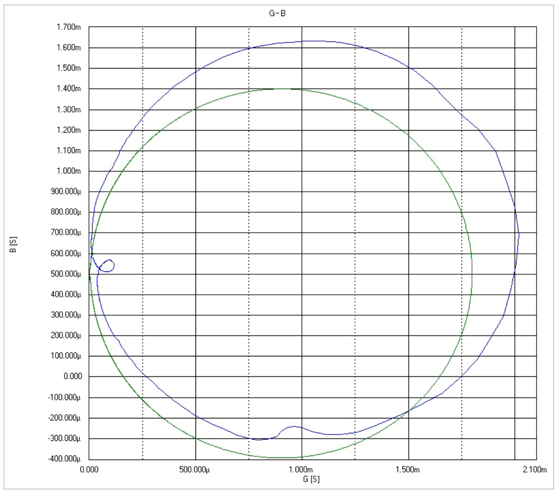


Figure 6-5 Graph output example (2)

7. Troubleshooting

7.1 Error messages

This section lists the error messages that are output by the ZGA5905, their causes, and required actions.
If a repair is needed, contact us or our agent.
When you request a repair of the ZGA5905, 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.

Table7-1 Error message list

No.	Error Message	Description
10001	An internal processing error occurred. Please restart the system.	This error occurs when the analysis section failed in connection during communication processing.
10002	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.
11001 ~ 11005	An internal processing error occurred. Please restart the system	This error occurs when there is any anomaly during hardware initialization.
20001	The system cannot open the file.	This error occurs when the file reading failed.
20002	Illegal file format. Please select correct file.	This error occurs when the file reading failed due to illegal file format.
21001	Failed to save the file.	This error occurs when the file saving failed.
22001	Abnormality was detected before completing the update.	This error occurs when an anomaly is detected before completion of the update.
22002	Update failed. Please retry the update.	This error occurs when an anomaly is detected before completion of the update.
30001	Please set a number.	This error occurs when a nonnumeric value is entered.
30002	Please set in the range xx - oo.	This error occurs when a value out of the range is entered.
30003	The data is invalid. Please set a maximum greater than the mimimum.	This error occurs when the minimum value is set to a value larger than the maximum value for the graph axis.
30005	(AC + DC) is beyond the range of setting. Please set (AC + | DC |) / (external amplifier gain) to 10V or less.	This error occurs when the sum of AC amplitude and DC bias exceeds 10 V.
30006	Can not log sweep. Do not set a range that includes zero.	This error occurs when you tries the log sweep in a range that includes zero.

Table7-1 Error message list (continued)

No.	Error Message	Description
30007	The specified scale is invalid.	This error occurs when you tried to set the Log scale for the time axis.
30008	Invalid operation during measurement or output on.	This error occurs when you tried to operate the [Selector] button during the measurement or with the output on.
31001	Please review your data or settings.	This error occurs when the measurement data is illegal.
32001	Please connect the USB memory.	This error occurs when you tried the import or export with no USB memory connected.
33001	Failed to operate the file.	This error occurs when the file operation failed.
34001	Ready to update. Restart the system.	This message is displayed when the system is ready for software update and restarting.
34002	The system cannot find the update file.	This error occurs when the update file was not detected.

Errors that occur during the external control (USBTMC) are not displayed on the monitor. They can be read using remote commands. See "ZGA5905 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 Electronic Instruments 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 Electronic Instruments to ask repair.
External control through USB cannot be done.	Wrong ProductID, VendorID, or SerialNo.	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 ZGA5905 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~+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

From the [Help] menu, click [About...] to view the version.

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 Electronic Instruments 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 - 10 V, 100 Hz - 10 kHz
  - DC voltage: Accuracy: ±0.1% 100 mV - 10 V
- Wideband multi-meter (the following measurement shall be possible):
  - AC voltage: Accuracy: ±0.5% 100 mV - 10 V, 100 kHz - 200 kHz
    Accuracy: ±1% for 100 mV - 10 V and 200 kHz - 1 MHz
    Accuracy: ±5% for 100 mV - 10 V and 1 MHz - 15 MHz
- Distortion meter: 0.1% or better for full-scale
- Others: BNC-BNC coaxial cable, T-type divider, and so on

8.5.2 Pretest preparations

a) Confirmation of test environment

Perform the test under the following conditions:

- Ambient temperature: +18 - +28 °C
- Ambient humidity: 25 - 75 %RH
- Power supply voltage: 90 - 132 VAC or 180 - 250 VAC

b) Confirmation of functions/operations

Check and confirm important functions, before the test, in an abbreviated manner according to **"2.4 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 ZGA5905 is specified on the basis of the status right after calibration.

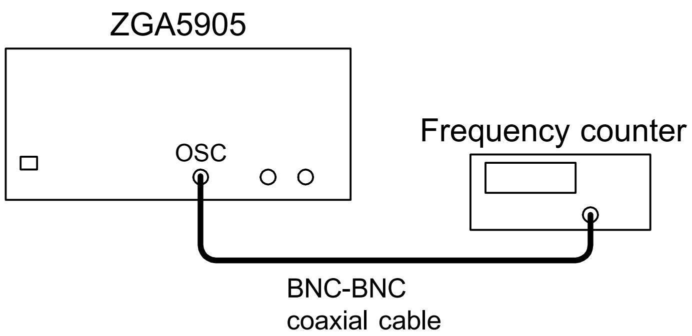
8.5.3 Oscillator output frequency accuracy

This section explains the testing on the oscillator output for output frequency accuracy.

a) Setting

ZGA5905		Frequency counter	
Output voltage		Gate time	10 sec.
AC	1 Vpk		
DC Bias	0 V		
Anytime ON status			

b) Connection



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 – 100.0010 kHz

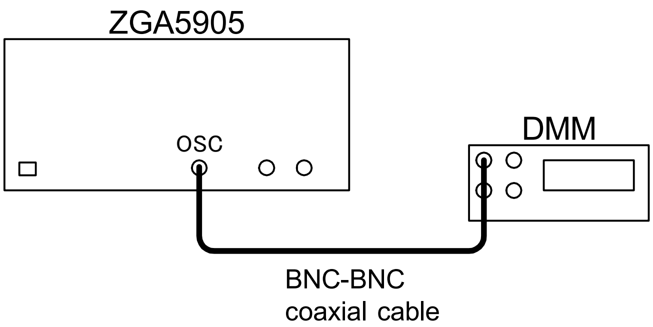
8.5.4 Oscillator output amplitude accuracy

This section explains the testing on the oscillator output for amplitude and frequency response.

a) Setting

ZGA5905		Multi-meter
Output voltage		Measurement mode AC voltage (True RMS)
AC	10 Vpk	
DC Bias	0 V	
Anytime ON status		

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: 1kHz, 100kHz, 1MHz, 15MHz

Derive the amplitude from the multi-meter indication by the following formula.

Amplitude accuracy (dB) = 20 x $\log_{10}$ [multi-meter indication (Vrms)] - 16.9897

d) Judgment

Oscillator output frequency	Multi-meter	Amplitude accuracy	Tolerance
1kHz	_________Vrms	_______dB	-0.30 – +0.30dB
100kHz	_________Vrms	_______dB	-0.30 – +0.30dB
1MHz	_________Vrms	_______dB	-1.00 – +1.00dB
15MHz	_________Vrms	_______dB	-3.00 – +3.00dB

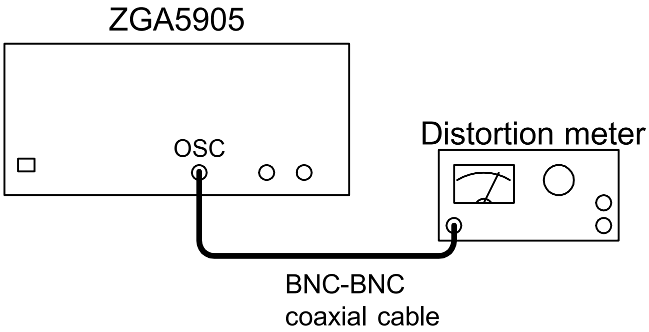
8.5.5 Oscillator distortion

This section explains the testing on the oscillator output for sine wave distortion rate.

a) Setting

ZGA5905		Distortion meter
Output wave voltage		Noise distortion (THD) measuring mode
AC	10 Vpk	
DC Bias	0 V	
Anytime ON status		

b) Connection



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

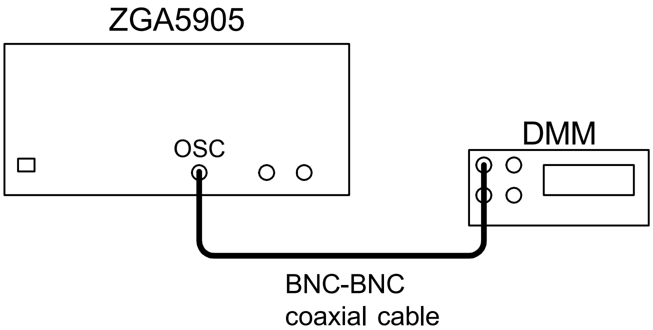
ZGA5905

Output voltage
  AC   0 Vpk
  Anytime ON status

Multi-meter

Measurement mode   DC voltage

b) Connection



c) Procedure

Set the oscillator output DC bias as follows and read the multi-meter indications.

Oscillator output DC bias: -10V, 0V,+10V

d) Judgment

Oscillator output DC Bias	Multi-meter	Tolerance
—10V	__________V	-10.130 – –9.870V
0V	__________V	-30.0 – +30.0mV
+10V	__________V	+9.870 – +10.130V

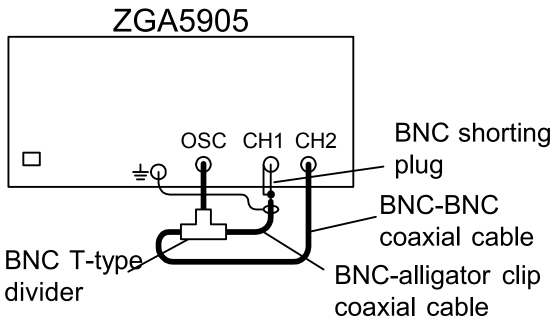
8.5.7 Analyzer IMRR

This section explains the testing on IMRR at 60 Hz.

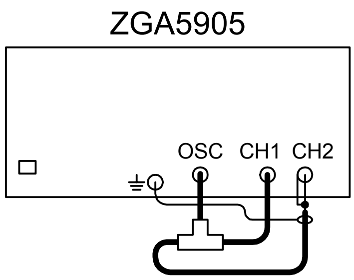
a) Setting

ZGA5905	
Measurement type	Gain-phase measurement
Measurement setting	
Number of integrations	100cycle
Sweep setting	Zero span, 100 points, 600s
Oscillator output section	
Frequency	60Hz
Output voltage	AC: 10 Vpk DC Bias: 0V

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 ZGA5905. 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

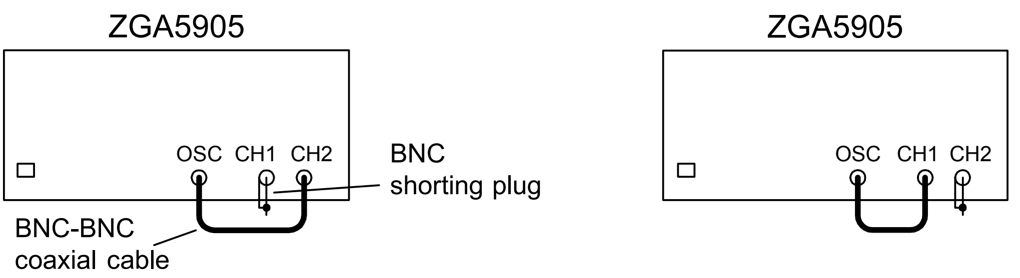
8.5.8 Analyzer dynamic range

This section explains the testing on the dynamic range.

a) Setting

ZGA5905	
Measurement type	Gain-phase measurement
Measurement setting	
Number of integrations	2,000cycle
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: 0V

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 ZGA5905.

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	140dB typ
CH2 (10 Hz to 1 MHz)	Gain =_______dB	140dB typ
CH1 (1 MHz to 15 MHz)	Gain =_______dB	80dB typ
CH2 (1 MHz to 15 MHz)	Gain =_______dB	80dB typ

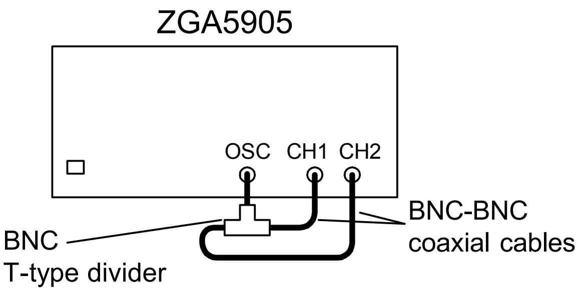
8.5.9 Analyzer measureing error frequency response

This section explains the testing on the frequency dependence of CH1/CH2 measured values at 100 mVpk output.

a) Setting

ZGA5905	
Measurement type	Gain-phase measurement
Measurement setting	
Number of integrations	50cycle
Sweep setting	10 Hz to 15 MHz, 100 points/sweep, Log sweep
Oscillator output section	
Output voltage	AC: 100 mVpk DC Bias: 0V

b) Connection



c) Procedure

Use the ZGA5905 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 – 20 kHz	________dB	-0.05 – +0.05 dB
	________deg	-0.3 – +0.3 deg
20 kHz – 500 kHz	________dB	-0.1 – +0.1 dB
	________deg	-0.5 – +0.5 deg
500 kHz – 2.2 MHz	________dB	-1.0 – +1.0 dB
	________deg	-2.0 – +2.0 deg
2.2 MHz – 15 MHz	________dB	-2.0 – +2.0 dB
	________deg	-5.0 – +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 in Advanced mode)

- Piezoelectric material analysis function

Admittance characteristics measurement/display	Graphically displays the admittance and phase
Piezoelectric parameter extraction	Shows the characteristic frequency and piezoelectric parameter
Matching support	Shows the matching inductance
Simulation	Shows 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 shows in graphs 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 shows in graphs 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	Displays the mutual inductance characteristics in a graph
Coupling coefficient measurement/display	Displays the coupling coefficient characteristics
Turn ratio measurement/display	Displays the frequency characteristics of the primary-to-secondary turn 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

(Measurement and analysis functions in Basic mode)

- 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

- Basic accuracy of gain-phase measurement

Gain display range: 1E-18 to 999.999E+15 and 0, up to 6 digits
-999.999 to +999.999dB with 0.001dB resolution
Phase display range: -9,999.999 to +9,999.999deg with 0.001deg resolution
Measurement accuracy of main unit alone, without signal cables
(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)

	≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
Amplitude ratio	±0.5% (±0.05dB)	±1% (±0.1dB)	±10% (±1dB)	±25% (±2dB)
Phase difference	±0.3deg	±0.5deg	±2deg	±5deg

- Measurement accuracy

This section describes the accuracy of measurement results obtained in each measurement type screen. "Typical value (theoretical value)" means the accuracy estimated from the basic gain-phase measurement accuracy.
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)
tanδx: tanδ (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 - typical value (theoretical value)

- Admittance |Y|[S]
- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- Conductance G[S] (when |θx| > 5 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- Susceptance B[S] (when |θx| < 85 deg)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Phase θ [deg]

  Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

○ Dielectric measurement accuracy - typical value (theoretical value)

- Parallel capacitance Cp[F] (when |θx| ≥ 85 deg)
- Parallel resistance Rp [Ω] (when |θx| ≤ 5 deg)
- Relative dielectric permittivity εs
- Real part of relative dielectric permittivity εs' (when |tanδx| ≤ 0.1)
- Imaginary part of relative dielectric permittivity εs'' (when |tanδx| ≥ 10)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- Parallel capacitance Cp[F] (when |θx| < 85 deg)
- Real part of relative dielectric permittivity εs' (when |tanδx| > 0.1)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Parallel resistance Rp [Ω] (when |θx| > 5 deg)
- Imaginary part of relative dielectric permittivity εs'' (when |tanδx| < 10)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- Dissipation factor of relative dielectric permittivity tanδ (when |tanδx| < 0.1)

  Display range: ±(0.000001 to 99,999.9) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.005	±0.01	±0.1	±0.25

* Accuracy of the value itself, not the percent (%).

○Magnetic measurement accuracy - typical value (theoretical value)

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.005	±0.01	±0.1	±0.25

* Accuracy of the value itself, not the percent (%).

○ Inductor measurement accuracy - typical value (theoretical value)

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- Phase θ [deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

- Quality factor Q

Display range: ±(0.000001 to 99,999.9) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.0052Qx^2}{1-0.0052Qx}$	$\pm\frac{0.0087Qx^2}{1-0.0087Qx}$	$\pm\frac{0.035Qx^2}{1-0.035Qx}$	$\pm\frac{0.087Qx^2}{1-0.087Qx}$

* Accuracy of the value itself, not the percent (%).

○ Capacitor measurement accuracy - typical value (theoretical value)

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- Phase θ [deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

- Quality factor Q

Display range: ±(0.000001 to 99,999.9) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.0052Qx^2}{1-0.0052Qx}$	$\pm\frac{0.0087Qx^2}{1-0.0087Qx}$	$\pm\frac{0.035Qx^2}{1-0.035Qx}$	$\pm\frac{0.087Qx^2}{1-0.087Qx}$

* 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.005	±0.01	±0.1	±0.25

* Accuracy of the value itself, not the percent (%).

○ Resistor measurement accuracy - typical value (theoretical value)

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- Resistance R[Ω] (when |θx| > 5 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- Reactance X[Ω] (when |θx| < 85 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Phase θ [deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

○ Transformer leakage inductance measurement accuracy - typical value (theoretical value)

- Leakage inductance Lleak[H] (when |θx| ≥ 85 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- Leakage inductance Lleak[H] (when |θx| < 85 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

○ Transformer mutual inductance measurement accuracy - typical value (theoretical value)

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Mutual inductance M[H]

  When (Inductance at aiding connection) > (inductance at opposing connection x 10)

  Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

○ Transformer coupling coefficient measurement accuracy - typical value (theoretical value)

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Coupling coefficient k

  Display range: 0.000 to 1.000 with 0.001 resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.01(1—kx)%	±0.02(1—kx)%	±0.2(1—kx)%	±0.5(1—kx)%

○ Transformer turn ratio measurement accuracy

Display range: 0.0001 to 9,999, up to 4 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

○ (Varactor) Diode measurement accuracy - typical value (theoretical value)

- Parallel capacitance Cp[F] (when Qx ≥ 10)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- Parallel capacitance Cp[F] (when Qx < 10)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Quality factor Q

Display range: ±(0.000001 to 99,999.9) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.0052Qx^2}{1-0.0052Qx}$	$\pm\frac{0.0087Qx^2}{1-0.0087Qx}$	$\pm\frac{0.035Qx^2}{1-0.035Qx}$	$\pm\frac{0.087Qx^2}{1-0.087Qx}$

○ Servo characteristics measurement accuracy - typical value (theoretical value)

- Loop gain Gloop[dB]
- Feedback gain Gfbk[dB]
- Closed loop gain Gclose[dB]

Display range: -999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

- Real part of loop gain Real(Gloop) (when |θx| ≤ 5 deg or 175 deg ≤ |θx|)
- Imaginary part of loop gain Imag(Gloop) (when 85 deg ≤ |θx| ≤ 95 deg)
- Real part of feedback gain Real(Gfbk) (when |θx| ≤ 5 deg or 175 deg ≤ |θx|)
- Imaginary part of feedback gain Imag(Gfbk) (when 85 deg ≤ |θx| ≤ 95 deg)
- Real part of closed loop gain Real(Gclose) (when |θx| ≤ 5 deg or 175 deg ≤ |θx|)
- Imaginary part of closed loop gain Imag(Gclose) (when 85 deg ≤ |θx| ≤ 95 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- Real part of loop gain Real(Gloop) (when 5 deg < |θx| < 175 deg)
- Real part of feedback gain Real(Gfbk) (when 5 deg < |θx| < 175 deg)
- Real part of closed loop gain Real(Gclose) (when 5 deg < |θx| < 175 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- Imaginary part of loop gain Imag(Gloop) (when |θx| < 85 deg or 95 deg < |θx|)
- Imaginary part of feedback gain Imag(Gfbk) (when |θx| < 85 deg or 95 deg < |θx|)
- Imaginary part of closed loop gain Imag(Gclose) (when |θx| < 85 deg or 95 deg < |θx|)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Phase θ [deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

○ Amplifier circuit gain-phase characteristics measurement accuracy

- Gain　Gain[dB]

  Display range:　-999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

- Phase　θ [deg]

  Display range:　-9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

- Group delay　GD[s]

  Display range:　±(1E-15 to 9.99999E+03) s and 0 s, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{1}{1200\times APT}$ s	$\pm\frac{1}{720\times APT}$ s	$\pm\frac{1}{180\times APT}$ s	$\pm\frac{1}{72\times APT}$ s

* APT: Aperture setting (Δf[Hz])

○ Amplifier circuit CMRR characteristics measurement accuracy - typical value (theoretical value)

- Common-mode gain　GainCOM[dB], Normal-mode gain　GainNORM[dB]

  Display range:　-999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

- Phase　θ [deg]

  Display range:　-9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

- CMRR[dB]　(When normal-mode gain are measured)

  Display range:　-999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.1dB	±0.2dB	±2dB	±4dB

- CMRR[dB]　(When normal-mode gain are setting constant)

  Display range:　-999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

○ Amplifier circuit PSRR characteristics measurement accuracy - typical value (theoretical value)

Display range: -999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

○ Amplifier circuit differential gain/phase characteristics measurement accuracy - typical value (theoretical value)

- Differential gain DG[dB]

Display range: -999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

- Differential phase DP[deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

○ Amplifier circuit saturation characteristics measurement accuracy - typical value (theoretical value)

Display range: -999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.1dB	±0.2dB	±2dB	±4dB

○ Filter circuit measurement accuracy

- Gain Gain[dB]

Display range: -999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

- Phase θ [deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

- Group delay GD[s]

Display range: ±(1E-15 to 9.99999E+03) s and 0 s, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{1}{1200 \times APT}$ s	$\pm\frac{1}{720 \times APT}$ s	$\pm\frac{1}{180 \times APT}$ s	$\pm\frac{1}{72 \times APT}$ s

* APT: Aperture setting (Δf[Hz])

○ Impedance measurement accuracy - typical value (theoretical value)

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- 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

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Phase θ [deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

○ Gain-phase measurement accuracy

- Gain [dB]

Display range: -999.999 to +999.999dB with 0.001dB resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.05dB	±0.1dB	±1dB	±2dB

- Real part of gain A (when |θx| ≤ 5 deg or 175 deg ≤ |θx|)
- Imaginary part of gain B (when 85 deg ≤ |θx| ≤ 95 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.5%	±1%	±10%	±25%

- Real part of gain A (when 5 deg < |θx| < 175 deg)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\cos\theta x}$ %	$\pm\frac{1}{\cos\theta x}$ %	$\pm\frac{10}{\cos\theta x}$ %	$\pm\frac{25}{\cos\theta x}$ %

- Imaginary part of gain B (when |θx| < 85 deg or 95 deg < |θx|)

Display range: ±(1E-18 to 999.999E+15) and 0, up to 6 digits

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
$\pm\frac{0.5}{\sin\theta x}$ %	$\pm\frac{1}{\sin\theta x}$ %	$\pm\frac{10}{\sin\theta x}$ %	$\pm\frac{25}{\sin\theta x}$ %

- Phase θ [deg]

Display range: -9,999.999 to +9,999.999deg with 0.001deg resolution

≤20kHz	≤500kHz	≤2.2MHz	>2.2MHz
±0.3deg	±0.5deg	±2deg	±5deg

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 10ms
  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°
  Set resolution 3 digits or 0.01°, either of whichever are greater

- 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 system-check and self error compensation in the instrument. It is automatically executed at power-on. Enabled to be executed at any point during operation. (Normal 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 ±5pF (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
- Measurement category I. 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 Vpk (AC+DC)
  A voltage when a supplied BNC cable is used
  30 Vrms (AC), ±60 V (DC), or ±42 Vpk (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
- Excessive level detection(over-detection)
  Detected voltage 250Vrms
  Actions taken Over lamp ON
- 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 Vpk, integration: 4,000 cycles)
- Input weighting 0 to 1.0E + 6 (resolution: 5-digit or 0.01E-9)
  Phase invert is possible.

Specifications for isolation withstand voltage between the oscillator (OSC) or analysis input (CH1 and CH2) and the cabinet with the supplied BNC cable used are presented below (figure 9-1).

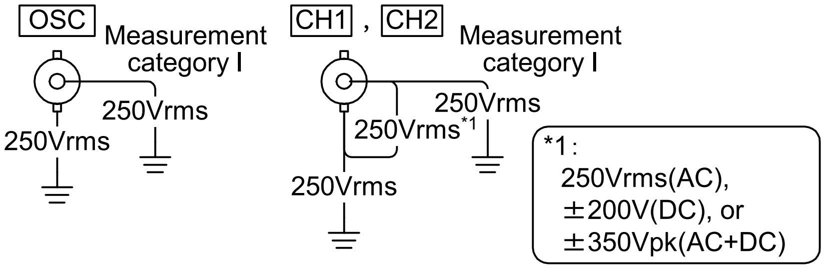


Figure 9-1 Specifications for Isolation Withstand Voltage (with supplied BNC cable used)

Figure 9-2 shows isolation withstand voltage specifications when other cable is used.

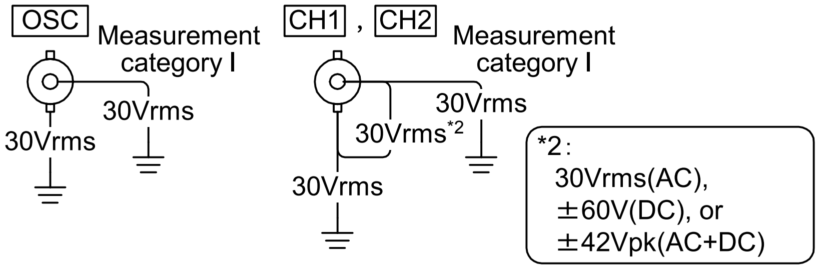


Figure 9-2 Specifications for Isolation Withstand Voltage (with other cable used)

Specifications for isolation withstand voltage between the oscillator (OSC) and analysis input (CH1 and CH2) with the supplied BNC cable used are presented in figure 9-3).

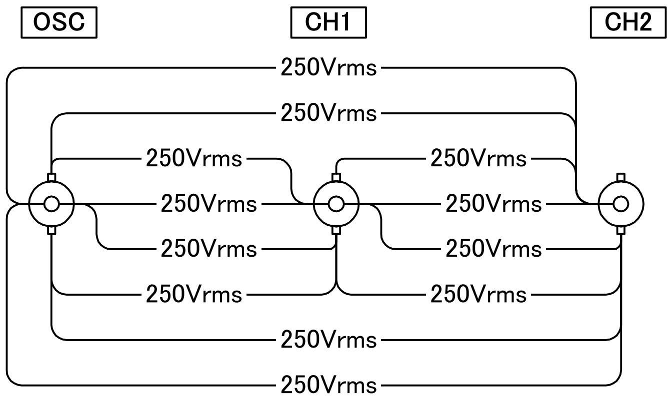


Figure 9-3 Specifications for Isolation Withstand Voltage between Oscillator and Analysis Input (with supplied BNC cable used)

Figure 9-4 shows isolation withstand voltage specifications between the oscillator (OSC) and analysis input (CH1 and CH2) when other cable is used.

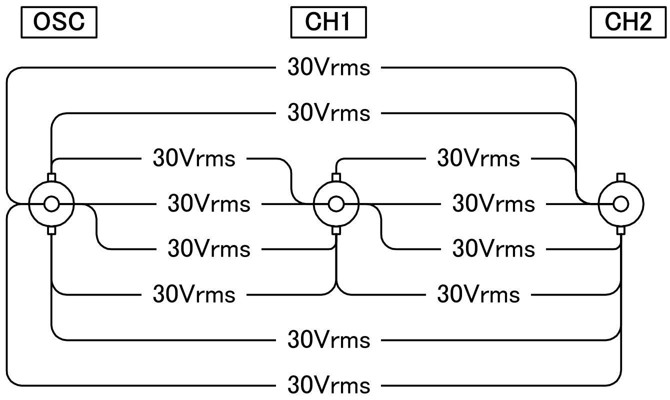


Figure 9-4 Specifications for Isolation Withstand Voltage between Oscillator and Analysis Input (with other cable used)

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 100kHz) Within ±1 dB (for no more than 1MHz) Within ±3 dB (for no more than 15MHz) (A value obtained immediately after calibration with it being set at 100mVpk 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 (time) sweep

Range	1.00 s to 21,474,836.00 s (approximately 240 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

- Measurement category: I. Maximum transient overvoltage: 1,500 Vrms

9.6 Display

- Monitor 1,280 x 1,024 dot, 19 inch
- Measurement 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	±999.999dB with 0.001dB resolution
Phase	-9,999.999 to +9,999.999deg with 0.001deg 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
Nr (transformer turn 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

- Status display

  Lamps that indicate states of this instrument.

  Displayed item

MEASURE	It is lit on during measurement
CALIBRATION	It is lit on during calibration
ERROR	It is lit on when an error occurs
ACCESS	It is lit on while accessing the internal drive
POWER	It is lit on during power-on
ON	It is lit on during oscillator output
OVER(1)	It is lit on while an excess voltage is inputting to the CH1
OVER(2)	It is lit on while an excess voltage is inputting to the CH2

9.7 Print output

This function prints a report or graph on a printer. It requires the included printer.

- Format ink-jet (color)
- Supported paper A4 plain paper
- Printed item

Report output	Prints the measurement result, condition, and record
Graph output	Prints only the graph area (equivalent to a screen hardcopy)

9.8 Internal strage

The internal storage (memory) of this instrument stores data, setting information, and so on.

● Measurement data	Data obtained from a measurement or simulation It can be saved by user operations Memory size: over 100 pieces of data
● Setting information	Various setting information of this instrument It can be saved by user operations Memory size: over 100 pieces of data
● Correction data	Data for correcting measurement system errors It is lost by power-off Memory size: one set for each
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

9.9 External strage

● External memory	USB 1.1 or USB 2.0 compliant USB memory
● Connector	Front panel, USB-A connector
● File system	FAT32
● 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
Meas condition	Measurer, location, temperature, humidity, atmospheric pressure, list of used instruments (entered by user)
• Graph output (hardcopy of graph area)	
File format	BMP format
• Measurement data	
File format	CSV format
• Transfer function	
File format	TXT format

9.10 Peripheral input/output functions

- USB(host)
  Connected with a keyboard, printer, trackball, USB memory (sold separately)

Standard	USB2.0
Number of ports	4 (2 on the front panel, 2 on the rear panel)
Connector	USB-A connector

- USB(function)
  Connected when this instrument is controlled through an external PC

Standard	USB1.1
Number of ports	1
Connector	Rear panel, USB-B connector
Device class	TMC

  There are following functional restrictions in the external 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 output section" are not available. Limited only to the frequency sweep.
  - Only the gain and phase can be read in "●Measurement data display in 9.6 Display."
- 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 ZGA5905 main unit. Do not connect anything.

Connector	Rear panel, MAINTENANCE1 and MAINTENANCE2

9.11 Miscellaneous specifications

(System common specifications)

- Power input * Check for the power input specification when you order this instrument.
  - Voltage AC90V~132V/180V~250V
  - Frequency 50Hz/60Hz ±2Hz
  - Overvoltage category II
- Environmental conditions
  - Ambient temperature/humidity range (excluding printer)
    - 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
  - Altitude 2,000 m or lower
- Safety standard EN 61010-1:2001
- EMC EN 61326-1:2006
  EN 61000-3-2:2006
  EN 61000-3-3:2008

(ZGA5905 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 500Vdc, between power inputs altogether and the enclosure)
- Withstand voltage 1500 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)

- Power consumption Maximum 45 W
- External dimensions 405(W) × 416(H) × 205(D)mm
- Weight About 6 kg

(Printer unit specifications)

- Power consumption — Maximum 40 W
- Operating temperature/humidity range — +15 to +30 °C, 15 to 90 %RH (no condensation)
- External dimensions — 340(W) × 81(H) × 164(D)mm
- Weight — About 2.1 kg

(Keyboard unit specifications)

- Power source — Supplied from the ZGA5905 main unit USB port
- External dimensions — 338(W) × 37(H) × 251(D)mm
- Weight — About 610 g

(Trackball unit specifications)

- Power source — Supplied from the ZGA5905 main unit USB port
- External dimensions — 87(W) × 43(H) × 166(D)mm
- Weight — About 200 g

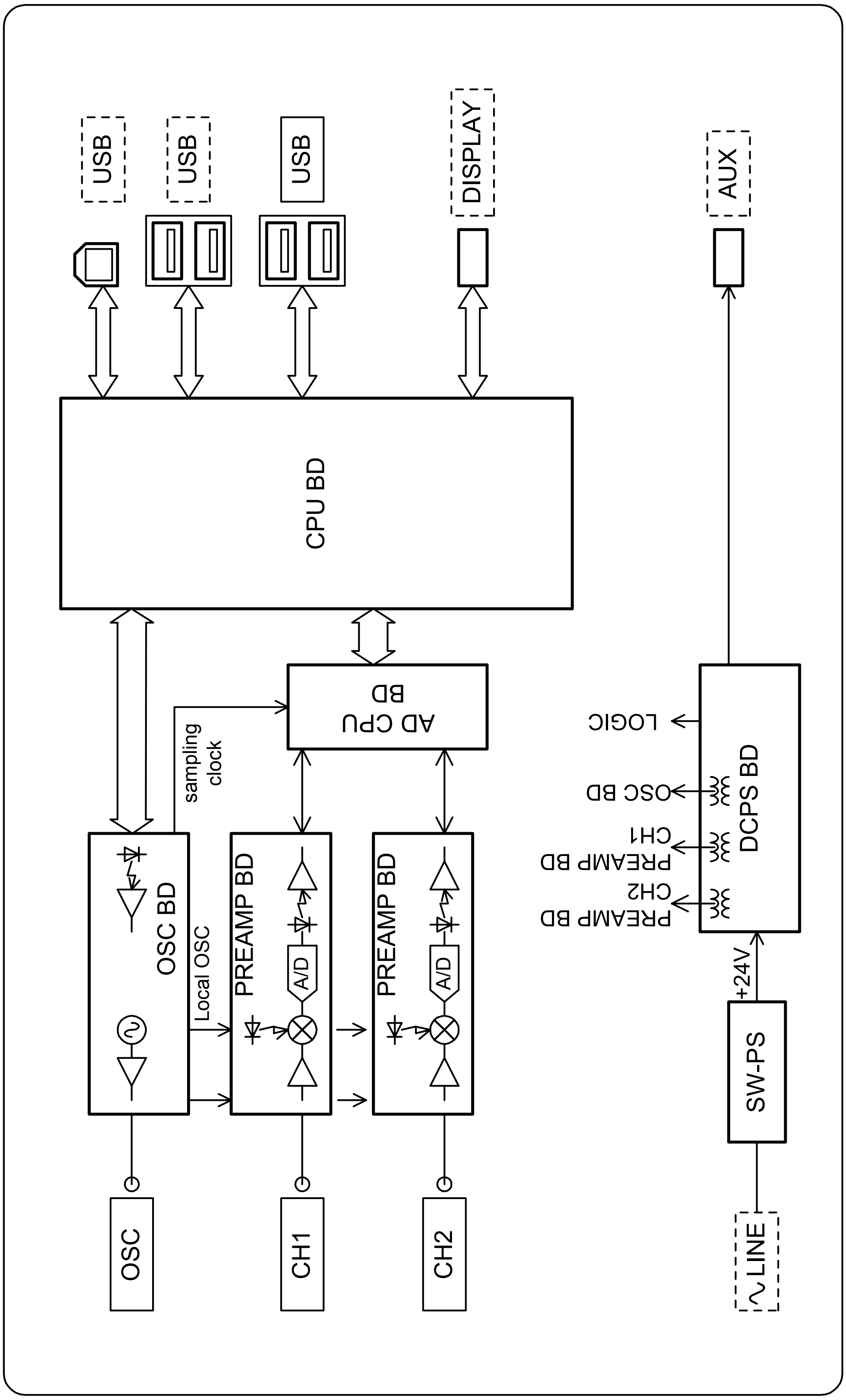
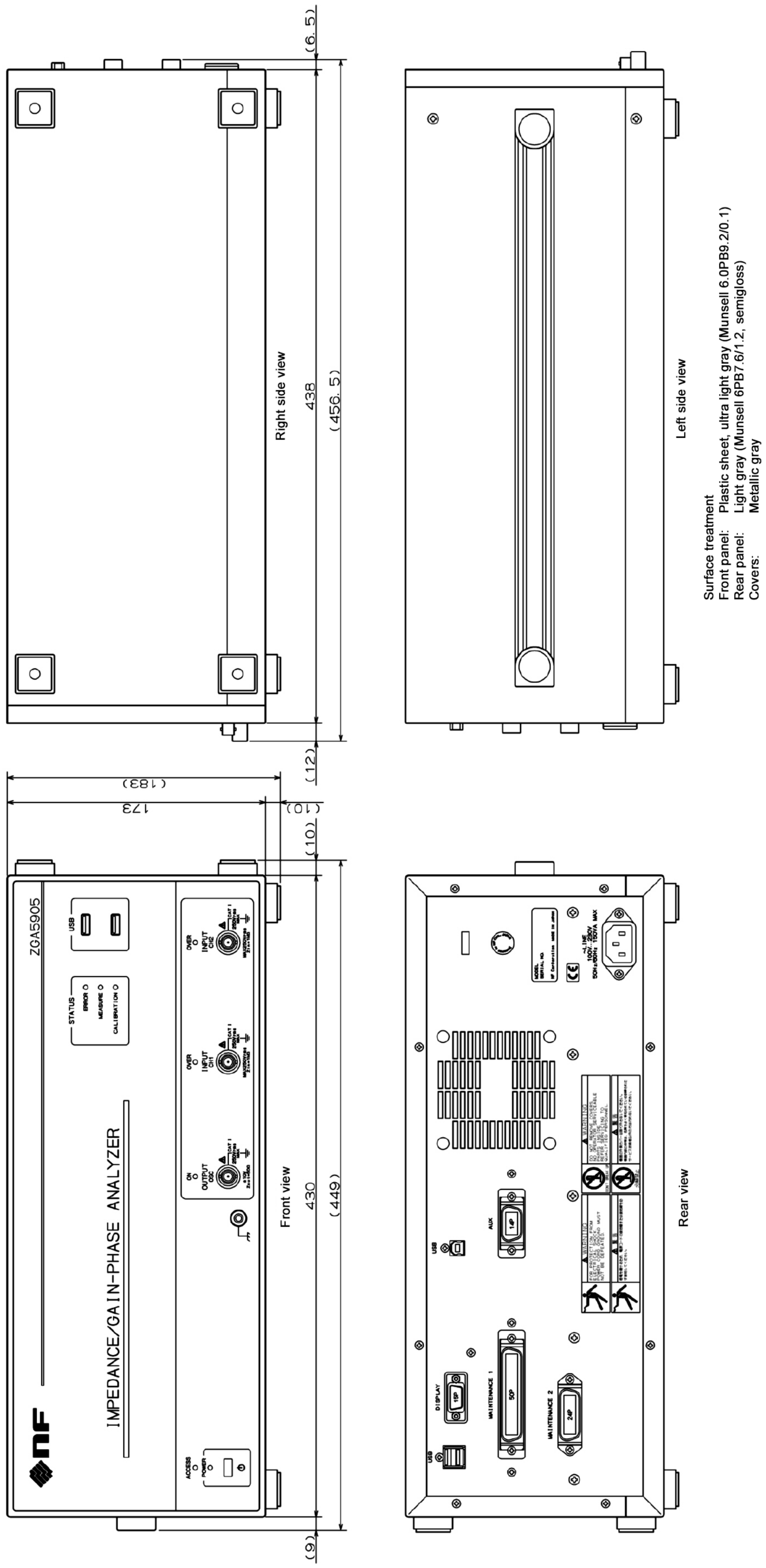


Figure 9-5 Block Diagram (Main unit)



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.

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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.

ZGA5905 Instruction Manual

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