HIOKI

RM2610

Instruction Manual

ELECTRODE RESISTANCE MEASUREMENT SYSTEM

Video

Scan this code to watch the instructional video(s).
Carrier charges may apply.

Be sure to read this manual before using the instrument. ▶ p.6

When using the instrument for the first time

Troubleshooting

EN

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RM2612A961-02 21-10H

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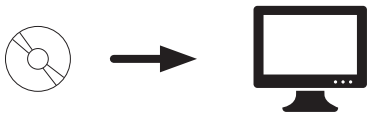
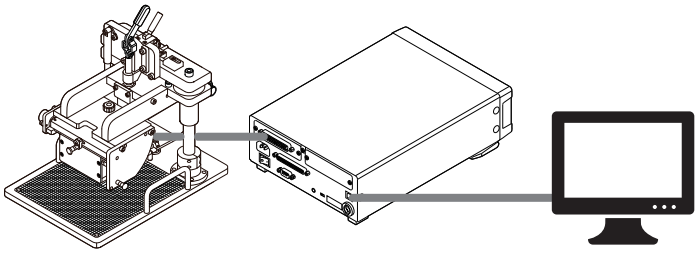
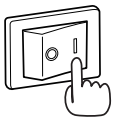


Connecting the equipment (p.24)

- Connect the RM2611 Electrode Resistance Meter to the RM9004 Test Fixture with the RM9005 Connection Cable.
- Connect the RM2611 Electrode Resistance Meter to the computer with a USB cable.



- Turn on the RM2611 Electrode Resistance Meter.



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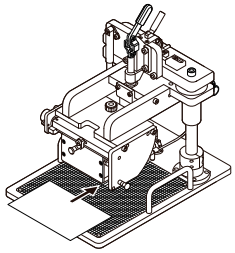

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Complete measurement and turn off the system.

Introduction

Thank you for choosing the Hioki RM2610 Electrode Resistance Measurement System. Preserve this manual carefully and keep it handy to make full use of this product for a long time. Familiarize yourself with the separate document entitled “Operating Precautions” before using the product.

Following manuals are available for the instrument. See manuals relevant to your purpose.

Name	Manual contents	Availability
RM2610 Probe Maintenance Guide*	Information about the proper probe maintenance procedures for obtaining correct measurement results	Downloadable edition
Operating Precautions	Information to ensure safe use of the product	Printed edition (0990A905)
RM2611 Electrode Resistance Meter Instruction Manual	Information about the RM2611 Electrode Resistance Measurement Meter	Printed edition (RM2611A961)
RM2610 Electrode Resistance Measurement System Instruction Manual (this manual)	Information about RM2611 Electrode Resistance Meter and RM2612 Resistance Calculation Software functionality, settings, specifications, etc.	Printed edition (RM2612A961)
RM9003 Press Unit Instruction Manual	Information about the RM9003 Press Unit	Printed edition (RM9003A961)
RM9004 Test Fixture Instruction Manual	Information about the RM9004 Test Fixture	Printed edition (RM9004A961)
RM9005 Connection Cable Instruction Manual	Information about the RM9005 Connection Cable	Printed edition (RM9005A960)

*: Carefully read the guide before use. The guide can be downloaded from Hioki’s website. (p.19)

Latest edition of instruction manual

The contents of this manual are subject to change, for example as a result of product improvements or changes to specifications.
The latest edition can be downloaded from Hioki’s website.
https://www.hioki.com/global/support/download

Intended audience

This instruction manual has been written for use by individuals who use the product or provide information about how to use the product. In explaining how to use the product, it assumes electrical knowledge (equivalent of the knowledge possessed by a graduate of an electrical program at a technical high school).

Trademarks

- Microsoft and Excel are either registered trademarks or trademarks of Microsoft Corporation in the United States and other countries.
- Intel is the trademark of Intel Corporation or its subsidiaries in the U.S. and/or other countries.
- Other products and company names are trade names, registered trademarks, or trademarks of their respective owners.

License agreement

The product ships with the RM2612 Resistance Calculation Software. Use of the software indicates acceptance of the terms of the license agreement found at the end of this manual.

About the Notations Used in This Manual

Safety notations

This manual classifies seriousness of risks and hazard levels as described below.

⚠ DANGER	Indicates an imminently hazardous situation that will result in death of or serious injury to the operator.
⚠ WARNING	Indicates a potentially hazardous situation that may result in death of or serious injury to the operator.
⚠ CAUTION	Indicates a potentially hazardous situation that may result in minor or moderate injury to the operator or damage to the product or malfunction.
IMPORTANT	Indicates information or content that is particularly important from the standpoint of operating or maintaining the product.
Tips	Indicates useful advice concerning product performance and operation.
	Indicates a high-voltage hazard. Failure to verify safety or improper handling of the product could lead to an electric shock, burns, or death.
	Indicates an action that must not be performed.
	Indicates an action that must be performed.

Symbols on equipment

	Indicates the need for caution or the presence of danger. For more information about locations where this symbol appears on product components, see “Operating Precautions” (p.6), warning messages listed at the beginning of operating instructions, and the document entitled “Operating Precautions” that comes with the RM2611 Electrode Resistance Meter.

Other symbols

*	Instructs the reader to see below for additional information.
☑	Indicates the default setting. When initialized, the product will revert to this value.
(p.)	Indicates the page number to reference.
START (Bold)	The names of user interface elements on the screen are printed in **bold** or enclosed in **brackets**.
[ ]	
Windows	Unless otherwise noted, the term “Windows” is used to refer to Windows 7, Windows 8, and Windows 10.

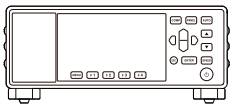
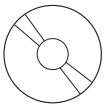
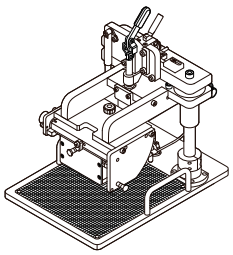
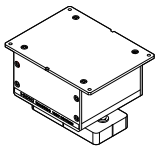
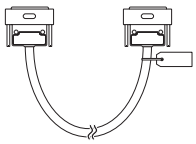
Accuracy notations

Hioki defines measurement tolerances in terms of f.s. (full scale), rdg. (reading), dgt. (digit), and setting values, as indicated below.

f.s.	(Maximum display value) The maximum displayable value or scale length. This is usually the name of the currently selected range.
rdg.	(Reading or displayed value) The value currently being measured and indicated on a measuring instrument.
dgt.	(Resolution) The smallest displayable unit on a digital measuring instrument, i.e., the input value that causes the digital display to show a “1” as the least-significant digit.
setting	(Setting) Indicates the value set as the output voltage, current, or other quantity.

Product Components

The RM2610 Electrode Resistance Measurement system (“the product”) consists of the components in the table below. To purchase an option*1, please contact your authorized Hioki distributor or reseller.

	Product	Description	Accessories
☐	RM2611 Electrode Resistance Meter 	Potential measurement (Calculated based on resistance values)	• Instruction manual*2 • Operating Precautions (0990A905) • Power cord • USB cable • Z2001 Temperature Sensor
☐	RM2612 Resistance Calculation Software*1 	Measurement and control software	• Instruction manual (this manual)*2 • PC application CD*3 • USB license key
☐	RM9003 Press Unit*1 	Measurement (The RM9003 Press Unit is used to connect the RM9004 Test Fixture.)	• Instruction manual*2 • Quick manual
☐	RM9004 Test Fixture*1 	Measurement (The RM9004 Test Fixture is connected to the RM2611 Electrode Resistance Meter in order to measure the composite layer resistivity and interface resistance of lithium-ion battery electrode sheets.)	• Instruction manual*2 • Test fixture case • Mounting screws ×4 • Probe inspection board
☐	RM9005 Connection Cable*1 	Connection	• Instruction manual*2

*1 Options are subject to change. Please check Hioki’s website for the latest information.

*2 The latest version of each instruction manual can be downloaded from Hioki’s website.

*3 The PC application software can be updated to the latest version (p. 110).

Operating Precautions

Familiarize yourself with the separate document entitled “Operating Precautions” before using the product and to observe the following precautionary information to ensure that the product can be used safely and in a manner that allows it to perform as described in its specifications. Use of the product should conform not only to its specifications, but also to the specifications of all accessories, options, and other equipment in use.

Installing the product

⚠ CAUTION

Do not place the product on an unstable or uneven surface. Doing so could cause the product to fall or turn over, causing bodily injury or damage to the product.

This product may cause interference if used in residential areas. Such use must be avoided unless the user takes special measures to reduce electromagnetic emissions to prevent interference to the reception of radio and television broadcasts.

Shipping precautions

Use the original product packaging when shipping the product. Store the packaging material after opening the product.

⚠ CAUTION

To avoid damage to the product, avoid subjecting it to vibration or mechanical shock during transport and handling. Exercise particular care to avoid subjecting the product to mechanical shock, for example by dropping it.

Precautions related to use of the PC application CD

- Exercise care to keep the disc’s recording surface free of dirt and scratches. When writing text and other information on the label surface, use a writing implement with a soft tip.
- Place the disc in a protective case and avoid exposure to direct sunlight as well as high temperature and humidity.
- Hioki is not liable for any computer system issues arising from, or accompanying, use of this disc.

RM9004 Test Fixture (option)

⚠ CAUTION

- Do not touch the tips of the probes. When an object other than the measurement target comes into contact with probes, they may be damaged.
- To avoid damaging the probes, always use the RM9004 Test Fixture in combination with the RM9003 Press Unit. Use of the fixture without the RM9003 Press Unit is considered outside the scope of the product warranty.

IMPORTANT

- Always use the test fixture case when storing or transporting the test fixture.
- Electrode sheets that have been measured by the instrument cannot be used in production batteries due to pressure marks left by the probes. Hioki is not liable for use of electrode sheets after measurement.

1 Overview

1.1 Product Overview and Features

The product comprises an electrode resistance measurement system that measures the composite layer volume resistivity and interface resistance of electrode sheets used in lithium-ion batteries. Its principal applications are research, development, and quality control.

New indicators for LIB electrode sheets: Quantifying composite layer resistivity and interface (contact) resistance

The product isolates and quantifies composite layer resistivity and interface resistance for LIB electrode sheets. This information can be used in the evaluation of batteries in R&D and quality control to speed up the development process.

Easy-to-understand display and simple measurement method

Simply move the cursor to a parameter to display guidance such as an explanation of the parameter and the applicable input range. Additionally, you can isolate and calculate composite layer resistance and interface resistance simply by placing the probes in contact with the surface of an electrode sheet and making measurements.

Improved work efficiency (automatic start function)

The instrument detects when the probes make contact with the sample and starts measurement, eliminating the need to click **[Start]**. (This function is disabled by default.)

High level of safety

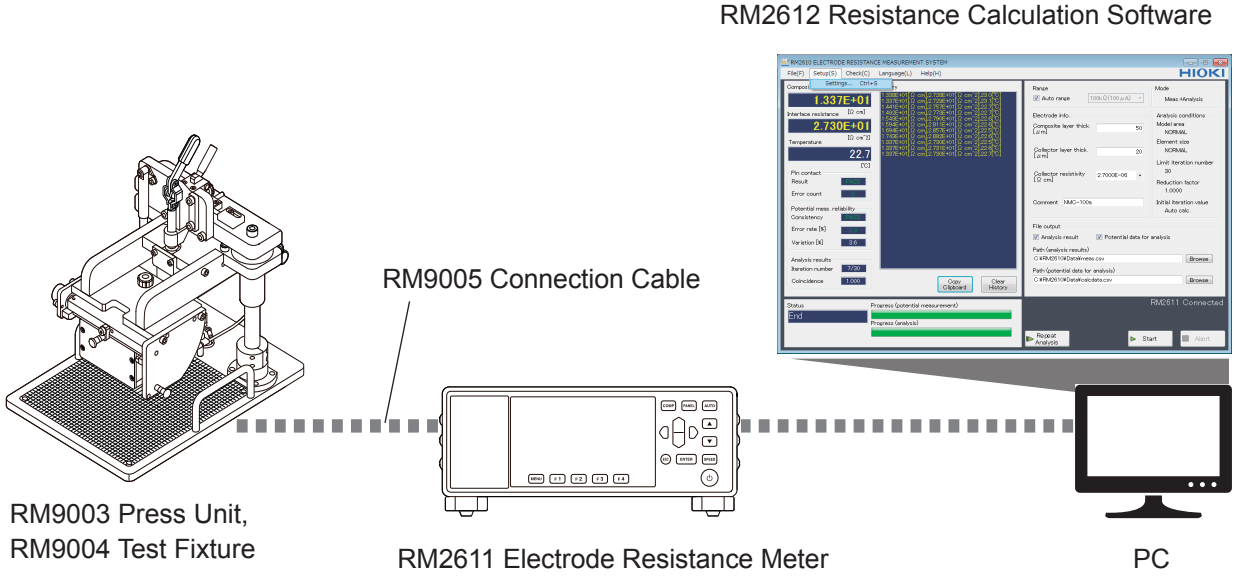
To prevent malfunctions caused by unintended operation, the RM9003 Press Unit has a lock lever. Probes can be raised and lowered by pulling the lock lever forward.

Easy maintenance

Probes can easily be inspected and cleaned since the system is designed so that the tips of the probes can be rotated to face forward without removing the RM9004 Test Fixture from the RM9003 Press Unit.

1.2 Part Names and Functions

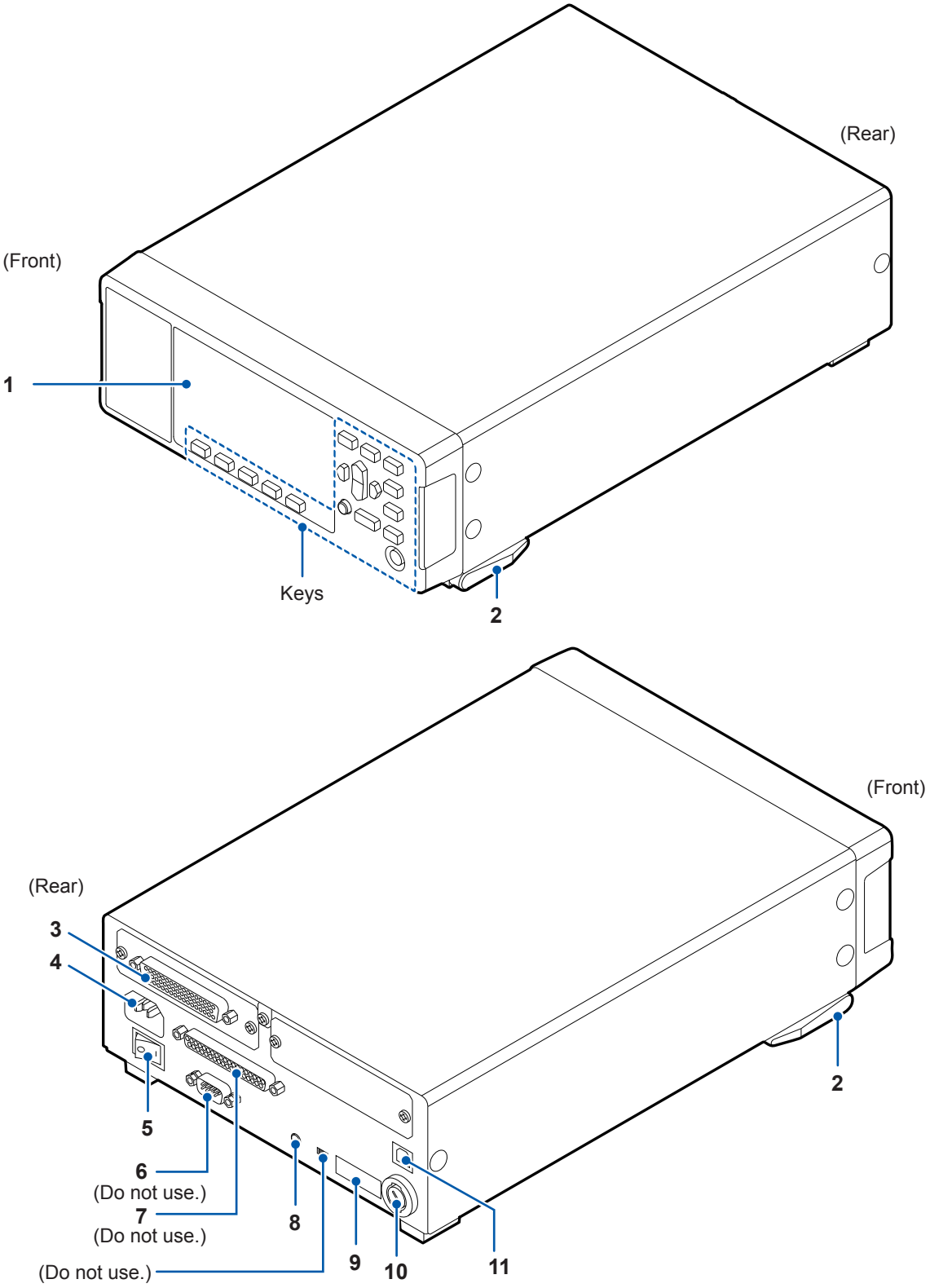
RM2610 Electrode Resistance Measurement System



RM2611 Electrode Resistance Meter

⚠ CAUTION

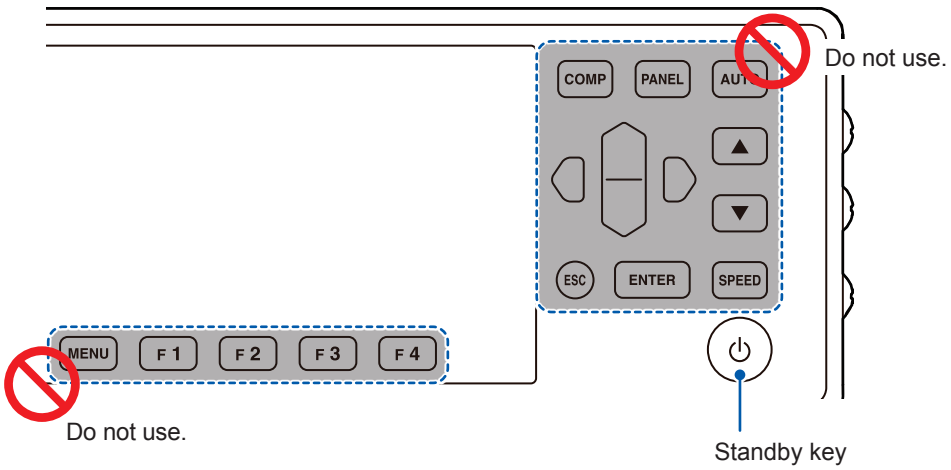
Do not connect anything to the maintenance ports (labeled "**6**" and "**7**" in the figure below). Connecting a cable to the maintenance ports could cause instrument malfunction or damage.



No.	Name	Description	See
1	Display	Displays the error number.	p.114
2	Stand	Tilts the RM2611 Electrode Resistance Meter so that the instrument's screen is easier to see.	–
3	Test fixture connector	Connect the RM9005 Connection Cable here.	p.25
4	Power inlet	Connect the included power cord here.	p.26
5	Main power switch	Turns the instrument on and off.	p.29
6	Maintenance port	Not used.	–
7	Maintenance port	Not used.	–
8	TEMP.SENSOR terminal	Connect the included Z2001 Temperature Sensor here.	p.28
9	Serial number	The 9-digit serial number indicates the year of manufacture (first two digits) and the month of manufacture (next two digits). Do not remove this sticker as the number is important.	–
10	Fuse holder	Holds the fuse that protects the measurement circuit. This is not a customer-replaceable part. Please contact your authorized Hioki distributor or reseller if you have an issue with the fuse.	–
11	USB port	Connects the RM2611 Electrode Resistance Meter to a PC.	p.27

Keys

IMPORTANT
Do not operate the keys on the RM2611 Electrode Resistance Measure (excerpt for the standby key).



Name	Description	See
Standby key	Toggles the RM2611 Electrode Resistance Meter's standby state. • No light: Power off (no power is being supplied) • Glowing red: Standby state (power is being supplied) • Glowing green: Power on	p.29

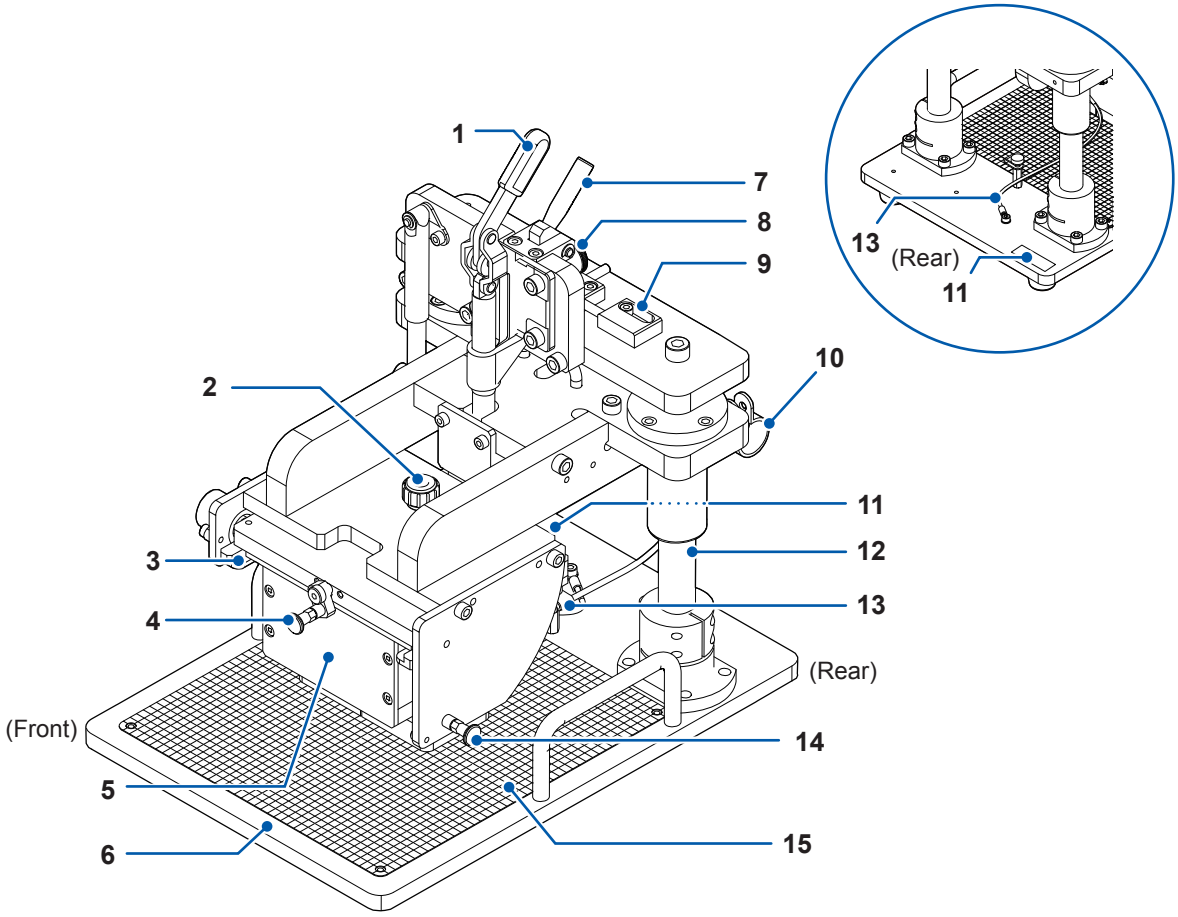
RM9003 Press Unit

⚠ CAUTION

To avoid equipment damage, turn off the RM2611 Electrode Resistance Meter before connecting or disconnecting the RM9005 Connection Cable.

IMPORTANT

- When connecting the RM9005 Connection Cable, insert the cable into the connector firmly and tighten it in place with screws. If the screws loosen, the resulting poor contact could cause a measurement error.
- The device ships with the up/down lever locked with the lock release lever clamp knob. Loosen the knob before using the device for the first time.

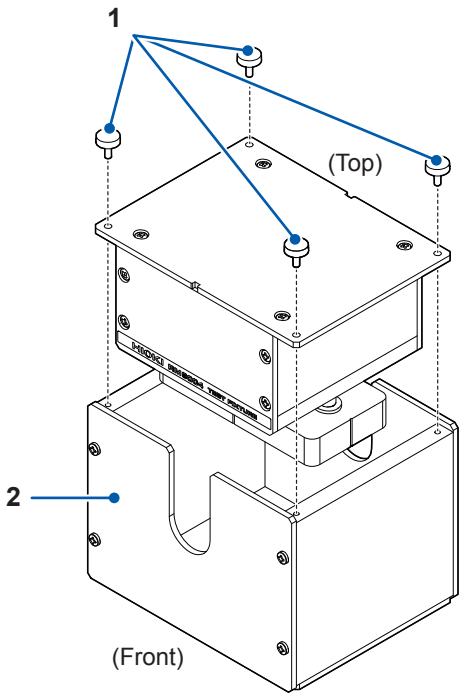


No.	Name	Description	See
1	Up/down lever	Raises and lowers the RM9004 Test Fixture.	–
2	Test fixture clamp knob	Rotates the RM9004 Test Fixture's probe toward the front. (The knob is used when cleaning the RM9004 Test Fixture.)	p.118
3	Test fixture insertion rail	Guides the RM9004 Test Fixture as it is inserted.	p.24
4	Test fixture lock lever	Clamps the RM9004 Test Fixture in place.	p.24 p.118
5	RM9004 Test Fixture	Places the probe in contact with the electrode sheet and measures the sheet.	p.14 p.45
6	Measurement stage	Accommodates the electrode sheet under measurement.	p.45
7	Lock release lever	Releases the RM9003 Press Unit's up/down lever. When lowering the RM9004 Test Fixture, pull the up/down lever towards you while pulling the lock release lever. The lock will engage automatically when the up/down lever is raised.	p.45
8	Lock release lever clamp knob	Tightening the lock release lever clamp knob locks the lock release lever in place so that it cannot be moved. (When transporting the product, tighten the lock release lever clamp knob after placing the up/down lever in the raised position.)	p.107
9	Lock disable pin	When this pin is enabled, the RM9004 Test Fixture can be raised and lowered using the up/down lever alone.	p.46
10	Clamp	Clamps the RM9005 Connection Cable.	p.25
11	Serial number	The 9-digit serial number indicates the year of manufacture (first two digits) and the month of manufacture (next two digits). Do not remove this sticker as the number is important.	–
12	Shaft	Supports the mechanism that moves the RM9004 Test Fixture up and down. Do not touch as the shaft is coated with lubricating oil.	–
13	Grounding cable	Connect the grounding cable to the RM9004 Test Fixture's ground terminal. It is recommended to connect the cable to the terminal in order to facilitate stable measurement.	p.24
14	Maintenance plunger	Locks the RM9004 Test Fixture in place. (The plunger is used when cleaning the RM9004 Test Fixture.)	p.118
15	Graduated plate	Indicates where to position electrode sheets. The probes will make contact at the intersection of the thick graduated lines.	p.45

RM9004 Test Fixture

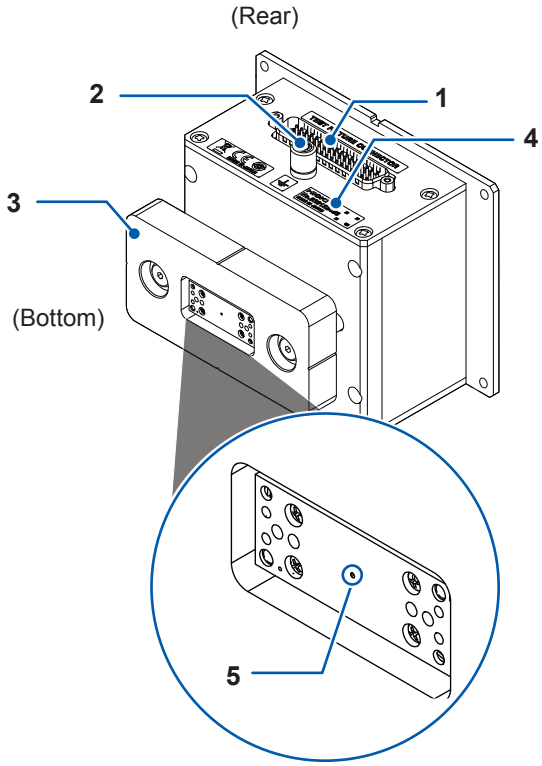
IMPORTANT
The RM9004 Test Fixture's probes are consumable parts. They require periodic replacement but are not customer-replaceable. Please contact your authorized Hioki distributor or reseller for more information.
It is recommended to purchase a spare RM9004 Test Fixture since the probe replacement process is time-consuming.

Front and top of the RM9004 Test Fixture



No.	Name	Description
1	Mounting screws ×4	Hold the RM9004 Test Fixture and the test fixture case together. When using the RM9004 Test Fixture, remove the mounting screw found at each of the four corners on top of the fixture and remove the RM9004 Test Fixture from its case.
2	Test fixture case	Used to store or transport the RM9004 Test Fixture.

Bottom and rear of the RM9004 Test Fixture



No.	Name	Description	See
1	Connector	Connect the RM9005 Connection Cable here.	p.25
2	Ground terminal	Connect the RM9003 Press Unit's grounding cable here. It is recommended to connect the cable to the terminal in order to facilitate stable measurement.	p.24
3	Probe guard	Protects the probes to prevent damage.	–
4	Serial number	The 9-digit serial number indicates the year of manufacture (first two digits) and the month of manufacture (next two digits). Do not remove this sticker as the number is important.	–
5	Probes	Make contact with, and measure, the measurement target. The probe layout is shown below. TP46 TP45 TP44 TP43 TP42 TP41 TP40 TP39 TP38 TP37 TP36 TP35 TP34 TP33 TP32 TP31 TP30 TP29 TP28 TP27 TP26 TP25 TP24 TP23 TP22 TP21 TP20 TP19 TP18 TP17 TP16 TP15 TP14 TP13 TP12 TP11 TP10 TP9 TP8 TP7 TP5 TP4 TP3 TP2 TP1 TP6	–

1.3 USB License Key and Screens (RM2612 Resistance Calculation Software)

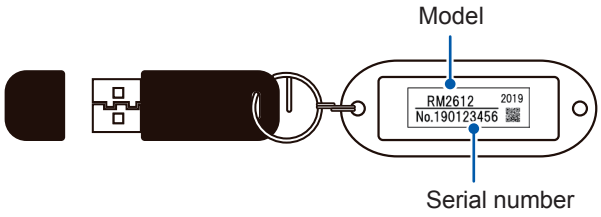
USB license key

⚠ CAUTION

Exercise care when using the USB license key because static electricity could damage the USB license key or cause a malfunction of the product.

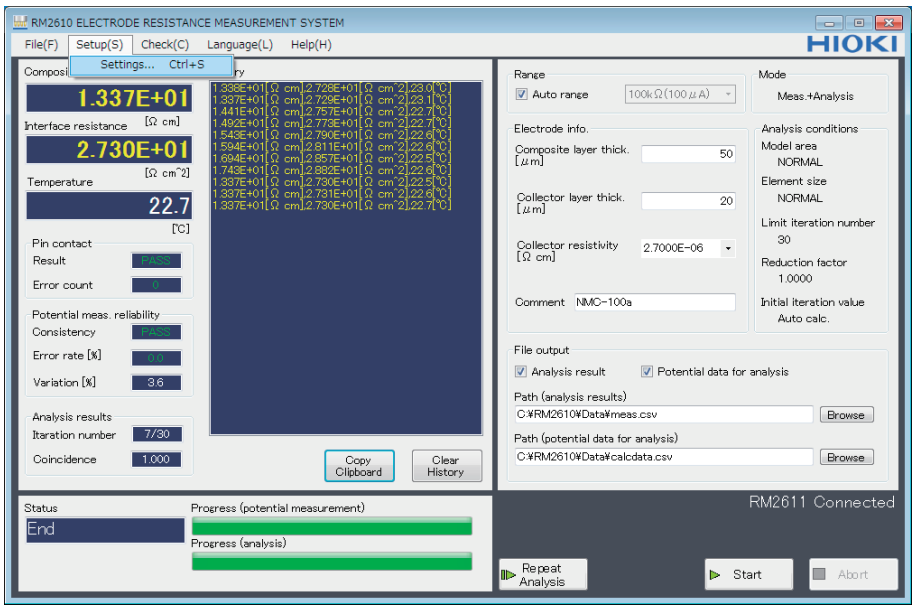
IMPORTANT
License authentication is performed when the RM2612 Resistance Calculation Software is launched and when measurement is started. Do not remove the USB license key while the application is running.

Insert the USB license key into the PC's USB port.



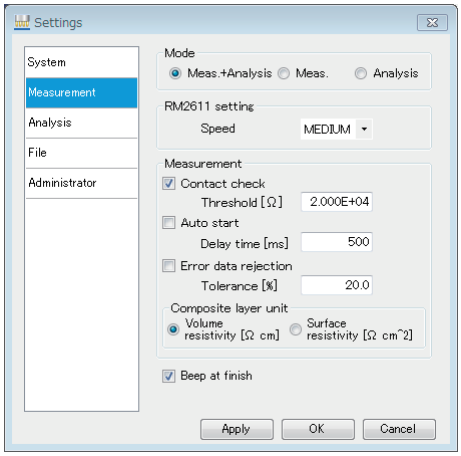
Main screen

The Main screen is used to enter measurement and calculation conditions, to start and stop measurement, and to display analysis results.



Settings screen

The Settings screen is used to configure detailed settings such as the operating mode and measurement conditions.



2 Preparing for Measurement

Carefully read the RM2610 Probe Maintenance Guide before use. The guide can be downloaded from Hioki's website. (Registration is required for downloading.)
https://www.hioki.com/global/support/download/guides?keyword=RM2610

2.1 Installing the RM2612 Resistance Calculation Software

IMPORTANT
- Install the RM2612 Resistance Calculation Software before connecting the RM2611 Electrode Resistance Meter to the PC with a USB cable. If you have already connected a USB cable, remove the cable and install the software.
- If you have Internet connectivity and can download files, the RM2612 Resistance Calculation Software's PC application can be updated. For more information, see "9.2 Updating the Software" (p. 110).

Installation confirmation items and precautions

What the RM2612 Resistance Calculation Software includes

- Dedicated Hioki USB driver
- RM2612 Resistance Calculation Software: setup_RM2612App_v(version number)*.exe

* The version number enclosed in the parentheses indicates the software version number.

System requirements (recommended)

Operating system	Windows 7 pro (32-bit/64-bit) Windows 8 pro (32-bit/64-bit) Windows 10 pro (32-bit/64-bit)
CPU	4 threads or better
Memory	8 GB or better recommended (4 GB of available RAM required)
Display	1,024 × 768 or better
HDD	At least 2 GB of available space
Interface	USB 2.0 or better

Measurement times vary with the measurement target and PC processing capacity.
Reference: Calculation time is about 35 s for a PC with an Intel Core i5-7200U. (Time varies with the measurement target.)

Installation procedure

Install all of the following:
- Microsoft .NET Framework 4.8 or later
- USB driver
- RM2612 Resistance Calculation Software

Installing Microsoft .NET Framework 4.8

Download and install the Microsoft .NET Framework from the Microsoft® website (see URL below) (download the runtime version). If Microsoft .NET Framework 4.8 has already been installed on your PC, proceed to “Installing the USB driver.”

https://dotnet.microsoft.com/download/dotnet-framework/net48

For more information about how to install Microsoft .NET Framework 4.8, see the Microsoft® website.

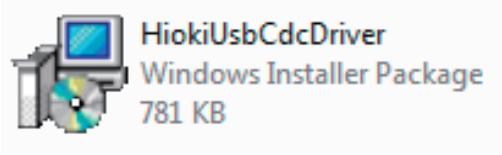
Installing the USB driver

A dedicated USB driver is required in order to connect the RM2611 Electrode Resistance Meter to a PC for the first time. The following procedure can be skipped if the dedicated USB driver has already been installed on your PC. The USB driver can be found on the RM2612 Resistance Calculation Software's PC application CD or downloaded from the Hioki website (http://www.hioki.com/en/). Do not connect the RM2611 Electrode Resistance Meter to your PC until the installation of the USB driver is complete.

1 **Log in to the PC with administrative privileges, for example as "administrator."**

2 **Exit all applications running on the PC.**

3 **Double-click X:\driver\HiokiUsbCdcDriver.msi (where "X" indicates the CD-ROM drive) on the RM2612 Resistance Calculation Software's installation disc or the [HiokiUsbCdcDriver] file you downloaded from the website.**



4 **The installer will launch. Follow the instructions on the screen to install the driver.**

It may take some time for the dialog box to display depending on the PC and its settings.

5 **Connect the RM2611 Electrode Resistance Meter to the PC with a USB cable.**

The RM2611 Electrode Resistance Meter will be recognized automatically.

Uninstalling the USB driver

Uninstall the driver if you no longer need it.

1 **Choose [Start] button-[Control Panels]-[Uninstall Programs].**

2 **Right-click [HIOKI USB CDC Driver].**

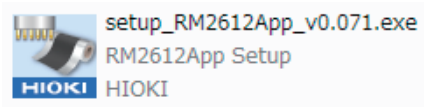
3 **Click [Uninstall] on the shortcut menu.**

Installing the RM2612 Resistance Calculation Software

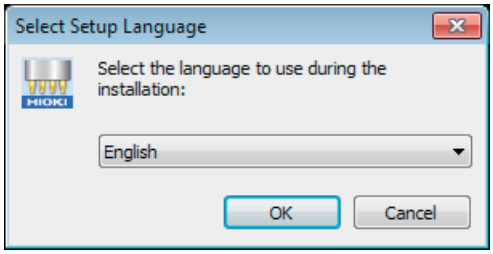
1 Log in to the PC with administrative privileges, for example as “administrator.”

2 Exit all applications running on the PC.

3 Double-click on [setup_RM2612App_v (version number).exe] on the RM2612 Resistance Calculation Software’s PC application CD.

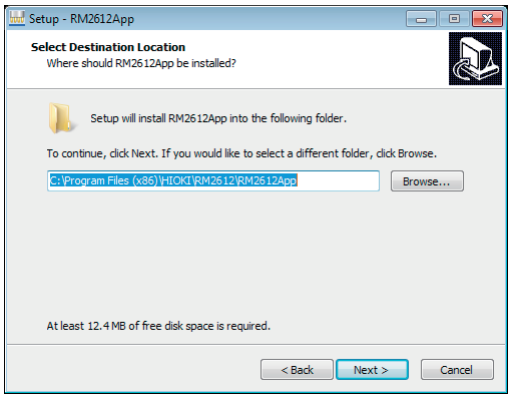


4 Choose a language and click [OK].

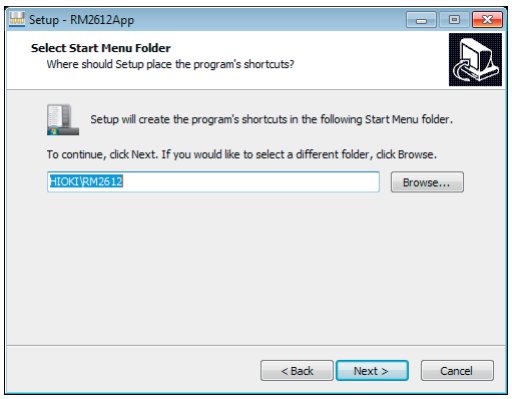


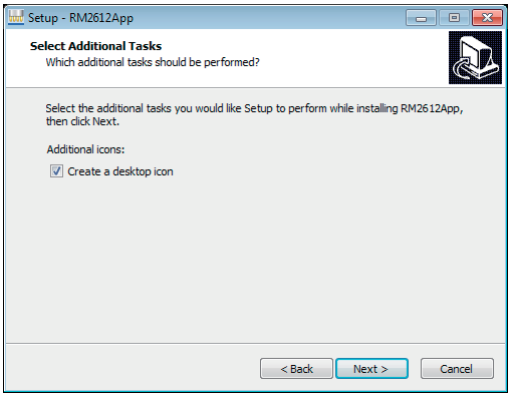
5 Click [Next].
The setup wizard will launch.

6 Specify the installation folder and click [Next].

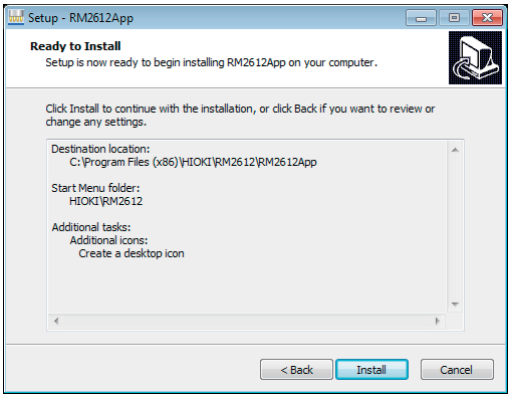


7 Specify where to create the program icon and click [Next].





8 **Choose [Create a desktop icon] and click [Next].**



9 **Review the settings and click [Install].**
The installation will continue.

10 **Click [Finish].**
An icon will be created on the desktop.

Installation is complete

IMPORTANT
The RM2612 Resistance Calculation Software will not launch without a USB license key (p.30).

Uninstalling the RM2612 Resistance Calculation Software

Uninstall the RM2612 Resistance Calculation Software if you no longer need it.

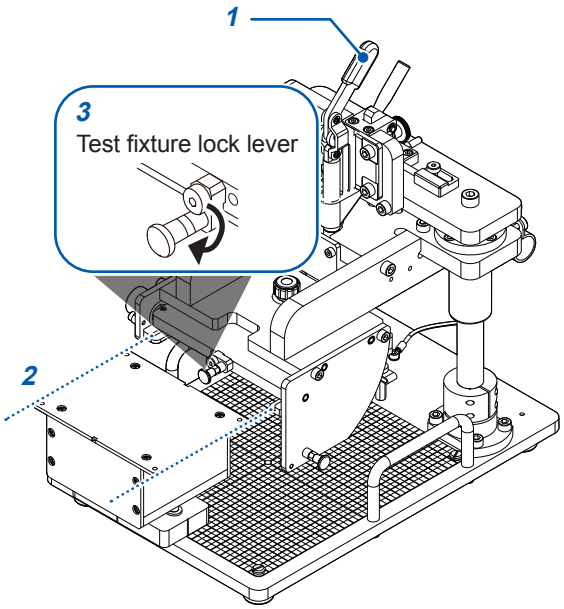
1 **Choose [Start] button-[Control Panels]-[Uninstall Programs].**

2 **Right-click [RM2612App Version X.XX.XX].**

3 **Click [Uninstall] on the shortcut menu.**

2.2 Mounting the RM9004 Test Fixture on the RM9003 Press Unit

IMPORTANT
Exercise care not to lose the test fixture case's mounting screws, which you will need in order to store the RM9004 Test Fixture during transport.



Preparations

Remove the four mounting screws from the top of the RM9004 Test Fixture and remove the test fixture from the test fixture case.

Assembly

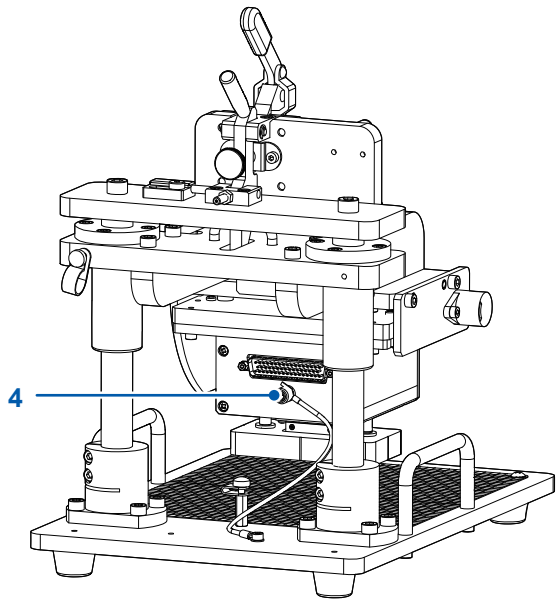
1 **Place the RM9003 Press Unit's up/down lever in the raised position.**

2 **Orienting the connector side of the RM9004 Test Fixture so that it's facing the rear, slide the test fixture into position along the RM9003 Press Unit's test fixture insertion rails.**

Push the test fixture toward the rear until it won't go any further.

3 **Pull the test fixture lock lever toward you and downward and then let go.**

The RM9004 Test Fixture will lock in place.



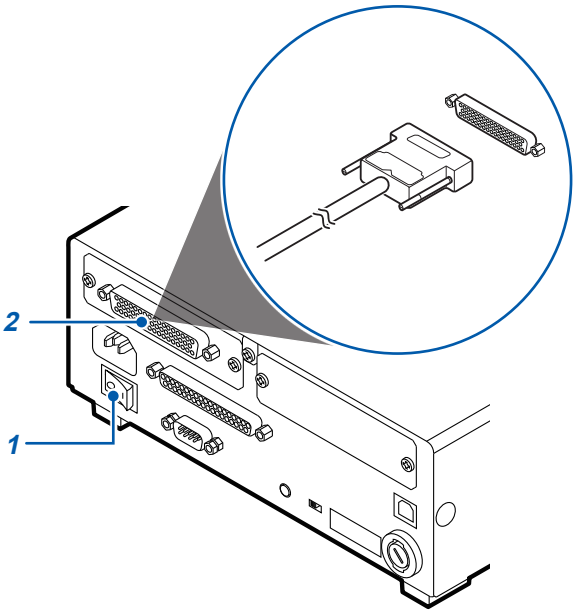
4 **Connect the grounding cable on the rear of the RM9003 Press Unit to the ground terminal on the RM9004 Test Fixture.**

2.3 Connecting the RM9005 Connection Cable

⚠CAUTION

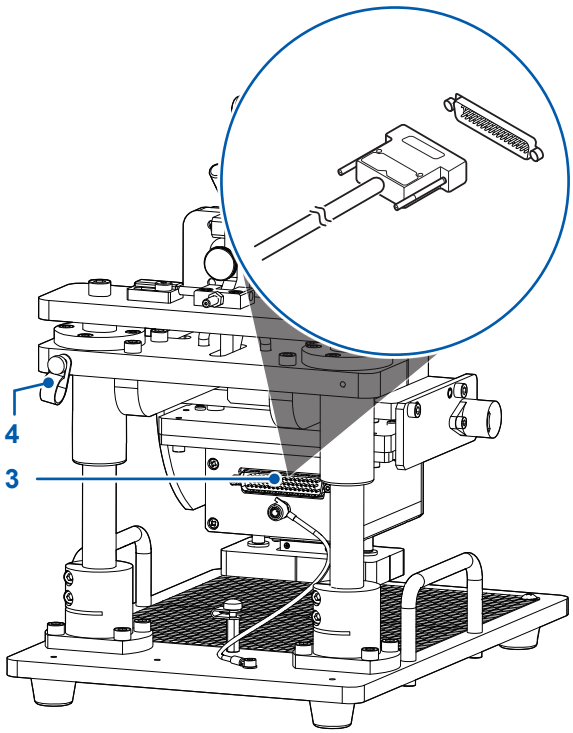
To avoid damaging the cable, connect and disconnect the RM9005 Connection Cable only after turning off the RM2611 Electrode Resistance Meter.

IMPORTANT
When connecting the RM9005 Connection Cable, tighten the screws after securely inserting the connector. Loose screws could result in incomplete contact, causing measurement errors.



1 **Verify that the RM2611 Electrode Resistance Meter's main power switch (on the rear of the instrument) is in the OFF (○) position.**

2 **Connect the male side connector of the RM9005 Connection Cable to the test fixture connector on the RM2611 Electrode Resistance Meter and tighten the screws that hold it in place.**

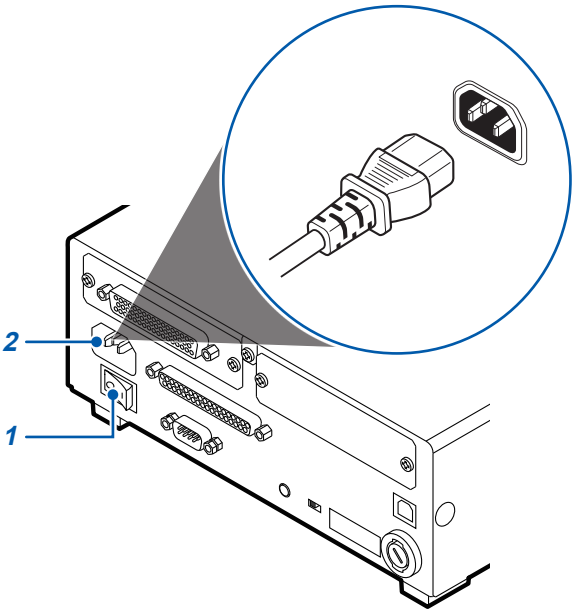


3 **Connect the female side connector of the RM9005 Connection Cable to the connector on the RM9004 Test Fixture and screws that hold it in place.**

4 **Secure the RM9005 Connection Cable in place with the cable clamp.**

There are screws for attaching the cable clamp on the left and right sides of the RM9003 Press Unit. Choose the appropriate side based on the position of the device.

2.4 Connecting the RM2611 Electrode Resistance Meter’s Power Cord



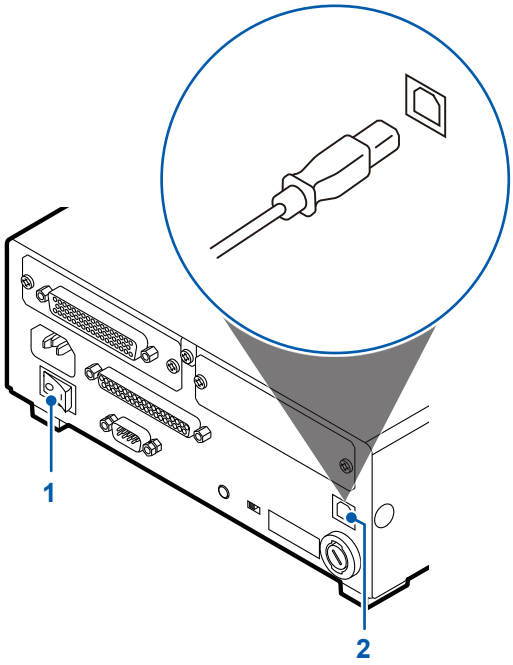
1. **Verify that the RM2611 Electrode Resistance Meter’s main power switch (on the rear of the instrument) is in the OFF (○) position.**
2. **Verify that the outlet provides the correct supply voltage and connect the power cord to the power inlet on the instrument.**
3. **Insert the power cord’s male plug into the outlet.**

If power is interrupted while the instrument is turned on (for example, by tripping a circuit breaker), the instrument will start up the next time power is supplied even if the standby key is not pressed.

2.5 Connecting the RM2611 Electrode Resistance Meter to a PC with a USB Cable

⚠CAUTION

- Before connecting the USB cable to the PC, be sure that you have installed the RM2612 Resistance Calculation Software. Installing the RM2612 Resistance Calculation Software after connecting the instrument to a PC with the USB cable will cause the instrument to malfunction or damage it.
- To avoid damage, do not disconnect the USB cable while the instrument is sending or receiving data.
- Use the same ground for the RM2611 Electrode Resistance Meter and the PC. If different ground circuits are used, there will be a potential difference between the RM2611 Electrode Resistance Meter ground and the PC ground. Connecting the USB cable while such a potential difference exists will cause the instrument to malfunction or damage it.



1 **Verify that the RM2611 Electrode Resistance Meter's main power switch (on the rear of the instrument) is in the OFF (○) position.**

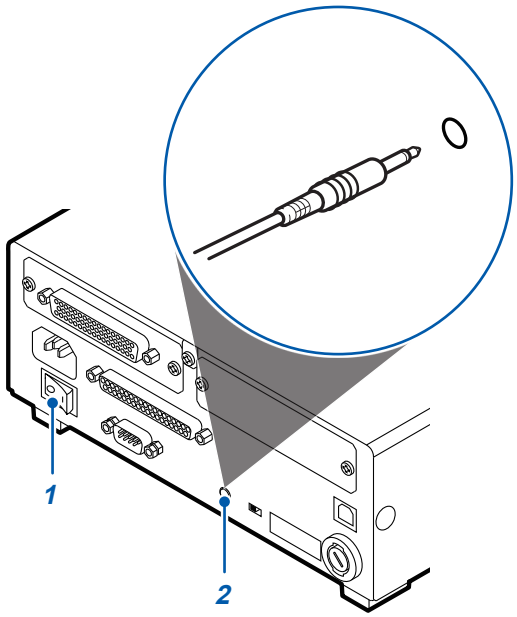
2 **Connect the USB cable to the USB port on the rear of the RM2611 Electrode Resistance Meter.**

3 **Connect the USB cable to a USB port on the PC.**

2.6 Connecting the Z2001 Temperature Sensor

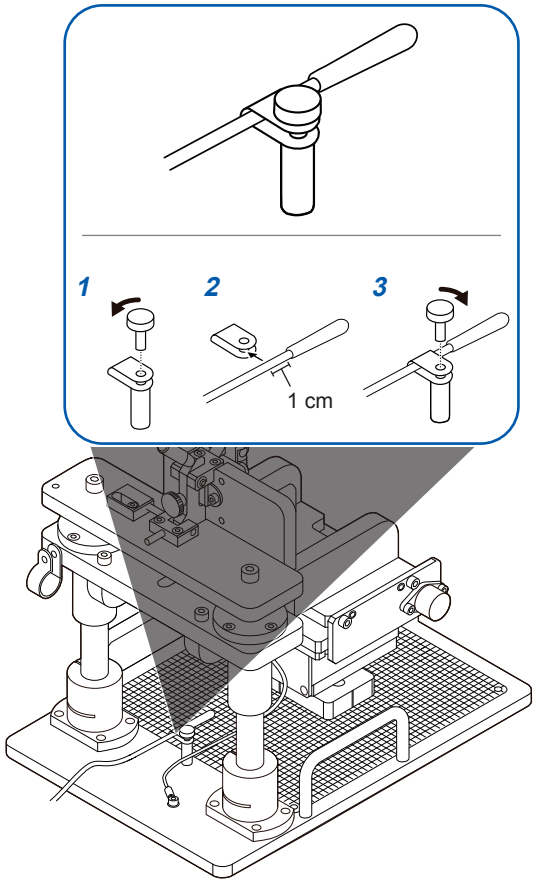
Connecting the Z2001 Temperature Sensor to the RM2611 Electrode Resistance Meter

When connecting the Z2001 Temperature Sensor to the RM2611 Electrode Resistance Meter, insert the connector firmly as far as it will go.



1. **Verify that the RM2611 Electrode Resistance Meter's main power switch (on the rear of the instrument) is in the OFF (○) position.**
2. **Connect the Z2001 Temperature Sensor to the TEMP.SENSOR terminal on the rear of the RM2611 Electrode Resistance Meter.**

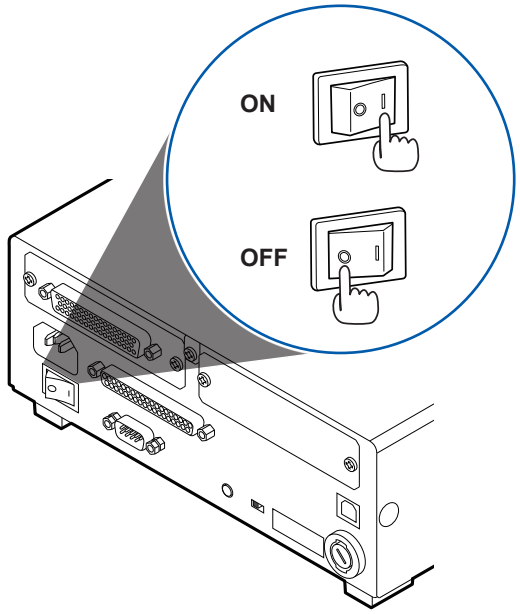
Connecting the Z2001 Temperature Sensor to the RM9003 Press Unit



1. **Remove the temperature sensor mounting screw on the RM9003 Press Unit.**
2. **Insert the Z2001 Temperature Sensor into the temperature sensor mounting clamp on the RM9003 Press Unit.**
   (Insert the wire until the base of the sensor unit protrudes about 1 cm past the clamp.)
3. **Tighten the screw on the RM9003 Press Unit's temperature sensor mounting clamp.**

2.7 Turning the RM2611 Electrode Resistance Meter On and Off

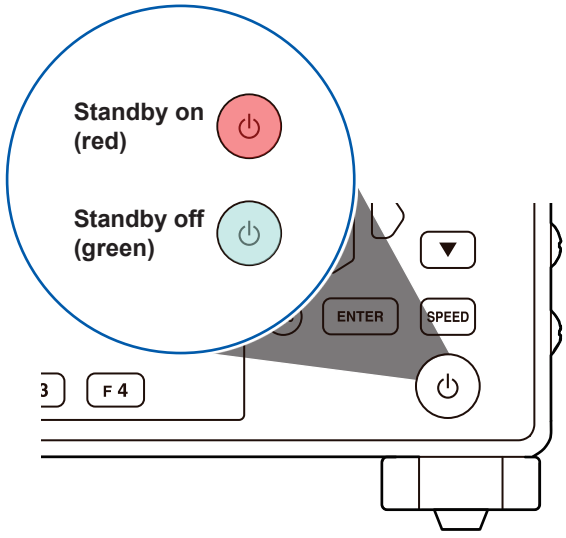
Turning the main power switch on and off



Place the RM2611 Electrode Resistance Meter's main power switch (on the rear of the instrument) in the ON (|) or OFF (○) position.

When the main power switch is turned on, the instrument will enter the standby state with the same settings as when the main power switch was turned off the last time.

Entering and exiting the standby state



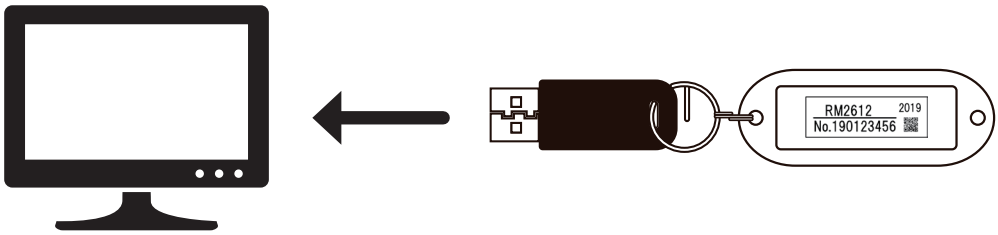
Press the standby key.
(Exit the standby state when starting measurement.)

When the instrument enters the standby state, the standby key will glow red.
When the instrument exits the standby state, the standby key will glow green.

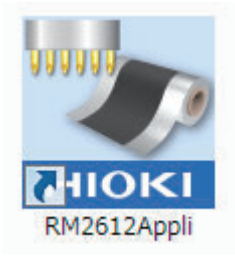
2.8 Launching the RM2612 Resistance Calculation Software

IMPORTANT
The RM2612 Resistance Calculation Software will not launch if the USB license key has not been inserted.

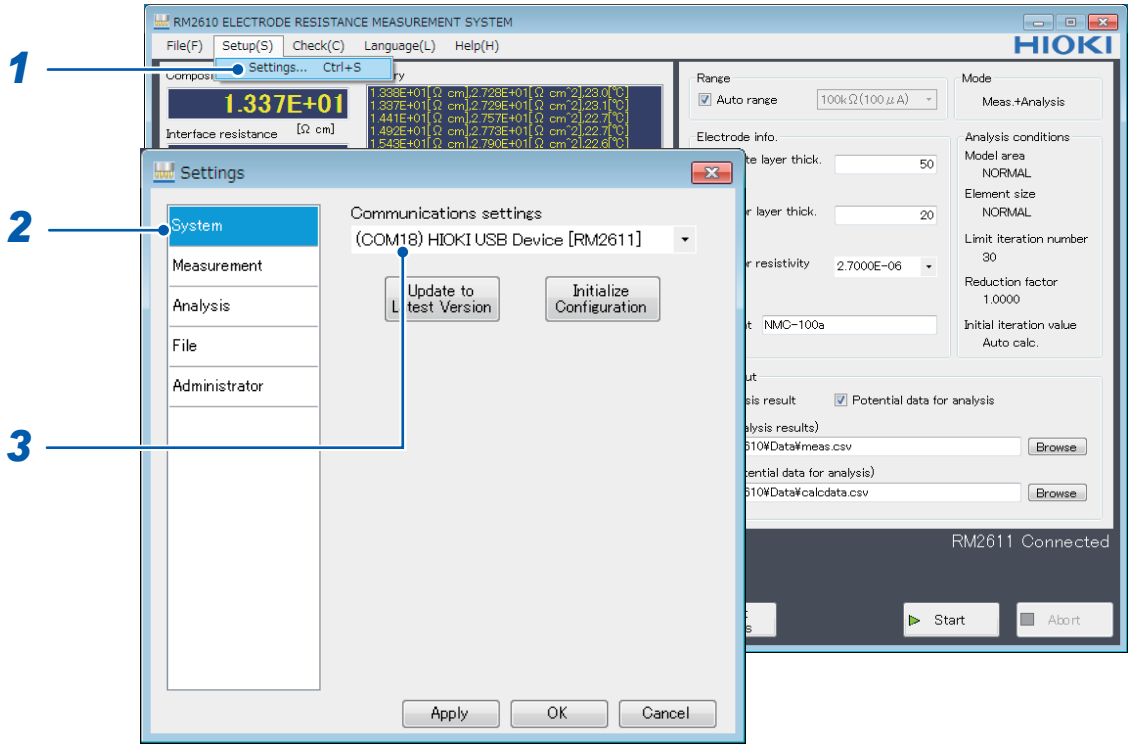
1 **Insert the USB license key into a USB port on the PC on which you wish to launch the RM2612 Resistance Calculation Software.**



2 **Double-click the icon created when you installed the software as described in “Installing the RM2612 Resistance Calculation Software” (p.22).**



Verify the connection between the RM2611 Electrode Resistance Meter and the PC



1 **Choose [Settings].**

2 **Choose [System].**

3 **Verify that [Communications settings] shows [(COMxx) HIOKI USB Device [RM2611]].**

If the [Communications settings] field is blank, the RM2611 Electrode Resistance Meter is not properly connected. Check the following items.

> **Tips** **If you are unable to establish a connection**
>
> • Have you turned on the RM2611 Electrode Resistance Meter? (p.29)
> If the RM2611 Electrode Resistance Meter has not been turned on, nothing will be displayed in the **[Communications settings]** field.
>
> • Have you connected the RM2611 Electrode Resistance Meter to the PC with a USB cable? (p.27)
> If the instrument has not been connected to the PC with a USB cable, nothing will be displayed in the **[Communications settings]** field.
>
> • Have you installed the dedicated Hioki USB driver? (p.19)
> If the USB driver has not been installed, nothing will be displayed in the **[Communications settings]** field.

To update the contents of the **[Communications settings]** field, close and reopen the **[Settings]** dialog box.

2.9 Pre-use Inspection

To ensure that the system is operating properly, conduct an inspection and check instrument operation to ensure that no damage has occurred during storage or transport.
(To complete the OPEN and SHORT inspections, use the probe check board that came with the RM9004 Test Fixture.)

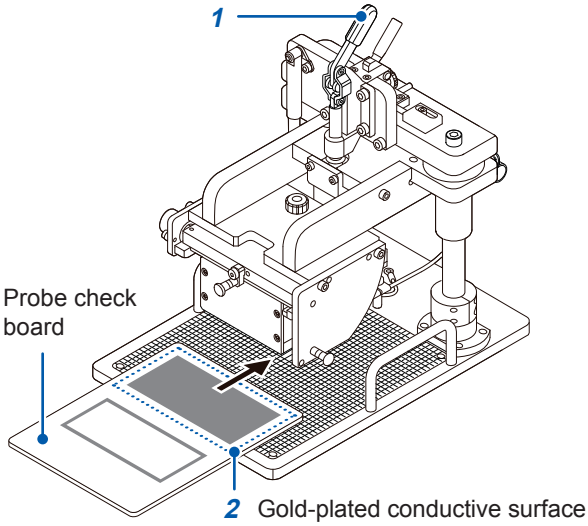
⚠CAUTION

Wipe the probe check board's gold-plated conductive surface clean with a cloth that has been slightly moistened with alcohol prior to use.

Do not move the probe inspection board while the inspection is in progress. Doing so could damage the probes.

Has the instrument been damaged?	▶	If so, have it repaired.
Is the insulation on the power cord or connection cords torn, or is any metal exposed?	▶	Cord damage could result in electric shock. Do not use the instrument. Replace the damaged cord with an undamaged cord.
When you turn on the RM2611 Electrode Resistance Meter, is the HIOKI logo displayed on the screen?	▶	If the HIOKI logo is not displayed on the screen, there may be a wiring break in the power cord or internal damage in the RM2611 Electrode Resistance Meter. Have the instrument repaired.
Has the instrument been properly connected?	▶	Verify that all equipment has been properly connected. • "Mounting the RM9004 Test Fixture on the RM9003 Press Unit" (p.24) • "Connecting the RM9005 Connection Cable" (p.25) • "Connecting the RM2611 Electrode Resistance Meter's Power Cord" (p.26) • "Connecting the RM2611 Electrode Resistance Meter to a PC with a USB Cable" (p.27) • "Connecting the Z2001 Temperature Sensor" (p.28)
Did you perform SHORT inspection?	▶	Verify continuity between the probes, RM2611 Electrode Resistance Meter, and measurement target (p.33). Once continuity of all probes has been verified, the **[Pass.]** dialog box will be displayed. If any continuity issues are found, the **[Abnormal contact resistance.]** or **[Abnormal potential distribution.]** dialog box will be displayed. If you see frequent errors after changing the measurement location and verifying continuity again, probes may be suffering incomplete contact. Take the following steps: • Use the error rejection function (p.53) • Clean the tips of the probes with air (p.118) • Replace the probes
Did you perform OPEN inspection?	▶	Verify that the probes are isolated from each other (p.34). Once all probes are confirmed to be isolated, the **[Pass.]**] dialog box will be displayed. If the **[Abnormal insulation resistance.]** dialog box is displayed, there may be an insulation defect (continuity) between probes. Clean the tips of the probes with air (p.118) and repeat the OPEN inspection.

SHORT inspection method

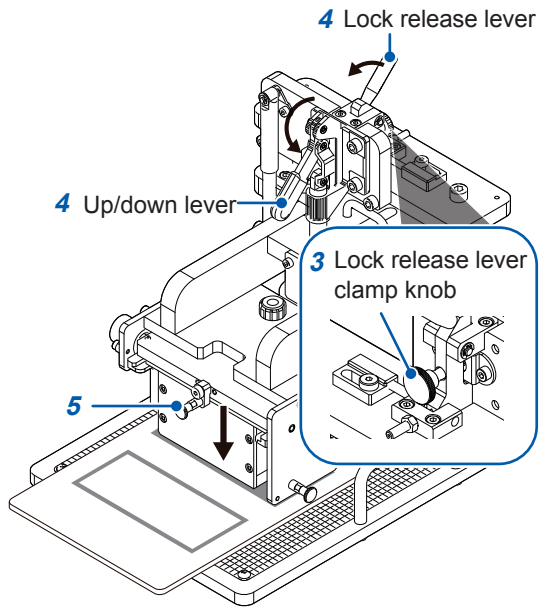


You will need: The probe check board

1 Verify that the up/down lever is in the raised position.

2 Place the probe check board's gold-plated conductive surface (the board came with the RM9004 Test Fixture) on the measurement stage.

The probes make contact with the bold graduated marks on the graduated plate. Position the probe check board so that the probes will make contact with the center of the gold-plated conductive surface.

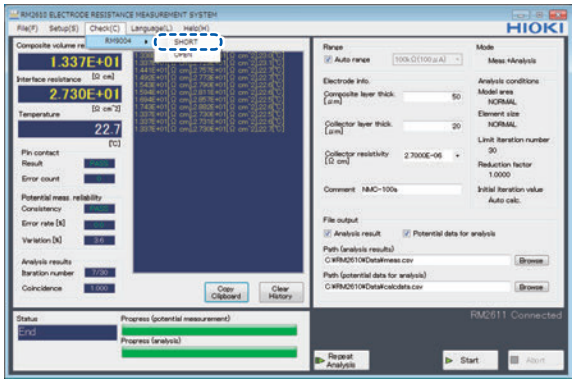


3 Verify that the clamp knob on the lock release lever is loose.

4 Pull the up/down lever toward you and down while pulling the lock release lever toward you.

The RM9004 Test Fixture will move downward under its own weight.

5 Verify that the RM9004 Test Fixture is fully lowered.



6 Choose [Check] on the RM2612 Resistance Calculation Software screen.

7 Choose [RM9004].

8 Choose [SHORT] to perform the SHORT inspection. (The [Pass.] dialog box will be displayed if the continuity of all probes is verified.)

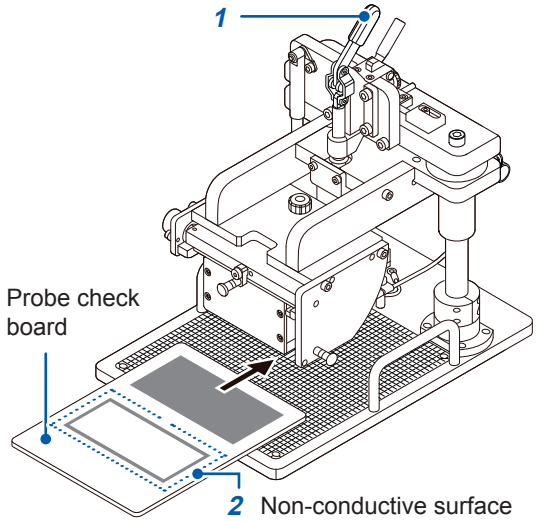
If any continuity issues are found, the **[Abnormal contact resistance.]** or **[Abnormal potential distribution.]** dialog box will be displayed. If you see frequent errors after changing the measurement location and verifying continuity again, the probe may be suffering incomplete contact. Take the following steps:

- Use the error rejection function (p. 53)
- Clean the tips of the probes with air (p. 118)
- Replace the probes

9 Once the inspection is complete, raise the up/down lever.

10 After verifying that the RM9004 Test Fixture is fully raised, remove the probe check board from the measurement stage.

OPEN inspection method

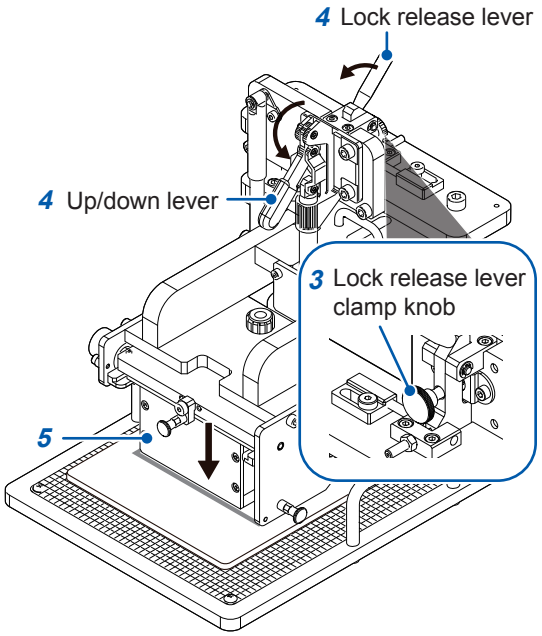


You will need: The probe check board

1 **Verify that the up/down lever is in the raised position.**

2 **Place the probe check board's non-conductive surface (the board came with the RM9004 Test Fixture) on the measurement stage.**

The probes make contact with the bold graduated marks on the graduated plate. Position the probe check board so that the probes will make contact with the center of the non-conductive surface.

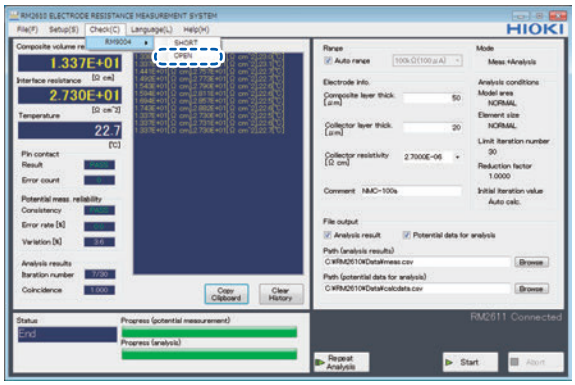


3 **Verify that the clamp knob on the lock release lever is loose.**

4 **Pull the up/down lever toward you and down while pulling the lock release lever toward you.**

The RM9004 Test Fixture will move downward under its own weight.

5 **Verify that the RM9004 Test Fixture is fully lowered.**



6 **Choose [Check] on the RM2612 Resistance Calculation Software screen.**

7 **Choose [RM9004].**

8 **Choose [OPEN] to perform the OPEN inspection. (The [Pass.] dialog box will be displayed if the isolated state of all probes is verified.)**

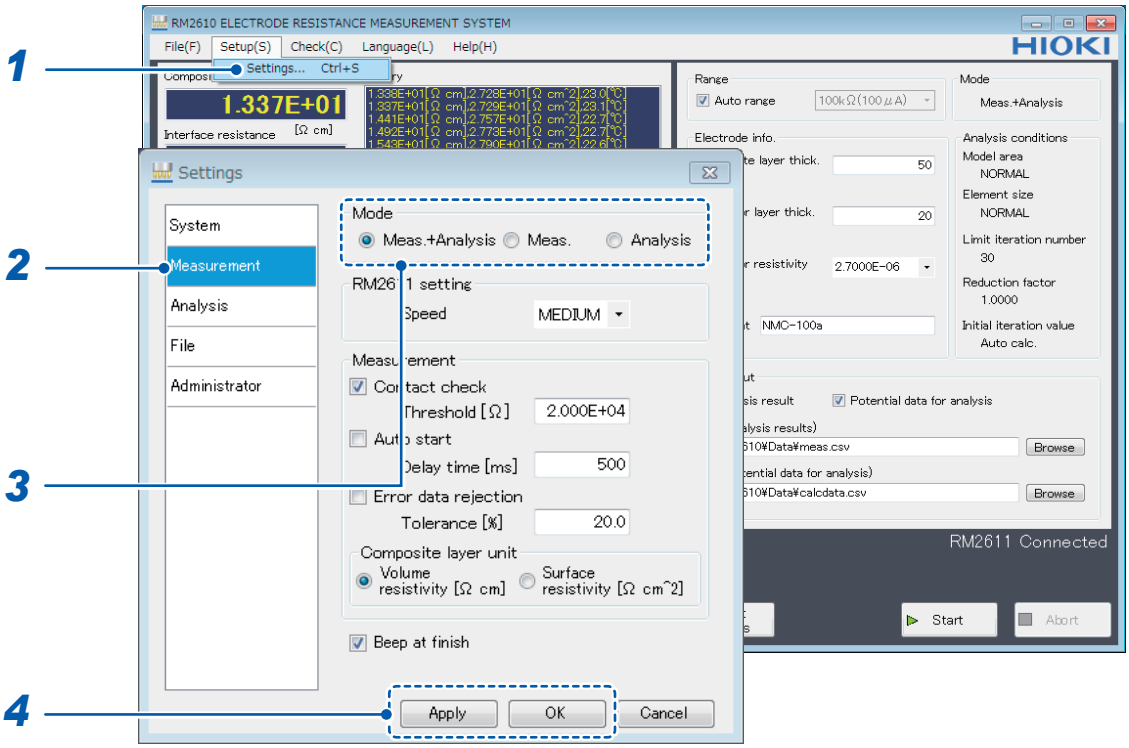
If the **[Abnormal insulation resistance.]** dialog box is displayed, there may be an insulation defect (continuity) between probes. Clean the tips of the probes with air (p. 118) and repeat the OPEN inspection.

9 **Once the inspection is complete, raise the up/down lever.**

10 **After verifying that the RM9004 Test Fixture is fully raised, remove the probe check board from the measurement stage.**

3 Basic Measurement

3.1 Setting the Operating Mode



1 **Choose [Settings].**

2 **Choose [Measurement].**

3 **Choose the [Mode] from the following options:**

Meas.+Analysis☑	Perform potential measurement and analysis and save the results to a file.
Meas.	Perform potential measurement and save the results to a file. One file will be created for each measurement.
Analysis	Load a potential measurement file, performs analysis, and save the results to a file. Multiple potential analysis files can be specified together.

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

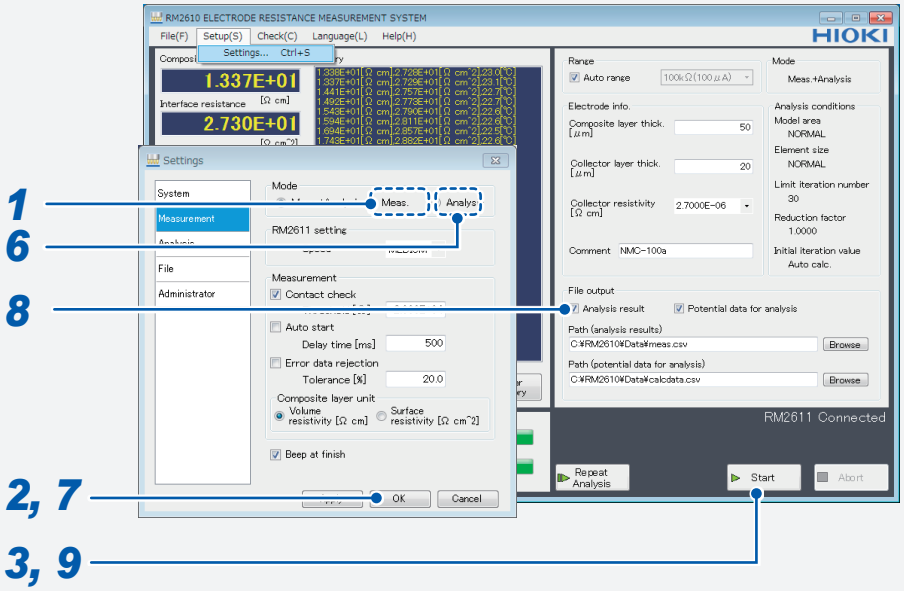
Tips **About operating modes**

Start of measurement — End of measurement

Potential measurement	Analysis
Meas.	**Analysis**
Meas. + Analysis	

You can choose the operating mode in order to streamline measurement work. When measuring a small number of electrode sheets, it is recommended to set the mode to **[Meas.+Analysis]** so that potential measurement and analysis are performed for each sheet.
When measuring multiple electrode sheets, efficiency suffers as the analysis step in **[Meas.+Analysis]** results in wait times. By choosing either **[Meas.]** or **[Analysis]** as the mode, you can use the time it takes for analysis results to be generated more effectively by grouping together analysis of multiple boards, boosting work efficiency.
This section describes the workflow when measuring multiple electrode sheets.

IMPORTANT
Each mode has its own **[File output]** setting. Before clicking **[Start]**, check the **[File output]** settings.



Potential measurement

1 **Choose [Meas.] under [Mode].**

2 **Click [OK] to accept the settings.**

3 **Place an electrode sheet in the RM9003 Press Unit and click [Start] to perform potential measurement (p.45).**

4 **A potential file for analysis use with a filename created by appending a time stamp to the filename as set in [Path (Analysis results)] will be output. (One file will be output for each measurement.)**

5 **Repeat the measurement step for each sheet (Step 3).**

Analysis

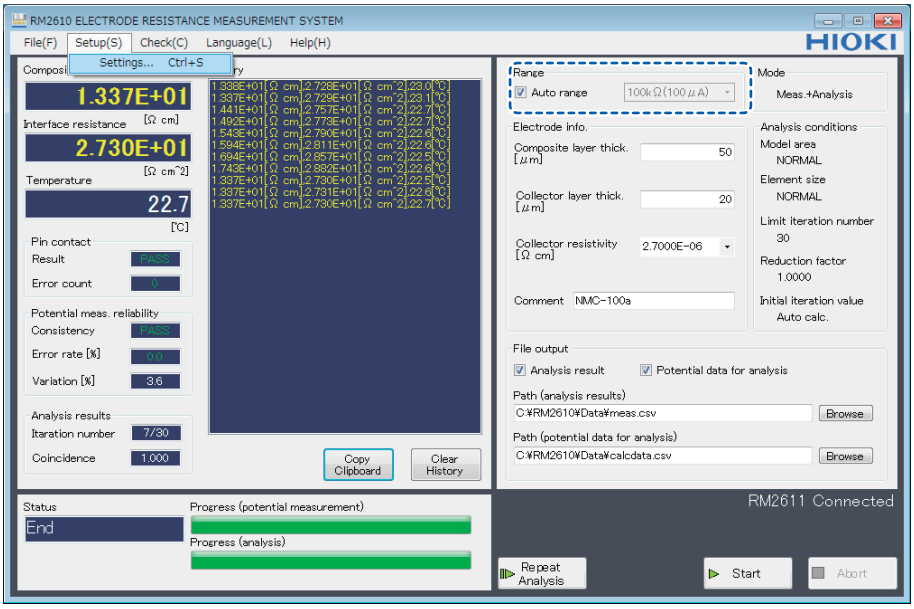
6 **Choose [Analysis] under [Mode].**

7 **Click [OK] to accept the settings.**

8 **Select [Analysis result] under [File output].**

9 **Click [Start] to display a file selection dialog box. Select multiple files output during [Meas.] operation and click [Open]. (Analysis will be performed one file at a time, and analysis results will be appended to the analysis results file.)**

3.2 Setting the Resistance Range



To indicate that potential measurement results obtained using the 10 MΩ range are merely values for reference purposes, values of the composite layer volume resistivity and interface resistance appear dimmed.

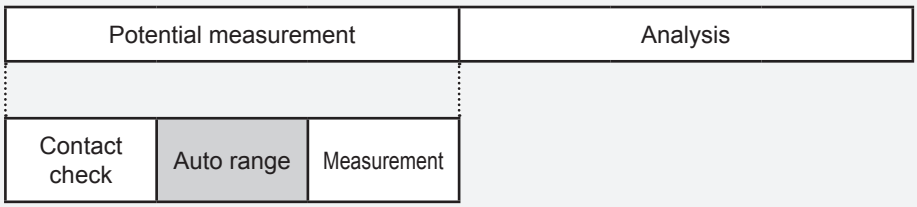
Auto range☑	Select the optimal resistance range automatically (recommended).
Resistance range	When **[Auto range]** is disabled, allows you to select the resistance range you wish to use. The measurement current (output current) is displayed next to the resistance range. **1000 mΩ**, **10 Ω**, **100 Ω**, **1000 Ω**, **10 kΩ**, **100 kΩ**, **1000 kΩ**, **10 MΩ*** *Potential measurement results obtained using the 10 MΩ range are merely values for reference purposes.

Tips **Choosing the range**

Although **[Auto range]** selects the optimal resistance range automatically, measurement will take more time than when the resistance range has been selected.
When measuring multiple electrode sheets with the same resistance value, perform the first measurement using **[Auto range]** and then choose the resistance range that was used by the **[Auto range]** function to perform the second and subsequent measurements in order to save time.
Change the setting as necessary.

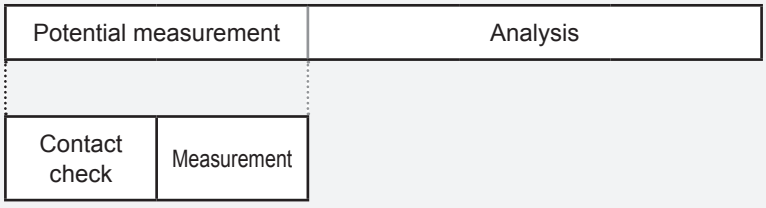
• Select **[Auto range]**.

Start of measurement — End of measurement



• Choose a resistance range.

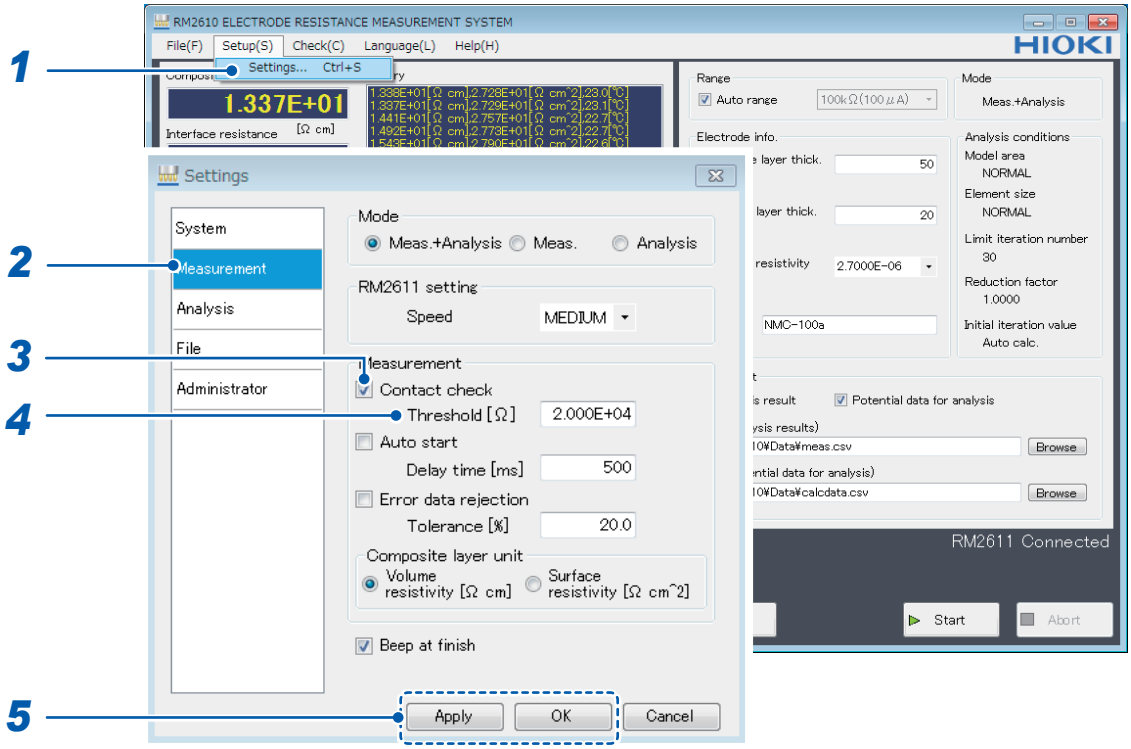
Start of measurement — End of measurement



The potential measurement using the 10 MΩ range requires a longer time because the delay time is needed.

3.3 Configuring the Contact Check Function

The contact check function measures the contact resistance of the measurement target and probes before measurement to detect probe contact errors and prevent decreased reliability of measured values due to incomplete probe contact. The function can identify pins with incomplete contact and prevent measurement errors.



1 **Choose [Settings].**

2 **Choose [Measurement].**

3 **Choose one of the following settings for [Contact check]:**

ON☑	Enable the contact check function.
OFF	Disable the contact check function. (Skip step 4 below.)

4 **Enter the error data threshold at which to stop measurement in the [Threshold] field.**

Initial value	Valid setting range
2.000E+04	1 Ω to 10 MΩ

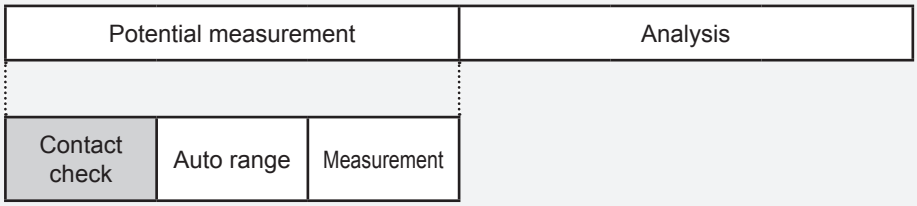
5 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

Using the contact check function

The contact check function improves the accuracy of potential measurement by detecting incomplete probe contact. Ordinarily you should enable the function, although you can shorten measurement times by disabling it. Change the setting as necessary.

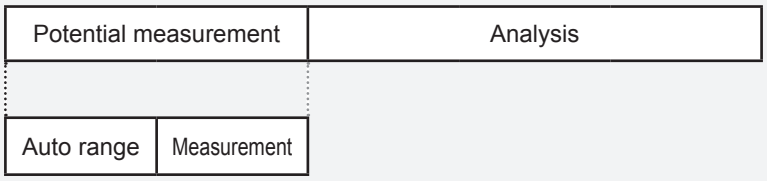
• Enable the contact check function.

Start of measurement End of measurement



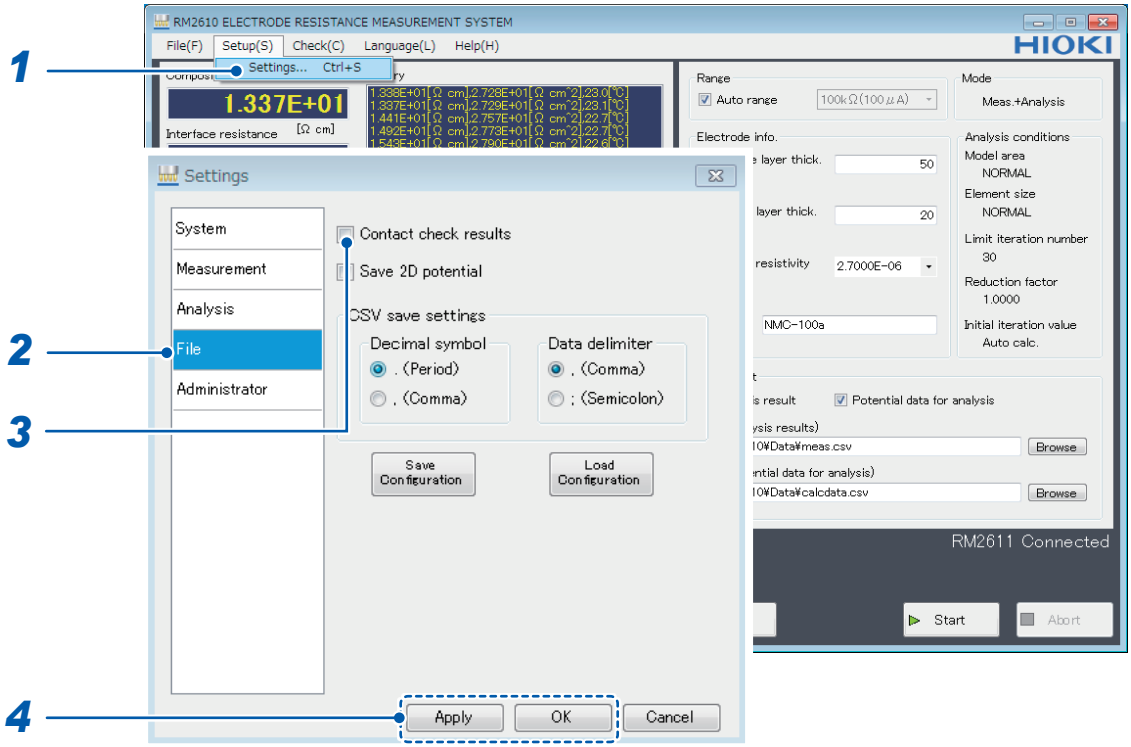
• Disable the contact check function.

Start of measurement End of measurement



3.4 Saving Contact Check Results

Contact check results can be output to a file. The filename is generated by adding “CC_” to the beginning of the filename set as the analysis results path. Results will be appended to the file if the name of an existing file is entered as the analysis results path. For more information about the output format, see “7.3 Output File Formats” (p.85).



1 **Choose [Settings].**

2 **Choose [File].**

3 **Choose one of the following settings for [Contact check results]:**

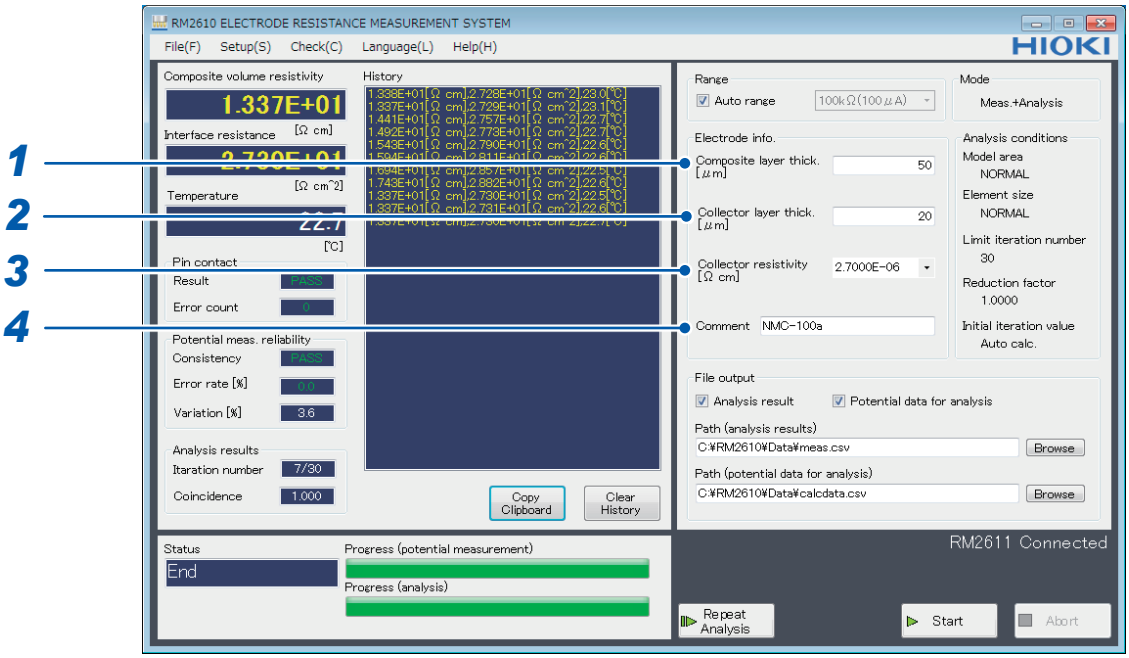
ON	Save contact check results.
OFF☑	Do not save contact check results.

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

3.5 Entering Electrode Sheet Information

In order to calculate electrode resistance, you will need to enter information about the electrode sheet being measured. Analysis cannot be performed without this information.

IMPORTANT
If the operating mode is set to **[Analysis]**, the electrode sheet information stored in the specified potential data for analysis file will be used instead of the electrode sheet information on the screen.



1 Enter the composite layer thickness in the [Composite layer thick. [μm]] field.

Valid setting range	Initial value	Format
0.0001 μm to 1000 μm	50	Decimal or exponential with 5 significant digits

2 Enter the collector layer thickness in the [Collector layer thick. [μm]] field.

Valid setting range	Initial value	Format
0.0001 μm to 1000 μm	20	Decimal or exponential with 5 significant digits

3 Enter the collector resistivity in the [Collector resistivity [Ωcm]] field.

Valid setting range	Initial value	Format
1.0000E-10 to 1.0000E+5	2.7000E-06*	Decimal or exponential with 5 significant digits

*Volume resistivity of aluminum

Tips **Volume resistivity (reference values)**

You can choose between aluminum and copper from the pull-down menu.

Aluminum	**2.7000E-06**
Copper	**1.7000E-06**

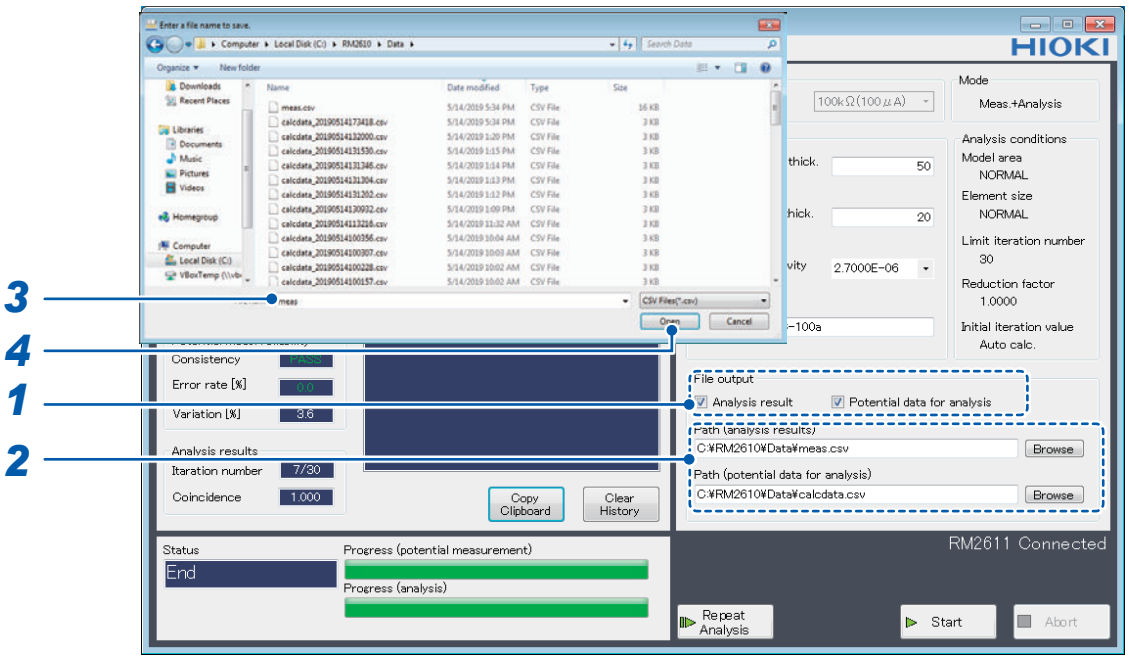
4 **Enter a comment if desired in the [Comment] field (up to 30 characters).**

The comment entered here will be added to the output file. Please note that commas (“,”) and semicolons (“;”) cannot be entered in this field.

3.6 Saving Measured Values

Measurement results and potential distribution data for analysis are saved in the CSV format. If you choose the data you wish to output before measurement, a CSV file will be created when measurement ends.

IMPORTANT
Measurement results will not be saved if you do not choose which data to output. The available settings for **[File output]** vary with the operating mode, so check which types of data are available before clicking **[Start]**.



1 **Choose the type(s) of data you wish to output under [File output] (choose the data you wish to output to a file).**

You can choose multiple types of data.

Analysis result	Save composite layer resistivity, interface resistance results, and measurement conditions. For more information about output file formats, see “7.3 Output File Formats” (p.85).
Potential data for analysis	Save potential measurement results. The data can then be used in **[Analysis]** operating mode (p.35).

2 **Specify the name of the file to which you wish to save the measurement results and click [Browse].**

Specify a folder and file for each data type. Be sure to specify a filename as well as a folder. For more information about output file formats, see “7.3 Output File Formats” (p.85).

Path (analysis results)	If you specify the name of an existing file, measurement results will be appended to the file. If you specify the name of a new file, the file will be created.
Path (potential data for analysis)	Generate one file for each potential measurement performed. A time stamp is appended to each filename so that you can differentiate among results.

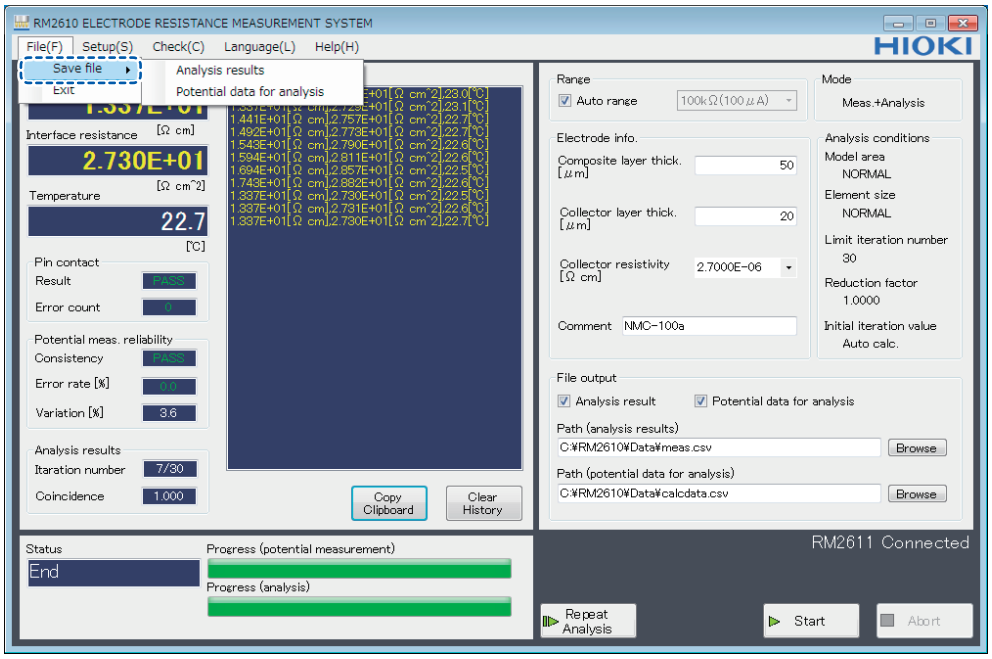
3 **Enter the name of the filename you wish to use.**

4 **Click [Open] to save the filename.**

Saving the current measurement results

Even if you did not choose data to save under **[File output]** before measurement, you can save the last analysis results and potential distribution data for analysis as a CSV file by choosing **[Save file]** on the **[File]** menu and choosing **[Analysis results]** or **[Potential data for analysis]**. The data will be saved to the filename set with the **[Path (analysis results)]** field.

IMPORTANT
If using this functionality to save analysis results or potential data for analysis, be sure to choose **[Save file]** before changing settings or electrode sheet information.



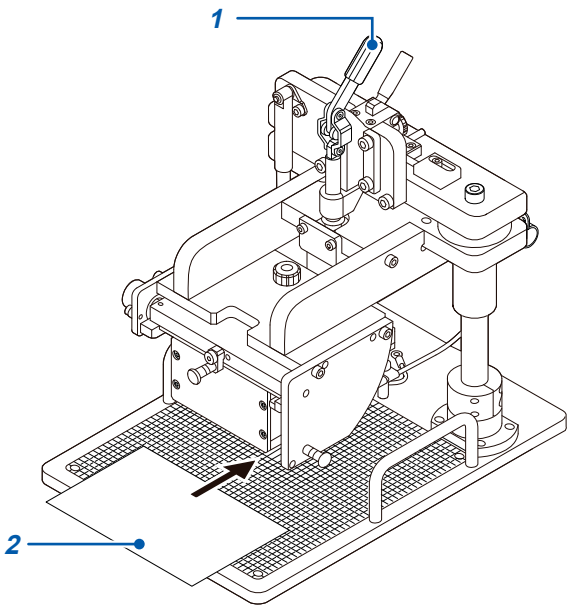
3.7 Loading an Electrode Sheet into the RM9003 Press Unit

⚠CAUTION

Do not move the electrode sheet if the RM9004 Test Fixture is in contact with it. Doing so may damage the probes.

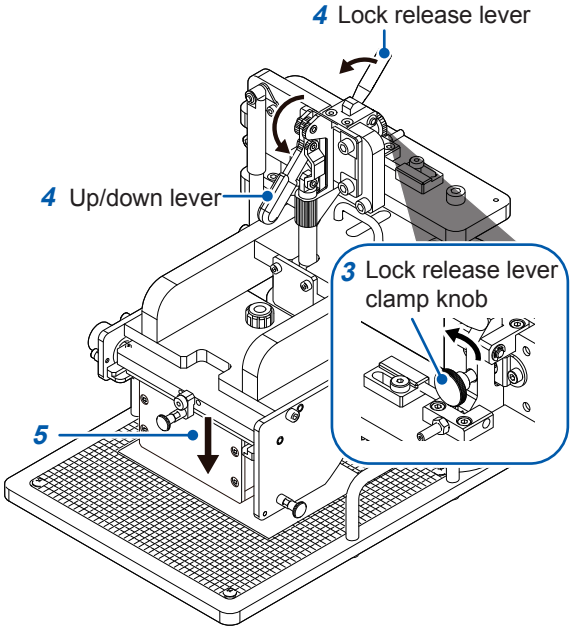
Start measurement after verifying that the RM9004 Test Fixture is in contact with the electrode sheet. Measurement cannot be performed if the RM9004 Test Fixture is not in contact with the electrode sheet.

IMPORTANT
Exercise caution not to pinch your fingers or other body parts when lowering the RM9004 Test Fixture.



1 **Verify that the up/down lever is in the raised position.**

2 **Place an electrode sheet on the measurement stage.**
The probes will make contact with the bold graduated marks on the graduated plate.



3 **Verify that the clamp knob on the lock release lever is loose.**

4 **Pull the up/down lever toward you and down while pulling the lock release lever toward you.**
The RM9004 Test Fixture will move downward under its own weight.

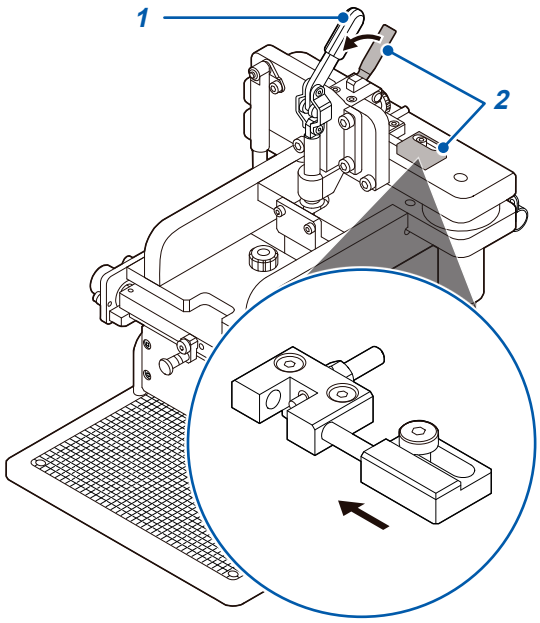
5 **Start measurement once the RM9004 Test Fixture is fully lowered. (p.47)**

6 **Once measurement completes, raise the up/down lever.**

7 **Remove the electrode sheet from the measurement stage after verifying that the RM9004 Test Fixture is fully raised.**

Operating the RM9004 Test Fixture using only the up/down lever (disabling the lock release lever)

IMPORTANT
When the lock release lever is disabled, the RM9004 Test Fixture can be raised and lowered using only the up/down lever. Exercise care not to pinch your fingers or other body parts by unintentionally lowering the RM9004 Test Fixture.



1 **Verify that the up/down lever is in the raised position.**

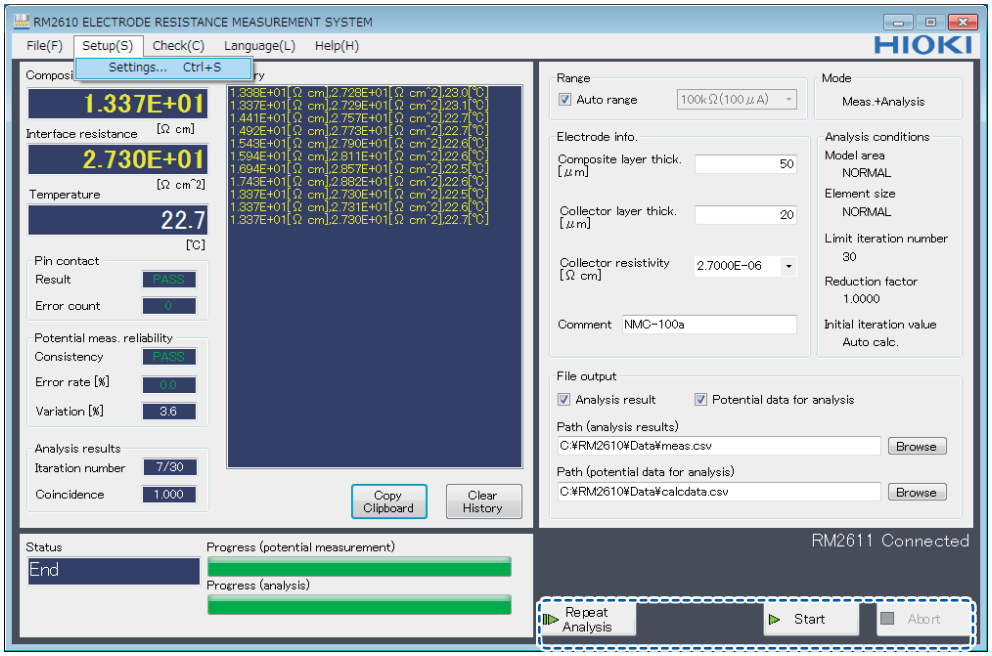
2 **Move the lock disable pin toward the inside while pulling the lock release lever toward you.**

The lock release lever will be disabled, allowing the RM9004 Test Fixture to be raised and lowered using only the up/down lever.

To reenable the lock release lever, perform this procedure in reverse to return the pin to its original position.

3.8 Starting Measurement

IMPORTANT
- Allow the instrument to warm up for at least 60 minutes to ensure measurement accuracy.
- Do not touch the RM9004 Test Fixture or other system components during measurement.



Start	Starts measurement.
Abort	Aborts measurement.
Repeat analysis	Uses the potential measurement results from the last measurement to repeat analysis. Use this function if you entered an incorrect value for the composite layer thickness or if you wish to repeat analysis after increasing the limit iteration number or decreasing the reduction factor after analysis has generated an error.

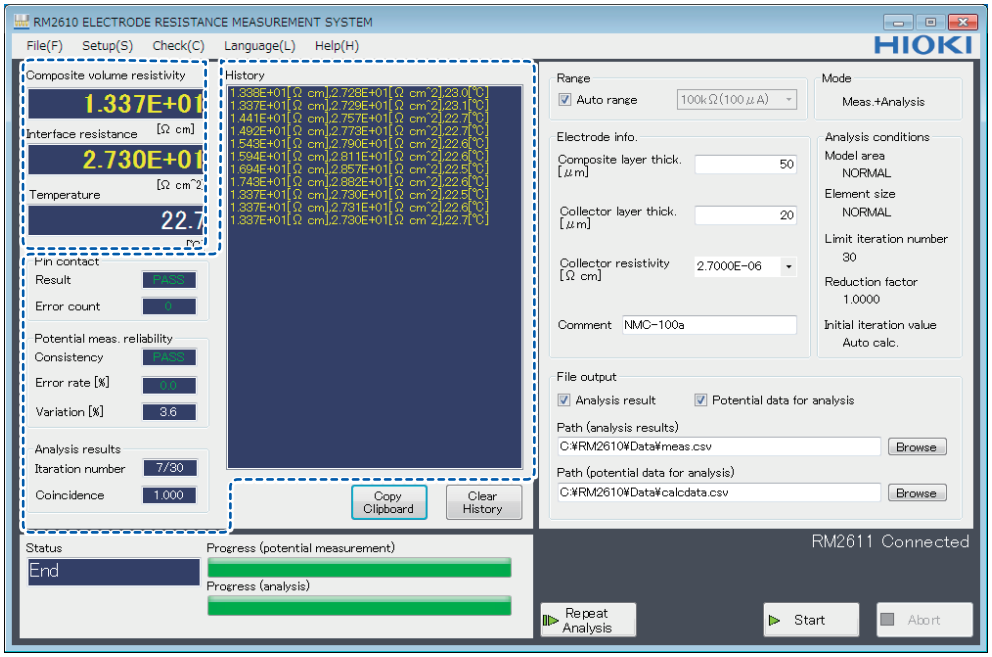
Tips **Counter function**

The RM2612 Resistance Calculation Software provides functionality for counting the number of measurements the instrument has performed. This information is output to the analysis results file and potential distribution data for analysis file as a rough indicator of the number of measurements performed by the RM9004 Test Fixture. See “7.3 Output File Formats” (p.85).

3.9 Checking Measurement Results

Once potential measurement and analysis have completed normally, the measurement results will be displayed.

IMPORTANT
If the error rejection function is enabled, measured values will be shown in red if error data has been rejected.



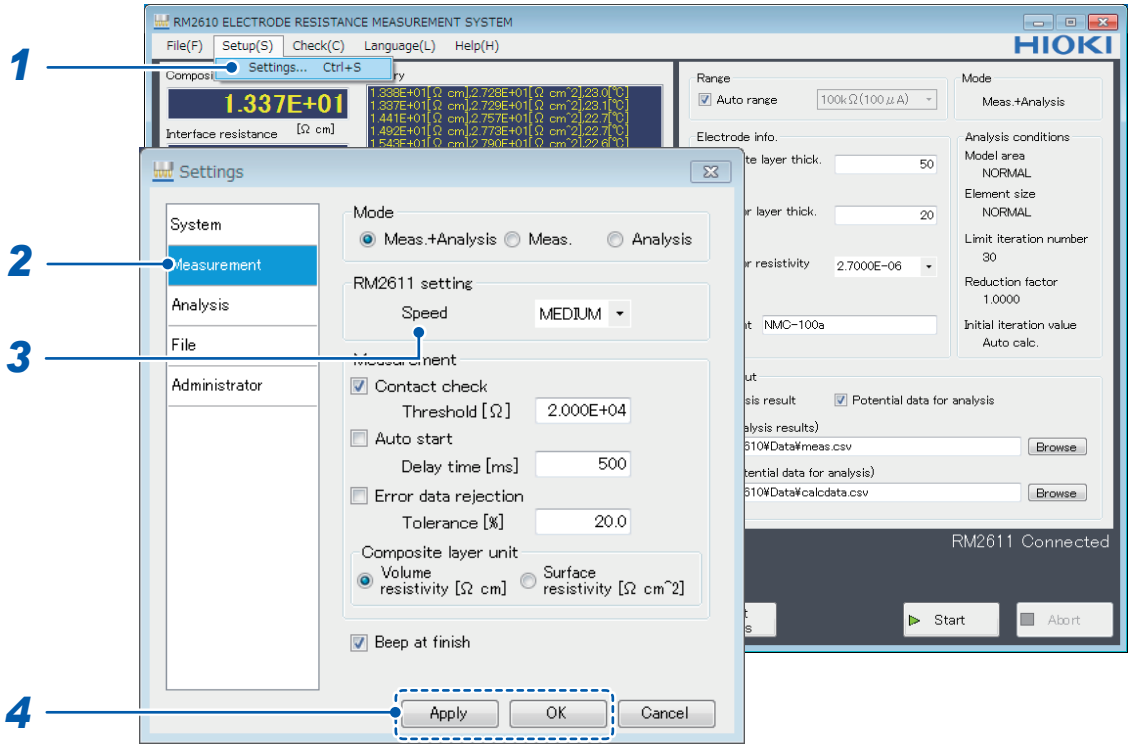
Composite volume resistivity	Indicates the calculated layer resistivity. You can choose between volume resistivity and surface resistivity in the settings.
Interface resistance	Indicates the calculated interface resistance.
Temperature	Indicates the temperature near the RM9004 Test Fixture as measured by the RM2611 Electrode Resistance Meter. The temperature when potential measurement was completed is shown.

Pin contact	
Result	Indicates FAIL if there was a contact error or PASS if there was no contact error.
Error count	Indicates the number of probes exhibiting a contact error.
Potential meas. reliability	
Consistency	Indicates PASS if the relative magnitudes of the potential measurement results suggest the proper potential gradient near the center. Indicates FAIL if the proper relationship is not observed, in which case operation will not proceed to analysis.
Error rate [%]	Indicates how many potential measurement results generated measurement errors as a percentage of all potential measurement results. (This value is not the same as the number of probes generating contact errors.)
Variation [%]	If multiple potential measurements were performed, indicates the amount of variation among potential results (i.e., the coefficient of variability) as a percentage.
Analysis results	
Iteration number	Indicates the number of iterative analyses performed, calculated as the number of iterations divided by the limit iteration number.
Coincidence	Indicates the extent to which the measured potential distribution matches the calculated potential distribution. A value of 1.000 indicates a perfect match, while smaller values indicate a less perfect match. (Negative values are possible.)
History	Displays the measurement history. New results are appended to the history as they are obtained. When analysis is performed, the history displays the composite layer resistivity, interface resistance, and temperature. If the operating mode is set to [Meas.], only the temperature [°C] will be shown.

4 Customizing Measurement Conditions

4.1 Choosing the Measurement Speed

You can choose the measurement speed from four options: FAST, MEDIUM, SLOW1, and SLOW2.



1 **Choose [Settings].**

2 **Choose [Measurement].**

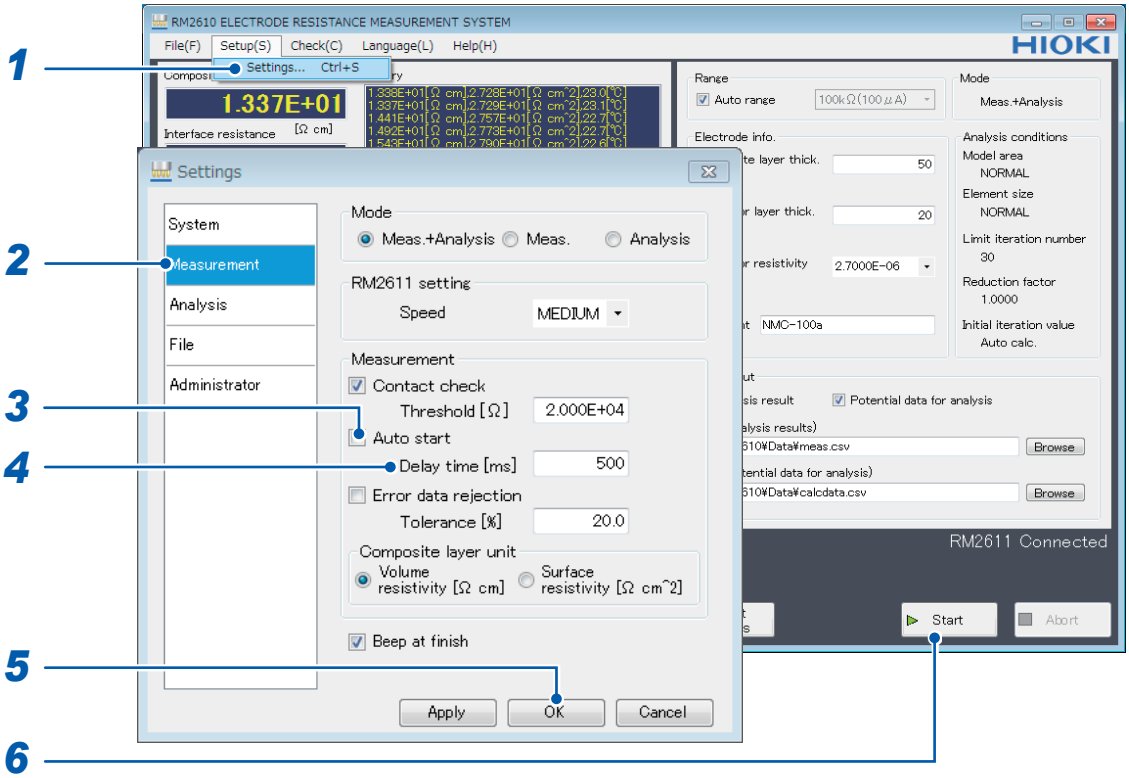
3 **Choose one of the following settings for [Speed]:**

FAST	The measurement speed can be set to any of the following four values: **FAST**, **MEDIUM**, **SLOW1**, and **SLOW2**. **MEDIUM**, **SLOW1**, and **SLOW2** have increased measurement precision compared to **FAST**, making measurements less susceptible to the effects of the external environment. However, those settings result in longer measurement times than **FAST**.
MEDIUM☑	
SLOW1	
SLOW2	

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

4.2 Auto Start Function

The auto start function allows you to start measurement automatically when the probes make contact with an electrode sheet. Since measurement starts without requiring you to click **[Start]**, this function is convenient when you need to measure multiple electrode sheets in a row. You can set the time (delay time) allowed to elapse from the time the probes make contact with the electrode sheet until measurement begins.



1 **Choose [Settings].**

2 **Choose [Measurement].**

3 **Choose one of the following settings for [Auto start]:**

ON	When you click **[Start]**, measurement will start once the time entered in the **[Delay time [ms]]** field has elapsed after the probes make contact with the measurement target. (If you encounter numerous contact errors, try increasing the delay time.)
OFF☑	Require user operation to start measurement. (Skip step 4 below.)

4 **Enter the time to allow to elapse before measurement starts in the [Delay time [ms]] field (0 ms to 2000 ms).**

5 **Click [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

6 **Click [Start] on the main screen.**

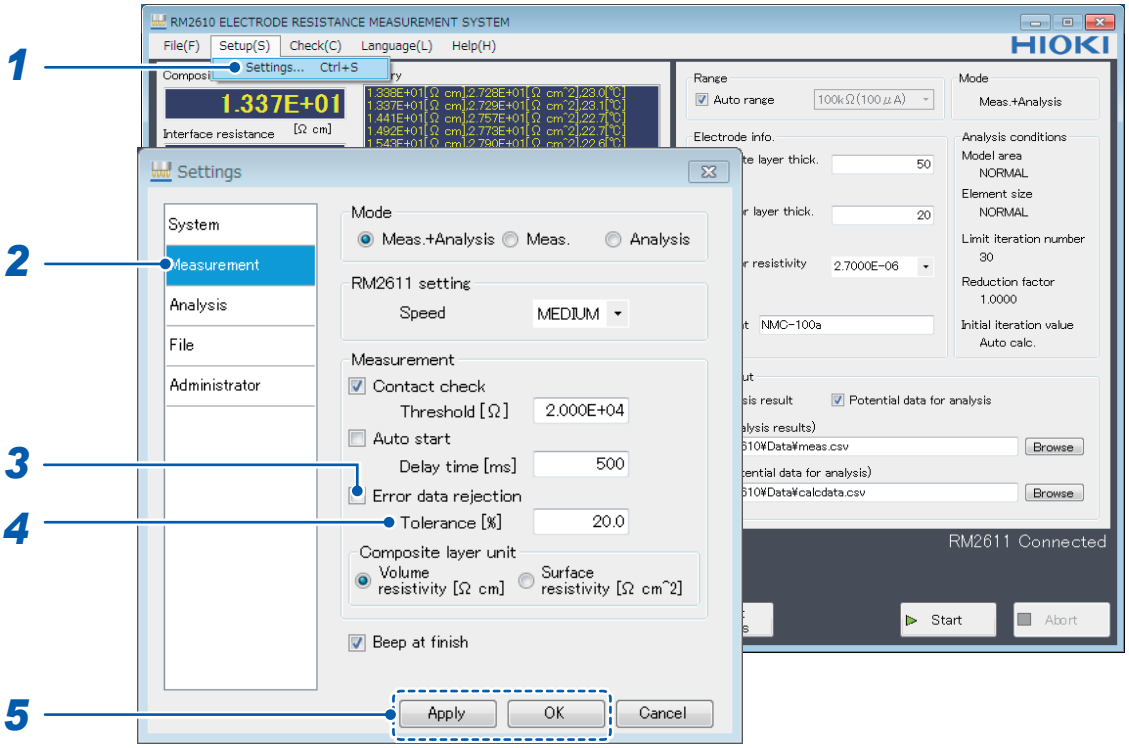
The instrument will begin monitoring the state of probe contact. Once the probes make contact with the electrode sheet, it will start measurement once the [Delay time [ms]] has elapsed. Once measurement is complete, the instrument will verify that probes are in the open state and then begin monitoring the contact state again.

4.3 Rejecting Error Data during Measurement (Error Data Rejection Function)

You can reject error data during measurement. Measurement will continue until a set threshold is exceeded, even if current errors, over-range errors, or contact errors are encountered.

Rejected error data

- Data with current errors
- Current channel data with a consistency result of FAIL
- Potential data from probes with contact errors



1 **Choose [Settings].**

2 **Choose [Measurement].**

3 **Choose one of the following settings for [Error data rejection]:**

ON	Reject error data.
OFF☑	Do not reject error data. (Skip step 4 below.) Potential measurement will stop if a single probe generates a contact error or if a single potential measurement step generates an error.

4 **Enter the error data threshold at which you wish to stop measurement in the [Tolerance [%]] field.**

Valid setting range	Initial value	Format
0.1 to 100.0	20.0	1 significant decimal digit (0.0)

Tips

Threshold (reference)

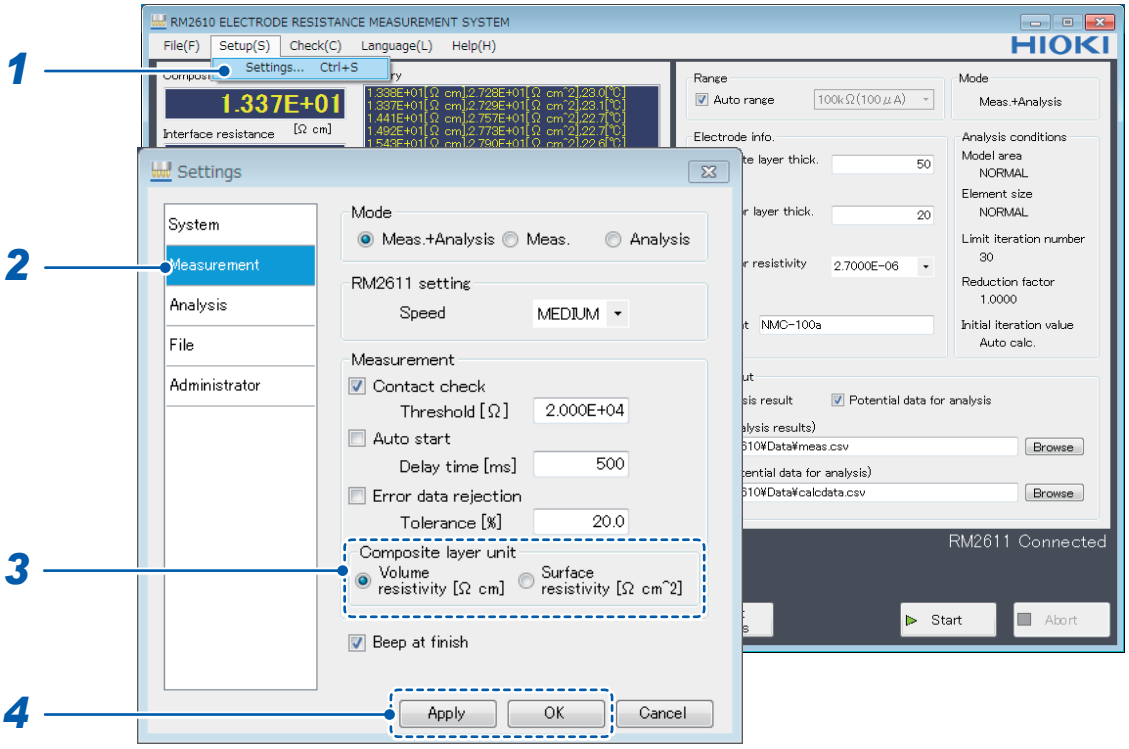
Potential measurement will stop when an error exceeding the tolerance occurs. The tolerance is set as a percentage, and the initial setting is 20%. It is recommended to use a setting of 10% to 20%. Use of a larger tolerance will increase tolerance for errors, but doing so will increase uncertainty in measurement results.

Tolerance [%]:
Potential measurement uses a large number of probes and involves multiple measurements. The error rate [%] is defined as the ratio of the number of measurements in which the instrument was unable to measure potential, for example due to a contact error or measurement error, to the total number of measurements, and tolerance [%] is defined as the amount of tolerance to exhibit relative to the error rate [%]. If all measurements were completed normally, the error rate would be 0%, while if all measurements failed, the error rate would be 100%. Determine the tolerance based on the electrode sheet being measured.

5 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

4.4 Choosing the Unit for Composite Layer Resistance

You can set the unit used to measure composite layer resistance to either **Volume resistivity [Ωcm]** or **Surface resistivity [Ωcm^2]**.



1 **Choose [Settings].**

2 **Choose [Measurement].**

3 **Choose one of the following settings for [Composite layer unit]:**

Volume resistivity [Ωcm]☑	Output the composite layer resistivity as volume resistivity [Ωcm]. Use this setting when calculating material properties.
Surface resistivity [Ωcm^2]	Output the composite layer resistivity as surface resistivity [Ωcm^2]. Use this setting when comparing the interface resistance [Ωcm^2] and resistance.

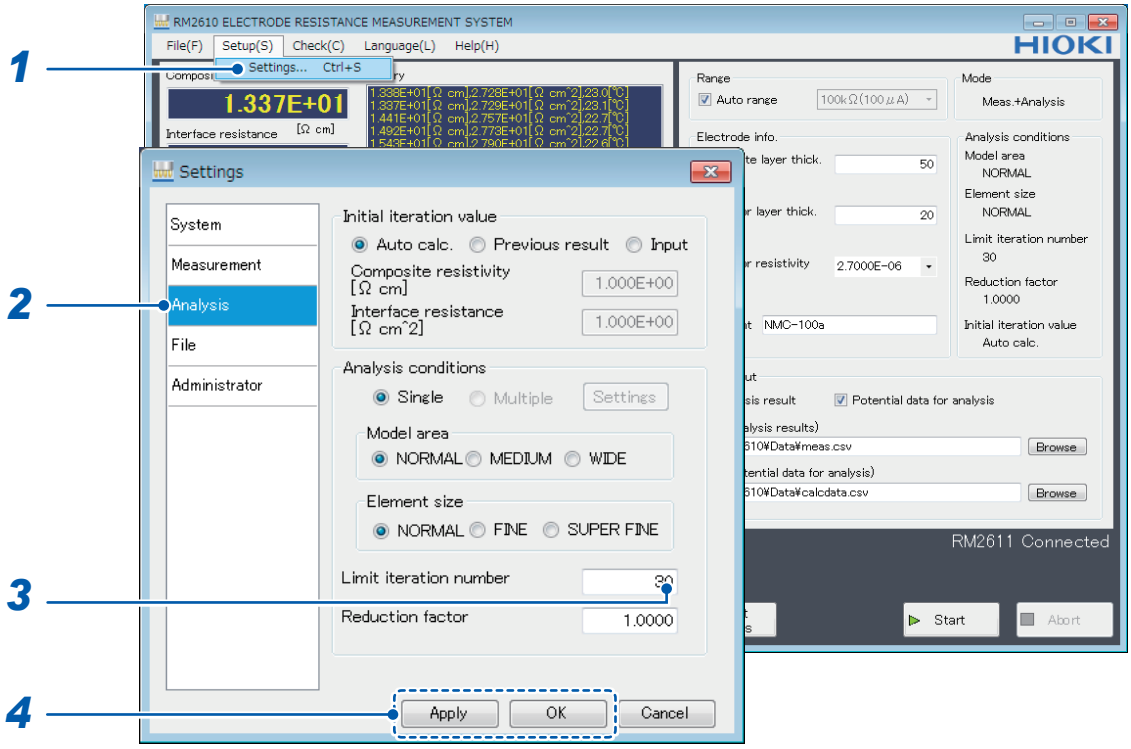
> **Tips** **Comparing the interface resistance [Ωcm^2] and resistance (p.99, p.100)**
>
> Formula:
> Composite layer volume resistivity [Ωcm] × composite layer thickness [cm]

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

Both the composite layer volume resistivity [Ωcm] and surface resistivity [Ωcm^2] will be output to the analysis results file.

4.5 Setting the Limit Iteration Number

This section describes how to set the limit on how many times analysis is performed.



1 **Choose [Settings].**

2 **Choose [Analysis].**

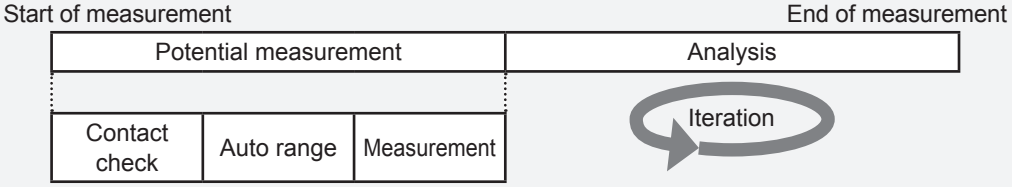
3 **Enter the upper limit for iterative calculations in the [Limit iteration number] field.**

Valid setting range	Initial value	Format
1 to 999	30	3-digit integer (000)

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

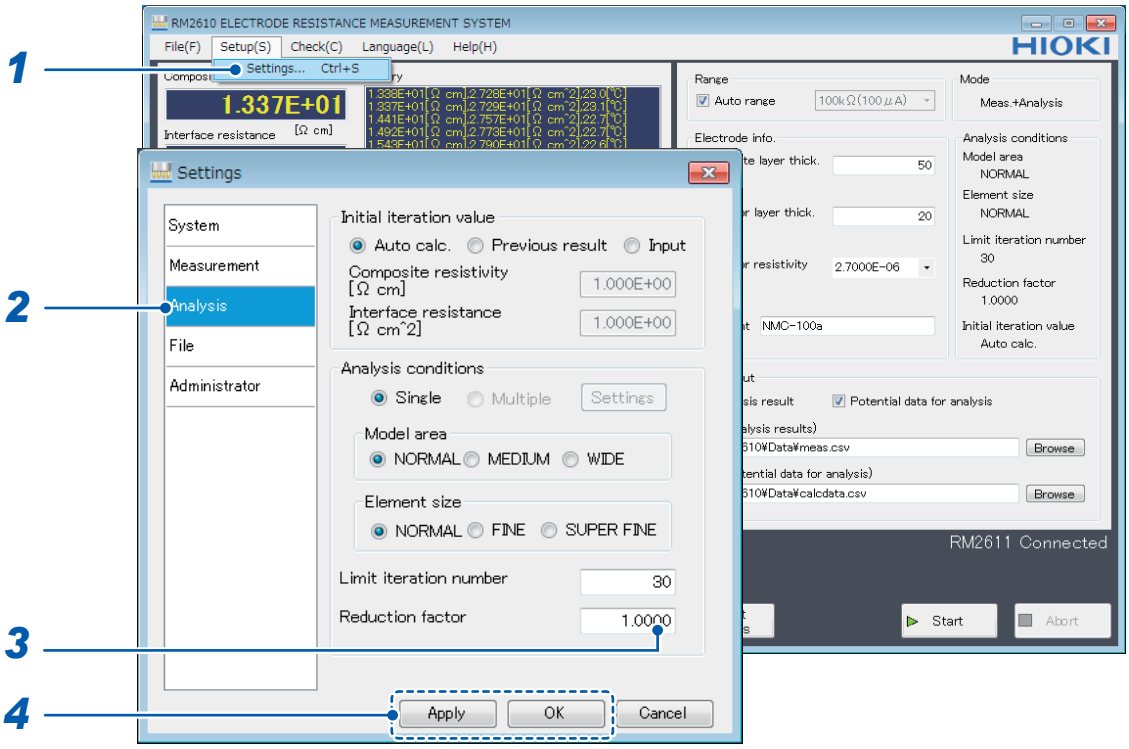
Tips **What is the limit iteration number?**

Set the **[Limit iteration number]** field to the maximum number of times to perform calculations before ending analysis. The instrument performs calculations repeatedly until the results converge, at which point it ends measurement and displays measured values. Ordinarily the initial value can be used, although the setting can be changed as necessary.



4.6 Setting the Reduction Factor

You can set the magnitude of the correction applied during iterative calculation of interface resistance (i.e., the reduction factor) to a value from 0.0001 to 1.0000.



1 **Choose [Settings].**

2 **Choose [Analysis].**

3 **Enter the desired value in the [Reduction factor] field.**

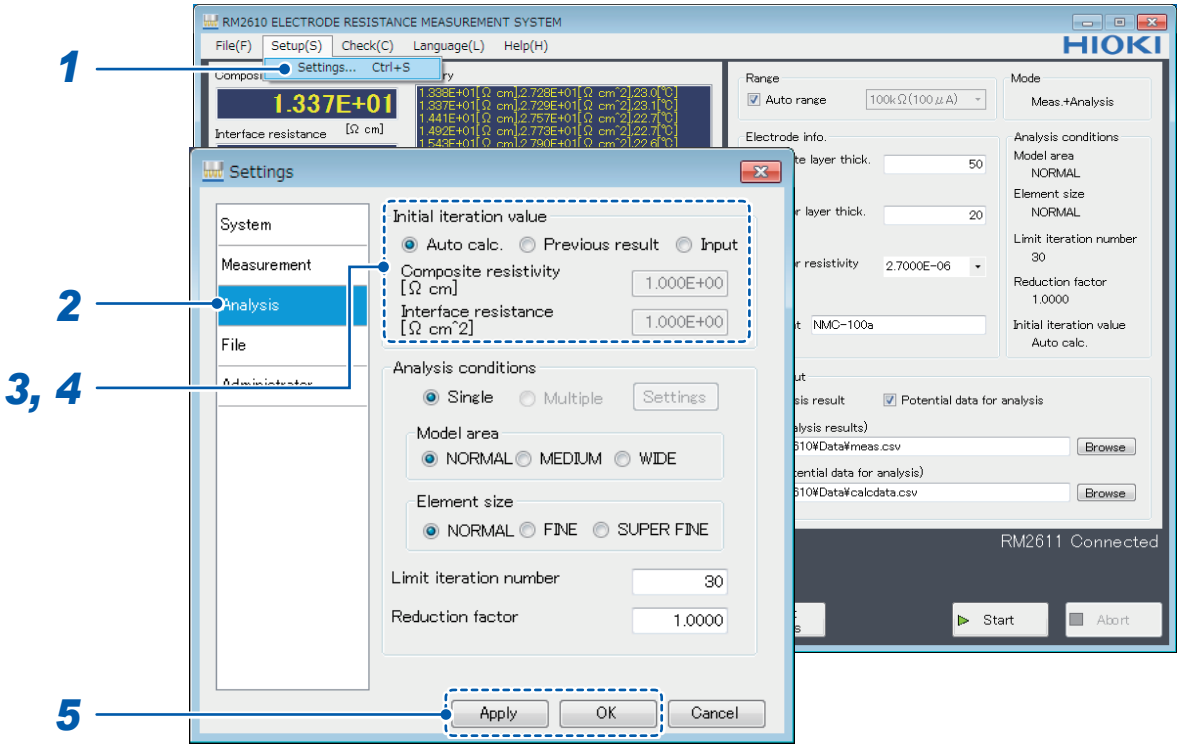
Valid setting range	Initial value	Format
0.0001 to 1.0000	1.0000	Decimal with 4 significant digits to the right of the decimal point (0.0000)

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

> **Tips** **What is the reduction factor?**
>
> The reduction factor is a parameter for adjusting the magnitude of the correction applied during iterative calculation of interface resistance. Use of a small value results in a more stable convergence process but incurs longer calculation times. When convergence is stable, it is recommended to use the initial setting of 1.0000. The setting can be changed as necessary (p.94).

4.7 Entering the Initial Iteration Value

This section describes how to enter the initial value for iterative calculations.



1 **Choose [Settings].**

2 **Choose [Analysis].**

3 **Choose one of the following initial resistance values for [Initial iteration value]:**

Auto calc.☑	(Skip step 4 below.)
Previous result	(Skip step 4 below.) If **[Previous result]** is selected, the initial resistance value will be used as the **[Auto calc.]** value if the previous analysis result is FAIL.
Input	Enter the **[Composite resistivity [Ωcm]]** and **[Interface resistance [Ωcm^2]]** (step 4).

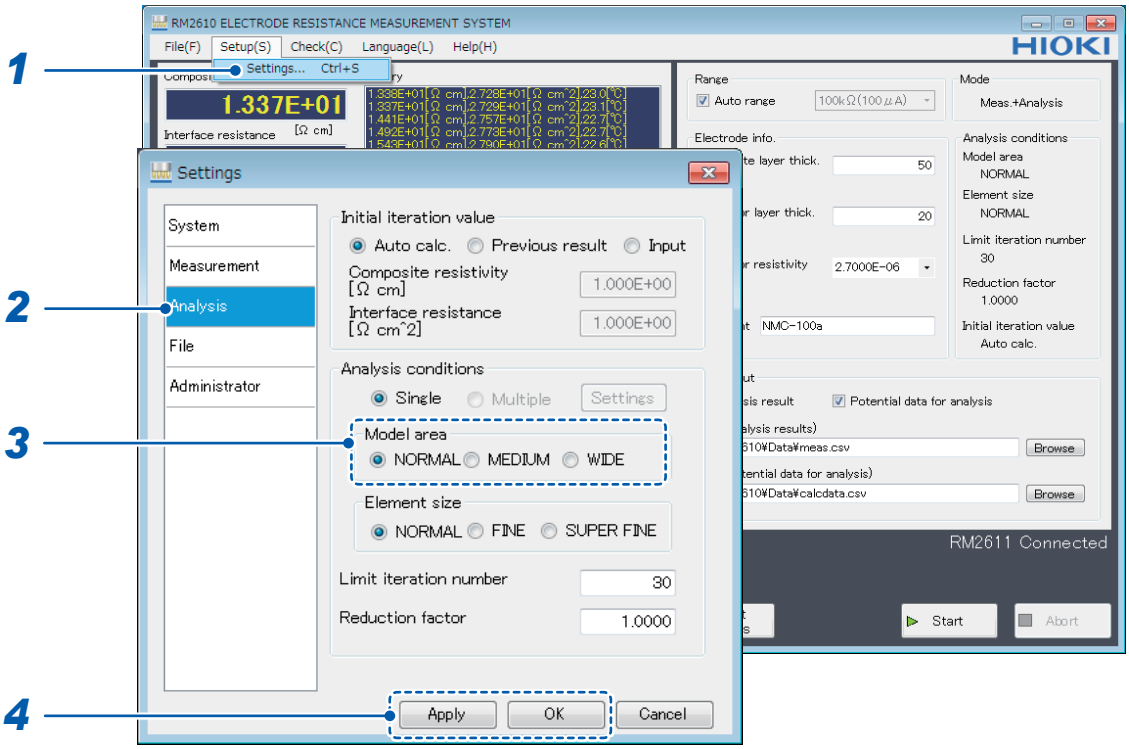
4 **Enter values for [Composite resistivity [Ωcm]] and [Interface resistance [Ωcm^2]].**

Valid setting range	Initial value	Format
1.0E-10 to 1.0E+5	1.000E+00	Decimal or exponential

5 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

4.8 Choosing the Model Area

This section describes how to choose a model area according to the measurement precision you require. Although measurement precision increases in proportion to the model area, calculation times will increase as well.



1 **Choose [Settings].**

2 **Choose [Analysis].**

3 **Choose one of the following settings for [Model area]:**

NORMAL☑	Perform analysis using the standard model area.
MEDIUM	Perform analysis using a model area that is about 2.5 times greater than the standard area (NORMAL).
WIDE	Perform analysis using a model area that is about 4 times greater than the standard area (NORMAL).

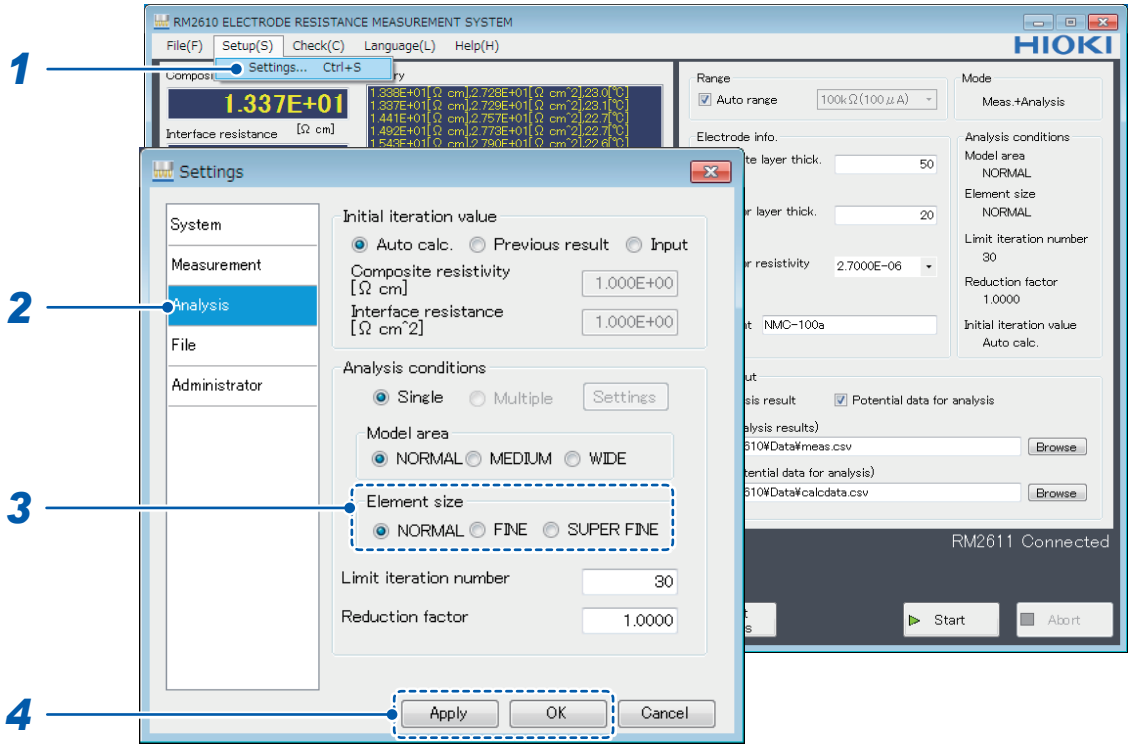
4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

Tips **What is model area? (p.97)**

Although increasing the model area setting will allow you to make measurements that more closely approach actual physical phenomena, calculation times will increase. Change the setting to reflect the degree of measurement precision that you require.

4.9 Choosing the Element Size

This section describes how to choose the element size.



1 **Choose [Settings].**

2 **Choose [Analysis].**

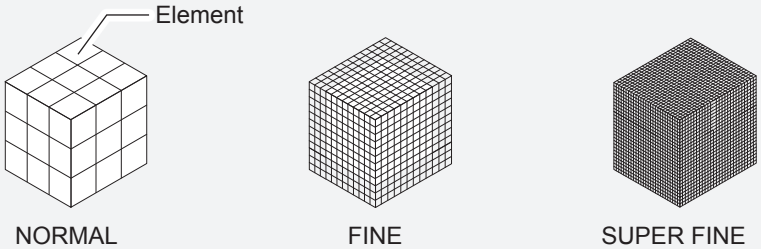
3 **Choose one of the following settings for [Element size]:**

NORMAL☑	Perform measurements at the standard element size.
FINE	Perform measurements at 1/4 of the standard element size (NORMAL).
SUPER FINE	Perform measurements at 1/9 of the standard element size (NORMAL).

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

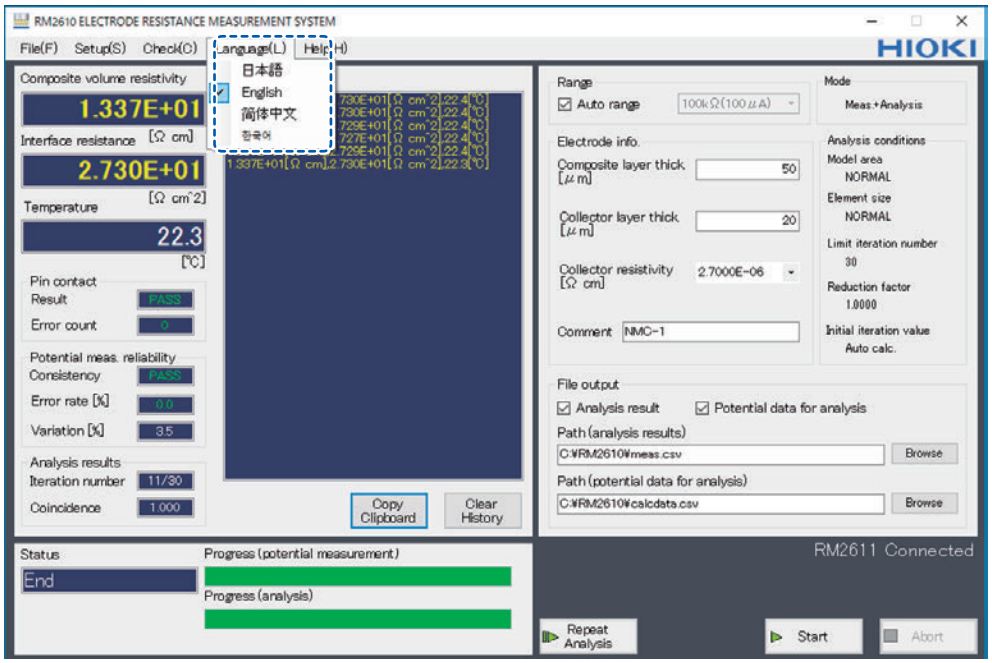
Tips **What is element size?**

Although using a small element size setting will allow you to make measurements that more closely approach actual physical phenomena, calculation times will increase. Change the setting to reflect the degree of measurement precision you require.



4.10 Switching the Display Language

This section describes how to choose the display language used by the RM2612 Resistance Calculation Software. Japanese, English, Simplified Chinese and Korean are available.



Language

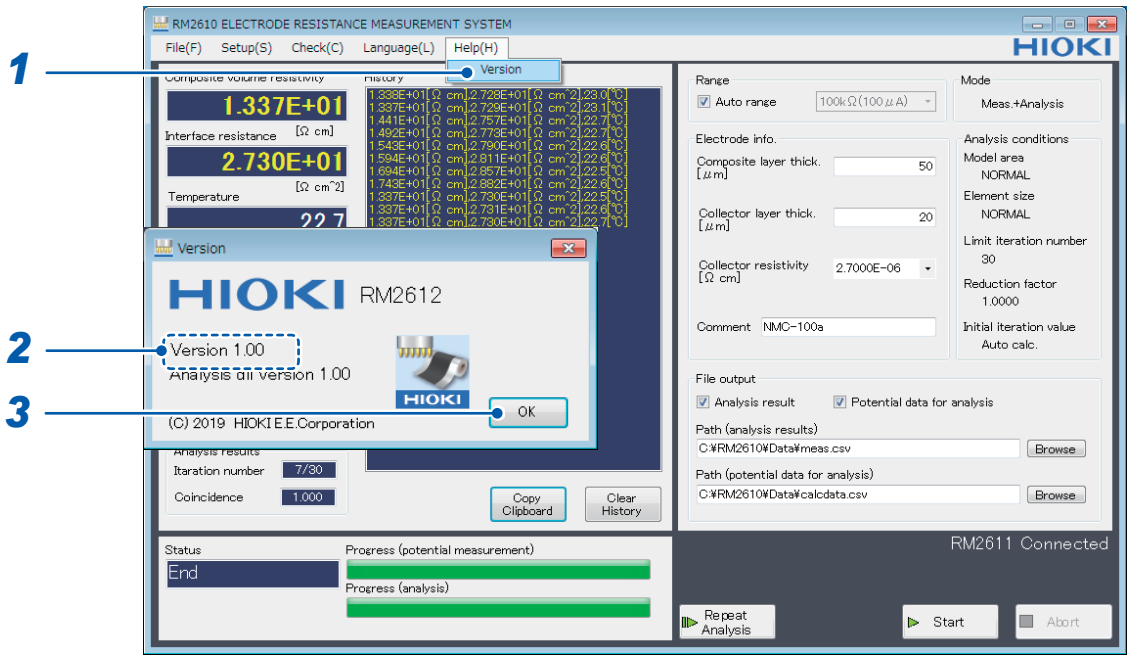
日本語 (Japanese)	Use Japanese as the display language.
English	Use English as the display language.
简体中文	Use Simplified Chinese as the display language.
한국어	Use Korean as the display language.

The default to the application language is set to the one chosen at the time of the installation.

4.11 Checking the Software Version

This section describes how to check the PC application's software version.

IMPORTANT
If you have Internet connectivity and can download files, the RM2612 Resistance Calculation Software's PC application can be updated. For more information, see "9.2 Updating the Software" (p.110).



1 **Choose [Version].**

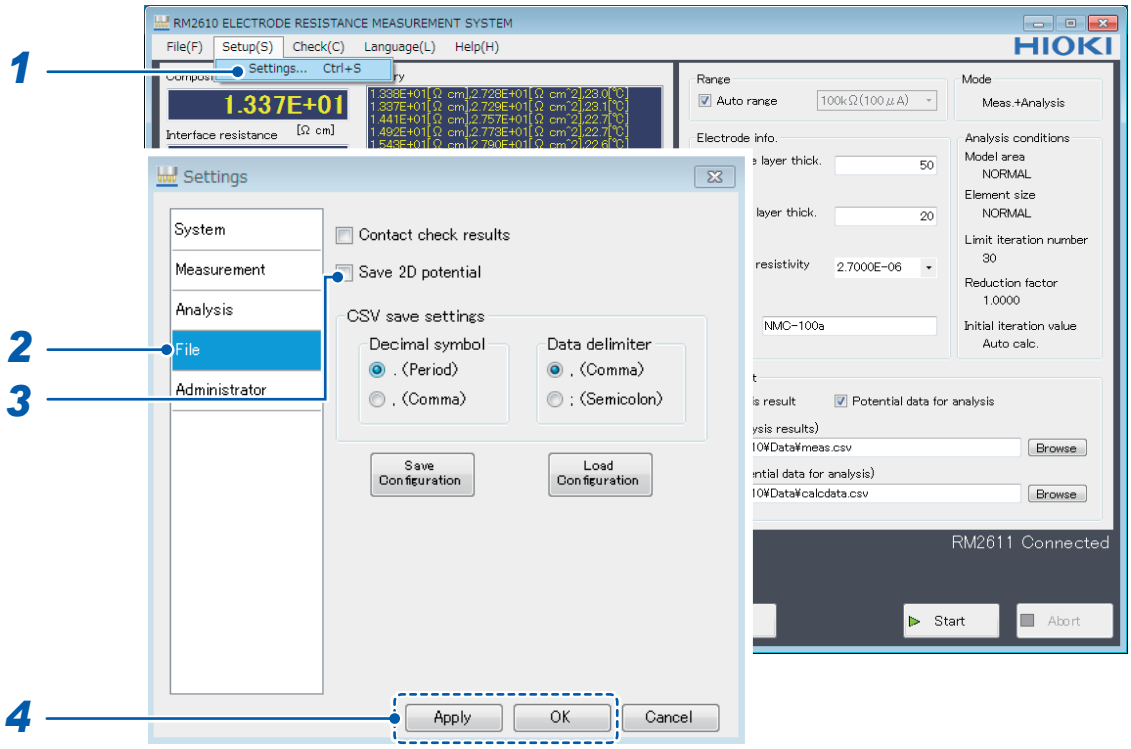
2 **Check the software version.**

The dialog box displays the version of the PC application and the version of the analysis DLL used internally by the software.

3 **Click [OK].**

4.12 Outputting a 2D Potential Distribution File

You can output a 2D potential distribution file of 5×5 potential measurements by enabling **[Save 2D potential]**. Data is subject to averaging processing.
The 2D potential distribution file allows you to view the potential gradient that exists when current flows to the electrode sheet. It can be used when you wish to perform analysis using a method other than the RM2610 Electrode Resistance Measurement System.
The output file uses a filename derived by adding “vpot_” to the beginning of the filename specified as the analysis results path.
For more information about the file format, see “2D Potential distribution file format” (p.86).



1 **Choose [Settings].**

2 **Choose [File].**

3 **Choose one of the following settings for [Save 2D potential]:**

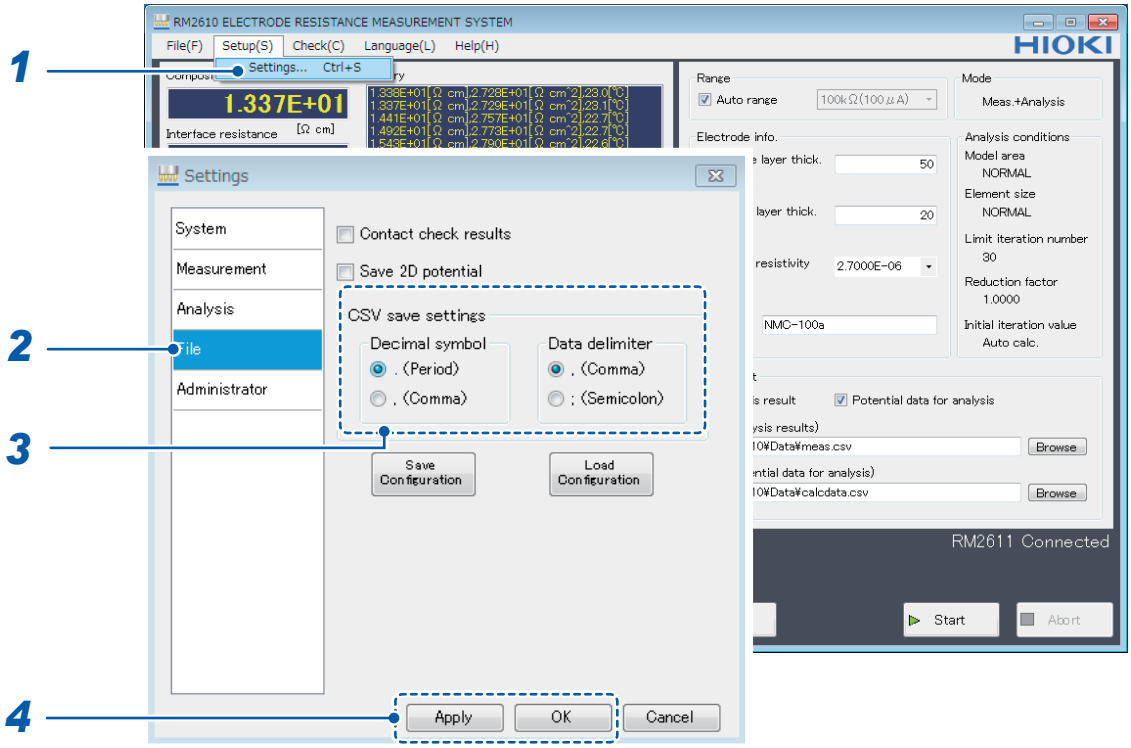
ON	Save 2D potential file output results.
OFF☑	Do not save 2D potential file output results.

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

4.13 Choosing the CSV Save Format

This section describes how to set the decimal symbol and choose the data delimiter for analysis results files and 2D potential distribution files.

IMPORTANT
You cannot choose the comma (“,”) as both the decimal symbol and the data delimiter.



1 **Choose [Settings].**

2 **Choose [File].**

3 **Choose one of the following settings for [CSV save settings]:**

Decimal symbol

. (Period)	Use the period (“.”) as the decimal symbol.
, (Comma)	Use the comma (“,”) as the decimal symbol.

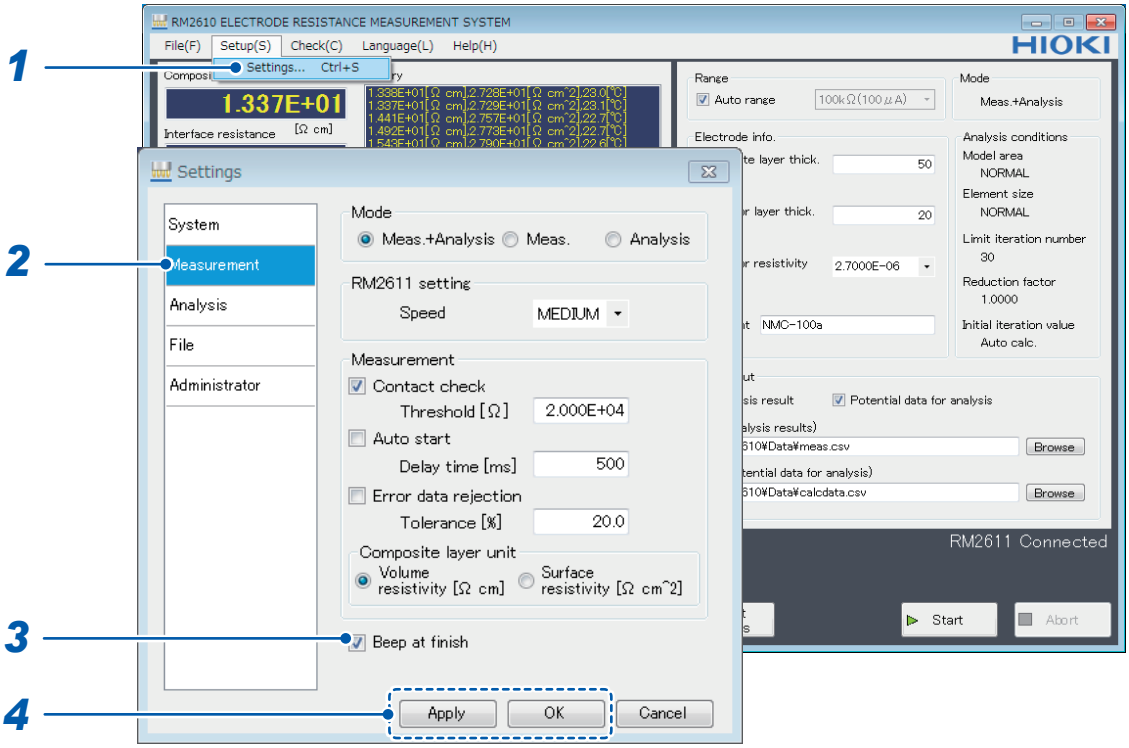
Data delimiter

, (Comma)	Use the comma (“,”) as the data delimiter.
; (Semicolon)	Use the semicolon (“;”) as the data delimiter.

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

4.14 Setting Whether to Beep at Measurement Completion

This section describes how to set whether to beep when measurement completes.



1 **Choose [Settings].**

2 **Choose [Measurement].**

3 **Choose one of the following settings for [Beep at finish]:**

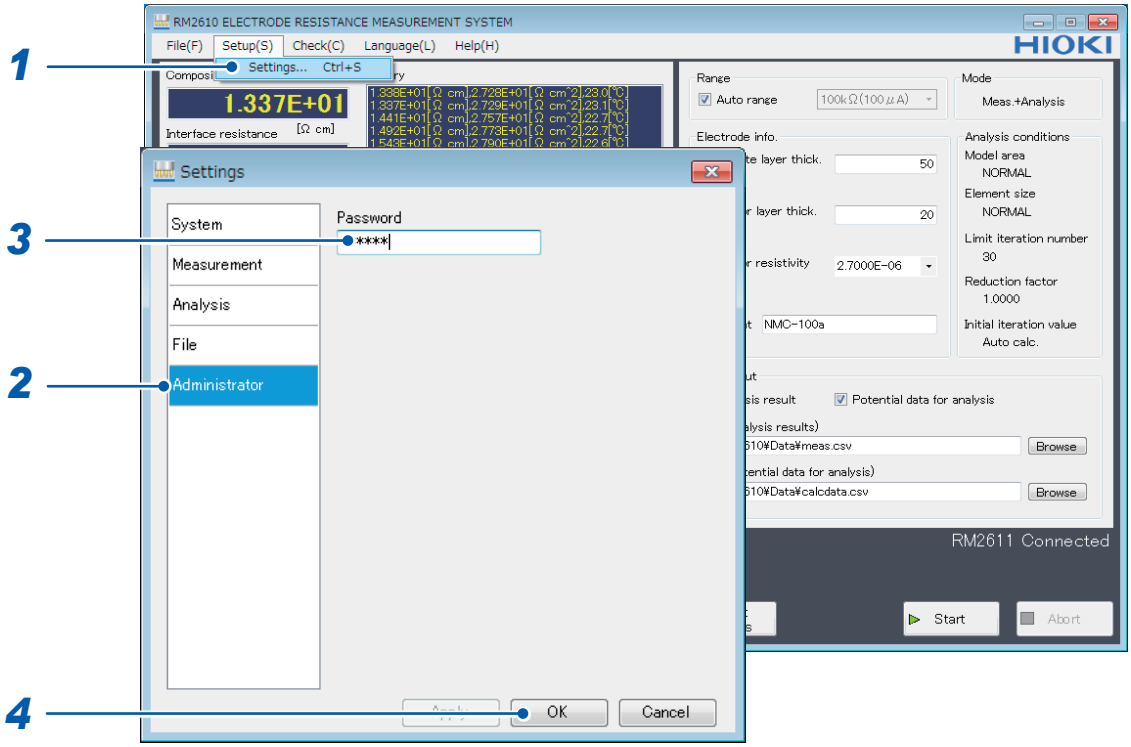
ON	Beep when measurement completes.
OFF☑	Do not beep when measurement completes.

4 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

4.15 Setting Administrator Mode

This functionality is not ordinarily used. Configure this setting only when you need to perform a special operation or verify system operation.

IMPORTANT
Follow instructions from Hioki when inspecting the RM2611 Electrode Resistance Meter.

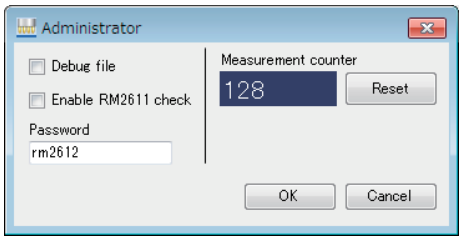


1 Choose **[Settings]**.

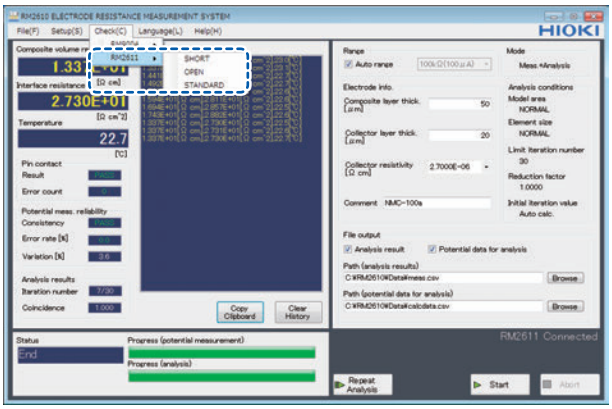
2 Choose **[Administrator]**.

3 Enter the **[Password]** (default password: rm2612).

4 Click **[OK]**.



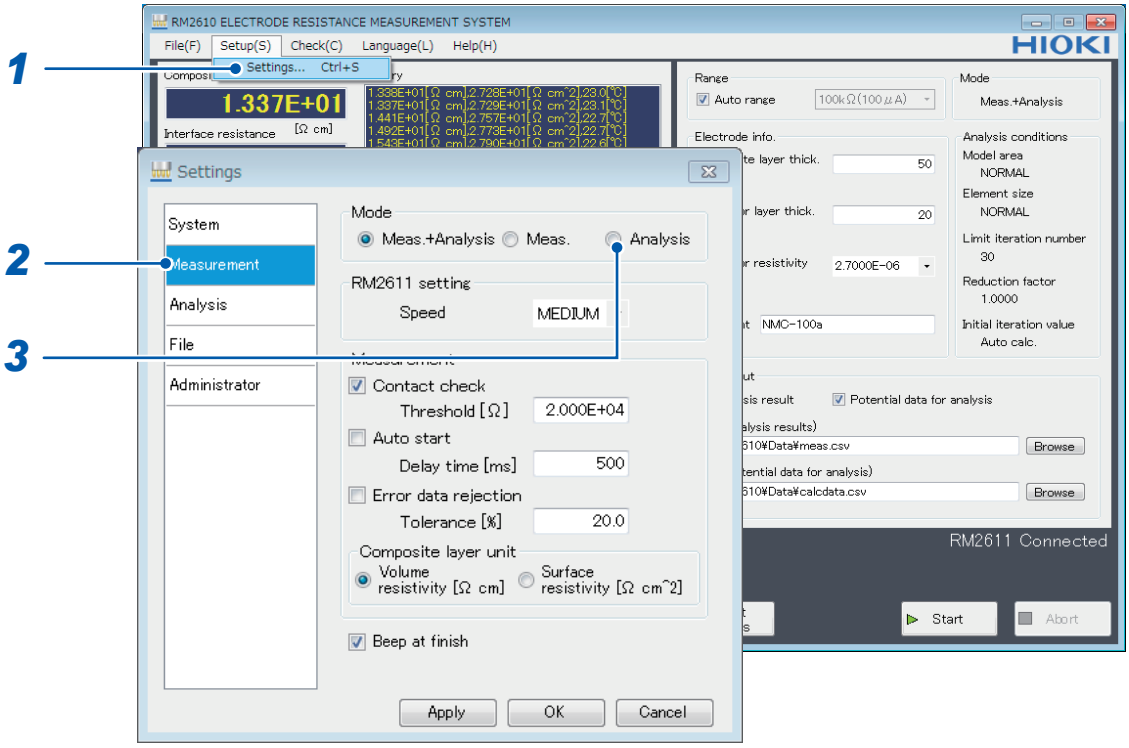
5 Configure the following settings:

Debug file	Enabling this setting causes intermediate reverse-analysis calculation results to be output to a file (for debugging use) (initial value: OFF). If you are unable to obtain satisfactory analysis results even after adjusting the reduction factor and other initial values, Hioki may ask you to send this file for examination (the file format is not publicly available).
Enable RM2611 check	Enabling this setting performs an inspection of the RM2611 Electrode Resistance Meter (initial value: OFF). Use this setting if you encounter issues as a way to discover potential causes. (Ordinarily, there is no need to inspect the RM2611 Electrode Resistance Meter.) Selecting the **[Enable RM2611 check]** checkbox in administrator mode will add **[RM2611]** to the **[Check]** on the main screen, allowing issues with the instrument to be diagnosed. Inspection results are output to a file, and you may be asked to send it to Hioki for examination. (A special jig is needed in order to inspect the RM2611.) 
Password	Set the password for accessing administrator mode. This setting may be changed as necessary. Initial value: rm2612
Measurement counter	Click **[Reset]** to reset the measurement counter to 0. The counter is incremented after each potential measurement to provide a rough guide as to the number of measurements that have been made with the RM9004 Test Fixture. Its value is output to the analysis results output file. Please reset the counter after replacing the RM9004 Test Fixture's probes.

5 Analysis

5.1 Analyzing One Potential Measurement under Multiple Conditions

Analysis can be performed continuously simply by specifying multiple analysis conditions for a single potential measurement datafile. When determining the analysis conditions, there is no need to perform multiple manual steps. The software can store up to 100 sets of conditions.

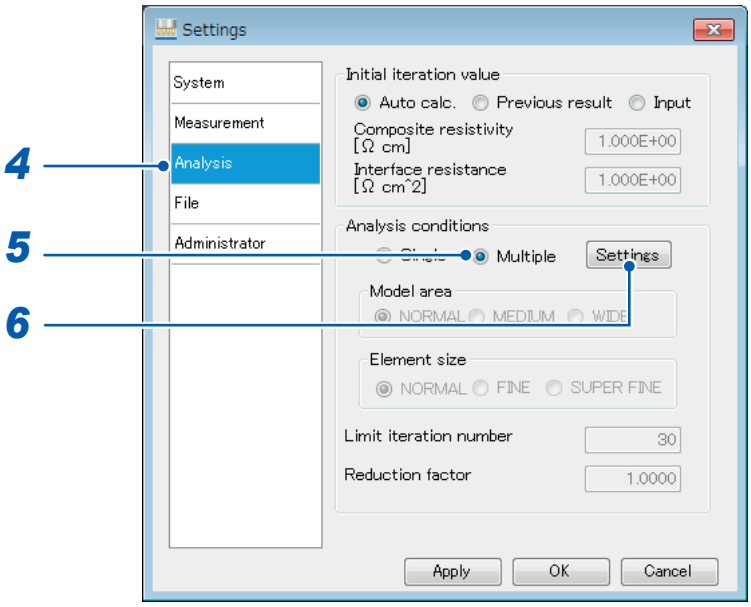


1 **Choose [Settings].**

2 **Choose [Measurement].**

3 **Choose [Analysis] as the [Mode].**

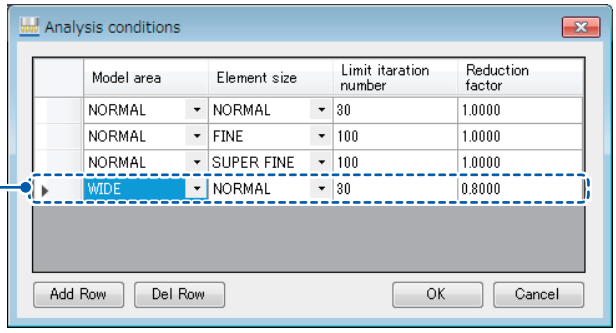
When specifying multiple analysis conditions, those conditions will apply to one file of potential data output for analysis use. Please save that file prior to setting the conditions.



4 Choose **[Analysis]**.

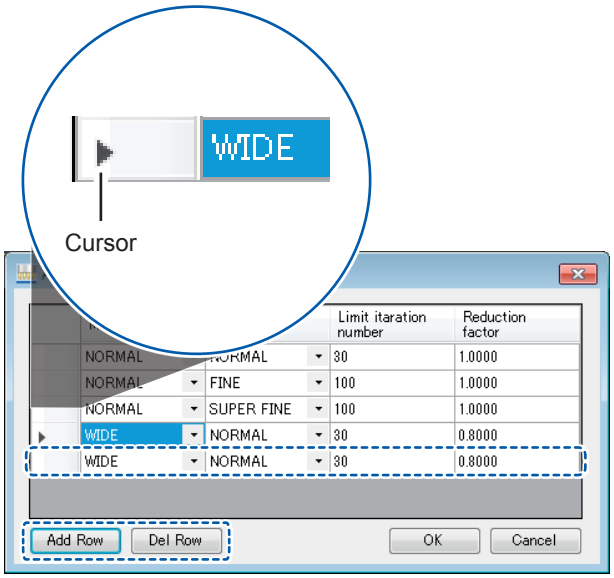
5 Choose **[Multiple]**.

6 Click **[Settings]**.



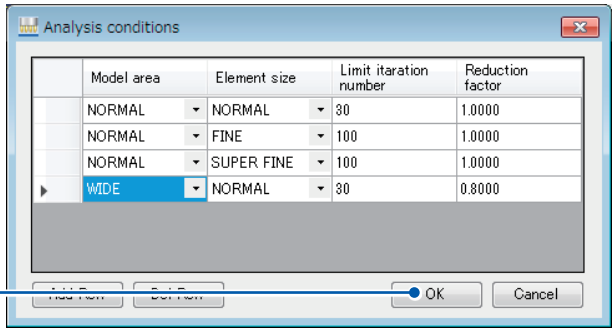
7 **Change the settings. The following four settings can be changed:**

Model area	**NORMAL**, **MEDIUM**, **WIDE**
Element size	**NORMAL**, **FINE**, **SUPER FINE**
Limit iteration number	1 to 999 (valid setting range)
Reduction factor	0.0001 to 1.0000 (valid setting range)

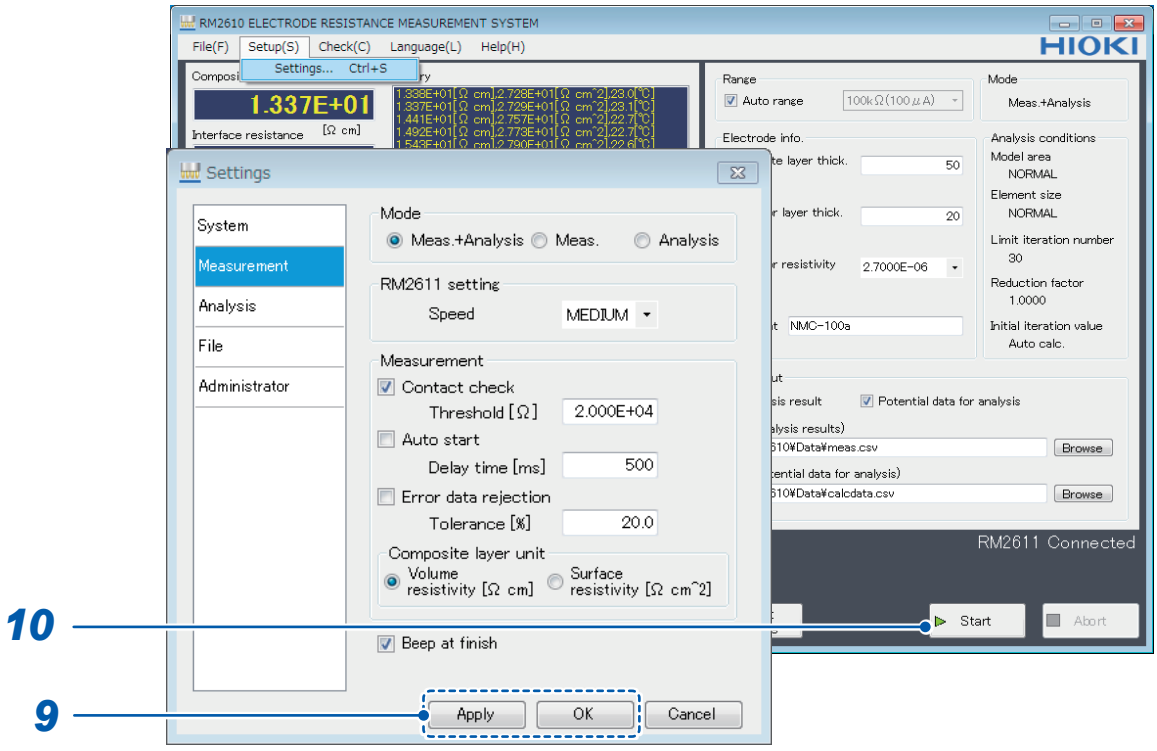


- Adding rows
  Click **[Add Row]** to add a row at the end of the list.

- Deleting rows
  Move the cursor (▶) to the row you wish to delete and click **[Del Row]** to delete the selected row. You can also select and delete multiple rows by holding down the SHIFT key or CTRL key on the PC while selecting rows with the mouse, or by dragging with the mouse.

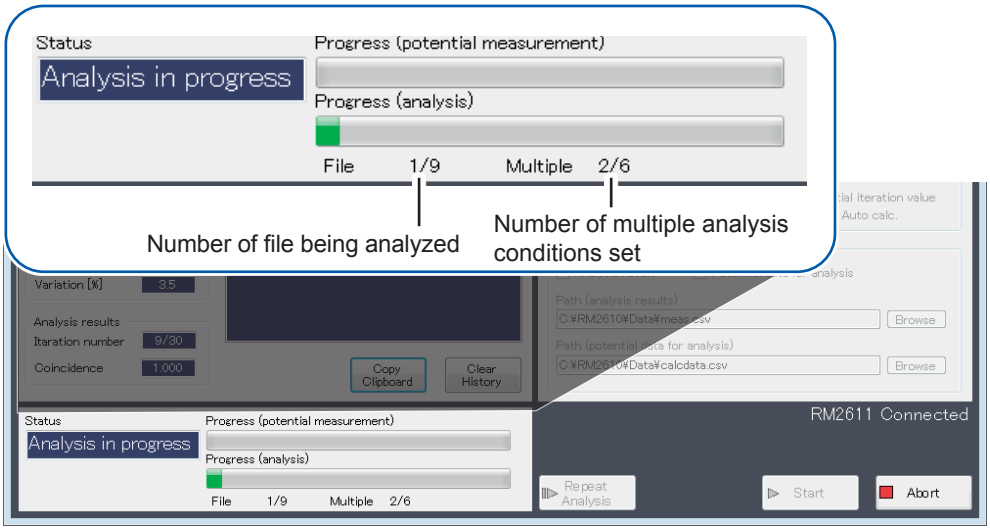


8 **Click [OK] to accept the changes.**
To cancel the configuration changes, click [Cancel].



9 **Click [Apply] or [OK] to accept the settings. (Clicking [OK] will cause you to return to the main screen.)**

10 **Click [Start] to open a dialog box that will ask you to choose a file and start analysis.**

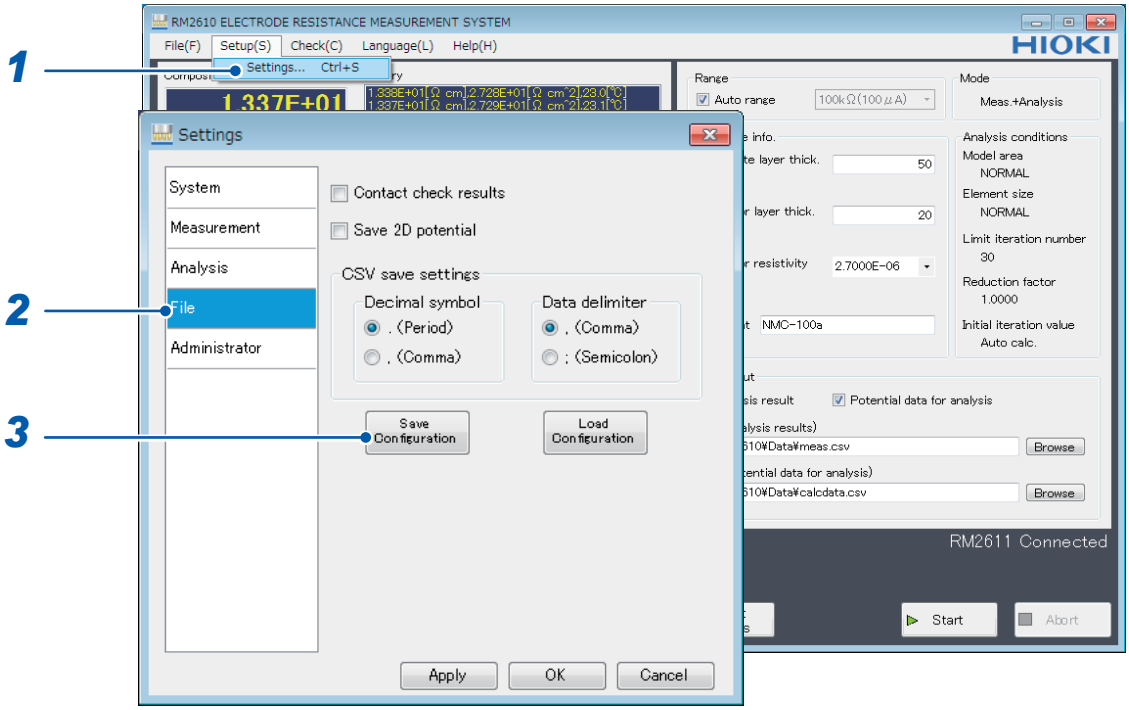


Progress will be displayed during analysis.

6 Saving and Loading Measurement Conditions

6.1 Saving Measurement Conditions

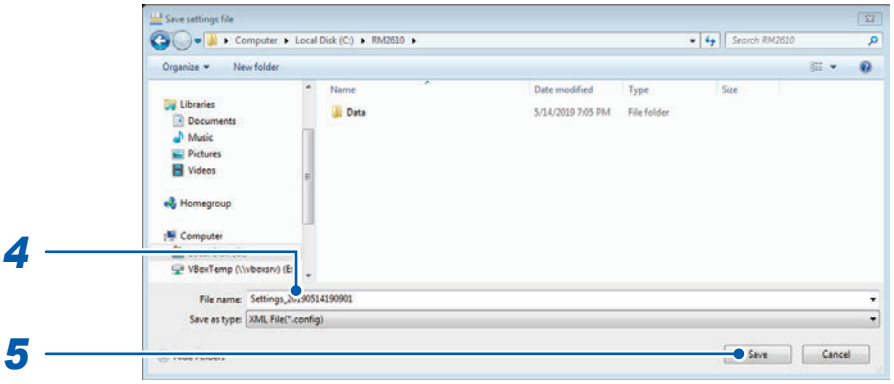
This section describes how to save the current measurement conditions in a user-specified folder on the PC.



1 Choose **[Settings]**.

2 Choose **[File]**.

3 Click **[Save Configuration]** to display the **[Save settings file]** dialog box.

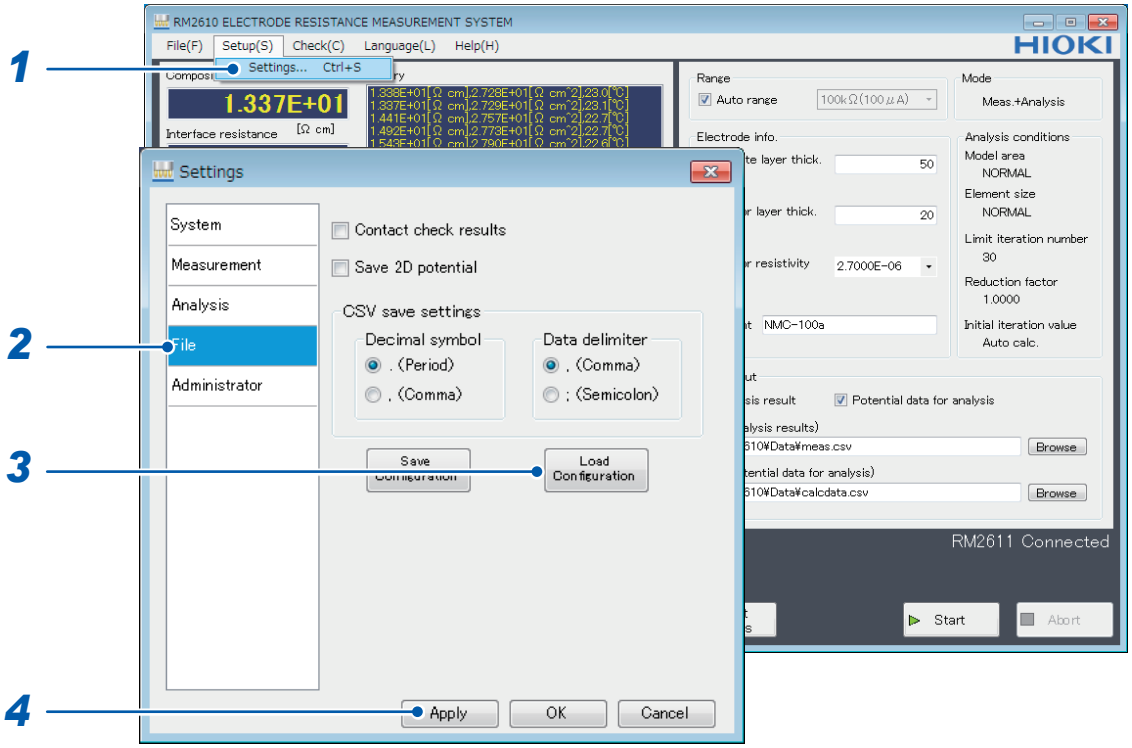


4 Provide a name for the file and choose a location in which to save the file.

5 Click **[Save]** to save the file.

6.2 Loading Measurement Conditions

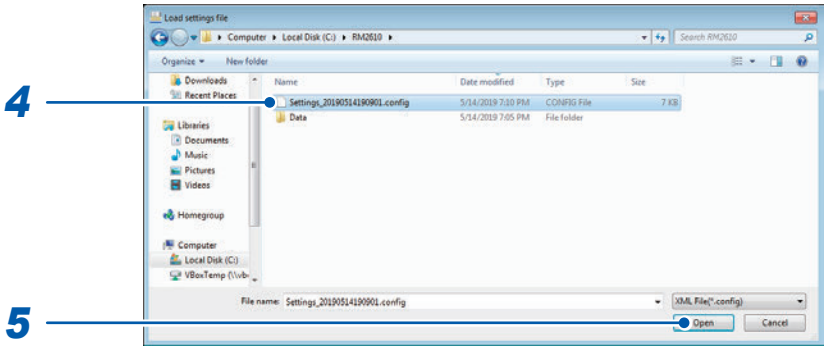
This section describes how to load previously saved measurement conditions.



1 Choose **[Settings]**.

2 Choose **[File]**.

3 Choose **[Load Configuration]** to display the **[Load settings file]** dialog box.



4 Choose the file you wish to load.

5 Click **[Open]**.

7 Specifications

Product components: See p. 5.

For more information about RM9003 Press Unit, RM9004 Test Fixture, and RM9005 Connection Cable specifications, please see those products' respective instruction manuals.

7.1 RM2611 Electrode Resistance Meter

General specifications

Operating environment	Indoors, Pollution Degree 2, altitude of up to 2000 m (6562 ft.)
Operating temperature and humidity	0°C to 40°C (32°F to 104°F), 80% RH or less (no condensation)
Storage temperature and humidity	0°C to 50°C (32°F to 122°F), 80% RH or less (no condensation)
Standards	Safety EN61010 EMC EN61326 Class A
Power supply	Commercial power Rated supply voltage: 100 V to 240 V AC (designed to accommodate voltage fluctuations of ±10% relative to the rated supply voltage) Rated supply frequency: 50 Hz, 60 Hz Anticipated transient overvoltage: 2500 V Maximum rated power: 40 VA (not including PC power)
Interfaces	• USB port (for connecting the instrument to a PC) • Test fixture connector • TEMP.SENSOR terminal (for connecting the instrument to the Z2001 Temperature Sensor)
Dimensions	Approx. 215W × 80H × 306.5D mm (8.46″W × 3.15″H × 12.07″D)
Weight	Approx. 3.4 kg (119.9 oz.)
Product warranty period	3 years
Fuse	F1.6AH 250 V ×1
Accessories	See p. 5
Options	See p. 5

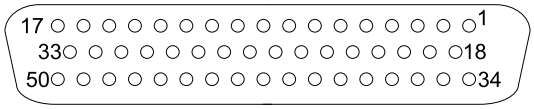
Input, output, and measurement specifications

Basic specifications

Measured parameters	DC resistance and temperature Automatic measurement is performed via the RM2612 Resistance Calculation Software. Measurement cannot be performed using the RM2611 Electrode Resistance Meter alone.
Resistance measurement signal	Constant current
Resistance measurement method	DC 4-terminal method
Resistance measurement terminal	Test fixture connector
Resistance measurement range	Ranges: 1000 mΩ, 10 Ω, 100 Ω, 1000 Ω, 10 kΩ, 100 kΩ, 1000 kΩ, 10 MΩ* For more information about range parameters, see "Table 1. RM2611 Electrode Resistance Meter Measurement Ranges" (p. 76). *Potential measurement results obtained using the 10 MΩ range are merely values for reference purposes.

Constant current generation range	1 µA (min.) to 10 mA (max.) For more information about range parameters, see “Table 1. RM2611 Electrode Resistance Meter Measurement Ranges” (p.76).
Test fixture connector	D-sub 50-pin receptacle
Temperature measurement terminal	TEMP.SENSOR terminal (for connecting the instrument to the Z2001 Temperature Sensor)

Test fixture connector pin assignments



No.	Pin name	No.	Pin name	No.	Pin name
1	TP6	18	TP16	34	N.C.
2	TP12	19	TP23	35	TP3
3	TP19	20	TP30	36	TP44
4	TP26	21	TP37	37	TP2
5	TP33	22	TP8	38	TP43
6	TP40	23	TP15	39	TP1
7	TP11	24	TP22	40	TP42
8	TP18	25	TP29	41	TP13
9	TP25	26	TP36	42	TP7
10	TP32	27	N.C.	43	TP20
11	TP39	28	N.C.	44	TP14
12	TP10	29	TP5	45	TP27
13	TP17	30	TP46	46	TP21
14	TP24	31	TP4	47	TP34
15	TP31	32	TP45	48	TP28
16	TP38	33	N.C.	49	TP41
17	TP9			50	TP35

Table 1. RM2611 Electrode Resistance Meter Measurement Ranges

f.s.= 1,000,000 dgt.

Range	Max. measurement range[*1]	Measurement range			Measurement current	Max. open voltage
1000 mΩ	1200.000 mΩ	0.000 mΩ	to	1200.000 mΩ	10 mA	5.5 V
10 Ω	12.00000 Ω	0.00000 Ω	to	12.00000 Ω	10 mA	5.5 V
100 Ω	120.0000 Ω	0.0000 Ω	to	120.0000 Ω	10 mA	5.5 V
1000 Ω	1200.000 Ω	0.000 Ω	to	1200.000 Ω	1 mA	5.5 V
10 kΩ	12.00000 kΩ	0.00000 kΩ	to	12.00000 kΩ	1 mA	20 V
100 kΩ	120.0000 kΩ	0.0000 kΩ	to	120.0000 kΩ	100 µA	20 V
1000 kΩ	1200.000 kΩ	0.000 kΩ	to	1200.000 kΩ	10 µA	20 V
10 MΩ[*2]	12.00000 MΩ	0.00000 MΩ	to	12.00000 MΩ	1 µA	20 V

*1: Negative values: To -10% f.s.

*2: Potential measurement results obtained using the 10 MΩ range are merely values for reference purposes.

Accuracy specifications

Accuracy guarantee conditions	Resistance measurement accuracy is defined when using the test fixture connector. Guaranteed accuracy period: 1 year Guaranteed accuracy period after adjustment made by Hioki: 1 year Temperature and humidity for guaranteed accuracy: 23°C ±5°C (73°F ±9°F), 80% RH or less Warm-up time: 60 min. or greater Power supply frequency: 50 Hz ±2 Hz, 60 Hz ±2 Hz
Resistance measurement accuracy	See Table 2 (p.77).
Temperature measurement accuracy	See Table 3 (p.77).

Table 2. RM2611 Electrode Resistance Meter Resistance Measurement Accuracy (Test Fixture Connector Resistance Measurement Accuracy)

Range	Max. measurement range	Resistance measurement accuracy (FAST) % rdg. + % f.s.	Resistance measurement accuracy (MEDIUM, SLOW1, SLOW2) % rdg. + % f.s.
1000 mΩ	1200.000 mΩ	0.5 + 1.0	0.3 + 0.7
10 Ω	12.00000 Ω	0.2 + 0.2	0.1 + 0.1
100 Ω	120.0000 Ω	0.2 + 0.2	0.1 + 0.1
1000 Ω	1200.000 Ω	0.2 + 0.2	0.1 + 0.1
10 kΩ	12.00000 kΩ	0.2 + 0.2	0.1 + 0.1
100 kΩ	120.0000 kΩ	0.2 + 0.2	0.1 + 0.1
1000 kΩ	1200.000 kΩ	1.0 + 1.0	0.5 + 0.5
10 MΩ*	12.00000 MΩ	3.0 + 3.0	3.0 + 1.0

*Potential measurement results obtained using the 10 MΩ range are merely values for reference purposes.

Table 3. Temperature Measurement Accuracy (Z2001 Temperature Sensor)

Measurement range: -10.0°C to 99.9°C
Measurement period (speed): 2 ±0.2 s
Guaranteed accuracy period: 1 year
Combination accuracy with the Z2001 Temperature Sensor

Temperature range	Accuracy
-10.0°C to 9.9°C	±(0.55 + 0.009 × |*t* -10|) °C
10.0°C to 30.0°C	±0.50 °C
30.1°C to 59.9°C	±(0.55 + 0.012 × |*t* -30|) °C
60.0°C to 99.9°C	±(0.92 + 0.021 × |*t* -60|) °C

t: Measurement temperature (°C); standalone accuracy of RM2611 Electrode Resistance Meter: ±0.2°C

Interface specifications

USB	USB 2.0 (Full Speed) Connector: Series B receptacle Exclusively for connecting the RM2611 Electrode Resistance Meter to a PC

7.2 RM2612 Resistance Calculation Software

General specifications

Operating requirement (PC)	CPU: Intel® Core™ i7, 2.4 GHz, 4 threads or better (recommended) RAM: 8 GB or more recommended (4 GB available RAM required) Hard disk: 2 GB or more available space Display: 1024 × 768 pixels or more, 65536 colors or more Interface: USB 2.0 or better Operating system: Windows 7 (32-bit/64-bit) Windows 8 (32-bit/64-bit) Windows 10 (32-bit/64-bit) Microsoft .NET Framework 4.8 (as of 2020/10/15)
Accessories	See p. 5
Product warranty period	1 year

Functional specifications (PC application functions)

Analysis parameters	• Composite layer volume resistivity [Ωcm], composite layer surface resistivity [Ωcm^2] (user-switchable) • Interface resistance [Ωcm^2]
Analysis method	Inverse problem analysis of potential distribution using the finite volume method
Display and output format	• Composite layer volume resistivity and interface resistance Exponential notation: 4 significant digits, “0.000E+00,” “Ωcm/Ωcm^2” • Temperature Decimal notation, “00.0°C”
Measurement times (representative values)	• Contact check: 4 s • Auto range: 8 s • Potential measurement: 18 s (MEDIUM) • Analysis: 30 s (until completion using the standard iteration number) Total: Approx. 60 s **Conditions** • Observed values when measuring a standard positive electrode sheet (reference) • Fine volume model area: NORMAL; element size: NORMAL • Calculation times are reference values obtained using an Intel® Core™ i7 4-core 2.4 GHz processor. • Calculation times depend on the processing throughput of the PC. • Measurement times are subject to change in the event the software is updated.
Resistance range selection functionality	• Auto range: ON/OFF (via checkbox) Automatic selection of the optimal resistance range for potential measurement (initial value: ON) • Resistance range selection (when Auto range is OFF) 1000 mΩ, 10 Ω, 100 Ω, 1000 Ω, 10 kΩ, 100 kΩ, 1000 kΩ, 10 MΩ* *Potential measurement results obtained using the 10 MΩ range are merely values for reference purposes.
Potential measurement speed	FAST, MEDIUM, SLOW1, SLOW2 (initial value: MEDIUM)

Operating modes	Operating modes (initial value: potential measurement + analysis) • Potential measurement + analysis • Potential measurement • Analysis **Explanation of operation** • Potential measurement + analysis: Instrument performs potential measurement and then analysis. • Potential measurement: Instrument saves measured potential data to a file (one file per measurement). • Analysis: Instrument loads a potential file saved during potential measurement, analyzes the file, and saves the results to a file. Multiple files can be selected, and analysis can be performed continuously.
Current error detection	The instrument detects current errors, aborts measurement, and recommends that the user change the range. Display: “ERROR”
Resistance over-range detection	The instrument detects over-range events and recommends that the user change the range. Display: “ERROR”
Contact check function	Contact check ON/OFF Resistance threshold: 1 Ω to 10 MΩ (Initial values: ON, 20 kΩ [2.000E+04]) Input format: Decimal, exponential, up to 3 decimal places “0.000E+0” • Display: “CONTACT ERROR” • The instrument performs a simple measurement of the contact resistance between the probes and the measurement target using two-terminal measurement and concludes that a contact error has occurred if the resulting value is less than the applicable threshold. • Contact error probe identification (estimation) function The instrument combines measurements of the resistance between probes using two terminals and identifies which probes triggered the contact error.
Measurement reliability indicator function	Provides the following data for measured potential: • Consistency (legitimacy of the relative magnitude of center 5 points): PASS/FAIL • Variability per current channel: Current coefficient of variability [%] • Percentage of data rejected by the error data rejection function (error rate): [%] (Measurement is stopped in the event of a FAIL result for consistency.)
Error data rejection function	Rejection function ON/OFF (initial value: OFF) Rejection of error data • Data with current errors is rejected. • Current channel data with a consistency result of FAIL is rejected. • Potential data from probes with contact errors is rejected from the calculation process.
Counter function	Functionality for counting the number of measurements performed since the application was launched (can be reset by user) Counter values are output to analysis results files and potential files for analysis to serve as a rough guide to the number of measurements performed by the RM9004 Test Fixture.
Comment entry function	Text entered into the comment field is linked to the measurement target and output to a file. 1 comment per measurement (up to 30 characters)

Entry of analysis conditions	• Upper limit on iterative calculations: 1 to 999 calculations Initial value: 30 [calculations] Input format: 3-digit integer “000” • Reduction factor: 1.0E-4 to 1 Initial value: 1.0 Input format: Decimal, up to 4 decimal places, “0.0000” • Resistance value initial value: Automatic calculation / user-entered value / reference to analysis results Composite layer volume resistivity and interface resistance input range: 1.0E-10 to 1.0E+5 Input format: Decimal, exponential • Finite volume model area: NORMAL, MEDIUM, WIDE Initial value: NORMAL • Element size: NORMAL, FINE, SUPER FINE Initial value: NORMAL
User-entered information about measurement targets	Information necessary for analysis • Composite layer thickness [µm] Valid setting range: 1.0E-4 µm to 1000 µm Input format: Decimal or exponential, 5 significant digits • Collector thickness [µm] Valid setting range: 1.0E-4 µm to 1000 µm Input format: Decimal or exponential, 5 significant digits • Collector volume resistivity [Ωcm] Valid setting range: 1.0E-10 to 1.0E+5 Input format: Decimal or exponential, 5 significant digits Initial value: Volume resistivity of aluminum • Display of candidate values for collector volume resistivity (aluminum [2.7000E-6 Ωcm] and copper [1.7000E-6 Ωcm])
Analysis reliability display function	Display of reliability of analysis results • Iteration number [iterations] • Agreement between measured potential and calculated potential (coefficient of determination)
Temperature measurement function	Measurement of the ambient temperature near the test fixture (using the Z2001 Temperature Sensor) Results can be displayed along with measured values on the screen and output to a file.
Progress display	Display of progress in the form of a progress bar Separate progress bars are shown for potential measurement and analysis.
Condition save function	• The application launches with the same conditions that were in effect when it was last exited. • Measurement and analysis conditions can be saved to a file and loaded as desired.
File save function	• Analysis results file • Potential file for analysis (can be used in repeated analysis) • 2D potential distribution file The user can specify the folder in which files are saved.
Test fixture continuity test function	Test of probes using the probe check board (RM9004 Test Fixture inspection) • OPEN Inspection • SHORT Inspection Identification of probes with continuity defects

Measurement start/stop	Methods for starting measurement: • Click **[Start]** in the application. • Press the [F5] key. Methods for stopping measurement: • Click **[Abort]** in the application.
Re-analysis function	Re-analysis after changing analysis conditions and measurement target information Previously measured potential data is used to repeat the analysis process. Re-analysis can be performed after changing analysis conditions and measurement target information.
Auto start function	• Perform one measurement when the probes make contact with an electrode sheet: ON / OFF • Start delay: Can be set from 0 ms to 2000 ms Initial value: OFF; delay: 500 ms
Security	• A USB license key is required in order to launch the application. • Functionality for automatically updating the application to a new version (Internet-connected installations only)
Language	Japanese, English, Simplified Chinese, Korean

Effects on analysis results (reference values)

The following tables provide information about various effects for use as reference values when the RM2611 Electrode Resistance Meter and RM9004 Test Fixture are used together.

Effect on calculation results of probe position precision (reference values)

Effect on resistance calculation results of probe position precision for a typical electrode sheet, where misalignment of probe coordinates is given by Δx and Δy and where the standard deviation for Δx and Δy is σ = 5 µm		
		Parameters of the electrode sheet used as a model
Negative electrode	Coefficient of variability for composite layer volume resistivity: 2.3% Coefficient of variability for interface resistance: 3.6%	Composite layer thickness: 33 µm Composite layer resistivity: 0.13 Ωcm Interface resistance: 0.06 Ωcm^2
Positive electrode	Coefficient of variability for composite layer volume resistivity: 2.7% Coefficient of variability for interface resistance: 2.5%	Composite layer thickness: 70 µm Composite layer resistivity: 10 Ωcm Interface resistance: 1 Ωcm^2

Coefficient of variability [%] = (Standard deviation) / (Average value) × 100

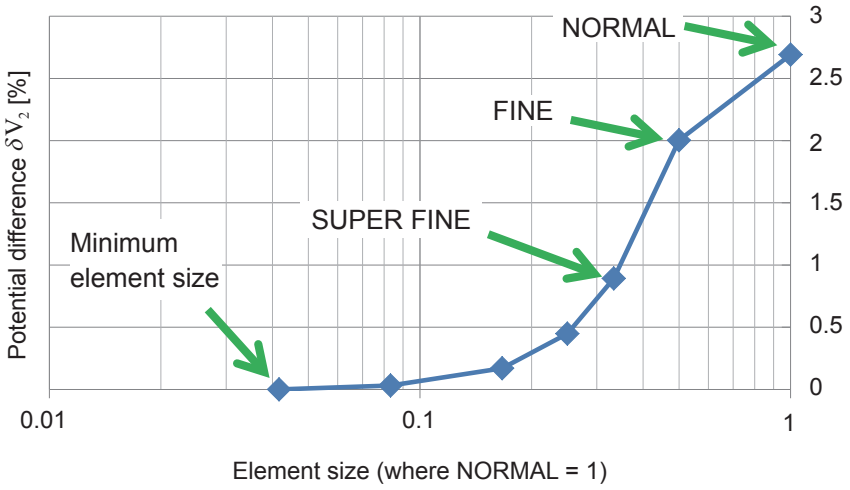
Effect of modeling

Effect of element size on calculated potential values in the finite volume model (reference values)

		Parameters of the electrode sheet used as a model
Negative electrode	NORMAL: 2.7% FINE: 2.0% SUPER FINE: 0.9%	Composite layer thickness: 33 µm Composite layer resistivity: 0.13 Ωcm Interface resistance: 0.06 Ωcm^2
Positive electrode	NORMAL: 3.3% FINE: 2.9% SUPER FINE: 1.4%	Composite layer thickness: 70 µm Composite layer resistivity: 10 Ωcm Interface resistance: 1 Ωcm^2

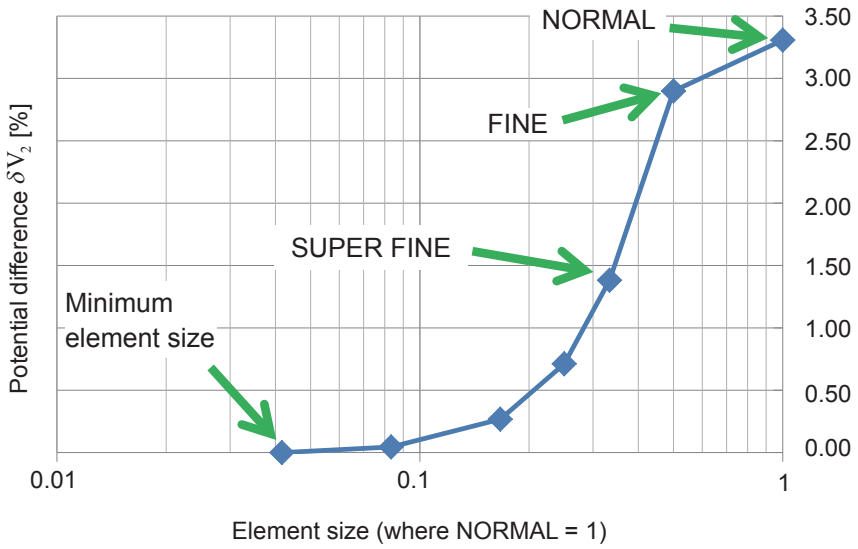
Calculation results with negative electrode representative values

Change in calculated potential values caused by element size
(Potential 120 µm from the probe applying the current)



Calculation results with positive electrode representative values

Change in calculated potential values caused by element size
(Potential 120 µm from the probe applying the current)



Minimum element size is set internally by Hioki.

The potential difference δV_2 is defined as follows:

$$\delta V_2 = \left| \frac{v\,(\text{Minimum element size}) - v\,(\quad \text{Element size} \quad)}{v\,(\text{Minimum element size})} \right| \times 100[\%]$$

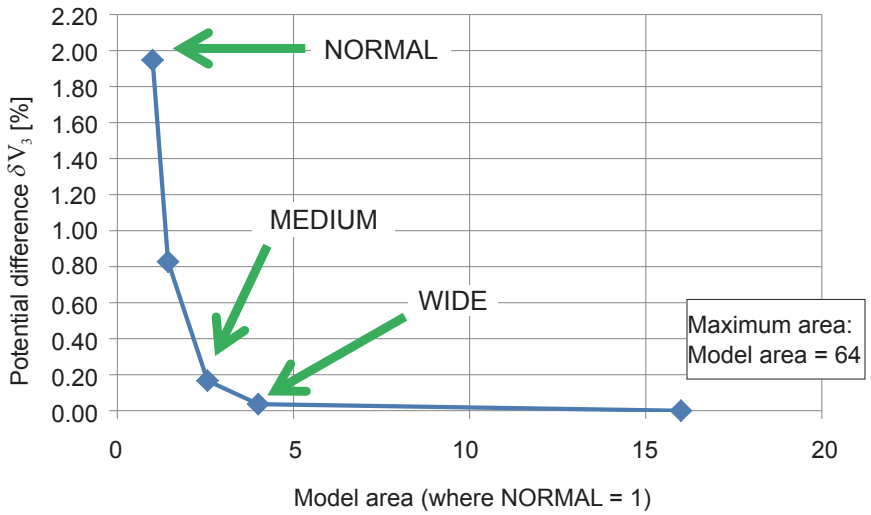
Effect of fine volume model area on calculated potential values (reference values)

		Parameters of the electrode sheet used as a model
Negative electrode	NORMAL: 2.0% MEDIUM: 0.17% WIDE: 0.04%	Composite layer thickness: 33 µm Composite layer resistivity: 0.13 Ωcm Interface resistance: 0.06 Ωcm^2
Positive electrode	NORMAL: 0.61% MEDIUM: 0.023% WIDE: 0.003%	Composite layer thickness: 70 µm Composite layer resistivity: 10 Ωcm Interface resistance: 1 Ωcm^2

Calculated results with negative electrode representative values

Change caused by model area

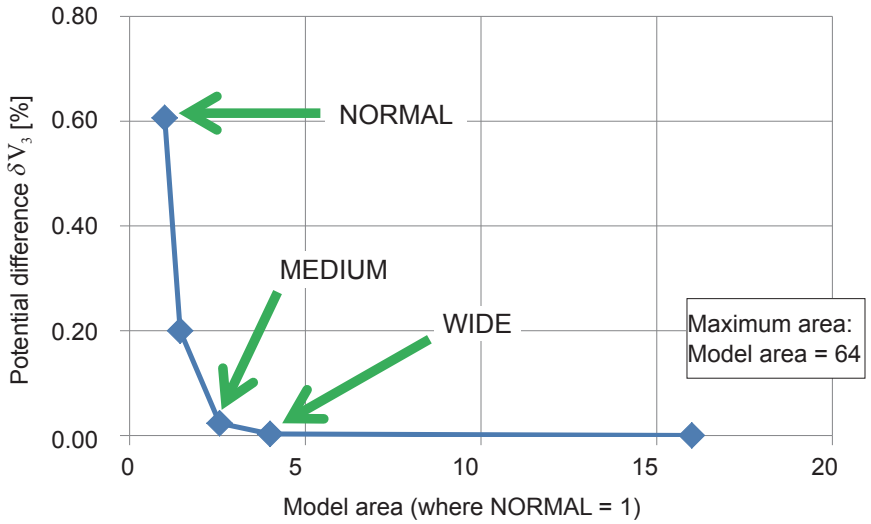
(Potential 120 µm from the probe applying the current)



Calculation results with positive electrode representative values

Change caused by model area

(Potential 120 µm from the probe applying the current)



Maximum area size is set internally by Hioki.

The potential difference δV_3 is defined as follows:

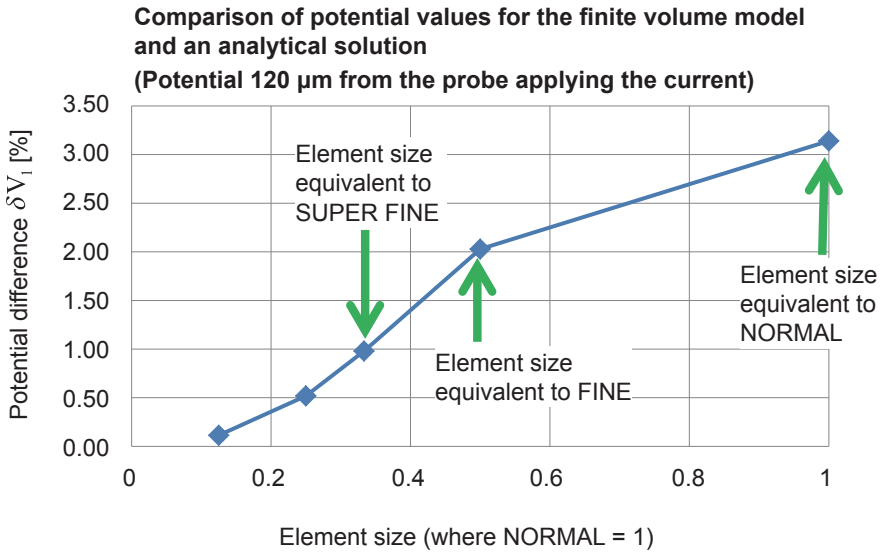
$$\delta V_3 = \left| \frac{v(\text{Maximum area}) - v(\text{Area})}{v(\text{Maximum area})} \right| \times 100[\%]$$

Comparison of potential values for the finite volume model and an analytical solution

The following table compares calculated potential values from an analytical solution and calculated potential values from the finite volume model for a single-layer substance:

		Parameters of the electrode sheet used as a model
Single-layer substance	NORMAL: 3.1% FINE: 2.0% SUPER FINE: 1.0%	Volume resistivity: 0.1 Ωcm Thickness: 100 µm

Analytical solution: Solution obtained by solving the Poisson equation for potential algebraically



The difference δV_1 relative to the analytical solution is defined as follows:

$$\delta V_1 = \left| \frac{v(\text{Analytical solution}) - v(\text{Finite volume model solution})}{v(\text{Analytical solution})} \right| \times 100[\%]$$

Calculation time based on element size and finite volume model area (reference values) [typ. min.]

		Element size		
		NORMAL	FINE	SUPER FINE
Finite volume model area	NORMAL	0.3	3	6
	MEDIUM	0.8	11	18
	WIDE	2	12	33

- Figures in the table are reference values. Actual times will vary with the electrode sheet's resistance values and potential state.
- In actual usage, calculation times are augmented by contact check times and potential measurement times.

7.3 Output File Formats

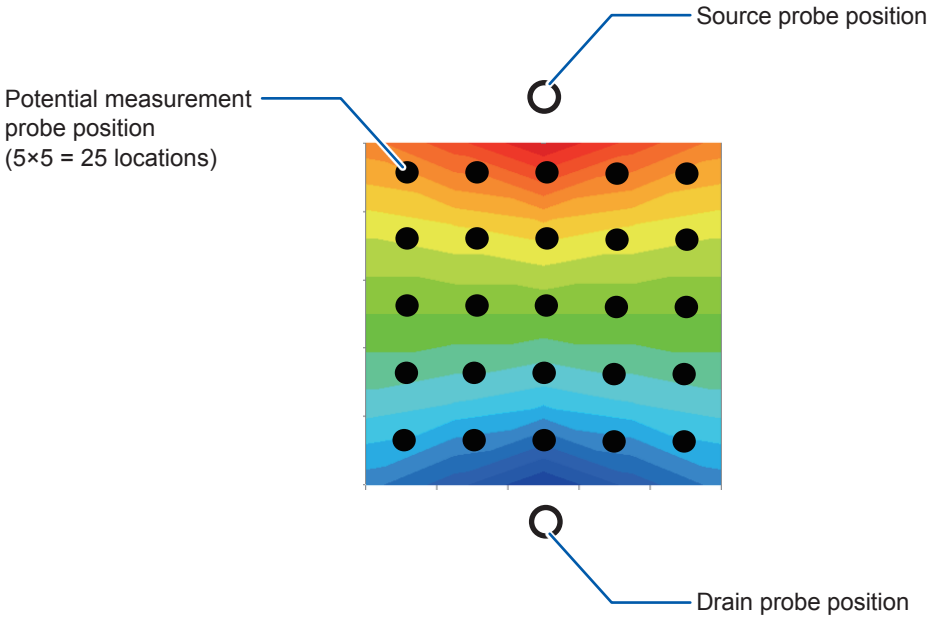
Analysis results file format

Header	Description
Counter	Counter [measurements]
Date	Measurement start date
Time	Measurement start time
Comment	Comment (up to 30 characters)
Composite volume resistivity [ohm cm]	Composite layer volume resistivity [Ωcm]
Interface resistance [ohm cm^2]	Interface resistance [Ωcm^2]
Composite surface resistivity [ohm cm^2]	Composite layer surface resistivity [Ωcm^2]
Range [ohm]	Resistance range
Speed	Potential measurement speed
TF-Type	Fixed value of 1
Composite layer thickness [um]	Composite layer thickness [µm]
Collector layer thickness [um]	Collector thickness [µm]
Collector resistivity [ohm cm]	Collector volume resistivity [Ωcm]
Model area	Model area {NORMAL | MEDIUM | WIDE}
Element size	Element size {NORMAL | FINE | SUPER FINE}
Limit iteration number	Limit iteration number [iterations]
Reduction factor	Reduction factor
Initial composite resistivity [ohm cm]	Composite layer volume resistivity initial value setting [Ωcm]
Initial Interface resistance [ohm cm^2]	Interface resistance initial value setting [Ωcm^2]
Contact check-V	Contact check results (32-bit hexadecimal value) (p.87)
Contact check-I	Contact check results (32-bit hexadecimal value) (p.87)
Potential consistency	Potential distribution consistency
Variation-V	Potential variability [%]
Error data	Number of error data rejections [rejections]
Measurement Time [s]	Potential measurement time [s]
Temperature [deg C]	Temperature [°C]
Calculation	Analysis results {PASS | FAIL}
Iteration number	Iteration number [iterations]
Coincidence	Coincidence
Calculation Time [s]	Analysis time [s]
RM2611 SN	RM2611 Electrode Resistance Meter serial number
RM2611 Version	RM2611 Electrode Resistance Meter firmware version
RM2612 Version	PC application version
RM2612 Analysis version	Analysis unit version

2D Potential distribution file format

Header	Description
Counter	Counter [measurements]
Date	Measurement start date
Time	Measurement start time
Comment	Comment (up to 30 characters)
Range [ohm]	Resistance range
Speed	Potential measurement speed
TF-Type	Fixed value of 1
Composite layer thickness [um]	Composite layer thickness [µm]
Collector layer thickness [um]	Collector thickness [µm]
Collector resistivity [ohm cm]	Collector volume resistivity [Ωcm]
Contact check-V	Contact check results (32-bit hexadecimal value) (p.87)
Contact check-I	Contact check results (32-bit hexadecimal value) (p.87)
Potential consistency	Potential distribution consistency
Variation-V	Potential variability [%]
Error data	Number of error data rejections [rejections]
Measurement Time [s]	Potential measurement time [s]
Temperature [deg C]	Temperature [°C]
RM2611 S/N	RM2611 Electrode Resistance Meter serial number
RM2611 Version	RM2611 Electrode Resistance Meter firmware version
RM2612 Version	PC application version
RM2612 Analysis version	Analysis unit version
V-Data	5×5 potential data

V-data (5×5 potential data)

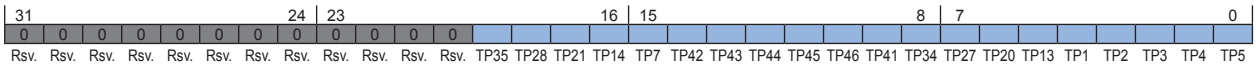


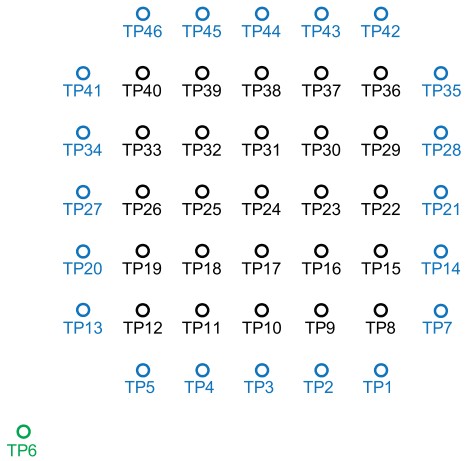
Contact check bit pattern

Analysis results files and 2D potential distribution files output contact check results for potential followed by current along with measurement results.
Probes that exhibited a contact error are indicated by a bit with the value 1, while normally functioning probes are indicated by a bit with the value 0.

Voltage probes*1 (Contact check-V): 25 bits of information (output as a 32-bit hexadecimal value)

Current probes*2 (Contact check-I) : 20 bits of information (output as a 32-bit hexadecimal value)





(TOP VIEW)

*1: Probes used to measure voltage (25 locations inside periphery)
TP8, TP9, TP10, TP11, TP12, TP15, TP16, TP17, TP18, TP19, TP22, TP23, TP24, TP25, TP26, TP29, TP30, TP31, TP32, TP33, TP36, TP37, TP38, TP39, TP40

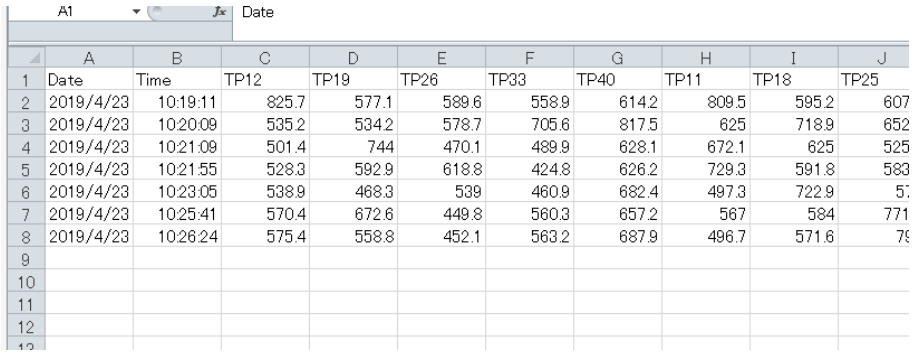
*2: Probes used to apply current to the measurement target (20 locations around the periphery)
TP1, TP2, TP3, TP4, TP5, TP13, TP20, TP27, TP34, TP41, TP46, TP45, TP44, TP43, TP42, TP35, TP28, TP21, TP14, TP7

- The TP interval is 120 µm in both the lengthwise and widthwise directions.
- TP6 has no electrical function, but rather is used to detect the orientation of the test fixture.

7.4 Contact Check Results File Output Format

The time, date, and contact resistance [Ω] resulting from a simple measurement of each probe are output to the file. If the analysis results file has the same name, this data is appended to that file.

IMPORTANT
Output resistance values are the result of a simple measurement process and as such differ from the true probe contact resistance.



A1 Date

	A	B	C	D	E	F	G	H	I	J
1	Date	Time	TP12	TP19	TP26	TP33	TP40	TP11	TP18	TP25
2	2019/4/23	10:19:11	825.7	577.1	589.6	558.9	614.2	809.5	595.2	607
3	2019/4/23	10:20:09	535.2	534.2	578.7	705.6	817.5	625	718.9	652
4	2019/4/23	10:21:09	501.4	744	470.1	489.9	628.1	672.1	625	525
5	2019/4/23	10:21:55	528.3	592.9	618.8	424.8	626.2	729.3	591.8	583
6	2019/4/23	10:23:05	538.9	468.3	539	460.9	682.4	497.3	722.9	57
7	2019/4/23	10:25:41	570.4	672.6	449.8	560.3	657.2	567	584	771
8	2019/4/23	10:26:24	575.4	558.8	452.1	563.2	687.9	496.7	571.6	79
9										
10										
11										
12										

7.5 Inspection Results File Format

When a SHORT inspection (p.33) and OPEN inspection (p.34) are performed for the RM9004 Test Fixture, the results are output to a file in the same folder as the analysis results file.

RM9004 SHORT inspection results file format

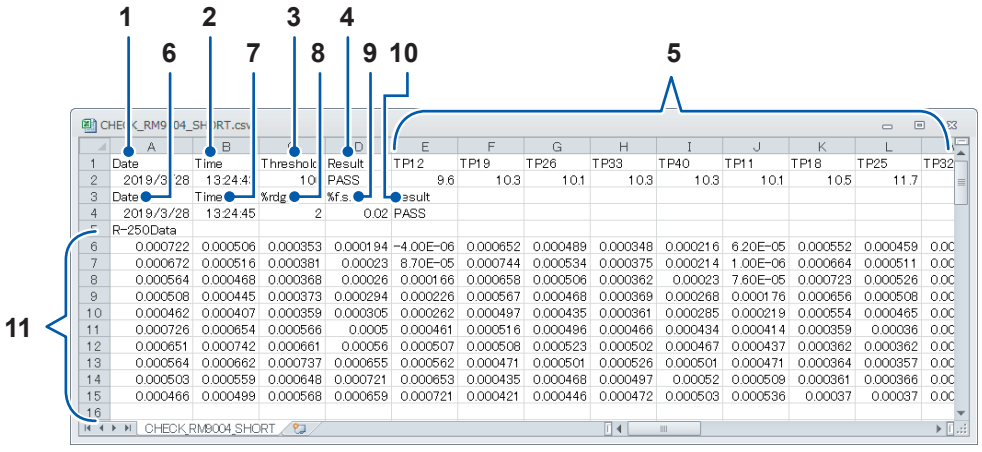
(Filename: CHECK_RM9004_SHORT.csv)

Contact resistance inspection

No.	Header	Description
1	Date	Inspection start date
2	Time	Inspection start time
3	Threshold	RM9004 contact resistance judgment threshold [Ω]
4	Result	RM9004 contact resistance inspection results
5	TP∗∗	Probe contact resistance values [Ω]

Resistance measured value inspection

No.	Header	Description
6	Date	Inspection start date
7	Time	Inspection start time
8	% rdg.	Resistance measurement judgment width (% rdg.)
9	% f.s.	Resistance measurement judgment width (% f.s.)
10	Result	Resistance measurement inspection result
11	R-250Data	Resistance measured values [Ω] (250 patterns)

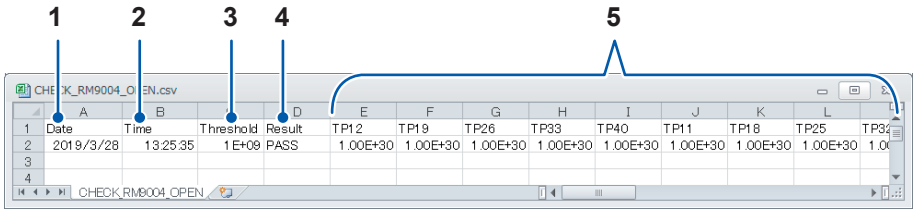


RM9004 Test Fixture OPEN inspection results file format

(Filename: CHECK_RM9004_OPEN.csv)

No.	Header	Description
1	**Date**	Inspection start date
2	**Time**	Inspection start time
3	**Threshold**	RM9004 OPEN judgment threshold [Ω]
4	**Result**	RM9004 OPEN inspection result
5	**TP∗∗**	Probe insulation resistance values [Ω]*

*A measured value of 1.00E+30 indicates sufficiently high insulation resistance.



8 FAQ

Q. About the reduction factor (p.94)

A. The reduction factor is a parameter for adjusting the magnitude of the correction applied during iterative calculation of interface resistance. Use of a small value results in a more stable convergence process but incurs longer calculation times.

Q. How is interface resistance calculated? (p.95)

A. By combining multipoint potential measurement (resistance measurement) and inverse analysis calculations, it is possible to isolate and calculate the composite layer volume resistivity and interface resistance for lithium-ion battery electrode sheets.

Q. What is the finite volume model? (p.97)

A. The finite volume model signifies a calculation domain that has been segregated into a finite number of elements (known as a mesh) in order to perform numerical calculations using the finite volume method (FVM).

Q. What kind of electrode sheets can be measured?

A. **Electrode sheet requirements***

*Whether a given electrode sheet can be measured depends on the balance of composite layer thickness, composite layer resistance, and interface resistance. The above information is not intended to provide a guarantee that any given electrode sheet can be measured.

Electrode sheets must:
- Have a conductive composite layer.
- Have a surface that lacks an insulating coating (for the measurement probes to contact).
- Have a firm composite layer (if the composite layer is too soft, the measurement probes will stick into the composite layer, resulting in unstable potential readings).
- Have a composite layer that is not too thin (guideline: composite layer thickness of 20 µm or greater).
- Have a composite layer that is not too thick (guideline: composite layer thickness of 200 µm or less).
- Have an interface resistance that is not too high.
- Have an interface resistance that is not too low.
- Have a composite layer resistance that is not too high.
- Have a composite layer resistance that is not too low.

Q. Can electrode sheets coated on both sides be measured? (p.98)

A. It makes no difference whether the electrode sheet being measured is coated on one side or both sides.

Q. What is volume resistivity? (p.99)

A. Volume resistivity is a physical property that indicates the comparative difficulty with which electricity passes through a material. It is also known as resistivity, specific resistance, and electrical resistivity. Volume resistivity is measured in [Ωm].

Q. What is surface resistivity? How do composite layer volume resistivity and composite layer surface resistivity differ? (p.100)

A. Surface resistivity indicates the difficulty with which electricity flows perpendicular to a surface that has no thickness or that is thin enough that its thickness can be ignored. The property is converted to a unit area and measured in [Ωm^2]. The value is unique and does not depend on the sheet's area.

Q. What precautions apply when performing maintenance of probe tips?

A. For more information about probe maintenance, refer to "RM9004 Test Fixture" (p.118). Performing measurements while the tips of the probes are dirty will lead to probe wear and greater measurement error. Consequently, the probe tips should be cleaned regularly with air.

Q. Is it possible to verify that the system is making the same measurements every day?

A. Yes. Use the probe check board to complete the pre-start inspection (p.32) before you start using the system daily. Inspection items include SHORT inspection (to check continuity among the probes, RM2611 Electrode Resistance Meter, and the measurement target) and OPEN inspection (to verify that probes are isolated from one other).

Q. How should I configure the settings for a collector with an undercoat? (p.101)

A. You can evaluate such a sheet by ignoring the thickness of the undercoat when you enter the conditions. The resistance value obtained by adding together the interface resistance between the collector and the undercoat, the resistance of the undercoat itself, and the interface resistance between the undercoat and the composite will be output as the interface resistance.

Q. It is possible to measure a sheet that has soaked up electrolyte? Additionally, is it possible to measure an electrode sheet from a disassembled battery?

A. If the electrode sheet is dry, yes. However, caution is necessary as any remaining electrolyte will corrode and damage the probes.

Q. What are analysis results? (p.102)

A. Analysis reliability provides an indicator of whether the inverse problem was performed correctly. Although the value is not intended to serve as an indicator of the absolute value or accuracy of the interface resistance or composite layer volume resistivity, it does offer a way to check the status of analysis.

Q. What is measurement reliability? (p.103)

A. Measurement reliability provides an indicator of whether potential measurement has been performed correctly. It allows you to check the status of potential measurement. Measurement reliability is indicated by three values: consistency, error rate, and variability (coefficient of variability).

Q. How much does entering an incorrect value for the composite layer thickness affect analysis results? (p.104)

A. How much entry of an inaccurate value affects analysis results depends on a variety of parameters, including electrode sheet resistance, composite thickness, and collector thickness. Please enter as accurate a thickness as possible before performing analysis. Additionally, the system provides re-analysis capability to repeat analysis for previous measurements (p.47).

Q. Why am I encountering frequent contact errors and measurement reliability errors?

A. The instrument may not be properly acquiring the potential distribution. Possible causes include cases in which measurement current pathways are not well-formed in the test area, for example due to there being only a small amount of conductive auxiliary agent, or a mixture of locations where there is conductive auxiliary agent and other locations where there is none. Enable the error rejection function and repeat measurement. You may be able to obtain results that more closely approach an accurate value by measuring multiple locations similarly and performing statistical processing (averaging, variability, etc.) of the results.

Q. Can I measure an electrode that has not yet been pressed?

A. You may be able to do so, depending on the softness of the composite layer. Such measurement is possible as long as the composite layer has a certain level of firmness, regardless of whether it has been pressed. If the composite layer is too soft, the probes may become embedded in the composite, resulting in a measurement reliability error or an analysis reliability error.

Q. Under what circumstances do contact errors occur? (p.105)

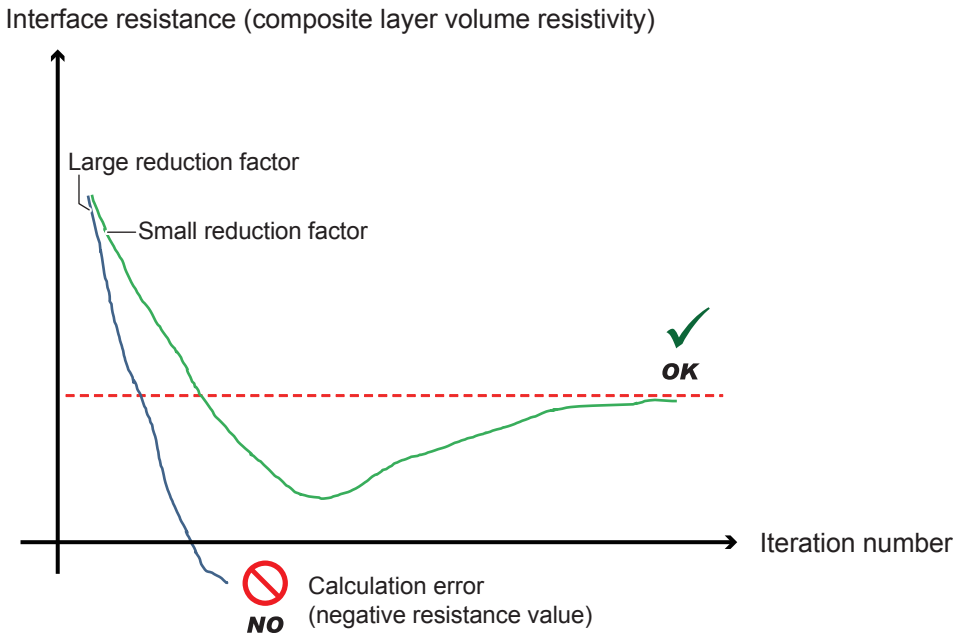
A. Contact errors are reported more often when the effect on measurement of the contact resistance between the probes and the measurement target becomes more pronounced. In terms of specific operation, 2-terminal resistance measurement is used to measure the resistance between the probes and the measurement target, and a contact error is concluded to have occurred if a certain threshold is exceeded.

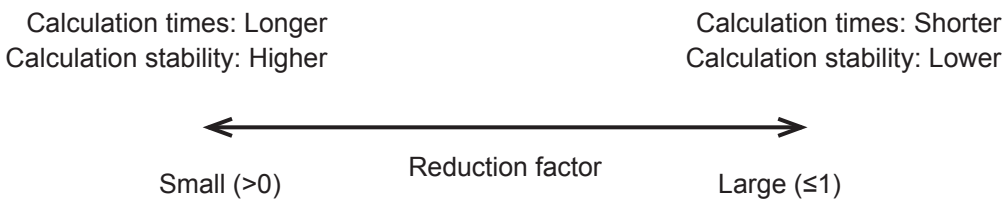
Q. What will happen if I use a PC with other than the recommended system requirements?

A. The system will function in most cases if you use a CPU that is not recommended (Intel® Core™ i7, 2.4 GHz, 4 threads or better), but PC application processing may slow.

8.1 About the reduction factor

In iterative calculations performed as part of an inverse problem analysis, calculations exhibit unstable convergence if the initial value differs greatly from the solution.
As shown by the line labeled “Large reduction factor” in the graph, excessive correction of the iterative calculation may result in negative resistance values. Adjusting the reduction factor in such cases may stabilize the iterative calculation.
The reduction factor is a parameter that regulates the magnitude of correction performed in the iterative calculation. The initial value of 1.0 results in maximum correction. Reducing this value (it must be greater than 0) has the effect of reducing the magnitude of correction, with the result that a phenomenon in which iteration undergoes too much correction can be reduced as shown in the line labeled “Small reduction factor” in the graph.
However, smaller reduction factors increase calculation times since more iteration is needed in order for calculations to converge. Consequently, it is recommended to use the initial value of 1.0 for the reduction factor when convergence is table.



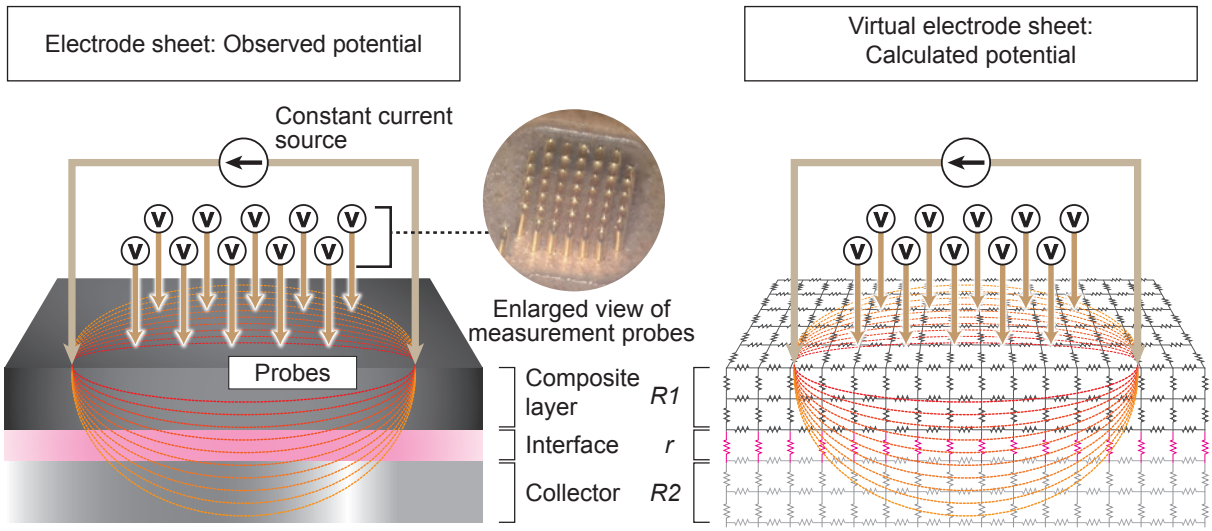


8.2 How is interface resistance calculated?

By combining multipoint potential measurement (resistance measurement) and inverse analysis calculations, it is possible to isolate and calculate the composite layer volume resistivity and interface resistance for lithium-ion battery electrode sheets.
In this way, it is possible to calculate interface resistance by means of a simple series of operations: configuring several settings, placing probes in contact with the surface of the electrode sheet, and stating measurement.

When you click **[Start]**, the system performs the following steps automatically:

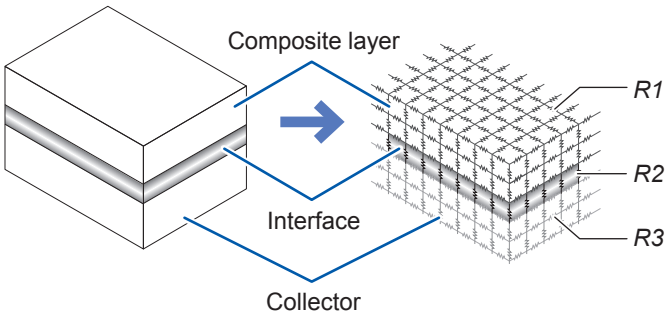
1. **The electrode sheet is treated as a virtual electrode sheet consisting of two layers and one interface layer, and the resistance of each layer is labeled *R1*, *R2*, and *r* (modeling).**
2. **A constant current is applied to the surface of the electrode sheet, and the potential distribution occurring on the surface is measured at multiple points (to acquire the observed potential).**
3. **A calculated potential that agrees with the observed potential is calculated repeatedly (using curvilinear regression) while treating *R1* and r as the variables.**
4. **The *R1* and r values for which the observed potential and calculated potential agree are output as the composite layer volume resistivity and interface resistance.**



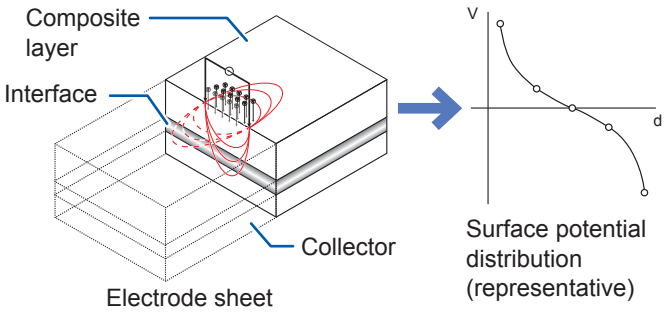
(It doesn't matter whether the electrode sheet that is measured is coated on one side or both sides. The composite layer resistivity and interface resistance on the probed surface are output.)

(*R1* and *R2* thickness [µm], and *R2* volume resistivity are entered by the user.)

1 Modeling



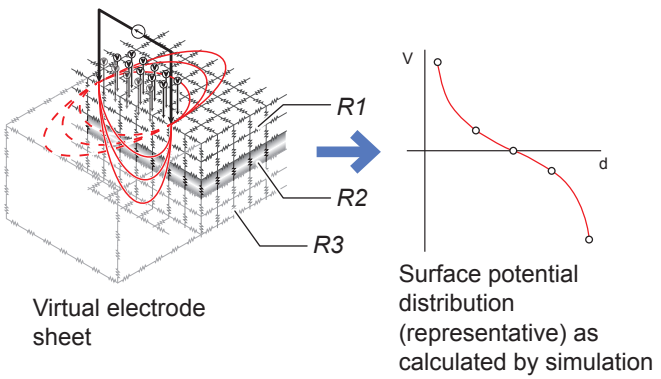
2 Potential measurement



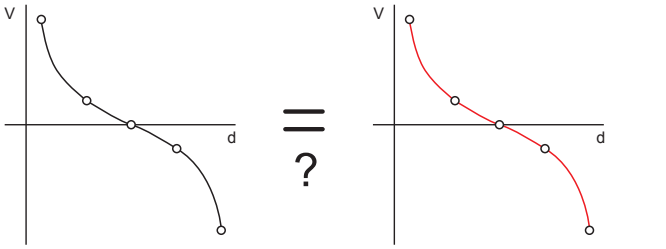
Update resistance value

Don't agree

3 Calculation of potential using a simulation



4 Comparison of observed potential and calculated potential

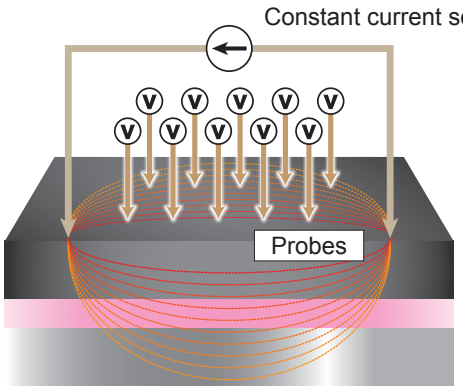


Agree

5 Output (end)

8.3 What is the finite volume model?

The finite volume model signifies a calculation domain that has been segregated into a finite number of elements (known as a mesh) in order to perform numerical calculations using the finite volume method (FVM).
The RM2612 Resistance Calculation Software calculates potential distribution using the FVM in order to calculate the interface resistance and composite layer volume resistivity. The finite volume model is equivalent to a circuit consisting of a three-dimensional resistance matrix, as shown below.



Electrode sheet diagram

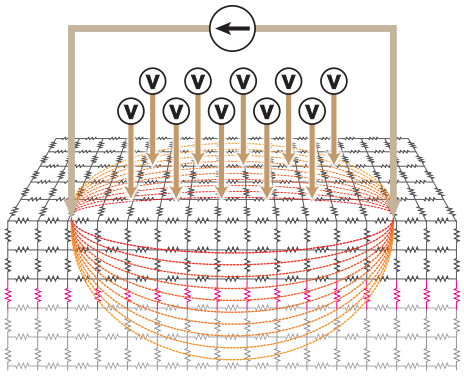


Illustration of finite volume model and equivalent resistance matrix

8.4 Can electrode sheets coated on both sides be measured?

It makes no difference whether the electrode sheet being measured is coated on one side or both sides.

However, exercise caution with regard to the following:

- The interface resistance and composite layer volume resistivity can only be measured on the top surface (the surface with which the probes make contact).
- In order to measure the resistance on the bottom of the sheet (the surface with which the probes do not make contact), you will have to turn the electrode sheet over and measure it again.
- The bottom surface has very little effect on the top surface.
  Since the resistivity of the composite layer and interface is much larger than the resistivity of the collector on a typical lithium-ion battery electrode sheet, the measurement current that flows to the collector after being applied to the top surface does not flow to the composite layer on the bottom of the sheet, with the result that the bottom surface has almost no effect on the surface potential of the top surface.

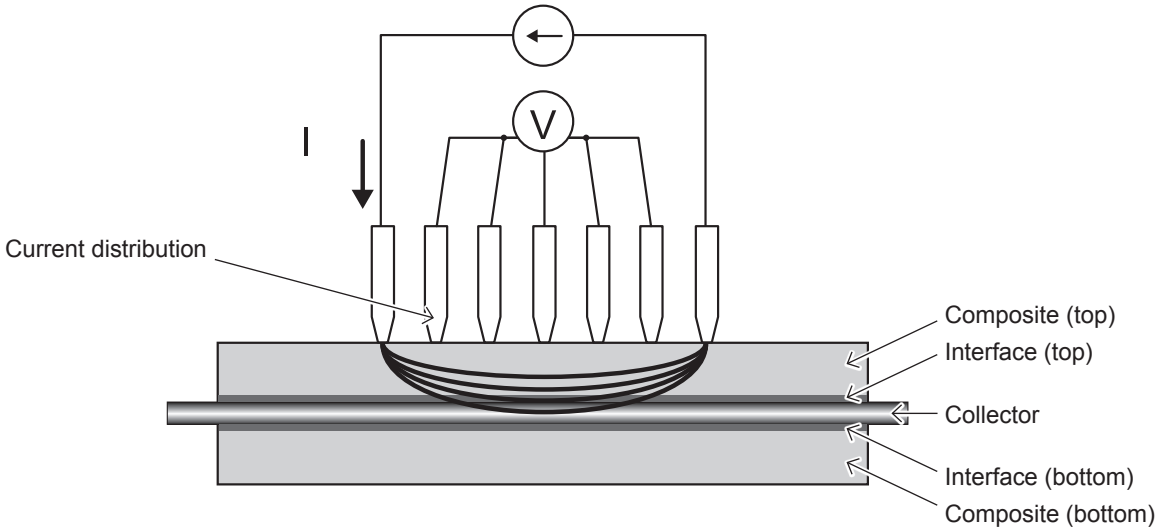


Figure: Cross-sectional diagram of measurement of double-coated electrodes

8.5 What is volume resistivity?

Volume resistivity is a physical property that indicates the comparative difficulty with which electricity passes through a material. It is also known as resistivity, specific resistance, and electrical resistivity. Volume resistivity is measured in [Ωm].
Each material has a characteristic volume resistivity that does not depend on its shape or size. As a result, the characteristic offers a convenient means of comparing the electrical conductivity of different materials.
The relationship between the volume resistivity ρ and the electrical resistance R is shown below.
[R = (V: Voltage drop) / (I: Current)]

$$\rho = R \times RCF \quad \cdots\cdots\text{(Equation 1)}$$

Here RCF is a correction coefficient that corrects for the effects of the material's shape, size, and measurement position. R and RCF vary with the shape, size, and measurement position of the material.

For example, for a columnar object with length L and cross-sectional area S, electrical resistance is proportional to the length L and inversely proportional to the cross-sectional area S.

$$R = \rho \times \frac{L}{S} \quad \cdots\cdots\text{(Equation 2)}$$

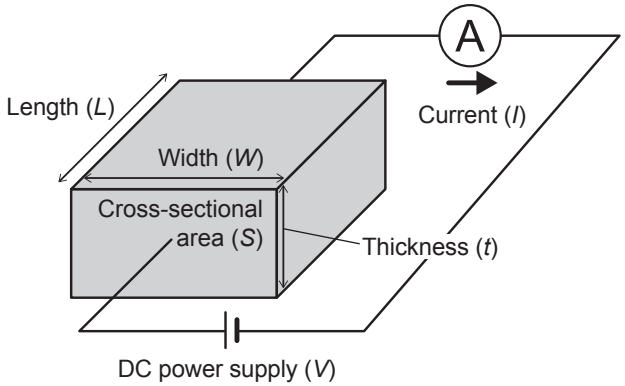
The proportionality coefficient here is the volume resistivity, and the equation can be changed as shown below so that it can be compared with Equation 1.

$$\rho = R \times \frac{S}{L} \quad \cdots\cdots\text{(Equation 3)}$$

Consequently, the object's *RCF* can be expressed as follows:

$$RCF = \frac{S}{L} \quad \cdots\cdots\text{(Equation 4)}$$

Methods for measuring the volume resistivity of a conductor include that described in JIS K 7194, "Testing method for resistivity of conductive plastics with four-point probe array."



Resistance *R*

$$R = \rho v \frac{L}{S} \rightarrow \rho v \frac{L}{tW} = \frac{\rho v}{t}\frac{L}{W} = \rho s \frac{L}{W}$$

Volume resistivity ρv

$$\rho v = \text{Resistance } R \times \underbrace{\frac{\text{Cross-sectional area } S}{\text{Length } L}}_{RCF}$$

Surface resistance ρs

$$\rho s = \text{Resistance } R \times \underbrace{\frac{\text{Width } W}{\text{Length } L}}_{RCF}$$

8.6 What is surface resistivity? How do composite layer volume resistivity and composite layer surface resistivity differ?

Surface resistivity indicates the difficulty with which electricity flows perpendicularly to a surface that has no thickness or that is thin enough that its thickness can be ignored. The property is converted expressed per unit area and measured in [Ωm^2]. The value is unique and does not depend on the sheet's area.
The instrument defines the resistance of the contact surface between the composite and collector as the interface resistance and expresses it in surface resistivity units. The interface resistance is the contact resistance between both surfaces, and since no substance actually exists there, the concept of thickness does not apply. (Another valid approach would be to assume the existence of an extremely thin non-conductive coating.) In such circumstances, surface resistivity is the most appropriate indicator of resistance to the flow of electricity.

Composite layer volume resistivity and composite layer surface resistivity are related by unit conversion. The figure below provides a diagram that defines surface resistivity. Composite layer surface resistivity is calculated by multiplying the composite layer volume resistivity by the thickness of the composite layer. In other words, the relationship can be expressed as follows:

Composite layer surface resistivity = Composite layer volume resistivity × composite layer thickness

Surface resistivity removes the concept of thickness from volume resistivity. It is necessary to exercise caution as the surface resistivity of the electrode composite may behave slightly differently since the electrode composite does in fact have thickness.

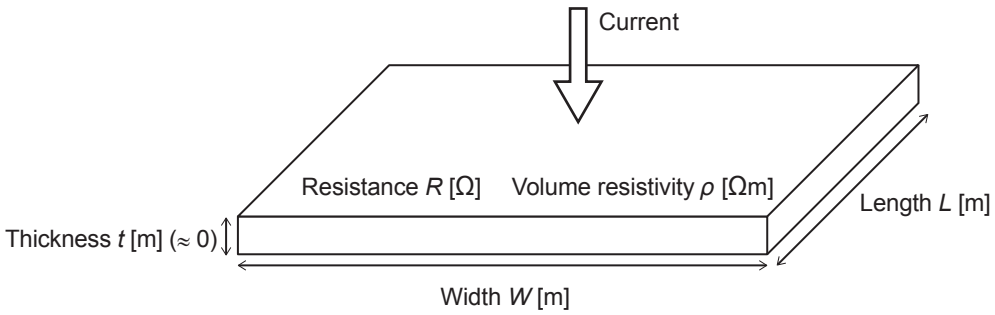


Figure: Definition of surface resistivity

$$R = \rho \frac{t}{W \times L} = \frac{\rho t}{W \times L} = \frac{R_l}{W \times L}$$

$$R_l \equiv \rho \times t \quad [\Omega m^2] \text{ Surface resistivity}$$

8.7 How should I configure the settings for a collector with an undercoat?

When the collector has an undercoat, it is recommended to measure the sheet by ignoring the thickness of the undercoat when you enter measurement conditions.

Because the thickness of the undercoat is negligible compared to that of the composite layer and collector layer, with the result that the effect of current flowing in the direction of the undercoat surface can be ignored, the resistance value obtained by adding together the interface resistance between the collector and the undercoat, the resistance of the undercoat itself, and the interface resistance between the undercoat and the composite will be output as the interface resistance.

Since the undercoat layer is thin, it would be difficult for the instrument to evaluate the interface resistance between the undercoat and the collector on a two-layer sheet made up of just an undercoat and collector. Please evaluate the interface resistance based on the above interpretation after applying the composite layer.

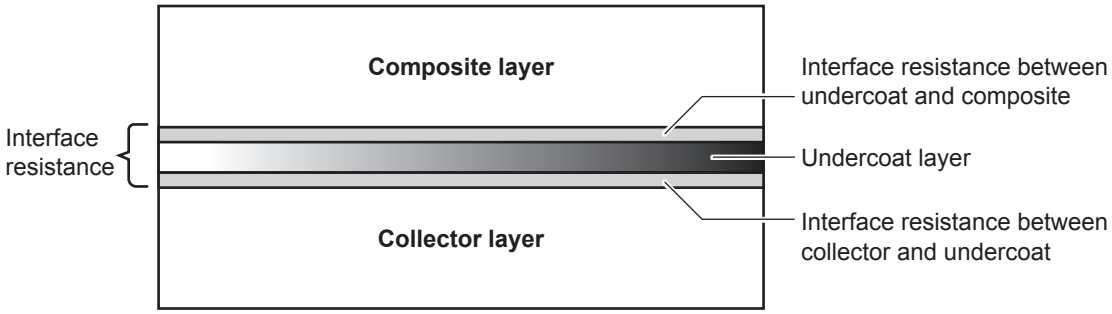


Figure: Diagram showing a cross-section of an electrode using a collector with an undercoat layer

8.8 What are analysis results?

Analysis reliability provides an indicator of whether the inverse problem was performed correctly. Although the value is not intended to serve as an indicator of the absolute value or accuracy of the interface resistance or composite layer volume resistivity, it does offer a way to check the status of analysis.
Two types of analysis results are provided:

Iteration number

The iteration number indicates the number of inverse analysis iterations. Ordinarily, there is no relationship between the number of iterations until analysis completes and the correctness of the analysis results, and the iteration number can be thought of as varying with the manner in which the initial value was calculated and the reduction factor setting. Please use the iteration number as a rough indicator of calculation time.

Coincidence between observed potential and calculated potential

The coincidence value expresses the extent to which the calculated potential distribution approaches the observed potential distribution. The more closely this value approaches 1, the smaller the relative difference between the measured potential and the calculated potential (i.e., the greater their relative coincidence). Coincidence [R^2] is defined as follows (it may have a negative value):

$$R^2 = 1 - \frac{6}{5}\frac{\sum_i (V_{meas,i} - V_{calc,i})^2}{\sum_i (V_{meas,i} - \overline{V})^2}$$

Here $V_{meas.i}$ indicates the measured potential; $V_{calc.i}$, the calculated potential; and $\overline{V}$, the average measured potential distribution.
Coincidence provides a numerical indication of the calculation status. It does not indicate electrode sheet quality.

8.9 What is measurement reliability?

Measurement reliability provides an indicator of whether potential measurement has been performed correctly. It allows you to check the status of potential measurement. Measurement reliability is indicated by three values.

Consistency [PASS/FAIL]

Consistency provides a judgment of whether the magnitude of the gradient in the potential distribution accords with the theoretical result that would be expected. Potential increases near the current source probe and decreases near the current drain probe, and consistency checks for the relationship that would be expected in theory and expresses the result as a PASS or FAIL value.

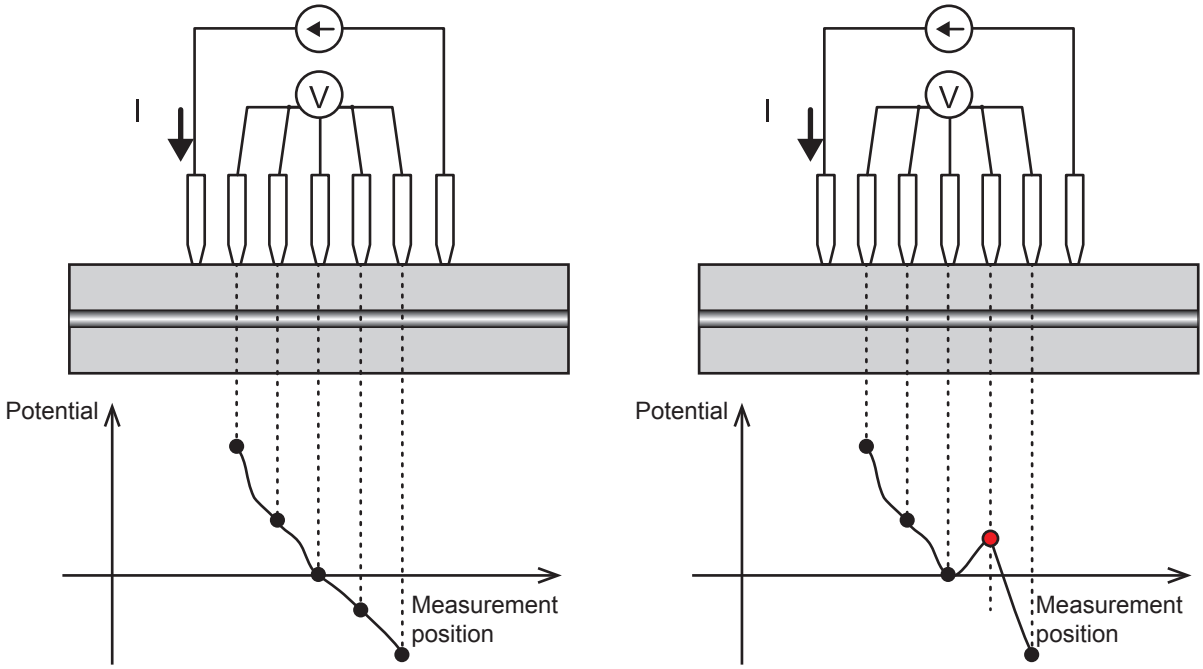


Figure: Illustration of consistency (left: PASS consistency; right: FAIL consistency)

Error rate [%]

The error rate expresses the number of measurements with a incomplete contact as a percentage of all measurements obtained during multipoint measurement of potential distribution. The error rejection function rejects error data with an error rate that falls below a certain threshold and performs analysis using only normal measurement data.

Coefficient of variability [%]

The coefficient of variability is defined as the result of dividing the standard deviation of measured potential by the average value.
The smaller coefficient of variability indicates that the smaller variation in measured potential.
The figure is calculated for the group that contains the most information about the measurement target after observed potential values have been divided into multiple groups.

8.10 How much does entering an incorrect value for the composite layer thickness affect analysis results?

How much entry of an inaccurate value affects analysis results depends on a variety of parameters, including electrode sheet resistance, composite thickness, and collector thickness. Please enter as accurate a thickness as possible before performing analysis. Additionally, the system provides re-analysis capability to repeat analysis for previous measurements (p.47). If you entered an incorrect value, please correct the composite layer thickness and then perform re-analysis.

Hioki evaluated the effect of entering an incorrect thickness when measuring a standard positive electrode sheet (with a composite thickness of 77 µm). This evaluation showed that the incorrectly entered thickness produced an error in analysis results on par with the ratio indicating the extent to which it differed from the correct thickness value.
(This relationship may not obtain for all electrode sheets.)
(These results are not suitable for use in correcting for the effects of thickness.)

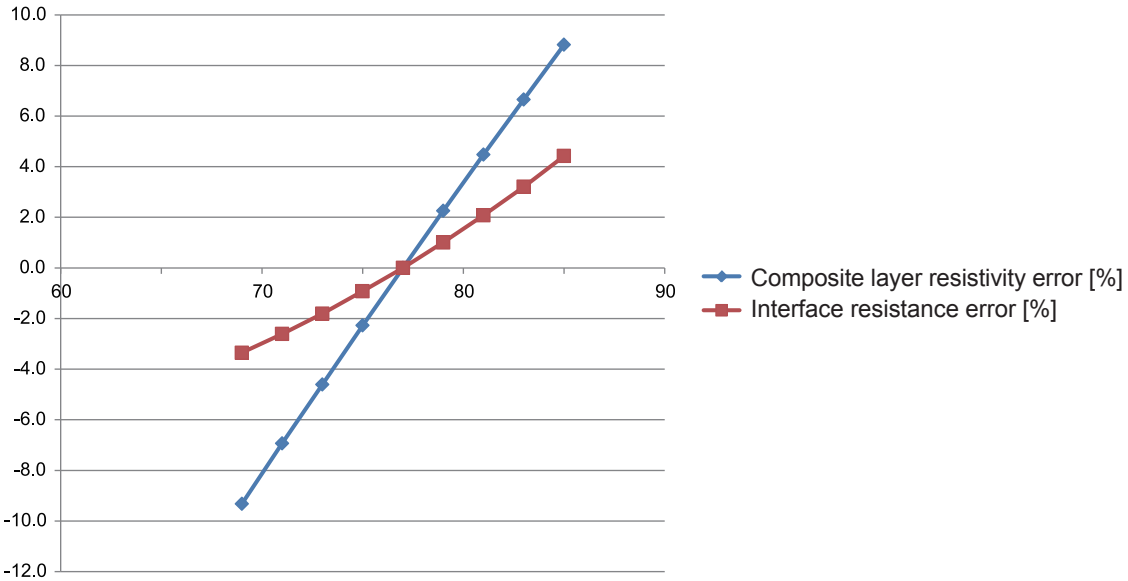


Figure: Effects of incorrectly entering the thickness (representative example for a positive electrode)

8.11 Under what circumstances do contact errors occur?

Contact errors are reported more often when the effect on measurement of the contact resistance between the probes and the measurement target becomes more pronounced. In terms of specific operation, 2-terminal resistance measurement is used to measure the resistance between the probes and the measurement target, and a contact error is concluded to have occurred if a certain threshold is exceeded.

- The RM2612 Resistance Calculation Software allows you to turn the contact check function on or off. When the function is on, the judgment process described above is performed. The initial value is ON.
- The threshold can be set as desired from 1 Ω to 10 MΩ. The initial value is 20 kΩ.
- The software also provides an error rejection function (p.53) that works with the results of contact checks between probes to identify which probes have generated contact errors.

9 Maintenance and Service

Precautions when transporting the product

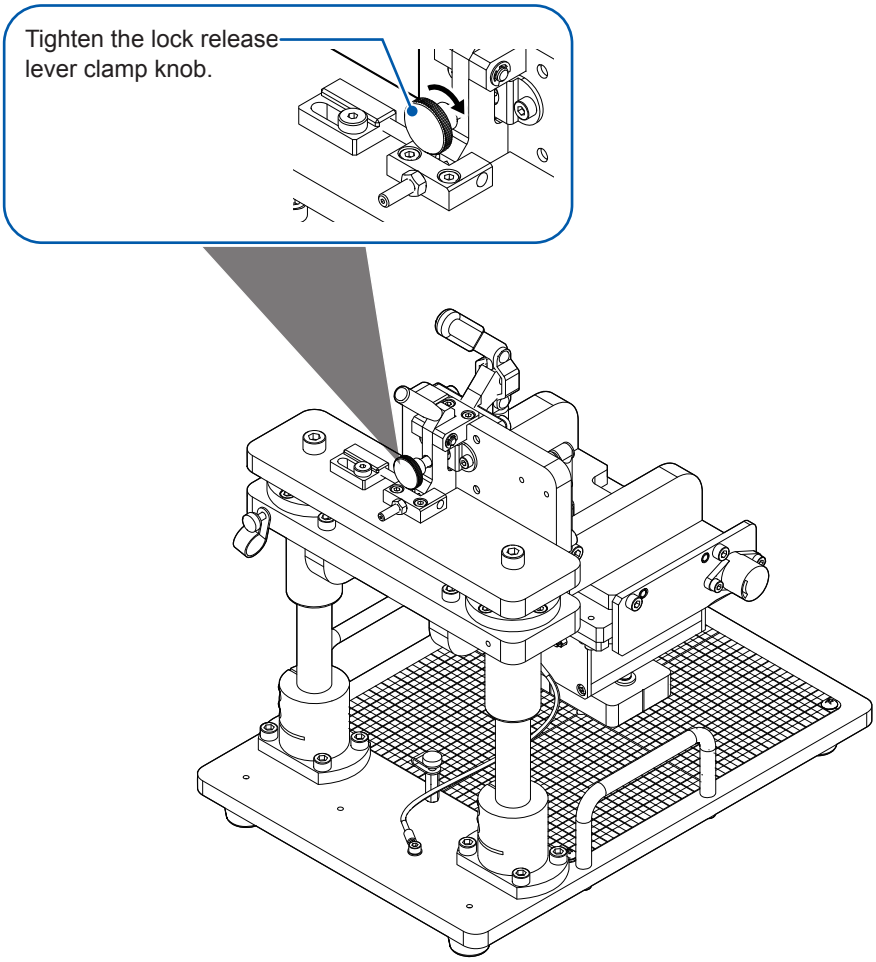
Be sure to follow these precautions when transporting the product:

- Remove accessories and options from the product in order to avoid damaging it. Additionally, use the packaging in which the product was packed when you purchased it, and be sure to double-box it. Accidental damage suffered in transit is not covered by the warranty.
- Attach a description of the issue when sending out your product for repair.

RM9003 Press Unit

IMPORTANT

- Raise the up/down lever and then tighten the lock release lever clamp knob to ensure that the press unit does not move up or down during transport.
- If the lock disable pin has been engaged, the up/down lever will be free to move even if the lock release lever knob has been tightened. Be sure to tighten the lock release lever clamp knob after disengaging the lock disable pin.



Service life of replaceable parts

The performance of some parts used in the product may degrade during the course of extended use. To ensure your ability to use the product into the indefinite future, Hioki recommends regular replacement of these parts. Please contact your authorized Hioki distributor or reseller when you need to do so.
Service life varies with the operating environment and frequency of use. Please note that performance is not guaranteed for the duration of the recommended replacement cycle.

Part name	Recommended replacement cycle	Remarks and conditions
RM2611 Electrode Resistance Meter		
Electrolytic capacitors	About 10 years	The circuit board on which these parts are mounted must be replaced.
LCD backlight (loss of half brightness)	About 50,000 hours	
Backup battery	About 10 years	Replace when the RM2611 Electrode Resistance Meter display shows the following error code: **[ERR:096 Backup data error.]**.
Relay	About 50 million cycles	
RM9004 Test Fixture		
Probes	The recommended replacement cycle for probes depends on the number of measurements made and the types of samples measured. Please have the probes replaced once you start to encounter frequent errors during SHORT and OPEN inspections of the RM9004 Test Fixture.	

9.1 Troubleshooting

If you believe the product may be broken, please review the suggestions described under "Before having your product repaired." If those steps fail to resolve the issue, please contact your authorized Hioki distributor or reseller.
If you are unsure of the cause of the issue, initialize the RM2612 Resistance Calculation Software to revert all settings to their factory default (p.111).

Before having your product repaired

Power supply issues

Symptom	Check item or cause		Solution	See also
I can't turn on the RM2611 Electrode Resistance Meter (nothing is shown on the display).	Standby key color	Red	The instrument is in the standby state. Press the standby key.	p.29
		No color	Power is not being supplied to the instrument. Check whether the power cord has been properly connected.	p.26

Display and operation issues

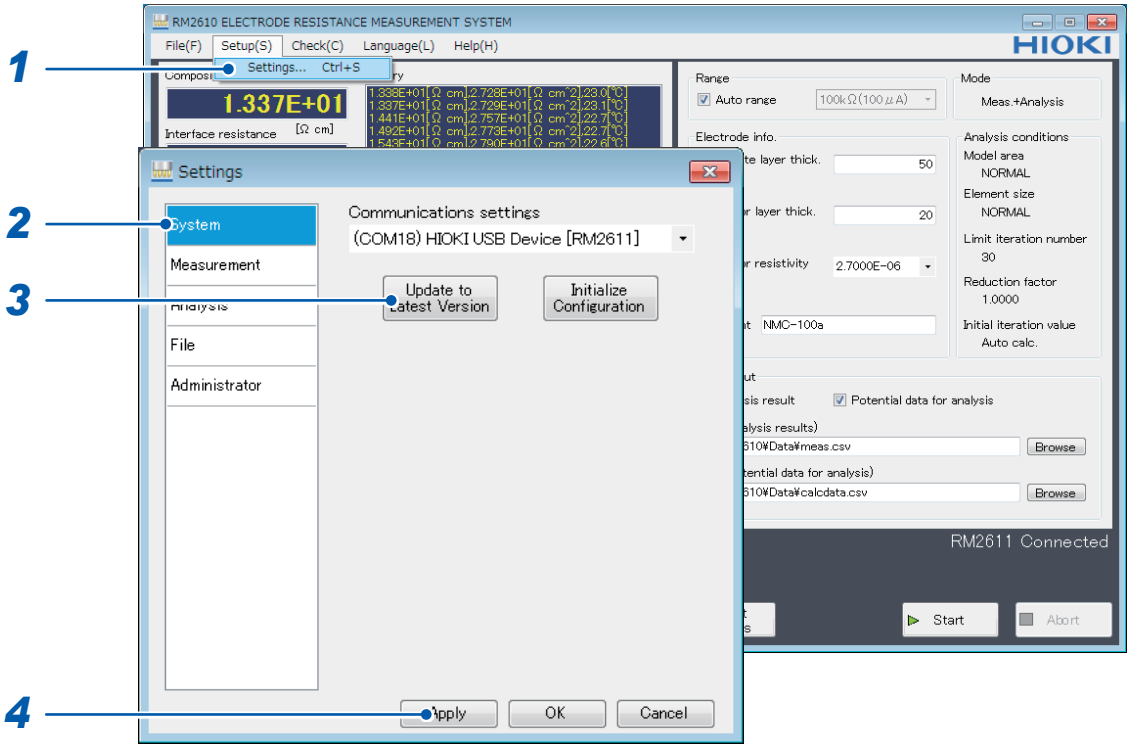
Symptom	Check item or cause	Solution	See also
The lock release lever on the RM9003 Press Unit won't move.	The lock release lever clamp knob has been tightened.	Loosen the lock release lever clamp knob.	p.45

Inspection errors

Symptom	Check item or cause	Solution	See also
I encountered an error during a SHORT inspection of the RM9004 Test Fixture.	Probes are not making contact with the gold-plated conductive surface on the probe check board.	Raise the up/down lever and adjust the position of the probe check board so that the probes make contact with the board's gold-plated conductive surface.	p.33
	Probes are making contact with the gold-plated conductive surface on the probe check board.	Raise the up/down lever and change the position at which the probes make contact with the gold-plated conductive surface. Then repeat the inspection. If the error persists, the probe tips may be experiencing incomplete contact. Perform the following steps: • Clean the probe tips with air • Use the error rejection function • Replace the probes	p.118 p.53
I encountered an error during an OPEN inspection of the RM9004 Test Fixture.	Probes are not making contact with the gold-plated conductive surface on the probe check board.	Do not allow the probes to make contact with the gold-plated conductive surface.	p.34
	Probes are making contact with the non-conductive surface on the probe check board.	A conductive substance or other foreign material may have become lodged between some of the probes. Clean the probe tips with air. If the error persists, have the probes replaced.	p.118

9.2 Updating the Software

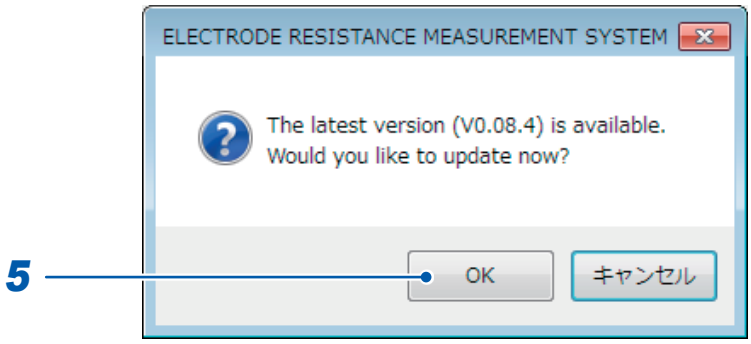
If you have an Internet connection and can download files, you can update the RM2612 Resistance Calculation Software's PC application.



1 Choose **[Settings]**.

2 Choose **[System]**.

3 Click **[Update to Latest Version]**.



4 If there is a new version available, the **[ELECTRODE RESISTANCE MEASUREMENT SYSTEM]** dialog box will be displayed.

5 To update the application to the latest version, click **[OK]**.

After clicking **[OK]**, follow the installation procedure (p.22) to update the software. Once the update is complete, the new version of the application will launch automatically.

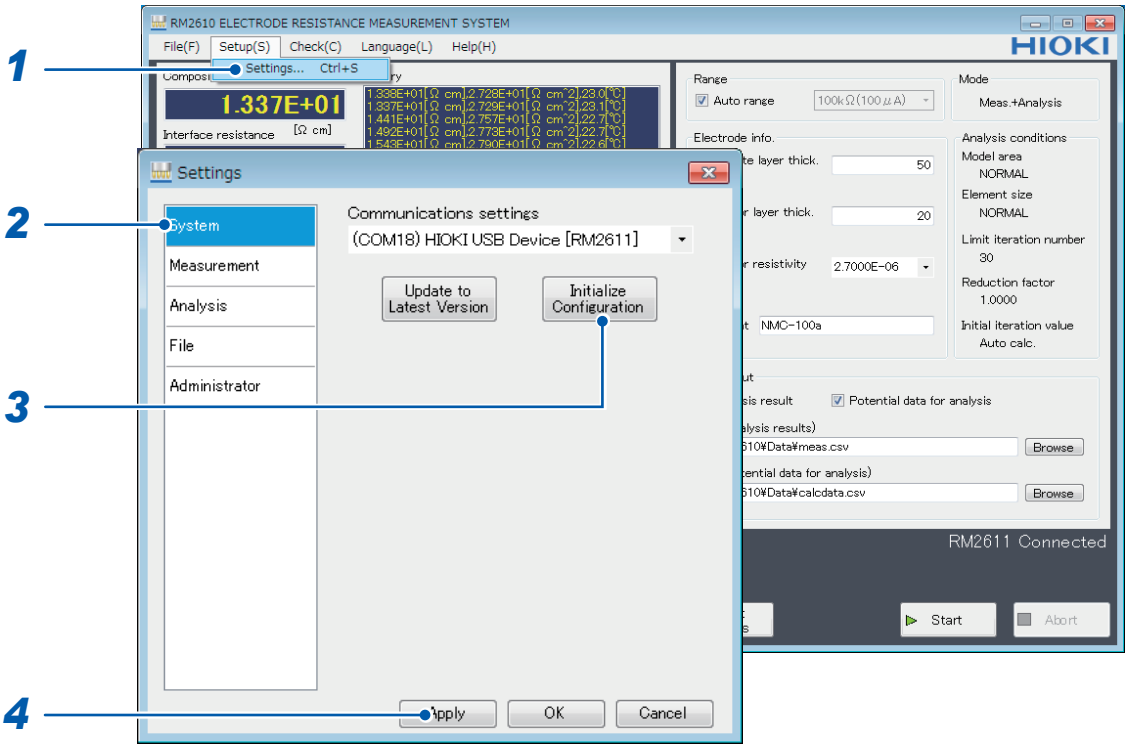
9.3 Initializing the Software

This section describes how to reset the RM2612 Resistance Calculation Software to its factory defaults.

IMPORTANT

Clicking **[Initialize configuration]** will reset all settings other than those listed below to the factory defaults. Follow the instructions in “6.1 Saving Measurement Conditions” (p.73) as necessary before initializing the software.

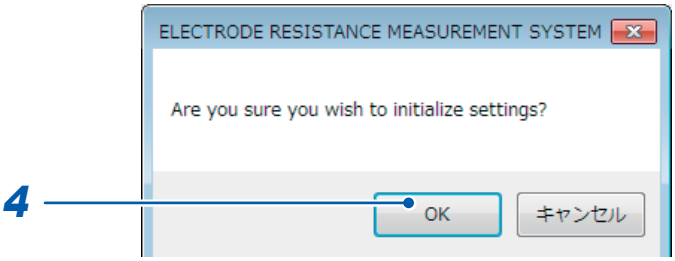
Settings that are not initialized: Communications settings, counter, password



1 **Choose [Settings].**

2 **Choose [System].**

3 **Click [Initialize Configuration].**



4 **Click [OK].**

The software will be initialized.

Factory default settings

Setting	Initial value

Measurement conditions

Auto range	ON
Resistance range	10 MΩ (1 μA)
Electrode sheet information	
Composite layer thickness [μm]	50
Collector thickness [μm]	20
Collector volume resistivity [Ωcm]	2.7000E-06
Comment	(Blank)

File output

Analysis results	OFF
Potential for analysis	OFF
Analysis results path	(User desktop)
Potential for analysis path	(User desktop)

System

Communications settings	(Device if connected)

Measurement

Operating mode	Potential measurement + analysis
Measurement speed	MEDIUM
Contact check	ON
Threshold [Ω]	2.000E+04
Auto start	OFF
Delay time [ms]	500
Error rejection	OFF
Error tolerance [%]	20.0
Composite layer units	Volume resistivity [Ωcm]
Beep at measurement completion	ON

Analysis

Initial value	Automatic calculation
Composite layer volume resistivity [Ωcm]	1.000E+00
Interface resistance [Ωcm^2]	1.000E+00
Conditions	Single
Multiple settings	Model area: NORMAL Element size: NORMAL Limit iteration number: 30 Reduction factor: 1.0000
Model area	NORMAL
Element size	NORMAL
Limit iteration number	30
Reduction factor	1.0000

File

Contact check results	OFF
2D potential file output	OFF

CSV save settings

Decimal symbol	Period
Delimiter	Comma

Administrator

Debug file	OFF
RM2611 enable	OFF
Password	rm2612

9.4 List of Error Messages

The table below lists messages displayed on the screen in the event of the product or measurement state error. If repair is necessary, please contact your authorized Hioki distributor or reseller.

RM2611 Electrode Resistance Meter

Display		Meaning	Solution
NO UNIT		The MUX unit has not been inserted.	Properly insert the MUX unit. If the error persists, the instrument is malfunctioning. Please have it repaired.
ERR:090	**ROM check sum error.**	Program ROM checksum error	The instrument is malfunctioning. Please have it repaired.
ERR:091	**RAM error.**	CPU RAM error	The instrument is malfunctioning. Please have it repaired.
ERR:092	**Memory access failed. Main power off, restart after 10s.**	Memory access error	Turn off the main power and wait at least 10 s before turning it back on.
ERR:093	**Memory read/write error.**	Memory read/write test error	The instrument is malfunctioning. Please have it repaired.
ERR:095	**Adjustment data error.**	Adjustment data error	The instrument is malfunctioning. Please have it repaired.
ERR:096	**Backup data error.**	Configuration backup error	The settings have been initialized. Reconfigure measurement conditions and other settings.
ERR:097	**Power line detection error. Select power line cycle.**	Power supply frequency detection error	The instrument was unable to detect the power supply frequency. The power line may be carrying significant noise. Either move the instrument away from the source of noise or affix a ferrite core or other noise-reducing device to the power cord.
ERR:098	**Blown FUSE or measurement lead is broken.**	The fuse is blown.	Replace the fuse. The fuse is not customer-replaceable, so please contact your authorized Hioki distributor or reseller.
ERR:100	**MUX unit error.**	MUX unit error	The instrument is malfunctioning. Please have it repaired.

RM2612 Resistance Calculation Software

Dialog box message	Solution
Check the connection with the RM2611.	The RM2611 Electrode Resistance Meter and PC are not connected. • Check the communications settings under **[Settings]**-**[System]** (p.31). Verify that the RM2611 Electrode Resistance Meter and PC are connected with a USB cable. • Verify that the RM2611 Electrode Resistance Meter is turned on (p.29).
Abnormal contact resistance.	One or more probes is suffering from incomplete contact. Change the measurement position of the probe check board and try measuring several times (p.32).
Directory does not exist. Please specify the file path again.	Check the path used to save files.
File is being edited. Please enable file operation.	The file to which the PC application is attempting to append data may have been opened by another application. Please close the file in question. If the error persists, check whether the file attributes allow write access by the PC application.
The file is a read-only file and cannot be saved. Please enable file operation.	The file to which the PC application is attempting to append data may have been opened by another application. Please close the file in question. If the error persists, check whether the file attributes allow write access by the PC application.
File save error.	The PC application was unable to output a file. Please check the following: • Does the application have write access to the output path (folder)? • Is there enough space available on the disk? • Has the output file been opened by another application?
Please insert the license key.	The PC application checks for the USB license key when it launches and when it starts measurement, among other times. Please insert the USB license key (p.30).
The MUX unit is not connected.	Please properly insert the MUX unit. If the error persists, the instrument is malfunctioning. Please have it repaired.
No additional analysis configurations can be added.	The maximum number of analysis conditions that can be added is 100. Please delete an existing row before attempting to add a new one.
Wrong password	Please enter the correct administrator password.
Out of range.	Please enter a value that falls within the valid setting range.
Failed to download the latest version.	Please verify that you have Internet connectivity and can download files. (Please check with the administrator of the network you're using.)
Not connected to the Internet.	Please connect to the Internet.
Abnormal potential distribution.	One or more probes is suffering from incomplete contact. Change the measurement position of the probe check board and try measuring several times.
Abnormal insulation resistance.	Check whether probes are in contact with the gold pattern on the probe inspection board. (Ensure that probes make contact with the non-conductive surface.)

Dialog box message	Solution
RM2612 application requires Microsoft .NET Framework 4.8. Please use Windows Update to install this version and then re-launch the RM2612 application setup program.	Please download and install Microsoft .NET Framework 4.8 (p.20).
Wrong file format.	The potential data for analysis file is using the wrong file format. Please load a file with the correct format.

9.5 Cleaning the System

IMPORTANT
Never use solvents such as benzene, alcohol, acetone, ether, ketone, thinners or gasoline. Doing so could deform and discolor the instrument.

RM2611 Electrode Resistance Meter

If the RM2611 Electrode Resistance Meter becomes dirty, slightly moisten a soft cloth with water or a neutral detergent and wipe it clean.

RM9003 Press Unit

If the RM9003 Press Unit becomes dirty, wipe it gently with a soft cloth. Do not wipe moving parts such as the shaft or up/down lever as they are coated with oil.

RM9004 Test Fixture

⚠CAUTION

- Do not operate the up/down lever while cleaning the device. Doing so could cause the RM9004 Test Fixture to lower while you're cleaning it, resulting in injury or damage to the device.
- Contacting the probes with cloth, cotton swabs, or other supplies while cleaning the device could deform the pins, increasing the error component of measurement results or making accurate measurement impossible.

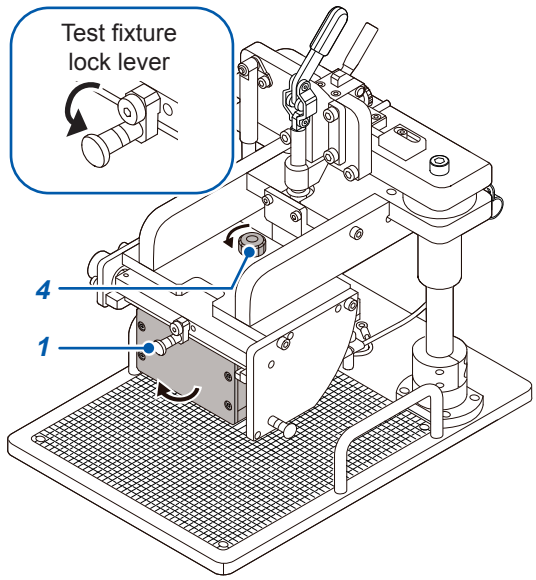
- Use a compressed air pressure of 207 kPa (2.1 kgf/cm^2, 30 psi) or less.
- Wear a dustproof mask and dustproof goggles while cleaning the device.

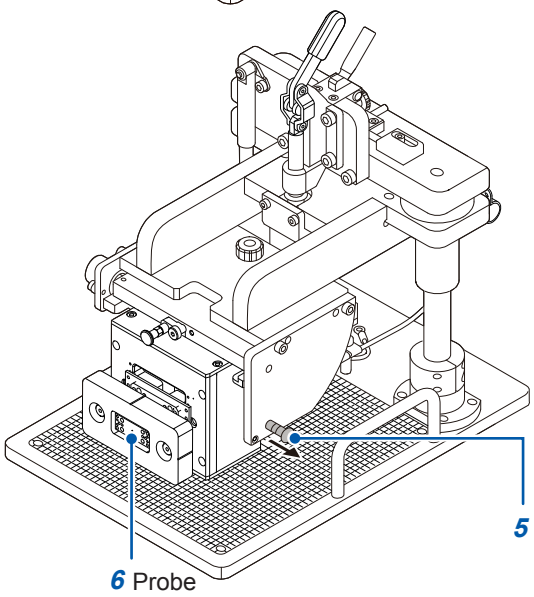
IMPORTANT

- The probes are extremely thin. Do not clean them with anything other than air.
- The RM9004 Test Fixture's probes are consumable parts. They require periodic replacement but are not customer-replaceable. Please contact your authorized Hioki distributor or reseller for more information.
- See also the RM2610 Probe Maintenance Guide (p. 19).

You will need:

A compressed air gun or blower (of the type used to clean camera lenses)





1 **Verify that the test fixture lock lever is in the lowered position.**

2 **Disconnect the RM9005 Connection Cable from the RM9004 Test Fixture.**

3 **Disconnect the grounding cable from the RM9004 Test Fixture's grounding terminal.**

4 **Rotate the test fixture clamp knob counterclockwise to disengage the lock.**

While doing so, rotate the test fixture clamp knob toward the UNLOCK position until the screw is fully removed while holding the RM9004 Test Fixture still. The base (bottom) of the RM9004 Test Fixture will gradually move so that it faces toward the front of the unit.

5 **Once the base of the test fixture is fully facing toward the front, pull out the maintenance plunger to lock the RM9004 Test Fixture in place.**

6 **Remove dust from the probes using the compressed air gun or blower.**

7 **Repeat the above procedure in reverse after cleaning to return the test fixture to its original state.**

9.6 Calibration

The calibration period varies with the conditions and environment of use. It is recommended to determine a calibration period based on those factors and to have the instrument regularly calibrated by Hioki.

9.7 Disposing of the RM2611 Electrode Resistance Meter

The RM2611 Electrode Resistance Meter uses a lithium battery to back up its clock. When disposing of the RM2611 Electrode Resistance Meter, remove this battery and follow all applicable regulations in your region.

Removing the lithium battery

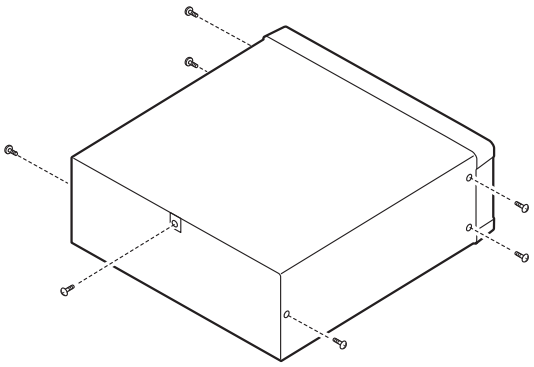
⚠DANGER

To prevent electric shock, turn off the RM2611 Electrode Resistance Meter's main power switch and disconnect the power cord and connection cable before removing the lithium battery from the instrument.

⚠CAUTION

Exercise care not to short the battery's positive and negative terminals. Doing so may cause sparks.

Necessary tools: Philips screwdriver (No. 1 size) and pair of tweezers (for removing the lithium battery)

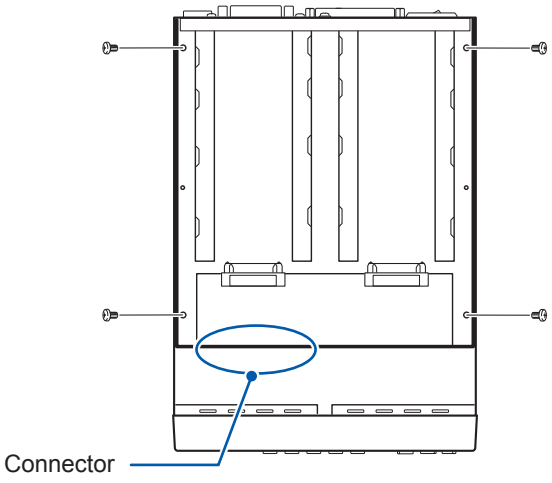


(As seen from above)

1 **Verify that the RM2611 Electrode Resistance Meter's main power switch (on the rear of the instrument) is in the OFF (○) position and disconnect all cords.**

2 **Remove the six screws from the sides and one screw from the rear.**

(Rear)

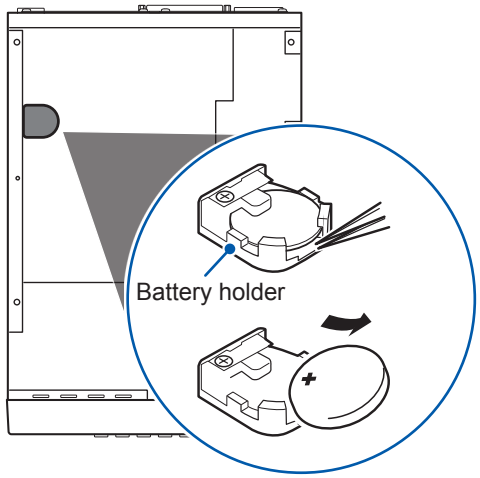


(Front)

3 **Remove the cover.**

4 **Remove the four screws and lift up the MUX unit frame. (Do not disconnect the connector that connects the MUX unit frame to the RM2611 Electrode Resistance Meter.)**

(As seen from above)



5 **Insert the tweezers into the space between the battery and the battery holder and remove the battery while lifting up on it, as shown in the figure.**

CALIFORNIA, USA ONLY
Perchlorate Material - special handling may apply.
See www.dtsc.ca.gov/hazardouswaste/perchlorate

10 Appendix

10.1 Rack Mounting

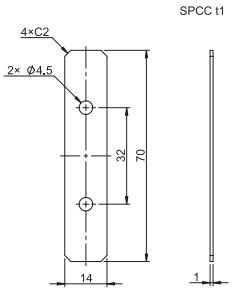
The screws on the sides of the RM2611 Electrode Resistance Meter can be removed and used to attach rack-mounting hardware.

⚠ WARNING

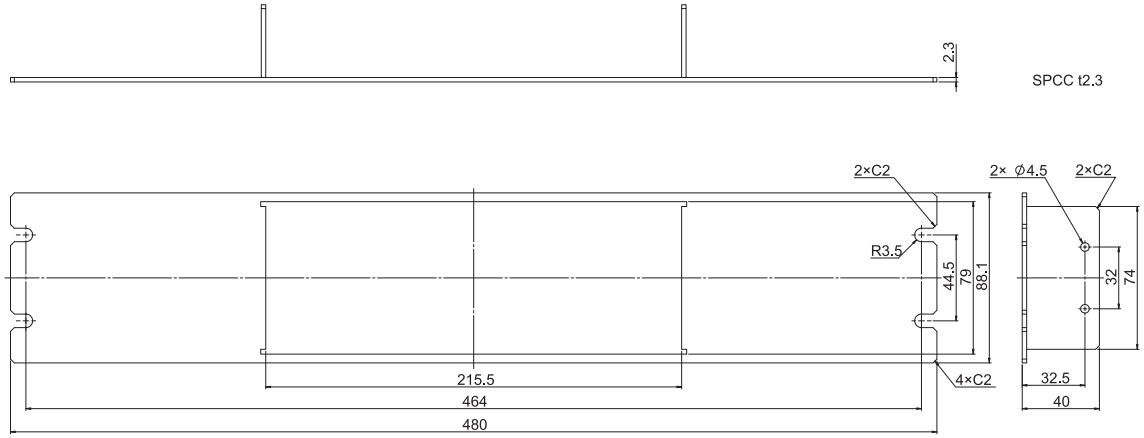
To prevent damage to the RM2611 Electrode Resistance Meter or electric shock, exercise care with regard to the following precautions concerning the type of screws used:
When installing rack-mounting hardware onto the sides of the instrument, ensure that the screws do not protrude into the RM2611 Electrode Resistance Meter more than 3.5 mm. When removing the rack-mounting hardware to return the instrument to its original state, use the same screws that were installed when it shipped from the factory.
(Support legs: M3 × 6 mm; sides: M4 × 6 mm)
If you lose or damage the screws, please contact your authorized Hioki distributor or reseller.

Rack-mounting hardware reference diagram and installation method

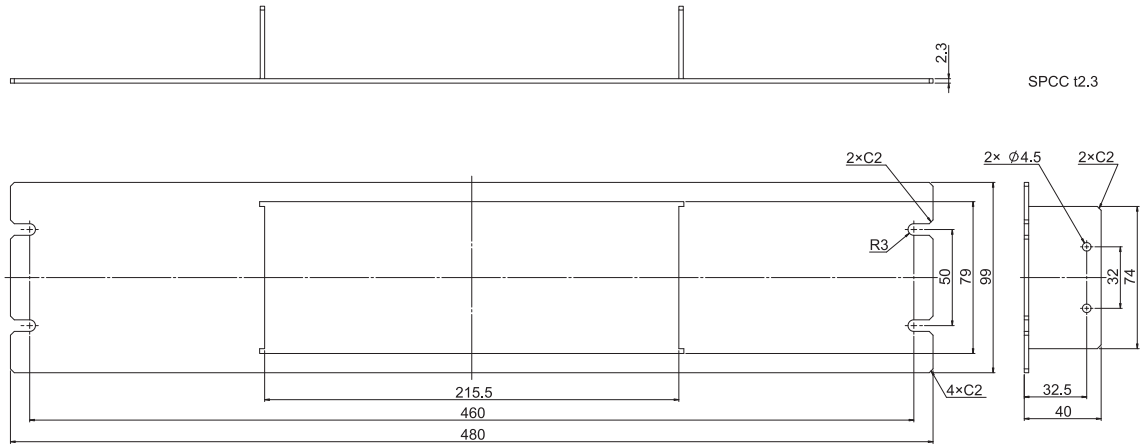
Spacers (use 2)

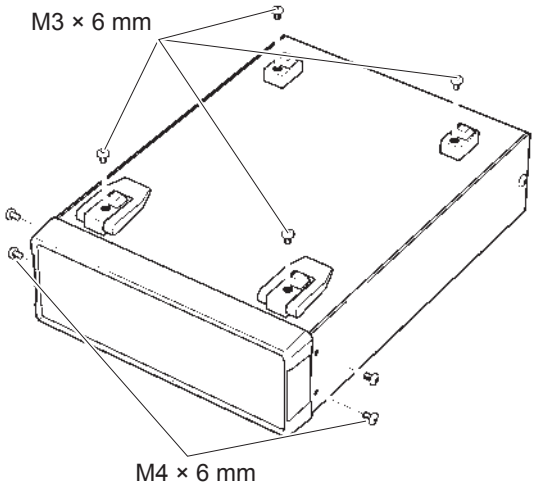


Rack-mounting hardware (EIA)

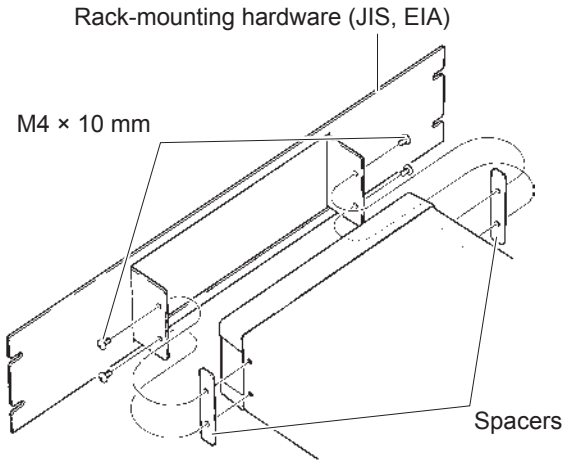


Rack-mounting hardware (JIS)





1 **Remove the screws from the RM2611 Electrode Resistance Meter's support feet (on the bottom) and side cover (total of 4 on the sides at the front).**



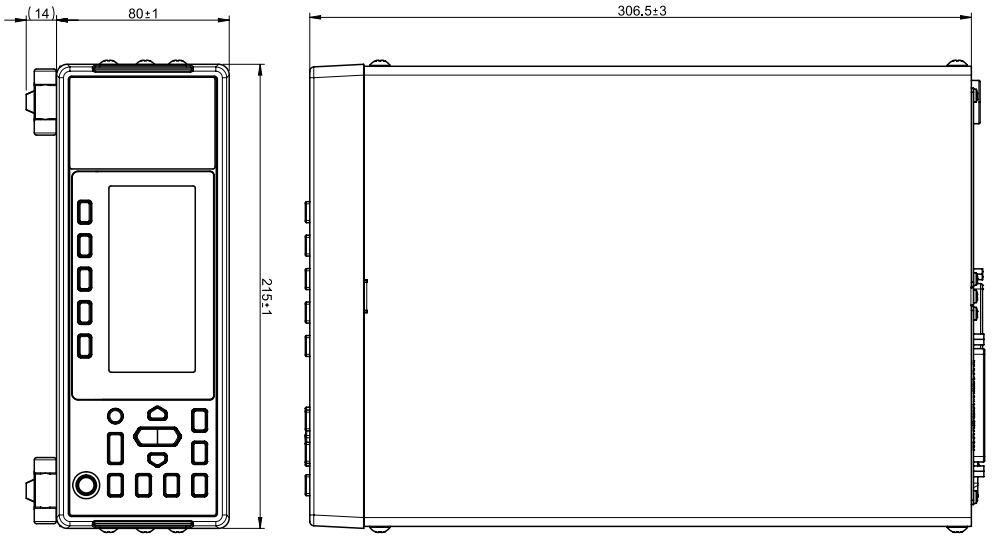
2 **Insert spacers on both sides of the RM2611 Electrode Resistance Meter and then install the rack-mounting hardware with M4 × 10 mm screws.**

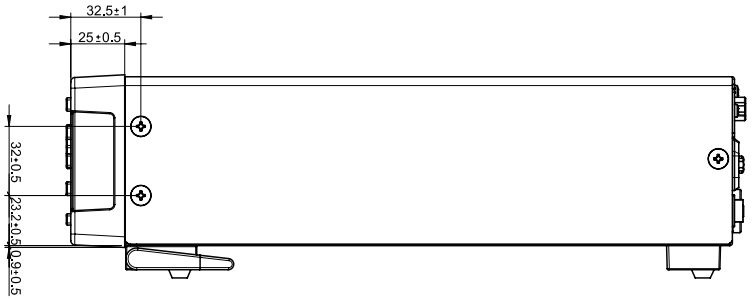
IMPORTANT
Use a commercially available stand or other equipment to reinforce the installation when mounting the instrument in rack.

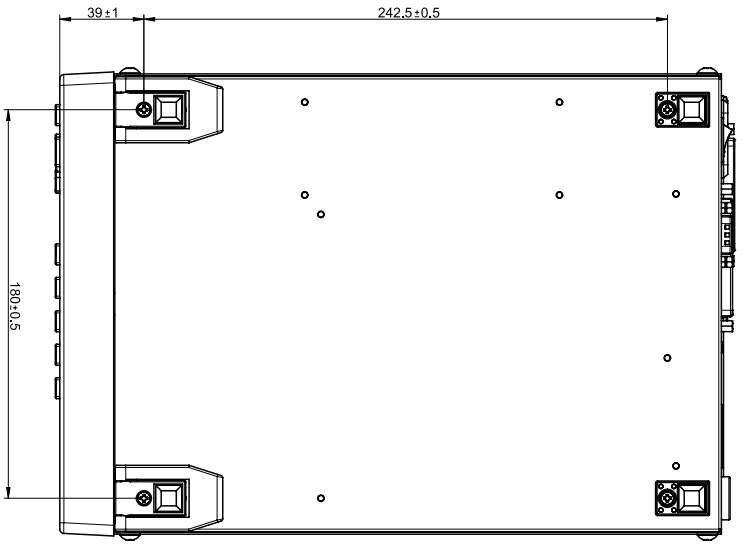
10.2 Dimensional Drawings

RM2611 Electrode Resistance Meter

Unit: mm



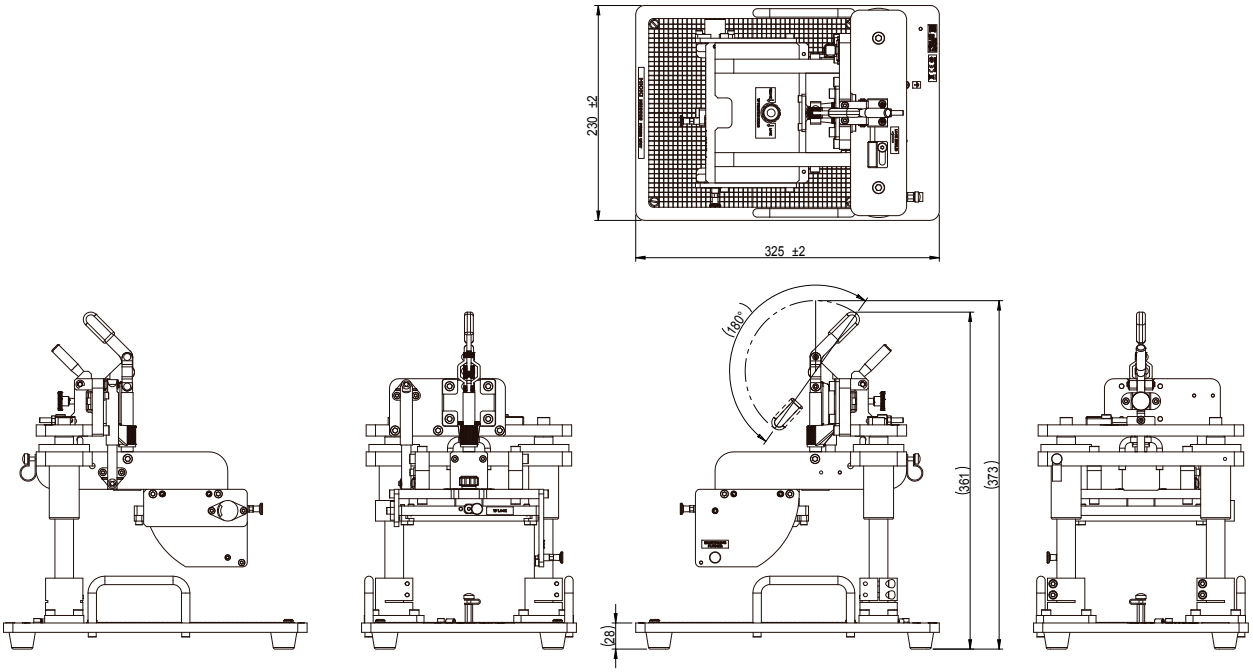




Weight : Approx. 3.4 kg

RM9003 Press Unit

Unit: mm

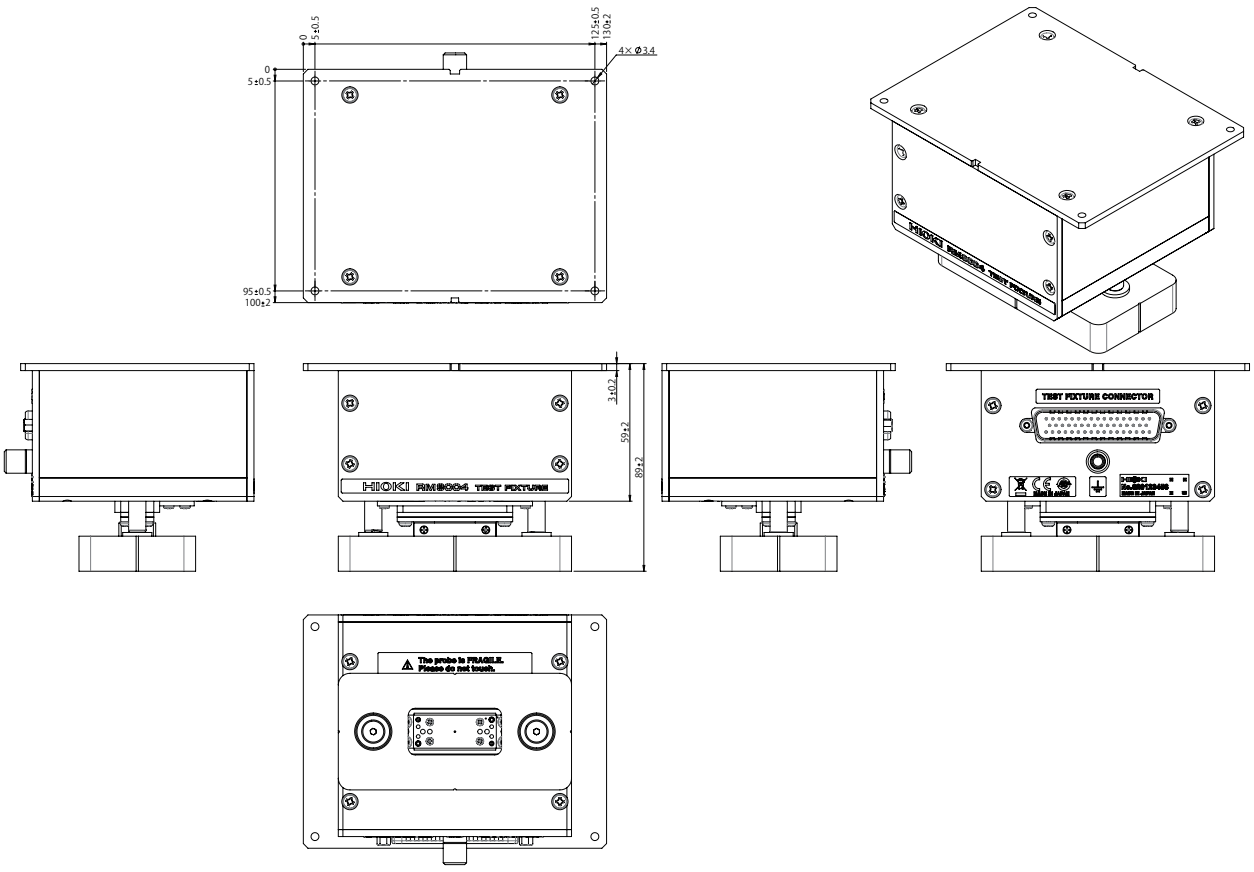


Weight : Approx. 8.5 kg

RM9004 Test Fixture

Probe loading (reference value): 0.044 N/probe

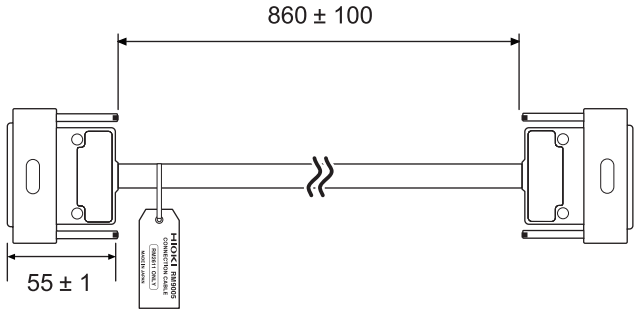
Unit: mm



Weight : Approx. 770 g

RM9005 Connection Cable

Unit: mm



Weight : Approx. 450 g

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