Part No. Z1-003-892, IB011533
May. 2016

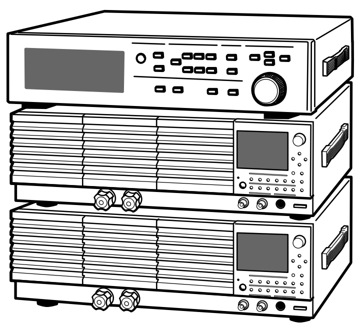
OPERATION MANUAL

Fuel Cell Impedance Measurement System

KFM2150SYSTEM

165-01A
660-01A
1320-02A
1980-03A
2640-04A
3300-05A

1000-01
3000-02
5000-03
7000-04
9000-05



KIKUSUI

Use of Operation Manual

Please read through and understand this Operation Manual before operating the product. After reading, always keep the manual nearby so that you may refer to it as needed. When moving the product to another location, be sure to bring the manual as well.

If you find any misplaced or missing pages in this manual, they will be replaced. If the manual gets lost or soiled, a new copy can be provided for a fee. In either case, please contact Kikusui distributor/agent, and provide the "Kikusui Part No." given on the cover.

This manual has been prepared with the utmost care; however, if you have any questions, or note any errors or omissions, please contact Kikusui distributor/agent.

⚠ Safety Symbols

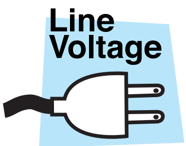
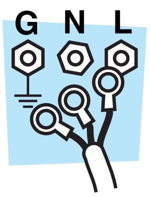
For the safe use and safe maintenance of this product, the following symbols are used throughout this manual and on the product. Note the meaning of each of the symbols to ensure safe use of the product. (Not all symbols may be used.)

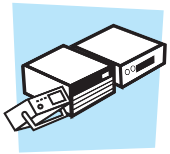
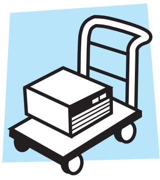
ϟ or ⚠	Indicates that a high voltage (over 1 000 V) is used here. Carelessly touching the part may cause fatal electric shock. If physical contact is required by your work, start work only after you make sure that no voltage is output here.
DANGER	Indicates an imminently hazardous situation which, if ignored, will result in death or serious injury.
⚠ WARNING	Indicates a potentially hazardous situation which, if ignored, could result in death or serious injury.
⚠ CAUTION	Indicates a potentially hazardous situation which, if ignored, may result in damage to the product and other property.
⊘	Shows that the act indicated is prohibited.
⚠	Indicates a general danger, warning, or caution. When this symbol is marked on the product, see the relevant sections in this manual.
⏚	Protective conductor terminal.
⊥	Chassis (frame) terminal.
|	On (supply)
○	Off (supply)
	In position of a bi-stable push control
	Out position of a bi-stable push control

⚠ Safety Precautions

The following safety precautions must be observed to avoid fire hazards, electric shock, accidents, and other failures. Keep them in mind and make sure to observe them.

Using the product in a manner that is not specified in this manual may impair the protection functions provided by the product.

Users 	• This product must be used only by qualified personnel who understand the contents of this operation manual. • If unqualified personnel is to use the product, be sure the product is handled under the supervision of qualified personnel (those who have electrical knowledge). This is to prevent the possibility of personal injury.
Purpose of use 	• Never use the product for purposes other than the product's intended use. • This product is not designed or manufactured for general home or consumer use.
Input power 	• Use the product within the rated input power voltage range. • For applying power, use the power cord provided. For details, see the respective page in the operation manual. • This product is designed as an equipment of IEC Overvoltage Category II (energy-consuming equipment supplied from the fixed installation).
Cover 	• Some parts inside the product may cause physical hazards. Do not remove the external cover.
Grounding 	• This product is an IEC Safety Class I equipment (equipment with a protective conductor terminal). To prevent the possibility of electric shock, be sure to connect the protective conductor terminal of the product to electrical ground (safety ground).

Installation 	• This product is designed for safe indoor use. Be sure to use it indoors. • When installing this product, be sure to observe the description in section 1.2, “Precautions Concerning Installation Location” in this manual.
Relocation 	• Turn off the POWER switch, and disconnect all cables before relocating the product. • When moving the product, have more than one person carry it. • When relocating the product, be sure to include the manual.
Operation 	• Before using the product, be sure to check the input power voltage and that there is no abnormality in the appearance of the power cord. Be sure to remove the power plug from the outlet before checking it. • If a malfunction or abnormality is detected on the product, stop using it immediately, and remove the power plug from the outlet. Make sure the product is not used until it is completely repaired. • Use cables or wires with sufficiently large current capacity for output wires and load cables. • Do not disassemble or modify the product. If you need to modify the product, contact your Kikusui distributor/agent.
Maintenance and inspection 	• To prevent the possibility of electric shock, make sure to unplug the power plug before carrying out maintenance or inspection. • Do not remove the external cover during maintenance or inspection. • To maintain the performance and safe operation of the product, it is recommended that periodic maintenance, inspection, cleaning, and calibration be performed.
Service 	• Kikusui service engineers will perform internal service on the product. If the product needs adjustment or repairs, contact your Kikusui distributor/agent.

How to Read This Manual

Preface

Thank you for purchasing the KFM2150 SYSTEM Fuel Cell Impedance Measurement System.

This manual is intended for first-time users of the KFM2150. It gives an overview of the fuel cell impedance measurement system and describes installation procedures and preparation.

Read this manual thoroughly to use the functions of the KFM2150 effectively. You can also review this manual when you are confused about an operation or when a problem occurs.

For details on the individual instruments making up the impedance measurement system such as the PLZ-4W Series Electronic Load Units and other external equipment, see the respective operation manuals.

How to read this manual

This manual is designed to be read from beginning to end. We recommend that you read the manual thoroughly from the beginning before using the KFM2150 for the first time.

Related manuals

The products listed below are used in the fuel cell impedance measurement system. For details, see the respective operation manual.

- KFM2151 FC Scanner (option)
- Application Software
- Communication Interface Manual (FC Impedance Meter)
  Electronic manual provided with the application software

Intended readers of this manual

This manual is intended for operators that control and use the impedance measurement system or persons teaching other users on how to operate the system.

It assumes that the reader has knowledge about fuel cells and electrical aspects of impedance measurement. Information on SCPI commands is provided with the premise that the reader has sufficient knowledge about controlling instruments using a personal computer.

Structure of the Manual

This manual consists of the Installation Part and Operation Part.

■ Installation Part

Describes the installation of the KFM2150.

Chapter 1 Description of the Installation

This chapter describes a general description of the installation. It also introduces the features of the product and indicates the firmware version of the product to which this manual applies.

Chapter 2 Installation of the Bench Top Type

This chapter describes the procedures from unpacking to installation of the bench top type.

Chapter 3 Installation of the Rack Mount Type

This chapter describes the procedures from unpacking to installation of the rack mount type.

■ Operation Part

Describes the operations of the impedance meter.

Chapter 4 Basic Operations

This chapter describes basic operations and how to use the various functions.

Chapter 5 Impedance Measurement

This chapter describes how to use the impedance measurement system.

Chapter 6 Maintenance

This chapter describes maintenance of the KFM2150 including cleaning, inspecting, calibrating, and troubleshooting.

Chapter 7 Specifications

This chapter describes the specifications of the KFM2150 system.

Appendix

The appendix describes an overview of the fuel cell and evaluation system and the basics of the electronic load unit and wiring.

Notations used in the manual

- The "KFM2150 FC Impedance Meter" is also simply referred to as "KFM2150" in this manual.
- The "PLZ-4W Series Electronic Load Unit" is also referred to as the "PLZ-4W" or the "PLZ-4W Series" in this manual.
- The word computer, controller, and PC used in the text are general terms that describe personal computers and workstations.
- The following markings are used in the explanations in the text.

⚠WARNING

Indicates a potentially hazardous situation which, if ignored, could result in death or serious injury.

⚠CAUTION

Indicates a potentially hazardous situation which, if ignored, may result in damage to the product and other property.

NOTE

Indicates information that you should know or convenient tips.

DESCRIPTION

Explanation of terminology or operation principle.

See

Indicates reference to detailed information.

>

Indicates menu settings that you select. Menu items to the right of the greater-than sign is are submenus.

SHIFT+key name (marked in blue)

Indicates an operation in which a key marked in blue is pressed while holding down the SHIFT key.

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Chapter 2 Installation of the Bench Top Type

Chapter 3 Installation of the Rack Mount Type

Operation Part

Chapter 4 Basic Operation

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Installation

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What are the types of system component instruments?	1.5.1, “Measurement System Types”	1-7
What kind of load wires should be used?	2.2, “Load Wires,” 3.2, “Load Wires”	2-6 3-6
The fuel cell is located far away. What are the points to be considered?		
I am concerned about the power supply capacity. What is the maximum power consumption?	2.8, “Connecting the Power Cord and Grounding (Earth),” 3.6, “Connecting the Power Cable and Grounding (Earth)”	2-22 3-18

Preparation

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Start

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Situation	Heading	See Page
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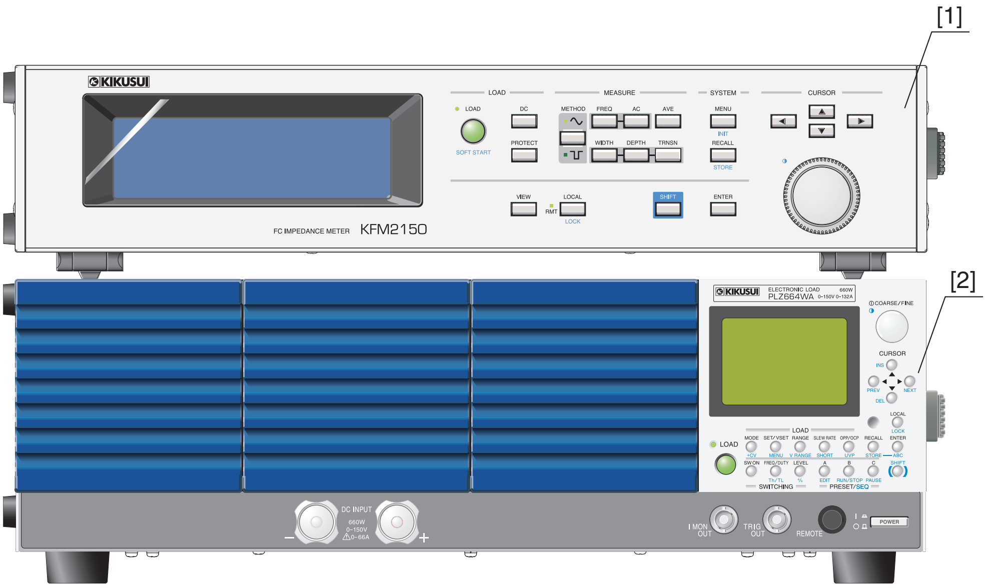
To make GO/NOGO judgement on the measured results.		

Front panel of the bench top type

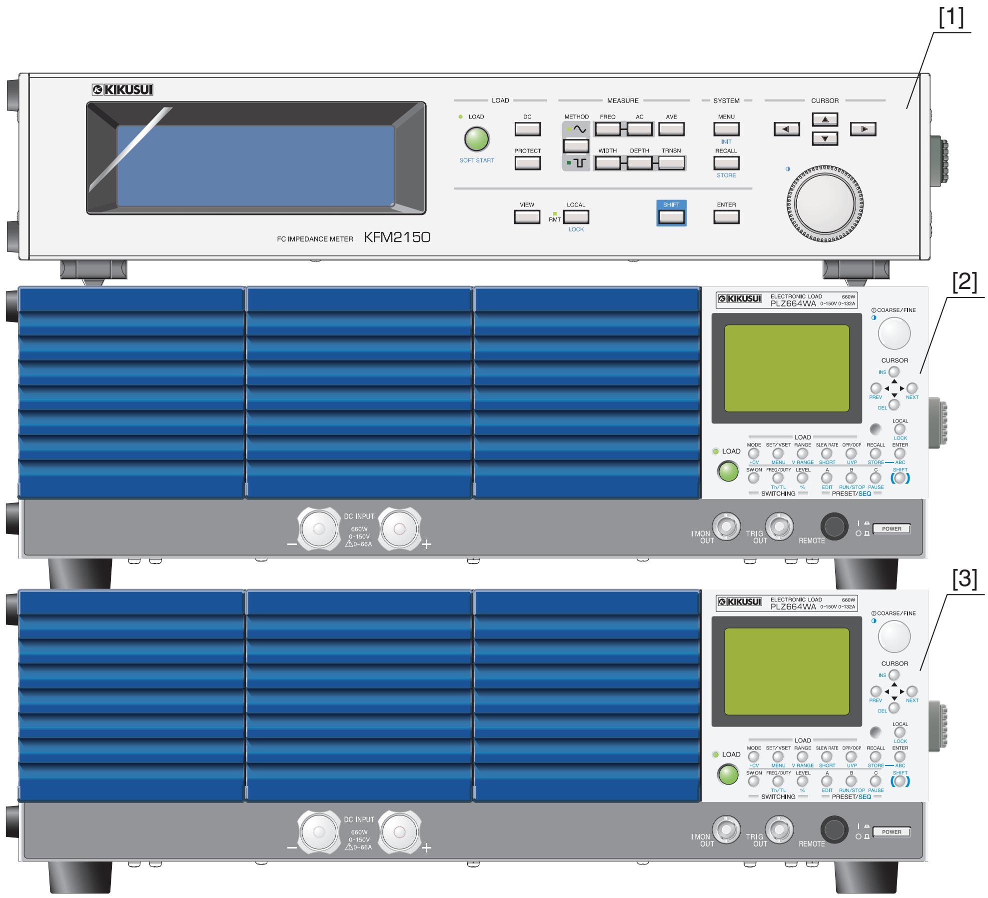
KFM2150 SYSTEM165-01A, 660-01A, and 1000-01



No.	Name	Description	See Page
1	FC Impedance Meter	KFM2150.	2-2
2	Electronic Load Unit	PLZ164WA, PLZ664WA, or PLZ1004W.	

Front panel of the bench top type

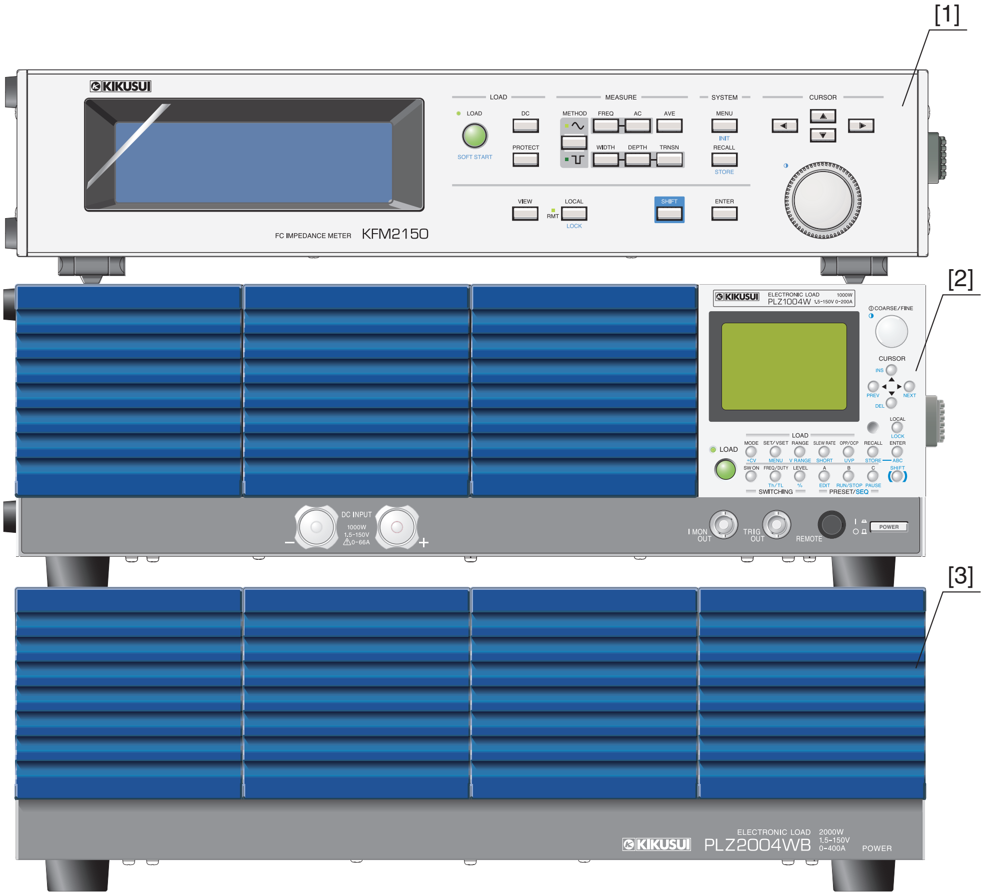
KFM2150 SYSTEM1320-02A



No.	Name	Description	See Page
1	FC Impedance Meter	KFM2150.	2-2
2	Electronic Load Unit	PLZ664WA.	
3	Electronic Load Unit	PLZ664WA.	

Front panel of the bench top type

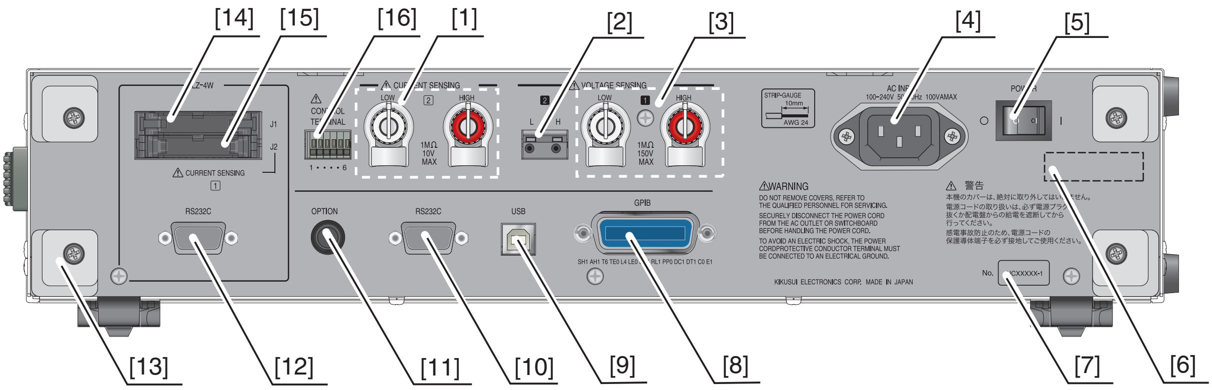
KFM2150 SYSTEM3000-02



No.	Name	Description	See Page
1	FC Impedance Meter	KFM2150.	2-2
2	Electronic Load Unit	PLZ1004W.	
3	Electronic Load Unit	PLZ2004WB.	

Rear panel of the bench top types

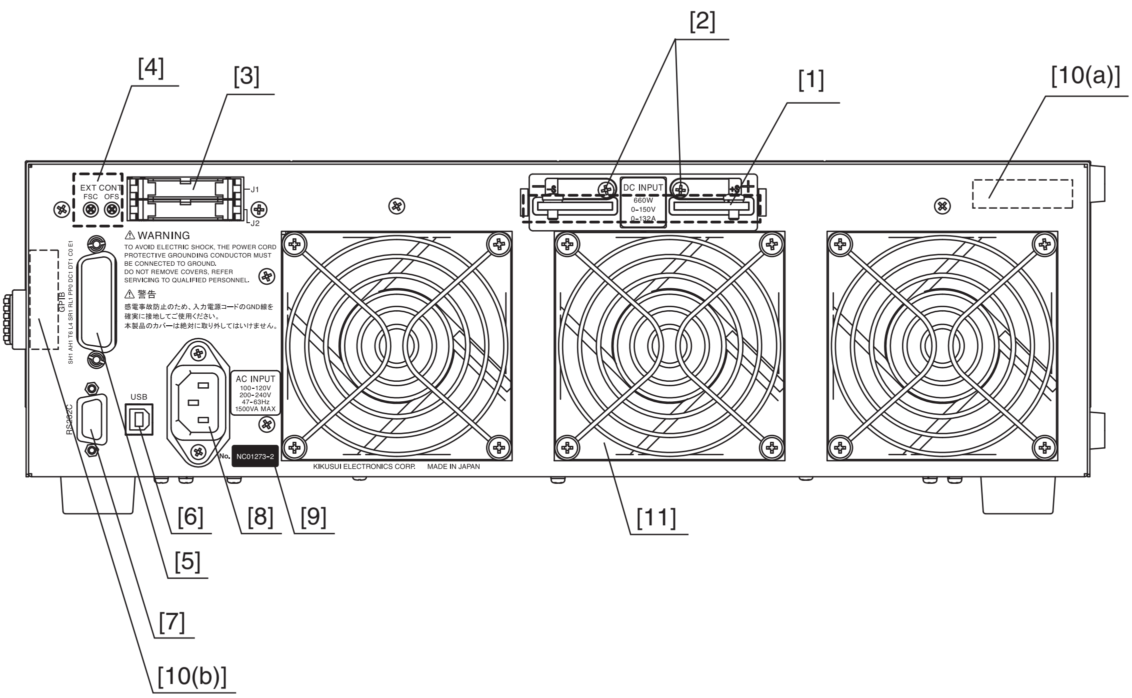
KFM2150 FC Impedance Meter



See "KFM2150 rear panel" on page 24 for the part name and description.

Rear panel of the bench top type

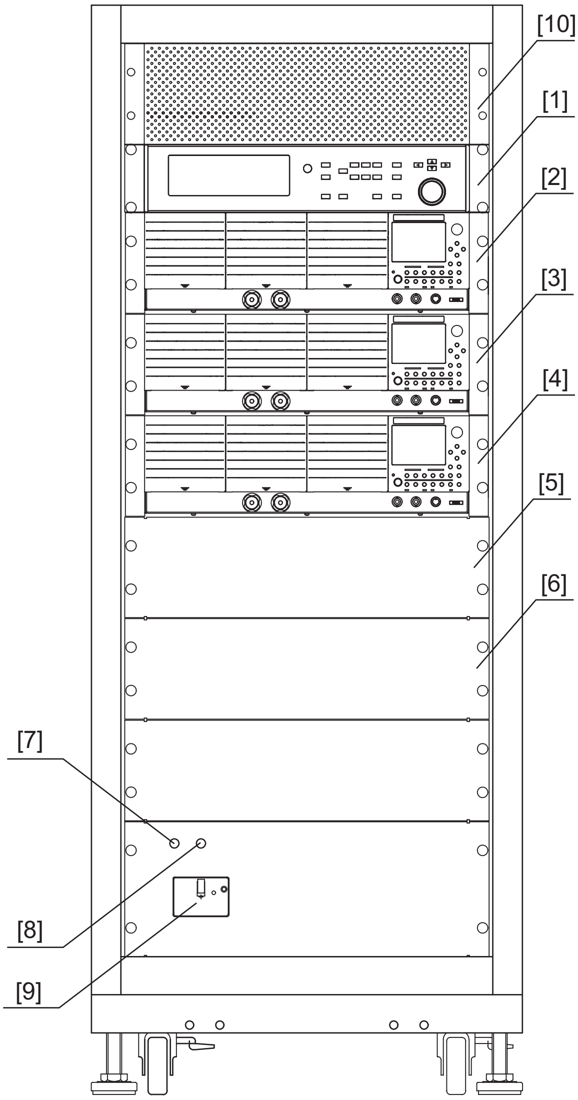
Electronic Load Unit



No.	Name	Description	See Page
1	DC INPUT	Load input terminal.	2-7
2	Remote sensing terminal	PLZ4W remote sensing terminal.	–
3	J1/J2	J1: Connector for controlling from the KFM2150. J2: Connector for parallel operation.	2-16
4	EXT CONT	External control. Variable resistor for adjusting the full scale and offset.	
5	GPIB	GPIB cable connector.	–
6	USB	USB cable connector.	
7	RS232C	RS232C cable connector (for control from the KFM2150).	2-16
8	AC INPUT	Connector for the power cord.	2-22
9	Serial number	The serial number of the PLZ-4W.	–
10	System serial number	The serial number for the impedance measurement system. (a) Models other than PLZ164WA. (b) PLZ164WA.	2-2
11	Exhaust port	Exhaust port for the cooling fan.	–

Front panel of the rack mount type

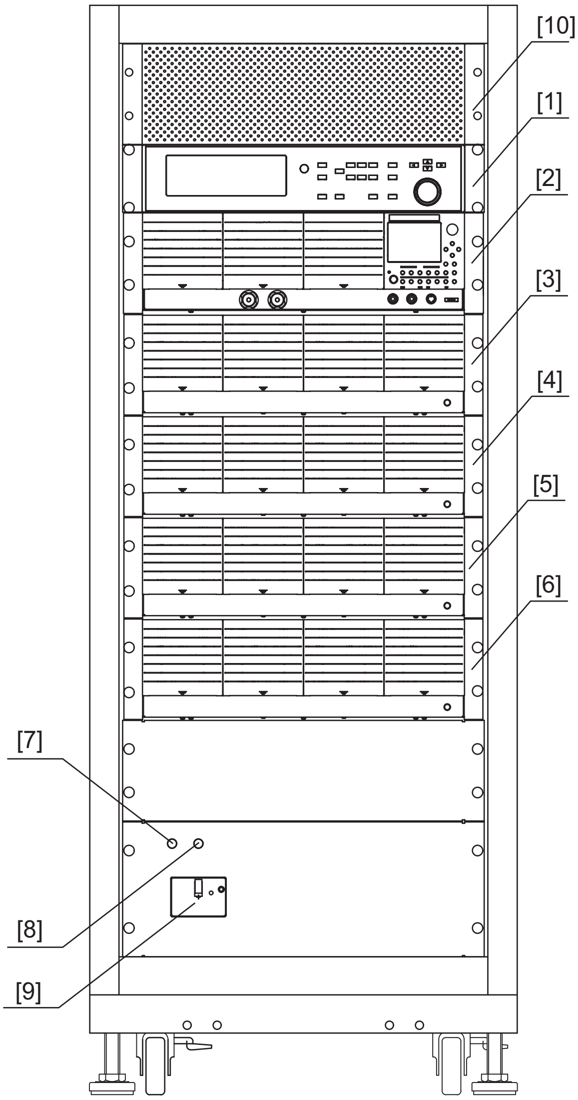
KFM2150 SYSTEM1980-03A, 2640-04A, and 3300-05A



No.	Name	Description	See Page
1	FC Impedance Meter	KFM2150.	3-2
2	Electronic Load Unit	PLZ664WA (KFM2150 SYSTEM1980-03A, 2640-04A, and 3300-05A).	
3	Electronic Load Unit	PLZ664WA (KFM2150 SYSTEM1980-03A, 2640-04A, and 3300-05A).	
4	Electronic Load Unit	PLZ664WA (KFM2150 SYSTEM1980-03A, 2640-04A, and 3300-05A).	
5	Electronic Load Unit	PLZ664WA (KFM2150 SYSTEM2640-04A and 3300-05A).	
6	Electronic Load Unit	PLZ664WA (KFM2150 SYSTEM3300-05A).	
7	LINE	AC line input indicator.	–
8	POWER	Power supply indication lamp.	2-22
9	POWER switch	POWER switch.	
10	FC Scanner	For the KFM2151 (option).	3-12

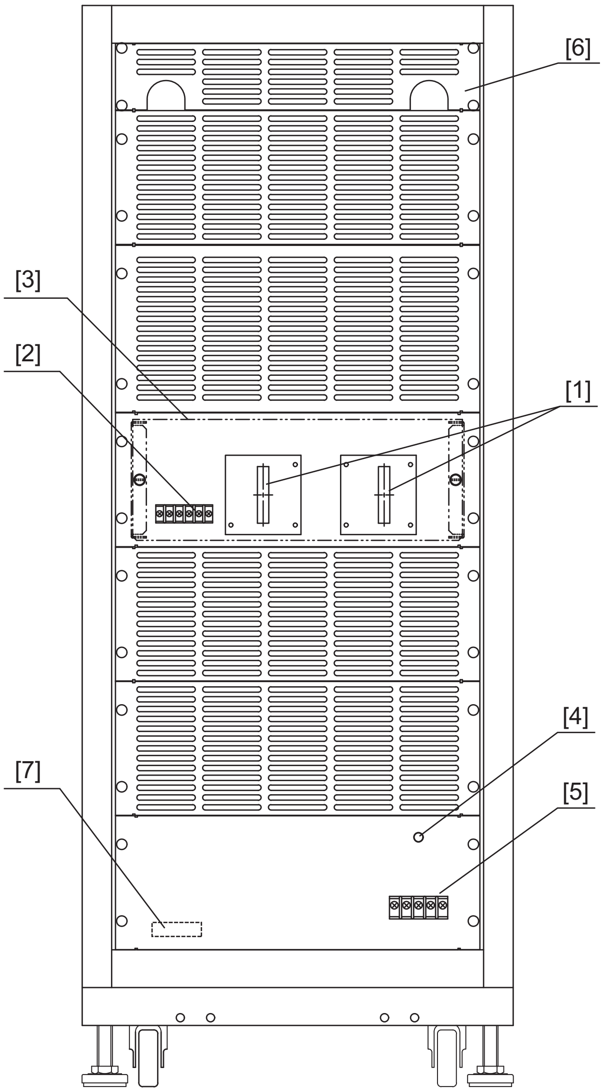
Front panel of the rack mount type

KFM2150 SYSTEM5000-03, 7000-04, and 9000-05



No.	Name	Description	See Page
1	FC Impedance Meter	KFM2150.	3-2
2	Electronic Load Unit	PLZ1004W (KFM2150 SYSTEM5000-03, 7000-04, and 9000-05).	
3	Electronic Load Unit	PLZ2004WB (KFM2150 SYSTEM5000-03, 7000-04, and 9000-05).	
4	Electronic Load Unit	PLZ2004WB (KFM2150 SYSTEM5000-03, 7000-04, and 9000-05).	
5	Electronic Load Unit	PLZ2004WB (KFM2150 SYSTEM7000-04 and 9000-05).	
6	Electronic Load Unit	PLZ2004WB (KFM2150 SYSTEM9000-05).	
7	LINE	AC line input indicator.	–
8	POWER	Power supply indication lamp.	3-16
9	POWER switch	POWER switch.	
10	FC Scanner	For the KFM2151 (option).	3-12

Rear panel of the rack mount type

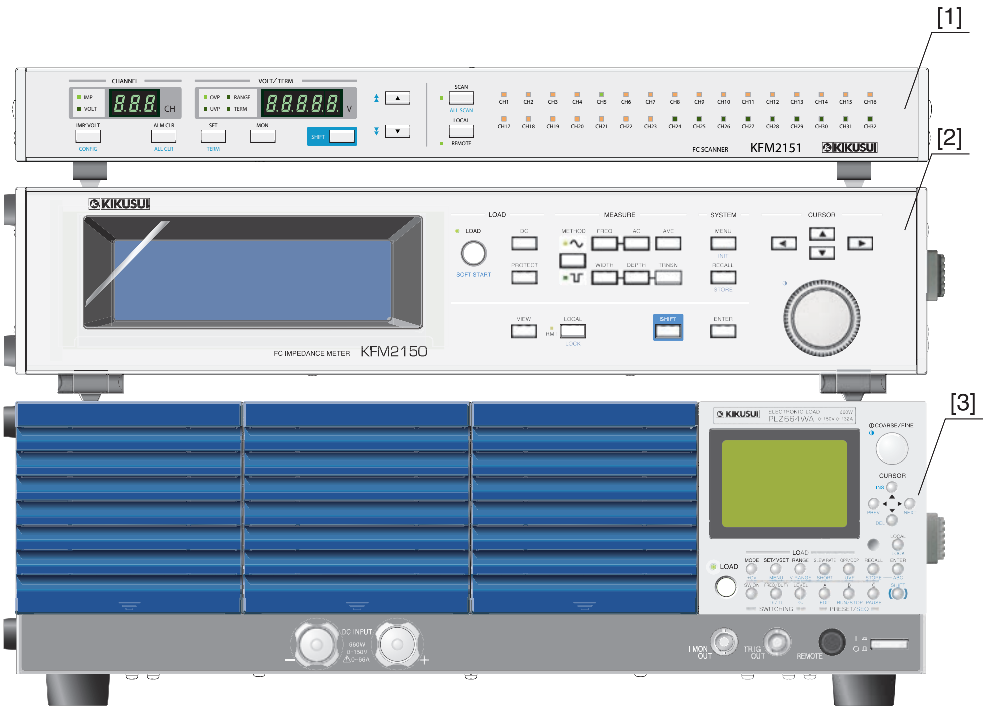


No.	Name	Description	See Page
1	Load input terminal	Links the DC INPUT of the installed electronic load units.	3-6
2	SENSING	Voltage sensing terminal and PLZ4W remote sensing terminal.	3-10
3	Terminal cover	Cover for the load input terminal and sensing terminal.	–
4	LINE	Illuminates when power is supplied to AC INPUT.	3-16
5	AC INPUT	Power input terminal block.	
6	Scanner terminal	Panel with a hole for wiring the SENSING terminal of the KFM2151 FC Scanner (option).	3-12
7	System serial number	Serial number for the impedance measurement system.	3-2

KFM2151 FC Scanner (Option)

Installation example to the KFM2150 SYSTEM165-01A, 660-01A, and 1000-01

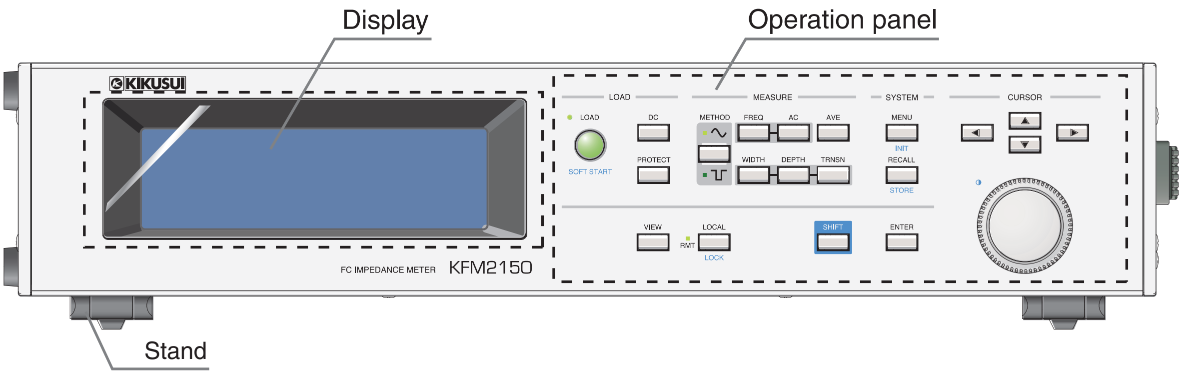
It can also be installed to the rack mount type.



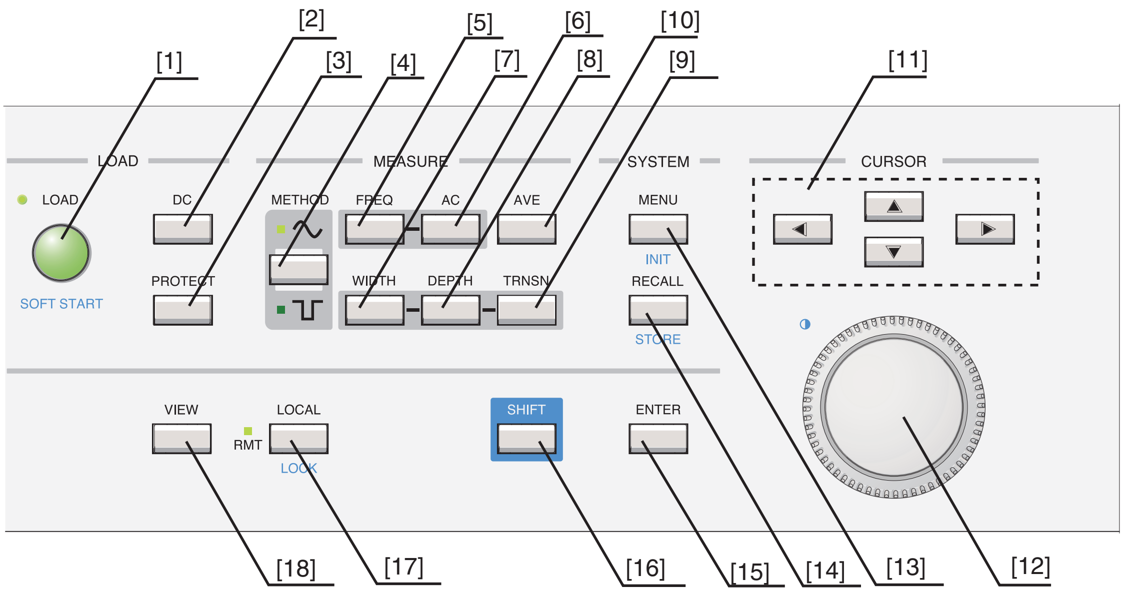
No.	Name	Description	See Page
1	FC Scanner	KFM2151 (option).	2-18
2	FC Impedance Meter	KFM2150.	2-2
3	Electronic Load Unit	PLZ164WA, PLZ664WA, or PLZ1004W.	

FC Impedance Mater KFM2150 panel

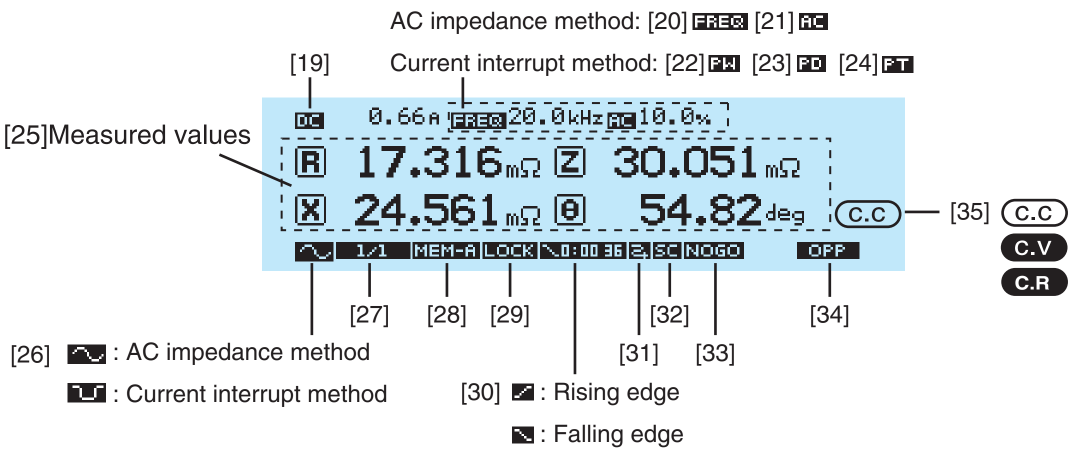
Front panel



Operation panel



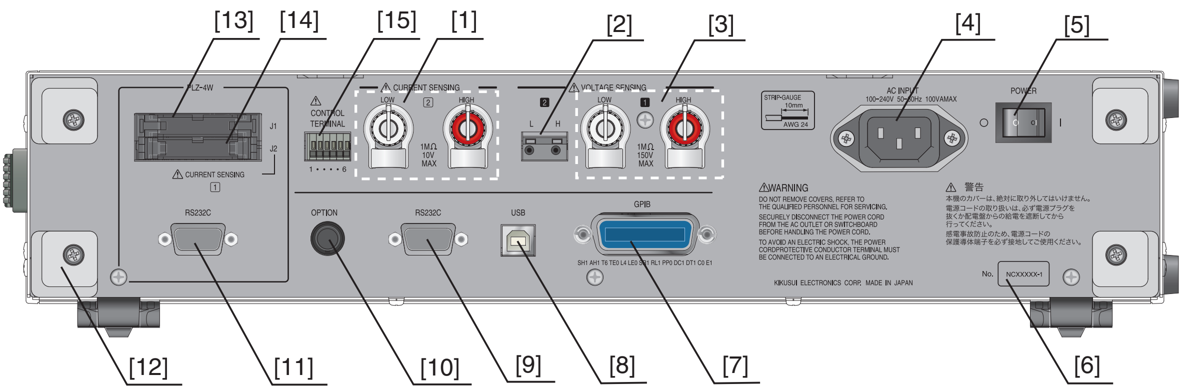
Display



No.	Name	+SHIFT	Description	See
1	LOAD		Load on/off switch.	5-6
		SOFT START	Load on (soft start rising)/load off (soft start falling) switch.	
2	DC		Load current set key.	5-4
3	PROTECT		Protection function set key.	4-8
4	METHOD		Key for switching between AC impedance method and current interrupt method.	5-10 5-14
5	FREQ		Measuring frequency set key (AC impedance method).	5-11
6	AC		Key for setting the measuring AC current and switching the unit between % and A (AC impedance method).	5-12
7	WIDTH		Pulse width set key of the interrupt current (current interrupt method).	5-15
8	DEPTH		Key for setting the pulse depth of the interrupt current and switching the unit between % and A (current interrupt method).	5-15
9	TRNSN		Pulse transition time set key of the interrupt current (current interrupt method).	5-16
10	AVE		Average count set key.	5-18
11	CURSOR ▲ ▼ ◀ ▶		Up, down, left, and right keys.	–
12	Rotary knob		Knob for changing values and settings.	–
		contrast ◑	Display contrast adjustment knob.	4-16
13	MENU		Menu key.	4-26
		INIT	Initialize (factory default) key.	4-17
14	RECALL		Memory recall key.	4-14
		STORE	Memory storage key (selectable memories are A, B, and C).	
15	ENTER		Key for applying settings and releasing the alarm.	4-12
16	SHIFT		Shift key. Accepts commands marked in blue on the panel.	6
17	LOCAL		Local mode switch key.	4-17
		LOCK	Key for locking/unlocking the panel operation.	4-16
18	VIEW		Setup window display key.	5-19
19	DC		Displays the load current.	5-4
20	FREQ		Displays the measuring frequency (AC impedance method).	5-11
21	AC		Displays the measuring current (AC impedance method).	5-12
22	PW		Displays the interrupt current pulse width (current interrupt method).	5-15
23	PD		Displays the interrupt current pulse depth (current interrupt method).	5-15
24	PT		Displays the interrupt current pulse transition time (current interrupt method).	5-16
25	Measured value		Displays the measured value.	5-19
26	METHOD		Displays the selected measurement method (AC impedance or current interruption).	5-10 5-14
27	AVE		Displays the average count.	5-18
28	MEM A/B/C		Displays the stored memory or recalled memory.	4-14
29	LOCK		Displays the lock status.	4-16
30	SOFT START		Displays the soft start rise time or fall time [hour:minute:second].	5-7
31	Scanner		Displayed for a scanner system in combination with the KFM2151.	5-20

No.	Name	Description	See
	+SHIFT		
32	SC	Display when the short-circuit correction function is enabled.	5-21
33	GO/NOGO	Displays the judgement result (when the judge function is enabled).	5-24
34	Alarm	Displayed when a protection function is activated (OPP/UVP/OVP/REV/OHP/EXT).	4-12
35	CC, CV, CR	PLZ-4W operation mode display (CC: Constant Current. CV: Constant Voltage. CR: Constant Resistance)	5-5

KFM2150 rear panel



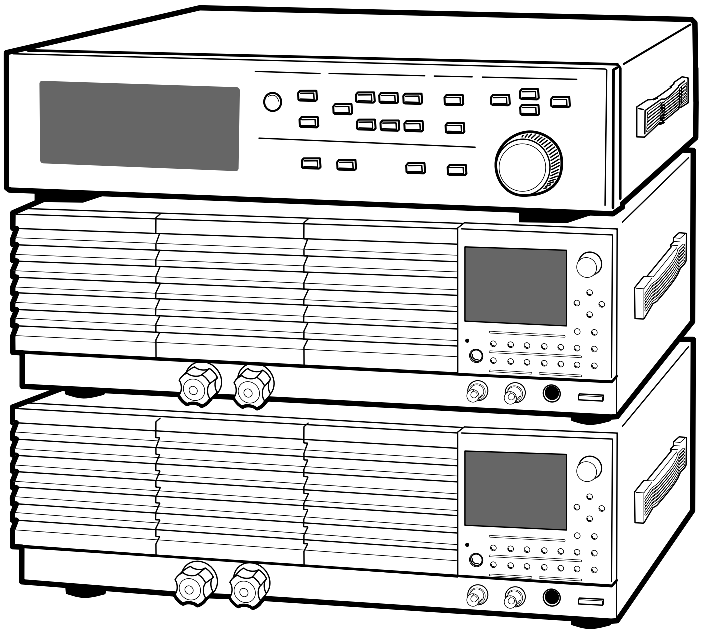
No.	Name	Description	See
1	CURRENT SENSING 2	Current sensing input channel 2.	A-4
2	VOLTAGE SENSING 2	Voltage sensing input channel 2. DC input voltage range: 0 V to 150 V. Input impedance: approx. 1 MΩ.	2-12 3-10 A-35
3	VOLTAGE SENSING 1	Voltage sensing input channel 1. DC input voltage range: 0 V to 150 V. Input impedance: approx. 1 MΩ.	
4	AC INPUT	Connector for the power cord.	2-22
5	POWER	POWER switch. Press the (I) side to turn the power on and the (O) to turn the power off.	2-22 4-2
6	System serial number	The serial number for the impedance measurement system.	2-2 4-4
7	Serial number	The serial number of the KFM2150.	–
8	GPIB	GPIB cable connector for remote control.	2-20 4-18
9	USB	USB cable connector for remote control.	
10	RS232C	RS232C cable connector for remote control.	
11	OPTION	Terminal for functional expansion.	–
12	RS232C (PLZ-4W)	Connector for controlling the PLZ-4W Series Electronic Load Unit.	2-16
13	Cord holder	Holder for winding the power cord for storage.	–
14	J1 (PLZ-4W)	Output connector for the PLZ-4W Series and KFM2150 status signals and other signals.	2-16
15	J2 (PLZ-4W)	Connector for controlling the PLZ-4W Series Electronic Load Unit.	
16	CONTROL TERMINAL	Signal terminal for the external electronic load unit.	A-3

Installation Part

OPERATION MANUAL

Impedance Measurement System

KFM2150SYSTEM



1

Description of the Installation

This chapter describes a general description of the installation. It also introduces the features of the product and indicates the firmware version of the product to which this manual applies.

1.1 Firmware Version

Check the firmware version.

1.1.1 Firmware Version of the Product to Which This Manual Applies

This manual applies to KFM2150 systems with firmware version 1.1X.

When making an inquiry about the product, please provide us with the following information.

- System model

  The system model is indicated on the front cover of this manual and at the bottom of the rear panel of the product. It is indicated on each product on the bench top type and on the rack on the rack mount type.

- Firmware version

  See p.4-2

  The firmware version is shown on the KFM2150 display. For the procedure to view the firmware version, “see 4.1, “Turning the System On.”

- Serial number

  The serial number is indicated at the bottom of the rear panel along with the system model. It is indicated on each product on the bench top type and on the rack on the rack mount type.

- System serial number

  The system serial number is a unique number of each system. Systems cannot be composed using products with different system serial numbers. The system serial number is indicated on the rear panel of the product separately from the serial number of the product.

1.1.2 Firmware Version of the PLZ-4W Series Electronic Load Unit

This system and the accompanying application software apply to the PLZ-4W Series Electronic Load Unit with firmware version 1.18 or higher.

When making an inquiry about the PLZ-4W Series Electronic Load Unit, please provide us with the following information.

- Model
- Firmware version

  The firmware version is shown on the display of the PLZ-4W Series Electronic Load Unit. For the procedure to view the firmware version, see the operation manual of the PLZ-4W Series Electronic Load Unit (indicated as the ROM version).

NOTE

- The serial number will be assigned specifically to the PLZ-4W unit when it is shipped as a part of the system configuration.Therefore, any other same model of PLZ unit can not be substitute as a replacement purpose.

1.2 Precautions Concerning Installation Location

Install the product indoors under the following conditions.

- **Do not use the product in a flammable atmosphere.**

  To prevent explosion or fire, do not use the product near alcohol, thinner or other combustible materials, or in an atmosphere containing such vapors.

- **Avoid locations where the product is exposed to high temperature or direct sunlight.**

  Do not install the product near a heater or in areas subject to drastic temperature changes.

  Operating temperature range: 0 °C to +40 °C

  Storage temperature range: -20 °C to +70 °C

- **Avoid humid environments.**

  Do not install the product in high-humidity locations near a boiler, humidifier, or water supply.

  Operating humidity range: 20 %rh to 85 %rh (no condensation)

  Storage humidity range: 0 to 90 %rh (no condensation)

  Condensation may occur even within the operating humidity range. If this happens, do not use the product until the condensation dries up completely.

- **Be sure to use it indoors.**

  This product is designed for safe indoor use.

- **Do not install the product in a corrosive atmosphere.**

  Do not install the product in a corrosive atmosphere or in environments containing sulfuric acid mist, etc. This may cause corrosion of various conductors and bad contacts of connectors inside the tester leading to malfunction and failure, or in the worst case, a fire.

- **Do not install the product in a dusty location.**

  Accumulation of dust may lead to electric shock or fire.

- **Do not use the product where ventilation is poor.**

  Secure adequate space around the product so that air can circulate around it.

- **Do not place objects on the product.**

  Placing heavy objects on top of the product may cause failures.

- **Do not install the product on an inclined surface or location subject to vibrations.**

  The product may fall or tip over causing damages and injuries.

- **Do not use the product in a location where strong magnetic or electric fields are nearby or a location where large amount of distortion and noise is present on the input power supply waveform.**

  The product may malfunction.

- **Use the product in an industrial environment.**

  The 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.

1.3 Precautions to Be Taken When Moving the Product

Note the following points when moving or transporting the product to the installation location.

- **Turn off the POWER switch.**

  Moving the product with the power is turned on may cause electric shock or damage to it.

- **Remove all wiring.**

  Moving the product with the cables connected may cause wires to break or injuries due to the product falling over.

- **When transporting the product, be sure to use the original packing materials.**

  Otherwise, damage may result from vibrations or from the product falling during transportation.

- **The rack mount type system weights at least 150 kg. Be sure that the work is performed by at least two persons.**

  Abrupt movements or work performed by a single person may cause the system to fall over or accidents from the system moving on its own inertia.

- **Check the direction of the caster wheels and the fixed wheels of the rack mount type system.**

  The system moves readily if you push the system toward the direction of the caster wheels. However, do not move the system abruptly. Take appropriate measures to prevent the system from falling over and the system from moving on its own inertia.

- **If you are moving away from the rack mount type system temporarily or if you are installing the system, be sure to lock the caster wheels. Be sure to also set the stopper bolt if available.**

- **Fix the rack in place such as by using a channel base, and take appropriate measures to prevent the system from falling over such as by using anti-vibration fittings.**

- **Be sure to include this manual.**

1.4 Parts That You Prepare

The figure below lists the parts that you must prepare, because they must be best suited for the fuel cell under measurement. Some of the parts can be purchased as options. For details, contact your Kikusui agent or distributor.

Table 1-1 Parts that you prepare

Parts name	Description	See Page
Load wire	Select wires that are best suited to the system. Conditions such as current capacity, length, shape, weight, and easiness of wiring must be met when selecting the load wires of the fuel cell.	2-6 3-6
PLZ4W remote sensing wire	Used when the voltage drop due to the resistance component of the load wire cannot be ignored.	2-10 3-8
Sensing wires	If the accessories cannot be used on the voltage sensing locations of the fuel cell, appropriate sensing wires are needed.	2-12 3-10
PC control wire	The system is equipped with GPIB, RS232C, and USB for remote control interfaces. Use a cable specific to the interface that you are using to connect to the PC.	2-20 3-14
Sensing wires of the scanner system	If you are using the system in combination with the KFM2151 FC Scanner, sensing wires are needed at the sensing locations. For details, see “Connecting the SENSING terminal and the fuel cell” in the KFM2151 FC Scanner Operation Manual.	2-14 3-12
Power supply wire (bench top type)	Each system component instrument has a power cord. Outlets for connecting the power cord plugs and wiring to the switchboard are required. Select the wires by taking the rated voltage and current capacity into consideration.	2-22
Power supply wires (rack mount type)	Power input terminal. Wiring to the switchboard is required. Select the wires by taking the rated voltage and current capacity into consideration.	3-16

1.5 Product Overview

The KFM2150 system measures the impedance characteristics of fuel cells. It can handle high voltage and large current. The system measures the impedance using the AC impedance method or the current interrupt method.

Impedance measurement system

The impedance measurement system comes in two types: bench top and rack mount. The system consists of the KFM2150 and the PLZ-4W Series Electronic Load Units.

The application software allows Cole-Cole plots to be obtained and various parameters to be calculated. It is an efficient way of executing impedance measurement tests.

Basic system

The KFM2150 controls the system. The load current of the fuel cell and impedance measuring AC current flow through the PLZ-4W Series. The current signal is passed from the PLZ-4W Series to the KFM2150. The voltage signal for the impedance measurement enters the KFM2150 directly from the fuel cell.

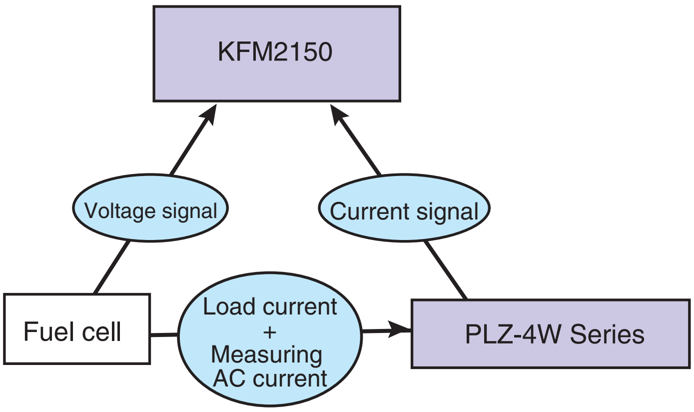


Fig. 1-1 Basic system

Scanner system

When used in combination with the KFM2151 FC Scanner, the voltage and impedance of each stack of the fuel cell can be measured. Each KFM2151 supports 32 channels of voltage signals, and up to five KFM2151 can be connected. The system can be expanded up to 160 channels.

Fig. 1-2 shows the impedance measurement system using a personal computer. The load current of the fuel cell and impedance measuring AC current flow through the PLZ-4W Series. The current signal is passed from the PLZ-4W Series to the KFM2150. The voltage signals for impedance measurement are scanned by the FC Scanner.

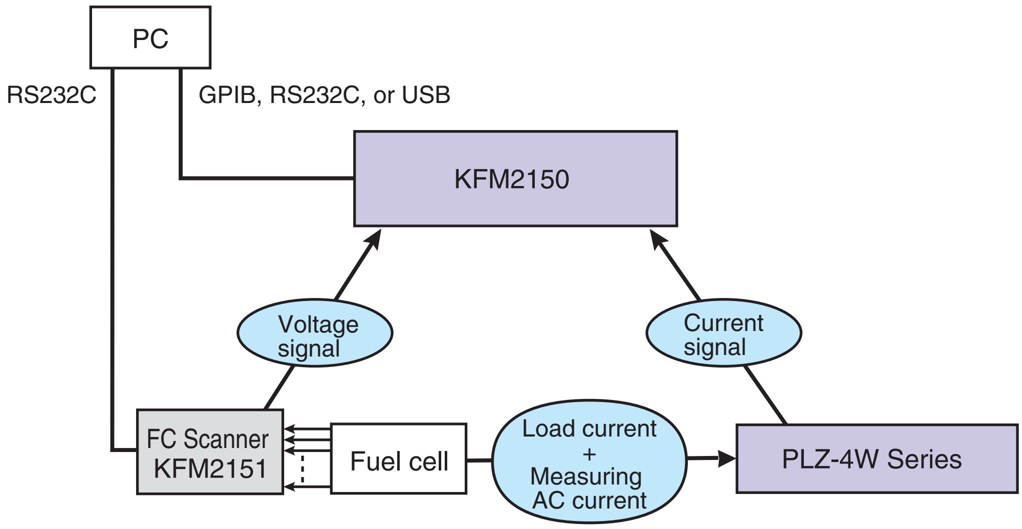


Fig. 1-2 Scanner system

1.5.1 Measurement System Types

The system hardware consists of the following three components.

- KFM2150 FC Impedance Meter
- PLZ-4W Series Electronic Load Unit
- KFM2151 FC Scanner (option)

Bench top type and rack mount type

There are two types of systems: bench top and rack mount. Table 1-2 shows the available system types and models.

Table 1-2 System types

Model	Voltage	Current	Notes
KFM2150 SYSTEM165-01A	0 V to 150 V	33 A	Bench top type
KFM2150 SYSTEM660-01A		132 A	
KFM2150 SYSTEM1320-02A		264 A	
KFM2150 SYSTEM1000-01	1.5 V to 150 V	200 A	
KFM2150 SYSTEM3000-02		600 A	
KFM2150 SYSTEM1980-03A	0 V to 150 V	396 A	Rack mount type
KFM2150 SYSTEM2640-04A		528 A	
KFM2150 SYSTEM3300-05A		660 A	
KFM2150 SYSTEM5000-03	1.5 V to 150 V	1000 A	
KFM2150 SYSTEM7000-04		1400 A	
KFM2150 SYSTEM9000-05		1800 A	

Bench top type

The figure below illustrates an example in which the hardware components are arranged on the test bench, and the components are mutually wired. The hardware components can be arranged relatively freely.

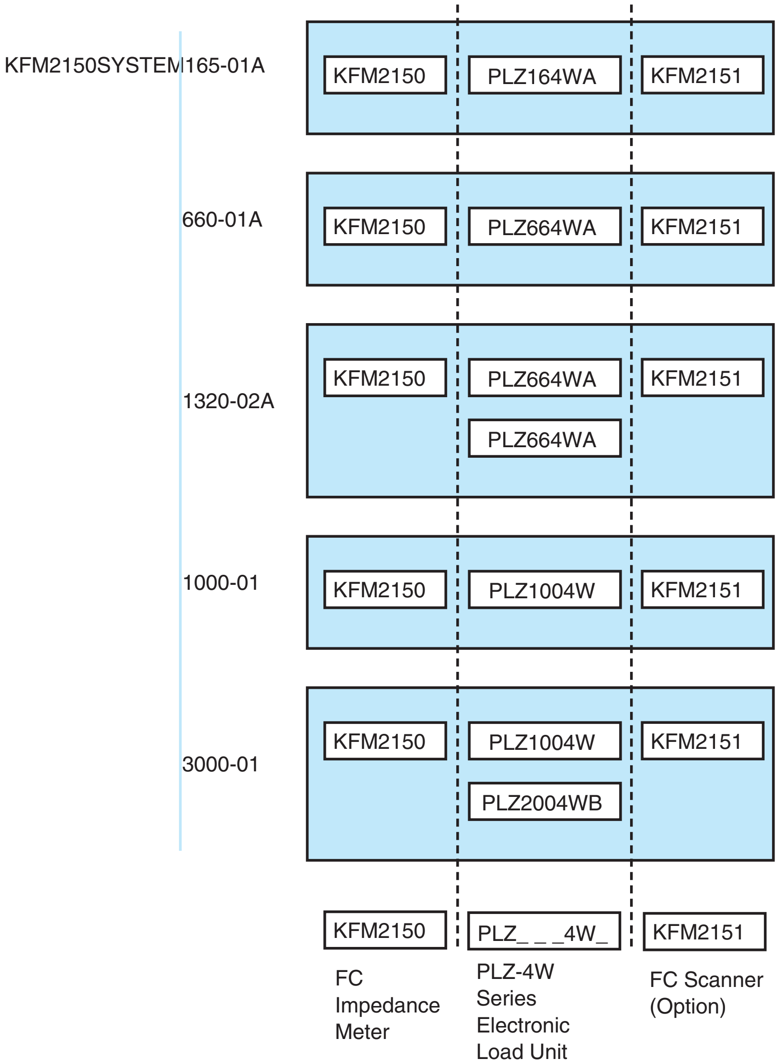


Fig. 1-3 Component instruments of the bench top type

Rack mount type

The figure below illustrates an example in which the hardware components are arranged on a rack, and the components are mutually wired. The components are fixed in place on a rack.

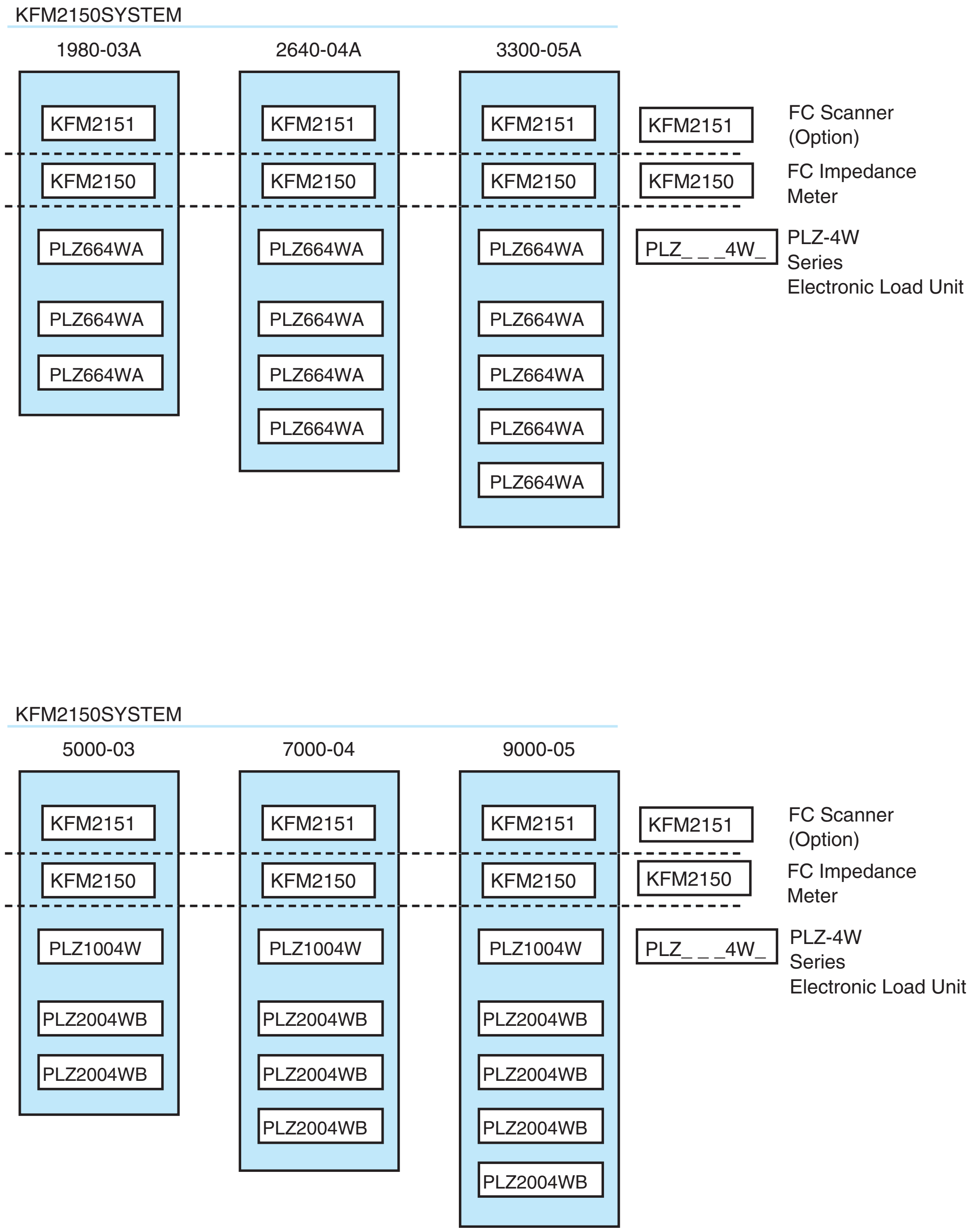


Fig. 1-4 Component instruments of the rack mount type

1.6 Features

- **Supports high voltage and large currents**

  The KFM 2150 system can received up to 150 V. You can select the optimal current capacity (33 A to 1800 A) using the PLZ-4W Series Electronic Load Unit.

- **Supports both AC impedance method and current interrupt method**

  You can switch the measurement method in the middle of the measurement.

  The measurement resolution of the minimum range is 0.1 μΩ. An averaging function is also available.

- **Provides two methods for setting the measuring AC current superimposed on the load current**

  The KFM2150 system superimposes the measuring AC current on the load current that flows through the PLZ-4W Series.

  You can set the measuring AC current using a ratio of the load current or an actual current value.

- **CC (constant current) and CV (constant voltage) modes**

  The KFM2150 system normally operates in CC mode. If the fuel cell voltage drops to a specified level, the KFM2150 system automatically switches to CV mode. The current is controlled to achieve the preset CV voltage without exceeding the current specified in CC mode.

- **Soft start function**

  The load current can be gradually increased or decreased to match the operation startup or termination of the fuel cell.

- **Memory function**

  There are three memories, A, B, and C in which measurement conditions can be stored.

- **Various protection functions**

  Equipped with overpower protection (PLZ4W OPP), undervoltage protection (PLZ4W UVP), overvoltage protection (PLZ4W OVP), reverse connection protection (PLZ4W REV), overheat protection (PLZ4W OHP), and voltage sensing undervoltage protection (SENSE UVP).

- **Short-circuit correction function**

  The short-circuit correction function can compensate for any residual impedances that may exist within the wiring between the PLZ-4W Series and fuel cell.

- **Judgement function**

  The measured results can be judged by setting upper and lower limits on the resistance and reactance. The upper and lower limits are set with the same width above and below the reference value that is acquired during measurement. The judgement result is displayed using GO and NOGO on the display.

- **Remote control interface**

  Equipped with three types of interfaces (GPIB, RS232C, and USB) from which you can select.

- **Application software**

  The application software can be used to obtain Cole-Cole plots and calculate various parameters allowing efficient execution of impedance measurement tests.

1.7 Options

The products below are available as options. For details, contact your Kikusui agent or distributor.

KFM2151 FC Scanner

A scanner system can be constructed by combining with the impedance measurement system. Each KFM2151 has 32 channels. The number of channels can be expanded to 160 by using five KFM2151s. This feature is best suited to the monitoring of each cell of the fuel cell.

Rack mount bracket

The rack mount bracket is for the KFM2150. The KRB2-TOS for the inch rack EIA standard and the KRB100-TOS for the metric rack JIS standard are available.

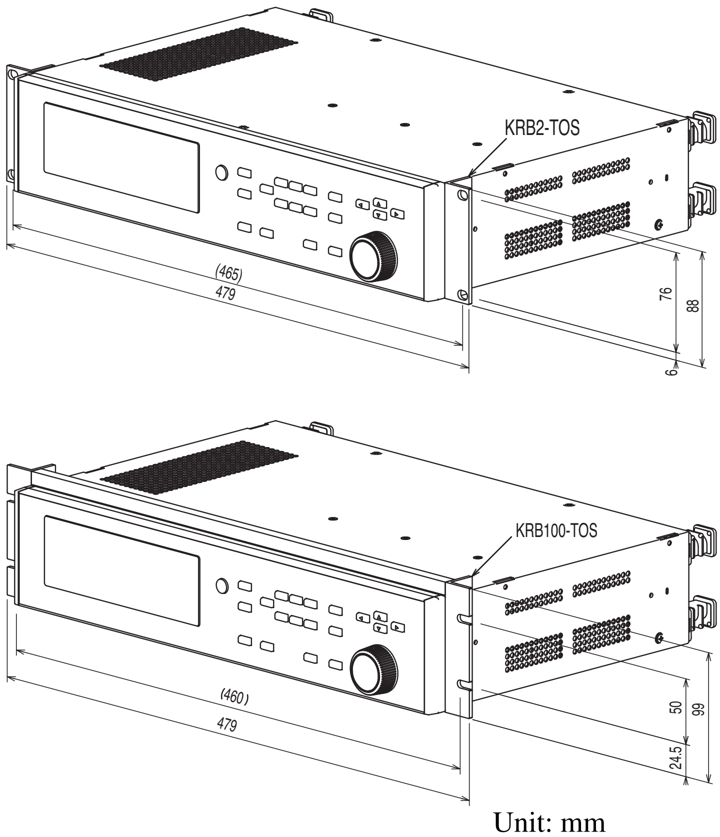


Fig. 1-5 Rack mount bracket

1.8 Application Software

Product overview

The “FCTester” that comes with the package is an application software used to retrieve measured data from the KFM2150. Integrating the FCTester in the KFM2150 impedance measurement system allows additional measurements to be made such as Cole-Cole plot measurements and I-V characteristics measurements. This feature streamlines the fuel cell evaluation tests.

Main features

■ Possible test modes

- I-V measurement
- V-I measurement
- Cole-Cole plot measurement
- AC impedance measurement
- Current interrupt measurement
- Constant current test
- Constant voltage test

■ Startup operation of the fuel cell

- Startup sequence
- Shutdown sequence

■ Sequence operation of the measurement mode

- Up to 15 sequences

2

Installation of the Bench Top Type

This chapter describes the procedures from unpacking to installation of the bench top type.

2.1 Checking the Package Contents

When you receive the product, check that all system component instruments and all accessories are included and that the product and accessories have not been damaged during transportation.

If any of the accessories are damaged or missing, contact your Kikusui agent or distributor.

See p.3-2

The KFM2150 system comes in two types: bench top and rack mount. The bench top type requires that you arrange the system component instruments and wire the instruments.

2.1.1 System Component Instruments

Checking the number of instruments

Check the number of system component instruments (Table 2-1). Each instruments are packaged separately.

Table 2-1 System component instruments of the bench top type

<table>
<tr><th>System model</th><th colspan="2">FC impedance meter</th><th colspan="2">Electronic load unit</th></tr>
<tr><td>KFM2150 SYSTEM165-01A</td><td rowspan="6">KFM2150</td><td rowspan="6">1 unit</td><td>PLZ164WA</td><td>1 unit</td></tr>
<tr><td>KFM2150 SYSTEM660-01A</td><td rowspan="2">PLZ664WA</td><td>1 unit</td></tr>
<tr><td>KFM2150 SYSTEM1320-02A</td><td>2 units</td></tr>
<tr><td>KFM2150 SYSTEM1000-01</td><td>PLZ1004W</td><td>1 unit</td></tr>
<tr><td rowspan="2">KFM2150 SYSTEM3000-02</td><td>PLZ1004W</td><td>1 unit</td></tr>
<tr><td>PLZ2004WB</td><td>1 unit</td></tr>
</table>

System serial number

See p.16, p.17

Check the system serial number of the system component instruments. Each instrument is managed by the same system serial number. Systems cannot be configured using products with different system serial numbers. The system serial number is indicated on the rear panel of the product separately from the serial number of the product.

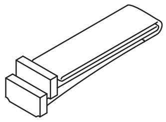
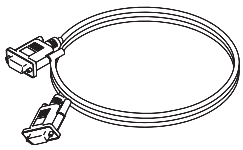
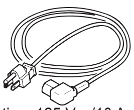
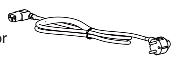
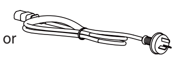
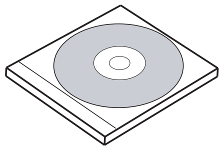
If any of the system serial numbers of the system components instruments do not match, contact your Kikusui agent or distributor.

The system component instruments are independent on the bench top type. Therefore, you can remove the component instrument from the system and use it for other applications. If you are placing the component instrument back into the system, check its system serial number. All of the system serial numbers of the system components instruments are must to be matched.

2.1.2 Accessories by Model

The table below lists the accessories of the KFM2150. The accessories for the PLZ-4W Series are not listed. See the operation manual of the PLZ-4W Series for its accessories.

■ Accessories and quantities for the bench top type

		Model KFM2150 SYSTEM				
Accessories		165-01A	660-01A	1320-02A	1000-01	3000-02
Flat cable 	PC01-PLZ-4W [84540]	-	1 pc.	2 pcs.	1 pc.	1 pc.
	PC02-PLZ-4W [84550]	1 pc.	-	-	-	1 pc.
RS232C cable [89-04-1340] 		1 pc.				
Sensing wire [91-80-5842] 		1 pc.				
Power cord The power cord that is provided varies depending on the destination for the product at the factory-shipment.		1 pc.  Rating: 125 Vac/10 A Plug: NEMA5-15 [85-AA-0003] or  Rating: 250 Vac/10 A Plug: CEE7/7 [85-AA-0005] or  Rating: 250 Vac/10 A Plug: GB1002 [85-10-0790]				
Wire that is 80 mm^2 in size and approx. 30 cm in length		None		2 pcs.	None	2 pcs.
CD-ROM (application software and communication interface manual) [SA-6020] 		1 pc.				

2.1.3 Wiring of the Bench Top Type

The following types of wiring are used for the bench top type. This section explains the wiring procedure. For the technical details of wiring, see the appendix in the Operation Part of this manual.

- Load wire (connection between the fuel cell and the PLZ-4W Series)
- Sensing wire (connection between the fuel cell and the KFM2150)
- Sensing wire of the FC Scanner (connection between the fuel cell and the KFM2151)
- Connection between the KFM2150 and the PLZ-4W
- Connection between the KFM2150 and the KFM2151
- PC control wire (connection between a PC and the KFM2150 or KFM2151)
- Power cord
- Grounding

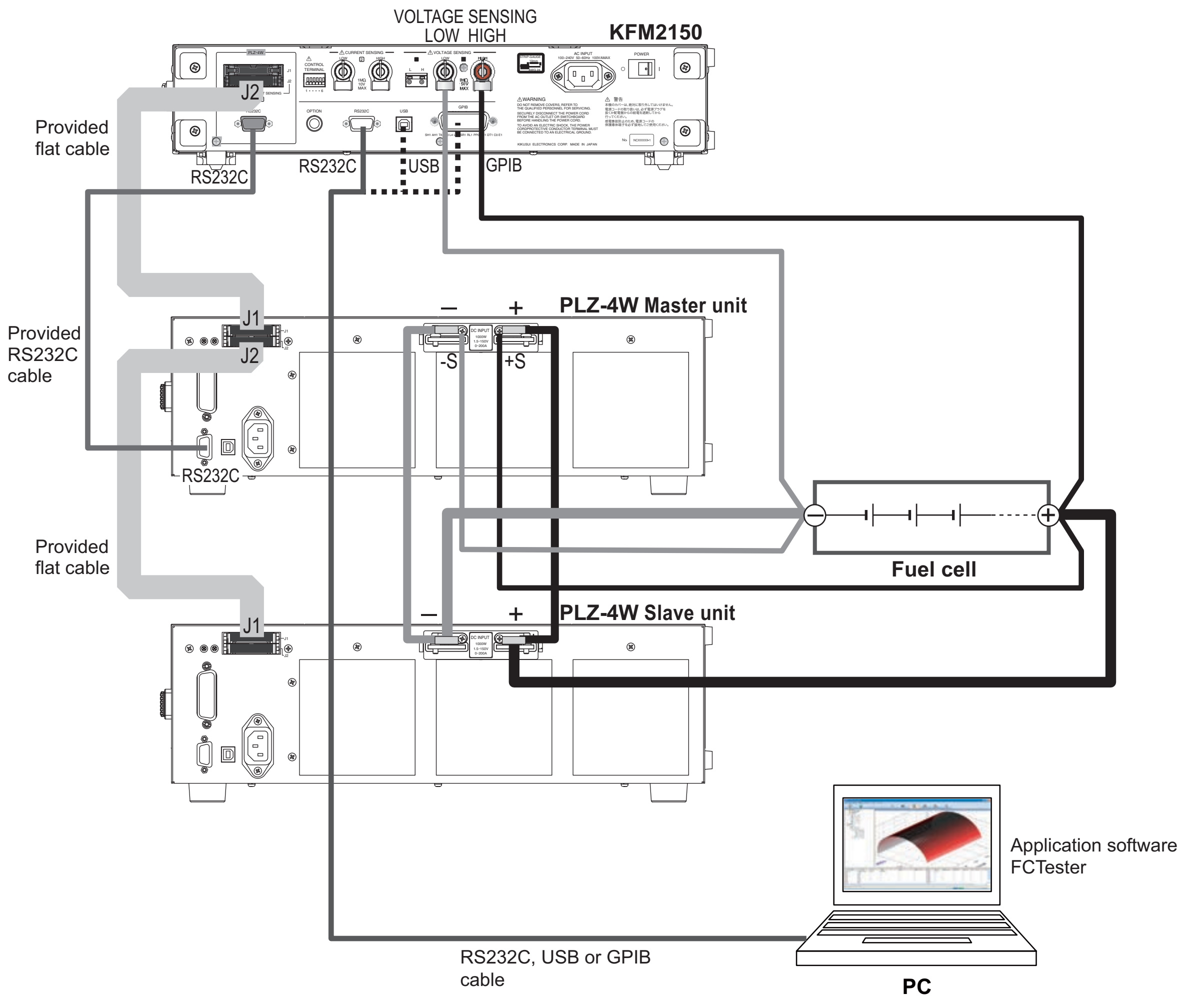


Fig.2-1 Example of bench top type basic system wiring

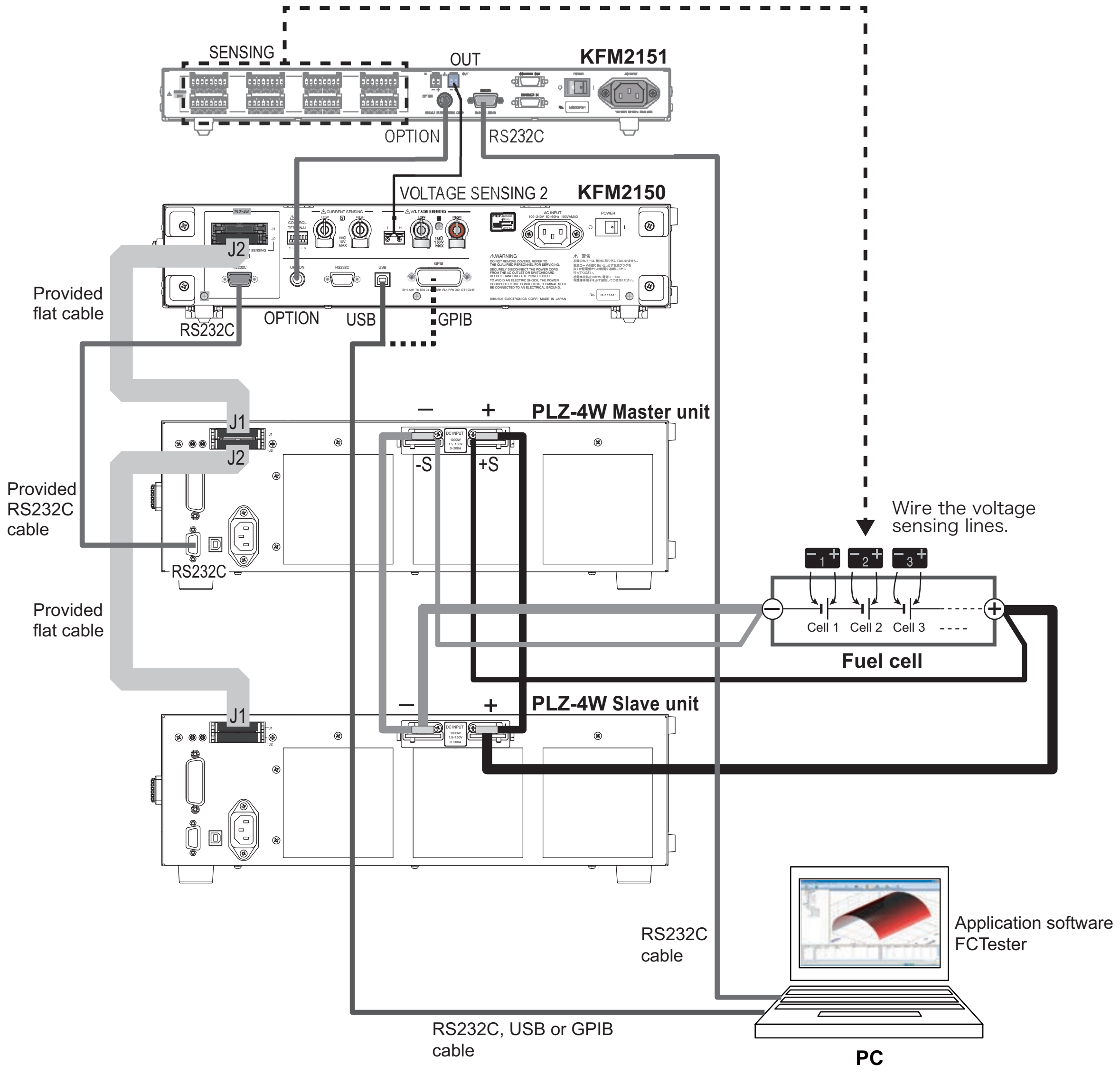


Fig. 2-2 Example of bench top type scanner system wiring

2.2 Load Wires

Use load wires with sufficient current capacity for the current drawn from the fuel cell. The current capacity is proportional to the conductive cross-sectional area of the wire. The conductive cross-sectional area is determined by the cross-sectional area of the wire and the number of wires as shown in Fig. 2-3. Therefore, the number of wires needed increases for large currents. As a result, the wires become thicker, and the weight per unit length becomes substantial. For large currents, some wires come with conductors that are woven (called earth cables, copper braided flat wire, or flexible annealed copper stranded wire).

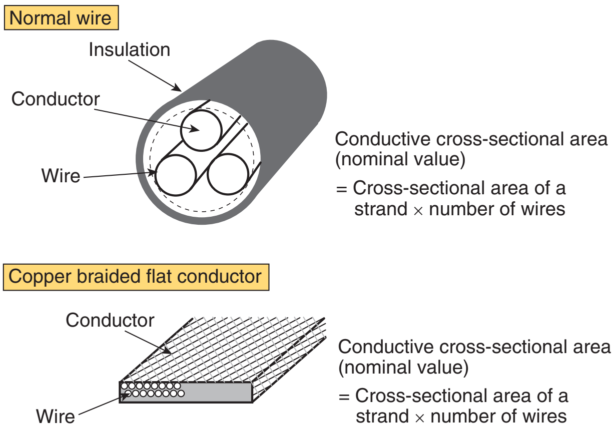


Fig. 2-3 Structure of the recommended load wire

⚠CAUTION

- Connect the positive terminal of the fuel cell to the positive load input terminal, and the negative terminal of the fuel cell to the negative load input terminal. If the polarity is reversed, overcurrent may damage the KFM2150 system or the fuel cell.

2.2.1 Wiring the Load Input Terminal

When using one electronic load unit

The following three system models are applicable.

- KFM2150 SYSTEM165-01A
- KFM2150 SYSTEM660-01A
- KFM2150 SYSTEM1000-01

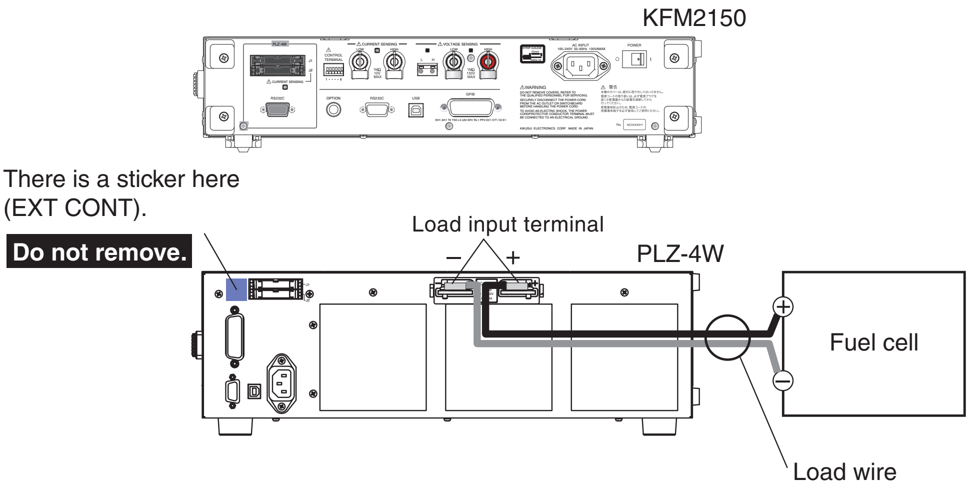


Fig. 2-4 When using one electronic load unit

1. Turn the POWER switch off of the KFM2150 and PLZ-4W Series.

2. Connect the load input terminal of the PLZ-4W Series to the fuel cell.

   Fix the wire in place using the screws provided with the electronic load unit. Twist the two wires (positive and negative wires) as much as possible and connect to the fuel cell at the shortest possible length. Do not let the two wires open wide. Table 2-2 shows the conductive cross-sectional area of the wire required for the wiring.

Table 2-2 Wire capacity

System model	Electronic load unit	Rated current	Conductive cross-sectional area of the wire
KFM2150 SYSTEM165-01A	PLZ164WA	33 A	At least 8 mm^2
KFM2150 SYSTEM660-01A	PLZ664WA	132 A	At least 80 mm^2
KFM2150 SYSTEM1000-01	PLZ1004W	200 A	

When using two electronic load units

The following two system models are applicable.

- KFM2150 SYSTEM1320-02A
- KFM2150 SYSTEM3000-02

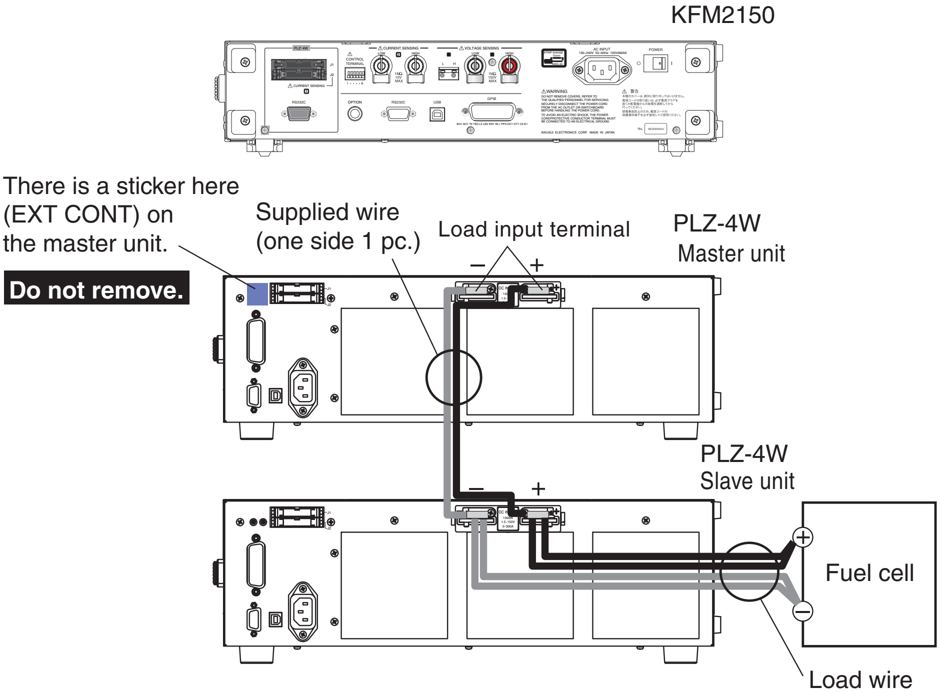


Fig. 2-5 When using two electronic load units

1 Turn the POWER switch off of the KFM2150 and PLZ-4W Series.

2 Stack one of the PLZ-4Ws on top of the other.

3 Connect the positive terminals of the PLZ-4W Series together. Do the same for the negative terminals.

A pair of wires (accompanying wires of size 80 mm^2 and approx. 30 cm in length) is used as one set. Fix the wire in place using the screws provided with the electronic load unit.

4 Connect the load input terminal of the PLZ-4W Series slave unit to the fuel cell.

Twist the positive and negative wires as much as possible and connect to the fuel cell at the shortest possible length. Table 2-3 shows the conductive cross-sectional area of the wire required for the wiring.

CAUTION • Be sure to connect the fuel cell to the load input terminals of the slave unit. Otherwise, the provided wires connecting the PLZ-4W Series master and slave units may burn out.

■ **KFM2150 SYSTEM1320-02A**

The rated current is 264 A. A pair of 80-mm^2 wires is used as one set to connect each polarity (four wires total). Twist these wires as much as possible (in a woven pattern if possible) to connect to the fuel cell.

■ **KFM2150 SYSTEM3000-02**

The rated current is 600 A. A pair of 150-mm^2 wires is used as one set to connect each polarity (four wires total). Twist these wires as much as possible (in a woven pattern if possible) to connect the PLZ2004WB terminals to the fuel cell.

In fact, it is quite difficult to connect a pair of these thick wires to a single terminal or twist them together. It may be necessary to use a copper bus bar to directly connect the input terminals of the electronic load unit to the fuel cell.

Table 2-3 Wire capacity

System model	Electronic load unit	Rated current	Conductive cross-sectional area of the wire
KFM2150 SYSTEM1320-02A	PLZ664WA 2 units	264 A	At least 160 mm^2
KFM2150 SYSTEM3000-02	PLZ1004W + PLZ2004WB	600 A	At least 300 mm^2

2.2.2 Relationship between the Minimum Input Operating Voltage and Impedance Measurement

See p.A-24

The typical wire inductance is approximately 1 µH per meter when the positive and negative wires are twisted together firmly. Let's assume that the electronic load unit and the fuel cell are connected using a 1-m wire (1-m wires for positive and negative terminals twisted together). We obtain that the wire inductance is 1 µH from the equation 1 µH/m × 1 m.

The reactance is given by ωL (where ω is the angular frequency given by frequency × 2 π and L is the inductance). The reactance is 0.628 mΩ at 100 Hz, 6.28 mΩ at 1 kHz, 62.8 mΩ at 10 kHz, and 125 mΩ at 20 kHz. If the measuring AC current is 10 Arms, a voltage drop of 1.25 Vrms (3.54 Vpp) occurs.

The wires also have DC resistance. Thus, the voltage obtained by subtracting these voltage drops from the output voltage of the fuel cell must be greater than or equal to the minimum input operating voltage of the electronic load unit.

Restrictions may be placed on the items below depending on the wiring conditions. For details, see the appendix in the Operation Part of this manual.

- Maximum value of the measuring AC current
- Upper limit of the measurement frequency
- Minimum value of the fuel cell output voltage

2.2.3 PLZ4W Remote Sensing Function

PLZ4W remote sensing is a function used to correct the voltage drop caused by the resistance of the load wire when it cannot be discarded. The voltage drop compensation is up to 2 V for a single line.

CAUTION • If the load wire comes loose while using PLZ4W remote sensing, the sensing wire or the PLZ-4W remote sensing circuit may break. Accidents can be prevented by connecting a protection fuse as shown in Figure 2-6. Use a fuse with a rated current of 0.5 A and a rated voltage greater than or equal to the output voltage of the fuel cell.

PLZ4W remote sensing wiring

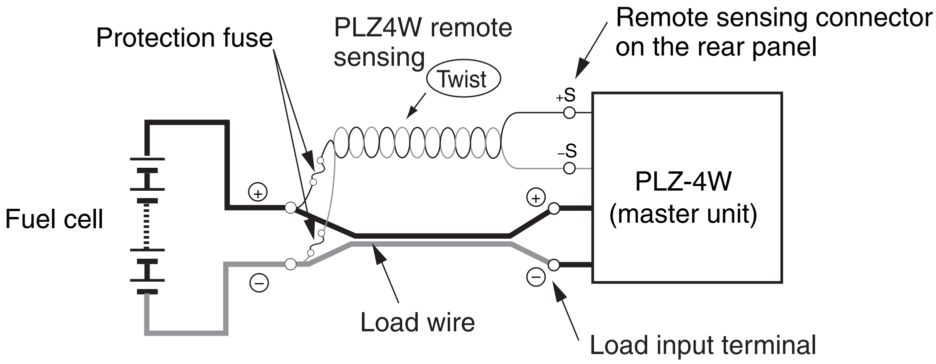


Fig. 2-6 PLZ4W remote sensing wiring

Connect the remote sensing terminal (+S) on the rear panel of the PLZ-4W Series (on the master unit if two units are being used) to the positive terminal of the fuel cell. Likewise, connect the remote sensing terminal (-S) to the negative terminal.

CAUTION • The PLZ4W remote sensing circuit may break. Do not connect the remote sensing terminals (+S and -S terminals) on the rear panel of the PLZ-4W series directly to the cell of the fuel cell (Fig. 2-7).

■ Example of a unrecommended wiring

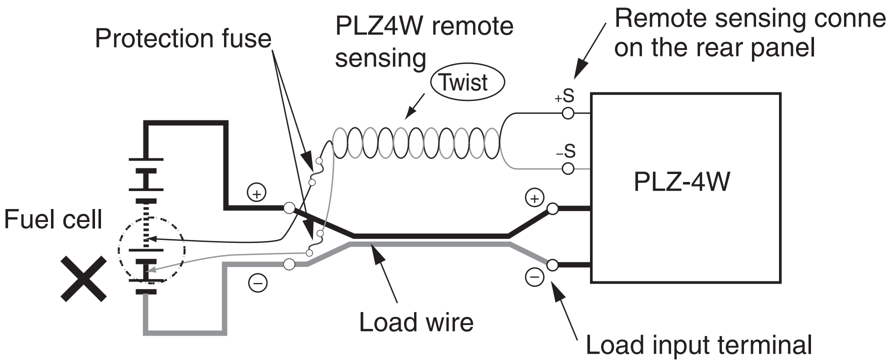


Fig. 2-7 Example of a unrecommended wiring

■ Wires used for PLZ4W remote sensing

You do not have to consider the current capacity as in the load wire. However, for mechanical strength, use a wire with a nominal conductive cross-sectional area that is at least 0.5 mm^2. Use crimping terminals for M3 screws to connect to the PLZ-4W Series.

2.3 Sensing Wires

Using sensing wires, connect the VOLTAGE SENSING terminal to the point where you want to measure the impedance. The voltage at the measurement point is the voltage signal (voltage sensing) of the impedance measurement.

There are two channels of VOLTAGE SENSING terminals. Both channels are isolated from the chassis (withstand voltage of 250 V). The DC input voltage range is 0 V to 150 V, and the input impedance is approx. 1 MΩ.

For selecting the channel, see “Setting the Menu Items” in the Operation Part of this manual.

Selecting channel

Select MENU key > Setup > Input Select > Voltage Sensing to select channel 1 or 2.

Channel 1 (VOLTAGE SENSING terminal)

We recommend that you use wires of size greater than or equal to AWG24. Use crimping terminals for M6 screws.

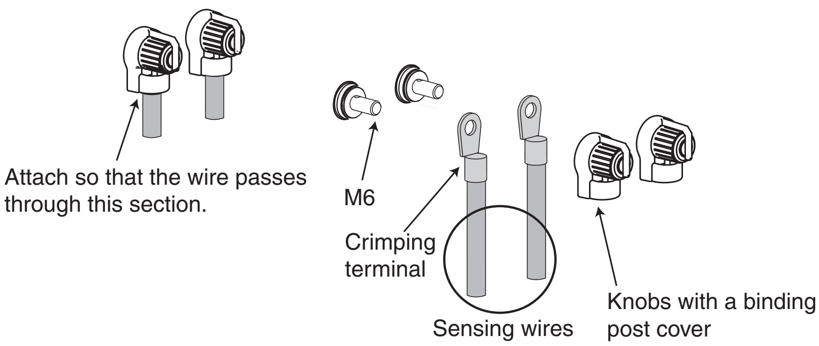


Fig. 2-8 Connecting the sensing wires for channel 1

WARNING • **Do not touch the VOLTAGE SENSING terminal while the power is turned ON, as it may cause electric shock. Be sure to use the binding post cover.**

Channel 2 (VOLTAGE SENSING terminal)

Use AWG24 wires. Remove 10 mm of the covering from the wire end.

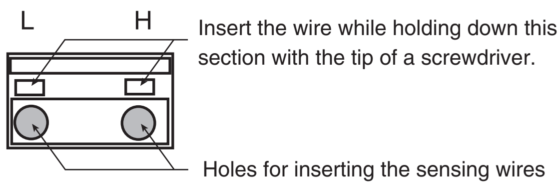


Fig. 2-9 Connecting the sensing wires for channel 2

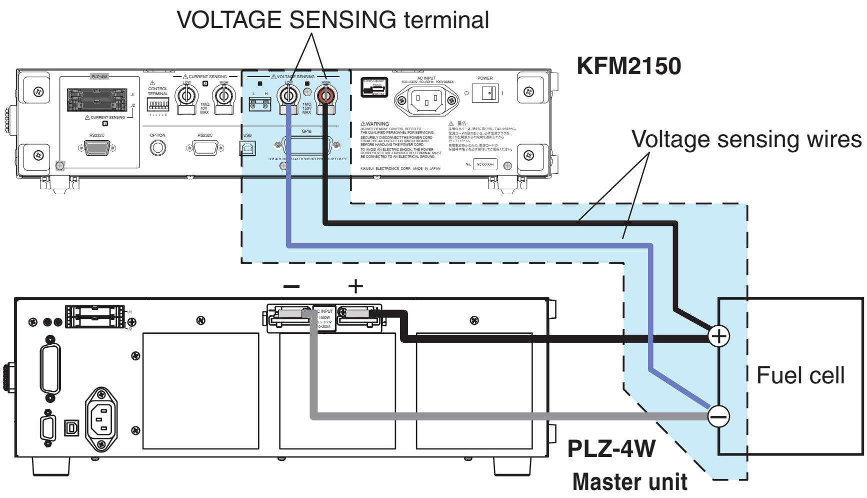


Fig. 2-10 Wiring the voltage sensing wires (channel 1 example)

Wiring

1. Turn the POWER switch off of the KFM2150 system and PLZ-4W Series.

2. Connect the desired sensing point of the fuel cell to the VOLTAGE SENSING terminal of the KFM2150 system using the sensing wires provided.

   Connect the positive and negative terminals of the fuel cell to the HIGH and LOW VOLTAGE SENSING terminals, respectively (Fig. 2-10). If you are using channel 1, attach the binding post cover (Fig. 2-8). If you are using channel 2, insert the wires using a screwdriver (Fig. 2-9).

   We recommend that you twist the wires to eliminate the effects of magnetic flux.

⚠CAUTION

- Check the rated temperature of the sensing wires that you are using. Pay close attention for fuel cells that operate at high temperatures.
  Even for fuel cells that run at relatively low temperatures such as a PEFC, the collecting electrode where the sensing wire is connected may be hot.

NOTE

- Connect the VOLTAGE SENSING terminal to the point where you want to measure the impedance or voltage. If you want to eliminate the effects of the electrode plate, connect the sensing terminal directly to the separator. If you want to measure the performance at the electrode terminal, connect it to the electrode terminal.

Wiring precautions

Because sensing wires are susceptible to the effect of noise, do not bundle them with load wires, input power wires of measuring instruments, power wires of gas control equipment, and signal wires. Correct and repeatable measurements cannot be made if noise affects the measurement. It may also cause malfunction in the measuring instrument or other control equipment.

2.4 Sensing Wires of the FC Scanner (Option)

Use the screwless terminal connector (8 poles) provided with the KFM2151 FC Scanner. A block contains four channels of terminals. Connect the SENSING terminal directly to the separator in order from cell 1.

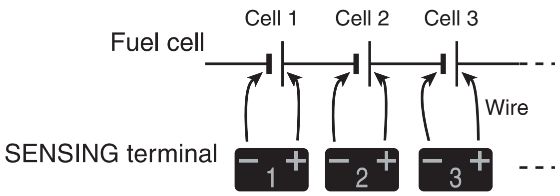


Fig. 2-11 Wiring the SENSING terminal

If you want to measure the performance at the electrode terminal, connect to it.

Use AWG24 wires. Remove 10 mm of the covering from the wire end. Using the strip gauge shown in Fig. 2-12 will ensure proper work.

NOTE

- Check the rated temperature of the wires that you are using. Pay close attention for fuel cells that operate at high temperatures. Even for fuel cells that run at relatively low temperatures such as a PEFC, the collecting electrode where the wire is connected may be hot.

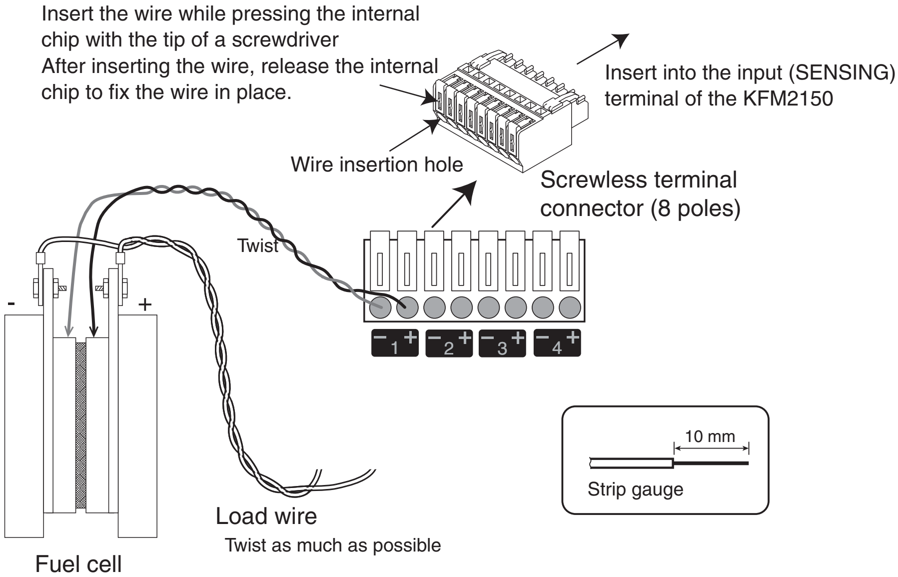


Fig. 2-12 Connection to the fuel cell

1 Turn the POWER switch off of the KFM2150 and PLZ-4W Series.

2 Using a screwdriver, insert the wire into the screwless terminal connector (8 poles) provided as shown in Fig. 2-12.

3 Twist the wires after inserting the positive and negative wires.

This completes the wiring of one channel. Insert and twist the wires for as many channels as necessary.

4 Insert the screwless terminal connector (8 poles) to the SENSING terminal of the KFM2151.

5 Connect the other end of the wires to the fuel cell by aligning the polarity.

See p.4-26

You must set the KFM2150 from the menu when using the KFM2151 FC Scanner. See 4.8, “ Details on Menu Setup.”

2.5 Connecting the KFM2150 and the PLZ-4W Series

When using one electronic load unit

The following three system models are applicable.

- KFM2150 SYSTEM165-01A
- KFM2150 SYSTEM660-01A
- KFM2150 SYSTEM1000-01

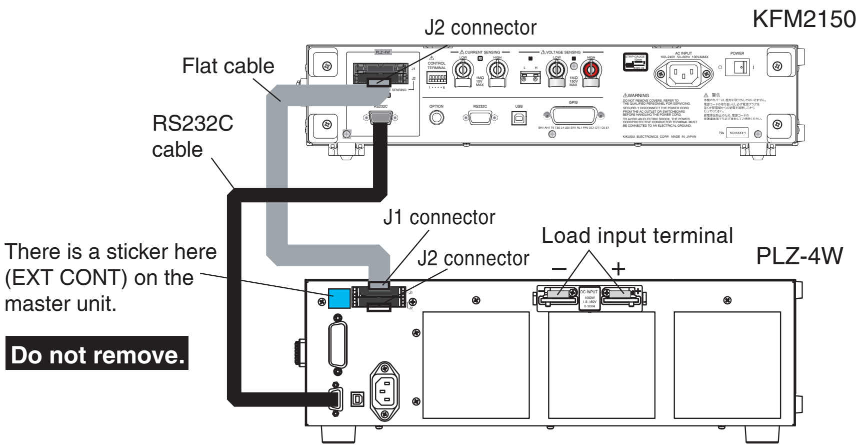


Fig. 2-13 When using one electronic load unit

1 Turn the POWER switch off of the KFM2150 and PLZ-4W Series.

2 Use the flat cable provided with the KFM2150 to connect the J2 connector of the KFM2150 to the J1 connector of the PLZ-4W Series.

3 Use the RS232C cable provided with the KFM2150 to connect the RS232C (PLZ-4W) connector of the KFM2150 to the RS232C connector of the PLZ-4W Series.

When using two electronic load units

The following two system models are applicable.

- KFM2150 SYSTEM1320-02A
- KFM2150 SYSTEM3000-02

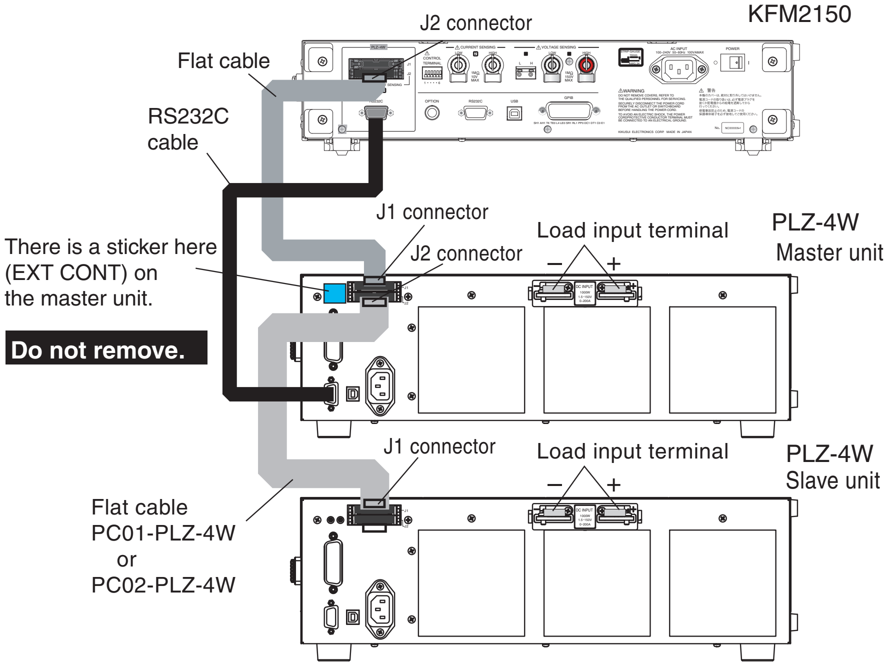


Fig. 2-14 When using two electronic load units

1. Turn the POWER switch off of the KFM2150 and PLZ-4W Series.
2. Use the flat cable provided with the KFM2150 to connect the J2 connector of the KFM2150 to the J1 connector of the PLZ-4W Series master unit.
3. Use the RS232C cable provided with the KFM2150 to connect the RS232C (PLZ-4W) connector of the KFM2150 to the RS232C connector of the PLZ-4W Series master unit.
4. Use the flat control cable to connect the J2 connector of the PLZ-4W Series master unit to the J1 connector of the slave unit.

CAUTION

- The KFM2150 may malfunction if you connect the J1 and J2 connectors incorrectly.
- Do not alter the variable resistor of the EXT CONT section on the PLZ-4W Series. There is a sticker attached to the variable resistor to prevent accidental operation. Operating the variable resistor will invalidate the calibration of the impedance measurement system.

2.6 Connecting the KFM2150 and KFM2151 (option)

Use AWG24 wires. Remove 10 mm of the covering from the wire end. Using the strip gauge shown in Fig. 2-15 will ensure proper work.

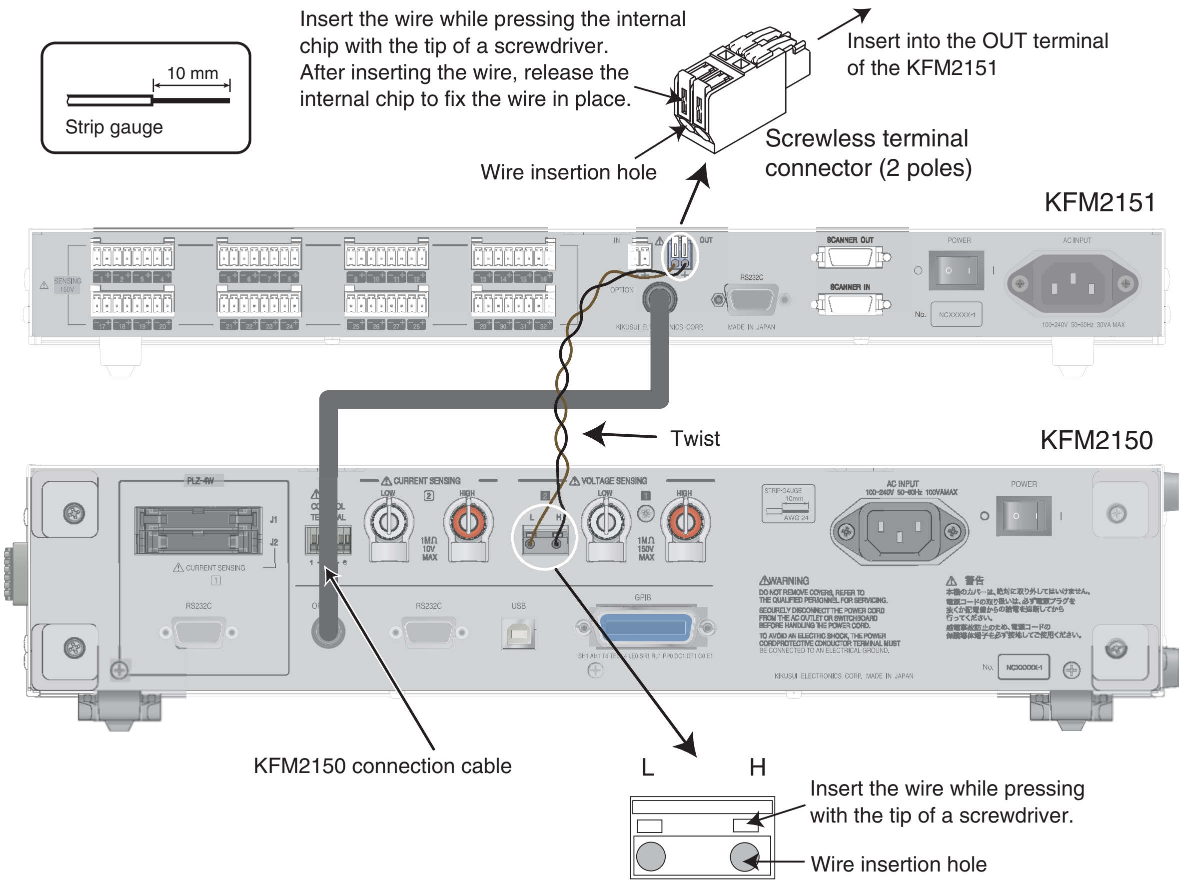


Fig. 2-15 Connecting the KFM2151 and KFM2150

1 Turn the POWER switch off of the KFM2151 and KFM2150.

2 Using a screwdriver, insert the wire into the screwless terminal connector (2 poles) provided as shown in Fig. 2-15.

3 After you insert the two wires, twist the wires together.

4 Insert the screwless terminal connector (2 poles) to the OUT terminal of the KFM2151.

5 Connect the other end of the wires to the VOLTAGE SENSING terminal (channel 2) of the KFM2150 as shown in Fig. 2-15.
Table 2-4 shows the polarity of the connection.

Table 2-4 Polarity of the connection

KFM2151	KFM2150
OUT+	VOLTAGE SENSING terminal 2-H
OUT–	VOLTAGE SENSING terminal 2-L

6 Using the KFM2150 connection cable provided with the KFM2151, connect the OPTION terminal of the KFM2151 to the OPTION terminal of the KFM2150.

For a description of the connection of multiple KFM2151s, see the operation manual of the KFM2151.

2.7 PC Control Wire

The PC control wire is used when performing impedance measurement using the application software provided with the KFM2150. The KFM2150 is equipped with GPIB, RS232C, and USB for remote control interfaces. The GPIB, RS232C, and USB interfaces cannot be used simultaneously. Prepare a cable specific to the interface that you are using to connect to the PC.

Connecting a PC and the KFM2150

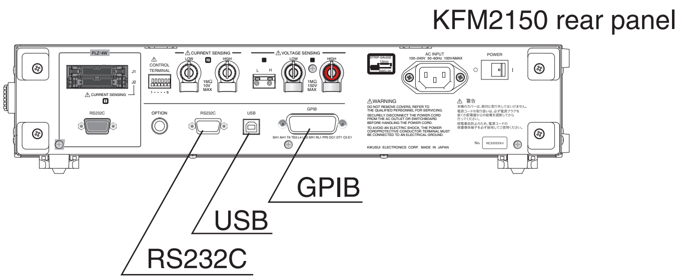


Fig. 2-16 Remote control interface

GPIB connection

Use a standard IEEE488 cable.

USB connection

Use a USB2.0 cable.

RS232C connection

Use a D-sub 9-pin female-to-female AT type cross cable (null modem cable) for the RS232C cable. Fig. 2-17shows the connector pin assignments.

Because the KFM2150 does not use hardware handshaking, the connection of “Cross cable example 2” shown in Fig. 2-17 will suffice. “Cross cable example 1” can also be used.

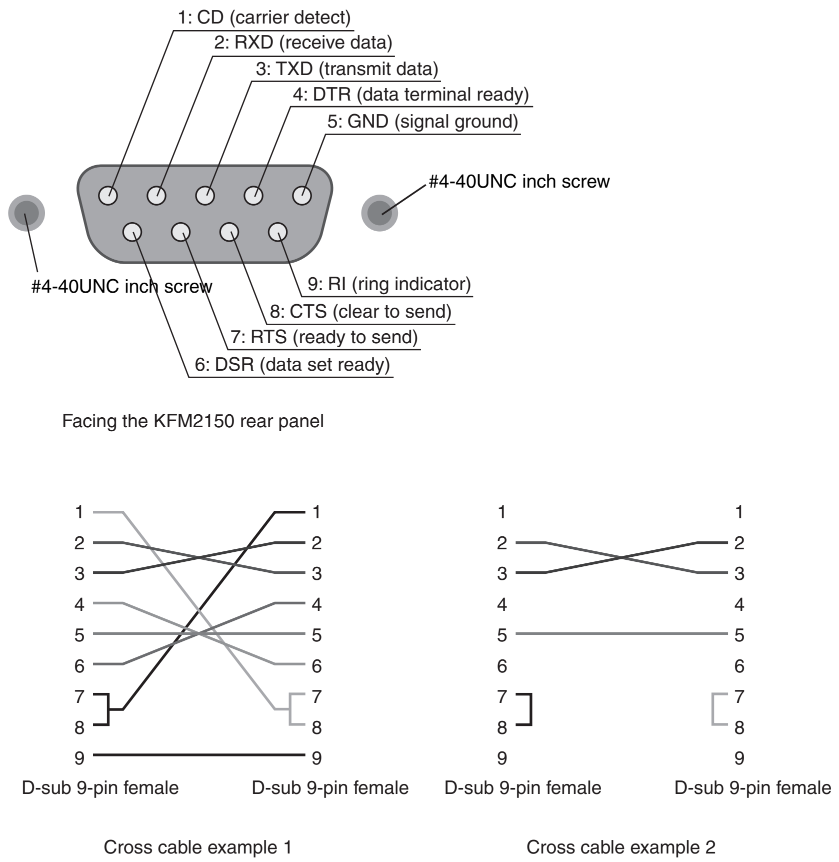


Fig. 2-17 9-pin AT type connector

Connecting a PC and the KFM2151

The remote control interface of the KFM2151 FC Scanner is RS232C. The connection procedure is the same as the RS232C connection of the KFM2150.

If you are using the KFM2151 as an impedance measurement system in combination with the KFM2150, connect the KFM2150 and the KFM2151 to the PC. We recommend that the KFM2150 be connected to the PC using USB or GPIB. If you are using the RS232C, you must use a PC that has two RS232C ports.

2.8 Connecting the Power Cord and Grounding (Earth)

Power cord

A dedicated power cord is provided separately for the KFM2150, PLZ-4W Series Electronic Load Unit, and KFM2151. Use the dedicated power cord to connect each system component instrument to the AC power line. Connect the instruments to a power supply with sufficient capacity.

The KFM2150 system is designed as an equipment to classify of IEC Overvoltage Category II (energy-consuming equipment supplied from the fixed installation).

WARNING **Possible electric shock.**

- **The KFM2150 system component instruments are an IEC Safety Class I equipment (equipment with a protective conductor terminal). Be sure to connect the protective conductor terminal to electrical ground (safety ground).**
- **The KFM2150 system component instruments are grounded through the power cord ground wire. Connect the protective conductor terminal to earth ground.**

NOTE

- Use the supplied power cord to connect to the AC line. If the supplied power cord cannot be used because the rated voltage or the plug shape is incompatible, have a qualified engineer replace it with an appropriate power cord that is 3 m or less in length. If obtaining a power cord is difficult, contact your Kikusui agent or distributor.
- The power cord with a plug can be used to disconnect the KFM2150 system from the AC line in an emergency. Connect the power plug to an easily accessible power outlet so that the plug can be removed from the outlet at any time. Be sure to allow enough space around the power outlet.
- Do not use the power cord provided with the KFM2150 on other equipment.

1 Check that the AC power supply meets the nominal input rating of the KFM2150 system.

The AC input voltage is any of the nominal power supply voltages in the range of 100 V to 240 V. The frequency is 50 Hz or 60 Hz.

2 Turn the POWER switch off of the KFM2150 and PLZ-4W Series.

3 Connect the power cord to the AC connector on the rear panel.

4 Insert the power plug into a grounded outlet.

CAUTION

- The power consumption is large in a parallel operation of PLZ-4W Series. Use the power cord provided to connect each PLZ-4W Series. Be sure to use a wire with sufficient current capacity for connecting the power cord plug to the switchboard. See Table 2-5.
- Check the current capacity of the power cord. If the current capacity is insufficient, the power cord may overheat or the switchboard breaker may shut down.

Table 2-5 Maximum power consumption of the KFM2150 system

System model	Maximum power consumption	Electronic load unit	
KFM2150 SYSTEM165-01A	550 VA	PLZ164WA	1 unit
KFM2150 SYSTEM660-01A	1600 VA	PLZ664WA	1 unit
KFM2150 SYSTEM1320-02A	3100 VA		2 units
KFM2150 SYSTEM1000-01	260 VA	PLZ1004W	1 unit
KFM2150 SYSTEM3000-02	460 VA	PLZ1004W	1 unit
		PLZ2004WB	1 unit

3

Installation of the Rack Mount Type

This chapter describes the procedures from unpacking to installation of the rack mount type.

3.1 Checking the Package Contents

When you receive the product, check that all system component instruments and all accessories are included and that the product and accessories have not been damaged during transportation.

If any of the accessories are damaged or missing, contact your Kikusui agent or distributor.

See p.2-2

The system comes in two types: bench top and rack mount. The rack mount type comes with the system component instruments installed on the rack and wired.

3.1.1 System Configuration of the rack mount type

Checking the number of instruments

Check the number of system component instruments (Table 3-1).

Table 3-1 System component instruments of the rack mount type

<table>
<tr><th>System model</th><th colspan="2">FC impedance meter</th><th colspan="2">Electronic load unit</th></tr>
<tr><td>KFM2150 SYSTEM1980-03A</td><td rowspan="9">KFM2150</td><td rowspan="9">1 unit</td><td rowspan="3">PLZ664WA</td><td>3 units</td></tr>
<tr><td>KFM2150 SYSTEM2640-04A</td><td>4 units</td></tr>
<tr><td>KFM2150 SYSTEM3300-05A</td><td>5 units</td></tr>
<tr><td rowspan="2">KFM2150 SYSTEM5000-03</td><td>PLZ1004W</td><td>1 unit</td></tr>
<tr><td>PLZ2004WB</td><td>2 units</td></tr>
<tr><td rowspan="2">KFM2150 SYSTEM7000-04</td><td>PLZ1004W</td><td>1 unit</td></tr>
<tr><td>PLZ2004WB</td><td>3 units</td></tr>
<tr><td rowspan="2">KFM2150 SYSTEM9000-05</td><td>PLZ1004W</td><td>1 unit</td></tr>
<tr><td>PLZ2004WB</td><td>4 units</td></tr>
</table>

System serial number

See p.18, p.16, p.17

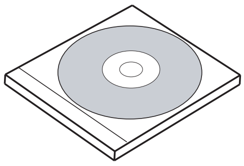
Check the system serial number of the system component instruments. Each instrument is managed by the same system serial number. Systems cannot be configured using products with different system serial numbers. The system serial number is indicated on the rear panel of the product separately from the serial number of the product.

If any of the system serial numbers of the system components instruments do not match, contact your Kikusui agent or distributor.

3.1.2 Accessories by Model

The table below lists the accessories of the KFM2150. The accessories for the PLZ-4W Series are not listed. See the operation manual of the PLZ-4W Series for its accessories.

■ Accessories and quantities for the rack mount type

	Model KFM2150 SYSTEM					
Accessories	1980-03A	2640-04A	3300-05A	5000-03	7000-04	9000-05
Load input terminal cover (comes attached)	1 pc.					
Power input terminal block cover (comes attached)	1 pc.					
CD-ROM (application software and communication interface manual) [SA-6020] 	1 pc.					

3.1.3 Wiring of the Rack Mount Type

The following types of wiring are used on the rack mount type. This section explains the wiring procedure. For the technical details of wiring, see the appendix in the Operation Part of this manual.

- Load wire (connection between the fuel cell and the KFM2150 system)
- Sensing wire (connection between the fuel cell and the KFM2150 system)
- Sensing wire of the FC Scanner (connection between the fuel cell and the KFM2151)
- PC control wire (connection between a PC and the KFM2150 and KFM2151)
- Power cord
- Grounding

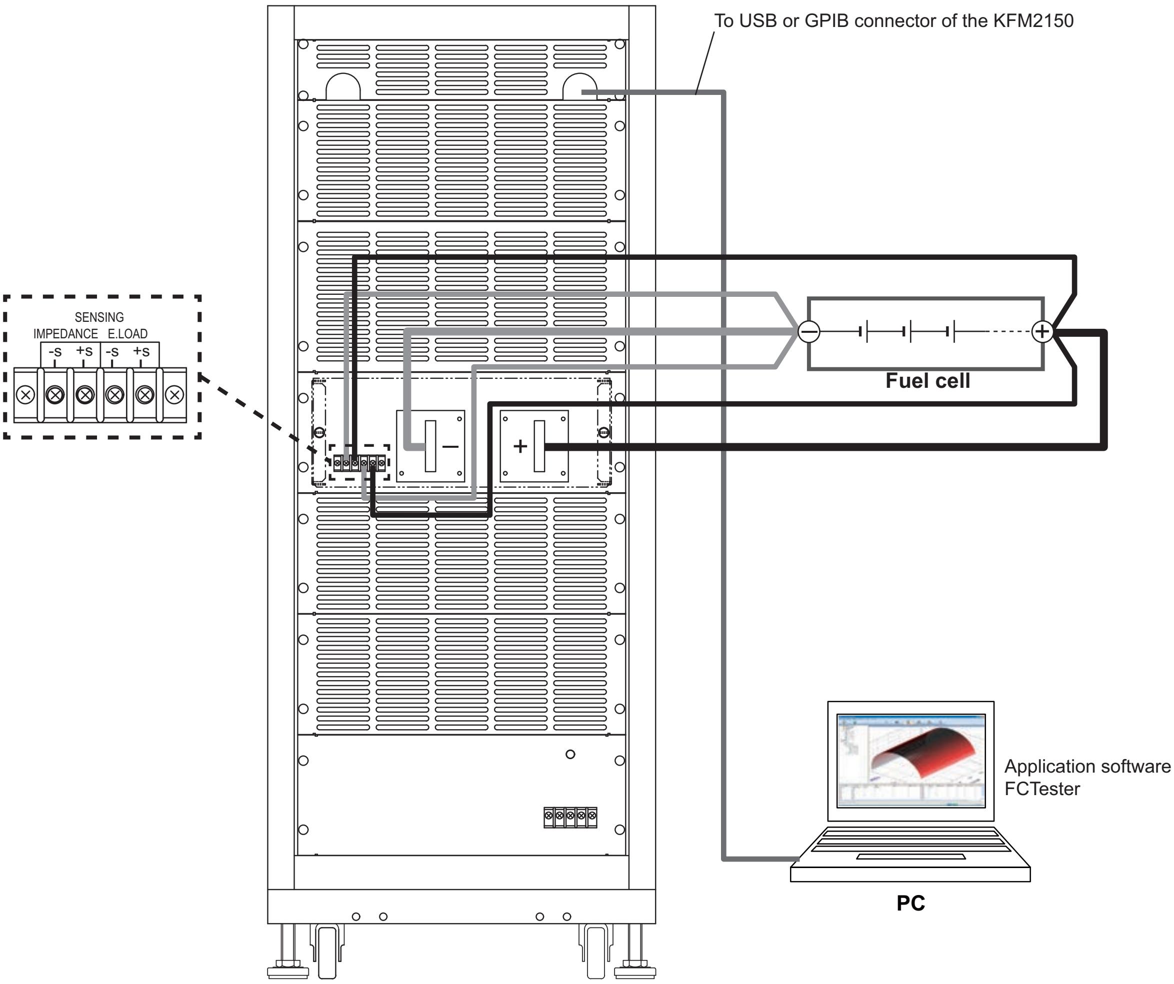


Fig.3-1 Example of rack mount type basic system wiring

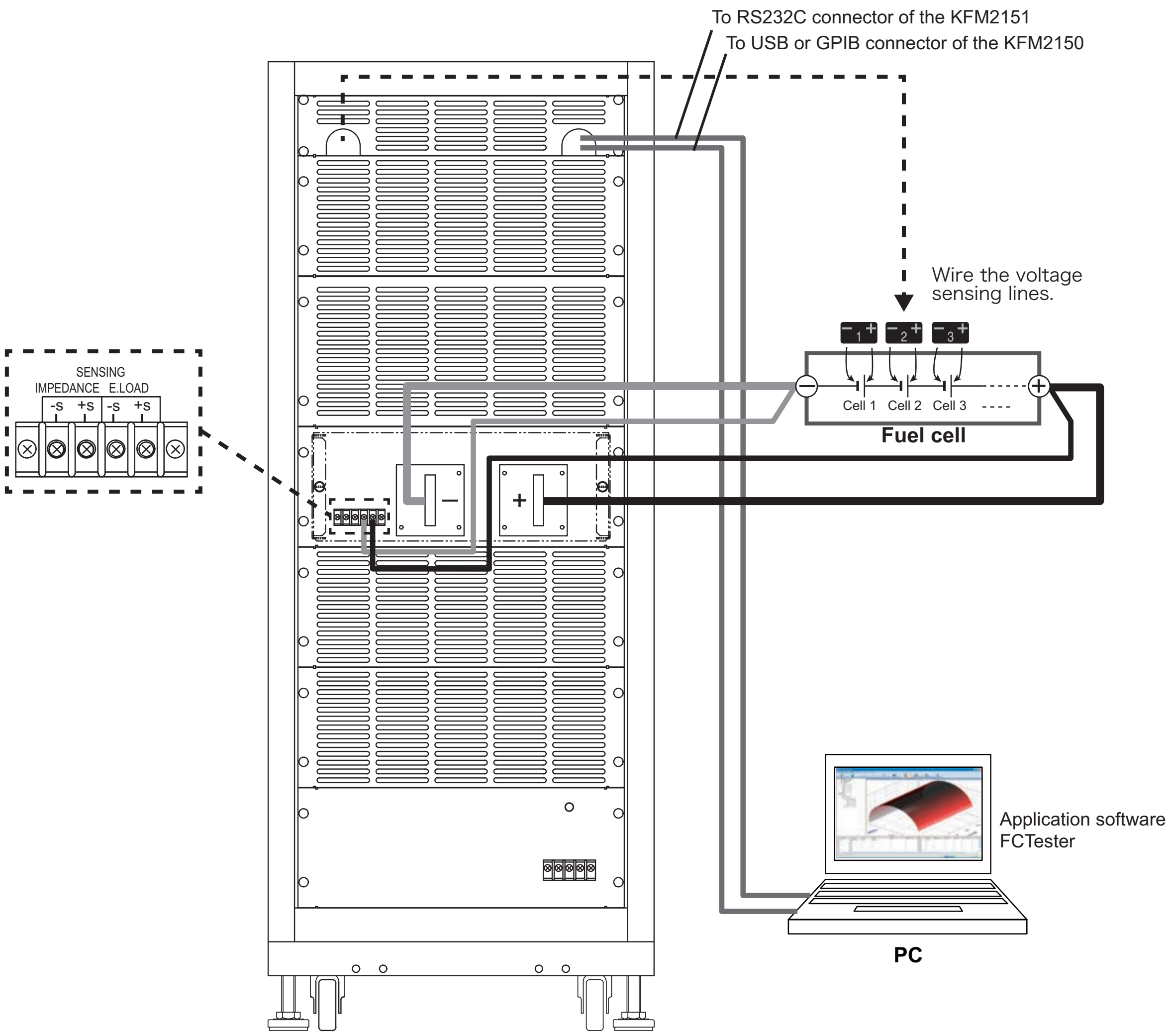


Fig. 3-2 Example of rack mount type scanner system wiring

3.2 Load Wires

Use load wires with sufficient current capacity for the current drawn from the fuel cell. The current capacity is proportional to the conductive cross-sectional area of the wire. The conductive cross-sectional area is determined by the cross-sectional area of the wire and the number of wires as shown in Fig. 3-3. Therefore, the number of wires needed increases for large currents. As a result, the wires become thicker, and the weight per unit length becomes substantial. For large currents, some wires come with conductors that are woven (called earth cables, copper braided flat wire, or flexible annealed copper stranded wire).

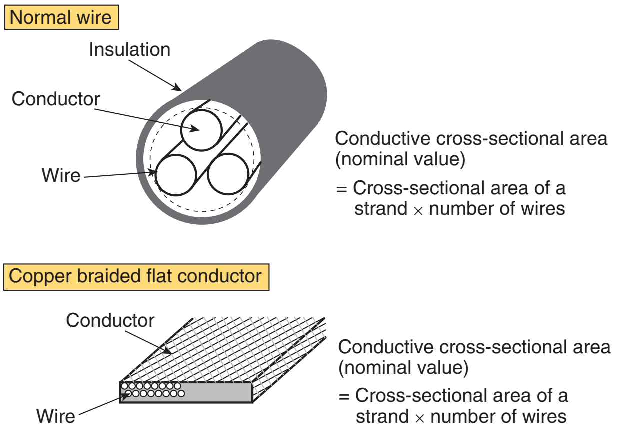


Fig. 3-3 Structure of the recommended load wire

CAUTION
- Connect the positive terminal of the fuel cell to the positive load input terminal, and the negative terminal of the fuel cell to the negative load input terminal. If the polarity is reversed, overcurrent may damage the system or the fuel cell.

3.2.1 Wiring the Load Input Terminal

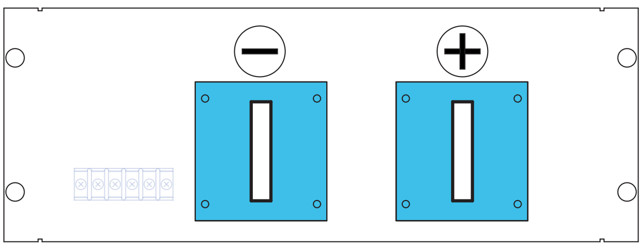


Fig. 3-4 Load input terminal

1 Turn the main power switch (uses a circuit breaker) off.

2 Connect the load input terminal of the KFM2150 system to the fuel cell.

The load input terminal of each contains four M12 bolts, four for the positive terminal and another four for the negative terminal. Be sure to connect the wires to the input terminals at the four points. Conductivity between the wire and input terminal is attained by the surface coming in contact with each other.

Securely attach the load input terminal cover provided.

⚠CAUTION • Securely connect the wire to the load input terminal using four bolts. Otherwise, smoke or fire may be emitted.

See Fig. 3-5

Table 3-2 shows the rated current by type. The required conductive cross-sectional area of the wire is quite large for 396 A to 1800 A. Even if multiple wires are used in a bundle, twisting them is troublesome. We recommend that you use a copper bus bar for the connection.

Using wires for the connection allows freedom in the arrangement of individual devices, but twisting the wires may not always be possible. In this situation, lay the positive and negative wires in close contact with each other and bundle them.

Table 3-2 System types

System model	Voltage	Rated current	Notes
KFM2150 SYSTEM1980-03A	0 V to 150 V	396 A	Rack mount type
KFM2150 SYSTEM2640-04A		528 A	
KFM2150 SYSTEM3300-05A		660 A	
KFM2150 SYSTEM5000-03	1.5 V to 150 V	1000 A	
KFM2150 SYSTEM7000-04		1400 A	
KFM2150 SYSTEM9000-05		1800 A	

The wires for large currents are heavy. Have more than one person connect the wire to the input terminal. After attaching the wire, fix the wire that has been laid out in place. Take measures to prevent people from tripping on the wire and prevent the wire from falling off the rack. Otherwise, the rack may move or fall over.

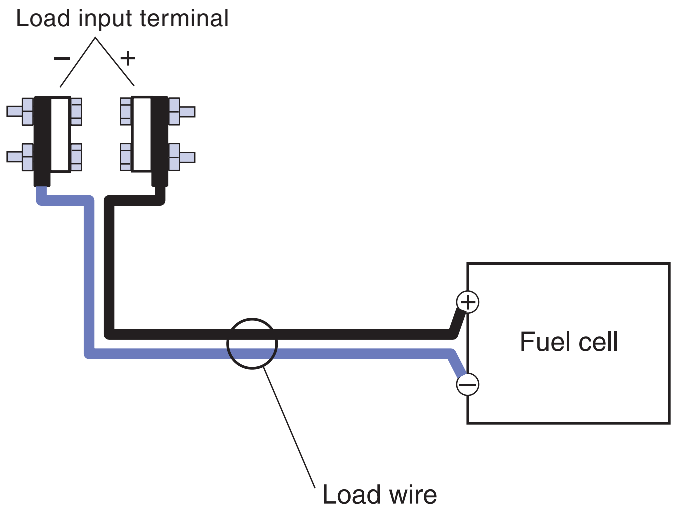


Fig. 3-5 Wires in contact with each other

3.2.2 Relationship between the Minimum Input Operating Voltage and Impedance Measurement

See p.A-24

The typical wire inductance is approximately 1 μH per meter when the positive and negative wires are twisted together well. Let's assume that the electronic load unit and the fuel cell are connected using a 1-m wire (1-m wires for positive and negative terminals twisted together). We obtain that the wire inductance is 1 μH from the equation 1 μH/m × 1 m.

The reactance is given by ωL (where ω is the angular frequency given by frequency × 2 π and L is the inductance). The reactance is 0.628 mΩ at 100 Hz, 6.28 mΩ at 1 kHz, 62.8 mΩ at 10 kHz, and 125 mΩ at 20 kHz. If the measuring AC current is 10 Arms, a voltage drop of 1.25 Vrms (3.54 Vpp) occurs.

The wires also have DC resistance. Thus, the voltage obtained by subtracting these voltage drops from the output voltage of the fuel cell must be greater than or equal to the minimum input operating voltage of the electronic load unit.

Restrictions may be placed on the items below depending on the wiring conditions. For details, see the appendix in the Operation Part of this manual.

- Maximum value of the measuring AC current
- Upper limit of the measurement frequency
- Minimum value of the fuel cell output voltage

3.2.3 PLZ4W Remote Sensing Function

PLZ4W remote sensing is a function used to correct the voltage drop caused by the resistance of the load wire when it cannot be discarded. The voltage drop compensation is up to 2 V for a single line.

See p.A-18

Also see A.6.3, " How to use CV mode and Remote Sensing."

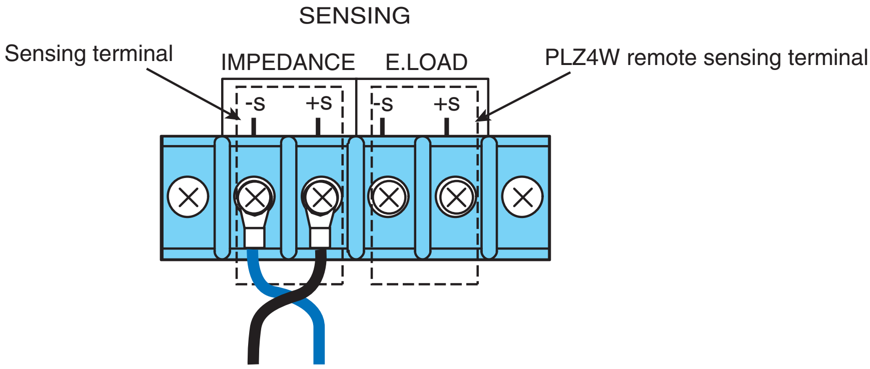


Fig. 3-6 PLZ4W remote sensing terminal (SENSING/E.LOAD)

CAUTION
- If the load wire comes loose while using PLZ4W remote sensing, the sensing wire or the PLZ-4W remote sensing circuit may break.
  Accidents can be prevented by connecting a protection fuse as shown in Figure 3-7. Use a fuse with a rated current of 0.5 A and a rated voltage greater than or equal to the output voltage of the fuel cell under test.

SENSING/E.LOAD wiring

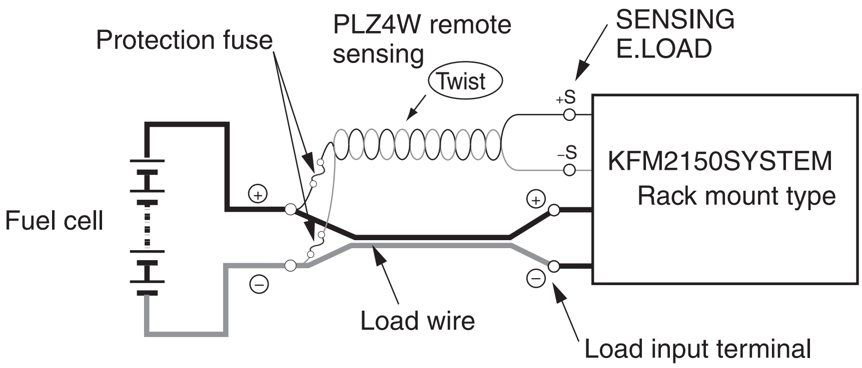


Fig. 3-7 PLZ4W remote sensing wiring

Connect the SENSING/E.LOAD (+S) terminal on the back side of the rack to the positive terminal of the fuel cell. Likewise, connect the SENSING/E.LOAD (-S) to the negative terminal of the fuel cell.

CAUTION • The PLZ4W remote sensing circuit may break. Do not connect the SENSING/E.LOAD (+S and -S) terminals on the back side of the rack directly to the cell of the fuel cell (Fig. 3-8).

■ Example of a unrecommended wiring

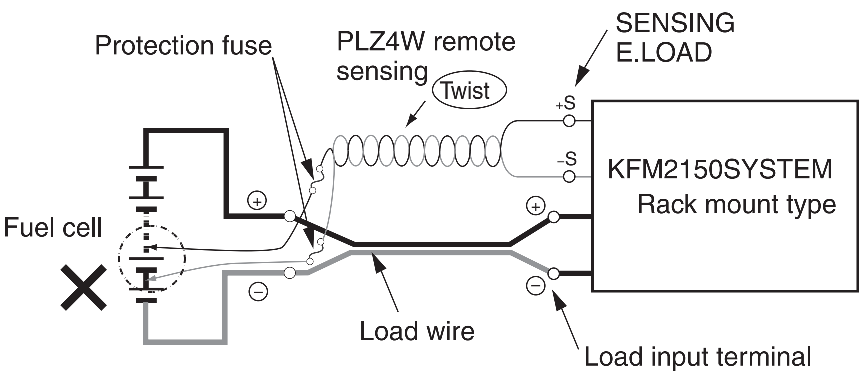


Fig. 3-8 Example of a unrecommended wiring

■ Wires used for PLZ4W remote sensing

You do not have to consider the current capacity as in the load wire. However, for mechanical strength, use a wire with a nominal conductive cross-sectional area that is at least 0.5 mm^2. Use crimping terminals for M4 screws to connect the wires to the SENSING/E.LOAD (+S and -S) terminals.

3.3 Sensing Wires

Using sensing wires, connect the SENSING/IMPEDANCE terminal to the point where you want to measure the impedance. The voltage at the measurement point is the voltage signal (voltage sensing) of the impedance measurement.

⚠WARNING • **Possible electric shock. Do not touch the SENSING/IMPEDANCE terminal while current is flowing.**

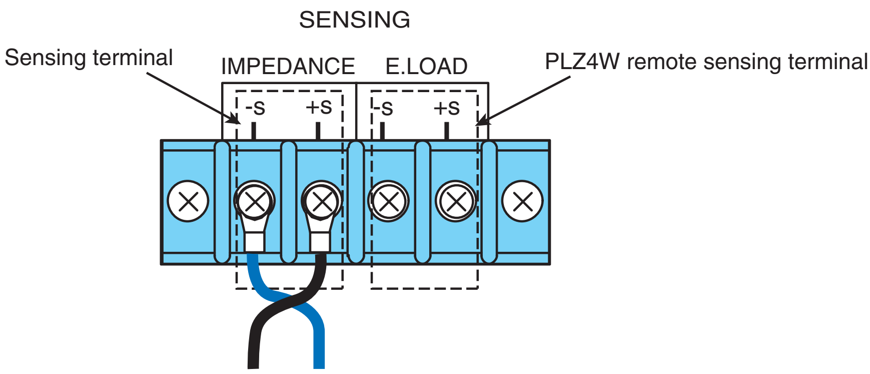


Fig. 3-9 Sensing terminal (SENSING/IMPEDANCE)

■ SENSING/IMPEDANCE

Connect the point where you want to measure the impedance or voltage of the fuel cell to the +S and -S terminals. We recommend that you twist the wires to eliminate the effects of magnetic flux.

Use wires with a nominal conductive cross-sectional area of at least 0.5 mm^2. Use crimping terminals for M4 screws for the connection.

The SENSING/IMPEDANCE terminal is isolated from the chassis (withstand voltage of 250 V). The DC input voltage range is 0 V to 150 V, and the input impedance is approx. 1 MΩ.

Selecting channel

Select MENU key > Setup > Input Select > Voltage Sensing to select channel 1 or 2.

The SENSING/IMPEDANCE terminal of the rack mount type is connected internally to channel 1 of the VOLTAGE SENSING terminal of the KFM2150.

Wiring

1 Turn the main power switch off (uses a circuit breaker).

2 Connect the desired sensing point of the fuel cell to the SENSING/ IMPEDANCE terminal of the system using the sensing wires.

Connect the positive and negative terminals of the fuel cell to the positive and negative SENSING/IMPEDANCE terminals respectively (Fig. 3-9).

We recommend that you twist the wires to eliminate the effects of magnetic flux.

⚠CAUTION

- Check the rated temperature of the sensing wires that you are using. Pay close attention for fuel cells that operate at high temperatures.
  Even for fuel cells that run at relatively low temperatures such as a PEFC, the collecting electrode where the sensing wire is connected may be hot.

NOTE

- Connect the SENSING IMPEDANCE terminal to the point where you want to measure the impedance or voltage. If you want to eliminate the effects of the electrode plate, connect the sensing terminal directly to the separator. If you want to measure the performance at the electrode terminal, connect it to the electrode terminal.

Wiring precautions

Because sensing wires are susceptible to the effect of noise, do not bundle them with load wires, input power wires of measuring instruments, power wires of gas control equipment, and signal wires. Correct and repeatable measurements cannot be made if noise affects the measurement. It may also cause malfunction in the measuring instrument or other control equipment.

3.4 Connecting the FC Scanner (Option)

Connect the point where you want to measure the impedance or voltage of the fuel cell to the SENSING terminal of the FC Scanner. Use the hole in the rear panel to connect the wire to the screwless terminals within the KFM2151.

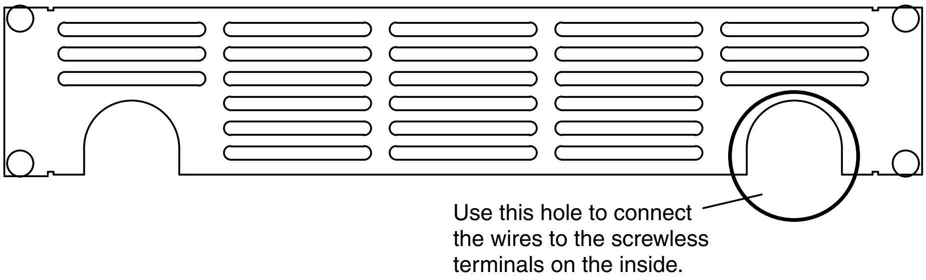


Fig. 3-10 Rear panel of where the FC scanner installed

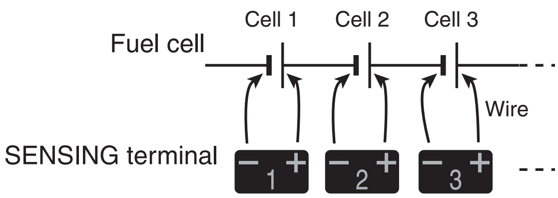


Fig. 3-11 Wiring the SENSING terminal

We recommend that you twist the wires to eliminate the effects of magnetic flux. Use wires with size AWG18 or greater.

NOTE

- Check the rated temperature of the wires that you are using. Pay close attention for fuel cells that operate at high temperatures. Even for fuel cells that run at relatively low temperatures such as a PEFC, the collecting electrode where the wire is connected may be hot.

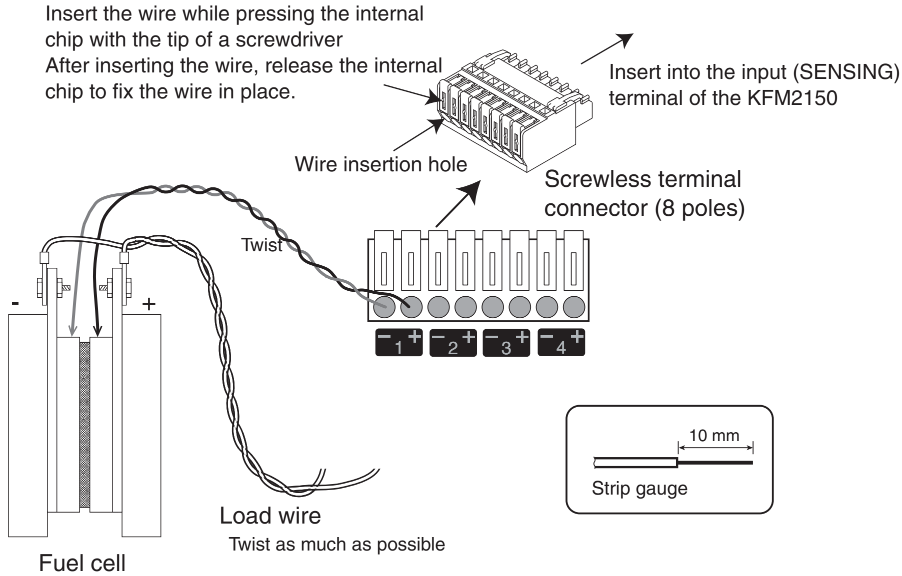


Fig. 3-12 Connection to the fuel cell

Wiring

1. Turn the main power switch off (uses a circuit breaker).
2. Using a screwdriver, insert the wire into the screwless terminal connector (8 poles) provided as shown in Fig. 3-12.
3. Twist the wires after inserting the positive and negative wires.

   This completes the wiring of one channel. Insert and twist the wires for as many channels as necessary.
4. Insert the screwless terminal connector (8 poles) to the SENSING terminal of the KFM2151.
5. Connect the other end of the wires to the fuel cell by aligning the polarity.

See p.4-26

You must set the KFM2150 from the menu when using the KFM2151 FC Scanner. See 4.8, “ Details on Menu Setup.”

3.5 PC Control Wire

The PC control wire is used when performing impedance measurement using the application software provided with the KFM2150. The KFM2150 is equipped with GPIB, RS232C, and USB for remote control interfaces. The GPIB, RS232C, and USB interfaces cannot be used simultaneously. Prepare a cable specific to the interface that you are using to connect to the PC.

Connecting a PC and the KFM2150

GPIB connection

Use a standard IEEE488 cable.

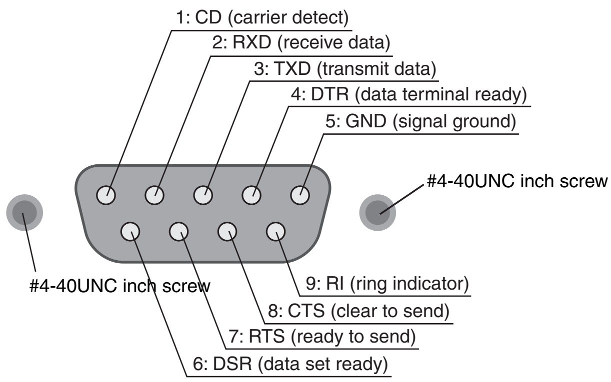
USB connection

Use a USB2.0 cable.

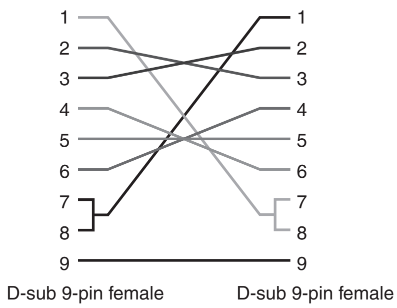
RS232C connection

Use a D-sub 9-pin female-to-female AT type cross cable (null modem cable) for the RS232C cable. Fig. 3-13shows the connector pin assignments.

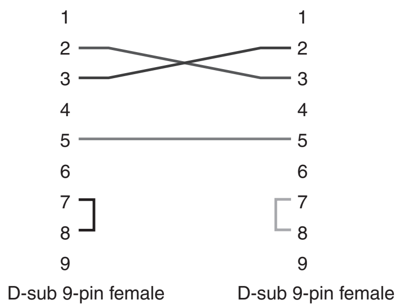
Because the KFM2150 does not use hardware handshaking, the connection of "Cross cable example 2" shown in Fig. 3-13 will suffice. "Cross cable example 1" can also be used.



Facing the KFM2150 rear panel



Cross cable example 1



Cross cable example 2

Fig. 3-13 9-pin AT type connector

Connecting a PC and the KFM2151

The remote control interface of the KFM2151 FC Scanner is RS232C. The connection procedure is the same as the RS232C connection of the KFM2150.

If you are using the KFM2151 as an impedance measurement system in combination with the KFM2150, connect the KFM2150 and the KFM2151 to the PC. We recommend that the KFM2150 be connected to the PC using USB or GPIB. If you are using the RS232C, you must use a PC that has two RS232C ports.

3.6 Connecting the Power Cable and Grounding (Earth)

Power cable

See p.3-18

The system is designed as an equipment to classify of IEC Overvoltage Category II (energy-consuming equipment supplied from the fixed installation).

Use a three-core PVC insulated power cable with a nominal cross-sectional area of at least 8 mm^2 for 600 Vac. The KFM2150 system does not come with a power cable.

The AC input voltage is 200 V to 240 V. Connect the instruments to a power supply with sufficient capacity.

⚠WARNING **Possible electric shock.**

- **The KFM2150 system is an IEC Safety Class I equipment (equipment with a protective conductor terminal). Be sure to connect the protective conductor terminal to electrical ground (safety ground).**
- **The KFM2150 system is grounded through the power cord ground wire. Connect the protective conductor terminal to earth ground.**
- **Turn off the switchboard breaker (switch that cuts off the power supply from the switchboard) before making the connection.**
- **Be sure to use a wire that is greater than or equal to the diameter of the power cable. If the grounding cable is thin, it may be insufficient in preventing accidents when a problem occurs.**

⚠CAUTION

- Inside the KFM2150 system, an appropriate protective circuit is connected to the input terminal. Be sure to connect the wires correctly by matching the L, N, and G ⏚(GND) between the switchboard and the KFM2150 system.

NOTE

- Be sure to have a qualified engineer connect the power cable to the switchboard.
- The POWER switch of the KFM2150 system can be used to disconnect the system from the AC line in an emergency. Provide adequate space around the POWER switch so that the POWER switch can be turned off at any time.

Connection procedure

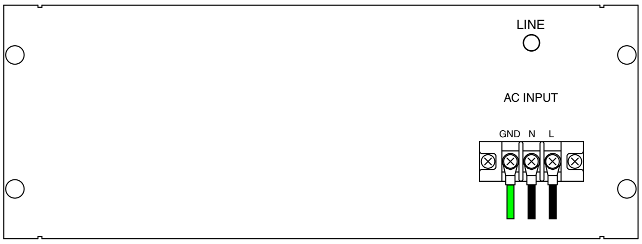


Fig. 3-14 Connecting the power cable

1. Check that the AC power supply meets the nominal input rating of the system.

   The AC input voltage is any of the nominal power supply voltages in the range of 200 Vac to 240 Vac. The frequency is 50 Hz or 60 Hz.

2. Turn the main power switch off (uses a circuit breaker).

3. Connect the power cable to the AC INPUT terminal block as shown in Figure 3-14.

   Attach crimping terminals that comply with the terminal screws on (M5) the terminal block and connect the power cable firmly so that it does not come loose. For a description of the crimping terminals, see “Connecting the Wires” in the Operation Part of this manual. Securely attach the terminal block cover provided.

4. Attach crimping terminals to the switchboard end of the power cable.

5. Turn off the switchboard breaker.

6. Connect the power cable to match the L, N, and ⏚(GND) of the switchboard.

   Attach crimping terminals that comply with the terminal screws on the switchboard and connect the power cable firmly so that it does not come loose. For a description of the crimping terminals, see “Connecting the Wires” in the Operation Part of this manual.

⚠CAUTION

- The power consumption may become large depending on the system configuration. For the wiring to the switchboard, use wires with sufficient current capacity by referring to Table 3-3.
- Check the current capacity of the power supply. If the current capacity is insufficient, the power supply cable may overheat or the switchboard breaker may shut down.

Table 3-3 Maximum power consumption of the system

System model	Maximum power consumption	Electronic load unit	
KFM2150 SYSTEM1980-03A	4600 VA	PLZ664WA	3 units
KFM2150 SYSTEM2640-04A	6100 VA		4 units
KFM2150 SYSTEM3300-05A	7600 VA		5 units
KFM2150 SYSTEM5000-03	660 VA	PLZ1004W	1 unit
		PLZ2004WB	2 units
KFM2150 SYSTEM7000-04	860 VA	PLZ1004W	1 unit
		PLZ2004WB	3 units
KFM2150 SYSTEM9000-05	1060 VA	PLZ1004W	1 unit
		PLZ2004WB	4 units

■ Earth leakage circuit breaker

The POWER switch uses an earth leakage circuit breaker. The rated sensitivity current is 30 mA.

■ Recommended power cable

A cable with a wire diameter (conductive cross-sectional area) greater than or equal to the values given in the following table is recommended.

Table 3-4 Recommended power cable

Nominal cross-sectional area [mm^2]	AWG	(Reference cross-sectional area) [mm^2]	Allowable current(*) [A] (Ta = 30 °C)	Kikusui-recommended current [A]
0.9	18	(0.82)	17	-
1.25	16	(1.31)	19	-
2	14	(2.08)	27	10
3.5	12	(3.31)	37	-
5.5	10	(5.26)	49	20
8	8	(8.37)	61	30
14	6	(13.3)	88	50
22	4	(21.15)	115	80
30	2	(33.62)	139	-
38	1	(42.41)	162	100

*Excerpts from Japanese laws related to electrical equipment.

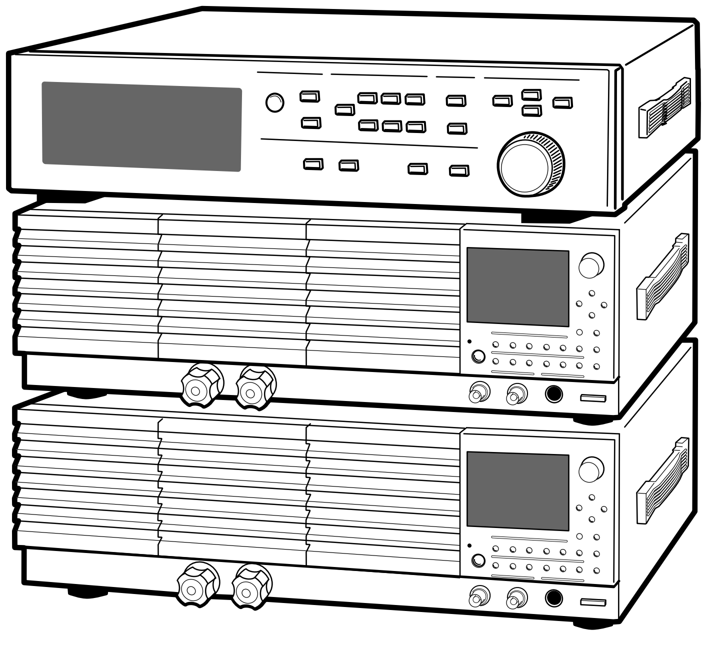
Table 3-4 gives examples of single-core cables. The values vary depending conditions such as the wire covering (insulator) and material (allowable temperature) and whether they are multi-core cables. For cables other than those listed in the table above, follow the indoor wiring regulations.

OPERATION MANUAL

Impedance Measurement System

KFM2150SYSTEM

Operation Part



4

Basic Operation

This chapter describes basic operations and how to use the various functions.

4.1 Turning the System On

This section explains the procedure to turn on the impedance measurement system. After turning on the power, the system is configured to start the impedance measurement.

The procedure to turn on the power differs between the bench top type and rack mount type.

The displays used in the following explanation are the displays of the KFM2150 in the system.

4.1.1 Bench Top Type

Turning the POWER switch on

NOTE

- Be sure to turn on the PLZ-4W Series first or simultaneously with the KFM2150. If you turn the KFM2150 on first, a response error or error shown in Fig. 4-4 will occur. If an error occurs, turn off the power switches of the KFM2150 and PLZ-4W Series, and carry out the power-up procedure in the correct order.

You can turn on/off the entire system using a single power switch by turning on the power switches of the system component instruments including the KFM2150 in advance.

The PLZ-4W Series are set to master unit or slave unit. For distinguishing between the two, refer to “When using two electronic load units” on page 2-8.

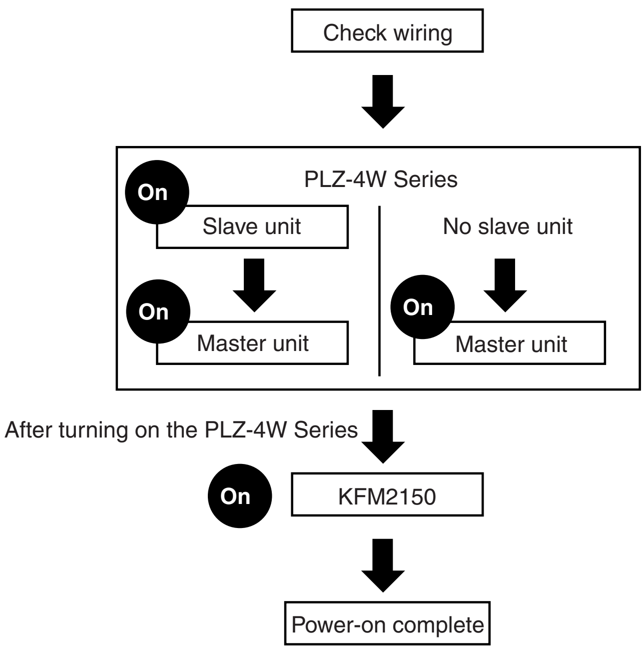


Fig. 4-1 Power-on sequence

1 Turn off the POWER switch of all system component instruments.

2 Check all wiring connections.

3 Turn on the POWER switches of the PLZ-4W Series and then turn on the POWER switch of the KFM2150.

As shown in Fig. 4-1, turn on the POWER switch of the PLZ-4W Series slave unit first and then the POWER switch of the master unit. If there is no slave unit, turn on the POWER switch of the master unit.

If you are using the PLZ-4W Series Booster, turn on the POWER switch of the PLZ-4W Series master unit. There is no power-on procedure for the booster. It is automatically turned on.

Then, turn on the POWER switch of the KFM2150. It can also be turned on simultaneously with the PLZ-4W Series.

NOTE

- If an alarm (PLZ4W EXT) is displayed on the KFM2150, press the ENTER key. The alarm is cleared, and the power-on procedure will complete.

Turning the POWER switch off

NOTE

- Be sure to turn off the POWER switch of the PLZ-4W Series first or simultaneously with the KFM2150. If you turn off the KFM2150 first, an alarm occurs on the PLZ-4W Series. If an alarm occurs, turn the PLZ-4W Series off.

1 Turn off the POWER switch of the PLZ-4W Series.

2 Turn off the POWER switch of the KFM2150.

Checking the Firmware Version

When the power is turned on, a buzzer sounds, and the model and firmware version are displayed. All LEDs illuminate for approximately 3 seconds, and a self-test starts.

```
KFM2150 Fuel Cell Impedance Meter
Version 1.00

KIKUSUI ELECTRONICS CORP.
Self Test...
```

Fig. 4-2 Version check display

See p.A-6

When the self-test completes, a startup display appears. The KFM2150 starts up in the condition in which the power was turned off the previous time. If you are using the KFM2150 for the first time, the KFM2150 starts up using factory default settings.

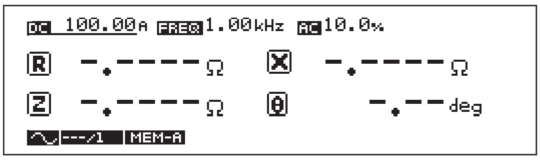


Fig. 4-3 Startup display example

Remedies when an error message is displayed

The system component instruments are checked when the KFM2150 is turned on. If the combination of the KFM2150 and the PLZ-4W Series is different from the combination registered at the factory, an error occurs.

See p.2-2, p.3-2

Check the system serial number of the system component instruments. The system component instruments are managed using a system serial number that is identical within a system. Systems cannot be configured using instruments with different system serial numbers. The system serial number is indicated on the rear panel of the product separately from the serial number of the product.

If any of the system serial numbers of the system components instruments do not match, contact your Kikusui agent or distributor.

The system component instruments are independent on the bench top type. Therefore, you can remove the component instrument from the system and use it for other applications. If you are placing the component instrument back into the system, check its system serial number. All of the system serial numbers of the system components instruments must match.

■ “PLZ NO RESPONSE” appears

This is an error message that appears when there is no response from the PLZ-4W Series.

Check the connection between the system component instruments.

Press the ENTER key to clear the error message.

■ Panel operation is not possible

All numeric displays show hyphens if the PLZ-4W Series model configuration cannot be retrieved.

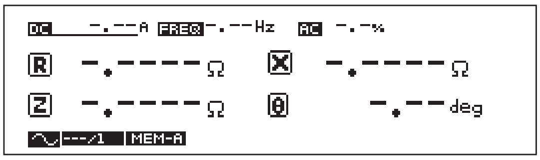


Fig. 4-4 PLZ-4W Series model configuration retrieval error

Check the connection between the system component instruments.

Press the DC key to start the retrieval of the PLZ-4W Series model configuration.

■ “PLZ FORMATION” appears.

This is an error message that appears when the system component instruments do not match those registered at the factory. Panel operation will not possible.

Check the system component instruments and system serial numbers. You can check the system component instruments using the Model Info menu.

Press the ENTER key to clear the error message.

If troubleshooting fails

■ Checking the settings of the PLZ-4W Series

Remove all wiring from the PLZ-4W, and turn the PLZ-4W Series on according to the operation manual.

After the power is turned on, check that the PLZ-4W Series display shows “CC: External V.” If not, set the PLZ-4W Series to external voltage control according to the operation manual of the PLZ-4W (from the menu, select 2. Configuration > 4. External > Control > V).

4.1.2 Rack Mount Type

On the rack mount type, turn the power on using the main power switch. Leave all the POWER switches of the system component instruments in the rack turned on.

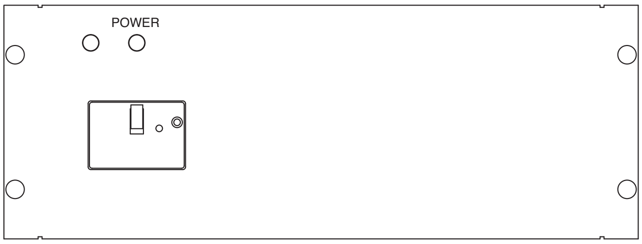


Fig. 4-5 Main power switch

Turning the POWER switch on

1. Turn off the main power switch (uses a circuit breaker).
2. Check all wiring connections.
3. Turn on the main power switch (uses a circuit breaker).
   The POWER indicator illuminates.

Turning the POWER switch off

1. Turn off the main power switch (uses a circuit breaker).
   The POWER indicator turns off.

Checking the firmware version

When the power is turned on, a buzzer sounds, and the model and firmware version are displayed. All LEDs illuminate for approximately 3 seconds, and a self-test starts.

```
KFM2150 Fuel Cell Impedance Meter
Version 1.00

KIKUSUI ELECTRONICS CORP.
Self Test...
```

Fig. 4-6 Version check display

See p.A-6

When the self-test completes, a startup display appears. The KFM2150 starts up in the condition in which the power was turned off the previous time. If you are using the KFM2150 for the first time, the KFM2150 starts up using factory default settings.

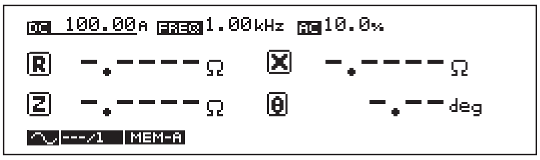


Fig. 4-7 Startup display example

4.2 Setting the Impedance Measurement System

The KFM2150 is a system controller of the impedance measurement system. You can set the conditions of the impedance measurement system with the KFM2150 menus. As a general rule, the menu items can be used at the factory default settings.

See p.4-26

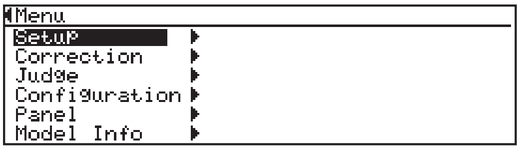


Fig. 4-8 Menu display

4.3 Protection Function

Protection Function Structure

The KFM2150 controls the protection function. The protection function operates when the load is turned on.

The detection and activation tasks are divided between the KFM2150 and the PLZ-4W Series.

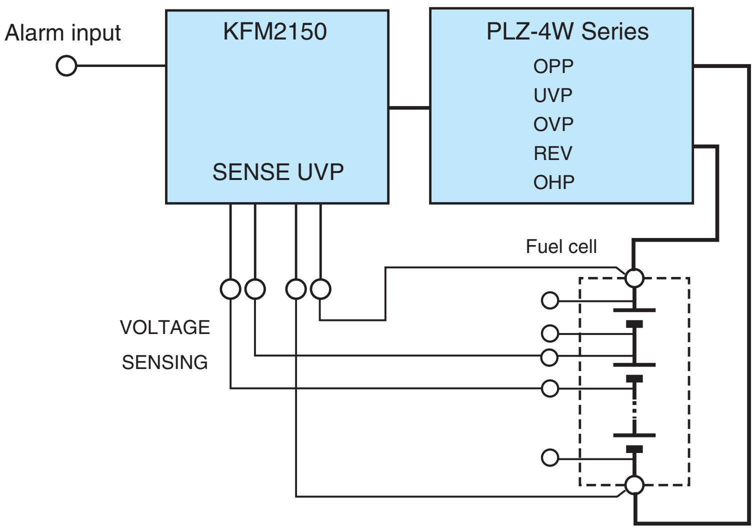


Fig. 4-9 Protection function structure

4.3.1 Types of protection functions

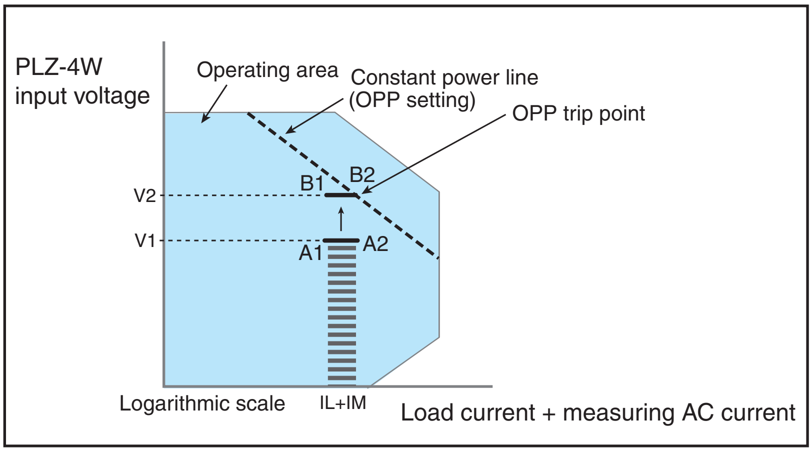
Table 4-1 shows the types of protection functions.

Table 4-1 Types of protection functions

Function type	Protected item	Activation description	Detection value	Detection and activation instruments
Overpower protection (PLZ4W OPP)	The entire fuel cell (detected by the load input terminal of the PLZ-4W Series)	Limits the load current when the power is greater than or equal to the detection value.[*1]	Preset value or 110 % of the range in use, whichever is smaller.	PLZ-4W Series
Undervoltage protection (PLZ4W UVP)	The entire fuel cell (detected by the load input terminal of the PLZ-4W Series)	Turns the load off when the voltage is less than or equal to the detection value.	Preset value or OFF	
Overvoltage protection (PLZ4W OVP)		Turns the load off when the voltage is greater than or equal to the detection value.	110 % of the rated voltage (fixed)	
Reverse connection protection (PLZ4W REV)	PLZ-4W Series (detected internally)	Turns the load off when the voltage of the load input terminal is reverse polarity.	Reverse polarity	
Overheat protection (PLZ4W OHP)		Turns the load off when the internal temperature of the PLZ-4W Series exceeds the detection value.	95 °C	

Function type	Protected item	Activation description	Detection value	Detection and activation instruments
Alarm input detection (USER)	External device connected to the alarm input	Turns the load off when an alarm input*2 is detected.	Low level	KFM2150
Voltage sensing undervoltage protection (SENSE UVP)	The section connected to the VOLTAGE SENSING input	Turns the load off UVP Mask Time after the voltage falls to less than or equal to the detection value.*3	Setting (Selectable range: -2.0 V to 150 V)	

*1. The input voltage (fuel cell voltage) and input current (load current + measuring AC current) of the PLZ-4W Series are driven by V1 and IL respectively. We denote this operating point as point A1. The operating point moves back and forth between points A1 and A2 due to measuring AC current IM.
If the input voltage (fuel cell voltage) of the PLZ-4W Series increases to V2, the operating point moves from segment A1-A2 to B1-B2. When the maximum current of IL + IM reaches point B2, the overpower protection (PLZ4W OPP) activates. When this occurs, the current is limited as a constant power load at point B2.
If the input current (load current + measuring AC current) decreases, the overpower protection (PLZ4W OPP) clears. The operating point returns within the operating area, and the operation returns to constant current mode (CC).



Current limiting when overpower protection is activated

*2. When a low level (TTL) signal is applied to the ALARM IN (pin 10) of the J1 connector on the rear panel of the KFM2150.

*3. If the voltage sensing undervoltage protection (SENSE UVP) is set to 0 V or less (negative value) when using the 0 V type of the PLZ-4W Series (PLZ164WA or PLZ664WA), the reverse connection protection of the PLZ-4W Series (PLZ4W REV) may activate when the fuel cell voltage drops.
You can set the voltage sensing undervoltage protection to 0 V or higher (positive value), so that the voltage sensing undervoltage protection is activated before the reverse connection protection.

4.3.2 Transition from CC Mode to CV Mode

See p.A-18

Also see “A.6.3 How to use CV mode and Remote Sensing.”

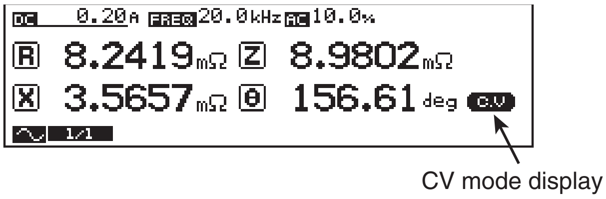


Fig. 4-10 CV mode display

The KFM2150 system normally operates in CC mode. If the fuel cell voltage drops to a specified CV mode transition voltage, the KFM2150 system automatically switches to CV mode. In CV mode, the indication on the display switches from CC to CV as shown in Fig. 4-10.

(Example) Let’s assume if we have a fuel cell with an open-circuit voltage of 10 V that drops to 9 V when 10 A of current flows and 7 V when 20 A flows. We do not know how much current flow at 8 V.

In such case, if you set the CV mode transition voltage to 8 V, the KFM2150 system operates in CC mode until the fuel cell voltage drops to 8 V. As the current is gradually increased and the fuel cell voltage drops to 8 V, the KFM2150 system switches to CV mode and controls the current so that 8 V is maintained without allowing the current to exceed the specified value. If the current is gradually decreased, the KFM2150 system automatically switches to CC mode.

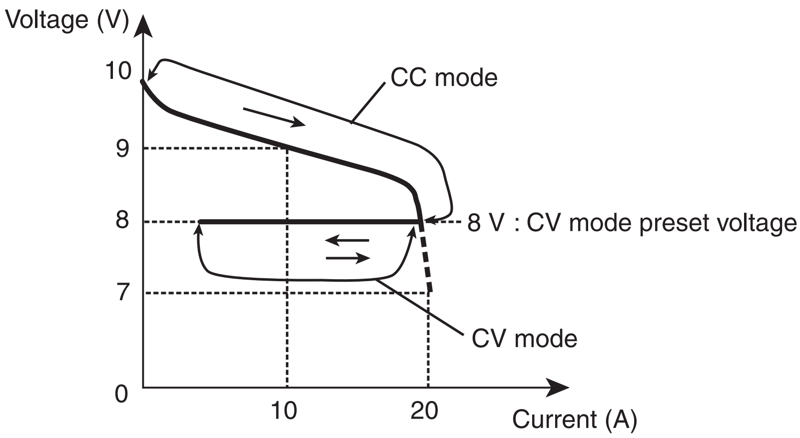


Fig. 4-11 Transition from CC mode to CV mode

4.3.3 Details of the Undervoltage Protection (PLZ4W UVP)

The undervoltage protection (PLZ4W UVP) is used to detect voltage drops in the entire fuel cell (stack). In normal operation mode (CC mode), the load turns off if the voltage of the entire fuel cell (stack) drops below the detection value as shown in Table 4-1. It is possible to disable this function.

If switching to CV mode, the activation condition varies depending on the setting value between the CV mode transition voltage and the PLZ4W UVP detection voltage.

- (CV mode transition voltage) < (PLZ4W UVP detection voltage)

  The undervoltage protection (PLZ4W UVP) is activated, and the load turns off (does not switch to CV mode) (Fig. 4-12-a).

- (CV mode transition voltage) > (PLZ4W UVP detection voltage)

  The KFM2150 switches to CV mode (Fig. 4-12-b).

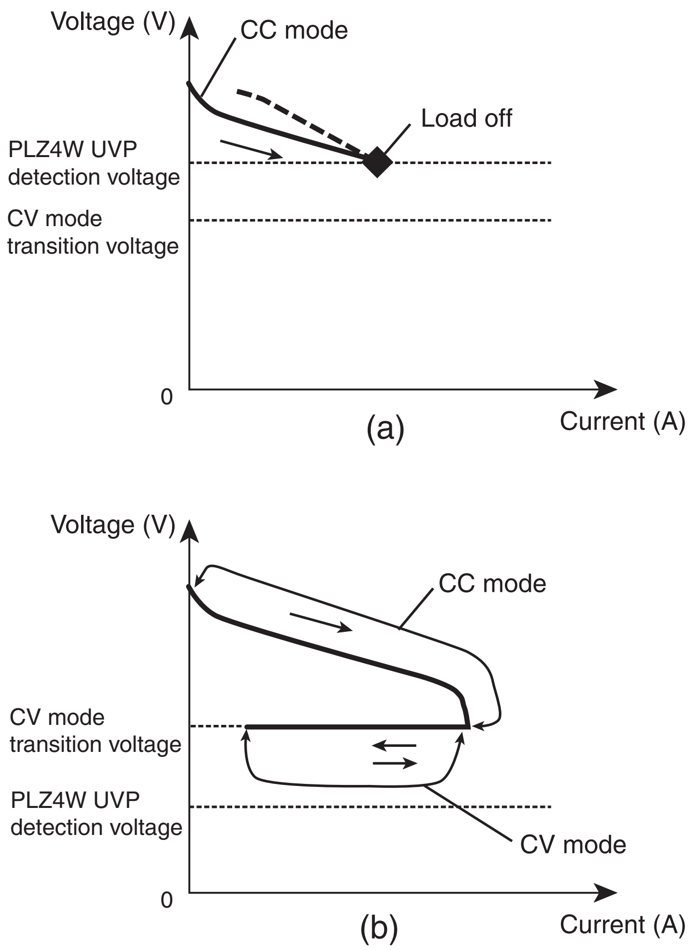


Fig. 4-12 PLZ4W UVP and CV mode transition voltage

4.3.4 Details of the Voltage Sensing Undervoltage Protection (SENSE UVP)

See p.4-12

The voltage sensing undervoltage protection (SENSE UVP) is used to detect the portion of the voltage drop where the impedance measurement is performed (detection section) such as in the unit of cell level of the fuel cell. In normal operation mode (CC mode), the load turns off after UVP Mask Time elapses if the voltage at the detection section drops below the detection value as shown in Table 4-1.

This function is independent feature from the function specified in the clause 4.3.3 of “undervoltage protection (PLZ4W UVP)”.

4.3.5 Setting the Protection Function

This section describes the procedure to set the overpower protection (PLZ4W OPP), undervoltage protection (PLZ4W UVP), and voltage sensing undervoltage protection (SENSE UVP).

1 Press the PROTECT key.

The PROTECT window appears.

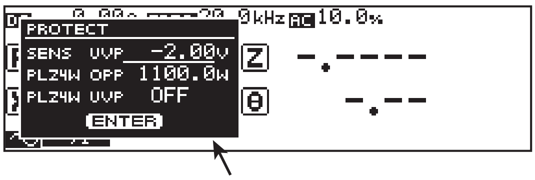


Fig. 4-13 PROTECT window

2 Press the ▲ or ▼ key to select the protection item.

See p.4-8

Select overpower protection (PLZ4W OPP), undervoltage protection (PLZ4W UVP), or voltage sensing undervoltage protection (SENSE UVP).

3 Press the ◀ or ▶ key to select the digit you want to set.

4 Turn the rotary knob to set the value.

5 Press the ENTER key.

The PROTECT window closes.

Voltage Sensing UVP Mask Time

You can set a time (delay) until the voltage sensing undervoltage protection (SENSE UVP) is activated.

Select MENU key > Select Setup > Protection > UVP Mask Time to set.

The selectable range is 0 s to 10 s.

4.3.6 Alarm Occurrence and Release

When a protection function activates, an alarm is activated. If you cannot clear the alarm even when all of the causes of the alarm are eliminated, the KFM2150 system may have malfunctioned. If this happens, stop using the KFM2150 system and contact your Kikusui agent or distributor.

■ Cause of alarms and remedies

Table 4-2 Cause of the alarm

Activated protection function	Cause of the alarm	Remedy
Overpower protection (PLZ4W OPP)	Overcurrent or increased fuel cell voltage	Review the operating or test condition of the fuel cell.
Undervoltage protection (PLZ4W UVP)	Decreased voltage	
Overvoltage protection (PLZ4W OVP)	Increased voltage	

Activated protection function	Cause of the alarm	Remedy
Reverse connection protection (PLZ4W REV)	The connection to the fuel cell is incorrect.	Check the fuel cell wiring.
Overheat protection (PLZ4W OHP)	Overheating of the PLZ-4W Series	Check that the vent holes of the PLZ-4W Series are not blocked and that the dust filter is not clogged.
Alarm input detection (USER)	Alarm signal input	Clear the alarm of the device connected to the J1 connector of the KFM2150.
Voltage sensing undervoltage protection (SENSE UVP)	Decreased voltage in the voltage sensing input	Review the operating or test condition of the fuel cell.
PLZ-4W other (PLZ4W OTHER)	Causes other than those listed above	If the alarm occurs many times, contact your Kikusui agent or distributor

When overpower protection (PLZ4W OPP) activates

When the overpower protection activates, “OPP” is shown at the bottom section of the display.

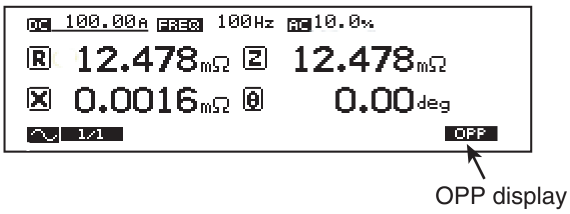


Fig. 4-14 OPP display

Review the operating or test condition of the fuel cell. When the alarm condition is cleared, the OPP indication clears, and the overpower protection is automatically released.

When other protection functions activates

When another protection function activates, an alarm message appears.

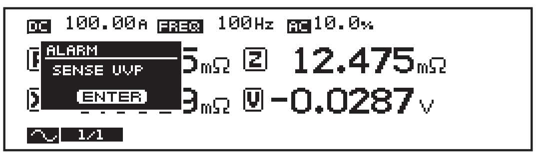


Fig. 4-15 Alarm message display example

1. Eliminate the cause of the alarm according to the alarm message.

   The alarm will be activated again if you do not correct the cause of the alarm.

2. Press the ENTER key.

   The alarm is cleared, and the alarm message display closes.

4.4 Memory Function

The settings can be stored to the memories. There are three memories: A, B, and C.

For those memories, A, B, and C can be applied in each of current range (LOW,/MID/HIGH). In addition, the voltage range (15 V/150 V) can be also added to these memories. By having those combinations of setting, there are up to 18 memories in total.

See p.4-26

The KFM2150 uses the PLZ-4W Series by fixing the current range and voltage range.

The current range is set using MENU key > Setup > DC Load > Range.

The voltage range is set using MENU key > Setup > DC Load > VRange

Saving to the memory

The settings that are saved are the items shown in Table 4-3 and menu items.

1 Press the STORE (SHIFT+RECALL) key.

The STORE window appears. The operation is not accepted if the connection to the PLZ-4W Series is incomplete and there is no response.

2 Turn the rotary knob to select the memory to save the settings.

The STORE window shows MEM-A, MEM-B, or MEM-C.

3 Press the ENTER key.

The STORE window closes. Saving of the settings is complete. The corresponding memory icon is shown in the status display section.

Table 4-3 Settings stored to memory (other than menu items)

Stored setting		Factory default settings
DC current		0 A
Protection function	Undervoltage protection (SENSE UVP)	-2 V
	Overpower protection (PLZ4W OPP)	Maximum value of the PLZ-4W Series that are connected
	Undervoltage protection (PLZ4W UVP)	OFF
Measurement method		AC impedance method
AC impedance method	Measuring frequency (FREQ)	20 kHz
	Measuring AC current	10 %
Current interrupt method	Pulse width (WIDTH)	10.0 ms
	Pulse depth (DEPTH)	100 %
	Pulse transition time (TRNSN)	0.01 ms
Average count (AVE)		1
Display (VIEW)	Upper left	R
	Lower left	X
	Upper right	Z
	Lower right	θ

Recalling the memory

The memory corresponding to each range of the current and voltage can be recalled from A, B, or C.

1 **Press the RECALL key.**

A RECALL window appears. The operation is not accepted if the connection to the PLZ-4W Series is incomplete and there is no response.

2 **Turn the rotary knob to select the memory to be recalled.**

The RECALL window shows MEM-A, MEM-B, or MEM-C.

To cancel the recall operation, press the RECALL key again.

3 **Press the ENTER key.**

The RECALL window closes. The settings in the selected memory is recalled. The corresponding memory icon is shown in the status display section.

The memory is cleared if you change the settings, because the settings are no longer the same as the contents of the recalled memory.

4.5 Other Settings

Locking the panel operation

The KFM2150 has a lock function that prevents accidental operation. When locked, all keys other than the LOAD, RECALL, and LOCK (SHIFT+LOCAL) keys are disabled.

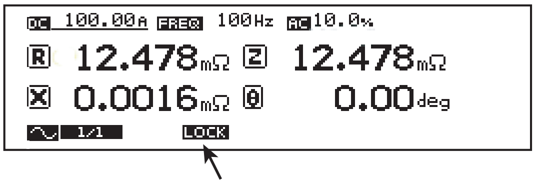


Fig. 4-16 LOCK display

■ Setting the lock

Press the LOCAL (SHIFT+LOCAL) key. A beep is sounded, and the panel operation is locked. “LOCK” is displayed in the bottom section of the display.

■ Releasing the lock

Press the LOCAL (SHIFT+LOCAL) key. Two beeps are sounded, and the lock is released. The LOCK indication clears.

Display contrast

You can adjust the display contrast by turning the rotary knob while holding down the SHIFT key.

Turn the rotary knob clockwise increase or counterclockwise to decrease the contrast.

Display color

You can select the display color.

1 Press the MENU key.

The MENU display appears.

2 Press the ▲, ▼, and ▶ arrow keys to move to Panel > LCD Color.

3 Turn the rotary knob to select the color (blue or white).

Switching from remote to local mode

Pressing the LOCAL key when the KFM2150 is being controlled remotely causes the KFM2150 to switch to panel operation (local mode). The RMT LED illuminates when the KFM2150 is being controlled remotely.

Setting the alarm volume

You can adjust the alarm volume.

1 Press the MENU key.

The MENU display appears.

2 Press the ▲, ▼, and ▶ arrow keys to move to Panel > Beep Volume.

3 Turn the rotary knob to select the volume (0 to 255).

Factory default settings

See p.A-6

You can initialize the KFM2150 to factory default settings.

1 Press the INIT (SHIFT+MENU) key.

A confirmation window (INITIALIZE?) appears.

2 Press the ENTER key.

The confirmation window closes. The KFM2150 is initialized to factory default settings.

4.6 Setting the Remote Control

In addition to using the front panel, the KFM2150 can be controlled remotely using the following interfaces.

- RS232C interface
- GPIB interface
- USB interface

The factory default remote control interface setting is GPIB. The GPIB, RS232C, and USB interfaces cannot be used at the same time.

The remote interface complies with IEEE 488.2 std. 1992 and SCPI Specification 1999.0. For details, see the Communication Interface Manual.

The KFM2150 conforms to the following standards.

- IEEE Std. 488.2-1992 IEEE Standard Codes, Formats, Protocols, and Common Commands For Use With IEEE Std. 488-1987
- IEEE Std. 488.1-1987 IEEE Standard Digital Interface for Programmable Instrumentation
- Standard Commands for Programmable Instruments (SCPI) version 1999.0
- Universal Serial Bus Specification Rev 2.0
- Universal Serial Bus Test and Measurement Class Specification (USBTMC) Rev 1.0
- Universal Serial Bus Test and Measurement Class, Subclass USB488 Specification (USBTMC-USB488) Rev 1.0

4.6.1 GPIB Interface

Setting the GPIB address

Set the GPIB address between from1 to 30. As a factory default,it is set to 3.

1. Check that the load is turned off.
2. Press the MENU key.
   The MENU display appears.
3. Press the ▲, ▼, and ▶ arrow keys to select Configuration > Interface > TYPE and turn the rotary knob to select GPIB.
4. Press the ▲ or ▼ arrow key to select Address, and turn the rotary knob to set the address (1 to 30).
5. Press the MENU key.
   The MENU display closes.

6 Turn the POWER switch off and then turn it back on.

The settings are fixed.

GPIB function

Table 4-4 GPIB functions

Function	Subset	Description
Source handshaking	SH1	Full capability
Acceptor handshaking	AH1	Full capability
Talker	T6	Function available
Listener	L4	Function available
Service request	SR1	Full capability
Remote local	RL1	Full capability
Parallel polling	PP0	No capability
Device clear	DC1	Full capability
Device trigger	DT1	Function available
Controller	C0	No capability
Electrical interface	E1	Open collector driver

IEEE488.1 get, dcl, sdc, llo, and gtl commands

Command		Description
get	Group Execute Trigger	Functions as a software trigger for starting the measurement (equivalent to the *TRG command).
dcl/sdc	Device Clear/ Selected Device Clear	Aborts the measurement and clears the command buffer.
llo	Local Lockout	Locks out the local keys of the KFM2150.
gtl	Go to Local	Sets the KFM2150 front panel to local control.

Service request

Service request and serial polling functions are implemented.

4.6.2 RS232C Interface

RS232C configuration

1. Check that the load is turned off.
2. Press the MENU key.
   The MENU display appears.
3. Press the ▲, ▼, and ▶ arrow keys to select Configuration > Interface > TYPE and turn the rotary knob to select RS232C.
4. Press the ▲ or ▼ arrow key to select Baudrate, and turn the rotary knob to set the baud rate.
5. Likewise, set Data, Stop, Parity, and Ack.
6. Press the MENU key.
   The MENU display closes.
7. Turn the POWER switch off and then turn it back on.
   The settings are fixed.

Protocol

Table 4-5 shows the RS232C protocol.

Underline indicates factory default setting.

Table 4-5 RS232C protocol

Item	Setting
Connector	9-pin D-sub terminal on the rear panel
Baudrate	2400 bps, 4800 bps, 9600 bps, or 19200 bps
Data (data length)	7 bits or 8 bits
Stop (stop bit)	1 bit or 2 bits
Parity	Fixed to none
Ack (acknowledge)	ON or OFF

Break signal

The break signal functions as a substitute for the IEEE488.1 dcl/sdc (Device Clear, Selected Device Clear) message.

RS232C communication

Use X-Flow control or acknowledge function for RS232C communication.

Transmission/reception may not work correctly through unilateral transmission.

X-Flow control

The transmission/reception on the KFM2150 can be controlled using Xon/Xoff.

DC (device control) codes are used as control codes.

Table 4-6 DC codes

Code	Function	ASCII code
DC1	Transmission request	11H
DC3	Transmission stop request	13H

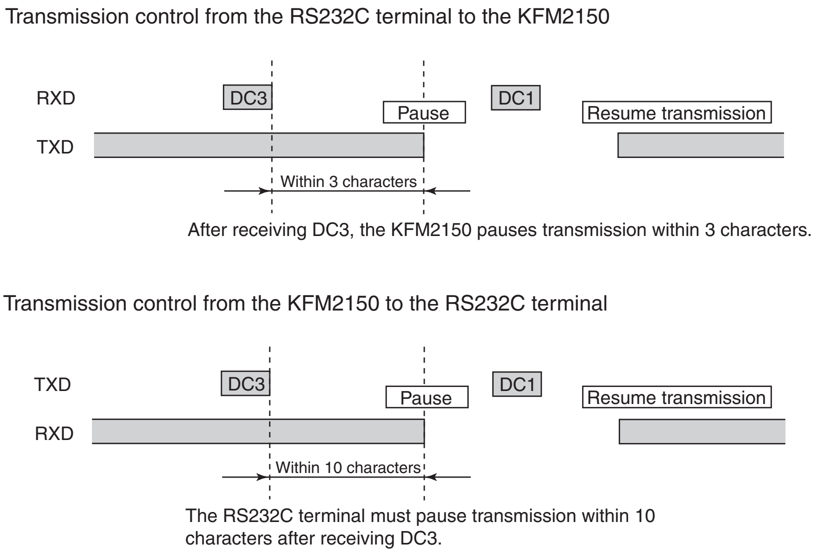


Fig. 4-17 RS232C terminal and transmission control of the KFM2150

Acknowledge message

An acknowledge message is information sent from the KFM2150 to the controller. It notifies that the processing of the program message has been completed.

The acknowledge message is an ASCII code string consisting of only the header. The following two types are available.

- OK: Normal completion
- ERROR: Error such as a syntax error or query error

See p.4-20

To use acknowledge messages, set Ack to On in the CONFIG settings.

On the controller, the RS232C configuration must be set to full-duplex operation.

4.6.3 USB Interface

A device driver supporting USB T&M Class (USBTMC) is required to control the KFM2150 through the USB interface. The USBTMC driver is automatically installed by one of the VISA libraries below.

KI-VISA 2.2.x or later

(downloadable from KIKUSUI Website:http://www.kikusui.co.jp/en/download/)

- NI-VISA 3.0 or later
  (downloadable from National Instruments Website)
- Agilent VISA (Agilent I/O Libraries) M01.00 or later
  (downloadable from Agilent Technologies Website)

USB configuration

1 Check that the load is turned off.

2 Press the MENU key.

The MENU display appears.

3 Press the ▲, ▼, and ▶ arrow keys to select Configuration > Interface > TYPE and turn the rotary knob to select USB.

4 Press the MENU key.

The MENU display closes.

5 Turn the POWER switch off and then turn it back on.

The settings are fixed.

Service request

Service request and serial polling functions are implemented.

USB function

Complies with USB Specification 2.0.

Complies with USBTMC Specification 1.0 and USBTMC-USB488 Specification 1.0.

Data rate: 12 Mbps maximum (full speed).

VID (vendor ID): 0x0B3E.

PID (product ID): 0x1008.

4.6.4 Command Details

For command details, see the Communication Interface Manual on the accompanying CD-ROM.

The communication interface manual is provided in HTML format. You can view it using the following browser.

Operating environment:	Windows 98 or later
Browser:	Microsoft Internet Explorer 5.5 or later

The list of messages in the communication interface manual is provided in PDF format. Adobe Reader 6.0 or later is required to view the list.

4.7 Installing the Application Software (FCTester)

PC system requirements

CPU	Pentium III 600 MHz or faster
OS	Microsoft Windows 2000 or XP
Memory	256 MB or more (512 MB or more recommended) or 512 MB or more (1 GB or more recommended) when using the scanner.
Display resolution	SVGA resolution or higher (800 × 600 dots or higher)
Hard disk	20 MB of free space is needed to save files
CD-ROM drive	
Mouse or pointing device	
Data analysis	Microsoft Excel
I/O interface	One of the following is required. • USB • RS232C • GPIB (National Instruments, Agilent Technologies, Contec Co., LTD. or Interface Co., Ltd.)
VISA library	NI-VISA3.0 or later, Agilent I/O Library M01.00 or later, or KI-VISA 2.5 or later

NOTE
- Turn off the power-saving mode on the OS, screen savers, and memory-resident programs.
- Avoid using the software with other applications.

■ Contents of the accompanying CD-ROM

- Application software

  FCTester and PLZ Detach

- Instrument driver

  KI-VISA 3.x.x

  The value for x varies depending on the revision of the VISA library stored on the CD-ROM.

- Document

  Communication Interface Manual (English and Japanese)

Installation

1 Load the accompanying CD-ROM into the CD-ROM drive.

2 Install the applications according to the instructions on the screen.

The operation manuals of the application softwares are stored on the CD-ROM.

Environmental settings

■ KFM2150 settings

See p.4-18

Set the interface that is to be used.

■ FCTester settings

Use the FCTester Configuration Tool to set the VISA resource to match the KFM2150 interface. For details, see chapter 3, “System Configuration” in the operation manual of the application software.

4.8 Details on Menu Setup

Menu Operation Basics

1. Check that the load is turned off.
2. Press the MENU key.
   The MENU display appears.
3. Press the arrow keys (▲, ▼, ▶, and ◀) to move to the condition you want to set.
4. Turn the rotary knob to set the condition.
   To set other conditions, repeat steps 3 and 4.
5. Press the MENU key.
   The MENU display closes.

Menu items

Underlined values or status are factory default values.

Table 4-7 Menu items

Item 1	Item 2	Item 3	Conditions	Description	Page
Setup	Soft Start Time	Rise	0:00 to 2:00 (Hour: minute)	Soft start rise time.	p.5-7
		Fall	0:00 to 2:00 (Hour: minute)	Soft start fall time.	
	Input Select	Voltage Sensing	1/2	Select channel 1 or 2 according to the terminal you are using.	p.2-12 p.3-10
		Current Sensing	1/2	Normally, select channel 1.	p.A-4[*1]
	DC Load	Range[*2]	LOW/MID/HIGH	Load current range of the PLZ-4W Series.	p.5-4
		VRange[*2]	15 V/150 V	Voltage range of the PLZ-4W Series.	p.5-5
		Voltage	0 V to 157.5 V	Sets the CV mode transition voltage of the PLZ-4W Series.	
	Aux DC Load	Output	0 A to 3500 A[*3]	Sets the load current of the external electronic load unit.	p.A-2
	iR Sampling	Position	0.00 ms to 9.99 ms (0.06 ms)	Sampling start position of the current interrupt method	p.5-16
		Region	0.002, 0.006, 0.014, 0.030, 0.062, 0.126, 0.254, or 0.510 ms	Sampling region of the current interrupt method.	
	Protection	UVP Mask Time	0 s to 10 s (4 s)	Sets the time for starting the activation after SENSE UVP is detected.	p.4-12
Correction	Short Correct	None	Disable or Enable	Short-circuit correction function.	p.5-21

Item 1	Item 2	Item 3		Conditions	Description	Page
Judge	GO or NOGO Judge Condition	None		Disable or Enable	Judgement function.	p.5-24
Configuration*4	Interface	Interface Type		GPIB, RS232C, or USB	Interface.	p.4-18
		GPIB	Address	1 to 30 (3)	GPIB address.	
		RS232C	Baudrate	2400, 4800, 9600, or 19200 bps	Baud rate.	
			Data	8 bits or 7 bits	Data length.	
			Stop	1 bit/2 bits	Stop bit.	
			Parity	NONE	Parity.	
			Ack	OFF/ON	Acknowledge message.	
		USB	VID	0x0B3E (display only)	Vendor ID.	
			PID	0x1008 (display only)	Product ID.	
			S/N	xxxx (display only)	Serial number.	
	Alarm	Alarm Status		Lo/Hi	Alarm status output (J1 connector #16 terminal)	p.A-5
	DC Load	Load On Output		Lo/Hi	Load on/off control signal output. (CONTROL TERMINAL #3 terminal)	p.A-3
		Load On Status		Lo/Hi	Load on status output. (J1 connector #13 terminal)	p.A-5
	Aux DC Load	Control		0.00 V to 10.50 V (10.00 V)	Control voltage used to supply the maximum load current of the external electronic load unit.	p.A-2
		Full Scale		0 A to 3500 A (200 A)	Maximum load current of the external electronic load unit.	
	Option	Scanner		Disable/Enable	Scanner (KFM2151) function.	p.A-34
Panel	Beep Volume			0 to 255 (64)	Alarm volume.	p.4-17
	LCD Color			Blue/White	LCD color.	p.4-16
model Info*5	Model			KFM2150	KFM2150 model.	-
	Version			1.1X	KFM2150 firmware version.	
	Serial No.			AB123456 (example)	KFM2150 serial number.	
	PLZ-4W			PLZ1004W (example)	Model of the master unit.	
				AB123456 (example)	Serial number of the master unit.	
				VerX.XX (example)	Firmware version of the master unit.	
				P:2 (example: parallel operation) B:3(example: booster)	Number of parallel units or boosters.	

*1. Channel 2 is used when connecting an external current detector.
*2. You cannot switch the range while the load is turned on.
*3. The selectable maximum value is the value specified by Configuration > Aux DC Load > Full Scale.
*4. Configuration conditions are fixed when you turn the POWER switch off and then turn it back on.
*5. Information about the KFM2150 and the PLZ-4W Series. These items cannot be changed.

5

Impedance Measurement

This chapter describes the impedance measurement and load current settings.

5.1 Impedance Measurement Basics

5.1.1 Running the Load Current

A load is connected to the fuel cell, and the load current is supplied. By changing the load current and measuring the cell voltage, you can determine the current and voltage characteristics as shown in Fig. 5-1. The KFM2150 system uses the PLZ-4W Series Electronic Load Unit to run the load current.

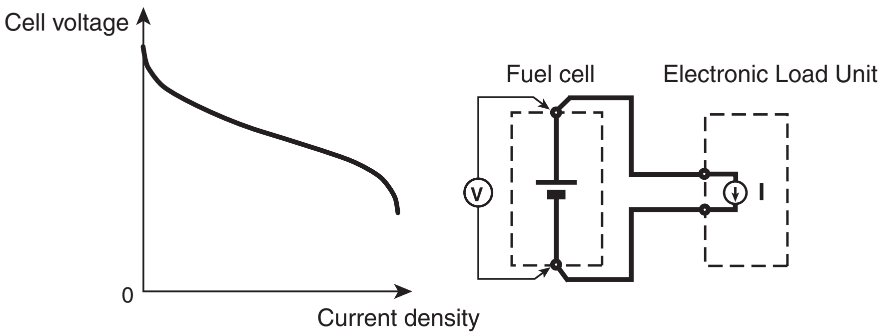


Fig. 5-1 Current and voltage characteristics

5.1.2 Operating Status of the Fuel Cell and Impedance Measurement

Measurement basics

The impedance characteristics are measured by supplying the load current to operate the fuel cell. There are two measurement methods: AC impedance method and current interrupt method.

The measurement is carried out in the load-on period of Fig. 5-2.

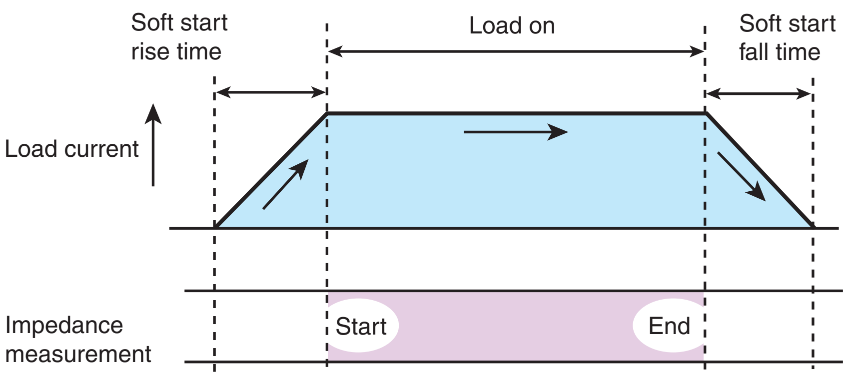


Fig. 5-2 Measurement and the operating status of the fuel cell

Synchronizing to the start and end times of the fuel cell (soft start)

The load current can be gradually increased or decreased to match the start and end times of the fuel cell.

The measuring AC current used to measure the impedance is set as a percentage of the load current. The measuring AC current can also be set as a current value in the AC impedance method.

5.1.3 Impedance Measurement System

System component instruments fixed at the factory

The KFM2150 is shipped with the serial number of the PLZ-4W Series Electronic Load Units registered as system component instruments. The PLZ-4Ws cannot be substitute as a replacement even if they are of the same model.

The combination of the KFM2150 and the PLZ-4W Series is checked at power-on. If it is different from the combination registered at the factory, an error occurs.

Functional assignments of the KFM2150 and PLZ-4W Series

The KFM2150 controls the system. The load current of the fuel cell and impedance measuring AC current flow through the PLZ-4W Series. The current signal is passed from the PLZ-4W Series to the KFM2150. The voltage signal for the impedance measurement enters the KFM2150 directly from the fuel cell.

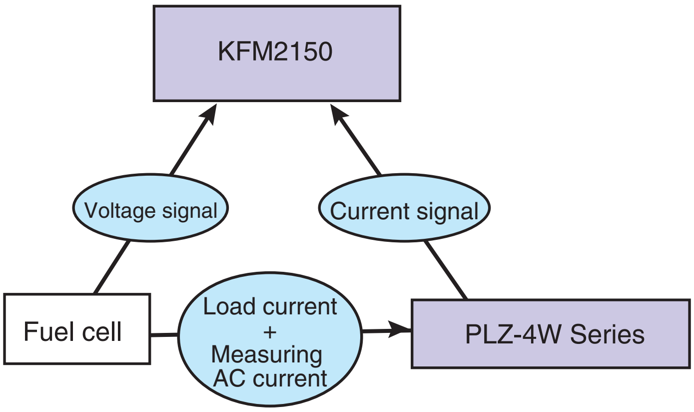


Fig. 5-3 Overview of the functional assignments

5.2 Setting the Load Current

This system operates in CC+CV mode, in which the system automatically switches between CC mode and CV mode. During normal operation, the system operates in CC mode, in which constant current runs independent of the voltage. If constant current can no longer run in CC mode, the system switches to CV mode and prevents overcurrent from flowing by maintaining the preset voltage.

- CC (constant current) mode

  CC mode allows a constant current to be run regardless of the voltage. The current value can be set in detail.

- CV (constant voltage) mode

  CV mode allows current to be run so that the voltage is kept constant. The voltage value can be set in detail.

5.2.1 Setting the Current Range

The selectable range of the load current is determined by the model configuration of the PLZ-4W Series and the current range of the PLZ-4W Series.

Select MENU key > Select Setup > DC Load > Range to select the PLZ-4W range (LOW, MID, or HIGH).

See p.7-2

- Select the range of the PLZ-4W Series for the load current you want to set. The load current that you can set varies depending on the system type. For details, see selectable range (range L, M, and H) in 7.1, “ Basic Performance.”
- LOW, MID, and HIGH in the menu correspond to L, M, and H in 7.1, “ Basic Performance.”
- You cannot switch the range while the load is turned on.

5.2.2 Setting the Current of CC Mode

The fuel cell is run at a given load (CC mode) such as in the I-V characteristics test. Set the measuring AC current used in the AC impedance method to zero.

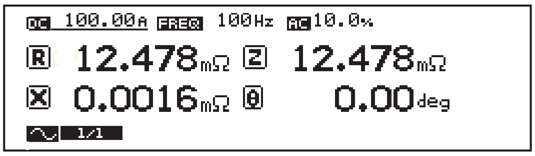


Fig. 5-4 Setting the load current

1 Press the DC key.

The cursor moves to DC on the display.

2 Turn the rotary knob to set the load current.

Use the ▶ or ◀ key to specify the digit.

3 Press the AC key.

The cursor moves to AC on the display.
The unit switches between % and A each time you press the key.

4 Turn the rotary knob to set the measuring AC current to 0 A or 0.0 %.

5.2.3 Setting the CV mode transition voltage

The CV mode transition voltage is set from the menu.

1 Press the MENU key.

The MENU display appears.

2 Press the ▲, ▼, and ▶ arrow keys to move to Setup > DC Load > VRange.

3 Turn the rotary knob to select the voltage range (15 V or 150 V).

4 Press the ▲, ▼, and ▶ arrow keys to move to Setup > DC Load > Voltage.

5 Turn the rotary knob to set the voltage.

The PLZ-4W series setting range is set depending on the VRange setting as follows:

VRange setting	PLZ-4W series setting range
150 V	0 V to 157.5 V
15 V	0 V to 15.75 V

5.3 Turning the Load On/Off (Turning the Load Current On/Off)

The phrase "turn the load on" is to define the supplying load current to the load. The phrase "turn the load off" is to define the shutting off the load current. The soft start function allows the load current to gradually increase when the load is turned on (soft start rising edge) or gradually decrease when the load is turned off (soft start falling edge).

You can turn the load on and off using keys. If a protection function is activated, the load is automatically turned off.

When the load is turned on, impedance measurement is executed. The measurement terminates when the load is turned off.

Four status of the load current

- Load on: The load current is at the preset constant current.
- Load off: No load current flows.
- Soft start rising edge: The load current gradually increases.
- Soft start falling edge: The load current gradually decreases.

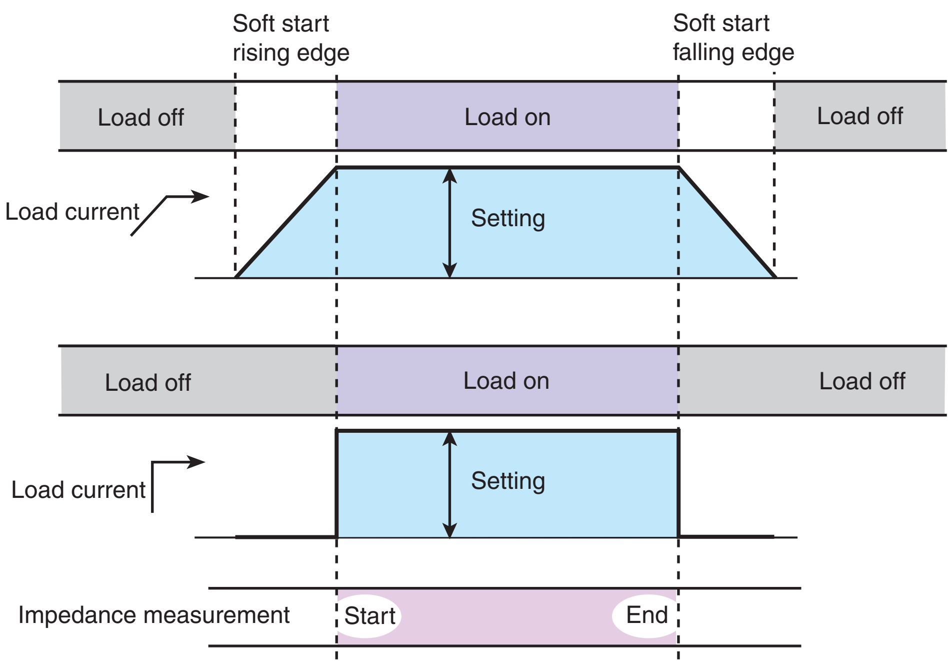


Fig. 5-5 Load current state

Details of soft start

The load current is changed step-wise at 1-s interval (Fig. 5-6). The step current is equal to the load current divided by the soft start time (in unit of seconds).

(Example) When the load current is 60 A and the soft start time is 10 minutes, the step current is 0.1 A.

$$\frac{60\ [\text{minutes}]}{10\ [\text{minutes}] \times 60} = 0.1\ [\text{A}]$$

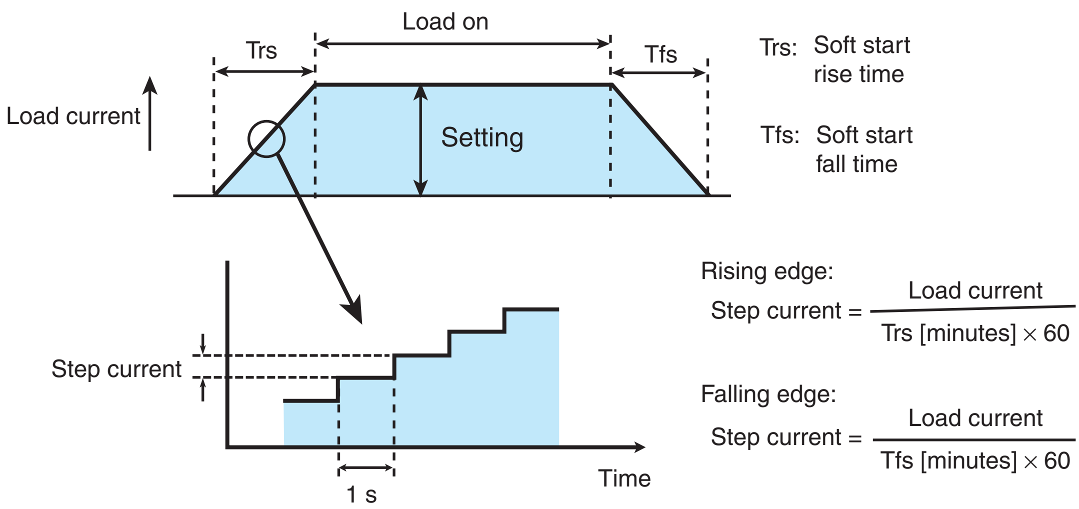


Fig. 5-6 Soft start

Setting the soft start time

The soft start rise time and soft start fall time are set according to the operating characteristics of the fuel cell in advance.

1. Select MENU key > Setup > Soft Start Time > Rise to set the soft start rise time.

   The selectable range is 0 hour 00 minute to 2 hour 00 minute.

2. Select MENU key > Setup > Soft Start Time > Fall to set the soft start fall time.

   The selectable range is 0 hour 00 minute to 2 hour 00 minute.

Impedance measurement

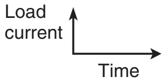
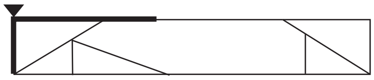
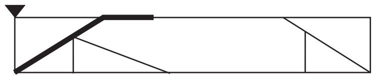
When the load current reaches the preset constant current, the impedance measurement is started. In other words, the measurement is executed when the load is on and terminated when the load is off. The measurement is not executed during the period between the soft start rise time and soft start fall time.

5.3.1 Load On and Soft Start Rising Edge

Table 5-1 indicates the operation and behavior of load on and soft start rising edge.

CAUTION • To turn the load on, be sure that the load current settings, connection to the fuel cell, polarity, wire selection, and the other settings are correct.

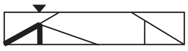
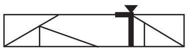
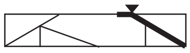
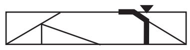
Table 5-1 Load on and soft start rising edge operation

▼ Operation timing 		Load on 	Soft start rising edge 
Condition immediately before the operation	Load current	Zero	
	LOAD LED	Off	
Operation		Press the LOAD key.	Press the SOFT START (SHIFT+LOAD) key.
Behavior or condition immediately after the operation	Load current	The load turns on immediately.	Gradually increases from zero.
	LOAD LED	On	Blinking
	Time display	None	Shows on the display the remaining time until the preset load current is reached.
Load on period	LOAD LED	On	
	Time display	None	

5.3.2 Load Off and Soft Start Falling Edge

Table 5-2 indicates the operation and behavior of load off and soft start falling edge.

Table 5-2 Load off and soft start falling edge operation

▼ Operation timing Load current / Time 		Load off during soft start falling edge 	Soft start falling edge during soft start rising edge 	Load off 	Soft start falling edge 	Load off during soft start rising edge 
Condition immediately before the operation	Load current	Gradually increases from zero.		Operating at the specified load current.		Gradually decrease.
	LOAD LED	Blinking		On		Blinking
	Time display	Shows on the display the remaining time until the preset load current is reached.		None		Shows on the display the remaining time until the load current falls to zero.
Operation		Press the LOAD key.	Press the SOFT START (SHIFT+LOAD) key.	Press the LOAD key.	Press the SOFT START (SHIFT+LOAD) key.	Press the LOAD key.
Behavior or condition immediately after the operation	Load current	The load turns off immediately.	Gradually decrease.	The load turns off immediately.	Gradually decrease.	The load turns off immediately.
	LOAD LED	Off	Blinking	Off	Blinking	Off
	Time display	None	Shows on the display the remaining time until the load current falls to zero.	None	Shows on the display the remaining time until the load current falls to zero.	None
Load off period	LOAD LED	Off				
	Time display	None				

5.3.3 Protection Function and Load Off

When the following protection functions are activated, the KFM2150 turns the load off.

See p.4-8

- Overvoltage protection (PLZ4W OVP)
- Undervoltage protection (PLZ4W UVP)
- Reverse connection protection (PLZ4W REV)
- Overheat protection (PLZ4W OHP)
- Alarm input detection (USER)
- Voltage sensing undervoltage protection (SENSE UVP)

5 Impedance Measurement

5.4 AC Impedance Method

Select the AC impedance method from the two available impedance measurement methods (AC impedance and current interrupt methods). The measurement method can be switched regardless of whether the load is turned on/off.

The settings required for the measurement are the frequency and value of the measuring AC current.

You can set the measurement conditions of the AC impedance method and switch to the AC impedance method while measurement is in progress using the current interrupt method. The new measurement conditions are activated when the measurement method is switched.

The load current maintains the previous setting even if the measurement method is switched.

Measurement items

R	Resistance
X	Reactance
Z	Absolute value of the impedance
θ	Phase angle
Vcycle	Measured voltage (voltage synchronized to the impedance measurement)
Icycle	Load current (current synchronized to the impedance measurement)
V	Measured voltage (voltage measured at a fixed cycle of the voltmeter)
I	Load current (current measured at a fixed cycle of the ammeter)

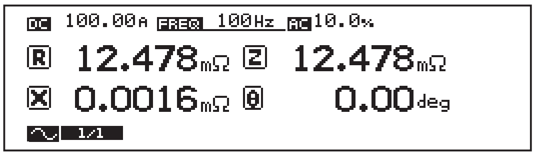


Fig. 5-7 Setup display of the AC impedance method

Frequency and value of the measuring AC current

Fig. 5-8 shows a conceptual diagram of the frequency (FREQ) and value (AC) of the measuring AC current. Because the percentage with respect to the load current takes precedence for the measuring AC current, changing the load current also changes the measuring AC current. Even when an absolute value is used to set the measuring AC current, it is stored as a percentage in the KFM2150.

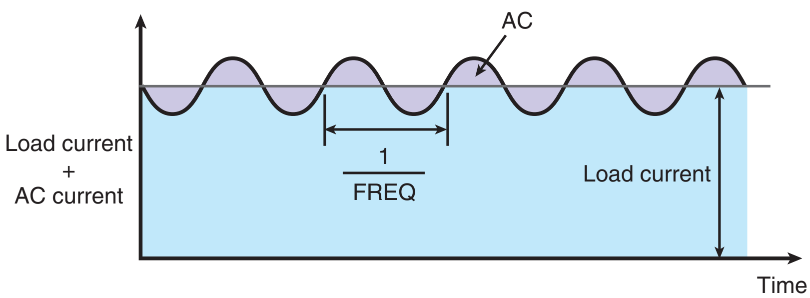


Fig. 5-8 Measuring AC current

5.4.1 Selecting the measurement method

■ When the load is turned off

Press the METHOD key to select ∿ .

It is selected for the AC impedance method. By pressing the METHOD key, it switches between AC impedance method (∿) and current interrupt method (⊔⊓). The LED of the selected method is illuminated.

■ When the load is turned on

1 Press the METHOD key.

A confirmation of (METHOD CHANGE?) is appeared on the display. Check that it is okay to change the measurement method.

2 Press the ENTER key.

It is selected the measurement method.

NOTE

- The confirmation display (METHOD CHANGE?) appears even during the soft start rise time or soft start fall time.

5.4.2 Setting the measuring frequency

1 Press the FREQ key.

The cursor moves to FREQ on the display.

The cursor moves to FREQ also when using the current interrupt method.

2 Turn the rotary knob to set the measuring frequency.

You can select from the frequencies that result by multiplying the values in column A by the values in column B.

A	B
1.00, 1.26, 1.58, 2.00, 2.51, 3.00, 3.16, 4.00, 5.00, 6.00, 6.30, 7.00, 8.00, 9.00	×10 mHz, ×100 m Hz, ×1 Hz, ×10 Hz, ×100 Hz, ×1 kHz, ×10 kHz

The lower and upper limits are 10 mHz and 20 kHz, respectively.

Turn the rotary clockwise to increase the value and counterclockwise to decrease the value.

NOTE

- When the measuring frequency is low (less than or equal to 1 Hz), the interval for updating the display is longer. The measured result of impedance varies depending on the measuring frequency. The display update interval is approximately equal to the interval of the measuring frequency.

5.4.3 Setting the Load Current

Set the load current to a value for operating the fuel cell under constant load. Changing the load current changes the measuring AC current. The percentage of the load current takes precedence for the measuring AC current.

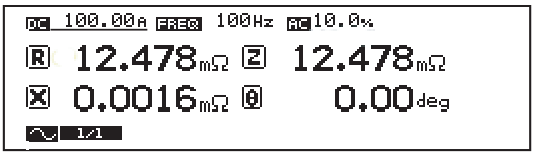


Fig. 5-9 Setting the load current

1 Press the DC key.

The cursor moves to DC on the display.

2 Turn the rotary knob to set the load current.

Use the ▶ or ◀ key to specify the digit.
The selectable range of the load current is determined by the model configuration and the current range of the PLZ-4W Series. The current range on the PLZ-4W Series is set using MENU key > Setup > DC Load > Range.

5.4.4 Setting the Measuring AC Current

There are two methods for setting the measuring AC current. The current value is an rms value in either method.

- Set as a percentage of the load current (AC-%)

  Select AC-%.

  Set the current in the range of 0.0 % to 10.0 % of the load current.

- Set the measuring AC current directly (AC-A)

  Select AC-A.

  The current value that you can set is a value in the range corresponding to 0.0 % to 10.0 % of the load current.

1 Press the AC key.

The cursor moves to AC on the display.
The unit switches between % and A each time you press the key.

2 Turn the rotary knob to set the measuring AC current.

NOTE

- You can set the measuring AC current in the range of 0.0 % to 10.0 % of the load current. If the measuring AC current (AC-%) is set to 10 %, the maximum load current at which 10 % can be maintained is approximately 87 % of the rated load current of the PLZ-4W.

■ Measuring AC current as a percentage of the load current

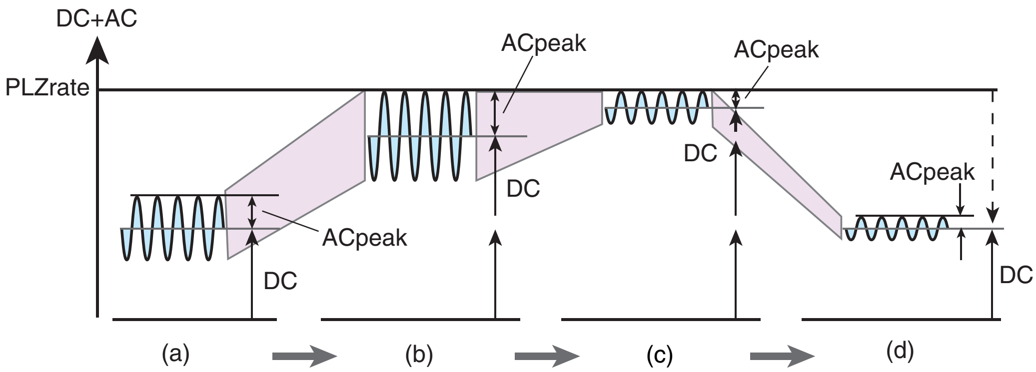
Set the measuring AC current as a percentage of the load current. The percentage is held constant. However, the ratio changes in the following condition.

- When the sum of the load current and the measuring AC current exceeds the rated load current of the PLZ-4W Series (Fig. 5-10 (c)).

The load current setting takes precedence in the above condition. When the load current is increased, the measuring AC current is decreased so that the sum of the load current and the peak value of the measuring AC current is equal to the rated load current of the PLZ-4W Series. Therefore, the measuring AC current that you specified as a percentage of the load current decreases (Fig. 5-10 (c).

If you decrease the load current in this condition, the decreased percentage does not return to the original value (Fig. 5-10 (d)).

You can reset the decreased percentage back to the original value.



DC: Load current
AC-Apeak: Peak value of AC-A
PLZrate: Rated load current of the PLZ-4W Series

Fig. 5-10 Relationship between the measuring AC current and load current

Table 5-3 Relationship between the measuring AC current and load current (example when PLZrate = 200 A)

Fig. 5-10	(a)	➜	(b)	➜	(c)	➜	(d)
Load current and measuring AC current	(DC+AC-Apeak) < PLZrate		(DC+AC-Apeak) = PLZrate		(DC+AC-Apeak) > PLZrate		(DC+AC-Apeak) < PLZrate
DC	100 A	Increase	175.4 A	Increase	190 A	Decrease	100 A
AC-%*1	10 %	Fixed	9.9 %	Change, limit, and store the limit*2	3.7 %*3	Limit*4	3.7 %*5
AC-A*6	10 Arms	Change	17.36 Arms	Change	7.03 Arms	Change	3.7 A

*1. AC-%: Rms measuring AC current as a percentage of the load current
*2. When the sum of the load current and the measuring AC current exceeds the rated load current of the PLZ-4W Series, the sum of the load current and the peak value of the measuring AC current is limited to the rated load current of the PLZ-4W Series. In this condition, the load current setting takes precedence, and the measuring AC current decreases. The percentage with respect to the load current changes.
*3. The percentage with respect to the load current changes from the specified 10 % to 3.7 %.
*4. If you decrease the load current, the decreased percentage does not return to the original value.
*5. The value 3.7 % maintained.
*6. AC-A: Measuring AC current as an rms current value.

5.5 Current Interrupt Method

Select the "current interrupt method" from the two available impedance measurement methods (AC impedance and current interrupt methods). The measurement method can be switched regardless of whether the load is turned on/off.

The settings required for the measurement are the pulse width, depth, and transition time (rise and fall time) of the interrupt current.

You can set the measurement conditions of the current interrupt method and switch to the current interrupt method while measurement is in progress using the AC impedance method. The new measurement conditions are activated when the measurement method is switched.

The load current maintains the previous setting even if the measurement method is switched.

Measurement items

IR	Internal resistance
Vcycle	Measured voltage (voltage synchronized to the impedance measurement)
Icycle	Load current (current synchronized to the impedance measurement)
V	Measured voltage (voltage measured at a fixed cycle of the voltmeter)
I	Load current (current measured at a fixed cycle of the ammeter)

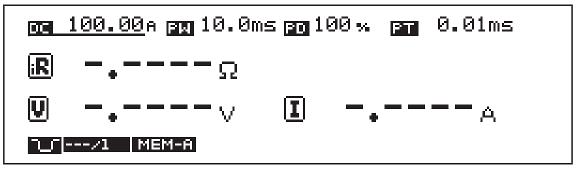


Fig. 5-11 Setup display of the current interrupt method

Pulse width, depth, and transition time of the interrupt current

Fig. 5-12 shows a conceptual diagram of the pulse width (PW), depth (PD), and transition time (PT) of the interrupt current that changes as a pulse. The repetition period of the pulse (T) is fixed to 100 ms.

Because the percentage with respect to the load current takes precedence for the pulse width, changing the load current also changes the pulse depth.

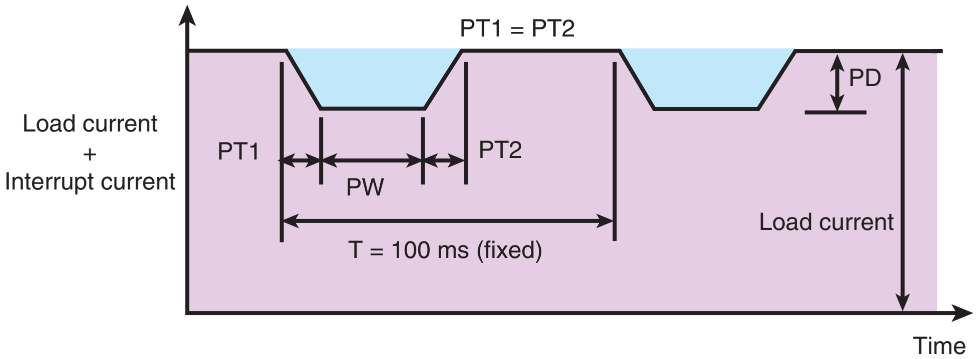


Fig. 5-12 Interrupt current pulse

Sampling (current interrupt method)

To obtain stable measurement results, set the sampling start position (Position: time from interrupt start) and the sampling region (Region).

5.5.1 Selecting the Measurement Method

■ When the load is turned off

Press the METHOD key to select ⊔ .

It is selected for the current interrupt method. By pressing the METHOD key, it switches between AC impedance method (∿) and current interrupt method (⊔). The LED of the selected method is illuminated.

■ When the load is turned on

1 Press the METHOD key.

A confirmation of (METHOD CHANGE?) is appeared on the display. Check that it is okay to change the measurement method.

2 Press the ENTER key.

It is selected the measurement method.

NOTE

- The confirmation display (METHOD CHANGE?) appears even during the soft start rise time or soft start fall time.

5.5.2 Setting the Pulse Width

1 Press the WIDTH key.

The cursor moves to PW on the display.

2 Turn the rotary knob to set the pulse width (0.1 ms to 10.0 ms).

5.5.3 Setting the Pulse Depth

There are two methods for setting the pulse depth.

- Set as a percentage of the load current (PD-%)

  Select PD-% to set the current value of the pulse depth in the range of 0 % to 100 % of the load current.

- Set the current value of the pulse depth directly (PD-A)

  Select PD-A to set the current value of the pulse depth directly.

1 **Press the DEPTH key.**

The cursor moves to PD on the display.
The unit switches between % and A each time you press the key.

2 **Turn the rotary knob to set the pulse width.**

5.5.4 Setting the Pulse Transition Time

1 **Press the TRNSN key.**

The cursor moves to PT on the display.

2 **Turn the rotary knob to set the pulse transition time (0.01 ms to 10.00 ms).**

NOTE

- The lower limit of the selectable range may be limited to a value greater than 0.01 ms. If the pulse transition time exceeds 0.01 ms depending on the relationship between the specified pulse depth, load current, and the slew rate of the PLZ-4W Series, the lower limit of the selectable range is set to a value greater than 0.01 ms.

5.5.5 Setting the Sampling

Internal resistance IR is determined by computation using the values measured according to the specified sampling start position (Position) and sampling region (Region).

Set the sampling start position and sampling region from the menu.

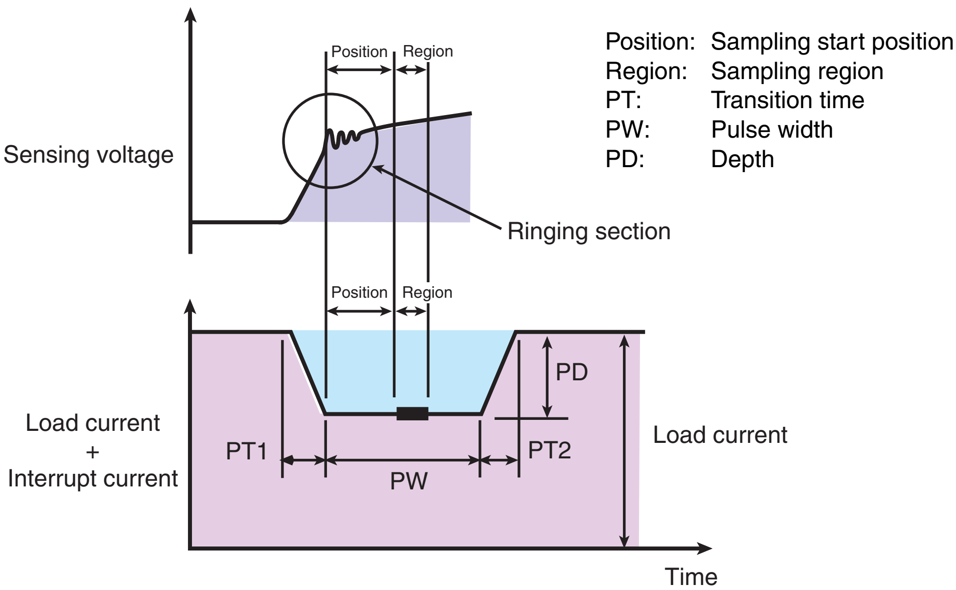


Fig. 5-13 Sampling start position and region

■ Sampling start position

Select MENU key > Setup > iR Sampling > Position to set the sampling start position.

Position specifies the time from when the pulse transition time has elapsed since the interrupt start till when sampling is started. As shown in Fig. 5-13, set the position so that the ringing section after the pulse transition time is avoided.

The selectable range is 0.00 ms to 9.99 ms. It is the time from the start point of the pulse change.

■ Sampling region

Select MENU key > Setup > iR Sampling > Region to set the sampling region.

Region specifies the time from the sampling start point till when sampling is finished. Set the region according to the time constant of the fuel cell. The selectable range is the following eight points (ms unit).

0.002, 0.006, 0.014, 0.030, 0.062, 0.126, 0.254, or 0.510

Detailed explanation of sampling

See p.A-30

An example regarding the pulse transition time (PT), sampling start position, and sampling region is given in the appendix.

5.5.6 Setting the Load Current

Set the load current to a value for operating the fuel cell under constant load. Changing the load current changes the pulse depth of the interrupt current. The percentage with respect to the load current takes precedence for the pulse width of the interrupt current.

The selectable range of the pulse transition time may be limited depending on the relationship between the response speed of the PLZ-4W Series and the load current.

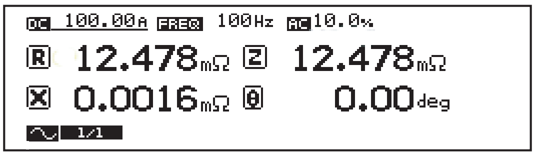


Fig. 5-14 Setting the load current

1 Press the DC key.

The cursor moves to DC on the display.

2 Turn the rotary knob to set the load current.

Use the ▶ or ◀ key to specify the digit.
The selectable range of the load current is determined by the model configuration and the current range of the PLZ-4W Series. The current range on the PLZ-4W Series is set using Menu key > Setup > DC Load > Range.

5.6 Setting the Average Count

The measured value of the KFM2150 is averaged by the specified count (moving average).

■ Measurement items that can be averaged

AC impedance method: Resistance, reactance, magnitude of the impedance, phase angle, voltage (impedance measurement cycle), and load current (impedance measurement cycle).

Current interrupt method: Internal resistance, voltage (impedance measurement cycle), and load current (impedance measurement cycle).

1 Press the AVE key.

A setup window appears.

2 Turn the rotary knob to set the average count.

The selectable average counts are 1, 2, 4, 8, 16, 32, 64, 128, or 256.

3 Press the AVE key.

The setup window closes.

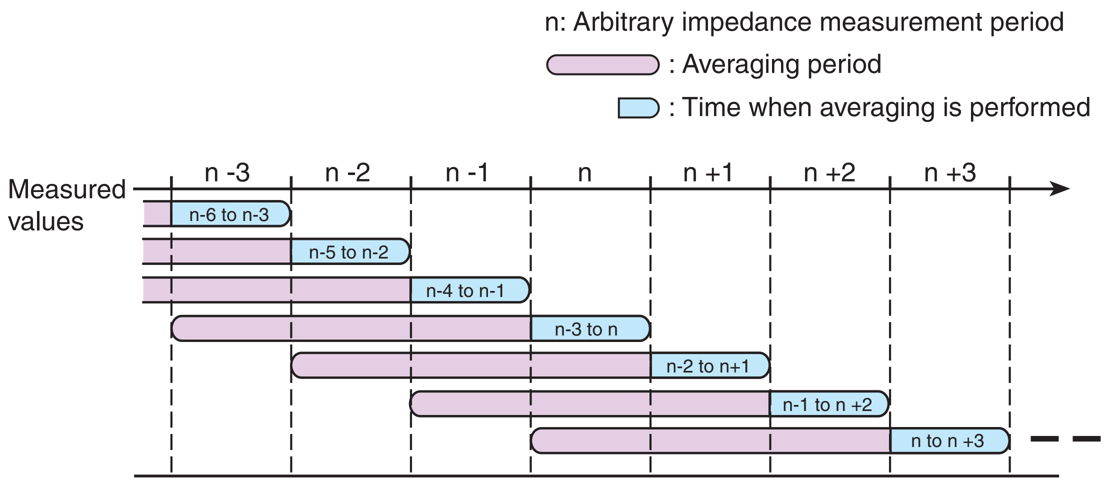


Fig. 5-15 When the average count is set to 4

5.7 Displaying the Measured Results

You can select the items to be shown on the display and their positions.

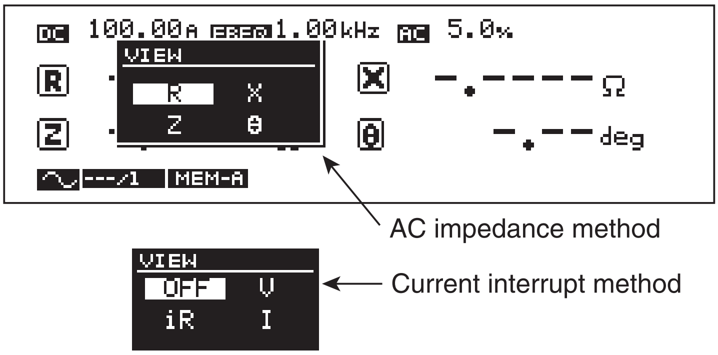


Fig. 5-16 Display setup window

Selecting the items to be displayed and their positions

1 Press the VIEW key.

The display setup window (Fig. 5-16) appears according to the current measurement method.

2 Select the display position using the cursor keys.

3 Turn the rotary knob to select the displayed item.

Table 5-4 shows the displayed items.

4 Press the VIEW key.

The display setup window closes.

Table 5-4 Displayed items

Displayed item		Description
OFF		No display.
AC impedance method	R	Resistance.
	X	Reactance.
	Z	Absolute value of the impedance.
	θ	Phase angle.
Current interrupt method	IR	Internal resistance.
Vcy (Vcycle)		Measured voltage (voltage synchronized to the impedance measurement).
Icy (Icycle)		Load current (current synchronized to the impedance measurement).
V		Measured voltage (voltage measured at a fixed cycle of the voltmeter).
I		Load current (current measured at a fixed cycle of the ammeter).

Difference between Vcycle/ Icycle and V/ I

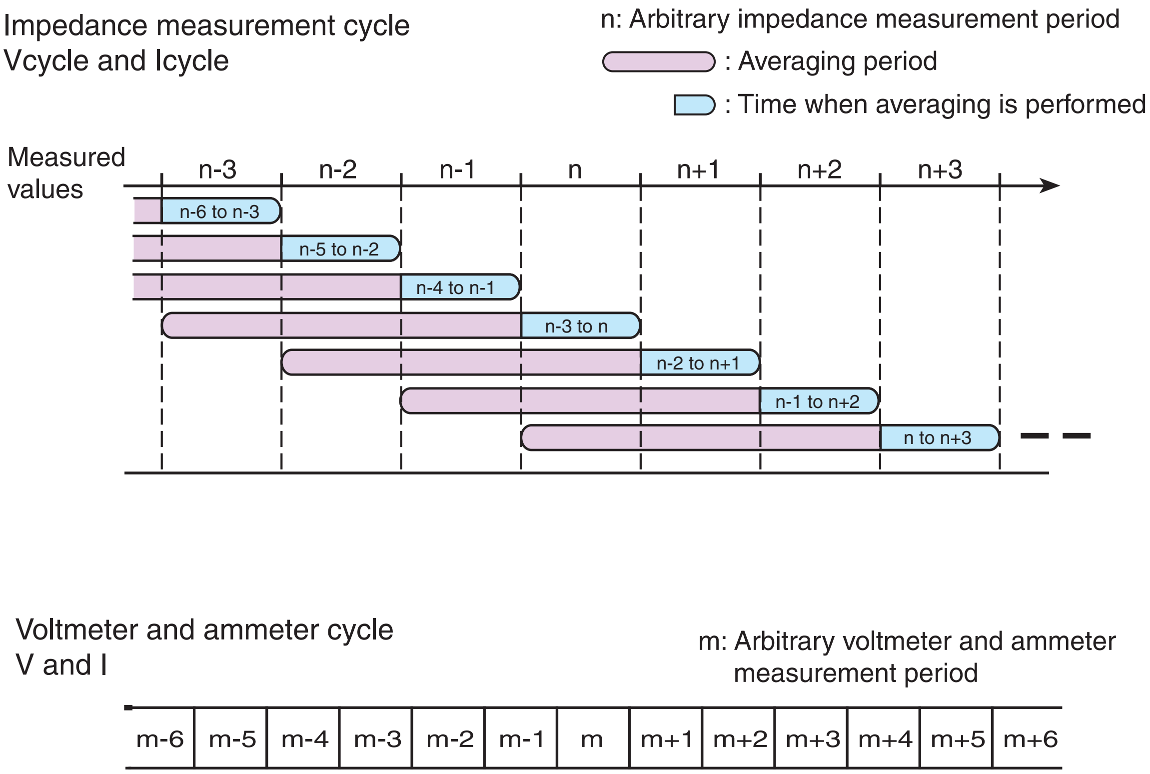


Fig. 5-17 Measurement cycle

Measured results of the scanner system

For a scanner system that incorporates the KFM2151 FC Scanner, a scanner display ( ) is shown as in Fig. 5-18. The voltage signal that the KFM2150 receives from the KFM2151 is processed internally and used in the impedance and voltage measurements.

As a result, the measurement accuracy of the displayed items of Table 5-4, is the sum of the basic measurement accuracy of the KFM2150 and the value specified in the KFM2151 specifications.

However, the value specified in the KFM2151 specifications is not added for Icycle and I, because they are not received from the KFM2151.

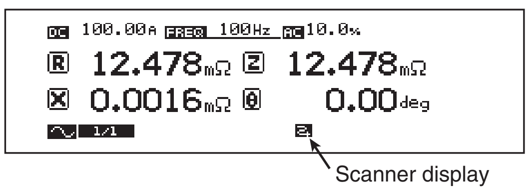


Fig. 5-18 Scanner display

5.8 Short-Circuit Correction Function

The short-circuit correction is a function used in the AC impedance method.

The KFM2150 can measure minute impedance. The measured result is affected by the wiring impedance in the connection of the PLZ-4W Series and the fuel cell. The short-circuit correction function is available to minimize this effect.

The short-circuit correction function is set on the menu display.

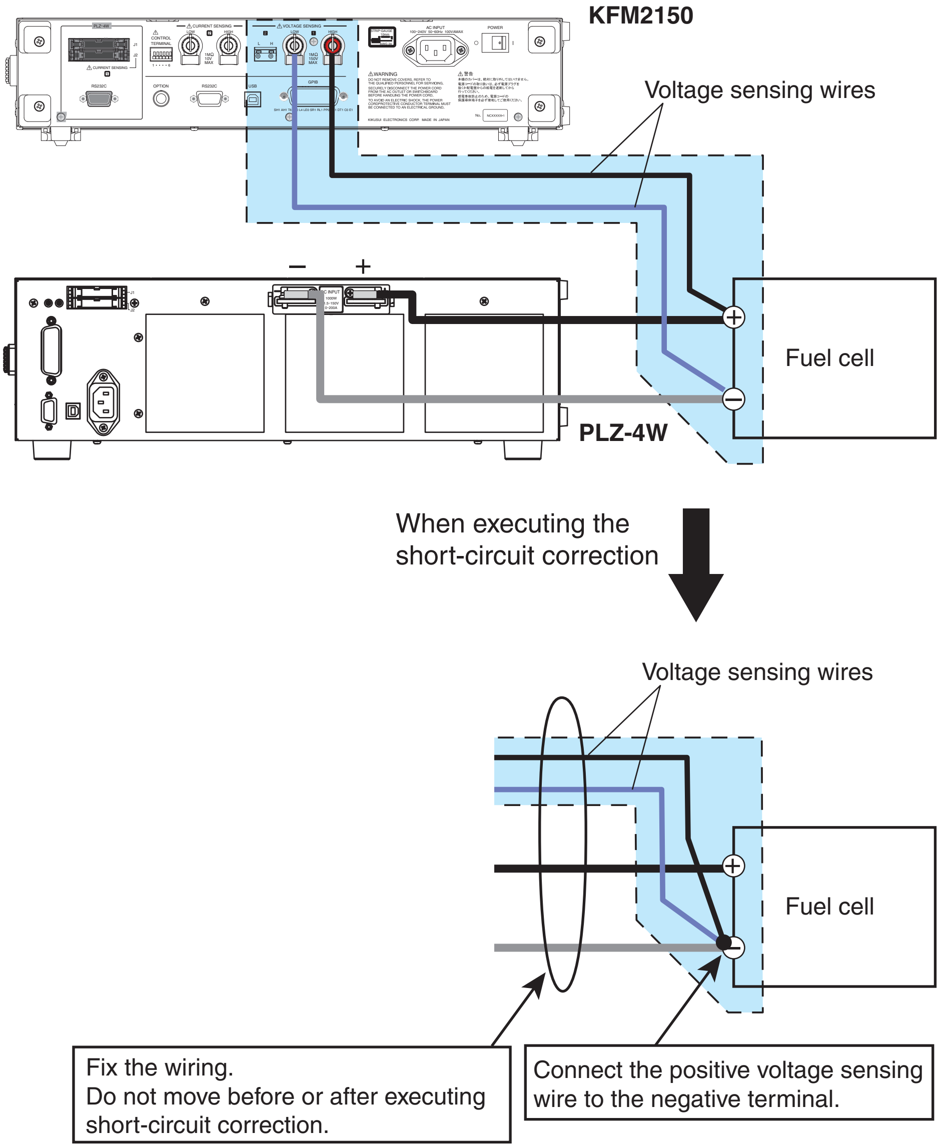


Fig. 5-19 Shorting the voltage sensing wires

CAUTION
- The short-circuit correction function is carried out during measurement. When turning the load on, be sure that the load current settings, connection to the fuel cell, polarity, wire selection, and the other settings are correct.

1 **Press the LOAD key to turn the load off.**

The LOAD LED turns off.

2 **Check the wiring of the impedance measurement system.**

The physical conditions of the measurement system including the current wiring affect the result of the short-circuit correction.

3 **Disconnect the voltage sensing wire connected to the positive terminal of the fuel cell.**

4 **Connect the voltage sensing wire that you removed to the negative terminal of the fuel cell.**

Only move the voltage sensing wire between these terminals. Do not move other wires.

5 **Press the METHOD key to select ∿ .**

The measurement method switches to AC impedance.

See p.5-10, p.5-4

6 **Set the measuring AC current and load current.**

7 **Press the LOAD key.**

The load turns on, and the LOAD LED illuminates.

8 **Press the MENU key and then the ▲, ▼, and ▶ arrow keys to move to Correction > Short Correct.**

9 **Turn the rotary knob to select Enable, and then press the ENTER key.**

The short-circuit correction starts. When the operation is completed, the display shows "COMPLETED." If the operation cannot be started, the display shows "CANCELED.".

If you want to execute the short-circuit correction again, press the ENTER key.

10 **Press the MENU key.**

The MENU display closes. "SC" (Fig. 5-20) is displayed in the bottom section of the display. This indicates that the short-circuit correction function is enabled.

11 **Press the LOAD key.**

The load turns off, and the LOAD LED turns off.

12 **Disconnect the voltage sensing wire that you connected in step 4 , and connect it to the positive terminal of the fuel cell.**

Be sure to move only the voltage sensing wire of the positive terminal. Otherwise, the actual correction value will be invalid. If you accidentally move other wires, redo the procedure from step 1 .

⚠ **CAUTION**
- Connect the voltage sensing wires from the positive and negative terminals of the fuel cell to the HIGH and LOW VOLTAGE SENSING terminals, respectively.

---

13 **Press the LOAD key.**

The load turns on, and the measurement starts.

The display shows the resultant value of the short-circuit correction.

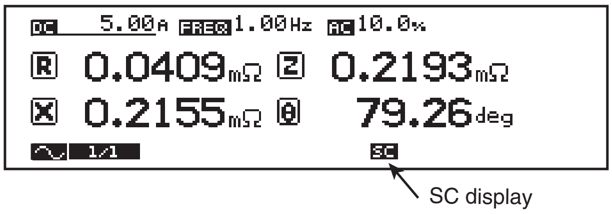


Fig. 5-20 SC display

NOTE

- If you change the measuring AC current or the load current, the actual correction value will be invalid. In this case, the short-circuit correction function is automatically canceled, and the “SC” indication shown at the bottom section of the display clears. To continue using the short-circuit correction function, redo the procedure from step 1 .
- The current correction value will be invalid also when the physical conditions of the measurement system including the wiring change. In this case, the KFM2150 cannot detect the change in the wiring condition, and the “SC” indicator remains displayed. To continue using the short-circuit correction function with a valid correction value, redo the procedure from step 1 .
- If you are not using the short-circuit correction function, select Disable for MENU key > Correction > Short Correct.

5.9 Judgement Function

You can set upper and lower limits with respect to a reference value (an arbitrary measured value assigned to be the reference) and judge whether the measured values are within the range (window). The values of upper and lower limits are moved above and below the reference value by the same amount (Fig. 5-21).

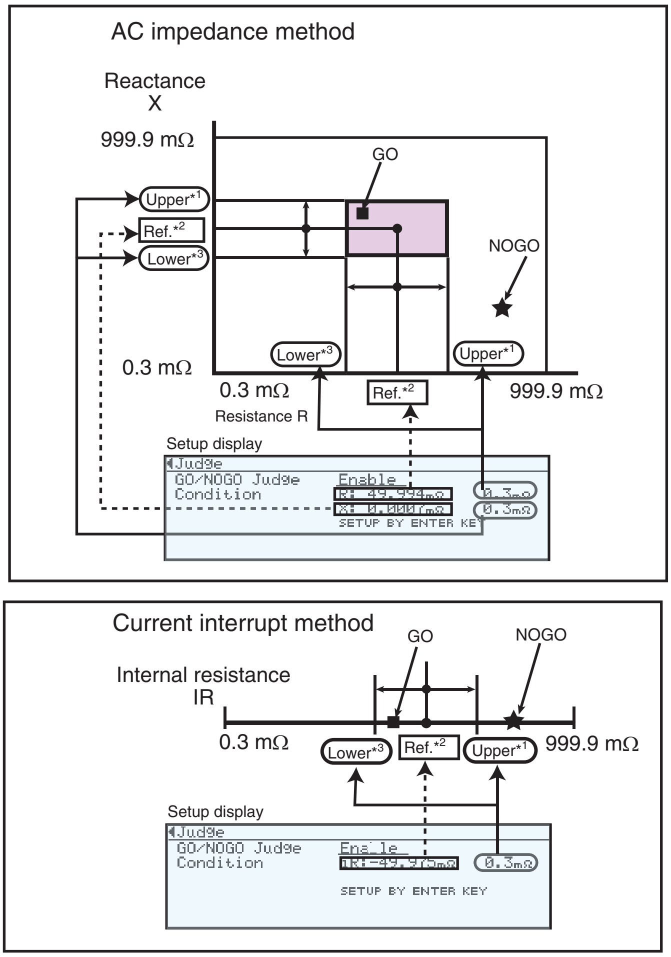
If the judgement function is enabled, the judgement result is shown as GO or NOGO at the bottom section of the display.

■ AC impedance method

Set the window consisting of the upper and lower limits of resistance R and reactance X. “GO” is displayed when the measured value is within the window and “NOGO” otherwise.

■ Current interrupt method

Set the window consisting of the upper and lower limits of internal resistance IR. “GO” is displayed when the measured value is within the window and “NOGO” otherwise.



*1 Upper limit
*2 Reference value
*3 Lower limit

Fig. 5-21 GO/NOGO judgement window

⚠CAUTION
- Make sure to set the upper and lower limits of the judgement function while the measurement is in progress. Before turning the load on, be sure that the load current settings, connection to the fuel cell, polarity, wire selection, and the other settings are correct.

Enabling the judgement function and judging the measurement results

1. Press the METHOD key to select ∿ (AC impedance method) or ⊔⊓ (current interrupt method).

   The LED of the selected method illuminates, and the measurement method switches.

2. Press the LOAD key.

   The load turns on, and the LOAD LED illuminates.
   The measured values are displayed.

3. Press the MENU key and then press the ▲, ▼, and ▶ arrow keys to move to Judge > GO/NOGO Judge Condition.

4. Turn the rotary knob to select Enable, and then press the ENTER key.

   The measured values of resistance R and reactance X are sampled as reference values in the case of the AC impedance method. Internal resistance IR is sampled as a reference value in the case of the current interrupt method.

NOTE
- When the measuring frequency is low (less than or equal to 1 Hz) or when the average count is increased, the interval for updating the display is longer. Be sure to wait sufficient time after changing the measurement method to sample the reference values.

5. Press the ▼ arrow key to move the cursor to the upper and lower limits.

6. Turn the rotary knob to set the upper and lower limits.

   Use the ▶ or ◀ key to specify the digit. The upper and lower limits cannot be set individually. The selectable range is from 0.3 mΩ to 999.9 mΩ.

AC impedance method

Set the upper and lower limits of resistance R and reactance X.

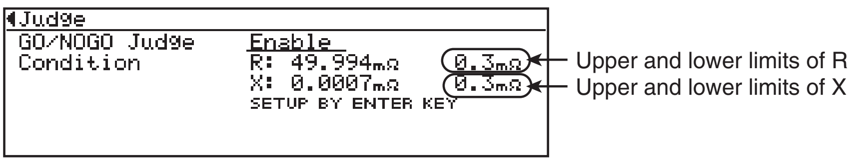


Fig. 5-22 Setting the upper and lower limits (AC impedance method)

Current interrupt method

Set the upper and lower limits of resistance IR.

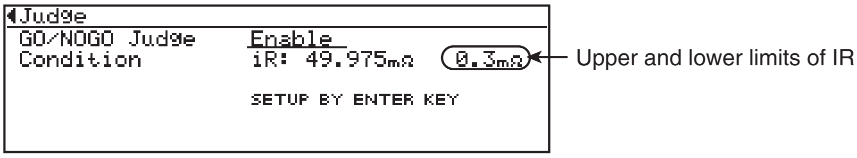


Fig. 5-23 Setting the upper and lower limits (current interrupt method)

7 Press the MENU key to return to the measurement.

The MENU display closes.

The judgement result is shown on the display until you disable the judgement function.

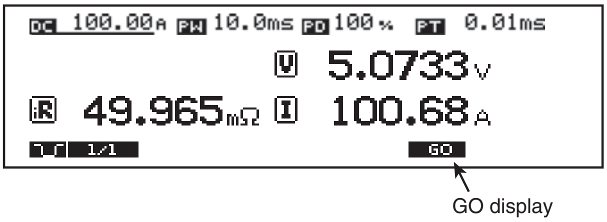


Fig. 5-24 Judgement result example

Disabling the judgement function

1 Press the MENU key.

The MENU display appears.

2 Press the ▲, ▼, and ▶ arrow keys to move to Judge > GO/NOGO Judge Condition.

3 Turn the rotary knob to select Disable.

NOTE

- The judgement function is disabled both for the AC impedance and current interrupt methods. You cannot disable the judgement function for one method and not the other.

6

Maintenance

This chapter describes maintenance of the KFM2150 including cleaning, inspecting, calibrating, and troubleshooting.

6.1 Cleaning and Inspection

Periodic cleaning and inspection are essential to maintain the initial performance of the KFM2150 system over an extended period.

⚠WARNING

- **There is a possibility of death or injury from electric shock. Be sure to turn off the POWER switch and remove the power cord plug before performing maintenance work.**

Cleaning the panels

If the panel needs cleaning, gently wipe the panel using a soft cloth with water-diluted neutral detergent.

⚠CAUTION

- Do not use volatile chemicals such as benzene or thinner as they may discolor the surface, erase printed characters, cloud the display, and so on.

Inspecting the Power Cord

Check the power cord for breaks in the insulation and cracks or rattling of the plug.

⚠WARNING

- **Tears in the insulation coating of the power cord may cause electric shock or fire. If a tear is found, stop using it immediately.**

Replacing the backup battery

The KFM2150 backs up panel settings with the internal battery even when the power is turned off. If the panel settings are different at the time the power is turned off and at the time the power is turned on again, the battery is already dead.

The battery life depends on the operating conditions. It is estimated about three years after the purchase. For battery replacement, contact your Kikusui agent or distributor.

6.2 Calibration

The KFM2150 system is shipped after carrying out appropriate calibrations. We recommend periodic calibration to maintain the performance over an extended period.

The KFM2150 and the PLZ-4W Series are calibrated at the factory as a single system. Therefore, the PLZ-4W Series must also be calibrated simultaneously. For details, contact your Kikusui agent or distributor.

⚠CAUTION • Do not alter the variable resistor of the EXT CONT section on the PLZ-4W Series. There is a sticker attached to the variable resistor to prevent accidental operation. Altering the variable resistor will invalidate the calibration of the impedance measurement system.

6.3 Troubleshooting

This section introduces troubleshooting measures. Typical symptoms are listed. Check whether any of the items below apply to your case. In some cases, the problem can be solved quite easily.

If the remedy does not solve the problem or if your case does not match any of the items, contact your Kikusui agent or distributor..

The KFM2150 system does not power up.

Symptom	Check Items	Remedy	See Page
The KFM2150 system does not operate when the POWER switch is turned on.	• Is the power cord disconnected from the power outlet? • Is the power cord inserted correctly into the AC INPUT connector on the rear panel?	• Connect the power cord correctly. • Power up the instruments in the correct order.	4-2
Response error occurs displaying the message “PLZ NO RESPONSE.”	• Is the wiring of the impedance measurement system correct?	• Wire the impedance measurement system correctly including the PLZ-4W Series.	4-2 4-16
System connection error occurs, and all the numeric displays are invalid (indicates “–”).	• Was the system powered up correctly? • Are there system component instruments that are not turned on?	• Power up the instruments in the correct order.	4-2
System configuration error occurs displaying the message “PLZ FORMATION.”	• Are the system component instruments correct? • Are the serial numbers of the system component instruments correct?	• Connect the correct system component instruments.	4-2

Keys operation do not work correctly.

Symptom	Check Items	Remedy	See Page
Panel key operations are not functioned.	• Is LOCK shown in the status display?	• The panel operation is locked. Press the LOCK (SHIFT+LOCAL) key to release the lock.	4-16
	• Is the RMT LED illuminated?	• The KFM2150 system is being remotely controlled via the external interface. Press the LOCAL key to release remote control.	4-16

The KFM2150 system does not operate according to the settings. The measured values are unstable.

Symptom	Check Items	Remedy	See Page
The current does not flow immediately when the load is turned on.	• Is the soft start rising time shown in the status display?	• This is a normal behavior. The current will be set to the preset load current when the soft start rising time reaches zero.	5-8
The current is not cut off immediately when the load is turned off.	• Is the soft start falling time shown in the status display?	• This is a normal behavior. The load current will be set to zero when the soft start rising time reaches zero.	5-9
The settings entered from the menu are not applied.	• Did you turn off the POWER switch after changing the settings?	• Turn off the POWER switch after you change the settings. The settings are applied when the power is turned back on.	4-26
The measured values are unstable.	• Is there a large loop in the sensing wire?	• Twist the wires.	A-14
	• Is the CV mark shown in the display? • Is the fuel cell voltage low?	• The KFM2150 switched from CC mode to CV mode. Decrease the load current.	4-10
The load turns off.	• Is the fuel cell voltage low?	• The undervoltage protection (PLZ4W UVP) is activated. Check the fuel cell.	4-12
	• Is the fuel cell voltage high?	• The overvoltage protection (PLZ4W OVP) is activated. Check the fuel cell.	
	• Is the polarity of the wiring to the fuel cell reversed?	• The reverse connection protection (PLZ4W REV) is activated. Check the fuel cell wiring.	
	• Is the air outlet of the PLZ-4W Series blocked?	• The overheat protection (PLZ4W OHP) is activated. Allow at least 20 cm between the air outlet and the wall. Do not place objects within 20 cm.	PLZ-4W Series Operation Manual
	• Is the dust filter of the PLZ-4W Series clogged?	• The overheat protection (PLZ4W OHP) is activated. Clean the dust filter.	
	• Is the voltage at the fuel cell sensing point low?	• The voltage sensing undervoltage protection (SENSE UVP) is activated. Check the fuel cell.	4-12

7

Specifications

This chapter describes the specifications of the KFM2150 system.

Unless specified otherwise, the following specifications are based on the setting and conditions

- Warm-up time: 30 minutes (with current flowing).
- Temperature: 20 °C to 30 °C
- Humidity: 20 %rh to 85 %rh
- typ: A typical value. It does not guarantee the performance.
- rdng: Indicates the read value.
- rng: Indicates the range value.
- f.s: Full scale

7.1 Basic Performance

Bench top type

System model			KFM2150 SYSTEM 165-01A	KFM2150 SYSTEM 660-01A	KFM2150 SYSTEM 1320-02A
System component instruments					
	Impedance meter		KFM2150		
	Electronic load unit		PLZ164WA (1 unit)	PLZ664WA (1 unit)	PLZ664WA (2 units)
Rating					
	Operating voltage[*1]		0 V to 150 V	0 V to 150 V	0 V to 150 V
	Current[*2]		33 A	132 A	264 A
	Power[*3]		165 W	660 W	1320 W
Constant current mode					
	Selectable range (ranges H, M, and L)	H	0 A to 33 A	0 A to 132 A	0 A to 264 A
		M	0 A to 3.3 A	0 A to 13.2 A	0 A to 26.4 A
		L	0 A to 0.33 A	0 A to 1.32 A	0 A to 2.64 A
	Resolution (ranges H, M, and L)	H	1 mA	10 mA	20 mA
		M	0.1 mA	1 mA	2 mA
		L	0.01 mA	0.1 mA	0.2 mA
	Setting accuracy (ranges H, M, and L)	H and M	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the H range.		
		L	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the L range.		
Ammeter display					
	Range	H	0.0000 A to 33.000 A	0.0000 A to 132.00 A	0.0000 A to 264.00 A
		M	0.0000 A to 3.3000 A	0.0000 A to 13.200 A	0.0000 A to 26.400 A
		L	0.0000 A to 0.3300 A	0.0000 A to 1.3200 A	0.0000 A to 2.6400 A
	Accuracy (ranges H, M, and L)	H and M	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the H range.		
		L	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the L range.		
Constant voltage mode					
	Selectable range	15 V	0 V to 15.75 V		
		150 V	0 V to 157.5 V		
	Resolution (Range)	15 V	1 mV		
		150 V	10 mV		
Voltmeter display					
	Range	10 V	0.0000 V to 9.9999 V		
		100 V	10.000 V to 99.999 V		
		150 V	100.00 V to 150.00 V		
	Accuracy	All ranges	±(0.1 % of rdng+0.1 % of rng)		

System model			KFM2150 SYSTEM 1000-01	KFM2150 SYSTEM 3000-02
System component instruments				
	Impedance meter		KFM2150	
	Electronic load unit		PLZ1004W (1 unit)	PLZ1004W (1 unit) PLZ2004WB (1 unit)
Rating				
	Operating voltage*1		1.5 V to 150 V	1.5 V to 150 V *4
	Current*2		200 A	600 A
	Power*3		1000 W	3000 W
Constant current mode				
	Selectable range (ranges H, M, and L)	H	0 A to 200 A	0 A to 600 A
		M	0 A to 20 A	0 A to 60 A
		L	0 A to 2 A	0 A to 6 A
	Resolution (ranges H, M, and L)	H	10 mA	30 mA
		M	1 mA	3 mA
		L	0.1 mA	0.3 mA
	Setting accuracy (ranges H, M, and L)	H and M	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the H range.	
		L	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the L range.	
Ammeter display				
	Range	H	0.0000 A to 200.00 A	0.0000 A to 600.00 A
		M	0.0000 A to 20.000 A	0.0000 A to 60.000 A
		L	0.0000 A to 2.0000 A	0.0000 A to 6.0000 A
	Accuracy (ranges H, M, and L)	H and M	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the H range.	
		L	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the L range.	
Constant voltage mode				
	Selectable range	15 V	0 V to 15.75 V	
		150 V	0 V to 157.5 V	
	Resolution (Range)	15 V	1 mV	
		150 V	10 mV	
Voltmeter display				
	Range	10 V	0.0000 V to 9.9999 V	
		100 V	10.000 V to 99.999 V	
		150 V	100.00 V to 150.00 V	
	Accuracy	All ranges	±(0.1 % of rdng+0.1 % of rng)	

*1 At the input terminal of the master unit under DC operation.

*2 Under DC operation. When measuring the AC impedance, the measuring AC current is superposed. The sum of the load current and the measuring AC current peak must not exceed this value. For example, if the measuring AC current is set to 10% of the load current, the load current that you can specify is approximately 87 % of this value.

*3 Under DC operation. When measuring the AC impedance, the measuring AC current is superposed. The power that is determined by the sum of the load current and the measuring AC current peak and the input voltage must not exceed this value. For example, if the measuring AC current is set to 10% of the load current, the power that you can use as a load is approximately 87 % of this value.

*4 If the product of the measurement frequency f (kHz) and measuring AC current I (Arms) exceeds 500 when measuring the AC impedance, the minimum operating voltage increases by 0.15 V for every 100 units that the product exceeds 500.

Rack mount type

System model			KFM2150 SYSTEM 1980-03A	KFM2150 SYSTEM 2640-04A	KFM2150 SYSTEM 3300-05A
System component instruments					
	Impedance meter		KFM2150		
	Electronic load unit		PLZ664WA (3 units)	PLZ664WA (4 units)	PLZ664WA (5 units)
Rating					
	Operating voltage*1		0 V to 150 V*4		
	Current*2		396 A	528 A	660 A
	Power*3		1980 W	2640 W	3300 W
Constant current mode					
	Selectable range (ranges H, M, and L)	H	0 A to 396 A	0 A to 528 A	0 A to 660 A
		M	0 A to 39.6 A	0 A to 52.8	0 A to 66 A
		L	0 A to 3.96 A	0 A to 5.28 A	0 A to 6.6 A
	Resolution (ranges H, M, and L)	H	30 mA	40 mA	50 mA
		M	3 mA	4 mA	5 mA
		L	0.3 mA	0.4 mA	0.5 mA
	Setting accuracy (ranges H, M, and L)	H and M	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the H range.		
		L	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the L range.		
Ammeter display					
	Range	H	0.0000 A to 396.00 A	0.0000 A to 528.00 A	0.0000 A to 660.00 A
		M	0.0000 A to 39.600 A	0.0000 A to 52.800 A	0.0000 A to 66.000 A
		L	0.0000 A to 3.9600 A	0.0000 A to 5.2800 A	0.0000 A to 6.6000 A
	Accuracy (ranges H, M, and L)	H and M	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the H range.		
		L	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the L range.		
Constant voltage mode					
	Selectable range	15 V	0 V to 15.75 V		
		150 V	0 V to 157.5 V		
	Resolution (Range)	15 V	1 mV		
		150 V	10 mV		
Voltmeter display					
	Range	10 V	0.0000 V to 9.9999 V		
		100 V	10.000 V to 99.999 V		
		150 V	100.00 V to 150.00 V		
	Accuracy	All ranges	±(0.1 % of rdng+0.1 % of rng)		

System model			KFM2150 SYSTEM 5000-03	KFM2150 SYSTEM 7000-04	KFM2150 SYSTEM 9000-05
System component instruments					
	Impedance meter		KFM2150		
	Electronic load unit		PLZ1004W (1 unit) PLZ2004WB (2 units)	PLZ1004W (1 unit) PLZ2004WB (3 units)	PLZ1004W (1 unit) PLZ2004WB (4 units)
Rating					
	Operating voltage*1		1.5 V to 150 V *5		
	Current*2		1000 A	1400 A	1800 A
	Power*3		5000 W	7000 W	9000 W
Constant current mode					
	Selectable range (ranges H, M, and L)	H	0 A to 1000 A	0 A to 1400 A	0 A to 1800 A
		M	0 A to 100 A	0 A to 140 A	0 A to 180 A
		L	0 A to 10 A	0 A to 14 A	0 A to 18 A
	Resolution (ranges H, M, and L)	H	50 mA	70 mA	90 mA
		M	5 mA	7 mA	9 mA
		L	0.5 mA	0.7 mA	0.9 mA
	Setting accuracy (ranges H, M, and L)	H and M	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the H range.		
		L	±(0.2 % of setting + 0.2 % of f.s), f.s: the full scale of the L range.		
Ammeter display					
	Range	H	0.0000 A to 1000.0 A	0.0000 A to 1400.0 A	0.0000 A to 1800.0 A
		M	0.0000 A to 100.00 A	0.0000 A to 140.00 A	0.0000 A to 180.00 A
		L	0.0000 A to 10.000 A	0.0000 A to 14.000 A	0.0000 A to 18.000 A
	Accuracy (ranges H, M, and L)	H and M	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the H range.		
		L	±(0.3 % of rdng + 0.3 % of f.s), f.s: the full scale of the L range.		
Constant voltage mode					
	Selectable range	15 V	0 V to 15.75 V		
		150 V	0 V to 157.5 V		
	Resolution (Range)	15 V	1 mV		
		150 V	10 mV		
Voltmeter display					
	Range	10 V	0.0000 V to 9.9999 V		
		100 V	10.000 V to 99.999 V		
		150 V	100.00 V to 150.00 V		
	Accuracy	All ranges	±(0.1 % of rdng+0.1 % of rng)		

*1 At the input terminal of the rack under DC operation.

*2 Under DC operation. When measuring the AC impedance, the measuring AC current is superposed. The sum of the load current and the measuring AC current peak must not exceed this value. For example, if the measuring AC current is set to 10% of the load current, the load current that you can specify is approximately 87 % of this value.

*3 Under DC operation. When measuring the AC impedance, the measuring AC current is superposed. The power that is determined by the sum of the load current and the measuring AC current peak and the input voltage must not exceed this value. For example, if the measuring AC current is set to 10% of the load current, the power that you can use as a load is approximately 87 % of this value.

*4 If the product of the measurement frequency f (kHz) and measuring AC current I (Arms) exceeds 500 when measuring the AC impedance, the minimum operating voltage increases by 0.45 V for every 100 units that the product exceeds 500.

*5 If the product of the measurement frequency f (kHz) and measuring AC current I (Arms) exceeds 500 when measuring the AC impedance, the minimum operating voltage increases by 0.6 V for every 100 units that the product exceeds 500.

7.2 Impedance measurement

<table>
<tr><td colspan="2">Method</td><td>AC impedance method
(variable measuring AC current)</td><td>Current interrupt method
(variable interrupt current parameter)</td></tr>
<tr><td colspan="2">Measurement items</td><td>R, X, |Z|, and θ</td><td>IR (internal resistance)</td></tr>
<tr><td colspan="2" rowspan="4">Measurement condition settings</td><td>Measuring frequency:
14 points/decade (1.00, 1.26, 1.58, 2.00, 2.51, 3.00, 3.16, 4.00, 5.00, 6.00, 6.30, 7.00, 8.00, and 9.00) in the 10 mHz to 20 kHz range</td><td>Measurement interval: Fixed to 100 ms</td></tr>
<tr><td rowspan="3">Measuring AC current:
0 % to 10 % (as a percentage of the load current in rms value)
Resolution: 0.1 %</td><td>Pulse depth: 0 % to 100 % (as a percentage of the load current) with a resolution of 1 %.</td></tr>
<tr><td>Pulse width: 0.1 ms to 10.0 ms with a resolution of 0.1 ms.</td></tr>
<tr><td>Pulse transition time: 0.01 ms to 10.00 ms[*1] with a resolution of 0.01 ms.</td></tr>
<tr><td rowspan="5">Impedance measurement: Display range and resolution</td><td>10 mΩ range</td><td colspan="2">0.0000 mΩ to 9.9999 mΩ</td></tr>
<tr><td>100 mΩ range</td><td colspan="2">10,000 mΩ to 99.999 mΩ</td></tr>
<tr><td>1 Ω range</td><td colspan="2">100.00 mΩ to 999.99 mΩ</td></tr>
<tr><td>10 Ω range</td><td colspan="2">1.0000 Ω to 9.9999 Ω</td></tr>
<tr><td>Phase angle</td><td>-180.00 deg to 180.00 deg</td><td>-</td></tr>
<tr><td colspan="2">Measurement accuracy</td><td>Measurement accuracy for R and X

The measurement AC current is less than or equal to 10 A:
±(the value (%) in the attached table for the |Z| reading + the value in Note 1 of the attached table)[*2]
The measurement AC current is greater than 10 A:
±(the value (%) in the attached table for the |Z| reading + 3 (%) + the value in Note 1 of the attached table)[*2]</td><td>±3 %
When a 10 mΩ resistor is connected in series with the power supply and measurements are taken under the following conditions</td></tr>
<tr><td colspan="2">Measurement conditions</td><td>• Load unit terminal input voltage[*3] : 1.5 V[*4] or 0 V[*5]
• Short-circuit correction function: Enabled
• Average count: 256 times
• Load wire length[*6] : 2 m
• Maximum value of the measuring current: 80 Arms[*4] or 50 Arms[*5]</td><td>• Load unit terminal voltage: 5 V
• Load current: 20 A
• Pulse depth: 50 % (10 A)
• Pulse width: 10 ms
• Pulse transition time: 10 ms
• Sampling position: 5 ms
• Sampling region: 0.51 ms
• Average count: 32 times</td></tr>
</table>

*1. The lower limit of the selectable range may be limited by a value greater than 0.01 ms depending on the rated current, pulse depth, and load current settings.
*2. Table 7-1 is used to look up the attached table containing the values for each system model.
*3. Includes the conditions indicated in footnotes *1, *4, and *5 for the operating voltage rating in “7.1 Basic Performance.”
*4. KFM2150 SYSTEM1000-01, 3000-02, 5000-03, 7000-04, and 9000-05
*5. KFM2150 SYSTEM165-01A, 660-01A, 1320-02A, 1980-03A, 2640-04A, and 3300-05A
*6. From the input terminal of the PLZ-4W Series slave unit for the bench top type and from the input terminal of the rack for the rack mount type.

Table 7-1 Reference to the values in the attached tables(%)

System type	System model	Attached table number
Bench top type	KFM2150 SYSTEM165-01A	Table 7-2
	KFM2150 SYSTEM660-01A	Table 7-3
	KFM2150 SYSTEM1320-02A	Table 7-4
	KFM2150 SYSTEM1000-01	Table 7-5
	KFM2150 SYSTEM3000-02	Table 7-6
Rack mount type	KFM2150 SYSTEM1980-03A	Table 7-7
	KFM2150 SYSTEM2640-04A	Table 7-8
	KFM2150 SYSTEM3300-05A	Table 7-9
	KFM2150 SYSTEM5000-03	Table 7-10
	KFM2150 SYSTEM7000-04	Table 7-11
	KFM2150 SYSTEM9000-05	Table 7-12

■ Determining the measurement accuracy (how to use the attached tables)

Use Table 7-2 to determine the measurement accuracy of bench top type KFM2150 SYSTEM165-01A. The values inside brackets indicate corresponding areas in Fig. 7-1.

- Example 1: Load current is 10 A [1], measuring AC current is 1 A [1], measuring frequency is 3 kHz [2], sensing terminal input voltage range is 10 V [3], and impedance range is 10 mΩ [4].

  Measurement accuracy = ±(4 % of the |Z| reading [5] + 0.3 mΩ [6])

  * Measurement accuracy = ±(4 % of the |Z| reading + 0.3 mΩ)

- Example 2: Load current is 30 A [1], measuring AC current is 3 A [1], measuring frequency is 3 kHz [2], sensing terminal input voltage range is 10 V [3], and impedance range is 100 mΩ [7].

  Measurement accuracy = ±(3 % of the |Z| reading [8])

  * Measurement accuracy = ±(3 % of the |Z| reading). There is no value for Note 1.

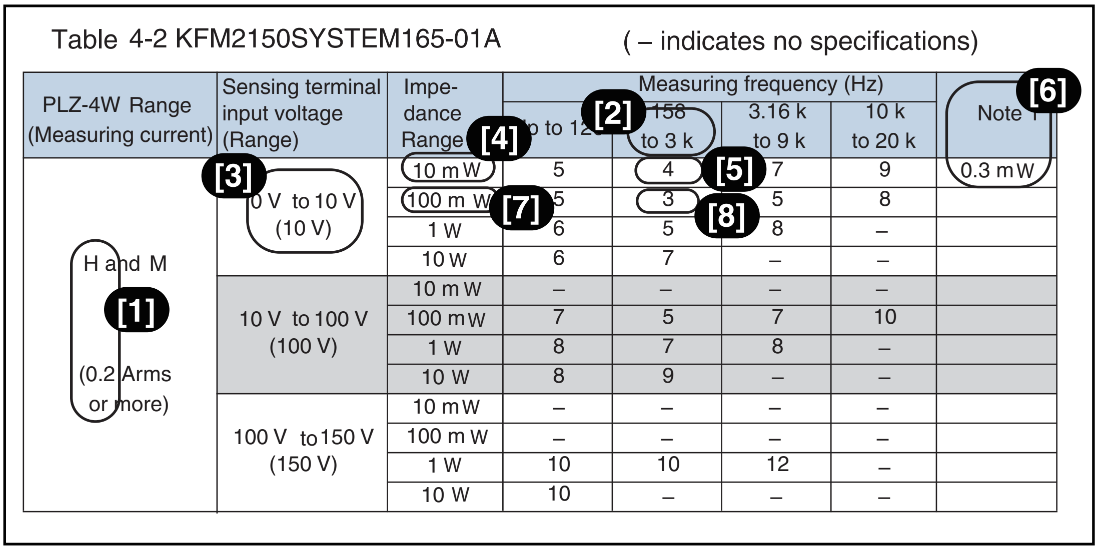


Table 4-2 KFM2150SYSTEM165-01A (– indicates no specifications)

PLZ-4W Range (Measuring current)	Sensing terminal input voltage (Range)	Impedance Range	Measuring frequency (Hz) [illegible] to 12[illegible]	158 to 3 k	3.16 k to 9 k	10 k to 20 k	Note 1
H and M (0.2 Arms or more)	0 V to 10 V (10 V)	10 m W	5	4	7	9	0.3 m W
		100 m W	5	3	5	8	
		1 W	6	5	8	–	
		10 W	6	7	–	–	
	10 V to 100 V (100 V)	10 m W	–	–	–	–	
		100 m W	7	5	7	10	
		1 W	8	7	8	–	
		10 W	8	9	–	–	
	100 V to 150 V (150 V)	10 m W	–	–	–	–	
		100 m W	–	–	–	–	
		1 W	10	10	12	–	
		10 W	10	–	–	–	

Fig. 7-1 How to use the attached tables (excerpt from Table 4-2)

7 Specifications

■ Attached tables for the AC impedance method (Table 7-2 to Table 7-12)

Table 7-2 KFM2150 SYSTEM165-01A (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (0.2 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	5	4	7	9	0.3 mΩ
		100 mΩ	5	3	5	8	
		1 Ω	6	5	8	–	
		10 Ω	6	7	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	7	5	7	10	
		1 Ω	8	7	8	–	
		10 Ω	8	9	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	–	–	–	–	
		1 Ω	10	10	12	–	
		10 Ω	10	–	–	–	
L	0 V to 10 V (10 V)	10 mΩ	–	–	–	–	
		100 mΩ	–	–	–	–	
		1 Ω	–	–	–	–	
		10 Ω	–	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	–	–	–	–	
		1 Ω	–	–	–	–	
		10 Ω	–	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	–	–	–	–	
		1 Ω	–	–	–	–	
		10 Ω	–	–	–	–	

Table 7-3 KFM2150 SYSTEM660-01A (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (0.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	3	2	3	4	0.3 mΩ
		100 mΩ	3	2	3	5	
		1 Ω	4	3	6[*1]	–	
		10 Ω	4	8[*2]	–	–	
	10 V to 100 V (100 V)	10 mΩ	5	3	5	6	0.3 mΩ
		100 mΩ	5	3	5	8	
		1 Ω	6	5	8[*1]	–	
		10 Ω	6	9[*2]	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	9	6	9	–	
		1 Ω	12	9	–	–	
		10 Ω	12	–	–	–	
L (0.05 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	3	2	3	4	0.3 mΩ
		100 mΩ	3	2	3	5	
		1 Ω	4	3	6[*1]	–	
		10 Ω	4	8[*2]	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	5	3	5	8	
		1 Ω	6	5	8[*1]	–	
		10 Ω	6	9[*2]	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	–	–	–	–	
		1 Ω	–	–	–	–	
		10 Ω	–	–	–	–	

*1 Up to 6.3 kHz
*2 Up to 1 kHz

Table 7-4 KFM2150 SYSTEM1320-02A (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (1 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	5	4	7	9	0.3 mΩ
		100 mΩ	5	4	7	10	
		1 Ω	8	7	–	–	
		10 Ω	8	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	7	5	7	9	0.3 mΩ
		100 mΩ	7	5	7	10	
		1 Ω	8	7	–	–	
		10 Ω	8	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	10	12	–	
		1 Ω	14	12	–	–	
		10 Ω	15	–	–	–	
L (0.1 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	5	4	7	9	0.3 mΩ
		100 mΩ	5	4	7	10	
		1 Ω	8	7	–	–	
		10 Ω	8	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	7	5	7	10	
		1 Ω	8	7	–	–	
		10 Ω	10	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	–	–	–	–	
		1 Ω	–	–	–	–	
		10 Ω	–	–	–	–	

Table 7-5 KFM2150 SYSTEM1000-01 (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (0.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	3	2	3	4	0.3 mΩ
		100 mΩ	3	2	3	5	
		1 Ω	4	3	6*1	–	
		10 Ω	4	8*2	–	–	
	10 V to 100 V (100 V)	10 mΩ	5	3	5	6	0.3 mΩ
		100 mΩ	5	3	5	8	
		1 Ω	6	5	8*1	–	
		10 Ω	6	9*2	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	9	6	9	–	
		1 Ω	12	9	–	–	
		10 Ω	12	–	–	–	
L (0.05 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	3	2	3	4	0.3 mΩ
		100 mΩ	3	2	3	5	
		1 Ω	4	3	6*1	–	
		10 Ω	4	8*2	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	5	3	5	8	
		1 Ω	6	5	8*1	–	
		10 Ω	6	9*2	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	–	–	–	–	
		1 Ω	–	–	–	–	
		10 Ω	–	–	–	–	

*1 Up to 6.3 kHz
*2 Up to 1 kHz

Table 7-6 KFM2150 SYSTEM3000-02 (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (1.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	6	6	9	10	0.3 mΩ
		100 mΩ	6	6	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	9	7	9	10	0.3 mΩ
		100 mΩ	9	7	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	14	12	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	
L (0.15 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	6	6	9	10	0.3 mΩ
		100 mΩ	6	6	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	9	7	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	12	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	

Table 7-7 KFM2150 SYSTEM1980-03A (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (1.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	6	6	9	10	0.3 mΩ
		100 mΩ	6	6	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	9	7	9	10	0.3 mΩ
		100 mΩ	9	7	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	14	12	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	
L (0.15 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	6	6	9	10	0.3 mΩ
		100 mΩ	6	6	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	9	7	9	12	
		1 Ω	10	9	–	–	
		10 Ω	10	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	12	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	

Table 7-8 KFM2150 SYSTEM2640-04A (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (2 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	8	8	10	12	0.3 mΩ
		100 mΩ	8	9	10	12	
		1 Ω	10	10	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	10	9	10	12	0.3 mΩ
		100 mΩ	10	9	10	12	
		1 Ω	12	10	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	15	15	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	
L (0.2 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	8	8	10	12	0.3 mΩ
		100 mΩ	8	9	10	12	
		1 Ω	12	10	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	10	9	10	12	
		1 Ω	12	12	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	12	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	

Table 7-9 KFM2150 SYSTEM3300-05A (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (2.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	8	8	10	12	0.3 mΩ
		100 mΩ	8	9	10	12	
		1 Ω	10	10	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	10	9	10	12	0.3 mΩ
		100 mΩ	10	9	10	12	
		1 Ω	12	10	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	15	15	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	
L (0.25 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	8	8	10	12	0.3 mΩ
		100 mΩ	8	9	10	12	
		1 Ω	12	10	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	10	9	10	12	
		1 Ω	12	12	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	12	–	–	
		1 Ω	15	15	–	–	
		10 Ω	–	–	–	–	

Table 7-10 KFM2150 SYSTEM5000-03 (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (2.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	8	8	10	12	0.3 mΩ
		100 mΩ	8	9	10	15*1	
		1 Ω	10	10	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	10	9	10	12	0.3 mΩ
		100 mΩ	10	9	10	15*1	
		1 Ω	12	10	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	15	15	–	–	
		1 Ω	15	–	–	–	
		10 Ω	–	–	–	–	
L (0.25 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	8	8	10	12	0.3 mΩ
		100 mΩ	8	9	10	15*1	
		1 Ω	12	12	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	10	9	10	15*1	
		1 Ω	12	10	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	12	–	–	
		1 Ω	15	–	–	–	
		10 Ω	–	–	–	–	

*1. Up to 10 kHz

Table 7-11 KFM2150 SYSTEM7000-04 (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (3.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	10	9	10	15	0.3 mΩ
		100 mΩ	10	9	10	–	
		1 Ω	12	–	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	12	10	12	15	0.3 mΩ
		100 mΩ	12	10	12	–	
		1 Ω	12	–	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	15	15	–	–	
		1 Ω	15	–	–	–	
		10 Ω	–	–	–	–	
L (0.35 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	10	9	10	15	0.3 mΩ
		100 mΩ	10	9	10	–	
		1 Ω	12	15	–	–	
		10 Ω	–	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	10	12	–	
		1 Ω	12	–	–	–	
		10 Ω	–	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	12	–	–	
		1 Ω	15	–	–	–	
		10 Ω	–	–	–	–	

Table 7-12 KFM2150 SYSTEM9000-05 (– denotes undefined)

PLZ-4W range (Measuring current)	Sensing terminal input voltage (Range)	Impedance range	Measuring frequency (Hz)				Note 1
			Up to 126	158 to 3 k	3.16 k to 9 k	10 k to 20 k	
H and M (4.5 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	10	9	10	15	0.3 mΩ
		100 mΩ	10	9	10	–	
		1 Ω	12	–	–	–	
		10 Ω	15	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	12	10	12	15	0.3 mΩ
		100 mΩ	12	10	12	–	
		1 Ω	12	–	–	–	
		10 Ω	15	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	15	15	–	–	
		1 Ω	–	–	–	–	
		10 Ω	–	–	–	–	
L (0.45 Arms or higher)	0 V to 10 V (10 V)	10 mΩ	10	9	10	15	0.3 mΩ
		100 mΩ	10	9	12	–	
		1 Ω	12	15	–	–	
		10 Ω	–	–	–	–	
	10 V to 100 V (100 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	10	12	–	
		1 Ω	12	–	–	–	
		10 Ω	–	–	–	–	
	100 V to 150 V (150 V)	10 mΩ	–	–	–	–	
		100 mΩ	12	12	–	–	
		1 Ω	15	–	–	–	
		10 Ω	–	–	–	–	

7.3 Functions and General Specifications

Bench top type

System model			KFM2150 SYSTEM 165-01A	KFM2150 SYSTEM 660-01A	KFM2150 SYSTEM 1320-02A
Electronic load function					
	Operation mode*1		Constant current (CC) and constant voltage (CV) mode.		
Remote interface			GPIB, RS232C, or USB (connect the KFM2150 using one of the interfaces).		
Protection function		SENSE UVP	Turns the load off and outputs an alarm status signal when the sensing terminal voltage reaches the setting (-2 V to 150 V).		
		PLZ-4W	Protection functions available on the PLZ-4W Series (OVP, OPP, OHP, UVP, and REV). OPP and UVP can be set from the KFM2150.		
Current monitor output			Directly outputs the current monitor output of the PLZ-4W Series and directly outputs 10 V f.s (H/L range), 1 V f.s (M range), or the input of current sensing terminal 2.		
Signal output	Load on status signal		Photocoupler open-collector output. Output logic switchable.		
	Alarm status signal				
Signal input	Voltage input for impedance measurement VOLTAGE SENSING 1/2	DC input voltage and range	0 V to 150 V. 10 V, 100 V, and 150 V range (auto switching).		
		Input impedance	Approx. 1 MΩ.		
		Isolation	250 V (between the chassis and LOW terminal).		
	Current signal input CURRENT SENSING 2	DC input voltage and range	0 V to 10 V		
		Input impedance	Approx. 1 MΩ.		
		Isolation	250 V (between the chassis and LOW terminal).		
	Alarm signal input		Low: 0 V and high: 5 V. Activates an alarm on a low level input. Turns the load off when an alarm is activated.		
General specifications	Nominal input voltage		100 Vac to 240 Vac, 50 Hz/60 Hz, single phase.		
	Input voltage range		90 Vac to 250 Vac		
	Input frequency range		47 Hz to 63 Hz		
	Power consumption		550 VAmax.	1600 VAmax.	3100 VAmax.
	Inrush current (typ.)		120 A.	120 A.	200 A.
	Operating temperature range		0 °C to 40 °C.		
	Operating humidity range		20 %rh to 85 %rh (no condensation).		
	Storage temperature range		-20 ° to 70 °C.		
	Storage humidity range		0 to 90 %rh (no condensation).		
	Operating conditions		Indoor use, Overvoltage Category II.		
	Withstand voltage (for KFM2150 unit)		Between input and chassis: No abnormalities at 1500 Vac for 1 minute		
	Insulation resistance (for KFM2150 unit)		Between input and chassis: 500 Vdc, 30 MΩ or more		
	External dimensions		See Fig. 7-2 and Fig. 7-4.	See Fig. 7-2 and Fig. 7-5.	
	Weight		Approx. 13.5 kg	Approx. 22 kg	Approx. 38 kg
Accessories	Flat cable		PC02-PLZ-4W: 1 pc.	PC01-PLZ-4W: 1 pc.	PC01-PLZ-4W: 2 pc.
	RS232C cable, sensing wire, and power cord		Each 1 pc.		
	Wire that is 80 mm^2 in size and approx. 30 cm in length		None		2 pcs.
	CD-ROM		1 pc,		

System model			KFM2150 SYSTEM 1000-01	KFM2150 SYSTEM 3000-02
Electronic load function				
	Operation mode[*1]		Constant current (CC) and constant voltage (CV) mode.	
Remote interface			GPIB, RS232C, or USB (connect the KFM2150 using one of the interfaces).	
Protection function		SENSE UVP	Turns the load off and outputs an alarm status signal when the sensing terminal voltage reaches the setting (-2 V to 150 V).	
		PLZ-4W	Protection functions available on the PLZ-4W Series (OVP, OPP, OHP, UVP, and REV). OPP and UVP can be set from the KFM2150.	
Current monitor output			Directly outputs the current monitor output of the PLZ-4W Series and directly outputs 10 V f.s (H/L range), 1 V f.s (M range), or the input of current sensing terminal 2.	
Signal output	Load on status signal		Photocoupler open-collector output. Output logic switchable.	
	Alarm status signal			
Signal input	Voltage input for impedance measurement VOLTAGE SENSING 1/2	DC input voltage and range	0 V to 150 V. 10 V, 100 V, and 150 V range (auto switching).	
		Input impedance	Approx. 1 MΩ.	
		Isolation	250 V (between the chassis and LOW terminal).	
	Current signal input CURRENT SENSING 2	DC input voltage and range	0 V to 10 V.	
		Input impedance	Approx. 1 MΩ.	
		Isolation	250 V (between the chassis and LOW terminal).	
	Alarm signal input		Low: 0 V and high: 5 V. Activates an alarm on a low level input. Turns the load off when an alarm is activated.	
General specifications	Nominal input voltage		100 Vac to 240 Vac, 50 Hz/60 Hz, single phase.	
	Input voltage range		90 Vac to 250 Vac	
	Input frequency range		47 Hz to 63 Hz	
	Power consumption		260 VAmax.	460 VAmax.
	Inrush current (typ.)		120 A.	200 A.
	Operating temperature range		0 °C to 40 °C.	
	Operating humidity range		20 %rh to 85 %rh (no condensation).	
	Storage temperature range		-20 °C to 70 °C.	
	Storage humidity range		0 to 90 %rh (no condensation).	
	Operating conditions		Indoor use, Overvoltage Category II.	
	Withstand voltage (for KFM2150 unit)		Between input and chassis: No abnormalities at 1500 Vac for 1 minute	
	Insulation resistance (for KFM2150 unit)		Between input and chassis: 500 Vdc, 30 MΩ or more	
	External dimensions		See Fig. 7-2 and Fig. 7-5.	See Fig. 7-2, Fig. 7-5, and Fig. 7-6.
	Weight		Approx. 21 kg	Approx. 45 kg
Accessories	Flat cable		PC01-PLZ-4W: 1 pc.	PC01-PLZ-4W: 1 pc. PC02-PLZ-4W: 1 pc.
	RS232C cable, sensing wire, and power cord		Each 1 pc.	
	Wire that is 80 mm^2 in size and approx. 30 cm in length		None	2 pcs.
	CD-ROM		1 pc.	

*1. The KFM2150 controls the PLZ-4W Series using the external voltage control function. Functions such as operation mode switching, switching mode, and sequence that are available when the PLZ-4W Series is used by itself cannot be used.

Rack mount type

System model			KFM2150 SYSTEM 1980-03A	KFM2150 SYSTEM 2640-04A	KFM2150 SYSTEM 3300-05A
Electronic load function					
	Operation mode[*1]		Constant current (CC) and constant voltage (CV) mode.		
Remote interface			GPIB, RS232C, or USB (connect the KFM2150 using one of the interfaces).		
Protection function		SENSE UVP	Turns the load off and outputs an alarm status signal when the sensing terminal voltage reaches the setting (-2 V to 150 V).		
		PLZ-4W	Protection functions available on the PLZ-4W Series (OVP, OPP, OHP, UVP, and REV). OPP and UVP can be set from the KFM2150.		
Current monitor output			Directly outputs the current monitor output of the PLZ-4W Series and directly outputs 10 V f.s (H/L range), 1 V f.s (M range), or the input of current sensing terminal 2.		
Signal output	Load on status signal		Photocoupler open-collector output. Output logic switchable.		
	Alarm status signal				
Signal input	Voltage input for impedance measurement VOLTAGE SENSING 1/2	DC input voltage and range	0 V to 150 V. 10 V, 100 V, and 150 V range (auto switching).		
		Input impedance	Approx. 1 MΩ.		
		Isolation	250 V (between the chassis and LOW terminal).		
	Current signal input CURRENT SENSING 2	DC input voltage and range	0 V to 10 V.		
		Input impedance	Approx. 1 MΩ.		
		Isolation	250 V (between the chassis and LOW terminal).		
	Alarm signal input		Low: 0 V and high: 5 V. Activates an alarm on a low level input. Turns the load off when an alarm is activated.		
General specifications	Nominal input voltage		200 Vac to 240 Vac, 50 Hz/60 Hz, single phase.		
	Input voltage range		180 Vac to 250 Vac		
	Input frequency range		47 Hz to 63 Hz		
	Power consumption		4600 VAmax.	6100 VAmax.	7600 VAmax.
	Inrush current (typ.)		280 A.	360 A.	450 A.
	Operating temperature range		0 °C to 40 °C.		
	Operating humidity range		20 %rh to 85 %rh (no condensation).		
	Storage temperature range		-20 °C to 70 °C.		
	Storage humidity range		0 to 90 %rh (no condensation).		
	Operating conditions		Indoor use, Overvoltage Category II.		
	Withstand voltage (for rack system)		Between input and chassis: No abnormalities at 1500 Vac for 1 minute Between input and load terminal: No abnormalities at 1500 Vac for 1 minute		
	Insulation resistance (for rack system)		Between input and chassis: 500 Vdc, 30 MΩ or more Between load terminal and chassis: 500 Vdc, 30 MΩ or more		
	External dimensions		See Fig. 7-7.		
	Weight		Approx. 170 kg	Approx. 185 kg	Approx. 200 kg
Accessories	Load input terminal cover Power input terminal block cover		Each 1 pc. (comes attached)		
	CD-ROM		1 pc,		

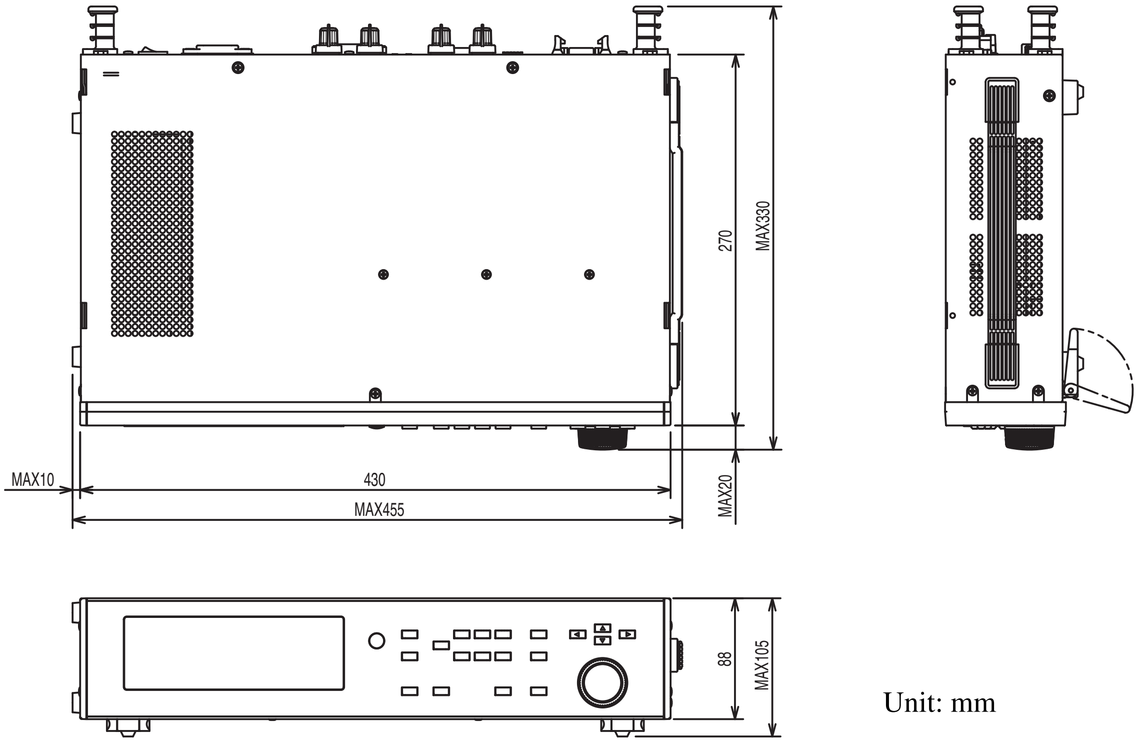
System model			KFM2150 SYSTEM 5000-03	KFM2150 SYSTEM 7000-04	KFM2150 SYSTEM 9000-05
Electronic load function					
	Operation mode[*1]		Constant current (CC) and constant voltage (CV) mode.		
Remote interface			GPIB, RS232C, or USB (connect the KFM2150 using one of the interfaces).		
Protection function		SENSE UVP	Turns the load off and outputs an alarm status signal when the sensing terminal voltage reaches the setting (-2 V to 150 V).		
		PLZ-4W	Protection functions available on the PLZ-4W Series (OVP, OPP, OHP, UVP, and REV). OPP and UVP can be set from the KFM2150.		
Current monitor output			Directly outputs the current monitor output of the PLZ-4W Series and directly outputs 10 V f.s (H/L range), 1 V f.s (M range), or the input of current sensing terminal 2.		
Signal output	Load on status signal		Photocoupler open-collector output. Output logic switchable.		
	Alarm status signal				
Signal input	Voltage input for impedance measurement VOLTAGE SENSING 1/2	DC input voltage and range	0 V to 150 V. 10 V, 100 V, and 150 V range (auto switching).		
		Input impedance	Approx. 1 MΩ.		
		Isolation	250 V (between the chassis and LOW terminal).		
	Current signal input CURRENT SENSING 2	DC input voltage and range	0 V to 10 V.		
		Input impedance	Approx. 1 MΩ.		
		Isolation	250 V (between the chassis and LOW terminal).		
	Alarm signal input		Low: 0 V and high: 5 V. Activates an alarm on a low level input. Turns the load off when an alarm is activated.		
General specifications	Nominal input voltage		200 Vac to 240 Vac, 50 Hz/60 Hz, single phase.		
	Input voltage range		180 Vac to 250 Vac		
	Input frequency range		47 Hz to 63 Hz		
	Power consumption		660 VAmax.	860 VAmax.	1060 VAmax.
	Inrush current (typ.)		200 A.	200 A.	200 A.
	Operating temperature range		0 °C to 40 °C.		
	Operating humidity range		20 %rh to 85 %rh (no condensation).		
	Storage temperature range		-20 °C to 70 °C.		
	Storage humidity range		0 to 90 %rh (no condensation).		
	Operating conditions		Indoor use, Overvoltage Category II.		
	Withstand voltage (for rack system)		Between input and chassis: No abnormalities at 1500 Vac for 1 minute Between input and load terminal: No abnormalities at 1500 Vac for 1 minute		
	Insulation resistance (for rack system)		Between input and chassis: 500 Vdc, 30 MΩ or more Between load terminal and chassis: 500 Vdc, 30 MΩ or more		
	External dimensions		See Fig. 7-8.		
	Weight		Approx. 190 kg	Approx. 215 kg	Approx. 240 kg
Accessories	Load input terminal cover Power input terminal block cover		Each 1 pc. (comes attached)		
	CD-ROM		1 pc,		

*1. The KFM2150 controls the PLZ-4W Series using the external voltage control function. Functions such as operation mode switching, switching mode, and sequence that are available when the PLZ-4W Series is used by itself cannot be used.

7 Specifications

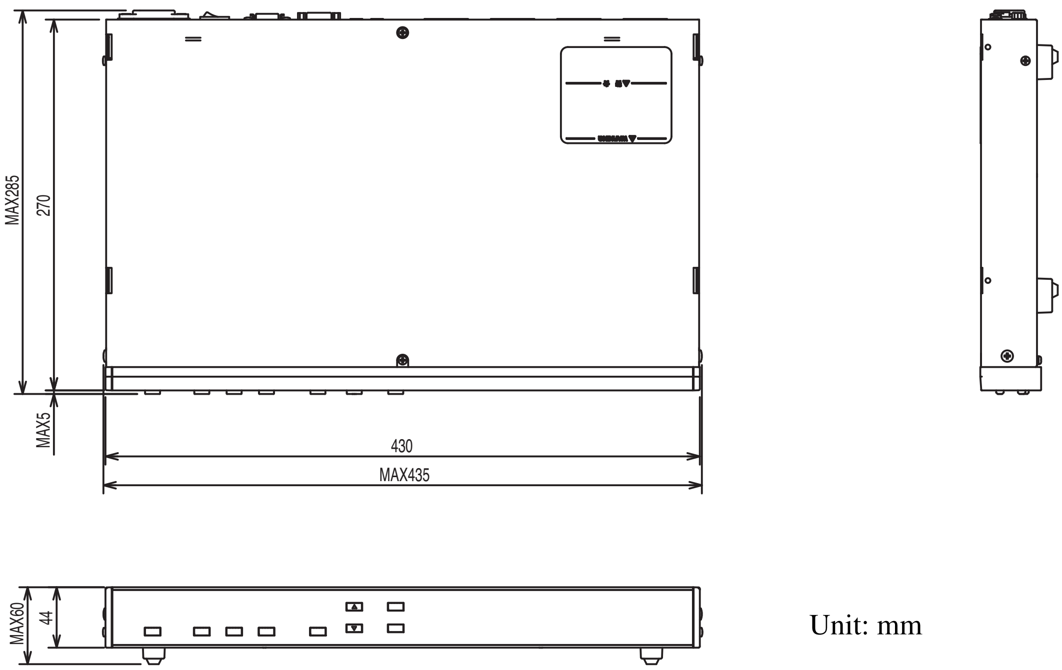
7.4 Outline Drawing

Bench top type



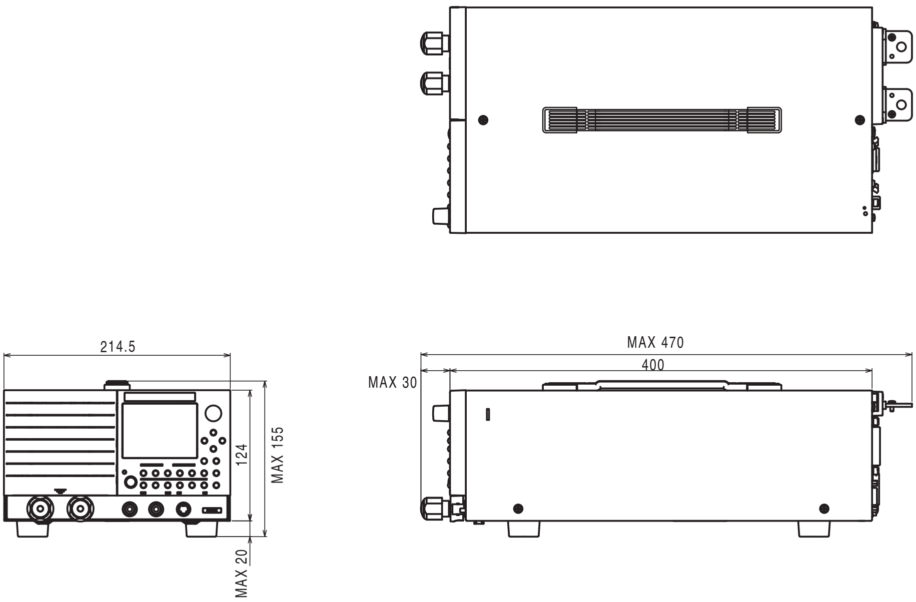
Unit: mm

Fig. 7-2 KFM2150 outline drawing



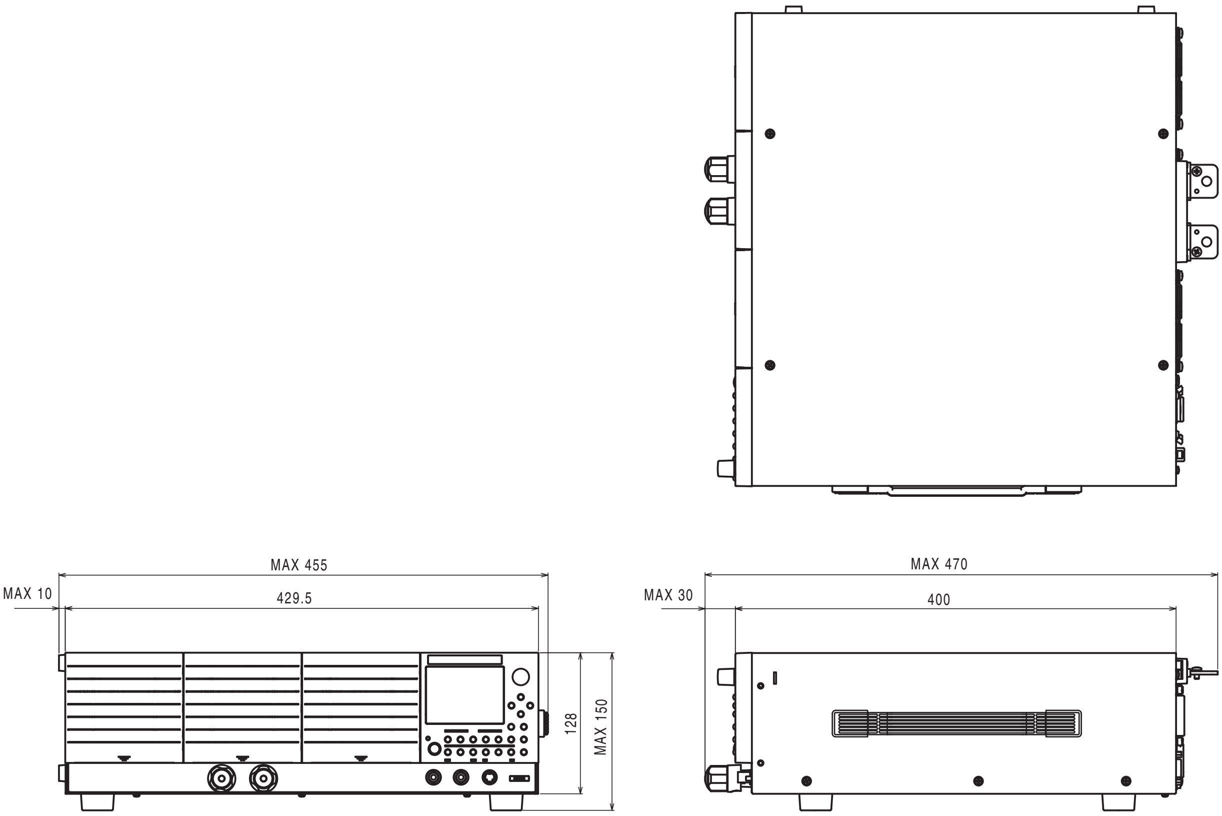
Unit: mm

Fig. 7-3 KFM2151 outline drawing



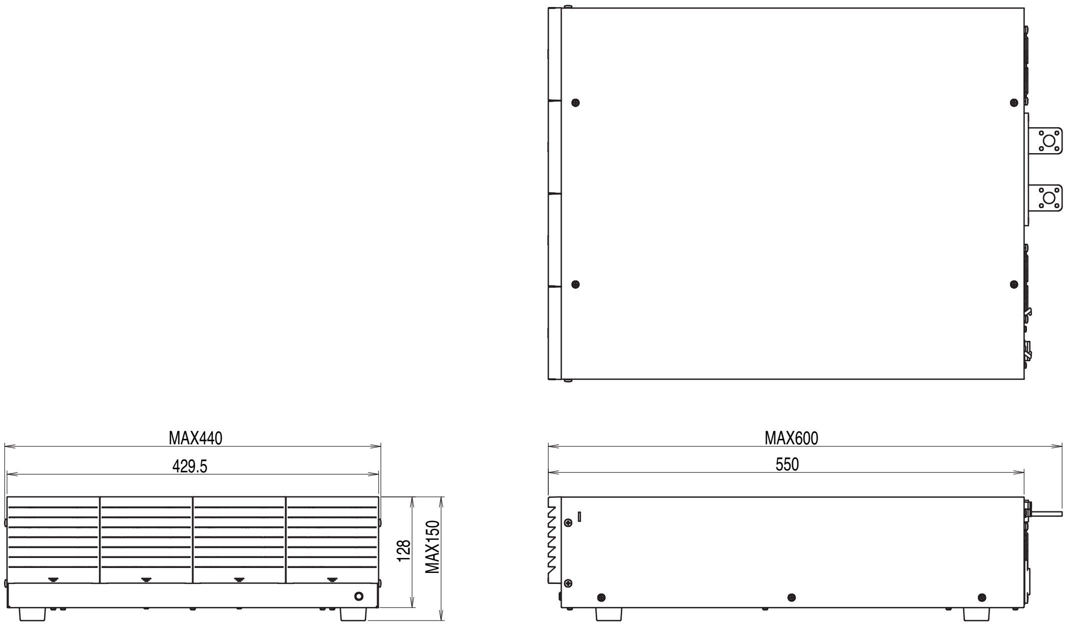
Unit: mm

Fig. 7-4 PLZ164WA outline drawing



Unit: mm

Fig. 7-5 PLZ664WA and 1004W outline drawings



Unit: mm

Fig. 7-6 PLZ2004WB outline drawing

Rack mount type

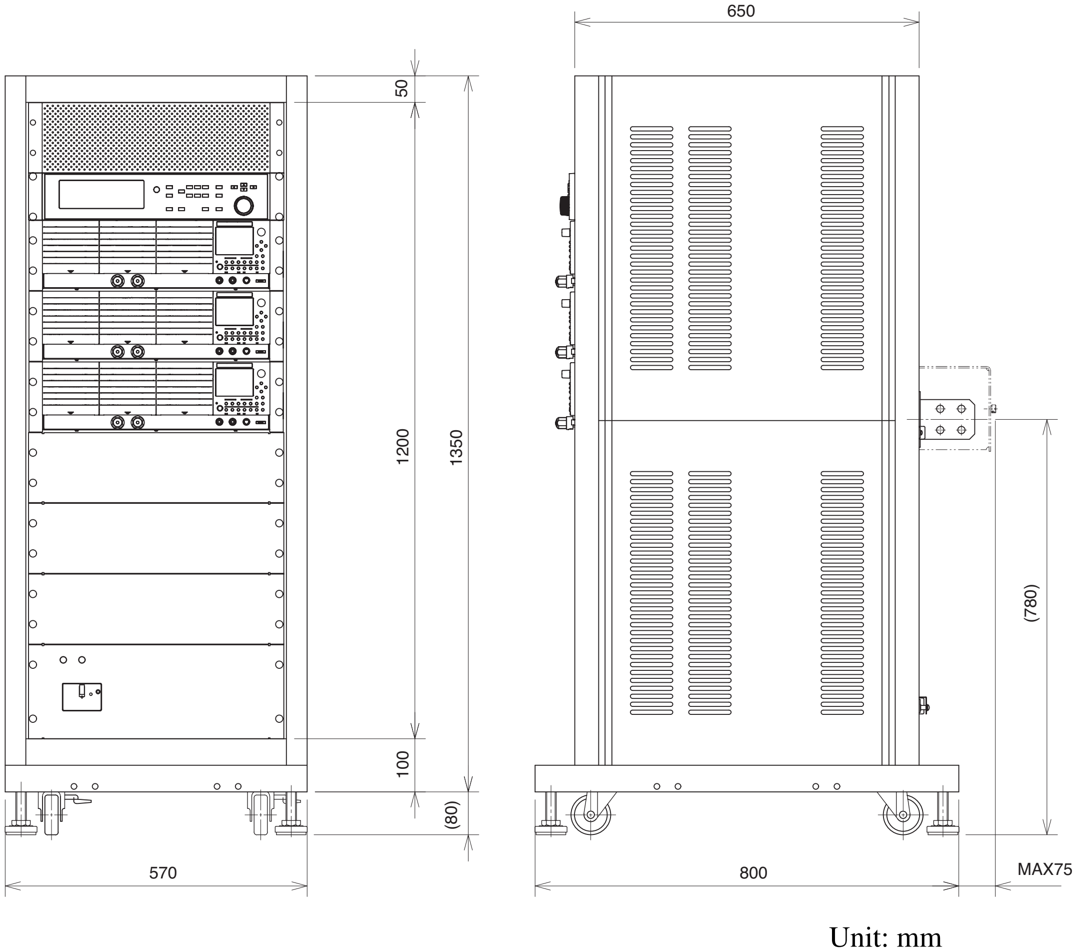


Fig. 7-7 KFM2150 SYSTEM1980-03A, KFM2150 SYSTEM2640-04A, and KFM2150 SYSTEM3300-05A outline drawings

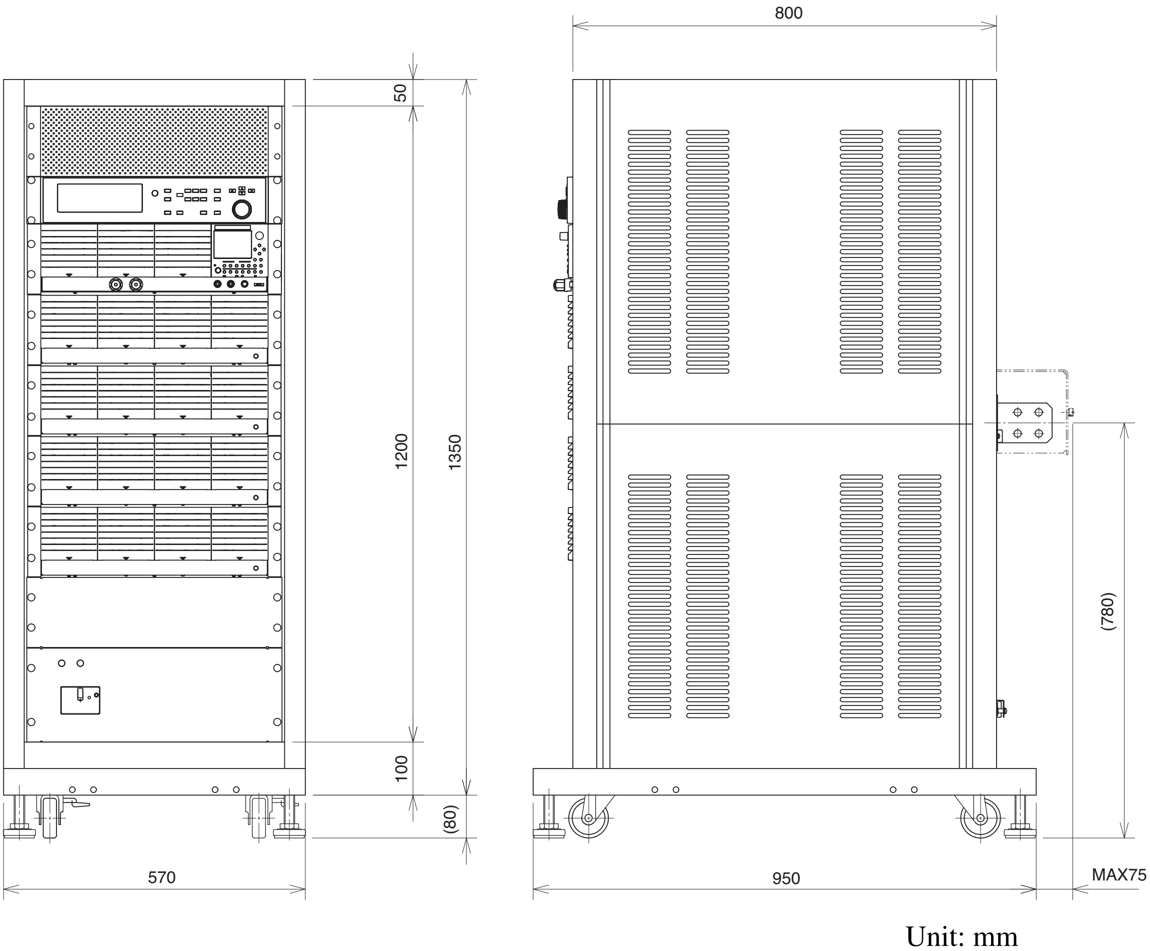


Fig. 7-8 KFM2150 SYSTEM5000-03, KFM2150 SYSTEM7000-04, and KFM2150 SYSTEM9000-05 outline drawings.

Appendix

A.1 Connection to External Devices

The KFM2150 FC Impedance Meter, a component instrument of this system, contains terminals used to connect external devices on the rear panel. They are used in the following three cases.

- When controlling an external electronic load unit.
- When connecting to an external current detector.
- When using status signal output such as load-on and alarm on an external instrument.

A.1.1 Controlling an External Load Unit

The KFM2150 FC Impedance Meter collectively controls the PLZ-4W Series. It can also simultaneously control an external electronic load unit. The conditions for controlling the external electronic load unit are set using the menus.

Setting the Aux DC Load menu (the control conditions of the external electronic load unit)

Set this menu item when using an external electronic load unit in addition to the PLZ-4W Series.

Table A-1 Setting the control conditions of the external electronic load unit

Menu item		Conditions to be set
Configuration > DC Load > Load On Output		Load on/off signal output
Configuration > Aux DC Load >		
	Control	Control voltage used to supply the maximum load current of the external electronic load unit.
	Full Scale	Maximum load current of the external electronic load unit.
Setup > Aux DC Load > Output		Load current of the external electronic load unit

1 Select MENU key > Configuration > DC Load > Load On Output to select the logic of the load on/off control signal output of the external electronic load unit (low or high).

The load on/off control signal output to the PLZ-4W Series is also changed to the same logic. Note that the PLZ-4W settings are changed automatically by the KFM2150.

2 Select Configuration > Aux DC Load > Control to set the control voltage used to supply the maximum load current of the external electronic load unit.

The selectable range is from 0.00 to 10.50 V.

3 Select Configuration > Aux DC Load > Full Scale to set the maximum load current of the external electronic load unit.

The selectable range is from 0 A to 3500 A.

4 Select Setup > Aux DC Load > Output to set the load current of the external electronic load unit.

The selectable range is from 0 A to the load current set in step 3.

5 Turn off the POWER switch of the KFM2150 and then turn it back on.

The settings are fixed.

■ Example

Set the electronic load unit as follows:

- Control voltage used to supply the maximum load current of the external electronic load unit: 10 V
- Maximum load current of the external electronic load unit: 200 A
- Load current of the external electronic load unit: 110 A

As shown in Fig. A-1, the control voltage that the KFM2150 delivers is 5.5 V.

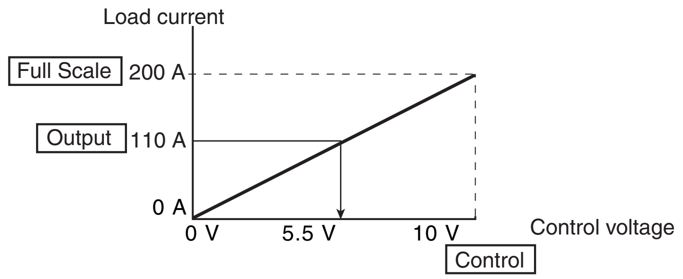


Fig. A-1 Aux DC Load control

Using the CONTROL TERMINAL

The control terminal is for an external electronic load unit other than the PLZ-4W Series. Screwless terminals are used. Use AWG24 wires and remove 10 mm of the covering from the tip of the wires.

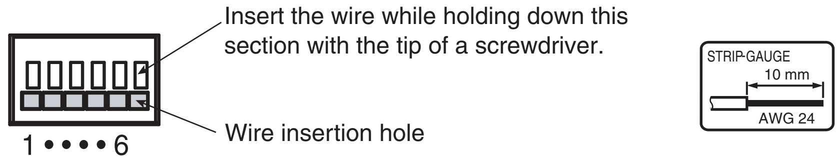


Fig. A-2 Screwless terminals and wires used

Table A-2 CONTROL TERMINAL arrangement

Terminal number	Signal name	Description
1	AUX DCLOAD REF	Current setting signal output: 0 V to 10 V.*1
2	AUX DCLOAD COM	Common for the current signal setting output.
3	LOAD ON/OFF CONT	Load on/off control signal output.*2 ,*3
4	ALARM OUT	Alarm output. Delivers a low level signal when an alarm occurs on the KFM2150 or the PLZ-4W Series.*2
5	AUX LOAD STATUS COM	Common for terminal number 3 and 4.
6	N.C.	(No connection)

*1. Fig. A-3 shows an example.
*2. Same logic as the PLZ-4W Series to the load on/off control signal.
*3. Open collector output by a photocoupler. Maximum applied voltage: 30 V, maximum current: 5 mA.

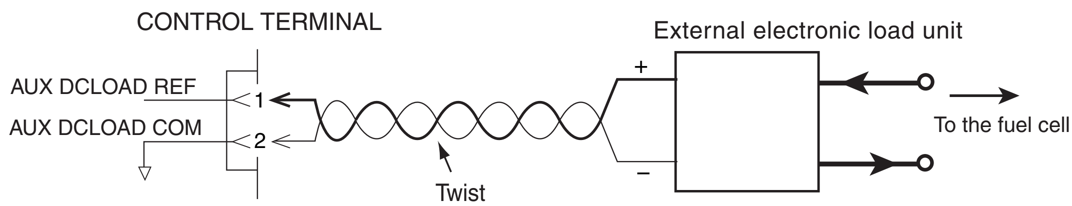


Fig. A-3 AUX DCLOAD REF output

A.1.2 Using Channel 2 of the CURRENT SENSING Terminal

The current signal of the impedance measurement is connected to the CURRENT SENSING terminal.

Channel 2 of the CURRENT SENSING terminal is used when connecting an external current detector.

Select MENU key > Setup > Input Select > Current Sensing to select channel 2.

The CURRENT SENSING terminal is insulated from the chassis. HIGH corresponds to high potential, and LOW corresponds to low potential. The DC input voltage range is 0 V to 10 V, and the input impedance is approx. 1 MΩ.

A.1.3 J1 Connector

See Table A-4

The J1 connector used to connect to an external system. It is used to perform interconnected operation such as turning the load off on the electronic load unit using commands from external equipment such as gas control equipment. Do not bundle the wires with other wires, and connect the wires to gas control equipment or a controller independently.

Do not bundle with the following types of wires

- Load wires of the electronic load unit.
- Sensing wires of the KFM2150.
- Wires to component fans or blowers and electromagnetic valve.
- AC power input wires of instruments

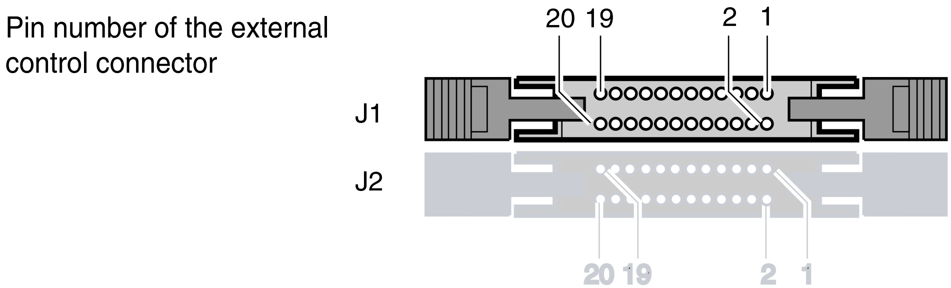


Fig. A-4 J1 and J2 connectors

CAUTION

- To disconnect the connector, remove the lock levers located on either side and pull the connector itself.
- Be sure to turn off the KFM2150 before attaching or removing the connector.

Use a standard MIL 20-pin connector for connecting to the J1 connector.

Table A-3 shows the recommended connectors.

NOTE

- When using a flat cable, be sure to use a connector with a strain relief.
- To press-fit discrete wires or flat cables, be sure to use a special tool. For a description of applicable cables and tools, see the relevant catalogs of connector manufacturers.

Table A-3 Connectors compatible with the J1 connector

Manufacturer	Product name	Note
Omron	XG5M-2032, XG5M-2035, or XG5S-1001 (2 pcs.)	For discrete wires
Omron	XG4M-2030 or XG4T-2004	For flat cables
KEL	6200-020-601	For flat cables

Table A-4 J1 connector pin arrangement

Pin No.	Signal name	Description
1	IMON	Current monitor output (IMON of the PLZ-4W Series). 10 V f.s (H/L range) and 1 V f.s (M range).
2	UI1	General purpose input 1: TTL level.
3	IMON COM	Common for current monitor output. Save electrical potential as the LOW terminal of the CURRENT SENSING input.
4	N.C.	Open-circuit pins for preventing malfunction due to incorrect connection. Do not connect anything to these pins.
5	N.C.	
6	N.C.	
7	UO1	General purpose 1: Open collector output.[*1]
8	UI2	General purpose input 2: TTL level.
9	UI3	General purpose input 3: TTL level.
10	ALARM IN	External alarm input: TTL level. Low level indicates alarm.
11	UI4	General purpose input 4: TTL level.
12	A COM	Common for the TTL level input.
13	LOAD ON STATUS	Load on status output. Delivers high or low signal when the load is on on the load unit.[*2] Open collector output by a photocoupler.[*3]
14	UO2	General purpose 2: Open collector output.[*1]
15	UO3	General purpose 3: Open collector output.[*1]
16	ALARM STATUS	Alarm status output. Delivers high or low signal when an alarm is detected.[*4] Open collector output by a photocoupler.[*3]
17	STATUS COM	Common for status output.
18	UO4	General purpose 4: Open collector output.[*1]
19	N.C.	Open-circuit pins for preventing malfunction due to incorrect connection. Do not connect anything to these pins.
20	N.C.	

*1. Maximum applied voltage: 50 V, maximum current: 100 mA.
*2. Set the logic using MENU key > Configuration > DC Load > Load On Status. The setting takes effect when the POWER switch is turned off and then turned back on.
*3. Maximum applied voltage: 30 V, maximum current: 5 mA.
*4. Set the logic using MENU key > Configuration > Alarm > Alarm Status. The setting takes effect when the POWER switch is turned off and then turned back on.

A.2 Factory Default Settings

The KFM2150 FC Impedance Meter, a component instrument of this system, is shipped with the settings shown in Table A-5.

Table A-5 Factory default settings

Item		Setting
Measurement method		AC impedance method
AC impedance method	Measuring frequency (FREQ)	20 kHz
	Measuring AC current	10 %
Current interrupt method	Pulse width (WIDTH)	10.0 ms
	Pulse depth (DEPTH)	100 %
	Pulse transition time (TRNSN)	0.01 ms
	Sampling start position	0.06 ms
	Sampling region	0.030 ms
Average count (AVE)		1
DC current		0 A
Soft start rise time		0:00 s
Soft start fall time		0:00 s
Display (VIEW)	Upper left	R
	Lower left	X
	Upper right	Z
	Lower right	θ
Scanner (KFM2151)		Not used
Display color		Blue
Alarm volume		64
Short-circuit correction function		Disabled
Judgement function		Disabled
VOLTAGE SENSING terminal		Channel 1
CURRENT SENSING terminal		Channel 1
Load current range of the PLZ-4W Series.		HIGH
Voltage range of the PLZ-4W Series		150 V
CV mode transition voltage of the PLZ-4W Series		0 V
Voltage sensing undervoltage protection (SENSE UVP)		-2 V
Voltage Sensing UVP Mask Time		4 s
Overpower protection (PLZ4W OPP)		Maximum value of the PLZ-4W Series that are connected
Undervoltage protection (PLZ4W UVP)		OFF
Remote control	Interface setting	GPIB
	GPIB address	3
	RS232C baud rate	19200 bps
	RS232C data length	8 bits
	RS232C stop bit	2 bits
	RS232C acknowledge message	Not used
External device connection	Load current of the external electronic load unit	0 A
	Control voltage used to supply the maximum load current of the external electronic load unit	10.00 V
	Maximum load current of the external electronic load unit	200 A
	Alarm status output	Hi
	Load on/off control signal output.	Hi
	Load on status output	Hi

A.3 Overview of the Fuel Cell and Evaluation System

A fuel cell is power generating equipment that produces power by a chemical reaction between the fuel (hydrogen or methanol) and oxygen. The evaluation system operates the fuel cell and analyzes its characteristics. This section summarizes the items related to the construction of an evaluation system.

A.3.1 Fuel Cell

- Fuel cell types

  There are various types of fuel cells such as phosphoric acid (PAFC), molten carbonate (MCFC), solid oxide (SOFC), proton-exchange membrane fuel cell (PEFC or PEMFC), and direct methanol (DMFC). Each type has its own characteristics such as the operating temperature, main location of use, and output capacity. The following explanation mainly focuses on the PEFC and DMFC.

- Fuel Cell Operation and Components

  Fuel cells do not operate on fuel cell alone. They always require accompanying devices such as a device for supplying fuel, fuel pump, and fan. These devices are often called components for the DMFC. The fuel cell system consisting of the fuel cell and components is needed to run the fuel cell as power generating equipment.

A.3.2 Installation Environment

- Evaluation system and components

  An evaluation system is needed to run the fuel cell and analyze its characteristics. Many of the evaluation systems have functions for controlling the fuel cell components including the pump, fan, bubbler (humidifier), heater, and electromagnetic valve. This is because such functions are necessary for evaluating the optimal operating conditions, etc.

  On the other hand, there are instruments that are needed in the evaluation system but do not function as components in running the fuel cell such as an electronic load unit and impedance meter.

- Construction of this system

  The electronic load unit absorbs the power that the fuel cell generates and consumes the power as heat during the fuel cell evaluation. The impedance meter measures the impedance, which is one of the parameters used to check the operating status of the fuel cell at that point. This system consists of the electronic load unit and impedance meter.

- Stable and sufficient power capacity

  The fuel cell evaluation system may use significant amount of power in controlling the components, gas flow and operating temperature control equipment and electromagnetic valves. Electronic load units that have a built-in power supply for operation (0 V type) also require large amount of power. It is important to ensure stable and sufficient power capacity in the installation of a fuel cell evaluation system.

- Noisy environment

For such environment, turning on and off of the temperature control heater, the operation of the electromagnetic valve may produce electrical noise. These types of noise could be entered into the KFM2150 system via the AC power supply or as electromagnetic waves. It is important to install the KFM2150 system so that the system receives as little effect as possible from the noise.

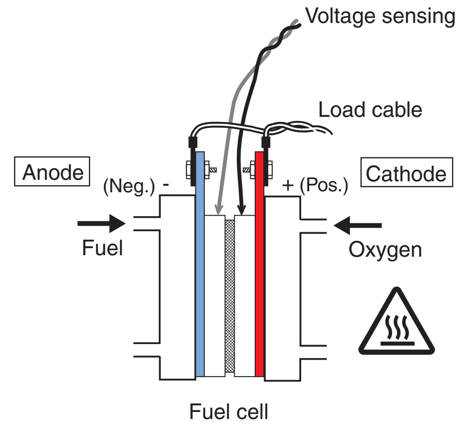
For example, the AC power line connected to a control device that turns on/off a large power supply should be of a separate system. In addition, those power cords need to be kept apart from the power cords of the KFM2150 system and not bundled together. The same holds true for the power supply of the load and the sensing wires.

- Operating temperature of the fuel cell and used parts

In principle, impedance measurement of the KFM2150 system can be carried out on all fuel cell types. However, special preparation (for example, wiring the electrodes for temperature measurement) is required for fuel cells that operate at high temperatures such as the SOFC. The parts provided with the KFM2150 are assumed to be used with fuel cells that operate at low operating temperatures such as the PEFC and DMFC. Even in this case, check the temperature before making actual measurements.

A.3.3 Precautions Concerning Installation

Precautions concerning the fuel cell



Negative polarity	Positive polarity
Anode	Cathode
Fuel electrode	Oxygen electrode
Electrode from which electrons flow out	Electrode to which electrons flow in

Fig. A-5 Fuel cell diagram

- Polarity

A fuel cell always has positive and negative polarities. The polarities are also called anode electrode and cathode electrode or fuel electrode and oxygen electrode. The anode and cathode are negative and positive terminals, respectively. The fuel electrode and oxygen electrode are anode and cathode, respectively. The terminal where the electrons flow in is the positive terminal, and the terminal where the electrons flow out is the negative terminal.

- Temperature

  The operating temperature varies depending on the type of fuel cell. The temperatures in actual locations where the fuel cells are in operation can range from several tens of degrees to several hundred degrees Celsius. The type of terminal from which current is drawn and its temperature are important parameters for selecting the wires used to connect the electronic load unit to the fuel cell.

- Wires

  The emitted voltage of a single fuel cell is 1 V to 1.2 V. However, large currents in the order of 100 A can be drawn by increasing the cell area involved in the reaction. As explained later, the wires needed to draw out current in the order of 100 A are quite large and thick.

Precautions concerning the electronic load unit

- Polarity

  The electronic load unit is a device that is connected to the fuel cell and absorbs the energy that the fuel cell generates. The electronic load unit draws out a specified current from the fuel cell and transforms the energy into heat inside the unit.

  The electronic load unit also has positive and negative polarities. The positive terminal is where the current flows in and is at a higher electric potential. The negative terminal is where the current flows out and is at a lower electric potential.

  The positive terminals of the electronic load unit and fuel cell are connected together as well as the negative terminals. The electronic load unit will break if you reverse the connection.

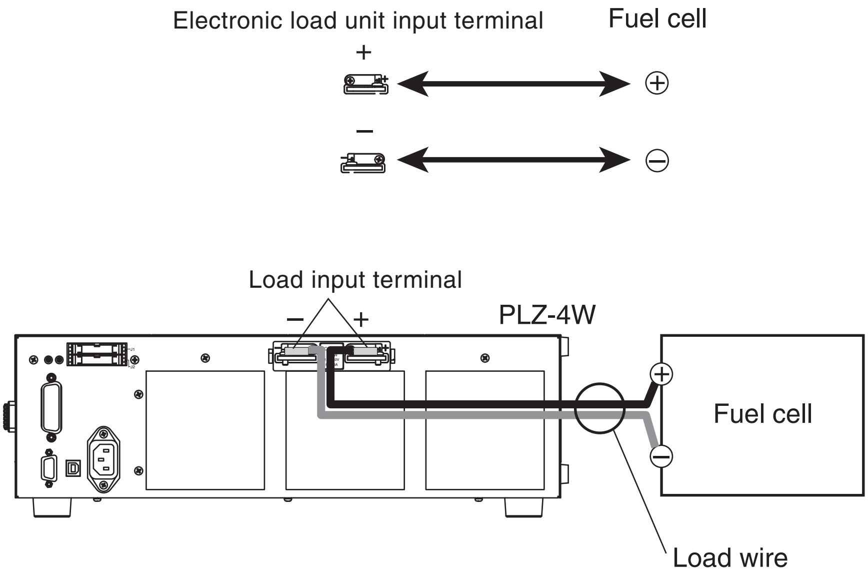


Fig. A-6 Polarities of the electronic load unit

- Rating

  The electronic load unit has a voltage rating, current rating, and power rating. None of the ratings can be exceeded.

A.4 Load Wires

The load wires conduct the output current from the fuel cell to the electronic load unit. The wires for large currents used to connect to the fuel cell are quite different from the wires you see in daily life. This section explains the structure and the current capacity of the load wires.

A.4.1 Wire Structure

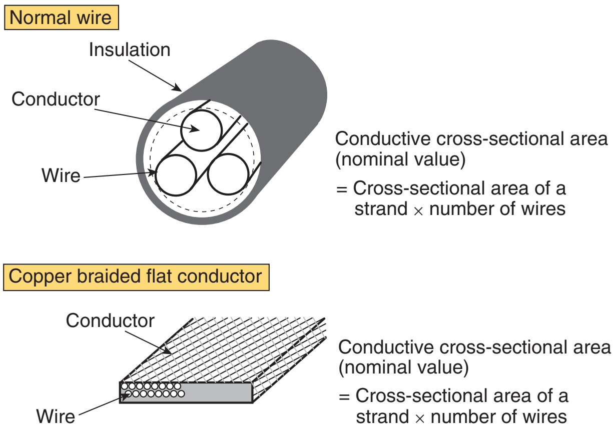


Fig. A-7 Wire structure and conductive cross-sectional area

Normally, the conductor of the load wires is made of copper with insulation covering on the outside (see Fig. A-7). For large currents, some wires come with conductors that are woven (called earth cables, copper braided flat wire, or flexible annealed copper stranded wire). Because a single copper wire is too hard to bend, many thin copper wires are normally twisted and bound together.

A.4.2 Current Capacity

- Heat Generation

A wire has a maximum current that it can handle. Because the conductor of a wire has resistance, power is consumed and heat is generated. The wire covering has an allowable temperature. If the temperature caused by the heat exceeds the allowable temperature, the wire may emit smoke or fire.

- Current capacity and conductive cross-sectional area

The current capacity is determined by the covering material, temperature characteristics of the conductor, etc. The temperature characteristics of the conductor are determined by the resistance of the conductor. The resistance of the conductor is mainly determined by its thickness. The thickness of the conductor is indicated by the cross-sectional area of the conductor. If several thin lines are bounded together, the thickness is represented by the sum of each cross-sectional area. This cross-sectional area is indicated in units of mm^2.

The current recommended by Kikusui shown in Table A-6 allows extra margin by taking into account the fact that the temperature increase in the wires is greater when the wires are bound together and also how the electronic load unit is used.

The wires used in a household power strip are approximately 2 mm^2 with an allowable current of 15 A. The allowable current of a wire with a cross-sectional area of about 80 mm^2 is 200 A. The diameter of this wire is 2 cm. This wire is quite heavy and weights approximately 1 kg/m.

A.5 Wiring

The wiring to connect the instruments is very important. You cannot simply connect the instruments with wires. The wiring is the major factor for operating the evaluation system stably and attaining repeatability in measurements in various types of environment described in section A.3.2, “Installation Environment.”

A.5.1 Connecting the Wires

- Using crimping terminals

A cannon connector for large currents may be used to connect the wires to the fuel cell. In general, however, wires are connected using crimping terminals as an inexpensive but reliable method. A crimping terminal is connected to the stripped section of the wire by crushing the terminal with pressure so that the terminal and the conductor are combined. This crimping terminal is then screwed to the electrode of the fuel cell.

Crimping terminals that match to the conductor diameter of the wire are used. A crimping tool is required to crimp the terminals. To crimp a wire with large conductor diameter, a hydraulic crimping tool is required.

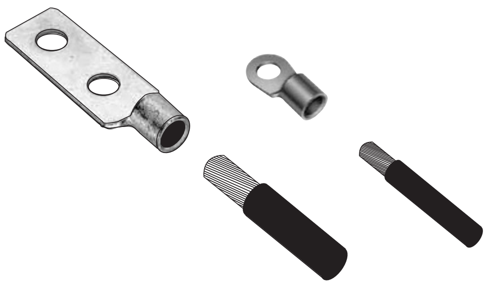


Fig. A-8 Crimping terminal

- Contact resistance

In wiring, there is always has a section where the wire comes in contact with the electrode. A contact resistance exists at the location where the terminal comes in contact with the electrode. Like the conductor resistance, this contact resistance is also a large value that cannot be ignored.

- Heavy wires

Thick wires are heavy. If the wire is used for rating of 200 A with length of 5 m. It is actually required of two wires for the positive and negative polarities, in this case we need for the total length of 10 m wire with a cross-sectional area of 80 mm^2. Because a wire with a cross-sectional area of 80 mm^2 weights 1 kg/m, the total weight becomes 10 kg. This may be heavier than the fuel cell.

A.5.2 Wiring the Load

- **Temperature at the contact section**

  Connect the wire so that the connected section is at a temperature lower than the value of the wire specifications taking into account the fuel cell type.

- **Current capacity**

  To determine the current capacity of the load wire, first consider how much current will be drawn from the fuel cell. Then, consider various cases such as normal tests and boundary tests. From the results, determine the cross-sectional area of the wire needed to perform normal tests and the cross-sectional area needed to perform boundary tests by referring to Table A-6. For currents above 300 A, you must use multiple 150-mm^2 wires or prepare a dedicated bus bar.

- **Length**

  Determine the length of the wires by considering the arrangement of the fuel cell and electronic load unit. Take into account the weight of the wire and the location supporting the wires. Make the wire as short as possible to minimize the inductance.

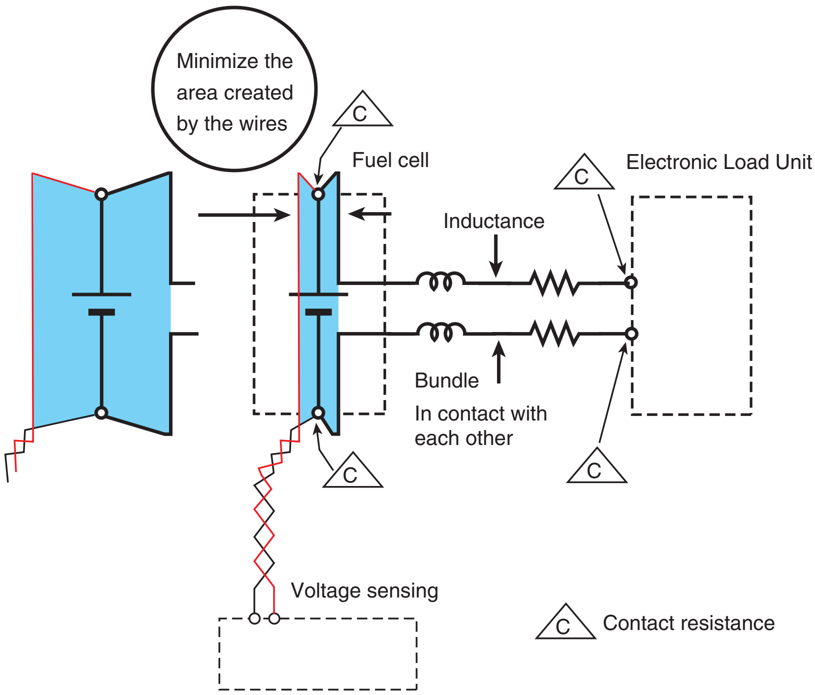


Fig. A-9 Minimum area wiring and wires in contact with each other

- **Inductance**

  The inductance depends on the wiring. Inductance acts as the impedance for the measuring AC signal. You must pay close attention to the inductance when measuring the impedance of the fuel cell. Because two wires for the positive and negative polarities are used, the wire inductance varies depending on how the wires are routed and bound together. These factors also require attention.

- **Wiring the KFM2150 system**

  Consider the wiring method by taking to the actual routing into consideration. Route the positive and negative wires in contact with each other, twisted with each other, or woven together. At the location where the wire is connected to the positive and negative terminals of the electronic load unit, connect the wires with the minimum length of separation.

In a rack mount type system, the wires may be quite thick and heavy. Routing the wires on the ground lowers the center of gravity and keeps the system stable, but the wiring distance tends to be longer. If the wires are routed horizontally, the wiring to the fuel cell will be shorter, but the wires need to be supported for mechanical stability. If the wires are raised for routing, the wires must be supported for stability. Routing the wires horizontally is advantageous in terms of measurements, but routing the wires on the ground is more mechanically stable.

- Wiring the fuel cell

Wires are connected in the same manner as the wiring of the KFM2150 system. The wires are connected to the positive and negative terminals with the minimum amount of separation at the contact points (minimum area wiring). Wires from the contact point to the actual electrodes of the fuel cell are also kept closely together or twisted together.

Do not move the load wires once they are routed. Moving the wires will degrade the repeatability of the impedance measurement values. In particular, never move the wires if the short-circuit compensation function is used.

- Load wires

Use wires of sufficient current capacity for the connection. Table A-6 indicates the nominal cross-sectional area and allowable current of wires.

Table A-6 Nominal cross-sectional area of wires and allowable currents

Nominal cross-sectional area [mm^2]	AWG	(Reference cross-sectional area) [mm^2]	Allowable current*1 [A] (Ta = 30 °C)	Current recommended by Kikusui [A]
2	14	(2.08)	27	10
3.5	12	(3.31)	37	-
5.5	10	(5.26)	49	20
8	8	(8.37)	61	30
14	6	(13.3)	88	50
22	4	(21.15)	115	80
30	2	(33.62)	139	-
38	1	(42.41)	162	100
50	1/0	(53.49)	190	-
60	2/0	(67.43)	217	-
80	3/0	(85.01)	257	200
100	4/0	(107.2)	298	-
125	-	-	344	-
150	-	-	395	300
200	-	-	469	-

*1. Excerpts from Japanese laws related to electrical equipment.

App

A.5.3 Wiring the sensing wires

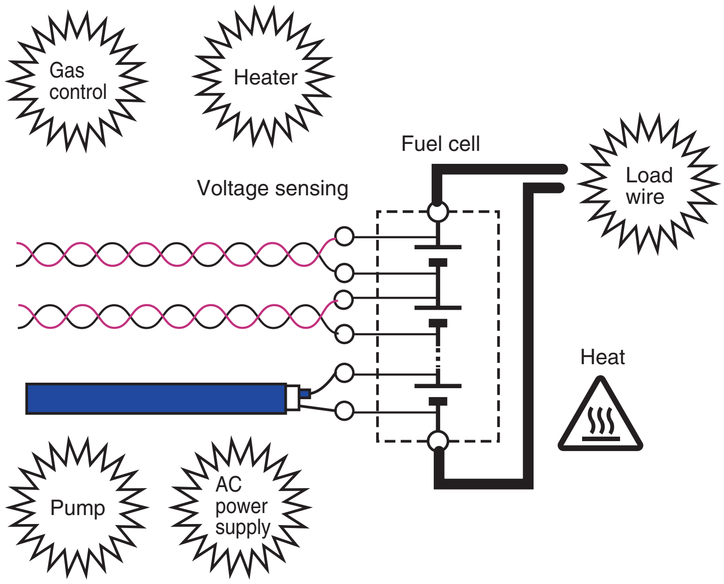


Fig. A-10 Sensing wire environment

- Wiring the KFM2150 system

Twist the sensing wires thoroughly or use shielded wires. Sensing wires are connected to the sensing terminals of the KFM2150 or the sensing terminals on the back of the rack on a rack mount system.

- Wiring the fuel cell

At the fuel cell, connect the sensing wires to the point where you want to measure. For example, if you want to measure the impedance of a cell, connect to the point where you want to measure the cell. Correct measurements cannot be made by simply connecting the sensing wires to the terminals of the electronic load unit or the terminals of the fuel cell where current is drawn even if these points are connected electrically to the same points.

Connect the sensing wires in a well twisted condition to the measurement point (minimum area wiring). If this area is open, the measurement is affected, and the results will not be correct. The sensing wires need to be connected directly to the point where you want to measure, but pay attention to the temperature at that point. The temperature may be quite high depending on the fuel cell type. If this is the case, special wires may be required.

- Wiring the system

The fuel cell evaluation system consists of components such as a pump, heater, gas control equipment as well as electronic load unit and impedance meter. Wiring is not limited to the electronic load unit and impedance meter. Wires are also connected to the pump and heater. Sensing wires are easily affected by the noise generated by the wiring of other equipment.

- Separating the sensing wires from the load wires

  Do not twist the sensing wires with the load wires. Measuring AC current is flowing through the load wires. If the sensing wires pass through the magnetic field created by the measuring AC current, noise is induced in the sensing wire, and correct measurements cannot be made. Separate the sensing wires from the load wires as much as possible, and lay them out through a route separate from the load wires to the fuel cell.

- Shortest wiring

  Like the load wires, route the sensing wires as short as possible. Noise may be picked up if the wires are long.

- Do not twist with other wires

  Do not twist the load wires and sensing wires together. In addition, do not twist the wires with the power lines of measuring instruments or other equipment such as gas control equipment or signal lines. If you do, the sensing wires will pick up noise and hinder correct and repeatable measurements. Furthermore, it may cause errors in the measuring instrument or other control equipment.

App

A.6 What Is an Electronic Load Unit

An electronic load unit is a load unit constructed of electronic circuits. It can achieve characteristics that are not available in a resistive load. A load is a device that consumes the power that the fuel cell generates. Normally, a resistor is connected, and the energy is consumed as heat. If a resistor is used as a load, the current varies depending on the voltage, and the consumed power varies. This is not desirable in an evaluation system.

A.6.1 Operation modes

An electronic load unit has the following typical operation modes.

- CC (constant current) mode

  CC mode allows a constant current to be run regardless of the voltage. The current value can be set in detail.

- CV (constant voltage) mode

  CV mode allows current to be run so that the voltage is kept constant. The voltage value can be set in detail.

- CR (constant resistance) mode

  CR mode allows a current to flow in proportion to the voltage. The resistance can be set in detail.

The PLZ-4W Series Electronic Load Unit also has CC+CV and CR+CV modes. These modes are suitable for examining the discharge characteristics of the battery. The KFM2150 system uses the PLZ-4W Series in CC+CV mode.

- CC+CV mode

  The PLZ-4W Series normally operates in CC mode. If the fuel cell voltage drops to a specified level, the PLZ-4W Series automatically switches to CV mode. For example, let's assume we have a fuel cell with an open-circuit voltage of 10 V that drops to 9 V when 10 A of current flows and 7 V when 20 A flows. We do not know how much current flow at 8 V. In such case, if we use CC+CV mode and set the CV mode transition voltage to 8 V, the PLZ-4W operates in CC mode until the fuel cell voltage drops to 8 V. As the current is gradually increased and the fuel cell voltage drops to 8 V, the PLZ-4W switches to CV mode and controls the current so that 8 V is maintained without allowing the current to exceed the specified value. If the current is gradually decreased, the PLZ-4W automatically switches to CC mode.

- CR+CV mode

  The PLZ-4W Series normally operates in CR mode. The mode switches to CV if a specified voltage is reached.

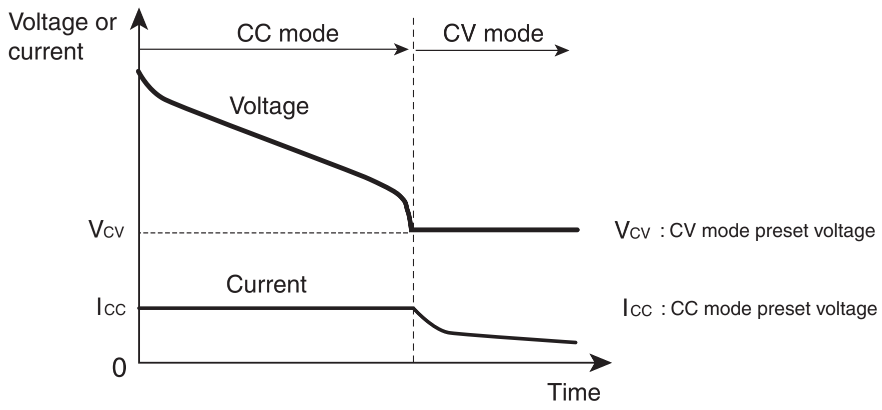


Fig. A-11 Battery discharge (transition from CC mode to CV mode)

A.6.2 Operating Voltage Range

A certain voltage is required for the electronic load unit to operate.

This voltage is the minimum operating voltage. There are two types of PLZ-4W Series depending on the operating voltage.

- Operating voltage range of 1.5 V to 150 V: PLZ-1004W and PLZ2004WB
- Operating voltage range of 0 V to 150 V: PLZ164WA and PLZ664WA

● Operating voltage range of 0 V to 150 V (0 V type)

The type that operates from 0 V operating voltage range contains a power supply with a voltage of approximately 1.5 V to allow it to operate even if the input voltage is 0 V. In other words, a voltage of approximately 1.5 V is applied to the internal electronic load circuit, so that operation is not interrupted even if the input voltage is 0 V. There is no need to worry about the internal power supply when using the electronic load unit, and the internal power supply cannot be used as a normal power supply. From the user point of view, either type of electronic load unit can be used in the same manner.

The voltage of a single fuel cell is approximately 1 V. If you need to evaluate a single cell, you must use the PLZ164WA or PLZ664WA that allows you to set the operating voltage to 0 V. Electronic load units that can be used from an operating voltage of 0 V are sometimes called the 0 V type or the 0 V input operating voltage type. Likewise, electronic load units that can be used from an operating voltage of 1.5 V are sometimes called the 1.5 V type or the 1.5 V input operating voltage type.

● Load on and load off

An electronic load unit can run or stop the current as a load. “Turning the load on” refers to the operation of enabling the current flow, and “turning the load off” refers to the operation of stopping the current.

App

A.6.3 How to use CV mode and Remote Sensing

This system operates in CC+CV mode, in which the system automatically switches between CC mode and CV mode. During normal operation, the system operates in CC mode, in which constant current runs independent of the voltage. If constant current can no longer run in CC mode, the system switches to CV mode and prevents overcurrent from flowing by maintaining the preset voltage. However, if the running current is large, due to the voltage drop in the wires, a voltage higher than the preset CV voltage will be maintained across the fuel cell output terminals. The PLZ-4W remote sensing feature can be used to compensate for this voltage drop and switch to CV mode at the correct voltage.

Remote sensing terminals are on the rear panel of the PLZ-4W on the bench top type and the rear panel of the rack on the rack mount type. When these terminals are connected to the fuel cell output terminals, the system will switch to CV mode when the voltage across the fuel cell output terminals reaches the preset CV voltage. The voltage compensation provided by the remote sensing feature is up to 2 V for a single line. In other words, if the voltage drop in the wires is greater than 2 V, the system will not operate at the correct preset CV voltage. In this situation, use wires that are sufficiently thick for the current and the shortest wires possible for the connection.

The PLZ-4W displays the voltage at the sensing point and activates the protective circuit on the basis of this voltage. If you don't use the remote sensing function, the sensing point will be at the PLZ-4W load input terminal, and when the load input terminal voltage reaches the preset CV voltage, the PLZ-4W will switch to CV mode. This will cause undesirable behavior. For example, while testing large currents on a single cell, the PLZ-4W will not be able to draw current even when there is sufficient cell voltage. This occurs because even when there is sufficient fuel cell voltage, when sensing is not used, the voltage at the PLZ-4W input terminal will drop to the preset CV voltage causing the PLZ-4W to switch to CV mode, or the voltage will drop 0 V preventing the PLZ-4W from drawing current.

A.7 I-V Characteristics Test

This section explains the points that need to be considered concerning the characteristics and wiring of the electronic load unit when performing I-V characteristics tests.

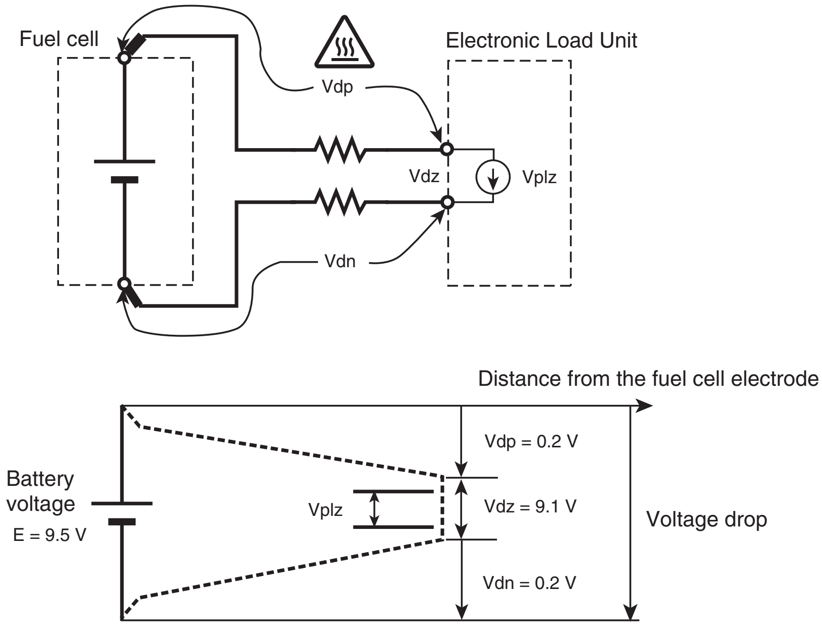


Fig. A-12 Voltage drop diagram (example for 100 A)

A.7.1 Voltage Drop Caused by the Wires

App

- Voltage drop occurrence

Because wires have conductor resistance, voltage drops occur even if wires of sufficient cross-sectional area are used to connect the electronic load unit to the fuel cell (conductor resistance is never zero).

- Voltage drop example

Let's assume a fuel cell with an open-circuit voltage of 10 V. Because no current is flowing through the electronic load, 10 V is applied across the input terminals of the electronic load unit. Let's assume that the fuel cell voltage falls to 9.5 V when 100 A of current is drawn. At this point, the voltage applied to the electronic load unit is not 9.5 V.

Let's assume that the conductor resistance of the wire from the fuel cell to the electronic load unit is 1 mΩ (corresponds about 2 m of wire with a cross-sectional area of 38 mm^2). Let's also assume that the contact resistance between the wire and the electronic load unit is 1 mΩ. What is the voltage drop when 100 A of current is drawn?

- The voltage drop in the wire from the fuel cell to the positive terminal of the electronic load unit is 100 A × 1 mΩ which is 0.1 V.
- The voltage drop in the wire from the negative terminal of the electronic load unit to the fuel cell is 0.1 V.

- In addition, the voltage drop due to the contact resistance between each wire and each input terminal of the electronic load unit is 0.1 V.

As a result, a total voltage drop of 0.4 V occurs. Therefore, the voltage at the input of the electronic load unit is 9.1 V even though the voltage at the output terminal of the fuel cell is 9.5 V. Note that the fuel cell voltage is not equal to the input voltage of the electronic load unit.

- Power loss and heating of the wires (example for 100 A)

Note that if there is a voltage drop of 0.1 V in the wire when a current of 100 A is flowing, 10 W of power is consumed by the wire as given by 0.1 V x 100 A. Likewise, 10 W is consumed in the other wire, and 10 W is consumed at each contact input terminal. This means that a total of 40 W is consumed. All the power is converted to heat, and you can see that the temperature at the input terminals and wires increases.

As the current increases, the voltage applied to the electronic load unit decreases. At the same time, the heat generated by the wires and contacts increases.

A.7.2 Operating Voltage of the Electronic Load Unit and Voltage Drop in the Wire

- Operating voltage of the electronic load unit

The minimum operating voltage is 1.5 V for the 1. 5 V type and 0 V for the 0 V type. This value is defined at the input terminal. Taking the PLZ1004W (1.5 V type) for example, if there is 1.5 V at the input terminal, the PLZ1004W can deliver the rated current of 200 A. This does not mean that the PLZ1004W can deliver 200 A when the fuel cell voltage is 1.5 V.

- Actual example of the operating voltage of the electronic load unit

If the fuel cell voltage is 1.5 V when 200 A of current is drawn in the example of section A.7.1, “Voltage Drop Caused by the Wires,” the voltage at the input of the electronic load unit ends up being 0.7 V, because a total voltage drop of 0.8 V occurs due to the wires and contact resistance.

Because the minimum operating voltage at the input terminal of the PLZ1004W is 1.5 V, current cannot flow at 0.7 V. In other words, a single PLZ1004W cannot run up to 200 A of current from a fuel cell whose voltage is 1.5 V. For details on the current that the PLZ1004W can run, see the operation manual of the PLZ-4W Series.

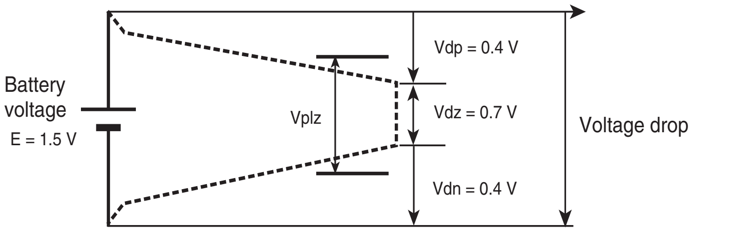


Fig. A-13 Voltage drop diagram (example for 200 A)

● Operating voltage of a 0 V type electronic load unit

The PLZ664WA can run the rated current down to an input voltage of 0 V. This also does not mean that the PLZ664WA can run the current until the fuel cell voltage is 0 V. If the voltage drops due to the wires and contact resistance and the voltage at the input terminals of the electronic load unit falls below 0 V (negative voltage), the PLZ664W cannot run the current.

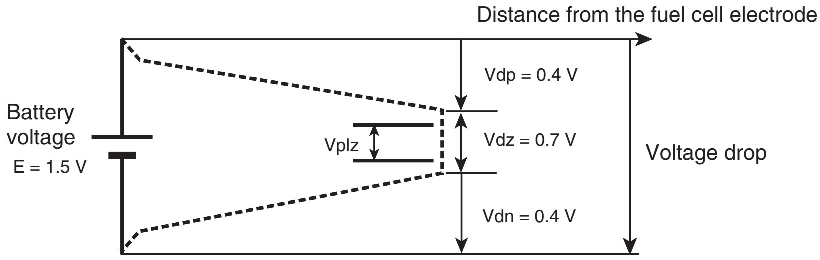


Fig. A-14 Voltage drop diagram (example for 0 V type)

A.7.3 Summary of the Required Test Conditions

Note the following items in the I-V characteristics tests of fuel cells in which the area of a single cell is large and the current is large.

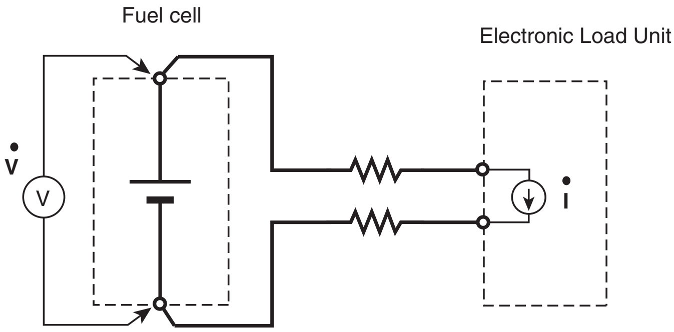
- If you do not minimize the voltage drop caused by the wires and contact resistance, the voltage at the input terminals of the electronic load unit may fall below the minimum operating voltage, and the desired current may not be obtained.
- The conductor resistance of a wire is determined by its cross-sectional area and length. Therefore, the conductor used in the wiring must be as thick and short as possible.
- The contact resistance at connection point can be reduced not only by fastening the screw with sufficient torque but also making the contact area large by fastening multiple screws.
- It may seem that increasing the voltage of the power supply built into the electronic load unit and allowing current to flow even if the input voltage becomes negative is a good idea. However, a voltage drop in the wire means that the wire is generating heat. You must use sufficiently thick and the shortest wires to prevent the possibility of smoke emission or fire.

App

A.8 AC Impedance Characteristics Test

This section explains the points concerning the characteristics and wiring of the electronic load unit that need to be considered when performing AC impedance characteristics tests.

A.8.1 Measurement Principles



Impedance $\dot{Z} = \frac{\dot{V}}{\dot{I}}$

Fig. A-15 Measurement principles

The principle used to measure the AC impedance is the Ohm's Law. The impedance is equal to the voltage divided by the current. Therefore, in order to measure the impedance, you can run a known, constant current through the object you want to measure, measure the voltage that is generated, and divide the voltage by the current. However, the voltage and current here are of alternating current. Thus, the voltage, current, and impedance contain information called magnitude (Z) and phase (θ). The information can also be represented as a real part and imaginary part on a complex plane. For impedance, the real part is the resistance (R), and the imaginary part is the reactance (X).

- **CC+CV mode**

  In the KFM2150 system, the PLZ-4W Series runs the value of constant current which was set, and the KFM2150 measures the voltage that is generated at the fuel cell to derive the impedance.

  The operation of constant current means that the PLZ-4W Series is normally used in CC mode. CC+CV mode is used so that if the fuel cell can no longer run the specified current, the PLZ-4W switches to CV mode to limit the current at a given voltage.

- **CV mode**

  It is important to remember that if the PLZ-4W Series automatically switches to CV mode, a known constant current is no longer flowing. Consequently, the impedance measurement result may not be correct. Therefore, the KFM2150 system shows the PLZ-4W Series mode on the KFM2150 display so that you can see the mode change if it does.

A.8.2 Wire Inductance

- Superposed measuring AC current

An AC current is run through the fuel cell to perform AC impedance characteristics tests. The electronic load unit runs the current in the KFM2150 system. This means that the measuring AC current is superposed on the DC load current in the wires.

- Generation of inductance

You must pay attention to the wire inductance when the measuring AC current is flowing. The inductance produces reactance that oppose AC current. The unit is H (Henry). The reactance increases in proportion to the frequency of the alternating current.

- Inductance example

The typical wire inductance is approximately 1 μH per meter when the positive and negative wires are twisted together well. If the wire of each terminal (positive and negative) is divided into multiple wires, and the wires are twisted in a woven pattern or a bus bar is connected closely in contact, the inductance can be lowered to approximately 0.5 μH/m. However, an inductance of 1 μH/m is essentially present in normal wiring. The inductance varies depending on the thickness and type of the wires, but it is basically 1 μH/m.

- Calculation of reactance

Let's assume that the electronic load unit and the fuel cell are connected using a 1-m wire (1-m wires for positive and negative terminals twisted together). The wire inductance is 1 μH from the equation 1 μH/m × 1 m.

The reactance is given by ωL (where ω is the angular frequency given by frequency × 2 π and L is the inductance). The reactance is 0.628 mΩ at 100 Hz, 6.28 mΩ at 1 kHz, 62.8 mΩ at 10 kHz, and 125 mΩ at 20 kHz. The reactance becomes extremely large at high frequencies as compared to the conductor resistance of the wire.

App

- Measuring AC current

Let's assume we have a fuel cell with an open-circuit voltage of 10 V that drops to 9.5 V when 100 A of current is run. We assume that the wire resistance to the load unit (DC resistance in this case) is 1 mΩ, the contact resistance at the input terminal is also 1 mΩ, the wire length* is 2 m, and the inductance is 2 μH. The DC voltage applied to the electronic load unit is 9.1 V (section A.7, "I-V Characteristics Test"). Here, we superpose a measuring AC current of 10 Arms, which corresponds to 10 % of the 100-A DC current, to measure the AC impedance of the fuel cell at 20 kHz.

* Length of the wire in one direction.

- AC voltage

A DC voltage of 9.1 V is applied to the electronic load unit. What's the voltage when the measuring AC current is superposed? Because the wire inductance is 2 μH, the reactance at 20 kHz is about 250 mΩ. Because 10 Arms of measuring AC current flows, a voltage of 2.5 Vrms appears as given by 250 mΩ × 10 Arms.

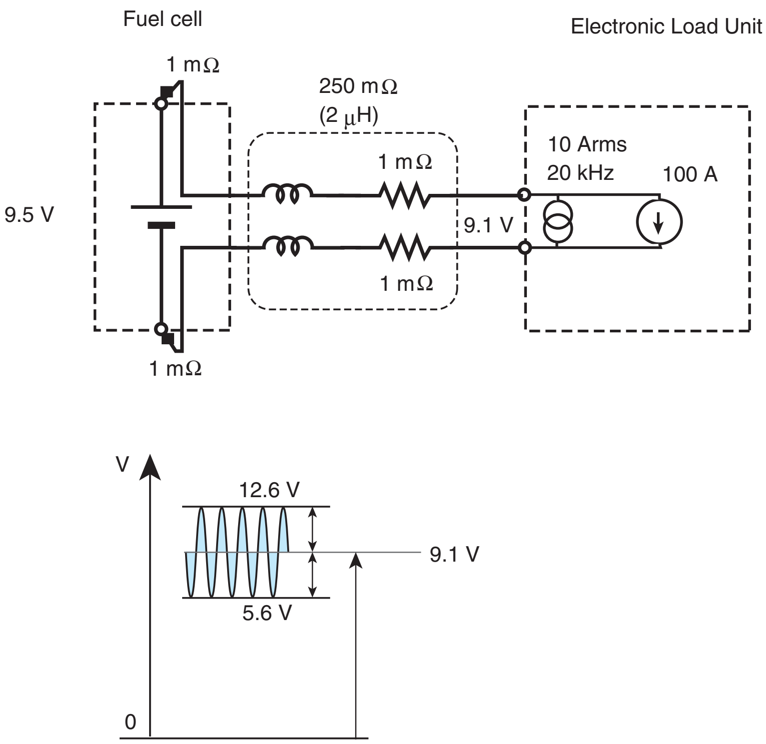


Fig. A-16 Voltage drop caused by the inductance

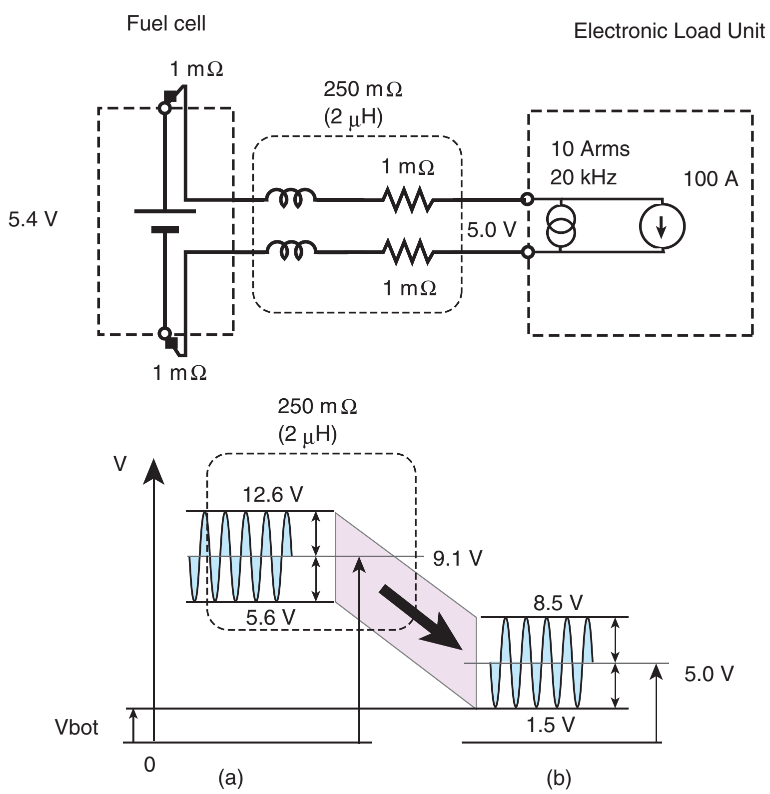
A voltage of 9.1 Vdc and 2.5 Vrms is applied to the input of the electronic load unit. This means that a peak voltage of 12.6 V and a bottom voltage of 5.6 V as well as an AC voltage with a peak-to-peak voltage of approximately 7 V around the DC voltage of 9.1 V are applied to the input (Fig. A-16).

A.8.3 Bottom Voltage

Bottom voltage and fuel cell voltage

- Bottom voltage

You need to pay attention to the bottom voltage. The minimum operating voltage is defined on the electronic load unit. For the PLZ1004W, it is 1.5 V. Let' assume that the open-circuit voltage of the fuel cell is 6 V, and the voltage drops to 5.0 V when 100 A is drawn given the same conditions. If an AC current that is 10 % of 100 A is run, the peak voltage is 8.5 V and the bottom voltage is 1.5 V at the input of the electronic load unit. If the fuel cell voltage drops or if a little more current is run, the bottom voltage applied to the electronic load unit falls below 1.5 V. This means that the specified measuring AC current cannot be run. If such condition actually occurs, the measuring AC current distorts, and correct measurements cannot be made (Fig. A-17).



Vbot: Bottom voltage

Fig. A-17 Bottom voltage

● Ensuring the bottom voltage

Parameters needed to ensure the bottom voltage are listed below.

- Fuel cell voltage.
- DC current run from the fuel cell (load current).
- Magnitude of the measuring AC current.
- Measurement frequency.
- Inductance (length and type of wires).

The wire inductance is pretty much determined by its length. To measure AC impedance at high frequency, the wires must be connected at the shortest length.

● Required fuel cell voltage

Table A-7 shows the fuel cell voltage that is required to keep the voltage at the electronic load unit from falling below the minimum operating voltage (bottom voltage) according to the wire length and measuring current. The figures are given by frequencies. Use them as guidelines. The measuring AC current is assumed to be an rms value corresponding to 10 % of the DC current (load current) and does not take into account the voltage drop caused by the DC current. The electronic load type is assumed to be a 0 V type.

As shown in Table A-7, wires must be shortened for AC impedance measurements of fuel cells with large currents. It can be seen that if the current of a single cell is large, measurement at high frequencies is difficult even if the wire length is less than 1 m.

One method is to measure using the smallest possible measuring current. However, a certain level of measuring current is needed to measure small AC impedance with high repeatability. You must also consider the upper limit of the measurement frequency.

■ How to view the table

1 Select the DC current (load current).

(Example) 100 A

2 Select the measurement frequency.

(Example) 10 kHz

3 Select the wire length. The cross point of the wire length and the measurement frequency is the fuel cell voltage that you are determining.

(Example) The cross point between a wire length of 2 m and 10 kHz is 1.776 V.

Table A-7 Required fuel cell voltage (V)

DC current (A)	Measuring frequency (Hz)	Wire length[*1] (m)			
		1	2	5	10
10	100	0.001	0.002	0.004	0.009
	1 k	0.009	0.018	0.044	0.089
	3 k	0.027	0.053	0.133	0.266
	10 k	0.089	0.178	0.444	0.888
	20 k	0.178	0.355	0.888	1.776
20	100	0.002	0.004	0.009	0.018
	1 k	0.018	0.036	0.089	0.178
	3 k	0.053	0.107	0.266	0.533
	10 k	0.178	0.355	0.888	1.776
	20 k	0.355	0.710	1.776	3.552
50	100	0.004	0.009	0.022	0.044
	1 k	0.044	0.089	0.222	0.444
	3 k	0.133	0.266	0.666	1.332
	10 k	0.444	0.888	2.220	4.440
	20 k	0.888	1.776	4.440	8.880
100	100	0.009	0.018	0.044	0.089
	1 k	0.089	0.178	0.444	0.888
	3 k	0.266	0.533	1.332	2.664
	10 k	0.888	1.776	4.440	8.880
	20 k	1.776	3.552	8.880	17.760
200	100	0.018	0.036	0.089	0.178
	1 k	0.178	0.355	0.888	1.776
	3 k	0.533	1.066	2.664	5.328
	10 k	1.776	3.552	8.880	17.760
	20 k	3.552	7.104	17.760	35.520

*1. Length of the wire in one direction.

Increasing bottom voltage

- Product of the measurement frequency and measuring current

The minimum operating voltage of the electronic load unit varies depending on various conditions. The minimum operating voltage of the PLZ1004W and PLZ664WA are 1.5 V and 0 V, respectively.

However, if the product of the measurement frequency (kHz) and the measuring current (Arms) exceeds 500, the minimum operating voltage increases. The amount of increase varies depending on the model. For example, we will look at KFM2150 SYSTEM5000-03. This system allows up to 1000 A of rated current.

If you run a DC current of 500 A, and set the measuring current to 5 % which is 25 Arms. If the measurement frequency is 20 kHz, the product of the measurement frequency and the measuring current is 20×25 which is 500. The minimum operating voltage up to this point is 1.5 V.

If you set the measuring current to 6 %, the measuring current is 30 Arms. In this case, the product of the measurement frequency and the measuring current is 20×30 which is 600. Because the minimum operating voltage increases by 0.45 V per 100 if 500 is exceeded, the minimum operating voltage is 1.5 V + 0.45 V = 1.95 V.

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A.9 Impedance Measurement Tests Using the Interrupt Method

The current interrupt method allows the ohmic resistance of the electrochemical/ electrical circuit (also called solution resistance and membrane resistance) to be determined. It is a value that is read from the voltage waveform when the current is interrupted.

Fuel cells operate as batteries by the chemical reaction that takes place at the boundary face of the electrode and electrolyte. This reaction can be represented as an equivalent circuit. There are many equivalent circuits that have been devised, but the circuit shown in Fig. A-18 is often used. Here, R1 is the ohmic resistance of the electrochemical/electrical circuit, R2 is the resistance to charge transfer at the electrolyte/electrode interface, and C is called the electric double layer capacitance. In the explanation below, we assume that the characteristics of the fuel cell can be represented by this equivalent circuit.

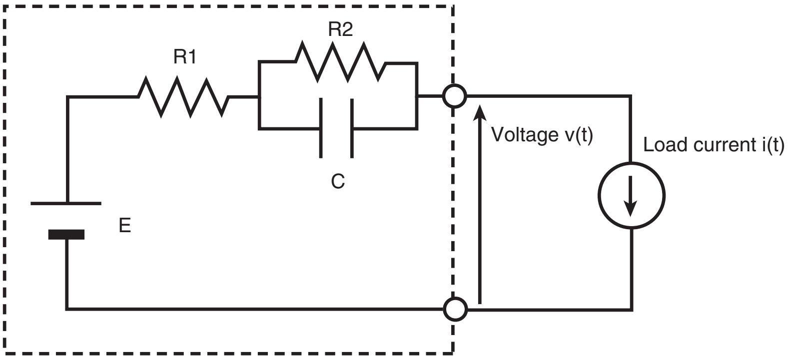

Fig. A-18 The simplest equivalent circuit of a fuel cell

Conventional current interrupt method

In the current interrupt method, the load current i(t) of Fig. A-18 is varied in a step pattern shown in Fig. A-19, and the ratio of the amount of change at the section where the waveform of the voltage across the output terminals of the fuel cell v(t) jumps abruptly (the V section in Fig. A-19) versus the amount of change of current at the corresponding point is determined. This value is assumed to be the ohmic resistance of the electrochemical/electrical circuit R1.

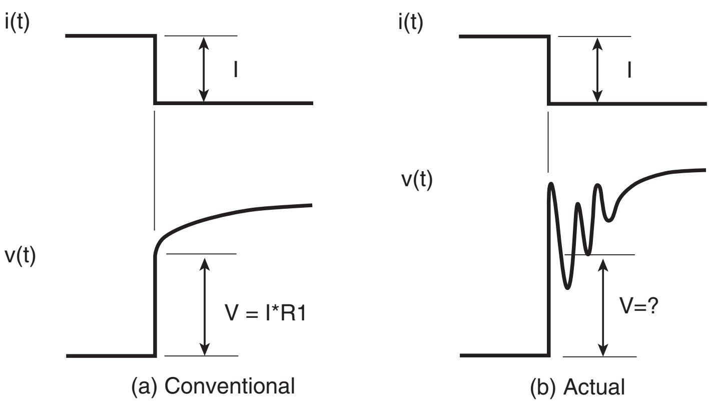

Fig. A-19 Conventional and actual interrupt current waveform

However, in the actual measurement, if load current i(t) is varied as shown in Fig. A-19 (a), the voltage response across the output terminals is as shown in Fig. A-19 (b) in most cases due to various effects such as the wire inductance.

Because the amount of change where the voltage response jumps (the V section in Fig. A-19 (b)) is unclear in this condition, the determination of ohmic resistance of the electrochemical/electrical circuit R1 from the ratio against the amount of change of current is difficult.

■ Technical Issues

- In the current interrupt method, the section where the voltage jumps can be read more clearly as the speed of the current interrupt is made faster (the time until the current is cut off is shortened). However, in reality, the voltage waveform is distorted as shown in Fig. A-19 (b) due to the wire inductance.
- If the ohmic resistance of the electrochemical/electrical circuit is determined in this condition, the value is not stable and carries no meaning as data.
- Because the wire length cannot be made zero, we must expect the waveform to distort to a certain extent due to the effects of inductance.
- Decreasing the speed of the current interrupt (making the time until the current is cut off longer) is effective in suppressing the waveform distortion if a certain level of inductance exists.
- In this case, the waveform distortion is decreased as shown in Fig. A-19 (a). But because the change is gradual, the section where the voltage jumps becomes unclear. If the ohmic resistance of the electrochemical/electrical circuit is determined in this condition, the value ends up being different from the value when the transition speed is fast.

A.9.1 Current Interrupt Method on the KFM2150

The KFM2150 provides the following three parameters to accommodate the conflicting issues given in “Technical Issues”.

- TRNSN that changes the current transition speed

  An independent key is provided on the panel as a parameter setting for the interrupt method. It is shown as PT on the display. This parameter sets the time until the current is cut off.

- Position for reading the voltage waveform
- Region for reading the voltage waveform

  These parameters are set using the MENU key. These parameters specify which section of the voltage waveform is to be read and used in the calculation.

Fig. A-20 shows the locations of the voltage waveform that are designated by the Position and Region parameters.

- Position is the time that has elapsed since the completion of the current interrupt. It is the start point for reading the voltage waveform.
- Region specifies which range of the waveform is to be read from the start point.

The KFM2150 calculates the intended ohmic resistance of the electrochemical/electrical circuit (the value calculated by the ratio of the amount of change in the current to the amount of change in the voltage when the interrupt speed is fast and the voltage waveform is not distorted) based on the waveform data in the specified region. We will not go into the details of the calculation, but it basically uses linear approximation of the data in the specified region.

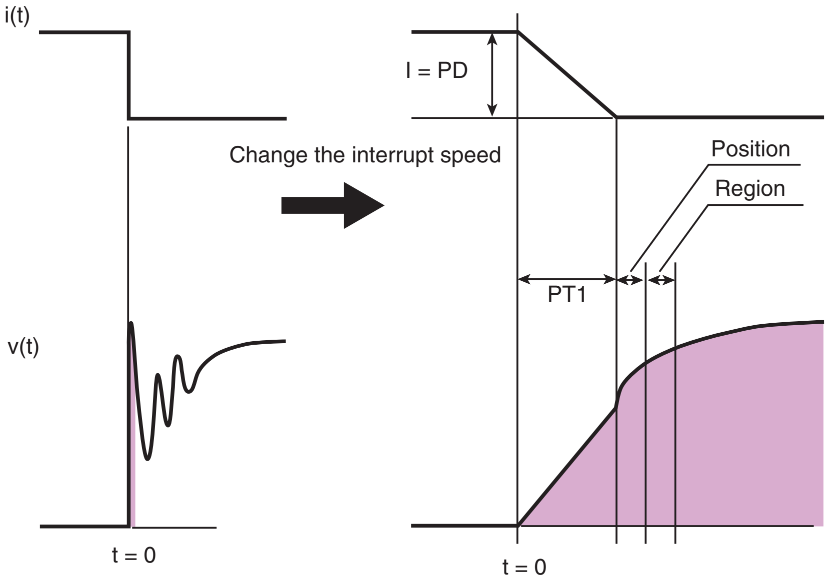

Fig. A-20 Current waveform and the corresponding voltage response waveform across the fuel cell terminals

- **Characteristics of the three parameters**

  How should we select the three parameters, TRNSN (hereafter written as PT), Position, and Region? To calculate the intended ohmic resistance of the electrochemical/electrical circuit, we should set PT to the smallest value, Position to zero, and Region to the smallest value. If a constant, stable value can be obtained using these parameter values, this is the best data. However, it is highly unlikely that a stable value can be obtained in this way due to the voltage waveform distortion caused by the wire inductance.

  The current interrupt method adopted by the KFM2150 varies the current in a ramp pattern to I = PD over time (PT1) and estimates ohmic resistance of the electrochemical/electrical circuit R1 from the transient response of the voltage. The reason for employing such method is to perform measurements by suppressing the ringing in the voltage response as shown in Fig. A-19 (b).

Points in setting the parameters

The three parameters roughly have the following effects.

- PT suppresses the waveform distortion (called ringing) caused by the wire inductance.
- Position prevents the effect of the waveform distortion from being received.
- Region reduces the waveform noise.

These parameters need to be selected appropriately according to the wiring environment of the test, test conditions, and the characteristics of the fuel cell. Normally, once the parameter values are set, there is no need to change them by a great amount.

■ Pulse transition time PT

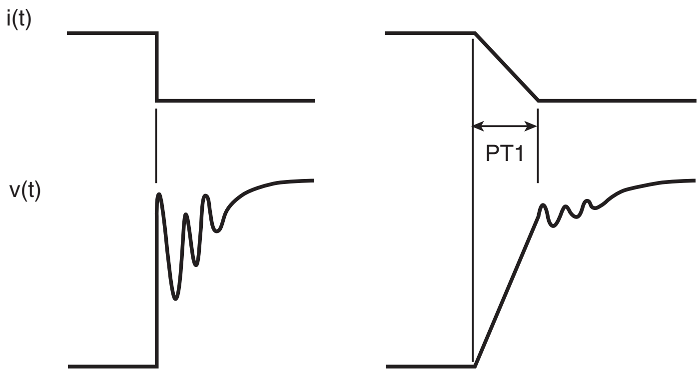

Fig. A-21 Pulse transition time PT1 and ringing

- Minimizing the effects of wiring

First, adjust the PT to minimize the waveform distortion caused by the effects of wiring. You must also take all possible measures to reduce the inductance such as twisting the load wires thoroughly and making them short according to 〆Wiring〸 on page A-11 .

- Checking the effects of the inductance

The best way to reduce the inductance is to observe the voltage waveform of the fuel cell directly by the instrument such as oscilloscope. If you do not have an oscilloscope or the waveform cannot be observed because it is buried in noise, you can use the option for checking the waveform in the application software provided.

- PT setting and waveform distortion

If you decrease the PT, the waveform distortion increases. You can probably see that the distortion decreases as the PT is increased. If the current to be interrupted is large (approximately 50 A or more) or the wiring is long (approximately several meters or longer), setting the PT to the minimum value of 0.01 ms will cause the waveform distortion to be too large. This may damage the electronic load unit or cause an alarm. Thus, set the PT around 1 ms to view the waveform.

- Selecting the PT value

Select a PT value so that the waveform distortion (ringing) disappears. However, you cannot set the PT so large that the point where there is a clear distinction in the waveform slope is no longer discernible. In such case, select the PT that causes the waveform distortion to settle in the shortest possible time even if ringing is present.

- If the waveform cannot be observed

If you cannot observe the waveform, set the PT to the largest value (10.00 ms). It is possible to select a value that is highly likely to be a good value using the method explained later. However, we recommend that you check the waveform to prevent unexpected results.

App

Setup procedure (example)

If you know in advance the value of PT that results in small voltage waveform distortion (ringing), use that value and start from step 6 . If you cannot observer the waveform, set the PT to the maximum value of 10.00 ms, and start from step 1 .

1 Set the Position value to the minimum 0.00 ms and Region to the maximum 0.510 ms.

2 Set the depth of the interrupt current and the interrupt pulse width.

It is easier to select the parameters by setting the interrupt pulse width as long as possible (maximum setting of 10.00 ms).

3 Start the impedance measurement using the interrupt method.

■ If the IR value is unstable or a negative value appears

4 Set the average count to around 8.

If the value is still unstable or a negative value appears, you must review the measurement environment such as making the wires shorter.

■ If the IR value is stable

5 Gradually decrease the PT value.

Check the location where the value was displayed changes drastically from the initial number (location where the value increases or decreases drastically or goes negative). Decrease the PT further and see if another drastic change in the value occurs. If another drastic change is found, set the PT value to the value immediately before the change. Otherwise, set the PT back to the value where the first drastic change occurred.

6 Set the Position value to 9.99 ms. Set the Region value to the maximum 0.510 ms.

7 Start the impedance measurement using the interrupt method.

Remember the IR value that is displayed.(It should be different from the value displayed in step 3 .)

8 Gradually decrease the Position value and find the place where the IR value is minimum.

If the value decreases smoothly down to 0.00 ms, leave the Position value at 0.00 ms.

9 Decrease the Region value stepwise.

The IR value changes by a small amount while the fluctuation in the value increases. If the fluctuation of the value is large, set the Region value back to a larger value stepwise. You can also increase the average count. The fluctuation of the value decreases by increasing the average count. Increase the average count within the possible range and set the Region value to a smaller value.

10 Decrease the PT value by a small amount.

If the IR value changes drastically, repeat the steps from step 6 . If the IR value does not change drastically, the parameter setting is tentatively complete. Check that the IR value does not change drastically when the PT is increased or decreased by a small amount.

If you change the measurement conditions (the depth and width of the current interrupt or load current), keep the Position and Region values and increase or decrease the PT to find a stable location.

If the IR value is stable, the parameters can be used without further changes. If not, redo the settings from step 6 , because the IR value may be affected by the wiring.

A.10 KFM2151 FC Scanner (Option)

A.10.1 Overview of the Scanner System

The KFM2151 FC Scanner has 32 channels of voltmeters and 32 channels of line selector functions. By using the line selectors along with the KFM2150 FC Impedance Meter, each cell of a stack can be scanned to measure the impedance.

- Scanning function

  The 32-channel voltmeter section repeats the operation of reading of 32 channels of voltage every second. Because overvoltage protection (OVP) and undervoltage protection (UVP) can be set on each channel, the KFM2151 can be used as a cell monitor.

  The line selector function can be used independently of the voltmeter at the same time. The voltage of all channels can be monitored even while being connected to the KFM2150 to determine the impedance of a given cell.

Using the KFM2151 FC Scanner

1. Select MENU key> Configuration > Option > Scanner to select Enable.

   If you disconnect the KFM2151 from the KFM2150, be sure to disable this item. Otherwise, the KFM2150 will not operate.

2. Select Setup > Input Select > Voltage Sensing to select channel 2.

3. Turn off the POWER switch of the KFM2150 and then turn it back on.

   The scanner display () appears on the KFM2150 enabling the use of the KFM2151.

A.10.2 Notes on Setting the Scanner System

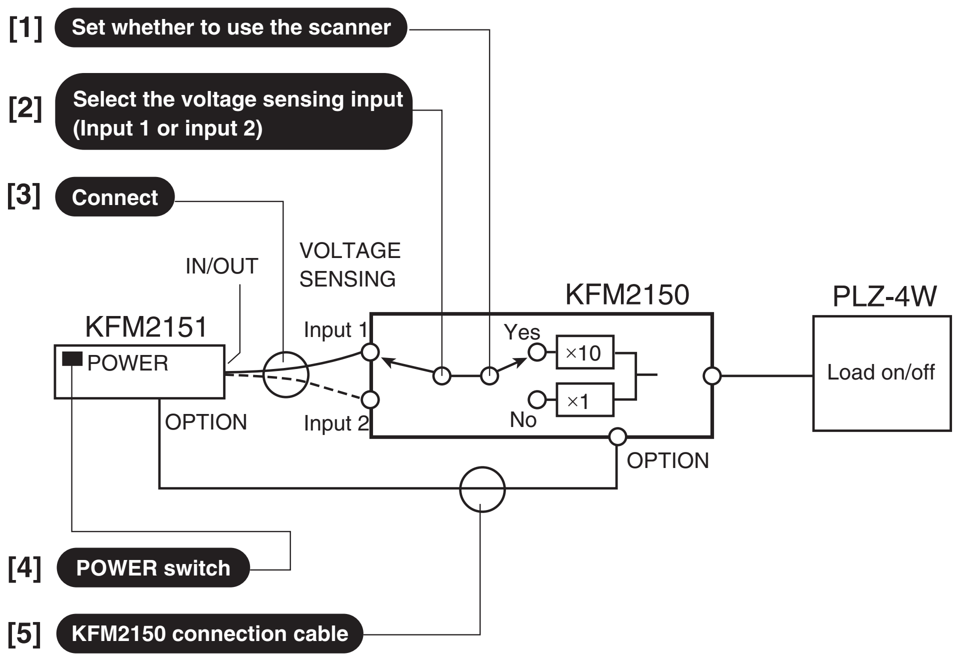

Fig. A-22 Check points

The numbers in brackets (1 to 5) used in the following tables correspond to the numbers indicated in Fig. A-22.

When using the FC scanner

■ The scanner icon  is not displayed.

Symptom	Points to check	Remedy
The scanner icon is not displayed even if the scanner function is enabled [1].	• [5] KFM2150 connection cable • [4] Is the POWER switch of the KFM2151 turned off?	[5] Connect the KFM2150 connection cable correctly. [4] Turn the POWER switch of the KFM2151 on.

If the scanner function is enabled and the KFM2150 is connected to the KFM2151, the KFM2150 panel shows the scanner icon. The icon is displayed only if the KFM2150 connection cable is connected. If the KFM2151 is not turned on, the icon is not displayed even if the KFM2150 connection cable is connected.

■ The measured values on the KFM2150 are odd.

Symptom	Points to check	Remedy
The measured values are odd even though the scanner function is enabled [1] and the scanner icon is displayed. • The KFM2150 connection cable {5] has been connected correctly. The POWER switch of the KFM2151 [4] is turned on.	• [2] Is the voltage sensing input selection on the KFM2150 incorrect? • [3] Is the sensing wire connected to a sensing input different from the one selected on the KFM2150?	Match the selected input with the connected input.

The KFM2150 panel does not indicate which voltage sensing input (input 1 or input 2) is being used.

When not using the FC scanner

■ The measured values on the KFM2150 are odd.

Symptom	Points to check	Remedy
The measured values are odd when the scanner is used and another measurement is made after disabling the scanner function [1].	• [2] Is the voltage sensing input selection on the KFM2150 incorrect? • [3] Is the sensing wire connected to a sensing input different from the one selected on the KFM2150?	Match the selected input with the connected input.

The KFM2150 panel does not indicate which voltage sensing input (input 1 or input 2) is being used.

■ The load of the PLZ-4W Series does not turn on.

Symptom	Points to check	Remedy
The load of the PLZ-4W Series does not turn on even when the LOAD key of the KFM2150 is pressed, and the impedance cannot be measured. • The KFM2150 connection cable [5] has been removed.	• [1] Is the scanner function enabled on the KFM2150?	[1] Disable the scanner function, turn the POWER switch of the KFM2150 off, and then turn it back on.

■ The measured values of the KFM2150 are ten times greater than the correct values.

Symptom	Points to check	Remedy
The measured values of the KFM2150 are 10 times greater than the correct values. • The KFM2150 connection cable [5] is connected and the POWER switch [4] of the KFM2151 is still turned on. • The signal has been connected [3] to the sensing input [2] that was selected on the KFM2150.	[1] Is the scanner function enabled on the KFM2150?	[1] Disable the scanner function.

Because the output signal of the KFM2151 is attenuated by a factor of 10, the KFM2150 amplifies the signal by 10 when the scanner function is enabled.

A.10.3 Voltmeter Display

● Voltmeter and ammeter display on the KFM2150 and the voltmeter display on the KFM2151

In a multi-channel impedance measurement system in which the KFM2151 and the KFM2150 are connected, which channel's voltage and current are displayed on the KFM2150?

If you want to measure the impedance of a given cell and select the corresponding channel on the KFM2151, the KFM2151 displays the cell voltage, and the signal from the cell is also applied to the KFM2150. The KFM2150 displays the cell voltage and the current value of the entire stack to which the PLZ-4W Series is connected.

- Voltage measurement accuracy of the KFM2150

  The KFM2150 and the KFM2151 indicate approximately the same value for the measured voltage. However, these measured values differ in the measurement accuracy.

  The impedance signal line selection circuit of the KFM2151 attenuates the input by a factor of 10 and delivers the signal to the KFM2150. The KFM2150 displays the value by multiplying the input value by 10. The voltmeter display of the KFM2150 contains the attenuation error when the signal is attenuated by a factor of 10.

A.10.4 Voltmeter Scanning Speed

The voltmeter scans the channels in order at approximately 30 ms per channel. The basic scanning speed is approximately 1 second per 32 channels (T32 of Fig. A-23). However, if there is voltage range switching between the channels, it takes longer.

The voltage range is stored. If the range is determined in the first scan, the range does not switch in the subsequent scanning operations unless a voltage outside the range is applied.

If you are performing communications with a PC for data logging, the communication time with the PC is added to the basic scanning time (Tlog of Fig. A-23). The scanning time and communication time increase in proportion to the number of KFM2151 units (the number of channels). The sum of the scanning time and communication time with the PC is approximately 1.9 seconds per 32 channels.

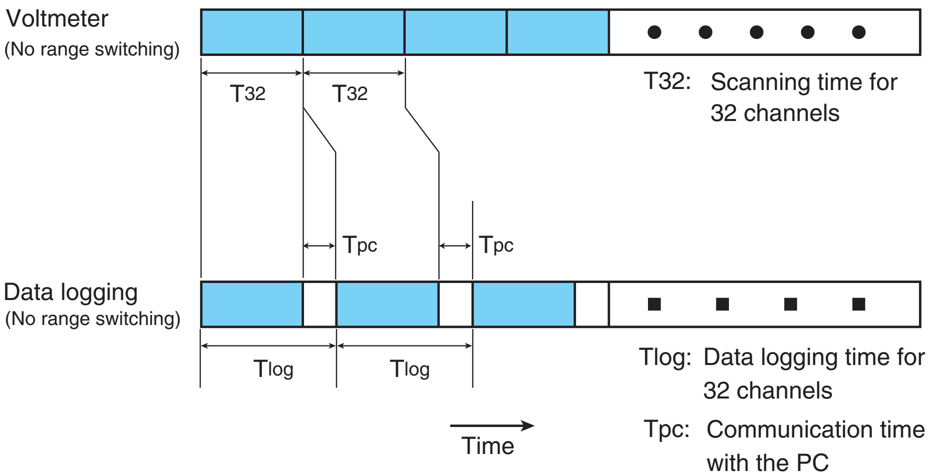

Fig. A-23 Scanning speed

App

A.10.5 Impedance Display and Scanning

- **Operation sequence**

The operation that a system in which the KFM2150 is connected to the KFM2151 performs when scanning each channel in order and measuring the impedance is given by the following sequence.

Sequence	Operation details
1	The KFM2151 selects a given channel.
2	The KFM2150 starts the impedance measurement. (Measurement conditions such as the measurement frequency are set on the KFM2150. If the measurement frequency is low, it takes to make the measurement longer.) When the impedance measurement is complete, the KFM2150 displays the measured values.
3	The measurement is interrupted, and the KFM2151 selects the next channel. Which is selected to apply for the scanning by the KFM2151 in numeric order from small number.
4	When the KFM2151 completes the selection, the KFM2150 starts the measurement again.
5	This operation is repeated to scan each channel and measure the impedance. If an average count is set in the measurement conditions in sequence 2, the KFM2150 repeats the measurement for the average count and it continues to sequence 3.

- **Displaying the measured impedance**

In a system in which the KFM2151 is connected and the impedance is measured while scanning the channels, which channel's impedance is displayed on the KFM2150?

- The KFM2151 indicates the selected channel with an orange LED.
- The transition time of channel during scanning is 1 second minimum.
- The KFM2150 displays "----" while the channel is being switched and while the measurement is in progress.

The measured value is displayed for the first time when the measurement is completed. If you check the channel on the KFM2151 and view the impedance on the KFM2150, that is the measured value of the corresponding channel.

- **Scanning and measurement frequency**

The transition time of channel during scanning on the KFM2151 is 1 second minimum. The maximum time varies depending on the impedance measurement conditions.

For example, let's assume the impedance measurement is performed at 10 mHz. This means that the cycle time is 100 seconds. In other words, a single measurement will not be completed until 100 seconds elapse. In this case, the transition to the next channel takes place 100 seconds later. During this period, the impedance measurement display on the KFM2150 shows "----".

Next, let's assume we measure the impedance at 1 Hz and set the average count to 8. A single measurement is completed in approximately 1 second (the impedance measurement display shows the average value for each measurement). Because this operation is repeated 8 times to obtain the average, it takes 8 seconds to retrieve a data value. Therefore, it takes 8 seconds to switches to the next channel. The KFM2151 switches to the next channel when the measurement of a channel is completed.

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