



## **Fuel Cell Impedance Measurement System KFM2150 system**

Capable of measuring impedance in the frequency range from 10 mHz to 20 kHz (KFM2150).

Capable of IR measurement with the current interrupt method (KFM2150).

For a load unit, enables selection and use of a Kikusui electronic load unit suitable to the power capacity of the fuel cells (KFM2150).

Provides 32-channel inputs (KFM2151). By connecting multiple KFM2151 in parallel, up to 160 channels can be supported.

Capable of not only current monitoring but also impedance measurement (KFM2151).

**Supports cell types ranging from single cells of several hundreds of amperes to stack fuel cells of several kilowatts.**



The FC impedance meter KFM2150 cannot be used alone. It needs to be combined with a Kikusui PLZ-4W series electronic load unit, and be calibrated.

KFM2150 SYSTEM 1000-01  
bench top type  
Upper unit: KFM2150  
Lower unit: PLZ1004W

## Fuel cell impedance measurement system

# KFM2150 SYSTEM

The fuel cell impedance measurement system is configured with an FC impedance meter KFM2150 and a Kikusui PLZ-4W series electronic load unit. Thus, the impedance measurement system can be configured to meet the output capacity of the fuel cells. Also, the system can support single fuel cells when configured with an electronic load unit supporting 0-V input. The system is capable of both impedance measurement with the AC impedance method and IR measurement with the current interrupt method, and is capable of acquiring the following types of data using the supplied application software: I-V characteristics and constant current characteristics; Cole-Cole plot data with the AC impedance method; and data with the current interrupt method. Also, the system provides a sequence function to execute tests for acquiring these types of data in the order they are specified.

### Features

- Capable of measuring impedance in the frequency range from 10 mHz to 20 kHz.
- Operating voltages: 1.5 V to 150 V, 0 V to 150 V\*
- Enables selection of current and power capacities by operating multiple units of the same model of the PLZ-4W series in parallel.
- Enables setting of a measurement AC current in the range of 0.1% to 10% (in 0.1% steps) of the DC load current.
- Enables changing of the DC load current while maintaining the setting (%) of the measurement AC current.
- Capable of IR measurement with the current interrupt method.
- Low voltage protection equipped as standard
- External interface equipped as standard (RS-232C, GPIB, and USB)

\* Value assumed when combined with a 0-V input type.

# System lineup and main specifications

Specifications	Units configuring the system			Rating			
	Model	Impedance meter	Operation modes: Electronic load unit constant current (CC) + constant voltage (CV)	Structure	Operating voltage V	Current A	Power W
KFM2150 SYSTEM 165-01A	KFM2150		PLZ164WA (1 unit)	Bench top type	0 to 150	33	165
KFM2150 SYSTEM 660-01A	KFM2150		PLZ664WA (1 unit)	Bench top type	0 to 150	132	660
KFM2150 SYSTEM 1320-02A	KFM2150		PLZ664WA (2 units)	Bench top type	0 to 150	264	1320
KFM2150 SYSTEM 1980-03A	KFM2150		PLZ664WA (3 units)	Rack mount type	0 to 150	396	1980
KFM2150 SYSTEM 2640-04A	KFM2150		PLZ664WA (4 units)	Rack mount type	0 to 150	528	2640
KFM2150 SYSTEM 3300-05A	KFM2150		PLZ664WA (5 units)	Rack mount type	0 to 150	660	3300
KFM2150 SYSTEM 1000-01	KFM2150		PLZ1004W (1 unit)	Bench top type	1.5 to 150	200	1000
KFM2150 SYSTEM 3000-02	KFM2150		PLZ1004W (1 unit) + PLZ2004WB (1 unit)	Bench top type	1.5 to 150	600	3000
KFM2150 SYSTEM 5000-03	KFM2150		PLZ1004W (1 unit) + PLZ2004WB (2 units)	Rack mount type	1.5 to 150	1000	5000
KFM2150 SYSTEM 7000-04	KFM2150		PLZ1004W (1 unit) + PLZ2004WB (3 units)	Rack mount type	1.5 to 150	1400	7000
KFM2150 SYSTEM 9000-05	KFM2150		PLZ1004W (1 unit) + PLZ2004WB (4 units)	Rack mount type	1.5 to 150	1800	9000

Specifications	Constant current mode (CC)			Ammeter display			Constant voltage mode (CV)		Voltmeter display		
	Allowable ranges (A)/Resolution (mA)			Accuracy <sup>*1</sup>			Allowable ranges (V)/Resolution (mV)		Accuracy <sup>*2</sup>		
	H range	M range	L range	H range (A)	M range (A)	L range (A)	15-V range	150-V range	10-V range (V)	100-V range (V)	150-V range (V)
KFM2150 SYSTEM 165-01A	0 to 33/1	0 to 3.3/0.1	0 to 0.33/0.01	0.0000 to 33.000	0.0000 to 3.3000	0.0000 to 0.3300	0 to 15.75/1	0 to 157.5/10	0.0000 to 9.9999	10.000 to 99.999	100.00 to 150.00
KFM2150 SYSTEM 660-01A	0 to 132/10	0 to 13.2/1	0 to 1.32/0.1	0.0000 to 132.00	0.0000 to 13.200	0.0000 to 1.3200					
KFM2150 SYSTEM 1320-02A	0 to 264/20	0 to 26.4/2	0 to 2.64/0.2	0.0000 to 264.00	0.0000 to 26.400	0.0000 to 2.6400					
KFM2150 SYSTEM 1980-03A	0 to 396/30	0 to 39.6/3	0 to 3.96/0.3	0.0000 to 396.00	0.0000 to 39.600	0.0000 to 3.9600					
KFM2150 SYSTEM 2640-04A	0 to 528/40	0 to 52.8/4	0 to 5.28/0.4	0.0000 to 528.00	0.0000 to 52.800	0.0000 to 5.2800					
KFM2150 SYSTEM 3300-05A	0 to 660/50	0 to 66/5	0 to 6.6/0.5	0.0000 to 660.00	0.0000 to 66.000	0.0000 to 6.6000					
KFM2150 SYSTEM 1000-01	0 to 200/10	0 to 20.0/1	0 to 2.00/0.1	0.0000 to 200.00	0.0000 to 20.000	0.0000 to 2.0000	0 to 15.75/1	0 to 157.5/10	0.0000 to 9.9999	10.000 to 99.999	100.00 to 150.00
KFM2150 SYSTEM 3000-02	0 to 600/30	0 to 60.0/3	0 to 6.00/0.3	0.0000 to 600.00	0.0000 to 60.000	0.0000 to 6.0000					
KFM2150 SYSTEM 5000-03	0 to 1000/50	0 to 100.0/5	0 to 10.00/0.5	0.0000 to 1000.0	0.0000 to 100.00	0.0000 to 10.000					
KFM2150 SYSTEM 7000-04	0 to 1400/70	0 to 140.0/7	0 to 14.00/0.7	0.0000 to 1400.0	0.0000 to 140.00	0.0000 to 14.000					
KFM2150 SYSTEM 9000-05	0 to 1800/90	0 to 180.0/9	0 to 18.00/0.9	0.0000 to 1800.0	0.0000 to 180.00	0.0000 to 18.000					

## [Accessories]

Instruction manual × 1, power cord × 1, sensing wires × 1 set, flat cable × 1 set, application software (CD) × 1, RS-232C cable × 1 set, 1 set of two parallel load cables (for the KFM2150 SYSTEM 1320-02A and the KFM2150 SYSTEM 3000-02 only)

\*1: H and M ranges: ±(0.3% of rdng + 0.3% of f.s), f.s: full scale of the H range  
 L range: ±(0.3% of rdng + 0.3% of f.s), f.s: full scale of the L range  
 \*2: All ranges: ±(0.1% of rdng + 0.1% of rng)  
 [Note] rdng: Stands for reading.  
 rng: Stands for range value.  
 f.s: Stands for full scale.

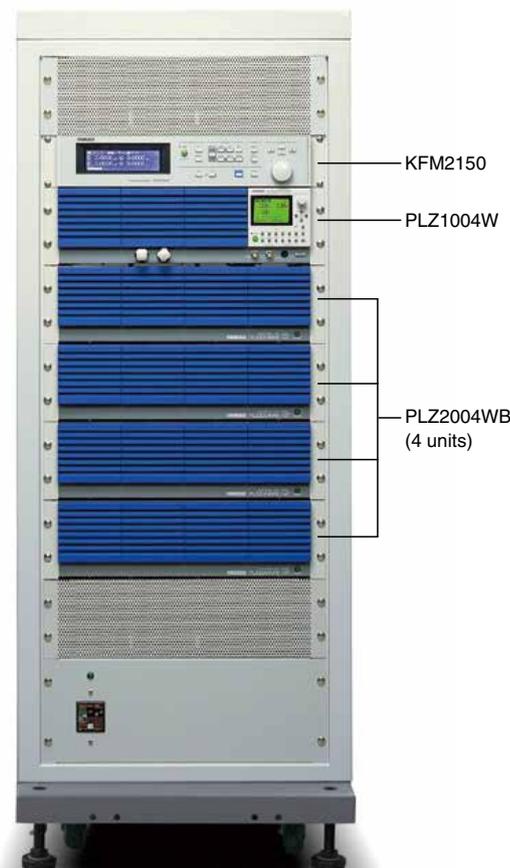
## ● System structure examples

### Bench top type



**KFM2150 SYSTEM 1000-01**

### Rack mount type



**KFM2150 SYSTEM 9000-05**

## Dimensions/weights

### ● Bench top type (only weights mentioned)

KFM2150 SYSTEM 165-01A: Approx. 13.5kg  
 KFM2150 SYSTEM 660-01A: Approx. 22kg  
 KFM2150 SYSTEM 1320-02A: Approx. 38kg  
 KFM2150 SYSTEM 1000-01: Approx. 21kg  
 KFM2150 SYSTEM 3000-02: Approx. 45kg

### ● Rack mount type

KFM2150 SYSTEM 1980-03A: 570W × 1430H × 875D mm/Approx. 170kg  
 KFM2150 SYSTEM 2640-04A: 570W × 1430H × 875D mm/Approx. 185kg  
 KFM2150 SYSTEM 3300-05A: 570W × 1430H × 875D mm/Approx. 200kg  
 KFM2150 SYSTEM 5000-03: 570W × 1430H × 1025D mm/Approx. 190kg  
 KFM2150 SYSTEM 7000-04: 570W × 1430H × 1025D mm/Approx. 215kg  
 KFM2150 SYSTEM 9000-05: 570W × 1430H × 1025D mm/Approx. 240kg

\* The blank panel may be different from that shown in the photo.

# FC Tester (supplied application software)

FC Tester enables control of the KFM system from a PC, conducting tests for acquiring the characteristics of fuel cells, such as I-V characteristics, constant current characteristics, and Cole-Cole plot and other data with the current interrupt method and the AC impedance method. It also enables tests to be conducted in the order they are specified. When combined with the FC scanner KFM2151, it can support measurement of the impedance of each cell while switching from one cell to another in sequence.

## Features

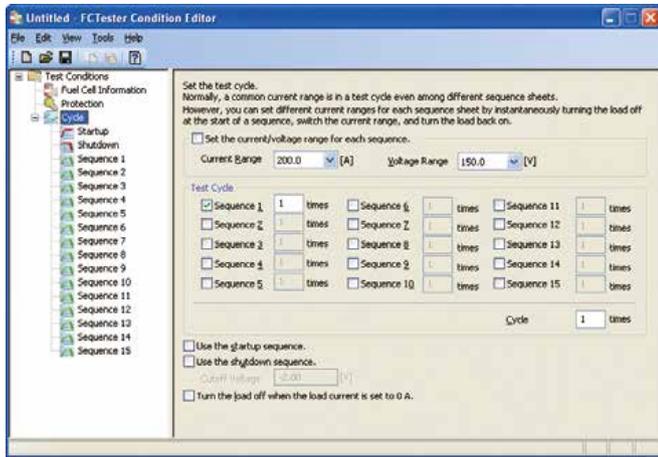
- Provides startup and shutdown sequences friendly to fuel cells.
- Provides test modes for I-V characteristics, constant current characteristics, and Cole-Cole plot data with the AC impedance method.
- Enables fuel cell cycle tests by combining sequence functions.
- Provides 2D/3D real-time graph functions.
- Enables output of test results data as CSV files (text format).
- Enables observation of voltage and current waveforms during the current interrupt method.
- Provides panel control functions that enable a PC to be used to perform operations equivalent to KFM2150 panel operations.
- Enables measurement of the impedance of each cell when combined with the FC scanner (KFM2151).
- FC Tester consists of three programs, Configuration Tool, Condition Editor, and Executive.

## ● Configuration Tool

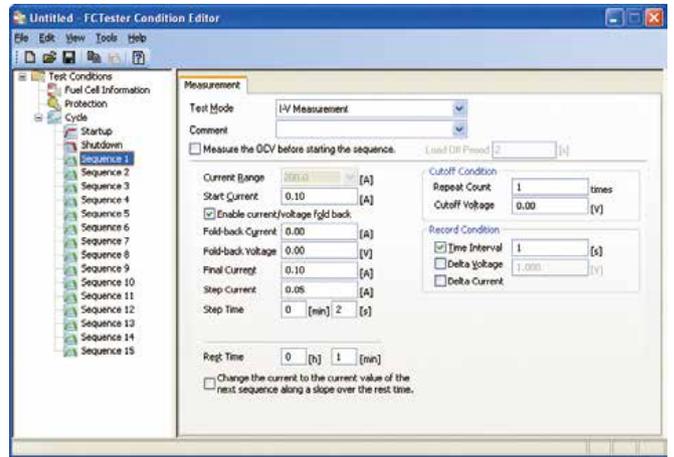
This program configures the fuel cell impedance measurement system. It is used to configure the system for the first time or to change the system configuration.

## ● Condition Editor

This program creates and edits test conditions. It enables setting of test mode conditions on 15 sheets in total, one sheet for one test mode. It also enables setting of the repeat count of each sheet and the repeat count (cycle) for all sheets.

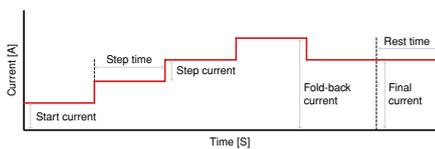


▲ Cycle window

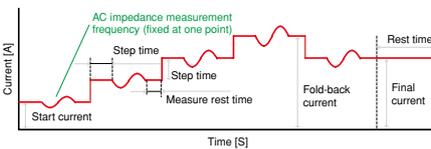


▲ Sequence window

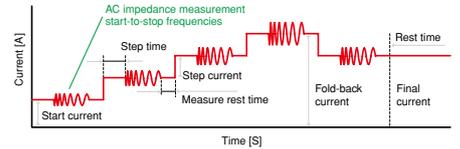
## [Conceptual diagrams of test mode operation]



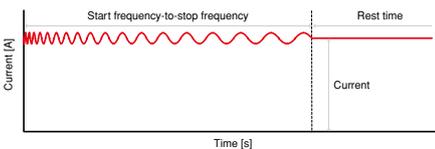
▲ I-V measurement



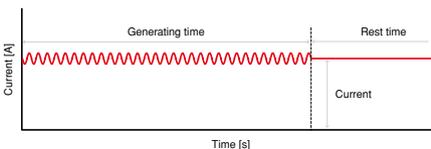
▲ I-V + AC impedance measurement



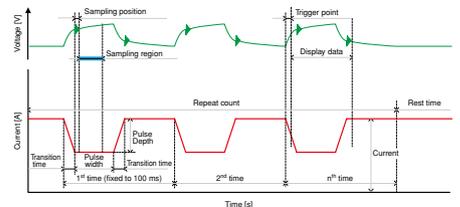
▲ I-V + Cole-Cole plot measurement



▲ Cole-Cole plot measurement



▲ AC impedance measurement



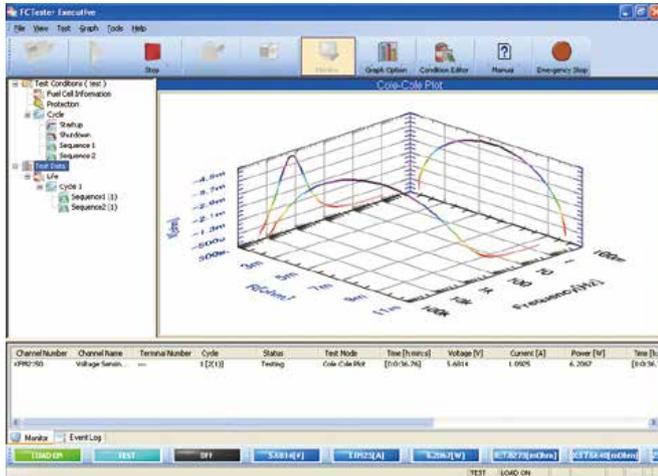
▲ Current interrupt measurement



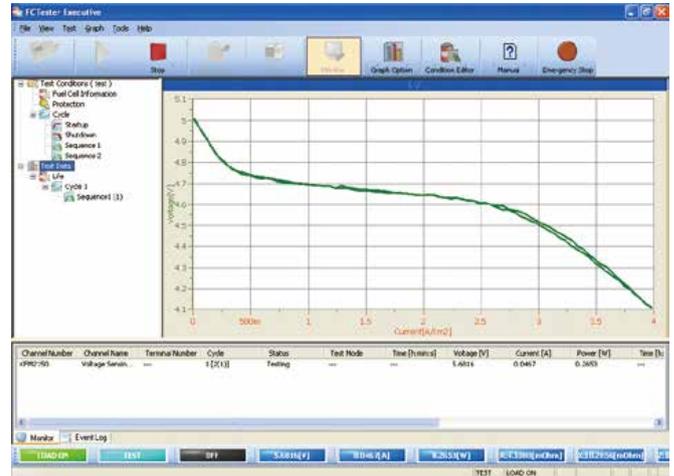
▲ Constant current test

## ● Executive

This program executes characteristic tests in accordance with the test condition file created with Condition Editor. It monitors each measurement at the start and stop of a test and during the test. It can graphically represent voltage, current, and impedance trends in real time.



▲ Cole-Cole plot window (3D graphic display)



▲ I-V characteristics window

### [Recommended operating environment]

The following are the hardware and software requirements for using the supplied application software.

- IBM-PC/AT or compatible, with a 600-MHz Pentium III microprocessor or equivalent or higher (Pentium 4 or equivalent or higher recommended)
- Microsoft Windows 2000 (Windows 2000 SP4 or later required), Microsoft Windows XP (Windows XP SP2 or later required)
- 256 MB memory or greater (512 MB or greater recommended). When using FC scanner (KFM2151), 512 MB or greater (1 GB or greater recommended)
- SVGA resolution or higher (800 x 600 dots or greater)
- 20 MB free hard disk space or greater (another free space required for data storage)
- CD-ROM drive
- Mouse or other pointing device
- Interface (RS-232C, GPIB, or USB)
- GPIB board (only if used with GPIB)
  - manufactured by one of National Instruments, Agilent, Contec Co., Ltd., and Interface Corporation.
- VISA
  - VISA library
    - One of NI-VISA3.0 or later, Agilent I/O Library M01.00 or later, and KI-VISA 2.5 or later
  - \* The Virtual Instrument Software Architecture (VISA) is a standard specification for software for connecting measuring instruments that was established by VXI plug&play Systems Alliance.
  - \* KI-VISA is an Kikusui Electronics Corporation's original I/O library conforming to the VXI plug&play VISA specification 3.0.
  - \* The latest KI-VISA is downloadable at our web site.

## KFM2151

### FC scanner



**32-channel voltage scanner that supports stack fuel cells. Capable of impedance measurement when combined with the KFM2150.**

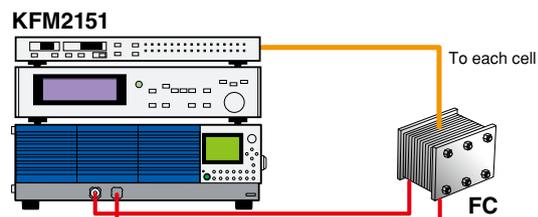
The FC scanner KFM2151 is a 32-channel scanner that meets the essential request to monitor each cell in the evaluation of stack fuel cells. To support stacks of various sizes, it is possible to support up to 160 channels by connecting multiple KFM2151 in parallel. As a mean to eliminate the cumbersome work of wiring, the KFM2151 provides a function whereby once it is connected to cells, the terminals allocated to channels can be changed so that the voltage and impedance of any cell can be measured without rewiring. For a voltage monitor function, it offers a scan speed of 32 channels per second, which is sufficient from the practical viewpoint.

#### Features

- Capable of impedance measurement at an input voltage up to 150 V when connected to the KFM2150 with a dedicated cable.
- One unit supports 32-channel inputs, and up to 160 channels can be supported by connecting multiple units in parallel.
- With its channel-allocated terminal changing function, enables measurement of the voltage and impedance of any cell once it is connected to cells.
- Enables setting of OVP and UVP for each channel.
- Capable of monitoring voltage at a scan speed of 32 channels per second.
- Can be operated alone as a voltage monitor.

#### ● Dimensions (maximum)/weight

430 (435) W × 44 (60) H × 270 (285) D mm/about 3.5 kg



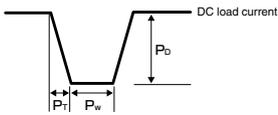
## KFM2150 specifications

### Common specifications

- Impedance measurement section (AC impedance method)
  - Frequency range ..... 10 mHz to 20 kHz
  - Frequency resolution ..... 14 points of 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/decade (decimal 7-digit range)
  - Measurement range ..... 0.0001 mΩ to 9.9999 Ω, indicated in five digits.
  - Measurement AC current ..... 0.1 to 10% of DC load current (settable in 0.1% steps). Note that the sum of the DC load current and the measurement AC current must not exceed the rating of the PLZ-4W series unit. The actual allowable current range varies depending on which PLZ-4W unit the KFM2150 is combined with. By setting the measurement AC current to 0%, it is possible to set the measurement AC current to OFF. The maximum measurement AC current is 80 Arms, 50 Arms\*
    - \* Value assumed when the KFM2150 is combined with a 0 V input type.
  - Measurement items ..... R, X, |z|, θ
  - Measurement accuracy (example of SYSTEM1000-01, 10 V range)

#### (Current interrupt method)

- Measurement range ..... 0.0001 mΩ to 9.9999 Ω, indicated in five digits.
- Measurement items ..... IR (internal resistance)
- Interrupt pulse parameters



- Pulse depth PD ..... 0 to 100% of DC load current (settable in 1% steps). Can be measured with consideration given to the effect on the fuel cells.
- Pulse width PW ..... 0.1 ms to 10 ms (settable in 0.1 ms steps). Can be measured with consideration given to the effect on the fuel cells and the DC load current.
- Pulse change time PT ..... 0.01 ms\* to 10 ms (settable in 0.01 ms steps). Can be measured with consideration given to the effect of the load wiring inductance.
  - \* The minimum is restricted by the slew rate of the PLZ-4W series unit used and the PD setting.
- Average setting ..... Moving average, 1 to 256 times
- Protection function
  - Low voltage protection (UVP) ..... Turns the load off at -2 V to 150 V (settable). Output an alarm signal.
  - Load protection ..... Turns the load off upon receiving an alarm signal from the PLZ-4W series unit. Output an alarm.
- External control
  - Interface ..... RS-232C, GPIB, USB
- General specifications
  - Input voltage range ..... 100 VAC to 240 V (90 VAC to 250 V), single phase
  - Input frequency range ..... 47 Hz to 63 Hz
  - Power consumption ..... 100 VA max.

## KFM2151 specifications

- Inputs
  - Number of inputs ..... 32 terminal pairs
  - Rated input ..... ±150 V (±200 V max.)
- Output terminals
  - Number of outputs ..... 1 channel. (The input of the impedance measurement channel during setting or scanning is 1/10 before being output.)
- Voltage measurement section
  - Number of channels ..... 32ch. An input terminal can be set for each channel. (Up to 160 channels can be supported by connecting multiple KFM2151 in parallel.)
  - Ranges ..... Auto ranges of 2 V, 20 V, and 200 V
  - Scan speed ..... 32 channels per second
  - OVP ..... -2 V to 200 V. Can be set for each channel. Setting resolution: 0.01 V
  - UVP ..... -2 V to 200 V. Can be set for each channel. Setting resolution: 0.01 V
  - Voltmeter ..... Display of 19999, accuracy: ± (0.1% of rdng + 0.1% of rng)
    - rdng: reading, rng: range value
- Impedance measurement channel switching section
  - Number of channels ..... 32ch. An input terminal can be set for each channel. (Up to 160 channels can be supported by connecting multiple KFM2151 in parallel.)
  - Switching ..... Auto scan, manual selection
  - Voltage at which impedance measurement is possible ..... Up to 150 V (when connected to the KFM2150). To remove the effect of the impedance meter on measurement accuracy (when connected to the KFM2150),
    - Frequencies up to 3 kHz ..... Add 2%
    - 3.16 kHz to 9 kHz ..... Add 3%
    - 10 kHz to 20 kHz ..... Add 5%
 to the |Z| percentage reading.
    - Note: For the 10 mΩ range only, add 3 mΩ to ±(|Z| percentage reading).
- Communication, IF
  - RS-232C interface for PC connection
  - I/O interface for impedance meter connection
  - Interface for parallel connection
- General specifications
  - Input voltage range ..... 100 VAC to 240 V (90 VAC to 250 V), single phase
  - Input frequency range ..... 47 Hz to 63 Hz
  - Power consumption ..... 30 VA max.
  - Insulation resistance ..... 30 MΩ or greater (500 VDC) between AC line and chassis
  - Withstand voltage ..... Free from defects when 1500 VAC is applied for 1 min. between AC line and chassis.

# System specifications

\* This catalog contains the specifications of KFM2150 SYSTEM 1000-01 (KFM2150 + PLZ1004W) as a typical example. For the specifications of other systems, contact Kikusui.

The specifications are specified by following setting and conditions, unless otherwise stated: ● Warmup time: 30 min. (state with current being flowed)

● Temperature: 20°C to 30°C ● Relative humidity: 20%rh to 85%rh

■ Accuracy of impedance measurement with the AC impedance method (2-meter load cable used)

If the current range on the load unit is H or M, and the measurement AC current is 0.5 Arms or greater.

● When the sensing end input voltage is 0 V to 10 V (10 V range)

± (% of the IZI reading)		Frequency			
		to 126Hz	158Hz to 3kHz	3.16k to 9kHz	10k to 20kHz
Accuracy R, X (of reading)	10 mΩ range	3%	2%	3%	4%
	100 mΩ range	3%	2%	3%	5%
	1000 mΩ range	4%	3%	6%	
	10 Ω range	4%	8% (to 1kHz)		

For the 10 mΩ range only, add 0.3 mΩ to ± (% of IZI reading).

The hatched portion is not specified

● When the sensing end input voltage is 10 V to 100 V (100 V range)

± (% of the IZI reading)		Frequency			
		to 126Hz	158Hz to 3kHz	3.16k to 9kHz	10k to 20kHz
Accuracy R, X (of reading)	10 mΩ range	5%	3%	5%	6%
	100 mΩ range	5%	3%	5%	8%
	1000 mΩ range	6%	5%	8%	
	10 Ω range	6%	9% (to 1kHz)		

For the 10 mΩ range only, add 0.3 mΩ to ± (% of IZI reading).

The hatched portion is not specified.

● When the sensing end input voltage is 100 V to 150 V (100 V range)

± (% of the IZI reading)		Frequency			
		to 126Hz	158Hz to 3kHz	3.16k to 9kHz	10k to 20kHz
Accuracy R, X (of reading)	10 mΩ range				
	100 mΩ range	9%	6%	9%	
	1000 mΩ range	12%	9%		
	10 Ω range	12%			

The hatched portion is not specified

■ Accuracy of IR measurement with the current interrupt method.....±3%

If, however, measurement is conducted under the conditions below, with 10 mΩ resistance connected to the power supply in series.

- Input terminal voltage ..... 5 V
- Load current ..... 20 A
- Pulse depth..... 50% (10 A)
- Pulse width ..... 10 ms
- Pulse change time ..... 10 ms
- Sampling position ..... 5 ms
- Sampling region..... 0.51 ms
- Average ..... 32 times

■ General specifications

- Input voltage range..... 90 VAC to 250 V, 47 Hz to 63 Hz, single phase
- Power consumption..... 260 VA max.
- Installation altitude ..... 2000 meters or less
- Specifications-assured temperature range.... 20°C to 30°C
- Specifications-assured humidity range ..... 20%rh to 85%rh (no condensation)
- Operating temperature range ..... 0°C to 40°C
- Operating humidity range..... 20%rh to 85%rh (no condensation)
- Weight ..... Approx. 21 kg

## [Effect of the load cable on measurement]

In the measurement of the impedance of fuel cells, an important point is the load cable to use.

In particular, if fuel cells with large current capacities are to be measured, measurement results are affected by the material, thickness, length, and other factors of the load cable. Bear this in mind before measurement.

<Points to consider>

● Use a sufficiently thick cable to measure fuel cells with large current capacities.

If a thin load cable is used, this will cause a large voltage drop, generating heat due to power loss, which is very dangerous.

If the voltage drop is large, the voltage may drop below the operating voltage of the electronic load unit, making it impossible to flow current.

● Use a thick and short one for AC impedance measurement.

In AC impedance measurement, the larger the measurement AC current and the higher the measurement frequency, the thicker and shorter the load cable must be used.

<Reference>

The photos show a load cable (example) that Kikusui use to test rack amount type systems with load currents of about 1000 A.



▲ Cable with coating



▲ Cable with its coating removed

\*Note: In actual measurement, be sure to use it with its coating intact.

Load cable example (1000 A class)

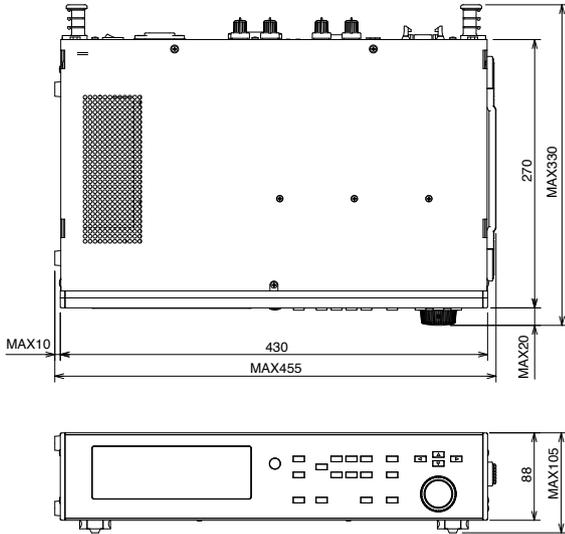
- Mounting hole diameter: 14 mm
- Mounting pitch: 40 mm
- Nominal cross sectional area: 600 mm<sup>2</sup>
- Length: about 2 meters
- Weight: Approx. 13 kg

○ Kikusui accept orders to manufacture load cables (custom made cables). Feel free to consult us when asking for an estimate of your system.

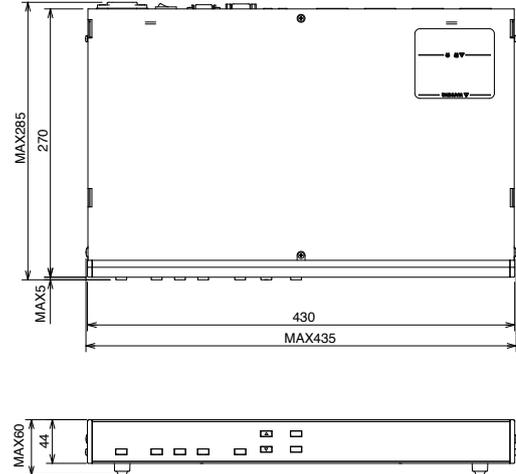
# Dimensional outline drawings

\* For outside dimensions of the PLZ-4W series units, refer to their respective catalogs.

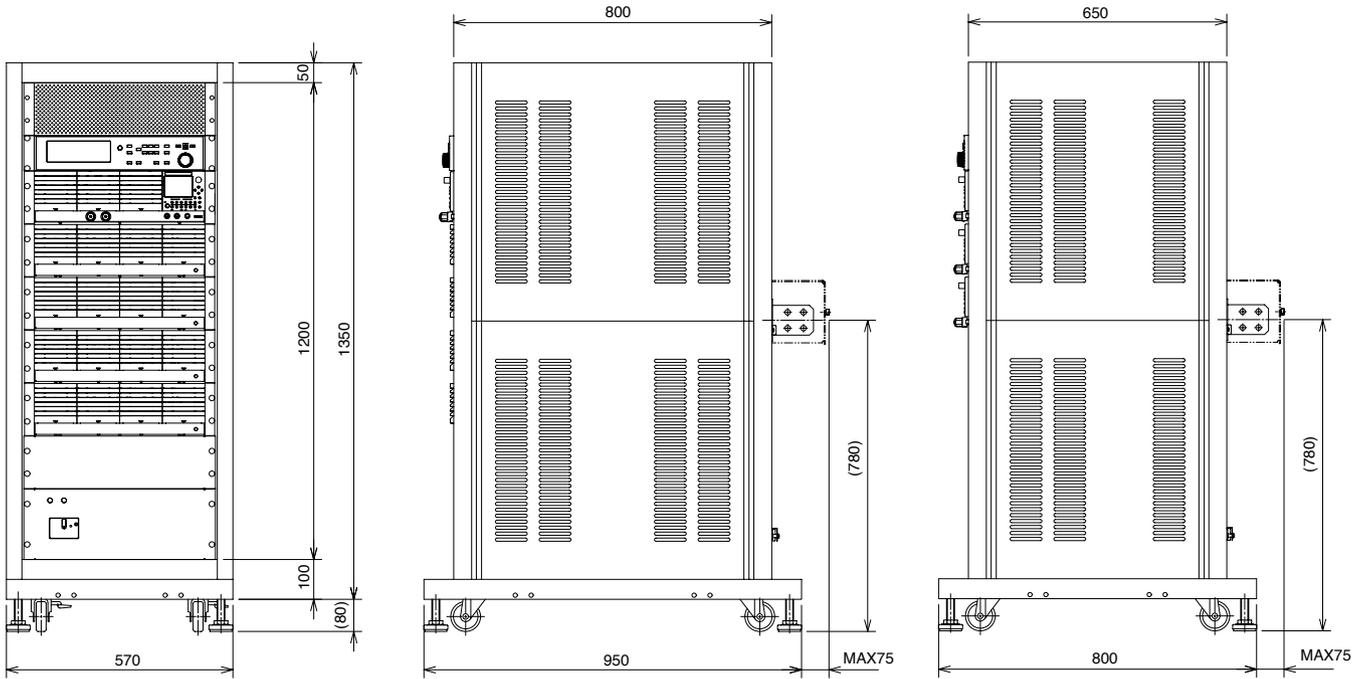
## ● KFM2150



## ● KFM2151



## ● KFM2150 SYSTEM (depth varies depending on the system)



### ▲ If using the PLZ2004WB (booster)

Systems to which these drawings apply

- KFM SYSTEM5000-03
- KFM SYSTEM7000-04
- KFM SYSTEM9000-05

### ▲ If not using the PLZ2004WB (booster)

Systems to which these drawings apply

- KFM SYSTEM1980-03A
- KFM SYSTEM2640-04A
- KFM SYSTEM3300-05A



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Printed in Japan

Issue: May 2008

2008051KJEC31