AS-7074
INSTRUCTION MANUAL
FOR
AG-4311B LCR METER

ANDO ELECTRIC CO., LTD.
Tokyo, Japan

1

AG-4311B OPERATING PRECAUTIONS

- Before connecting a capacitor with the apparatus, be sure to discharge the capacitor.

  This AG-4311B is provided with a protective circuit which blocks the flow of excessive discharge current from a capacitor connected with the apparatus. However, if a capacitor charged at high voltage (35 V or more) is connected with the apparatus, it may cause damage to the apparatus. To avoid this, be sure to discharge the capacitor to be measured, before connecting it with the apparatus.

NOTE

Even if once discharged, a capacitor may return to a slightly charged state with the lapse of time, because of the charge absorption effect.

If a charged capacitor is connected with the apparatus, it will be discharged through a direct current resistance (about 153 Ω). Since this discharge current may affect the measurement, the measurement should be started after the lapse of time at least ten times longer than the time constant (C·R). This precaution should be observed especially when a large-capacity capacitor is to be measured.

- Before operating the apparatus, please read this manual thoroughly to obtain optimum performance from the apparatus.

NOTE

Be sure to observe the instructions given in the WARNING, CAUTION, NOTE, and REMARKS in this manual which cover items particularly important to ensure proper and safe operation of the apparatus.

CONTENTS

PAGE

SECTION 1 GENERAL INFORMATION
- 1.1 INTRODUCTION .... 1 - 1
- 1.2 GENERAL .... 1 - 1
- 1.3 SPECIFICATIONS .... 1 - 3
- 1.4 COMPOSITION .... 1 - 3

SECTION 2 PREPARATION FOR USE
- 2.1 INTRODUCTION .... 2 - 1
- 2.2 UNPACKING AND ACCEPTANCE INSPECTION .... 2 - 1
- 2.3 POWER .... 2 - 1
- 2.4 POWER CORD .... 2 - 3
- 2.5 REPACKING .... 2 - 4

SECTION 3 OPERATION
- 3.1 INTRODUCTION .... 3 - 1
- 3.2 DESCRIPTION OF THE CONTROLS .... 3 - 1
- 3.3 OPERATING PRECAUTIONS .... 3 - 1
- 3.4 BASIC OPERATING PROCEDURES .... 3 - 10
- 3.5 CONNECTING THE SAMPLE .... 3 - 13
- 3.6 MEASURING GROUNDED SAMPLE .... 3 - 15
- 3.7 ZERO OFFSET ADJUSTMENT .... 3 - 16
- 3.8 MEASUREMENT PARAMETERS .... 3 - 17
- 3.9 EQUIVALENT CIRCUITS .... 3 - 22
- 3.10 SETTING AND MONITORING OF MEASURING SIGNAL .... 3 - 25
- 3.11 MEASURING RANGE .... 3 - 26
- 3.12 STARTING MEASUREMENT .... 3 - 26
- 3.13 MEASUREMENT SPEED MODES .... 3 - 27
- 3.14 DEVIATION MEASUREMENT .... 3 - 28
- 3.15 COMPARATOR FUNCTION .... 3 - 30
- 3.16 EXTERNAL DC BIAS .... 3 - 33
- 3.17 MEASUREMENT BY USE OF EXTERNAL FREQUENCY .... 3 - 37
- 3.18 EXTERNAL CONTROL INTERFACE .... 3 - 44
- 3.19 GP-IB INTERFACE .... 3 - 48
- 3.20 ERROR INDICATION .... 3 - 81
- 3.21 BASIC INSPECTION AND MAINTENANCE PROCEDURES .... 3 - 83

3

LIST OF FIGURES AND TABLES

PAGE

Fig. 2-1. Line Voltage Setting Procedure .... 2 - 2
Fig. 2-2. Power Fuse Replacement Procedure .... 2 - 3
Fig. 3-1. 4-terminal Pair Connection .... 3 - 13
Fig. 3-2. Connection of Special Measuring Jigs .... 3 - 15
Fig. 3-3. Vector Representation of Impedance .... 3 - 17
Fig. 3-4. Equivalent Circuit Expressions .... 3 - 22
Fig. 3-5. Maximum Bias Current .... 3 - 33
Fig. 3-6. Application of External DC Bias .... 3 - 35
Fig. 3-7. Setups for Measurement by Use of External Frequency .... 3 - 38

Table 1-1. Specifications .... 1 - 4
Table 1-2. Reference Data .... 1 - 23
Table 2-1. Power Fuse .... 2 - 2
Table 3-1. Front Panel .... 3 - 3
Table 3-2. Rear Panel .... 3 - 8
Table 3-3. Basic Operating Procedures .... 3 - 10
Table 3-4. Accessories .... 3 - 14
Table 3-5. Residual Parameter Value Ranges and Measuring Frequencies Allowable for Offset Adjustment .... 3 - 16
Table 3-6. |Z| and θ of Ideal L, C, and R .... 3 - 17
Table 3-7. Parameter Calculation Formulas .... 3 - 21
Table 3-8. Equivalent Circuits .... 3 - 24
Table 3-9. Reference Value Range .... 3 - 28
Table 3-10. Allowable Limit Value Ranges .... 3 - 30
Table 3-11. Comparator Judgment Condition .... 3 - 32
Table 3-12. Functions of External Frequency Interface .... 3 - 39
Table 3-13. Functions of External Control Interface .... 3 - 45
Table 3-14. Functions of GP-IB Interface .... 3 - 49
Table 3-15. Error Indications .... 3 - 82
Table 3-16. Memory Back-up and Initial Settings .... 3 - 83
Table 3-17. Self Test Error Indications .... 3 - 85
Table 3-18. Basic Periodic Inspections .... 3 - 86
Table 3-19. Troubleshooting .... 3 - 88

APPENDICES

PAGE

Appendix A. Top Cover Removing Procedure .... A-1 - A-2

Appendix B. Battery Replacement Procedure .... B-1 - B-2

Appendix C. Functions of the Internal DIP Switches .... C-1 - C-5

LIST OF ATTACHED DRAWINGS

Table 1. List of Standard Accessories

Fig. 1. Front Panel View of AG-4311B LCR METER ASD-7074-1/3

Fig. 2. Rear Panel View of AG-4311B LCR METER ASD-7074-2/3

Fig. 3. Outside View of AG-4311B LCR METER ASD-7074-3/3

5

SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

This manual contains a general description of the AG-4311B LCR Meter, its preparation for use, and its operating procedures. (The AG-4311B LCR Meter will be referred to simply as the apparatus or the AG-4311B throughout this manual.)

Section 1 describes the outline of the apparatus, its specifications, and other general information on it.

1.2 GENERAL

The AG-4311B LCR Meter is designed to analyze the AC impedances of ordinary LCR parts, semiconductors, composite parts, electronic materials, and other samples as vectors, and fully automatically measure their parameters (inductance, capacitance, loss factor, resistance, absolute impedance value, and phase angle, etc.).

This apparatus covers a measuring frequency range of 100 Hz to 100 kHz and a measuring signal level range of 1 mV to 5 V, and it can also make deviation and high resolution measurements, and that with high accuracy. These features make this apparatus usable for a wide variety of applications ranging from research and development to manufacturing tests and product quality inspection.

Further, this apparatus is supplied as standard with a comparator function and a GP-IB interface, so it can be applied to automatic measuring systems for automatic evaluation or sorting of parts or processing of parts characteristics data.

(1) Varieties of measurable parameters and deviation measurement function

Any of eleven different parameters can be measured for optimum evaluation of the sample; they are inductance (L), resistance (R), capacitance (C), dissipation factor (D), Q factor, equivalent series resistance (ESR), conductance (G), reactance (X), susceptance (B), absolute impedance value (|Z|), and phase angle (θ).

In addition, for L, C, R, and |Z|, their deviations from the reference (△) or their percent deviations (△%) can be displayed to facilitate evaluation of the temperature characteristics or quality of parts. For deviation measurement, a measured value can be stored as the reference, or a desired value can be set as the reference.

(2) Wide measurement ranges

This apparatus can measure parameters over wide ranges; L ranges from 0.00001 μH to 1.999 kH, C from 0.0001 pF to 1990 mF, and R and |Z| from 0.00001 Ω to 19.99 MΩ. Its measurement accuracy is between 0.1% and 10%. (The measurement ranges and accuracy depend on the measuring frequency, signal level range, and measured value.) D, Q, ESR, or G can be displayed

6

together with L or C in L or C measurement, X or B together with R in R measurement, and θ together with |Z| in |Z| measurement.

(3) Up to 5 1/2-digit display

Three measurement speed modes, FAST, NORMAL, and SLOW, are available. The optimum measurement speed and resolution can be selected according to the application.

FAST:	Up to 4-digit measured data (4999 counts maximum) can be obtained during a measurement period of about 150 to 250 ms. This mode is ideally suited for parts inspection and evaluation in the manufacturing process.
NORMAL:	Up to 4 1/2-digit measured data (19999 counts maximum) can be obtained during a measurement period of about 250 to 350 ms.
SLOW:	Ten measured values are averaged and the average data is displayed up to 5 1/2 digits (199999 counts maximum). This mode is effective in measuring slight changes as in the temperature characteristics of parts at high resolution.

(4) Internal measuring frequency and external frequency interface

The internal measuring frequency can be selected from among a total of 31 values, including frequently used 120 Hz, 1 kHz, and 10 kHz, in the range of 100 Hz to 100 kHz; they are almost equally spaced in terms of logarithm.

The apparatus is equipped with an external frequency interface. Measurement can be made at any frequency between 100 Hz and 100 kHz by entering a signal whose frequency is 16 times higher than the measuring frequency and, at the same time, specifying frequency data. Frequency data can be specified through use of either the external frequency data interface or the GP-IB interface.

(5) Level monitor function

In addition to the two digital displays that indicate measurement parameters, this apparatus is provided with a digital display that shows the measuring frequency, signal level, and other data. This display can be used to monitor the measurement condition, for example, the value of signal voltage or current applied to the sample, while carrying out a parameter measurement. With this function, the inductance of a coil or transformer with a signal current characteristic can be measured while monitoring the signal current.

(6) Automatic zero adjustment function

This offset adjustment function is used to measure the stray capacitance, residual inductance, and resistance of the measuring tools (test fixture and leads) in advance, and correct the measurements of parameters by subtracting their parasitic impedance so as to obtain the accurate parameter values of the sample. The offset values (the stray capacitance being 20 pF or less, the residual inductance 2 μH or less, the resistance 0.5 Ω or less, and the conductance 5 μS or less) are automatically applied to the measurements, and the corrected measurements are displayed.

7

(7) Comparator function

Measured data can be compared with preset limits (upper and lower limits) for quality evaluation or sorting of parts. The result of the judgment is indicated by the PASS, HIGH, or LOW LED. The loudspeaker can be made to sound at the same time. The result of the judgment is also output to the EXT CONTROL connector as an external control signal.

(8) GP-IB interface

This apparatus is supplied as standard with a GP-IB remote control interface. This interface allows the apparatus to be remotely controlled or built into an automatic measuring system. Setting of a measurement condition or delivery of measured data can be made via this GP-IB interface.

(9) Memory back-up function

The front panel key settings, deviation measurement reference, and judgment limits are retained even after power is turned off. When power is turned on again. the previous operating conditions (except the EXT DC BIAS key setting and offset adjustment data) are reproduced and need not be set again.

1.3 SPECIFICATIONS

The specifications and general performance characteristics of the apparatus are listed in Table 1-1. General properties other than the specifications are shown in Table 1-2; they are just reference data which seems to be necessary for operating the apparatus. The apparatus has been factory adjusted to meet the specifications listed in Table 1-1.

1.4 COMPOSITION

The apparatus is supplied with the standard accessories listed in Table 1 at the end of this manual.

8

Table 1-1. Specifications

1. Measurement Items

(1) Parameters:

C (capacitance) D (dissipation factor) X (reactance)
L (inductance) Q (Q factor = 1/D) B (susceptance)
R (resistance) ESR (equivalent series resistance) G (conductance)
|Z| (absolute impedance value) θ (phase angle)

(2) Measuring circuit modes:  (series equivalent circuit),  (parallel equivalent circuit), AUTO (automatic selection)

(3) Parameter combinations

 (Series equivalent circuit)	 (Parallel equivalent circuit)
C-D, Q, or ESR L-D, Q, or ESR R-X or L |Z| - θ	C-D, Q, or G L-D, Q, or G R-B or C |Z| - θ

(4) Measurement speed modes: FAST, NORMAL, and SLOW

(5) Display: The display depends on the measurement speed mode.

Measurement Speed Mode	Number of Digits Displayed	Maximum Count
FAST	Up to 4 digits	4999
NORMAL	Up to 4 1/2 digits	19999
SLOW	Up to 5 1/2 digits	199999

The number of significant digits varies with the measurement range, measuring frequency, and signal level range.

2. Deviation Measurement (L, C, R, and |Z| only)

(1) Reference value setting: As the reference value, measured data can be stored or a desired value can be keyed in.

(2) Display: The deviation from the reference value (△ = measured value − reference value) or its percentage (△%). The display is within the measurement limits determined by the range. In the △% display mode, the display range varies with the measurement speed mode.

Measurement Speed Mode	Display Range in the △ % Mode
FAST	− 199.9 - + 199.9 %
NORMAL	− 199.99 - + 199.99 %
SLOW	− 199.999 - + 199.999 %

Table 1-1. Specifications (Continued)

3. Range Selection: Auto or manual (UP or DOWN)

4. Start of Measurement: Auto (repetitive operation), manual, or external control

5. Measurement Terminals: Four terminal pairs

6. Measurement Signals

(1) Measuring frequency: 100 Hz to 100 kHz Internal frequency: 31 frequencies

100, 120, 150, 200, 250, 300, 401, 500, 601, 801 Hz
1.00, 1.20, 1.50, 2.00, 2.50, 3.00, 4.01, 5.00, 6.01, 8.01 kHz
10.0, 12.0, 15.1, 20.2, 25.0, 30.5, 40.3, 50.0, 62.5, 78.1, 100 kHz
(The above frequency values are nominal ones.)

(2) Measuring signal level: 1 mV to 5 Vrms, continuously variable over four ranges (10 mV, 100 mV, 1 V, 5 V)

(3) Level monitor: The signal voltage or current across the sample can be monitored.

7. Automatic Zero Adjustment Function:

The residues caused by the measuring jigs can be removed within the following ranges.

C: 20 pF or less, G: 5 μS or less, L: 2 μH or less, R: 0.5 Ω or less

8. Comparator Function:

Measured data is compared with preset upper and lower limits, and the result of the judgment is displayed.

Display	Criterion
PASS	Lower limit ≦ Measured value ≦ Upper limit
HIGH	Measured value > Upper limit
LOW	Measured value < Lower limit

9. Memory Back-up Function:

The front panel key settings, deviation measurement reference, and judgment limits are stored and reproduced when power is turned on again. (The EXT DC BIAS key setting and offset adjustment data are excluded.)

10. DC Bias: An external DC power source is used.

Maximum applied voltage: ±35 V, maximum current: 100 mA

(The maximum current may be limited, depending on the signal level range and measuring frequency.)

Table 1-1. Specifications (Continued)

11. Measurement Ranges and Accuracies

The measurement ranges, the number of significant display digits, and the measurement accuracies are shown below.

11.1 Measurement limits and measurement ranges

(1) Measurement limits

Measurement Parameter	Measurement Limits
C	0.0001pF - 1990mF
L	0.00001μH - 1.999kH
R, |Z|, ESR, X	0.00001Ω - 19.99MΩ
D	0.0001 - 9.99
Q (1/D is calculated and displayed.)	0.1 - 9000
G, B	0.0001μS - 199.9S
θ	– 180.00deg - + 180.00deg

The measurement limits vary with the measuring frequency, signal level range, and measurement speed mode. (The measurement limits shown at left indicate the maximum ranges in the NORMAL measurement speed mode.)

(2) Measurement ranges

For measured data (main parameters L, C, R, and |Z|) shown on the main display, the display range varies with the measurement range. In the accuracy table given in 11.3, measurement range representatives are shown as the range representatives. (The range codes corresponding to the range representatives are also shown in the table.)

The measurement limits in each measurement range are expressed in terms of α_0 in the table below.

$$\alpha_0 = \frac{\text{Main parameter measured value}}{\text{Main parameter range value}}$$

Measurement Limits	Measurement Range	α_0
Range representative × α_0	Maximum range	About 0.17 to 1.99 or more
	Normal range	About 0.17 to about 1.8
	Minimum range	0 to about 1.8

REMARKS:

1) The maximum value of α_0 as the maximum range varies with the signal level range, in regard to the number of significant display digits.

2) The above values of α_0 are the values in the AUTO range. In the fixed range, the maximum value of α_0 as the normal or minimum range is about 2, and the minimum value of α_0 as the maximum or normal range is about 0.1 or less.

3) In the 1 kΩ range for |Z| measurement, for example, the value of α_0 as the normal range is applied. The measurement limits are about 170 Ω and about 1.8 kΩ (in the AUTO range).

Table 1-1. Specifications (Continued)

(3) Range control

If the impedance of the sample is within the impedance range determined from the upper and lower limits in each measurement range, the range is judged appropriate and a measurement is started. If the impedance of the sample is close to a range boundary value, the measured value may not correspond to the range.

REMARKS:

The judgment limits (upper and lower limits) for each measurement range are calculated from reactance $X_L = \omega L$ at $D = 0$ in L measurement, reactance $X_C = 1/\omega C$ at $D = 0$ in C measurement, and the value of R at $Q = 0$ in R measurement.

11.2 Number of significant display digits

(1) The number of display digits in the NORMAL measurement speed mode is shown in the accuracy table given in 11.3.

How to read the number of display digits

- The number of display digits in each signal level range is shown in the parenthesis.

  Example: (4, 4, 3, 2)

  2 ―― Number of display digits in the 10 mV range
  3 ―― Number of display digits in the 100 mV range
  4 ―― Number of display digits in the 1 V range
  4 ―― Number of display digits in the 5 V range

- In the display of the number of digits, the highest order digits 1 of the range value display is not included. (4 represents a 4 1/2-digit display.)

  Example:

  When the range value is 100 and the number of display digits is 4: 100.00

  When the range value is 100 and the number of display digits is 1: .... $10_{\underline{0}}$.

  ↑ A small zero indicating the insignificant digit is displayed.

- The - mark indicates a 1/2-digit display. When the range value is displayed, 1 is displayed.
- In $|Z|$ - θ measurement, the minimum digit (deg) of θ is shown in < >,
- The number of digits preceded by △ in the table varies with the measured value.

(2) When the measurement speed mode is SLOW

The number of digits increases by one as long as it does not exceed 5 1/2 digits.

(3) When the measurement speed mode is FAST

The number of digits not preceded by △ decreases by one.

Table 1-1. Specifications (Continued)

11.3 Measurement accuracy

(1) The measurement accuracy for each parameter in the NORMAL measurement speed mode is shown in 11.3.1 to 11.3.4.

The measurement accuracy is specified at the front panel measuring terminal under the following conditions.

Accuracy prescribing conditions

1. Warm-up period: 30 min or more
2. Measuring signal level: The LEVEL FINE adjuster is set at the MAX (rightmost) position in each of the 5 V, 1 V, and 100 mV level ranges.
3. Measurement speed mode: NORMAL
4. Auto offset adjustment (open/short) has been made.
5. Ambient temperature: (23 ± 5)°C
6. DC bias: OFF
7. Significant measured data count: 20 or more
   The accuracy count is specified at the number of significant display digits in the table. Small zeros indicating the insignificant digits are not included.

(2) Accuracy in the SLOW measurement speed mode

The value in the accuracy table is used. However, the count is specified at the number of significant digits in the NORMAL mode, except the display digits added in the SLOW mode.

(3) Accuracy in the FAST measurement speed mode

Double the error shown in the accuracy table

(4) The error limit is doubled at an ambient temperature of 5 to 18°C or 28 to 35°C. (No error is specified at an ambient temperature of 0 to 5°C or 35 to 40°C.)

Table 1-1. Specifications (Continued)

11.3.1 |Z| - θ measurement

For the accuracy of |Z| or θ in |Z| - θ measurement, refer to table A-1.

- How to read the accuracy table

Upper column:	Accuracy of |Z|: ±(reading % + count)
Lower column:	Accuracy of θ: ±(angle (°) + count)

- Accuracy factor

$$\alpha_0 = \frac{\text{Measured value of } |Z|}{\text{Range value of } |Z|}$$

Table A-1. Accuracy of |Z| or θ

|Z| range				
Code	Value			
R19	10 MΩ	Δ(3, 2, 1, -) <0.01, 0.1, 1, 10>	5%+1 0.1°+(0.1 α_o)°+1	
R18	1 MΩ	Δ(3, 3, 2, 1) <0.01, 0.01, 0.1, 1>	3%+1 0.05°+(0.1 α_o)°+1	
R17	100 kΩ	Δ(3, 3, 3, 2) <0.01, 0.01, 0.01, 0.1>	(0.1+0.2 α_o)%+1 0.05°+(0.05 α_o)°+1	
R16	10 kΩ			
R15	1 kΩ			
R14	100 Ω	(4, 4, 4, 3) <0.01, 0.01, 0.01, 0.1>	0.1%+3 0.05°+(0.05/ α_o)°+1	
R13	10 Ω			
R12	1 Ω	(4, 4, 3, 2) <0.01, 0.01, 0.1, 1>	0.3%+5 0.05°+(0.05/ α_o)°+1	
R11	0.1 Ω	(4, 3, 2, 1) <0.01, 0.1, 1, 10>	0.8%+2 0.3°+(0.3/ α_o)°+1	1.2%+2 0.3°+(0.3/ α_o)°+1
		100	20k	100k

Measuring frequency (Hz)

REMARKS:

1) Number of significant display digits

- The number of display digits of |Z| in the NORMAL measurement speed mode (with the range value displayed) is shown in the parenthesis ( ). The number of digits marked with Δ varies with the measured value.
- The minimum digit (deg) of θ in the NORMAL measurement speed mode is shown in the bracket < >.

2) Measurement range in the 1 V range in the NORMAL mode

|Z|: 0.0001 Ω to 19.9 MΩ

θ: -180.00 to + 180.00°

Table 1-1. Specifications (Continued)

11.3.2 R-X/B, L/C measurement

(1) For the accuracy of R in R-X/B or L/C measurement, refer to table B-1.

- How to read the accuracy table

Accuracy of R: ± (reading % + count)

- The accuracy of R is valid when $Q \leqq 0.1$ $(D \geqq 10)$.
- The accuracy of R is not specified when the display of subparameter X, B, L, or C is OF, CF.
- Accuracy factor

$$\alpha_0 = \frac{\text{Measured value of R}}{\text{Range value of R}}$$

Table B-1. Accuracy of R

R range				
Code	Value			
R19	10 MΩ	Δ(3, 2, 1, -)	5%+1	
R18	1 MΩ	Δ(3, 3, 2, 1)	3%+1	
R17	100 kΩ	Δ(3, 3, 3, 2)	$(0.1+0.2\alpha_0)$%+1	
R16	10 kΩ			
R15	1 kΩ			
R14	100 Ω	(4, 4, 4, 3)	0.1%+3	
R13	10 Ω			
R12	1 Ω	(4, 4, 3, 2)	0.3%+5	
R11	0.1 Ω	(4, 3, 2, 1)	0.8%+2	1.2%+2

100 ●————————○ ●——— 20k ——— ● 100k

Measuring frequency (Hz)

REMARKS:

1) Number of significant display digits
The number of display digits of R in the NORMAL measurement speed mode (with the range value displayed) is shown in the parenthesis ( ). The number of digits marked with Δ varies with the measured value.

2) Measurement range in the 1 V range in the NORMAL mode
R: 0.0001 Ω to 19.9 MΩ

Table 1-1. Specifications (Continued)

(2) For the accuracy of X or B in R-X/B measurement, refer to table B-3.

- The subparameter is X in the  measuring circuit mode and B in the  measuring circuit mode.
- The measurement range for X or B is automatically selected by the R range. Refer to Table B-2.
- How to read the accuracy table.

Upper column: Accuracy of X
Lower column: Accuracy of B

Accuracy: ±(reading % + count + residue)

- Accuracy factor

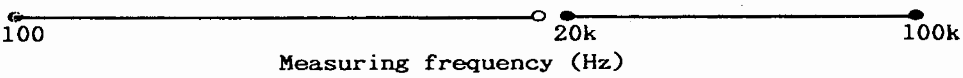
$$\alpha_0 = \frac{\text{Measured value of R}}{\text{Range value of R}} \qquad \gamma = \frac{\text{Measured value of X}}{\text{Range value of X}}$$

Table B-2. X, B Range Selection

R range		Range value	
Code	Value	X	B
R19	10 MΩ	10 MΩ	1 μS
R18	1 MΩ	1 MΩ	10 μS
R17	100 kΩ	100 kΩ	100 μS
R16	10 kΩ	10 kΩ	1000 μS
R15	1 kΩ	1 kΩ	10 mS
R14	100 Ω	100 Ω	100 mS
R13	10 Ω	10 Ω	1000 mS
R12	1 Ω	1 Ω	10 S
R11	0.1 Ω	0.1 Ω	100 S

Table B-3. Accuracy of X or B in R-X/B Measurement

Range value				
X	B			
10 MΩ	1 μS	Δ(3, 2, 1, -) (4, 3, 2, 1)	5%+1+(0.05 α_o+0.2 α_o^2)MΩ 3%+5+(0.0002/ α_o)μS	
1 MΩ	10 μS	Δ(3, 3, 2, 1) (4, 4, 3, 2)	3%+1+(0.005 α_o+0.02 α_o^2)MΩ 1%+3+(0.002/ α_o)μS	
100 kΩ	100 μS	Δ(3, 3, 3, 2) (4, 4, 4, 3)	(0.1+0.2 γ)%+1+(0.3 α_o+2 α_o^2)kΩ 0.1%+3+(0.02/ α_o)μS	
10 kΩ	1000 μS	Δ(3, 3, 3, 2) (4, 4, 4, 3)	(0.1+0.2 γ)%+1+(0.03 α_o+0.2 α_o^2)kΩ 0.1%+3+(0.2/ α_o)μS	
1 kΩ	10 mS	Δ(3, 3, 3, 2) (4, 4, 4, 3)	(0.1+0.2 γ)%+1+(0.003 α_o+0.02 α_o^2)kΩ 0.1%+3+(0.002/ α_o)mS	
100 Ω	100 mS	(4, 4, 4, 3) Δ(3, 3, 3, 2)	0.1%+3+(0.1 α_o)Ω 0.1%+1+(0.2/ α_o+0.2/ α_o^2)mS	
10 Ω	1000 mS	(4, 4, 4, 3) Δ(3, 3, 3, 2)	0.1%+3+(0.01 α_o)Ω 0.1%+1+(2/ α_o+2/ α_o^2)mS	
1 Ω	10 S	(4, 4, 3, 2) Δ(3, 3, 2, 1)	0.3%+5+(0.001 α_o)Ω 0.3%+1+(0.02/ α_o+0.02/ α_o^2)S	
0.1 Ω	100 S	(4, 3, 2, 1) Δ(3, 2, 1, -)	0.8%+2+(0.0002 α_o)Ω 1%+1+(0.3/ α_o+0.5/ α_o^2)S	1.2%+2+(0.0002 α_o)Ω 1%+1+(0.3/ α_o+0.5/ α_o^2)S



REMARKS:

1) Number of significant display digits

Upper column( ) : Number of display digits of X
Lower column( ) : Number of display digits of B

The number of display digits shown is one in the case where the measurement speed mode is NORMAL and the range value is displayed. The number of digits marked with △ varies with the measured value.

2) Measurement range in the 1 V range in the NORMAL mode

X: 0.0001 Ω to 19.9 MΩ

B: 0.001 μS to 199 S

16

Table 1-1. Specifications (Continued)

(3) In R-L/C measurement, L and C are calculated based on the following formulas.

$$L = \frac{X}{2\pi f} \qquad C = \frac{B}{2\pi f}$$

The measurement range for L or C in R-L/C measurement is automatically selected according to the R range and measuring frequency. Refer to Tables B-4 and B-5.

REMARKS:

The number of significant display digits and the display range for L or C are the same as those for L in L-D, Q, or ESR/G measurement or C in C-D, Q, or ESR/G measurement. (The measurement accuracy of L or C in R-L/C measurement is not specified.)

Table B-4. L Range Selection in R-L Measurement

R range		Range value of L (R-L measurement)			
Code	Value				
R19	10 MΩ	10 kH	1 kH	100 H	10 H
R18	1 MΩ	1 kH	100 H	10 H	1 H
R17	100 kΩ	100 H	10 H	1 H	100 mH
R16	10 kΩ	10 H	1 H	100 mH	10 mH
R15	1 kΩ	1 H	100 mH	10 mH	1 mH
R14	100 Ω	100 mH	10 mH	1 mH	100 μH
R13	10 Ω	10 mH	1 mH	100 μH	10 μH
R12	1 Ω	1 mH	100 μH	10 μH	1 μH
R11	0.1 Ω	100 μH	10 μH	1 μH	0.1 μH

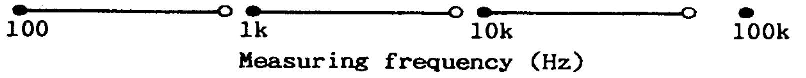


Table B-5. C Range Selection in R-C Measurement

R range		Range value of C (R-C measurement)			
Code	Value				
R19	10 MΩ	1 nF	100 pF	10 pF	1 pF
R18	1 MΩ	10 nF	1 nF	100 pF	10 pF
R17	100 kΩ	100 nF	10 nF	1 nF	100 pF
R16	10 kΩ	1 μF	100 nF	10 nF	1 nF
R15	1 kΩ	10 μF	1 μF	100 nF	10 nF
R14	100 Ω	100 μF	10 μF	1 μF	100 nF
R13	10 Ω	1 mF	100 μF	10 μF	1 μF
R12	1 Ω	10 mF	1 mF	100 μF	10 μF
R11	0.1 Ω	100 mF	10 mF	1 mF	100 μF

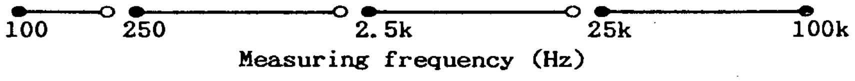


Table 1-1. Specifications (Continued)

11.3.3 C-D, Q, or ESR/G measurement

(1) For the accuracy of C in C-D, Q, or ESR/G measurement, refer to Table C-1.

- How to read the accuracy table

Accuracy of C: ±(reading % + count) or ±(reading % + count + residue)

- The accuracy of C is valid when D ≦ 0.1.
- The accuracy of C is not specified when the display of subparameter D, Q, ESR, or G is OF, CF.
- The accuracy for --- in the table is not specified.
- Accuracy factor

$$\alpha = k_0 \cdot \frac{\text{Measured value of C}}{\text{Range value of C}}$$ (For k_0, refer to graph (b) on page 1-21.)

For β, refer to graph (a) on page 1-21.

Table C-1. Accuracy of C

C range					
Code	Value				
R23	1000 mF	Δ(2,1,-,-)* 10%+1			
R22	100 mF	Δ(3,2,1,-) 3%+1	Δ(2,1,-,-)* 5%+1 10%+1		
R21	10 mF	Δ(3,3,2,1) 1%+1	Δ(3,2,1,-) 3%+1	Δ(2,1,-,-)* ----	
R20	1 mF	Δ(3,3,3,2) (0.1+0.1α)%+1	Δ(3,3,2,1) 1%+1	Δ(3,2,1,-) 3%+1	Δ(2,1,-,-)* ----
R19	100 µF		Δ(3,3,3,2) (0.1+0.1α)%+1	Δ(3,3,2,1) 1%+1 3%+1	Δ(3,2,1,-) ----
R18	10 µF	(4,4,4,3) 0.1%+(1+β)		Δ(3,3,3,2) (0.1+0.1α)%+1	Δ(3,3,2,1) 3%+1
R17	1 µF		(4,4,4,3) 0.1%+(1+β)		Δ(3,3,3,2) (0.1+0.1α)%+1
R16	100 nF			(4,4,4,3) 0.1%+(1+β)	
R15	10 nF	(4,4,3,2) 0.1%+(1+β)			(4,4,4,3) 0.1%+(1+β)
R14	1 nF	(4,3,2,1) 0.1%+(1+β)	(4,4,3,2) 0.1%+(1+β)		
R13	100 pF		(4,3,2,1) 0.1%+(1+β)	(4,4,3,2) 0.1%+(1+β)	
R12	10 pF			(4,3,2,1) 0.1%+(1+β)	(4,4,3,2) 0.3%+(1+β)+0.001pF
R11	1 pF				(4,3,2,1) 0.3%+(1+β)+0.001pF

100 250 1k 2.5k 20k 25k 100k

Measuring frequency (Hz)

REMARKS: 1) The number of display digits of C in the NORMAL measurement speed mode with D≦0.1 (with the range value displayed) is shown in the parenthesis ( ). The number of digits marked with Δ varies with the measured value.

2) In the highest range (indicated by *), ten measurements are made and their average is determined.

3) Measurement range in the 1 V range in the NORMAL mode

C: 0.001 pF to 1900 mF (depending on the measuring frequency)

Table 1-1. Specifications (Continued)

(2) For the accuracy of D in C-D measurement, refer to Table C-2.

- How to read the accuracy table

  Accuracy of D: ±(reading % + count + residue)

- The accuracy for --- in the table is not specified.
- Accuracy factor

$$\alpha = k_0 \cdot \frac{\text{Measured value of C}}{\text{Range value of C}}$$

(For k_0, refer to graph (b) on page 1-21.)

(3) The result of calculation 1/D is displayed as Q in C-Q measurement.

(The measurement accuracy of Q is not specified.)

Table C-2. Accuracy of D in C-D Measurement

C range					
Code	Value				
R23	1000 mF	10%+1 +(0.01+0.03α)			
R22	100 mF	3%+1 +(0.002+0.01α)	5%+1 +(0.01+0.03α) 10%+1+(0.01+0.03α)		
R21	10 mF	1%+1 +(0.001+0.002α)	3%+1 +(0.002+0.01α)	----	
R20	1 mF	(0.3+0.1α)%+1 +(0.0005+0.002α)	1%+1 +(0.001+0.002α)	3%+1 +(0.002+0.01α)	----
R19	100 μF		(0.3+0.1α)%+1 +(0.0005+0.002α)	1%+1 +(0.001+0.002α) 3%+1+(0.001+0.002α)	----
R18	10 μF	(0.3+0.03/α)%+1 +(0.0005+0.0003/α)		(0.3+0.1α)%+1 +(0.0005+0.002α)	3%+1 +(0.001+0.002α)
R17	1 μF		(0.3+0.03/α)%+1 +(0.0005+0.0003/α)		(0.3+0.1α)%+1 +(0.0005+0.002α)
R16	100 nF			(0.3+0.03/α)%+1 +(0.0005+0.0003/α)	
R15	10 nF				(0.3+0.03/α)%+1 +(0.0005+0.0003/α)
R14	1 nF				
R13	100 pF				
R12	10 pF				(0.5+0.06/α)%+1 +(0.001+0.0006/α)
R11	1 pF				

100 250 1k 2.5k 20k 25k 100k

Measuring frequency (Hz)

REMARKS:

1) In the highest range for C, ten measurements are made and their average is determined.

2) Measurement range in the 1 V range in the NORMAL mode

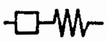
D: 0.0001 to 9.99

Q: 0.1 to 9000 (The result of calculation 1/D is displayed.)

The number of display digits of D or Q varies with the measurement range for C, signal level range, and measured value.

Table 1-1. Specifications (Continued)

(4) For the accuracy of ESR or G in C-ESR/G measurement, refer to Table C-3.

- The subparameter is ESR in the  measuring circuit mode and G in the  measuring circuit mode.
- The measurement range for ESR or G is automatically selected according to the range for C and the measuring frequency. Refer to Table C-4.
- How to read the accuracy table.

Upper column: Accuracy of ESR Lower column: Accuracy of G

Accuracy: ±(reading % + count + residue)

- Accuracy factor

$$\alpha = k_0 \cdot \frac{\text{Measured value of C}}{\text{Range value of C}}$$ (For k_0, refer to graph (b) on page 1-21.)

Table C-3. Accuracy of ESR or G in C-ESR/G Measurement

Range value				
ESR	G			
10 MΩ	1 μS	Δ(3、2、1、-) (4、3、2、1)	$3\%+2+(0.01/\alpha+0.05/\alpha^2)$MΩ $3\%+5+(0.0005\alpha)$μS	
1 MΩ	10 μS	Δ(3、3、2、1) (4、4、3、2)	$1\%+2+(0.001/\alpha+0.005/\alpha^2)$MΩ $1\%+3+(0.003\alpha)$μS	
100 kΩ	100 μS	Δ(3、3、3、2) (4、4、4、3)	$0.2\%+2+(0.1/\alpha+0.5/\alpha^2)$kΩ $0.1\%+3+(0.03\alpha)$μS	
10 kΩ	1000 μS	Δ(3、3、3、2) (4、4、4、3)	$0.2\%+2+(0.01/\alpha+0.05/\alpha^2)$kΩ $0.1\%+3+(0.3\alpha)$μS	
1 kΩ	10 mS	Δ(3、3、3、2) (4、4、4、3)	$0.2\%+2+(0.001/\alpha+0.005/\alpha^2)$kΩ $0.1\%+3+(0.003\alpha)$mS	
100 Ω	100 mS	(4, 4, 4, 3) Δ(3, 3, 3, 2)	$0.1\%+2+(0.01/\alpha)$Ω $0.1\%+1+(0.5\alpha+0.5\alpha^2)$mS	
10 Ω	1000 mS	(4, 4, 4, 3) Δ(3, 3, 3, 2)	$0.1\%+2+(0.001/\alpha)$Ω $0.1\%+1+(5\alpha+5\alpha^2)$mS	
1 Ω	10 S	(4, 4, 3, 2) Δ(3, 3, 2, 1)	$0.3\%+3+(0.0001/\alpha)$Ω $0.3\%+1+(0.05\alpha+0.1\alpha^2)$S	
0.1 Ω	100 S	(4, 3, 2, 1) Δ(3, 2, 1, -)	$0.8\%+2+(0.00002/\alpha)$Ω $1\%+1+(\alpha+6\alpha^2)$S	$1.2\%+2+(0.00002/\alpha)$Ω $1\%+1+(\alpha+6\alpha^2)$S
			100 ●———○	20k ●———● 100k

Measuring frequency (Hz)

REMARKS:

1) Number of significant display digits

Upper column ( ) : Number of display digits of ESR Lower column ( ) : Number of display digits of G

The number of display digits is one in the case where the measurement speed mode is NORMAL and the range representative is displayed. The number of digits marked with Δ varies with the measured value.

2) Measurement range in the 1 V range in the NORMAL mode

ESR: 0.0001 Ω to 19.9 MΩ

G : 0.001 μS to 199 S

Table 1-1. Specifications (Continued)

Table C-4. Range Selection for ESR or G in C-ESR/G Measurement

C range					
Code	Value				
R23	1000 mF	0.1 Ω/ 100 S			
R22	100 mF		0.1 Ω/ 100 S		
R21	10 mF	1 Ω/ 10 S		0.1 Ω/ 100 S	
R20	1 mF	10 Ω/1000 mS	1 Ω/ 10 S		0.1 Ω/ 100 S
R19	100 μF	100 Ω/ 100 mS	10 Ω/1000 mS	1 Ω/ 10 S	
R18	10 μF	1 kΩ/ 10 mS	100 Ω/ 100 mS	10 Ω/1000 mS	1 Ω/ 10 S
R17	1 μF	10 kΩ/1000 μS	1 kΩ/ 10 mS	100 Ω/ 100 mS	10 Ω/1000 mS
R16	100 nF	100 kΩ/ 100 μS	10 kΩ/1000 μS	1 kΩ/ 10 mS	100 Ω/ 100 mS
R15	10 nF	1 MΩ/ 10 μS	100 kΩ/ 100 μS	10 kΩ/1000 μS	1 kΩ/ 10 mS
R14	1 nF	10 MΩ/ 1 μS	1 MΩ/ 10 μS	100 kΩ/ 100 μS	10 kΩ/1000 μS
R13	100 pF		10 MΩ/ 1 μS	1 MΩ/ 10 μS	100 kΩ/ 100 μS
R12	10 pF			10 MΩ/ 1 μS	1 MΩ/ 10 μS
R11	1 pF				10 MΩ/ 1 μS
		100 ●—○ 250	250 ●—○ 2.5k	2.5k ●—○ 25k	25k ●—● 100k

Measuring frequency (Hz)

REMARKS:

1) How to read the table

ESR range representative/G range representative

2) In the highest range for C, ten measurements are made and their average is determined.

Table 1-1. Specifications (Continued)

11.3.4 L-D, Q, ESR/G measurement

(1) For the accuracy of L in L-D, Q, or ESR/G measurement, refer to Table D-1.

- How to read the accuracy table

Accuracy of L: ±(reading % + count) or ±(reading % + count + residue)

- The accuracy of L is valid when D ≦ 0.1.
- The accuracy of L is not specified when the display of subparameter D, Q, or ESR/G is OF, CF.
- The accuracy for --- in the table is not specified.
- Accuracy factor

$$\alpha = k_2 \cdot \frac{\text{Measured value of L}}{\text{Range value of L}}$$ (For k_2, refer to graph (c) on page 1-21.)

Table D-1. Accuracy of L

L range					
Code	Value				
R22	10 kH	Δ(3,2,1,-) ----			
R21	1 kH	Δ(3,3,2,1) 3%+1	Δ(3,2,1,-) ----		
R20	100 H	Δ(3,3,3,2) (0.1+0.2α)%+1	Δ(3,3,2,1) 3%+1	Δ(3,2,1,-) ----	
R19	10 H		Δ(3,3,3,2) (0.1+0.2α)%+1	Δ(3,3,2,1) 3%+1	Δ(3,2,1,-) ----
R18	1 H			Δ(3,3,3,2) (0.1+0.2α)%+1	Δ(3,3,2,1) 3%+1
R17	100 mH	(4,4,4,3) 0.2%+3			Δ(3,3,3,2) (0.1+0.2α)%+1
R16	10 mH	(4,4,4,3) 0.1%+3	(4,4,4,3) 0.2%+3		
R15	1 mH	(4,4,3,2) 0.3%+3	(4,4,4,3) 0.1%+3	(4,4,4,3) 0.2%+3	
R14	100 μH	(4,3,2,1) 0.5%+5	(4,4,3,2) 0.3%+3	(4,4,4,3) 0.1%+3	(4,4,4,3) 0.2%+3
R13	10 μH		(4,3,2,1) 0.5%+5	(4,4,3,2) 0.3%+3	(4,4,4,3) 0.1%+3
R12	1 μH		0.5%+5+0.0001μH →	(4,3,2,1) 1%+5+0.0001μH	(4,4,3,2) 0.3%+3
R11	0.1 μH				(4,3,2,1) 1%+5+0.0001μH

●——○ ●——○ ●—○ ●——○ ●

100 1k 10k 20k 100k

Measuring frequency (Hz)

REMARKS:

1) Number of significant display digits

The number of display digits of L in the NORMAL measurement speed mode with D ≦ 0.1 (with the range value displayed) is shown in the parenthesis ( ). The number of digits marked with △ varies with the measured value.

2) Measurement range in the 1 V range in the NORMAL mode

L: 0.0001 μH to 1.999 kH (depending on the measuring frequency)

Table 1-1. Specifications (Continued)

(2) For the accuracy of D in L-D measurement, refer to Table D-2.

- How to read the accuracy table

  Accuracy of D: ±(reading % + count + residue)

- The accuracy for — in the table is not specified.
- Accuracy factor

$$\alpha = k_2 \cdot \frac{\text{Measured value of L}}{\text{Range value of L}}$$ (For k_2, refer to graph (c) on page 1-21.)

(3) The result of calculation 1/D is displayed as Q in L measurement.

(The measurement accuracy of Q is not specified.)

Table D-2. Accuracy of D in L-D Measurement

<table>
<tr><th colspan="2">L range</th><th></th><th></th><th colspan="2"></th><th></th></tr>
<tr><th>Code</th><th>Value</th><th></th><th></th><th colspan="2"></th><th></th></tr>
<tr><td>R22</td><td>10 kH</td><td>----</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>R21</td><td>1 kH</td><td>3%+1
+(0.001+0.002α)</td><td>----</td><td colspan="2"></td><td></td></tr>
<tr><td>R20</td><td>100 H</td><td rowspan="3">(0.3+0.1α)%+1
+(0.001+0.002α)</td><td>3%+1
+(0.001+0.002α)</td><td colspan="2">----</td><td></td></tr>
<tr><td>R19</td><td>10 H</td><td rowspan="3">(0.3+0.1α)%+1
+(0.001+0.002α)</td><td colspan="2">3%+1
+(0.001+0.002α)</td><td>----</td></tr>
<tr><td>R18</td><td>1 H</td><td colspan="2" rowspan="3">(0.3+0.1α)%+1
+(0.001+0.002α)</td><td>3%+1
+(0.001+0.002α)</td></tr>
<tr><td>R17</td><td>100 mH</td><td rowspan="2">(0.3+0.03/α)%+1
+(0.001+0.0003/α)</td><td rowspan="3">(0.3+0.1α)%+1
+(0.001+0.002α)</td></tr>
<tr><td>R16</td><td>10 mH</td><td rowspan="2">(0.3+0.03/α)%+1
+(0.001+0.0003/α)</td></tr>
<tr><td>R15</td><td>1 mH</td><td>(0.5+0.05/α)%+1
+(0.001+0.0005/α)</td><td colspan="2" rowspan="2">(0.3+0.03/α)%+1
+(0.001+0.0003/α)</td></tr>
<tr><td>R14</td><td>100 μH</td><td>(1+0.3/α)%+1
+(0.001+0.003/α)</td><td>(0.5+0.05/α)%+1
+(0.001+0.0005/α)</td><td rowspan="2">(0.3+0.03/α)%+1
+(0.001+0.0003/α)</td></tr>
<tr><td>R13</td><td>10 μH</td><td></td><td>(1+0.3/α)%+1
+(0.001+0.003/α)</td><td colspan="2">(0.5+0.05/α)%+1
+(0.001+0.0005/α)</td></tr>
<tr><td>R12</td><td>1 μH</td><td></td><td></td><td>(1+0.3/α)%+1+(0.001+0.003/α)</td><td>(2+0.3/α)%+1+(0.001+0.003/α)</td><td>(0.5+0.05/α)%+1
+(0.001+0.0005/α)</td></tr>
<tr><td>R11</td><td>0.1 μH</td><td></td><td></td><td colspan="2"></td><td>(2+0.3/α)%+1
+(0.001+0.003/α)</td></tr>
<tr><td></td><td></td><td>100</td><td>1k</td><td>10k</td><td>20k</td><td>100k</td></tr>
</table>

Measuring frequency (Hz)

REMARKS: Measurement range in the 1 V range in the NORMAL mode

D: 0.0001 to 9.99

Q: 0.1 to 9000 (The result of calculation 1/D is displayed.)

The number of display digits of D or Q varies with the measurement range for L, signal level range, and measured value.

Table 1-1. Specifications (Continued)

(4) For the accuracy of ESR or G in L-ESR/G measurement, refer to Table D-3.

- The subparameter is ESR in the  measuring circuit mode and G in the  measuring circuit mode.
- The measurement range for ESR or G is automatically selected according to the range for L and the measuring frequency. Refer to Table D-4.
- How to read the accuracy table

Upper column: Accuracy of ESR
Lower column: Accuracy of G

Accuracy: ± (reading % + count + residue)

- The accuracy for --- in the table is not specified.
- Accuracy factor

$$\alpha = k_2 \cdot \frac{\text{Measured value of L}}{\text{Range value of L}}$$ (For k_2, refer to graph (c) on page 1-21.)

Table D-3. Accuracy of ESR or G in L-ESR/G Measurement

Range value				
ESR	G			
10 MΩ	1 μS	Δ(3,2,1,-) (4,3,2,1)	---- ----	
1 MΩ	10 μS	Δ(3,3,2,1) (4,4,3,2)	$1\%+2+(0.003\alpha+0.01\alpha^2)$MΩ $1\%+3+(0.002/\alpha)$μS	
100 kΩ	100 μS	Δ(3,3,3,2) (4,4,4,3)	$0.2\%+2+(0.3\alpha+\alpha^2)$kΩ $0.1\%+3+(0.02/\alpha)$μS	
10 kΩ	1000 μS	Δ(3,3,3,2) (4,4,4,3)	$0.2\%+2+(0.03\alpha+0.1\alpha^2)$kΩ $0.1\%+3+(0.2/\alpha)$μS	
1 kΩ	10 mS	Δ(3,3,3,2) (4,4,4,3)	$0.2\%+2+(0.003\alpha+0.01\alpha^2)$kΩ $0.1\%+3+(0.002/\alpha)$mS	
100 Ω	100 mS	(4,4,4,3) Δ(3,3,3,2)	$0.1\%+2+(0.06\alpha)$Ω $0.1\%+1+(0.2/\alpha+0.2/\alpha^2)$mS	
10 Ω	1000 mS	(4,4,4,3) Δ(3,3,3,2)	$0.1\%+2+(0.006\alpha)$Ω $0.1\%+1+(2/\alpha+2/\alpha^2)$mS	
1 Ω	10 S	(4,4,3,2) Δ(3,3,2,1)	$0.3\%+3+(0.0006\alpha)$Ω $0.3\%+1+(0.02/\alpha+0.02/\alpha^2)$S	
0.1 Ω	100 S	(4,3,2,1) Δ(3,2,1,-)	$0.8\%+2+(0.0001\alpha)$Ω $1\%+1+(0.3/\alpha+0.5/\alpha^2)$S	$1.2\%+2+(0.0001\alpha)$Ω $1\%+1+(0.3/\alpha+0.5/\alpha^2)$S

100 ●————○ ●———● 20k 100k

Measuring frequency (Hz)

REMARKS:

1) Number of significant display digits

Upper column ( ) : Number of display digits of ESR
Lower column ( ) : Number of display digits of G

The number of display digits is one in the case where the measurement speed mode is NORMAL and the range representative is displayed. The number of digits marked with △ varies with the measured value.

2) Measurement range in the 1 V range in the NORMAL mode

ESR : 0.0001 Ω to 1.999 MΩ

G : 0.001 μS to 199 S

Table 1-1. Specifications (Continued)

Table D-4. ESR/G Range Selection in L-ESR/G Measurement

L range					
Code	Value				
R22	10 kH	10 MΩ/ 1 µS			
R21	1 kH	1 MΩ/ 10 µS	10 MΩ/ 1 µS		
R20	100 H	100 kΩ/ 100 µS	1 MΩ/ 10 µS	10 MΩ/ 1 µS	
R19	10 H	10 kΩ/1000 µS	100 kΩ/ 100 µS	1 MΩ/ 10 µS	10 MΩ/ 1 µS
R18	1 H	1 kΩ/ 10 mS	10 kΩ/1000 µS	100 kΩ/ 100 µS	1 MΩ/ 10 µS
R17	100 mH	100 Ω/ 100 mS	1 kΩ/ 10 mS	10 kΩ/1000 µS	100 kΩ/ 100 µS
R16	10 mH	10 Ω/1000 mS	100 Ω/ 100 mS	1 kΩ/ 10 mS	10 kΩ/1000 µS
R15	1 mH	1 Ω/ 10 S	10 Ω/1000 mS	100 Ω/ 100 mS	1 kΩ/ 10 mS
R14	100 µH	0.1 Ω/ 100 S	1 Ω/ 10 S	10 Ω/1000 mS	100 Ω/ 100 mS
R13	10 µH		0.1 Ω/ 100 S	1 Ω/ 10 S	10 Ω/1000 mS
R12	1 µH			0.1 Ω/ 100 S	1 Ω/ 10 S
R11	0.1 µH				0.1 Ω/ 100 S
		100	1k	10k	100k

Measuring frequency (Hz)

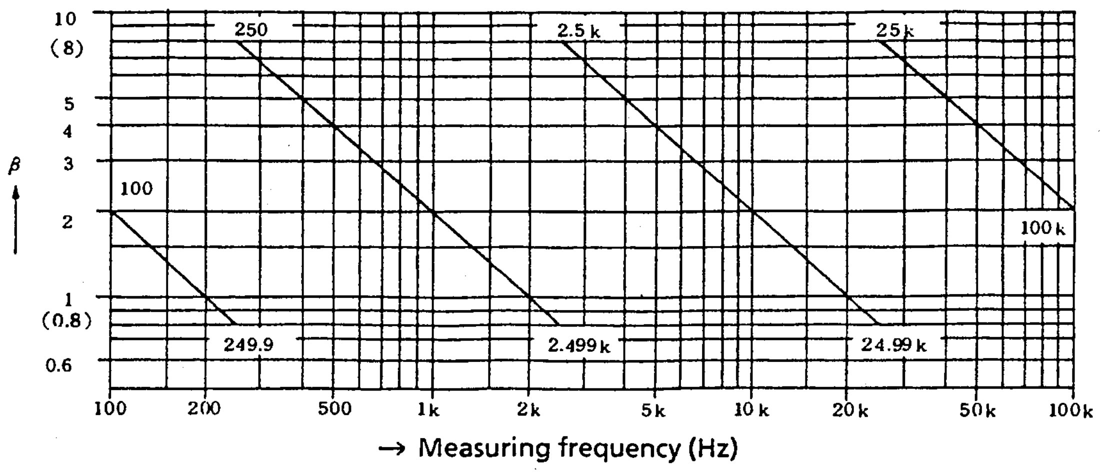
REMARKS: How to read the table

ESR range value/G range value

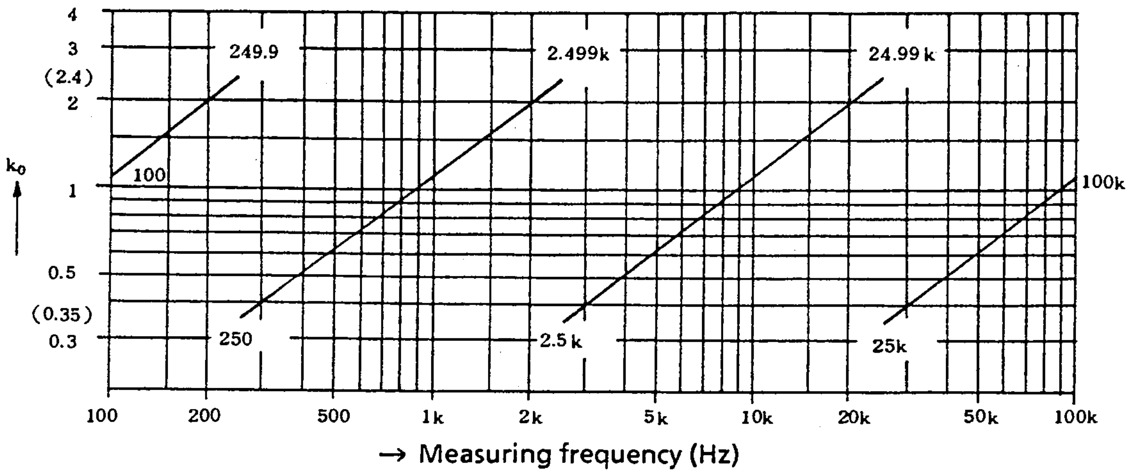
25

Table 1-1. Specifications (Continued)

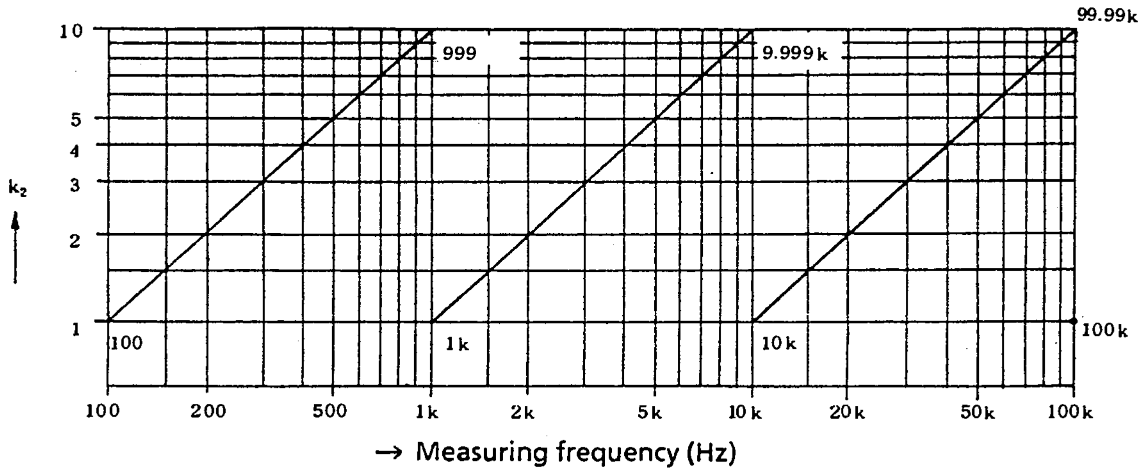
Graph (a) Accuracy factor β in C measurement (High impedance)



Graph (b) Accuracy factor k_0 in C measurement (Low impedance)



Graph (c) Accuracy factor k_2 in L measurement



26

Table 1-1. Specifications (Continued)

12. External Interface

(1) GP-IB interface: Remote control and measured data output (IEEE-488 compatible)

Interface function	SH1, AH1, T5, L4, SR1, RL1, DT1, DC1
Remote program function	Remote programming of all front panel key functions, except the power switch and OSC LEVEL FINE adjuster
Data output	Data shown on the main and sub displays: Measured value, deviation measurement reference, judgment limits, monitor signal voltage or current, and internal settings

(2) External control interface: External measurement start input signal, comparator judgment output signal, and overall judgment relay contact output

(3) External frequency input and external frequency data interface:
Measurement can be made at an external frequency by entering a signal whose frequency is 16 times higher than the measuring frequency and specifying the frequency value.

Measuring frequency range	100Hz - 100kHz
Input frequency	A signal whose frequency is 16 times higher than the measuring frequency is entered. (1.6 kHz to 1.6 MHz)
Frequency value specification	Specification can be made through the GP-IB interface or external frequency data interface

13. General Specifications

(1) Power requirements: 100/120/220/240 VAC ± 10%, 50/60 Hz

(2) Power consumption: 55 VA maximum

(3) Operating temperature/humidity ranges: temperature +5 to +35°C, relative humidity 40% to 80%

(4) Working temperature range : 0 to +40°C

(5) Storage temperature range : -20 to +60°C

(6) Dimensions: approx. 177(H) x 425(W) x 450(D) mm (The protrusions are not included.)

(7) Mass : approx. 17 kg

Table 1-2. Reference Data

1. Measurement Accuracy

(1) Errors with the signal level range is set for 10 mV (with the OSC LEVEL FINE adjuster set for MAX)

$\lvert Z\rvert$ - θ measurement	For $\lvert Z\rvert$, the term containing α_0 is multiplied by 10. (The accuracy of θ is not specified.)
R-X/B, L/C measurement	All % error terms that contain α_0 or γ are multiplied by 10.
C-D/Q measurement	All terms that contain α are multiplied by 10.
C-ESR/G measurement	Same as given in the specification. However, the error increases as the number of digits decreases.
L-D/Q measurement	All terms that contain α are multiplied by 10.
L-ESR/G measurement	Same as given in the specification. However, the error increases as the number of digits decreases.

(2) Accuracy of C or L when $D > 0.1$ and accuracy of R when $Q > 0.1$

Accuracy of C or L when $D > 0.1$	The specified accuracy is multiplied by $(1 + D^2)$.
Accuracy of R when $Q > 0.1$ ($D < 10$)	The specified accuracy is multiplied by $(1 + Q^2)$.

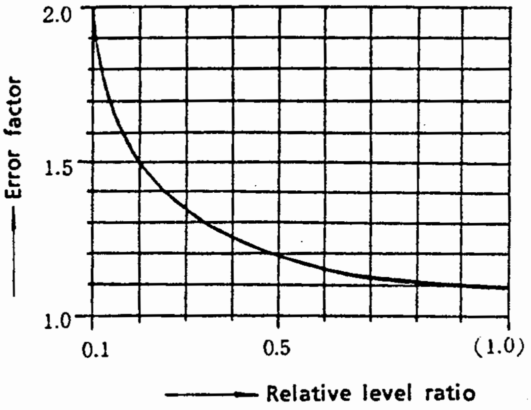
(3) Error with the OSC LEVEL FINE adjuster set to a position other than MAX

When the OSC LEVEL FINE adjuster is set to a position other than MAX, the following factor is multiplied.

$$\left(1 + \frac{0.1}{{}^{*}\text{relative level ratio}}\right)$$

* Relative level ratio when the open voltage at H_{CUR} is 1 with the OSC LEVEL FINE adjuster set for MAX

(About $0.1 \leqq$ (relative level ratio) < 1)



2. Level Monitor Display Range and Accuracy

Level Monitor	Display Range	Accuracy
Voltage (V)	0.001 mV to 5.00 V or more	± (3% of reading + 1 count) at 1 mV to 5 V
Current (mA)	0.001 mA to 100 mA or more	± (3% of reading + 1 count)

3. H_{CUR} Signal Output Impedance: about 50 Ω

Table 1-2. Reference Data (Continued)

4. Measurement Time (Typical)

The measurement time varies with the measuring frequency and measurement speed mode.

Measurement Speed Mode	Measurement Time (Typical)
FAST	About 150 to 200 ms (f≧1 kHz) About 150 to 250 ms (f<1 kHz)
NORMAL	About 250 to 300 ms (f≧1 kHz) About 250 to 350 ms (f<1 kHz)
SLOW	About 9 times the measurement time in the NORMAL mode

REMARKS:

1) The measurement time is the time interval from the instant an external measurement through the external control interface is started to the moment the measurement end signal is output. It is measured by the internal frequency.
2) When the measuring voltage or current is monitored, the measurement time is increased by about 100 to 150 ms.
3) When the measurement range is changed, the time for changing the range, 0.2 to 1.5 sec, is added.
4) When the comparator is used, about 10 ms is added.

5. Signal Stabilization Time

(1) When the measuring frequency or signal level range is changed: about 600 to 850 ms
(The apparatus automatically waits for the above time period.)

(2) When the OSC LEVEL FINE adjuster is used: about 2 to 3 sec

6. Internal Measuring Frequency and Frequency Accuracy

(1) Internal measuring frequency

The measuring frequency is calculated by the following formula.

$$f = \frac{20 \times 10^6}{16 \cdot N} \text{ (Hz)}$$ (N is the frequency division ratio shown on the next page.)

(2) Frequency accuracy

For 100, 200, 250, 500, 1k, 2k, 2.5k, 5k, 10k, 25k, 50k, 62.5k, 100kHz, the accuracy is within $\pm 1 \times 10^{-4}$.

For other frequencies, the fractions below the lowest-order digit of their nominal values are ignored.

29

Table 1-2. Reference Data (Continued)

Measuring Frequency and Frequency Division Ratio

Nominal Value (Hz)	Measuring Frequency (kHz)	Division Ratio (N)	Nominal Value (Hz)	Measuring Frequency (kHz)	Division Ratio (N)
100	0.1	12500	4.01 k	4.00641	312
120	0.120077	10410	5.00 k	5.	250
150	0.150060	8330	6.01 k	6.00962	208
200	0.2	6250	8.01 k	8.01282	156
250	0.25	5000	10.0 k	10.	125
300	0.300481	4160	12.0 k	12.0192	104
401	0.400641	3120	15.1 k	15.0602	83
500	0.5	2500	20.2 k	20.1613	62
601	0.600962	2080	25.0 k	25.	50
801	0.801282	1560	30.5 k	30.4878	41
1.00 k	1.	1250	40.3 k	40.3226	31
1.20 k	1.20077	1041	50.0 k	50.	25
1.50 k	1.50060	833	62.5 k	62.5	20
2.00 k	2.	625	78.1 k	78.125	16
2.50 k	2.5	500	100 k	100	(12.5)
3.00 k	3.00481	416			

(The above measuring frequencies are calculated values.)

7. Measurement by an External Frequency

(1) Input frequency: A signal whose frequency is 16 times higher than the measuring frequency is entered. (1.6 kHz to 1.6 MHz)

(2) Input level: 100 mVp-p to 5 Vp-p, sine wave or square wave

(3) Input impedance: 1 kΩ or more

(4) Input frequency specification: Specification is made through the GP-IB interface or external frequency data interface. (The value 16 times the measuring frequency is specified.)

(5) Measurement accuracy: Conforms to the accuracy of measurement by the internal frequency when the external frequency accuracy is within ± 1×10^{-4}, the frequency value is specified by five digits, and the phase noise (residual FM) is -50 dB or less.

30

SECTION 2
PREPARATION FOR USE

2.1 INTRODUCTION

This section deals with unpacking, acceptance inspection, power, and repacking.

2.2 UNPACKING AND ACCEPTANCE INSPECTION

This apparatus has been factory inspected, mechanically and electrically, prior to shipment to ensure that it gives satisfactory performance. When your order is received, promptly unpack it and check it for damage in transmit.

When unpacking the apparatus, save the wooden box, corrugated cardboard box, cushions, and other packing materials except consumables like steel bands and wrapping paper where possible so that they may be reused when the apparatus is to be packed again for shipment.

(1) Mechanical inspection

inspect the apparatus for damage in transmit, and check its switches, terminals, and other parts exposed to view for looseness or other faults. Check the types and quantity of accessories and spare parts against the packing list.

(2) Performance test

If the apparatus is found by the mechanical inspection to be in good order externally, then test it to check its performance. If the apparatus is found damaged or faulty in the acceptance inspection, immediately report the damage or fault to your nearest Ando dealer.

2.3 POWER

This apparatus is designed to operate on 100, 120, 220, or 240 VAC. The AC voltage setting should be set by the AC line voltage selector located on the rear panel of the apparatus. The voltage setting procedure is shown in Fig. 2-1.

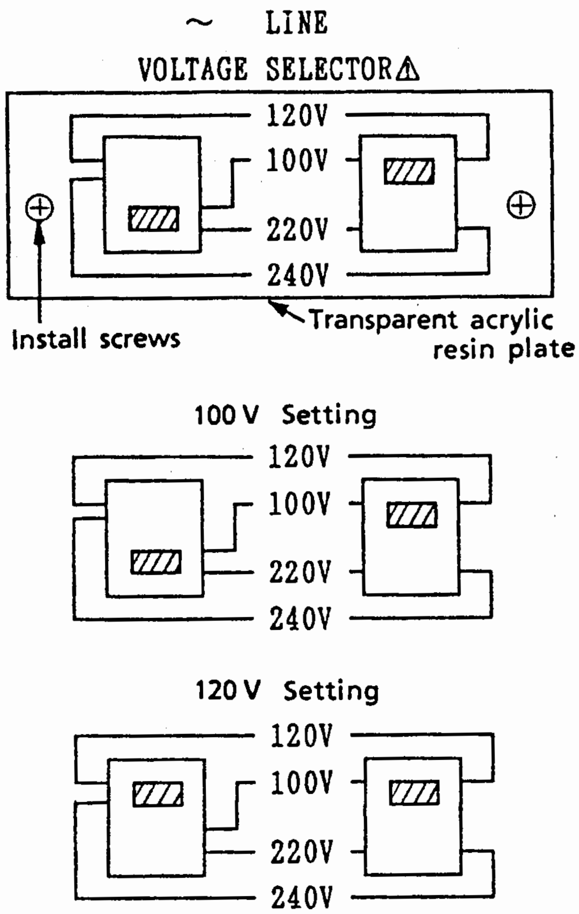
A power fuse with an appropriate capacity should be used according to the line voltage. If the voltage setting is changed, replace the fuse in the fuse holder with a proper one shown in Table 2-1. The AC voltage setting of the apparatus has been factory set at 100 V (standard setting).

NOTE

Before turning on the apparatus, be sure to check that the voltage setting of the AC line voltage selector on the rear panel agrees with the AC line voltage to be used, and also check that the power fuse is suited for the line voltage.

The power fuse is installed inside the AC line connector module on the rear panel of the apparatus. The power fuse replacement procedure is shown in Fig. 2-2.

Line Voltage Setting Procedure



A line voltage selector as shown in the left figure is provided on the rear panel of the apparatus. An appropriate line voltage setting should be set, performing the following steps.

(1) Set the power switch to OFF, and remove the power cord.

(2) Loosen off the transparent acrylic resin plate-retaining screws, and remove the acrylic resin plate.

(3) Shift each switch to the desired voltage position indicated by a line by inserting the blade of a small regular screwdriver into the groove in the switch (indicated by hatched lines).

In the left figure, the switches are set to the 100 V and 120 V settings.

(4) After setting the voltage, install the transparent acrylic resin plate again with the screws.

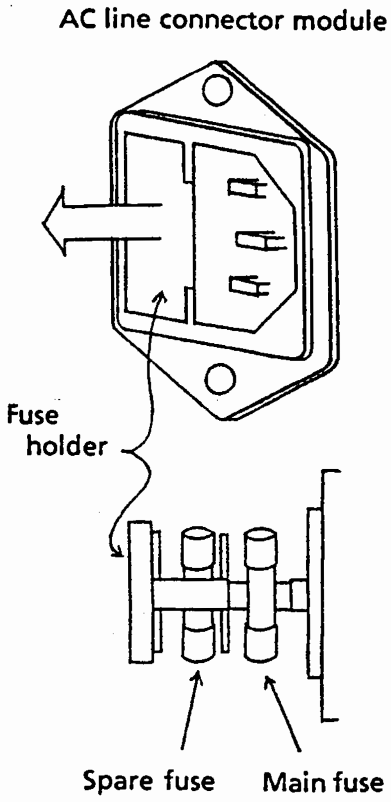
NOTE
The switches should be securely set upward or downward.

Fig. 2-1. Line Voltage Setting Procedure

Table 2-1. Power Fuse

AC Line Voltage		Power Fuse	Remarks
240 V	216 - 264 V	0.5A/250 V	Fast acting type (5.2 ϕ x 20 mm)
220 V	198 - 242 V		
120 V	108 - 132 V	1A/250 V	
100 V	90 - 110 V		

Power Fuse Replacement Procedure



An AC line connector module as shown in the left figure is provided on the rear panel of the apparatus. A power fuse, together with a spare fuse, is installed in the fuse holder in the AC line connector module. To replace the power fuse, perform the following steps.

(1) Turn off the power switch, and remove the power cord.
(2) Draw out the fuse holder, using a small regular screwdriver.
(3) Remove the blown main fuse on the back side, and install the spare fuse on the front side in place of the main fuse.
(4) Supply the fuse holder with a proper fuse shown in Table 2-1 as a spare.
(5) Securely reinstall the fuse holder to the original position, and connect the power cord.

> **NOTE**
> The fuse holder cannot be removed from the AC line connector module. Do not apply an excessive force to it.

Fig. 2-2. Power Fuse Replacement Procedure

2.4 POWER CORD

This apparatus is supplied with a removable 3-core power cord. On the ends of the power cord are provided plugs for connection with the apparatus and power outlet.

Connect the apparatus side plug to the AC line connector module on the rear panel of the apparatus, and the other plug to a grounded 3-pole power outlet. Use of the supplied 3-core power plug shorts the apparatus to ground via the ground line so that accidental electrical shocks from the AC line can be prevented.

> **NOTE**
> The shape of plug on the apparatus side may differ with supply voltages. The maximum rated voltage for the power cord (UL3P type) supplied as a standard accessory is 125 VAC. When a voltage higher than 125 VAC is to be used, use a power plug-attached power cord suited for the operating voltage.

REMARKS

If a 2-pole power outlet with no ground terminal is to be used, use the supplied 3-to-2 pole conversion adapter. When using the adapter, short its ground terminal or the FG (frame ground) terminal on the rear panel to ground for safety. (The conversion adapter is provided only when the UL3P power cord (100-120 VAC) is supplied.)

2.5 REPACKING

When repacking the apparatus, use the packing materials, if saved for later use. If they have not been saved, repack the apparatus exercising care as suggested below.

(1) Wrap the apparatus in strong paper like tarpaulin paper or vinyl sheeting. Protect all the protrusions with cushions against damage.

(2) Place the wrapped apparatus in a wooden or cardboard box which is larger by about 10 cm than the apparatus on all sides.

(3) Fill all open spaces between the apparatus and the box with polyurethane foam or any other suitable cushioning material. The apparatus may rattle and be damaged in transit, if cushioning is insufficient.

(4) Cover the wooden box and brace it up with steel bands. If a corrugated cardboard box is used, seal it with adhesive tape.

(5) Indicate the contents and shipping marks in a legible and durable way.

34

SECTION 3
OPERATION

3.1 INTRODUCTION

This section describes the functions of the panel controls of the apparatus, operating precautions, and typical measuring procedures. Be sure to observe the precautions given in this section so as to protect the operator and the apparatus against accidents.

3.2 DESCRIPTION OF THE CONTROLS

The names and functions of the panel controls are shown in Tables 3-1 and 3-2. As these controls will be referred to by the names given in this section throughout this manual, it is recommended that the operator familiarize himself with their names and functions before operation. The letters or symbols in brackets indicate markings provided on the front and rear panels of the apparatus.

3.3 OPERATING PRECAUTIONS

CAUTION

Improper operation of the apparatus not only provides incorrect measurements but also causes malfunction of or damage to the apparatus. To ensure proper operation, be sure to observe the precautions given in this section.

(1) Installation

① Place the apparatus on a stable flat table.
If the apparatus is set on a wobbling or inclined table, it may drop to the floor, causing damage to itself or hurting the operator.

② Do not install the apparatus in a place subject to direct sunlight.
The apparatus should be used indoors at a temperature of 5 to 35°C and at a relative humidity of 40% to 80%.
If the apparatus is exposed to direct sunlight, it may be excessively heated and damaged.

③ Allow at least 10 cm clearance between the rear panel and the wall or any other instrument.
The inside of the apparatus is cooled by the fan motor provided on the rear panel. If the rear panel is blocked or the apparatus is used in an ill-ventilated place, the inside of the apparatus will be excessive heated, causing damage to the apparatus. Also avoid using the apparatus in a place subject to excessive dust or corrosive gases.

④ Do not use the apparatus in a location near noise sources.
If the apparatus is used near a noise-generating device (fluorescent lamp, motor, television set, or large current switch), it may not make measurements correctly.

(2) Operating voltage and grounding

① Before connecting the power cord, check that the setting of AC line voltage selector agrees with the AC line voltage to be used. (To change the AC voltage setting, perform the steps described in Section 2.3.)

② As the power cord, use the 3-core cord supplied. Be sure to short the apparatus to ground. When using a 2-pole conversion adapter with no grounding terminal, be sure to short the grounding terminal of the conversion adapter or the FG terminal on the rear panel to ground.

WARNING

If you touch a metallic part of the apparatus while it is being used without being grounded, you may receive an electric shock or the sample may be destroyed. To avoid electric shock hazards, be sure to short the apparatus to ground before operation.

(3) Connection of a charged capacitor

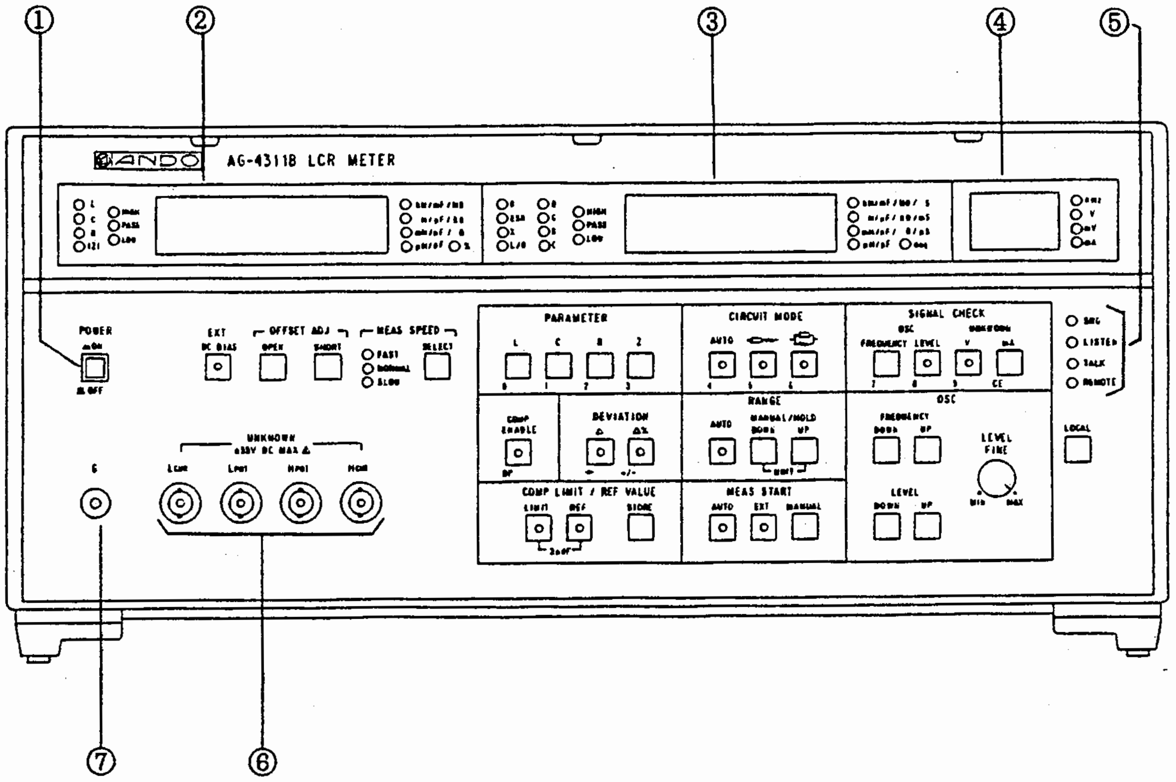
CAUTION

Before connecting a capacitor with the apparatus, be sure to discharge the capacitor.

This apparatus is provided with an input protective circuit which blocks the flow of excessive discharge current from a capacitor connected with the apparatus. However, if the apparatus is connected with a capacitor charged at a voltage higher than 35 V, the apparatus may be damaged. When a capacitor is to be measured, be sure to discharge it before connecting it with the apparatus.

36

Table 3-1. Front Panel



No.	Name and Marking	Function
①	Power switch [POWER] [▀ ON] [█ OFF]	• If this switch is pressed, it is set to ON to apply power to the apparatus. • If it is pressed again, its knob comes up and it is set to OFF.
②	MAIN DISPLAY	• The measured value of main parameter L, C, R, or |Z|, its unit, and the result of comparator judgment are displayed. • When a reference value or limit values are set, the reference value or main parameter upper and lower limits are displayed.
③	SUB DISPLAY	• The measured value of subparameter D, Q, ESR, G, X, B, L, C, or θ, its unit, and the result of comparator judgment are displayed. • When limit values are set, the subparameter upper and lower limits are displayed.
④	CHECK DISPLAY	• The measuring frequency, signal level range, signal voltage monitor value, or current monitor value is displayed. The item to be displayed should be selected by the SIGNAL CHECK key.
⑤	GP-IB status LEDs [SRQ] [LISTEN] [TALK] [REMOTE]	• The status of the apparatus in the GP-IB control mode is indicated.
⑥	Measurement terminals [UNKNOWN] [H_{CUR}] [H_{POT}] [L_{POT}] [L_{CUR}]	• These terminals are used for connecting the sample or measuring tools (test fixture, test lead, measurement cable, etc.). • These terminals consist of the following pairs: current terminal H_{CUR} and voltage terminal H_{POT} on the HIGH side, and current terminal L_{CUR} and voltage terminal L_{POT} on the LOW side.
⑦	Guard terminal [G]	• This terminal is used to guard the apparatus. It is connected to the chassis of the apparatus.

Table 3-1. Front Panel (Continued)

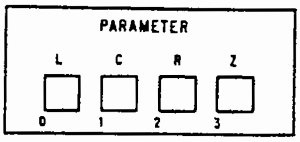
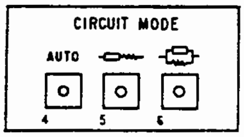
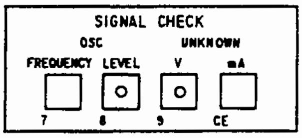
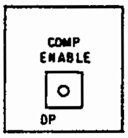
<table>
<tr><th>No.</th><th>Name and Marking</th><th>Function</th></tr>
<tr><td>8</td><td>PARAMETER keys
 </td><td>These keys are used for measurement parameter selection.
● The main parameter can be selected directly by these keys.
● The subparameter can be selected by repetitively pressing the same key.
<table>
<tr><th rowspan="2">PARAMETER key</th><th rowspan="2">MAIN DISPLAY</th><th colspan="2">SUB DISPLAY</th></tr>
<tr><th>-□-ΛΛΛ- Series equivalent circuit</th><th>Parallel equivalent circuit</th></tr>
<tr><td>L</td><td>L (Inductance)</td><td rowspan="2">D→Q→ESR</td><td rowspan="2">D→Q→G</td></tr>
<tr><td>C</td><td>C (Capacitance)</td></tr>
<tr><td>R</td><td>R (Resistance)</td><td>X→L</td><td>B→C</td></tr>
<tr><td>Z</td><td>|Z| (Absolute impedance value)</td><td>θ</td><td>θ</td></tr>
</table>
When a reference value or limit values are to be set (the LIMIT or REF key LED is on), these keys are used as 0-3 number keys.</td></tr>
<tr><td>9</td><td>CIRCUIT MODE keys
 </td><td>These keys are used for equivalent circuit mode selection.
● If AUTO is pressed, either the series (-□-ΛΛΛ-) or parallel ( ) equivalent circuit is automatically selected, according to the impedance of the sample.
When a reference value or limit values are to be set, these keys are used as 4-6 number keys.</td></tr>
<tr><td>10</td><td>SIGNAL CHECK keys
 </td><td>These keys are used to select the item to be shown on the check display.
<table>
<tr><th>SIGNAL CHECK</th><th>Display Item</th></tr>
<tr><td>FREQUENCY Key</td><td>Measuring frequency</td></tr>
<tr><td>LEVEL Key</td><td>Signal level range</td></tr>
<tr><td>V Key</td><td>Signal voltage (voltage across the sample)</td></tr>
<tr><td>mA Key</td><td>Signal current (current flowing through the sample)</td></tr>
</table>
When a reference value or limit values are to be set, these keys are used as 7-9 number keys and a CE (clear) key.</td></tr>
<tr><td>11</td><td>COMP ENABLE key
 </td><td>This key is used to turn on or off the comparator.
● Each time the key is pressed, either ON (LED ON) or OFF (LED OFF) is alternately selected.
● To perform comparator operation, it is necessary to set limit values in advance.
When a reference value or limit values are to be set, the key is used as a DP (decimal point) key.</td></tr>
</table>

Table 3-1. Front Panel (Continued)

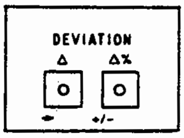
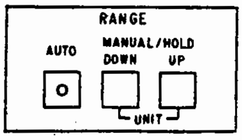
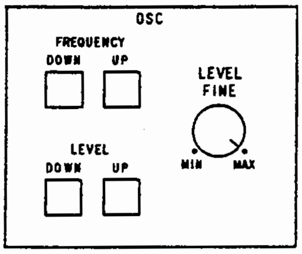
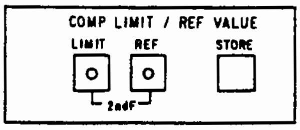
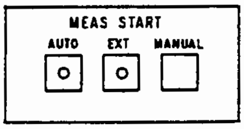
No.	Name and Marking	Function
12	DEVIATION keys  	These keys are used to specify deviation measurement (deviation display Δ or percent deviation display Δ%). ● Each time any of these keys is pressed, either ON (LED ON) or OFF (LED OFF) is alternately selected. ● To make a deviation measurement, it is necessary to set a reference value in advance. When a reference value or limit values are to be set, these keys are used as → (cursor movement) and +/- (polarity change) keys.
13	RANGE keys  	These keys are used for measurement range selection. ● In the AUTO mode, the optimum range is automatically selected, according to the impedance of the sample. ● If the UP or DOWN key is pressed after measurement in the AUTO mode, the measurement range selected during the measurement is held. ● If OF or UF is displayed during measurement in the MANUAL range, it means that the measured data is outside the set range. If such is the case, change the measurement range by using the UP or DOWN key, or select AUTO. When a reference value or limit values are set, these keys are used as unit select keys. ● When limit values are set, the unit at the cursor position (MAIN DISPLAY or SUB DISPLAY) can be selected.
14	FREQUENCY and LEVEL keys  	FREQUENCY UP/DOWN keys These keys are used for measuring frequency selection. ● Select the desired frequency by pressing the UP or DOWN key. DOWN 100 Hz ↕ ∫ UP 100kHz ● If the UP or DOWN key is pressed and held down, the frequency is continuously changed until the upper limit (100 kHz) or lower limit (100 Hz) is reached.
		LEVEL UP/DOWN keys These keys are used for signal level range selection. ● Select the desired level range from among four ranges 5 V, 1 V, 100 mV, and 10 mV, by pressing the UP or DOWN key. DOWN 10 mV ↕ 100 mV 1 V UP 5 V
		LEVEL FINE adjuster This adjuster is used to make a fine adjustment of the signal level. ● The signal level can be adjusted over the range of ×0.1 (MIN) to ×1 (MAX) in the range selected by the LEVEL UP or DOWN key.

Table 3-1. Front Panel (Continued)

<table>
<tr><th>No.</th><th>Name and Marking</th><th>Function</th></tr>
<tr><td>15</td><td>LIMIT/REF keys
 </td><td>These keys are used to set limit values (upper and lower limits) for comparator measurement or a reference value for deviation measurement.

If the LIMIT key is pressed, the key LED comes on, the limit setting mode is entered, and main parameter/subparameter upper and lower values can be set in order named.
If the REF key is pressed, the key LED comes on, the reference setting mode is entered, and a reference value can be set.

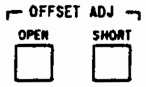
<table>
<tr><th>Key</th><th>CHECK DISPLAY</th><th>Setting</th><th>Entry</th></tr>
<tr><td>LIMIT</td><td>UPL</td><td>Upper limit</td><td>Enter the desired value by using the 0-9, DP, CE, →, and UNIT keys.</td></tr>
<tr><td></td><td>LoL</td><td>Lower limit</td><td></td></tr>
<tr><td>REF</td><td>—</td><td>Reference value</td><td></td></tr>
</table>

If the STORE key is pressed in the limit or reference setting mode, the entered value is set.
If the STORE key is pressed with neither the LIMIT or REF key LED on, the value shown on the main display is set as the reference.
</td></tr>
<tr><td>16</td><td>MEAS START keys
 </td><td>This key is used for measurement start mode selection.
<table>
<tr><th>MEAS START</th><th>Measurement Start</th></tr>
<tr><td>AUTO</td><td>Measurement is automatically repeated.</td></tr>
<tr><td>EXT</td><td>Measurement is started when an $\overline{\text{EXT}\cdot\text{MST}}$ signal is entered from the EXT CONTROL connector on the rear panel.</td></tr>
<tr><td>MANUAL</td><td>Measurement is started each time the key is pressed.</td></tr>
</table></td></tr>
<tr><td>17</td><td>LOCAL key
 </td><td>This key is used to change the GP-IB remote control mode to the local mode (operations by the panel keys).
<p>REMARKS</p>

When the apparatus is in the remote mode (the GP-IB status REMOTE LED is on), all keys other than the LOCAL key are inoperative.
In the LLO (local lockout) state, the local mode is not entered even if the LOCAL key is pressed.
</td></tr>
</table>

Table 3-1. Front Panel (Continued)

<table>
<tr><th>No.</th><th>Name and Marking</th><th>Function</th></tr>
<tr><td>18</td><td>EXT DC BIAS key
 </td><td>This key is used to turn on or off the DC bias function.
● Each time this key is pressed, either ON (LED ON) or OFF (LED OFF) is alternately selected.
● The ON position applies the voltage appearing at the rear panel EXT DC BIAS INPUT terminal to the sample.

CAUTION
The key operation should be performed when no voltage is applied to the rear panel EXT DC BIAS INPUT terminal. Otherwise, an excessively large current may flow into the sample or the internal circuitry of the apparatus may be destroyed.</td></tr>
<tr><td>19</td><td>Zero offset adjustment keys
 </td><td>These keys are used for zero offset adjustment.
● Pressing the SHORT key carries out short ADJ operation.
● Pressing the OPEN key carries out open ADJ operation.

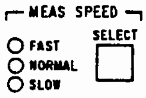
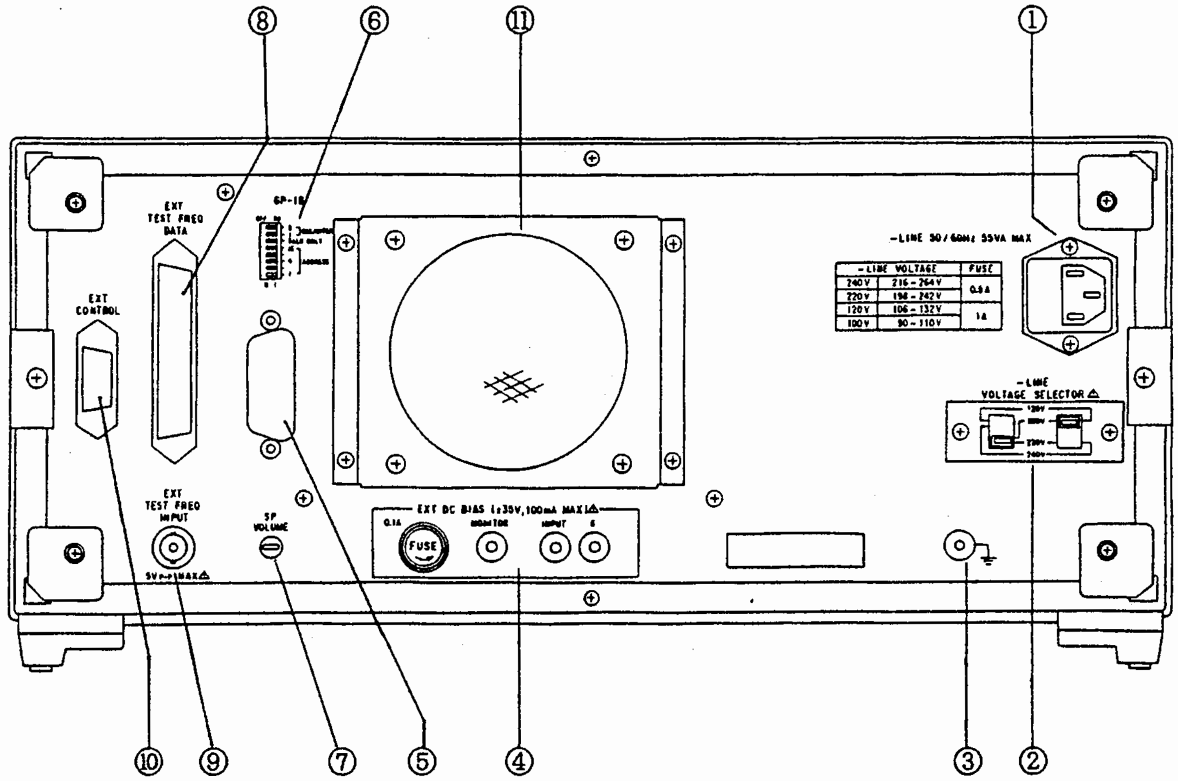
REMARKS
Zero offset adjustment should be made with the EXT DC BIAS key set to OFF. Otherwise, a proper correction value may not be obtained.</td></tr>
<tr><td>20</td><td>MEAS SPEED key
 </td><td>This key is used for measurement speed mode selection.
● The desired speed mode can be selected by repetitively pressing the SELECT key.
<table>
<tr><th>Measurement Speed</th><th>Measurement Mode</th></tr>
<tr><td>FAST</td><td>High-speed measurement</td></tr>
<tr><td>NORMAL</td><td>Normal measurement</td></tr>
<tr><td>SLOW</td><td>High-resolution measurement (ten measurements and their averaging)</td></tr>
</table>
</td></tr>
</table>

Table 3-2. Rear Panel



No.	Name and Marking	Function
①	AC line connector module [~ LINE 50/60 Hz]	• This connector is used for connecting the 3-core power cord. Power is taken from an AC power outlet. A power fuse is installed in this connector module.
②	Line voltage selector [~ LINE VOLTAGE SELECTOR]	• This line voltage selector is used to select the desired voltage from among 100, 120, 220, and 240 VAC.
③	FG terminal [⏚]	• A terminal connected with the frame ground of the apparatus. It is also connected with the signal ground inside the apparatus.
④	External DC bias input [EXT DC BIAS] [INPUT][G] terminals [MONITOR] terminal [FUSE][0.1 A]	• An external DC bias input terminal, monitor terminal, and fuse holder. To apply a DC bias to the sample, connect an external DC power source with the INPUT terminal and press the EXT DC BIAS key on the front panel. A voltage of up to ± 35 V and a current of up to 100 mA can be input from an external power source. A 0.1A fuse is installed in the fuse holder.
⑤	GP-IB connector [GP-IB]	• This GP-IB interface connector is used to connect the GP-IB cable for data transfer to or from another GP-IB device.
⑥	GP-IB address switch	• This switch is used for GP-IB mode selection, GP-IB address setting, and GP-IB output data delimiter setting.
⑦	Speaker volume control [SP VOLUME]	• A speaker sound volume control. Turning it fully counterclockwise minimizes the sound volume, and turning it fully clockwise maximizes the sound volume. It should be adjusted so as to obtain an appropriate sound volume.
⑧	External frequency data connector [EXT TEST FREQ DATA]	• This connector is used to specify in BCD code the frequency of a signal input to the external frequency input connector (⑨), when making measurement by an external frequency.

Table 3-2. Rear Panel (Continued)

No.	Name and Marking	Function
⑨	External frequency input connector [EXT TEST FREQ INPUT]	• This connector is used to input a square or sine wave whose frequency is 16 times higher than the measuring frequency, when making measurement by an external frequency. The maximum input level is 5 Vp-p.
⑩	External control connector [EXT CONTROL]	• An external control connector. An external measurement start input signal and comparison result output signals are connected.
⑪	Fan motor ventilating holes	• Ventilating holes for the internal cooling fan motor. At least 10 cm should be allowed between the rear panel and the wall or any other instrument.

43

3.4 BASIC OPERATING PROCEDURES

The basic procedures for measuring the sample are shown in Table 3-3. Perform the steps in the order of the numbers shown in the table.

Table 3-3. Basic Operating Procedures

<table>
<tr><th>No.</th><th>Step</th><th>Section to be Referred to</th></tr>
<tr><td>1</td><td>Power-on
(1) Press the power switch to set it to the ON position. The apparatus is then powered up.
(2) Check the result of the memory back-up check and self-test.
● On power-on, this apparatus automatically carries out a memory back-up check and self-test. Check that no error display is given.</td><td>3.21 BASIC INSPECTION AND MAINTENANCE</td></tr>
<tr><td>2</td><td>Connecting measuring tools (test fixture, test lead, etc.)
● Connect the test fixture or test lead to the measuring terminal of the apparatus.
● When using the AG-4911 Test Fixture, AG-4912 Test Lead, or any other accessory, connect it properly, following the instructions given in its instruction manual.
● If using a special tool, refer to Section 3.5.</td><td>3.5 CONNECTING THE SAMPLE</td></tr>
<tr><td>3</td><td>Measurement condition setting
(1) Select the measurement parameter by using the PARAMETER keys.
● Some of the subparameters (ESR/G, X/B, L/C) are automatically selected, according to the equivalent circuit mode.
Select the equivalent circuit mode by the CIRCUIT MODE key, if necessary.
<table>
<tr><th rowspan="2">PARAMETER key</th><th rowspan="2">MAIN DISPLAY</th><th colspan="2">SUB DISPLAY</th></tr>
<tr><th> (Series equivalent circuit)</th><th> (Parallel equivalent circuit)</th></tr>
<tr><td>L</td><td>L (Inductance)</td><td rowspan="2">D→Q→ESR</td><td rowspan="2">D→Q→G</td></tr>
<tr><td>C</td><td>C (Capacitance)</td></tr>
<tr><td>R</td><td>R (Resistance)</td><td>X→L</td><td>B→C</td></tr>
<tr><td>Z</td><td>|Z| (Absolute impedance value)</td><td>θ</td><td>θ</td></tr>
</table>
(2) Select the measuring frequency by using the FREQUENCY key.
(3) Select the signal level range by using the LEVEL key.
● The LEVEL FINE adjuster should be set to the MAX (rightmost) position.
(4) Set the measurement range to AUTO.
(5) Select the measurement speed mode by using the MEAS SPEED key.</td><td>3.8 MEASUREMENT PARAMETERS
3.10 MEASUREMENT SIGNAL SETTING AND MONITORING
3.11 MEASUREMENT RANGES
3.13 MEASUREMENT SPEED MODES</td></tr>
</table>

Table 3-3. Basic Operating Procedures (Continued)

No.	Step	Section to be Referred to
4	Zero offset adjustment (1) Make preparation for open ADJ. Disconnect the test fixture or test lead from the sample. • When using a special tool, connect the H_{CUR} and H_{POT} core conductors, and the L_{CUR} and L_{POT} core conductors on the sample side so that the sample may be disconnected. (2) Press OFFSET OPEN key to carry out open ADJ. • If the main display shows *OP-P*, it means that the open ADJ has been normally completed. (3) Make preparation for short ADJ. • Connect the shorting bar with the test fixture or test lead. • When using a special tool, connect the H_{CUR}, H_{POT}, L_{CUR}, and L_{POT} core conductors together. (4) Press the OFFSET ADJ SHORT key to carry out short ADJ. If the main display shows *SH-P*, it means that the short ADJ has been normally completed. **REMARKS** If an error display is given during zero offset adjustment, check the connections. If the connections are correct, it means that the residual parameter value is outside the correction range. In this case, the correction value is cleared and the measured value is displayed without compensating for the residual parameter value. **NOTE** The zero offset correction value is valid until power is disconnected. However, after replacing the test fixture or test lead, or after changing the signal level range or measurement speed mode, be sure to make zero offset adjustment (open/short ADJ) again, because the measurement condition differs from the previous one.	3.7 ZERO OFFSET ADJUSTMENT

45

Table 3-3. Basic Operating Procedures (Continued)

No.	Step	Section to be Referred to
5	Measurement	
	(1) Connect the sample with the test fixture or test lead.	
	(2) Set MEAS START to AUTO (repetitive measurement). • While the MEASURE LED (LED at the upper left of the MAIN DISPLAY digital display) is on, measurement is in progress. Immediately after a measurement ends, the MEASURE LED goes off and the measured value is displayed.	3.12 STARTING MEASUREMENT
	(3) Monitoring and fine adjustment of the signal level • To monitor the signal voltage at the sample end or signal current flowing through the sample, press the SIGNAL CHECK V key or mA key. • To change the signal voltage or signal current, slowly adjust the LEVEL FINE adjuster to the desired voltage or current value, while monitoring the check display.	3.10 MEASUREMENT SIGNAL SETTING AND MONITORING

Messages regarding measured data

Display	Meaning
OF (Over Frow) *UF* (Under Flow)	When the measurement range is AUTO: Not within the measurement limits. When the measurement range is MANUAL: Not within the measurement limits in the present measurement range. Change the measurement range to AUTO or an appropriate range.
CF (Change Function)	Improper measurement parameter setting. Change the measurement parameter.

46

3.5 CONNECTING THE SAMPLE

The UNKNOWN terminals for connecting the sample with the apparatus consist of four BNC connectors: H_{CUR}, H_{POT}, L_{POT}, and L_{CUR}. The H_{CUR} and L_{CUR} terminals are used to flow a signal current through the sample. A measurement signal is output from the H_{CUR} terminal. The H_{POT} and L_{POT} terminals are used to detect the signal voltage applied to the sample.

Fig. 3-1 shows how to connect the sample with the apparatus. As shown in the figure, the core conductors of the H_{CUR} and H_{POT} terminals on the HIGH side are connected to one end of the sample, and the core conductors of the L_{POT} and L_{CUR} terminals on the LOW side are connected to the other end of the sample. The outer conductors of these terminals are connected to the connection with the sample. In this arrangement, the measurement signal current flows from the core conductor of the H_{CUR} terminal through the sample to the core conductor of the L_{CUR} terminal. The signal current further flows from the outer conductor of the L_{CUR} terminal, passes through the cable, and returns to the outer conductor of the H_{CUR} terminal.

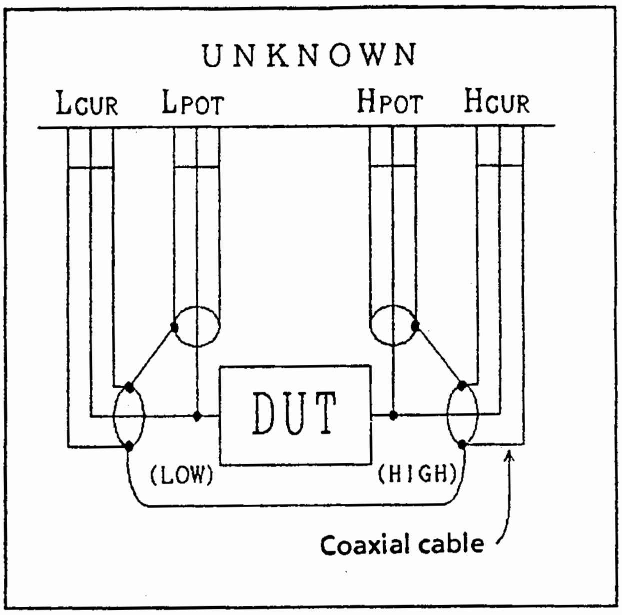


Fig. 3-1. 4-terminal Pair Connection

The signal current flowing through the core conductor of the L_{CUR} terminal is automatically controlled so that the signal voltage (detection voltage at the L_{POT} terminal) at one end (LOW side) of the sample may be close to zero. While such a balance is being maintained, the signal voltage between the H_{POT} and L_{POT} terminals (voltage across the sample) and the signal current flowing into the L_{CUR} terminal are detected internally to determine the impedance of the sample. With the connections shown in Fig. 3-1, the error due to the intercable inductance can be minimized and measurement can be made with high accuracy.

To make measurement using the four connectors in the above-described way requires a special test fixture and measurement cables. As accessories directly connectable with the measuring terminal of the apparatus, the AG-4911 Test Fixture, AG-4912 Test Lead, and AG-4917 Test Lead are available. For detailed information on how to use these accessories, refer to the instruction manuals for them.

REMARKS

To connect the sample with a special jigs, use coaxial cables as shown in Fig. 3-2.

47

Table 3-4. Accessories

Accessory Name	Description
AG-4911 Test Fixture	Lead-attached parts (radial type/axial type) can be easily connected.
AG-4912 Test Lead	Measuring lead with a large-sized alligator clip. Operating condition: C: 1000 pF or more, L: 100 μH or more, Z: 1 Ω to 1 MΩ
AG-4917 Test Lead	Three-terminal type measuring lead with a small-sized alligator clip. Suited for measurement of comparatively high impedance samples. Operating condition: C: 1000 pF or more, L: 100 μH or more, Z: 1 Ω to 1 MΩ

⚠CAUTION

Before connecting a capacitor with the apparatus, be sure to discharge the capacitor.

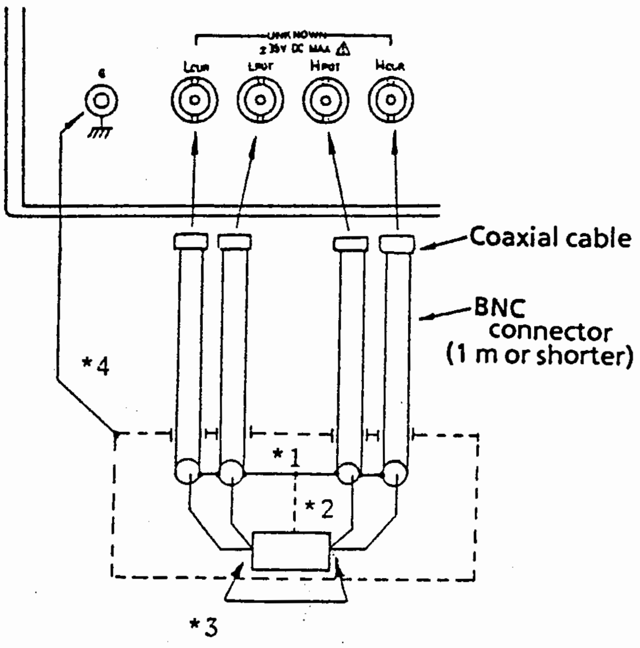
This apparatus is provided with an input protective circuit which blocks the flow of excessive discharge current from a capacitor connected with the apparatus. However, if the apparatus is connected with a capacitor charged at a voltage higher than 35 V, the apparatus may be damaged. When a capacitor is to be measured, be sure to discharge it before connecting it with the apparatus.

NOTE

Even if once discharged, a capacitor may return to a slightly charged state with the lapse of time, because of the charge absorption effect.

If a charged capacitor is connected with the apparatus, it will be discharged through a direct current resistance (about 153 Ω). Since this discharge current may affect the measurement, the measurement should be started after the lapse of time at least ten times longer than the time constant (C·R). This precaution should be observed especially when a large-capacity capacitor is to be measured.

48



Coaxial cable: RG-58A/U, 3C-2V, 5D-XV, or similar one (1 m or shorter)

BNC connector: BNC-GP-58U, BNC-GP-3C, BNC-GP-2.5D, or similar one

*1 Connect the outer conductor of the cables to a point near the sample.

*2 If the sample is provided with a guard terminal, connect it to the outer conductors of the cables.

*3 Connect the core conductors of the cables to the corresponding terminals of the sample. The core conductors should be as short as possible.

*4 If an overall shield cover is provided, connect it to the G terminal.

Fig. 3-2. Connection of Special Measuring Jigs

3.6 MEASURING GROUNDED SAMPLE

If a sample has a terminal (other than a guard terminal) shorted to ground, theoretically, it cannot be connected to the apparatus in a 4-terminal pair arrangement, so that the apparatus cannot make measurement on such a sample.

In the actual circuit, there exists some impedance between the ground to which the apparatus is connected (front panel G terminal, rear panel FG terminal, power cord grounding terminal) and the sample, and if the ground impedance of the sample is low, a bridge balance may not be attained or the displayed value may be unstable. When one end of the sample connected with the HIGH (H_{CUR} or H_{POT}) terminal of the apparatus is grounded, the measuring signal is grounded without being supplied to the sample.

When one end of the sample connected with the LOW (L_{POT} or L_{CUR}) terminal is grounded, the signal current flowing into the sample cannot be detected by the apparatus. Further, in this case, the bridge may not be balanced because of the effect of grounding noise or its operation may be unstable because of the entry of noise current.

For correct measurement, it is necessary to sufficiently insulate the grounding point of the apparatus from the measuring terminal of the sample, and assure a sufficiently high grounding impedance.

Examples in which measurement cannot be made correctly:

- Sample shorted to ground or the grounding point of the apparatus
- Sample to which power is directly supplied from a device other than the apparatus
- Large-sized sample whose grounding impedance relative to the ground or grounding point is extremely low

NOTE

When measurement is made on a grounded sample, the performance of the apparatus is affected by the impedance of ground, for example, the measuring range is restricted or the displayed value is unstable, so that the measurement accuracy is not specified for such measurement.

3.7 ZERO OFFSET ADJUSTMENT

The test fixture, test lead, and other measuring jigs to be connected with the apparatus have specific amounts of stray capacitance, residual inductance, and residual resistance. The zero offset function is used to measure these residual parameters in advance and automatically remove them from the measured data to minimize the error due to the residual parameters.

Offset adjustment can be made in the open ADJ mode and short ADJ mode. In the open ADJ mode, the stray capacitance and residual conductance of the measuring jigs are measured, whereas, in the short ADJ mode, their residual inductance and residual resistance are measured; the measured values are stored as the correction values.

The ranges of residual parameter values of the measuring jigs that can be covered by offset adjustment, and the measuring frequencies at which offset adjustment can be made are listed in Table 3-5. The apparatus measures the residual parameters at the frequencies shown in Table 3-5. The residual parameter values to correct the parameter values measured at different frequencies are obtained by using the linear interpolation (approximation by a line over the measuring frequency range).

NOTE

If the residual parameter values of the measuring jigs are too large, or if the measuring jigs have a resonance characteristic, the difference between the total residual parameter value calculated by approximation and the real total residual parameter value increases, causing a measurement error. Make sure that the residual parameter values are within the allowable ranges shown in Table 3-5.

Table 3-5. Residual Parameter Value Ranges and Measuring Frequencies Allowable for Offset Adjustment

	Residual Parameter Value		Measuring Frequencies (Hz) at which offset adjustment is made
	Allowable Range	Limit Value	
Capacitance (C)	20 pF or less	100 pF	100, 150, 200, 401, 1k, 2k, 4.01k, 10k, 20.2k, 40.3k, 78.1k, 100k (These frequencies are nominal values.)
Conductance (G)	5 μS or less	100 μS	
Resistance (R)	0.5 Ω or less	20 Ω	
Inductance (L)	2 μH or less	200 μH	

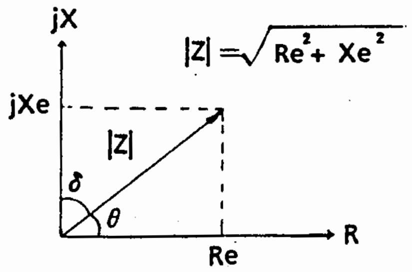
50

3.8 MEASUREMENT PARAMETERS

3.8.1 Description of the Measurement Parameters

(1) |Z|, θ

|Z| and θ represent the most fundamental parameters of a sample against an AC signal applied between its two terminals; the absolute value and phase angle of impedance.



Z : Impedance (Z = Re + jXe)
Re: Effective resistance
Xe: Reactance
$Re = |Z| \cos\theta$
$Xe = |Z| \sin\theta$
Dissipation factor (D) = $\frac{Re}{Xe} = \tan\delta$

Fig. 3-3. Vector Representation of Impedance

As shown in Fig. 3-3, the impedance of a sample can be represented by a vector on a complex plane. When the values of effective resistance Re are laid off along the real axis, and the values of reactance Xe along the imaginary axis, impedance Z is expressed as follows.

$$Z = Re + jXe$$

The values of |Z|, and θ of an ideal coil, an ideal capacitor, and an ideal resistor are listed in Table 3-6. In reality, however, a sample has its residual resistance, residual inductance, and stray capacitance, and phase angle θ changes depending on the frequency.

The LCR meter measures the two parameters, |Z| and θ, and calculates the values of other parameters based on a given equivalent circuit.

Table 3-6. |Z| and θ of Ideal L, C, and R

	|Z| (Ω)	θ (deg)
Coil having inductance L (H)	2πfL	+ 90°
Capacitor having capacitance C (F)	1/2πfC	− 90°
Resistor having resistance R (Ω)	R	0°

* f: Measuring frequency (Hz)

(2) L, C

L and C represent inductance and capacitance, respectively. Their values are calculated differently according to whether the loss resistance is connected in series or in parallel in the equivalent circuit. When the dissipation factor is small, the value of L or C is not affected by the choice of the equivalent circuit. When D is great ($D > 0.03$), there will be a difference between Ls or Cs in the series equivalent circuit and Lp or Cp in the parallel equivalent circuit.

REMARKS

The measurement of L or C may be displayed as a negative value, since L and C are represented as vectors with opposite polarities on the imaginary axis. In terms of reactance, L and C have the following relationship.

$$X_C = -\frac{1}{\omega C} \qquad \omega = 2\pi f$$

$X_L = \omega L$ f: Measuring frequency

(3) R

R represents the effective resistance of a sample against AC. Its value is calculated differently according to whether the reactance component (quantity called the C component or L component) is connected in series (R_S) or in parallel (Rp) in the equivalent circuit.

When the reactance component is great, the L or C parameter is used for measurement.

(4) D, Q

D represents the dissipation factor which may also be referred to as tan δ (dielectric loss tangent) for a capacitor. A capacitor with a smaller D is regarded as being of higher performance. In terms of tan δ, the dissipation factor is expressed as a power of 10 or a percentage.

$$D = 0.01 \rightarrow \tan\delta = 10^{-2} \text{ (or 1\%)}$$

Q is the value of 1/D. A greater Q represents higher performance. It is often referred to for coils. Resistors are required to have a greater D and a smaller Q.

(5) ESR (equivalent series resistance)

ESR represents the series resistance component (ESR or R_S) of a series equivalent circuit. Its value is used, for example, when estimating the heat generation and loss caused by an alternate current flowing through an electrolytic capacitor.

52

(6) G (conductance)

G represents the inverse-number value G ($G = 1/Rp$) of the parallel resistance component (Rp) of a parallel equivalent circuit. It is useful in estimating the loss caused in a capacitor to be used under high voltage.

(7) X, L

The values of these parameters can be indicated during resistance measurement (the main parameter: R) being made by use of a series equivalent circuit; L represents the residual inductance, and X represents the reactance equal to $2\pi fL$. They are used, for example, when estimating the AC characteristics of a wire-wound resistor.

(8) B, C

The values of these parameters can be indicated during resistance measurement being made by use of a parallel equivalent circuit; C represents the parallel floating capacitance of the resistance component, and B represents the susceptance equal to $2\pi fC$. They are used, for example, when estimating the AC characteristics of a high-resistance element.

3.8.2 Measurement Parameter Setting and Selection

Measurement parameter setting is performed by using the PARAMETER L, C, R, and Z keys. The main parameter displayed on the main display is determined by these keys. The subparameter shown on the sub display can be selected by pressing the same key again.

The main parameter should be selected according to the properties and characteristics of the sample. Mainly, C should be selected for capacitor measurement, L for coil or transformer measurement, and R for resistance measurement. For composite elements and communication transformers, Z may sometimes be selected. When the properties of the sample is unknown, $|Z|$ - θ measurement should be once made, and then the main parameter should be selected based on the values of $|Z|$ and θ. In general, if the value of θ is positive (inductive) and within +45 and +90°, L should be selected. If it is negative (capacitive) and within -45 and -90°, C should be selected. For a sample whose $|Z|$ or θ value varies with the measuring frequency, it should be evaluated based on $|Z|$ - θ measurement.

Examples of uses of the measurement parameters are shown below.

(1) Low-loss capacitor measurement .... C-D or C-G

In a measurement of a low-loss ($D < 10^{-3}$) capacitor, the value of capacitance is virtually the same regardless of whether the equivalent circuit is series or parallel. In general, when the impedance is high (the value of C is small), the parallel equivalent circuit (Cp-D or Cp-G measurement) should be selected. When the impedance is low (the value of C is great), the series equivalent circuit (Cs-D measurement) should be selected.

53

REMARKS

If the loss caused in a sample is very small, the value of its D may be indicated as being negative (within the allowable measuring error range).

If a low-loss sample whose dissipation factor is already known or a sample whose dissipation factor is so small as to be negligible is available as the reference sample, the unknown dissipation factor of another low-loss sample can be calculated highly accurately using the following formula:

$D \doteqdot D_2 - (D_1 - D_S)$ where D = real dissipation factor of the sample

D_2 = dissipation factor of the sample measured by the apparatus

D_1 = dissipation factor of the reference sample, whose real dissipation factor is known, measured by the apparatus

D_S = real dissipation factor of the reference sample (If a sample whose dissipation factor is negligible is used as the reference sample, assign 0 as D_S.)

(2) Large-capacitance capacitor measurement ..... C-D or C-ESR

In a measurement of a low-impedance capacitor such as an electrolytic capacitor, the series equivalent circuit is used to evaluate the series loss caused by the electrode and lead resistances. (Cs-D or Cs-ESR measurement)

By measuring the value of ESR, the heat generation in the capacitor can be easily calculated based on the value of the operating current.

(3) Coil/transformer measurement .... L-Q or L-ESR

Generally, the loss occurring in a coil or transformer is greater than that occurring in a capacitor (its D is greater and its Q is smaller). Select either the parallel equivalent circuit or series equivalent circuit, depending on the actual circuit conditions under which the coil or transformer is to be used, and clearly note the equivalent circuit (Ls or Lp) used for evaluation. Generally, the value of ESR differs from that of the series winding resistance due the properties of the magnetic substance and the manner in which the wire is wound. It may also vary with the measuring frequency or measuring signal level.

(4) High-resistance element measurement .... R-C or R-B

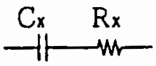
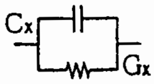
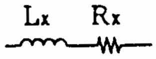
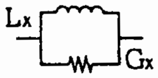
For a high-resistance element, the parallel equivalent circuit is selected and Rp-C or Rp-B measurement is made to evaluate the effect of the stray capacitance. The value of the current to flow through the stray capacitance can be easily calculated as "(applied voltage) x B".

(5) Low-resistance element measurement .... R-L or R-X

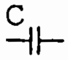
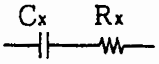
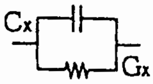
For a low-resistance element, the series equivalent circuit is selected and Rs-L or Rs-X measurement is made to evaluate the effect of the resistor or lead wire inductance.

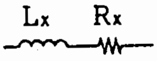
54

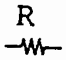
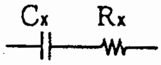
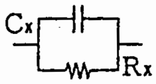
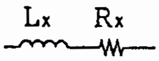
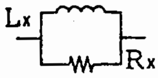
Table 3-7. Parameter Calculation Formulas

Z				
$\lvert Z\rvert$	$\sqrt{\frac{1}{\omega^2 Cx^2}+Rx^2}$	$\frac{1}{\sqrt{\omega^2 Cx^2+Gx^2}}$	$\sqrt{\omega^2 Lx^2+Rx^2}$	$\frac{\omega Lx}{\sqrt{1+\omega^2 Lx^2 Gx^2}}$
θ	$-\tan^{-1}\left(\frac{1}{\omega Cx Rx}\right)$	$-\tan^{-1}\left(\frac{\omega Cx}{Gx}\right)$	$\tan^{-1}\left(\frac{\omega Lx}{Rx}\right)$	$\tan^{-1}\left(\frac{1}{\omega Lx Gx}\right)$

$$Z=R+jX=|Z|(\cos\theta+j\sin\theta),\quad |Z|=\sqrt{R^2+X^2}\qquad \omega=2\pi f$$

	MAIN DISPLAY		SUB DISPLAY				
	C	$\lvert Z\rvert$	D	Q	ESR	G	θ
	Cx	$\sqrt{\frac{1}{\omega^2 Cx^2}+Rx^2}$	$\omega Cx Rx$	$\frac{1}{\omega Cx Rx}$	Rx	—	$-\tan^{-1}\left(\frac{1}{\omega Cx Rx}\right)$
	Cx	$\frac{1}{\sqrt{\omega^2 Cx^2+Gx^2}}$	$\frac{Gx}{\omega Cx}$	$\frac{\omega Cx}{Gx}$	—	Gx	$-\tan^{-1}\left(\frac{\omega Cx}{Gx}\right)$

	MAIN DISPLAY		SUB DISPLAY				
	L	$\lvert Z\rvert$	D	Q	ESR	G	θ
	Lx	$\sqrt{\omega^2 Lx^2+Rx^2}$	$\frac{Rx}{\omega Lx}$	$\frac{\omega Lx}{Rx}$	Rx	—	$\tan^{-1}\left(\frac{\omega Lx}{Rx}\right)$
	Lx	$\frac{\omega Lx}{\sqrt{1+\omega^2 Lx^2 Gx^2}}$	$\omega Lx Gx$	$\frac{1}{\omega Lx Gx}$	—	Gx	$\tan^{-1}\left(\frac{1}{\omega Lx Gx}\right)$

	MAIN DISPLAY		SUB DISPLAY				
	R	$\lvert Z\rvert$	X	B	L	C	θ
	Rx	$\sqrt{Rx^2+\frac{1}{\omega^2 Cx^2}}$	$-\frac{1}{\omega Cx}$	—	—	—	$-\tan^{-1}\left(\frac{1}{\omega Cx Rx}\right)$
	Rx	$\frac{Rx}{\sqrt{1+\omega^2 Cx^2 Rx^2}}$	—	ωCx	—	Cx	$-\tan^{-1}(\omega Cx Rx)$
	Rx	$\sqrt{\omega^2 Lx^2+Rx^2}$	ωLx	—	Lx	—	$\tan^{-1}\left(\frac{\omega Lx}{Rx}\right)$
	Rx	$\frac{\omega Lx Rx}{\sqrt{Rx^2+\omega^2 Lx^2}}$	—	$-\frac{1}{\omega Lx}$	—	—	$\tan^{-1}\left(\frac{Rx}{\omega Lx}\right)$

(6) Transformer impedance measurement .... $|Z|-\theta$

The impedance of a communication transformer can be measured on the primary winding by terminating the secondary winding in a specified value of resistance. The frequency characteristic can also be easily measured by changing the measuring frequency.

3.8.3 Parameter Calculation Formulas

The parameter calculation formulas are listed in Table 3-7.

3.9 EQUIVALENT CIRCUITS

3.9.1 Equivalent Circuit Expressions

A sample can be represented as impedance Z or admittance Y which is the inverse of the impedance. Z and Y are expressed as follows:

$Z = R + jX$ where R = effective resistance X = reactance

$Y = G + jB$ where G = conductance B = susceptance

Each equivalent circuit is expressed using the impedance and admittance as shown in Fig. 3-4. The real-number term and the imaginary-number term of each expression represent the loss resistance elements (R and G) and reactance elements (X and B), respectively.

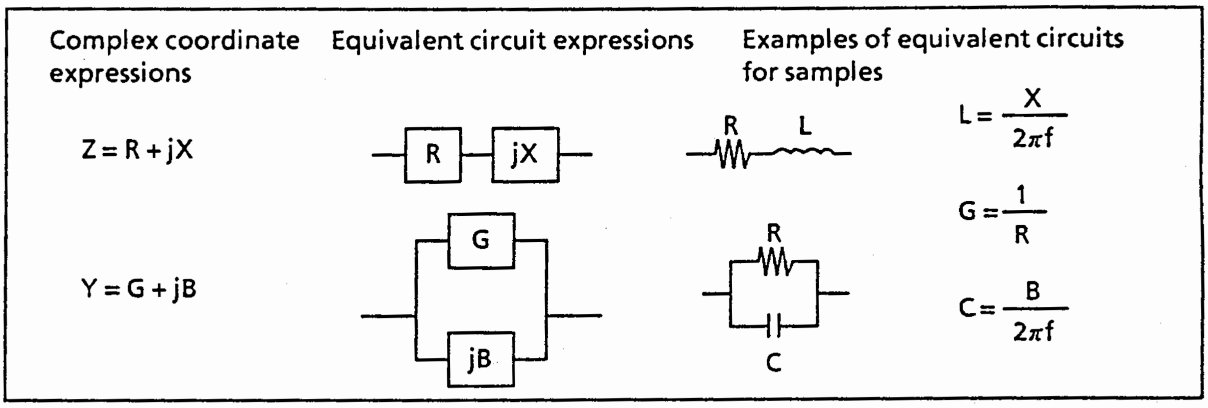


Fig. 3-4. Equivalent Circuit Expressions

The impedance and admittance have significance only when they are related to a measuring frequency. For example, reactance X of a coil is proportional to the measuring frequency, whereas its susceptance B is inversely proportional to the measuring frequency. Therefore, they are not always appropriate as parameters to evaluate a sample. Depending on the case, therefore, they may be converted into the inductance and capacitance for a specified measuring frequency. Dissipation factor D which is often used in measurement of a capacitor can be obtained from the following expression:

$$D = \frac{R}{X} = \frac{G}{B}$$

The equivalent circuit expression to be used for actual measurement is to be determined by taking into account the specification to be applied to the sample, the properties of the sample, the purposes for which the measured values are to be used, and other conditions. This apparatus is capable of making measurement using any equivalent circuit specified, calculating parameter values, and outputting the values to the displays.

3.9.2 Equivalent Circuit Selection

A sample can be represented by a circuit consisting of loss resistance elements (R and G) and reactance elements (L, C, X, and B) connected in series () or parallel (), as shown by the equivalent circuit mode markings (CIRCUIT MODE) on the panel. The equivalent circuit with such elements connected in series or parallel is referred to as the series or parallel equivalent circuit. If the same measuring frequency is used, the values of such elements can be correctly measured whether the series equivalent circuit is used or the parallel equivalent circuit is used. As shown in Table 3-8, the values of elements of an equivalent circuit can be related to those of another equivalent circuit using dissipation factor D which has no bearing on the equivalent circuits.

Generally, the value of capacitance of an electrolytic capacitor measured using a series equivalent circuit differs from that measured using a parallel equivalent circuit. The difference is larger, if the dissipation factor of the sample is larger.

For a no-loss capacitor whose dissipation factor D is 0 ($Rs = 0$, $Rp = \infty$), the value of capacitance Cs of its series equivalent circuit is equal to that of capacitance Cp of its parallel equivalent circuit. If the values of D and Cp of a capacitor are 0.1 and 1000 pF respectively, it is equivalent to another capacitor whose Cs is 1010 pF with the dissipation factor being the same between the two. Where D is 0.03 or smaller, such differences are not larger than 1/1000, that is, different types of equivalent circuits causes virtually no difference in the parameter values.

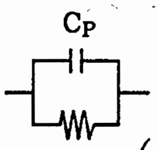
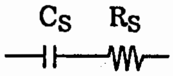
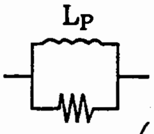
To correctly evaluate a sample, it is necessary to use a circuit matching the specifications and conditions to be applied to the sample or an equivalent circuit precisely representing the sample.

Generally, for high-impedance samples like ceramic and plastic film capacitors, parallel equivalent circuits are used for measurement; for, the losses caused in them are considered mainly attributable to parallel resistance.

For low-impedance samples like electrolytic capacitors in which the losses are largely attributable to series loss components like the electrode resistance and lead resistance, series equivalent circuits are used for measurement.

If the CIRCUIT MODE is set to AUTO, the apparatus automatically selects the parallel equivalent circuit for a sample whose impedance is about 1.8 kΩ or more, or the series equivalent circuit for a sample whose impedance is less than 1.8 kΩ.

Table 3-8. Equivalent Circuits

Measurement Item	Equivalent Circuit	Impedance	Dissipation factor	Conversion Expression
C	 $R_P=\left(\frac{1}{G}\right)$	$Z=\frac{R_P}{1+j\omega C_P R_P}$	$D=\frac{1}{\omega C_P R_P}$	$C_S=(1+D^2)C_P$ $R_S=\frac{D^2}{1+D^2}R_P$
		$Z=R_S+\frac{1}{j\omega C_P R_P}$	$D=\omega C_S R_S$	$C_P=\frac{1}{1+D^2}C_S$ $R_P=\frac{1+D^2}{D^2}R_S$ $\left(G=\frac{D^2}{1+D^2}\cdot\frac{1}{R_S}\right)$
L	 $R_P=\left(\frac{1}{G}\right)$	$Z=\frac{j\omega L_P R_P}{R_P+j\omega L_P}$	$D=\frac{\omega L_P}{R_P}=\frac{1}{Q}$	$L_S=\frac{1}{1+D^2}L_P$ $R_S=\frac{D^2}{1+D^2}R_P$
		$Z=R_S+j\omega L_S$	$D=\frac{R_S}{\omega L_S}=\frac{1}{Q}$	$L_P=(1+D^2)L_S$ $R_P=\frac{1+D^2}{D^2}R_S$ $\left(G=\frac{D^2}{1+D^2}\cdot\frac{1}{R_S}\right)$

* $\omega=2\pi f$ f = measuring frequency (Hz)

58

3.10 SETTING AND MONITORING OF MEASURING SIGNAL

To maintain the reliability of measurement, each sample must be measured under the conditions closely resembling the actual operating conditions for the sample. To meet such requirements, this apparatus offers 31 measuring frequencies and such a wide range of measuring signal level as 1 mV to 5 V. These features of the apparatus are very important for samples which are sensitive to measuring conditions; such as semiconductor elements, and coils and transformers having magnetic cores.

The measuring frequency and measuring signal level can be set using the FREQUENCY and LEVEL keys under OSC and the LEVEL FINE adjuster on the front panel.

To set a desired measuring frequency, use the FREQUENCY UP and DOWN keys. If either key is successively pressed, the frequency is changed successively with the check display indicating the updated frequency every time the key is pressed.

To set the measuring signal level, use the LEVEL UP and DOWN keys, and the LEVEL FINE adjuster. Any one of the four ranges, 5 V, 1 V, 100 mV, and 10 mVrms ranges, can be selected using either the UP or DOWN key. Each time the key is pressed, the selected level range is shown on the check display. The measuring signal level in the selected level range can be finely adjusted using the LEVEL FINE adjuster in the range of × 1 to × 0.1.

The actual level of the signal applied to the sample can be monitored by pressing the UNKNOWN V key under SIGNAL CHECK. Similarly, the signal current flowing through the sample can be monitored by pressing the UNKNOWN mA key. (No monitoring can be made if all four UNKNOWN terminals are open.)

The oscillator output impedance (output impedance of the H_{CUR} terminal) of this apparatus has been designed to be about 50 Ω, and the four level range values are nominal values for a state with the LEVEL FINE adjuster placed at MAX without any sample connected to the apparatus. When measurement is made on a low-impedance sample like a coil, the signal voltage actually applied to the sample may be lower than the level range value.

To finely adjust the signal voltage or current actually applied to or flowing through the sample, press the UNKNOWN V key or mA key under SIGNAL CHECK and, while observing the check display, adjust the LEVEL FINE adjuster.

3.11 MEASURING RANGE

If the RANGE is set to AUTO, the apparatus automatically selects the range suitable for the sample. If the MANUAL UP or DOWN key is pressed during measurement in the AUTO mode, the current measuring range is fixed and the MANUAL mode is entered.

In the MANUAL mode, the measuring range is stepped up or down every time the UP or DOWN key is pressed. If an unallowable range is set, *OF* (overflow) or *UF* (underflow) is displayed.

The RANGE should be normally set to AUTO. In the AUTO mode, it takes some time for the apparatus to select the range suitable for the sample. When measuring samples whose approximate data are known one after another, the MANUAL mode should be selected to shorten the measurement time.

REMARKS

If the RANGE UP or DOWN key is pressed, the range code is shown on the check display for a short period of time. After measurement in the AUTO mode, the range in which the measurement was made can be checked by pressing the UP or DOWN key.

Display example: In the case of range code R11, *r 11* is displayed.

(When the AUTO key is pressed, *r 00* is displayed.)

For the relationship between the range codes and measuring ranges, refer to the accuracy table in paragraph 11 in Table 1-1 Specifications.

3.12 STARTING MEASUREMENT

Measurement can be started automatically, manually, or by the use of an external signal. If the MEAS START AUTO key is pressed, the AUTO mode is entered and measurement is automatically repeated according to the internal timing. If the MANUAL key is pressed during measurement in the AUTO mode, the measurement is discontinued and the most recently measured values are kept on the displays. After that, measurement is executed every time the MANUAL key is pressed.

If the EXT key is pressed, the external start mode is entered. In the external start mode, measurement is made every time a trigger signal is input to the EXT CONTROL connector on the rear panel.

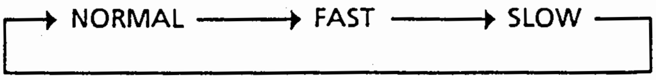
REMARKS

For information on the external trigger signal, refer to the description of the external control interface function in Table 3-13.

60

3.13 MEASUREMENT SPEED MODES

Each time the MEAS SPEED SELECT key is pressed, the measurement speed is changed as shown below.



The measurement speed has an effect on the resolution and accuracy of measured data. Select an appropriate measurement speed, according to the purpose of the measurement.

NORMAL: Standard measurement mode. The maximum number of measurement display digits is 4 1/2 (19999 counts). The cycle period in AUTO measurement is about 250 to 350 ms.

FAST: High-speed measurement mode. Since the time for integration by the integrating A/D converter is reduced to speed up measurement, the measurement accuracy is lower than that in the NORMAL mode. The maximum number of measurement display digits is 4 (4999 counts). The cycle period in AUTO measurement is about 150 to 250 ms.

SLOW: High-resolution measurement mode. Measurements are made ten times in the NORMAL mode, the measured values are averaged, and the average value is displayed. Although the accuracy is not improved, the display variation is reduced to about 1/3 to 1/4 and the number of display digits is greater by one than that in the NORMAL mode. The maximum number of display digits is 5 1/2 (199999 counts). The cycle period in AUTO measurement is about nine times longer (about 2 to 3 sec) than that in the NORMAL mode.

REMARKS

The measurement accuracy and the number of display digits are affected by the measuring range, measuring frequency, signal level range, and measured data. For details, refer to Table 1-1 Specifications.

3.14 DEVIATION MEASUREMENT

3.14.1 Deviation Value Indication, and Deviation Percentage Indication

Deviation measurement can be made for parameters L, C, R, and |Z|. Deviation measurement is useful in measuring small changes in the value of a specified parameter or deviation of the parameter value from a specified value, or for part quality inspection. Deviation measurement can be specified by pressing the △ key or △% key under DEVIATION; pressing the △ key causes the measured deviation value to be indicated, and pressing the △% key causes the measured deviation percentage to be indicated. Deviation measurement requires a reference value to be set beforehand; if deviation measurement is specified without any reference value set, an error indication is displayed.

$$\text{Value indicated in } \triangle \text{ mode} = (\text{measured value}) - (\text{reference value})$$

$$\text{Value indicated in } \triangle\ \%\text{ mode} = \frac{(\text{measured value}) - (\text{reference value})}{(\text{reference value})} \times 100 \ \text{(Unit: percent)}$$

Table 3-9. Reference Value Range

Parameter	Allowable Reference Value Range
C	0 - 9999.9 mF
L	0 - 99.999 kH
R, |Z|	0 - 99.999 MΩ

3.14.2 Deviation Reference Value Setting

A deviation measurement reference value can be set for each of main parameters L, C, R, and |Z|. Either a measured value shown on the main display or an arbitrary numerical value can be set as the reference value by keying-in operation.

(1) Setting arbitrary numeric value as reference value

① Select the measurement parameter for the reference value to be set, using the PARAMETER key.

② Press the REF key. Then, the key LED comes on and the reference value setting mode is entered. The previously set reference value (or --- if no reference value has been set) is shown on the main display.

③ Set the reference value using the 0-9, DP (decimal point), CE (clear), → (cursor movement), and UNIT (unit selection) UP and DOWN keys.

REMARKS

The → key is used to move the cursor (blinking display). If no setting is set, the cursor will not move.

62

④ Press the STORE key to store the set value as the reference value. If the value is correctly stored, the REF key LED goes off. If an error display is given and the REF key LED remains on, the setting is outside the allowable reference value range. Check the setting, and perform the steps ③ onward again.

Example: Setting R = 1.2 kΩ as the reference value

a. Select R measurement by pressing the PARAMETER R key.
b. Press the REF key to enter the reference value setting mode.
c. Press the 1, DP, and 2 keys in order named, and select unit kΩ by using the UNIT UP or DOWN key. If you inadvertently specified a wrong value, press the CE key and enter the correct value again, or move the cursor to the setting to be changed by using the → key.
d. After verifying the setting shown on the main display, press the STORE key to store the setting.

(2) Entering measured value

① Select the measurement parameter for the reference value to be set, using the PARAMETER key.

② Measure the reference sample, and display the measured value on the main display.

REMARKS

Deviation measurement should be made in the OFF condition (both the Δ and Δ % key LEDs being on).

③ After verifying the measured value shown on the main display, press the STORE key to store the value as the reference value.
If the value is correctly stored, the REF key LED comes on and the stored value is shown on the main display. If an error display is given and the REF key LED remains off, it means that the measured value is outside the allowable range and cannot be set as the reference value.

④ To change the displayed reference value, perform the steps ③ and subsequent steps in (1) Setting arbitrary numerical value as the reference value.
When the reference value need not be changed, press the REF key. Then, the key LED goes off and the display returns to normal.

3.15 COMPARATOR FUNCTION

For the main parameter and subparameter, the measured value can be compared with the preset limits. If the COMP ENABLE key is pressed, the key LED comes on and the apparatus becomes ready for comparator operation. To perform the comparator operation, upper and lower limits have to be set in advance. For a parameter whose limit values are not set, no comparison can be made.

Desired upper and lower limits can be set for each parameter by keying-in operation.

Table 3-10. Allowable Limit Value Ranges

Main Parameter	Allowable Setting Range	Subparameter	Allowable Setting Range
C	0 - 9999.9 mF	D	0 - 9.9999
L	0 - 99.999 kH	Q	0 - 9999
R	0 - 99.999 MΩ	G	0 - 999.99 S
|Z|	0 - 99.999 MΩ	ESR	0 - 99.999 MΩ
		X	– 99.999 MΩ - 99.999 MΩ
		B	– 999.99 S - 999.99 S
		L	0 - 99.999 MΩ
		C	0 - 9999.9 mF
		θ	– 180.00 - 180.00 deg

(1) Setting comparator limit values

① Select the measurement parameter for the limit values to be set, using the PARAMETER key.

② Press the LIMIT key. Then, the key LED comes on and the limit setting mode is entered. Make sure that *UPL* (upper limit setting mode) is shown on the check display. The previously set upper limit (---- if no upper limit is set) is shown on the main and sub displays.

③ Set the main parameter upper limit on the main display and the subparameter upper limit on the sub display by using the 0-9, DP (decimal point), CE (clear), → (cursor movement), and UNIT (unit selection) UP and DOWN keys.

REMARKS

The → key is used to move the cursor (blinking display). Selection of the unit can be made for the main or sub display over which the cursor is located.

64

④ Press the STORE key to store the setting as the upper limit. If the upper limit is correctly stored, the indication on the check display changes to *LoL* (lower limit setting mode). If an error display is given and the indication on the check display remain unchanged, it means that the set value is outside the allowable limit setting range. Check the setting, and perform the steps ③ onward again.

⑤ Set the main parameter and sub parameter lower limits in the same manner as in ③.

⑥ Press the STORE key to store the setting as the lower limit. If the lower limit is correctly set, the LIMIT key LED goes off and the apparatus leaves the limit setting mode. If an error display is given and the indication on the check display remain the same (*LoL*), check the setting and perform the steps ⑤ onward again.

Setting example: Setting C = 1.05 μF and D = 0.12 as the upper limits and C = 0.95 μF and D = 0.01 as the lower limits for C-D measurement

a. Select C-D measurement by pressing the PARAMETER C key.

b. Press the LIMIT key to enter the limit setting mode. Check that *UPL* is shown on the check display.

c. Check that the indication on the main display is blinking, and set the upper limit of C. (If a numerical value is already set, press the CE key to clear it.)
Press the 1, DP, 0, and 5 keys in order named, and select unit μF by pressing the UNIT UP or DOWN key.

d. Move the blinking display to the sub display by pressing the → key, and set the upper limit of D. (If a numerical value is already set, press the CE key to clear it.)
Press the DP, 1, and 2 keys in order named.

e. After checking the upper limit settings of C and D, press the STORE key to store these values.

f. Check that *LoL* is shown on the check display.

g. Set the lower limit of C in the same manner as in c. Press the DP, 9, and 5 keys in order named, and select unit μF by pressing the UNIT UP or DOWN key.

h. Set the lower limit of D in the same manner as in d. Press the DP, 0, and 1 keys in order named.

i. After checking the lower limit settings of C and D, press the STORE key to store these values.

(2) Comparator judgment result

The main parameter judgment result is indicated by the HIGH, PASS, or LOW LED on the main display, while the subparameter judgment result is indicated by the HIGH, PASS, or LOW LED on the sub display.

Table 3-11. Comparator Judgment Condition

Judgment Result	Judgment Condition
HIGH	Measured value > Upper limit
PASS	Upper limit ≧ Measured value ≧ Lower limit
LOW	Measured value < Lower limit

Thus, in this case, a judgment is made as to whether the measured value is greater than the upper limit or smaller than the lower limit. (When only the upper limit is set, the display is either HIGH or PASS. When only the lower limit is set, the display is either PASS or LOW.)

REMARKS

If the limit settings are such that the upper limit is smaller than the lower limit, they are judged to be inappropriate and the HIGH and LOW LEDs come on at the same time.
When *OF*, *UF*, and *CF* are shown on the main or sub display, the HIGH and LOW LEDs also come on at the same time.

The loudspeaker inside the apparatus sounds at the same time an indication is given by the LEDs. In the case of PASS, a PASS tone (normally about 2 kHz) is produced. Otherwise, an NG tone (normally about 500 Hz) is produced.

REMARKS

A PASS tone is produced by the loudspeaker only when the overall judgment result is PASS.
For the loudspeaker ON/OFF control and tone frequency setting, refer to the description of the internal DIP switch function in Appendix C.

(3) Judgment result output

A comparator judgment result signal (indicating the same state as given by the HIGH, PASS, and LOW LEDs on the front panel) is output to the EXT CONTROL connector on the rear panel. An overall judgment result relay contact output (PASS, COM, $\overline{\text{PASS}}$) is also available.

REMARKS

For information on the EXT CONTROL connector, refer to Table 3-13 External Control Interface Functions.

66

3.16 EXTERNAL DC BIAS

There are many samples which require a DC bias to be applied to them during measurement. For example, an electrolytic capacitor requires a DC voltage corresponding to its polarity to be applied to it, and a variable capacitance diode also requires a DC voltage to be applied to it when its capacity characteristic is to be measured. This apparatus allows the use of an external DC power supply to apply a bias to the sample. Fig. 3-6 shows how to obtain an external DC bias.

⚠ CAUTION

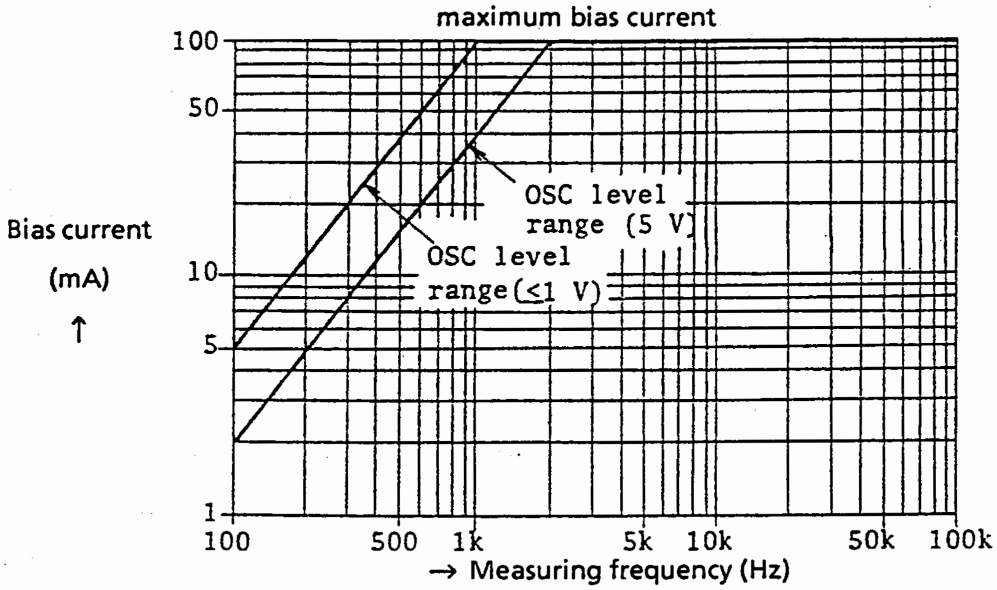
Be sure that the external DC bias voltage is within ±35 V.

The external DC bias must ramain within the following ranges.

Maximum applied voltage : ±35 VDC

Maximum current : 100 mA DC

(The maximum bias current is further limited, depending on the measuring frequency and signal level range. See Fig. 3-5.)



NOTE: The maximum bias current depends on the measuring frequency and signal level range. The maximum bias current should be within the range indicated by the above graph.

Fig. 3-5. Maximum Bias Current

⚠CAUTION

The external DC bias voltage is applied to the H_{CUR} and H_{POT} terminals through the internal protective resistor. If a charged capacitor is connected while an external DC bias is being applied, an excessive discharge current (DC current) may flow into the internal circuit, causing damage to it.

Before apply a DC bias, be sure to set the external DC supply voltage to zero and discharge the capacitor to be connected.

When superimposition of a DC bias voltage is necessary, some time is required before the bias voltage applied to the sample reaches the designated value. The time is determined by the capacitance of the sample connected to the measuring terminal, the protective resistor (about 153 Ω) inside the apparatus, and the signal-bypass capacitor (about 1000 μF), as long as the output resistance of the external DC power source is negligibly small.

Where a DC bias voltage is applied to a capacitor, the charging time constant is roughly expressed by the following formula (Cx being the capacitance of the sample), on the assumption that the output resistance of the external DC power source is negligible.

$$\text{Charging time constant} \simeq (Cx + 1000\mu F) \times 153\ \Omega$$

The settling time from the instant the DC bias is applied to the moment the measurement is started must be several to several tens of times longer than the charging time constant.

REMARKS

For a sample with a low capacitance (1 μF or less), for example, the time (about seven times the time constant) required for the bias voltage to reach 0.999 times the voltage setting is about one second.

When the capacitance of the sample is large, more settling time is required.

The voltage applied to the sample can be monitored using the MONITOR terminal. Its output impedance is about 30 kΩ. Use the terminal when the bias current is small (2 mA or less).

REMARKS

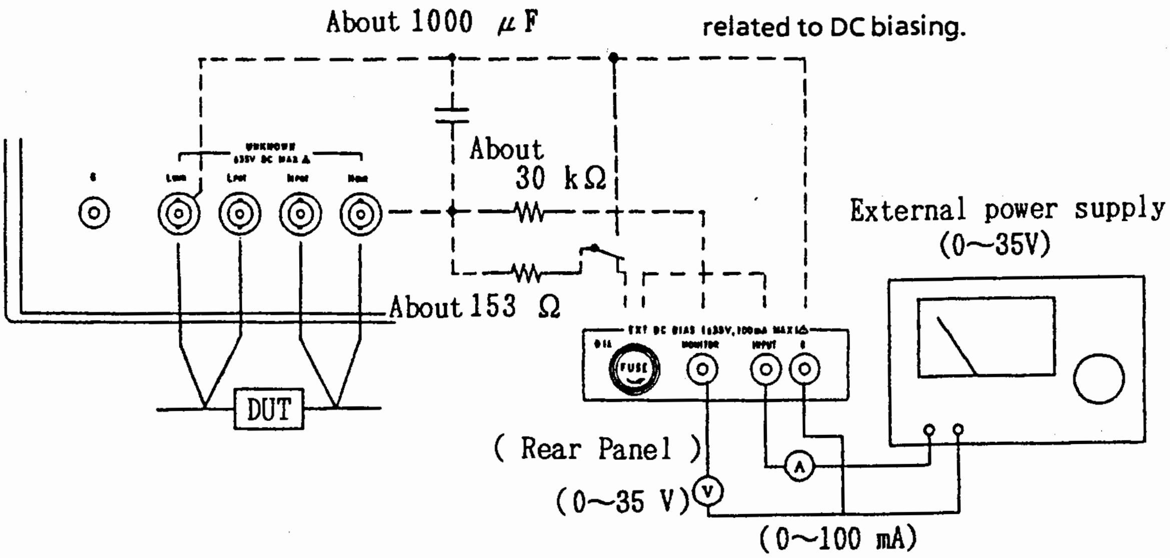
The voltage value monitored using the MONITOR terminal without any bias current flowing agrees with the voltage actually applied to the sample. If a bias current is made to flow, however, the two voltages differ because of the impedance of the internal circuit. Therefore, use the MONITOR terminal only if the bias current is small (2 mA or less).

NOTE

When no DC bias is to be used, press the EXT DC BIAS key on the front panel to turn off the key LED (DC bias OFF).

Application of External DC Bias

* The dotted lines outline the internal circuit related to DC biasing.



1. Have on hand a floating-type, 0-35 V power supply, set the maximum current to 100 mA or less, and set the output voltage to 0 V.
   Connect the external power supply to the EXT DC BIAS INPUT terminal. When applying a bias current, externally connect a DC ammeter

CAUTION

Use an external DC power supply that produces as little ripple and noise as possible.

2. Press the EXT DC BIAS key on the front panel and check that the key LED comes on. With this condition maintained, the DC voltage (0 V) applied to the INPUT terminal appears at the H_{CUR} terminal.

3. Connect a sample, and set the voltage or current provided by the external power supply to a desired value by increasing the voltage from 0 V.

REMARKS

Be sure to keep the DC bias voltage at ± 35 V or less and the current at 100 mA or less.
There is a limitation on current biasing, depending on the measuring frequency and signal level range. Use care so that the applied current may not exceed the maximum current value shown in Fig. 3-5.

Fig. 3-6. Application of External DC Bias

CAUTION

- Make sure that neither the voltage nor current applied to the sample exceeds the maximum rating of the sample. For a sample like an electrolytic capacitor whose operation is dependent on its polarity, observe the correct polarity.
- Be careful not to short the HIGH measuring terminal and LOW measuring terminal (or coaxial connector/coaxial cable outer conductor or grounding terminal) with a DC bias voltage or current applied.

4. Read the measurements after the applied bias voltage or current has settled.
5. After completing the measurement, gradually change the output voltage of the external DC power supply to 0 V.
6. When another sample is to be measured, replace the sample with the new one, and perform the steps 3 onward.
7. When no DC bias is required, press the EXT DC BIAS key on the front panel to turn off the key LED (DC bias OFF).

NOTE

To prevent the apparatus from being damaged by an excessive current, a protective fuse is install in the fuse holder in the EXT DC BIAS section of the rear panel. If the fuse is blown, replace it with a 0.1A fuse. Before replacing the fuse, set the bias voltage to 0 V and check that the EXT DC BIAS key LED is off.

DC bias fuse: 0.1 A/250 V Fast acting type (6.35 mm in diam. × 31.75 mm)

REMARKS

The voltage applied to the sample can be monitored using the MONITOR terminal. Its output impedance is about 30 kΩ. Use the terminal only when the bias current is small (2 mA or less). The value of the bias current to flow through the sample can be approximated by the following expression:

$$\text{Bias current (A)} \doteqdot \frac{\text{external supply voltage (V)}}{R_{XDC} + 153\ \Omega}$$

R_{XDC}: DC resistance (Ω) of the sample

Fig. 3-6. Application of External DC Bias (Continued)

70

3.17 MEASUREMENT BY USE OF EXTERNAL FREQUENCY

To make measurement by use of an external frequency, an external oscillator (for example, a frequency synthesizer) to generate an external frequency signal is required and the external frequency information must be input to the apparatus; input an external frequency signal (1.6 kHz to 1.6 MHz) whose frequency is 16 times the measuring frequency to the EXT TEST FREQ INPUT connector on the rear panel of the apparatus, and specify the frequency information via the GP-IB interface or the external frequency data interface.

Fig. 3-7 shows schematic diagrams of setups for making measurement using an external frequency. Setup ① is for making measurement using an external frequency and specifying the external frequency value via the GP-IB interface. In the setup, the controller is to control the external oscillator and input the frequency value to the apparatus. In this way, measurement can be made in a frequency range of 100 Hz to 100 kHz. For the method of external frequency specification via the GP-IB interface, see Table 3-14.

Setups ② and ③ shown in Fig. 3-7 are for making measurement using the external frequency and specifying the external frequency value via the eternal frequency data interface. Setup ② includes an external oscillator and an external frequency counter; setup ③ includes a special oscillator containing a crystal oscillator circuit. In both setups, the external frequency value is to be input in BCD code to the EXT TEST FREQ DATA connector. For the functions of the external frequency data interface, see Table 3-12. The operator is required to familiarize himself with the signal names and connector pin numbers listed in the table beforehand. Also, be sure to observe the precautions set forth in the table so as to use the apparatus correctly and safely.

NOTE

To make measurement using an external frequency, an external frequency signal whose frequency is 16 times the measuring frequency and the frequency value information must be input to the apparatus. If they are not consistent with each other, correct measurement cannot be made. Use an external oscillator whose frequency accuracy is $\pm 1 \times 10^{-4}$ or less and whose phase noise (residual FM) is -50 dB or less.

71

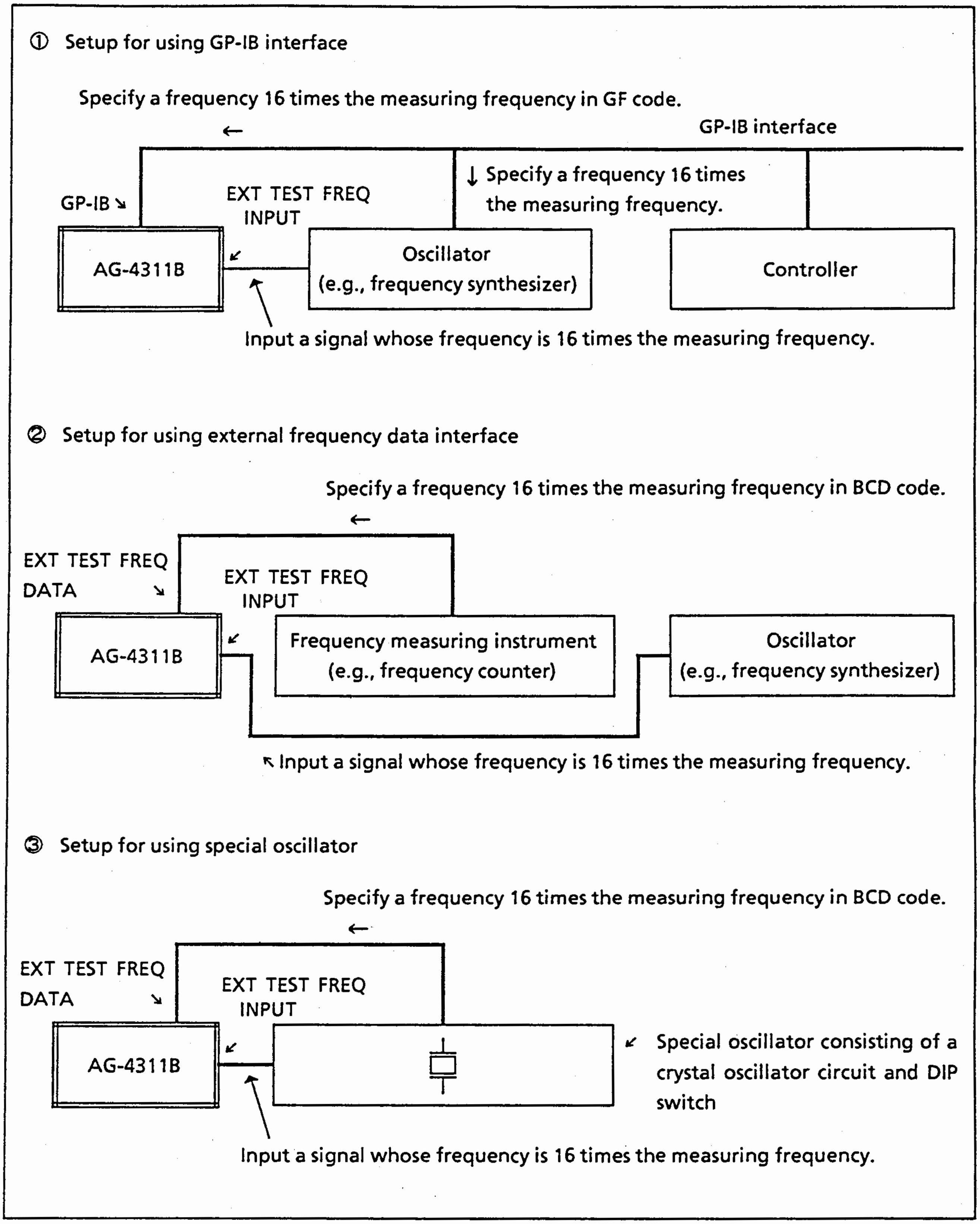


Fig. 3-7. Setups for Measurement by Use of External Frequency

Table 3-12. Functions of External Frequency Interface

1. General

This apparatus can make measurement at any frequency between 100 Hz and 100 kHz through use of an external frequency interface.

To make measurement using an external frequency, a frequency signal generated by an external oscillator (for example, a frequency synthesizer) must be input to the apparatus, and its frequency must be specified. The external frequency (1.6 kHz to 1.6 MHz) must be 16 times the measuring frequency. The frequency can be specified via the GP-IB interface or the external frequency data interface.

The external frequency data interface is for use in specifying an external frequency. Data consisting of a mantissa, a decimal point, and a unit can be specified in BCD code using the interface.

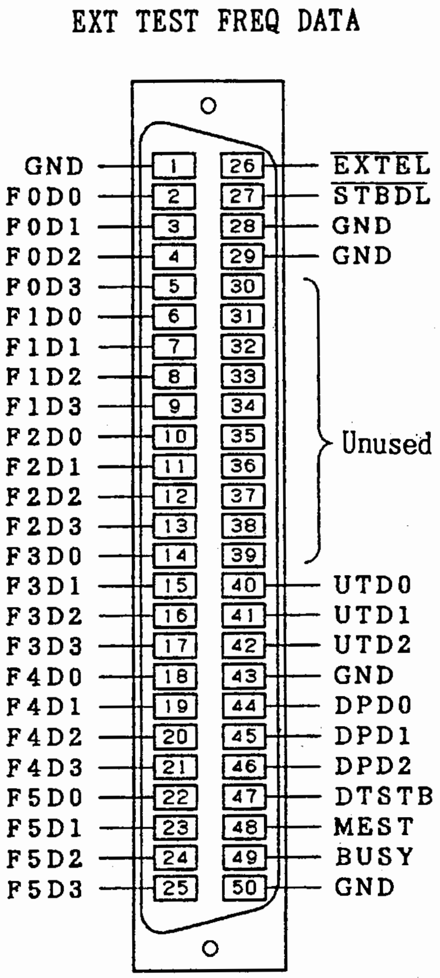
2. EXT TEST FREQ DATA Connector

The EXT TEST FREQ DATA connector is a 50-pole connector. Its pin assignment and the names of signals connected to it are shown at right.

Matching connector: 57-30500 (male)
connector or equivalent

REMARKS

As the male connector to engage with the EXT TEST FREQ DATA connector, use the accessory to the apparatus or equivalent.



3. Signal Level

TTL level only

"0": 0 V (nominal)

"1": + 5 V (nominal)

Table 3-12. Functions of External Frequency Interface (Continued)

4. Signals and Functions

Pin No.	Signal Name	FUNCTION
1	GND	Signal ground
2	F0D0	1st digit of mantissa ($F \times 10^{0} \cdot D_0 - D_3$)
3	F0D1	
4	F0D2	
5	F0D3	
6	F1D0	2nd digit of mantissa ($F \times 10^{1} \cdot D_0 - D_3$)
7	F1D1	
8	F1D2	
9	F1D3	
10	F2D0	3rd digit of mantissa ($F \times 10^{2} \cdot D_0 - D_3$)
11	F2D1	
12	F2D2	
13	F2D3	
14	F3D0	4th digit of mantissa ($F \times 10^{3} \cdot D_0 - D_3$)
15	F3D1	
16	F3D2	
17	F3D3	
18	F4D0	5th digit of mantissa ($F \times 10^{4} \cdot D_0 - D_3$)
19	F4D1	
20	F4D2	
21	F4D3	
22	F5D0	6 th digit of mantissa ($F \times 10^{5} \cdot D_0 - D_3$)
23	F5D1	
24	F5D2	
25	F5D3	
26	$\overline{\text{EXTEL}}$	When this signal is set to 0 or connected to ground, the external frequency data interface is enabled.
27	$\overline{\text{STBDL}}$	If DTSTB signal is not used, keep this signal at 0 or connected to GND.
28	GND	Signal ground
29	GND	Signal ground
30 ~ 39		No used
40	UTD0	Unit data ($UNIT \cdot D_0 - D_2$)
41	UTD1	
42	UTD2	
43	GND	Signal ground
44	DPD0	Decimal point data ($DP \cdot D_0 - D_2$)
45	DPD1	
46	DPD2	
47	DTSTB	Strobe signal to be input for data latching
48	MEST	This signal is output to start the external frequency counter.
49	BUSY	This signal being 1 indicates the busy state in which data cannot be received.
50	GND	Signal ground

Table 3-12. Functions of External Frequency Interface (Continued)

5. External Frequency Input Format

The external frequency data is divided into a mantissa, a decimal point position, and a unit. The mantissa may consist of up to six digits, and it can be specified in BCD code. The decimal point position data consists of three bits which can specify six different positions. The unit data consists of three bits used to specify either Hz or kHz. The possible decimal point positions for a mantissa are shown below.

10^5	10^4	10^3	10^2	10^1	10^0	....	F x 10^5 - F x 10^0
1.	6.	0.	0.	0.	0.		
↑	↑	↑	↑	↑	↑		
DP5	DP4	DP3	DP2	DP1	DP0	....	Decimal point position

Mantissa data

Numerical value	F5 - F0			
	D3	D2	D1	D0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
No used	1	0	1	0
		~		
	1	1	1	1

Decimal point data

Decimal point	DP		
	D2	D1	D0
DP0	0	0	0
DP1	0	0	1
DP2	0	1	0
DP3	0	1	1
DP4	1	0	0
DP5	1	0	1
No used	1	1	0
	1	1	1

Unit data

Unit	UT		
	D2	D1	D0
Hz	0	0	0
kHz	0	0	1
No used	0	1	0
	0	1	1
	1	0	0
	1	0	1
	1	1	0
	1	1	1

Example: Inputting 160.000 kHz.

Specify mantissa 160000, decimal point position DP3, and unit kHz.

Mantissa	F5 D3 - D0	F4 D3 - D0	F3 D3 - D0	F2 D3 - D0	F1 D3 - D0	F0 D3 - D0
160000	0001	0110	0000	0000	0000	0000

Decimal point	DP D2 - D0
DP3	011

Unit	UT D2 - D0
kHz	001

Table 3-12. Functions of External Frequency Interface (Continued)

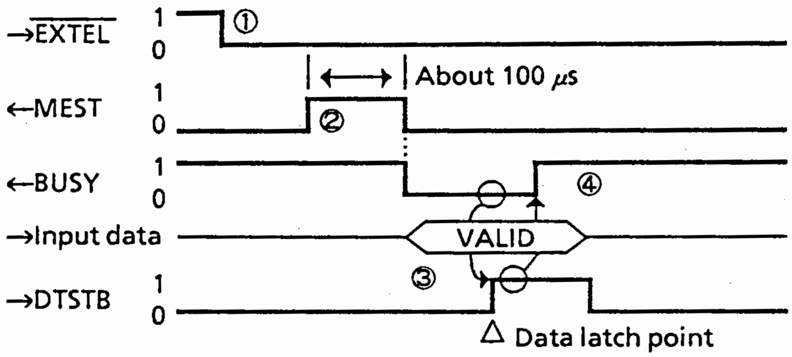
6. Control Signals

Control signals $\overline{\text{EXTEL}}$ and $\overline{\text{STBDL}}$, and the control signals concerning the fetching of the DTSTB, MEST, and BUSY data are connected to the EXT TEST FREQ DATA connector.

The $\overline{\text{EXTEL}}$ signal must be set to "0" when the external frequency data interface is to be used. While it is at "0", the MEST signal is output every time measurement is started.

The MEST signal can therefore be used as the frequency measurement starting signal for an external frequency counter. After the MEST signal is set to "0", the BUSY signal is set to "0" to indicate that frequency data may be input. While the BUSY signal is at "0", the external frequency counter if connected to the apparatus may output the numerical, unit, and decimal point data, and also a strobe signal (DTSTB) for data fetching to the apparatus. When the DTSTB signal is received, the apparatus latches the data. At the same time, the BUSY signal is reset to "1".

$\overline{\text{STBDL}}$: "1" level



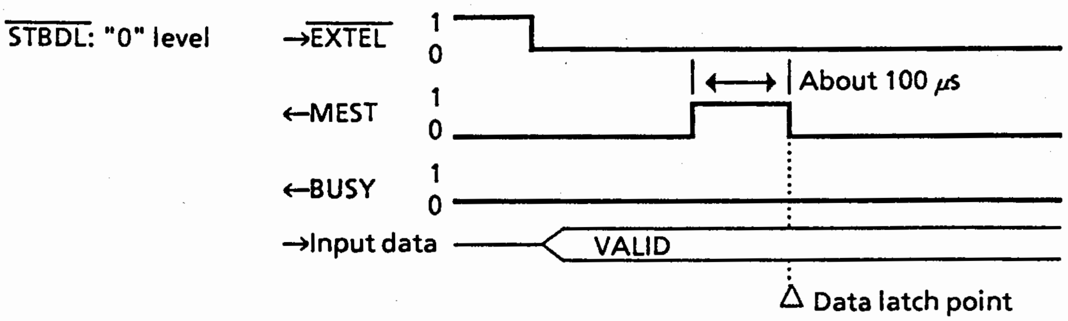
NOTES:
① When the $\overline{\text{EXTEL}}$ signal is set to "0", the external frequency data interface is enabled.
② After the $\overline{\text{EXTEL}}$ signal is set to "0", the MEST signal is output, and the BUSY signal is then set to "0", enabling the input of the frequency data.
③ Input the DTSTB signal when the external frequency data input from the outside settles.
④ The apparatus latches the data upon receipt of the DTSTB signal. When data latching is completed, the BUSY signal is reset to "1".
The DTSTB signal must have a pulse width of 100 μs or more.

REMARKS

When the external frequency data is input and latched, the apparatus calculates the measuring frequency as being 1/16 of the external frequency and then calculates various parameter values for the calculated measuring frequency. Therefore, specify the external frequency to be 16 times the desired measuring frequency. Setting the $\overline{\text{EXTEL}}$ signal to "0" sets the external frequency mode causing the MEST signal to be output. When the DTSTB signal is subsequently set to 1 in the external frequency mode, the external frequency data is read and measurement is started. The MEST signal is output every time measurement is started, so that the measuring time used by the apparatus for each measurement is equal to the time from the output of a MEST signal to the output of the subsequent DTSTB signal. Resetting the $\overline{\text{EXTEL}}$ signal to "1" restores the internal frequency mode.

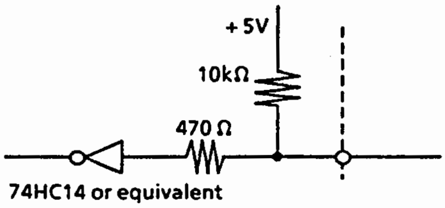
Table 3-12. Functions of External Frequency Interface (Continued)

While the $\overline{\text{STDBL}}$ signal is at "0", the apparatus latches the data at each MEST signal without depending on the DTSTB signal. This mode can be used when the external frequency is fixed.

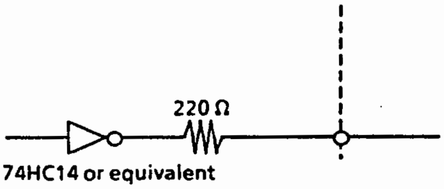


7. External Interface

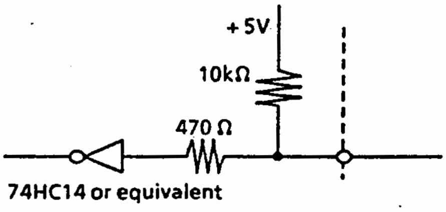
(1) Data input circuit



(2) Control signal output circuit



(3) Control signal input circuit



REMARKS

Use an external driver circuit of open collector type TTL or 74HC series TTL.
Use an external input circuit of 74 HC series TTL.
Use connection cables not longer than 0.5 m each.

8. Precautions

(1) The allowable external frequency range is from 1.6 kHz to 1.6 MHz. The number of significant digits of the external frequency is five. Inputting an external frequency outside the allowable range causes an error indication to be displayed.

(2) The mantissa to be input as the external frequency data may consist of up to six digits. Since the input circuit for each mantissa digit is of positive logic, keep the unused digits at "0" or connected to a GND pin.

(3) When connecting an external frequency counter and/or other external devices to the apparatus, interconnect their frame ground (FG) terminals and short the interconnected terminals to ground.

(4) The connection cable should be 0.5 m or less in length. Be sure to connect it to the frame ground. To prevent the apparatus from malfunctioning due to external noise, shield the entire cable. (The shield should be connected to pin 50.)

3.18 EXTERNAL CONTROL INTERFACE

Various signals related to the external measurement start input and comparator are available at the EXT CONTROL connector on the rear panel of the apparatus. By using these signals, the apparatus can be controlled by external devices or the external devices can be controlled by the apparatus.

A description of the functions of the external control interface is given in Table 3-13. The operator is required to familiarize himself with the signal names and connector pin numbers shown in the table.

Be sure to observe the precautions set forth in the table so as to use the apparatus correctly and safely.

Table 3-13. Functions of External Control Interface

1. General

An external measurement start signal, measurement end signal, and comparator measurement result signal can be obtained from the EXT CONTROL connector on the rear panel.

The external measurement start signal becomes effective when the MEAS START EXT key on the front panel is pressed to enter the external start mode. Measurement is made each time a start signal is entered from outside.

The measurement end signal is output as a pulse the moment the measured data is displayed.

The comparator measurement result output signal indicates the same state as represented by the LEDs on the front panel. In addition, an overall judgment result relay contact output is provided.

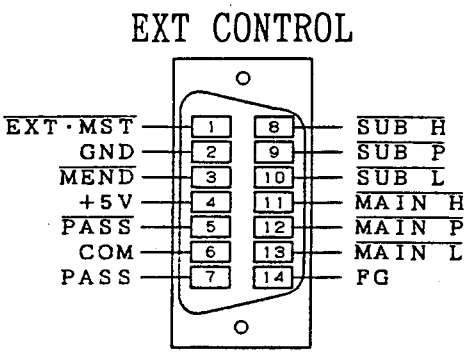
By using these control signals, the apparatus can be remotely controlled by external devices, and the external devices can be controlled based on the result of the judgment by the comparator.

2. EXT CONTROL Connector

The EXT CONTROL connector is a 14-pole connector.

Its pin assignment and signal names are shown at right.

Matching connector: 57-30140 (male) plug
or equivalent



REMARKS

As the connector to engage with the EXT CONTROL connector, use the accessory to the apparatus or equivalent.

3. Signal Level

For all signals except $\overline{\text{PASS}}$, COM, and PASS, a TTL level is used.

"0": 0 V (nominal)

"1": +5 V (nominal)

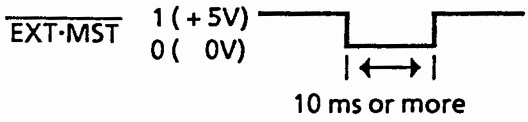
Table 3-13. Functions of External Control Interface (Continued)

4. Signal Names and Functions

Pin No.	Signal Name	Input/Output	Description of the Function
1	$\overline{\text{EXT·MST}}$	Input	An external measurement start signal is input.
2	GND	——	Signal ground
3	$\overline{\text{MEND}}$	Output	A pulse is output the moment a measurement ends.
4	+5V	Output	+5 V power supply (output impedance: about 50 Ω)
5	$\overline{\text{PASS}}$	——	Overall judgment relay contact output (A current path is formed between COM and PASS only when the result of the overall judgment is PASS.)
6	COM	——	
7	PASS	——	
8	$\overline{\text{SUB H}}$	Output	"0" level when the subparameter judgment result is HIGH.
9	$\overline{\text{SUB P}}$	Output	"0" level when the subparameter judgment result is PASS.
10	$\overline{\text{SUB L}}$	Output	"0" level when the subparameter judgment result is LOW.
11	$\overline{\text{MAIN H}}$	Output	"0" level when the main parameter judgment result is HIGH.
12	$\overline{\text{MAIN P}}$	Output	"0" level when the main parameter judgment result is PASS.
13	$\overline{\text{MAIN L}}$	Output	"0" level when the main parameter judgment result is LOW.
14	FG	——	Connected with the frame ground of the apparatus.

5. Measurement Start Signal

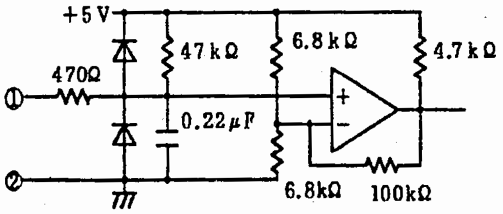
If the MEAS START EXT key on the front panel is valid (the EXT key LED is on), measurement is made each time the $\overline{\text{EXT·MST}}$ signal is input.



REMARKS

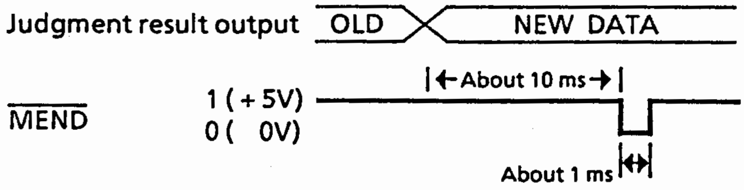
If the $\overline{\text{EXT MST}}$ signal is successively set to the "0" level, measurement is repeatedly made. If much chattering occurs when measurement is started directly by a foot switch, adequate provision should be made against chattering.

Input circuit



6. Measurement End Signal

The measurement end signal ($\overline{\text{MEND}}$) is output as a pulse the moment a measurement and display is completed.



Output circuit

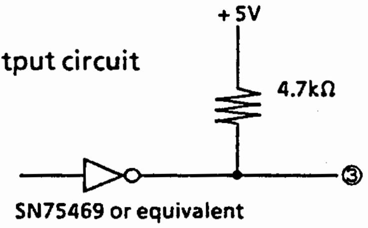


Table 3-13. Functions of External Control Interface (Continued)

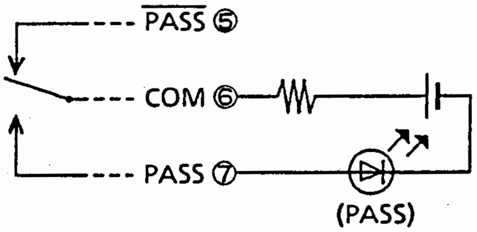
7. Overall Judgment Relay Contact Output

Normally, a current path is formed between the $\overline{\text{PASS}}$ and COM terminals. Current can flow between the PASS and COM terminals only when the result of the overall judgment is PASS.

Internal relay contact capacity

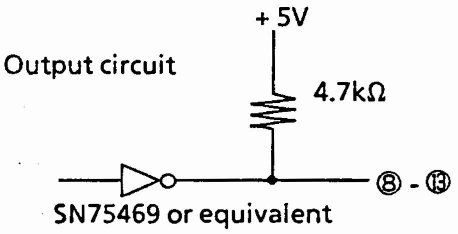
Maximum allowable voltage : 10 VDC
Maximum allowable current : 100 mA DC

Example of application of the relay contact output circuit



8. Judgement Result Signal

The main parameter/subparameter judgment result output is the same as indicated by the HIGH, PASS, and LOW LEDs on the front panel.



9. Precautions

(1) Use the 74LS series TTL or equivalent as the external input circuit that receives a measurement end signal or judgment result output signal.

(2) The connection cable should be 0.5 m or less in length. Be sure to connect it to the frame ground. To prevent the apparatus from malfunctioning due to external noise, shield the entire length of the cable. (The shield should be connected to pin 14 (FG).)

(3) When the apparatus is to be connected with another instrument, connect their frame ground (FG) terminals together and short them to ground.

3.19 GP-IB INTERFACE

The GP-IB interface (complying with IEEE-488) enables a controller (for example, a personal computer) to remotely control the apparatus and process the data obtained by the apparatus, so that the apparatus can be incorporated into an automatic measuring system to process data on various parts or to inspect parts to determine whether they are acceptable for use.

The functions of the GP-IB interface are explained in Table 3-14. To remotely control the apparatus via the GP-IB interface, the controller requires a GP-IB control program. The programmer to generator such a program must familiarize himself with the program codes and data formats shown in the table beforehand. Also, be sure to observe the precautions set forth in the table so as to use the apparatus correctly and safely.

REMARKS

For the GP-IB control program, refer to the instruction manual for the controller.

82

Table 3-14. Functions of GP-IB Interface (1/32)

1. General

The GP-IB interface, a remote interface for automatic measurement, enables the apparatus to be remotely controlled by the controller and to output data to an external device.

(1) It can become a talker and a listener in a GP-IB system which has a controller.

(2) It can become a talker (TALK ONLY) in a GP-IB system which has no controller.

(3) GP-IB interface functions: SH1, AH1, T5, L4, SR1, RL1, DT1, DC1

2. Connection with Other GP-IB Devices

When connecting other GP-IB devices to the apparatus via the GP-IB interface using GP-IB cables, use the following procedure:

(1) Set the power switches of the apparatus and the GP-IB devices to be connected to it to OFF.

(2) Interconnect the frame ground (FG) terminals of all devices to be connected, and short them to ground.

(3) Connect the GP-IB devices to the apparatus, using GP-IB cables.

(4) Set the power switches of the apparatus and the GP-IB devices to ON.

REMARKS

The GP-IB connector is a 24-pin connector.

Its pin assignment and the names of signals connected to it are shown in the right figure.

(IEEE-488 compatible)

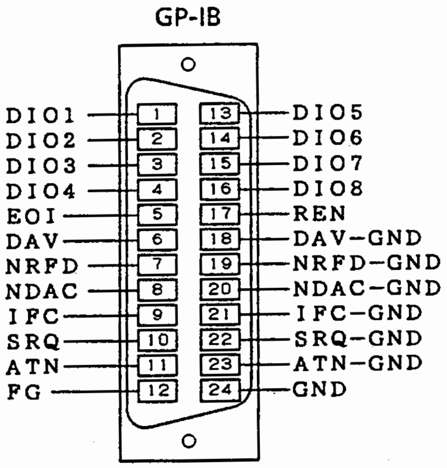


Table 3-14. Functions of GP-IB Interface (Continued) (2/32)

3. GP-IB Status Indications

When the apparatus is used in a GP-IB system, its status is indicated by its GP-IB status LEDs as follows:

SEQ	The apparatus has sent a SRQ (service request) signal to the GP-IB bus line.
LISTEN	The apparatus has been designated as listener.
TALK	The apparatus has been designated as talker.
REMOTE	The apparatus is under remote control by the controller.

In the TALK ONLY mode, only the TALK LED is on.

4. LOCAL Mode and REMOTE Mode

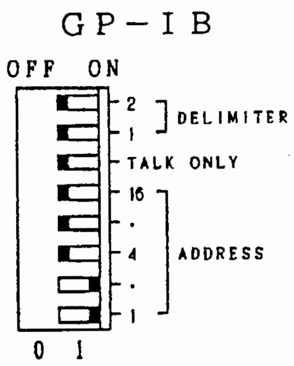
LOCAL mode	When the apparatus is switched on, it is set in the LOCAL mode (for manual-controlled operation). The LOCAL mode is also entered when a GTL (Go To Local) signal is received in the REMOTE mode, or when the LOCAL key is pressed in a state other than LLO (Local Lockout) state.
REMOTE mode	The REMOTE mode is entered when a MLA (My Listen Address) signal is received from the controller.

The LOCAL key is used to restore the apparatus that has been under remote control by the controller via the GP-IB interface into the LOCAL mode in which it can be controlled by keying on its front panel. The LOCAL key is not operable when a LLO state has been set by the controller.

Table 3-14. Functions of GP-IB Interface (Continued) (3/32)

5. GP-IB Address Switches

The GP-IB address switches are used to make switching between ADDRESSABLE and TALK ONLY and to set the GP-IB address of the apparatus. Prior to shipment from the factory, the switches have been set to ADDRESSABLE and MA (My Address) = 3.



DELIMITER

An output data format is set.

2	1	Mode	Description of the Function
OFF	OFF	MODE0	• Measured data (MAIN, SUB) is output as one line, being separated by commas. • CR LF is sent at the end of the output data. EOI is transmitted at the same time LF is sent.
OFF	ON	MODE1	• Measured data is output as one line, being separated by commas. • CR LF is not sent at the end of the output data. EOI is transmitted when the final byte of the data is sent.
ON	OFF	MODE2	• Measured data is divided into two lines and output. • CR LF is sent at the end of each line. EOI is transmitted at the same time the LF on the second line is sent.
ON	ON	Unused	Same operation as MODE2.

TALK ONLY

OFF (ADDRESSABLE):

The address setting switches are operable. (Normal GP-IB system)

ON (TALK ONLY):

The address setting process as performed in the command mode is omitted, and data can be transferred by three-line handshaking. If a printer having the LISTEN ONLY function is connected to the apparatus, only measured data can be output to the printer.

ADDRESS

Address setting switches

16	·	4	·	1	Address (decimal)	Remarks
0	0	0	0	0	0	Arbitrarily settable
0	0	0	0	1	1	
		⌇			⌇	
1	1	1	1	0	30	
1	1	1	1	1	30	Unusable (replaced with 30)

REMARKS

1) In a GP-IB system, the GP-IB address of every device must be unique.
2) The apparatus is represented by a one-level address.
3) GP-IB address 31 is unusable. If all address switches are set to ON (1), the address is automatically replaced with 30.

Table 3-14. Functions of GP-IB Interface (Continued) (4/32)

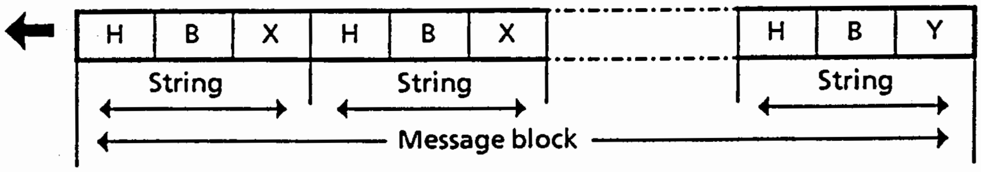
7. Remote Program

The program codes usable to control the apparatus are listed in the table of remote program codes for the AG-4311B. Using a code which is not listed in the table constitutes a program error; an error indication is displayed.

7.1 Function setting format

To set functions, for example, to define measuring conditions, use the format as shown below. In the format, each function constitutes a string; two or more strings make up a message block. Each message block must end with a block delimiter to indicate the end of the message.

<Basic function setting format>



H:	Header	Control character assigned to each function
B:	Body	Number assigned to each function (omitted depending on the case)
X:	String delimiter	"," (comma) code to delimit a string. This delimiter is omissible.
Y:	Block delimiter	LF, or CR + LF to delimit the message block. ("EOI" alone can be a block delimiter.)

<Function setting example>

A10,	C0,	H0,	V3,	F21,	R00,	T2,	I0	CR LF
(1)	(2)	(3)	(5)	(6)	(7)	(8)	(10)	(EOI)

NOTES:

1) Numbers shown in ( ) correspond to numbers in the table of remote program codes.
2) The "," (comma) code may be omitted.
3) Strings may be entered in any order.
4) When the last specifications need not be changed, the corresponding strings may be omitted.
5) If a program code error is detected, an error indication is output. If a program code error is detected with SRQ READY (I1) specified, the SRQ LED goes on and the error is indicated by status byte bit 1.
6) Execution of the above message block results in the following settings:

PARAMETER	C-D
CIRCUIT MODE	AUTO
MEAS SPEED	NORMAL
OSC LEVEL RANGE	1 V
TEST FREQUENCY	1 kHz
RANGE	AUTO
MEAS START	MANUAL
SRQ READY	OFF

Table 3-14. Functions of GP-IB Interface (Continued) (5/32)

Remote Program Codes for the AG-4311B (1/8)

No.	FUNCTION	Setting	Program Code	Remarks
1	PARAMETER	L-D	A00	● A □ □ Main parameter selection Subparameter selection
		L-Q	A01	
		L-ESR/G	A02	
		C-D	A10	
		C-Q	A11	
		C-ESR/G	A12	● A02, A12, A20, and A21 cause the subparameter to be determined by the circuit mode.
		R-X/B	A20	
		R-L/C	A21	
		$\|Z\|$-θ	A30	
2	CIRCUIT MODE	AUTO	C0	
			C1	
			C2	
3	MEAS SPEED	NORMAL	H0	
		SLOW	H1	
		FAST	H2	
4	DEVIATION	OFF	D0	● Setting Δ or Δ% requires a reference value to be input beforehand.
		Δ	D1	
		Δ%	D2	
5	OSC LEVEL RANGE	10 mV	V1	● Values are nominal values for a state with the OSC LEVEL FINE adjuster placed at MAX (right most position).
		100 mV	V2	
		1 V	V3	
		5 V	V4	

Table 3-14. Functions of GP-IB Interface (Continued) (6/32)

Remote Program Codes for the AG-4311B (2/8)

No.	FUNCTION	Setting	Program Code	Remarks
6	TEST FREQUENCY	EXT FREQ DATA	F00	• Execution of F00 sets the mode requiring the external frequency to be specified via the external frequency data interface.
		GP-IB FREQ DATA	F01	• Execution of F01 sets the mode requiring the external frequency to be specified via the GP-IB interface. (The external frequency must be specified in GF code.)
		100 Hz	F11	• F11 to F14 (31 frequencies) Internal oscillator frequency selection (Frequencies are nominal values.)
		120 Hz	F12	
		150 Hz	F13	
		200 Hz	F14	
		250 Hz	F15	
		300 Hz	F16	
		401 Hz	F17	
		500 Hz	F18	
		601 Hz	F19	
		801 Hz	F20	
		1.00 kHz	F21	
		1.20 kHz	F22	
		1.50 kHz	F23	
		2.00 kHz	F24	
		2.50 kHz	F25	
		3.00 kHz	F26	
		4.01 kHz	F27	
		5.00 kHz	F28	
		6.01 kHz	F29	
		8.01 kHz	F30	
		10.0 kHz	F31	
		12.0 kHz	F32	
		15.1 kHz	F33	
		20.2 kHz	F34	
		25.0 kHz	F35	
		30.5 kHz	F36	
		40.3 kHz	F37	
		50.0 kHz	F38	
		62.5 kHz	F39	
		78.1 kHz	F40	
		100 kHz	F41	

Table 3-14. Functions of GP-IB Interface (Continued) (7/32)

Remote Program Codes for the AG-4311B (3/8)

No.	FUNCTION	Setting	Program Code	Remarks
7	RANGE	AUTO MANUAL/HOLD 1pF / 0.1μH / 0.1 Ω 10pF / 1μH / 1 Ω 100pF / 10μH / 10 Ω 1nF / 100μH / 100 Ω 10nF / 1mH / 1kΩ 100nF / 10mH / 10kΩ 1μF / 100mH / 100kΩ 10μF / 1 H / 1MΩ 100μF / 10 H / 10MΩ 1mF / 100 H 10mF / 1kH 100mF / 10kH 1000mF	R00 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19 R20 R21 R22 R23	● Execution of R00 sets the AUTO mode. ● Execution of R10 causes the current range to be fixed. ● Execution of one of R11 to R23 causes the specified range to be fixed. If the specified range is not allowable for the specified parameter or measuring frequency, the nearest allowable range is set.
8	MEAS START	AUTO EXT MANUAL	T0 T1 T2	● Execution of T0 sets the AUTO mode. ● Execution of T1 sets the external trigger mode in which measurement is started by an $\overline{\text{EXT}\cdot\text{MST}}$ signal input to the EXT CONTROL connector. ● Execution of T2 causes measurement to be made every time a measurement starting command is received from the GP-IB.
9	SIGNAL CHECK	OSC FREQUENCY OSC LEVEL UNKNOWN V UNKNOWN mA	M0 M1 M2 M3	● Used to select the item to be indicated on the check display.

Table 3-14. Functions of GP-IB Interface (Continued) (8/32)

Remote Program Codes for the AG-4311B (4/8)

No.	FUNCTION	Setting	Program Code	Remarks
10	SRQ READY	OFF ON	I0 I1	• Control codes related to the service request function. If the service request function is to be used, set the SRQ READY state by executing I1; if the function is not to be used, set I0. • When measurement is terminated with the SRQ READY (I1) set, a SRQ signal is output. (The readiness of output data is indicated by status byte bit 0.)
11	EXT DC BIAS	OFF ON	B0 B1	• DC bias ON/OFF selection • When an external DC bias is to be used, execute B1.
12	COMP ENABLE	OFF ON	P0 P1	• Comparator ON/OFF selection • Execution of P1 makes the comparator ready for operation. The result of the judgment is output to the measured data status. (When comparator operation is to be performed, it is necessary to set the limit values (upper and lower limits) beforehand.)
13	HEADER	OFF ON	HR0 HR1	• Used to specify whether a GP-IB output data header is to be provided or not. • If HR0 is executed, the header for GP-IB output data is not output.

90

Table 3-14. Functions of GP-IB Interface (Continued) (9/32)

Remote Program Codes for the AG-4311B (5/8)

No.	FUNCTION	Setting	Program Code	Remarks
14	REFERENCE VALUE	SET	SL SC SR SZ	• SL, SC, SR, and SZ are used to set the reference values for parameters L, C, R, and |Z|, respectively. The numeric value must be specified in an exponential format.
		STORE	ST	• Execution of ST causes the current measurement to be stored as the reference value.
			SA	• Execution of SA recalls the reference value.
15	OSC FREQUENCY & LEVEL RANGE		OF	• Execution of OF causes the measuring frequency to be output.
			OV	• Execution of OV causes the measuring signal level range to be output.
16	UNKNOWN VOLTAGE & CURRENT		LV	• Execution of LV causes the signal voltage being applied to the sample to be output.
			LA	• Execution of LA causes the signal current flowing through the sample to be output.
17	KEY STATUS		K	• Execution of this code causes the current status of internal settings to be output.
18	EXT TEST FREQUENCY (For GP-IB)		GF	• This code is used by the controller to set an external frequency, which is 16 times the measuring frequency. The numerical value must be input in an exponential format. • F01 must be executed in advance of execution of this code to make measurement by the use of an external frequency.

91

Table 3-14. Functions of GP-IB Interface (Continued) (10/32)

Remote Program Codes for the AG-4311B (6/8)

No.	FUNCTION	Setting	Program Code	Remarks
19	OFFSET ADJ	OPEN SHORT	Y1 Y2	• Offset adjustment starting commands. Execute Y1 to make offset adjustment in open ADJ mode; execute Y2 to make offset adjustment in short ADJ mode. An open mode loop and a short mode loop must be arranged beforehand. • The resultant data is output the moment the offset adjustment is completed. • When measurement is terminated with the SRQ READY set, a SRQ signal is output. (The termination is indicated by status byte bit 2, and the NG/PASS decision is indicated by status byte bit 3.)
20	SELF TEST		Z	• Execution of this code starts the self test (the same test as that initially executed when the apparatus is switched on.) • The resultant data is output the moment the self test is terminated. • When the test is terminated with the SRQ READY set, a SRQ signal is output. (The termination is indicated by status byte bit 2, and the NG/PASS decision is indicated by status byte bit 3.)
21	EXECUTE (Measurement start)		E	• Execution of this code starts measurement (measurement starting command). (Measurement can also be started by address command, GET message.) • The measured data is output the moment the measurement is completed.

92

Table 3-14. Functions of GP-IB Interface (Continued) (11/32)

Remote Program Codes for the AG-4311B (7/8)

No.	FUNCTION	Setting	Program Code	Remarks
22	LIMIT VALUE SET		SUL SLL SUC SLC SUR SLR SUZ SLZ SUD SLD SUQ SLQ SUG SLG SUER SLER SUSL SLSL SUSC SLSC SUX SLX SUB SLB SUT SLT	● These codes are used to set comparator limit values (upper and lower limits). Numerical values should be entered in an exponential format. ● S □ ▭ Limit value code U: Upper limit L: Lower limit Parameter code L, C, R, Z, D, Q, G, ER, SL, SC, X, B, T (ER: ESR SL: Subparameter L SC: Subparameter C T : θ)

Table 3-14. Functions of GP-IB Interface (Continued) (12/32)

Remote Program Codes for the AG-4311B (8/8)

No.	FUNCTION	Setting	Program Code	Remarks
23	LIMIT VALUE RECALL		UL LL UC LC UR LR UZ LZ UD LD UQ LQ UG LG UER LER USL LSL USC LSC UX LX UB LB UT LT	● These codes are used to read comparator limit values (upper and lower limits). ● Execution of these codes causes the specified limit value to be output in an exponential format. ● □ ▭ Limit value code U: Upper limit L: Lower limit Parameter code L, C, R, Z, D, Q, G, ER, SL, SC, X, B, T (ER: ESR SL: Subparameter L SC: Subparameter C T : θ)

Table 3-14. Functions of GP-IB Interface (Continued) (13/32)

7.2 Starting measurement

There are two commands that can be used to start measurement on the apparatus; remote program code E (Execute) and GP-IB address command, GET message. (The apparatus outputs measured data when it is designated as a talker after measurement is started by execution of an E code or GET message.)

(1) Inputting E code

① Inputting E code along

E CR LF
(EOI)

② Inputting E code together with function settings

Function settings , E CR LF
(EOI)
Enter as the last string.

(2) GET message

When address command, GET (08H) message, is received, the apparatus starts measurement.

(For information on the use of the GET message, refer to the instruction manual for the controller.)

7.3 Setting deviation reference value

Either a measured value or an arbitrary value can be set under control by the GP-IB as the reference value for use in the deviation measurement mode.

(1) Setting measured value as reference value

Execution of remote program code ST causes the measured value currently indicated to be stored as the reference value.

ST CR LF
(EOI)

NOTE: Execution of ST requires measurement to be started and a measured value to be indicated beforehand; if no value is indicated, an error indication is displayed.

(2) Setting arbitrary value as reference value

Specify an arbitrary value of parameter L, C, R, or |Z| in an exponential format using remote program code SL, SC, SR, or SZ.

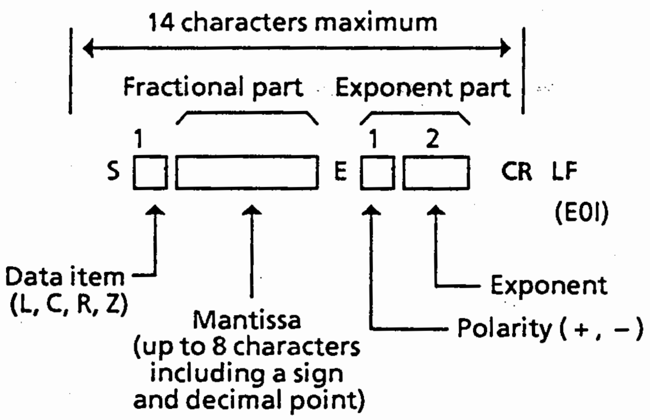
Table 3-14. Functions of GP-IB Interface (Continued) (14/32)

<Reference value range>

PARAMETER	Allowable reference value range
C	0 - 9999.9 mF
L	0 - 99.999 kH
R, |Z|	0 - 99.999 MΩ

NOTE: The number of significant digits is five. If a value outside the allowable range is set, an error indication is displayed.

<Reference value input format>



NOTES:

1) The positive polarity (+) of the fractional part is represented by a space. (In the example, it is represented by △.)
2) The number of significant digits of the mantissa is five.
3) The exponent part consists of four characters.

E + 06	$\times 10^{6}$
E + 03	$\times 10^{3}$
E + 00 (E-00)	× 1
E − 03	$\times 10^{-3}$
E − 06	$\times 10^{-6}$
E − 12	$\times 10^{-12}$

Example: Setting 1.2345 μF as the reference value for parameter C.

SC△1.23450E-06 CR LF
(EOI)

<Clearing reference value>

To clear (reset) the reference value, set 1E-30 as numerical data.

S☐△ 1E-30 CR LF
(EOI)

Data item
(L, C, R, Z)

Table 3-14. Functions of GP-IB Interface (Continued) (15/32)

7.4 Setting external frequency (for GP-IB)

This apparatus can make measurement using an external frequency. To make such measurement, an external frequency 16 times the measuring frequency must be input to the EXT TEST FREQ INPUT connector, and the frequency value must be specified via the GP-IB interface or the external frequency data interface.

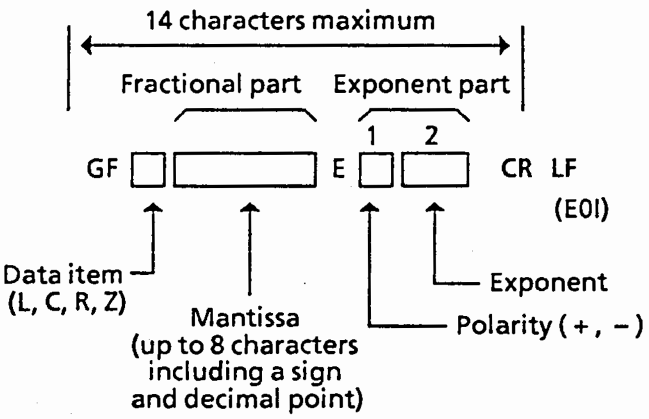
To specify an external frequency under control by the GP-IB, use remote program code GF, and input the numerical data in an exponential format. (The numerical data must specify the external frequency that is 16 times the measuring frequency.)

<External frequency range>

Program code	Allowable range
GF	1.6 kHz - 1.6 MHz

NOTE: The number of significant digits is five. If a value outside the allowable range is set, an error indication is output.

<External frequency input format>



NOTES:
1) The positive polarity (+) of the fraction part is represented by a space. (In the example, it is represented by △.)
2) The number of significant digits of the mantissa is five.
3) The exponent part consists of four characters.

E + 06 .... × 10^6 (MHz)

E + 03 .... × 10^3 (kHz)

E + 00 .... × 1 (Hz)

Example: Setting an external frequency of 16 kHz (with the measuring frequency being 1 kHz).

GF△16.0000E + 03 CR LF
(EOI)

Table 3-14. Functions of GP-IB Interface (Continued) (16/32)

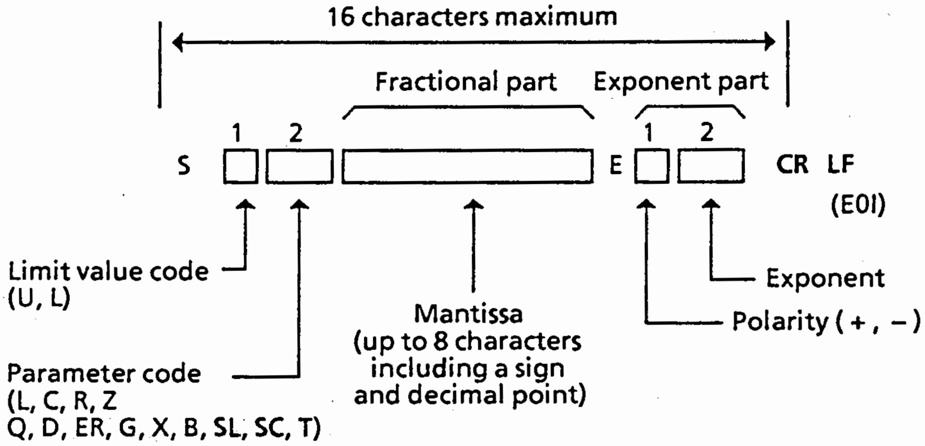
7.5 Setting comparator limit values

Limit values (upper and lower limits) for comparator operation can be specified for each measurement parameter. Specify numerical data in an exponential format, using remote program code S ☐☐.

<Limit value input range>

Main parameter	Allowable range	Subparameter	Allowable range
C	0 - 9999.9 mF	D	0 - 9.9999
L	0 - 99.999 kH	Q	0 - 9999
R	0 - 99.999 MΩ	G	0 - 999.99 S
Z	0 - 99.999 MΩ	ESR	0 - 99.999 MΩ
		X	− 99.999 MΩ - 999.99 MΩ
		B	− 999.99 S - 999.99 S
		L	0 - 99.999 MΩ
		C	0 - 9999.9 mF
		θ	− 180.00 - 180.00 deg

<Limit value input format>



NOTES:

1) The positive polarity (+) of the fractional part is represented by a space. (In the example, it is represented by △.)

2) The maximum number of significant digits of the mantissa is five.

3) The exponent part consists of four characters.

E + 06	$\times 10^{6}$	E − 03	$\times 10^{-3}$
E + 03	$\times 10^{3}$	E − 06	$\times 10^{-6}$
E + 00	× 1	E − 09	$\times 10^{-9}$
		E − 12	$\times 10^{-12}$

Table 3-14. Functions of GP-IB Interface (Continued) (17/32)

Example 1: Setting the upper limit for parameter C to 1.2345 μF

SUC△△1.2345E-06 **CR LF**
(EOI)

Example 2: Setting the lower limit for parameter C to 1 μF

SLC△△1E-06 **CR LF**
(EOI)

<Clearing limit values>

To clear (reset) limit values, set 1E-30 as numerical data.

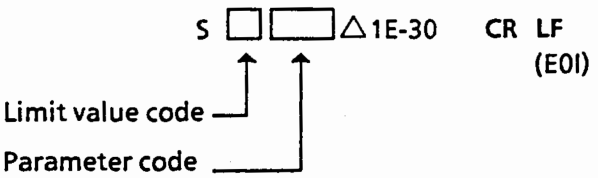


Table 3-14. Functions of GP-IB Interface (Continued) (18/32)

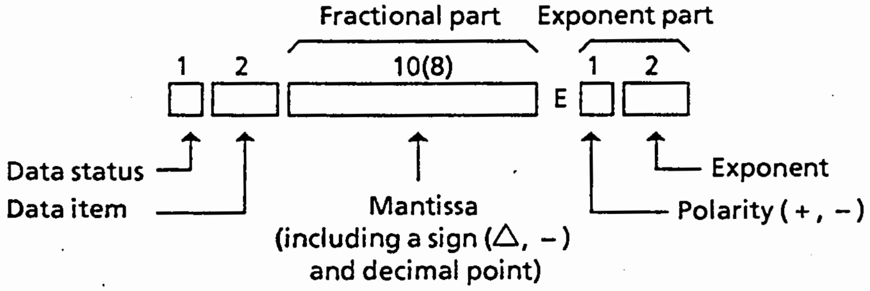
8. Data Output

This apparatus can output the following ten items of data.

No.	Output data	Relevant remote program code
1	Measured values (MAIN, SUB)	E (GET message)
2	Measuring frequency	OF
3	OSC output level range	OV
4	Signal voltage applied to sample	LV
5	Signal current flowing through sample	LA
6	REFERENCE VALUE	SA
7	Internal setting	K
8	LIMIT VALUE	Limit value code Parameter code
9	Self test result data	Z
10	Offset adjustment result data	Y1, Y2

8.1 Basic output format for numerical data

Numerical data is output in an exponential format (fractional part + exponent part) to which data status and data item codes are attached as shown below. (For HR1)



NOTES:

1) The positive polarity (+) of the fractional part is represented by a space. (In the example, it is represented by △.)

2) The exponent part consists of four characters; for the percent deviation mode (△%), △PER is entered.

E + 06 .... × 10^{6}
E + 03 .... × 10^{3}
E + 00 .... × 1
E − 03 .... × 10^{-3}
E − 06 .... × 10^{-6}
E − 09 .... × 10^{-9}
E − 12 .... × 10^{-12}
△PER .... percent

Table 3-14. Functions of GP-IB Interface (Continued) (19/32)

Data Output Codes for the AG-4311B (1/2)

No.	FUNCTION	Setting	Output Code	Remarks
①	CIRCUIT MODE		S	Series Mode
			P	Parallel Mode
②	TEST FREQUENCY	F00, F01 F11 - F41	F□□	Same as remote program code
③	OSC LEVEL RANGE	V1 - V4	V□	Same as remote program code
④	MEAS SPEED	NORMAL	△	(Space)
		FAST	F	
		SLOW	H	
⑤	DATA STATUS	Normal	N	
		OF	O	Over Flow
		UF	U	Under Flow
		CF	C	Change Function
		HIGH	H	Judgment result output with COMP ENABLE on (P1) (Output when DEVIATION is off (D0) and the data is normal. The W code indicates a limit value setting error.)
		PASS	P	
		LOW	L	
		Warning	W	
⑥	PARAMETER			
	MAIN	L	△L	
		C	△C	
		R	△R	
		|Z|	△Z	
		△ or △% of L	DL	Deviation measurement
		△ or △% of C	DC	
		△ or △% of R	DR	
		△ or △% of |Z|	DZ	
	SUB	D	△D	
		Q	△Q	
		ESR	ER	
		G	△G	
		X	△X	
		B	△B	
		L	△L	
		C	△C	
		θ	△T	

NOTE: The mark △ in output codes represents a space.

Table 3-14. Functions of GP-IB Interface (Continued) (20/32)

Data Output Codes for the AG-4311B (2/2)

No.	FUNCTION	Setting	Output Code	Remarks
⑦	Fractional part of data			Characters including a sign and decimal point. They are displayed from the rightmost position.
⑧	Exponent part of data		E□□□ △PER	E + 06, E + 03, E + 00 E − 03, E − 06, E − 09, E − 12 In △% mode (MAIN only)
⑨	Limit value code	Upper limit	U	
		Lower limit	L	
⑩	LIMIT VALUE Parameter code MAIN	L	L△	
		C	C△	
		R	R△	
		|Z|	Z△	
	SUB	D	D△	
		Q	Q△	
		ESR	ER	
		G	G△	
		X	X△	
		B	B△	
		L	SL	
		C	SC	
		θ	T△	

NOTE: The mark △ in output codes represents a space.

Table 3-14. Functions of GP-IB Interface (Continued) (21/32)

8.2 Measured data (MAIN, SUB) output format

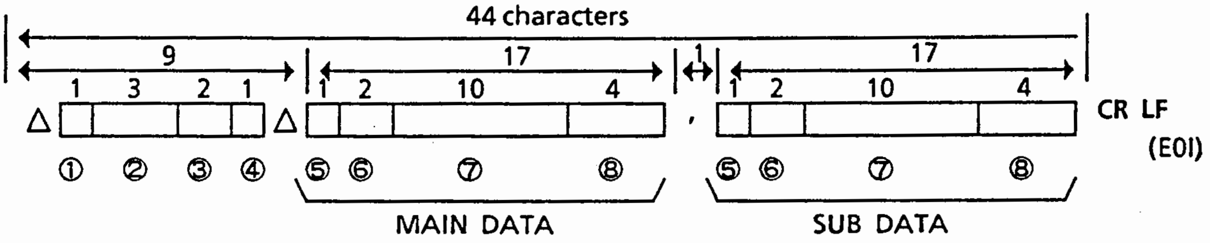
This apparatus starts measurement when remote program code E or GET message is received, and it outputs measured data when it is designated as the talker. The data is output in one of the two formats depending on the setting of the DIP switch DELIMITER on the rear panel.

(1) DELIMITER mode 0/1

When DELIMITER mode 0 or 1 is selected, measured data is separated by commas and output as one line.

NOTE: In DELIMITER mode 1, CR LF is not added, and EOI is output at the same time the final data is output.

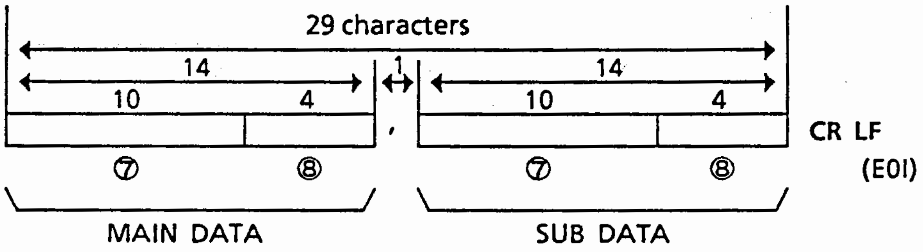
<HEADER ON (HR1)>



Example: ΔPF21V3ΔΔNΔCΔΔ23.05000E-09, NΔDΔΔΔ0.00120E + 00

Parallel Mode 1kHz, 1 V Range MEAS SPEED Normal	MAIN PARAMETER (C = 23.05nF)	SUB PARAMETER (D = 0.0012)

<HEADER OFF (HR0)>



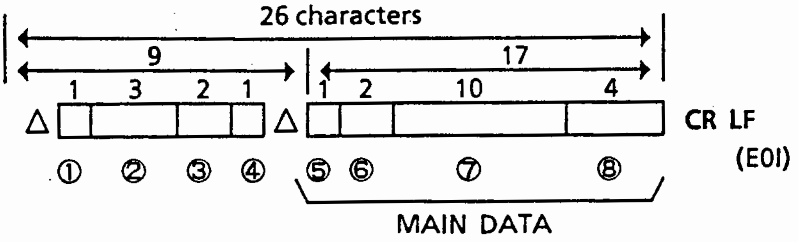
Example: ΔΔ23.05000E-09, ΔΔΔ0.00120E + 00

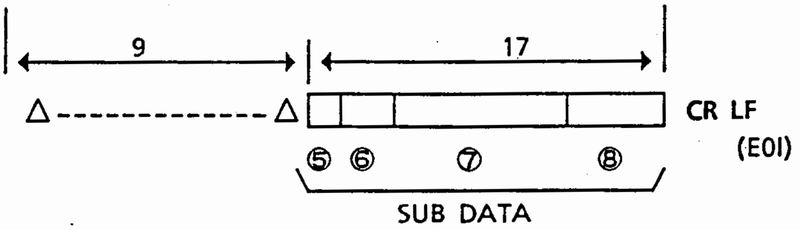
Table 3-14. Functions of GP-IB Interface (Continued) (22/32)

(2) DELIMITER mode 2

Measured data is divided into two lines and output.

<HEADER ON (HR1)>

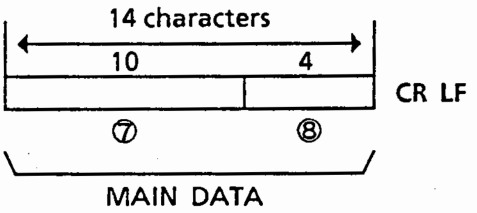


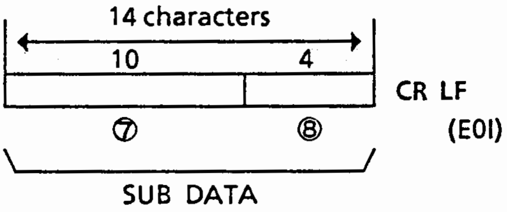


Example: △PF 21 V3△△N△C△△23.05000E−09

△△△△△△△△△N△D△△△0.00120E+00

<HEADER OFF (HR0)>





Example: △△23.05000E−09

△△△0.00120E+00

104

Table 3-14. Functions of GP-IB Interface (Continued) (23/32)

NOTES:

1) The mark △ represents a space. The circled numbers correspond to those in the table of data output codes.
2) When deviation measurement is OFF (D0) and comparator operation is ON (P1), the normal data status becomes comparator judgment result H, P, L, or W.
3) When the data status is O (OF), U (UF), or C (CF), numerical data is as shown in the table below.

Status	Numerical data
O	1E + 20
U	1E − 20
C	1E − 30

4) In the deviation measurement (DEVIATION △, △%) mode, a space is set in the SUB DATA part.
5) In the deviation percent measurement (DEVIATION △%) mode, the exponent part (⑧) is △PER for normal data.

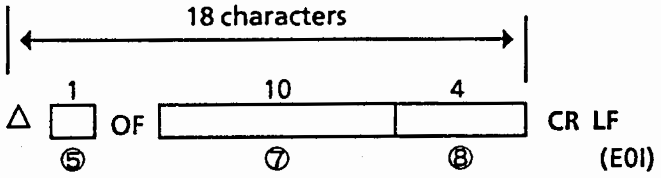
105

Table 3-14. Functions of GP-IB Interface (Continued) (24/32)

8.3 Measuring frequency output format

When remote program code OF is executed, the measuring frequency value (in Hz) is output in the following format.

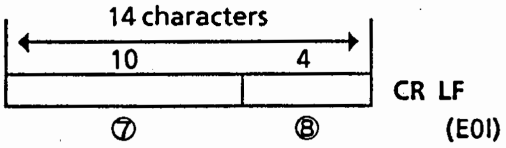
<HEADER ON (HR1)>



Example: 1 kHz

△NOF△△△1.00000E + 03

<HEADER OFF (HR0)>

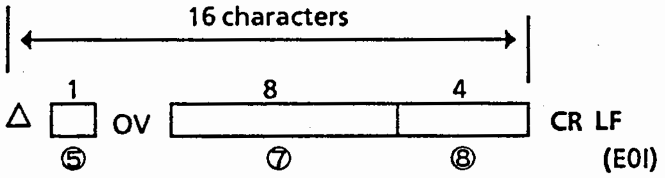


Example: △△△1.00000E + 03

8.4 Level range output format

When remote program code OV is executed, the value (in V) of the OSC level range is output in the following format.

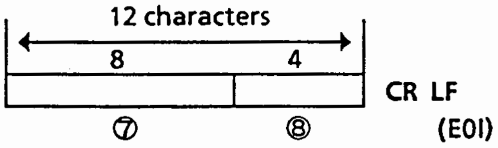
<HEADER ON (HR1)>



Example: 1 V range

△NOV△△△1.000E + 00

<HEADER OFF (HR0)>



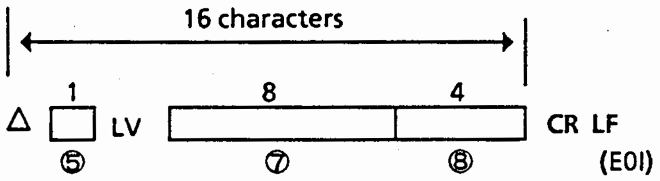
Example: △△△1.000E + 00

Table 3-14. Functions of GP-IB Interface (Continued) (25/32)

8.5 Signal voltage output format

When remote program code LV is executed, the value (in V) of the signal voltage applied to the sample is output in the following format.

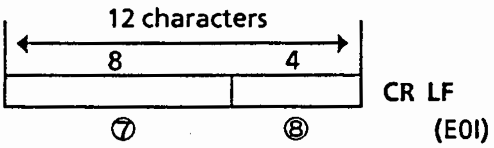
<HEADER ON (HR1)>



Example: 39.9 mV

ΔNLVΔΔ39.900E – 03

<HEADER OFF (HR0)>

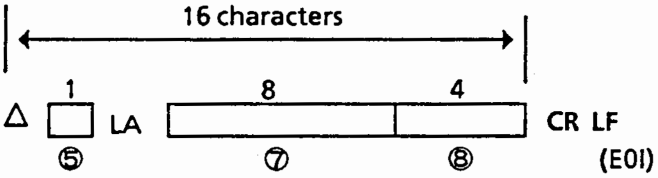


Example: ΔΔ39.900E – 03

8.6 Signal current output format

When remote program code LA is executed, the value (in A) of the signal current flowing through the sample is output in the following format.

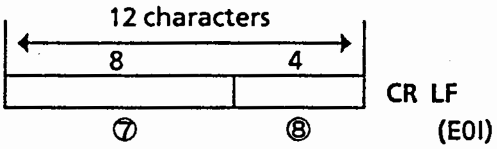
<HEADER ON (HR1)>



Example: 18.2 mA

ΔNLAΔΔ18.200E – 03

<HEADER OFF (HR0)>



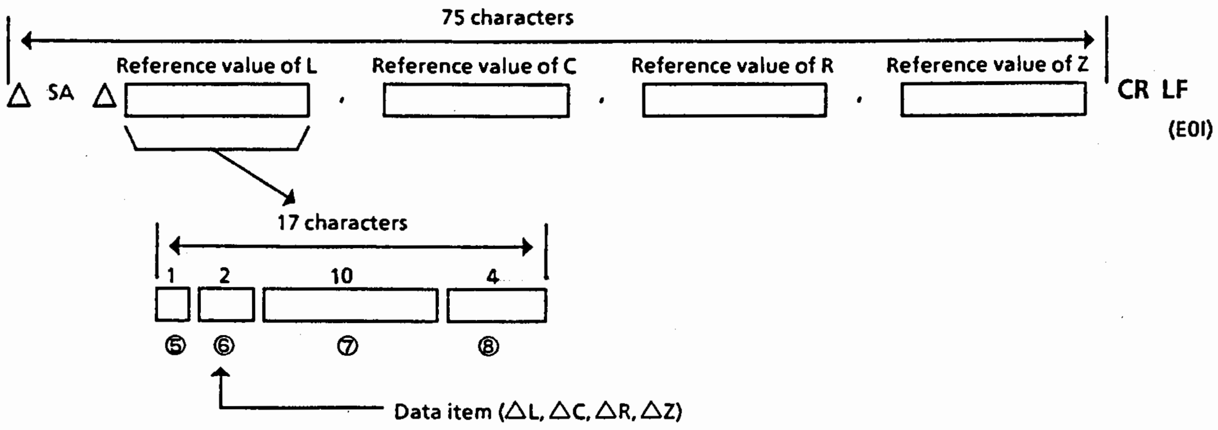
Example: ΔΔ18.200E – 03

Table 3-14. Functions of GP-IB Interface (Continued) (26/32)

8.7 Reference value output format

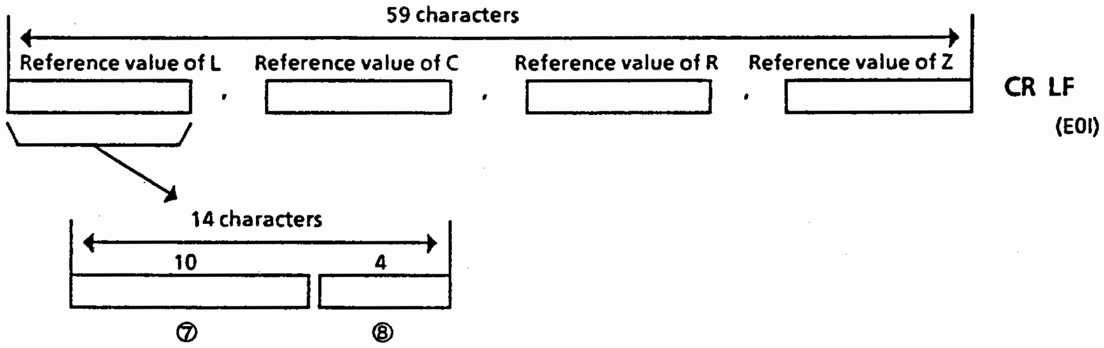
When remote program code SA is executed, the reference value is output in the following format.

<HEADER ON (HR1)>



Example: ΔSAΔNΔLΔΔΔ1. 00000E – 03, NΔCΔΔΔ1. 25000E – 09,
NΔRΔΔΔ1.20000E + 03, NΔZΔΔΔ4. 72000E + 00

<HEADER OFF (HR0)>



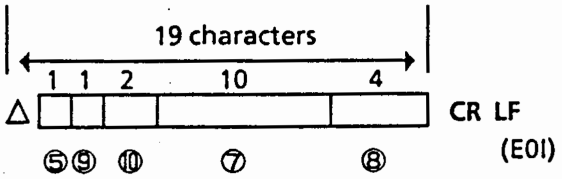
Example: ΔΔΔ1. 00000E – 03, ΔΔΔ1. 25000E – 09, ΔΔΔ1. 20000E + 03, ΔΔΔ4. 72000E + 00

Table 3-14. Functions of GP-IB Interface (Continued) (27/32)

8.8 Limit value output format

When remote program code $\boxed{\text{limit value code}}$ $\boxed{\text{parameter code}}$ is executed, the limit values are output in the following format.

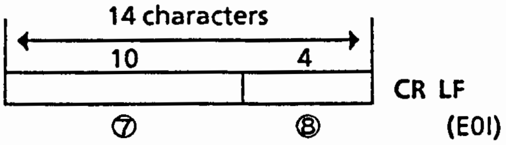
<HEADER ON (HR1)>



Example: When the lower limit for C is 1.23 pF

ΔNUCΔΔΔΔ1.23000E – 12

<HEADER OFF (HR0)>



Example: ΔΔΔ1.23000E – 12

8.9 Internal setting output format

When remote program code K is executed, the internal settings are output in the following format.

ΔA□□C□H□D□F□□V□R□□T□M□I□B□P□HR□ CR LF

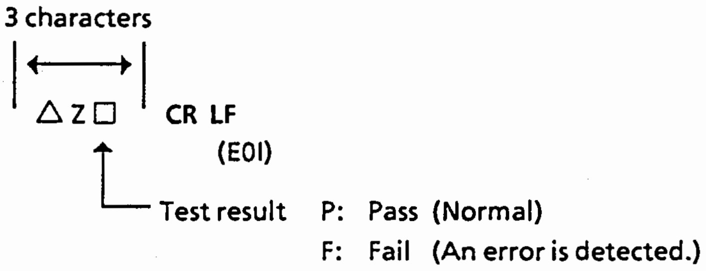
(1) (2) (3) (4) (6) (5) (7) (8) (9) (10) (11) (12) (13) (E0I)

NOTE: The numbers in ( ) correspond to the numbers listed in the table of remote program codes.

Table 3-14. Functions of GP-IB Interface (Continued) (28/32)

8.10 **Self test result output format**

When remote program code Z is executed, the result of the self test is output in the following format.



8.11 **Offset adjustment result output format**

When remote program code Y1 or Y2 is executed, offset adjustment is made and its result is output in the following format.

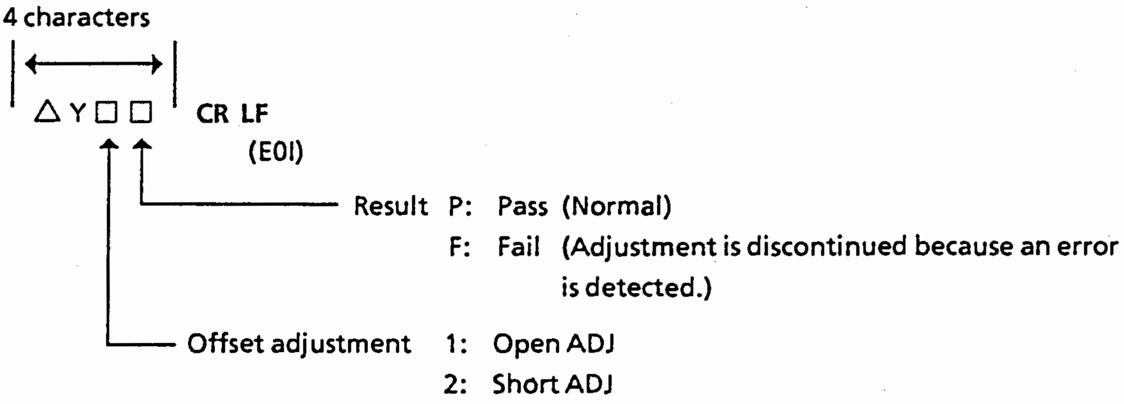


Table 3-14. Functions of GP-IB Interface (Continued) (29/32)

9. Service Request Status Byte (STB)

Remote program code I1 (SRQ READY) enables the apparatus to make a service request by serial polling. To use the service request function, set I1.

The contents of the status byte are shown below. If any one or more of the low-order four bits are set to 1, the RQS (Request Service) bit if set to 1 and the SRQ line turns true.

<STB bit arrangement>

BIT 7	6	5	4	3	2	1	0
0	RQS	0	0	TEST ERROR	TEST END	PROGRAM ERROR	DATA READY
(DIO8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)

BIT 6: RQS (Request Service)

If any event represented by bits 0-3 occurs, this bit is set to "1" causing the SRQ line to turn true.

BIT 3: TEST ERROR

If the self test or offset adjustment fails, this bit is set to "1".

BIT 2: TEST END

When the self test is terminated, this bit is set to "1".

BIT 1: PROGRAM ERROR

If an erroneous remote program code or numerical data is received, this bit is set to "1".

BIT 0: DATA READY

When data to be output after receipt of a remote program code has been prepared, this bit is set to "1".

Table 3-14. Functions of GP-IB Interface (Continued) (30/32)

10. TALK ONLY Mode

The TALK ONLY mode is entered when the TALK ONLY GP-IB address switch is set to ON. In the TALK ONLY mode, the address setting process as performed in the command mode is omitted so that data transfer by three-line handshaking can be made. If a proper output device, for example, a printer having the LISTEN ONLY function is connected to the apparatus, the measured values of the main parameter and subparameter can be output to it every time measurement is executed. For the data output format, see Section 8.2 in this table.

CAUTIONS

1) If MEAS START is set to AUTO, measurement is repeated, and data is output for each measurement.
2) As shown in 8.2, the data output format in the TALK ONLY mode varies depending on the DELIMITER MODE and HEADER ON/OFF settings.
   The DELIMITER MODE can be selected by the DIP switches on the rear panel, whereas HEADER ON/OFF control can be exercised only by remote program codes. Operation is performed according to the state (HR0 or HR1) entered when the TALK ONLY mode is set. The apparatus has been factory set to HEADER ON (HR1) prior to shipment.

112

Table 3-14. Functions of GP-IB Interface (Continued) (31/32)

11. Precautions on GP-IB Programming

(1) Procedures for starting measurement and reading data

To make measurement and read the measured data (MAIN, SUB) by remote control of the apparatus, proceed as follows.

① Designate the apparatus as a listener, and set the required functions. At the time, set the MEAS START to MANUAL (T2).

② Start measurement by issuing an E code or a GET message from the controller.
(The E code can start measurement whether it is specified together with the functions to be used or it is specified alone.)

③ Designate the apparatus as a talker, and read the measured data (MAIN, SUB).

REMARKS

If MEAS START is set to AUTO (T0), measurement is repeatedly made. When, with this condition maintained, measurement is started by an external signal from the GP-IB and the apparatus is designated as a talker, measured data is output if it has been obtained at the time when the apparatus is set as a talker.
When the apparatus is to be controlled by a measurement start signal from the GP-IB, set MEAS START to MANUAL (T2).

(2) Operation performed when output data overlaps

If a program code (e.g., E, K, OF, OV) involving data output is executed without designating the apparatus as a taker after executing such a program code, data for the latter program code is output.

If a program code involving output of two or more data is contained in one line, data for the last program code is output.

(3) Operation performed when a DCL (device clear) message is received

When a device clear message (DCL or SDC) is received from the controller, the following initial settings are set. If the apparatus is making measurement, self test, or offset adjustment, the processing is discontinued. Further, all service request status bytes are cleared.

FUNCTION	Initial setting	Program code	FUNCTION	Initial setting	Program code
PARAMETER	C-D	A10	MEAS START	AUTO	T0
CIRCUIT MODE	AUTO	C0	SIGNAL CHECK	OSC FREQ	M0
MEAS SPEED	NORMAL	H0	SRQ READY	OFF	I0
DEVIATION	OFF	D0	EXT DC BIAS	OFF	B0
OSC LEVEL	1V	V3	COMP ENABLE	OFF	P0
TEST FREQUENCY	1 kHz	F21	HEADER	ON	HR1
RANGE	AUTO	R00			

113

Table 3-14. Functions of GP-IB Interface (Continued) (32/32)

12. GP-IB Program Example

An example of GP-IB interface control by NEC's PC-9801 series personal computer system is shown below.

This program shows basic procedures for remotely controlling the apparatus and reading output data.

> REMARKS
>
> For details on the GP-IB programming by the personal computer, refer to the instruction manual for the computer.

<Program list>

(GP-IB address of the AG-4311B: 3)

```
100   REM AG-4311B GP-IB CONTROL PROGRAM (FOR PC-9801)
110   ISET IFC
120   ISET REN
130   CMD DELIM = 0
140   CMD TIMEOUT = 5
150   PRINT@ 3;"T2, E"
160   LINE INPUT@ 3;A$
170   PRINT A$
180   WBYTE 3 + 32, 1;
190   IRESET REN
200   END
```

<Output data example>

```
      PF21V3  N C  23. 05000E-09, N D    0.00120E + 00
```

<Explanation of the program list>

Line 110	Transmission of IFC (interface clear)
Line 120	REN (remote enable) is set to true.
Line 130	Specification of a delimiter (CR + LF)
Line 140	Time-out specification
Line 150	Transmission of remote program codes T2 and E
Line 160	Data from the AG-4311B is stored in A$.
Line 170	The contents of A$ are displayed on the console.
Line 180	Transmission of a GTL (Go To Local) command
Line 190	REN is set to false.

114

3.20 ERROR INDICATION

If an improper key setting or erroneous sample connection is detected, an error indication appears on the main display. The meanings of the error indications are explained in Table 3-15. If an error indication is output, locate the cause by referring to the table and take proper corrective action.

Table 3-15. Error Indications

MAIN DISPLAY	Explanation
Err01	• This indication appears if a residual parameter value is found to be beyond the limit value during offset adjustment in the open or short ADJ mode. If this error indication appears, the correction value is initialized to zero. (Offset adjustment in the open ADJ mode and that in short ADJ mode are independent of each other.)
Err02	• This indication appears if either of the following reference value setting errors is committed; the presently valid reference value is retained. ① Pressing the STORE key with the main display showing an OF or UF indication, or no measured value. ② Pressing the STORE key with the deviation measurement mode (△ or △%) already set.
Err03	• This indication appears if any of the following operation errors for deviation measurement is detected. ① Specifying deviation measurement without any reference value set ② Specifying △% mode with the reference value being 0.
Err04	• This indication appears if an operation error associated with the reference value or limit values (upper and lower limits). ① An attempt is made to input a value outside the allowable range. ② The lower limit is greater than the upper limit.
Err05	• This indication appears if a program error is detected during GP-IB interface operation, that is, if unprocessible data is given by the GP-IB interface.
Err06	• This indication appears if the RANGE UP or DOWN key is pressed after the upper or lower measurement range limit is reached, or if a measuring range inconsistent with the set frequency is selected. If this indication appears, the nearest allowable range is automatically set.
Err07	• This indication appears if an open circuit or a broken wire is detected in the measuring jigs (test fixture, leads, etc.) connected to the UNKNOWN terminals.
Err08	• This indication appears if either of the following errors is committed for measurement by the use of an external frequency. ① Making measurement with an external frequency signal connected to the apparatus but without any external frequency specified. ② Specifying an external frequency outside the range of 1.6 kHz to 1.6 MHz.
Err09	• This indication appears if a control signal issued for the external frequency data interface is found improper.

116

3.21 BASIC INSPECTION AND MAINTENANCE PROCEDURES

(1) Initial Indication and Memory Back-up Check

Immediately after power is initially turned on, the setting of the GP-IB address switch is shown on the main display. If TALK ONLY is OFF, the display *Ad-* is followed by the GP-IB address. If TALK ONLY is ON, nothing is displayed (the GP-IB status LED TALK comes on).

At the same time, a memory back-up check is made; if an abnormality is detected in the stored data, an error indication is shown on the sub display.

REMARKS

If a memory back-up error indication (*Err00*) is given, immediately replace the battery. (For the battery replacement procedure, refer to Appendix B.)

In the event of a memory back-up error, the apparatus is automatically set to the initial settings (shown in Table 3-16), so the apparatus may be used without installing a battery.

Table 3-16. Memory Back-up and Initial Settings

No.	FUNCTION	Memory back-up	Initial setting	Remarks
1	PARAMETER	○	C-D	• The mark x in the memory back-up column indicates that the initial value is set when power is turned on.
2	CIRCUIT MODE	○	AUTO	
3	MEAS SPEED	○	NORMAL	
4	DEVIATION	○	OFF	
5	OSC LEVEL	○	1V	
6	TEST FREQUENCY	○	1kHz	
7	RANGE	○	AUTO	
8	MEAS START	○	AUTO	
9	SIGNAL CHECK	○	FREQUENCY	
10	SRQ READY	x	OFF	
11	COMP ENABLE	○	OFF	
12	EXT DC BIAS	x	OFF	
13	HEADER	x	ON	
14	REF VALUE	○	Not set	
15	LIMIT VALUE	○	Not set	
16	EXT TEST FREQ	○	Not set	
17	OFFSET ADJ	x	Correction value cleared	

117

(2) Self Test

After the memory back-up check is made (or GP-IB remote program code Z is received), a self test is carried out.

The self test is a basic check made to ensure that the apparatus performs operations properly. Perform the following steps to check that the self test is normally made.

① LED turn-on check

All LEDs on the panel are lit for about 0.8 second. Visually check that all LEDs are on.

② Main internal circuit operation check

Six minus signs (–) are shown on the main display to indicate that a self diagnosis is started. The self diagnosis consists of six steps. First, the leftmost minus sign turns into *8*, which means execution of step 1. After completion of step 1, the *8* display successively moves to the right and steps 2-6 are performed. If an abnormality is detected during the self diagnosis, the *8* display stays at the step in which the abnormally is found, an error indication is shown on the sub display, and the apparatus proceeds to the next step. The alarm displays in each step and their meanings are given in Table 3-17.

REMARKS

If an error indication is given during the main internal circuit operation test, make the following checks.

(1) Check that the LEVEL FINE adjuster is set at MAX (the rightmost position).
(2) Check that the EXT CONTROL connector on the rear panel is open.

If the same error indication is given immediately after power is turned on again, the apparatus may not operate properly.

118

Table 3-17. Self Test Error Indications

Step	MAIN DISPLAY	SUB DISPLAY	Function
1	*8* - - - - -	*Err10*	• A key open check of the front panel is made. If a key is held down or is faulty, this error indication is given.
		Err11	• The $\overline{\text{EXT}\cdot\text{MST}}$ signal at the rear panel EXT CONTROL connector is checked for openness. If the $\overline{\text{EXT}\cdot\text{MST}}$ signal is at the "L" level (shorted or faulty), this error indication is given.
2	- *8* - - - -	*Err20* *Err21* *Err22*	• The A/D converter is divided into three block and each block is checked for proper operation in the NORMAL MEAS SPEED mode. If an abnormality is detected in any of these blocks, an error indication is given.
		Err23 *Err24* *Err25*	• The A/D converter is divided into three blocks and each block is checked for proper operation in the FAST MEAS SPEED mode. If an abnormality is detected in any of these blocks, an error indication is given.
3	- - *8* - - -	*Err30* *Err31*	• The analog measuring section is divided into two blocks and each block is checked for proper gain control. If an abnormality is detected in any of these blocks, an error indication is given.
4	- - - *8* - -	*Err40* *Err41*	• The analog measuring section is divided into two blocks and each block is checked for proper range operation. If an abnormality is detected in any of these blocks, an error indication is given.
5	- - - - *8* -	*Err50* *Err51*	• The analog measuring section is divided into two blocks and each block is checked for proper ATT control. If an abnormality is detected in any of these blocks, an error indication is given.
6	- - - - - *8*		(No Operation)

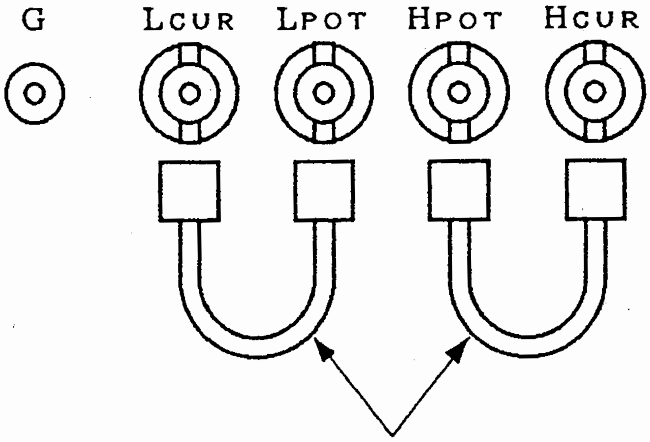
(3) Periodic Inspection

Periodic inspections are effective in obtaining optimum performance from the apparatus throughout its life and finding the malfunctioning elements, if any, before a trouble occurs. Inspection periods are determined according to the conditions of operation and storage.

The apparatus is designed and constructed to give long periods of stable and reliable service with a minimum amount of maintenance. However, it is recommended that periodic inspection be performed once or twice a year.

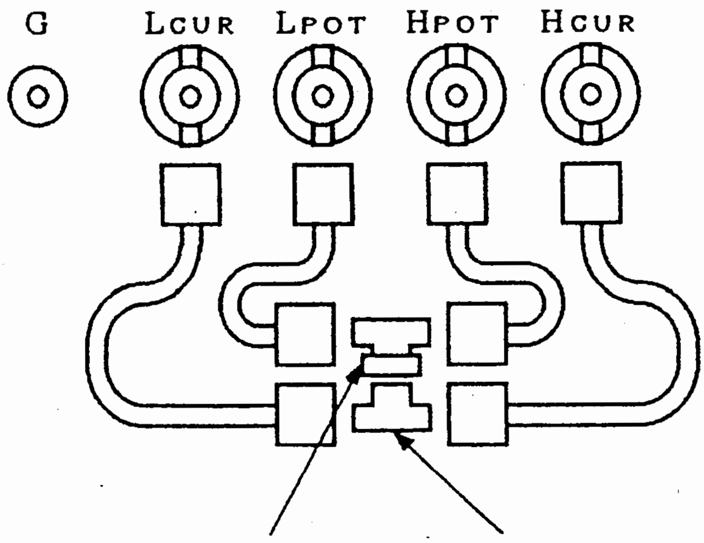
The procedures for making basic periodic inspections are shown in Table 3-18.

Table 3-18. Basic Periodic Inspections

No.	Inspection Item	Inspection Procedure
1	Self test	This self test is performed immediately after power is turned on. Check that no error indication is given.
2	Open connection check	① Have on hand two about 10 cm-long coaxial cables with BNC plugs on both ends, and connect H_{CUR} with H_{POT} and L_{CUR} with L_{POT}, using these cables. ② Set the measurement parameter to C-G, the measurement range to AUTO, the level range to 1 V, the measuring frequency to 1 kHz, and the LEVEL FINE adjuster to MAX. ③ Check that the indications of C and G are about 0 pF and about 0 μS, respectively, in the AUTO MEAS START mode. ④ Display the signal voltage and signal current on the check display, and check that the signal voltage is 1 V or more and the signal current is 0 mA. ⑤ Make open ADJ and check that the adjustment is normally made.  Coaxial cables with BNC plugs on both ends REMARKS Open connection may be made by connecting no sample with the AG-4911 Test Fixture.

120

Table 3-18. Basic Periodic Inspections (Continued)

No.	Inspection Item	Inspection Procedure
3	Short connection check	① Have on hand four about 10 cm-long coaxial cables with BNC plugs on both ends and two T-shaped adapters, and short all measuring terminals together, using these cables and adapters. ② Set the measurement parameter to R-X, the measurement range to AUTO, the level range to 1 V, the measuring frequency to 1 kHz, and the LEVEL FINE adjuster to MAX. ③ Check that the indications of both R and X are about 0 Ω in the AUTO MEAS START mode. ④ Display the signal voltage and signal current on the check display, and check that the signal voltage is about 0 V and the signal current is about 20 mA or more. ⑤ Make short ADJ and check that the adjustment is normally made.  T-shaped adapter A (e.g., BNC-TA-JPJ, UG-274/U) T-shaped adapter B (e.g., BNC-TA-JJJ) REMARKS Short adjustment may be made by inserting a low-impedance lead wire into the AG-4911 Test Fixture.
4	Measured value check	Measure a standard sample whose data is already known, and check the measured value. REMARKS Use a stable sample that varies little with temperature or time.

(3) Troubleshooting

If it seems that the apparatus does not operate properly, locate and remove the cause of trouble, referring to Table 3-19.

REMARKS

If the apparatus is obviously at fault, immediately turn power off, remove the power cord, and report the trouble and the serial number marked on the rear panel to your nearest Ando dealer for inspection and repair.

Table 3-19. Troubleshooting

No.	Problem	Remedy
1	Nothing is displayed even if the power switch is turned on.	● Check if the power cord is disconnected from the plug module or if the power cord is broken. ● Check if the power fuse is blown.
2	The power fuse is blown.	● Check if the fuse is an appropriate one. ● Check if the supply voltage is correct.
3	*Err00* is displayed when power is turned on.	● Replace the battery. (For the battery replacement procedure, refer to Appendix B.)
4	An error indication is given during self test.	
	Err 10	● Check if a key is held down.
	Err 11	● Check that the EXT CONTROL connector on the rear panel is open.
	Err 20 ~ *Err 51*	● The apparatus is obviously at fault. Contact your local dealer to ask for repair.
5	No measurement can be made even if a sample is connected, or an abnormal value is displayed.	● Check the measuring jigs (test fixture, test leads, etc.) for abnormality. (Check for broken or shorted cables or poor contacts.)
6	No external DC bias voltage is developed at the H_{CUR} terminal.	● Check if the fuse in the rear panel EXT DC BIAS section is blown.

Appendix A. Top Cover Removing Procedure

The PC board installed in the apparatus is equipped with a memory back-up battery and DIP switches. When the battery is to be replaced or the DIP switch settings are to be changed, remove the top cover and the internal shield cover, performing the following steps.

CAUTION

After the top cover and the internal shield cover is removed for battery replacement or DIP switch setting change, do not tamper with the internal circuitry of the apparatus except the specified portions.

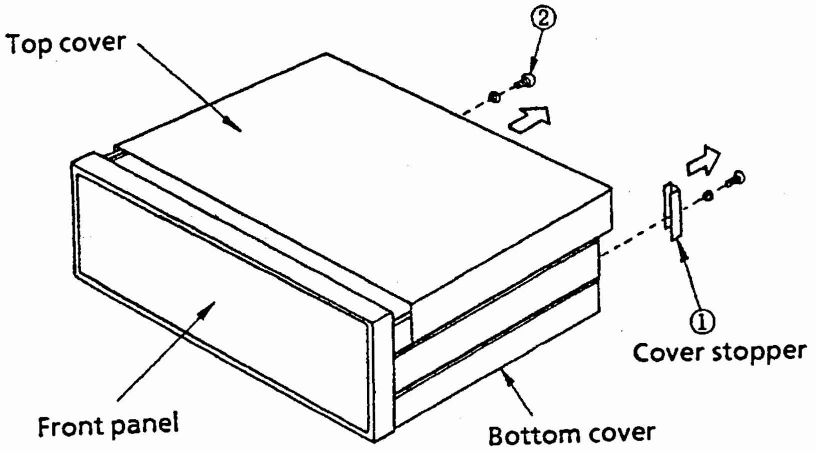
(1) Set the power switch to OFF, and remove the power cord.

NOTE

Before removing the cover, be sure to set the power switch to OFF and remove the power cord.

(2) Loosen off the two rear panel cover stopper-retaining screws ①, and remove the cover stoppers.

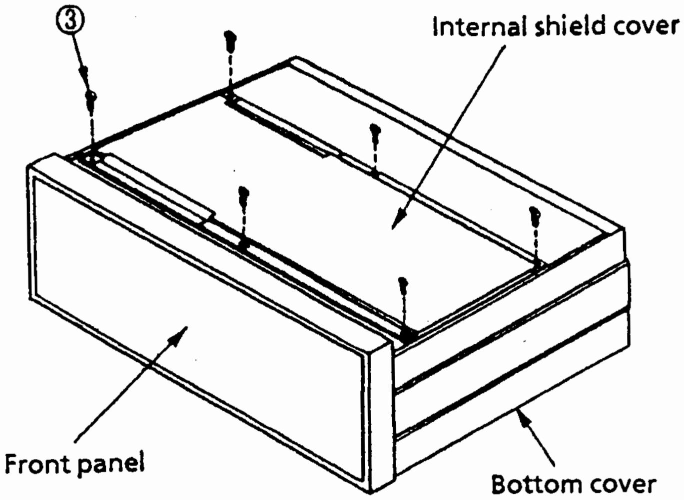
(3) Loosen off the top cover-retaining screw ②, and remove the top cover by sliding it toward the rear panel.



123

Appendix A. Top Cover Removing Procedure (Continued)

(4) When the top cover is removed, the internal shield cover is exposed to view. Loosen off the six internal shield cover-retaining screws ③, and remove the internal shield cover.



(5) Replace the battery or change the DIP switch settings, referring to Appendix B or C.

REMARKS

For battery replacement, refer to Appendix B. For internal DIP switch setting change, refer to Appendix C.

(6) Reinstall the internal shield cover.

CAUTION

When reinstalling the shield cover, be careful so that the coaxial cables for internal wiring may not be caught between the board shelf bend and the shield cover.

(7) Reinstall the top cover and cover stoppers.

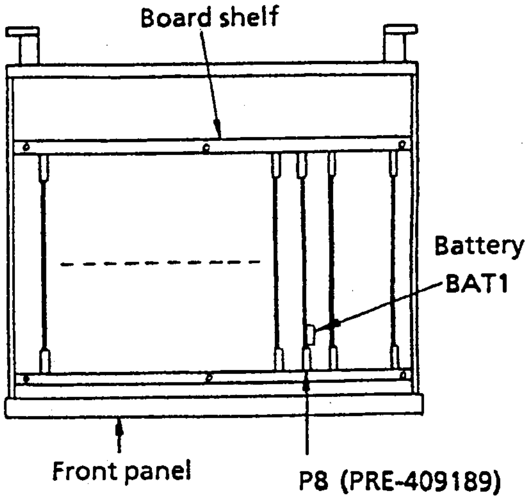
Appendix B. Battery Replacement Procedure

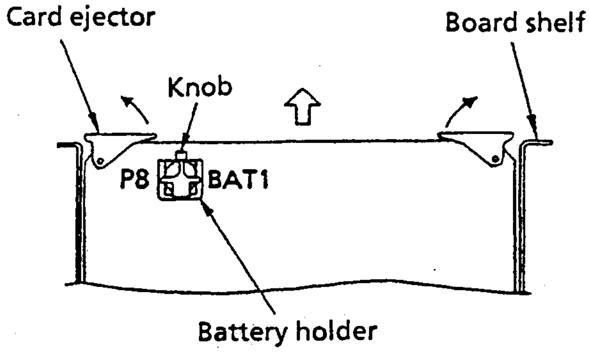
The memory back-up battery is installed in the battery holder on the PC board P8 (PRE-409189) inside the apparatus. If the battery is obviously low on power (a memory back-up error indication (*Err00*) is displayed at all times), replace the battery, performing the following steps.

(1) Remove the top cover and internal shield cover, performing the steps (1) through (4) given in Appendix A.

(2) When the internal shield cover is removed, the PC board P8 is exposed to view. Its location is shown in the right figure.

The PC board P8 is of plug-in type. Slowly raise the card ejector to remove the PC board from the board shelf. While holding the card ejector with your fingers, draw out the PC board P8 from the board shelf.





REMARKS

The battery is installed in the battery holder (BAT1) shown in the right figure.

(3) Remove the battery by lifting the knob of the battery holder on the PC board P8.

REMARKS

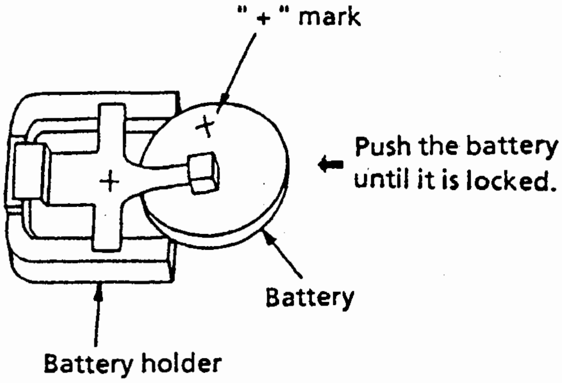
The battery slips out of the battery holder by lifting the battery holder knob with the card ejector facing downward.

Appendix B Battery Replacement Procedure (Continued)

(4) Have a new battery on hand, and install it into the battery holder with the " + " mark on the battery up.

REMARKS

Battery used: CR2032 Lithium battery



CAUTION

When installing the battery, be careful not to reverse the battery polarity.

(5) Reinstall the PC board P8 into the board shelf.

REMARKS

Align the PC board P8 with the board shelf slot, and push the PC board into the board shelf, while applying equal forces to the two card ejectors with your thumbs. After pushing the PC board into the board shelf, check if it is securely installed.

CAUTION

The PC board P8 should be installed into the board shelf so that its component side may be on the righthand side (as viewed from the front panel). When inserting the PC board into the board shelf, use care not to apply excessive forces to the PC board.

(6) Reinstall the internal shield cover and top cover, performing the steps (6) and (7) given in Appendix A.

126

Appendix C Functions of the Internal DIP Switches

The PC boards P8 (PRE-409189) and P9 (PRE-409190) inside the apparatus are provided with DIP switches. By using these DIP switches, the PASS/NG tone frequency for comparator operation and key buzzer ON/OFF setting can be set.

To change the DIP switch settings, perform the following steps.

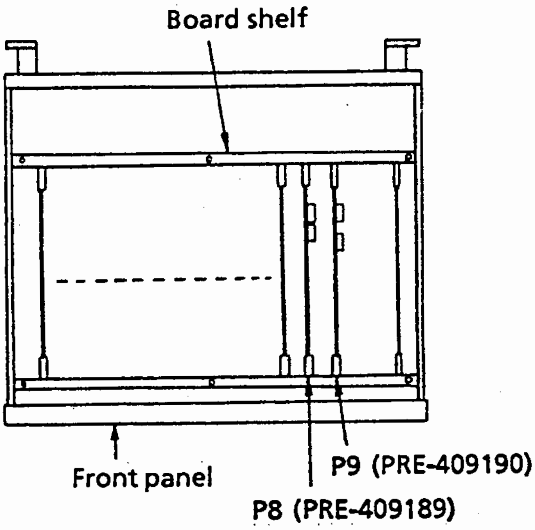
(1) Remove the top cover and internal shield cover, performing the steps (1) through (4) given in Appendix A.

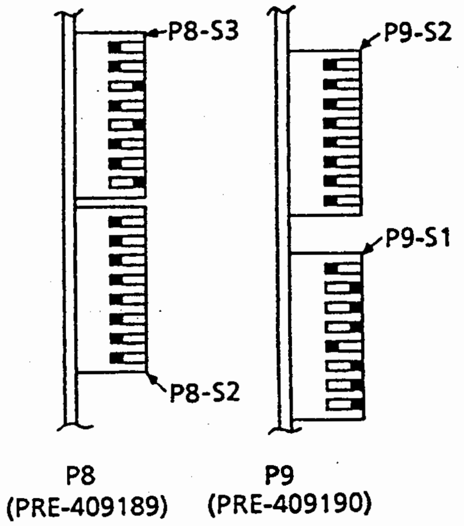
(2) When the internal shield cover is removed, the PC boards P8 and P9 are exposed to view. Their locations are shown in the right figure.

The PC board P8 is provided with DIP switches S2 and S3, and the PC board P9 is provided with DIP switches S1 and S2. Their locations are shown in the lower right figure. (The figure is the one viewed from the top side of the board shelf.)

Before changing the DIP switch settings, the description of the DIP switch functions should be thoroughly read and understood.

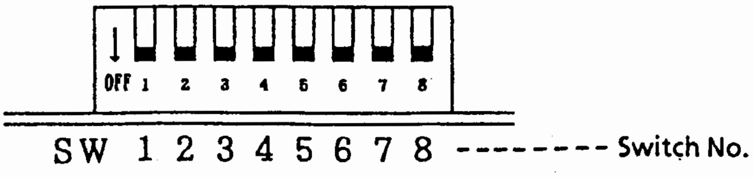
(3) After changing the settings, reinstall the internal shield cover and top cover, performing the steps (6) and (7) given in Appendix A.





Appendix C Functions of the Internal DIP Switches (Continued)

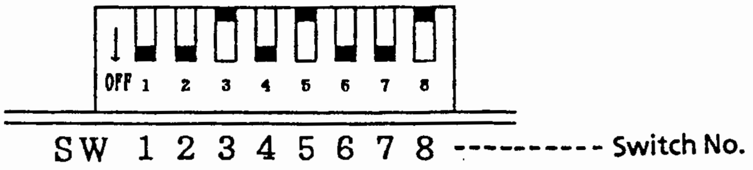
P8-S2



Switch No.	Function	Standard Setting
SW1		OFF
SW2	● EXT CONTROL connector PASS relay contact output OFF: Relay operation is performed. ON : No relay operation is performed ($\overline{\text{PASS}}$ at all times).	OFF
SW3		OFF
SW4		OFF
SW5		OFF
SW6		OFF
SW7		OFF
SW8		OFF

Appendix C Functions of the Internal DIP Switches (Continued)

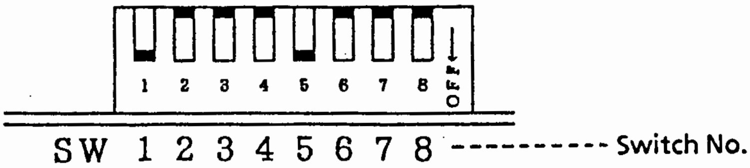
P8-S3



<table>
<tr><th>Switch No.</th><th>Function</th><th>Standard Setting</th></tr>
<tr><td>SW1</td><td>● Buzzer tone produced when the key is pushed.
OFF: The buzzer sounds.
ON : The buzzer does not sound.</td><td>OFF</td></tr>
<tr><td>SW2</td><td>● Buzzer tone produced when an external measurement start signal is received
OFF: The buzzer sounds.
ON : The buzzer does not sound.</td><td>OFF</td></tr>
<tr><td>SW3</td><td rowspan="3">● Frequency of the PASS tone from the loudspeaker
<table>
<tr><th>SW3</th><th>SW4</th><th>SW5</th><th>Frequency</th><th></th></tr>
<tr><td>OFF</td><td>OFF</td><td>OFF</td><td>OFF (No tone)</td><td></td></tr>
<tr><td>OFF</td><td>OFF</td><td>ON</td><td>500 Hz</td><td></td></tr>
<tr><td>OFF</td><td>ON</td><td>OFF</td><td>800 Hz</td><td></td></tr>
<tr><td>OFF</td><td>ON</td><td>ON</td><td>1 kHz</td><td></td></tr>
<tr><td>ON</td><td>OFF</td><td>OFF</td><td>1.5kHz</td><td></td></tr>
<tr><td>ON</td><td>OFF</td><td>ON</td><td>2 kHz</td><td>←Standard setting</td></tr>
<tr><td>ON</td><td>ON</td><td>OFF</td><td>3 kHz</td><td></td></tr>
<tr><td>ON</td><td>ON</td><td>ON</td><td>3.4kHz</td><td></td></tr>
</table></td><td>ON</td></tr>
<tr><td>SW4</td><td>OFF</td></tr>
<tr><td>SW5</td><td>ON</td></tr>
<tr><td>SW6</td><td rowspan="3">● Frequency of the NG tone from the loudspeaker
<table>
<tr><th>SW6</th><th>SW7</th><th>SW8</th><th>Frequency</th><th></th></tr>
<tr><td>OFF</td><td>OFF</td><td>OFF</td><td>OFF (No tone)</td><td></td></tr>
<tr><td>OFF</td><td>OFF</td><td>ON</td><td>500 Hz</td><td>←Standard setting</td></tr>
<tr><td>OFF</td><td>ON</td><td>OFF</td><td>800 Hz</td><td></td></tr>
<tr><td>OFF</td><td>ON</td><td>ON</td><td>1 kHz</td><td></td></tr>
<tr><td>ON</td><td>OFF</td><td>OFF</td><td>1.5kHz</td><td></td></tr>
<tr><td>ON</td><td>OFF</td><td>ON</td><td>2 kHz</td><td></td></tr>
<tr><td>ON</td><td>ON</td><td>OFF</td><td>3 kHz</td><td></td></tr>
<tr><td>ON</td><td>ON</td><td>ON</td><td>3.4kHz</td><td></td></tr>
</table></td><td>OFF</td></tr>
<tr><td>SW7</td><td>OFF</td></tr>
<tr><td>SW8</td><td>ON</td></tr>
</table>

Appendix C Functions of the Internal DIP Switches (Continued)

P9-S1



REMARKS: P9-S1 consists of a switch for selecting either the unit (UNIT)/decimal point (DP) internal setting mode or the external setting mode (EXT TEST FREQ DATA connector) for the external frequency data interface, and switches for internal setting of a unit and decimal point.

Switch No.	Function	Standard Setting
SW1	• Unit data external setting/internal setting selection OFF: EXT (By UTD0-UTD2 signals through the EXT TEST FREQ DATA connector) ON : INT (By the settings of SW2-SW4)	OFF
SW2	• Unit data internal setting (see table below)	ON
SW3		ON
SW4		ON
SW5	• Decimal point data external setting/internal setting selection OFF: EXT (By DPD0-DPD2 signals through the EXT TEST FREQ DATA connector) ON : INT (By the settings of SW6-SW8)	OFF
SW6	• Decimal point data internal setting (see table below)	ON
SW7		ON
SW8	REMARKS: For decimal point positions DP0-DP5, refer to Table 3-12 Functions of the External Frequency Interface.	ON

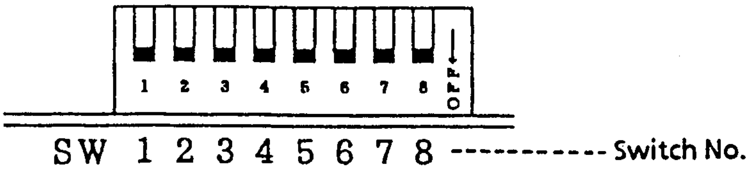
SW2	SW3	SW4	Unit	
ON	ON	ON	Hz	←Standard setting
OFF	ON	ON	kHz	
Other settings			kHz	

SW6	SW7	SW8	Decimal point position	
ON	ON	ON	DP0	←Standard setting
OFF	ON	ON	DP1	
ON	OFF	ON	DP2	
OFF	OFF	ON	DP3	
ON	ON	OFF	DP4	
OFF	ON	OFF	DP5	
Other settings			DP5	

130

Appendix C Functions of the Internal DIP Switches (Continued)

P9-S2



Switch No.	Function	Standard Setting
SW1	GP-IB exponent part output data in the △% mode OFF: △PER (△: Indicates a space.) ON : E+00	OFF
SW2		OFF
SW3		OFF
SW4		OFF
SW5		OFF
SW6		OFF
SW7		OFF
SW8		OFF

MEMO:

Table 1. List of Standard Accessories

No.	Accessory Name	Qty	Remarks
1	Power cord	1	About 2.8 m in length
2	Voltage conversion adapter	1*1	For 3-pole/2-pole conversion For 100/120 VAC
3	Power fuse	2*2	1 A (for 100/120 VAC) or 0.5 A (for 220/240 VAC) 1 installed, 1 reserved
4	DC bias fuse	1	0.1 A (for DC biasing) 1 installed, 1 reserved
5	57-30140 connector	1	For the external control interface
6	57-30500 connector	1	For the external frequency data interface
7	Instruction manual	1	

NOTES

*1 Supplied when the power cord is of UL-3P type.

*2 A 1A fuse is supplied when the supply voltage is 100 or 120 VAC, and a 0.5A fuse is supplied when the supply voltage is 220 or 240 V.
(The spare power fuse is installed in the fuse holder in the AC line connector module.)

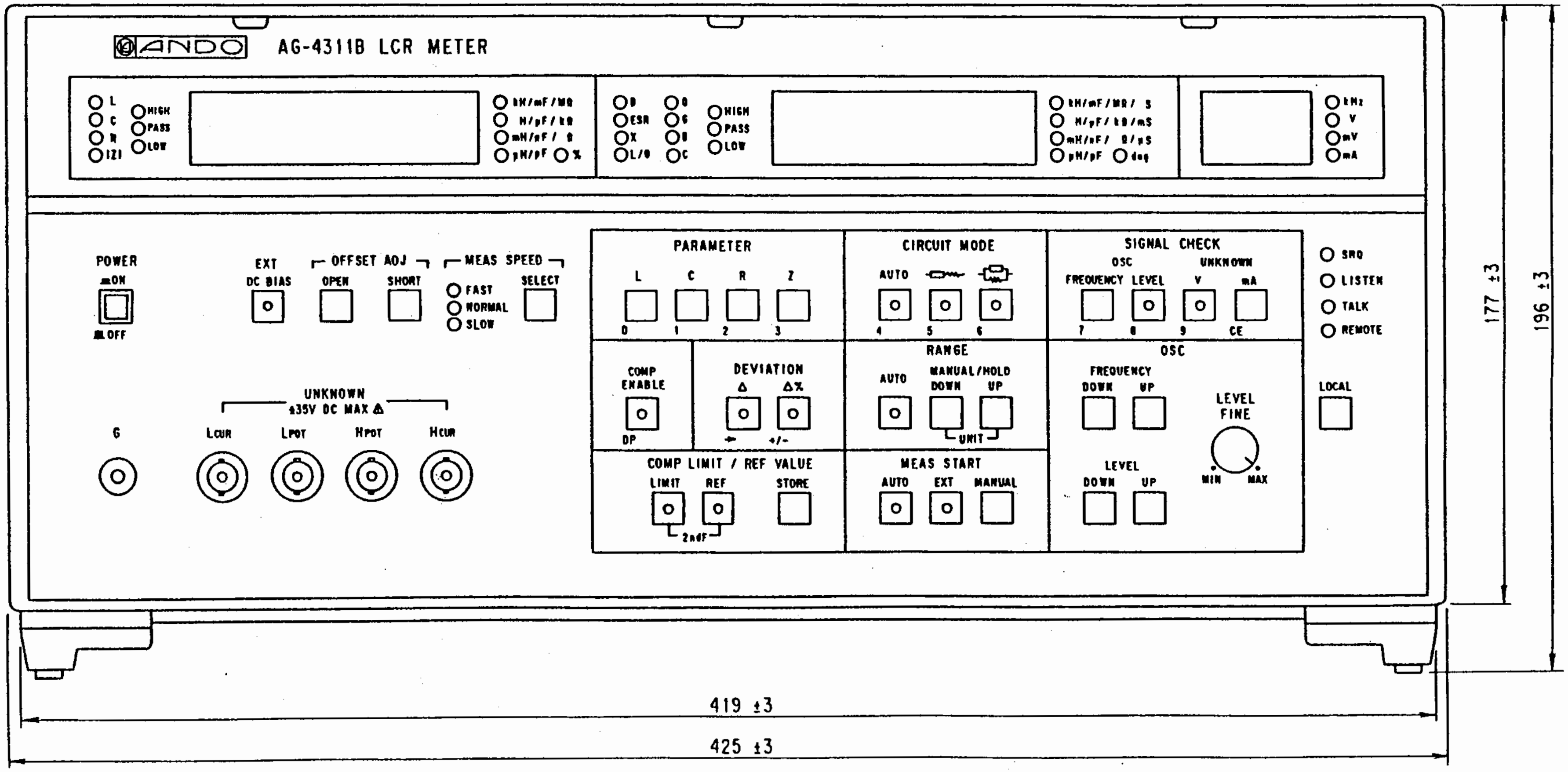


Fig. 1 Front Panel View of AG-4311B LCR METER

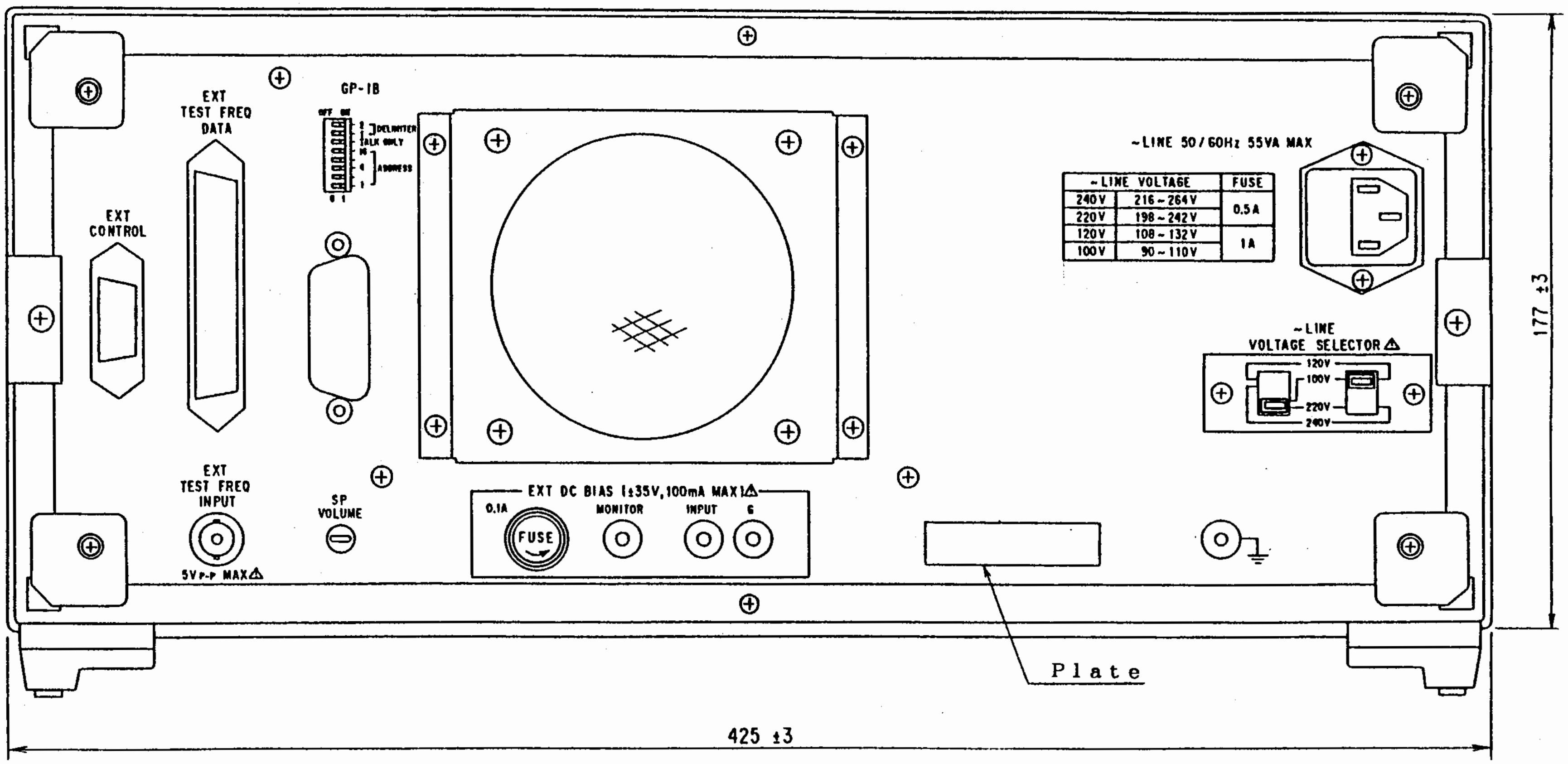
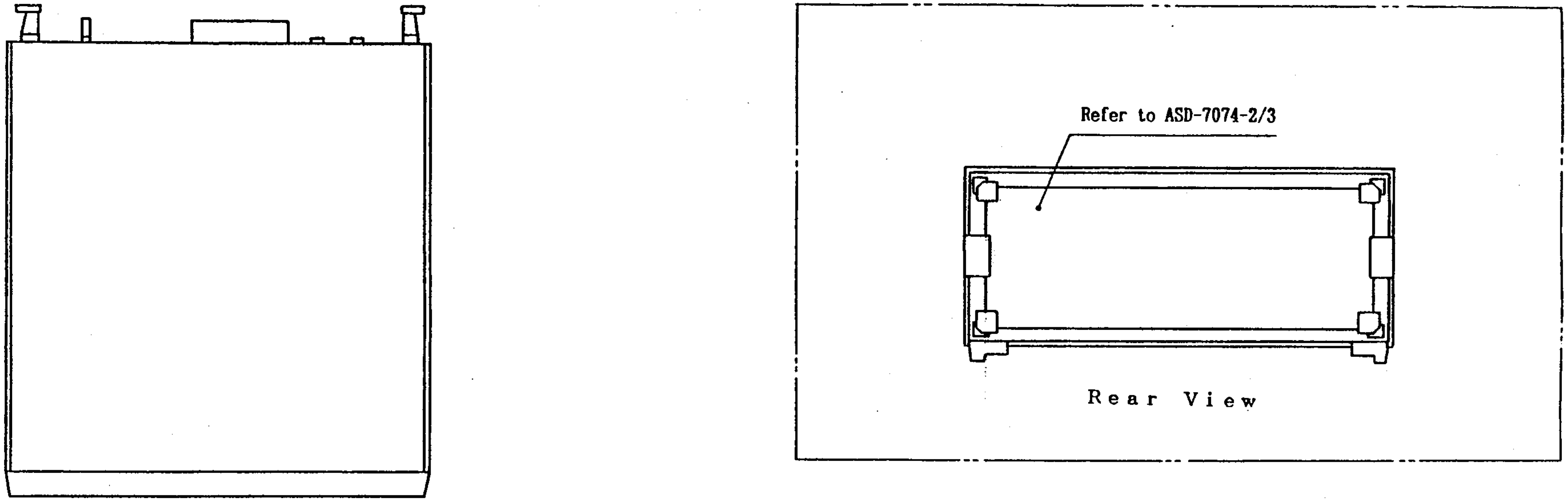
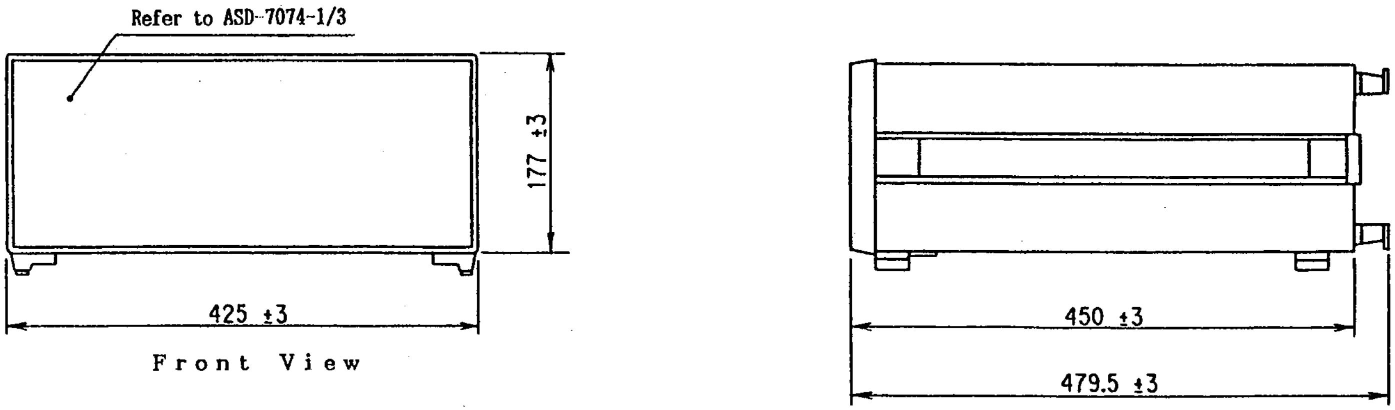


Fig. 2 Rear Panel View of AG-4311B LCR METER



Top View

Rear View



Front View

Side View

Fig. 3 Outside View of AG-4311B LCR METER

NOTES

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(2) The contents of this manual are subject to change without prior notice.

(3) Reasonable efforts have been taken in the preparation of this manual to assure its accuracy. However, if you find an error or omission in the manual or if you have any question on its contents, contact your Ando dealer.

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