MODEL 161D

AC VOLTMETER

OPERATION MANUAL

KIKUSUI ELECTRONICS CORP

CONTENTS

1. GENERAL DESCRIPTION

Kikusui Electronics' Model 161D is a transistorized high-sensitivity voltmeter which desplays the mean value of the AC voltage measured. Using semiconductor elements in all circuits, Model 161D is compact, lightweight and consuming little power.

Model 161D consists of an impedance converter having a high input impedance, a voltage divider, a preamplifier, an indicator circuit an output section, and a voltage regulator circuit.

Model 161D measures an AC voltage within a range of 1 mV ~ 300 V_{RMS} (-60~+52 dBm, -60~ +50 dBV) whose frequency is 5 Hz ~ 3 MHz.

It has ten measureing ranges in 10 dB steps, and the meter scale is graduated in equal divisions by the effective value of sine wave. Further, Model 161D can give an AC voltage output of approximately 1 V in full scale from the output terminal. Therefore, measurement can be monitored or the equipment can be used as a preamplifier.

2. SPECIFICATIONS

Type of Instrument	AC voltmeter	
Model	161D	
Meter	105 mm in scale length, two-colored scale, 1 mA full-scale.	
Graduation	Effective value of sine wave, and dBm value with respect to 1 mW 600 Ω, dBv value with 0 dBv to 1.0 V.	
Input:		
Input Terminals	UHF-type receptacle and GND terminal, 19 mm (3/4") spacing.	
Input Resistance	1 MΩ for each range	
Input Capacitance	10 mV ~ 1 V ranges	30 pF or less
	3 V ~ 300 V ranges	20 pF or less
Maximum Input voltage	AC component	300 V in effective value ±450 V in peak value
	DC component	±400 V
Ranges	10 ranges:	
	On RMS scale	10/30/100/300 mV and 1/5/3/10/30/100/300 V
	On dBm and dBv scale	-40/-30/-20/-10 and 0/10/20/30/40/50 dB
Accuracy	±3% of full scale at 1 kHz	

Stability	Less than 0.2% of full scale against ±10% fluctuation of power voltage	
Temperature coefficient	0.05%/°C TYP at 1 kHz	
Frequency Response	5 Hz ~ 3 MHz	±10% with respect to 1 kHz
	10 Hz ~ 1 MHz	±5% with respect to 1 kHz
	20 Hz ~ 500 kHz	±3% with respect to 1 kHz
	Less than 1% by short-circuiting the input terminals.	
Output:		
Output Terminals	5-way type, 19 mm (3/4") spacing	
Output Voltage	Approximately 1 V at full scale	
Distortion Factor	Less than 2% at full scale and 1 kHz	
Frequency Response	10 Hz ~ 1 MHz	$^{+1}_{-3}$ dB
Ambient temperature & humidity	0°C ~ 45°C, less than 85%	
Power Requirement	__________V, 50/60 Hz, approx. 3.5 VA	
Dimensions	140 (D) x 150 (W) x 200 (H) mm	
(Maximum)	(186 (D) x 160 (W) x 213 (H) mm)	
Weight	Approx. 2.5 kg	
Accessories	Type 941B terminal adaptor	1
	Operation manual	1
	Test data	1

3. OPERATION

3.1 Parts on front panel (See Fig. 3-2)

(1)	POWER	A push button switch turning on and off power supply, and the power is supplied in the state that the button is pushed and stands back, and when the button is pushed again, the power is turned off. For about 10 seconds after the switch is turned on, the meter pointer may possibly deflect irregularly.
(2)	Range	Black dial in the center of the panel. 10 ranges; 10 mV ~ 300 V (clockwise)
(3)	INPUT terminals	Terminals to which the voltage to be measured will be connected. They consist of a UHF receptacle and a GND (ground) terminal. For connection, a UHF-type (5/8"-24) or M-type (16ø - 1P) plug, or a standard (spacing: 3/4"=19mm) dual banana plug is suitable. A banana plug may be connected to the center conductor of the receptacle. Also, by inserting the accessory "Kikusui Type 941B Terminal Adapter, "a banana plug, spade lug, alligator clip, 2-mm tip

or a lead wire 2 mm or less in diameter can be connected.

The outer conductor of the receptacle and the GND terminal are electrically connected to the panel and chassis.

④ Output terminals

Output terminals for using Model 161D as an amplifier. For connection, a standard dual banana plug with a coaxial cable is convenient. A banana plug, spade lug, alligator clip, 2-mm tip or lead wire 2 mm or less in diameter is usable similarly to that for the input terminals. The black terminal is the grounding side. This equipment can perform both as a voltmeter and as an amplifier simultaneously.

However, if load impedance is too low, several deficiencies are caused as follows.

When resistive component of the load impedance is too low, the lower end of frequency response is sacrificed in the output circuit. However, the frequency response up to output circuit is not affected.

When capacitive component of the load impedance is dominant, the higher end of frequency response is significantly affected, Figure 3-1 shows an example of the effect of capacitance connected to the output terminals on the frequency response of the amplifier. However, this effect may vary among each voltmeter and as to power line voltage.

Influence of capacity load to metering circuit gradually increases around high frequency.

It is approximately by 1 persent.

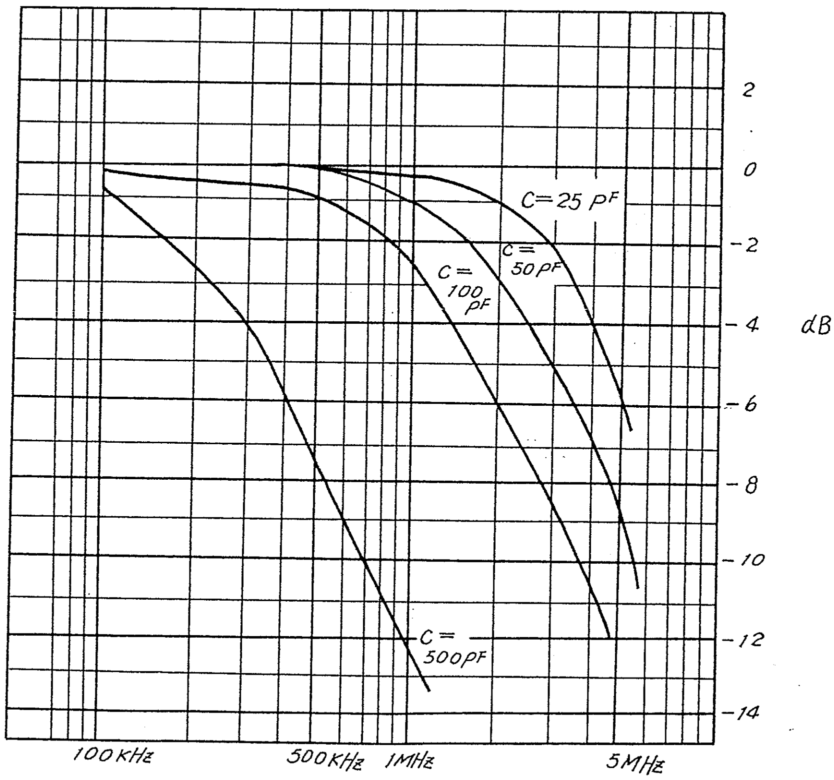


Fig. 3-1

⑤ Meter

The meter has the following scales;

1. "1-scale" This scale is used with 10/100 mVand 1/10/100 V ranges.

2. "3-scale" This scale is used with 30/300 mV and 3/30/300 V ranges.
3. "dBv-scale" This scale is used to read 1.0 V in the dBv value with respect to 0 dBv. This scale is used for all 10 ranges, -40 ~ 50 dB.
4. "dBm-scale" This scale is used to read the measured voltage in the dBm value with respect to 1 mW, 600 Ω. This scale is used for all 10 ranges, -40 ~ +50 dB.

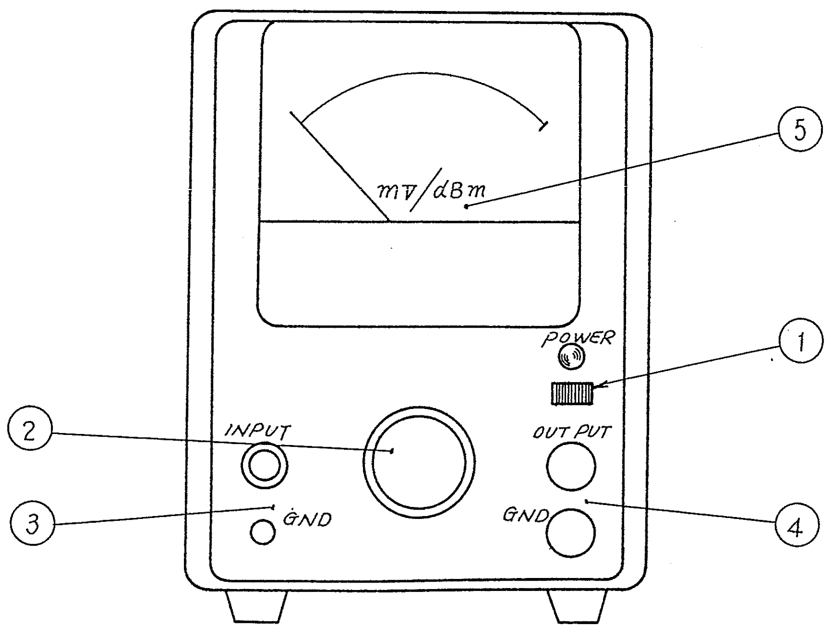


Fig. 3-2

3.2 Preparation for measuring operation

(1) Turn off the power switch.

(2) Check that the meter pointer is at the center of the zero point on the scale. If not, conduct zero adjustment.

The zero adjustment during use should be effected more than five minutes after the power switch is turned off so that the pointer settles near the zero point.

(3) Connect the power cord to the required power source.

(4) Set the range switch dial to the 300 V range position.

(5) Turn on the power switch, and above the switch will be illuminated.

For about 10 seconds after the power switch is turned on, the meter pointer may possibly deflect irregularly. This irregular pointer deflection may also occur when the power switch is turned off.

(6) When the meter pointer settles, Model 161D is ready for a measuring operation.

3.3 Measurement of AC voltage

(1) Using the 1 and 3 scales of the meter as appropriate, read the display as in Table 3-1.

Table 3-1

Range		Scale	Multiplier	Voltage Unit
10 mV	-40 dB	1	x 10	mV
30 "	-30 "	3	"	"
100 "	-20 "	1	x 100	"
300 "	-10 "	3	"	"
1 V	0 "	1	x 1	V
3 "	10 "	3	"	"
10 "	20 "	1	x 10	"
30 "	30 "	3	"	"
100 "	40 "	1	x 100	"
300 "	50 "	3	"	"

Example: When the meter indicates 2.7 in the 30 V range, it should be read as 27 volts. When the meter indicates the same value is the 300 mV range, it should be read as 270 millivolts or 0.27 volts. In the same manner the meter indication of 6 should be read as 6 volts in the 10 V range, and 60 millivolts in the 100 mV range.

(2) When measuring a voltage by the dBm value with respect to 1 mW, 600 Ω, use the dBm scale, common to all ranges, and read the display as follows:

The "0" marked in the middle of the dB scale denotes the level the range name represents; therefore, the measured value will be the meter reading plus the dB value the range name represents.

Example: With range switch placed in 30 dB (30 volt) range, if meter indication is 2 dBm scale, the dBm value of the measured voltage is;

2 + 30 = 32 dBm

Example: In this condition, if range switch is turned to 40 dB range, meter pointer now indicates -8 dBm scale.

The dBm value is then;

-8 + 40 = 32 dBm

Example: With range switch placed in -20 dB (100 mV) range, if meter indication is -1 dBm scale, the measured voltage is:

-1 + (-20) = -21 dBm

Example: In this condition, if range switch is turned to -10 dB (300 mV) range, meter pointer now indicates -11 dBm scale.

The dBm value is therefore:

-11 + (-10) = -(11 + 10) = -21 dBm

(3) When measuring a voltage by the dBv value with respect to 1.0V, use the dBv scale, common to all ranges, and read the display as the above mentioned.

Example: With range switch placed in 30 dB (30 volt) range, if meter indication is -2 dBv scale, the dBv value of the measured voltage is:

-2 + 30 = 28 dBv

Example: In this condition, if range switch is turned to 40 dB range, meter pointer now indicates -12 dBv scale.

The dBv value is then;

-12 + 40 = 28 dBv

Example: With range switch placed in -20 dB (100 mV) range, if meter indication is -5 dBv scale, the measured voltage is:

-5 + (-20) = -25 dBv

Example: In this condition, if range switch is turned to -10 dB (300 mV) range, meter pointer now indicates -15 dBv scale.

The dBv value is therefore;

-15 + (-10) = -25 dBv

3.4 Measurement of AC current

When using Model 161D for measuring an AC current, let the current (I) flow through a known non-inductive resistance (R), measure the voltage across the resistance, and calculate I = E/R. In this case, note that the negative (-) terminal of the input terminals of Model 161D is grounded.

For the convenience of current measurement, Type 921 Shunt Resistors which have standard resistances of 0.1, 1, 10, 100 and 1000Ω, respectively, are available as optional accessories. Also available are 4, 8, 16 and 600 Ω resistors. Each resistance can be connected to the input terminals of Model 161D by using banana plugs.

Example: To measure the heater current (nominal: 6.3V, 0.3 A) of a vacuum tube, connect the circuit to Model 161D as in Fig. 3-3 by using Type 921-0.1 (resistance: 0.1 Ω) as the standard resistance.

If 29 mV is read on Model 161D, the heater current will be

$$I = \frac{29 \times 10^{-3}}{0.1} = 290 \times 10^{-3} = 290 \text{ (mA)}$$

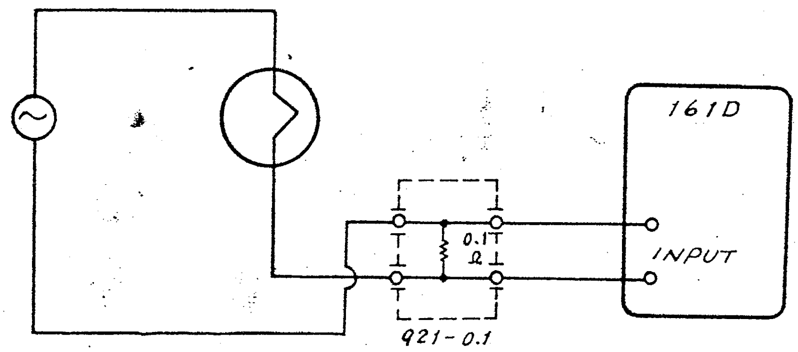


Fig. 3-3

3.5 Use of Model 161D as output meter

By measuring the voltage (E) applied across an impedance (X), the apparent power (VA) of the impedance can be obtained by solving $VA = E^2/X$. If the impedance is ohmic resistance (R) the power (P) consumed in the resistance will be

$$P = E^2/R$$

Since Model 161D has a dBm scale, the power can be read in decibels as it is, provided R = 600 Ω. If the load resistance is within the range from 1 Ω to 10 kΩ, the power can be read in decibels by adding the value obtained from the decibel conversion charts, Fig. 3-4 and 3-5.

Type 921 Shunt Resistors having resistance of 4, 8 and 16Ω, respectively, which are identical with the voice coil impedances of the loudspeakers in general use, are available. They can be utilized as a load resistance of small capacity when using Model 161D as an output meter.

3.6 Waveform error

Model 161D is a "mean value" voltmeter that indicates a value proportional to the mean value of the measured voltage.

Since the meter scale is calibrated by the effective value of sine wave, however, the correct effective value may not be displayed, giving rise to an error, when a voltage distorted in waveform is measured. Table 3-2 shows this relationship.

Table 3-2

Measured Voltage	Effective Value	Model 161D Display
100%-amplitude fundamental	100%	100%
100% fundamental + 10% second harmonic	100.5	100
100% fundamental + 20% second harmonic	102	100 - 102
100% fundamental + 50% second harmonic	112	100 - 110
100% fundamental + 10% third harmonic	100.5	96 - 104
100% fundamental + 20% third harmonic	102	94 - 108
100% fundamental + 50% third harmonic	112	96 - 116

3.7 Use of decibel conversion table and charts

(1) Decibel

"Bel" is a logarithmic (common) unit expressing the ratio of two powers. One "decibel" (abbreviated dB) is one-tenth of a Bel. The dB is defined as follows:

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

That is, how large the power P_2 is in comparison with the power P_1 is represented with 10 times the common logarithm.

If the impedances at the places where P_1 and P_2 exist are equal to each other, the ratio of powers may be expressed with the ratio of voltages or currents as follows:

$$dB = 20 \log_{10} \frac{E_2}{E_1} \quad \text{or} \quad 20 \log_{10} \frac{I_2}{I_1}$$

Decibel is originally the ratio of powers as explained above. However, the common logarithm of the ratio of other values has also been called "decibel" for a long time. For example, when the input voltage of an amplifier is 10 V/10 mV = 1,000 times. This is also expressed in dB as follows:

$$\text{Degree of amplification} = 20 \log_{10} \frac{10\ V}{10\ mV} = 60\ (dB)$$

Also, the output voltage of a standard RF signal generator is expressed in dB to represent how many times of 1 μV the output voltage is. An output of 10 mV, for example, is

$$10\ \text{mV} = 20 \log_{10} \frac{10\ \text{mV}}{1\ \mu\text{V}} = 80\ (\text{dB})$$

Such a decibel notation must have the reference, namely, 0 dB, clarified. For example, the output voltage of the above signal generator should be expressed "80 dB (1 µV = 0 dB)."

(2) dBm

"dBm" is abbreviation of dB (mW). This decibel value expresses the power ratio with respect to 1 mW that is 0 dB. Normally "dBm" implies the condition that the power exists in an impedance of 600Ω.

So "dBm" generally means "dB (mV 600Ω)."

As mentioned before, if the power and impedance are definite, the decibel can express voltage and current as well as power. Therefore, "0 dBm" signifies the following:

0 dBm = 1 mW or 0.775 V
or 1.291 mA

The decibel scale of Model 161D is graduated by the dBm value as explained above. Therefore, when measuring a decibel value that is expressed with respect to other than " 1 mW 600Ω, " the reading on Model 161D should be corrected. Because of the character of logarithm, this correction can be effected by adding a value to the reading, referring to Table 3-4 and Fig. 3-5.

(3) Use of decibel conversion table and charts

Fig. 3-4 is used to convert the ratio of values into a decibel value.

Different decibel scales are provided for power (or equivalent) and voltage (or current) ratios.

Example: How many decibels is 5 mW with respect to 1 mW?

Since this is a power ratio, the left scale is used. From the power ratio of 5 mW/1 mW = 5.7 dB (mW) is obtained as shown with a dotted line in Fig. 3-4.

Example: How many decibels are 50 and 500 mW with respect to 1 mW?

When the ratio is 0.1 or less, or 10 or more, the decibel value is obtained by using Fig. 3-4 and Table 3-5. as follows:

50 mW = 5 x 10 = 7 + 10 = 17 dB

500 mW = 5 x 100 = 7 + 20 = 27 dB

Table 3-3

Ratio		Decibel	
		Power Ratio	Voltage or Current Ratio
10.000	= 1×10^{4}	40 dB	80 dB
1.000	= 1×10^{3}	30 "	60 "
100	= 1×10^{2}	20 "	40 "
10	= 1×10^{1}	10 "	20 "
1	= 1×10^{0}	0 "	0 "
0.1	= 1×10^{-1}	-10 "	-20 "
0.01	= 1×10^{-2}	-20 "	-40 "
0.001	= 1×10^{-3}	-30 "	-60 "
0.0001	= 1×10^{-4}	-40 "	-80 "

Example: What is 15 mV in dB(V)?

Since 1 V is the reference, 15 mV/1 V = 0.015 is calculated first. By using the voltage (current) scale of Fig. 3-4, and Table 3-3,

$0.015 = 1.5 \times 0.01 \rightarrow 3.5 + (-40) = -36.5$ dB(V)

or

1 V/15 mV $= 66.7 \times 10 \rightarrow 16.5 + 20 = 36.5$ dB(V)

$\therefore -36.5$ dB(V)

(4) Use of decibel addition chart

Fig. 3-5 is used for obtaining the power from the dBm value read out from Model 161D.

Example: When the voltage across the voice coil, having an impedance of 8Ω, of a loudspeaker is measured by Model 161D, the meter indicates -4.8 dBm. What is the power (more precisely, apparent power) in watts supplied to the speaker? By using Fig. 3-5, the value to be added, corresponding to 8Ω, is obtained to be +18.8 as shown with a dotted line in Fig. 3-5.
The power expressed in dB (mW 80Ω) is obtained by adding the +18.8 to the meter reading, as follows:

dB (mV 8Ω) = -4.8 + 18.8 = +14

This 14 dB (mW 8Ω) is converted, by using Fig. 3-4, into the following wattage:

14 dB (mW 8Ω) 25 mW

Example: What voltage in volts should be applied to supply a power of 1 W to a load of 10 kΩ ?

Since 1 W is 1,000 mW, it is 30 dB (mW): therefore, the voltage corresponding to 30 dB (mW 10 kΩ) is the value being sought. A value of -12. 2 to be added for the 600Ω, 10 kΩ conversion is obtained from Fig. 3-5.

Therefore, the meter indication on Model 161D should be 30 - (-12. 2) = 42. 2 on the dB (mW 600Ω) scale.

The voltage with which Model 161D indicates 42. 2 - 40 = 2. 2 dBm on the 40 dBm range (0 ~ 100 V) is the value sought. That is, 42. 2 dBm = 100 V.

4. PRINCIPLE OF OPERATION

Model 161D AC Voltmeter consists of an input section, a preamplifier, a meter driver, an output terminal, and a power supply.

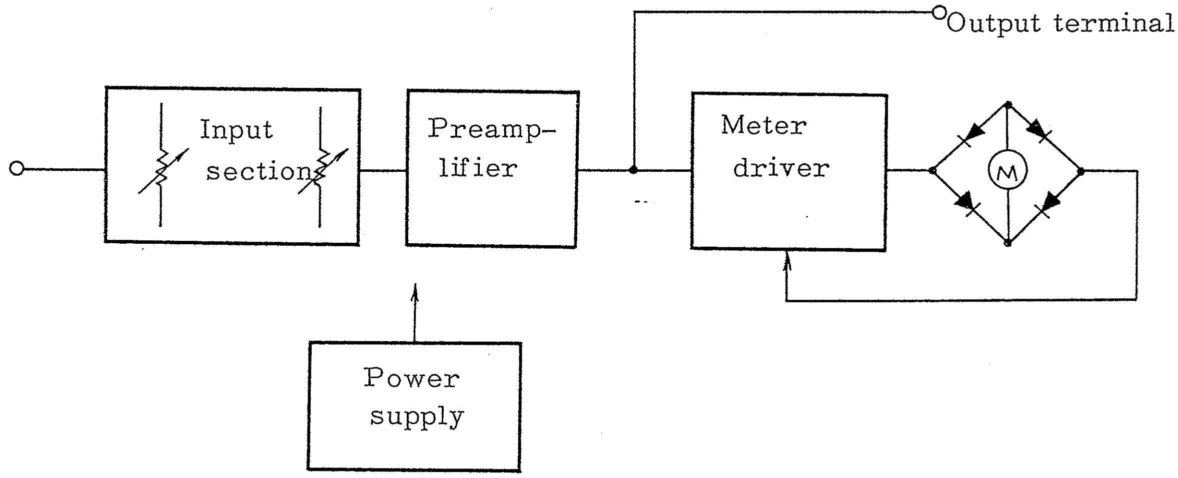


Fig. 4-1

4.1 Input section

The input section consists of a voltage pre-divider (0/50 dB), an impedance converter, and a main voltage divider composed of five ranges in 10 dB steps (0/10/20/30/40) as shown in Fig.4-2.

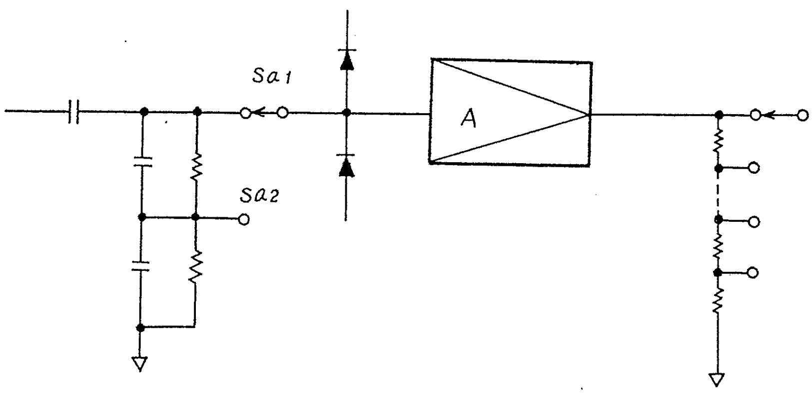


Fig. 4-2

For 10 mV ~ ..1 V ranges, the range switch is connected to contact Sa_1; for 3 ~ 300 V ranges, to contact Sa_2. The input having passed the voltage pre-divider enters the impedance converter. The converter consists of transistors Q_1 and Q_2, with the FET in the first stage. The high-impedance signal is converted into low-impedance output and then supplied to the main voltage divider.

The main voltage divider divides the signal to approximately 10 mV according to the signal level.

4. 2 Preamplifier

The preamplifier is a negative feedback amplifier, consisting of three transistors, for amplifying the faint signal delivered from the input section.

4. 3 Meter driver

This is an amplifier using transistor Q_6.

A current feedback is applied from the collector to base through rectifier diodes.

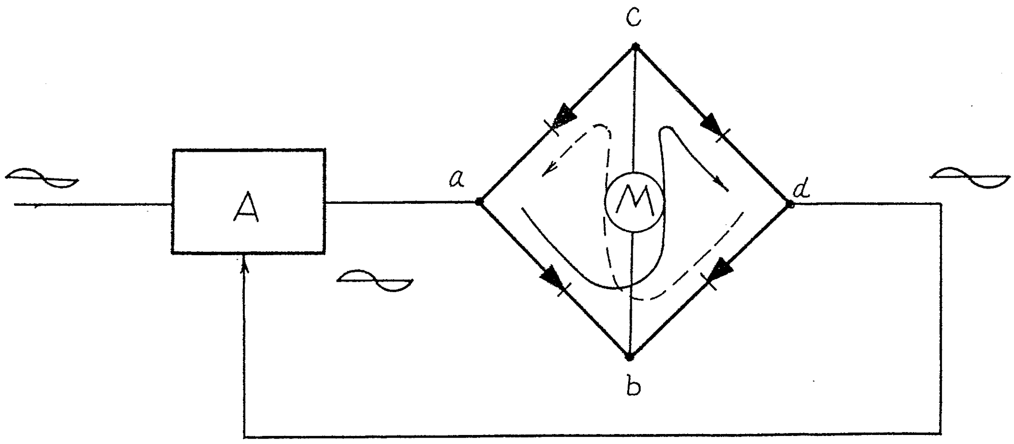


Fig. 4. 3

For the above reason, the diodes are driven with nearly constant current, improving the non-linearity of diode and enabling linear meter indication. Fig. 4-3 illustrates the performance. During the positive output voltage cycle of the amplifier, current flows a→b→c→d as shown with a solid line; during the negative cycle, current flows d→b→c→a as shown with a dotted line. This makes the meter be driven according to the mean value of the current flow.

4.4 Output terminal

The collector voltage of transistor Q_4 in the preamplifier taken outside.

The output terminal gives an output of approximately 1 V at the full-scale meter indication.

4.5 Power supply

The power supply has regulated +25V output.

The +25 V voltage regulator circuit uses the reference voltage produced zener diod amplifies the error by transistor Q_8, and conducts series control by transistor Q_7 to obtain the regulated voltage.

5. MAINTENANCE

5.1 Inspect parts inside the cabinet.

When it is necessary to inspect parts inside the cabinet, remove one plus screws located on the rear of the cabinet, and pull out to the front. Location of components, with the side panels removed, is illustrated in Fig. 5-1

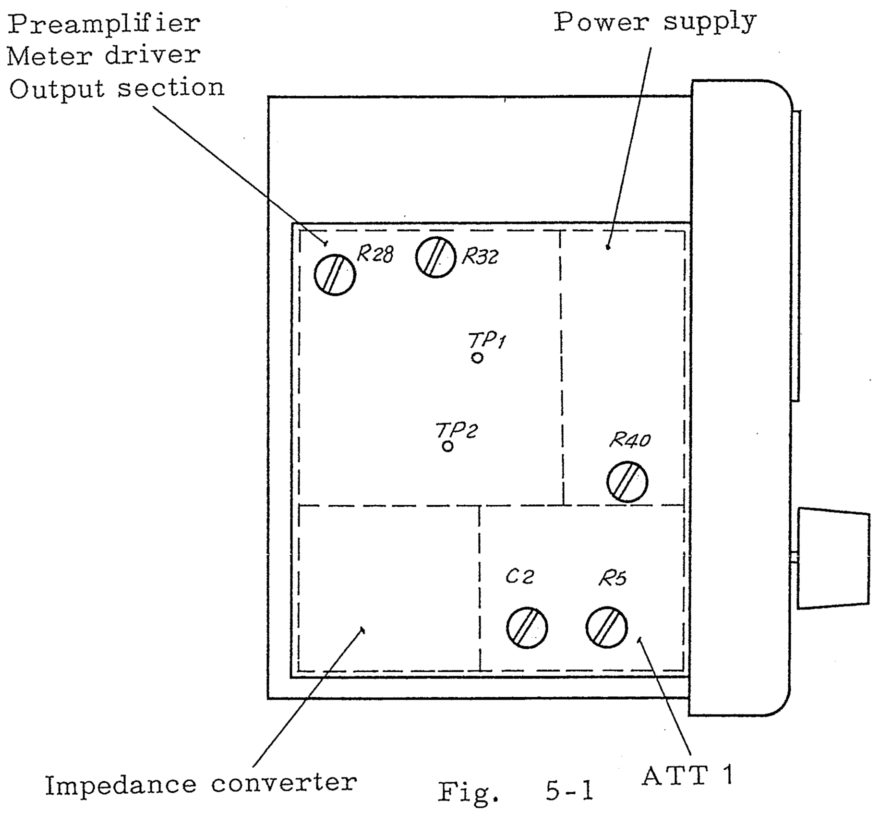


Fig. 5-1

5.2 Adjustment and calibration

When adjustment or calibration is needed during a long period of use or after repair, follow the instructions below:

(1) Adjustment of voltage regulator circuit:

Connect a DC voltmeter between test point TP_2 in the power supply circuit, and the ground. Adjust variable resistor R_{40} so that the DC voltmeter indicates +25V.

(2) Adjustment of preamplifier:

Adjust a variable resistor R_{32} in preamplifier so that voltage between testpoint TP_1 and ground to 13 volts.

(3) Adjustment of sensitivity:

Set the range switch to the 100 mV range, apply a calibration voltage (sine wave of low distortion factor) of 100 mV, 400 Hz or 1,000 Hz, 100 mV, to the input terminal, and adjust variable resistor R_{28} of the meter-driver so that the meter has the full-scale indication precisely.

(4) Adjustment of voltage pre-driver:

Set the range switch to the 3 V range, apply a calibration voltage of 3 V, 400 Hz, to the input terminal, and adjust variable resistor R_5 of the voltage divider for the full-scale meter indication.

Change the frequency of the calibration voltage to 40 kHz and adjust trimmer capacitor C_2 for the full-scale meter indication.

Repeat the 400 Hz and 40 kHz, 1 V adjustments two or three times for the complete calibration.

5.3 Reference voltages for troubleshooting

Model 161D is carefully assembled and adjusted, and then inspected under strict control before shipment. If the AC voltmeter should fail because of an accident or parts life, check the voltage distribution at various points against the following tables.

Tables 5-1, 5-2 and 5-3 show the no-signal voltage distribution measured with respect to the ground by Kikusui Electronics' Model 107A V.TVM (input resistance: 11 MΩ).

(1) Impedance converter

Table 5-1

Transistor	Emitter Source (V)	Base Gate (V)	Collector Drain (V)
Q_1 2SK 30	13.0		25.0
Q_2 2SC372	12.4	13.0	24.4

(2) Preamplifier, meter driver

Table 5-2

Transistor	Emitter (V)	Base (V)	Collector (V)
Q_3 2SC383		0.7	6.4
Q_4 2SC372	11.7	12.3	22.3
Q_5 2SA495	11.6	10.9	4.2
Q_6 2SC372	3.6	4.2	12.5

(3) Power supply

Table 5-3

Transistor	Emitter (V)	Base (V)	Collector (V)
Q_7 2SC515	25.0	25.6	39.4
Q_8 2SC372	9.9	10.5	25.7

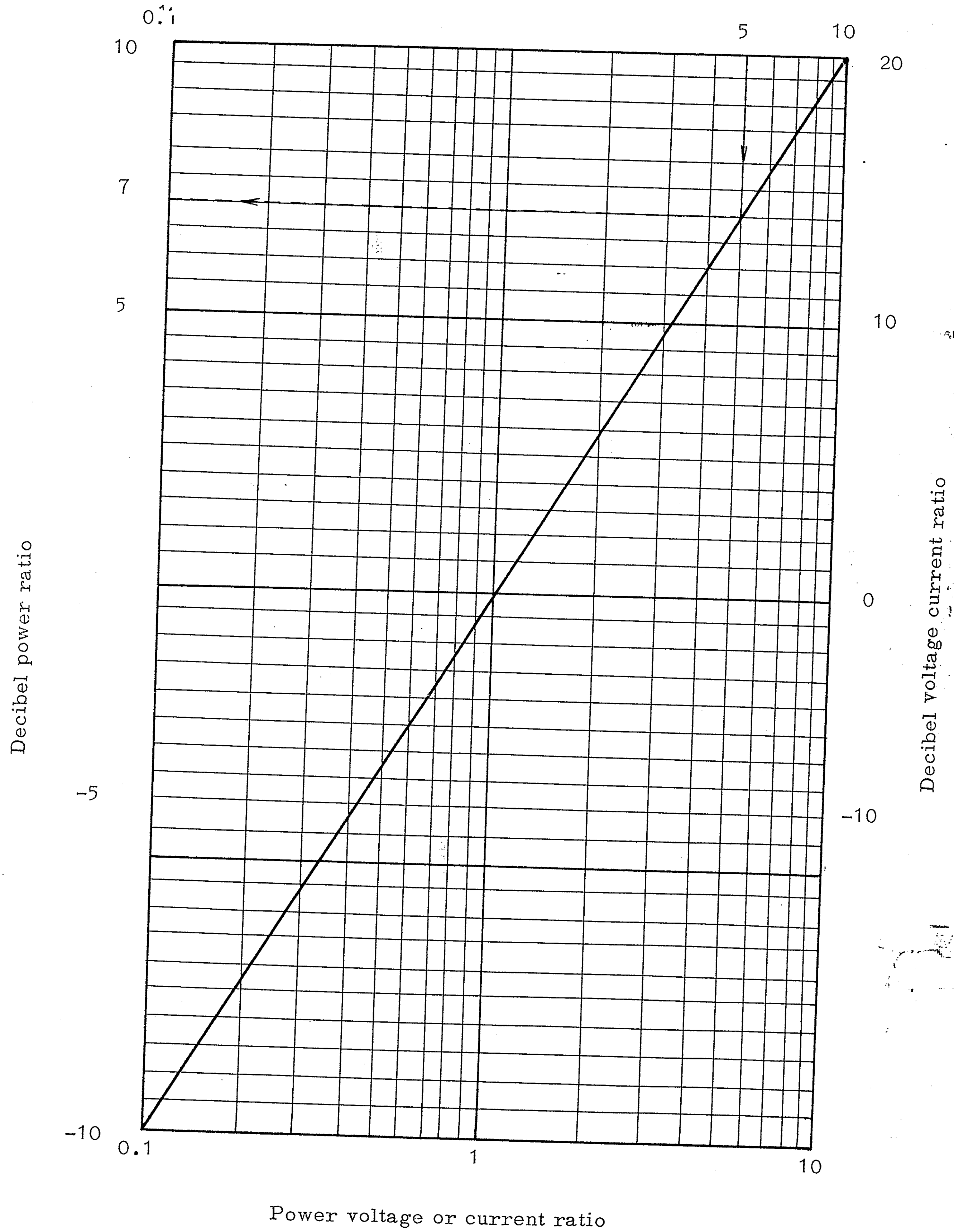
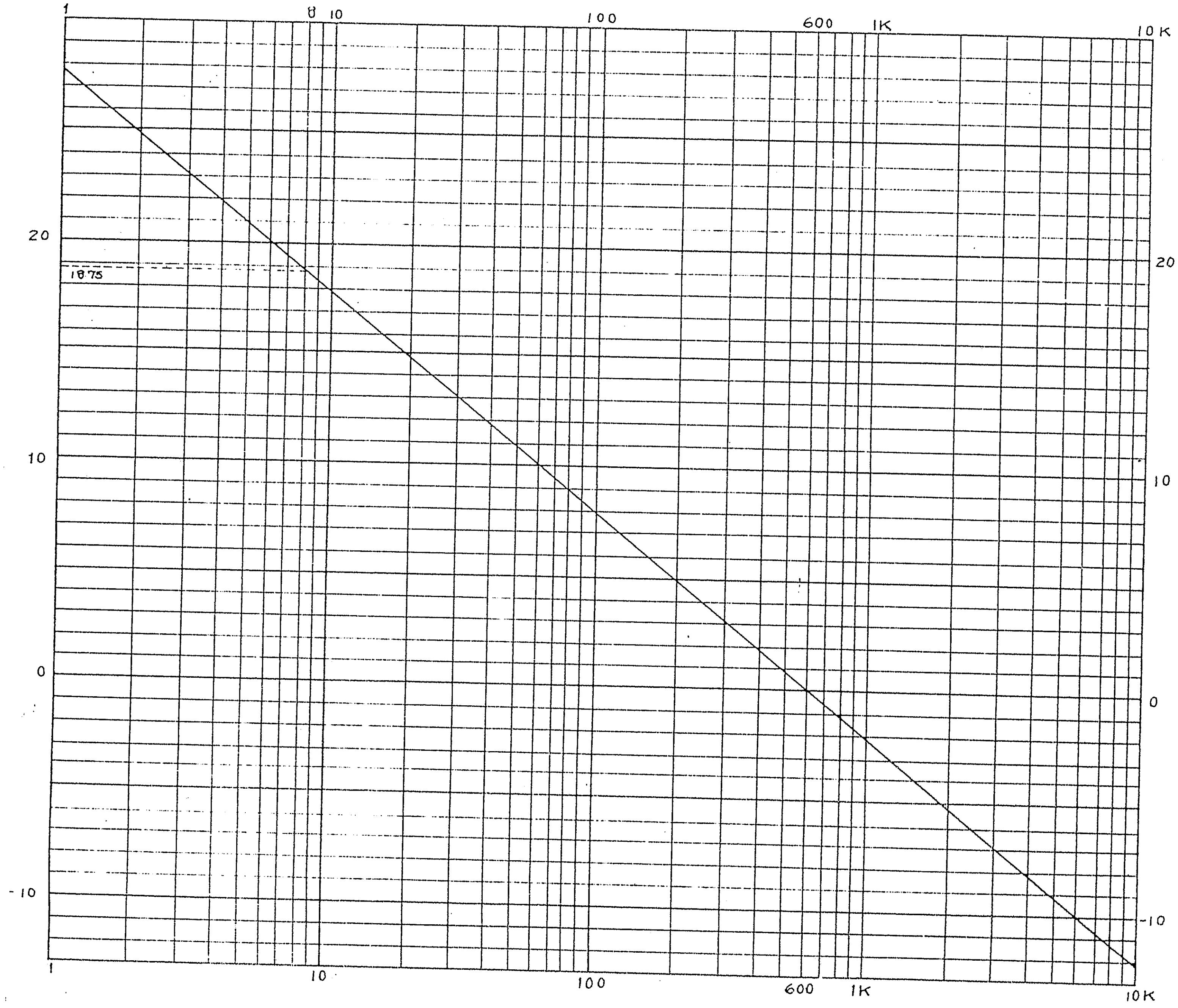

0.1
5
10
10
20
7
5
10
0
-5
-10
-10
0.1
1
10
Decibel power ratio
Decibel voltage current ratio
Power voltage or current ratio

Fig. 3-4



Added value (dB)
20
10
0
-10
18.75
1
8 10
100
600
1K
10K
Load resistance (Ω)

Fig 3-5