MODEL 165

ELECTRONIC VOLTMETER

OPERATION MANUAL

印刷表紙使用のこと

KIKUSUI ELECTRONICS CORP.

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1. Summary

KIKUSUI ELECTRONICS' MODEL 165 ELECTRONIC VOLTMETER is a high sensitive broad-band transistor voltmeter that performs indication in correspondence with the average value of test voltage, and is designed to be little in power consumption, compact in size and light in weight by employing semiconductors through the circuit.

This instrument consists of an impedance conveter, voltage divider, pre-amplifier, meter circuit and constant-voltage circuit. Particularly, field effect transistors are used therein for obtaining high input impedance and low noise characteristic, and small type reed relays for improving the high frequency characteristic of the input divider, thus attaining the rise of the performance.

This instrument enables to measure the AC voltage of 5 Hz ~ 10 MHz in the measuring range of 0.1mV ~ 500V RMS (-80 ~ 56 dBm) divided into 12 ranges in the geometrical step of 10dBm and graduated in equal division by the RMS value of sine wave.

Furthermore, this instrument enables to take out the AC output voltage of approx. 100mV full scale from the output terminal provided at the back of the case, so that this one can also be utilized as a monitor during measurement or as a broad-band pre-amplifier.

Note: 1 Hz (hertz) = 1 c/s (cycle/second)

2. Specifications

Title	Electronic Voltmeter
Model	165
Power Supply	___V 50/60 Hz approx. 10VA
Dimensions	140(W) x 190(H) x 255(D) mm
(maximum)	140(W) x 206 H) x 300(D) mm
Weight	approx. 3.5 kg
Meter	Scale length 105mm with mirror, ~~3~~ 2-color scale F.S. ~~1mA~~ 100μA
Graduation	RMS value of sine wave and 1mw, dBm value on the basis of 600Ω
Input Terminal	Type UHF receptacle and GND terminal Space 19mm (3/4")

Input Resistance	Each range	10 MΩ
Input Capacitance	1.5mV ~ 500mV range	less than 40PF
	1.5V ~ 500V range	less than 25PF

Max. Input Voltage

1.5mV ~ 500mV range
*AC component: 150V RMS value, ±200V peak value
DC component: ±400V

1.5V ~ 500V range
AC component: 500V RMS value, ±700V peak value
DC component: ±400V

Range 12 ranges

In case of RMS scale 1.5/5/15/50/500mV & 1.5/5/15/50/150/500V

In case of dBm scale -60/-50/-40/-30/-20/-10 & 0/10/20/30/40/50dBm

*For more than 100KHz, 50VRMS, ±75 peak

Accuracy ± 3% of the full scale at 1KHz

Frequency Characteristic 5Hz ~ 10MHz ± 10% to 1KHz
10Hz ~ 5MHz ± 5% "
20Hz ~ 1MHz ± 3% "

Stability Less than 0.5% of the full scale
to ± 10% flucuation of power voltage

Noise Less than 30μV or 2% with the input terminal short-circuited

Output Terminal 5 Way type space 19mm (3/4")

Output Voltage Approx. 100mV at the full scale

Distortion Factor Less than 1% at 1KHz "

Frequency characteristic 3Hz ~ 15MHz within $^{+1}_{-3}$dB

Ambient Temperature 5°C ~ 35°C

3. Operation Method

3.1 Descriptions of panel furnishings and terminals (see Fig 3.1)

① POWER is the push-button switch for turning the power on and off, 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.

② Range Switch is the black dial provided at the center of the panel, and the illuminating lamp is lighted on and off by the switching of the power supply. And the numerical figures and letters given above the dial stand for the following meanings.

The outer	stand for the full scale voltage values figures in orange color are mV (=1/1000V) white figures are V.
The inner	stand for the dBm values (to be described later) at the approximate center, and are in red color.

When the range switch is rotated clockwise, higher voltage ranges are obtained, and when rotated counter-clockwise, lower voltage ranges are obtained.

③ IN PUT Terminals are the input terminals to which the test voltage is to be given and include a Type UHF receptacle and GND (ground) terminal.

For connecting between them, it is convenient to use a Type UHF (5/8" - 24), Type M (16ø - 1P) plug or standard (spaced by 3/4"=19mm) twin banana plug.

Besides the above, it is also possible to use a banana plug to the center conductor of the receptacle, and, by inserting the accessory "KIKUSUI Type 941B terminal adaptor", to connect in the same manner as the GND terminal a banana plug, spade lug, alligator clip, 2mm chip and conductor less than 2mm therewith.

The outer conductor of the receptacle and the GND terminal are electrically connected with the panel and chassis of this instrument.

4) Meter

The meter of this instrument has three kinds of scales as mentioned below. If they are explained from the outer one,

1) "50 Scale" to be used at the time of 5/50/500mV and 5/50/500V ranges
2) "15 Scale" to be used at the time of 1.5/15/150mV and 1.5/15/150V ranges
3) "dBm Scale" enables to read the test voltage in dBm based on 1mW, 600Ω, and is to be used for the 12 ranges of -60 ~ +50dBm with the same scale.

5) Output Terminal

is the output terminal to be used when this instrument is utilized as an amplifier, and is found at the back of the case. For the connection at this terminal, a banana plug, spade lug, alligator clip, 2mm chip and conductor less than 2mm can be used just as "KIKUSUI Type 941" terminal adaptor, but a standard twin banana plug with coaxal cable is convenient. The black terminal is of the polarity of grounding side.

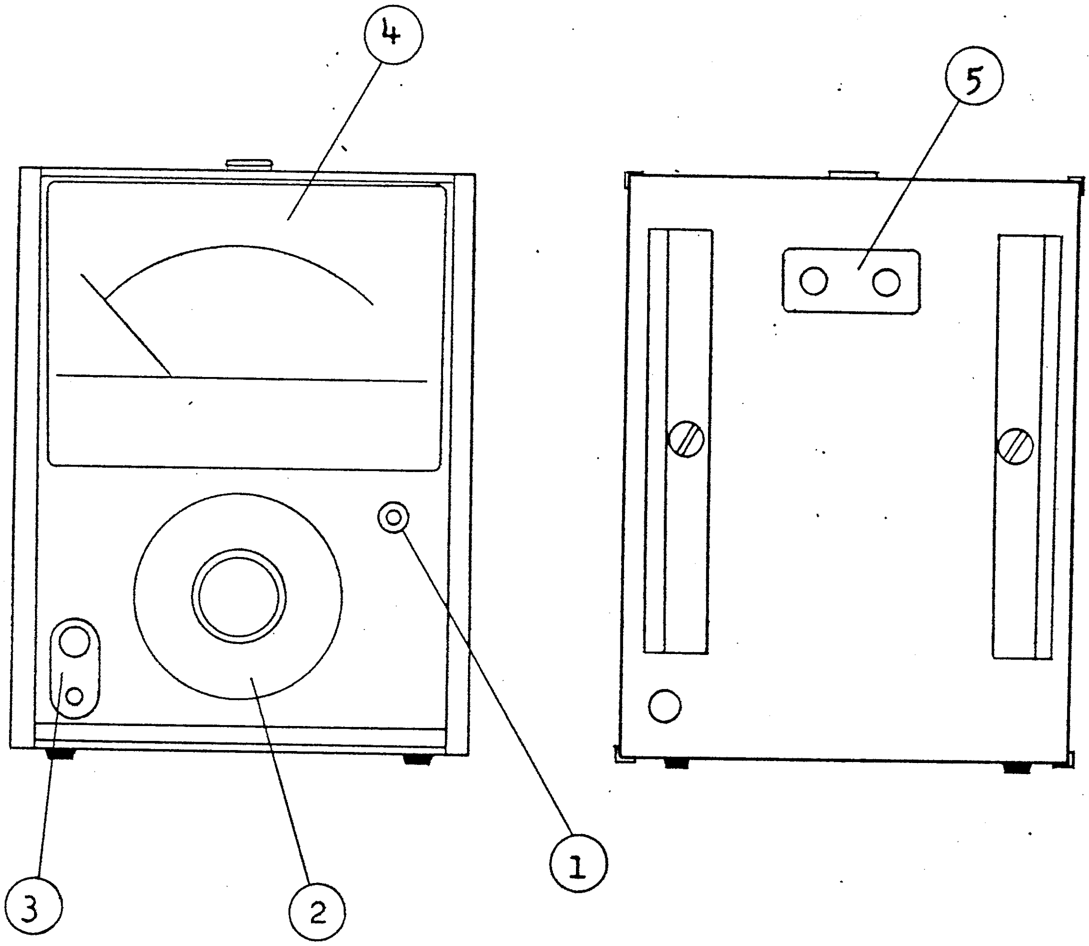


Fig 3 - 1

3.2 Preparations for measurement

1) Turn off the power switch provided on the right side of the panel.

2) Confirm if the pointer of the meter is at the center of the zero point on the scale, and, if out of the position, perform zero adjustment correctly. If the power of this instrument has been on, make this instrument pass some 5 minutes after turning off the power and perform the zero adjustment after the pointer having returned completely back near to the zero point.

3) Connect the power plug to a ___V 50 or 60 Hz outlet.

4) Change the range dial to 500V range.

5) Push the power switch, and the dial range face will be illuminated and the power be supplied. For some seconds after turning on the switch, the pointer of the meter may swing irregularly. In like manner, when the switch is turned off, the same state may be brought about.

6) When the swing of the pointer is stabilized, this instrument is ready for operation, and the preparations for measurement are finished.

3.3 Measurement of AC voltage

1) In case of the test voltage being small, or the impedance of the measuring power supply comparatively high, the measurement shall be performed by using a shielded conductor or coaxal

cable in consideration of the frequency in order to avoid induction from the outside. When the test voltage is of low frequency and high level, and the power supply impedance is also low, the accessory Type 941B terminal adaptor can be used conveniently.

(Caution: It is advised in case of 1.5mV range that the measurement is performed by using a shielded conductor or coaxal cable for avoiding coupling that may be caused by radiation from the meter.)

2) The measurement shall be begun with the highest voltage range and be changed to lower voltage ranges in sequence depending upon the indication in the meter, thus avoiding unnecessary overload that may be given to this instrument.

3) Read the meter scales using both 15, 50 scale as per Table 3-1.

Table 3-1

Range		Scale	Multiple	Unit
1.5mV	-60 dBm	15	X 0.1	mV
5 "	-50 "	50	"	"
15 "	-40 "	15	X 1	"
50 "	-30 "	50	"	"
150 "	-20 "	15	X 10	"
500 "	-10 "	50	"	"
1.5V	0 "	15	X 0.1	V
5 "	10 "	50	"	"
15 "	20 "	15	X 1	"
50 "	30 "	50	"	"
150 "	40 "	15	X 10	"
500 "	50 "	50	"	"

4) When the test voltage is measured in dBm value based on 1mw, 600Ω, the dBm range that is common to the respective ranges shall be used and read as follows. Since "0" located approximately at the center of the dBm indicates the level of the range, the value of the scale reading added by the dBm value shown by the range becomes the measured value.

Example 1 When 5.5 is pointed on the dBm scale at "30dBm (50V) range",

5.5 + 30 = 35.5 dBm

Example 2 When 3dBm is indicated at "-20dBm (-150mV)range",

3 + (-20) = 3 - 20 = -17dBm

3.4 Measurement of AC current

For measuring AC current by this instrument, flow the AC current I to be tested to the non-inductive resistor R, measure the voltage at the both ends, and I will be calculated from I = E/R. Be careful that the (-) terminal of the input terminals of this instrument is grounded at this time.

The accessory Type 921 shunt resistors, that are accessories to order, are standards resistors convenient for this measurement and are prepared in 0.1Ω, 1Ω, 10Ω, 100Ω and 1000Ω, and, besides these, in 4Ω, 8Ω, 16Ω and 600Ω. Any of them can be used by inserting a banana plug into the input terminal of this instrument.

Example: If it is desired to measure the heater current of a vacuum tube (nominally 6.3V, 0.3A).......

Use Type 921-0.1 of resistance value 0.1Ω as the standard resistor, and read the indication of this instrument by connecting with the test tube as shown in Fig 3-2. Then, if 29mV was obtained, the following value can be obtained by the following equation.

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

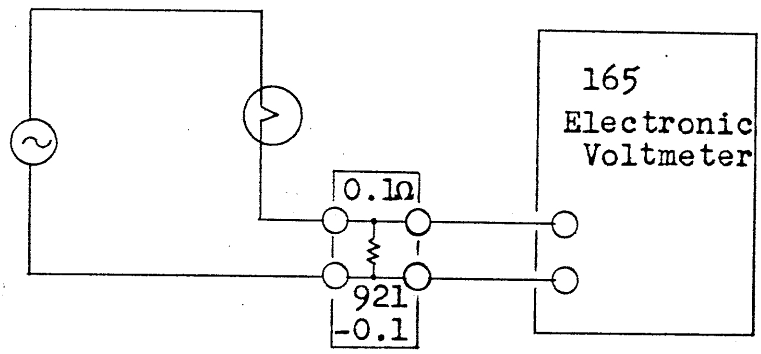


Fig 3 - 2

3.5 Utilization as output meter

If voltage E impressed upon the both ends of a certain impedance X is measured, the apparent power VA in the impedance X can be obtained by $VA = E^2/X$. If the impedance X is the pure resistance R at this time, the power P consumed within the R is $P = E^2/R$.

Since this instrument is provided with the dBm scale, the power can be, as described in the separate section, read in decibel as it is, in case of R = 600Ω. Also, if such decibel conversion charts as Fig 3-3 and 3-4 are utilized, the power can be read in decibel by adding a determined number to be obtained from the charts even in case that the load resistance is 1Ω ~ 10KΩ.

Type 921 shunt resistors include 4Ω, 8Ω, 16Ω of the same resistance values as the voice coil impedance of the speaker that is ordinarily used, and can be put to use as the load resistors of small capacity (0.3W), so that this instrument can be utilized as an output meter.

3.6 As regards error in wave form

This instrument is an "average value indicator type" voltmeter that performs indication proportionate to the average value of the test voltage, but the scale is calibrated by the RMS values of sine wave. Because of this reason, if a distortion is included in the test voltage, this instrument may not indicate the correct RMS values but produce error. Table 3-2 shows this relation.

Test Voltage	RMS value	Indication by this instrument
Amplitude 100% fundamental wave	100 %	100 %
100% fundamental wave + 10% 2nd harmonic wave	100.5	100
" + 20% "	102	100 ~ 102
" + 50% "	112	100 ~ 110
100% fundamental wave + 10% 3rd harmonic wave	100.3	96 ~ 104
" + 20% "	102	94 ~ 108
" + 50% "	112	90 ~ 116

Table 3-2

3.7 How to use the decibel conversion table

1) Decibel

Bel (B) is a fundamental division using logarithm, and represents the ratio of two power quantities to be compared in the form of common logarithm based on 10. Decibel (dB) is 1/10 of the unit B, with the small letter d attached thereto, and is defined as follows.

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

That is to say, it represents the approximate quantity of the power P_2 to the power P_1 in the value decuple as much as the common logarithm.

If the impedance at the point where P_1 and P_2 exist is equal on this occasion, the ratio of the powers can also be represented decisively in the ratio of voltage or current 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, as mentioned above, defined as the ratio of power quantity, but since a long time ago, the ratios of general numerical values represented in common logarithm have been customarily called decibel, interpreting the meaning of decibel widely.

For example, if the input voltage of an amplifier is 10mV and the output voltage is 10V, the amplification degree is 10V/10mV = 1000 times, but this can be

$$\text{Amplification Degree} = 20 \log_{10} \frac{10V}{10mV} = 60 \text{ (decibel)}$$

Also, in order to represent the output voltage as for RF standard signal generator, decibel is used for representing how many times the output voltage is to 1 V, and 10mV is respresented as follows.

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

When decibel is represented in this manner, it may be necessary to have the standard, that is dB, clarified. For example, the output voltage of the above signal generator shall be 10mV = 80dB (1μV=0dB), and the value corresponding to 0dB be put in ( ).

2) dBm

dBm is the abbreviation of dB(mW) to represent the power ratio with 1mW assumed 0dB. Ordinarily, it invloves in the most cases that the impedance at the point where the power exists is 600Ω, and in such a case, dB (mW 600Ω) becomes the correct mark.

As mentioned above, if the power and impedance are determined, decibel can not only represent the power but also the voltage and current as well, so that dBm becomes the standard for the several values as mentioned below.

0 dBm = 1 mW or 0.775 V
or 1.291 mA

The decibel scale of this instrument is graduated in such dBm value, so that, in case of decibel measurement based on some value other than (1mW 600Ω), the indicated values by this instrument shall be converted. This conversion can be made by adding certain numerical values because of the nature of logarithm, and Table 3-3 and 3-4 shall be used.

3) Method of using the decibel conversion table

Table 3-3 is the chart to be used for representing the ratio of numerical values in decibel, and the measure to be read differs depnding upon whether the quantities under comparison are power (or the relevant) or voltage·current.

Example 1 What decibel is 5mW on the basis of 1mW?........ Since this is a power ratio, the left side measure shall be used. Calculate 5mW/1mW=5 and obtain 7dB(mW) as shown by the dotted line in the figure.

Example 2 What decibel are 50mW and 500mW on the basis of 1mW? .... In case of the ratio being lower than 0.1 time and more than 10 times, the decibel can be obtained by addition utilizing the relation shown in Table 3-3.

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

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

Ratio		Decibel	
		Power ratio	Voltage Current ratio
10000	$= 1 \times 10^{4}$	40 dB	80 dB
1000	$= 1 \times 10^{3}$	30 "	60 "
100	$= 1 \times 10^{2}$	20 "	40 "
10	$= 1 \times 10^{1}$	10 "	20 "
1	$= 1 \times 10^{0}$	0 "	0 "
0.1	$= 1 \times 10^{-1}$	-10 "	-20 "
0.01	$= 1 \times 10^{-2}$	-20 "	-40 "
0.001	$= 1 \times 10^{-3}$	-30 "	-60 "
0.0001	$= 1 \times 10^{-4}$	-40 "	-80 "

Table 3-3

Example 3 How much is 15mV in dB(V)? .... Since being based on 1V, calculate first 15mV/1V=0.015 and then use the voltage·current measure and obtain 0.015 = 1.5 x 0.01 = 3.5 + (-40) = -36.5 dB(V), or as the reverse operation to the foregoing, 1V/15mV = 66.7

$$66.7 = 6.67 \times 10 \longrightarrow 16.5 + 20 = 36.5 \text{ dB(V)}$$

4) Method of using the decibel addition table

Fig 3-4 shows the addition table to be used when the power is sought from the dBm values measured by this instrument.

Example 1 The voice coil impedance of a speaker is 8Ω, and the measurement of the voltage at the both ends by this instrument indicated -4.8 dBm. What W is the power (apparent power to describe correctly) that was supplied to the speaker? .... Obtain +18.8 as the addition value to 8Ω corresponding with the dotted line in Fig 3-4, and the sum with the indicated value becomes the power represented in dB (mW, 8Ω).

$$\text{dB (mW, } 8\Omega) = -4.8 + 18.8 = +14$$

For converting this 14dB (mW, 8Ω) to Watt, use Fig 3-3 and obtain 14dB (mW, 8Ω) ⟶ 25mW

Example 2 How many volts shall be impressed in order to supply the load of 10KΩ with 1W power? .... As 1W is 1000mW and 30dB (mW), this can be answered by calculating the voltage of 30dB (mW, 10KΩ).

If the addition value of 600Ω ⟶ 10KΩ is sought in Fig 3-4, it is -12.2, so that the indication in this instrument has to be 30 - (-12.2) = 42.2 on the dB(mW, 600Ω) scale.

The voltage that makes this instrument indicate 42.2-40=2.2dBm on the 40dBm range (0 - 150V) thereof is the answer to obtain, and becomes 42.2 dBm = 100V.

4. Operation Principle

MODEL 165 Electronic Voltmeter consists of, as shown in Fig 4-1, an input circuit, pre-amplifier circuit, meter driving circuit, output circuit and power supply.

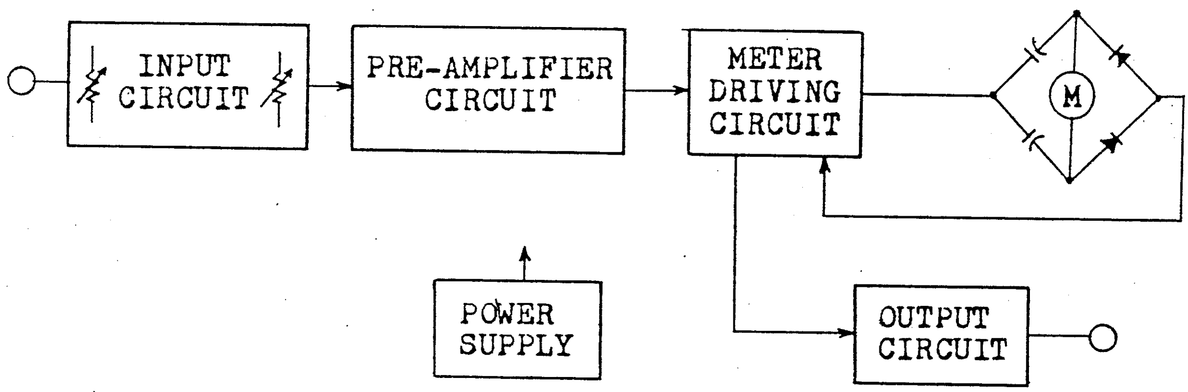


Fig 4-1

4.1 Input circuit

The input circuit consists of, as shown in Fig 4-2, an early-stage divider (0/60dB), impedance converter and late-type divider (0/10/20/30/40/50dB) comprising 10dB step 6 ranges.

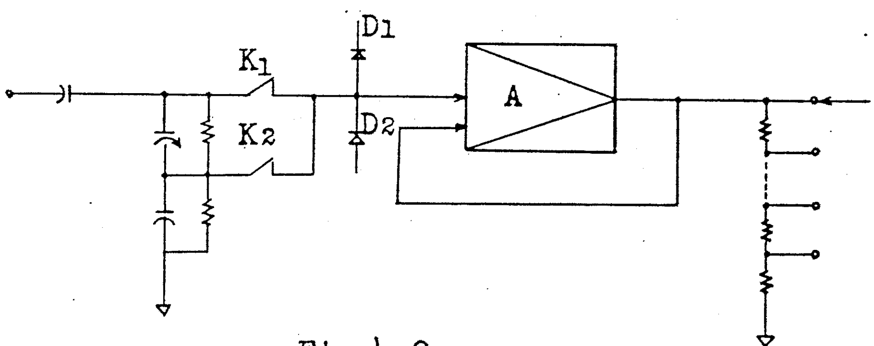


Fig 4-2

When the range switch is at 1.5mV ~ 500mV, reed relay K_1 operates, and when at 1.5V ~ 500V range, K_2 operates respectively, thus dividing the signal as predetermined and then make it enter into the impedance transducer. The transducer by transistors Q_1, Q_2, Q_3 employing FET on the first step reduces the high impedance to low impedance and transmits the signal to the late step divider. The late step divider divides to a voltage lower than approximately 1.5mV depending upon the signal level. And, the diodes D_1 and D_2 in the diagram operate so as to protect this circuit in case of over input.

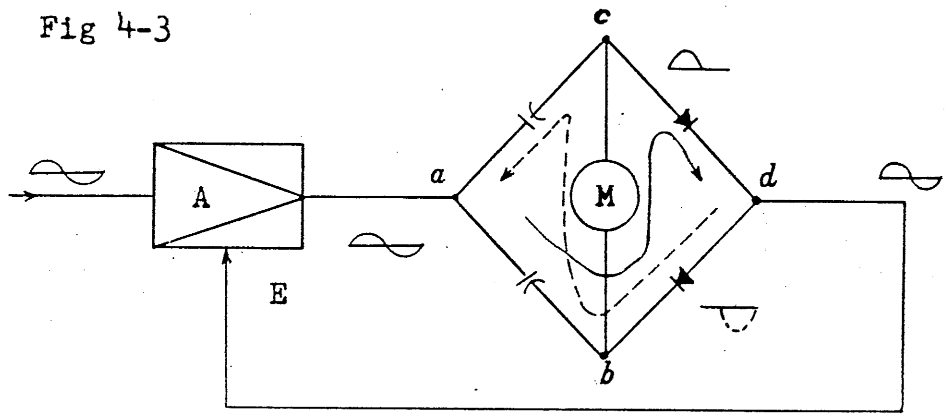
4.2 Pre-amplifier

The pre-amplifier, consisting of 4 transistors, is a negative feedback amplifier of low noise and broad-band for amplifying the small signal coming from the input circuit to approx. 40dB. In the first place, the input signal is impressed upon the base of the emitter-grounded transistor Q_4, amplified by Q_5, Q_6 and Q_7 , and the output voltage is obtained from the collector of Q_7. In order to improve the stability, negative feedback is performed from Q_7 emitter to Q_4 emitter, and furthermore for obtaining the stability to temperature, a part of Q_7 collector voltage is subjected to direct current feedback to Q_4 base.

4.3 Meter driving circuit

This circuit is a broad-band amplifier employing transistors Q_8, Q_9, Q_{10}, and a large quantity of current feedback is applied from Q_{10} collector to Q_8 emitter via the rectifying diode.

Fig 4-3



Because of this reason, the diode comes to be driven almost by constant-current, the non-linearity of the diode is remarkably improved, and the meter scale becomes straight.

Fig 4-3 shows this operation, and when the output voltage of the amplifier is positive cycle, the current flows in the direction of $a \rightarrow b \rightarrow c \rightarrow d$ as illustrated by the full line, and when negative cycle, it flows in the direction of $a \rightarrow b \rightarrow c \rightarrow d$ as by the dotted line, and thus the meter is driven in accordance with the average values of these currents.

4.4 Output circuit

The emitter voltage of the transistor Q_8 in the meter driving circuit is taken to the outside as the output voltage by the 2 step emitter follower of Q_{11}, Q_{12}. This is performed particularly to reduce the influence of the output terminal load to appear in the indication at high frequency. Also, this output terminal enables to take out approx. 100mV when the meter is in full scale.

4.5 Power supply

This consists of +25V and -25V constant-voltage power supply and the range dial illuminating AC 6.3V.

The -25V constant-voltage circuit generates the reference voltage by the zener diode D_{12}, Q_{16} amplifies the error, Q_{18}, Q_{19} perform series control by complementary connection, and Q_{17} performs the constant-current driving of the base current of the control transistor and the collector current of Q_{16}.

The +25V constant-voltage circuit, having -25V as the reference voltage and using Q_{13}, Q_{14}, and Q_{15}, is constituted in the same manner as the -25V power supply approximately.

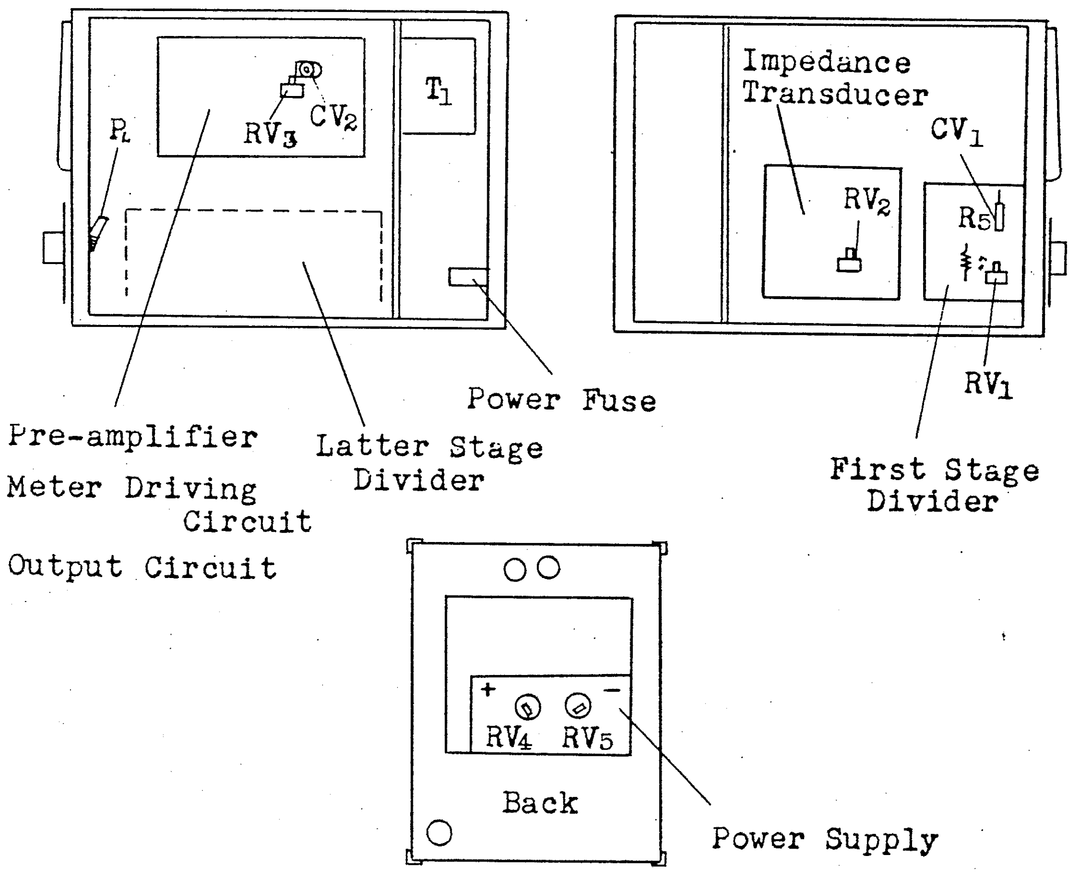
5. Maintenance

5.1 Internal inspection

The internal inspection can be performed by pulling backwards the top board, bottom board and both side boards after unfastening and removing the two screws provided at the back of the case.

Fig 5-1 shows the arrangement plan of the respective parts at the time when the both side boards were taken off.

Fig 5-1



5.2 Adjustment and calibration

If the specifications are not fulfilled after this instrument has been used for a long time or repairs were performed, the adjustment and calibration shall be conducted in the following method.

1) Adjustment of constant-voltage circuit

Connect a DC voltmeter between the collector of the transistor Q_{19} of the power supply circuit and the ground in the first place, and then adjust the variable resistor RV_5 so that the indication becomes -25V.

And then, adjust the variable resistor RV_4 so that the voltage between the emitter of Q_{15} and the ground also becomes +25V.

2) Adjustment of impedance transducer bias

Connect a VTVM between the source of the transistor Q_1 and the ground, and adjust the variable resistor RV_2 so that the voltage becomes +1.5V. On this occassion, it is necessary to rotate the RV_2 slowly, since the deflection of the VTVM is slow.

3) Calibration at low and high frequency (pre-amplifier)

Prior to making the calibration, perform the zero adjustment of the meter in the manner as mentioned in 2) in the section 3.2. The calibration shall be performed in the following order.

Change the range switch to 500mV range, give to the input terminal the calibration voltage (sine wave of low distortion factor) of 400Hz 500mV, and adjust the variable resistor RV_3 of the pre-amplifier so that the correct full scale is obtained.

And,Turn the frequency of the calibrating voltage to 10MHz, and adjust the trimmer condenser CV_2 inserted in VR_3 in parallel so that the same value is obtained.

4) Adjustment of first stage divider

Change the range switch to 1.5V range, give the calibrating voltage of 400Hz 1.5V to the input terminal, and adjust the variable resistor RV_1 of the divider so that the full scale is attained.

And, turn the frequency of the calibrating voltage to 100KHz and adjust the trimmer condenser CV_1 so that the full scale is attained. The foregoing 400Hz and 100KHz adjustment shall be repeated 2 ~ 3 times for completing the calibration.

Furthermore, if error is large in a position around 10MHz after the above adjustment having been made, adjust the fixed resistor R_5.

5.3 Repair

This instrument was assembled carefully, inspected under severe control and delivered out of our factory, but in case of an accidental trouble or other kinds of troubles caused by the life of the component parts, refer to the voltage distribution to each part as mentioned in this paragraph.

One example of voltage distribution to each part at the time of non-signal is shown in Table 5-1, 2, and 3. These volts are the values measured by the VTVM (KIKUSUI ELECTRONICS' 107A) of input resistance 11MΩ, referring to the ground.

1) Impedance transducer

Transistor	Emitter *Source (V)	Base *Gate (V)	Collector *Drain (V)
Q_1 *2SK13	+1.5	-	+8.5
2 2SA495	+9.2	+8.5	+2.8
3 2SC318	+2.2	+2.8	+24

Table 5-1

2) Pre-amplifier, meter driving circuit and output circuit

Transistor	Emitter(V)	Base (V)	Collector(V)
Q_4 2SC318	+0.1	+0.75	+44
5 "	+44	+5	+8.9
6 2SA495	+9.5	+8.9	+1.4
7 2SC318	+0.78	+1.4	+11.4
8 2SA495	-0.15	-0.82	-9.5
9 2SC318	-10	-9.5	-0.63
10 "	-0.63	0	+11.2
11 2SC372	-0.85	-0.25	+21
12 2SC318	-1.45	-0.85	+21

Table 5-2

3) Power supply

Transistor	Emitter(V)	Base (V)	Collector(V)
Q3 2SC352	0	+0.6	+26
14 2SB55	+37	+36.8	+26
15 2SC515	+25	+26	+42
16 2SB55	-7.4	-7.6	-25
17 2SC372	-36.4	-36	-25
18 2SB55	-25.2	-25	-38.5
19 2SC515	-39	-38.5	-25

Table 5-3

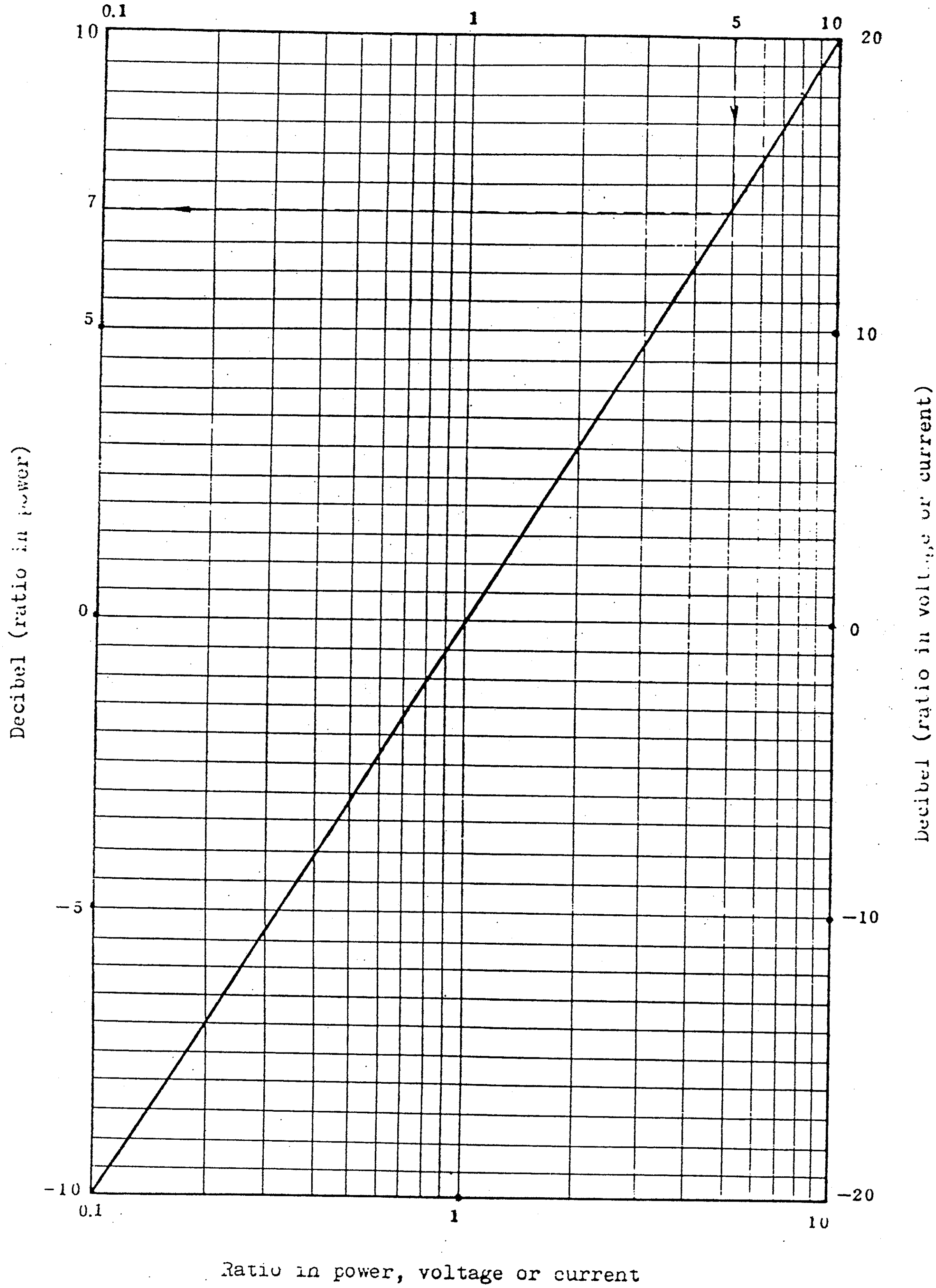
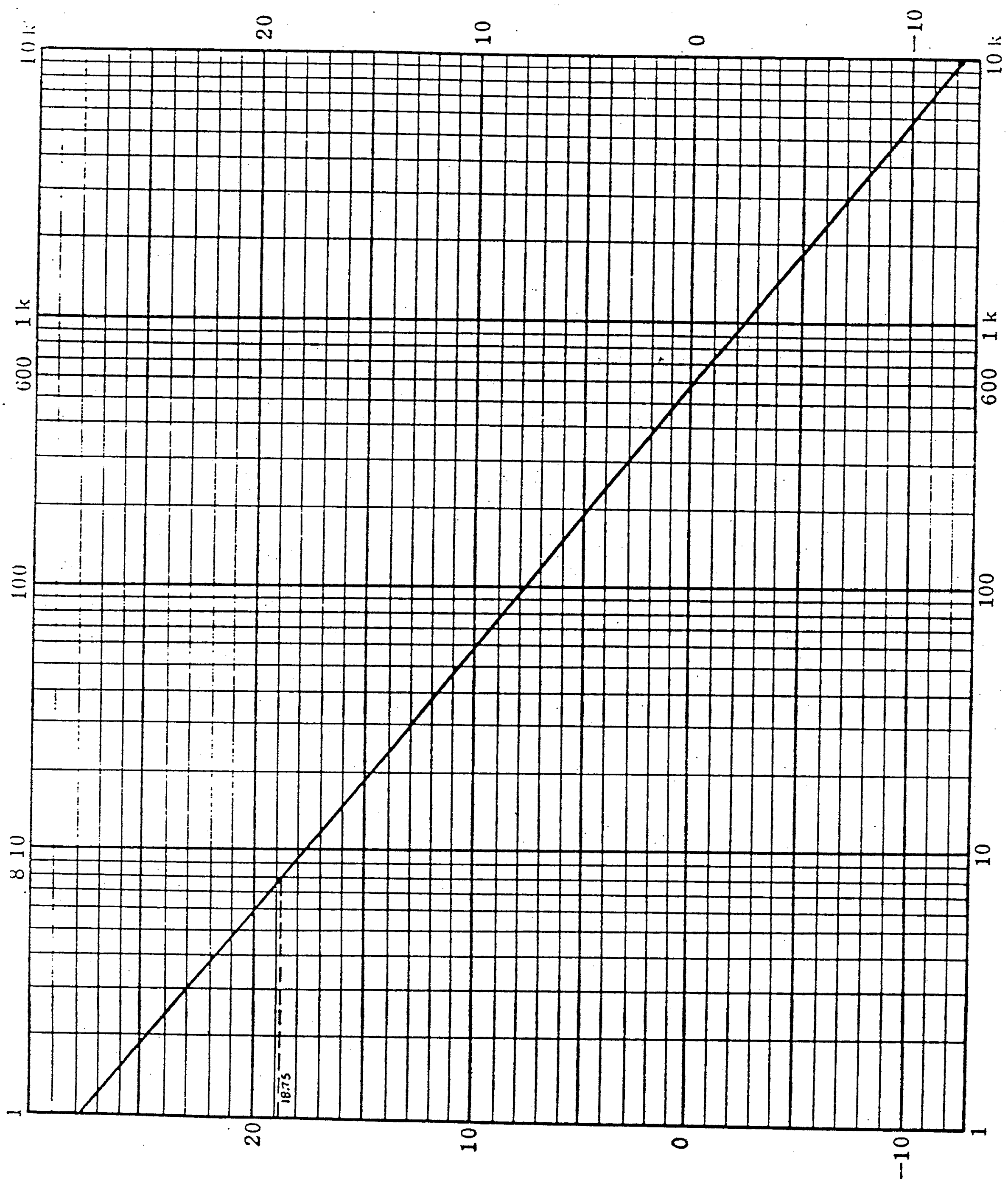

0.1
1
5
10
10
20
7
5
10
0
0
-5
-10
-10
-20
0.1
1
10
Decibel (ratio in power)
Ratio in power, voltage or current

Table 3-3



Resistance (Ω)

Table 3-4

Addition chart (dB)