MODEL 164

VACUUM TUBE VOLTMETER

OPERATION MANUAL

印刷表紙使用のこと

KIKUSUI ELECTRONICS CORP.

This is a compact, high-sensitivity Vacuum Tube Voltmeter to indicate mean value of AC voltage, and is operated by 100 v. commercial power source. Employing a stable feed-back amplifier with print wiring and a germanium-diode full-wave rectifier circuit, this Voltmeter measures AC voltage ranging from 5 Hz to 200 kHz in frequency. The direct-reading meter indicator is calibrated in effective values of sine waves, and the voltage 0.1 mV to 500 V (-80 to 56 dBm) are divided into 12 ranges at the equal ratio of 10 dBm.

SPECIFICATIONS

Type:	Mean value indication type.
Power Source:	_____V., 50 to 60 Hz approx. 25 VA.
Dimensions: (Maximum)	200 (D) x 140 (W) x 190 (H) mm. 270 (D) x 140 (W) x 205 (H) mm.
Weight:	Approx. 4.2 kg.
Meter:	Scale length 105 mm; Three-colored scale; Sensitivity 100 μA.
Tubes used:	6 A U 6 — 2 1 2 A X 7 — 1 6 B L 8 — 1 6 X 4 — 1 V R 1 5 0 - M T — 1 (S D - 3 4) — 2 (1 0 D - 6) — 2
Scale:	Calibrated in dBm in reference to sine-wave effective value and 1 mW, 600 ohms.
Input Terminal:	UHF-type receptacle and GND terminal spaced at 19 mm (3/4") interval. (Both UHF-type and M-type plugs are applicable.)

Input Impedance:	1 megohm shunted by 25 ±2 pF in all ranges.
Maximum Input:	AC component 500 V RMS maximum ±700 V peak maximum DC component ±400 V maximum
Ranges:	12 ranges; 1.5/5/15/50/150/500 mV, and 1.5/5/15/50/150/500 V in RMS. -60/-50/-40/-30/-20/-10/0/10/20/30/40/50 dBm.
Accuracy:	±3% of full scale at 1 kHz.
Stability:	±2% of full scale at 1 kHz against ±10% change in line voltage.
Frequency Characteristic:	Between 5 Hz and 200 kHz ± 10% of full scale against 1 kHz. Between 10 Hz and 150 kHz ± 5% of full scale against 1 kHz. Between 20 Hz and 100 kHz ± 3% of full scale against 1 kHz.
Noise:	Less than 1% of full scale with input terminal short-circuited.
Output Terminal:	5-Way type; Spaced at 19 mm (3/4") interval.
Output Voltage:	Approx. 2.5 V in full-scale. Distortion; approx. 3.5% in full scale. S/N Ratio; approx. 35 dB in full scale.

ACCESSORIES

941B-type Terminal Adapter	1
Operation Manual	1
Test Data	1

OPERATION

The Vacuum Tube Voltmeter is operable by _____v. 50- or 60-cycle AC power line. As shown in Figure 1 and Specifications, the meter indication is little affected even by a wide variation in power line voltage. However, for longer life of this equipment, it is preferred that the line voltage be kept within _____v. ± 5 v.

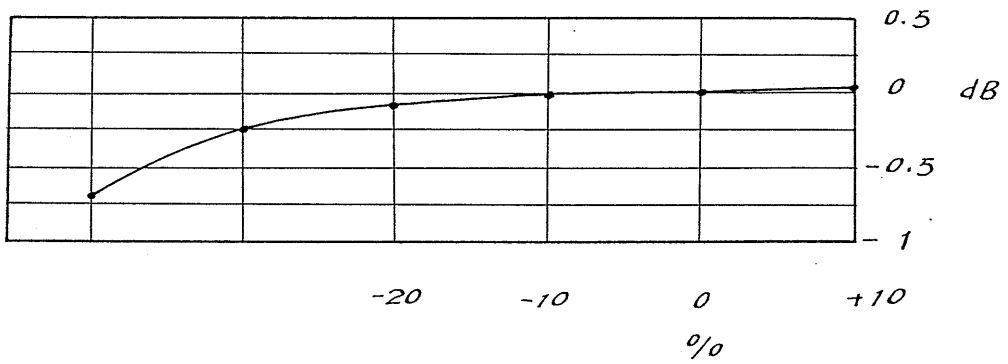

Fig. 1

1. INSTRUCTIONS OF PANEL ARRANGEMENTS

1) POWER (OFF)

Snap Switch to turn the power on or off. The power is supplied by turning this switch upward, and the dial of the range switch is illuminated.

For about 20 seconds after switching on, the meter pointer may swing irregularly. Also, the same may happen for about 10 seconds after switching off.

2) RANGE SWITCH

This is a black-colored dial on the center of the panel. The figures on the dial have following meanings:

Figures on external circumference: These figures indicate full scale voltages.

Orange-colored figures indicate mV (= 1/1000 V)

White-colored figures indicate V.

Figures on internal circumference: These red-colored figures indicate center scale voltage in dBm. (dBm will be explained later.)

When turned clockwise, the range switch steps for higher voltage range, and when turned in a reverse direction, it steps for lower voltage range. In measurement, set first the dial at high voltage range, and then gradually lower the voltage range until an appropriate indication is obtained so as to avoid the excessive load to the equipment.

3) INPUT TERMINAL

This is the input terminal to connect the voltage to be measured, consisting of a UHF-type receptacle and GND (Grand) terminal. UHF-type plug (5/8" - 24) or M-type plug (16ø - 1P) is applicable for connection. Also, a standard, 2-pole banana plug with 3/4" (19 mm) spacing can be used.

In addition, UHF-type receptacle can accept the banana plug as its center conductor, and, furthermore, accept Type 941B Terminal Adapter. This terminal adapter, like GND terminal, can hold any of banana plug, spade lug, alligator clip, 2-mm prod and wires less than 2 mm in diameter.

External conductor of UHF-type receptacle and GND terminal are electrically connected to the panel and chassis of this equipment.

In series to input circuit, a DC blocking capacitor of 600 v. oil condenser is connected. Input impedance has been adjusted to 1 megohm with a shunt capacitance of 25 $\pm$ 2 pF and is constant in all ranges.

4) OUTPUT TERMINAL

These terminals are used when this equipment is used as an amplifier. Like 941B Terminal Adapter, they can hold any of banana plug, spade lug, alligator clip, 2 mm-prod and wires less than 2 mm in diameter. But, a standard, 2-pole banana plug is more convenient.

This equipment can perform as a voltmeter and as an amplifier simultaneously. However, if load impedance is too low, the following deficiencies may occur:

Resistive Component - When resistive component of the load impedance is too low, lower frequency characteristic between input and output terminals may deteriorate. On the other hand, the frequency characteristic between input terminal and meter changes little.

Capacitive Component - When capacitive component of the load impedance is dominant, the higher end of frequency characteristic is significantly affected. Figure 2 shows an example of the effect of capacitance connected to the output terminals on the frequency characteristic of the amplifier. However, this effect may vary according to each voltmeter and power line voltage.

Output terminals deliver 2.5 v output when meter indication is full scale. Since this equipment employs a negative feed-back circuit

utilizing the current flowing in the meter, when certain load is connected, distortion and S/N characteristic may also deteriorate.

5) METER SCALE

The meter indication of this equipment has the following three scales:

(1) Scale calibrated from 0 to 50

This scale is read when range switch is set at any one of 5, 50, 500 mV and 5, 50, 500 v ranges. The figure 50 means 50 mV when range switch is set at 50 mV and 500 v when range switch is set at 500 v, and so on.

Example: - If meter indication is 37 with range switch set at 500 v, the measured voltage is 370 v, and if meter indication is 37 with range switch set at 500 mV, the measured voltage is 370 mV (= 0.37 v).

(2) Scale calibrated from 0 to 15

This scale is read when range switch is set at any one of 1.5, 15, 150 mV and 1.5, 15, 150 v ranges. The meaning of the figures are same as explained above.

(3) Scale calibrated in dBm

This scale is read when it is necessary to measure voltage in dBm value. The same scale is used for all 12 ranges.

The dBm value of the measured voltage can be obtained just by adding the dBm value indicated on the dial to the meter indication.

Example: - If meter indication is 5.5 on dBm scale with range switch set at 30 dBm (30 v) range, the dBm value of the measured voltage is: 5.5 + 30 = 35.5 dBm.

Example: - In this condition, if range switch is turned to 40 dBm (150 v) range, meter pointer now indicates --4.5 on dBm scale. The dBm value is then: --4.5 + 40 = 35.5 dBm.

Example: - If meter indication is 3 on dBm scale with range switch set at -20 dBm (150 mV) range, the measured voltage is: 3 + (-20) = 3 - 20 = -17 dBm.

Example: - In this condition, if range switch is turned to -10 dBm (500 mV) range, meter pointer now indicates -7 on dBm scale. The dBm value is therefore: -7 + (-10) = -7 - 10 = -17 dBm.

The explanation of dBm will appear in later section.

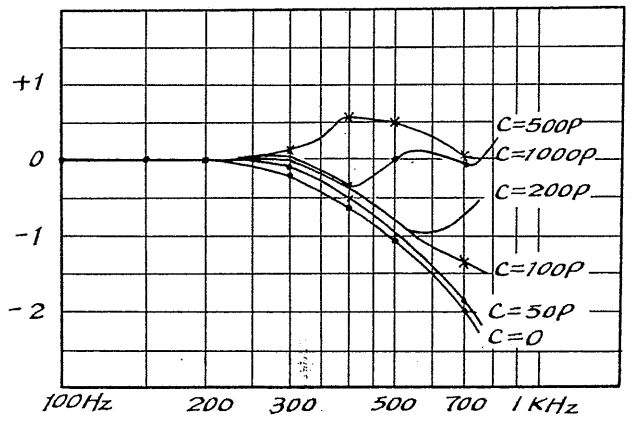

Fig. 2

2. ERRORS CAUSED BY DISTORTED WAVEFORMS

This equipment is a voltmeter to indicate "mean value" of AC voltage to be measured. However, the scale is calibrated in RMS value. For this reason, if the measure voltage is not sinusoidal, the meter indication may deviate from accurate RMS value. Table 1 shows several examples.

Table 1.

Waveform of Measured Voltage	Calculated RMS Value	Indication of Meter
Purely sinusoidal (100% fundamental)	100%	100%
100% fundamental + 10% 2nd harmonic	100.5	100
100% fundamental + 20% 2nd harmonic	102	100 ~ 102
100% fundamental + 50% 2nd harmonic	112	100 ~ 110
100% fundamental + 10% 3rd harmonic	100.3	96 ~ 104
100% fundamental + 20% 3rd harmonic	102	94 ~ 108
100% fundamental + 50% 3rd harmonic	112	90 ~ 116

3. MEASUREMENT OF AC CURRENT

This equipment can also be used to measure AC current. In measurement, a known registor is connected in series to the AC current circuit, and a voltage drop across such registor is measured. The current is calculated by formula:

$$I = E/R$$

In this measurement, it should be noted that GND terminal of this equipment is connected to the panel and chassis.

Type-921 Shunt Registors, available upon your separate order, are the standard registors convenient for measurement of currents. Resistance values of 0.1 ohm, 1 ohm, 10 ohm, 100 ohm and 1000 ohm, and in addition, 4 ohm, 8 ohm, 15 ohm and 600 ohm are available. All of them can be used with their banana plugs fixed to the input terminals

of this equipment.

Example: - How to measure heater current of a tube with rating of 6.3 v. 0.3 A? Using Type 921 0.1-ohm Shunt Resistor, a precision 0.1-ohm resistor, meter indication of 29 mV is read off in the connections as shown in Figure 3. Then, heater current is:

$$I = 29 \times 10^{-3}/0.1 = 290 \times 10^{-3} \text{ A} = 290 \text{ mA.}$$

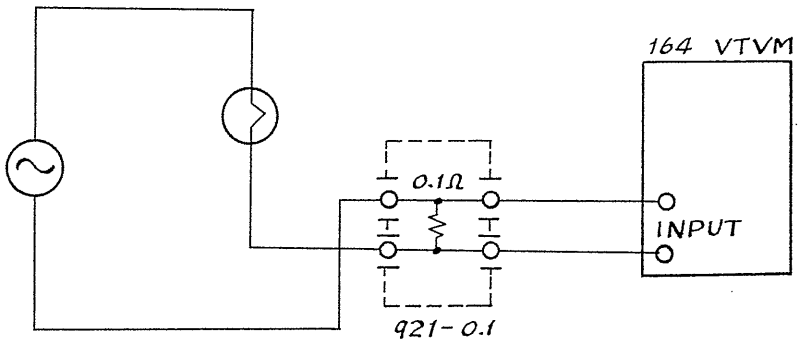

Fig. 3

4. MEASUREMENT OF OUTPUT POWER

This equipment can also be used to measure the output power. If a voltage across an impedance is obtained, the power across the impedance is calculated by the formula:

$$VA = E^2/ X$$

In this case, if the impedance is identical with a pure resistance, the power is then:

$$P = E^2/ R$$

In case of 600-ohm load, the power is directly read in decibels on the dBm scale of the meter. When load impedance is different from 600

ohms, the power is also obtained in decibels by adding a figure read in Figures 4 and 5 for load impedance values between 1 ohm and 10 k ohms.

Type-921 Shunt Resistors are also available in resistance values of 4 ohm, 8 ohm and 15 ohm, which are the same as nominal voice-coil impedance of common loud speakers, and these shunt resistors are used as load impedances in measurement of output powers up to 0.3 watt.

5. HOW TO USE DECIBEL CONVERSION CHARTS

DECIBEL: - Bell (B) is a unit given to a common logarithm of a ratio of two values of power with base of 10, and decibel (dB) is one tenth of bell. Decibel is therefore defined by following formula:

$$dB = 10 \log^{10} \frac{P2}{P1}$$

In other words, the ratio of P1 to P2 is represented by the decuple of common logarithm.

Herein, if impedance at which P1 and P2 are to be measured are equal, ratio of power simultaneously gives ratio of voltage or current, and the formulas are:

$$dB = 20 \log^{10} \frac{E2}{E1}$$

$$dB = 20 \log^{10} \frac{I\ 2}{I\ 1}$$

DB SUFFIX: - As shown above, decibel was originally defined in terms of a ratio of values of power. However, a fairly long time ago, the meaning of decibel was expanded and all the ratios of values in general expressed in terms of logarithm are now customerily called decibel.

Thus, when decibel is used, it is necessary to determine its basis, say, 0 dB beforehand.

For example, if input voltage of an amplifier is 10 mV and output is 10 v, its amplification is 10 v/10 mV or 1000. In decibels,

$$\text{Amplification} = 20 \log^{10} 10 \text{ v}/10 \text{ mV} = 60 \text{ decibels.}$$

In RF signal generators, output voltage is expressed in decibels in reference to 1 mV. For example, 10 mV is:

$$10 \text{ mV} = 20 \log^{10} 10 \text{ mV}/1 \ \mu\text{V} = 80 \text{ decibels}$$

In above-mentioned signal generators, the output voltage is expressed as follows:

$$10 \text{ mV} = 80 \text{ dB } (1 \ \mu\text{V} = 0 \text{ dB})$$

Thus, the value corresponding to 0 dB is shown in parenthesis.

dBm: - dBm is an abbreviation of dB (mW), and a unit given to a value of power as compared to 1 mW assuming an impedance of 600 ohms. Therefore, 0 dBm equals:

$$\begin{aligned} 0 \text{ dBm} &= 1 \text{ mW} \\ &= 0.775 \text{ V} \\ &= 1.291 \text{ mA} \end{aligned}$$

The meter indicator of this equipment is calibrated in dBm. Therefore, in order to obtain decibel value with other reference than 1 mW into 600 ohms, a constant figure should be added or subtracted from the meter indication. Such figure can be obtained by using Figures 4 and 5.

FIGURE 4: - Figure 4 is convert ratio of voltages, currents or powers into decibels.

Example: - How many decibels is 5 mW as referred to 1 mW?

Ratio 5 mW/1mW = 5 is obtained, and 7 dB is obtained as shown by

dotted lines in Figure 4.

Example: - How many decibels are 50 mW and 500 mW as referred to 1 mW? When ratio is more than 10 or less than 0.1, the relation shown in Table 2 is used, and decibel values are obtained as follows:

50 mW = 5 mW x 10 = 7 dB + 10 dB = 17 dB.
500 mW = 5 mW x 100 = 7 dB + 20 dB = 27 dB.

Example: - How many decibels is 15 mV as compared to 1 v?

15 mV/1v = 1.5 x 0.01 = 3.5 dB + (-40) dB = -36.5 dB.

Table 2.

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

FIGURE 5: - Figure 5 is used to obtain power value converting dBm reading on the meter indicator.

Example: - Measuring a voltage across voice coil of 8-ohm speaker, an indication of -4.8 dBm is obtained on the meter. Then, what is the power delivered to the speaker in milliwatt?

In Figure 5, a figure +18.8 is obtained as shown by dotted line. This figure is added to meter indication:

-4.8 + 18.8 = -14 dB

Then, using Figure 4, -14 dB can be converted into 25 mW.

Example: - How many volts of voltage is required to deliver a power

of 1 W into a 10 k ohm load?

1 W is equal to 1000 mW and is 30 dB as referred to 1 mW. In Figure 5, a figure -12.2 is obtained. Then, meter indication should be 30 - (-12.2) = 42.2 dBm to deliver 1 W into 10 k ohm load. The indication 42.2 dBm is 2.2 dBm in range of 40 dBm (150 v), and equal to 100 v.