Assembly

and

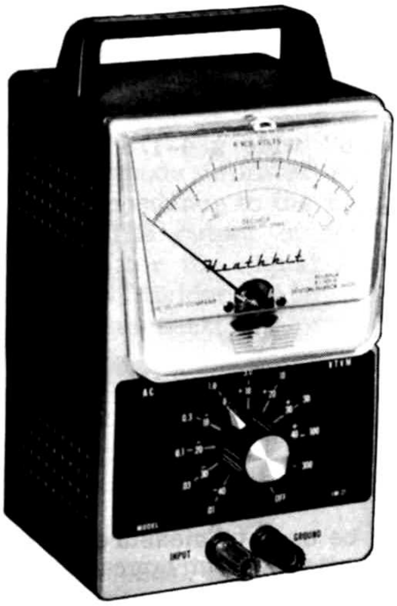
Operation

of the

HEATHKIT by Daystrom

VACUUM TUBE VOLTMETER

MODEL IM-21



HEATH COMPANY,

BENTON HARBOR,

MICHIGAN

a subsidiary of DAYSTROM, INCORPORATED

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SPECIFICATIONS

Frequency Response	±1 db from 10 cps to 500 kc, all ranges. ±2 db from 10 cps to 1 mc, all ranges.
Ranges	Ten ranges, marked both in volts and db.
Volts	.01, .03, .1, .3, 1, 3, 10, 30, 100, 300 volts rms full scale.
Decibels	-40, -30, -20, -10, 0, +10, +20, +30, +40, +50 db (0 db is equal to 1 milliwatt in 600 Ω).
Input Impedance	10 megohms shunted by 12 $\mu\mu$f on all ranges from .01 volt to 300 volts. 10 megohms shunted by 22 $\mu\mu$f on all ranges from .01 volt to 3 volts.
Power Requirements	105-125 volts, 50/60 cps AC, 10 watts.
Dimensions	7-3/8" high x 4-11/16" wide x 4-1/8" deep.
Accuracy	Within 5% of full scale.
Net Weight	3 lbs.
Shipping Weight	4 lbs.

INTRODUCTION

The Model IM-21 Vacuum Tube Voltmeter is designed to measure AC voltages from 10 cycles per second to 1 megacycle. These AC voltages can be read on 10 ranges; the 10 millivolt range is lowest and the 300 volt range is highest. Each of these ten ranges is also calibrated in decibels (db) for your convenience.

A high input impedance (10 megohms) is provided so that the VTVM can be used to measure voltages in sensitive circuits without appreciable loading.

The VTVM normally is used to indicate steady AC voltages. It can also be used like a VU meter to indicate changing AC voltages, such as found in speech or music equipment. (The VU meter is a standard level meter used in the broadcasting and recording fields.)

CIRCUIT DESCRIPTION

It may be helpful to refer to the Schematic Diagram while reading the following description.

The circuit of this VTVM may be divided into four general sections: The input section, which consists of the input cathode follower and the input attenuators; the amplifier section; the meter circuit; and the power supply.

The input AC voltage is first applied to the frequency-compensated, 1000-to-1 voltage divider in the grid circuit of input cathode follower V1A. Input voltages for the lower six ranges are coupled directly to the grid of V1A from the top of the voltage divider. Input signals for the higher four ranges are divided by 1000 and coupled to the grid of V1A from the lower tap of the voltage divider.

The cathode follower stage, V1A, represents a high impedance to the input signal applied to its grid. The output of V1A is a low impedance source for the signal applied to the precision voltage divider which feeds the input of the amplifier section.

The precision voltage divider divides the signal from the cathode follower into the six different levels to provide ten scales, with readings from 10 millivolts to 300 volts.

The amplifier section consists of V1B, V2, and the various circuit components in these two stages. Approximately 19 db of negative feedback is returned through the meter circuit from V2 to the cathode circuit of V1B. This negative feedback provides high stability and uniform gain over the wide frequency range of the amplifier.

The meter circuit consists of a 200 microampere meter, with a full-wave bridge rectifier that uses four germanium diodes. For calibration purposes, the amount of meter current can be adjusted by means of the calibrate control. This control determines the amount of meter current by adjusting the amount of negative feedback to the cathode of V1B.

The power supply consists of a half-wave rectifier circuit, containing a silicon rectifier and capacitor C17. The power supply also supplies filament voltage to the tubes and pilot lamp. In order to minimize hum, the filament winding of the power transformer is balanced to ground through resistors R28 and R29.

CONSTRUCTION NOTES

This manual is supplied to assist you in every way to complete your kit with the least possible chance for error. The arrangement shown is the result of extensive experimentation and trial. If followed carefully, the result will be a stable instrument, operating at a high degree of dependability. We suggest that you retain the manual in your files for future reference, both in the use of the instrument and for its maintenance.

UNPACK THE KIT CAREFULLY AND CHECK EACH PART AGAINST THE PARTS LIST. In so doing, you will become acquainted with the parts. Refer to the charts and other information on the inside covers of the manual to help you identify the components. If some shortage or parts damage is found in checking the Parts List, please read the Replacement section and supply the information called for therein. Include all inspection slips in your letter to us.

Resistors generally have a tolerance rating of 10% unless otherwise stated in the Parts List. Tolerances on capacitors are generally even greater. Limits of +100% and -20% are common for electrolytic capacitors.

ADJUSTMENTS

For maximum accuracy, use an accurate AC voltmeter, and/or an accurate AC voltage source to calibrate your VTVM. If these are not available, you can make an approximate calibration by using your 117 volt power line voltage as a calibrating source.

LINE VOLTAGE CALIBRATION

( ) Before turning the VTVM on, adjust the meter needle to be exactly over zero on the front panel by turning the small screw near the bottom center section of the meter face.

( ) Turn on your VTVM by turning the range switch to the 300 volt range. Allow it to operate for fifteen minutes for a thorough warmup period. If the filaments do not light or if any indication of malfunction appears, turn the unit off immediately and refer to the In Case Of Difficulty section.

( ) Connect the test leads of the VTVM to the 117 volt power line.

(CAUTION: A 117 volt line is dangerous. Proceed with care. Hold only one lead at a time.)

( ) Adjust the calibrate control so the meter needle indicates 117 volts. Disconnect the leads from the 117 volt power line.

( ) Turn the trimmer capacitor (on the range switch) to the position shown in Figure 2. This compensates the input voltage divider approximately for frequencies throughout the range of the VTVM.

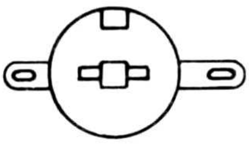


Figure 2

INSTRUMENT CALIBRATION

Use an AC voltmeter of known accuracy, and an audio signal generator.

( ) Turn the VTVM on by turning the range switch to the 3 volt range. Allow the unit to warm up for fifteen minutes. If the filaments do not light or if any indication of malfunction appears, turn the unit off immediately and refer to the In Case Of Difficulty section.

( ) Place the VTVM in its cabinet, but do not secure in place.

( ) Set the frequency of the signal generator to 1000 cps. Set the output of the signal generator to 3 volts, as measured with the standard meter.

( ) Now connect the test leads of the IM-21 VTVM to the output of the signal generator.

( ) Adjust the calibrate control so that the meter indicates 3 volts.

( ) Remove the cabinet from the VTVM.

( ) Turn the range switch to the 10 volt range and adjust the trimmer capacitor (on the range switch) so that the meter indicates exactly 3 volts.

This completes the adjustment.

( ) Install the VTVM in the cabinet, using two 6-32 x 1/2" screws as shown in Figure 3.

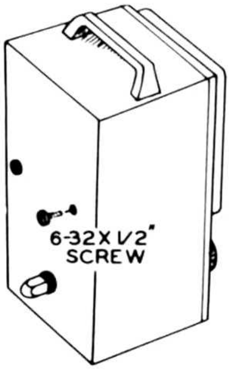


Figure 3

( ) Install the plastic control guard on the calibration control.

OPERATION

The OFF position of the range switch is just above the highest voltage range. This protects the instrument by insuring that it is always turned to the highest voltage range when first turned on. On the lower ranges, the meter may indicate some voltage when no connections are made to the input terminals. This residual voltage is caused by the extreme sensitivity of the instrument. Reverse the AC line plug to determine which way gives the lowest residual voltage.

The range switch positions cover the 300, 100, 30, 10, 3, 1, .3, .1, .03, and .01 volt ranges. The meter scale is marked 0-3 and 0-10 for voltage measurements. Be sure to place the decimal in the proper place in order to indicate the correct voltage for each range.

> Example 1: Using the .03 range, the meter reads 2. Move the decimal point two places to the left for the correct voltage; in this case .02 volt.

> Example 2: The meter reads 6.4 on the .1 volt range. Move the decimal point two places to the left for the correct voltage; in this case .064 volt.

The decibel (db) scales range from -40 db to +50 db. When reading the db scale, add the meter reading to the range indication.

> Example 1: The meter indicates -5 db and the range switch is on the +20 db range; the actual value is +15 db.

> Example 2: The meter indicates -4 db and the range switch is turned to the -10 db position; the actual value is -14 db.

Do not touch the input terminals when the range switch is set to one of the low ranges. Stray electric fields picked up by the human body will deflect the pointer beyond full scale, causing the meter pointer to bang against the limit pin. Repeated extreme overloads could bend the pointer.

Although the pointer can be bent by repeated extreme overloads, the electronic circuit limits the signal applied to the meter to a safe value, thus protecting the coil windings of the meter from being damaged. NOTE: Occasionally, switching transients will cause the meter to deflect to full scale when switching from one range to another. These transients are normal, and will not harm the meter.

APPLICATIONS

Almost any type of AC voltage, filament voltage, power line voltage, noise voltage, or even output or gain measurements can be made quickly and accurately with your AC VTVM. It is calibrated to read the root-mean-square (rms) value of a pure sine wave. This is 70.7% of the peak voltage.

COMPLEX WAVEFORMS

As in most rectifier-type AC VTVMs, meter deflection is proportional to the average value of the input waveform. When measuring odd-shaped waveforms (square waves, sawtooth waves or pulses) the meter reading must be given special interpretation. Special reading material on this subject will be found listed in the Bibliography.

READING DB

Since a power level in a circuit with a fixed impedance varies with the square of the voltage, the voltage reading is indicative of the power level. Therefore, a voltmeter can be calibrated with a db scale, which provides a convenient method of measuring power loss or gain.

Basically, the db is defined as follows:

$$db = 10 \log \frac{P_1}{P_2} = \log \frac{\left(\frac{E_1}{R}\right)^2}{\left(\frac{E_2}{R}\right)^2} = 10 \log \frac{(E_1)^2}{(E_2)^2} = 20 \log \frac{(E_1)}{(E_2)}$$

Being logarithmic, it parallels to some extent the human impression of light and sound intensities. Thus a change in signal level of a number of db will give the same impression regardless of the nominal operating level, although the change in power may be milliwatts (for low level signals) or tens of watt (for high level signals).

Since the decibel only indicates a ratio between two power levels, it is not normally referenced to any definite level. The term dbm, decibels related to 1 milliwatt, came into use so that decibels could indicate a definite level as well as a ratio. This VTVM is calibrated to read directly in dbm when connected across a 600 Ω load. (0 dbm equals 1 milliwatt into a 600 Ω load.)

CIRCUIT IMPEDANCES

Circuit impedances should be considered when comparing one db level to another. An example of this could be where the gain of an amplifier is being measured. If the input impedance is the same as the output impedance, the db gain can be measured directly with the VTVM. If the input and output impedances are different, it is necessary to adjust each reading mathematically to a common reference level.

VU APPLICATIONS

Because of the VU-type ballistics (rapid action) of the meter movement, the VTVM can be used to indicate changing AC voltages such as those that occur in speech or music. This enables you to use the VTVM to monitor audio signals, such as the input to a tape recorder, in order to insure proper recording level.

BIBLIOGRAPHY

Langford-Smith, RADIOTRON DESIGNERS HANDBOOK, 4th Edition, Chapter 19, Published by RCA.

Rider, J.F., VACUUM TUBE VOLTMETER, 2nd Edition.

Turner, BASIC ELECTRONIC TEST INSTRUMENTS, Rinehart, 1953.

HEWLETT-PACKARD Journal, ARTICLES ON WAVEFORM, April-May-June 1955, Vol. 6, Numbers 8, 9, and 10.

IN CASE OF DIFFICULTY

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the constructor.

2. It is interesting to note that about 90% of the kits that are returned for repair, do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure that they are soldered as described in the Proper Soldering Techniques section of this manual.

3. Check to be sure that both tubes are in their proper locations. Make sure that they light up properly.

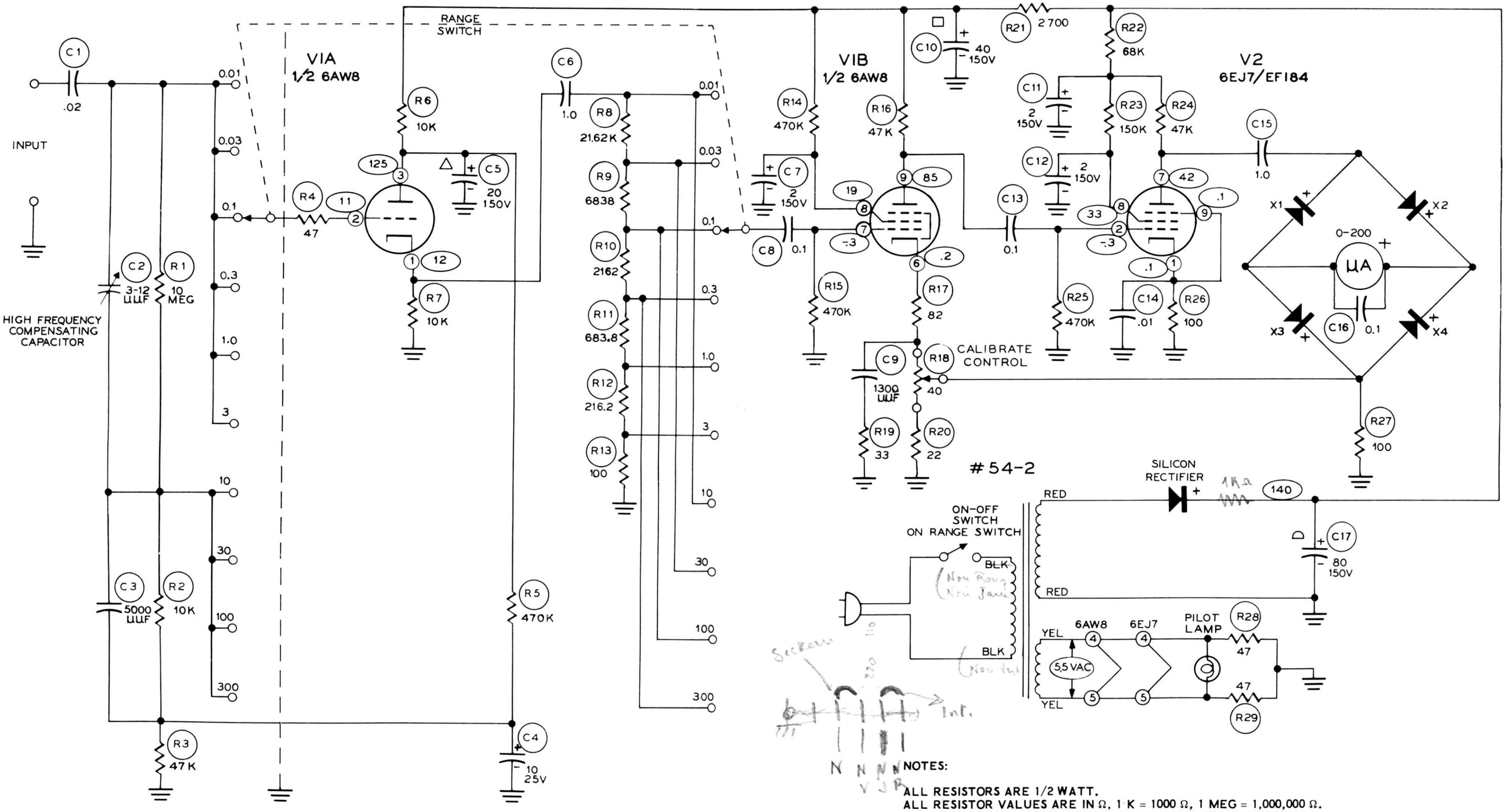
4. Check for bits of solder, wire ends or other foreign matter which may be lodged in the wiring.

5. Check the values of the component parts. Be sure that the proper part has been wired into the circuit, as shown in the pictorial diagrams and as called out in the wiring instructions.

6. Check the tubes with a tube tester or by substitution of tubes of the same types which are known to be good.

7. If, after careful checks, the trouble is still not located and a voltmeter is available, check voltage readings against those found on the Schematic Diagram. NOTE: All voltage readings were taken with an 11 megohm input vacuum tube voltmeter. Voltages may vary as much as 10% due to line voltage variations. Larger variations may lead you to the cause of the trouble.

8. A review of the Circuit Description will prove helpful in indicating where to look for the cause of the trouble.



NOTES:

ALL RESISTORS ARE 1/2 WATT.
ALL RESISTOR VALUES ARE IN Ω, 1 K = 1000 Ω, 1 MEG = 1,000,000 Ω.
ALL CAPACITOR VALUES ARE IN μfd UNLESS SHOWN OTHERWISE.

ALL VOLTAGES ARE FROM POINT INDICATED TO CHASSIS GROUND EXCEPT AC VOLTAGES ON POWER TRANSFORMER WINDINGS. READINGS WERE TAKEN WITH AN 11 MEGOHM INPUT VTVM.

VOLTAGES WERE TAKEN WITH INPUT TERMINALS SHORTED AND RANGE SWITCH IN 300 V POSITION.

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