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The AEROVOX Research Worker

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Vacuum-Tube Voltmeters

PART 2

By the Engineering Department, Aerovox Corporation

WHEN using the VTVM for radio frequency measurement, extreme care must be taken to keep the input capacity of the measuring device and its leads as small as possible. By that is meant not more than 5 mmfd., and if at all possible 1 mmfd. This can be done by connecting the grid cap of the VTVM tube directly to the point to be investigated. The easiest way of doing this is to make a probe utilizing only the VTVM tube. The 954 acorn tube can be used for the purpose as it is small and has a very low input capacity. For peak voltmeter measurements an 879 tube is recommended as its grid to plate capacity is approximately 1 mmfd. This type of VTVM can be built easily; kits for its construction are available. Shielding of the complete unit is of great importance and every possible care should be taken to see that all shields are solidly connected.

In checking a receiver for poor operation or inoperation, a systematic and intelligent method of investigation will save hours of fruitless testing. Most servicemen have their own method of attack but all start with the power supply. As we are primarily interested in i.f. and r.f. tests we will assume that the power supply functions properly and that all tubes have their proper voltages at their proper terminals, and have been tested and found satisfactory.

The equipment required for these tests is a signal generator and a VTVM. A cathode ray oscillograph may be used if available. If a signal generator is unavailable the signal of a local broadcast station may be used. In addition a high resistance multi-range voltmeter is required.

To check a radio frequency receiver it is first necessary to provide a signal which is fed to the antenna input terminals. The VTVM is connected from the plate of the first r.f. tube to ground, with a small coupling condenser of .0005 mfd. in series with the grid terminal of the VTVM. The grid circuit of the r.f. tube is tuned to the frequency of the signal by watching the deflection of the VTVM which is a maximum at resonance of the grid circuit. The frequency of the input signal is varied and the circuit is returned to the new frequency. By noting the variation in output voltage for various frequencies with a constant input voltage, the performance of the r.f. stage is determined. This test will give the characteristics of the antenna transformer. The circuit and the constants for the dummy antenna are given in Figure 1. A circuit diagram of a typical tuned radio frequency receiver is shown in Figure 2. The dummy antenna can be made up of ordinary resistances and mica condensers. Constants for the coil are as follows:

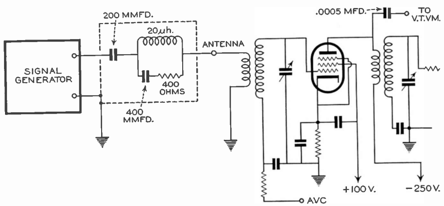

Figure 1

28 turns of #28 enamelled copper wire wound on a one-inch diameter tube, the winding being spread to cover one half inch of space. The dummy antenna should be mounted in a metal can for shielding. The coil should be placed so that no part of the winding is less than the diameter of the coil from the can.

After the antenna stage has been checked and is found to be satisfactory, the following stages can be checked individually by connecting the signal generator to the grid of the preceding tubes after the grid cap is removed. For these checks the dummy antenna is not required and is removed from the circuit. When each stage has been tested, the over-all radio frequency characteristic can be found by feeding a signal through the dummy antenna into the antenna terminals of the receiver and measuring the output voltage across the output windings of the diode transformer. At the high frequency end of the spectrum the capacity of the VTVM may seriously detune the circuit. The trimmer condenser of the triode circuit can be adjusted to compensate for the capacity of the VTVM while it is connected to the circuit. The output of the radio frequency portion of the receiver can be determined also by measuring the diode current but since this current is of the order of 100 microamperes or less and the smallest meter usually available in the average service shop is 1 milliampere full scale, this is not always feasible. Connecting the VTVM across the diode load resistance will give the d.c. voltage drop produced by the rectified r.f. signal voltage.

If the gain of any stage is found to be low the cause can be traced by first checking the r.f. voltage across the by-pass condensers. The r.f. voltage across an open by-pass condenser will be found to be equal to the total voltage of the circuit. Condensers that have intermittent opens or partial opens such as connection to only a few turns instead of all turns will show up as having an appreciable r.f. voltage across them. Thus the condensers can be checked without removing these condensers from the circuit. The interstage coupling transformer can be checked for performance—good or poor—by connecting the signal generator to the grid of the preceding tube and connecting the VTVM to the secondary of the transformer. As the signal generator is very slowly tuned through the resonant frequency of the transformer and its condenser, the VTVM should rise rapidly to a maximum value and suddenly drop. The readings of the VTVM when plotted against frequency will give a curve similar to *a* in Figure 3. If the transformer has high losses or a low Q the curve will appear similar to *b*. Of course the efficiency of the circuit depends upon the characteristics of the variable condenser but poor variable condensers are rarely found and when found their faults are apparent physically, such as dust between plates or corroded connections or contacts.

Regeneration in tuned radio frequency circuits increases the sharpness of the resonance curves and if selectivity is wanted a small amount of feedback is used. An excessive amount of feedback will cause self-sustained oscillations. This can be detected by measuring the voltage drop across the a.v.c. decoupling resistor as this resistor is the only path for the d.c. grid current produced by the self-sustained oscillations.

The stability of any amplifier can be checked by connecting the VTVM to the output of the amplifier. The input voltage should be reduced to zero and the output voltage noted. The amplifier should have all its proper voltages applied. If the amplifier is stable and non-oscillating, the voltage read by the VTVM should be zero with no input signal and should increase with

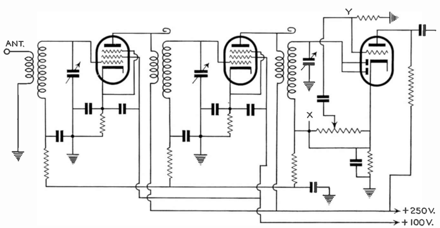

Figure 2

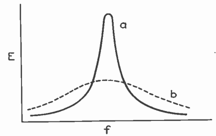

Figure 3

the input voltage. When the amplifier is unstable, the output voltage with zero input voltage may be zero but when a small input signal is applied the output voltage will jump to its maximum value.

The cause of excessive feedback or regeneration is quite difficult to determine experimentally. Regeneration is produced by coupling between the grid and plate circuit of one tube or even between the grid of any tube to the plate of any other succeeding tube. A common impedance in the plate supply is usually a reason for regeneration. This can be determined by measuring r.f. voltages between points suspected of acting as common impedances, such as plate supply units dropping resistors or potentiometers. These measurements must be made while the voltages and signal are applied to the system under consideration. The r.f. voltage between these points indicates a high impedance which is a source of feedback.

The second detector or demodulator can be checked with the VTVM by measuring the ratio of the rectified voltage appearing across the diode load to the r.f. voltage applied, as measured from diodes to cathode. The diode current should be directly proportional to the r.f. carrier voltage and any deviation from this proportion as the r.f. input voltage is varied both in magnitude and frequency indicates improper operation. The capacities and resistances can then be checked for incorrect values. One cause of distortion in receivers using diode detectors is improper filtering of the r.f. from the grid of the triode or pentode amplifier following the diodes. This distortion is most apparent when the volume control is set at low values. The second detector circuits can be checked for r.f. voltages by using the VTVM with a small coupling condenser of .0001 mfd. in series with the grid lead of the VTVM. No r.f. voltages should be present at the points *x* and *y* in the diagram of the r.f. receiver shown in Figure 2. If r.f. voltages are found, increased filtering and shielding are necessary to eliminate the r.f. from the circuit. The preceding tests should be carried out with an unmodulated signal.

The tests described above apply to superheterodyne receivers as well as to tuned radio frequency. The VTVM can be used in the i.f. section to check gain of i.f. amplifier stages and the efficacy of the i.f. filters. The oscillator of the superheterodyne receiver can be checked for output voltage and dead spots by connecting the VTVM to the plate circuit of the oscillator through a .0001 mfd. mica condenser.

The voltage output of the oscillator is noted while the oscillator condenser is tuned over operating range. A slight variation of voltage will be apparent but no great variation should exist. The voltage will fall off at the low frequency end of each band but at no time should the voltage drop to or nearly zero. If the voltage over any one band is much lower than the average over the other bands, the coils used for that band should be inspected for insufficient coupling or defective padder condensers.

The component parts of a receiver can be checked by using the signal generator and VTVM as a Q meter. For this purpose a variable condenser and several coils having a high Q. The signal generator and VTVM are connected as shown in Figure 4. The quantity Q is a factor of merit for any coil or condenser. It is defined as the ratio of the coil or condenser voltage in a tuned resonant circuit to the induced voltage in the circuit.

$$Q = \frac{\omega L}{R} = \frac{1}{\omega C R}$$

R = EQUIVALENT SERIES RESISTOR

In the circuit of Figure 4 the ratio of the voltage of the coil or condenser to the voltage across the .5 ohm resistance is equal to the Q of the unit being tested, unless the resistance of the unit is very much larger than the reactance of the coil or condenser. If a thermo milliammeter is not available the VTVM can be used by measuring the voltage drop across a shunt of 10 ohms which is in series with the line. The .5 ohm resistance should be non-inductive and can be made of a straight piece of wire several inches long, the length depending on the diameter and material. This wire can be wound on a thin bakelite or mica card one-half inch wide and about two inches long.

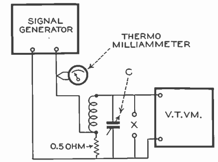

Figure 4

When using this Q meter for the checking of coils, the frequency of the signal generator is adjusted so that the coil to be tested will resonate with the calibrated variable condenser C. The output of the signal generator is adjusted so that the VTVM has a readable deflection. The input current or voltage is read and the voltage across the .5 ohm resistor is calculated. The ratio of the VTVM to the voltage across the .5 ohm resistor is Q of the coil. The inductance of the coil can be found from the capacity of the condenser *C* and the frequency of the applied voltage. A more detailed explanation of these measurements and calculations will be found in the July 1938 issue of the Aerovox Research Worker.

Another use of the VTVM which is a great convenience is its use with a search coil for the determinations of field strength and patterns. When used with a loop antenna, tuned or untuned, it can be used to locate the origin of interference signals. If the VTVM is connected to the high side of an audio transformer the best location for minimizing hum pickup can be found quickly.