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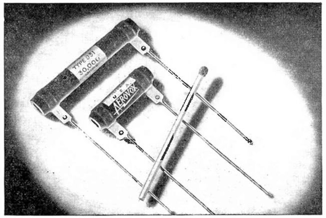

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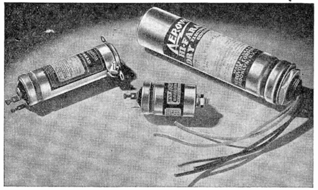

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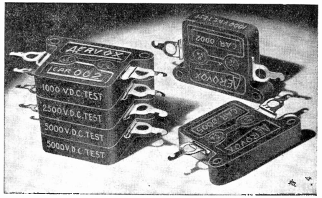

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The Aerovox Research Worker is a monthly house organ of the Aerovox Corporation. It is published to bring to the Radio Experimenter and Engineer authoritative, first hand information on condensers and resistances for radio work.

VOL. 8, NO. 6 JUNE, 1936 50c per year in U.S.A. 60c per year in Canada

Peak Voltages

By the Engineering Department, Aerovox Corporation

SOMETIMES it happens that condensers in a certain circuit keep burning out for no apparent reason. A d.c. voltmeter placed across the condenser shows that the potential is well below the maximum rating. One answer may be that there are alternating voltages, not shown by the meter, which subject the condenser to potentials above the maximum allowable limit. In addition to constantly recurring peaks of this nature there may be occasional peaks due to surges in the line or sometimes when switching the apparatus "on" or "off".

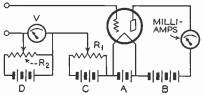

Fig. 1

A typical example of a condenser subject to peaks is the first filter condenser in a power pack. Blocking condensers in an output stage have an alternating voltage super-imposed on the direct voltage. So, instead of being subjected to only 250 or 300 volts, the potential across such a condenser may vary between 50 and 500 volts. When a receiver is not operating properly it may be that conditions exist which cause abnormally high peak voltages.

The question is now how to test for the condition and how to measure the voltage across a suspected condenser. There is, of course, the cathode-ray tube and its associated sweep circuit which will enable the user to observe wave shapes and to measure voltages. However, it can be done with rather simple and inexpensive apparatus.

One suitable type of peak voltmeter consists of a slide-back vacuum-tube-voltmeter. Such an instrument is shown in Figure 1. It consists of a vacuum tube with its A, B, and C-supply and a plate milliammeter. By means of the adjustable bias control, R1, the tube is adjusted to a very low but definite plate current. This may be the lowest current which will be indicated on the meter. When this adjustment is made, R2 should be adjusted so the reading on the voltmeter V is zero and the input terminals must be shorted. The latter requirement may be met by connecting the instrument across the condenser to be measured before the apparatus is turned on. Then turn R2 to the other extreme position or to a point which shows on V a potential which is about equal to the expected peak voltage. Connect the apparatus under test to the line and adjust R2 until the same low reading again occurs. The reading of V shows the peak voltage. If it is impractical to have a battery D of such a high voltage, a voltage divider may be employed as in Figure 1a. This multiplies the reading of the meter V by a factor (R3 + R4)/R3. There is of course no objection to operating the instrument from a power pack as in Figure 2. It should be clear that the negative end of the power pack cannot be grounded as a general rule. Usually the point P can be grounded but it all depends on the circuit under test.

A modification of the above circuit, which is better adapted for the measurement of high peak voltages, is shown in Figure 3. Here the unknown voltage is applied to the plate circuit while the grid is tied to the cathode. As before, with the input terminals closed, first adjust the slider S1 for the lowest current which the milliammeter can show. Then adjust slider S2 far enough towards the right to safeguard the meter, apply the unknown voltage and adjust the slider S2 for the same low current as before. The voltmeter shows the peak voltage across the input terminals. If desired, the voltage divider of Figure 1a may be used again. The value of R3 and R4 must be very high so as not to draw any appreciable power from the circuit under test.

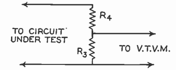

Fig. 1a

Another type of peak voltmeter consists of a diode rectifier, a large condenser and a very high resistance with a micro-ammeter. The circuit is shown in Figure 4. If the resistance across the condenser is very high the current through it will be very low and the condenser will charge up to the

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peak voltage of the circuit under test—very nearly. The recommended values in Figure 4 would provide a peak voltmeter with a full scale indication of 1000 volts. The tube can be any of the usual rectifiers although some triodes can be employed by connecting grid and plate together.

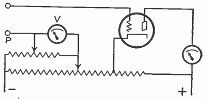


Fig. 2

When using any of these instruments it is important to observe the continuous peaks as well as the occasional peaks. For instance the d.c. voltage across a condenser might be 400 while the continuous peaks—those re-curring each cycle—are 440 volts. Then, at the moment the set is turned on the peaks may rise to over 500 volts. Sometimes these occasional peaks can occur only when the set has come up to temperature while in some cases they can exist only when the set is turned on after it has cooled. These things have to be taken into consideration. The peak voltage has to be observed when turning on the set, then they have to be measured again while the apparatus in normal operation, finally another measurement has to be made of peaks occurring when the set is heated, turned off and on again.

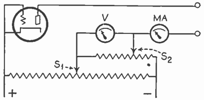


Fig. 3

It is felt that readers will be amply repaid when making one of the described testing instruments.

Methods of Phase Inversion

Phase inversion consists of obtaining the input for a push-pull stage from a single-ended stage by resistance coupled circuits and without the use of a push-pull input-transformer.

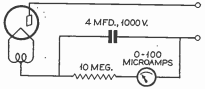


Fig. 4

The chief reason for existence of the phase inverter is the fact that a relatively simple and inexpensive arrangement may yield results which could not be equalled unless a transformer of excellent quality and consequently high price were used. When properly designed a phase inverter can be made to deliver two signal voltages exactly 180 degrees out of phase and of equal amplitude. Moreover there need not be any frequency distortion and phase shifts can be reduced to a negligible amount.

First let us consider a circuit which has been used in the past but which is now more or less out of date. Figure 5 shows the output stage of an amplifier where the inversion is accomplished by the output tube A. The signal voltage in the plate circuit of a tube is opposite in phase to that in the grid circuit. If the grid voltage becomes positive (rather, less negative) the plate current increases, and the voltage drop across the plate load increases making the plate voltage lower. This is so when the load is a resistor but when the load contains reactance as in the case of Figure 5, the voltage drop across the load is not in phase with the current through it and consequently, the plate and grid circuits do not have signal voltages in exact opposite phase.

The second requirement, that of equal amplitudes can be met by employing a voltage divider with the proper ratio so as to supply to tube B the same voltage as was applied to tube A.

The system of Figure 5 thus suffers from a phase shift which results in some distortion and in the inability to obtain full output.

The next step obviously leads to a circuit with a resistance load which would remove the above objection. There are several variations of this but they are really all the same. Figure 6 illustrates a system widely used in Europe. It accomplishes the same thing as Figure 5 but the load is resistive therefore the signal voltages in plate and grid circuits are opposite in phase. The voltage divider must be adjusted carefully so as to make the voltage across R1 equal to the voltage e of the input.

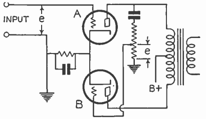


Fig. 5

The condenser is necessary in order to prevent the plate voltage from reaching the grid of the following tube. This condenser causes a small phase shift which varies with frequency. Usually the shift is of the order of a fraction of a degree for average values used. The idea is to make the resistors of a high value and the condenser of a high value. The reactance will then be so low as to have negligible effect.

There is another drawback to this system. For the convenience of having R1 and R2 standard resistance values, symmetry is often sacrificed. The two sides are then not exactly the same. Moreover, suppose that the divider has been perfectly adjusted for a symmetrical output, any variation in line voltage or in the characteristics of the tube with age will unbalance the circuit. These effects are generally not very large and the system has become quite popular.

There is of course no gain provided by the tube. It delivers a voltage equal to e and in opposite phase but there is no amplification. Some consider that the gain equals 2.

In Figure 7 is shown the American version of the same idea. Really it is exactly the same as Figure 6 but with a resistance-coupled stage ahead of it. A double triode is often used but there is no objection to employing two different triodes. The gain of the two tubes may be considered as twice the gain of one, in other words, the phase inversion tube again has a gain of 2. Otherwise this cricuit has the same characteristics and drawbacks as the one in Figure 6.

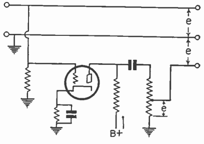


Fig. 6

In a radio receiver employing a diode detector it is possible to obtain perfect inversion in the detector circuit. This arrangement is illustrated in Figure 8. The load resistor of the diode circuit is simply divided into two equal parts and the center is grounded. Each of the sections has to be filtered individually. The circuit delivers two signals which are exactly 180 degrees out of phase and which are equal if the resistors are equal. There are no changing tube characteristics which may upset the balance later. However, if it is necessary to control volume in the same circuit a tandem control must be used; it will be very difficult to find two volume controls which will always be equivalent at all positions of the moving arm.

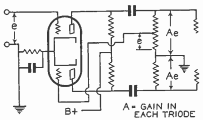
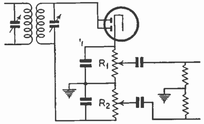


Fig. 7

This difficulty is overcome in the circuit of Figure 9. The inversion in this case is not done in the diode circuit but in the first audio stage. It depends on the following principle: The signal voltage across a resistor in the plate circuit of a tube is out of phase with the signal in the grid circuit as explained above. If the plate load is placed in the cathode circuit, the voltage drop across it will be in phase with the input signal. Then, if it is possible to divide the plate load equally between the plate circuit and the cathode circuit, the two sides of the push-pull signal can be obtained. The two signals must be equal when the resistors are equal and they are exactly opposite in phase because both sides will have the same number of coupling condensers.

The fly in the ointment is that such an arrangement requires the input circuit to be insulated from ground because the grid return is not at zero potential; it goes up and down with the signal. This is no objection in the case of the diode detector of a superheterodyne since the secondary can be completely isolated from ground. Figure 9 shows how it is connected. The bias can be obtained by means of a small battery or it may be supplied by the voltage drop across a portion of the cathode resistor. This portion must then be by-passed by a high-capacity electrolytic condenser. It does not count as a part of the plate load. R1 and R2 should be equal (Figure 9) but R3 is determined by the required bias and it is not a part of the cathode load. The volume control in this case can be at the same time the load of the diode tube.

Many an experimenter has burned the midnight oil trying to make the circuit of Figure 9 suitable for an input device which has one terminal grounded. There are several solutions but they are really all the same. The secret consists of establishing a suitable grid-return point which is being held at a fixed potential above the chassis, so that the proper bias can be applied to the tube. If this point remains fixed, the signal can be applied between ground and grid through the usual condensers.



R1, R2 = IDENTICAL VOLUME CONTROLS, ON COMMON SHAFT

Fig. 8

The circuit of Figure 10 is due to Richter (Electronics for October 1935). The tube is a 76, R1 and R2 are the two equal load resistances. When the tube is operated properly there will be a voltage drop of 70 volts across the cathode resistor R2. The required bias is 8 volts. The grid circuit now returns to a point on the voltage divider which is 8 volts negative with respect to the cathode. This point is 62 volts positive with respect to ground. The voltage divider must be bypassed with a large condenser. C1 might be .1 mfd. paper but C2 should be a high capacity electrolytic condenser.

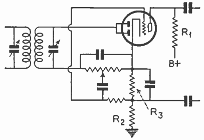


Fig. 9

It was explained before that this arrangement insures the two halves of the signal to be equal and exactly opposite in phase. It is not affected by changes in the plate voltage nor by changes in the characteristics of the tube.

The total gain obtainable from a stage like this is less than 2. It is obvious that any voltage, e, applied to the grid circuit appears amplified in the cathode circuit and would have a value of Ae volts. Another signal of Ae volts is developed across the plate load R1. The total gain is then 2A. The next question is how large is A. Whatever voltage is developed across the cathode resistor, R2, is again applied to the grid in a direction so as to oppose the orginal voltage, e. Then Ae must be less than e if there is going to be something left over; then A is less then unity and 2A must be less than 2. The actual value of A is somewhere around .8 or .9 depending on the mu of the tube and the design of the circuit. The fact that the tube does not deliver any gain is really not serious; the whole circuit might be considered as a replacement for a push-pull transformer. Since there is no reactance in the plate load or in the grid circuit there is no frequency discrimination.

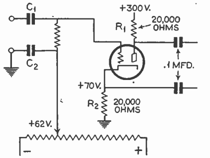


Fig. 10

Another way of accomplishing the same result is shown in Figure 11. The equal load resistances are R1 in the plate circuit and the combination of R2, R3, and R4 in the cathode circuit. These have been so selected that their combined effect is equal to R1. R2 is of the proper size to obtain the required bias. R3, in parallel with R4 as far as the signal is concerned, is very much larger than R4. The equivalent resistance of R3 and R4 in parallel added to R2 should equal R1. The condenser C2 is again very large so that its impedance is nearly zero for alternating currents. It will be seen that the grid is at the same potential as the junction of R2, R3 and R4 and that it is being kept constant due to the resistance-capacity filter R3-C2. The circuit has the same degeneration effects as the one in Figure 10; the gain is less than 2.

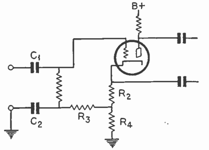


Fig. 11

It is recommended to use triodes only for the purpose of inversion since the screen supply of tetrodes or pentodes would offer another problem.