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The AEROVOX Research Worker

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The Importance of Proper Cathode Bias Filtering

By the Engineering Department, Aerovox Corporation

IT is common practice to secure bias for amplifier tubes by inserting a resistor in the cathode lead of the stage under consideration and connecting both the grid return lead and the negative plate voltage lead to the end of this resistor furthest from the cathode connection. Plate current returning to the cathode flows through this resistor and produces a voltage drop across it. The negative end of this resistor being connected to the grid return gives the grid a corresponding negative bias.

A.C. currents in the plate circuit returning to the cathode pass through this resistor and set up voltages there which are 180° out of phase with the grid voltage—and in fact detract from the voltage actually applied to the grid.

The cathode bias system therefore is a source of trouble and may cause bad degeneration at some frequencies, or may cause regeneration and distortion if not properly handled.

The common practice is to by-pass this resistor with a fairly large capacity, but economy makes it desirable to keep this capacity as low as possible. To make more effective a small capacity across the bias resistor, a filter resistor is placed in series with the plate voltage supply forcing a.c. currents to flow directly to the cathode bias resistor. Certain combinations of filter resistance and shunt capacity produce good effects; certain others may produce regeneration or severe loss of low frequencies.

The nature of the load impedance affects the degenerative effect produced in the grid circuit causing not only a loss in voltage, at some frequencies, but a shift in phase as well. The entire problem, therefore, is not as simple as it might appear at first glance. At audio frequencies the problem becomes of importance, especially where a good frequency characteristic is desired. At the low frequencies the effective filtering of the plate and grid circuits assumes considerable importance.

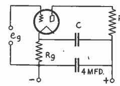

FIG. 1

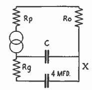

FIG. 2

Fig. 2 is the equivalent of Fig. 1 in which a voltage eg becomes multiplied by the mu-factor of the tube. A filter resistor placed between the plate load resistance and the plate voltage supply makes more effective the shunt capacity C in preventing degeneration due to the impedance of Rg being common to both grid and plate circuits.

Consider Fig. 1 which is the typical case where an input voltage eg. is applied to the tube which has a resistance load, the 4 mfd. condenser being the capacity across the output of the power supply. This may be represented by Fig. 2 where the voltage applied to the grid becomes multiplied by the mu-factor of the tube when it reappears in the plate circuit. Therefore this value mu eg. may be shown as in series with the load resistance, the cathode bias resistance and the internal resistance of the tube.

Calculations on the degradation of voltage will show the effects of various combinations of bias resistor, capacity and filter resistance in the plate circuit.

In a particular case a tube with a mu-factor of 10 and an internal resistance of 5000 ohms had a resistance load of 10,000 ohms. The bias resistance was 1000 ohms by-passed with 2 mfd. having a reactance of 1000 ohms at 80 cycles. Across the B voltage supply was 4 mfd.

The voltage actually applied to the grid under these conditions was 0.757 per volt impressed across the input circuit. In other words for every volt impressed only 0.757 actually got to the grid. This was at 80 cycles; at higher frequencies where the reactance of the by-pass capacity becomes lower its effect becomes greater and of course more voltage will get to the grid. The important point, however, is the fact that at the lower audio frequencies the inclusion of insufficient by-pass capacity lowers the response.

If the amplification of the stage is reduced to 3, for example, instead of 10, the effective voltage applied to the grid is increased—there is less degenerative effect. Increasing the by-pass capacity will have the same effect. Putting a filter resistor in the plate voltage supply at X will eliminate the bad effects of small by-pass capacity—but will cause a loss in plate voltage.

If the tube load is a transformer with a resistance of 100 ohms and a reactance of 10,000 ohms at 80 cycles the voltage on the grid becomes 0.915 per volt applied to the input—which is less loss than occurs with the resistive load.

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If with the resistive load the by-pass capacity is increased to 8 mfd. the grid voltage will become 0.92 instead of 0.757—but the cost of the condenser and the space required for it go up. If a suppressor resistance of 5000 ohms is inserted at X the grid voltage becomes 0.966 instead of 0.757. The voltage loss across this filter resistance would become prohibitive if the circuit were that of a power tube drawing appreciable current. In this case a choke of low resistance but high inductance might be employed. Under these conditions the voltage getting to the grid might be greater than that applied from the preceding stage indicating an actual amplification or regeneration effect in the tube.

All of which shows that cathode bias circuits are not to be taken lightly.

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CAPACITY TEST FOR ELECTROLYTIC CONDENSERS

It is often necessary or desirable for engineers or service men to determine the capacity of electrolytic condensers. This problem is not so simple a matter as measuring the capacity of an air dielectric condenser or of mica or paper condenser. The circuit in Fig. 3, however is simple, does not require costly apparatus, and measures the capacity of this type of condenser accurately.

It consists essentially of an a. c. transformer of about 6 volts across the secondary. Across this secondary is placed, in series with a switch, a 0.7 ohm resistor to improve the regulation by providing a load for the transformer to work into. The 100-ohm potentiometer permits adjustment of the voltage to be applied to the condenser under test.

The meters are both 1-milliampere Weston rectifier type units, one reading voltage and the other milliamperes (1.0 ma full scale). Various shunts are provided for reducing the sensitivity of the ammeter in measuring condensers of various capacities. In measuring large capacities the loading resistor across the secondary of the transformer is removed to permit sufficient voltage to be impressed across the capacity. This is necessary due to the poor regulation of the transformer which may be the type ordinarily used to supply power to light the heaters of automotive type tubes (6.3 volts).

In practice the voltage across the condenser is set at exactly 2.65 volts Then the reading in milliamperes will be equal to the condenser capacity in microfarads.

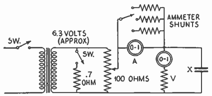

FIG. 3

The following table gives the values of shunting resistance to be used across the ammeter for various capacity ranges.

Ammeter Shunting Resistance

Range	Res. Ohms	Range	Res. Ohms
10 mfd.	1149.0	3 mfd.	317.2
100 mfd.	106.7	30 mfd.	31.5
1000 mfd.	11.55	300 mfd.	3.6
10,000 mfd.	1.05	3000 mfd.	0.34

Total voltmeter resistance—5,430 ohms.

All the shunts are of the variable type except the 1.05 and 0.34 ohm units.

This test instrument will prove very useful in testing electrolytic condensers of practically any capacity and will give reasonably accurate results provided the unit is carefully constructed. Of course one of the most important points is the shunt resistances across the milliameter, for the accuracy obtained will depend almost entirely on how careful these shunt resistors are made. It is desirable that the resistance of the meter used be measured to determine its resistance, although for general service shunts of the value indicated will be satisfactory.

One of the advantages of this instrument, of course, lies in the fact that the reading in milliamperes will be equal to the capacity in mfds. That this is true can be seen from the following.

The current in amperes flowing through a condenser at 60 cycles is equal to 377 times the voltage times the capacity in farads as shown in the formula below:

$$I = 377 \times E \times C$$

In terms of mfds. and milliamperes the current is equal to 377 times the voltage times the capacity in mfds. times 10^{-3}.

$$I\ ma = 377 \times E \times C\ mfds. \times 10^{-3}$$

Solving this equation we have

If I ma = C mfds. then

$$\frac{I\ ma}{C\ mfds.} = 1$$

therefore $1 = 377\ E \times 10^{-3}$

$$\text{and } E = \frac{10^{-3}}{377} = \frac{1000}{377} = 2.65 \text{ volts}$$

The last equation indicates that when the voltage is equal to 2.65 volts then the current in milliamperes is equal to the capacity in mfds.

This method of measurement is, of course, in error slightly due to the fact that the impedance of a condenser is not exactly determined by its capacity but is determined by its capacity and its series resistance. However, the error involved is not large and the method therefore is generally satisfactory.

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IMPROVED TYPE 48 OUTPUT TUBE

New ratings have been announced on the type 48 tubes, the 30-volt heater type tubes used in power output stage of universal-type receivers. These new ratings are based on new values of plate and grid voltages. The tubes now have a mutual conductance of 3800 micromhos.

With 96 volts on the plate and — 19 on the grid, a power output of 2 watts can be secured into a 1500 ohm load. With 125 on the plate and — 20 on the grid the output becomes 2.5 watts into 1500 ohms. The distortion under the two cases is 9.0 percent.

When operated as a triode, two of these tubes in push-pull deliver 3 watts with maximum distortion of 3 percent; as a tetrode the output becomes 5 watts with 9 percent distortion.

Thus the 48 is a versatile tube. It has the advantage of a high filament voltage useful in universal receivers.

New Data On the 6A7

Some trouble has been had in the past with the 1A6, the 2A7 and the 6A7 both with short life and with oscillation irregularity on the higher frequencies. The lack of good life was apparently due to faulty coil design which permitted the plate current to reach too high values with the result that the cathode coating flaked off and poor emission resulted.

An additional tube bridged across the 2A7, and others of this type, enable greater excitation to be secured at the higher frequencies. A simpler method has been suggested consisting simply in putting a suppressor resistance in the grid lead. On the higher frequencies where the input reactance of the tube becomes low the effect of these resistors (500 or 1000 ohms in value) becomes less on limiting the oscillation than at low frequencies where the input reactance is high. Therefore the inclusion of such resistors irons out unevenness in oscillation amplitude and produces a more uniform voltage.

A microammeter placed in series with the grid lead will register the steady rectified current to the grid. This value of current multiplied by the grid resistance give an indication of the output of the tube. With present circuits this voltage may vary over rather wide limits as the frequency is changed. Thus one tube manufacturer states that the value of Ig Rg may vary between 9 and 13 volts, a range of 4 volts or even more. With the suppressor in the circuit this variation may be ironed down to a change of only 2 volts. Thus oscillation occurs much more evenly over the band covered in multi-range receivers.

Another method of producing a steady output is to use a series padding condenser providing additional coupling between oscillator primary and secondary. The trouble in the past has been that sufficient coupling between coils to produce steady oscillations at low frequencies produces harmonics or parasitic oscillations at high frequencies. If the coupling is loosened to be proper at high freqencies the coupling is too loose at low frequencies. Therefore, if in addition to the mutual coupling between coils, a condenser connects the two coils, some additional coupling will be secured at low frequencies. This is true because any current flowing through this capacity at high frequencies will produce only a small voltage (because of the low reactance of the condenser) but at low frequencies the reactance of the condenser is higher and any current flowing through the condenser will increase the coupling between primary and secondary.

Greater ease in starting oscillation will be secured in some cases by connecting the grid resistance to ground instead of to the cathode. The plate voltage may be reduced in such cases materially.

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If there are any particular subjects dealing with the use of condensers and resistors in radio circuits that you would like to have discussed in these articles appearing in the Research Worker, please let us know and we shall endeavor to meet your wishes with interesting and helpful information on the subjects.

RIPPLE CURRENT RATINGS OF ELECTROLYTIC CONDENSERS

In the use of electrolytic condensers it is important not only that the d.c. voltage ratings not be exceeded, but, theoretically at least, that the a.c. ratings are not exceeded. We say "theoretically" since the amount of a.c. current which an electrolytic condenser can handle is definitely limited, although, practically we find that the circuits in which electrolytic condensers are used generally apply to the condenser less a.c. voltage than the condenser is able to withstand. As a result there is generally no difficulty in using electrolytic condensers in ordinary filter circuits because in such filter circuits there is not sufficient a.c. to overload the condenser.

The a.c. currents to which we refer to above are the so-called "ripple currents" which are present in the output of a rectifier tube. It is, of course, the function of the filter condenser to absorb these a.c. ripple voltages so as to apply only pure d.c. to the radio receiver. However, the effect of these ripple currents flowing through the condenser is to cause the condenser to become warm and therefore an excessive amount of a.c. current through the condenser would cause the temperature of the condenser to rise excessively.

To give some idea of the manner in which condensers are rated with respect to the ripple voltage they can handle the following figures will be of interest. A complete chart of these ratings will be found on page 3 of the December, 1933, issue of the Research Worker. These figures refer to ripple voltage at 120 cycles which represents the frequency output from a full wave rectifier. The voltages given are peak a.c. voltages. The voltages as read on an a.c. voltmeter would, of course, be equal to these peak voltages divided by 1.4.

For example, an 8 mfd. 450 volt working voltage condenser is rated for a peak a.c. voltage of 25 volts. For higher capacities the a.c. voltage the condenser can withstand is lower. For example, 15 mfd. condenser can only withstand 15 volts peak a.c. The larger capacities can stand less voltage because the current will naturally be much greater with larger capacities. On the other hand, low capacity condensers, for example, a 1 mfd. can stand a higher voltage in the order of about 30 volts peak a.c.

Of course, it will be noted that in all cases the condenser has placed on it a d.c. voltage in addition to the a.c. voltage. Readers will appreciate this since they are undoubtedly familiar with the fact that ordinary electrolytic condensers are designed only for polarized service and are not to be used on a.c. only.