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The Aerovox Research Worker

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The Use of Condensers in Radio Receivers

Part 2

By the Engineering Department, Aerovox Corporation

CONTINUING with the discussion of condensers and their applications, the next group of applications includes those where a condenser is used in order to obtain frequency discrimination. A typical example is the conventional tone control.

The most common type of tone control consists simply of a fixed condenser and a variable resistor. A device of this nature hardly deserves the name of tone control for its controlling action is very much limited. It can reduce some of the high notes but cannot do anything about either the low or the middle notes. Furthermore, the cut-off of high notes is not sharp but very gradual as we shall see. This type of tone control, however, has been found useful for the reduction of harsh noises as well as balancing the deficiency of low notes in midget receivers so that the total becomes acceptable.

Fig. 8 illustrates a tone control, used in the plate circuit of an output tube. For the sake of numerical examples it is necessary to give values to all circuit elements and we shall consider that the output tube is a pentode like the 2A5, 42 or 18 all of which have the same characteristics as an amplifier. The results obtained from these examples, however, are equally applicable to other tubes and other tone control circuits.

If the voice coil of the speaker is correctly matched to the tube, it is reflected as 7000 ohms into the plate circuit. For the purposes of this article, it will be assumed that this load is resistive. We can then draw the equivalent circuit as shown in Fig. 9. The tube can be replaced by a generator delivering a voltage equal to *mu times the signal voltage applied to the grid,* and having a series resistance

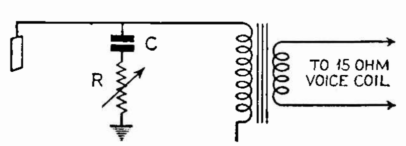


Fig. 8

equal to the plate resistance. The manufacturers give this plate resistance as 79000 ohms.

It is now required to find the variation in current or voltage delivered to the 7000 ohm load. The voltage across the 7000 ohm load will be proportional to the current flowing through it. But this current is out of phase with the current flowing through the tone control circuit, the phase difference being less than 90 degrees. The vector sum of the two currents is of course in phase with the current through the tube but the voltages across the tube and the load are again out of phase by a different odd angle. Therefore it is necessary to determine the voltage across the combination load and tone control by calculating the equivalent impedance of the parallel branches adding it vectorially to the impedance of the tube and finding the total impedance. The voltage divides across the tube and the load in proportion to their impedance, so we can find the voltage across the load. When this is done for different values of C and R and at different frequencies, it is possible to get an idea what happens to the frequency characteristic when this type of tone control is used.

Supposing it is required to attenuate the 5000 cycle notes at least 20 db (reducing the voltage to 10% of its normal value) with the tone control fully advanced. The required value of the condenser to accomplish this purpose can be found from the law of impedances in parallel. The nearest commercial value is .05 mfd. This will reduce the voltage across the load to 8.1% of its normal value at 5000 cycles.

The table below, Table I shows what percentage remains at several selected frequencies and also what happens at these frequencies when the resistor R has different values.

TABLE I

R (ohms)	Voltage across load in percent at 100c.	500c.	1000c	2500c.	5000c.
0	98	70.5	44.5	19	8.1
1,000	97.5	65	41	19.3	16
5,000	94.5	62.4	48.5	42	44
10,000	93.3	65	63	61	60

The table shows how gradual the attenuation is at fully advanced tone control setting, when R equals zero. The 500 cycle and 1000 cycle notes are also reduced appreciably. When the tone control is retarded, resistance is added in series with the condensers, the higher notes gradually *increase* and the lower notes *decrease* slightly thereby straightening out the response curve. It is not yet straightened out when R is 10,000 ohms, but when it becomes 100,000 ohms the tone control has practically no effect.

That the low notes decrease slightly when resistance is added in series with C is unbelievable. Consequently,

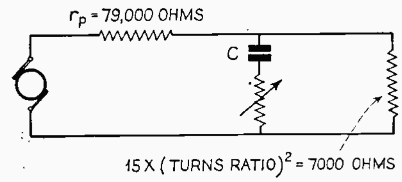


Fig. 9

the method of calculating the figures given in the foregoing table is as follows:

When the resistance R equals zero, the impedance of the condenser and the load in parallel is found by the equation

$$Z = \frac{X R}{\sqrt{X^2 + R^2}}$$

At 100 cycles, the impedance of the condenser is 1/6.28 x 100 x .05 x 10^{-6} = 32,000 ohms. Inserting the values for R and X we find

$$Z = \frac{7 \times 32 \times 1000}{\sqrt{32^2 + 7^2}} = \frac{224 \times 1000}{\sqrt{1024 + 49}} =$$

$$\frac{224 \times 1000}{\sqrt{1073}} = 6840 \text{ ohms}$$

Adding this vectorially to the plate resistance, gives us a total of 85,700 ohms. The voltage across the load is then

$$\frac{86}{7} \times \frac{85.7}{6.84} \times 100 = 98\%$$

Now figuring the same when 10,000 ohms has been added to the tone control, the calculation becomes more

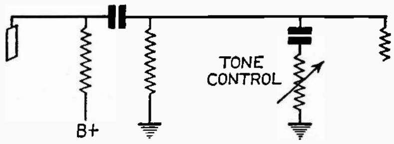


Fig. 10

complicated. The example will therefore not be worked out, but for those interested, the impedance for the parallel branches is found from the equation

$$Z_L = \frac{Z_1 + Z_2}{Z_1 Z_2}$$

the notation of complex algebra must be used in this equation. Similarly, the total impedance of the whole circuit is found from

$$Z = R_p + \frac{Z_1 + Z_2}{Z_1 Z_2}$$

When the correct values are substituted, the answer for the first equation is 6,480 ohms and for the second 8,540 ohms. This gives us the 93.3% shown in the table; note that it is less than the voltage across the load with just the condenser C across it.

Of course, it is not necessary that the tone control be placed in the plate circuit of the output tube. Many prefer to place it in the grid circuit as

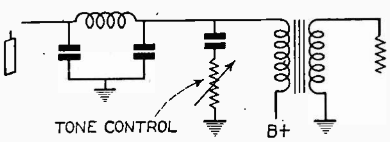


Fig. 11

shown in Fig. 10. It can equally well be placed in the plate circuit of a previous tube or a detector as in Fig. 11. The action of the control in this position is the same as discussed previously but the value of the condenser will have to be smaller when it is connected across a higher resistance load and larger across a lower resistance load. The variation is in the same proportion as the load resistance in order to get the same effect. The series plate resistance also affects this action somewhat. When it is very high, say ten times the load resistance, the tone control acts as in Table I, but when the tube is a triode with a relatively low plate resistance, the effect is slightly less pronounced, due to the variation in impedance matching.

Another system of tone control, which many consider superior, employs no series resistor but varies the value of the condenser either continuously or in steps. Fig. 12 shows such a system, employing fixed mica condensers in the plate circuit of a pentode amplifier tube, such as the 6B7 or the 6C6. Table II below shows the percentage of voltage remaining at

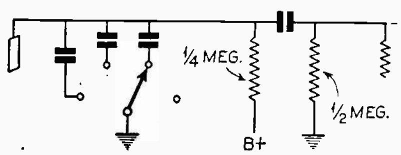


Fig. 12

different frequencies for several sizes of condensers. The conventional ¼ megohm plate resistor and a ½ megohm grid leak have been assumed and the influence of the coupling condenser has been neglected because it is really negligible.

TABLE II

C mmfd.	Voltage across load in percent at 100c.	500c.	1000c.	2500c.	5000c.
50	100	99.7	99.6	99	97
100	100	99.6	99.3	97	91
500	99.5	97	91	64.5	39
1,000	99.3	91	73	39	21.6
2,500	97	64.5	39	17	8.4

When a circuit such as this is employed, there should be an off position on the switch, otherwise the tone control could never be cut out entirely.

APPLICATIONS OF GROUP 3

The use of condensers in the usual tuned circuits and filters has been discussed so often that it need not be repeated here. Condensers in power supply filters have been described in the October and November 1934 issues of the Research Worker. At this time some special applications will be pointed out.

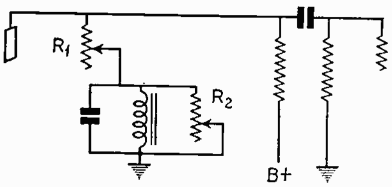


Fig. 13

Quite often it is desired to step up certain low frequencies. It may be done by the use of either a series tuned or parallel tuned circuit, illustrated in Figs. 13 and 14. In Fig. 13, a parallel tuned circuit is connected across the load, making the impedance of the combination highest at the resonant frequency of the tuned circuit and lower at all others. The response curve can be broadened by the use of series and parallel variable resistors, R1 and R2.

Fig. 14 illustrates a series tuned circuit, sometimes used in resistance coupled circuits. At the resonant frequency, the voltage across the choke builds up very high—higher than the impressed voltage and this is the voltage delivered to the grid of the next tube. The correct size for condensers and chokes in these circuits is found from the usual equation:

$$f = \frac{159.2}{\sqrt{LC}}$$

where f is the frequency in cycles per second, L the inductance in henries, and C the capacity in microfarads.

In one successful design of an audio amplifier, two such tuned stages were used. The two stages were tuned to slightly different frequencies, 70 and 80 cycles, which results in raising the level of the low notes.

MISCELLANEOUS APPLICATIONS

When a condenser is being charged or discharged through a resistor, the voltage varies nearly linearly for a part of the time and the speed of the action can be controlled by choosing the right size of condenser and resistor. This phenomenon finds many applications, outside of radio receivers for timing industrial processes, but also in radio sets, for instance in a.v.c. circuits.

The time constant, RC, of a condenser resistor combination, shows the time in seconds which the condenser would take to discharge if it kept going at the initial rate. However, it tapers off and it discharges only partly in that time.

The time constant is of importance in a.v.c. circuits where the time to discharge has to be made so long that there is no appreciable discharge during one cycle of the modulation frequency. A time constant of 1/10th of a second is often used in this circuit.

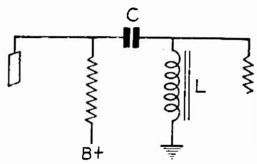


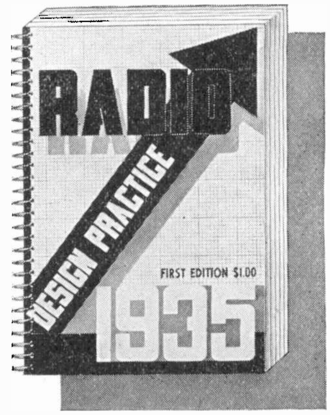
Fig. 14

When finding the time constant of an a.v.c. circuit, the values of all resistances should be added and the result multiplied with the sum of all the filter capacities. When the resistors are measured in megohms and the condensers in microfarads, the time constant will be in seconds.

Other applications which utilize the principle of charging or discharging a condenser through a resistor are found in relaxation oscillators, such as the neon lamp oscillator and the grid-leak and condenser in a modulated oscillator.

The neon lamp oscillator may have a condenser across the lamp and a resistance in series with it. When the current is turned on, the condenser first has to be charged through the resistor to the ignition voltage of the lamp, then the lamp flashes and the condenser discharges. This process is then repeated.

In the self-modulated oscillator, the grid current charges the grid condenser making the grid so negative that the oscillation stops. The charge must then leak off through the grid leak before the tube will oscillate again and the cycle is repeated. In both cases, the frequency is inversely proportional to the product RC, the time constant.



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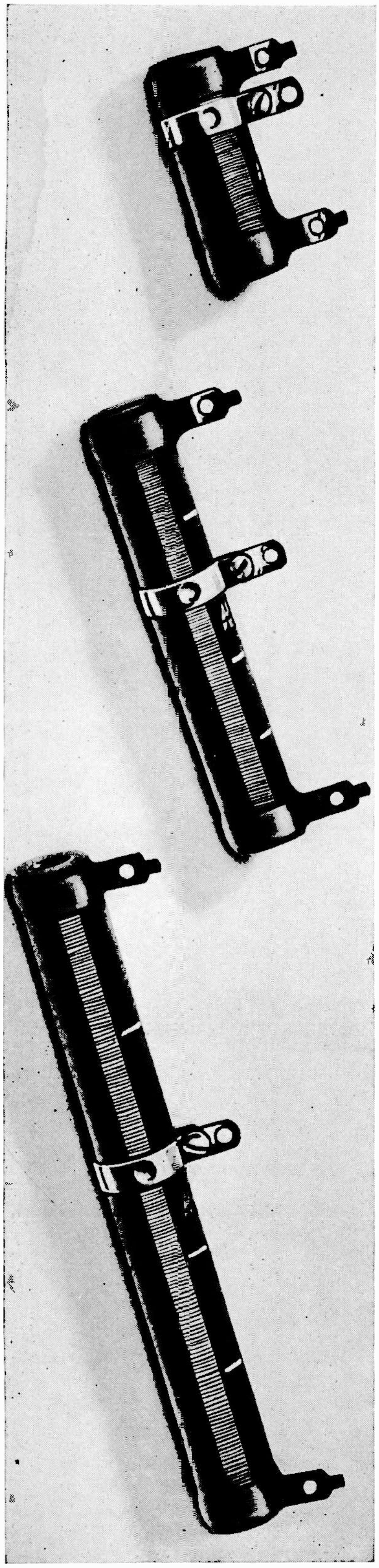

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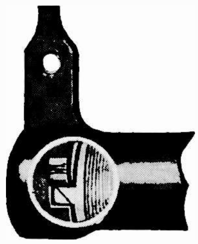

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