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Voltage Dividers Their Application and Design

By the Engineering Department, Aerovox Corporation

STRANGE as it seems, the voltage divider is one of the most misunderstood parts used in the radio field. Yet, it represents only ordinary d.c. engineering and should be readily understood by anyone who is acquainted with the fundamental laws of electricity. Questions are being received from radiomen who wish to find the specifications for voltage dividers of new sets which they have built; there are also many inquiries regarding a solution for the man who wishes to repair an old set when replacement parts are no longer available. It is hoped that this article will provide an answer for all such questions.

PURPOSE OF VOLTAGE DIVIDERS

Since there are some receivers which do not have voltage dividers it is useful to explain their purpose and advantage here.

Curves of any rectifier will show that the output voltage varies with the load and that without a load the voltage may go up to the peak value of the transformer secondary voltage. For the sake of economy it is not customary to employ filter condensers which are able to withstand this high voltage with some margin left over for surges. Therefore, a voltage divider would be necessary as a safety measure to provide a minimum load should the tubes be removed and the set turned on or in case the load is removed due to a defect.

The name "voltage divider" already shows another one of its purposes—to "divide" the voltage or to supply to various parts of the circuit the different potentials required. This can be accomplished, however, by a simple series resistance which is cheaper from the standpoint of first cost as well as current consumption. Therefore, a voltage divider is used when in addition to this second purpose, it is also desired to provide a certain amount of regulation so that the voltages at different tube elements will not vary too much when the tube's plate current varies.

Summarizing the above remarks, a voltage divider has three purposes: (1) to protect the condensers from overload, (2) to "divide" the voltage, and (3) to provide a certain degree of regulation.

APPLICATION OF VOLTAGE DIVIDERS

The average problem in providing a voltage divider runs about as follows: Given a power supply with a certain voltage and current rating and given the number and type of tubes to be employed with their operating currents and potentials, how can we supply these tubes satisfactorily, in the simplest and yet satisfactory way.

Let us take an example: A small superheterodyne having the following tubes; 58 as r.f. stage, a 2A7 oscillator-mixer, a 58 i.f. tube, a 2B7 detector and a pentode output stage, is to be supplied with the proper voltages. Assuming now that all tubes are self biased and that all plates are supplied directly from the power supply, the problem reduces to supplying the screens. This could be done in three ways.

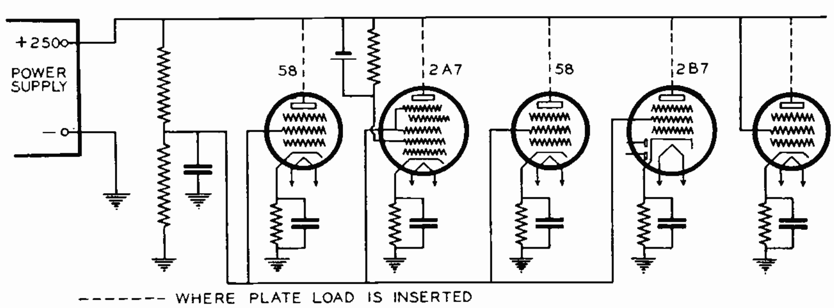


Fig. 1A

The tube manual will show that all tubes require the same screen voltage (100 volts) and so it would be possible to supply these screens from a voltage divider with a single tap as shown in Fig. 1A. This divider can also consist of two separate resistors of the right value. Lately, many of the small sets have no longer a vitreous enamelled resistor but include a divider made up from two or more carbon resistors. As long as the current to be supplied is not too heavy this method can be used to advantage. It is recommended that the power consumption for each section be calculated and the resistor be chosen accordingly.

It is also possible to supply the screens through a series resistor from the high voltage supply (Fig. 1B), but in that case the regulation will be bad, for the screen voltage will drop when the volume control is turned up

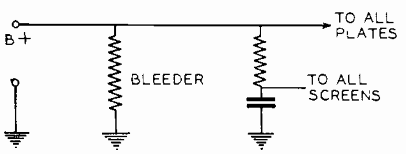


Fig. 1B

full and when the variable tubes draw maximum current. Also, if this is done there should be a separate bleeder. The lack of regulation is sometimes an advantage for when the tubes are self biased and the bias resistor is variable, the actual screen voltage applied to the tube is equal to the potential difference between the cathode and the screen and not between the chassis and the screen. So, in order to arrive at the actual screen voltage one must subtract the cathode-to-ground potential from the screen-to-ground potential. When the cathode-to-ground potential is varied by means of the volume control the actual screen voltage increases with higher volume control settings. This effect is opposite to that of the bad regulation so they tend to neutralize each other. From this standpoint the

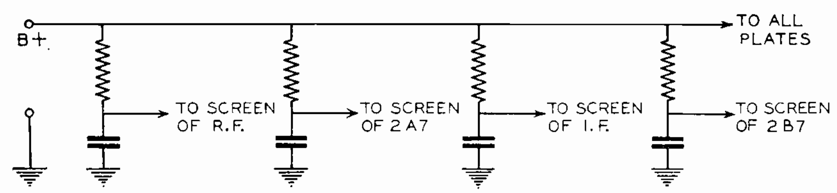


Fig. 1C

second method is better than the first when volume control is obtained by means of varying the self bias. However, with a.v.c. the first method is better.

A third possible method is to use individual series resistors for each screen as in Fig. 1C. This has the advantage of less coupling between stages. The actual calculation of correct values will be discussed later.

In certain cases where the advantages of regulation and of isolation are to be combined, individual dividers for each stage are being used. This method shown in Fig. 1D, is sometimes employed in amplifiers having several high gain stages so that it is very important to guard against any source of intercoupling between stages.

Fig. 2 represents a voltage divider for a somewhat more complicated set which may have a pentode output tube, several r.f. pentodes, an oscillator of the 57 or 58 type which is being fed lower voltages and the set has a separate a.v.c. tube of the 56 type which requires a negative voltage supply because its plate is connected to the chassis through a load. Furthermore, it is assumed that the bias of the pentode is to be taken from the voltage divider instead of using self bias. This figure is given as an illustration of what a voltage divider of a rather complicated set may look like and not as a design of a receiver nor as an opinion that these are necessarily the most desirable operating potentials. Presently it will be shown how the correct resistor values can be obtained.

Finally some receivers have even more complicated voltage dividers, consisting of several tapped resistors in parallel. These may be used in large sets when it is essential to prevent coupling between certain sections, or it may have been designed with a view to keeping the voltage between certain points constant.

DESIGN OF VOLTAGE DIVIDERS

The calculation of the correct resistance values and the power rating of voltage dividers involves nothing but the use of Ohm's Law and Kirchoff's Law ($\Sigma i=o$). When a voltage divider as in Fig. 1A and Fig. 2 is to be used one can arrive at the proper values by experimentation or by calculation. For an experimenter or a designer of just one set or for the replacement of a divider which is no longer made, it is perhaps easiest to employ a so-

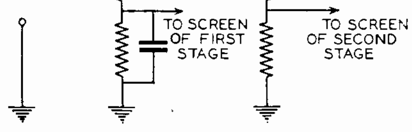


Fig. 1D

called "adjustable voltage divider". In its most up-to-date form, this unit consists of a vitreous enamelled resistor having the enamel removed along a line running the entire length of the resistor and about a quarter inch wide so that sliding straps can make contact with the bare wire. This type is available in different lengths and with several adjustable sliders as shown in Fig. 3. The sliders can be adjusted until the voltages and currents are correct as determined by suitable measuring instruments. There remains to be determined the correct size to use.

The total resistance depends on the bleeder current that is to be allowed; in order to provide the best regulation the bleeder current should be as high as possible without overloading any part in the power supply. In gen-

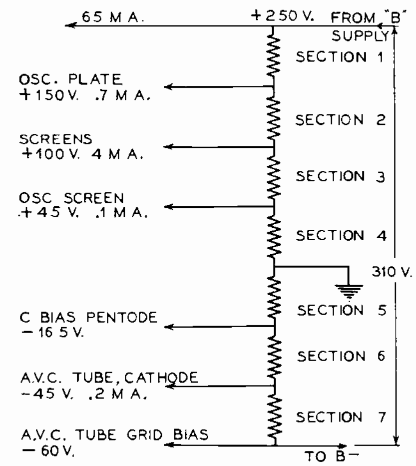


Fig. 2

eral. about 20 ma. is a good value. Right here it is necessary to point out a common error. Supposing the power supply (after passing through the choke and perhaps the speaker-field) is 240 volts and a 20 ma. bleeder current is desired. Many radiomen conclude that the total resistance of the divider should be 12000 ohms because this will allow just 20 ma. to flow when connected across 240 volts. However, when the resistor is tapped and some current is drawn from the tap, this current must pass through the upper section, making the voltage drop across the upper portion larger, across the lower portion smaller and thus reducing the bleeder current to less than 20 ma. Therefore, if exactly 20 ma. bleeder current is desired, the total resistance will have to be smaller than 12000 ohms in this case. If the correct resistance value is not known and the experimenter is not mathematically inclined he could employ a 12000 ohm divider and connect his B-plus lead to the upper variable tap, leaving the upper portion unused. All taps then have to be adjusted, the upper one too and the bleeder current ought to be measured.

Another method to follow is to employ several power rheostats, temporarily adjust them until the proper operating conditions are obtained, then measure the resistance of each section and replace them with the nearest commercial value of fixed resistor or have a special tapped one made up (in the case of quantity production).

Finally there is the method of calculation. The following procedure is to be followed:

1. Determine what voltage is required at each tap and what current is to be drawn from it. The tube manual will give this information. If this is not the case, the required data can be obtained by measurement.
2. Determine what bleeder current is desired. It depends on how much the total drain of all tubes is and how much more the power supply can deliver without overheating.
3. Determine the current which will flow in each section of the divider (by Kirchoff's Law).
4. Calculate the resistance of one section at a time by means of Ohm's Law.
5. Determine the power rating. When a single divider with several taps and uniform power rating is used. The power rating should be obtained by employing the equation

$$\text{Watts} = \frac{I^2R}{1000000}$$

, when I is expressed in milliamperes.

The value of I here should be the highest current any section is required to carry. If the divider is to consist of several resistors the wattage for each section should be calculated separately and the actual current in that section should be used for the calculation. This sounds complicated but it isn't. As an example the voltage divider shown in Fig. 2 will be discussed.

Step 1 requires us to find the current at all taps and in order to visualize for the reader how currents leave the divider and return to it later, the same divider has been shown again in Fig. 4 with the external paths shown in dotted lines. The current in each section is also given.

The currents which pass through the tubes finally arrive at the chassis and then join the bleeder current again. At the same tap, the ground tap, where all these currents return, the plate current for the a.v.c. tube leaves the divider.

Step 2 requires the determination of the bleeder current. The total of all currents drawn by tubes, as shown in Fig. 2, is 70 ma. Assuming that a transformer is used which is rated at 100 ma., wishing not to overheat it, the maximum current could be restricted to 90 ma. This leaves 20 ma. for the bleeder.

Now supposing that all currents and voltages at the taps are known the current in each section is found by simple addition. Beginning with secton 4, the current here is equal to the

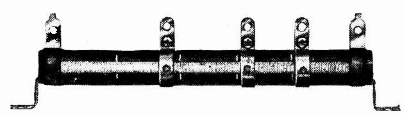


Fig. 3

bleeder current plus the .2 ma. for the a.v.c. tube; a total of 20.2 ma. Section three must carry in addition the .1 ma. which leaves at the 45 volt tap, a total of 20.3 ma.

Section two carries 4 ma. more which makes 24.3 ma. Section one carries again .7 ma. more or 25 ma.

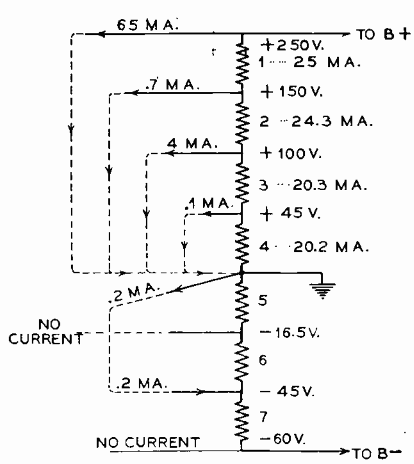


Fig. 4

At the ground tap all these currents return but .2 ma. leaves. The current in section 5 is then

$20.2 + .1 + 4$
$+ .7 + 65 - .2 = 89.8$ ma.

The current in section 6 is the same and in section seven the .2 ma. has returned making a total of 90 ma.

Step 4 requires us to find the resistance of each section. This is simply an application of Ohm's Law. Section 1 has 100 volts across its terminals and a current of 25 ma. flowing through it, the resistance is then

$$\text{Section 1} \ \frac{100}{25} \times 1000 = 4000 \text{ ohms}$$

Similarly, the resistance values of the other sections are

$$\text{Section 2} \ \frac{50}{24.3} \times 1000 = 2058 \text{ ohms}$$

$$\text{Section 3} \ \frac{55}{20.3} \times 1000 = 2710 \text{ ohms}$$

$$\text{Section 4} \ \frac{45}{20.2} \times 1000 = 2228 \text{ ohms}$$

$$\text{Section 5} \ \frac{16.5}{89.8} \times 1000 = 184 \text{ ohms}$$

$$\text{Section 6} \ \frac{28.5}{89.8} \times 1000 = 317 \text{ ohms}$$

$$\text{Section 7} \ \frac{15}{90} \times 1000 = 167 \text{ ohms}$$

Total resistance 11664 ohms

Assuming that the divider is to be of uniform power rating, the current to be considered is the largest one, 90 ma. The power rating is then

$$\frac{11664 \times 90^2}{1000000} = 27.9 \text{ watts approx.}$$

In the case that separate resistors are used, the power of each section is found by multiplying the voltage across each section by the current flowing in it. If this current is expressed in ma. the result should be divided by 1000. Thus the power consumed in section 1 is

$$\frac{100 \times 25}{1000} = 2.5 \text{ watts}$$

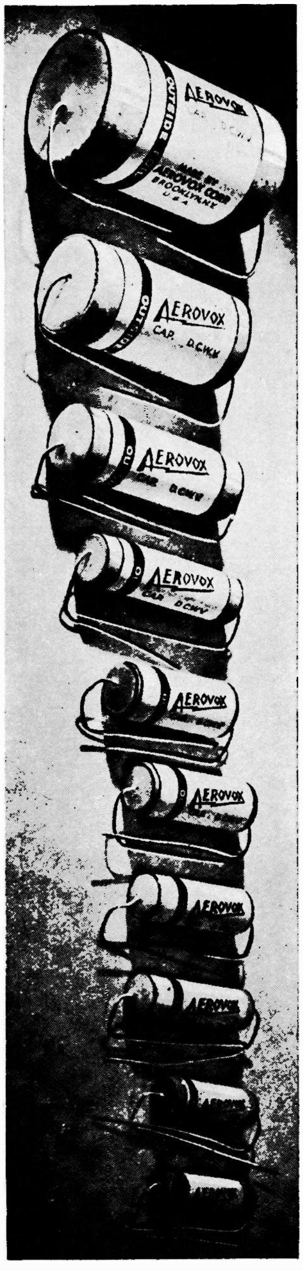
The other sections are treated in the same way.

Power supplies of the type shown in Fig. 1B and 1C are simply series resistors. After finding what the current consumption is and what the voltage across this dropping resistor should be, the resistance is at once found by Ohm's Law.

It is at once obvious that the voltage divider offers a common impedance to several circuits and so may give rise to regeneration or degeneration. The obvious remedy for this is to employ bypass condensers and if necessary extra filters stages in individual supply leads. It should be remembered that in order to constitute an efficient bypass, the condenser reactance should be considerable lower, about .1 of the resistance being bypassed, at the lowest frequency to be amplified. This becomes difficult when the resistance value is small and low audio frequencies should be amplified.

By regulation we mean the ability of the resistance network to maintain constant voltage with varying load, due to volume control for instance. The only way to obtain satisfactory regulation is to employ a bleeder current which is large compared to the variations in load current. Even so, it is impossible to obtain perfect regulation for this would require an infinitely large bleeder current. These two problems of decoupling and regulation will be discussed in the following issue.

CARTRIDGE CONDENSERS



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