The AEROVOX Research Worker

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Voltage Dividers Their Application and Design

PART 2

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THE first part of this article in the December, 1934 issue, Vol. 6, No. 12, was devoted to the calculation of the resistance values and power rating of typical voltage dividers. In this issue some notes on bypassing and regulation will be given.

The voltage divider offers a common impedance to several circuits and so may give rise to regeneration or degeneration. The obvious remedy is to employ bypass condensers and extra filter stages in the individual supply leads, if necessary. It should be remembered that in order to constitute an efficient bypass, the condenser reactance should be considerably lower, than the resistance being bypassed; the ratio should be about 1 to 10. This becomes difficult when the resistance is small and the low audio frequencies have to be amplified. For instance, in the example of Fig. 4, where section 5 was found to be 184 ohms, the bypass condenser should have a reactance of about 20 ohms at 100 cycles. This would require a capacity of

$$C = \frac{1,000,000}{2\pi f X_c} = \frac{1,000,000}{6.28 \times 20 \times 100} = \frac{1,000,000}{12560} = 80 \text{ microfarads}$$

If a smaller capacity is used, the lower frequencies will be attenuated.

By regulation is meant the ability of a circuit to maintain constant voltage with varying load. In the case of a voltage divider, the variations may be 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. Even so it is impossible to obtain perfect regulation, for this would require an infinitely large bleeder current. Since the bleeder current represents waste it should be cut down as much as possible without making the regulation too bad. The question comes up then, how much regulation is to be expected with a given bleeder current and how do we design a voltage divider to satisfy given regulation requirements. These questions will be answered here for a divider with one tap only.

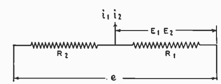

Fig. 5

It can be shown mathematically that when two resistors of known resistance are connected across a constant voltage source and different currents are drawn from the tap, the relation between these currents and the accompanying voltage is linear. For instance, in Fig. 5, resistors R1 and R2 are connected across the source e. Now, if different currents, i_1, i_2, etc., are drawn from the junction, and these current values are plotted against the accompanying voltages E_1, E_2, etc., across R1, the result will be a straight line. Two points will suffice to draw the line; these are easily found. When the current drawn from the tap is zero, the voltages divide in proportion to the resistances, R1 and R2, so the voltage is known. The second point is obvious when the voltage is zero (R1 short circuited) the current equals e/R2. The line can then be drawn and it will show what the voltage will be for any current drawn with the given resistance values and applied voltage. In fact, this "characteristic" can be drawn on the characteristic of a tube in the usual way, similar to a loadline which will sometimes prove very instructive.

Coming to the second question. Suppose for some reason it is necessary to restrict the screen voltage of two r.f. or i.f. stages to a fluctuation of not more than 10 volts, say from

105 to 95 volts, and that the current varies from 1 ma. to 4 ma. and the power supply delivers 250 volts. What should be the values of R1 and R2.

In order to solve this problem for once and for all, for any kind of fluctuation, a solution has been derived as follows. Call the supply voltage e and the required voltage at the junction E_1 for a current of i_1 and E_2 for a current of i_2. Then, by Ohm's Law and Kirchoff's Law

$$\left(\frac{E_1}{R_1} + i_1\right) R_2 = e - E_1$$

$$\left(\frac{E_2}{R_1} + i_2\right) R_2 = e - E_2$$

These are two simultaneous equations of the first degree with two unknowns. Solving for R_1 and R_2

$$R_1 = \frac{e\,(E_1 - E_2)}{i_2\,(e - E_1) - i_1\,(e - E_2)} \times 1000 \text{ ohms (1)}$$

$$R_2 = \frac{e\,(E_1 - E_2)}{i_2\,E_1 - i_1\,E_2} \times 1000 \text{ ohms (2)}$$

Where i_1 and i_2 are currents in milliamperes.

Returning to the example, $e = 250$,

$E_1 = 105$, $i_1 = 1$ $E_2 = 95$, $i_2 = 4$

Substituting values in (1)

$$R_1 = \frac{250\ (105-95) \times 1000}{4\ (250 - 105) - 1\ (250 - 95)}$$

$$\frac{2500000}{425} = 5882 \text{ ohms approx.}$$

Substituting values in (2)

$$R_2 = \frac{250\ (105 - 95) \times 1000}{4 \times 105 - 95} =$$

$$\frac{2500000}{325} = 7692 \text{ ohms approx.}$$

As a check, consider the first condition, where E_1=105 volts and i_1=1 ma. Then, having R1 equal to 5882 ohms, the bleeder current (flowing through R_1 is 105/5882=.0179 amp., or 17.9 ma.

The current in R2 must then be 1 ma. more, or 18.9 ma. This calls for a voltage across R_2 of .0189×7692=145 volts, which agrees with the requirements. In the second condition, E_2= 95 volts and i_2=4 ma. The bleeder current will then be 95/5882=.0161 amp. or 16.1 ma. The current through R_2 is then 4 ma. more, or 20.1 ma. The voltage across R_2 is then .0201 ×7692=155 volts, which again checks with the requirements.

These equations (1) and (2) are suitable for all similar cases. Just substituting the given values will give the required resistance for R1 and R2.

In the above problem the voltage of the power supply was assumed to be constant. It is interesting to note that a solution can be obtained mathematically even if this voltage has varied. However, it will be found that the variations cannot be assumed entirely at random, for certain values of e and e_1 will give negative or indeterminate answers.

Assuming then the same symbols as before and adding e_1 for the second value of the power supply, we may write

$$\left(\frac{R_1}{E_1} + i_1\right) R_2 = e - E_1$$

$$\left(\frac{E_2}{R_1} + i_2\right) R_2 = e_1 - E_2$$

Solving for R1 and R2

$$R_1 = \frac{e_1\,E_1 - e\,E_2}{i_2\,(e - E_1) - i_1\,(i_1 - E_2)} \times 1000 \text{ ohms (3)}$$

$$R_2 = \frac{e_1\,E_1 - e\,E_2}{E_1\,i_2 - E_2\,i_1} \times 1000 \text{ ohms (4)}$$

It is even possible to find a solution for similar problems involving dividers with two taps. This gives us three equatons wth three unknowns. However, the given conditions must be consistent or the equations cannot be solved. Furthermore, we should like to leave the solution of this problem for others.

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A CORRECTION

In the November, 1934, issue of the Research Worker, the following corrections should be noted:

On the first page, third column, the equation should read:

$$E = E_0\,\xi^{-\frac{t}{rc}}$$

where E=instantaneous voltage, E_0 = voltage before discharge, t = time in seconds, ξ = 2.718, R=load resistance, C=capacity in farads.

On the second page, second column, the first equation should read:

$$C = \frac{1}{\pi f_c R} = \frac{.3183}{f_c R} \text{ farads} = \frac{318300}{f_c R} \text{ microfarads}$$

Peak Voltage Ratings of Dry Electrolytic Condensers

IT has been standard practice for some time past to rate electrolytic condensers in terms not only of their rated working voltage but also in terms of surge voltage. Up to the present the information given on this method of rating in terms of both working and surge voltage has been confined to condensers of relatively high working voltage; specifically to condensers rated at working voltages of 350 and above.

However, this method of rating has now been extended to include the entire range of working voltages from 25 volts up to 500 volts. These ratings together with the maximum ripple voltage ratings are given in the accompanying table. By comparison of this table with a similar tabulation given in the December 1933 issue of the Research Worker it will be noted, as explained above, that the difference lies in the specification of surge voltage ratings in the lower range of working voltages.

Surge voltage ratings were originally confined to those condensers of relatively high working voltage for the reason that these condensers were used in the filter circuits of radio receivers, and it is in such circuits that the most serious surges are found. In filter circuits the surge voltage is important from the standpoint of condenser breakdown.

On the other hand, the surge voltage ratings of the low voltage condensers are of prime importance for reasons other than breakdown. For example, a 25 volt condenser has a surge voltage rating of 40 volts but the possibility of a 25 volt condenser breaking down because voltages slightly above 40 are applied is so slight as to be negligible.

In the lower range of working voltages the surge ratings are better considered as the maximum voltages which can be applied momentarily to the condenser and cause negligibly permanent changes in the characteristics of the condenser. Taking the 25 volt condenser as an example, the effect of applying relatively high voltages to such a condenser is to cause a reduction in capacity and an increase in power factor. This is the result of the higher voltage film which tends to form on the foil whenever the original film voltage is exceeded by any marked amount for any appreciable period of time. The surge voltage ratings of low voltage electrolytic condensers are important in certain receiver designs where such low voltage condensers may have applied to them higher than rated voltage during certain periods in the operation of the receiver, as for example, when the set is first turned on.

In order to make complete the story of electrolytic condenser ratings as they stand at present the table of ratings given below has been preceded by definitions of the various factors involved. It is suggested that this table of defininitions and ratings be put into a form convenient for ready reference as an aid in the specification of electrolytic condensers to meet specific requirements.

Defiinitions and Terms as Applied To Electolytic Condensers

Definitions of Voltage Rating Terminology:

D. C. OPERATING OR WORKING VOLTAGE
D. C. potential as measured with a potentiometer or equivalent method.

PEAK VOLTAGE
The peak voltage is the value as measured with a peak reading voltmeter and is equal to the d. c. voltage plus the peak a. c. ripple voltage.

PEAK RIPPLE VOLTAGE OR A. C. COMPONENT
The peak a. c. ripple voltage is the maximum instantaneous value of a.c. voltage across the condenser due to the a. c. component in the condenser. This can be measured with a cathode ray oscillograph or with a vacuum tube voltmeter.

MAXIMUM SURGE VOLTAGE
This represents the maximum potential the condenser will withstand without breakdown or permanent injury, for a period of five minutes when applied to a series combination of the condenser and resistance, the resistance having a value in Ohms, equal to $\frac{20{,}000}{C}$ where C is the rated capacity in mfd.

VOLTAGE RATINGS:

D.C. Operating Volts	Maximum Surge Voltage	MAX. PEAK A.C. RIPPLE VOLTAGE AT 120 CYCLES Mfd. 1-2-3	Mfd. 4-5-6	Mfd. 7-8-9	Mfd. 10-12	Mfd. 13-16	Mfd. 17-25	Mfd. 26-35	Mfd. 36-50
25	40	10	10	10	10	10	8	8	5
50	75	15	15	15	15	10	8	8	5
100	150	25	20	20	20	15	10	8	5
150	200	25	20	20	20	15	10	8	5
200	250	30	27	25	20	15	10	8	5
250	300	30	27	25	20	15	10	8	5
300	350	30	27	25	20	15	10		
350	400	30	27	25	20	15	10		
450	525	30	27	25	20	15	10		
475	600	30	27	25	20	15	10		
500	600	30	27	25	20	15	10		