A Two-Tap Bass and Treble Compensated Volume Control

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A simplified analysis of the method of determining the constants for a loudness control which will simulate the Fletcher-Munson curves to a reasonable degree of accuracy.

ANYONE who has adjusted the uncompensated volume control of an amplifier when music was being played has noted that as the control was rotated from its full volume position to its minimum, less and less bass and treble were heard as compared to the amount heard in the maximum or full-volume position. This is borne out by the Fletcher-Munson sound pressure curves appearing in engineering texts. As the curves show, it is necessary to boost the bass—and to a lesser degree, the treble—more and more as the control is lowered to make up for the hearing curve of the ear.

By adding a tap on the volume control and running the sliding arm down to this tap we have an "L" type tone compensating network as shown in *Fig.* 1. The network can be figured so as to give correct compensation for hearing losses at this one point. Now it becomes apparent that in order to have a 100 per cent perfect control, we would have to have an infinite number of taps on the control with an equal number of networks. This is impractical from a mechanical and economical standpoint.

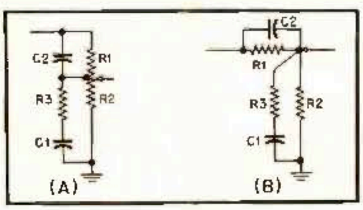

Fig. 1. Basic arrangement of components for L-pad compensation of frequency response.

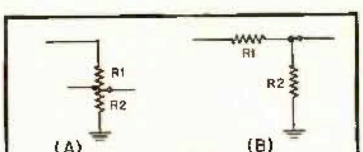

Fig. 2. Simplified equivalent of uncompensated volume control.

The next choice would be three controls back to back on the same shaft—one acting as a volume control, one as a continuously variable bass-compensation network, and the other a continuously variable treble-compensation network as described by E. E. Johnson.[1] For those in the radio manufacturing industry where cost is a great factor, a good but cheaper method might be desired.

It is possible to make two well located taps on a single control approach the desired boost requirement to a very acceptable degree. This has been done in commercial radio equipment for many years in the form of one or two tap volume controls; however, only bass compensation was obtained. On recent designs treble compensation has shown up on a single-tapped control. The development of a two-tap control with both bass and treble compensation, as proposed by the author, is to be discussed in this paper. Let us start with a single tapped volume control as shown at (A) in *Fig.* 2. If the slider is set at the tap, we have an L pad divider made up of R_1 and R_2 as shown at (B). The voltage ratio will be $R_2/(R_1+R_2)$. If $R_1 = 0.25$ meg and $R_2 = 0.25$ meg, then $\frac{0.25}{0.25+0.25} = 0.5$, or 6db attenuation of voltage. If C_1 is now connected from tap to ground as at (A) in *Fig.* 3, we would have a definite attenuation of voltage at some desired center frequency. Above this frequency, the reactance of C_1 decreases at a constant rate, attenuating the highs. Below this frequency, the reactance of C_1 increases at a constant rate, thus effectively boosting the bass (by attenuating the high frequencies). Since this bass-boost circuit should not function at the expense of losing treble, it is necessary to insert R_3 in series with C_1. At the frequency when the reactance of $C_1 = R_3$ the curve will begin to flatten out. This frequency is known as the bass turnover frequency. It is subject to change with each design engineer from a minimum of 250 to a maximum of 1000 cps. Since 800 cps has been chosen as the center frequency of the audio spectrum, a bass turnover frequency of 1000 cps will tend to raise the midrange too much, while a 250-cps turnover will not allow the bass to rise to a sufficiently high amplitude. It is thus desirable to stay within 250 and 1000 cps. It

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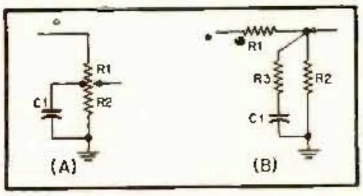

Fig. 3. Volume control with single tap, allowing for one bass turnover frequency.

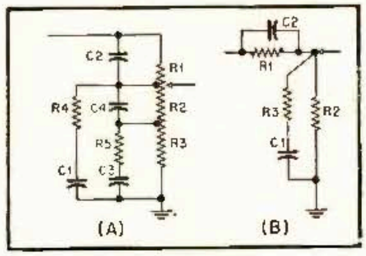

Fig. 5. Development of dual-tap control.

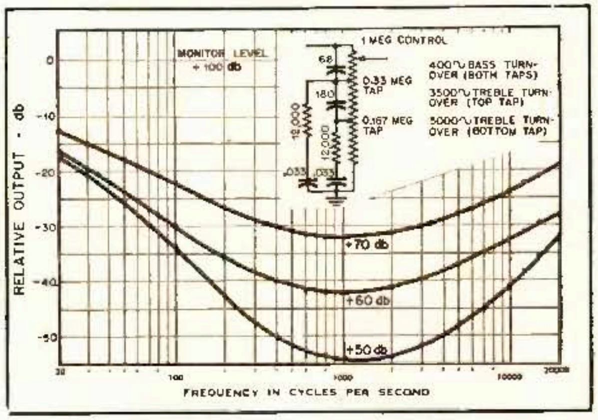

Fig. 4. Response curves for dual-tap control shown in the boxed-in schematic.

[1] "A continuously variable loudness control," AUDIO ENGINEERING, Dec. 1950.

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has been suggested that all manufacturers use 400 cps as the bass turnover frequency. The curves in *Fig.* 4 are plotted around this point. The next step is to add treble compensation (*Fig.* 1).

There are two reasons for adding this compensation:

1. To make up for the loss in highs due to adding the bass compensation. (The turnover of C_1 and R_1 causes a flattening out of the curve, but not 100 per cent. There is always some attenuation of highs above the turnover point.)
2. To make up for the hearing loss in highs as the volume is lowered, in accordance with the Fletcher-Munson curve.

Selection of Boost Frequencies

From the hearing curves we can pick out the necessary treble boost for this tap point. Since the tap is already set, the value of R_1 is fixed. If capacitor C_2 is added across R_1, the highs above the turnover point are boosted. This upper turnover frequency is the point at which $X_{C_2} = R_1$. (Refer to *Fig.* 1.) A suggested treble turnover frequency would be 2500 cps to make the turnover frequencies of bass and treble symmetrical on each side of 1000 cps. The curve can now be calculated or an oscillator and vacuum-tube voltmeter can be used to obtain the curve experimentally. This control can be designed as a separate unit from the amplifier, or together with it as desired. If it is designed together with the amplifier, the tone controls on the amplifier should be set to the "flat" position. Then with the volume control in maximum volume position, a flat reference curve is obtained. Let this flat curve be equal to the 100-db Fletcher-Munson curve which is flat and add the boosts accordingly as the midrange level is reduced at the different taps. If more bass compensation is needed, lower R_1 and increase C_1, thus keeping the same turnover frequency. If more treble boost is desired and R_1 is fixed by the tap, it is attained by increasing C_2, which turns over at a lower frequency and allows the curve to start rising sooner. If less treble boost is desired, decrease C_2, making the turnover frequency higher and the treble rise will start later.

In adding the networks for the second tap, the same procedure should be followed. Keep the same bass turnover frequency as before for the network C_3 and R_3 as in *Fig.* 5. The treble boost network is C_4 and R_2. Referring to the sound pressure curves again, it can be seen that the treble increases as the bass increases with each successively lower tap but to a lesser degree. To do this, the treble turnover frequency at this second tap must be increased, thus allowing the treble to start rising later in the curve. C_4 does not return to the top of the control, but only to the tap above it. It only continues the treble rise started by the first tap.

One thing might be pointed out. Do not run the treble boost capacitor from the top of the control to the arm for continuously variable treble boost, because even though this works well as the arm is lowered from the top down to the tap, treble boosting continues below the tap while the bass boost stops at the tap. This over-boosts treble response.

The taps can be located as desired, but it is found that a nice result is obtained by setting the top tap at one-third the total resistance and the bottom tap at one-sixth total resistance. On a 1-meg control, these would be 0.33 and 0.167 meg. respectively. The curves of *Fig.* 4 show how closely the respective bass and treble boosts follow the Fletcher-Munson curves at each tap point.

A check of the hearing curves will indicate that the 100-db curve is approximately flat. For a reference level, it must be assumed that the maximum volume position is at this flat position. The nearer to this 100-db level the maximum volume of the amplifier is, the closer to reality the music will sound.

It is hoped that this article will indicate a simple but complete way of designing this type of control. The component values will change with different turnover frequencies, and are not to be taken as fixed values that must be used. It is realized that when used with certain amplifier curves, it may be desirable to under-compensate or over-compensate the volume control.