An Improved Loudness Control

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While many music lovers and hi-fi enthusiasts would not be caught dead with a loudness control, there are at least as many more who wouldn't do without one. For them as likes 'em, here is a new arrangement with several advantages.

THERE HAS BEEN MUCH discussion of the relative merits of the loudness control, in which the signal level is varied in accordance with the Fletcher-Munson subjective loudness curves, as compared with the simple gain control, which raises or lowers the signal level an equal amount at all frequencies. It is not the author's intention to reopen the controversy at this time. The purpose of this paper is to present, for those who favor the use of a loudness control, an improved circuit that gives a good approximation to the Fletcher-Munson curves, while using less expensive or complicated components than any other such circuit the author has seen.

Continuously-variable loudness control circuits published to date usually depend on the use of either a tapped potentiometer or a special control made up of several potentiometer elements on a single shaft.[1,2,3] As a result, such controls tend to be expensive and of limited flexibility, and to present other serious disadvantages, such as an appreciable insertion loss, a variation in the impedance presented to the previous stage, a lack of mechanical strength, or the like. Furthermore, because they include several moving parts, or, in the case of the multitapped control, a rather complicated mechanical arrangement, maintenance troubles are multiplied.

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The circuit shown in *Fig.* 1 includes only one moving part—an ordinary single-section potentiometer, with no taps. All of the other components are standard low-cost resistors and capacitors. The frequency-response curves of this circuit are shown in *Fig.* 2 (solid curves). As may be seen by comparison with the dashed Fletcher-Munson curves, the output is very well matched to the response of the average human ear over a 40-db variation in sound level.

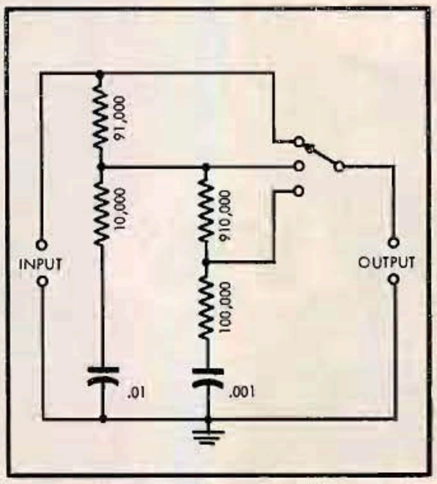

Fig. 1. Schematic diagram of the author's improved loudness control.

Other features of this type of circuit which compare favorably with conventional circuits are: (1) it introduces no insertion loss, and (2) the impedance it presents to the previous stage does not vary with the setting of the control.

Because the variable element in the control is a simple potentiometer, this configuration lends itself to a flexibility of operation that is not possible to other circuits. For example, the potentiometer can be replaced by the combination of a fixed resistor and a vacuum-tube resistance element. Then, since the setting of the control can be varied by adjusting a direct voltage, the loudness-control effect can be obtained with remote control.

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automatic volume control, or compressor/expander operation. Various other applications might be devised by using fixed resistors in conjunction with other types of variable resistance elements, such as varistors or thermistors. Care should be taken in such applications, however, not to introduce large amounts of phase shift or distortion in the control circuit, as the shape of the over-all response curves depends greatly on the phase relationships within the circuit.

Principle of Operation

The principles of operation of the control can be more easily understood if the circuit is considered in three parts. The frequency response of the two-stage integrating (low-pass) network made up of R_1, R_2, R_3, R_4, and the two capacitors is shown in *Fig.* 3. The output of this circuit is added to the output of the potentiometer via the summing network consisting of R_5 and R_6. However, since the two summed outputs are not in phase with each other, the voltages do not add directly, but in such manner as to produce the response curves given in *Fig.* 2.

Another feature of the circuit is that it can easily be converted to a conventional gain control, merely by breaking the circuit at point "A" (*Fig.* 1). It might well be argued that such a feature is of doubtful utility, since this circuit, like all loudness controls should be operated with an auxiliary level control, which is used to set the over-all signal

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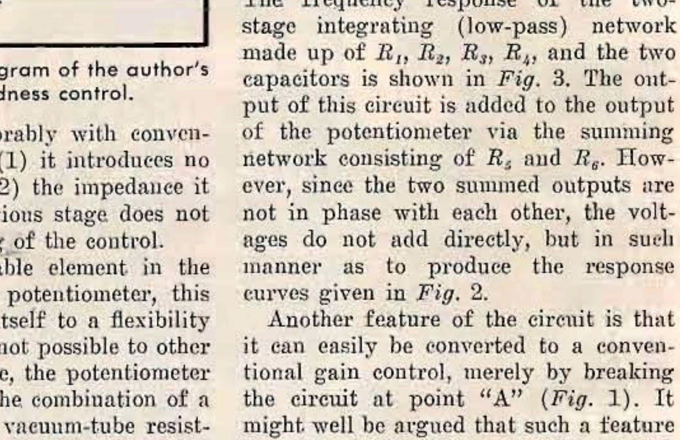

Fig. 2. Frequency response curve for the circuit shown in Fig. 1.

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[1] E. E. Johnson, "A continuously variable loudness control." AUDIO ENGINEERING, December, 1950.

[2] Ray C. Williams, "A feedback loudness control." *Radio & Television News,* March, 1954.

[3] J. W. Turner, "Construction details of a continuously variable loudness control." AUDIO ENGINEERING, October, 1949.

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amplitude. The superiority of the proposed circuit is that the change to gain-control operation can be made in this manner at any loudness level without changing the midfrequency level (i.e., the apparent loudness) by more than one db.

It is noted that the response of this circuit closely approximates the Fletcher-Munson contours only over a loudness range of 40 db. No apology will be made for this limitation, as the more complicated circuits previously described do no better. More serious, perhaps, is the fact that the total range of variation is limited to some 60 db at high and middle frequencies, and to 20 db at low frequencies. However, since this range represents the difference in loudness between a lion's roar and the background noise of a quiet residence,[4] the limitation is probably of minor significance. If a further range of variation is desired, the control can be supplemented with the stepped attenuator shown in *Fig.* 4, which will provide a 0–20–40 db variation in loudness level. The attenuator should be separated from the master loudness control by an isolating amplifier.

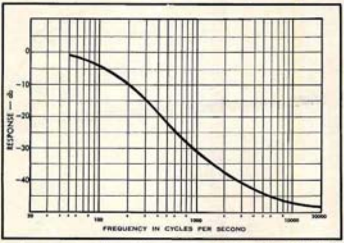

Fig. 3. Frequency response of a two-stage integrating network.

No treble compensation is included, as the Fletcher-Munson curves have all very nearly the same shape at the high-frequency end, and the author prefers to effect this correction by means of a separate tone control. However, if it is desired to explore the possibilities of adding high-frequency compensation, R_1 and/or R_3 can be shunted by capacitors.

Circuit Location

As a matter of general note, the amount of distortion generated in an amplifier can depend materially on the location of the frequency-selective circuits. In general, it is good practice to place near the output those circuits that emphasize low frequencies (or reduce highs), while high-frequency boost (or bass cut) should be located near the input. The reason for this rule is as follows. By far the greatest part of the distortion components developed in an amplifier are at higher frequency than the signal. Accordingly, a treble-cut (bass-boost) network at the output will reduce the distortion-to-signal ratio, while a treble-boost (bass-cut) circuit will accentuate all distortion fed into it. However, extreme bass cut should not be incorporated so early in the circuit that hum becomes appreciable.

The loudness control, which is essentially a bass-boost circuit, should therefore be placed as near the amplifier output as other circuit considerations will permit. Unfortunately, the control must usually be located near the input, to avoid overloading the succeeding stages. The answer, of course, is to seek the best compromise. It goes without saying that no frequency-selective circuit should be expected to function properly

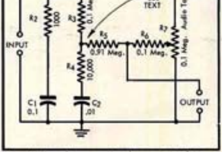

Fig. 4. Loudness control converted to a stepped attenuator circuit, the type more commonly known as a "contour control."

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[4] "*Reference Data For Radio Engineers.*" Second Edition, Page 177.

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if it is placed within a feed-back loop.

It should be remembered that the published Fletcher-Munson contours represent the response of the "average" ear, and can be expected to deviate widely from the response of any individual ear. Therefore, any painstaking attempt to match the curves with mathematical exactness would be a bit ridiculous. For this reason, it is suggested that components of plus or minus 5 per cent tolerance would be quite satisfactory.

If it is desired, the impedance level of the circuit can be raised or lowered, without affecting the response of the control, by multiplying all resistors by a common factor, and dividing all capacitor values by the same factor. The limits of variation are set, of course, by circuit considerations—the amount of loading of the previous stage that can be tolerated, the impedance to be presented to the succeeding stage, the susceptibility to hum pickup and so on. Æ