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RADIO CRAFT

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ELECTRONIC
EGG GRADER
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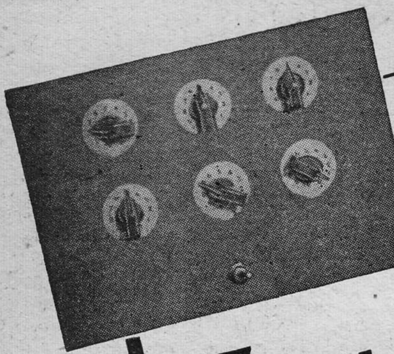

Response Equalization

By J. W. STRAEDE

MOST reproducing or recording systems require some form of frequency response correction. The bass or lower frequencies may be attenuated in recording or high frequencies may need emphasizing after passing through a selective radio tuner.

The majority of "tone controls" affect the high-frequency response only, and then only between fixed limits. A few amplifiers are provided with attenuators for low frequencies, but again the rate of attenuation and frequency from which attenuation starts are fixed.

In the system described here, the bass attenuation may start at any of 5 (or more) frequencies, the attenuation may be kept constant below a given frequency or the amount of attenuation may be varied. But that is not all. The lower frequencies may be emphasized or boosted below any of 5 (or more) frequencies, and the amount of boost is controllable. *It is even possible to boost some low frequencies while attenuating others.*

The same thing goes for the high-frequency end of the spectrum, except that in the practical version of the circuit, no provision is made for rate of attenuation above a determined frequency and, instead, sharper cutoff is provided as this is generally more useful.

Response correction types

What are the commonly required types of response correction? There are bass attenuation combined with slight high-frequency boost for ordinary recording, bass boost with extreme high-frequency boost for orthacoustic recording, the opposites of these first two for reproduction; large bass boost at very low frequencies below the main speaker resonances, high-frequency equalization for good crystal pickups, and the same with a boost of only the infra-low bass for cheaper crystal pickups.

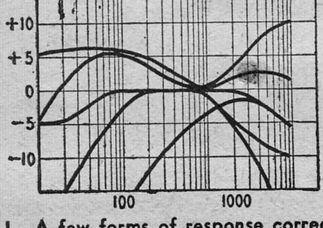

Fig. 1—A few forms of response correction.

Some of the possible frequency corrections are shown in Fig. 1, a maximum variation of about 10 db being obtainable except for the high-frequency attenuation which can be obtained at the rate of about 12 db per octave.

Simple circuit used

These boosts and attenuations are obtained with a relatively simple circuit. There are no multigang potentiometers, no inductance to pick up hum, and no nonstandard parts. All the work is done by ordinary radio resistors, condensers, switches, and potentiometers. The tolerance of the resistors may be 10% and that of the condensers 15% before any noticeable effect occurs (unless, of course, the circuit is used to equalize some amplifier within 1 db for laboratory work).

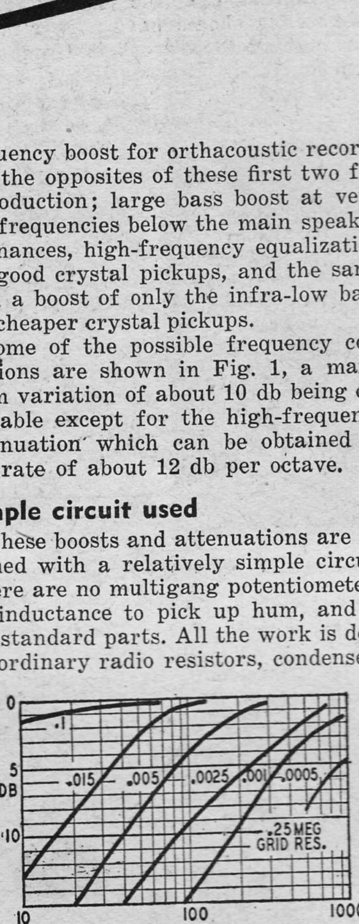

Fig. 2—Effect of coupling condenser on lows.

The whole job is very compact if the power supply is taken from the rest of the amplifier. The single 6J7 or 6SJ7 tube provides a mid-frequency gain of about 10 db after loss in the circuit has been allowed for. All the results are obtained by well-known circuit networks.

Coupling condensers

It is well known that coupling condenser size affects low-frequency response. What is not so well known is that the size of the condenser also determines the frequency from which bass attenuation takes place (that frequency is the one at which attenuation is 2 db). The rate of attenuation is approximately 6db per octave and this rate does *not* depend on condenser size.

In most recording work, the attenuation must start from 250 to 700 cycles, while in public address work the bass cut must begin at about 1,000 cycles when maximum intelligibility and extreme audibility are required. So the first step in designing the circuit was to provide a variable coupling condenser (actually a number of condensers controlled by a simple 5-way switch). A simple rule for determining the frequency at which attenuation commences is

$$f = \frac{R}{5C}$$

where R is the grid resistance in megohms and C is the size of coupling condenser in microfarads. The effects of these condensers is shown in Fig. 2. It might be argued that only a limited number of capacitances is obtainable, but in practice the capacitance is not at all critical.

Amount of low-frequency attenuation is controlled by varying a resistance shunted across the coupling condenser (see Fig. 3). Actually the maximum value of the variable resistance limits the amount of attenuation obtainable—this is usually not of importance, but if necessary the end of the resistance element can be scraped away so that circuit can be opened completely.

Low-frequency boost

The method for boosting the bass is to attenuate to a fixed degree all frequencies above a certain point. This is done by a voltage divider such as is shown in Fig. 4, the lower arm consisting of a resistor and condenser in series. The frequency below which the boost starts is controlled by the condenser size, the maximum rate of boost being nearly 6 db per octave. Just where the bass boost is to be introduced is decided by the work to be done. When English records are to be played with a "flat" pickup, the boost should commence at about 250 cycles, while for American

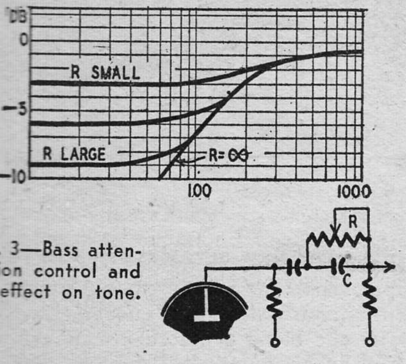

Fig. 3—Bass attenuation control and its effect on tone.

records the boost should start nearer the 700 cycle mark.

To reduce the amount of bass boost the condenser is shunted by a variable resistor. It should be noted that the graphs of Figs. 3 and 4 are similar except that one is inverted; but remember that the bass boost and bass cut can start at different frequencies so that a hump or a dip may be obtained around some frequency.

In Fig. 5 the complete circuit for low-frequency compensation is shown. The values are those which have been found most suitable in practice. Remember that resistor size controls *amount* of attenuation while condenser size controls the *frequency* at which a cut or boost commences.

High-frequency equalization

It is well known that high-frequency signals can be attenuated by shunting a condenser between the plate and cathode of a tube. The rate of attenuation at higher frequencies is 6 db per octave, the starting frequency being decided by the type of tube, size of load resistor, and size of shunt condenser. (The load resistor includes the grid resistor effectively connected in parallel as regards h.f. with the resistor that goes to the high-frequency supply.)

For a given product of capacitance and load resistance, a pentode tube gives greater attenuation than a triode, an approximate formula for the attenuation of a pentode being:

$$\text{Attenuation in db} = 20 \log \frac{Xc}{\sqrt{R^2 + Xc^2}},$$

where R is resistance of load and Xc the reactance of the shunt capacitor

$$(Xc = \frac{1}{2\pi fc}$$

where f is the frequency in cycles per second and C is the capacitance in farads).

Such a shunt condenser may not provide sufficiently sharp cutoff. An extra attenuation of nearly the same rate may be obtained by using another shunt condenser at a later point in our circuit, for example, after the ¼-megohm resistor that supplies signal to the bass-boost network. The reactance of this condenser, as a first approximation, should bear the same ratio to the 0.025-megohm resistor as the anode shunt condenser bears to the 0.1-megohm anode resistor.

To prevent too much attenuation of the highs when ordinary records (which have only a limited h.f. boost) are played, a resistor may be connected in series with the by-pass condensers, although most people seem to prefer fairly sharp attenuation. High-frequency boosting is wanted for recording and for the realistic reproduction of speech—the former requires a boost commencing at about 1,000 cycles, the latter from 5,000 cycles or from wherever the microphone and speaker performance begin to fall off.

The easiest way to obtain the boost is to connect a small condenser in paral-

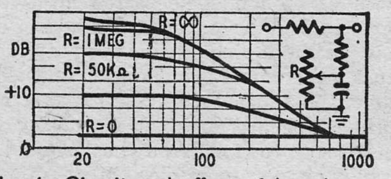

Fig. 4—Circuit and effect of bass booster.

lel with the ¼-megohm resistor that reduces the mid-frequency gain by about 20 db. This shunt condenser reduces the

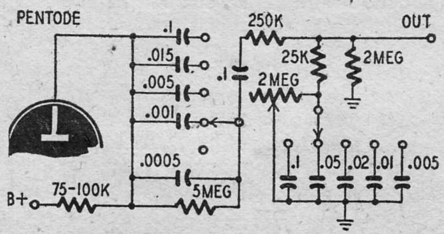

Fig. 5—Practical low-frequency compensator.

loss from over 20 db to about 11 db at high frequencies, so an effective boost of nearly 10 db is obtained. Just as in the rest of the circuit, the capacitance of the condenser is inversely proportional to the frequency at which any given amount of boost occurs, a small condenser of the order of 100 micromicrofarads being required for boosting the frequencies around 10 kilocycles, and about 10 times this capacitance for recording. As shown in Fig. 6, a switch is used to change the capacitance. To control the amount of boost and to keep the rise in gain limited to a certain frequency band, a variable resistor is connected in series with the boost condenser.

Fig. 7 is the final practical circuit. A controls the frequency of bass cut, and B the frequency of bass boost. C controls the amount of bass boost. D varies the frequency of cutoff of highs, while E controls the frequency of high boost, and F its amount.

This final circuit is simplified by omitting the variable resistor that had been connected in series with the high-frequency attenuating condensers and also the variable resistor that had been connected across the low-frequency attenuating condensers. It was found that it was far more important to be able to control the frequencies at which attenuation started than to control the amount of attenuation.

Setting of controls

For recording on discs, the low-frequency attenuator (*A* in Fig. 7) is set to give a fair amount of attenuation. If the recording is done at over 100 lines per inch, the 0.001-µf coupling condenser is used, otherwise the 0.005-µf condenser gives enough reduction. Pipe-organ and dance-band music usually require greater attenuation than a female chorus or soprano singer. If an orthacoustic response is required, a bass boost is provided at the very low frequencies by turning the 2-megohm resistor *C* to maximum value and setting *B* to 0.05 µf. Otherwise *C* is left at minimum resistance and the setting of *B* is unimportant.

The high-frequency attenuator *D* is turned off and the high-frequency boost controls are adjusted. *E* is set to about the middle position and *F* adjusted to a value of about 0.25 megohm (for a boost of about 5 db).

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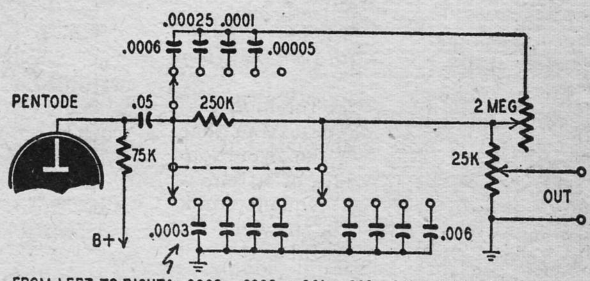

Fig. 6—Circuit for boost and attenuation of the high frequencies.

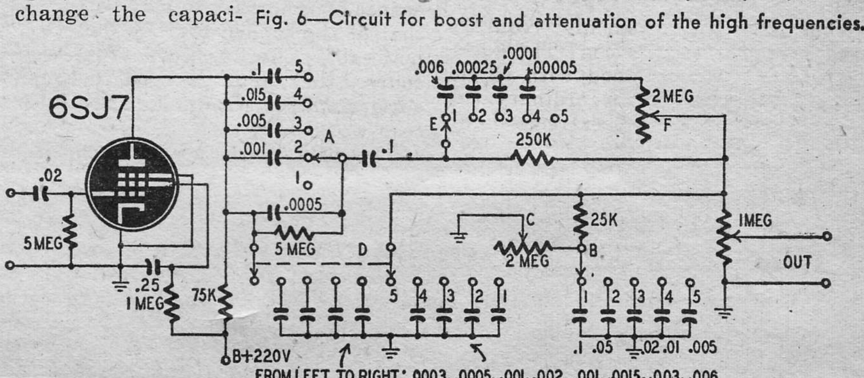

Fig. 7—This complete practical circuit combines all the features of previous figures.

RESPONSE EQUALIZATION

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When playing back, the position is quite different. Unless orthacoustic recordings are to be played, there is no low-frequency attenuation. *A* is set to 0.1 μf (to 0.005 μf for orthacoustic), and a bass boost is provided by setting *C* to maximum value and then adjusting *B* for the frequency at which the boost is to begin, 0.01 to 0.02-μf being the values generally employed.

For public-address work with a good microphone, the controls are set as follows:

A to 0.005-μf; *B*, anywhere; *C*, at minimum resistance; *D*, off; *E*, at 50 μμf; *F*, at minimum resistance or about 0.25 megohm.

The setting assumes that a good speaker is to be used and the amplifier is not being overrun. *If as much intelligible sound as possible is required without regard to naturalness*, then the setting is modified to:

A, at minimum capacity; *B*, anywhere; *C*, off; *D*, at from 0.0005/0.0015 μf (middle position); *E*, at from 0.00025 μf or 0.0006 μf;*F*, at almost minimum resistance.

The 6 controls (and an on-off switch) are mounted on a panel 10 inches by 7 inches, and a metal case affords screening against hum. A much smaller case could have been used, but space was allowed for a power-pack.