Bass Compensation

A System Using Negative Feedback

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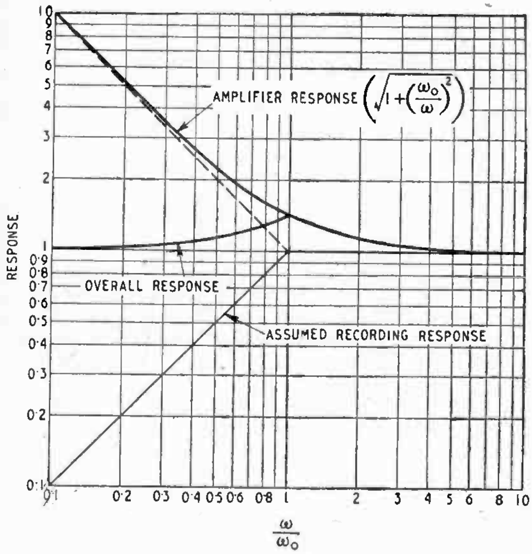

Fig. 1. Calculated response when feedback is 90 degrees out of phase.

IN a disc recording the output from the pickup is proportional to the transverse velocity of the needle in the groove. Hence, with constant output the recording amplitude is inversely proportional to the frequency, and the required amplitude for very low notes becomes impracticably large. This is normally overcome by having a recording response which is constant above a given frequency (usually about 250 c/s), and proportional to frequency below this.

In order to restore the response, the gain of the reproducing amplifier must be constant above 250 c/s and inversely proportional to frequency below this.

The usual circuits amplify above the normal level required and produce a response of approximately the right shape by a series of R-C filters. These can be made very close to the theoretical response with a carefully designed circuit, but have the disadvantage that they tend to be critical in the choice of component values and it is difficult to vary the frequency at which correction starts.

The following system is based on the fact that in an amplifier of high gain with negative feedback the response is inversely proportional to the amount of feedback (β); so that if this is made proportional to frequency, the output may be expressed as $\frac{\omega_0}{\omega}$ where ω is the angular frequency and ω_0 is the angular frequency at which the gain is unity.

If this response is added to the original signal the response is $\frac{\omega_0}{\omega} + 1$, which is correct at low and high frequencies, but when $\omega = \omega_0$ the gain is 2 instead of 1. If however the two components are 90° out of phase the magnitude is $\sqrt{1 + \left(\frac{\omega_0}{\omega}\right)^2}$ which is $\sqrt{2}$ when $\omega = \omega_0$. This is only 3db up on what is required, giving an overall response of $\pm 1\frac{1}{2}$ db.

Fig. 1 shows the response from a device of this form It is expressed in terms of $\frac{\omega}{\omega_0}$.

A simple circuit having this response is shown in Fig. (2).

If the input is v_i and the output is v_o and the gain of the amplifier is high the voltage at the grid of the valve can be taken as zero, so

$$v_i \frac{R_2 + \frac{1}{j\omega C}}{R_1 + R_2 + \frac{1}{j\omega C}} + v_o \frac{R_1}{R_1 + R_2 + \frac{1}{j\omega C}} = 0$$

$$\therefore \text{Response} = \frac{v_o}{v_i} = -\frac{R_2 + \frac{1}{j\omega C}}{R_1}$$

$$= -\frac{R_2}{R_1}\left(1 + \frac{1}{j\omega C R_2}\right)$$

Thus the normal gain is $\frac{R_2}{R_1}$, and $\omega_0 = \frac{1}{CR_2}$.

By making $R_2 > R_1$ this circuit can provide gain as well as bass compensation, but of course this reduces the available increase for low frequencies since the upper limit of gain is the normal gain of the valve without feedback.

With an R.F. pentode and a fairly high H.T. voltage, a gain of 200 can be obtained. In pushing up the gain, however, R should be kept small in comparison with R_2 to avoid a shunting effect by R_2 since R and R_2 are effectively in parallel as the grid is nearly at earth potential.

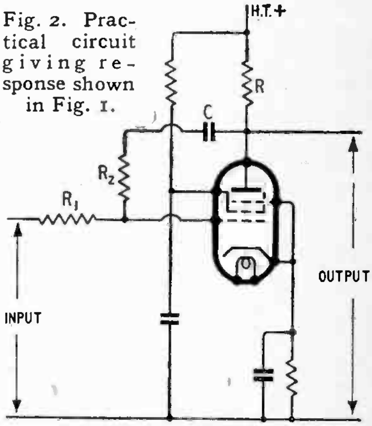

Fig. 2. Practical circuit giving response shown in Fig. 1.

The best theoretical way of varying ω_0 is by making C variable, but it is often more convenient in practice to vary R_2. This alters the gain unless a double-ganged potential divider is used and R_1 made proportional to R_2. This complicates matters by altering the impedance of the feedback circuit and seriously

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limits the upper value of R_1 and R_2, due to the difficulty of obtaining high-value "pots."

If then a fixed value of ω_0 or only a small adjustment is required this circuit provides an accurate bass compensation with a simple circuit and 20 per cent tolerance components. Of course, more accurate values are required to give a precise value of ω_0, but as ω_0 can be varied easily this is of little importance. Moreover, this circuit is practically distortionless because of the large proportion of negative feed-back, for although the feedback may not be very great at low frequencies in some cases the feedback at the harmonic frequencies will be much more effective and it is the harmonics in the output which cause the trouble.

If a wide variation of ω_0 is required, the rather more complex circuit of Fig. 3 is better. This, roughly, produces a response of $j\frac{\omega_0}{\omega}$ and this is added to the original. ω_0 can be varied by

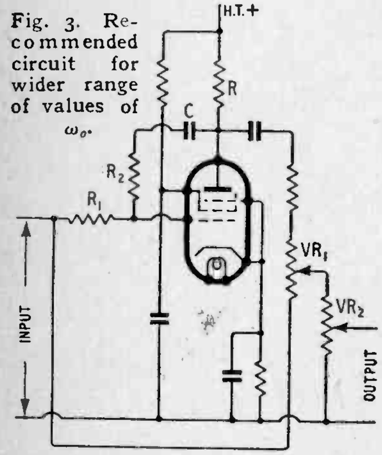

Fig. 3. Recommended circuit for wider range of values of ω_0.

altering the proportion added to the original signal. Call this proportion α, then the response is :

$$1 - \alpha\frac{R_2}{R_1}\left(1 - \frac{1}{\omega CR_2}\right)$$

$$= 1 - \alpha\left(1 - \frac{1}{\omega CR_2}\right), \text{ if } R_1 = R_2$$

$$= (1 - \alpha)\left(1 + \frac{\alpha}{j\omega CR_2(1 - \alpha)}\right)$$

$$= (1 - \alpha)\left(1 + j\frac{\omega_0}{\omega}\right),$$

where $\omega_0 = \frac{\alpha}{CR_2(1 - \alpha)}$.

α is varied by VR_1. By varying α between 0 and 1, ω_0 can be varied between 0 and ∞.

I have not given exact circuit values for these two circuits as they will vary with the type of valve used, the H.T. supply available, the gain required and the amount of variation of ω_0 required.

Using the circuit of Fig. 2 and requiring unity gain and a frequency of 250 c/s for the start of the correction, with an H.T. supply of 250 volts, and using an EF36 $R_1 = R_2 = 1M\Omega$, $R = 220\,k\Omega$, $C = 600\,\mu\mu F$ and a screen-dropping resistance of $2.2M\Omega$ should give good results. A pot included as part of R_2 will provide fine adjustment for ω_0.

In the circuit of Fig. 3 $R_1 = R_2 = 1M\Omega$, $R = 220k\Omega$, $C = 200\mu\mu F$ will give $\omega_0/2\pi = 250$c/s when $\alpha = 0.25$. VR_1 and VR_2 should be high, preferably with $VR_2 > VR_1$ and $R_3 = VR_1$. Of course, if no volume control is needed at this point VR_2 is simply the grid leak of the next valve, or is left out altogether if there is a D.C. path to earth through the input.

In adding one of these circuits before an existing A.F. amplifier it must be remembered that it acts as an additional stage and "motor-boating" may be experienced due to low-frequency feedback through the power supply unless the usual precautions for multistage amplifiers are observed.

Measuring Gear at Stockholm

Lost British Opportunities

(From a Correspondent)

AMERICAN, British, Czech, Danish, French, Finnish, Swiss, Swedish, Italian, Dutch, Norwegian and Austrian firms were all represented at the international exhibition of measuring instruments and laboratory equipment held in Stockholm from May 31 to June 3. It was surprising to find how little new there was in the radio and electronic field and how closely the Continental equipment resembled the British and American familiar designs. Six years of isolation have produced no major differences in technique.

The exhibition, like that of the Physical Society, covered a very wide range of equipment. On the fringe of the radio engineers' field were three exhibits of electron microscopes, one Swedish, one Dutch and one American, all giving very satisfactory demonstrations.

Generally speaking, it was all rather discouraging to a British visitor. Sweden is a "hard-currency" country and is anxious to buy equipment. Great Britain is supposed to be anxious to sell goods abroad, and the light-current electrical industry has an almost ideal export article, using relatively little material for a high price. The enormous capital investment in war-time "know-how" is an asset, but a wasting one, and every instrument sold now is some return on this capital. British manufacturers and their agents did not appear to be making the most of their opportunities in Stockholm.

There were some notable exceptions. Cambridge Instruments and Sullivan both showed equipment which was unmistakable and well maintained the British reputation in their field. Here indeed there was no question of our supremacy. Only Johnson Matthey and Avo were notable among the other exhibitors. Johnson Matthey showed a wide range of their materials, including ceramics, and silvered mica condensers, while Avo, represented by Svenska Radio A.B., had their full range of test equipment on view, and a very willing demonstrator. Only one stand showed any micro-wave equipment, and this was merely a jumble of magnetrons, T.R. gaps and bits of wave guides. A great opportunity was wasted here, for commonplaces of British technique are novelties in Sweden, and the future for navigational aids for shipping is a very great one.

The British Council stand deserves special mention in this note. Throughout the morning of my visit it was deserted, and a collection of out-of-date textbooks lay where they had fallen when dusted the day before. The main feature was a screen carrying photographs of early English navigational aids. There are some British devices later than Harrison's chronometer—indeed, there are so many that no one seems to know which to use. And there are some new books, too. Copies of *Wireless Engineer*, the *Journal of Scientific Instruments* and the *Proceedings* of the Radio-location Convention of the I.E.E. would have been fitting supporters.