AUDIO DESIGN NOTES

NEGATIVE FEEDBACK CIRCUITS

• Non-linear distortion is reduced by application of negative feedback, and other circuit disturbances may be minimized in many cases. In any event, signal output is reduced by the amount indicated in *Fig. 1*. As a result, a sufficient margin of gain must be provided to realize the desired output level when the feedback mesh is connected into the circuit. This margin of gain is likewise indicated in the chart.

The amount by which non-linear distortion is reduced for a given amount of feedback may be stated as

$$D_f = D/(1-AB)$$

where

D_f is the distortion remaining with use of feedback
D is the distortion present without feedback
A is the gain of the amplifier
B is fraction of output voltage fed back

Because of the many desirable features of negative feedback, it has come to be regarded in some circles as a panacea for all amplifier shortcomings. This, of course, is not quite true and may be particularly untrue in the case of hum.* With a transformer-coupled load, feedback voltage should not be taken from the plate, as the hum level will rise rather than diminish. Instead, the feedback connection should be made on the output side. When using pentodes or tetrodes, additional filtering of the screen supply will be found highly desirable to minimize hum.

*Radio, June 1946, p. 22

In a typical case, it was found that when feeding back from the voice coil without auxiliary screen filtering, the hum was 16 per cent of the source hum voltage, but was reduced to 1 per cent with auxiliary screen filtering. Without feedback, these values were found to be 180 per cent and 2 per cent respectively. A conventional pentode with transformer output was used.

Properties of negative feedback amplifiers are dependent upon whether current or voltage circuits are used. Voltage feedback causes a tube to operate as if it had a lower plate resistance

$$R_{p1} = R_p/(1+B\mu)$$

where

R_{p1} is the apparent plate resistance
R_p is the plate resistance of the tube
B is the fraction of output voltage fed back
μ is the amplification factor of the tube

Thus voltage feedback frequently aids in obtaining desired speaker damping.

Current feedback, on the other hand, causes the tube to assume an apparent plate resistance

$$R_{p1} = R_p+R_k(1+\mu)$$

where R_k is the value of the unby-passed cathode resistance.

The cathode follower is a special case of current feedback in which $B = 1$. Another special case includes half the load resistance in the cathode circuit and half in the plate circuit, forming the useful phase-splitter inverter.

When feeding back over more than one stage, there is the possibility that phase shifts in the coupling networks and other circuit reactances will cause positive feedback to occur at some frequency, with resulting oscillation. This oscillation frequency may be outside the frequency range of immediate interest, and hence the complete response characteristic of the amplifier should be taken into consideration when analyzing oscillation conditions.

Nyquist[1] has established the analytical requirement for non-oscillation. The term AB is separated into real and quadrature components, and plotted upon Cartesian coordinates over a complete range of frequency. The curve

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[1]Bell System Tech. Journal, Jan., 1932, p. 126

Fig. 1. Gain required to restore original output when negative feedback is used.