A Power Amplifier "Improver"*

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An add-on facility for audio power amplifiers is described, by which nonlinear distortion products in the audible range of frequencies are reduced by a typical 25–30 dB. The improver uses the principle of nested differentiating feedback loops to increase the feedback around the amplifier. The improver also corrects phase nonlinearity in amplifiers, improves loudspeaker damping, increases isolation between stereo channels, and reduces hum, noise, and dc drift.

0 INTRODUCTION

A recent paper [1] describes a new feedback structure, a nest of differentiating feedback loops, by means of which Bode's limiting value of loop gain can be exceeded. Increased feedback around an amplifier results in reduced nonlinear distortion. A second paper [2] describes an audio power amplifier which uses the new structure; power transistor f_T is only 2 MHz, yet loop gain is at least 25 000 (88 dB) over the range 20 Hz to 20 kHz, and distortion products in the same range are less than 20 ppm.

The present paper describes an add-on "improver" for existing audio power amplifiers, again using nested differentiating loops to increase the feedback. Harmonic distortion and intermodulation products between sinusoids in the audible frequency range are reduced by a typical 25–30 dB, down to a lower limit below 10 ppm. Transient intermodulation distortion is reduced by a similar factor, provided the rate of change of the input signal is not so great that the amplifier is driven to its limiting slew rate.

The amplifier improver also reduces linear distortion. System response is flat and phase linear from 20 Hz to 20 kHz, so that step waveforms are reproduced without overshoot and low-frequency square waves without tilt. Loudspeaker damping and crosstalk between channels of a stereo amplifier are also improved by increased feedback. Drift at the output of a dc amplifier is reduced through the use of a feedback factor which increases with decreasing frequency and reaches unity at zero frequency. Noise is reduced for all but the very lowest noise amplifiers; the spectral density referred to the system input is below 20 $nV/\sqrt{Hz}$ with 2 kHz flicker corner, corresponding to −112 dB relative to 1 V, A-weighted dc to 20 kHz.

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1 LOW-PASS THEORY

Readers should refer to Cherry [1] for the complete theory of nested differentiating feedback loops, and to Cherry [2] for a simplified but more readable account.

Fig. 1 shows a block diagram of the improver in a system. One of the nested differentiating feedback factors is the block sC_F, and others are provided within typical amplifiers by lag-compensating networks. The following design constraints are necessary between elements in the improver:

$$G_T R_T = 1 \tag{1}$$

$$G_T \beta \tau_X = C_F. \tag{2}$$

The high-frequency response of the amplifier to be improved is modeled as a two-pole function—surely more realistic than the single-pole model used in so many papers on feedback and distortion in amplifiers. The amplifier midband gain is A_0, the undamped natural frequency and damping ratio of its poles are $1/\tau_0$ and ζ, respectively. Network analysis shows that the voltage