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Novel feedback topology obviates the need for high loop gain

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Abstract

A novel feedback topology is presented, differing from 'classical' feedback by an additional feedback term, inversely proportional to the open-loop transfer function. The result is the elimination of the open-loop transfer function from the closed-loop equation, without requiring high loop gain. An example circuit, implemented with simple means, is discussed, showing a distortion reduction of several orders of magnitude.

0. Introduction.

Classical negative feedback in an amplifier goes back to Black [1], [2]. It is a widely used technique to reduce amplifier shortcomings like distortion and noise in the system output signal. Briefly, for a circuit with an open-loop transfer function A and feedback factor β (see Fig. 1a), the closed loop transfer function is described by the well-known expression

$$\frac{V_o}{V_i} = \frac{A}{1 + A\beta} \text{-----(1)}$$

where the term $A\beta$ represents the loop gain. When the loop gain is made high enough, the closed-loop system transfer function approaches $1/\beta$. As a result, the influence of the open-loop transfer function A on the closed-loop transfer function becomes vanishingly small. However, Bode [3] showed that the loop gain cannot be made arbitrarily high; it

must be limited if the system is to remain stable, thus limiting the beneficial effects of negative feedback that can be realized. There are other drawbacks to high loop gain, like the increased susceptibility to internal overdrive under transient conditions, to name just one. It is therefor logical that various schemes have been developed to obtain low distortion with limited loop gain (for example feed-forward), or to circumvent Bode's limit on loop gain (for example nested differential feedback). However, these approaches significantly increase system complexity and cost, with limited benefits.

1. New approach.

Traditionally, designers strive to maximize loop gain while maintaining stability so that the significance of the term '1' in the denominator of equation (1) is reduced and can be ignored. The present approach however aims at eliminating this term from the expression of the closed-loop transfer function altogether, irrespective of the loop gain. This can be done by replacing the generic term ' β ' in equation (1) by ' $\beta - 1/A$ ', which would eliminate the term ' A ' from the closed-loop transfer function. The conceptual approach is shown in Figure 1b. There are two feedback paths: the path via V_f of a fraction β of V_o to the inverting input of the summing network (the 'classical' path), and an additional, positive, feedback via V_c to the non-inverting input of the summing network, of a fraction $1/A$ of V_o . By treating the two feedback-paths separately, as described by Graeme [4], the compound *negative* feedback-factor F becomes:

$$F = \beta - \frac{1}{A}$$

Substituting this for β in equation (1) yields the closed-loop transfer function:

$$\frac{1}{\beta}$$

which is what we were after.