A Low-Distortion Output Stage with Improved Stability for Monolithic Power Amplifiers

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Abstract —A new low-distortion class *AB* output stage with improved stability suitable for monolithic power amplifiers ($P_o \geqslant 40$ W) is described. The concept has been verified on a 12-W breadboard version as well as on a partly integrated prototype, and is supported by computer simulations for $P_o \geqslant 40$ W. A new biasing control law is implemented which guarantees predictable conduction of both output transistors at all times. This reduces crossover distortion and allows the customary quasi-p-n-p compound transistor to be eliminated, thus also improving stability. Linearity is improved by use of local negative feedback. Phase margin is improved by application of high-frequency feedforward. Measured phase margin is around 60° and total harmonic distortion for a load of 7 Ω is about −80 dB at 20 kHz.

I. Introduction

POWER amplifiers perform a fundamental interfacing function between low-level signal processing circuits and the "real world." An important application area is audio amplifiers where, since the advent of digital signal sources (CD and DAT), the required distortion specification poses a major design challenge. The output stage of power amplifiers has always been a problem in this context, particularly when designed for monolithic realization. Obtaining accurate quiescent current control, low distortion, and adequate high-frequency stability in a standard bipolar process which does not provide high-current p-n-p transistors requires new circuit techniques.

This paper describes a power amplifier design with a new class *AB* output stage which successfully addresses the above-mentioned problems and which is implemented in a standard bipolar process. The amplifier is intended for high output power (⩾ 40 W) and features low distortion (THD of −80 dB at 20 kHz) and good stability (phase margin 60°).

The paper is organized as follows. In Section II the problems associated with the classic design approach are discussed. Section III introduces the new improved amplifier principle. Section IV describes a local feedback technique with high-frequency signal feedforward. S[...] presents a new class *AB* biasing technique whic[h] [...]tees conduction of both output transistors at all ti[mes]. [The] complete power amplifier circuit is discussed in Se[ction] [...] Experimental circuit realization is the topic of Sec[tion] [...] The measured results are presented in Section VIII[...] conclusions are formulated in Section IX.

II. Problems of Classic Power Outpu[t] Stage Designs

Most presently available integrated power ampli[fiers] conform to the basic op-amp structure as depic[ted in] Fig. 1 [1].

The required high-current p-n-p transistor in the o[utput] stage is synthesized from a combination of a small [...] p-n-p transistor Q_3 and a large n-p-n transistor Q_2. [How]ever, this "quasi-p-n-p" compound transistor is unst[able at] high currents unless special measures are taken [1]–[4]. [Its] stability properties are best discussed with the aid o[f ...] which represents the quasi-p-n-p structure as a fe[edback] amplifier [5].

The open-loop response of the circuit model o[f Fig. ...] has two poles due to the parasitic capacitances C_1 a[nd ...] In addition, the lateral p-n-p transistor contributes [...] phase shift; together this results in negative phase m[argin] when closing the loop (dotted line). This explain[s the] persistent local parasitic oscillations produced by [the] quasi-p-n-p structure, particularly at high current[s when] the p-n-p transistor has a high transconductance.

A second problem associated with classic output [stages] is nonlinearity caused by V_{BE} variations of the o[utput] emitter followers which pass the large output current[s (up] to 4 A). Referring to Fig. 1, the signal transfer to no[de N] is quite linear. However, the nonlinear V_{BE} variati[ons of] Q_1 and Q_3 pollute the signal when it is transferred [from] node N to the output. In the recent past an error [com]pensation technique has been applied which measu[res the] nonlinear error signal and subtracts it from the inpu[t] [4]. In contrast, our present technique, which will be [dis]cussed in the next sections, uses local negative feedba[ck to] improve the open-loop linearity.

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