

ticated quasi-class A designs does not alter the performance with respect to this distortion source, since their output impedance also varies with signal level. The use of FETs, VFETs, or MOSFETs does not seem to be an attractive solution due to their low inherent transconductance, giving rise to a high output impedance. These devices will, at least at low frequencies, always be regarded as voltage controlled.

3 A PRACTICAL CASE

The output stage of an Electrocompaniet Ampliwire II was modified to check the validity of the theory outlined above on practical amplifiers. Fig. 4 shows a schematic of the output stage of this amplifier. Each emitter resistor is $1\ \Omega$; the total quiescent current is 0.6 A . The emitter resistors were reduced to $0.47\ \Omega$. The results of this modification are shown in Table 1. The measurement floor was -120 dB . Note that the distortion figures are for the amplifier in closed-loop condition. The overall loop feedback is 38 dB .

4 THE CURRENT-CONTROLLED DESIGN

A simplified block diagram of a current controlled output stage is shown in Fig. 5. The transfer function for this system for low and medium frequencies can be given by

$$U_o/U_{in} = \frac{R_L h_{fe} g_m}{1 + sCR(R_L h_{fe} g_m)} \quad (11)$$

where

- s = the complex frequency variable
- R_L = the load resistance
- h_{fe} = the current gain of the output stage
- g_m = the transconductance of the driver stage
- C = the compensation capacitance
- R = the driving resistance.

Table 1. Level of distortion components for two values of the emitter resistors.

Harmonic Number	$R_e = 1\ \Omega$	$R_e = 0.47\ \Omega$
THD	0.025%	0.017%
2	-84.4 dB	-86.8 dB
3	-73.1 dB	-76.5 dB
4	-108.2 dB	-106.0 dB
5	-85.5 dB	-91.2 dB
6	-111.9 dB	-112.3 dB
7	-95.0 dB	-102.4 dB
8	-109.6 dB	-111.7 dB
9	-115.5 dB	-117.9 dB
10	-110.1 dB	-113.5 dB
11	-106.9 dB	-111.6 dB
12	-114.8 dB	-120.0 dB
13	-105.2 dB	-112.9 dB
14	< -120 dB	< -120 dB
15	-109.0 dB	-118.7 dB
16	-118.9 dB	< -120 dB
17	-117.0 dB	< -120 dB
18	-117.7 dB	< -120 dB
19	-118.9 dB	< -120 dB
20	-119.7 dB	< -120 dB
21	-116.8 dB	< -120 dB

The output level is 10 V rms into a $4\text{-}\Omega$ load.

As mentioned in the introduction, h_{fe} is a nonlinear function of the emitter current. This means that the low-frequency gain will vary with the signal level. The gain above the cut-off frequency will remain constant, since the cut-off frequency also varies with h_{fe} . When the stage transfers from class A to class B operation, the excursion around the operating point increases rapidly, since only one of the transistors conducts this current. This causes a rapid increase in the variation of the low-frequency gain.

The variation of the cut-off frequency of this system, which will most probably be the open-loop cut-off frequency of a feedback system, will cause large amounts of phase intermodulation. Since this cut-off frequency would be expected to be no higher than a few hundred hertz in a typical power amplifier, one would expect the phase intermodulation distortion to appear at low and medium frequencies. Since both the nonlinearity and the phase angles of the frequencies of interest are large, one should expect this distortion to reach rather high values.

5 CONCLUSION

It has been shown that class AB output stages exhibit large amounts of distortion at the transition point from class A to class B operation in the voltage-controlled mode. It has further been indicated that the current-controlled output stage is subject to large amounts of phase intermodulation distortion.

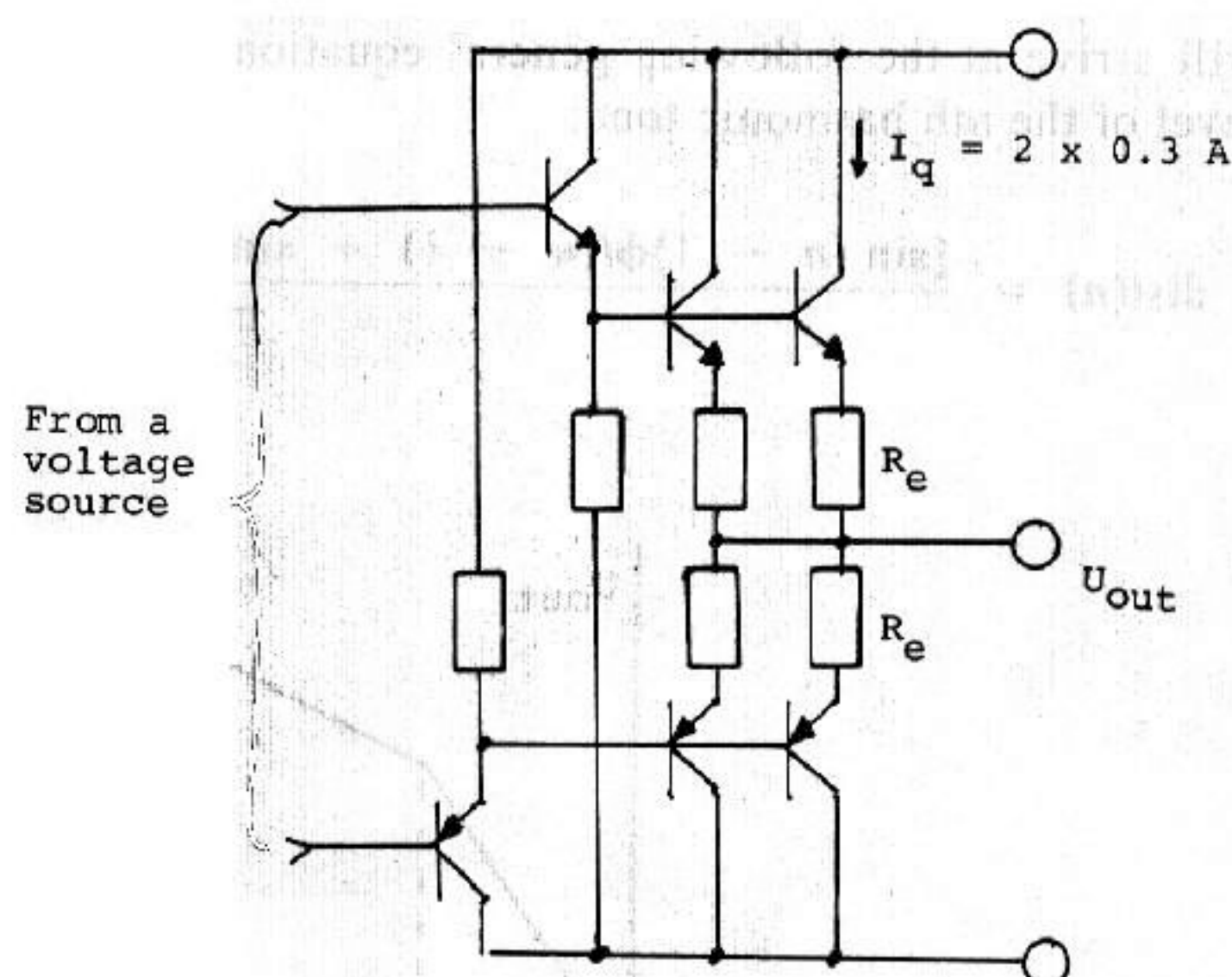


Fig. 4. Output stage of Electrocompaniet Ampliwire II

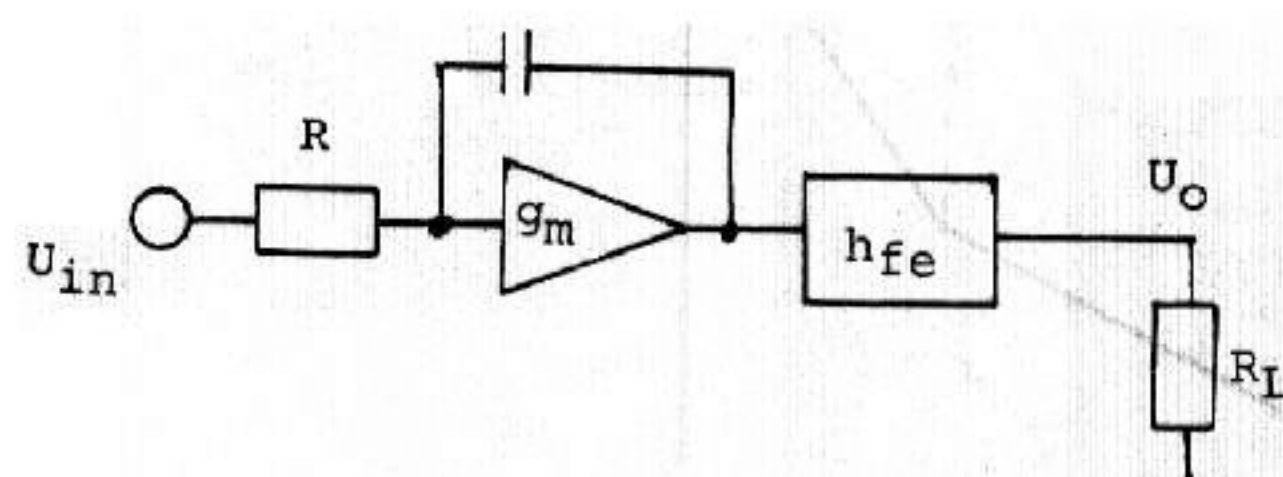


Fig. 5. Block schematic of current-controlled output stage.