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Transient low-end performance of audio non inverting feedback preamplifiers and power amplifiers

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AN AUDIO ENGINEERING SOCIETY PREPRINT

TRANSIENT LO-END PERFOMANCE OF AUDIO NON INVERTING FEEDBACK PREAMPLIFIERS AND POWER AMPLIFIERS.

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All non inverting feedback preamplifiers and power amplifiers are subject to transient response variations at the lo end due to an unwanted zero in their transfer function. Several cases of these response deviations from the ideal case are considered, and a simple but effective method is described to extract impecable transient response from current designs.

0 INTRODUCTION

Having looked to several commercial preamp and power amp designs from various manufacturers, their "shock" response to suddenly applied signals, commom in contemporary music and their behaviour under overdrive conditions, we decided to study transient response over the generalized model of the non--inverting double ac coupled amplifier topology and search for the validity of a solution we are designing into our own systems, to avoid lo frequency intermodulation, cone "overhang" when dealing with heavy percussive signals, and excessive turn-on "thumps".

1 ANALYSIS

We proceed to look to the non inverting double ac coupled configuration of fig. 1, which is characteristic of many current designs.

The transfer function is of the form:

$$(1)\quad \frac{Eo}{Ei} = \frac{S}{S+\frac{1}{R_1C_1}} * \frac{(R2+R3)\,C2S+1}{C_2R_3S+1}$$

If we make the substitutions:

$$(2)\quad W_1 = \frac{1}{R_1C_1}$$

$$(3)\quad W_2 = \frac{1}{(R_2+R_3)C_2}$$

$$(4)\quad W_3 = \frac{1}{R_3C_2}$$

$$(5)\quad \frac{Eo}{Ei} = \frac{W3}{W2} * \frac{S}{S+W1} * \frac{S+W2}{S+W3}$$

Clearly this transfer function has two zeros and two poles. We will be concerned with the transient behaviour of this circuit so we proceed to see what happens when:

$$(6)\quad Ei = \frac{1}{S}$$

That is, when the input is the step function pictured in fig. 2.

Applying eq 6 to eq 5 yelds:

$$(7)\quad Eo = \frac{W3}{W2} * \frac{S+W2}{(S+W1)(S+W3)}$$

Which can be expanded to [1]

$$(8)\quad Eo = \frac{W3}{W2(W1-W3)} * \left(\frac{W1-W2}{S+W1} + \frac{W2-W3}{S+W3}\right)$$

And finally, to check response in the time domain rather than in the frequency domain, inverse transformed to:

$$(9)\quad Eo\ (t) = \frac{W3}{W2(W1-W3)} \left[(W1-W2)\ e^{-W1t} + (W2-W3)\ e^{-W3t} \right]$$

We can now proceed to consider a typical 50W 4Ω amplifier which has the configuration of fig. 1, featuring a full power sensivity of OdBU = 775V rms, and a small signal f3 of

$$f3 = 2Hz$$

Which in turn implies a closed loop gain (and $\frac{W3}{W2}$ of 18.3), so

$$f2 = 0.11Hz$$

We will consider three examples

a) f1 = 10f2

b) f1 = f2

c) $f1 = \frac{f2}{10}$

CASE a) is close to most of the available designs, and so we proceed to calculate response using a programmable personal calculator, which gives the transient response pictured in fig. 3 a), and lo frequency response shown in fig. 4 a). Clearly the response of fig. 3 a) is far from being perfect, giving rise to a negative hump before the gain drops to the final zero equilibrium value.

CASE b) represents our proposal of cancelling the unwanted zero in the second stage (at W2) with the first-stage pole W1, giving rise to a -6dB/oct first-order cuttoff featuring an impecable transient response, as pictured in fig. 3 b), and lo-frequency response shown in fig. 4 b).

CASE c) gives rise to no hump in transient response but has the drawback of both very high decay time (fig 3 c) and undesirable lo frequency slope variation (fig. 4 c) which may be objectionable in what concerns record rumble and excentricity effects and microphone-induced wind and shock noises.

2 CONCLUSION

A very simple method has been described that can be of some benefit to transient response of ac coupled feedback non-inverting amplifiers and amplifiers used for audio purposes, speeding up their recovery from transient conditions and supressing lo-frequency instabilities which may be harmfull not only from the standpoint of listening, because this instabilities can create audible modulation effects [2, 3, 4] but also because they demand for increased cone excursion in loudspeaker systems, shortening its useful life. In addition, it can cut down drastically turn-on thumps in audio equipment.

3 REFERENCES

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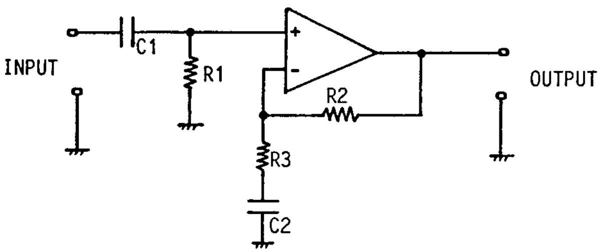
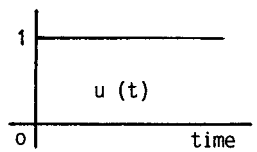


FIG. 1



$$u(t) = \begin{cases} 0 & \text{if } t < 0 \\ 1 & \text{if } t > 0 \end{cases}$$

FIG. 2

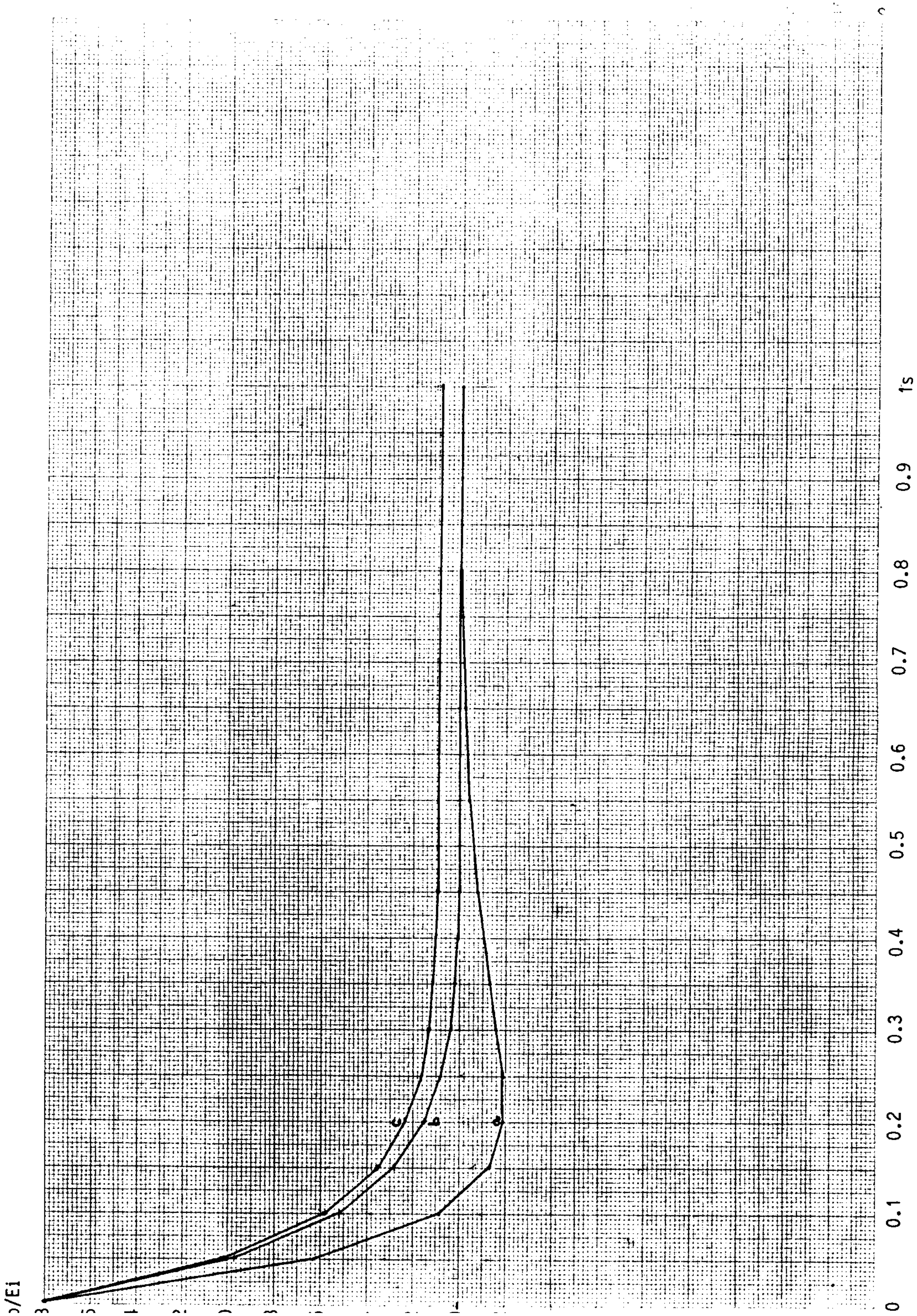


FIG. 2

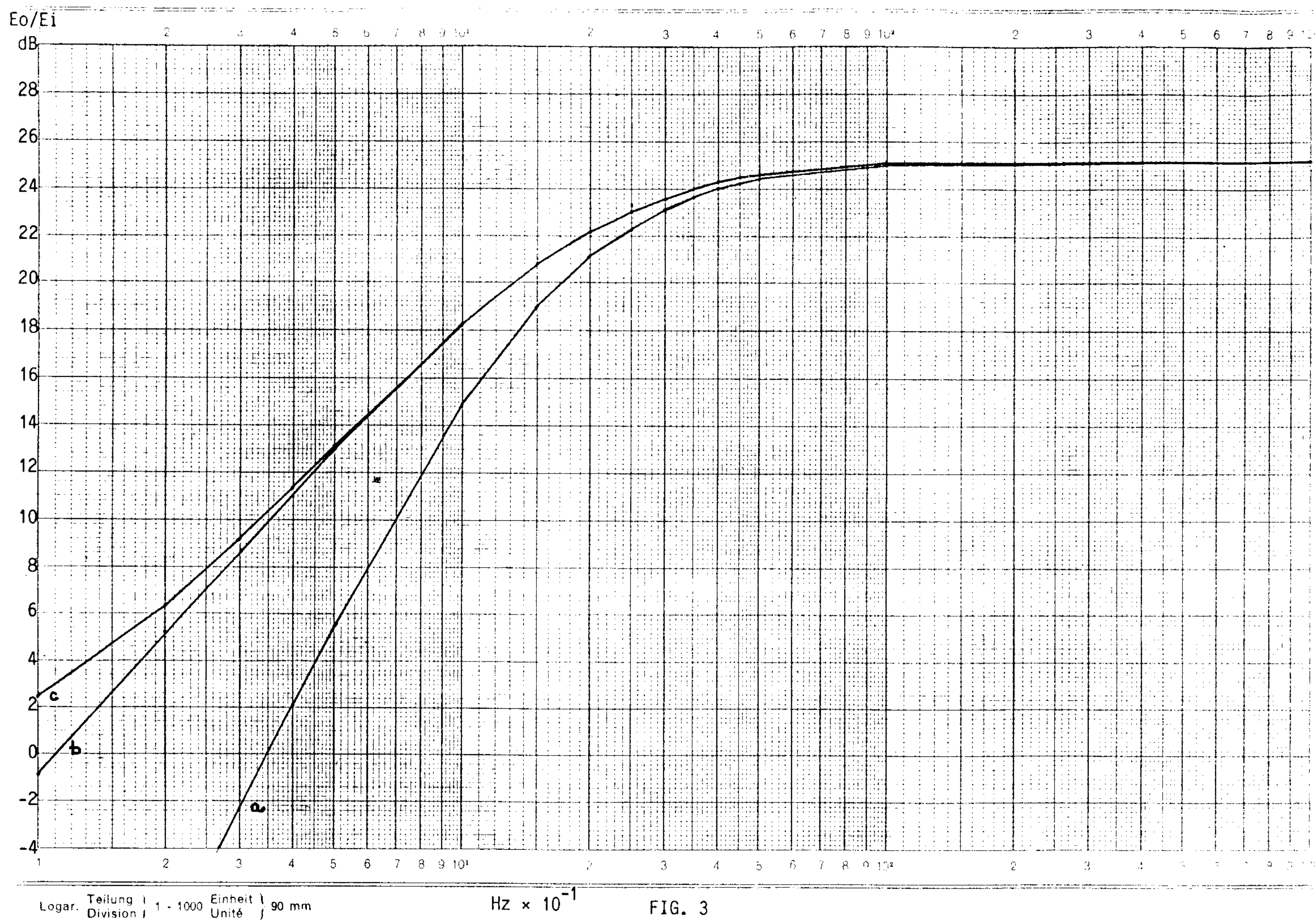

Eo/Ei
dB
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
c
b
a
1
2
3
4
5
6
7
8
9
10³
10⁴
Logar. Teilung / Division 1 - 1000 Einheit / Unité 90 mm
Hz × 10⁻¹

FIG. 3