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Correction to "Planar Least Squares Inverse Polynomials: Part I—Algebraic Properties"

PHILIPPE DELSARTE, YVES V. GENIN, AND YVES G. KAMP

In the above paper[1] the caption of Table I on p. 63 is missing. This caption should read as follows: S means $a_{1,1}$ stable for all b, I means $a_{1,1}$ unstable for appropriate b, and I^* means $a_{1,1}$ "almost" stable for all b (its only possible zeros in Δ are on $|z_1|=|z_2|=1$).

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[1] P. Delsarte, Y. V. Genin, and Y. G. Kamp, *IEEE Trans. Circuits Syst.*, vol. CAS-26, pp. 59–66, Jan. 1979.

Correction to "Limit Cycle Oscillations in Digital Incremental Computers"

AHMAD I. ABU-EL-HAIJA

In the above paper[1] some errors were made in the typesetting process for assigning figures with their captions. The following corrections are necessary.

1) The drawing above the caption of Fig. 6 should appear above the caption of Fig. 4.

2). The drawings above the captions of Figs. 4 and 5 should appear above the captions of Figs. 5 and 6, respectively.

3) In the caption of Fig. 6 the phrase "as for Fig. 4" should be replaced by the phrase "as for Fig. 5."

Also, [4] should read:

[4] A. I. Abu-El-Haija and A. M. Peterson, "A structure of digital notch filters," *IEEE Trans. Acoust., Speech, Signal Processing*, vol. ASSP-27, pp. 193–195, Feb. 1979.

Manuscript received April 24, 1979.

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[1] A. I. Abu-El-Haija and A. M. Peterson, "Limit cycle oscillations in digital incremental computers," *IEEE Trans. Circuits Syst.*, vol. CAS-25, pp. 902–908, Nov. 1978.

Passive Compensation of Op-Amp VCVS and Weighted Summer Building Blocks

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***Abstract*—By general analysis of the passive compensated operational amplifier (op-amp) inverting voltage controlled voltage source (VCVS) proposed by Wilson, it is found that the addition of only one compensating capacitor instead of two will result in less phase and magnitude errors. It is found also that the addition of two compensating capacitors has another important application which is the compensation of the op-amp VCVS when looked upon as a generalized three port active building block. Passive compensation of the op-amp weighted summer, when considered as a multiinput VCVS is deduced.**

I. INTRODUCTION

It is well known that the finite and complex open-loop gain nature of the op-amps degrades the performance of active *RC* networks significantly [1]–[6]. Much of the literature have discussed passive and active compensation techniques to improve the performance of active networks with respect to the use of imperfect amplifiers. The authors of [1] and [4] have looked at this problem in such a way that the actual closed-loop performance of an active building block, comprising an op-amp and its feedback elements is separately adjusted to behave in an approximately ideal manner up to a specified frequency. Reported here, a general analysis obtained by investigation of Wilson's passive compensated inverting VCVS proposed in [1]. The general analysis includes passive compensation of op-amp VCVS and weighted summer structures when looked upon as generalized active building blocks.

If the op-amp is assumed to have a single-pole open-loop response with a unity gain bandwidth w_t, then its gain is approximately given by

$$A(s)\simeq\frac{w_t}{s}. \tag{1}$$

The closed-loop gain of the inverting VCVS of Fig. 1(a) is given by

$$\frac{V_0}{V_1}=-K\epsilon(s) \tag{2}$$

where

$$\epsilon(s)=\frac{1}{1+s\tau} \tag{3}$$

and

$$\tau=\frac{K+1}{w_t}. \tag{4}$$

Wilson [1] has shown that for the inverting VCVS the addition of two compensating capacitors as shown in Fig. 1(b) such that $CR=\tau$ will result in the following closed-loop gain expressions:

$$\frac{V_0}{V_1}=-K\epsilon_w(s) \tag{5}$$

where

$$\epsilon_w(s)=\frac{1+s\tau}{1+s\tau+s^2\tau^2}. \tag{6}$$

From (6) it is seen that the phase and magnitude of $\epsilon_w(s)$ are given by

$$\left.\begin{aligned}\arg[\epsilon_w(jw)]&\simeq-w^3\tau^3\\ |\epsilon_w(jw)|&\simeq1+w^2\tau^2\end{aligned}\right\}\quad w\tau\ll1. \tag{7}$$

II. THE MODIFIED COMPENSATED INVERTING VCVS

Fig. 2 represents the new compensated inverting VCVS which requires only a single compensating capacitor. Selecting the

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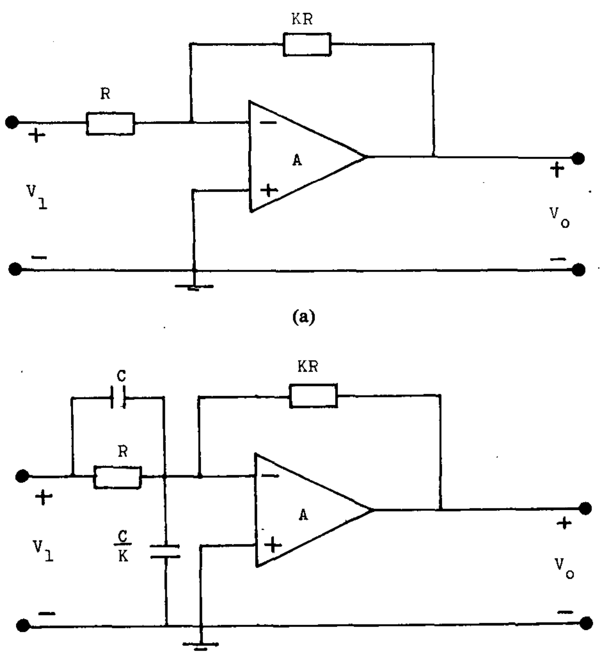

(a)

(b)

Fig. 1. (a) The inverting VCVS. (b) Wilson's compensated inverting VCVS.

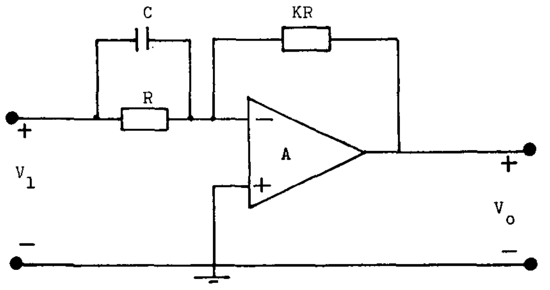

Fig. 2. The modified compensated inverting VCVS.

capacitor C such that

$$CR=\tau=\frac{K+1}{w_t}. \tag{8}$$

By analysis the closed-loop gain is obtained as

$$\frac{V_0}{V_1}=-K\epsilon_c(s) \tag{9}$$

where

$$\epsilon_c(s)=\frac{1+s\tau}{1+s\tau+s^2\tau\tau_c} \tag{10}$$

and

$$\tau_c=\frac{K}{w_t}. \tag{11}$$

$\epsilon_c(s)$ is the compensated remaining error function in this case. Its phase and magnitude are expressed as

$$\left.\begin{aligned}\arg[\epsilon_c(jw)]&\simeq -w^3\tau^3\frac{K}{K+1}\\ |\epsilon_c(jw)|&\simeq 1+w^2\tau^2\frac{K}{K+1}\end{aligned}\right\}\quad w\tau\ll 1. \tag{12}$$

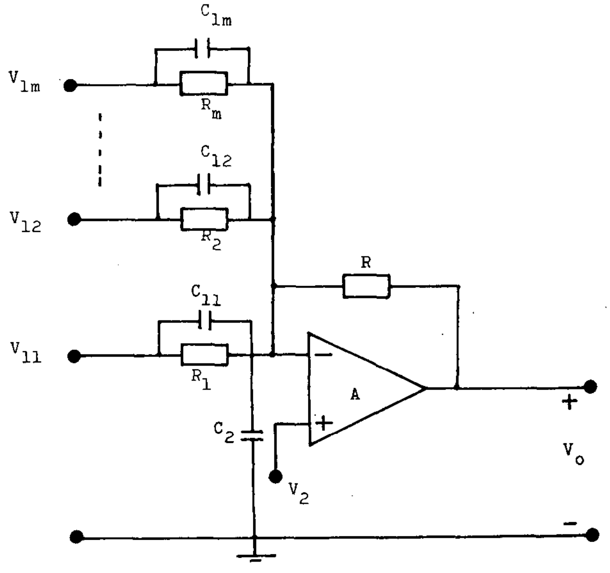

Fig. 3. Generalized compensated weighted summer.

Comparing this result with (7) it is clear that the remaining phase and magnitude errors are smaller than those obtained using Wilson's compensation scheme of Fig. 1(b). The reduction in both cases being in the ratio of $K/(K+1)$.

III. Compensation of Weighted Summers

Following the same approach used throughout the above analysis, compensation of op-amp weighted summers can be deduced. Considering the generalized compensated weighted summer of Fig. 3, two cases will be discussed.

1) Port 2 is shorted to ground to realize an inverting weighted summer. In this case only one compensating capacitor is required per input port. Omitting C_2 and selecting C_{1i} such that:

$$C_{1i}R_i=\tau=\frac{K+1}{w_t},\qquad i=1,2,\cdots,m \tag{13}$$

where

$$K=R\left(\frac{1}{R_1}+\frac{1}{R_2}+\cdots+\frac{1}{R_m}\right). \tag{14}$$

The following compensated expression is obtained:

$$V_0=\left[-\sum_{i=1}^{m}\frac{R}{R_i}V_{1i}\right]\epsilon_c(s). \tag{15}$$

2) Port 2 is nongrounded to realize a generalized weighted summer. In this case the grounded compensating capacitor C_2 is necessary. Selecting C_{1i} such that $C_{1i}R_i=\tau$ and $C_2=C/K$, where

$$C=\sum_{i=1}^{m}C_{1i}. \tag{16}$$

The following compensated expression is obtained:

$$V_0=\left[(K+1)V_2-\sum_{i=1}^{m}\frac{R}{R_i}V_{1i}\right]\cdot\epsilon_w(s). \tag{17}$$

It is worth noting that this generalized weighted summer includes the generalized double input VCVS as a special case.

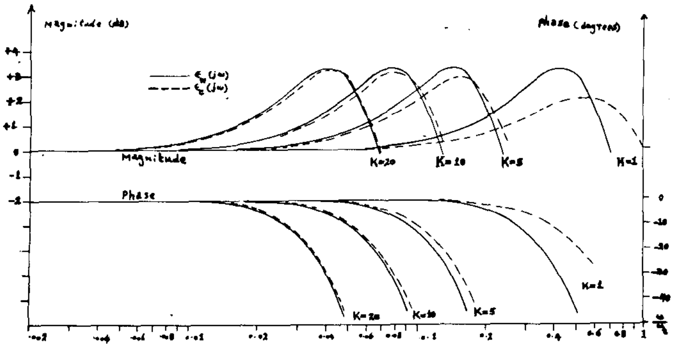

Fig. 4. Calculated phase and magnitude of $\epsilon_w(jw)$ and $\epsilon_c(jw)$ plotted versus w/w_t with K as a parameter.

Thus it is seen that two capacitors are necessary for the passive compensation of the generalized three-port active building block.

The efficiency of the compensation techniques discussed above is comparatively dependent upon the realized parameter K and the used op-amp w_t (since it is assumed that $w\tau \ll 1$ throughout the analysis). Therefore, it is of importance to clarify to what extent this dependence is strong. Fig. 4 shows a set of calculated curves for the phase and magnitude of both $\epsilon_w(jw)$ and $\epsilon_c(jw)$ plotted versus w/w_t with K as a parameter.

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