INSTRUMENTATION AMPLIFIERS WITH IMPROVED BANDWIDTH

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ABSTRACT

Active magnitude compensation methods for the finite bandwidth of operational amplifiers when employed in the differential voltage controlled voltage source structures are given. The results are summarized in a Table.

The differential voltage controlled voltage source (DVCVS), which is also known as the instrumentation amplifier, is shown in Figure 1. [1], [2] The assumption of an ideal DVCVS cannot be sustained except at very low frequencies. It is well known that the finite and complex open loop gain nature of the operational amplifier (op amp) results in both phase and magnitude errors [3-7].

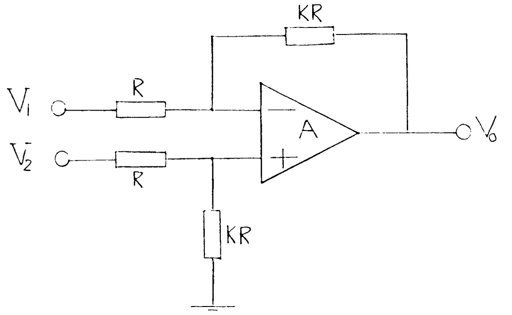


Fig. 1

The purpose of this correspondence is to describe and compare several DVCVS structures employing two op amps and having negligible magnitude error up to an extended frequency range. It is assumed that matched op amps are used and that the open loop gain of the op amp is represented by the single pole model:

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

where ω_t is the unity gain bandwidth of the op amp.

In all the circuits shown, V_1 and V_2 are the inverting and the non-inverting inputs respectively, and V_0 is the output which is given by:

$$V_0 = K(V_2 - V_1) \cdot \epsilon \tag{2}$$

where ϵ is the error function contributed by the finite gain bandwidth of the op amps. Table 1 includes the error function, the condition for a maximally flat magnitude (MFM) response, and the normalized bandwidth for all the DVCVS structures considered here. The following comments are made:

(1) The DVCVS of Figure 2 [4], which includes the Budak noninverting VCVS [3] as a special case, has a bandwidth larger than the DVCVS structures of Figure 3 for a given DC gain K.
(2) The circuits of Figure 3 are generalizations of two of the inverting VCVS structures reported recently [7], and they have the same bandwidth which is larger than that of the uncompensated DVCVS for $K > \sqrt{2}$.
(3) The circuit for Figure 2 has a bandwidth larger than that of the two equivalent circuits of Figure 4 [5], [6] for $K > 1.965$.
4) The bandwidth of the DVCVS's of Figure 3 is larger than the bandwidth of the circuits of Figure 4 for $K > 4.4$.

It should also be noted here that the MFM noninverting VCVS reported by Geiger [8] is not suitable by its nature for the differential mode of operation.

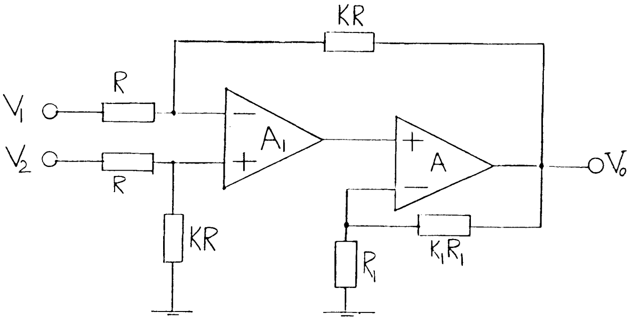
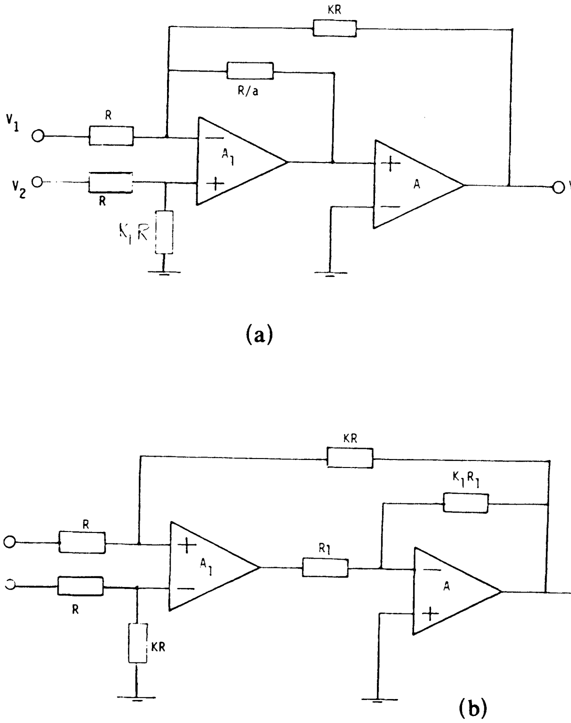


Fig. 2

DVCVS Fig. No	Error Function $\in$	Condition for MFM Response	Realizability Condition	Normalized Bandwidth $BW_n = \frac{BW}{\omega_t}$
1	$\frac{1}{1+\frac{(K+1)}{A}}$	—	—	$\frac{1}{(K+1)}$
2	$\frac{1}{1+\frac{(K+1)}{(K_1+1)A_1}+\frac{(K+1)}{AA_1}}$	$K_1=\sqrt{\frac{(K+1)}{2}}-1$	$K \geq 1$	$\frac{1}{\sqrt{(K+1)}}$
3(a)	$\frac{1}{1+\frac{Ka}{A}+\frac{K(a+1)+1}{AA_1}}$	$a=\frac{\sqrt{(2K+3)}+1}{K}$ $K_1=\frac{K}{\sqrt{(2K+3)}+2}$	—	$\frac{\sqrt{2}}{\sqrt{(2K+3)}+1}$ $=\frac{1}{\sqrt{(K+2)+\sqrt{2K+3}}}$
3(b)	$\frac{1}{1+\frac{(K+1)}{K_1A_1}+\frac{(K+1)(K_1+1)}{K_1AA_1}}$	$K_1=\frac{\sqrt{(2K+3)}-1}{2}$		
4(a),(b)	$\frac{1+\frac{(K_1+1)}{A_1}}{1+\frac{(K+1)}{A}+\frac{(K+1)(K_1+1)}{AA_1}}$	$K_1=(\sqrt{2}-1)(K+1)-1$	$K \geq \sqrt{2}$	$\frac{1.722}{(K+1)}$

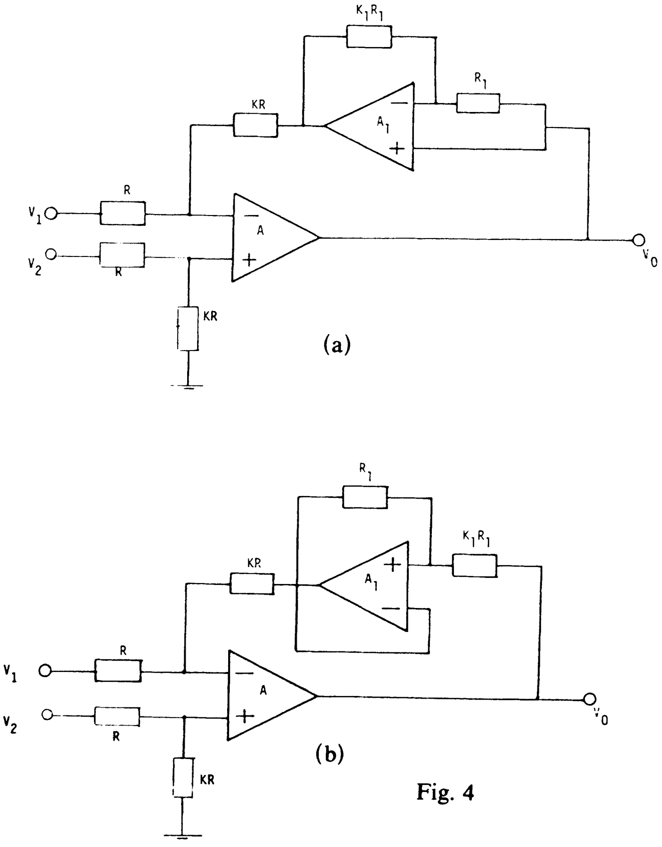
Table 1



(a)

(b)

Fig. 3



(a)

(b)

Fig. 4

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