and the one-variable inner determinants[6] are found to be

$$\Delta_1^1(y) = 32(5 + 4y)$$
$$\Delta_3^1(y) = 1024(5 + 4y)(16y^4 + 8y^3 - 15y^2 - 8y - 1)$$

We can show the zeros and sign distribution of inner determinants in the region of $y \in [-1, +1]$ as follows:

	-1	I_1	$-0{\cdot}25$	I_2	$+1$
$\Delta_1^1(y)$		$+ + +$		$+ + + + +$	
$\Delta_3^1(y)$	0	$- - -$	0	$- - - - -$	0

Due to the theorem 2, we find

$$N_{(-1,\,1/4)} = \text{var}\,(+, -, -) - \text{var}\,(+, +, -) = 0$$
$$N_{(-1/4,\,+1)} = \text{var}\,(+, -, -) - \text{var}\,(+, +, -) = 0$$

where $N_{(-1,\,-1/4)}$ and $N_{(-1/4,\,+1)}$ denote the number of real zeros in x of $G(x, y)$ for any fixed value of y in $(-1, -\frac{1}{4})$ and $(-\frac{1}{4}, +1)$, respectively. However, we can show that $N_{-1/4} = 2$, where $N_{-1/4}$ is the number of real zeros of $G(x, -\frac{1}{4})$. Taking $y = -\frac{1}{4}$, $V(x, -\frac{1}{4}) = 64x^2 + 112x - 49$, which has a real root in $-1 \leq x \leq 1$. From theorem 1 we conclude that $B(z_1, z_2)$ has zero(s) on the unit polydisc. Hence the filter function is unstable.

Example 2: Suppose

$$B(z_1, z_2) = (12 + 10z_1 + 2z_1^2) + (6 + 5z_1 + z^2)z_2.$$

The first and second conditions are satisfied; the third condition (eqn. 3*c*) will determine the stability. We obtain $G(x, y)$ as

$$G(x, y) = (4y + 5)^2(24x^2 + 70x + 50)^2$$

One-variable inner determinants are

$$\Delta_1^1(x) = 32(24x^2 + 70x + 50)^2; \quad \Delta_3^1(x) \equiv 0$$

Neither Δ_1^1 and Δ_3^1 have any real root in the interval $I = (-1, +1)$, $N_I = 0$. Since the number N_I of real roots is equal to zero, the lemma guarantees that $B(z_1, z_2)$ has no zero on the distinguished boundary, i.e. $B(e^{j\omega_1}, e^{j\omega_2}) \neq 0$. The filter function is stable. Since this is an example of a separable system, simpler techniques for assessing stability are available.

Remark: In the second example above, $\Delta_3^1(x) \equiv 0$ implies the presence of a common factor in $G(x, y)$ and $G'(x, y) = \delta G(x, y)/\delta y$, and this can be extracted via rational operations.[6]

Conclusion: A new stability testing method for two-dimensional digital filters has been proposed. One-variable inner determinants have been used for the determination of the zeros on the unit bidisc.

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NOVEL PHASE COMPENSATED 3-PORT VCVS WITHOUT MATCHED OPERATIONAL AMPLIFIERS

Indexing terms: Active networks, Circuit design

A new active phase compensated differential voltage controlled voltage source is given. The proposed network does not require matched operational amplifiers. Stability analysis based on the two-pole model of the operational amplifier is discussed.

Introduction: Passive and active phase compensation methods for generalised three-port voltage controlled voltage source (VCVS) structures have been reported in the literature.[1-3] In this letter a new active phase compensated differential VCVS is introduced. The proposed network has the advantage that the phase compensation condition is independent of the gain-bandwidth of the operational amplifiers (op amps) employed in the circuit.

New 3-port VCVS: The proposed differential VCVS is shown in Fig. 1. Straightforward analysis of the circuit yields the following expression for the output voltage V_0 in terms of the noninverting input V_2 and the inverting input V_1:

$$V_0 = \frac{V_2[K(a+1)+1][1+\{(K_1+K_2+1)/A_1\}] - V_1 K[1+\{K_1[K(a+1)+1]/KA_1\}]}{1+\{K_2[K(a+1)+1]/A_1\} + \{[K(a+1)+1][K_1+K_2+1]/A_1A_2\}} \tag{1}$$

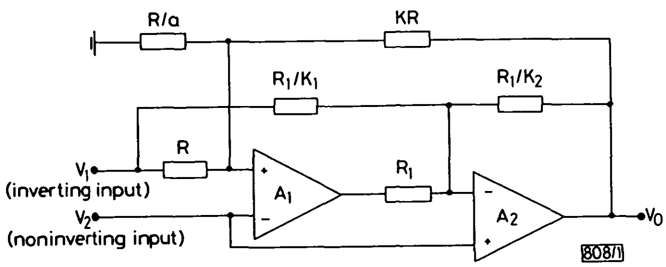

Fig. 1 *Proposed differential VCVS*

From the above equation it is seen that for the three-port mode of operation it is necessary to have

$$K_2 = K_1\left(a + \frac{1}{K}\right) - 1 \tag{2}$$

In this case eqn. 1 reduces to

$$V_0 = [V_2[K(a+1)+1] - V_1 K]\varepsilon \tag{3}$$

where

$$\varepsilon = \frac{1+\{K_1[K(a+1)+1]/K\}(1/A_1)}{1+\{K_1[a+(1/K)]-1\}[K(a+1)+1](1/A_1) + (K_1/K)[K(a+1)+1]^2(1/A_1A_2)} \tag{4}$$

ε is the remaining error function of the compensated circuit.

Let the open loop gain of each of the two op amps be characterised by the single pole model given by

$$A_i(s) \simeq \omega_{ti}/s \qquad (i = 1, 2) \tag{5}$$

where ω_t is the unity gain bandwidth of the op amp. From eqn. 5 in eqn. 4, therefore,

$$\varepsilon(s) = \frac{1 + \{K_1[K(a+1)+1]/K\}(s/\omega_{t1})}{1 + \{K_1[a + (1/K)] - 1\}[K(a+1)+1](s/\omega_{t1}) + (K_1/K)[K(a+1)+1]^2(s^2/\omega_{t1}\omega_{t2})} \tag{6}$$

From the above equation, it is seen that the phase compensation condition is given by

$$K_1 = 1/a \tag{7}$$

Thus it is seen that the phase compensation condition is independent of the ω_t of the op amps used, and it is not necessary to use matched op amps with this differential VCVS network. The compensated error function reduces to

$$\varepsilon_c(s) = \frac{1 + [\{K(a+1)+1\}/Ka](s/\omega_{t1})}{1 + [\{K(a+1)+1\}/Ka](s/\omega_{t1}) + \{[K(a+1)+1]^2/Ka\}(s^2/\omega_{t1}\omega_{t2})} \tag{8}$$

For frequencies such that

$$\omega \ll \omega_{t1}\left[\frac{Ka}{K(a+1)+1}\right]; \quad \omega \ll \omega_{t2}\left[\frac{1}{K(a+1)+1}\right] \tag{9}$$

the remaining phase and magnitude errors are given by

$$\phi \simeq \arg[\varepsilon_c(j\omega)] \simeq -\frac{\omega^3}{\omega_{t1}^2\omega_{t2}}[K(a+1)+1]^3[1/Ka]^2 \tag{10}$$

$$\gamma \simeq |\varepsilon_c(j\omega)| - 1 \simeq \frac{\omega^2}{\omega_{t1}\omega_{t2}}[K(a+1)+1]^2[1/Ka] \tag{11}$$

The remaining errors are dependent on the parameters K, a and ω_t of both op amps.

Stability analysis: Assuming matched op amps are used and representing the op amp open loop gain by the two-pole model,[4]

$$A(s) \simeq \frac{\omega_t}{s[1 + (s/\omega_2)]} \tag{12}$$

where ω_2 is the magnitude of the second op amp pole ($\omega_2 > \omega_t$). Substituting for $A(s)$ from eqn. 12 into eqn. 4 and using eqn. 7, it follows that a necessary condition for the stability of the differential VCVS is that

$$\frac{\omega_2}{\omega_t} > \frac{2Ka - 0{\cdot}5}{K(a+1)+1} \tag{13}$$

As an example, taking $a = 1$ results in a stable differential VCVS (for $\omega_2 > \omega_t$). In this case $K_1 = 1$, $K_2 = 1/K$, and the errors in phase and magnitude are given respectively by

$$\begin{aligned}\phi &\simeq -(\omega/\omega_t)^3(2K+1)^3/K^2 \\ \gamma &\simeq (\omega/\omega_t)^2(2K+1)^2/K\end{aligned} \qquad \omega \ll \omega_t K/(2K+1) \tag{14}$$

Conclusions: A new active phase compensated three-port VCVS is proposed. To this author's knowledge this is the first active phase compensated differential VCVS which has a phase compensation condition independent of the gain-bandwidth of the operational amplifiers. It is of interest to note that:

(*a*) If the inverting input V_1 is short-circuited and the two resistors R/a and R_1/K_1 are open-circuited ($a = K_1 = 0$), one obtains Reddy's[5] noninverting VCVS.

(*b*) If the noninverting input V_2 is short-circuited and the resistor R/a is open-circuited, one obtains the inverting VCVS reported in Reference 6.

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LOW LOSS HIGH-DENSITY OPTICAL CABLE WITH NYLON-EXTRUDED FIBRE UNITS

Indexing terms: Optical fibres, Cables

A low loss, highly dense cable containing nylon-extruded six-fibre units was examined. Suitable unit parameters were determined by measuring loss increases with lateral force and at low temperature. 216-fibre cable was manufactured using the nylon-extruded units, and cabling loss increase was found to be only 0·1 dB/km.

Establishment of techniques for compact packaging of optical fibres[1,2] will provide the possibility of manufacturing a small lightweight cable with high space factor. It is practically important to suppress the optical loss increase due to packaging with a highly dense structure. An ultra-low-loss optical cable with unit structure[3] has been reported which exhibited no loss increase during manufacturing process and practical use in the field. The cable was equipped with a stiff central member in each fibre unit in order to prevent bending of fibres due to cabling and installation.

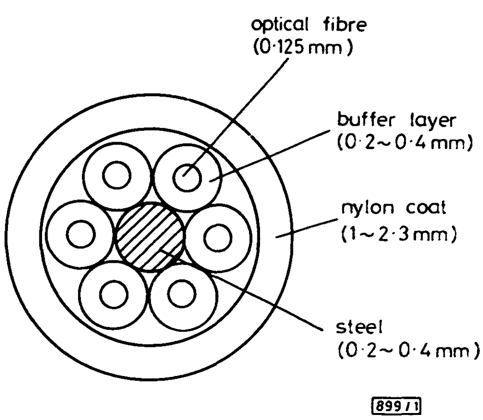

Fig. 1 *Unit composition*
Figures refer to diameters