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Allpass Network Using a Current Conveyor

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ABSTRACT

A new current mode low sensitivity first order allpass network using a second generation current conveyor CC II is proposed. The CC II nonidealities ($\epsilon_{i,\,v}$) alter only the phase component (ϕ_z) of the zero without affecting that of the pole (ϕ_p). This deviation can be precisely corrected by an additional compensating shunt resistor (r_c) for an equidistant pole-zero configuration, thus realising a true allpass function.

Key Words: allpass filter, current conveyor, analog signal processing

The topic of current mode active circuits using CC IIs is receiving considerable attention at present. Several such function circuits have been proposed (Fabre *et al.*, 1990; Chang *et al.*, 1993; Nandi, 1994; Higashimura and Fukui, 1990) which exhibit extremely low sensitivity owing to the relatively accurate port current/voltage characteristics of the CC II with negligible transfer errors ($\epsilon_{i,v}<<1$). In addition, current mode circuits are considered to be superior to their voltage mode versions because of several advantages described in the literature (Roberts and Sedra, 1989; Wilson, 1990).

This paper presents the realisation of a first order allpass current transfer function using a CC II and only three passive components. With the nonideal CC II having finite port current and voltage tracking errors ($\epsilon_{i,v}\neq0$), only the numerator polynomial is slightly altered; i.e., the phase component ϕ_z is changed while ϕ_p remains unaffected. This functional deviation can be readily compensated by inserting an additional compensating shunt resistor (r_c) of appropriate value, which yields $\phi_z=\phi_p$ for the desired allpass function.

Comparison of the proposed scheme with that of Higashimura and Fukui (1990) indicates that four passive components were required in their scheme, among which two resistors had to match at an equal value for realisability with an ideal CC II; however, when the CC II became nonideal, $\phi_{z,p}$ were affected and the realisation (Higashimura and Fukui, 1990) was not amenable to precise single-resistor compensation which is derivable in the circuit proposed here.

Writing the CC II port characteristics as $i_z=-(1-\epsilon_i)i_x$, $i_y=0$ and $v_x=(1-\epsilon_v)v_y$, one obtains the current transfer $F(s)\triangleq I_o/I_i$ (assuming r_c disconnected) as

$$F(s)=\frac{sC-\dfrac{(1-\epsilon_i)(1-\epsilon_v)}{R_1}}{sC+\dfrac{1}{R_2}}. \tag{1}$$

Considering an ideal CC II ($\epsilon_{i,v}=0$), one obtains the phase shift of the network $\phi\triangleq\angle F(jw)$ as

$$\phi=\phi_z-\phi_p, \tag{2}$$

where $\phi_z=-\arctan\,(W\ C\ R_1)$

and $\phi_p=\arctan\,(W\ C\ R_2)$. (3)

For an allpass function with an equidistant pole-zero configuration ($\phi_z=\phi_p$), we select $R_1=R_2=R$, which gives

$$\phi=-2\arctan\,(W\ C\ R). \tag{4}$$

At a given frequency, the network thus introduces a variable phase shift $0\leq\phi\leq\pi$ with a unity gain current transmission for $0\leq RC\leq\infty$. Equation (1) suggests that with a nonideal CC II ($\epsilon_{i,v}\neq0$), only ϕ_z is affected, which may be compensated by connecting r_c as shown in Fig. 1. The compensation design may be derived by using

$$(1-\epsilon_o)\left(\frac{1}{r_c}+\frac{1}{R}\right)=\frac{1}{R}, \tag{5}$$

which yields

$$r_c = R(1-\epsilon_o)/\epsilon_o, \quad (6)$$

where $\epsilon_o = \epsilon_t + \epsilon_v$; products of errors are neglected as the error magnitudes are quite low.

The active sensitivity of ϕ_z is estimated at a given frequency ($w=w_o=1/RC$ say) by evaluating $s_{\epsilon}^{\phi_z}=[(d\phi_z/\phi_z)/(d\epsilon_o/\epsilon_o)]_{w=w_o}$, given by

$$s_{\epsilon_o}^{\phi_z} = \frac{2\epsilon_o}{\pi(1-\epsilon_o)} << 1\ ; \quad s_{\epsilon_o}^{\phi_p} = 0$$

Since $\epsilon_o << 1$, the phase response of the network can be considered as being practically active-insensitive. Also, the gain of the phase shifter is insensitive to $\epsilon_{t,v}$.

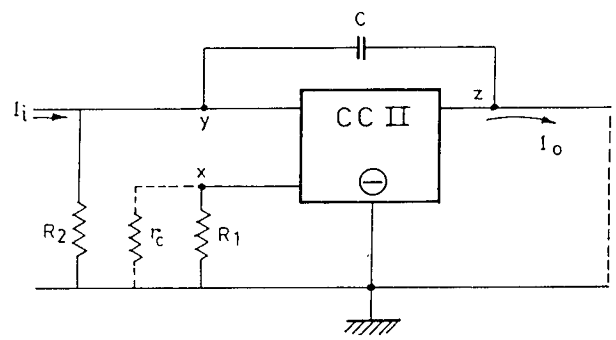

Fig. 1. Current allpass circuit.

In Fig. 1 a virtual short had been assumed, which is valid for all practical purposes. The CC II is essentially a current source, and its z-port internal resistance is sufficiently high compared to any load connected across the port. Hence, the load practically takes the short circuit signal current delivered by the CC current source, creating a virtual short (Chang *et al.*, 1993) at the z-port.

In conclusion, a novel current mode first order allpass function circuit realisation scheme using a CC II has been proposed in which the effect of the CC II errors on ϕ_z can be precisely compensated, and where the true allpass function can be obtained even with a nonideal device.

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利用電流輸送器做全通電路

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摘　要

本文提出一個新的電流模式低敏感度一階全通電路，這個電路是利用第二代電流輸送器(CCII)來設計。第二代電流輸送器的非理想係數只改變分子根值的相位，而不影響分母根值的相位，這項偏移值可以外加並聯電阻來修正，如此就可以得到一個全通方程式。