A Capacitor-Grounded Current-Tunable Current Mode All-Pass Network

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ABSTRACT

A first-order current-mode all-pass section (CM-APS) using two current-controlled conveyors (CCCII) and a grounded capacitor are presented. The current-mode first order section consists of one single-output CCCII, one dual-output CCCII and one grounded capacitor. The circuit operation in current mode; and it can be directly employed as a subsystem of monolithic circuit. PSpice simulation results are carried out in order to verify the theory.

1. INTRODUCTION

All-pass filters, having constant frequency independent gain, with electronic-controlled phase shifts, are widely useful in many applications, for example, they can be employed as the frequency determining elements in electronic-controlled oscillator, or they can be directly employed as phase modulators in communication systems. Many all-pass circuits exist in the literature. However, the majority of them have been designed using one or more CCII [1]-[2], FTFN [3], CDBA [4], CCIII [5] with passive RC elements. Hence, they are not easily electronic adjustable.

By using the second-generation current controlled conveyors (CCCII), current conveyor applications can be extended to the domain of electronically adjustable function [6]. In the recent past, a all-pass filter electronically adjustable transfer functions employing one or more CCCII have been proposed in [7], but these proposed required the floating capacitors, therefore it not suitable for IC implementation.

In this paper, a simple first-order CM-APS using one positive single-output current controlled conveyor (CCCII+), one negative dual-output current controlled conveyor (CCCII-) and a single grounded capacitor is proposed. The circuits also operate in current mode. Thus it can be directly employed in many monolithic circuits without extra conversion stages. The proposed current-mode all-pass sections require no external resistor and are electronically adjustable by controlling the bias current of conveyor. The use of grounded capacitors is beneficial to IC implementation [8], [9].

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2. PROPOSED CIRCUITS

The port relations of a CCCII is shown in Fig. 1, and characterized by the relationship;

$$\begin{bmatrix} I_y \\ V_x \\ I_x \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & R_X & 0 \\ 0 & \pm k & 1 \end{bmatrix} \begin{bmatrix} V_y \\ I_x \\ V_z \end{bmatrix} \quad (1)$$

When k is current transfer ratio of circuit, R_X is input resistance at port X, for $I_z=kI_x$ and $I_z=-kI_x$ can obtained the positive (CCCII+) and negative (CCCII-) current conveyors respectively. Bipolar realization circuit of CCCII- is illustrated in Fig. 2 [11]. A dual output CCCII- has an additional mirror stage to provide another Z- output. For the circuit of Fig. 2 the parasitic resistance R_X, can be expressed as;

$$R_X = \frac{V_T}{2I_O} \quad (2)$$

Where VT is the thermal voltage and Io is the bias current of the conveyor.

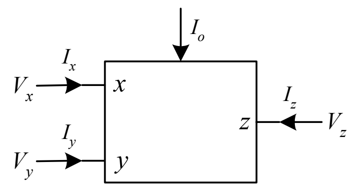

Fig. 1 CCCII symbol.

The proposed first-order CM-APS with one CCCII+ and one dual-output CCCII- and a grounded capacitor is shown in Fig. 3. Note that the use of grounded capacitors is particularly attractive for integrated circuit implementation [8], [9]. Routine analysis yields the following current transfer function:

$$\frac{I_{out}}{I_{in}} = \frac{1 - R_{X2}Cs}{1 + R_{X2}Cs} \quad (3)$$

From (3), it is seen that the circuit of Fig. 3 realizes a first-order current-mode all-pass filter, where R_{X2} is the intrinsic resistance of the conveyor controllable by the bias current I_{o2}, k is current transfer ratio. The current transfer function for the circuit of Fig. 4 with k=2 is achieved by multiple transistors Q16 and Q19 in which 2 times of emitter area of transistors.

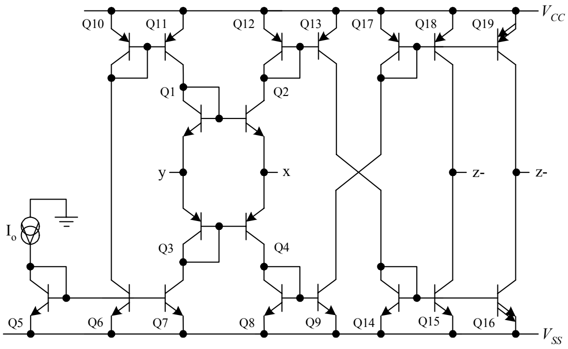

Fig. 2 Schematic implementation of dual output and having current gain CCCII-.

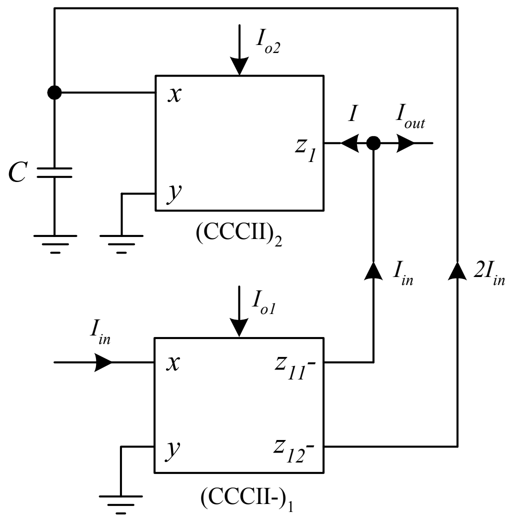

Fig. 3 Simple all-pass section with one CCCII, one dual-output CCCII- and one grounded capacitor.

The equation (3) implies that the proposed circuits easily realize first order current mode all-pass filter. From equation (3) it can be seen that the circuit yields a phase shift from 0 to -180. The corner frequency ωo of the circuit is found as:

$$\omega_O = \frac{1}{CR_{X2}} = \frac{2I_O}{V_T C} \tag{4}$$

From equation (4) one can realize that the pole frequency of the all-pass filter can be controlled with adjusting current IO.

The effect of the non-ideal current transfer gains of both outputs defined by αi and αij for the ith CCCII, the j^{th} IZ of CCCII, where $I_{zi}=\alpha_i I_{xi}$, $I_z1_i=-\alpha_{1i}I_x1_i$ and $I_{z2i}=-\alpha_{2i}I_{x2i}$, is considered next. Assuming that all-pass filter of Fig. 3 is analyzed taking into account the non-idealities of a CCCII equation (3) can be modified. The transfer function can be rewritten as;

$$\frac{I_{out}}{I_{in}} = \frac{2\alpha_1\alpha_{22} - \alpha_{21} - \alpha_{21}sCR_{X2}}{1 + sCR_{X2}} \tag{5}$$

Where $\alpha_i=(1-\varepsilon_i)$, $\alpha_{ij}=(1-\varepsilon_{ij})$, $\varepsilon_j(|\varepsilon_j|<<1)$,and $\varepsilon_{ij}(|\varepsilon_{ij}|<<1)$ denote the current tracking error. Thus, even with a non-ideal CCCII, the circuit of Fig. 3 is capable of realizing an all-pass filter with a slightly altered value of the gain and corner frequency.

3. SIMULATION RESULTS

To verify the proposed circuit, PSPICE simulation is used. The CCCII- is simulated using the schematic implementation shown in Fig. 2 with a DC supply voltage ±2.5V. The BJT model parameters of the NR100N and PR100N transistors are used in the simulation [11]. Fig. 4 show the magnitude and phase of current transfer function versus frequency obtained from the simulation using, as an example, capacitor C=12nF, $I_{o1}=I_{o2}$=100µA. It can be seen from Fig. 4 that, for the phase shift at –90 degree, the corresponding corner frequency are 100 kHz.

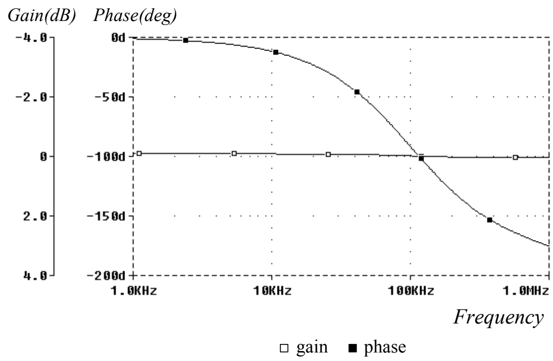

Fig. 4 Magnitude and phase characteristics of I_{out}/I_{in} versus frequency using the capacitor C=12nF and $I_{o1}=I_{o2}$=100µA.

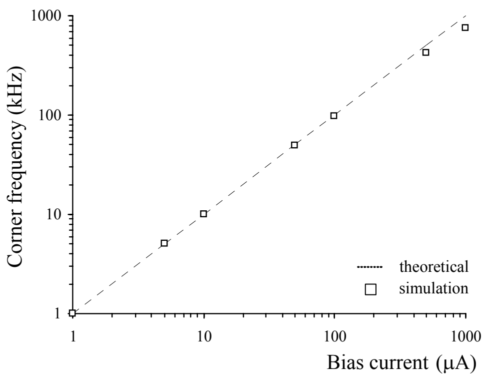

Fig. 5 Current-tuning of corner frequency with bias current I_o for C=12nF.

Fig. 5 depicts the simulation results of both the corner frequency and corresponding magnitude of I_{out}/I_{in}, for the phase shift at –90 degree, versus the bias current I_o, using fixed capacitor C=12nF. It can be seen from Fig. 5 that the simulation results are consistent, and the corner frequency is linear current-tunable.

4. CONCLUSIONS

In this paper, we realize electronic tunable simple current mode first order all-pass filters, where one CCCII+, one dual-output CCCII- and one grounded capacitor was used. The circuit is high impedance outputs, which enables easy cascading for applications. The use of grounded capacitor is more beneficial to IC implementation than the previous proposed.

5. ACKNOWLEDGMENTS

This research is financial supported form the Thailand Research Fund through the Royal Golden Jubilee Ph.D. Program (Grant No. PHD/0166/2546) to student's initials and advisor's initials.

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