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Analysis of CMOS Second Generation Current Conveyors

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***Abstract*— This paper describes the current conveyors used as a basic building block in a variety of electronic circuit in instrumentation and communication systems. Today these systems are replacing the conventional Op-amp in so many applications such as active filters, analog signal processing. Current conveyors are unity gain active building block having high linearity, wide dynamic range and provide higher gain-bandwidth product. The authors have simulated above configuration using TSMC 0.18µm CMOS technology and the results are also tabulated for comparison.**

***Keywords*— Current conveyor, Current mode, Current mirror, CCII, CFOA.**

I. INTRODUCTION

In analog circuit design, there is often a large request for Amplifiers with specific current performance for signal processing. The *current-mode* approach [5,7] considers the information flowing on time-varying currents. Current-mode techniques are characterized by signals as typically processed in the current domain. The current-mode approach is also powerful if we consider that all the analog IC functions, which traditionally were been designed in the *voltage-mode*, can be also implemented in current-mode. In voltage mode circuits, the main building block used to add subtract, amplify, attenuate, and filter voltage signals is the operational amplifier.

A well-known current-mode circuit is the *Current-Feedback Operational Amplifier* (CFOA) [8,9,10]. This circuit, if compared to the traditional voltage OA, shows a constant bandwidth with respect to the closed-loop gain and a very high slew-rate. This makes this circuit of primary importance in the design of modern LV LP ICs The first stage of CFOA is the *current conveyor* (CCII) and the second stage is a voltage follower which can be implemented using CCII since, CCII Architecture consist of voltage follower followed by Current follower.

Current conveyors and related current-mode circuits have begun to emerge as an important class of circuits with properties that enable them to rival their voltage-mode counterparts in a wide range of applications. As a matter of facts, CCII can be considered the basic current-mode building block because all the active devices can be made of a suitable connection of one or two CCIIs. It will be particularly attractive in the environment of portable systems where a low supply voltage, given by a single cell battery, is used. These LV circuits have to show also a reduced power consumption to maintain a longer battery lifetime. This implies a reductions of the biasing currents in the amplifier stages, with consequent reduction in some amplifier performance. The current-mode approach suffers less from this limitation, while showing full dynamic characteristics also at reduced supply levels and good high-frequency performance.

II. CURRENT CONVEYOR

Current conveyors are unity gain active elements exhibiting high linearity, wide dynamic range and high frequency performance than their voltage mode counterparts. A current-mode approach is not just restricted to current processing, but also offers certain important advantages when interfaced to voltage-mode circuits. Since their introduction in 1968 by Smith and Sedra [4] and subsequent reformulation in 1970 by Sedra and Smith [5]**,** current conveyors lot of research has been carried out to prove usefulness of this CCII. The CCII is a functionally flexible and versatile, rapidly gaining acceptance as both a theoretical and practical building block. CCII is a three terminal device, schematically represented as:

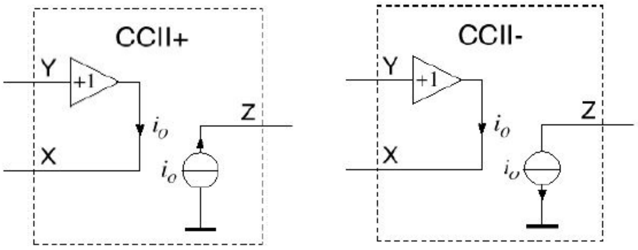

Figure 1: Second generation current conveyors.

The current-mode approach suffers less from this limitation, while showing full dynamic characteristics also at reduced supply levels and good high-frequency performance.

The electrical characteristics of CCII can be shown using matrix:

$$\begin{bmatrix} Iy \\ Vx \\ Iz \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} Vy \\ Ix \\ Vz \end{bmatrix}$$

CCII Node	Impedance level
X	Low (ideally 0)
Y	High (ideally ∞)
Z	High (ideally ∞)

Figure 2: Characteristics of CCII.

The output current *IZ* thus depends only on the input current at terminal X, in Fig. 1. This current may be injected directly at X, or it may be produced by the copy of the input voltage *VY*, from terminal Y, acting across the impedance connected at X. In a class II current conveyor input Y draws no current, whereas, for the older class I formulation, the impedance connected at X is also reflected at Y. The + sign indicates whether the conveyor is formulated as an inverting or non-inverting circuit, termed CCII- or CCII+. By convention, positive is taken to mean *IX* and *IZ* both flowing simultaneously towards or away from the conveyor [6].

III. CHARACTERIZATION OF CURRENT CONVEYORS

A. Class AB Second generation Current Conveyor based on Current Mirror.

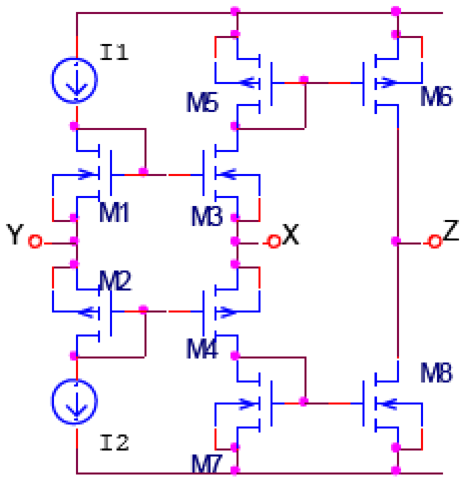

Figure 3: Class AB CCII based on Current Mirror.

In this circuit, IBias1 and IBias2 have to be equal [7, 8]. Considering the products $g_m r_0$ much greater than 1, the voltage characteristic is very close to the ideal one [1]. In fact:

$$\alpha = \frac{V_x}{V_y} = \frac{1}{1+\frac{1}{(gm\,3+gm\,5)(r03/r04)}} \cong 1 \qquad (1)$$

Considering loads connected to X and Z nodes to be $g_m r_0$ >>1 β can be given as:

$$\beta = \frac{I_z}{I_x} = \frac{g_{m3}g_{m6}g_{m7} + g_{m4}g_{m5}g_{m8}}{g_{m5}g_{m6}(g_{m3}+g_{m4})} \cong 1 \qquad (2)$$

$$\text{If } g_{m5} = g_{m7} \text{ and } g_{m6} = g_{m9}$$

The impedance level at Y node can be ensured by employing good biasing sources showing high resistances as:

$$Z_y = \frac{\left(\frac{r_{01}}{1+g_{m1}\,r_{01}} + R_{ibias\,1}\right)}{\left(\frac{r_{02}}{1+g_{m2}r_{02}} + R_{ibias\,2}\right)} \cong \frac{R_{ibias\,1}}{R_{ibias\,2}} \qquad (3)$$

The X node impedance can be obtained by neglecting some components as:

$$Z_x = \frac{1}{g_{m3}+g_{m4}+\frac{r_{03}+r_{04}}{r_{03}r_{04}}} \cong \frac{1}{g_{m3}+g_{m4}} \qquad (4)$$

The impedance seen at Z node is typically high and it is given by:

$$Z_z = \frac{r_{07}r_{08}}{r_{07}+r_{08}} \qquad (5)$$

B. Class AB Second generation Current Conveyor based on a Differential Pair.

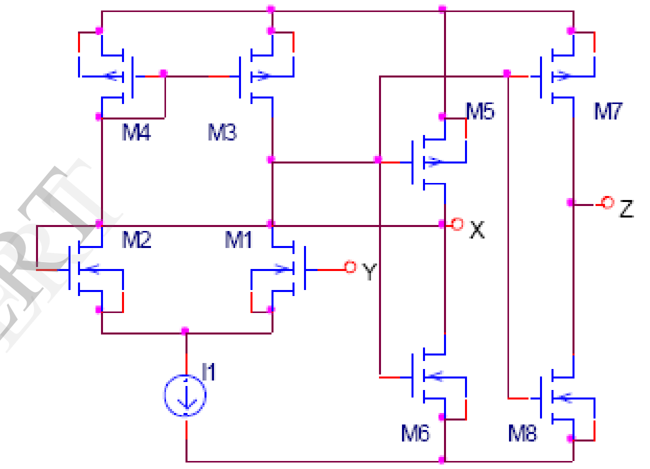

Figure 4: Class AB CCII based on Differential Pair.

In this circuit, if the MOS output resistance is negligible, the voltage transfer error α is always close to unity [1].

$$\alpha = \frac{V_x}{V_y} = \frac{\frac{r_{05}r_{06}}{r_{05}+r_{06}}(g_{m5}+g_{m6})\frac{r_0}{2}g_{m2}}{\frac{r_{05}r_{06}}{r_{05}+r_{06}}(g_{m5}+g_{m6})\frac{r_0}{2}g_{m1}+1} \cong \frac{g_{m2}}{g_{m1}} \qquad (6)$$

If the load resistances are not very high compared to the MOS output resistances, the current transfer β is given as [1]:

$$\beta = \frac{I_z}{I_x} \cong \frac{g_{m8}+g_{m7}}{g_{m6}+g_{m5}} \qquad (7)$$

The parasitic impedance at Y node is given only by the input transistor gate. Its value is easily evaluated knowing transistor sizes and the unitary capacitance of the input gate [1].

$$Z_y = \gamma\omega(M1)L(M1)C_{ox} \qquad (8)$$

The X node impedance is inductive. Its resistance part is given by [1]:

$$R_x \cong \frac{2}{g_{m2}r_0(g_{m5}+g_{m6})} \qquad (9)$$

and its inductive part is given by:

$$L_x \cong \frac{\frac{2}{P_0}}{g_{m2}r_0(g_{m5}+g_{m6})} \qquad (10)$$

The Z node impedance is high because it is a parallel of two transistor output resistances [1].

$$Z_z = \frac{r_{07}r_{08}}{r_{07}+r_{08}} \qquad (11)$$

C. Current Feedback Operational Amplifier (CFOA).

The current-feedback operational amplifier is positive second generation current-conveyor CCII+ with an additional voltage buffer at the conveyor current output (6,9). The non-inverting port (Y) exhibits high impedance to voltage signals where as the inverting port (X) present low impedance to the input current signals. The current at the inverting input (X) of the current-feedback operational amplifier is transferred to the high impedance current-conveyor output Z, causing a large change in output voltage. The current-feedback operational amplifier has a trans-resistance equal to the impedance level at the conveyor Z-output. Therefore, in the literature, the current-feedback operational amplifier is also referred to as a trans-impedance amplifier.

The most commercial current-feedback operational amplifier is AD844, where the user has access to the high impedance node TZ. This amplifier can also be utilized as a second generation current conveyor and current to-voltage converter.

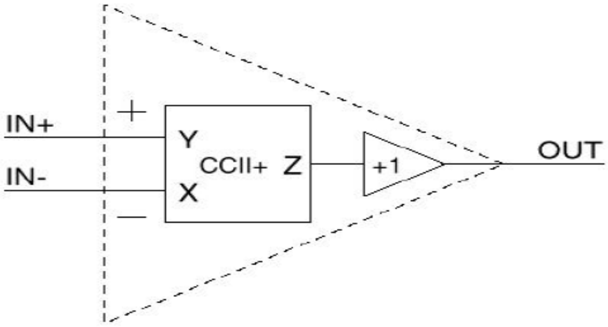

Figure 5: Current feedback Op-Amp.

The applications and advantages in realizing active filter transfer function using CFAs have received great attention because the amplifier enjoys the feature of constant feedback independent of closed loop gain and high slew rate besides having low output impedance. Thus it is advantageous to use CFA as a basic building block in the accomplishment of various analog signal-processing tasks .CFOA offers a higher slew rate, lower distortion, and feedback component restriction. It has a high linearity, constant gain bandwidth product and frequency response is high.

IV. SIMULATION RESULTS.

Simulations are carried out in Eldo Spice tool of Mentor Graphics for all circuits for 0.35u and 0.18u for both circuits as discussed earlier. Different characteristics are observed.

A. Simulation results of Class AB CCII based on Differential pair.

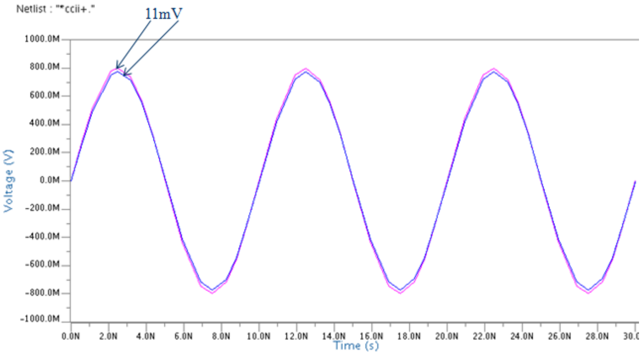

Figure 6: Vx VS Vy.

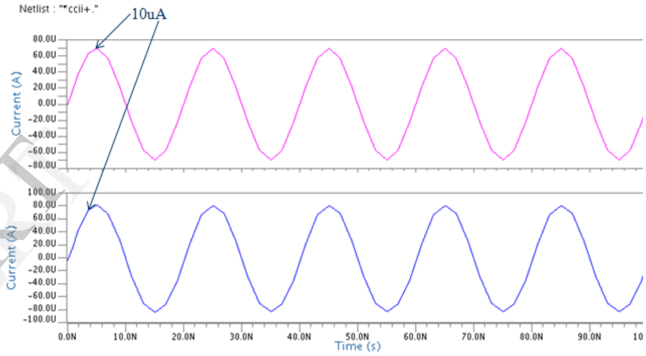

Figure 7: Ix VS Iz.

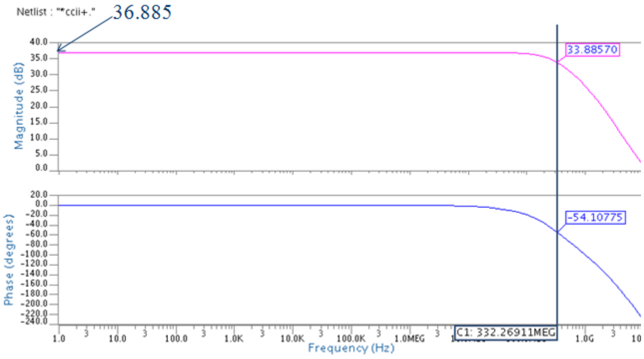

Figure 8: Frequency Response of CCII.

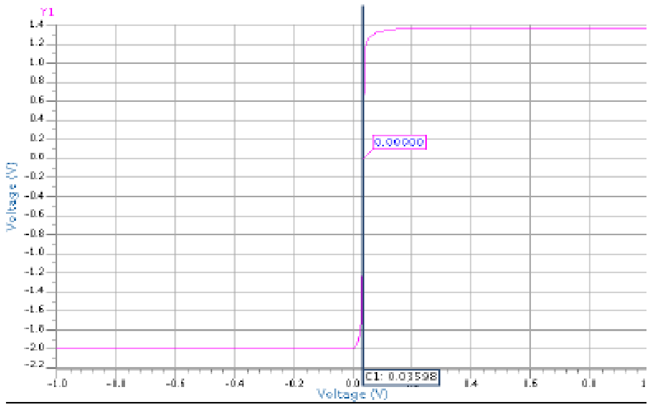

Figure 9: Offset.

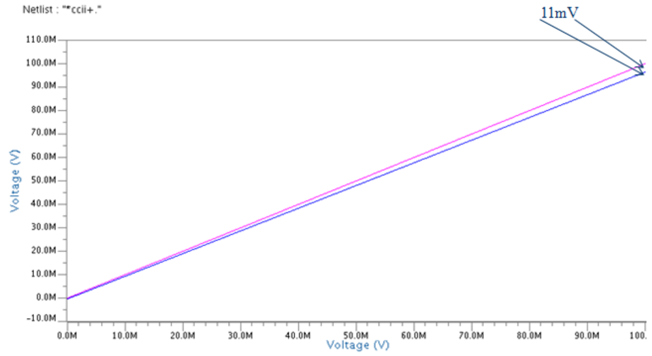

Figure 10: Linearity between Vx and Vy.

TABLE I: SIMULATION RESULTS FOR CCII BASED ON DIFFERENTIAL PAIR.

Parameters	**CCII characteristics simulated value.**	
	0.35um	**0.18um**
Supply voltage	1.5V	1.8V
Bias current	7uA	4uA
Current gain	1	1
Voltage gain	1	1
Current B.W	90MHz	105MHz
Voltage B.W	190MHz	332MHz
Offset	12mV	35mV
Power Consumption	2.9mV	70uW

V. CONCLUSION

In this paper CCII based on differential pair is simulated using TSMC 0.18um CMOS technology with 1.8v power supply. Differential pair partially improves for power dissipation and Terminal impedances but bandwidth reduces a when scaled down from 0.35um to 0.18um.CCII can be used as a voltage buffer and current buffer.

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