Improvement of current mode controlled amplifier using current conveyors

Zineb M'HARZI*, Mustapha ALAMI**
Laboratory CSE,
INPT, 2 Avenue Allal El Fassi, Madinat Al Irfane,
RABAT, MOROCCO
*Mh.zineb@yahoo.fr
**Alami@inpt.ac.ma

Farid TEMCAMANI
Laboratory ECS,
ENSEA, 6 Avenue Ponceau, 95014
Cergy-Pontoise Cedex, FRANCE
Farid.Temcamani@ensea.fr

***Abstract*—Two controlled current conveyors (CCCII) with positive and negative current transfers are described. The electrical characteristics of these two conveyors (current transfer, voltage transfer and parasitic impedances…) were determined. A controlled current amplifiers based on these two current conveyors are analyzed. PSPICE simulation results shows that the conveyor with negative current transfer ($CCCII^-$) presents interesting characteristics compared to the conveyor with positive transfer ($CCCII^+$). A comparison between the proposed amplifiers and the current amplifier described in [1] is presented. The latter confirms the improvement brought by our amplifiers at the level of the wide range of adjustability of the gain, and bandwidth observed.**

Keywords—Second generation controlled current conveyors with positive and negative current transfers, current mode circuit, current controlled amplifiers.

I. INTRODUCTION

From the time when SEDRA and SMITH are introduced the second generation current conveyor (CCII) in 1970 [2], this component have emerged rapidly as a basic element of many applications at high frequency due to its voltage follower and current follower properties [3]. Subsequently, more than hundred articles were published on the theory and applications of current conveyors circuits [3-6]. A. Fabre has developed the second generation controlled current conveyor (CCCII), which exhibits an intrinsic series resistance R_X which value depends on the bias current [1]. This property has given rise to controllable electronic functions on high frequency (filters, amplifiers, oscillators…) [7-9].

The current controlled amplifier made from CCCII present interesting characteristics: high frequency operation, low surface to the substrate… Furthermore, this circuit does not require additional outside resistances [1].

In this paper, two types of current conveyors are presented, CCCII with positive current transfer, described in [10], and a new one with negative. Both rely only on NPN transistors to convey the signal and use CMOS transistors for biasing. Both solutions are designed using a BiCMOS 0.35µm technology. New current amplifiers based on $CCCII^-$ conveyor and another based on $CCCII^+$ are proposed. These two structures provide us with a wider controllable gain and increased -3dB bandwidth in respect to a previous proposed solution.

II. SECOND GENERATION CONTROLLED CURRENT CONVEYOR

A. Characteristics of the two conveyors CCCII:

The second generation controlled current conveyor CCCII can be described by the following matrix relationship that exists between the input and output variables.

$$\begin{pmatrix} I_Y \\ V_X \\ I_Z \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ 1 & R_X & 0 \\ 0 & \pm 1 & 0 \end{pmatrix} . \begin{pmatrix} V_Y \\ I_X \\ V_Z \end{pmatrix} \quad (1)$$

In this expression, the transfer of the current I_Z/I_X is equal to +1 for $CCCII^+$ and to -1 for $CCCII^-$.

The schematic implementations of $CCCII^-$ and $CCCII^+$ are shown in Fig. 1(a) and (b) respectively. The $CCCII^-$ conveyor uses only two NPN transistors, Q_1 and Q_2, to convey the signal and four sources of continuous current for bias circuits. For the $CCCII^+$, a complementary current mirror Q_3-Q_4 has been added to the precedent circuit (Fig. 1(a)), in order to reverse the sign of the output current on port Z. The transistors Q_5 and Q_6 connected in diode operate as a level shift between the collector voltages of Q_2 and Q_3 [10].

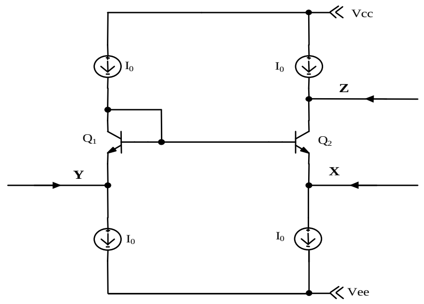
In the real case, the biasing current sources are replaced by NMOS and PMOS current mirrors, so as to control the value of the resistance R_X seen on the port X, by changing the bias current, whose value is:

$$R_X = \frac{V_T}{I_0} \quad (2)$$

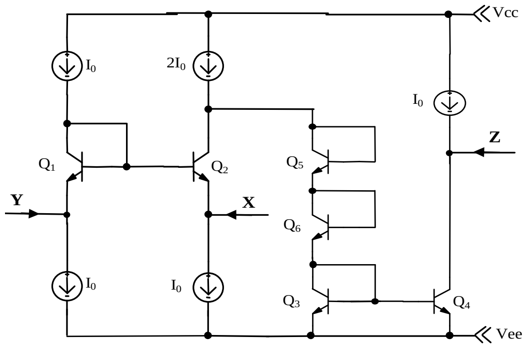
With V_T is the thermal voltage (≈ 26 mV at 27 °C).

B. Simulation Results:

Table 1 summarizes the main characteristics of conveyors $CCCII^-$ and $CCCII^+$ (Fig. 1) for a bias current I_0=100 µA. The voltage gain β(s) and current gain α(s) are very close to the units which are in good accordance with theoretical values. These structures of conveyors, we allow to increase the input and output resistances (R_Y and R_Z) of the current conveyors.



(a)



(b)

Fig. 1. Schematic implementation of conveyors

(a) $CCCII^-$ (b) $CCCII^+$

The $CCCII^-$ presents a very good frequency performance with low power dissipation and a small number of transistors. Furthermore, it functions in class AB, which is say; the amplitude of the current to be treated may exceed the value of the bias current. In opposite, the $CCCII^+$ consumes more power, uses six NPN transistors to operate and functions in class A.

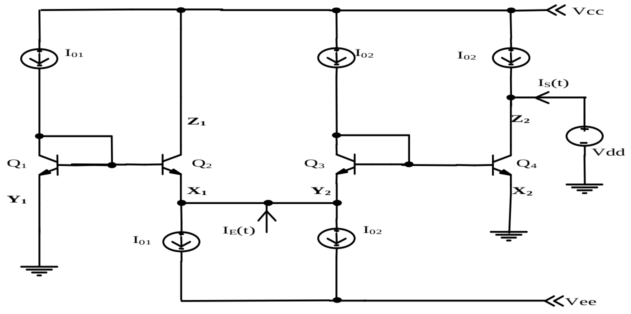
III. CURRENT CONTROLED AMPLIFIERS

A. Characteristics of current amplifiers:

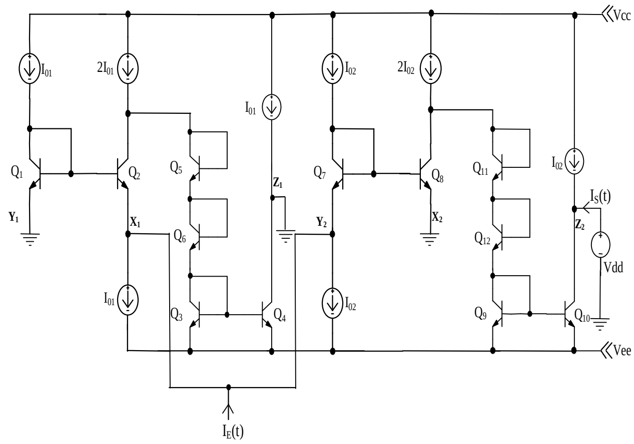
A current controlled current mode amplifier, with high gain, can be formed by cascading two second generation controlled current conveyors circuits. This circuit requires no external passive components [1]. Fig. 2 represents the schematic of the current controlled amplifiers based in $CCCII^-$ and $CCCII^+$ previously analyzed.

TABLE I. CHARACTERISTICS OF CONVEYORS AT 27°C

CONVEYORS	$CCCII^-$	$CCCII^+$
Current gain α(s)=Iz / Ix	0.995	0.988
-3dB Bandwidth of α(s)	719.78 MHz	196.79MHz
Voltage gain β(s)=Vx / Vy	0.973	0.9733
-3dB Bandwidth of β(s)	27.4 GHz	67.22 GHz
Input impedance (Ry//Cy)	1.98 MΩ//0.31 pF	1.987 MΩ//0.28 pF
Intrinsic resistance Rx	272 Ω	272.2 Ω
Output impedance (Rz//Cz)	1.43 MΩ//0.42pF	1.43 MΩ//0.42 pF
Voltage output offset at X	-169.7µV	-8.9 µV
Current output offset at Z	249nA	116.1 nA
Supply voltage	±0.75	±2.2V
Power dissipated	0.3mW	0.6mW
Class of operation	AB	A



(a)



(b)

Fig. 2. Current amplifiers

(a) Based in $CCCII^-$ (b) Based in $CCCII^+$

The current gain that depends only on the two bias currents of the conveyors $CCCII^-$ and $CCCII^+$ are respectively:

$$G_I = \frac{I_S(t)}{I_e(t)} = \frac{R_{X1}}{R_{X2}} = \frac{I_{02}}{I_{01}} \quad (3)$$

$$G_I = \frac{I_S(t)}{I_e(t)} = -\frac{R_{X1}}{R_{X2}} = -\frac{I_{02}}{I_{01}} \quad (4)$$

These circuits can be simplified by eliminating the output Z_1 of the first conveyor that is connected to ground.

To extract the output current $I_S(t)$, we must fix the potential Z_2 of the second conveyor to a reference voltage equal to 0.5V (load impedance Z_L=0).

B. Simulation results:

The theoretical and simulated values of gain of the two amplifiers (Fig.2) are compared on Fig. 3 as a function of the current I_{02} with I_{01}=100µA and Ie(t)=10µA. On the same graph, the variations of the gain obtained by simulating the current amplifier described in [1] are represented.

The gap which appears between the theoretical and the simulated gains comes from the difference exists between the theoretical and simulated values of the intrinsic resistance R_{X2} when the current I_{02} becomes important.

It is clear that the proposed current controlled current mode amplifiers are characterized by an interval of gain control wider and close to the theoretical gain than that of the previous proposed solution. We can explain this difference, in that, the last one is made based on a current conveyor that uses multiple NPN and PNP transistors, and operates with a supply voltage of the order of ±2.5V. As against, given our current amplifiers are formed from conveyors $CCCII^+$ and $CCCII^-$ which have a lesser number of NPN transistors only, and operates under a lower supply voltage.

For example, for I_{02}= 2mA the amplifier made from $CCCII^-$ provides value of gain equal to 15 and the amplifier made from $CCCII^+$ has a current gain equal to 14.34, but the gain of the current amplifier of [1] is 4.5.

The variation of the -3dB cutoff frequencies of current amplifiers realized from $CCCII^+$ and $CCCII^-$ is illustrated for a theoretical gain equal to 5, according to I_{02} in Fig. 4. The bandwidth at -3dB of the amplifier described in [1] has given in the same figure.

We notice that the current amplifiers constituted by $CCCII^-$ and $CCCII^+$ can go to a frequency of 1.7GHz and of 1.3GHz respectively for I_{02} = 2mA, while the other current amplifier does not exceed 400MHz.

IV. Conclusion

In this paper, we have presented a comparison of functioning between two second generation controlled current conveyors, one with positive current transfer and the other with negative transfer. Then, we have analyzed two controlled current amplifiers based on these two conveyors. These amplifiers were compared to the previous proposed solution.

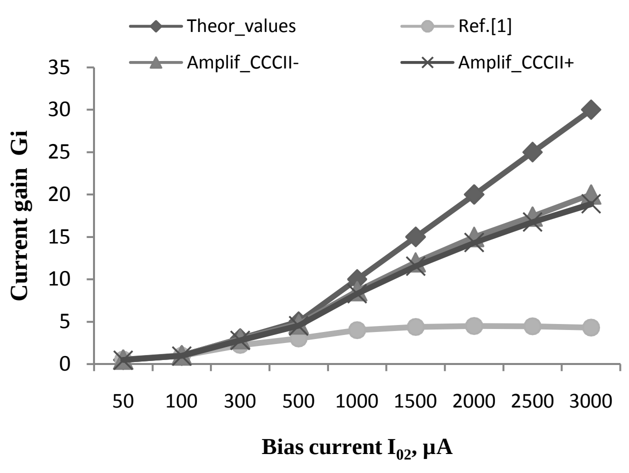


Fig. 3. Variation of current gain G_I as a function of I_{02}, for I_{01}=100µA

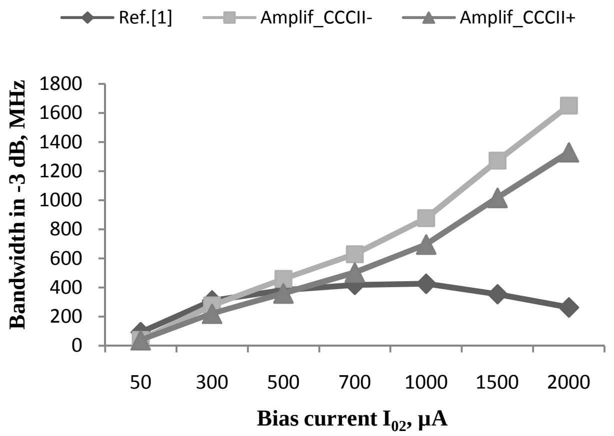


Fig. 4. Evolution of bandwidth in -3dB for transfer gain equal to 5 according to I_{02}.

Simulation results show that, the $CCCII^-$ has better characteristics than $CCCII^+$, and the current amplifier consisting of this conveyor presents a better control gain according to bias current. For the bandwidth, this current amplifier reached 1.7 GHz for I_{02}= 2mA and that with a supply voltage lower than 1V and a low power consumption.

In other hand, the exclusive use of NPN transistors with a reduced number gives us low characteristics of stability for our circuits.

References

[1] A. Fabre, O. Saaid, F. Wiest, C. Boucheron, “High frequency applications based on a new current controlled conveyor”, IEEE Transaction on Circuits and Systems, Part I, Vol. 43, No. 2, pp. 82-91, February 1996.

[2] A. Sedra and K. C. Smith, “A second generation current conveyor and its applications”, IEEE Transactions on Circuit Theory, Vol. CT17, pp. 132-134, February 1970.

[3] A. Fabre, O. Saaid, H. Barthelemy, “On the frequency limitations of the circuits based on second generation current conveyors”, Analog integrated circuits and signal processing, vol. 7, pp. 113-129, 1995.

[4] C. Toumazou, F. J. Lidgey, and D. G. Haigh (Eds.), “Analog IC design: the current mode approach”, Peter Peregrinus: London, 1990.

[5] C. Toumazou, N. Battersby, S. Porta, “Circuits and Systems Tutorials”; New York, IEEE Press, c1996.

[6] B. Wilson, “Recent developments in current conveyors and current mode circuit”, IEE Proceedings, Part. G, Vol. 137, pp. 63-77, 1990.

[7] A. Fabre, M. Alami, “Insensitive current-mode biquad implementation based on translinear current conveyors”, IEEE Proceedings of the EUROASIC’90 Conf., pp. 126-130, Paris, 2-4 June, 1992.

[8] Z. Abbas, G. Scotti, M. Olivieri, “Current controlled current (CCCII) and application using 65nm CMOS technology”, World Academy of Science, Engineering and Technology, Paris, France, July 27-29, 2011.

[9] A. fabre, O. Saaid, F. Wiest, and C. Boucheron, “high frequency, high Q BiCMOS current mode bandpass filter and mobile communication applications”, IEEE Journal of Solid-State Circuits, 1998, 33, (4), pp. 614-625.

[10] F. Seguin and A. Fabre, “2 GHz controlled current conveyor in standard 0.8 µm BiCMOS technology”, Elctronics Letters, No. 6, Vol. 37, pp. 329-330, 2001.

[11] STMicroelectronics, “0.35 µm SiGe BiCMOS process parameters”, Grenoble (France), 1994.