DESIGN AND ANALYSIS OF CMOS CURRENT CONVEYOR

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ABSTRACT: *Current conveyor is a high performance analog building block. It exhibits high linearity, wide bandwidth, lower power consumption, simpler circuitry and better high frequency performance. It has unity gain current and voltage. Current conveyor is a combination of voltage and current follower. In this report different second generation current conveyors are simulated for low voltage, low power and high bandwidth applications. The main feature of this current conveyor is their wide voltage and current transfer bandwidth which make them suitable for high frequency applications. The current conveyors are simulated using 130nm CMOS technology model parameters on NGSPICE using1.2Vsupply voltage.*

Keywords-Current conveyor, Current mode circuit, Voltage mode circuit

1. INTRODUCTION

Since the beginning of electronics the need of new active device has been very important. It has driven the birth of transistor. It used in many applications, in particular voltage operational amplifier has rapidly become the main analog block and has dominated the market. But there is a limitation of its constant gain band-with product and trend of between speed and band-width. To overcome this limitation new configuration called current mode circuits is implemented, so that the performance can improved in terms of low voltage characteristics, slew rate and band-width.

With the reduction in the supply voltage and device threshold voltage of CMOS technology, the performance of CMOS voltage-mode circuits has greatly affected which results in a reduced dynamic range, an increased propagation delay and reduced low noise margins. Current Conveyors represent the emerging class of high performance analog circuit design based on current-mode approach. They have simple structure, wide bandwidth and capability to operate at low voltages. Current conveyors are unity gain active elements exhibiting higher linearity, wider dynamic range and beter high frequency
performance.

2. CMOS CURRENT CONVEYORS

The current conveyor is a basic building block that can be implemented in analog circuit design. This was introduced by Sedra and Smith in 1968. In recent years, current-mode circuits have emerged as an important class of circuits with

Current conveyors can be used in variety of applications ranging from multifunction and universal filters, oscillators etc. Current conveyors can give larger band-width and are suitable for low voltage applications. Operational amplifier do not perform well where a current output signal is needed and consequently there is an application field for current conveyor circuits. There is no any feedback in current conveyor, so it give high frequency behaviour compare to Opamp. Because in Opamp there is a gain bandwith product limitation so it is not suitable at high frequency.

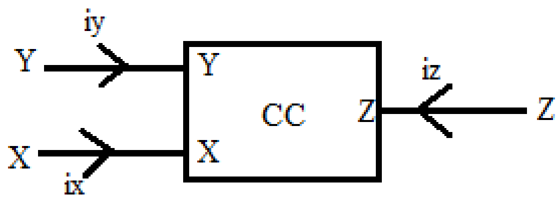

Figure- 1 block diagram of current conveyor[8]

A current conveyor is a three port network. Block representation of current conveyor is given in figure-1.

Matrix representation of CC

properties of accuracy, high frequency range and versatility in a wide range of applications. Current conveyor represents the emerging class of high performance analog circuit design based on current mode approach. It has simple architecture, wider bandwidth and capability to operate at low voltag generations:

- First Generation Current conveyor, CCI.
- Second Generation Current conveyor, CCII.
- Third Generation Current conveyor, CCIII.

3. Second Generation Current Conveyor (CCII)

The second generation current conveyor (CCII) is one of the most versatile current-mode building block for many applications, a high impedance input port is preferable in order to avoid loading effect. So, second generation current conveyor was developed to fulfil this requirement. It has one high and one low impedance input port rather than the two low impedance input ports of CCI. Since its introduction in 1970, it has been used in a wide range of applications and several circuits have been realized using this block. The CCII can be considered as the basic analog circuit design block because all the active devices can be made of a suitable connection of one or two CCIIs. It is a three terminal device and the block representation of this conveyor is shown in figure-2

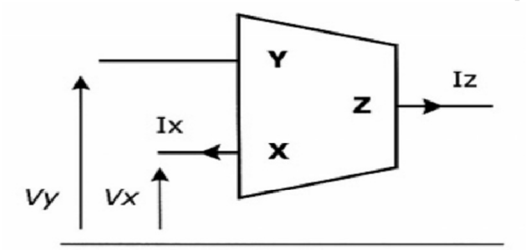

Figure-2 block diagram of CCII[13]

Table-1 impedance level of CCII

CCII Ports	Impedance Level
X	Low (ideally zero)
Y	High (ideally infinite)
Z	High (ideally infinite)

This current conveyor differs from the first generation current conveyor in a sense that the port Y is a high impedance port i.e. there is no current flowing into port Y. The port Y of the second generation current conveyor is used as a voltage input and port Z is used as a current output port.

$$\begin{bmatrix} i_Y \\ v_X \\ i_Z \end{bmatrix} = \begin{bmatrix} 0 & A & 0 \\ B & R_X & 0 \\ 0 & C & 0 \end{bmatrix} \cdot \begin{bmatrix} v_Y \\ i_X \\ v_Z \end{bmatrix}$$

Where A, B and C assume either 1,0 or -1

R_x= Intrinsic resistance offer by port-X to the input current.

For ideal current conveyor R_x=0 and V_x=V_y. But in practical R_x is a nonzero positive value.

The current conveyors can be classified into three

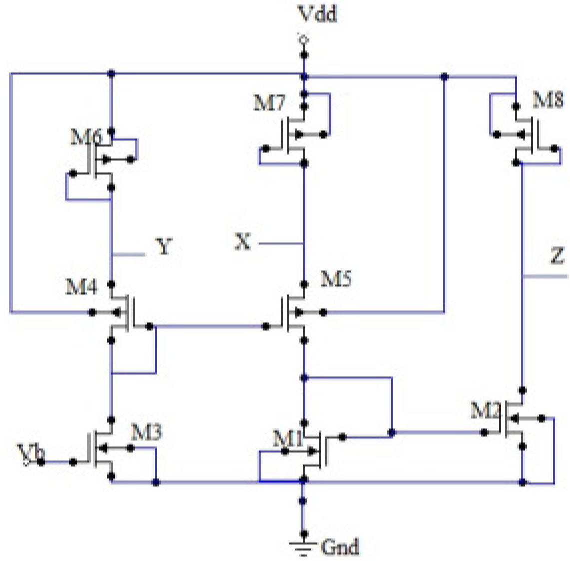

Figure-3 circuit diagram of CCII-classA [8]

Figure-3 is shows the second generation class-A current conveyor. If a voltage is applied to terminal Y, an equal potential will appear on the input terminal X. The current flow through Y is zero(ideally). The current will be conveyed to output terminal Z such that Z has the characteristics of a current source with high output impedance. Potential of X is set by that of Y, which is independent of the current applying at port X.

Whereas, the port X can be used as a voltage output or as a current input port. Therefore, this current conveyor can be used to process both voltage and current signals.
There are two types of second generation current conveyors:

- Positive current conveyor (CCII+) in which the currents ix and iz have the same direction as in a current mirror.
- Negative current conveyor (CCII-) in which currents ix and iz have the different direction as in current buffer

The current transfer characteristics is given by

$$\beta = \frac{gm3gm6gm7 + gm4gm5gm8}{gm5gm6(gm3 + gm4)} \cong 1$$

If $g_{m5}=g_{m7}$ and $g_{m6}=g_{m8}$
The impedance level at Y node can be ensured by employing good biasing sources showing high resistances as:

$$zy = \left(\frac{ro1}{1 + gm1ro1} + Ribias1\right) || \left(\frac{ro2}{1 + gm2ro2} + Ribias2\right)$$

$$\cong \frac{Ribias1}{Ribias2}$$

Impedance level at port X,

$$Zx = \frac{1}{gm3 + gm4 + \frac{ro3 + ro4}{ro3ro4}}$$

$$\cong \frac{1}{gm3 + gm4}$$

Impedance level at port Z is typically high and it is given as,

$$Zz = \frac{ro7ro8}{ro7 + ro8}$$

4. ANALYSIS OF CCII CLASSA

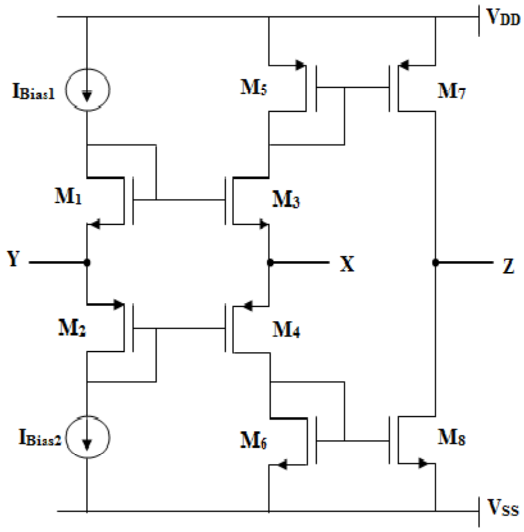

Figure-4 circuit diagram of CCII-classAB[12]

The class AB topology of second generation current conveyor has been shown in figure 4. To ensure correct operation the bias current I_{bias1} and I_{bias2} have to be equal. Unlike in the first generation push-pull conveyor, in this conveyor the quiescent current is set directly by to I_B by two current sources. Here the current flow through X is nonlinearly divided in to signal path through either an NMOS or a PMOS current mirror which are summed up at port Z. The voltage transfer characteristics is nearly 1.
consider $g_m r_o$>>>1.

$$\alpha = \frac{Vx}{Vy} = \frac{1}{1 + \frac{1}{(gm3 + gm4)(ro3||ro4)}} \cong 1$$

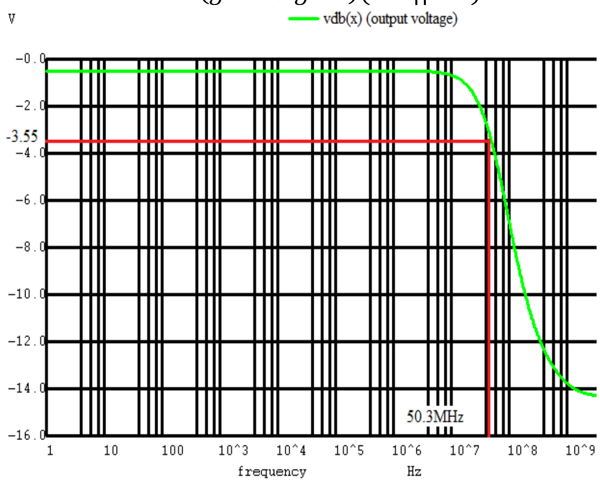

Figure-6 frequency response of voltage gain between terminals Y and X

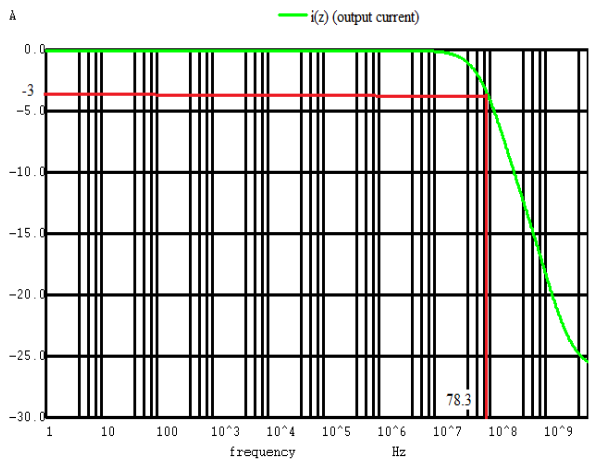

Figure-5 frequency response of current gain between terminals X and Z

Figure-5 and 6 represent the current and voltage gain, we notice that current and voltage gain is near to unity.

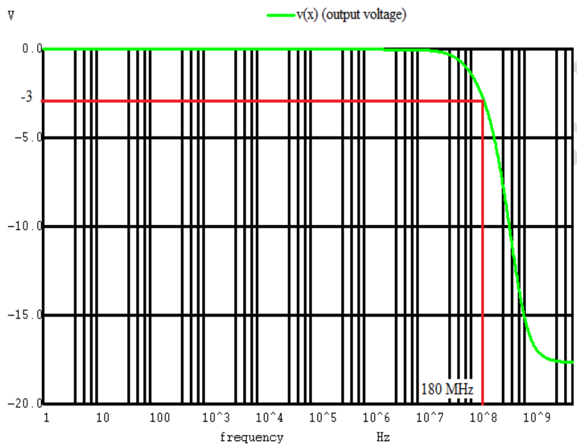

Figure-9 frequency response of voltage gain between terminals Y and X

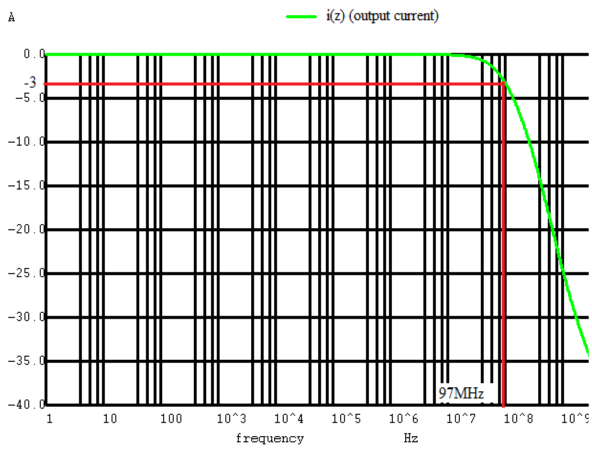

Figure-10 frequency response of current gain

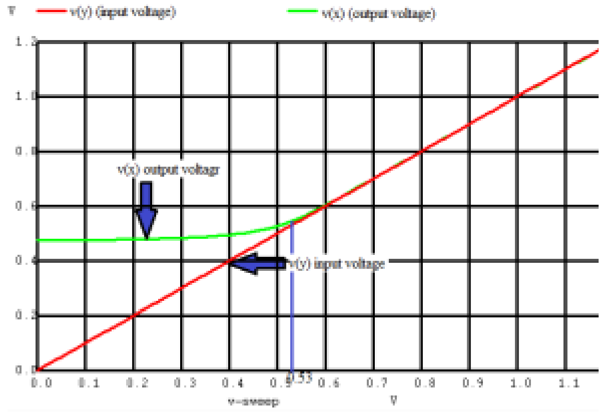

Figure-7 voltage transfer characteristics between port X and Z

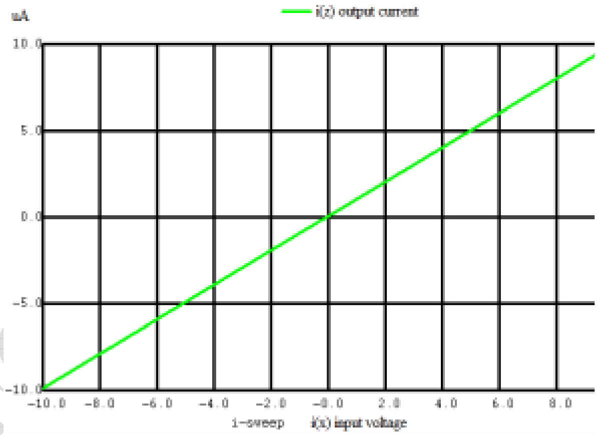

Figure-8 currenr transfer characteristics between port X and Z

Figure-7 and 8 represent the voltage and current transfer characteristics. In figure-7 after 0.53v I got exact voltage transfer characteristics and in figure-8 I got output current 10uA.

V: ANALYSIS OF CCII CLASSAB

Figure-9 and 10 represent the voltage and current gain which i got exact gain and higher B.W than classA.

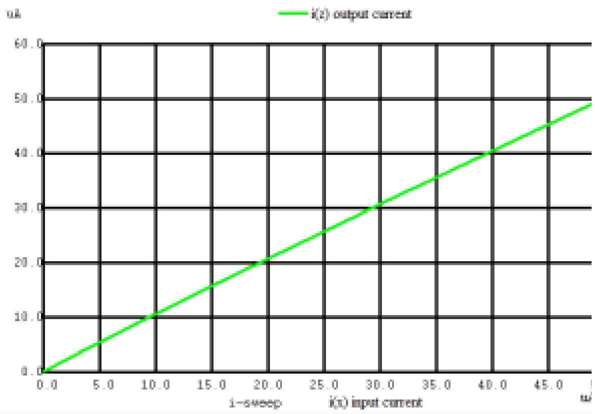

Figure-12 currenr transfer characteristics between port X and Z

V: COMPARATIVE RESULT OF CCII CLASSA AND

between terminals Y and X

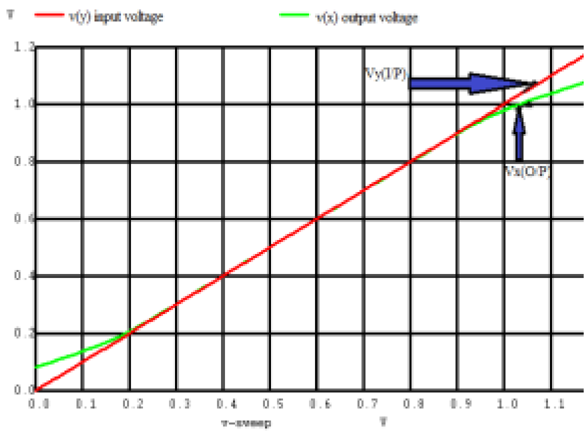

Figure-11 voltage transfer characteristics between port X and Z

Figure-11 and 12 shows the voltage and current linearity and I got voltage linearity between 0.2v and 1v. Also got output current 50uA.

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CCII CLASSAB

Table-2 parameter comparison

Parameters	Class-A (CCII)	Class-AB (CCII)
Supply voltage	1.2v	1.2v
Bias current	10uA	50uA
Current gain	1	1
Voltage gain	0.66	1
Current B.W	78.3MHZ	97MHz
Voltage B.W	50.3MHz	180MHz
Power consumption	25.2uW	50.1uW

Here I use 1.2v supply and 130nm technology to simulate the circuit in NGSPICE. CCII classAB gives more biasing current than classA. It also gives higher voltage and current bandwidth than classA. Unity gain result shows that CCII can be used as a voltage and current buffer.

5. Conclusion

From above experimental result i can conclude that CCII can be used as a voltage buffer and current buffer. The higher bandwith shows that it can be used in high frequency applications. And the power consumption is also can be reduced by using CCII.

6. References

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