Current Conveyor: A Novel Active Building Block Prevailing Op-Amp Limitations

Kamlesh Kumar Singh, Geetika Srivastava, Ravi Shankar Mishra, Deepak Tiwari

Abstract— There has been significant development in the circuit implementation of current conveyors as a key element because of its low voltage low power characteristics and wide dynamic operating range.The current conveyor agreements numerous benefits over the conventional Op-Amp. Unambiguously the current conveyor circuit can arrange for a higher voltage gain over a larger signal bandwidth under small or large signal conditions. In contemporaneous consequence current conveyors are substituting the conformist Op-amp in numerous applications such as analog signal processing, active filters, and converters.

Keywords— Current Conveyor (CC I), Differential voltage current conveyor, Current Mirror (CM), Operational Amplifiers (OA).

I. INTRODUCTION

Firstly the current conveyor was introduced by Sedra in 1968, then it was not vibrant what compensations the current conveyor presented over the conventional op-amp [2].At that time it was not clear that how the current conveyor is going to proof its benefits, so the electronics industry did not succeed to develop a monolithic current conveyor realization. After so many research works on performance improvement of current conveyor in terms of their low voltage, low power and high frequency operation, these novel building blocks have proven their usefulness over the conventional op-amp. We can achieve these low voltage and low power operation characteristics by negotiating between different parameters of the current conveyor. The high frequency operation can be obtained by making small modification in existing circuit configuration. These compromises may vary in various configurations of the different generation's current conveyors.

Fundamentally the current conveyor is a four terminal device. When a current conveyor is accomplished with some additional electronic elements in a quantified configuration, it is proficient of executing different advantageous analog signal processing functions [1]-[2]. The method applied for simplification of circuit design is comparable to that of a conventional op-amp. The current conveyor offers an alternative way of abstracting complex circuit functions, thus aiding in the creation of new and useful implementations. The real terminal performance of the current conveyor, parallel to the op-amp, goes up quiet meticulously to its ideal behaviour.

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This information suggests that current conveyor circuits can be intended that work at the levels which are very adjacent to their ideal (or theoretical) performance. There has been astonishing advancement in the field of current conveyors since their introduction in 1968. The different type of current conveyors available till date can be classified into three generations.

II. CLASSIFICATION OF CURRENT CONVEYORS

A. First Generation Current Conveyor (CCI)

The first generation current conveyor (CCI) was a 3-port device at its introduction time. In the figure shown below these ports can be identified as port Y, port X, and port Z respectively.

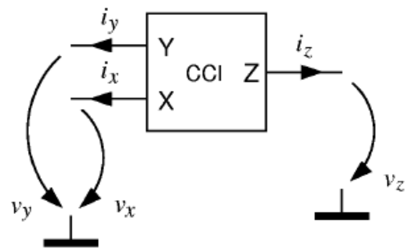

Fig. 1: Block diagram representation of CCI

If a voltage is applied to terminal Y, same potential will appear on the input terminal X. An input current I being forced into terminal X will result the same amount of current flowing into terminal Y. The current I will be conveyed to output terminal Z such that terminal Z has the characteristics of a current source, of value I, having high output impedance. Potential of X being set by that of Y, is independent of the current being forced into port X. Current through port Y being fixed by X is independent of the voltage applied to Y [4]. Nullator-norator representation of first generation current conveyor is shown in the following figure-

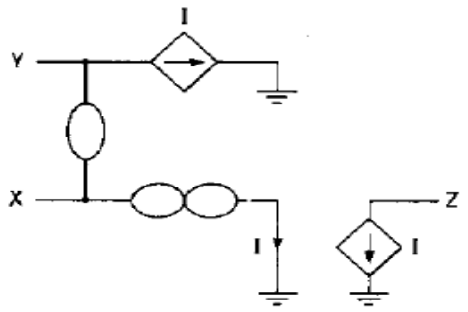

Fig. 2: Nullator- norator representation of CCI

First generation current conveyor can be represented in an equivalent matrix form. If at the node X, current and voltage be I_x, and V_x respectively, at node Y, current and voltage be I_y and V_y respectively and at the node Z, current and voltage be I_z and V_z respectively, then the matrix equivalent of first generation current conveyor can be given as

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

$$Ix = Iy = Iz$$

$$Vx = Vy$$

B. The second generation current conveyor (CCII)

To increase the flexibility of the current conveyor, a second version of current conveyor in which no current flows in terminal Y, was introduced. In the past years, few circuit realizations of the second generation current conveyor have been reported. Some of these utilize operational amplifiers only, others utilize integrated circuit operational amplifier together with bipolar junction transistor integrated circuits arrays and others yet utilize cmos technology, resulting in fully integrated conveyors. At the present time several monolithic bipolar realizations of the negative second generation current conveyor have been fabricated, although these have been labelled as monolithic nullor elements. Although the block diagram utilized for the second generation current conveyor was almost similar to the first generation current conveyor except having the change, there was no current flow in terminal Y. Thus, terminal Y exhibits infinite input impedance. The voltage at X follows that applied to Y, thus X exhibits zero input impedance. The current supplied to X is conveyed to the high impedance output terminal Z where it is supplied with either positive polarity (in CCII+) or negative polarity (in CCII-).

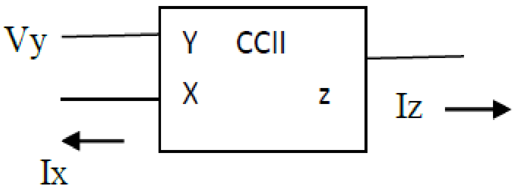

Fig. 3: Block diagram of CCII

When the currents flowing in the terminals Z and X are in the opposite direction then current conveyor is denoted as negative current conveyor. If the currents flowing in the terminals Z and X are same in the direction then the current conveyor is denoted as positive current conveyor [2]-[4]. At that time it was applied in the realization of controlled sources, impedance convertors, impedance inverters, gyrators, and various analogue computation elements.

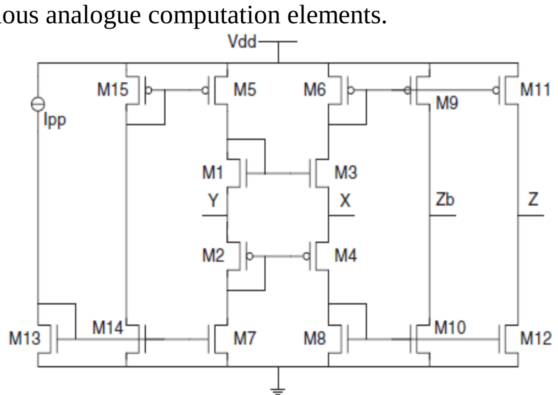

Fig. 4: Traditional second-generation current conveyor.

Matrix representation of second generation current conveyor is given as follows-

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

The ± sign shows the flow of current in same or opposite direction respectively, between nodes X and Z.

C. Third Generation Current Conveyor (CCIII)

Third generation current conveyor (CCIII) was proposed by Fabre in 1995. Third generation current conveyors (CCIIIs) can be considered as current controlled current sources. The third generation current conveyors show unity gain. The third generation current conveyor is useful in taking out the current flowing through a floating branch of a circuit and can be utilized in various multifunction filters, inductance simulation and active filters [3].The main features of the third generation current conveyor are low gain errors or high accuracy, high linearity and wide frequency response. High output resistance at terminal Z of the third generation current conveyor is necessary to allow easy cascading without the need for additional active elements in applications. Because of the limited linearity and low output resistance of the basic current mirrors used in the structure of the conventional third generation current conveyor, its DC and AC performances are low. By using high performance current mirrors in the structure of the third generation current conveyor, it is possible to achieve good linearity, high accuracy and high output resistance.

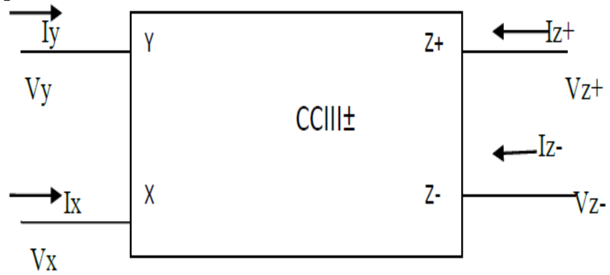

Fig. 5: Block diagram representation of CCIII

Matrix representation of third generation current conveyor is given as follows-

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

According to this equation an ideal dual-output CCIII has a (+1) voltage gain between terminals X and Y, a (+1) current gain between terminals X and Z+, and a (-1) current gain between terminals X and Z–.

III. CURRENT CONTROLLED CURRENT CONVEYOR

When signals are widely distributed as voltages, the parasitic capacitances are charged and discharged with the full voltage swing, which limits the speed and increases the power consumption of voltage-mode circuits. Current-mode circuits cannot avoid nodes with high voltage swing either but these are usually local nodes with less parasitic capacitances. Therefore, it is possible to reach higher speed and lower dynamic power consumption with current-mode circuit techniques.

Current-mode interconnection circuits in particular show very good performance.

For low-voltage operating circuits the current mode techniques are better suited in comparison with voltage-mode techniques.

IV. DIFFERENTIAL VOLTAGE CURRENT CONVEYOR

Differential voltage current conveyor circuits are powerful building blocks, especially for applications requiring differential or floating inputs like impedance converter circuits and current mode instrumentation amplifiers. The applications suitable for VLSI are then considered by using the differential voltage current conveyor to realize a MOS transconductor and a continuous-time current mode MOSFET current filter.

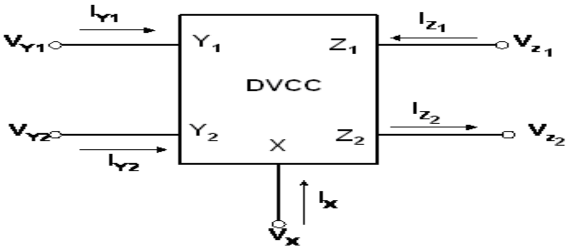

Fig. 6: Schematic Diagram of DVCC

The conventional differential voltage current conveyor can be represented in an equivalent matrix form.

$$\begin{bmatrix} Vx \\ Iy1 \\ Iy2 \\ Iz1 \\ Iz2 \end{bmatrix} = \begin{bmatrix} 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} Ix \\ Vy1 \\ Vy2 \\ Vz1 \\ Vz2 \end{bmatrix}$$

$$Vx = Vy1 - Vy2$$

$$Iy1 = Iy2 = 0$$

$$Iz1 = +Ix$$

$$Iz2 = -Ix$$

Vy1= voltage at node Y1

Vy2= voltage at node Y2

Ix= current at node X

Iz1= current at node Z1

Iz2= current at node Z2

V. COMPARISON WITH CONVENTIONAL OP-AMP

The current conveyor is getting substantial consideration as they compromise analog designers some momentous advantages over the conventional op-amp. Some advantages are enumerated underneath-

- Tractability of driving current or voltage signal output at its two detached nodes, hence Appropriate for current and voltage mode devices.
- The supply voltage of integrated circuits can be reduced comparatively.
- Accurate port transfer ratios equal to unity hence engaged in low sensitivity design.
- We can achieve enhanced AC performance with better linearity.
- One important advantage is obligation of smaller number of passive components to perform a specific function.
- It is suitable for the operation relatively at higher frequencies.
- It is desirable to achieve wider and approximately constant bandwidth independent of closed loop gain.
- We can obtain moderately High slew rate.

VI. APPLICATION OF CURRENT CONVEYORS

Current Conveyors can be applied through numerous methods in field of analog computation, such as current amplifier, current differentiator, current integrator, current summer and weighted current summer. Current Conveyors are extensively used as basic active building blocks to realize innumerable current-mode active filters. The universal filter is among the most popular analog filters as it can provide several standard functions like low pass, high pass, band pass, band reject and all pass [5]. Current Conveyors are also very helpful in the active network synthesis. They can be applied in various configurations, such as voltage controlled voltage source, voltage controlled current source, current controlled current source, current controlled voltage source, Gyrator etc. Current conveyors are suitable in the design of integrated filters and oscillators also.

VII. CONCLUSION

In this paper a transitory overview of current conveyors has been revealed in terms of their different generations. Due to its versatile characteristics and compatibility with several circuits we observe that current conveyor offers several advantages over the conventional op-amp such as removal of gain bandwidth limitation, improved slew rate etc. Due to its low voltage low power characteristics the current conveyors are going to define an era in the field of electronics.

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