International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-3, Issue-8, August 2015

Study of Current Mode Active Devices

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Abstract— **In today communication system, current conveyors are getting significant attention in current analog IC's design due to their higher bandwidth, unity gain, greater linearity, larger dynamic range, simpler circuitry, low power consumption and less chip area. Current conveyors are used as a basic building block in a variety of electronic circuits in instrumentation and communication systems. Today these systems are replacing the conventional operational amplifiers in so many applications such as active filters, analog signal processing and convertors. So now a day, current conveyor has revolutionized the electronic technological area.**

Index Terms— **current conveyors, communication system, op-amp, active filters.**

I. INTRODUCTION

Initially we use voltage mode devices such as BJT, MOSFETs, OP–AMP etc. which has some limitations such as low impedance. Due to these limitations researchers developed current mode devices to overcome the limitations of conventional voltage mode devices.

Voltage-Mode versus Current-Mode

All conventional analog circuits are voltage mode circuits (VMCs) where the circuit performance is determined in terms of voltage level at various nodes including the input and the output nodes. But these circuits suffer from the following disadvantages:

(i)Output voltage cannot change instantly when there is a sudden change in the input voltage due to stray and other circuit capacitances

(ii) Bandwidth of op amp based circuits is usually low because of finite unity-gain bandwidth

(iii) Slew rate is dependent on the time constants associated with the circuit

(iv) Circuits do not have high voltage swings

(v) Require higher supply voltages for better SNR.

Clearly, VMCs are not suitable for use in high frequency applications. This unsuitability is due to the fact that in voltage-mode circuits, the high-valued resistors with parasitic capacitances create a dominant pole at a relative low frequency, which limits the bandwidth.

CM circuits offer a better alternative to VMC in high-frequency applications.

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Following are the advantages of the CM approach:

(i)Improved AC performance with better linearity.

(ii) Wide and nearly constant bandwidth independent of closed loop gain.

(iii) Relatively high slew rate.

(iv) Easy addition, subtraction and multiplication of signals

(v) Higher dynamic range

(vi) Suitability of operation in reduced power supply environment,

(vii) Simpler circuit structure

(viii)Low-power consumption

(ix) Low-voltage operation

(x) Micro-miniaturization.

(xi) They do not require a high voltage gain, so high performance amplifiers are not needed.

(xii) Requirement of smaller number of passive components to perform a specific function. They can be designed entirely with transistors.

(xiii)They show high performance in terms of speed, bandwidth and accuracy.

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 promising performance.

In 1968, Sedra and Smith first introduced the concept of current conveyor. That time, the benefits of this concept was not clear. In fact, at that same time, the electronic companies started to put their main efforts in the fabrication of monolithic op- amp's as a consequence the relevant value of new invention was partially overshadowed.

II. CURRENT MODE CIRCUITS

A. First generation current conveyor(CCI) :

The CCI is a three terminal device with the terminals designated as x, y, z. The voltage at x equals whatever voltage is applied to y. Whatever current flows into y also flows into x, and is mirrored at z with a high output impedance as a variable constant current source.

CCI has two low impedance inputs.

In CCI+, current into Y produces current into Z.

In CCI-, current into Y produces current out of Z.

The functionality of CCI can be described by following hybrid equation:

T $$\begin{bmatrix} i_y \\ v_x \\ i_z \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} v_y \\ i_x \\ v_z \end{bmatrix}$$

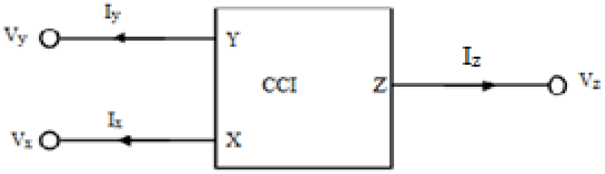

Figure1: Symbolic representation of CCI.

The design of circuits based on CCI can in some cases turn out to be quite problematic, since the current flows in all the block terminals. This limit of CCI device reduces its flexibility and versatility.

B. Second generation current conveyor(CCII):

In many applications, only one of the virtual grounds in terminals X and Y of the first generation current-conveyor is used and the unused terminal must be grounded or otherwise connected to a suitable potential. This grounding must be done carefully since a poorly grounded input terminal may cause unwanted negative impedance at the other input terminal. Moreover, for many applications a high impedance input terminal is preferable. For these reasons, the second generation current-conveyor was developed. It has one high and one low impedance input rather than the two low impedance inputs of the CCI [2]. So in1970, Sedra and Smith introduced second generation current conveyor (CCII). It has one high and one low impedance input rather than two low impedance inputs of the CCI.

The matrix representation of the second generation current conveyor (CCII) is:

$$\begin{bmatrix} i_y \\ v_x \\ i_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & h & 0 \end{bmatrix} \begin{bmatrix} v_y \\ i_x \\ v_z \end{bmatrix}$$

Where h = $\underline{+}$ 1
If h =1 the hybrid matrix corresponds to a positive polarity ideal CCII $\underline{+}$.
If h = -1 the hybrid matrix corresponds to a negative polarity CCII-.

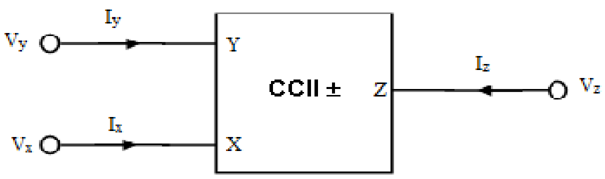

Figure2: Symbolic representation of CCII.

Here, Y terminal is a voltage input
Z terminal is a current output
X terminal can be used as a voltage output or as a current input.
Therefore, this conveyor can easily be used to process both current and voltage signals unlike the first generation current conveyor or the operational amplifier.
The CCII based circuit requires no external resistor; hence it is very suitable for integration. The only difference in CCI and CCII is that in CCII the current at the input terminal Y is zero.

Reasons to use CCII

1. CCII allows implementation of electronic function usable at high frequency.
2. The other reason is that its parasitic resistance at terminal X is controllable. The controllable resistance is usable for the applications of tunable circuits, such as filters.

C. Third Generation Current Conveyor (CCIII):

The third generation current conveyor was proposed in 1995 [4] by Fabre. The characteristics of third generation current conveyor are shown in hybrid matrix given as below:

$$\begin{bmatrix} i_y \\ v_x \\ i_z \end{bmatrix} = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} v_y \\ i_x \\ v_z \end{bmatrix}$$

The third generation current conveyor CCII is similar to that of the first generation current conveyor CCI with the exception that the currents in parts X and Y flow in opposite directions.

Advantages of current conveyor

1. Bandwidth of current conveyor based amplifier is large as current conveyors operate in open loop without the gain bandwidth product limitations.
2. A current conveyor is said to be capable of simplifying the circuit design in much the same manner as the conventional op amps along with the added advantages of current mode approach.

Added advantages of current mode:-
(i)Low voltage reduces problem related to power dissipation and reliability issues.
(ii) Current mode design techniques offer high bandwidth useful in high frequency circuit design applications.

III. IMPLEMENTATION

Current conveyors can be used as a low pass filter (LPF), or as a band pass filter (BPF), or as a high pass filter (HPF). In this implementation of current conveyors we have used 2 operation amplifiers, namely AD844 and LF411. The AD844 is a high speed monolithic operational amplifier. It combines high bandwidth and very fast large signal response with excellent dc performance. The AD844 can be used in place of traditional op amps, but its current feedback architecture results in much better ac performance, high linearity and an exceptionally clean pulse response. This type of op amp provides a closed loop bandwidth that is determined primarily by the feedback resistor and is almost independent of the closed loop gain. The AD844 is free from the slew rate limitations inherent in traditional op amps and other current feedback op amps.

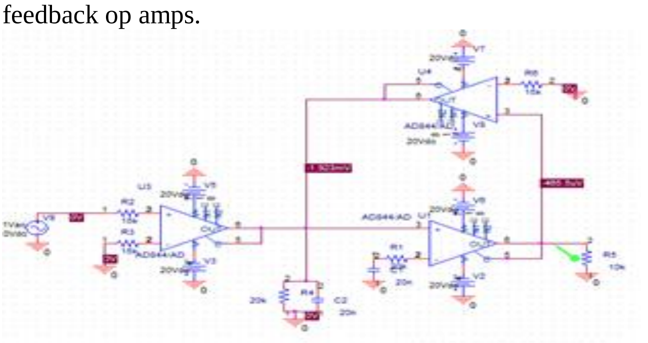

Figure3: Current Conveyor using op amp

In the above figure we have used only AD844 operational amplifier and in such a way that it operates as a band pass filter (BPF).

The LF411 is low cost, high speed, JFET input operational amplifier with very low input offset voltage and input offset voltage drift. They require low supply current yet maintain a large gain bandwidth product and fast slew rate. These amplifiers may be used in applications such as high speed integrators, fast D/A convertors, sample and hold circuit, high speed current booster and many other circuits requiring low input offset voltage and drift, low input bias current, high input impendence, high slew rate and bandwidth.

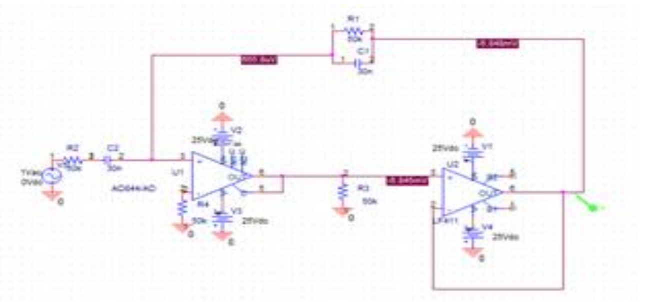

Figure4: Current Conveyor as LPF

In this implementation we have used both the AD844 and LF411 operational amplifiers and configurations are done in such a way that it operates as a low pass filter (LPF).

IV. RESULT AND ANALYSIS

These circuits are simulated using orcad version 9.2 and the frequency response of above mentioned circuits is taken which confirms their working as a filter.

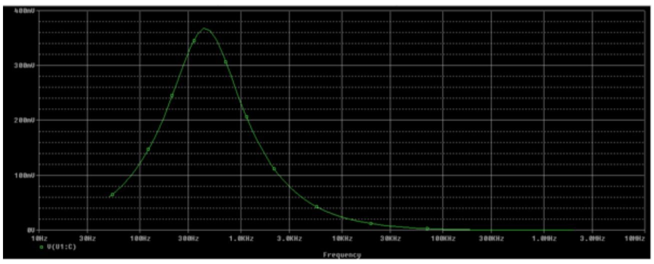

Figure5: Current Conveyor as BPF

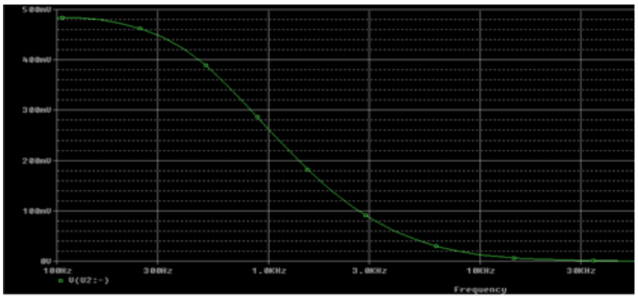

Figure6: Current Conveyor as LPF

V. CONCLUSION

A voltage mode operational amplifier does not perform well in applications where a current output signal is needed. So there is an application field for current conveyors circuits. Current conveyors operates on current amplifying techniques so they have high linearity, wide dynamic range, low power consumption, and better high frequency performance than their voltage mode counterparts. Current conveyors have some other distinct advantages over earlier circuits like use of grounded capacitors, use of lesser number of passive components. It also operates without any global feedback.

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