Practical Realization of Current Mode Active Elements Using AD844 and some Applications

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ABSTRACT
In this paper various Current Mode active elements like first generation current conveyor (CCI), third generation current conveyor (CCIII), Differential voltage Current Conveyor (DVCC) and Dual-X-CCII (DXCCII) have been realized using commercially available chip AD844. The DXCCII is used as a building block to show its application as Amplifier, Integrator and All-pass filter. The proposed circuits are composed of only grounded passive components, which is suitable for designing in the Integrated circuits. PSPICE simulation has been done to verify the results.

1. Introduction
The operational amplifiers (opamps) suffer from the finite gain-bandwidth product which limits accuracy and reduces the frequency range of operation.[1-6] Therefore, many circuits such as oscillators, current-mode and voltage mode filters, simulated inductors, rectifiers etc. are constructed employing different types of current conveyors (CC) such as second-generation positive-type current conveyor (CCII+), second-generation negative-type current conveyor (CCII-), dual-output second-generation current conveyor (DOC-CCII), first-generation current conveyor (CCI), third-generation current conveyor (CCIII), differential voltage current conveyor (DVCC), dual X current conveyor (DXCC), positive-type current gain variable CCII (CVGCII+), positive-type voltage gain variable CCII (CVGCCII+). Current conveyors (CCI, CCII and CCIII) have received considerable attention since their introduction mainly due to their wider bandwidth and their capability to give current as well as voltage output. But one of the disadvantages of this current mode circuits is that there is only one commercially available chip in the market that is AD844 [7]. In fact, the AD844 is a current feedback Operational amplifier (CFOA) which can be used also as a positive type second generation current conveyor (CCI+). In this paper the CCI+ is not realized because the AD844 verifies its port characteristics. For practical purposes, it is very important to realize different types of CCs and other active devices using AD844 or CCII+s.

2. Current Mode Active elements
2.1 Positive-type first-generation Current Conveyor (CCI+)
The port characteristics of CCI+ are shown as matrix equation (1)

\[
\begin{bmatrix}
I_Y \\
I_Z^+ \\
V_X \\
V_Y
\end{bmatrix} = \begin{bmatrix}
\gamma & 0 & 0 & 0 \\
0 & \alpha & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
I_X \\
V_X \\
V_Y \\
V_Y
\end{bmatrix}
\]

(1)

It can be realized with three CCII+s and three resistors as shown in fig.1. The current gains of the Z+ and Y terminals are equal to

\[
\alpha = \frac{R_1}{R_2} \quad \text{and} \quad \gamma = \frac{R_1}{R_3}
\]

2.2 Positive-type third-generation Current conveyor (CCIII+)
The Port relation of CCIII+ can be described as:

\[
\begin{bmatrix}
I_Y \\
I_Z^+ \\
V_X \\
V_Y
\end{bmatrix} = \begin{bmatrix}
-1 & 0 & 0 & 0 \\
0 & \alpha & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
I_X \\
V_X \\
V_Y \\
V_Y
\end{bmatrix}
\]

(2)

It can be realized with three CCII+s and two resistors as shown in fig.2. The current gains of the Z+ terminal is equal to \(\alpha = \frac{R_1}{R_2}\).

2.3 Differential voltage Current conveyor (DVCC)
The DVCC is a four port active element described by:

\[
\begin{bmatrix}
I_y_1 \\
I_y_2 \\
I_{z+} \\
V_x
\end{bmatrix} =
\begin{bmatrix}
0 & 0 & 0 & I_x \\
0 & 0 & 0 & V_y_1 \\
1 & 0 & 0 & 0 \\
0 & \beta & -\beta & 0
\end{bmatrix}
\begin{bmatrix}
I_x \\
V_y_1 \\
V_y_2 \\
I_{z+}
\end{bmatrix}
\tag{3}
\]

It can be realized with three CCII+s and two resistors as shown in fig.3. The voltage gain of the DVCC is equal to \(\beta = R_2 / R_1\).

Fig.3 Differential voltage current conveyor (DVCC)

2.4 Dual X Current conveyor (DXCCII)
A DXCCII can be implemented with two CCII+s, one CCII- (CCII- is formed by two CCII+) and two resistors as shown in fig.4 and symbol of DXCCII is shown in fig.5.

The DXCCII is a five port active element with:
- One high impedance, voltage input terminals: \(Y\)
- Two low impedance, current input terminals: \(X_p, X_n\)
- Two high impedance, current output terminals: \(Z_p, Z_n\)

The input – output characteristic of DXCCII is defined as:

\[
\begin{bmatrix}
I_y \\
I_{z+} \\
I_{z-} \\
V_{y+} \\
V_{y-}
\end{bmatrix} =
\begin{bmatrix}
0 & 0 & 0 & 1 & 0 \\
1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
I_{y+} \\
I_{z+} \\
I_{z-} \\
V_{y+} \\
V_{y-}
\end{bmatrix}
\tag{4}
\]

3. Simulation Results
PSPICE simulation using AD844 Model has been done. This simulation has been done at supply voltage of \(\pm 10\) volt and \(R_1 = R_2 = 1K\).

Fig. 6(a) Verification of Voltage Relation

Fig. 6(b) Verification of Current Relation

Fig. 6(c) Verification of Voltage Relation in Frequency Domain
Fig. 7(a) Verification of Voltage Relation

Fig. 7(b) Verification of Current Relation

Fig. 7(c) Verification of current Relation in Frequency Domain

Fig. 8(a) Verification of Voltage Relation

Fig. 8(b) Verification of Current Relation

Fig. 8(c) Verification of Voltage Relation in Frequency Domain

Fig. 9(a) Verification of Voltage Relation

Fig. 9(b) Verification of Current Relation
Fig. 9(c) Verification of current Relation in Frequency Domain

The simulated results which are shown in fig.6(a), 6(b) and 6(c) show the port characteristics verification of the CCI+. Fig. 7(a), 7(b) and 7(c) show the practical realization of CCIII+, fig 8(a), 8(b) and 8(c) is of DVCC and fig.9(a), 9(b) and 9(c) is of DXCCII. All the above result verified its port relations.

4. Applications of DXCCII
4.1 Amplifier

Fig. 10 proposed circuit for current mode Amplifier

The transfer function of the proposed amplifier is given by:

\[ \frac{I_{out}}{I_{in}} = \frac{R_3[R_2 - R_1]}{R_1R_2} \]  

(5)

4.2 Integrators

Fig. 11(a) Proposed CM Loss-less Integrator

The transfer function of the proposed current mode loss-less Integrator is given by:

\[ \frac{I_{out}}{I_{in}} = \left[ \frac{R_2 - R_1}{sC_3R_1R_2} \right] \]  

(6)

4.3 All pass filter

The transfer function of the proposed current mode All pass filter is given by:

\[ \frac{I_{out}}{I_{in}} = -C_2 \left( \frac{s - 1}{C_2R_1} \right) / C_3 \left( s + 1 / C_3R_3 \right) \]  

(7)

\[ \omega_0 = 1 / C_3R_3 \]

Fig. 11(b) Proposed CM Lossy Integrator

Fig. 11(c) Proposed CM All-pass filter

Fig. 12 Proposed CM All-pass filter

Fig. 13 Input / Output current Waveform
5. Simulation Results

PSPICE simulation using AD844 Model has been done. This simulation has been done at supply voltage of ±10 volt. Taking $R_1 = 0.5k$, $R_2 = 1k$, $R_3 = 2k$, and $I_{in} = 2mA_{pp}$, the relation given by eqn.(5) shows non-inverting Amplifier with no error in Fig.13 of the CM integrated circuit.

Taking $R_1 = 2k$, $R_2 = 1k$, $C_3 = 7.96nf$, $I_{in} = 1mA$, and $f_o = 10kHz$ then the relation given by eqn.(6) shows the loss-less integrator for square wave input and output is shown in fig14(a). Taking $R_1 = 0.5k$, $R_2 = 1k$, $R_3 = 1k$, $f_o = 100kHz$, $C_3 = 1.59nf$ and $I_{in} = 1mA$, the relation of eqn.(7) shows CM LPF in fig.14 (b) with cut-off frequency of 85.94kHz and with gain error of 0.105.

Taking $R_1 = R_3 = 5k$, $I_{in} = 1mV$, design frequency $f_o = 10kHz$, then after calculation $C_2 = C_3 = 3.184nf$, the response of eqn.(8) shows CM APF as shown in fig. 15.

6. Conclusion

The Current mode active elements have been realized using commercially available chip AD844, CC1+, CCIII+, DVCC and DXCCII port relations are verified. The DXCCII is used as a building block to show its applications as Amplifiers, Integrators and All-pass filters in the current mode topology. All the proposed circuits are composed of only grounded passive components, which are suitable for designing them in the integrated circuits.

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