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Tunable Current-Mode Tow-Thomas Biquad Filter Based On Cdta

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Abstract

A new current-mode Tow-Thomas biquad filter based on employing current differencing transconductance amplifiers (CDTAs) is introduced. The filter circuit uses two grounded capacitors and realizes a lowpass (LP) and a bandpass (BP) responses, simultaneously. The proposed circuit is electronically tunable by adjusting the biasing current of the CDTAs. The circuit requires no component matching conditions for realizing the transfer functions listed above. Additionally, the circuit parameters Q and ω0 can be tuned orthogonally by adjusting the bias currents of the CDTAs and grounded capacitors. It is clear from sensitivity analysis that the proposed biquad circuit has very low sensitivities with respect to the circuit components.

Keywords: Current differencing transconductance amplifie(CDTA), Current Mode ,CMOS, Tow - Thomas Biquad filter, two grounded capacitors

1.Introduction

With the rapid and continuous advances in integrated electronics, all efforts are to build a low-power and low-cost systems. Op-amps have been used extensively for implementation of different types of electronic circuits because these elements are used widely due to their small sizes and good performance. Today demand for low power, battery operated portable equipments increasing considerably. For this reason, designers have begun to look into different architectures to fit these demanding designs. To solve this issue by using voltage mode elements is not a easy since the voltage supply if reduced will cause problems with realizing good, fully-functional circuits.

The purpose of this paper is to implement Tow Thomas biquad filters by using a minimum component current differencing transconductance amplifier (CDTA). The proposed biquad filters employ two CDTA and two grounded capacitors. The features of the circuit are that: the pole frequency and quality factor can be electronically tuned via the input bias currents.

2.System Model

A Current Differencing Transconductance Amplifier (CDTA) receive considerable attention due to their larger dynamic range and wider bandwidth. Employing these new active elements for analog design and using CMOS technology for implementation, the circuit designers obtained new possibilities to solve their problems. CDTA device is a synthesis of the well-known advantages of the CDBA and an output transconductance amplifier to facilitate the implementation of current mode analog signal processing.

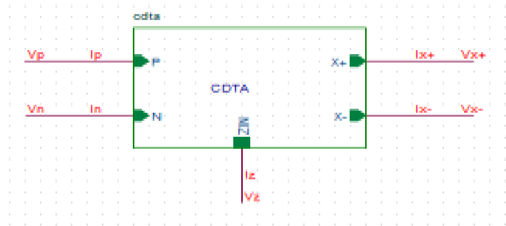

Figure 2.1 the circuit symbol

A CDTA is a 5-terminal current-mode active building block. It can be also considered as a current operational amplifier as in figure 5-(a) and its defining equation.

$V_p = V_n = 0$ …… 2a

$I_z = I_p - I_n$ ………2b

$I_x + = g_m V_z$ …….2c

$I_x - = -g_m V_z$ …….2d

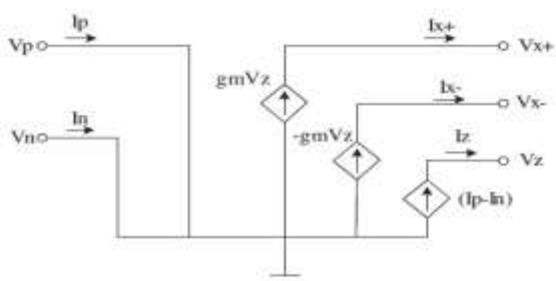

Figure 2.2 Equivalent circuit of the CDTA

The defining equation matrix is given.

$$\begin{bmatrix} V_p \\ V_n \\ I_z \\ I_x \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & \pm g_m \end{bmatrix} \begin{bmatrix} I_p \\ I_n \\ V_x \\ V_z \end{bmatrix}$$

Where

P and *N* are input terminals;

Z and $\pm x$ are output terminals;

g_m is the transconductance gain;

And Z_z is external impedance connected at the terminalz.

3. Previous Work

[1] Existing CDTA Design With CMOS

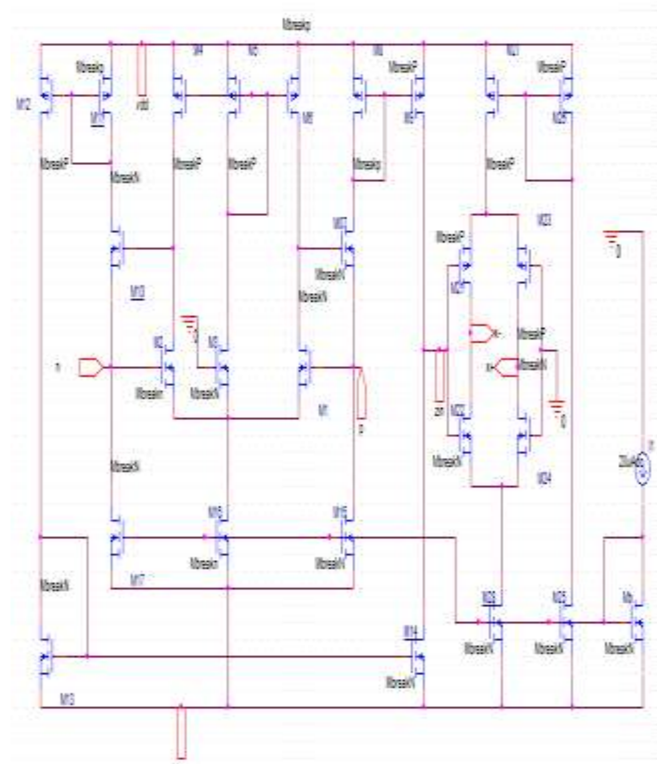

Figure 3.1 CMOS based CDTA

The transistors $\boldsymbol{M_1}$ to $\boldsymbol{M_{17}}$ form the input differential current-controlled source (DCCCS) stage. Which is used for transforming the differential input current to the intermediate voltage or the voltage at the Z terminal. The transistors $\boldsymbol{M_{21}}$ to $\boldsymbol{M_{28}}$ from the high performance dual-output transconductance stage.

[2] Simulation analysis and results of CDTA

The performance of the proposed CDTA was verified using the PSpice simulation program. The MOS transistors were simulated using TSMC CMOS 0.35-$\boldsymbol{\mu m}$ process module parameters. The aspect ratios of the transistors are given in Table 3.1. The supply

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voltages and biasing current are given by V_{DD} = - V_{SS} = 3.8, I_{B1}=40uA respectively.

Table 3.1 -Aspect ratios of the transistors (W/L) in micrometer

M1-M3	70/0.7
M26	58.5/0.7
M25,M27,M28	56/0.7
M15-M17	35/0.7
M7,M10	42/0.7
M21	28.7/0.7
M4,-M6,M23	28/0.7
M22,M24	16.1/0.7
M8,M9,M11,M13M14	10.5/0.7
M12	9.8/0.7
MB	7/0.7

The input terminal current transfer characteristics are given in Figure. 3.2 and 3.3 obtained when one input is open-circuited.

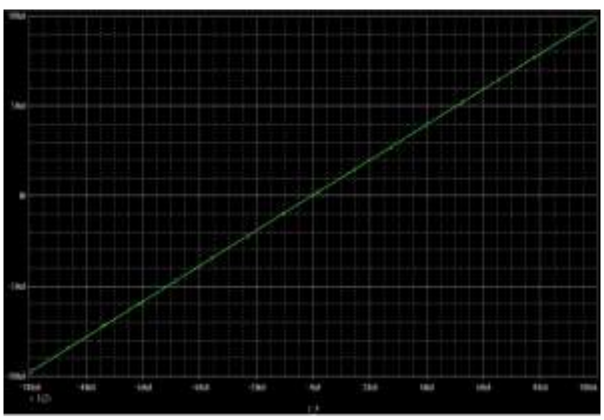

Figure3.2 Variation of the Z terminal current with respect to P (input) terminal current

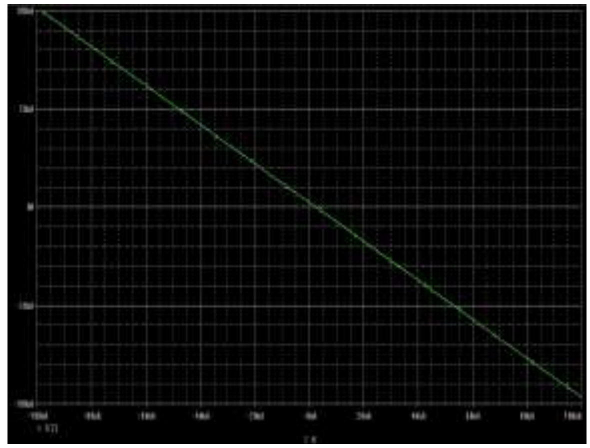

Figure 3.3 Variation of the Z terminal current with respect to N (input) terminal current

The input stage transfers the difference of the input currents to the z terminal with good accuracy as demonstrated in the Figures. Since few internal nodes exist over the signal path from the input to stage a high frequency operation is satisfied exploiting the high frequency capability of current mode signal processing

In figure 3.4 and 3.5 variation of current transfer from the N terminal and P terminal to Z terminal with frequency is given. 3 dB bandwidths of those characteristics are quite large, 48.507MHz for I_z/I_p and 59.099MHZ for I_z/I_n.

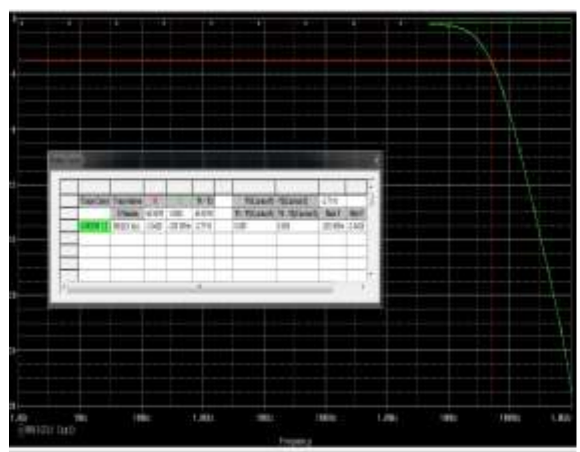

Figure 3.4 frequency response of Iz/ Ip

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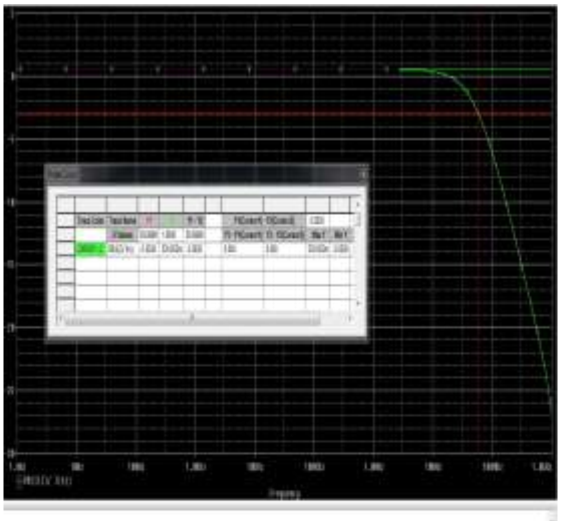

Figure 3.5 frequency response of Iz/In

The variation of the current of output terminals X- and X+ terminal with respect to input current Ip and In(Z terminal is loaded with a 20k impedance.

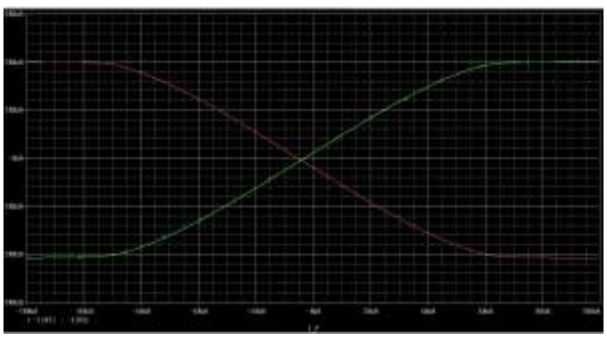

Figure 3.6 Variation of the current of x− and x+ terminals with respect to input current (z terminal is loaded with a 20 k_ impedance)

Transconductance parameter of the CDTA element in the circuit is determined by the transconductance of output transistors. It can be approximated as

$$g_m = \sqrt{u c_{ox} \frac{w}{l} i_b}$$

Power consumption of the circuit is 6.2mW when the transconductance is set to 446.494u A/V by adjusting the biasing current of the circuit If transconductance of the circuit is to be tuned without changing the bias current of the output transconductors..

4.Proposed Methodology

A biquad filter is a type of linear filter that implements a transfer function that is the ratio of two quadratic functions. That is also called biquadratic filter. Biquad filters are typically active and implemented with two-integrator loop topology or a single-amplifier biquad.

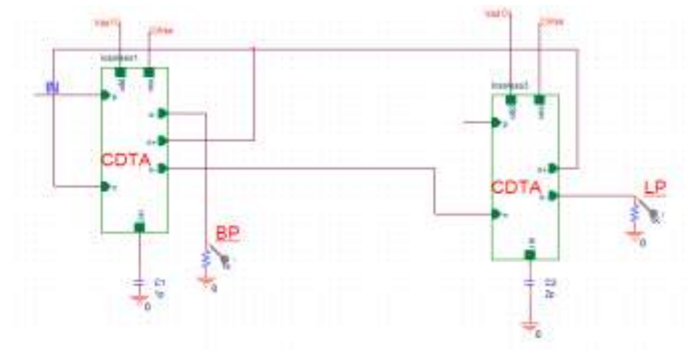

Figure 4.1 Proposed Tow-Thomas biquad filter

Tow-Thomas biquad is state the variable type filter. It consists of two CDTA integrators and two grounded capacitors shown in figure 4.1 And It provide second-order Low-pass (LP) and Band-pass (BP) filtering responses simultaneously and there transfer functions of the filter outputs are given.

$$\frac{I_{BP}}{I_{IN}} = \frac{g_{m1}/C_1 S}{D(S)} \qquad 4.a$$

$$\frac{I_{LP}}{I_{IN}} = \frac{g_{m1}g_{m2}/C_1C_2}{D(S)} \qquad 4.b$$

Where

$$D(S) = S^2 + \left(\frac{g_{m1}}{C_1}\right) S + \frac{g_{m1}g_{m2}}{C_1C_2} \qquad 4.c$$

From equation 4.b the pole frequency and quality factor can be expressed as

$$W_0 = \sqrt{\frac{g_{m1}g_{m2}}{C_1C_2}} \qquad 4.d$$

$$Q = \sqrt{\frac{g_{m2}C_1}{g_{m1}C_2}} \qquad 4.e$$

Simulation analysis and results

In the filter, passive element values are chosen as $\boldsymbol{C_1}$ = 1P, and $\boldsymbol{C_2}$ = 2P .The electronic tunability of the Tow-Thomas biquad filter, different values of MOS bias currents I_{B3} of the CDTAs as 100uA, 125uA, 150uA, 175uA and 200uA are selected to obtain different resonance frequencies for the LP and BP response of the filter as shown in Figure 4.2.

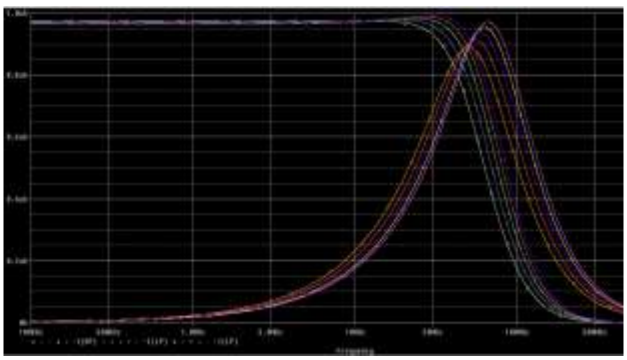

Figure 4.2 frequency response tunable Tow-Thomas biquad filter

In the filter, passive element values are chosen as $\boldsymbol{C_1}$ = 1P, and $\boldsymbol{C_2}$ = 2P which gives cut-off frequency Spice simulations show in figure 4.3 and this value as 65.2 MHz. The electronic tunability of the Tow-Thomas biquad filter, different values of MOS bias currents I_{B3} of the CDTAs as 100uA, selected to obtain different resonance frequencies for the LP and BP response of the filter as shown in Figure 4.3.

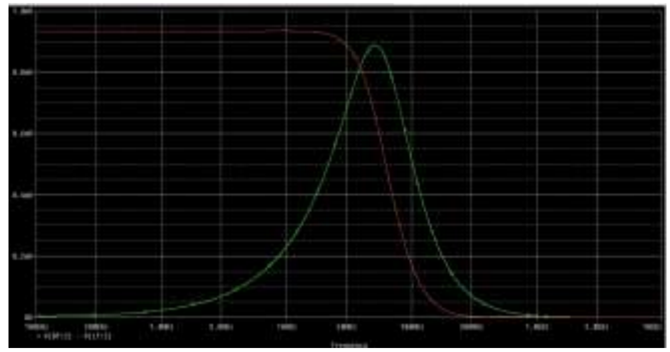

Figure 4.3 frequency response Tow-Thomas biquad filter

In the filter, passive element values are chosen as $\boldsymbol{C_1}$ = 1P, and $\boldsymbol{C_2}$ = 2P which gives cut-off frequency Spice simulations show in figure 6-(d) and this value as 66.2 MHz. The electronic tunability of the Tow-Thomas biquad filter, different values of MOS bias currents I_{B3} of the CDTAs as 125uA selected to obtain different resonance frequencies for the LP and BP response of the filter as shown in Figure 4.5.

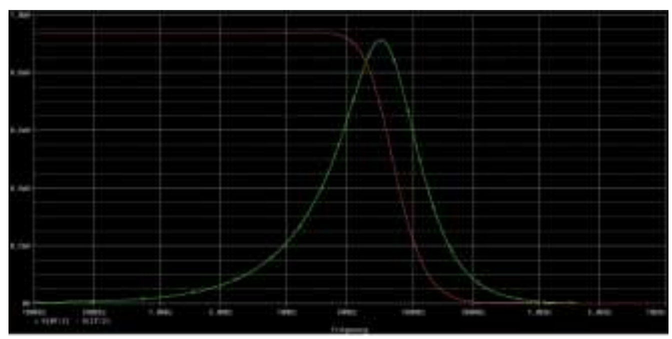

Figure 4.5 frequency response Tow-Thomas biquad filter

In the filter, passive element values are chosen as $\boldsymbol{C_1}$ = 1P, and $\boldsymbol{C_2}$ = 2P which gives cut-off frequency Spice simulations show in figure 4.6 and this value as 67.2 MHz. The electronic tunability of the Tow-Thomas biquad filter, different values of MOS bias currents I_{B3} of the CDTAs as 150uA, are selected to obtain different resonance frequencies for the LP and BP response of the filter as shown in Figure 4.6

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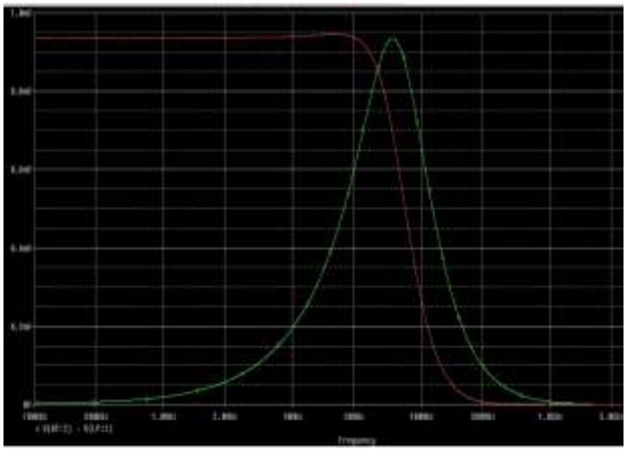

Figure 4.6 frequency response Tow-Thomas biquad filter

In the filter, passive element values are chosen as C_1 = 1P, and C_2 = 2P which gives cut-off frequency Spice simulations show in figure 4.7 and this value as 68.2 MHz. The electronic tunability of the Tow-Thomas biquad filter, different values of MOS bias currents I_{B3} of the CDTAs as, 175uA selected to obtain different resonance frequencies for the LP and BP response of the filter as shown in Figure 4.7.

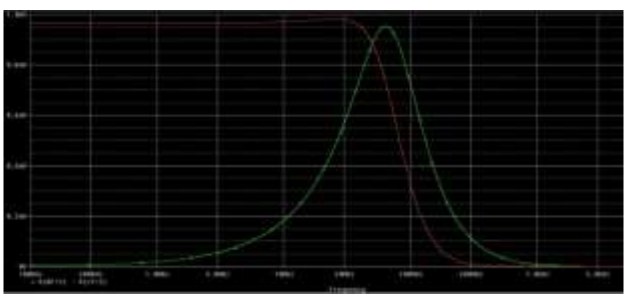

Figure 4.7 frequency response Tow-Thomas biquad filter

In the filter, passive element values are chosen as C_1 = 1P, and C_2 = 2P which gives cut-off frequency Spice simulations show in figure 4.8 and this value as 69.2 MHz. The electronic tunability of the Tow-Thomas biquad filter, different values of MOS bias currents I_{B3} of the CDTAs as 200uA are selected to obtain different resonance frequencies for the LP and BP response of the filter as shown in Figure 4.8.

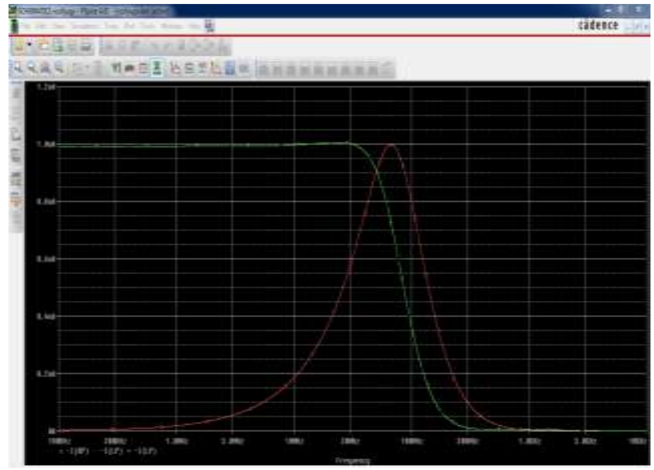

Figure 4.8 frequency response Tow-Thomas biquad filter

5.Proposed Simulation/Experimental Results

The transistors M_1 to M_{12} form the input differential current-controlled source (DCCCS) stage. Which is used for transforming the differential input current to the intermediate voltage or the voltage at the Z terminal. The transistors M_{13} to M_{24} from the high performance dual-output transconductance stage.

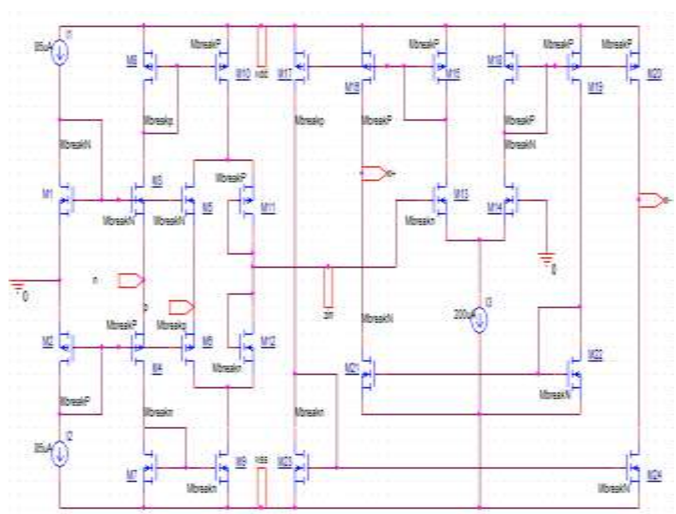

Figure 5.1 CMOS based CDTA

Simulation analysis and results of CDTA

The performance of the proposed CDTA was verified using the PSpice simulation program. The MOS transistors were simulated using TSMC CMOS 0.5-μm process module parameters. The aspect ratios of the transistors are given in Table 5.1 The supply voltages and biasing current are given by V_{DD} = - V_{SS} = 2.5V, I_{B1}= I_{B2}=100μA and I_{B3}= 200μA respectively.

Table 5.1 -Aspect ratios of the transistors (W/L) in micrometer

M1-M6	14/1
M7-M10	13/1
M11-M12	20/1
M13-M14	16/1
M15-M20	6/1
M21-M24	4/1

The input terminal current transfer characteristics are given in Figure. 5.2 and 5.3 obtained when one input is open-circuited. The input stage transfers the difference of the input currents to the z terminal with good accuracy as demonstrated in the Figures. Since few internal nodes exist over the signal path from the input to stage a high frequency operation is satisfied exploiting the high frequency capability of current mode signal processing.

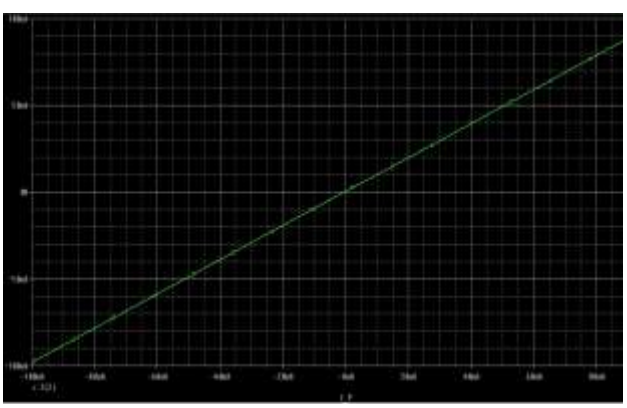

Figure5. 2 Variation of the Z terminal current with respect to P (input) terminal current

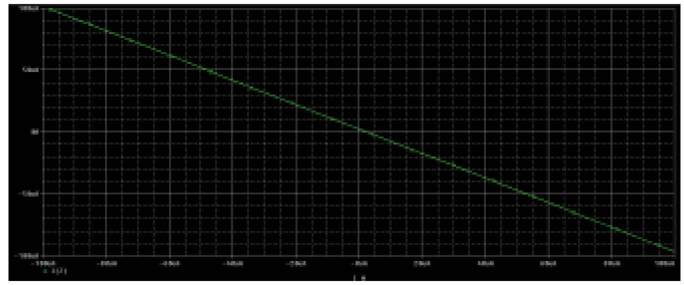

Figure 5.3 Variation of the Z terminal current with respect to N (input) terminal current

In figure 5.4 and 5.5 variation of current transfer from the N terminal and P terminal to Z terminal with frequency is given. 3 dB bandwidths of those characteristics are quite large, 81.508MHz for I_z/I_p and 80.463MHZ for I_z/I_n.

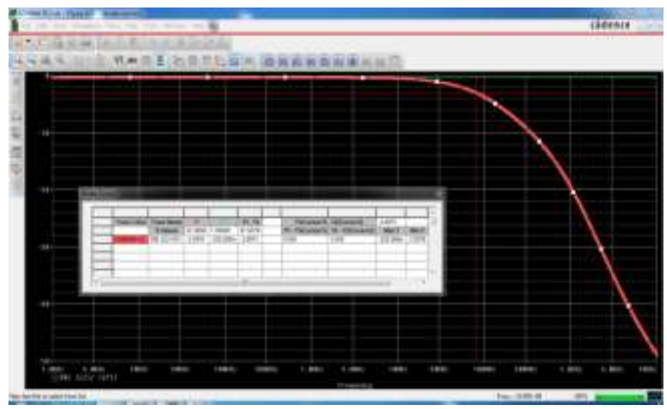

Figure 5.4 frequency response of Iz/ Ip

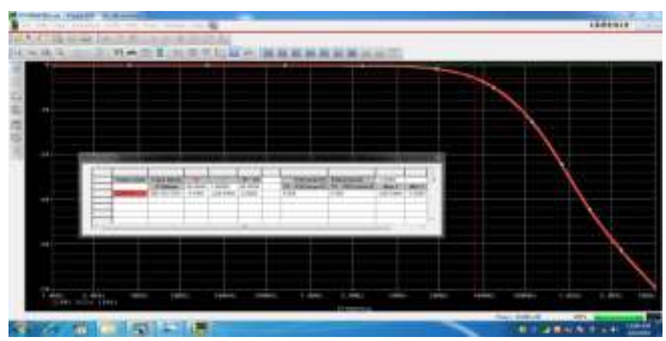

Figure 5 .5 frequency response of Iz/In

The variation of the current of output terminals X- and X+ terminal with respect to input current Ip and In(Z terminal is loaded with a 5.k impedance.

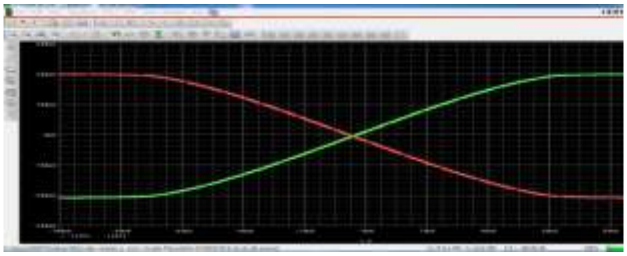

Figure 5.6 Variation of the current of x− and x+ terminals with respect to input current (z terminal is loaded with a 5 k_ impedance)

Transconductance parameter of the CDTA element in the circuit is determined by the transconductance of output transistors. It can be approximated as

$$g_m = \sqrt{uc_{ox}\frac{w}{l}i_b}$$

Summary of the simulation results of the CDTA elements given in Table 5.2. As seen from Table 5.2, current transfer from p and n terminals to the z node is achieved over a very large bandwidth. Output transconductor stage is build by floating current sources which is also reported for high- frequency operation [10]. Input resistances of the P and N terminals are moderately low at 25Ω. Power consumption of the circuit is 3.8mW when the transconductance is set to 757 µA/V by adjusting the biasing current of the circuit If transconductance of the circuit is to be tuned without changing the bias current of the output transconductors.

Table 5.2 - Simulation results of CDTA

	CDTA	**PROPOSED CDTA**
Supply Voltages	±3.8V	±2.5V
I_Z/I_P (-3dB Bandwidth)	48.507MHZ	81.508MHZ
I_z/I_n (-3dB Bandwidth)	59.088MHZ	80.463MHZ
Power Consumption	6.2mW	3.8Mw
Transconductaance	446.494µA/v	757.855µA/v

6.Conclusion & Future Scopes

The Realization of current–mode Two-Thomas biquad filter using CDTA has been described. The circuit structure employs two CDTA and two grounded capacitors, which is convenient for integrations. Two-Thomas biquad filter realizes LP and HP from the same topology. The circuit also provides independent current control of w_0 and Q and the filter with high Q value can be obtained by simply tuning the ratio CDTA bias current. With mentioned features, it is very suitable to realize the proposed circuit in monolithic chip to use in battery-powered, portable electronic equipments such as wireless communication system devices.

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