A Current Mode Second Order Filter Using Dual Output CDTA

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Abstract— A new current mode 2nd order filter employing single current differencing transconductance amplifier(CDTA), using current mode approach which provides high pass(HP), band pass(BP), low pass(LP) responses simultaneously, has been presented. The current outputs of lowpass(LP) and bandpass(BP) types for driving independent loads and single highpass(HP) current output, flowing through one of working capacitors. The circuit employes one CDTA, two capacitors and one resistors. It uses a minimum number of passive and active components, which provides low active and passive sensitivities. SPICE simulation results which utilizes the CMOS transistor based CDTA model, are enclosed.

***Keywords*—CDTA, Analog Signal Processing, Current Mode Filter, SPICE.**

I. INTRODUCTION

Current differencing transconductance amplifier (CDTA) is used especially for current mode analog signal processing[1].It has been introduced for the synthesis of active filters previously.A variety of applications of Current differencing transconductance amplifier (CDTA) can be found in various literature[2]-[5].The active filters in CM have wider band width, simpler circuitry, greater linearity, wider dynamic range and lower power consumption as compared to their voltage mode counterparts[6].The circuits reported so far suffer from the drawbacks of employing either excessive number of components[2][3] or need to change the circuit topology to realize different filtering responses .A number of papers deal with the design of 2nd order CDTA based filter, most of them contains[2][3] two CDTAs.CDTA can be thought as a combination of a Current differencing unit followed by a dual-output operational transconductance amplifier, DO-OTA.OTA is a voltage-controlled current source device and can be described by:

$$Ix = g_m(V_+ - V_-)$$

where Ix is output current, V_+ and V_- , denote non-inverting and inverting input voltage of the OTA, respectively.

This paper presents, a new Current mode 2nd order filter, consisting of a Dual output single CDTA, one resistor and two grounded capacitors.The HP output can be obtained as a superposition of I_{LP} and I_{BP} .SPICE simulation results have been incorporated to check the workability of the proposed circuit.

II. CIRCUIT DESCRIPTION

Normally The CDTA element[3] with its behavioural model and schematic symbol is shown in Fig.1.

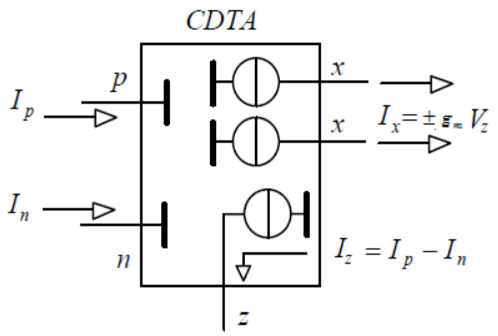
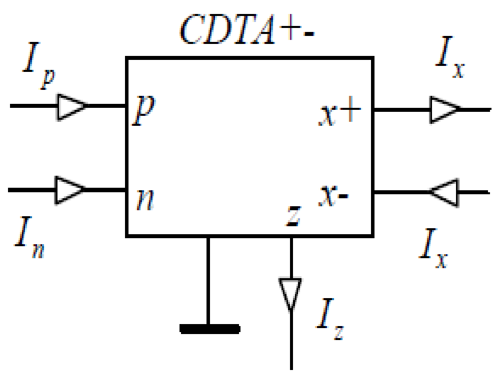


Fig.1-(a) Behavioural model



(b) symbol of CDTA element

The difference of currents of low input impedance p and n terminals flows out of the z terminal as current Iz. Here output terminal currents are equal in magnitude, but flows in opposite directions, and the product of transconductance (g_m) and the voltage at the z terminal gives their magnitudes.Therefore this active element can be characterized with the following equations:

$$V_p = V_n = 0, \qquad Iz = I_p - I_n$$

$$Ix+ = g_m V_z, \qquad Ix- = -g_m V_z$$

$V_z = I_z Z_z$, and Z_z is the external impedance connected to z.

The proposed CM 2nd order filter is shown in Fig.2.

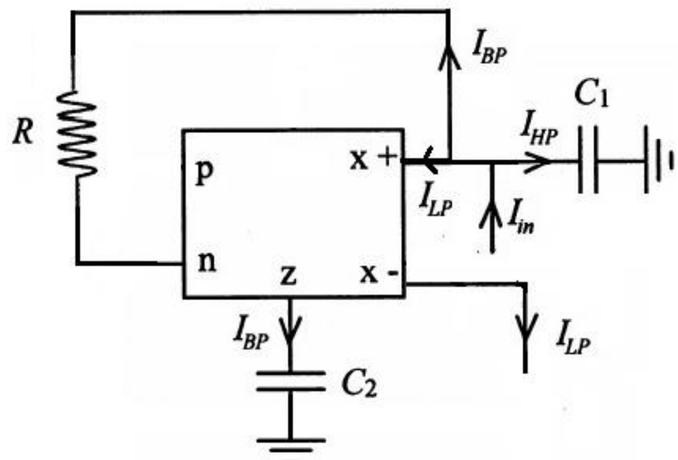


Fig.2-Proposed Current Mode 2nd order Filter

Considering the ideal model of the CDTA, the current transfer functions for LP, BP and HP responses of the proposed circuit, shown in Fig.2, are as follows:

$$\frac{I_{LP}}{I_{in}} = \frac{g_m}{RC_1C_2s^2 + sC_2 + g_m} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\frac{I_{HP}}{I_{in}} = \frac{RC_1C_2s^2}{RC_1C_2s^2 + sC_2 + g_m} \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\frac{I_{BP}}{I_{in}} = \frac{sC_2}{RC_1C_2s^2 + sC_2 + g_m} \quad \ldots\ldots\ldots\ldots \quad (3)$$

The filter performance factors Natural frequency(w_o), Bandwidth(B) and Quality factor(Q) are given by:

$$w_o^2 = \frac{g_m}{RC_1C_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$Q_o^2 = \frac{g_m RC_1}{C_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$B = \frac{1}{RC_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

From equations(4)-(6),it is clear that w_o can be electronically tuned by g_m independently of bandwidth B and Q_o can be tuned by C_2 without upsetting bandwidth B.

III. SENSITIVITY

The active and passive sensitivities of the circuit are given by:

$$S_{gm}^{Q} = \frac{\delta Q / Q}{\delta g_m / g_m}$$

$$S_{C_1}^{Q} = -S_{C_2}^{Q} = S_{R}^{Q} = \frac{1}{2} \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$S_{g_m}^{w_0} = -S_{C_1}^{w_0} = -S_{C_2}^{w_0} = -S_{R}^{w_0} = \frac{1}{2} \ldots\ldots \quad (8)$$

$$S_{R}^{B} = S_{C_1}^{B} = S_{R}^{Q} = -1 \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The active and passive sensitivities of the filter are low.the circuit provides the LP and BP transfer functions with high impedances of the corresponding outputs.Moreover, it provides the HP transfer function, but the output is a current flowing through the working capacitor C_1.The current I_{HP} for driving an independent load can be obtained by combining other currents according to the formula:

$I_{HP} = I_{in} - I_{LP} - I_{BP}$, as in Fig.2.

IV. SIMULATION RESULTS

The performance characteristics of the proposed filter and CDTA was simulated in SPICE for its verification.For this 0.5um MIETEC real transistor model parameters are implemented for all transistors.Transistor aspect ratios are indicated as in Table1.

Table 1.Transistor W/L ratios used in CDTA.

Transistor	W/L(micrometer)
M1-M6	14/1
M7-M10	13/1
M11-M12	20/2
M13-M14	16/1
M15-M20	6/1
M21-M24	4/1

Simulated Results of CDTA Circuit:

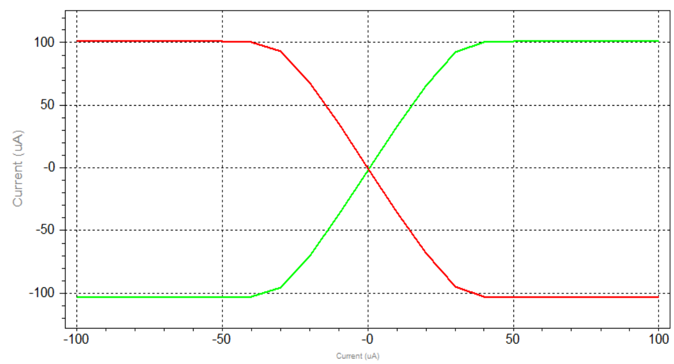


Fig.3(a) Variation of Ix+ and Ix- with respect to Ip

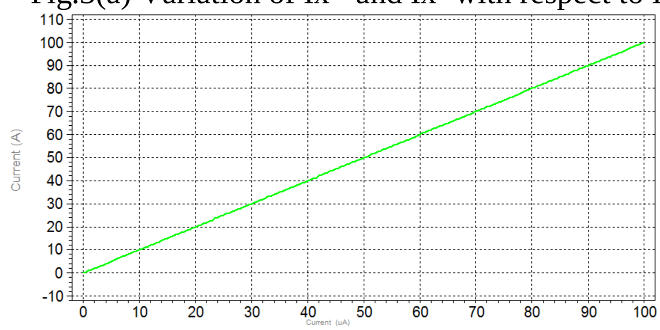


Fig.3(b) Iz/Ip Plot of CDTA

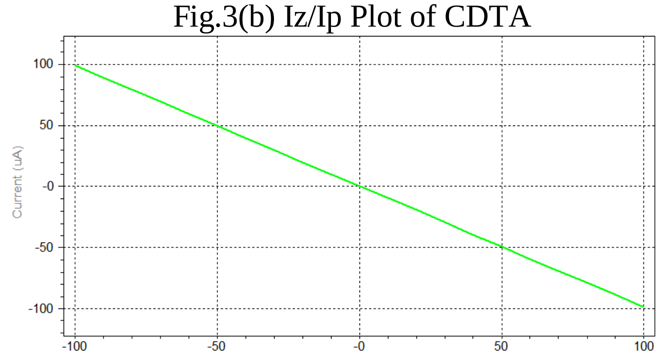


Fig.3(c) Iz/In Plot of CDTA

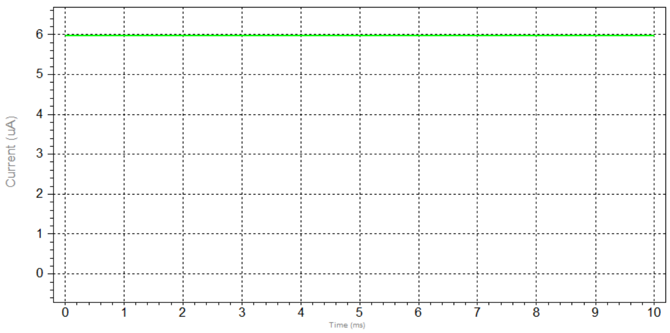


Fig.3(d) Iz Vs time Plot When I_p =10uA, I_n =4uA

Simulated Result of Proposed Circuit:

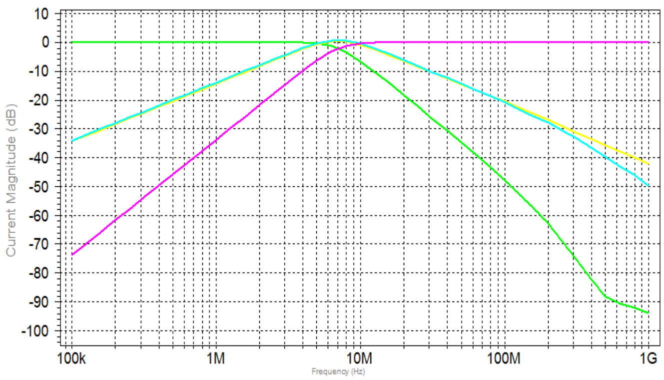


Fig.4- Response of Proposed Current mode 2^{nd} order

The CDTA bandwidth is approximately 1 GHz.The transconductance was set to 627 nA/V via a bias current of 40uA, Supply Voltages ± 1.5V, $C_1 = C_2$ =8pF, R=0.2Kohm.

V. Conclusion

A novel current mode 2^{nd} order filter using Dual Output CDTA is described in this paper.The circuit besides using minimum number of active and passive components can simultaneously provides three basic filtering functions viz LP, HP and BP. w_o and B Are orthogonally tunable. SPICE simulation of this circuit confirms the theoretical conclusions.

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