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Single CDTA Based Current-Mode Universal Filter with grounded Capacitors

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Abstract: In this paper, a new current-mode universal filter based on current differencing transconductance amplifier (CDTA) is presented. The proposed circuit uses one CDTA, two grounded capacitors and two resistors. The filter has single input and three outputs which realize lowpass, bandpass and highpass filter responses from the same circuit configuration. The proposed circuit can also be used to realize an allpass and bandreject current-mode filters. The PSPICE simulation results are shown. The simulated results agree with the theoretical analysis.

Keywords*:* Analog signal processing, Analog filters, Current-mode circuits, CDTA

1. INTRODUCTION

Analog filters are widely used in many areas like communication, instrumentation and control system. These days portable and battery operated equipments are in great demands which makes low voltage operating circuits necessary. The circuits based on current-mode technique are suited for these applications. The current-mode circuits have many advantages like larger dynamic range, higher bandwidth, greater linearity, simple circuit and low power consumption [1,2]. The current-mode circuits based on current conveyors(CCII) [3], current feedback amplifier (CFA) [4,5], operational transconductance amplifier (OTA) [6,7], current differencing buffered amplifier (CDBA) [8] and operational transresistance amplifier (OTRA) [9,10] have been developed.

The current differencing transconductance amplifier (CDTA) is a new active building block suitable for current-mode analog signal processing application [11]. CDTA exhibits better performance such as higher speed and better bandwidth, free from parasitic input capacitances and electronic tenability. Some current-mode filters have been realized using CDTA as an active building block [11-16].

In this paper, a new current-mode universal filter circuit is described. The proposed circuit with single input and three outputs uses one CDTA, two grounded capacitors, one grounded resistor and one virtually grounded resistor. Since all capacitors are grounded, the is beneficial for integrated circuit. The circuit provides basic filtering functions such as lowpass, bandpass and highpass filters simultaneously from the same configuration. PSPICE simulation results agree with the theoretical analysis. The passive and active sensitivities are low.

2. CDTA FUNDAMENTALS

A current differencing transconductance amplifier (CDTA) consists of an input current differencing unit and two transconductance unit. The input stage takes the difference of input signals and converts to a voltage at the Z terminal through a load impedance. Then the voltage is converted to balanced current outputs with a transconductance parameter g of the dual output transconductance stage. A circuit symbol of CDTA is shown in Figure 1, where p and n are two low impedance input terminal, z and x are output terminals. The characteristics equations are given in equation (1).

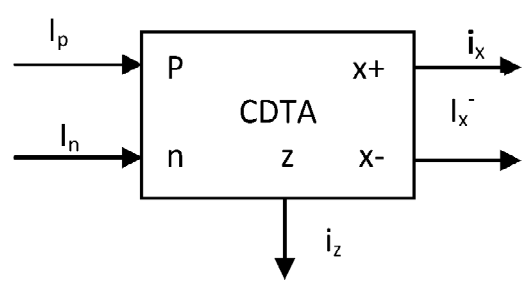

Figure 1: Circuit Symbol of CDTA

$$v_p = _{Vn} = 0 \quad Iz = Ip - \text{In} \quad I_x^+ = gV_z \quad \text{and} \quad I_x^- = -gV_z \qquad (1)$$

where g is the transconductance gain of CDTA. From eq. (1) current flowing out of the terminal *Z* is the difference between the currents through the terminals *p* and *n*. The current flow though impedance *Z* results in voltage *Vz*. The voltage at the terminal *Z* is transferred to a current *Ix* at terminal *X* by a transconductance *g* which is electronically controlled by an external bias current. The CDTA element can be realized by using CFA and OTA. The transconductance gain g of the CDTA is directly proportional to the external bias current I_B which can be written as

$$g = \frac{1_B}{2V_T}$$

where V_T = 26mV at 27°C is the thermal voltage.

3. PROPOSED CIRCUIT CONFIGURATION

The proposed current-mode universal filter based on CDTA is shown in Figure 2. The circuit of the proposed filter consists of one CDTA, two grounded capacitor ad two resistors. Since all capacitors are grounded which makes filter attractive for integrated circuit (IC) implementation. The circuit analysis of proposed filter using characteristic eqn (1) gives the current transfer function of the filter as

$$\frac{I_1}{I_{in}} = \frac{Y_1 Y_3}{Y_1 Y_3 + Y_2 Y_3 + Y_3 Y_4 + Y_2 g} \quad (2)$$

$$\frac{I_4}{I_{in}} = \frac{Y_3 Y_4}{Y_1 Y_3 + Y_2 Y_3 + Y_3 Y_4 + Y_2 g} \quad (3)$$

$$\frac{I_x^-}{I_{in}} = \frac{Y_2 g}{Y_1 Y_3 + Y_2 Y_3 + Y_3 Y_4 + Y_2 g} \quad (4)$$

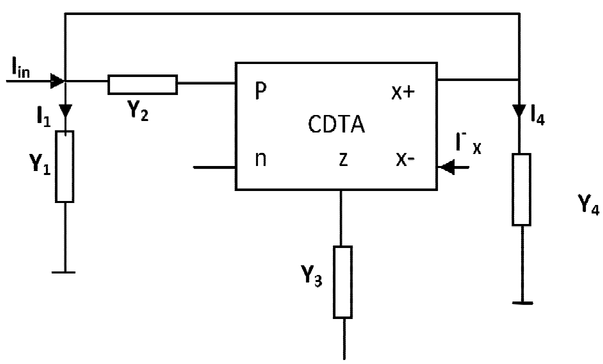

Figure 2: Proposed Current-Mode Universal Filter

By choosing the admittances as $Y_1 = G_1$, $Y_2 = G_2$, $Y_3 = sC_3$, $Y_4 = sC_4$, the transfer function becomes

$$\frac{I_1}{I_{in}} = \frac{\frac{sG_1}{C_4}}{s^2 + \frac{s(G_1+G_2)}{C_4} + \frac{G_2 g}{C_3 C_4}} \quad (5)$$

$$\frac{I_4}{I_{in}} = \frac{s^2}{s^2 + \frac{s(G_1+G_2)}{C_4} + \frac{G_2 g}{C_3 C_4}} \quad (6)$$

$$\frac{I_x^-}{I_{in}} = \frac{\frac{G_2 g}{C_3 C_4}}{s^2 + \frac{s(G_1+G_2)}{C_4} + \frac{G_2 g}{C_3 C_4}} \quad (7)$$

The angular frequency ω_o and quality factor Q are given by

$$\omega_o = \sqrt{\frac{G_2 g}{C_3 C_4}} \quad (8)$$

$$Q = \frac{1}{G_1 + G_2}\sqrt{\frac{G_2 g}{C_3}} \quad (9)$$

4. NON-IDEAL ANALYSIS

Taking the non-idealities of CDTA into consideration, the terminal relations can be expressed as

$$v_p = v_n = 0,\ i_z = \alpha_p ip - \alpha_n p_n \text{ and } i_x = gV_z \quad (10)$$

where $\alpha_p = 1-\varepsilon_p$ ($\varepsilon_p << 1$), $\alpha_n = 1-\varepsilon_n$ ($\varepsilon_n << 1$) , and ε_p and ε_n are current tracking errors from the terminal p to the terminal z and from the terminal n to the terminal z, respectively. Taking the effect of the tracking errors into consideration, the natural angular frequency and quality factor of the proposed circuit can be expressed as

$$\omega_o = \sqrt{\frac{\alpha_p G_2 g}{C_3 C_4}}$$

$$Q = \frac{1}{G_1 + G_2}\sqrt{\frac{\alpha_p G_2 g}{C_3}}$$

The active and passive sensitivities of the proposed circuit are as follows:

$$S_{\alpha_p}^{\omega o} = S_{G_2}^{\omega o} = S_{g}^{\omega o} = -S_{C_3}^{\omega o} = -S_{C_4}^{\omega o} = \frac{1}{2}$$

$$S_{\alpha_p}^{Q} = S_{g}^{Q} = S_{C_4}^{Q} = -S_{C_3}^{Q} = \frac{1}{2},\ S_{G_1}^{Q} = -\frac{3}{2},\ S_{G_2}^{Q} = -1$$

The active and passive sensitivities are quite low.

5. SIMULATION RESULT

The proposed CDTA based current mode universal filter has been simulated with PSPICE simulation program. The CDTA active element was realized by using commercially available ICs ie CFA AD 844 and OTA LM13600 as shown in Figure 2. The power supply voltage used are taken as ±12V and bias current is I_{BIAS}=100uA. The values of the passive components are chosen are R_1= R_2= 1Kohm,

$C_3 = C_4$ = 1nf. Figure 3 shows the simulation result of the proposed universal filter. The simulation result obtained agree with the theoretical analysis.

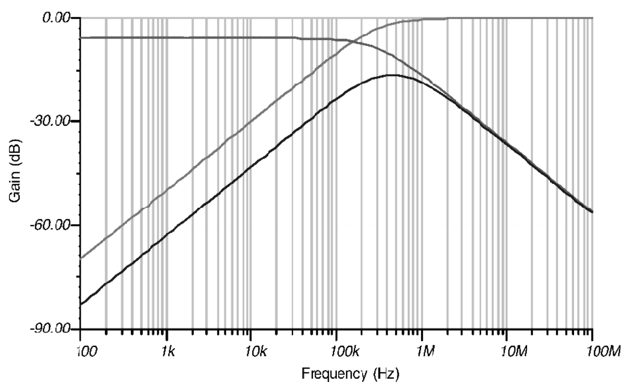

Figure 3: Simulated Result Obtained from Circuit of Figure 2

6. CONCLUSION

The current-mode universal filter based on CDTA is presented. The circuit employs one CDTA, two grounded capacitors, one grounded resistor and one virtually grounded resistor. The proposed circuit performs lowpass, bandpass and highpass filter responses from the same circuit configuration. The circuit provides electronic control of natural frequency and quality factor. The grounded capacitors make the circuit suitable for integrated circuits (IC) implementation. The non-ideal analysis of the proposed circuit shows that the active and passive sensitivities are less than unity. The simulated result agree with theoretical analysis.

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