

Current-mode biquad employing single CDTA

D Biolek, V Biolkova & Z Kolka

Departments of EE & Radioelectronics, UD & BUT, Brno, Czech Republic

E-mail: dalibor.biolek@unob.cz

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This paper presents a novel current-mode (CM) second-order filter, employing one current-differencing transconductance amplifier (CDTA), two grounded capacitors and one virtually grounded resistor. The filter provides two current outputs of lowpass (LP) and bandpass (BP) types for driving independent loads and one high pass (HP) current output, flowing through one of working capacitors. The results of the PSpice simulation, which utilizes the CDTA model on the level of CMOS transistor structure, are enclosed.

Keywords: CDTA, PSpice, Current-mode filters

1 Introduction

A number of applications of the current differencing transconductance amplifier¹ (CDTA) can be found in the literature. Its input-to-output behaviour predetermines this circuit component, particularly, for current-mode signal processing. The difference of input currents of the low-impedance p and n terminals flows out of the z terminal as current I_z . The voltage between the z terminal and the ground is transformed via a multiple-output operational transconductance amplifier (OTA) into a set of currents I_x . Fig. 1 shows the CDTA+- version² with a pair of bi-directional currents $+I_x$ and $-I_x$. The application potential of the CDTA can be increased by extending the circuit with an auxiliary mz terminal, which provides a copy of current I_z .

A number of papers deal with the design of 2nd order CDTA-based filters. Most of them contain¹⁻⁵ two CDTAs. A biquad, employing a single CDTA, has been published⁶. It provides the BP and HP outputs, or LP and BP outputs after the RC:CR

transformation. However, an analysis shows that the filter consists of a passive 1st order current divider and an active 1st order CDTA-based filter. That is why the transfer functions contain only two real poles, and the quality factor cannot exceed the value of 0.5. Another drawback of the filter providing the HP and BP outputs consists in utilizing the floating capacitor. Together with the parasitic resistance of the p -terminal of CDTA, it forms an RC cell which degrades the filter behaviour in the high-frequency region.

In this paper, a novel current-mode filter, consisting of a single CDTA, two grounded capacitors and one resistor, which is pseudo-grounded through the low-impedance CDTA input, is described. No Q-limitation⁶ form exists for this filter. The biquad provides simultaneously a pair of LP and BP current outputs into independent loads and an HP current output to working capacitor. If the HP output to an independent load is also required, one can generate this current, for example, as a superposition of the input current and the currents² I_{LP} and I_{BP} .

2 Circuit Description

The proposed single-CDTA biquad is shown in Fig. 2. Considering the ideal model of the CDTA, the transfer functions of the filter are as follows:

$$\frac{I_{BP}}{I_{in}} = \frac{s}{RC_1 D(s)}, \quad \frac{I_{LP}}{I_{in}} = \frac{g_m}{RC_1 C_2 D(s)}, \quad \frac{I_{HP}}{I_{in}} = \frac{s^2}{D(s)},$$

... (1a, b, c)

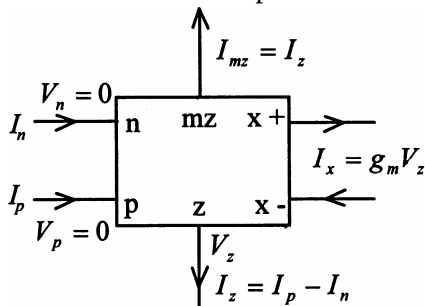


Fig. 1—Active CDTA element containing the “mz” (mirrored z -current) terminal, which provides a copy of the current I_z

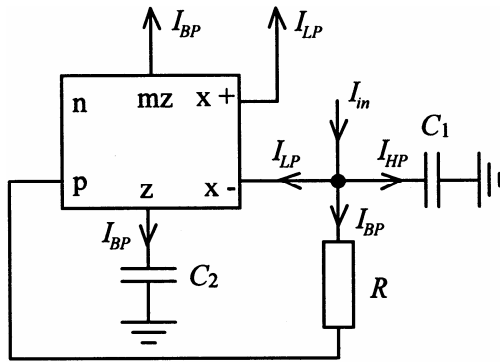


Fig. 2—Proposed CM biquad

where

$$D(s) = s^2 + \frac{s}{RC_1} + \frac{g_m}{RC_1 C_2} \quad \dots (2)$$

Natural frequency ω_0 , quality factor Q , and bandwidth $B = \omega_0/Q$ are given by:

$$\omega_0 = \sqrt{\frac{g_m}{RC_1 C_2}}, Q = \sqrt{g_m R \frac{C_1}{C_2}}, B = \frac{1}{RC_1} \quad \dots (3a, b, c)$$

The sensitivities of ω_0 and Q to variations in g_m , R , C_1 , and C_2 are $\pm 1/2$, the sensitivities of B to variations in R and C_1 are -1 . As obvious from Eq. (1), the circuit in Fig. 1 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 $I_{HP} = I_{in} - I_{LP} - I_{BP}$ (Fig. 2). However, this solution can suffer from large sensitivities to matching errors⁸.

The passive and active sensitivities of the filter are low. The frequency ω_0 can be tuned independently of B by changing the transconductance g_m . Note that the n terminal of the CDTA is not utilized. This fact can be used to simplify the input circuitry of the CDTA for this concrete application.

3 Results of Computer Simulation

The performance of the proposed filter was verified using the simulation in PSpice. The CDTA model⁷ was used, employing the n -well CMOS process TSMC 0.35 μ m. The CDTA was designed for a bandwidth⁷ of about 1GHz. The transconductance was set to 888 μ S via a bias current of 40 μ A. The following values of passive components were used:

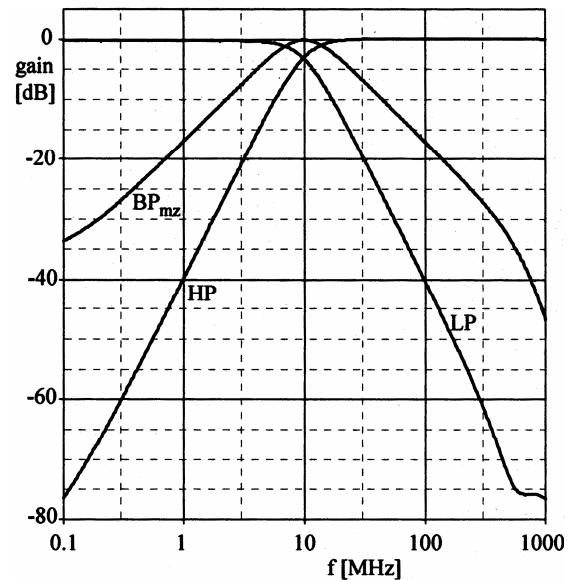


Fig. 3—Results of PSpice simulation of proposed circuit

$C_1 = C_2 = 20$ pF, $R = 563$ ohms. According to Eq. (3), the theoretical values of f_0 and Q are 10 MHz and 0.707.

The results of ac analysis are given in Fig. 3. Both the natural frequency and the quality factor are in accordance with the proposed values.

4 Conclusions

A novel 2nd order current-mode filter employing a single CDTA is described in this paper. The remaining filter components are two grounded capacitors and one pseudo-grounded resistor. In contrast to the hitherto known single-CDTA filters, this topology provides, without the necessity of modifying the input current gate or the RC:CR transformation, a couple of high-impedance current outputs of the BP and LP types. The output current I_{HP} flows through the working capacitance. Where appropriate, it can be implemented as an output for driving an independent load, using one of the known circuit techniques. The sensitivities of ω_0 and Q to variations in the parameters of the passive components are $\pm 1/2$. PSpice simulations on the level of transistor CMOS structure of the CDTA confirm the theoretical conclusions.

Acknowledgement

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