Realization of CDTA based current-mode universal filter

N A Shah, Munazah Quadri & S Z Iqbal
Department of Electronics and Instrumentation Technology, University of Kashmir, Srinagar 190 006

Received 12 April 2006; revised 31 January 2007, accepted 10 January 2008

A new current-mode (CM) filter capable of providing simultaneously lowpass (LP), bandpass (BP) and highpass (HP) responses has been presented. The realization of notch and allpass (AP) responses can be easily achieved without matching or rotation of components. The circuit employs a single current differencing transconductance amplifier (CDTA), two capacitors and one resistor. The circuit uses a minimum number of active and passive components and permits orthogonal tunability of pole frequency \( \omega_o \) and bandwidth \( \omega_o/Q \) along with enjoying low active and passive sensitivities. PSPICE simulation results are obtained.

Keywords: Current-mode universal filter, CDTA, Analog signal processing, Continuous-time active filters

1 Introduction

There has been tremendous advancement in the field of active filters. Common functions of active filters required are high quality audio systems, equalized preamplifiers, active tone control and graphic equalizers\(^1\). There has also been a growing interest in designing CM filter circuits employing different active devices such as operational transconductance amplifiers, current conveyors, four terminal floating nullors, current conveyors and current feedback amplifiers. This is attributed to the fact that continuous-time active filters in CM have wider bandwidth, wider dynamic range, simpler circuitry, greater linearity and lower power consumption as compared to their voltage-mode counterparts\(^2,7\). The circuits reported so far suffer from the drawbacks of employing either excessive number of components\(^4,5\) or need to change the circuit topology to realize different filtering responses\(^6,9\). Recently, a new active element namely current differencing transconductance amplifier CDTA has been introduced\(^8-10\). This device seems to be very suitable for the synthesis of active filters especially in current-mode operation. The use of CDTA as active component simplifies the circuit implementation thereby yielding compact circuits\(^11\) with lesser number of active and passive components vis-à-vis its counterparts.

In the present paper, a new CM universal filter based on recently introduced active device CDTA has been proposed. The circuit employs a single CDTA, two capacitors and a resistor. The circuit is capable of implementing simultaneously three basic filtering functions (LP, BP and HP) while the other two responses (notch and AP) can be obtained by connecting the appropriate output currents without any requirement for change in the nature of the components or topology. It is worth to mention that LP response is achieved at high output impedance thereby facilitating cascading for higher order LP filters. This filtering signal has the advantage of using grounded capacitors which are ideal for integration. The cutoff frequency \( \omega_o \) and bandwidth \( \omega_o/Q \) are independently tunable but in a sequential manner. The active and passive sensitivities are low. PSPICE simulations results have been incorporated to check the workability of the circuit.

2 Circuit Description

The behavioral model and schematic symbol of CDTA is shown in Fig. 1. Its defining relations are:

\[
I_z = I_p - I_n, \quad V_p = V_n = 0 \quad \text{and} \quad I_x = \pm gV_z
\]

Fig. 1 — (a) Behavioral model, (b) symbol of CDTA element
The current transfer functions for LP, BP and HP responses of the proposed circuit, shown in Fig. 2, are as follows:

\[
\frac{I_{LP}}{I_{in}} = \frac{g}{s^2 + \frac{s}{C_1 R} + \frac{g}{C_1 C_2 R}} \quad \cdots (1)
\]

\[
\frac{I_{BP}}{I_{in}} = \frac{g}{s^2 + \frac{s}{C_1 R} + \frac{g}{C_1 C_2 R}} \quad \cdots (2)
\]

\[
\frac{I_{HP}}{I_{in}} = \frac{s^2}{s^2 + \frac{s}{C_1 R} + \frac{g}{C_1 C_2 R}} \quad \cdots (3)
\]

The AP response can be realized by summing up \( I_{HP} \), \(-I_{BP} \) and \( I_{LP} \) and is given by:

\[
\frac{I_{AP}}{I_{in}} = \frac{s^2 - \frac{s}{C_1 R} + \frac{g}{C_1 C_2 R}}{s^2 + \frac{s}{C_1 R} + \frac{g}{C_1 C_2 R}} \quad \cdots (4)
\]

The notch response can be obtained by the summation of \( I_{HP} \) and \( I_{LP} \) and is given by:

\[
\frac{I_{notch}}{I_{in}} = \frac{s^2 + \frac{g}{C_1 C_2 R}}{s^2 + \frac{s}{C_1 R} + \frac{g}{C_1 C_2 R}}
\]

The filter performance factors \( \omega_o \), \( \omega_o/Q \) and \( Q \) are given by:

\[
\omega_o = \sqrt{\frac{g}{C_1 C_2 R}} \quad \cdots (5)
\]

\[
\frac{\omega_o}{Q} = \frac{1}{C_1 R} \quad \cdots (6)
\]

\[
Q = \frac{g C_1 R}{C_2} \quad \cdots (7)
\]

From Eqs (4) - (7), it is clear that \( \omega_o \) can be electronically tuned by \( g \) independently of \( \omega_o/Q \) and \( Q \) can be tuned by \( C_2 \) without upsetting \( \omega_o/Q \).

2.1 Sensitivity

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

\[
S^a_g = S^a_{C_1} = S^a_{C_2} = S^a_{R_1} = 1
\]

\[
S^p_{C_1} = S^p_{R_1} = -1
\]

\[
S^Q_g = S^Q_{C_1} = S^Q_{C_2} = S^Q_{R_1} = \frac{1}{2}
\]

which are no more than unity.

2.2 Simulation results

To verify the theoretical analysis, the proposed circuit has been simulated using a PSPICE simulation program. Fig. 3 shows the simulated results of the
basic responses obtained with $C_1 = C_2 = 1\text{nF}$, $R = 1\text{k}\Omega$ and $g = 1\text{mS}$ for the pole frequency of 159 KHz and $Q = 1$. The simulated results agree quite well with the theoretical analysis.

3 Conclusions
A new current-mode filter employing a single recently introduced active device CDTA, two capacitors and a single resistor is presented. The circuit besides using minimum number of active and passive components can simultaneously provide three basic filtering functions viz. LP, HP and BP while notch and AP can be implemented without inducing any change in the components or topology. The filtering parameters $\omega_o$ and $\omega_o/Q$ are orthogonally tunable.

References