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Scientific Research

An Active-Only Temperature-Insensitive Current-Mode Biquad Filter Based on Differentiator Structures Employing CCCCTAs

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ABSTRACT

This article presents an active-only current-mode universal biquad filter performing three standard functions: low-pass, high-pass and band-pass function, which can be readily modified to achieve the rest functions (band-stop and all-pass). The circuit principle is based on active-only circuit designed by using differentiators which are constructed from current controlled current conveyor transconductance amplifier (CCCCTA) cooperating with an internally frequency compensated operational amplifier (OA). The features of the circuit are that: the pole frequency and quality factor can be independently tuned via the input bias currents and it is ideally temperature-insensitive, its circuit description is very simple, consisting of 3 CCCCTAs and 2 operational amplifiers, and the proposed circuit is very appropriate for further developing into integrated circuit architecture. The PSpice simulation results are shown. The given results agree well with the theoretical anticipation.

Keywords: Active-Only; CCCCTA; Current-Mode; Biquad Filter

1. Introduction

An analog filter is an important building block, widely used for continuous-time signal processing. It can be found in many fields: including, communications, measurement, instrumentation, and control systems [1,2]. One of the most popular analog filters is a universal biquad filter, since it can simultaneously provide several functions in the same circuit topology. Recently, a universal filter working in current-mode has been more popular than the voltage-mode type. Since last two decades, there has been much effort to reduce the supply voltage of analog systems. This is due to the demand for portable and battery-powered equipment. Since a low-voltage operating circuit becomes necessary, the current-mode technique is ideally suited for this purpose. Actually, a circuit using the current-mode technique has many other advantages, such as, larger dynamic range, higher bandwidth, greater linearity, simpler circuitry and lower power consumption [3,4].

The synthesis and design of analog signal processing circuits using only active elements without passive elements are important in fully integrated circuit (IC) technology. This technique makes circuit becoming smaller chip area, lower power consumption, wider frequency range of operation and programmability [5-8], where the applications can be easily seen in many literatures, for example filter [7], oscillator [9], inductance simulator [10] and etc.

From the past, creation of differentiator circuit must use an inductor worked together with an active element which affected on circuit as large sized. So, it was not popular to create circuit with differentiator. But nowadays, we can design differentiator-based circuit without any inductor, then causing a reduction in circuit sized smaller than creation circuit in the past. Biquadratic transfer function is widely used in order to synthesize the filters. Many kinds of filters can be realized based on only integrators as building blocks [11-14]. However,

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integrator circuit performs as a low-pass filter. At high frequency, stage-gain of integrator is decayed due to components bandwidth and integrator characteristic. In order to realize filter, magnitude response of filter in high-frequency would be unstable according to the mentioned characteristics. Differentiator circuit can perform as a high-pass filter that compensated with component bandwidth for stabilization of magnitude response in high-frequency [15].

A reported 5-terminals active element, namely current convey transconductance amplifier (CCTA) [16] has been proposed in 2005, it seems to be a versatile component in the realization of a class of analog signal processing circuits, especially analog frequency filters. It is a really current-mode element whose input and output signals are currents. In addition, the output current gain can be adjusted via input bias current. However, the parasitic resistance at current input port of the CCTA cannot be controlled. Recently, Siripruchyanun and Jaikla have proposed the modified-version CCTA, whose parasitic resistance at current input port can be controlled by an input bias current. It is newly named current controlled current conveyor transconductance amplifier (CCCCTA) [17]. It seems to be a useful building block, since many circuits and systems can be implemented by employing only single CCCCTA. Presently, the CCCCTA has been extensively used, such as filters [18,19], oscillators [20, 21], inductance simulators [22], and etc.

From our recent survey, it is found that several implementations of current-mode universal biquad filters using active-only principle have been reported. Unfortunately, these reported circuits suffer from one or more of following weaknesses:

- Excessive use of the active elements [23,24].
- Lack of electronic adjustability [23,24].
- The pole frequency and quality factor cannot be independently tuned [18,25].

The aim of this paper is to propose a new current-mode universal biquad filter. The features of proposed circuit are that: it employs 3 CCCCTAs and 2 internally frequency compensated operational amplifiers; the proposed universal biquad filter can provide 3 standard functions including low-pass, high-pass and band-pass functions in the same time without changing circuit topology, where the rest functions (band-stop and all-pass) can be readily obtained by small modification; the circuit description is very simple, which results in a small-size of the monolithic chip. In addition, it is electronically tunable and convenient to use. The quality factor and pole frequency can be electronically and independently adjusted. The PSpice simulation results are also shown, which are in correspondence with the theoretical analysis.

2. Theory and Principle

2.1. Implementation Topology of the Proposed Filter

The filter is designed by cascading current adder and the current-mode lossless differentiators fed-back by current amplifier whose gain of k as systematically shown in **Figure 1**. From block diagram in **Figure 1**, its transfer function can be found to be

$$\frac{I_{LP}}{I_{in}} = \frac{\frac{1}{ab}}{s^2 + \frac{sk}{b} + \frac{1}{ab}}, \tag{1}$$

$$\frac{I_{BP}}{I_{in}} = \frac{\frac{s}{b}}{s^2 + \frac{sk}{b} + \frac{1}{ab}}, \tag{2}$$

and

$$\frac{I_{HP}}{I_{in}} = \frac{s^2}{s^2 + \frac{sk}{b} + \frac{1}{ab}}. \tag{3}$$

From Equations (1)-(3), the pole frequency (ω_0) and quality factor (Q_0) can be respectively expressed as

$$\omega_0 = \sqrt{\frac{1}{ab}}, \tag{4}$$

and

$$Q = \frac{1}{k}\sqrt{\frac{b}{a}}. \tag{5}$$

It is found that the pole frequency can be adjusted by either a or b, by keeping their ratio to be constant where the quality factor can be tuned through k without effecting the pole frequency.

2.2. Basic Concept of CCCCTA

The principle of the CCCCTA was firstly published in 2008 by Siripruchyanun and Jaikla [17]. The schematic symbol and the ideal behavioral model of the CCCCTA are shown in **Figures 2(a)** and **(b)**, respectively. The characteristics of the ideal CCCCTA are represented by

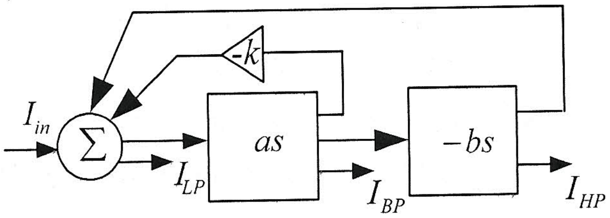

Figure 1. Block diagram for proposed filter implementation.

