Abstract. A new current-mode current-controlled three-input single-output universal filter, which employs only five plus-type second-generation current-controlled current conveyors (CCCIIs) and two grounded capacitors, is presented in this paper. The proposed configuration provides lowpass, bandpass, highpass, bandstop, and allpass current responses at a high impedance terminal, which enables easy cascadability of the circuit. The filter also offers independent electronic control of the natural frequency $\omega_0$ and the quality factor $Q$ through adjusting of the bias current of the CCCI. Derived analytical expressions for the filter parameter deviations due to CCCI nonidealities are also included. PSPICE simulation results are performed to confirm the theoretical analysis.

Key words: Current-controlled current conveyor, universal filter, current-mode circuit.

1. Introduction

In recent years, there has been great emphasis on the design and implementation of current-mode active filters using second-generation current conveyors (CCIIIs). This is due to the fact that CCIIIs provide higher signal bandwidth, greater linearity, and larger dynamic range than their voltage-mode counterparts. Since then a number of current-mode CCII-based universal biquadratic filters have been proposed [1], [2], [4], [9], [11], [12], [14], [17], [18], [20]. Considering the number of input and output ports, the current-mode universal filters may be divided into
two categories: (a) a single-input, multiple-output (SIMO) type [4], [11], [12], [14], [18], and (b) a multiple-input, single-output (MISO) type [1], [2], [9], [13], [17], [20]. Generally, the SIMO filter can simultaneously realize three basic filter functions, i.e., lowpass (LP), bandpass (BP), and highpass (HP). However, for the realizations of allpass (AP) and bandstop (BS) functions, component matching conditions are usually required. On the other hand, in comparison with the SIMO filter, the MISO configuration provides a variety of circuit characteristics with different input and output currents, and usually does not require any parameter matching conditions. In addition, the MISO filter may lead to a reduction in the number of active elements used. Moreover, to realize a larger variety of filter functions such as inverting- and/or noninverting-type functions, the MISO configuration seems to be more suitable than the single-input configuration. Of special interest in this paper is the second category where different filter functions will be realized by simply connecting appropriate input currents.

Recently, by introducing a second-generation current-controlled current conveyor (CCII) [7] in the filter design, the CCII applications can be extended in the domain of electronic controllable functions. Some MISO current-mode CCII-based active universal filters have already been proposed in the technical literature [1], [2], [9], [13], [17], [20]. However, the reported filters suffer from one or more of the following disadvantages:

1. A lack of electronic tunability [1], [9], [13], [17], [20].
2. Interdependency of the parameters $\omega_o$ and $Q$ [1], [9], [13], [17], [20].
3. Use of an excessive number of active or passive components [1], [9], [13], [17], [20].
4. Use of dual-output positive/negative CCIIIs or the use of both the positive and negative types of CCIIIs [2], [9], [17], [20].

In general, the positive CCII configuration is simpler than the negative CCII counterpart. From the point of ease of the filter implementations, it is preferable to realize the CCII-based active filters by using only plus-type CCIIIs [10]. Moreover, a minimum number of grounded capacitors without any external passive resistor requirement is also preferable for an integrated circuit (IC) fabrication process.

Considering this fact, in this work, we present a current-controlled current-mode universal biquadratic filter with three inputs and one output. The proposed circuit configuration employs only five plus-type CCIIIs and two grounded capacitors, which provides the advantage of an electronic tuning capability and is especially interesting from the IC fabrication point of view [3], [15]. By properly selecting different input signals, the circuit can realize all the standard biquadratic filtering functions of LP, BP, HP, BS, and AP at a high impedance output, which enables easy cascading in current mode. The filter performance parameters $\omega_o$ and $Q$ can be orthogonally and electronically tuned over a wide range, by adjusting the bias current of the CCII. No critical matching conditions are required in realizing the LP, BP, HP, and BS responses, and all the incremental parameter