J. of Active and Passive Electronic Devices, Vol. 4, pp. 55–62
Reprints available directly from the publisher
Photocopying permitted by license only

Current Mode Universal Filters with Grounded Passive Elements and Using Single Output Current Conveyors

AHMED M SOLIMAN

Electronics and Communication Engineering Department Cairo University, Giza Egypt 12613

Four current mode universal filters using single output current conveyors are considered and compared in this paper. The circuits considered are those having independent control on the filter quality factor and using grounded resistors and capacitors. Important new results regarding the minimum number of circuit components of the filter to achieve these desirable features are given.

Keywords: Current mode filters, current conveyors.

1 INTRODUCTION

Recently there has been a great interest by many authors to propose active filters using current conveyors CCII [1] to realize current transfer functions. This type of filters will be referred to in this review paper as current mode filters [2]. The circuits considered in this paper are those having independent control on the filter quality factor and using grounded resistors and capacitors [3–7]. Several current mode filters introduced in the literature are of limited practicality since they employ floating resistors and floating capacitors [8–11]. Besides they do not have independent control on the filter Q [8–11]. Although the filter reported in [8] has a very low input impedance it delivers the high-pass and band-pass currents in two capacitors, to use these currents with single output CCIIs, two current followers are needed resulting in a

*Corresponding author: asoliman@ieee.org

floating capacitor circuit. The circuit also uses two-output CCII and thus is not to be included among the circuits that are tabulated in this paper. The circuit reported in [9] suffers from the finite and frequency dependent input impedance besides it employs two floating resistors and two floating capacitors and has no independent control on Q. The two circuits given in [10] are related to each other by RC: CR transformation and both circuits have no independent control on Q and employ floating resistors and capacitors. Although the circuit introduced in [11] has a very low input impedance and uses grounded resistors and capacitors it has no independent control on Q and it uses multiple output CCII thus it is not to be considered among the circuits in this review paper.

The above discussion indicates that most of the recently reported current mode filters [8–11] introduced in the literature concentrate on the circuit components count without achieving the desirable features of a proper current mode filter. Recently classification and a review of different types of current mode filters are given in [12].

It is the objective of this paper to concentrate on the current mode filters with grounded resistors and grounded capacitors and with independent control on Q, and having very low input resistance. Four circuits are discussed in this paper; two of them are generated from high input impedance voltage mode universal filters. All filters discussed here have very low sensitivities to the circuit components [3–7]. A comparison Table is given to demonstrate the similarity and differences among the circuits reviewed in this paper.

2 THE UNIVERSAL CURRENT MODE FILTERS

Fig. 1 represents the generalized block diagram of the current mode filters considered in this paper. Fig. 2 represents the universal current mode filter which is generated from the voltage mode universal filter introduced in [3]. The transformation method used to convert the voltage mode filter to a current

TABLE 1
Comparison between the current mode filters using single output current conveyors.

Fig.	Reference	All Pass Polarity	CCII+	CCII−	R	C	Z_{in}
2	Generated from [3]	Inverting	7	1	8	2	Very Low
3	Generated from [6]	Inverting	6	1	7	3	Very Low
4	[5]	Non-inverting	4	3	8	2	Frequency Dependent
5	[7]	Non-inverting	3	5	8	2	Very Low

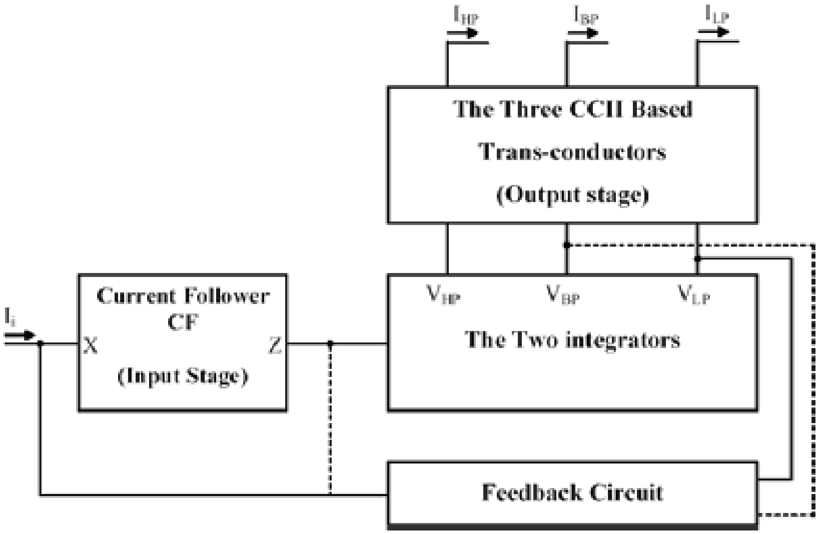

FIGURE 1
The block diagram of a universal current mode filter employing single output CCIIs.

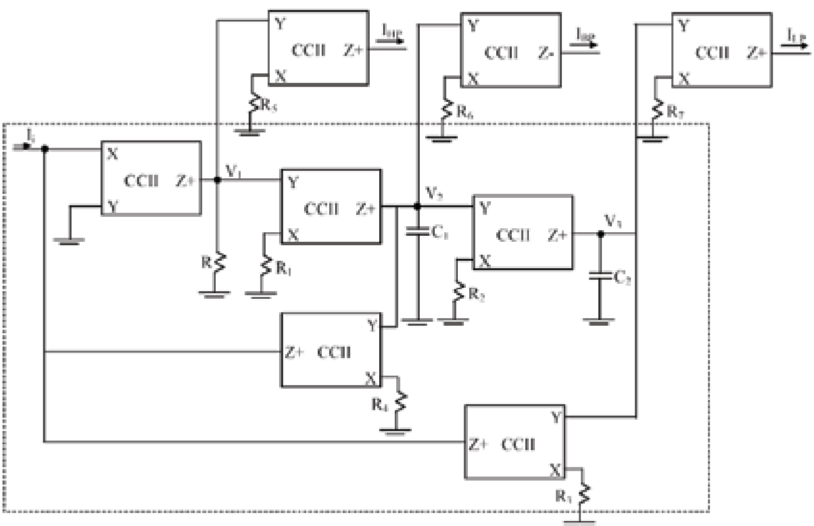

FIGURE 2
The inverting current mode universal filter derived from the KHN circuit [3].

mode filter has been used before in [4] to obtain the current mode filter. The three output voltages are converted to the three output currents using three more current conveyors acting as trans-conductors. The extraction of output currents using single outputs CCII was first used in [5].

The current transfer functions are given by:

$$\frac{I_{HP}}{I_i}=\frac{-\frac{s^2R}{R_5}}{D(s)},\quad \frac{I_{BP}}{I_i}=\frac{\frac{s\ R}{C_1R_1R_6}}{D(s)},\quad \frac{I_{LP}}{I_i}=\frac{-\frac{R}{C_1C_2R_1R_2R_7}}{D(s)} \tag{1}$$

D(s) is the same as given in [3] and is given by:

$$D(s)=s^2+\frac{R}{C_1R_1R_4}s+\frac{R}{C_1C_2R_1R_2R_3} \tag{2}$$

From (2) the ω_o and the Q of the filter are given by:

$$\omega_o=\sqrt{\frac{R}{C_1C_2R_1R_2R_3}},\qquad Q=R_4\sqrt{\frac{C_1R_1}{C_2R\ R_2R_3}} \tag{3}$$

It should be noted that R_4 controls Q without affecting ω_o of the filter.

Note also that the ω_o and the Q sensitivities are very low (≤ 1), as given in [3].

To realize a given ω_o and Q, the design equations as given in [3] are summarized here:

$$C_1=C_2=C,\qquad R_1=R$$

$$R_2=R_3=\frac{1}{\omega_oC},\qquad R_4=\frac{Q}{\omega_oC} \tag{4}$$

An inverting notch response is obtained by connecting I_{HP} and I_{LP} and the design equations for R_5, R_7 are given by:

$$R_5=R,\qquad R_7=R_3 \tag{5}$$

An inverting all pas response is obtained by connecting the three outputs currents with the necessary condition given by:

$$R_6=R_4 \tag{6}$$

Notice that the polarity of the CCII delivering I_{BP} is – so that an all pass is realizable.

Several sign combinations are possible as explained in [3] however the one shown in Fig. 2 is the most economical one as far as the number of CCIIs is considered, since the CCII− is practically realizable using two CCII+.

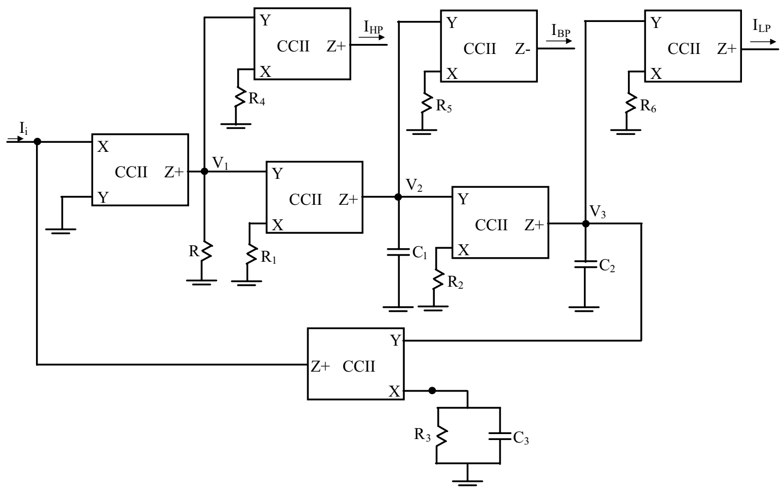

FIGURE 3
The non-canonic inverting current mode universal filter derived from the voltage mode filter [6].

The second current mode filter considered in this paper is shown in Fig. 3 and is generated from the voltage mode universal filter introduced in [6].

The current transfer functions are given by:

$$\frac{I_{HP}}{I_i}=\frac{-\dfrac{s^2R}{R_4}}{D(s)},\quad \frac{I_{BP}}{I_i}=\frac{\dfrac{sR}{C_1R_1R_5}}{D(s)},\quad \frac{I_{LP}}{I_i}=\frac{-\dfrac{R}{C_1C_2R_1R_2R_6}}{D(s)} \tag{7}$$

Where

$$D(s)=s^2+\frac{sC_3R}{C_1C_2R_1R_2}+\frac{R}{C_1C_2R_1R_2R_3} \tag{8}$$

From (8) the ω_o and the Q of the filter are given by:

$$\omega_o=\sqrt{\frac{R}{C_1C_2R_1R_2R_3}},\qquad Q=\frac{1}{C_3}\sqrt{\frac{C_1C_2R_1R_2}{RR_3}} \tag{9}$$

The disadvantage of this circuit over the previous circuit is that the independent control on Q is achieved by varying a capacitor not a resistor. On the other hand it uses one CCII+ less than the previous circuit.

The third universal filter was introduced in [5] and is shown in Fig. 4. The circuit is drawn as in [5] but the suffixes of R and C has been changed to be the same as in Fig. 2.

The current transfer functions are given by:

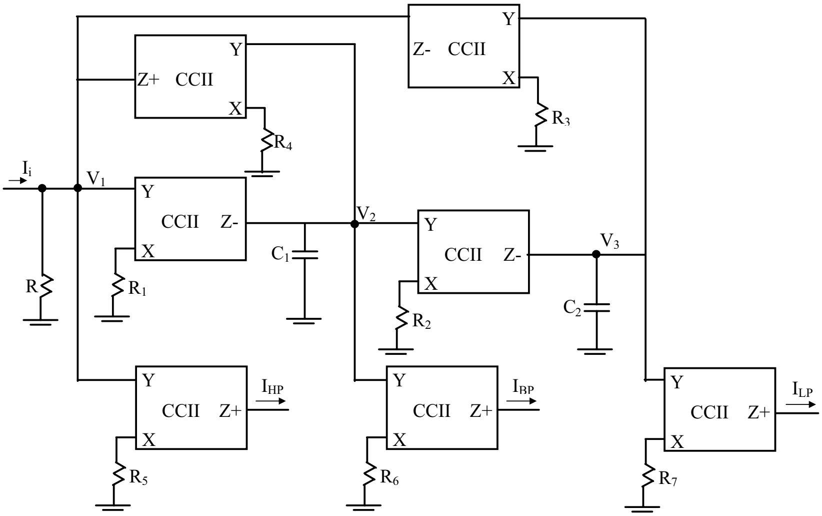

FIGURE 4
The non-inverting current mode universal filter [5].

$$\frac{I_{HP}}{I_i}=\frac{\frac{s^2 R}{R_5}}{D(s)},\quad \frac{I_{BP}}{I_i}=\frac{-\frac{s\ R}{C_1 R_1 R_6}}{D(s)},\quad \frac{I_{LP}}{I_i}=\frac{\frac{R}{C_1 C_2 R_1 R_2 R_7}}{D(s)} \tag{10}$$

Where D(s) is the same as given by (2) and of course ω_o and the Q of the filter are the same as given by (3). This filter does not employ an input stage as demonstrated in Fig 1 which is one of the most desirable features of the current mode filters. It is seen that all responses are non-inverting except the band-pass response, in order to make the all pass realizable by adding the three output currents together.

The fourth universal filter is shown in Fig. 5 and has been introduced in [7] to illustrate how to vary the filter coefficients electronically. The circuit is very similar to the circuit of Fig. 2 except that the feedback currents are injected at the Z terminal of the input stage current follower CF instead of being injected at the X terminal as in Fig. 2. Of course this necessitates that some of the CCII polarities are to be inverted. It is seen that all responses are non-inverting except the band-pass response, in order to make the all pass realizable by adding the three output currents together.

3 CONCLUSIONS

Four current mode universal filters using single output current conveyors are considered and compared in this paper. The circuits considered are those having

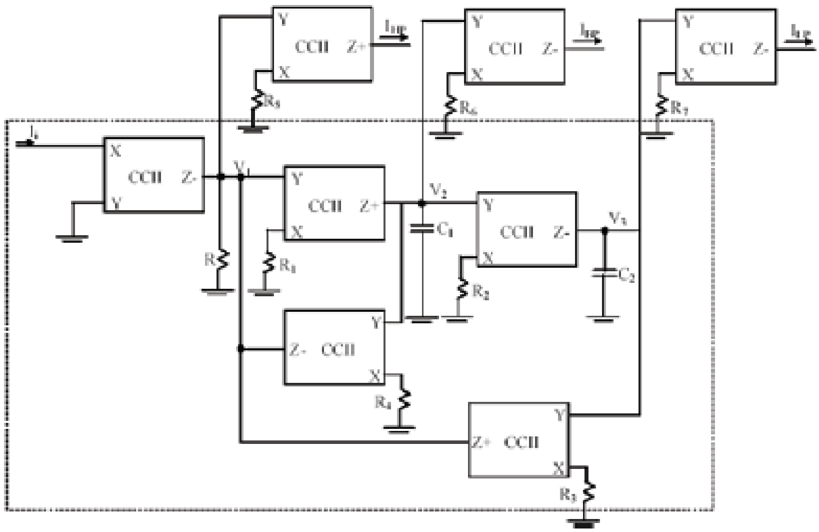

FIGURE 5
The non-inverting current mode universal filter given in [7].

independent control on the filter quality factor and using grounded resistors and capacitors. It should be noted that adding a current follower to act as input stage of the circuit given in Fig. 4 will make it identical to that of Fig. 5. Of course some of the CCII polarities may be different but of course there are several possibilities as demonstrated clearly in [3].

Based on the previous circuit examples the minimum number of circuit components to realize a current mode universal filter with independent control on Q by a resistor, having ideally zero input impedance and using grounded resistors and capacitors is 8 CCII+, 8 R and two C. However to realize an all pass the polarity of the CCII delivering the band-pass current must be inverted.

REFERENCES

[1] Sedra, A. S. and Smith, K. C. (1970) A Second Generation Current Conveyor and its Applications, IEEE Trans Circuit Theory, CT-**17**, 132–134.
[2] Higashimura, M. (1991) Current Mode Transfer Function Using CCIIs with Grounded Passive Elements, IEICE Transitions, **E74**, 1017–1019.
[3] Soliman, A. M. (1995) Current Conveyors Steer Universal Filter, IEEE Circuits and Devices Magazine, **11**, 45–46.
[4] Soliman, A. M. (1998) Current Conveyor Filters: Classification and Review, Microelectronics Journal, **29**, 133–149.
[5] Chang, C. M. (1993) Universal Active Current Filter with Single Input and Three Outputs Using CCIIs, Electronics Letters, **29**, 1932–1933.
[6] Horng, J. W, Lay, J. R, Chang, C. W and Lee, M. H. (1997) High Input Impedance Voltage Mode Multifunction Filters Using Plus Type CCIIs, Electronics Letters, **33**, 472–473.

[7] Papazoglou C. A. and Karybakas, C. A. (1997) Non-interacting Electronically Tunable CCII Based Current Mode Bi-Quadratic Filters, Proc IEE Circuits, Devices, Systems, **144**, 178– 184.
[8] Gunes E. O. and Anday, F. (1996) Realization of current mode universal filter using CFCCIIs, Electronics Letters, **32**, 1081–1082.
[9] Ozoguz, S. and Acar, C. (1997) Universal current mode filter with reduced number of active and passive components, Electronics Letters, **33**, 948–949.
[10] S. Ozoguz, S, Toker, A. and Cicekoglu, C. (1998) High output impedance current mode multifunction filter with minimum number of active and reduced number of passive elements, Electronics letters, **34**, 1807–1809.
[11] Wang H. Y. and Lee, C. T. (2001) Versatile insensitive current mode universal biquad implementation using current conveyors, IEEE Trans Circuits and Systems II, **48**, 409–413.
[12] Soliman, A. M. (2008) Current mode universal filters using current conveyors: classification and review, Journal of Circuits Systems and Signal Processing, **27,** 405–427.