CFTA Based MISO Current-mode Biquad Filter

PEERAWUT SUWANJAN and WINAI JAIKLA
Department of Engineering Education, Faculty of Industrial Education
King Mongkut's Institute of Technology Ladkrabag
Chalongkrung Rd., Ladkrabang, Bangkok, 10520
THAILAND
kspeeraw@gmail.com winai.ja@hotmail.com http://webserv.kmitl.ac.th/kawinai/

Abstract: - This article presents a four-inputs single output biquadratic filter performing completely standard functions: low-pass, high-pass, band-pass, band-reject and all-pass functions, based on single current follower transconductance amplifier (CFTA). The features of the circuit are that; the quality factor and natural frequency can be tuned electronically via the input bias current; the circuit description is very simple, consisting of merely 1 CFTA, 1 resistor and 2 grounded capacitors; the filter does not require inverting-type input current signal. Additionally, each function response can be selected by suitably selecting input signals with digital method. Using only single active element and grounded capacitors, the proposed circuit is very suitable to further develop into an integrated circuit. The PSPICE simulation results are depicted. The given results agree well with the theoretical anticipation. The total power consumption is approximately 2.01mW at ±1.25V supply voltages.

Key-Words: - analog filter, current mode, CFTA, multiple-inputs single-output.

1 Introduction

Recently, current-mode circuits have been receiving considerable attention due to their potential advantages such as inherently wide bandwidth, higher slew-rate, greater linearity, wider dynamic range, simpler circuitry and lower power consumption [1]. One of the standard research topics in current-mode circuit design is an analog filter. This circuit is important in electrical and electronic applications, widely used for continuous-time signal processing. It can be found in many fields: including, communications, measurement, and instrumentation, and control systems [2-3]. One of most popular analog current-mode filters is a multiple-input single-output biquadratic filter (MISO) which different output filter functions can be realized simply by different combinations of switching on or off the input currents where the selection can be done digitally using a microcontroller. Moreover, the high-output impedance of current-mode filters are of great interest because they make it easy to drive loads and they facilitate cascading without using a buffering device [4-5].

From our survey, it is found that several implementations of MISO current-mode filters have been reported [6-21]. Unfortunately, these reported circuits suffer from one or more of following weaknesses:

- Use more than one active element [7, 9, 13, 14, 16, 17, 18, 19, 20, 21].
- Excessive use of the passive elements, especially external resistors [7, 9, 10, 11, 14, 15, 16].
- Requirement of inverting-type input current signal(s) to realize all the responses [6, 14, 15, 17, 18, 20].
- Lack of electronic adjustability [7, 10, 11, 15, 16].
- Requirement of changing circuit topologies to achieve several functions [10].
- Requirement of element-matching conditions [10, 11, 15, 18].
- Use of floating capacitor which is not desirable for IC implementation [15].

The current follower transconductance amplifier (CFTA) is a recently reported active component. It seem to be a versatile component in the realization of a class of analog signal processing circuits, especially analog frequency filters [22-23]. It is really current-mode element whose input and output signals are currents. In addition, it can also adjust the output current gain.

This work is arranged to propose a new MISO current–mode biquadratic filter, emphasizing on use of single CFTA. The features of proposed circuit are that: the proposed universal filter can provide

ISBN: 978-1-61804-085-5

completely standard functions without changing circuit topology by appropriately selecting the input signals: the circuit description is very simple, it consists of single CFTA, single resistor and 2 grounded capacitors, which is suitable for fabricating in monolithic chip: the filter does not require inverting-type input current signal(s). In addition, the natural frequency and the bandwidth can be tuned electronically by adjusting the bias currents. Its performances are illustrated by PSPICE simulations, they show good agreement as mentioned.

2 Principle of Operation

2.1 Basic concept of CFTA

Since the proposed circuit is based on CFTA, a brief review of CFTA is given in this section. The schematic symbol and the ideal behavioural model of the CFTA are shown in Fig. 1(a) and (b), respectively. It has one low-impedance current input *f* port. The current i_f flows from port *z*. In some applications, to utilize the current through *z* terminal, an auxiliary z_c (z-copy) terminal is used [22]. The internal current mirror provides a copy of the current flowing out of the *z* terminal to the z_c terminal. The voltage v_z on *z* terminal is transferred into current using transconductance g_m, which flows into output terminal *x*. The gm is tuned by I_B. In general, CFTA can contain an arbitrary number of x terminals, providing currents I_x of both directions. The characteristics of the ideal CFTA are represented by the following hybrid matrix:

$$\begin{bmatrix} V_f \\ I_{z,zc} \\ I_x \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & \pm g_m \end{bmatrix} \begin{bmatrix} I_f \\ V_x \\ V_z \end{bmatrix}. \qquad (1)$$

For CMOS CFTA, the gm is written as

$$g_m = \sqrt{kI_B}\ , \qquad (2)$$

where $k = \mu_O C_{OX}(W/L)$. Here k and I_B are the physical transconductance parameter of the MOS transistor and input bias current, respectively.

2.2 Proposed MISO current-mode filter

The proposed MISO current-mode filter is shown in Fig. 2. Straightforwardly analyzing the circuit in Fig. 2, the output current can be obtained as

$$I_{out} = \frac{-s\frac{1}{RC_1}\left(I_{in1}+I_{in2}\right) - \frac{g_m}{RC_1C_2}I_{in3} + \left(s^2 + s\frac{1}{RC_1} + \frac{g_m}{RC_1C_2}\right)I_{in4}}{s^2 + s\frac{1}{RC_1} + \frac{g_m}{RC_1C_2}}. \qquad (3)$$

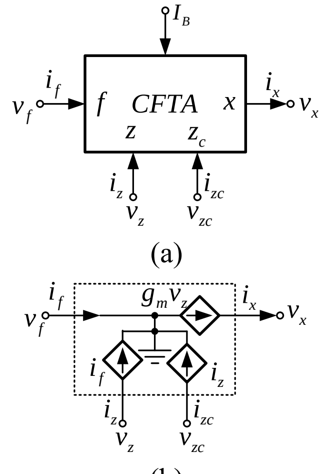

Figure 1. CFTA (a) Symbol (b) Equivalent circuit.

From Eq. (3), the magnitudes of input currents I_{in1}, I_{in2}, I_{in3} and I_{in4} can be chosen as in Table I to obtain a standard function of the network. The circuit of digital selection can be seen in [24]. It is found that the proposed filter does not require inverting-type input current signal to synthesis all the filter responses. From Eq. (3), the natural frequency (ω_0) and quality factor (Q_0) of each filter response can be expressed as

$$\omega_0 = \sqrt{\frac{g_m}{C_1C_2R}}\ , \qquad (4)$$

and

$$Q_0 = \sqrt{\frac{C_1Rg_m}{C_2}}\ . \qquad (5)$$

It is found from Eqs. (4) and (5) that if $g_m = \sqrt{kI_B}$, the natural frequency and quality factor can be electronically adjusted.

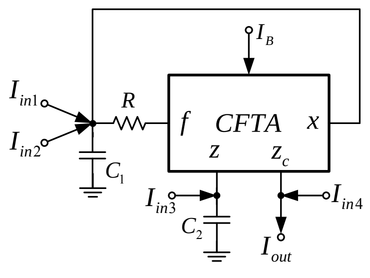

Figure 2. Proposed MISO current-mode biquadratic filter.

ISBN: 978-1-61804-085-5

TABLE I

The I_{in1}, I_{in2}, I_{in3} and I_{in4} value selections for each filter function response

Filter Responses	Input selections			
I_O	I_{in1}	I_{in2}	I_{in3}	I_{in4}
LP	0	0	1	0
HP	1	0	1	1
BP	1	0	0	0
BR	1	0	0	1
AP	1	1	0	1

2.3 Circuit sensitivities

The sensitivities of the proposed circuit can be found as

$$S^{\omega_0}_{C_1,C_2,R} = -\frac{1}{2}, S^{\omega_0}_{g_m} = \frac{1}{2}, \qquad (6)$$

and

$$S^{Q_0}_{C_1,R,\,g_m} = \frac{1}{2};\; S^{Q_0}_{C_2} = -\frac{1}{2}. \qquad (7)$$

Therefore, all the active and passive sensitivities are equal or less than unity in magnitude.

3 Simulation Results

To prove the performances of the proposed filter, the PSPICE simulation program was used for the examination. Internal construction of CFTA used in simulation is shown in Fig. 4. The PMOS and NMOS transistors have been simulated by respectively using the parameters of a 0.25µm TSMC CMOS technology [25]. The aspect ratios of PMOS and NMOS transistor are listed in Table II. The circuit was biased with ±1.25V supply voltages, V_{BB}=-0.55V, C_1=C_2=0.1nF, I_B=100µA and R=1kΩ. It yields the natural frequency of 1.71MHz. The results shown in Fig. 4 are the gain and phase responses of the proposed biquad filter from Fig. 2. There are seen that the proposed filter can provide low-pass, high-pass, band-pass, band-reject and all-pass functions dependent on selection as shown in Table I, without modifying circuit topology.

TABLE II
Dimensions of the MOS transistors

MOS Transistors	$W(\mu m)/L(\mu m)$
M1, M2	1/0.25
M15, M16	20/0.25
M14	4.5/0.25
Another PMOS	5/0.25
Another NMOS	3/0.25

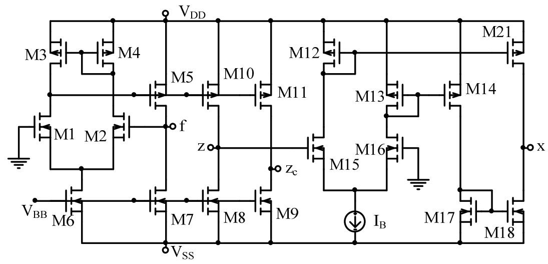

Figure 3. Internal construction of CFTA.

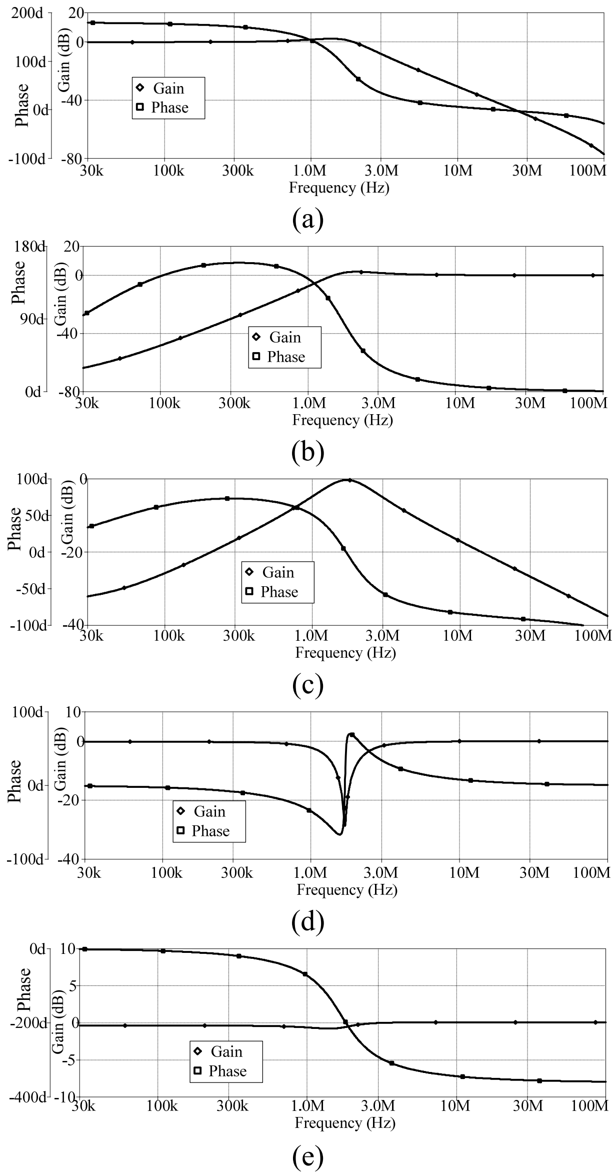

Figure 4. Gain and phase responses of the biquad filter in voltage-mode for (a) LP (b) HP (c) BP (d) BR (e) AP.

Fig. 5 shows gain responses of band-pass function where I_B is set for several values. It is found that natural frequency can be adjusted electronically. The transient response of the proposed filter from band-pass function for center frequency of 1.71MHz can be seen in Fig. 6. Total power consumption is about 2.01mW.

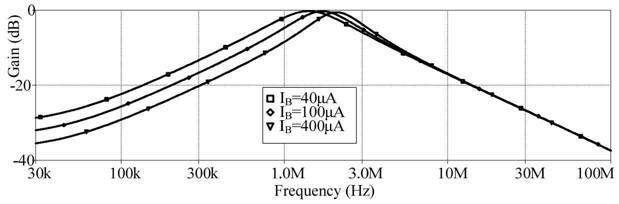

Figure 5. Current-mode band-pass responses for different values of I_B.

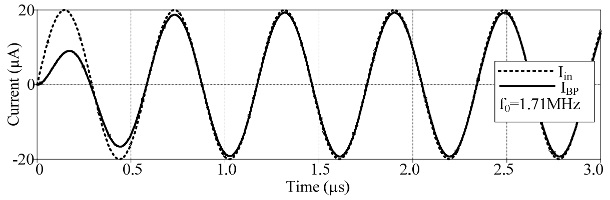

Figure 6. Transient responses at center frequency of 1.71MHz obtained from the proposed filter for BP function.

4 Conclusion

The multiple-inputs single output biquadratic filter based on single CFTA is presented. The advantages of the proposed circuit are that: it performs low-pass, high-pass, band-pass, band-reject and all-pass functions dependent on an appropriate selection of three signals: the bandwidth and the natural frequency can be electronically controlled via input bias currents, it is easily modified to use in control systems using a microcontroller [1]. The circuit description comprises only 1 CFTA, 1 resistor and 2 grounded capacitors. With mentioned features, it is very suitable to realize the proposed circuit in monolithic chip to use in battery-powered, portable electronic equipments such as wireless communication system devices.

References:

[1] C. Toumazou., F. J. Lidgey, and D. G. Haigh, Analogue IC design: the current-mode approach, London: Peter Peregrinus, 1990.

[2] A. S. Sedra, and K. C. Smith, Microelectronic circuits, 3rd ed., Florida: Holt, Rinehart and Winston, 1991.

[3] M. A. Ibrahim, S. Minaei, and H. A. Kuntman, “A 22.5 MHz current-mode KHN-biquad using differential voltage current conveyor and grounded passive elements,” International Journal of Electronics and Communication (AEU), vol. 59, pp. 311-318, 2005.

[4] A. M. Soliman, “New current mode filters using current conveyors,” International Journal of Electronics and Communication (AEU), vol. 51, pp. 275-278, 1997.

[5] W. Tangsrirat and W. Surakampontorn, “Systematic realization of cascadable current-mode filters using CDTAs,” Frequenz, vol. 60, pp. 241-245, 2006.

[6] M. Siripruchyanun and W. Jaikla, “Electronically controllable current-mode universal biquad filter using single DO-CCCDTA,” Circuits System Signal Processing, vol. 27, no. 1, pp. 113-122, 2008.

[7] J-W. Horng, “Current-mode universal biqudaratic filter with five inputs and one output using tree ICCIIs,” Indian Journal of Pure & Applied Physics, vol. 49, pp. 214-217, 2011.

[8] S. V. Singh, S. Maheshwari, D. S. Chauhan, “Single MO-CCCCTA-based electronically tunable current/trans-impedance-mode biquad universal filter,” Circuits and Systems, vol. 2, pp. 1-6, 2011.

[9] C.-N. Lee, “Multiple-mode OTA-C universal biquad filters,” Circuits Syst Signal Process, vol. 29, pp. 263–274, 2010.

[10] E. Arslan, B. Metin, O. Cicekoglu, “Multi-input single-output cacadable current-mode universal filter topology with a single current conveyor,” Proceedings of the Third IASTED International Conference Circuits, Signals, and Systems, pp. 62-66, 2005.

[11] R. Senani, K. K. Abdalla, D. R. Bhaskar, “A state variable method for the realization of universal current-mode biquads,” Circuits and Systems, vol. 2, pp. 286-292, 2011.

[12] N. Pandey, S. K. Paul, “VM and CM universal filters based on single DVCCTA,” Active and Passive Electronic Components, vol. 2011, Article ID 929507.

[13] S. V. Singh, S. Maheshwari, D. S. Chauhan, “Electronically tunable current-mode SIMO/MISO universal biquad filter using MOCCCCTAs,” International J. of Recent Trends in Engineering and Technology, vol. 3, no. 3, pp. 65-70, 2010.

[14] W. Chunhua, L. Haiguang, Z. Yan “Universal current-mode filter with multiple inputs and one output using MOCCII and MO-CCCA,” International Journal of Electronics and Communication (AEU), vol. 63, pp. 448-453, 2009.

[15] S. Özcan, H. Kuntman, O. Çiçekoglu "A novel multi-input single-output filter with reduced number of passive elements using single current conveyor," Proceedings of 43rd IEEE Midwest Symp. on Circuits and Systems, pp. 1-3, 2000.
[16] V. Sawangarom, T. Dumawipata, W. Tangsrirat, W. Surakampontorn "Cascadable three-input single-output current-mode universal filter using CDBAs," The 2007 ECTI International Conference, pp. 53-56, 2007.
[17] O. Channumsin, T. Pukkalanun, W. Tangsrirat, "Universal current-mode biquad with minimum components," Proceedings of the 2011 International Multi-Conference of Engineering and Computer Scientists, 2011.
[18] W. Tangsrirat and W. Surakampontorn, "Electronically tunable current-mode universal filter employing only plus-type current-controlled conveyors and grounded capacitors," Circuits System Signal Processing, vol. 27, no. 6, pp. 701-713, 2006.
[19] W. Tangsrirat, "Cascadable current-controlled current-mode universal filters using CDTAs and grounded capacitors," Journal of Active and Passive Electronic Devices, vol. 4, pp. 135–145, 2009.
[20] W. Tangsrirat, T. Dumawipata, W. Surakampontorn "Multiple-input single-output current-mode multifunction filter using current differencing transconductance amplifiers," International Journal of Electronics and Communication (AEU), vol. 61, pp. 209-214, 2007.
[21] W. Tangsrirat, T. Pukkalanun, "Structural generation of two integrator loop filters using CDTAs and grounded capacitors," International Journal of Circuit Theory and Applications, vol. 39, pp. 31-45, 2011.
[22] D. Biolek, R. Senani, V. Biolkova, Z. Kolka, "Active elements for analog signal processing: classification, review, and new proposals," Radioengineering, vol. 17, no. 4, p. 15-32, 2008.
[23] N. Herencsar, J. Koton, K. Vrba and J. Misurec, "A novel current-mode SIMO type universal filter using CFTAs," Contemporary Engineering, Sciences, vol.2, no.2, pp.59-66, 2009.
[24] Y. Maruyama, A. Hyogo, and K. Sekine, "A digitally programmable CMOS biquad filter using current-mode integrators," IEICE Transactions on fundamentals, vol. E85-A, pp. 316-323.
[25] P. Prommee, K. Angkeaw, M. Somdunyakanok, K. Dejhan. "CMOS-based near zero-offset multiple inputs max–min circuits and its applications," Analog Integr. Circuits Signal Process, vol. 61, pp. 93–105, 2009.

ISBN: 978-1-61804-085-5