วิศวกรรมสาร ม.ข. ปีที่ 31 ฉบับที่ 4 (337-344) มกราคม - ธันวาคม 2547
KKU Engineering Journal Vol. 31 No. 4 (337-344) October –December 2004

วงจรกรองสัญญาณไบควอดราทิกโหมดกระแสแบบหนึ่งอินพุทและสามเอาท์พุทโดยใช้วงจร OMA แบบหลายเอาท์พุท

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บทคัดย่อ

บทความนี้จะเป็นการนำเสนอวงจรกรองสัญญาณในโหมดกระแสแบบไบควอดราทิกที่มีหนึ่งขั้วสัญญาณอินพุทและสามขั้วสัญญาณเอาท์พุทโดยใช้วงจร OMA (Operational Mirrored Amplifier) จำนวนสามตัวทำหน้าที่เป็นอุปกรณ์แอคทีฟหลัก วงจรที่นำเสนอสามารถสังเคราะห์ฟังก์ชันกรองสัญญาณกระแสแบบกรองผ่านความถี่ต่ำ กรองผ่านแถบความถี่ และกรองผ่านความถี่สูง ได้พร้อมกันโดยปราศจากการเปลี่ยนแปลงรูปแบบของวงจรและอุปกรณ์ วงจรที่สังเคราะห์ขึ้นมีค่าความไวต่อการเปลี่ยนแปลงค่าอุปกรณ์พาสซีฟและแอคทีฟที่ต่ำและใช้อุปกรณ์พาสซีฟแบบเทียบกราวด์เท่านั้น นอกจากนี้พารามิเตอร์ ω_0 และ Q-factor ของวงจรยังสามารถปรับแต่งค่าได้อย่างอิสระไม่ส่งผลกระทบต่อกัน

A single-input and three-output current-mode biquadratic filter using multiple-output OMAs

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Abstract

A single-input and three-output current-mode biquadratic filter employing three multiple-output operational mirrored amplifiers is proposed. With high outputs impedance, the circuit simultaneously realizes lowpass, bandpass and highpass filter functions without changing its configuration and elements. The filter provides low sensitivities, uses only grounded passive elements and the parameters ω_0 and Q-factor can be orthogonally tuned.

Introduction

Recently, there has been great emphasis in the design and implementation of analog signal processing circuits using operational mirrored amplifiers (OMAs) and four-terminal floating-nullors (FTFNs) as active elements, owing to the usefulness and advantages over current conveyors [M. Higashimura. 1991]. Several techniques for realizing current-mode filters have been described [M.T. Abuelma'atti, and H.A. Al-Zaher. 1999, J. Malhotra and R. Senani. 1994, C.M. Chang. 1993 and S. Ozoguz and C. Acar. 1998]. Among these is a single-input and three-output (SITO) type current-mode multifunctional filter using OMAs [S. Ozoguz and C. Acar. 1998]. The filter offers particularly attractive features, such as, simultaneously realizes lowpass (LP), bandpass (BP) and highpass (HP) characteristics without changing the circuit configuration and elements, and provides high impedance outputs. However, its drawbacks are that it employs four OMAs and its natural angular frequency ω_0 and Q-factor are interdependent. More importantly, it requires floating passive elements. In monolithic ICs, it is highly desirable to have all the passive elements, in particular the grounded capacitors. Also the parasitic capacitances can be absorbed, since they are in parallel with the grounded capacitors [M. Bhusan and R.W. Newcomb. 1967., M.T. Abuelma'atti, A.A. Al-ghumaiz, and M.H. Khan. 1995].

The goal of this paper is to present the current-mode SITO biquadratic filter employing only three multiple-output OMAs, where all the passive elements are grounded. The proposed filter realizes three current transfer functions, i.e., lowpass (LP), bandpass (BP) and highpass (HP) simultaneously with high output impedances, and all passive and active sensitivities are low. Moreover, it also offers the attractive feature of independent grounded element control of the filter parameters ω_0 and Q-factor.

Proposed configuration

In this work, a multiple-output OMA that is modified from the conventional OMA realization[Malhotra and R. Senani. 1994, S. Ozoguz and C. Acar. 1998] by adding new output terminals is introduced. Fig.1 shows the circuit implementations and representations of the multiple-output OMAs using power-supply current-sensing technique. This building blocks can be characterized by the following port relations :

$$v_2 = v_1 \ , \ i_1 = i_2 = 0 \ \text{and} \ \ i_n = \ldots = i_5 = i_4 = i_3 \tag{1}$$

Using the above building blocks, Fig. 2 shows the proposed current-mode SITO filter using three multiple-output OMAs, four grounded resistors and two grounded capacitors. An element circuit analysis shows that the current transfer functions of this circuit can be expressed as :

$$T_{HP} = \frac{i_{o1}}{i_{in}} = \frac{s^2\left(\frac{R_3}{R_4}\right)}{D(s)} \tag{2}$$

$$T_{BP} = \frac{i_{o2}}{i_{in}} = -\frac{s\left(\frac{R_2R_3C_2}{R_4}\right)}{D(s)} \tag{3}$$

and

$$T_{LP} = \frac{i_{o3}}{i_{in}} = -\frac{\left(\frac{R_3}{R_1R_2R_4C_1C_2}\right)}{D(s)} \tag{4}$$

where

$$D(s) = s^2 + s\left(\frac{R_3}{R_1R_4C_1}\right) + \left(\frac{R_3}{R_1R_2R_4C_1C_2}\right) \tag{5}$$

It is shown from above equations that this filter can realize HP (T_{HP}), BP (T_{BP}) and LP (T_{LP}) current transfer functions simultaneously without changing the circuit configuration and elements. It also provides high impedance output ports, which is very suitable for cascading systems. Moreover, the filter employs only grounded passive elements, which is beneficial for IC implementation.

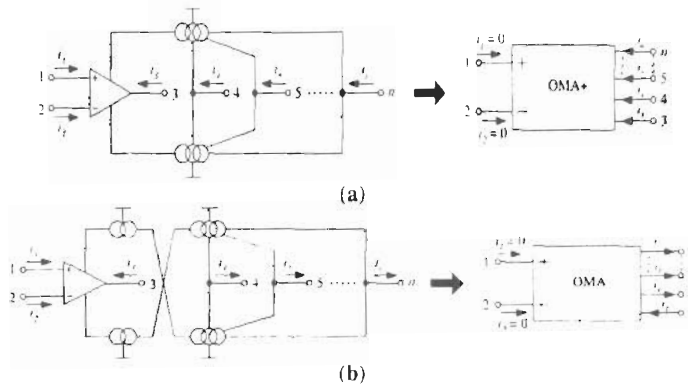

Figure 1 : Circuit implementation and circuit representation of the multiple-output OMAs
(a) positive multiple-output OMA (b) negative multiple-output OMA

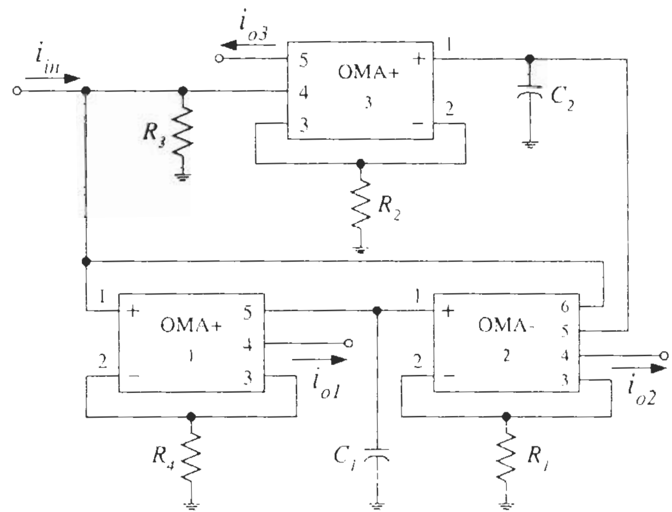

Figure 2 : Proposed SITO current-mode biquadratic filters Using multiple-output OMAs

The natural angular frequency ω_o and the Q-factor of this configuration can be given by

$$\omega_o = \sqrt{\frac{R_3}{R_1 R_2 R_4 C_1 C_2}} \tag{6}$$

and

$$Q = \sqrt{\frac{R_1 R_4 C_1}{R_2 R_3 C_2}} . \tag{7}$$

The sensitivities of ω_0 and Q-factor to the passive elements are equal to 0.5 in magnitude, all of which are small. Furthermore, by setting $R_1 = R_4 = R_A$, $R_2 = R_3 = R_B$ and $C_1 = C_2 = C$, then the parameters ω_0 and Q-factor of this filter can be rewritten as

$$\omega_o = \frac{1}{R_A C} \tag{8}$$

and

$$Q = \frac{R_A}{R_B} . \tag{9}$$

It is important to point out that the ω_0 can be tuned by the grounded resistors R_1 and R_4 and/or the grounded capacitors C_1 and C_2 without disturbing the Q-factor. Moreover, the Q-factor can be independently adjusted through the grounded resistors R_2 and R_3. This means that the parameters ω_o and Q-factor can be orthogonally tuned through grounded passive elements. In addition, if the grounded resistors R_1 and R_4 are replaced by such as FETs-based voltage-controlled resistors, then the ω_0 can be electronically tuned. On the other hand, if we fix R_A and the grounded resistors R_2 and R_3 are replaced by voltage-controlled resistors, the Q-factor can also be electronically tuned.

By taking into consider the non-ideal performance of the multiple-output OMA, its characteristics can be modeled as $v_2 = \beta_i v_1$, $i_n = \ldots = i_5 = i_4 = \alpha_i i_3$ where $\beta_i = 1 - \varepsilon_i (|\varepsilon| \ll 1)$, denotes the input voltage tracking error, and $\alpha_i = 1 - \delta_i (|\delta| \ll 1)$, represents the output current tracking error of the i-th multiple-output OMA (i = 1, 2, 3). Reanalysis of the configuration in Fig.2 shows that the parameters ω_{on} and Q_n -factor become :

$$\omega_{on} = \frac{1}{R_A C}\sqrt{\beta_1 \beta_2 \beta_3 \alpha_1 \alpha_2 \alpha_3} \tag{10}$$

and

$$Q_n = \frac{R_A}{R_B}\sqrt{\frac{\beta_3 \alpha_3}{\beta_1 \beta_2 \alpha_1 \alpha_2}} \tag{11}$$

For example, if $\beta_i \cong 0.99$ and $\alpha_i \cong 0.98$, the divergence of the parameters ω_{on} and Q_n from their ideal values (ω_0 and Q) are found to have the deviation of 4.43% and 1.52% respectively. In addition, it can easily be verified from equations (10) and (11) that that all of its active sensitivities with respect to β_i and α_i are also equal to 0.5 in magnitude.

Simulation results

The proposed filter of Fig.2 has been simulated through the use of a PSPICE simulation program. The multiple-output OMAs were built by employing AD704 operational amplifier together with improved Wilson current mirrors composed of *pnp* 2N2907A and *npn* 2N2222A transistors. The power supplies used were taken as $\pm V = \pm 15\,\text{V}$ and $C_1 = C_2 = 5\,\text{nF}$. Fig.3 shows the simulated frequency responses for $R_A = R_B = 10\,\text{k}\Omega$, $Q = 1$ and $f_0 = 3.18\,\text{kHz}$. It can be seen that the proposed filter performs well for all the three current transfer functions.

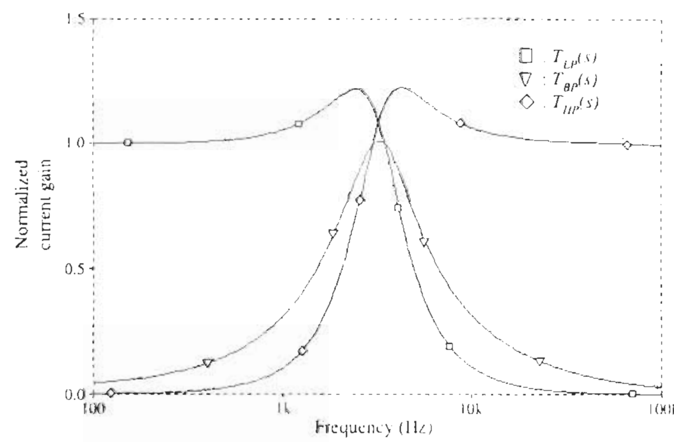

Figure 3 : Frequency responses of LP, BP and HP filters when $R_A = R_B = 10\,\text{k}\Omega$ and $C_1 = C_2 = 5$ nF.

For the controllability of the ω_0, Fig.4 shows BP output responses for three different values of $R_i = R_A = R_B$; i.e., $R_i = 5\,\text{k}\Omega$, 10 kΩ and 20 kΩ. The corresponding ω_0 obtained by simulation are 6.45 kHz, 3.23 kHz and 1.62 kHz, respectively, and the calculated values from eqn. (4) are 6.36 kHz, 3.18 kHz and 1.59 kHz, respectively. The simulated values are in good agreement with the predicted values. The obtained responses of the BP output for variable Q-factor (i.e.; Q-factor = 1, 2, 10) are shown in Fig.5, while R_A set to constant at 10 kΩ. This figure shows that the various values of Q-factor can be obtained by varying R_B without disturbing the parameter ω_0. It can be concluded from above mentioned that in both cases the filter characteristics are very close to the theoretical analysis.

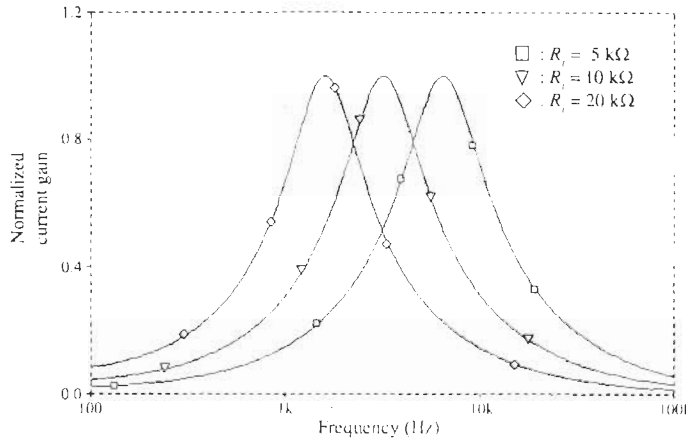

Figure 4 : Simulation results of BP response for various values of ω_0

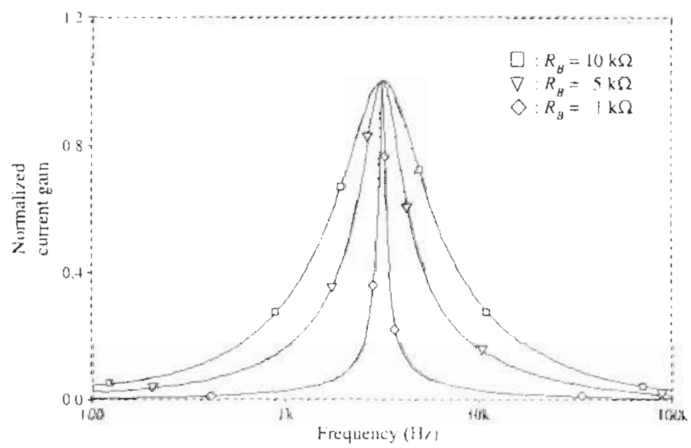

Figure 5 : Simulation results of BP response for various values of Q-factor

Conclusions

A current-mode SITO biquadratic filter using only three multiple-output OMAs has been proposed. The circuit provides the following advantages: (i) simultaneous realization of LP, BP and HP filters without changing the circuit configuration and elements, (ii) employment of only grounded passive elements, (iii) suitable for cascading structure, (iv) independent controlling of the parameters ω_o and Q-factor, and (v) low passive and active sensitivities. The validity of the proposed filter has been confirmed by the PSPICE simulation results.

Acknowledgment

This work is partly funded by the Thailand Research Fund (TRF) under the Senior Research Scholar Program; grant number RTA4680003.

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