Chung Yuan Journal, Vol. 31, No. 1 / 2003, March/ pp. 49-51

The KHN filter employing tunable transresistance amplifiers (TRAs)

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(Received: April 25, 2002; Accepted: May 30, 2002)

ABSTRACT

The KHN filter employing transresistance amplifiers (TRAs) is proposed and simulation results using HSPICE are demonstrated. This TRA is composed of three positive-type second generation current conveyors (CCII+'s) and a resistor for simulation. Simulation results that confirm the theoretical analysis are obtained.

Key words: *transresistance amplifier(TRA), positive-type 2nd generation current conveyor (CCII+).*

I. Introduction

Recently there is a growing interest to current-mode circuit applications [1], because the traditionally designing methods based on op-amps are no longer adequate. Also, it is well known that the bandwidth of a voltage mode op-amps depends on the closed-loop voltage gain. TRA is an essential building block [2-3] found wide applications in multipliers/dividers [4] and MOSFET-C integrators [5-6]. The time constant of a TRA is small and insensitive to parasitic capacitances. Furthermore, the operational transconductance amplifier (OTA), which is widely used as a basic VLSI circuit block [7-9], can also be substituted by a TRA, and its transfer characteristic is opposite to that of the OTA.

In this paper, we propose a biquad using TRAs, which is constructed with three CCII+'s and one resistor (Rm). The proposed KHN circuit can be simultaneously realized as lowpass, bandpass and highpass filters.

II. Circuit description

Figure 1(a), 1(b) show a CCII+ and a TRA, respectively. The characteristics of a CCII+ and a TRA can be represented by

$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \quad \text{(For a CCII+)} \qquad (1)$$

$$\begin{bmatrix} V_+ \\ V_- \\ V_{out} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ R_m & -R_m & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_0 \end{bmatrix} \quad \text{(For a TRA)} \qquad (2)$$

Obviously, both input terminals of a TRA are virtually grounded and the output voltage is the difference of two input currents multiplied by a tunable transresistance Rm. Thus, the TRA constructing with three CCII+'s and one resistor is shown in figure 2 for simulation.

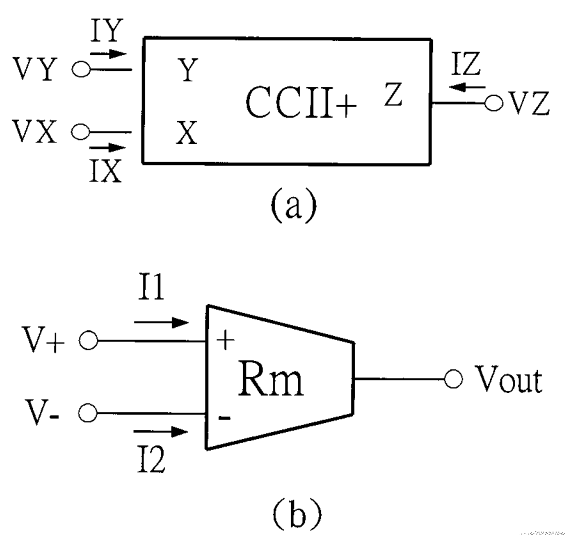

Fig. 1. symbol of (a) CCII+ and (b) TRA

We can then utilize the TRA (Figure 2) to implement the KHN biquad. The signal flow diagram of the biquad is shown in Figure 3. Figure 4 illustrates its actual circuit.

The transfer functions for this biquad can be obtained through Figure 3. The output voltage of Figure 4 can be expressed as

$$\frac{V_{lp}}{V_i}=\frac{\frac{R_3R_{m3}}{R_2R}+\frac{R_{m1}R_{m2}R_{m3}}{R_2R^2}}{1+\frac{R_{m1}}{R_f}+\frac{R_3R_{m3}}{R_1R^2}+\frac{R_{m1}R_{m2}R_{m3}}{R_2R^2}+s(R_{m2}C+R_{m3}C+\frac{R_{m1}R_{m2}C}{R_f}+\frac{R_{m1}R_{m3}C}{R_f})+S^2C^2R_{m2}R_{m3}}$$

$$\frac{V_{bp}}{V_i}=\frac{-S(R_3R_{m3}C+\frac{R_{m1}R_{m2}R_{m3}C}{R})}{1+\frac{R_{m1}}{R_f}+\frac{R_3R_{m3}}{R_1R^2}+\frac{R_{m1}R_{m2}R_{m3}}{R_2R^2}+s(R_{m2}C+R_{m3}C+\frac{R_{m1}R_{m2}C}{R_f}+\frac{R_{m1}R_{m3}C}{R_f})+S^2C^2R_{m2}R_{m3}}$$

$$\frac{V_{hp}}{V_i}=\frac{S^2C^2R_{m1}R_{m2}R_{m3}}{1+\frac{R_{m1}}{R_f}+\frac{R_3R_{m3}}{R_1R^2}+\frac{R_{m1}R_{m2}R_{m3}}{R_2R^2}+s(R_{m2}C+R_{m3}C+\frac{R_{m1}R_{m2}C}{R_f}+\frac{R_{m1}R_{m3}C}{R_f})+S^2C^2R_{m2}R_{m3}}$$

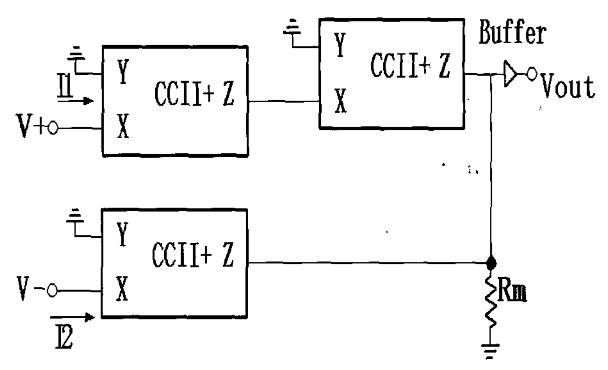

Fig. 2. TRA using CCII+'s

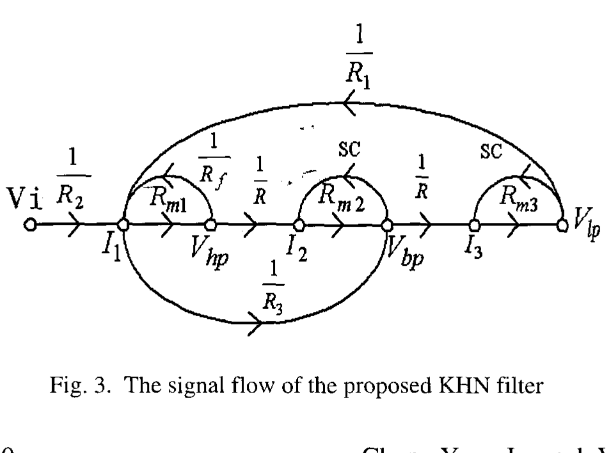

Fig. 3. The signal flow of the proposed KHN filter

III. Sensitivity analysis

By definition, The sensitivities of the frequency ω_o and Q to the transresistance parameter R_{m1} of the first TRA are given by $S^{\omega_0}_{R_{m1}}=\frac{\partial\omega_0}{\partial R_{m1}}\frac{R_{m1}}{\omega_0}=\frac{1}{2}$ while $\frac{R_{m1}R_{m2}R_{m3}}{R_1R_L}+\frac{R_{m1}}{R_f}>>\frac{R_3R_{m3}}{R_1R}+1$ $S^{Q}_{R_{m1}}=\frac{\partial Q}{\partial R_{m1}}\frac{R_{m1}}{Q}=1$ while $R_{m1}+R_{m3}>>R_{m1}(\frac{R_{m1}+R_{m3}}{R_f})$ Likewise, $S^{\omega_0}_{R_{m2}}$, $S^{\omega_0}_{R_{m3}}$, $S^{Q}_{R_{m2}}$, and $S^{Q}_{R_{m3}}$ can also be obtained in the same manner.

IV. Simulation results

To confirm the theoretical analysis, we simulated the circuit presented in Figure 4 by means of H-spice. Meanwhile, we selected passive element values of,

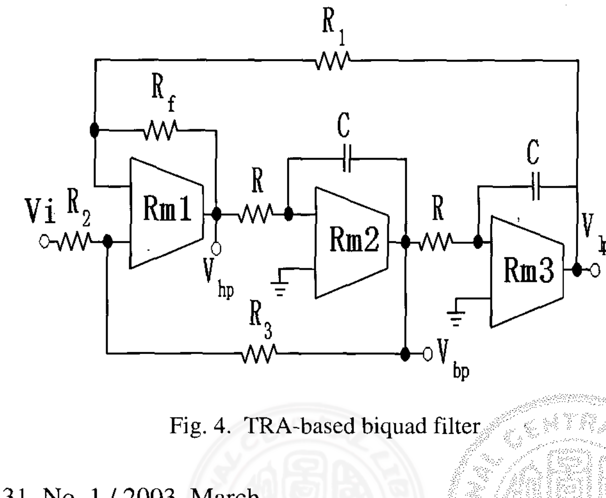

Fig. 4. TRA-based biquad filter

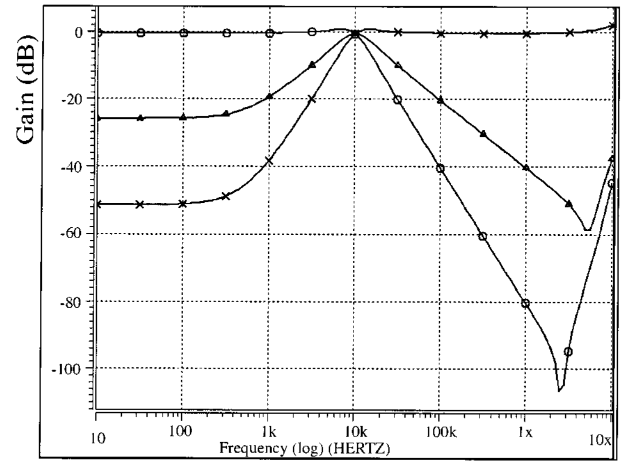

Fig. 5. HSPICE simulation results of the proposed circuit. Δ, simulated bandpass filter response; ○, simulated lowpass filter response; ×, simulated highpass filter response.

$R_{m1} = R_{m2} = R_{m3} = 300k\Omega$ $R = R_1 = R_2 = T_f = 15.9k\Omega$, $R_3 = 16k\Omega$, C = 1nF. The power supply of a TRA is ±5V.

Figure 5 shows the simulation results. It appears that these results are consistent with the theoretical results. The difference in the high frequency region is stemming from the parasitic impedances of the current conveyors.

V. Conclusion

A new biquad using tunable TRAs for realizing lowpass, bandpass and highpass functions is presented. Simulation results which confirm the theoretical analysis are obtained.

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以可調轉阻放大器(TRAs)實現 KHN 濾波器

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摘　要

這篇提出以可調轉阻放大器(TRA)來設計的KHN濾波器，其模擬結果也以 HSPICE 驗證。因模擬時TRA 是由三個第二代正型電流傳輸器(CCII+'s)及一個電阻器所構成，故其適用於高頻及IC實現。模擬結果也證實理論分析。

關鍵詞：轉阻放大器，第二代電流追隨器(正型)。