A VERSATILE CURRENT-MODE BIQUAD USING OPERATIONAL AMPLIFIERS

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Abstract A versatile current-mode biquadratic filter using three operational amplifiers and nine passive elements is proposed. By suitably choosing the output branch, lowpass, bandpass, highpass, bandstop and allpass transfer functions are realized simultaneously without changing the circuit configuration and elements. Two circuits, one is for low frequency application and the other for high frequency, are proposed. The center frequency, quality factor and gain constants of the circuit can be tuned independently. Simulated results show that the circuits work successfully.

Key words Current-mode circuit; Transfer function; Biquad filter; Operational amplifier

I. Introduction

Recently, many circuits for realizing current-mode transfer function using active devices have been reported[1-11]. Current-mode circuits have the potential advantages of inherent wide bandwidth, wide dynamic range, low power dissipation and simple circuitry over the voltage-mode counterparts. One technique for obtaining a current-mode circuit is to apply duality or adjoin network concept to the well-developed voltage-mode circuits[1'3]. The other is the direct synthesis of current-mode transfer function using active devices such as operational amplifiers (OPA’s), current conveyors (CCII’s) and operational transconductance amplifiers (OTA’s)[2,4'11]. Most of these circuits need more than three active devices and have the limited versatility in the realizable transfer function and moreover, the quality factor Q, center frequency ω₀ and gain constant H cannot be tuned independently.

In this paper, two versatile current-mode biquads using three OPA’s are proposed, one of which is for low frequency application and the other is for high frequency. By the suitably choosing the output branch, five current-mode biquad transfer functions with lowpass(LP), bandpass(BP), highpass(HP), bandpass(BP) and allpass(AP) characteristics are realized simultaneously without changing the circuit configuration and elements. Q, ω₀ and H of these circuits can be tuned independently. Single pole model of OPA gain is utilized to develop a biquad for high frequency. The realized circuit is simple and needs no frequency compensation. Computer simulation show that the proposed circuits work successfully.

II. Circuit Analysis

1. Fundamental biquad

Fig.1 shows the fundamental current-mode biquad circuit using three nullator-norator pairs. Replacing nullator-norator pair with OPA’s, we obtain the biquad circuit as shown in Fig.2.
Voltage-current relationship of the circuit in Fig.2 is expressed by

\[
\begin{bmatrix}
0 & 1 & 0 & 0 & A_1 & 0 \\
0 & 0 & 1 & 0 & 0 & A_2 \\
1 + A_3 & 0 & 0 & -A_3 & 0 & 0 \\
0 & -sC_0 & 0 & -G_0 & G_0 + sC_0 & 0 \\
0 & 0 & -G_3 & -G_2 & 0 & G_2 + G_3 \\
0 & -G_1 & 0 & G_0 + G_1 + G_2 + sC_1 & -G_0 & -G_2 \\
\end{bmatrix}
\begin{bmatrix}
V_1 \\
V_2 \\
V_3 \\
V_4 \\
V_5 \\
V_6 \\
\end{bmatrix} =
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
0 \\
I_i \\
\end{bmatrix}
\]  

(1)

where \(I_i\) is the input current and \(A_k (k = 1, 2, 3)\) are the open-loop gain of OPA's. From Eq.(1), the output voltage \(V_m (m = 1, 2, 3)\) are given by

\[
\begin{bmatrix}
V_1 \\
V_2 \\
V_3 \\
\end{bmatrix} = \begin{bmatrix}
(1 + A_3^{-1})^{-1}[sC_0 + (G_0 + sC_0)A_1^{-1}][G_3 + (G_2 + G_3)A_2^{-1}] \\
-G_0[G_3 + (G_2 + G_3)A_2^{-1}] \\
-G_2[sC_0 + (G_0 + sC_0)A_1^{-1}] \\
\end{bmatrix} \frac{I_i}{F}
\]  

(2)

where

\[
F = [G_3 + (G_2 + G_3)A_2^{-1}][(G_0 + G_1 + G_2 + sC_1)[sC_0 + (G_0 + sC_0)A_1^{-1}] + G_0(G_1 - G_0A_1^{-1})] - G_2^2[sC_0 + (G_0 + sC_0)A_1^{-1}]A_2^{-1}
\]  

(3)