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Novel Plus Type DVCC-Based Current-Mode Biquadratic Circuit

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Abstract: This paper presents a novel current-mode biquadratic circuit employing only plus type DVCCs (differential voltage current conveyors). The circuit enables LP (low-pass), BP (band-pass), HP (high-pass), BS (band-stop) and AP (all-pass) responses by the selection and addition of the input and output currents without any component matching constraints. Moreover the circuit parameters ω_0 and Q can be set orthogonally adjusting the circuit components. A design example is given together with simulation results by PSPICE.

Key words: Analogue circuit, biquadratic characteristic, DVCC, CMOS technology.

1. Introduction

High performance analogue circuits have received considerable attention. The circuit designs using active devices such as CCIIs (second generation current conveyors), DVCCs (differential voltage current conveyors), OTAs (operational trans-conductance amplifiers), etc. have been reported in the literature [1-4]. A DVCC is a very useful active device, and DVCC-based circuit is suitable for wide band operation. The plus type DVCC is composed of simpler circuit configuration than the minus type one. Hence it has wide band operation and low power performance compared with the minus type DVCC.

The biquadratic circuit is a convenient second-order function block for realizing high-order circuit transfer functions. Several biquadratic circuits using the DVCCs have been discussed previously [2, 4]. However the plus type DVCC-based biquadratic circuit [5] has not yet been studied sufficiently.

This paper introduces a current-mode universal biquadratic circuit employing only the plus type DVCCs and grounded passive components. First we show a basic current-mode biquadratic circuit, and then typical current-mode circuit is consisted of using the basic current-mode one. The circuit enables LP (low-pass), BP (band-pass), HP (high-pass), BS (band-stop) and AP (all-pass) responses by the selection and addition of the input and output currents with no component matching constraints. Moreover the circuit parameters ω_0 and Q can be set orthogonally adjusting the circuit components.

A design example is given with PSPICE simulation, and the circuit workability is confirmed.

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2. DVCC

The symbol of the plus type DVCC is given in Fig. 1. The DVCC is characterized by the following terminal equation:

$$V_x = V_{y1} - V_{y2}, \quad I_z = I_x \tag{1}$$

Fig. 2 shows the DVCC [4] with MOS transistors.

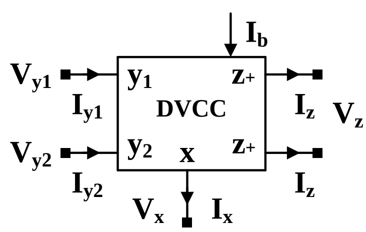


Fig. 1 Symbol of DVCC.

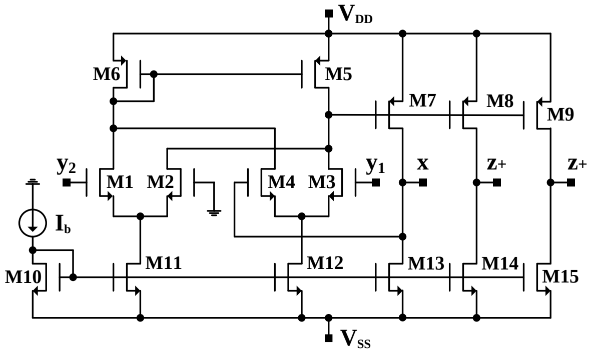


Fig. 2 Plus type DVCC with MOS transistors.

3. DVCC-Based Current-Mode Biquadratic Circuit

Fig. 3 shows a basic current-mode biquadratic circuit configuration. This circuit is constructed with 3 plus type DVCCs and grounded passive components.

The current outputs $I_{o1}(s)$ and $I_{o2}(s)$ are given by:

$$I_{o1}(s) = -\frac{1}{s^2C_1C_2R_1R_2 + sC_2R_1R_2/R_3 + 1} I_i(s) \quad (2)$$

$$I_{o2}(s) = -\frac{sC_2R_1R_2/R_3}{s^2C_1C_2R_1R_2 + sC_2R_1R_2/R_3 + 1} I_i(s) \quad (3)$$

Fig. 4 shows the typical current-mode biquadratic circuit employing the basic current-mode one. This circuit can realize various circuit responses by selection and addition of the circuit currents.

The LP and BP responses can be achieved by selection of the current output as follows:

$$T_{LP}(s) = \frac{I_{o1}(s)}{I_{in}(s)} = -\frac{R_a}{R_b}\frac{1}{s^2C_1C_2R_1R_2 + sC_2R_1R_2/R_3 + 1} \quad (4)$$

$$T_{BP}(s) = \frac{I_{o2}(s)}{I_{in}(s)} = -\frac{R_a}{R_b}\frac{sC_2R_1R_2/R_3}{s^2C_1C_2R_1R_2 + sC_2R_1R_2/R_3 + 1} \quad (5)$$

Moreover the HP, BS and AP responses are realized by the current additions of $I_{HP}(s) = I_i(s) + I_{o1}(s) + I_{o2}(s)$, $I_{BS}(s) = I_i(s) + I_{o2}(s)$ and $I_{AP}(s) = I_{BS}(s) + I_{o2}(s)$, respectively. The circuit transfer functions are given as:

$$T_{HP}(s) = \frac{I_{HP}(s)}{I_{in}(s)} = \frac{R_a}{R_b}\frac{s^2C_1C_2R_1R_2}{s^2C_1C_2R_1R_2 + sC_2R_1R_2/R_3 + 1} \quad (6)$$

$$T_{BS}(s) = \frac{I_{BS}(s)}{I_{in}(s)} = \frac{R_a}{R_b}\frac{s^2C_1C_2R_1R_2 + 1}{s^2C_1C_2R_1R_2 + sC_2R_1R_2/R_3 + 1} \quad (7)$$

$$T_{AP}(s) = \frac{I_{AP}(s)}{I_{in}(s)} = \frac{R_a}{R_b}\frac{s^2C_1C_2R_1R_2 - sC_2R_1R_2/R_3 + 1}{s^2C_1C_2R_1R_2 + sC_2R_1R_2/R_3 + 1} \quad (8)$$

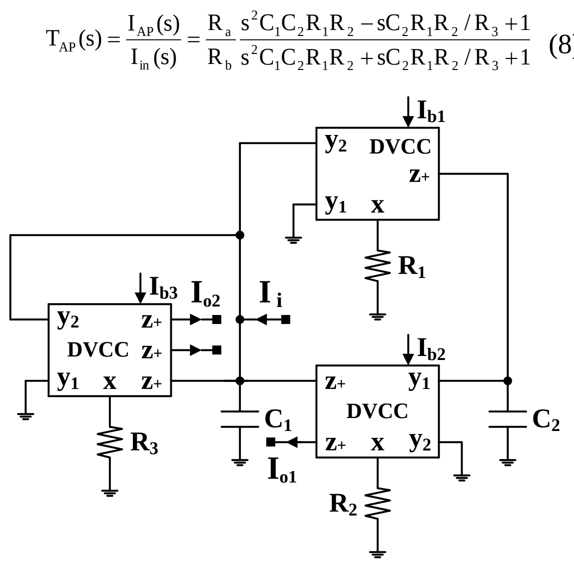


Fig. 3 Basic current-mode biquadratic circuit.

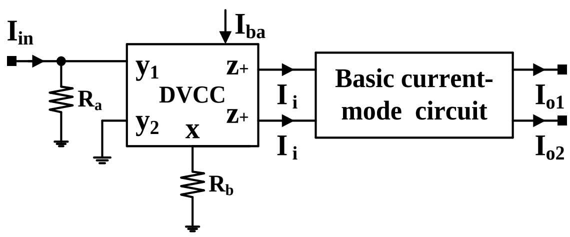


Fig. 4 Typical current-mode biquadratic circuit.

Thus five standard circuit responses can be obtained by the selection and addition of the circuit currents.

The circuit parameters ω_0, Q and H are represented as below:

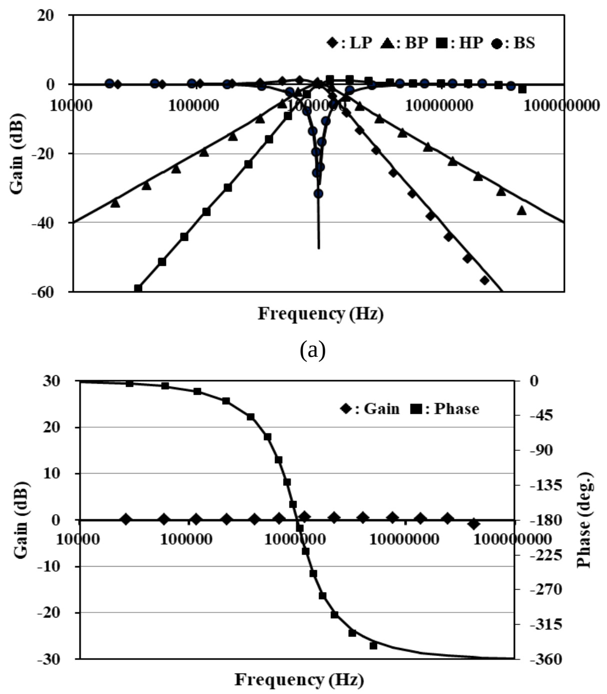
$$\omega_0 = \sqrt{\frac{1}{C_1C_2R_1R_2}}, \quad Q = R_3\sqrt{\frac{C_1}{C_2R_1R_2}}, \quad H = \frac{R_a}{R_b} \quad (9)$$

The circuit parameter ω_0 and Q can be set orthogonally according to the circuit components, meanwhile the parameter H is able to set independently.

In addition, voltage-mode biquadratic circuit can easily be realized using the basic current-mode one.

4. Design Example and Simulation Responses

We verified the circuit operation using PSPICE simulation program. As a design example, we tried to achieve a current-mode circuit with a specification of f_0



(a)

(b)

Fig. 5 Simulation responses.

$= (\omega_0/2\pi) = 1$ MHz, Q = 1.0 and H = 1.0. In the simulation, we have used the DVCC shown in Fig. 2. In order to achieve the specification above, we set that the circuit resistors and capacitors were $R_1 = R_2 = R_3 = R_a = 12$ kΩ, $R_b = 10$ kΩ and $C_1 = C_2 = 12$ pF, respectively.

Fig. 5 shows the simulation responses. Fig. 5a shows the LP, BP, HP and BS responses, and the AP response is shown in Fig.5b. This can be viewed as an excellent result over a wide frequency range. Here we set that the input current, bias currents and DC supply voltages of the DVCCs were $I_{in} = 10$ μA, $I_{b1} = I_{b2} = I_{b3} = I_{ba} = 10$ μA and $V_{DD} = -V_{SS} = 0.8$ V. The power dissipation was 0.351 mW.

In this simulation, we have set the aspect ratio W/L = 20 μm/0.5 μm (M1-M4), 30 μm/2 μm (M5-8, M13) and 10 μm/2 μm (M9-12, M14-15), respectively. And we have used device parameters of MOSIS 0.5 μm for other parameters.

5. Conclusions

A novel current-mode biquadratic circuit employing only the plus type DVCCs and grounded passive components has been proposed. We have demonstrated that the circuit can achieve five standard circuit responses by selecting and adding the input and output currents without the component matching constraints. The achievement example has been given together with simulation results by PSPICE. The simulation responses were appropriate enough over a wide frequency range.

The non-idealities (i.e., x-terminal resistance, voltage and current tracking errors) of the DVCC affect the circuit performances. The solution for this will be discussed in the future.

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