A Plus Type CC-Based Current-Mode Universal Biquad

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Abstract: This paper introduces a current-mode universal biquad circuit using only plus type CCs (current conveyors) (i.e. DVCCs (differential voltage current conveyors) and CCIIIs (second generation 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/or addition of the input and output currents without any component matching constraints. Moreover, the circuit parameters $\omega_0$ and $Q$ can be set orthogonally adjusting the circuit components. A design example is given together with simulation responses by PSPICE.

Key words: Analog circuit, biquad responses, current conveyors, CMOS technology.

1. Introduction

High performance active circuits have received much attention. The circuit designs using active devices such as the CCs (current conveyors), OTAs (operational trans-conductance amplifiers), OTRAs (operational trans-resistance amplifiers), etc. have been reported in [1-3]. A CC is a very useful active device, and CC-based circuit is suitable for high frequency operation. There are some kinds of CCs (e.g. CCII (second generation current conveyor), CCIII (third generation current conveyor), DVCC (differential voltage current conveyor, etc.). The plus type CCs are composed of simpler circuit configuration than the minus type ones. Hence they have wide frequency operation and low power performance compared with the minus type CCs.

The biquad circuit is a convenient second-order function block. Several biquad circuits using the CCs have been discussed previously [4, 5]. However, the plus type CC-based biquad circuit has not yet been studied sufficiently.

This paper introduces a current-mode universal biquad circuit using only the plus type CCs (i.e. DVCCs and CCIIIs) and grounded passive components.

First we show a basic current-mode biquad circuit, and then typical current-mode circuit is consisted of using the basic current-mode one. The circuit enables LP, BP, HP, BS and AP responses by the selection and/or addition of the input and output currents with no component matching constraints. Moreover, the circuit parameters $\omega_0$ and $Q$ can be set orthogonally adjusting the circuit components.

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

2. DVCC and CCII

The symbols of the plus type DVCC and CCII are given in Fig. 1. The DVCC and CCII are characterized by the following terminal equations:

$$V_x = V_{yi} - V_{yz} - I_x R_x, \quad I_x = I_y$$
$$V_y = V_{yi} - I_x R_x, \quad I_y = I_x$$

where $R_x$ denotes the parasitic resistance at the x-terminal.

Fig. 2 shows the DVCC [5] and CCII [1] with MOS transistors.

3. CC-Based Current-Mode Biquad

Fig. 3 shows a basic current-mode biquad circuit configuration. In this circuit, all the x-terminals of the CCs are connected to grounded resistors for minimizing the parasitic effects.
The current outputs $I_{o1}(s)$ and $I_{o2}(s)$ are given by:

$$I_{o1}(s) = \frac{(s^2 + 1/C_1/C_2R_3R_4)I_{in1}(s) - (1/C_1R_1)sI_{in2}(s)}{s^2 + (1/C_1R_1)s + 1/C_1C_2R_3R_4}$$  \hspace{1cm} (3)

$$I_{o2}(s) = \frac{-(1/C_1C_2R_3R_4)I_{in1}(s) + s^2 + (1/C_1R_1)sI_{in2}(s)}{s^2 + (1/C_1R_1)s + 1/C_1C_2R_3R_4}$$  \hspace{1cm} (4)

This circuit enables the LP, BP and BS responses by selection of the input and output currents as follows:

$$T_{lp}(s) = \frac{I_{o1}(s)}{I_{o1}(s)} = \frac{1/C_2C_3R_3}{s^2 + (1/C_1R_1)s + 1/C_1C_2R_3R_4}$$  \hspace{1cm} (5)

$$T_{bp}(s) = \frac{I_{o2}(s)}{I_{o2}(s)} = \frac{(1/C_1R_1)s}{s^2 + (1/C_1R_1)s + 1/C_1C_2R_3R_4}$$  \hspace{1cm} (6)

$$T_{bp}(s) = \frac{I_{o2}(s)}{I_{o2}(s)} = \frac{(1/C_1R_1)s}{s^2 + (1/C_1R_1)s + 1/C_1C_2R_3R_4}$$  \hspace{1cm} (7)

Moreover the HP response can be achieved by the current addition of $I_{hp}(s) = I_{o1}(s) + I_{o2}(s)$, and the AP response is performed selecting the input current $I_{in}(s) = I_{in1}(s) = I_{in2}(s)$. The circuit transfer functions are given as:

$$T_{hp}(s) = \frac{I_{o2}(s)}{I_{o1}(s)} = \frac{s^2}{s^2 + (1/C_1R_1)s + 1/C_1C_2R_3R_4}$$  \hspace{1cm} (8)

$$T_{ap}(s) = \frac{I_{o2}(s)}{I_{o2}(s)} = \frac{s^2 - (1/C_1R_1)s + 1/C_1C_2R_3R_4}{s^2 + (1/C_1R_1)s + 1/C_1C_2R_3R_4}$$  \hspace{1cm} (9)

Thus five standard circuit transfer functions can be obtained by choosing the circuit currents.

The typical current-mode biquadratic circuit is consisted of using the basic current-mode one shown in Fig. 4.

The circuit parameters $\omega_0$, $Q$ and $H$ are represented as below.
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![Image](310x551 to 537x693)

**Fig. 4** Typical current-mode biquad circuit.

$$\omega_0 = \frac{1}{\sqrt{C_1C_2R_1R_2}}, \quad Q = \frac{C_1}{C_2R_1R_2}, \quad H = \frac{R_a}{R_b} \quad (10)$$

The circuit parameters $\omega_0$ and $Q$ can be set orthogonally according to the circuit components, and meanwhile the parameter $H$ is set independently.

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

### 4. Design Example and Simulation Responses

We verified the circuit operation using PSPICE simulation program. As an example, we tried to achieve a current-mode circuit with $f_0 (= \omega_0/2\pi) = 1$ MHz, $Q = 1.0$ and $H = 1.0$. To achieve the specification above, we set the circuit resistors listed in Table 1.

![Image](310x380 to 537x536)

**Table 1** Circuit components.

| $x$   | LP     | BP     | HP     | BS     | AP   |
|-------|--------|--------|--------|--------|------|
| $R_1$ (kΩ) | 10.5   | 11.5   | 12.0   | 11.2   | 11.1 |
| $R_2$ (kΩ) | 10.5   | 11.5   | 12.0   | 11.2   | 11.1 |
| $R_3$ (kΩ) | 10.5   | 11.5   | 12.0   | 11.2   | 11.1 |

![Image](258x593 to 322x1058)

**Fig. 5** Simulation responses.

(M5 to M9), 10 μm/2 μm (M10 to M15), and the aspect ratios were 20 μm/1 μm (M1 to M4) and 10 μm/1 μm (others) in the CCII. And we used the model parameters from MOSIS 0.5 μm.

### 5. Conclusions

A current-mode universal biquad circuit employing plus type CCs and grounded passive components has been proposed. We have demonstrated that the circuit can achieve five circuit responses by selecting and/or 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. voltage and current tracking
errors) of the CC affect the circuit performances. The solution for this will be discussed in the future.

References

[1] Fabre, A., et al. 1996. “High Frequency Applications Based on a New Current Controlled Conveyor.” *IEEE Transactions on Circuits and Systems* 43 (2): 82-91.

[2] Abuelma’atti, M. T., et al. 2005. “A Novel Mixed-Mode OTA-C Universal Filter.” *International Journal of Electronics* 92 (7): 375-83.

[3] Cakir, C., et al. 2005. “Novel Allpass Filter Configuration Employing Single OTRA.” *IEEE Transactions on Circuits and Systems* 52 (3): 122-25.

[4] Ibrahim, M. A., et al. 2005. “A 22.5 MHz Current-Mode KHN-Biquad Using Differential Voltage Current Conveyor and Grounded Passive Elements.” *International Journal of Electronics and Communications* 59: 311-8.

[5] Tsukutani, T., et al. 2007. “Novel Current-Mode Biquadratic Circuit Using Only Plus Type DO-DVCCs and Grounded Passive Components.” *International Journal of Electronics* 94 (12): 1137-46.