Current Mode KHN-Equivalent Biquad using Dual-output Current Conveyors

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ABSTRACT

This study presents a current mode realization of the Kerwin-Huelsman-Newcomb (KHN) biquad using dual output current conveyors (DO-CCIIs). This cascadable insensitive circuit employs minimum number of all-grounded passive components. This is not the case in previously proposed CM KHN biquads, as well as other DO-CCII-based biquad filters that realize three basic filter transfer functions.

I. INTRODUCTION

The Kerwin-Huelsman-Newcomb (KHN) biquad [1] is a fundamental second order building block in many analog signal processing applications. It offers low passive and active sensitivities, low component spread and good stability. In order to overcome the limited frequency-bandwidth properties of the operational amplifiers, many KHN biquads based on different active components are reported in literature. Most of these KHN filters operate in voltage mode (VM) or transadmittance type [2-14], and only few of them operate in current mode (CM). In one of these [15], Ozoguz et.al. propose a Current Differencing Buffered Amplifier (CDBA)-based CM KHN circuit employing six resistors, two of which are floating. Another multi-input single-output type CM KHN configuration is introduced in [16] employing five current controlled current conveyor elements (CCCIIs). Since both of these circuits are of multi-input single-output type, they can realize only one filter transfer function at a time. On the other hand, Ibrahim et al. [17, 18] propose a CM KHN filter using three differential voltage current conveyors, four resistors and two capacitors.

In this work, taking into consideration the advantages of CM circuits over their VM counterparts, such as greater linearity, lower power consumption and wider bandwidth, we propose a new CM KHN-equivalent circuit using dual output current conveyors (DO-CCII), and minimum number of all-grounded passive components (i.e., only two resistors and two capacitors).

II. DO-CCII BASED CM KHN-EQUIVALENT BIQUAD

The symbolic notation of the DO-CCII is shown in Figure 1. This five terminal active element is characterized with the following equations [19-24]:

$$V_x=V_y, \quad I_y=0, \quad I_{z+}=I_x, \quad I_{z-}=-I_x \tag{1}$$

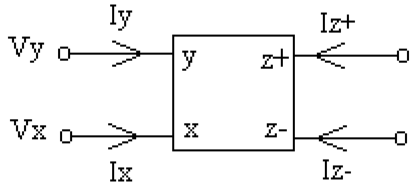

Figure 1. The dual output current conveyor symbol.

The proposed current mode KHN-equivalent biquad employing DO-CCII as active elements is shown in Figure 2.

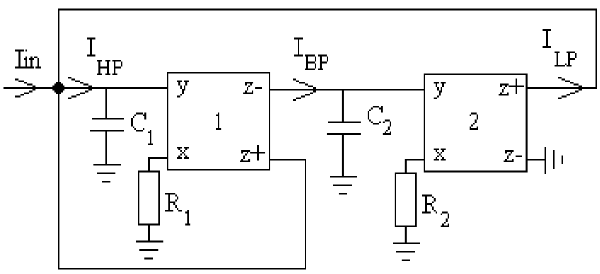

Figure 2. CM KHN-equivalent biquad using DO-CCII.

Analysis of this circuit yields the following current transfer functions:

$$\frac{I_{HP}}{I_{in}}=\frac{s^2}{D(s)}, \frac{I_{BP}}{I_{in}}=\frac{\frac{1}{R_1C_1}s}{D(s)}, \frac{I_{LP}}{I_{in}}=\frac{\frac{1}{R_1C_1R_2C_2}}{D(s)} \tag{2}$$

where

$$D(s) = s^2 + \frac{1}{R_1 C_1} s + \frac{1}{R_1 R_2 C_1 C_2} \quad (3)$$

The natural angular frequency and the quality factor can be given as

$$\omega_o = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}, \qquad Q = \sqrt{\frac{R_1 C_1}{R_2 C_2}} \quad (4)$$

Here, passive ω_o and Q sensitivities are all calculated as 1/2 in magnitude.

The main drawback of the current conveyor-based CM filters in the literature [25, 26] as well as that in Figure 2 is that some of the output currents are those of the involved passive components. Since in DO-CCII based filters the current of a grounded passive component can be taken from a high impedance terminal, the current of a grounded component can be easily retrieved [21]. This leads to a CM KHN filter which simultaneously realizes HP, BP, and LP responses at high impedance outputs, as shown in Figure 3, which enables easy cascading in CM.

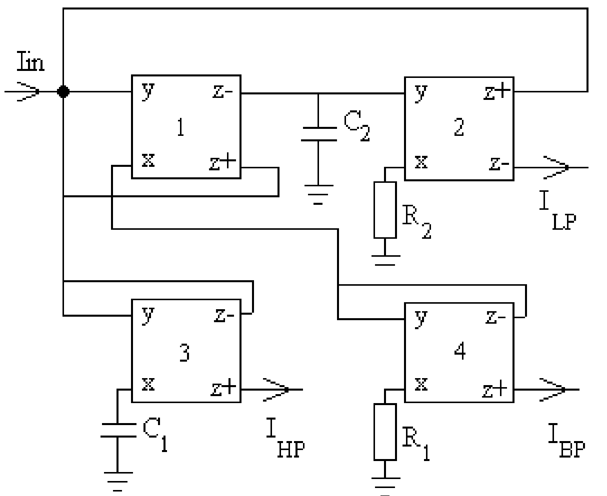

Figure 3. DO-CCII-based CM KHN-equivalent biquad which simultaneously realizes HP, BP, and LP responses at high impedance outputs.

III. THE EFFECT OF DO-CCII NON-IDEALITIES

Taking the non-idealities of the DO-CCII into account, its terminal relationships can be rewritten as follows:

$$V_x = \beta V_y, \quad I_y = 0, \quad I_{z+} = \alpha I_x, \quad I_{z-} = -\alpha I_x \quad (5)$$

where α, and β are current and voltage gains, respectively, and $\alpha = 1 - \varepsilon_i$, $\beta = 1 - \varepsilon_v$. Here, ε_i, ε_v are current and voltage tracking errors of the DO-CCII and their magnitudes are much less than unity.

Taking these non-idealities of the DO-CCII into account, characteristic polynomial of current transfer functions in (2) becomes

$$D(s) = s^2 + \frac{\alpha_1 \beta_1}{R_1 C_1} s + \frac{\alpha_1 \alpha_2 \beta_1 \beta_2}{R_1 R_2 C_1 C_2} \quad (6)$$

Hence the natural angular frequency and the quality factor can be calculated as

$$\omega_0 = \sqrt{\frac{\alpha_1 \alpha_2 \beta_1 \beta_2}{R_1 R_2 C_1 C_2}}, \qquad Q = \sqrt{\frac{\alpha_2 \beta_2 R_1 C_1}{\alpha_1 \beta_1 R_2 C_2}} \quad (7)$$

Active sensitivities of the natural angular frequency and the quality factor for the circuit in Figure 2 are

$$S_{\alpha 1}^{\omega_o} = S_{\alpha 2}^{\omega_o} = S_{\beta 1}^{\omega_o} = S_{\beta 2}^{\omega_o} = -S_{\alpha 1}^{Q} = S_{\alpha 2}^{Q} = -S_{\beta 1}^{Q} = S_{\beta 2}^{Q} = \frac{1}{2} \quad (8)$$

IV. SIMULATION RESULTS

In order to confirm the practical validity of the proposed circuit, it is simulated in SPICE using the CMOS DO-CCII given in Figure 4 [24], employing MIETEC 0.5µ process parameters. The designed CMOS DO-CCII is supplied with ±2.5V DC.

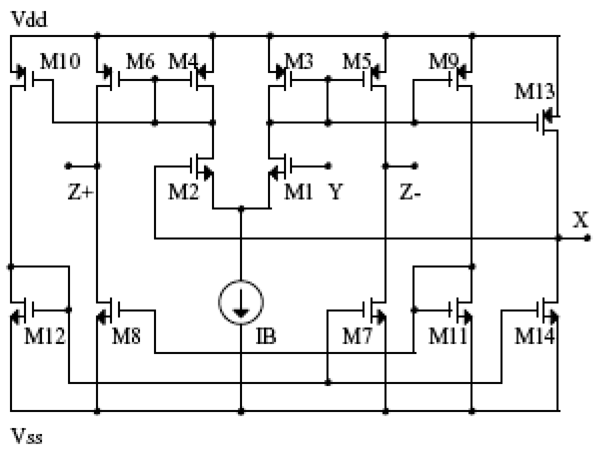

Figure 4. Simplified CMOS DO-CCII. I_B =100µA. [24].

Table 1 lists the dimensions of nMOS and pMOS transistors of this circuit. Figure 5 displays the simulation results for the proposed filter. Here, component values are selected as R1=R2=1kΩ, and C1=C2=1nF to yield f_o=159kHz and Q=1.

Table 1.Transistor W/L aspect ratios in figure 4.

Transistor	W / L
M1, M2, M5-M14	100/1
M3, M4	5/1

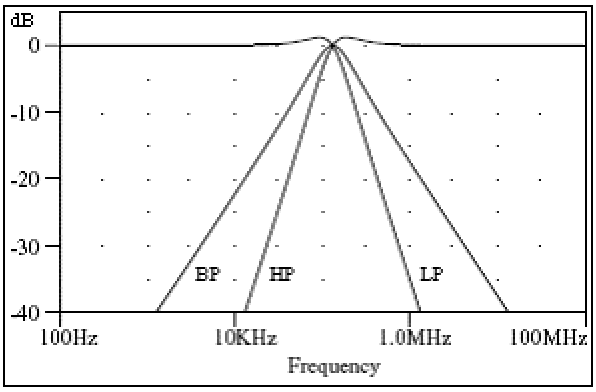

Figure 5. Results of circuit simulations for basic filter responses of the proposed CM KHN circuit for f_o=159kHz and Q=1.

To test the input dynamic range of the filter, the simulation has been repeated for a sinusoidal input signal at f_o=159kHz. The dependence of the output harmonic distortion of BP filter on input current amplitude is illustrated in Figure 6. From Figure 6, we see that the harmonic distortion rapidly increases if the input signal is increased beyond 600μA for the chosen DO-CCII implementation.

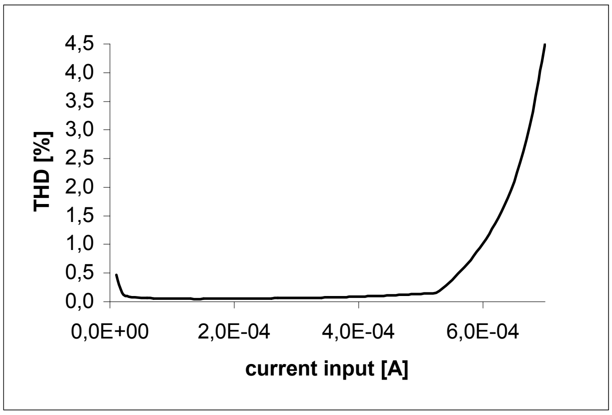

Figure 6. Output harmonic distortion of BP filter as a function of input current amplitude.

V. CONCLUSION

In this work, a new DO-CCII based CM KHN-equivalent biquad is presented. This filter employs four passive components, and they are free from passive parameter matching conditions. Note that, the number of passive components is minimum, and all of them are grounded. Simultaneous realization of this condition is neither the case in op-amp KHN biquad [1], nor in some more recently proposed CM KHN filters [15-18], and other types of DO-CCII-based biquads [19-23]. Therefore the proposed CM KHN filter offers ease of integration and tuning advantages. Moreover, output total harmonic distortion of this circuit is less than other CM KHN filters [e.g., 17] under similar circumstances. Since all output currents can be obtained at high impedance terminals, the circuit is easily cascaded. The circuit simulation results are in agreement with theory.

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