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NEW SECOND GENERATION CURRENT CONVEYOR-BASED CURRENT-MODE FIRST ORDER ALL-PASS FILTER AND QUADRATURE OSCILLATOR

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ABSTRACT

A new current-mode first order all-pass filter configuration is proposed and as it's an application a current-mode quadrature oscillator circuit is also presented in this paper. The proposed circuit consists of a second generation current conveyor (CCII), two different type resistors and one type capacitors. Since the output of the filter exhibits low output impedance, the synthesized filter can be cascaded without additional buffers. Furthermore, it does not impose any component matching constraint in analog signal processing circuits. To explore the performance of the proposed all-pass filter section, a new current-mode quadrature oscillator is implemented. The performances of the proposed all-pass filter as well as the quadrature oscillator are also investigated by applying sensitivity analysis to the both proposed circuits. Finally the theoretical results are verified with PSPICE simulations using a CMOS realization of CCII.

Keywords: Current Mode Filters, All-Pass Filter, Current Conveyors, Quadrature Oscillator, Sensitivity Analysis

YENİ İKİNCİ NESİL AKIM TAŞIYICI TEMELLİ AKIM MODLU BİRİNCİ DERECEDEN ALL-PASS FİLTRE VE QUADRATURE OSİLATÖR

ÖZET

Bu makalede yeni akım modlu birinci dereceden tümgeçiren filtre yapısı önerilmiş ve onun uygulaması olan akım modlu quadrature osilatör devresi gerçekleştirilmiştir. Önerilen devre ikinci nesil akım taşıyıcı (CCII), iki farklı direnç ve bir kondansatörden oluşmaktadır. Filtrenin çıkışı düşük empedansa sahip olduğundan sentezlenen devre kaskat olarak ek bir devre istemeden bağlanabilmektedir. Ayrıca bu devrenin Analog işaret işleme devrelerine uyarlanmasında her hangi bir zorlukla karşılaşılmamaktadır. Önerilen tümgeçiren devrenin performansını incelemek için yeni akım modlu quadrature osilatör devresi gerçekleştirlmiştir. Tümgeçiren devrenin performansını incelerken olduğu gibi, quadrature osilatörün performansını incelerken de duyarlılık analizi yapılmıştır. Teorik sonuçlar CMOS ile CCII gerçekleştirilerek PSPICE simulasyonu ile doğrulanmıştır.

Anahtar Kelimeler: Akım Modlu Filtre, Tümgeçiren Filtre,, Akım Taşıyıcı, Quadrature Osilatör, Duyarlılık Analizi

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1. INTRODUCTION

All-pass filters are one of the most important building blocks of many analog signal-processing applications and therefore have received much attention. They are generally used for introducing a frequency dependent delay while keeping the amplitude of the input signal constant over the desired frequency range. Other types of active circuits such as oscillators and high-Q band-pass filters are also realized by using all-pass filters (Schauman and Valkenburg, 2001). The active devices that have been used for the realizations of the first order all-pass circuits include operational amplifiers (OP-AMP), second generation current conveyor (CCII), current feedback op-amps (CFOA), operational trans-conductance amplifier (OTA) and 4 terminal floating nullor (FTFN). Current-mode filters reported in literature, either do not offer all-pass configurations at all, or are excess in the number of components and require component matching constraints (Chang, 1991; Lui, and Hwang, 1997; Higashimura, and Fukai, 1998; Higashimura, 1991; Cam et al 2000; Toker et al 2000). First order all-pass filters are widely used to shift the phase or an input signal from 0 to π or from π to 0, while keeping its amplitude constant over the frequency range of interest (Ponsonby, 1966). The all-pass filters can be also used to synthesize multiphase oscillators and second order band-pass filters (Comer et al. 1997). Considering the advantages of the current mode circuits, such as inherent wider bandwidth and wider dynamic range (Toumazou 1999), several all-pass filters based on current conveyors have been presented (Salawu, 1980; Higashimura and Fukui, 1988; Higashimura and Fukui, 1990). However the inverting second generation current conveyor (ICCII) has also been receiving attention since it was proposed by Awad and Soliman in 1999 (Higashimura and Fukui, 1990; Ozoguz et. al. 2000; Toker et. al. 2002).

The positive second generation current conveyor (CCII+) has been used to implement many all-pass sections, but no current mode configuration employing (CCII+) has been presented until now. Moreover, the previous configuration imposes element matching conditions. In this study, we present new active current mode first order all-pass filter based on CCII. Also a new current mode quadrature oscillator is implemented to show usefulness of the proposed all-pass filter section as an illustrating example. The theoretical results are verified by SPICE simulations using CMOS realization of CCII.

2. THE PROPOSED CIRCUITS

The CCII, whose circuit symbol is shown in Figure 1, is characterized by the following port relations

$$I_Y = 0, V_X = -\beta V_Y, I_Z = \pm \alpha I_X \qquad (1)$$

Where the positive sign indicates the CCII+ and the negative sign indicates the CCII-. In Equation (1), $\beta=1-\epsilon_v$ is the voltage gain, and $\alpha=1-\epsilon_i$ is the current gain of the CCII, where ϵ_v denotes the voltage tracking error between the X and Y terminals and ϵ_i denotes the current tracking error between the Z and X terminals.

Figure 1. Symbol of The CCII

Figure 2 shows the proposed first order all-pass filter circuit. Routine analysis yields the current transfer function as follows:

$$H(s)=\frac{I_{out}}{I_{in}}=\pm\alpha\frac{sC+(1-2\beta)G}{sC+(3-2\beta)G} \tag{2}$$

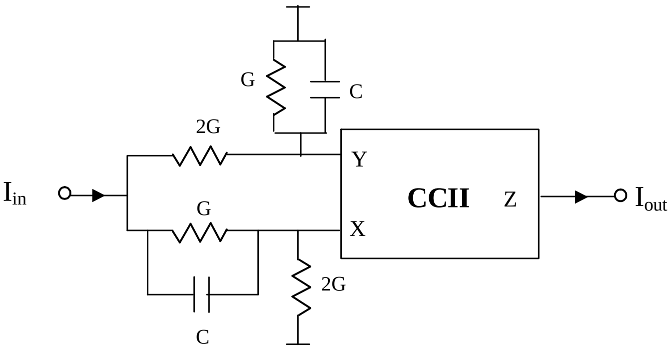

Figure 2. The Proposed Current-Mode First Order All-Pass Filter Configuration

For ideal CCII taking the condition $\alpha=\beta=1$ into account, transfer function given in Equation (2) becomes as

$$H(s) = \pm \frac{sC - G}{sC + G} \tag{3}$$

In the ideal case, the proposed all-pass filter section doesn't require any matching conditions between the passive elements. But in the non-ideal case, matching condition is satisfied if only β=1. It is noted that gain, and pole and zero frequencies of the all-pass filter are influenced by the tracking errors of CCII. The pole sensitivities of the proposed circuit shown in Figure 2 are given as

$$S_{R,C}{}^{w} = -1 \tag{4}$$

which are no more than unity in magnitude. The effects of tracking error parameters of CCII on gain, and pole and zero frequencies of the all-pass filter can be investigated by applying more sensitivity analysis.

3. QUADRATURE OSCILLATOR IMPLEMENTATION

It is a well-known fact that a sinusoidal quadrature oscillator can be realized using an all-pass section and an integrator (Toker et al. 2002). CCII-based current-mode quadrature oscillator can be implemented using this general structure mentioned above. In the oscillator circuit, the proposed all-pass filter and a current-mode integrator employing a CCII with a grounded resistor and capacitor are employed as shown in Figure 3. For providing a sinusoidal oscillation, the loop gain of the circuit is set to unity at $s = j\omega$, i.e.

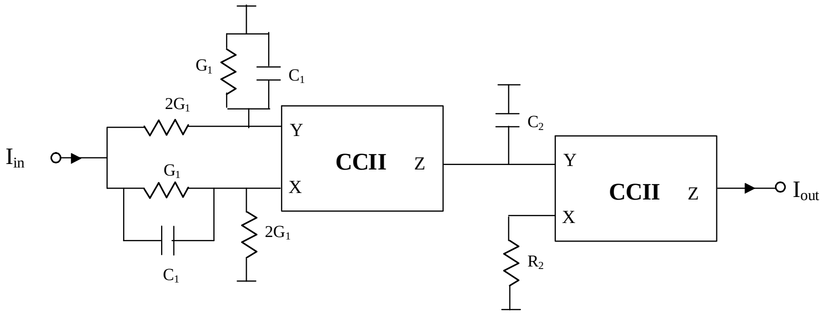

Figure 3. CCII- Based Quadrature Oscillator Circuit

$$\alpha_1 \left(\frac{sC_1 + (1 - 2\beta_1)G_1}{sC_1 + (3 - 2\beta_1)G_1} \right) \left(\frac{\alpha_2 \beta_2}{sR_2 C_2} \right)_{s=jw} = -1 \tag{5}$$

From Equation (3) oscillation condition and oscillation frequency can be found respectively as

$$(3-2\beta_1)R_2C_2 = \alpha_1\alpha_2\beta_2R_1C_1 \tag{6}$$

$$w = \frac{\sqrt{(2\beta_1-1)(3-2\beta_1)}}{R_1C_1} \tag{7}$$

For ideal CCIIs, from Equation (6) and Equation (7) oscillation condition and oscillation frequency become respectively

$$R_2C_2 = R_1C_1 \tag{8}$$

$$w = \frac{1}{R_1C_1} \tag{9}$$

It is remarked that oscillation frequency is affected by the tracking error parameters and passive components of the all-pass filter. But oscillation frequency is not influenced by the tracking error parameters and passive components of the integrator. Sensitivity analysis of the oscillation frequency with respect to passive elements and tracking error parameters of the all-pass filter respectively yields

$$S_{R_1,C_1}{}^{w} = -1 \tag{10a}$$

$$S_{\beta_1}{}^{w} = \frac{2\beta_1}{(2\beta_1-1)} \tag{10b}$$

It is clearly observed from Equations (10a-10b) with respect to passive elements and tracking errors sensitivities are equal or lower than unity in magnitude. It should be noted that oscillation frequency depends on obtaining Equation (9). Inaccurate component values due to manufacturing tolerances and tracking error parameters of CCII reduce the oscillation frequency w.

4. SIMULATION RESULTS

In order to demonstrate the applicability of the proposed all-pass filter, SPICE circuit simulations were performed using a CMOS CCII realization (Toker et. al., 2000). The supply voltages were taken as $V_{DD} = 5V$ and $V_{SS} = -5V$. To verify the theoretical results, the first order all-pass filter was constructed and simulated with PSPICE program. For this purpose, passive components were chosen as R=1kΩ and

C=10pF which results in a 15.9 MHz center frequency. MOS transistor aspect ratios and parameters were taken as in (Toker et al., 2000). Simulation results of the filter response given in Figure 4. which follows theoretical results. The deviations in the frequency response of the filter from theoretical values are caused by nonzero parasitic input resistances at p and n terminals. Actually, the parasitic resistances and capacitances and tracking error parameters of the CMOS- CCII, that is not mentioned in the limited space available here, causes the deviations in the frequency and phase response of the filter from theoretical values. Figure 5 shows the time-domain response of the filter. A sinusoidal input at the frequency of 1.59MHz was applied to the all-pass network constructed with above mentioned passive element values. Quadrature oscillator employing the proposed all-pass filter has also been simulated using PSPICE. In this simulation all resistances and capacitances were taken as $R_1 = R_2 = 1\ k\Omega$, $C_1 = C_2 = 10$ pF respectively which results in a 15.9 MHz oscillation frequency. The output waveforms of the oscillators shown in Figure 6, which is in good agreement with the predicted theory. Actually, the parasitic resistances and capacitances and tracking error parameters of the CMOS- CCII cause the deviations in the output waveforms of the filter and oscillator.

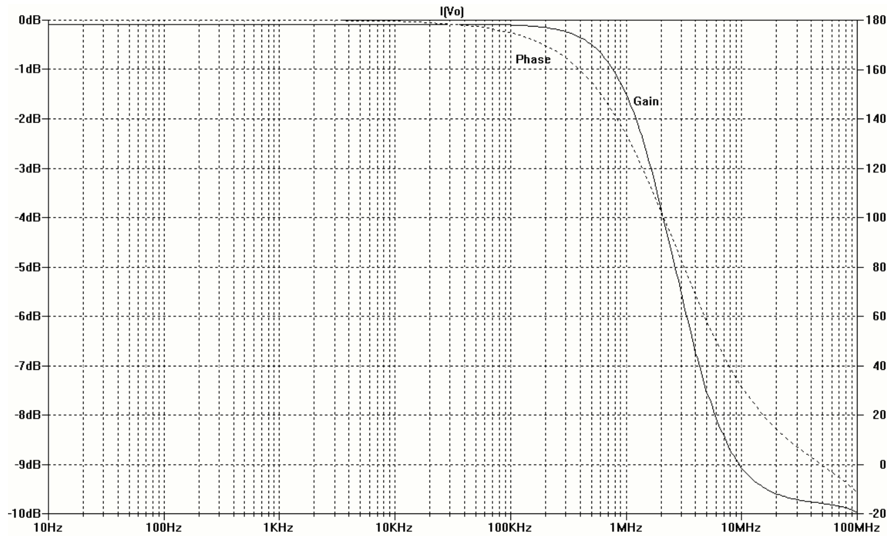

Figure 4. PSPICE Simulation Results of The Proposed All-Pass Filter (Amplitude —, Phase ---)

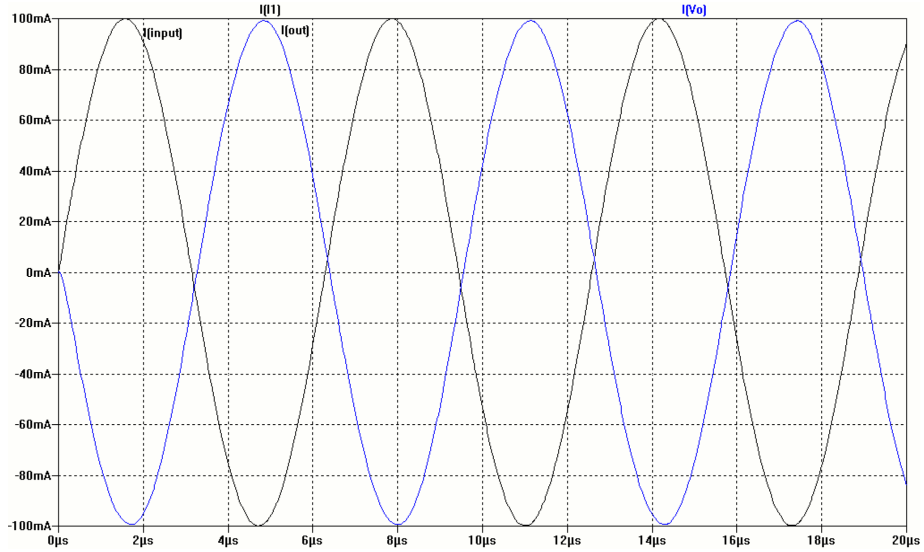

Figure 5. Simulated Time-Domain Response of The Proposed All-Pass Filter

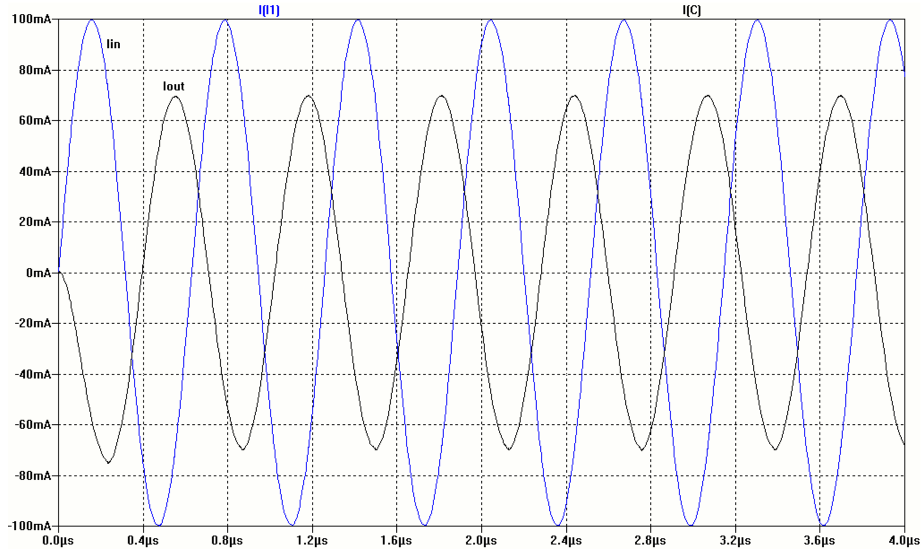

Figure 6. Simulated Output Waveforms of The Quadrature Oscillator

5. CONCLUSION

A new current-mode first order all-pass filter and quadrature oscillator configurations are presented. The proposed all-pass filter circuit uses only a single CCII, resistors and capacitors. Since the output of the filter exhibits low impedance the synthesized current-mode filter can be cascaded without additional buffers. Furthermore, it does not impose any component matching constraint in analog signal processing circuits. Higher order all-pass filter can be obtained directly by connecting in cascade form the proposed all-pass sections. Most of the effects of parasitic input impedances disappear for the proposed all-pass filter due to use grounded passive elements at the input terminals of CCII. As an application of the all-pass filter, a new current-mode quadrature oscillator was also implemented by employing two CCIIs. Furthermore, in the non-ideal case the effects of tracking errors parameters of CCII and passive elements on all-pass filter gain and oscillation frequency are investigated by applying sensitivity analysis for both the proposed all-pass filter and oscillator circuits. PSPICE simulations were performed by using CMOS realization of CCII. PSPICE simulation results of the filter and quadrature oscillator responses are in good agreement with the predicted theory.

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