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A Mixed Mode RC Oscillator Using Current Conveyors

Adisak Monpapassorn Sanae Maitreechit Sakarin Sonanta and Natth Junkrob
Assistant Professor, Department of Electronic Engineering, South-East Asia University

Abstract

A mixed mode RC oscillator using current conveyors (CCIIs) is presented in this paper. The proposed oscillator consists of three CCIIs, two grounded resistors, one ungrounded resistor, and two grounded capacitors. An output frequency can be adjusted by means of a single grounded resistor with independent of the frequency and the condition of oscillation. Both current and voltage outputs are obtained from the proposed oscillator. Simulation oscillator performance using the PSPICE program with a model of the commercial CCII from Analog Devices demonstrates that the proposed oscillator yields low harmonic distortion outputs.

วงจรกำเนิดความถี่แบบอาร์ซีโหมดร่วมที่ใช้วงจรสายพานกระแส

อดิศักดิ์ มนต์ประภัสสร เสน่ห์ ไมตรีจิตร์ ศักรินทร์ โสนันทะ และณัฐ จันทครบ
ผู้ช่วยศาสตราจารย์ สาขาวิชาวิศวกรรมอิเล็กทรอนิกส์ มหาวิทยาลัยเอเชียอาคเนย์

บทคัดย่อ

บทความนี้นำเสนอวงจรกำเนิดความถี่แบบอาร์ซีโหมดร่วมที่ใช้วงจรสายพานกระแส วงจรกำเนิดความถี่ที่นำเสนอประกอบด้วยวงจรสายพานกระแส (CCII) 3 วงจร ตัวต้านทานที่ต่อกราวด์ 2 ตัว ตัวต้านทานที่ไม่ต่อกราวด์ 1 ตัว และตัวเก็บประจุที่ต่อกราวด์ 2 ตัว ความถี่เอาต์พุตของวงจรที่นำเสนอสามารถปรับได้โดยการปรับค่าตัวต้านทาน 1 ตัว โดยความถี่นี้จะเป็นอิสระจากสภาวะการกำเนิดความถี่ เอาต์พุตของวงจรที่นำเสนอมีทั้งแรงดันและกระแส ผลการเลียนแบบการทำงานโดยโปรแกรม PSPICE ด้วยโมเดลของวงจรสายพานกระแสที่ผลิตออกจำหน่ายจากบริษัท Analog Devices แสดงให้เห็นว่าเอาต์พุตของวงจรกำเนิดความถี่ที่นำเสนอมีการผิดเพี้ยนทางฮาร์โมนิกส์ต่ำ

Introduction

Due to its distinct advantage over an operational amplifier, a current conveyor (CCII) [A.S. Sedra and K.C. Smith, 1970] is getting popularity as the alternative building block for analog signal processing applications. One application is an oscillator.

Recently, RC oscillators using CCIIs as active elements have been presented, for example, oscillators in [C.P. Chong and K.C. Smith, 1986, M.T. Abuelma'atti and N.A. Humood, 1987, D. R. Bhaskar and R. Senani, 1993, C.M. Chang, 1994, M.T. Abuelma'atti, A.A. Al-ghumaiz and M.H. Khan, 1995] Unfortunately, most of the presented oscillators provide only the voltage output. It is well known that the oscillator is used for supplying an output signal to both voltage and current mode circuits. Hence, it will be convenient for applications if the oscillator can provide both voltage and current outputs.

In this paper, we propose a new RC oscillator that yields both current and voltage output sine waves with the use of three CCIIs, two grounded resistors, one ungrounded resistor, and two grounded capacitors. The features of the proposed oscillator are the uncoupled control of the frequency and the condition of oscillation, and the frequency adjustment through a grounded resistor (suitable for voltage controlled oscillator applications). With only one ungrounded passive element used, the proposed oscillator is suitable for IC fabrication. Additionally, the proposed oscillator yields perfect output impedance. Namely, it yields high output impedance (node Z of CCII) for the current output and yields low output impedance (node X of CCII) for the voltage output.

Proposed oscillator

A symbol of the CCII is shown in figure 1. It consists of ports X, Y, and Z. The relations of the voltages and currents at these ports can be written as

$$\left.\begin{aligned} i_Y &= 0 \\ v_X &= v_Y \\ i_Z &= i_X \end{aligned}\right\} \qquad (1)$$

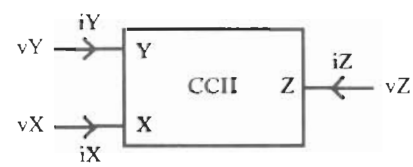

Fig. 1 Current conveyor (CCII).

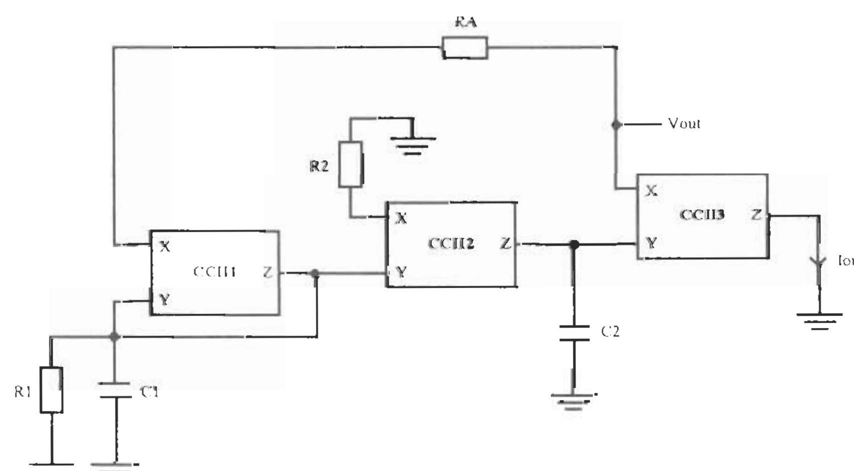

Fig. 2 Proposed oscillator.

Figure 2 shows a proposed oscillator, which is composed of three CCIIs, three resistors, and two capacitors. With the operation of the CCII in (1), the characteristic equation of the proposed oscillator is

$$s^2C_2C_1R_2R_A - \left(1 - \frac{R_A}{R_1}\right)sC_2R_2 + 1 = 0 \tag{2}$$

This leads to the frequency of oscillation as

$$f_0 = \frac{1}{2\pi\sqrt{C_1C_2R_2R_A}} \tag{3}$$

and the condition of oscillation being

$$R_A = R_1 \tag{4}$$

From (3) and (4), it is evident that the frequency of oscillation can be gotten by adjusting R_2 and the condition of oscillation can be obtained by adjusting R_1. In order to achieve low power consumption, applying (1), R_A and R_2 with high resistance should be chosen.

For the operation of the proposed oscillator at very high frequency, the parasitic capacitance at the nodes of CCII [J.A. Svoboda, L. McGory and S. Webb, 1991] will affect the oscillation frequency. This should be considered additionally for the practical accuracy output frequency.

Simulation results

To verify the theoretical design, a proposed oscillator was simulated by using the PSPICE program with the model of a commercial current conveyor (AD844) from Analog Devices. A supply voltage used is ±10 V. Resistors R_1 and R_A chosen are 10 kΩ. Capacitors $C_1 = C_2 = 100\,\text{pF}$ are fixed. Both theory and simulation frequencies with R_2 changed from 1 Ω to 100 kΩ are shown in figure 3. Figure 4 shows the voltage output (V_{out}) and figure 5 shows the frequency spectrum of the proposed oscillator, where $R_2 = 100\,\text{k}\Omega$. Moreover, using this resistor, the current output (I_{out}) and its frequency spectrum are shown in figure 6 and figure 7. Using (1), the current I_{out} is equal to V_{out} / resistance between node X of CCII3 and ground. Note that the harmonic distortion of the current output from figure 7 (two harmonics evidently seen) is higher than one of the voltage output from figure 5 (only one harmonic evidently seen) because of the additional transferring of the current from node X to node Z of CCII3.

Note from the output sine waves of figure 4 and figure 6 that, from $t = 0$ ms to $t = 0.3$ ms, the close loop gain of the proposed oscillator is more than 1. After $t = 0.3$ ms, the close loop gain is 1 due to the limitation of the supply voltage; hence, the outputs are uniform. These are basically for oscillation. Figure 8 and figure 9 show the voltage and current output frequency spectrums in case $R_2 = 1\,\Omega$, 100 Ω, and 10 kΩ. They are clearly seen in all figures that show frequency spectrums that the harmonic spectrums are few and low. This means that the proposed oscillator yields low harmonic distortion output sine waves.

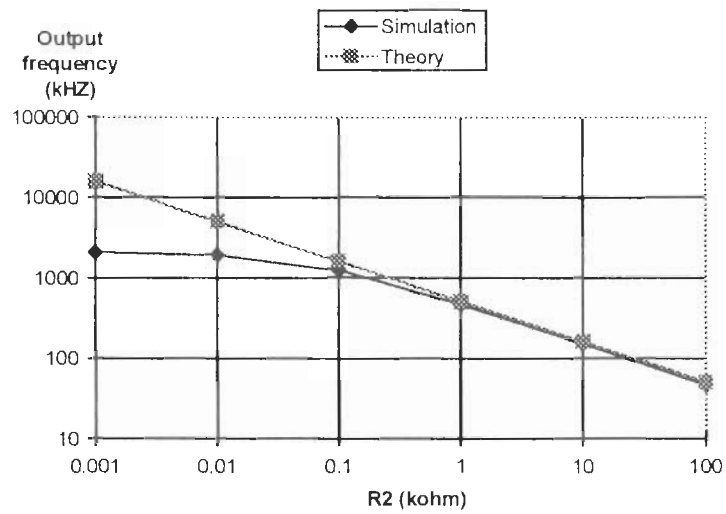

Figure 3 Output frequencies of the proposed oscillator when R_2 ranged from 1 Ω to 100 kΩ.

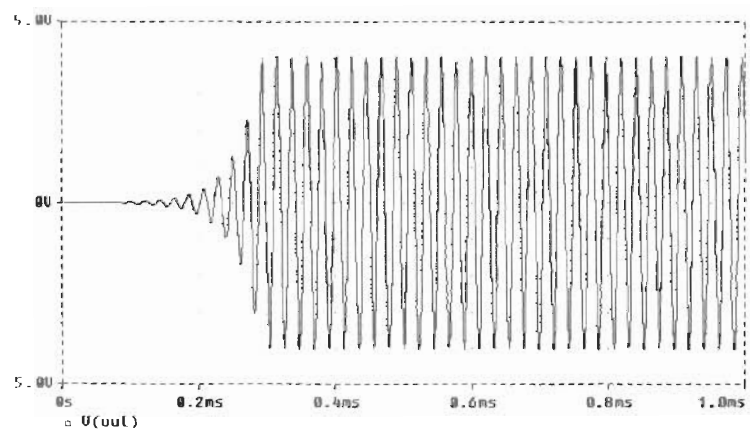

Figure 4 Output voltage of the proposed oscillator, R_2 = 100 kΩ.

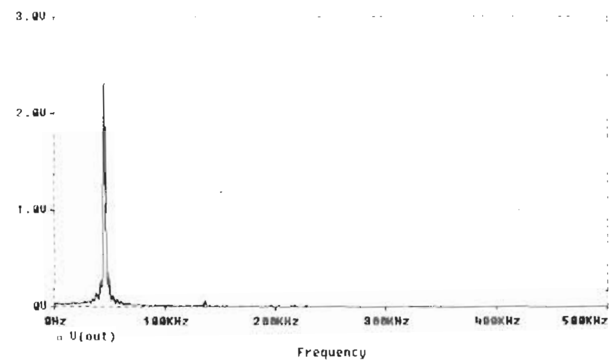

Figure 5 Frequency spectrum of the signal in figure 4, R_2 = 100 kΩ.

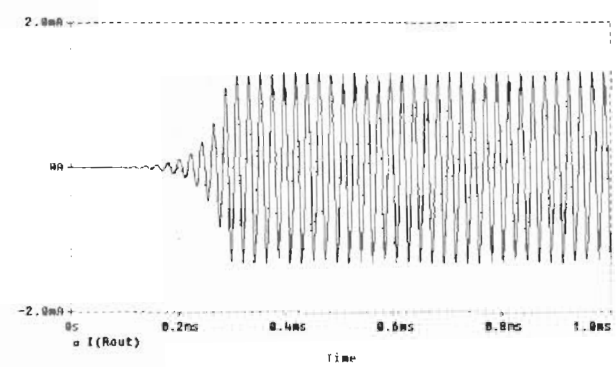

Figure 6 Output current of the proposed oscillator, R_2 = 100 kΩ.

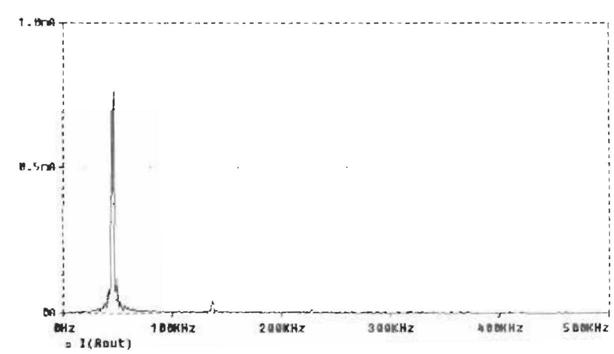

Figure 7 Frequency spectrum of the signal in figure 6, R_2 = 100 kΩ.

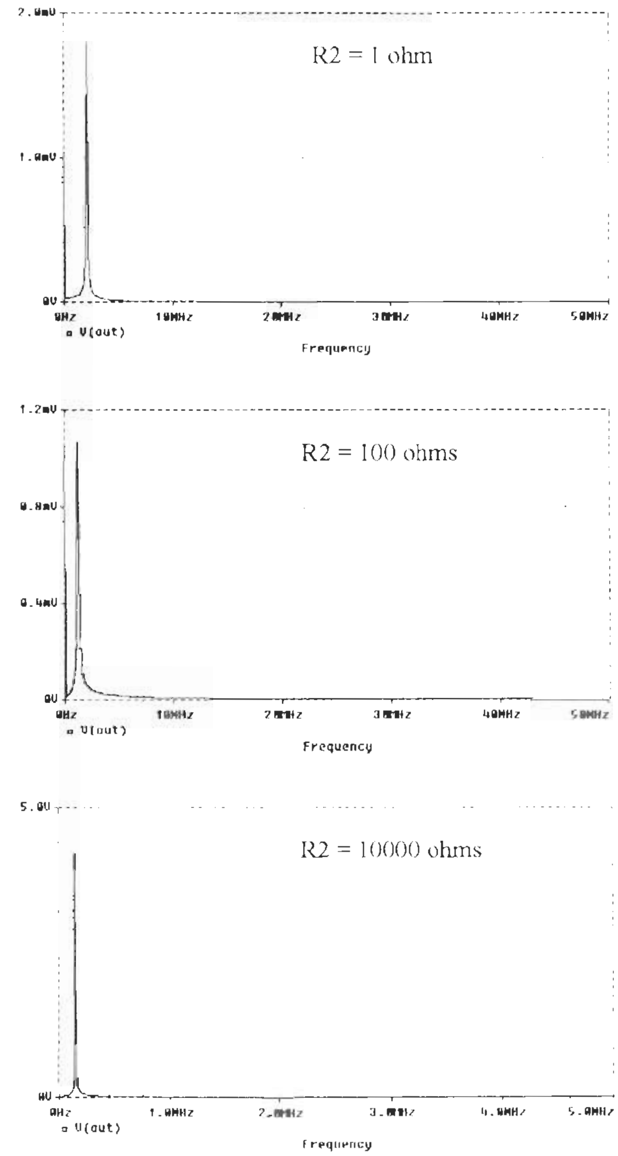

Figure 8 **Frequency spectrums of voltage outputs when $R_2 = 1\ \Omega$, 100 Ω, and 10 kΩ.**

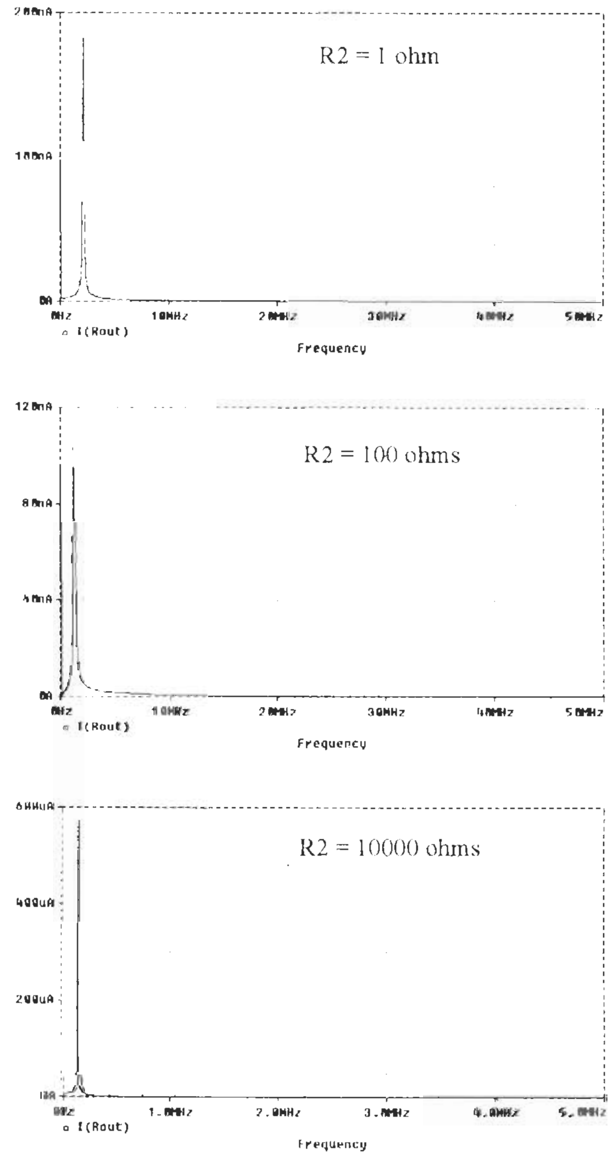

Figure 9 Frequency spectrums of current outputs when R_2 = 1 Ω, 100 Ω, and 10 kΩ.

Conclusion

In this paper, we have reported the design and simulation of a new mixed mode RC oscillator using current conveyors that yields the uncoupled control of the frequency and the condition of oscillation. The proposed oscillator can supply both current and voltage sine wave outputs, which their frequency can be controlled by a grounded resistor therefore it is easy for the voltage controlled oscillator application. Simulation results show the low harmonic distortion of output signals. The proposed oscillator is suitable for electronic and communication applications.

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