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Current-mode oscillators using single output current conveyors

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Abstract

It is shown that the voltage-mode oscillators employing noninverting or inverting voltage controlled voltage sources can be transformed directly to current-mode oscillators by element replacement technique and using composite current conveyors. Examples of the Wien oscillator and the phase shift oscillator together with PSpice simulation results are included. © 1998 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Recently there has been a great interest in transforming the Wien-type oscillator to an equivalent current conveyor (CCII) [1] based sinusoidal oscillator [2–4]. The transformation method given in Ref. [2] is based on replacing the voltage controlled voltage source (VCVS) together with the feedback resistor by an equivalent CCII+ based transconductance amplifier. The Wien oscillator given in Ref. [3] is based on using the operational floating conveyor (OFC) as a VCVS, with the OFC realized using two CCII+. The Wien oscillator given in Ref. [4] and generated based on the nullor concept is similar to that given in Ref. [3] except that it employs two CCII−, instead of two CCII+ as in Ref. [3]. Oscillators employing inverting VCVS as the active element have also been transformed to CCII based oscillators; in particular, the phase shift oscillator given in Ref. [3] is obtained based on using the OFC as a CCCS.

Very recently new procedures were presented that yield cascadable op amp based current-mode biquads from voltage-mode biquads without the use of voltage-mode to current-mode transformation [5]. The procedure is based on adding admittances from the output of each op amp to the virtual ground input of the next circuit in cascade. The op amps in the resulting current-mode circuits can be replaced by CCIIs producing circuits that are fully current-mode. In oscillator circuits, however, the same procedure can be used without the addition of any admittances to the original op amp oscillator circuit, as will be explained in this paper. The basic idea relies on the removal of the ground from terminal Z of the second CCII which acts as a voltage buffer in the CCII based VCVS circuits.

2. Composite current conveyors

Fig. 1 represents the well known CCII based noninverting VCVS realization, with the second CCII acting as a voltage buffer [6]. In this composite CCII, however, the Z terminal of the second CCII is used as an output current terminal, instead of being grounded as in the VCVS realization [6]. This two-CCII, two-resistor, three-port network is described by the following matrix equation:

$$\begin{bmatrix} I1 \\ V2 \\ I3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ K & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} V1 \\ I2 \\ V3 \end{bmatrix} \tag{1}$$

The above equation describes a generalized CCII, with an adjustable K that can be greater, equal to or less than one. If the second CCII is a CCII−, the composite conveyor will be a special case from that reported in Ref. [7].

Fig. 2(a) represents an inverting VCVS buffered with a second CCII and with an ungrounded Z terminal. This composite CCII represents a new building block, which is described by the following matrix equation:

$$\begin{bmatrix} I1 \\ V2 \\ I3 \end{bmatrix} = \begin{bmatrix} 1/R1 & 0 & 0 \\ -K & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} V1 \\ I2 \\ V3 \end{bmatrix} \tag{2}$$

Fig. 2(b,c) represents two alternative realizations of a generalized inverting voltage gain CCII, with an adjustable K.

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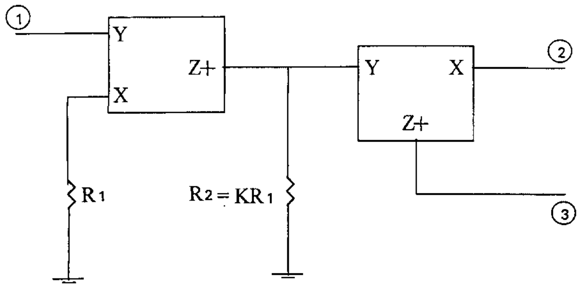

Fig. 1. The composite CCII based on the noninverting VCVS.

The matrix equation in this case is the same as given by Eq. (1), except that $V2 = -KV1$.

These composite current conveyors may have several important applications. The objective here is to demonstrate their practicality in transforming well known op amp oscillators employing noninverting or inverting VCVSs to current-mode oscillators.

3. Current-mode oscillators

Fig. 3(a) represents the generalized configuration of a voltage-mode oscillator which employs the op amp as a VCVS of gain K. Replacing the op amp VCVS by the composite CCII of Fig. 1 results in the new current-mode oscillator circuit shown in Fig. 3(b) with the oscillator output current Io taken from the Z port of the second CCII.

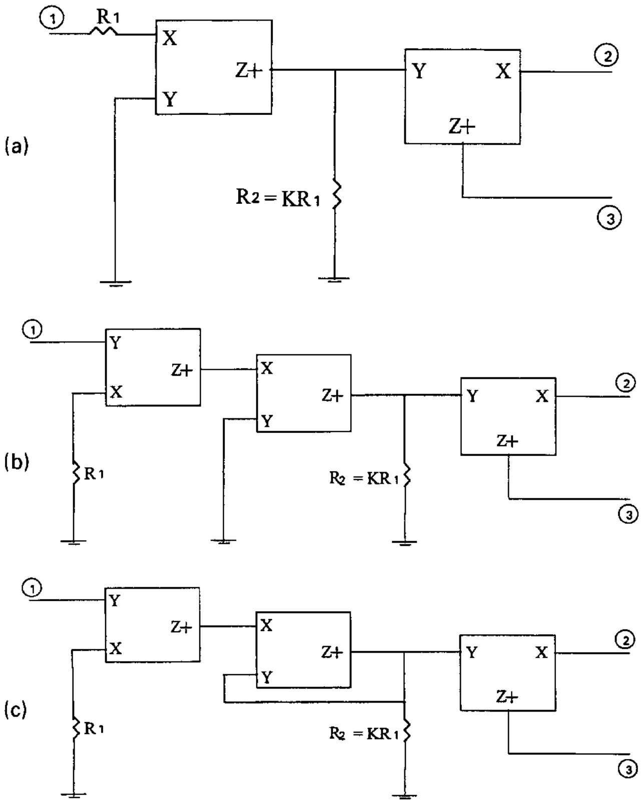

Fig. 2. Three alternative composite CCII circuits based on the inverting VCVS.

Similarly, the oscillator circuit of Fig. 4(a) which employs the op amp as an inverting VCVS of gain $-K$ can be transformed to the current-mode oscillator shown in Fig. 4(b) which uses the composite CCII of Fig. 2(a).

Examples of the Wien bridge oscillator and the phase shift oscillator are considered in the following subsections.

3.1. Wien oscillators

Consider the well-known Wien oscillator shown in Fig. 5(a), with the op amp and the two resistors $R3$ and $R4$ realizing a VCVS of gain K. Replacing the VCVS of Fig. 5(a) by the composite CCII of Fig. 1 results in the new current-mode oscillator of Fig. 5(b), with the output current taken from the Z port of the second CCII. The ratio between the two resistors $R4$ and $R3$ is taken equal to K instead of $(K - 1)$ in the op amp circuit of Fig. 5(a), so that the two circuits will have the same condition of oscillation given by:

$$K = \frac{C_1}{C_2} + \frac{R_2}{R_1} + 1 \tag{3}$$

The radian frequency of oscillation is given by:

$$\omega_0 = \frac{1}{\sqrt{C_1 C_2 R_1 R_2}} \tag{4}$$

It should be noted that the proposed realization given in Fig. 5(b) is different from that given in Fig. 11 of [3] which is based on the operational floating conveyor (CFO) working as a VCVS. The proposed realization is also different from those given in [2] and based on using a single CCII as a VCCS.

Fig. 5(c) and (d) represents two additional current-mode Wien oscillators [8,9] using the composite CCII of Fig. 1. Although the oscillator of Fig. 5(d) is related to that of Fig. 5(c) by the $RC{:}CR$ transformation of the passive RC circuit, the oscillator of Fig. 5(c) is superior to that of Fig. 5(d) since it can absorb the effect of Rx of the second CCII in the resistor $R1$.

3.2. Phase shift oscillator

A phase shift oscillator based on using an OFC as a CCCS was given in Fig. 8 of [3]. Here an alternative realization of the phase shift oscillator is given. Fig. 6 represents the proposed current-mode phase shift oscillator based on using the composite CCII of Fig. 2(a). The condition of oscillation and the radian frequency of oscillation are given by:

$$K = 29 \tag{5}$$

$$\omega_0 = \frac{1}{\sqrt{6}RC} \tag{6}$$

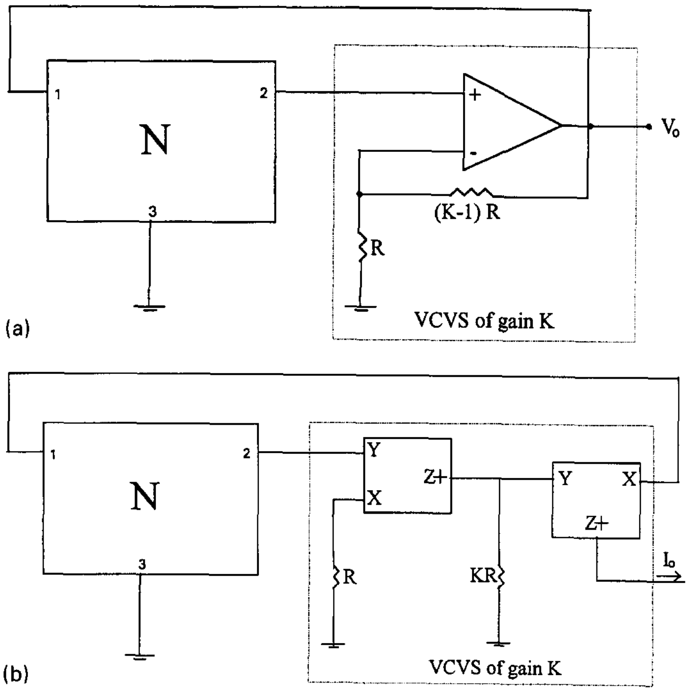

Fig. 3. (a) The noninverting VCVS based oscillator using an op amp; (b) the generalized current-mode oscillator using the composite CCII of Fig. 1.

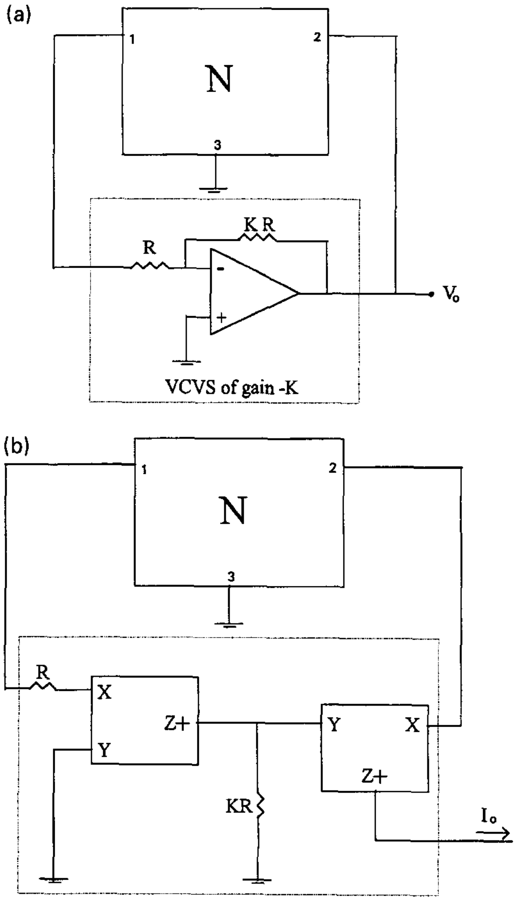

Fig. 4. (a) The inverting VCVS based oscillator using an op amp; (b) the generalized current-mode oscillator using the composite CCII of Fig. 2(a).

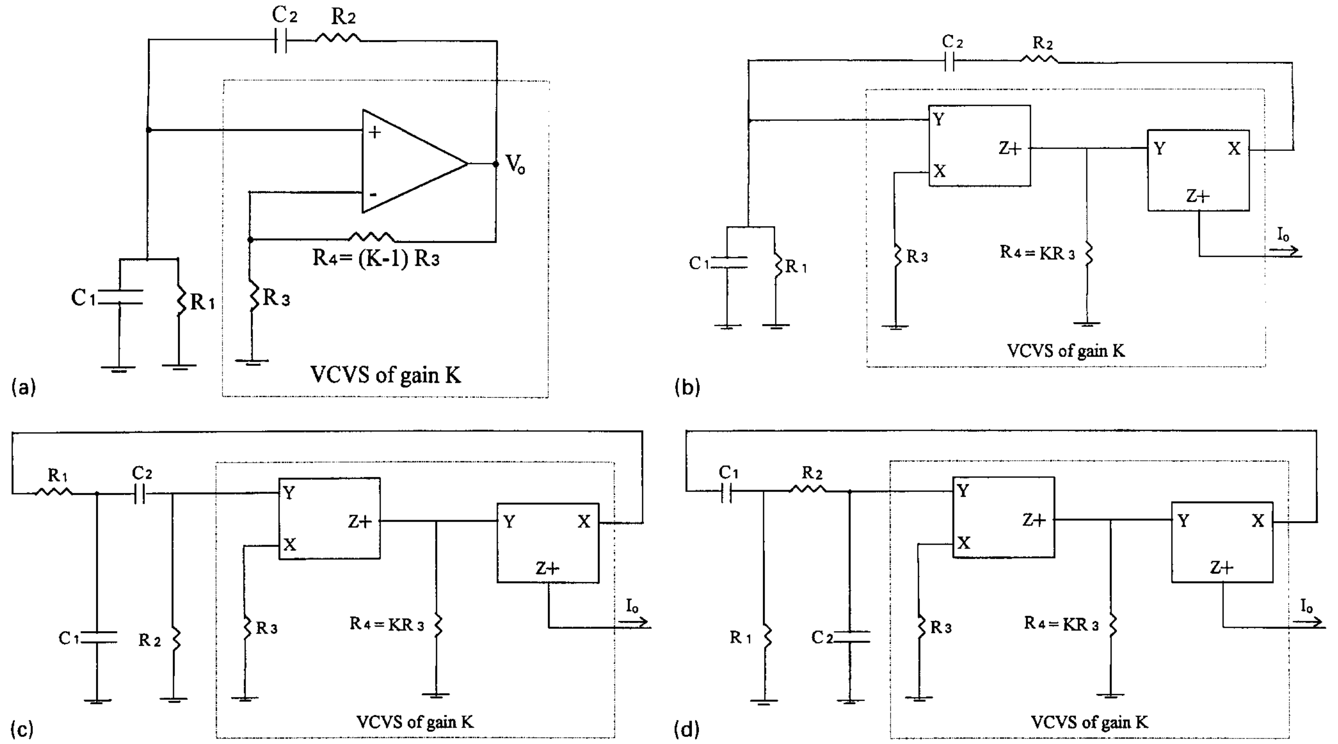

Fig. 5. (a) The well-known Wien oscillator using an op amp; (b) the proposed current-mode Wien oscillator based on the composite CCII of Fig. 1; (c) and (d) two additional current-mode Wien oscillators.

4. Simulation results

PSpice simulations have been carried out using the AD844 from Analog Devices biased with ±9 V.

Fig. 7(a) represents the simulated current waveform of the oscillator of Fig. 5(c) with a load of 1 KΩ. The simulations are based on taking $R1 = R2 = 10$ KΩ, $C1 = C2 = 1$ nF, $R4 = 10$ KΩ. To start oscillations $R3$ was decreased from its theoretical value of 3.33 KΩ to 3.25 KΩ. (This is due to Rx of the first CCII which adds to the value of $R3$).

Fig. 7(b) represents the frequency spectrum, from which it is seen that $f_0 = 15.887$ kHz, which is slightly less than its theoretical value of 15.915 kHz. This error which equal to −0.18%, is mainly due to Rx of the second CCII, which adds to the value of $R1$.

Fig. 8 represents the simulated current waveform of the oscillator of Fig. 6 with a load of 1 KΩ, $C = 10$ nF, $R = 1$ KΩ. To start oscillations $R1$ was increased from its theoretical value of 29 KΩ to 32.5 KΩ (again, this is due to the effect of Rx of the first CCII). The simulated f_0 equal to 6.25 kHz which is slightly less than the theoretical value of 6.5 kHz.

5. Conclusion

It has been demonstrated how composite current conveyors can be used to obtain a current-mode oscillator from an op amp VCVS based oscillator. Examples of the Wien oscillator and the phase shift oscillator together with PSpice simulation results are included.

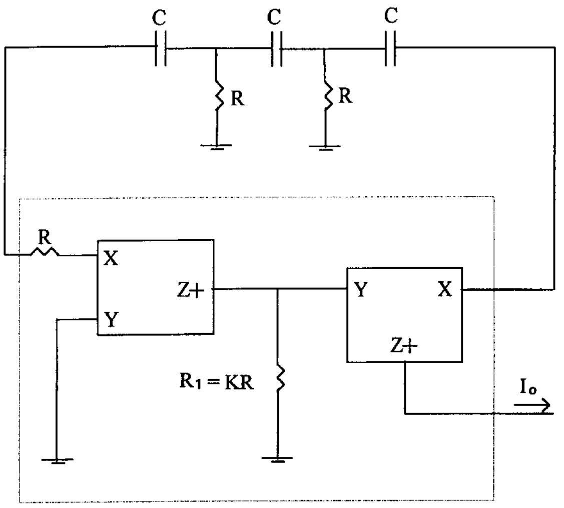

Fig. 6. The current-mode phase shift oscillator based on the composite CCII of Fig. 2(a).

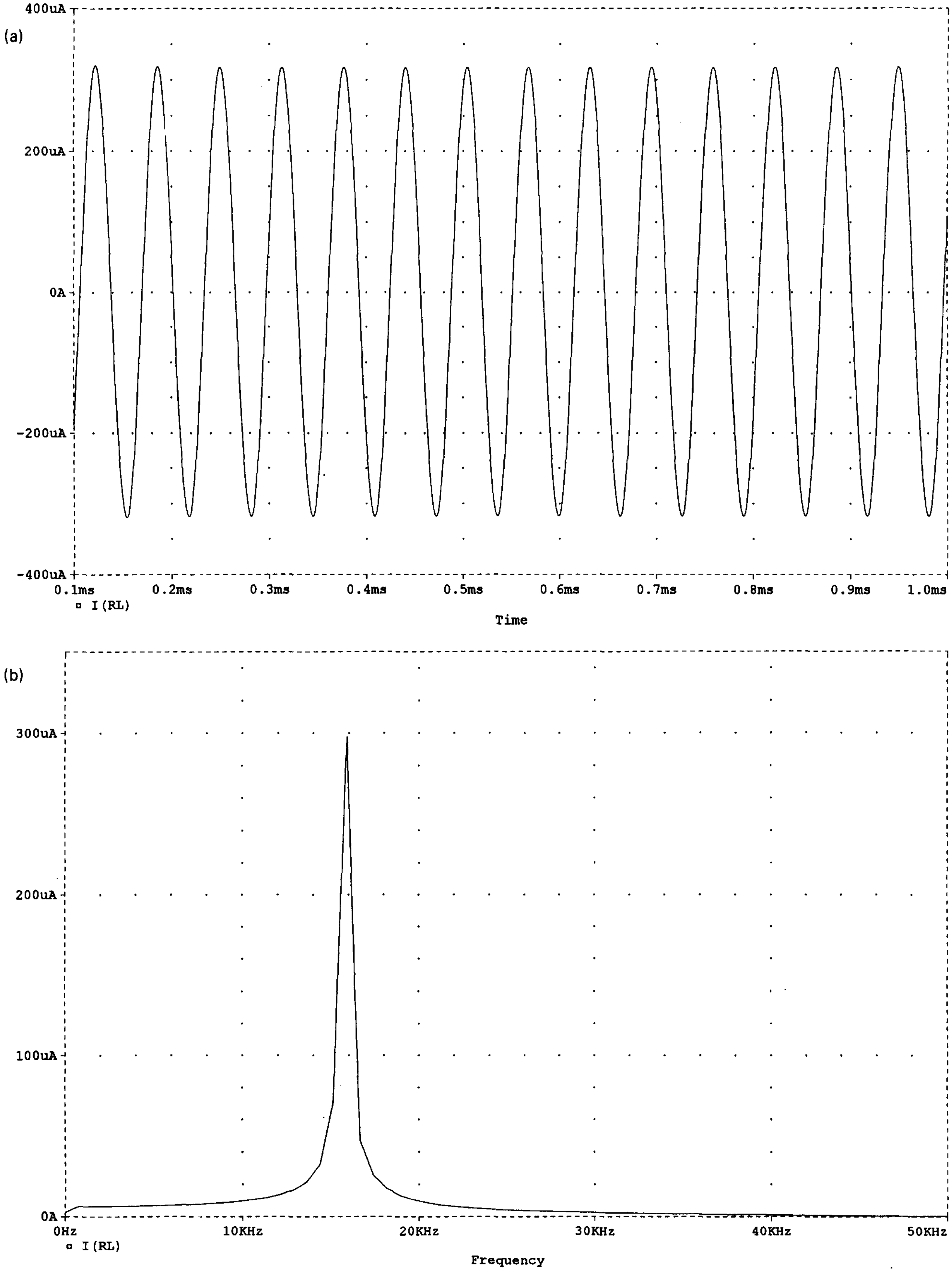

Fig. 7. (a) The current waveform of the oscillator of Fig. 5(c); (b) the frequency spectrum of the oscillator of Fig. 5(c).

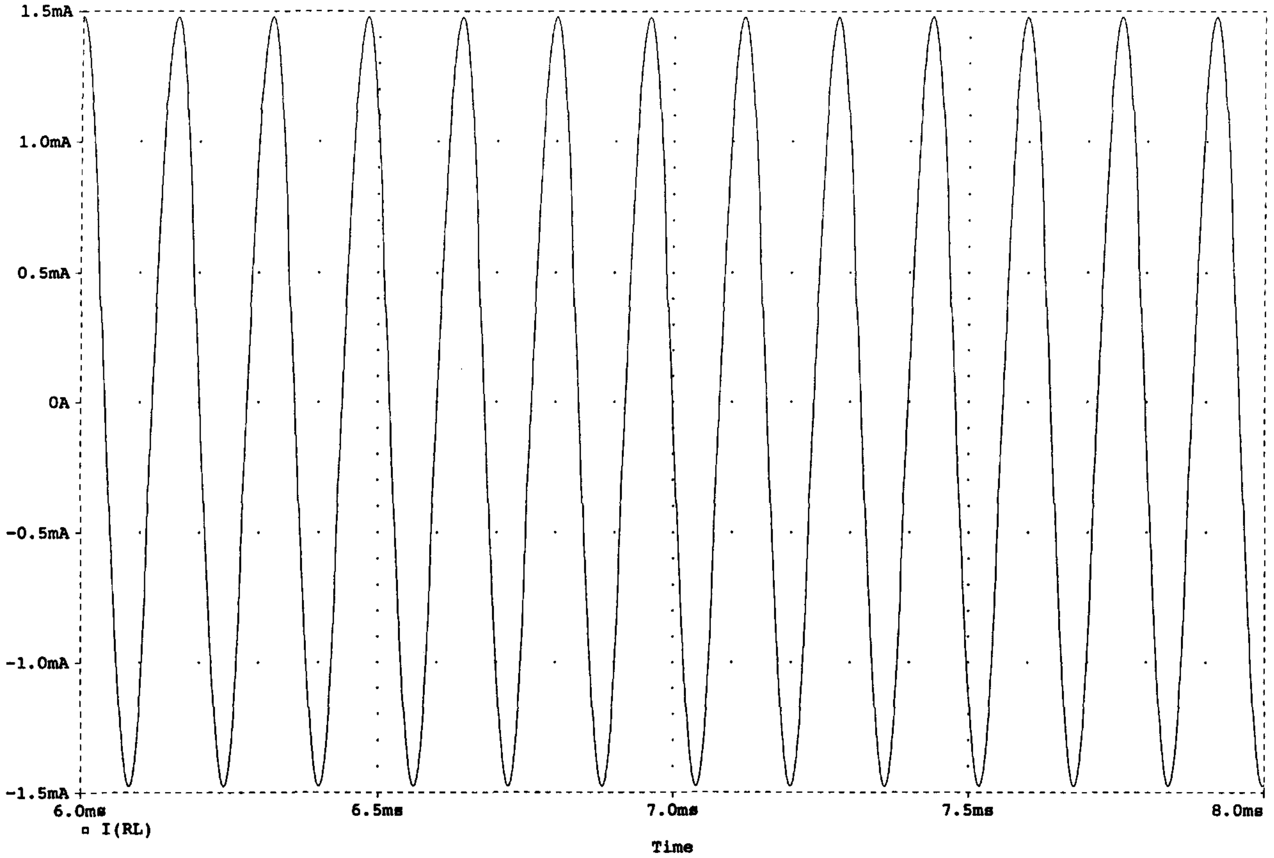

Fig. 8. The current waveform of the oscillator of Fig. 6.

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