Current Or/And Voltage-Mode Quadrature Oscillators With Grounded Capacitors And Resistors Using FDCCIIs

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Abstract: - Two quadrature oscillator circuits each using one fully differential second-generation current conveyor (FDCCII), two grounded capacitors and two grounded resistors are presented. The current-mode quadrature signals can be obtained from the first proposed circuit. The current-mode and voltage-mode quadrature signals can be simultaneously obtained from the second proposed circuit. In both proposed circuits, the current-mode quadrature signals have the advantage of high output impedance. The oscillation conditions and oscillation frequencies are orthogonal controllable. The use of only grounded capacitors and resistors makes the proposed circuits ideal for integrated circuit implementation. Simulation results are included.

Key-Words: - Quadrature oscillator, Current-mode, Voltage-mode, Current conveyor, FDCCII.

1 Introduction

A quadrature oscillator is used because the circuit provides two sinusoids with 90° phase difference, as for example in telecommunications for quadrature mixers and single-sideband generators or for measurement purposes in vector generators or selective voltmeters. Therefore, quadrature oscillators constitute an important unit in many communication and instrumentation systems [1-16]. Note that, the quadrature oscillators in [1-10] generated voltage-mode signals and the ones in [11-16] generated current-mode signals.

Current-mode oscillators with high output impedance are of great interest because that make easy to drive loads without using buffering device [17-19]. On the other hand, circuits that employ only grounded capacitors and resistors are beneficial from the point of view of integrated circuit implementation [19-21]. The previous current-mode quadrature oscillators presented in [11-13] employ floating passive components and require additional current followers for sensing and taking out the quadrature outputs therein and the use of these additional current followers with the virtual grounded input may result in floating capacitors realization for what is originally described as grounded capacitors realization.

The fully differential second-generation current conveyor (FDCCII) [22] was proposed to improve the dynamic range in mixed-mode applications where fully differential signal processing is required. Because the fully differential of the input voltage signals are conveyed to the x terminals and the x terminals current signals are conveyed to the z terminals in FDCCII. The applications of FDCCIIs in filters and oscillators design often using only grounded passive components and were demonstrated in [22-24]. The use of only grounded capacitors and resistors is ideal for integrated circuit implementation [19-21]. Some applications of FDCCIIs in the designs of fully differential second-order filters and voltage-mode universal second-order filters were also presented in [25-26]. In 2002, Chang *et al.* proposed a current-mode sinusoidal oscillator with high output impedance using one FDCCII, two grounded capacitors and three grounded resistors [23]. In 2006, Horng *et al.* proposed two quadrature oscillator circuits [27]. Each oscillator circuit in [27] uses one FDCCII, two grounded capacitors and two/three resistor. The current-mode quadrature output signals can be obtained in the first circuit. The current-mode and voltage-mode quadrature output signals can be obtained, simultaneously, in the second circuit. However, the design of FDCCII based quadrature oscillators has not been studied sufficiently.

In this paper, another two new current-mode quadrature oscillator circuits each using only one

FDCCII, two grounded capacitors and two grounded resistors are presented. Each of the proposed circuit exhibits two high output impedance sinusoidal currents with 90^o phase difference. The oscillation conditions and oscillation frequencies of the proposed circuits are orthogonal controllable. Although the proposed circuits using more complicated active components (FDCCIIs) with respect to the previous current-mode quadrature oscillators in [11-13], the proposed circuits having the advantages of employing only grounded passive components; high output impedance current signals without using additional current followers and the oscillation conditions and oscillation frequencies can be orthogonal controllable through grounded passive components. With respect to the high output impedance current-mode quadrature oscillators in [14-16], the current-mode and voltage-mode quadrature signals can be simultaneously obtained in the second proposed circuit. With respect to the high output impedance current-mode sinusoidal oscillators in [23], high output impedance quadrature current signals can be obtained in the proposed circuits and employing less resistors. Moreover, the voltage-mode quadrature signals can be simultaneously obtained in the second proposed circuit. With respect to the FDCCIIs based quadrature oscillators in [27], two new quadrature oscillator circuits are presented in this paper.

2 Proposed Circuits

The FDCCII is defined by the equations [22]:

$$\begin{bmatrix} i_{y1} \\ i_{y2} \\ i_{y3} \\ i_{y4} \\ v_{xa} \\ v_{xb} \\ i_{zai} \\ i_{zbi} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \pm 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \pm 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} v_{y1} \\ v_{y2} \\ v_{y3} \\ v_{y4} \\ i_{xa} \\ i_{xb} \\ v_{zai} \\ v_{zbj} \end{bmatrix} \tag{1}$$

The first proposed quadrature oscillator is shown in Fig. 1. The characteristic equation of the circuit can be expressed as

$$s^2C_1C_2 + sG_2(C_1 - C_2) + G_1G_2 = 0 \tag{2}$$

The oscillation condition and oscillation frequency can be obtained as

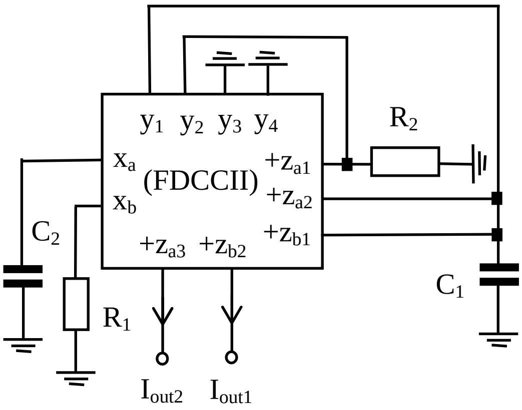

Fig. 1 The first proposed quadrature oscillator.

$$C_1 = C_2 \tag{3}$$

$$\omega_o = \frac{1}{\sqrt{C_1C_2R_1R_2}} \tag{4}$$

From equations (3) and (4), the oscillation condition and oscillation frequency can be orthogonal adjustable. From Fig. 1, under steady state, the relationships between output currents I_{out1} and I_{out2} are

$$I_{out1} = \frac{1}{\omega C_2 R_1} e^{j90^o} I_{out2} \tag{5}$$

ensuring the currents I_{out2} and I_{out1} to be in quadrature.

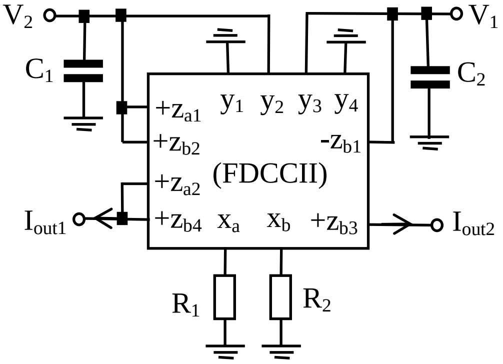

Fig. 2 The second proposed quadrature oscillator.

The second proposed quadrature oscillator is shown in Fig. 2. The characteristic equation of the circuit can be expressed as

$$s^2C_1C_2 + sC_2(G_1 - G_2) + G_1G_2 = 0 \tag{6}$$

The oscillation condition and oscillation frequency can be obtained as

$$R_1 = R_2 \tag{7}$$

$$\omega_o = \frac{1}{\sqrt{C_1C_2R_1R_2}} \tag{8}$$

From equations (7) and (8), the oscillation condition and oscillation frequency can be orthogonal adjustable. From Fig. 2, under steady state, the relationships between output voltages V_1 and V_2 are

$$V_1 = \frac{1}{\omega C_2R_2}e^{j90^o}V_2 \tag{9}$$

ensuring the voltages V_2 and V_1 to be in quadrature. The relationships between output currents I_{out1} and I_{out2} are

$$I_{out1} = \frac{1}{\omega C_2R_2}e^{j90^o}I_{out2} \tag{10}$$

ensuring the currents I_{out2} and I_{out1} to be in quadrature.

The proposed quadrature oscillator circuits employ only grounded capacitors and resistors. The use of grounded capacitors and resistors is particularly attractive for integrated circuit implementation [19-21]. Because the output impedances of the currents I_{out1} and I_{out2} in Fig. 1-2 are very high, the two output terminals, I_{out1} and I_{out2}, can be directly connected to the next stage. The current-mode and voltage-mode quadrature signals can be simultaneously obtained from Fig. 2. From equations (5), (9) and (10), the magnitudes of the quadrature signals are not the same. For the applications needing equal magnitude quadrature outputs, other amplifying circuits are needed.

3 Non-Ideal Effects

Taking the non-idealities of the FDCCII into account, the relationship of the terminal voltages and currents can be rewritten as: $v_{xa} = \alpha_{a1}v_{y1} - \alpha_{a2}v_{y2} + \alpha_{a3}v_{y3}$, $v_{xb} = -\alpha_{b1}v_{y1} + \alpha_{b2}v_{y2} + \alpha_{b4}v_{y4}$, $i_{y1} = i_{y2} = i_{y3} = i_{y4} = 0$, $i_{zai} = \pm\beta_{ai}\,i_{xa}$ and $i_{zbj} = \pm\beta_{bj}\,i_{xb}$, where $\alpha_{ak} = 1- \varepsilon_{avk}$ and ε_{avk} ($\left|\varepsilon_{avk}\right| <<1$) is the voltage tracking error from the k-th v_y terminal to the v_{xa} terminal of the FDCCII, $\alpha_{bk} = 1- \varepsilon_{bvk}$ and ε_{bvk} ($\left|\varepsilon_{bvk}\right| <<1$) is the voltage tracking error from the k-th v_y terminal to the v_{xb} terminal of the FDCCII, $\beta_{ai} = 1- \varepsilon_{ai}$ and ε_{ai} ($\left|\varepsilon_{ai}\right| <<1$) is the output current tracking error from the v_{xa} terminal to the i-th v_{za} terminal of the FDCCII, $\beta_{bj} = 1- \varepsilon_{bj}$ and ε_{bj} ($\left|\varepsilon_{bj}\right| <<1$) is the output current tracking error from the v_{xb} terminal to the j-th v_{zb} terminal of the FDCCII. The characteristic equation of Fig. 1 becomes

$$\begin{aligned}&s^2C_1C_2\alpha_{a2}\beta_{a1} + \\ &s[G_2(C_1 - C_2\alpha_{a1}\beta_{a2}) + C_2G_1\beta_{a1}\beta_{b1}(\alpha_{a2}\alpha_{b1} - \alpha_{a1}\alpha_{b2})] + \\ &\qquad G_1G_2\alpha_{b1}\beta_{b1} = 0\end{aligned} \tag{11}$$

The modified oscillation condition and oscillation frequency are

$$C_1 = C_2\alpha_{a1}\beta_{a2} - \frac{C_2R_2\beta_{a1}\beta_{b1}(\alpha_{a2}\alpha_{b1} - \alpha_{a1}\alpha_{b2})}{R_1} \tag{12}$$

$$\omega_o = \sqrt{\frac{\alpha_{b1}\beta_{b1}}{C_1C_2R_1R_2\alpha_{a2}\beta_{a1}}} \tag{13}$$

The active and passive sensitivities of the quadrature oscillator are all low and obtained as

$$S^{\omega_o}_{\alpha_{b1},\beta_{b1}} = -S^{\omega_o}_{\alpha_{a2},\beta_{a1}} = \frac{1}{2};\quad S^{\omega_o}_{C_1,C_2,R_1,R_2} = -\frac{1}{2}$$

The characteristic equation of Fig. 2 becomes

$$\begin{aligned}&s^2C_1C_2 + sC_2(G_1\alpha_{a2}\beta_{a1} - G_2\alpha_{b2}\beta_{b2}) + \\ &\qquad G_1G_2\alpha_{a3}\alpha_{b2}\beta_{a1}\beta_{b1} = 0\end{aligned} \tag{14}$$

The modified oscillation condition and oscillation frequency are

$$R_1 = \frac{R_2\alpha_{a2}\beta_{a1}}{\alpha_{b2}\beta_{b2}} \tag{15}$$

$$\omega_o = \sqrt{\frac{\alpha_{a3}\alpha_{b2}\beta_{a1}\beta_{b1}}{C_1 C_2 R_1 R_2}} \qquad (16)$$

The active and passive sensitivities of the quadrature oscillator are all low and obtained as

$$S^{\omega_o}_{\alpha_{b2},\alpha_{a3},\beta_{a1},\beta_{b1}} = -S^{\omega_o}_{C_1,C_2,R_1,R_2} = \frac{1}{2}$$

4 Simulation Results

The quadrature oscillators were simulated using HSPICE. The FDCCII was realized by the CMOS implementation in Fig. 1 of [22] and is shown in Fig. 3 (using 0.18 μ m MOSFET from TSMC). The aspect ratios of the MOS transistors were chosen as in Table 1. The multiple current outputs can be easily implemented by adding output branches. Fig. 4(a) represents the current-mode quadrature sinusoidal output waveforms of Fig. 1 with C_1 = 45pF, C_2 = 47pF, R_1 = 2kΩ, R_2 = 2kΩ, V_{bp} = 0V, V_{bn} = 0V, I_B = 1.1mA, I_{SB} = 2.2mA and the power supply ± 2.5V where C_2 was designed to be larger then C_1 to ensure the oscillations will start. The power dissipation is 84.2897mW. Fig. 4(b) shows the simulated frequency spectrum of I_{out1} and I_{out2} in Fig. 1. The results of the I_{out1} total harmonic distortion analysis are summarized in Table 2.

Fig. 5(a) and (b) represents the current-mode quadrature sinusoidal output waveforms and spectrums of Fig. 2 with C_1 = 45pF, C_2 = 45pF, R_1 = 2kΩ, R_2 = 1.9kΩ where R_1 was designed to be larger then R_2 to ensure the oscillations will start. Fig. 5(c) and (d) represents the voltage-mode quadrature sinusoidal output waveforms and spectrums of Fig. 2. The power dissipation is 118.0935mW. The results of the V_2 total harmonic distortion analysis are summarized in Table 3.

5 Conclusion

In this paper, two new quadrature oscillators each using one FDCCII, two grounded capacitors and two grounded resistors are proposed. The oscillation conditions and oscillation frequencies of the proposed quadrature oscillators have the advantage of being orthogonal controllable. Two high output impedance sinusoid currents with 90^o phase difference are available in each circuit configuration. The use of only grounded capacitors and resistors makes the proposed circuits ideal for integrated circuit implementation. The current-mode and voltage-mode quadrature signals can be simultaneously obtained in the second proposed circuit.

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Table 1 Aspect ratios of the MOS in Fig. 3.

MOS transistors	Aspect ratio (W/L)
M_1-M_6	60/4.8
M_7, M_8, M_9, M_{13}	480/4.8
M_{10}, M_{11}, M_{12}, M_{24}	120/4.8
M_{14}, M_{15}, M_{18}, M_{19}, M_{25}, M_{29}, M_{30}, M_{33}, M_{34}, M_{37}, M_{38}, M_{41}, M_{42}, M_{45}, M_{46}, M_{49}, M_{50}, M_{53}, M_{54}, M_{57}, M_{58}	240/2.4
M_{16}, M_{17}, M_{20}, M_{21}, M_{26}, M_{31}, M_{32}, M_{35}, M_{36}, M_{39}, M_{40}, M_{43}, M_{44}, M_{47}, M_{48}, M_{51}, M_{52}, M_{55}, M_{56}, M_{59}, M_{60}	60/2.4
M_{22}, M_{23}, M_{27}, M_{28}	4.8/4.8

Table 2 Total harmonic distortion analysis of I_{out1} in Fig. 1.

Harmonic Number	Frequency (hz)	fft_mag (db)	fft_mag	fft_phase (deg)
1	1.6500M	-81.7466	81.7847u	144.7815
2	3.3000M	-125.6550	521.4919n	144.7815
3	4.9500M	-126.7989	457.1448n	132.6606
4	6.6000M	-132.4139	239.5004n	149.4873
5	8.2500M	-134.0486	198.4120n	155.6472
6	9.9000M	-135.1182	175.4245n	162.0686
dc component: mag(db)= -1.212E+02				
total harmonic distortion = 953.7518m percent				

Table 3 Total harmonic distortion analysis of V_2 in Fig. 2.

Harmonic Number	Frequency (hz)	fft_mag (db)	fft_mag	fft_phase (deg)
1	1.7250M	-11.6281	262.1778m	97.8863
2	3.4500M	-49.1946	3.4695m	105.9968
3	5.1750M	-58.3716	1.2062m	-63.7087
4	6.9000M	-76.4800	149.9684u	165.8535
5	8.6250M	-69.9217	319.0907u	-65.7638
dc component: mag(db)= -4.654E+01				
total harmonic distortion = 1.4075 percent				

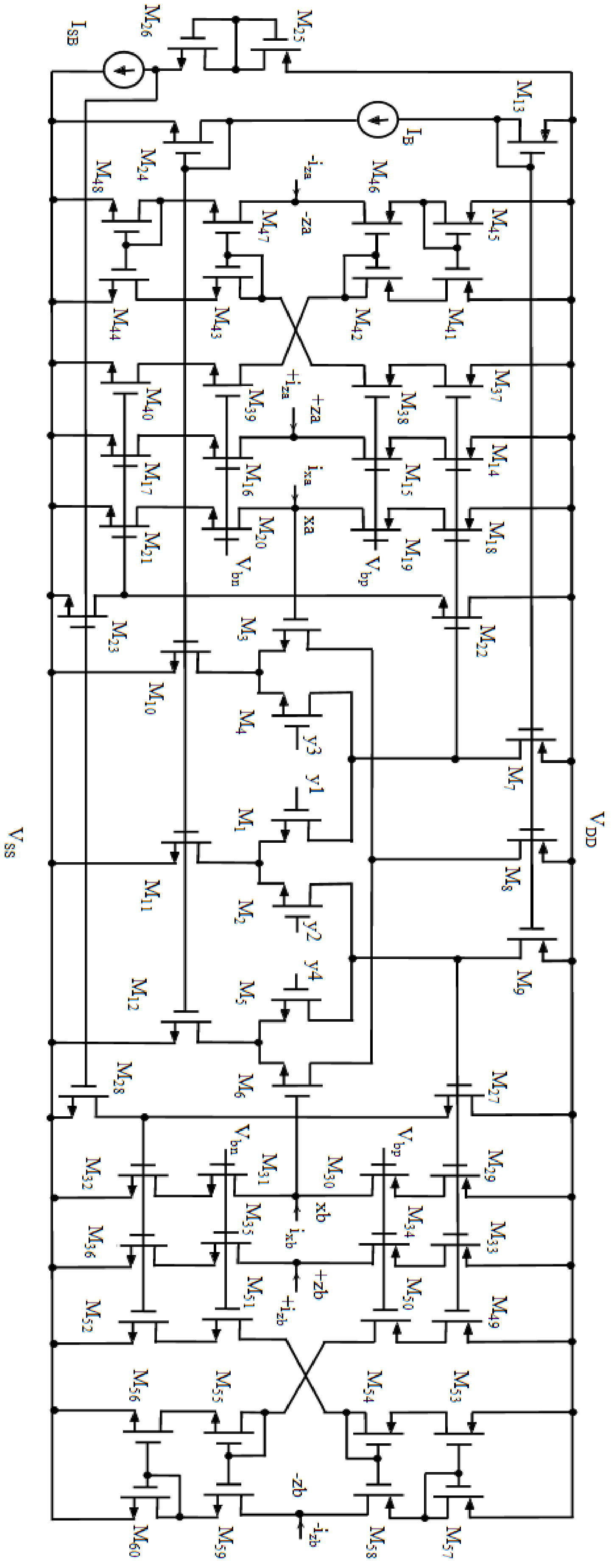
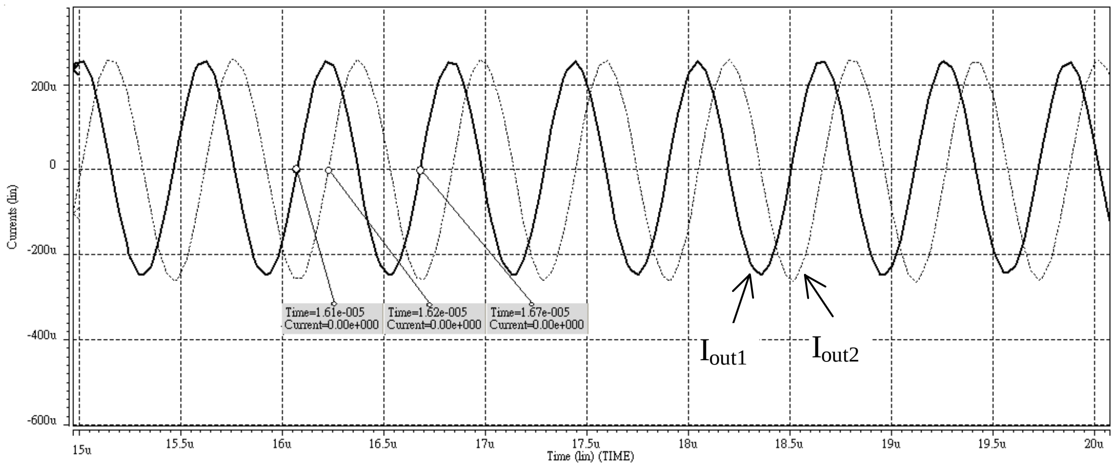


Fig. 3 The implementation of FDCCII.



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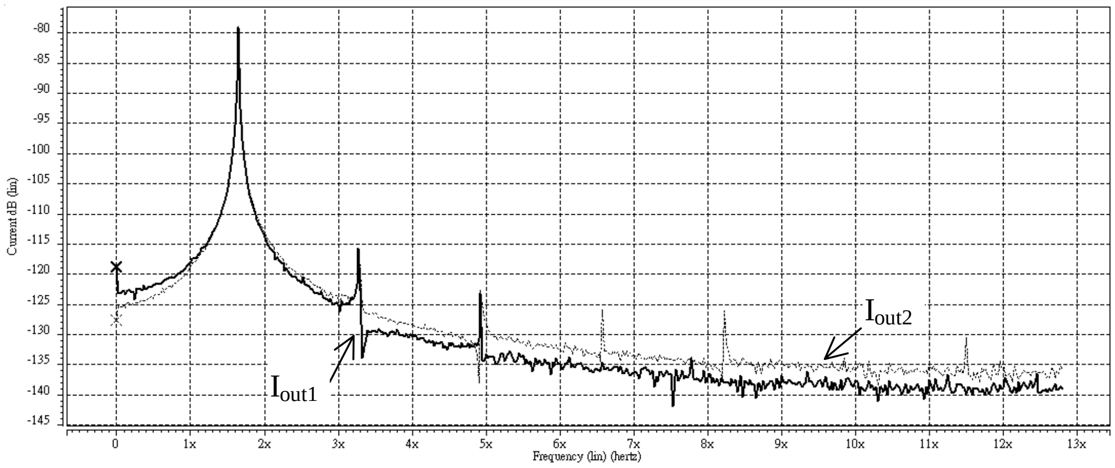
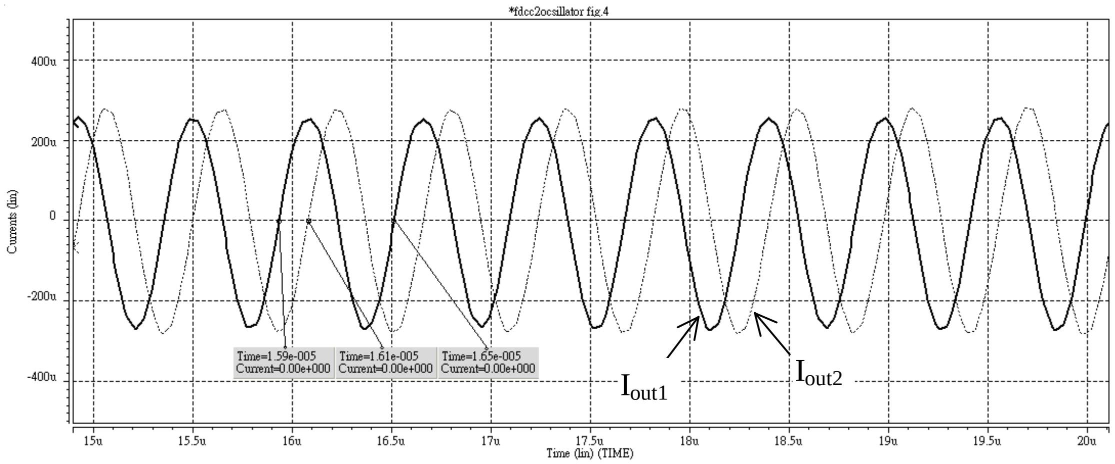


(b)

Fig. 4 (a) The simulated current-mode quadrature output waveforms of Fig. 1.
(b) The simulated frequency spectrum of I_{out1} and I_{out2} in Fig. 1.



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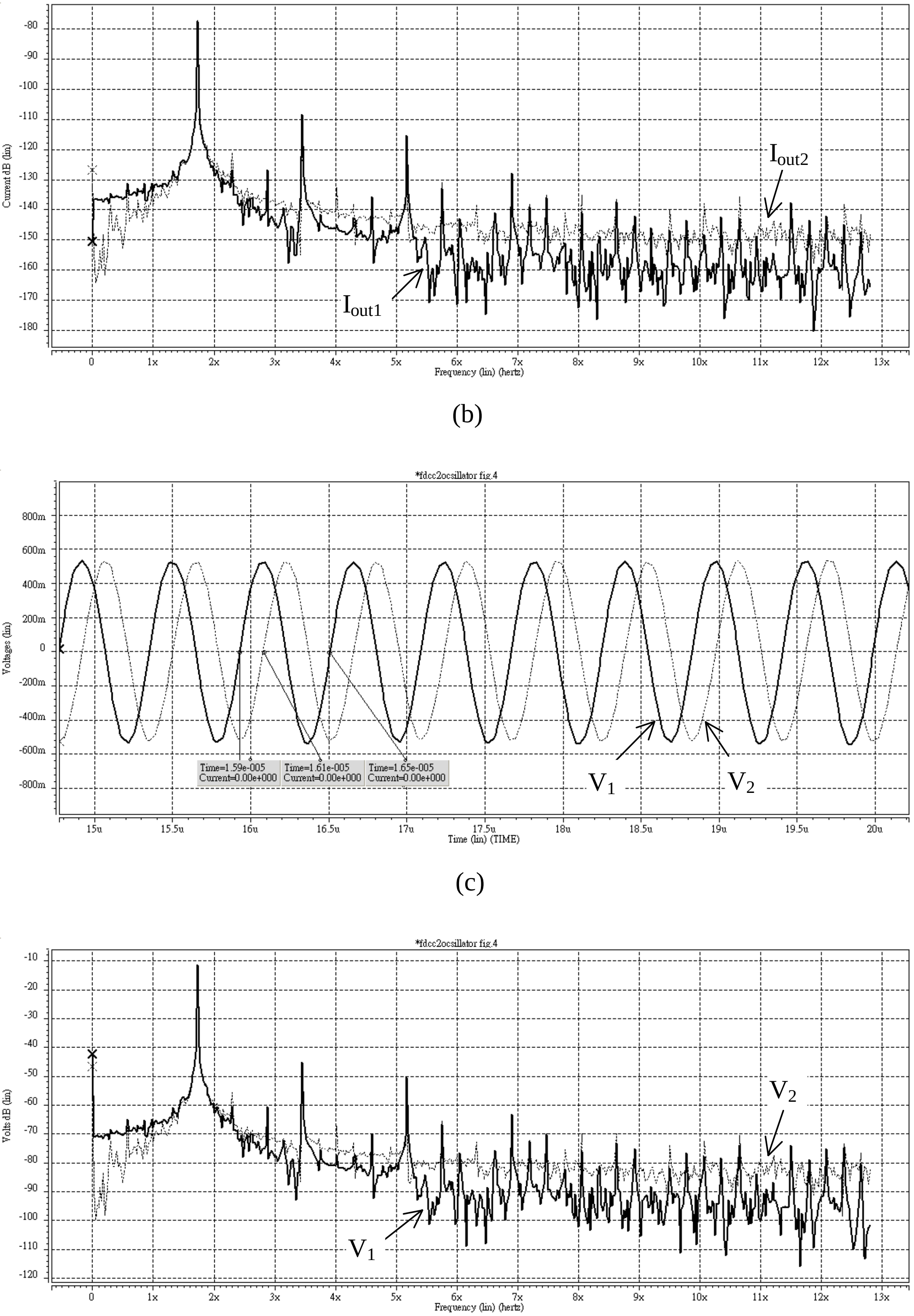

(b)

(c)

(d)

Fig. 5 (a) The simulated current-mode quadrature output waveforms of Fig. 2.
(b) The simulated frequency spectrum of I_{out1} and I_{out2} in Fig. 2.
(c) The simulated voltage-mode quadrature output waveforms of Fig. 2.
(d) The simulated frequency spectrum of V_1 and V_2 in Fig. 2.