

Dual-Output Second-Generation Current Conveyor-based Voltage-Mode Sinusoidal Oscillator modified for Chaos Generators

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Abstract— Two chaos generator circuits using dual-output second-generation current conveyors [DO-CCII]s as active devices with grounded passive components are realized. The starting circuit is a voltage-mode four-phase sinusoidal quadrature oscillator [VMFPSQO] circuit for realizing both the chaos generators. The first chaos generator is derived by modifying the VMFPSQO by inserting an additional frequency dependent negative resistor [FDNR]. This is to introduce the non-linearity into the sinusoidal oscillator. In the second chaos generator, non-linearity in the sinusoidal oscillator is introduced by using an additional block consists of an FDNR followed by a differentiator. The use of all grounded passive components makes both the generator circuits most suitable for monolithic implementation in contemporary IC technologies. The chaos generators are designed and verified using PSPICE simulation with good results.

Index Terms—Sinusoidal oscillators, CCII, chaos generator.

I. INTRODUCTION

Recently, second-generation current conveyors (CCII) have become very popular for implementing either voltage-mode or current-mode signal processing circuits, as these devices provide high performance and greater functional versatility in realizations [1-5]. Quadrature oscillator has been widely used in telecommunication and measurement systems. A number of quadrature oscillators based on different devices and different design techniques have been developed [2,3,5]. During recent years, a large number of chaos generators have been proposed [6-17]. In particular, the interest of many researchers has focused on analog circuits, because their structural simplicity which make their realization easy. Also there is an increasing interest in studying the possible chaotic nature of conventional sinusoidal oscillators using current conveyors because of their numerous advantages [7,8]. Design of simple chaotic circuits is important not only to explicate non-linear phenomena but also for engineering applications. Moreover, emphasis is on realizing inductor less chaotic oscillators [17].

In this paper two chaos generator circuits, voltage-mode chaos generator-I (VMCG-I) and voltage-mode chaos generator-II (VMCG-II), are presented. Both the circuits are based on sinusoidal oscillators. Starting with a sinusoidal oscillator, that is later modified for chaos

allows for attractive features obtained via linear design techniques to be transformed into the non-linear domain. The proposed chaos generators have the following attractive features:

- Sinusoidal oscillator exhibits the chaos by introducing and adjusting the non-linearity via a non-linear composite.
- Both the circuits are tuned through single grounded resistor.
- No inductor is used in their realizations.
- Use of grounded passive components, which make the circuits suitable for modern IC technologies.

II. CIRCUIT DESCRIPTION

The voltage-mode four-phase quadrature oscillator (VMFPSQO) circuit [5] used for obtaining both the voltage-mode chaos generators (VMCG) is shown in Fig.1. Routine analysis of Fig.1 yields the state space representation as

$$\frac{dV_1}{dt} = \left(\frac{1}{R_2 C_2} - \frac{1}{R_3 C_3} \right) V_1 - \frac{1}{R_1 C_1} V_2 \quad (1)$$

$$\frac{dV_2}{dt} = \frac{1}{R_3 C_3} V_1 \quad (2)$$

Equation (1) and (2) results in the condition of oscillation as (for $C_2 = C_3 = C$)

$$R_2 \geq R_3 \quad (3)$$

And the frequency of oscillation as

$$\omega_o = \left[\frac{1}{R_1 R_3 C_1 C_3} \right]^{1/2} \quad (4)$$

Equations (3) and (4) show that R_1 can independently control the frequency of oscillations without affecting the condition of oscillations.

The phase relationship between V_1 and V_2 at oscillating frequency ω_o can be obtained as,

$$V_2 = \frac{1}{sC_3 R_3} V_1 \Big|_{s=j\omega_o} \quad (5)$$

$$V_2 = -jKV_1 \quad (6)$$

Where $k = 1/\omega_o C_3 R_3$

Thus, the result in two quadrature outputs. Resistors R_4 and R_5 give the inversion of V_1 and V_2 as V_3 and V_4 . With

$R_4 = R_5 = R$, the phase relationship between V_1, V_2, V_3 and V_4 at oscillating frequency, ω_0 , is given by

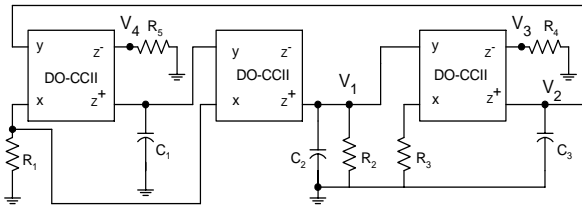


Fig.1 Voltage-mode four-phase sinusoidal quadrature oscillator (VMFPSQO).

$$\begin{aligned} V_3 &= -V_1 \\ \text{and } V_4 &= -V_2 \end{aligned} \quad (7)$$

Thus, the oscillator of Fig1. generates a four phase quadrature outputs.

a) Circuit description of VMCG-I

The voltage-mode chaos generator-I (VMCG-I) is shown in Fig. 2. For realizing this from VMFPSQO of Fig.1, an additional frequency dependent negative resistance (FDNR) is connected at the output voltage terminal V_{03} . The FDNR consists of two DO-CCIIS, two capacitors C_4 and C_5 and a resistor, R_6 . A resistor, R_7 is also used to obtain an output voltage, V_6 .

$$\text{The input impedance of the FDNR, } Z_{in} = \frac{1}{s^2 D}.$$

$$\text{Where, } D = R_6 C_4 C_5 \quad (8)$$

D has the unit of Farad sec and 's' is the complex radian frequency ($j\omega$).

Equation (8) has the s^2 term in its denominator, which shows its nonlinearity. The nonlinearity of the FDNR provides the non-linear mechanism for generation of chaos in the circuit of Fig.2 of VMCG-I. The VMCG-I is described by the following state space equations:

$$\frac{dV_1}{dt} = \left(\frac{1}{R_2 C_2} - \frac{1}{R_3 C_3} \right) V_1 - \frac{1}{R_1 C_1} V_2 \quad (9)$$

$$\frac{dV_2}{dt} = -\frac{1}{R_3 C_3} V_1 \quad (10)$$

$$\frac{dV_3}{dt} = -\frac{1}{R_6 C_4} \quad (11)$$

$$\frac{dV_5}{dt} = -\frac{1}{R_7 C_5} V_6 \quad (12)$$

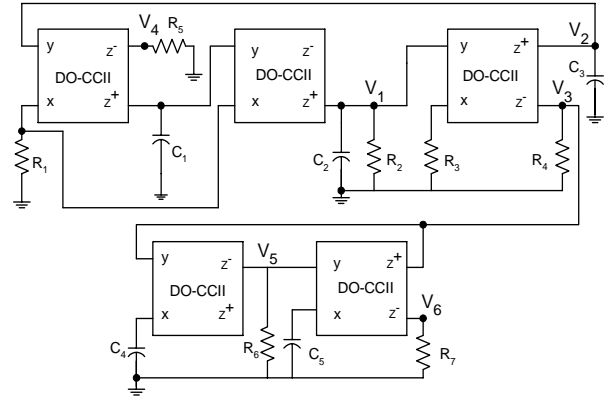


Fig. 2. Voltage-mode chaos generator -I (VMCG-I)

The above equations shows that VMCG-I is governed by the same condition of oscillation as that of the VMFPSQO. For studying the chaotic behaviour of the chaos-I generator, resistor R_7 was tuned as the chaos control parameter.

b) Circuit Description of VMCG-II

The voltage-mode chaos generator-II (VMCG-II) is shown in Fig.3. It is derived by connecting the voltage output terminal V_{03} of VMFPSQO of Fig.1 to a nonlinear composite, consisting of an FDNR followed by a differentiator. The FDNR of the composite has the input impedance, $Z_{in} = \frac{1}{s^2 D}$.

From Fig.3 the parameter D can be expressed as

$$D = R_7 C_5 C_6 \quad (13)$$

Where, R_7, C_5 , and C_6 are the resistor and capacitors used for the realization of the FDNR.

The voltage transfer function of the composite circuit is as follows,

$$\frac{V_5}{V_3} = -\frac{s C_3 R_5}{(s^2 R_5 D + 1)} \quad (14)$$

Substituting the values of D from (13) into (14) we get

$$\frac{V_5}{V_3} = -\frac{s C_3 R_5}{s^2 C_5 C_6 R_5 R_7} \quad (15)$$

In Equation (15), the s^2 term in the denominator shows the non-linearity of the composite circuit. The non-linearity of the composite circuit provides the non-linear mechanism for the generation of chaos in the VMCG-II circuit. The VMCG-II circuit of Fig.3 can be described by the following set of state equations:

$$\frac{dV_1}{dt} = \left(\frac{1}{R_2 C_2} - \frac{1}{R_3 C_3} \right) V_1 - \frac{1}{R_1 C_1} V_2$$

$$\frac{dV_2}{dt} = -\frac{1}{R_3 C_3} V_1$$

$$\frac{dV_3}{dt} = -\frac{1}{C_4 R_6} V_6 + \frac{C_6}{C_4} \frac{dV_6}{dt}$$

$$\frac{dV_5}{dt} = -\frac{1}{C_5 R_7} V_6$$

$$\frac{dV_6}{dt} = \frac{C_4}{C_6} \frac{dV_3}{dt} + \frac{1}{C_6 R_6} V_5$$

Where V_1, V_2, V_3, V_4, V_5 and V_6 are the voltages available at different output nodes of the VMCG-II.

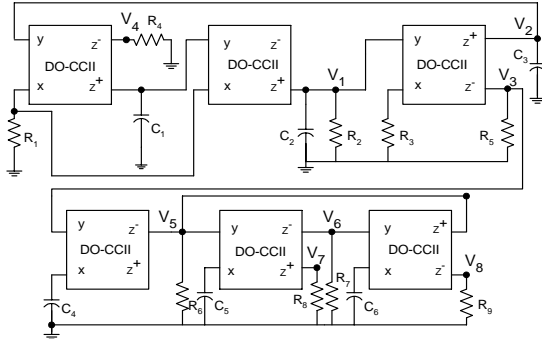


Fig. 3 Voltage-mode chaos generator-II (VMCG-II).

III. SIMULATION RESULTS

The voltage-mode four-phase sinusoidal quadrature oscillator circuit of Fig.1 is designed and simulated, using 0.35 μm CMOS DOCCII model, derived from [18], as shown in Fig.4. The W/L parameters of MOS transistors are given in Table.1, where M_{Nxx} and M_{Pxx} are the index of the different transistors. The supply voltages and bias currents were $V_{DD} = -V_{ss} = 2.5V$ and $I_B = 100\mu A$. The designed values for an oscillating frequency of 1MHz were found as $R_1 = R_2 = R_3 = 10K$, and $C_1 = C_2 = C_3 = 0.0159$ nf. The values of R_4 and R_5 are taken as 10K. The output waveforms obtained through PSpice simulation are shown in Fig.5. For the realization of VMCG-I, the design values of the components of the sinusoidal oscillator were the same as for VMFPSQO, except the value of R_4 . The component values for frequency dependent negative resistance (FDNR) were $C_4 = C_5 = 0.0159$ nF, $R_6 = 1.4$ K, $R_7 = 10.5$ K and the value of R_5 was 62K. The associated phase-space trajectory generated by PSpice of the chaotic voltages V_5 and V_6 are shown in Fig..6. Which proves the output voltages of VMCG-I are chaotic in nature.

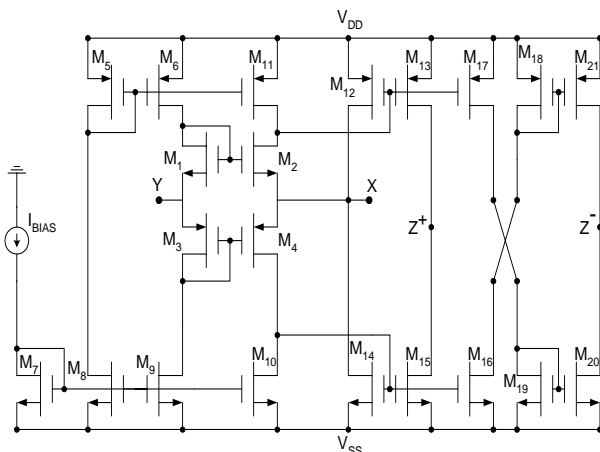


Fig. 4. CMOS model of DO-CCII.

TABLE CMOS MODEL PARAMETERS

Device Name	Aspect ratio W/L(μm)
M1, M2	12/0.35
M3, M4	36/0.35
M_{Pxx} (in PMOS current mirrors)	18/0.35
M_{Nxx} (in NMOS current mirrors)	6/0.35

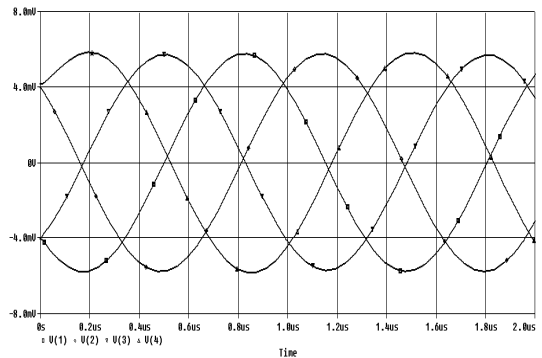


Fig. 5. Simulated results of VMFPSQO of Fig.1

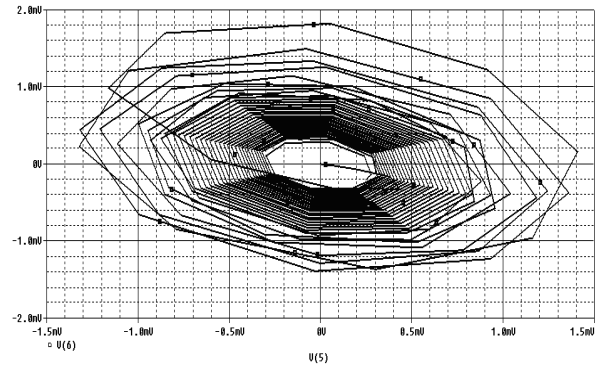


Fig. 6. Phase-space trajectory of VMCG-I of Fig. 2

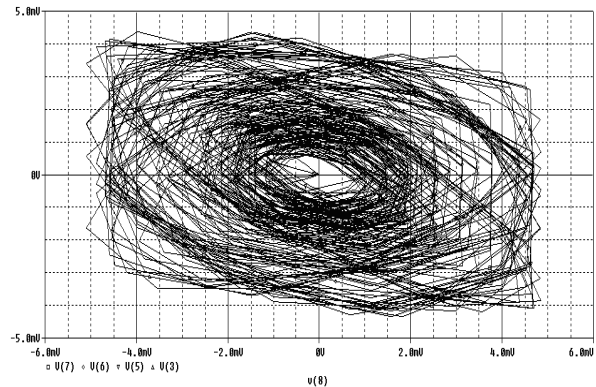


Fig. 7. Phase-space trajectory of VMCG-II of Fig. 3

For the realization of VMCG-II of Fig.3., the design values of the components of the sinusoidal oscillator were the same as for VMCG-I. The values taken for the non-linear circuit composite were $C_4 = C_5 = C_6 = 0.0159$ nF, $R_5 = 9.286K$, $R_6 = 11.27K$, $R_7 = 10K$, and the value of R_4 was 7.052K. The phase-space trajectory, generated by PSpice of the chaotic voltages is shown in Fig .7.

IV. CONCLUSION

A voltage-mode four-phase sinusoidal quadrature oscillator, using CCII and grounded passive components, is modified for the chaos generators,

VMCG-I and VMCG-II. The nonlinearity is introduced by an FDNR to obtain the VMCG-I, while the VMCG-II is derived by introducing the nonlinearity from a nonlinear composite which consists of a FDNR followed by a differentiator. The attractive features of both the realized chaos generators circuits are such as (i) No inductor used in their realization. (ii) Tuning is obtained through grounded single resistor, (iii) use of grounded passive components and (iv) suitability for the modern IC technologies. The simulation results verify the proposed theory.

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