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New Current-mode Quadrature Sinusoidal Oscillator Using Single DVCCTA as Active Element

***Abstract**. This paper presents the design of a current-mode quadrature sinusoidal oscillator. It can generate two current-mode sinusoidal outputs with 90 degree phase difference called as quadrature signal. The proposed sinusoidal oscillator employs single differential voltage current conveyer transconductance amplifier (DVCCTA), two grounded capacitors and three resistors. The tuning of frequency of oscillation (FO) and condition of oscillation (CO) can be done independently. Also the frequency of oscillation can be electronically tuned which is suitable for modern control system using microcontroller or microprocessor. The impedance at output node is high impedance which can directly drive an external load or connect to another circuit without the use of current buffers. A number of simulation results based on PSPICE program using 0.25 µm TSMC CMOS parameters are included to exhibit performance, workability and effectiveness of the proposed sinusoidal oscillator.*

***Streszczenie.** W artykule opisano projekt prądowego generatora sinusoidalnego. Może on generować sygnały z przesunięciem 90°. Generator wykorzystuje różnicowy przetwornik napięcie prąd ze wzmacniaczem transkonduktancyjnym – DVCCTA., dwa uziemione kondensatory I trzy rezystory. Generator może być strojony elektronicznie.* ***Nowy generator sinusoidalny wykorzystujący jako aktywny element układ DVCCTA**.*

Keywords: qudrature sinusoidal oscillator; current-mode; DVCCTA.
Słowa kluczowe: generator sinusoidalny, układ DVCCTA.

Introduction

In electrical and electronic engineering, the sinusoidal signal has gained much of importance. The circuit which generates the sine wave is called as oscillator. Ideally, the oscillator should generate the sinusoidal signal with low total harmonic distortions (THD). Especially, the quadrature sinusoidal oscillator which provides two sinusoidal signals with 90° degree phase difference is very useful in many applications, for example, in measurement system found in vector generators and in selective voltmeters and in telecommunication found in single sideband modulators, in quadrature mixers, in direct-conversion receivers etc. [1-4]. “The synthesis of analog signal processing circuits using active building blocks, taking into account several various criteria such as minimum number of active elements or others, has been receiving considerable attention [5]. Recently, a new mixed-mode active element, namely, differential voltage current conveyer transconductance amplifier (DVCCTA), was introduced [6]. This building block with two voltage inputs and two kinds of output current is constructed from the well-known advantages of the differential voltage current conveyer (DVCC) and the operational transconductance amplifier (OTA). It provides the facility for the implementation of voltage and current mode signal processing. Moreover, its transconductance gain (g_m) can be electronically tuned which is easy to use in the modern microcontroller or microprocessor based electronic systems.” [7]. A lot of electronic circuits using DVCCTA have been proposed in literature which can be found in [6-15]. Most of them were introduced for analog signal processing for example, capacitance multiplier [6], inductance simulator [8], first order allpass filter [8-9], wave active filter [10], multifunction filter [11-13] and sinusoidal oscillator [7, 9, 14-15]. In this study, the oscillator using DVCCTA as active element will be focused and reviewed. The voltage-mode quadrature oscillator consisting of single DVCCTA, two grounded capacitors and two grounded resistors was proposed [14]. The condition of oscillation and frequency of can be orthogonally controlled. The frequency of oscillation can be electronically adjusted. However, the frequency of oscillation and condition of oscillation cannot be electronically tuned. The sinusoidal oscillator in [9] was designed from the connecting of first order allpass filter and integrator. It consists of two DVCCTAs, two grounded capacitors and two grounded resistors. The circuit can provide quadrature signal in both voltage and current mode. The frequency of oscillation can be electronically tuned. However, it cannot provide the independent control of frequency of oscillation and condition of oscillation. Two current-mode sinusoidal oscillators were proposed in [15]. The first one consists of single DVCCTA, two grounded capacitors and two grounded resistors. The frequency of oscillation and condition of oscillation can be orthogonally controlled. However, the frequency of oscillation cannot be electronically adjusted. Moreover, this circuit cannot provide quadrature output waveform. The second oscillator consists of single DVCCTA, two grounded capacitors and single resistor. The frequency of oscillation can be electronically tuned. However, condition of oscillation is tuned by adjusting the value of two capacitors. Also, this circuit cannot provide quadrature output waveform. Recently, the voltage-mode quadrature oscillator using DVCCTA was proposed [7]. This quadrature oscilaltor consists of single DVCCTA, two grounded capacitors and single resistor. The frequency of oscillation and condition of oscillation can be electronically tuned. However, it cannot provide the independent control of frequency of oscillation and condition of oscillation. In 2011, the current-mode quadrature sinusoidal oscillator was presented [3]. This oscillator consists of single active building block which is widely used in current-mode signal processing [16-17], namely current controlled current differencing transconductance amplifier (CCCDTA) and two grounded capacitors. In this oscillator, the frequency of oscillation and condition of oscillation can be electronically controlled. Moreover, the two output current nodes are exhibit high impedance which allows circuit can be cascaded to other circuit without the use of any buffers. However, the frequency of oscillation and condition of oscillation cannot be independently tuned.

In this paper, a current-mode sinusoidal oscillator, consisting of single DVCCTA, two grounded capacitors and three resistors is proposed. It can provide quadrature sinusoidal waveform in current-mode with high output impedance. The frequency of oscillation and condition of oscillation can be independently adjusted. Also, the frequency of oscillation can be electronically tuned. The simulation results using PSpice program agree well with theoretical anticipation.

Theory and Principle

Basic Concept of DVCCTA

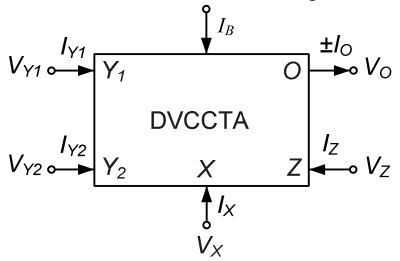
The realization of electronic circuits using active building block has been gained significant attention [18-23]. In this realization, the differential voltage current conveyer transconductance amplifier (DVCCTA) is main active building block. It was firstly proposed in [6]. DVCCTA is constructed from the well-known differential voltage current conveyer (DVCC) and operational transconductance amplifier (OTA). An electrical symbol of DVCCTA is ideally given in Fig. 1(a) and its electrical symbol is shown in Fig. 1(b). According to Fig. 1, it is found that DVCCTA is a five terminal active device. Ideally, the voltage input terminals Y_1 and Y_2 are high impedance, while X terminal is low impedance. The current output terminals Z and O are high impedance. The voltage at Z terminal is sent to be current at O terminal via tranconducance (g_m). The DC bias current I_B is used to control the transconductance of the current at O terminal. The input and output terminal relations of DVCCTA can be characterized by the matrix shown as follows

(1) $$\begin{pmatrix} I_{Y1} \\ I_{Y2} \\ V_X \\ I_Z \\ I_O \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \pm g_m & 0 \end{pmatrix} \begin{pmatrix} I_X \\ V_{Y1} \\ V_{Y2} \\ V_Z \\ V_O \end{pmatrix}.$$

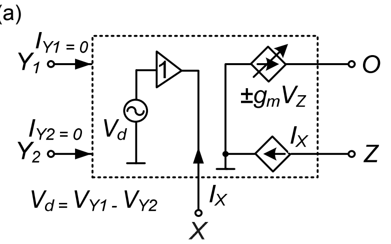
The CMOS implementation of DVCCTA can be shown in Fig. 4. Assume that M_{14}-M_{15} are matched and operating in saturation region, the gm are written as

(2) $$g_m = \sqrt{\mu_n C_{OX} \left(W/L\right) I_B}\ .$$

I_B are the input bias current to control gm and is used to control the gm. μ is the effective channel mobility. C_{ox} is the gate oxide capacitance per unit area. W is the channel width and L is the channel length.



(a)



(b)

Fig.1. DVCCTA (a) Symbol (b) Equivalent circuit [7]

Implementation of Quadrature Sinusoidal Oscillator

The generalized structure of the quadtrature sinusoidal oscillator is shown in Fig. 2 which consists of the two lossless integrators and amplifier. The parameters *a* and *b* are the time conductance of integrators, respectively. The *k* is the gain of current amplifier. From block diagram in Fig. 2, the characteristic equation is written as

(3) $$s^2 ab + sa(k-1) + 1 = 0\ .$$

Considering in Eq. (3), the frequency of oscillation and condition of oscillation are expressed as

(4) $$\text{OF: } \omega = \sqrt{\frac{1}{ab}}\ ,$$

and

(5) $$\text{OC: } 1 \geq k\ .$$

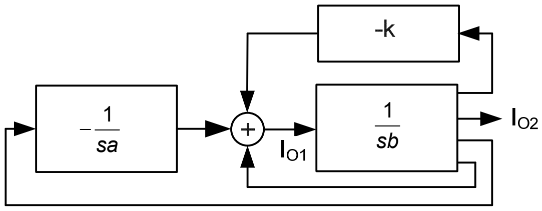


Fig.2. The generalized structure of current-mode quadrature sinusoidal oscillator

Considering Eqs. (4) and (5), the CO can be controlled independently of the FO by the current gain *k*, while the FO can be changed by *a* and b without affecting CO.

The relationship between output current I_{o1} and I_{o2} is as follows:

(6) $$\frac{I_{o1}}{I_{o2}} = \frac{1}{sb}$$

It is found from Eq. (6) that the phase difference between I_{o1} and I_{o2} are 90 degree which is the quadrature signal.

Proposed Current-mode Quadrature Sinusoidal Oscillator

Based on the block diagram in Fig. 2, the proposed current-mode quadrature sinusoidal oscillator is illustrated in Fig. 3. It consists of one DVCCTA, three resistors and two grounded capacitor. The quadrature output currents are I_{O1} and I_{O2}. It is found that the proposed oscillator uses only single active elements with grounded capacitors which is attractive for monolithic chip point of view. Moreover, the impedance of the output currents is high impedance which can be cascaded or driven external load without the use of buffering circuit. From the circuit in Fig. 3, the characteristic equation is obtained as

(7) $$s^2 C_1 C_2 R_X + sC_1\left(R_2 - R_1\right) + g_m = 0\ .$$

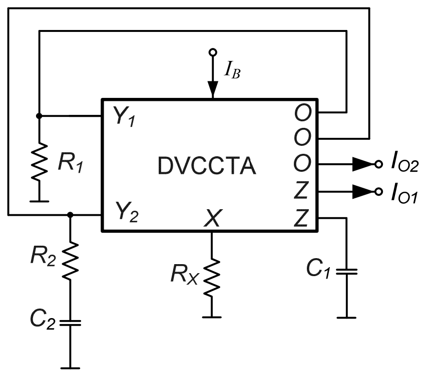


Fig.3. DVCCTA-based current-mode quadrature sinusoidal oscillator

According to Eqs. (4) and (5), the FO and CO are as follows:

(8) OF $\omega = \sqrt{\dfrac{g_m}{C_1 C_2 R_X}}$,

and

(9) CO: $R_1 \geq R_2$.

If g_m is equal to Eq. (2), the FO in Eq. (8) is written as

$$FO: \quad \omega = \sqrt{\frac{\left(\mu_n C_{OX} \left(W/L\right) I_B\right)^{\frac{1}{2}}}{C_1 C_2 R_X}} \tag{10}$$

From Eqs. (9) and (10), it can be seen that the FO can be adjusted electronically/independently from the CO by varying I_B while the CO can adjusted independently from the FO by R_1 and R_2.

Analysis of Non-ideal Case

In practically, the characteristic of DVCCTA is written as

$$V_x = \beta_1 V_{y1} - \beta_2 V_{y2}; I_z = \alpha i_x; I_o = \gamma g_m V_z , \tag{11}$$

where α is the parasitic current transfer gains from *X* terminals to *Z* terminal. β_1 and β_2 are the parasitic voltage transfer gains from Y_1 and Y_2 terminals to *X* terminal. *γ* is the parasitic current gains associated with copies of the current from o terminal.

Considering the non-ideal effects, characteristic equation get modified to

$$s^2 C_1 C_2 R_x + s C_2 \alpha\gamma g_m \left(\beta_2 R_2 - \beta_1 R_1\right) + \alpha\beta_2\gamma g_m = 0 . \tag{12}$$

Then the frequency of oscillation and condition of oscillation of the proposed current-mode quadrature oscillator from Eqs.(8)-(9) become

$$FO: \quad \omega = \sqrt{\frac{\alpha\beta_2\gamma g_m}{C_1 C_2 R_X}} , \tag{13}$$

and

$$\text{CO: } R_1 \geq \frac{\beta_2}{\beta_1} R_2 . \tag{14}$$

It is found that non-ideal parameters will affect both frequency of oscillation and condition of oscillation. These parameters are dependent on temperature variations. Consequently, these errors affect the sensitivity to temperature and the high frequency response of the proposed circuit, the DVCCTA should be carefully designed to minimize these errors. Moreover, the stray/parasitic capacitance at terminal y_1, y_2, *z* and *o* can be absorbed into the external grounded capacitors as they appear in shunt with them.

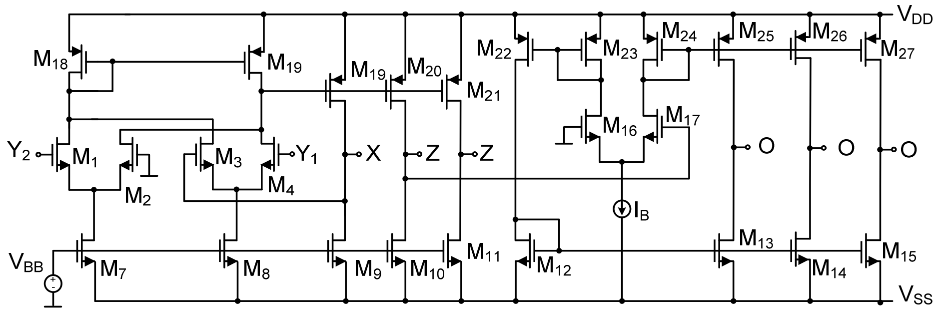


Fig.4. Internal construction of DVCCTA

Simulation Results

To verify the theoretical analysis, the proposed oscillator was simulated with PSPICE simulation using CMOS schematic of DVCCTA as given in Fig. 4 The circuit was designed and simulated based on the 0.25μm TSMC CMOS technology [24]. The optimal aspect ratios of PMOS and NMOS transistor are listed in Table I. The active parameters and the passive elements in the proposed oscillator are chosen as ±1.25V supply voltages, *V_{BB}=-0.55V*, *R_1=1.35kΩ*, *R_2=1kΩ*, *R_x=3.8kΩ*, *C_1=C_2=33pF* and *I_B=70μA*. The transient responses from initial state until steady state and during the steady state are respectively shown in Fig. 5 and 6. It is found that the output currents I_{O1} and I_{O2} are quadrature signal. Figure 7 shows the output spectrums. The simulated frequency of oscillation achieved 1.36 MHz. The total harmonic distortions (THD) for I_{O1} and I_{O2} are 2.054% and 2.359%, respectively.

Table 1. Aspect ratio W/L for MOSFETs

Transistor	W (μm)	L (μm)
M1-M4	1	0.25
M7-M15	3	0.25
M16-M17	2	0.25
M18-M21	15	0.25
M22-M27	5	0.25

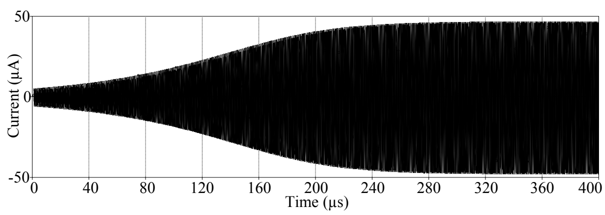


Fig.5. Output waveforms during initial

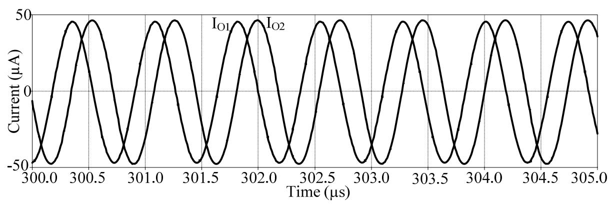


Fig.6. Output current of the proposed quadrature sinusoidal oscillator

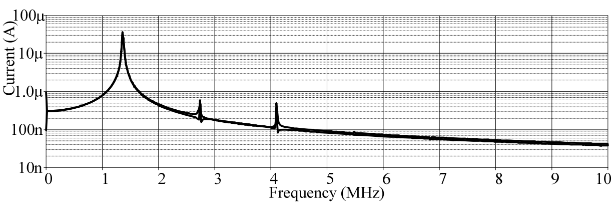


Fig.7. Spectrum of signal in Fig.6

Conclusions

In this paper, a current-mode quadrature sinusoidal oscillator employing single DVCCTA, two grounded capacitors and three resistors is presented. The main advantage of proposed oscillator is that it employs only single active element which is useful for integrated circuit implementation. It can provide current-mode quadrature sinusoidal signals (I_{O1} and I_{O2}) with high output impedance resulting in easy cascadability with other current-mode circuits or directly driving load without the use of current buffer. The tuning of frequency of oscillation and condition of oscillation is independently. The frequency of oscillation can be electronically controlled which is easy for microcontroller or microcomputer controllability. The performances of the proposed oscillator were verified by PSpice simulation results, which show strong agreement with the theoretical analyses.

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