

New Voltage Mode Sinusoidal Oscillator Using Voltage Differencing Transconductance Amplifiers (VDTAs)

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Abstract

The purpose of this paper is to introduce a new electronically controlled voltage mode sinusoidal oscillator (VMSO) using Voltage Differencing Transconductance Amplifiers (VDTA). The proposed circuit provides electronic control of ω_0 and independent condition of oscillation (CO). It is found that the oscillator works very satisfactorily and pure sinusoidal waveforms are available at the outputs. The PSPICE simulation confirms the theoretical results. The proposed oscillator circuit employs only two VDTAs, along with two grounded capacitor and single grounded resistor. The circuit exhibits low active and passive sensitivities for ω_0 . Simulation results are obtained by using PSPICE software with TSMC CMOS 0.18 μm process parameters.

Keywords

Voltage Differencing Transconductance Amplifier (VDTA), Voltage-Mode Circuit, Oscillator

1. Introduction

In recent years the focus has been on the design of various applications based on advanced analog building blocks [1]-[4]. Sinusoidal oscillators find wide applications in communication engineering, electronic instrumentation and control systems [5] [6]. The voltage differencing transconductance amplifier (VDTA) is an active versatile building block used in the realization of analog signal processing circuits and analog wave generation. It is also attractive due to its capability of adjusting the output current gain.

However, these circuits suffer from

- Lack of electronic adjustability [7].

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- Excessive use of passive elements, especially external resistors.
- Use of a floating capacitor, which is not convenient to further fabrication in IC.
- Oscillation conditions (CO) and oscillation frequencies cannot be independently controllable.

Various filters and oscillators are designed using active building blocks such as CFTAs [8] [9], CCCFTAs [10], CDTA, VDTA, CFA, CC-II [11]-[18].

The purpose of this paper is to present new voltage mode sinusoidal oscillator by using two VDTAs, two grounded capacitors and one resistor. PSPICE simulation results are provided, which verify the workability of the proposed circuit. The resulting circuit is low-power and provides independent control of the condition of oscillation (CO) and frequency of oscillation (FO). The important feature of VDTA is that this new element exhibits two different values of transconductances so that several applications such as oscillator, filters, inductance and FDNR (frequency dependent negative resistor) simulator can be realized with a single active block employing one or two capacitors. One more important feature is that this block can be used easily at transconductance mode applications such that the input terminals is voltage and output terminals is current. The proposed circuit employs minimum number of passive and active components. The use of additional VDTA facilitates the achievement of independent control of ω_0 , which is an attractive feature of the circuit.

2. Circuit Description

The Voltage Differencing Transconductance Amplifier (VDTA), whose schematic symbol is shown in **Figure 1**, consists of an input current follower that transfers the input current to the z terminal and an output transconductance amplifier stage, which is used to convert the voltage at the z terminal into output currents. Relations between the individual terminals of VDTA can be described by the following hybrid matrix:

$$\begin{bmatrix} I_z \\ I_{x+} \\ I_{x-} \end{bmatrix} = \begin{bmatrix} g_{m1} & -g_{m1} & 0 \\ 0 & 0 & g_{m2} \\ 0 & 0 & -g_{m2} \end{bmatrix} \begin{bmatrix} V_{VP} \\ V_{VN} \\ V_Z \end{bmatrix} \quad (1)$$

where g_m is transconductance gain of the VDTA which is given by Equations (2) & (3). Internal construction of VDTA used for simulation is shown in **Figure 2**. The introduced circuit employs two transconductances. Input and output transconductances parameters of VDTA element in the circuit are determined by the transconductance of outputs transistors. It can be approximated as

$$g_{m1} = \frac{g_3 + g_4}{2}, \quad (2)$$

$$g_{m2} = \frac{g_5 + g_8}{2} \text{ or } g_{m2} = \frac{g_6 + g_7}{2} \quad (3)$$

where g_i is the transconductance value of i^{th} transistor defined by

$$g_i = \sqrt{I_{Bi} u_i C_{ox} \left[\frac{W}{L} \right]}, \quad (4)$$

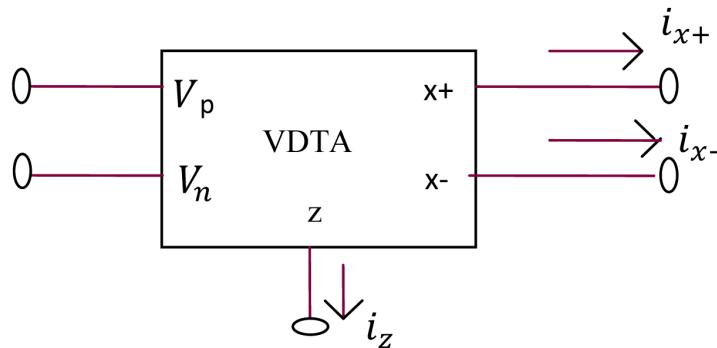


Figure 1. The VDTA schematic symbol.

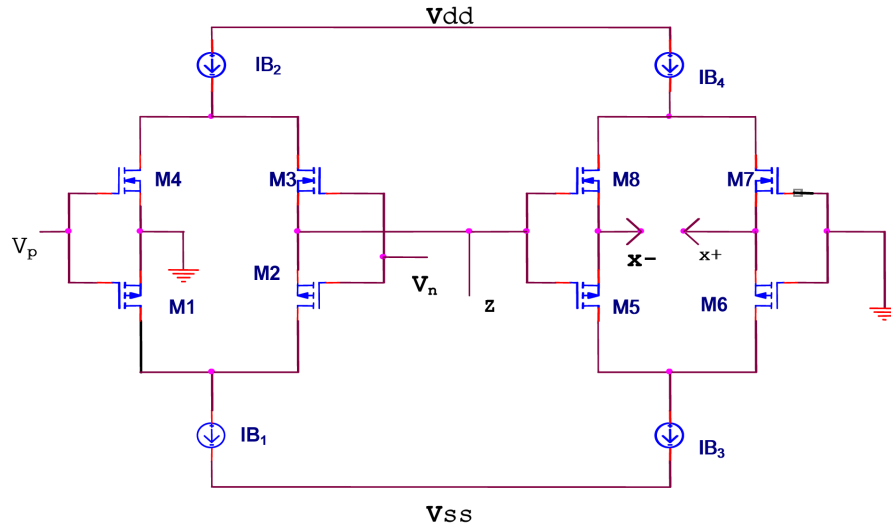


Figure 2. Internal construction of VDTA using CMOS used for simulation.

u_i is ($i = n, p$) the mobility of the carrier for NMOS (n) and PMOS (p) transistors, C_{ox} is the gate-oxide capacitance per unit area, W is the effective channel width, L is the effective channel length and I_{Bi} is bias current of i^{th} transistor. The proposed VMSSO using VDTA [18] is shown in **Figure 4**. It consists of 2 VDTAs, 2 grounded capacitors and one resistor.

3. Proposed Circuit Realization of VMSSO Using Voltage Differencing Transconductance Amplifier (VDTA)

The oscillator is designed by cascading an inverting second order low-pass filter and the lossless integrators as shown in **Figure 3**. From block diagram as shown in **Figure 3**, we obtain the characteristic equation of a sinusoidal oscillator as

$$s^3 + bs^2 + as + ck = 0 \tag{5a}$$

Hence, from Equation (5a), the condition of oscillation (OC) and frequency of oscillation (FO) can be written as

$$OC : ab = ck \tag{5b}$$

and

$$\omega_0 = \sqrt{a} \tag{5c}$$

From Equation (5a), if $a = c$, the oscillation condition and oscillation frequency can be adjusted independently, *i.e.* the oscillation condition can be controlled by b and k , while the oscillation frequency can be tuned by a . The proposed voltage mode sinusoidal oscillator using VDTA is shown in **Figure 4**. The frequency of oscillation (FO) and condition of oscillation (CO) are found to be

$$\omega_0 = \sqrt{\frac{g_{m1}}{c_1 c_2} (g_{m2} + g_{m4})}$$

If $c_1 = c_2 = c$

$$FO : \omega_0 = \frac{1}{c} \sqrt{g_{m1} (g_{m2} + g_{m4})} \tag{6}$$

$$CO : \frac{1}{R_1} - (g_{m2} + g_{m4}) \leq 0 \tag{7}$$

From the above equations it is clear that condition of oscillation can be set by R_1, g_{m2}, g_{m4} . Frequency of

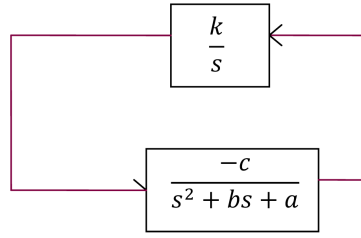


Figure 3. Block diagram for the design of proposed oscillator.

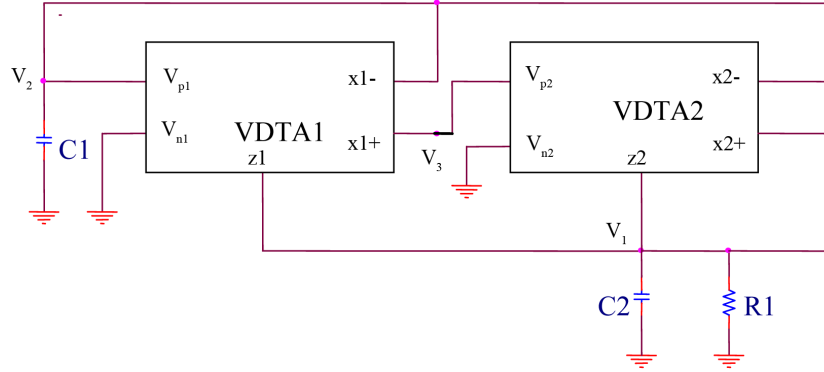


Figure 4. Proposed VMSO using VDTA.

oscillation is controlled independently by g_{m1} which is independent of CO. The voltage mode transfer function obtained from Figure 4 is

$$\frac{V_2(s)}{V_1(s)} = -\frac{(g_{m2} + g_{m4})}{sC_1} \quad (8)$$

Therefore, the proposed circuit provides two voltage mode sinusoidal oscillations across output simultaneously.

4. Non Ideal and Sensitivity Analysis

The FO and CO for the circuit shown in Figure 5 are given as:

$$FO: \omega_0 = \sqrt{\frac{\frac{1}{R_{x-}} \left(\frac{1}{R_1} + \frac{1}{R_{x+}} + \frac{1}{R_z} \right) + g_{m1}(g_{m2} + g_{m4}) - (g_{m2} + g_{m4}) \left(\frac{1}{R_{x-}} \right)}{(C_1 + C_p)(C_2 + C_z)}} \quad (9)$$

$$CO: \left\{ (C_1 + C_p) \left(\frac{1}{R_1} + \frac{1}{R_{x+}} + \frac{1}{R_z} \right) + \frac{1}{R_{x-}} (C_2 + C_z) - (g_{m2} + g_{m4}) (C_1 + c_p) \right\} \leq 0 \quad (10)$$

From Figure 5, it shows that parasitic capacitances C_p and C_z are in parallel with the external capacitances C_1 and C_2 respectively. Therefore, the influence of the parasitic capacitances can be eliminated easily by reducing the values of external capacitances. If R_{x-} is infinite, the frequency of oscillation and condition of oscillation are independently tunable even under the influence of VDTA parasitic. The effect of changes in active and passive element values is determined by evaluating sensitivity coefficients which are found to be

$$S_{g_{m1}}^{e_0} = S_{g_{m2}}^{e_0} = S_{g_{m4}}^{e_0} = \frac{1}{2}, \quad S_{R_1}^{e_0} = 0, \quad S_{C_1}^{e_0} = S_{C_2}^{e_0} = -\frac{1}{2} \quad (11)$$

Therefore, all the active and passive sensitivities of ω_0 are low. The non ideal equivalent circuit of proposed oscillator under the influence of VDTA parasitic [14] is shown in Figure 5.

5. Simulation Results

The performance of the proposed voltage mode sinusoidal oscillator circuit in **Figure 4** has been verified by PSPICE simulation results. The PMOS and NMOS transistors have been simulated by respectively using the parameters of a 0.18 μm TSMC CMOS technology [11] [18]. The aspect ratios of PMOS and NMOS transistors are indicated in **Table 1**. The circuit was biased with $\pm 0.9\text{ V}$ power supply voltage, $V_{BB} = -0.55\text{ V}$, $I_{B1} = I_{B2} = I_{B3} = I_{B4} = 150\ \mu\text{A}$. The transconductance values of VDTA are $g_{m1} = g_{m2} = g_{m3} = g_{m4} = 636.3\ \frac{\mu\text{A}}{\text{V}}$ and the parasitic capacitance at the Z terminal is specified as $C_p = 0.15\text{ pF}$. The values of the capacitors were chosen as: $C_1 = C_2 = 1\text{ nF}$ and $R_1 = 1.5\text{ k}\Omega$. In **Figure 6**, time domain response of the proposed VMSO using VDTA is shown using PSPICE 16.3 which confirms the validity of design equations of oscillator shown in Equations (6) and (7). Frequency of oscillation was found to be $f_0 = 15.56\text{ MHz}$.

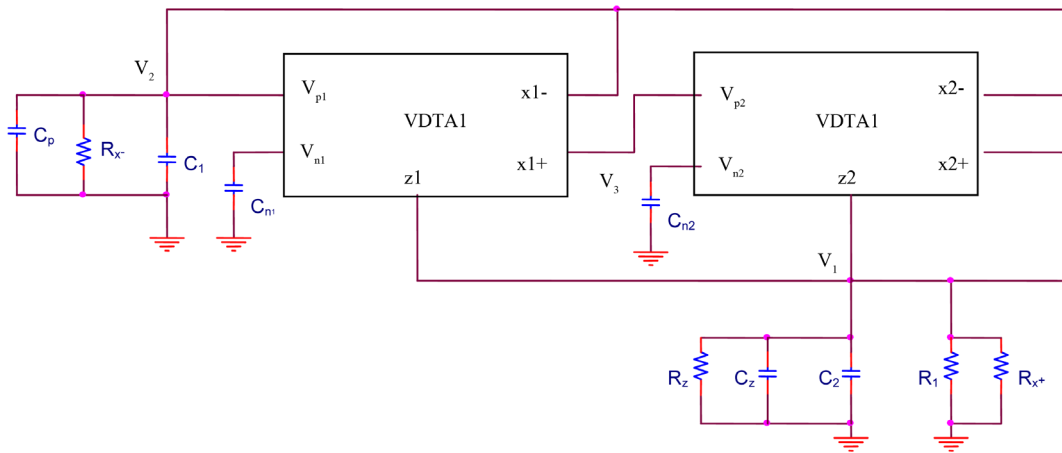


Figure 5. Non ideal equivalent circuit of proposed VMSO.

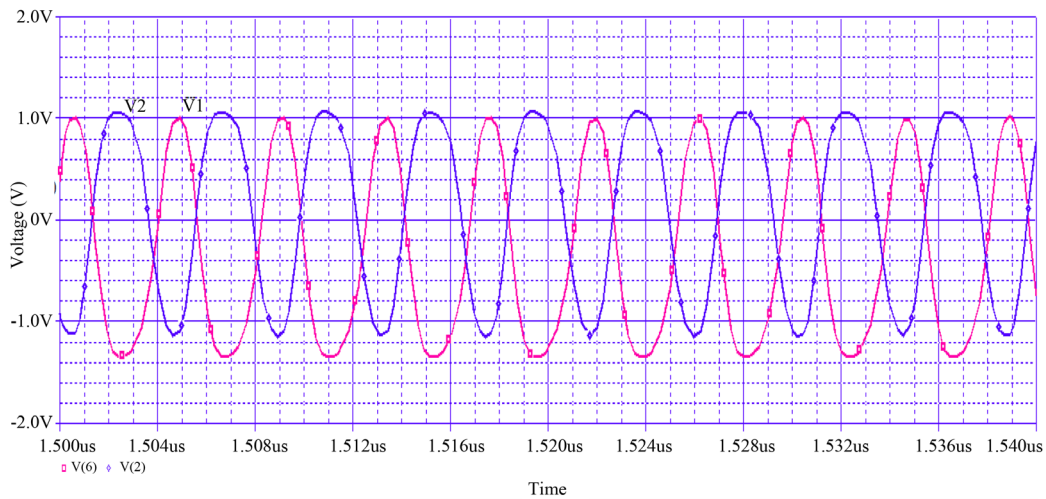


Figure 6. Time domain response of the proposed VMSO using VDTA.

Table 1. Dimensions of the transistors.

Transistor	W (μm)	L (μm)
M1, M2, M5, M6	3.6	0.36
M3, M4, M7, M8	16.64	0.36

6. Conclusion

In this paper, a new VMISO using VDTAs (Voltage Differencing Transconductance Amplifier) is presented as shown in the PSPICE. The circuit is realized by using two VDTAs, two grounded capacitors and one resistor. The circuit has the features of low active and passive sensitivities, low voltage supply and large bandwidth. It has low-input and high-output impedances and is also convenient for electronic controllability through transconductance gain g_m of VDTAs.

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