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Corrigendum

Corrigendum to: An Integrator Circuit Using Voltage Difference Transconductance Amplifier

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1. Introduction

The voltage difference transconductance amplifier (VDTA) is functionally verified through experiment active device introduced by D. Biolek [1]. The active block, VDTA consists of a voltage-difference unit ensued by the dual output transconductance amplifier. Thus, the VDTA is built as the difference of input voltages controlled by the current source and has a multi-output transconductance amplifier. It is more versatile, adaptable and can use either in voltage or current mode. The structure of VDTA uses two distinct values of g_m, which can be easily realized without using a resistor, hence also called as transconductance (g_m) based element, and attains more propitious feature compared to other active elements. The g_m value of this element is adaptable and is electronically tunable by varying bias currents. Because of having these properties, VDTA element is most useful and has various applications such as filters, oscillators, simulation of inductance and capacitance availing one VDTA block with the use of capacitors [2-11]. Some, such current-mode devices available are current conveyor (CC) [12-15], operational transconductance amplifier (OTA) [16-18], operational trans-resistance amplifier (OTRA) [19-21], differential difference current conveyor transconductance amplifier (DDCCTA) [22], current differencing transconductance amplifier (CDTA) [23,24], current through transconductance amplifier (CTTA) [25] and so on. Furthermore, the ports of VDTA element exhibits higher impedance value so that it is easy for designing of differential and floating input circuits.

The integrator is one of the prominent blocks availed in the designing of continuous-time filter structures. An integrator circuit is the one in which the output signal is the time integral of its incoming signal. These are widely employed in ADC's, analog computers, wave-shaping circuits and also considered as an important block in analog signal processing systems. For measuring volt-second product and electric charge, voltage and current integrators are used. Voltage integrator performs the time integration of an electronic voltage where as the current integrator does the time integration of an electronic current. Low pass filter circuits are also called as integrator for when the time constant is very long compared to the pulse width, the step input is converted to ramp output. Most of the RC integrator circuits are designed based on operational amplifier. The major drawback of using these op-amp based circuits is, it doesn't provide the spacious bandwidth and wider dynamic range. Later on, a few integrator circuits are proposed employing different current/voltage - mode devices such as the OTA, CC, second generation current conveyor (CCII), DDCCTA, etc., and are presented in the literature survey [26-37].

The present paper is organized into different sections. VDTA fundamentals are explained in Section 2. A new integrator circuit availing one VDTA and a capacitor is proposed Sections 3 and simulation results are discussed in 4, respectively. At last, conclusions are presented in Section 5.

2. VDTA Fundamentals

Fig. 1 depicts the transistor level implementation of VDTA element. Fig. 2 presents VDTA symbol. The I/O ports of this active element exhibit higher impedance value.

The relationship among the I/O ports of this device can be given in the form of a matrix as:

$$\begin{bmatrix} I_p \\ I_n \\ I_Z \\ I_{X+} \\ I_{X-} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ +g_{mI} & -g_{mI} & 0 \\ 0 & 0 & +g_{mO} \\ 0 & 0 & -g_{mO} \end{bmatrix} \begin{bmatrix} V_p \\ V_n \\ V_Z \end{bmatrix} \tag{1}$$

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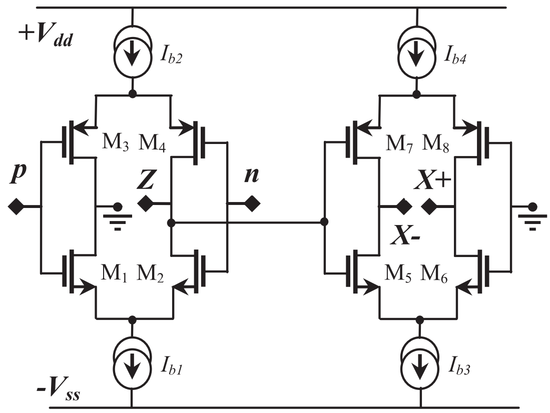

Fig. 1. Transistor level implementation of VDTA element.

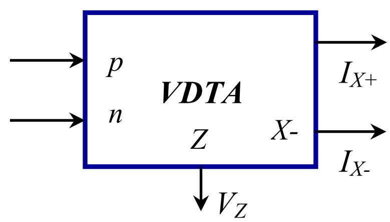

Fig. 2. VDTA Symbol.

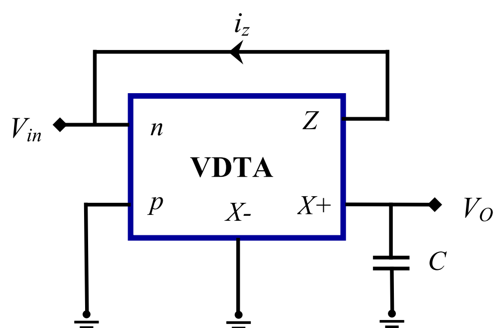

Fig. 3. Proposed Integrator Circuit.

Here g_{mI} and g_{mO} are first and second transconductance gains of VDTA. In voltage difference transconductance amplifier, the differential voltage is present between the input ports and this voltage is transformed as current at the intermediate port (Z) by first transconductance gain, g_{mI}. Afterwards, the voltage drop presented at the output port Z is converted into a current at output ports by second transconductance gain, g_{mO}. Transconductances g_{mI} and g_{mO} are also called as Arbel-Goldminz Transconductance [38] and can be expressed as:

$$g_{mI} \cong \frac{g_{m1}g_{m2}}{g_{m1}+g_{m2}} + \frac{g_{m3}g_{m4}}{g_{m3}+g_{m4}} \tag{2}$$

$$g_{mO} \cong \frac{g_{m5}g_{m6}}{g_{m5}+g_{m6}} + \frac{g_{m7}g_{m8}}{g_{m7}+g_{m8}} \tag{3}$$

where, g_{mk} is the k^{th} MOS transistor transconductance of the VDTA and the expression is given as:

$$g_{mk} = \sqrt{I_{bk}\,\mu_k \left[\frac{W}{L}\right]_k C_{ox}} \tag{4}$$

where k = 1, 2, 3,... 8; I_{bk} is the k^{th} transistor bias current; μ_k is carrier-mobility for the k^{th} transistor (k =NMOS or PMOS); C_{ox} represents the gate oxide capacitance per unit area; L and W represent the length and width of MOS transistors respectively. The transconductance value of this element can be adaptable and is electronically tunable with the help of external bias current (I_b).

3. Proposed Integrator Circuit

The proposed integrator circuit availing single VDTA element is depicted in Fig. 3. In this proposed circuit, the input signal is given to the inverting input (n) terminal and the output is acquired from the X+ terminal, to which a capacitor is connected. From Z terminal, a feedback path is provided to the inverting input (n) terminal so that the voltages at those terminals are equal. The non-inverting input terminal (p) and X- terminals are connected to ground.

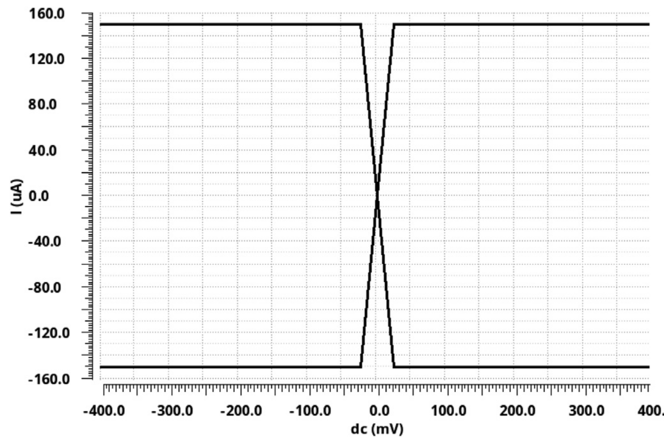

Fig. 4. Simulated DC transfer Characteristic of VDTA.

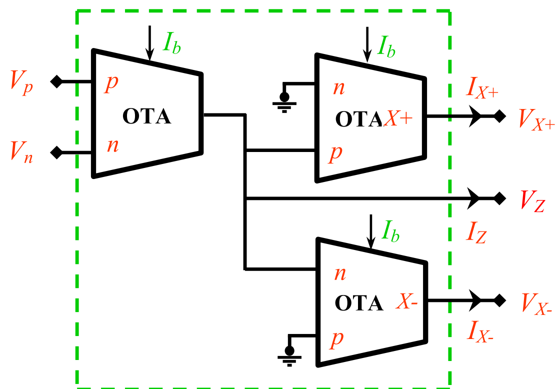

Fig. 5. Experimental setup of VDTA using OTA's (LM 13700).

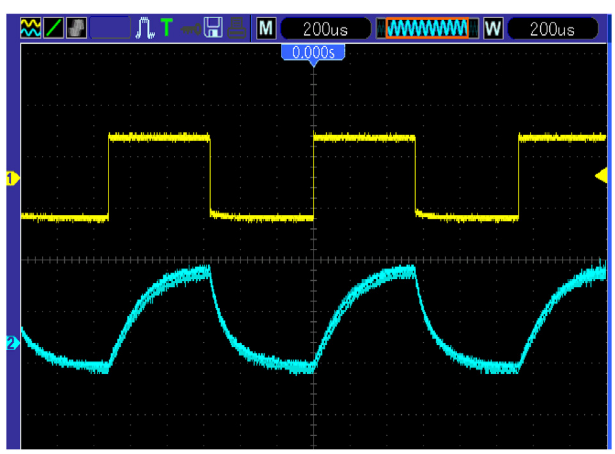

Fig. 6. Output waveform for square-wave input with C= 0.01 μF of Fig. 3, Scale: X-axis 200 μs/div and Y-axis 5 V/div.

Now, an input square signal is applied at the inverting input (n) terminal. The transfer function of the proposed circuit can be obtained using Eq. (1) and is given as,

$$\frac{V_o}{V_{in}} = \frac{g_m}{sC} \tag{5}$$

From Eq. (5), the time constant (τ) and unity gain frequency (ω_c) can be written as

$$\omega_c = \frac{g_m}{C} = \frac{1}{\tau} \tag{6}$$

4. Results

The circuit is simulated in the Cadence Virtuoso tool of the gpdk180 nm CMOS process. The length and width ratios of MOS transistors availed for the internal structure of VDTA are presented in Table 1. Fig. 3 adopts the supply rail voltage of ±0.9 V and the biasing

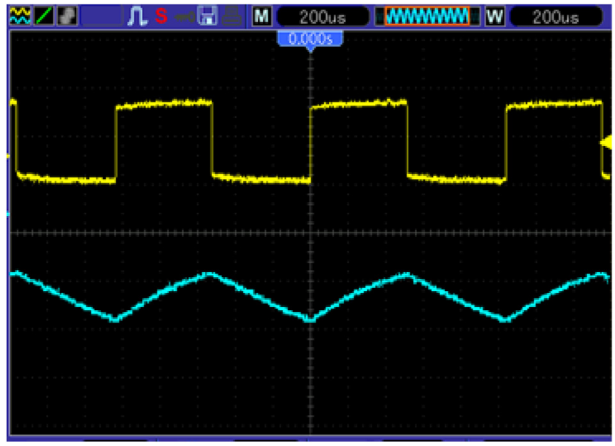

Fig. 7. Output waveform for square-wave input with C= 0.06 μF of Fig. 3, Scale: X-axis 200 μs/div and Y-axis 5 V/div.

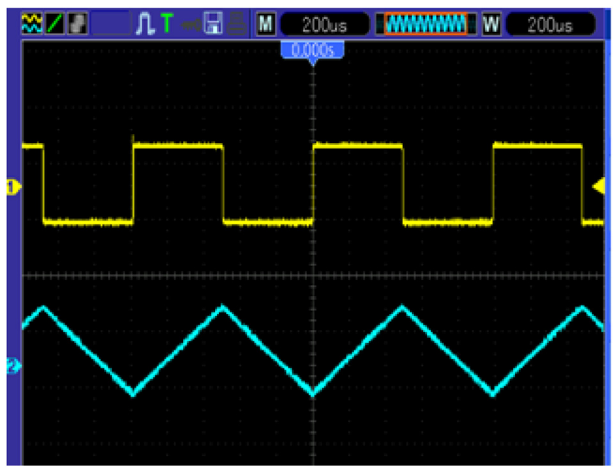

Fig. 8. Output waveform for square-wave input with C= 0.1 μF of Fig. 3, Scale: X-axis 200 μs/div and Y-axis 5 V/div.

Table 1
Transistor Aspect Ratios (W/L) of VDTA.

Transistors	L (μm)	W (μm)
M_1-M_2, M_5-M_6	0.36	3.6
M_3-M_4, M_7-M_8	0.36	16.64

Table 2
Comparitive Analysis Of Candidate Designs.

Ref	Type of Active Element	No. of Active Blocks	No. of Passive Elements
[26]	Op-Amp	1	2
[27]	CCII	1	2
[28]	CCII	2	4
[28]	CCII	1	2
[30]	DDCCTA	1	1
Proposed VDTA Integrator Fig. 3		1	1

current of 150 μA ($I_{b1} = I_{b2} = I_{b3} = I_{b4}$). An input square wave of amplitude 1 V, frequency of 1 kHz is applied to the devised circuit. Fig. 4 presents the transfer characteristics of VDTA element. The output is verified with three time constants by varying the different values of the capacitor. As the measured output/input waveforms with different values of capacitor plots obtained from the simulated results more or less replicate the experimental ones, simulation results are not included here. It dissipates a power of 270 μW. Table 2 provides the comparative study of the proposed circuit with the conventional integrator circuits available in the literature. In order to validate the proposal, VDTA is experimentally implemented using LM13700 ICs and the setup is shown in Fig. 5. The proposed circuit was practically implemented in a laboratory to which a square wave of frequency 1 kHz is applied, uses a supply voltage of ±7 V and is verified by selecting $C = 0.01$ μF, $C = 0.06$ μF, and $C = 0.1$ μF for realizing the three time constants. The corresponding output/input waveforms from the oscilloscope screen with three values of capacitor are shown in Figs. 6, 7 and 8, respectively. A reasonable replication of input is obtained if the time constant value is small compared to the time period of the input signal and is shown in Fig. 6. If the time constant value is comparable to the time period of the input signal, output will be shown in Fig. 7. When the time constant value is large compared to the time period of the input signal, the square input signal is converted into triangle output and is shown in Fig. 8. The integrator realized using VDTA is suitable for low power applications.

5. Conclusion

A new voltage-mode integrator circuit availing one VDTA is proposed. The devised integrator circuit presented in this paper uses only one single capacitor without the use of resistor. This gives the advantage for easy implementation and manufacturing of IC's in VLSI design. The designed circuit is simulated in a Cadence Virtuoso tool of 180 nm CMOS technology and works with a supply voltage of $\pm$0.9 V. The theoretical results are almost analogous to the simulation results and also the proposed circuit is practically implemented in a laboratory and is experimentally verified. The proposed VDTA based integrator is highly useful in the dual slope/integrating type analogue to digital converters for higher resolutions. The circuit has wider applications such as waveform generators, control systems, microwave communication systems and instrumentation systems.

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