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Realization of Current Mode Full Wave Rectifier using VDTA

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ABSTRACT: This paper presents the implementation of current-mode full-wave rectifier circuit using a single active component. The proposed rectifier circuit consists of only one voltage differential transconductance amplifier (VDTA), two MOS transistors and three resistors. The functional working of proposed VDTA based rectifier circuit is confirmed through SPICE simulation using 180nm TSMC technology parameters.

KEYWORDS: VDTA, Current Mode, Full Wave Rectifier.

I. INTRODUCTION

The current mode approach for analog signal processing applications has come forward as an alternative to the traditional voltage mode circuits because of their potential performance features like the simpler circuit, wide bandwidth, low power consumption, wide dynamic range, and high operating speed [1-3]. Therefore, an enormous number of current mode building blocks were introduced by the researchers and are reviewed in literature [4-11]. Voltage differencing transconductance amplifier (VDTA) is a recently introduced analog active block. It was first discussed by Biolek et al. in [5], and its CMOS implementation is reported in [11]. The internal circuit of VDTA is the same as that of CDTA [10] except that the input section of VDTA is voltage differencing rather than current differencing. The VDTA [11] has gained popularity in the recent past due to its simpler structure and availability of electronically tunabletransconductor, which facilitates resistorless and electronic tunable realization.

RF demodulators, piecewise linear function generators, DC converters, wattmeter, AC voltmeters, and numerous non-linear analogue signal-processing systems, such asinstrumentation, measurement and control, all require full-wave rectifier circuits. Traditional diode-based rectifiers are limited by the threshold voltage of diodes (0.3 V for germanium diodes and 0.7 V for silicon diodes), and are utilised in just a few applications, such as DC voltage supplies. Also, the Simple diode rectifiers cannot be employed for applications demanding accuracy in the threshold voltage range. The precision rectifiers based on operational amplifiers (op-amp), diodes and resistors have been presented in [12-14]. Traditional op-amp circuits have limited bandwidth at large closed-loop gains due to the constant gain-bandwidth product. In addition, the op-amp's slow slew rate influences large-signal behaviour for high-frequency operation [1, 15].Ref. [16] presents the full wave rectifier circuit using single Operational transconductance amplifier (OTA)or single differential voltage current conveyor (DVCC) along with diodes and resistors. In this paper, a new design of current-mode full-wave rectifier circuits using a single active element namely-VDTA is presented. The proposed circuit employs a lesser number of passive components.

II.VDTA

The voltage differencing transconductance amplifier (VDTA) is an analog building block and was introduced in 2008 [5]. The block diagram representation of VDTA is shown in Fig.1.In Fig.1, P and N are the input terminals while the output terminals of VDTA are Z, X+, and X-.The impedance values of all terminals are extremely high.The terminals relationship of an ideal VDTA is described in (1).

$$\begin{bmatrix} I_Z \\ I_{X+} \\ I_{X-} \end{bmatrix} = \begin{bmatrix} g_{m1} & -g_{m1} & 0 \\ 0 & 0 & g_{m2} \\ 0 & 0 & -g_{m2} \end{bmatrix} \begin{bmatrix} V_P \\ V_N \\ V_Z \end{bmatrix} \quad (1)$$

And in equation form, it can be represented as-

$$I_Z = g_{m1}(V_P - V_N)$$

$$I_{X+} = g_{m2}V_Z \quad \text{and} \quad I_{X-} = -g_{m2}V_Z$$

where g_{m1} and g_{m2} represent the first stage and second stage transconductance gain of VDTA.

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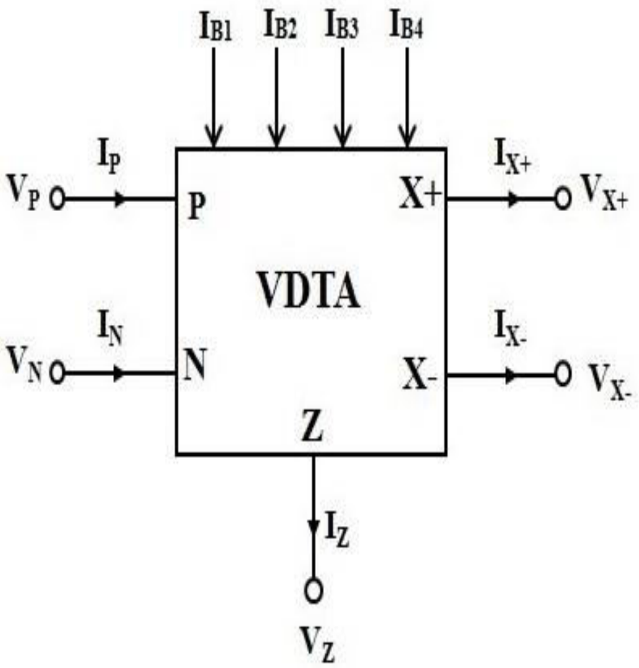

Fig.1 Block diagram representation of VDTA

The CMOS based circuit of VDTA was presented by Yesil et. al. in 2011 and is depicted here in Fig.2 [11].The internal circuit of VDTA is a cascade of two Arbel-Goldminz transconductances – the first stage is formed by transistor pairs (M1-M2, and M5-M6) and current sources I_{B1} and I_{B2} while the second comprises of transistor pairs (M3-M4 and M7-M8)

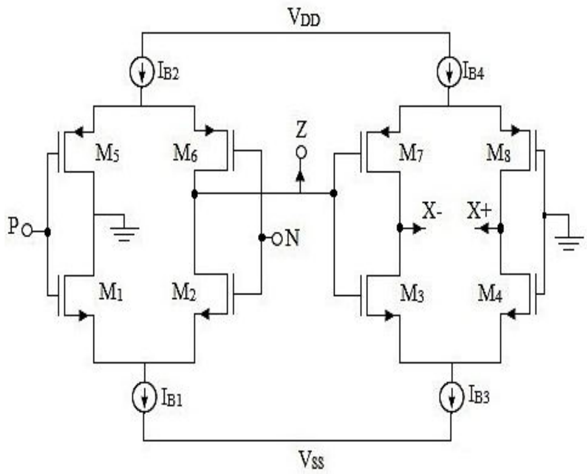

Fig.2 CMOS circuit of VDTA [11]

and current sources I_{B3} and I_{B4}. The transconductance gain of the first and second stage (g_{m1} and g_{m2}) are determined by the output transistor's transconductances as follows-

$$g_{m1} \cong \frac{g_1 g_2}{g_1 + g_2} + \frac{g_5 g_6}{g_5 + g_6} \tag{2}$$

$$g_{m2} \cong \frac{g_3 g_4}{g_3 + g_4} + \frac{g_7 g_8}{g_7 + g_8} \tag{3}$$

where g_i denotes the transconductance value of i^{th} transistors and is expressed as-

$$g_i = \sqrt{\mu_{n,p} C_{ox} \left(\frac{W}{L}\right)_i I_{B_i}} \tag{4}$$

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Here μ_n and μ_p are the mobility of NMOS or PMOS transistor respectively, C_{ox} is oxide capacitance per unit area, $(W/L)_i$ and $I_{Bi}$is the aspect ratio and bias currents of i^{th} (i=1,2,3,…8) MOS transistor respectively. Equation (4) shows that the dependency of transconductance gain on bias current.

III. PROPOSED FULL WAVE RECTIFIER (FWR) CIRCUIT

The proposed realization of current-mode full wave rectifiers with two MOSFET is shown in Fig. 3. The Mp and Mn are diode connected NMOS transistor. The rectified output in current form is obtained at X^+ and X^-..

The working operation of the proposed circuit depends on the ON and OFF instances ofinput transistor Mn and Mpwhen the input current is applied.During positive half cycle of input current, the transistorMp is ON and transistor Mn is OFF.Therefore, the voltage is developed at P terminal of VDTA, while the voltage of N terminal is zero. The voltage of P terminal is converted into current at Z terminal through first transconductor of VDTA. The current of Z terminal is converted into voltage through resistance Rz. Finally, the voltage of Z terminal is converted into output current at X^+ and X^-terminal via second transconductor of VDTA. Similar operation is performed in negative half cycle when input transistors Mn is ON and Mp is OFF.

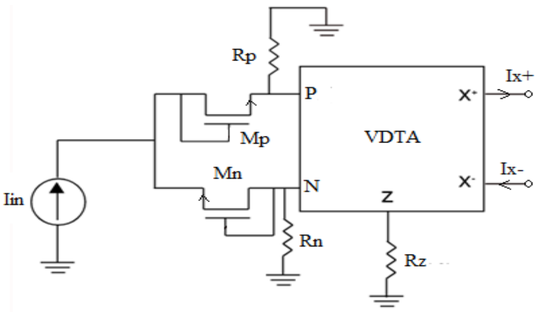

Fig 3. Full wave rectifier Using VDTA

IV. SIMULATION RESULT

The proposed rectifier circuit is simulated through SPICE using 180nm TSMC technology parameters. The aspect ratios of the transistors used in VDTA and input transitors Mn, Mp are given in Table 1. Supply voltages for VDTA are taken as VDD = −VSS = 0.9 V and the all the bias currents IB1, IB2, IB3, IB4 are taken as 150 µA. For these values of bias current, the obtained value of transconductance gains of VDTA are gm1 = gm2 = 636.3 µA/V.The external resistors are set at Rp = Rn = 80Ω and Rz = 1.594 KΩ. The input current, simulated rectified output at X+ terminal and inverted rectified out at X- terminal are shown in Fig.4.

Table 1 Aspect ratio of the MOS transistors used in VDTA based rectifier circuit

Transistors	W(µm) / L (µm)
M_1, M_2, M_3 and M_4	3.6 / 0.18
M_5, M_6, M_7 and M_8	16.64 / 0.18
M_n and M_p	0.9 / 0.18

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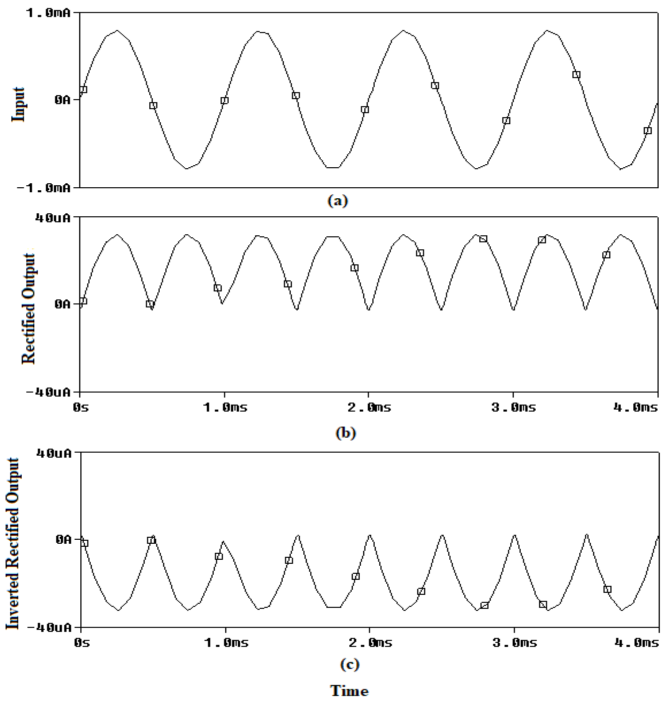

Fig. 4 Simulated Results of Full Wave Rectifier (a) Input Current (b) Simulated Rectified Output (c) Inverted Rectified Output.

V. CONCLUSION

In this paper, the implementation of a current mode full wave rectifier using VDTA is presented. The presented circuit consist of only a single active block, two diode connected MOS transistors and three resistors. The proposed circuit is capable of providing rectified output in true and inverted phase without alteration of circuit topology. The functionality of the proposed rectifier circuit is confirmed with PSPICE simulation using 180 nm technology parameters.

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