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Design of Low Voltage Extra X Current Conveyor Transconductance Amplifier in 0.18µm CMOS Technology

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Abstract
Advancement in VLSI technology has led to largernumber of components on a single chip making it a reality to realizeportable systems. Analog circuits are important in every VLSI systemsuch as filters, current and voltage amplifiers, comparators, A/D andD/A converters, etc. Miniaturization in circuit design requires lowpower low-voltage (LPLV) analog integrated circuits to be designed.Analog signal processing's inherent advantage of low power and highspeed has led to extensive research in analog domain. Current domainprocessing having advantages of higher bandwidth, large dynamicrange, greater linearity, simple circuitry seems to be the solution.Among the number of current mode topologies current conveyor is themost versatile building block. In this research floating gate technique is used in the design a versatile current mode active block the extra x current conveyor (EXCCTA). The EXCCTA is designed using 0.18µm technology in Spice software for a supply voltage of ±0.9V. thorough simulation analysis are done to evaluate the dynamic range, frequency range and parasitic impedance of the EXCCTA.

Keywords: *Analog circuits, Current mode, Current conveyor, Signal processing*

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I. INTRODUCTION

With scaling down of CMOS to comply with large scaleintegration and system on chip requirements together withincreased demand for portable and battery-operated devices, lowpower low voltage (LP LV) devices are need of the hour. Thecurrent mode devices are more suited for (LP LV) operation thantheir voltage counterpart [1, 2]. Current mode circuits are moreimmune to noise, less sensitive to supply voltage and have lowelectrostatic discharge, low propagation delay, high slew rate etc.[2,4]. Among various current mode devices current conveyor(CC) is the most functional device by virtue of its versatilefeatures such as simplicity in design, higher gain bandwidthproduct, linearity, high frequency operation, less chip area, lowpower dissipation [4-7] etc. In 1968 [1] the current conveyor(CC) was introduced and has since found recognition in bothconceptual and practical implementation. Research publishedin last few years reveals that analog circuit designers are nowconsidering the CC as a building block for designing multitude ofapplications like signal processing, amplification,instrumentation etc. [1,8,9]. A CC is a three-terminal devicehaving a low impedance input, a high impedance inputsimultaneously with a characteristic of virtual short and a highimpedance output terminal [1,3]. Since its introduction manytopologies of CC have been developed, but second generation. current controlled current conveyor (CCII) gathers largerattention from designers due to its high versatility [1,2,10].Amount many variants of CCII the ones having electronic tunability are the most popular like current conveyor transconductance amplifier(CCTA) [16], current follower transconductance amplifier(CFTA) [17], current controlled current conveyortransconductance amplifier (CCCCTA) [6]etc.

In this research a recently introduced active building block the extra x current conveyor transconductance amplifier (EXCCTA) is designed in 0.18µm bulk CMOS technology using the Spice software. The CMOS implementation of EXCCTA is discussed and thorough simulation analysis are done to evaluate the dynamic range, frequency range and parasitic impedance of the EXCCTA.

II. Extra X Current Conveyor Transconductance Amplifier (EXCCTA)

The extra x current conveyor transconductance amplifier (EXCCTA) is functionally an improved and more versatile version of extra x current conveyor (EXCCII). The EXCCTA [20] includes features of current and voltage followers and operational transconductance amplifier (OTA) making it more versatile. The voltage current (V-I) characteristics of the developed EXCCTA are given in Equations (1-5) and the block diagram is presented in Figure 1.

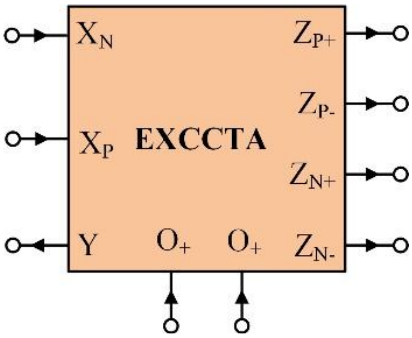

Figure 1. Block Diagram of EXCCTA

$$V_{XP} = V_{XN} = V_Y \quad (1)$$

$$I_{XP} = I_{ZP+} = I_{ZP-} \quad (2)$$

$$I_{XN} = I_{ZN+} = -I_{ZN-} \quad (3)$$

$$I_{O+} = g_m(V_{ZP+}) \quad (4)$$

The expression for transconductance (g_m) is given in Equation 5.

$$g_m = \sqrt{\mu_n C_{OX} \frac{W}{L} I_B} \quad (5)$$

where C_{OX} is the gate oxide capacitance, μ_n is the mobility of electrons in NMOS, g_m denotes the transconductance of OTA set via bias current I_B and $\frac{W}{L}$ is the aspect ratio of the transistors.

The CMOS implementation of the EXCCTA is presented in Figure 2. The Y terminal is high impedance voltage input node and X_P& X_N low impedance voltage output/current input nodes. The O_+, Z_{P+}& Z_{N+} terminals are high impedance current output nodes. The number of current output terminals ($I_{ZP+}, I_{ZP-}, I_{ZN+}, I_{ZN-}, O_+, O_-$) can be increased by simply adding two MOS transistors.

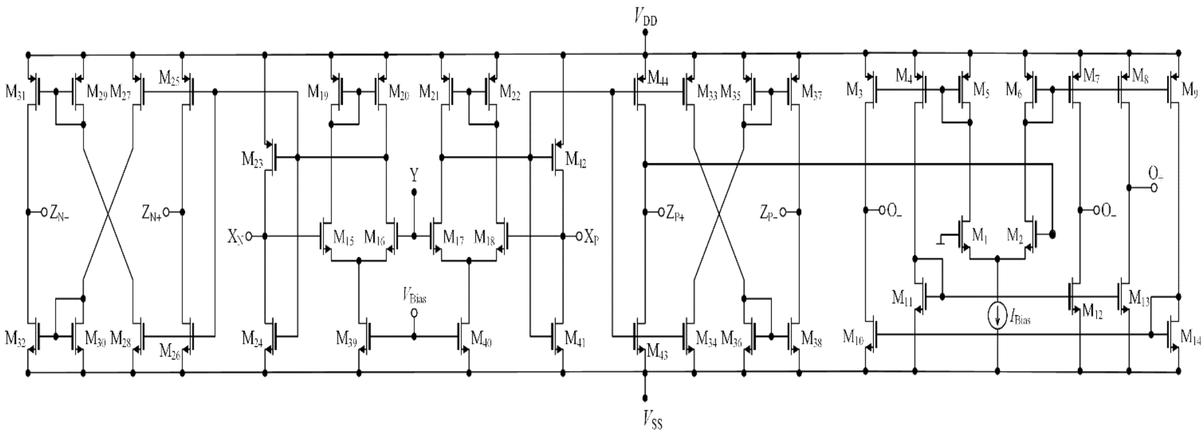

Figure 2 CMOS implementation of EXCCTA

III. Non-Ideal Analysis of EXCCTA

In this section the non-idealities of the VD-DXCC are considered and their influence on the proposed filter circuits is analyzed. The frequency dependent non-ideal voltage (β), current (α) andtransconductance transfer (γ/γ') gains cause a slight change in the current and voltage signals during transfer leading to undesired response. Considering the effect of frequency dependent current and voltage transfer gains the V-I characteristics of VD-DXCC are modified as given below in Equations 6-11.

$$I_{ZP} = I_{ZP} = \alpha_P I_{XP} \quad (6)$$

$$I_{ZN} = I_{ZN} = \alpha_N I_{NP} \quad (7)$$

$$V_{XN} = \beta_N V_W \quad (8)$$

$$V_{XP} = \beta_P V_W \quad (9)$$

$$I_{ZC+} = I_W = \gamma g_m (V_P - V_N) \quad (10)$$

$$I_{ZC-} = -\gamma' g_m (V_P - V_N) \quad (11)$$

Where α is the current transfer gain, β stands for voltage transfer gain and γ denotes the transconductance transfer gain. Ideally their values should be unity.

IV. RESULT AND DISCUSSION

In this section the EXCCTA is designed in 0.18μm CMOS technology and simulated using the Spice software. The supply voltage is set at ±0.9V and the bias currents of the voltage follower section is fixed at 50μA. The bias current of the OTA is fixed at 100μA resulting in the transconductance value of 984μs.The AC, DC and time domain analysis are done to evaluate the dynamic range, bandwidth, voltage and current transfer gains.

4.1 DC Analysis

The dc analysis is done to measure the dynamic range, linearity and accuracy of the voltage follower, current follower and transconductor section of the EXCCTA.

First, the dc analysis is carried out to measure the dynamic range of the EXCCTA. A dc sweep of ±1V is applied at the voltage input Y terminal and the voltage at the X_P and X_N terminals is noted. As can be seen from the Figure 3 the dynamic range of the voltage follower is ±750mV. It is also seen that the output closely follows the input with minimum deviation. Second, the dc analysis of the current followers is done. The Y terminal is grounded and the dc current sweep of ±200μA is applied at the X_P and X_N terminals and the resulting output current following through the Z_P and Z_N nodes is measured as given in Figure 4. The dynamic range of the current follower section is found to be ±130μA with negligible error. Third, dc analysis of the OTA section is carried out to deduce the linearity range of the transconductor. A voltage sweep of ±300mV is applied at the V_{Z1} node and the output current flowing from the $O+$ and $O-$ nodes are plotted. The linear range of the OTA is ±200mV after this the output current began to saturate as can be inferred from Figure 5.

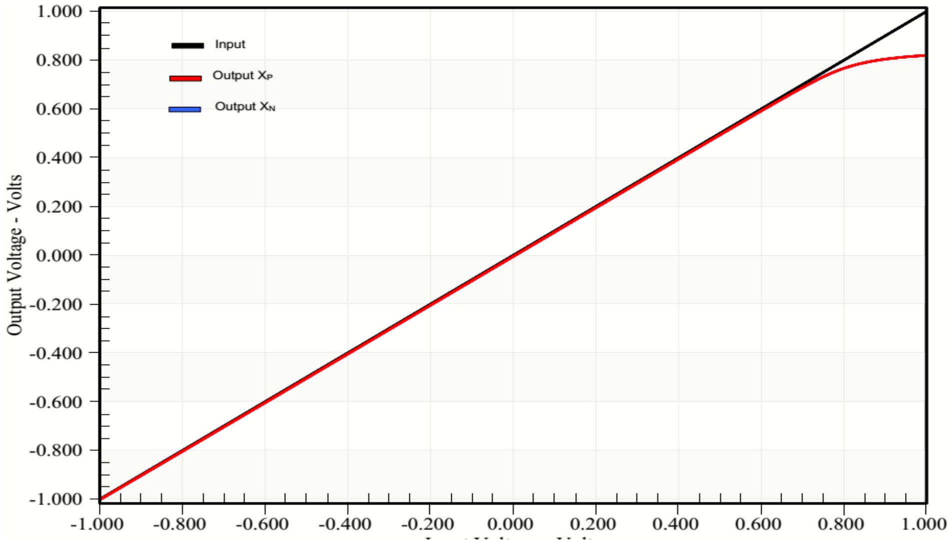

Figure 3: DC analysis of the voltage transfer stage

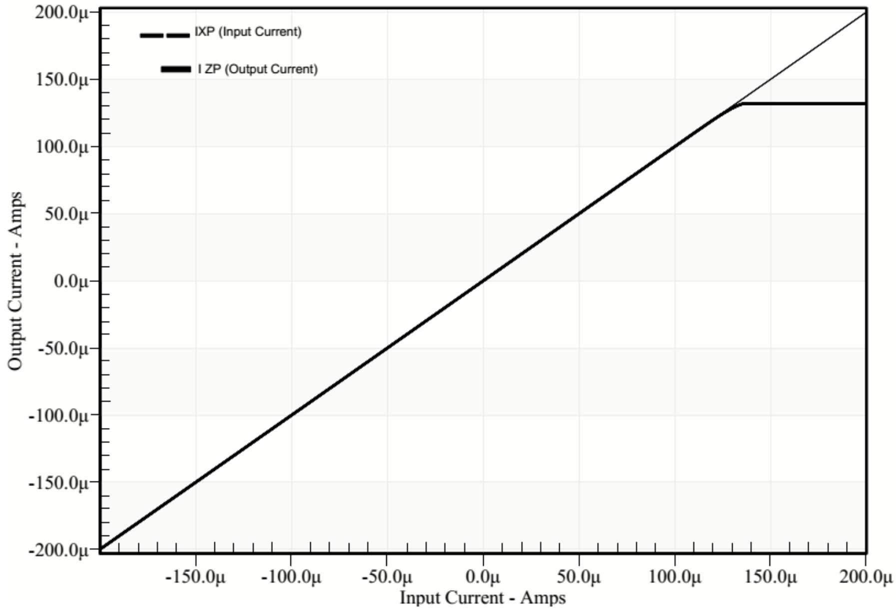

Figure 4: DC analysis of the current follower stage

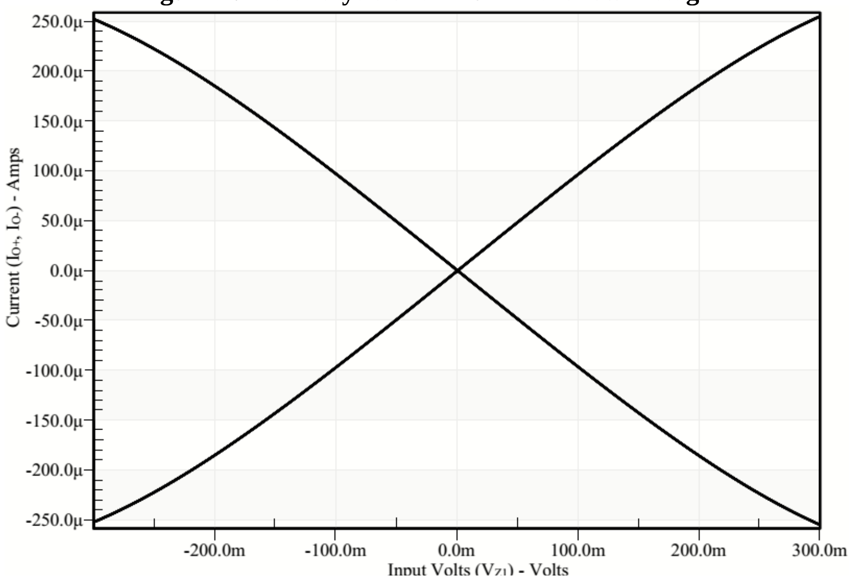

Figure Error! No text of specified style in document.**: DC transconductance transfer characteristic of OTA**

4.2 AC Analysis

The ac analysis is conducted to measure the voltage transfer ratio and bandwidth, current transfer ratio and bandwidth, the transconductor bandwidth and the parasitic resistances presents at different nodes of the EXCCTA.

First the Ac analysis is done to measure the voltage transfer bandwidth and the voltage transfer gain of the voltage follower stage. An ac signal with unity magnitude is applied at the Y node and the voltages at the X_P and X_N are plotted. The ratio of the output to input gives the voltage transfer ratio ($\frac{V_{XP}}{V_Y}, \frac{V_{XN}}{V_Y}$). The ac results are shown in Figures 6-7. The voltage transfer ratio for both X_P and X_N terminals are found to be 0.99 which is very close to the ideal value of unity. The bandwidth of the voltage follower section is found to be 2.52GHz. Second, the current follower bandwidth is evaluated. The node Y is grounded, and ac analysis is done on X_P and X_N nodes. The current transfer ratio ($\frac{I_{ZP}}{I_{XP}}, \frac{I_{ZN}}{I_{XN}}$) is measured. The current transfer ratio is calculated to be 1.02 which is near to the ideal value of one. The current transfer bandwidths are found to be 2.42GHz for both ($\frac{I_{ZP}}{I_{XP}}, \frac{I_{ZN}}{I_{XN}}$) since the circuit is symmetric. Third, the transconductance transfer bandwidth is measured by applying an ac voltage at node V_{Z1} and measuring the output currents I_{O+} and I_{O-}. The ratio of ($\frac{I_{O+}}{V_{Z1}}, \frac{I_{O-}}{V_{Z1}}$) gives the bandwidth of the OTA which is found to be 330MHz. The Figure 8 gives the value of transconductance when the bias current is set at 100µA which is found to be 984µs.

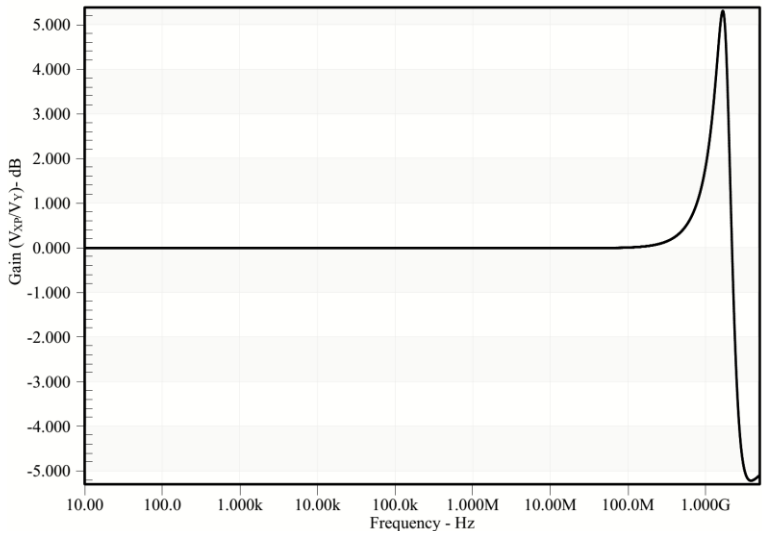

Figure 6: AC analysis result of the voltage transfer stage

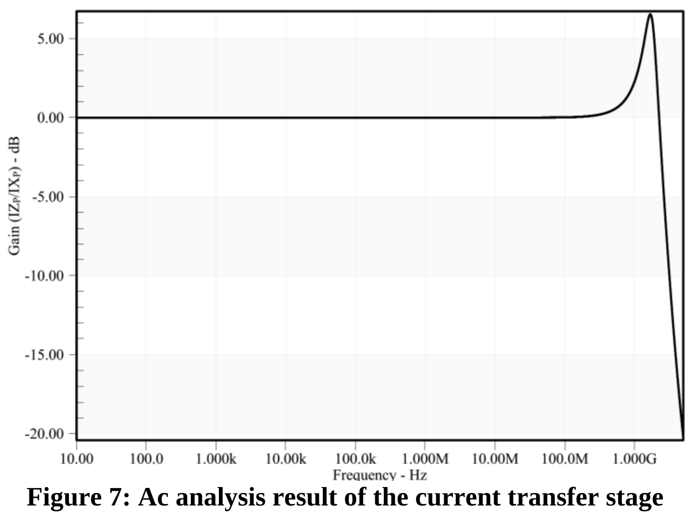

Figure 7: Ac analysis result of the current transfer stage

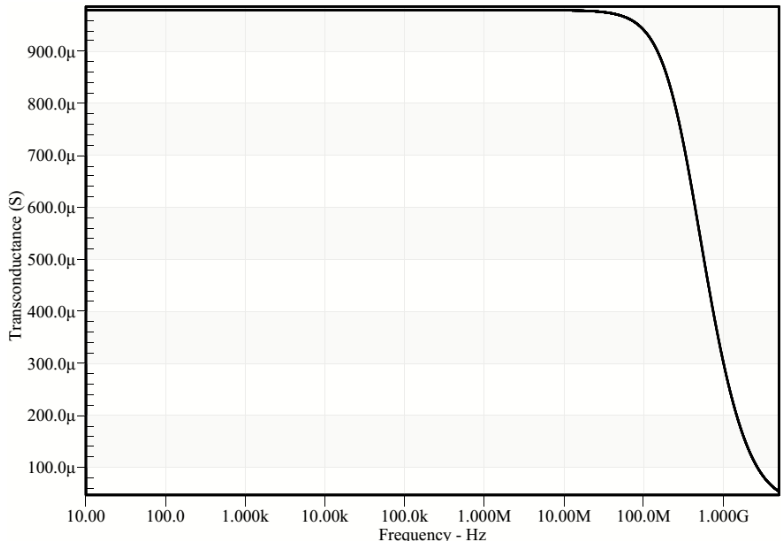

Figure 8: AC analysis of the OTA stage

The ac analysis is also useful in calculating the parasitic resistance present at the various node in the circuit. The most critical nodes are X_P, X_N, Z_P, Z_N, $O+$ and $O-$.

4.3 Time Domain Analysis

The transient analysis is done to validate the signal processing capabilities of the voltage and current transfer stages. It is also used to check whether the different stages have correct phase relations between input and output signals. To verify the functioning of the voltage transfer stage a sinusoidal voltage signal of ±500mV at 1.5MHz is applied at the Y node and the voltage output at the X_P and X_N nodes are noted. It can be inferred from the Figure 9 that the signal is transferred with negligible drop in amplitude and as well as no phase error. Now the current follower stage is verified. The node Y is grounded and a sinusoidal current signal of ±100µA at 20MHz is applied at the X_P and X_N nodes and the resulting output currents are noted. As can be seen from Figure 10 current follower stages operate correctly.

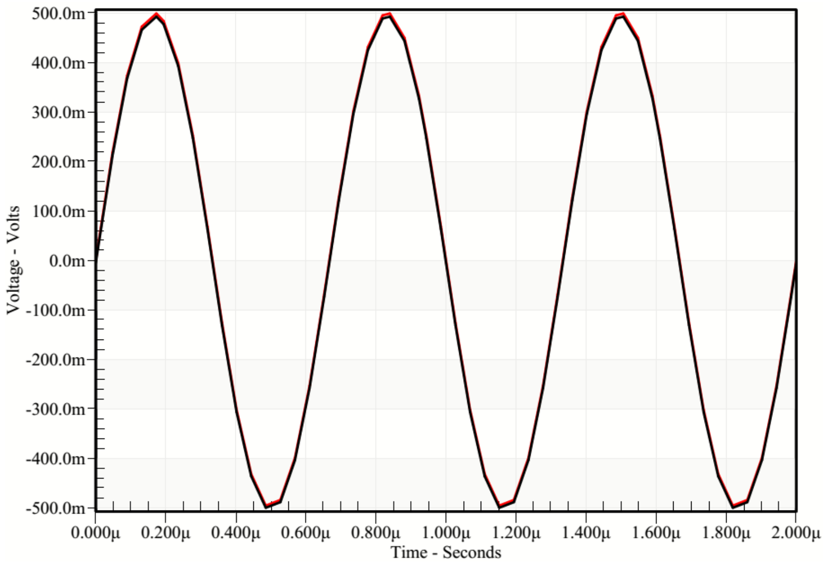

Figure 9: Transient analysis of the voltage follower stage

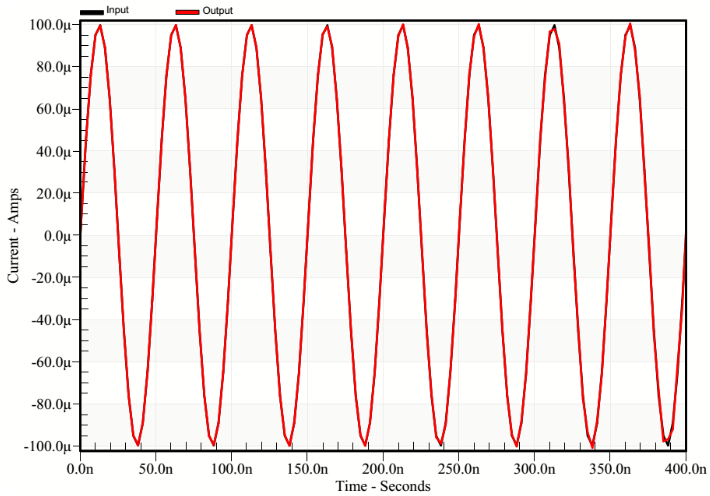

Figure 10: Transient analysis of the current transfer stage

V. CONCLUSION

In this study a low voltage low power (LVLP) active block, the EXCCTA is designed using the 0.18µm bulk CMOS technology. The EXCCTA is a very versatile active block and it can be used in the design of analog signal processing units. The EXCCTA is design to offer large dynamic range and exhibit high frequency operation. The design is validated using Spice software. The EXCCTAworks at a supply voltage of ±0.9V and AC, DC and transient analysis are done to validate the signal processing capability of the design.

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