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A Low Power and High Gain CMOS Tunable OTA with Cascade Current Mirrors

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Abstract

The nonlinearity of a Balanced OTA can be removed using cascading of two balanced OTAs through a resistor. However in literature, balanced OTA is implemented using simple current mirrors which have limitations of copying currents. In the present work, this limitation has been overcome, using cascade current mirrors in place of simple current mirrors. Also the simulation results show appreciable improvement in terms of gain and power consumption. The Tunable OTA designed with cascade current mirrors in the present work has a gain of 40 dB and it consumes power of 9 mW. The circuits are implemented in 130nm using TSMC MOSIS Level-49 model in TANNER EDA S-Edit simulator.

Key words: *OTA, Tunable OTA, OTA- C filters, Transconductance, CMRR, Slew Rate*

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Introduction

Operational Transconductance Amplifiers (OTAs) or Transconductors is a voltage controlled current source (VCCS). It takes the difference of two voltages as the input for the current conversion. Thus the output of OTA is current. At higher frequencies, Conventional Op-Amps become band limited and require a lot of compensation techniques such as frequency or miller compensation and resistor compensations to obtain high frequency performance. An OTA can operate linearly even at high frequency with or without these techniques. Thus integrators implemented using OTAs [1] and capacitors can be used in active realization of wide band high-order continuous-time filters [5]. Such active filters are called OTA- C filters. The major limitation on the performance of OTA- C filters is the intrinsic non-linearity of ordinary OTA. Generally, the input stage of OTA consists of a differential pair. Besides offering good high frequency performance and low noise, the differential pair shows nonlinear linear input, voltage output current characteristic. Due to harmonics of the input signal are mostly generated. Here the term "linearity" is about the linear relationship in between the input differential [2] voltage and the output current and with the transconductance parameter gm being tuned by some DC bias voltage or current. Several linearization techniques [3-4] have been reported to linearize the OTA's transfer characteristic, but precise cancellation of non-linearities is limited by matching accuracy.

Tunable OTA

The transconductor given in [1] is implemented using two cascaded Balanced OTA through an active resistor. (Fig. 1)

A balanced OTA consists of a basic differential pair M1- M2 with four simple current mirrors. IB is the biasing tail constant current source. The Transconductance of Balanced OTA circuit is

$$g_m = \sqrt{\mu_n C_{ox} \frac{W}{L}_{1,2} I_B} \tag{1}$$

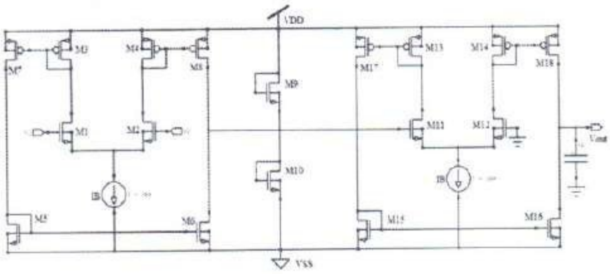

Figure 1

given by the equation

Where μn is the mobility of carrier (electron), Cox is the gate oxide capacitance per unit area, W and L are the effective width and length of the channel of the transistors of a differential pair of Balanced OTA i.e. M1 and M2. We can see that g_m of Balanced OTA is not linearly dependent on bias current I_B [6] .

The active resistor is implemented using two matched NMOS transistors M9 –M10. The equivalent resistance R of active resistor is given

$$R = \frac{1}{2\mu_n C_{ox} \frac{W}{L}_{9,10} (V_{DD} - V_T)} \tag{2}$$

by expression

The current output of the first balanced OTA of tunable OTA is converted to a voltage output by active resistor R. This voltage output is then fed to the second balanced OTA. The output current of the first stage is given by (3)

$$i_{o1} = g_{m1} V_{in}$$

Here g_{m1} is the transconductance of first balanced OTA. Thus the voltage drop across the active resistor is given by

$$V_R = i_{o1} R \tag{4}$$

Total Output Current of Tunable OTA is

$$i_o = g_{m2} V_R = g_{m1} g_{m2} V_{in} R \tag{5}$$

Here g_{m1} is transconductance of second balanced OTA. Thus the transconductance of tunable OTA is

$$g_{mT} = \frac{i_{out}}{V_{in}} = g_{m1} g_{m2} R \tag{6}$$

If tail bias currents of both the cascaded balanced OTAs are same and if their differential pair transistors M1,2 and M11,12 are matched then the above equation gets deduced to the following form

$$g_{mT} = \frac{I_{out}}{V_{in}} = I_B \frac{\frac{W}{L}_{1,2}}{2\frac{W}{L}_{9,10} (V_{DD} - V_T)} \tag{7}$$

So the transconductance of the tunable OTA is linear with respect to tail current. Hence it is said to be tunable OTA.

Proposed OTA

Tunable OTA uses simple current mirrors. In case of simple current mirrors, channel length modulation effect results in significant error in copying currents [7]. In order to suppress the effect of channel length modulation, cascade current mirrors can be used. Fig. 2 shows the circuit diagram of Modified Low Voltage

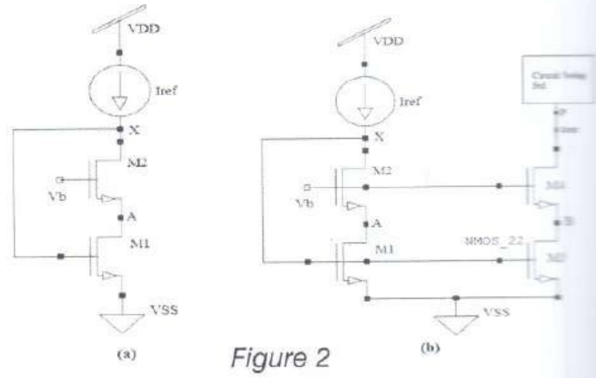

Figure 2

Cascade Current Mirror.

Consider the circuit of fig. 2(a). In this circuit, we must have $V_b - V_{TH2} <= V_x (= V_{GS1})$ for M_2 to be saturated and $V_{GS1} - V_{TH1} < V_A (= V_b - V_{GS2})$ for M_1 to be saturated. This can be possible only if $V_{GS2} + (V_{GSI} - VT_{H1}) <= V_{GS1} + V_{TH2}$, i.e., if $V_{GS2} - V_{TH2} <=$

V_{THI} • Thus we must therefore size M_2 so that its overdrive voltage remains less than one threshold voltage. Now consider the circuit shown in fig.2 (b), where all the transistors are in saturation. If $(W/L)_4/(W/L)_2 = (W/L)_3/(W/L)_1$, then $V_{GS2} = V_{GS4}$ and $V_A = V_B$ or $V_{ds3} = V_{ds1}$ and $_{id3}$ tracks i_{d1}.

Fig. 3 shows the circuit diagram of the proposed

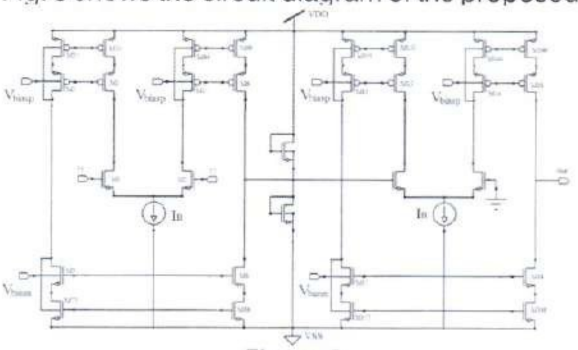

Figure 3

OTA.

It is said to be Tunable OTA with Cascade Current

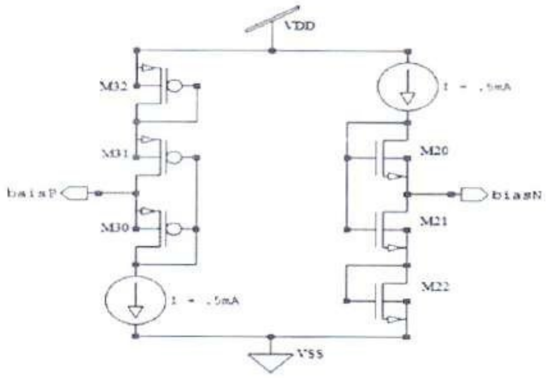

Figure 4

Table 1 contains the aspect ratios of different transistors of Tunable OTA with Cascade Current Mirrors

Transistor Name	Aspect ratio (W/L in um)
M1, M2, M11, M12	5.2 / 0.13
M3, M4, M33, M44, M5, M6, M55, M66, M7, M8, M77, M88	7.8 / 0.13
M13, M14, M133, M144, M15, M16, M155, M166, M17, M18, M177, M188	7.8 / 0.13
M9, M10	3.5 / 0.13
M20	150 / 0.13
M21, M22	7.8 / 0.13
M30	370 / 0.13
M31, M32	7.8 / 0.13

Table 1

Simulation Results

Tunable OTA and Tunable OTA with Cascade Current Mirrors are designed and simulated for frequency response. All the circuits are designed and simulated using BSIMv3 LEVEL 49 MOS model parameters at TSMC MOSIS 130nm technology. Tunable OTA used a bias current of 2mA and for Tunable OTA with cascade current mirrors used bias current of 1mA. Both the OTA used power supply of ±1.5V. All the simulations are verified using Tanner EDA S- edit simulator. It is observed that the Tunable OTA with Cascade Current Mirrors demonstrated better performance in terms of gain and power consumption.

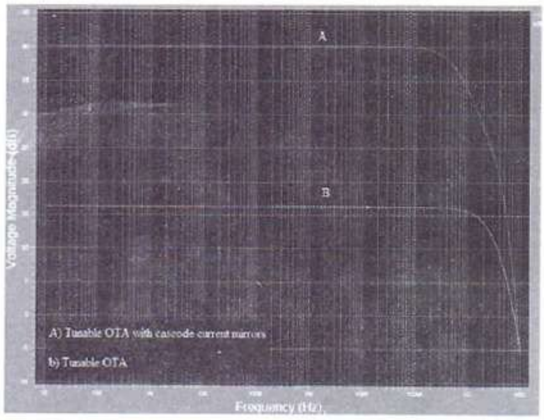

Figure 5: Frequency Response of Tunable OTA and Tunable OTA with Cascade Current Mirrors.

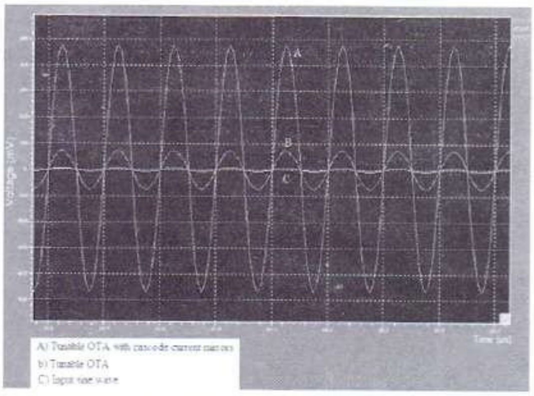

Figure 6: Frequency Response of Tunable OTA and Tunable OTA with Cascade Current Mirrors.

Results are tabulated as shown in the Table 2.

Property	Tunable OTA with simple current mirrors	Tunable OTA with cascade current mirrors
Bias current	2 mA	1 mA
Power supply	±1.5 V	±1.5 V
Power consumption	12 mW	9 mW
DC gain	16.22 dB	40 dB

Table 2

Conclusion

A high gain, high slew rate and high CMRR Tunable OTA has been implemented using cascade current mirrors. A gain of 40 dB has been achieved. It consumes a power of 9 mW from a 1.5 V power supply . All the circuits are designed using BSIMv3 LEVEL 49 MOS model parameters at TSMC MOSIS 130nm technology. All the simulations are verified using Tanner EDA S-edit simulator.

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Use of renewable and environmental friendly jatropha curcas oil is an advantage in cooking stoves. In this study, blends of jatropha curcas oil and kerosene were used as alternative fuel in kerosene wick stove without any design modification. Performance of the stove running of these fuel blends was compared with that of pure kerosene. The analysis showed that the performance of stove running on 5% JCO blend was found to be best among all other blends tested. Deposit formation tendency of JCO blends should be investigated in order to establish long-term durability of JCO as cooking stove fuel.

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