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Output impedance improvement of a Low Voltage Low Power Current mirror based on body driven technique

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ABSTRACT

This paper improved the output impedance of a Low Voltage Low Power (LVLP) current mirror by using body driven technique and transconductance enhancement. The applied technique increases the output impedance of current mirror significantly compared to other works. Also, it provides 0.5 Ω and 6 MHz improvement in input resistance and bandwidth, respectively. Operation principle of current mirror circuit with proposed improvement is discussed, the most important formulas are derived and the comparison between the performance of this circuit and the primary one is verified by simulation in TSMC 0.18 μm CMOS technology. An output resistance of 39.5 GΩ is achieved for the improved circuit that shows 5 GΩ increment in comparison with primary circuit. Besides, simulation results show an input resistance of 12.8 Ω and −3 dB cut-off frequency of 216 MHz for the improved current mirror circuit while it consumes only 42.5 μW. Also, other specifications still remain unchanged. It should be noted that in this simulation, the power supply is 1 V and the input current is 15 μA.

1. Introduction

Current mirrors are one of the most important and efficient block of each analog integrated circuit due to providing bias conditions and active loading role, thus optimum design has significant enhancement on the performances of the circuit. Accuracy, linearity, output and input impedance, bandwidth and noise are the factors of the current mirrors which should be considered for optimum design [1,2].

High output impedance is one of the most important factor of each current mirror that many methods are proposed to achieve it. Cascode structure is a traditional method that supports this idea [3,4]. In some cases, Quasi-Floating- gate MOSFETs (QFGMOS) transistors are used to increase output impedance [5,6]. Some papers, presented a feedback gain stage to enhance this factor [7]. Also, in some cases, feedback structures are used to increase the output impedance [1]. Fig. 1 shows another structure that not only does it increases output impedance but also enhances accuracy by equalization of drain-source voltage and decreasing channel length modulation. However, Conventional cascode current mirrors need more power supply. Thus due to importance of low voltage low power technology, some methods are considered to minimize voltage and power. For instance, using floating gate MOSFETs (FGMOS) transistors [8] or body driven technique are suggested [9].

Besides all benefits, some drawbacks are reported for these methods. For example, current offset problem and low bandwidth are reported as a consequence of using body driven technique [1]. So, achieving advantages of this idea needs wise and accurate circuit design to have an LVLP current mirror with body driven structure. Also, minimizing transistors width and length is another way to decrease power supply but nowadays, it has been limited by technology [2].

This paper improves the performance and the output impedance of an LVLP current mirror by using body driven technique. In Sections 2 and 3 the main concepts of idea are described and circuit analysis of current mirror is presented in Section 4. Simulation results are presented in Section 5. Finally, the paper is concluded in Section 6.

2. Body driven and g_m boosting

Almost, depending on the applied technology the bulk of MOSFET transistor is connected to source terminal or power supply, Vdd (or Vss) [10], in integrated circuit designs. But in some applications, this terminal can be used in another ways. Sometimes the bulk terminal connects to a dc bias voltage and cause an effect on bias conditions, which is known as body bias technique

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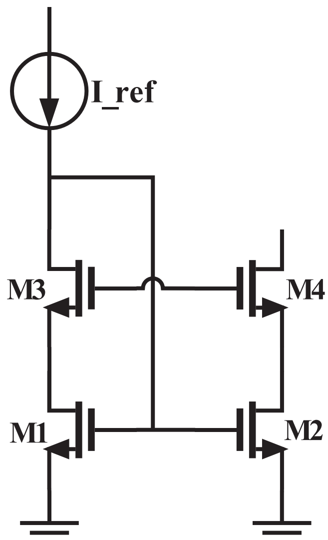

Fig. 1. Cascode current mirror with high output impedance.

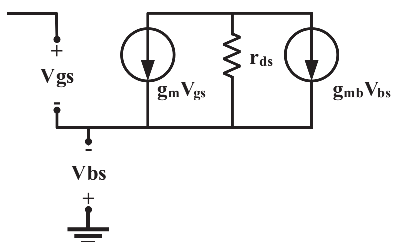

Fig. 2. Small signal model of MOSFET with bulk terminal.

[11]. Another way is called a body driven technique which is applying a signal to the bulk terminal [11]. Body driven technique modifies the effective g_m of MOSFET that can change the circuit parameters. Fig. 2 illustrates the small signal model of a MOSFET with body effect.

According to nature rules of each transistor, following equations show g_{mb} calculation [12]:

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}} = \mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TH})\left(-\frac{\partial V_{TH}}{\partial V_{BS}}\right) \quad (1)$$

$$\frac{\partial V_{TH}}{\partial V_{BS}} = -\frac{\partial V_{TH}}{\partial V_{SB}} = -\frac{\gamma}{2}\left(2\varphi_F + V_{SB}\right)^{-\frac{1}{2}} \quad (2)$$

$$g_{mb} = g_m \frac{\gamma}{2\sqrt{2\varphi_F + V_{SB}}} = \eta g_m \quad (3)$$

The first time, Blalock et al. used body driven method for MOSFET analog circuit design [13]. Any signal processing required some drain bias current to do a specific process. Gate driven circuits prepare this current when the gate voltage exceeds MOS threshold voltage, but in body driven circuits which is shown in Fig. 3, input signal is applied to bulk terminal and the transistor is set in saturation region to make constant drain current.

This technique is useful in low voltage application. In general case, bulk terminal is used in one of the three forms as follow. The first form which is shown in Fig. 4(a), input signal is applied to gate terminal while bulk terminal effects on bias point through V_{bias} [9]. The second form is vice versa, input signal is applied to bulk and bias voltage is connected to gate (Fig. 4(b)) [7]. The final form which is the base of this paper idea, two input signals are applied, one of them is applied to gate and another one is applied to bulk terminal. Fig. 4(c) shows this form clearly [14].

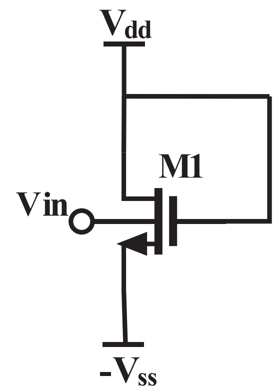

Fig. 3. Body driven technique.

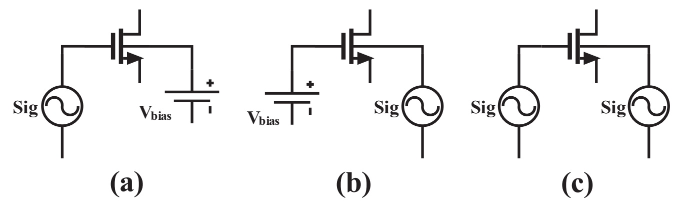

Fig. 4. Body and gate derive techniques.

One of the disadvantages of this idea is the linearity problem in current mirror circuits, because the last transistor sets in saturation region thus input and output current do not have linearity, unlike in the gate driven current mirror. There are some suggestions to solve this problem according to applications [2,15].

3. Current mirror performance enhancement by body driven technique

This paper presents an LVLP current mirror with higher output impedance by applying the body driven technique to the one which is proposed in [1] . Fig. 5 shows the circuit diagram.

In this paper some parameters improvement are achieved such as higher output impedance, lower input impedance, desired BW, good accuracy and low current transfer error.

The proposed idea is applying an extra signal to bulk terminal of M5 which is shown in Fig. 5. This new signal path that is shown with dash-line in Fig. 6, enhances the output impedance and improves the current transfer error of LVLP current mirror through

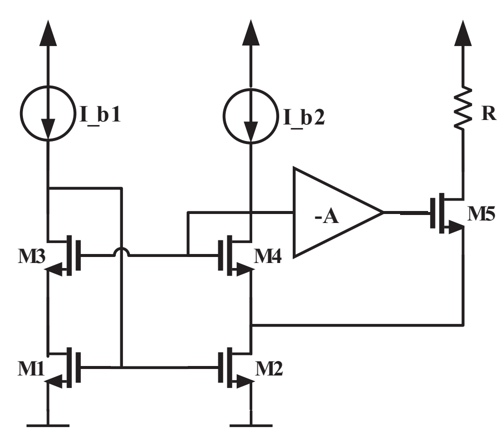

Fig. 5. Current mirror circuit proposed in [1].