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# A new wideband regulated cascode amplifier with improved performance and its application

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A B S T R A C T

This paper presents a new high frequency Regulated Cascode (RGC) amplifier with improved performance. The split-length compensation technique is used to increase both the bandwidth and output impedance, and decrease the input impedance of the conventional RGC. The bandwidth of the proposed RGC amplifier is 5.81 GHz, which is about 2.7 GHz larger than that of simple one. The improved performance of the introduced circuit is achieved with no additional passive element and DC power dissipation. In the paper, output impedance and bandwidth of the proposed circuit are derived by using small signal analysis and have also been compared with the traditional one. In addition, a wideband high performance current mirror is designed in the work as an application of the proposed RGC structure. The bandwidth extension ratio (BWER) of the modified wideband current mirror is 1.37. The proposed circuits are designed by using TSMC 0.18 μm CMOS process and BSIM3 Level 49 device model. The circuits are simulated on Spectre simulator of Cadence to validate the analytical results obtained in the paper.



## 1. Introduction

The increasing requirement of portable devices has forced the aggressive scaling of the integrated circuits [1,2]. These systems require high performance, low power and small chip area, which is almost impossible for designers to achieve simultaneously. The requirement of high-gain leads to multistage design with long channel devices biased at low current levels, while high-speed requires single stage circuits with short channel length devices biased at high current levels [3]. In the literature several bandwidth extension techniques are available such as resistive compensation [4–6], inductive peaking [7,8], negative capacitance compensation [9], feed-forward compensation [10], etc.

Today researchers are focusing to find an optimum technique to improve the performance of analog and mixed signal circuits. A split-length transistor (also known as self-cascode (SC) transistor) can be a solution to the above mentioned problems. It is a two transistor structure (shown in Fig. 1(a)) and can be treated as a single composite transistor that has much larger effective channel length and output impedance [11,12]. In this structure, transistor M2 is working in saturation region and transistor M1 can be operated in either saturation or triode region. In this work transistor M1 is operated in triode region so that it can behave as a resistor. Another important feature of SC structure is its size; the aspect ratio ($W/L$) of transistor M2 is kept larger than that of transistor M1 for proper operation ($(W/L)_2 = m(W/L)_1$, $m > 1$). Since transistor M1 is working in triode region, there is not much increment in drain to source saturation voltage ($V_{DSAT}$). The transfer function ($A_v(s)$) of a SC amplifier is

$$A_v(s) = -\frac{(g_{m1}g_{m2}r_{o2}R_L)}{\{1 + r_{o2}(sC_{gs2} + g_{m1} + g_{m2}) + R_L(sC_{gs2} + g_{m1})\}} \quad (1)$$

For $r_{o2} >> R_L$, the bandwidth ($\omega_0$) of SC circuit is [13]

$$\omega_0 = \frac{(g_{m1} + g_{m2})}{C_{gs2}} \quad (2)$$

The output impedance ($Z_{out}$) of SC circuit is

$$Z_{out} = \frac{1 + (g_{m2} + g_{m1})r_{o2} + sC_{gs2}r_{o2}}{g_{m1} + sC_{gs2}} \quad (3)$$

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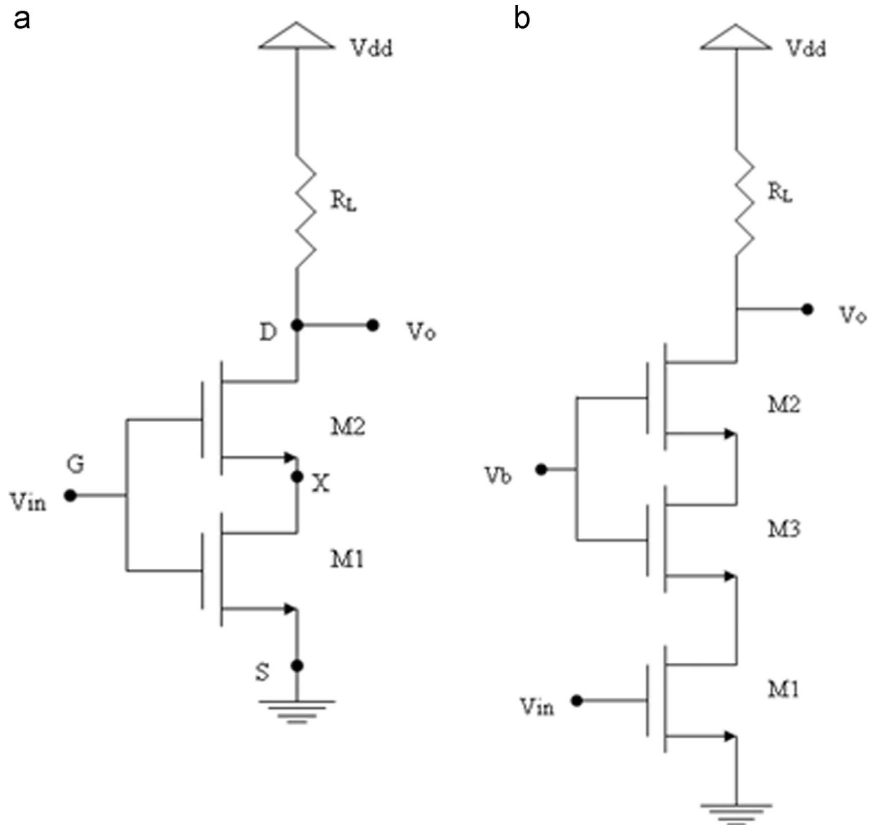


**Fig. 1.** (a) A simple SC amplifier, (b) SC based CS-CG amplifier.

When $s=0$, then output resistance $R_{out}$

$$R_{out}=\frac{1+(g_{m2}+g_{m1})r_{o2}}{g_{m1}} \tag{4}$$

where $g_{mi}$ and $r_{oi}(i=1,2)$ are referred as transconductance and channel length modulation resistance of '$i$' MOS transistor, respectively. $C_{gsi}(i=1,2)$ is the gate-to-source capacitance of MOS transistor and $R_L$ is the load resistance in the circuit.

Eq. (4) can be expressed as

$$R_{out}=R_{out,equiv.}+\left(\frac{g_{m2}}{g_{m1}}\right)r_{o2}+\left(\frac{1}{g_{m1}}\right) \tag{5}$$

where $R_{out,equiv.}$ of the DC equivalent transistor is $r_{o2}$.

From Eqs. (2) and (5), it can be seen that the SC structure has higher cut-off frequency and output impedance due to its shorter physical channel length compared to its DC equivalent long-channel transistor [14,15]. Due to these advantages of SC transistor, it has been used by researchers to improve the performance of cascode (CS-CG) circuit [16,17]. The SC based CS-CG circuit is shown in Fig. 1(b). The transfer function of SC based CS-CG amplifier is

$$A_v(s)=-\frac{g_{m1}g_{m2}g_{m3}R_L}{\{sC_{gs2}g_{m3}+g_{m2}g_{m3}\}} \tag{6}$$

The bandwidth of SC based CS-CG amplifier is [13]

$$\omega_0 \cong \frac{g_{m2}}{C_{gs2}} \tag{7}$$

where $C_{gs2}$ of SC based CS-CG structure is much smaller than $C_{gs2}$ of simple one because of reduced channel length [12,18]. The output impedance is given by

$$Z_{out}=\frac{\{1+g_{m3}(r_{o1}+r_{o2}+r_{o1}r_{o2}(sC_{gs2}+g_{m2}))+r_{o2}(sC_{gs2}+g_{m2})\}}{\{g_{m3}+sC_{gs2}(1+g_{m3}r_{o1})\}} \tag{8}$$

When $s=0$, then

$$R_{out}=R_{out,conv.}+\left(\frac{g_{m2}}{g_{m3}}\right)r_{o2}+\left(\frac{1}{g_{m3}}\right) \tag{9}$$

where $R_{out,conv.}$ is $(r_{o1}+r_{o2}+g_{m2}r_{o1}r_{o2})$ [19]

It can be concluded from Eqs. (7)–(9) that SC based CS-CG circuit has both larger bandwidth and output impedance than that of simple one [19]. Therefore, a SC stage is suitable for high-speed, low-voltage analog applications [17,20].