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An inductorless wideband noise-cancelling CMOS low noise amplifier with variable-gain technique for DTV tuner application

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A B S T R A C T

In this paper, we propose an inductorless CMOS wideband low noise amplifier (LNA), operated in the range from 100 to 900 MHz, with current reuse, mirror bias, gain control and input matching device using noise-cancellation technologies. The traditional wideband LNAs have different input reflection coefficient parameters (S11) at different gain control modes, and they always implement with inductors for wideband matching. Therefore, the proposed LNA which can save power consumption at low gain mode, and implement without inductor on its design. Moreover, its S11 parameter has smaller variation at different gain control modes. The wideband CMOS LNA for digital video broadcasting-handheld (DVB-H), terrestrial-digital multimedia broadcasting (T-DMB), and digital video broadcasting-cable (DVB-C) tuner application is designed using TSMC 0.18−μm RF CMOS process. The post-simulation results at high gain mode show that the gain is 13−15.8 dB, the noise figure (NF) is less than 2.75 dB. The LNA consumes power between 7.25 mW (low gain mode) and 17.8 mW (high gain mode) at 1.8 V power supply. The core area is $0.435 \times 0.67\,\mathrm{mm}^2$.

1. Introduction

Most research and design of RFIC mainly focus on narrow band system, such as using for GSM (global system for mobile communications) or GPS (global positioning system). However, the current trend is integration of different functions in the same terminal, for example, the receiver which integrates DVB-H, DVB-C and T-DMB standards in the same terminal needs about 800 MHz bandwidth. Therefore, narrowband receivers cannot meet our needs, and it increases the design difficulty comparing with narrowband receiver. In addition, the application of mobile TV is more and more popular, especially in the more advanced society, so the mobile TV will become an everyday part of human life. Based on the foregoing consideration, we need to always carry the mobile receiver, it may be used in different places with different input powers, and it will be required to have higher performance at low costs, low power consumption, high dynamic range, and smaller size on its design. But on the application of mobile system, it not only meets the above demands, but also needs to satisfy in wider bandwidth, low noise, good gain flatness and small variation in parameter S11 at the same time. Because of these reasons, we need to develop a new technology for the new compound TV products.

A good LNA design becomes very important because it is one of key circuit blocks in radio receiver system. Since the LNA can be directly added to the first stage in the receive path, it usually dominates the NF and bandwidth in the receiver, and a variable gain LNA can improve the dynamic range of the whole receiver [1]. Especially in mobile communication or video electronic products, we need an LNA which has good NF performance wide bandwidth and larger dynamic range in its specification. However, it is not necessary to meet these specifications at the same time. For example, the most important thing of mobile TV application is to deal with input signal. In this condition, we will try to reduce the power consumption and cost. In other words, we need more power consumption to improve the performance of gain and noise figure at low input signal power, but we will sacrifice the performance of the gain and noise figure to reduce the power consumption at high input signal power. It is because the high input signal power has higher gain and better signal-to-noise ratio than lower input signal power, and the higher input signal power does not need higher gain and better noise figure. Therefore, we care the noise figure at minimum input signal power, and reduce the gain and power consumption at maximum input signal power.

The traditional wideband LNA technology always is designed based on inductors and capacitors for wideband matching [2,3], which implements with large size and higher cost. Another issue worth exploring is the inductors and the capacitors variation because it usually damages the gain flatness of wideband LNA.

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Especially when inductors and the capacitors were produced on the chip, the inductance and capacitance of the variation will be more serious. Because of this reason, the inductorless CMOS wideband LNA is proposed. It is usually designed based on the shunt feedback amplifier technique [4–7]. And the shunt feedback amplifier technique usually has a good bandwidth and implement without inductor. However, this technology has the inherent disadvantage of low trans-conductance, which not only reduces the gain performance but also degrades the noise performance.

In this paper, we propose an on chip inductorless CMOS wideband LNA, which integrates several kinds of technologies on its design. And the LNA can achieve the requirement of low noise figure, gain control function, wider bandwidth, less inductor and save the power consumption at higher input signal power. In addition, the S11 parameter has smaller variation at different gain control modes.

2. Proposed circuit analysis

An on-chip CMOS LNA with features of wide-band matching, gain flatness, small size, wider dynamic range, low power consumption, and low noise is required for mobile TV application. In order to make the on-chip CMOS LNA to meet specifications for mobile TV, we analyze and employ several techniques on the proposed LNA circuit. Fig. 1 shows the proposed wideband gain control LNA circuit. The analysis of this circuit is shown as follows.

2.1. Current reused technique

The current reuse technique increases amplifier trans-conductance (gm) for the LNA without increasing power dissipation, compared with the standard topologies [4,8]. Fig. 2(a) is the traditional current reused LNA, and Fig. 2(b) is the simplified equivalent circuit. The input impedance of traditional current reused LNA can be derived as (disregard the gate–drain capacitance)

$$Z_{in,trad.} = \left(j\omega L_1 + \frac{1}{j\omega C_{gs,Mn1}} + \frac{gm_{M_{n1}} L_1}{C_{gs,Mn1}}\right) // \left(j\omega L_2 + \frac{1}{j\omega C_{gs,Mp1}} + \frac{gm_{M_{p1}} L_2}{C_{gs,Mp1}}\right). \quad (1)$$

Eq. (1) shows that the input reflection coefficient (S11) of traditional LNA will change with different gate–source capacitances and trans-conductances [9]. So, the S11 has variation from different gate–source capacitances and trans-conductances.

In Fig. 1, the drain currents of $Mp1$ and $Mp2$ are reused in $Mn1$ and $Mn2$. So, focusing on the proposed LNA, the trans-conductance in this stage is

$$gm = gm_{M_{p1}} + gm_{M_{p2}} \left(\frac{1 + gm_{M_{p3}} ro_{M_{p3}}}{1 + \frac{ro_{M_{p3}}}{R_7}}\right) + gm_{M_{n1}} + gm_{M_{n2}} \left(\frac{1 + gm_{M_{n3}} ro_{M_{n3}}}{1 + \frac{ro_{M_{n3}}}{R_6}}\right). \quad (2)$$

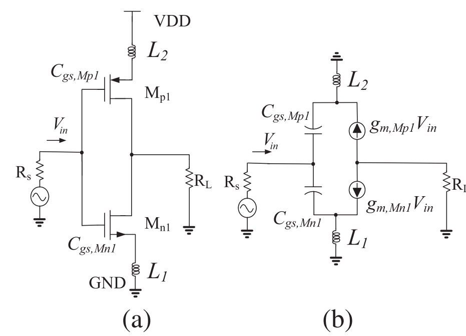

Fig. 2. (a) The schematic of traditional current reused LNA and (b) its simplified equivalent circuit.

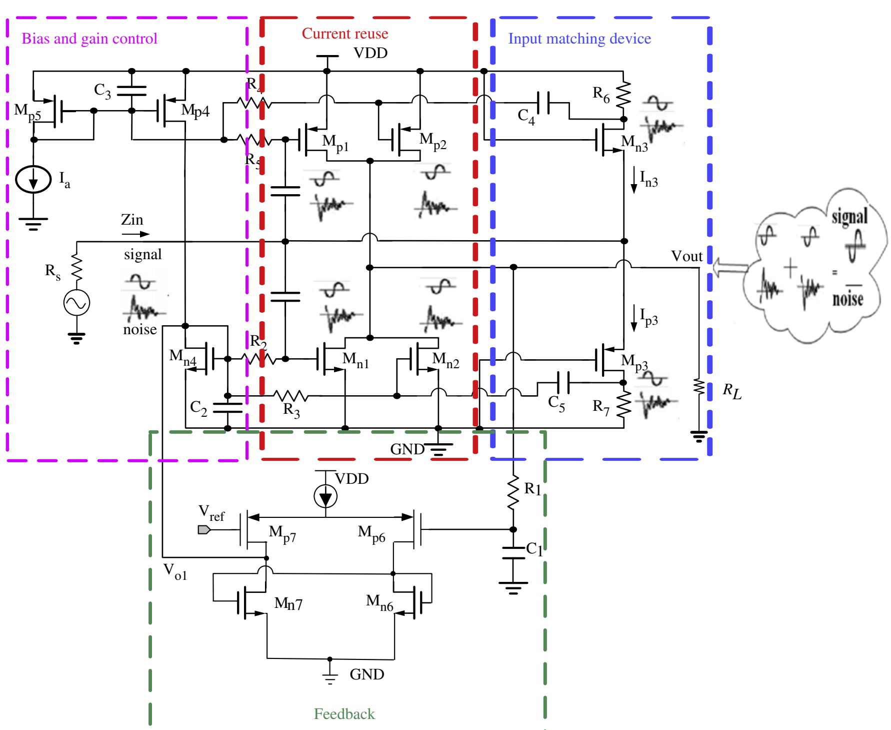

Fig. 1. The schematic of the proposed wide-band gain control LNA circuit.