Low-Voltage UWB Low-Noise Amplifier

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Introduction

One conventional ultra-wideband (UWB) system is a pulse-based, carrier-free, time-domain wireless technology that transmits sub-nanosecond impulses using very low power over a wide bandwidth ranging form 3.11 to 10.6 GHz. Since the energy of signal is spread across wide bandwidth, its signal level is lower than the noise floor. Due to the unique nature of UWB technology, design of UWB LNA faces the following challenges: sufficient gain to amplify the low signal level over the whole band while keeping the noise figure acceptable.

This paper focuses on the design and implementation of an LNA for UWB applications based on conventional CMOS technology. A low-voltage UWB low-noise amplifier (LNA) is designed and fabricated in a standard 0.18 μm CMOS technology. A folded cascode topology with RC-feedback is used to achieve a flat gain from 12 dB to 14 dB, the noise figure is about 3 dB. A low dc power consumption of 12.9 mW is achieved with 0.75 V supply without using output buffer. The input and output return losses are lower than -10 dB. The input referred 1-dB compression point is $P_{1\text{dB}} = -13.1$ dBm. The chip size is 0.59 mm^2.

Design Approach

Compared with narrow-band LNA, one design challenge in using the shunt-series topology is to ensure circuit stability at the presence of the negative feedback. Other challenges include input / output matching, flat gain and low noise figure over the band. Many UWB LNA topologies have been proposed in the literatures, the input matching networks frequently used are Chebychev bandpass filter [1], [2] and common-gate(CG) configuration [3].

Input/output matching.

Fig.1 shows the schemetic of the proposed UWB LNA, which is a folded cascode amplifier with resistive shunt-feedback. The input matching is achieved by using the combination of L_1 and C_1. The output matching is implemented by using an output buffer. The impendence look into the source end of transistor M_3 is $1/g_m$ which approaches 25 Ω. By turning the width of M_3, it is easy to achieve output matching.

Low-voltage bias design.

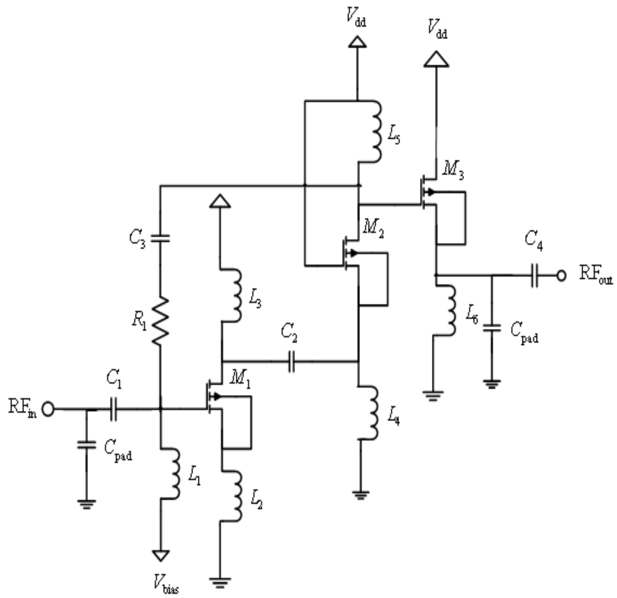

Figure 1: Schematic of the proposed UWB LNA.

In order to alleviate the drawback of limited output swing of telescopic cascode topology, a folded cascode LNA is used and implemented by using L_4 and C_2 to couple the RF signal and provide conjugate matching between M_1 and M_2.

Cascode amplifier with resistive shunt-feedback.

The capacitor C_2 provides an ac coupling, and R_1 is the resistance of the feedback network. Due to the feedback mechanism, wideband input matching is achieved, and the Q factor of the resonant narrowband cascode LNA is reduced to obtain flat gain over the whole band.

Stability.

The unconditional stability condition requires $K_f > 1$ with

$$K_f = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{|S_{21}S_{12}|}$$

where $\Delta = S_{11}S_{22} - S_{12}S_{21}$.

Results and Conclusion

The proposed LNA has been fabricated in TSMC 0.18 μm CMOS process, and it takes a die area of 0.8 mm $\times$ 0.7 mm, including test pads. The measurement will be conducted on wafer by applying high-frequency probes on the input and output

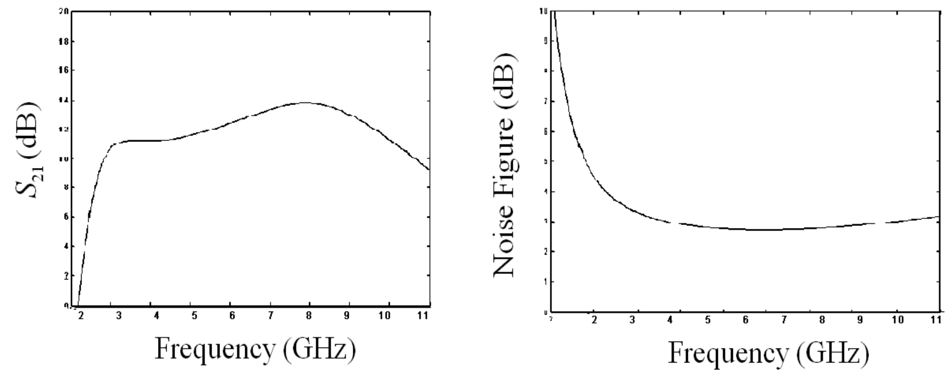

Figure 2: Gain and noise figure of the LNA.

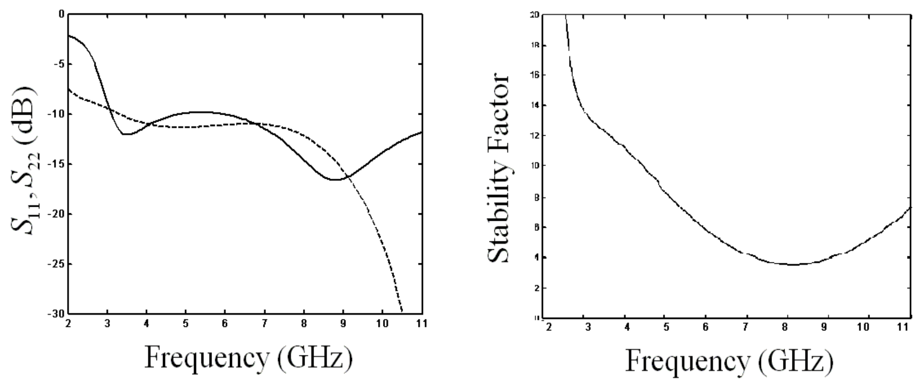

Figure 3: Input (——) / output (– – –) return loss and stability factor of the LNA.

ports of the LNA chip. The dc supply and ground pads are wire-bonded on the testing board. The power gain, input / output return losses will be measured using HP 8510 network analyzer. The noise figure will be measured with Agilent N8975A noise figure meter.

Fig. 2 shows the simulated gain and noise figure of the LNA using Agilent Advance Design System (ADS). The gain varies between 11.5 and 14 dB within the band of interest, which does not include the loss of the output buffer. The noise figure lies between 2.6 and 4.64 dB over 3 - 10 GHz.

Fig. 3 shows the input and outpur return losses of the LNA. Both are lower than -10 dB over the band of interest. Fig. 3 also shows the stability factor of the LNA, which is higher than 1 over the band of interest. The lowest stability factor of 3.8 appears at 8 GHz. Thus, the proposed UWB LNA is unconditionally stable.

The isolation is lower than -40 dB over the band. The input referred 1-dB compression point is $P_{1\mathrm{dB}} = -13.1$ dBm. The power consumption of the LNA without output buffer is 12.9 mW.

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