Single Stage Common Source Cascode LNA Design at 1.5 GHz

eSim Marathon – Circuit Design and Simulation with IHP SG13G2

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Contents

1 Introduction **2**
1.1 Objective 2

2 Project Overview **2**

3 Circuit Design **2**
3.1 Circuit Description 2
3.2 Circuit Schematic 3

4 Simulation and Results **3**
4.1 Simulation Setup 3
4.2 Results 4

5 Discussion **5**

6 Conclusion **5**

1 Introduction

Low Noise Amplifiers (LNAs) are a critical component in RF receiver front-ends, as they determine the overall system sensitivity. This projec focuses on design and simulation of a single-stage common-source cascode LNA operating at 1.5 GHz using the IHP SG13G2 technology node with open-source EDA environment (eSim + Ngspice).

1.1 Objective

The primary objective was to design and simulate a low-noise, high-gain LNA with good input/output matching and low power consumption.

2 Project Overview

This project was developed based on the proposal titled *"Single Stage Common Source Cascode LNA Design at 1.5 GHz"* submitted for the eSim Marathon.

The LNA employs a cascode configuration to improve gain and isolation while minimizing Miller capacitance. Inductive source degeneration was used to achieve 50 Ω input matching, and a load inductor provided resonance at the target frequency.

3 Circuit Design

3.1 Circuit Description

The schematic of the LNA includes the following components:

- Common-source transistor (M1)
- Cascode transistor (M2)
- Gate inductor (L_g)
- Source degeneration inductor (L_s)
- Load inductor (L_d)
- AC coupling capacitor (C_p)

3.2 Circuit Schematic

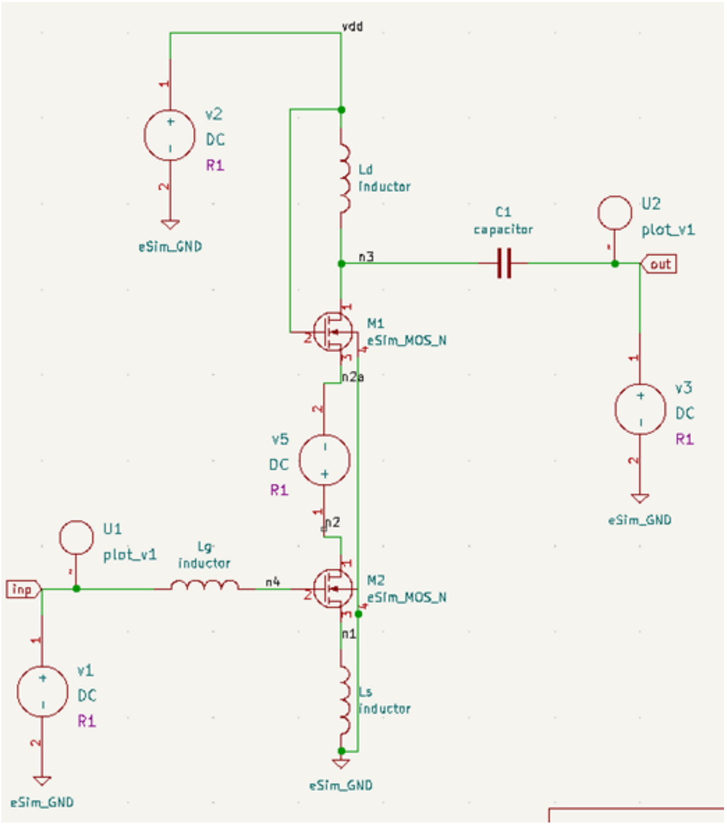

Figure 1: Common-source cascode LNA schematic implemented in eSim

4 Simulation and Results

4.1 Simulation Setup

Circuit simulations was performed in open-source SPICE simulator Ngspice via eSim using IHP SG13G2 PDK SPICE models. Since eSim does not support S-parameter analysis and only supports DC, AC and TRAN simulations, the `lna.cir.out` netlist generated using the 'Convert KiCad to NgSpice' tool in eSim had to be manually modified to enable the required SP analysis for RF characterization of LNA, including setup for plotting S11, S21, S12, and S22 parameters.

Another challenge was that Ngspice's native waveform viewer, GTKWave, does not support marker functionality for measuring S-parameter values at specific frequencies of interest. To overcome this limitation, a more suitable analog waveform viewer GAW was installed. The simulation output `lna.cir.out.raw` file was imported into GAW to generate required s-parameter plots.

Key LNA parameters such as gain, input/output return loss and reverse isolation were evaluated. Other important parameters like noise figure and P1dB could not be implemented due to unavailability of direct simulation features in Ngspice for these RF parameters, unlike commercial EDA tools. While these measurements are technically feasible, they would require additional effort, which was not possible within constraint timeline for marathon.

4.2 Results

The measured results were compared with typical design specifications, as summarized in Table 1.

Table 1: Comparison of Typical Specifications vs Simulation Results

Parameter	Typical Specification	Simulation Result
Frequency band	1.55 – 1.60 GHz	1.55 GHz
Gain (S21)	20 dB	17.4 dB
Noise Figure (NF)	< 2 dB	Not simulated
Input Return Loss (S11)	< -10 dB	-9.2 dB
Output Return Loss (S22)	< -10 dB	-0.4 dB
Reverse Isolation (S12)	< -30 dB	-42 dB
P1dB	-15 to -10 dBm	Not simulated
Power Consumption	< 10 mW	0.42 mW
Supply Voltage	1.8 V	3.3 V

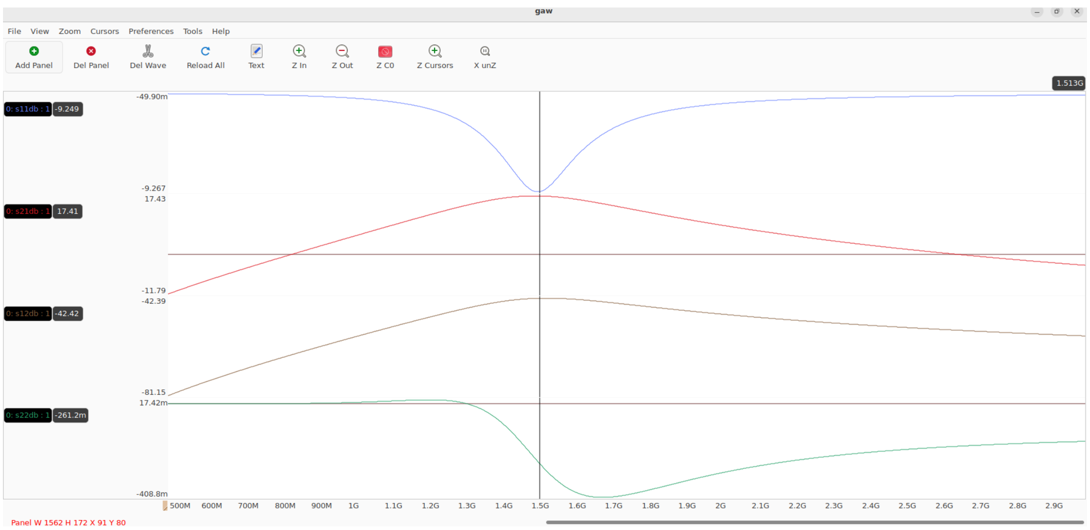

Figure 2: Simulated S-parameter response of the designed LNA

5 Discussion

The simulated LNA achieved a gain of 17.4 dB at 1.55 GHz, which is close to the design target of 20 dB. The reverse isolation (S_{12}) was excellent at -42 dB, confirming strong stability. However, S_{11} showed a slight mismatch that can be improved through fine-tuning. The main challenge encountered was achieving good output matching (S_{22}), for which a separate matching network using L_s and C_p is required. The power consumption was extremely low (0.42 mW), well below the design specification.

The noise figure and P1dB could not be simulated due to limitations in directly measuring these parameters in `ngspice`.

6 Conclusion

A single-stage cascode LNA at 1.5 GHz was designed and its s-parameters simulated using open-source EDA tools (eSim + Ngspice). The LNA achieved high gain, strong reverse isolation and low power consumption, validating the design approach. Further optimization of the input and output matching networks can yield performance closer to required specifications. Additionally, the availability of advanced analysis features in these open-source tools can enable comprehensive characterization of other important LNA specifications

References

1. B. Razavi, *RF Microelectronics*, Prentice Hall, 2011.

2. T. H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, Cambridge University Press, 2004.