Analog Integrated Circuit Design Using Open-Source Tools

Philip Wig, Adviser: Dan White, Ph.D.

Abstract

Over the last couple of years the open-source chip design community has experienced rapid growth with the release of SkyWater Foundries SKY130 process design kit (PDK) [1]. Google has sponsored the OpenMPW program which allows hobbyists and researchers the opportunity to submit custom integrated circuit (IC) designs to get manufactured free of charge. Before these initiatives, most of the tools and knowledge of IC design were limited to large corporations willing to incur the costs of designing their own chips. So far, the open-source community has made tremendous strides in the design of digital ICs with projects such as OpenROAD [2] and Tiny Tapeout [3] making designing a chip easier than ever.

Digital is only half the story, and analog design is a critical component of building functional ICs. Here we present an overview of the analog design process and the various open-source tools through the design of a low noise amplifier (LNA) that might be used as part of a communications frontend in applications such as satellite communication.

Analog Design Overview

Unlike digital systems which can be described in hardware description languages like Verilog or VHDL, analog designs are designed on the transistor level using schematics. Each component must be individually designed based on the performance requirements of the system which necessitates accurate modeling and simulation tools. While projects like OpenFASoC [4] use synthesizable analog cells, there remains little end-to-end automation for analog design.

SKY 130 PDK

The SKY130 PDK is a general-purpose 130nm IC process that is not optimized for high-performance analog designs. Nevertheless, it still allows designers to create functional analog circuits. The PDK contains a variety of different devices ranging from NMOS and PMOS FETs with various voltage ratings, diodes, NPN and PNP transistors, resistors, MiM and vertical parallel plate capacitors. Beyond these predefined devices, designers have the freedom to design their own structures if the design passes all the manufacturing design rule checks (DRC) for the process.

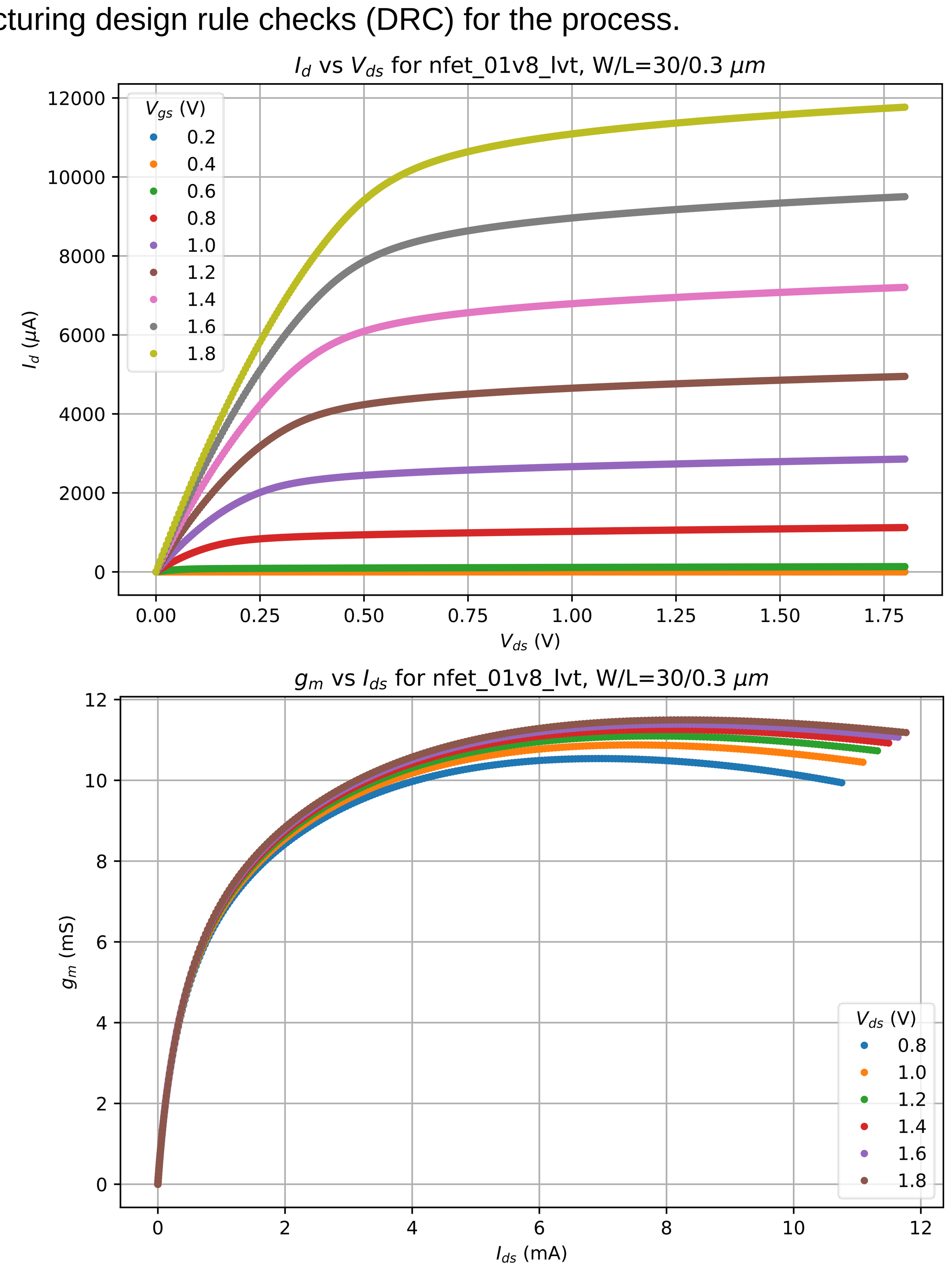

Figure 1: Current vs. Voltage and Transconductance Characteristics of nfet_01v8_lvt device

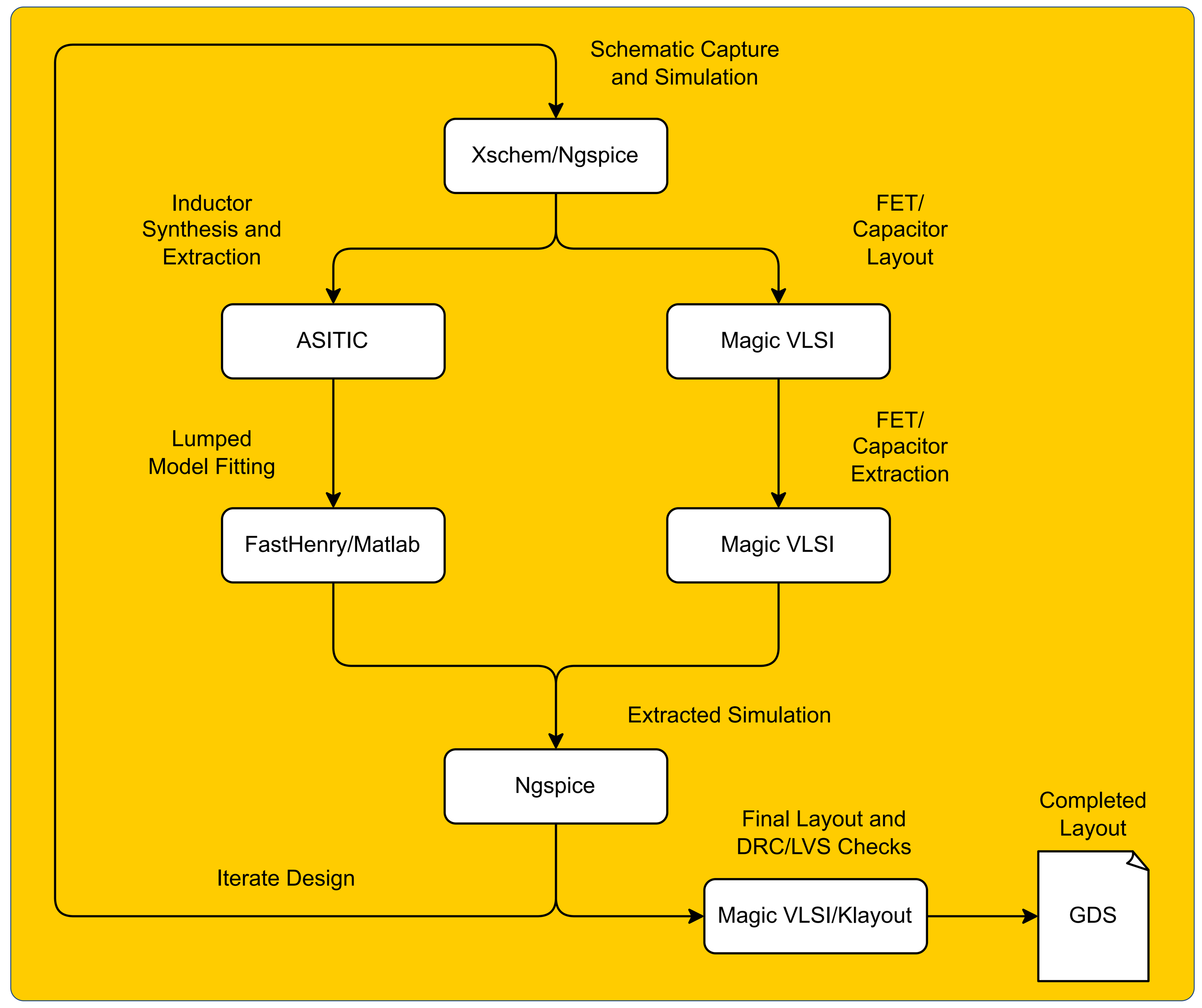

Figure 2: Analog design workflow

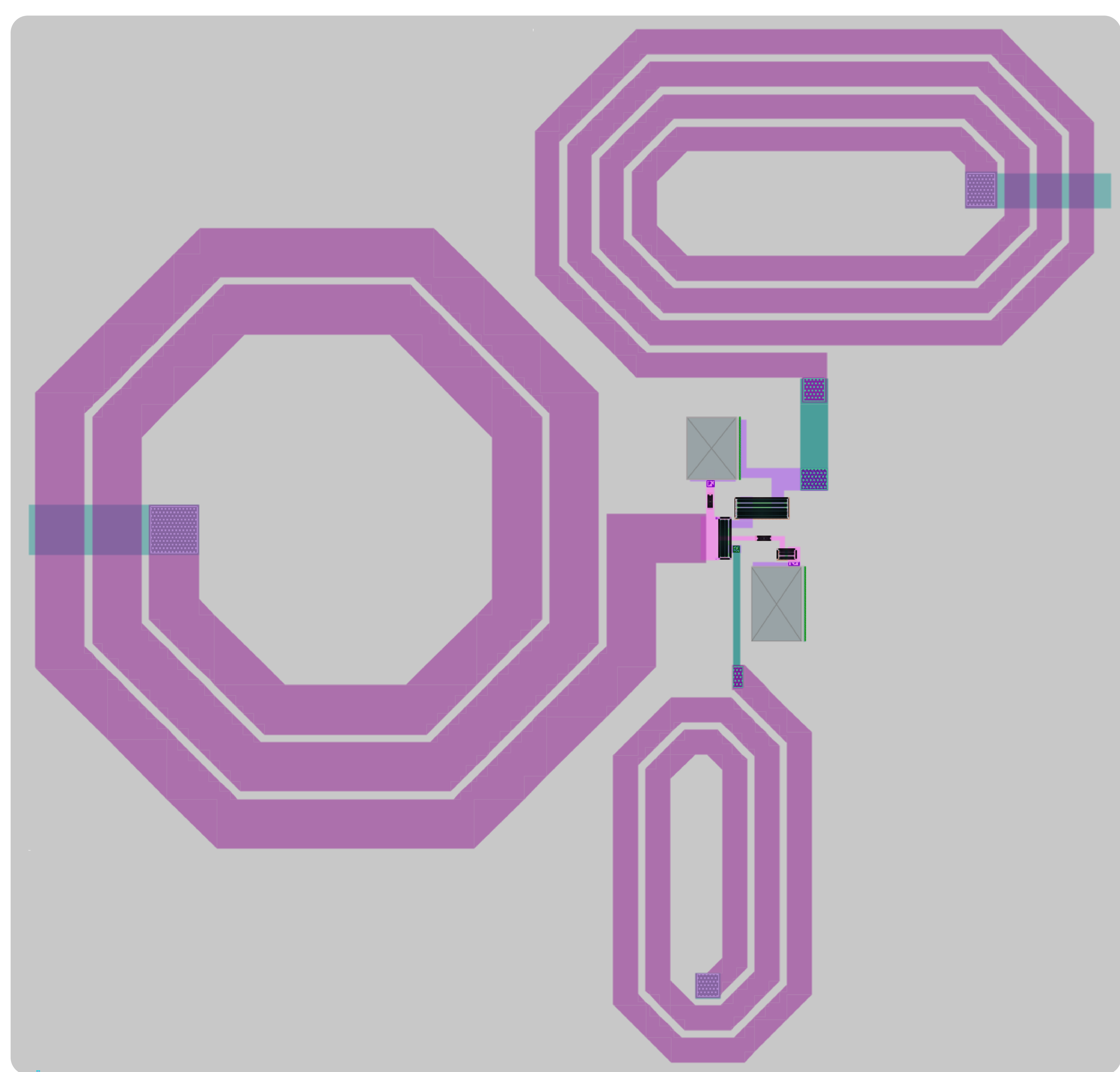

Figure 3: LNA Layout in Magic VLSI

LNA Design

To demonstrate the analog capabilities of the SKY130 process, we designed an LNA to illustrate an analog design flow with the PDK and surrounding open-source software. Xschem [5] and Ngspice [6] were used for schematic capture and circuit simulation. ASITIC [7] was used to design and characterize the inductors. Magic VLSI [8] was used for the final layout

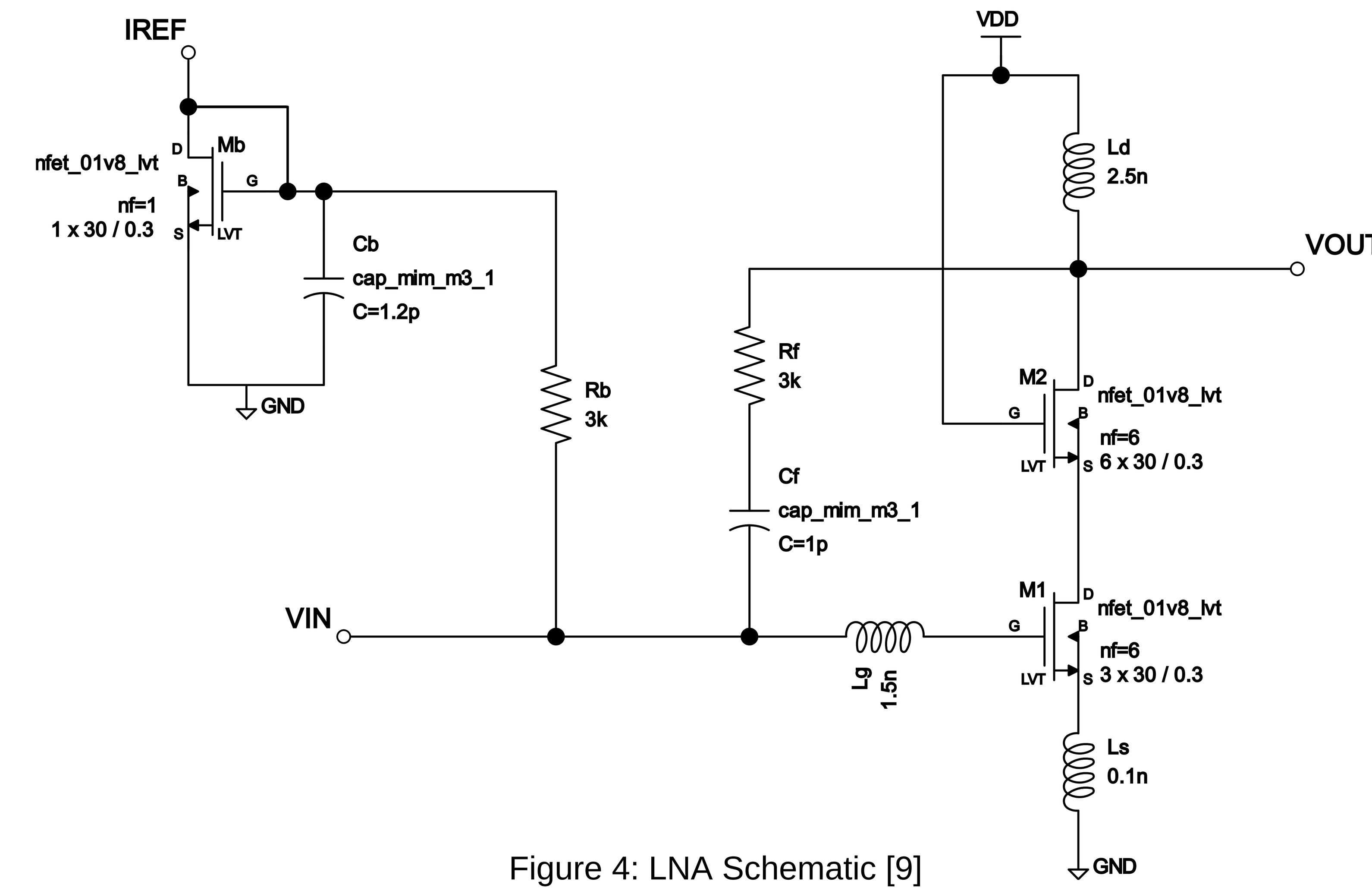

Figure 4: LNA Schematic [9]

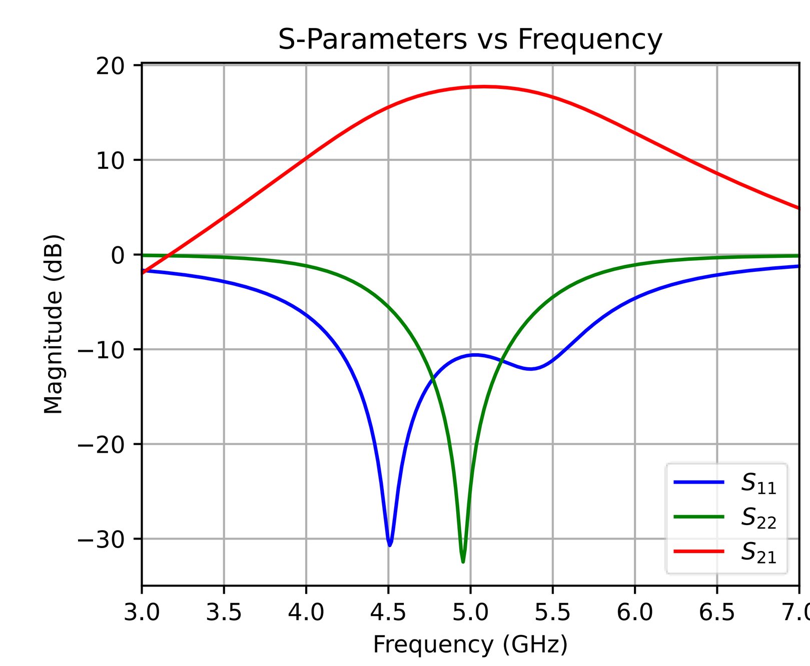

Figure 5: S-Parameters

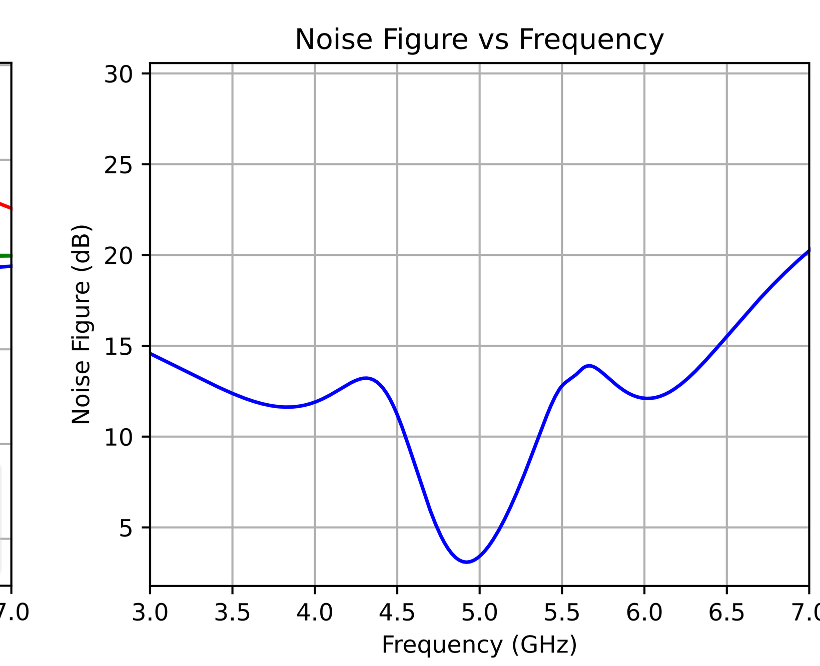

Figure 6: Noise Figure

Performance	
Center Frequency	5 GHz
Bandwidth	500 MHz
Gain (@ 5GHz)	17.7 dB
Noise Figure (@ 5GHz)	3.41 dB
Power Consumption	8 mW
Area	435 x 415 um

References:

[1] "SkyWater SKY130A PDK documents." SkyWater SKY130 PDK. Accessed: Apr. 16, 2023. [Online]. Available: https://skywater-pdk. readthedocs.io/en/main/index.html
[2] "OpenROAD project." OpenROAD. Accessed: Apr. 16, 2023. [Online]. Available: https://theopenroadproject.org/
[3] "Tiny Tapeout." Matt Venn. Accessed: Apr. 16, 2023. [Online]. Available: https://tinytapeout.com/
[4] "OpenFASoC." FASoC Project. Accessed Apr. 16, 2023. [Online]. Available: https://github.com/idea-fasoc/OpenFASOC
[5] "Xschem." Stefan Schippers. Accessed: Apr. 16, 2023. [Online]. Available: https://xschem.sourceforge.io/stefan/index.html
[6] Ngspice. Accessed: Apr. 16, 2023. [Online]. Available: https://ngspice.sourceforge.io/index.html
[7] "ASITIC: Analysis and simulation of spiral inductors and transformers for ICs." ASITIC. Accessed: Apr. 16, 2023. [Online]. Available: http://rfic.eecs.berkeley. edu/~niknejad/asitic.html
[8] "Magic VLSI." Open Circuit Design. Accessed: Apr. 16, 2023. [Online]. Available: http://opencircuitdesign.com/magic/index.html
[9] B. Razavi, RF Microelectronics. Upper Saddle River, NJ, USA: Prentice-Hall, 2012.

WIRED
Wireless Research and Electronic Discovery

VALPARAISO UNIVERSITY
ENGINEERING