NOVA SCHOOL OF
SCIENCE & TECHNOLOGY

MEEC/MIEEC

Radio Frequency Electronics

Low Noise Amplifier - Part I

Authors:

Martim Duarte Agostinho (70392) md.agostinho@campus.fct.unl.pt
Francisco Simões Coelho Sá da Costa (70386) fsc.costa@campus.fct.unl.pt
Sofia Margarida Mafra Dias Inácio (58079) sm.inacio@campus.fct.unl.pt

2024/2025 – 2nd Semester, DEEC

Contents

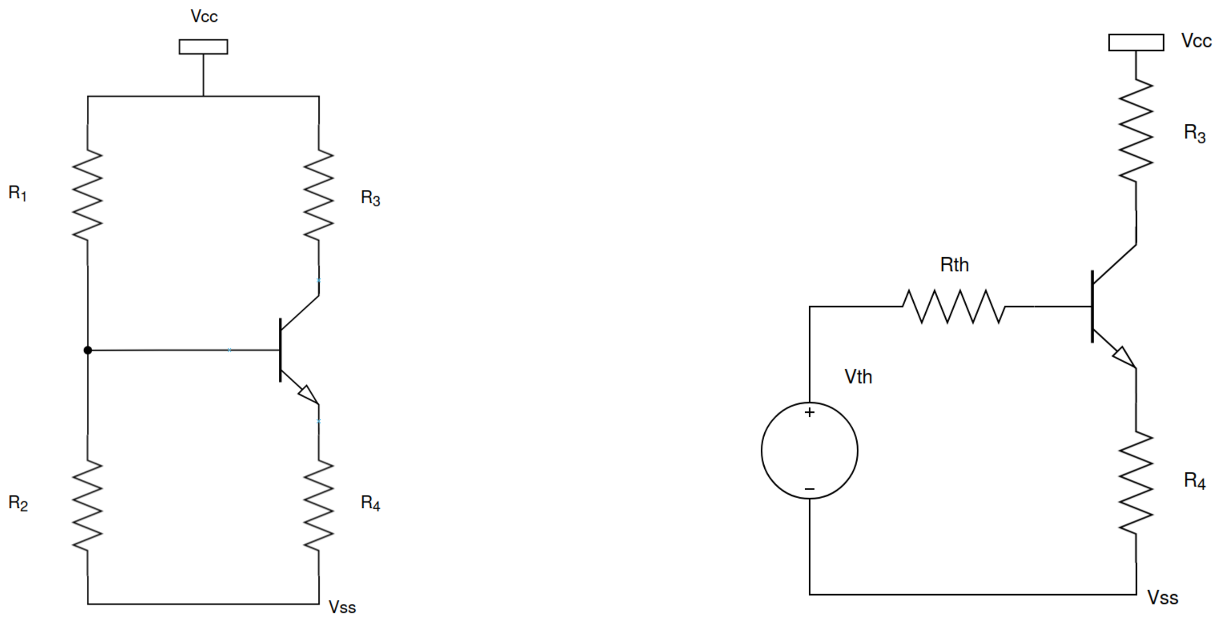
List of Figures

1 Introduction

2 Design of the LNA

2.1 Transistor Bias Network

The DC bias point of a transistor directly influences its small-signal S-parameters, and hence the gain, noise figure and stability of the LNA. This makes this step crucial. Figure ?? shows the biasing circuit and its Thévenin equivalent used to simplify analysis.



(a) Transistor DC biasing circuit

(b) Bias circuit equivalent circuit

As shown in Figure 1b the Thévenin equivalent is given by the equations 1, replacing the R_1, R_2 voltage divider.

$$\begin{aligned} R_{TH} &= R_1//R_2 \\ V_{TH} &= V_{cc}\frac{R_2}{R_1+R_2} \end{aligned} \tag{1}$$

Using Kirchhoff voltage law, the equations 2 are derived, the first starts at V_{TH} goes through R_{TH}, V_{BE} and R_4. The second goes from V_{CC} through R_3, V_{CE} and R_4.

$$\begin{cases} 0 = V_{TH} - I_b \cdot R_{TH} - V_{BE} - I_E \cdot R_4 \\ 0 = V_{CC} - R_3 \cdot I_C - V_{CE} - I_E \cdot R_4 \end{cases} \tag{2}$$

Solving the system of equations, assuming fixed values for R_2 and R_4, originates the equations 3.

$$
\begin{aligned}
R_1 &= \frac{R_2\left(-I_C R_4 \beta - I_C R_4 - V_{BE}\beta + V_{CC}\beta\right)}{I_C R_2 + I_C R_4 \beta + I_C R_4 + V_{BE}\beta} \\
R_3 &= \frac{-I_C R_4 \beta - I_C R_4 + V_{CC}\beta - V_{CE}\beta}{I_C \beta}
\end{aligned} \tag{3}
$$

The Table 1, shows the provided values for the biasing circuit and the fixed values for R_2 and R_4.

Table 1: Transistor biasing parameters

Parameter	Value
R_2	$1\,\mathrm{k\Omega}$
R_4	$100\,\Omega$
β	72.534
I_C	$9\,\mathrm{mA}$
V_{CC}	$10\,\mathrm{V}$
V_{BE}	$1\,\mathrm{V}$
V_{CE}	$5\,\mathrm{V}$

Resulting in $R_1 = 4\,\mathrm{k\Omega}$ and $R_3 = 454\,\Omega$.
FALTA SIM E JUSTIFICAR A SIM

2.2 S-parameters with packaging effects

2.3 Transistor validation for the given bias point

2.4 Stability

2.5 Input and output matching networks for maximum gain

The adaptation for maximum gain is done using the line impedance transformation method. The input and output matching networks are designed to transform the input and output impedances of the transistor to the desired values, which are $50\,\Omega$ in this case. In the Smith chat, the matching is done with inductors and capacitors and lines and stubs.

2.5.1 Matching with lumped elements

The matching networks are designed using the Smith chart, which allows for the visualization of the impedance transformation. The input and output impedances of the transistor are transformed to $50\,\Omega$ using a combination of inductors and capacitors. The values of the components are also calculated using the equations for impedance transformation.

The matching using the Smith Chart for the input and output are shown in Figures 2 and 4, where the input and output impedances of the transistor are transformed to $50\,\Omega$ using a combination of inductors and capacitors.

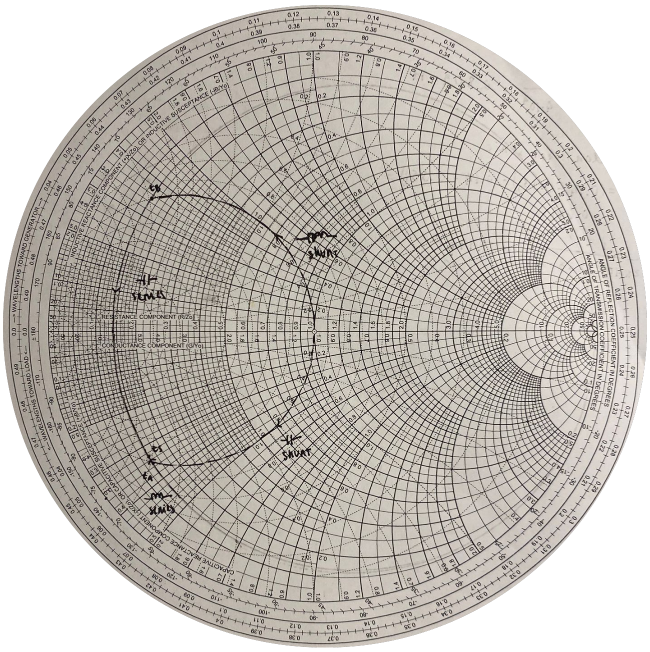


Figure 2: Smith chart for input matching with lumped elements

The adaptation mesh for the input was done with a shunt inductor and a series capacitor and the equivalent circuit is shown in Figure 3. The values of the components were also calculated using the equations for impedance transformation as a form of validation.

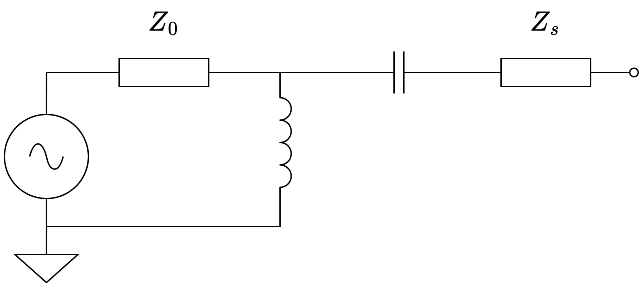


Figure 3: Matching circuit for input

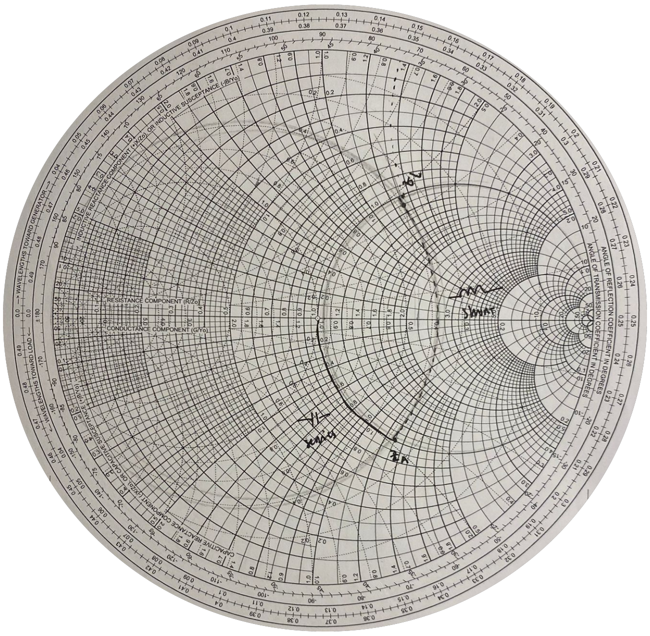


Figure 4: Smith chart for output matching with lumped elements

The adaptation mesh for the output is done with a series capacitor and a shunt inductor and the equivalent circuit is shown in Figure 5. The values of the components were also calculated using the equations for impedance transformation as a form of validation.

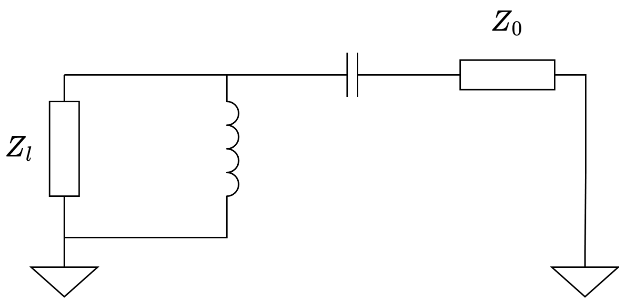


Figure 5: Matching circuit for output

The resulting circuit is shown in Figure 6, where the input and output matching networks are designed using a combination of inductors and capacitors.

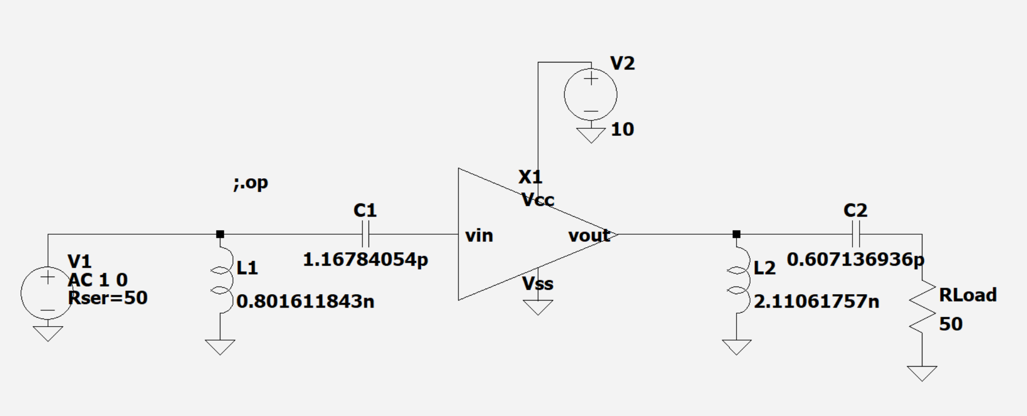


Figure 6: Matching circuit for input and output with values

2.5.2 Matching lines and stubs

The matching networks were also designed using transmission lines and stubs, these type of adaptation allows grater frequencies (more than 1 GHz) in real conditions. The input and output impedances of the transistor are transformed to 50 Ω using a combination of transmission lines and stubs. The values of the components are also calculated using the equations for impedance transformation.

2.6 Gain and Noise Factor

3 Simulation

3.1 Validation of the LNA design

3.2 Input and output matching networks design optimization

4 Conclusion

References