Chalmers University of Technology

EME102: Active Microwave Circuits

Home Assignment

LNA Design

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Contents

1 Abstract **3**

2 Design criteria **3**

3 Stability **3**

4 Unilateralism **4**

5 Design **5**

List of Figures

1 Stability circles obtained by $L_StabCircleandS_StabCircleinADS$. 4

2 Plot of noise circle along with Γ_{opt} and $\Gamma_M S$. 6

3 Plot of equations used in the creation of the VSWR circle. 7

4 Plot of VSWR circle along side the noise circle. 8

5 Plot of final design parameters. 9

1 Abstract

The purpose of this task is to use ADS software tool and design a low noise amplifier (LNA) under certain design criteria. The logic will go as follows, first stability is analyzed, followed by considering the optimal gain matching (conjugate matching) and optimal noise matching will be considered, if the design criteria is not met then a compromise will be used to find a design that fits both noise figure, gain and VSWR ratios. Finally a matching network will be design to satisfy the required Γ_S and Γ_L at the source and load, respectively.

2 Design criteria

S_{11}	$0.93\angle-60.1°$
S_{12}	$0.028\angle57.7°$
S_{21}	$1.61\angle128.7°$
S_{22}	$0.43\angle-172.3°$

Table 1: S parameters.

Transistor limitations:

- $\Gamma_{Opt} = 0.78\angle58°$
- $F_{min} = 0.7dB$
- $R_n = 22\Omega$

Amplifier design criteria:

- $F \leqslant 0.9dB$
- $VSWR_{in} \leqslant 2$
- $VSWR_{out} \leqslant 1.9$
- $G_T \geqslant 14dB$

Now that the criteria are defined, the design can begin.

3 Stability

First stability is checked.

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \tag{1}$$

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

I find that $|Delta| = 0.379$ and $K = 1.037$, found in ADS. Both K is greater than unity and magnitude of delta is less than one, therefore the transistor is unconditionally stable in the case of a passive load.

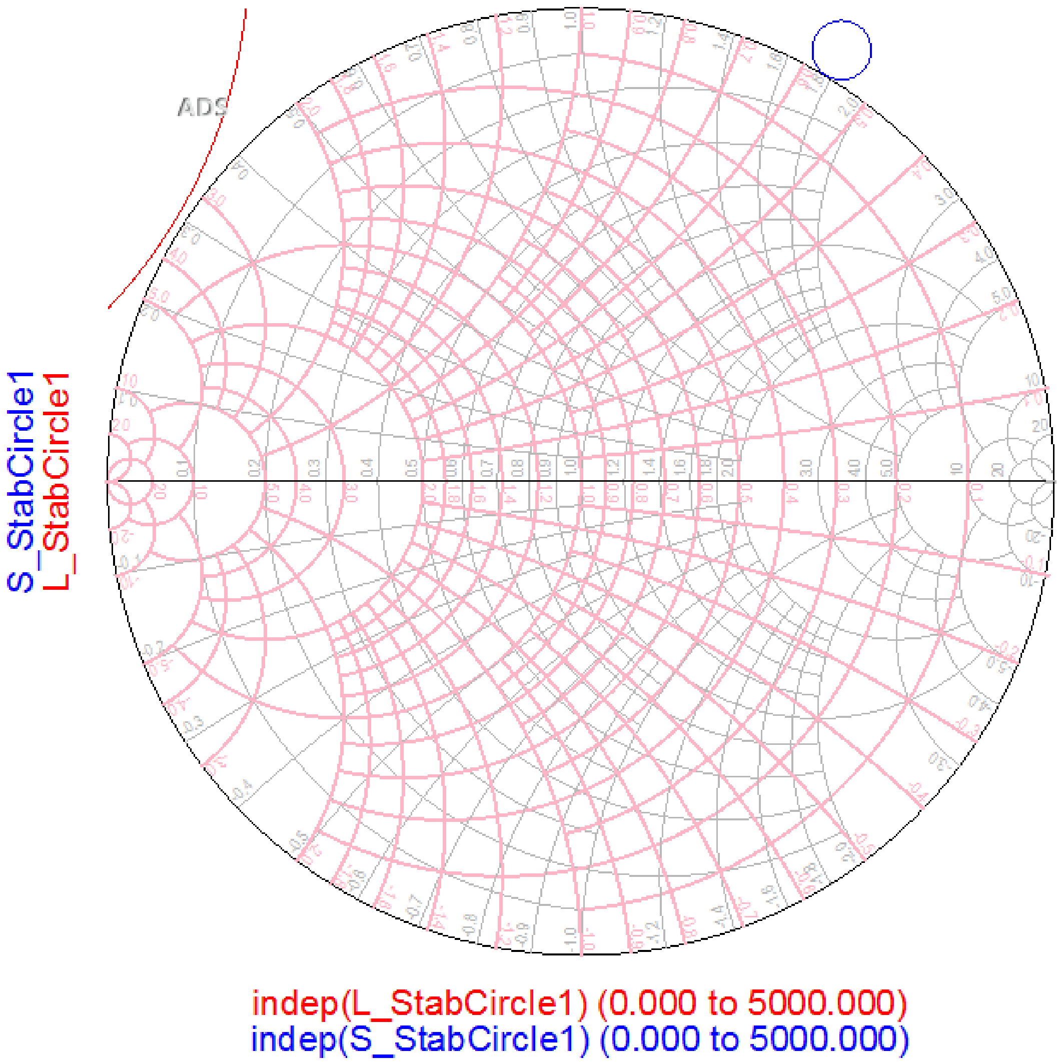

Figure 1: Stability circles obtained by L$_S tabCircleandS_S tabCircleinADS$.

4 Unilateralism

$$U = \frac{|S_{12}||S_{21}||S_{11}||S_{22}|}{(1 - |S_{11}|^2)(1 - |S_{22}|^2)} \tag{3}$$

By ADS U is found to be 0.164, making the transistor clearly not unilateral.

5 Design

Doing some designs on paper I see that the optimal conditions of maximum transducer gain:

$$\Gamma_{IN} = \Gamma_{MS} * \Gamma_{OUT} = \Gamma_{ML}* \tag{4}$$

Will not meet the noise criterion. Next we can try the noise optimal condition:

$$\Gamma_S = \Gamma_{Opt}\Gamma_L = \Gamma_{Out}* \tag{5}$$

This will not give the required gain, so we must have a compromise.

1. In a smith chart plot the minimum noise circle along with Γ_{opt} and $\Gamma_M S$.

$$\Gamma_{MS} = \frac{B_1 + \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \tag{6}$$

$$B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \tag{7}$$

$$C_1 = S_{11} - \Delta S_{22}* \tag{8}$$

2. Here I plot the previously mentioned points and noise circle. We pick the point between the points lying on the noise circle.

$$\Gamma_S = 0.9\angle 58.6^\circ \tag{9}$$

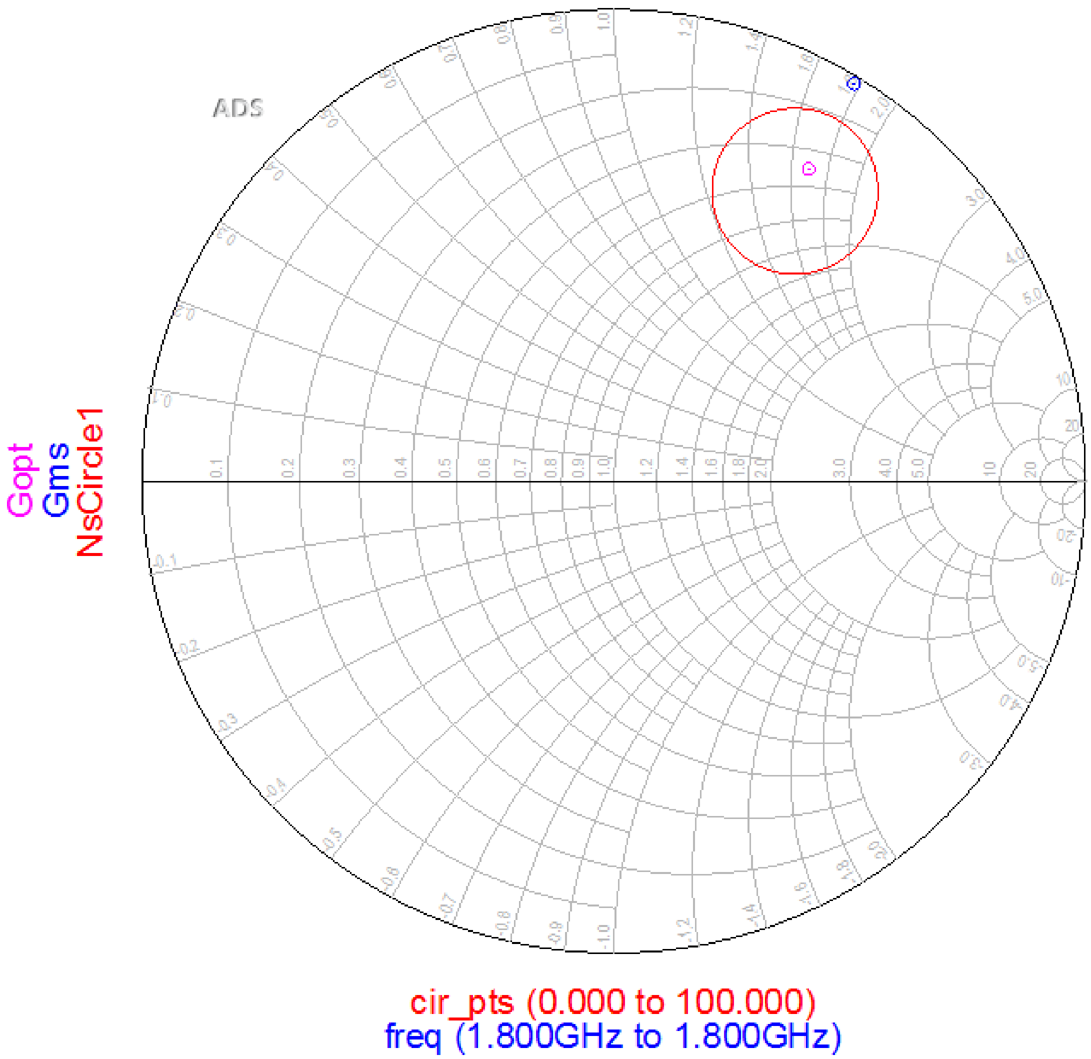

Figure 2: Plot of noise circle along with Γ_{opt} and $\Gamma_M S$.

3. Now we can calculate Γ_{out}

$$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S} \tag{10}$$

And if we assume the largest allowed output VSWR ratio of 1.9 then we can draw the circle and pick Γ_L:

```
Eqn VSWR_out=1.9

Eqn Gamma_out = S(2,2) + (S(1,2)*S(2,1)*Gamma_s)/(1-S(1,1)*Gamma_s)

Eqn Gamma_b = (VSWR_out-1)/(VSWR_out+1)

Eqn C_vio1=(conj(Gamma_out)*(1-(Gamma_b**2))/(1-(abs(Gamma_b*Gamma_out))**2))

Eqn r_vio1=(Gamma_b*(1-(abs(Gamma_out)**2))/(1-(abs(Gamma_b*Gamma_out)**2)))

Eqn VSWRout_circle=expand(circle(C_vio1,r_vio1,numpts))
```

Figure 3: Plot of equations used in the creation of the VSWR circle.

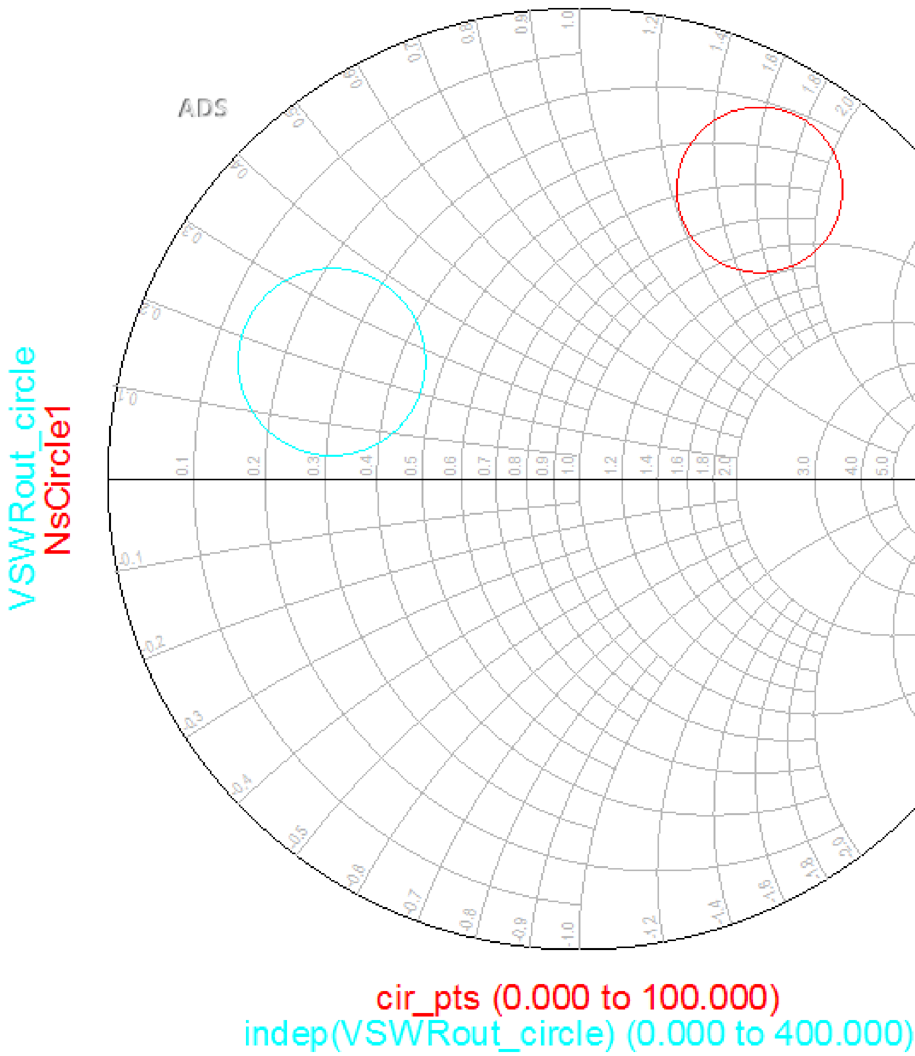

Figure 4: Plot of VSWR circle along side the noise circle.

4. From this circle we can pick Γ_L.

$$\Gamma_L = 0.38\angle 156^\circ \tag{11}$$

5. With these calculations we can get $VSWR_{in}$.

$$\Gamma_{in} = S_{11} + \frac{S_{21}S_{12}\Gamma_L}{1 - S_{22}\Gamma_L} \tag{12}$$

$$VSWR_{in} = \frac{1 + |\Gamma_a|}{1 - |\Gamma_a|} \tag{13}$$

$$|\Gamma_a| = |\frac{\Gamma_{in} - \Gamma_s^*}{1 - \Gamma_{in}\Gamma_s}| \tag{14}$$

6. Finally the ultimate measures are the noise figure and the transducer gain. The following equations were employed in calculating these:

$$G_T = \frac{1 - |\Gamma_S|^2}{|1 - \Gamma_{in}\Gamma_S|^2}|S_{21}|^2\frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2} \tag{15}$$

$$F = F_{min} + \frac{4R_n}{Z_0} \frac{|\Gamma_S - \Gamma_{opt}|^2}{(1 - |\Gamma_S|^2)|1 + \Gamma_{opt}|^2} \tag{16}$$

7. After several iterations of selection of Γ_L then I get the following results. As one can see everything is satisfied in the design criteria.

freq	Gamma_out	Gamma_in	VSWR_in	G_t	Gamma_s	F_final	VSWR_out
1.800 GHz	0.619 / -154.636	0.946 / -59.320	1.925	14.237	0.900 / 58.600	0.755	1.900

Figure 5: Plot of final design parameters.