ECE 3113

BUILDING MATCHING NETWORKS AND UNILATERAL GAIN COMPUTATIONS OF AN RF TRANSISTOR

Objective

Once a properly biased transducer device is characterized by its S-parameters and analyzed with respect to stability at the target RF frequency, you can determine the maximum gain. However, this gain can only be achieved by matching the active device to the conjugate complex of the input and output impedances, or equivalently the input and output reflection coefficients. In Figure 1 you see the generic arrangement.

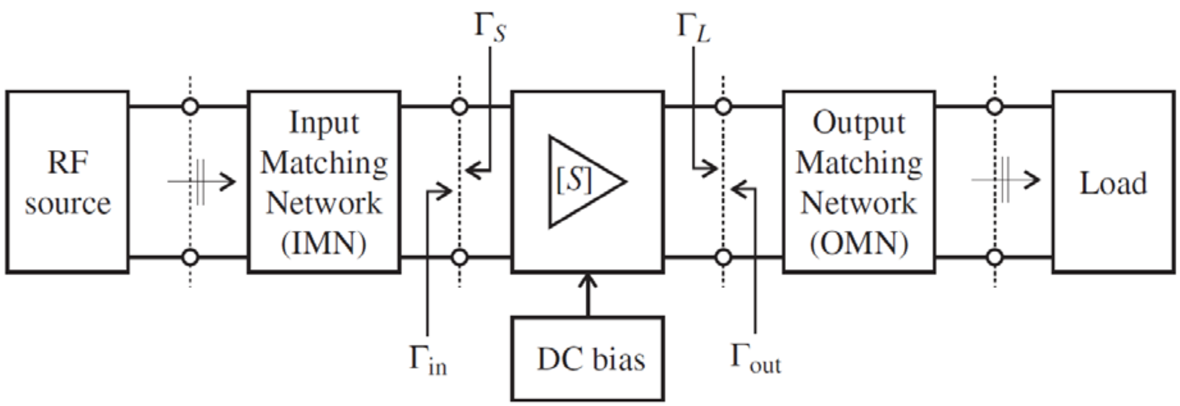


Figure 1. Building input matching networks for maximum gain.

As you will learn in class, matching for maximum gain is accomplished if the source reflection coefficient is the conjugate complex of the input reflection coefficient and if the load reflection coefficient is the conjugate complex of the output reflection coefficient. For the unilateral case, this requires

$$\Gamma_S = \Gamma_{in}^* \approx S_{11}^* \text{ and } \Gamma_L = \Gamma_{out}^* \approx S_{22}^*$$

under unilateral conditions. The maximum unilateral gain is computed according to the following formula:

$$G_{TUmax} = \frac{1}{|1 - |S_{11}|^2|^2} |S_{21}|^2 \frac{1}{|1 - |S_{22}|^2|^2}$$

Assignment

1. For the previously selected device BFR92A from the ADS library find the maximum unilateral gain at 1GHz and at 3GHz.

1GHz

freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)	delta
1.000 GHz	0.081 / -131.236	0.110 / 76.196	3.872 / 80.035	0.501 / -16.718	0.404 / -28.527

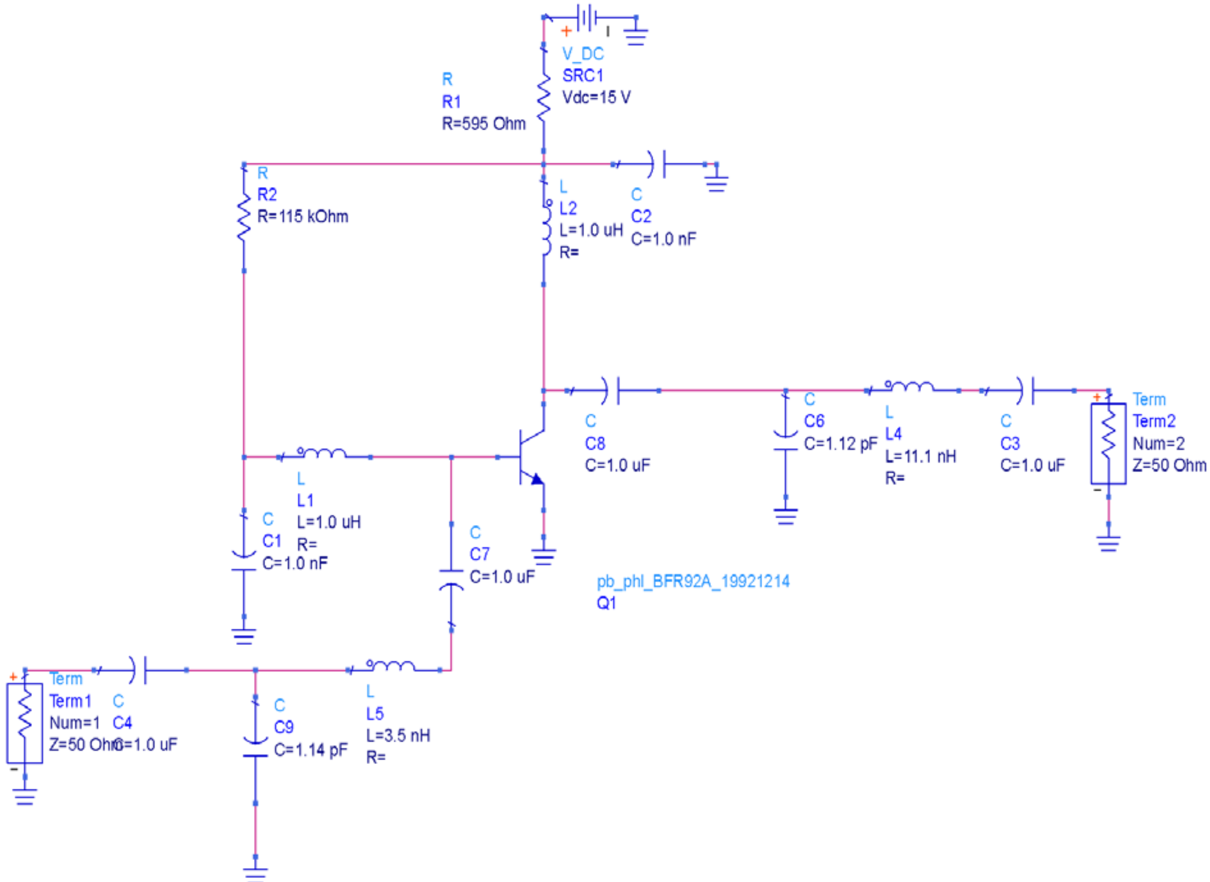
$$G_{TUmax} = \frac{1}{|1-|S_{11}|^2|^2} |S_{21}|^2 \frac{1}{|1-|S_{22}|^2|^2} = \text{ 13.04 dB}$$

3 GHz

freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)
3.000 GHz	0.216 / 122.203	0.346 / 59.271	1.495 / 38.344	0.339 / -30.248

$$G_{TUmax} = \frac{1}{|1-|S_{11}|^2|^2} |S_{21}|^2 \frac{1}{|1-|S_{22}|^2|^2} = \text{4.23 dB}$$

2. Construct a lumped 2-element input and output matching networks at 1GHz and report your gain computations. Carefully detail your matching strategy by providing explicit values for the chosen inductors and capacitors.



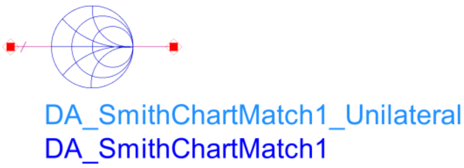
The two 1 uF capacitors at the terminals are used to decouple the DC bias from the RF signal path. The input matching network consists of a 1.14 pF shunt capacitor and 3.5 nH series inductor. The output matching network is comprised of a 1.12 pF shunt capacitor and 11.1 nH series inductor. The matching networks are constructed by starting from:

$\Gamma_{in} = S_{11}$ = 0.081 / -131.2 $\Gamma_{out} = S_{22}$ = 0.5 / -16

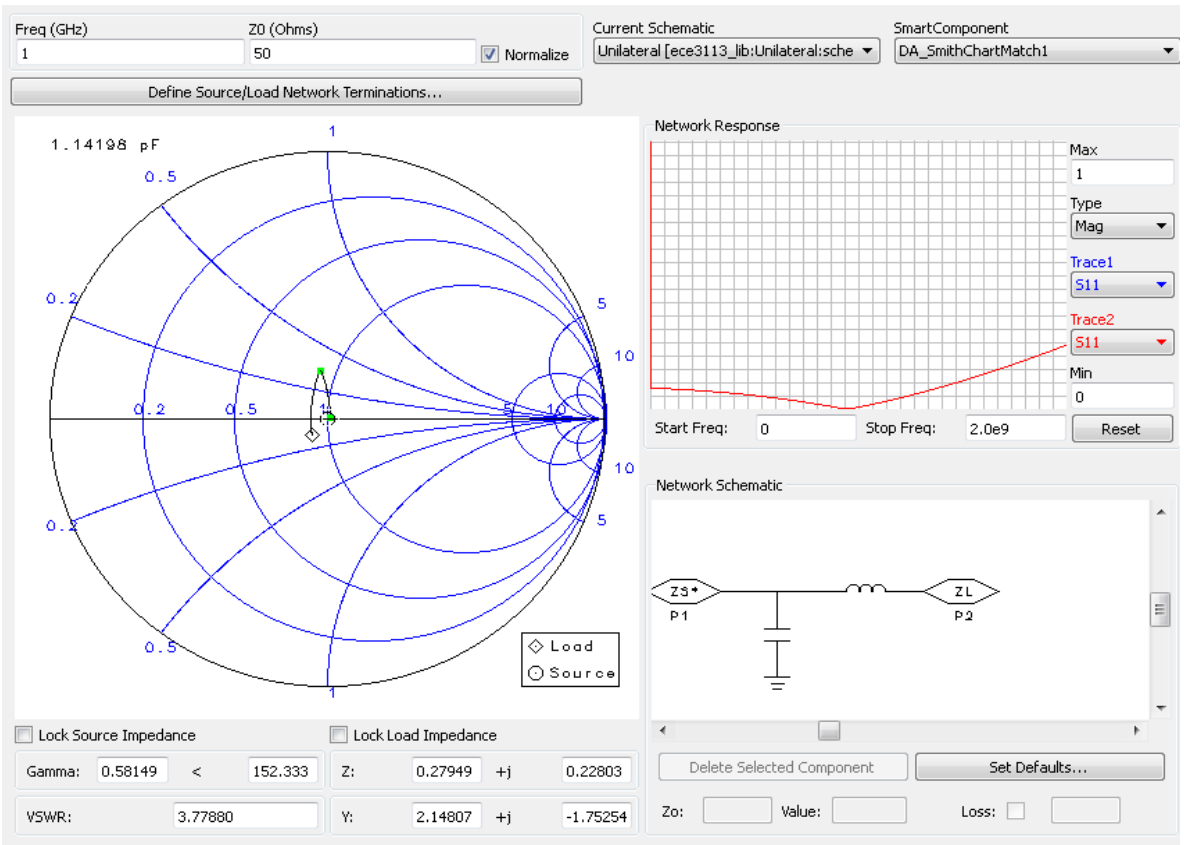
This results in

$$\Gamma_S = \Gamma_{in}^* \quad \Gamma_L = \Gamma_{out}^*$$

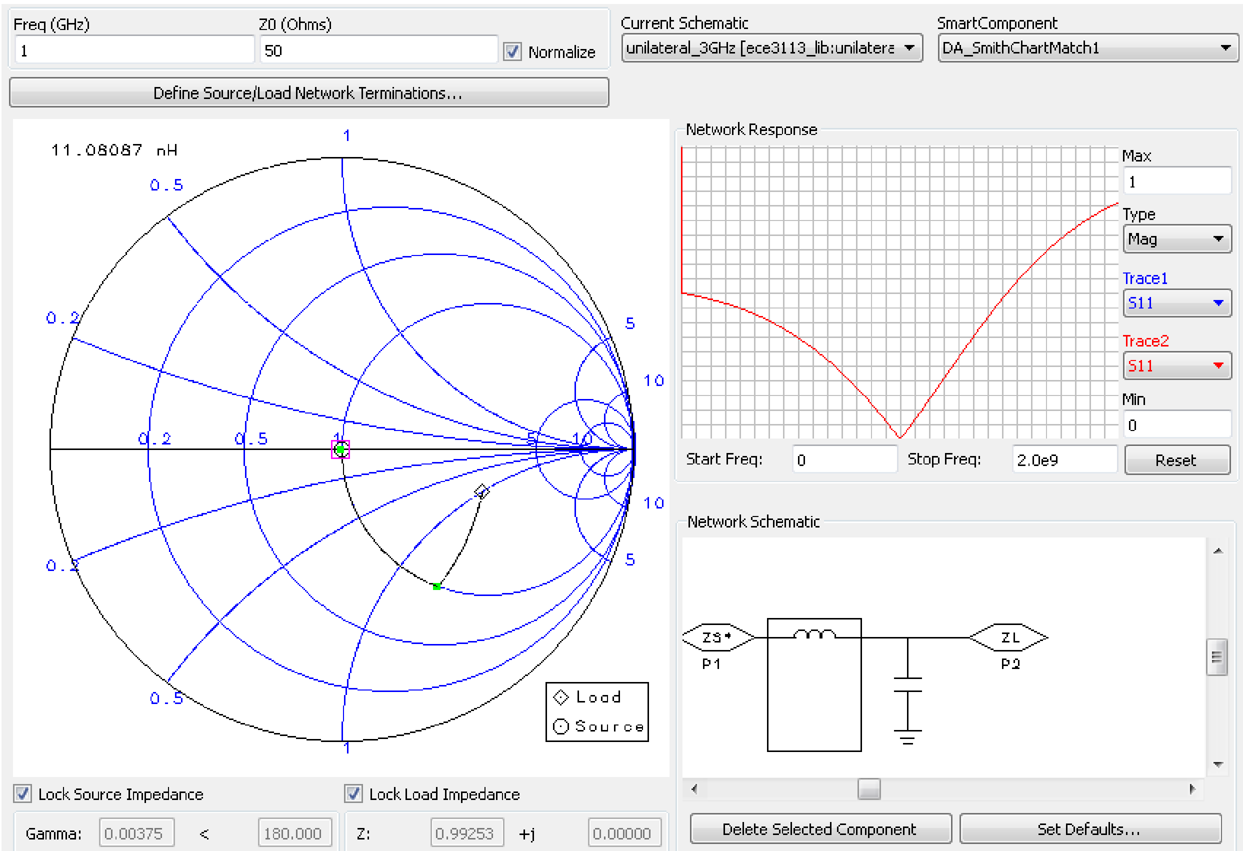
We next can use the approach discussed in class. Alternatively, you can use the Smith Chart matching network from the ADS tool palettes . Specifically, you need to choose the lumped elements to match Γ_{in} and Γ_{out} to the origin, or 50 Ω matching point.



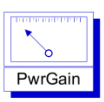
For the input matching network you see the following transformation:



For the output matching network you have to go through the transformation shown below:



The power gain at 1 GHz in ADS is predicted to be 13.151dB.

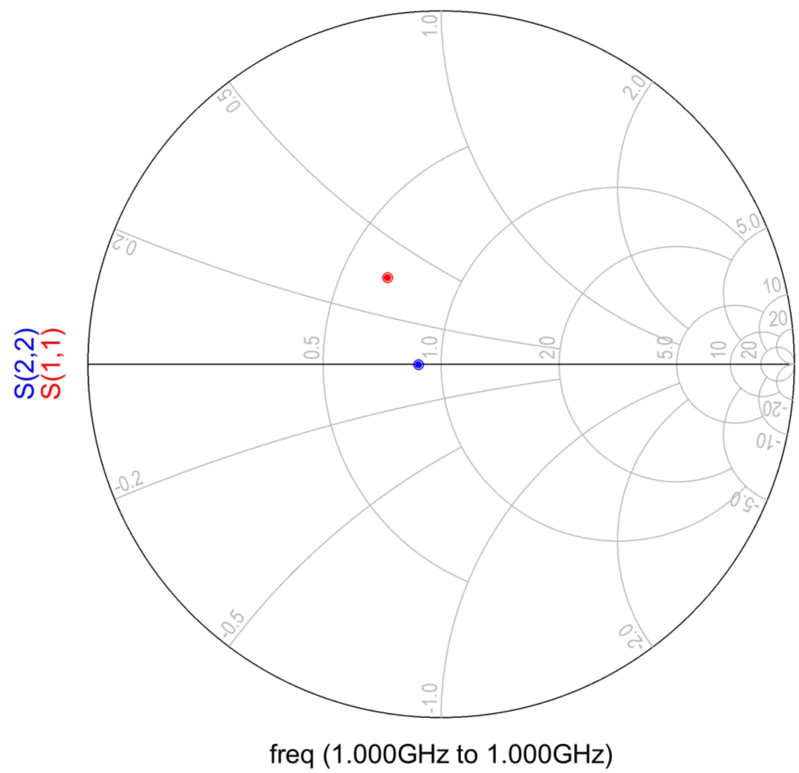


PwrGain
PwrGain1
PwrGain1=pwr_gain(S,PortZ1,PortZ2)

freq	PwrGain1
1.000 GHz	13.151

The simulated value of 13.15 dB has to be compared to the theoretical value for the unilateral gain of 14.3 dB.

The discrepancy between the maximum unilateral gain and the simulation can be explained by taking a look at S_{11} and S_{22} in the Smith Chart. Ideally, both values should be at the center. However, due to feedback we observe a slight mismatch:



The departure from the matching point is due to the fact that the S_{12} is not exactly zero.