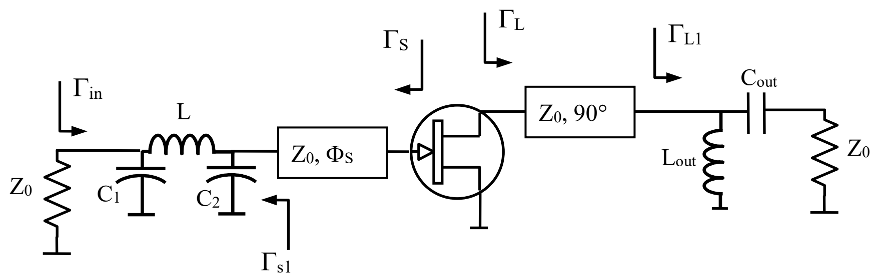
RF SYSTEMS – End Term test
22th January 2020

Surname & Name
Identification Number
Signature

Exercise 1

The following scheme shows a an amplifier operating at 6.5 GHz (Z_0=50 Ohm)



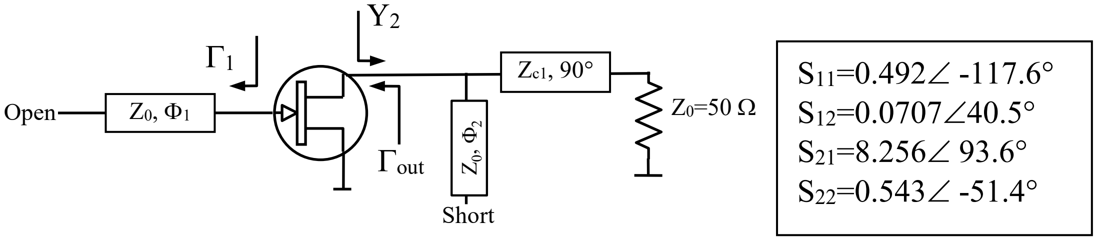
The transistors are characterized by the following parameters (Z_0=50 Ω):
$S_{11}=0.814\angle -144.78°$, $S_{12}=0.075\angle -15.38°$ $S_{21}=2.612\angle 45.62°$ $S_{22}=0.55\angle -108.91°$
NF_{min}=1 dB, $\Gamma_{min}=0.8\angle 122$, r_n=0.26
Note that the transistor is potentially instable with MSG=15.4 dB

The input network is constituted by an assigned PI circuit (C_1=0.6 pF, L=3.82 nH, C_2=0.182 pF), followed by a transmission line with electrical length Φ_S and characteristic impedance Z_0. Note that Γ_{s1} and Γ_s differ only by the phase value.

1) The Power Gain (G_P) of the amplifier is required to be 15 dB. Chose a real value of Γ_L in order this requirement is satisfied
2) Evaluate Γ_S in order to get the Transducer Gain (G_T) equal to G_P.
3) Evaluate Γ_{s1} from the assigned PI network with the electronic Smith Chart. Verify that $|\Gamma_S|=|\Gamma_{s1}|$
4) Compute the electrical length Φ_S to get the required Γ_S.
5) Design the transforming network at output. Note that L network transforms 50Ω into Γ_{L1}, which can be evaluated from Γ_L being the electrical length of the output line assigned (Φ =90°). Note: the computed values of the lumped components in the network must be positive!
6) Evaluate the noise figure and the input reflection coefficient Γ_{in} of the amplifier

Exercise 2

The following scheme refers to an oscillator working at f_{osc}=2 GHz. The S parameters of the transistor are also reported on the figure (defined with respect to Z_0=50 Ω).



1) Find the value of Γ_1 (realizable with the assigned network) that determines the maximum of $|\Gamma_{out}|$. Hint: draw various mapping circles of Γs with increasing value of $|\Gamma_{out}|$ until the mapping circle does not intersect the unit circle.
2) Evaluate the electrical length Φ_1 of the input stub.
3) From Γ_{out} evaluate the admittance Y_2 and compute the parameters Φ_2 and Z_{c1} of the output network. Hint: the 90° line transforms the load impedance into a pure resistance; the short-circuited stub add a pure susceptance in parallel to the transformed resistance.
4) Assuming about constant the S parameters, verify if the oscillation is still possible at 2.35 GHz

Solutions

Exercise 1

1) Draw the circle G_P=15 dB and select the intersection with the real axis. $\Gamma_L=0.389\angle 180°$.
2) To get $G_T=G_P$ we must impose the input matched. Then $\Gamma_S = \Gamma_{in}^*=0.893\angle 144.13°$.
3) First we must evaluate the normalized susceptance and reactance of the circuit elements:
   $b_1 = \frac{2\pi f_0 C_1}{Y_0} = 1.225, \quad b_2 = \frac{2\pi f_0 C_2}{Y_0} = .3717, \quad x = \frac{2\pi f_0 L}{Z_0} = 3.12$
   We enter the current point in the S.C. as the admittance with g=1 and b=b1. Then we give the following increments: reactance=3.12, susceptance=.3717. We get $\Gamma_{s1}=0.893\angle 0$. Actually $|\Gamma_S|=|\Gamma_{s1}|$.
4) Store Γ_s. Enter Γ_{s1}. The phase of Delta Gamma divided by 2 is the length $\Phi_S=107.94°$
5) First evaluate Γ_{L1} by increasing of 180° the phase of Γ_L. $\Gamma_{L1}=0.389\angle 0°$. Then evaluate b_{out} and x_{out} with the S.C. Note that both of them must be negative to be implemented with the imposed components. We get: b_{out} =-0.496, x_{out} =-1.129. Then we derive the lumped components:
   $$L_{out} = -\frac{1}{2\pi f_0 \cdot b_{out} \cdot Y_0} = 2.47 \text{ nH}, \; C_{out} = -\frac{1}{2\pi f_0 \cdot X_{out} \cdot 50} = 0.434 \text{ pF}$$
6) To get the noise figure we enter Γ_S in the S.C. and ask for the optimum Γ_L. We get NF=3 dB. The input reflection coefficient is zero because we imposed the input matched (and the input network is lossless).

Exercise 2

1) Following the suggestion we get $|\Gamma_1|=1\angle 129.1$ with $|\Gamma_{out}|=1.58$.
2) Store Γ_1. Enter the open circuit ($\Gamma=1$). The increment of Delta Gamma Phase divided by 2 is $\Phi_1=115.44°$.
3) With the computed Γ_1 we get $Y_{out}=-0.348+j0.705$. Then $Y_L=0.115-j0.705$. The short-circuited stub must produce b=-0.705 → x=1.4184 → Φ_2=atan(x)=54.82°. The 90° line must transform 50 Ohm into 1/(0.02·0.115)=434.78 Ohm. We get $Z_{c1} = \sqrt{50 \cdot 434.78} = 147.44\ \Omega$.
4) At f=2.35 GHz the electrical length of the input line becomes: $\Phi_1' = \Phi_1 \frac{f}{f_0} = 135.64°$. Then $\Gamma_1=1\angle 88.72°$. Entering this value in the S.C. we get $|\Gamma_{out}|=0.93$ then oscillation is not possible.