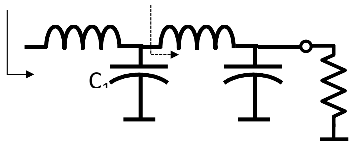
RF SYSTEMS – 2nd part
30 January 2018

Surname & Name	
Identification Number	
Signature	

Exercise 1

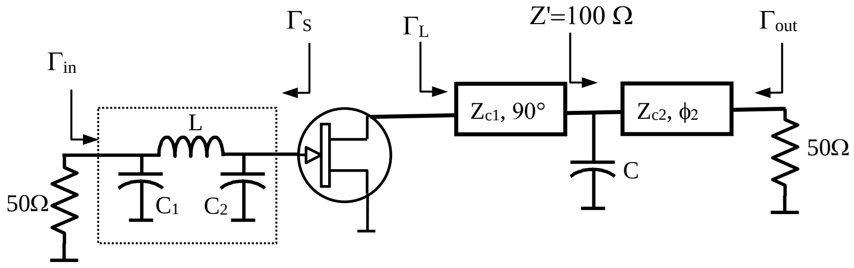
A matching network transforming 150Ω into 75Ω at 1GHz must be designed. The following scheme must be used (it is constituted by two cascaded L-shaped networks with lumped components, where the intermediate impedance is set to 100Ω).



1) Evaluate L1, L2, C1 and C2
2) Propose an alternate solution giving the same impedances (100 Ω and 75Ω), using only two distributed components

Exercise 2

The following scheme shows a single stage power amplifier operating at 3 GHz.



The S parameters of the transistors are given as following:

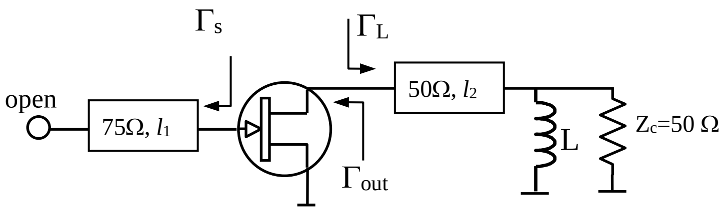
$S_{11}=0.83\angle 149°$, $S_{12}=0.076\angle 48°$, $S_{21}=0.9\angle 9.3°$, $S_{22}=0.62\angle 164.7°$

The transistor is pre-matched at input with a lumped network having the following components value: $C_1=0.877$ pF, $C_2=3.92$ pF, L=1.31 nH.

1) Evaluate Γ_S and the corresponding value of Γ_L that determines the maximum transducer gain G_T
2) Compute the value of G_T
3) Design the output network imposing the intermediate impedance Z' real (100 Ω) and assigning $Zc_2=100\ \Omega$ (evaluate the parameters ϕ_2, C and Zc_1). Note that the first line is an impedance inverter (approximate (Γ_L to a real number)
4) Evaluate the magnitude of the reflection coefficient at output (Γ_{out}) of the amplifier
5) The above scattering parameters are measured at the operating power delivered to the load (P_L). The transistor has $P_{1dB}=33$ dBm and $\Delta p=9$ dB. Knowing that the transistor is operating with 3 dB backoff, evaluate the mean power P_L delivered to load and the Carrier-to-Intermodulation CI (2-tone signal).

Exercise 3

The following scheme refers to an oscillator working at unknown frequency. The S parameters of the transistor are also reported on the figure.



S_{11}=0.847∠ -90°
S_{12}=0.158∠32.88°
S_{21}=4.855∠ 117.8°
S_{22}=0.956∠ -49.5°

The input line (Zc=75Ω, length l_1, relative dielectric constant ε_r=2.2) is open circuited. It is known that l_1=12.64 mm and Γ_s=-1.

1) Compute the oscillation frequency (hint: is the frequency determining Γs =-1). Verify that the condition $|\Gamma_{out}|>1$ is satisfied.
2) Assign a suitable value for Γ_L and verify that all the conditions for starting the oscillation are fulfilled
3) Design the output network, i.e. compute the values of l_2 and L (assume ε_r=2.2)

Solutions

Ex 1

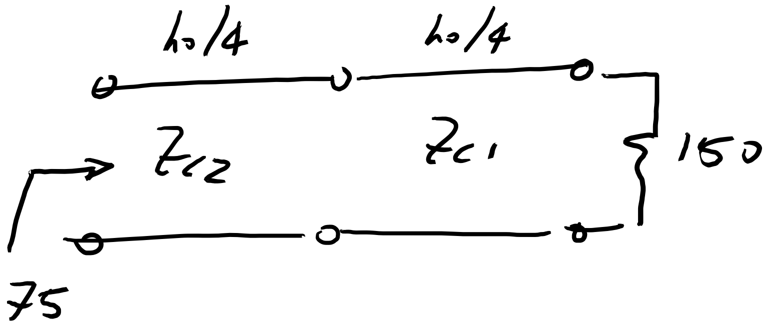
$$B_1 = \sqrt{\frac{1}{100}\left(\frac{1}{75} - \frac{1}{100}\right)} = \frac{1}{173.2} \Rightarrow C_1 = \frac{B_1}{2\pi f_0} = 0.92\,pF$$

$$X_1 = 75 \cdot 100 \sqrt{\frac{1}{100}\left(\frac{1}{75} - \frac{1}{100}\right)} = 43.3 \Rightarrow L_1 = \frac{X_1}{2\pi f_0} = 6.9\,nH$$

$$B_2 = \sqrt{\left(\frac{1}{100} - \frac{1}{150}\right)\frac{1}{150}} = \frac{1}{212.13} \Rightarrow C_2 = \frac{B_2}{2\pi f_0} = 0.75\,pF$$

$$X_2 = 150 \cdot 100 \sqrt{\frac{1}{150}\left(\frac{1}{100} - \frac{1}{150}\right)} = 70.7 \Rightarrow L_2 = \frac{X_2}{2\pi f_0} = 11.25\,nH$$

with distributed components:



$$Z_{c1} = \sqrt{150 \cdot 100} = 122.5\,\Omega$$

$$Z_{c2} = \sqrt{100 \cdot 75} = 86.6\,\Omega$$

Ex 2

1) Using the S.C. we get $\Gamma_S = 0.82 \angle -154.4^\circ$

2) $(G_T)_{MAX}$ is obtained by imposing the conjugate match at the trans. output. The optimum Γ_L is obtained with the S.C.: $\Gamma_L = 0.653 \angle -179.9^\circ$

$G_T = 6.25\ dB$

3) Z_{C1} is obtained by imposing the transformation of 100Ω into the real impedance $R_L = \frac{(1+\Gamma_L)}{1-\Gamma_L} 50 =$

$= 10.5\ \Omega \Rightarrow Z_{C1} = \sqrt{100 \cdot R_L} = 32.1\ \Omega$

The remaining part of the network is a classical single stub matching network (all components normalized to 100Ω, $\Gamma' = 0$).

With the S.C. we get: $\phi_2 = 35.2^\circ$; $b = 0.7$

$\Rightarrow C = \frac{b \cdot 0.01}{2\pi f} = 0.37\ pF$

4) The output is matched, then $\Gamma_{out} = 0$

5) $P_{in} = P_{1dB} - B.O. = 30\ dBm$

$BO = \frac{CI}{2} - \Delta p - 3 \Rightarrow CI = 30\ dB$

Ex 3

1) To get $\Gamma_s = -1$ the line length must be $\frac{\lambda_0}{4}$ then: $l_1 = \frac{\lambda_0}{4} = \frac{c}{4\pi f_0 \sqrt{\varepsilon_r}}$

we get $f_0 = 4\ GHz$

2) We compute Γ_{out} with the S.C. imposing $\Gamma_s = -1$: $\Gamma_{out} = 1.34\angle -27.7°$

Then $z_{out} = -1.95 - j2.9$ from which:

$z_L = +0.65 + j2.9$ $(\Gamma_L = 0.88\angle 36°)$

for this value of Γ_L we get $|\Gamma_{in}| = 2.1$

oscillation ok!

3) Using the S.C. we get:

$\Phi_2 = 57.2° = \beta l_2 \Rightarrow l_2 = \frac{57.2 \cdot c}{360 \cdot f_0 \sqrt{\varepsilon_r}} = 8.03$ mm

$b_L = -3.6 \Rightarrow \frac{1}{\omega_0 L} = 3.6 \cdot 0.02 \Rightarrow$

$\Rightarrow L = 0.55\ nH$