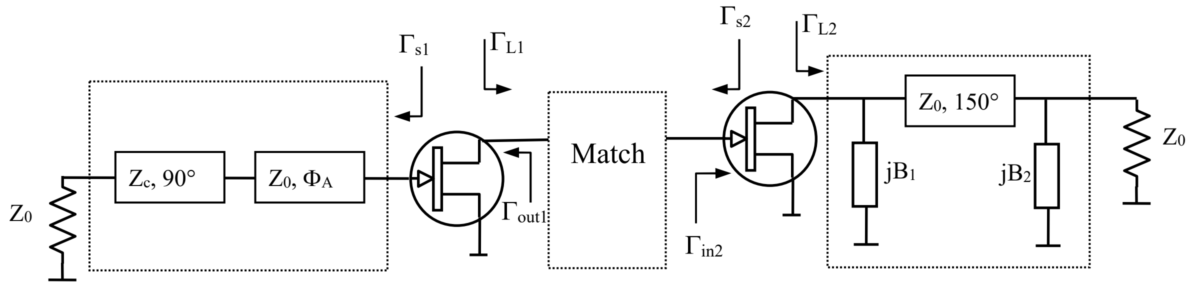
RF SYSTEMS – 2nd Midterm test
1th February 2017

Surname & Name	
Identification Number	
Signature	

Exercise 1

The following scheme shows a 2 stage low noise amplifier operating at 12 GHz



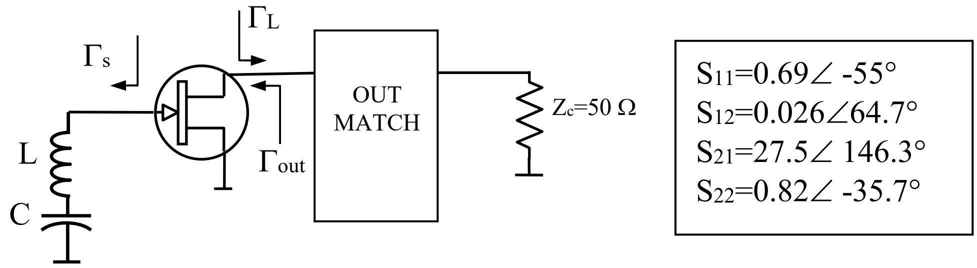
The transistors are equal and are characterized by the following parameters (Z_0=50 Ω):
$S_{11}=0.569\angle 78.2°$, $S_{12}=0.1\angle -58.5°$ $S_{21}=3.226\angle -52.1°$ $S_{22}=0.132\angle 120.7°$
$NF_{min}=0.51$ dB $\Gamma_{min}=0.358\angle -137.2$ $r_n=0.12$

The first stage must be designed for NF=0.8 dB while the second stage must be designed for the maximum transducer gain (compatibly with stability). It is also requested that the inter-stage network ("Match") operates in conjugate matching both at input and output ($\Gamma_{L1}=\Gamma^*_{out1}$, $\Gamma_{s2}=\Gamma^*_{in2}$).

1) Evaluate Γ_{s1}, Γ_{L1}, Γ_{s2}, Γ_{L2} in order to fit the requirements
2) Compute the available gain of the two stages and the noise figure of the second stage
3) Compute the overall transducer gain and the overall noise figure of the amplifier (Hint: the overall available gain is the sum (in dB) of the available gain of the stages, then being the output matched…)
4) Design the input and output transforming networks. The parameters of the first are Z_c and Φ_A; the unknowns of the second are B_1 and B_2.

Exercise 2

The following scheme refers to an oscillator working at f_{osc}=425 MHz. The S parameters of the transistor are also reported on the figure.



The resonant circuit resonates at f_{res}=400 MHz, where it can be replaced with a short circuit.

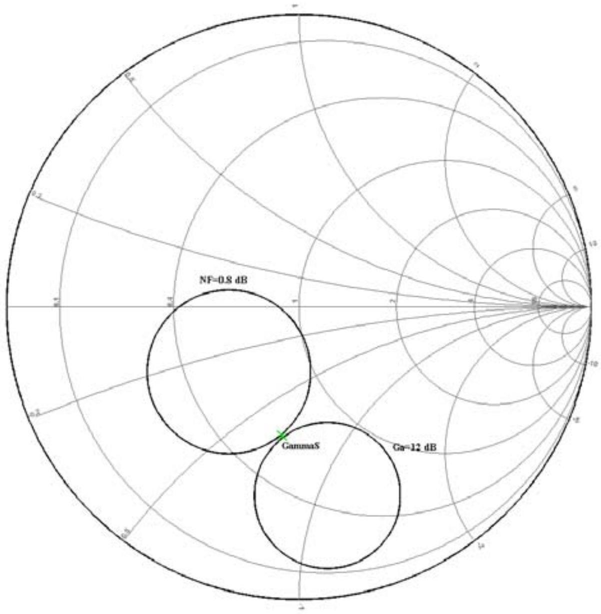
1) Imposing $|\Gamma_{out}|$=1.3 compute the values of Γ_S and Γ_L determining the start of oscillation
2) Verify that for Z_s=0 (short circuit) the start of oscillation is not possible. This happens at the resonance frequency f_{res} of the resonator.
3) Evaluate the values of L and C determining the requested value of Γ_S at f_{osc}=425 MHz and the resonance at f_{res}=400 MHz (Hint: the reactance of the series resonator is given by $X_s=\omega L-1/\omega C$ with $\omega=2\pi f$. The resonance frequency is given by $f_{res}=\frac{1}{2\pi\sqrt{LC}}$
4) Chose a topology and design the output network

<u>Solution</u>

<u>Exercise 1</u>

Inserting the S parameters in the e-Smith Chart we discover that the transistors are unconditionally stable with G_{Tmax}=12.788, $\Gamma_{S,opt}$=0.74∠-81.4, $\Gamma_{L,opt}$=0.51∠-155.2.

1) The first stage must be however designed for NF_1=0.8, so we draw the circle with this NF value on the S. C. Then, in order to find the value of Γ_{s1} determining the maximum available gain compatible with the assigned NF, we draw some circles with Ga=cost (< G_{Tmax}) and look for the one about tangent to the NF circle:



We found Ga1=11.96 dB. The tangent point gives Γ_{s1}=0.44∠-97.9°. In order to get Ga=GT we impose conjugate matching at the output of transistor 1 and we get (from the S.C.):
$\Gamma_{L1}=(\Gamma_{out1})^*$=0.311∠-135°. The second stage operates for the maximum transducer gain so it has $\Gamma_{s2}=\Gamma_{S,opt}$, $\Gamma_{L2}=\Gamma_{L,opt}$.

2) The overall Ga is the sum (in dB) of the Ga of the two stages (the second is equal to G_{Tmax}), so Ga=Ga1+G_{Tmax}=24.74 dB. The noise figure of the second stage is obtained by assigning the current point on the S.C. equal to $\Gamma_{s2}=\Gamma_{S,opt}$ and asking for the optimum gamma load. We get NF_2=2.53 dB.

3) The overall transducer gain coincides with the overall Ga because the output of the second transistor is matched: GT=Ga=24.74 dB. The overall noise figure is given by the following formula:

$$\left(NF\right)_{TOT}=NF_1+\frac{NF_2-1}{G_{a1}}=10^{0.08}+\frac{10^{0.253}-1}{10^{1.2}}=1.252\rightarrow 0.98\text{ dB}$$

4) First network: we move on the circle with $|\Gamma|=|\Gamma_{s1}|$ toward the load up to the intersection with the real axis → Φ_A=48.9°.The impedance seen in this point is Z=2.571·50=128.55 Ω. The characteristic impedance Zc of the landa/4 transformer is the given by Zc=sqrt(128.55*50)=80.17 Ω.

Second network: draw the circle g=1 rotated by 300° toward the source. Set the current point to Γ_{L2} and store in memory. Draw the circle g=cost passing for Γ_{L2} and select one intersection between the two circles (Γ=0.385∠172.69°). The value of imaginary part of DeltaY with the sign reversed gives b1=1.537. Give an increment to the current point Γ by 300°; the new current point has y=1+jb2 → b2=-0.834.

Exercise 2

Inserting the scattering parameter into the S.C. we discover the device potentially instable and the suitable for an oscillator.

1) Draw the mapping circle for $|\Gamma out|=1.3$ and select one of the intersection with the unit circle: $\Gamma s=1\angle 132.31°$. The corresponding reactance results $Xs=0.442\cdot 50=22.1\ \Omega$. Evaluate $\Gamma out=1.3\angle -10.4$ → $Zout=-5.21-j3.53$. The assign $Z_L=1.7+j3.52$. Using the S.C. we enter this value as current point and compute $|\Gamma in|=1.79$, so the oscillation start up is guaranteed.

2) Assigning $\Gamma_s=-1$ (short circuit) as current point we compute $|\Gamma out|=0.957$ so the oscillation cannot start.

3) We have at fosc=425 MHz: $X_s = \omega_{osc}L - \frac{1}{\omega_{osc}C} = \omega_{osc}L - \frac{\omega_{res}^2 L}{\omega_{osc}} = 22.1$. Replacing $\omega_{osc}=2\pi\cdot 425$ MHz and $\omega_{res}=2\pi\cdot 400$ MHz we get L=72.48 nH. Then $C = \frac{1}{\omega_{res}^2 L} = 2.18\ \text{pF}$.

4) Using a single stub network: $\Phi=58.75°$, $b=-2.73$.