Homework 5

Wednesday, December 2, 2020 9:50 AM

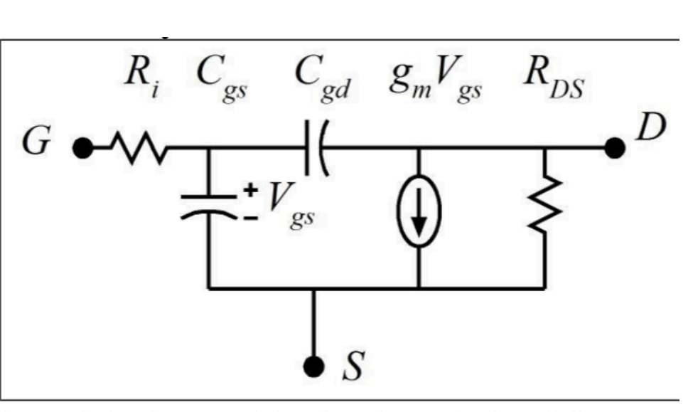
Problem 1:

$g_m = 3mS/\mu m \cdot W_g \quad R_i = 1.5/g_m$

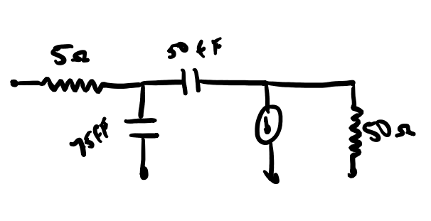
$C_{gd} = 0.5fF/\mu m \cdot W_g$

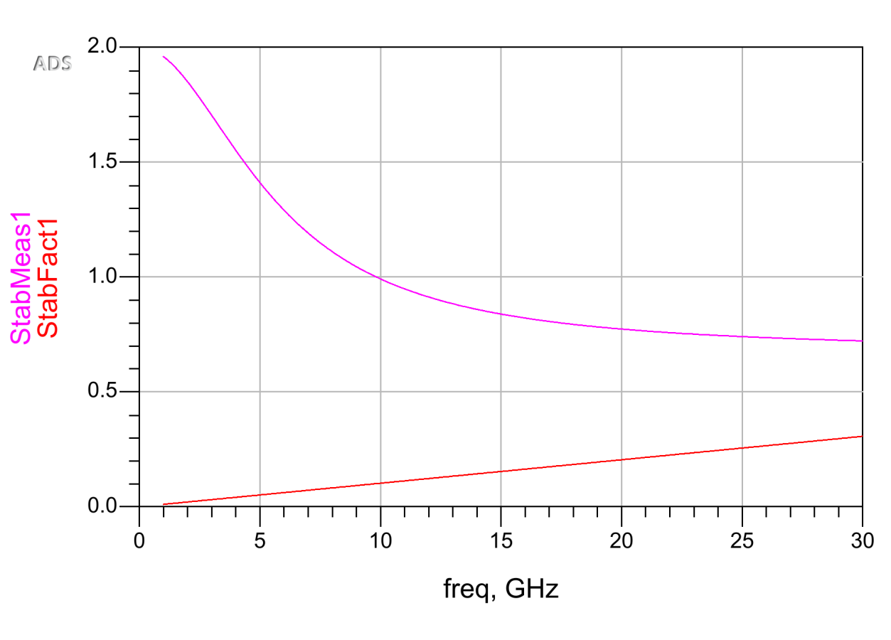
$C_{gs} = 0.75fF/\mu m \cdot W_g$

$G_{ds} = 0.2mS/\mu m \cdot W_g$

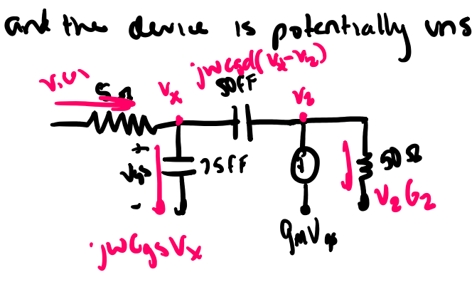


part a) Taking W_g=100 microns for the bilateral device model, Plot the MAG/MSG stability factor K and B1 for the device of problem 1 vs frequency. At what frequencies is the device unconditionally stable ? At a design frequency of 10GHz, what is the maximum stable gain ? Calculate this by hand (!) and then compare to the ADS simulation.





The device is unconditionally stable from 0- ~9.8GHz, since K>1 and B1>0 in this range. After this, K<1 and the device is potentially unstable



$V_x = \frac{1/j\omega C_{gs}}{R_i + 1/j\omega C_{gs}} = \frac{1}{R_i j\omega C_{gs}+1} = \frac{1/R_i}{j\omega C_{gs}+1/R_i} = \frac{G_i}{j\omega C_{gs}+G_i}$

$Y_{21} = g_m + j\omega C_{gd}\left(\frac{G_i}{j\omega C_{gs}+G_i}\right)$

$= g_m + \left(\frac{j\omega C_{gd} G_i}{j\omega C_{gs}+G_i}\right)$

$= g_m(j\omega C_{gs}+G_i)+j\omega C_{gd}G_i$

$0.3(7.5\times10^{-4}j+0.2)+1\times10^{-4}j$

$(2.25\times10^{-4}j+0.06)+1\times10^{-4}j$

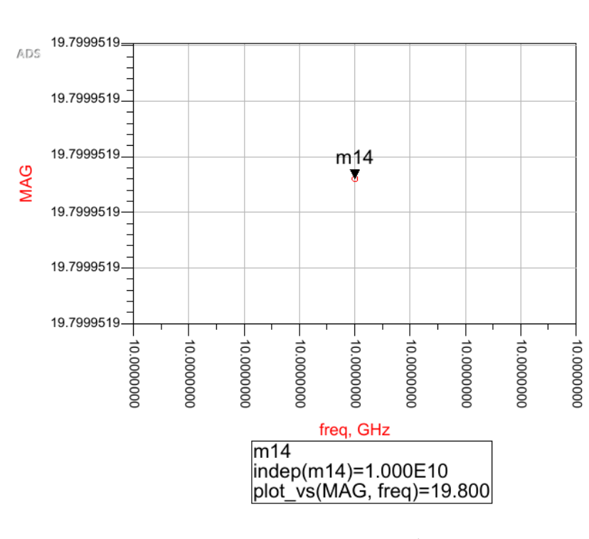
$Y_{21} = 3.25\times10^{-4}j+0.06$

$\boxed{||Y_{21}|| = 0.06}$

$Y_{12} = -j\omega C_{gd} = 0.00314159j$

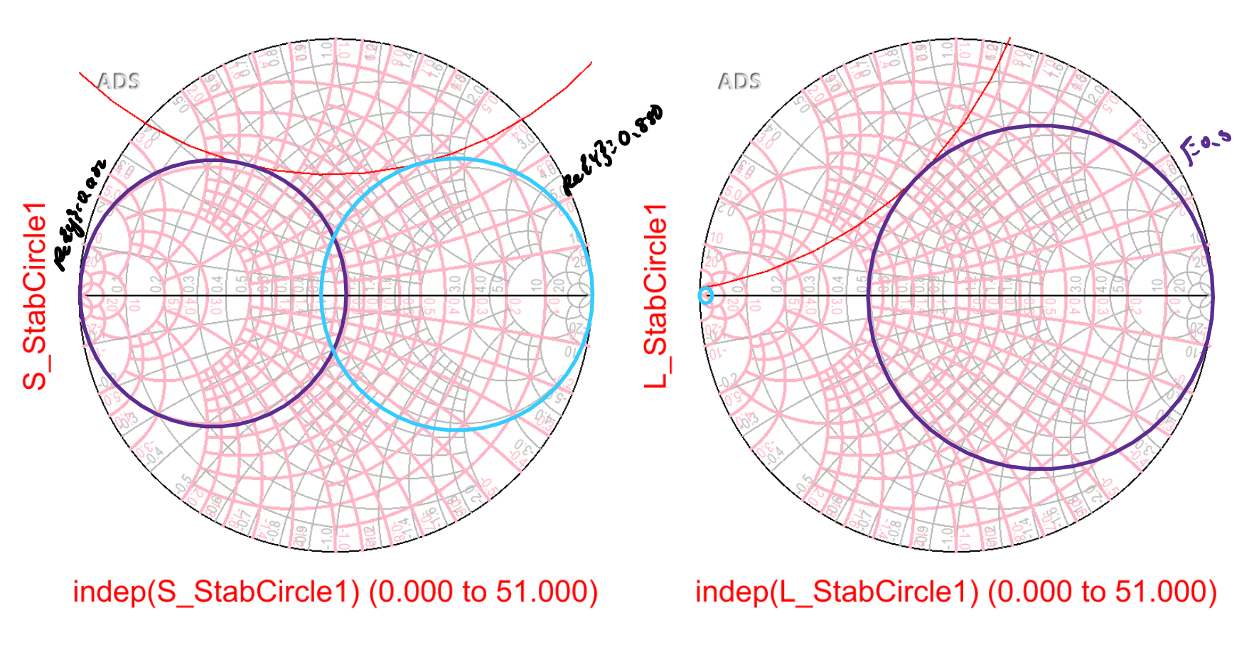
$||Y_{12}|| = 0.00314159$

$MSG = \frac{||Y_{21}||}{||Y_{12}||} = \frac{0.06}{0.00314159} = \boxed{19.0986}$



m14
indep(m14)=1.000E10
plot_vs(MAG, freq)=19.800

MSG calculation is a bit lower than true MSG of the system at 10GHz.



Since $||S_{11}||, ||S_{22}|| < 1$ want to constrain Smith chart to values outside of $||\Gamma|| = 1$ curve

For source:

Series resistor:
$50(0.880)$
$\boxed{= 44\Omega}$

Shunt resistor
$G = \frac{1}{50}(0.902)$
$= 0.1804$
$\boxed{R = 55.43}$

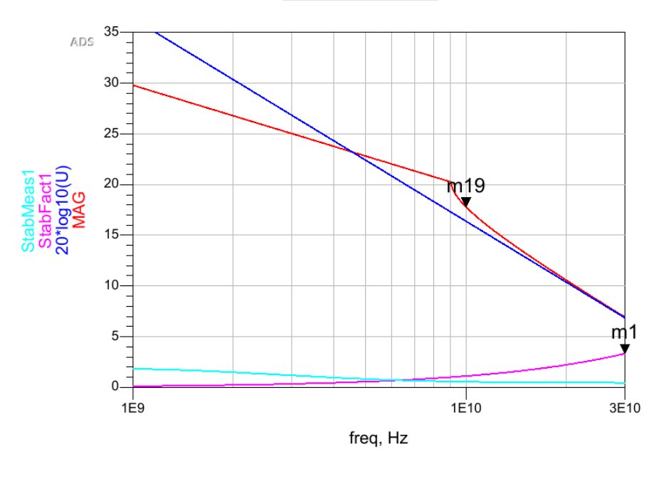
For Load:

Series resistor:
$R = 50(0.5)$
$\boxed{=25}$

Shunt resistor:
$G = \frac{1}{50}(30.425)$
$= 0.6085$
$\boxed{R = 1.64\Omega}$

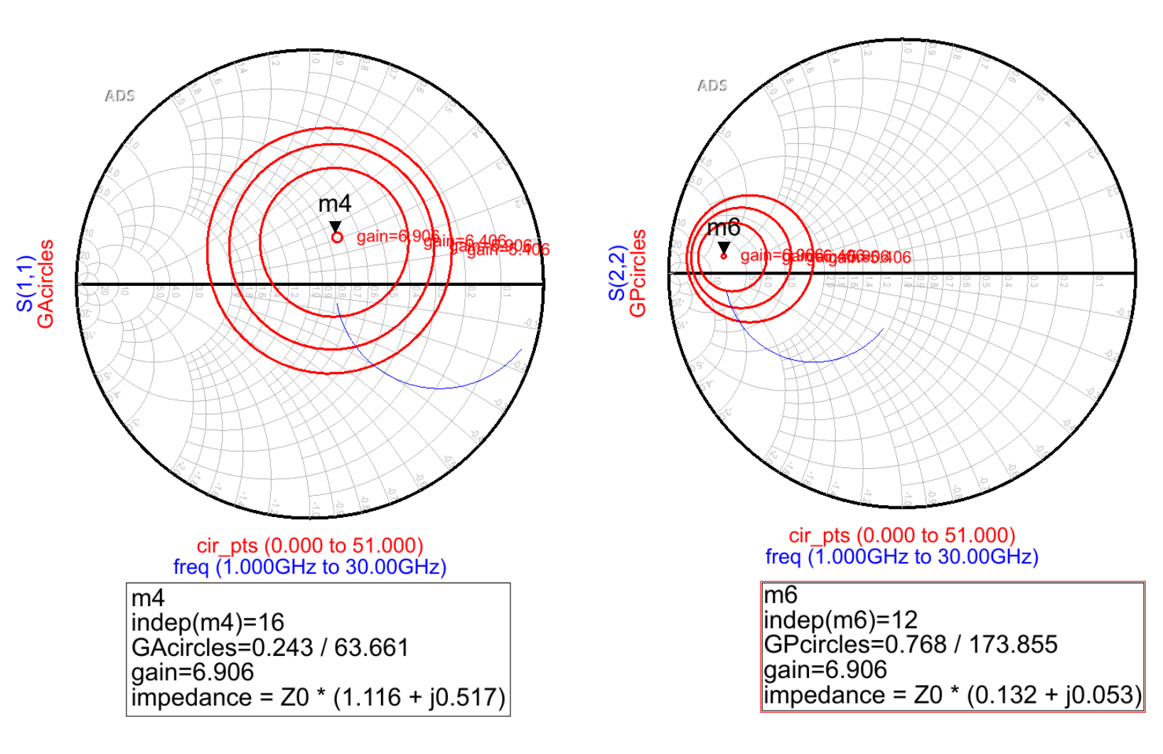
m19
freq=10.00GHz
MAG=17.800

m1
freq=30.00GHz
StabFact1=3.322



Since MSG^T was 19.8 dB, over stabilize for 17.8dB.

This required a resistor value of 54.89 ohms



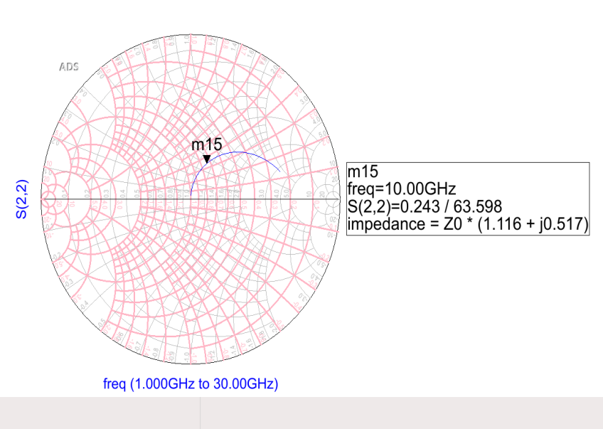
m4
indep(m4)=16
GAcircles=0.243 / 63.661
gain=6.906
impedance = Z0 * (1.116 + j0.517)

m6
indep(m6)=12
GPcircles=0.768 / 173.855
gain=6.906
impedance = Z0 * (0.132 + j0.053)

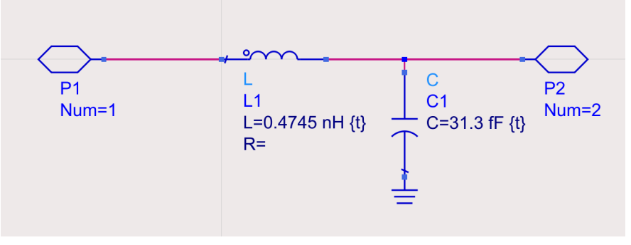
$G_A \propto \Gamma_{in}$

Use LC lumped element network on input to move:
$Z_0(1.116+j0.517) \rightarrow Z_0(1+0j)$

Match S22 of input network to $Z_0(1.116+j0.517)$



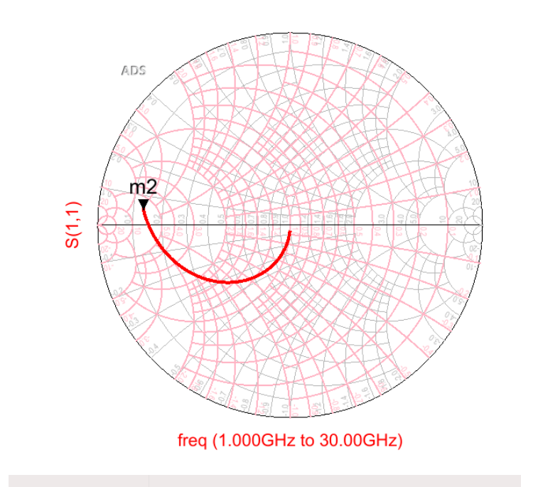
m15
freq=10.00GHz
S(2,2)=0.243 / 63.598
impedance = Z0 * (1.116 + j0.517)

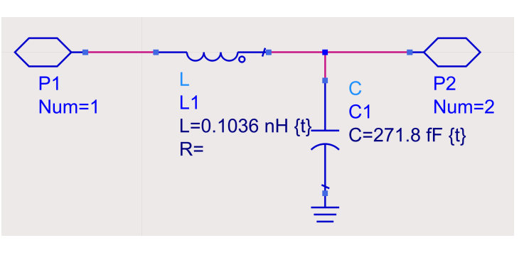


$G_p \propto \Gamma_{out}$

Match S11 of output network to $Z_0(0.132+j0.053)$

m2
freq=30.00GHz
S(1,1)=0.767 / 173.963
impedance = Z0 * (0.132 + j0.052)

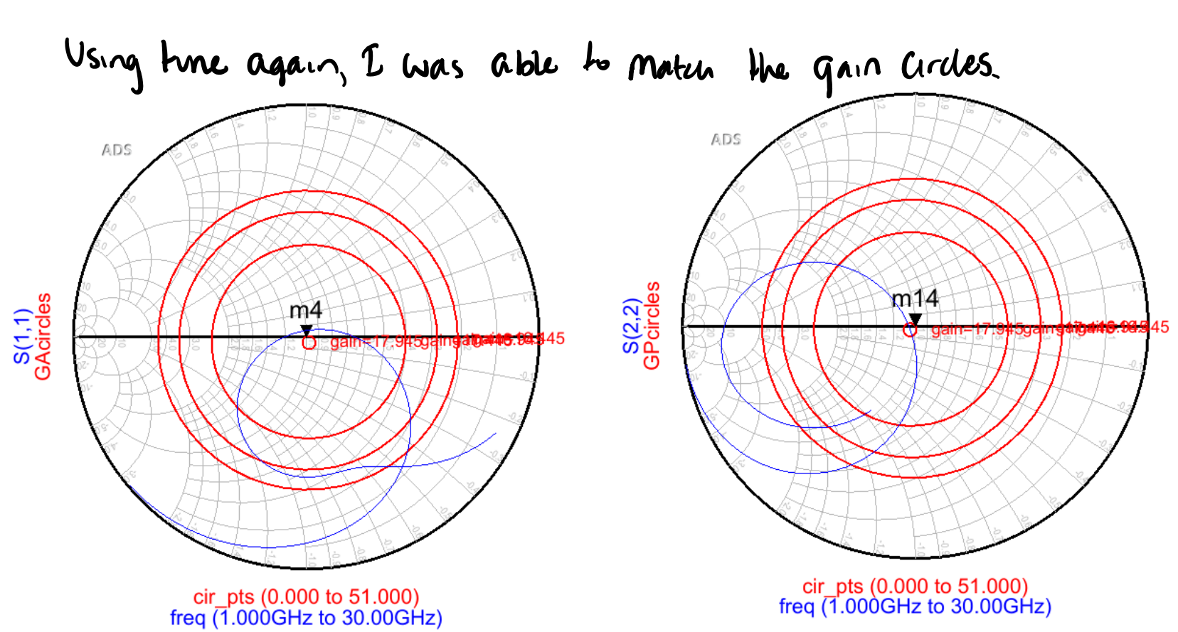




This was incorrectly matched at 30GHz, which was incorrect. I matched again at 10GHz, but this match ended up being inaccurate.

Using these matching circuits, the gain circles did not match once the circuit was put together.

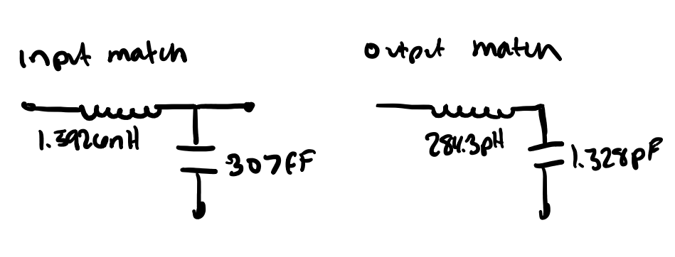
Using tune again, I was able to match the gain circles.

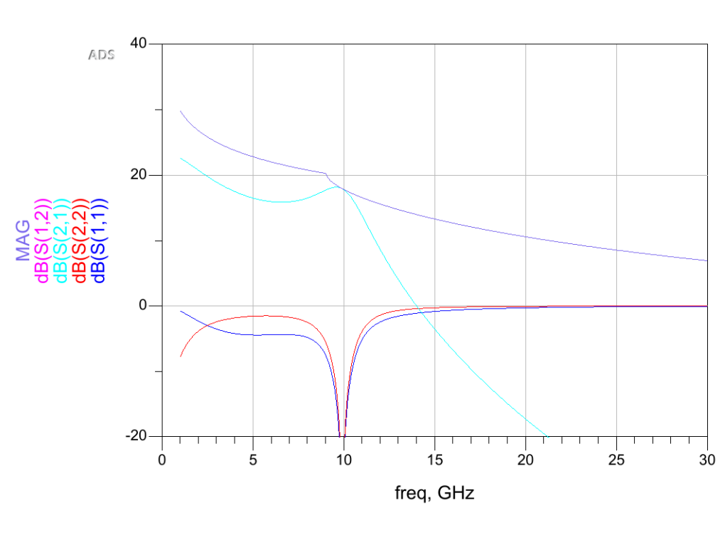


m4
indep(m4)=16
GAcircles=2.282E-4 / -108.792
gain=17.945
impedance = Z0 * (1.000 - j4.320E-4)

m14
indep(m14)=5
GPcircles=3.230E-4 / 87.060
gain=17.945
admittance = Y0 * (1.000 - j6.452E-4)

This match was achieved when

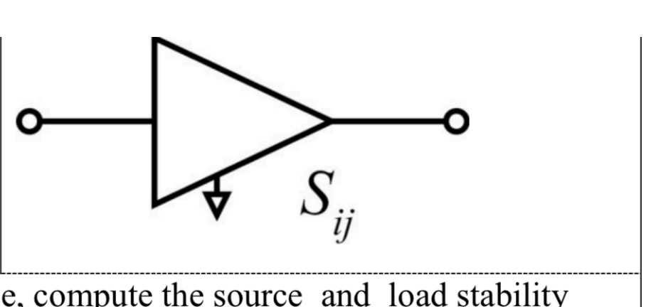




At 10GHz, S_{21} = MSG = 17.773dB, which is very close to the calculated values of Gain after the −2dB overstabilization. S_{11} and S_{22} also have singularities at 10 GHz, indicating a correct input/output match.

Problem 2: An amplifier has the following S parameters

S11=S22=0
S21=2
S12=1



part a) Using a 50 Ohm reference impedance, compute the source and load stability circles, and draw them carefully on separate Smith charts.

part b) Is the device unconditionally stable or potentially unstable ? Note: It is not sufficient to check K alone.

part c) The network can be stabilized by an attenuator, ie a device with S11=S22=0 S21=X=S12. What maximum value of X is allowable for unconditional stability ?

part d) After you have stabilized the device, and then matched input and output, what power gain will you obtain ?

$S = \begin{bmatrix} 0 & 1 \\ 2 & 0 \end{bmatrix}$

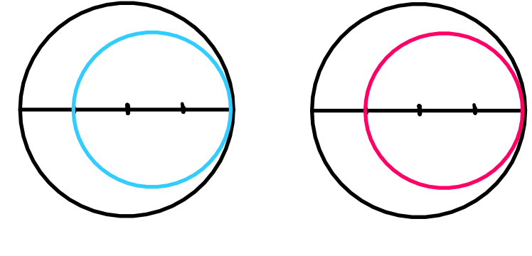
a) $\Gamma_{in} = \frac{S_{21}S_{12}\Gamma_L}{1-\Gamma_L S_{22}}$ $\quad \Gamma_{out} = \frac{S_{21}S_{12}\Gamma_S}{1-\Gamma_S S_{11}}$

$\Gamma_{in} = 2\Gamma_L \quad ||\Gamma_{out}|| = 1$

$||\Gamma_{in}|| = 1 \quad \frac{1}{2} = \Gamma_S$

$1 = 2\Gamma_L$

$\frac{1}{2} = \Gamma_L$



b) $K = \frac{1-0-0+||1-2||^2}{2||1\cdot 2||}$

$= \frac{5}{4}$

$K > 1$

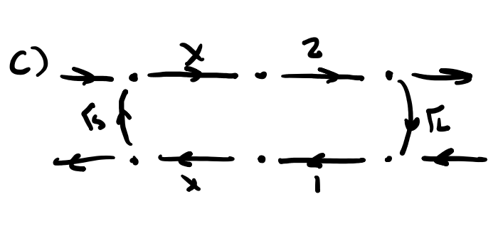
$Det(S) = ||1-2|| < 1$

$2 < 1$

x

The system is potentially unstable because det(S) is not <1

c)



$\tilde{S}_{21} = \frac{2x}{1-2x^2\Gamma_L\Gamma_S} = \frac{2x}{1-\frac{x^2}{2}} = \frac{4x}{2-x^2}$

$\tilde{S}_{12} = \frac{x}{1-2x^2\Gamma_L\Gamma_S} = \frac{2x}{2-x^2}$

$\tilde{S}_{21}\tilde{S}_{12} = \frac{4x}{2-x^2}\cdot\frac{2x}{2-x^2}$

$= \frac{8x^2}{(2-x^2)^2}$

$Det(S) < 1$

$\left|\left|\frac{-8x^2}{(2-x^2)^2}\right|\right| < 1$

$8x^2 < (2-x^2)^2$

$2\sqrt{2}x < 2-x^2$

$x^2+2\sqrt{2}x-2 < 0$

Use positive soln:

X = 0.586 for unconditional stability

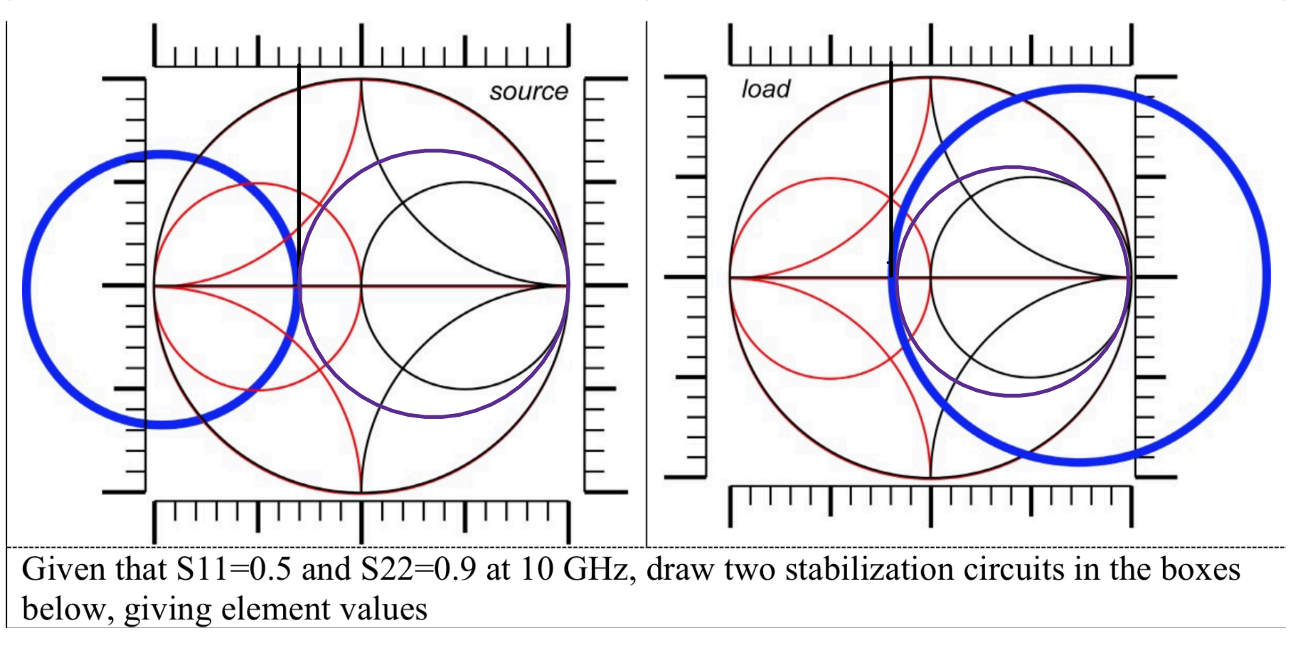
d) After device is stabilized, msg =

$\left|\left|\frac{S_{21}^T}{S_{12}^T}\right|\right|$

$= \left|\left|\frac{2}{1}\right|\right| = \boxed{2}$

Problem 3:

Source stability circle | load stability circle



Given that S11=0.5 and S22=0.9 at 10 GHz, draw two stabilization circuits in the boxes below, giving element values

$S_{11}, S_{22} < 1$, want to stabilize outside of source stability circle, inside load stability circle, both series

Since $\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{11}\Gamma_L}$ if $\Gamma_L = 0$, $\Gamma_{in} = S_{11}$

$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{22}\Gamma_S}$, if $\Gamma_S = 0$, $\Gamma_{out} = S_{22}$

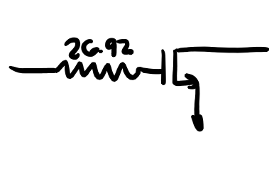
} Since $S_{11}, S_{22} < 1$, Stable in this region

1. Want R to contact circle at $Z = 50(0.7+0j)$. Source stability depends on Γ_{out}

$R_{in,stab} = 50\left(\frac{1+\Gamma}{1-\Gamma}\right)$

$= 50\left(\frac{1-0.3}{1+0.3}\right)$

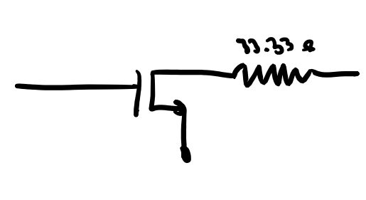
$\boxed{= 26.92\Omega}$



2. Want R to contact circle at $Z = 50(0.8+0j)$

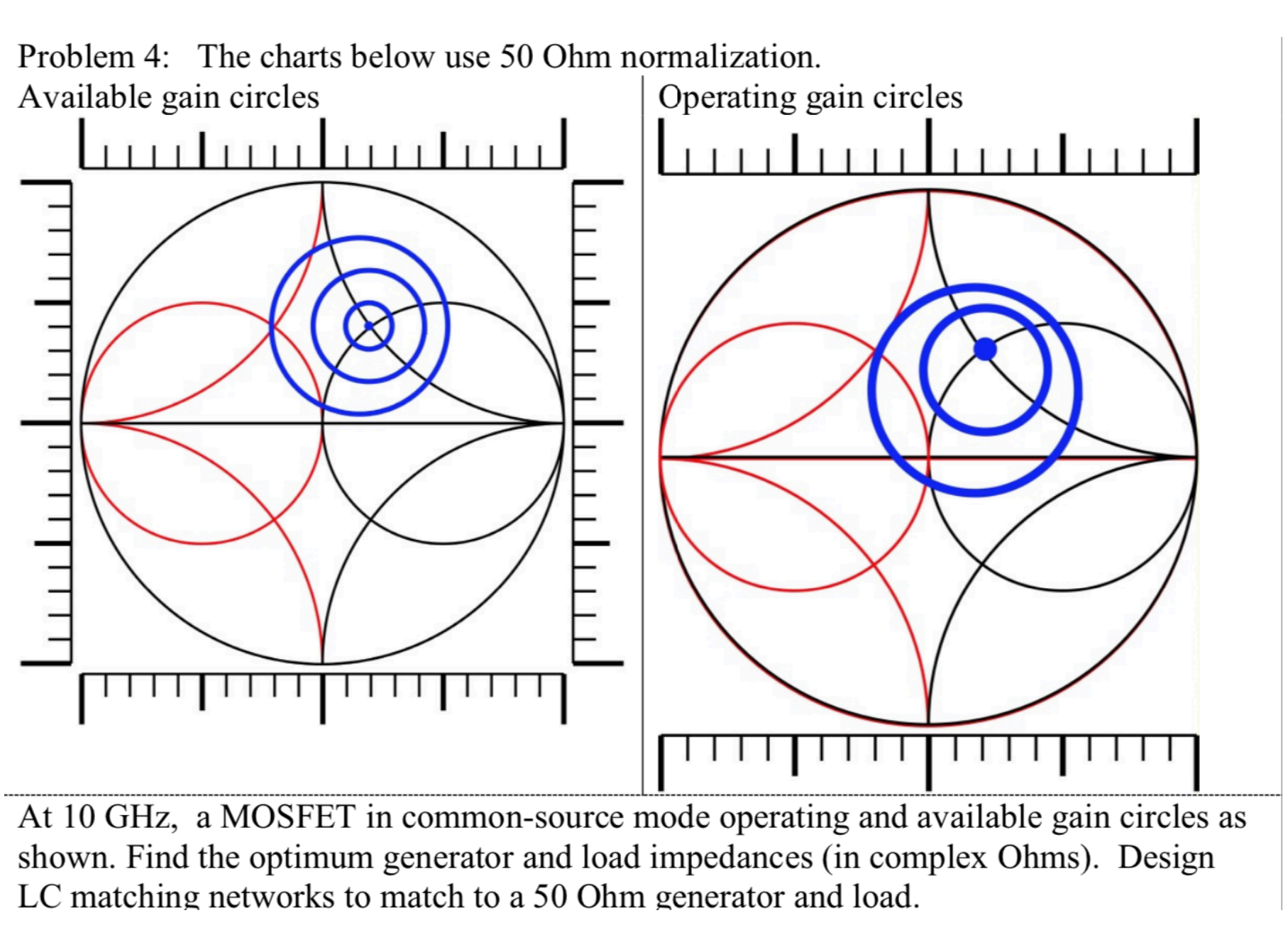
$R_{out,stab} = 50\left(\frac{1-0.2}{1+0.2}\right)$

$\boxed{= 33.33\Omega}$



Problem 4: The charts below use 50 Ohm normalization.

Available gain circles | Operating gain circles



At 10 GHz, a MOSFET in common-source mode operating and available gain circles as shown. Find the optimum generator and load impedances (in complex Ohms). Design LC matching networks to match to a 50 Ohm generator and load.

$G_A \rightarrow$ Source $\qquad G_{op} \rightarrow$ Load

Both at $50(1+j)$

Want to match to $50(1+0j) \rightarrow$ Optimum generator and load impedances are $-50j\Omega$

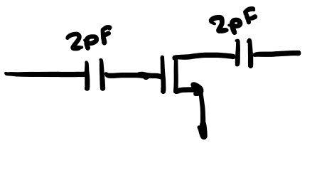
Use series capacitor

$\cancel{-j}/\omega C = \cancel{+}50\cancel{j}$

$1/10^9 \cdot C = 50$

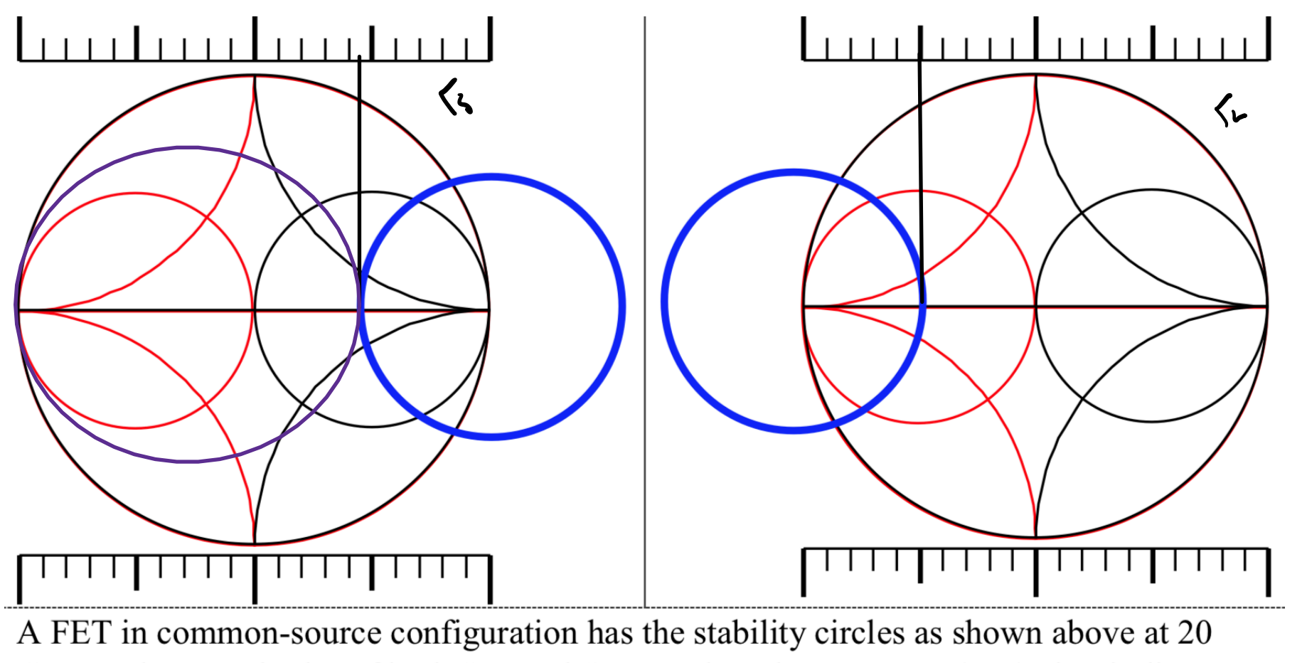
$2\times10^{-12}F = C$

$\boxed{2pF = C}$



Problem 5: The charts below use 50 Ohm normalization.

input stability circle | load stability circle



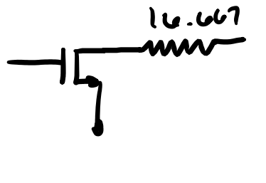
A FET in common-source configuration has the stability circles as shown above at 20 GHz. The magnitudes of both S11 and S22 are less than 1. Draw (two) circuit diagrams of two (different) stabilization methods for the transistor, giving required numerical element values. Use the scales above, along with a straight edge (edge of paper, a calculator, a book..) to aid you.

Γ_L-plane
Output series resistor

$R_{stab} = \left(\frac{1+\Gamma_S}{1-\Gamma_S}\right)Z_0$

$= \left(\frac{1-0.5}{1+0.5}\right)Z_0$

$\boxed{= 16.6667}$



Γ_S-plane
input shunt resistor

$G_{stab} = \frac{1}{Z_0}\left(\frac{1-\Gamma_L}{1+\Gamma_L}\right)$

$= \frac{1}{50}\left(\frac{1-0.45}{1+0.45}\right)$

$G_{stab} = 0.00759$

$\boxed{R_{stab} = 131.81\Omega}$