Specifications

- Design an amplifier which achieves exactly 13 dB gain (use the unilateral transducer gain approach)
- The amplifier has to operate at 1 GHz
- The operating point for the collector current should not exceed 60 mA.

Approach

- Select BJT and pick optimal DC operating conditions
- At 1 GHz (and based on the DC conditions) find the S-parameters
- Determine the maximum power gain (source side, transistor, load side)
- Design the matching networks by assigning to each matching network the appropriate gain
- Investigate the overall design in ADS
DC analysis and S-parameter recording (in ADS)
SELECT RF BJT

Pick a Motorola device with an $f_T$ of 4.5 GHz, $h_{fe} = 90$, 2.5 W.

BJT: MRF 9011L (SOT143) at $V_{ce} = 10V$, $I_c = 50 mA$

Check for stability at 1 GHz

Decide on the recommended operating conditions
S-parameters

freq (990.0 MHz to 1.010 GHz)

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S-parameters

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**Constant gain circles in the Smith Chart**

\[
G_{S_{\text{max}}} = \frac{1}{1 - |S_{11}|^2}
\]

\[
g_S = \frac{G_S}{G_{S_{\text{max}}}} = \frac{1 - |\Gamma_S|^2}{|1 - \Gamma_S S_{11}|^2} (1 - |S_{11}|^2)
\]

(in our case: 1.8676 dB)

\[
G_{L_{\text{max}}} = \frac{1}{1 - |S_{22}|^2}
\]

\[
g_L = \frac{G_L}{G_{L_{\text{max}}}} = \frac{1 - |\Gamma_L|^2}{|1 - \Gamma_L S_{22}|^2} (1 - |S_{22}|^2)
\]

(in our case: 0.3865 dB)

\[
g_i = \frac{G_i}{G_{i_{\text{max}}}} = \frac{1 - |\Gamma_i|^2}{|1 - \Gamma_i S_{ii}|^2} (1 - |S_{ii}|^2)
\]

This can be written as a circle equation
Constant Gain Amplifier (unilateral design)

\[ G_{TU} = \frac{1 - |\Gamma_S|^2}{|1 - S_{11}\Gamma_S|^2} \times |S_{21}|^2 \times \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2} \]

\[ G_{TU} (dB) = G_S (dB) + G_0 (dB) + G_L (dB) \]

Assign gain: 1 dB 11.78 dB 0.22 dB = 13 dB
Circle equation and graphical display at load side MN

\[ (\Gamma_S^R - d_{gS}^R)^2 + (\Gamma_S^I - d_{gS}^I)^2 = r_{gs}^2 \]

\[ d_{gS} = \frac{g_S S_{11}^*}{1 - |S_{11}|^2 (1 - g_S)} \]

\[ r_{gs} = \frac{\sqrt{1 - g_S (1 - |S_{11}|^2)}}{1 - |S_{11}|^2 (1 - g_S)} \]

Constant source gain circle of 1dB

Pick (let’s say)
L – type matching network at the source side

Series: $C = 4.41 \text{pF}$

Shunt: $C = 3.51 \text{pF}$

$Z_S = 40\Omega$

Point is arbitrary (or chosen to meet additional constraints)

Series: $C = 4.41 \text{pF}$

Shunt: $C = 3.51 \text{pF}$
Alternative matching networks (at source side)

Shunt: $L = 3.68 \, \text{nH}$
Series: $C = 3.76 \, \text{nF}$

Series: $L = 5.74 \, \text{nH}$
Shunt: $C = 7.47 \, \text{nF}$
Circle equation and graphical display at load side MN

\[
(\Gamma^R_L - d_{g_L}^R)^2 + (\Gamma^I_L - d_{g_L}^I)^2 = r_{g_L}^2
\]

\[
d_{g_L} = \frac{g_LS_{22}^*}{1 - |S_{22}|^2 (1 - g_L)}
\]

\[
r_{g_L} = \frac{\sqrt{1 - g_L (1 - |S_{22}|^2)}}{1 - |S_{22}|^2 (1 - g_L)}
\]

Constant load gain circle of 0.22 dB

Pick (let’s say)
L – type matching network at the load side

Point is again arbitrary (or chosen to meet additional constraints)

\[ Z_L = 50\Omega \]

Series: \( L = 9.75 \text{ nH} \)

Shunt: \( C = 0.90 \text{ pF} \)
Design with matching networks and current and voltage sources
Complete design with biasing networks
How well did we do?

\[ m_1 \]
\[ \text{freq} = 1.000 \times 10^9 \]
\[ \text{our_pgain} = 13.501 \]

\[ \text{Gamma_out} = S(2,2) \]

\[ \text{Gamma_in} = S(1,1) \]