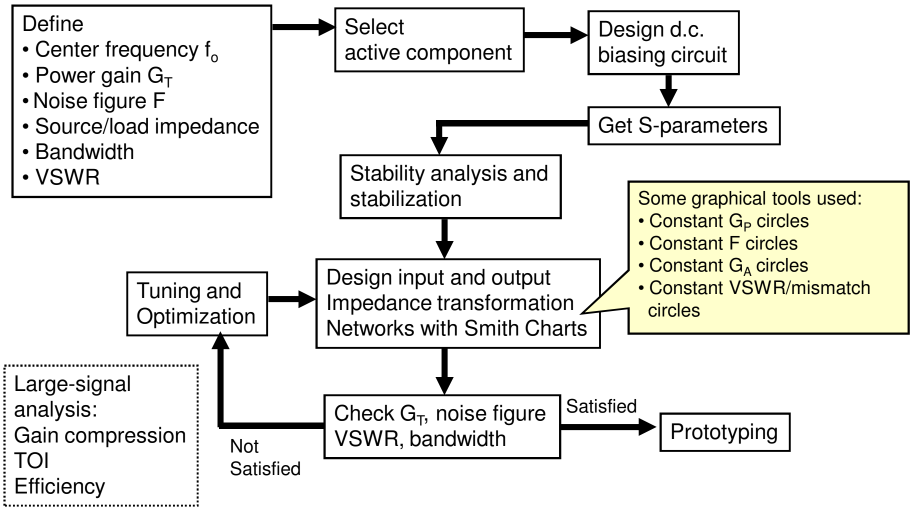
8A – Small-Signal Amplifier Design: Design for Maximum Power Gain and Design for Fixed Transducer Power Gain

References

- [1]* D.M. Pozar, “Microwave engineering”, 3rd Edition, 2005 John-Wiley & Sons.
- [2] R.E. Collin, “Foundations for microwave engineering”, 2nd Edition, 1992 McGraw-Hill.
- [3] R. Ludwig, P. Bretchko, “RF circuit design - theory and applications”, 2000 Prentice-Hall.
- [4]* G. Gonzalez, “Microwave transistor amplifiers - analysis and design”, 2nd Edition 1997, Prentice-Hall.
- [5] Gilmore R., Besser L.,”Practical RF circuit design for modern wireless systems”, Vol. 1 & 2, 2003, Artech House.

Basic Single-Stage Small-Signal Amplifier Design Flow



Linear/Quasi-Linear Amplifier Types

Amplifier Types	Required Γ_s	Required Γ_L	Graphical tools
Maximum Unilateral G_T	s_{11}^*	s_{22}^*	None
Maximum $G_{T(max)}$	Γ_{sm}	Γ_{Lm}	None
Fixed G_T with user defined F and input mismatch	Tunable	Tunable	• Constant G_P circle • Constant F circle • Constant VSWR/Mismatch circle • Constant G_A circle
Lowest noise	Γ_m	Tunable (typically = Γ_2^*)	Constant F circle
Maximum Output Power	Γ_{sm}	Γ_{OL}	Constant P_L contour

Good for lower frequency, f_o < 500MHz. Not discussed here, see [1], [4] and [5]

Discussed in High Power Circuits

1.0 Maximum G_T Amplifier - Simultaneous Conjugate Match

Simultaneous Conjugate Match in Amplifier (1)

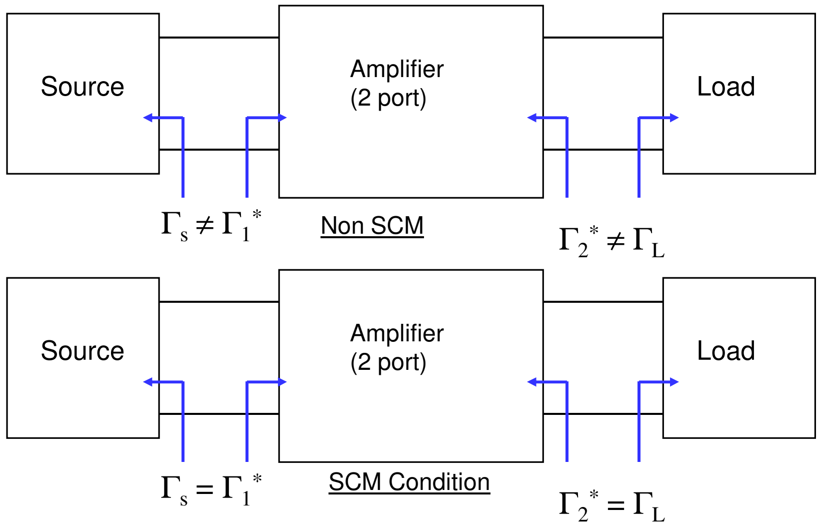
- To maximize power transfer in amplifier, both input and output ports of the amplifier have to be conjugately matched.
- When both input and output impedance of the amplifier are conjugately matched to the source and load impedance, the amplifier is called Simultaneous Conjugately Match (SCM).
- It is not easy to achieve SCM, as Γ_L affects Γ_1 , and Γ_s affects Γ_2 . Only under special condition can SCM occurs.

$$\Gamma_1 = \frac{S_{11} - D\Gamma_L}{1 - S_{22}\Gamma_L}$$

$$\Gamma_2 = \frac{S_{22} - D\Gamma_s}{1 - S_{11}\Gamma_s}$$

- Under SCM, $G_p = G_A = G_T$, and the gain obtained from the amplifier is the maximum, $G_{T(max)}$.
- Most of the time the condition for SCM is not fulfilled and we can only optimized the power gain of the amplifier while $G_{T(max)}$ is not attainable.

Simultaneous Conjugate Match in Amplifier (2)



Load and Source Impedance for Simultaneous Conjugate Match (1)

- The input and output reflection coefficient of an amplifier are given by:

$$\Gamma_1 = \frac{S_{11} - D\Gamma_L}{1 - S_{22}\Gamma_L} = \text{Input Reflection Coeff.} \qquad \Gamma_2 = \frac{S_{22} - D\Gamma_s}{1 - S_{11}\Gamma_s} = \text{Output Reflection Coeff.}$$

- When we want the input and output port of the amplifier to be conjugately matched to source and load impedance, $\Gamma_s = \Gamma_1^*$ and $\Gamma_L = \Gamma_2^*$.
- Thus we need to solve the following simultaneous equations:

$$\Gamma_s^* = \Gamma_1 = \frac{S_{11} - D\Gamma_L}{1 - S_{22}\Gamma_L} \qquad \Gamma_L^* = \Gamma_2 = \frac{S_{22} - D\Gamma_s}{1 - S_{11}\Gamma_s}$$

- This can only happen for a particular set of source and load impedance (as Γ_s affects Γ_2 and Γ_L affects Γ_1).

Load and Source Impedance for Simultaneous Conjugate Match (2)

- Solving both equations simultaneously results in (1.1a) and (1.1b), Example 9-10 of Ludwig, Bretchko [3] provide the details.

$$\Gamma_{Sm} = \frac{1}{2B_1}\left(A_1 - \left(A_1^2 - 4|B_1|^2\right)^{\frac{1}{2}}\right)$$
$$A_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |D|^2$$
$$B_1 = S_{11} - DS_{22}^*$$

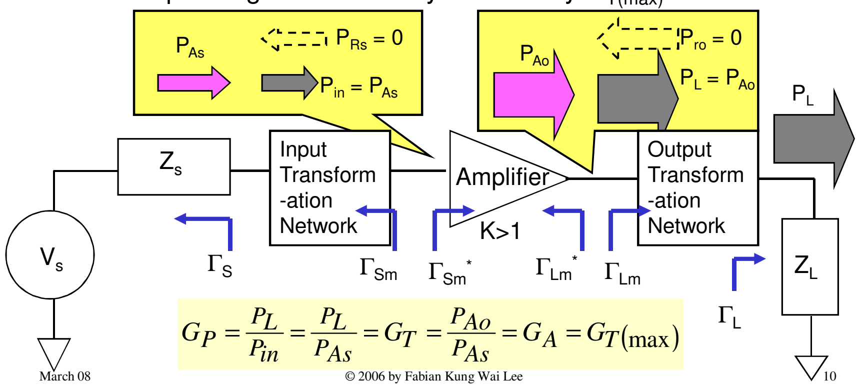
(1.1a)

$$\Gamma_{Lm} = \frac{1}{2B_2}\left(A_2 - \left(A_2^2 - 4|B_2|^2\right)^{\frac{1}{2}}\right)$$
$$A_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |D|^2$$
$$B_2 = S_{22} - DS_{11}^*$$

(1.1b)

Power Gain During Simultaneous Conjugate Match (1)

- When we connect source and load impedance having Γ_{Sm} and Γ_{Lm} to an amplifier, $P_{in} = P_{As}$, $P_L = P_{Ao}$.
- As a result $G_P = G_T = G_A$.
- Also note that transducer power gain G_T under this condition is the maximum power gain! Commonly denoted by $G_{T(max)}$.



$$G_P = \frac{P_L}{P_{in}} = \frac{P_L}{P_{As}} = G_T = \frac{P_{Ao}}{P_{As}} = G_A = G_T(\max)$$

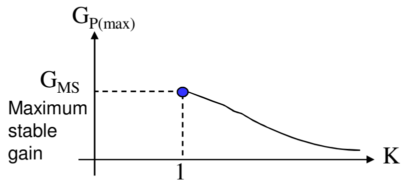
Power Gains During Simultaneous Conjugate Match (2)

- Substituting (1.1a) and (1.1b) into the expression for G_P will give us $G_{T(max)}$.

$$G_p = G_T = G_A = G_{T(max)}$$

$$G_P = \frac{|S_{21}|^2\left(1-|\Gamma_L|^2\right)}{|1-S_{22}\Gamma_L|^2\left(1-|\Gamma_1|^2\right)}$$

Γ_{Lm} → $$\Gamma_1 = \frac{S_{11}-D\Gamma_L}{1-S_{22}\Gamma_L}$$



$$G_{T(max)} = \frac{|S_{21}|}{|S_{12}|}\left(K-\sqrt{K^2-1}\right) \quad \textbf{(1.2a)}$$

Roulette Stability Factor →

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|D|^2}{2|S_{12}S_{21}|} \quad \textbf{(1.2b)}$$

Summary for SCM Amplifier Design

- SCM to obtain maximum power gain, can only be applied when the amplifier is unconditionally stable with input and output port conjugately matched.
- And when this happens, the maximum power gain that can be obtained is:

$$G_{T(max)} = \frac{|S_{21}|}{|S_{12}|}\left(K-\sqrt{K^2-1}\right) \qquad G_{MS} = \frac{|S_{21}|}{|S_{12}|} \quad \textbf{(1.3)}$$

- The limit for $G_{T(max)}$ is G_{MS}. It is the largest maximum stable power gain that can be achieved for an amplifier.
- From the above relations for $G_{T(max)}$, it is only real if $K \geq 1$. Thus an amplifier can only be simultaneously conjugate matched when it is unconditionally stable (pass K factor test).
- If the amplifier is only conditionally stable, then SCM or maximum power gain cannot be achieved. The required values for Γ_{Lm} and Γ_{Sm} will falls outside the unit disc of the Smith Chart. We can only optimize G_T up to a certain point.

Example 1.1 - SCM Amplifier Design

- A BJT with I_C=10mA and V_{CE}=6V is operated at 2.4GHz. The corresponding S-parameters are S_{11}=0.3<30º, S_{12}=0.2<-60º, S_{21}=2.5<-80º, S_{22}=0.2<-15º. Determine whether the transistor is unconditionally stable and find the values for Γ_s and Γ_L that provide maximum power gain. Sketch the schematics of the system (use a box to represent the amplifier).

Solution to Example 1.1

$$S_{11} = 0.260 + j0.150$$
$$S_{21} = 0.434 - j2.462$$
$$S_{12} = 0.100 - j0.173$$
$$S_{22} = 0.193 - j0.052$$

Stability Test:

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |D|^2}{2|S_{12}S_{21}|} = 1.178 \qquad |D| = |S_{11}S_{22} - S_{12}S_{21}| = 0.555$$

Since K > 1 and |D| < 1, the amplifier is unconditionally stable.
We can maximize the power gain G_p by carrying out simultaneous conjugate match design.

Solution to Example 1.1 Cont...

Use (1.1a) to find

$$\Gamma_{Lm} = \frac{1}{2B_2}\left(A_2 - \sqrt{A_2^2 - 4|B_2|^2}\right) = 0.044 + j0.116$$

Use (1.1b) to find

$$\Gamma_{sm} = \frac{1}{2B_1}\left(A_1 - \sqrt{A_1^2 - 4|B_1|^2}\right) = 0.281 - j0.091$$

Convert to impedance:

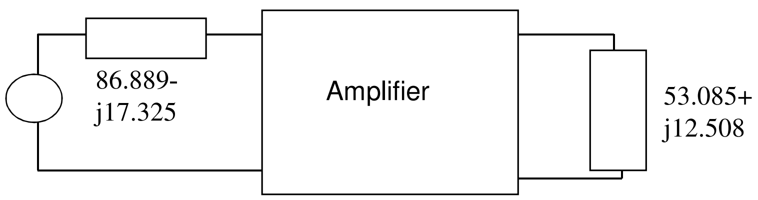
$$Z_{Lm} = Z_o \frac{1+\Gamma_{Lm}}{1-\Gamma_{Lm}} = 53.085 + j12.508$$

$$Z_{sm} = Z_o \frac{1+\Gamma_{sm}}{1-\Gamma_{sm}} = 86.889 - j17.325$$

Solution to Example 1.1 Cont...

Finding maximum power gain:

$$G_{p(\max)} = \frac{|S_{21}|}{|S_{12}|}\left(K - \sqrt{K^2 - 1}\right) = 6.942$$



Appendix 1
Derivation of Source and Load Impedance for Simultaneous Conjugate Match and Constant Power Gain Circle

The Condition for Maximum G_P (1)

- We start by looking at the expression for power gain G_P.

$$\Gamma_1 = \frac{S_{11} - D\Gamma_L}{1 - S_{22}\Gamma_L}$$

$$\Gamma_2 = \frac{S_{22} - D\Gamma_s}{1 - S_{11}\Gamma_s}$$

Even though the method presented here is much longer, it gives more insight into the characteristics of the power gain G_P.

$$|G_P| = \frac{|S_{21}|^2\left(1 - |\Gamma_L|^2\right)}{|1 - S_{22}\Gamma_L|^2\left(1 - |\Gamma_1|^2\right)} = \frac{\left(1 - |\Gamma_L|^2\right)|S_{21}|^2}{|1 - S_{22}\Gamma_L|^2 - |S_{11} - D\Gamma_L|^2} = g_2|S_{21}|^2$$

$$g_2 = \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2 - |S_{11} - D\Gamma_L|^2}$$

We call this the normalized power gain. Notice that it is dependent on Γ_L.

The Condition for Maximum G_P (2)

- If we could maximize $|g_2|$, then G_P can be maximized.
- Using

$$\Gamma_L = U_2 + jV_2 \qquad C_2 = S_{22} - DS_{11}^{\;*}$$

$$g_2 = \frac{1-|\Gamma_L|^2}{1-|S_{11}|^2 + |\Gamma_L|^2\left(|S_{22}|^2 - |D|^2\right) - 2\,\mathrm{Re}(\Gamma_L C_2)}$$

Because $|S_{21}|$ is fixed, it is an important parameter in amplifier design. It sets the limit of power gain.

- Using

$$\mathrm{Re}(\Gamma_L C_2) = U_2\,\mathrm{Re}(C_2) - V_2\,\mathrm{Im}(C_2) \qquad |\Gamma_L|^2 = U_2^2 + V_2^2$$

- We can rewrite the above expression as (See Chapter 1 of [3]):

$$U_2^2 + V_2^2 + \frac{2U_2 g_2\,\mathrm{Re}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2} - \frac{2V_2 g_2\,\mathrm{Im}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2} = \frac{-1+g_2-|S_{11}|^2 g_2}{-1-|S_{22}|^2 g_2 + |D|^2 g_2}$$

The Condition for Maximum G_P (3)

- This can be further expanded into (see extra notes) a circle equation in the complex plane:

$$\left[U_2 + \frac{g_2\,\mathrm{Re}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2}\right]^2 + \left[V_2 - \frac{g_2\,\mathrm{Im}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2}\right]^2 = \rho_{2c}^2 \qquad \textbf{(A.1)}$$

Coordinate for center of a circle

The radius of a circle

- Where

$$\rho_{2c}^2 = \frac{-1+g_2-|S_{11}|^2 g_2}{-1-|S_{22}|^2 g_2 + |D|^2 g_2} + \frac{g_2^{\,2}\left|S_{22} - DS_{11}^*\right|^2}{\left(-1-|S_{22}|^2 g_2 + |D|^2 g_2\right)^2} \qquad \textbf{(A.2)}$$

The Condition for Maximum G_P (4)

- ρ_{2c}^2 can be further simplified using the identity

$$\mathrm{Re}^2(C_2)+\mathrm{Im}^2(C_2)=\left|S_{22}-DS_{11}^*\right|^2=\left|S_{12}S_{21}\right|^2+\left(1-\left|S_{11}\right|\right)^2\left(\left|S_{22}\right|^2-\left|D\right|^2\right)$$

- To

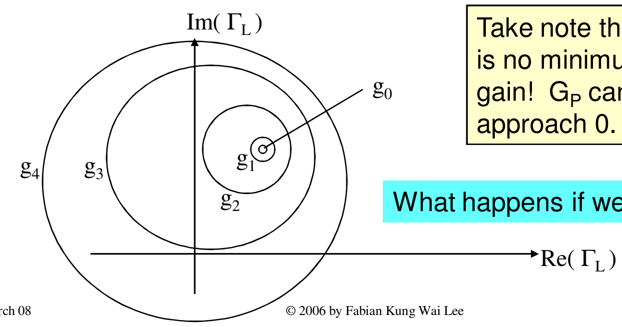
$$\rho_{2c}^2=\frac{1-2K\left|S_{12}S_{21}\right|g_2+\left|S_{12}S_{21}\right|^2 g_2^2}{\left(-1-\left|S_{22}\right|^2 g_2+\left|D\right|^2 g_2\right)^2} \qquad \textit{(A.3)}$$

- Where

$$K=\frac{1-\left|S_{11}\right|^2-\left|S_{22}\right|^2+\left|D\right|^2}{2\left|S_{12}S_{21}\right|} \qquad \textit{(A.4)}$$

The Condition for Maximum G_P (5)

- Expression (A.1) again represents a circle in the complex $\Gamma_L = U_2+jV_2$ plane.
- For each value of g_2 , a circle can be drawn. Thus each circle represents the contour of constant power gain G_P for a given load Z_L. When $\rho_{2c}^2=0$, the power gain is the maximum.



Take note that there is no minimum power gain! G_P can only approach 0.

What happens if we set $g_2 > g_o$?

The Condition for Maximum G_P (6)

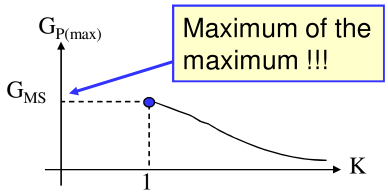
- From (A.3), when $\rho_{2c}^2=0$:

$$g_{2(\max)} = \frac{1}{|S_{12}S_{21}|}\left(K - \sqrt{K^2 - 1}\right)$$

- Since $g_{2(max)}$ only exist if K > 1, this implies maximum gain only exist when the amplifier is unconditionally stable.
- At K=1,

$$g_{2(\max)} = \frac{1}{|S_{12}S_{21}|}$$

$$G_{P(\max)} = \frac{1}{|S_{12}S_{21}|}\cdot|S_{21}|^2 = \frac{|S_{21}|}{|S_{12}|}$$



- And this power gain is known as Maximum Stable Gain, G_{MS}. This is the maximum power gain that is achievable !!! It is often specified in datasheet of an amplifier or amplification device and gives the theoretical maximum gain achievable.

Corresponding Load Impedance for Maximum Power Gain

- From (A.1) and putting $\rho_{2c}^2=0$:

$$\left[U_{2m} + \frac{g_2\,\mathrm{Re}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2}\right]^2 + \left[V_{2m} - \frac{g_2\,\mathrm{Im}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2}\right]^2 = 0$$

$$\Rightarrow U_{2m} + \frac{g_2\,\mathrm{Re}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2} = 0 \qquad \textbf{(A.5a)}$$

$$\Rightarrow V_{2m} - \frac{g_2\,\mathrm{Im}(C_2)}{-1-|S_{22}|^2 g_2 + |D|^2 g_2} = 0 \qquad \textbf{(A.5b)}$$

Load Impedance for Maximum Power Gain

- By expanding (A.5a) and (A.5b) using $g_{2(max)}$, we can show that:
- Or $\Gamma_{Lm} = U_{2m} + jV_{2m}$

$$\Gamma_{Lm} = \frac{1}{2B_2}\left(A_2 - \left(A_2{}^2 - 4|B_2|^2\right)^{\frac{1}{2}} \right)$$
$$A_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |D|^2 \qquad \textit{(A.6a)}$$
$$B_2 = S_{22} - DS_{11}^*$$

- The proof is extremely tedious and will not be shown here. You can refer to the extra hand-written notes for the proof.

Source Impedance for Maximum Power Gain

- Using $\Gamma_1 = \frac{S_{11} - D\Gamma_L}{1 - S_{22}\Gamma_L}$
- We can obtain the corresponding Γ_1 .
- And requiring that $\Gamma_S = \Gamma_1{}^*$, the source reflection coefficient can be obtained.

$$\Gamma_{Sm} = \frac{1}{2B_1}\left(A_1 - \left(A_1{}^2 - 4|B_1|^2\right)^{\frac{1}{2}} \right)$$
$$A_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |D|^2 \qquad \textit{(A.6b)}$$
$$B_1 = S_{11} - DS_{22}^*$$

2.0 Design for Fixed Transducer Power Gain G_T – The Constant G_P Circle Approach

Constant Power Gain Circles (1)

- From the Dependency Diagram of previous chapter we see that G_P only depends on Γ_L. Indeed it is possible to determine the range of Γ_L which would give a fixed G_P, and this range actually falls on the locus of a circle on Smith Chart.
- From the equation (A.1) of Appendix 1, the radius and center of the Constant Power Gain Circle are given by:

$$C_2 = s_{22} - D s_{11}^* \quad \textbf{(2.1a)}$$

Normalized G_P

$$g_2 = \frac{G_P}{|s_{21}|^2} \quad \textbf{(2.1b)}$$

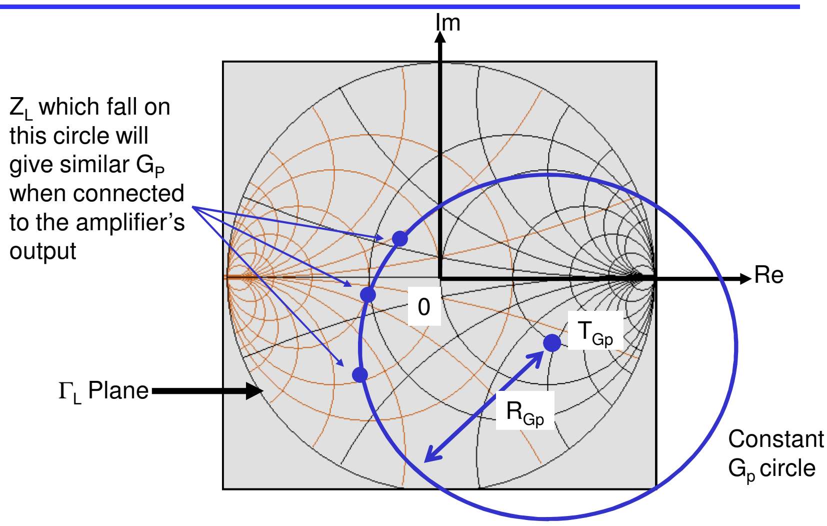
Center of circle

$$T_{GP} = \frac{-g_2 \operatorname{Re}(C_2)}{-1-|s_{22}|^2 g_2 + |D|^2 g_2} + j\frac{g_2 \operatorname{Im}(C_2)}{-1-|s_{22}|^2 g_2 + |D|^2 g_2} \quad \textbf{(2.1c)}$$

Radius of circle

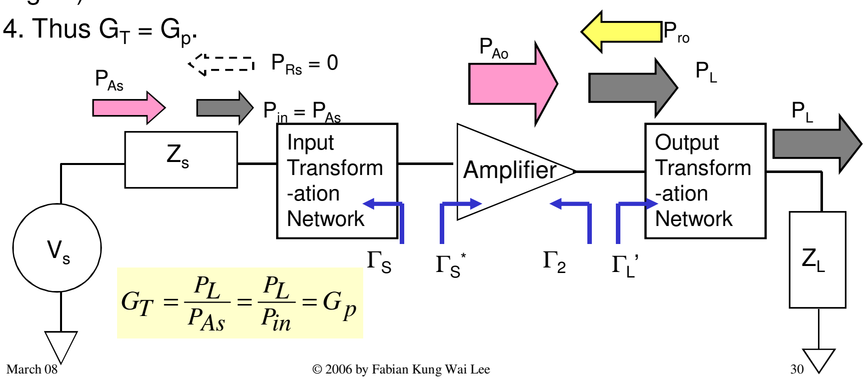
$$R_{GP} = \frac{\sqrt{1-2K|s_{12}s_{21}|g_2 + |s_{12}s_{21}|^2 g_2^2}}{\left|-1-|s_{22}|^2 g_2 + |D|^2 g_2\right|} \quad \textbf{(2.1d)}$$

Constant Power Gain Circles (2)



The Constant G_p Circle Approach

- 1. Use constant G_p circles together with LSC (if amplifier is conditionally stable) to select the appropriate Γ_L.
- 2. From the selected Γ_L determine Γ_1.
- 3. Conjugate match the input port (make sure Γ_s is in the stable region).
- 4. Thus $G_T = G_p$.



$$G_T = \frac{P_L}{P_{As}} = \frac{P_L}{P_{in}} = G_p$$

Example 2.1 - Constant G_P Amplifier Design

- A microwave BJT has S_{11}=0.9<60º, S_{12}=0.06<60º, S_{21}=3<120º, S_{22}=0.82<-30º at 1.2GHz. Design a single-stage amplifier having 50Ω input and output transmission lines, with a required transducer power gain between 40-50.

- Solution…
- K = 0.902 and |D|=0.898, so the amplifier is conditionally stable.
- S-parameters at 1.2GHz:

$$S11 = 0.45 + 0.7794i \qquad S12 = 0.03 + 0.052i$$

$$S21 = -1.5 + 2.5981i \qquad S22 = 0.7101 - 0.41i$$

$$D = 0.8191 + 0.369i$$

Example 2.1 Cont...

Plot Load Stability Circle…

Since $|S_{11}|$=0.9 < 1 and the LSC encloses the origin, the stable region is as indicated.

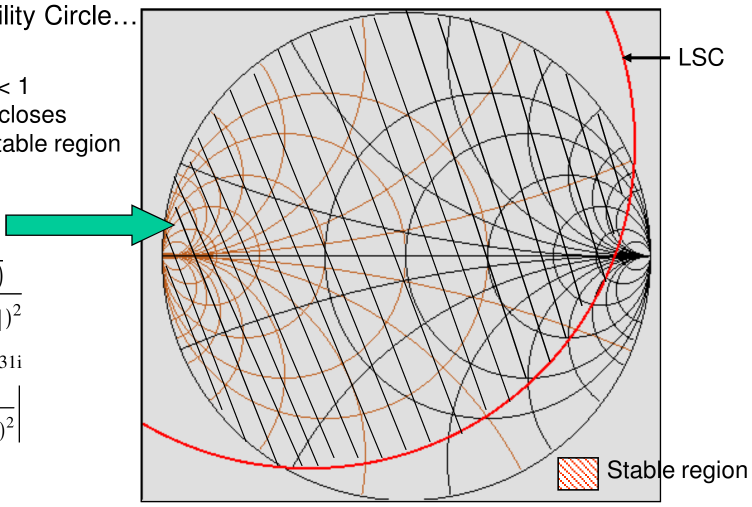
Plane for Γ_L

$$CL := \frac{\overline{(S22 - D \cdot \overline{S11})}}{(|S22|)^2 - (|D|)^2}$$

$$CL = -0.4003 + 0.4631i$$

$$RL := \left| \frac{S12 \cdot S21}{(|S22|)^2 - (|D|)^2} \right|$$

$$RL = 1.336$$



Example 2.1 Cont...

Constant G_P Circle for $G_p = 36$

$$C2 := S22 - D\cdot\overline{S11} \qquad C2 = 0.0539 + 0.0624i$$

$$g2 := \frac{36}{(|S21|)^2} \qquad g2 = 4$$

$$Cgp := \frac{1}{-1 - (|S22|)^2\cdot g2 + (|D|)^2\cdot g2}\cdot(-g2\cdot Re(C2) + i\cdot g2\cdot Im(C2))$$

$$Cgp = 0.4678 - 0.5413i$$

$$K := \frac{1 - (|S11|)^2 - (|S22|)^2 + (|D|)^2}{2\cdot|S21\cdot S12|}$$

$$K = 0.902 \qquad -1 - (|S22|)^2\cdot g2 + (|D|)^2\cdot g2 = -0.4611$$

$$Rgp := \frac{\sqrt{1 - 2\cdot K\cdot|S12\cdot S21|\cdot g2 + (|S12\cdot S21\cdot g2|)^2}}{\left|-1 - (|S22|)^2\cdot g2 + (|D|)^2\cdot g2\right|}$$

$$Rgp = 1.0161$$

Constant G_P Circle for $G_p = 45$

$$C2 := S22 - D\cdot\overline{S11} \qquad C2 = 0.0539 + 0.0624i$$

$$g2 := \frac{45}{(|S21|)^2} \qquad g2 = 5$$

$$Cgp := \frac{1}{-1 - (|S22|)^2\cdot g2 + (|D|)^2\cdot g2}\cdot(-g2\cdot Re(C2) + i\cdot g2\cdot Im(C2))$$

$$Cgp = 0.8262 - 0.956i$$

$$K := \frac{1 - (|S11|)^2 - (|S22|)^2 + (|D|)^2}{2\cdot|S21\cdot S12|}$$

$$K = 0.902 \qquad -1 - (|S22|)^2\cdot g2 + (|D|)^2\cdot g2 = -0.3264$$

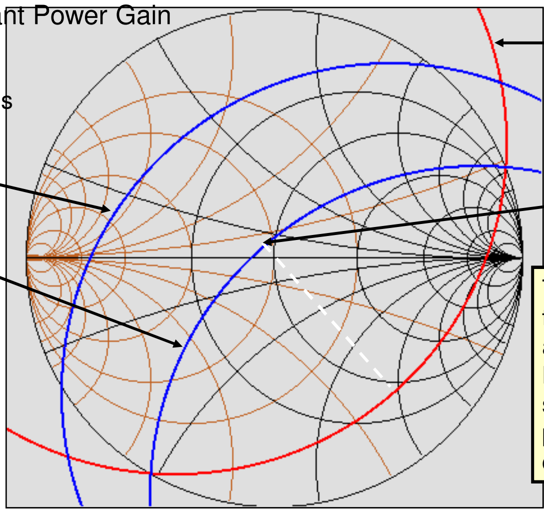
$$Rgp := \frac{\sqrt{1 - 2\cdot K\cdot|S12\cdot S21|\cdot g2 + (|S12\cdot S21\cdot g2|)^2}}{\left|-1 - (|S22|)^2\cdot g2 + (|D|)^2\cdot g2\right|}$$

$$Rgp = 1.3228$$

Example 2.1 Cont...

Draw the Constant Power Gain Circles…

Constant G_P circles on the Γ_L plane



This point is the farthest away from the LSC, it is less susceptible to parameter changes.

Example 2.1 Cont...

- Finding the corresponding load impedance

$$\Gamma_L = 0.05 < 0.6177 rad = 0.041 - j0.029$$

$$Z_L = Z_o \frac{1+\Gamma_L}{1-\Gamma_L} \quad Z_o = 50$$

$$Z_L = 54.154 - j3.144$$

Example 2.1 Cont...

- Finding the corresponding input impedance and taking its complex conjugate:

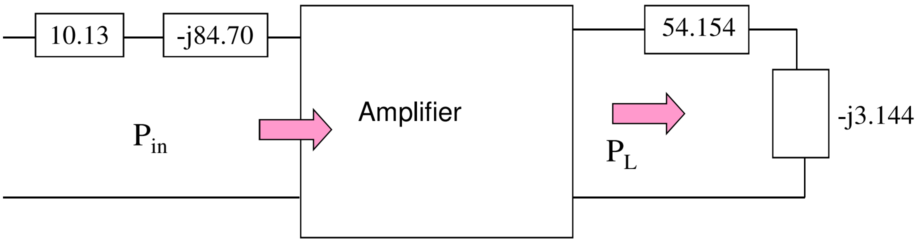
$$\Gamma_1 = \frac{S_{11} - D\Gamma_L}{1 - S_{22}\Gamma_L} = 0.4472 + j0.785$$

$$Z_1 = \frac{1+\Gamma_1}{1-\Gamma_1} Z_o = 10.129 + j84.704$$

$$Z_s = Z_1^* = 10.129 - j84.704$$

Example 2.1 Cont...

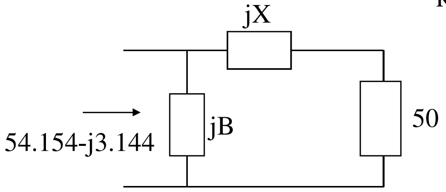
- The block diagram...



$G_T = P_L/P_{in} = 45$

Example 2.1 Cont...

- Since actual Z_s and Z_L are 50Ω , impedance transformation network is needed to change the 50Ω load impedance into 54.154 - j3.144, and to 10.13-j84.70 for source impedance. We may use either 2 or 3 elements impedance transformation network. This is shown below for the load network.



R_L=50, X_L=0, R_s=54.154, X_s = -3.144

$$X = -X_L \pm \sqrt{R_L(R_s - R_L) + \frac{R_L}{R_s}X_s^2} = 14.725$$

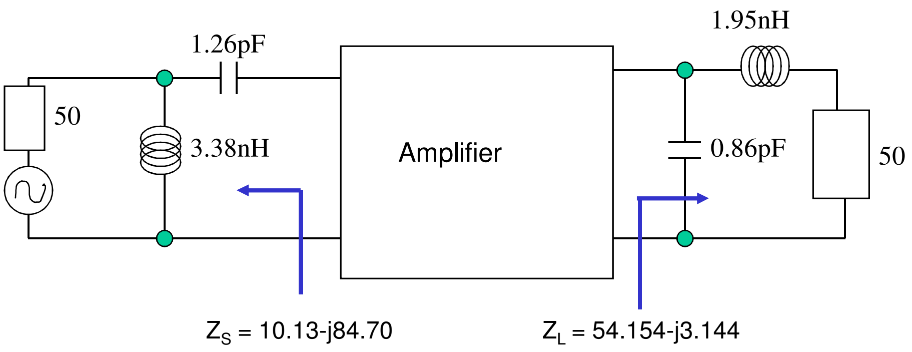
$$L = \frac{X}{2\pi f} = 1.95nH$$

$$B = \frac{R_s - R_L}{R_s X_L + R_L X_s + R_s X} = 6.488\times10^{-3}$$

$$C = \frac{B}{2\pi f} = 0.86pF$$

Example 2.1 Cont...

- The final network...



$G_T = P_L/P_{in} = 45$

3.0 Design for Fixed Transducer Power Gain G_T – The Constant G_A Circle Approach

Extra

Preliminary

- The approach is just the dual of the Constant G_P Approach.
- Instead of tuning Γ_L for fixed G_P we tune Γ_s for fixed G_A, therefore constant G_A circles and Γ_s plane for the Smith Chart are employed.
- This approach is useful we need to take into account the final transducer power gain G_T and noise figure of the amplifier.

Extra

Constant Available Power Gain Circles (1)

- From the Dependency Diagram of previous chapter we see that G_A only depends on Γ_s. Indeed it is possible to determine the range of Γ_s which would give a fixed G_A, and this range actually falls on the locus of a circle on Smith Chart.
- The derivation is similar to the procedures in Appendix 1, see [4] for the details.

$$C_1 = s_{11} - Ds_{22}^* \quad \textit{(3.1a)}$$

Normalized G_A

$$g_1 = \frac{G_A}{|s_{21}|^2} \quad \textit{(3.1b)}$$

Center of circle

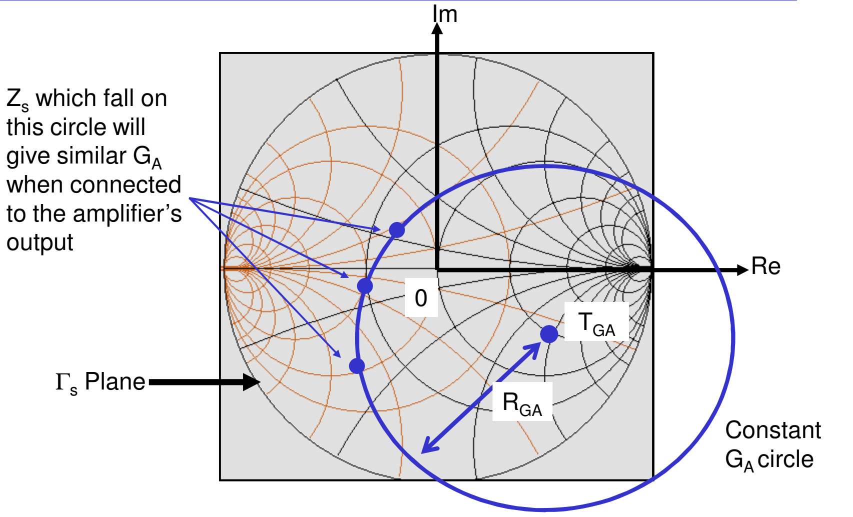
$$T_{G_A} = \frac{g_1 \operatorname{Re}(C_1)}{1+|s_{11}|^2 g_1 - |D|^2 g_1} - j\frac{g_1 \operatorname{Im}(C_1)}{1+|s_{11}|^2 g_1 - |D|^2 g_1} \quad \textit{(3.1c)}$$

Radius of circle

$$R_{G_A} = \frac{\sqrt{1-2K|s_{12}s_{21}|g_1 + |s_{12}s_{21}|^2 g_1^2}}{\left|1+|s_{11}|^2 g_1 - |D|^2 g_1\right|} \quad \textit{(3.1d)}$$

Constant Available Power Gain Circles (2)

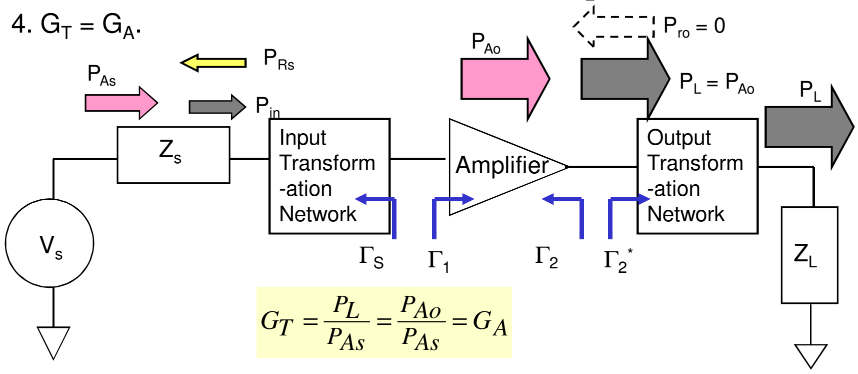
Extra



The Constant G_A Circle Approach

Extra

- 1. Use constant G_A circles together with SSC (if amplifier is conditionally stable) to select the appropriate Γ_s.
- 2. From the selected Γ_s determine Γ_2.
- 3. Conjugate match the output port (make sure Γ_L is in stable region).
- 4. $G_T = G_A$.



$$G_T = \frac{P_L}{P_{As}} = \frac{P_{Ao}}{P_{As}} = G_A$$