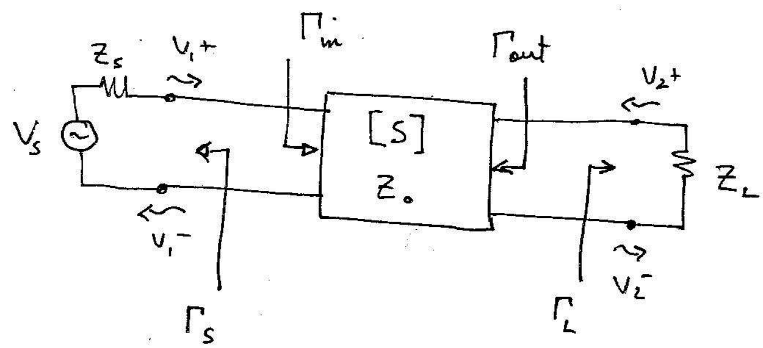
Transistor Amplifier — Power Gain Eqns. 1



Usando como referencia Z_0, $\Gamma_s = \dfrac{Z_s - Z_0}{Z_s + Z_0}$, $\Gamma_L = \dfrac{Z_L - Z_0}{Z_L + Z_0}$

Sabemos que: $V_1^- = S_{11} V_1^+ + S_{12} V_2^+$,

$V_2^- = S_{21} V_1^+ + S_{22} V_2^+$, pero $\Gamma_{in} = \dfrac{V_1^-}{V_1^+}$

De aquí,

$$V_1^- = S_{11} V_1^+ + S_{12} \Gamma_L V_2^- \text{ --- } (*) \qquad \Gamma_L = \frac{V_2^+}{V_2^-}$$

$$V_2^- = S_{21} V_1^+ + S_{22} \Gamma_L V_2^-$$

$$\to V_2^- = \frac{S_{21} V_1^+}{1 - S_{22}\Gamma_L}$$

Sustituyendo en (*)

$$V_1^- = S_{11} V_1^+ + S_{12} \Gamma_L \left(\frac{S_{21} V_1^+}{1 - S_{22}\Gamma_L} \right)$$ Eq. en terminos de V_1^+ y V_1^-

de aquí

$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12} S_{21} \Gamma_L}{1 - S_{22}\Gamma_L} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \text{ --- } (1)$$

De la misma forma,

$$\Gamma_{out} = \frac{V_2^-}{V_2^+} = S_{22} + \frac{S_{12} S_{21} \Gamma_s}{1 - S_{11}\Gamma_s} \text{ --- } (2)$$

Deseo expresión de potencia que entra a la red.

$$P_{in} = \frac{|V_1^+|^2}{2Z_0}\left(1 - |\Gamma_{in}|^2\right)$$

Hallar expresión para V_1^+;

$$V_1 = \frac{V_s Z_{in}}{Z_s + Z_{in}} = V_1^+ + V_1^- = V_1^+(1 + \Gamma_{in})$$

$$V_1^+ = \frac{V_s Z_{in}}{(Z_s + Z_{in})(1+\Gamma_{in})}, \quad \text{pero} \quad Z_{in} = Z_0 \frac{1+\Gamma_{in}}{1-\Gamma_{in}}$$

$$\therefore V_1^+ = \frac{V_s \frac{\cancel{1+\Gamma_{in}}}{1-\Gamma_{in}} Z_0}{(Z_s + Z_{in})(\cancel{1+\Gamma_{in}})} = \frac{V_s Z_0}{(Z_s + Z_0)(1-\Gamma_{in})}$$

$$V_1^+ = \frac{V_s Z_0}{Z_0\left(\frac{1+\Gamma_s}{1-\Gamma_s} + \frac{1+\Gamma_{in}}{1-\Gamma_{in}}\right)(1-\Gamma_{in})} = \frac{V_s(1-\Gamma_s)}{2(1-\Gamma_s\Gamma_{in})}$$

$$\boxed{P_{in} = \frac{|V_s|^2 \, |1-\Gamma_s|^2}{8 Z_0 \, |1-\Gamma_s\Gamma_{in}|^2}\left(1 - |\Gamma_{in}|^2\right)}$$

De la misma forma,

$$P_L = \frac{|V_2^-|^2}{2Z_0}\left(1 - |\Gamma_L|^2\right)$$

$$\boxed{P_L = \frac{|V_s|^2}{8Z_0} \frac{|S_{21}|^2 \left(1 - |\Gamma_L|^2\right) |1-\Gamma_s|^2}{|1 - S_{22}\Gamma_L|^2 \, |1 - \Gamma_s \Gamma_{in}|^2}}$$

Definimos "Power Gain"

$$\boxed{G = \frac{P_L}{P_{in}} = \frac{|S_{21}|^2 \left(1 - |\Gamma_L|^2\right)}{\left(1 - |\Gamma_{in}|^2\right) |1 - S_{22}\Gamma_L|^2}}$$

Depende de Γ_L

Eq. 11.8

"Available Gain", G_A

$$G_A = \frac{P_{AVN}}{P_{AVS}} \; ; \qquad P_{AVN} = P_L \Big|_{\Gamma_L = \Gamma_{out}^*}$$

$$P_{AVS} = P_{in} \Big|_{\Gamma_{in} = \Gamma_s^*}$$

$$P_{AVS} = \frac{|V_s|^2}{8Z_0} \frac{|1 - \Gamma_s|^2}{|1 - |\Gamma_s|^2|^2} \cancel{\left(1 - |\Gamma_s|^2\right)} = \frac{|V_s|^2}{8Z_0} \frac{|1 - \Gamma_s|^2}{1 - |\Gamma_s|^2}$$

$$P_{AVN} = \frac{|V_s|^2}{8Z_0} \frac{|S_{21}|^2 \left(1 - |\Gamma_{out}|^2\right) |1 - \Gamma_s|^2}{|1 - S_{22}\Gamma_{out}^*| \, |1 - \Gamma_s \Gamma_{in}|^2}$$

pero $\Gamma_{in} = S_{11} + \dfrac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} = S_{11} + \dfrac{S_{12}S_{21}\Gamma_{out}^*}{1 - S_{22}\Gamma_{out}^*}$

$$P_{AVN} = \frac{|V_s|^2}{8Z_0} \frac{|S_{21}|^2 |1 - \Gamma_s|^2}{|1 - S_{11}\Gamma_s|^2 \left(1 - |\Gamma_{out}|^2\right)}$$

$$\boxed{G_A = \frac{P_{AVN}}{P_{AVS}} = \frac{|S_{21}|^2 \left(1 - |\Gamma_s|^2\right)}{|1 - S_{11}\Gamma_s|^2 \left(1 - |\Gamma_{out}|^2\right)}}$$

Depende de Γ_S

Eq. 11.12

"Transducer Power Gain" 4

$$\boxed{G_T = \frac{P_L}{P_{AVS}} = \frac{|S_{21}|^2 \left(1-|\Gamma_S|^2\right)\left(1-|\Gamma_L|^2\right)}{|1-\Gamma_S\Gamma_{in}|^2 \; |1-S_{22}\Gamma_L|^2}}$$

Depende Γ_S y Γ_L

Eq. 11.13

Si $\Gamma_L = \Gamma_S = 0$ $\quad G_T = |S_{21}|^2$

Caso especial $\longrightarrow$ <u>caso unilateral</u> $\Longrightarrow S_{12} = 0$

Si $S_{12} = 0$ entonces $\Gamma_{in} = S_{11}$ (eq. 1), $\Gamma_{out} = S_{22}$ (eq. 2)

y G_T se reduce a

$$G_{TU} = \frac{|S_{21}|^2 \left(1-|\Gamma_S|^2\right)\left(1-|\Gamma_L|^2\right)}{|1-S_{11}\Gamma_S|^2 \; |1-S_{22}\Gamma_L|^2}$$

Ejemplo:

$S_{11} = 0.45\angle 150^\circ \qquad S_{12} = 0.01\angle -10^\circ$

$S_{21} = 2.05\angle 10^\circ \qquad S_{22} = 0.4\angle -150^\circ$

Si $Z_S = 20\,\Omega$ y $Z_L = 30\,\Omega$

$\Gamma_S = -0.429$; $\Gamma_L = -0.250$

De aquí;

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L} = 0.455^\circ\angle 150^\circ$$

$$\Gamma_{out} = 0.408\angle -151^\circ$$

$G = 5.94 \qquad G_A = 5.85 \qquad G_T = 5.49$

Podemos Dividir ganancia en tres términos:

$$G_T = G_S \; G_o \; G_L$$

Donde $G_S = \dfrac{1-|\Gamma_S|^2}{|1-\Gamma_S\Gamma_{in}|^2}$; $G_o = |S_{21}|^2$; $G_L = \dfrac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$

$G_S \Rightarrow$ Input Matching Network

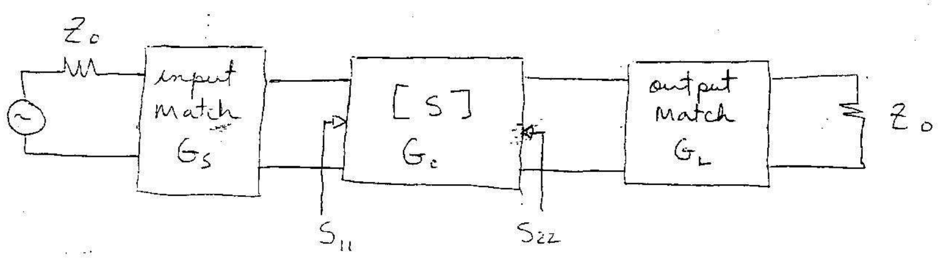
$G_L \Rightarrow$ output " "

$G_o \Rightarrow$ transistor (S_{21})

Caso especial (unilateral) existe si $\boxed{S_{12}=0}$

De esta condición: $\Gamma_{in} = S_{11}$; $\Gamma_{out} = S_{22}$

$$G_{TU} = \frac{|S_{21}|^2\,(1-|\Gamma_S|^2)\,(1-|\Gamma_L|^2)}{|1-S_{11}\Gamma_S|^2\;|1-S_{22}\Gamma_L|^2}$$



$G_S = \dfrac{1-|\Gamma_S|^2}{|1-S_{11}\Gamma_S|^2}$ $\quad G_o = |S_{21}|^2$ $\quad G_L = \dfrac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$

Proximo Tema: Estabilidad

Estabilidad: El amplificador es estable si $|\Gamma_{in}| < 1$ y $|\Gamma_{out}| < 1$. Γ_{in} y Γ_{out} dependen de Γ_S y Γ_L, por lo que Γ_S y Γ_L controlan la estabilidad del amplificador. Deseamos valores de Γ_L y Γ_S para que Γ_{in} y Γ_{out} resulten < 1. Habran valores que ocasionen: $\left.\boxed{|\Gamma_{in}| > 1 \qquad |\Gamma_{out}| > 1}\right\}$ inestable

Usando las ecuaciones de Γ_{in} y Γ_{out}, podemos derivar expresiones para identificar valores de Γ_L y Γ_S deseados; usando el "Smith Chart". Hay dos tipos:

1) Estabilidad sin condición: $|\Gamma_{in}|$ y $|\Gamma_{out}|$ son < 1 para cualquier Γ_L y Γ_S.

2) Estabilidad condicional $|\Gamma_{in}|$ y $|\Gamma_{out}| < 1$ para algunos valores de Γ_L y Γ_S. ¿Cómo identifico estos valores?

$|\Gamma_{in}| = 1$ $\quad |\Gamma_{out}| = 1$ podemos determinar valores de Γ_s y Γ_L donde ésto se cumple.

$$|\Gamma_{in}| = \left| S_{11} + \frac{S_{12} S_{21} \Gamma_L}{1 - S_{22} \Gamma_L} \right| = 1$$

$$|\Gamma_{out}| = \left| S_{22} + \frac{S_{12} S_{21} \Gamma_S}{1 - S_{11} \Gamma_S} \right| = 1$$

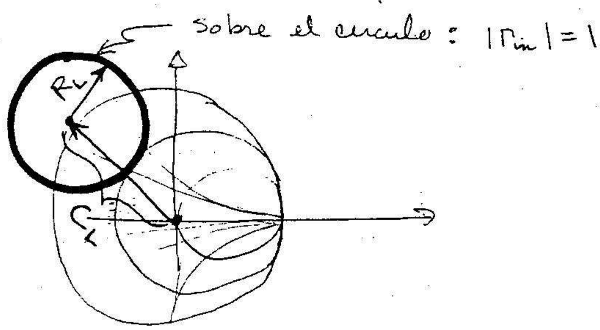
De aquí resulta ecuaciones de círculo:

Centro $\qquad$ Radio

$$C_L = \frac{(S_{22} - \Delta S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} \qquad R_L = \left| \frac{S_{12} \, S_{21}}{|S_{22}|^2 - |\Delta|^2} \right|$$

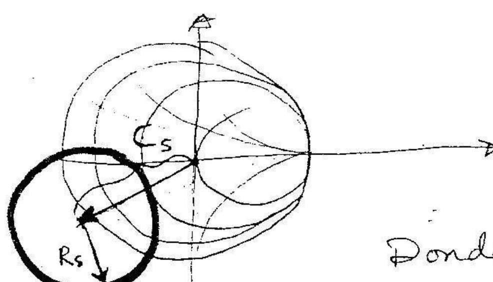
En plano de Γ_L

"Output Stability circle"



En plano de Γ_S

"Input Stability circle"



$$C_S = \frac{(S_{11} - \Delta S_{22}^*)^*}{|S_{11}|^2 - |\Delta|^2}$$

$$R_S = \left| \frac{S_{12} \, S_{21}}{|S_{11}|^2 - |\Delta|^2} \right|$$

Donde:

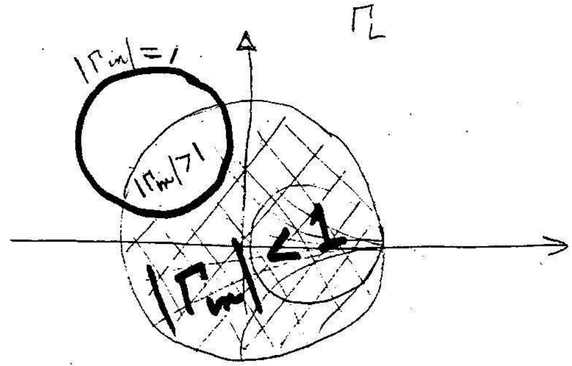
$\Delta = S_{11} S_{22} - S_{12} S_{21}$

¿Como Determine si region estable es dentro o fuera del circulo?

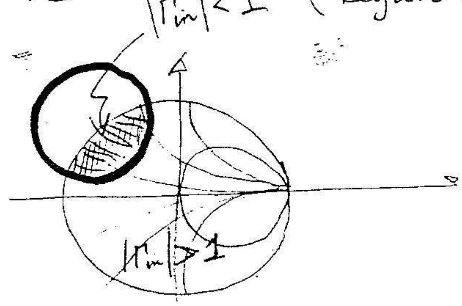
Usar punto facil: $\Gamma_L = 0$ (centro del S.C.)

$$\therefore \quad |\Gamma_{in}| = \left| S_{11} + \frac{S_{12} S_{21} \Gamma_L}{1 - S_{22}\Gamma_L} \right| = |S_{11}|$$

Si $|S_{11}| < 1$, la region que contiene el centro del S.C. es estable

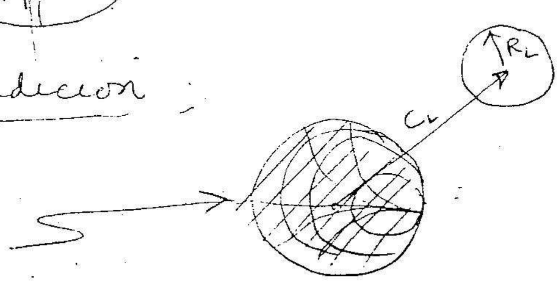


Si $|S_{11}| > 1$ $\quad |\Gamma_{in}| < 1$ (Region estable)



Estable Sin Condicion:

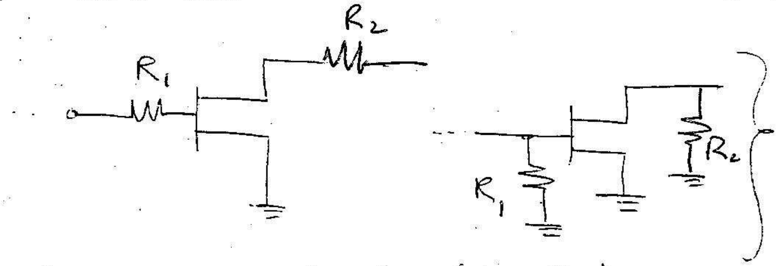
Todo Γ_L resulta en $|\Gamma_{in}| < 1$



si el transistor es estable con condición, 6

podemos cambiar esta condición a estable

sin condición con "resistive loading".



Sacrifica Ganancia

Usar **uno** de los dos (R_1, R_2)

Diseño de Amplificador (Ganancia Maxima)

$\Gamma_{in} = \Gamma_S^*$ (Maxima tanferencia en entrada de amplificador)

$\Gamma_{out} = \Gamma_L^*$ (Maxima transferencia en salida del amplificador).

$$G_{T\,max} = \frac{1}{1-|\Gamma_S|^2}\,|S_{21}|^2\,\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

$$\Gamma_{in} = \Gamma_S^* = S_{11} + \frac{S_{12}\Gamma_L S_{21}}{1-S_{22}\Gamma_L}$$

$$\Gamma_{out} = \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{11}\Gamma_S}$$

Dos ecuaciones dos desconocidas! Γ_L y Γ_S

De aquí resulta que:

$$\Gamma_S = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1}$$

$$\Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2}$$

Donde $B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2$

$$B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2$$

$$C_1 = S_{11} - \Delta S_{22}^*$$

$$C_2 = S_{22} - \Delta S_{11}^*$$

Para caso unilateral;

$$\Gamma_S = S_{11}^* \qquad \Gamma_L = S_{22}^*$$

$$G_{TU\,max} = \frac{1}{1-|S_{11}|^2}\,|S_{21}|^2\,\frac{1}{1-|S_{22}|^2}$$

Otras condiciones matemáticas de estabilidad

Estable sin condición:

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2}{2|S_{12}S_{21}|} > 1$$

y $|\Delta| < 1$

$$\mu = \frac{1-|S_{11}|^2}{|S_{22}-S_{11}^*\Delta| + |S_{21}S_{12}|} > 1$$