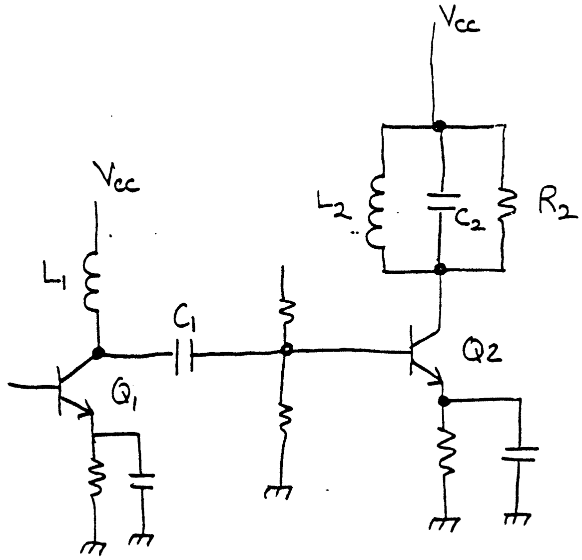
design of a small signal r.f. amplifier:



from data sheets Q_1 & Q_2 are identical

$y_{ie} = 10 + j10 \ m\mho$

$y_{re} = -j0.001 \ m\mho$

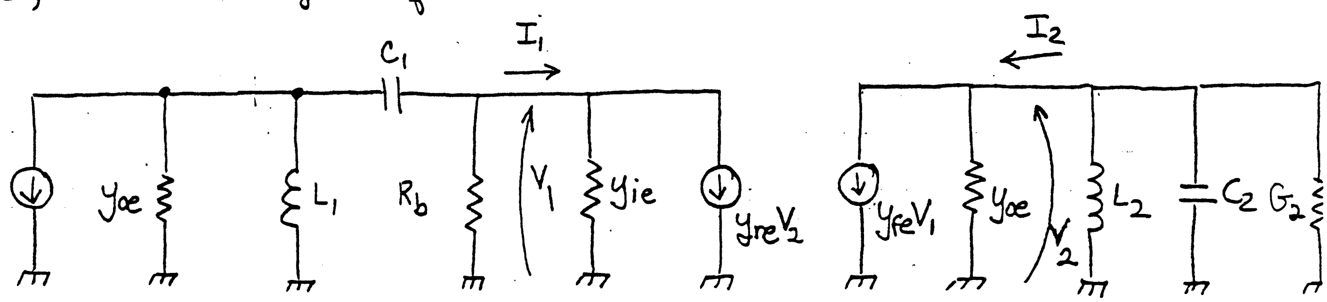
$y_{fe} = 10 \times 10^{-3}$

$y_{oe} = 0.1 \times 10^{-3}$

design for $f_o = 50$ MHz

BW = 0.5 MHz

First, draw small signal equivalent circuit:



two port transistor model

assumed to be at resonance

$Z_{in} \longrightarrow$

$$Z_{in} = \frac{V_1}{I_1} = \frac{V_1}{y_{ie} V_1 + y_{re} V_2}$$

at resonance: $y_{fe} V_1 + g_{oe} V_2 = -G_2 V_2$

$$\therefore \quad V_2 = -\frac{y_{fe}}{g_{oe} + G_2}$$

at resonance.

$$\therefore \quad Z_{in} = \frac{V_1}{y_{ie}V_1 - \dfrac{y_{re}\,y_{fe}}{g_{oe} + G_2}V_1} = \frac{1}{y_{ie} - \dfrac{y_{re}\,y_{fe}}{g_{oe} + G_2}}$$

$$\text{or} \quad Y_{in} = y_{ie} - \frac{y_{re}\,y_{fe}}{g_{oe} + G_2}$$

$$= (10 + j10)\times 10^{-3} + \frac{(10\times 10^{-3})(-j.001\times 10^{-3})}{0.1\times 10^{-3} + 10\times 10^{-3}}$$

use complex number calculator

$$Y_{in} \approx (10 + j10)\ m\mho + \underbrace{j.001\ m\mho}_{\text{negligible effect of load}}$$

$$Z_{in} = \frac{1}{Y_{in}} = \frac{1}{10 + j10\ m\mho} = 50 - j50\ \Omega$$

find C_{IN}:
at 50 MHz

$$\frac{1}{j\omega_0 C_{IN}} = -j50$$

$$C_{IN} = \frac{1}{50\ \ 2\pi(50\times 10^6)} = 63.7\ pf$$

what is A_V at resonance?

$$A_V = \frac{V_2}{V_1}$$

$$I_1 = y_{ie}V_1 + y_{re}V_2$$

$$I_2 = y_{fe}V_1 + y_{oe}V_2$$

$$\text{but } I_2 = -\left(j\omega C_2 + \frac{1}{j\omega L_2} + G_2\right)V_2$$

$$\therefore \quad y_{fe} V_1 + y_{oe} V_2 = \left(-j\omega C_2 - \frac{1}{j\omega L_2} - G_2\right) V_2$$

$$V_1 = \frac{\left(-j\omega C_2 - \frac{1}{j\omega L_2} - G_2 - y_{oe}\right) V_2}{y_{fe}}$$

$$A_v = \frac{V_2}{V_1} = \frac{V_2}{\left(-j\omega C_2 - \frac{1}{j\omega L_2} - G_2 - y_{oe}\right) \frac{V_2}{y_{fe}}}$$

$$= -\frac{y_{fe}}{j\omega C_2 + \frac{1}{j\omega L_2} + G_2 + y_{oe}}$$

$$y_{oe} = g_{oe} + j b_{oe} = g_{oe} + \underbrace{j\omega_0 C_{oe}}_{\text{at resonance}}$$

$$= -\frac{y_{fe}}{(G_2 + g_{oe}) + j\underbrace{\left(\omega_0 C_2 + \omega_0 C_{oe} - \frac{1}{\omega_0 L_2}\right)}_{\text{goes to zero at resonance}}}$$

$$\omega_0^2 = \frac{1}{L_2(C_2 + C_{oe})}$$

at resonance

$$A_v = -\frac{y_{fe}}{G_2 + g_{oe}} \qquad y_{fe} = |y_{fe}| e^{j\theta}$$

Since I am only interested in gain use the magnitude

$$|A_v| = -\frac{|y_{fe}|}{G_2 + g_{oe}}$$

to find bandwidth I need to understand how the y-parameters vary with frequency.

For narrow band circuits the y-parameters are usually simple functions of frequency and can be expanded in a Taylor series about ω_o, i.e.

$$y_{ie} = g_{ie} + j b_{ie}$$

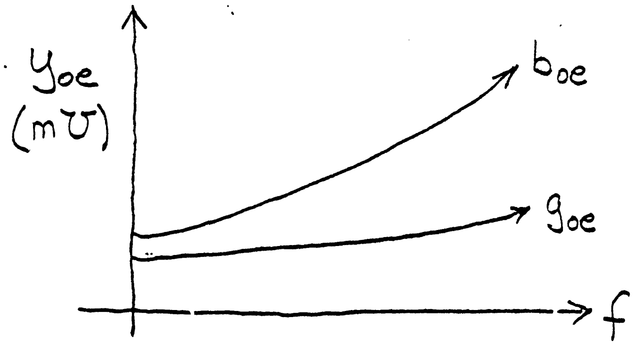
$$\cong g_{ie} + j b_{ie}\Big|_{\omega-\omega_o} + j(\omega-\omega_o)\frac{\partial b_{ie}}{\partial \omega}\Big|_{\omega=\omega_o}$$

In general, b_{ie} will be capacitive at high frequencies and g_{ie} will be independent of frequency (approximately)

For the transistor amplifier

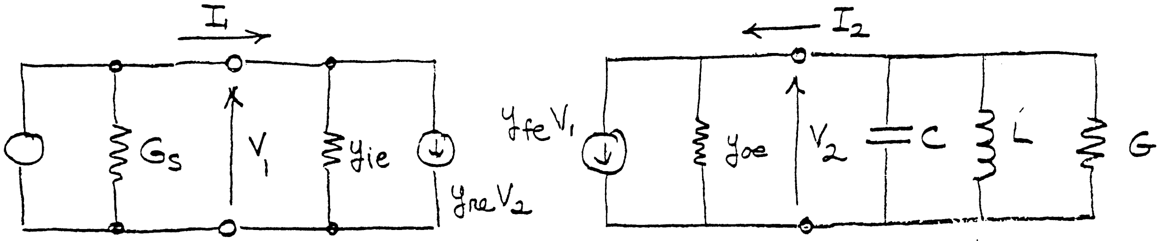
this term is not involved in resonance

$$A_v(f) = -\frac{y_{fe}}{\underbrace{(G_2 + g_{oe})}_{\text{independent of } f} + j\underbrace{(\omega C_2 + b_{oe} - \frac{1}{\omega L_2})}_{\text{only this term is a \underline{sharp} functio[n] near resonance}}}$$



introduction to stability

consider the small signal tuned amplifier shown below

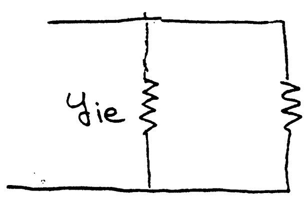


input admittance can be shown to be

$$Y_{IN} = y_{ie} - \frac{y_{fe}\,y_{re}}{y_{oe} + G_L}$$

this was the basic result of our last homework problem

input then looks like



$$-\frac{y_{fe}\,y_{re}}{y_{oe} + G_L} = Y_{MILLER}$$

this is the feedback due to y_{re}.

examine this feedback term

- y_{fe} is usually real (for $f < f_T$)

$y_{re} \cong -j\omega C_{re}$ (due to capacitive nature of feedback

the negative sign is due to the phase inversion between the input and output

$$Y_{MILLER} = -\frac{g_{fe}(-j\omega C_{re})}{y_{oe} + Y_L} = \frac{+j\omega C_{re}\,g_{fe}}{y_{oe} + Y_L}$$

if $f < f_0$ (the resonant frequency of the tank) Y_L is inductiv

$f > f_0$ Y_L is capacitive

for $f < f_o$ $\qquad y_{oe} + Y_L = R - jB$

$$Y_{MILLER} = \frac{j\omega C_{re}\, g_{fe}}{R - jB} \; \frac{R + jB}{R + jB} = -\frac{\omega C_{re}\, g_{fe} B + j\omega R C_{re}\, g_{fe}}{R^2 + B^2}$$

note $Y_{MILLER} < 0$ for $f < f_o$

this can give rise to $\mathrm{Re}(Y_{IN}) < 0$ and will result in oscillation. One way to keep an amplifier from oscillating is to add a suitable positive conductance at the input terminals.

stability : what happens to Y_{IN} with different loads

$$Y_{IN} = y_{11} - \frac{y_{12}\, y_{21}}{y_{22} + Y_L}$$

$$g_{IN} = g_{11}\,\frac{(g_{22}+g_L)^2 + (b_{22}+b_L)^2 - (g_{22}+g_L)\,\mathrm{Re}\,(y_{12}y_{21}) - (b_{22}+b_L)\,\mathrm{Im}\,y_{12}y_{21}}{(g_{22}+g_L)^2 + (b_{22}+b_L)^2}$$

consider two cases

I. $g_L = \infty$ a short circuit

$$g_{IN} \rightarrow g_{11}\,\frac{g_L^2 - g_L\,\mathrm{Re}(y_{12}y_{21})}{g_L^2} \longrightarrow g_{11}$$

simply require $g_{11} > 0$ for stability

II. $g_L = 0$ open circuit

complicated expression

examine $g_{IN,\,MIN}$

minimize $g_{IN,\,MIN}$ by taking $\frac{\partial g_{IN}}{\partial b_L}$ (since $g_L = 0$ don't need it)

result is $g_{11}\, g_{22}^2 - g_{22}\,\mathrm{Re}\,(y_{12}y_{21}) - \frac{\mathrm{Im}\,(y_{12}y_{21})}{4 g_{11}} > 0$

if this is satisified, $g_{IN,\,min} > 0$

III. general case of $Y_L = g_L + jb_L$

minimize g_{IN} by differentiating $\frac{\partial g_{IN}}{\partial g_L}$, $\frac{\partial g_{IN}}{\partial b_L}$

we get $\begin{cases} g_L = 0 \\ b_L = -b_{22} + \dfrac{\mathrm{Im}(y_{12}y_{21})}{2g_{11}} \end{cases}$

as worse case

evaluate $$g_{IN,MIN} = \frac{\left[g_{22} - \dfrac{\mathrm{Re}(y_{12}y_{21})}{2g_{11}}\right]^2 - \dfrac{|y_{12}y_{21}|^2}{4g_{11}^2}}{(g_{22})^2 + \dfrac{[\mathrm{Im}(y_{12}y_{21})]^2}{4g_{11}^2}}$$

for stability $$g_{22} - \frac{\mathrm{Re}(y_{12}y_{21})}{2g_{11}} > \frac{|y_{12}y_{21}|}{2g_{11}}$$

re-write as $$\underbrace{\frac{|y_{12}y_{21}|}{2g_{11}g_{22} - \mathrm{Re}(y_{12}y_{21})}}_{\text{Linvill stability factor usually labeled } C} < 1$$

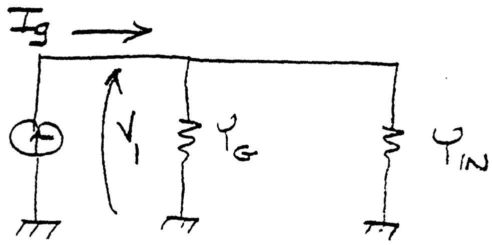
For $0 < C < 1$ a device is <u>unconditionally</u> stable

$C \geq 1$ device is <u>conditionally</u> stable

in terms of C

$$A_{MAG} = 2\,\frac{1 - \sqrt{1 - C^2}}{C^2}\,G_{\infty}$$

where $$G_{\infty} = \frac{|y_{21}|^2}{4g_{11}g_{22} - 2\,\mathrm{Re}(y_{12}y_{21})}$$



$$I_g = Y_G V_1 + y_{IN} V_1$$
$$= (Y_G + y_{IN}) V_1$$

$$\therefore \quad A_T = 4 g_G g_L \frac{|V_2|^2}{|Y_G + y_{IN}|^2 |V_1|^2}$$

$$A_T = \frac{4 g_G g_L}{|Y_G + y_{IN}|^2} \frac{|y_{21}|^2}{|y_{22} + Y_L|}$$

Usually we want to maximize A_T. How?

$$A_T = f(g_G, b_G, g_L, b_L)$$

take partial derivatives with respect to these variables and set all derivatives equal to zero.

$$A_{T,\,MAX} = A_{MAG} = \frac{|y_{21}|^2}{2 g_{11} g_{22} - \mathrm{Re}(y_{12} y_{21}) + \sqrt{(2 g_{11} g_{22} - \mathrm{Re}(y_{12} y_{21})) - |y_{12} y_{21}|^2}}$$

the necessary terminations are

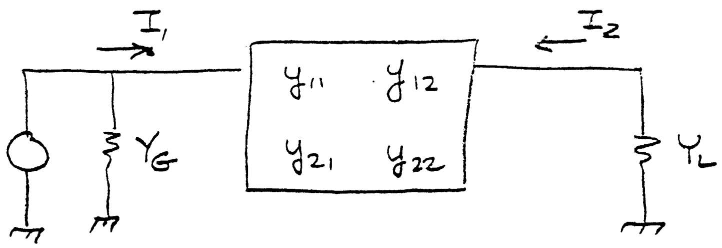
$$g_{LO} = \frac{1}{2 g_{11}} \sqrt{2 g_{11} g_{22} - \mathrm{Re}(y_{12} y_{21})^2 - |y_{12} y_{21}|^2}$$

$$b_{LO} = -b_{22} + \frac{\mathrm{Im}(y_{12} y_{21})}{2 g_{11}}$$

$$g_{GO} = \frac{g_{11}}{g_{22}} g_{LO}$$

$$b_{GO} = -b_{11} + \frac{\mathrm{Im}(y_{12} y_{21})}{2 g_{22}}$$

P. 358 notes amplifier gains in terms of y-parameters



$$\boxed{\begin{aligned} Y_{IN} &= y_{11} - \frac{y_{12}y_{21}}{y_{22}+Y_L} \\ Y_{OUT} &= y_{22} - \frac{y_{12}y_{21}}{y_{11}+Y_G} \end{aligned}}$$

$$\left.\begin{aligned} I_1 &= y_{11}V_1 + y_{12}V_2 \\ I_2 &= y_{21}V_1 + y_{22}V_2 \end{aligned}\right\} \text{from definitions}$$

but $I_2 = -V_2 Y_L$

$$-V_2 Y_L = y_{21}V_1 + y_{22}V_2$$

$$\boxed{\frac{V_2}{V_1} = \frac{-y_{21}}{y_{22}+Y_L}}$$

simple expression for A_P

$$A_P = \frac{P_L}{P_{IN}} = \frac{|V_2|^2 g_L}{|V_1|^2 g_{IN}} = \left|-\frac{y_{21}}{y_{22}+Y_L}\right|^2 \frac{g_L}{g_{11} - Re\left\{\frac{y_{12}y_{21}}{y_{22}+Y_L}\right\}}$$

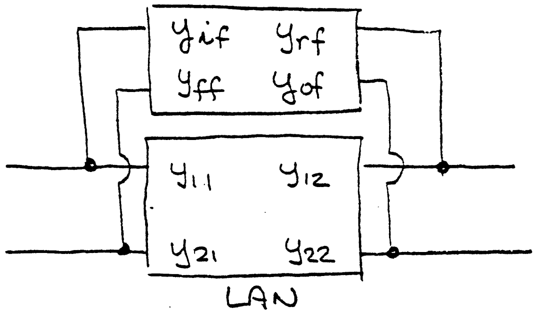
$$A_T = \frac{P_L}{P_{AS}} = \frac{|V_2|^2 g_L}{\frac{|I_g|^2}{4g_G}} = 4g_G g_L \left|\frac{V_2}{I_g}\right|^2$$

get I_g by examining input circuit

unilateralized amplifier :

- use an external feedback network to make a compositie $y_{12} = 0$

- increases input – output isolation

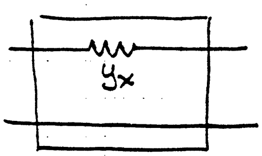


since devices are in parallel.

$$\text{composite } [Y]_c = \underbrace{\begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}}_{\text{LAN}} + \underbrace{\begin{bmatrix} y_{if} & y_{rf} \\ y_{ff} & y_{of} \end{bmatrix}}_{\text{feedback}} = \underbrace{\begin{bmatrix} y_{11}+y_{if} & y_{12}+y_{rf} \\ y_{21}+y_{ff} & y_{22}+y_{of} \end{bmatrix}}_{\text{composite}}$$

for unilateralization want $y_{12} + y_{rf} = 0$

typical feedback element

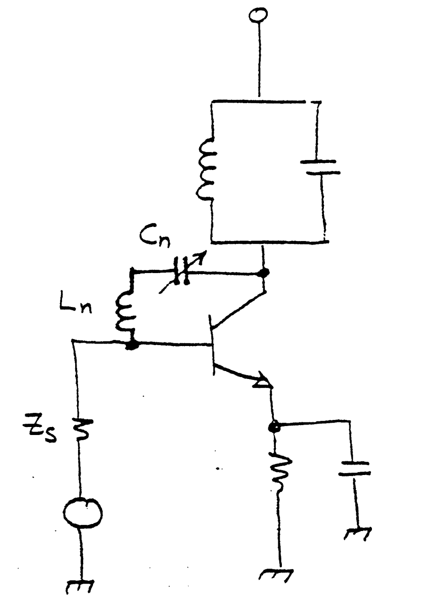


$$[Y]_{feedback} = \begin{bmatrix} y_x & -y_x \\ -y_x & y_x \end{bmatrix}$$

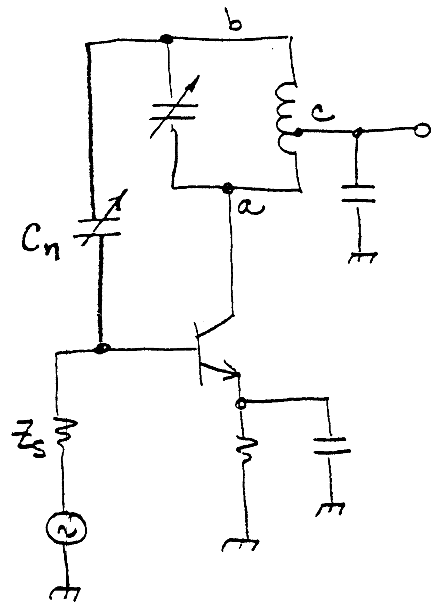
neutralization

just cancel $\mathrm{Im}\, y_{12,\text{composite}}$ for neutralization
real part remains , usually amplifier is stable with just resitive $y_{12,\text{composite}}$

examples of neutralization



tune L_n-C_n to below resonance (inductive) to cancel capacitive feedback from collector to base.

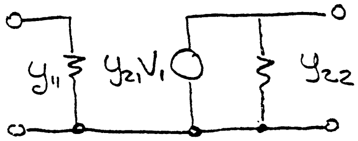


This is a clever circuit. center-tap of transformer (c) provides ground reference. Points (a) and (c) are 180° out of phase ⟹ C_n looks like its phase is <u>inverted</u>, i.e. an inductance to the base of the transistor

few remaining topics

unilateral amplifiers

$y_{12} = 0$ (no feedback)



$$A_{MAG} = \frac{|y_{21}|^2}{2g_{11}g_{22} - Re(y_{12}y_{21}) + \sqrt{[2g_{11}g_{22} - Re(y_{12}y_{21})]^2 - |y_{12}y_{21}|^2}}$$

if $y_{12} = 0$

$$A_{MAG} \to \frac{|y_{21}|^2}{2g_{11}g_{22} + \sqrt{[2g_{11}g_{22}]^2}} = \frac{|y_{21}|^2}{4g_{11}g_{22}}$$

conjugate matching : $Y_L = y_{22}^*$

$$A_P = \frac{|y_{21}|^2 g_L}{\underbrace{|y_{22}+Y_L|^2}_{2g_{22} \text{ since imaginary parts cancel}} g_{IN}} \longrightarrow \frac{|y_{21}|^2 g_{22}}{4g_{22}^2 g_{IN}} = \frac{|y_{21}|^2}{4g_{22}g_{IN}} \equiv G_{oo}$$

G_{oo} is the Linvill figure of merit for a transistor

$$g_{IN} = g_{11} - Re\left[\frac{y_{12}y_{21}}{y_{22}+Y_L}\right] = g_{11} - \frac{Re(y_{12}y_{21})}{2g_{22}}$$

$$= \frac{2g_{11}g_{22} - Re(y_{12}y_{21})}{2g_{22}}$$

$$G_{\infty} = \frac{|y_{21}|^2}{4g_{22}\left[2g_{11}g_{22} - Re(y_{12}y_{21})\right]}$$

maximum unilateral gain

Stern stability factor

suppose we evaluate a transistor for which $C > 1$

$$C = \frac{|y_{12} y_{21}|}{2g_{11} g_{22} - Re(y_{12} y_{21})}$$

We can make this transistor stable by increasing the product $2g_{11}g_{22}$ until $C<1$. This can be done by external loading, i.e. adding g_L and g_G to get

$$g_{11}' = g_{11} + g_G$$

$$g_{22}' = g_{22} + g_L$$

Note: adding g_L and g_G means lowering R_L and R_G so that the stability criteria becomes:

$$\frac{|y_{12} y_{21}|}{2(g_{11} + g_G)(g_{22} + g_L) - Re(y_{12} y_{21})} < 1$$

cross-multiplying:

$$2(g_{11} + g_G)(g_{22} + g_L) - Re(y_{12} y_{21}) > |y_{12} y_{21}|$$

$$2(g_{11} + g_G)(g_{22} + g_L) > |y_{12} y_{21}| + Re(y_{12} y_{21})$$

$$K \equiv \frac{2(g_{11} + g_G)(g_{22} + g_L)}{|y_{12} y_{21}| + Re(y_{12} y_{21})} > 1$$

This is defined to be the Stern stability factor and the terminated device is stable as long as $K>1$.

Typical values might be $K=2$ for a good amplifier

Sensitivity

A final factor is the degree of interaction between the input and output tuned circuits. We define this sensitivity to be

$$S = \frac{\left|\frac{\Delta Y_{IN}}{Y_{IN}}\right|}{\left|\frac{\Delta Y_{OUT}}{Y_{OUT}}\right|} = \frac{\text{fractional change in input}}{\text{fractional change in output}}$$

$$= \frac{\Delta Y_{IN}}{\Delta Y_{OUT}} \frac{Y_{OUT}}{Y_{IN}} = \frac{dY_{IN}}{dY_{OUT}} \frac{Y_{OUT}}{Y_{IN}}$$

we can use our prior results that

$$Y_{IN} = y_{11} - \frac{Re\,(y_{12}y_{21})}{y_{22} + Y_L}$$

$$Y_{OUT} = y_{22} - \frac{Re\,(y_{12}y_{21})}{y_{11} + Y_G}$$

The result of evaluating S is

$$S = \frac{|y_{12}y_{21}|\,|Y_L|}{|y_{22} + Y_L|\,|y_{11}(y_{22} + Y_L) - y_{12}y_{21}|}$$

A good amplifier will have $S \leq 0.3$ We can always lower S by adding resistance (loading) to the LAN, i.e. let

$$y_{11}' = y_{11} + g_G'$$

$$y_{22}' = y_{22} + g_L'$$

This can get complicated to analyze as adding g_G and g_L will change C so a change in loading will change C, S and A_{MAG}

Design with unconditionally stable device

$$[Y] = \begin{bmatrix} 8 + j6.8 & 0 - j0.1 \\ 53 - j22 & 0.4 + j1.5 \end{bmatrix} \qquad \begin{array}{ll} y_i = 8+j6.8 & y_r = 0-j0.1 \\ y_f = 53-j22 & y_o = 0.4+j1.5 \end{array}$$

Evaluate Linvill stability factor

$$C = \frac{|y_f y_r|}{2 g_i g_o - Re(y_f y_r)}$$

$$y_f y_r = (-j0.1)(53 - j22) = -2.2 - j5.3 = 5.74\angle -112.5^\circ$$

$$\therefore C = \frac{5.74}{2(8)(0.4) - (-2.2)} = \frac{5.74}{8.6} = 0.67 < 1$$

$\therefore$ device is unconditionally stable

MAG is the maximum available gain $\left(\begin{array}{l} y_r = 0 \\ \text{source \& load matched} \end{array} \right)$

$$G_T = \frac{4 G_S G_L |y_f|^2}{|(y_i + Y_S)(y_o + Y_L) - y_f y_r|^2}$$

if $y_i = Y_S^*$ $\quad y_o = Y_L^*$ $\quad y_r = 0$

$$G_T = \frac{4 G_S G_L |y_f|^2}{|(2g_i)(2g_o) - 0|^2} = \frac{4 G_S G_L |y_f|^2}{16 (g_i g_o)^2}$$

but $g_i = G_S$, $g_o = G_L$ for conjugate matching

MAG $\quad G_T = \dfrac{|y_f|^2}{4 g_i g_o} =$

$$G_A = \frac{|y_f|^2 G_S}{Re[(y_i y_o - y_f \underbrace{y_r}_{\to 0} + y_o Y_s)(y_i + Y_s)^*]} \leftarrow \text{use other equation}$$

$$= \frac{|y_f|^2 G_S}{Re[\, y_o \underbrace{(y_i + Y_s)(y_i + Y_s)^*}\,]}$$

for conjugate match $\quad y_i = G_S - jB_S$

$$Y_S = G_S + jB_S$$

$$\therefore \; y_i + Y_S = 2G_S$$

$$= \frac{|y_f|^2 G_S}{Re[\, y_o (2G_S)(2G_S)\,]} = \frac{|y_f|^2}{4 \underbrace{G_S}_{g_i} g_o} = \frac{|y_f|^2}{4 g_i g_o}$$

$$\therefore \; G_{MAG} = \frac{|53 - j22|^2}{4(8)(0.4)} = \frac{|57.4|^2}{12.8} = \frac{3294.8}{12.8} = 257$$

how could we neutralize: Need a feed back element

$$-y_x + (-j0.1 m℧) = 0$$

$$\therefore \; y_x = -j0.1 m℧$$

this is an inductance.

composite y parameters $[Y]_c = \begin{bmatrix} 8 + j6.8 - j0.1 & -j0.1 + j0.1 \\ 53 - j22 + j0.1 & 0.4 + j1.5 - j0.1 \end{bmatrix}$

$$= \begin{bmatrix} 8 + j6.7 & 0 \\ 53 - j21.9 & 0.4 + j1.4 \end{bmatrix}$$

note this is neutralized <u>and</u> unilateralized

since $\; y_f = 0$

$$Y_{IN} = 8 + j6.7$$

$$Y_{OUT} = 0.4 + j1.4$$

to maximize gain conjugate match at input & output

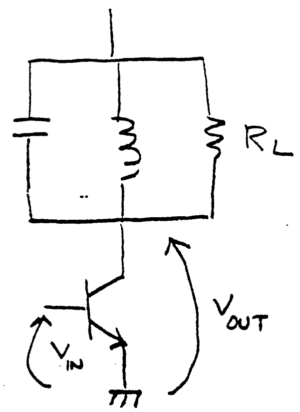
i.e. $Y_S = 8 - j6.7$

$Y_L = 0.4 - j1.4$

maximum transducer gain

$$G_{T,max} = \frac{|y_{f,c}|^2}{4 g_{i,c} g_{o,c}} = \frac{|53 - j21.9|^2}{4(8)(0.4)} = \frac{|57.35|^2}{12.8} = 2\text{:}$$

pole - zero analysis of tuned amplifiers



The gain for such a circuit <u>might</u> be written as

at resonance $A_V(\omega_o) = -g_m V_{IN} R_L$

off resonance $A_V(s) = -g_m V_{IN} \dfrac{1}{G + sC + \frac{1}{sL}}$ where $G = \frac{1}{R_L}$

in general, an amplifier transfer function can be written as

$$\frac{s}{(s-s_1)(s-s_2)}$$

with a single zero at $s=0$ and poles at $s = s_1, s_2$

If we solve $A_V(s)$ for s_1 and s_2 we get

$$s_1, s_2 = -\frac{G}{2C} \pm \sqrt{\left(\frac{G}{2C}\right)^2 - \frac{1}{LC}}$$

If we recognize

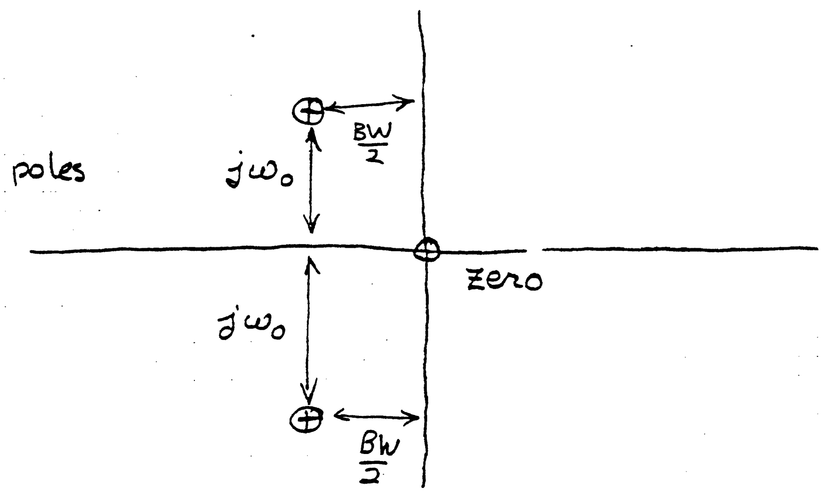
Bandwith $BW = \dfrac{1}{R_L C}$ and $\omega_o^2 = \dfrac{1}{LC}$

then, by substitution,

$$s_1, s_2 = -\frac{BW}{2} \pm \sqrt{\left(\frac{BW}{2}\right)^2 - \omega_o^2}$$

if we have a high-Q circuit where $\frac{\omega_0}{BW} \gg 1$

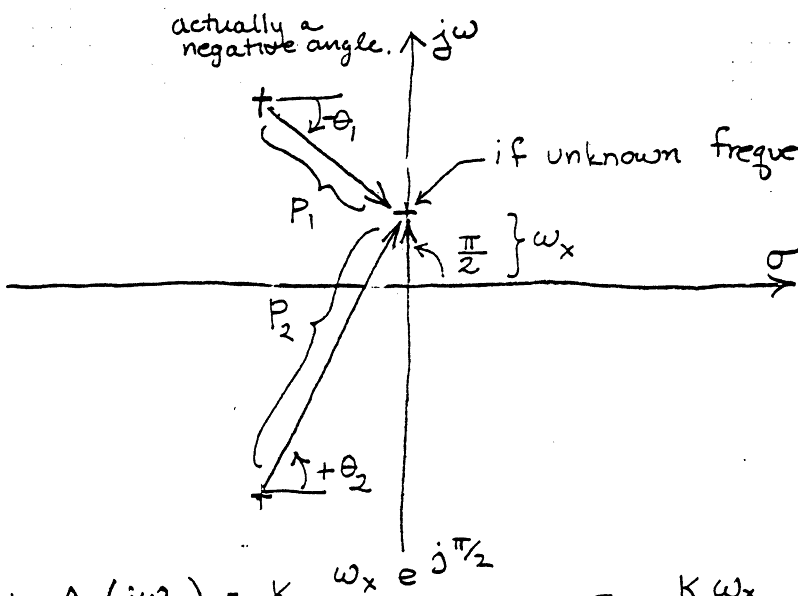
then $s_1, s_2 \approx -\frac{BW}{2} \pm j\omega_0$



If our original transfer function can be re-written

$$A_v(s) = K \frac{Z_1}{(s-s_1)(s-s_2)}$$

where K is a gain constant, and Z_1 is the zero. Then, from the pole-zero diagram.



if unknown frequency is $j\omega_x$ then

$$Z_1 = \omega_x e^{j\pi/2}$$
$$s-s_1 = P_1 e^{j\theta_1}$$
$$s-s_2 = P_2 e^{j\theta_2}$$

Then $A_v(j\omega_x) = K \dfrac{\omega_x e^{j\pi/2}}{P_1 e^{j\theta_1} P_2 e^{j\theta_2}} = \dfrac{K\omega_x}{P_1 P_2} e^{j\frac{\pi}{2} - \theta_1 - \theta_2}$

Notice that as ω_x approaches ω_o (one of the poles) P_1 (or P_2) will decrease in magnitude <u>increasing</u> $A_v(s)$

and near a pole

$$A_v = \frac{K\omega_x}{P_1 P_2} e^{j(\frac{\pi}{2} - \theta_1 - \theta_2)} \cong \frac{K \omega_o}{P_1 \, 2\omega_o} e^{j(\frac{\pi}{2} - \theta_1 - \frac{\pi}{2})} = \frac{K}{2P_1} e^{-j\theta_1}$$

This is called the single pole approximation since everything about the circuit is described by the single pole.

HOW TO ANALYZE TUNED RF AMPLIFIERS

FORMULAS:

Linvill stability factor:

$$C = \frac{|y_{12}y_{21}|}{2g_{11}g_{22}-\mathrm{Re}\{y_{12}y_{21}\}}$$

Stern stability factor:

$$K = \frac{2(g_{11}+G_S)(g_{22}+G_L)}{|y_{12}y_{21}| + \mathrm{Re}\{y_{12}y_{21}\}}$$

Optimum terminations for MAG:

$$g_{LO} = \frac{1}{2g_{11}}\sqrt{2g_{11}g_{22}-[\mathrm{Re}\{y_{12}y_{21}\}]^2-|y_{12}y_{21}|^2}$$

$$g_{SO} = \frac{g_{11}}{g_{22}}\,g_{LO}$$

$$b_{LO} = -b_{22} + \frac{\mathrm{Im}\{y_{12}y_{21}\}}{2g_{11}}$$

$$g_{SO} = \frac{g_{11}}{g_{22}}\,g_{LO}$$

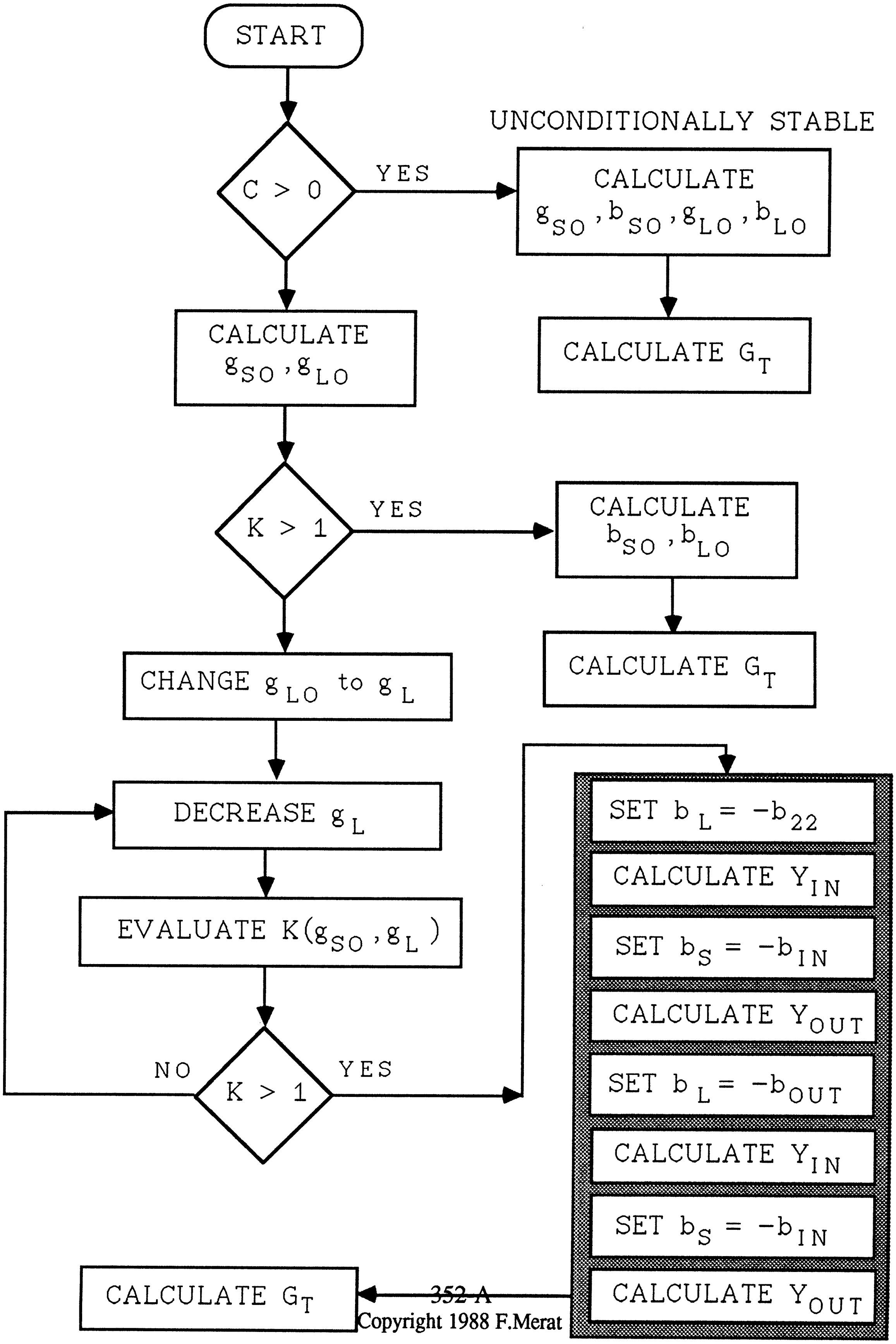
$$b_{SO} = -b_{11} + \frac{\mathrm{Im}\{y_{12}y_{21}\}}{2g_{22}}$$

Transducer gain (general case):

$$G_T = \frac{4G_SG_L\,|y_{21}|^2}{|(y_{11}+Y_S)(y_{22}+Y_L)-y_{12}y_{21}|^2}$$

Maximum available gain (unilateralized and conjugate matched):

$$MAG = \frac{|y_{21}|^2}{4g_{11}g_{22}}$$


START
C > 0
YES
UNCONDITIONALLY STABLE
CALCULATE $g_{SO}, b_{SO}, g_{LO}, b_{LO}$
CALCULATE G_T
CALCULATE g_{SO}, g_{LO}
K > 1
YES
CALCULATE b_{SO}, b_{LO}
CALCULATE G_T
CHANGE g_{LO} to g_L
DECREASE g_L
EVALUATE $K(g_{SO}, g_L)$
NO
K > 1
YES
SET $b_L = -b_{22}$
CALCULATE Y_{IN}
SET $b_S = -b_{IN}$
CALCULATE Y_{OUT}
SET $b_L = -b_{OUT}$
CALCULATE Y_{IN}
SET $b_S = -b_{IN}$
CALCULATE Y_{OUT}
CALCULATE G_T