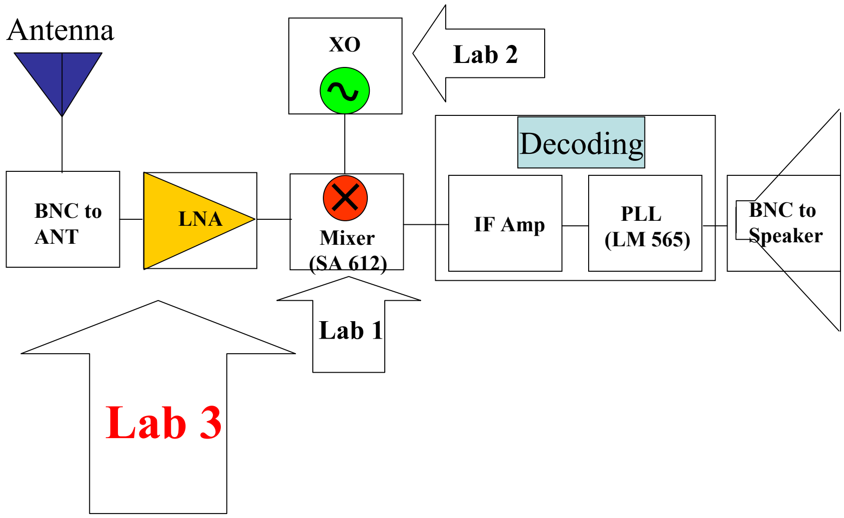
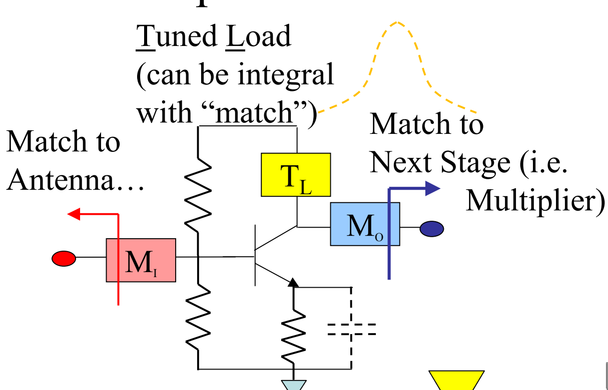
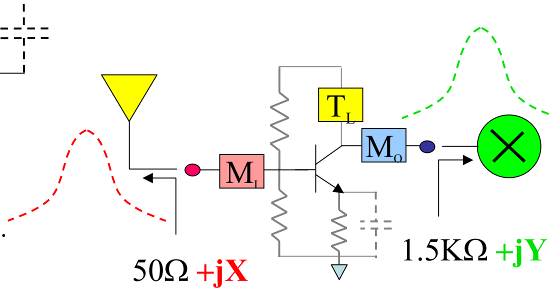
Blocks for SPAM Receiver



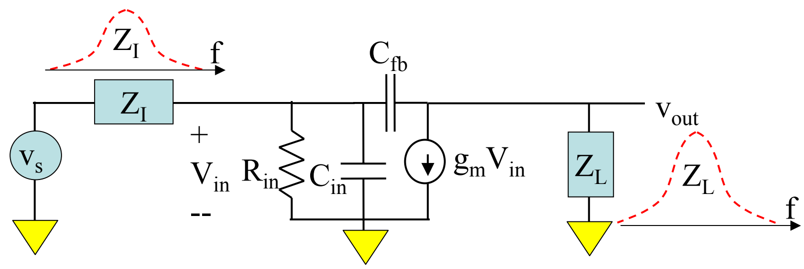
RF Amplifier from Antenna (and "LNA")



What does "Matched" mean? Handout (developed by SPAM "Alumni") shows that conjugate gives maximum power transfer…



Small-Signal View of Amplifier



<u>At low frequencies</u> (neglecting resonance effects) :

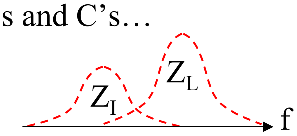
V_{in} = voltage divider (at R_{in})

$V_{out} = -g_m V_{in} R_L$

<u>At high frequencies</u>:

We need to consider both Z(ω)'s and C's…

<u>Look Ahead</u>:
If ω_0 for two Z(ω) are NOT the same…problems



Reminders about ac Parameters

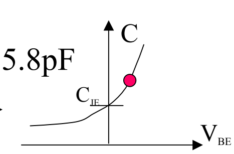
For I_C=5mA, β=80, τ_F=30ps (and other parameters per SPICE deck)

$g_m = qI_C/kT = 0.193$ and $r_\pi = \beta/g_m = 414\Omega$

$C_\pi = C_{JE}(V_{BE}) + g_m\tau_F$

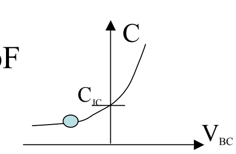
$= 1.3\text{pF } f(V_{BE}) + 5.8\text{pF}$

$\sim 7.1\text{pF}$

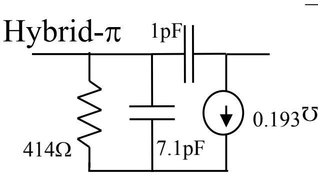


Parameter	Value
β	80
τ_F	30ps
C_{JE}	1.3pF
C_{JC}	1.0pF

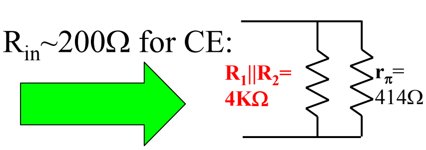
$C_\mu = C_{JC}(V_{BC}) \sim C_{JC} = 1\text{pF}$



Hybrid-π

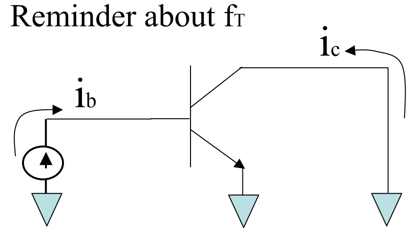


$R_{in}\sim 200\Omega$ for CE:



A quick comment about f_T

Reminder about f_T



$$\frac{i_c(s)}{i_b(s)} = \beta(s)$$

$$at..\omega_T..\beta(s) = 1$$

(a review from EE113 notes…)

$$\beta(s) = \frac{\beta}{1 + s r_\pi (c_\pi + c_\mu)}$$ **<=1/2πf$_{3dB}$**

$$\omega_T = \frac{g_m}{c_\pi + c_\mu}$$ **=2πf$_T$**

(from data sheet)

@20mA g_m=0.772

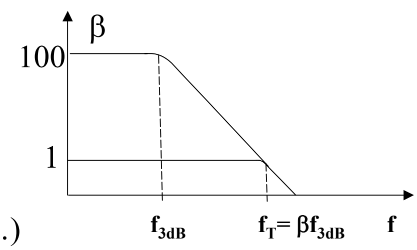
$C_\pi + C_\mu = (0.772)/(2\pi\ 5\times10^9)$

(I.e. f_T)

= 24.6pF

$C_\pi + C_\mu = C_{JE} + C_{JC} + g_m \tau_F$

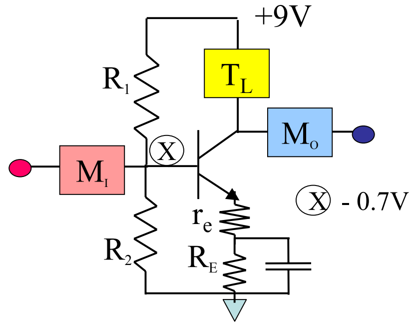
(now check out the SPICE deck…)



<u>About Today's Lecture</u>:

- More on Feedback (**HO#11**)
  (including example with r_e)
- Smith Chart (**HO#10 + #12**)
- Examples on Matching (**HO#10**)
  ✓(Radmanesh examples…<u>HO#8</u>!!)
  ✓<u>Last Year's</u> **MT**…(no HO#…
  solutions in another week)

A Simple (Practice) Biasing Example



Assume I_C=5mA
$I_{R1}=I_{R2}$=0.5mA (a bit big but…)
and Ⓧ=3V

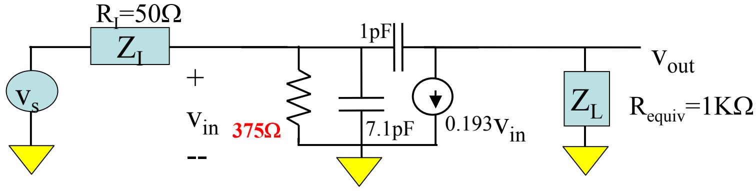
$9V/(R_1+R_2) = 0.5mA$
thus $R_1+R_2 = 18K\Omega$
and given Ⓧ=3V
$R_2 = 6K\Omega$, $R_1 = 12K\Omega$
$R_1||R_2=4K\Omega$

Turning to the I_C biasing
$(3V - 0.7V)/R_E = 5mA$
which in turn gives $r_e+R_E=460\Omega$

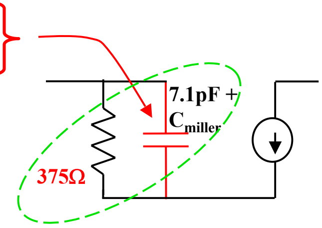
Note: for "fun" you might think about finding R's for **3mA** and **1mA** $=I_C$

Now, moving on the the small-signal (**ac**) modeling...
(we'll continue to consider the matching issues, per the last few lectures, after we address the basic small-signal issues)

Putting these numbers together…



$g_mR_{equiv}=0.193 \times 10^3=193$
$C_{miller}=C_{fb}(1+g_mR_{equiv})=194pF$
$C_{in}=7.1pF$
$v_{in}=v_s\ 375/(375+50)=0.88\ v_s$
$v_{out}= -(194)(0.88)v_s=-171v_s$

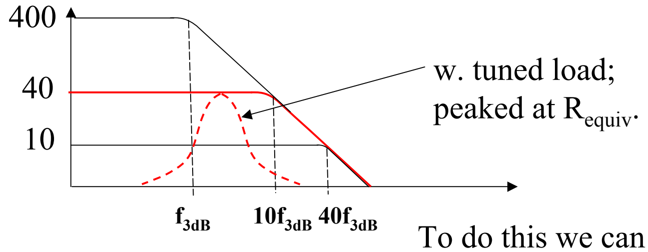


$1/2\pi R_{in}C_T$~2.1 MHz!

Large voltage gain is not always good…
Bandwidth and Low Noise are key metrics…

How do we get modest gain and BW!

Gain-BandWidth-Product (GBP)…trade-off gain for BW*



Comment about Noise (as in LNA):
Resistor (Thermal or Johnson) Noise--
$\overline{v^2}=4kT\,R\,[BW]$
Reduced BW->less total noise
(more about noise soon…)

To do this we can use
FEEDBACK…**
$A_{cl}=A_{ol}/(1+A_{ol}f)$
Where "ol" is "open-loop" and "cl" is "closed-loop"

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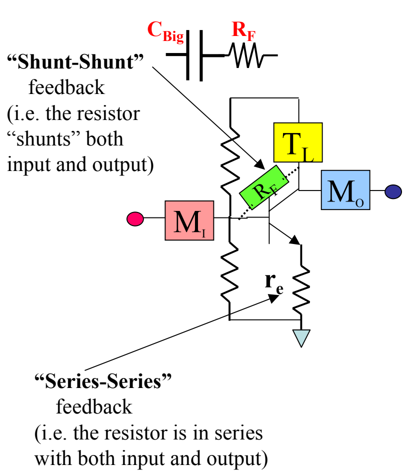
* Assumption: Single-pole roll-off
** For the full story…see Brodersen Notes (UCB :)

FB Configurations and "bottom-line" Results--

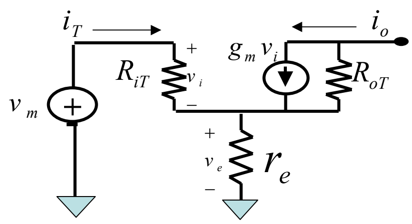
Gain, Resistances and BW



Gain Expressions:
(extreme limiting cases…see supplemental notes for derivations)
A_v(shunt-shunt)~-R_F/R_S
A_v(series-series)~-R_L/r_e
Impedances (either Output or Input) :
Series…$R_{in}|_{o-l}$ [1+T]…$T=A_{ol}f$
Shunt…$R_{in}|_{o-l}$/[1+T]…(same T)
Bandwidth:
$\omega_{3dB}|_{c-l}=\omega_{3dB}|_{o-l}[1+T]$

What is T? ("loop gain")…
(now let's see what this really means!)

Series-Series--Nodal Analysis Results…



Comment: Natural Units are "transconductance gain" i_o/v_{in}

$f = v_{fb}/i_o = r_e$

$$\frac{v_m}{i_T} \approx R_{iT}(1+g_m r_e)$$

$$i_o = \frac{g_m}{(1+g_m r_e)} \cdot v_m$$

$$\frac{v_{Test}}{i_o} \approx R_{oT}(1+g_m r_e)$$

All three terms are "scaled" by:

$$(1+g_m r_e)$$

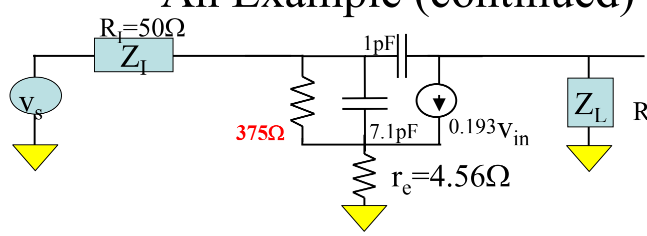
going to A_v…

$$\frac{v_o}{v_m} = \frac{-g_m R_L}{1+g_m r_e}$$

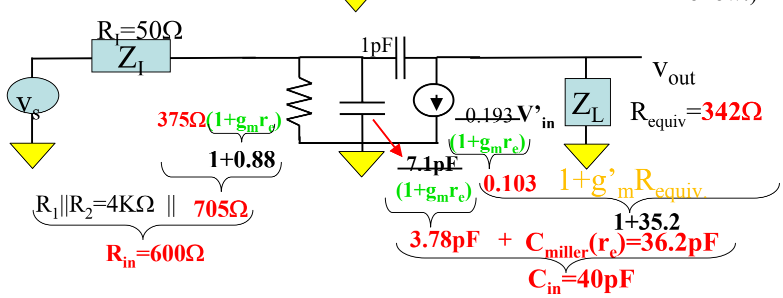
$$\approx \frac{-g_m R_L}{g_m r_e} = \frac{-R_L}{r_e}$$

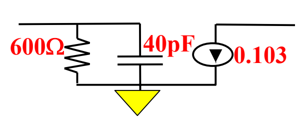
Approximately (if 1 << than the second term in the denominator)

An Example (continued)



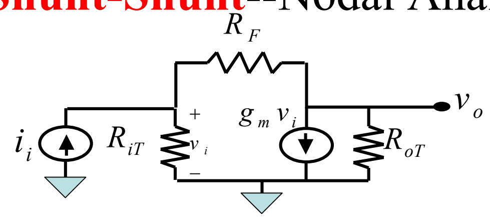
Lower R_{equiv} (motivation to follow:)





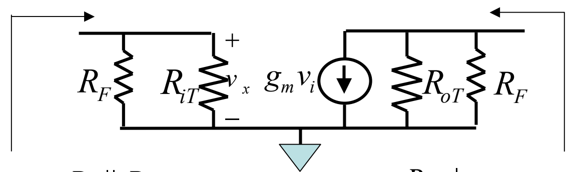
Voltage Gain (w.fb):
-35.2
($-R_{equiv}/r_e$=75)

Shunt-Shunt--Nodal Analysis Results…



Comment: Natural Units are "transresistance gain" v_o/i_{in}

$f = i_{fb}/v_o = 1/R_F$



$R_{in}|_{open-loop} = R_F \,||\, R_{iT}$

$R_{out}|_{open-loop} = R_{oT} \,||\, R_F$

Open-loop

$$v_o = -g_m \left(R_F \,||\, R_{iT}\right)\left(R_{oT} \,||\, R_F\right) \cdot i_i$$

$a = v_o/i_i$

The **"closed-loop"** expressions will then be modified by this expression for 1+T

$$\left[1 + \underbrace{\frac{g_m \left(R_F \,||\, R_{oT}\right)\left(R_F \,||\, R_{iT}\right)}{R_F}}_{af=T}\right] = 1 + T$$

Gain Expression (Shunt-Shunt)

Closed-loop

$$\frac{v_o}{i_i} = \frac{-g_m \left(R_F \,||\, R_{oT}\right)\left(R_{iT} \,||\, R_F\right)}{1 + \dfrac{g_m \cdot \left(R_F \,||\, R_{oT}\right) \cdot \left(R_{iT} \,||\, R_F\right)}{R_F}}$$

$$\frac{v_o}{i_i} \approx -R_F$$

Approximately (if 1 << than the second term in the denominator)

$$i_i = \frac{v_s}{R_S}$$

$$\therefore A_v = \frac{v_o}{v_s} = \frac{v_o}{i_i}\frac{1}{R_S}$$

$$A_v \approx \frac{-R_F}{R_S}$$