Lecture 28: Inspection Analysis & Miller Effect

- **Announcements:**
- HW#9 online and due Friday via Gradescope
- Extend Lab#5 due date by one week
  - Now due Tuesday, Nov. 6, 5 p.m.
- Hopefully, you watched Monday's video lecture
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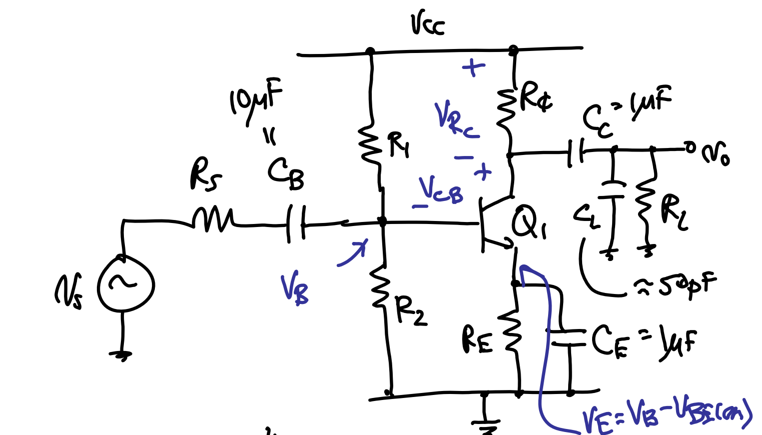
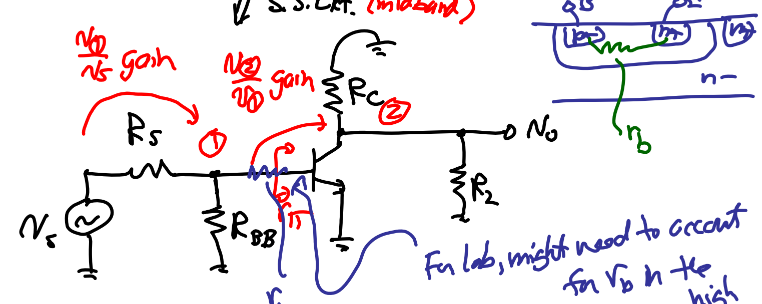
- Lecture Topics:
  - Intro. to Inspection Analysis
  - C.E. Design Project Hints
  - Other Amplifier Configurations
  - Generally-Loaded Transistor
- ------------------------------------
- **Last Time:**
- Started introduction to inspection analysis
- Now continue with this …

Intro. to Inspection Analysis (w/ Lab#5 hints)



⇓ S.S.Ckt. (midband)

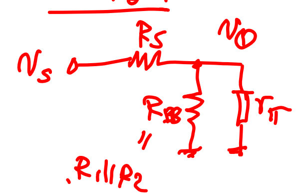


For lab, might need to account for r_b in the high freq. hybrid-π model

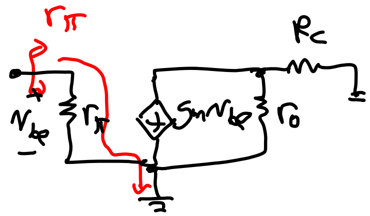
⇒ get gains from node-to-node, then combine.

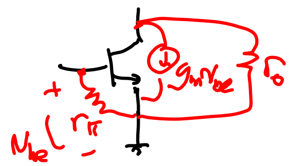
⇒ account for load resistance for each gain calculation for each stage

1st Stage:



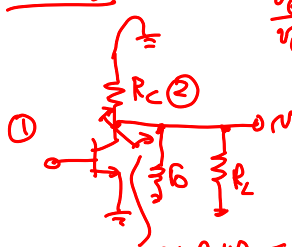
$$\frac{v_1}{v_s} = \frac{r_\pi \| R_{BB}}{R_s + r_\pi \| R_{BB}}$$





2nd Stage:

$\frac{v_{②}}{v_{①}} = \frac{v_o}{v_{①}} = \underbrace{(-g_m(R_c \| R_L))}_{\text{from memory}}$



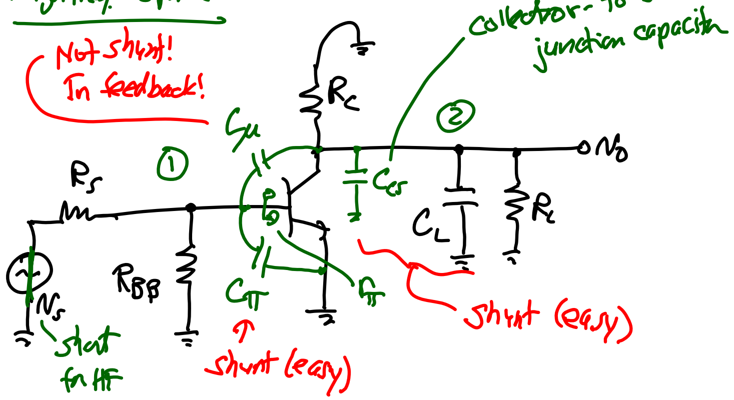
$r_o \| R_c \| R_L = R_c \| R_L$

$[r_o = \text{large}]$

$$\frac{v_o}{v_s} = \frac{v_{①}}{v_s} \cdot \frac{v_o}{v_{①}} = \boxed{-\frac{r_\pi \| R_{BB}}{R_s + r_\pi \| R_{BB}} g_m (R_c \| R_L) = \frac{v_o}{v_s}}$$

High Freq. Response:

Not short! In feedback!



Collector-to-substrate junction capacitance

short for HF

shunt (easy)

shunt (easy)

memorize (maybe)

$$\boxed{\omega_H = \frac{1}{C_\pi R' + (C_L + C_{cs})R'' + C_\mu(R' + R'' + g_m R' R'')}}$$

$\tau_{①}$ $\tau_{②}$ all cap. f/ node ① to gnd

$\tau_{①}$: $\tau_{①} = C_\pi \underbrace{(R_s \| R_{BB} \| r_\pi)}_{\text{all resistance f/ node ① to gnd}} = C_\pi R'$

$\tau_{②}$: $\tau_{②} = \underbrace{(C_L + C_{cs})}_{\text{all cap f/ node ② to ground}} \underbrace{(R_c \| R_L \| r_o)}_{\text{all resistance f/ node ② to gnd}} \simeq (C_L + C_{cs})(R_c \| R_L)$

$= (C_L + C_{cs})R''$

For lab:

$\frac{v_o}{v_s} = -\frac{r_\pi \| R_{BB}}{R_s + r_\pi \| R_{BB}} \underbrace{g_m R_c}$

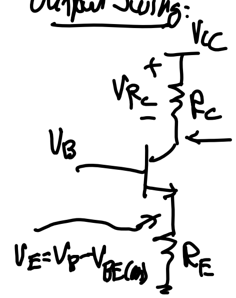
$\frac{I_C}{V_T} R_c = \frac{I_C R_c}{V_T} = \frac{V_{R_c}}{V_T}$

Want more gain $\Rightarrow$ $V_{R_c} \uparrow \rightarrow V_{CB} \downarrow \rightarrow C_\mu \uparrow \rightarrow \omega_H \downarrow$

trade-off

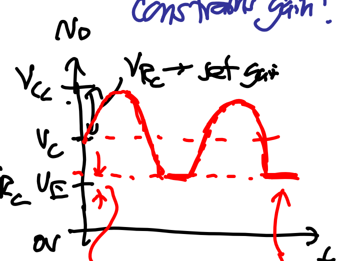
Freq. Response constrains gain!

Output Swing:



$\leftarrow V_c$ set by V_{R_c}

$V_E = V_B - V_{BE(on)}$



$V_{R_c} \rightarrow$ set gain

0.2V = $V_{CE(sat)}$

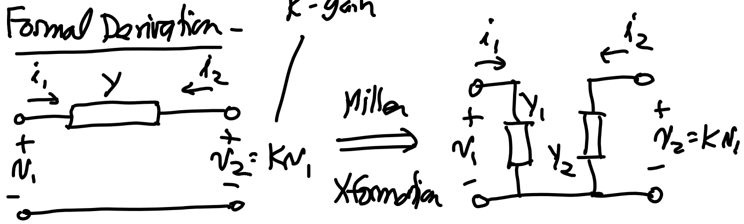
nonlinear clipping

The Miller Effect

⇒ useful to transform a ckt. w/ feedback into a simpler ckt. w/ feedback

Formal Derivation –

K = gain



Find Y_1: (equate i_1 for both ckts.)

(original)

$$i_1 = Y(v_1 - v_2) = Y(v_1 - Kv_1) = Y(1-K)v_1$$

(Miller)

$$i_1 = Y_1 v_1$$

$$\boxed{Y_1 = Y(1-K)}$$

Find Y_2: (equate i_2 for both ckts.)

(original)

$$\left[v_1 = \frac{1}{K}v_2\right] \Rightarrow$$

$$i_2 = (v_2 - v_1)Y = \left(v_2 - \frac{1}{K}v_2\right)Y = \left(1 - \frac{1}{K}\right)Yv_2$$

(Miller)

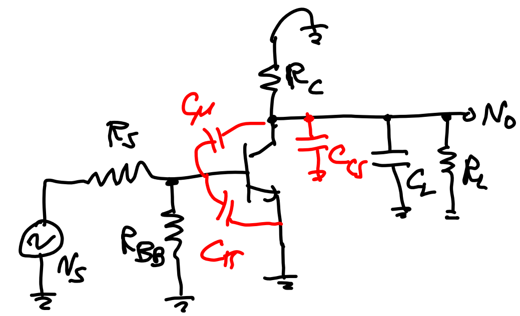
$$i_2 = Y_2 v_2$$

$$\boxed{Y_2 = Y\left(1 - \frac{1}{K}\right)}$$

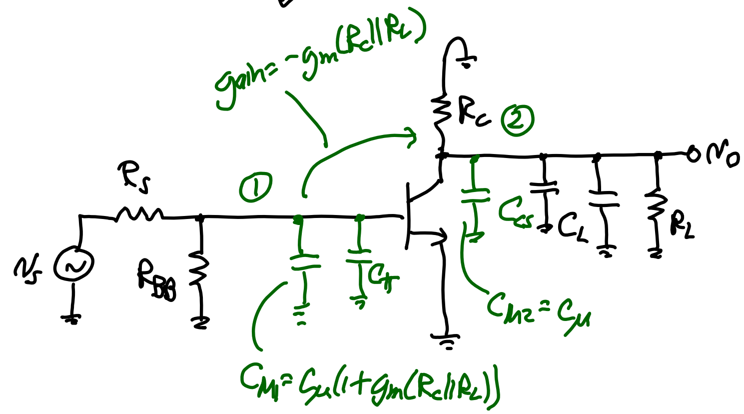
$$C_\mu\left(1 - \frac{1}{\underset{\text{BIG}}{K}}\right) = C_\mu$$

⇒ no longer have FB → easy…

C.E. Inspection Analysis for HF Using the Miller Effect



⇓ Miller Xform



$$\tau_{①} = \left[C_\pi + C_\mu(1 + g_m\underbrace{(R_C \| R_L)}_{R''})\right]\underbrace{(R_S \| R_{BB} \| r_\pi)}_{R'}$$

$$\tau_{②} = (C_L + C_{CS} + C_\mu)\underbrace{(R_C \| R_L)}_{R''}$$

$$\omega_H = \frac{1}{\tau_{①} + \tau_{②}}$$

All terms from previous analysis captured here!
(same answer… no need to deal w/ FB)