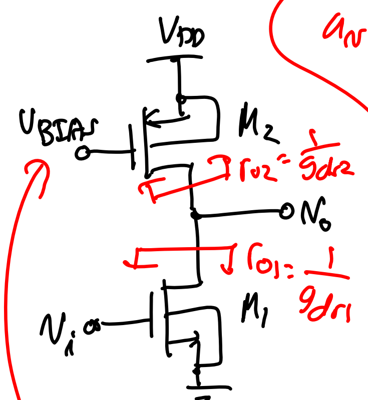
Lecture 8: Active Loads II

- Announcements:
  - HW#3 due tomorrow at 8 a.m.
  - HW#4 will be online soon
  - Labs in session
    - Go to your lab this week
    - Lab update online, plus HSPICE tutorials
- Lecture Topics:
  - Analysis of actively loaded circuits
  - Current Sources
- ------------------------------------
- Last Time:

PMOS Current Source Load



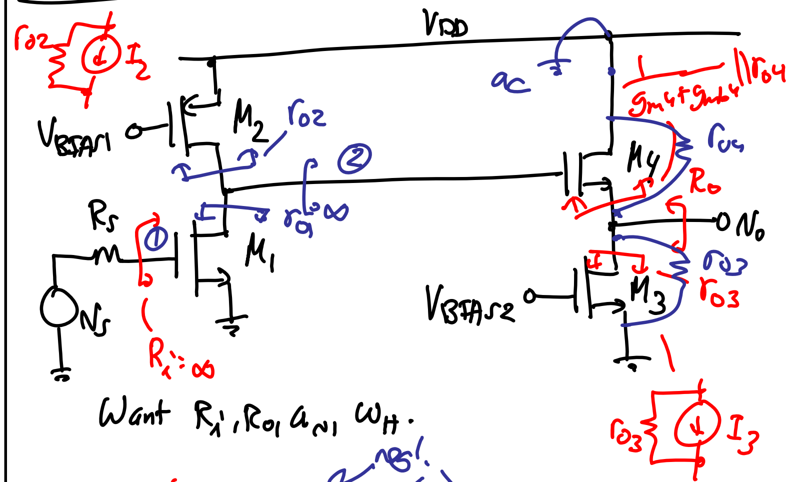
$$a_v = \frac{v_o}{v_i} = -g_{m1}(r_{o1}||r_{o2})$$
$$= -\frac{g_{m1}}{g_{ds1}+g_{ds2}}$$

⇒ gain is huge! (because r_o = huge)

⇒ but requires V_{BIAS}

- We will learn how to provide Vbias later
- For now, consider an example inspection analysis on a circuit with active loads

Ex. Multi-Stage Actively-load MOS Ckt.



Want R_i, R_o, a_v, ω_H.

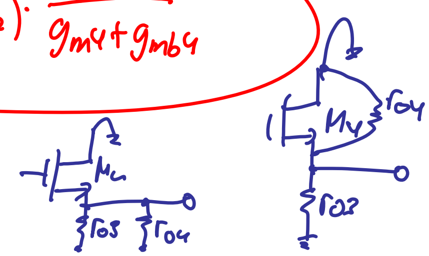
$$R_o = \frac{1}{g_{m4}+g_{mb4}} || \cancel{r_{o4}} || \cancel{r_{o3}}$$

neg! → much larger than $\frac{1}{g_m+g_{mb}}$

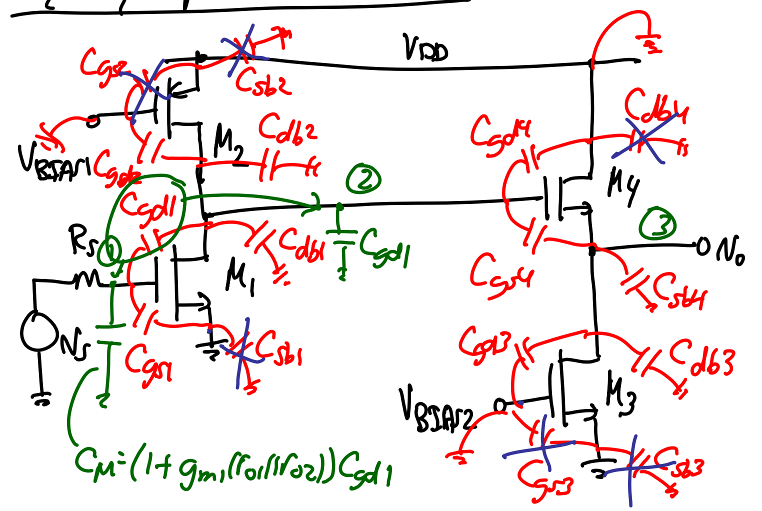
$$a_v = \frac{v_1}{v_s}\cdot\frac{v_2}{v_1}\cdot\frac{v_o}{v_2}$$
$$= (1)\left(-g_{m1}(r_{o1}||r_{o2})\right)\cdot\frac{g_{m4}(\cancel{r_{o3}||r_{o4}})}{\cancel{1+}(g_{m4}+g_{mb4})(\cancel{r_{o3}||r_{o4}})}$$

neg!

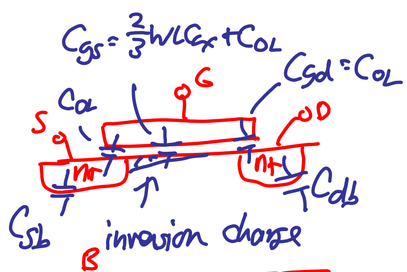
$$a_v = -g_{m1}(r_{o1}||r_{o2})\cdot\frac{g_{m4}}{g_{m4}+g_{mb4}}$$



Frequency Response (HF cut-off)



$C_M = (1+g_{m1}(r_{o1}||r_{o2}))C_{gd1}$



$\tau_1 = \{C_{gs1} + C_{gd1}(1+g_{m1}(r_{o1}||r_{o2}))\}R_S$ include

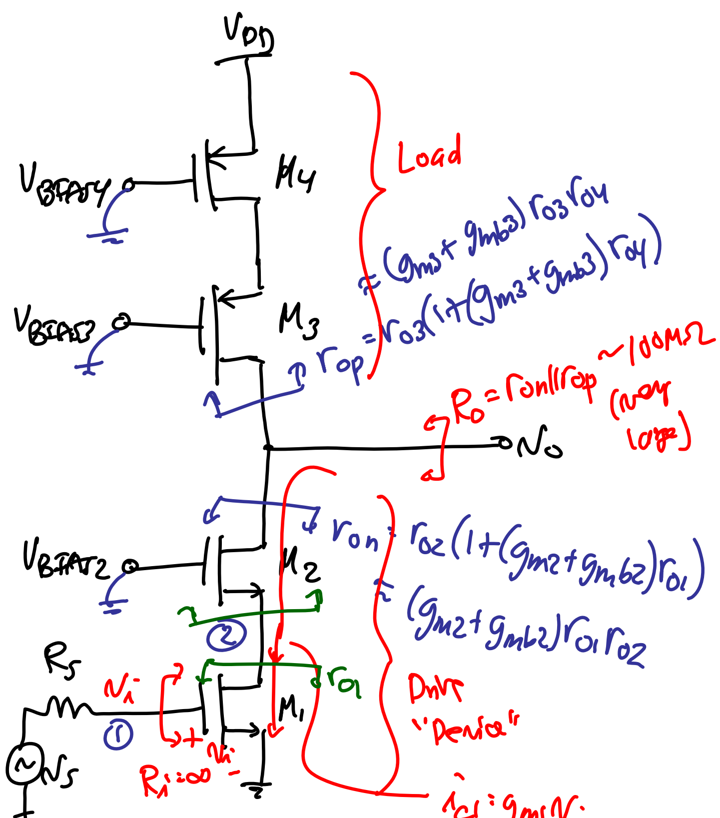
$\tau_2 = \{C_{db1} + C_{db2} + C_{gd2} + C_{gd1} + C_{gd4}\}(r_{o1}||r_{o2})$

$\tau_3 = \{C_{gd3} + C_{db3} + C_{sb4}\}\left(\frac{1}{g_{m4}+g_{mb4}} || \cancel{r_{o3}} || \cancel{r_{o4}}\right)$ not X

$\tau_{gs4} = C_{gs4}\left\{\frac{(r_{o1}||r_{o2}) + (r_{o3}||r_{o4})}{\cancel{1+}(g_{m4}+g_{mb4})(r_{o3}||r_{o4})}\right\} \sim C_{gs4}\left(\frac{2}{g_{m4}+g_{mb4}}\right)$ X

$$\omega_H = \frac{1}{\tau_1 + \tau_2 + \cancel{\tau_3} + \cancel{\tau_{gs4}}}$$

Cascode Drive & Load



$a_v = -G_m R_o = -g_{m1}R_o$

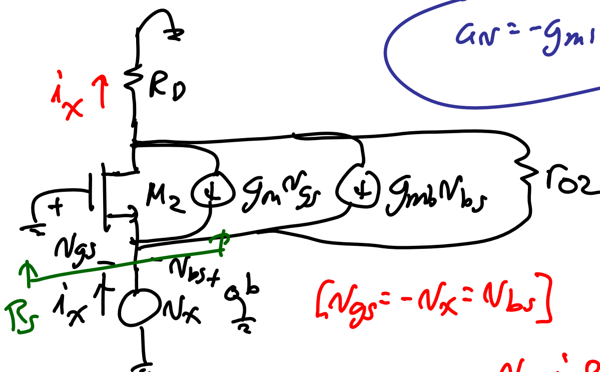
Gain: (node-to-node)

$$a_v = \frac{v_{①}}{v_s}\cdot\frac{v_{②}}{v_{①}}\cdot\frac{v_o}{v_{②}}$$

$$(1)(-g_{m1}R_{②})(G_{m2}R_o)$$

$$-g_{m1}\left(\frac{\cancel{1+r_{op}/r_{o2}}}{\cancel{g_{m2}+g_{mb2}}}\right)\left(\frac{\cancel{g_{m2}+g_{mb2}}}{\cancel{1+r_{op}/r_{o2}}}\right)R_o$$

$$a_v = -g_{m1}R_o$$



$[v_{gs} = -v_x = v_{bs}]$

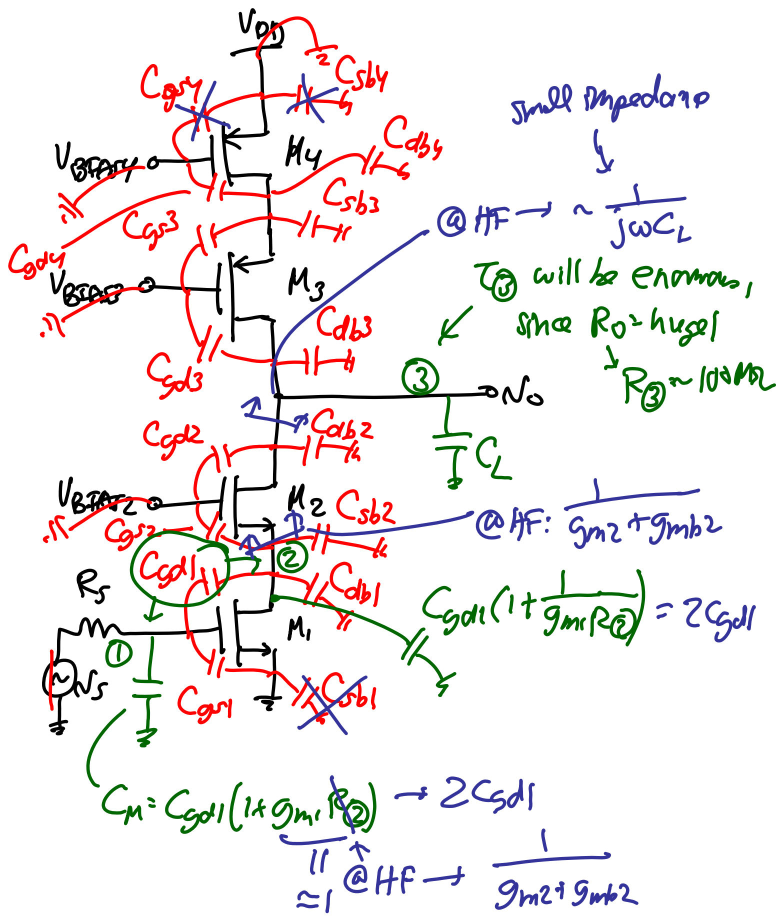
$$i_x = -g_{m2}v_{gs} - g_{mb2}v_{bs} + \frac{v_x - i_xR_D}{r_{o2}}$$

$$i_x\left(1+\frac{R_D}{r_{o2}}\right) = (g_{m2}+g_{mb2})v_x + \cancel{\frac{v_x}{r_{o2}}}$$ neg!

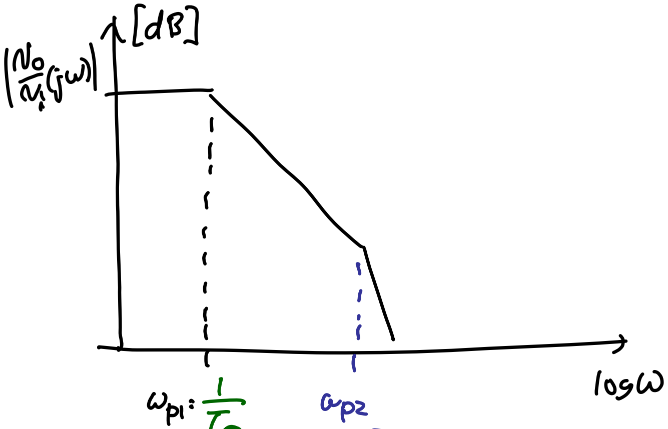
$$R_S = \frac{v_x}{i_x} = \frac{(1+R_D/r_{o2})}{g_{m2}+g_{mb2}} = \frac{1+\frac{g_{m3}r_{o3}r_{o4}}{r_{o2}}}{\underbrace{g_{m2}+g_{mb2}}_{\sim 80k\Omega}} \cancel{\| \underbrace{r_{o1}}_{400k\Omega}}$$ neg!

$$G_{m2} = \frac{i_x}{v_x} = \frac{g_{m2}+g_{mb2}}{1+R_D/r_o}$$

Freq. Response –



$$\tau_{③}: (C_{gd3} + C_{gd2} + C_{db2} + C_{db3} + C_L) R_o$$



midband

$$a_v(s) = |a_v| \cdot \frac{1}{(s+\omega_{p1})} \cdot \frac{1}{(s+\omega_{p2})}$$

$$\omega_{p2} = \frac{1}{\tau_{②}}$$

$$\tau_{②}: (2C_{gd1} + C_{db1} + C_{sb2} + C_{gs2})\left(\frac{1}{g_{m2} + g_{mb2}}\right)$$