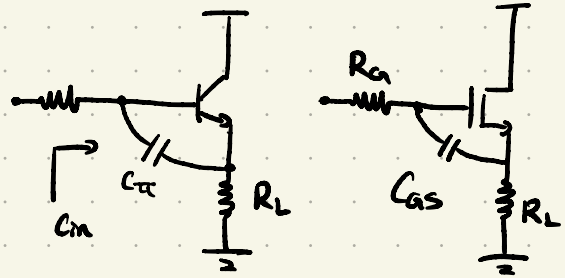
Lec 25

- Output Impedance of Followers
- Freq. Response of Cascodes
- Freq. Response of Diff. Pairs
- The Transit Frequency, f_T

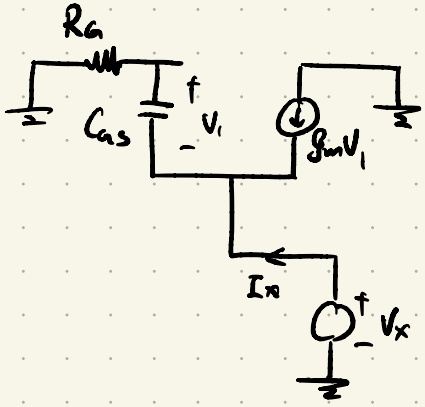
- Review of Lec. 24



① Input cap =

$$\frac{C_\pi}{1+g_m R_L}, \quad \frac{C_{gs}}{1+g_m R_L}$$

② Output Impedance of Source Follower



$$\frac{V_x}{I_x} = Z_{out} = \frac{1 + R_G C_{gs} \cdot s}{C_{gs}\, s + g_m}$$

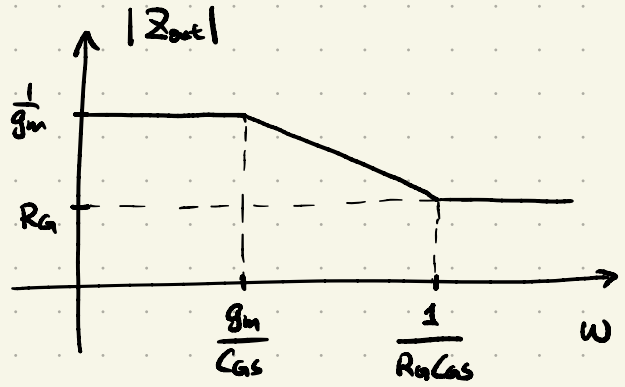
$$\omega_z = \frac{-1}{R_G C_{gs}}$$

$$\omega_p = -\frac{g_m}{C_{gs}}$$

- Let's plot $|Z_{out}|$

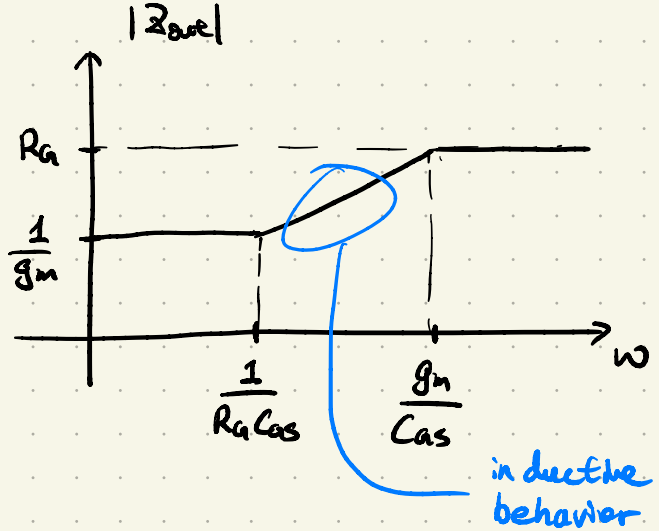
Case I:

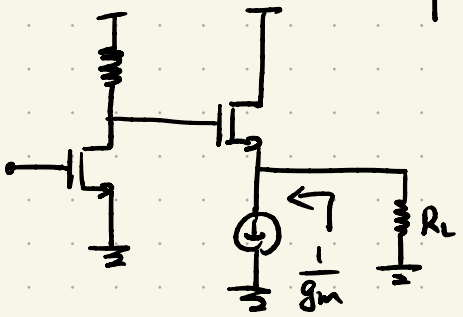
$$g_m < \frac{1}{R_G}$$



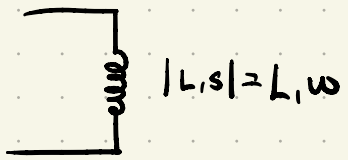
Case II:

$$g_m > \frac{1}{R_G}$$





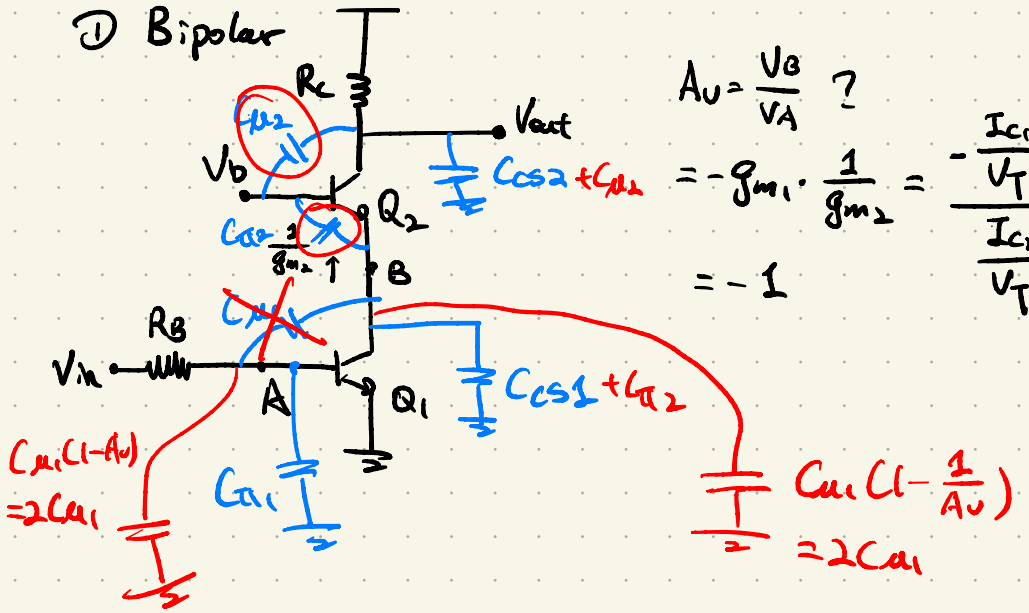
we are interested in the case $\frac{1}{g_m} \ll R_G$ (Case II)



(we can build "active inductor")

• Freq. Response of Cascodes

① Bipolar



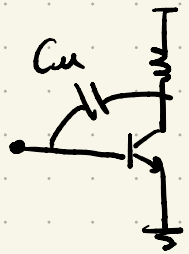
$$A_v = \frac{V_B}{V_A} \; ? \qquad = -g_{m1}\cdot\frac{1}{g_{m2}} = \frac{-\frac{I_{C1}}{V_T}}{\frac{I_{C2}}{V_T}} \qquad = -1$$

$$\omega_{p,A} = \frac{1}{(R_B // r_\pi)\,C(C_{\pi 1}+2C_{\mu 1})}$$

$$\omega_{p,out} = \frac{1}{R_C C(C_{cs2}+C_{\mu 2})}$$

$$\omega_{p,B} = \frac{1}{\frac{1}{g_{m2}}C(C_{cs1}+C_{\pi 2}+2C_{\mu 1})}$$ ⇔ typically very high

Compare with simple CE stage

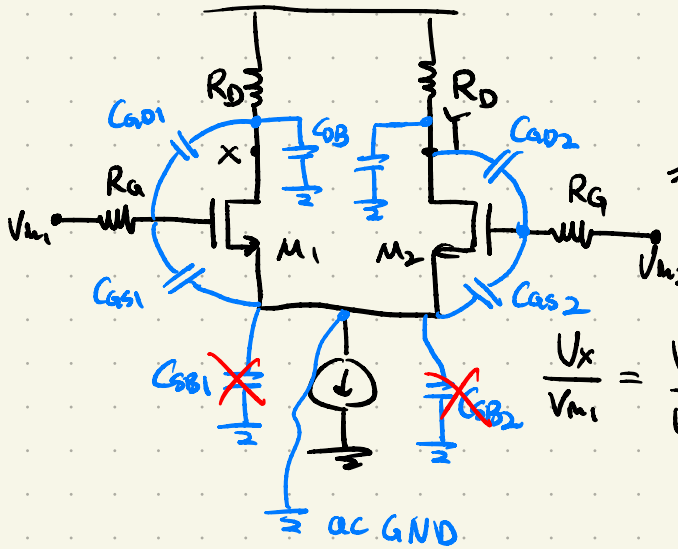


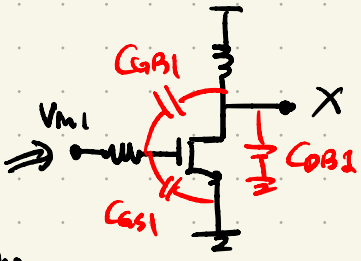
$C_{in} = C_\mu(1+g_m R_C)$

C to ground)

has a greater miller multiplication than cascode structure

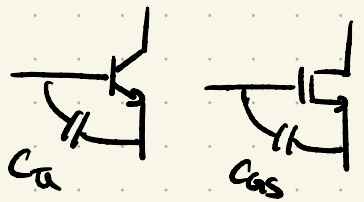
• Freq. Response of Diff. Pairs



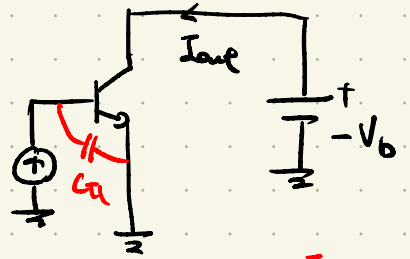


$$\frac{U_x}{V_{in1}} = \frac{V_x - V_Y}{V_{in1}-V_{in2}}$$

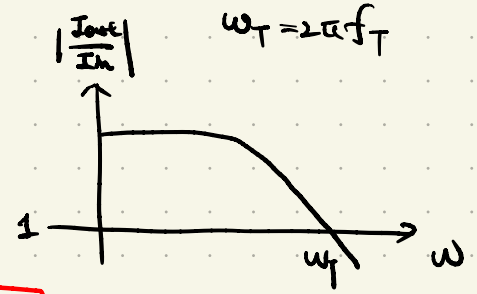
The Transit Freq., f_T: the freq. at which the current gain of the device drop to 1

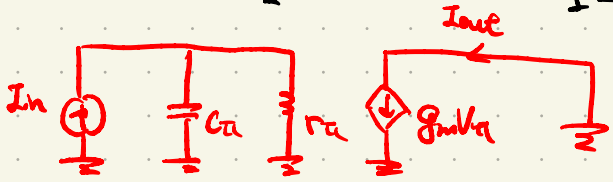


$$\left|\frac{I_{out}}{I_{in}}CS=j\omega_T\right| = 1$$



$\omega_T = 2\pi f_T$





$$\frac{r_\pi}{r_\pi C_\pi S+1}\, g_m I_{in} = I_{out}$$

$$\frac{I_{out}}{I_{in}} = \frac{g_m r_\pi}{r_\pi C_\pi s + 1} \to \beta \qquad \left|\frac{I_{out}}{I_{in}}(s=j\omega)\right|^2 = \frac{\beta^2}{r_\pi^2 C_\pi^2 \omega^2 + 1} = 1$$

$$\Rightarrow \omega_T = \frac{\beta}{r_\pi C_\pi} = \frac{g_m}{C_\pi}$$

MOS: $\omega_T = \frac{g_m}{C_{gs}}$

$$f_T = \frac{g_m}{2\pi C_{gs}}$$

For integrated circuits:

$f_T \approx$ several hundred GHz

Example:

How to maximize f_T?

$$f_T = \frac{\sqrt{2\mu_n C_{ox} \frac{W}{L} I_D}}{2\pi C_{gs}} \uparrow$$

(for MOS)