$$R_i C_\pi \frac{dv_o}{dt} + (1+R_i g_\pi) v_o(t) = -g_m\left(\frac{r_o R_c}{r_o+R_c}\right) v_i(t)$$

If $v_i(t) = V_i e^{st}$ then $v_o(t) = V_o e^{st}$ results if

$$R_i C_\pi s V_o e^{st} + (1+R_i g_\pi) V_o e^{st} = -g_m\left(\frac{r_o R_c}{r_o+R_c}\right) V_i e^{st}$$

as $e^{st} \neq 0$ for all t $\Rightarrow$ can cancel

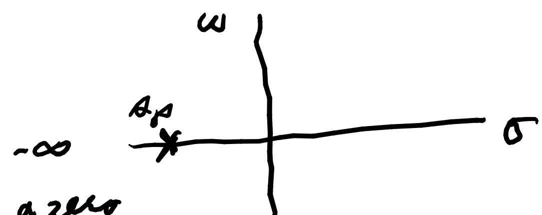
$$\frac{V_o}{V_i} = \frac{-g_m\left(r_o R_c/(r_o+R_c)\right)}{R_i C_\pi s + (1+R_i g_\pi)}$$

this is a function of complex variable

$s = \sigma + j\omega$

has a pole at

$$s_p = -\frac{(1+R_i g_\pi)}{R_i C_\pi}$$



For more physical circuits look at

$$v_o(t) = V_o e^{st} 1(t)$$

$1(t) = \text{unit step} = \begin{cases} 0 & \text{for } t<0 \\ 1 & \text{for } t>0 \end{cases}$

$\delta(t) = d\,1(t)/dt$

on the left

$$R_i C_\pi V_o s e^{st} 1(t) + R_i C_\pi V_o \underbrace{e^{st}\delta(t)}_{\substack{e^{s\cdot 0}\cdot\delta(t) \\ = \\ \delta(t)}} + (1+R_i g_\pi) V_o e^{st} 1(t) = -g_m\left(\frac{r_o R_c}{r_o+R_c}\right) v_i(t)$$

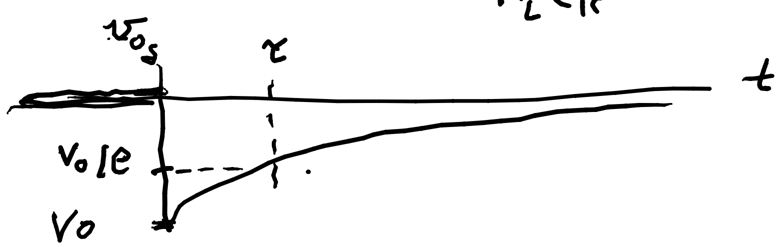
cancel by choosing $s = s_p = -(1+R_i g_\pi)/(R_i C_\pi)$

$$R_i C_\pi V_o \delta(t) = -g_m \frac{r_o R_c}{r_o+R_c} v_i(t) \Rightarrow v_i(t) = \frac{\delta(t)\cdot R_i C_\pi V_o}{-g_m\left(\frac{V_o R_c}{r_o+R_c}\right)}$$

$\Rightarrow$ implies $V_o e^{-\frac{(1+R_i g_\pi)}{R_i C_\pi}\cdot t} 1(t)$ is the impulse response if $V_o = -g_m\left(\frac{r_o R_c}{r_o+R_c}\right) / (R_i C_\pi)$

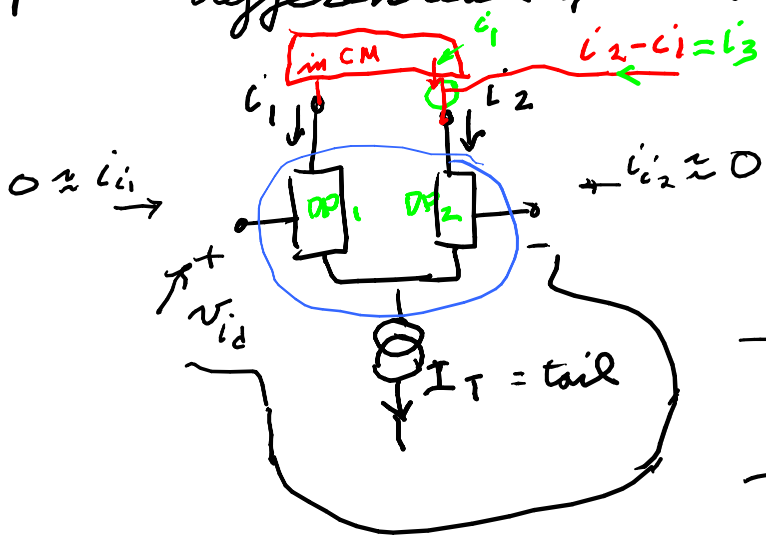
∴ the impulse response is

$$v_{o_s}(t) = -g_m \frac{(r_o R_c/(r_o+R_c))}{R_i C_\pi}\, e^{-\frac{(1+R_i g_\pi)}{R_i C_\pi}\cdot t}\, 1(t)$$



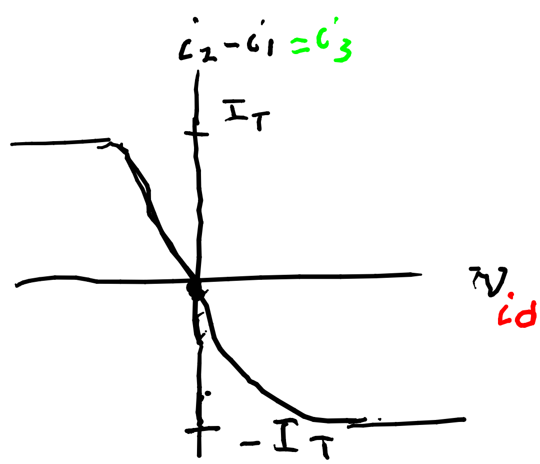
$$\tau = \frac{R_i C_\pi}{1+R_i g_\pi} = \text{time constant}$$

Next topic: differential pairs



KCL: $0 = i_1 - i_2 + i_3$

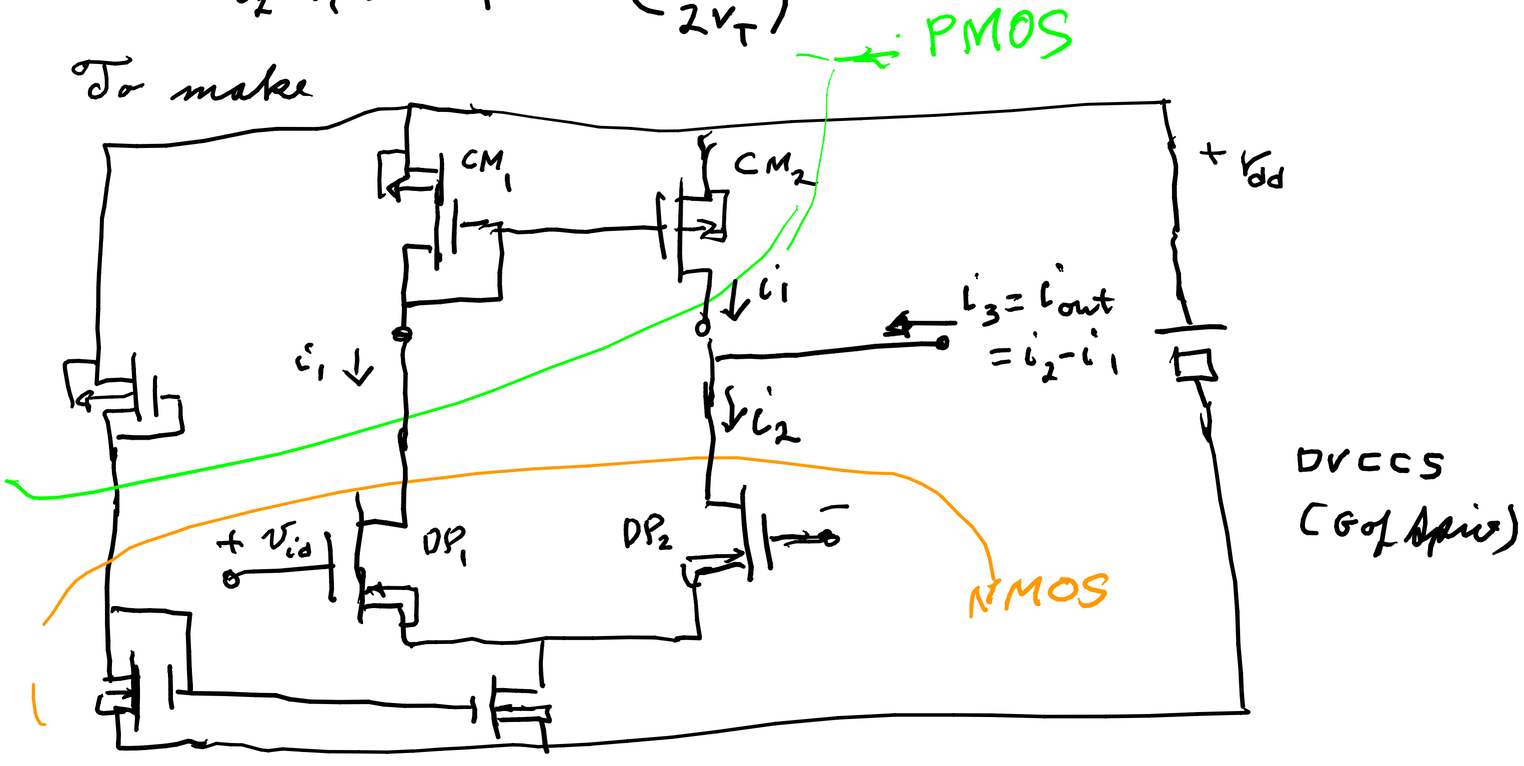
$I_T = i_1 + i_2$



if DP's are BJT then

$$i_2 - i_1 = -I_T \tanh\left(\frac{v_{id}}{2V_T}\right)$$

To make



To put symmetric loads on DP_1 & DP_2