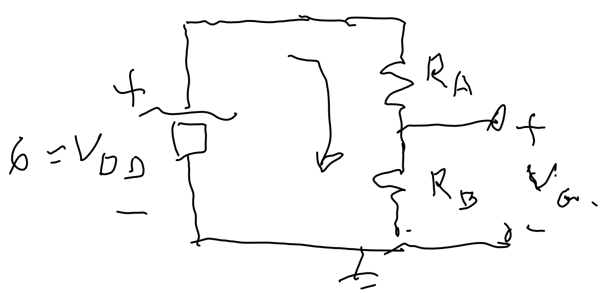
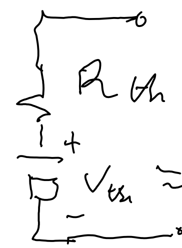
ENEE 303
03/05/19

chapter 9 = differential pairs
chapter 10 = frequency response



$\Rightarrow$

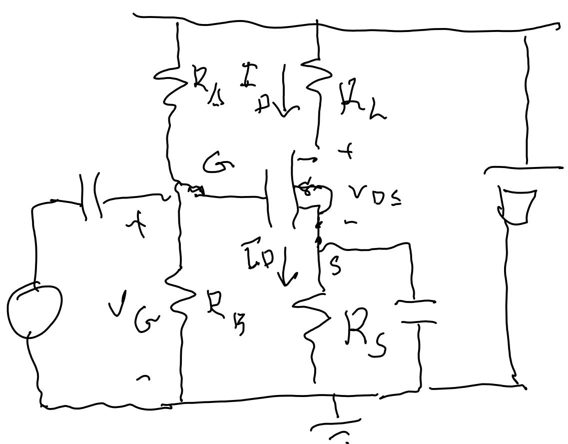


$R_{th} = \dfrac{V_{OC}}{I_{SC}} = \dfrac{R_A R_B}{R_A + R_B}$ $I_{SC}\Big|_{v_G = 0} = \dfrac{V_{DD}}{R_A}$, $V_{OC} = \dfrac{R_B}{R_A + R_B} \cdot V_{DD}$

$V_{th} = \dfrac{R_B}{R_A + R_B} \cdot V_{DD}$ = OC voltage (open circuit)

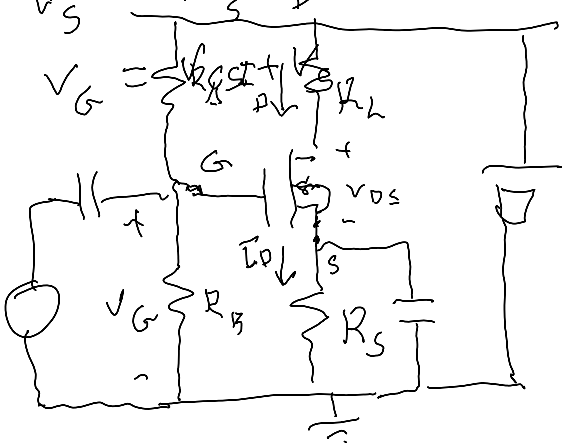
$= \dfrac{1}{1 + \frac{R_B}{R_A}} \cdot V_{DD}$

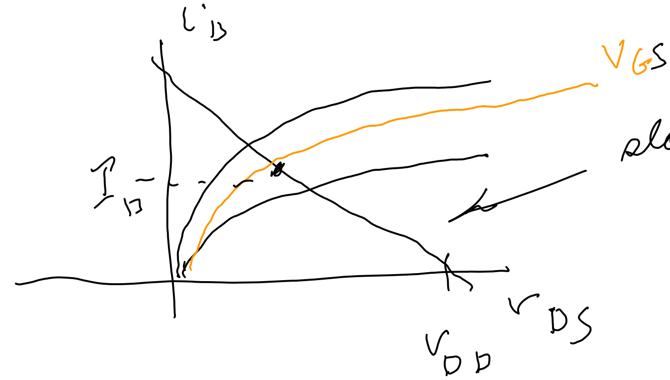
can choose one of R_A & R_B



$V_S = R_S I_D$

$V_G = V_{GS} + V_S$

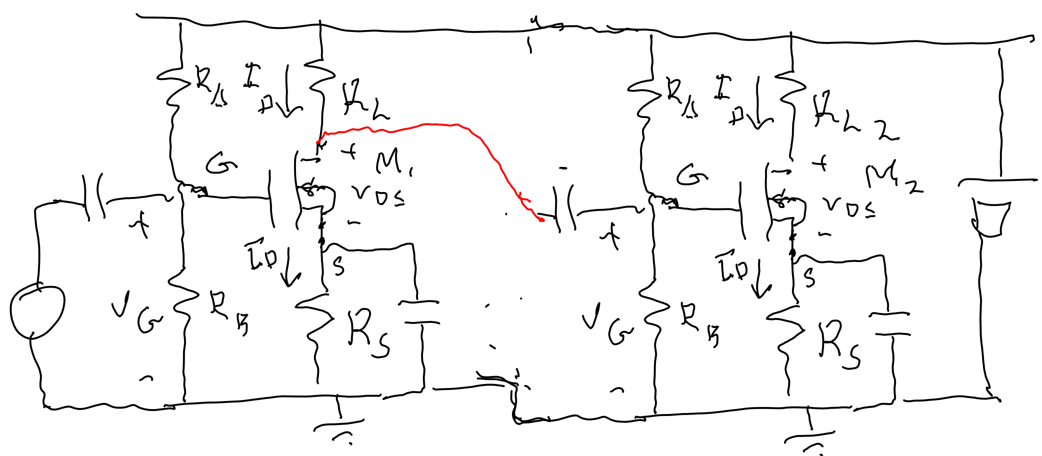




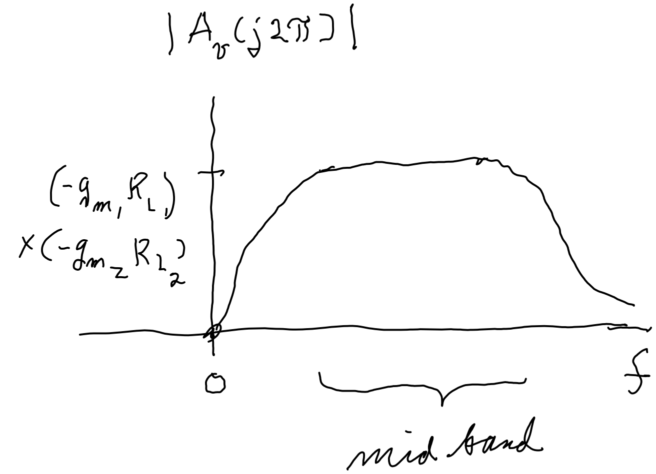
$slope = \frac{1}{R_L + R_S}$

$gain = A_v = -g_m R_L = -8$

$I_D = k(V_{GS} - V_{TO})^2$; $g_m = 2k(V_{GS} - V_{TO}) = \frac{2 \cdot I_D}{V_{GS} - V_{TO}}$

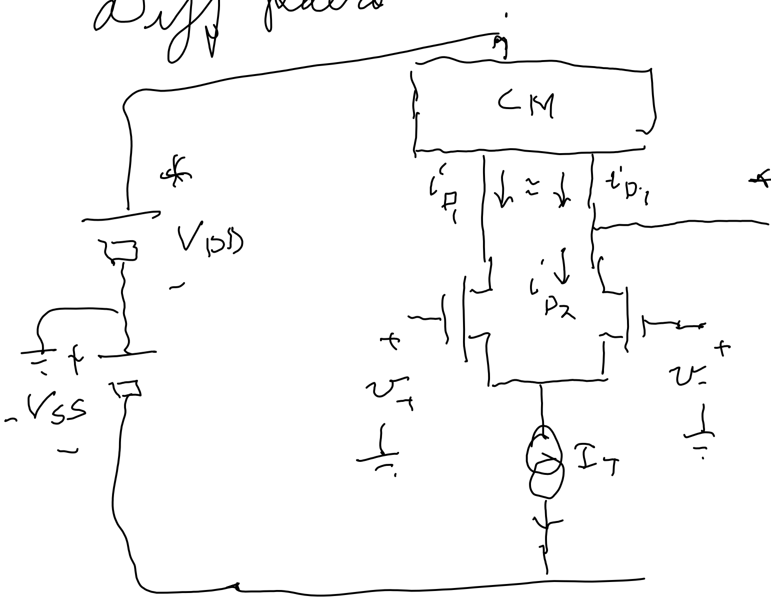


R_1 I_D R_L
G
$+$ M_1
v_{DS}
$-$
$+$
v_G
$-$
R_2
I_D
S
R_S
R_1 I_D R_{L2}
G
$+$ M_2
v_{DS}
$-$
$+$
v_G
$-$
R_2
I_D
S
R_S



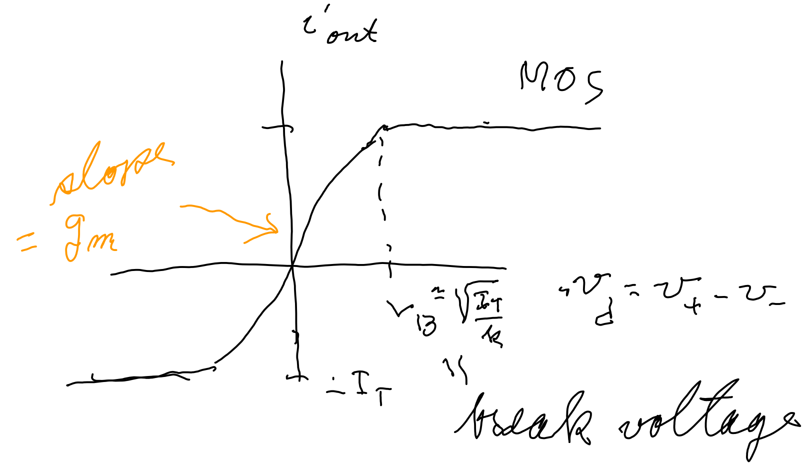
$|A_v(j2\pi f)|$
$(-g_{m_1}R_{L_1})$
$\times(-g_{m_2}R_{L_2})$
0
f
mid band

Diff pairs



$i_{out} = i_{D_2} - i_{D_1}$

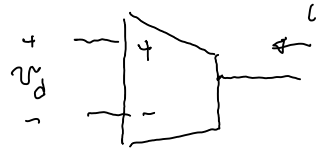
$I_T > 0$



if diff pair is BJT

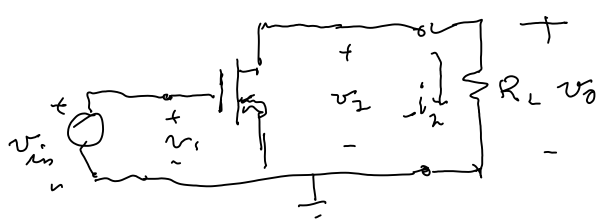
$i_d = I_T \tanh(v_d/2V_T)$; $g_m = I_T \left(1 - \tanh^2 \frac{v_d}{2V_T}\right) \frac{1}{2V_T} = I_T/2V_T$ @ $v_d = 0$

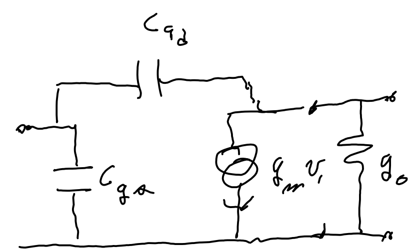
gives a multiplier if vary I_T



$i_o = g_m v_d$ for small signals

return to CS amplifier for frequency response





$$Y \Rightarrow \begin{bmatrix} s(C_{gs}+C_{gd}) & -sC_{gd} \\ g_m - sC_{gd} & g_o + sC_{gd} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} i_1 \\ i_2 = -\frac{v_2}{R_L} = -G_L v_2 \end{bmatrix}$$

$$(g_m - sC_{gd})v_1 + (g_o + sC_{gd})v_2 = -G_L v_2$$

$$A_v(s) = \frac{v_2}{v_1} = \frac{v_{out}}{v_{in}} = \frac{g_m - sC_{gd}}{-((g_o + G_L) + sC_{gd})} \Rightarrow s = d/dt \; ; \; i_c = \frac{d(Cv_c)}{dt} = C\frac{dv_c}{dt} = Cs \cdot v_c$$

$$\left[(g_o + G_L) + s\,C_{gd}\right] v_2 = -(g_m - s\,C_{gd})\,v_1 \quad\Longrightarrow\quad \underbrace{C_{gd}\frac{dv_2}{dt} + (g_o+G_L)\,v_2 = C_{gd}\frac{dv_1}{dt} - g_m v_1}_{\text{ODE}}$$

$$\left(s \to \frac{d}{dt}\right)$$

Look for solutions

$$v_1(t) = V_1 e^{st}, \quad V_2 e^{st} = v_2(t)$$

$$-\infty < t < \infty$$

$$C_{gd} V_2 s e^{st} + (g_o+G_L) V_2 e^{st} = C_{gd} V_1 s\, e^{st} - g_m V_1 e^{st}$$

$$\left(s C_{gd} + (g_o+G_L)\right) V_2 \cancel{e^{st}} = (C_{gd}\cdot s - g_m)\, V_1 \cancel{e^{st}}$$

as $e^{st} \neq 0 \;\forall$ finite time

$$\Longrightarrow \frac{V_2}{V_1} = A_v(s)$$

But $e^{st} = e^{(\sigma + j\omega t)} = e^{\sigma t}(\cos\omega t + j\sin\omega t) \Longrightarrow$ now $s = \sigma + j\omega$ = complex frequency

$$A_v(j\omega) = \frac{j\omega C_{gd} - g_m}{j\omega C_{gd} + (g_o + G_L)} = |A_v(j\omega)|\, e^{j\angle A_v(j\omega)} \Longrightarrow |A_v(j\omega)|^2 = \frac{\omega^2 C_{gd}^2 + g_m^2}{\omega^2 C_{gd}^2 + (g_o+G_L)^2} = \frac{|\text{num}|^2}{|\text{den}|^2}$$

But also $\mathcal{L}[f] = \int_{-\infty}^{\infty} f(t) e^{-st} dt$; $d_1 \frac{dv_2}{dt} + d_0 v_2 = n_1 \frac{dv_1}{dt} + n_0 v_1$

$$\mathcal{L}\left[d_1 \frac{dv_2}{dt}\right] + \mathcal{L}[d_0 v_2] = d_1 \mathcal{L}\left[\frac{dv_2}{dt}\right] + d_0 \mathcal{L}[v_2] = d_1 s \mathcal{L}[v_2] + d_0 \mathcal{L}[v_2] = (d_1 s + d_0)\mathcal{L}[v_2]$$

$$= n_1 s \mathcal{L}[v_1] + n_0 \mathcal{L}[v_1] \Rightarrow \frac{\mathcal{L}[v_2]}{\mathcal{L}[v_1]} = \frac{s C_{gd} - g_m}{s C_{gd} + (g_0 + G_L)}$$

now s is a complex variable $s = \sigma + j\omega$