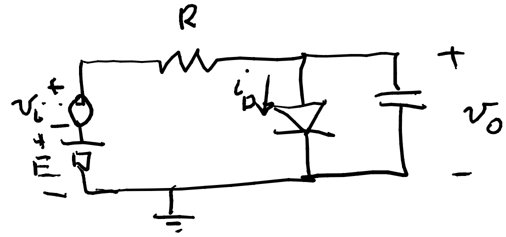
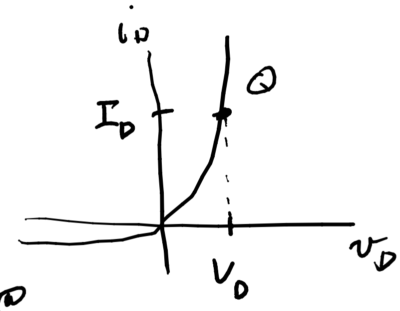
EE 303 H
02/12/09



$|v_i| << E$

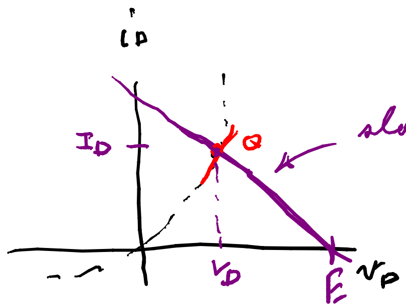


$$I_D = I_S\left(e^{V_D/V_T} - 1\right)$$

$$V_T \ln\left(\frac{I_D}{I_S} + 1\right) = V_D \quad , \quad V_T = \frac{kT}{|q|} \approx 26\,mV \text{ @ room T}$$

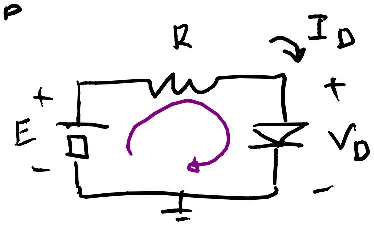
I_S a constant for a given diode

$|q|$ = electronic charge



$$i_{cap} = C\,\underbrace{\frac{dv_{cap}}{dt}}_{\text{zero for bias}}$$

for bias



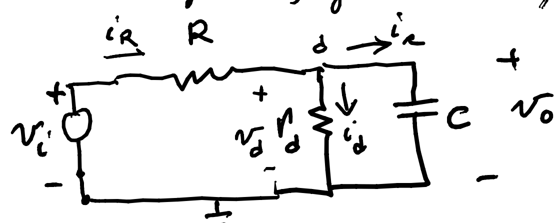
$$E = RI_D + V_D$$

$$I_D = \frac{E - V_D}{R}$$

$$R = \frac{E - V_D}{I_D}$$

$$R = -\frac{dV_D}{dI_D}$$

for signal (small signal) for v_i & for changes



$$i_D = I_D + \frac{\partial i_D}{\partial v_D}\bigg|_Q \underbrace{(v_D - V_D)}_{v_d} + \cdots \Rightarrow i_d = g_d \cdot v_d$$

$$i_D - I_D = i_d$$

$$g_d = \frac{\partial i_D}{\partial v_D}\bigg|_Q \approx \frac{I_D}{V_T}$$

$$r_d = \frac{1}{g_d}$$

$v_i = R i_R + v_o$ KVL $v_o = v_d$

$= R(i_d + i_c) + v_o$ KCL $i_R = i_d + i_c$

$= R g_d v_d + R i_c + v_o$

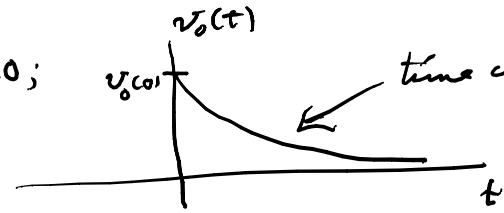
$= R g_d v_o + RC \frac{dv_o}{dt} + v_o$

$= (1+Rg_d) v_o + RC \frac{dv_o}{dt}$ $v_o(0)$ given

$$V_i(s) = (1+Rg_d)V_o(s) + RC\, s\, V_o(s)$$

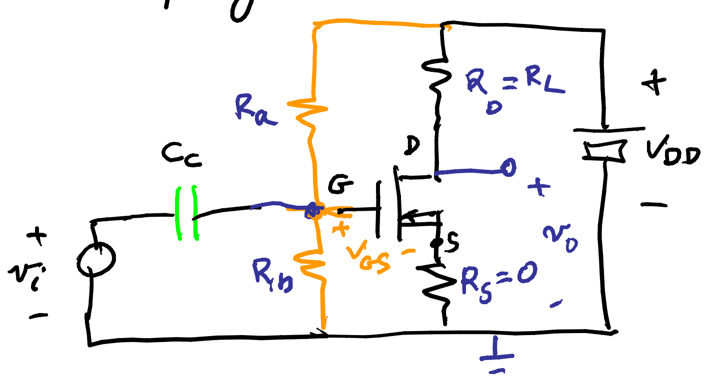
$$\frac{V_o(s)}{V_i(s)} = \frac{1}{RCs + (1+Rg_d)} = \frac{1/RC}{s + \frac{(1+Rg_d)}{RC}}, \quad s = \sigma + j\omega$$

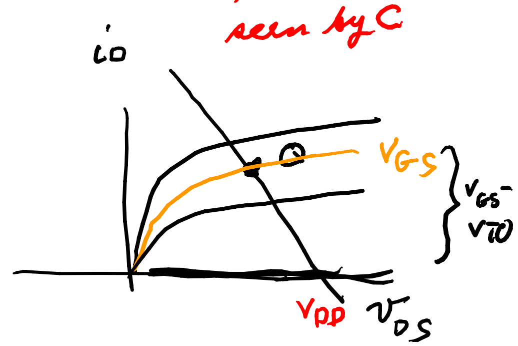
If $v_i = 0$;



time constant $\frac{R}{1+Rg_d}\cdot C = \underbrace{\frac{1}{\frac{1}{R}+\frac{1}{r_d}}}_{\text{parallel resistance seen by C}}\cdot C$

MOS amplifier

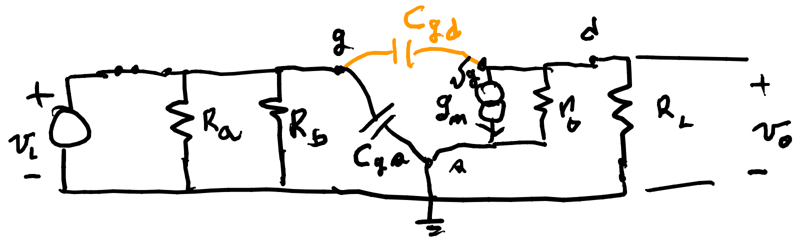




$$V_{GS} = \frac{R_b}{R_a+R_b} V_{DD} \text{ if } R_S = 0$$

$Z_c(s) = \frac{1}{sC_c}$ if $s = j\omega \to |Z_c(j\omega)| = \frac{1}{\omega C_c}$ choose C_c large to allow signal frequencies to pass through

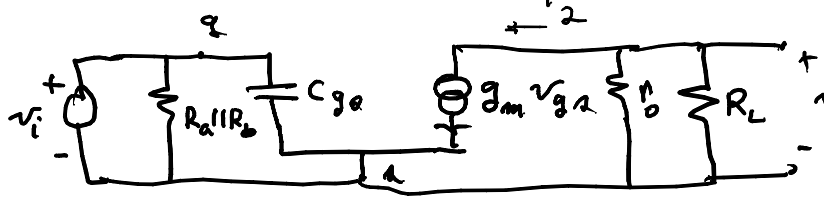
Use small signal equivalent circuit



If M is in saturation $C_{gd}=0$, $C_{gs}=\frac{2}{3}C_{ox}\times W\times L$

see p. 321

If in saturation



$$v_o = -(r_o \| R_L)\cdot i_2 = -\frac{R_L \cdot r_o}{R_L+r_o}\cdot g_m \cdot v_i$$

$$\frac{v_o}{v_i} = -g_m \cdot R_{L_{effective}} \qquad i_D=\frac{KPW}{2L}(v_{GS}-VTO)^2 \times (1+\lambda v_{DS})$$

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = \frac{2 I_D}{(V_{GS}-VTO)}$$

Ex: $I_D = 2\,mA$

$V_{GS}=2.9$, $VTO = 0.9V$

$$= \frac{2\times 2\times 10^{-3}}{(2.9-0.9)} = 2\times 10^{-3}\,\mho = \text{mutual conductance} = \text{transconductance}$$

If $R_L = 10\,K\Omega$ Then $\frac{v_o}{v_i} = -2\times 10^{-3}\times 10^{3}\times 10$

$= -20$

Effect of $\lambda = 15\times 10^{-3}$: $g_o = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q = \lambda\left(\frac{KP}{2}\frac{W}{L}(V_{GS}-VTO)^2\right)$

$$= \lambda\frac{I_D}{1+\lambda V_{DS}}$$

$$= \frac{15\times 10^{-3}\times 2\times 10^{-3}}{1+15\times 10^{-3}\cdot V_{DS}} \approx \frac{15\times 2\times 10^{-6}}{1}$$

$r_o \approx 30.3\,K\Omega$

$$= g_o = 30\,\mu\mho;\quad r_o = \frac{10^6}{30} = 10^4\times\frac{100}{30}$$

To find V_{DS} : $\quad I_D = 2\times10^{-3} = \frac{KP}{2}\frac{W}{L}(\underbrace{2.9}_{V_{GS}} - \underbrace{0.9}_{VT0})^2(1+15\times10^{-3}V_{DS})$

$$\approx \frac{KP}{2}\frac{W}{L} = \frac{2\times10^{-3}}{2^2} = \frac{1}{2}\times10^{-3} \text{ if } \lambda = 0$$

$\therefore \quad r_o \parallel R_L \neq R_L$ but $R_{L_{eff}} = \frac{r_o R_L}{r_o + R_L} = \frac{30.3\times10^3\times10\times\cancel{10^3}}{(30.3+10)\cancel{10^3}}$

$$= \frac{303\times10^3}{40.3} \approx 8\,K\Omega$$

$\Rightarrow$ gain decreases due to the Early effect

gain $= \frac{V_o}{V_i} = -20$ when no Early effect

$\Rightarrow -2\times10^{-3}\times\times8\times10^3 = -16$ when an Early effect.