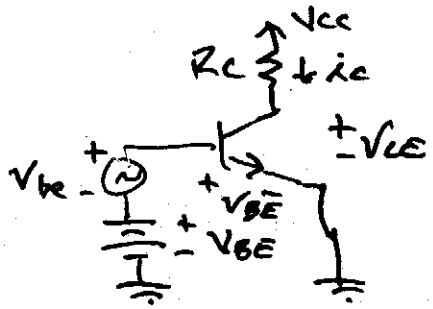
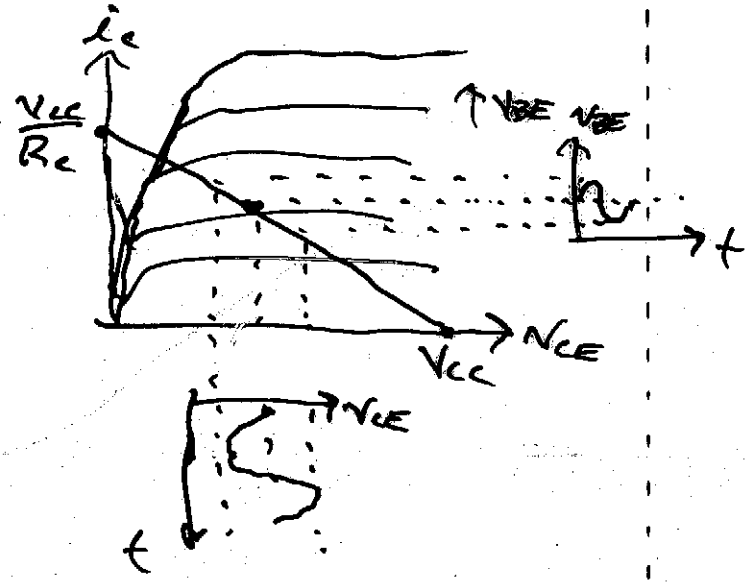
Transistor Amplifiers

1.) BJT Amp



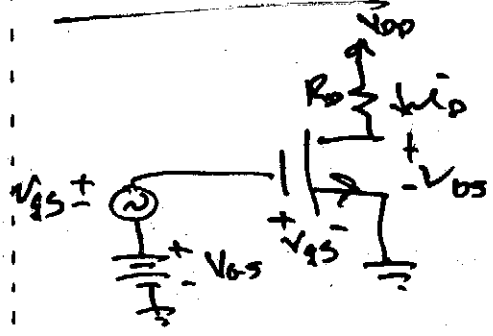


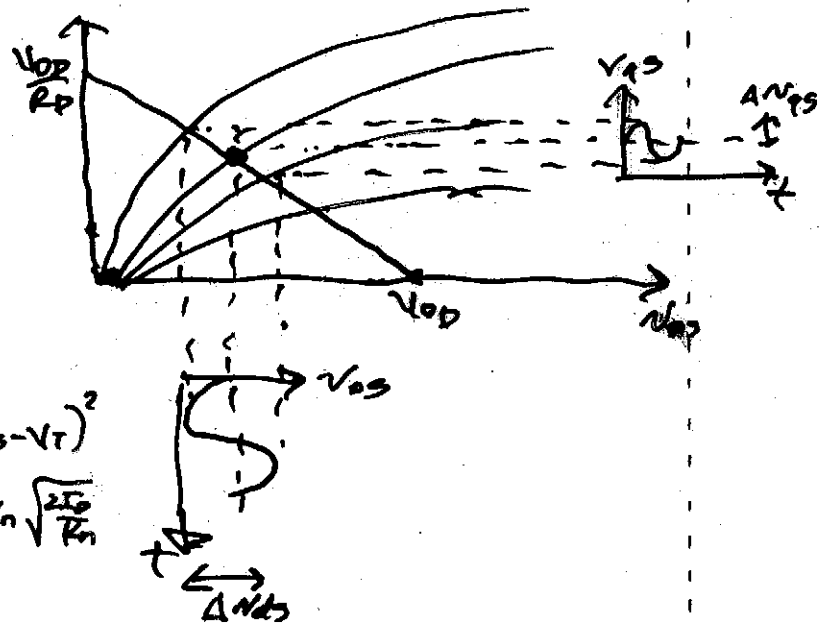
$$G_{MA} = \frac{\Delta V_{CE}}{\Delta V_{be}}$$

$$V_{CE} = V_{cc} - i_c R_c = V_{cc} - R_c I_S \exp\left(\frac{V_{BE}}{V_t}\right)$$

$$\left.\frac{dV_{CE}}{dV_{BE}}\right|_{V_{BE}} = -\frac{R_c I_S}{V_t}\exp\left(\frac{V_{BE}}{V_t}\right) = -\frac{R_c}{V_t} I_C \Rightarrow \frac{-10K}{25mV}\,1mA = -400\,\frac{V}{V}$$

MOSFET AMPS





$$V_{DS} = V_{DD} - I_D R_D = V_{DD} - R_D \frac{K_n}{2}(V_{GS} - V_T)^2$$

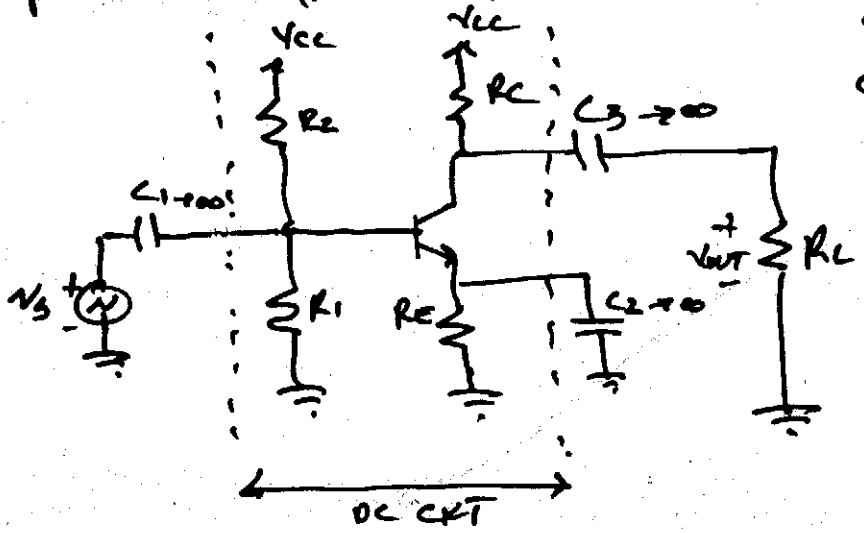
$$\left.\frac{\partial V_{DS}}{\partial V_{GS}}\right|_{V_{GS}} = -R_D K_n (V_{GS} - V_T) = -R_D K_n \sqrt{\frac{2I_D}{K_n}}$$

$$= -R_D\sqrt{2K_n I_D}$$

$$= -10K\sqrt{2 \cdot 250 \cdot 1mA}$$

$$= -7.07\ V/V$$

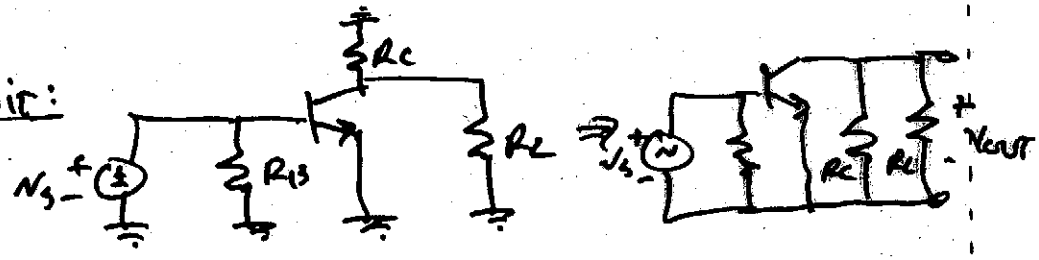
3.) Coupling and Bypass Capacitors



C_1, C_3 coupling caps

C_E bypass cap

Ac circuit:



4.) Diode small-signal model

Large signal $i_D = I_S\left[\exp\left(\frac{v_D}{V_T}\right) - 1\right]$

$$i_d + I_D = I_S\left[\exp\left(\frac{v_d + v_D}{V_T}\right) - 1\right] = I_S\left[\exp\left(\frac{v_D}{V_T}\right)\exp\left(\frac{v_d}{V_T}\right) - 1\right]$$

expand $\frac{v_d}{V_T}$ by a Maclaurin series

$$i_d + I_D = I_S\left\{\left[\exp\left(\frac{v_D}{V_T}\right)\right]\left[1 + \frac{v_d}{V_T} + \frac{1}{2}\left(\frac{v_d}{V_T}\right)^2 + \cdots\right] - 1\right\} \rightarrow I_D$$

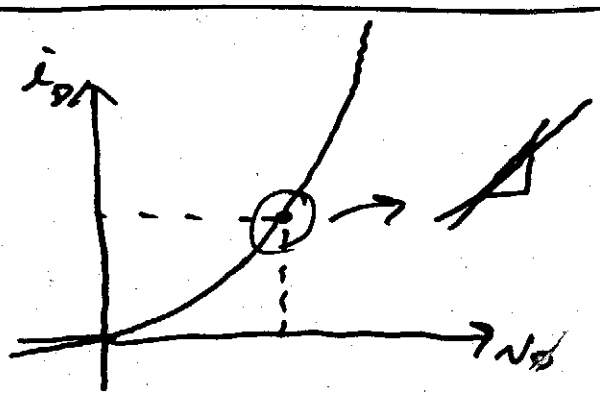
$$i_d + I_D \cong I_S\left[\exp\left(\frac{v_D}{V_T}\right)\right]\left[1 + \frac{v_d}{V_T}\right] - I_S = I_S\left[\exp\left(\frac{v_D}{V_T}\right) - 1\right] + \left[I_S \exp\left(\frac{v_D}{V_T}\right)\right]\left(\frac{v_d}{V_T}\right)$$

$$i_d + \cancel{I_D} = \cancel{I_D} + \left[I_S \exp\left(\frac{v_D}{V_T}\right)\right]\left(\frac{v_d}{V_T}\right)$$

$$\hookrightarrow i_d = \frac{(I_D + I_S)}{V_T} v_d = g_m v_d$$

$$\therefore g_m = \frac{I_D + I_S}{V_T} \cong \frac{I_D}{V_T}$$

DIODE small signal model (cont)



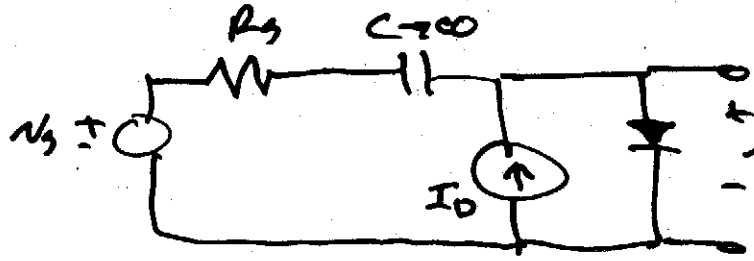
$I_S = 100\ fA$

$I_D = 1mA \rightarrow g_m = \frac{1mA}{25mV} = 0.04\,S$

$I_D = 0 \rightarrow g_m = \frac{100fA}{25mV} = 4E\text{-}12\,S$
$4 \times 10^{-12}\,S$

$I_D = I_S \rightarrow g_m = 0$

Example CURRENT CONTROLLED small-signal attenuator



$$v_{out} = \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_S} v_S = \frac{1}{1 + g_m R_S} v_S$$

$$\boxed{v_{out} = \frac{1}{1 + \frac{I_D R_S}{V_T}}}$$