ASSIGNMENT 1

1. The collector current, I_C, from the large signal characteristic of a bipolar junction transistor (BJT) is given by the following equation

$$I_C = I_S\left(1 + \frac{V_{CE}}{V_A}\right)\exp\frac{V_{BE}}{V_T}$$

where I_S is the constant saturation current which value is 10^{-15}A, V_A is the Early voltage in the order of 50V, V_T is the thermal voltage, V_{CE} is the reverse-biased collector to emitter voltage and V_{BE} is the forward-bias base to emitter voltage. The BJT large signal model is shown in Figure 1.

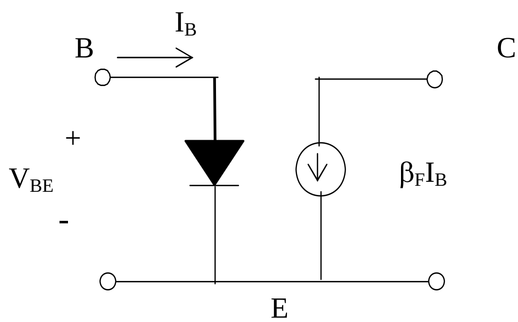


Figure 1

Given $I_S = \frac{qAD_n n_{po}}{W_B}$ and $\beta_F = \frac{1}{\frac{W_B^2}{2\tau_b D_n} + \frac{D_p}{D_n}\frac{W_B}{L_p}\frac{N_A}{N_D}}$, prove that the base current is $I_B = \left(\frac{1}{2}\frac{n_{po}W_B qA}{\tau_b} + \frac{qAD_p}{L_p}\frac{n_i^2}{N_D}\right)\exp\frac{V_{BE}}{V_T}$

where q is the electronic charge with value of 1.6 x 10^{-19}C, A is the cross-sectional area of the emitter, D_n and D_p are the diffusion constants for electrons and holes, respectively, n_{po} is the equilibrium concentration of electrons in the base, W_B is the width of the base, τ_b is the minority-carrier lifetime, L_p is the diffusion length for holes in the emitter and N_A and N_D are the base doping density and donor concentration in emitter, respectively.

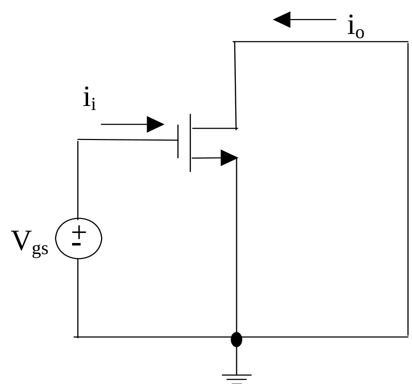
2. Draw the small signal equivalent circuit by ignorlng collector-base resistance, r_μ and emitter lead series resistance, r_{ex}. Show that the ac current gain is $B(j\omega) = \frac{g_m}{j\omega(C_\pi + C_\mu)}$ and the unity gain frequency is $f_T = \frac{1}{2\pi} \frac{g_m}{C_\pi + C_\mu}$.

3. Given electron mobility $\mu_n = 1350 \frac{cm^2}{V.S}$ and hole mobility $\mu_p = 480 \frac{cm^2}{V.S}$, $W_B = 1\mu m$, $N_A = 10^{17} cm^{-3}$, $N_D = 10^{18} cm^{-3}$ and $\tau_b = 10ns$. Calculate β_F using Einstein's relation, $\frac{D}{\mu} = \frac{kT}{q}$ and $L = \sqrt{D\tau}$. Comment on the answer. Given also $I_C = 2mA, C_\mu = 100\,fF, C_{je} = 100\,fF$ and $C_b = 100\,fF$, calculate f_T. Comment also on this answer.

4. Given a MOS transistor as shown in Figure 2. Draw the small signal model of the transistor. Assume $V_{sb} = V_{ds} = 0$, g_{mb}, r_o, C_{sb} and C_{db} are ignored. Prove that

$$f_T = \frac{1}{2\pi} \frac{g_m}{C_{gs} + C_{gb} + C_{gd}}$$

Compare the above expression with the unity gain frequency expression for the BJT.



5. Find the overdrive voltage V_{ov}, transconductance g_m dan g_{mb}, output resistance r_o and all capacitances C_{sb}, C_{db}, C_{ox} and C_{gs} (in other words, derive the complete small signal model for the NMOS). Given $I_D = 200\mu A, V_{SB} = 1.5V, V_{DS} = 2V$. Device parameters are:

$\phi_f = 0.3V, W = 20\mu m, L = 1\mu m, \gamma = 0.5V^{1/2}, k' = 200\frac{\mu A}{V^2}, \lambda = 0.02V^{-1}, t_{ox} = 10nm,$ $\psi_o = 0.6V, C_{sbo} = C_{dbo} = 10\,fF$. Overlap capacitance from gate to source and gate to drain is 1fF. Assume $C_{gb} = 6\,fF$. Find also the unity gain frequency, f_T .