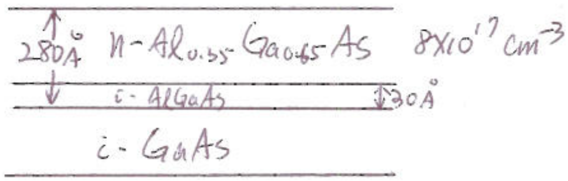
ECE 6453 HW # 6 Solution
(Selected)

6.2



$L_g = 0.25\,\mu m$

$W_g = 500\,\mu m$

$\phi_B = 1.0\ eV$

$V_{gs} = 0.3\,V, \quad V_{DS} = 2V.$

(a) $\phi_{00}' = \dfrac{1.6\times10^{-19}\times8\times10^{17}}{2\times1.159\times10^{-12}}\left(250\times10^{-8}\right)^2 = 0.345\ (V)$

$\dfrac{E_{f0}}{q} = 0.0518\ (V)$ (P.337 of Liu's)

$V_T = 1.0 + 0.0518 - 0.345 - 0.244 = \underline{0.463\,(V)}$ #

(b) ~ (d) calculate α:

$V_{Dsat} = V_{GS} - V_T = 0.3 - 0.463 = -0.163 < 0$ ..

actually, $V_T = 0.463\,(V) > V_{GS} \Rightarrow$ The HFET is cut-off

$\Rightarrow \boxed{g_m = g_d = 0}$

$\Rightarrow \alpha = 0$, $C_{ox}' = \dfrac{1.159\times10^{-12}}{280\times10^{-8}+68\times10^{-8}} = 3.33\times10^{-7}\ F/cm^2$

$\therefore C_{gs} = WL\,C_{ox}'\cdot\frac{2}{3} = 4.1625\times10^{-13}\times\frac{2}{3} = 2.78\times10^{-13}\ F$

$\boxed{C_{gg} = WL\,C_{ox}'\cdot\frac{2}{3} = 2.775\times10^{-13}\ F}$

$\boxed{C_{gd} = WL\,C_{ox}'\cdot 0 = 0}$

$\boxed{C_{dg} = WL\,C_{ox}'\cdot\frac{4}{15} = 1.11\times10^{-13}\ F}$

$\boxed{C_{dd} = WL\,C_{ox}'\cdot 0 = 0}$

common-source y-parameters:

$$[Y] = \begin{bmatrix} y_{gg} & y_{gd} \\ y_{dg} & y_{dd} \end{bmatrix}$$

Assume quasi-static,

$$y_{gg} = j\omega C_{gg} = j\omega \times 2.775\times10^{-13}$$

$$y_{gd} = -j\omega C_{gd} = 0$$

$$y_{dg} = g_m - j\omega C_{dg} = -j\omega \times 1.11\times10^{-13}$$

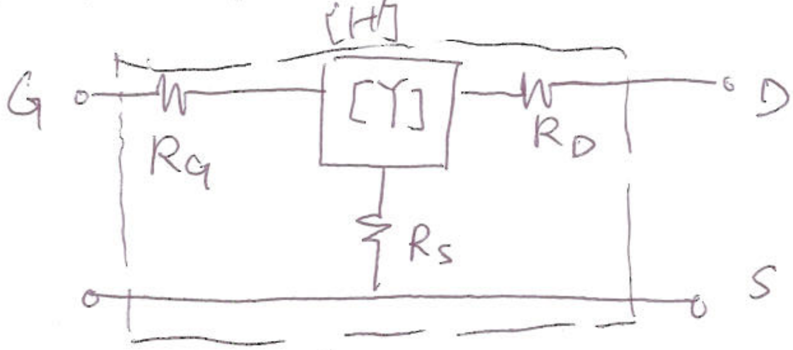
$$y_{dd} = g_d + j\omega C_{dd} = 0$$

$$[Y] = \begin{bmatrix} j\omega\times2.775\times10^{-13} & 0 \\ -j\omega\times1.11\times10^{-13} & 0 \end{bmatrix} = \underline{j\omega \begin{bmatrix} 2.775\times10^{-13} & 0 \\ -1.11\times10^{-13} & 0 \end{bmatrix}}$$

Note that the bias condition at $V_{gs} < V_T \Rightarrow$ The channel is not formed w/ $V_{gs} = 0.3V$, The only small-signal components left in the y-parameters are capacitive.

6.10 $[Y] = \begin{bmatrix} j\omega C_{gg} & -j\omega C_{gd} \\ g_m - j\omega C_{dg} & g_d + j\omega C_{dd} \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} j\,4\times10^{-3} & -j\,3\times10^{-3} \\ 0.4 - j\,1\times10^{-3} & 0.1 + j\,9.5\times10^{-4} \end{bmatrix}$

When the parasitic resistances are included,



with the help of (6-232) & (6-233) & the conversion table provided in the class. one may find the h_{21}' of the new two-port network is:

$$h_{21}' = + \frac{-Z_{21}'}{Z_{22}'} = - \frac{R_S - y_{21}/\Delta}{R_D + R_S + y_{11}/\Delta}$$

$$= + \frac{y_{21} - R_S \Delta}{y_{11} + (R_S + R_D)\Delta}, \qquad \Delta = y_{11} y_{22} - y_{12} y_{21}$$

Calculate $\Delta = j(4\times10^{-3}) \times [0.1 + j\,9.5\times10^{-4}] + [j\,3\times10^{-3} \times (0.4 - j\,1\times10^{-3})]$

$$\Rightarrow h_{21}' = -0.45 - j\,23.81$$

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Note that, if you use the equation provided in eq. (6-234), You will never get this answer. (Because that equation is just an approximation form → find the correction by yourself!!)

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$$U = \frac{\left|(y_{12} - y_{21})/\Delta y\right|^2}{4\left\{ Re\left[R_S + R_G + y_{22}/\Delta y\right) Re(R_S + R_D + y_{11}/\Delta y) - Re(R_S - y_{12}/\Delta y) Re(R_S - y_{21}/\Delta y) \right\}}$$

$$\boxed{U = 150.2}$$

3.1 $$\beta = \frac{I_C}{I_B} \cong \frac{I_C}{I_{Bp} + I_{B,bulk}}$$

$$I_{B,bulk} = A_E \frac{q\, n_{iB}^2 W_B}{2 N_B \tau_n} \exp\left(\frac{qV_{BE}}{kT}\right)$$

$$I_{Bp} = A_E \frac{q D_{pE} n_{iE}^2}{W_E N_E} \exp\left(-\frac{\Delta E_V}{kT}\right) \exp\left(\frac{qV_{BE}}{kT}\right)$$

$$I_C \cong A_E \frac{q D_{nB} n_{iB}^2}{W_B N_B} \exp\left(\frac{qV_{BE}}{kT}\right)$$

From 1.7 estimate τ_n, D_{pE}, D_{nB}, n_{iE}, & n_{iB}

For example, $\tau_n \cong 2\times10^{-9}$ ns for $N_B = 5\times10^{18}\ cm^{-3}$

$\tau_n \cong 10^{-11}$ ns for $N_B = 1\times10^{20}\ cm^{-3}$

$n_{iE} = n_{i\,Al_{0.35}Ga_{0.65}As} = 3.6\times10^2\ cm^{-3}$

$n_{iB} = n_{i\,GaAs} = 1.79\times10^6\ cm^{-3}$

$$\beta = \frac{\dfrac{D_{nB} n_{iB}^2}{W_B N_B}}{\dfrac{n_{iB}^2 W_B}{2 N_B \tau_n} + \dfrac{D_{pE} n_{iE}^2}{W_E N_E} \exp(-\Delta E_V/kT)}$$

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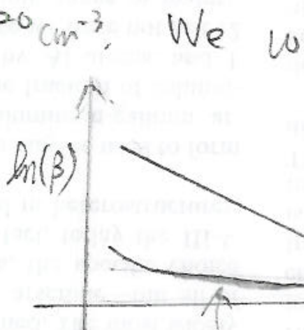
Note that the textbook assume that $n_{iB} = n_{iE}$ which is not totally true -- You know why

Assume that the temperature range is set s.t. D_n, D_p are constants.

(a) at $N_B = 5\times10^{18}\ cm^{-3}$, $I_{B,bulk}$ is about 100× lower than that for $N_B = 10^{20}\ cm^{-3}$, We will expect $\beta \propto \exp(\Delta E_V/kT)$,



(b) at $N_B = 10^{20}\ cm^{-3}$, $I_{B,bulk} \simeq I_{B,p}$

$$\beta = \frac{1}{\tau_B + \dfrac{D_{pE}\, n_{iE}^2\, W_B N_B}{D_{nB}\, n_{iB}^2\, W_E N_E} \exp\left(-\dfrac{\Delta E_V}{kT}\right)}$$

$$\tau_B = \frac{W_B^2}{2\tau_n D_{nB}}$$