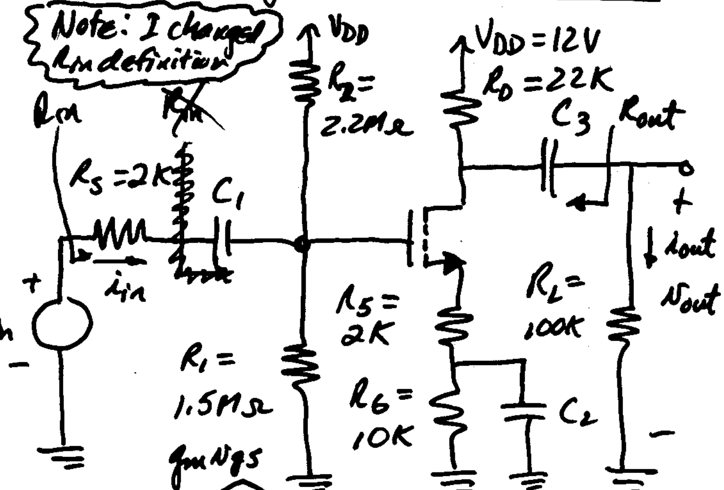
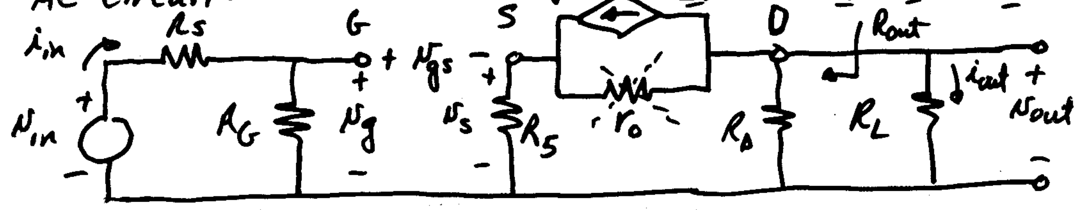
Quiz #4 - CE and/or CS amplifier ($R_{in}, R_{out}, \frac{v_{out}}{v_{in}}, \frac{i_{out}}{i_{in}}$)

Common Nothing NMOS (Inverting) Amplifier - Cont'd

If $K_N = 0.5 mA/V^2$, $V_{TN} = 1V$ and $\lambda = \frac{1}{50V}$, find R_{in}, R_{out}, and $\frac{v_{out}}{v_{in}}$ also $\frac{i_{out}}{i_{in}}$.



AC circuit -



$R_G = R_1 || R_2 = 0.892 M\Omega$

Assume we can neglect r_o.

- r_o is large other external resistors are small
- Lot of work for no effort.

$$\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{v_{gs}}\right)\left(\frac{v_{gs}}{v_g}\right)\left(\frac{v_g}{v_{in}}\right)$$

$$\frac{v_{out}}{v_{gs}} = -g_m(R_D || R_L)$$

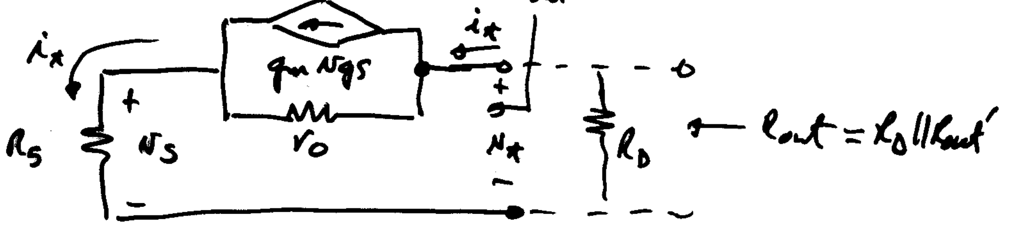
"v_{ab} trick" → $v_{ab} = v_a - v_b$ → $v_{gs} = v_g - v_s$

$$v_{gs} = v_g - g_m v_{gs} R_5 \rightarrow v_{gs}(1 + g_m R_5) = v_g$$

$$\frac{v_{gs}}{v_g} = \frac{1}{1 + g_m R_5}$$

$$\therefore \frac{v_{out}}{v_{in}} = \left[-g_m(R_D || R_L)\right]\left[\frac{1}{1 + g_m R_5}\right]\left[\frac{R_G}{R_S + R_G}\right]$$

$R_{in} = R_S + R_G = 894K$ $R_{out} = ?$



a.) $r_o = \infty$

$$i_x = g_m v_{gs} = g_m(v_g - v_S) = -g_m v_S$$
$$v_S = i_x R_S$$

$R_{out}' = \frac{v_x}{i_x}$ If we apply v_x, $i_x = 0 \Rightarrow R_{out}' = \infty$

$\therefore$ $R_{out} = R_D = 22k\Omega$

b.) $r_o \neq \infty$

$$v_x = r_o[i_x - g_m v_{gs}] + i_x R_S$$
$$v_{gs} = v_g^{\,0} - v_S = -v_S = -i_x R_S$$

$\therefore$ $v_x = r_o i_x - g_m r_o(-i_x R_S) + i_x R_S$

$$\frac{v_x}{i_x} = r_o + R_S + g_m r_o R_S = 223K + 2K + (509)(0.223)2K = 452K$$

$$R_{out} = R_D \| [r_o + R_S + g_m r_o R_S] = 22K \| 452K = 20.98K$$

Assume $I_{DS} = 241\mu A \rightarrow V_{GS} = 1.982V$ & $V_{DS} = 3.81V$

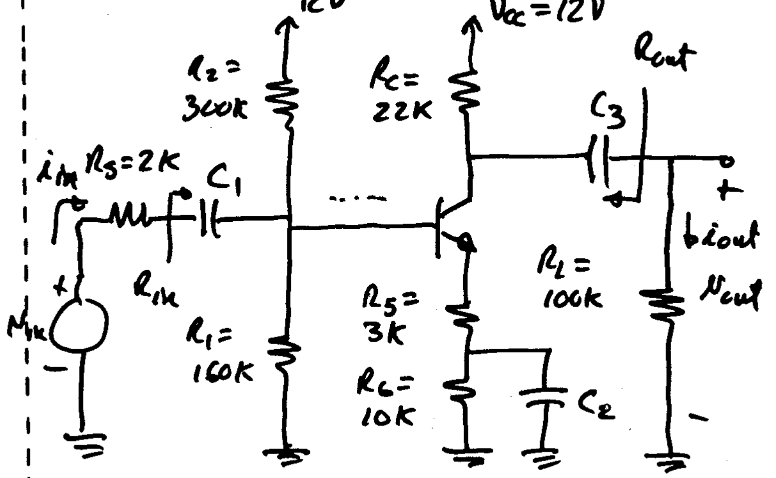
$$g_m = \sqrt{2K_N I_{DS}(1+\lambda V_{DS})} = \sqrt{2 \cdot 500 \cdot 241\left(1+\frac{3.81}{50}\right)} = 509\mu S$$

$$r_o = \frac{\frac{1}{\lambda} + V_{DS}}{I_{DS}} = \frac{50 + 3.81}{0.241 mA} = 223k\Omega$$

$$\frac{v_{out}}{v_{in}} = \frac{(-509\mu S)(22K \| 100K)}{1 + (509\mu S)(2K)}\left(\frac{892}{894}\right) = -4.54 \text{ V/V}$$

$$\frac{i_{out}}{i_{in}} = \frac{v_{out}/R_L}{v_{in}/R_{in}} = \left(\frac{v_{out}}{v_{in}}\right)\left(\frac{R_{in}}{R_L}\right) = -4.54\left(\frac{894K}{100K}\right) \cong -40 \frac{A}{A}$$

"Inverting CE" Amplifier



$\beta_F = \beta_o = 100$

$V_A = 50V$

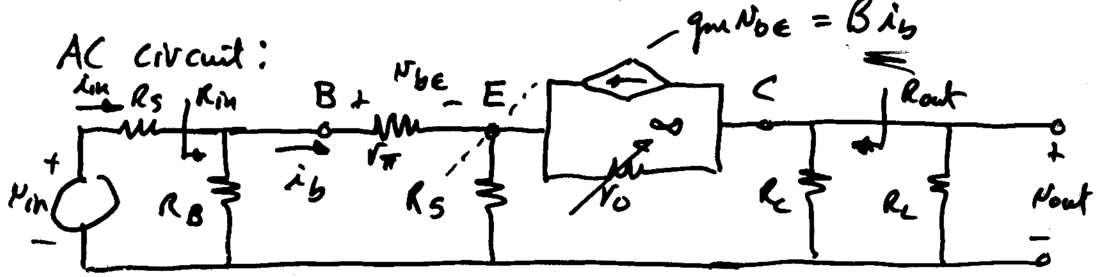
Room temperature

Find $\frac{v_{out}}{v_{in}}$, R_{in} & R_{out}

if $I_{CQ} = 245\mu A$

$V_{CEQ} = 3.64V$

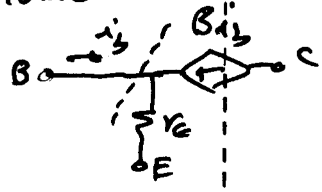
AC circuit:

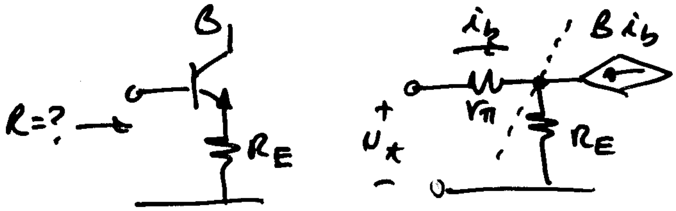


$R_B = R_1 \| R_2 = 104k\Omega$

$g_m = \frac{I_{CQ}}{V_T} = \frac{245\mu A}{25mV} \approx 10mS$

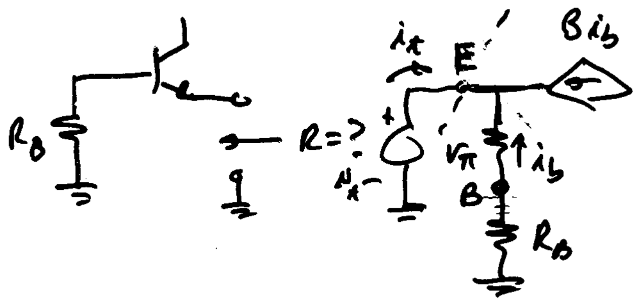
$r_\pi = \frac{\beta}{g_m} = \frac{100}{245\mu A} 25mV = \underline{10.2k\Omega}$





$v_x = i_b r_\pi + (1+\beta) i_b R_E$

$\frac{v_x}{i_b} = \underline{r_\pi + (1+\beta) R_E}$



$v_x = -i_b (r_\pi + R_B)$

$i_x = -i_b (1+\beta)$

$v_x = + \frac{r_\pi + R_B}{1+\beta} i_x$

$\therefore R = \underline{\frac{r_\pi + R_B}{1+\beta}}$

$\therefore\ R_{in} = R_B \| [r_\pi + (1+\beta)R_S]$

$R_{out} = R_C$

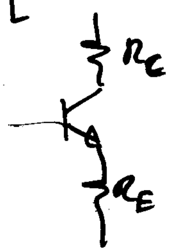
$$\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{i_b}\right)\left(\frac{i_b}{i_{in}}\right)\left(\frac{i_{in}}{v_{in}}\right)$$

$$= \left[-\beta(R_C \| R_L)\right]\left[\frac{R_B}{R_B + r_\pi + (1+\beta)R_S}\right]\left[\frac{1}{R_{in}+R_S}\right]$$

$R_{in} = 104k \| [10.2k + (101)3k] = 104k \| 313k = \underline{\underline{78.3k\Omega}}$

$R_{out} = \underline{\underline{22k\Omega}}$

$$\frac{v_{out}}{v_{in}} = \left[-100 \cdot 22k \| 100k\right]\left[\frac{104k}{104k + 313k}\right]\left[\frac{1}{80.3k}\right] = \underline{\underline{-5.61\,\frac{V}{V}}}$$



gain $\rightarrow -\dfrac{R_C}{R_E} = \dfrac{-22K}{3K} = -7\ V/V$