## LECTURE – 15

1.) Signal flow in transistors.

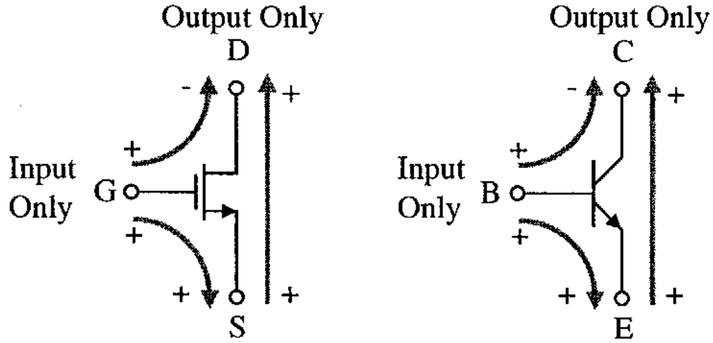
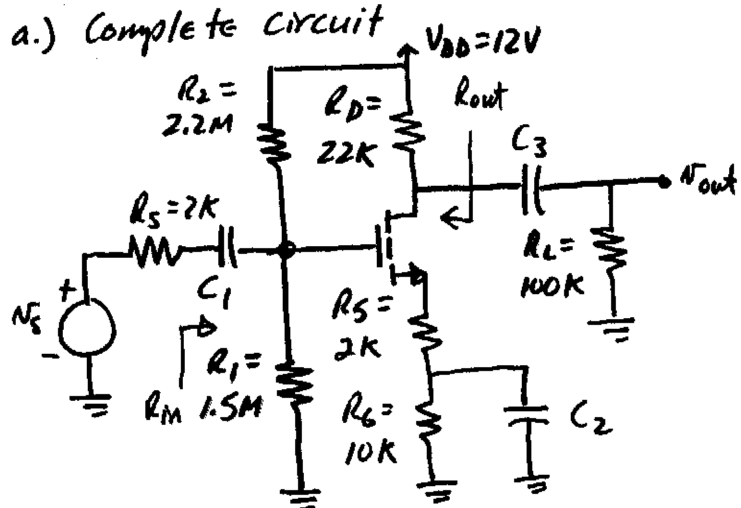


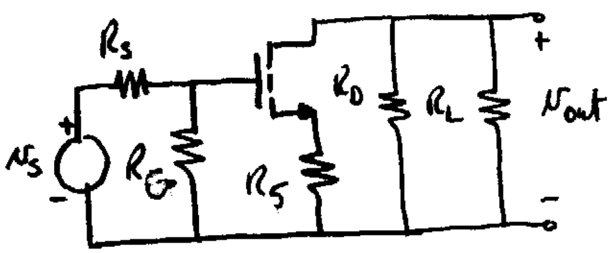

Fig. 4.3-12B

2.) Inverting Amplifiers – Common Source

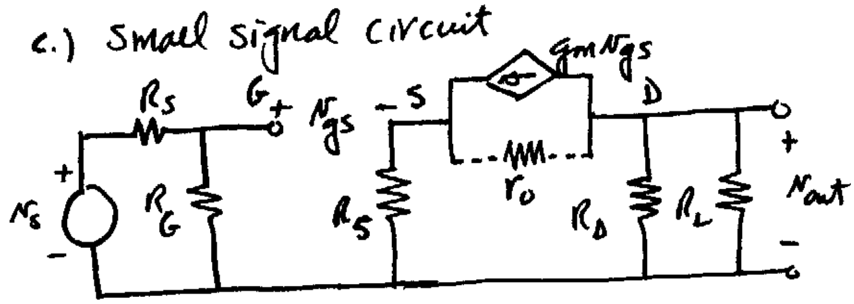
a.) Complete circuit




b.) AC circuit




c.) Small signal circuit



## Inverting Amplifiers - CS - Continued

d.) Small-signal calculations -

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

Assume $r_o$ can be neglected -

$$\frac{v_{out}}{v_{gs}} = -g_m(R_D||R_L) \quad , \quad \frac{v_g}{v_s} = \frac{R_G}{R_S+R_G} \quad , \quad \frac{v_{gs}}{v_g} = ?$$

$$v_{gs} = v_g - v_s = v_g - g_m v_{gs} R_S \rightarrow \frac{v_{gs}}{v_g} = \frac{1}{1+g_m R_S}$$

$$\therefore \frac{v_{out}}{v_s} = \frac{-g_m(R_D||R_L)}{1+g_m R_S}\,\frac{R_G}{R_S+R_G} \qquad R_G = R_1||R_2 = 0.892 M\Omega$$

e.) Assume $K_n = 500\mu A/V^2$, $V_{TN} = 1V$ and $\lambda = 0.02V^{-1}$. Evaluate the gain. Solving the dc circuit gives $I_{DS} = 241\mu A$, $V_{DS} = 3.81V$ and $V_{GS} = 1.982V$.

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

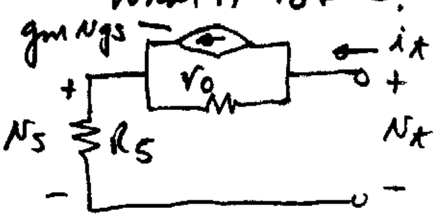
$$r_o = \frac{\frac{1}{\lambda}+V_{DS}}{I_{DS}} = \frac{50+3.81V}{241\mu S} = 223k\Omega$$

$$\therefore \frac{v_{out}}{v_s} \cong \frac{(-509\mu S)(22K||100K)}{1+(509\mu S)(2K)}\left(\frac{892}{894}\right) = \frac{-9.178}{2.018}\left(\frac{892}{894}\right) = \underline{-4.54 V/V}$$

f.) $R_{in}$ and $R_{out}$

$$R_{in} = R_G \quad \text{and} \quad R_{out} = R_D \qquad \text{if } r_o = \infty$$

What if $r_o \neq \infty$?




$$v_x = (i_x - g_m v_{gs})r_o + i_x R_S$$

but $v_{gs} = v_g - v_s = 0 - v_s = -i_x R_S$

$$\therefore v_x = i_x[r_o + R_S + g_m r_o R_S] \rightarrow R_x = \frac{v_x}{i_x}$$

$v_g = 0$ because $v_s = 0$ ← Very important

$R_{out} = R_D || R_x$

## Inverting CS Amplifier – Cont'd

g.) Evaluate $R_{in}$ and $R_{out}$

$$R_{in} = R_G = \underline{892\,k\Omega} \qquad R_{out}(r_o = \infty) = \underline{22\,k\Omega}$$

$$R_x = r_o + R_S + g_m r_o R_S = 223k + 2k + (509)(0.223)2k$$

$$= 225k + 227k = 452\,k\Omega$$

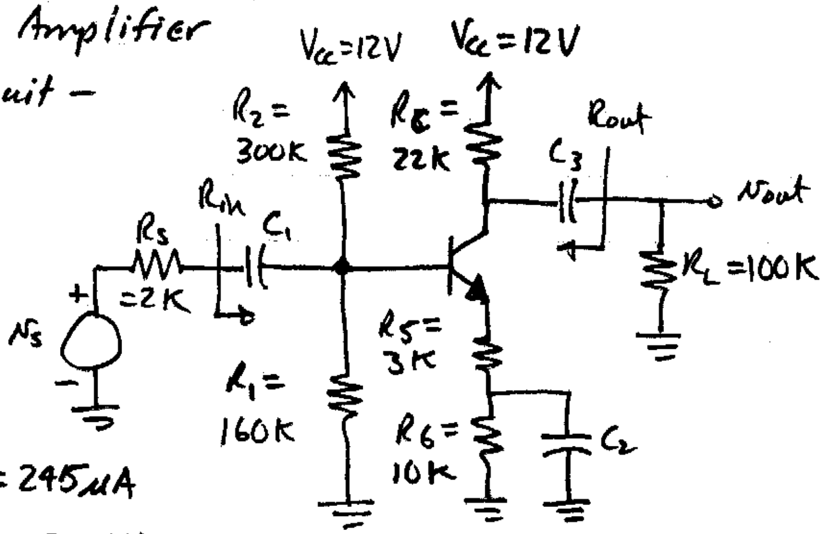
$$\therefore\ R_{out}(r_o \neq \infty) = 22k \| 452k = \underline{20.98\,k\Omega} \quad \left(\text{Not worth the effort}\right)$$

3) Inverting CE Amplifier

Complete circuit –

$\beta_F = 100$

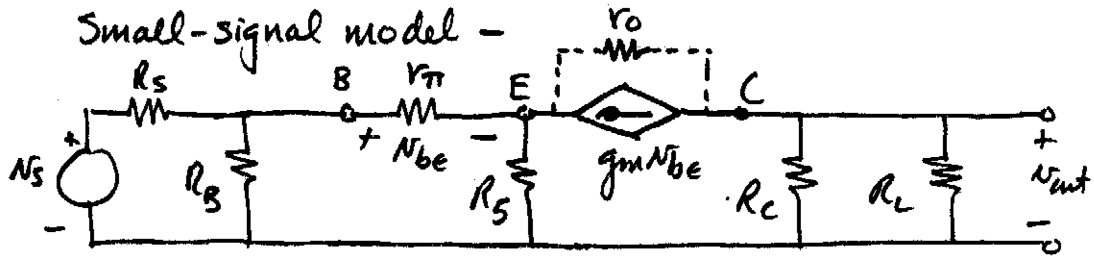
$V_A = 50V$



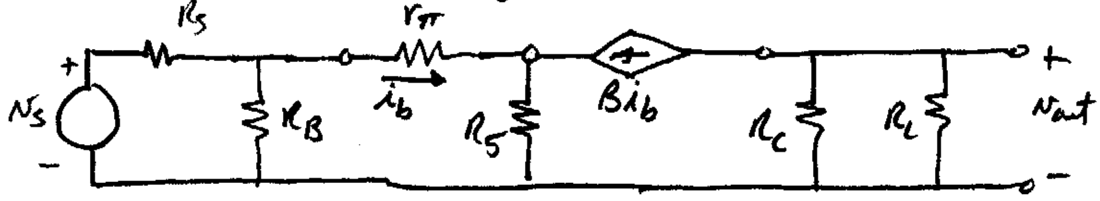

Q-point: $I_C = 245\,\mu A$

$V_{CE} = 3.64V$

Small-signal model –




or $\qquad R_B = R_1 \| R_2 = 104.35\,k\Omega$




$$g_m v_{be} = g_m r_\pi i_b = \beta_F i_b$$

$$r_\pi = \frac{\beta_F}{g_m} = \frac{V_T \beta_F}{I_C} = \frac{25}{.245}100 = 10.2\,k\Omega$$