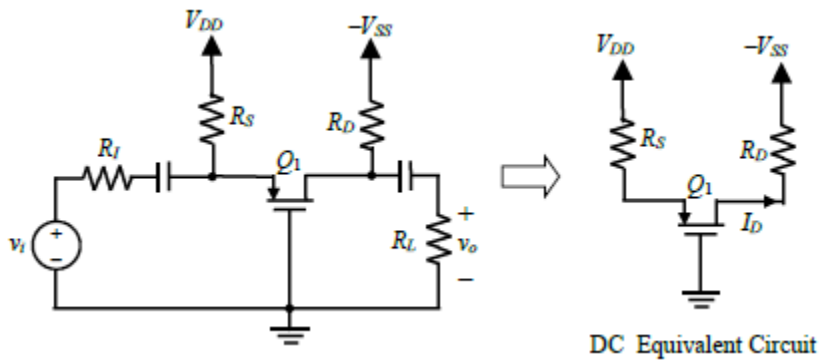


EE3122 Analogue Circuit Fundamentals Tutorial 3



DC analysis

$$I_D = \frac{K_P}{2} (V_{GS} - V_{TP})^2 = \frac{2 \times 10^{-4}}{2} (V_{GS} + 1)^2 \dots\dots\dots (1)$$

$$I_D = \frac{V_{DD} - V_{SG}}{R_S} = \frac{15 + V_{GS}}{68 \times 10^3} \dots\dots\dots (2)$$

$$10^{-4} (V_{GS} + 1)^2 = \frac{15 + V_{GS}}{68 \times 10^3}$$

$$6.8(V_{GS}^2 + 2V_{GS} + 1) = 15 + V_{GS}$$

$$6.8V_{GS}^2 + 12.6V_{GS} - 8.2 = 0$$

$$V_{GS} = \frac{-12.6 \pm \sqrt{12.6^2 - 4(6.8)(-8.2)}}{2 \times 6.8} = \frac{-12.6 \pm 19.54}{13.6}$$

$$= -2.363V \text{ or } 0.510V \text{ (infeasible since } V_{GS} < V_{TP})$$

Alternatively,

$$I_D = \frac{K_p}{2} (|V_{GS}| - |V_{TP}|)^2 = \frac{2 \times 10^{-4}}{2} (|V_{GS}| - 1)^2 \dots \dots \dots (1a)$$

$$I_D = \frac{V_{DD} - |V_{GS}|}{R_S} = \frac{15 - |V_{GS}|}{68 \times 10^3} \dots \dots \dots (2a)$$

Then, $6.8|V_{GS}|^2 - 12.6|V_{GS}| - 8.2 = 0$ and

$|V_{GS}| = 2.363$ or -0.510 (infeasible because $|V_{GS}| \geq 0$)

$$I_D = \frac{15 - 2.363}{68 \times 10^3} = 186 \mu A$$

$$V_{DD} - I_D R_S - V_{SD} - I_D R_D + V_{SS} = 0$$

$$V_{DS} = -30 + 186 \mu (68k + 43k) = -9.35 V$$

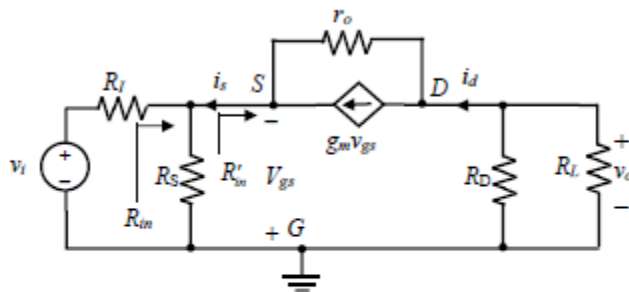
$$\therefore |V_{DS}| = 9.35 V > |V_{GS} - V_{TP}| = 1.363 V,$$

PMOS is working in the saturation (pinchoff) region.

$$g_m = \sqrt{2K_p I_D} = \sqrt{2 \times 2 \times 10^{-4} \times 186 \times 10^{-6}} = 273 \mu S$$

Since $\lambda=0$, r_o can be ignored as open circuit.

AC analysis

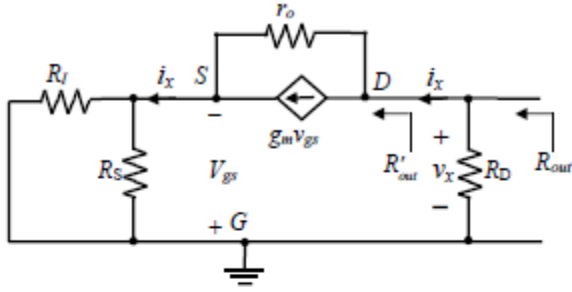


$$R'_in = \frac{v_{gs}}{i_s} = \frac{v_{gs}}{g_m v_{gs}} = \frac{1}{g_m} = \frac{1}{273 \mu} = 3.66 k\Omega$$

$$R_{in} = R_S \parallel R'_in = 68k \parallel 3.66k = 3.47 k\Omega$$

$$A_{vt} = \frac{v_d}{v_s} = \frac{-g_m v_{gs} (R_D \parallel R_L)}{-v_{gs}} = g_m (R_D \parallel R_L) = 273 \times 10^{-6} \times 35.4 \times 10^3 = 9.66$$

$$A_v = \left(\frac{R_{in}}{R_{in} + R_I} \right) A_{vt} = \left(\frac{3.47 \times 10^3}{3.47 \times 10^3 + 250} \right) (9.66) = 8.98$$



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

$$v_{gs} = -i_x (R_S \parallel R_I)$$

$$v_x = (i_x + g_m (R_S \parallel R_I) i_x) r_o + i_x (R_S \parallel R_I)$$

$$\approx i_x (1 + g_m (R_S \parallel R_I)) r_o$$

$$R'_{out} = \frac{v_x}{i_x} \approx (1 + g_m (R_S \parallel R_I)) r_o$$

$$\therefore r_o \approx \infty$$

$$R_{out} \approx R'_{out} \parallel R_D \approx R_D = 43 \text{ k}\Omega$$