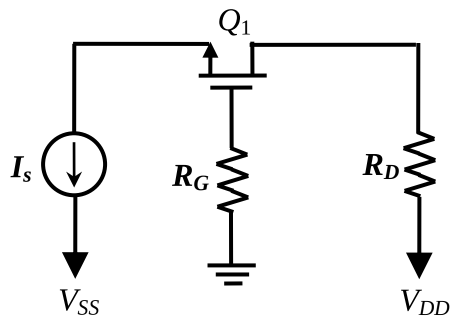
Nanyang Technological University
School of Electrical & Electronic Engineering
E2002 Analog Electronics – Asssignment 1

(a)
Draw DC equivalent circuit



(b)

$I_D = I_S = 1$ mA.
Assume Q_1 in saturation.

$$I_D = \frac{K_n}{2}\left(V_{GS} - 1\right)^2$$

$$1\times10^{-3} = \frac{2\times10^{-3}}{2}\left(V_{GS} - 1\right)^2$$

$$1 = V_{GS}^2 - 2V_{GS} + 1$$

$$V_{GS}(V_{GS} - 2) = 0$$

$$V_{GS} = 0 \text{ V (infeasible) or } 2 \text{ V}$$

$V_G = 0$ V
$V_S = 0 – 2$ V $= –2$ V.
$V_D = 5 – 1\text{m}\times4\text{k} = 1$ V.

$V_{DS} = 1 – (–2) = 3$ V $> V_{GS} – V_{TN} = 2 – 1 = 1$.
The transistor is in saturation mode.

(c)

$I_D = 1$ mA, $V_{DS} = 3$ V.
Q point: (1 mA, 3 V)
The Q-point will not change if $R_G = 0\ \Omega$ because gate current $I_G = 0$.

(d)

If I_D = 2 mA, then $2\times10^{-3} = \frac{2\times10^{-3}}{2}\left(V_{GS}-1\right)^2$

$V_{GS}^2 - 2V_{GS} - 1 = 0$

$V_{GS} = 2.41$ V or -0.41 V (infeasible)

$V_G = 0$ V

$V_S = 0 - 2.41$ V $= -2.41$ V.

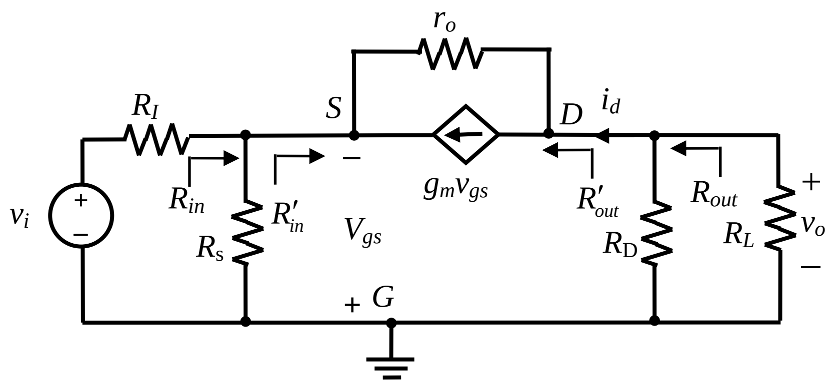
$V_D = 5 - 2\text{m}\times4\text{k} = -3$ V.

$V_{DS} = -3 - (-2.41) = -0.59$ V $< V_{GS} - V_{TN} = 2.41 - 1 = 1.41$ V.

The transistor is in triode region.

(e)

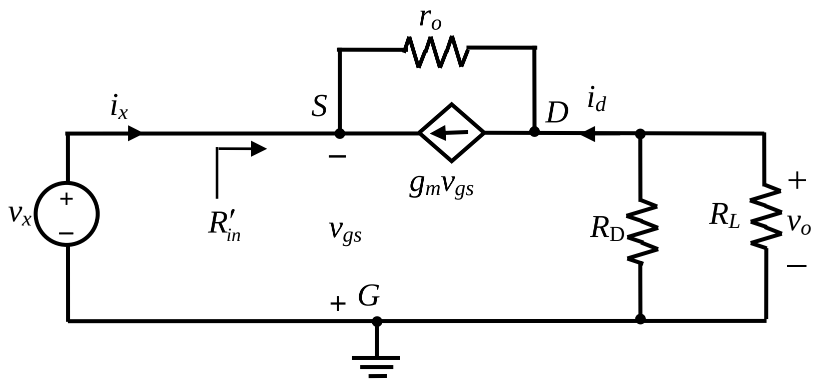
Draw small signal equivalent circuit of the amplifier



(f)

$g_m = \sqrt{2\times2m\times1m} = 2\ mS$

$r_o = \frac{\frac{1}{0.01}+1}{1m} = 101\ k\Omega$ or $r_o \approx \frac{1}{0.01\times1m} = 100\ k\Omega$



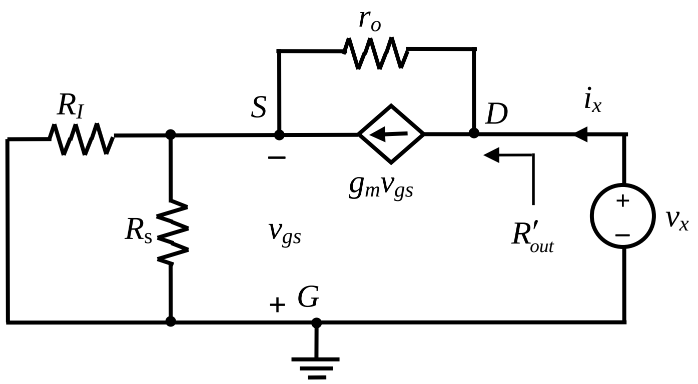
$v_x = -v_{gs}$

$i_x \approx -g_m v_{gs}$

$$R'_{in} = \frac{v_x}{i_x} = \frac{-v_{gs}}{-g_m v_{gs}} = \frac{1}{g_m}$$

$$= \frac{1}{2m} = 500\ \Omega$$

$$R_{in} = R_s \| R'_{in} = 1M \| 500 = 499.75 \approx 500\ \Omega$$



$$v_x = \left(i_x - g_m v_{gs}\right) r_o + v_s$$
$$v_s = i_x \left(R_s \| R_I\right) = \left(1M \| 300\right) i_x \approx 300 i_x$$
$$v_{gs} = -v_s = 300 i_x$$
$$v_s = i_x \left\{1 + g_m \left(R_s \| R_I\right)\right\} r_o + \left(R_s \| R_I\right)$$
$$R'_{out} = \frac{v_x}{i_x} \approx (1 + 0.6) 100k = 160\ k\Omega$$

$$R_{out} = 160k \| 4k \approx 4\ k\Omega$$

(g)

$$A_{vt} = \frac{-g_m v_{gs} \left(R_D \| R_L\right)}{-v_{gs}} = 2m\left(4k \| 4k\right) = 4$$

$$A_v = \left(\frac{500}{500 + 300}\right) \times 4 = 0.625 \times 4 = 2.5$$

(h)

$$A_i = \frac{\dfrac{v_o}{R_L}}{\dfrac{v_i}{R_I + R_{in}}} = A_v \times \frac{R_I + R_{in}}{R_L} = 2.5 \times \frac{300+500}{4000} = 0.5$$

(i)

$$|v_{gs}| = \left(\frac{R_{in}}{R_I + R_{in}}\right)|v_i| = \left(\frac{500}{300+500}\right)|v_i| = 0.625|v_i|$$

$$|v_{gs}| \le 0.2(V_{GS} - V_{TN}) = 0.2(2-1) = 0.2\ V$$

$$0.625|v_i| \le 0.2$$

$$|v_i| \le \frac{0.2}{0.625} = 0.32\ V$$

(j)

$|v_o| = |i_o| \times R_L = 0.1m \times 4k = 0.4$ V

$|v_i| = |v_o|/A_v = 0.4/2.5 = 0.16$ V

The output waveform will not be distorted since $|v_i| = 0.16$ V < 0.32 V.

Alternatively, the output waveform will not be distorted since
$|v_{gs}| = |v_o|/A_{vt} = 0.4/4 = 0.1$ V < 0.2 V.

(k)

$$A_v = \left(\frac{R_{in}}{R_I + R_{in}}\right)A_{vt} = \left(\frac{500}{R_I + 500}\right) \times 4$$

$$A_v = 1 \Rightarrow \left(\frac{500}{R_I + 500}\right) \times 4 = 1$$

$$R_I = 2000 - 500 = 1.5\ k\Omega$$