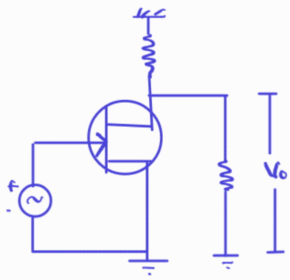
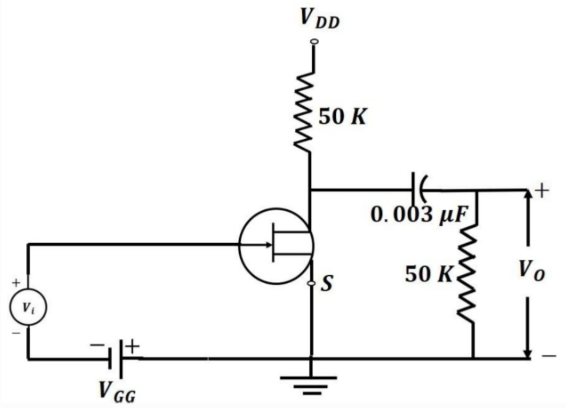
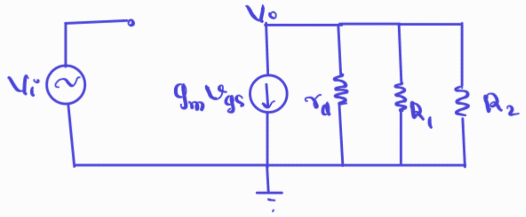
1. Calculate the voltage gain $A_v = {V_o}/{V_i}$, at 1 kHz for the circuit shown below. The FET parameters are $g_m = 2\ mA/V$ and $r_d = 10\ K$. Neglect capacitances.

AC - analysis





$R_1 = R_2 = R$



$$g_m V_{gs} = -V_o\left(\frac{1}{r_d}+\frac{1}{R}+\frac{1}{R}\right)$$

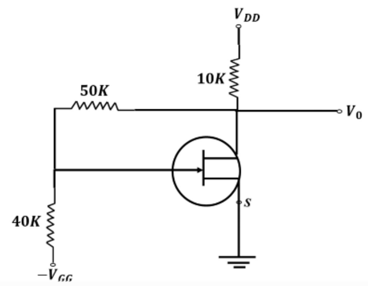
$$\Rightarrow \frac{V_o}{V_{in}} = \frac{-g_m}{\frac{1}{r_d}+\frac{2}{R}} = \frac{2\ mA/V}{\left(\frac{1}{10}+\frac{2}{50}\right)10^{-3}}$$

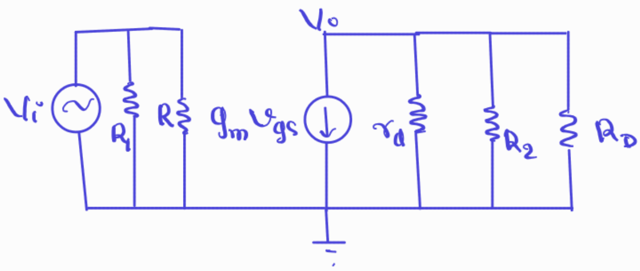
$$= \frac{100}{7}$$

2. If an input signal V_i is impressed between gate and ground, find the amplification $A_v = V_o/V_i$. Apply Miller's theorem to the 50 K resistor. The FET parameters are $\mu = 30$ and $r_d = 5K$. Neglect capacitances.

$R_1 = \frac{50}{1-A_v}$ $\qquad R_2 = \frac{50}{1-\frac{1}{A_v}}$

$R = 40\ K$ $\qquad R = 10\ K$





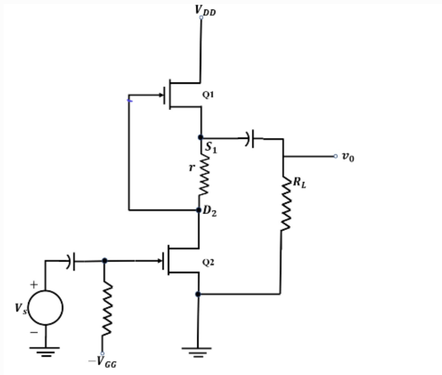
$$-g_m \frac{V_{gs}}{V_o} = \frac{1}{r_d}+\frac{1}{R_2}+\frac{1}{R_D}$$

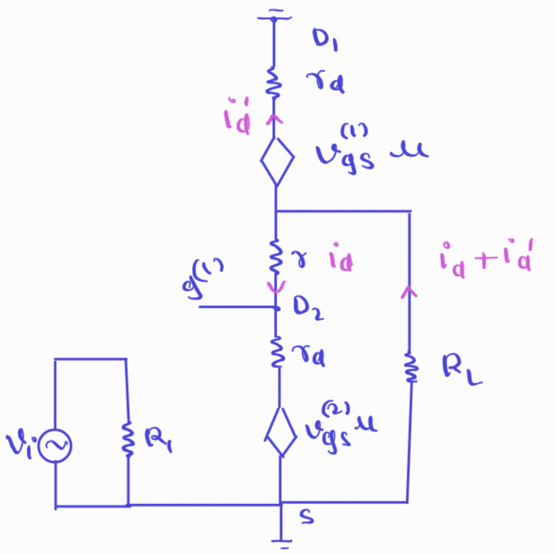
$$\Rightarrow A_v = \frac{V_o}{V_{in}} = \frac{-g_m}{\frac{1}{r_d}+\frac{1}{R_2}+\frac{1}{R_D}}$$

3. (a) Prove that the magnitude of the signal current is the same in both FETs provided that

$$r = \frac{1}{g_m} + \frac{2R_L}{\mu}$$

Neglect the reactance of the capacitors.





$$v_{gs}^{(1)} = -i_d r$$

$$\mu r = r_d + 2R_L$$

$$i'_d r_d + \mu v_{gs}^{(1)} + i_d R_L + i'_d R_L = 0$$

$$\Rightarrow i'_d r_d + i_d R_L + i'_d R_L = \mu i_d r$$

$$\Rightarrow i'_d r_d + \cancel{i_d R_L} + i'_d R_L = i_d r_d + \cancel{2} i_d R_L$$

$$\Rightarrow i'_d (r_d + R_L) = i_d (r_d + R_L)$$

$$\Rightarrow \boxed{i'_d = i_d}$$

(b) If r is chosen as part a, prove that the voltage gain is given by

$$A = \frac{-\mu^2}{\mu + 1} \frac{R_L}{R_L + r_d/2}$$

$$v_o = -2 i_d R_L$$

$$\frac{v_o}{v_i} = -\frac{\mu^2}{\mu+1} \frac{2R_L}{r_d + 2R_L}$$

$$= -\frac{\mu^2}{\mu+1} \frac{R_L}{R_L + \frac{r_d}{2}}$$

$$\mu v_{gs} + i_d r + i_d r_d + 2 i_d R_L = 0$$

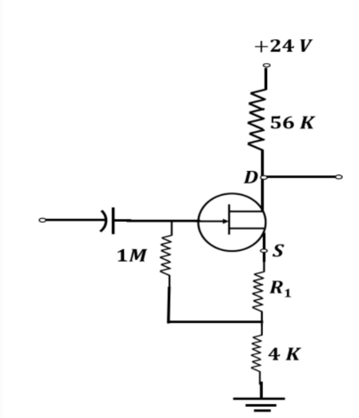
$$\Rightarrow i_d = \frac{-\mu v_{gs}}{r + r_d + 2R_L}$$

$$= \frac{-\mu v_{gs}}{\frac{r_d}{\mu} + \frac{2R_L}{\mu} + r_d + 2R_L}$$

$$= \frac{-\mu v_{gs}}{r_d\left(\frac{1}{\mu} + 1\right) + 2R_L\left(\frac{1}{\mu} + 1\right)}$$

$$= -\frac{\mu^2}{\mu+1} \frac{v_{gs}}{r_d + 2R_L}$$

4. The amplifier stage shown uses an n-channel FET having $I_{DSS} = 1\ mA, V_p = -1V$. If the quiescent drain to ground voltage is 10 V, find R_1.



$$I_d = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$I_d = \frac{24-10}{56} = \frac{1}{4}\ mA$$

$$\frac{1}{4} = 1\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

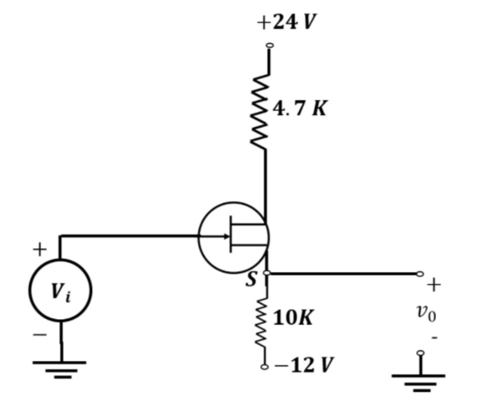
$$\Rightarrow \frac{V_{GS}}{V_P} = 1 \pm \frac{1}{2} = \frac{3}{2}, \frac{1}{2}$$

x ✓

$$V_{GS} = \frac{V_P}{2} = -\frac{1}{2} = -R_1 I_d$$

$$\Rightarrow R_1 = \frac{1}{2 I_d} = 2\,k\Omega$$

5. The FET shown has the following parameters, $I_{DSS} = 5.6\ mA, V_p = -4V$.
(a) If $v_i = 0$, find v_o;
(b) If $v_i = 10\ V$, find v_0;
(c) If $v_0 = 0\ V$, find v_i;
Note: v_0 and v_i are constant voltages (and not small signal voltages).



$$V_S = V_o = -12 + I_d(10)$$

$$V_{GS} = V_G - V_S$$
$$= V_i + 12 - 10\,I_d$$

$$I_d = 5.6\left(1 + \frac{V_i + 12 - 10\,I_d}{4}\right)^2$$

b) $v_i = 10\ V$

$I_d = 2.88\ mA$ $\quad V_o = 16.87$

$I_d = 2.34\ mA$ $\quad V_o = 11.41$

a) $V_i = 0$

$V_o = 6.28\ V$ $\quad V_o = 2\ V$

c) $I_d = 1.2$