II. Common Source Amplifier w/ Source Resistor

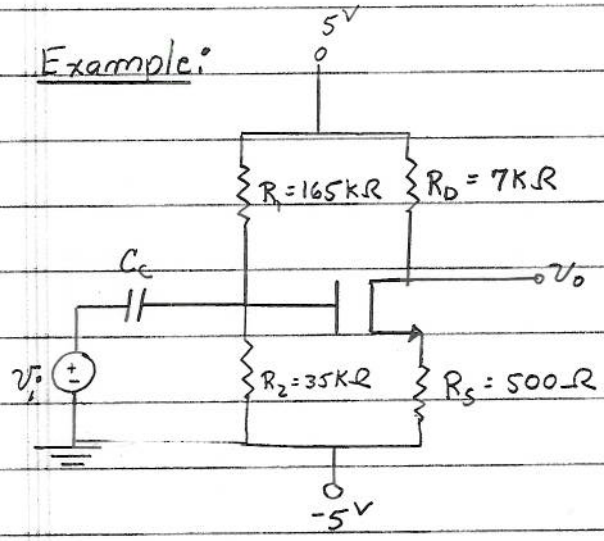
Advantages of Source Resistor

- Stabilizes Q pt. for variation in transistor parameters

Disadvantage:

- Reduces the small signal gain of amplifier.

Example:



$V_{TN} = 0.8^V$

$K_n = 1\ ^{mA}/_{V^2}$

$\lambda = 0$

1. DC Analysis

$$V_G = \left(\frac{35}{165+35}\right)10 - 5 = -3.25^V$$

$$I_D = \frac{V_S - (-5^V)}{R_S} = \frac{V_G - V_{GS} + 5}{R_S} = K_n (V_{GS} - V_{TN})^2$$

$$V_G - V_{GS} + 5 = R_S K_n (V_{GS} - V_{TN})^2$$

$$-V_{GS} + 1.75 = \tfrac{1}{2}(V_{GS} - 0.8)^2 = \tfrac{1}{2}\{V_{GS}^2 - 1.6 V_{GS} + 0.64\}$$

$$V_{GS}^2 + 0.4 V_{GS} - 2.86 = 0$$

$$V_{GS} = -0.2 \pm 1.7 = \boxed{1.5^V} \text{ or } \cancel{-1.9^V}$$

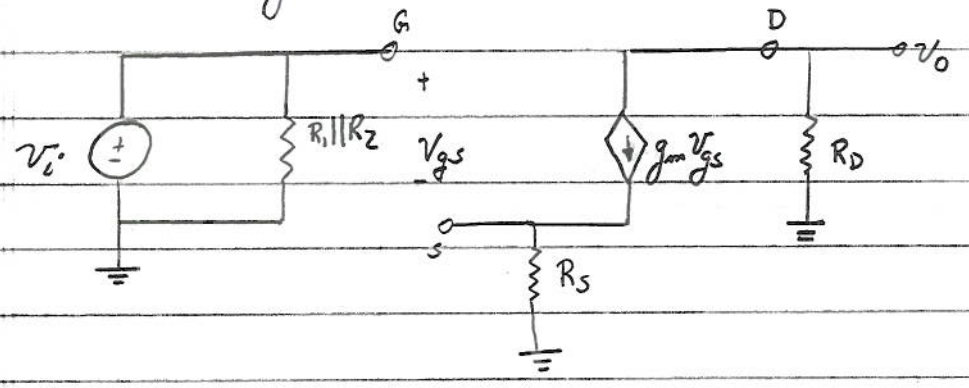
$$I_D = 1\ ^{mA}/_{V^2}\,(1.5 - 0.8)^2 = \boxed{0.5\ mA}$$

$$V_{DS} = V_D - V_S = 10 - (0.5^{mA})\,7.5K = \boxed{6.25^{V}}$$

$$g_m = 2K_n (V_{GS} - V_{TN}) = 2(1)(1.5 - 0.8) = \boxed{1.4\ ^{mA}/_{V}}$$

$$r_o = \frac{1}{\lambda I_{DQ}} = \boxed{\infty}$$

2. The small signal model is:



3. The output voltage is:

$$v_o = -g_m v_{gs} R_D$$

KVL: $\quad -v_i + v_{gs} + g_m v_{gs} R_S = 0$

$$v_{gs} = v_i \left(\frac{1}{1 + g_m R_S}\right)$$

4. The small signal gain is:

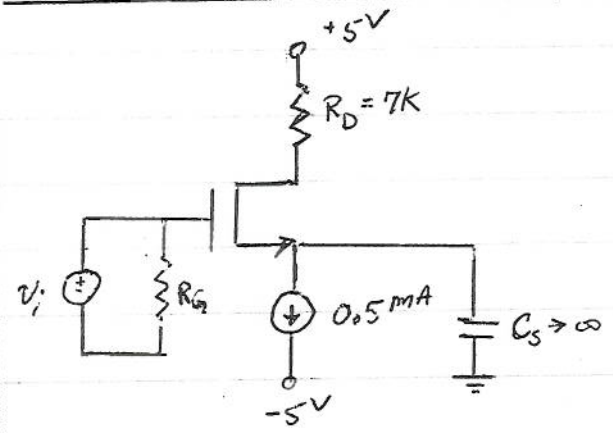
$$\boxed{A_V = \frac{v_o}{v_i} = \frac{-g_m R_D}{1 + g_m R_S}} = \frac{-(1.4)(7)}{1 + (1.4)(0.5)} = \boxed{-5.76}$$

Note:

K_n (mA/V^2)	g_m (mA/V)	A_v	
0.8	1.17	-5.17	16% change
1.0	1.40	-5.76	
1.2	1.62	-6.27	

50% change

Common Source w/ Bypass Capacitor



$K_n = 1\ mA/V^2$

$V_{TN} = 0.8\ V$

$\lambda = 0$

① DC Analysis

$$I_{DQ} = K_n (V_{GSQ} - V_{TN})^2$$

$$0.5\ mA = (1\ mA/V^2)(V_{GSQ} - 0.8)^2$$

$$V_{GSQ} = 1.51\ V = V_G^{\,0} - V_S$$

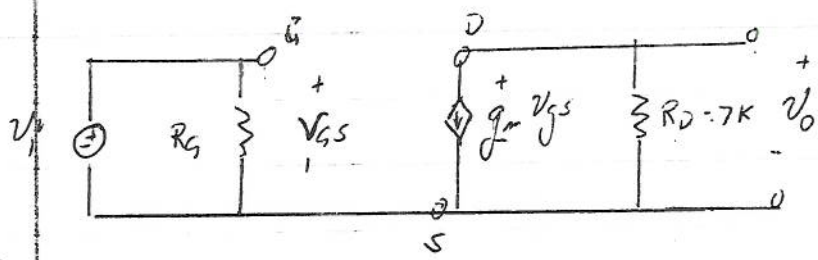
$$V_{DSQ} = V_{DD} - I_D R_D - V_S$$

$$= 5 - (0.5)7 - (-1.51)$$

$$= 3.01\ V \checkmark$$

$$V_{DSQ} > V_{DS(SAT)} = V_{GS} - V_{TN} = 1.51 - 0.8 = 0.71\ V \checkmark$$

② Small Signal Model



$$V_o = (-g_m V_{gs}) R_D$$

$$V_{gs} = V_i$$

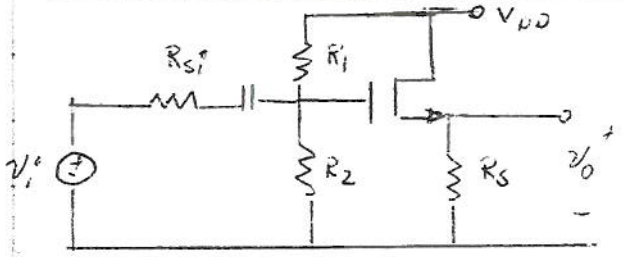
③ Voltage gain

$$g_m = 2\sqrt{K_n I_{DQ}} = 1.414\ ;$$

$$A_V = V_o/V_i = -g_m R_D$$

$$= -9.9$$

Source Follower Example



$V_{DD} = 12^V$ $\quad V_{TN} = 1.5^V$

$R_1 = 162K$ $\quad k_n = 4^{mA/V^2}$

$R_2 = 463K$ $\quad \lambda = 0.01\ V^{-1}$

$R_S = 0.75K$ $\quad R_{si}' = 4K$

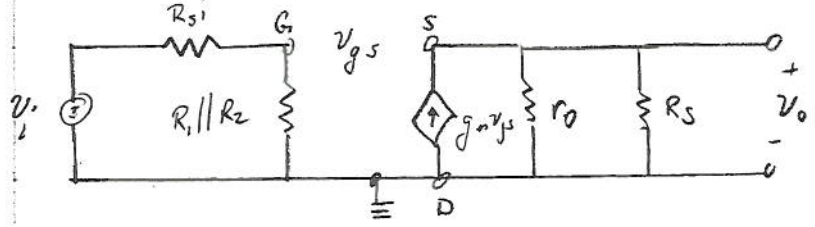
① DC ANALYSIS

CAN you show $I_{DQ} = 7.97^{mA}$, $V_{GSQ} = 2.91^V$?

② Small Signal model

$$g_m = 2\sqrt{k_n I_{DQ}} = 2\sqrt{(4)(7.97)} = 11.3^{mA/V^2}$$

$$r_o = \frac{1}{\lambda I_{DQ}} = \frac{1}{0.01(7.97)} = 12.5K\Omega$$

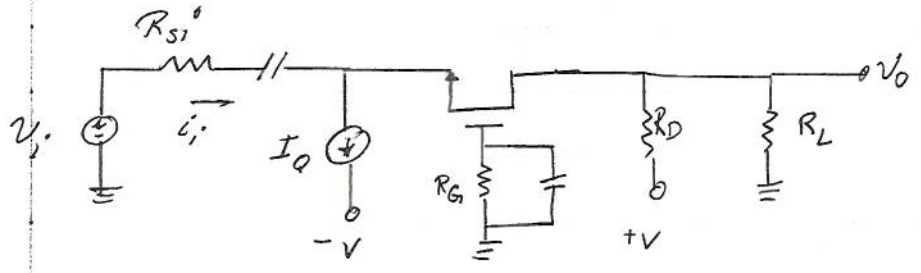


$$R_i' = R_1 \| R_2 = 162 \| 463 = 120K\Omega$$

$$A_v = \frac{R_S \| r_o}{\frac{1}{g_m} + R_S \| r_o} \left(\frac{R_i'}{R_i' + R_{si}'} \right)$$

$$= \frac{(0.75 \| 12.5)}{\frac{1}{11.3} + 0.75 \| 12.5} \left(\frac{120}{120 + 4K} \right) = 0.86$$

Common Gate Example (Ex 4.10)



$V_{TN} = 1\,V$

$K_n = 1\,mA/V^2$

$\lambda = 0$

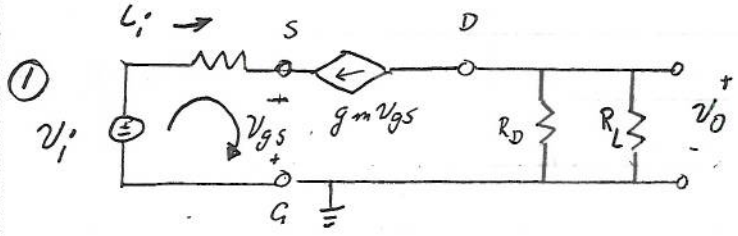
Given: $I_Q = 1\,mA$, $V^+ = 5\,V$, $V^- = -5\,V$, $R_G = 100k\Omega$

$R_D = 4K$, $R_L = 10K$

$i_i = (100\,\mu A)\sin \omega t$

$R_{si} = 50\,\Omega$

Find v_o



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

$-v_i + i_i R_{si} - v_{gs} = 0$

$-v_i - g_m v_{gs} R_{si} - v_{gs} = 0$

$v_{gs} = -\dfrac{v_i}{1 + g_m R_{si}}$

② $g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{(1)(1)} = \underline{2\,mA/V}$

③ $v_o = v_i \left(\dfrac{g_m (R_D \| R_L)}{1 + g_m R_{si}} \right) = (I_i R_{si}) \left(\dfrac{g_m (R_D \| R_L)}{1 + g_m R_{si}} \right)$

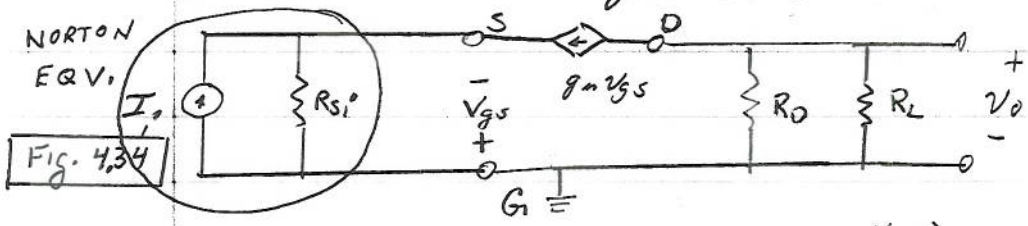


Fig. 4.34

$v_o = (100\mu A)(50) \left(\dfrac{2\,(4 \| 10)}{1 + 2(0.05)} \right) = \boxed{26\,mV \sin \omega t}$

~ 5.2

TEXT SOLUTION IS WRONG!