II. Common Source Amplifier w/ Source Resistor

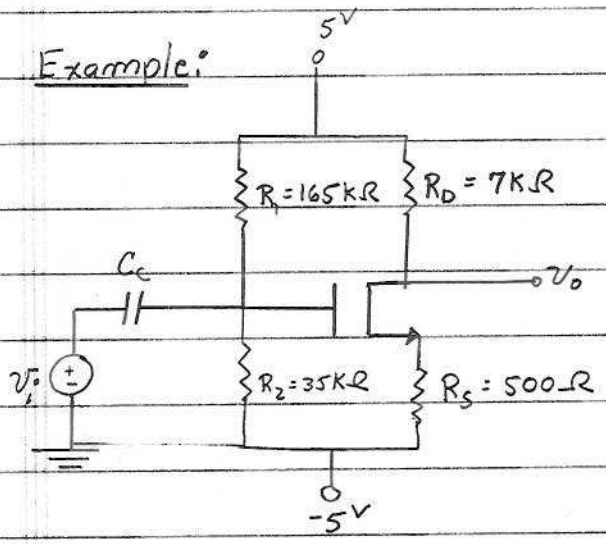
Advantage of Source Resistor

- 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**

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

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

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

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

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

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

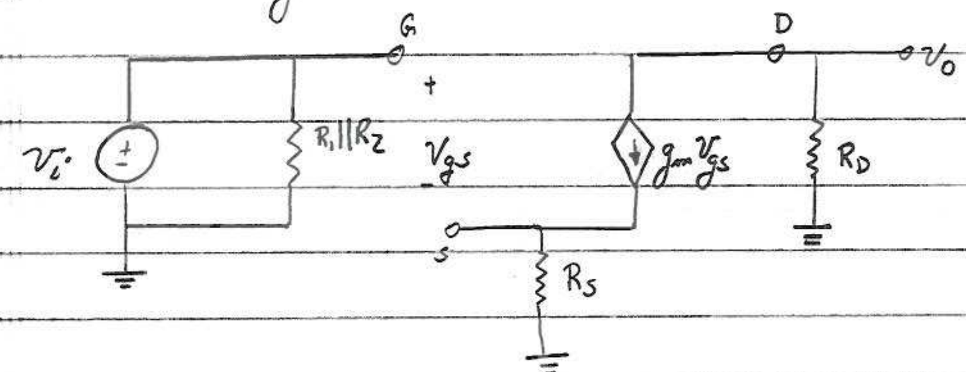
$$I_D = 1^{mA/V^2}(1.5 - 0.8)^2 = 0.5^{mA}$$

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

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

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

2. The Small signal model is:



3. The output voltage is:

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

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

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

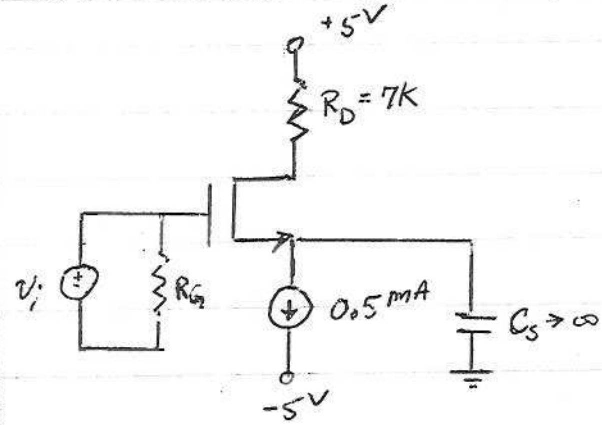
4. The small signal gain is:

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

Note:

	K_n (mA/V^2)	g_m (mA/V)	A_v	
50% change	0.8	1.17	-5.17	16% change
	1.0	1.40	-5.76	
	1.2	1.62	-6.27	

Common Source w/ Bypass Capacitor



$K_n = 1\,^{mA}/_{V^2}$
$V_{TN} = 0.8^V$
$\lambda = 0$

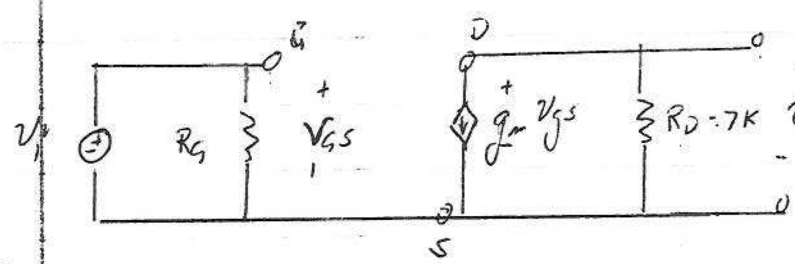
① DC Analysis

$$I_{DQ} = K_n\,(V_{GSQ} - V_{TN})^2$$
$$0.5^{mA} = (1\,^{mA}/_{V^2})\,(V_{GSQ} - 0.8)^2$$
$$V_{GSQ} = 1.51^V = \cancel{V_G}^{\,0} - V_S$$

$$V_{DSQ} = V_{DD} - I_D R_D - V_S$$
$$= 5 - (0.5)\,7 - (-1.51)$$
$$= 3.01 \checkmark$$

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

② Small Signal Model

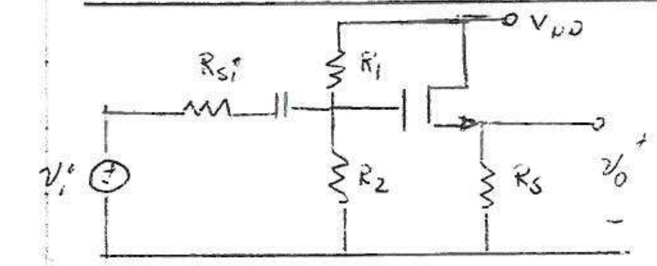


$$= (-g_m v_{gs}) R_D$$
$$v_{gs} = v_i$$

③ Voltage gain

$$g_m = 2\sqrt{K_n I_{DQ}} = \underline{1.414}, \quad A_v = {}^{v_0}/_{v_i} = -g_m R_D$$
$$= -9.9$$

Source Follower Example



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

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

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

$R_S = 0.75K$ $\quad R_{Si} = 4K$

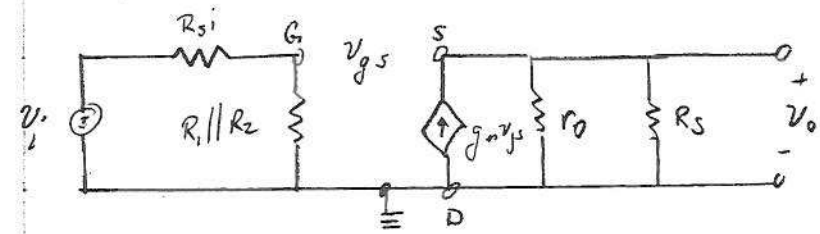
① DC ANALYSIS

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

② Small signal model

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

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

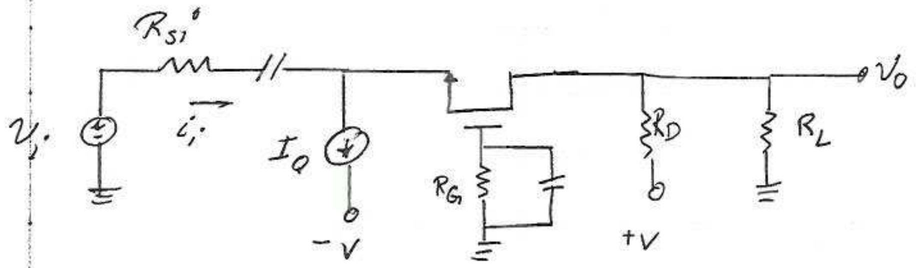


$$R_i = R_1 \| R_2 = 162 \| 463 = \underline{120K\Omega}$$

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

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

Common Gate Example (Ex 4.10)



$V_{TN} = 1^V$

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

$\lambda = 0$

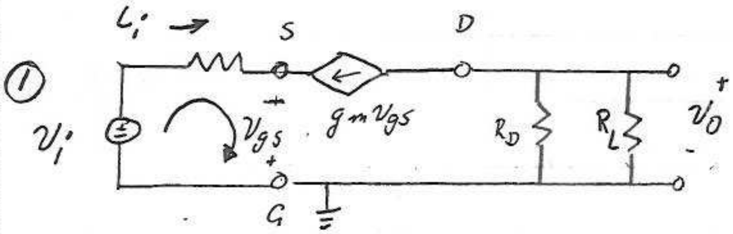
Given: $I_Q = 1^{mA}$, $V^+ = 5^V$, $V^- = -5^V$, $R_G = 100K\Omega$

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

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

$R_{Si} = 50\Omega$

Find v_o

① 

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

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

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

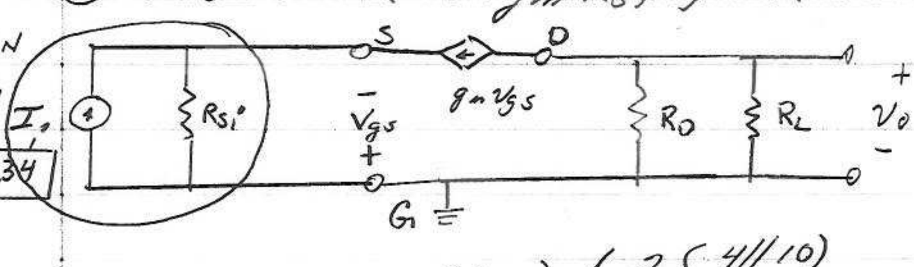
$$v_{gs} = -\frac{v_i}{1 + g_m R_{Si}}$$

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

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

NORTON EQV.

Fig. 4.34



$$v_o = (100\mu A)(50)\underbrace{\left(\frac{2(4\|10)}{1 + 2(0.05)}\right)}_{\sim 5.2} = \boxed{26^{mV}\sin \omega t}$$

TEXT SOLUTION IS WRONG!