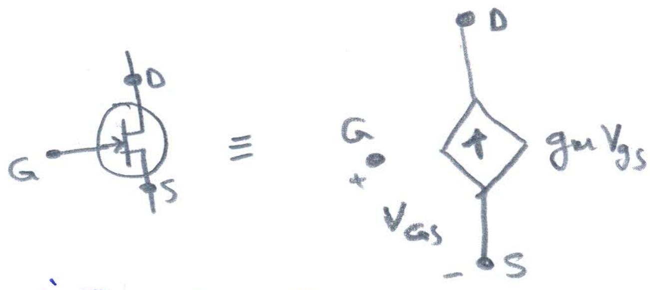
Ch. 9 HW Solution

1 $g_m = 6000\,\mu S$



$\because I_D = g_m V_{GS}$

a) $I_D = 6000 * 10^{-6} * 10 * 10^{-3} = 6 * 10^{-5}$

$\therefore \underline{I_D = 60\,\mu A}$

b) $I_D = 6000\,\mu S * 150\,mV = \underline{900\,\mu A}$

c) $I_D = 6000\,\mu S * 0.6\,V = \underline{3.6\,mA}$

d) $I_D = 6000\,\mu S * 1\,V = \underline{6\,mA}$

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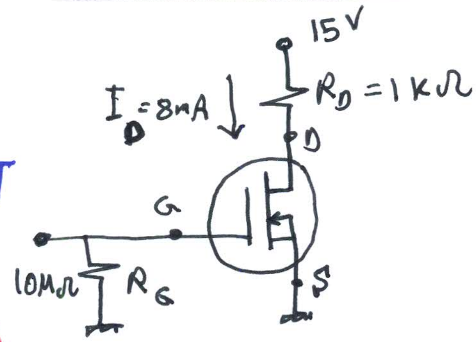
5 & **6**

a)



→ It is N-Channel D-MOSFET

→ Zero biased.

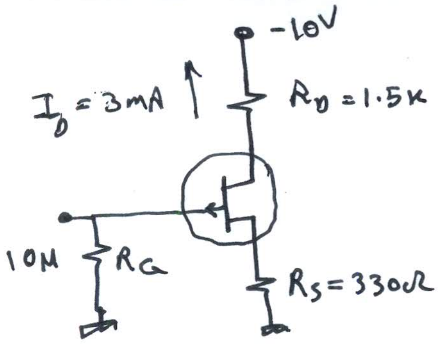
$\underline{V_G = V_S = 0}$ $\therefore \boxed{V_{GS} = 0}$

$\because V_D = V_{DD} - I_D R_D = 15 - 8\,mA * 1K$

$\therefore \underline{V_D = 7\,V}$

5 & 6 (2)

b)



→ It is P-channel FET

→ self biased

→ $\boxed{V_G = 0}$, $V_S = -I_D R_D$

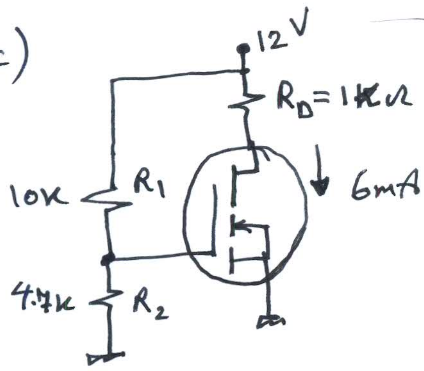
$= -3mA * 1.5k\Omega$

$\therefore \boxed{V_S = -4.5V}$

$\therefore \boxed{V_{GS} = 4.5V}$

$V_D = -10 + 3mA * 1.5k\Omega = -5.5$ $\therefore \boxed{V_D = -5.5V}$

c)



→ It is N-channel E-MOSFET

→ Voltage-divider bias

$$V_G = \frac{R_2}{R_1 + R_2} V_{DD} = \frac{4.7}{14.7} * 12$$

$\therefore$

$$\boxed{\begin{aligned} V_G &= 3.837\ V \\ V_S &= 0\ V \\ V_{GS} &= 3.837\ V \\ V_D &= 6\ V \end{aligned}}$$

$V_D = 12 - 6*10^{-3} * 1*10^{3}$

8

from the graph

at $V_{GS} = -0.5$:

$I_D \simeq 3.9mA$

at $V_{GS} = -3.5$:

$I_D \cong 1.3mA$

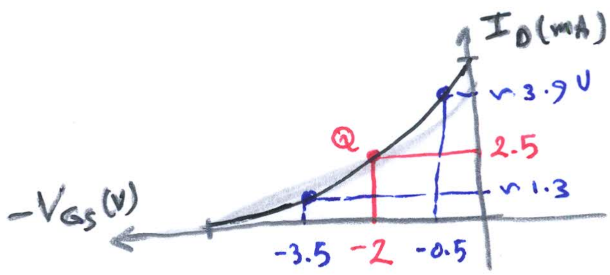
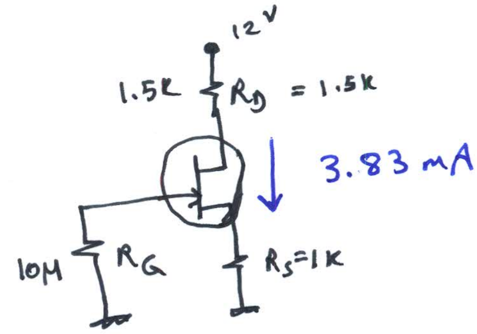


Fig. 9-16(a)

$\therefore \boxed{I_{D(pp)} = 3.9 - 1.3 = 2.6\ mA}$

10 $I_D = 2.83\,mA$, $V_{GS(off)} = -4^V$, $I_{DSS} = 8\,mA$

DC-model of Fig. 9-56:



To get V_{GS}:

$$\because \quad I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

or ((anther soln))

$$V_S \simeq I_D R_S = 2.83\,m * 1K = 3.83V$$

$$V_G = 0$$

$$\therefore \boxed{V_{GS} = -2.83^V}$$

to get V_{DS}:

$$\because \quad V_D = V_{DD} - I_D R_D = 12 - 3.83\,mA * 1.5k$$

$$\therefore \quad V_D = 7.755\ V$$

$$\therefore \quad V_{DS} = 7.755 - 2.83$$

$$\therefore \boxed{V_{DS} \simeq 4.93\ V}$$

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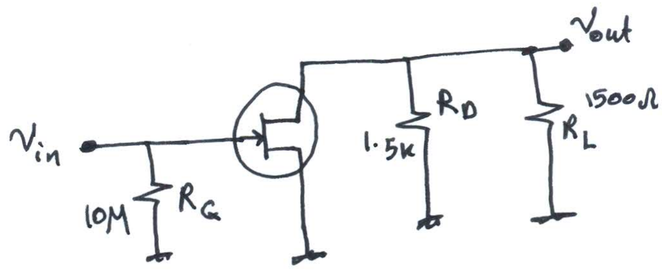
12 $g_m = 5000\,\mu S$, $V_{in} = 50\,mV$ (rms)

AC-model of Fig. 9-56:



⇓ Common-Source amp.

$$\because \quad A_V = \frac{V_{out}}{V_{in}} = g_m\,(R_D \,//\, R_L)$$

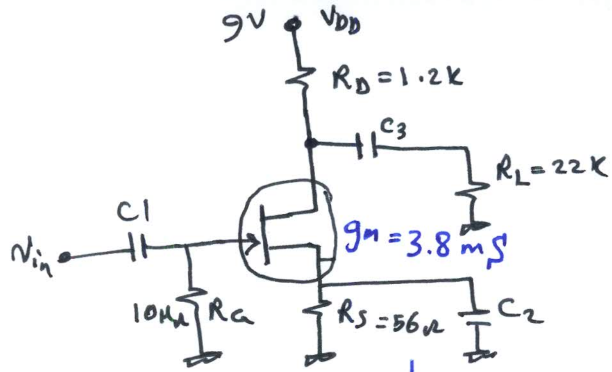
$$\therefore \quad V_{out} = g_m\,(R_D \,//\, R_L)\,V_{in}$$

$$= 5000\,\mu S * \frac{1500 * 1500}{1500 + 1500} * 50\,mV$$

$$= 5000 * 10^{-6} * 750 * 50 * 10^{-3}$$

$$\therefore \boxed{V_{out} = 187.5\ mV\ rms}$$

13 a) $A_V = ??$

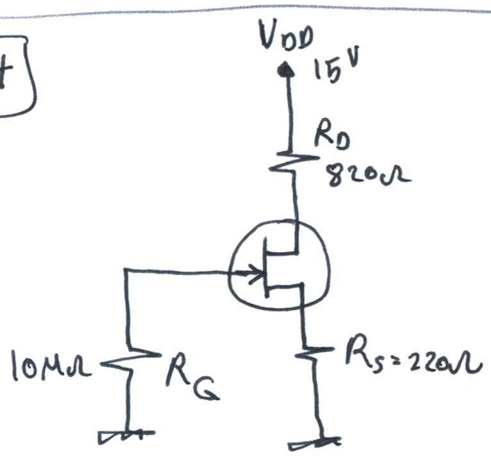


→ Common-Source Amplifier

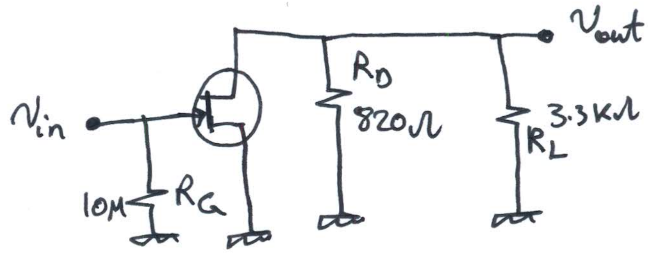
$$\therefore A_V = g_m (R_D \parallel R_L)$$

$$= 3.8 \times 10^{-3} \left(\frac{1.2 \times 22}{1.2 + 22} \right) \times 10^3 \simeq \underline{4.32}$$

14



DC-equivalent cct.



AC equivalent cct.

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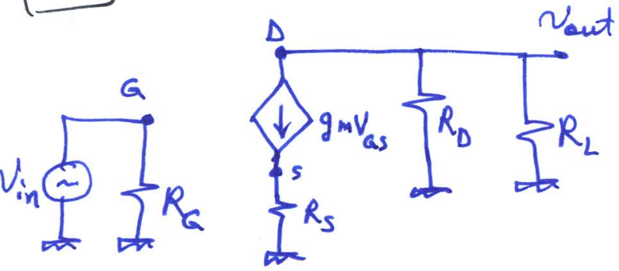
15 $I_{DSS} = 15\ mA$, $V_{GS(off)} = -4$, $I_D = ??$

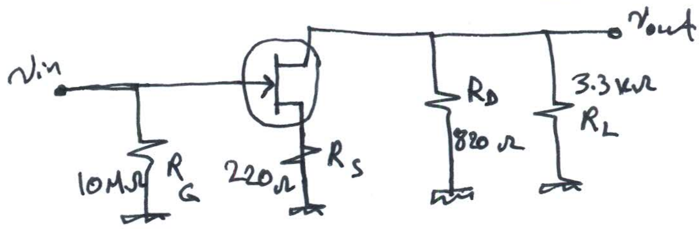
since, the Q-Point is centered :

$$\therefore I_D = \frac{I_{DSS}}{2} = \underline{7.5\ mA}$$

16



cct. model ⟸



ac model

↙

not common source

from eqv. cct model :

$V_G = v_{in}$, $V_D = v_{out} = -g_m V_{GS} (R_D \| R_L)$, $V_S = g_m V_{GS} R_S$

$\therefore \quad V_{GS} = V_G - V_S = v_{in} - g_m V_{GS} R_S$

or $v_{in} = (1 + g_m R_S) V_{GS}$

$\therefore A_v = \dfrac{v_{out}}{v_{in}} = -\dfrac{g_m \cancel{V_{GS}} (R_D \| R_L)}{1 + g_m R_S \cancel{V_{GS}}}$ $\therefore$ $\boxed{A_v = -\dfrac{g_m (R_D \| R_L)}{1 + g_m R_S}}$

→ To get g_m : assume dc-parameters of Q.15 (if Q-point is centered)

$\therefore I_D = 7.5\,mA$, $\because V_S = I_D R_S = 7.5\,mA * 220\,\Omega$, $V_G = 0$

$\therefore V_{GS} = -1.65\,V$

$\because g_m = \dfrac{2 I_{DSS}}{|V_{GS(off)}|} \left(1 - \dfrac{V_{GS}}{V_{GS(off)}}\right) = \dfrac{2 * (15m)}{4} \left(1 - \dfrac{-1.65}{-4}\right)$

$\therefore g_m \simeq 4.41\ mS$

$\therefore A_v = -\dfrac{4.41\,mS * \dfrac{820 * 3300}{820 + 3300}}{1 + 4.41\,mS * 220} = -1.47$

or $\boxed{|A_v| = 1.47}$

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17 assume the same g_m of 16

$A_v = g_m (R_D \| R_L \| 4.7k) = g_m \dfrac{1}{\frac{1}{R_D} + \frac{1}{R_L} + \frac{1}{4.7K}}$

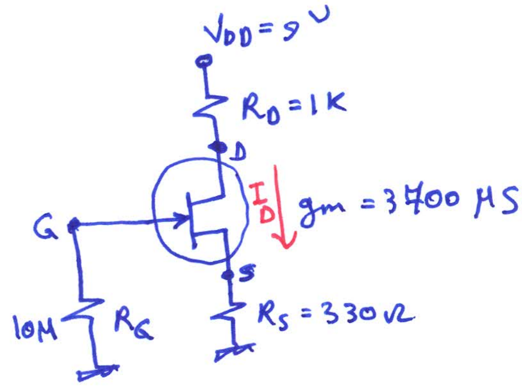
$\therefore A_v = g_m * (576.3)$

$= 4.41 * 10^{-3} * 576.3$

$\therefore \boxed{A_v = 2.541}$

18 $I_{DSS} = 9\,mA$, $V_{GS(off)} = -3^V$
centered Q-Point

dc equivalent cct. :-



as centered Q-Point :

$$\therefore I_D = \frac{I_{DSS}}{2} = \boxed{4.5\,mA}$$

$$V_G = 0\,V$$

$$V_S = I_D R_s = 4.5 * 10^{-3} * 330 = 1.485\,V$$

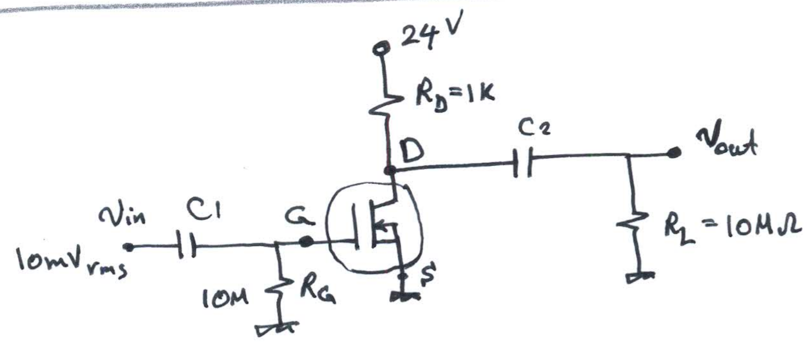
$$\therefore V_{GS} = V_G - V_S = -1.485^V$$

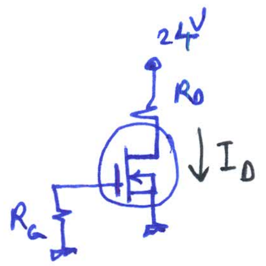
$$V_D = V_{DD} - I_D R_D = 9 - 4.5\,mA * 1\,k\Omega = 4.5^V$$

$$\therefore V_{DS} = 4.5 - (+1.485) = 3.015$$

$$\therefore \boxed{V_{GS} \simeq -1.49\,V, \quad V_{DS} \simeq 3^V}$$

22 $g_m = 4.8\,mS$, $I_{DSS} = 15\,mA$





① dc-analysis :

$V_G = 0$, $V_S = 0$

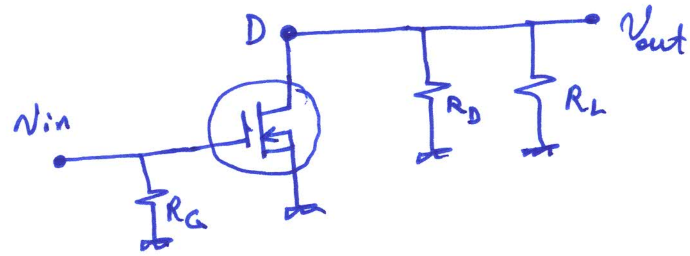
$\therefore V_{GS} = 0$

$\therefore I_D = I_{DSS} = 15\,mA$

$\because V_D = V_{DD} - I_D R_D = 24 - 15m * 1K$

$$\therefore \boxed{V_D\Big|_{dc} = 9\,V}$$

② ac - analysis:



$\because \quad A_v = g_m \, (R_D \,//\, R_L)$

$\therefore \quad A_v = 4.8 * 10^{-3} * \left(\dfrac{10^3 * 10 * 10^6}{10^3 + 10 * 10^6} \right)$

$\therefore \quad A_v \simeq 4.8$

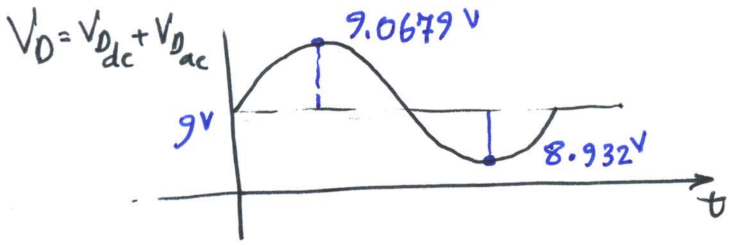
$\because \quad A_v = \dfrac{v_{out}}{v_{in}} \quad \therefore \quad v_{out} = A_v \, v_{in}$

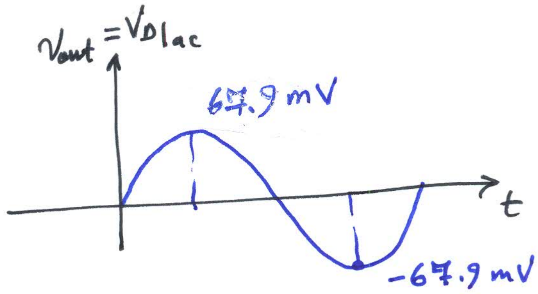
$= 4.8 * 10 \text{ mV}$

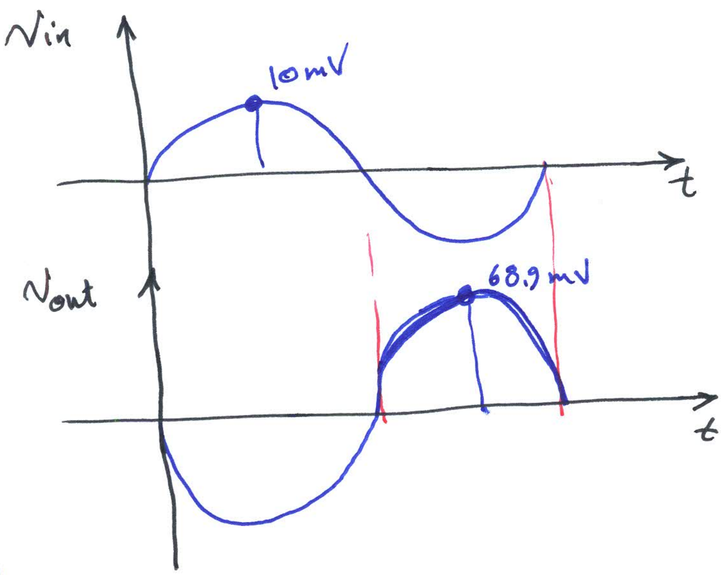
$\therefore \; v_{out} = 48 \text{ mV rms}$

$\because \quad v_{out(p)} = \sqrt{2} * 48 \text{ mV} = 67.9 \text{ mV}$

and $\quad V_{D|ac} \text{ (Peak)} = 67.9 \text{ mV}$





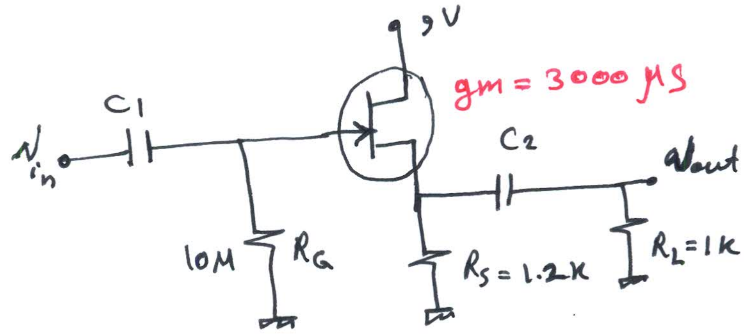


⇒ Don't forget that v_{out} is 180° phase shift to v_{in}

$A_{v_1} = -g_m \, (R_D // R_L)$

exact

25 $I_{GSS} = 50\,pA$, $V_{GS} = -15V$



↳ Common-drain amp.
or
Source follower

$$A_V = \frac{g_m (R_S // R_L)}{1 + g_m (R_S // R_L)}$$

$$\because R_S // R_L = \frac{1.2K * 1k}{1.2K + 1.K} = 545.4\ \Omega$$

$$\therefore A_V = \frac{3000 * 10^{-6} * 545.4}{1 + 3000*10^{-6}*545.4}$$

$$\therefore \boxed{A_V \simeq 0.621}$$

$$\because R_{In} = R_G // r_{gin} \quad ; \quad r_{gin} = \frac{|V_{GS}|}{I_{GSS}} = \frac{15}{50*10^{-12}} = 3*10^{11}\ \Omega$$

$$\therefore R_{In} = \frac{10*10^6 * 3*10^{11}}{10^7 + 3*10^{11}} = 9.99967*10^6 \simeq 10\ M\Omega$$

$$\therefore \boxed{R_{In} \cong 10\ M\Omega}$$

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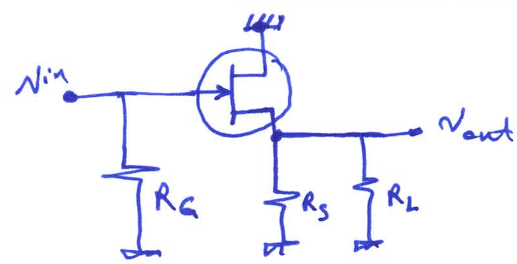
ac - equivalent cct.:



a) $$A_V = \frac{g_m (R_S // R_L)}{1 + g_m (R_S // R_L)}$$

$$R_S // R_L = \frac{4.7 * 47}{4.7 + 47}\ k\Omega = 4.273\ k\Omega$$

$$\therefore A_V = \frac{3*10^{-3} * 4.273*10^{3}}{1 + 3\,mS * 4.273\,k\Omega}$$

$$\therefore \boxed{A_V \simeq 0.928}$$

b) $$R_S // R_L = \frac{100 * 1000}{100 + 1000}\ \Omega = 90.91\ \Omega$$

$$A_V = \frac{4300 * 10^{-6} * 90.91}{1 + 4300*10^{-6}*90.91}$$

$$\therefore \boxed{A_V \simeq 0.281}$$

... gate amp. , $gm = 4\ mS$, $R_d = 1.5\ K\Omega$, $A_V = ??$

$\because A_V = gm\, R_d$

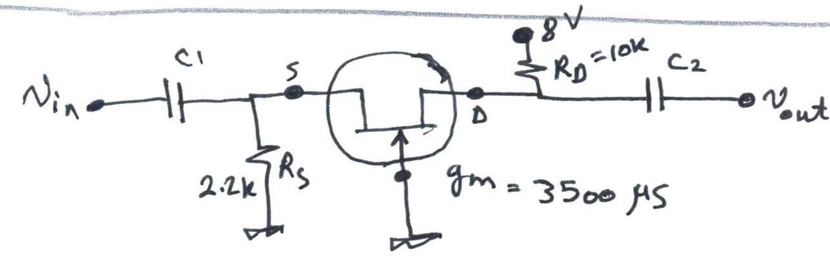
$= 4\,m * 1.5\,K$ $\therefore \boxed{A_V = 6}$

$\boxed{29}$ $R_{in} = ??$

$\because R_{in}|_{source} = \frac{1}{gm} = \frac{1}{4\,mS}$

$\therefore \boxed{R_{in} = 250\ \Omega}$

$\boxed{30}$ $A_V = ?$, $R_{in} = ?$



A common gate amp.

$A_V = gm\, R_D$

$= 3500 * 10^{-6} * 10 * 10^{3}$

$\therefore \boxed{A_V = 35}$

$R_{in} = R_S // (r_{in}|_{source})$; $r_{in}|_{source} = \frac{1}{gm} = 285.7\ \Omega$

$\therefore R_{in} = \frac{2200 * 285.7}{2200 + 285.7} = 252.86\ \Omega$

$\therefore \boxed{R_{in} \simeq 253\ \Omega}$