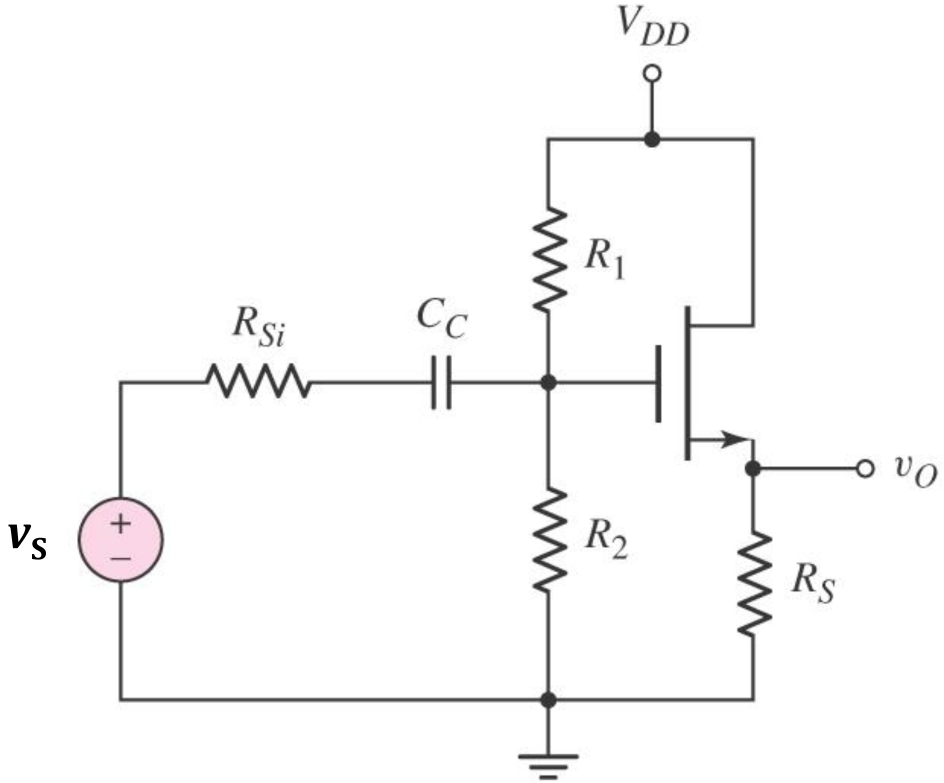
The MOSFET Amplifier - COMMON DRAIN

- The output is measured at the source terminal
- The gain is positive value



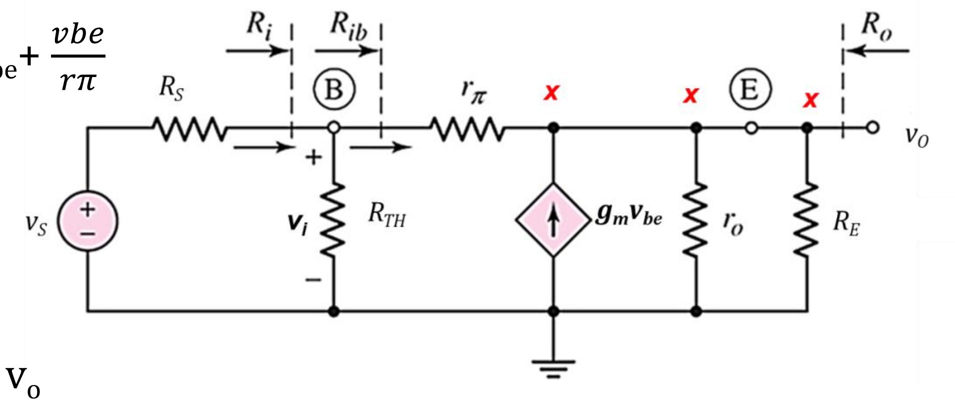
COMMON COLLECTOR

OUTPUT SIDE

1. Get the equivalent resistance at the output side, R_{eq}
2. At node *x*, use KCL and get i_o where $i_o = g_m v_{be} + \frac{vbe}{r\pi}$
3. Get the v_o equation where $v_o = i_o R_{eq}$

INPUT SIDE

4. Calculate $R_{ib} = r\pi + (1+\beta) R_{eq}$
5. Calculate $R_i = R_{ib} // R_{TH}$
6. v_{be} in terms of v_i using supermesh, $v_i = v_{be} + v_o$



COMMON DRAIN

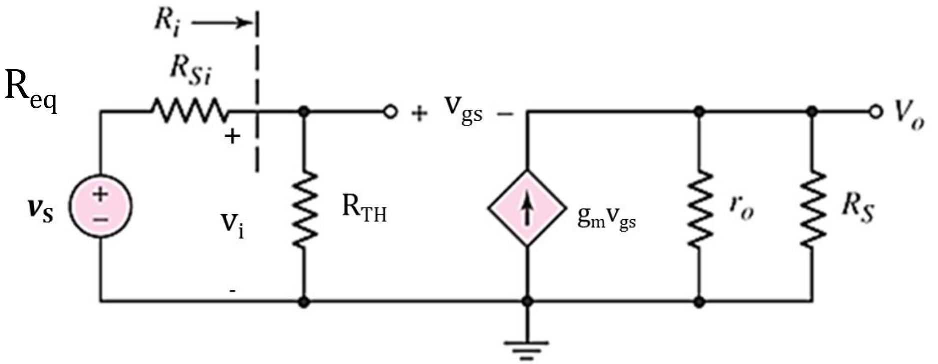
OUTPUT SIDE

1. Equivalent resistance at the output side, R_{eq}
2. Calculate $v_o = g_m v_{gs} R_{eq}$

INPUT SIDE

3. Find v_i in terms of v_{gs} using supermesh

$$v_i = v_{gs} + v_o$$



OUTPUT SIDE

1. Equivalent resistance at the output side, $R_{eq} = r_o||R_S$
2. Calculate $v_o = g_m v_{gs} R_{eq} = g_m v_{gs} (r_o||R_S)$

INPUT SIDE

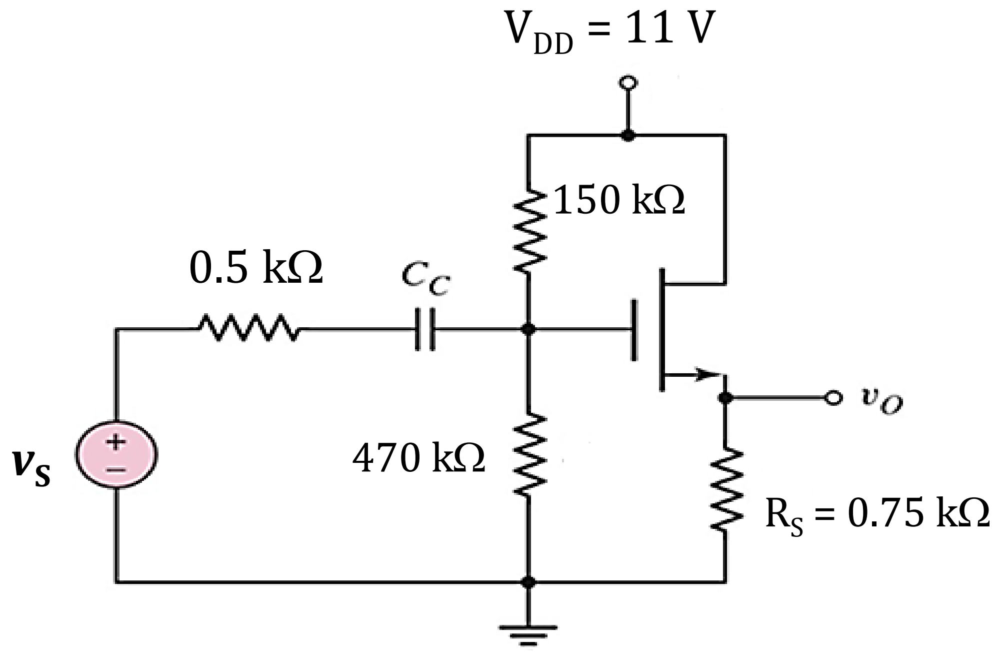
3. Find v_i in terms of v_{gs} using supermesh

$$v_i = v_{gs} + v_o = v_{gs} + g_m v_{gs} (r_o||R_S) = v_{gs}(1 + g_m(r_o||R_S))$$

4. $A_v v_i = v_o = g_m v_{gs} (r_o||R_S)$ ← open circuit voltage

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

$$A_v = \frac{g_m(r_o\|R_S)}{1+g_m(r_o\|R_S)}$$ ← open circuit voltage gain



$V_{TN} = 0.92$ V, $K_n = 4$ mA /V^2 , $\lambda = 0.01\ V^{-1}$

R_{TH} = 113.7 kΩ

V_{TH} = (470 / 620) x 11 = 8.34 V

DC ANALYSIS

1. Calculate the value of V_{GS}

KVL at GS loop:

$0 + V_{GS} + 0.75(I_D) - 8.34 = 0$

$V_{GS} = 8.34 - 0.75I_D$

2. Assume the transistor is biased in the saturation region, the drain current:

$$I_D = K_n(V_{GS} - V_{TN})^2$$

$$I_D = 4(8.34 - 0.75I_D - 0.92)^2 = 4(7.42 - 0.75I_D)^2$$

$$I_D = 4(55.06 - 11.13I_D + 0.5625I_D{}^2)$$

$$2.25I_D{}^2 - 45.52I_D + 220.24 = 0$$

$I_D = 12.22$ mA → Replace in V_{GS} equation in step 1: $V_{GS} = 2 - 3I_D$ → $V_{GS} = -0.825$ V

$I_D = 8$ mA → Replace in V_{GS} equation in step 1: $V_{GS} = 2 - 3I_D$ → $V_{GS} = 2.34$ V

Why choose $V_{GS} = 2.34$ V ?
Because it is bigger than V_{TN}

3. Use KVL at DS loop

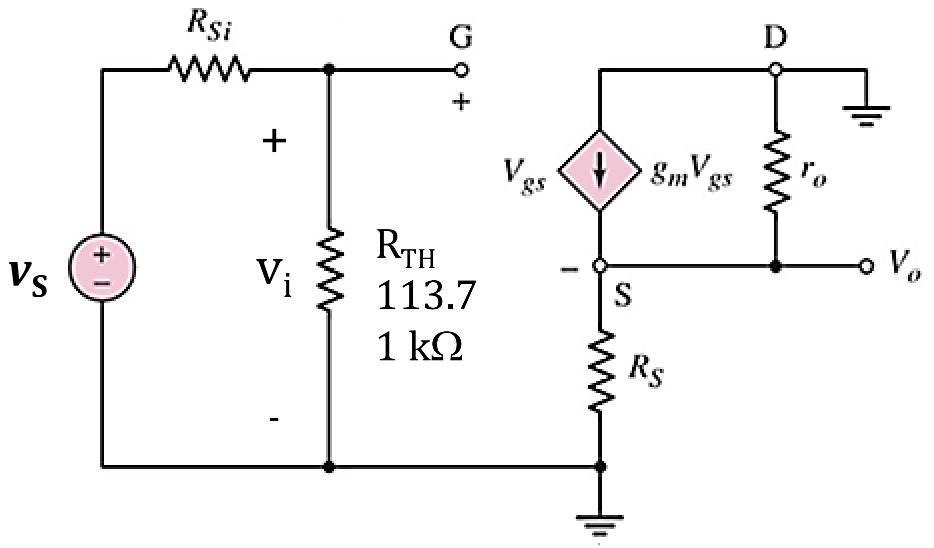
$$V_{DS} + I_D R_S - 11 = 0$$
$$V_{DS} = \mathbf{5\ V}$$

4. Calculate $V_{DSsat} = V_{GS} - V_{TN} = 2.34 - 0.92 = \mathbf{1.42\ V}$

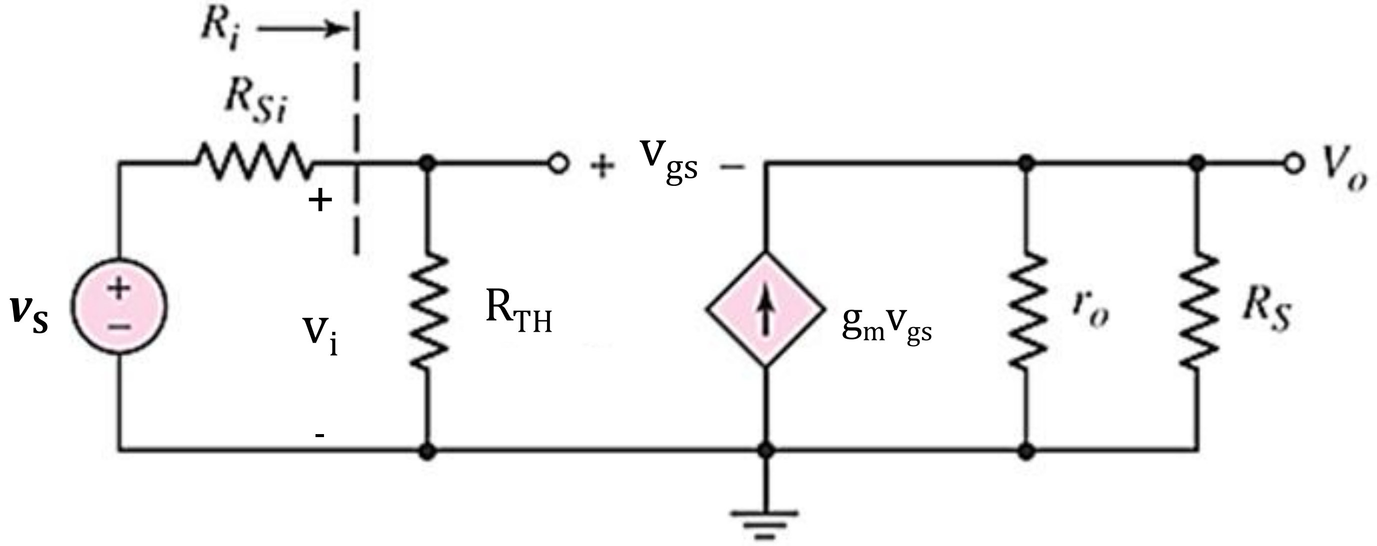
5. Confirm your assumption: $\mathbf{V_{DS} > V_{DS\,sat}}$, our assumption is correct

$$g_m = 2\sqrt{K_n I_{DQ}} \Rightarrow g_m = 11.3\ mA/V$$

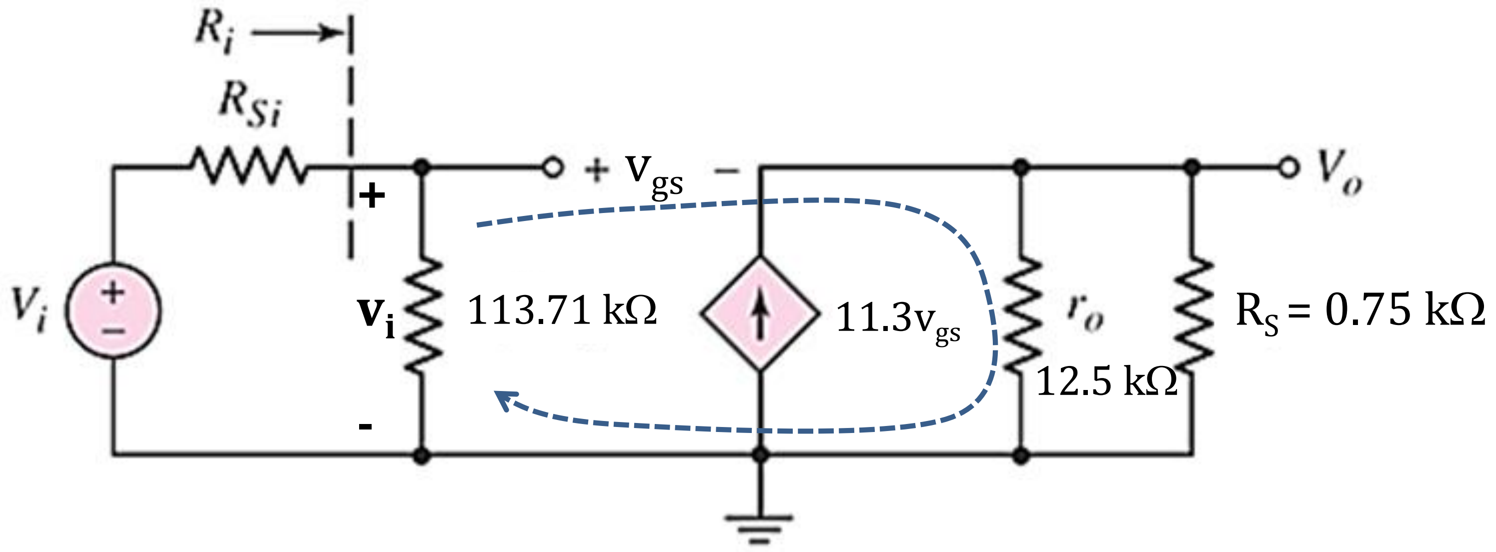
$$\lambda = 0.01\ V^{-1} \Rightarrow V_A = 100\ V \Rightarrow r_o = 12.5\ k\Omega$$



R_{Si}
G
D
+
+
V_{gs}
$g_m V_{gs}$
r_o
v_S
V_i
R_{TH}
113.7
1 kΩ
−
S
V_o
R_S
-



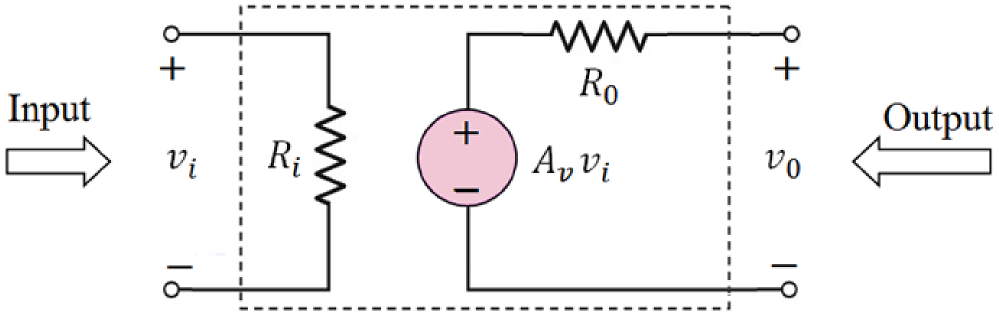
R_i
R_{Si}
+
+ V_{gs} −
V_o
v_S
V_i
R_{TH}
$g_m v_{gs}$
r_o
R_S
-



1. The output resistance: $R_{eq} = ro \,||\, R_s = 0.70755\ k\Omega$
2. The output voltage $v_o = g_m v_{gs}\ (R_{eq}) = 11.3\ v_{gs}\ (0.70755) = 8\ v_{gs}$
3. Find v_i in terms of v_{gs} using supermesh

$$v_i = v_{gs} + v_o$$

$$v_i = v_{gs} + 8\ v_{gs} = 9\ v_{gs}$$



Equivalent circuit of a voltage amplifier

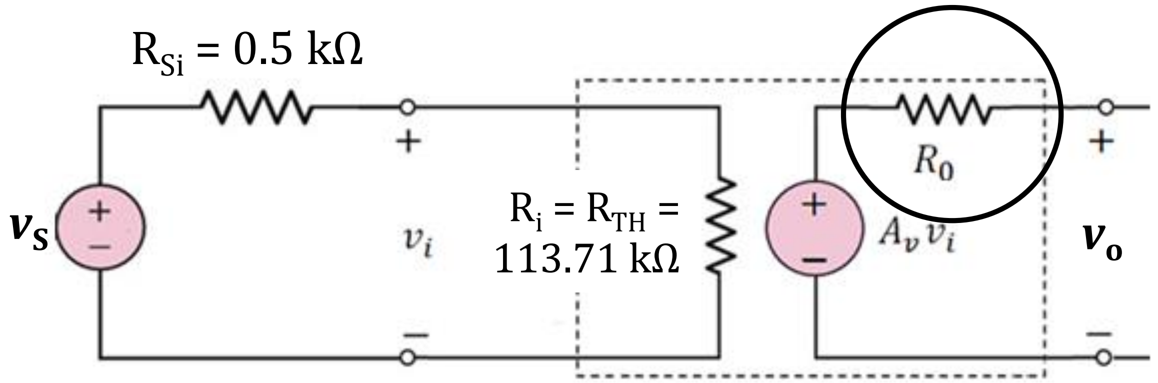
Equation of v_o : $v_o = v_o = g_m v_{gs} (R_{eq}) = 11.3\ v_{gs} (0.70755) = 8\ v_{gs}$

$v_i = 9\ v_{gs}$

$A_v v_i = v_o$ ← open circuit voltage

$A_v \not{v_i} = 8\ v_{gs} = \dfrac{8\ \not{v_i}}{9}$

$A_v = 0.889$ ← open circuit voltage gain



Equivalent circuit of a voltage amplifier

To find new voltage gain, v_o/v_s with input signal voltage source, v_s

v_i in terms of v_s → use voltage divider:

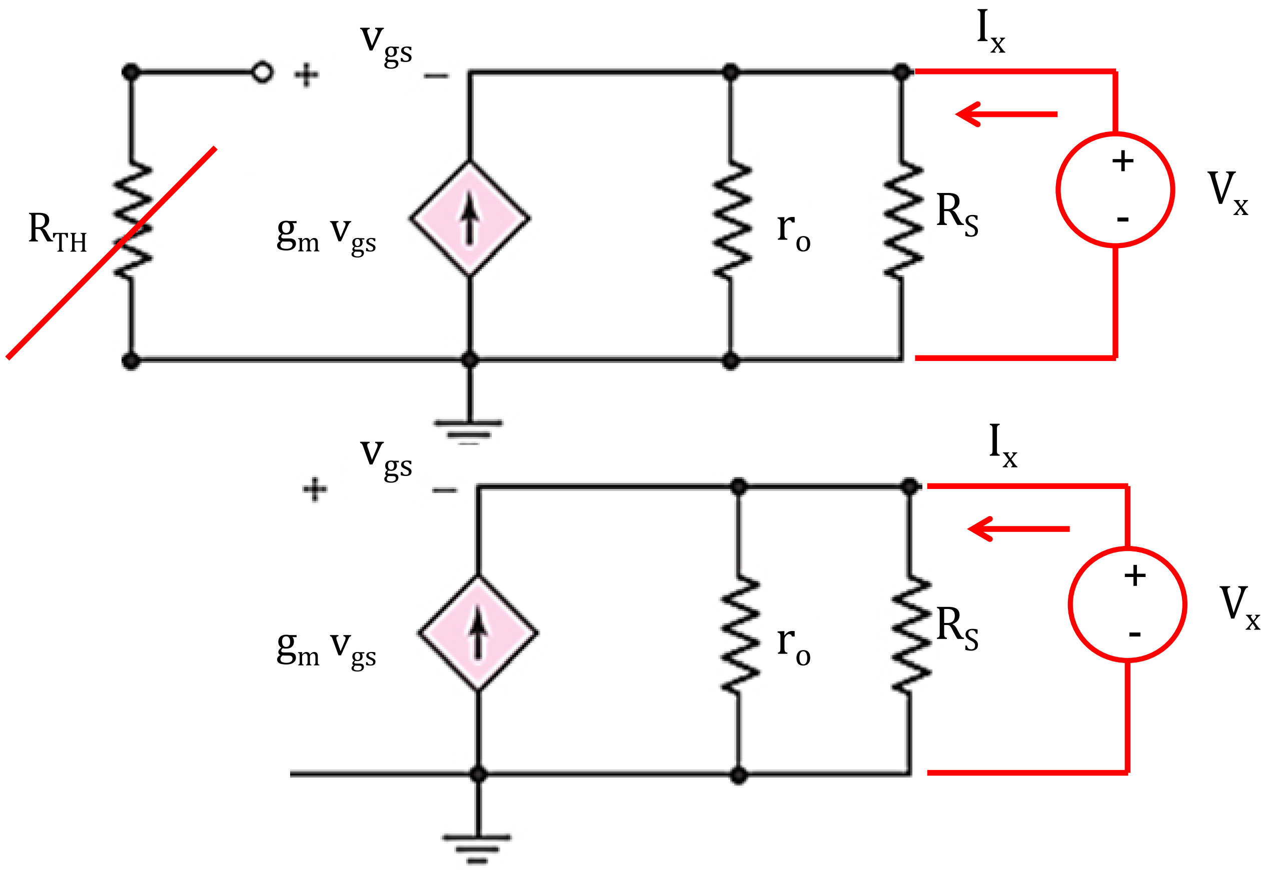
$v_i = [\, R_i / (\, R_i + R_s\,)] * v_s \; = 0.9956\, v_s$

$v_o = A_v v_i$ ← because there is no load resistor

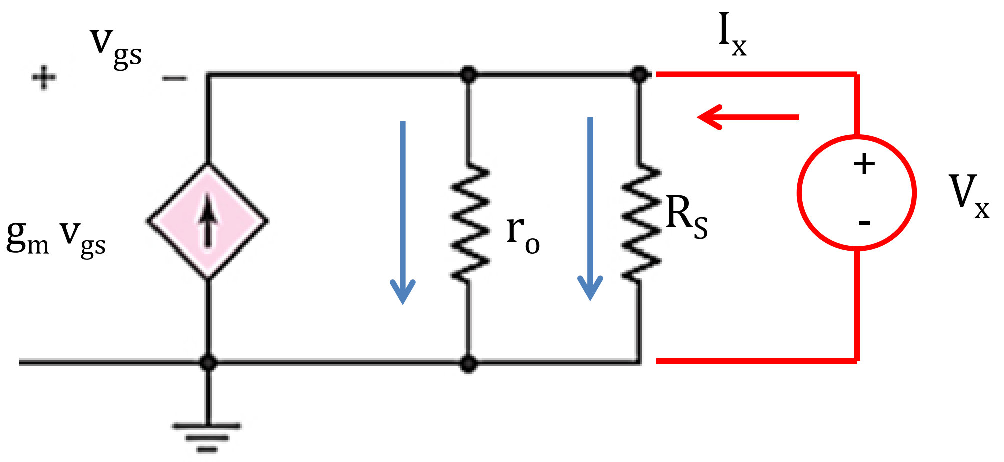
$v_o = 0.889\, (0.9956\, v_s)$

$v_o/v_s = 0.885$

Output Resistance for Common Drain



v_{gs} in terms of V_x where $v_{gs} = -V_x$



Use nodal analysis

$$\frac{V_x}{r_o} + \frac{V_x}{R_s} = g_m v_{gs} + I_x$$

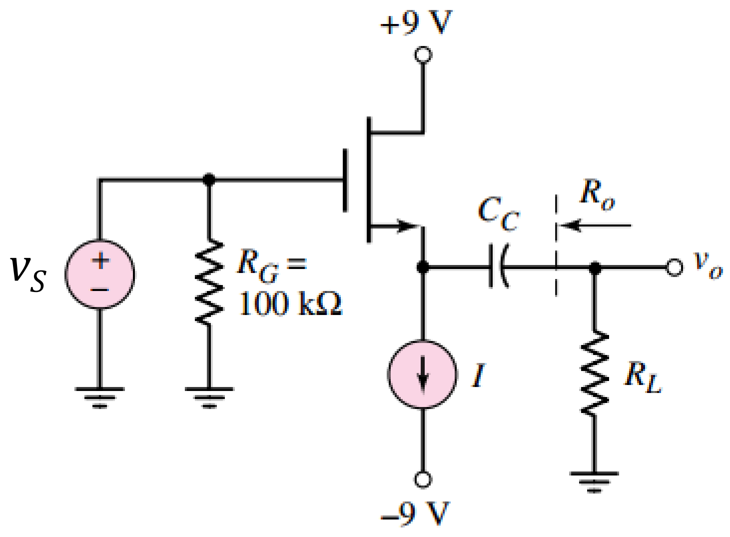
$$\frac{V_x}{r_o} + \frac{V_x}{R_s} = -g_m V_x + I_x$$

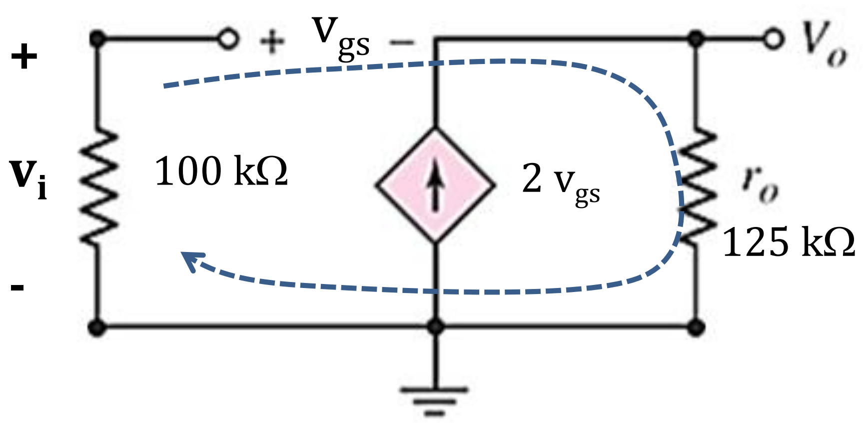
$$\frac{V_x}{r_o} + \frac{V_x}{R_s} + g_m V_x = I_x$$

$$R_0 = \left(\frac{1}{g_m} \middle\| R_S \| r_0\right)$$

Using DC analysis, calculate the values of g_m and r_0. Assuming that, $R_G = 100\ k\Omega$, $K_n = 1.25\ mA/V^2$, $V_A = 100\ V$, $I = 0.8\ mA$ and $R_L = 4\ k\Omega$

Calculate the gain $A_v = \frac{v_o}{v_s}$ and R_o

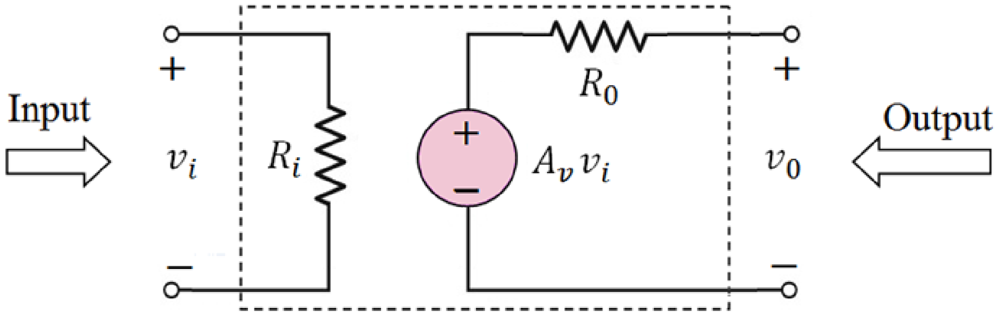




1. The output resistance: $R_{eq} = r_o = 125\ k\Omega$
2. The output voltage $v_o = g_m v_{gs} (R_{eq}) = 2\ v_{gs}\ (125) = 250\ v_{gs}$
3. Find v_i in terms of v_{gs} using supermesh

$$v_i = v_{gs} + v_o$$

$$v_i = v_{gs} + 250\ v_{gs} = 251\ v_{gs}$$



Equivalent circuit of a voltage amplifier

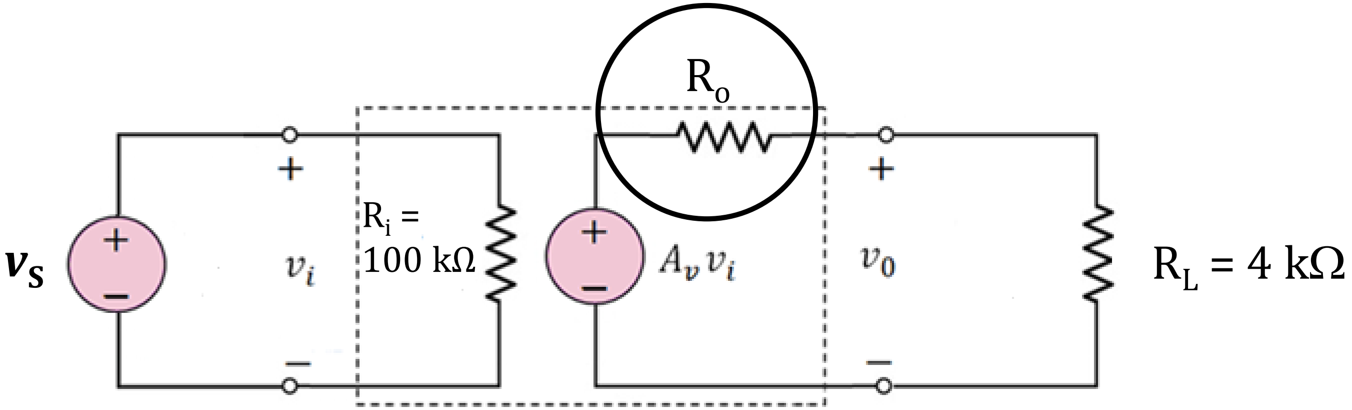
Equation of v_o : $v_o = v_o = g_m v_{gs} (R_{eq}) = 250\ v_{gs}$

$v_i = 251\ v_{gs}$

$A_v v_i = v_o$ ← open circuit voltage

$A_v \not{v_i} = 250\ v_{gs} = \dfrac{250\ \not{v_i}}{251}$

$A_v = 0.996$ ← open circuit voltage gain



Since we have R_L we have to calculate R_o

$r_o = 125\ k\Omega$, $g_m = 2\ mA/V$ and there is no R_S

$$R_0 = \left(\frac{1}{g_m} \middle\| R_S \| r_0\right)$$

So, $R_o = 0.498k\Omega$

v_i in terms of v_S

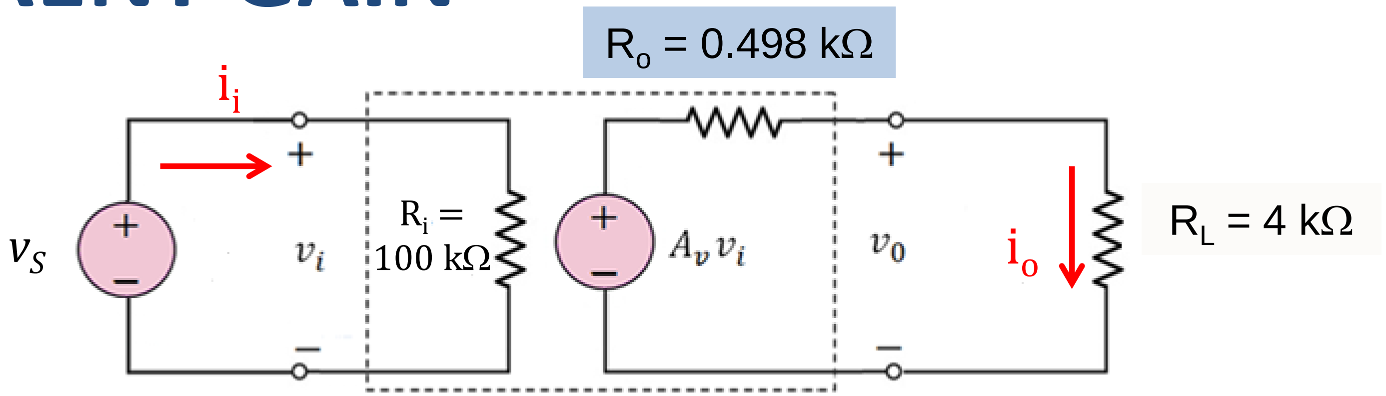
$v_i = v_s$ ← in parallel

$v_o = [R_L / (R_L + R_o)] * A_v v_i$ ← this is because we have load resistor R_L

$v_o = [4 / (4.498)] (0.996\ v_s)$

$v_o / v_s = 0.886$

CURRENT GAIN



- Output side: $i_o = v_o / 4 = v_o / 4$
- Input side: $i_i = v_s / R_i = v_S / 100$

Current gain

$= i_o / i_i$

$$= \frac{v_o (100)}{v_s (4)} = 0.886 * 25$$

= <u>22.15</u>

TYPE OF BJT AMPLIFIER	OPEN CIRCUIT VOLTAGE GAIN	INPUT RESISTANCE, R_i	OUTPUT RESISTANCE, R_O
COMMON SOURCE WITH SOURCE GROUNDED	$A_{voc} = -\,(r_o \vert\vert R_D)\, g_m$	R_{TH} or R_G	$r_o \vert\vert R_D$
COMMON SOURCE WITH R_S (assume $r_o = \infty$)	$A_{voc} = \left(\frac{-R_D\, g_m}{1+g_m R_S}\right)$	R_{TH} or R_G	R_D
COMMON SOURCE WITH BYPASS CAPACITOR, C_S	$A_{voc} = -\,(r_o \vert\vert R_D)\, g_m$	R_{TH} or R_G	$r_o \vert\vert R_D$
COMMON DRAIN	$A_{voc} = \frac{g_m(r_o \vert\vert R_S)}{1 + g_m(r_o \vert\vert R_S)}$	R_{TH} or R_G	$\frac{1}{g_m} \vert\vert r_o \vert\vert R_S$