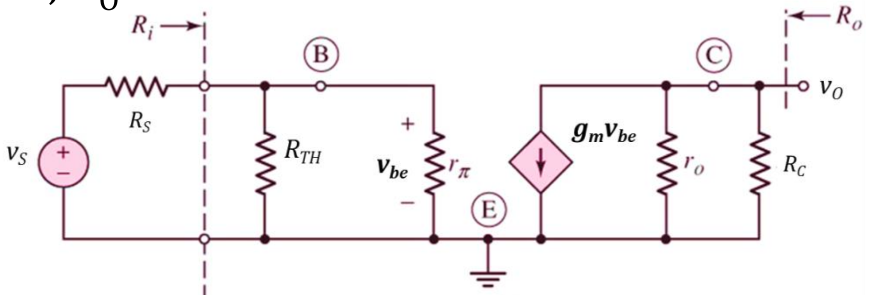
# Type 3: With Source Bypass Capacitor, $C_S$

- **Circuit with Source Bypass Capacitor**
  - An **source bypass capacitor** can be used to effectively create a short circuit path during ac analysis hence avoiding the effect $R_S$
  - $C_S$ becomes a short circuit path – bypass $R_S$; hence similar to Type 1

## COMMON EMITTER with $C_E$

### OUTPUT SIDE

1. Get the equivalent resistance at the output side, $R_O$
2. Get the $v_o$ equation where $v_o = -g_m v_{be} R_O$




### INPUT SIDE

3. Calculate $R_i$
4. Get $v_{be}$ in terms of $v_i$

## COMMON SOURCE with $C_S$

### **OUTPUT SIDE**

1. Equivalent resistance at the output side, $R_O$
2. Get the $v_o$ equation where $v_o = -g_m v_{gs} R_O$

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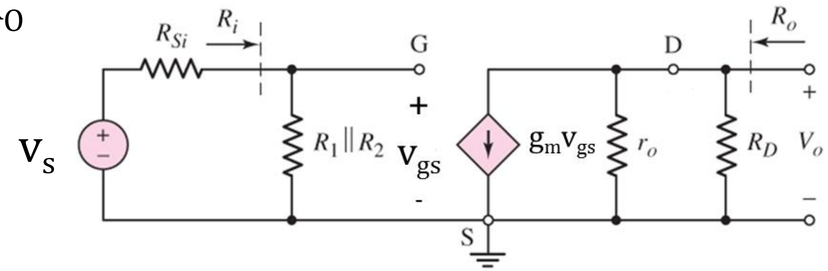


### **INPUT SIDE**

3. Get $v_{gs}$ in terms of $v_i$

## OUTPUT SIDE

1. Equivalent resistance at the output side, $R_O = r_o || R_D$
2. Get the $v_o$ equation where $v_o = -g_m v_{gs} R_O = -g_m v_{gs} (r_o || R_D)$

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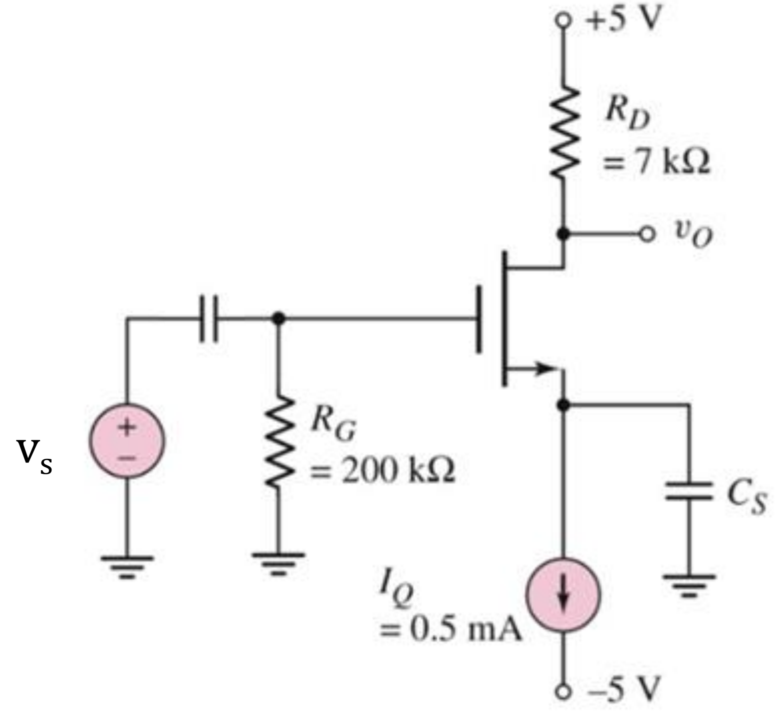
## INPUT SIDE

3. Get $v_{gs}$ in terms of $v_i \rightarrow v_{gs} = v_i$

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

   $A_v v_i = -g_m v_i (r_o || R_D)$

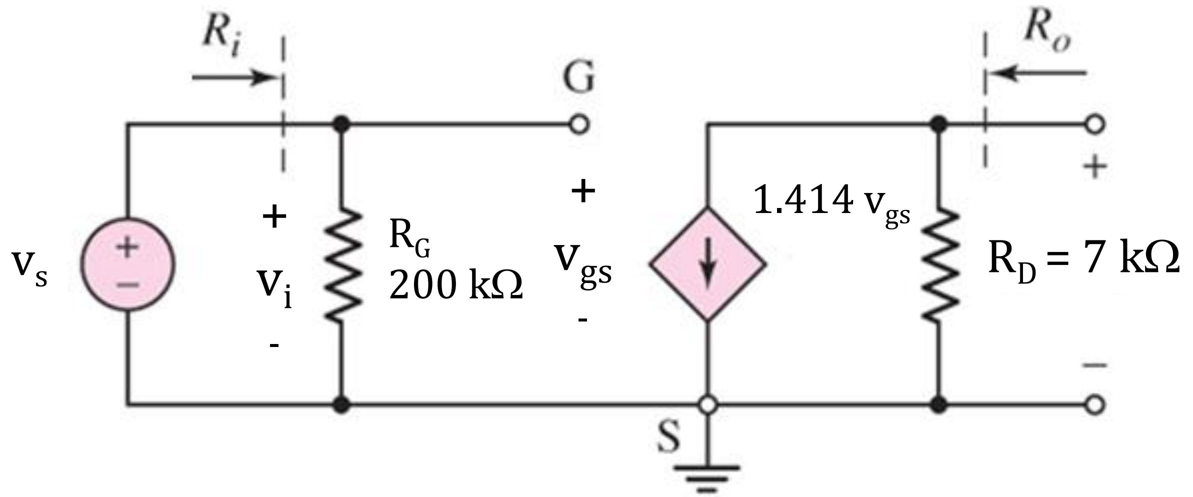
   $A_v = -g_m (r_o || R_D)$ ← open circuit voltage gain

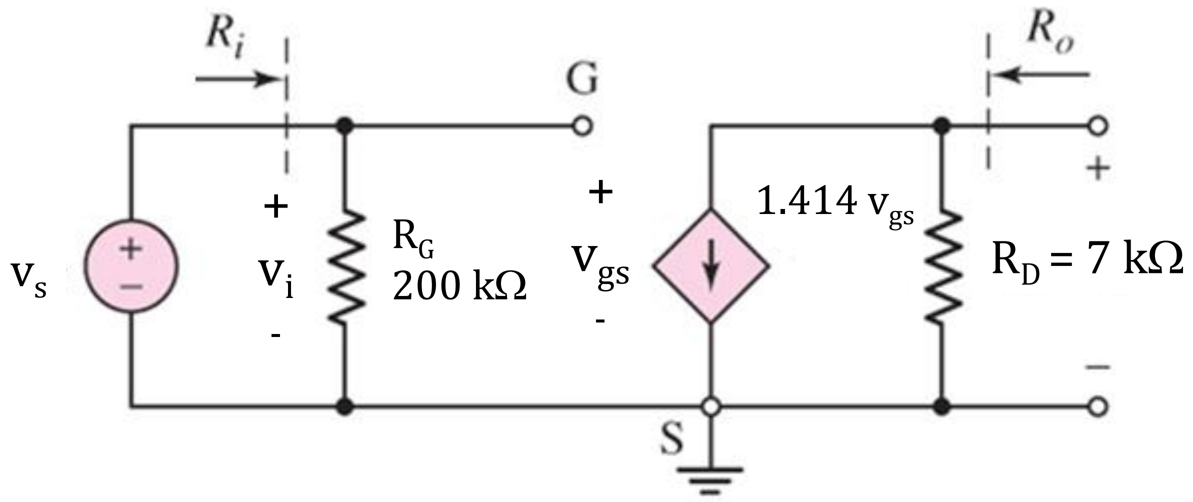



$I_Q$ = 0.5 mA hence, $I_D$ = 0.5 mA

$r_o = \infty$

$g_m = 2\sqrt{K_n I_{DQ}}$ ⇒ $g_m$ = 1.414 mA/V






1. The output resistance, $R_o = R_D = 7\ k\Omega$
2. The output voltage:

$$v_o = -\ g_m v_{gs}\ (R_D) = -1.414\ (7)\ v_{gs} = -\ 9.898\ v_{gs}$$

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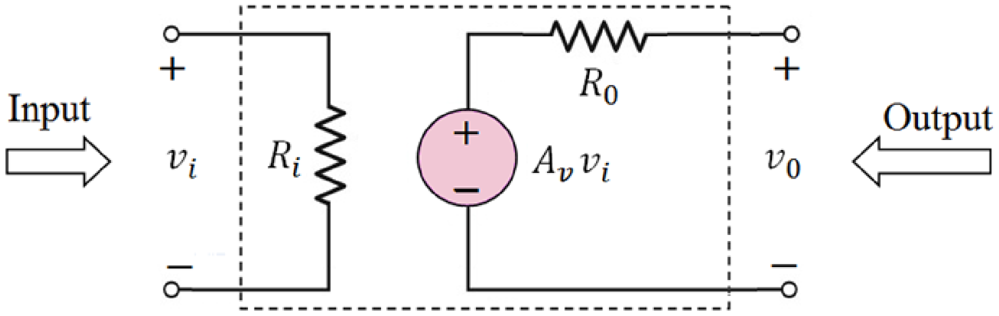
3. The gate-to-source voltage:

$$v_{gs} = v_i$$




Equivalent circuit of a voltage amplifier

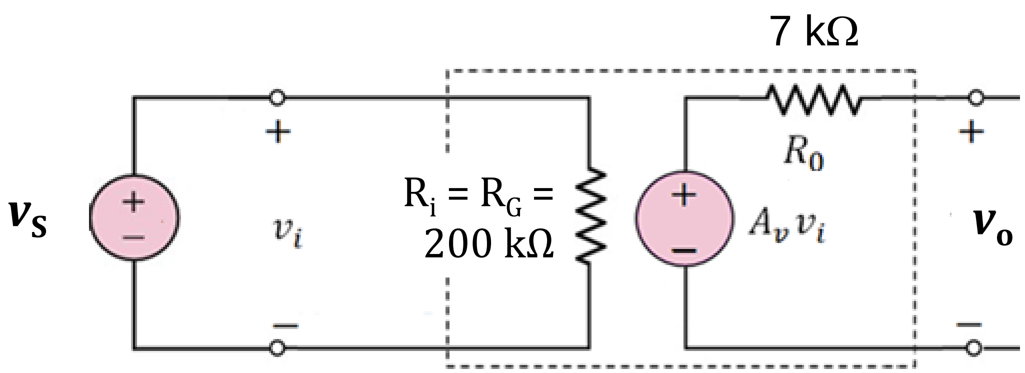
Equation of $v_o$ : $v_o = - g_m v_{gs} (R_D) = -1.414\ (7)\ v_{gs} = - 9.898\ v_{gs}$

$v_i = v_{gs}$

$A_v v_i = v_o$ ← open circuit voltage

$A_v \not{v}_i = -9.898\ v_{gs} = -9.898\ \not{v}_i$

$A_v = - 9.898$ ← 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 $v_s$

$v_i = v_s$ ← in parallel

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

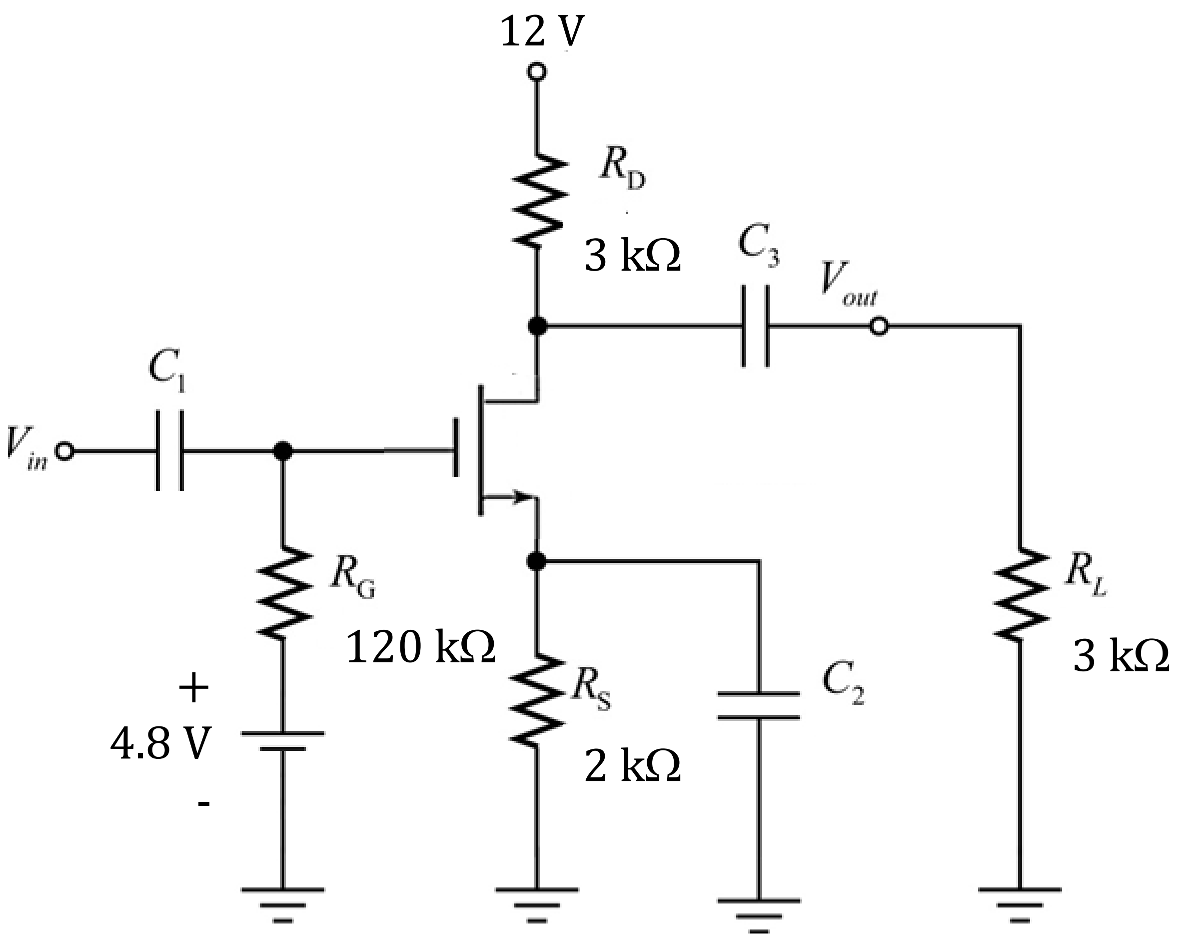
$v_o = -9.898\ (v_s)$

$v_o/v_s = -9.898$

| TYPE OF BJT AMPLIFIER | OPEN CIRCUIT VOLTAGE GAIN | INPUT RESISTANCE, $R_i$ | OUTPUT RESISTANCE, $R_O$ |
|---|---|---|---|
| COMMON SOURCE WITH SOURCE GROUNDED | $A_{voc} = -(r_o \| R_D) g_m$ | $R_{TH}$ or $R_G$ | $r_o \| R_D$ |
| 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, $C_S$ | $A_{voc} = -(r_o \| R_D) g_m$ | $R_{TH}$ or $R_G$ | $r_o \| R_D$ |

# Example

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




1. Without bypass capacitor – TYPE 2
2. With bypass capacitor – TYPE 3

## DC ANALYSIS

1. Calculate the value of $V_{GS}$

   **KVL at GS loop:**

   $0 + V_{GS} + 2(I_D) - 4.8 = 0$

   $V_{GS} = 4.8 - 2I_D$

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

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

$$I_D = 1(4.8 - 2I_D - 2)^2 = 1(2.8 - 2I_D)^2$$

$$I_D = 1(7.84 - 11.2I_D + 4I_D^2)$$

$$4I_D^2 - 12.2I_D + 7.84 = 0$$

$V_{TN} = 2$ V, $K_n = 1$ mA / V$^2$

→ $I_D = 2.13$ mA → Replace in $V_{GS}$ equation in step 1, $V_{GS} = 4.8 - 2I_D$ → $V_{GS} = 0.54$ V

→ $I_D = 0.92$ mA → Replace in $V_{GS}$ equation in step 1, $V_{GS} = 4.8 - 2I_D$ → $V_{GS} = 2.96$ V

Why choose $V_{GS} = 2.96$ V ?
Because it is bigger than $V_{TN}$

3. Use KVL at DS loop

$$3I_D + V_{DS} + 2I_D - 12 = 0$$
$$V_{DS} = \mathbf{7.4\ V}$$

4. Calculate $V_{DSsat} = V_{GS} - V_{TN} = 4.8 - 2 = \mathbf{2.8\ V}$

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

$$g_m = 2\sqrt{K_n I_{DQ}} \Rightarrow g_m = 1.92\ mA/V$$

$$\lambda = 0 \Rightarrow V_A = \infty \Rightarrow r_o = \infty$$