Huazhong University of Science and Technology
The Department of Electronics and Information Engineering

Electronic Circuit Analysis and Design

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Ch4 Basic FET Amplifiers

4.1 The MOSFET Amplifier

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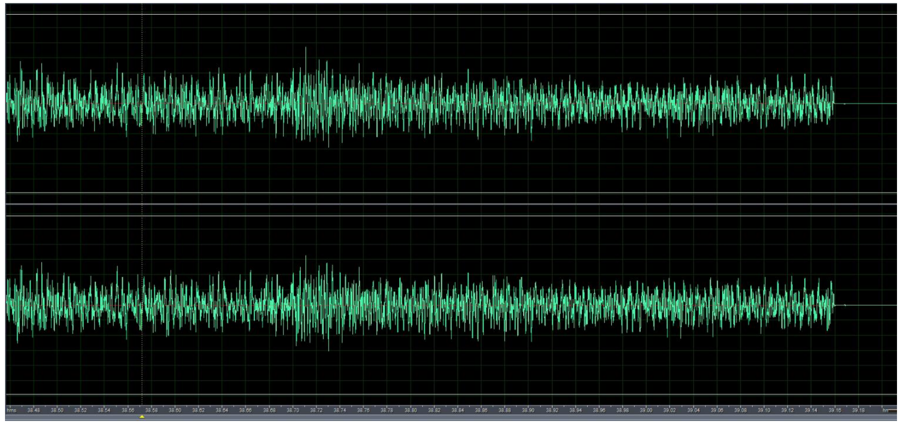
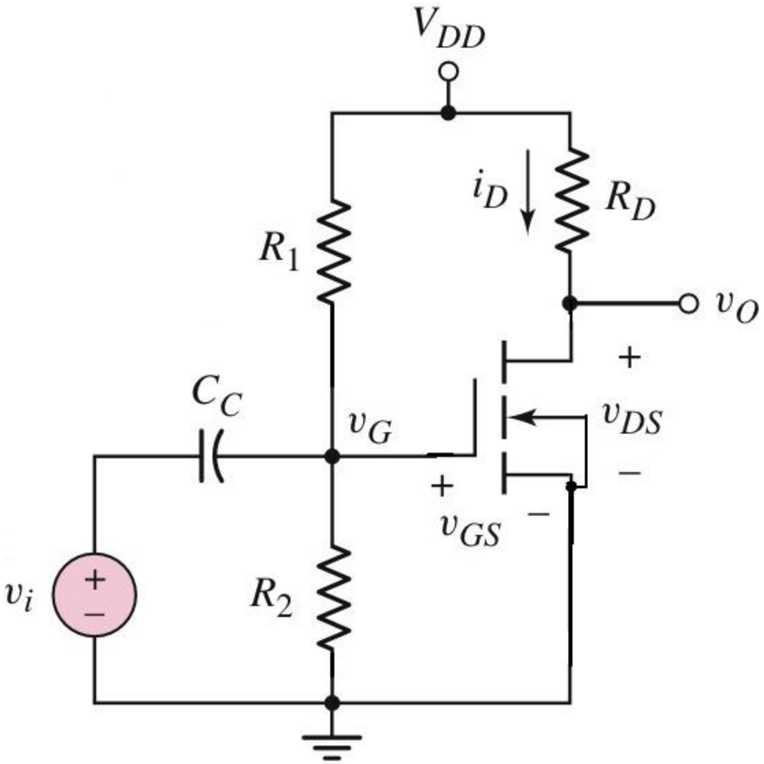
4.1 The MOSFET Amplifier



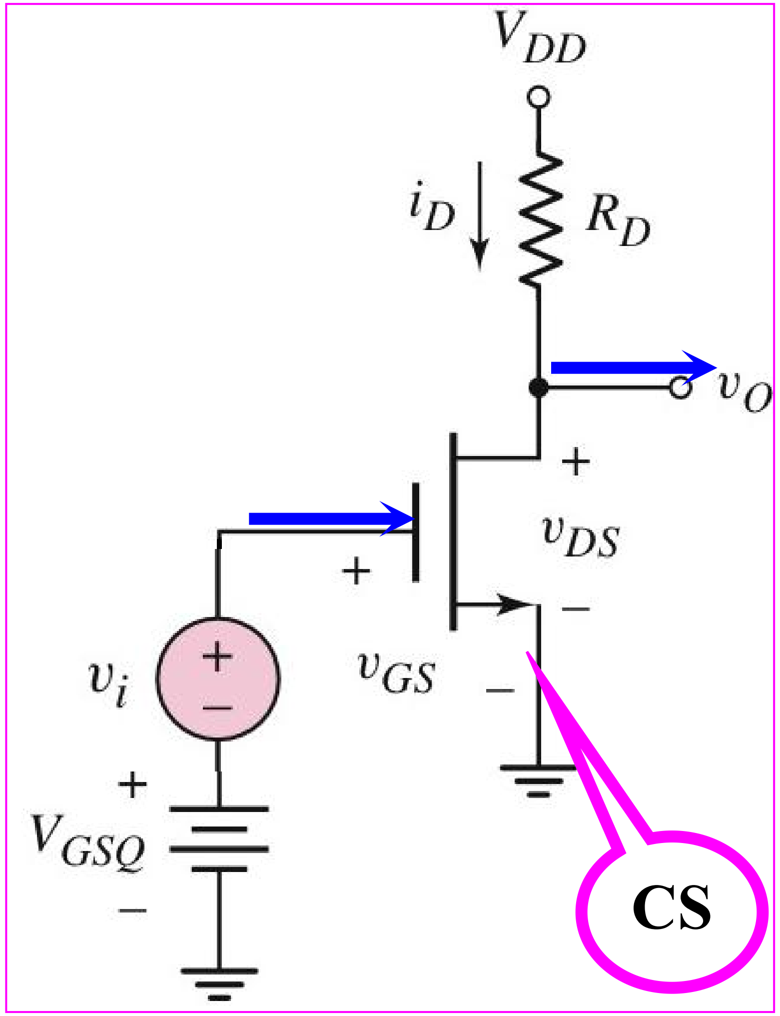
signals sound

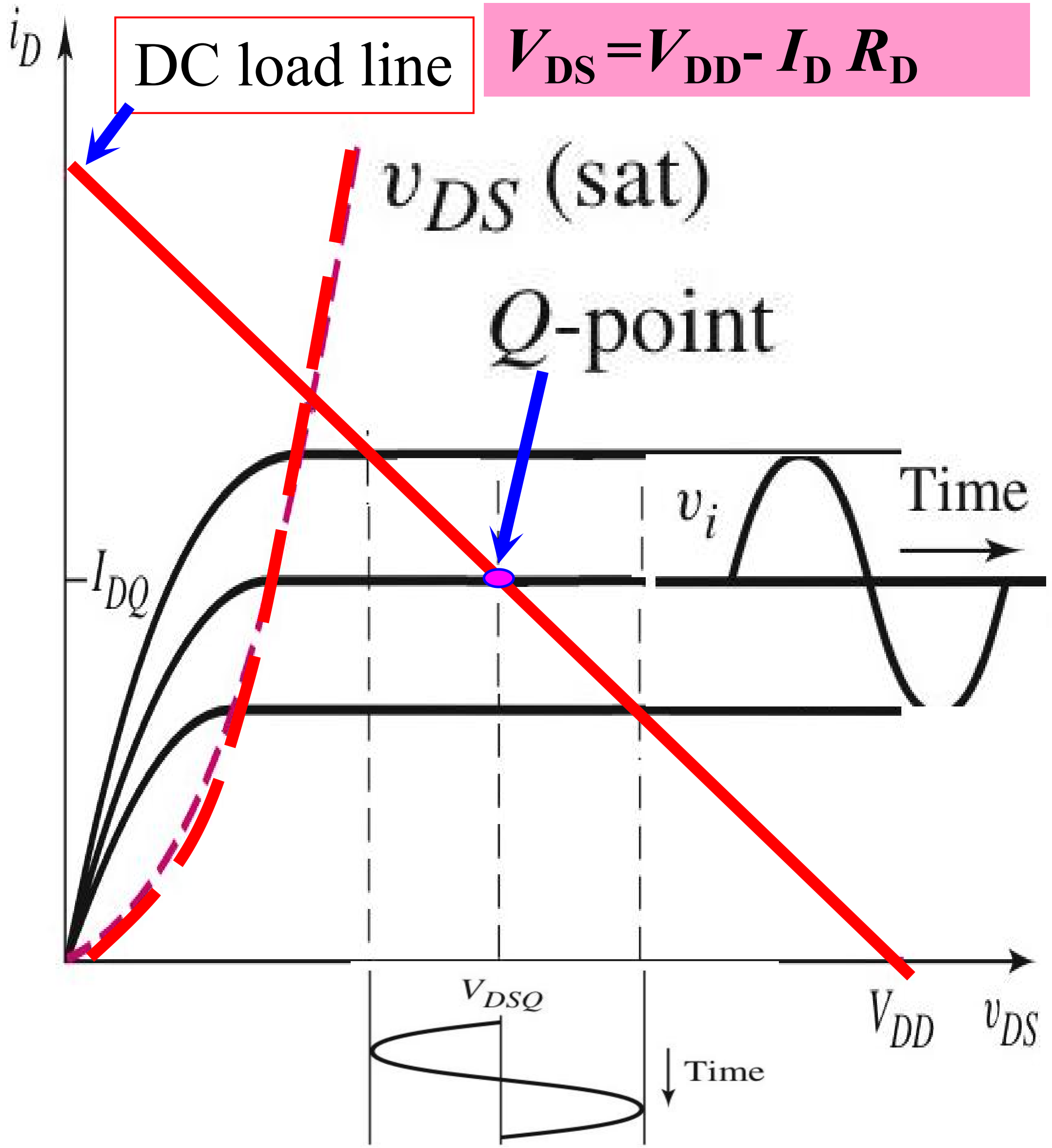
Analog circuits



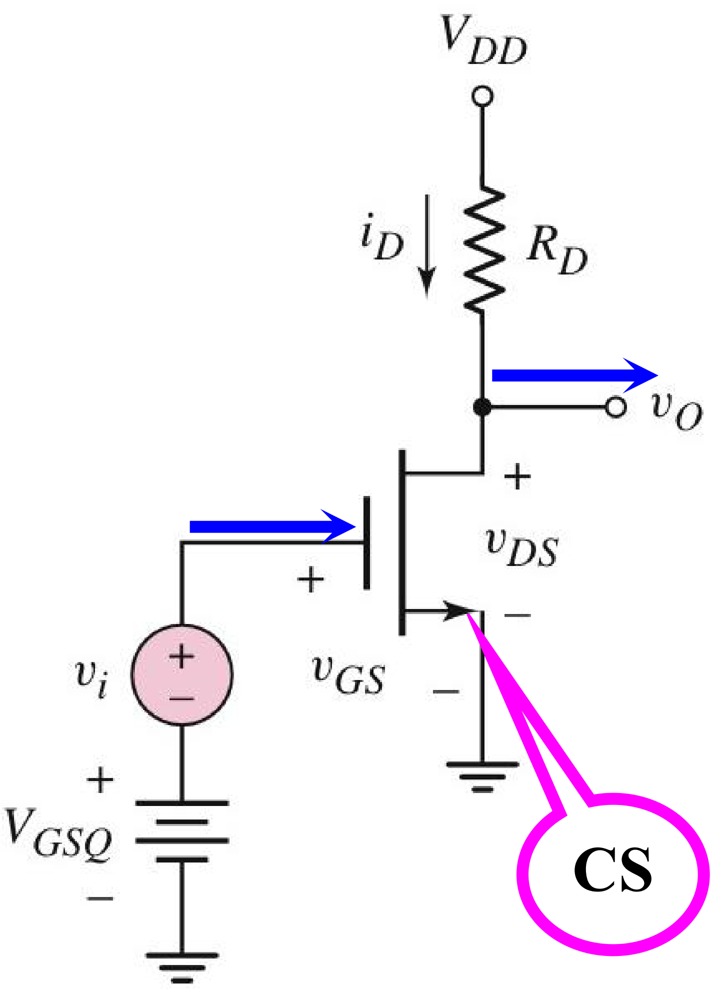
amplifiers

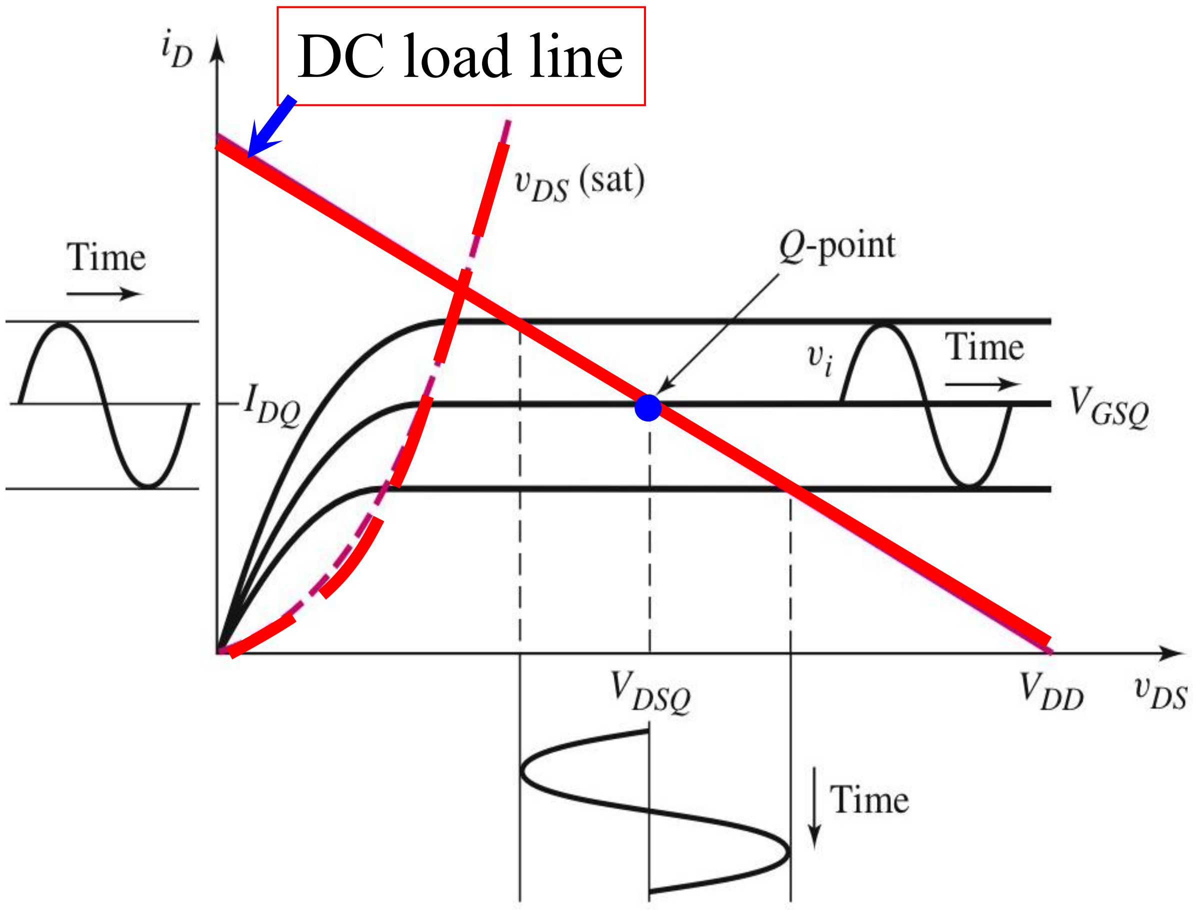
4.1.1 Graphical Analysis, Load line, and small signal parameters





4.1.1 Graphical Analysis, Load line, and small signal parameters

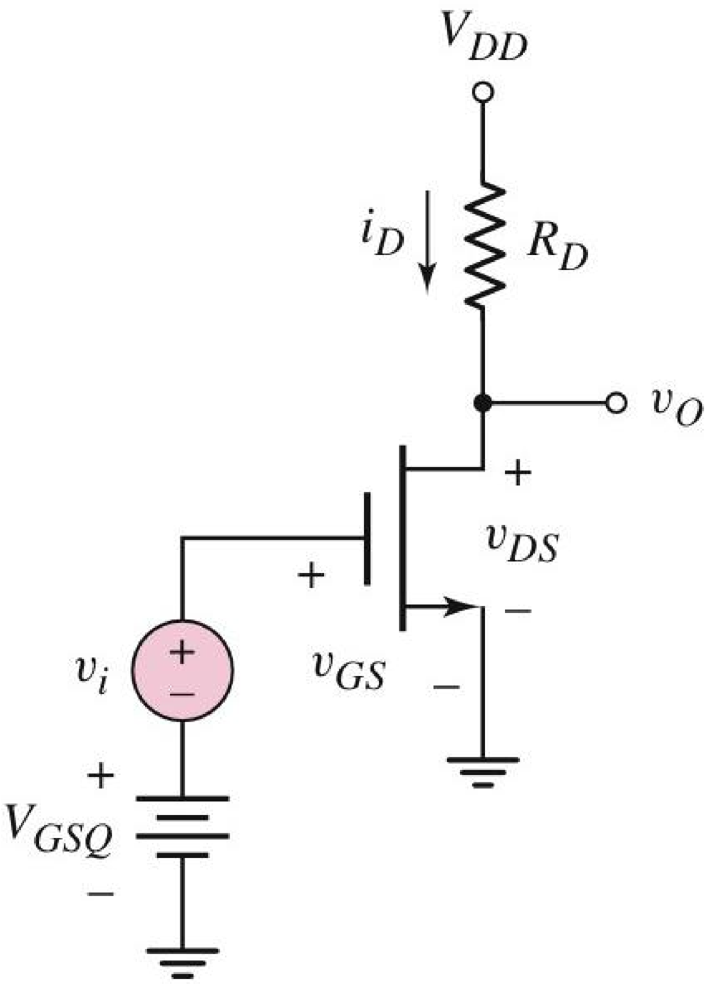




4.1.1 Graphical Analysis, Load line, and small signal parameters

Summary of notation	
Variable	**Meaning**
i_D, v_{GS}	Total instantaneous values
I_D,V_{GS}	DC values
i_d, v_{gs}	instantaneous ac values
I_d, V_{gs}	Phase values

4.1.1 Graphical Analysis, Load line, and small signal parameters



$v_{GS}=V_{GSQ}+v_i=V_{GSQ}+v_{gs}$

$$i_D=K_n(v_{GS}-V_T)^2$$

$$=K_n(V_{GSQ}+v_{gs}-V_T)^2$$

$$=K_n(V_{GSQ}-V_T)^2$$

$$+2K_n(V_{GSQ}-V_T)v_{gs}+K_n v_{gs}^2$$

$$=I_{DQ}+g_m v_{gs}+\cancel{K_n v_{gs}^2}$$

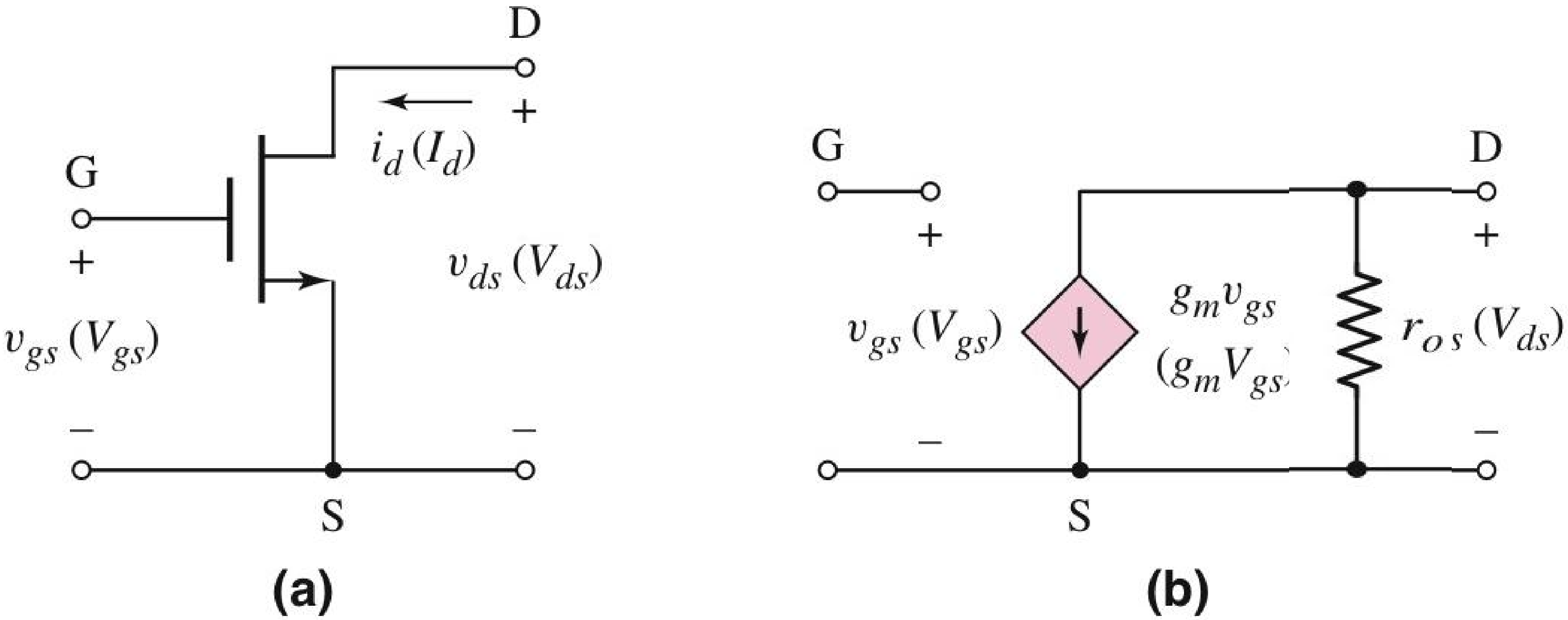
$v_{gs} \ll 2(V_{GSQ}-V_T)$

$$\boxed{i_D=I_{DQ}+g_m v_{gs}=I_{DQ}+i_d}$$

$$\boxed{i_d=g_m v_{gs}}$$

4..1.2 small signal equivalent circuit

$$\boldsymbol{i}_{\mathbf{d}} = \boldsymbol{g}_{\mathbf{m}} V_{\mathbf{gs}} \qquad \lambda \neq 0$$



$$g_m = 2K_n(V_{GSQ} - V_{TN}) = 2\sqrt{K_n I_{DQ}}$$

4.1.1 Graphical Analysis, Load line, and small signal parameters

- **Values depends on Q-point**

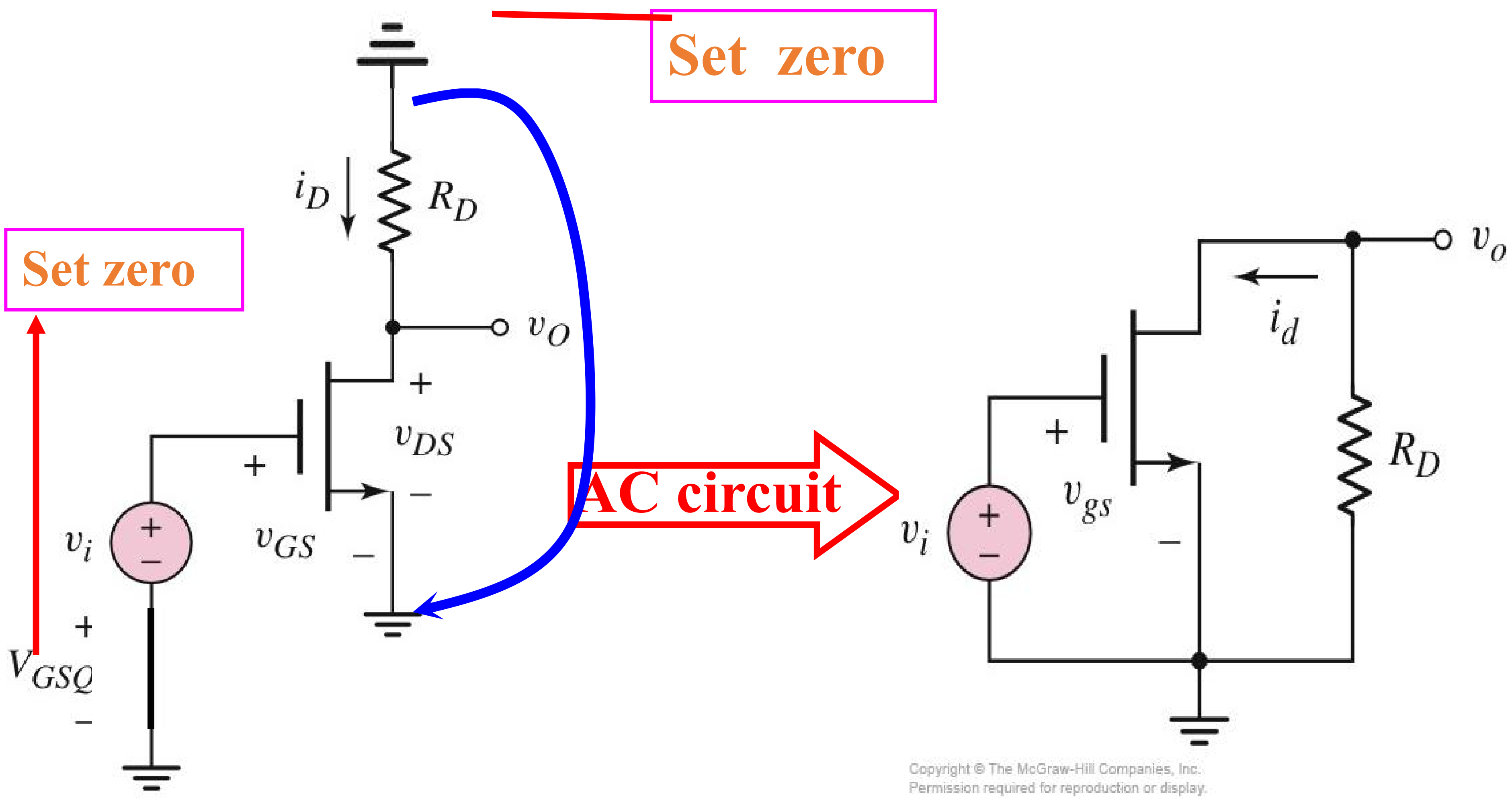
$$g_m = \frac{\partial i_D}{\partial v_{GS}} = \frac{i_d}{v_{gs}}$$

$$g_m = 2K_n(V_{GSQ} - V_{TN}) = 2\sqrt{K_n I_{DQ}}$$

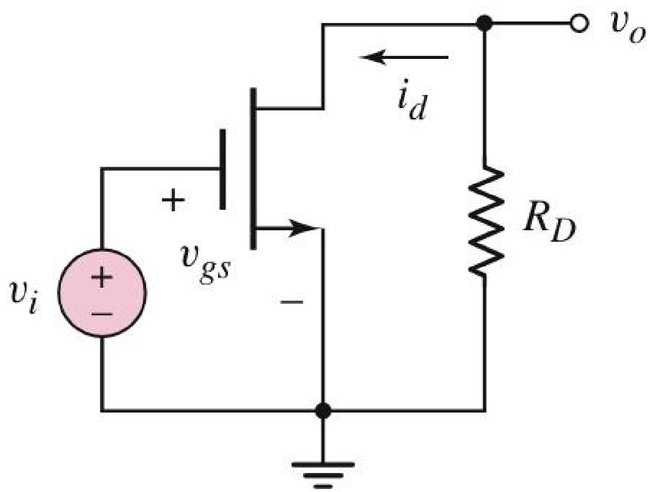
$$r_o = \left(\frac{\partial i_D}{\partial v_{DS}}\right)^{-1}$$

$$r_o = [\lambda K_n (V_{GSQ} - V_{TN})^2]^{-1} \cong [\lambda I_{DQ}]^{-1}$$

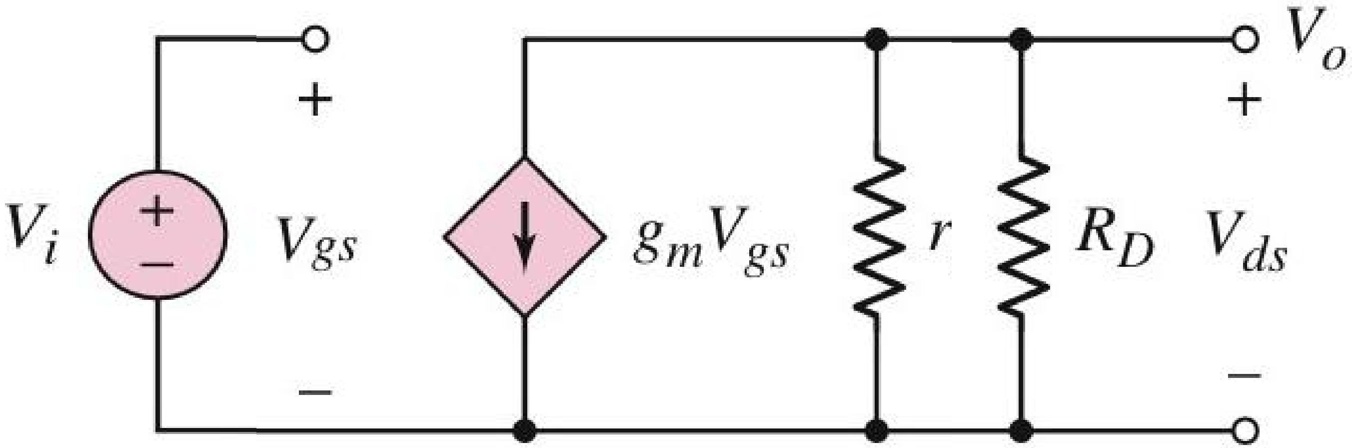
4.1.1 Graphical Analysis, Load line, and small signal parameters



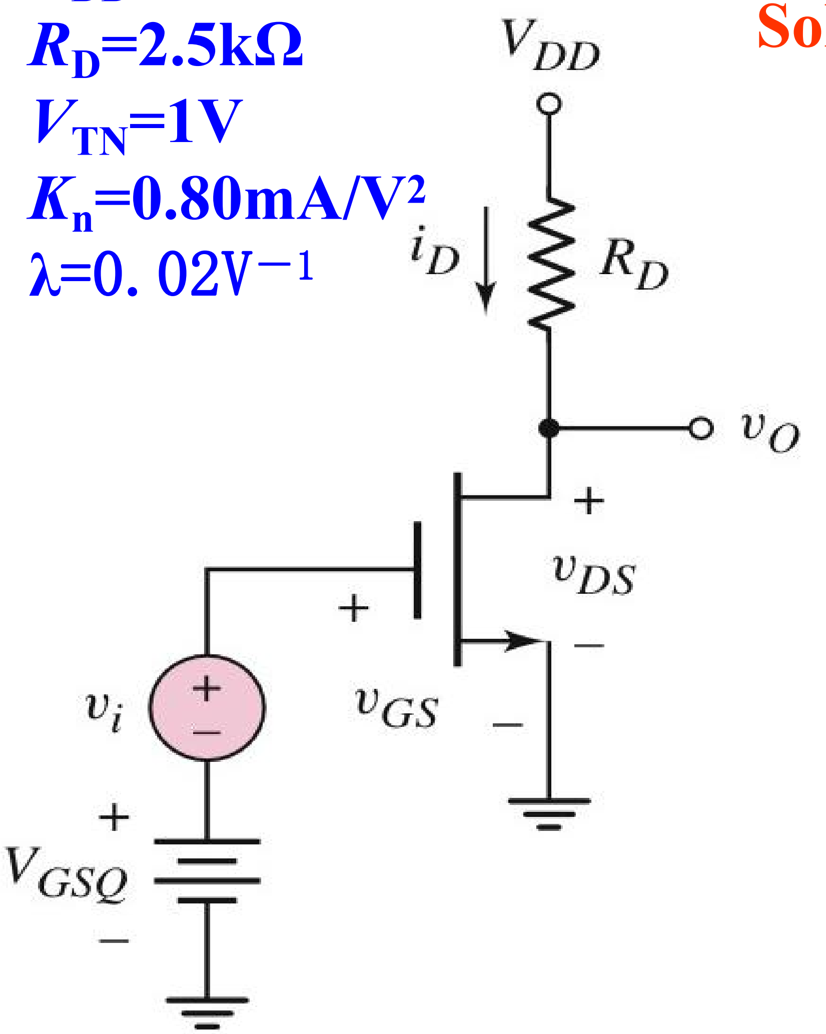
4..1.2 small signal equivalent circuit



small signal equivalent circuit



V_{GSQ}=2.12V
V_{DD}=5V
R_D=2.5kΩ
V_{TN}=1V
K_n=0.80mA/V²
λ=0. 02V^{-1}



Determine small voltage gain.

Sol:

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

$$= 0.8(2.12-1)^2 = 1\text{mA}$$

$V_{DS} = V_{DD} - I_D R_D$ =5- 1*2.5 =2.5V

V_{DSQ} =2.5V> V_{GS}-V_{TN}

=2.12-1=1.12V

Which region? **Saturation region**

$$g_m = 2K_n(V_{GSQ} - V_{TN})$$

$$= 2\times 0.8(2.12-1) = 1.79\text{mS}$$

Determine small voltage gain.

V_{GSQ}=2.12V

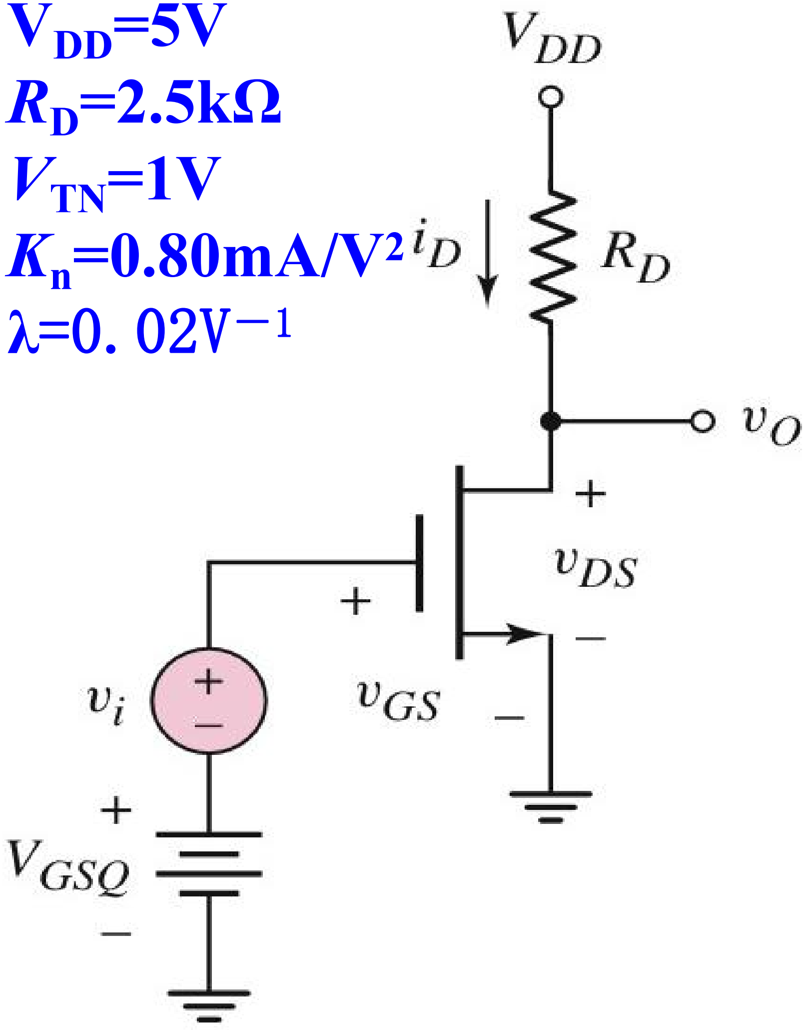
V_{DD}=5V

R_D=2.5kΩ

V_{TN}=1V

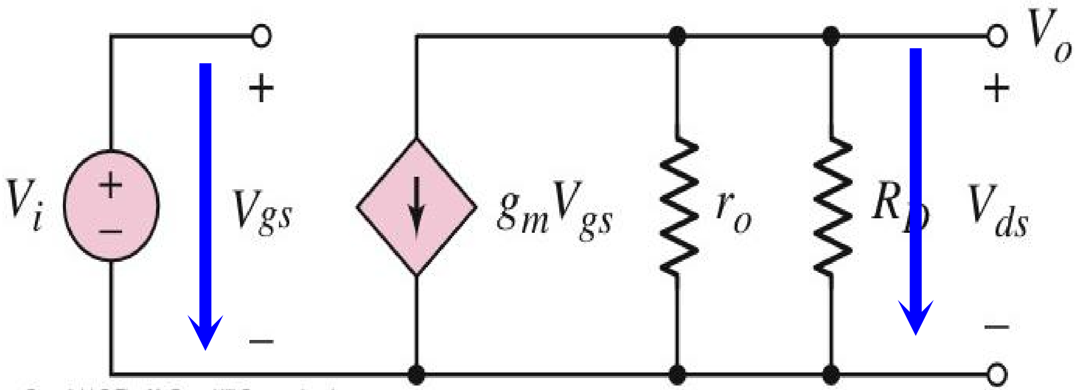
K_n=0.80mA/V²

λ=0. 02V⁻¹



Sol:

$$r_o \cong [\lambda I_{DQ}]^{-1} = 50\text{k}\Omega$$



$$V_i = V_{gs}$$

$$V_o = -g_m \bullet V_{gs} \bullet (r_o // R_D)$$

$$A_v = V_o / V_i = -g_m (r_o \| R_D)$$

$$= -4.26$$

Problem-Solving Technique: MOSFET AC Analysis

1. **Analyze circuit with only the dc sources to find quiescent solution. Transistor must be biased in saturation region for linear amplifier.**
2. **Replace elements with small-signal model.**
3. **Analyze small-signal equivalent circuit, setting dc sources to zero, to produce the circuit to the time-varying input signals only.**

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4.4 The Common Drain（Source Follower） Amplifier

4.5 The Common Gate Configuration

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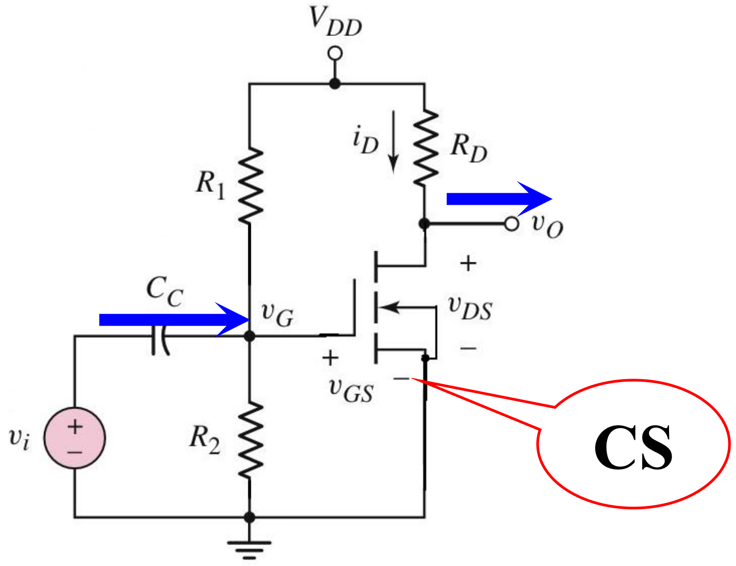
4.5.2 Input and output Impedance

4.6 The Three Basic Amplifier Configuration: Summary and comparison

4.2 Basic Transistor Amplifier Configurations

Common source



Common Drain

Common gate

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4.3 The Common Source Amplifier

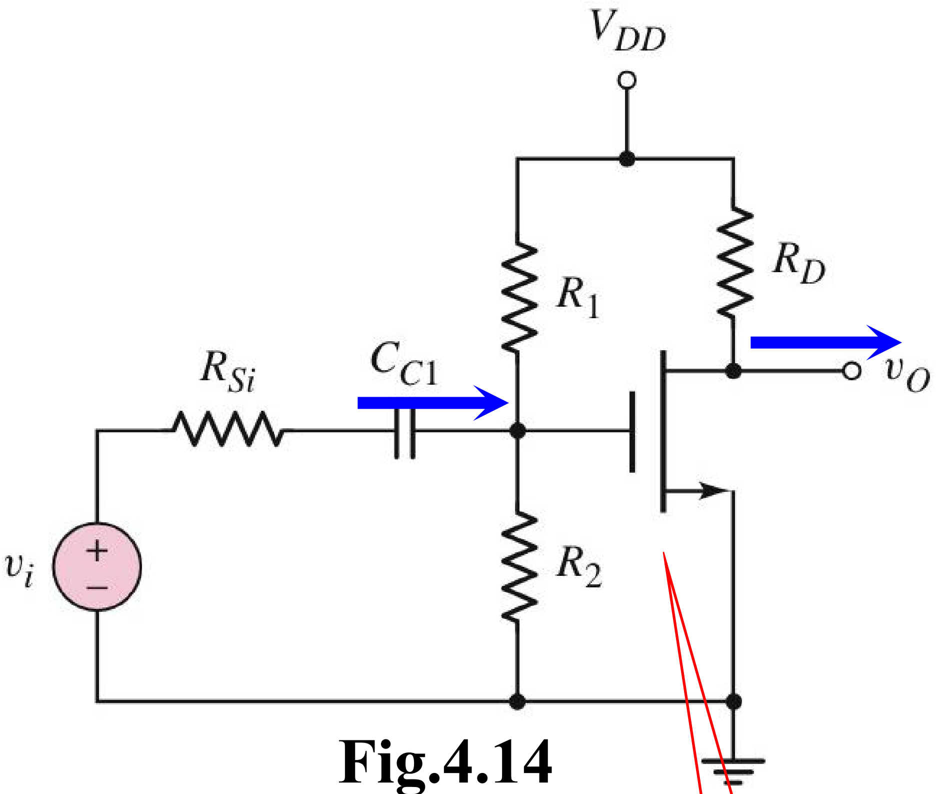


Fig.4.14

CS

DC analysis:

Coupling capacitor is assumed to be open.

AC analysis:

Coupling capacitor is assumed to be a short.

DC voltage supply is set to zero volts.

4.3 The Common Source Amplifier

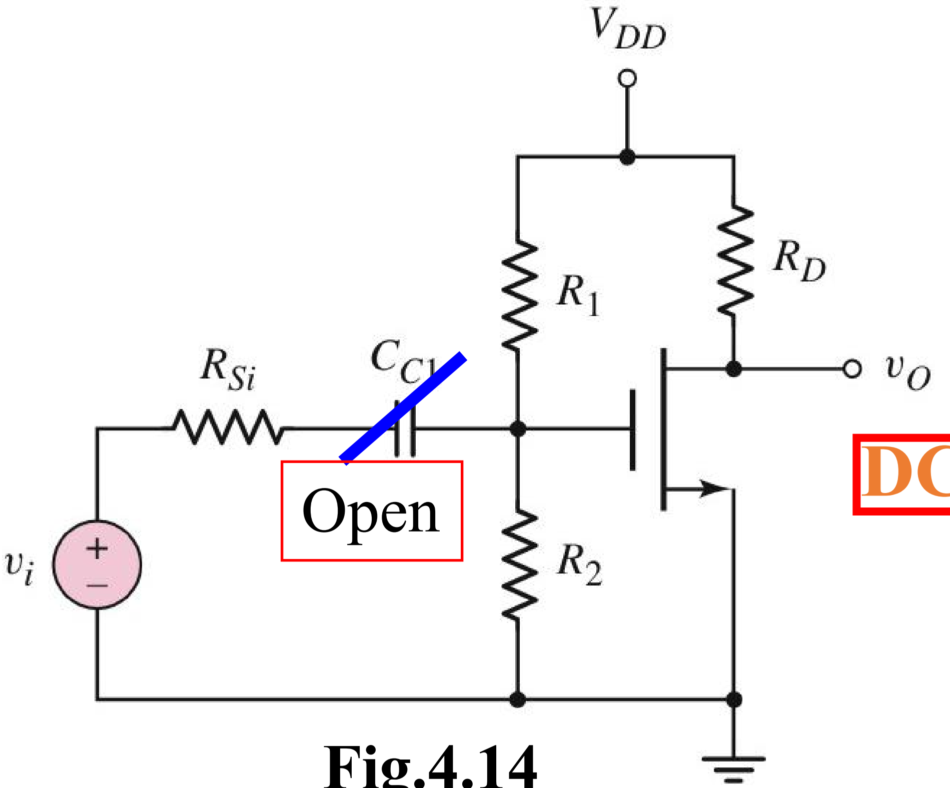
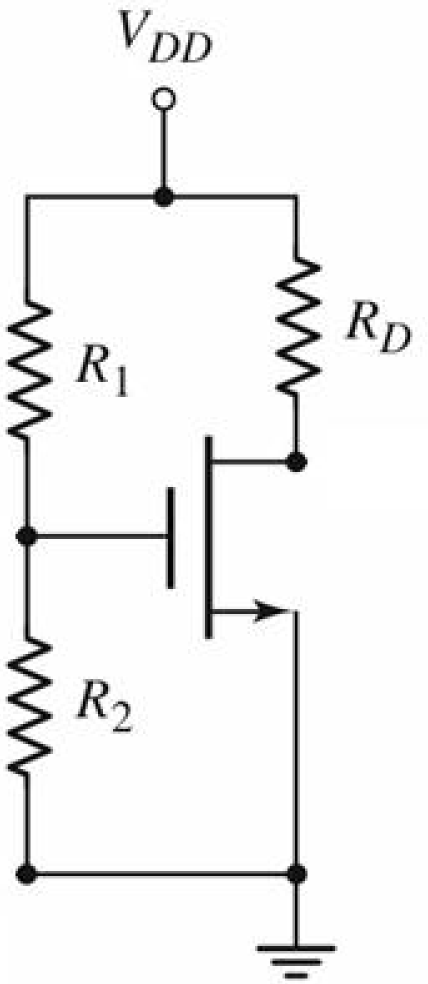


Fig.4.14

DC circuit



4.3.1 A Basic Common Source Configuration

$$C_C = 10\ \mu\text{F}$$
$$f = 2\ \text{kHz.}$$

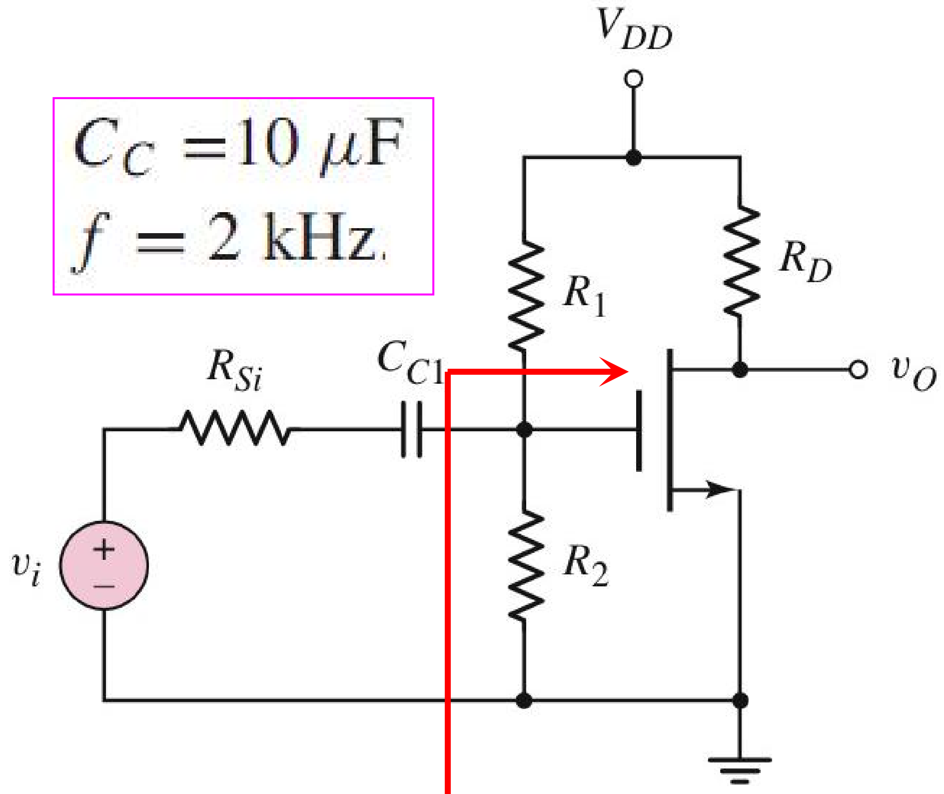


Fig.4.14

$$|Z_c| = \frac{1}{2\pi f C_C}$$

$$= \frac{1}{2\pi(2\times10^3)(10\times10^{-6})} \cong 8\ \Omega$$

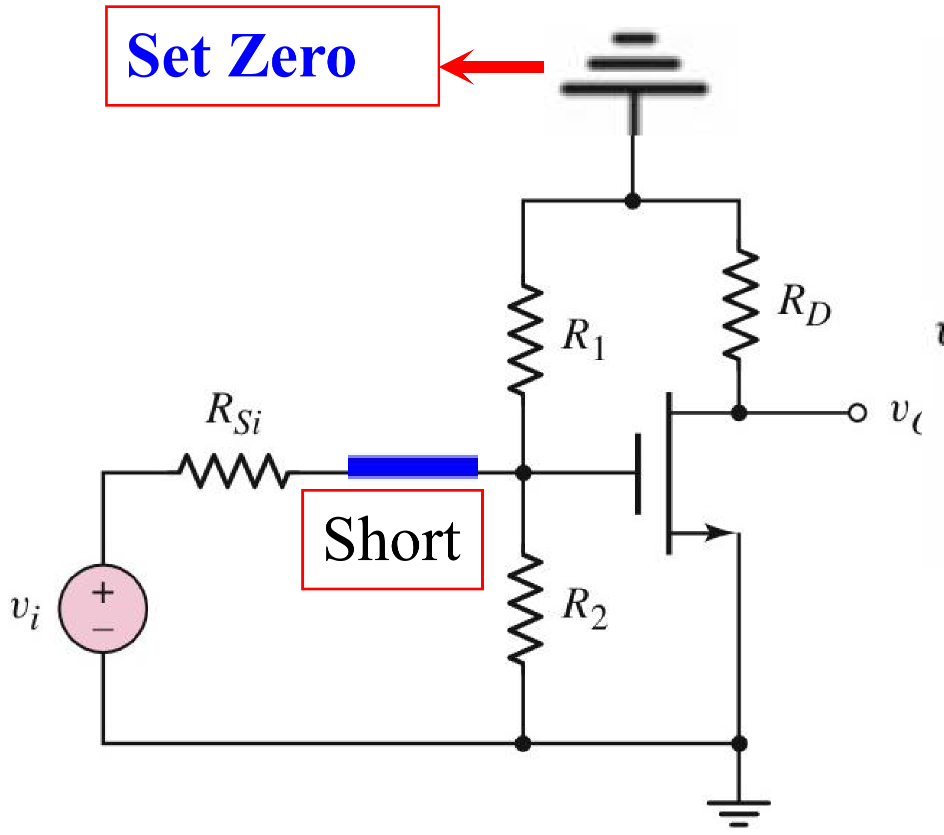
2-port Networks equivalent input impedance

$$R_1 \| R_2$$

$$|Z_c| << R_1 \| R_2$$

capacitor is essentially a short circuit to signals with frequencies greater than 2 kHz.

4.3.1 A Basic Common Source Configuration



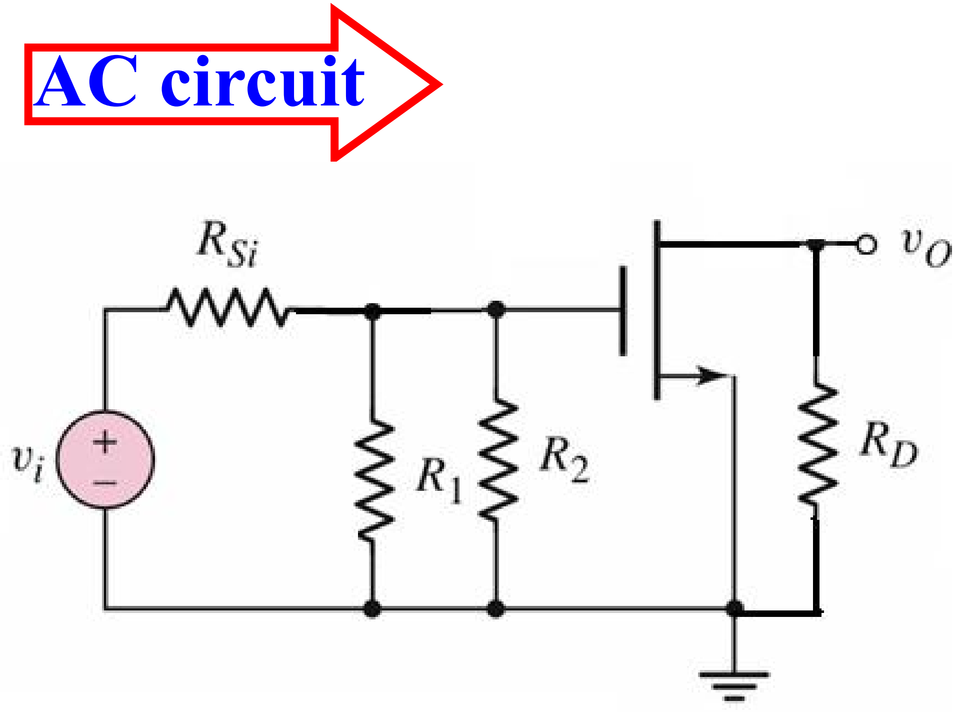
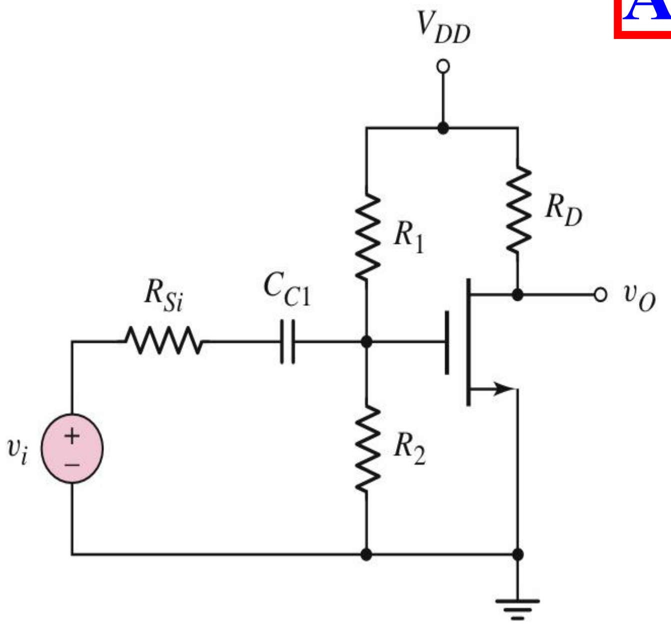
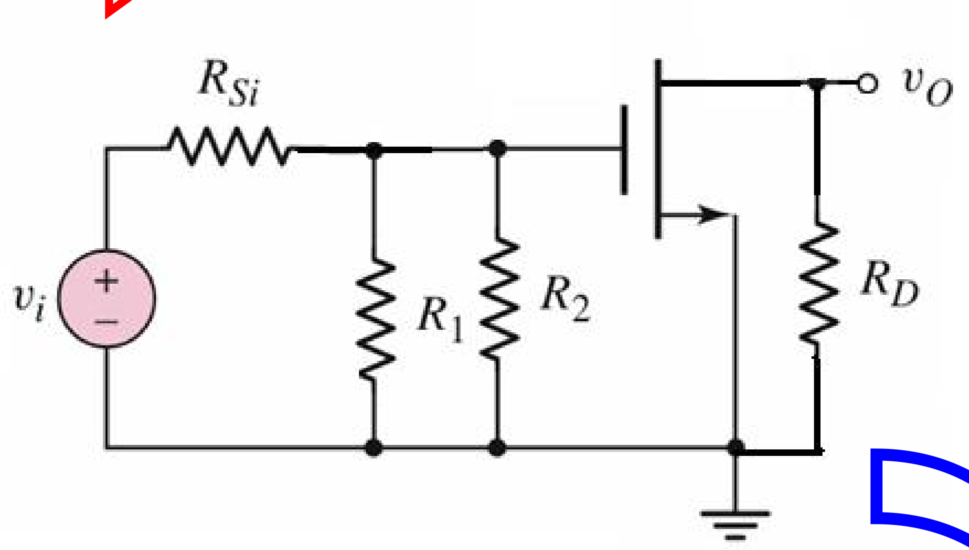


Fig.4.14

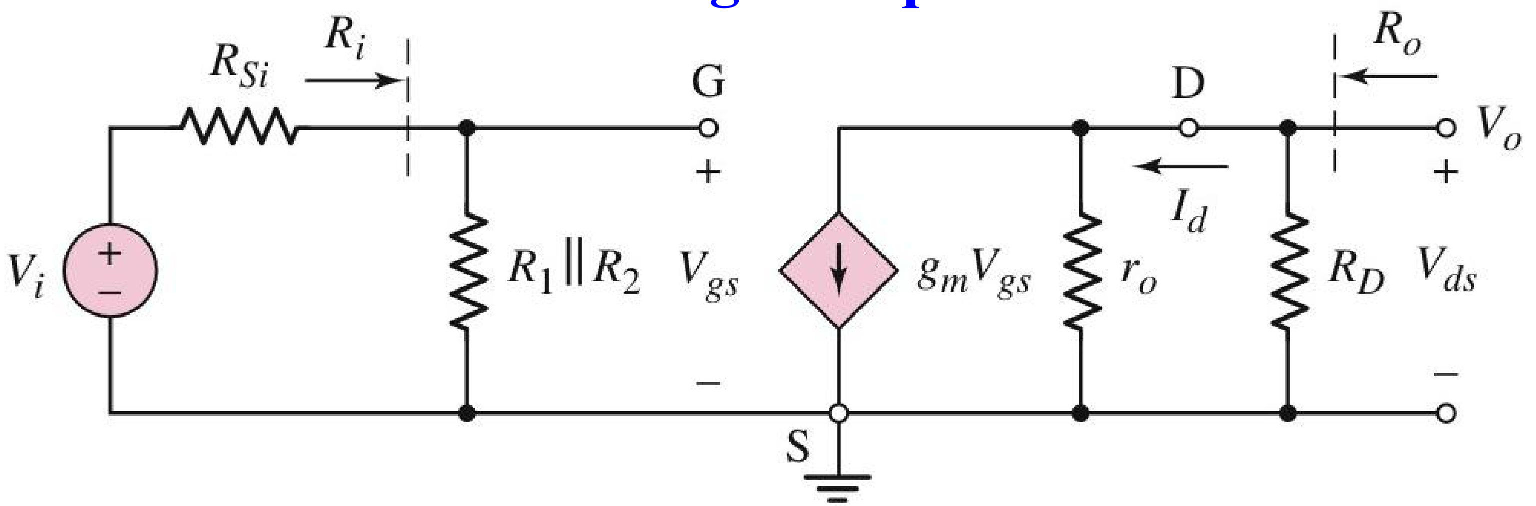
4.3.1 A Basic Common Source Configuration



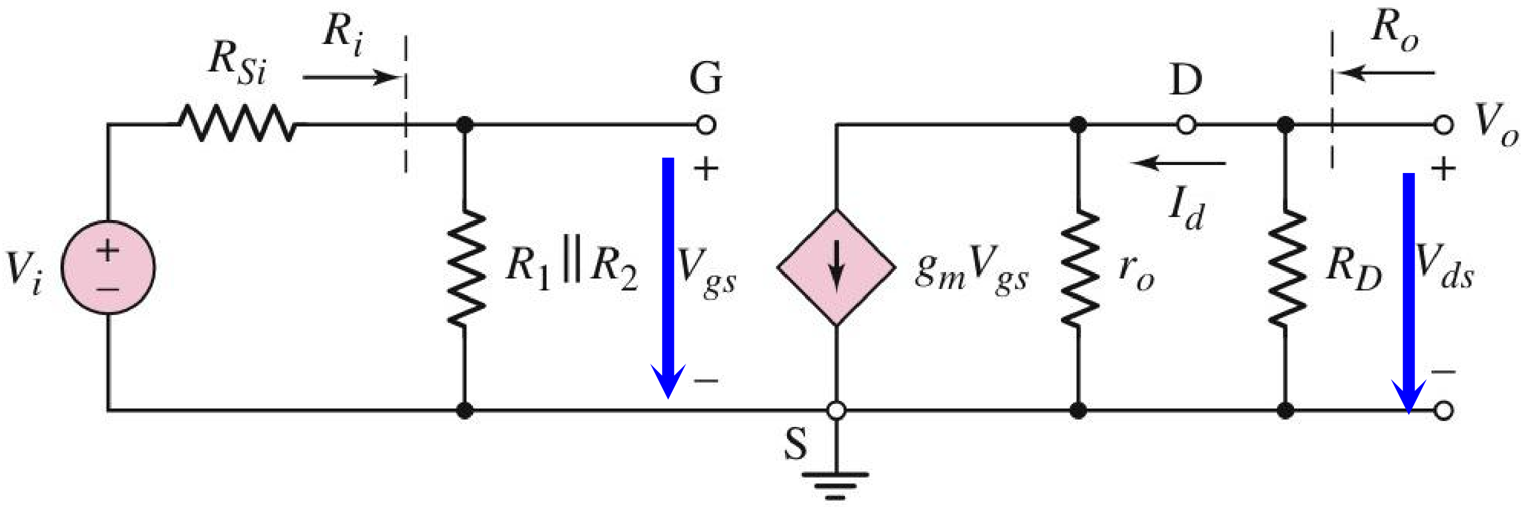
AC circuit



Small-Signal Equivalent Circuit



4.3.1 A Basic Common Source Configuration



$$V_{gs} = V_i \cdot \left(\frac{R_i}{R_i + R_{Si}}\right) \qquad V_o = -g_m \bullet V_{gs} \bullet (r_o // R_D)$$

$$A_v = V_o / V_i = -g_m (r_o \| R_D)\left(\frac{R_i}{R_i + R_{Si}}\right)$$

4.3.1 A Basic Common Source Configuration

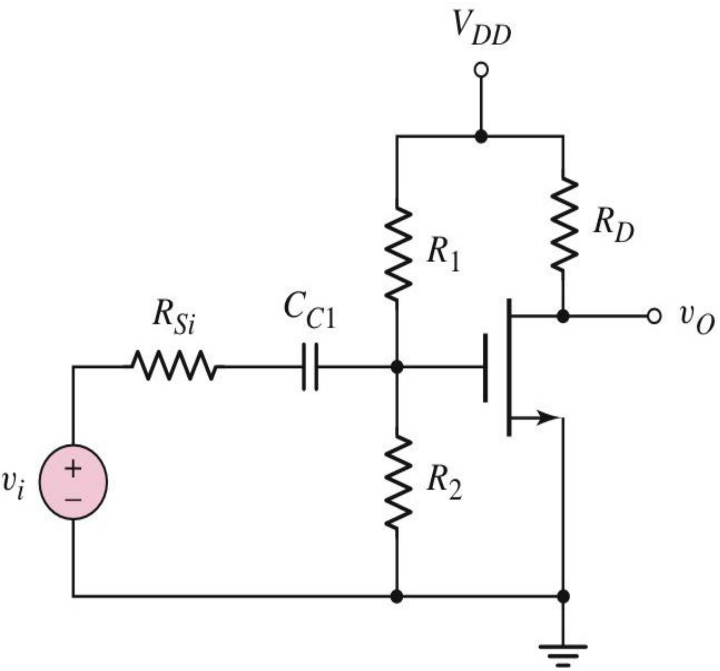
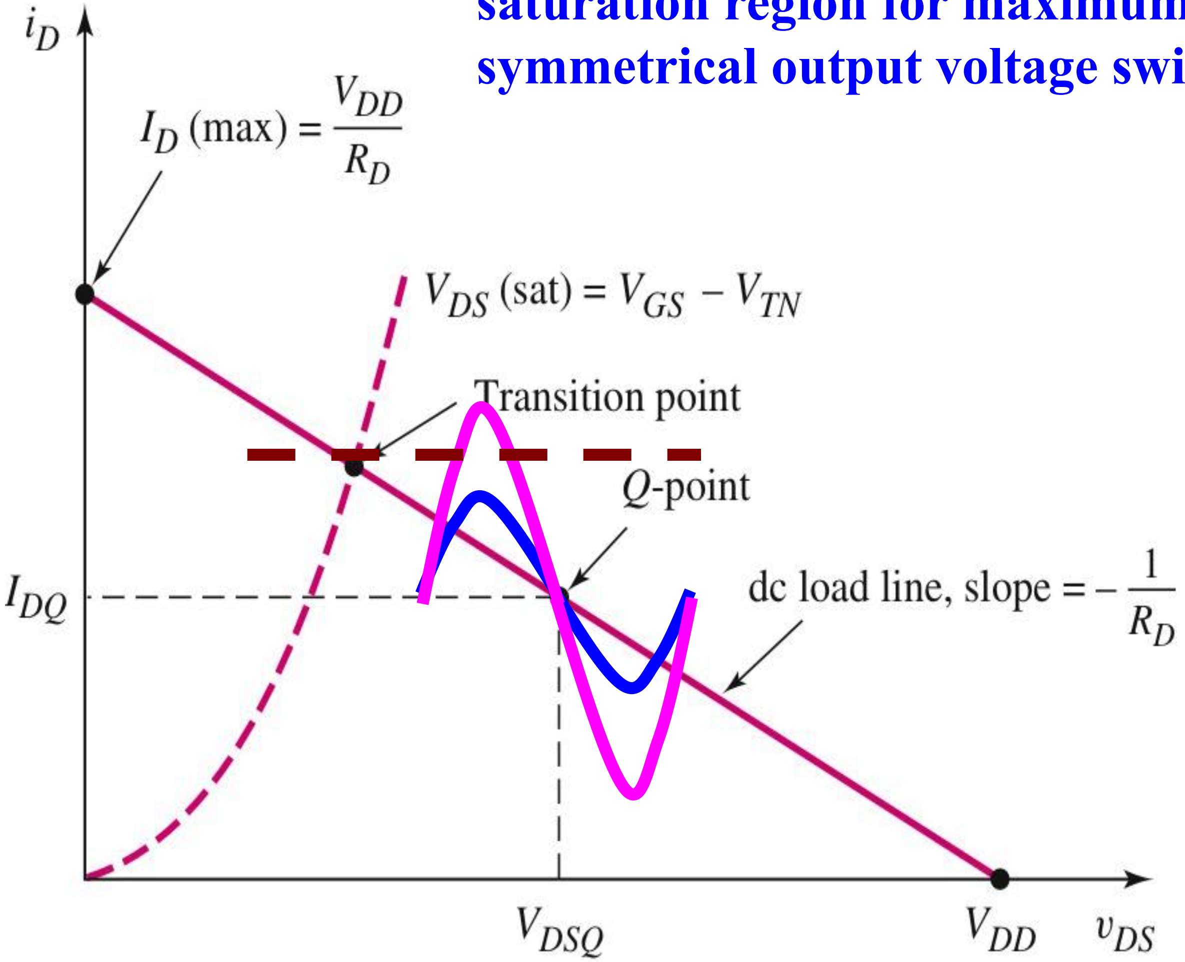


Fig.4.14

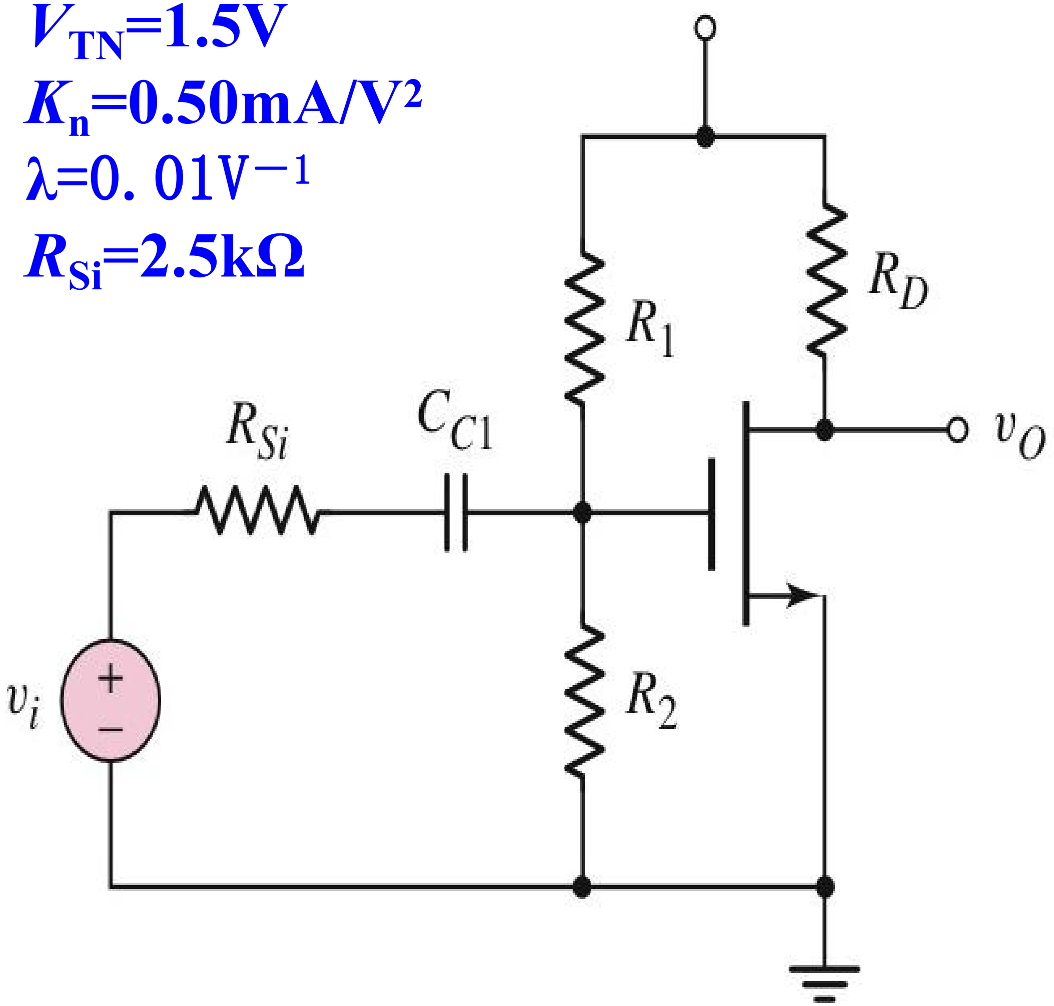
Q-point near the middle of the saturation region for maximum symmetrical output voltage swing,.



Small AC input signal for output response to be linear.

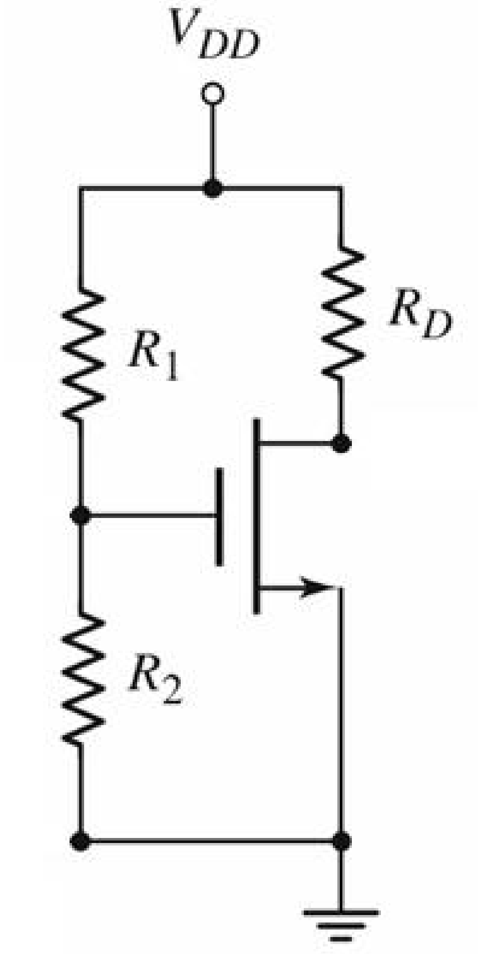
4.3.1 A Basic Common Source Configuration

V_{DD}=10V
R_1=70.9kΩ， R_2=29.1kΩ
R_D=2.5kΩ
V_{TN}=1.5V
K_n=0.50mA/V²
λ=0. 01V⁻¹
R_{Si}=2.5kΩ



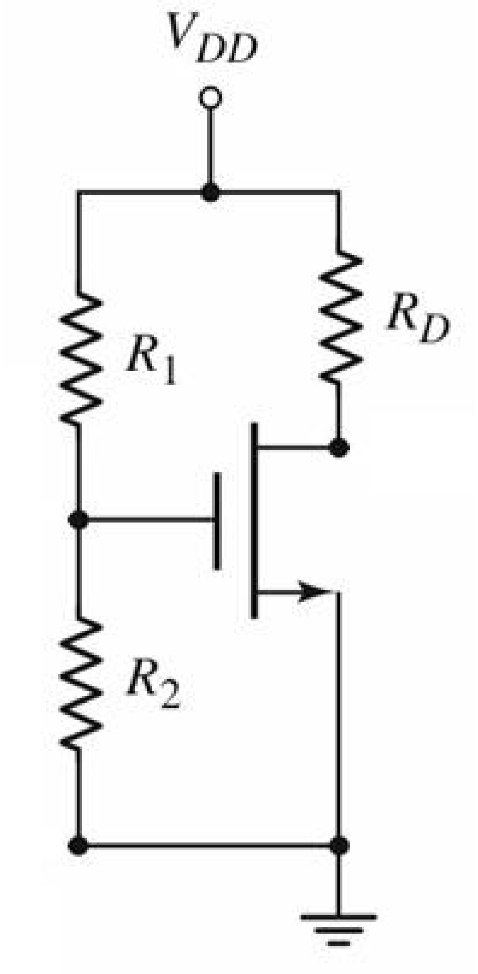
SOL：

DC Analysis



4.3.1 A Basic Common Source Configuration

V_{DD}=10V
R_1=70.9kΩ
R_2=29.1kΩ
R_D=5kΩ
V_{TN}=1.5V
K_n=0.50mA/V²
λ=0. 01V^{-1}
R_{Si}=4kΩ



SOL:

DC Analysis

$$V_{GSQ}=\frac{R_2}{R_1+R_2}V_{DD}$$

$$=\frac{29.1}{70.9+29.1}10=2.91\text{V}$$

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

$$=0.5(2.91-1.5)^2=1\text{mA}$$

$V_{DS}=V_{DD}-I_D R_D$

$=10-(1)(5)=5\text{V}$

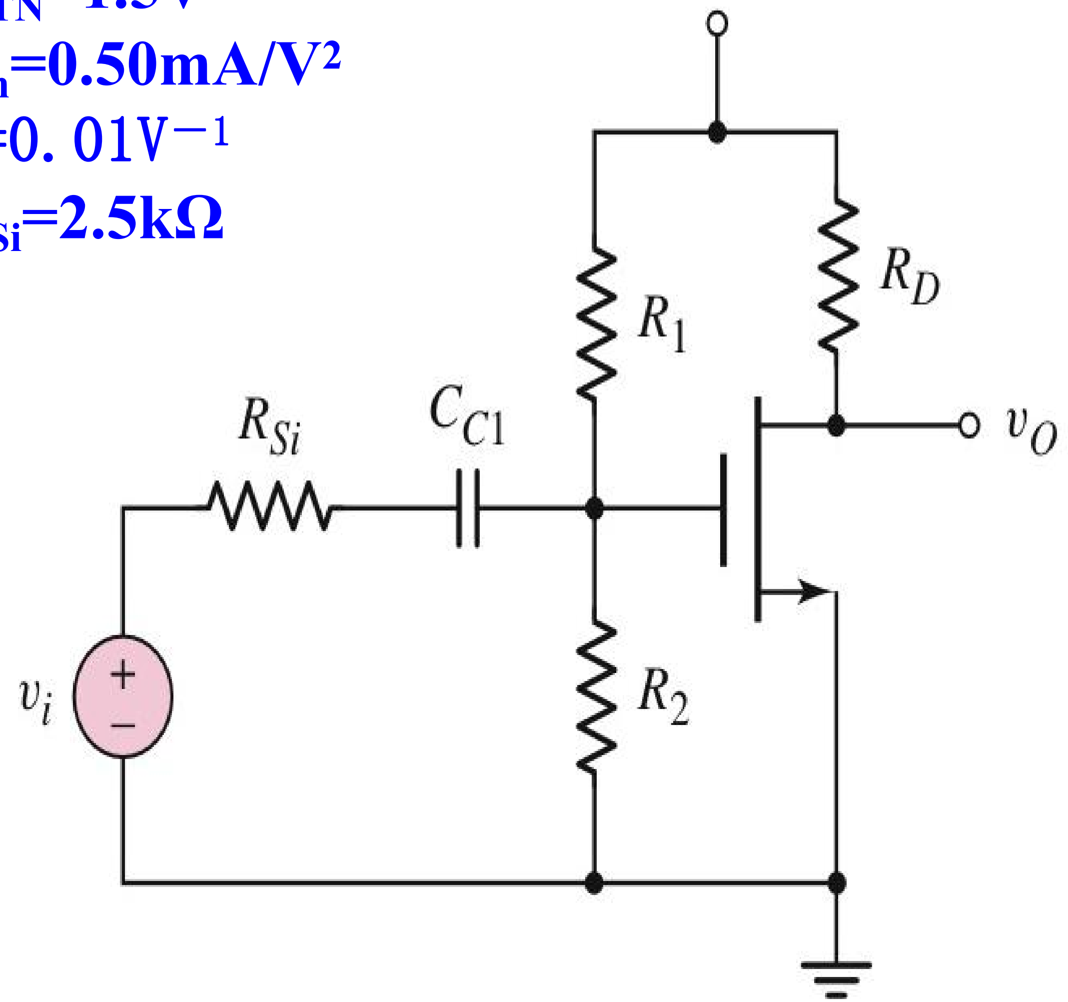
$V_{DSQ}=5\text{V}> V_{GS}-V_{TN}$

Saturation region

$=2.91-1.5=1.41\text{V}$

4.3.1 A Basic Common Source Configuration

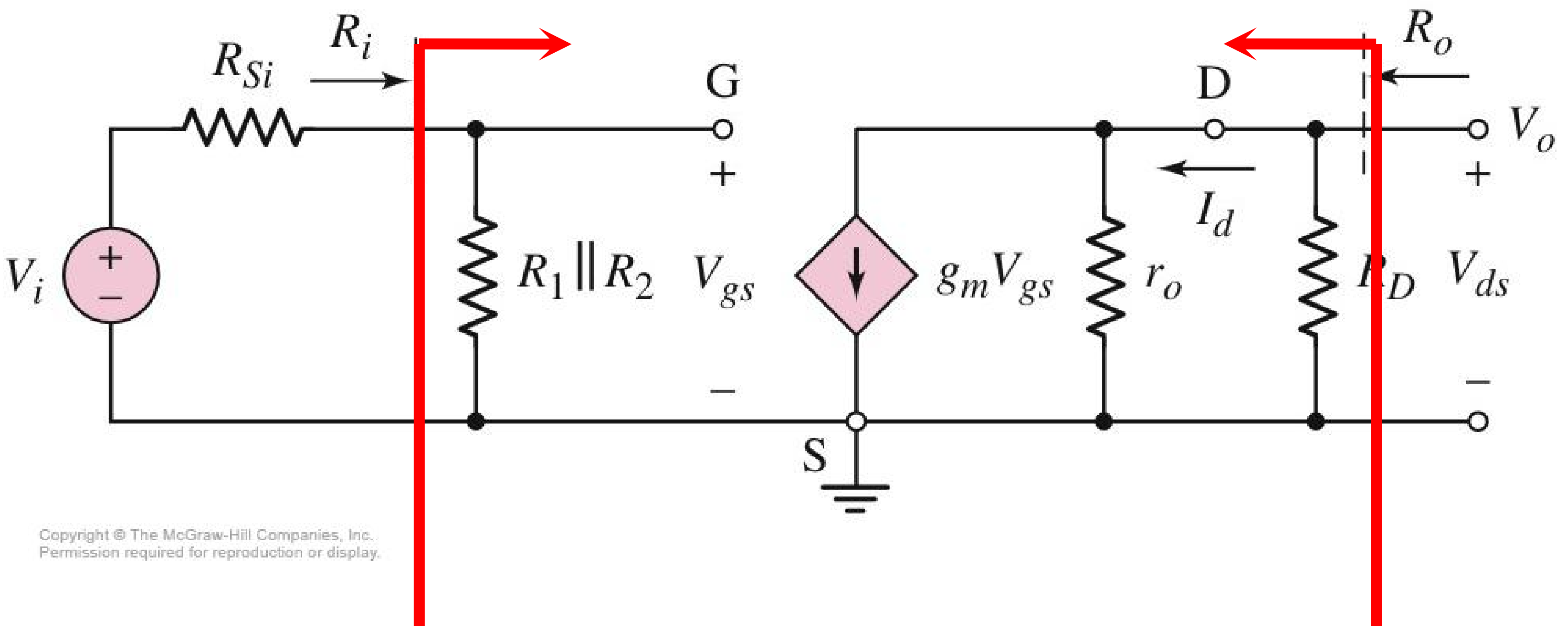
V_{DD}=10V
R_1=70.9kΩ， R_2=29.1kΩ
R_D=2.5kΩ
V_{TN}=1.5V
K_n=0.50mA/V^2
λ=0. 01V^{-1}
R_{Si}=2.5kΩ



$$g_m = 2K_n(V_{GSQ} - V_{TN})$$
$$= 2 \times 0.5(2.91 - 1.5)$$
$$=1.41\text{mS}$$

$$r_o \cong [\lambda I_{DQ}]^{-1} = 100\text{k}\Omega$$

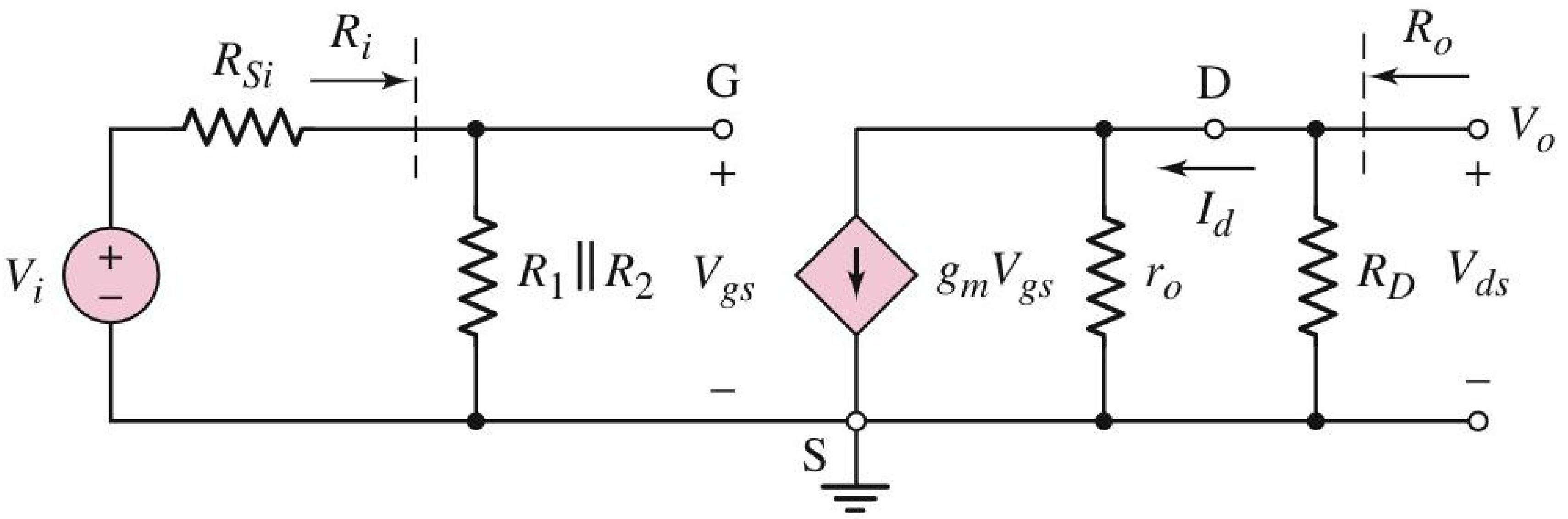
4.3.1 A Basic Common Source Configuration



$$R_i = R_1 // R_2 = 70.9 // 29.1 = 20.6\text{k}\Omega$$?

$$R_o = R_D // r_o = 5 // 100 = 4.76\text{k}\Omega$$?

4.3.1 A Basic Common Source Configuration



$$V_{gs} = V_i \cdot \left(\frac{R_i}{R_i + R_{Si}}\right) \qquad V_o = -g_m \cdot V_{gs} \cdot (r_o // R_D)$$

$$A_v = V_o / V_i = -g_m (r_o \| R_D) \left(\frac{R_i}{R_i + R_{Si}}\right) = -5.62$$

4.3.2 Common Source Amplifier with Source resistor

V_{TN}=0.8V
K_n=1mA/V^2
λ=0

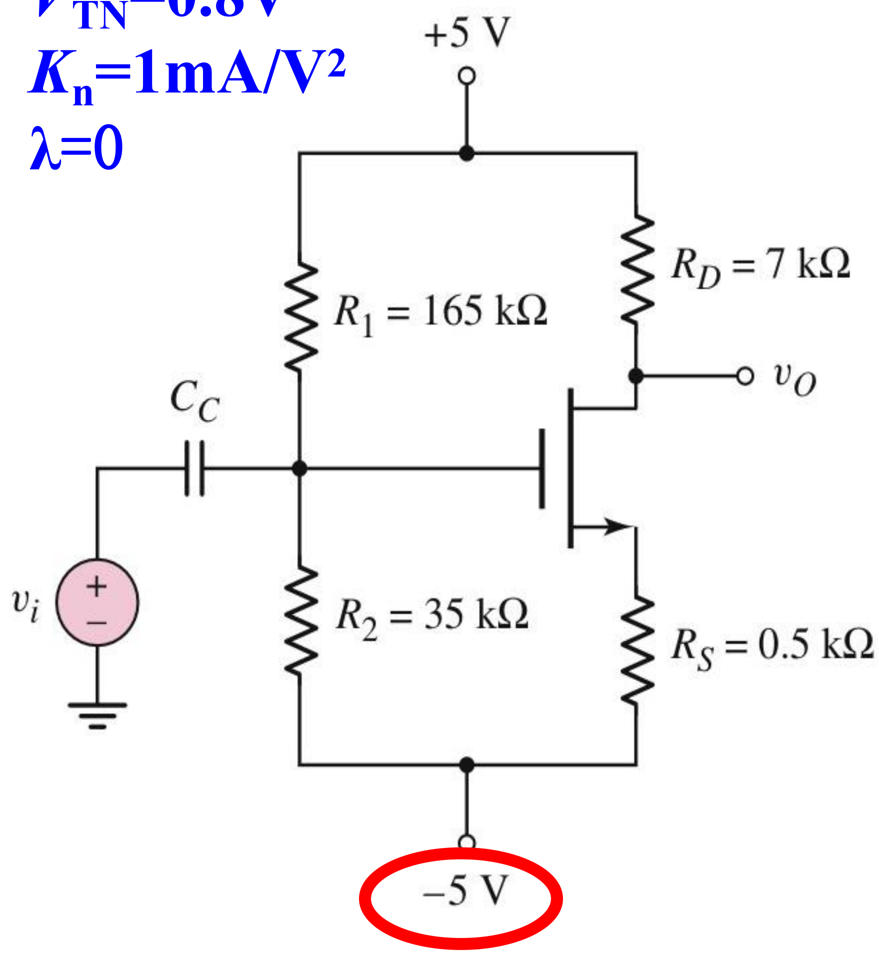


Fig.4.19

SOL：

DC Analysis

$$V_{GSQ} = 1.50\text{V}$$

$$I_D = 0.50\text{mA}$$

$$V_{DS} = 6.25\text{V}$$

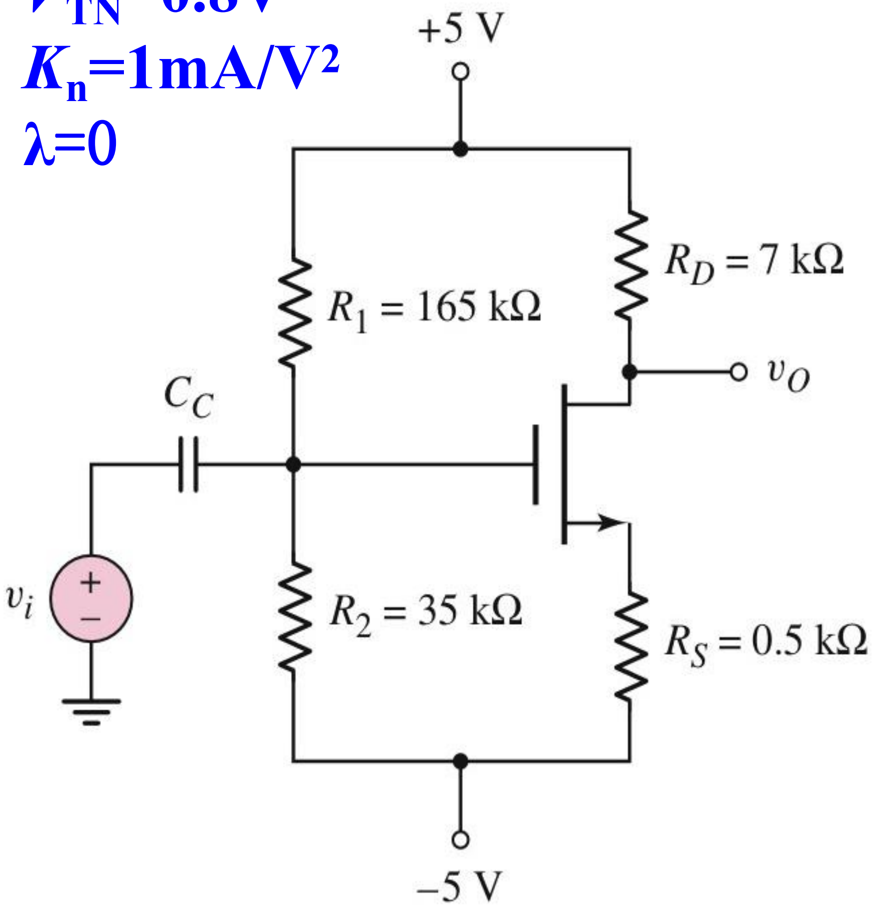
$$g_m = 2K_n(V_{GSQ} - V_{TN})$$

$$= 1.4\text{mS}$$

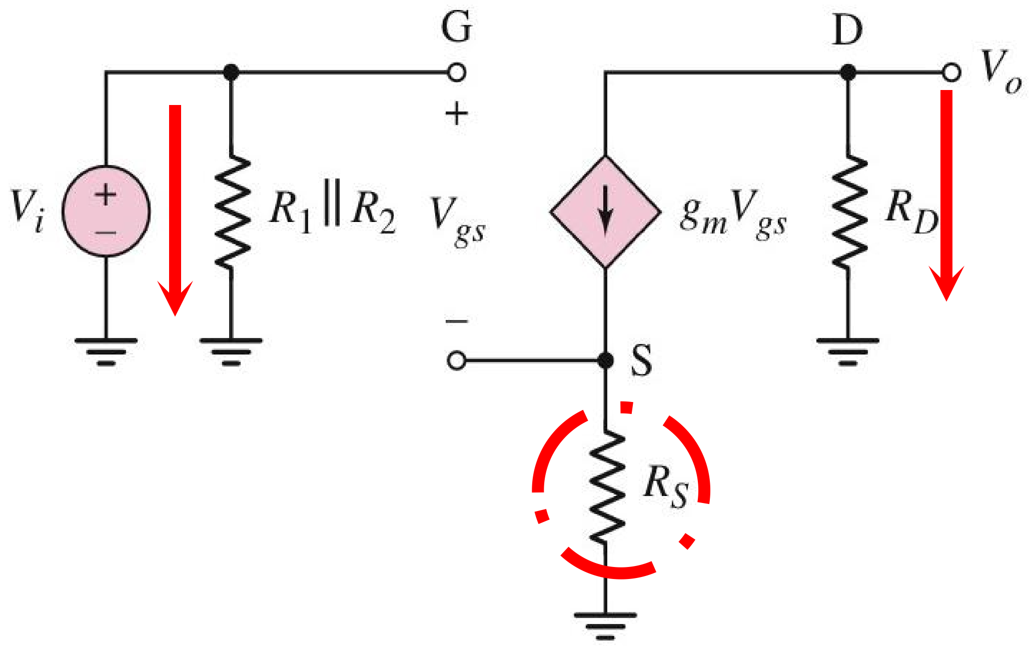
$$r_o \cong [\lambda I_{DQ}]^{-1} = \infty$$

4.3.2 Common Source Amplifier with Source resistor

V_{TN}=0.8V
K_n=1mA/V^2
λ=0



Small-Signal Equivalent Circuit



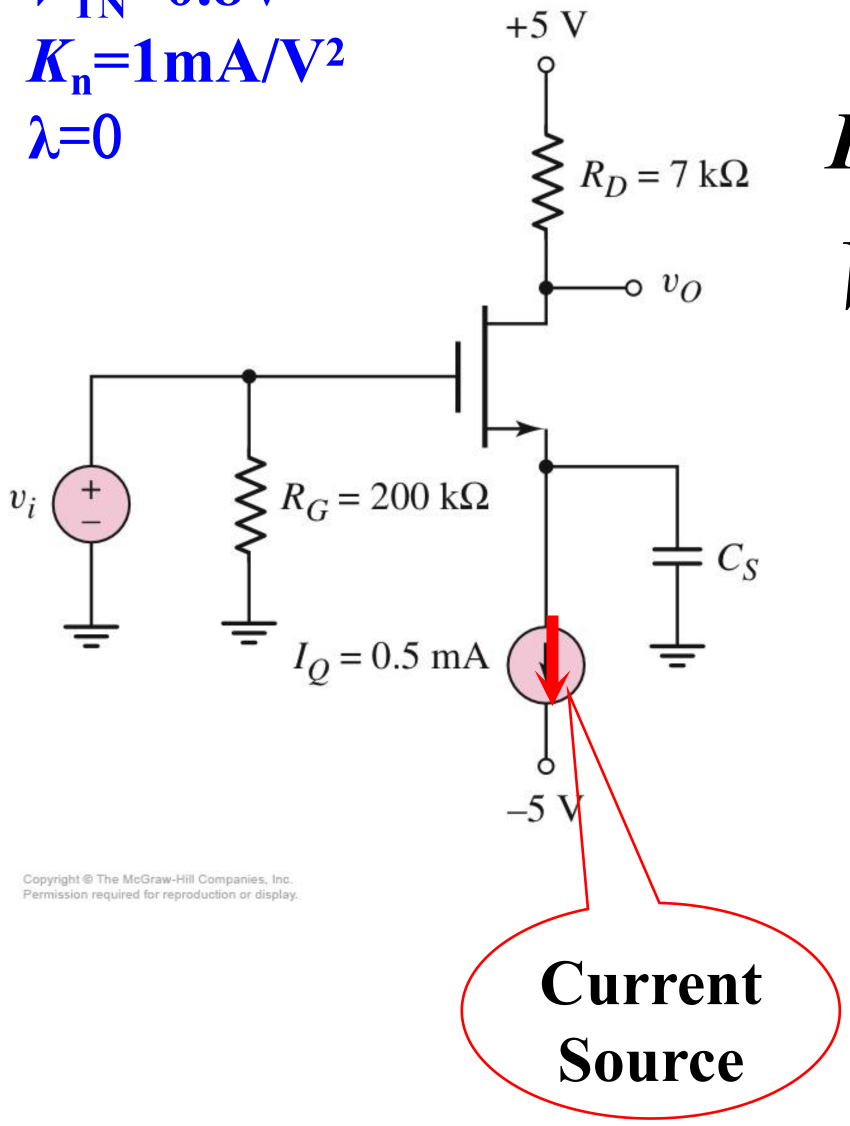
$$V_o = -g_m \cdot V_{gs} \cdot R_D$$

$$V_i = V_{gs} + g_m \cdot V_{gs} \cdot R_S$$

$$A_v = \frac{-g_m R_D}{1 + g_m R_S}$$

4.3.3 Common Source Circuit with Source bypass Capacitor

V_{TN}=0.8V
K_n=1mA/V²
λ=0



SOL:

DC Analysis

$$I_D = K_n(V_{GS} - V_{TN})^2 = 0.5\text{mA}$$

$$V_{GSQ} = -V_S = 1.51\text{V}$$

$$V_{DS} = V_{DD} - I_D R_D - V_S \quad = 3.01\text{V}$$

$$V_{DSQ} = 3.01\text{V} > 1.51 - 0.8$$

$$= 0.71\text{V}$$

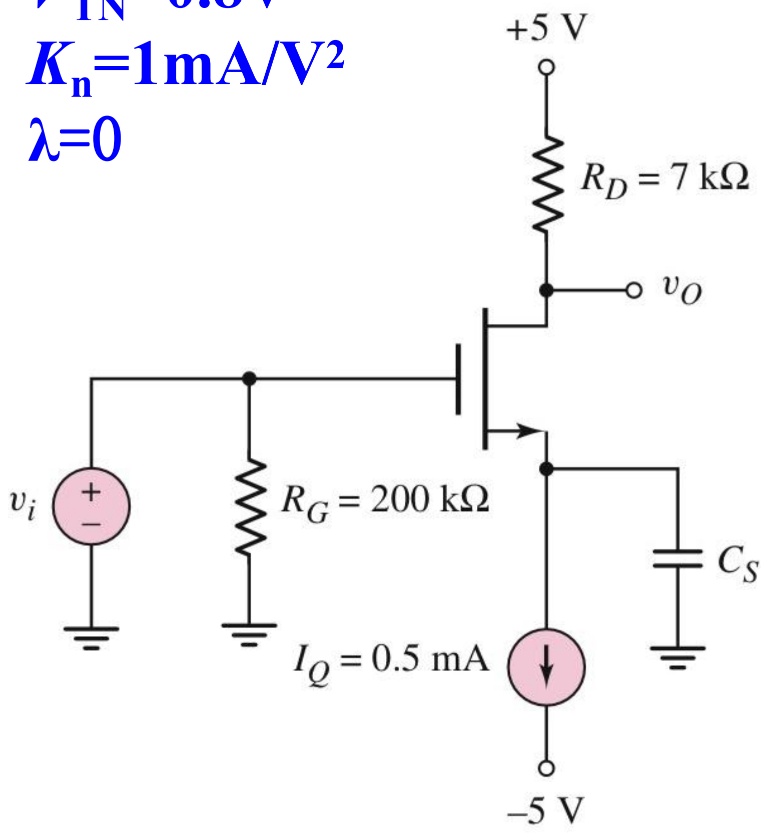
$$g_m = 2K_n(V_{GSQ} - V_{TN})$$

$$= 2 \cdot 1(1.51 - 0.8)$$

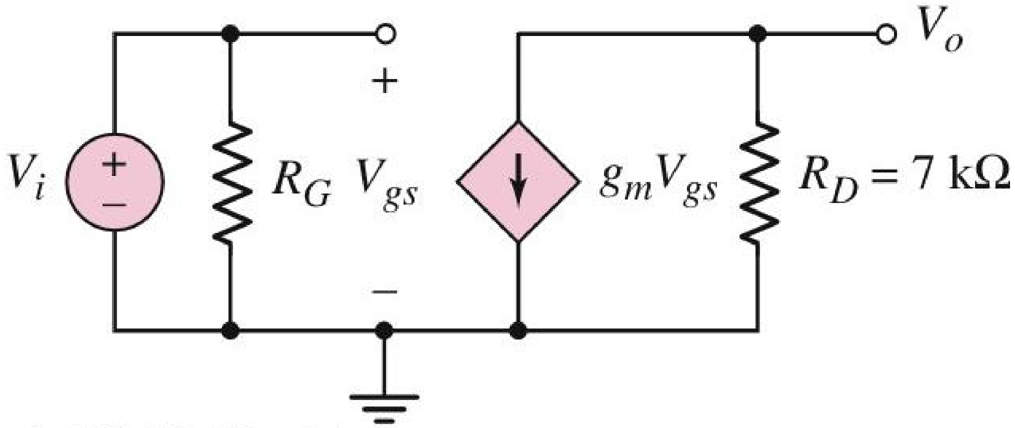
$$= 1.42\text{mS}$$

4.3.3 Common Source Circuit with Source bypass Capacitor

V_{TN}=0.8V
K_n=1mA/V^2
λ=0



Small-signal equivalent circuit



$$V_o = -g_m \cdot V_{gs} \cdot R_D$$

$$A_v = -g_m R_D = -9.9$$

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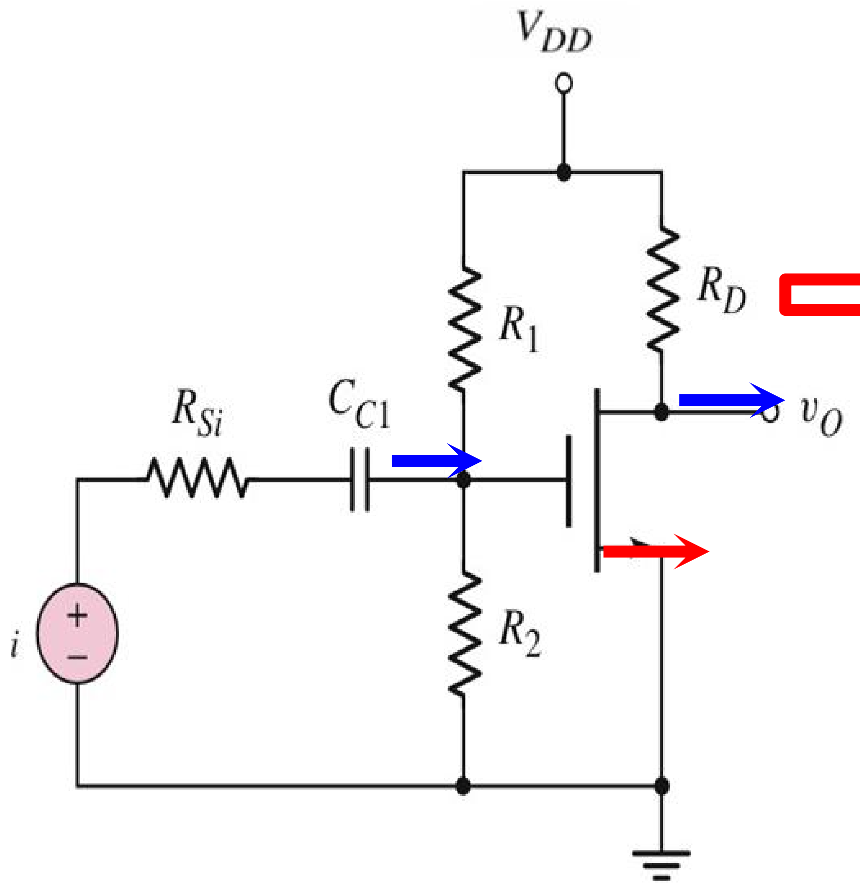
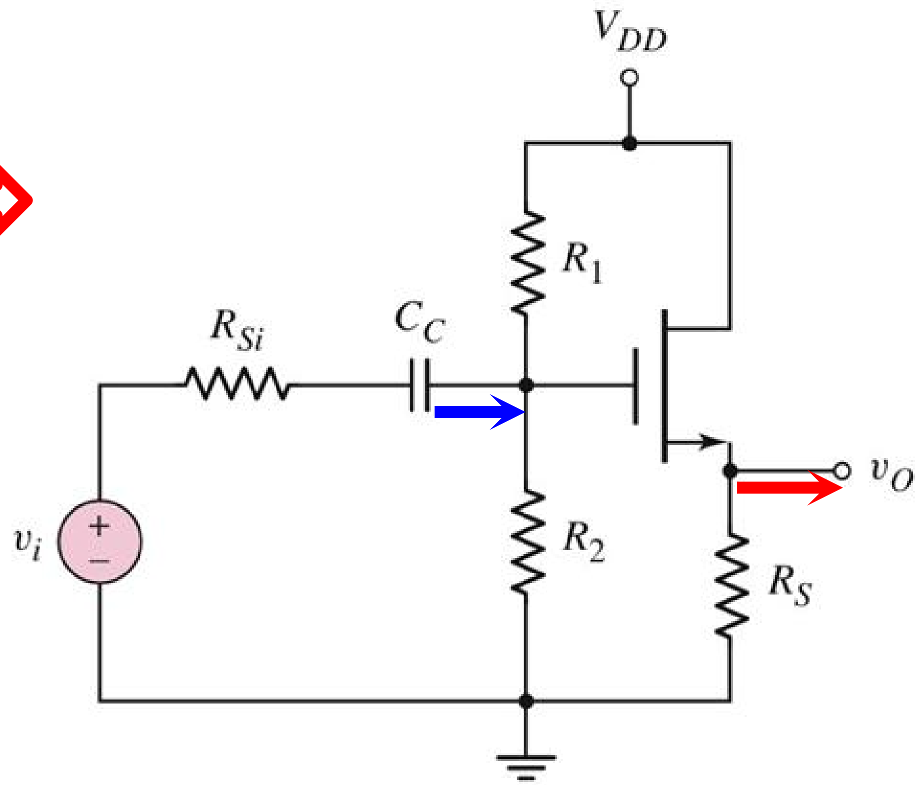
Review





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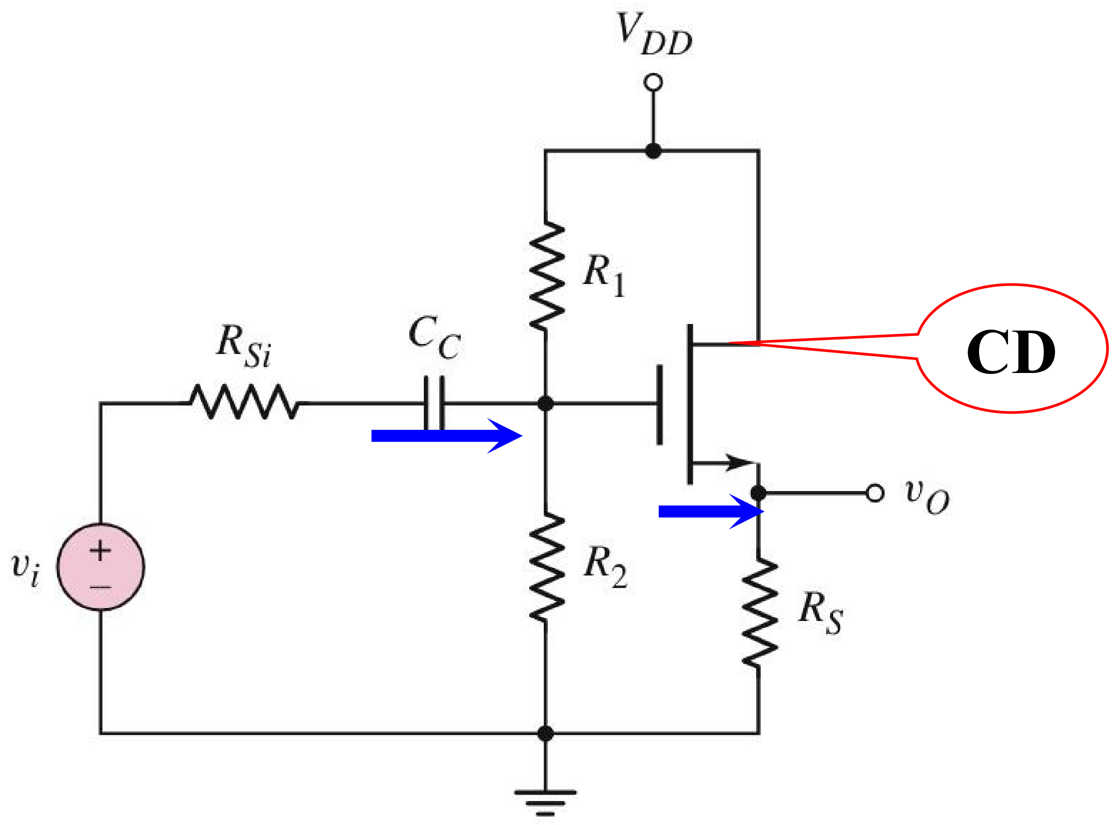
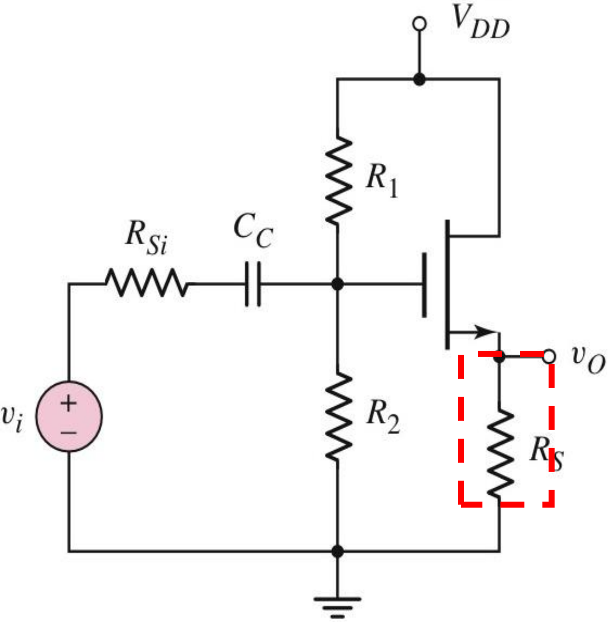
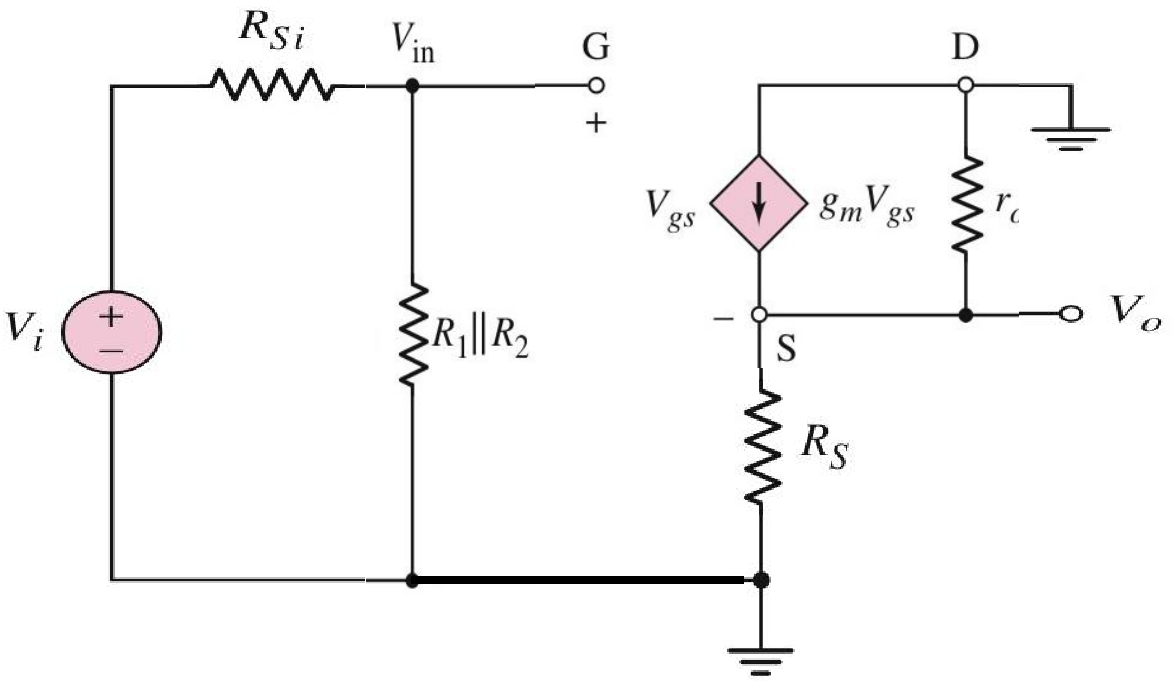
4.4 The Common Drain（Source Follower） Amplifier



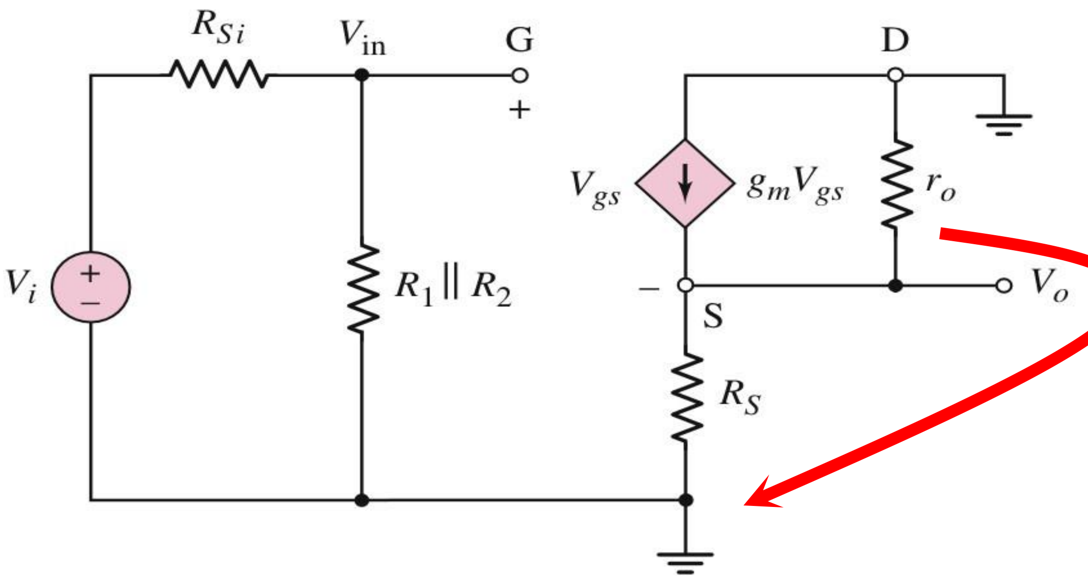
Source Follower

Small-Signal Equivalent Circuit

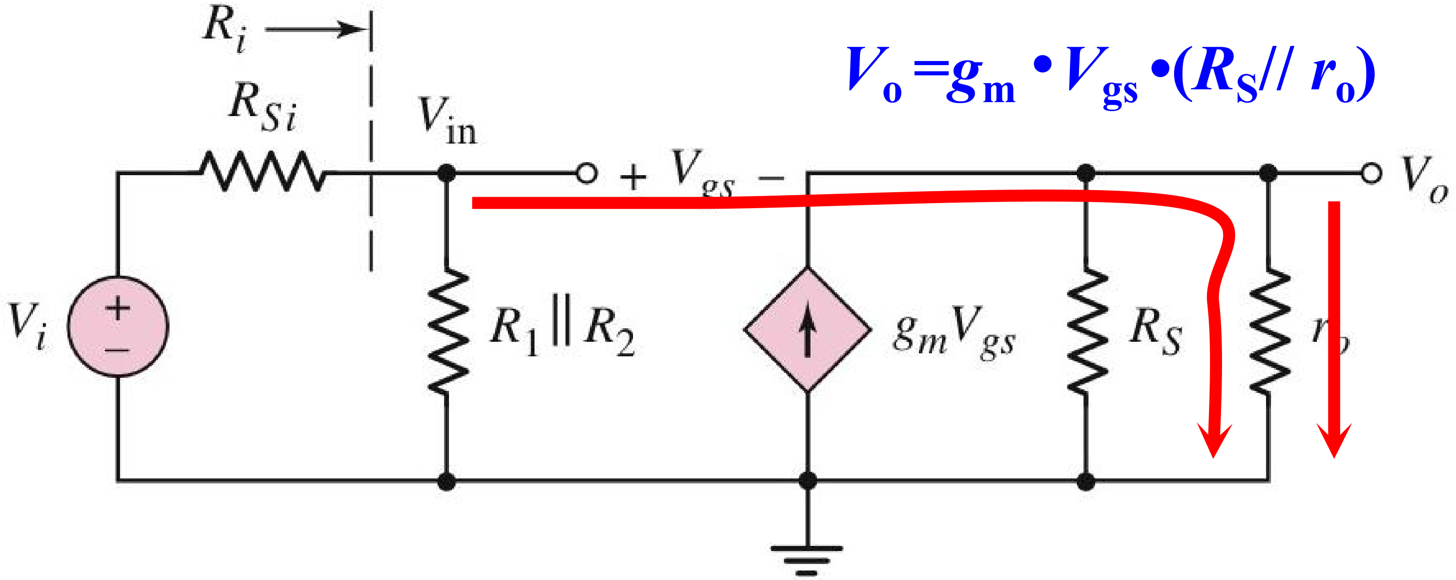




4.4.1 Small-signal voltage gain



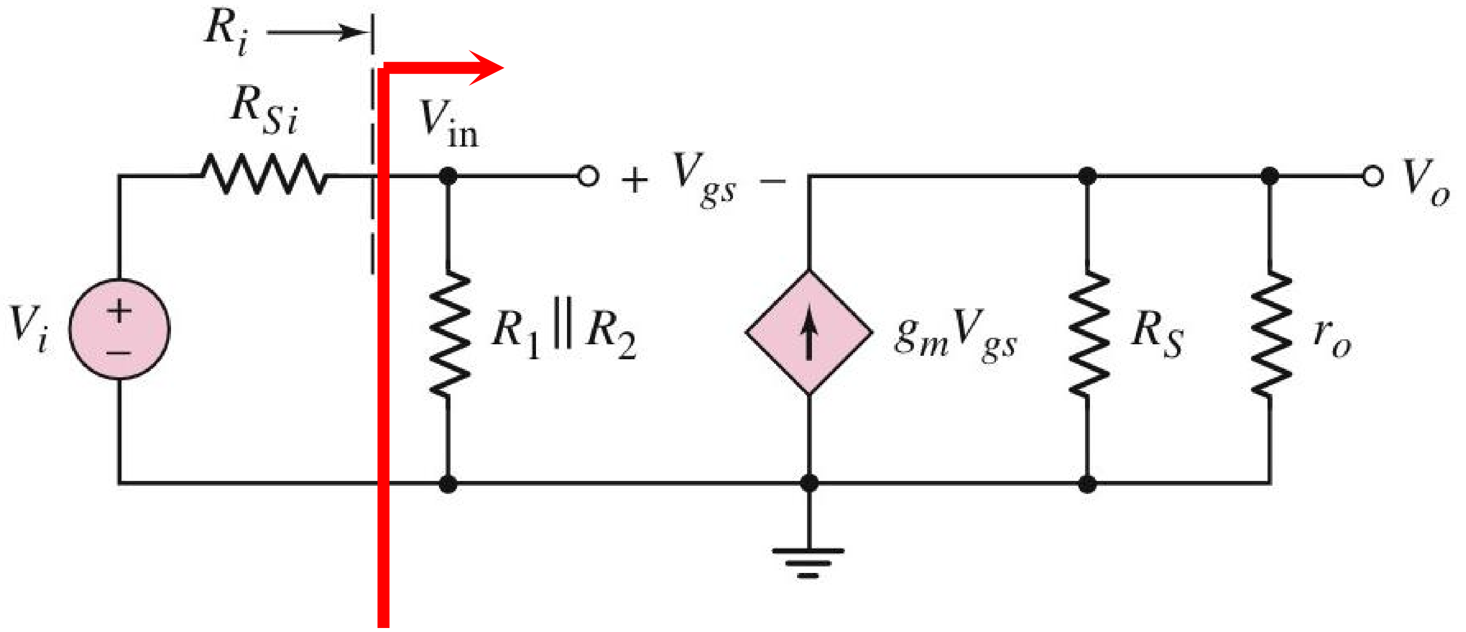
$$A_v = \frac{R_S \| r_o}{\dfrac{1}{g_m} + R_S \| r_o} \left(\frac{R_i}{R_i + R_{Si}} \right)$$



$$V_o = g_m \cdot V_{gs} \cdot (R_S // r_o)$$

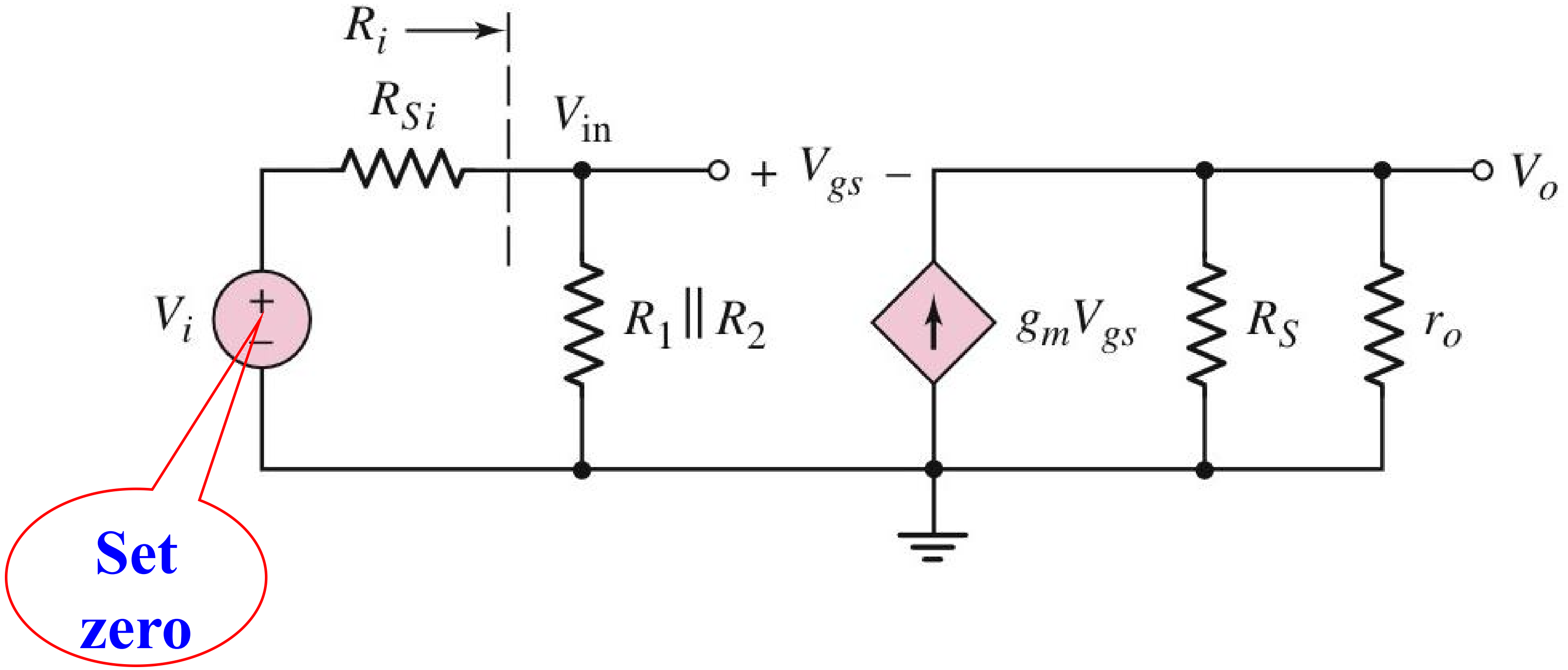
$$V_{in} = V_{gs} + V_O = V_{gs} + g_m \cdot V_{gs} \cdot (R_S // r_o)$$

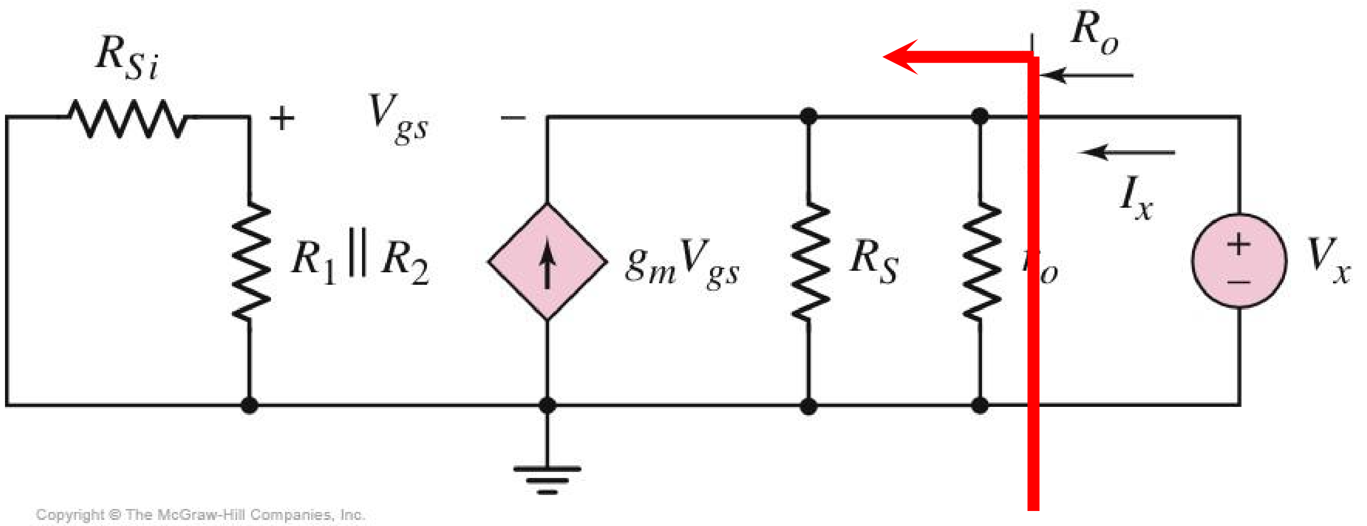
4.4.2 Input and Output Impedance



$$R_i = R_1 // R_2$$

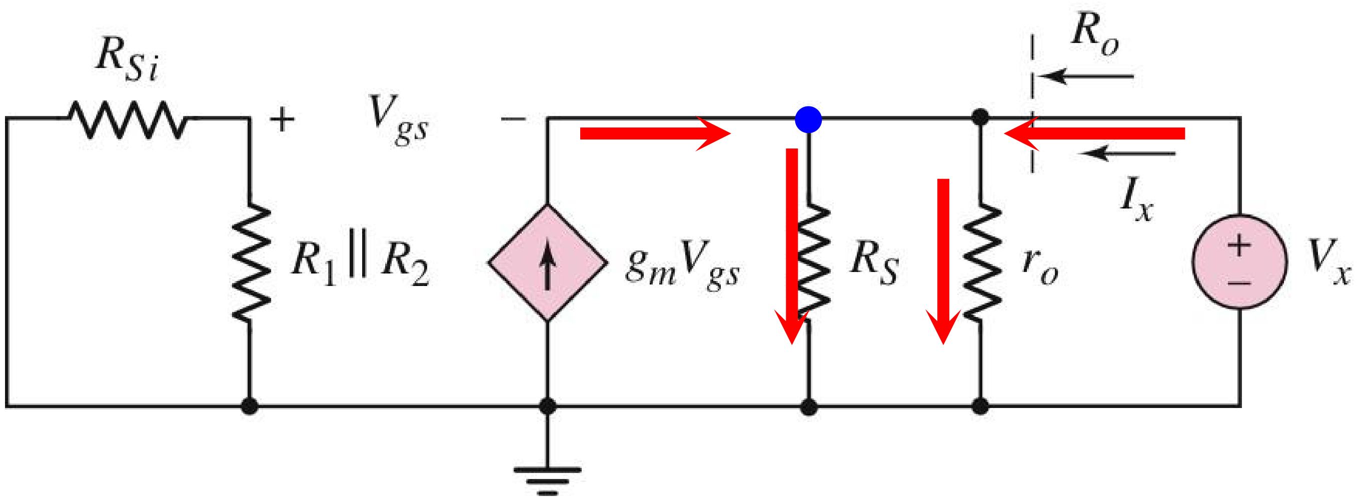
4.4.2 Input and Output Impedance





$$R_O = \frac{V_x}{I_x}$$

4.4.2 Input and Output Impedance



$$I_x + g_m V_{gs} = \frac{V_x}{R_S} + \frac{V_x}{r_o}$$

$$R_O = \frac{V_x}{I_x} = \frac{1}{g_m} \left\| R_S \right\| r_o$$

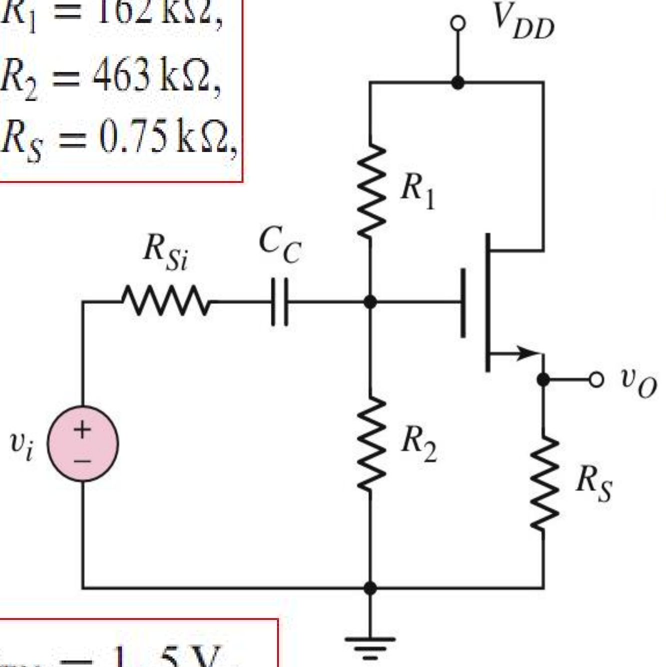
Output Resistance is very low.

Without significant loading effects.

Example Calculate the small-signal voltage gain

$V_{DD} = 12\,\mathrm{V}$
$R_1 = 162\,\mathrm{k\Omega}$,
$R_2 = 463\,\mathrm{k\Omega}$,
$R_S = 0.75\,\mathrm{k\Omega}$,

Solution: dc analysis

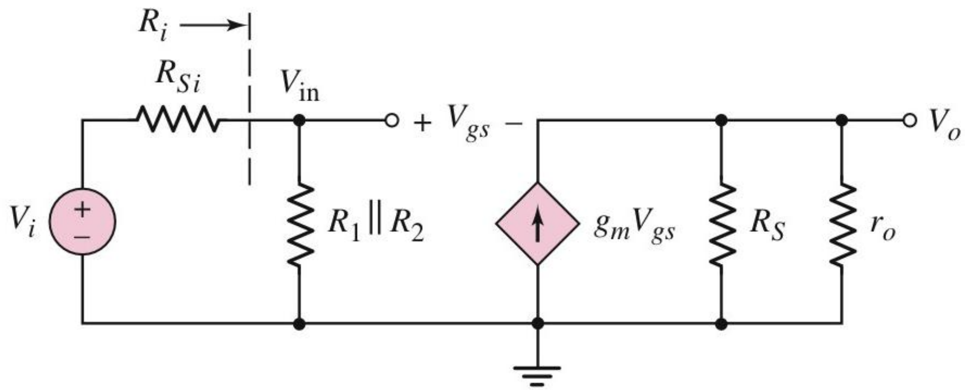


$V_{TN} = 1,5\,\mathrm{V}$,
$K_n = 4\,\mathrm{mA/V^2}$,
$\lambda = 0.01\,\mathrm{V^{-1}}$
$R_{Si} = 4\,\mathrm{k\Omega}$.

$$I_{DQ} = 7.97\,\mathrm{mA} \quad V_{GSQ} = 2.91\,\mathrm{V}.$$

$$g_m = 2K_n(V_{GSQ} - V_{TN}) = 2(4)(2.91 - 1.5) = 11.3\,\mathrm{mA/V}$$

$$r_o \cong [\lambda I_{DQ}]^{-1} = [(0.01)(7.97)]^{-1} = 12.5\,\mathrm{k\Omega}$$



$$R_i = R_1 \| R_2 = 162 \| 463 = 120\,\mathrm{k\Omega}$$

$$A_v = \frac{g_m(R_S \| r_o)}{1 + g_m(R_S \| r_o)} \cdot \frac{R_i}{R_i + R_{Si}} = \frac{(11.3)(0.75 \| 12.5)}{1 + (11.3)(0.75 \| 12.5)} \cdot \frac{120}{120 + 4} = +0.860$$

Contents

Ch4 Basic FET Amplifiers

4.1 The MOSFET Amplifier

4.2 Basic Transistor Amplifier Configurations

4.3 The Common Source Amplifier

4.4 The Common Drain（Source Follower） Amplifier

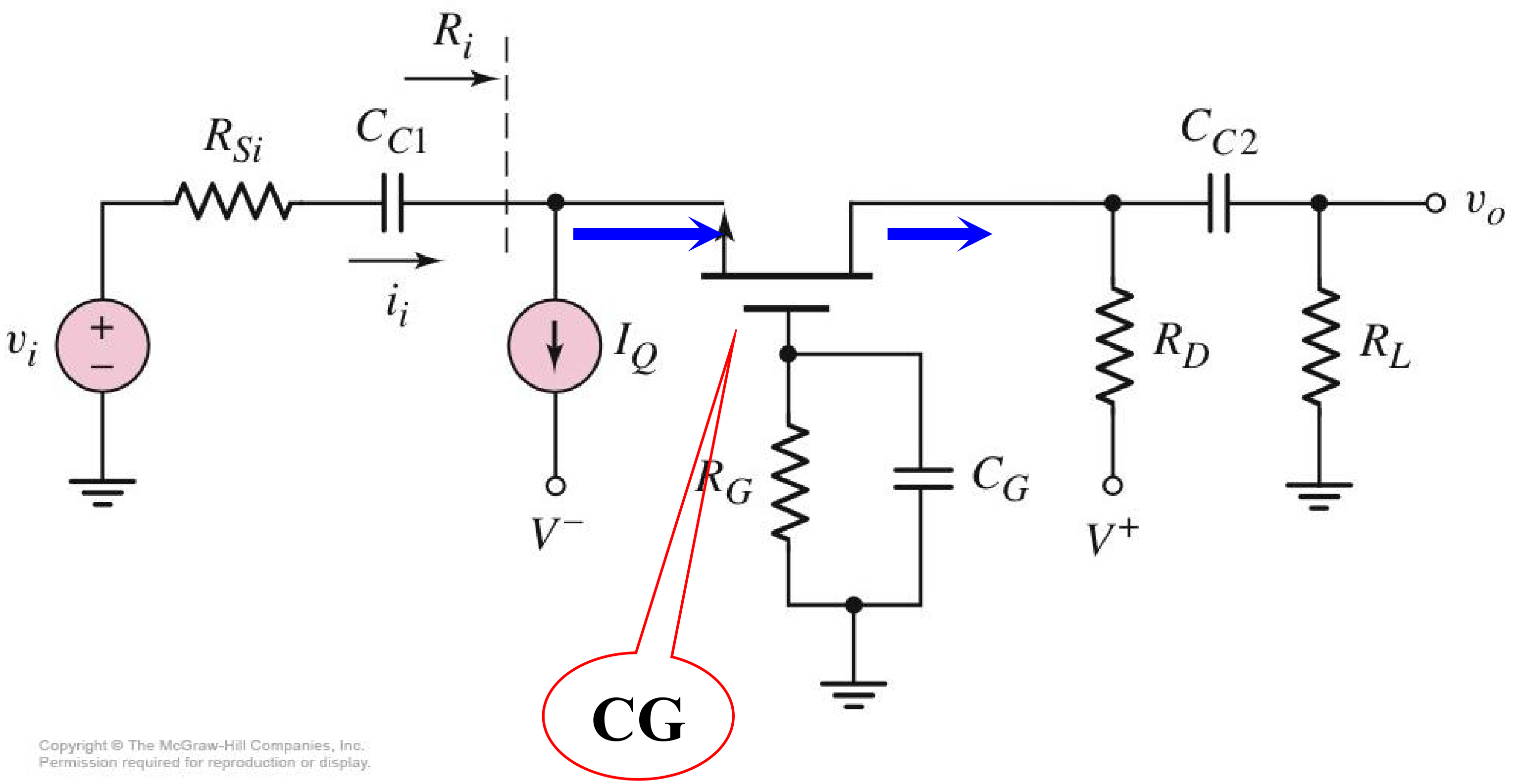
4.5 The Common Gate Configuration

4.5.1 Small voltage and current gains

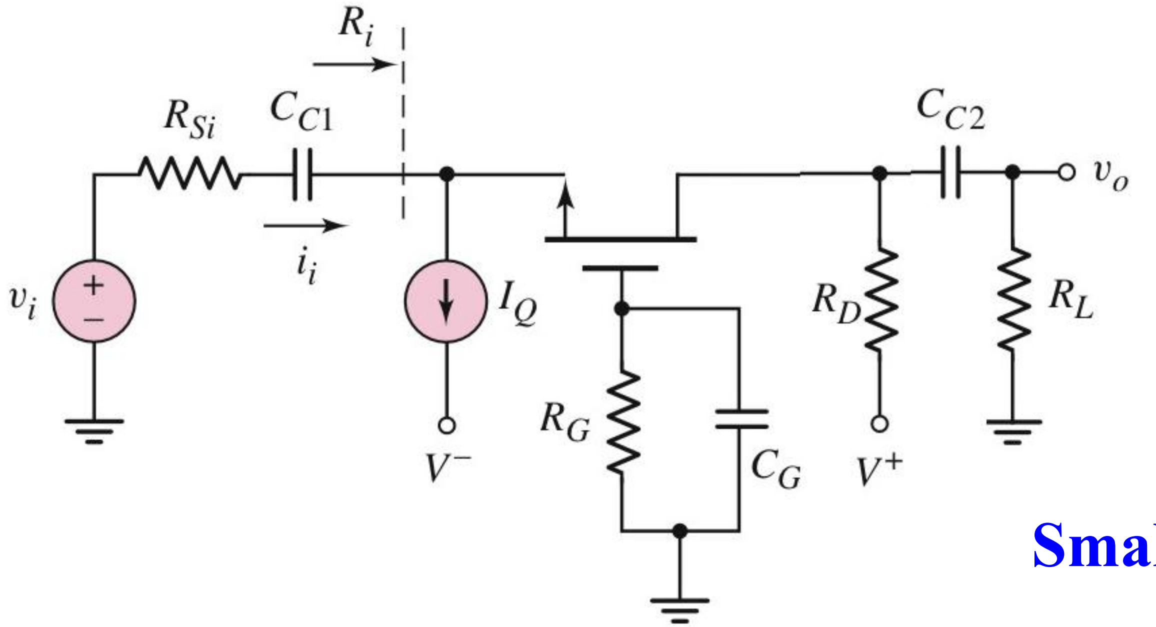
4.5.2 Input and output Impedance

4.6 The Three Basic Amplifier Configuration: Summary and comparison

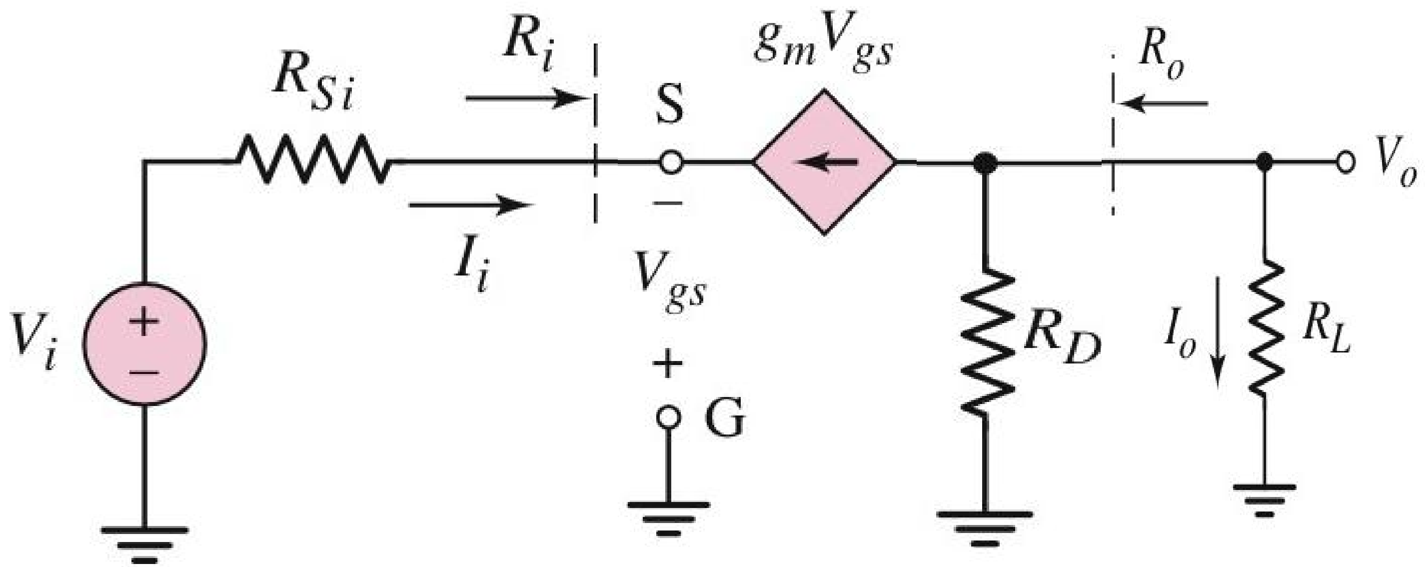
4.5 The Common Gate Configuration



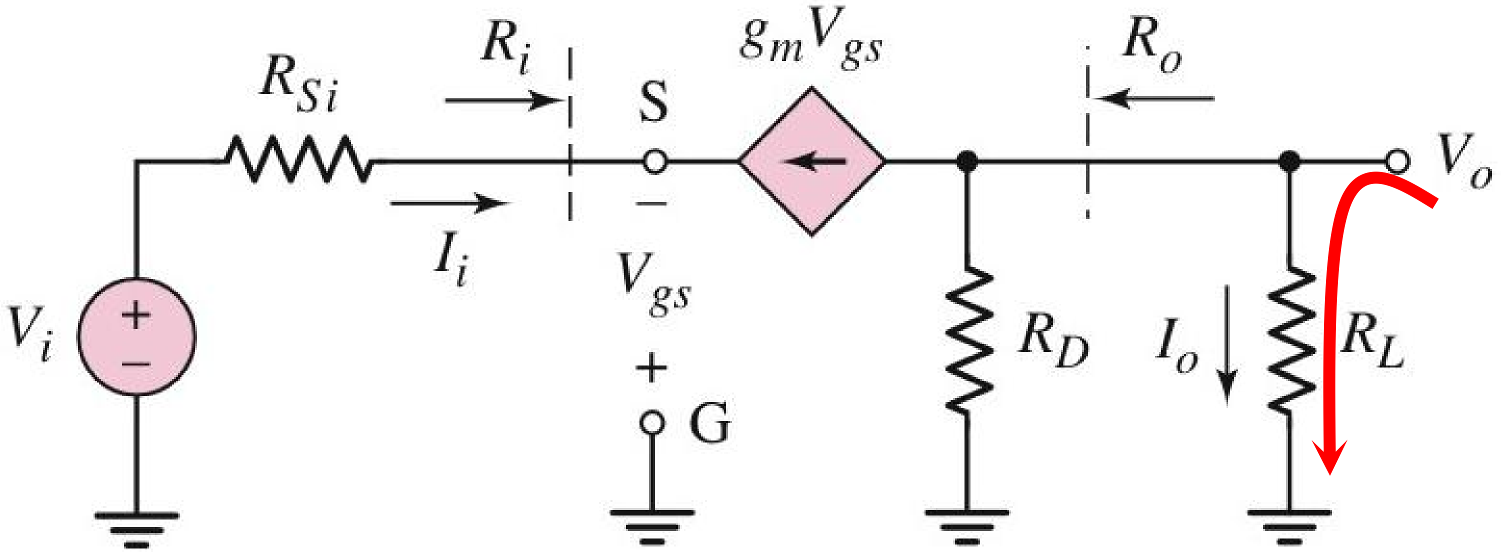
4.5.1 Small voltage and current gains



Small-Signal Equivalent Circuit



4.5.1 Small voltage and current gains



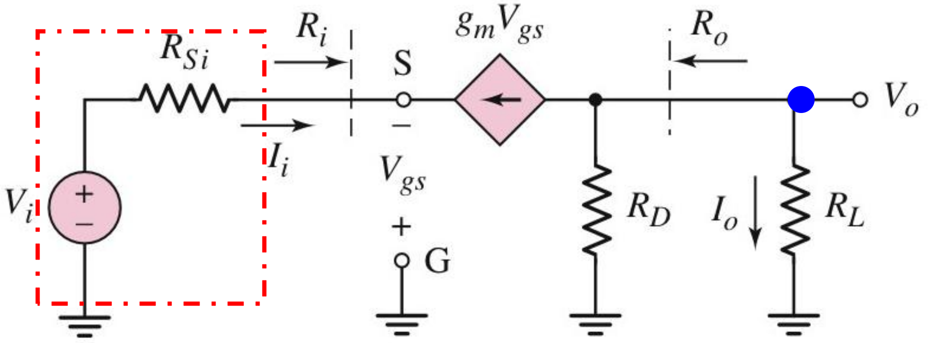
$$V_o = -g_m \cdot V_{gs} \cdot (R_D // R_L)$$

$$V_i = I_i \cdot R_{Si} - V_{gs}$$

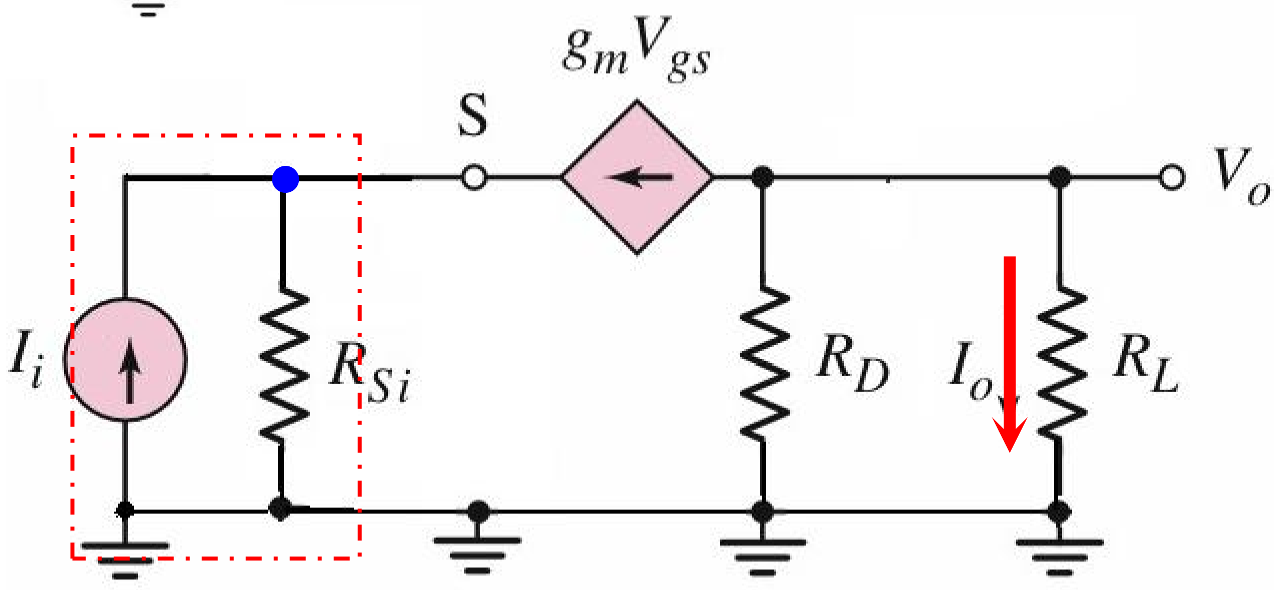
$$I_i = -g_m \cdot V_{gs}$$

$$\boxed{A_v = \frac{g_m (R_D \| R_L)}{1 + g_m R_{Si}}}$$

4.5.1 Small voltage and current gains



Norton equivalent circuit

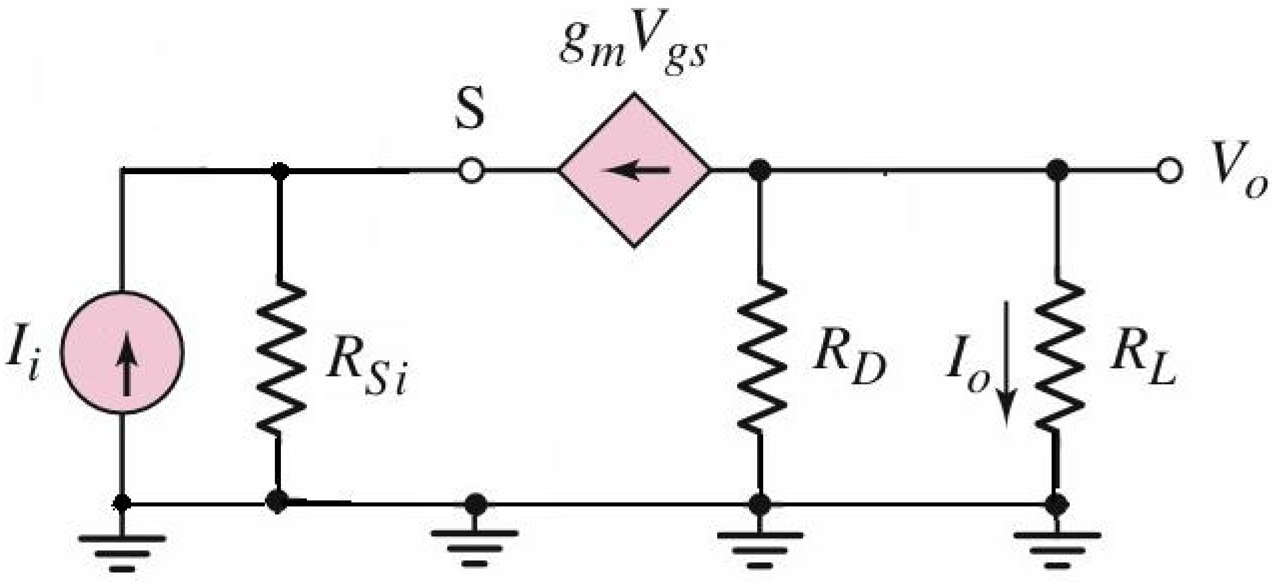


$$I_o = \frac{R_D}{R_D + R_L}\left(-g_m V_{gs}\right)$$

$$I_i + g_m V_{gs} + \frac{V_{gs}}{R_{Si}} = 0$$

$$A_i = \frac{I_O}{I_i} = \left(\frac{R_D}{R_D + R_L}\right)\left(\frac{g_m R_{Si}}{1 + g_m R_{Si}}\right)$$

4.5.1 Small voltage and current gains



$$A_i = \frac{I_O}{I_i} = \left(\frac{R_D}{R_D + R_L}\right)\left(\frac{g_m R_{Si}}{1 + g_m R_{Si}}\right)$$

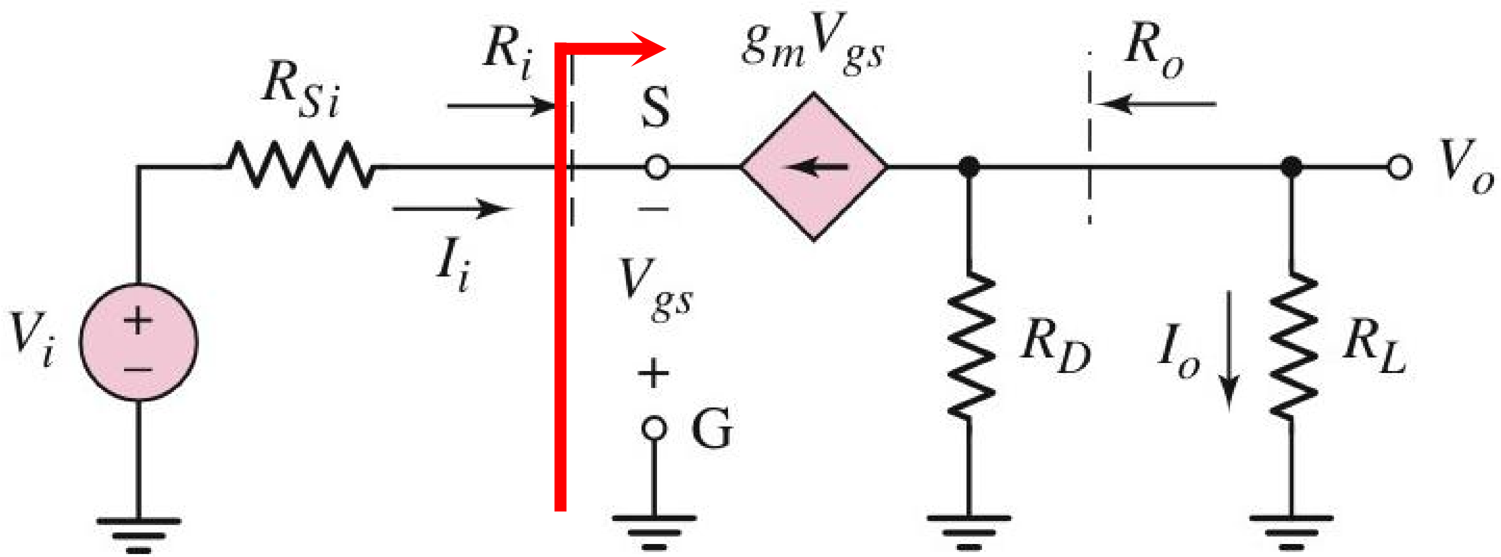
$$R_D >> R_L$$

$$g_m R_{Si} >> 1$$

$$A_i = 1$$

Current follower

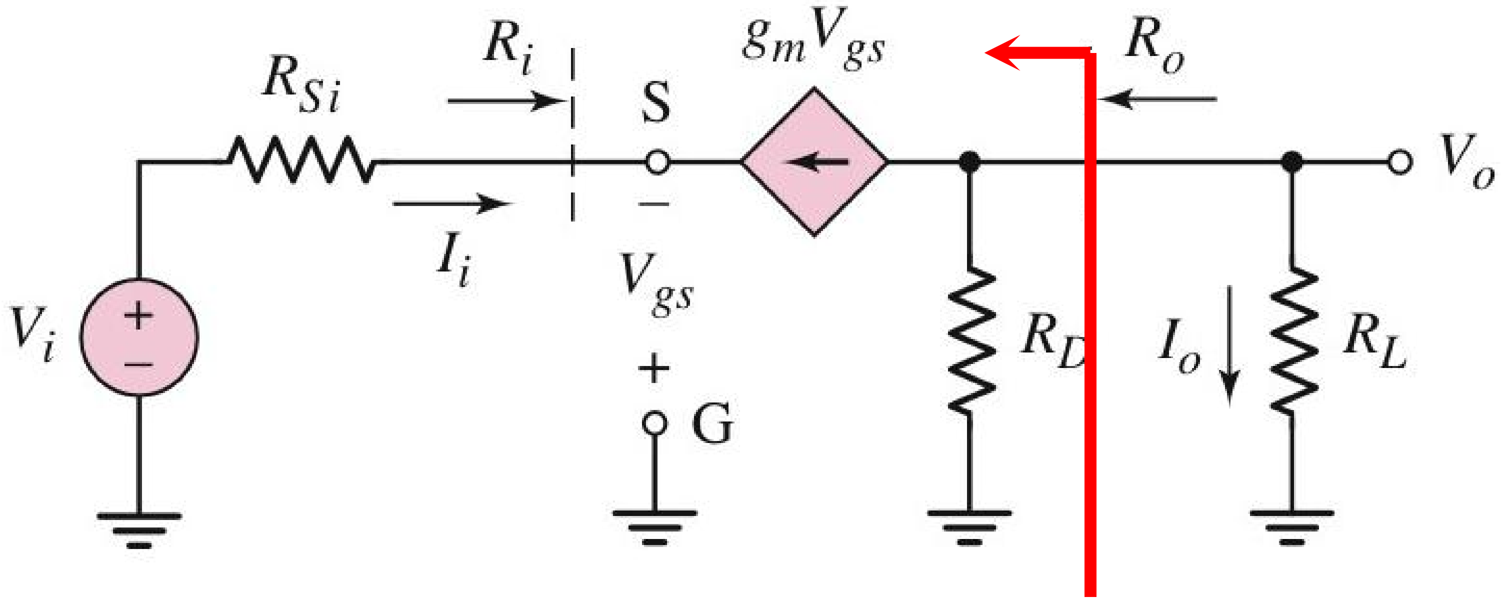
4.5.2 Input and output Impedance



$$R_i = \frac{-V_{gs}}{I_i} = \frac{-V_{gs}}{-g_m V_{gs}} = \frac{1}{g_m}$$

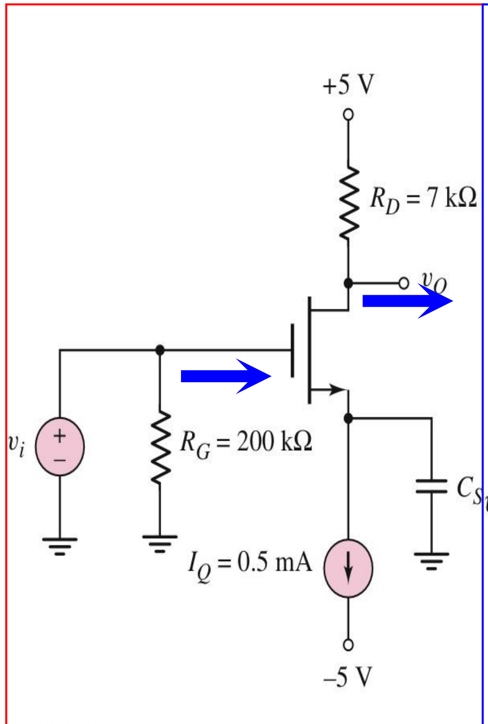
Input Impedance is very low

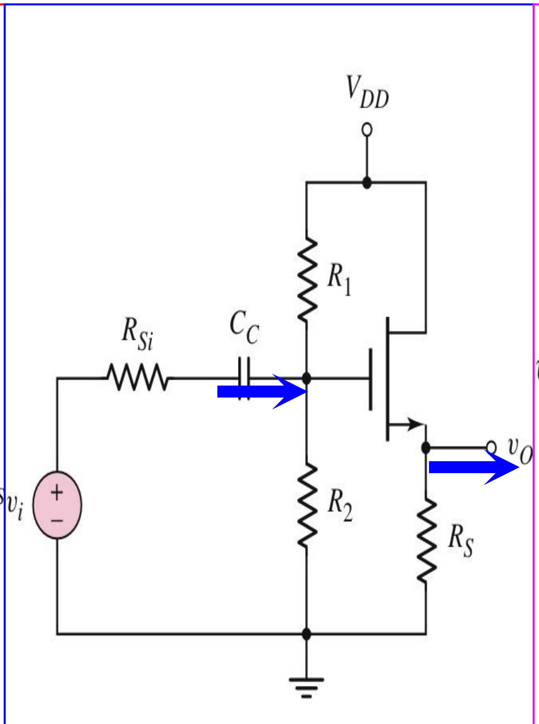
4.5.2 Input and output Impedance

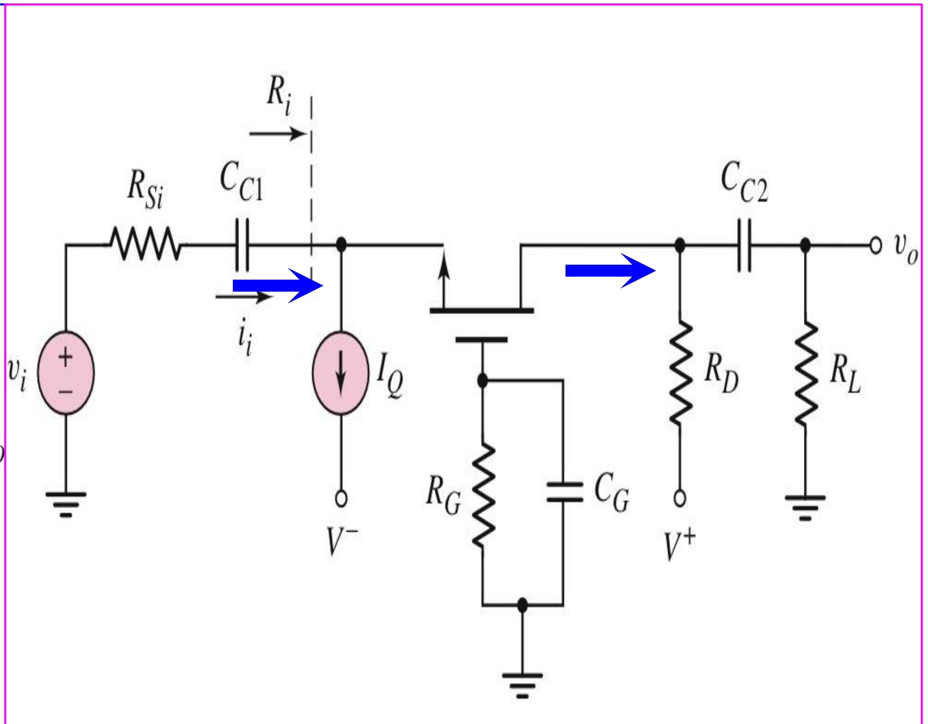


$$R_O = R_D$$

4.6 The Three Basic Amplifier Configuration:Summary and comparison

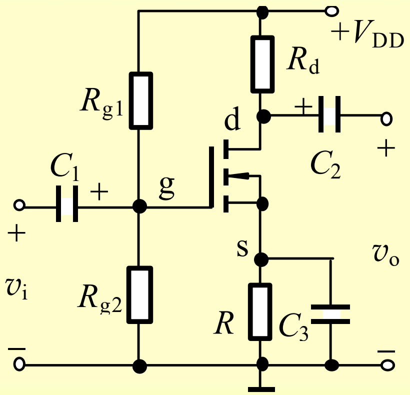
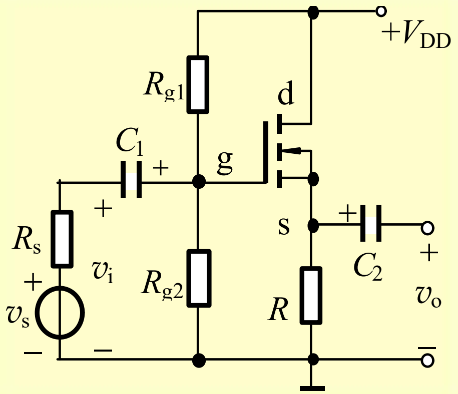
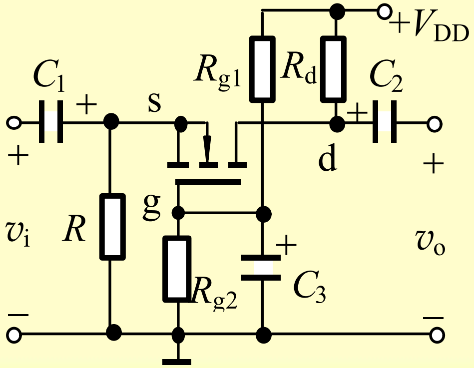






CS **CD** **CG**

Comparing three basic circuit of field effect transistor

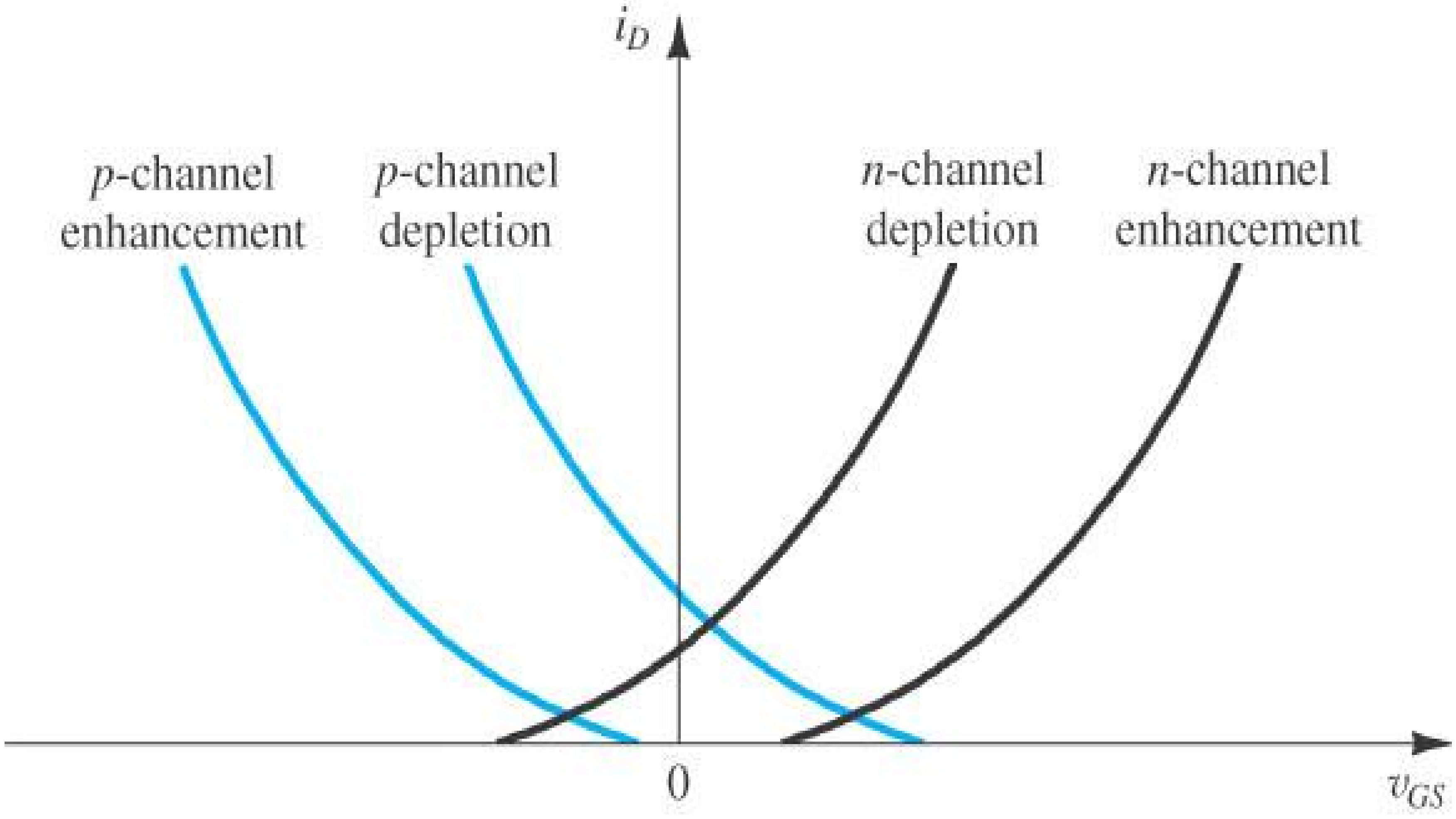
	Common-source	Common-drain	Common-gate
Circuit			
Voltage-gain	$A_V = -g_m(R_d // r_o)$	$A_V = \dfrac{g_m(R_d//r_o)}{1+g_m(R_d//r_o)}$	$A_V = \dfrac{(g_m + 1/r_o)R_D}{1+(R_D/r_o)} \approx g_m R_D$
Input resistor	$R_i = R_{g1} // R_{g2}$	$R_i = R_{g1} // R_{g2}$	$R_i = \dfrac{1}{g_m} // R$
Output resistor	$R_o = R_d // r_o$	$R_o = \dfrac{1}{g_m} // R // r_o$	$R_o = R_d // r_o$
Features	1.Voltage gain is large 2.Input and output voltage have opposing phase 3.Input resistance is large	1.Voltage gain is less than 1 and similar to 1 2.Input and output voltages have same phase 3.Input resistance is large 4.Output resistance is small	1.Voltage gain is large 2.Input and output voltages have same phase 3.Input resistance is small

Comparing three basic circuit of field effect transistor

Configuration	Voltage Gain	Current Gain	Input Resistance	Output Resistance
Common Source	$A_v > 1$	—	R_{TH}	Moderate to high
Source Follower	$A_v \approx 1$	—	R_{TH}	Low
Common Gate	$A_v > 1$	$A_i \approx 1$	Low	Moderate to high

Overview

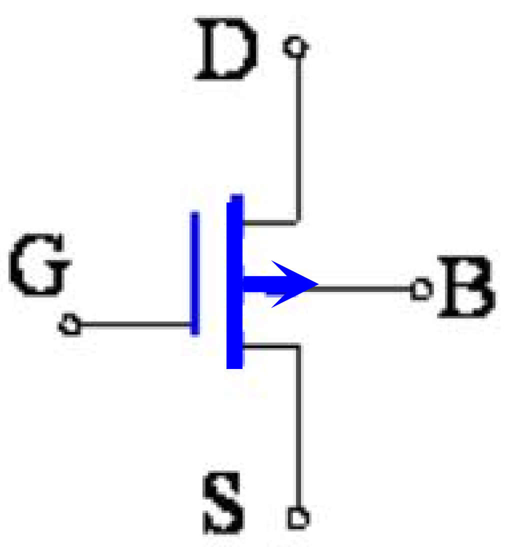
The i_D–v_{GS} Characteristic in Saturation

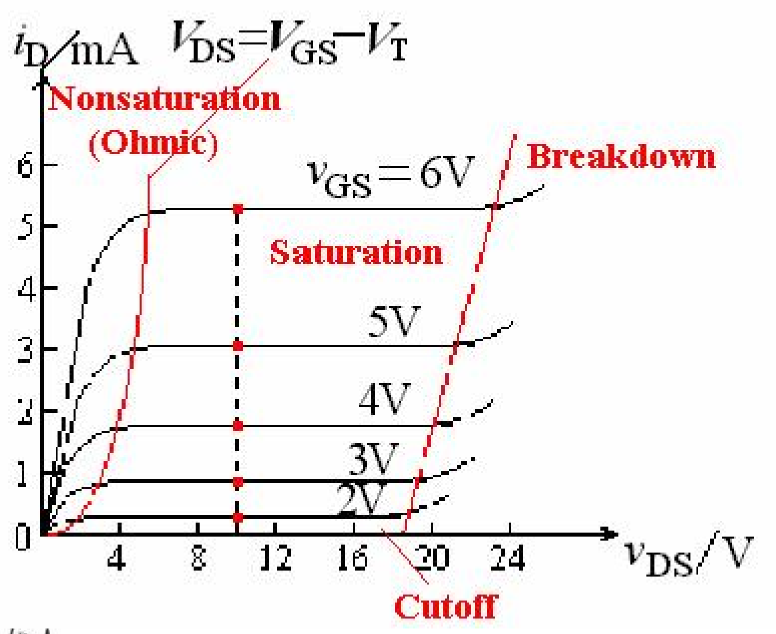


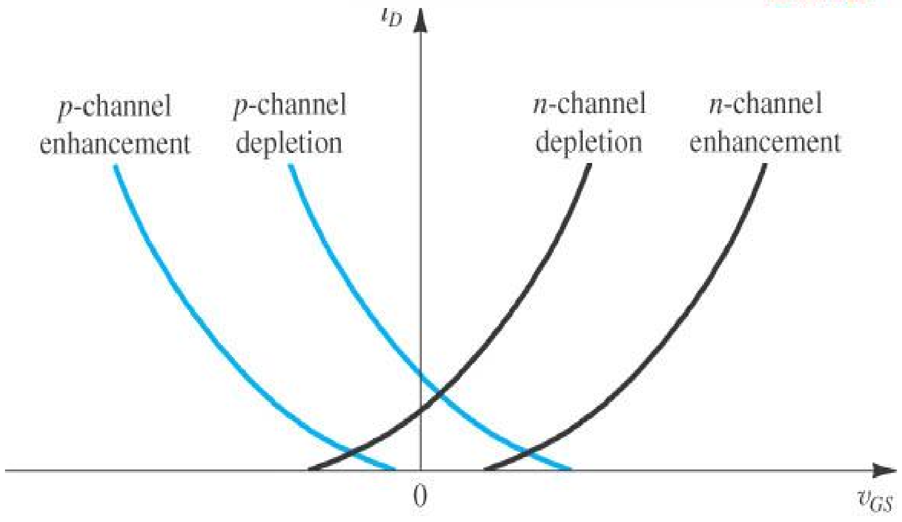
Overview

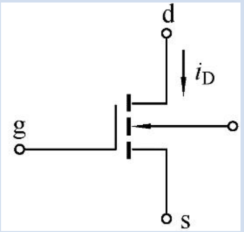
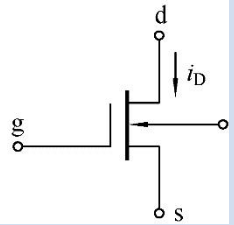
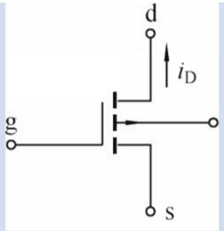
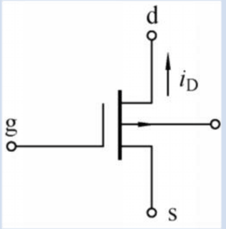
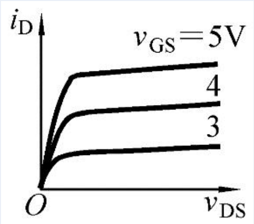
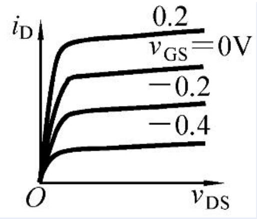
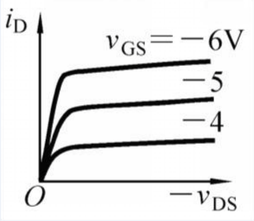
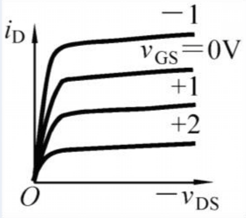
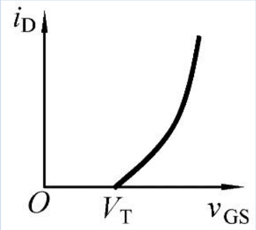
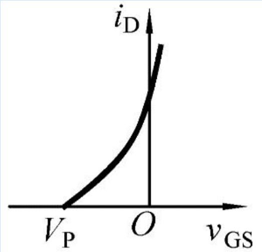
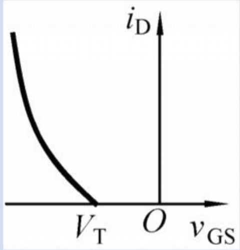
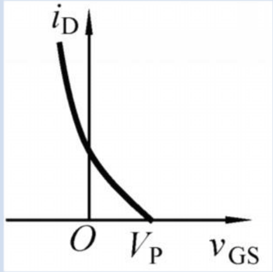
For chapter 3 and chapter 4:

1、MOSFET structure， feature, i-v characteristic







	NMOS E-Mode	NMOS D-Mode	PMOS E-Mode	NMOS D-Mode
Circuit Symbol				
Output Characteristic				
Transfer Characteristic				
V_{GS} **(Saturation Reg.)**	$V_{GS} > V_{TN} > 0$	$V_{GS} > V_P$	$V_{GS} < V_{TP} < 0$	$V_{GS} < V_P$
V_{DS} **(Saturation Reg.)**	$V_{DS} > V_{GS} - V_{TN} > 0$	$V_{DS} > 0$	$V_{DS} < V_{GS} - V_{TP} < 0$	$V_{DS} < 0$

2、DC analysis

Calculate V_{GS}、I_D、V_{DS}

A、For enhancement NMOS

Saturation region

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

$$V_{DS} = 2V_{DD} - I_D(R_d + R)$$

Non-saturation region

$$I_D = 2K_n(V_{GS} - V_T)V_{DS}$$

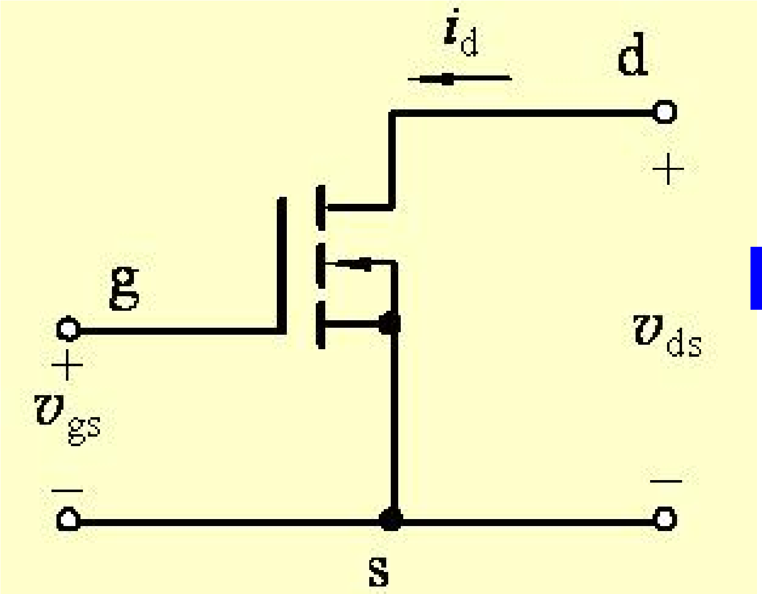
$$V_{DS} = 2V_{DD} - I_D(R_d + R)$$

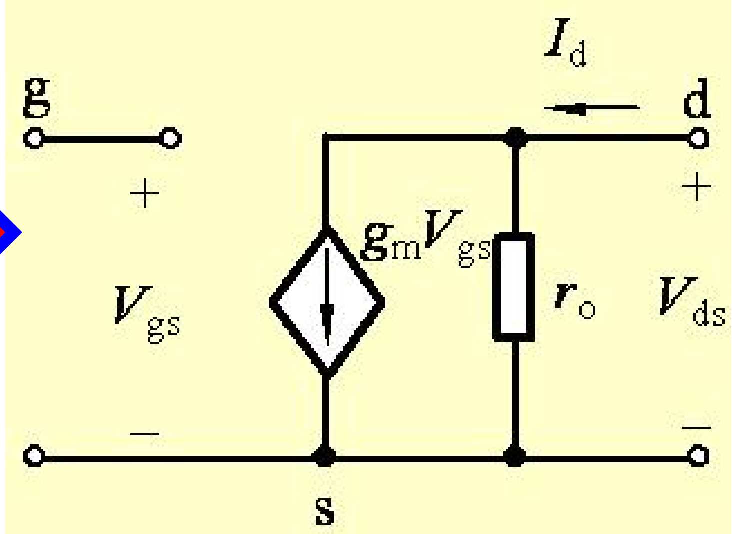
B、For depletion NMOS

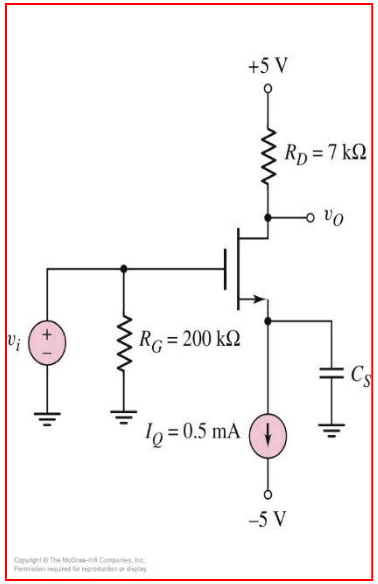
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \qquad (V_P \le V_{GS})$$

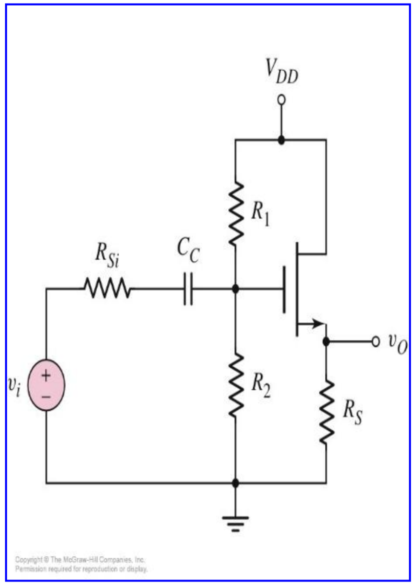
Overview

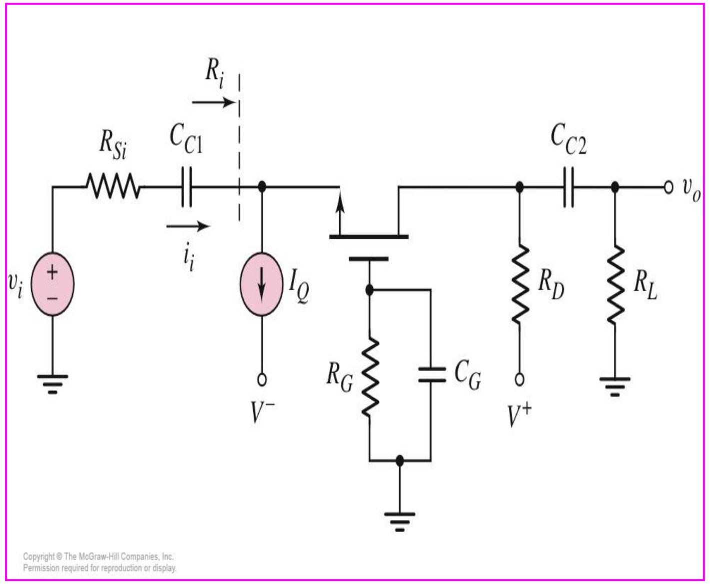
3、AC analysis











(1) The Reason of Using Multistage Circuit

A single transistor amplifier will not be able to meet the combined specifications of a given amplification factor, input resistance, and output resistance.

(2) Cascade Configuration

3 circuits are connected in series, or cascaded. Each circuit can be CE, CC, or CB configuration

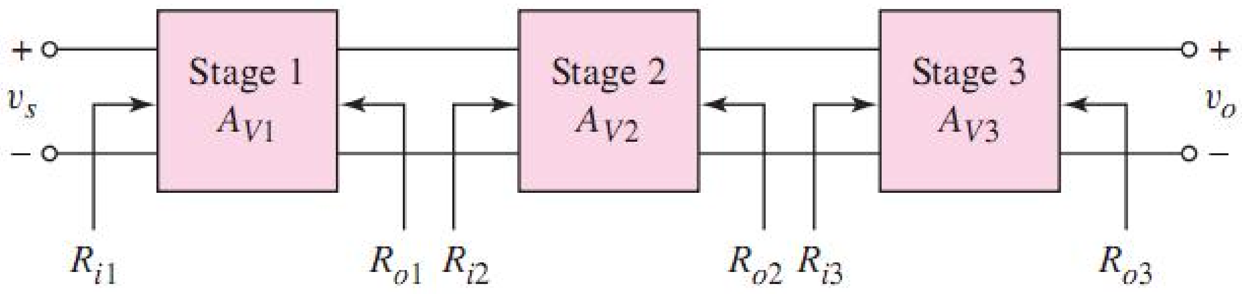


Figure 6.68 A generalized three-stage amplifier

(3) Loading effect

E.g. R_{i2} is the load of stage 1.

$$R_{i2} = R_{L1}$$

$$R_{o1} = R_{S2}$$

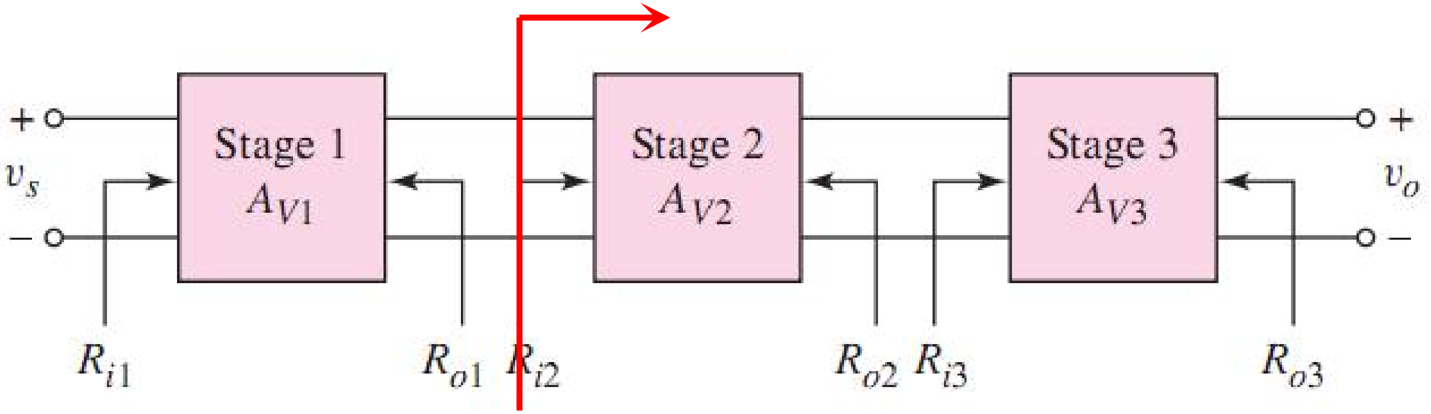
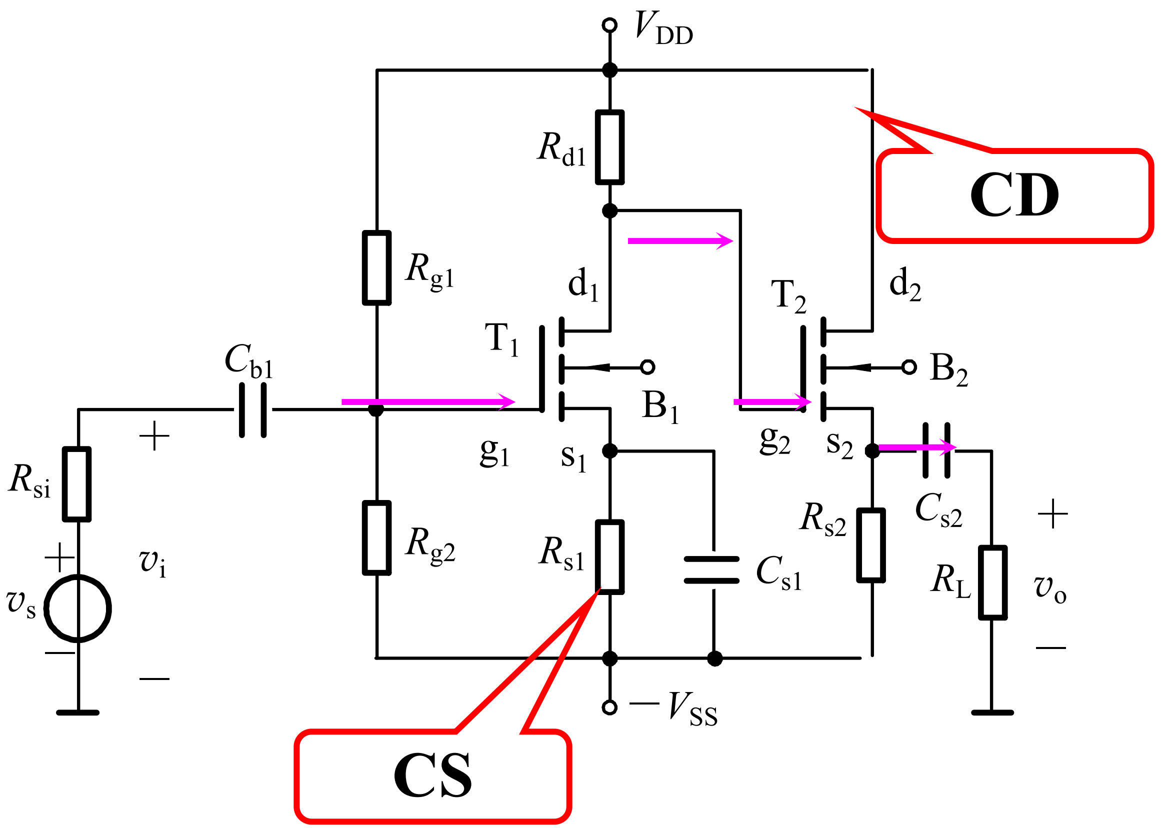


Figure 6.68 A generalized three-stage amplifier



V_{DD}
R_{d1}
CD
R_{g1}
d_1
T_2
d_2
T_1
C_{b1}
B_2
B_1
g_1
s_1
g_2
s_2
R_{si}
v_i
R_{g2}
R_{s1}
C_{s1}
R_{s2}
C_{s2}
R_L
v_o
v_s
$-V_{SS}$
CS

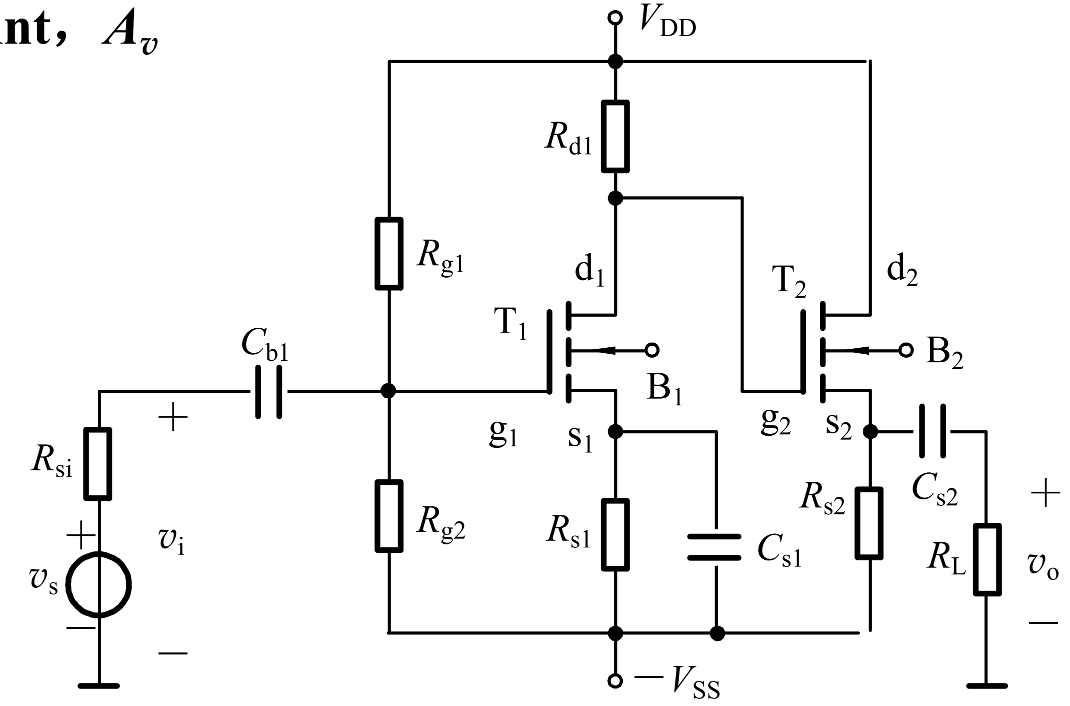
CS-CD

$K_{n1} = 0.5\,\mathrm{mA}/V^2, K_{n2} = 0.2\,\mathrm{mA}/V^2, V_{TN1} = V_{TN2} = 1.2\mathrm{V}, \lambda_1 = \lambda_2 = 0$

$R_{d1} = 16\mathrm{k}\Omega, R_{s1} = 3.9\mathrm{k}\Omega, R_{g1} = 390\mathrm{k}\Omega, R_{g2} = 140\mathrm{k}\Omega,$

$R_{si} = 5\mathrm{k}\Omega, R_{s2} = 8.2\mathrm{k}\Omega, \quad R_L = 4\mathrm{k}\Omega, V_{DD} = V_{SS} = 5\mathrm{V}$

Determine Q-point，A_v

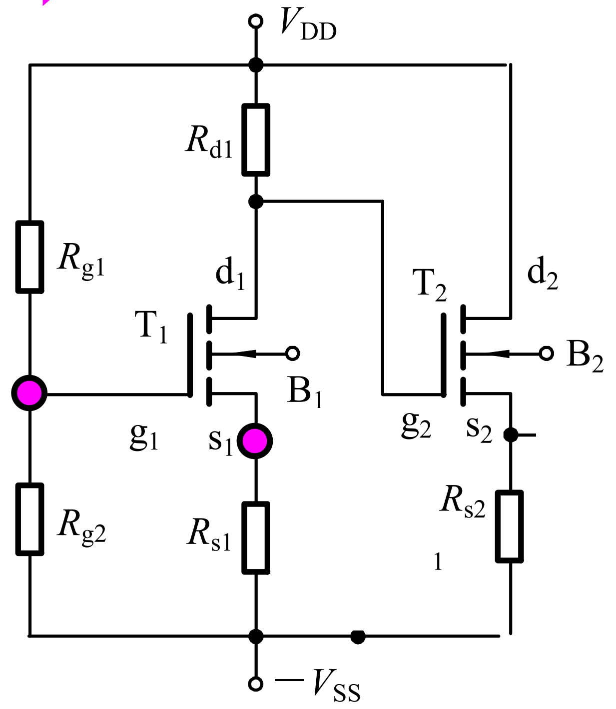


SOL：1.Q-point

DC Circuit

$$V_{GSQ1}=V_{G1}-V_{S1}=\frac{R_{g2}}{R_{g1}+R_{g2}}(V_{DD}+V_{SS})-I_{DQ1}R_{S1}$$

$$=\frac{140}{390+140}\times 10-3.9I_{DQ1}=2.64-3.9I_{DQ1}$$



In sat.

$$I_{DQ1}=K_{n1}(V_{GSQ1}-V_{TN1})^2=0.5(V_{GSQ1}-1.2)^2$$

$$V_{GSQ1}=2.64-3.9\times 0.5(V_{GSQ1}-1.2)^2$$

$$V_{GSQ1}=\frac{3.68\pm\sqrt{3.68^2-4\times 1.95\times 0.168}}{2\times 1.95}\text{V}$$

$$=\frac{3.68\pm 3.497}{3.9}\text{V} \quad \text{get} \quad V_{GSQ1}=1.84\text{V}$$

$$I_{DQ1}=0.5(V_{GSQ1}-V_{TN1})^2=0.2\text{mA}$$

$$V_{DSQ1}=V_{DD}+V_{SS}-I_{DQ1}(R_{d1}+R_{S1})=6.02\text{V}$$

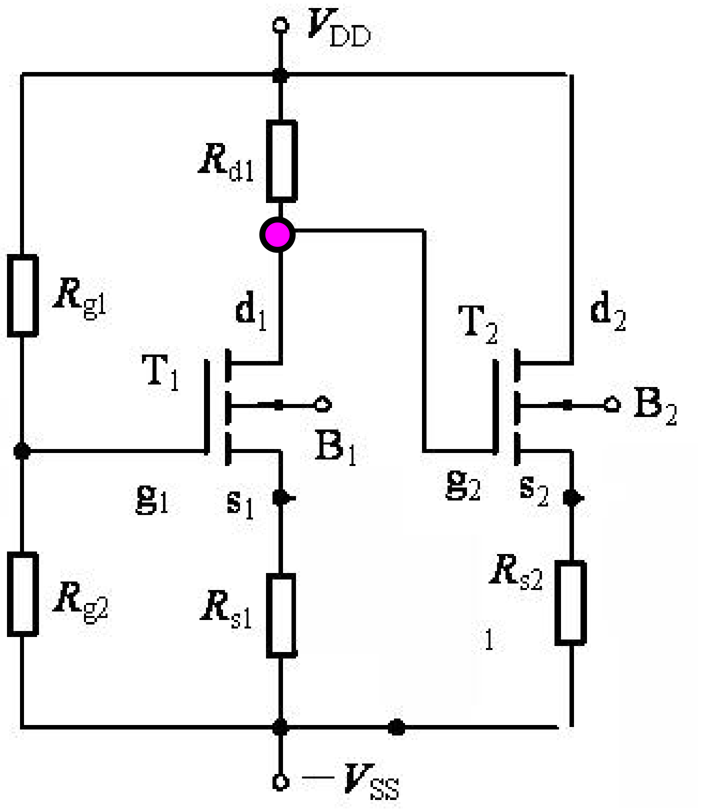
For T_2

$$V_{G2} = V_{D1} = V_{DD} - I_{DQ1}R_{d1} = (5 - 0.2\times 16)\text{V} = 1.8\text{V}$$

$$V_{GSQ2} = V_{G2} - V_{S2} = 1.8 - I_{DQ2}R_{S2} + V_{SS}$$

$$\begin{aligned} I_{DQ2} &= K_{n2}(V_{GSQ2} - V_{TN2})^2 \\ &= 0.2(1.8 - I_{DQ2}\times 8.2 + 5 - 1.2)^2 \\ &= 0.2(5.6 - 8.2I_{DQ2})^2 \end{aligned}$$

$$I_{DQ2}^2 - 1.44I_{DQ2} + 0.466 = 0$$



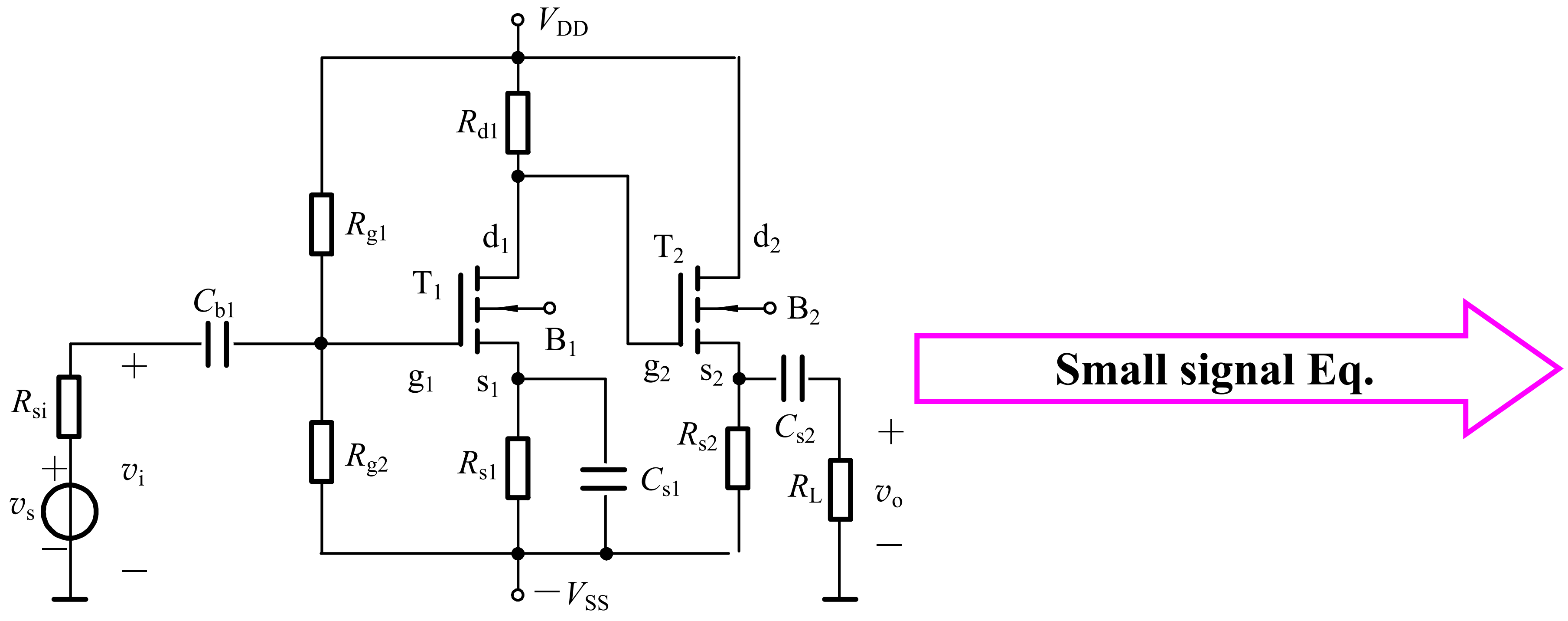
$$I_{DQ2} = \frac{1.44 \pm \sqrt{1.44^2 - 4\times 0.466}}{2}\text{mA} = \frac{1.44 \pm 0.458}{2}\text{mA}$$

get $I_{DQ2} = (1.44 - 0.458)/2 \approx 0.49\text{mA}$

$$V_{GSQ2} = (1.8 + 5 - 0.49\times 8.2)\text{ V} = 2.78\text{V}$$

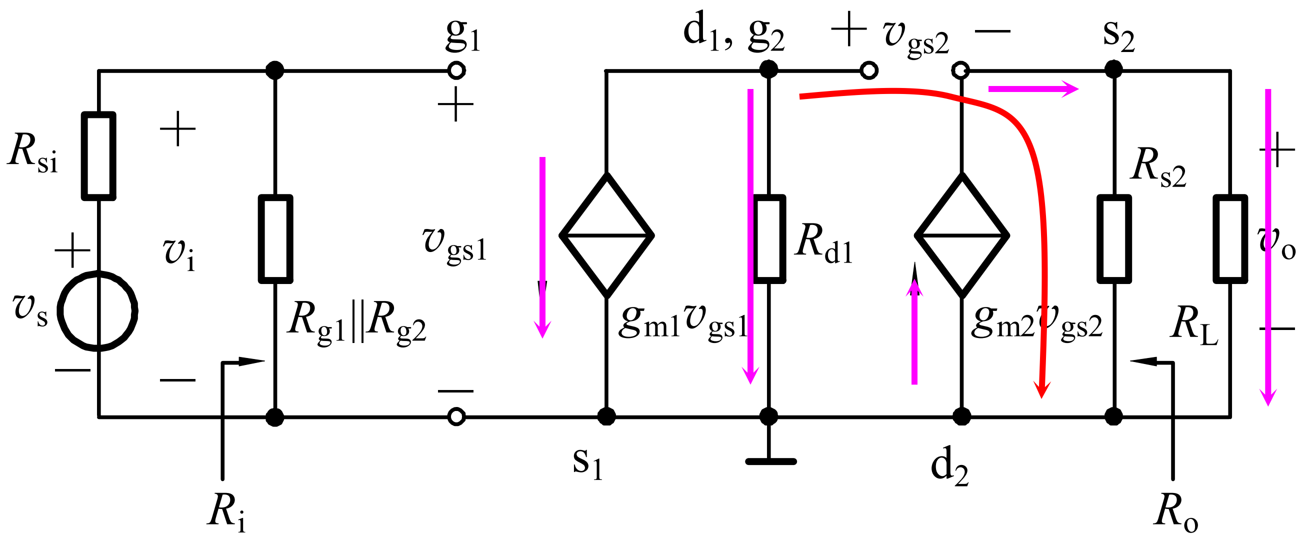
$$V_{DSQ2} = V_{DD} + V_{SS} - I_{DQ2}R_{S2} = (10 - 8.2\times 0.49)\text{ V} = 5.98\text{V}$$

2. A_v



$$g_{m1} = 2K_{n1}(V_{GSQ1} - V_{TN1}) = 2 \times 0.5(1.84 - 1.2)\text{mA} \bullet \text{V}^{-1} = 0.64\text{mA} \bullet \text{V}^{-1}$$

$$g_{m2} = 2K_{n2}(V_{GSQ2} - V_{TN2}) = 2 \times 0.2(2.78 - 1.2)\text{mA} \bullet \text{V}^{-1} = 0.632\text{mA} \bullet \text{V}^{-1}$$

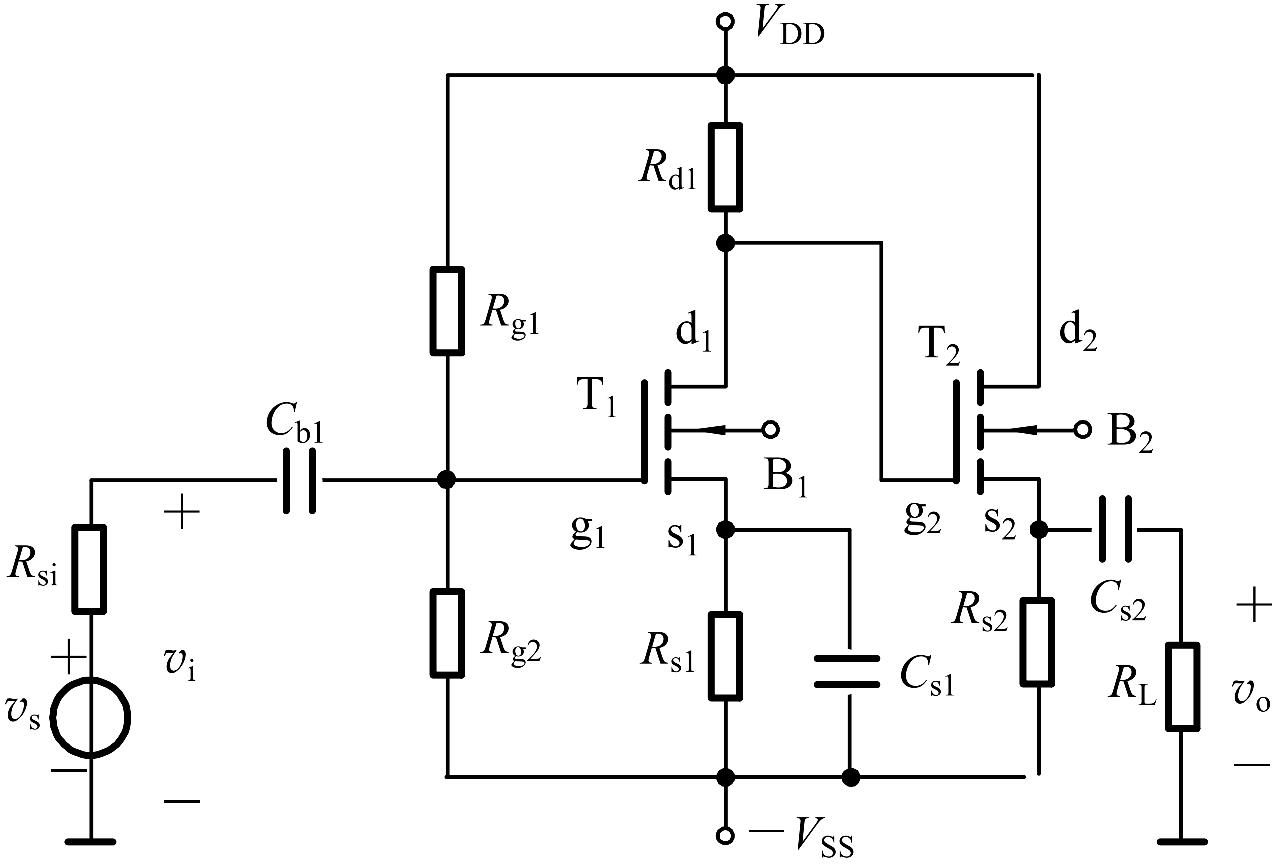


$$v_0 = g_{m2}v_{gs2}(R_{S2}//R_L)$$

$$v_{gs2} + v_0 = -g_{m1}v_{gs1}R_{d1}$$

$$A_v = \frac{v_0}{v_i} = \frac{v_0}{v_{gs1}} = -\frac{g_{m1}g_{m2}R_{d1}(R_{S2}//R_L)}{1+g_{m2}(R_{S2}//R_L)}$$

If not sketch this small signal circuit, how to get this?



V_{DD}
R_{d1}
R_{g1}
d_1
T_1
T_2
d_2
C_{b1}
B_1
B_2
g_1
s_1
g_2
s_2
R_{si}
$+$
v_i
v_s
$-$
R_{g2}
R_{s1}
C_{s1}
R_{s2}
C_{s2}
R_L
v_o
$-V_{SS}$

1 、(**12** points)

For the NMOS amplifier in Figure 1, the circuit parameters are:

K_n=1mA/V², $\lambda=0$; V_T =2V, $g_m = 2K_n(V_{GSQ} - V_T) = 2\sqrt{K_n I_{DQ}}$,

In the saturation region,the drain current is $i_D = K_n(v_{GS} - V_T)^2$,

In the nonsaturation region, the drain current is $i_D \approx 2K_n(v_{GS} - V_T)v_{DS}$,

(1) Find the Q-point;

(2) Sketch the Small-Signal Equivalent Circuit;

(3) Find $A_v = v_o / v_i$;

(4) Find R_i and R_o