第五章 基本放大电路

—— 5.4 各种基本组态放大电路的分析比较

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第五章内容

5.1 放大电路的组成及技术指标

5.2 放大电路的分析方法

5.3 放大电路的稳定偏置

5.4 各种基本组态放大电路的分析与比较

5.5 放大电路的频率相应

5.6 一般组合放大电路

5.4 各种基本组态放大电路的分析比较

本节内容

5.4.1 共基组态基本放大电路

5.4.2 共集组态基本放大电路

5.4.3 场效应管放大电路

5.4.4 共源组态基本放大电路

5.4.5 共栅组态基本放大电路

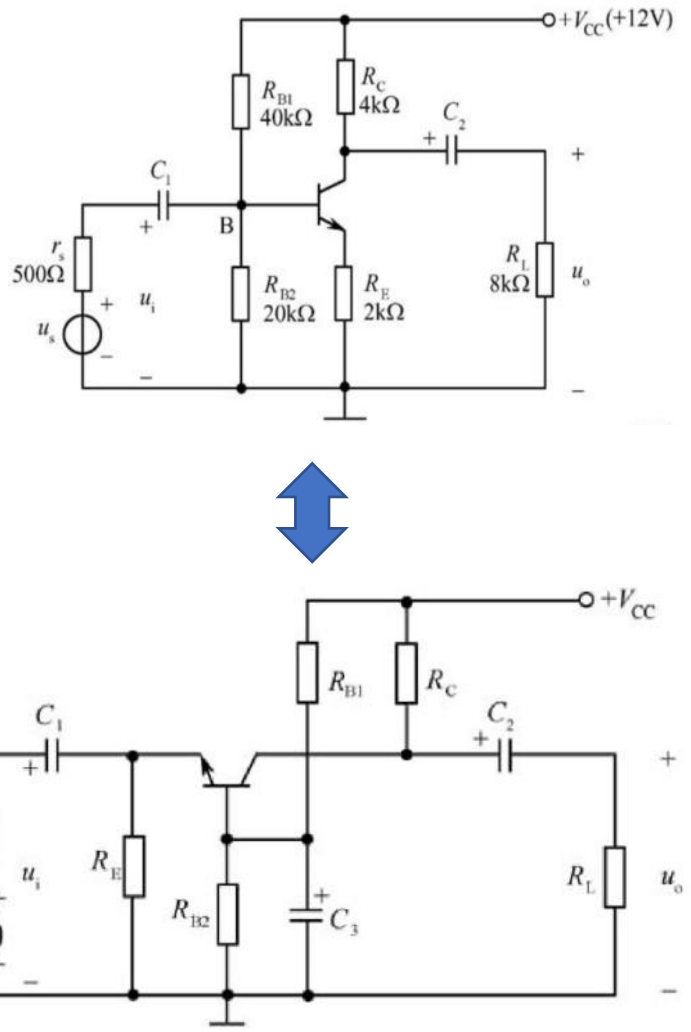
5.4.6 共漏组态基本放大电路

5.4.7 各种组态放大电路的比较

5.4.8 复合管

5.4.1 共基组态基本放大电路

- ✓ **直流分析：**
  - 与共射组态相同
- ✓ **交流分析：**
  - 增益



5.4.1 共基组态基本放大电路

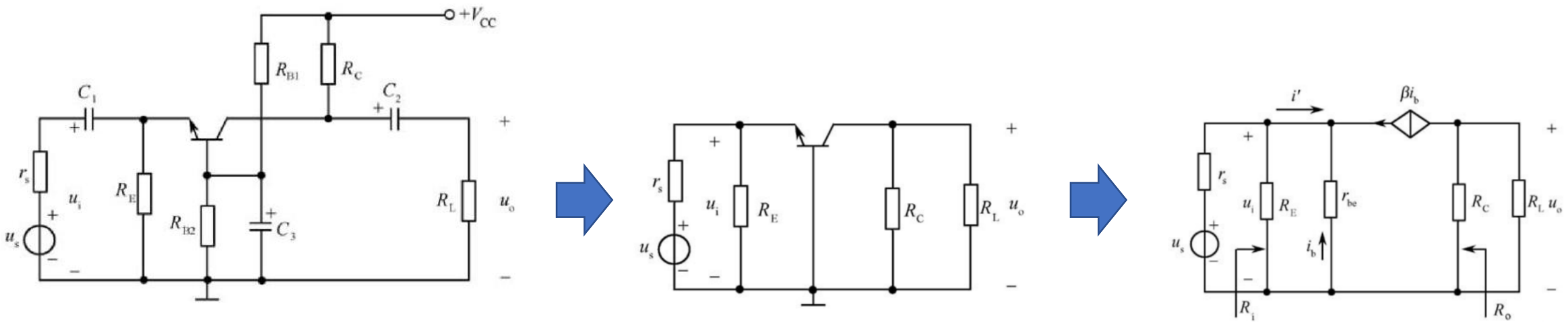
✓ **直流分析：**

- 与共射组态相同

✓ **交流分析：**

- 增益：

$$A_u = \frac{u_o}{u_i} = \frac{\beta R'_L}{r_{be}} \qquad R'_L = R_C // R_L$$



5.4.1 共基组态基本放大电路

✓ **交流分析：**

- 输入电阻：

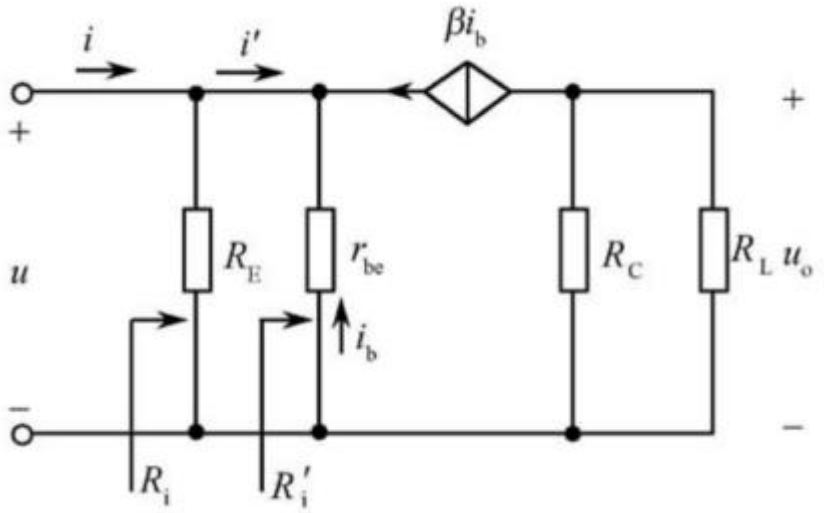
$$u = -i_b \cdot r_{be}$$

$$i' = -(i_b + \beta \cdot i_b)$$

$$R'_i = u / i' = \frac{r_{be}}{1+\beta}$$

$$R_i = R_E \| R'_i = R_E \left\| \frac{r_{be}}{1+\beta} \right. \approx \frac{r_{be}}{1+\beta}$$

- 输出电阻：$R_O \approx R_C$



5.4.1 共基组态基本放大电路

✓ **共基极电路特点：**

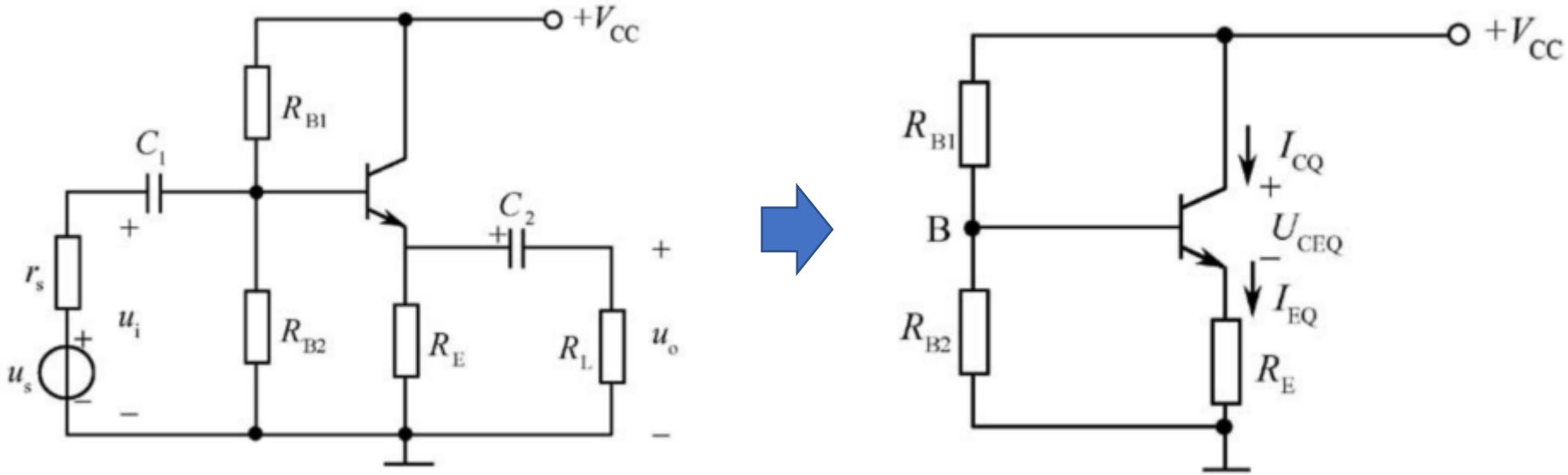
- 放大倍数：与共发射极相同，但相位相反
- 输入电阻：低
- 输出电阻：与共发射极相同

5.4.2 共集组态基本放大电路

✓ **直流分析：**

$$U_B = \frac{R_{B2}}{R_{B1}+R_{B2}} * V_{CC} \qquad I_{CQ} \approx I_{EQ}$$

$$I_{EQ} = \frac{U_B - U_{BEQ}}{R_E} \qquad U_{CEQ} = V_{CC} - I_{EQ} \cdot R_E$$



5.4.2 共集组态基本放大电路

✓ **交流分析：**

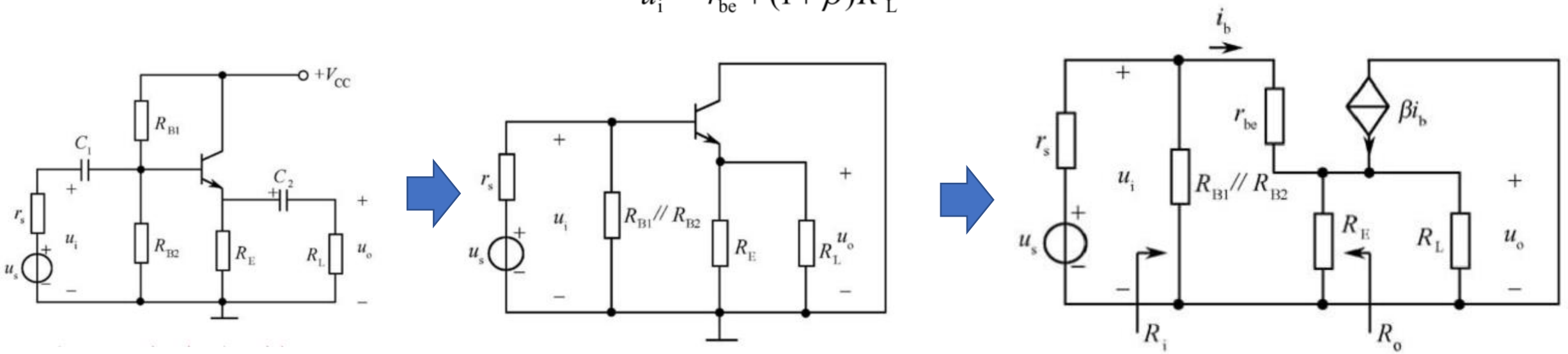
- 电压放大倍数：

$$R_L' = R_E \| R_L$$

$$u_i = i_b \cdot r_{be} + (i_b + \beta \cdot i_b) \cdot R_L'$$

$$u_o = (i_b + \beta \cdot i_b) \cdot R_L'$$

$$\dot{A}_u = \frac{u_o}{u_i} = \frac{(1+\beta) R'_L}{r_{be} + (1+\beta) R'_L}$$



5.4.2 共集组态基本放大电路

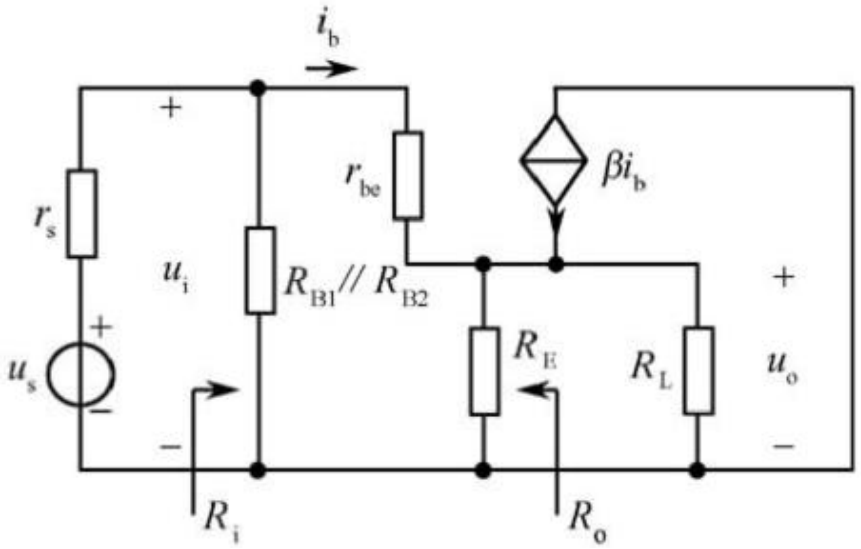
✓ **交流分析：**

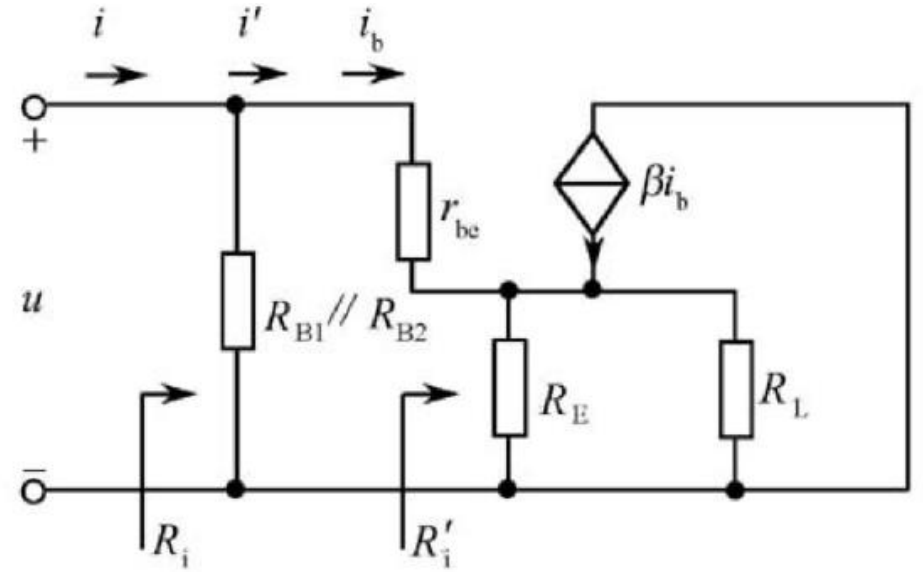
- 输入电阻：

$$u = i_b \cdot r_{be} + (i_b + \beta \cdot i_b) \cdot R_L'$$

$$R_i' = \frac{u}{i_b} = r_{be} + (1+\beta) \cdot R_L'$$

$$R_i = R_{B1} \| R_{B2} \| R_i'$$

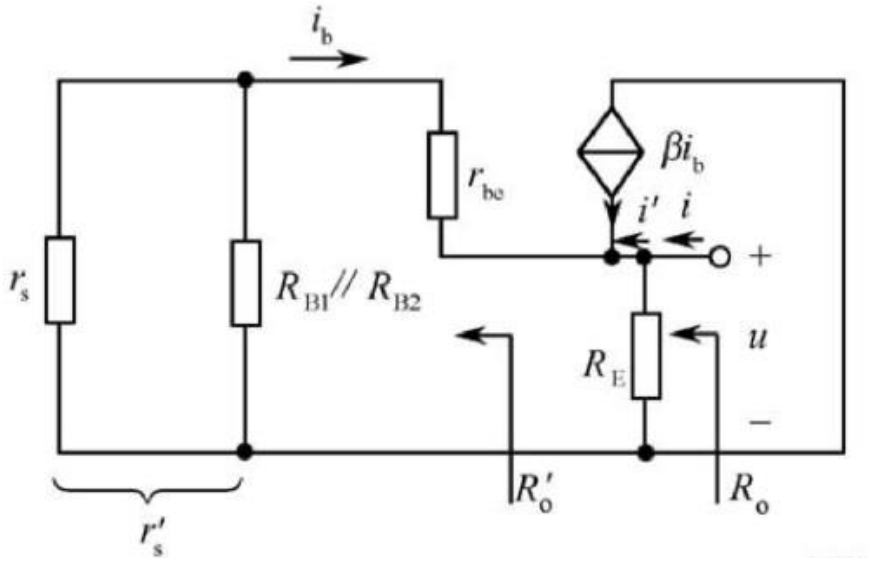




5.4.2 共集组态基本放大电路

✓ **交流分析：**

- 输出电阻：将输入信号短路，负载开路，由所加的电压可以求出电流



$$i_b = -\frac{u}{r_{be} + r'_s} \quad , \quad r'_s = r_s \,//\, R_{B1} \,//\, R_{B2}$$

$$i' = -(1+\beta)\cdot i_b = \frac{(1+\beta)\cdot u}{r_{be} + r'_s}$$

$$R_o' = \frac{u}{i'} = \frac{r_{be} + r'_s}{1+\beta}$$

$$R_o = R_E \,\|\, R_o' = R_E \,//\, \frac{r_{be} + r'_s}{1+\beta}$$

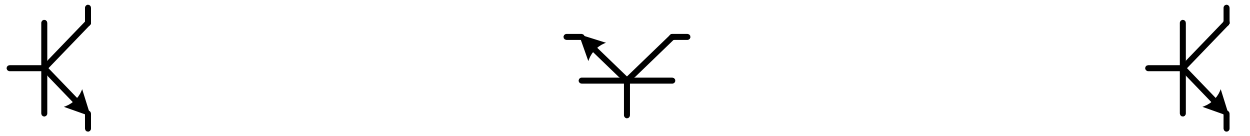
5.4.2 共集组态基本放大电路

✓ **共集极电路特点：**

- 放大倍数：约等于1，电压跟随器
- 输入电阻：高
- 输出电阻：低

5.4.2 共集组态基本放大电路

✓ **不同组态的对比：**

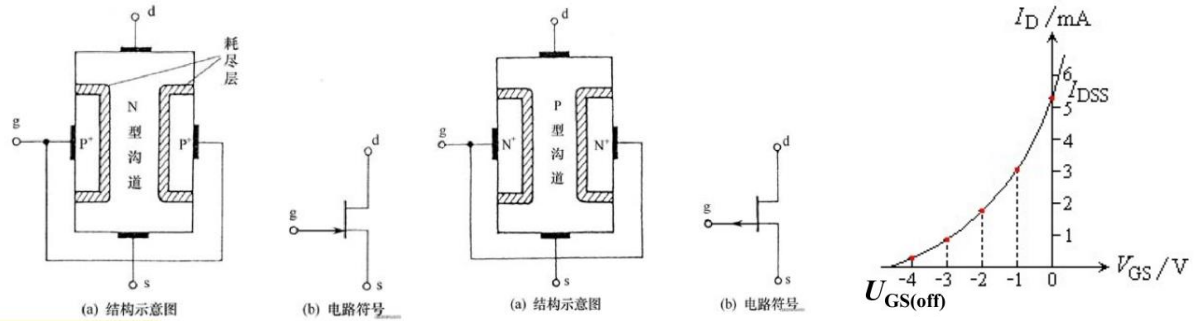


	共发射极	共基极	共集电极
电流增益	β	α	1+β
电压增益	大	大	<1
输入电阻	中	小	大
输出电阻	大	大	小

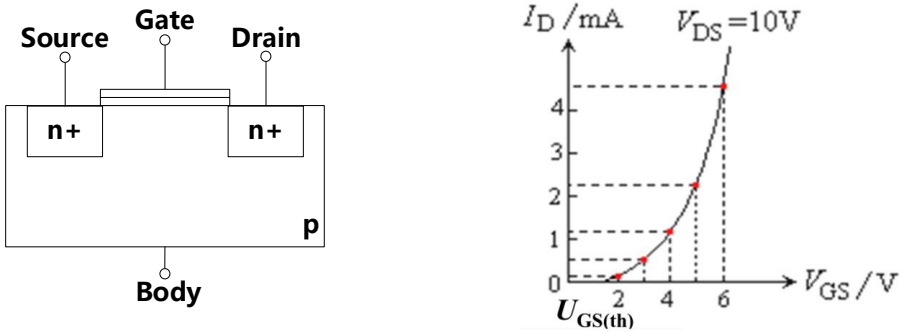
5.4.3 场效应管放大电路

✓ **场效应晶体管：**

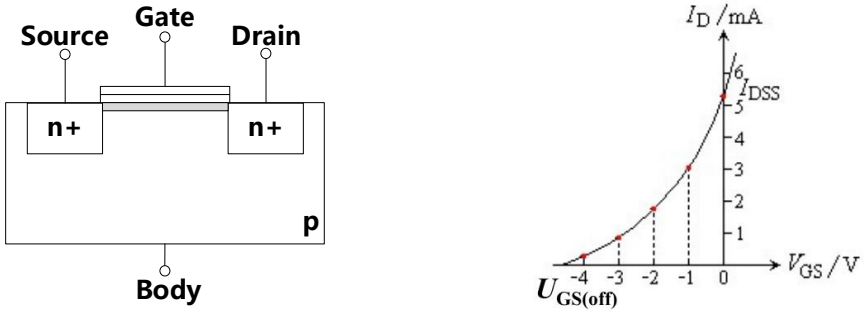
- 结型：P沟道、N沟道



- 绝缘栅增强型：P沟道、N沟道

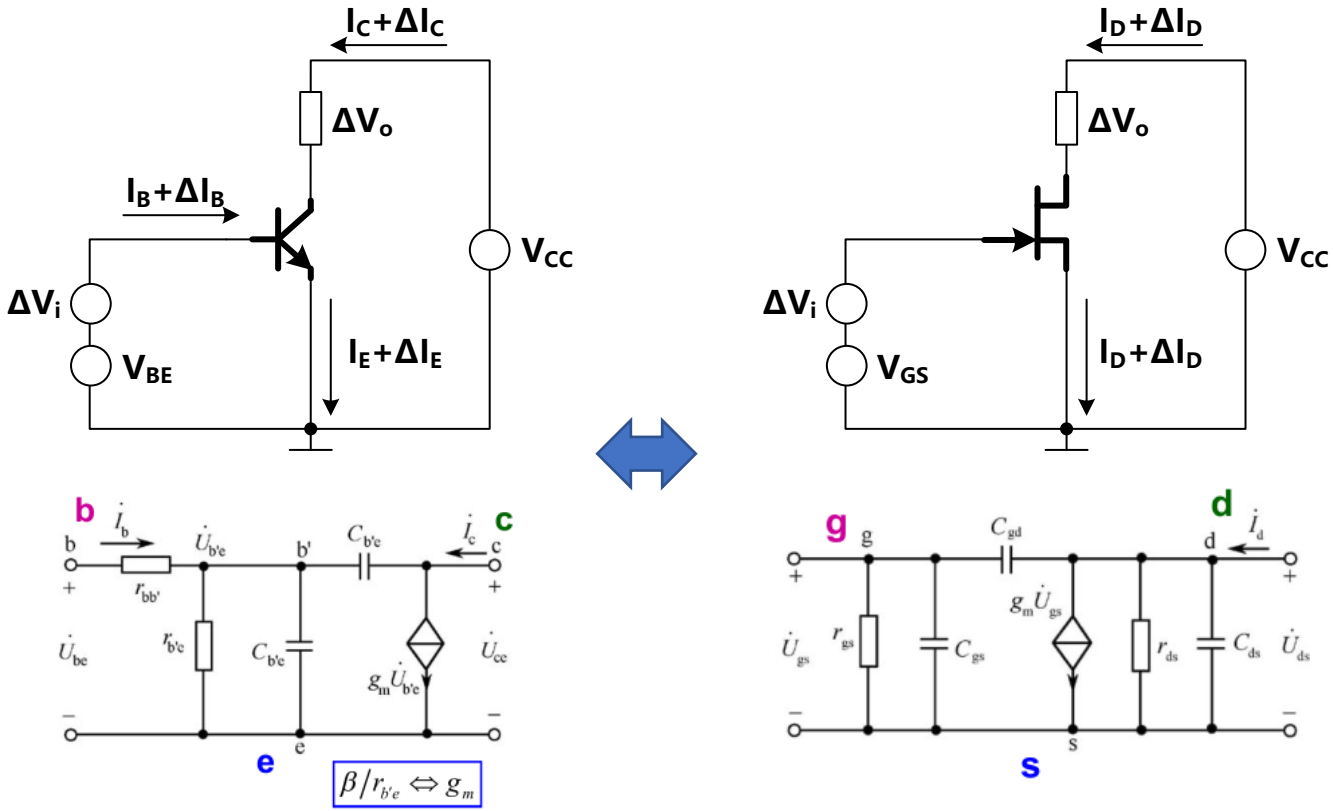


- 绝缘栅耗尽型：P沟道、N沟道



5.4.3 场效应管放大电路

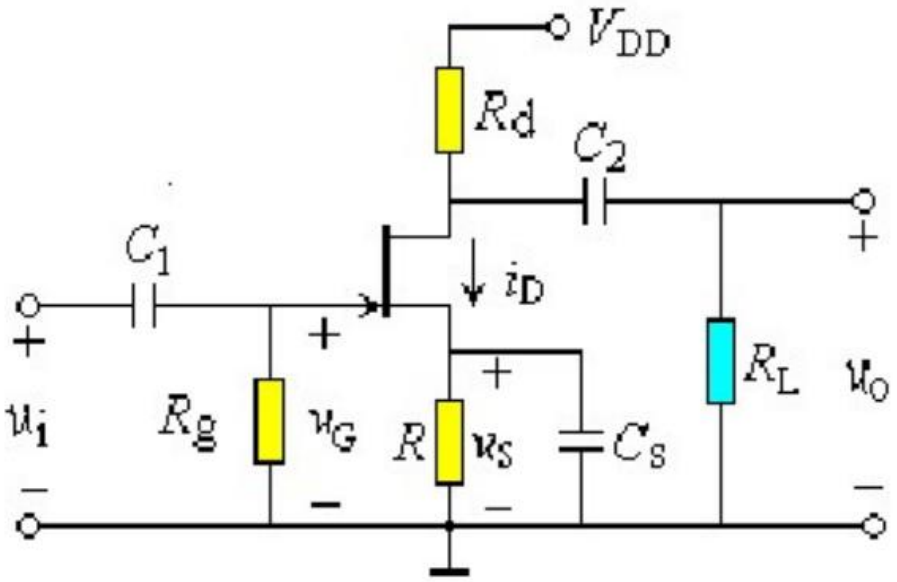
- ✓ **双极型晶体管：**流控电流源（CCCS）
- ✓ **场效应晶体管：**压控电流源（VCCS）
  - 受控方式不同
  - 偏置电路不同
- ✓ **以共发射/共源为例**



5.4.4 共源组态基本放大电路

✓ **自偏压JFET共源放大电路：**

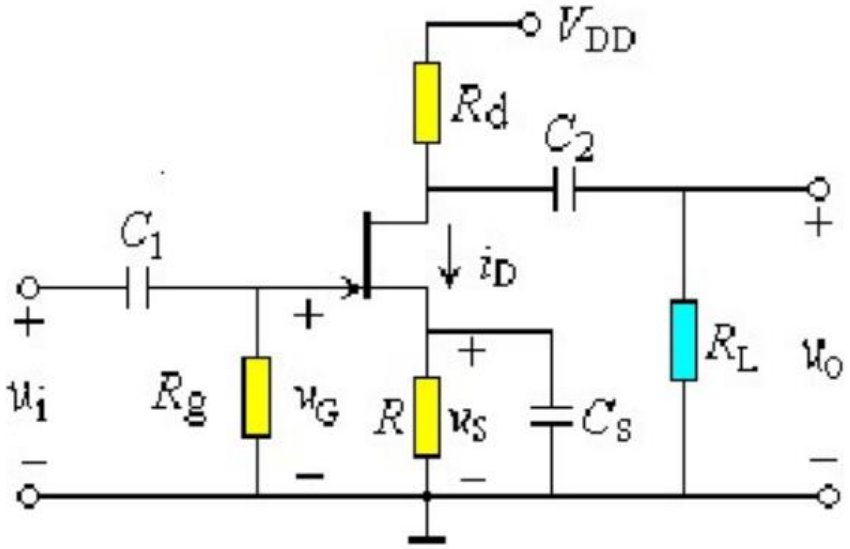
- **静态分析**
- **动态分析**

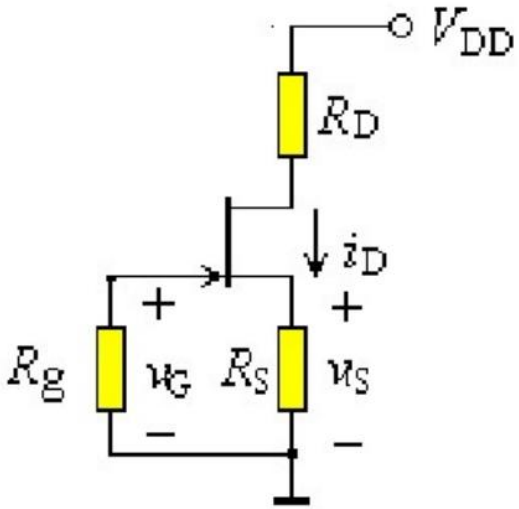


5.4.4 共源组态基本放大电路

✓ **自偏压JFET共源放大电路：**

- 静态分析：U_{GS}、I_D、U_{DS}



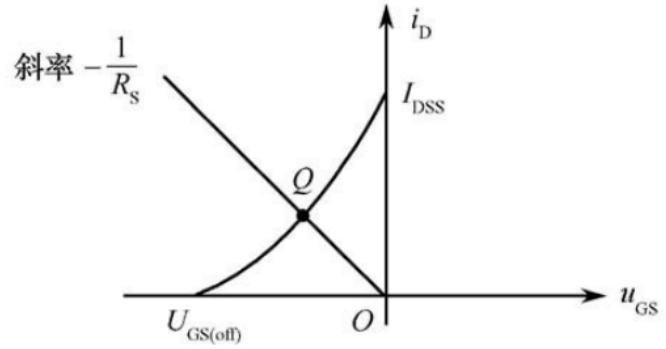


计算法：

$$\begin{cases} U_{GS}=U_G-U_S=-I_D R_S \\ I_D=I_{DSS}[1-(U_{GS}/U_{GS(off)})]^2 \end{cases}$$

$$U_{DS}=V_{DD}-I_D(R_D+R_S)$$

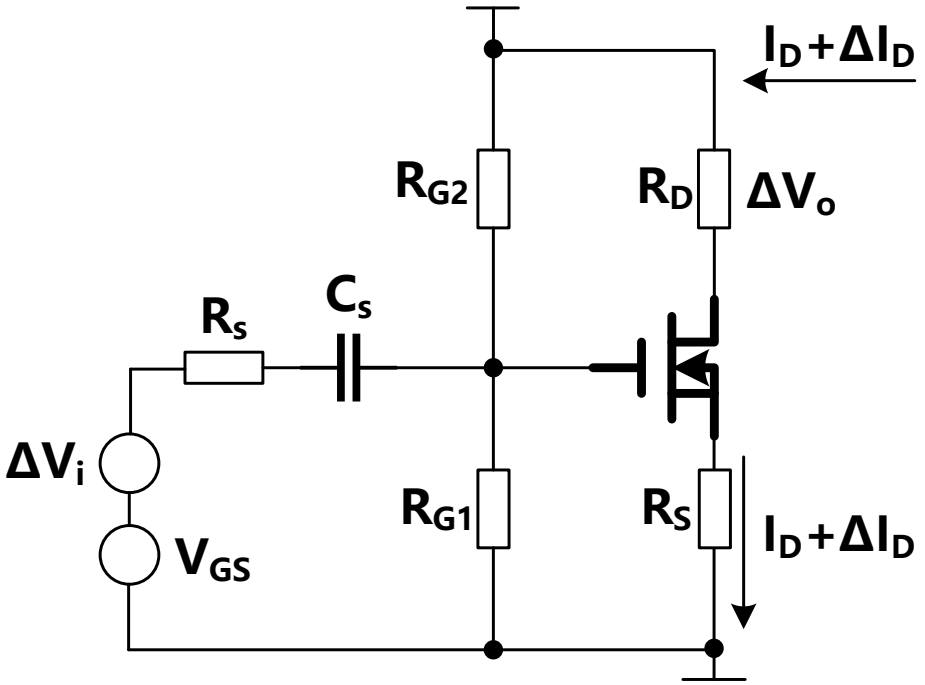
图解法：



5.4.4 共源组态基本放大电路

✓ 自偏压MOSFET共源放大电路：

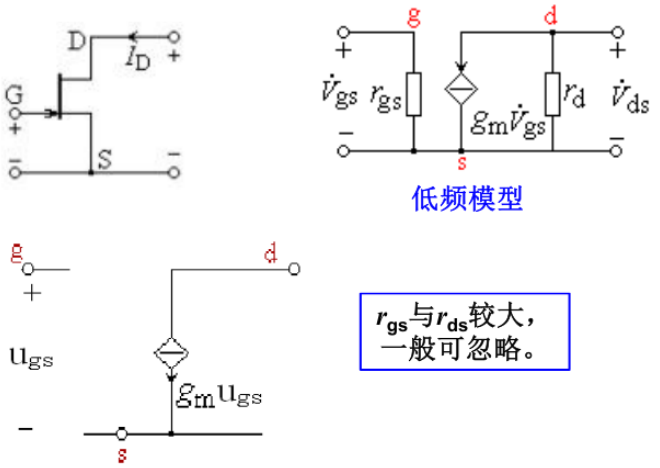
- 静态分析：U_{GS}、I_D、U_{DS}

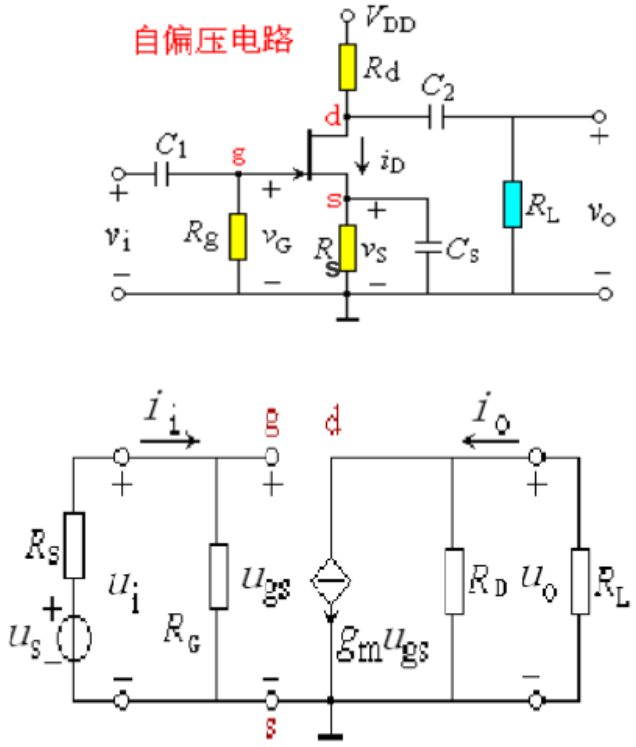


5.4.4 共源组态基本放大电路

✓ **自偏压JFET共源放大电路：**

- 交流分析：从基本模型开始，到具体电路计算放大倍数、输入输出电阻





①电压放大倍数（反相）

$$\dot{A}_u = \frac{u_o}{u_i} = -\frac{g_m u_{gs}(R_D // R_L)}{u_{gs}}$$

$$= -g_m R'_L$$

$$R'_L = R_D // R_L$$

②输入电阻（大）

$$R_i = \frac{u_i}{i_i} = R_g$$

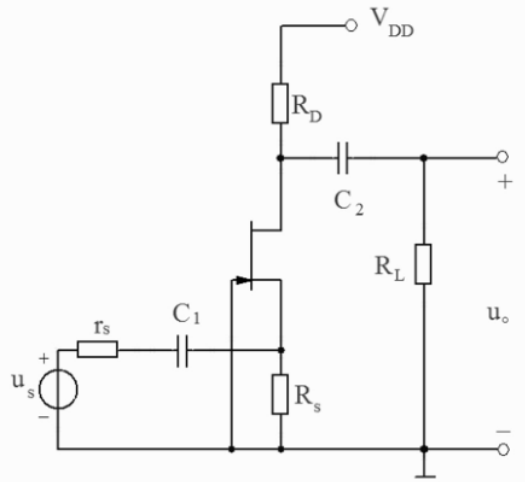
③输出电阻

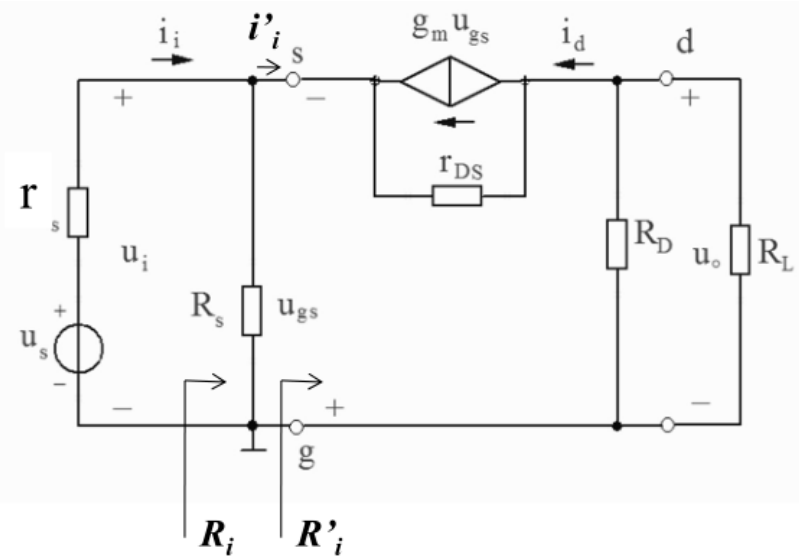
$$R_o = \frac{u'_o}{i'_o}\Big|_{R_L=\infty, u_s=0} = R_d$$

5.4.5 共栅组态基本放大电路

✓ **自偏压JFET共栅放大电路：**

- **静态分析**
- **交流分析**





① 电压放大倍数

$$u_o = -i_d(R_D \| R_L) = -g_m u_{gs} R_L'$$

$$u_i = -u_{gs}$$

$$\dot{A}_u = \frac{u_o}{u_i} = \frac{g_m u_{gs} R_L'}{u_{gs}} = g_m R_L'$$

② 输入电阻

$$R_i' = \frac{u_i}{i_i'}$$

$$u_i = -u_{gs} \Rightarrow R_i' = \frac{1}{g_m} \Rightarrow R_i = R_s // \frac{1}{g_m}$$

$$i_i' = -g_m u_{gs}$$

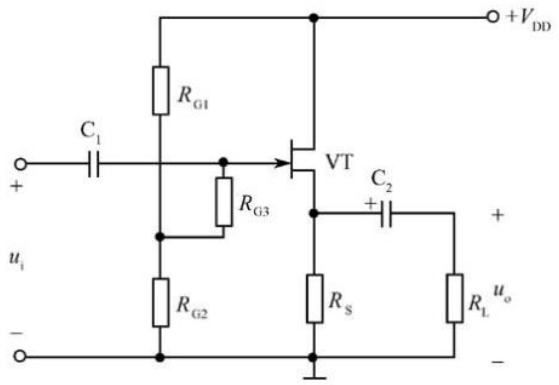
③ 输出电阻

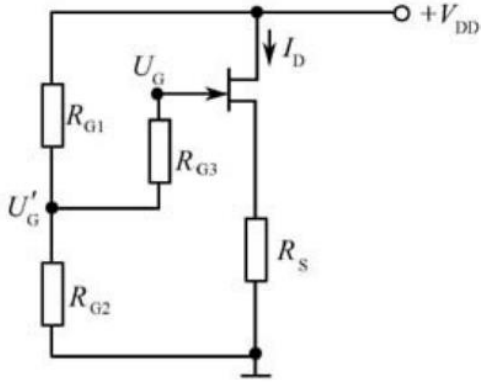
$$R_o \approx R_D$$

5.4.6 共漏组态基本放大电路

✓ **自偏压JFET共漏放大电路：**

- 静态分析



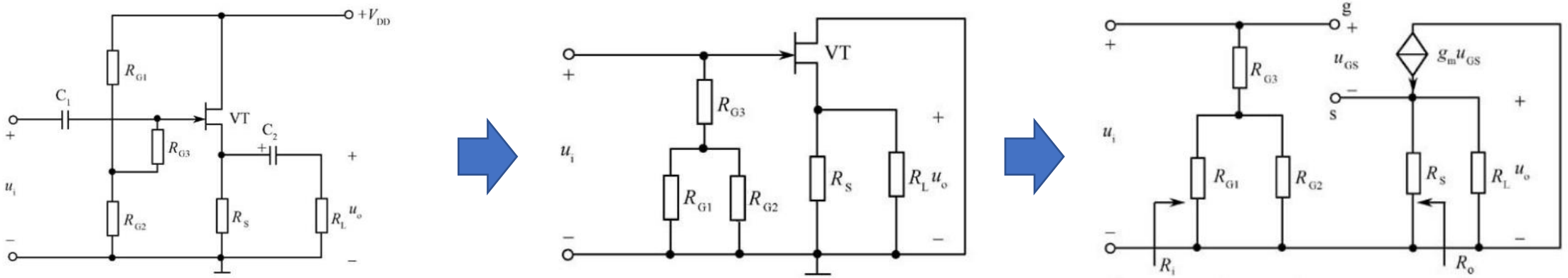


$$\begin{cases} U_G = U'_G = \dfrac{R_{G2}}{R_{G1}+R_{G2}} \cdot V_{DD} \\ U_{GS} = U'_G - I_D \cdot R_S \\ I_D = I_{DSS}\left(1 - \dfrac{U_{GS}}{U_{GS(off)}}\right)^2 \\ U_{DS} = V_{DD} - I_D \cdot R_S \end{cases}$$

5.4.6 共漏组态基本放大电路

✓ 自偏压JFET共漏放大电路：

- 交流分析



① 电压放大倍数

$$\dot{A}_u = \frac{u_o}{u_i} = \frac{g_m u_{gs}(R_s // R_L)}{u_{gs} + g_m u_{gs}(R_s // R_L)} = \frac{g_m R'_L}{1 + g_m R'_L} \qquad (R'_L = R_S // R_L)$$

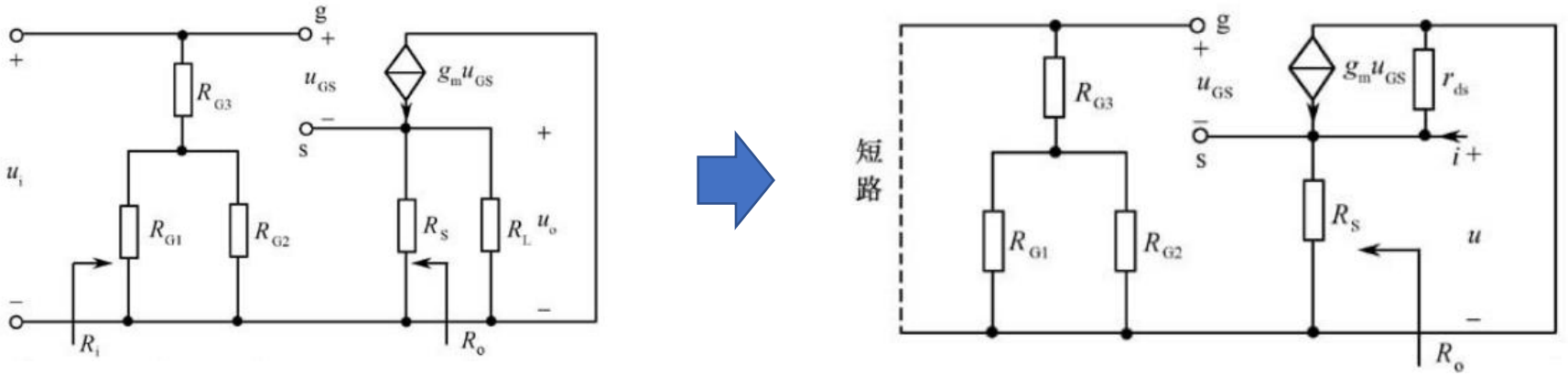
② 输入电阻

$$R_i = R_{G3} + (R_{G1} // R_{G2})$$

5.4.6 共漏组态基本放大电路

✓ 自偏压JFET共漏放大电路：

- 交流分析



③ 输出电阻

$$R_o = \frac{u}{i}\Big|_{R_L=\infty, u_s=0}$$

$$u = -u_{gs}$$

$$i = \frac{u}{R_S} + \frac{u}{r_{ds}} - g_m u_{gs} = u \cdot \left(\frac{1}{R_S} + \frac{1}{r_{ds}} + g_m\right)$$

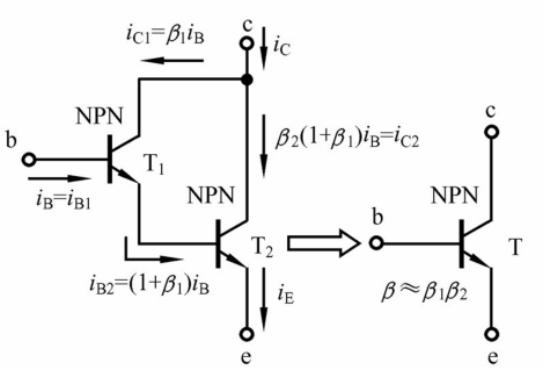
$$R_o = \frac{u}{i} = R_S \,//\, r_{ds} \,//\, \frac{1}{g_m} \approx R_S \,//\, \frac{1}{g_m}$$

5.4.7 各种组态放大电路的比较

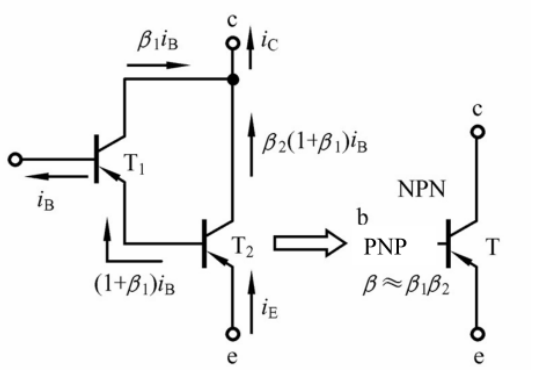
	CE/CB/CC		CS/CG/CD	
电压增益	**CE**	$-\frac{\beta R'_L}{r_{be}}$	**CS**	$-g_m R'_L$
	CB	$\frac{\beta R'_L}{r_{be}}$	**CG**	$g_m R'_L$
	CC	$\frac{(1+\beta)R'_L}{r_{be}+(1+\beta)R'_L}$	**CD**	$\frac{g_m R'_L}{1+g_m R'_L}$
输入电阻	**CE**	$R_B//r_{be}$	**CS**	R_G
	CB	$R_B//[r_{be}/(1+\beta)]$	**CG**	$R_S//(1/gm)$
	CC	$R_B//[r_{be}+(1+\beta)R'_L]$	**CD**	$R_{G3+(}R_{G1//}R_{G2)}$
输出电阻	**CE**	R_C	**CS**	R_D
	CB	R_C	**CG**	R_D
	CC	$R_E//[(r_{be}+r'_s)/(1+\beta)]$	**CD**	$R_S//(1/gm)$

5.4.8 复合管

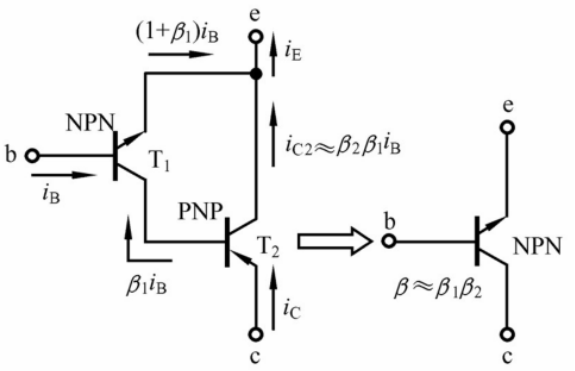
- ✓ **也叫达林顿管（Darlington）、复合管，组合原则：**
  - 每一个管子都在放大区
  - 前级的集电极或者发射极连接次级的基极，且电流方向一致
  - 电流放大倍数约为两级电流放大倍数的乘积
- ✓ **实质可等效为一个晶体管**



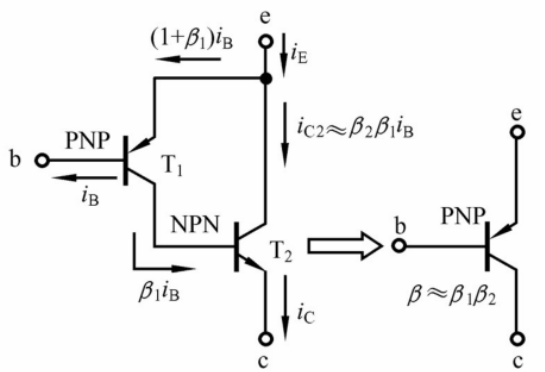
NPN+NPN



PNP+PNP



NPN+PNP



PNP+NPN

5.4.8 复合管

✓ 同型BJT复合管：NPN+NPN 或 PNP+PNP

- 电流放大倍数倍增：

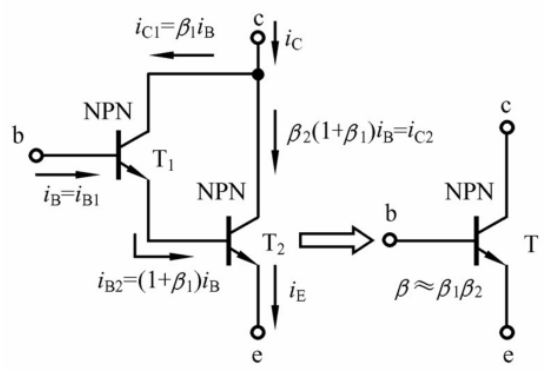
$$i_C = i_{C1} + i_{C2} = \beta_1 i_B + \beta_2 (1+\beta_1) i_B$$
$$\beta = \beta_1 + \beta_2 (1+\beta_1) \approx \beta_1 \beta_2$$

- 输入电阻倍增：

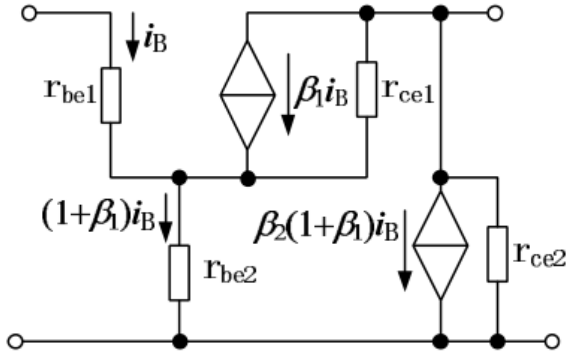
$$r_{be} = r_{be1} + (1+\beta_1) r_{be2}$$

- 输出电阻减小：

$$r_o \approx r_{ce1} \parallel r_{ce2}$$



NPN+NPN



5.4.8 复合管

✓ 异型BJT复合管：NPN+PNP

- 电流放大倍数倍增：

$$i_C = i_{C1} + i_{C2} = \beta_1 i_B + \beta_2\beta_1 i_B$$

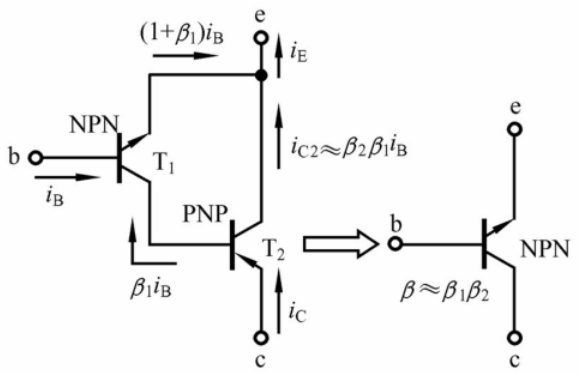
$$\beta = \beta_1 + \beta_2\beta_1 \approx \beta_1\beta_2$$

- 输入电阻倍增：

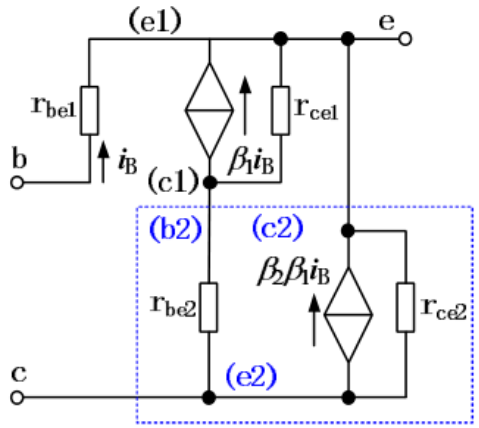
$$r_{be} = r_{be1}$$

- 输出电阻减小：

$$r_o \approx r_{ce1} \parallel r_{ce2}$$



NPN+NPN



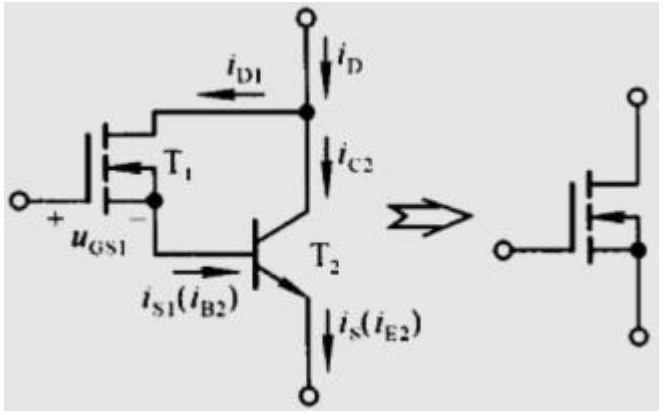
5.4.8 复合管

✓ FET与BJT复合管：NMOS+NPN

- 电流放大倍数倍增：

- 输入电阻倍增：

- 输出电阻减小：



NMOS+NPN