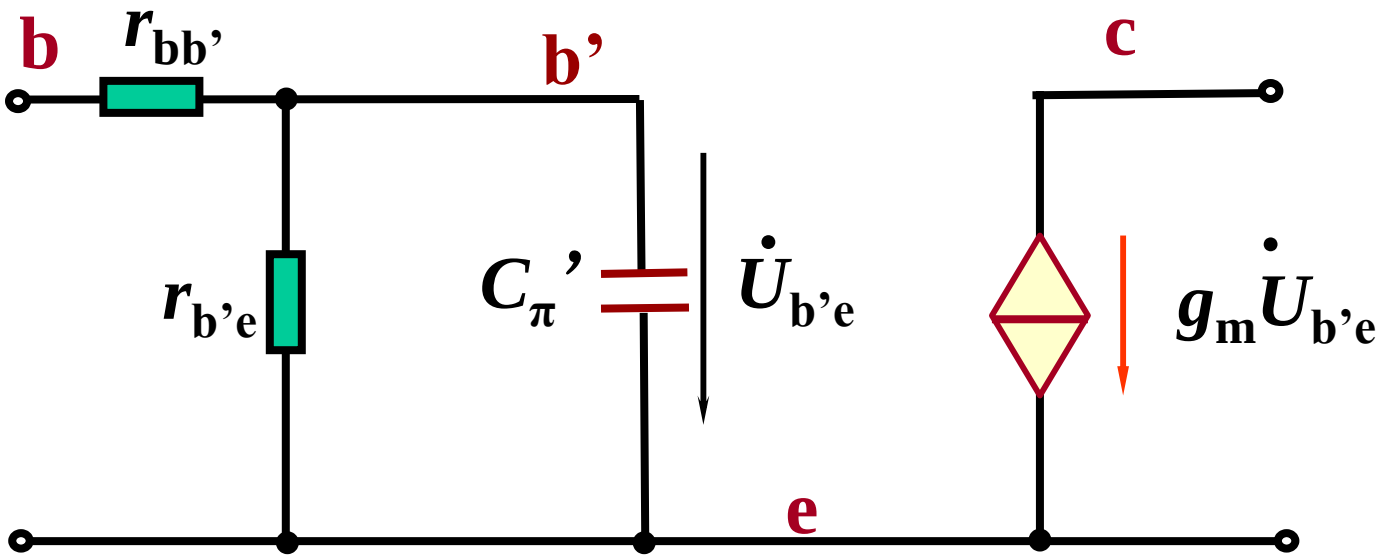


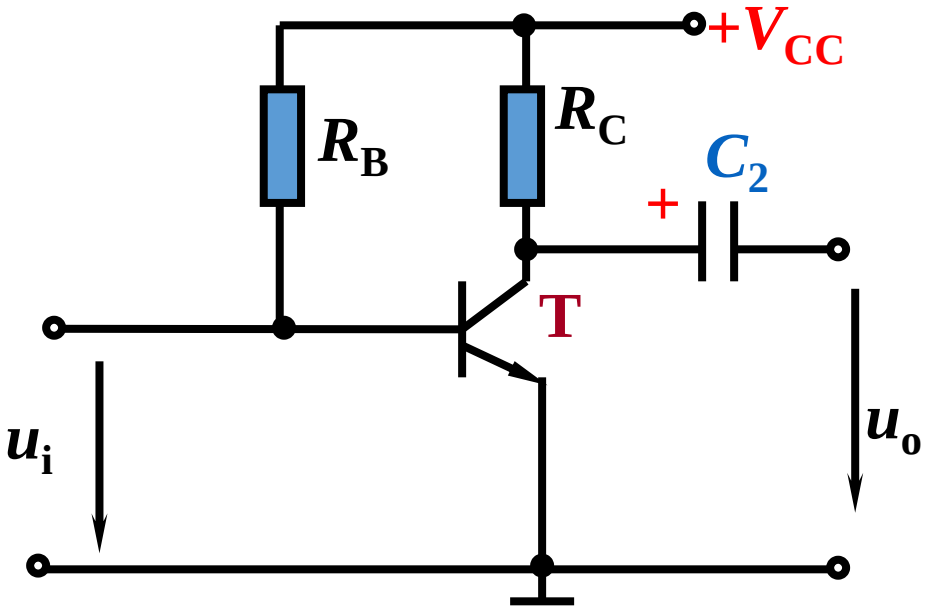
$$C_\pi' = C_\pi + C_\mu'$$

$$C_\mu' = C_\mu(1-K)$$

$$K = \frac{\dot{U}_{ce}}{\dot{U}_{b'e}}$$

$$f_\beta = \frac{1}{2\pi r_{b'e}(C_\pi + C_\mu)}$$

$$g_m = \beta_0 \frac{1}{r_{b'e}} \approx \frac{I_E}{U_T}$$


+VCC
RB
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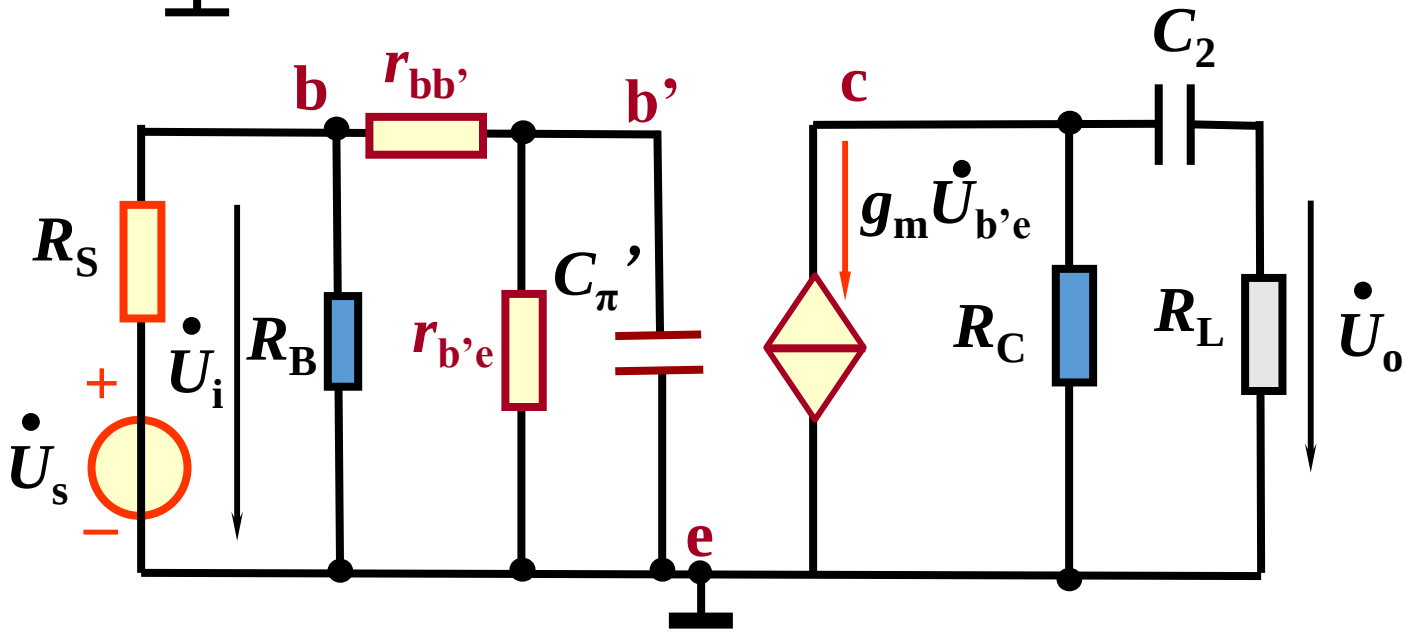
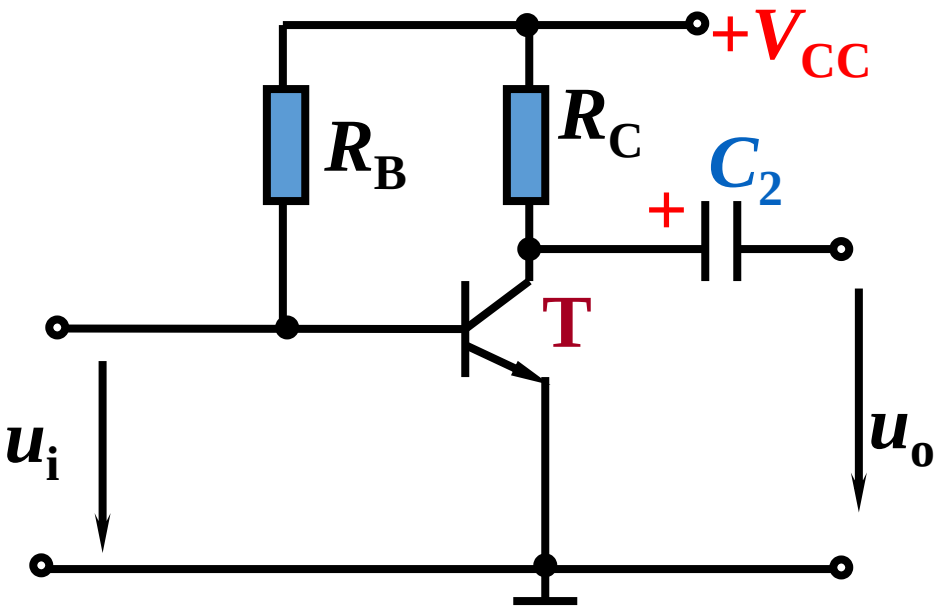
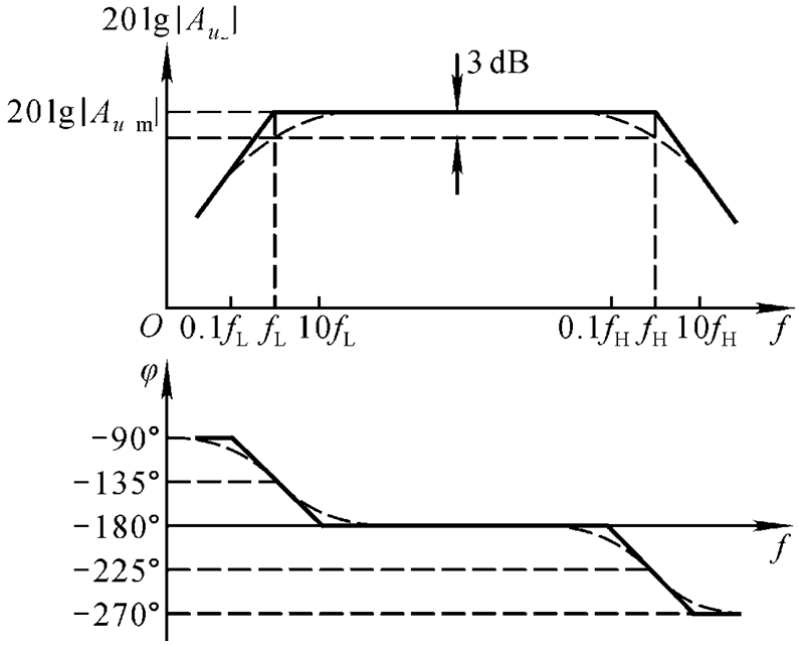

b
rbb'
b'
c
C2
gmU̇b'e
RS
U̇i
RB
rb'e
Cπ'
RC
RL
U̇o
+
U̇s
−
e



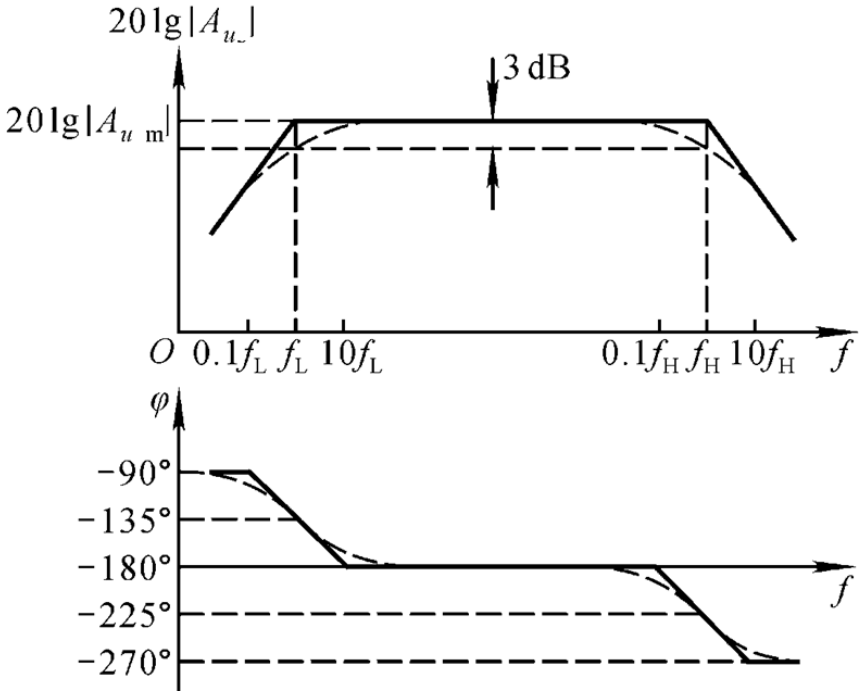
$$A_u = \frac{\dot{U}_o}{\dot{U}_i} = A_{um} \frac{j\frac{f}{f_L}}{(1+j\frac{f}{f_L})(1+j\frac{f}{f_H})}$$

$$f_L = \frac{1}{2\pi(R_C + R_L)C_2} \qquad f_H = \frac{1}{2\pi R C_\pi'}$$

$$f_{BW} = f_H - f_L$$



4.4 单管放大电路的频率响应

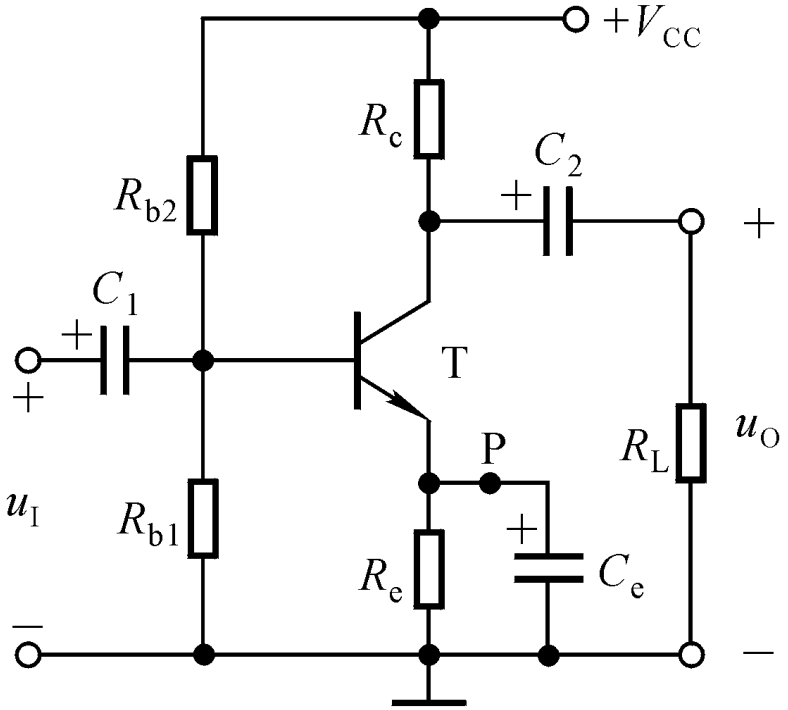


增益带宽积：　$\left|A_{um} f_{BW}\right| \approx$ 常数

4.4 单管放大电路的频率响应

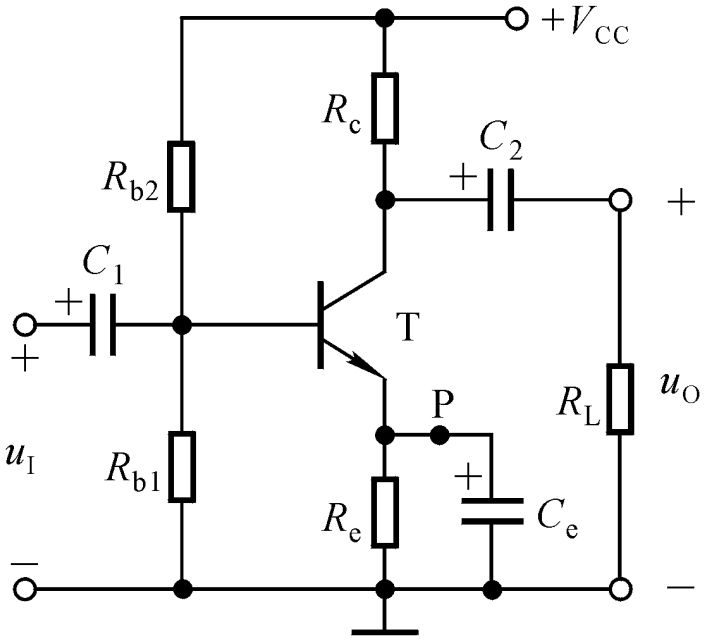
北京航空航天大學 BEIHANG UNIVERSITY

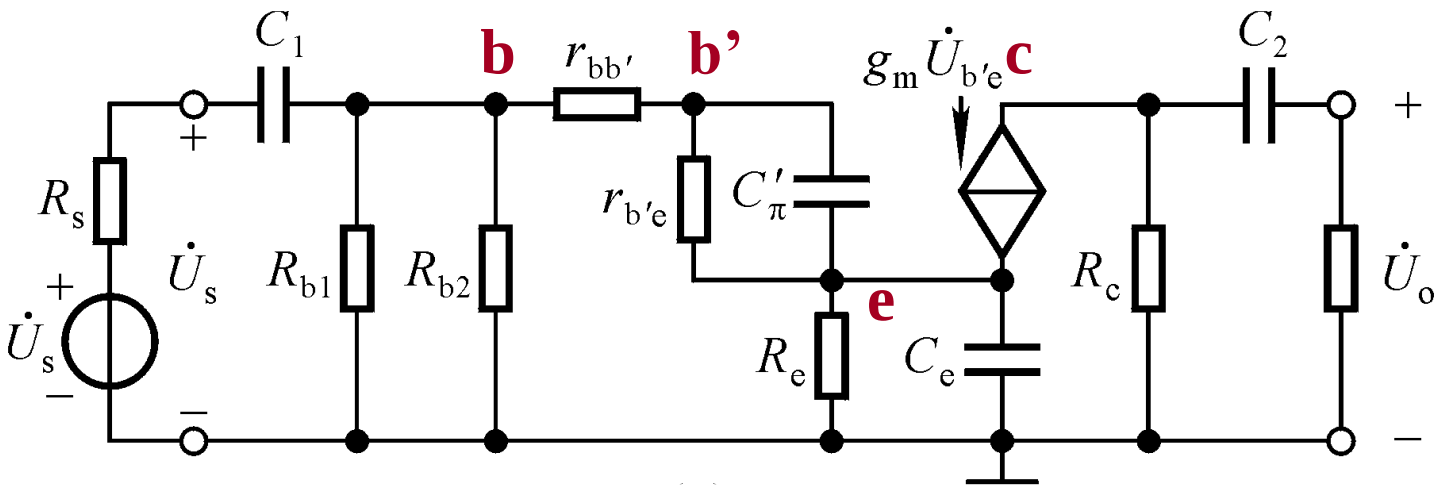
多个耦合电容的分析



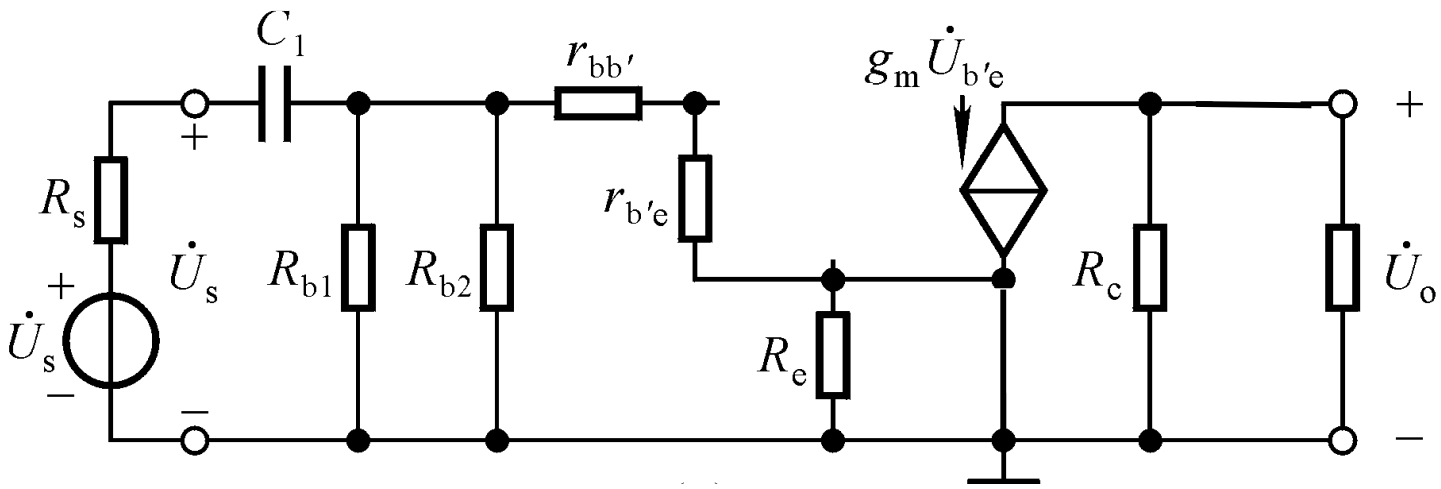
$$f_{L1}=\frac{1}{2\pi R_1 C_1} \qquad f_{L2}=\frac{1}{2\pi R_2 C_2} \qquad f_{Le}=\frac{1}{2\pi R_3 C_e}$$

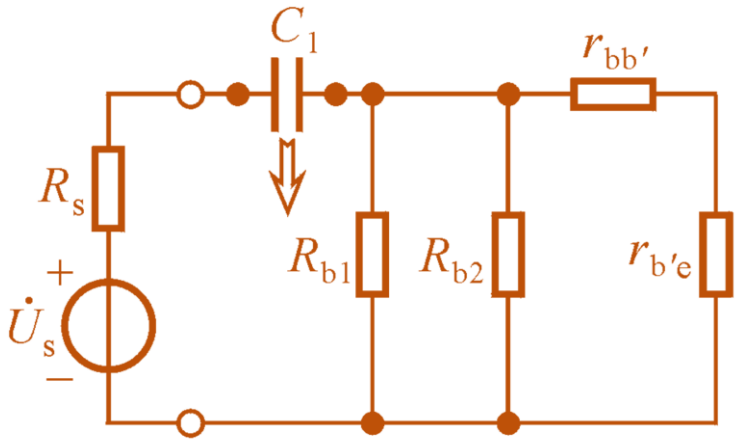
4.4 单管放大电路的频率响应





4.4 单管放大电路的频率响应



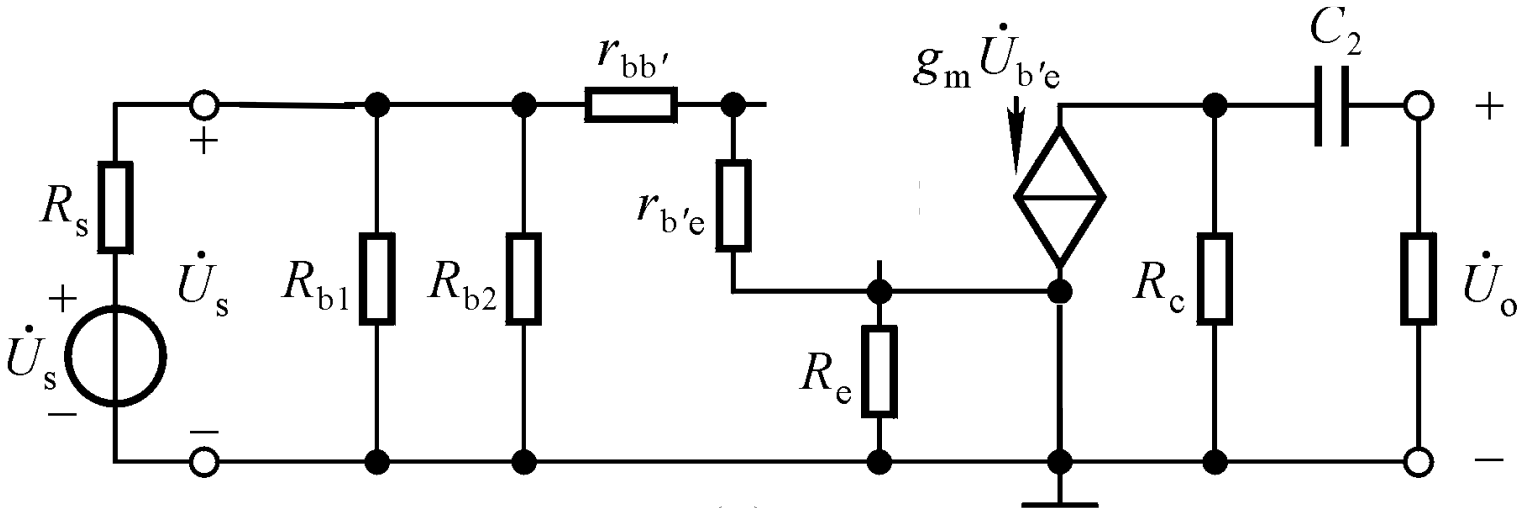


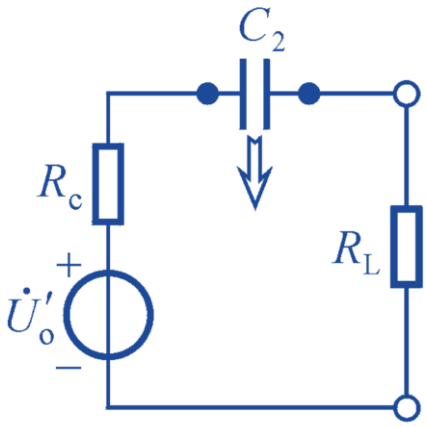
C_2、C_e短路，C'_π开路：

$$\tau_1 = (R_s + R_{b1} \,//\, R_{b2} \,//\, r_{be})C_1$$

$$f_{L1} = \frac{1}{2\pi\tau_1}$$

4.4 单管放大电路的频率响应



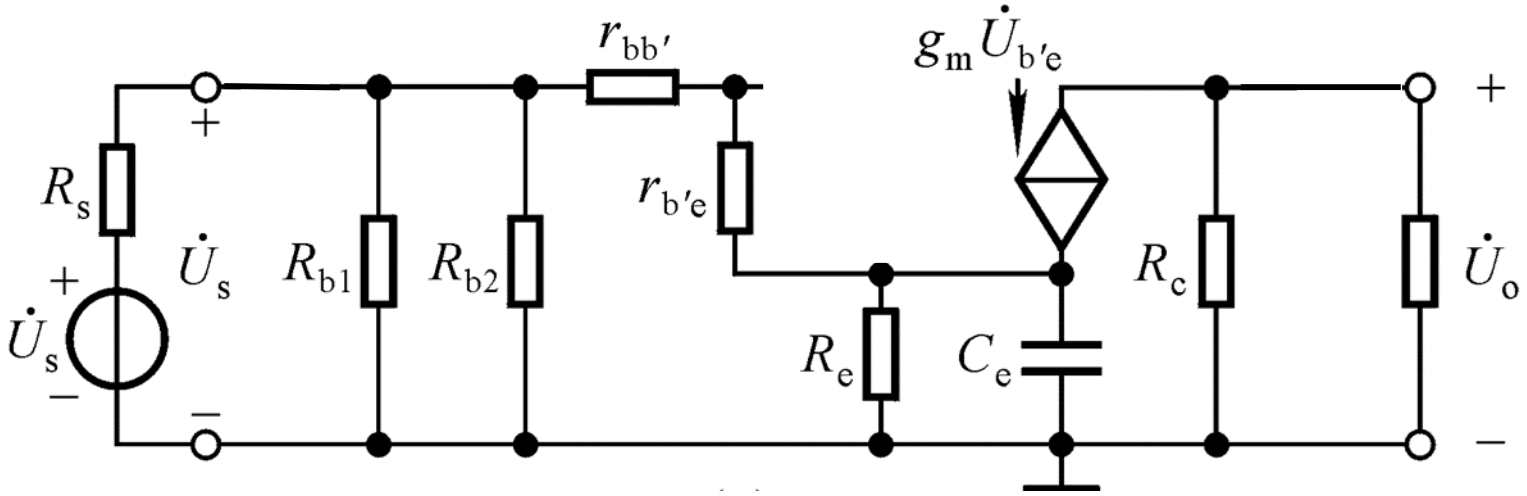


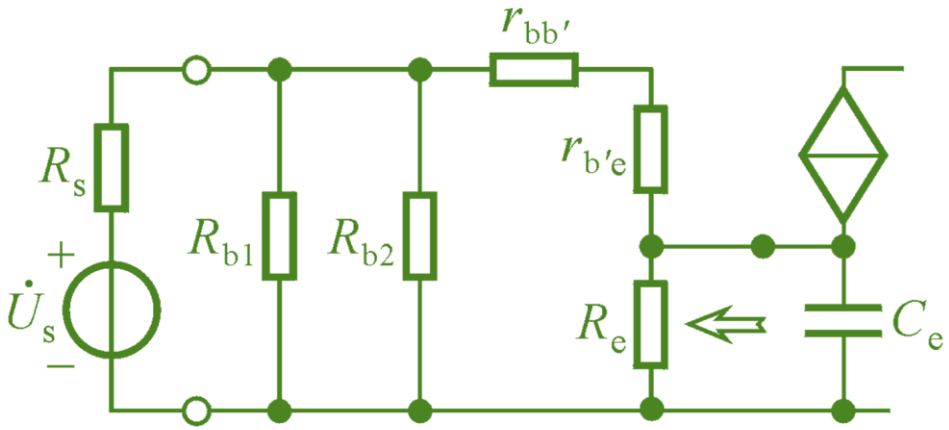
C_1、C_e短路，C'_π 开路：

$$\tau_2 = (R_c + R_L)C_2$$

$$f_{L2} = \frac{1}{2\pi\tau_2}$$

4.4 单管放大电路的频率响应



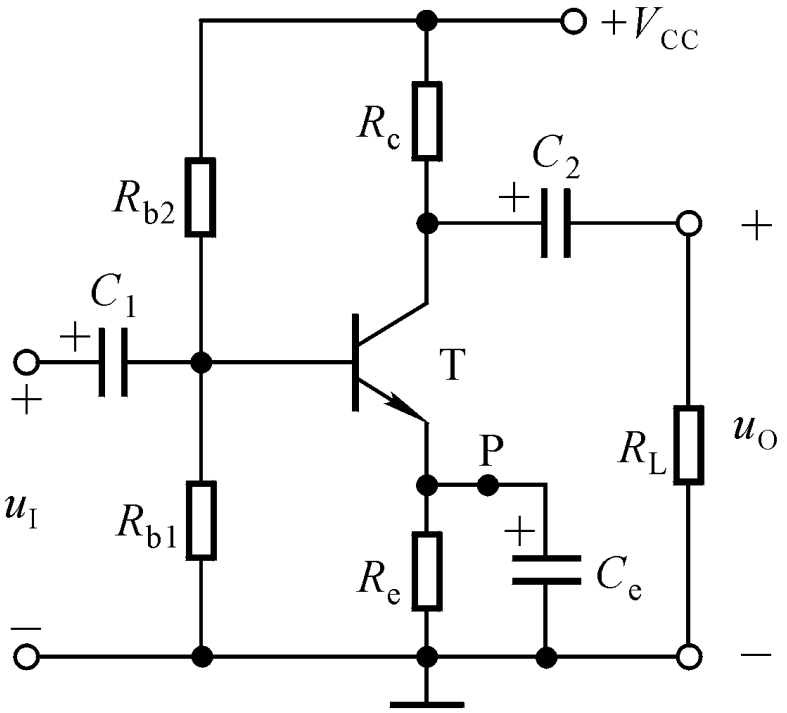


C_1、C_2短路，C'_π开路：

$$\tau_e = (R_e // \frac{r_{be} + R_s // R_{b1} // R_{b2}}{1+\beta})C_e$$

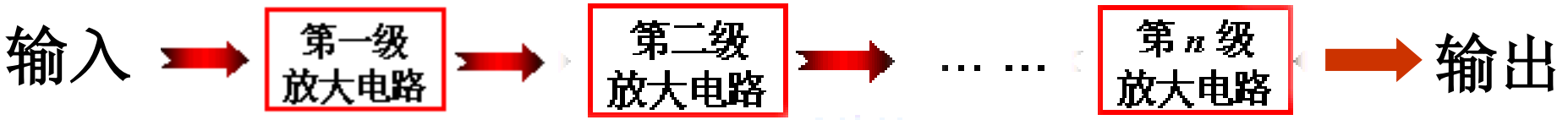
$$f_{Le} = \frac{1}{2\pi\tau_e}$$

4.4 单管放大电路的频率响应



$$f_{L1}=\frac{1}{2\pi R_1 C_1} \qquad f_{L2}=\frac{1}{2\pi R_2 C_2} \qquad f_{Le}=\frac{1}{2\pi R_3 C_e}$$

4.5 多级放大电路的频率响应



$$A_u = A_{u1} \cdot A_{u2} \cdot A_{u3} \cdots\cdots A_{un}$$

- 对数幅频特性和相频特性

$$20\lg|A_u| = 20\lg|A_{u1}| + 20\lg|A_{u2}| + \cdots + 20\lg|A_{un}|$$

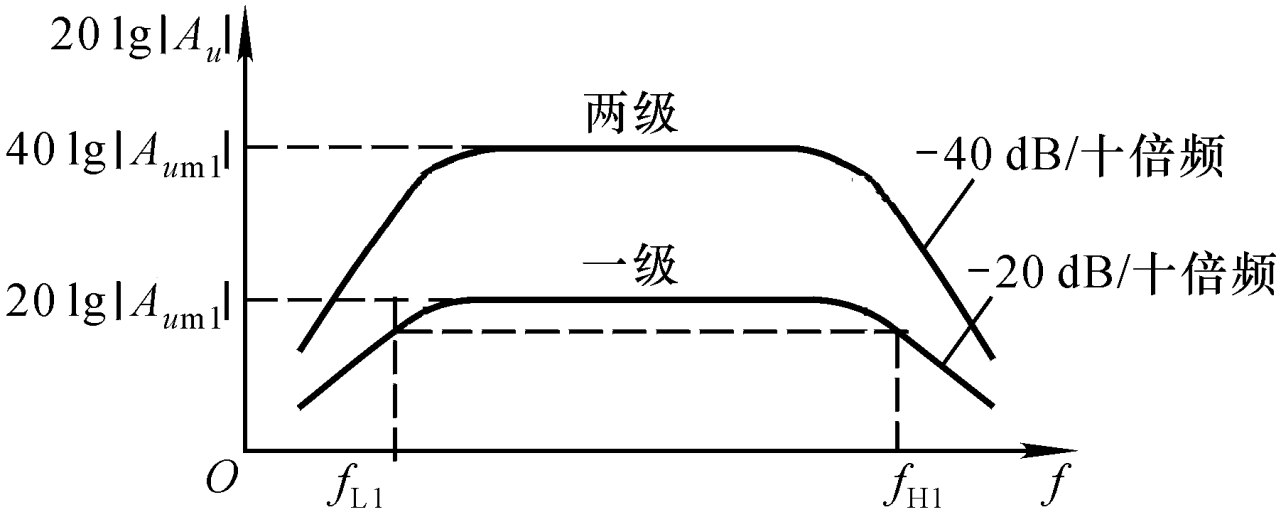
$$\varphi = \varphi_1 + \varphi_2 + \cdots + \varphi_n$$

电路的增益是各级放大电路增益之和，

相移是各级放大电路相移之和

4.5 多级放大电路的频率响应

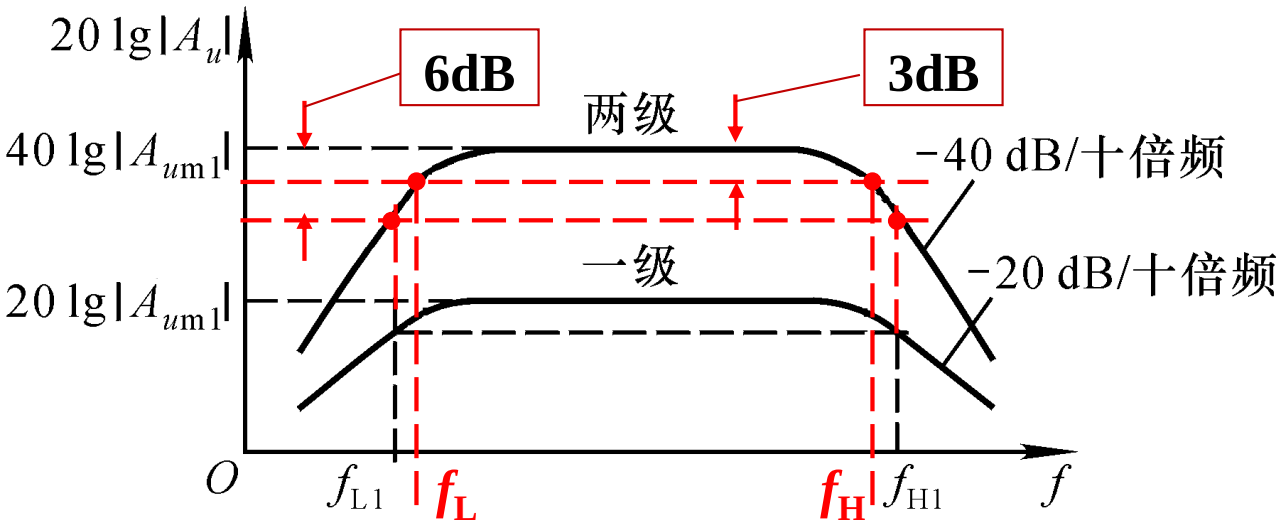
两级放大电路：$A_{u1}=A_{u2}$



4.5 多级放大电路的频率响应

两级放大电路：$A_{u1}=A_{u2}$

- 注意—按照增益下降3dB计算截止频率和工作带宽



4.5 多级放大电路的频率响应

多级放大电路截止频率的估算

$$f_{\mathrm{L}} \approx 1.1\sqrt{\sum_{k=1}^{n} f_{\mathrm{L}k}^{2}}$$

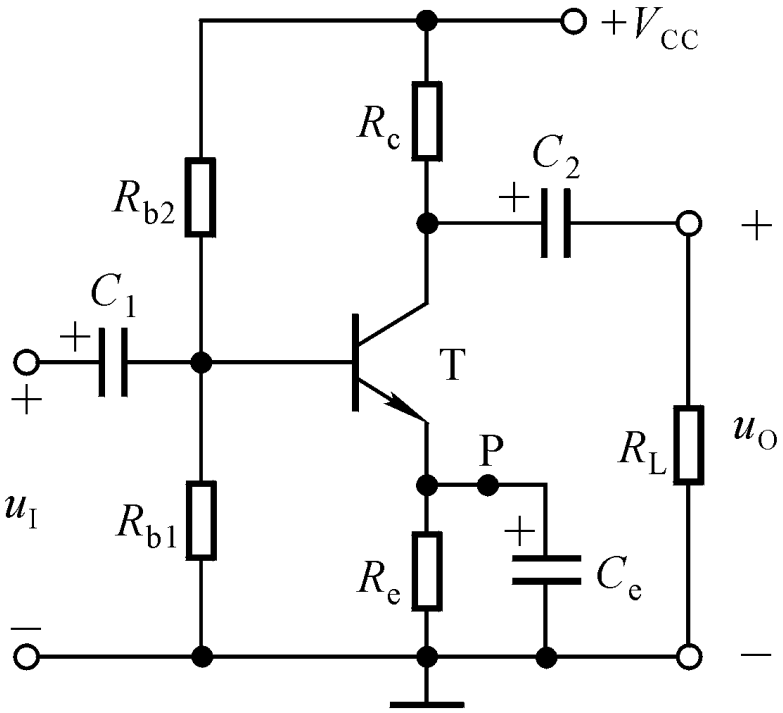
$$\frac{1}{f_{\mathrm{H}}} \approx 1.1\sqrt{\sum_{k=1}^{n} \frac{1}{f_{\mathrm{H}k}^{2}}}$$

多级放大电路的下截止频率升高、上截止频率降低、总工作频带变窄。

增益带宽积：$\left|A_{\mathrm{um}} f_{\mathrm{BW}}\right| \approx$ 常数

4.4 单管放大电路的频率响应

多个耦合电容

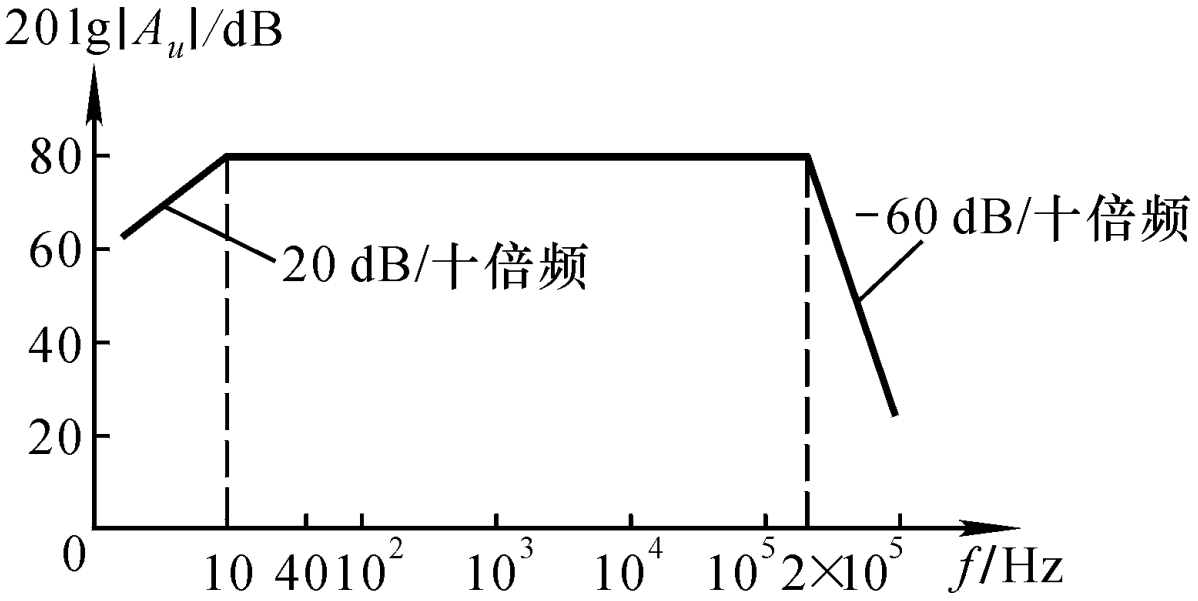


$$f_{L1}=\frac{1}{2\pi R_1 C_1} \qquad f_{L2}=\frac{1}{2\pi R_2 C_2} \qquad f_{Le}=\frac{1}{2\pi R_3 C_e}$$

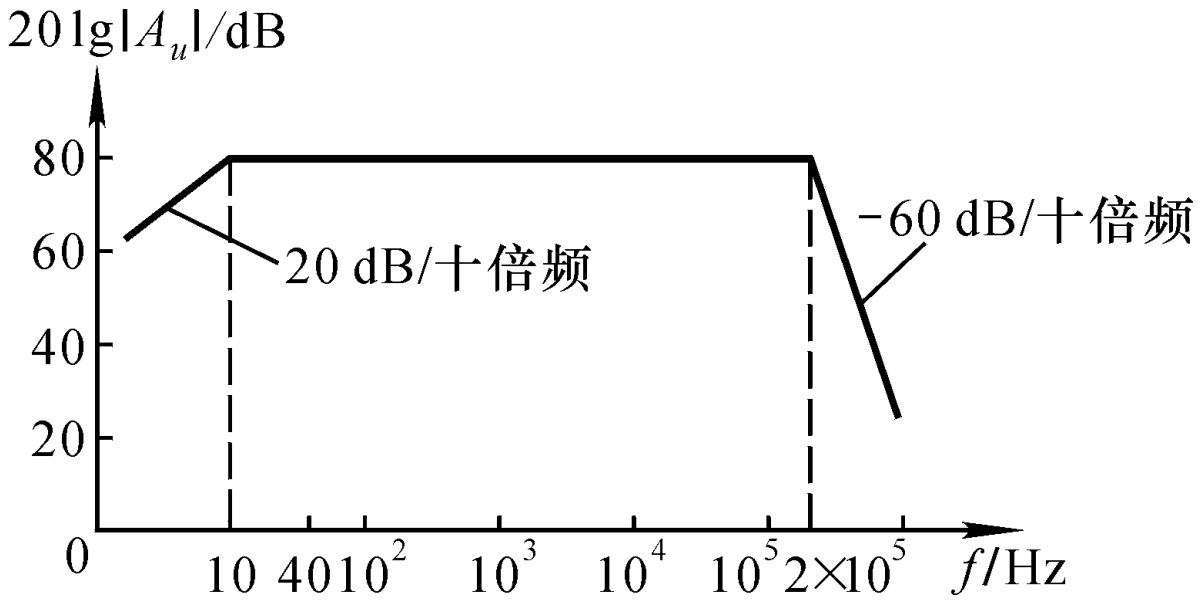
$$f_L \approx 1.1\sqrt{\sum_{k=1}^{n} f_{Lk}^2}$$

4.5 多级放大电路的频率响应

例：已知某电路的各级均为共射放大电路，其幅频特性如图所示，求下截止频率f_L，上截止频率f_H和电压放大倍数A_u



4.5 多级放大电路的频率响应

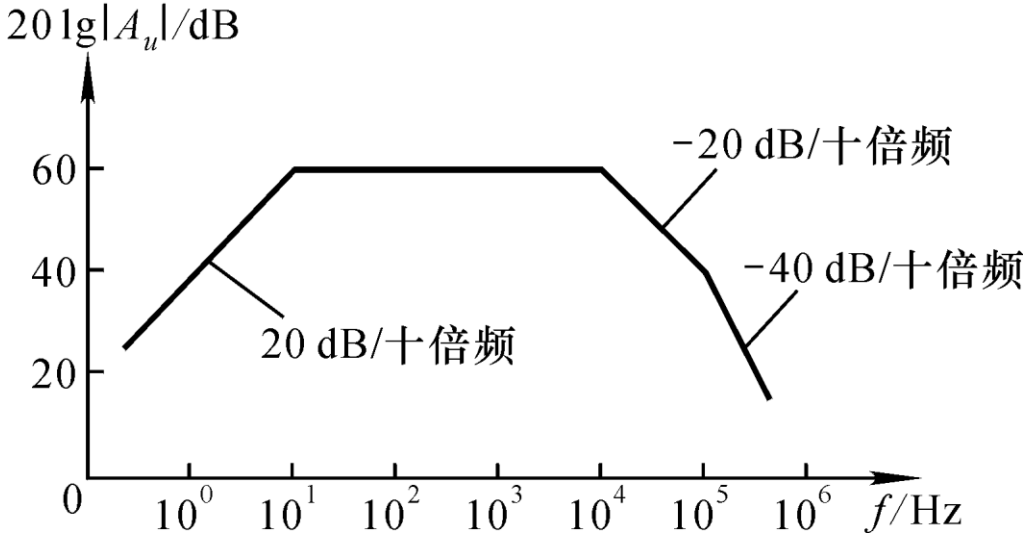


f_L=10Hz　　f_H=0.52×2×10^5Hz=104kHz

$$A_u = -10^4 \times \frac{j\frac{f}{10}}{(1+j\frac{f}{10})(1+j\frac{f}{10^5})^3}$$

4.5 多级放大电路的频率响应

例 某放大电路的波特图如图所示



（1）电路的中频增益 $20\lg|A_{um}| = (\ 60\ )\ \text{dB}$，$A_{um} = (\pm 10^3)$

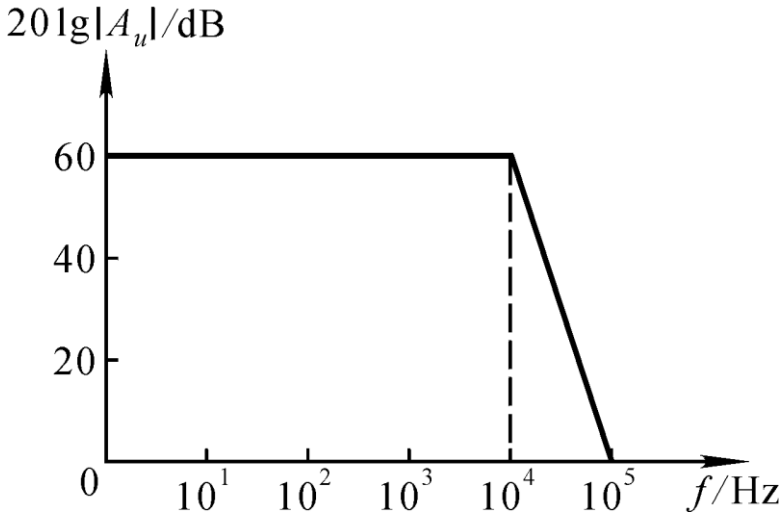
（2）电路的下限频率f_L=（ 10）**Hz**，上限频率f_H=（ 10^4 ）**Hz**

（3）

$$A_u = \pm 10^3 \times \frac{j\dfrac{f}{10}}{(1+j\dfrac{f}{10})(1+j\dfrac{f}{10^4})(1+j\dfrac{f}{10^5})}$$

4.5 多级放大电路的频率响应

例 已知某电路的幅频特性如图所示



（1）该电路的耦合方式？ 下限截止频率为0，直接耦合电路；

（2）该电路由几级放大电路组成？ 三级放大电路

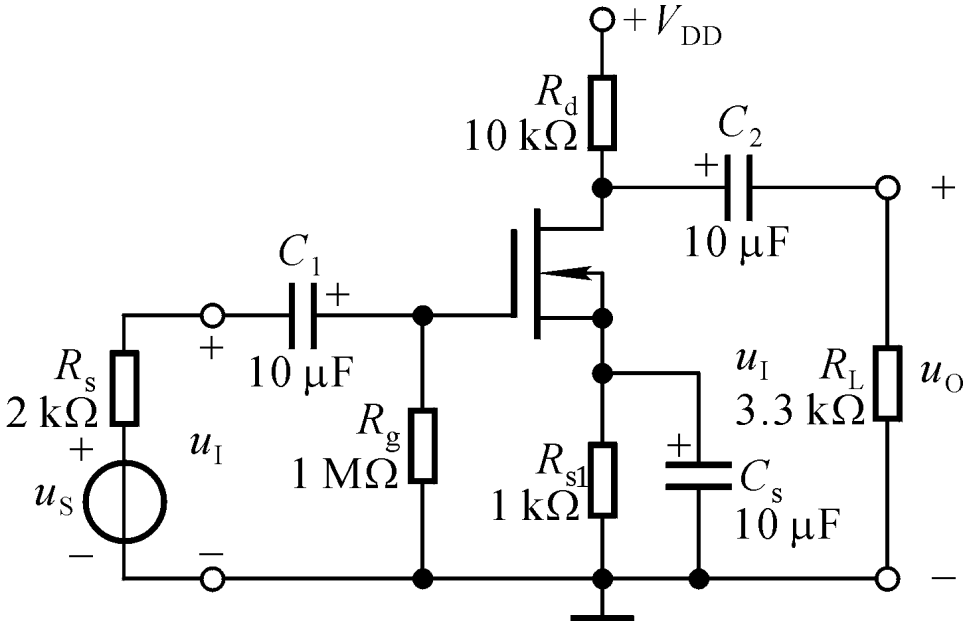
（3）当 $f=10^4$ Hz时，附加相移是多少？ $\varphi' = -135^o$

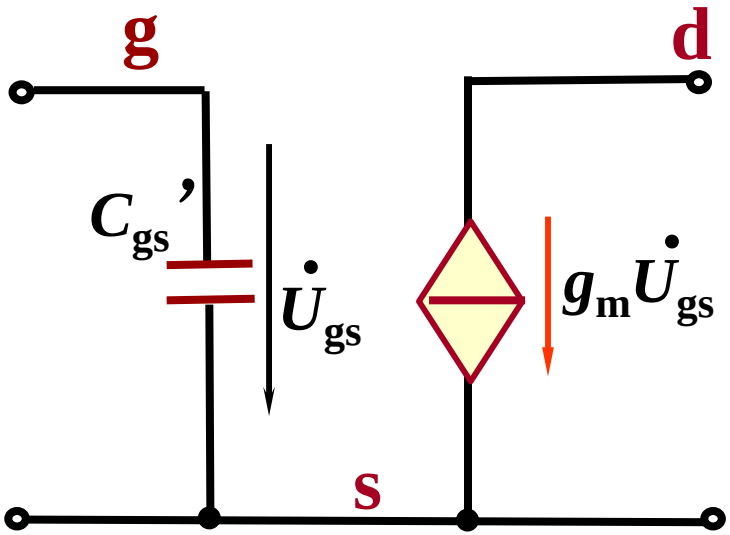
当 $f=10^5$ Hz时，附加相移又是多少？ $\varphi' \approx -270^o$

（4）该电路的上限频率f_H约为多少？ $f \approx 0.52 f_1 \approx 5.2\text{k Hz}$

4.5 多级放大电路的频率响应

例：已知$C_{gs}=C_{gd}=5pF$，$g_m=5mS$，$C_1=C_2=C_S=10\mu F$。试求出f_H，f_L各约多少。



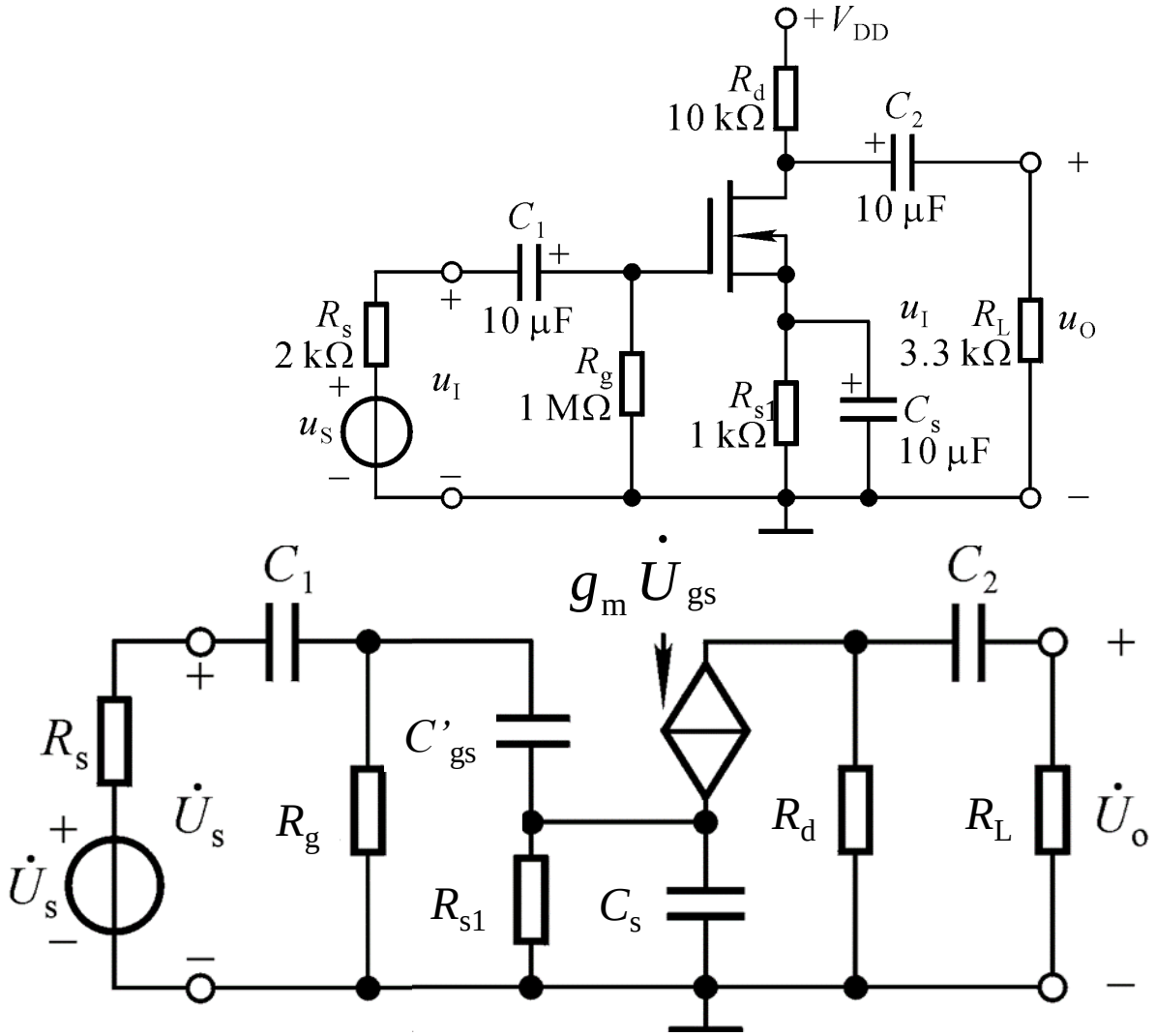


$$K \approx -g_m R_L'$$

$$C_{gs}' = C_{gs} + (1-K)C_{gd}$$

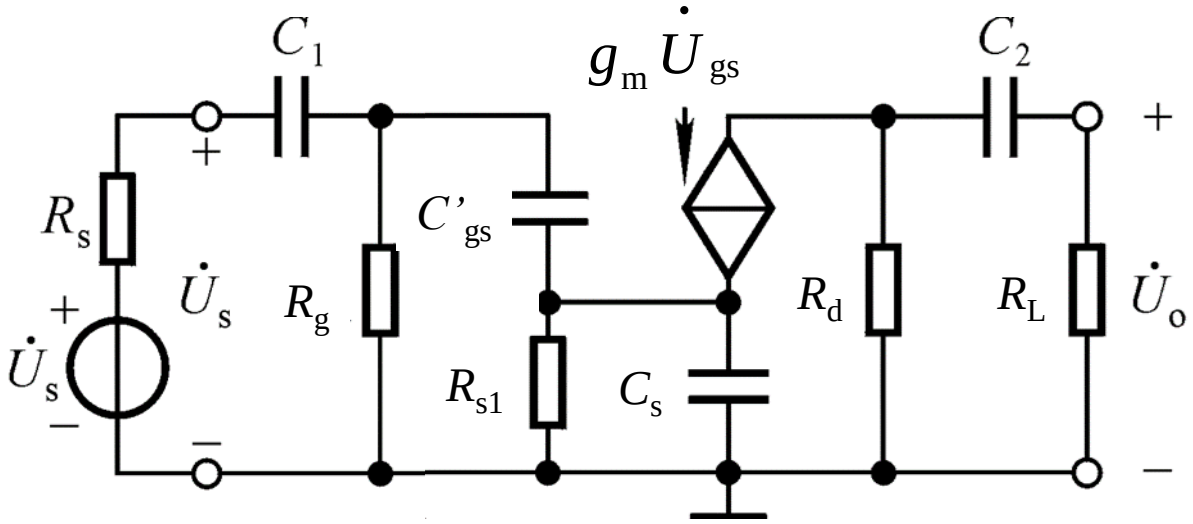
4.5 多级放大电路的频率响应

已知$C_{gs}=C_{gd}=5pF$，$g_m=5mS$，$C_1=C_2=C_S=10\mu F$。试求出f_H，f_L各约多少。



4.5 多级放大电路的频率响应

已知$C_{gs}=C_{gd}=5pF$，$g_m=5mS$，$C_1=C_2=C_S=10\mu F$。试求出f_H，f_L各约多少，并写出A_{us}的表达式



$$C_{gs}^{'}=C_{gs}+(1-K)C_{gd}$$

$$K=-g_mR_L^{'}=-12.4$$

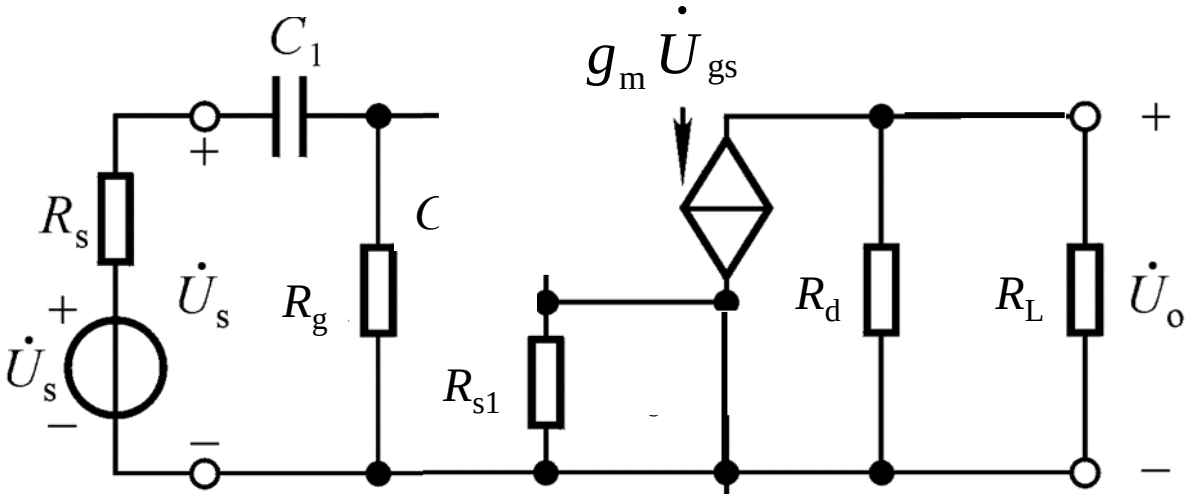
$$C_{gs}^{'}=C_{gs}+(1-K)C_{gd}=72\text{pF}$$

$$R_{gs}^{'}=R_s//R_g\approx R_s$$

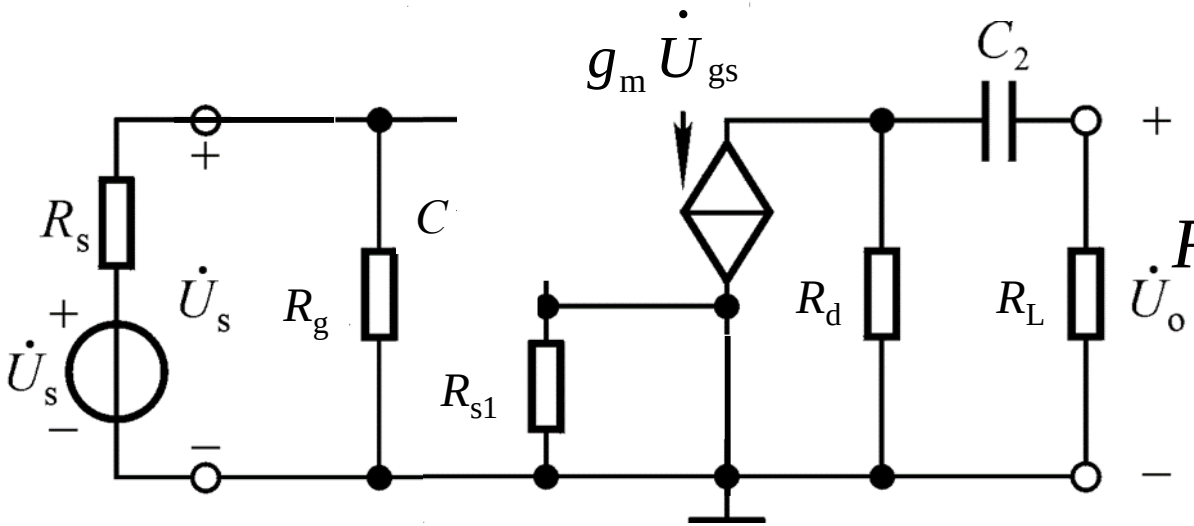
$$f_H=\frac{1}{2\pi R_sC_{gs}^{'}}$$

4.5 多级放大电路的频率响应

已知$C_{gs}=C_{gd}=5pF$，$g_m=5mS$，$C_1=C_2=C_S=10\mu F$。试求出f_H，f_L各约多少，并写出A_{us}的表达式



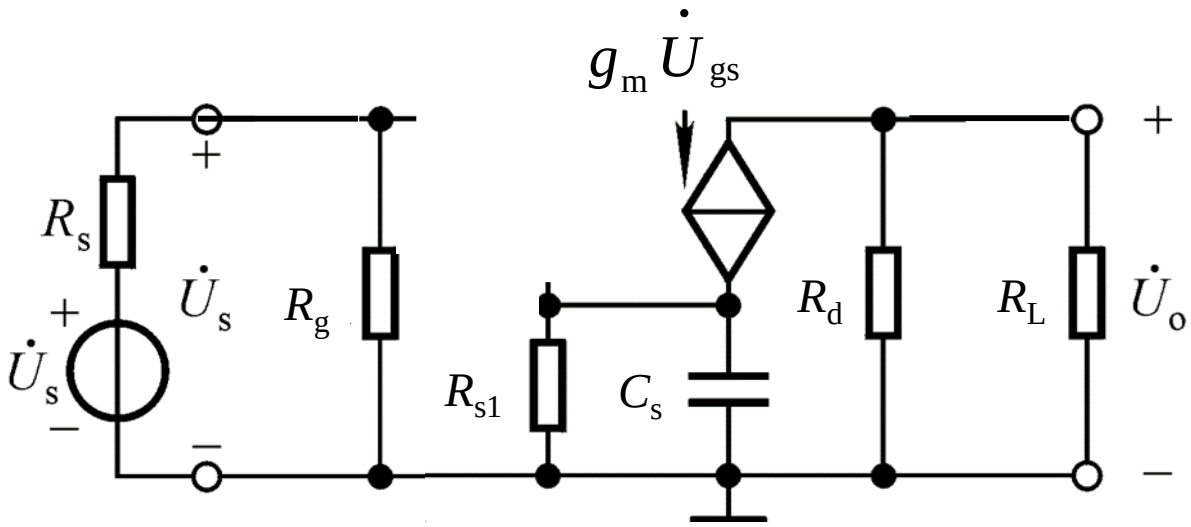
$$R_1 = R_s + R_g \approx 1M\Omega$$



$$R_2 = R_d + R_L = 13.3k\Omega$$

4.5 多级放大电路的频率响应

已知$C_{gs}=C_{gd}=5pF$，$g_m=5mS$，$C_1=C_2=C_S=10\mu F$。试求出f_H，f_L各约多少，并写出A_{us}的表达式



$$R_1 = R_s + R_g \approx 1M\Omega$$

$$R_2 = R_d + R_L = 13.3k\Omega$$

$$R_{cs} = R_{s1} // \frac{1}{g_m}$$

$$R_{cs} \ll R_1, R_{cs} \ll R_2,$$

$$f_L = \frac{1}{2\pi R_{cs} C_s} \qquad f_H = \frac{1}{2\pi R_s C'_{gs}}$$

作业

4.3

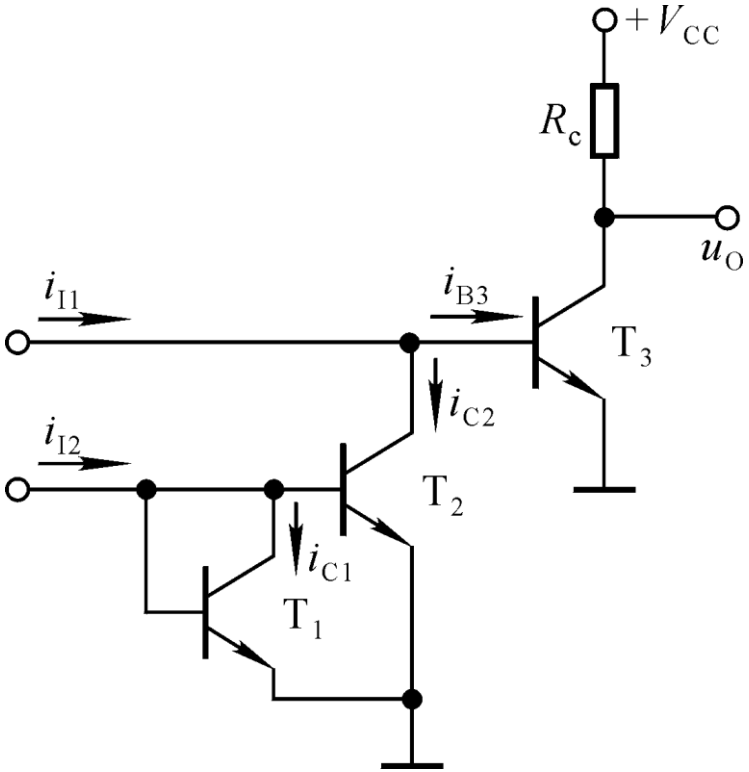
4.6

4.12

4.13

习题3.16已知T_1～T_3管的特性完全相同，$\beta>>2$；反相输入端的输入电流为i_{I1}，同相输入端的输入电流为i_{I2}。试问：

（1）$i_{C2}\approx$? （2）$i_{B3}\approx$? （3）$A_{ui}=\Delta u_O/\ \Delta(i_{I1}-i_{I2})\approx$?



解：T_1和T_2为镜像关系，

$$i_{C2}\approx i_{C1}\approx i_{I2}$$

$$i_{B3}=i_{I1}-i_{C2}\approx i_{I1}-i_{I2}$$

$$\Delta u_O=-\Delta i_{C3}R_c=-\beta_3\ \Delta i_{B3}R_c$$

$$=-\beta_3\ \Delta\left(i_{I1}-i_{I2}\right)R_c$$

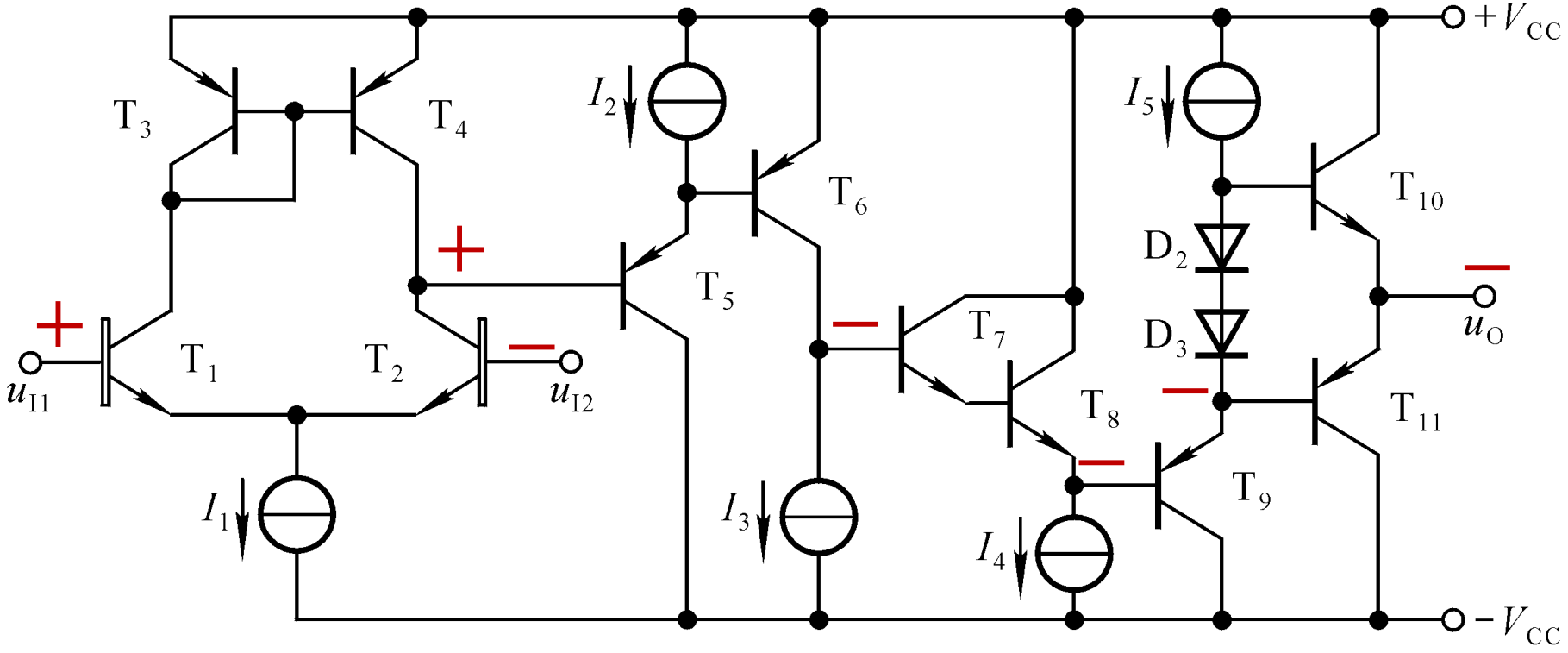
$$A_{ui}=\Delta u_O/\Delta(i_{I1}-i_{I2})=-\beta_3 R_c$$

习题3.18 （1）两个输入端中哪个是同相输入端，哪个是反相输入端；

（2）T_3与T_4的作用；

（3）电流源I_3的作用；

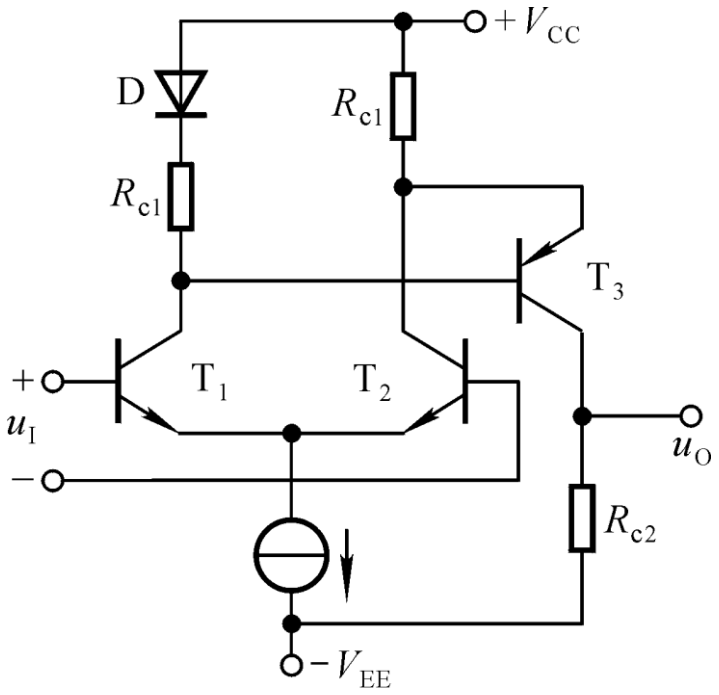
（4）D_2与D_3的作用

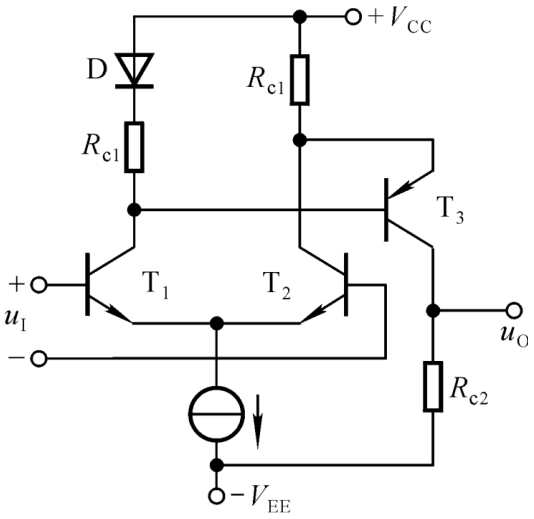


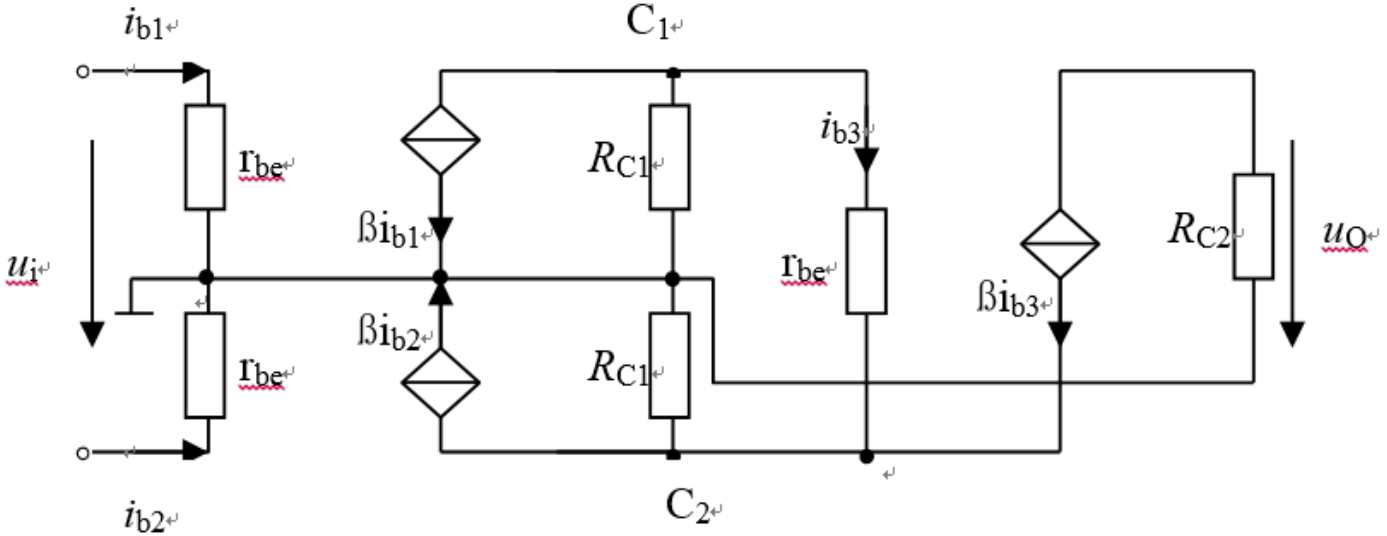
电路如图所示，T_1与T_2管的特性相同，所有晶体管的β均相同，R_{c1}远大于二极管的正向电阻。当$u_{I1}=u_{I2}=0V$时，$u_O=0V$。求解

（1）电压放大倍数的表达式

（2）有共模输入电压时，u_o=？简述理由




+VCC
D
Rc1
Rc1
T3
T1
T2
+
uI
−
uO
Rc2
−VEE


ib1
C1
rbe
RC1
ib3
ßib1
rbe
RC2
uO
uI
ßib2
ßib3
rbe
RC1
ib2
C2