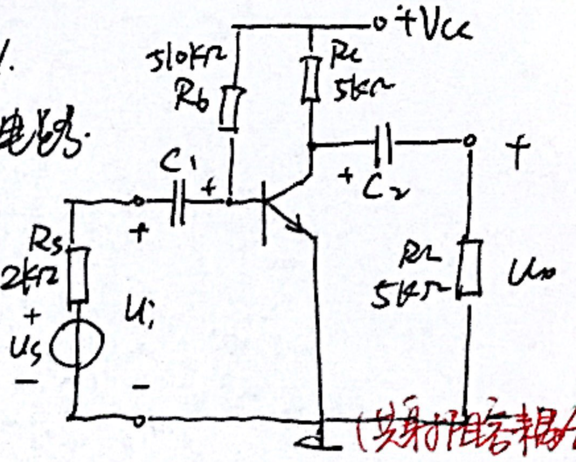
0. 右图中已知 $\beta=80$. $r_{be}=1k\Omega$. $U_i=20mV$.
$U_{BEQ}=0.7V$. $U_{CEQ}=4V$. $I_{BQ}=20\mu A$. 分析电路.
(想出直流通路和交流通路).



(共射阻容耦合)

$$\dot{A}=-\underbrace{\frac{\dot{U}_o}{\dot{U}_i}}=-\underbrace{\frac{\beta I_B\cdot R_C}{I_B\cdot r_{be}}}=-\frac{\beta R_C}{r_{be}}.$$

$$\Rightarrow \dot{A}=-\frac{80\times5}{1}=-400.$$

$R_i=\underbrace{R_b // r_{be}}\approx k\Omega$, $R_o=R_C=5k\Omega$ (注意不包括 R_L!!! 痛哭哩).

由叠加定理: $U_i=I_{BQ}\cdot R_s+U_s=20\mu A\cdot 2k\Omega+U_s=20mV$.

0 ~~上~~下图, $R_L=\infty$ 和 $R_L\neq\infty$ 时: 稳定电路才成立.
~~[illegible]~~. 直接用 $U_{BEQ}=0.7V$ (题目未提及时).

(1) $R_L=+\infty$:

静态: $\boxed{分压 \Rightarrow U_{BEQ}=\frac{V_{cc}}{R_s+R_b}}$ (V_{BB}), $I_{BQ}=\frac{V_{cc}-U_{BEQ}}{R_b}-\frac{U_{BEQ}}{R_s}$.
$I_{CQ}=\beta I_{BQ}$, $U_{CEQ}=V_{cc}-I_{CQ}R_c$.

动态: $\dot{A}=-\frac{\beta I_B\cdot R_C}{I_B\cdot r_{be}}=-\frac{\beta R_c}{r_{be}}$, $R_i=R_b//r_{be}$, $R_o=R_c$.

(2) $R_L\neq+\infty$:

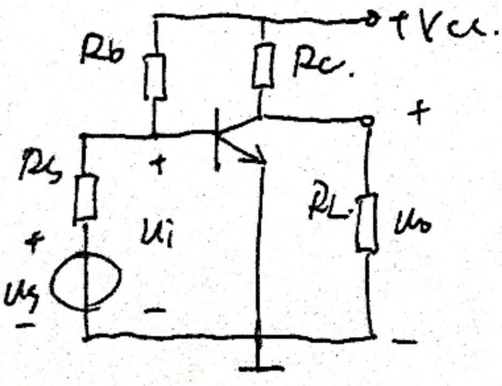
$\Rightarrow U_{BEQ}=\frac{\cancel{V_{cc}}}{\cancel{R_s+R_b}}$, I_{BQ} 不变. I_{CQ} 不变. ~~U_{CEQ}~~

U_{CEQ} 满足式: $\left(\frac{U_{CEQ}}{R_L}+I_{CQ}\right)R_C+U_{CEQ}=V_{cc}$.

$\dot{A}=-\frac{\beta I_B\cdot(R_L//R_C)}{I_B\cdot r_{be}}=-\frac{R_L//R_c}{r_{be}}$, $R_i=R_b//r_{be}$, $R_o=R_C$.

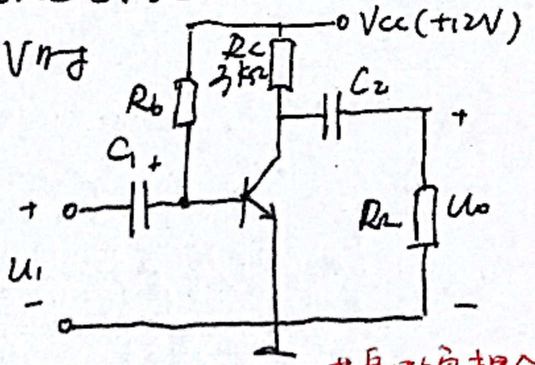
⇓ 从 R_C 变为 $R_L//R_C$!!!

⇓ 不包括 R_L!!!



(共射直接耦合)

○ 右图阻容耦合电路 $\beta=100$. $r_{be}=1k\Omega$. 若 $R_L=5k\Omega$. ~~Rc~~ 静态管压降 $U_{CEQ}=6V$. 若要使 $U_i=1mV$ 时 $U_o>220mV$. R_c 至少为多少千欧?



(共射阻容耦合)

⇒ 由静态工作点, ∵ $U_{CEQ}=6V$

$$I_{CQ}=\frac{V_{CC}-U_{CEQ}}{R_c}=2mA \Rightarrow I_{BQ}=20\mu A$$

所以 $R_b=\frac{V_{CC}-U_{BEQ}}{\cancel{R_b}I_{BQ}}=\frac{12-0.7V}{20\mu A}=565k\Omega$.

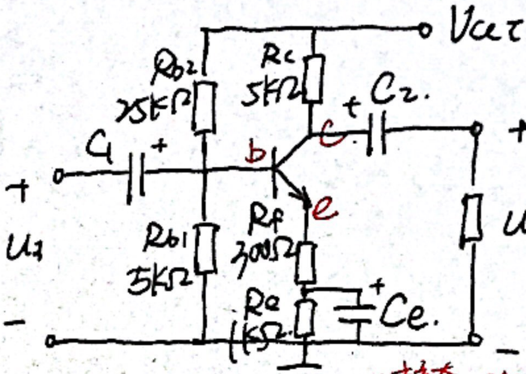
由 $\dot{A}=-\frac{\beta(R_c//R_L)}{r_{be}}=-220$ 得 $R_c//R_L=2.2k\Omega$. 代入 $R_L=5k\Omega$ 得 $R_c=3.9k\Omega$

○. $\beta=100$, $r_{bb'}=100\Omega$.

(1) 求电路Q点、A_u、R_i、R_o.

(2) 若改用 $\beta=200$ 晶体管. Q点如何变?

(3) C_e 开路. 怎么变化?



(静态工作点稳定电路)

⇒(1) 静态分析: 由于 $(1+\beta)(R_f+R_e)>>(R_{b1}//R_{b2})$.

所以 $U_{BQ}\approx\frac{R_{b1}}{R_{b1}+R_{b2}}V_{CC}=2V \Rightarrow I_{EQ}=\frac{U_{BQ}-U_{BEQ}}{R_f+R_e}=1mA$.

⇒ $I_{BQ}=\frac{I_{EQ}}{1+\beta}=10\mu A$, $I_{CQ}=\beta I_{BQ}=1mA$. $U_{CEQ}=V_{CC}-I_{EQ}R_c-I_{EQ}(R_e+R_f)=5.7V$.

动态分析:

(直接公式) $R_i=R_{b1}//R_{b2}//(r_{be}+(1+\beta)R_f)$.

$r_{be}=r_{bb'}+(1+\beta)\frac{26mV}{I_{EQ}}=2.73k\Omega$. $R_i=3.7k\Omega$

$$\boxed{R_i=\frac{U_i}{I_i}=\frac{I_b r_{be}+I_e R_f}{I_b+\frac{I_b r_{be}+I_e R_f}{R_{b1}//R_{b2}}}=[r_{be}+(1+\beta)R_f]//R_{b1}//R_{b2}.}$$

$R_o=R_c=5k\Omega$.

$$\dot{A}_u=-\frac{\beta I_B R_c}{I_B r_{be}+I_{EQ}R_f}=-\frac{\beta R_c}{r_{be}+(1+\beta)R_f}=-7.6$$

(2). β 变大后, I_{EQ} 不变. $I_{CQ}=\frac{\beta}{1+\beta}I_{EQ}\approx I_{EQ}$ 则 I_{CQ} 基本不变!!!

而 I_{BQ} 减小. $I_{BQ}=\frac{I_{EQ}}{1+\beta}\approx 5\mu A$

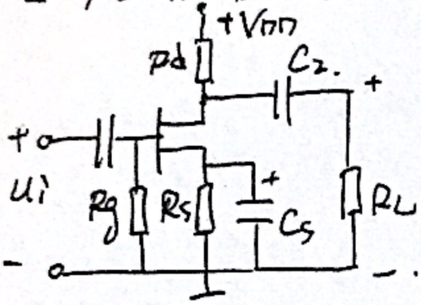
画出交流通路,求输入电阻和输出电阻时若有电阻跨接在两端均用此方法!!!

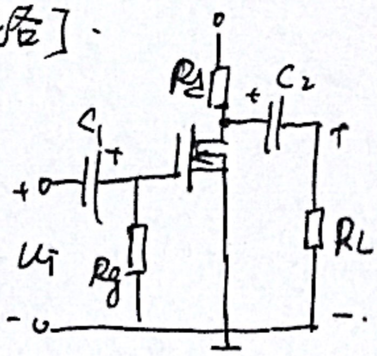
(3). C_e 开路后, 直流通路即静态工作点无影响.

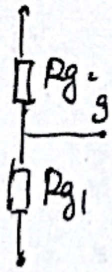
动态参数. $R_i=R_{b1}//R_{b2}//[r_{be}+(1+\beta)(R_f+R_e)]$ 变大

$$\dot{A}_u=-\frac{\beta R_c}{r_{be}+(1+\beta)(R_f+R_e)}$$ 变小.

【场效应管放大电路】







$\Rightarrow I_g=0$

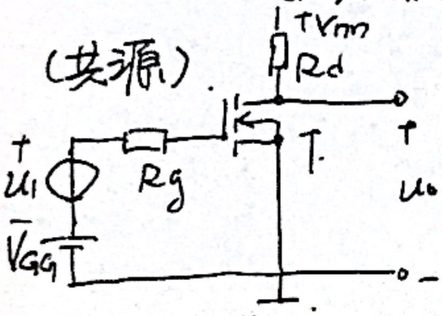
用分压来设置偏压

$U_{GS}<0$ (自给偏压式)

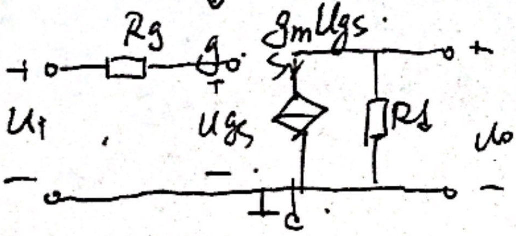
U_{GS}

(分压偏置式)

(共源)



$$\Rightarrow \begin{cases} R_i=\infty, \quad R_i=R_d \Rightarrow \boxed{r_{ds}=\infty} \\ \dot{A}=-\dfrac{g_m U_{gs}\cdot R_d}{U_{gs}}=\underbrace{-g_m R_d} \end{cases}$$

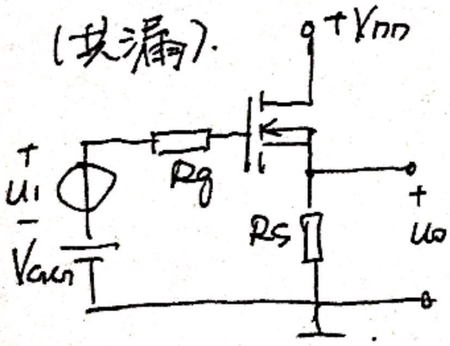


$$\Delta\ g_m=\frac{2}{U_{GS(th)}}\sqrt{I_{DQ}I_{DO}}$$

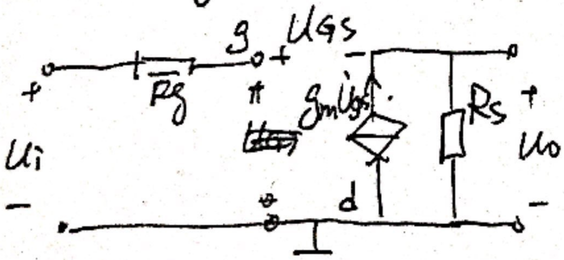
$$I_D=I_{DO}\left(\frac{U_{GS}}{U_{GS(th)}}-1\right)^2$$

$$\begin{cases} I_{DQ}=I_{SQ}.\ I_{GQ}=0,\ U_{GSQ}=U_i \\ U_{DSQ}=V_{DD}-I_{DQ}R_d \end{cases}$$

(共漏)

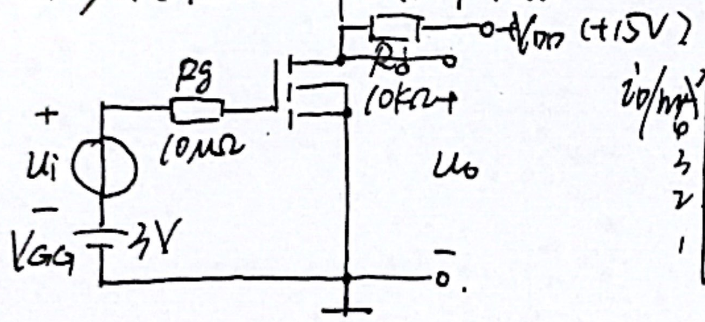


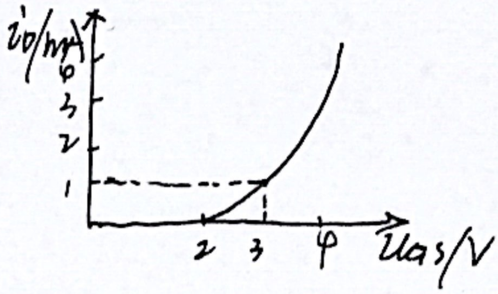
$$\Rightarrow \begin{cases} R_i=\infty, \quad R_o=R_s + \underbrace{\frac{1}{g_m}}\ (\text{并联}) \\ \dot{A}_u=\dfrac{U_o}{U_i}=\dfrac{I_d R_s}{\underbrace{U_{gs}+I_d R_s}}=\dfrac{g_m R_s}{1+g_m R_s}\ (<1) \end{cases}$$



0. 已知转移特性. 求解Q点和$\dot{A}_u$.

(基本).





由题知. $U_{GS}=V_{GG}=3V$. 再由转移曲线知此时 i_D 为 1mA.

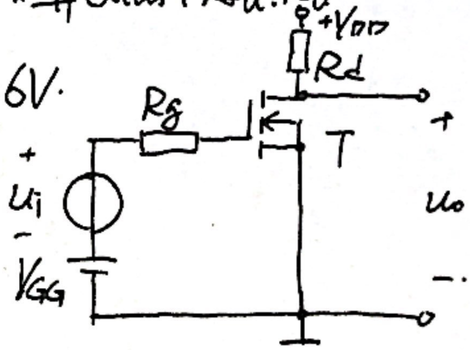
则 $I_{DQ}=I_{SQ}=1mA$. $U_{DQ}=V_{DD}-I_{DQ}R_d=5V$.

动态分析: 由 $I_{DQ}=I_{DO}(\frac{V_{GG}}{U_{GS(th)}}-1)^2$ 得 $I_{DO}=4mA$. $[I_D=I_{DO}(\frac{U_{GS}}{U_{GS(th)}}-1)^2]$.

则 $g_m=\frac{2}{U_{GS(th)}}\sqrt{I_{DQ}I_{DO}}=2mS$.

$\Rightarrow \dot{A}_u=-\frac{g_m U_{GS}\cdot R_d}{U_{GS}}=-g_m R_d=-20$. $R_i=\infty$. $R_o=R_d=10k\Omega$

0 $V_{GG}=6V$. $R_d=3k\Omega$. $U_{GS(th)}=4V$. $I_{DO}=mA$. 估算Q点, $\dot{A}_u$. R_o



$\Rightarrow I_{DQ}=I_{DO}(\frac{V_{GG}}{U_{GS(th)}}-1)^2=2.5mA$, $U_{GS}=V_{GG}=6V$.

$U_{DSQ}=V_{DD}-I_{DQ}R_d=4.5V$.

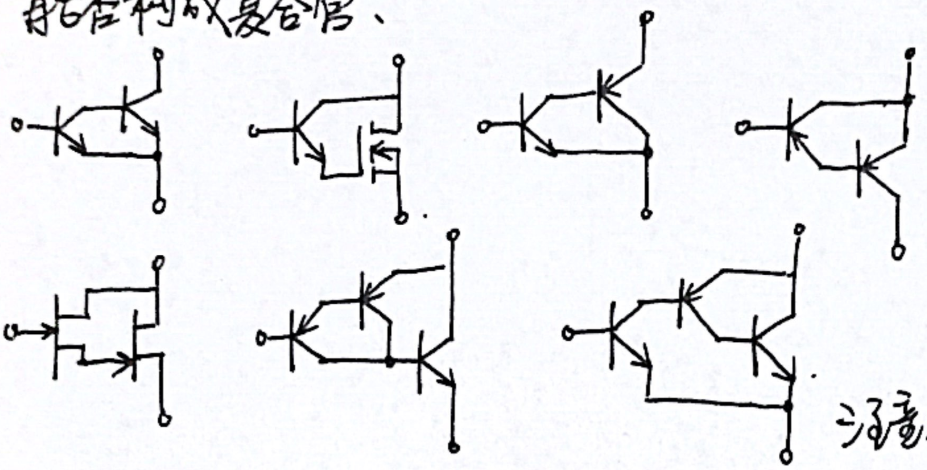
$g_m=\frac{2}{U_{GS(th)}}(\cancel{\frac{V_{GG}}{U_{GS(th)}}})\sqrt{I_{DQ}I_{DO}}=2.5mS$

$\Rightarrow \dot{A}=-g_m R_d=-7.5$. $R_o=R_d=3k\Omega$.

Scanned with CamScanner

【复合管】.

① 能否构成复合管、



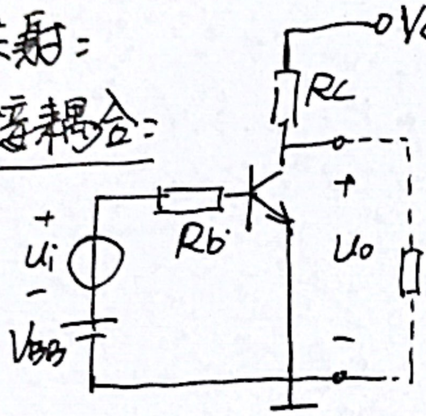
注意方向.

⑴ 复合管共射

[晶体管放大电路].

① 共射:

直接耦合:

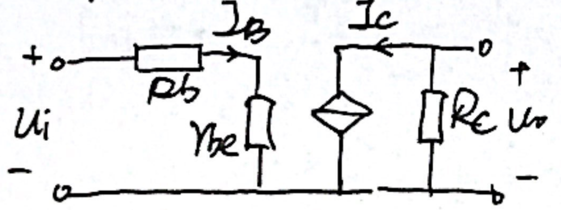


Q点(静态): [直流通路受R_L影响].

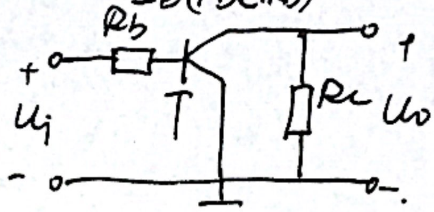
$$\Rightarrow \begin{cases} I_{BQ} = \dfrac{V_{BB} - U_{BEQ}}{R_b} \quad (U_{BEQ} = 0.7V). \\ I_{CQ} = \beta I_{BQ}. \\ U_{CEQ} = V_{CC} - I_{CQ} R_c \end{cases}$$

动态:(用交流通路). $r_{be} = r_{bb'} + (1+\beta)\dfrac{26mV}{I_{EQ}}$

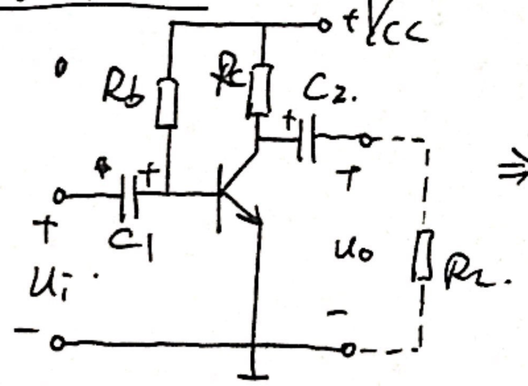
$$R_i = R_b + r_{be},\quad R_o = R_c,\quad \dot{A} = -\frac{\beta I_b \cdot R_c}{I_b(r_{be}+R_b)} = -\frac{\beta R_c}{r_{be}+R_b}.$$



或者



阻容耦合:



Q点(静态). [直流通路不受R_L影响].

$$\Rightarrow \begin{cases} I_{BQ} = \dfrac{V_{CC} - U_{BEQ}}{R_b} \\ I_{CQ} = \beta I_{BQ}. \\ U_{CEQ} = V_{CC} - I_{CQ} R_c. \end{cases}$$

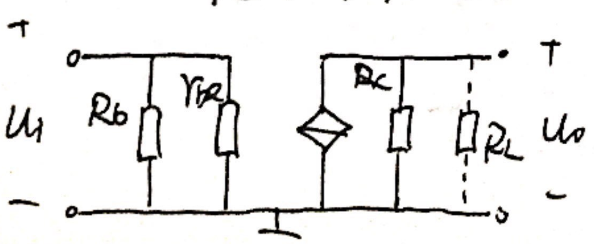
动态:(不带负载):

$$R_i = R_b // r_{be},\quad R_o = R_c,\quad \dot{A}_u = -\frac{\beta R_c}{r_{be}}.$$

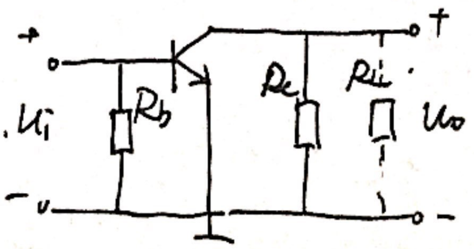
(带负载):

$$R_i = R_b // r_{be},\quad R_o = R_c,\quad \dot{A}_u = -\frac{\beta (R_c // R_L)}{r_{be}}.$$

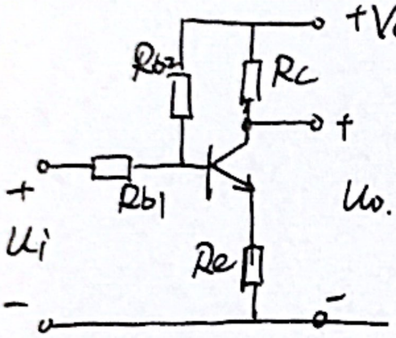
有时考虑信号源内阻 ~~内阻~~ R_s.



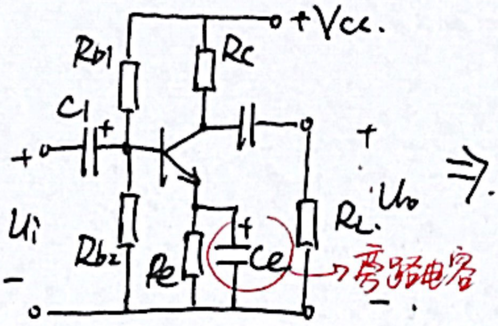
或者



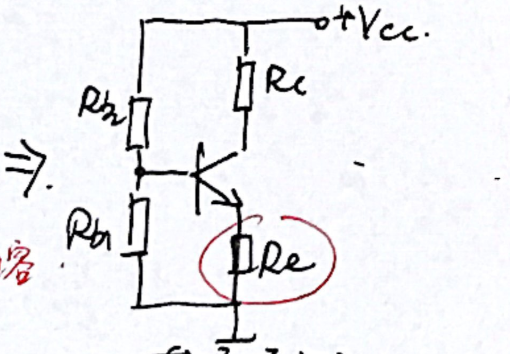
静态工作点稳定电路



(直接耦合).



(阻容耦合).



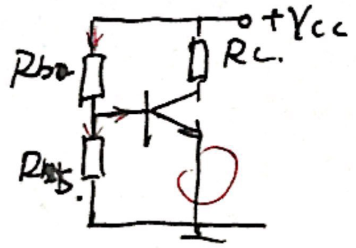
直流通路

直接耦合、阻容耦合的静态分析相同:

由于 $I_1 >> I_{BQ}$. 则 $U_{BQ} \approx \frac{R_{b1}}{R_{b1}+R_{b2}} \cdot V_{cc} \Rightarrow I_{EQ} = \frac{U_{BQ}-U_{BEQ}}{R_e}$.

且 $I_{CQ} \approx I_{EQ}$, $\Rightarrow U_{CEQ} = V_{cc} - I_{CQ}(R_c+R_e)$. $I_{BQ} = \frac{I_{EQ}}{1+\beta}$.

(注意)若直流通路为:

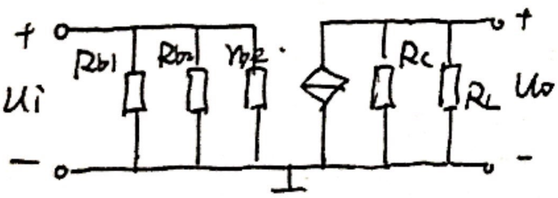


⇒ e支路上并没有Re.因此不属于稳定电路.

则 $I_{BQ} = \frac{V_{cc}-U_{BEQ}}{R_b} - \frac{U_{BEQ}}{R_s}$.

∴ $I_{CQ} = \beta I_{BQ}$. $U_{CEQ} = V_{cc} - I_{CQ}R_c$.

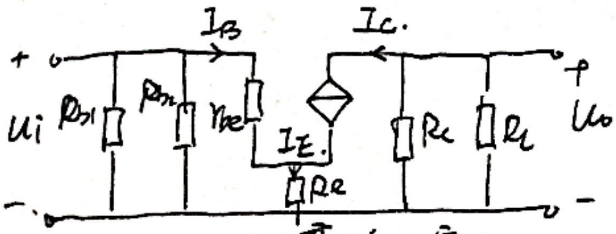
动态分析(阻容耦合):



(有旁路电容).

⇓

$$\begin{cases} R_i = R_{b1} // R_{b2} // r_{be} \\ R_o = R_c // \cancel{R_L} \\ \dot{A}_u = -\frac{\beta(R_c // R_L)}{r_{be}} \end{cases}$$



(无旁路电容).

WOW!

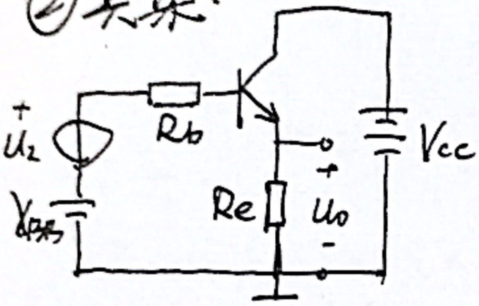
(Re折算)

⇓

$$\begin{cases} R_i = R_{b1} // R_{b2} // [(1+\beta)R_e + r_{be}] \\ R_o = R_c \end{cases}$$

$$\dot{A}_u = -\frac{\beta(R_c // R_L)}{r_{be}+(1+\beta)R_e}$$

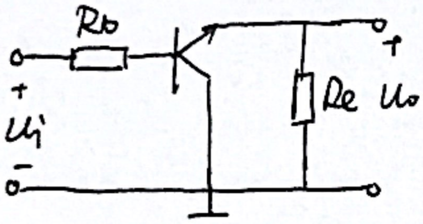
② 共集.



静态(Q点):

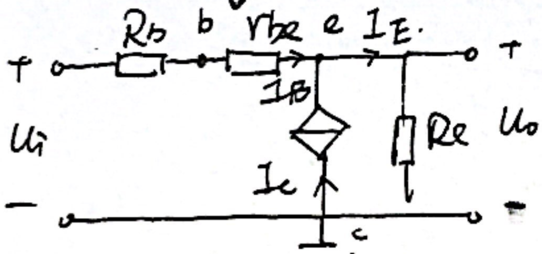
$$\Rightarrow \begin{cases} I_{BQ} = \dfrac{V_{CC}-U_{BEQ}}{R_b+(1+\beta)R_e} \\ U_{CEQ} = V_{CC} - I_{EQ}R_e \end{cases} \qquad I_{EQ}=(1+\beta)I_{BQ}.$$

动态:



$$\boxed{R_i = R_b + r_{be},\quad R_o = R_e. \qquad \dot{A}_u = -\frac{\beta R_e}{r_{be}}} \times$$

勿和共射电路弄混!!!



由于 $U_i = I_B(R_b+r_{be}) + I_E R_e$
$= I_B(R_b+r_{be}) + (1+\beta)I_B R_e$.

则 $\underbrace{R_i = \dfrac{U_i}{I_i} = R_b + r_{be} + (1+\beta)R_e}$

将 U_i 短路后,可得: $R_o = \dfrac{U_o}{I_o} = \dfrac{U_o}{\frac{U_o}{R_e}+(1+\beta)\frac{U_o}{R_b+r_{be}}} = \dfrac{1}{\frac{1}{R_e}+(1+\beta)\frac{1}{R_b+r_{be}}}$.

(推导: $I_b = \dfrac{U_o}{R_b+r_{be}}$, $I_e = (1+\beta)\dfrac{U_o}{R_b+r_{be}}$, $I_{Re} = \dfrac{U_o}{R_e}$, $I_o = I_{Re}+I_e$).

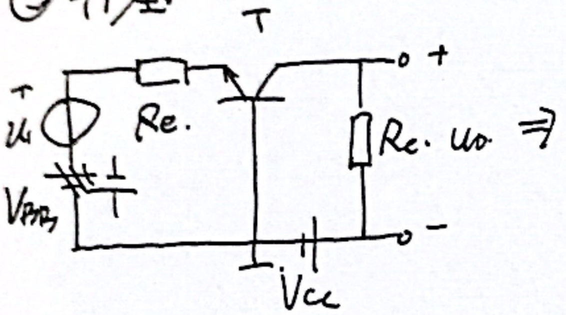
$\underbrace{\Rightarrow R_o = R_e // \dfrac{R_b+r_{be}}{1+\beta}}$ (可直接用等效电阻方法计算). 前后都要考虑.

$\dot{A} = \dfrac{\dot{U}_o}{\dot{U}_i} = \underbrace{\dfrac{I_e R_e}{I_b(R_b+r_{be})+I_e R_e}} = \underbrace{\dfrac{(1+\beta)R_e}{R_b+r_{be}+(1+\beta)R_e}}$ (始终根据定义来).

↳ ≤ 1 (不放大电压).

Scanned with CamScanner

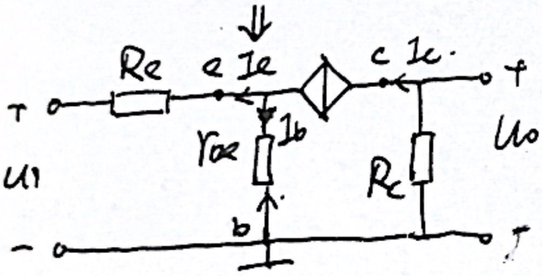
③共基.



静态（Q点）：

$$\begin{cases} I_{EQ} = \dfrac{V_{BB} - U_{BEQ}}{R_e} \\ I_{BQ} = \dfrac{I_{EQ}}{1+\beta} \end{cases}$$

$$U_{CEQ} = U_{CQ} - U_{EQ} = V_{CC} - I_{CQ}R_e + U_{BEQ}$$

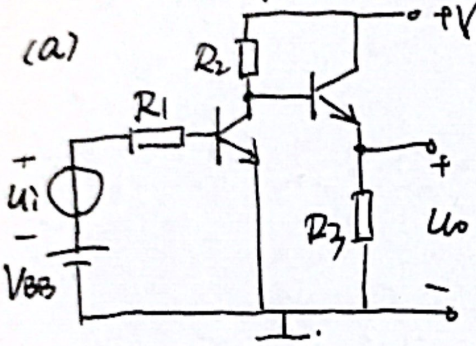


动态：

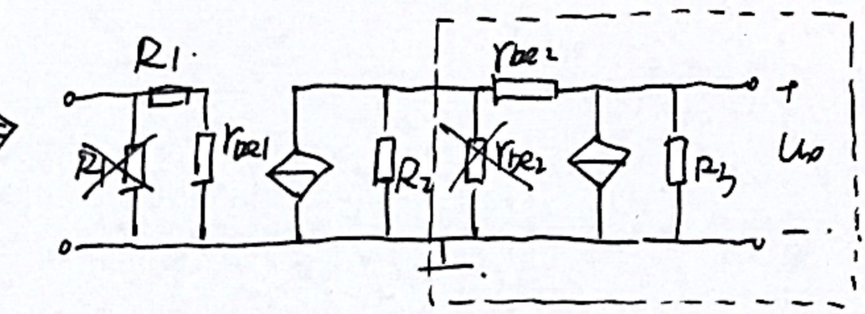
$$\begin{cases} R_i = \dfrac{I_e R_e + I_b r_{be}}{I_e} = R_e + \dfrac{r_{be}}{1+\beta} \\ R_o = R_c \\ \dot{A}_u = \dfrac{u_o}{u_i} = \dfrac{I_c R_c}{I_e R_e + I_b r_{be}} = \dfrac{\beta R_c}{(1+\beta)R_e + r_{be}} \end{cases}$$

○ 各电路静态工作点合适，画出交流通路，写出 $\dot{A}_u, R_i, R_o$ 表达式.

(a)



$\Rightarrow$



前级电路的输出电阻

① 第一级为共射电路，因此 $R_i = \cancel{R_1 // r_{be}}\ R_1 + r_{be1}$.

② 第二级为共集电路，因此 $R_o = \frac{U_o}{I_o} = \frac{U_o}{\frac{U_o}{R_2 + r_{be2}}(1+\beta_2) + \frac{U_o}{R_3}} = R_3 // \frac{R_2 + r_{be2}}{1+\beta_2}$

③ 从后往前计算，先写虚线框内部分：

$$\dot{A}_{u2} = \frac{U_o}{U_i} = \frac{I_e \cdot R_3}{I_b r_{be2} + I_e R_3} = \frac{(1+\beta_2) R_3}{r_{be2} + (1+\beta_2) R_3}.$$

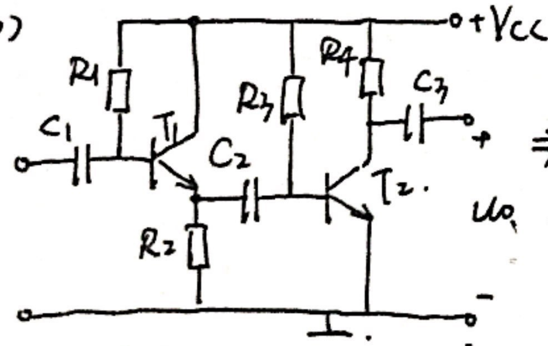
再写共射电路部分，此时第二级电路的输入电阻为其负载.

~~$\dot{A}_{u1}$~~ 共集电路的输入电阻：$R_i' = \frac{I_b r_{be2} + I_e R_3}{I_b} = r_{be2} + (1+\beta_2) R_3$.

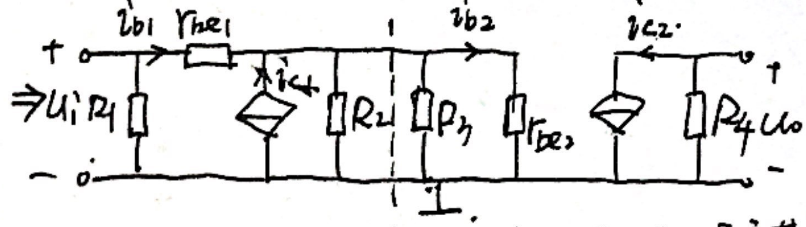
$$\dot{A}_{u2} = -\frac{\beta_1 (R_2 // R_i')}{R_1 + r_{be1}} = -\frac{\beta [R_2 // (r_{be2} + (1+\beta_2) R_3)]}{R_1 + r_{be1}}.$$

$$\Rightarrow \dot{A}_u = \dot{A}_{u1} \cdot \dot{A}_{u2} = -\frac{\beta [R_2 // (r_{be2} + (1+\beta_2) R_3)]}{R_1 + r_{be1}} \cdot \frac{(1+\beta_2) R_3}{r_{be2} + (1+\beta_2) R_3}.$$

(b)



$\Rightarrow$



(标出电流位置方便确定范围).

① 第二级为共射电路. 则 $R_o = R_4$.

② 第一级为共集电路：第二级电路的输入电阻为其负载电阻.

$R_i' = R_3 // r_{be2}$. 则 $R_i = \cancel{R_1 + (1+\beta) R_2 // R_i'} = R_1 // [(1+\beta) R_2 // R_3 // r_{be2} + r_{be1}]$.

③ 先写共射部分(第二级)：$\dot{A}_{u2} = -\frac{\beta R_4}{r_{be2}}$.

再写共集部分(第一级)：~~$\dot{A}_{u1}$~~ R_i' 为其负载.

$$\dot{A}_{u1} = \frac{I_e \cdot R_2 // R_i'}{I_b \cdot r_{be1} + I_e \cdot R_2 // R_i'} = \frac{(1+\beta_1)(R_2 // R_3 // r_{be2})}{r_{be1} + (1+\beta_1)(R_2 // R_3 // r_{be2})}.$$

$$\Rightarrow \dot{A}_u = \dot{A}_{u1} \dot{A}_{u2} = \frac{(1+\beta_1)(R_2 // R_3 // r_{be2})}{r_{be1} + (1+\beta_1)(R_2 // R_3 // r_{be2})} \cdot \left(-\frac{\beta R_4}{r_{be2}}\right).$$

四.

上一题中的$R_i = R_i = \frac{\dot{U}_i}{\dot{I}_i} = \frac{I_{b1} r_{be1} + I_{e1}(R_2 // R_i')}{I_{b1} + \frac{I_{b1} r_{be1} + I_{e1}(R_2 // R_i')}{R_1}}$

$$= \frac{1}{\frac{I_{b1}}{I_{b1} r_{be1} + I_{e1}(R_2 // R_3 // r_{be2})} + \frac{1}{R_1}} = \frac{1}{\frac{1}{r_{be1} + (1+\beta_1)(R_2 // R_3 // r_{be2})} + \frac{1}{R_1}} = R_1 // [r_{be1} + (1+\beta_1)(R_2 // R_3 // r_{be2})].$$

Δ 共集电路的输入电阻和输出电阻都用了那种方法（当有电阻跨接在两端时）.

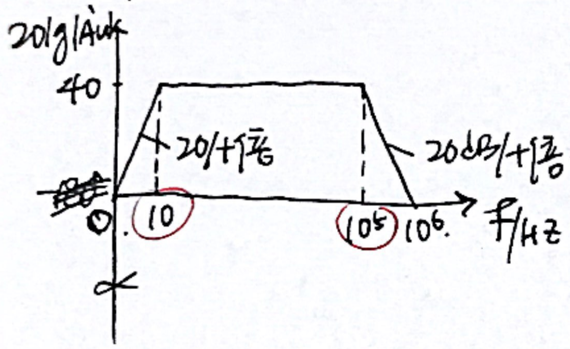
[题型：根据$\dot{A}_u$表达式画波特图]

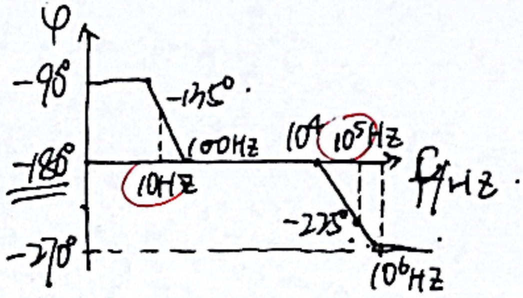
(1)

$$\dot{A}_u=\frac{-10jf}{(1+j\frac{f}{10})(1+j\frac{f}{10^5})} \Rightarrow \dot{A}_u=\frac{-100}{(1+\frac{10}{jf})(1+\frac{jf}{10^5})} \Rightarrow f_L=10Hz,\ f_H=10^5Hz$$

$\dot{A}_{ums}=100$ ($\varphi=-180°$)

⇒两个拐点，均为一级放大电路。 $20\lg|\dot{A}_{usm}|=40$.



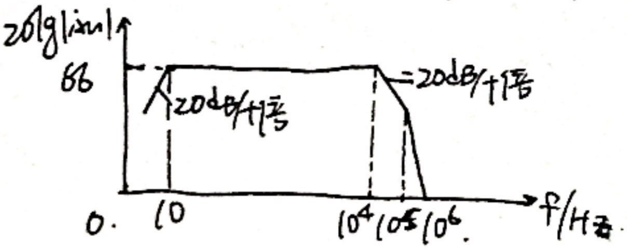


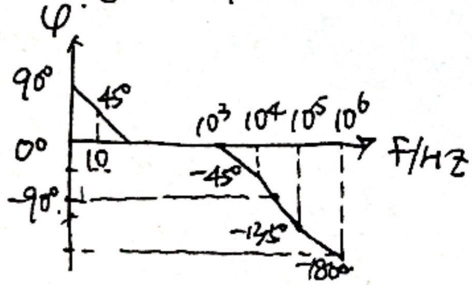
(2)

$$\dot{A}_u=\frac{200jf}{(1+j\frac{f}{10})(1+j\frac{f}{10^4})(1+j\frac{f}{10^5})} \Rightarrow \dot{A}_u=\frac{2000}{(1+\frac{10}{jf})(1+\frac{jf}{10^4})(1+\frac{jf}{10^5})} \Rightarrow f_L=10Hz,\ f_H=10^4, 10^5Hz$$

$\dot{A}_{usm}=2000$ ($\varphi=0°$)

⇒低频段一个拐点，高频段两个拐点。 $20\lg|\dot{A}_{usm}|=66$.





☆ 第五章「反馈」

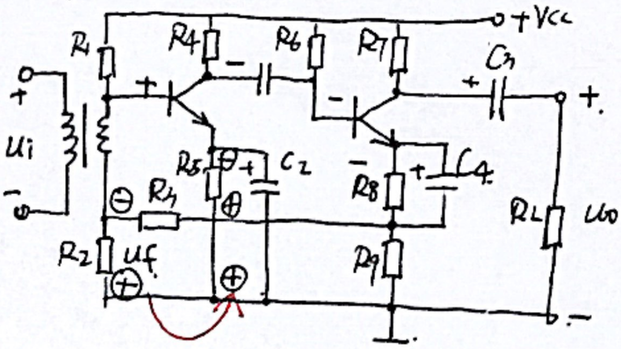
○ 设所有电容对交流信号均短路，求电路中所反馈组态并求 $\dot{A}_{uf}$.

反馈支路为 $T_2 \cdot C_4 \cdot R_3 \cdot R_2$.

反馈所取电流 I_f 为：$I_f = \frac{R_9}{R_2+R_3+R_9} \cdot I_o$.

反馈量以 ~~[illegible]~~ 电压 的形式进入

故为电流串联负反馈.



又 $u_o = i_o R_L' = i_o (R_7 // R_L)$. $u_f = i_f R_2 = \frac{R_2 R_9}{R_2+R_3+R_9} \cdot I_o$

~~所以 $\dot{A}_{uf} = \frac{u_o}{u_i} = \frac{(R_2+R_3+R_9)(R_7//R_L)}{R_2 R_9}$~~

所以. $\dot{A}_{uf} = \frac{u_o}{u_i}$ ~~$\approx$~~ $= \frac{I_o (R_L // R_L)}{u_i} \approx \frac{1}{F_{ui}} \cdot (R_L // R_7)$.

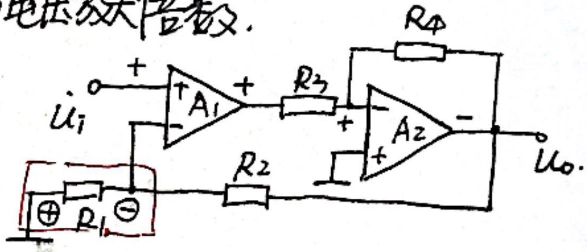
$= \frac{I_o}{u_f} \cdot (R_7 // R_L) = \frac{(R_2+R_3+R_9)(R_L // R_7)}{R_2 R_9}$.

A 用反馈系数 F 计算 $\dot{A}_{uf}$.

○ 判断反馈类型并求理想运放条件下的电压放大倍数.

(1) 交直流反馈并存. 由瞬时极性知为正反馈

（u_i 输入为正时. R_1 两端压降 ~~降~~ 正 同相端反相端电压差增大. 故为正反馈）.



电路反馈支路：$A_2 \cdot R_2 \cdot R_1$.（通常考虑的是整个电路）.

反馈量取自 u_o. 转化为 R_1 上的分压. ⇒ 电压串联.

综上：引入了直流正反馈和交流电压串联正反馈.

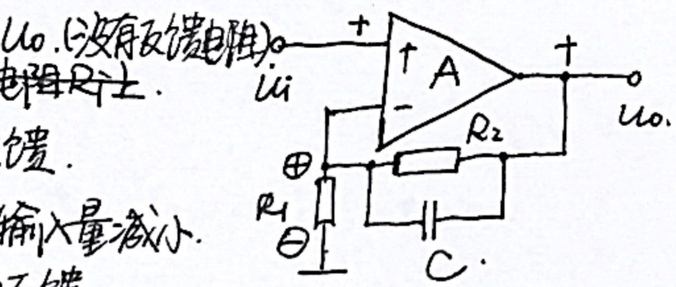
$\dot{A}_{uf} = \frac{u_o}{u_i} = \frac{u_o}{\frac{R_1}{R_1+R_2} u_o} = 1 + \frac{R_2}{R_1}$（电压串联）. $F_{uu} = \frac{u_f}{u_o} = \frac{\frac{R_1}{R_1+R_2} u_o}{u_o} = \frac{R_1}{R_1+R_2}$.

① 交/直流？若无电容，则交直流并存. 存在电容，将电容短路后为直流反馈. 考虑电容后新增的为交流反馈

② 正/负反馈？从 u_i 为正开始. 标记各节点极性（对地电压的正负）. 看使净输入量变大还是变小.（压降反馈电阻的压降或反馈支路分流等等）

③ 串/并联？找出反馈量是电压还是电流.

(2).



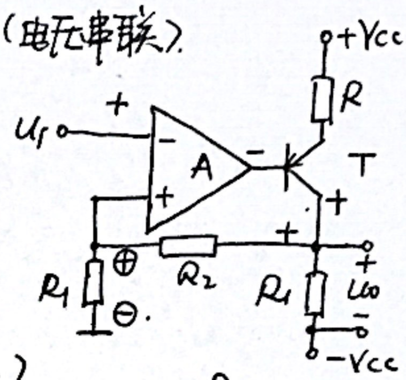
电容短路，判断极性如图. 反馈量为~~电阻R_1上~~

~~的压升~~ 其使净输入量减小. 为负反馈.

去掉电容，反馈量仍为R_1上的分压. 使输入量减小.

为负反馈. 综上：交直流电压串联负反馈.

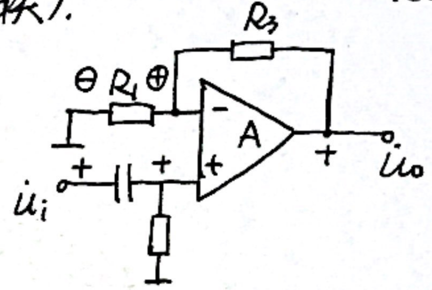
交流反馈放大倍数：$\dot{A}_u = \frac{\dot{U}_o}{\dot{U}_i} = \frac{\dot{U}_o}{\frac{R_1}{R_1+R_2}\dot{U}_o} = 1+\frac{R_2}{R_1}$（电压串联）.



(3). 无电容. 交直流反馈并存.

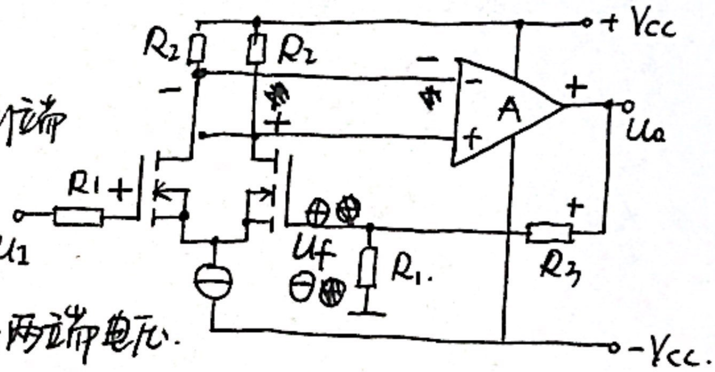
标记极性（三极管B、C反相）. R_1两端有压升. 其使净输入量减小. 为负反馈. ⇒ 交直流电压串联负反馈.

交流负反馈放大倍数：$\dot{A}_u = \frac{\dot{U}_o}{\dot{U}_i} = 1+\frac{R_2}{R_1}$（电压串联）.



(4). 电容~~短~~断路时为直流电压串联负反馈.

去掉电容时为交流电压串联负反馈.



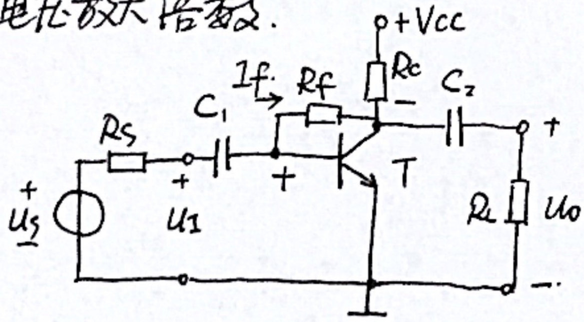
(5). 无电容. 交直流反馈并存.

标记极性（注意差分放大电路，同侧端反馈相异侧同相）. 反馈电阻R_1两端压升使净输入量减小（差模信号增大，共模信号减小）. 故为负反馈. R_1两端电压为U_o在R_1上的分压. ⇒ 交直流电压串联负反馈.

$\dot{A}_{uf} = \frac{\dot{U}_o}{\dot{U}_I} \approx \frac{\dot{U}_o}{\dot{U}_f} = \frac{\dot{U}_o}{\frac{R_1}{R_1+R_3}\dot{U}_o} = 1+\frac{R_3}{R_1}$（注意反馈量约等于输入量 即 $U_I \approx U_f$）.

○ 判断反馈，并计算深度负反馈条件下的电压放大倍数。

(1). 交直流电压并联负反馈。



放大倍数：$\dot{A}_{usf} = \frac{\dot{U}_o}{\dot{U}_s} \approx \frac{\dot{U}_o}{\dot{I}_f R_s} = -\frac{R_f}{R_s}$

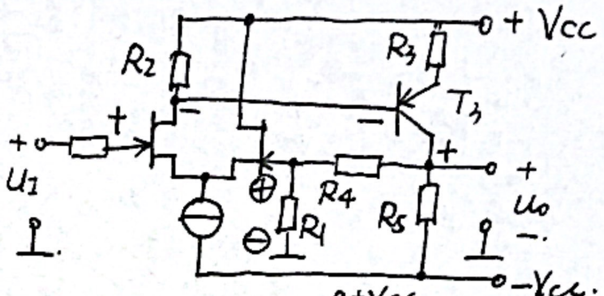
(电压并联反馈信号源必须带内阻Rs)。

忽略净输入(基极电流)，Rs两端电压即为Us，且电流等于反馈电流If。(P238)

$F_{iu} = \frac{\dot{I}_f}{\dot{U}_o} = -R_f$ (电压并联)。

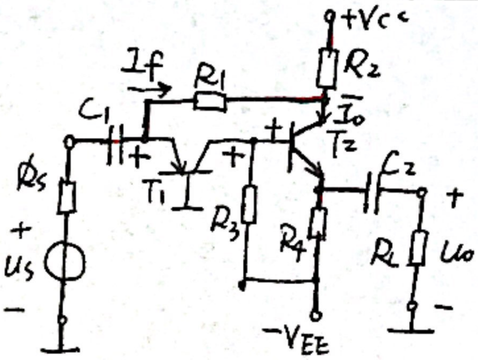
(2). 交直流电压串联负反馈。

注意极性(差分放大电路和晶体管)。



(3). 交直流电流并联负反馈。

注意极性(晶体管)。



放大倍数：

$$\dot{A}_{usf} = \frac{\dot{U}_o}{\dot{U}_s} \approx \frac{\dot{U}_o}{\dot{I}_f R_s} = \frac{\dot{I}_o \cdot R_L'}{\dot{I}_f \cdot R_s}$$

$$= \frac{\frac{R_1+R_2}{R_2}\dot{I}_f \cdot R_4 // R_L}{\dot{I}_f \cdot R_s} = (1+\frac{R_1}{R_2})\frac{R_4//R_L}{R_s}$$

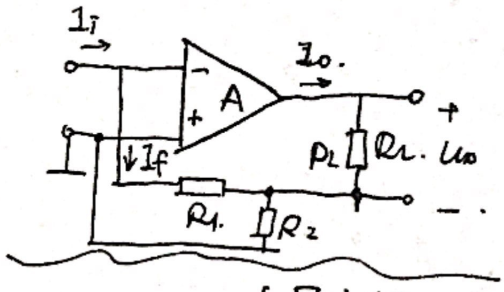
<典例>。

注意. 忽略T_1管发射极输入电流，Us全部降在Rs上. $\dot{U}_s \approx \dot{I}_f R_s$.

在T_2管中集电极端由分流可知：$I_f = \frac{R_2}{R_1+R_2} I_o$. 可求出$I_o$.

忽略T_2管基极输入电流，则 $I_e = I_c = I_o$

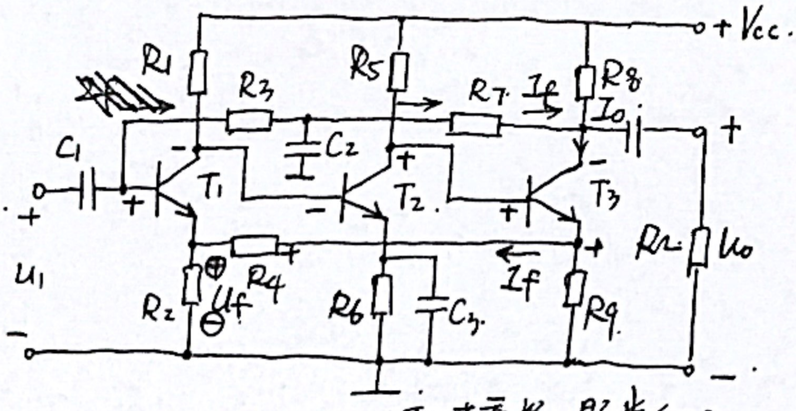
近似后的通路为红线部分。



(P234)

△判断反馈组态 → 分离出反馈网络 → 求解F / Af → 求解Auf / Ausf.

(14).



R_3、R_7引入直流电压并联负反馈.

R_4引入交直流电流串联负反馈.

(注意看电容的位置).

(R_2.R_6.R_9分别给各晶体管引入直流负反馈)

(和本章第一题类似).

交流负反馈下放大倍数:

$$\dot{A}_{uf}=\frac{\dot{U}_o}{\dot{U}_i}=\frac{\dot{I}_o\cdot R_L'}{\dot{U}_f}=\frac{\dot{I}_o\cdot(R_7/\!/R_8/\!/R_L)}{\dot{I}_f\cdot R_2}=\frac{\dot{I}_o\cdot(R_7/\!/R_8/\!/R_L)}{\frac{R_9}{R_2+R_4+R_9}\dot{I}_o\cdot R_2}$$

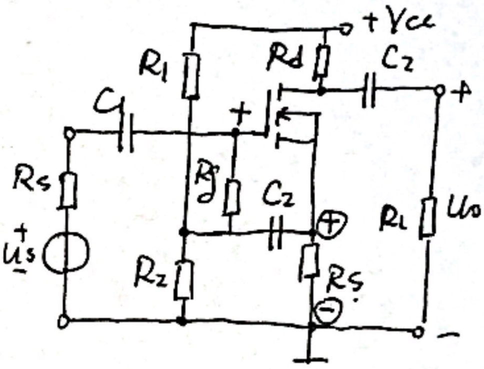
$$=\frac{(R_2+R_4+R_9)(R_7/\!/R_8/\!/R_L)}{R_2R_9}.$$

注意在T_3集电极I_o经过了R_7.R_8.R_L分流. 故$U_o=I_o\cdot(R_7/\!/R_8/\!/R_L)$

在T_3发射极I_o经过了R_2+R_4.R_9分流. 故$I_f=\frac{R_9}{R_2+R_4+R_9}I_o$.

忽略T_1基极电流. $U_i\approx U_f$ 即输入量=反馈量.

(15).



R_S引入直流负反馈(R_S上正下负).

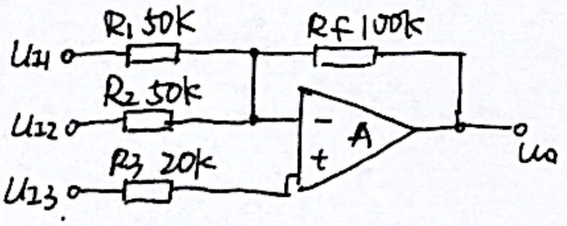
R_1.R_2.R_S引入交流负反馈. ?

C_2.R_g引入交流正反馈

第六章「运放」

0. 求运算关系（加减运算）.

(1) 用叠加定理求解：



① u_{I1} = (u_{I2}、u_{I3} 接地)

$u_{O1} = -\frac{R_f}{R_1}u_{I1}$.

② u_{I2}:(u_{I1}、u_{I3} 接地)：$u_{O2} = -\frac{R_f}{R_2}u_{I2}$.

③ u_{I3}:(u_{I1}、u_{I2} 接地)：$u_{O3} = (1+\frac{R_f}{R_1//R_2})u_{I3}$

综上：$u_{O1} = -\frac{R_f}{R_1}u_{I1} - \frac{R_f}{R_2}u_{I2} + (1+\frac{R_f}{R_1//R_2})u_{I3} = -2u_{I1}-2u_{I2}+5u_{I3}$.

或直接用公式求解：

反相求和：$u_{O1} = -\frac{R_f}{R_1}u_{I1} - \frac{R_f}{R_1}u_{I2} = -2u_{I1}-2u_{I2}$

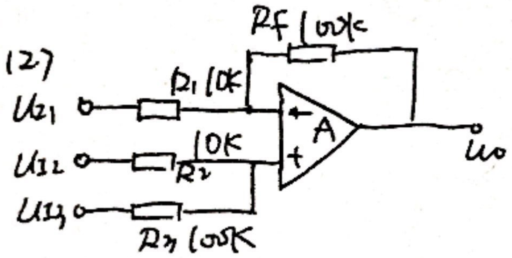
同相求和：$u_{O2} = \frac{R_N}{R_P}\cdot(\frac{R_f}{R_3}u_{I3}) = \frac{R_f}{R_3}u_{I3} = 5u_{I3}$ ⇒ 注意 R_N, R_P!!!

⇒ $u_O = u_{O1}+u_{O2} = -2u_{I1}-2u_{I2}+5u_{I3}$.

注：Δ反相求和公式：$u_O = -R_f(\frac{u_{I1}}{R_1}+\frac{u_{I2}}{R_2}+\cdots)$

同相求和公式：$u_O = \frac{R_N}{R_P}\cdot R_f(\frac{u_{I1}}{R_1}+\frac{u_{I2}}{R_2}+\cdots)$

(2)

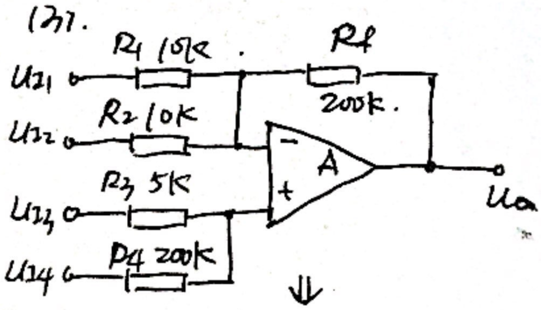


⇓

$\frac{R_N}{R_P} = \frac{\frac{1000}{110}}{\frac{1000}{110}} = 1$.

直接由公式写出：$u_O = -10u_{I1}+10u_{I2}+u_{I3}$.

(3).

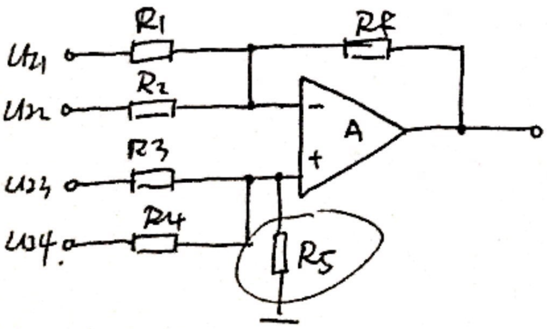


⇓

$\frac{R_N}{R_P} = \frac{5//200}{5//200} = 1$.

直接由公式：$u_O = -20u_{I1}-20u_{I2}+40u_{I3}+u_{I4}$

注意：



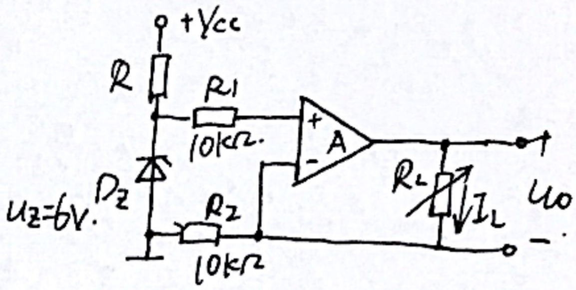
⇒ $R_N = R_1//R_2//R_f$

$R_P = R_3//R_4//R_5$.

若有 $R_1//R_2//R_f = R_3//R_4$，则 R_5 可去掉.

Scanned with CamScanner

0. 恒流源电路。已知稳压管工作在稳压状态，试求负载电阻R_L中的电流；若要求R_L中电流变化范围是1~10mA，电阻R_2应如何变化。



⇒由稳压管知运放同相端电位为+6V

则 $I_L = \frac{U_Z}{R_2} = \frac{6V}{10k\Omega} = 0.6mA$

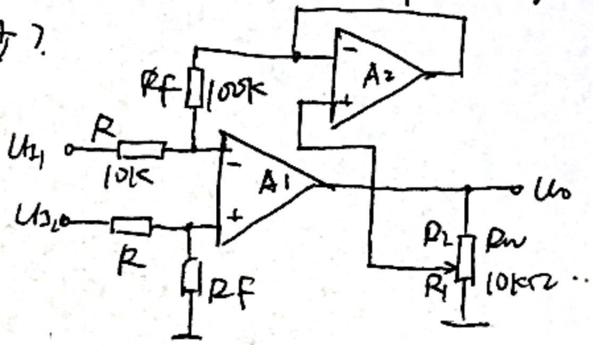
$R_{21} = \frac{U_Z}{I_{L1}} = \frac{6V}{1mA} = 6k\Omega$

$R_{22} = \frac{U_Z}{I_{L2}} = \frac{6V}{10mA} = 600\Omega$

故R_2需换成0.6kΩ电阻与5.4kΩ电位器串联。

0 (1) u_O与u_{I1}、u_{I2}运算表达式

(2) u_O最大为±14V，输入电压最大值$u_{I1max}=10mV$，$u_{I2max}=20mV$，最小值均为0。为了保证集成运放工作在线性区，R_2最大为多少？



⇒(1) A_2同相端：

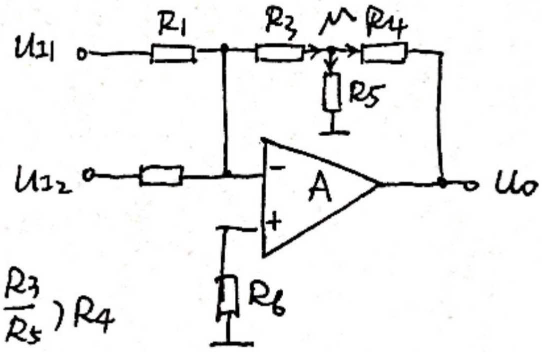
$u_{P2} = u_{N2} = \frac{R_1}{R_1+R_2}u_O$

对A1列式：有 $\frac{R_1}{R_1+R_2}u_O = \frac{R_f}{R}(u_{I2}-u_{I1})$

得 $u_O = (1+\frac{R_2}{R_1})10(u_{I2}-u_{I1})$

(2) 令 $u_O = \frac{10k\Omega}{R_{1min}}\times 10(20mV-0) = 14V$ 得 $R_{1min}=143\Omega$ 则 $R_{2max}=9.86k\Omega$

0 求解运算关系



(1) $u_M = -R_3(\frac{u_{I1}}{R_1}+\frac{u_{I2}}{R_2})$

$I_4 = I_3 - I_5 = \frac{u_{I1}}{R_1}+\frac{u_{I2}}{R_2}-\frac{u_M}{R_5}$

⇒ $u_O = u_M - I_4R_4$

$= -R_3(\frac{u_{I1}}{R_1}+\frac{u_{I2}}{R_2}) - (\frac{u_{I1}}{R_1}+\frac{u_{I2}}{R_2})(1+\frac{R_3}{R_5})R_4$

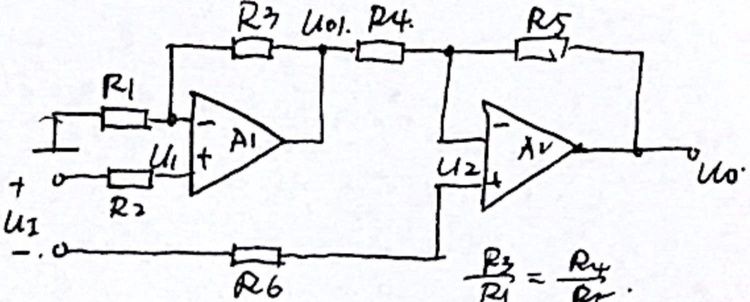
$= -(R_3+R_4+\frac{R_3R_4}{R_5})(\frac{u_{I1}}{R_1}+\frac{u_{I2}}{R_2})$

注意：此电路与上题有区别。上题中A_2同相端无电流，有$u_O=\frac{R_1}{R_1+R_2}u_{P2}$关系，该题中$R_4$、$R_5$中电流不相等，$u_M = \frac{R_5}{R_4+R_5}u_O$不成立，是分流的关系不是分压。

(2) 令 $u_I = u_1 - u_2$.

对A_1有：$u_{o1} = (1+\frac{R_3}{R_1})u_1$

对A_2有：



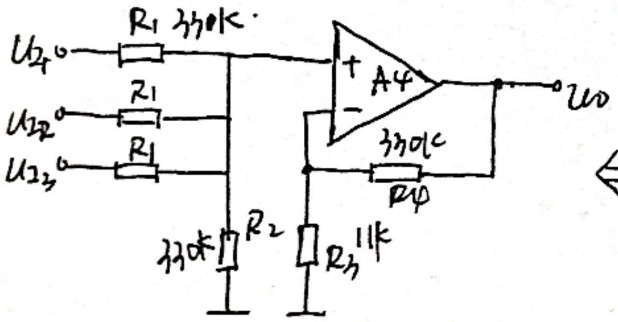
$\frac{R_3}{R_1} = \frac{R_4}{R_5}$.

$$u_o = -\frac{R_5}{R_4}u_{o1} + (1+\frac{R_5}{R_4})u_2$$

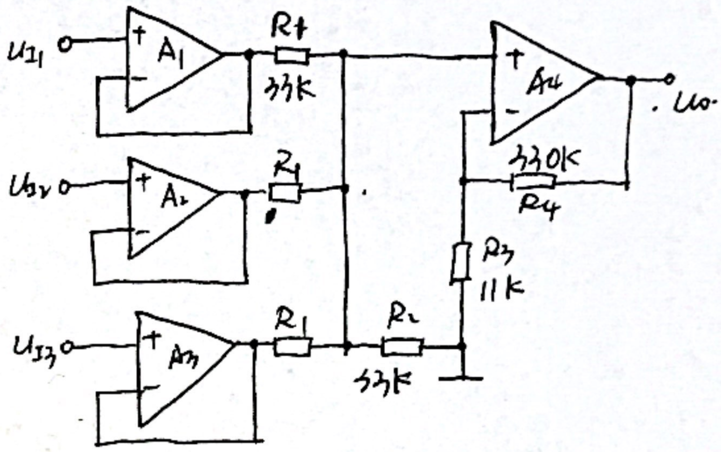
$$= -\frac{R_5}{R_4}(1+\frac{R_3}{R_1})u_1 + (1+\frac{R_5}{R_4})u_2 = (1+\frac{R_5}{R_4})(u_2-u_1) = (1+\frac{R_5}{R_4})u_I.$$

注意 A_2 同相端反相端均有输入..

(7).



⇐



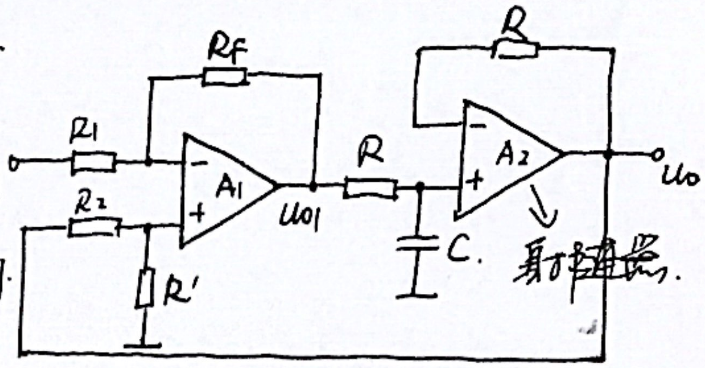
电路可转化为左边所示电路，且 $\frac{R_N}{R_P} = \frac{11K//330K}{11K//330K} = 1$.

所以 $u_o = \frac{R_4}{R_1}(u_{I1}+u_{I2}+u_{I3}) = 10(u_{I1}+u_{I2}+u_{I3})$.

° $R_1=R=R'=R_2=R_f=100k\Omega$. $C=1\mu F$.

(1) 求 u_o、u_I 运算关系.

(2) t=0时 $u_o=0$. u_I 由0跃变为-1V. 求输出电压由0上升到+6V所需时间.



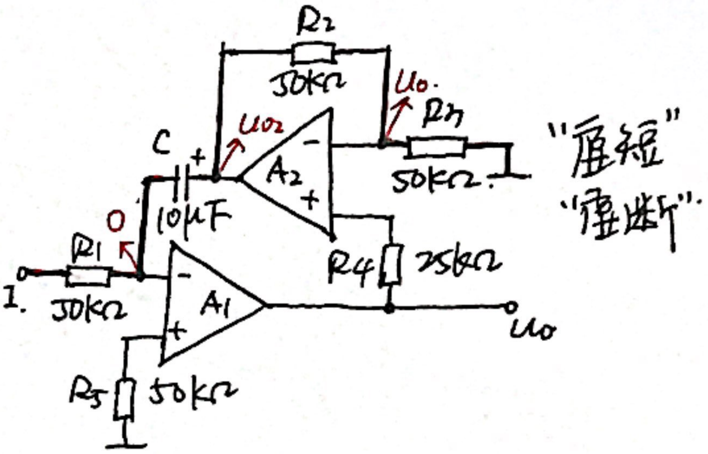
⇒(1) $u_{o1}=u_o-u_I$ (A1).

对A2有: $u_o=u_c=\frac{1}{C}\int I_c dt$, $I_c=\frac{u_{o1}-u_-}{R}=\frac{u_{o1}-u_c}{R}=-\frac{u_I}{R}$.

则 $u_o=\frac{1}{C}\int -\frac{u_I}{R}dt=-\frac{1}{RC}\int u_I dt=-10\int u_I dt$.

(2) 由(1)有: $u_o=-10u_I t$ ⇒ $10t=6$ ⇒ $t=$ ~~6s~~ $0.6s$.

° 求出 u_o、u_I 运算关系.



⇒ $u_{o2}=(1+\frac{R_2}{R_3})u_o=2u_o$

$u_{o2}=-u_c=-\frac{1}{C}\int I_c dt$

$=-\frac{1}{C}\int\frac{u_I}{R_1}dt=-\frac{1}{RC}\int u_I dt$

$=-2\int u_I dt$

⇒ $u_o=-\int u_I dt$

° $u_{I1}=4V$、$u_{I2}=1V$.

(1) 开关S闭合时. 求A、B、C、D、u_o电压.

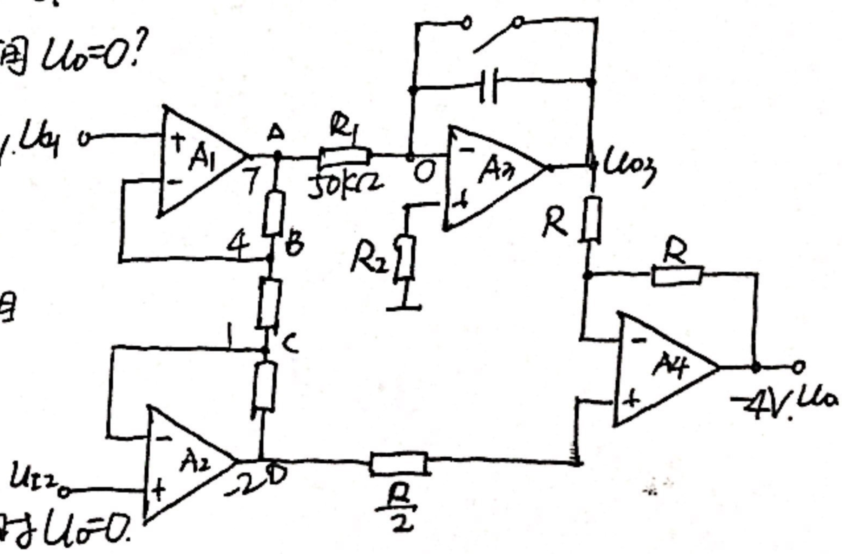
(2) t=0时S打开, 经过多长时间 $u_o=0$?

⇒(1) A、B、C、D 依次为7、4、1、-2V. u_o为-4V.

(2) S打开时. A4相当于有了反相端输入. 进行减法运算.

$u_o=2u_D-u_{o3}$.

又 $2u_D$ 恒为-4V. 则 $u_{o3}=-4V$时 $u_o=0$.



对A3分析: A3进行积分运算: $u_{o3}=-\frac{1}{R_1C}\int u_A dt=-\frac{1}{R_1C}u_A t=-4$.

⇒ $t=\frac{4R_1C}{u_A}=28.6ms$.