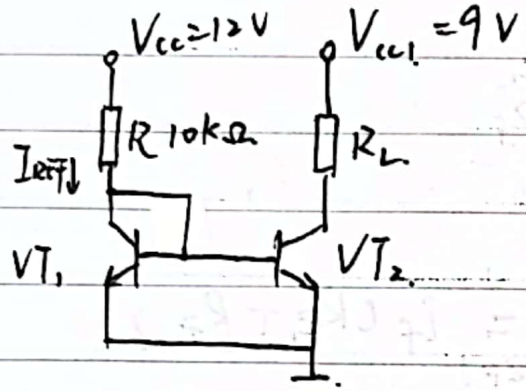
第七章 集成运放

7.1. 1) 假如是理想的电流镜，求其输出电阻及输出电流 I_o。2) 如果 $R_L=10k\Omega$，试求其输出电流 I_o。3) 如果 $R_L=1k\Omega$，试求其输出电流 I_o。



$U_{BE1}=U_{BE2}=0.6V$.

$\beta_1=\beta_2=50$. $r_{ce1}=r_{ce2}=100k\Omega$.

1) $r_o=r_{ce2}=100k\Omega$.

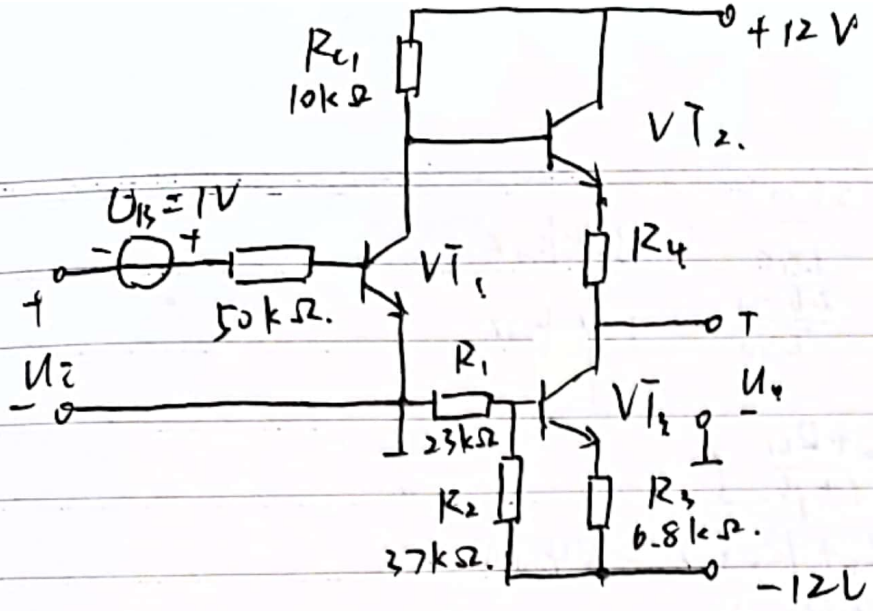
$I_o=\dfrac{V_{cc}-U_{BE}}{R}=1.14mA$

2) V_{T2} 饱和区. $I_o=\dfrac{V_{cc}}{R_L}=0.9mA$

(没有达到放大倍数 $\Rightarrow U_{CE}\to 0$)

3) $I_o=\dfrac{V_{cc}-U_{BE}}{R}=1.14mA$.

题 7.5. 设所有三极管 $\beta=50$, $U_{BE}=0.6V$ $r_{ce}=100k\Omega$, 同时要求输入为零时输出为零 1) R_4 阻值. 2) 放大电路的静态工作点. 3) 放大电路的源电压放大倍数. 输入输出电阻



1. $U_{B3} = -12 \times \frac{23}{37+23} = -12 \times \frac{23}{60} = -4.6V$

$I_{E3} = \frac{U_{B3} - U_{BE} + 12}{R_3} = 1mA \approx I_{C3}$

$I_{B1} = \frac{U_B - U_{BEQ}}{50k} = 8 \times 10^{-6} A = 8\mu A$

$I_{C1} = \beta I_{B1} = 50 \times 8 = 0.4mA$

$U_{C1Q} = 12 - 10k \times 0.4m = 8V$

$\approx U_{B2Q}$

$U_{E2Q} = U_{B2Q} - U_{BE} = 8 - 0.6 = 7.4V$

零输入零输出

$\frac{U_{E2Q}}{R_4} = I_{E2Q} = I_{C3Q} = 1mA$

$\Rightarrow R_4 = 7.4k\Omega$

2). VT_1 $I_{B1Q} = 8\mu A$ $U_{CE1} = 8V$

VT_2 $I_{B2Q} = \frac{1mA}{50} = 20\mu A$ $U_{CE2} = 12 - 7.4 = 4.6V$

VT_3 $I_{B3Q} = \frac{1mA}{50} = 20\mu A$ $U_{CE3} = 0 - (-12 + 6.8 \times 1)$

$= 5.2V$

3) $r_{be1} = r_{bb'} + (1+\beta)\frac{26mV}{I_{E1Q}} = 3.4k\Omega$.

$r_{be2} = r_{bb'} + (1+\beta)\frac{26mV}{I_{E2Q}} = 1.4k\Omega$.

$R_i = r_{be1} = 3.4k\Omega$

$R_o = r_{ce} // [R_4 + \frac{r_{be2}+R_{c1}}{1+\beta}]$

$R_{i2} = r_{be2} + (1+\beta)(R_4 + R_{o3}) = 5478\Omega$

$A_{us1} = -\frac{\beta(R_{c1} // R_{c2})}{r_{be1} + R_s}$

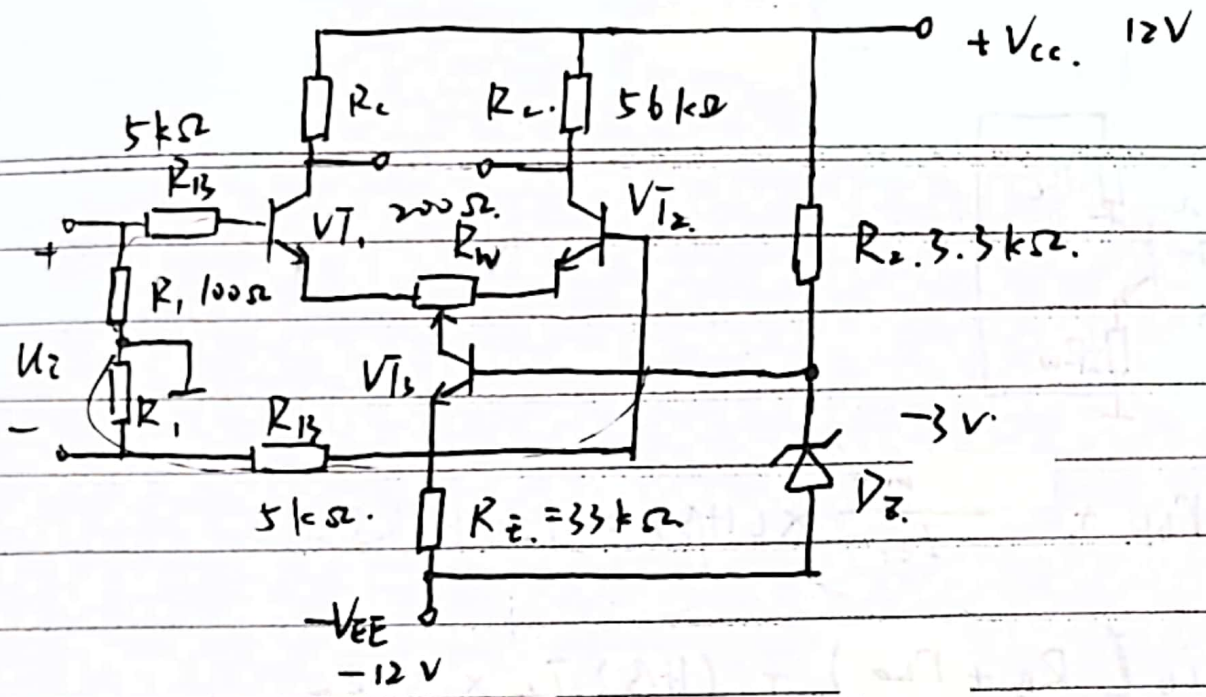
$\therefore A_{us1} = -9.1$

$A_{u2} = \frac{(1+\beta)R_{o3}}{r_{be2} + (1+\beta)(R_4 + R_{o3})} = 0.96$

$A_u = A_{u1} \cdot A_{u2} = -8.73$

$A_{us} = \frac{R_s}{R_s + r_{be1}} A_u = -8.14$

7.8 如图所示的差分放大电路 $V_{cc} = V_{EE} = 12V$，$R_{B3} = 5k\Omega$. $R_C = 56k\Omega$ $R_E = 33k\Omega$ $R_1 = 100\Omega$ $R_2 = 3.3k\Omega$. $R_W = 200\Omega$，其滑动端调在中点，稳定管的稳定电压为9V，各晶体管的 β 值均为50. $r_{bb'} = 200\Omega$，$U_{BE} = 0.6V$ 求 (1) 各晶体管的静态工作点、(2) 差模电压放大倍数 A_{ud} 和差模输入电阻 R_{id} (不计 R_1 影响)



1). $I_{E3} = \frac{(-3) - 0.6 - (-12)}{R_E} = \frac{8.4}{33\times10^3} = 254.5\,\mu A$

$I_{C3} \approx I_{E3} = 254.5\,\mu A$.

$I_{E1} = I_{E2} = \frac{1}{2} I_{C3} = 127.27\,\mu A$.

$\Rightarrow I_{B1} = I_{B2} = \frac{I_{E1}}{50} = 2.545\,\mu A$

$U_{B1} = (100 + 5\times10^3) \times I_{B1} = 12.98\,mV$.

$U_{C1} = 12 - 56\times 127.27\times10^{-3} = 4.88\,V$

$U_{CE1} = U_{CE2} = U_{C1} - U_{B1} + U_{B1E}$

$= 4.88 - 12.98\times10^{-3} + 0.6 = 5.467\,V$

$U_E = 4.88 - 5.467 = -0.587\,V$

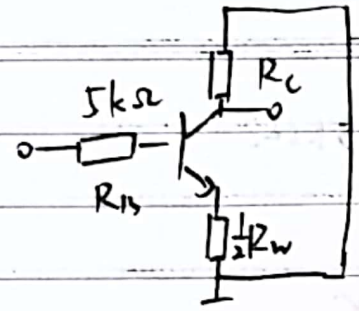
$U_{C3} = -0.587 - 254.5\times100\times10^{-6}$

$= -0.61245\,V$

$U_{CE3} = +3.6 - 0.61245 \approx 2.99\,V$

2) $\begin{cases} I_{B1} = I_{B2} = 2.545\,\mu A \\ U_{CE1} = U_{CE2} = 5.467\,V \end{cases}$ $\begin{cases} I_{C3} = 254.5\,\mu A \\ U_{CE3} = 2.99\,V \end{cases}$

2).



$$r_{be} = r_{bb'} + \frac{26mV}{I_{E1}} \times (1+\beta) = 10.6\,k\Omega.$$

$$u_i = i_b\left(R_B + r_{be}\right) + (1+\beta) i_b \times \frac{1}{2} R_W$$

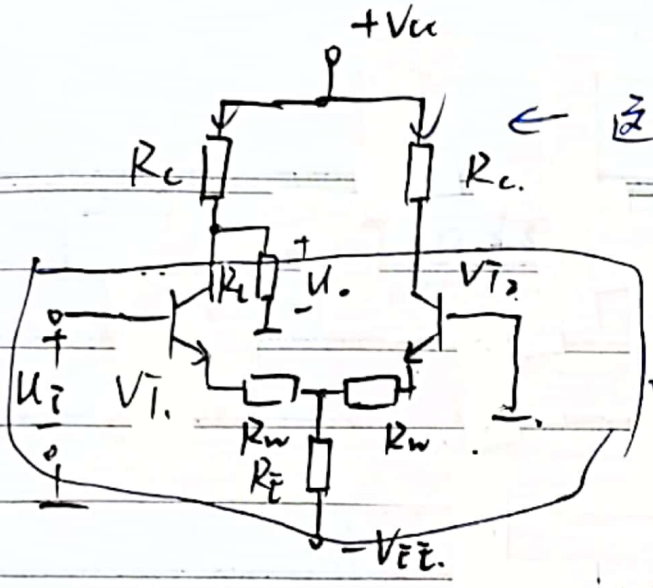
$$u_o = 0 - \beta i_b R_C.$$

$$\Rightarrow A_{ud} = \frac{u_o}{u_i} = \frac{-\beta R_C}{R_B + r_{be} + \frac{1+\beta}{2} R_W} = -136.9$$

$$R_{id} = 2\frac{u_i}{i} = \frac{(R_B + r_{be} + \frac{1+\beta}{2} R_W) i_b}{i_b} \times 2.$$

$$= 41.4\,k\Omega$$

题7.9 $\beta = 80$ $r_{be} = 1k\Omega$，电阻 $R_C = R_L = 10k\Omega$，$R_E = 20k\Omega$，$R_W = 100\Omega$，$V_C = V_{EE} = 12V$ (1)求静态工作点 2)画出差模等效电路计算放大倍数、差模输入、输出电阻 3)画出共模等效电路并计算共模电压倍数和共模输入电阻 4)求共模抑制比 K_{CMR}



← 这两边电流不一样

← 只有这一块对称

(1) 相当于两个放大电路并联对打

$U_E = 0 - 0.6 = -0.6V$

$I_{EQ} \approx \frac{-0.6+12}{\frac{1}{2}\times 100 + 20\times 10^3} \approx 568.58\ \mu A$

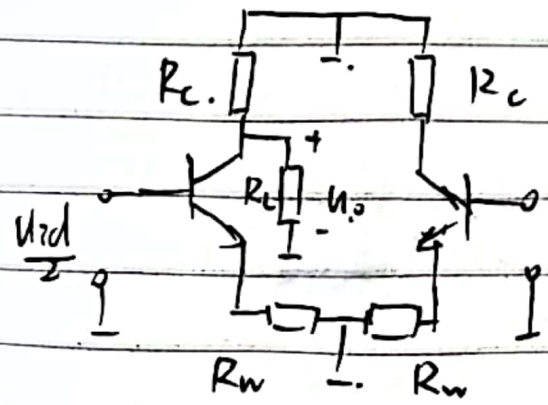
$U_{C_1Q} \approx 12 - \frac{1}{2}\times 10\times 10^3 \times 568.58\times 10^{-6} \approx 9.157V$

$\begin{cases} U_{CE_2} = 9.157 - (-0.6) = 9.757V \\ I_{E_2} = \frac{1}{2} I_{EQ} = 284.29\ \mu A \end{cases}$

$\frac{U_{C1}}{R_L} + I_{C_1} \approx \frac{V_{CC} - U_{C_1}}{R_C} \Rightarrow U_{C_1} = 4.575V$

$U_{CEQ} = U_{C1} - (-U_{BE}) = 3.975V$

(2)



$\frac{U_{id}}{2} = i_b r_{be} + (1+\beta) i_b R_w$

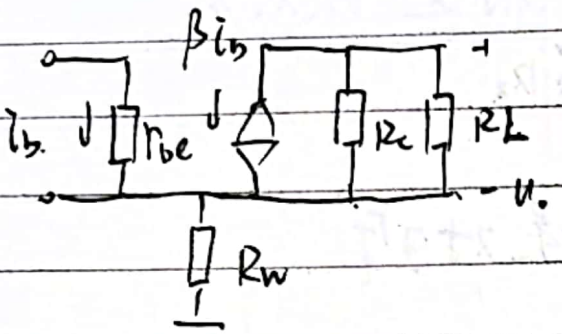
$\frac{U_{C1}}{R_L} + I_{C_1} = \frac{0 - U_{C_1}}{R_C}$

$U_o = U_{C_1} = -\frac{\beta i_b}{\frac{1}{R_L} + \frac{1}{R_C}} = -\frac{\beta R_C R_L}{R_C + R_L} i_b$

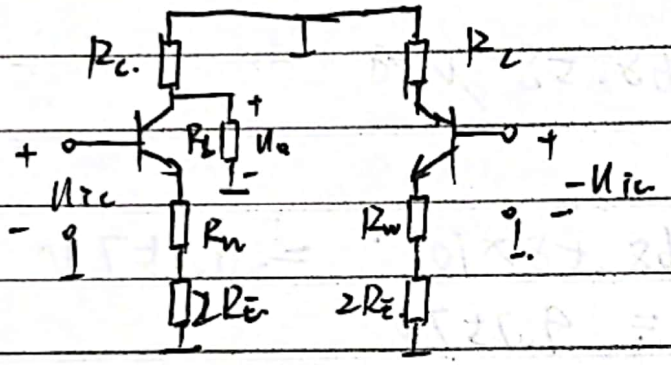
$A_{ud} = \frac{-\beta R_C R_L}{2 r_{be}(R_C + R_L) + 2(1+\beta) R_w} = -21.98$

$R_i \approx 2r_{be} + 2(1+\beta)R_w = 18.2k\Omega$ 这里是 $\frac{U_{id}}{i}$

$R_o \approx R_c = 10k\Omega$



(3).



$u_{ic} = i_b r_{be} + (1+\beta) i_b (R_w + 2R_E)$

$u_o = -\beta i_b \times (R_c // R_L)$

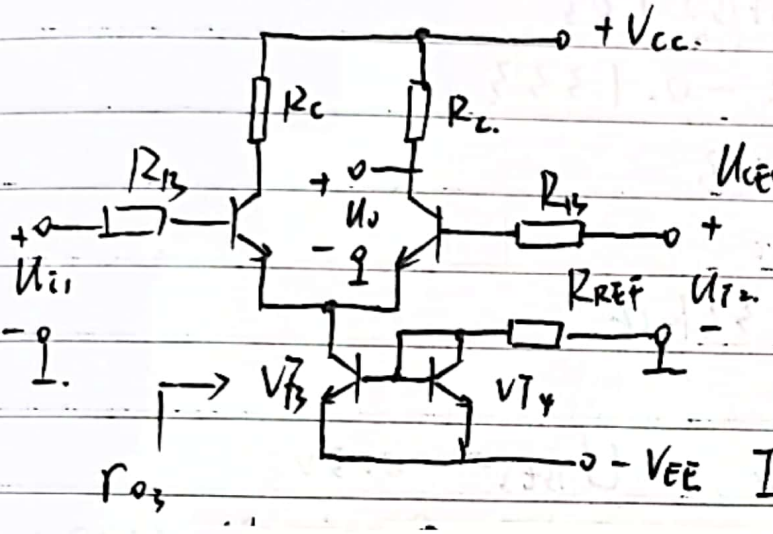
$A_{uc} = \frac{u_o}{u_{ic}} \approx -\frac{\beta(R_c // R_L)}{r_{be} + (1+\beta)(R_w + 2R_E)} \approx -0.125$

$R_i = r_{be} + (1+\beta)(R_w + 2R_E) \approx 3.25M\Omega$

(4) 共模抑制比.

$K_{CMR} = \left|\frac{A_{ud}}{A_{uc}}\right| = 175.84$

7.10. 如图所示的差分放大电路中 $\beta=80$ $r_{bb'_1}=r_{bb'_2}=100$
$U_{BE}=0.6V$ $r_{ce3}=r_{ce4}=100k\Omega$. $V_{CC}=V_{EE}=12V$ $R_{B1}=1k\Omega$
$R_C=27k\Omega$. $R_{REF}=47k\Omega$. (1) 直流工作点 (2) 差模增益.
共模抑制比 K_{CMR} 和输入电阻



(1)
$U_{CE4}=U_{C4}-U_{E4}=U_{B4}-U_{BE4}$
$=0.6V$
$U_{E4}=-12V$
$U_{B4}=-11.4V$
$I_{C3}=I_{C4}=\frac{0-(-11.4)}{R_{REF}}=242.55\mu A$

到这一步 U_{CE3} 不好算出?

$I_{E1}=I_{E2}=\frac{1}{2}I_{C3}=121.3\mu A$
$I_{B1}=I_{B2}=1.52\mu A$
$U_{B1}=U_{B2}=1.516mV$
$U_{C1}=U_{C2}=12-121.3\times.27\times10^{-3}=8.725V$
$U_{CE1}=U_{CE2}=8.725-1.516\times10^{-3}+0.6=9.36V$

2) $\frac{U_{id}}{2}=i_b\times(r_{be}+R_{B1})$
$U_o=-\beta i_b R_C$ $\Rightarrow A_{ud}=\frac{-\beta R_C}{2(r_{be}+R_{B1})}$
$r_{be}=r_{bb'}+\frac{26mV}{1.52\mu A}=17.21k\Omega$

$\Rightarrow A_{ud}=-\frac{80\times.27\times10^3}{2\times(17.21\times10^3+10^3)}=-59.31$

$u_{ic} = i_{b3} \times (R_{B3} + r_{be}) + 2(1+\beta) i_b r_{o3}$

$u_o = \beta i_b R_c$

$\Rightarrow A_{uc} = \dfrac{\beta R_c}{R_{B3} + r_{be} + 2(1+\beta) r_{o3}}$

$r_{o3} = r_{ce3} \Rightarrow A_{uc} = -0.1332$

$K_{CMR} = \left| \dfrac{A_{ud}}{A_{uc}} \right| = 445.3$

$R_i = 2(R_{B3} + r_{be}) = 37 k\Omega$

7.16 $U_{BE1} = U_{BE2} = U_{BE4} = 0.6V$ $U_{BE3} = -0.3V$

$\beta_1 = \beta_2 = \beta_4 = 100$ $\beta_3 = 80$ (1) 设电阻 R_{B1} 和 R_{B2} ($1k\Omega$) 上的压降可忽略，求静态时 I_{C2} 的值 (2) 设 $R_{C2} = 6.8 k\Omega$，求 I_{C2} 的值 (3) 求放大电路的闭环电压放大倍数，判断放大电路的同相反相端 (4) 零输入时零输出，求 R_{C2} 的值 (5) 若要求输入电阻高，输出电阻低，其中的接法应该如何变动？求闭环电压放大倍数

(1) $U_E = 0 - 0.6 = -0.6V$ $I_{EE} = \dfrac{-0.6+12}{5.7 \times 10^3} = 2 mA$

$I_{E1} = I_{E2} = \frac{1}{2} I_{EE} = 1 mA = I_{C1} = I_{C2}$

(2) $U_{C2} = 12 - 6.8 \times 1 = 5.2V = U_{B3}$

$U_{E3} = 5.2 + 0.3 = 5.5V$

$I_{E3} = \dfrac{12 - 5.5}{3.3} = 1.97 mA \approx I_{C3}$

(3) 电压并联负反馈

$A_{uf} = -\dfrac{R_F}{R_{S1}} = -8.2$ 看PPT推导

也忽略 R_{b3} 的压降了.

(4) $I_{E4} = \frac{12}{12k} = 1mA$ ← 这里为啥不考虑反馈电阻上电流

$U_{B4} = 0.6V$ $I_{C3} = \frac{12+0.6}{4.2k} = 3mA$

$U_{E3} = 12 - 3.3 \times 3 = 2.1V$ $U_{B3} = 2.1 - 0.3 = 1.8V$

$I_{E1} = 1mA$ $\frac{12-1.8}{R_{C2}} = 1mA$

$\Rightarrow R_{C2} = 10.2k\Omega$ VT_1 同相 VT_2 反相

(5) 输入高 $\Rightarrow$ 串联 $\Rightarrow$ 负反馈

输出低 $\Rightarrow$ 电压

R_F 接到 VT_2 的基极上 ← 负? 正?

$A_f = \frac{1}{F} = 9.2$

7.18 $U_{BE} = 0.6V$ (1) 求直流工作点 (2) 假使电路为负反馈, 标出运放A的同相端和反相端 (3) 判断引入负反馈的类型, 并求闭环电压放大倍数 (4) 假如反馈电阻 R_F 的一端断开与节点 P_2 的连接并连接到节点 P_1 处, 重求解 (1) (2) (3)

(1) $U_{B3} = -12 + \frac{6}{24+6} \times 24 = -12 + 4.8 = -7.2V$

$U_{E3} = -7.2 - 0.6 = -7.8V$

$I_{E3} = \frac{-7.8+12}{6.8} = 0.618mA$

$I_{E1} = I_{E2} = \frac{1}{2} I_{C3} = 0.309mA$

$U_{CEQ1} = U_{CEQ2} = 12 + U_{BE} - R_{C1} I_{CQ} = 7.672V$

(2) 上正 下负

(3) 电压 串联负反馈 $U_f = \frac{1}{1+10} U_o = \frac{1}{11} U_o$ $F = \frac{1}{11}$

$\Rightarrow A = 11$

M1 ① 不变 ② 上负下正

③ 电压并联负反馈 $A_{uf} = -\frac{R_F}{R_{B1}} = -10$

第八章

8.1 a) 不能 $\varphi_A = 180°$ $\varphi_F = -90° \sim 90°$

b) 不能 $\varphi_A = 180°$ $\varphi_F = -90° \sim 90°$

8.2 (1) 满足 $\varphi_A = 0°$ $\varphi_F = -90° \sim 90°$

(2) 电压并联负反馈

$A_f = 1 + \frac{R_F}{R_E} = 1 + \frac{4.7}{2.7} = 2.74 < 3$ 不满足

(3) $f = \frac{1}{2\pi RC} = 53kHz$ 改变 R 和 C.

(4) 为了满足起振条件 $R_F > 2R_E$

并且满足稳幅 ⇒ 负温度系数的 R_F

8.4 a) 不能 $\varphi_A = -180°$ $\varphi_F \in (0, 180°)$ 开区间

b) 不能 $\varphi_A = 0$ $\varphi_F = 0 \sim -270°$ 开区间

8-5 a) 不能. 电感三点式 但静态工作点有问题

在反馈至射极的通路中加入隔直电流

b) 不能 互换 C_1 和 L 电容三点式

c) 不能 互换 C_1 和 L