國立臺灣科技大學答案卷

National Taiwan University of Science and Technology Answer Sheet

評分 Score	教師簽章 Signature of Lecturer
98	

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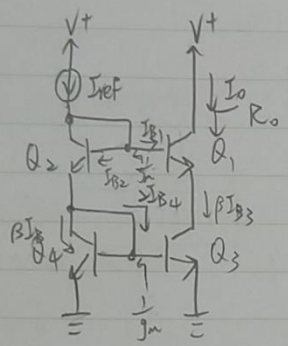
科目/Course title 電子學 日期/Date 112.6.7

記分欄

從此處開始寫起。試卷用紙務須節用，非經主試認可不得續用其他紙張作答。/Please write from here.

1.



$\frac{I_o}{I_{ref}} = ?$

$I_{E2} = (1+\beta) I_{B4} \Rightarrow I_{C2} = \alpha I_{E2} = \frac{\beta}{1+\beta} \cdot (1+\beta) I_{B4} \Rightarrow I_{B2} = \frac{1+\beta}{1+\beta} I_{B4}$ —(2)

$I_{B4} = I_{B3} \Rightarrow I_{C3} = \beta I_{B4} \Rightarrow I_o = I_{C1} = \alpha I_{E1} = \alpha I_{C3} = \frac{\beta}{1+\beta} \cdot \beta I_{B4}$ —(5)

$\Rightarrow I_{B1} = \frac{I_{C1}}{\beta} = \frac{\beta}{1+\beta} I_{B4}$ —(3)

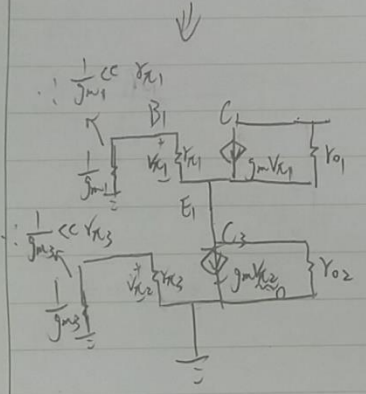
$\Rightarrow I_{ref} = I_{C2} + I_{B2} + I_{B1} = \frac{\beta}{1+\beta} \cdot (2+\beta) I_{B4} + \frac{1+\beta}{1+\beta} I_{B4} + \frac{\beta}{1+\beta} I_{B4}$ —(4)

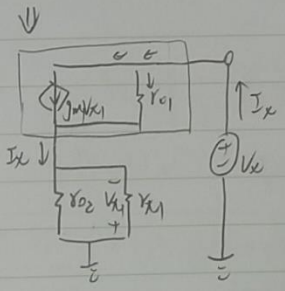
(by (1) by (2) by (3))

by (4) (5) $\Rightarrow \frac{I_o}{I_{ref}} = \frac{\frac{\beta}{1+\beta} \cdot \beta}{\frac{\beta}{1+\beta} \cdot (2+\beta) + \frac{1+\beta}{1+\beta} + \frac{\beta}{1+\beta}} = \frac{\beta^2}{(2+\beta)\beta + 2 + 2\beta} = \frac{1}{1 + \frac{4}{\beta} + \frac{2}{\beta^2}}$ #1.

$= 2\beta + \beta^2 + 2 + 2\beta$

$= \beta^2 + 4\beta + 2$





$V_x = r_{o1}(I_x - g_{m1} v_{\pi 1}) + I_x (r_{o2} // r_{\pi 1})$ —(1)

$v_{\pi 1} = -I_x$

$v_{\pi 1} = -I_x (r_{\pi 1} // r_{o2})$ —(2)

Subs. (2) into (1):

$V_x = r_{o1}\left(I_x + g_{m1} I_x (r_{\pi 1} // r_{o2})\right) + I_x (r_{o2} // r_{\pi 1})$

$I_x (1 + g_{m1} (r_{\pi 1} // r_{o2}))$

$\Rightarrow R_o = \frac{V_x}{I_x} = r_{o1}(1 + g_{m1}(r_{\pi 1} // r_{o2})) + (r_{o2} // r_{\pi 1})$

$= r_{o1} + g_{m1} r_{o1} (r_{\pi 1} // r_{o2}) + (r_{o2} // r_{\pi 1})$

$(r_{\pi 1} // r_{o2}) \doteq r_{\pi 1}$, $(r_{o2} // r_{\pi 1}) \doteq r_{\pi 1}$

$\doteq r_{o1} + g_{m1} r_{o1} r_{\pi 1}$

$\doteq \beta r_{o1}$ #1

可轉頁再寫。

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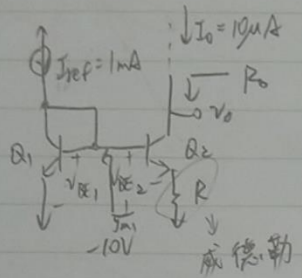
$\frac{2^3}{2^2} = \frac{8}{4} = 2^{3-1}$

2.



(a) $I_{ref}=1m$, $I_0=10\mu$, $\beta=100$, $R=?$

$I_{ref} \doteq I_{C1} \doteq I_S \cdot e^{\frac{V_{BE1}}{V_T}}$

$I_0 = I_{C2} = I_S \cdot e^{\frac{V_{BE2}}{V_T}}$

$\Rightarrow \frac{I_{ref}}{I_0} = e^{\frac{V_{BE1}-V_{BE2}}{V_T}} \Rightarrow V_T \ln\left(\frac{I_{ref}}{I_0}\right) = V_{BE1}-V_{BE2}$ —(1)

$\Rightarrow 26m \cdot \ln\left(\frac{10^{-3}}{10^{-5}}\right) = I_{E2}R = \frac{\beta+1}{\beta} I_0 \cdot R = \frac{101}{100}\cdot 10^{-5}$

$\Rightarrow R = \frac{26m \cdot \ln(10^2)}{\frac{101}{100}\cdot 10^{-5}} \doteq 11.85\,k\Omega$ #2(a)

(b) $V_A=100V$, $R_0=?$

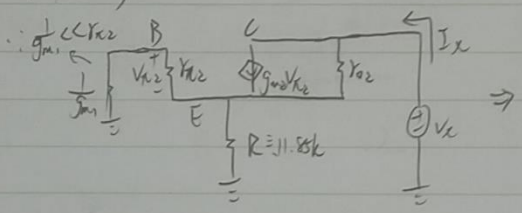
DC Analysis:

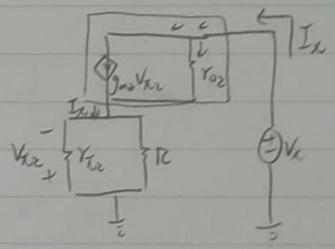
$r_{o2} = \frac{V_A}{I_{CQ2}} = \frac{10^2}{10^{-5}} = 10^7\,\Omega$, $r_{\pi 2} = \frac{V_T}{I_{BQ2}} = \frac{26m}{\frac{10\mu}{100}} = 260k\Omega$, $\beta = g_{m2}r_{\pi 2}$

$\Rightarrow g_{m2} = \frac{\beta}{r_{\pi 2}} \doteq 0.3846\,mS$

AC Analysis:

$\because \frac{1}{g_{m1}} \ll r_{\pi 2}$





$V_x = r_{o2}(I_x - g_{m2}V_{\pi 2}) + I_x(r_{\pi 2} /\!/ R)$

$V_{\pi 2} = -I_x(r_{\pi 2} /\!/ R)$

$= r_{o2}\left(I_x + g_{m2}I_x(r_{\pi 2} /\!/ R)\right) + I_x(r_{\pi 2} /\!/ R)$

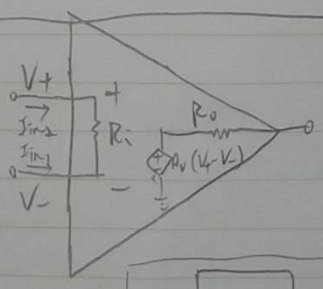
$= r_{o2}I_x + g_m r_{o2} I_x (r_{\pi 2} /\!/ R) + I_x(r_{\pi 2} /\!/ R)$

$\Rightarrow R_o = \frac{V_x}{I_x} = \underbrace{r_{o2}}_{10M\Omega} + g_{m2}r_{o2}\underbrace{(r_{\pi 2} /\!/ R)}_{=260k /\!/ 11.85k \doteq 11.33k\Omega} + \underbrace{(r_{\pi 2} /\!/ R)}_{\doteq 0.3846m} \doteq 53.60\,M\Omega$ #2(b)

(c) $\Delta V_0 = 1V$, $\Delta I_0 = ?$

$\Delta V_0 = R_o \cdot \Delta I_0 \Rightarrow 1 = 53.60M \cdot \Delta I_0 \Rightarrow \Delta I_0 \doteq 18.66\,nA$ #2(c)

3.



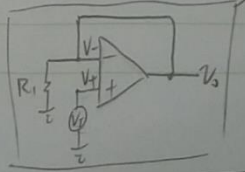
理想 OPA,

$R_i=\infty$, $R_o=0$, $A_v=\infty$, B.W. $=\infty$, $I_{in2}=I_{in1}=0$

$A_v=\infty \Rightarrow V_o = A_v(V^+ - V^-) = A_v(V_i - V_o) \Rightarrow (1+A_v)V_o = A_v V_i \Rightarrow V_o = V_i = V_+ = V_-$ 虛短路

$CMRR = \frac{A_d(單)}{A_{cm}(單)} \approx \infty$

$CMRR \geq \sim 2$



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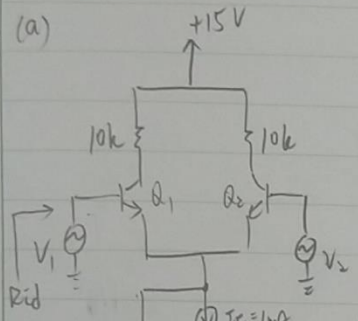
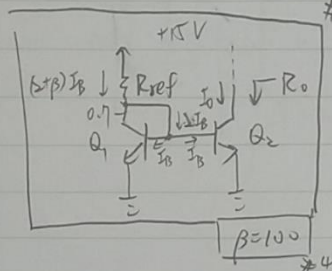
4. (a)



I_E之功能為為電晶體Q_1、Q_2提供直流偏壓電流，此種偏壓方式能使電壓增益受電晶體β的影響程度降至最低
R_E為非理想電流源之輸出阻抗，它可以提供溫度補償的功能，使電晶體更不易發生熱跑脫現象。 #4(a)

(b)



#4(b)

$R_o = r_{o2} = 100k$

設 V_A=100V #4(b)

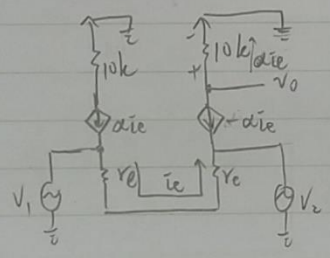
$r_{o2} = \frac{V_A}{I_{CQ_2}} = \frac{10^2}{I_{CQ_2}} = 10^5 \Rightarrow I_{CQ_2} = I_o = 1mA$

$\frac{I_o}{I_{ref}} = \frac{\beta}{1+\beta} = \frac{10^3}{I_{ref}} = \frac{100}{102}$

$\Rightarrow I_{ref} = 10^{-3} \cdot \frac{102}{100} = \frac{14.3}{R_{ref}}$

$\Rightarrow \boxed{R_{ref}} = 14.3 \cdot \frac{1}{10^{-3} \cdot \frac{102}{100}} \doteq \boxed{14.02k\Omega}$ #4(b)

(c)



DC Analysis:

V_1、V_2短路：

AC: $I_{E_1} = I_{E_2} = 0.5mA \Rightarrow r_e = \frac{V_t}{I_{EQ}} = 52\Omega$

設 V_1=正端差分輸入；V_2=負端差分輸入

$v_d = v_1 - v_2 = 2i_e r_e$

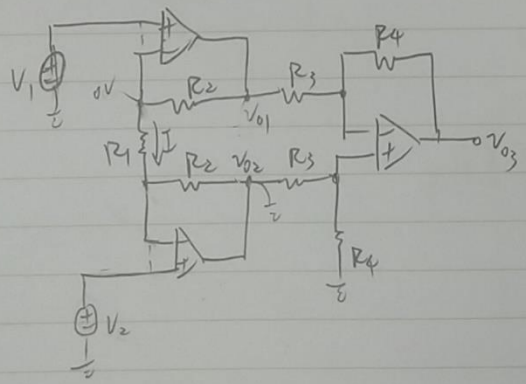
$v_o = 10k \cdot \alpha i_e$

$\Rightarrow \boxed{\frac{v_o}{v_d}} = \frac{10k \cdot \frac{100}{101}}{2r_e} \doteq \boxed{95.20 V/V}$ #4(c)

(d)

$\boxed{R_{id}} = (1+\beta) \cdot 2r_e \doteq \boxed{10.50k\Omega}$ #4(d)

5. (a)



短 V_2：　　短 V_1：

$I = \frac{V_1}{R_1}$　　$I = -\frac{V_2}{R_1}$

$\Rightarrow \boxed{I = \frac{V_1 - V_2}{R_1}}$ #5(a)

短 V_2：　　短 V_1：

$v_{o1} = V_1(1+\frac{R_2}{R_1})$　　$v_{o1} = -V_2 \cdot \frac{R_2}{R_1}$

$v_{o2} = -V_1 \cdot \frac{R_2}{R_1}$　　$v_{o2} = V_2 \cdot (1+\frac{R_2}{R_1})$

$\Rightarrow v_{o1} = V_1(1+\frac{R_2}{R_1}) - V_2(\frac{R_2}{R_1})$

$v_{o2} = V_2(1+\frac{R_2}{R_1}) - V_1(\frac{R_2}{R_1})$

短 v_{o1}：　　短 v_{o2}：

$v_{o3} = v_{o2} \cdot \frac{R_4}{R_4+R_3}(1+\frac{R_4}{R_3})$　　$v_{o3} = v_{o1} \cdot (-\frac{R_4}{R_3})$

$\Rightarrow \boxed{v_{o3}} = v_{o2} \cdot \frac{R_4}{R_4+R_3}(1+\frac{R_4}{R_3}) - v_{o1}(\frac{R_4}{R_3})$ #5(b)

$= \boxed{\left[V_2(1+\frac{R_2}{R_1}) - V_1(\frac{R_2}{R_1})\right] \cdot \frac{R_4}{R_4+R_3}(1+\frac{R_4}{R_3}) - \left[V_1(1+\frac{R_2}{R_1}) - V_2(\frac{R_2}{R_1})\right] \cdot \frac{R_4}{R_3}}$

第二頁

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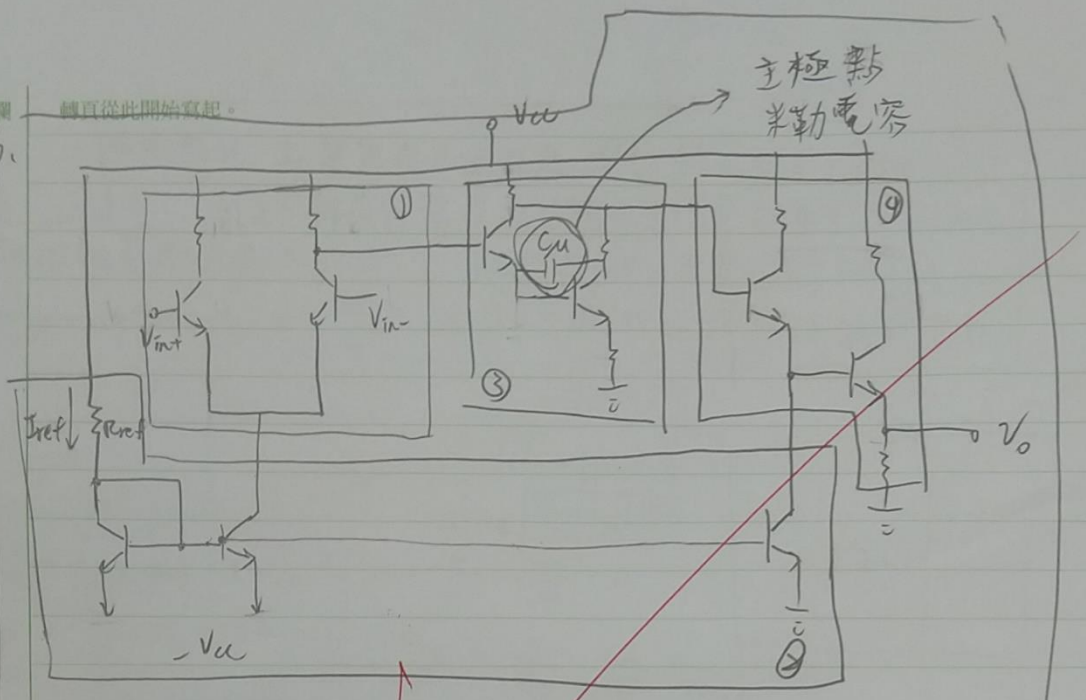
6.



① 差動輸入級：差動信號輸入

② 電流鏡：提供穩定直流偏壓

③ 增益級：提供電壓增益

④ 輸出級：降低輸出阻抗，提供大輸出電流

#6