# 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 |
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| | |

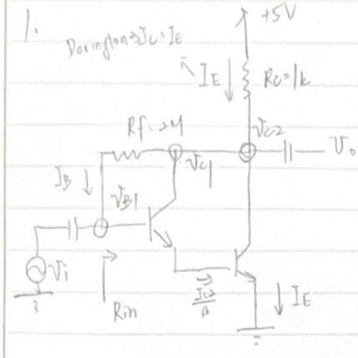
姓名/Name ________ 學號/Student ID ________ 班級/Class ________

科目/Course title ________ 日期/Date ________

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.




$\frac{I_{c2}}{\beta} \ll I_{c2}$

⇒ 達靈頓電路 看成一個大的BJT

$\beta_{達靈頓} = \beta^2 = 100^2 = 10000$

(a)

$V_{c1} = V_{c2} = 5 - R_C \cdot I_E$

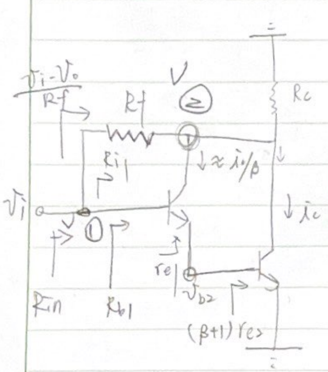
$V_{B1} = 5 - R_C \cdot I_E - R_f\, I_B = 5 - 1k \cdot I_E - 2M \cdot \frac{I_E}{\beta^2} = 5 - I_E\left(1k + \frac{2M}{10000}\right)$

$= 5 - I_E(1.2k)$

又 $V_{B1} = 0.7 + 0.7 = 1.4V$

$\therefore I_E = \frac{5 - 1.4}{1.2k} = \frac{3.6}{1.2k} = 3mA \approx I_{C2}$ #

$I_{B1} = \frac{3m}{\beta^2} = 3 \cdot 10^{-7} A$ # $\therefore I_{C1} = \beta \cdot 3 \cdot 10^{-7} = 3 \cdot 10^{-5} A \approx I_{E1} = I_{B2}$ #




(b)

$V_{b2} = V_i \frac{(\beta+1) r_{e2}}{(\beta+1) r_{e2} + r_{e1}}$

$r_{e2} = \frac{V_T}{I_{E2}} = \frac{25m}{3m} = 8.33\ldots$

$r_{e1} = \frac{V_T}{I_{E1}} \approx \frac{25m}{3 \cdot 10^{-5}} = 833.33\ldots$

$V_{b2} = V_i \frac{101 \cdot 8.33}{101 \cdot 8.33 + 833} \doteq 0.5 V_i$

$i_c = g_{m2} V_{b2} = g_{m2} \cdot 0.5 V_i$

又 $g_{m2} = \frac{I_{C2}}{V_T} = \frac{3m}{25m} = 0.12\ A/V$

$\therefore i_c = 0.12 \cdot 0.5 V_i = \underline{0.06 V_i}$

node equation: ↓代入

$\frac{V_o}{R_C} + i_c + \frac{V_o - V_i}{R_f} + \frac{i_c}{\beta} = 0$

$V_o\left(\frac{1}{1k} + \frac{1}{2M}\right) = -V_i\left[\left(1 + \frac{1}{100}\right) \cdot 60m - \frac{1}{2M}\right]$

$A_v = \frac{V_o}{V_i} = -\frac{\frac{101}{100} \times 60 - \frac{1}{2000}}{1 + \frac{1}{2000}} \doteq -60.57$ #

(c)

$R_{b1} = (\beta+1)\left[r_{e1} + (\beta+1) r_{e2}\right]$

$= 101 \cdot [833 + 101 \cdot 8.33]$

$\doteq 169.107k$

$R_{i1} = \frac{V_i}{(V_i - V_o)/R_f}$

$= \frac{R_f}{1 - (V_o/V_i)}$

$= \frac{2M}{1 + 60.57}$

$\doteq 32.483k$

$R_{in} = R_{b1} \parallel R_{i1}$

$\doteq 27.248k$ #

可轉頁再寫。

For dc analysis, open-circuit the two coupling capacitors. Then replace the 9-V source and the two 20-kΩ resistors by their Thévenin equivalent, namely, a 4.5-V source and a 10-kΩ series resistance. The latter can be added to the 10-kΩ resistor that is connected to the base. The result is the circuit shown in Fig. 1, which can be used to calculate $I_E$.

(a) $I_E = \dfrac{4.5 - 0.7}{2 + \dfrac{20}{\beta + 1}}$

$= \dfrac{3.8}{2 + \dfrac{20}{101}} = 1.73$ mA

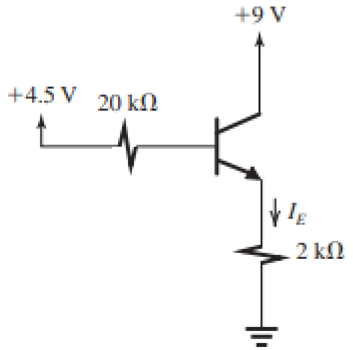



Figure 1

$I_C = \alpha I_E = 0.99 \times 1.73$ mA

$= 1.71$ mA

$g_m = \dfrac{I_C}{V_T} = 68.4$ mA/V

$r_e = \dfrac{V_T}{I_E} = \dfrac{25 \text{ mV}}{1.73 \text{ mA}} = 14.5\ \Omega$

$= 0.0145$ kΩ

$r_\pi = (\beta + 1)r_e = 101 \times 0.0145$

$= 1.46$ kΩ

(b) Replacing the BJT with its $T$ model (without $r_o$) and replacing the capacitors with short circuits results in the equivalent-circuit model shown in Fig. 2.

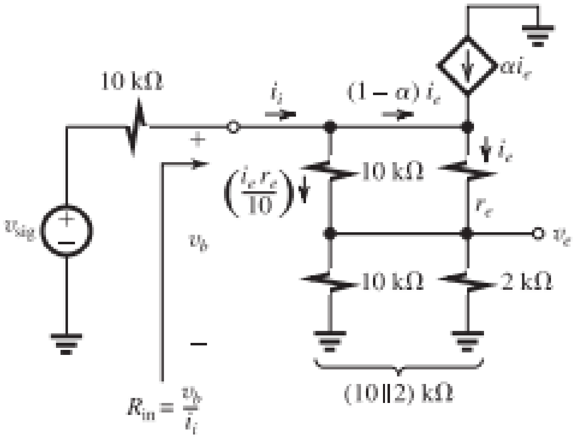



Figure 2

From Fig. 2 we see that

$$v_e = \left(i_e + i_e \frac{r_e}{10}\right)(10 \parallel 2)$$

$$v_b = v_e + i_e r_e = i_e(10 \parallel 2)\left(1 + \frac{r_e}{10}\right) + i_e r_e$$

$$i_i = (1 - \alpha)i_e + i_e \frac{r_e}{10}$$

$$= \frac{i_e}{\beta + 1} + i_e \frac{r_e}{10}$$

We can now obtain $R_{in}$ from

$$R_{in} \equiv \frac{v_b}{i_i} = \frac{(10 \parallel 2)\left(1 + \frac{r_e}{10}\right) + r_e}{\frac{1}{\beta + 1} + \frac{r_e}{10}}$$

$$= \frac{(\beta + 1)(10 \parallel 2)\left(1 + \frac{r_e}{10}\right) + (\beta + 1)r_e}{1 + (\beta + 1)\frac{r_e}{10}}$$

$$= \frac{101 \times (10 \parallel 2) \times (1 + 0.00145) + 101 \times 0.0145}{1 + 101 \times 0.00145}$$

$$= \frac{168.577 + 1.4645}{1 + 0.14645} = 148.3\ \text{k}\Omega$$

$$\frac{v_b}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{148.3}{148.3 + 10} = 0.937$$

$$\frac{v_o}{v_b} = \frac{v_e}{v_b} = \frac{i_e\left(1 + \frac{r_e}{10}\right)(10 \parallel 2)}{i_e\left(1 + \frac{r_e}{10}\right)(10 \parallel 2) + i_e r_e}$$

$$= \frac{1.00145 \times (10 \parallel 2)}{1.00145 \times (10 \parallel 2) + 0.0145}$$

$$= 0.991\ \text{V/V}$$

$$G_v \equiv \frac{v_o}{v_{sig}} = 0.937 \times 0.991 = 0.93\ \text{V/V}$$

(2)

$20 \times \frac{3.5}{16.5+3.5} = 20\frac{3.5}{20} = 3.5\ (V_g)$

$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2 = I_{DSS}\left(1-\frac{V_G-V_S}{V_P}\right)^2$

$= V_S/3k$

$= 12m\left(1+\frac{3.5-V_S}{5}\right)^2 = \frac{V_S}{3k}$

$= 3\cdot 12\left(1+\frac{3.5-V_S}{5}\right)^2 = V_S$

$= 36\left(1.7-0.2V_S\right)^2 = V_S$

$36\cdot\left(2.89-0.68V_S+0.04V_S^2\right) = V_S$

$104.04 - 24.48V_S + 1.44V_S^2 = V_S$

$1.44V_S^2 - 25.48V_S + 104.04 = 0$

$V_S = \frac{25.48\pm\sqrt{25.48^2-4\cdot1.44\cdot104.04}}{2.88} = \frac{25.48\pm\sqrt{49.96}}{2.88}$

$= 11.3$ or $\underline{6.393}$ ✓ ※

$V_{GS} = 3.5-6.4 = -2.9(V)$ ※

$3.5-11.3 = -7.8$ (cutoff) ✗

3.5-6.4

$I_D = 12m\cdot\left(1+\frac{-2.9}{5}\right)$

$= 5.04\ mA$ ※

$r_o = \frac{300}{5.04m} \Rightarrow \frac{v_o}{v_i} = -g_m(R_D // R_L // r_o)$

$g_m \Rightarrow -\frac{2I_{DSS}}{V_P}\left(1-\frac{V_{GS}}{V_P}\right)$

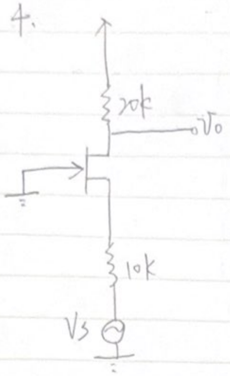
$\Rightarrow -\frac{24m}{-5}\left(1-\frac{-2.9}{-5}\right)$

$-g_m(R_D // R_L // r_o)$

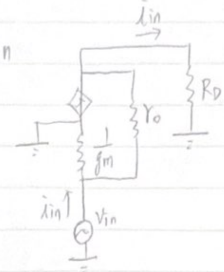
$= -\frac{24m}{5}\cdot0.42\cdot(1.5k // 59.523k)$

$= -2.95$

4.




(b) Rin




$$(i_{in} - g_m v_{in}) r_o + i_{in} R_D = v_{in}$$

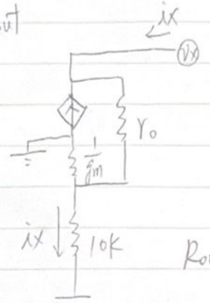
$$i_{in}(r_o + R_D) = v_{in}(1 + g_m r_o)$$

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{r_o + R_D}{1 + g_m r_o} = \frac{100k + 20k}{1 + 2m \cdot 100k}$$

$$= \frac{120k}{201}$$

$$\doteqdot 600\,\Omega \text{ ※}$$

(c) Rout




$$(i_x + g_m i_x \cdot 10k) r_o + i_x \cdot 10k = v_x$$

$$i_x(1 + g_m 10k) r_o + i_x \cdot 10k = v_x$$

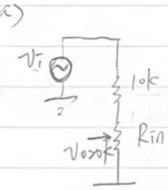
$$R_{out} = \frac{v_x}{i_x} = (1 + g_m 10k) r_o + 10k$$

$$= 100k + 2m \cdot 10k \cdot 100k + 10k$$

$$= 100k + 2000k + 10k$$

$$= 2110k \text{ ※}$$

(a)




$$\frac{v_o}{v_i} = \frac{20k}{10k + R_{in}} = \frac{20k}{10k + 600} \doteqdot 1.89 \text{ ※}$$

$$\frac{g_m r_o + 1}{r_o + g_m r_o \cdot 10k + 20k} \cdot 20k$$

$$= \frac{200 + 1}{100k + 2000k + 20k} \cdot 20k$$

$$= \frac{201}{2120} \times 20 \doteqdot 1.89$$

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(5)

$$5 \times \frac{54.6}{95.4+150+54.6} = 5 \times \frac{54.6}{300} = 0.91 \quad (Q_1 \text{的 } V_g)$$

$I_D \cdot R_S = 0.4m \times 10k = 4 \Rightarrow Q_1$ 的 $V_S = -5+4 = -1$

驗證：$k_n(V_{gs}-V_t)^2 = 0.8(0.91-(-1)-1.2)^2$

$= 0.8 \times (0.71)^2$

$\doteqdot 0.4\,(mA)$ sat

由於 $\lambda = 0$ ∴ $r_o = \infty$

$$\frac{v_o}{v_i} \doteqdot -g_m(R_D \parallel g_m r_o^2) \quad \because r_o = \infty \therefore \frac{v_o}{v_i} \doteqdot -g_m R_D$$

$\doteqdot -g_m R_D$

$= 2 \cdot k_n (V_{gs}-V_t) \cdot R_D$

$= 2 \cdot 0.8m \cdot 0.71 \cdot 2.5k$

$= 2.84$ #

$g_m = 2k_n V_{ov}$

$= \frac{2I_D}{V_{ov}}$

$= 2\sqrt{k_n I_D}$

3種算出來差不多

可轉頁再寫。