# 101 學年四技二專第五次聯合模擬考試
# 電機與電子群　專業科目（一）　詳解

101-5-03-4
101-5-04-4

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | C | A | D | A | D | C | A | C | B | A | D | D | B | C | B | C | C | B | D | A | C | B | D | A |
| 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
| D | D | C | B | A | B | C | B | A | A | D | C | B | A | D | B | C | C | D | A | A | C | C | D | B |

## 第一部份：基本電學

1. $I = Anev$，$I_A = \dfrac{\dfrac{2.5\times10^{19}}{6.25\times10^{18}}}{4} = 1\text{ A}$，$I_B = \dfrac{2}{4} = 0.5\text{ A}$

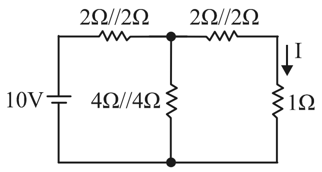
$\therefore \dfrac{v_A}{v_B} = \dfrac{I_A}{I_B} = \dfrac{1\text{ A}}{0.5\text{ A}} = 2$，$\therefore v_A = 2v_B$

2. $H = 0.24\,Pt = ms\Delta T$

$0.24\times500\times0.75\times5\times60 = 1\times1000\times\Delta T$，$\Delta T = 27°C$

$T = 20 + 27 = 47°C$

3. 將電路化簡爲下圖，$I = \dfrac{10}{2}\times\dfrac{2}{2+2} = 2.5\text{ A}$




4. $\because R_1 = \dfrac{R_a\times R_b + R_b\times R_c + R_c\times R_a}{R_c}$

$\therefore 20 = \dfrac{10\times R_b + 15\times R_b + 15\times10}{15}$

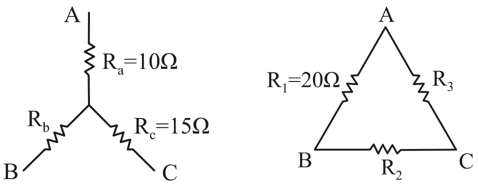
$15\times20 = 25\,R_b + 150$，$R_b = \dfrac{150}{25} = 6\,\Omega$

$R_2 = \dfrac{10\times6 + 6\times15 + 15\times10}{10} = 30\,\Omega$

$R_3 = \dfrac{10\times6 + 6\times15 + 15\times10}{6} = 50\,\Omega$

$R_{AB} = R_a + R_b = 10 + 6 = 16\,\Omega$

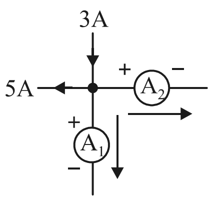
$R_{BC} = R_b + R_c = 6 + 15 = 21\,\Omega$




5. $A_1$與$A_2$依電流方向視爲流出

$3 = 5 + A_1 + A_2$

$A_1 + A_2 = -2\text{ A}$




6. $\begin{cases} 12 = 2(I_1 - I_3) + 5(I_1 - I_2) + 15 \\ 15 = 5(I_2 - I_1) + 3(I_2 - I_3) + I_2 \end{cases}$

$\because I_3 = 2\text{ A}$，$\begin{cases} 7I_1 - 5I_2 = 1 \\ 5I_1 - 9I_2 = -21 \end{cases}$，$I_1 = 3\text{ A}$，$I_2 = 4\text{ A}$

$V_{2\Omega} = 1\times2 = 2\text{ V}$，$V_{3\Omega} = 2\times3 = 6\text{ V}$

7. $R_{TH} = (8\text{ k}//8\text{ k}) + (10\text{ k}//15\text{ k}) = 4\text{ k} + 6\text{ k} = 10\text{ k}$

$E_{TH} = 100\dfrac{15\text{ k}}{15\text{ k}+10\text{ k}} - 100\dfrac{8\text{ k}}{8\text{ k}+8\text{ k}} = 60 - 50 = 10\text{ V}$

$I = \dfrac{10}{10\text{ k}+10\text{ k}} = 0.5\text{ mA}$

8. ① 12 V，$I' = \dfrac{12}{4} = 3\text{ A}$

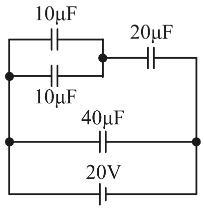
② 2 V，$I'' = \dfrac{-2}{4} = -0.5\text{ A}$

③ 2 A，$I''' = 0\text{ A}$

④ 1 A，$I'''' = -1\dfrac{2}{2+2} = -0.5\text{ A}$

$I_N = I' + I'' + I''' + I'''' = 2\text{ A}$

9. 將電路化簡爲右圖




$Q_{20\mu F} = C\times V$

$= 20\,\mu\times10\text{ V} = 200\,\mu C$

10. $\overline{E} = k\dfrac{Q}{d^2}$，$\overline{E} = \overline{E_1} + \overline{E_2} = 0\text{ N/C}$，$V = k\dfrac{Q}{d}$

$V = V_1 + V_2 = 9\times10^9\dfrac{1\times10^{-9}}{1} + 9\times10^9\dfrac{1\times10^{-9}}{1} = 18\text{ V}$

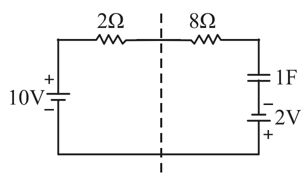
11. $\overline{F} = \dfrac{\mu_o\times\ell\times I_1\times I_2}{2\pi\times d} = \dfrac{4\pi\times10^{-7}\times1\times10\times20}{2\pi\times10^{-2}} = 4\times10^{-3}\text{ N}$

12. $e = B\ell v\sin\theta$，∵導線與移動方向之間角度爲 53°

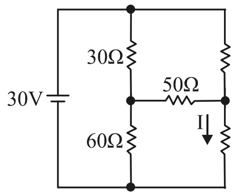
$\therefore e = 20\times10^{-1}\times5\times\sin53° = 8\text{ V}$

13. $\tau = (2+8)\times1 = 10\text{ s}$，$V_c(t) = (-2) + [10 - (-2)](1 - e^{-\frac{t}{10}})$

$= -2 + 12(1 - e^{-0.1t}) = 10 - 12\,e^{-0.1t}\text{ V}$



14. $\because$ L $\Rightarrow$ 短路
C $\Rightarrow$ 開路
$\because$電橋平衡
$\therefore I = \dfrac{30}{20+40} = 0.5$ A




15. $v(t=12.5\text{ mS}) = 100\sqrt{2}\sin(314\times 12.5\text{ m})$
$= 100\sqrt{2}\sin(2\pi\times 50\times\dfrac{1}{80}) = 100\sqrt{2}\sin(\dfrac{5}{4}\pi) = -100$ V

16. $v(t) = 100\sin(377t+30°)$，$i(t) = -10\cos(377t+60°)$
$= 10\sin(377t+60°+90°-180°) = 10\sin(377t-30°)$
$\therefore$電壓超前電流 60°

17. $\bar{I} = \dfrac{\bar{V}_C}{\bar{X}_L} = \dfrac{50\angle -45°}{5\angle -90°} = 10\angle 45°$ A
$\bar{Z} = 5 - j5 = 5\sqrt{2}\angle -45°\ \Omega$
$\bar{V} = \bar{I}\times\bar{Z} = 10\angle 45°\times 5\sqrt{2}\angle -45° = 50\sqrt{2}\angle 0°$ V

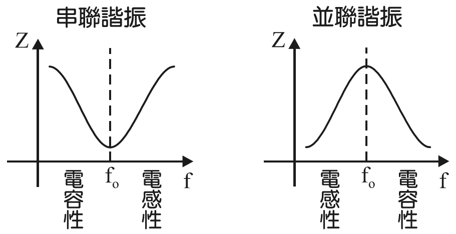
18. $V = \sqrt{{V_R}^2 + (V_L - V_C)^2}$，$100 = \sqrt{60^2 + (20 - V_C)^2}$
$(20 - V_C)^2 = 100^2 - 60^2 = 6400$，$V_C = 100$ V

19. $\bar{V} = \dfrac{30}{\sqrt{2}}\angle 30°$，$X_L = \omega L = 250\times 8\text{ m} = 2\ \Omega$
$X_C = \dfrac{1}{\omega C} = \dfrac{1}{250\times 1\text{ m}} = 4\ \Omega$
$\bar{G} = \dfrac{1}{3} - j\dfrac{1}{2} + j\dfrac{1}{4} = \dfrac{1}{3} - j\dfrac{1}{4} = \dfrac{5}{12}\angle -37°\ ℧$
$\bar{I}_R = \dfrac{\dfrac{30}{\sqrt{2}}\angle 30°}{3\angle 0°} = \dfrac{10}{\sqrt{2}}\angle 30°$ A
$I_R(t) = 10\sin(250t+30°)$ A $= 10\cos(250t-60°)$ A
$\bar{I}_L = \dfrac{\dfrac{30}{\sqrt{2}}\angle 30°}{2\angle 90°} = \dfrac{15}{\sqrt{2}}\angle -60°$ A
$I_L(t) = 15\sin(250t-60°)$ A $= 15\cos(250t-150°)$ A
$\bar{I}_C = \dfrac{\dfrac{30}{\sqrt{2}}\angle 30°}{4\angle -90°} = \dfrac{7.5}{\sqrt{2}}\angle 120°$ A
$I_C(t) = 7.5\sin(250t+120°)$ A $= 7.5\cos(250t+30°)$ A
$\bar{I} = \dfrac{30}{\sqrt{2}}\angle 30°\times\dfrac{5}{12}\angle -37° = \dfrac{12.5}{\sqrt{2}}\angle -7°$ A
$I(t) = 12.5\sin(250t-7°)$ A $= 12.5\cos(250t-97°)$ A

20. $P(t) = VI\cos\theta - VI\cos(2\omega t+\theta)$
$S = VI = 100\times 5 = 500$ VA
$P = VI\cos\theta = 100\times 5\times\cos 60° = 250$ W
$Q = VI\sin\theta = 100\times 5\times\sin 60° = 250\sqrt{3}$ VAR
$P_{max} = P + S = 750$ W，$P_{min} = P - S = -250$ W

21. $S = 500\sqrt{2}$ VA，$P = S\times PF = 500$ W
$Q_C = P(\tan\theta_1 - \tan\theta_2) = P(\dfrac{\sin\theta_1}{\cos\theta_1} - \dfrac{\sin\theta_2}{\cos\theta_2})$
$= 500(\dfrac{\frac{\sqrt{2}}{2}}{\frac{\sqrt{2}}{2}} - \dfrac{0}{1}) = 500$ VAR
$C = \dfrac{Q_C}{E^2\times\omega} = \dfrac{500}{(\frac{100}{\sqrt{2}})^2\times 500} = 200\ \mu$F

22.




23. $Q_P = R\sqrt{\dfrac{C}{L}} = 100\sqrt{\dfrac{100\ \mu}{0.4\text{ m}}} = 50$

24. $\overline{V_{ao}} = 100\angle 30°$ V，$\overline{V_{bo}} = 100\angle 150°$ V
$\overline{V_{co}} = 100\angle -90°$ V
$\overline{V_{bc}} = \overline{V_{bo}} - \overline{V_{co}} = 100\angle 150° - 100\angle -90 = 173\angle 120°$ V

25. $V_\ell = \sqrt{3}\ V_P$，$I_\ell = I_P$，$S_T = \sqrt{3}\ V_\ell I_\ell = 3\ V_P I_P$
$P_T = S_T\cos\theta = \sqrt{3}\ V_\ell I_\ell\cos\theta = 3\ V_P I_P\cos\theta$
$Q_T = S_T\sin\theta = \sqrt{3}\ V_\ell I_\ell\sin\theta = 3\ V_P I_P\sin\theta$

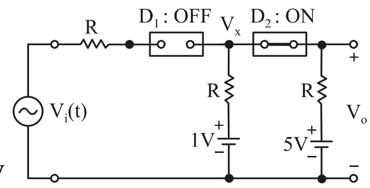
## 第二部份：電子學

26. $\because$磷為 5 價元素，$\therefore$此半導體為 N 型半導體
$\dfrac{5\times 10^{22}}{N_D} = \dfrac{10^7}{1} \Rightarrow N_D = 5\times 10^{15}$
$n\times P = {n_i}^2 \Rightarrow P = \dfrac{{n_i}^2}{n} = \dfrac{{n_i}^2}{N_D} = \dfrac{(1.5\times 10^{10})^2}{5\times 10^{15}}$
$= 4.5\times 10^4$

27. $N\uparrow \Rightarrow V_{BR}\downarrow$

28. $W = W_P + W_N$，$(W_P\times A)\times N_A = (W_N\times A)\times N_D$
$\Rightarrow W_P\times N_A = W_N\times N_D$，$\therefore W_P < W_N \Rightarrow N_A > N_D$

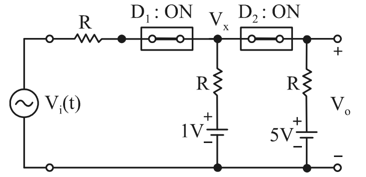
29. ① 當 $V_i = +3$ V 時
$\Rightarrow\begin{cases} D_1：OFF \\ D_2：ON \end{cases}$




$\because V_o = V_x = \dfrac{\frac{1}{R}+\frac{5}{R}}{\frac{1}{R}+\frac{1}{R}} = +3$ V

② 當 $V_i = +9$ V時 $\Rightarrow\begin{cases} D_1：ON \\ D_2：ON \end{cases}$

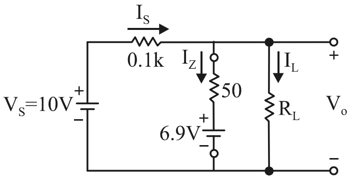
$\Rightarrow V_o = V_x = \dfrac{\frac{+9}{R}+\frac{+1}{R}+\frac{+5}{R}}{\frac{1}{R}+\frac{1}{R}+\frac{1}{R}}$




$= \dfrac{15}{3} = +5$ V

30. $K.C.L \Rightarrow I_S = I_Z + I_L$ ，$\because R_{L(min)}$

$\therefore I_{L(max)} = I_S - I_{Z(min)}$




$= \dfrac{V_S - V_o}{R_S} - I_{ZK}$

$= \dfrac{10-7}{0.1\,k} - 2\,m$

$= 30\,mA - 2\,mA = 28\,mA$

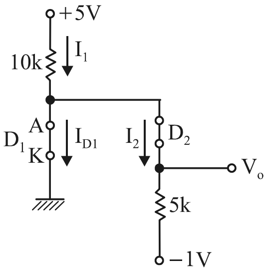
$V_o = I_{ZK} \times 50 + V_{ZK} = 7\,V$

$R_{L(min)} = \dfrac{V_o}{I_{L(max)}} = \dfrac{7\,V}{28\,mA} = 250\,\Omega$

31. 假設 $D_1$：0N

$D_2$：ON

$V_o = +0\,V$




$I_1 = \dfrac{5-0}{10\,k} = 0.5\,mA$

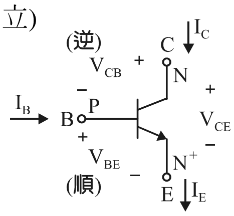
$I_2 = \dfrac{0-(-1)}{5\,k} = 0.2\,mA(I_{D2} = I_2)$

$K.C.L \Rightarrow I_1 = I_{D1} + I_2 \Rightarrow I_{D1} = I_1 - I_2$

$= 0.5\,m - 0.2\,m = 0.3\,mA$

$\because \begin{cases} I_{D1} > 0 \\ I_{D2} > 0 \end{cases}$，$\therefore \begin{cases} D_1：ON(假設成立) \\ D_2：ON \end{cases}$

32. 此為半波式二倍壓電路




33. $V_{BE} > 0$

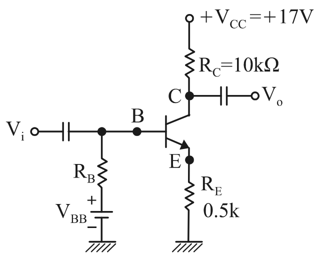
$V_{CE} > V_{CE(sat)} > 0$

$V_{BC} < 0$

34. $\because (1+\beta)R_E >> (R_{B1} // R_{B2})$ 不成立

∴需採用精確解

等效電路




$V_{BB} = V_{CC} \times \dfrac{R_{B2}}{R_{B1} + R_{B2}}$

$= +1.7\,V$

$R_B = R_{B1} // R_{B2}$

$= 90\,k // 10\,k = 9\,k\Omega$

$I_B = \dfrac{1.7 - 0.7}{9\,k + 100 \times 0.5\,k} \cong 16.9\,\mu A \Rightarrow I_C = \beta I_B = 1.68\,mA$

$\because \beta I_B \ge I_{C(max)} = \dfrac{17-0.2}{10\,k + 0.5\,k} = 1.6\,mA$

∴BJT 工作於飽和區( $V_{BC} > 0$ )

假設 $V_E$ 為未知數，$\therefore \begin{cases} V_B = V_{BE} + V_E = V_E + 0.7 \\ V_C = V_{CE(sat)} + V_E = V_E + 0.2 \end{cases}$

$$\begin{cases} I_B = \dfrac{V_{BB} - V_B}{R_B} = \dfrac{1.7 - V_E - 0.7}{9\,k} = \dfrac{1 - V_E}{9\,k} \\ I_C = \dfrac{V_{CC} - V_C}{R_C} = \dfrac{17 - V_E - 0.2}{10\,k} = \dfrac{16.8 - V_E}{10\,k} \\ I_E = \dfrac{V_E}{R_E} = \dfrac{V_E}{0.5\,k} = 2\,V_E \end{cases}$$

$K.C.L \Rightarrow I_B + I_C = I_E$ ，$\dfrac{1 - V_E}{9\,k} + \dfrac{16.8 - V_E}{10\,k} = 2\,V_E$

$\therefore V_E = 0.81\,V$ ，$\Rightarrow I_B = \dfrac{1 - 0.81}{9\,k} = 0.021\,mA$

$I_C = 1.599\,mA$ ，$I_E = 1.62\,mA$

$V_C = V_{CE(sat)} + V_E = 0.2 + 0.81 = 1.01\,V$

35. (1) 先求工作點：$I_B = \dfrac{V_{CC} - V_{BE}}{R_B} = \dfrac{10.7 - 0.7}{1\,M} = 10\,\mu A$

$I_C = \beta I_B = 1\,mA$

$V_{CE} = V_{CC} - I_C R_C = 10.7 - 1\,m \times 5\,k = 5.7\,V$

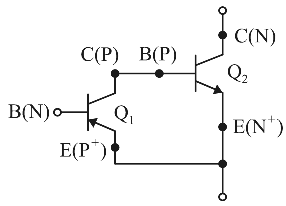
(2) $r_\pi = \dfrac{\eta V_T}{I_{BQ}} = \dfrac{25\,mV}{10\,\mu A} = 2.5\,k\Omega$

$|A_V| = \beta \times \dfrac{R_C // R_L}{r_\pi} = 100 \times \dfrac{5\,k // 15\,k}{2.5\,k} = 150$

$|A_I| = \dfrac{R_B}{R_B + r_\pi} \times \beta \times \dfrac{R_C}{R_C + R_L}$

$= \dfrac{1000\,k}{1000\,k + 2.5\,k} \times 100 \times \dfrac{5\,k}{20\,k} \cong 25$

36. 若 $Q_1$ 導通時，$V_{EC1} > 0$，此電壓對 $Q_2$ 的 B-E 接面為逆偏，B-C 接面為順偏，故無法達到達靈頓電路之功能




37. 先求工作點，∵

$(1+\beta)R_E >> [R_{B3} // (R_{B1} + R_{B2})]$

∴此分壓式偏壓可以使用近似解法：

$V_{B1} = (+25\,V) \times \dfrac{5\,k}{10\,k + 10\,k + 5\,k} = +5\,V$

$I_{E1} = \dfrac{5 - 0.7}{1\,k} = 4.3\,mA \Rightarrow r_{e1} \cong \dfrac{\eta V_T}{I_{E1}} = \dfrac{26\,mV}{4.3\,mA} \cong 6.05\,\Omega$

$I_{E2} = \alpha_1 \times I_{E1} \cong 14.28\,mA \Rightarrow r_{e2} = \dfrac{\eta V_T}{I_{E2}} = \dfrac{26\,mV}{4.28\,mA} \cong 6\,\Omega$

$A_{VT} = \dfrac{V_{o2}}{V_i} = \dfrac{V_{o1}}{V_i} \times \dfrac{V_{i2}}{V_{o1}} \times \dfrac{V_{o2}}{V_{i2}}$

$\Rightarrow$ ∵CE 串 C.B，且 $V_{i2} = V_{o1} = A_{V1} \times 1 \times A_{V2}$

$A_{V1} = \dfrac{V_{o1}}{V_i} = -\beta \times \dfrac{r_{e2}}{r_{\pi 1}} \cong \dfrac{-r_{e2}}{r_{e1}} = -1$

$A_{V2} = \dfrac{V_{o2}}{V_{i2}} = +\alpha \times \dfrac{R_C // R_L}{r_{e2}} \cong 1 \times \dfrac{2\,k // 2\,k}{6} = +166.7$

$\therefore A_{VT} = A_{V1} \times 1 \times A_{V2} = (-1) \times (+166.7) = -166.7$

38. FET 為通道長度調變(Channel Length Modulation $\Rightarrow$ C.L.M )

39. ∵在 $I_C$ 不變的條件下，由 B 端進入 E 端的電洞愈多，則 E 端發射的自由電子亦愈多，$\therefore I_E \uparrow, \alpha \downarrow$

40. ① N-ch EMOS 工作在 Ω 區，在 $V_{DS}$ 固定下，$V_{GS}$ 愈小，則由 D 到 S 通道電阻愈大

② $g_m = 2\,K(V_{GS} - V_t)^1 = 2 \times \sqrt{I_D \times K}$

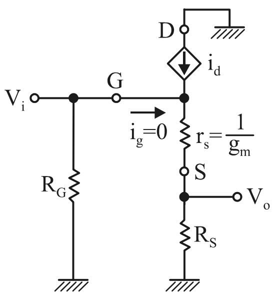
$\Rightarrow g_m \propto \sqrt{I_D}$ (非線性關係)

③ N-ch EMOS 工作於飽和區時，$V_{DS}$ 愈小，$I_D$ 稍微下降(∵通道長度調變的原因)

41. ① P-ch JFET 最高電壓爲源極(S)
② N-ch JFET，通道厚度愈窄，$|V_P|$ 下降
③ 當 S 端發生夾止時，D 端早已夾止
故 $I_D = 0$(截止區)

42. $V_{GS} = 0 - I_D \times 1 = -I_D$
$I_D = 8\times(1-\frac{-I_D}{-4})^2 = \frac{8}{16}(4-I_D)^2 \Rightarrow I_D{}^2 - 10I_D + 16 = 0$
$\therefore I_D = 2\text{ mA or } 8\text{ mA}$(不合)
( $\because V_{GS} = 0 - 8\text{ m}\times 1\text{ k} = -8\text{ V} < V_P \Rightarrow I_D = 0$ )
N-ch JFET 進入飽和區之條件 ⇒ D 端恰好夾止
$\Rightarrow V_{GD} \le V_P$
$V_{GD} = V_G - V_D = 0 - (V_{DD} - 2\text{ m}\times 2\text{ k}) \le -4$
$\Rightarrow -V_{DD} + 4 \le -4$，$\therefore V_{DD} \ge +8\text{ V} \Rightarrow V_{DD(min)} = +8\text{ V}$

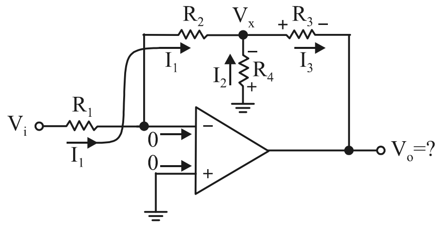
43. ① 先求交流互導因數 $g_m$




$g_m = \frac{2I_{DSS}}{|V_P|}(1-\frac{V_{Gs}}{V_P})$
$= \frac{2\times 16\text{ m}}{4}\times(1-\frac{-2}{-4}) = 4\text{ m℧}$
$r_s = \frac{1}{g_m} = 250\ \Omega$
② 求 $R_S$ = ？$\because V_{GS} = -2\text{ V}$
$\therefore I_D = 16\text{ m}\times(1-\frac{-2}{-4})^2 = 4\text{ mA}$
又 $V_{GS} = V_G - V_S = 0 - I_D\times R_S = -2$
$\therefore R_S = \frac{2\text{ V}}{I_D} = \frac{2\text{ V}}{4\text{ mA}} = 500\ \Omega$
$A_V = \frac{V_o}{V_i} = \frac{R_S}{r_s + R_S} = \frac{500}{250+500} = \frac{+2}{3}$

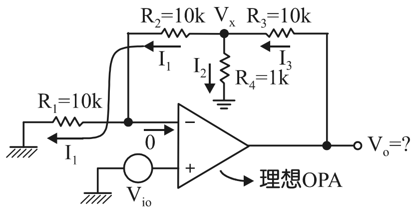
44. ① P-ch DMOS：$V_P > 0$，且有預置通道
② N-ch EMOS：$V_t > 0$，且無預置通道
③ P-ch DMOS：工作在飽和區之條件
$V_{GD} \ge V_P \Rightarrow V_{GS} - V_{DS} \ge V_P \Rightarrow V_{DS} \le V_{GS} - V_P$

45. $I_1 = \frac{V_i - V_-}{R_1} = \frac{V_i}{R_1} = \frac{V_i}{10\text{ k}}$




∵OPA 有 N.F.B，$\therefore V_- = V_+ = 0\text{ V}$
$\therefore R_2$ 與 $R_4$ 可視爲並聯 $\Rightarrow I_1\times R_2 = I_2\times R_4$
$\therefore I_2 = \frac{V_i}{10\text{ k}}\times\frac{100\text{ k}}{1\text{ k}} = 10\ V_i\ (\text{mA})$
依據 K.C.L $\Rightarrow I_3 = I_1 + I_2 = 10.1\ V_i\ (\text{mA})$
$V_o = (-I_3\times R_3) + (-I_2\times R_4) = (-1010\ V_i) + (-10\ V_i)$
$= -1020\ V_i$，$\therefore A_V = \frac{V_o}{V_i} = -1020$

46. P.S 將非理想的 $V_{io}$ 等效在一理想 OPA 的正端外側
∵OPA NFB 且 $V_o \ne \pm V_{sat}$，$\therefore V_- = V_+ = V_{io}$
$I_1 = \frac{V_- - 0}{R_1} = \frac{\pm 10\text{ mV}}{10\text{ k}\Omega} = \pm 1\ \mu\text{A}$
$V_x = I_2\times R_4 = I_1\times(R_2+R_1) \Rightarrow I_2\times 1\text{ k} = (\pm 1\ \mu\text{A})\times(20\text{ k})$
$\Rightarrow I_2 = \pm 20\ \mu\text{A}$
依據 K.C.L $\Rightarrow I_3 = I_1 + I_2 = \pm 21\ \mu\text{A}$
$V_o = (+I_3\times R_3) + (+I_2\times R_4) = (\pm 21\ \mu\times 10\text{ k}) + (\pm 20\ \mu\times 1\text{ k})$
$= (\pm 210\text{ mV}) + (\pm 20\text{ mV}) = \pm 230\text{ mV}$




47. 依據重疊定理：
$V_o = \frac{-R_2}{R_1}\times V_y + (1+\frac{R_2}{R_1})\times[\frac{R_4}{R_3+R_4}\times V_x] = -5\ V_y + 3\ V_x$
$\because 1 + \frac{R_2}{R_1} = 1 + \frac{10\text{ k}}{2\text{ k}} = 6$
$(1+\frac{R_2}{R_1})\times\frac{R_4}{R_3+R_4} = 3 \Rightarrow \frac{R_4}{4\text{ k}+R_4} = \frac{3}{6} \Rightarrow R_4 = 4\text{ k}\Omega$

48. $f_o = \frac{1}{2\pi\sqrt{6}RC}$

49. $\beta = \frac{R_1}{R_1+R_2}$，$T = 2\,RC\ln(\frac{1+\beta}{1-\beta})$

50. $f_o = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$ (Hz)，振盪條件：$\frac{R_3}{R_4} \ge \frac{R_1}{R_2} + \frac{C_2}{C_1}$