12/18/2007.

Midterm Exam-2.

MoonFox.

1.°(a) $I_{C1} = I_{C2} = 10\mu A$.

$\Rightarrow I_{B1} = \frac{10}{200} = 0.05\mu A$.

$I_{B2} = \frac{10}{250} = 0.04\mu A$ offset current $= 0.01\mu A$.

(b) $I_{C11} = 1mA \Rightarrow \because$ 題目有給 information.

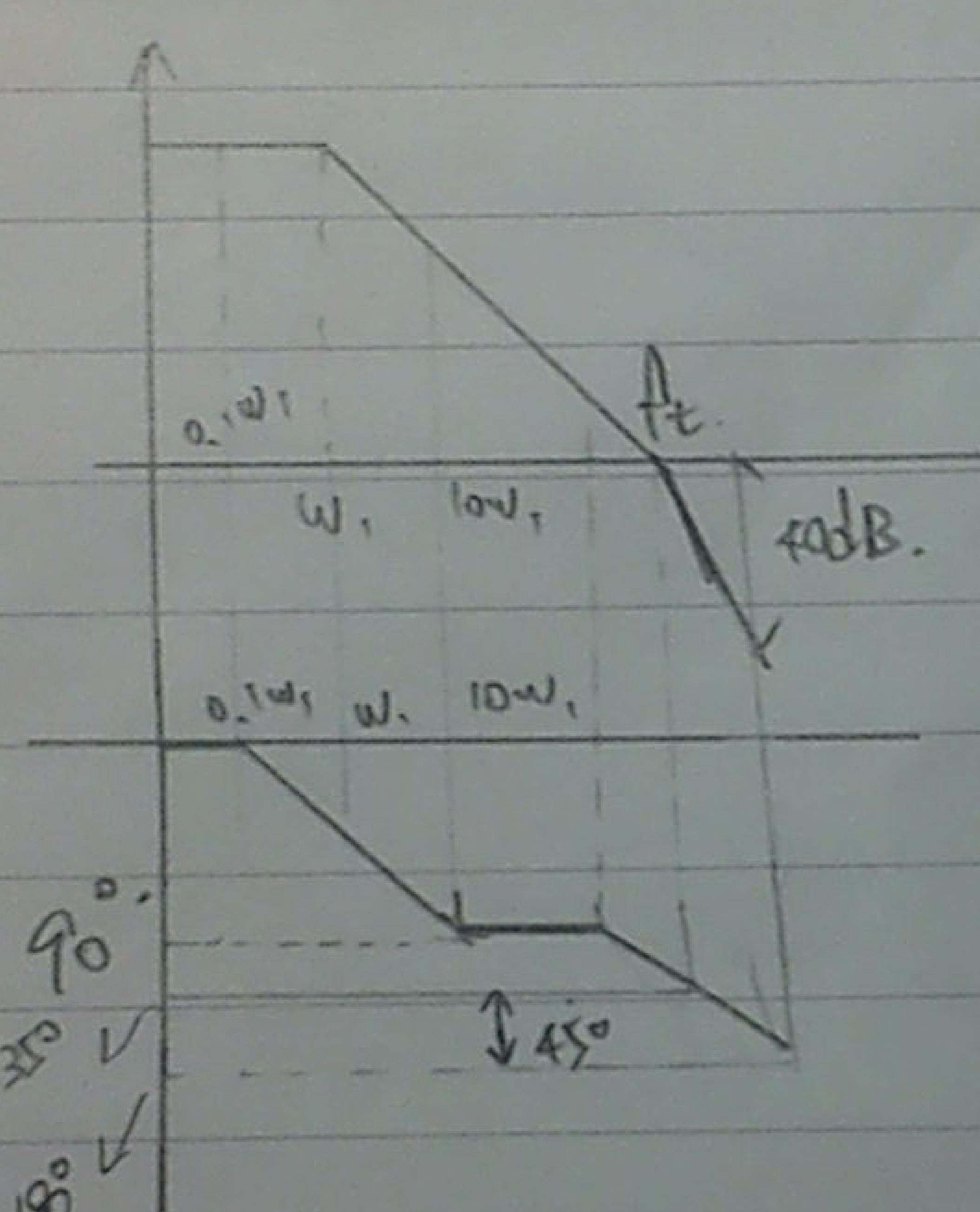
$\therefore V_{BE11} = 0.7 V$.

$\frac{I_{C11}}{I_{C10}} = \frac{I_s e^{\frac{V_{BE11}}{V_T}}}{I_s e^{\frac{V_{BE10}}{V_T}}} \Rightarrow \frac{10^{-3}}{10^{-5}} = e^{\frac{0.7-x}{V_t}} \Rightarrow 0.025 \times \ln\left|\frac{10^{-3}}{10^{-5}}\right| = 0.7 - x$

$\Rightarrow x = 0.585\ (V)$.

$0.585 + 10^{-3} \times R_4 = 0.7$, $R_4 = 11.5k\Omega$.

(c)



$\Rightarrow f_t$ 為 $\omega_2 = 5MHz$.

$f_t = \frac{g_m}{2\pi C_c} = f_{-3dB} \times A$

$\Rightarrow f_{-3dB} = \frac{5MHz}{105dB} = \underline{28.12Hz}$ //

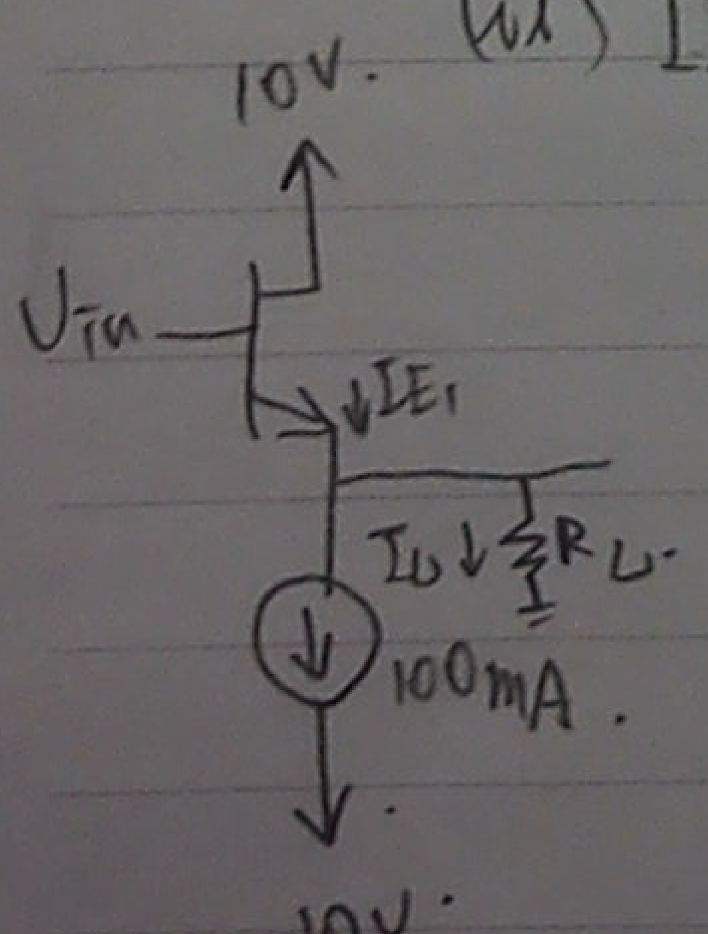
$C_c = \frac{2 \times 10^{-3}}{2\pi \times 5 \times 10^6} = 6.37 \times 10^{-11}(F)$.

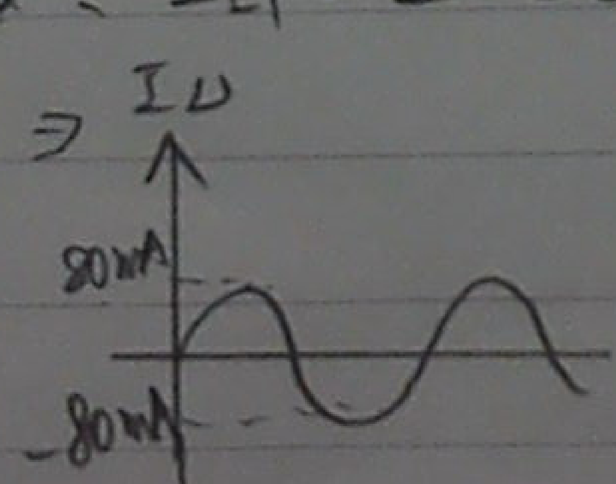
2. WTF

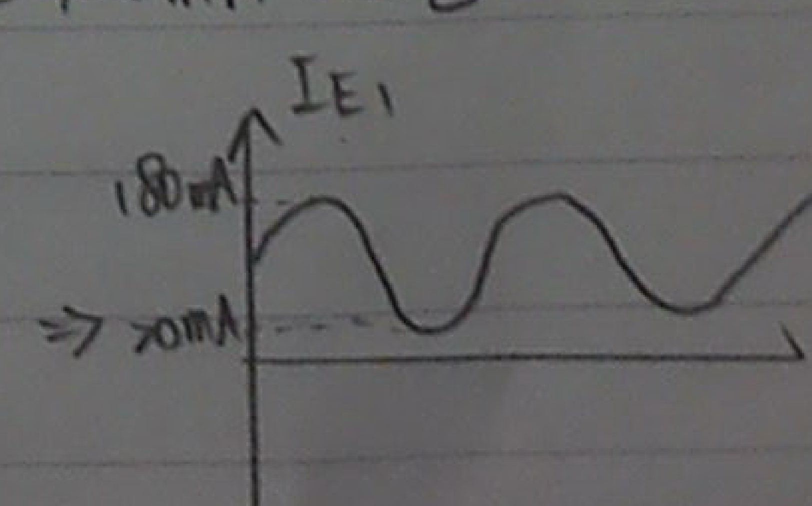
3. (a). (i) Power $= \frac{V_{rms}^2}{R} = \frac{64}{2} \div 100 = 0.32\ (W)$

(ii) $I_L$peak 值 $= \frac{V_m}{R} = 0.08(A)$. ∵忽略 Q_3 之能.

$\because I_{E1} = I + I_L = 100mA + I_L$.







$\Rightarrow P_{in} = P_{Q1} + P_{Q2}$.

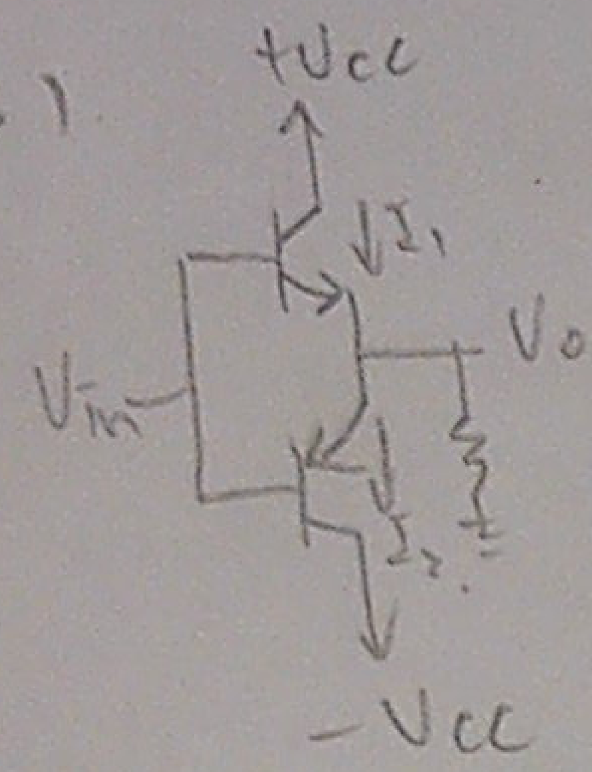
$= V_{CC} \times I_{Eavg} + (-V_{CC})(-I)$.

$= 10 \times 100m + 10 \times 100m$

$= \underline{2\ (W)}$ //

(iii) efficiency $= \frac{0.32}{2} \times 100\% = 16\%$.

(b)



不考慮 crossover disstrotion.

V_o max 為 V_{cc},

$$V_o \begin{cases} V_o = V_{cc}\sin(\omega t) \\ I_o = I_o \sin(\omega t) \end{cases}$$

$$P_o = I_{rms} \cdot V_{rms} = \frac{V_{cc} I_o}{2}$$

$$P_{in} = I_{avg} \times V_{cc} \times 2 = \frac{4}{\pi} I_o V_{cc}.$$

$$\eta_{max} = \frac{P_o}{P_{in}} = \frac{\frac{V_{cc} I_o}{2}}{\frac{2}{\pi} I_o V_{cc}} = 78.5\%.$$

4. (a) $P_{max} = \frac{T_{Jmax} - T_A}{\theta_{JA}} = \frac{100}{62.5} = 1.6W$

(b). $T_S = T_A + P \times \theta_{SA} = 50 + 1.6 \times 4 = 56.4°C$

$T_C = T_S + P \times \theta_{CS} = 56.4 + 1.6 \times 0.5 = 57.2°C$.

(c) infinite heat sink $\Rightarrow \theta_{CA} = 0$

$\Rightarrow \theta_{JA} = \theta_{JC}$.

$\theta_{JC} = 62.5 - 0.5 - 4 = 58$ °C/W.

$$P_{max} = \frac{T_{Jmax} - T_A}{\theta_{JC}} = \frac{100}{58} = 1.724 \,(W)$$

12/09/2008 Mid-2.

MoonFox.

$\frac{\sqrt{k}\times 4\sqrt{k}\sqrt{I_{REF}}}{16R\sqrt{k}\sqrt{I_{REF}}}$

$\sqrt{1+}$

$2\sqrt{k}$

1. (a) $I_{REF} = k\times(V_{GS1}-V_t)^2$. $\Rightarrow \sqrt{\frac{I_{REF}}{k}}+V_t = V_{GS1}$.

$I_{out} = 4k\times(V_{GS2}-V_t)^2$. $\Rightarrow \sqrt{\frac{I_{out}}{4k}}+V_t = V_{GS2}$

$\Rightarrow V_{GS1} = V_{GS2} + I_{out}\times R$

$\sqrt{\frac{I_{REF}}{k}} = \sqrt{\frac{I_{out}}{4k}} + I_{out}\times R$. ，令 $\sqrt{I_{out}} = x$.

$x = \frac{-\frac{1}{\sqrt{4k}} \pm \sqrt{\frac{1}{4k}+4R\sqrt{\frac{I_{REF}}{k}}}}{2R} = \frac{-1+\sqrt{1+16R\sqrt{k\times I_{REF}}}}{4R\sqrt{k}}$ 電流不為負(取正).

$I_{out} = \frac{1-2\sqrt{1+16R\sqrt{k\times I_{REF}}}+1+16R\sqrt{k\times I_{REF}}}{16R^2k}$

$= \frac{1-\sqrt{1+16R\sqrt{k\times I_{REF}}}+8R\sqrt{k\times I_{REF}}}{8R^2k}$.

(b) $\frac{I_{C10}}{I_{REF}} = \frac{I_s\cdot e^{\frac{V_{BE10}}{V_T}}}{I_s\cdot e^{\frac{V_{BE11}}{V_T}}} = e^{\frac{V_{BE10}-V_{BE11}}{V_T}}$.

$\frac{2}{10}=\frac{1}{5}$

又 $V_{BE11} - V_{BE10} = I_{C10}\times 5k$

$\Rightarrow I_{C10} = I_{REF}\times e^{\frac{-I_{C10}\times 5k}{V_T}} = 10^{-3}\times e^{-I_C\times 2\times 10^5}$.

$\ln(I_C\times 10^3) = -I_C\times 2\times 10^5$.

$I_C = \frac{-\ln(I_C\times 10^3)}{2\times 10^5}$.

迭代法，設 $I_C = 10^{-5}A$，$I_C = \frac{-\ln(10^{-5}\times 10^3)}{2\times 10^5} = 2.3\times 10^{-5}$.

設 $I_C = 2.3\times 10^{-5}A$，$I_C = 1.886\times 10^{-5}$.

設 $I_C = 1.886\times 10^{-5}$，$I_C = 1.985\times 10^{-5}$

設 $I_C = 1.985\times 10^{-5}$，$I_C = 1.96\times 10^{-5}$

$I_C = 1.96\times 10^{-5}$，$I_C = 1.966\times 10^{-5}$

$I_C = 1.966\times 10^{-5}$，$I_C = 1.965\times 10^{-5}$.

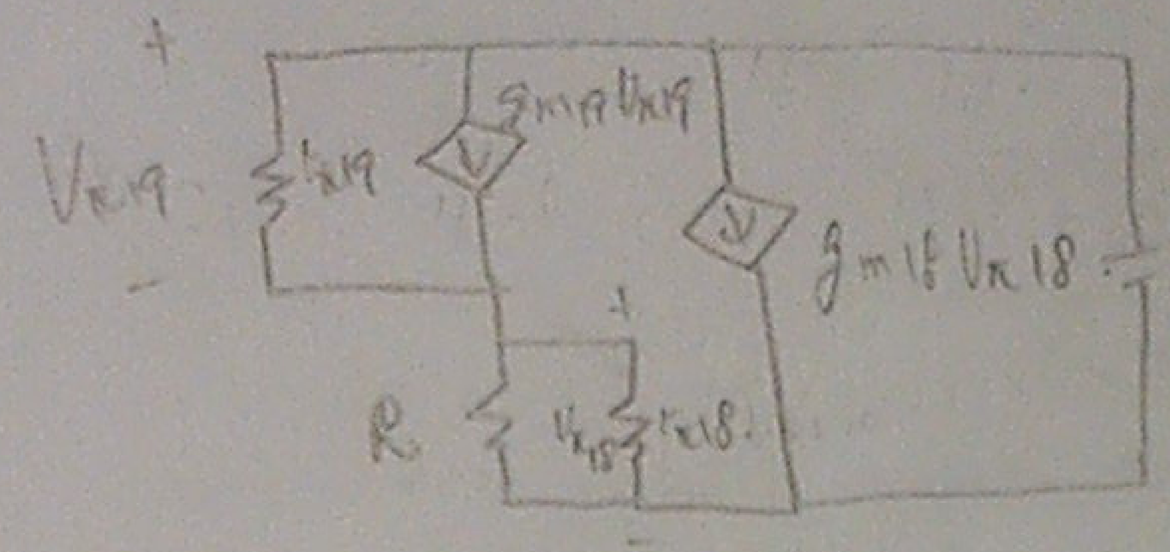
⋮

$\Rightarrow I_{C10} = 1.965\times 10^{-5}$ (A)

2. 3. WTF.

4. (a).

小訊號:



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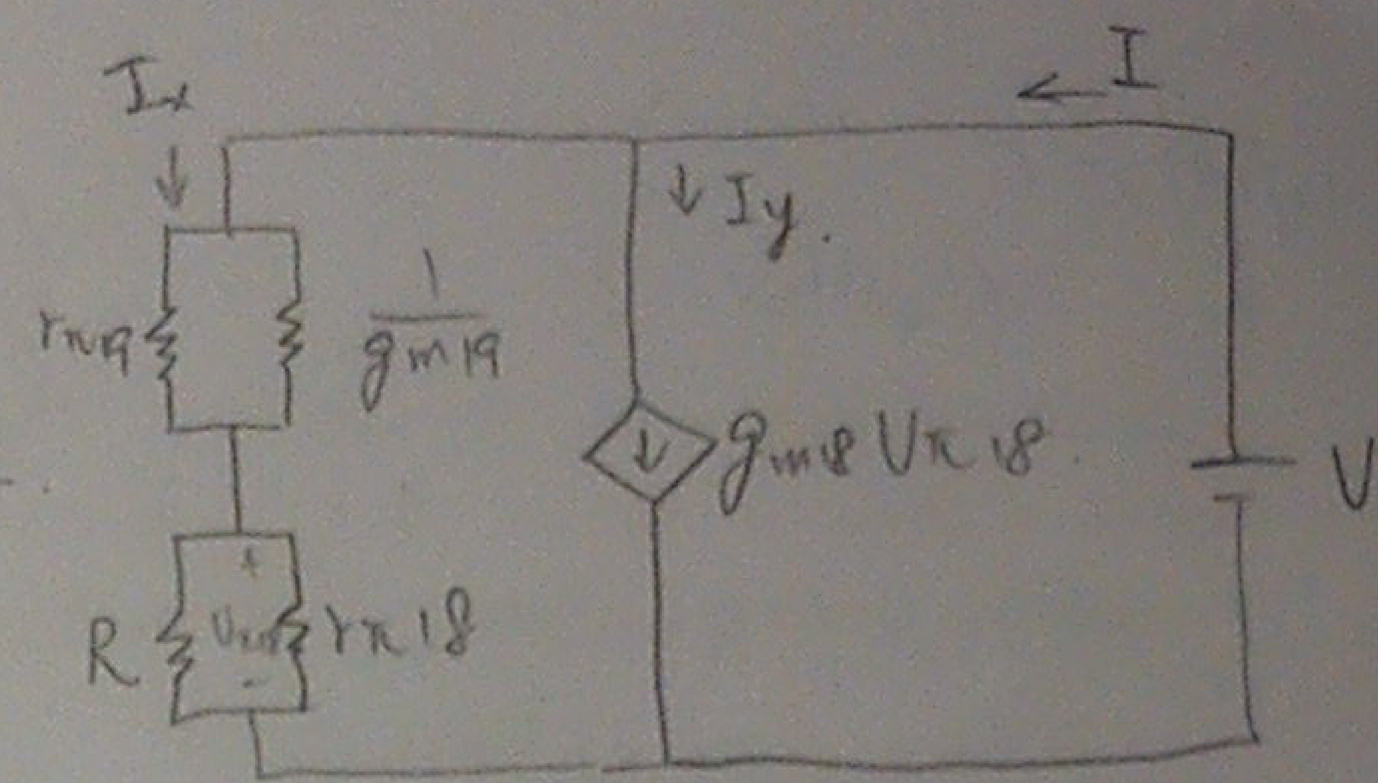


$\Rightarrow V = V_{\pi 19} + V_{\pi 18}$.

$V_{\pi 18} = I_x \cdot (R // r_{\pi 18})$.

$I_y = g_{m18} \cdot (R // r_{\pi 18}) \cdot I_x$

$V = I_x \cdot [(r_{\pi 19} // \frac{1}{g_{m19}}) + (R // r_{\pi 18})]$

$g_{m18} = \frac{I_{C18}}{V_T} = 6.6 \times 10^{-3}$.

$g_{m19} = \frac{I_{C19}}{V_T} = 6.4 \times 10^{-4}$.

$r_{\pi 18} = \frac{\beta}{g_{m18}} = 30.3 k\Omega$.

$r_{\pi 19} = 312.5 k\Omega$.

$R = 40 k\Omega$.

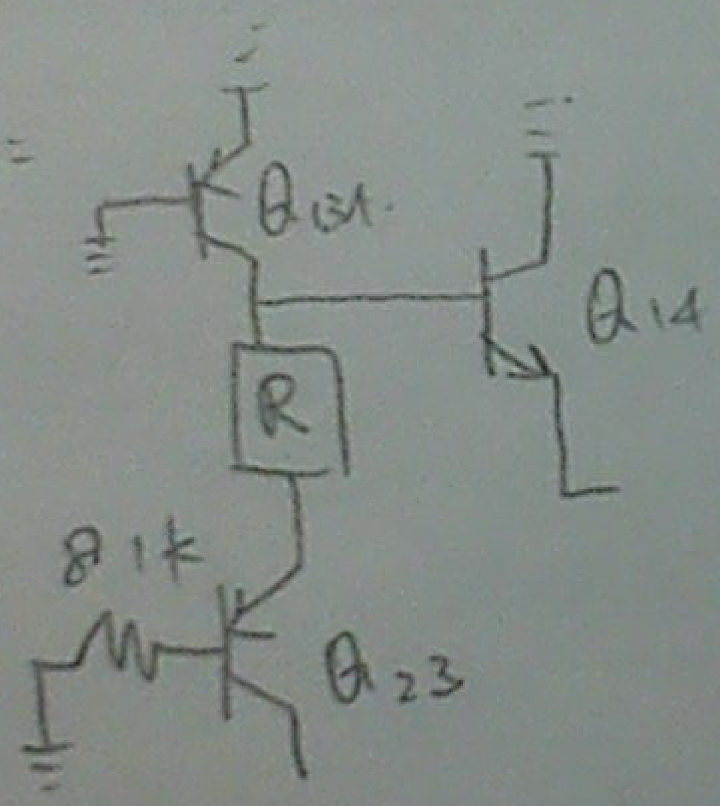
$$Z = \frac{V}{I} = \frac{I_x \cdot [(r_{\pi 19} // \frac{1}{g_{m19}}) + (R // r_{\pi 18})]}{I_x + g_{m18} \cdot (R // r_{\pi 18}) \cdot I_x}$$

$$= \frac{(r_{\pi 19} // \frac{1}{g_{m19}}) + (R // r_{\pi 18})}{1 + g_{m18} (R // r_{\pi 18})}$$

$$= \frac{7.77 + 17.24 \times 10^3}{1 + 113.78} = 150.26\ \Omega.$$

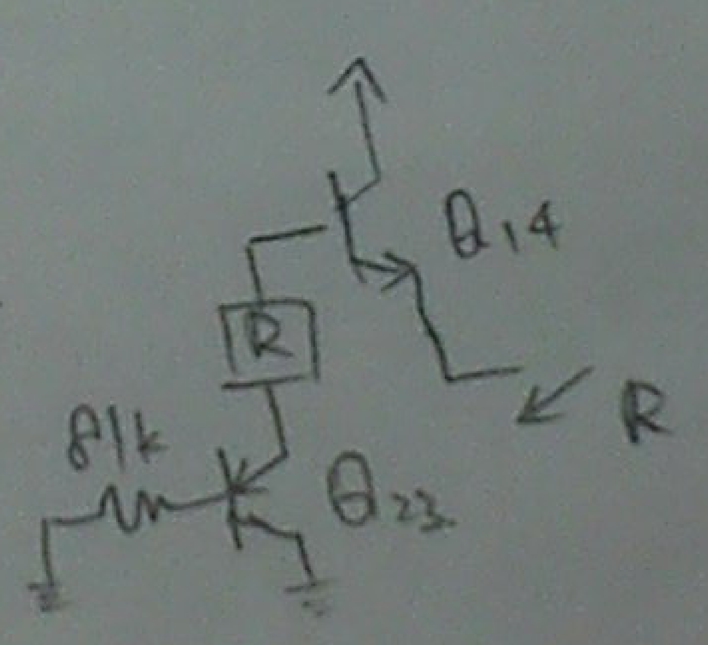
(b)

原:



$\because$ neglecting Q_{13}.

$\Rightarrow$



$$R_{out} = \frac{\frac{r_{\pi 14} + R}{1 + \beta_{14}} + \frac{r_{\pi 23} + 81k}{1 + \beta_{23}}}{}$$

$$= \frac{5000 + 150.26 + \frac{6900 + 81000}{51}}{201}$$

$= 34.2\ \Omega$.

$r_{\pi 14} = \frac{V_T}{I_C} \times \beta = 5k$.

$\beta_{23} = 50$.

$r_{\pi 23} = \frac{V_T}{I_{C23}} \times \beta$

$= \frac{0.025}{181 \mu A} \times 50 = 6.9k$

5. 6. WTF!

Final - 01/13/2009.

1. 2. 3. WTF!

4. (a) if input $= i_i = I_1 \cos\omega t$

output $i_o = I_0 + I_1\cos\omega t + I_2\cos(2\omega t) + I_3\cos(3\omega t) \cdots$

Nth harmonic distortion $D_N = \left|\frac{I_N}{I_1}\right|$, $N = 2, 3, 4$

total harmonic distortion $= \sqrt{D_2^2 + D_3^2 + D_4^2 \cdots}$

(b) if input $= i_i = I_a[\cos(\omega_1 t) + \cos(\omega_2 t)]$

output $i_o = G\, i_i^2$

$= G I_a [\cos^2(\omega_1 t) + \cos(\omega_1 t)\cos(\omega_2 t) + \cos^2(\omega_2 t)]$.

$= G I_a [\frac{1}{2} + \frac{1}{2}\cos(2\omega_1 t) + \frac{1}{2}\cos[(\omega_1+\omega_2)t] + \frac{1}{2}\cos[(\omega_1-\omega_2)t]$

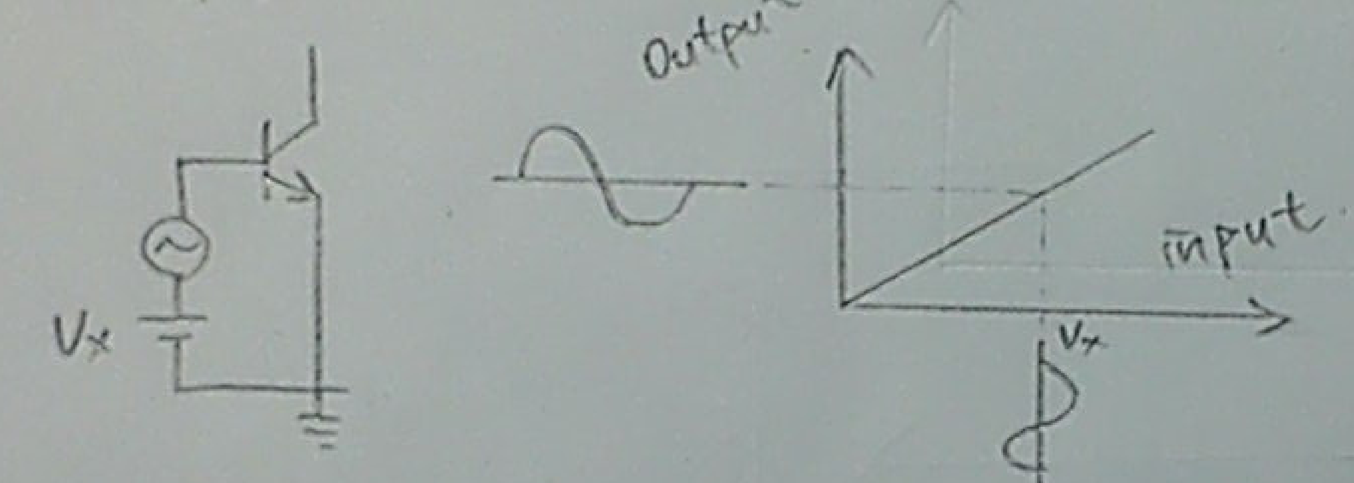
$+ \frac{1}{2} + \frac{1}{2}\cos(2\omega_2 t)]$.

$\Rightarrow$ 頻率有 $\omega_1, \omega_2, 2\omega_1, 2\omega_2, \omega_1+\omega_2, \omega_1-\omega_2$

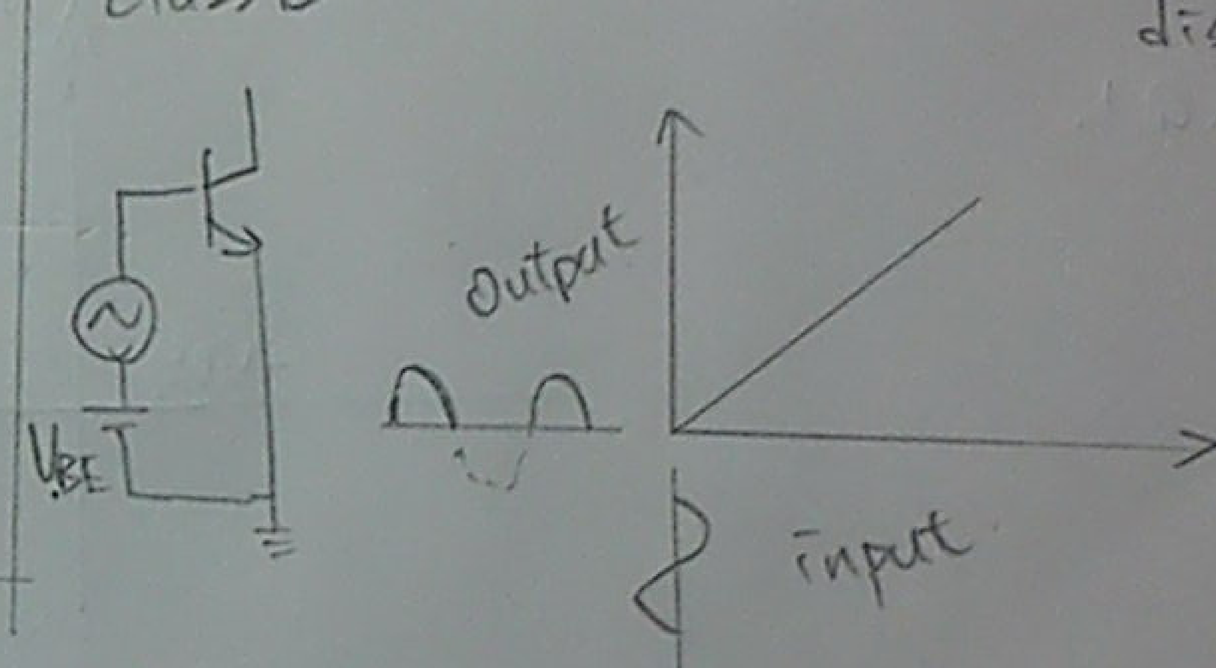
inter-modulation distortion.

(c)

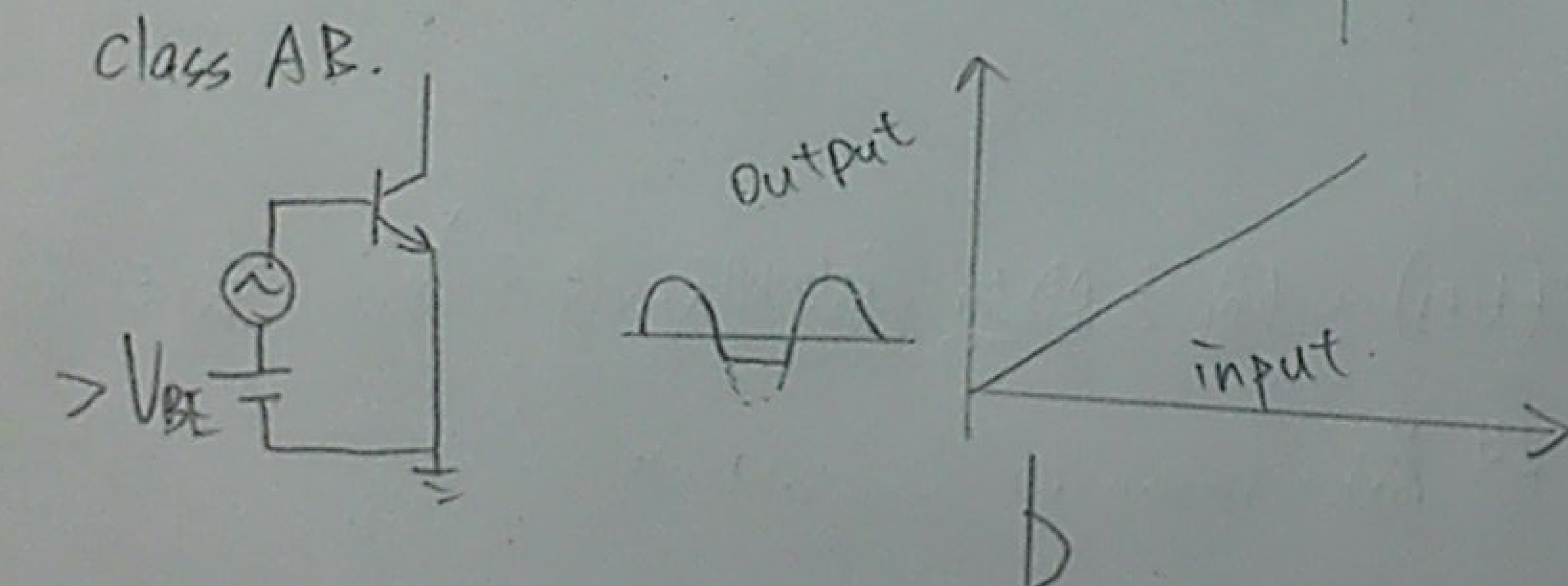
Class A.



Class B

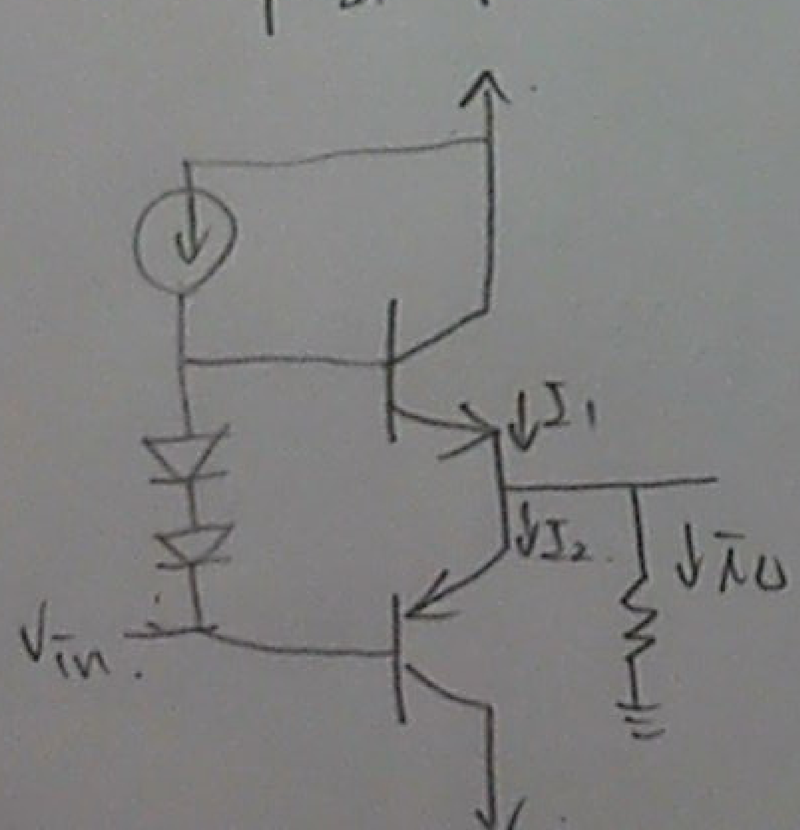


Class AB.



(d).

push-pull



if $i_1 = I_0 + I_1\cos(\omega t) + I_2\cos(2\omega t) + I_3\cos(3\omega t) \cdots$

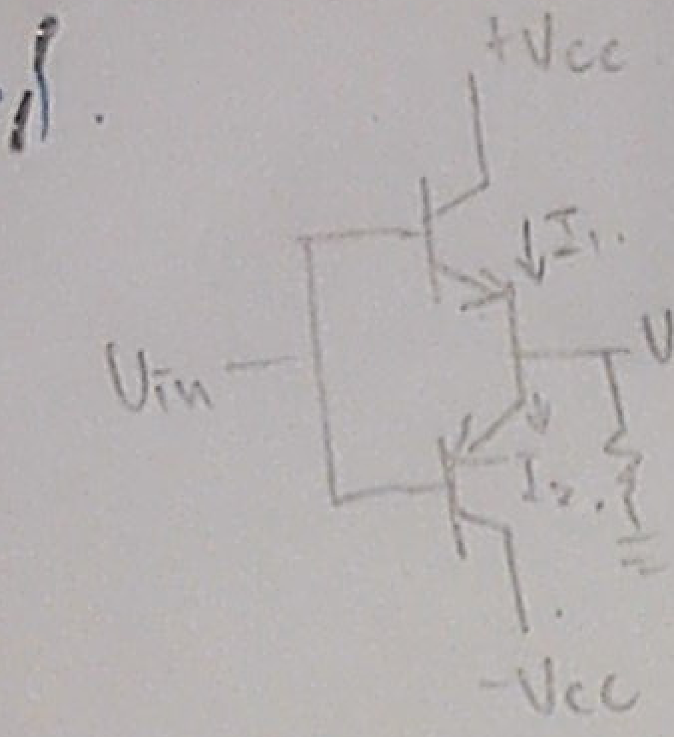
$\because i_1(\omega t) = i_2(\omega t + \pi)$.

$\therefore i_2 = I_0 - I_1\cos(\omega t) + I_2\cos(2\omega t) - I_3\cos(3\omega t)$.

$i_o = I_1 - i_2 = 2I_1\cos(\omega t) + 2I_3\cos(3\omega t)$

$\Rightarrow$ even-order harmonics are eliminated.

(e) 1.



不失真 crossover distrotion

output: V_o 之 max 為 $\pm V_{cc}$. $\begin{cases} V_o = V_{cc}\sin(\omega t) \\ I_o = I_o \sin(\omega t) \end{cases}$

$$P_o = I_{rms} \cdot V_{rms} = \frac{V_{cc}}{\sqrt{2}} \cdot \frac{I_o}{\sqrt{2}} = \frac{V_{cc} I_o}{2}$$

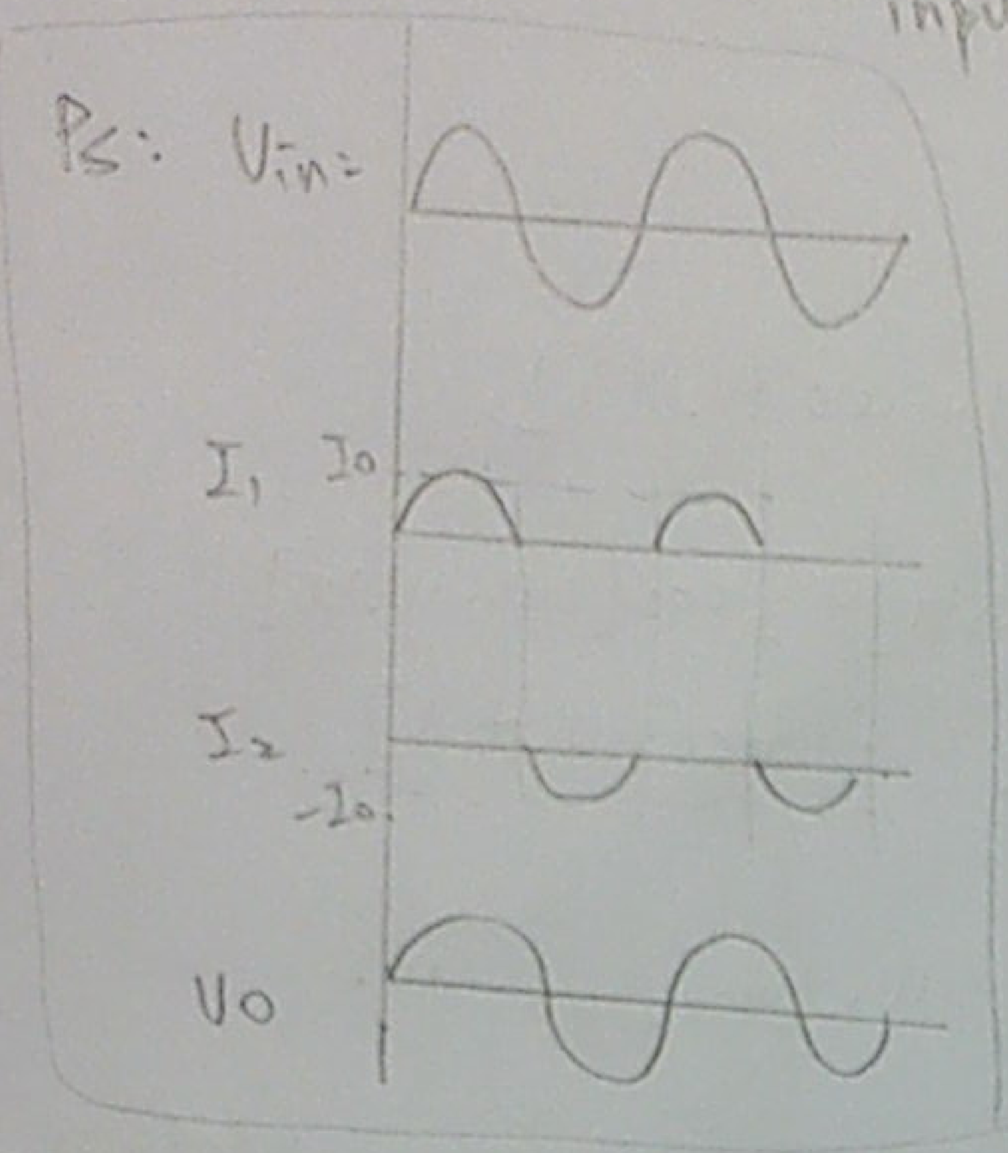
input: $P_{in} = I_{avg} \times V_{cc} \times 2$

(∵ V_{cc} 為定值, $P = IV$, 故 I 不用 rms 而用 I_{avg})

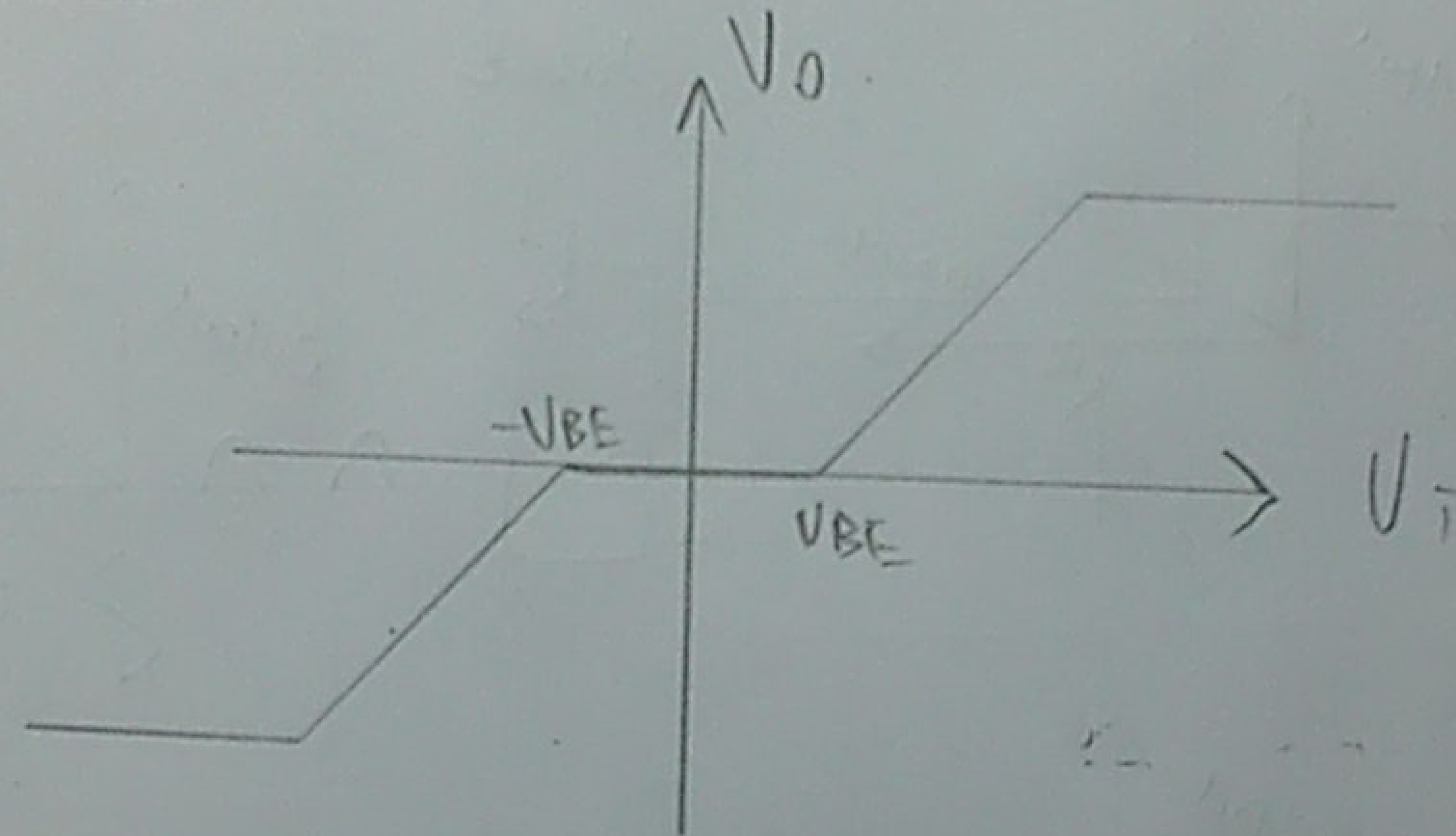
(最後 ×2 是因為上下2個 BJT)

$$= \left(\frac{1}{\pi} I_o\right) \times V_{cc} \times 2 = \frac{2}{\pi} I_o V_{cc}$$

$$\eta_{max} = \frac{P_{out}}{P_{in}} = \frac{\frac{V_{cc} I_o}{2}}{\frac{2}{\pi} I_o V_{cc}} = \frac{\pi}{4} = 78.5\%.$$



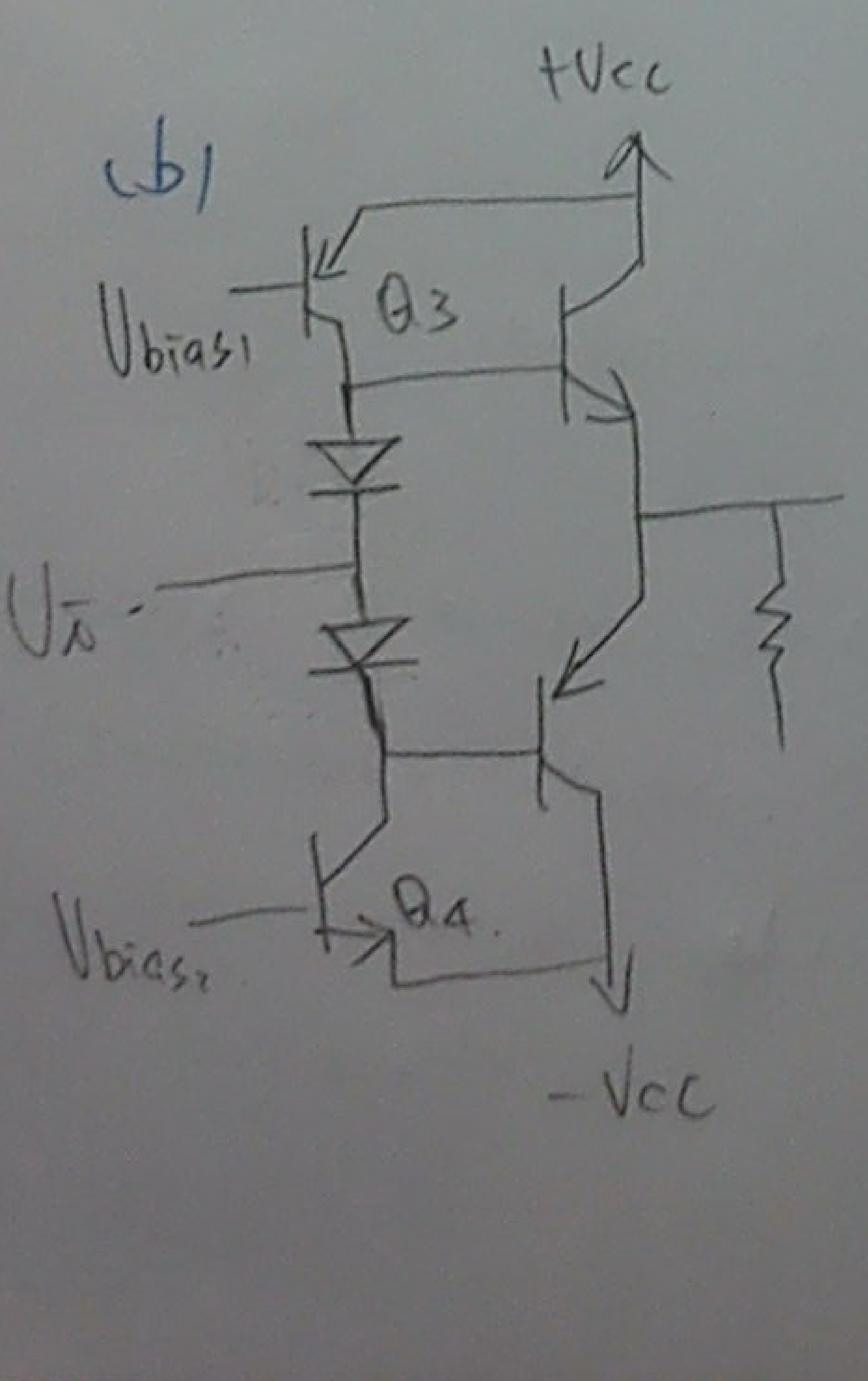
I. (a) 1.



∵ output 在 $(-V_{BE}) \sim V_{BE}$ 之間無放大 (=0), 為死帶 dead band

故為 crossover distortion.

(b)



V_{bias1} 和 V_{bias2}

要使 Q3 Q4 持續有電流通過

12/15/2009

Mid - II.

MoonFox.

1.(a) $I_{M_1} = I_{REF} = k_n (V_{GS_1} - V_t)^2 \Rightarrow V_{GS_1} = V_t + \sqrt{\frac{I_{REF}}{k}}$

$I_{M_2} = I_O = k_n (V_{GS_2} - V_t)^2 \Rightarrow V_{GS_2} = V_t + \sqrt{\frac{I_O}{k}}$

又∵ $V_{GS_1} = V_{GS_2} + I_O R$

$$\Rightarrow \sqrt{\frac{I_{REF}}{k}} = \sqrt{\frac{I_O}{k}} + I_O R$$

$$\sqrt{I_O} = \frac{-\sqrt{\frac{1}{k}} + \sqrt{\frac{1}{k} + 4R\sqrt{\frac{I_{REF}}{k}}}}{2R} = \frac{-1 + \sqrt{1 + 4R\sqrt{k \cdot I_{REF}}}}{2R\sqrt{k}}$$

$$I_O = \frac{1 - 2\sqrt{1 + 4R\sqrt{k \cdot I_{REF}}} + 1 + 4R\sqrt{k \cdot I_{REF}}}{4R^2 k}$$

$$= \frac{1 - \sqrt{1 + 4R\sqrt{k \cdot I_{REF}}} + 2R\sqrt{k \cdot I_{REF}}}{2R^2 k}$$

(b)

$$\frac{I_O}{I_{REF}} = \frac{I_s e^{\frac{V_{BE2}}{V_T}}}{I_s e^{\frac{V_{BE1}}{V_T}}} \Rightarrow I_O = I_{REF} \cdot e^{\frac{V_{BE2} - V_{BE1}}{V_t}}$$

又∵ $V_{BE1} = V_{BE2} + I_O R \Rightarrow V_{BE2} - V_{BE1} = -I_O R$.

$$\Rightarrow I_O = I_{REF} e^{\frac{-I_O R}{V_T}}$$

$$\ln \frac{I_O}{I_{REF}} = \frac{-I_O R}{V_T}$$

$$\Rightarrow I_O = -\frac{V_T}{R} \cdot \ln \frac{I_O}{I_{REF}} = -2.5 \times 10^{-6} \cdot \ln \frac{I_O}{10^{-3}}$$

迭代法. 設 $I_O = 10^{-5}$ A, $I_O = -2.5 \times 10^{-6} \ln \frac{10^{-5}}{10^{-3}} = 1.15 \times 10^{-5}$

設 $I_O = 1.15 \times 10^{-5}$, 則 $I_O = 1.116 \times 10^{-5}$.

設 $I_O = 1.116 \times 10^{-5}$, 則 $I_O = 1.1238 \times 10^{-5}$.

$I_O = 1.1238 \times 10^{-5}$, 則 $I_O = 1.1224 \times 10^{-5}$.

$$\Rightarrow I_O \doteq 1.1224 \times 10^{-5} \text{ A}$$

$$= 11.224\ \mu A.$$

2. (a). $I_R = \frac{0.6}{40k} = 15\mu A$.

設 $I_{C18} = x$.

則 $I_{B18} = \frac{x}{200} \Rightarrow I_{E19} = I_R + I_{B18} = 15\mu A + \frac{x}{200}$.

又∵ $I_{E19} + I_{C18} = 180\mu A$.

$15 + \frac{x}{200} + x = 180$.

$\frac{201}{200} x = 165$, $\underline{x = 164.18\,\mu A} \rightarrow I_{C18}$.

又∵ 0.6是近似值.

∴ 估較正確之 $V_{BE18} = V_T \times \ln\frac{I_{C18}}{I_S} = 0.588\,(V)$

$\underline{I_{C19} = 15.82\,\mu A}$.

$V_{BE19} = V_T \times \ln\frac{I_{C19}}{I_S} = 0.5295\,(V)$.

$\Rightarrow V_{BE14} + V_{EB20} = V_{BE19} + V_{BE18} = 1.1175$.

又∵ I_S同, I_C同.

∴ $V_{BE14} = V_{EB20} = \frac{1.1175}{2} = 0.55875$.

$I_{C14} = I_S \cdot e^{\frac{V_{BE14}}{V_T}} = 3\times10^{-14} \times e^{\frac{0.55875}{0.025}}$

$= 1.526\times10^{-4}\,(A)$

(b).

$V_{BE1} = V_T \times \ln\frac{I_{C1}}{I_S} = 0.5903 = V_{BE2}$.

$V_{BE1} + V_{BE2} = V_{BE14} + V_{EB20}$.

又∵ Q14 和 Q20 之 I_S同, I_C同.

∴ $V_{BE14} = V_{EB20} = 0.5903$.

$I_{C14} = I_S \cdot e^{\frac{V_{BE14}}{V_T}} = 3\times10^{-14} \times e^{\frac{0.59034}{0.025}}$

$= 5.4\times10^{-4}$

(是 I_{C1} 的3倍).

3.4.5.6 WTF!

01/12/2010.

Final.

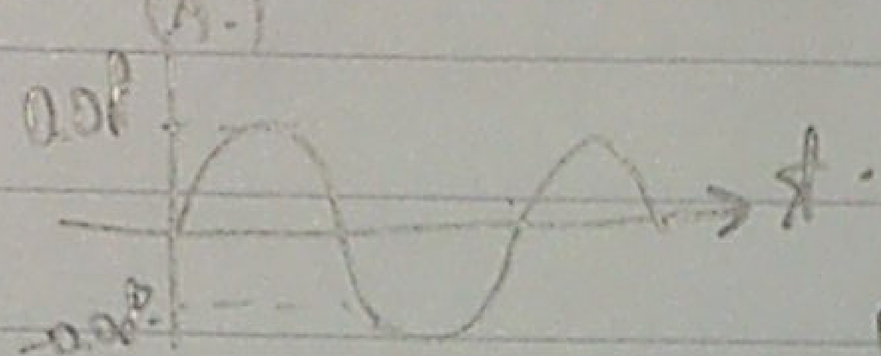
MoonFox.

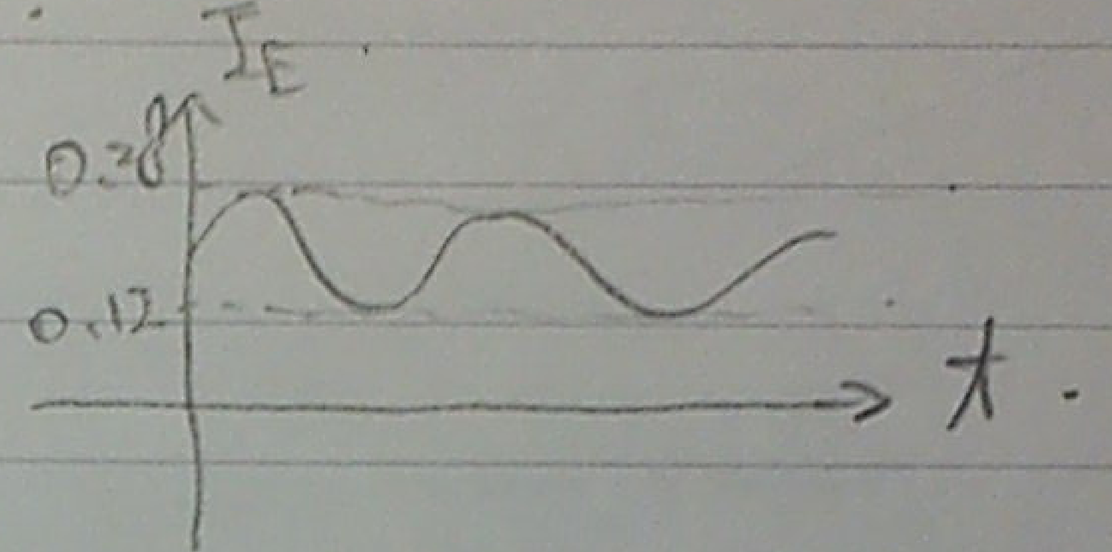
1. 2 WTF

3. (A型)

(a) $P_{out} = \frac{V_{rms}^2}{R} = \frac{64}{2} \times \frac{1}{100} = \underline{0.32\,W}$ //

(b) $I_\Delta =$





$\Rightarrow I_{E_1} = I_\Delta + I_{bias} \Rightarrow$.

$P_{in} = P_{Q_1} + P_{Q_2}$.

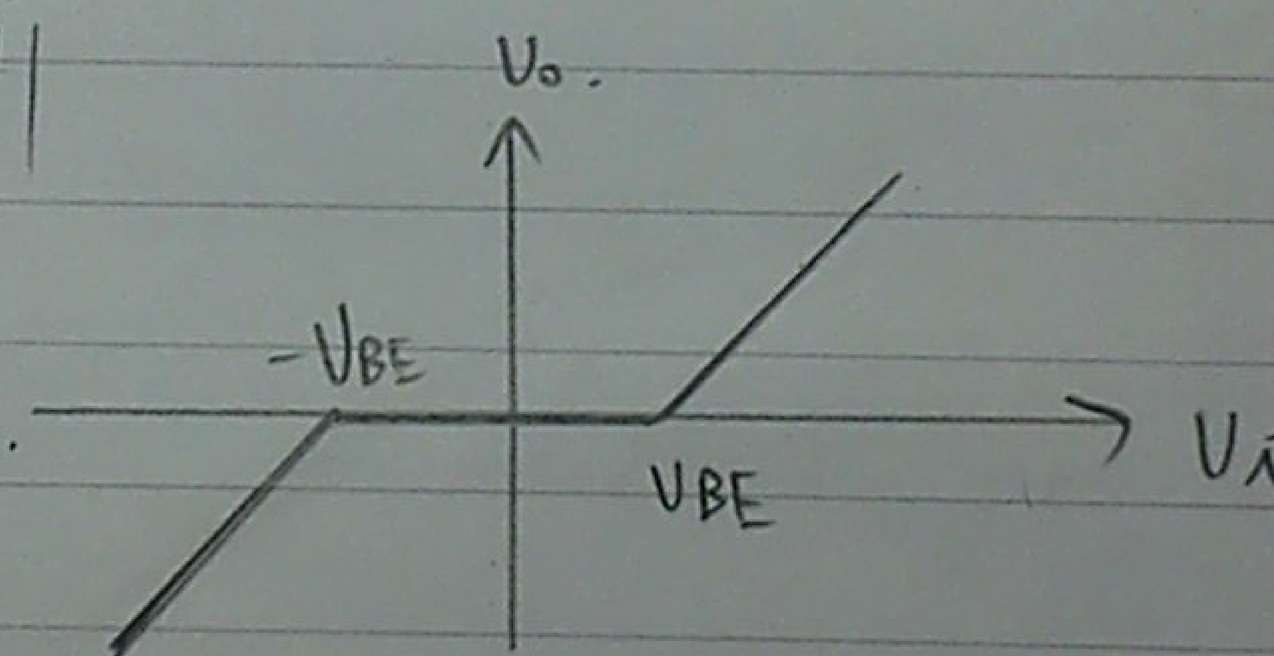
$= I_{Eavg} \cdot V_{cc} + (-I_{bias})(-V_{cc})$. （忽略 Q_3, R 的作功，用 I_{Eavg} 是 ∵ V_{cc} 為定值）.

$= 0.2 \times 10 \times 2 = \underline{4\,W}$ //

(c) $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

$= \underline{8\,\%}$ //

4. (a) $V_{in} - V_o$ 之圖

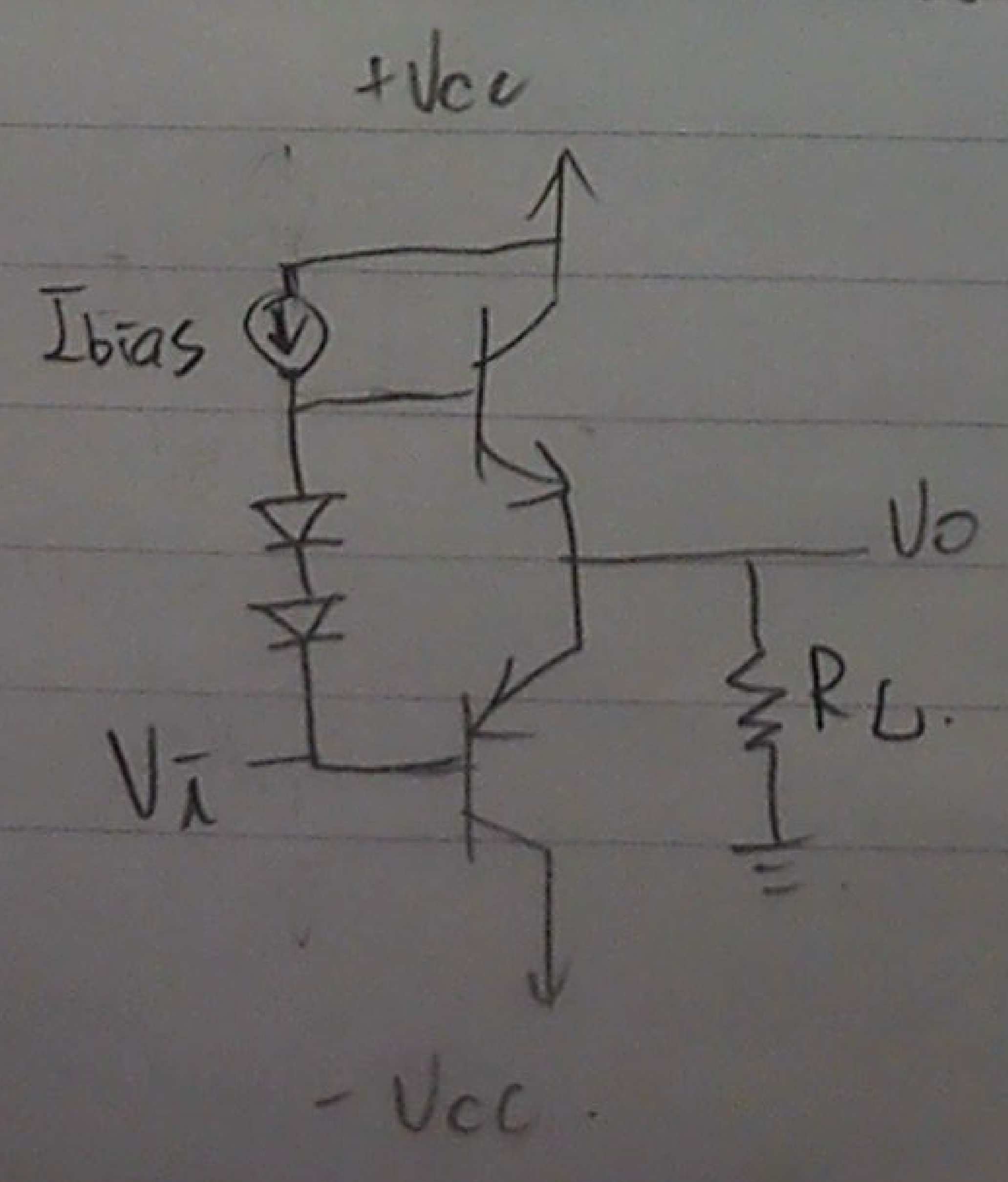


∵ output 在 V_{in} 為 $(-V_{BE}) \sim V_{BE}$ 之間無放大（為 0）.

此區為死帶 dead band.

所以 V_o 不隨 V_{in} 做線性放大，為 crossover distrotion

(b)



5. (a)

$$P_D = \frac{T_C - T_A}{\theta_{CS} + \theta_{SA}} = \frac{70}{0.7} = 100\,(W)$$

$$\Rightarrow T_S = T_A + P_D \cdot \theta_{SA} = 30 + 10 = 40^\circ C$$

(b) 100 (W)

(c) $\theta_{JC} = \frac{T_J - T_C}{P_D} = \frac{50^\circ}{100W} = 0.5^\circ C/W$

6. (a) 設 input $i_i = I_i \cos \omega t$

output $i_o = I_0 + I_1 \cos\omega t + I_2 \cos(2\omega t) + I_3 \cos(3\omega t) \cdots$

nth harmonic distrotion $D_n = \left|\frac{I_n}{I_1}\right|$, $n = 2, 3, 4 \cdots$

$$THD = \sqrt{D_2^2 + D_3^2 + D_4^2 \cdots}$$

(b) 設 input $i_i = I_a(\cos\omega_1 t + \cos\omega_2 t)$

output $i_o = G(i_i)^2 = G I_a [\cos^2(\omega_1 t) + 2\cos(\omega_1 t)\cos(\omega_2 t) + \cos^2(\omega_2 t)]$

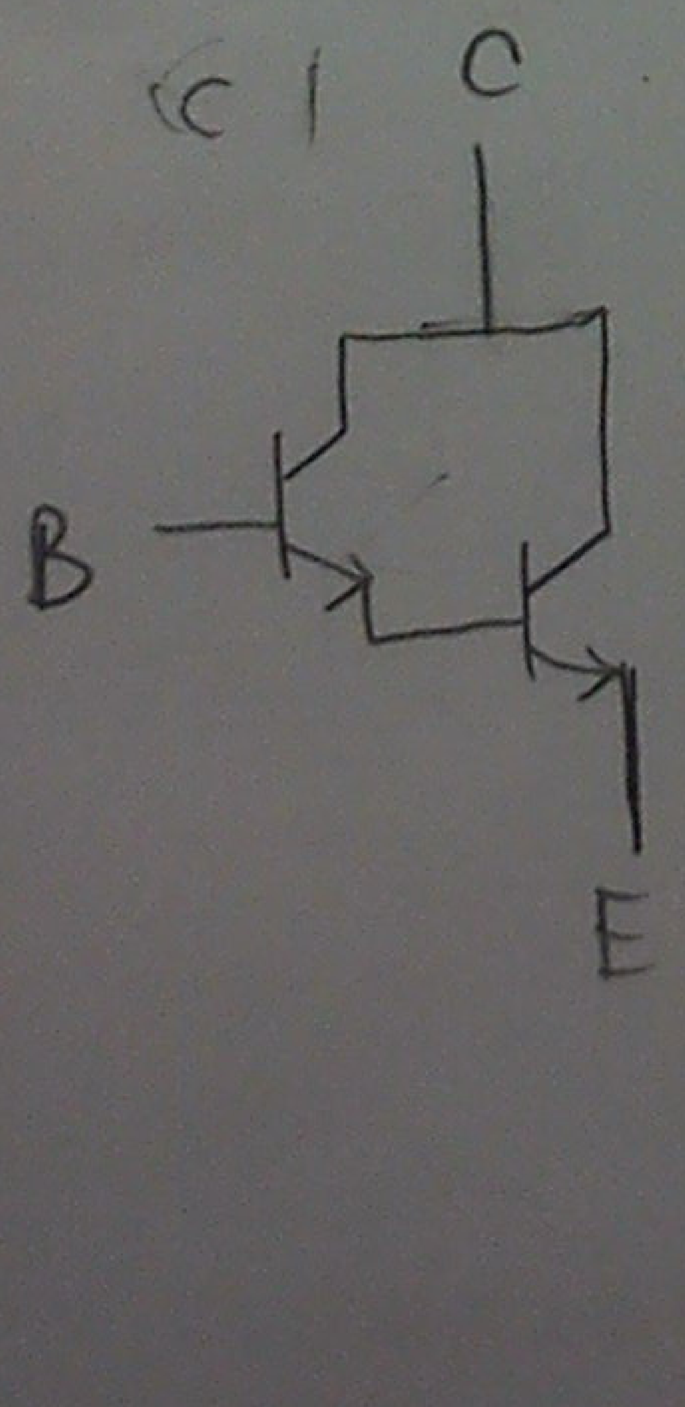
$$= G_1 I_a \left[\tfrac{1}{2} + \tfrac{1}{2}\cos(2\omega_1 t) + \cos[(\omega_1+\omega_2)t] + \cos[(\omega_1-\omega_2)t] + \tfrac{1}{2} + \tfrac{1}{2}\cos(2\omega_2 t)\right].$$

$\Rightarrow$ 頻率有 $\omega_1, \omega_2, 2\omega_1, 2\omega_2, \omega_1+\omega_2, \omega_1-\omega_2$

inter-modulation distortion

(有非原頻率之整數倍的即是)

(c)



用2個BJT合成的BJT.
電流放大倍率更高!!
但 V_{BE} 為原本的2倍

2010/12/07

1、(a) $I_{C19} = \frac{V_{BE18}}{R_{10}} = 15\,\mu A$ //

$I_{C19} = I_S \cdot e^{\frac{V_{BE}}{V_T}}$ (設 β 很大，所有 $I_B \approx 0$).

$\Rightarrow V_{BE} = V_T \ln\left(\frac{I_{C19}}{I_S}\right) = 0.025 \times \ln\left(\frac{15\,\mu A}{10^{-14}}\right) = 0.528\ (V)$

$\therefore V_{BE14} + V_{EB20} = V_{BE19} + V_{BE18} = 1.128$

$\Rightarrow V_T \ln\frac{I_{C14}}{I_S} + V_T \ln\frac{I_{C20}}{I_S} = 1.128$

$\Rightarrow I_{C14} = I_S \cdot e^{\frac{V_{BE14}}{V_T}} = 3\times 10^{-14} \times e^{\frac{0.564}{0.025}} = \underline{18.83\ mA}$ //

$I_{C18} = 280\,\mu A - 15\,\mu A = \underline{265\,\mu A}$ //

(b)

$V_{BE25} = V_T \times \ln\frac{I_{C25}}{I_S} = 0.025 \times \ln\frac{280\,\mu A}{10^{-14}} = 0.6014\ (V)$.

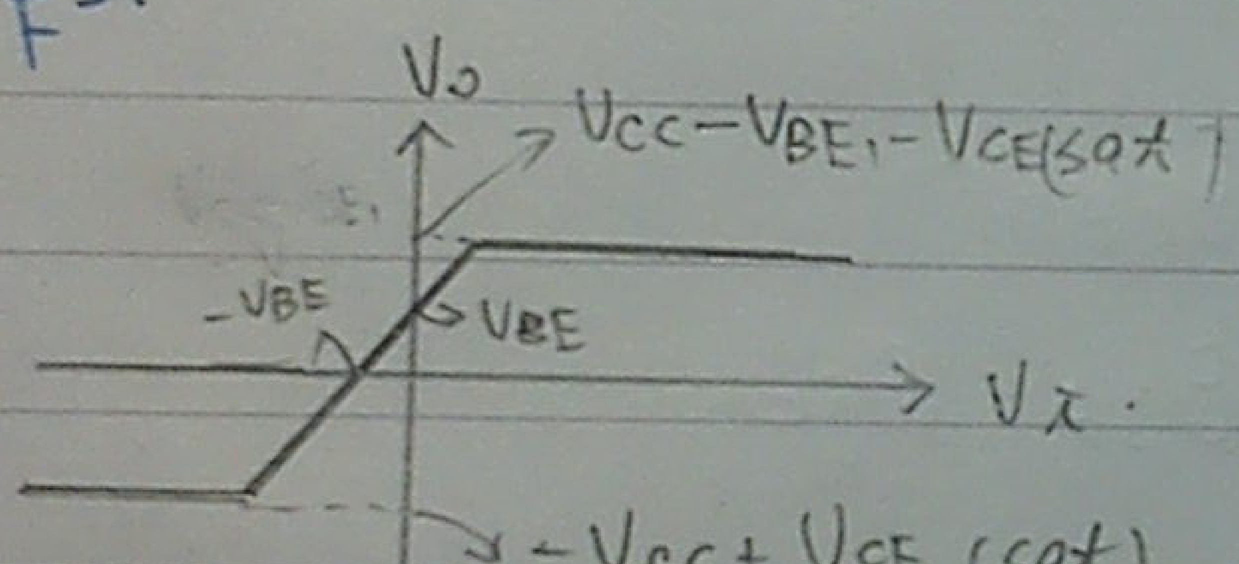
$I_{C14} = I_S \cdot e^{\frac{V_{BE14}}{V_T}} = 3\times 10^{-14} \times e^{\frac{0.6014}{0.025}} = 8.4\times 10^{-4}\ (A)$

2. WTF

3. WTF^2.

4. WTF^3.

5. (a)



(b) 減少 crossover distrotion

(c) 設 input $= i_I = I_i \cos\omega t$

output $i_O = I_0 + I_1\cos\omega t + I_2\cos(2\omega t) + I_3\cos(3\omega t) \cdots$

Nth. harmonic distortion $D_N = \left|\frac{I_N}{I_1}\right|$. $N = 2.3.4\cdots$

$THD = \sqrt{D_2^2 + D_3^2 + D_4^2 \cdots}$

(d) 設 $i_N = I_0 + I_1\cos(\omega t) + I_2\cos(2\omega t) + I_3\cos(3\omega t) + I_4\cos(4\omega t)$.

$\because i_P(\omega t) = i_N(\omega t + \pi)$.

$\therefore i_P = I_0 - I_1\cos(\omega t) + I_2\cos(2\omega t) - I_3\cos(3\omega t) + I_4\cos(4\omega t)$

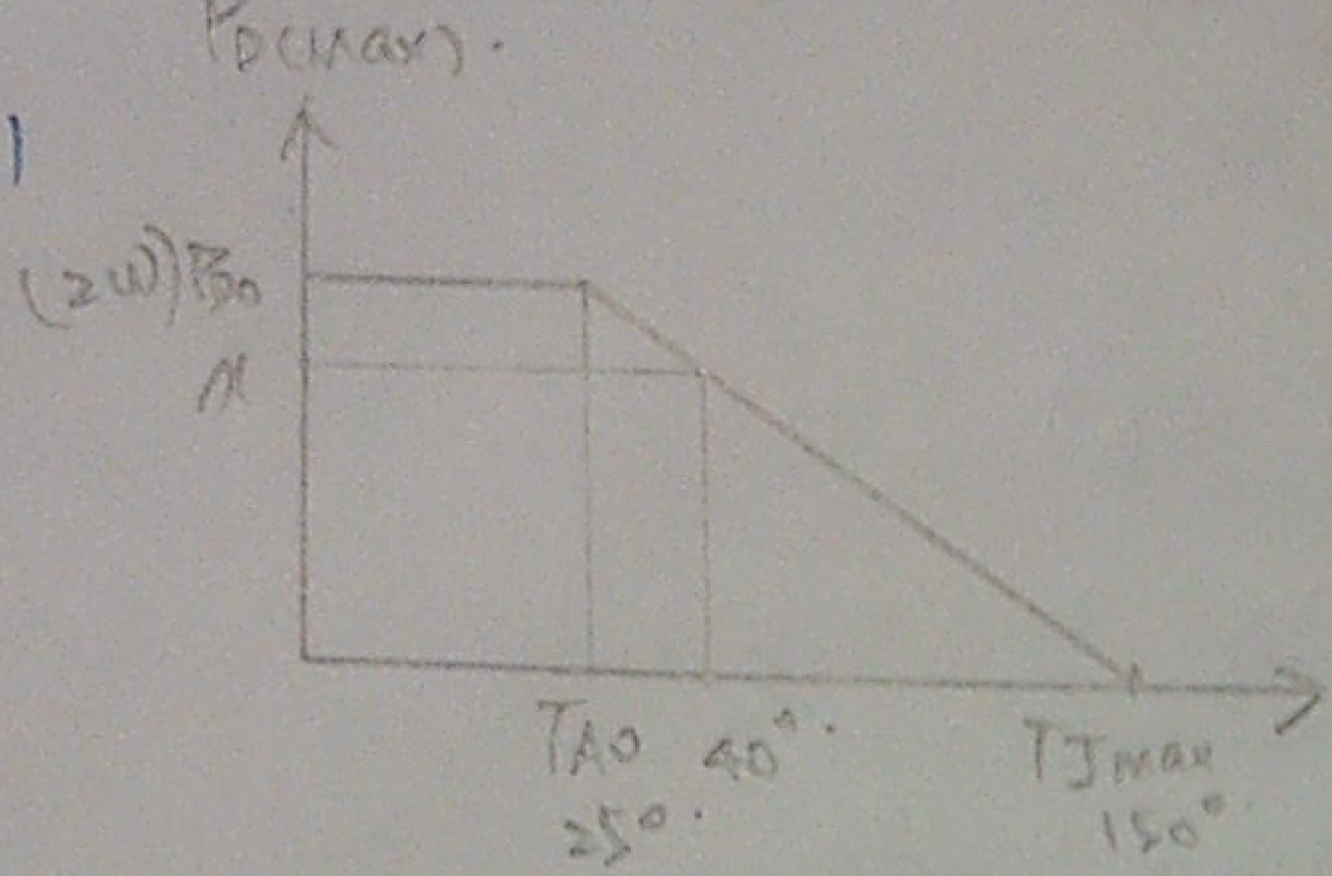
$i_O = i_N - i_P = 2I_1\cos(\omega t) + 2I_3\cos(3\omega t) + \cdots$

=> even-order harmonics are eliminated.

3. (a) Thermal Resistance，代表一物体阻止熱流通過的能力.

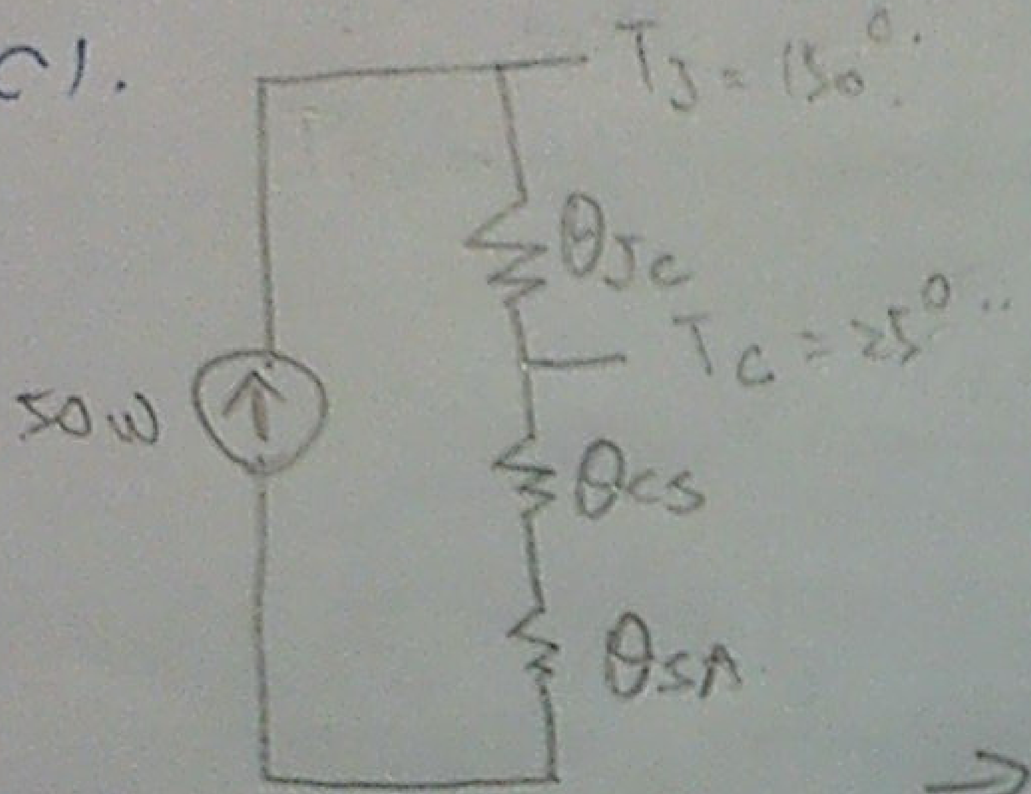
公式為 $\dfrac{\text{物体2面温度差}}{\text{流過的功率}}$

(b)



$x = 1.76(W)$ //

(c)



$$\theta_{JC} = \frac{150° - 25°}{50} = 2.5\ °C/W$$

$$\Rightarrow \theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA} = 2.5 + 0.5 + 5 = 8\ °C/W$$

$$P_{Dmax} = \frac{T_{Jmax} - T_A}{\theta_{JA}} = \frac{150 - 40}{8} = 13.75\ (W)$$ //

(D)

The infinite heat sink $\Rightarrow \theta_{CA} = 0$

$\Rightarrow \theta_{JA} = \theta_{JC}$

$$P_{Dmax} = \frac{150 - 50}{2.5} = 40\ (W)$$ //