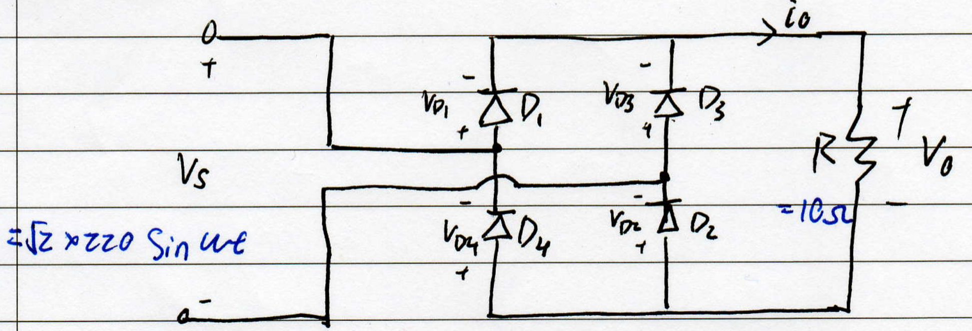
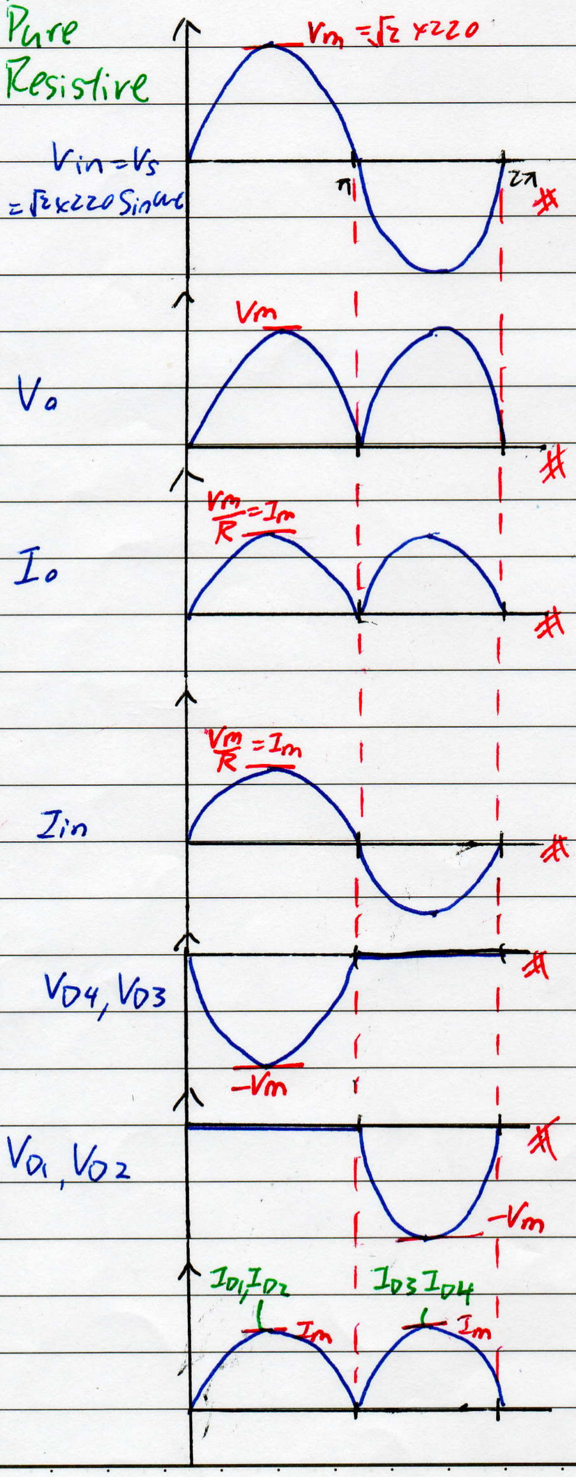
PYP EE4532 NOV/DEC 14 Megarine Tee

1)



a:) ~~Purle~~ Pure Resistive



$V_{o\,rms} = V_m/\sqrt{2}$

$= 220V$ #

$I_{o\,rms} = (V_m/R)/\sqrt{2}$

$= 22A$ # $\Rightarrow V_{o\,rms}/R$

$V_{o\,avg} = \frac{1}{2\pi}\int_0^{2\pi} V_o(\omega t)\, d\omega t$

$= \frac{2}{2\pi}\int_0^{\pi} V_m \sin \omega t \, d\omega t$

$= \frac{V_m}{\pi}\left[-\cos \omega t\right]_0^{\pi}$

$= \frac{2}{\pi}V_m = 198.07V$ #

$I_{o\,avg} = V_{o\,avg}/R$

$= 19.807A$ #

ii) $V_m = 311.127V$

$I_m = 31.1127A$

iii) $V_{in\,rms} = 220V$

$I_{in\,rms} = I_m/\sqrt{2} = 22A$

Transformer Rating $= V_{in\,rms} \times I_{in\,rms} = 4840VA$ #

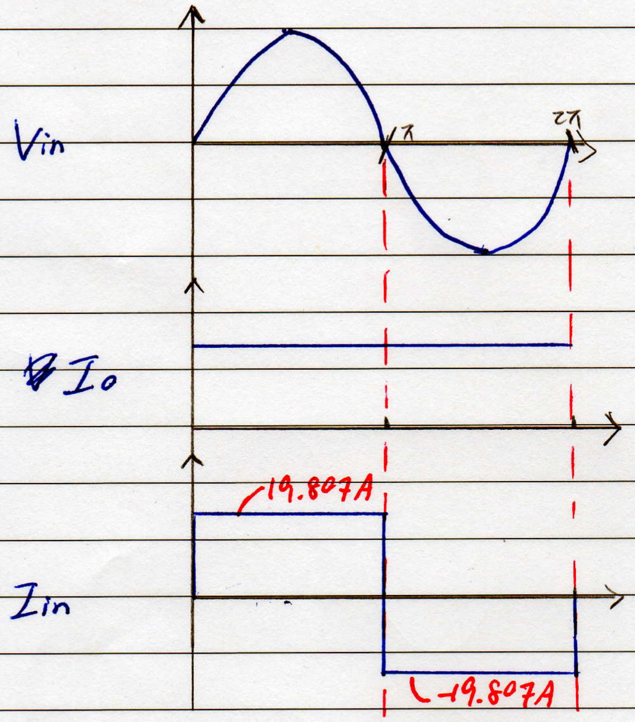
$PIV = V_m = 311.127V$ #

$I_{D\,peak} = I_m = 31.1127A$ #

$I_{D\,avg} = I_{o\,avg}/2 = 9.9035A$ #

$I_{D\,rms} = I_{o\,rms} \times \sqrt{\frac{1}{2}} = 15.556A$ #

b) For high inductive load, I_o is constant, all voltage wave no change



$I_{o\,rms} = I_{o\,peak} = I_{o\,avg}$

$I_{o\,avg} = V_{o\,avg}/R = 19.807A$

$V_{in\,rms} = 220V$

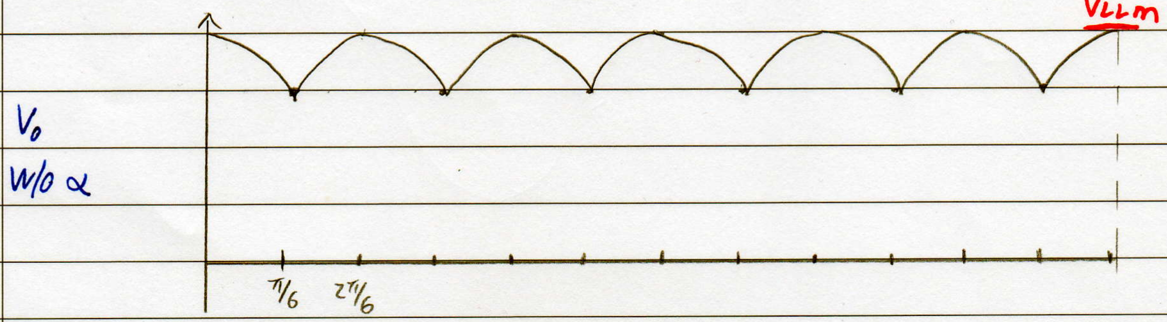
$I_{in\,rms} = 19.807A$

Transformer Rating $= V_{in\,rms} \times I_{in\,rms}$

$= 4357.54\,VA$ #

2) $V_{Ln\,rms} = 220V$, $V_{LL\,m} = 220 \times \sqrt{2} \times \sqrt{3} = 538.89V$

Highly inductive load, $R = 10\Omega$, $f = 50Hz$

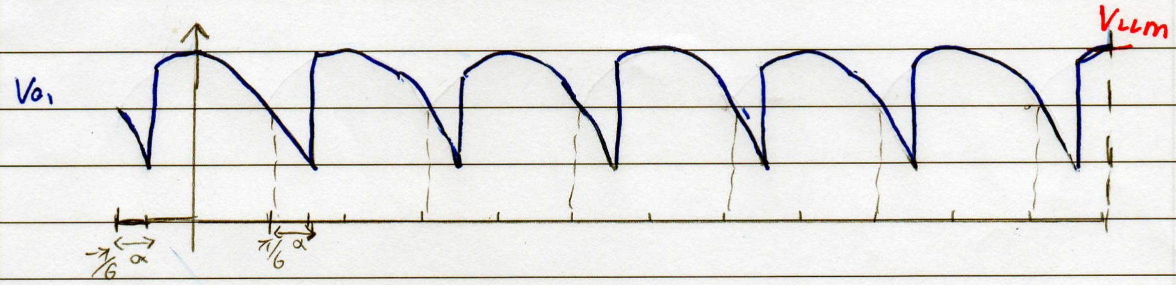


when $\alpha = 0$, $V_{o\,avg}$ is max.

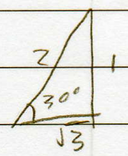
$$V_{o\,avg} = \frac{1}{2\pi}\int_0^{2\pi} V_o(\omega t)\,d\omega t = \frac{1}{2\pi} \times 12 \times V_{LLm}\int_{0}^{\pi/6} \cos\omega t\,d\omega t$$

$$= \frac{6}{\pi}V_{LLm}\left[\sin\omega t\right]_0^{\pi/6} = \frac{3}{\pi}V_{LLm} = 514.6V$$

ai)



$V_{o1\,avg} = 80\%\, V_{o\,avg} = 411.68V$



$$V_{o1\,avg} = \frac{1}{2\pi}\int_0^{2\pi} V_{o1}(\omega t)\,d\omega t = \frac{1}{2\pi} \times 6\int_{-\pi/6+\alpha}^{\pi/6+\alpha} V_{LLm}\cos\omega t\,d\omega t$$

$$= \frac{3}{\pi}V_{LLm}\left[\sin\omega t\right]_{-\pi/6+\alpha}^{\pi/6+\alpha} = \frac{3}{\pi}V_{LLm}\left[\sin(\pi/6+\alpha) - \sin(-\pi/6+\alpha)\right]$$

$$= \frac{3}{\pi}V_{LLm}\left[\sin(\pi/6)\cos(\alpha) + \cos(\pi/6)\sin(\alpha) - \sin(\alpha)\cos(\pi/6) + \cos(\alpha)\sin(\pi/6)\right]$$

$$= \frac{3}{\pi}V_{LLm}\left[\frac{1}{2}\cos\alpha + \cancel{\frac{\sqrt{3}}{2}\sin\alpha} \cancel{-\frac{\sqrt{3}}{2}\sin\alpha} + \frac{1}{2}\cos\alpha\right] = \frac{3}{\pi}V_{LLm}\cos\alpha$$

$\frac{3}{\pi}V_{LLm}\cos\alpha = 411.68 \Rightarrow \alpha = 36.87°$ #

ii) $I_{o1\,avg} = V_{o1\,avg} / R = 41.168A$ #

$I_{o1\,rms} = I_{o1\,peak} = I_{o1\,avg} = 41.168A$ # (highly inductive)

iii) Since each thyrsitor conduct for 2 pulses out of 6 pulses,

$\therefore I_{T1\,avg} = I_{o1\,avg} \times \frac{2}{6} = 13.723A$ #

$I_{T1\,rms} = I_{o\,rms} \times \sqrt{\frac{2}{6}} = 23.768A$ #

iv) $P_{o1\,avg} = V_{o1\,avg} \times I_{o1\,avg} = 16.948\ kVA$

$P_{in\,rms} = V_{in\,rms} \times I_{in\,rms}$ (Per phase)

$V_{a\,rms} = 220V$

$I_{a\,rms} = I_{o1\,rms} \times \sqrt{\frac{4}{6}} = 33.613A$

$P_{a\,rms} = 7.395\ kVA$

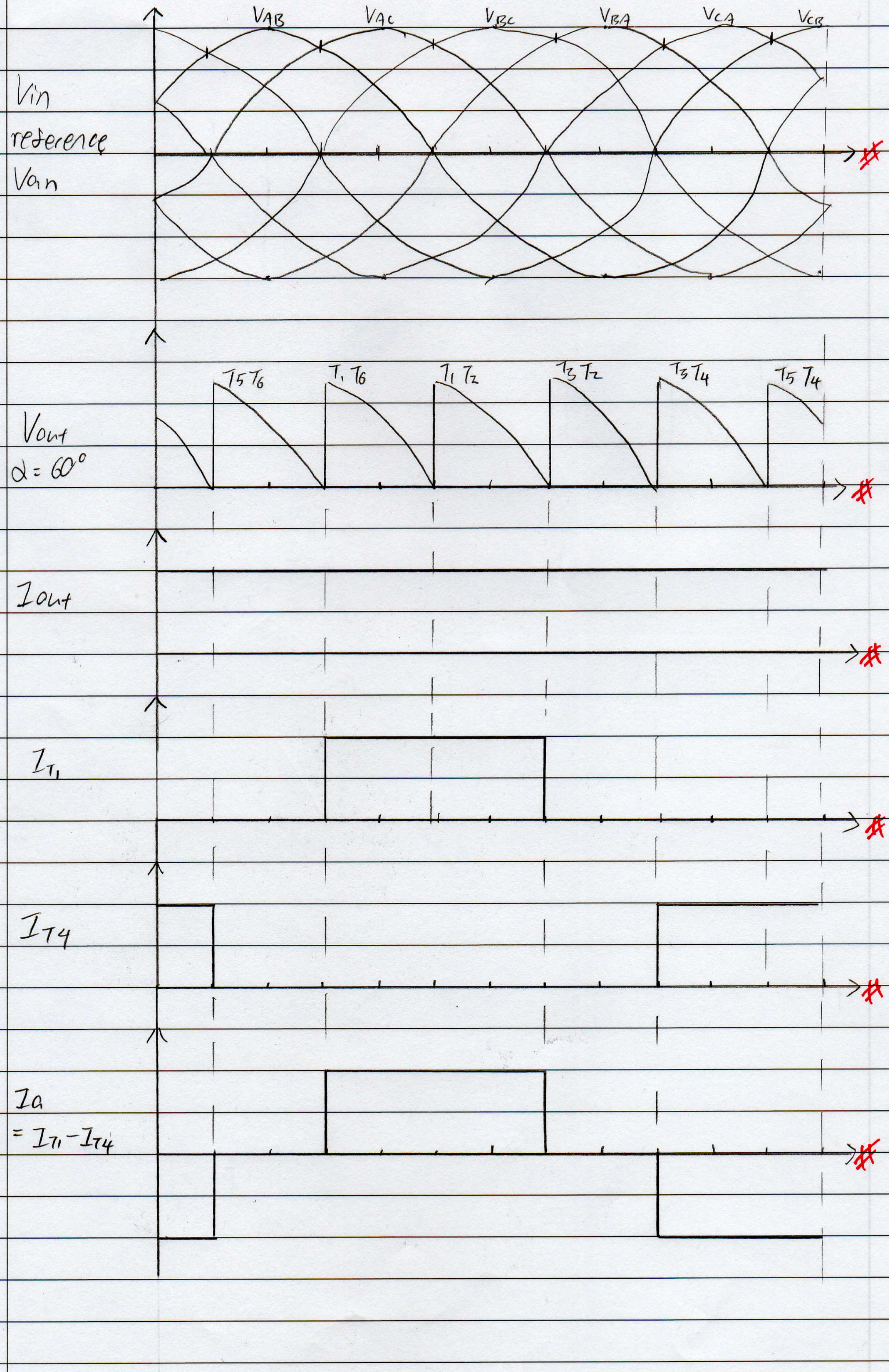
$TUF = \frac{P_{o1\,avg}}{3 P_{a\,rms}} = 76.39\%$ #

v) Transformer rating $= 3 P_{a\,rms} = 22.185\ kVA$

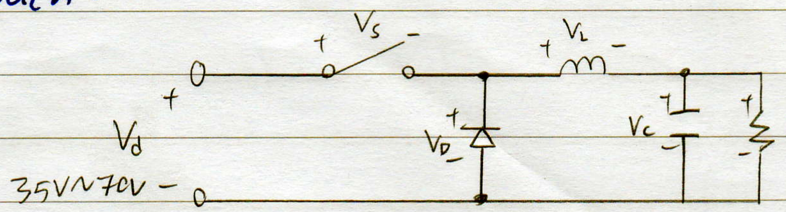
Transformer actual rating $= \frac{1}{0.8} \times 22.185\ kVA$

$= 27.73\ kVA$ #

b)


VAB
VAC
VBC
VBA
VCA
VCB
Vin
reference
Van
T5 T6
T1 T6
T1 T2
T3 T2
T3 T4
T5 T4
Vout
α = 60°
Iout
IT1
IT4
Ia
= IT1 - IT4

3) Buck:



$V_o = 20V$

$P_{omax} = 500W$

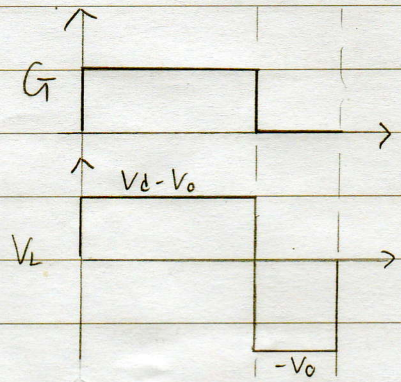
CCM: $P_{omin} = 5\% P_{omax} = 25W$

$f_s = 100kHz \Rightarrow T_s = 0.01ms$

$\Delta V_o \leq 200mV$

$P_o = P_{in}$, $V_{L\,avg} = 0V$, $I_{c\,avg} = 0A$

a)



$[V_d - V_o] t_{on} + [-V_o] t_{off} = 0$

$V_d t_{on} = V_o (t_{on} + t_{off})$

$t_{on} = DT_s$, $t_{on} + t_{off} = T_s$

$V_d \; DT_s = V_o T_s$

$\Rightarrow \frac{V_o}{V_d} = D$ # (prove)

$P_o = V_o I_o = V_d I_d$

$\Rightarrow \frac{V_o}{V_d} = \frac{I_d}{I_o} = D \quad \therefore \frac{I_o}{I_d} = \frac{1}{D}$ # (prove)

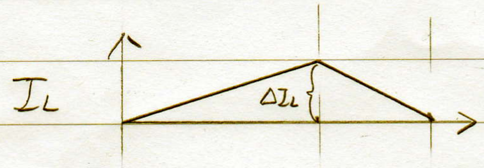
When $V_d = 40V$, $P_o = 500W$, $V_o = 20V$:

$D = \frac{V_o}{V_d} = \frac{20}{40} = 0.5$ #

$I_o = P_o / V_o = 25A$ #

$I_d = I_o D = 12.5A$ #

b) At BCM:



$I_L = I_C + I_O$

$I_{Lavg} = I_{Cavg} + I_O = I_O$

$I_{LB} = I_{OB} = \left[\frac{1}{2} \times T_s \times \Delta I_L\right] / T_s = \frac{1}{2} \Delta I_L$

$\Delta I_L = \frac{V_O}{L}(1-D)T_s$

$I_{OB} = \frac{V_O(1-D)T_s}{2L} = \frac{V_O}{R_B} \Rightarrow L = \frac{(1-D)R_B}{2 f_s}$ (prove) #

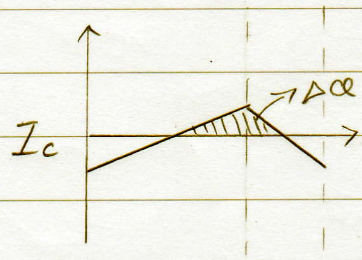
For $V_d = 35V \sim 70V$, $V_O = 20V \Rightarrow D = \cancel{\frac{20}{35}}\ \frac{20}{70} \sim \frac{20}{35}$

Under BCM, $P_{omin} = 25W \Rightarrow R_B = V_O^2 / P_{omin} = 16\Omega$

To guarantee CCM, L must be large $\Rightarrow$ D must be small

$$L = \frac{(1-D)R_B}{2 f_s} = \frac{\left(1-\frac{20}{70}\right) \times 16}{2 \times 100 \times 10^3} = 57.143 \mu H$$ #

c) $\Delta V_O = \frac{\Delta Q}{C} = \frac{1}{C}\left[\frac{1}{2} \times \frac{T_s}{2} \times \frac{\Delta I_L}{2}\right] = \frac{V_O(1-D)T_s^2}{8LC}$



$\Rightarrow \frac{\Delta V_O}{V_O} = \frac{T_s^2}{8LC}(1-D)$ prove #

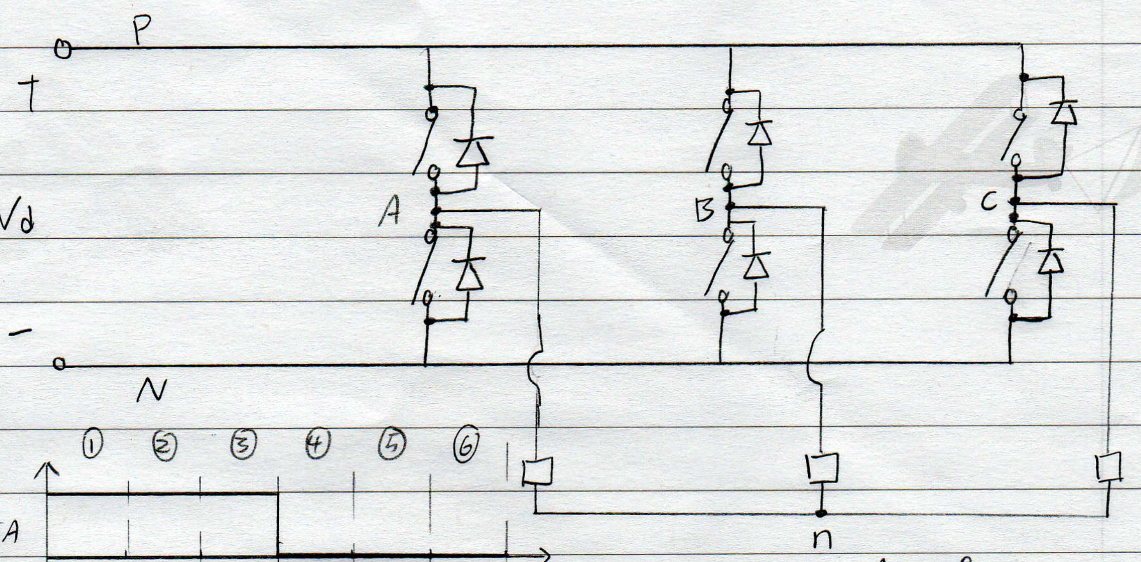
$\Delta V_O \leq 200mV$,

For ΔV_O to be small, C must be big $\Rightarrow$ D must be small

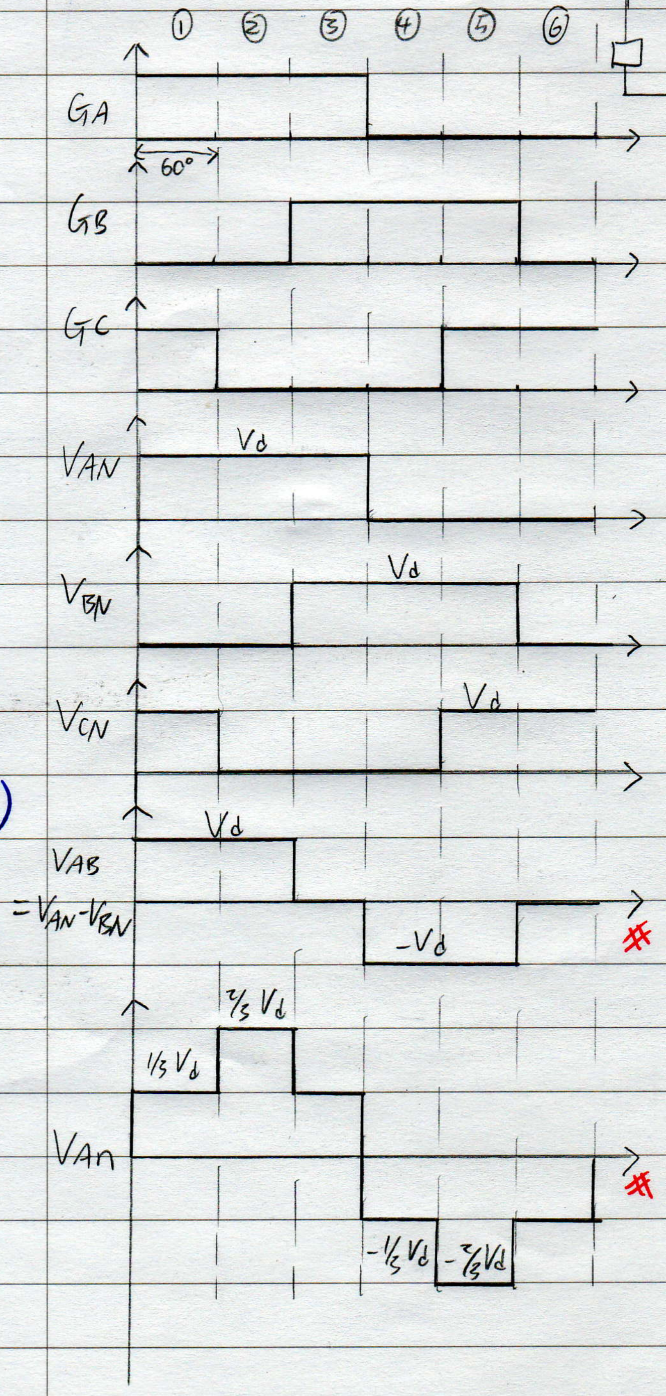
$$\frac{\Delta V_O}{V_O} = \frac{T_s^2}{8LC}(1-D) = \frac{(0.01 \times 10^{-3})^2 \times \left(1-\frac{20}{70}\right)}{8 \times 57.143 \times 10^{-6} \times C} = \frac{200 \times 10^{-3}}{20}$$

$\Rightarrow C = 15.625 \mu F$ #

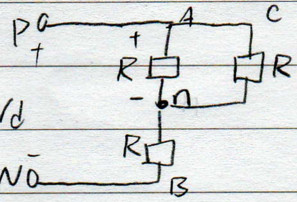
4)



a)

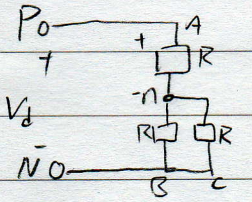


①



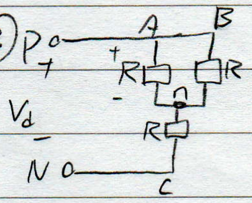
$$V_{An} = \frac{R//R}{R+R//R} \times V_d = \frac{1}{3}V_d$$

②



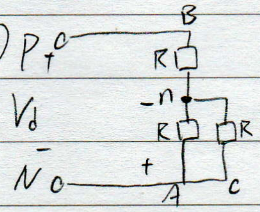
$$V_{An} = \frac{R}{R+R//R} V_d = \frac{2}{3}V_d$$

③



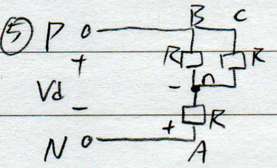
$$V_{An} = \frac{R//R}{R+R//R} V_d = \frac{1}{3}V_d$$

④



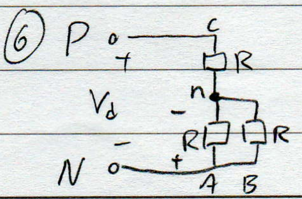
$$V_{An} = -V_d \frac{R//R}{R+R//R} = -\frac{1}{3}V_d$$

⑤



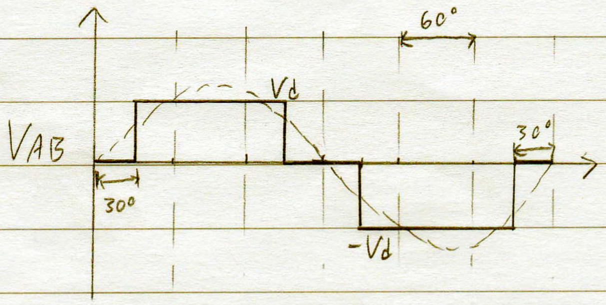
$$V_{An} = -V_d \frac{R}{R+R//R} = -\frac{2}{3}V_d$$

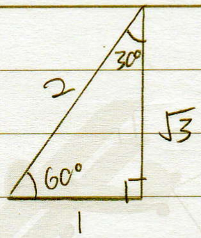
⑥



$$V_{An} = -V_d \frac{R//R}{R+R//R} = -\frac{1}{3}V_d$$

b)





$$\cos(5\pi/6) = -\cos(5\pi/6 - 6\pi/6)$$
$$= -\cos(-\pi/6)$$
$$= -\cos(\pi/6)$$
$$= -\sqrt{3}/2$$

Since finding fundamental, set $n=1$

$$b_1 = \frac{1}{\pi}\int_0^{2\pi} V_{AB}\sin(\omega t)\,d\omega t = \frac{2}{\pi}\int_{\pi/6}^{5\pi/6} V_d \sin(\omega t)\,d\omega t = \frac{2V_d}{\pi}\Big[-\cos(\omega t)\Big]_{\pi/6}^{5\pi/6}$$

$$= \frac{2V_d}{\pi}\Big[\cos(\pi/6) - \cos(5\pi/6)\Big] = \frac{2V_d}{\pi}\Big[\frac{\sqrt{3}}{2} + \frac{\sqrt{3}}{2}\Big] = \frac{2\sqrt{3}}{\pi}V_d$$

$$b_1 = V_{AB\,peak} \Rightarrow V_{AB\,rms} = \frac{V_{AB\,peak}}{\sqrt{2}} = \frac{2\sqrt{3}}{\sqrt{2}\pi}V_d = \frac{2\sqrt{2}\sqrt{3}}{\sqrt{2}\sqrt{2}\pi}V_d = \frac{2}{2}\frac{\sqrt{2}\sqrt{3}}{\pi}V_d = \frac{\sqrt{6}}{\pi}V_d \text{ (prove)}$$
#

$$b_1 = \frac{1}{\pi}\int_0^{2\pi} V_{An}\sin(\omega t)\,d\omega t = \frac{4}{\pi}\int_0^{\pi/3}\frac{1}{3}V_d\sin(\omega t)\,d\omega t + \frac{2}{\pi}\int_{\pi/3}^{2\pi/3}\frac{2}{3}V_d\sin(\omega t)\,d\omega t$$

$$= \frac{4V_d}{3\pi}\Big[-\cos\omega t\Big]_0^{\pi/3} + \frac{4V_d}{3\pi}\Big[-\cos\omega t\Big]_{\pi/3}^{2\pi/3}$$

$$\cos 2\pi/3 = -\cos(2\pi/3 - 3\pi/3)$$
$$= -\cos(-\pi/3)$$
$$= -\cos\pi/3$$
$$= -1/2$$

$$= \frac{4V_d}{3\pi}\Big[1 - \cos\pi/3 - \cos 2\pi/3 + \cos\pi/3\Big]$$

$$= \frac{4V_d}{3\pi}\Big[1 - \cos 2\pi/3\Big]$$

$$= \frac{4V_d}{3\pi}\Big[\frac{3}{2}\Big]$$
$$= \frac{2}{\pi}V_d$$

$$b_1 = V_{An\,peak} \Rightarrow V_{An\,rms} = \frac{V_{An\,peak}}{\sqrt{2}} = \frac{2}{\sqrt{2}\pi}V_d = \frac{\sqrt{2}\,2}{\pi\sqrt{2}\sqrt{2}}V_d = \frac{2}{2}\frac{\sqrt{2}}{\pi}V_d = \frac{\sqrt{2}}{\pi}V_d \text{ (prove)}$$
#

c) —