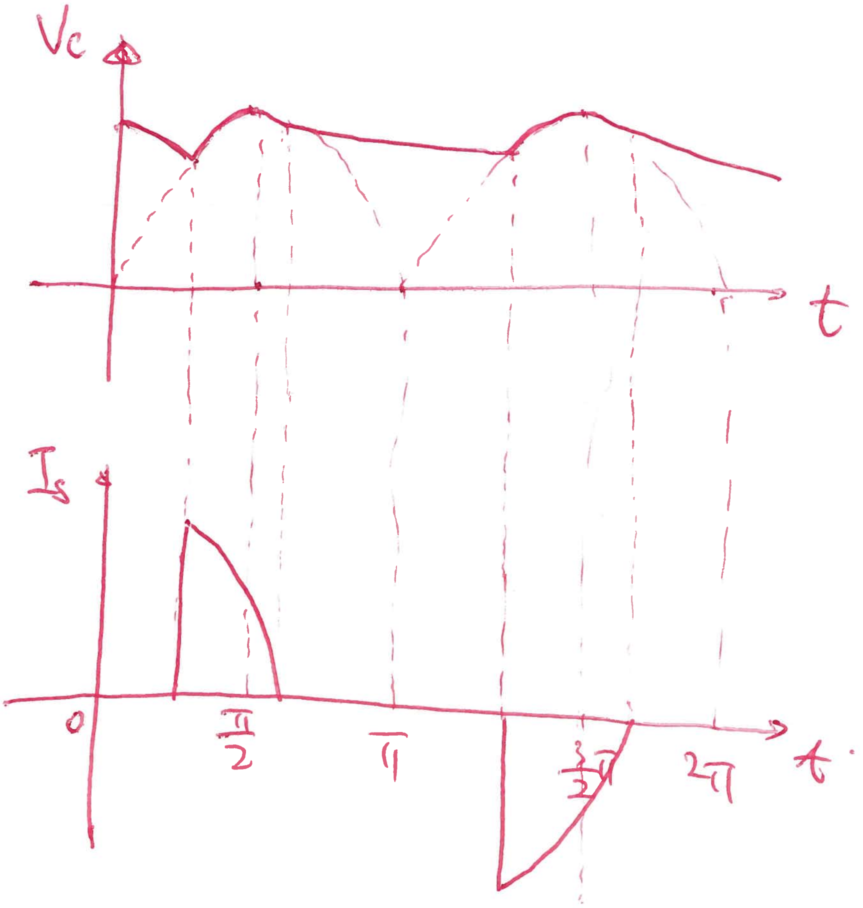
Crib 2018

Q1 a)

i)



ii) Input current is largely distorted, resulting in high harmonics. Power factor (pf) is:

$$pf = \frac{1}{\sqrt{1+THD_i^2}} \cos\theta$$

, THDi of current.

Large THDi, poor p.f.

iii) Assume: ① Linear discharge of capacitor.

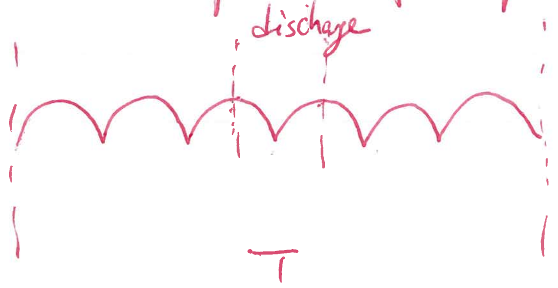
② Very large capacitor so entire half cycle ($\frac{\pi}{2}$ to π) is for capacitor discharge.

$$\Delta V = \hat{V} - \hat{V}\left(1 - \frac{1}{2fR_LC}\right) = \frac{\hat{V}}{2fR_LC}$$

, $I = \frac{\hat{V}}{R_L}$, $\Delta V = \frac{I}{2fC}$.

b) i) $V_{DCpeak} = 415 \times \sqrt{2} = 587$ V

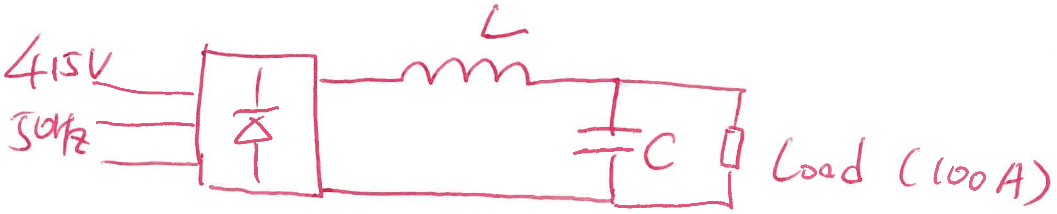
Assuming discharge between two peaks of every two consecutive pulses.



$$\Delta V = I \cdot \frac{\Delta T}{C},, \qquad C = \frac{\Delta T \cdot I}{\Delta V}$$

$$\left\{\begin{array}{l} \Delta V = 587 \times 0.05 \\ \Delta T = \frac{1}{6f} = \frac{1}{6 \times 50} \\ I = 100 \end{array}\right. \Rightarrow C = \frac{100}{6 \times 50 \times 587 \times 0.05} = 11.36\,mF.$$

ii)



The dominate harmonics is at $6 \times 50 = 300Hz$.

As constant load current, load impedance $Z_{load} \approx \frac{587}{100} = 5.87$

At 300Hz, the capacitor Impedence $|Z_C| = \left|\frac{1}{j2\pi \times 300 \times 11.36m}\right|$

$$= 0.047\,\Omega$$

$|Z_C| << Z_{load}$, thus. $|Z_C| // Z_{load} \approx |Z_C|$.

1% voltage ripple means $\frac{|Z_C|}{|Z_C| + |Z_L|} = 0.01$

$$\frac{|Z_C|}{|Z_C|+|Z_L|} = \frac{\left|\frac{1}{j\omega C}\right|}{\left|\frac{1}{j\omega C}\right| + |j\omega L|} = \frac{1}{1+\omega^2 LC} = 0.01.$$

$$L = \frac{99}{\omega^2 C} = \frac{99}{(50\times6\times2\pi)^2\times11.36\times10^{-3}} = \cancel{2.35\,\mu H}\ \mathbf{2.45\ mH}$$

iii) The inductor keeps the current flowing. The supply current then becomes more sinusoidal with less harmonics. Less THD of current then higher power factor.

Q2. i)

a) A free-wheel diode is needed to clamp MOSFET voltage to the supply rail otherwise the voltage will keep rising causing MOSFET breakdown.

100V, 75A diode is required and the diode needs to be fast recovery diode.

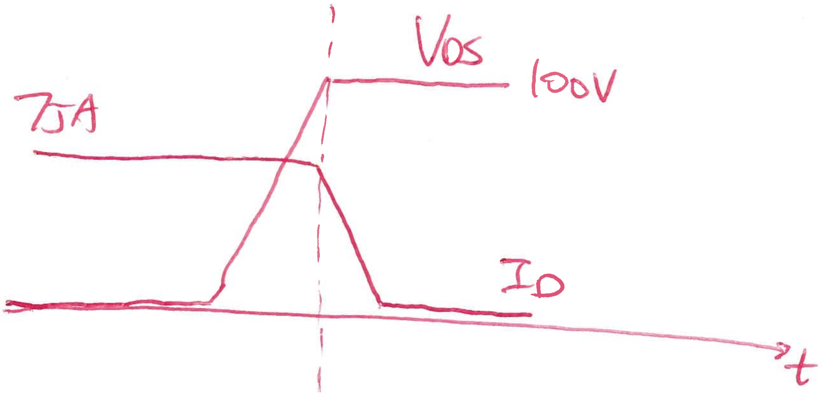
ii) Conduction loss: $75 \times 75 \times 0.007 \times 0.5 = 19.7W$.

Switching losses (ON and OFF):

$$2 \times \frac{1}{2} \times 75 \times 100 \times 10^3 \times 50 \times 10^{-9} \times 100 = 37.5W.$$

Total loss: $37.5 + 19.7 = 57.2W$.

iii) Turn-off.

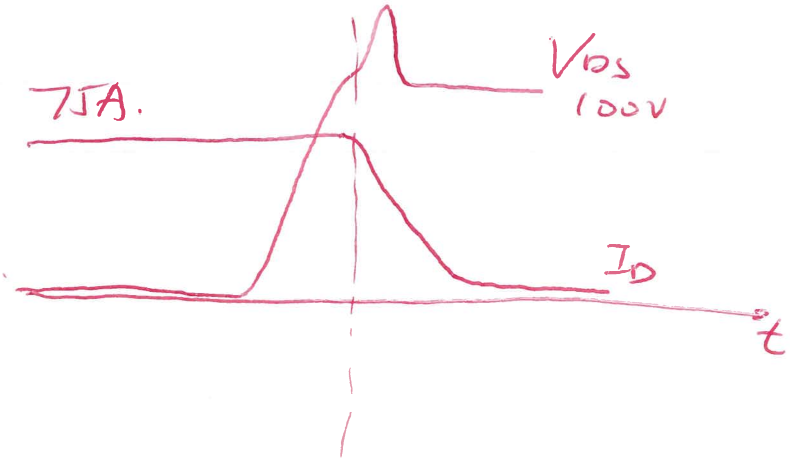


$$75 = 150(V_{GS}-2)^2 \longrightarrow V_{GS} = 2.71V.$$

$$I_G = C\frac{dv}{dt} = 50 \times 10^{-12} \times \frac{100}{20 \times 10^{-9}} = 250mA.$$

$$R_G = \frac{V_{GS}}{I_G} = \frac{2.71}{250\times10^{-3}} = 10.84\,\Omega.$$

iv)

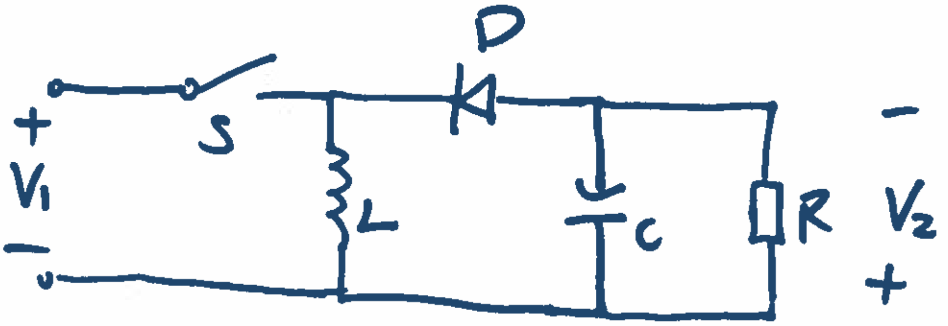


b) Good: ① Very fast $\frac{di}{dt}$ so low losses

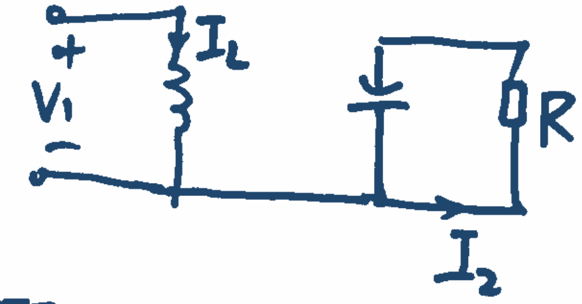
② Overcomes any miller capacitor induced voltages in an inverter application.

Bad: ① Very fast $\frac{di}{dt}$ will cause ringing due to stray inductances in the circuit. Some resistance can be added to damp ~~[illegible]~~ ringing but with additional costs.

3. (a)



i) ON

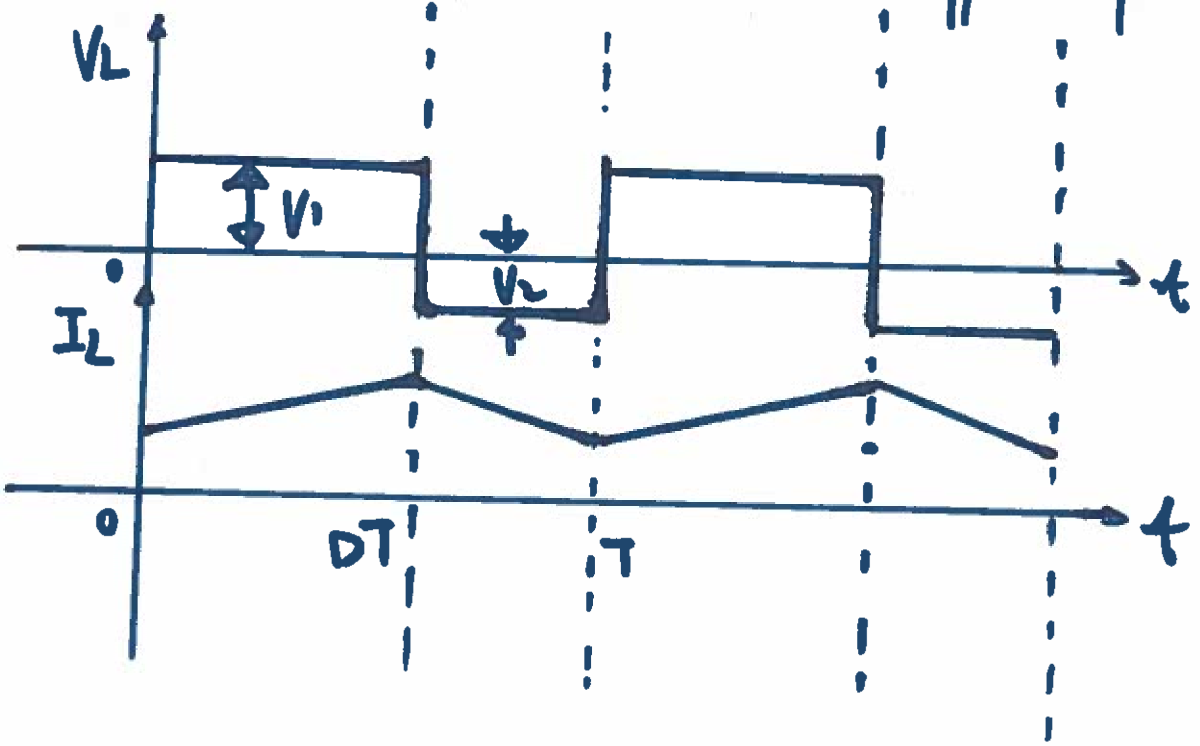


$V_1 = L\frac{\Delta I_L}{DT}$, $\Delta I_L = \frac{DTV_1}{L}$

OFF

$L\frac{\Delta I_L}{(1-D)T} = V_2$

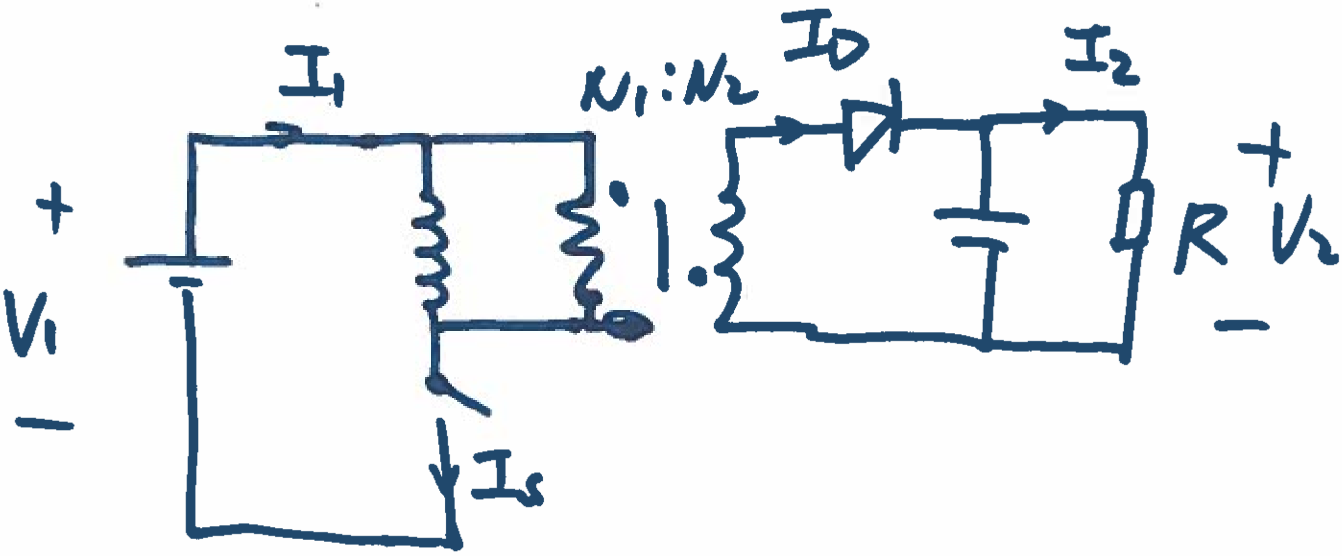
$\therefore \left(\frac{D}{1-D}\right)V_1 = V_2$, V_2 has opposite polarity to V_1.



iii) - Cannot be grounded.

- input current is discontinuous.

b)



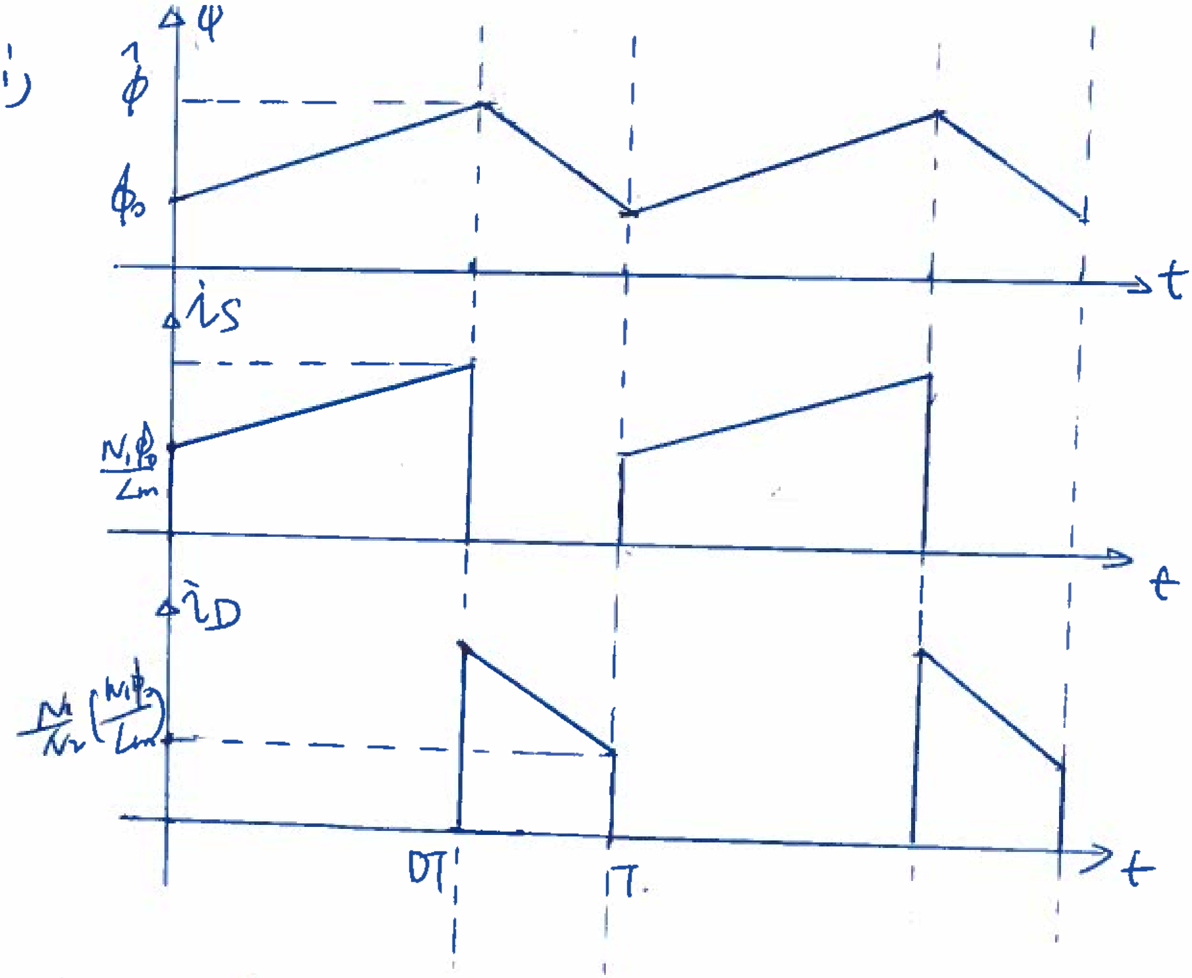
ON: $\Delta\phi = \int_0^{DT} \frac{V_1}{N_1} dt = DT \frac{V_1}{N_1}$

OFF: $\Delta\phi = \int_{DT}^{T} \frac{V_2}{N_2} dt = (1-D)T \frac{V_2}{N_2}$

$\therefore \quad DT \frac{V_1}{N_1} = (1-D)T \frac{V_2}{N_2}$

$\frac{V_1}{V_2} = \frac{N_1}{N_2}(1-D)/D. \quad \frac{V_2}{V_1} = \frac{N_2}{N_1}\left(\frac{D}{1-D}\right)$

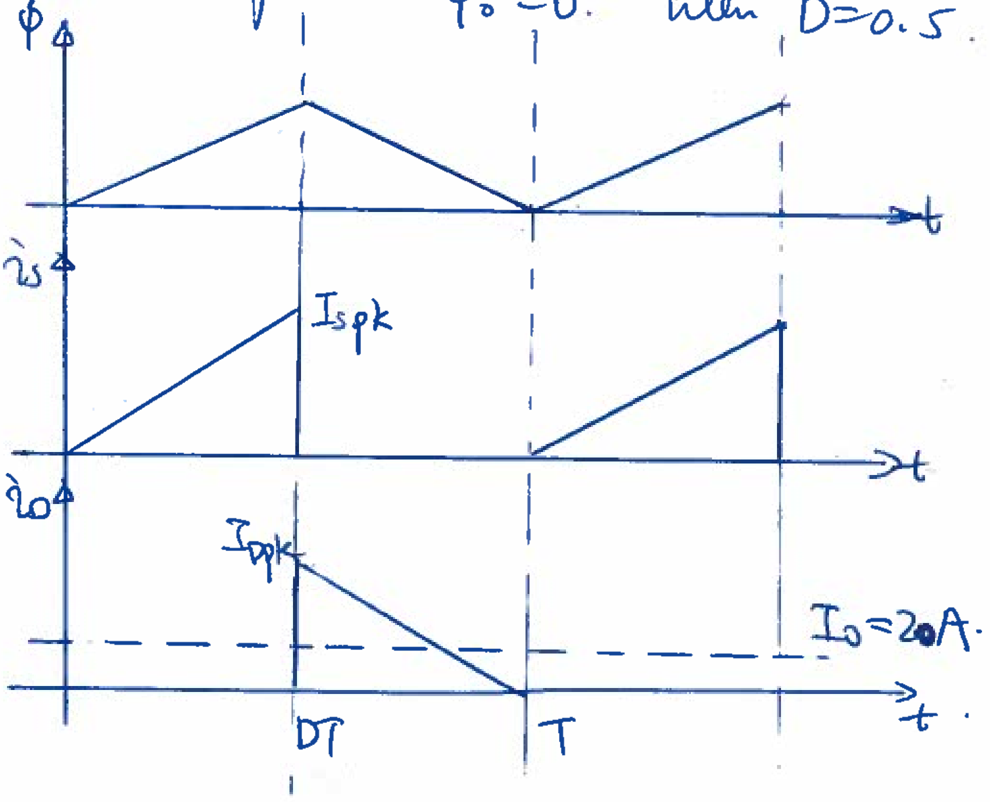
b) (ii)



iii) The initial flux should be as small as possible to avoid saturation of the transformer core.

iv) $\frac{V_2}{V_1} = \frac{N_2}{N_1}\frac{D}{1-D} \Rightarrow N_2 = 20$

At desired operation, $\phi_0 = 0$. when $D = 0.5$.



The output average current I_o

$$I_o = \frac{V_2}{R} = \frac{50}{25} = 2A.$$

At the secondary side, the diode current must have:

$$I_o \cdot T = \frac{1}{2} I_{Dpk} \cdot DT,$$ (I_Dpk is the diode peak current)

$$\Rightarrow \quad I_{Dpk} = 4 \cdot I_o = 8A.$$

$$\frac{I_{spk}}{I_{Dpk}} = \frac{N_2}{N_1}, \quad I_{spk} = \frac{20}{60} \times 8 = \frac{8}{3} A.$$ (I_spk is the switch peak current)

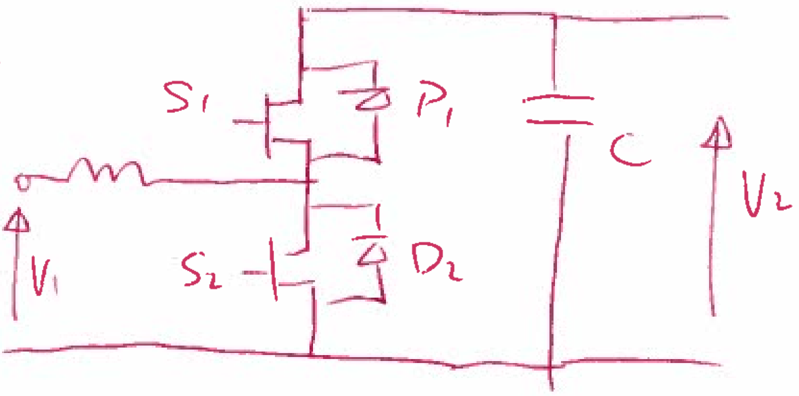
$$\Delta\phi = I_{spk} \cdot \left(\frac{L_m}{N_1}\right) = \int_0^{DT} \frac{V_1}{N_1}\, dt.$$

$$I_{spk} L_m = D \cdot \frac{1}{f} V_1$$

$$f = \frac{D \cdot V_1}{I_{spk} \cdot L_m} = \frac{0.5 \times 150}{0.001 \times 8/3} = 28.125\, kHz.$$

Q4.

a) i)



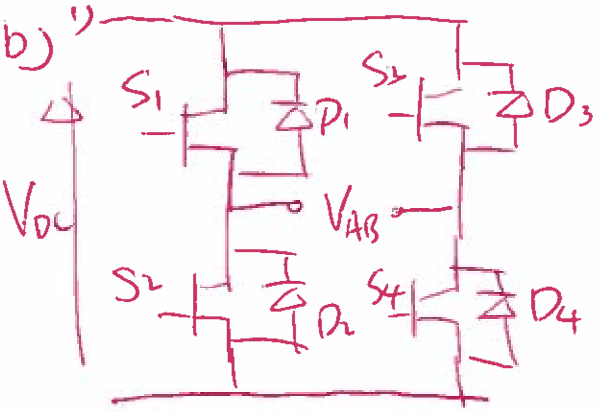
S_1 is inhibited permenantly. Switch S_2 only.

ii) $V_2 = (\frac{1}{1-D})V_1$

$I_{OB} = \frac{1}{2}\Delta I_o = (1-D)\Delta I_L = \frac{V_1 \cdot T}{2L}(D-D^2)$

$I_{OB} = \frac{V_2 T}{2L}(1-D)^2 \cdot D$

b) i)

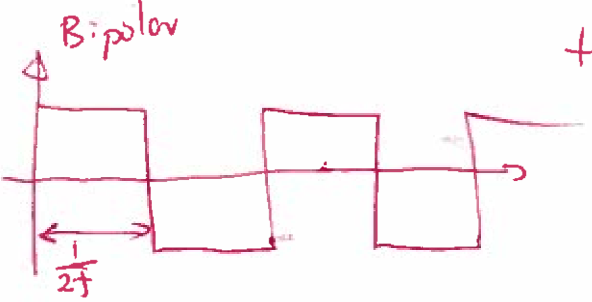


bipolar: S_1, S_4 switch together
S_3, S_2 switch together
S_1, S_2 switch complementary

Unipolar. S_1, S_4 not switch together

Unipolar doubles the ripple frequency when line voltage is used, reducing the size of the filter.

ii)

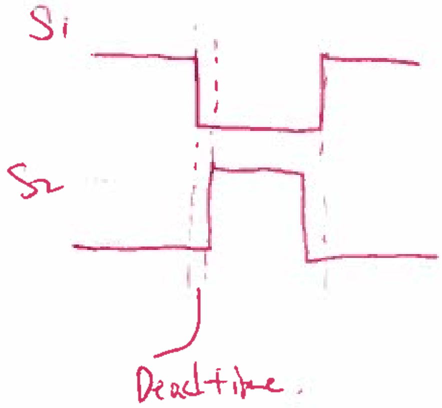


$V_{AB} = \frac{4}{\pi} V_{DC} \sin\omega t$, $(\omega = 2\pi f)$

$V_{AB} = \frac{4}{\pi} V_{DC} \sin\omega t \cdot \cos\frac{\alpha}{2}$. $(\omega = 2\pi f$

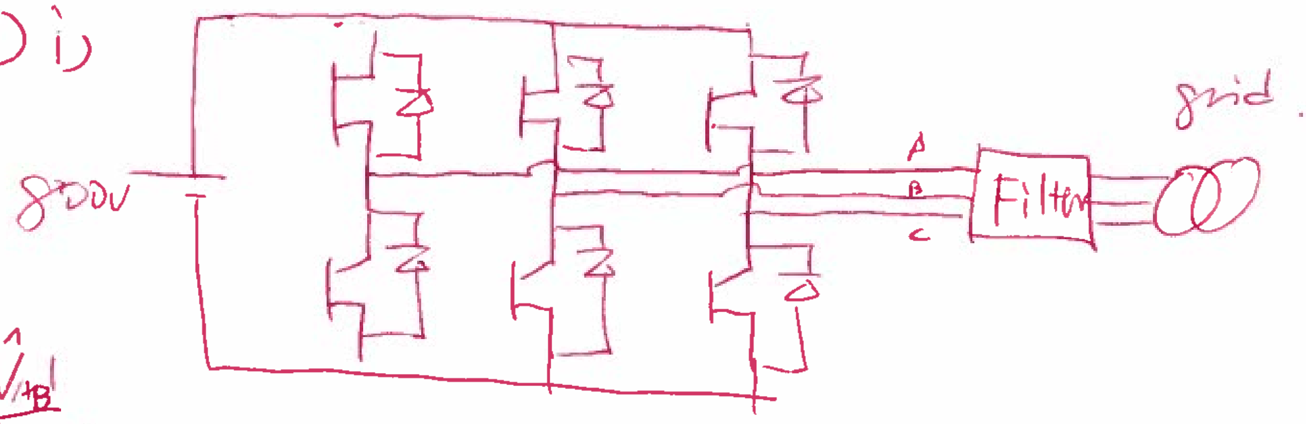
(Using Fourier transform from Databooks)

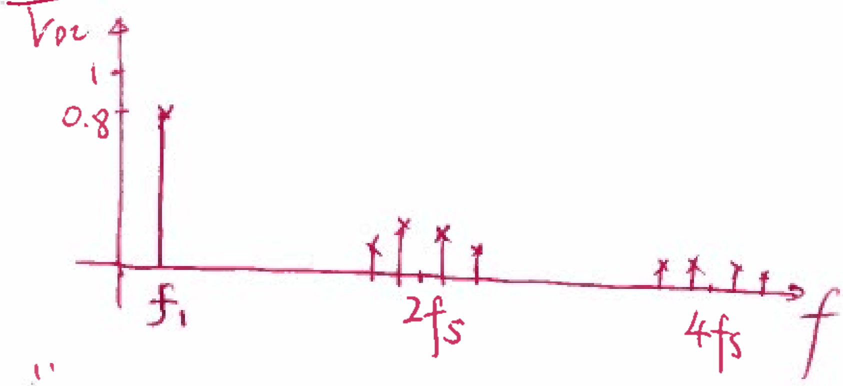
iii) S1 and S2 have a short of time both switched of, (Deadtime)



The deadtime ensures ~~the~~ both of ~~be~~ devices never switched on together even some delay of devices.

c) i)





ii)

SinPWM: $\hat{V}_{AB} = 0.866 \cdot V_{dc} =$ ~~490V, V_{AB} =~~ 693 V

$V_{AB} = \frac{693}{\sqrt{2}} = 490V$ (rms)

SVPWM: $\hat{V}_{AB} = V_{DC} = 800V$.

$V_{AB} = \frac{800}{\sqrt{2}} = 566\ V$ (rms)

iii) Increasing fs. Drawback: Switching losses increase lower efficiency.