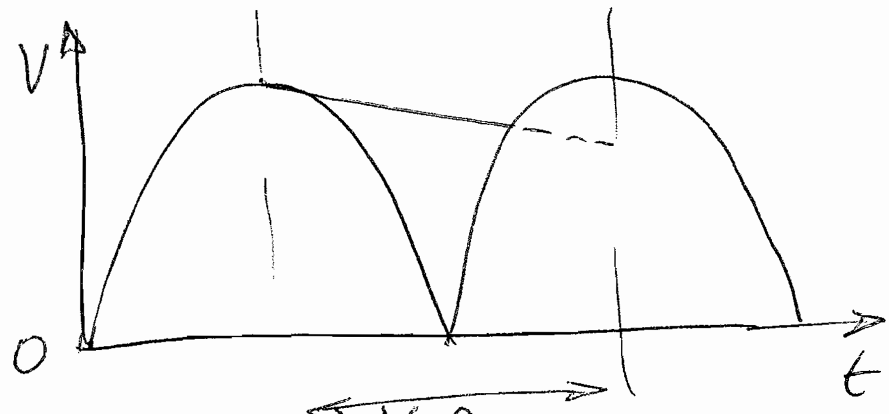
3B3 Crib 2009 - Dr PR Palmer

1a/



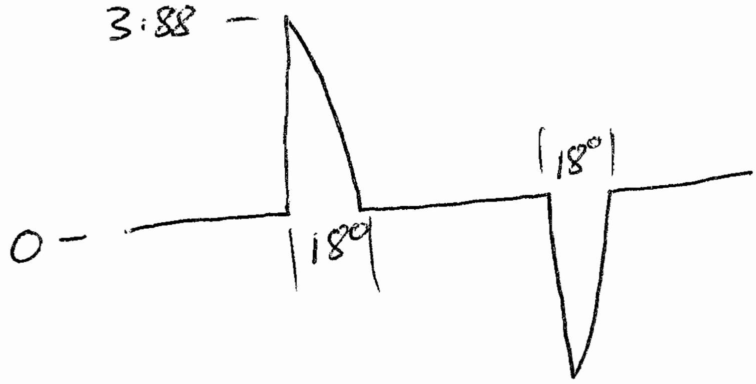
$\Rightarrow \Delta V = \dfrac{I}{2fC}$ — ①

$V_{dc} = \hat{V} - \dfrac{I}{4fC}$.

5% Ripple : $\sin^{-1} 0.95 = 72°$

Assume conduction stops at 90°

$I = C\dfrac{dV}{dt}$



$\hat{I} = C\omega \cos 72°$

$= \cancel{615\mu}\ 40m \times 100\pi \cos 72°$

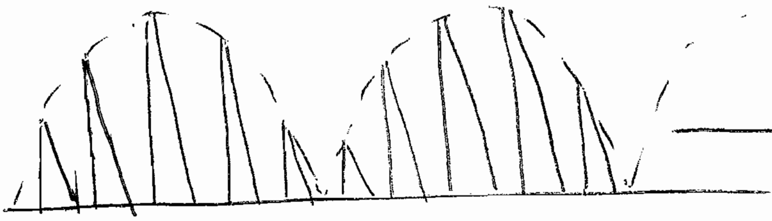
$= 3.88A$

① $C = \dfrac{1}{2 \cdot 50 \cdot 0.05 \cdot 5}$ $= \cancel{615\mu F}$ $40mF$

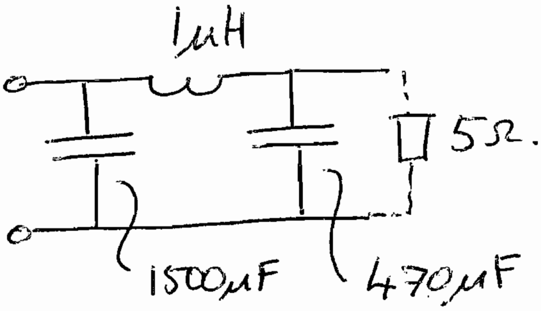
2 Diode drops with 5V out so we have

$\eta = \dfrac{5}{5+2} = 0.71$ 71%

1b/



1A average.



1st harmonic
$\omega = 2\pi 100$

$1\mu \times 200\pi \approx 0.6 m\Omega$
neglect!

$1/1970\mu \times 200\pi j = 0.8 j\Omega$ (so neglect load)

Fourier components: $\frac{2}{\pi} + \frac{4}{3\pi}\cos 2\omega_0 t - \dots\dots$

$\therefore I_{DC} = 1A = \frac{2}{\pi}\hat{I}$ So at $2\omega_0 t$ $\frac{4}{3\pi} \cdot \frac{\pi}{2} = \frac{2}{3} A$

$\therefore$ Voltage ripple at 100 Hz $= 0.8 \times \frac{2}{3} = \underline{0.53\ V}$

(Next component is $\frac{4\pi}{15}$ at 200Hz into $0.4 j\Omega$)

Low standby current because the MOSFET T_1 can be turned off.

High efficiency as the diode voltages are small compared to 230V mains; the transformer is small as it operates at a high frequency ~ (low core losses, short winding length), so low losses compared to a 50Hz "brick".

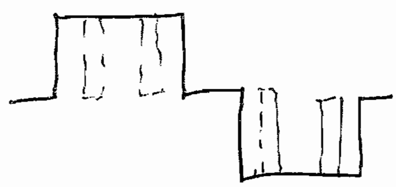
To reduce ripple: Feedback ~ but may upset the nice AC current waveshape; Add another regulator stage; Add more capacitance smoothing.

2/ a) The IGBT allows easy gate drive, high current turn off/on easily. Audible because the current is high so could be high switching losses. 3

The effect is called "gear changing". The switching is an integer ratio of the output frequency and to keep within a sensible range the integer ratio is changed if necessary. This improves the frequency spectrum. and keeps low switching losses. (Various schemes are possible – must have integer mp) 5

b) $V_{ab} = V_a - V_b$

	a	b	c	V_{ab}
V_1	1	0	0	1
V_2	1	1	0	0
V_3	0	1	0	-1
V_4	0	1	1	-1
V_5	0	0	1	0
V_6	1	0	1	1
V_7	1	1	1	0
V_8	0	0	0	0



Magnitude may be reduced by putting V_7 & V_8 in (dotted)

2b cont.

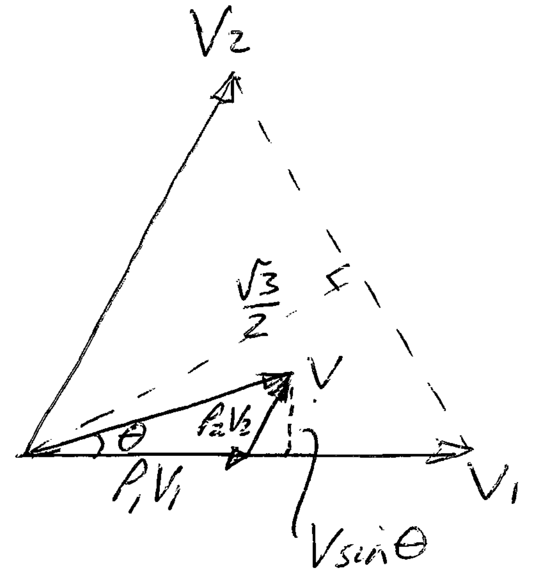
Better to use pairs of vectors. Then the modulation can be improved into a sinewave easily; eg.

$V_8 V_1 V_2 V_7 V_7 V_2 V_1 V_8$

V_8	0	0	0
V_1	1	0	0
V_2	1	1	0
V_7	1	1	1
V_2	1	1	0
V_1	1	0	0
V_8	0	0	0

Six switches.

2/ c)



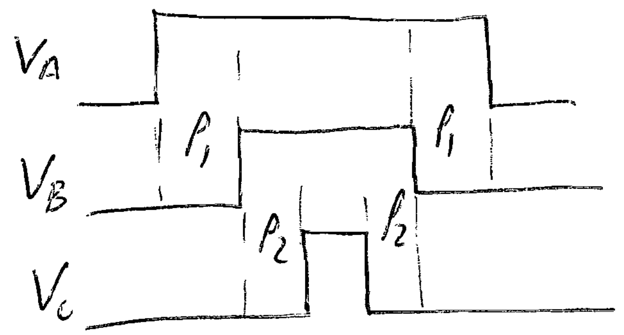
$$\rho_2 |V_2| \cos 30^\circ = V \sin\theta$$

$$= m \hat{V} \sin\theta$$

$$\rho_2 |V_2| \cdot \frac{\sqrt{3}}{2} = m \frac{\sqrt{3}}{2} |V_2| \sin\theta$$

$$\rho_2 = m \sin\theta$$

Similarly $\rho_1 = m \sin(\pi/3 - \theta)$



$\rho_1 = \rho_2 = 0.25 \sin 30 = 0.125$

$T_0 = T(1 - 0.125 - 0.125) = 0.75\,T$

T_0 is split into 7 & 8 equally.

$\therefore \rho_A = 0.375 + 0.125 + 0.125 = 0.625$

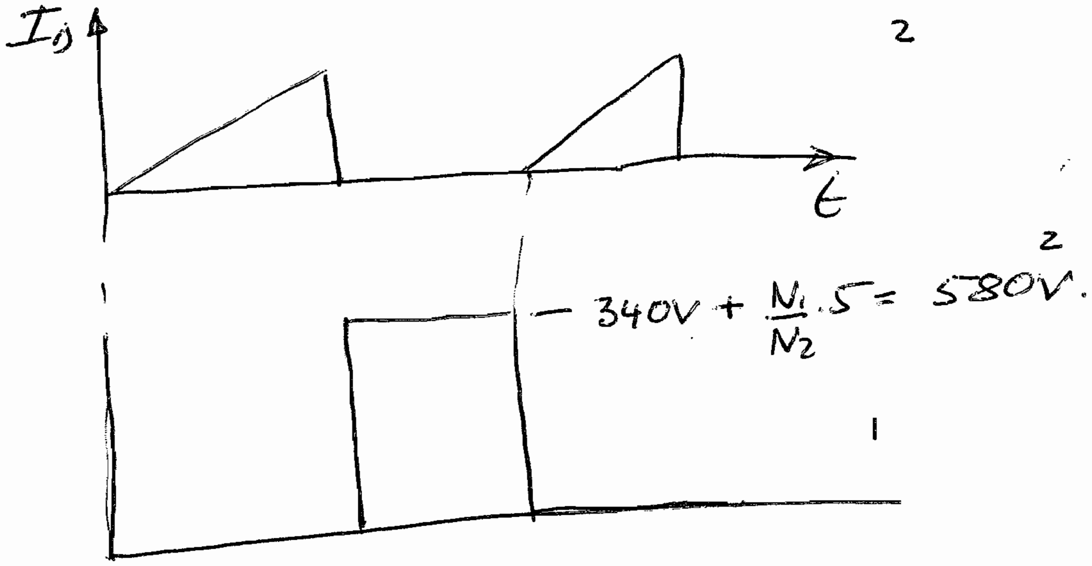
3 a/ 5W, 230V ⇒ 22mA if 100% efficient.

A very small high voltage MOSFET is sufficient and has defined switching under variable loads, and can easily switch at a high frequency such as 100kHz 4

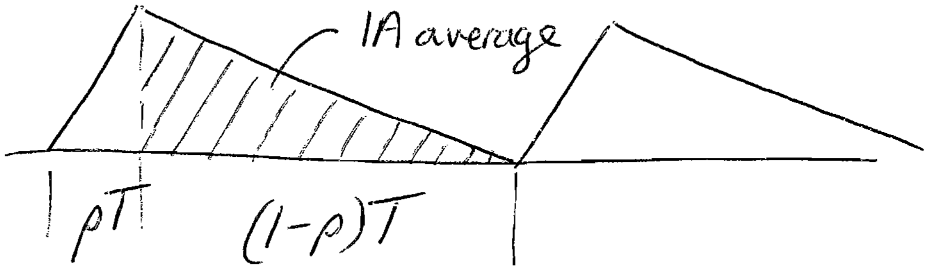
(b) $$\int_0^{\rho T} V_{dc}\,dt = \int_{\rho T}^{T} \frac{N_1}{N_2} V_o\,dt.$$

$$V_{dc}\,\rho T = \frac{N_1}{N_2}(1-\rho)T\,V_o$$

$$V_o = V_{dc}\frac{N_2\,\rho}{N_1(1-\rho)}$$ 5



3/ b) cont. 5V, 1A output.



240V: $\frac{\rho}{1-\rho} = \frac{5}{240} \cdot \frac{240}{5} = 1$ $\qquad \underline{\rho = 0.5}$

And $\frac{1}{2}(1-\rho)\hat{I} = 1 \Rightarrow \hat{I} = 4A$ (output side)

$$\hat{I}_{IN} = \frac{4}{240} \times 5 = 83.3\,mA$$

$$\hat{I} = \frac{1}{L}\int_0^{\rho T} V\,dt = \frac{1}{1.5m} \cdot 240 \cdot 0.5T$$

$$f_s = \frac{1}{T} = \underline{960\,kHz}$$

300V; $\frac{\rho}{1-\rho} = \frac{5}{300} \cdot \frac{240}{5} = \frac{4}{5}$ $\qquad 9\rho = 4$

$$\hat{I}_{IN} = \frac{5}{240} \cdot \frac{2}{(1-4/9)} = \frac{1}{1.5m} \cdot 300 \cdot \frac{4}{9}T$$

$$f_s = 1185\,kHz.$$

To stay in "transition mode" i.e. on the edge of discontinuous, the frequency must change. (Pretty clear from the sketch so calculation is not needed)

4(a) Voltage, current, base drive required
switching losses.

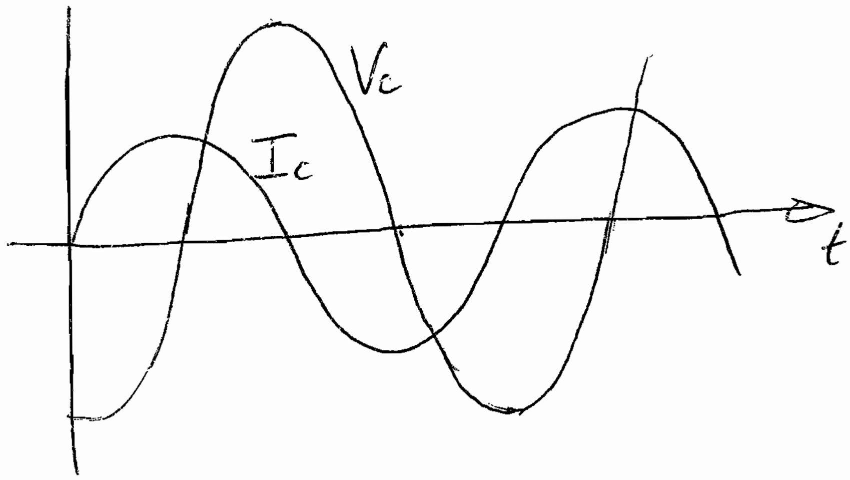
(b) Well defined operation with Sinewaves.
Just one inverter leg required
Possibly zero switching losses
Easy to control (any two)

4/c Series resonance. Need to find L

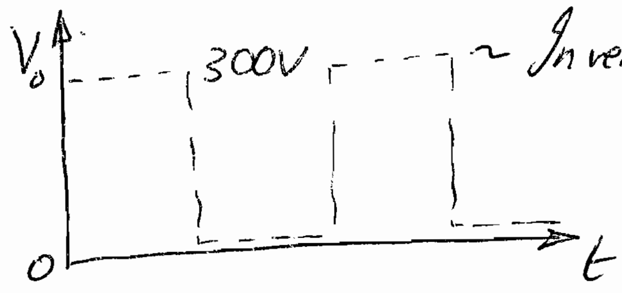
33nF in series with 3.3nF $\Rightarrow$ 3nF

$$\omega_0 = \frac{1}{\sqrt{LC}} = 2\pi \times 40k \qquad L = 5.3\,mH$$

assumes Q is $\gg 1$



On resonance, L & C impedances cancel.



~ Inverter output.

Fundamental

$$\frac{300}{2} \times \frac{4}{\pi} = 191V(pk)$$

$$\hat{I} = \frac{191}{2 \times 192} = 0.5A$$

$$V_c = 0.5 \times \frac{1}{2\pi \cdot 40 \times 10^3 \times 3.3n} = 600V \approx V_{XY}$$

Plenty to strike the arc.

Alternate: C_4 & C discharged then turn on Q_2

Voltage on C_4 & C doubles V_{DC} to 600V.

$$V_{C_4} = 600 \times \frac{1}{1.1} = 546.$$

4(c) cont/

Now $C = 33nF$, $L = 4.8mH$, $R = 224\,\Omega$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{33\mu \cdot 4.8\mu H}}$$

$f_0' = 12.6\ kHz$

BUT runs at 40kHz

$f > f_0$

$$I = 300 \times \frac{4}{\pi} \cdot \frac{1}{(224 + j\,4.8\mu \times 40 \times 10^3 \times 2\pi - j\,1/33\mu \times 40 \times 10^3 \times 2\pi)}$$

$(224 + j\,1206 - j\,120)$

$(224 + j\,1086)$ Inductive!

$$= 300 \cdot \frac{4}{\pi} \cdot \frac{1}{1109} = \underline{0.34A}$$