Dr P K Palmer

3B3 2008

1 (a) Minimises smoothing required.

High voltage so $2 \times V_f$ is negligible

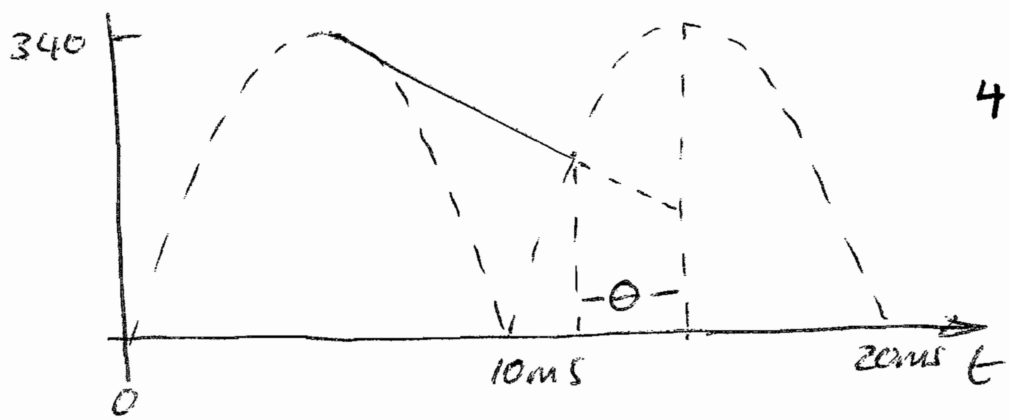
Symmetrical ac waveform (1000's of lamps) 3

240V rectified gives 340V dc.

$$I = \frac{11}{340} = 32\,mA.$$

Voltage ripple is approximately $\frac{I}{2fC}$

$$= \frac{32m}{2 \times 50 \times 2{\cdot}2\mu} = 145\,V$$



4

Estimate ⇒ 7mS not 10mS.

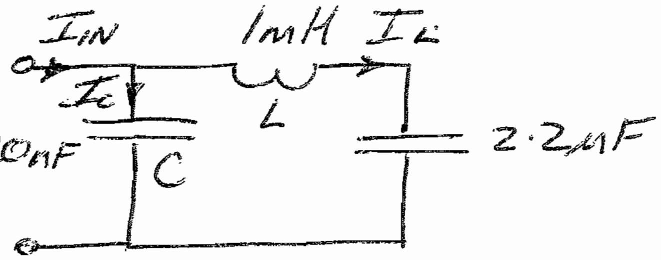
$$\Delta V = \frac{7}{10} \times 145 \approx 101\,V$$

$$\theta = \cos^{-1} \frac{239}{340} = 45^\circ$$

$$I = C\frac{dV}{dt} = 2{\cdot}2\mu \times \frac{d}{dt} 325 \sin\omega t = 2{\cdot}2\mu \cdot 2 \times 50 \times \pi \times 325 \cos\omega t$$

$\omega t = 45^\circ$ $I = 157\,mA$ 6

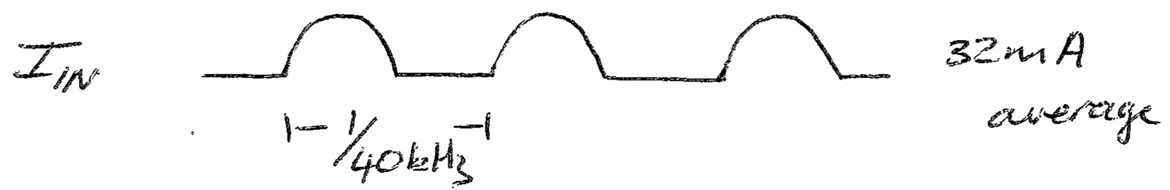
Filter calculation ~ turn it around!



40kHz 2.2μF ⟹ −1.81jΩ.
(251k rads/sec) 220nF ⟹ −18jΩ.
1mH ⟹ 250jΩ.

∴ neglect 2.2μF capacitor.

$$I_L = I_{IN} \cdot \frac{1/j\omega C}{j\omega L + 1/j\omega C} = I_{IN} \cdot \frac{-18j}{250j - 18j} = -0.08\, I_{IN}$$



Want 1st harmonic component.

5

The HF ripple would otherwise go back through the AC mains

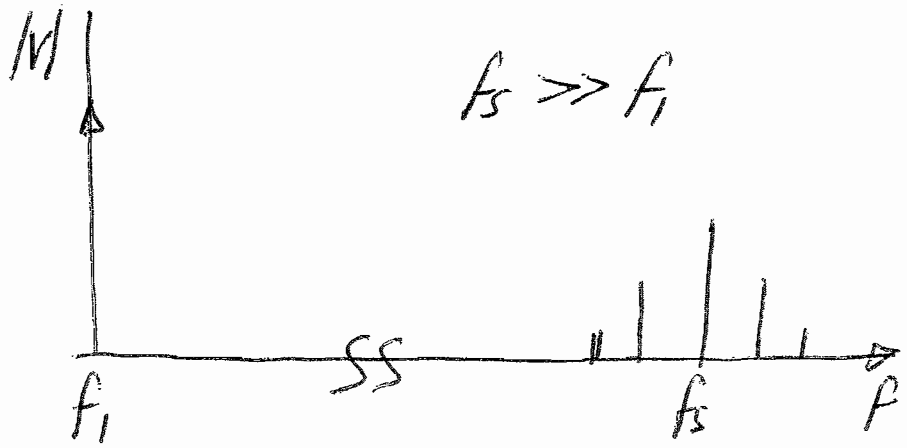
HF ripple causes losses in the smoothing capacitor reducing its life. This is a high quality lamp!

2

2(a) The inverter leg consists of two step-down converters. The leg current may be in either direction. To make sure the output voltage is stepped down it is essential to operate the two choppers at the same time, ie. T_1 on T_4 off, T_4 on T_1 off and so on. With a defined voltage independent of the direction of the current the power factor is unimportant (Inductive only!)

The deadtime depends on the speed of switching of the IGBTs and variation in the signalling delays. **5**

(b)



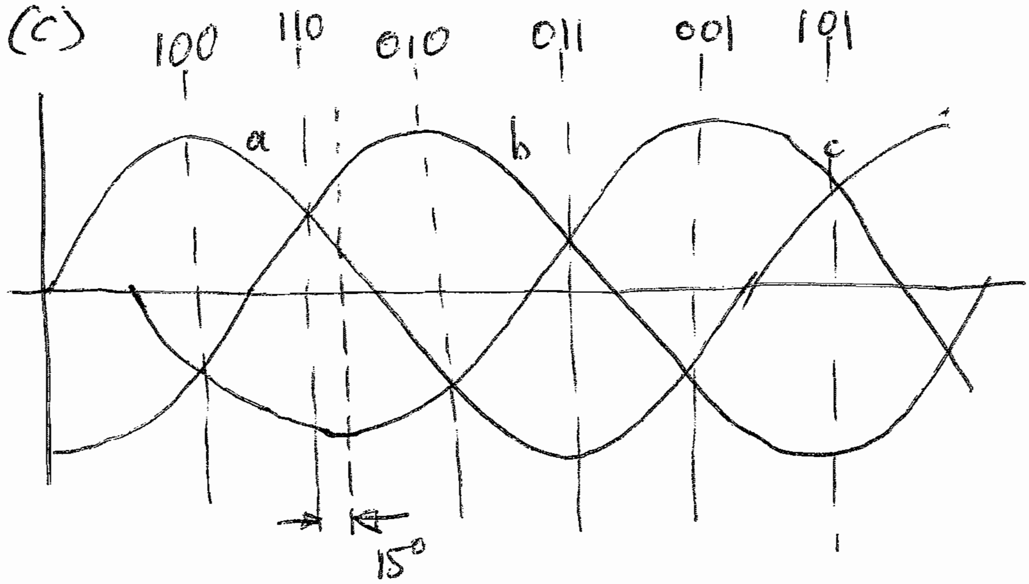
f_s has a harmonic spectrum around it.

High f_s ⟹ easy to filter, low ripple

⟹ Subharmonics very small so f_s does not need to be int. $\times f_1$

⟹ Increased switching losses **3**

2(c)



2

Three phase voltages may be represented as phasors ~ magnitude and direction (+ rotation)

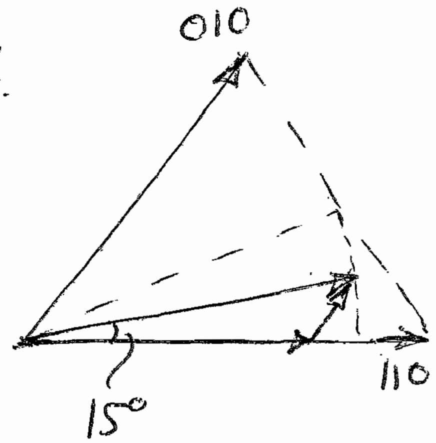
Each of the codes above is alligned with a phasor, so has magnitude and direction ie a vector. Adding in 000 and 111 allows for the magnitude to be changed in the manner of pwm making "space vector modulation".

0	1	1	1	1	1	1	0
0	0	1	1	1	1	0	0
0	0	0	1	1	0	0	0

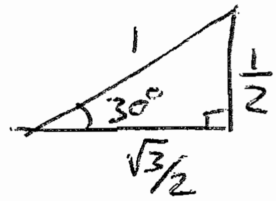
The direct-inverse sequence. This then has the timings adjusted to move the vector.

3

2(c) cont.



Radius of the circle



By geometry it is tricky. Inspection of the waveforms is easier.

a → sin 15° → 0.258
b → sin 45° → 0.707
c → cos 15° → 0.965.

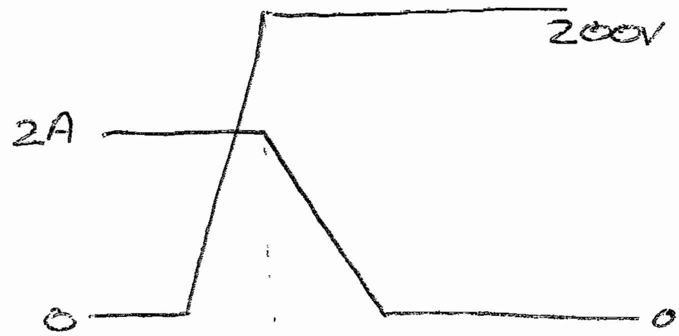
Timings $\frac{0.258}{0.965} \times 0.5$ & $\frac{0.707}{0.965} \times 0.5$

13.4% 36.6%

0.5 of the period in the zero states

Since we maybe switching a switch with a big current we get more losses. Therefore switch somewhere else! ie SVM changes with p.f.

3(a) 22V to 200V 50W ≈ 2A average



2

Voltage rises before the current falls.

$I = C_{gd}\frac{dV_{gd}}{dt}$ from the gate circuit.

Current falls depending on the fall in V_{gs}

Choose a 5A, 350V Mosfet to give some margin in voltage and improve efficiency as it has to carry the low voltage side 2A for significant periods. Also >200V Mosfets are not so great in terms of $R_{DS_{ON}}$. ∴ it will be expensive. **2**

The switching losses are disproportionate as it switches both the higher current and the higher voltage whereas the power through is low. Keep the losses down by choosing 15 kHz. **2**

Keep the losses down by fast switching.

assume eg. $3CR \approx 1\mu s$. $C_{iss} = 450\,pF$

$R = 1\mu / 3 \times 450p \approx 680\Omega$ (Ignores gate plateau)

Check $\frac{VIt}{2} \times f = 3W$. Still quite high. **4**

3(b) The volts-seconds on the inductor must come back to zero at the end of a cycle.

$$V_{pv}\,\rho\,T + (V_{pv} - V_o)(1-\rho)T = 0$$

$$V_{pv} - V_o(1-\rho) = 0$$

$$V_o = \frac{V_{pv}}{1-\rho} \quad \text{or} \quad \frac{V_o - V_{pv}}{V_o} = \rho$$ 4

(i) 18V approximately from the graph.

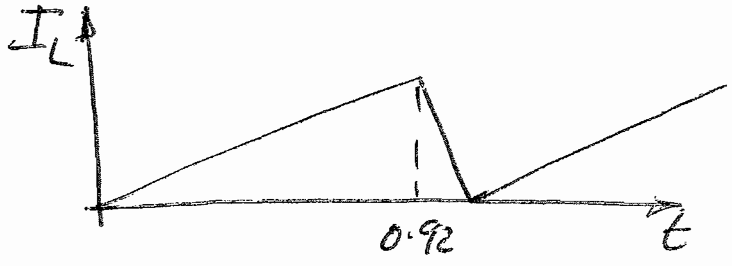
$$\rho = \frac{200-18}{200} = 0{\cdot}91$$

(ii) 16V approximately from the graph

$$\rho = \frac{200-16}{200} = 0{\cdot}92$$ @ 0·5A from graph

It is more likely to be discontinuous at lower currents.

$I_{pk} = 2 \times 0{\cdot}5$



$$I_L = \frac{1}{L}\int_0^{\rho T} V\,dt \Rightarrow L = \frac{1}{\hat{I}} \cdot V \rho T$$

$$= \frac{1}{1} \cdot 16 \times 0{\cdot}92 \times \frac{1}{15k} = 0{\cdot}98\,mH$$

6

4(a) 40W mains powered 110–240V

$$\frac{40}{110\sqrt{2}} = 260mA.$$

This is a very small current so a small BJT with no heatsink is fine, base drive of about 25mA. 3

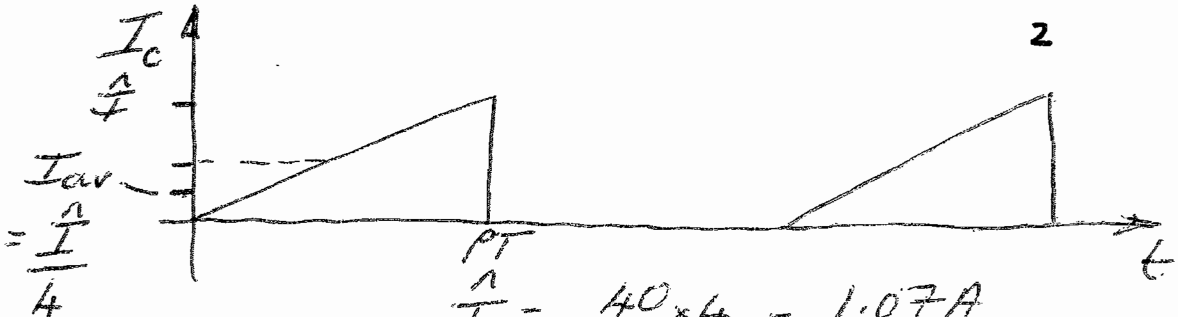
BJTs are very cheap.

If the base drive is excessive it will switch slowly. Too small and it will not saturate leading to high losses 2

(b) A forward converter so the 9V at the output is referred across to the primary when the transistor is on.

So 136 V − 120V appears across the leakage inductance.

Discontinuous so starts at zero



$$\hat{I} = \frac{40}{150} \times 4 = 1.07A$$ 3

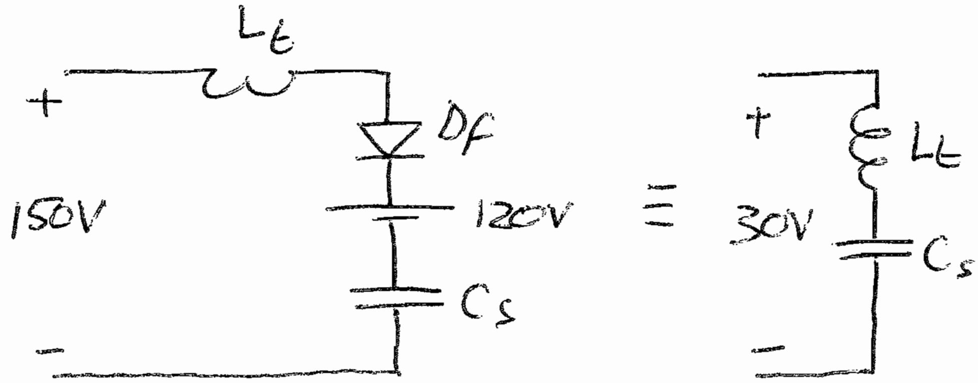
4(b) cont.

At turn-off the transistor has current.

As long as the primary has current and a voltage of 120V the diode D_f will be on and the primary voltage will be constant $\Rightarrow$ C_s resonates with L_t

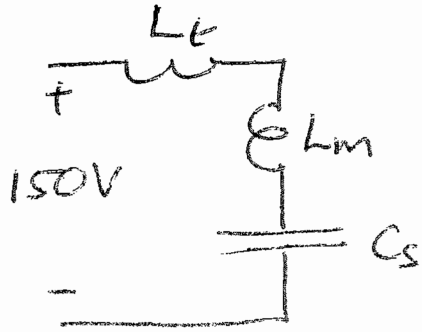
If D_f goes off then C_s resonates with $(L_t + L_m)$ 2

As D_f starts by being on and in fact carrying the same current as the transistor we have the following circuit:-



$$\frac{1}{2} L_t \hat{I}^2 = \frac{1}{2} C_s \hat{V}_1^2 \qquad \omega_0 = 1/\sqrt{L_t C_s}$$

When the current reaches near zero D_f recovers:-



$$\omega_0 = 1/\sqrt{(L_t + L_m) C_s}$$

4(b) cont

$$\Delta I = \frac{1}{L_t}\int_0^{\beta T}(136-120)\,dt$$

$$= \frac{1}{150\mu} \cdot 16 \cdot \frac{1}{2} \cdot \frac{1}{50k} = 1.07\,A.$$

Ignores current in L_m: $1.07 \times \frac{150\mu}{17m} = 9.4mA$ Ok

1st rise $\frac{1}{2} \cdot 150\mu \times 1.07^2 = \frac{1}{2} \cdot 200p \cdot V^2$

ie $V = I\,Z_{0_1} = 1.07\sqrt{\frac{150\mu}{200p}} = \sqrt{\frac{150}{200}} \times 1000$

$\doteq 866V$ 4

2nd rise $Z_{0_2} = \sqrt{\frac{17m}{200p}} = 9.2\,k\Omega$.

$9.2k \times 9.4mA \Rightarrow 86.7V$

The peak voltage $= 866 + 87 = \underline{953V}$ 1

Zero current turn on

Zero current turn off

Small transformer with forward topology. 3