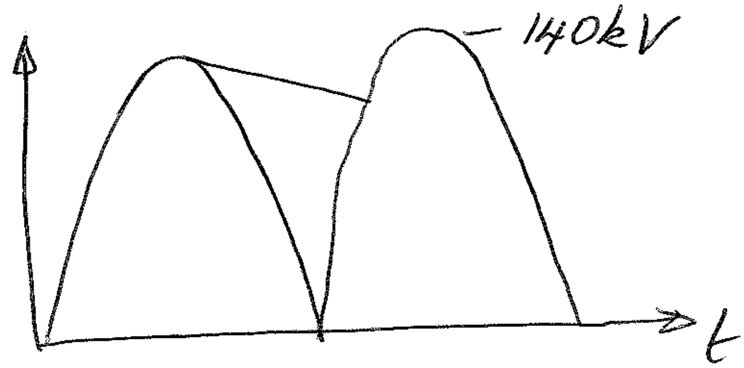
Dr P R Palmer

3B3 Crib 2011

1 a/



10% ripple

$$V_0 = \hat{V} - \frac{\Delta V}{2} = 140k - \frac{14k}{2} = 133kV$$

$$I = \frac{10000}{133k} = 75mA.$$

Low ripple at 10% – assume constant current (linear decay)

– assume ½ wave periods (instant charging)

$$I = C\frac{dV}{dt} \therefore \Delta V = \frac{I}{2fC}$$

$$C = \frac{I}{2f\Delta V} = \frac{75m}{2 \times 10^4 \times 14k} = 268pF$$

$50pF\,m^{-1} \Rightarrow \simeq 5m$ needed.

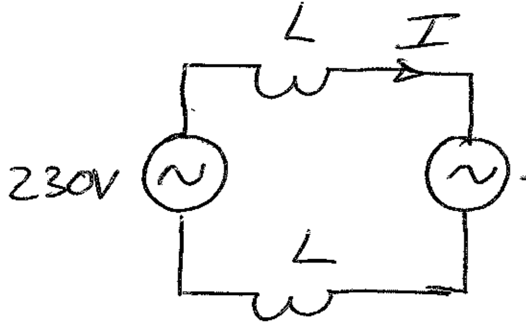
Less cable? Any two of: higher f; different cable (diameter, materials); add an inductor (tricky at h.v. but worth considering)

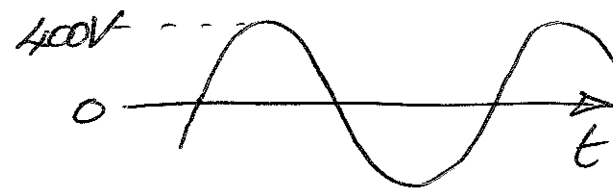
1b/ 3 phase rectification into a battery ~

peak voltage of $230\sqrt{3}\sqrt{2} = 563V$

(quoting $\frac{3\sqrt{6}V}{\pi} = 538V$ works too!)

Sinusoidal Unity pf. ⇒ Inverter works using switching





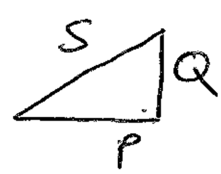
assume no resistance & neglect on-state voltages.

$V_{ac} = \frac{400}{\sqrt{2}}$

$P = 230 \times 30$

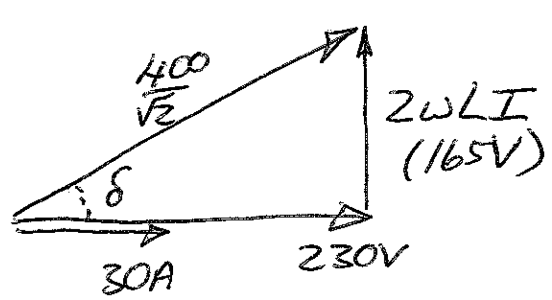
$Q_L = 30^2 . 2\omega L$

} matches $S_I = \frac{400}{\sqrt{2}} . 30$



$\omega L = 2\pi f L = \frac{1}{2 \times 30^2} \sqrt{\left(\frac{400 \times 30}{\sqrt{2}}\right)^2 - (230 \times 30)^2}$ (30s cancelled)

$= 2.74 j\Omega$. $L = 8.7 mH$.



This must be controlled to happen: Change δ to set magnitude of 2ωLI ie the current

20 kHz is out of audible range.

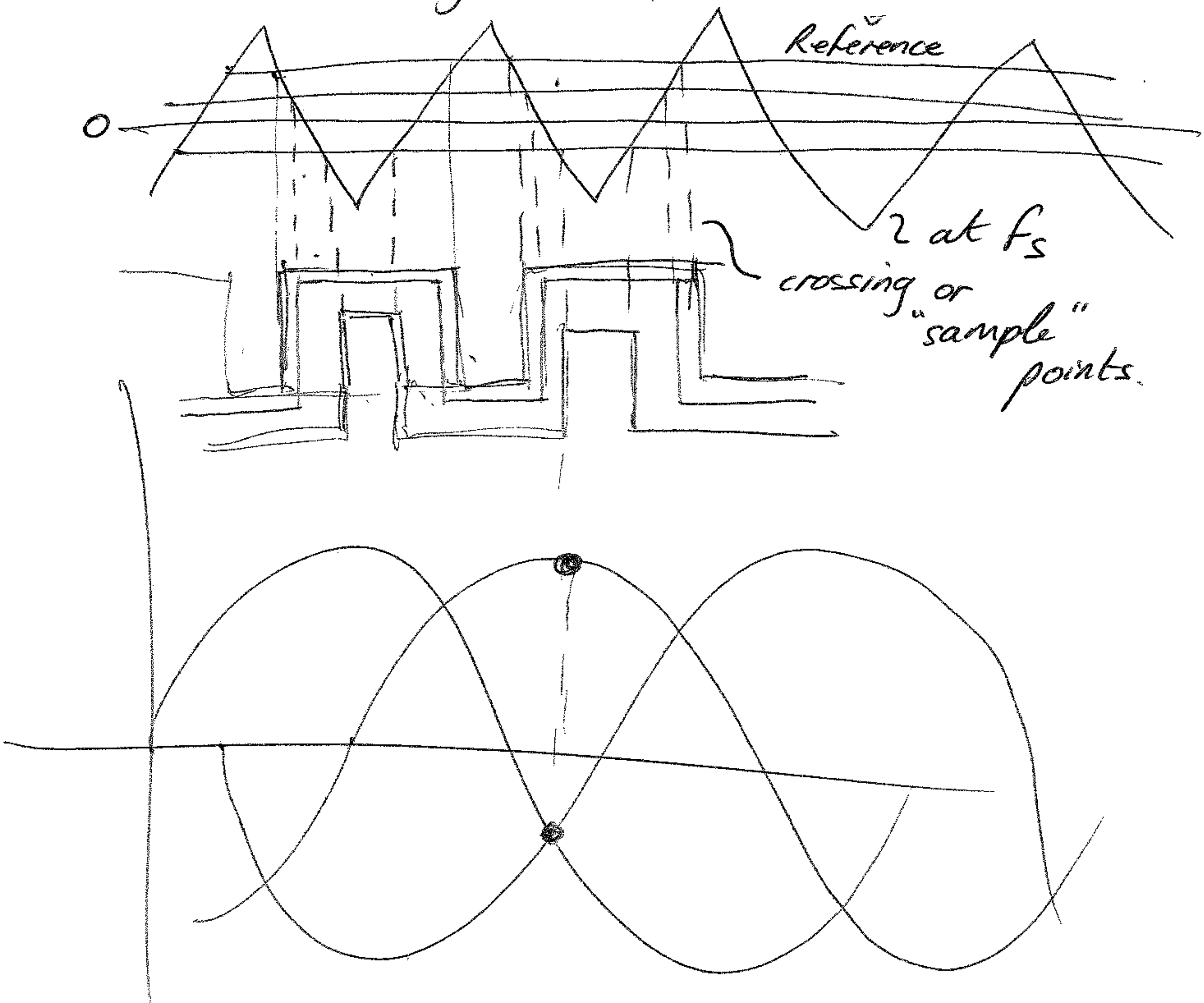
1 b cont.

check 20 kHz. $\hat{V} = L\frac{\hat{di}}{dt}$

$\therefore \hat{di} = \frac{1}{2L} \times 165\sqrt{2} \cdot \frac{1}{2f_s}$

$= 0.335\,A. \quad (\ll 30\sqrt{2}\,A)$

2 a/ *3 references are required.
+ triangular carrier



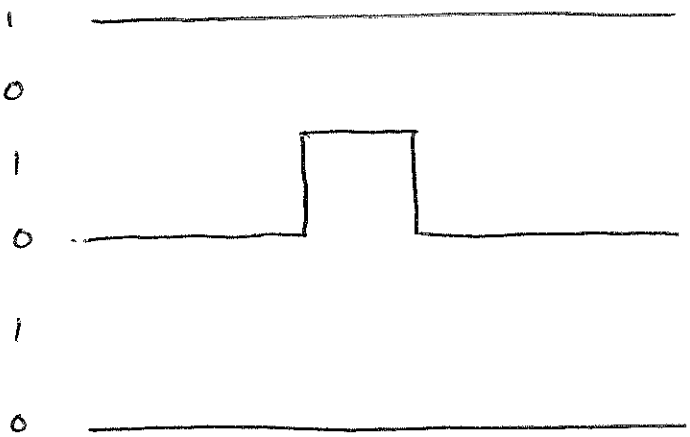
0	1	1	1	0
0	0	1	0	0
0	0	1	0	0

Three-phase references & outputs, so 3rd harmonics <u>all</u> cancel. *

(odd so $\frac{1}{2}$ series.)

Integer avoids subharmonics, but puts a 'gear' ratio in between f_s & f_1. So use gear changing <u>OR</u> repeat pulses.
digital electronics, μP

2b/

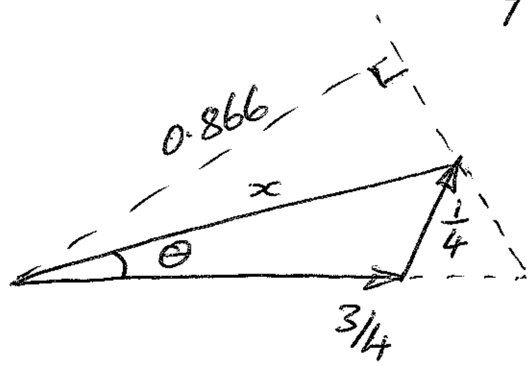


$\rho_A = 1$

$\rho_B = 0.25$

$\rho_C = 0$

$\therefore \quad \rho_1 = 3/4 \;, \quad \rho_2 = \frac{1}{4}$



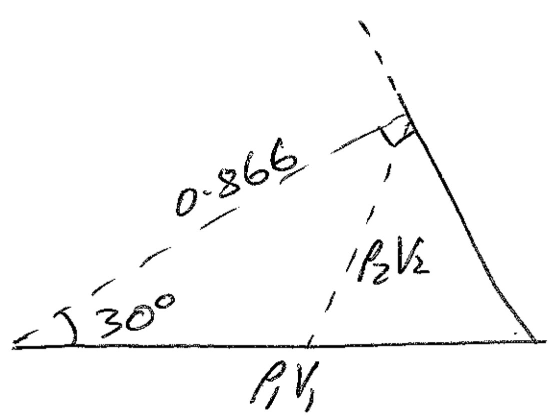
$\theta = 13.9°$

$x = 0.9$

(Using ρ_A & ρ_B directly is quicker for the vector expert!)

"Relatively": $m = \frac{0.9}{0.866} = 1.041$ or $\underline{0.9\, V_{DC}}$
OK

The vector cannot go outside the hexagon envelope.

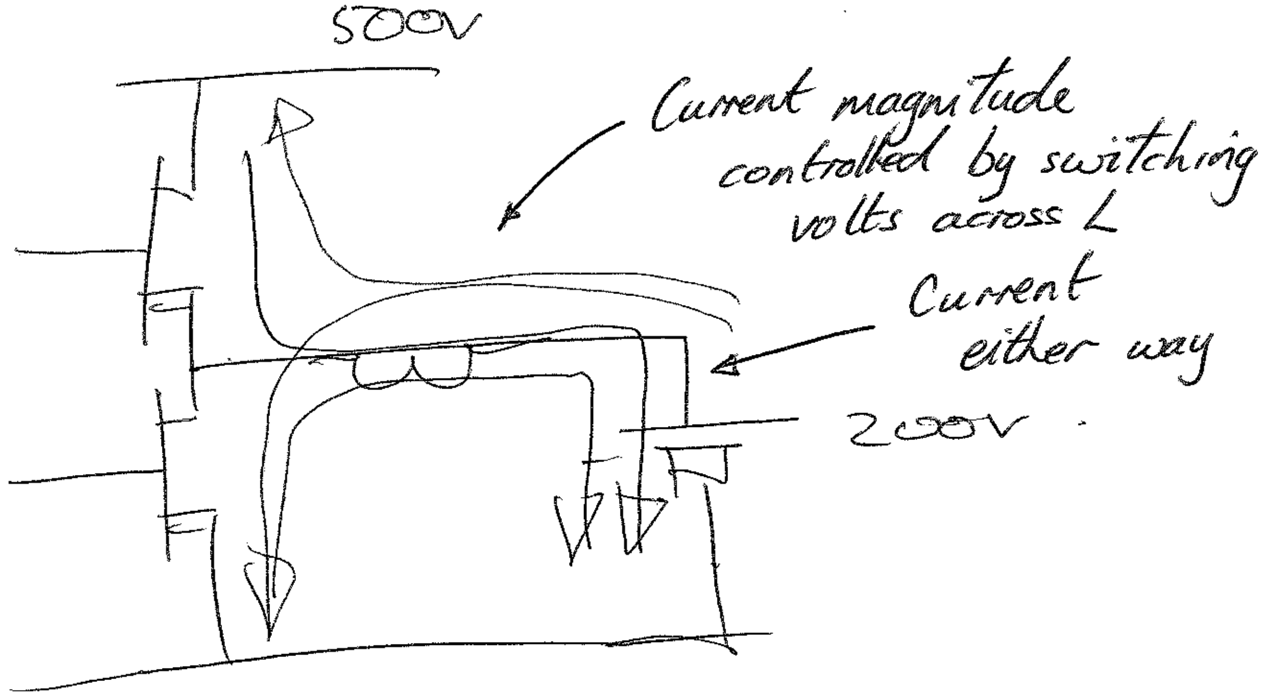


$\rho_1 = \rho_2 = 0.5$

$\underline{0.866\ V_{DC}}$

$(\rho_A = 1,\ \rho_B = 0.5,\ \rho_C = 0)$

3/ a



5kHz, 30kW, 200V

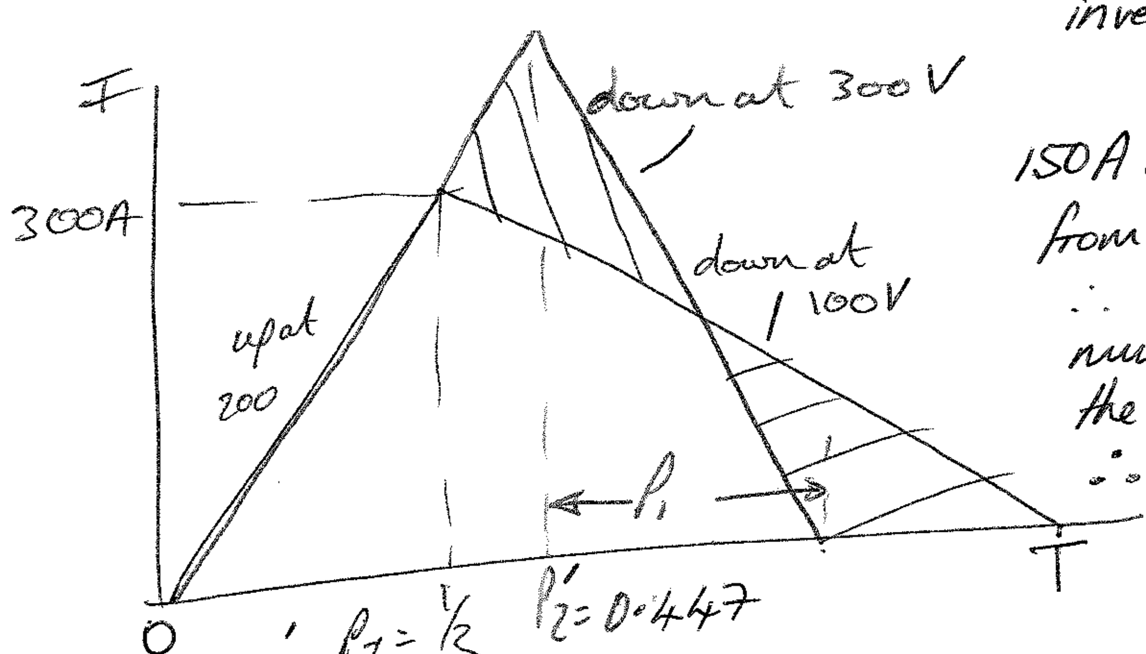
$\frac{30{,}000}{200}$ = 150A, 5kHz, 500V

Say 1μs switching time
150 × 500 × 1μ × 5k = 375W losses.

1/ No turn on losses,
2/ No diode recovery current
3/ Avoids Saturation of the inductor
(or smaller L!)

Last part of b: Current direction depends on which of T_1 and T_2 is switched in any cycle.

3b "200V in 300 out" Current into inverter



150A average from 200V ∴ area must remain the same. ∴ Discont.

∴ $\rho_2 = \frac{1}{3}$ $\rho_2' = 0.447$

200V, 30 kW => 150A average. 300 A peak

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

$$L = \frac{1}{300} \cdot \frac{1}{3} \times \frac{1}{5k} \times 200 = 44.4\mu H$$

At 500V on the inverter – fully discontinuous.

Find $\hat{I}$. $\rho_1 \times 500 \times \frac{1}{2}\hat{I} = 30\,kW$

$$\hat{I} = \frac{1}{L}\rho_1 T \times 300 = \frac{1}{L}\rho_2 T \cdot 200.$$

$$\rho_1 \times 500 \times \frac{1}{2} \cdot \frac{1}{L}\rho_1 T \times 300 = 30k.$$

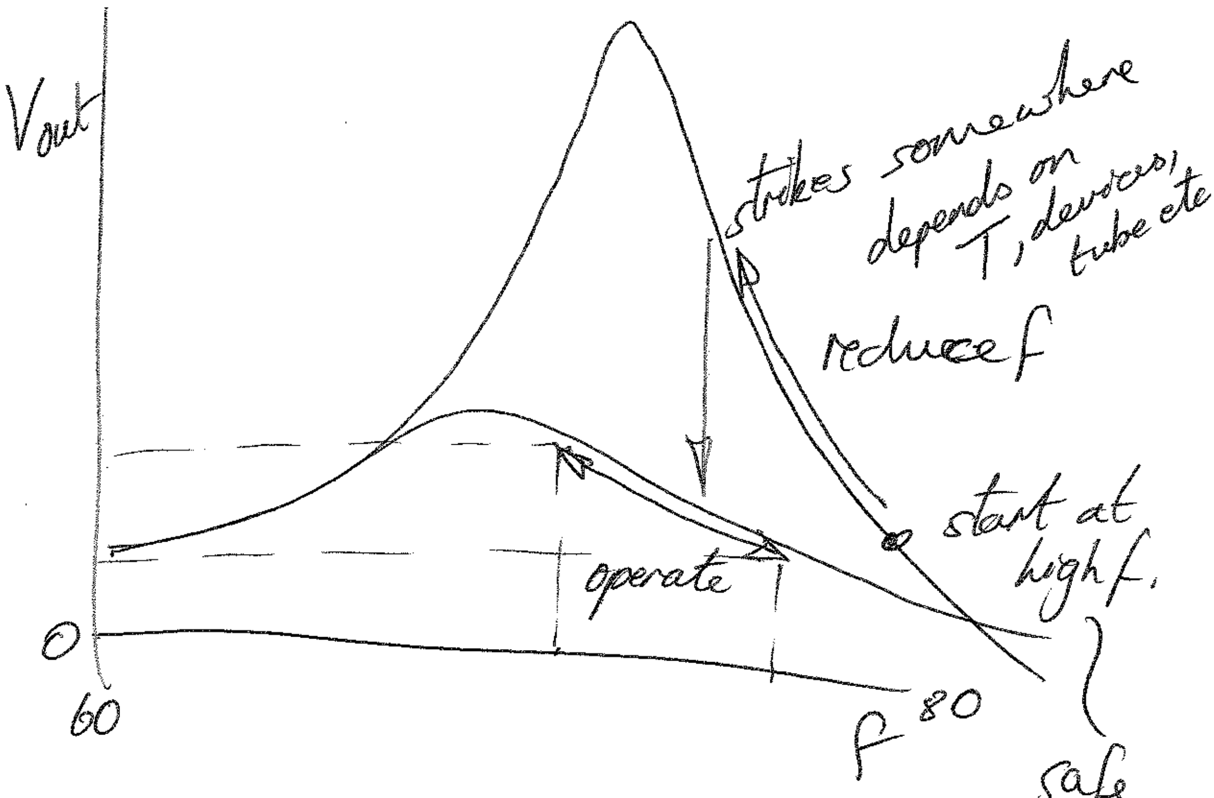
$$\rho_1^2 = \frac{30k \times 2 \times 44.4\mu \times 5k}{500 \times 300} = 0.0888$$

$\rho_1 = 0.298$ $\hat{I} = 402\,A$

$\rho_2' = \rho_1 \times \frac{300}{200}$ $\rho_2' = 0.447$

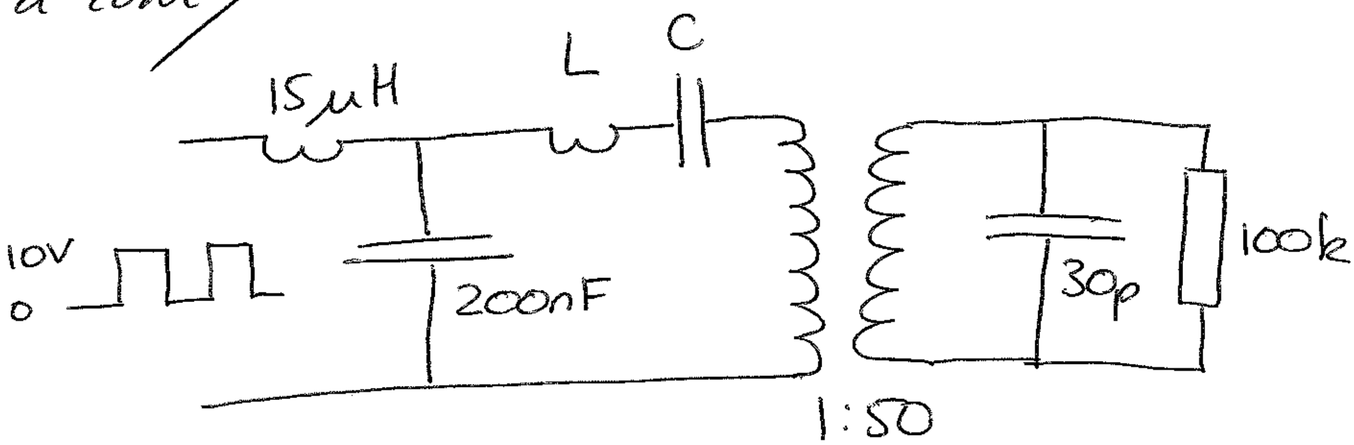
4 a/ Inductor L needed as capacitive load. Put in series resonance / high Q so half bridge is simple & cheap.

But uses a Pch Mosfet (CMOS) which is lossey or expensive.



(light $\propto V^2$ so bigger adjustment than it first appears)

4 a cont/



\ from 5(b)

15μF/200nF act as filter, so we take the fundamental of the input.

$\Rightarrow \frac{10}{2} \times \frac{4}{\pi}$ sinewave peak.

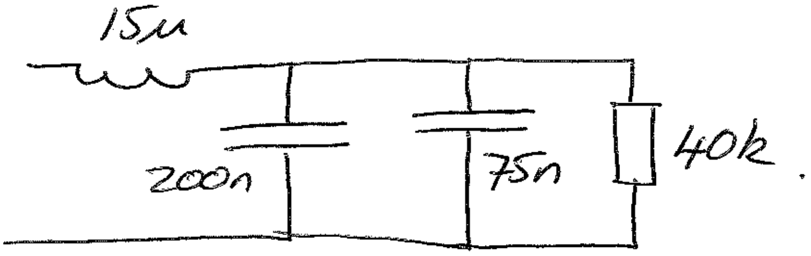
@ 69kHz

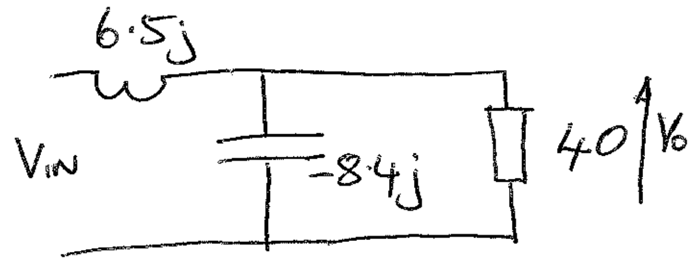
$N^2 = 2500$

$30p \times 2500 = 75nF$

$100k / 2500 = 40$

Peak resonance, so L & C disappear.





$40 \gg 8.4$

$V_0 \simeq \frac{8.4j}{(6.5 - 8.4)j} V_{IN}$

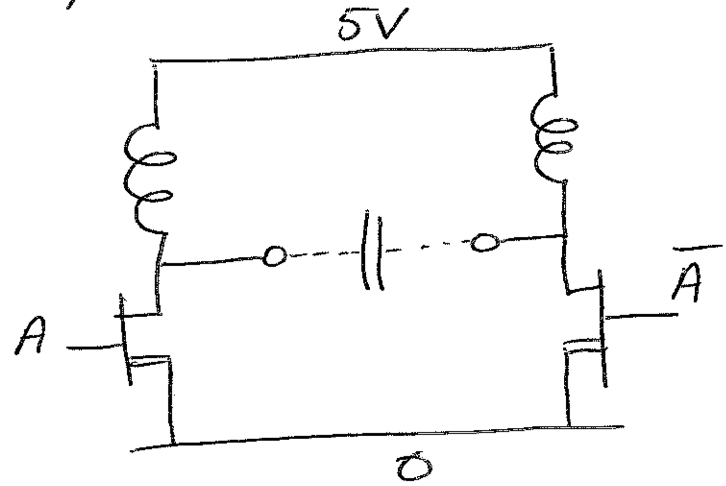
$\simeq 4.42$

$\frac{10}{2} \times \frac{4}{\pi} \times 4.42 \times 50 = 1407\,V$

although the filter is working as a filter it does give a significant increase in voltage!

4 b./ Could replace pMOS with NMOS and a bootstrap driver IC. Lower losses but complicated.

Use full resonance ideas.



i) Two lowside NMOS so easy gate drives.

ii) Low losses with good NMOS

(∵ Lossless switching if operated carefully)

(+/- Voltage swing ~ like full bridge)