MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.334 Power Electronics — Practice Exam 1

Problem 1

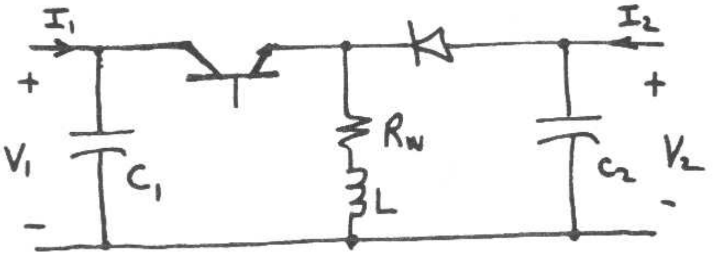

Fig. 1

The buck/boost converter of Fig. 1 contains a very large inductor, L, with a winding resistance, $R_w = 0.1\Omega$. The circuit is operating under the following conditions:

$$D = 0.25$$
$$I_1 = 10\ A$$
$$V_1 = 40\ V$$

Determine V_2.

Problem 2

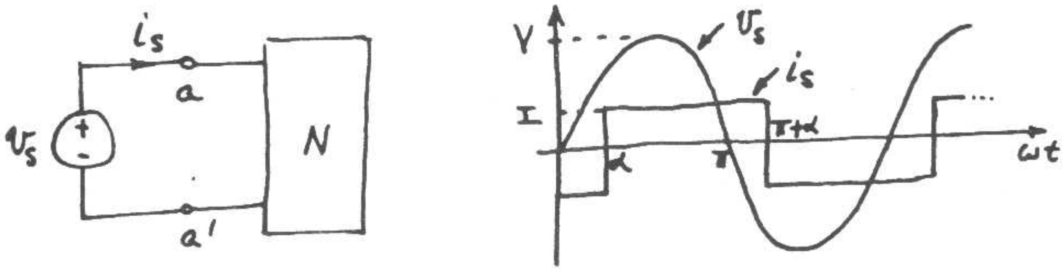

Fig. 2

The network N of Fig. 2 is supplied by a sinusoidal voltage source, $v_s = V \sin \omega t$, and draws a current i_s as shown in the figure. What is the power factor of the network N at terminal pair a - a'?

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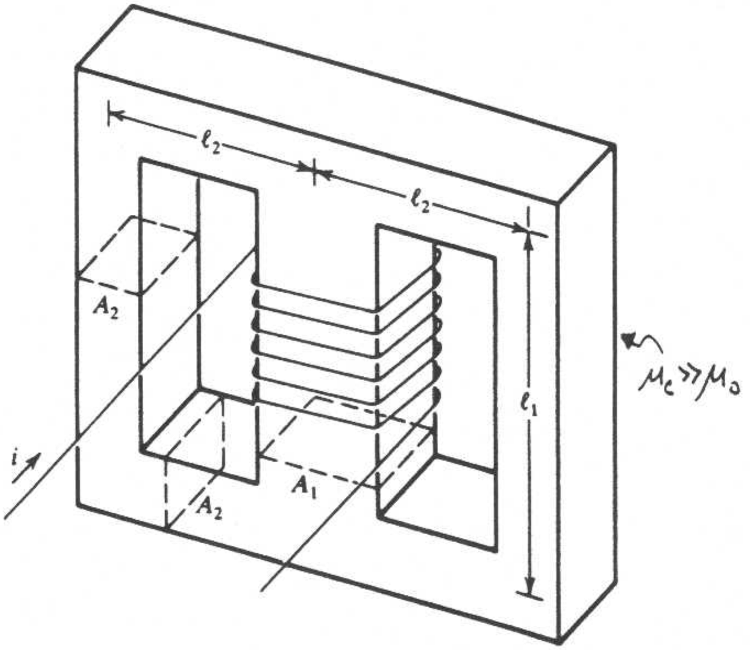
Problem 3

Figure 20.2 shows an inductor made of a three-legged core with a winding of N turns on the center leg. The two outer legs have cross-sectional areas different from that of the center leg. What is the inductance of the winding?



(a)

Figure 20.2 (a) Magnetic structure with one winding of N turns and three legs. The two outer legs have cross-sectional area A_2, and the inner leg has area A_1. The core material has permeability μ_c.

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6.334 Power Electronics — Practice Exam 2

Problem 1

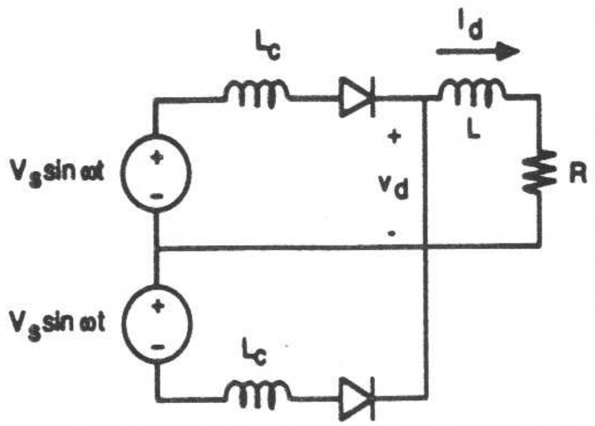

Figure 1

Assume I_d is constant in the circuit above.

(a) Sketch v_d for $L_c = 0$.

(b) Derive the load regulation characteristic of this rectifier, i.e., $< v_d > = f(I_d, V_s, X_c)$

(c) Sketch the load regulation curve for this circuit.

Problem 2

A transformer coupled dc/dc converter is shown in Fig. 2. Assume the transformer is ideal.

(a) What is the voltage conversion ratio V_B/V_A for this converter assuming periodic steady state continuous conduction mode operation?

(b) In which direction(s) can time average power flow in this converter?

(c) Determine the peak switch and diode voltage stresses and suggest an appropriate switch implementation.

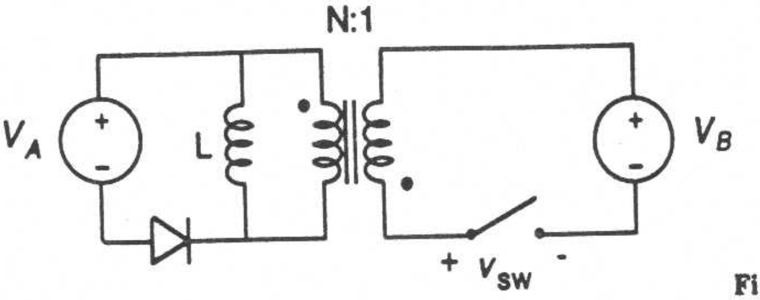

Figure 2

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6.334 Power Electronics — Practice Exam 3

Problem 1

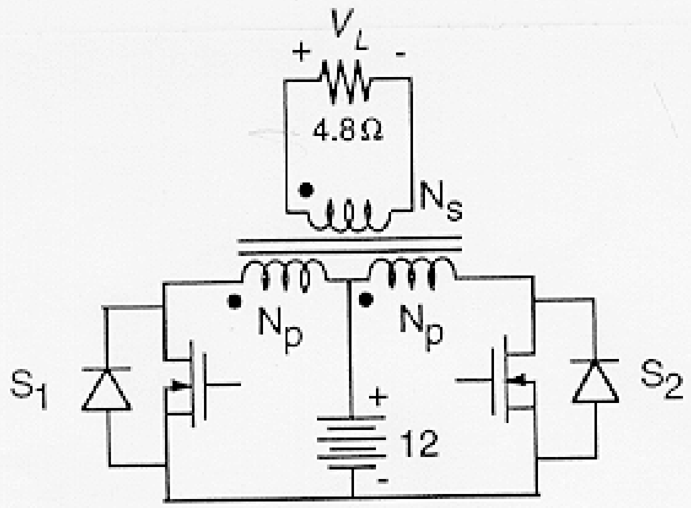


Figure 1

Consider the centertapped inverter of Fig. 1. The transformer is ideal.

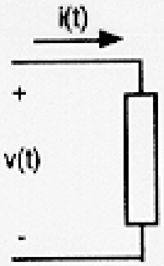
(a) The switches S1 and S2 are controlled with a 50% duty ratio to generate a 48 V square wave across the 4.8 Ω load. What turns ratio Np:Ns is required to generate the desired square-wave output?

(b) Compute the peak switch stresses on S_1 and S_2 under the conditions of (a).

(c) How would you control the switches to eliminate the 3rd harmonic in the load voltage, v_L?

(d) What are the load power and rms switch currents for the switches controlled as specified in (c)?

Problem 2



The non-linear load above exhibits the following terminal variables:

$$v(t) = V_1 \sin\omega t + V_3 \sin(3\omega t)$$

$$i(t) = I_1 \sin(\omega t+\phi_1) + I_3 \sin(3\omega t+\phi_3) + I_5 \sin(5\omega t+\phi_5)$$

What is the power factor of this load?

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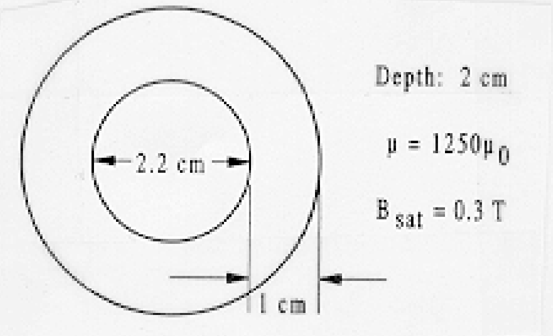
6.334 Power Electronics Practice Exam 4

Problem 1 A ferrite core, shown in Fig. 1, has a mean core length l_c of 10 cm and a cross-sectional area of 2 cm^2. Its saturation flux density is 0.3 T, and the permeability of the core is $1250\mu_o$ (where $\mu_o = 4\pi \times 10^{-7}$ H/m).

a. If 10 turns of wire are placed on the core, how much current can the coil carry without saturating the core?

b. What is the minimum number of turns on the core necessary so that the core will not saturate when a 120 V (**rms !**), 60 Hz sinusoidal voltage is applied across the coil?

Figure 1



Problem 2

(a) What is the minimum value of V_c needed to permit the circuit of Fig. 2 to operate at $D = 0.2$?

(b) Sketch and dimension i_1, i_c, and v_S for $D = 0.2$.

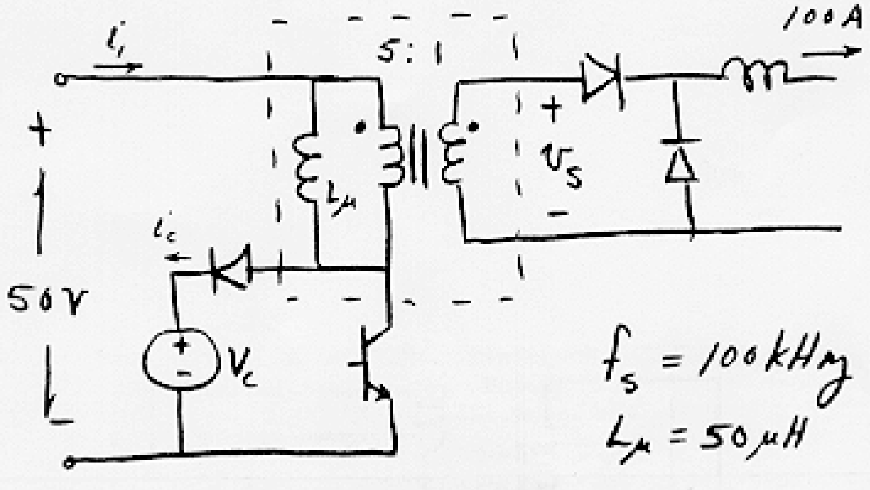


Fig. 2

6.334 Power Electronics   Practice Exam 1 Sol'ns

Prob 1 $\langle i_{C1}\rangle = D I_2 - (1-D) I_1 = 0$ $\{ I_L = I_1 + I_2 \}$

$$\therefore \quad \frac{I_1}{I_2} = \frac{D}{1-D}$$

$$\langle V_L \rangle = D\left[V_1 - (I_1+I_2)R\right] + (1-D)\left[V_2 - (I_1+I_2)R\right] = 0$$

$$= D V_1 + (1-D)V_2 - (I_1+I_2)R = 0$$

combining these $(1-D)V_2 = \left(\frac{1}{D}\right) I_1 R - D V_1$

$$\therefore \quad \boxed{\begin{aligned} V_2 &= -\frac{D}{1-D} V_1 + \frac{1}{D(1-D)} I_1 R \\ &\simeq -8.0 \ \text{V} \end{aligned}}$$

Prob 2 $v_{s,rms} = \frac{V}{\sqrt{2}}$ $i_{s,rms} = I$

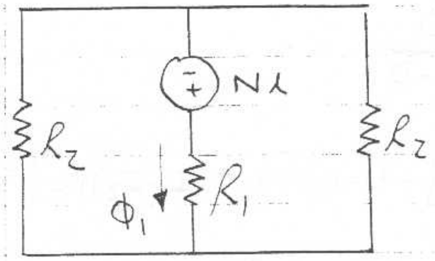
$$\langle P \rangle = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} VI \sin\varphi \, d\varphi = \frac{2VI}{\pi}\cos\alpha$$

$$K_p = \frac{\langle P \rangle}{V_{rms}\, i_{rms}} = \frac{\frac{2VI}{\pi}\cos\alpha}{\frac{1}{\sqrt{2}} V I}$$

$$\boxed{K_p = \frac{2\sqrt{2}}{\pi}\cos(\alpha)}$$

6.334 Power Electronics Practice Exam 1 Sol'ns

Prob 3 {Note: this is example 20.3 in KSV}



$$\mathcal{R}_1 = \frac{\ell_1}{\mu_c A_1} \qquad \mathcal{R}_2 = \frac{2\ell_2 + \ell_1}{\mu_c A_2}$$

$$\mathcal{R}_{net} = \mathcal{R}_1 + \frac{1}{2}\mathcal{R}_2$$

$$= \frac{\ell_c A_2 + (\frac{1}{2}\ell_1 + \ell_2) A_1}{\mu_c A_1 A_2}$$

$$L = \frac{N\Phi}{\lambda} = \frac{N^2}{\mathcal{R}_{Net}}$$

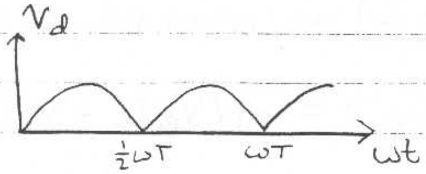
$$\therefore \boxed{L = \frac{N^2 \mu_c A_1 A_2}{\ell_1 A_2 + (\frac{1}{2}\ell_1 + \ell_2) A_1}}$$

6.334 Power Electronics Practice Exam 2 Sol'n's

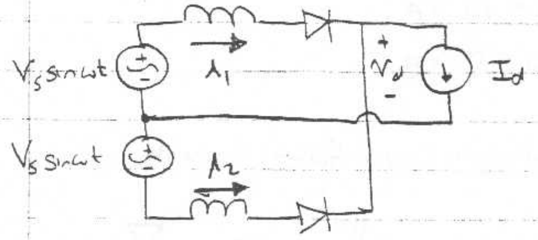
Prob 1

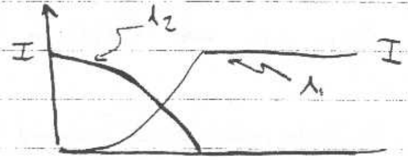
If $L_c = 0$

(full-wave / half bridge)



If $L_c \neq 0$ we must commutate current between 2 diodes (during which both will be on)



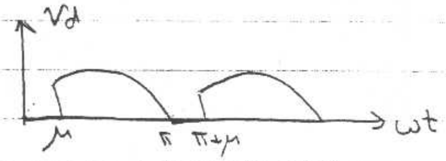


during commutation $\frac{d\lambda_1}{dt} = \frac{1}{2L}\cdot 2V_s\sin(\omega t)$

$$\lambda_1 = \frac{V_s}{\omega L}\int_0^{\omega t}\sin\varphi\, d\varphi$$

$$I_d = \frac{V_s}{\omega L}\int_0^{\mu}\sin\varphi\, d\varphi = \frac{V_s}{\omega L}\left[1-\cos\mu\right]$$

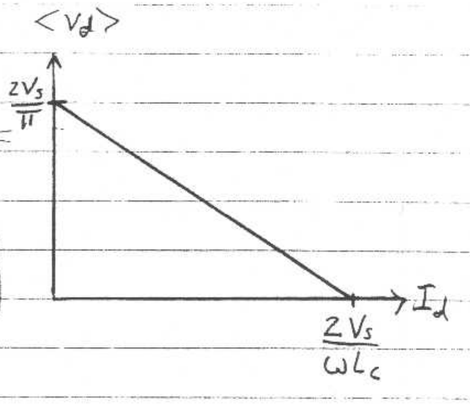
$$\boxed{\cos\mu = 1 - \frac{X_c I_d}{V_s}}$$



$$\langle V_d\rangle = \frac{1}{\pi}\int_{\mu}^{\pi} V_s\sin\varphi\, d\varphi$$

$$= \frac{V_s}{\pi}\left[\cos\mu + 1\right] =$$

$$\boxed{\langle V_d\rangle = \frac{2V_s}{\pi}\left[1 - \frac{X_c I_d}{2V_s}\right]}$$



6.334 Power Electronics Practice Exam 2 Sol'ns

Prob 2 This is essentially an isolated indirect (flyback) converter

A. $\langle v_L \rangle = -N V_B D + V_A(1-D) = 0 \Rightarrow \frac{V_B}{V_A} = \frac{1-D}{ND}$

B. The diode orientation constrains power flow to be from right to left.

C. Sw. off → $v_{SW} = V_B + \frac{1}{N} V_A$

Sw. on → $v_{diode} = V_A + N V_B$

Switch must block forward voltage & carry forward current

∴

MOSFET

OR

BJT

OR

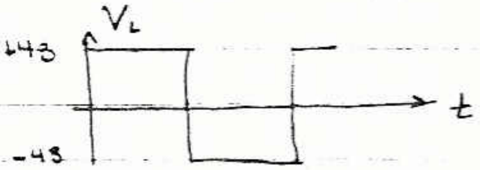
IGBT

OR

GTO

6.334 Power Electronics Practice Exam 3 Soln's

Prob 1



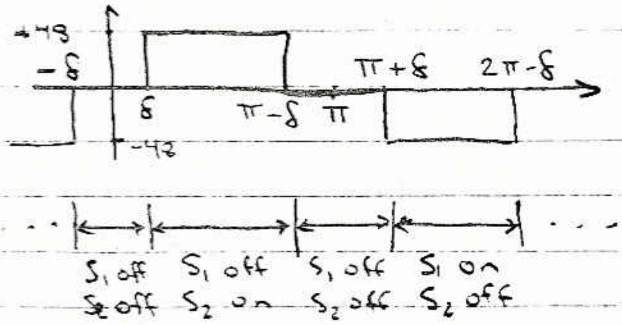
A. $N_p : N_s = 1:4$

B. Sw. off : $V_{sw} = 2 \times 12 = 24V$

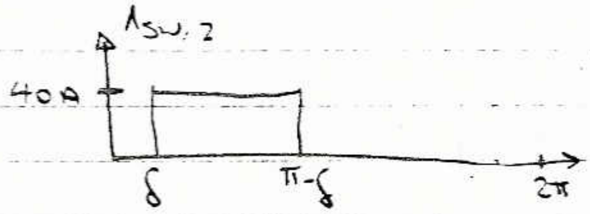
Sw. on : $I_{sw} = 4 \times 10 = 40A$

$\therefore$ each switch has $V_{pk} I_{pk} = 960$ VA

C. Notch the waveform with $\delta = 30^\circ$ (3rd harmonic elim)



D. $\langle P \rangle = \left\langle \frac{V^2}{R} \right\rangle = \frac{\frac{2}{3}(48)^2}{4.8} = 320 W$



$$I_{sw,rms} = \sqrt{\frac{120}{360}(1600)} = 23.1 A$$

6.334 Power Electronics Practice Exam 3 Sol'ns

Prob 2

$$V_{rms} = \sqrt{\frac{1}{2}\left(V_1^2 + V_3^2\right)}$$

$$I_{rms} = \sqrt{\frac{1}{2}\left(I_1^2 + I_2^2 + I_3^2\right)}$$

$$\langle P \rangle = \langle v(t)\, i(t) \rangle = \frac{1}{2} V_1 I_1 \cos\varphi_1 + \frac{1}{2} V_3 I_3 \cos(\varphi_3)$$

$$K_p = \frac{\langle P \rangle}{V_{rms} I_{rms}} = \frac{\frac{1}{2} V_1 I_1 \cos\varphi_1 + \frac{1}{2} V_3 I_3 \cos\varphi_3}{\frac{1}{2}\sqrt{\left(V_1^2 + V_3^2\right)\left(I_1^2 + I_2^2 + I_3^2\right)}}$$

$$\boxed{K_p = \frac{V_1 I_1 \cos\Phi_1 + V_3 I_3 \cos\Phi_3}{\sqrt{\left(V_1^2 + V_3^2\right)\left(I_1^2 + I_2^2 + I_3^2\right)}}}$$

6.334 Power Electronics Practice Exam 4 Sol'ns

Prob 1 (A) $\lambda = N\Phi_B = NBA_c$

$$L = \frac{N^2}{R} = \frac{N^2\mu_c A_c}{l_c}$$

$$\therefore \lambda = Li \Rightarrow NBA_c = \frac{N^2\mu_c A_c}{l_c} i$$

$$\therefore \boxed{i_{max} = \frac{B_{SAT} l_c}{N\mu_c} = \frac{(0.3T)(0.1m)}{(10)(1250\times 4\pi\times 10^{-7})} \simeq 1.91A}$$

(B) $\lambda_{max} = \int V dt = NBA_c$

We require $B \le B_{sat}$ $\therefore$ $N \ge \frac{\int V dt}{B_{sat} A_c}$

@ 60 Hz, $\omega = 377$ rad/sec, max $\int V dt$ is for $\frac{1}{2}$ cycle

$$\lambda_{max} = \frac{1}{377}\int_0^\pi 120\sqrt{2}\sin\varphi \, d\varphi = \frac{120\sqrt{2}}{377}\cdot 2 = 0.9 \text{ V-s}$$

$$\therefore \boxed{N \ge \frac{0.9}{(0.3)(2\times 10^{-4})} \cong 15{,}000 \Rightarrow \text{Very big!}}$$

Prob 2

(A) We Require $V_{IN}D \le (V_C - V_{IN})(1-D)$
So transformer core will reset during 1-D time period.

$$\therefore V_c \ge V_{IN}\frac{D}{1-D} + V_{IN}$$

$$\boxed{V_C \ge \frac{V_{IN}}{1-D} = \frac{50}{0.8} \approx 62.5}$$

Note that a higher clamp voltage is needed at higher

6.334 Power Electronics Practice Exam 4 Soln's

$$\Delta I_{\mu,pp} = \frac{V_1}{L_\mu} DT = 2A$$