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FINAL EXAMINATION

December 11, 2001

ECE359 – Industrial Electronics

Examiner: P.W. Lehn

Duration: 2.5 Hours

Exam Type: C
(Single aid sheet and non-programmable calculators)

ANSWER ALL QUESTIONS IN THE EXAM BOOKS PROVIDED

IF YOU USE 2 BOOKS, INDICATE THIS CLEARLY ON BOTH BOOKS

[20 Marks] DC-DC Converters

1. You want to run a 3.3 V CPLD from a single 1.5 V battery. The CPLD will draw between 10 and 50 mA. It requires that its voltage ripple be less than 0.1 V peak-peak. The device should run off any type of battery. Ni-Cad batteries produce only 1.25 V while regular batteries produce up to 1.65 V.

   a) Sketch and name the type of converter you will use.

   b) If you switch at 100kHz, what is the minimum inductance value you can use?

   c) Using the value of L found in part b) what is the minimum capacitance value you can use?

   d) If you use an alkaline battery that outputs 1.55V what duty cycle will you need to operated the converter at to produce the desired output voltage?

   e) Given your design, what would happen if the CPLD were now only to draw 5 mA?

[20 Marks] DC Machines

2. You want to put up a large windmill and sell power to hydro. You connect a dc machine to the shaft of the windmill and you connect the armature of the dc machine to a dc/ac converter. The dc machine is rated at:
   P = 60 kW
   Va = 600 V
   Ia = 110 A
   Ra = 0.2 Ω
   N = 3600 rpm
   It draws a rated field current of 1 A from 600 V

   a) What is the efficiency of the machine at its rated operating point?

   b) If you want the machine to output 60 kW of **electrical power**, how much torque must the windmill produce?

   c) You have only the components listed above (i.e. one converter, an ac source, a dc machine and the windmill to supply torque). Give a schematic of how you would need to connect the windmill, machine, converter, and ac system. Don't forget to sketch in the field winding connections.

   d) *Neglect rotational losses for this part.*
   The system is configured as in part c). Also you may assume that the windmill's output torque is proportional to speed according to $Tq = 1.0 \times \omega_m$. Sketch the speed torque diagram for the windmill and machine if:
      (i) the converter has 600 V at its dc terminals
      (ii) the converter has 300 V at its dc terminals

[20 Marks] PM SM

3. The nameplate of the 3-phase PM SM in the lab states the following:
   Maximum continuous current 11.5 Arms
   Maximum continuous stall torque 5.26 N*m (this is at the above current and $\delta = 90°$)
   Rated speed 6000 rpm
   Rated voltage 100 Vrms

   a) Give a formula relating the machine current, angle δ, and the output torque.

   b) What is the minimum number of phases the machine can have yet still produce ripple free torque?

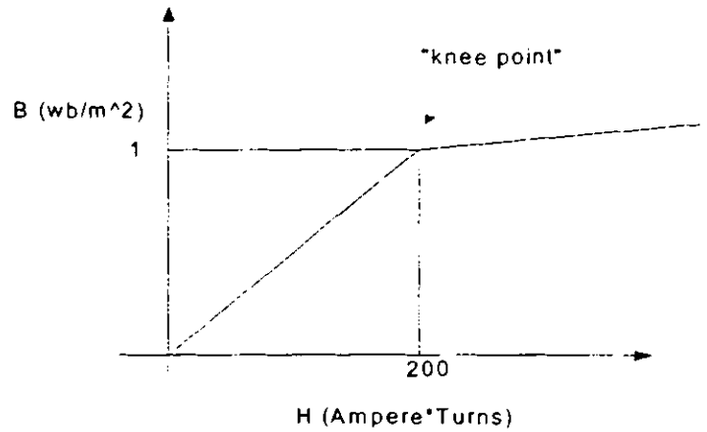
   c) If you supply the motor from a SPWM converter connected to a 300 V dc source, what is the maximum modulation index you could use?

   d) You plan to use the motor in an electric go-cart. You want to drive the motor from a sinusoidally pulsewidth modulated converter to minimize ripple torque and losses. The problem is that you only have a 50 V lithium-ion battery pack. Sketch the power electronic circuitry you would need to operated the motor at rated voltage.

   e) The mechanical engineer on your go-cart design team wants to put a "gas pedal" on the go cart. Should this "gas pedal" adjust the frequency of the PM SM supply or should it adjust the torque of the PM SM. In other words, would you run the machine as a controlled torque machine for this application. Explain.

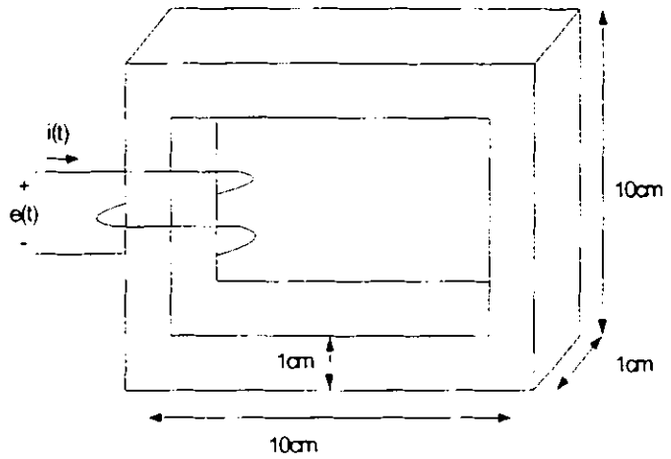
[20 Marks] Magnetics

4. You are given a magnetic material with a "B-H curve" as shown.



a) What is the relative permeability of this material if you avoid saturation?
Note: $\mu_o = 4\pi \times 10^{-7}$.

b) The inductor in the figure below has a dc current rating Irated. When the rated dc current flows then the flux is at the knee point of the B-H curve. What is the dc current rating, Irated, of this inductor?



c) What is the inductance of the coil in part b), assuming you operate below the rated current.

d) If you drive an ac current into the coil of $i(t)=2\cos(\omega t)$, what is
(i) the resulting flux in the magnetic material
(ii) the voltage e(t)

e) In practice an inductor is not ideal and will dissipate power. List the sources of energy loss in a real inductor.

[20 Marks] Induction Machine

5. A subway car is built with 4 squirrel cage induction motors, one on each axle. Each is rated at 60 hp, 60 Hz, 600V and 3450 rpm. The motors are all fed from a single converter using V/f control.

   You may neglect rotational losses for all parts

   a) For acceleration you run the motors at rated torque. What is the total torque output that accelerates the subway car?

   b) If you run at half rated torque and the converter output voltage is at a frequency of 30 Hz then
      (i) how fast is the motor running
      (ii) what is the frequency of the the rotor current

   c) How much torque can each machine produce if the supply frequency is pushed up to 120 Hz?

   d) One motor fails and you replace it with a new IM of slightly different rating. The new IM is rated 60hp, 600V and 3500 rpm. If you want to accelerated with the same torque as in part a) how much torque must this new machine produce? Express you answer as a percentage of the machines rated torque.