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FINAL EXAMINATION

December 12, 2000

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

[25 Marks]

1. You are working on the power management system on a laptop. Power is supplied by a 15 V lithium ion battery, but your CPU requires only 3 V.

   To make your supply and its filters small you want to switch at very high frequency. Switching losses, however, increase with frequency. After performing a cost/benefit analysis you decide that a switching frequency of 50 kHz is a reasonable compromise at the power level you are working at. Your minimum load is 3 W. Full load is 30 W.

   a) Draw the circuit of the converter you propose and calculate the duty cycle you will need to run.

   b) What is the the minimum inductance value you can use without going into discontinuous conduction mode?

   c) What capacitance value will you require if the maximum voltage ripple you can tolerate is 0.1 V peak-peak?

   d) You have optimally designed your converter for a 3W minimum output as stated in the specs for a mobile PIII CPU. Your boss now wants to use a 3V Transmeta CPU since it uses less power. It's minimum consumption is only 2W. How, if at all, will this affect the performance of your power supply and CPU?

[20 Marks]

2. Two identical separately excited dc machines are physically connected together. The machines have the following nameplate data:

   Vrated = 110 V

   Irated = 8 A

   After several tests you ascertain that the armature resistance is 1 Ω.

   The machines both rotate in the positive direction when positive armature voltage is applied. (Thus they are **not** counter-rotating.)

   Machine 1 is the dynamometer.
   It has the field set at ½ rated flux, giving $k\Phi_1=1$ V*s.
   It has an external resistance in series with the armature of 3.3 Ω.
   It is connected to a 110 V supply.

   Machine 2 is the machine under study.
   It has the field set at full rated flux, giving $k\Phi_2 = 2$ V*s.
   It has no external resistance in series with the armature.
   It is connected to a 110 V supply.

   You may neglect mechanical losses.

   a) **Draw to scale** the speed torque curves of the dynamometer and the machine under study.

   b) What is the torque and speed at the operating point? (You may obtain this graphically.)

   c) Determine the armature currents in the two machines.

   d) How could you reduce the armature current in the dynamometer, yet operate at the same torque **and** speed?

[20 Marks]

3. A 60 Hz, 4-pole, 3-phase squirrel cage induction machine is connected to a dc dynamometer. Since this is a squirrel cage machine, you have no access to the rotor circuit.
   The machine has nameplate data:
   Vrated = 208 V (line-line, rms)
   P = 3 kW
   speed = 1750 rpm

   You may neglect mechanical losses and assume stator resistance and reactance are negligible.

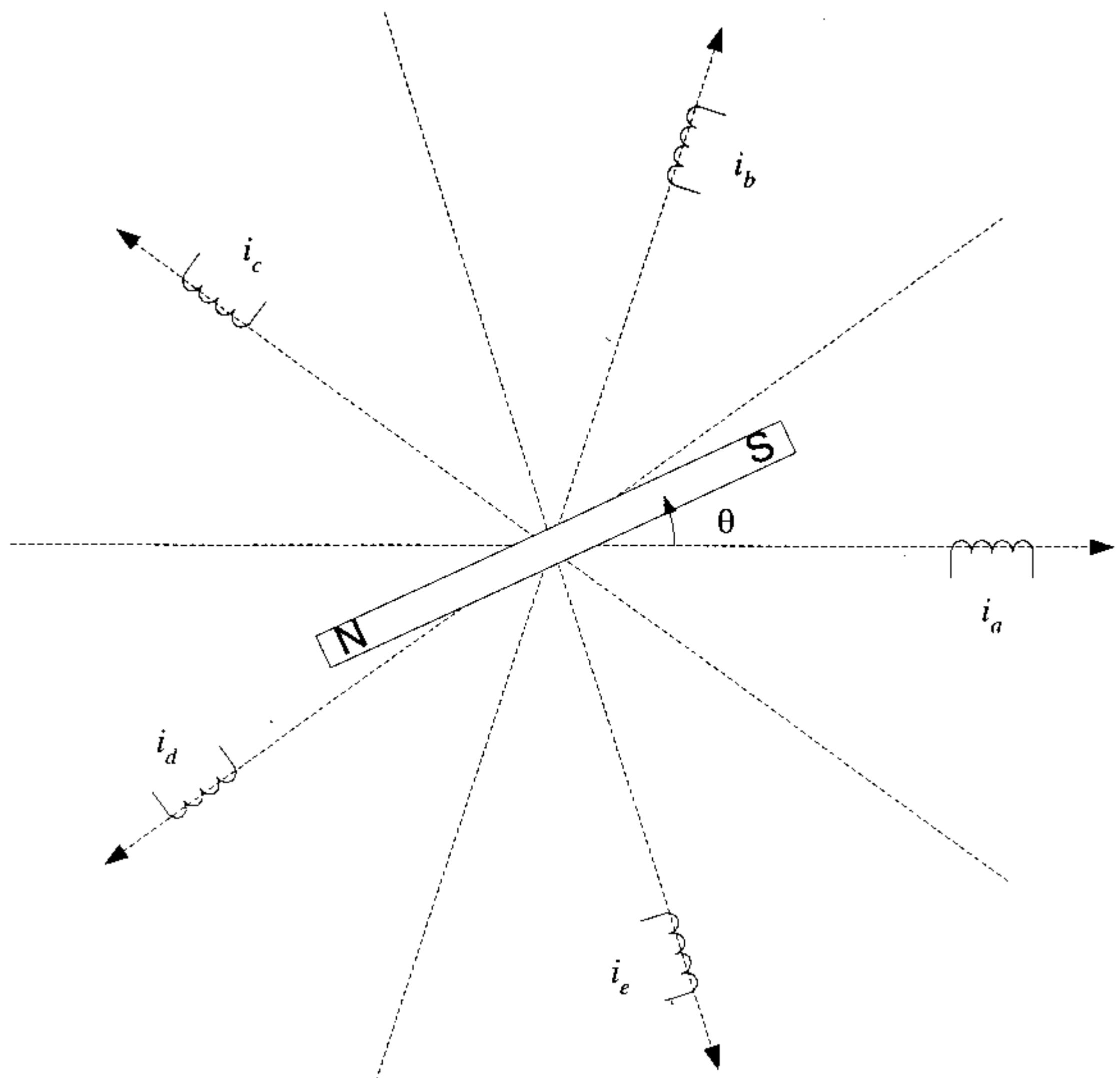
   a) What is the rated torque on this machine?

   b) What is the frequency of the current induced on the rotor at rated torque?

   c) You now keep the voltage amplitude at its rated value, but increase the frequency of the voltage to 120 Hz. How much torque can you produce without exceeding the rated rotor current?

[10 Marks]

4. Below is a simplified diagram of a obscure 2-pole, 5-phase synchronous machine. Each phase winding produces flux along its axis which is proportional to the current in the winding.
   E.g. a positive current i_a in winding "a" will produce a flux only along the x-axis, in the direction shown by the arrow. Thus positive current i_a produces flux $\Phi_x = +k*i_a$.



[over]

You want to display the direction of the stator flux in the machine on an oscilloscope, just like in the synchronous machine's laboratory. This requires that the 5 currents be transformed into flux components along the x-axis and along the y-axis. Therefore you must find the matrix **A** in the equation:

$$\begin{bmatrix} \Phi_X \\ \Phi_Y \end{bmatrix} = k\,\mathbf{A} \begin{bmatrix} i_a \\ i_b \\ i_c \\ i_d \\ i_e \end{bmatrix}$$

where k is the proportionality constant between current and flux.

a) Find the matrix A which relates the currents $i_a \ldots i_e$ to the x- and y-axis flux.

b) If you apply the currents:

$$i_a(t) = I\cos(\omega t)$$
$$i_b(t) = I\cos(\omega t - \pi/5)$$
$$i_c(t) = I\cos(\omega t - 2\pi/5)$$
$$i_d(t) = I\cos(\omega t - 3\pi/5)$$
$$i_e(t) = I\cos(\omega t - 4\pi/5)$$

Then the stator produces an constant amplitude mmf rotating in the positive direction. Thus the machine will move in a positive direction and supply constant, ripple free torque.

You now want to run backwards. Give the set of currents that would produce a constant amplitude mmf rotating in the negative direction.

[25 Marks]

5. A dc machine, a squirrel cage induction machine and a pump are all mounted on the same shaft. Both the dc and induction machine drive the shaft in the positive direction. (Thus the two machines are **not** counter-rotating.) Together they run the pump.

   The 3-phase 6-pole induction machine is rated at: 60Hz
   Vrated = 660 V (line-line rms)
   Prated = 10 kW
   rated speed = 1150 rpm

   The dc machine is rated at:
   Vrated = 440 V
   Irated = 25 A
   Prated = 10 kW
   rated speed = 1200 rpm
   rated kΦ = 3.18 V*s
   Ra = 1.6 Ω

   The load is a speed torque characteristics given by:
   Tq = 1.0* ωm
   E.g. To drive the pump at 1 rad/s will require 1 N*m torque.

   The 3-phase induction machine is supplied by a 660 V (line-line rms) 3-phase source. The dc machine is supplied by a 440 V dc source, and runs at rated flux.

   Neglect mechanical losses.

   a) Find the speed and torque at the operating point. (If you use a graphical approach it must offer respectable accuracy.)

   b) Sketch a speed torque diagram that can be used to graphically find the operating point in part (a)