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MIDTERM EXAM

CLOSED BOOK (120 MIN) **POWER ELECTRONICS (EECE 473E)** APRIL 15, 2009

NAME: ____________________ **ID#: ____________________**

1. Answer briefly the following questions.
   a) What are the gating characteristics of bipolar junction transistors, MOSFETS, and gate turn-off switches? How many stages there are in a drive circuit and what is a frequently encountered problem and how is it solved?
   b) Discuss how power electronics are used in elevators, electric cars, and HVDC transmission. What are the main systems or blocks, the devices used, and the control objective in these three applications and how this objective is achieved?

2. A high-power application magnet is supplied via a three-phase bridge converter from a 1200 V, 50Hz source. The magnet winding has a resistance R= 2Ω and an inductance L= 200 mH. The three-phase supply is via a transformer having a per-phase leakage inductance L_S= 0.2mH.
   a) Draw and label the converter circuit diagram, plot the line-to-neutral supply voltages, the voltage across the load, the thyristor currents, and the current supplied by the ac source, showing clearly the effect of commutation overlap. Provide the plots on the attached plot sheets.
   b) When the average output voltage value is 1400V calculate the average load current (I_o), the firing angle delay (α), and the angle of commutation overlap (u).
   c) Calculate the rms value of the input current, and the rms diode current, the power factor, and the total harmonic distortion of the input current. Explain briefly formulae used and justify any approximations.
   d) How can the energy stored in the inductor be be recovered by the supply? What is the firing delay and output voltage needed to recover this energy in minimum time? Bonus: estimate the time needed!

3. It is required to design a buck converter to supply a permanent dc motor from a 240V dc source. The motor voltage is to be controlled in the range 100 to 200 V with an allowable peak to peak ripple of 5%. The motor current is constant at 5A with negligible ripple. The converter may be built using a power BJT that can operate in the range 1 to 25 kHz. The circuit diagram of the converter is shown in Fig. 1.
   a) Describe the operation of the converter clearly identifying which devices are on and off and describing qualitatively the current and voltage in the various components. Draw the current waveforms in the inductor, transistor and capacitor, and draw the voltage waveforms across the capacitor, inductor and diode.
   b) Determine the range of duty cycle operation. And given that the frequency is 10 kHz select a proper value for the inductor L and capacitor C. Note that the current ripple in the inductor is to be limited to ±5 around the average. What is the peak transistor current?
   c) The transistor is to be driven using the drive circuit of Fig. 2. What kind of drive circuit is this and what is its main advantage? Describe briefly how it operates and derive expression relating the transformer turns ratio to β the device current gain. Derive an expression to calculate the transformer core area A_c.

d) The main switching device gain is β_{MIN}= 100 minimum, $I_{C(\mathrm{MAX})}$= 8A, $V_{BE(\mathrm{ON})}$= 1.8V, $V_{CE(\mathrm{SAT})}$= 1.4V. The driver devices have a maximum collector current of 500mA. Select an appropriate overdrive factor (ODF) and design the transformer appropriately by determining its turns on the primary and secondary and its core area. The supply voltage V_{CC}= 12V, the ferrite core has a saturation magnetic flux density of B_s= 0.6T and μ= 1500μ_0 with μ_0= 4π×10^{-7} H/m. Determine the magnetizing inductance and current and the transformer base current and select suitable values for R_1 and R_2.

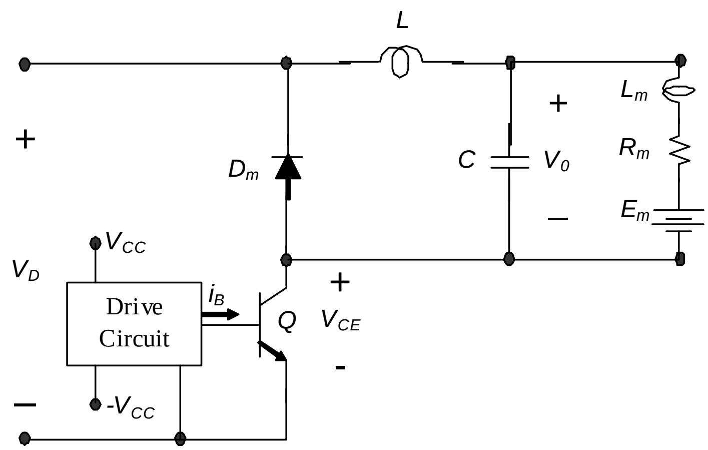

Fig. 1: Switching converter driving a dc motor

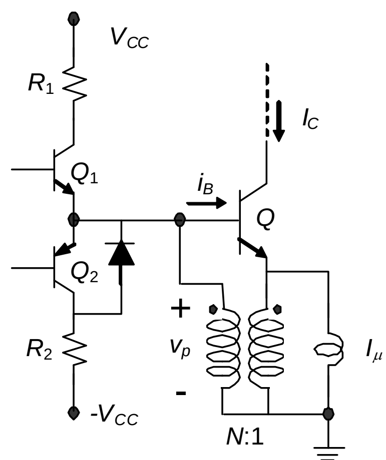

Fig. 2: Drive Circuit for the main switching device