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MIDTERM EXAM

CLOSED BOOK (120 MIN) **POWER ELECTRONICS (EECE 473E)** APRIL 14, 2010

NAME: _____ **ID#:** _____

1. Answer briefly the following questions.
   a) What are snubber circuits used for? Draw different types of snubber circuits that are shown in their context of usage and explain how do they work and how the values of their circuit components are determined.
   b) 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?

2. A high-power application magnet is supplied via a three-phase bridge converter from a 380 V, 50Hz source. The current in each thyristor may reach an rms value of 25 A. The drive circuit of a typical thyristor in the three-phase set up is as shown in Fig. 1. The data sheet of the thyristor being used (i.e. 2N6504 series) is attached. The supply voltage V_{CC}= 12V. In carrying out the design select standard resistance values attached. Provide brief explanations for various choices that you make in your design.

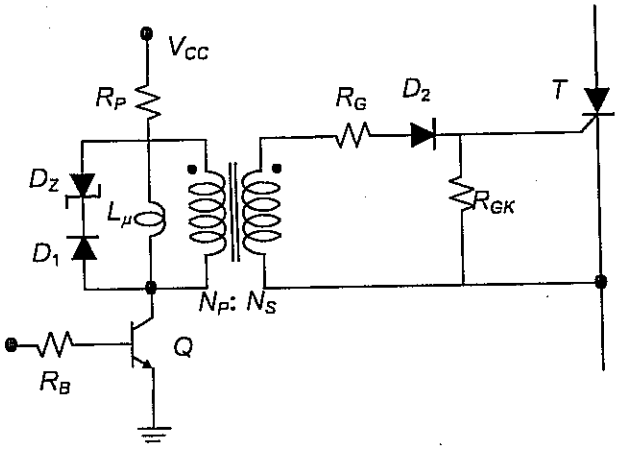

Fig. 1: Drive Circuit of a Thyristor

   a) Explain the general operation of the drive circuit of Fig. 1. Also explain the the functions of the various components R_G, R_{GK}, diode D_2, the transformer, the resistance R_P, the diode D_1 and the zener diode D_Z.
   b) Select the appropriate thyristor based on the data sheet of the 2N6504 series. Select an appropriate gate current to design for and deduce the transformer secondary current and voltage. Determine appropriate values for resistances R_G and R_{GK}.
   c) Select an appropriate transformer turns ratio with justification and calculate the minimum transformer core area required if the transformer core is made from ferrite with $\mu_r = 4\times10^4$. Select an appropriate core from the set of available cores (attached). Which one of the wires available in the attached table would you select? Briefly explain.
   d) Calculate the magnetizing inductance of the transformer, the magnetizing current, and an appropriate value of R_P. Determine R_B if the base supply has a Thevenin equivalent voltage and resistance of 5V and 100Ω, respectively. Note that the maximum collector current of the transistor Q (2N2222A) is 600 mA and that its minimum current gain is h_{FE} = 75.

3. It is required to design a boost converter to supply a permanent magnet dc motor from a 36V dc source. The motor voltage is to be controlled in the range 40 to 80 V with an allowable peak to peak ripple of 5%. The motor current varies in the range 2 to 8A, with negligible ripple. The converter may be built using the IRF150 power MOSFET (data sheet attached) that may be operated at a frequency up to 1000 kHz, but the selected frequency is 25 kHz. The circuit diagram of the converter is shown in Fig. 2.

   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 in relation to the supply voltage. Draw your wave forms for a duty cycle of about 0.3.

   b) Determine the range of duty cycle operation. Select a proper value for the inductor L and capacitor C for continuous operation. What is the peak transistor current and the peak voltage it must withstand? Is the IRF 150 a suitable choice? Explain.

   c) The transistor is to be driven using the drive circuit of Fig. 3. What kind of drive circuit is this and what is its main advantage? Describe the operation of this circuit and calculate the values of R_1, R_2, and R_B knowing that the supply voltage V_{CC} is 12V and that the pulse generator behind R_B has 12V 100 Ω Thevenin equivalent. Note that the maximum collector current of the 2N2222A (Q_1) is 600 mA and that its minimum current gain is $h_{FE} = 75$, and that the maximum collector current of the 2N3906 (Q_2) is 200 mA and that its minimum current gain is $h_{FE} = 30$.

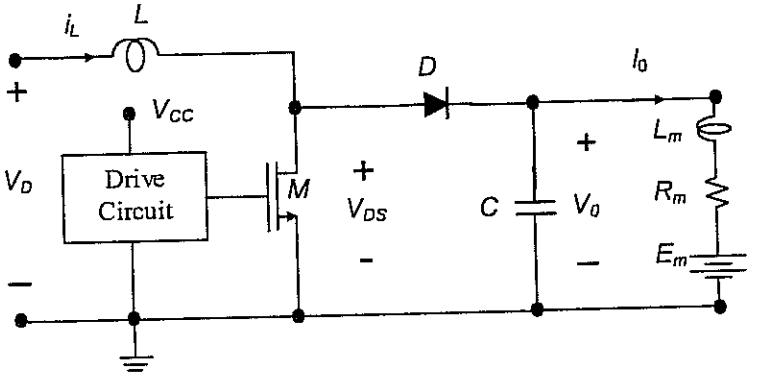

Fig. 2: Switching boost converter driving a dc motor

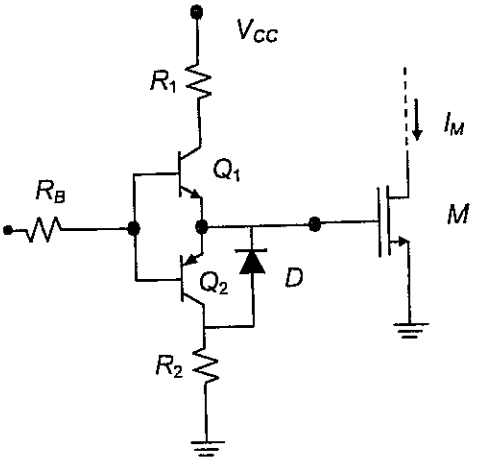

Fig. 3: MOSFET drive circuit