Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2011-2012 (2 hours)

EEE6022 Motion Control and Servo Drives

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. Figure 1 shows the schematic of a servo drive system in which a purely inertial load is coupled to the motor via a gearbox. If the efficiency of the transmission is η, show that the required torque rating of the motor will be minimum when the gear ratio *a* is given by:

$$a = \sqrt{\eta \frac{J_m}{J_L}}$$

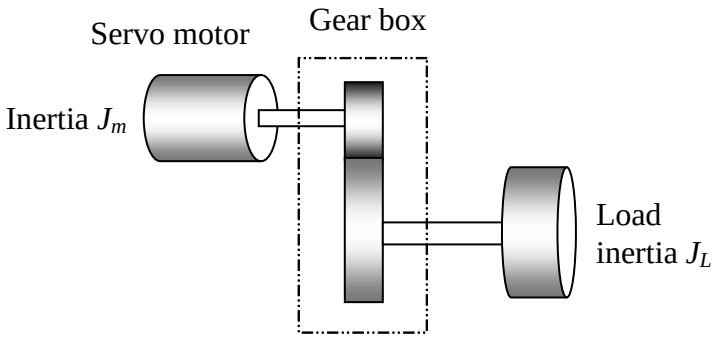

Figure 1 **(8)**

b. Given the servo motor in Fig. 1 with an inertia of 0.0005 kgm^2 and peak torque rating of 2Nm, find the time taken to move the purely inertial load of 0.002 kgm^2 through 10 revolutions using a trapezoidal velocity profile and the optimal gear arrangement and determine the maximum speed and rms torque of the motor. The movement is to start and finish at standstill and the transmission efficiency is 0.95. **(7)**

c. If the same movement is performed using a triangular velocity profile, determine the rms torque of the motor and whether such a movement could be executed repeatedly given that the rms torque rating of the motor is 1.65Nm. **(5)**

2. A permanent magnet dc servomotor with the following parameters

rated torque = 10Nm

rated current = 20A

armature resistance R_a = 0.4Ω

armature inductance L_a = 3.2 mH

is connected to a 200V dc supply via the H-bridge which operates in the bipolar mode at 20 kHz switching frequency, as shown in Fig. 2.

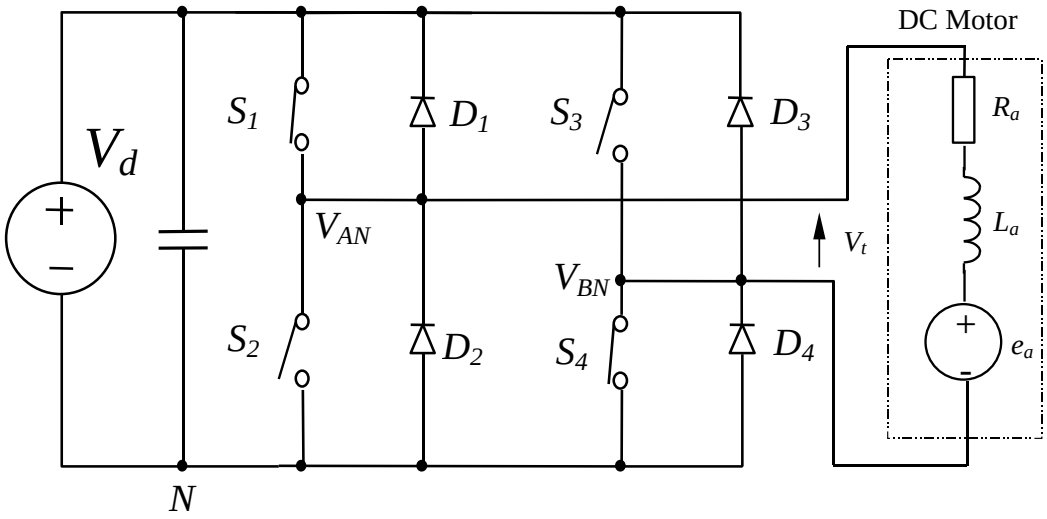

Figure 2

a. Describe, with the aid of appropriate waveforms, bi-polar operation of the converter. **(6)**

b. Calculate the motor terminal voltage v_t, the duty ratio of the pulse width modulation and the current ripple in steady state for a payload torque of 5 Nm at a speed of 1500 rpm. **(6)**

c. Assuming that the armature resistance R_a has a negligible effect on the current ripple, show that the maximum current ripple of the bi-polar operation is given by:

$$\Delta I_{pp} = \frac{V_d}{2L_a f_c}$$

where f_c is the carrier frequency. **(8)**

3. **a.** The transformation matrix from a stationary ($\alpha\beta$) system to a 3-phase (*abc*) system is given by:

$$C_{abc\leftarrow\alpha\beta} = \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix}$$

Show that the electrical input power of a 3-phase motor is given by:

$$P = \frac{3}{2}\left(v_\alpha i_\alpha + v_\beta i_\beta\right)$$

where v_α, v_β, i_α and i_β are the α and β axis components of the motor voltage and current, respectively. **(6)**

b. A three-phase, 6-pole, star-connected synchronous permanent-magnet ac servomotor has a measured line-to-line open-circuit rms voltage of 190 V at a rotor speed of 2000 rpm. The phase resistance and synchronous inductance of the motor are 1.05 Ω and 5.8 mH, respectively.

(i) Calculate the no-load peak flux-linkage and the torque constant of the motor, and sketch the phasor diagram for maximum torque per Ampere operation. **(3)**

(ii) If the motor is required to deliver 30 Nm torque at a speed of 1500 rpm, calculate the minimum rms phase current, rms phase voltage, and the power factor of the operation. **(6)**

(iii) If the motor is to operate at unit power factor for the same torque and speed outputs, sketch the phasor diagram and calculate the rms current and rms phase voltage. **(5)**

4. A three-phase, 4-pole star-connected induction motor has a rated speed of 1450 rpm, when operating from a 415V, 50Hz supply. The machine has the following parameters measured at 50Hz and referred to the stator:

Magnetising reactance	= 48.6 Ω
Stator resistance	= 0.35 Ω
Rotor resistance	= 0.55 Ω
Stator leakage reactance	= 1.20 Ω
Rotor leakage reactance	= 0.95 Ω

a. Sketch the equivalent circuit diagram of the motor operation **(2)**

b. If the motor operates at 50% rated torque, calculate the rotor speed, stator current, power factor, air-gap flux linkage, and efficiency. **(9)**

c. If the motor is supplied by a three-phase inverter which is modulated using the Space Vector Modulation technique at a frequency of 2 kHz with a dc link voltage of 600V, determine the time duration for the two active vectors and zero vectors in order to achieve the required operation in 4(**b**) when the air-gap flux-linkage is at 55 electrical degrees with respect to phase *a* axis, and sketch the per-cycle switching sequence waveforms. **(9)**

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