NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

Degree of Master of Engineering

2nd SEMESTER MAIN EXAMINATION

COURSE	**:**	COMPUTER CONTROL OF MANUFACTURING SYSTEMS
CODE	**:**	TIE 6120
DATE	:	APRIL/MAY 2014
DURATION	**:**	3 HOURS

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INSTRUCTIONS TO CANDIDATES

1. ***Answer FIVE questions altogether.***
2. ***Each question carries 20 marks and the marks allocated to the questions are indicated on the right hand margin against the subsection.***
3. ***This paper contains seven (7) questions.***
4. ***There are five (5) printed pages.***

Question 1

(a) What is a programmable logic controller (PLC)? [2]

(b) With the aid of a diagram name and describe the functions of the basic components that comprise a PLC? [10]

(c) What are the advantages of using a PLC over using conventional relays and other hardware elements? [4]

(d) Briefly describe the operating cycle of a PLC. [4]

Question 2

(a) Name the basic hardware components of a servo. [4]

(b) Figure Q2 shows a block diagram of a servomotor and a positional servomechanism. Given τ_m = 0.2 sec, K_m = 2 (rad/sec), H = 0.4 V/(rad/sec), K_p = 125 V/mm, K_a = 20, r = 0.1 (mm/rad), determine

(i) the parameters of the servomotor with the tacho feedback, K_{CL} (rad/sec) and τ_{CL} (sec). [4]

(ii) The natural frequency ω_n (rad/sec) and damping ratio ς of the positional servo. [4]

(iii) The initial acceleration $\ddot{x}$ (mm/sec^2) at the start of a step command x_{com} = 4 mm. [4]

(iv) The magnitude of the position error er_p (mm) in a steady-state motion with a velocity of $\dot{x}$ = 5 mm/sec. [4]

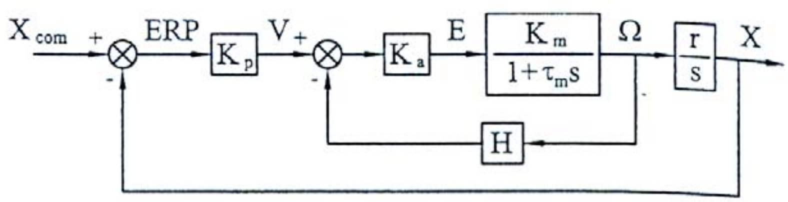

Figure Q2 Servomotor and a positional servomechanism block diagram

Question 3

(a) Explain why it is necessary to implement an adaptive control strategy to NC machining. [4]

(b) Draw the diagram of the software and hardware components of the system for adaptive control for constant milling force. [8]

(c) Explain, briefly, the purpose and action of each component. [8].

Question 4

Figure Q4 shows a linear circuit model of a DC servomotor armature. Given that R_a is the total amature resistance (including that due to the brushes). R_L is a resistance that represents the magnetic losses in tha armature (and is normally >> R_a). L_a is the armature inductance and E_g is the back EMF produced when the armature rotates in a DC magnetic field. K_E is the back EMF constant of the motor. K_T is the torque constant, I_a is the armature current. J_M and J_L are the armature and reflected inertias, J_T is the sum of the the inertias ($J_T = J_M + J_L$). T_f is the friction torque of motor and the load (including the gears etc) and T_{gr} is the gravitational torque load.

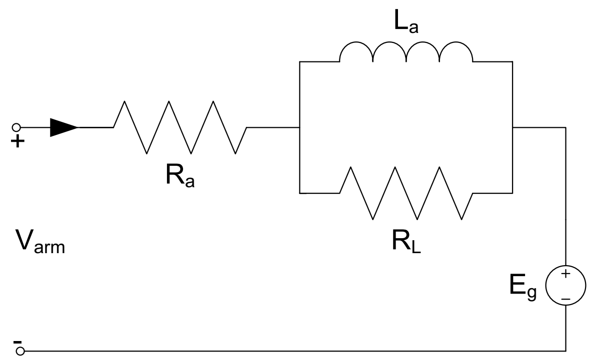

Figure Q4 Circuit model of a DC servomotor armature

(a) Assuming that there is no resonance in the system and all the components of the rotary system turn in phase:
   (i) Develop the block diagram for the servomotor including the gravitational and friction disturbance torques. [7]
   (ii) Using block diagram reduction techniques, show that the transfer function of the motor can be shown as

$$G_m(s) = \frac{\Omega(s)}{V_{arm}(S)} = \frac{K_T/L_aJ_T}{s^2 + [(R_aJ_T + L_aB)/L_aJ_T]s + (K_TK_E + R_aB)/L_aJ_T}$$

[7]

(b) Consider a CNC worktable driven by a closed-loop control system consisting of a servomotor, leadscrew, and optical encoder. The leadscrew has a pitch, p = 5mm and is coupled to the motor shaft with a screw to motor gear ratio of 1 :4. The encoder generates 150 pulses per revolution of the leadscrew. If the number of pulses and the pulse rate received by the control system are 2250 and 200 Hz respectively, calculate
   (i) Table speed. [2]
   (ii) Motor speed in RPM. [2]
   (iii) Distance travelled by the table. [2]

Question 5

(a) Figure Q5 shows a model for a position servo model. Assuming that the amplifier bandwidth is 1000Hz (i.e. $\tau_A = 1/6280$) and the inertial load is 0.007. The tach open-loop transfer function can be given by

$$GH(s) = \frac{14.1AK_g}{\left(1 + \frac{s}{6280}\right)\left(1 + \frac{s}{44.14}\right)\left(1 + \frac{s}{439.73}\right)}$$

   (i) Plot the Bode plot for the system [10]
   (ii) Determine its stability [2]

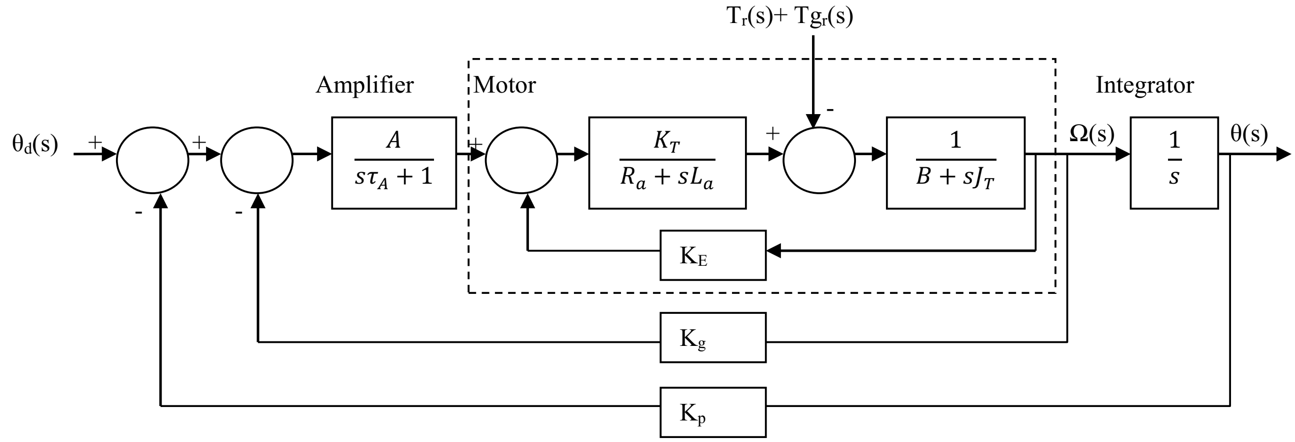

Fig Q5 Position servo model

(b) A CNC milling machine has to cut a slot located between the points (0,0) and (4,3) on the XY-plane where the dimensions are in mm.

(i) If the speed along the slot is to be 2.54 mm/sec, find the cutting time and axial velocities. [2]

(ii) If the velocity is Y-axis is off by 10%, what would be the new position? [2]

(c) A stepping motor of 200 steps per revolution is mounted on the leadscrew of a drilling machine. If the pitch is 2.54 mm/rev.,

(i) What is the BLU ? [2]

(ii) If the motor receives a pulse frequency of 2000 Hz, what is the speed of the table? [2]

Question 6

A sliding gate should be opened and closed with a bidirectional contactor circuit. In order to minimize the accident risk while cars are driving in and out, a light beacon, which is mounted at the gate, has to be switched on while the gate is moving. Mechanical limit switches (B1 and B2) as well as IR-receivers and an emergency off switch are mounted on either side of the wall. The mechanical limit switches must switch the sliding gate off when they reach the end brackets.

The switch S0 switches the system on. If button S2 is activated or if the IR remote control is activated (button 1 = 50 Hz), the gate slides “Open” until it reaches its limit switch. Limit switch B1 switches “off”. The gate has to close automatically after an opening time of 10 sec. Activation of button S3 closes the gate till it reaches its end bracket. Limit switch B2 switches “off”. The moving procedure can be stopped at any time with the emergency “off” button. Should the gate be passed by a car or by a pedestrian during the closing procedure (gate closing), the action of the motor has to be reversed by means of a light beam and the gate should open again.

(i) Develop the flow diagram for the system. [8]

(ii) Write the ladder logic diagram for the gate. [12]

Question 7

(a) About 80% of commercial robot controllers are of the PID type. Give reasons for this huge preference of the PID controller over other types of controllers. [5]

(b) Name and briefly describe any other type of controller that may be used instead of the PID controller. [4]

(c) Write the mathematical model of the PID controller in

(i) the time domain. [3]

(ii) the *s*-domain [3]

(e) In practice, how are the constants mentioned in (d) above determined? [5]

END OF EXAMINATION