Department of Electronics and Telecommunication Engineering
University of Moratuwa
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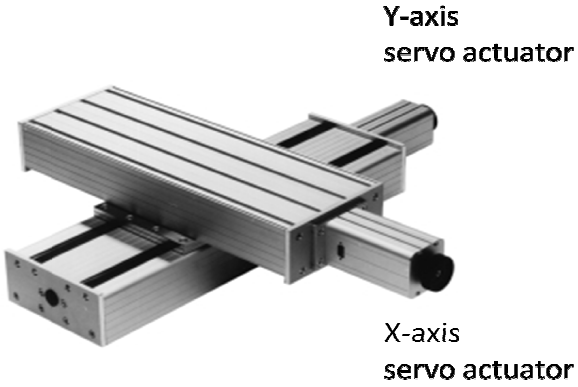
PG Diploma/ MSc. in Electronics and Automation 2008/09 - Semester 3
ME5144 Mechatronics and Robotics

Answer all questions **Time allowed: 2h 30m**

Question 1

A two degree of freedom lateral axis motion control system is shown below



1.1 Suppose you are asked to use a two-axis servo development kit (SDK) for the motion control system shown above. You need to couple the motors to the X-Y mechanism through gears. Explain how you would tune the SDK for optimum performance.

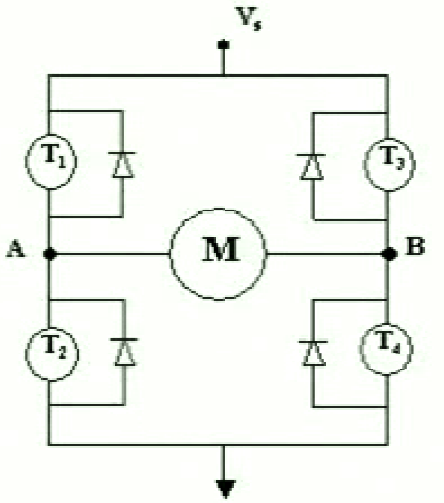
1.2 During the tuning process, you adjust PID gains, and at some point you experience accurate tracking response together with a high pitch noise/vibration. What could be the reasons for this anomaly? And how could you attempt to achieve smooth tracking response?

1.3 After tuning the SDK, you experience an unacceptable end-point error in X-Y positioning. If your application is point-to-point, explain how you should plan to modify the servo system to improve end-point accuracy using an additional encoder.

1.4 Now you are asked to customize the X-Y mechanism to perform automated welding. The welding torch has to be moved along a given trajectory. Explain how you should rearrange the servo controller to achieve accurate tracking performance.

Question 2

A full H-Bridge is shown below



2.1 Draw the voltage and current waveforms for 40% PWM duty cycle, and explain how you could reduce torque ripple.

2.2 The motor has to drive a load at 750RPM, and at this state it draws 2.5A. If the series resistance of the motor circuit is 4Ω and the supply voltage is 24VDC, determine the required PWM duty ratio. Also determine the current drawn from the 24VDC source. (back EMF constant = 8V/kRPM)

2.3 Explain what role is performed by the diodes in the H-bridge

2.4 If by accident both transistors on the same branch turn on, H-bridge will be short circuited and burnt. Explain how modern H-bridge chips have resolved this anomaly.

2.5 If you want to exercise linear PWM voltage in the range [Vs,-Vs] how should you switch the transistors.

Question 3

A BLDC hub motor is shown below.

3.1 Identify the components and describe three-phase, six-state commutation process.

3.2 You are asked to improve smooth motion beyond what could be realized by a six-state commutor. Describe reasons that cause non-smooth rotor motion. What changes would you suggest in the commutation peocess for smooth motion.

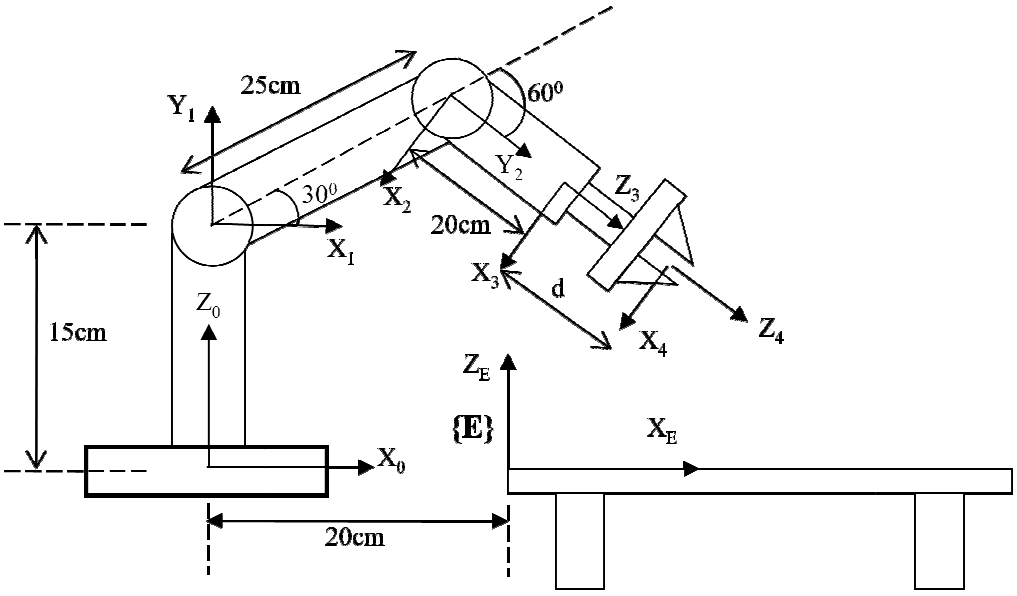
3.3 For peak sinusoidal current of 5A, determine the torque generated by the BLDC motor assuming torque constant K=10Nm/A, and zero-error commutation.

3.4 If commutation takes place with an error $\varepsilon=10°$, determine the useful torque generated. Also explain what is hapenning inside the motor in this state of motion.

3.5 Explain how a BLDC motor can be destabilized by improper commutation.

Question 4

A three-link robot manipulator and work table are shown below



4.1 Draw the wireframe of the manipulator at home position. Etermine the DH table partly filled as shown below [Hint: move **{0}** to **{1}**, and **{3}** to **{2}**]

joint	a	α	D	θ
1				
2				
3				
4			d+20	

4.2 Write homogeneous transformation matrices using ***rot()*** and ***transl()*** keywords. Use Matlab and determine them numerically.

4.3 Determine the end-point with respect to **{0}** for arm configuration shown above with d=5cm

4.4 Determine the end-point with respect to the work table **{E}**

Question 5

5.1 Path planning for robot manipulators can be done in either cartesian space or joint space. Describe under what conditions cartesian path planning should be used, and how to deal with the associated singularity issue.

5.2 Explain why there wont be singularity issues in joint space path planning.

5.3 Plan a joint space point-to-point path for a single joint using a cubic polynomial and satisfying following boundary conditions θ_o=10º, θ_f=20º, T = 4s [Note: assume zero speed at end points]

5.4 Due to a change in application, it is now required to insert a via point θ_v=16º, t = 2s. Replan the path through the via point. Use Matlab and draw position, velocity, and acceleration profiles of the path.

5.5 Identify the uncontrollable kinematic variables in cubic polynomial path planning. And, comment on how they affect the actual motion of the joint.