DEPARTMENT OF ELECTRICAL ENGINEERING

SOLUTION & MARKING SCHEME

(Semester 2, 2021/22)

SUBJECT (Code & Title)	EE520/EE520A Intelligent Motion Systems

SUBJECT EXAMINER	Dr N.C. Cheung
SUBJECT MODERATOR	Dr S.X. Niu

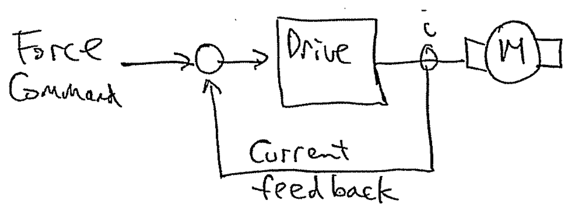
QUESTION NO.	SOLUTION	MARKS

Q1

(a)

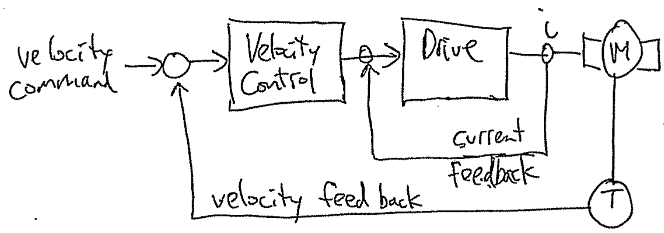
Force Control
Operation: To insert force onto an object with minimum deviation from the force command
Application: Robot Gripper
Block Diagram

3



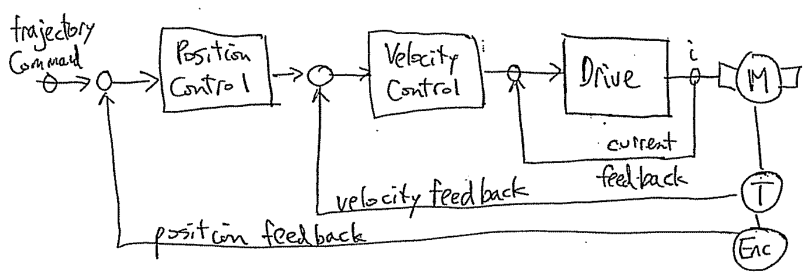
Velocity Tracking
Operation: To follow a continuous velocity profile command with minimum velocity deviation
Application: Fan blower
Block Diagram

3

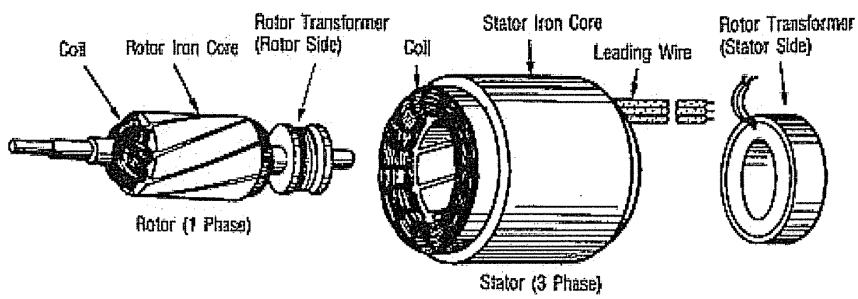


Trajectory Path Tracking
Operation: To follow a continuous line command path with minimum position deviation
Application: Graph Plotter
Block Diagram:

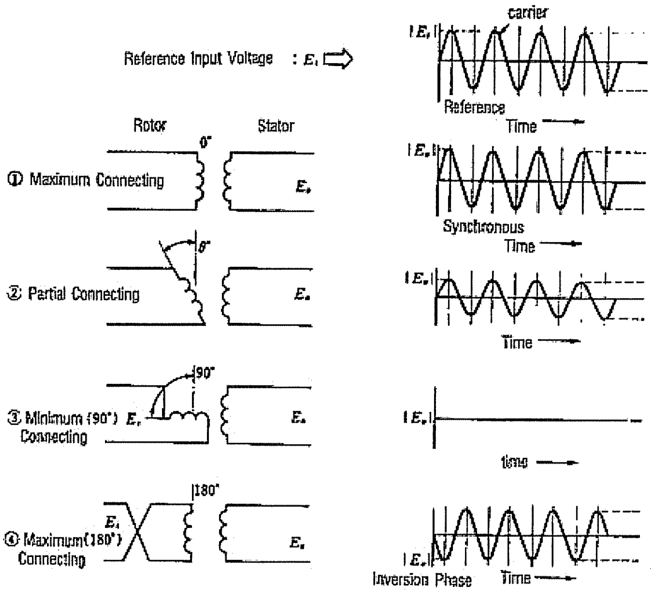
3



(b)

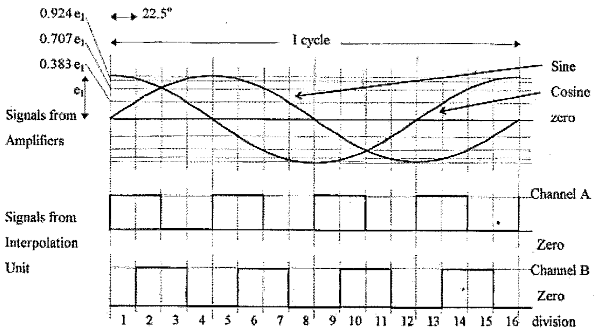
QUESTION NO.	SOLUTION	MARKS
	A high speed elevator needs to go through a series of motion modes: 1. Accelerate to maximum speed 2. Maintain at maximum speed 3. Decelerate to slow speed 4. Constant slow speed 5. Stop For switching between motion modes: Start 1 >>> 2 --- switch mode until the maximum speed is reached 2 >>> 3 --- switch mode when the lift is at a certain distance from destination 3 >>> 4 --- switch mode when the minimum speed is reached 4 >>> 5 --- switch mode when the required destination is reached End The passenger loading is an important factor. E.g. if the passenger loading is lighter than the counter balance, instead of motoring, the motor needs to go into braking mode. Other modes will be affected.	11
Q2 (a)	Construction of a Synchro 	4

QUESTION NO.	SOLUTION	MARKS
	Operation principle: a transformer coupling method is used. When 2 coils are fully aligned, there is max coupling and maximum signal. When 2 coils are perpendicular: min coupling, When 2 coils are aligned, but inverted, we have inverted coupling, and a negative signal output	4



Q2 (b) — Marks: 12

To convert the signal according to the format below:

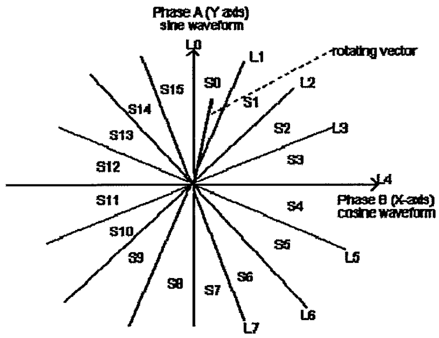


The two waveforms can be compared with each other to find out the angle of the rotating vector, and deduce the immediate position values.

Design the boundary conditions L0-L7:

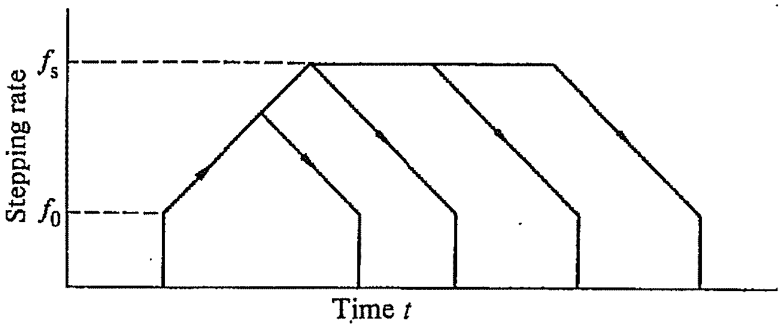
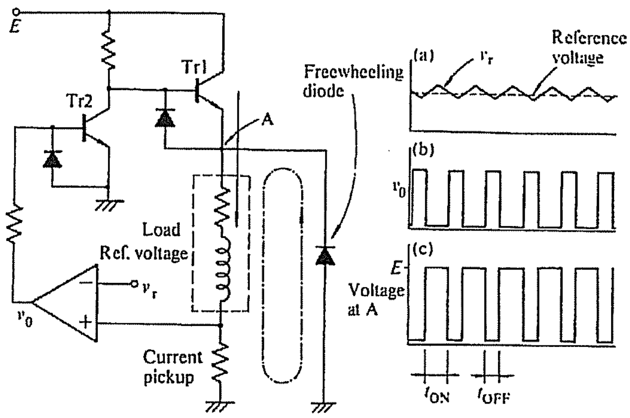
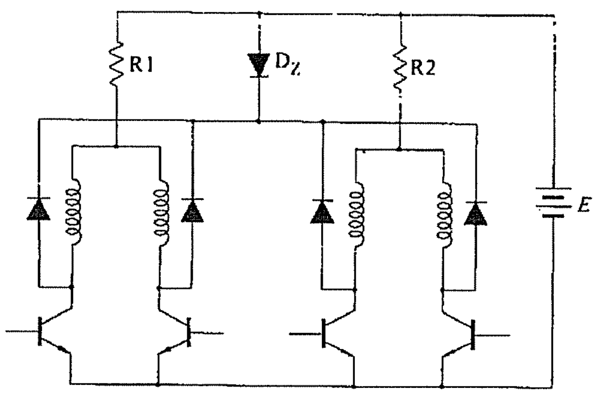
L0: Y=0 L1: X=0.414Y L2: Y=X L3: Y=0.414X

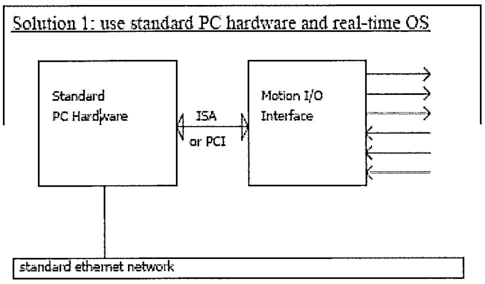
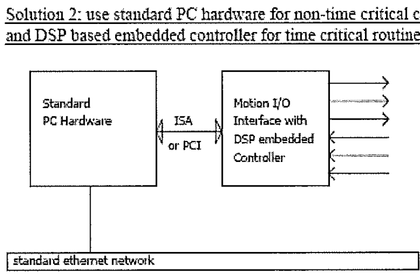
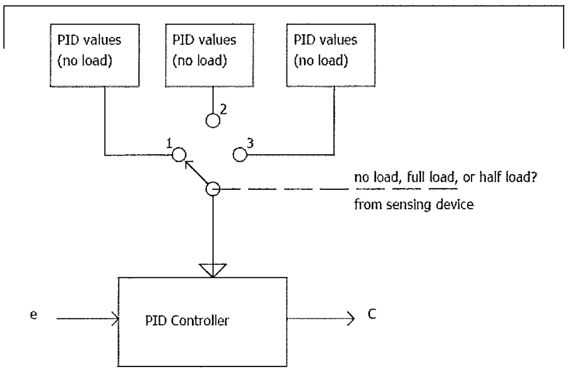
L4: X=0 L5: Y=-0.414X L6: Y=-X L7: X=-0.414Y



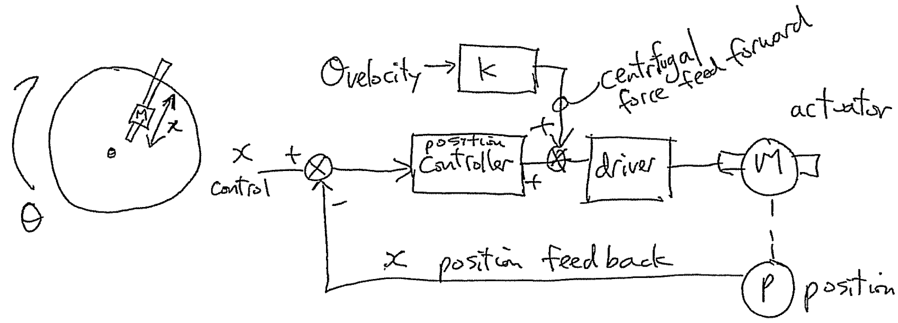
Output	Input	Output Sector
Channel A	(x>0) & (y>x)	S1,S2 high
	(y<0) & (-y<x)	S5,S6 high
	(y<0) & (y<x)	S9,S10 high
	(y>0) & (-y>x)	S13,S14 high
Channel B	(0.414y<x) & (y>0.414x)	S2,S3 high
	(-y>0.414x) & (-0.414y<x)	S6,S7 high
	(0.414y>x) & (y<0.414x)	S10,S11 high
	(-y<0.414x) & (-0.414y>x)	S14,S15 high

Thus the digital signal above can be realized.

QUESTION NO.	SOLUTION	MARKS
Q3 (a)	To reach from A to B in the shortest time, follow this profile: Start at max starting speed fo >> ramp up speed >> travel at max speed fs>> ramp down speed >> stop at the maximum stopping speed fo.  **Fig. 5.48.** Commanded speed vs. time profile relation. Suggest solution: Driving pulse rise time. Improving turn on time by high voltage PWM  **Fig. 5.32.** PWM (= pulse width modulated) circuit and waveforms. Suggest solution: Driving pulse fall time. Improving turn off time by zener diode Dz  **Fig. 5.20.** Example of four-phase driver with zener diode suppressor.	 5 5

QUESTION NO.	SOLUTION	MARKS
Q3 (b)	  Solution 1: Most cheapest, but need a real time OS (or DOS), need to drivers and low level routine. Software intensive development. Solution 2: Need an extra DSP, need to program the control routine language. Much higher performance. PC is idle for most of the time.	10
Q4 (a)	Gain Scheduling ☐ For predictable condition changing and predictable timing ☐ Under discrete operation environment (e.g pick and place robots) ☐ Use a different set of PID values for different situation ☐ Care should be taking when changing the PID values  	6
(b)	<u>Add a 3 stage cascade PI controller diagram</u>. • D control is use to control the changing dynamics • However, the control block forward already take care of this • For the position control block, the block in front is the velocity control block • For the velocity control block, the block in front is the force (current) block.	6
(c)	Auto-tuning process 1. Tune P value until maximum performance is reached 2. Tune I value until maximum performance is reached 3. Is this the Peak performance of PI values? 4. If yes, then tuning process is finished 5. If no, return to step 1 In some case, the peak performance cannot be reached, because it can tune to a local maximum, not the global maximum. (<u>use a 3D diagram to illustrate this point</u>)	8

<table>
<tr><th>QUESTION NO.</th><th>SOLUTION</th><th>MARKS</th></tr>
<tr><td>Q6

(a)</td><td>Centrifugal force compensation (add explanation)

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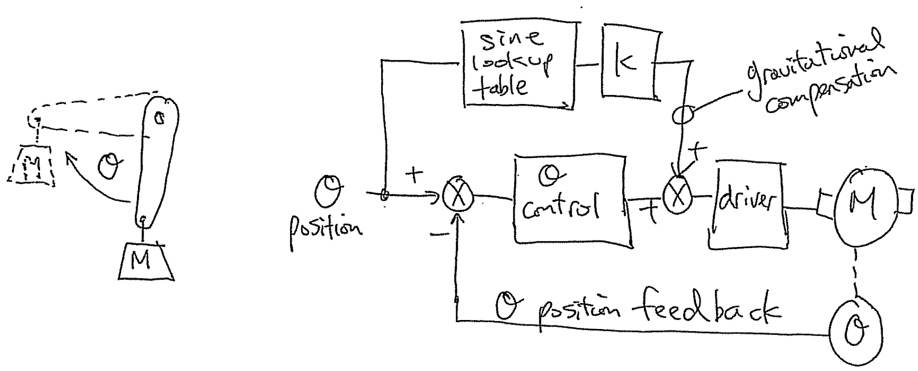
5</td></tr>
<tr><td>(b)</td><td>Gravitation force variation compensation (add explanation)

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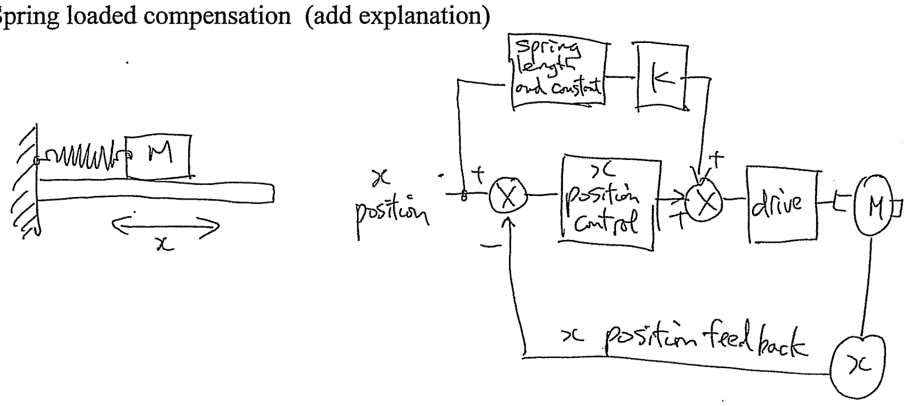
<tr><td>(c)</td><td>Spring loaded compensation (add explanation)

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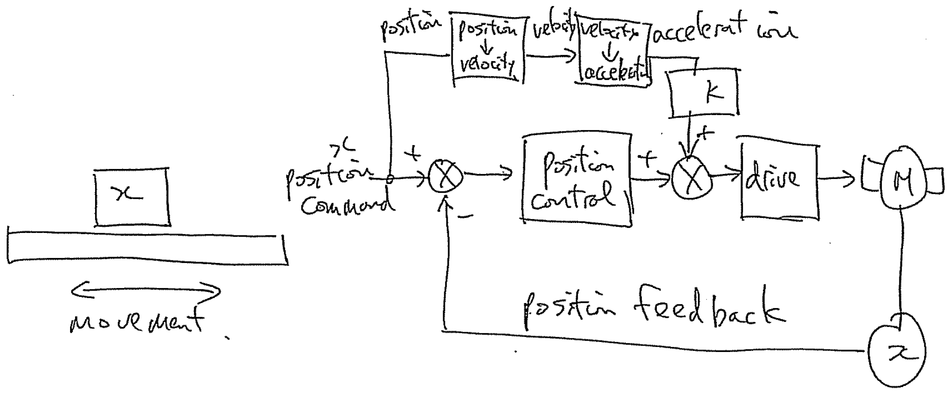
5</td></tr>
<tr><td>(d)</td><td>Acceleration and deceleration compensation (add explanation)

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