DEPARTMENT OF ELECTRICAL ENGINEERING

SOLUTION & MARKING SCHEME

(Semester 2, 2022/23)

SUBJECT (Code & Title)	EE520 Intelligent Motion Systems

SUBJECT EXAMINER	NC Cheung
SUBJECT MODERATOR	SX Niu

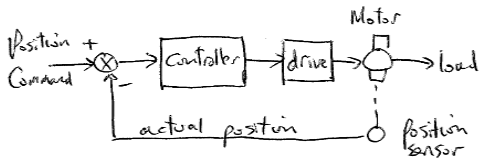
<table>
<tr><th>QUESTION NO.</th><th>SOLUTION</th><th>MARKS</th></tr>
<tr><td>1 a</td><td>

Operation Differences:

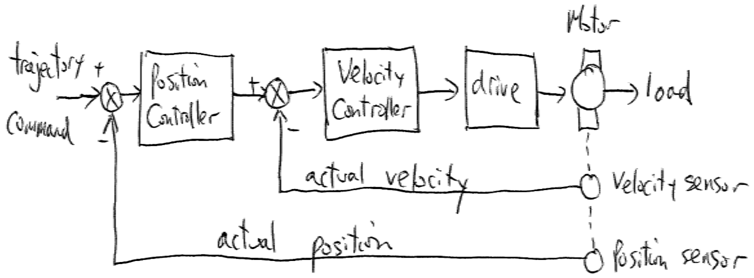
Point-to-point: to move from point A to point B within the shortest possible time, without regard for the travel path.

Trajectory path tracking: to move from point A to point B according to a fixed travel path, motion velocity, inter-axes synchronization.

Control Hardware Structures:

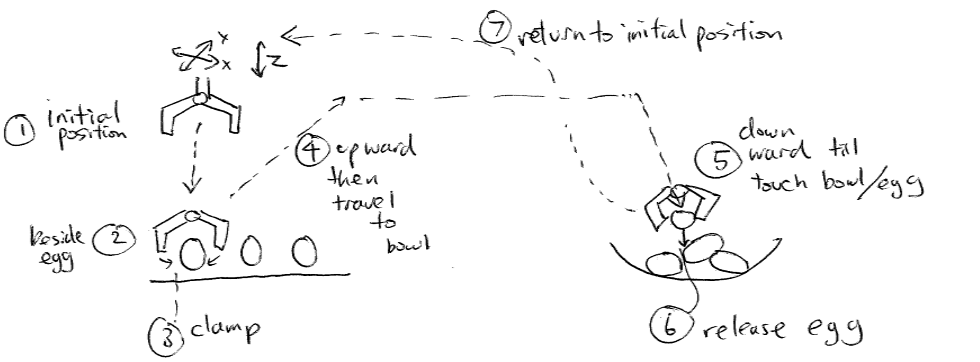
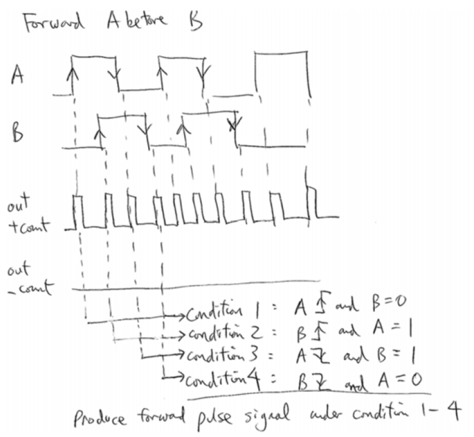
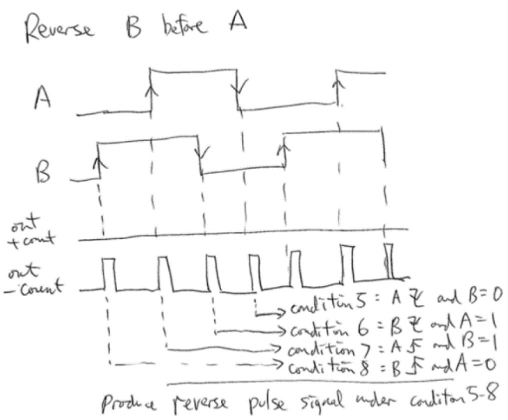
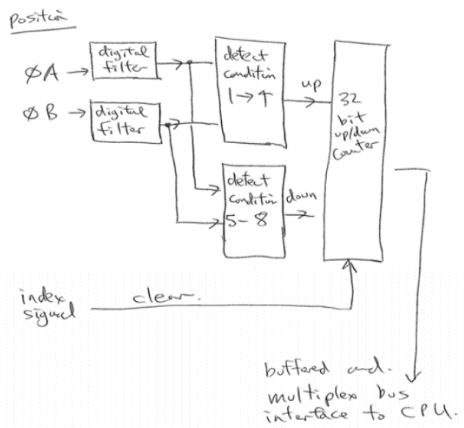


point-to-point hardware controller structure



Trajectory path tracking controller structure

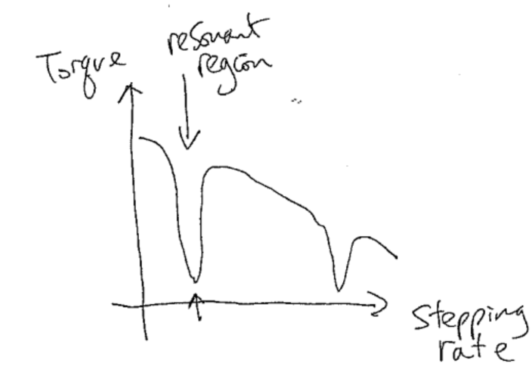
</td><td>6</td></tr>
<tr><td>1b</td><td>Mixed mode motion control – For one cycle of repeated motion path, there exist more than one form of motion control mode.</td><td>4</td></tr>
</table>

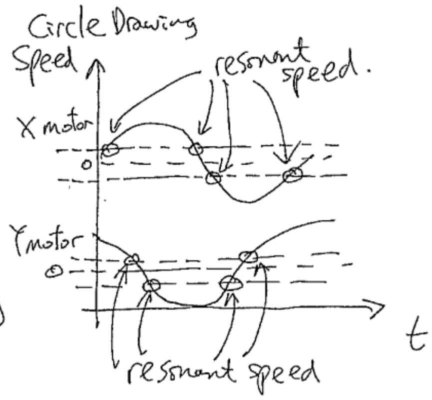
QUESTION NO.	SOLUTION	MARKS
1c	Define one motion cycle: a. Start, position 1 b. trajectory motion X,Y and Z to position 2 c. clamp motion (trajectory path > slow speed search > touch object > clamp force) d. trajectory motion (Z axis: trajectory path, X&Y: trajectory path) e. clamp with egg position directly on top of bowl, position 5 f. Downwards Z axis (trajectory > slow speed search > touch object > release clamp) g. Return to initial position (X, Y, Z: trajectory path mode) h. Finish one cycle 	10
Q2 (a)	velocity use $\frac{P_1 - P_2}{t}$ and calculate inside the CPU.	12

<table>
<tr><th>QUESTION NO.</th><th>SOLUTION</th><th>MARKS</th></tr>
<tr><td>Q2b</td><td>DC Motor: brush wear out, which causes change in control behaviour.
BLDC: No brush

DC Motor: brush limits the max current delivered to motor
BLDC: No brush

DC Motor: Coil inside case, heat dissipation problem
BLDC: Coil is outside the case, no heating problem</td><td>8</td></tr>
<tr><td>Q3a</td><td>Stepping motor experience resonance at low speed (see graph).
At that region, the torque is small, sometimes virtually zero.
Drawing large circle at low speed will come across that region.
Therefore it may experience missing step at this region.





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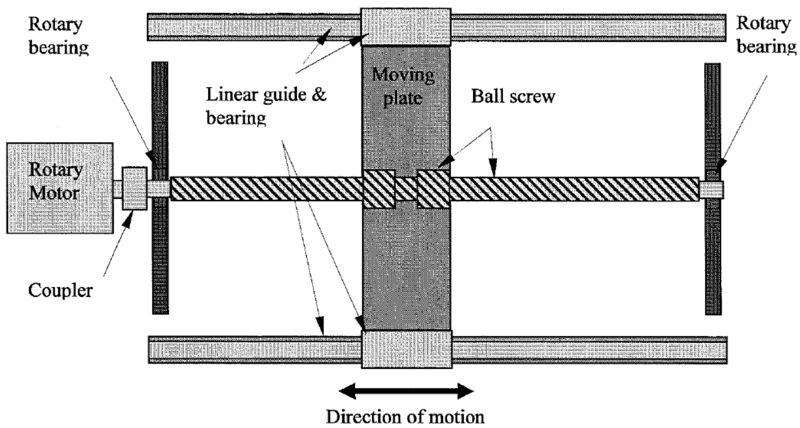
<tr><td>Q3b</td><td>



1. The two linear guides and the ball screw may not be perfectly parallel with each other.
2. The shaft of the rotary motor may not align perfectly with the ball screw.
3. The ball screw may not be perfectly straight.
4. The two ends of the shafts attached to the coupler may not be exactly aligned
5. The coupling between the ball screw and the nut may have backlash
6. The rotary bearing mounts may not be perfectly perpendicular with the motor mount and the lead screw.</td><td>6</td></tr>
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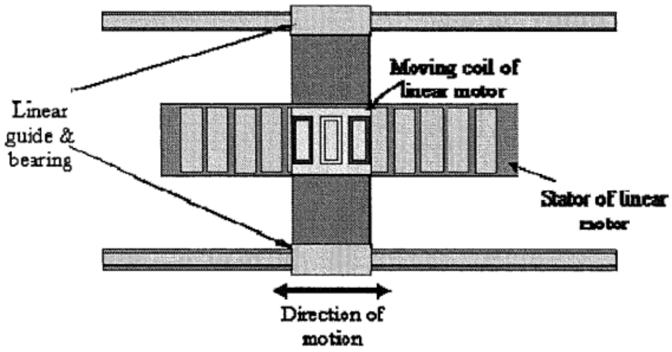
QUESTION NO.	SOLUTION	MARKS
Q3b Cont'	• Construction of the PM linear brushless motor  1. No ball screw. No need to align the ball screw with the linear guides 2. No motor shaft. No need for shaft alignment. 3. No ball screw to cause precision trouble 4. No shaft coupler to cause precision problem 5. No nut to cause trouble 6. No ball bearing mounting to cause trouble	6
Q4a	For wiring one axes motor feedback control: Phase A+,A-,B+,B-,Z : 5 wires Limit switches both ends: 2 Power+5V: 1 3 phase PWM signal: 3 Ground: usually 3 or more Protection lines: 3 or more Therefore, typically one axis needs 20 wires connection A typical robot has 6 axes, 120 wires connection! Any one failure will make the robot not working. Advantages: 1. SERCOS reduces the number of wirings to two (optical fibre ring) 2. SERCOS is a ring structure, therefore it can self-check any wiring problem 3. Optical fibre is more interference free 4. Exact synchronization between axes 5. Standardized parameters of servo control components, and motion modes 6. Rich auxiliary functions made SERCOS very suitable for motion control.	10
Q4b	SISO systems – single input and single output system Identification – perform experiments to obtain the system behaviour Modelling – equations to represent the behaviour of the plant Control Strategy Development – develop the control scheme according to plant model Simulation – to predict the control performance by running the model in computer Implementation – to operate the system in actual hardware experiment Performance Index – a list of criteria to determine how good is the system performance System Robustness – system can operate normally in spite of parameter deviations External Disturbance – external condition that may affect the system performance MIMO systems – multi input and multi output system	10

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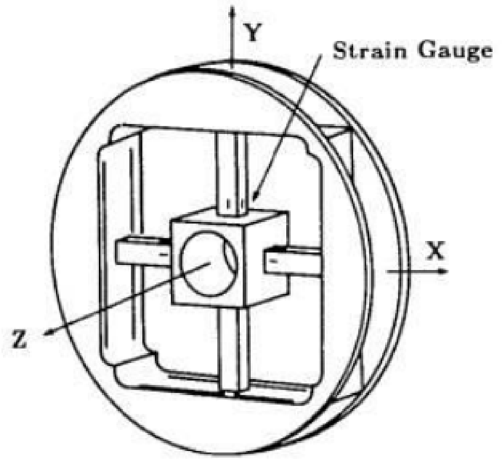
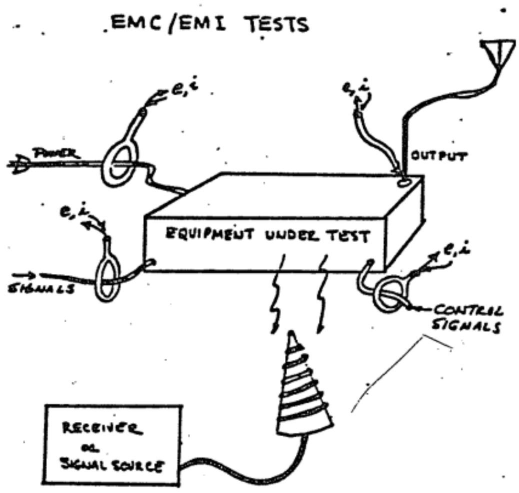
<tr><td>Q5a</td><td>


$$\begin{bmatrix} F_X \\ F_Y \\ F_Z \\ M_X \\ M_Y \\ M_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & c_{13} & 0 & 0 & 0 & c_{17} & 0 \\ c_{21} & 0 & 0 & 0 & c_{25} & 0 & 0 & 0 \\ 0 & c_{32} & 0 & c_{34} & 0 & c_{36} & 0 & c_{38} \\ 0 & c_{42} & 0 & 0 & 0 & c_{46} & 0 & 0 \\ 0 & 0 & 0 & c_{54} & 0 & 0 & 0 & c_{58} \\ c_{61} & 0 & c_{63} & 0 & c_{65} & 0 & c_{67} & 0 \end{bmatrix} \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \epsilon_4 \\ \epsilon_5 \\ \epsilon_6 \\ \epsilon_7 \\ \epsilon_8 \end{bmatrix}$$

Fig. 16. Scheinman force-sensing wrist.

Add explanation</td><td>10</td></tr>
<tr><td>Q5b</td><td>


Measure the conductive interference – Add explanation</td><td>10</td></tr>
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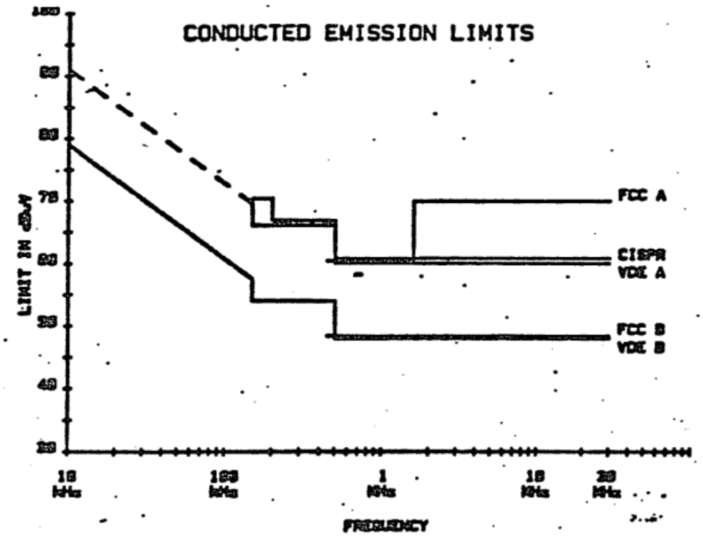

Measure frequency range

Precautions:

1. The system must be free from all external interference
2. Usually, the experiment must be carried out inside an EM free chamber
3. The item under test must be measured from all sides and on all connection wires.

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