UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACHELOR OF ENGINEERING TECHNOLOGY INDUSTRIAL ENGINEERING
SUBJECT	:	**AUTOMATION 2B**
CODE	:	**AUTMIB2**
DATE	:	JANUARY SSA EXAMINATION 2020 10 JANUARY 2020
DURATION	:	08:00-11:00 (SESSION 1)
WEIGHT	:	40: 60
TOTAL MARKS	:	100

ASSESSOR	:	DR. G. MUYENGWA
MODERATOR	:	DR. F. CHIROMO
NUMBER OF PAGES	:	6 PAGES

INSTRUCTIONS	:	ONLY ONE POCKET CALCULATOR PER CANDIDATE MAY BE USED. PLEASE ANSWER ALL QUESTIONS. UNDERLINE EACH AND EVERY CALCULATION ANSWER

INSTRUCTIONS TO STUDENTS

QUESTION 1

Figure Q1 shows a flexible automated manufacturing cell with two machine tools and a robot. The two CNC machine tools can be loaded and unloaded by an industrial robot with parts from a carousel.

a) Management has asked you to give a detailed report on all the automation features that you have considered when designing this flexible manufacturing cell. (20 marks)

b) Design an appropriate robot that can be used in the flexible manufacturing cell. (5 marks)

c) Design the robot interlock system. (10 marks)

[Total Marks 35]

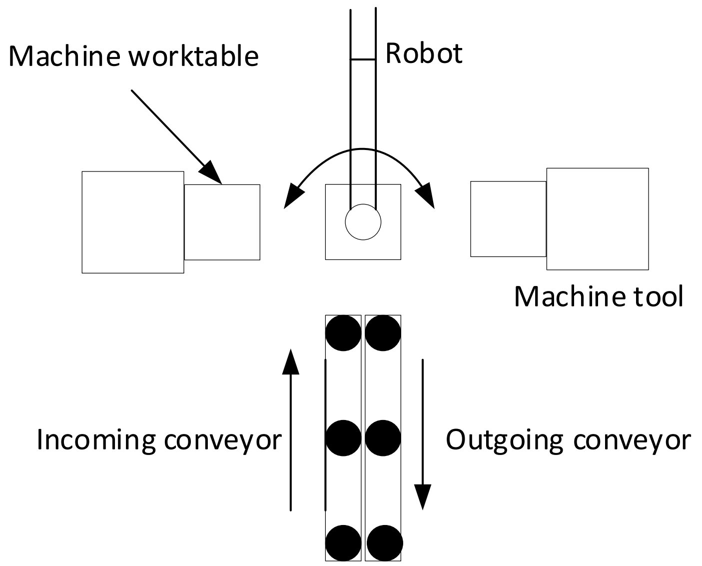

Figure Q1: Automated manufacturing cell with two machine tools and robot.

QUESTION 2

Robotics Engineers at DKK Precision Control would like to establish parameters of a positioning table, such as control resolution, rotational speeds, and the corresponding pulse train frequencies. There are two axes of an *x*-*y* positioning table and each is driven by a stepping motor connected to a lead screw with a 10:1 gear reduction. The number of step angles on each stepping motor is 20. Each lead screw has a pitch = 4.5 mm and provides an axis range = 300 mm. There are 16 bits in each binary register used by the controller to store position data for the two axes. Their desire is to drive the table at 500 mm/min in a straight line from point (30,30) to point (100,200). Ignore acceleration and deceleration. **(20 marks)**

QUESTION 3

Thabelo Robotics is a small engineering company that is into the design of 4IR's Autonomous Robots. Engineers at Thabelo Robotics are working on an industrial robot that performs a machine loading and unloading operation. A PLC is used as the robot cell controller. The cell operates as follows: (1) a human worker places a workpart into a nest, (2) the robot reaches over and picks up the part and places it into an induction heating coil, (3) a time of 10 seconds is allowed for the heating operation, and (4) the robot reaches in and retrieves the part and places it on an outgoing conveyor. A limit switch X1 (normally open) will be used in the nest to indicate part presence in step (1). Output contact Y1 will be used to signal the robot to execute step (2) of the work cycle. This is an output contact for the PLC, but an input interlock for the robot controller. Timer T1 will be used to provide the 10 second delay in step (3). Output contact Y2 will be used to signal the robot to execute step (4).

a) Design a ladder logic diagram for this system. (10 marks)
b) Develop the low level language statements for this system. (10 marks)

[Total Marks 20]

QUESTION 4

Trainee Engineers at Thabelo Robotics are running some experiments were they are applying a voltage of 26 V to a DC servomotor whose torque constant = 0.117 N-m/A and voltage constant = 0.087 V/(rad/sec). Armature resistance = 1.85 ohms. The motor is directly coupled to a pump shaft for an industrial process. What would be the operating point of the motor if the torque-speed characteristic of the pump is given by the following equation: $T_L = K_{L1}\omega + K_{L2}\omega^2$, where T_L = load torque/(N-m); ω = angular velocity/(rad/sec); K_{L1} = 0.006 N-m/(rad/sec), and K_{L2} = 0.00022 N-m/(rad/sec)^2. **(15 marks)**

QUESTION 5

The following data was gathered by Thabelo Engineering employees, in an effort to establish manufacturing lead time and plant utilization. An average part is produced in a certain batch and is processed sequentially through five machines on average. Twenty eight (28) new batches of parts are launched each week. Average operation time = 5 min., average setup time = 8 hours, average batch size = 50 parts, and average nonoperation time per batch = 11 hrs/machine. There are 18 machines in the plant working in parallel. Each of the machines can be set up for any type of job processed in the plant. The plant operates an average of 72 production hours per week. Scrap rate is negligible. **(10 marks)**

TOTAL = 100

Production Relationship

$Q_f = \sum_{j=1}^{P} Q_j$ $\quad Q_f = PQ$

$P = \sum_{j=1}^{P_1} P_{2j}$

$n_{pf} = \sum_{j=1}^{P} Q_j n_{pj}$ $\quad n_{pf} = PQn_p$

$n_{of} = \sum_{j=1}^{P} Q_j n_{pj} \sum_{j=1}^{n_{pj}} Q_j n_{ojk}$

$n_{of} = PQn_p n_o$

$S = C + ms \quad T = K_t I_a \quad E_b = K_v + \omega$

Automation and Process Control

$N = \frac{60\omega}{2\pi}$ $\quad I_a = \frac{Vin}{R_a} = \frac{V_{in} - Eb}{R_a}$

$T = K_t\left(\frac{V_{in} - Kv\omega}{R_a}\right)$ $\quad T_L = K_L\omega$

$HP = \frac{T\omega}{745{,}7}$ $\quad P = T\omega$

$745{,}7 = 1hp$ $\quad \alpha = \frac{360}{n_s}$

$A_m = n_p\alpha$ $\quad \omega = \frac{2\pi fp}{n_s}$

$N = \frac{60fp}{n_s}$ $\quad v = \frac{Q}{A}$

$F = pA \quad \omega = KQ \quad N_q = 2^n$

$R_{ADC} = \frac{L}{N_q - 1} = \frac{L}{2^n - 1}$

Quantization error $= \pm\frac{1}{2}R_{ADC}$

$E_o = E_{ref}\{0{,}5B_1 + 0{,}25B_2 + 0{,}125B_3 + \ldots + (2^n)^{-1}B_n\}$

$E(t) = E_o \quad E(t) = E_o + \alpha t \quad \alpha = \frac{E_o - E(-\tau)}{\tau}$

Production Performance Metrics

$T_c = T_o + T_h + T_t$ $\quad T_c = \text{Max } T_o + T_r$

$T_b = T_{su} + QT_C$ $\quad A = \frac{MTBF - MTTI}{MTBF}$

$T_p = \frac{T_b}{Q}$ $\quad PC = \frac{nHpwRp}{n_o}$

$R_p = \frac{60}{T_p} = \frac{1}{T_p}$ $\quad PC = Hpc\sum_{i=1}^{n} R_{pi}$

$R_c = \frac{60}{Tc} = \frac{1}{Tc}$ $\quad R_{pph} = \frac{\sum_{j=1}^{n}\sum_j f_{ij}R_{pij}}{n_{oj}}$

$R_{ppw} = H_{pw}R_{pph}$ $\quad U_i = \sum_j f_{ij}$ $\quad U = \frac{\sum_j Ui}{n}$

$WL = \sum_i \sum_j Q_{ij}T_{pij}$ $\quad MLT = n(T_{su} + Q_{Tc} + T_{no})$

$MLT = n_o(\max T_o + T_r) + T_{no}$ $\quad TC = C_f + C_v Q$

$WIP = R_{pph}(MLT)$ $\quad UAC = IC(A/P,i,N))$

$FOHR = \frac{FOHC}{DLC}$ $\quad COHR = \frac{COHC}{DLC}$

$C_o = C_L(1 + FOHR_L) + C_m(1 + FOHR_m)$

$C_{pc} = C_m + \sum_{j=1}^{P}(CoiTpi + Cti)$

$(A/,P,i,N) = \frac{i(1+i)^n}{(1+i)^n - 1}$

Open Loop System

$N = \frac{V}{\pi D}$ $\quad f_r = N n_t f$ $\quad \alpha = \frac{360}{n_s}$ $\quad A_m = n_p \alpha$ $\quad A_s = \frac{n_p \alpha}{r_g} = \frac{A_m}{r_g}$ $\quad r_g = \frac{A_m}{A_s} = \frac{N_m}{N_s}$

$x = \frac{pA_s}{360}$ $\quad n_p = \frac{360 x r g}{p\alpha} = \frac{n_s x r_g}{p}$ $\quad N_s = \frac{60 f p}{n_s r_g}$ $\quad v_t = fr = N_s p$

$f_p = \frac{v t n_s r_g}{60p} = \frac{f r n_s r_g}{60p} = \frac{N_m n_s}{60} = \frac{N_s n_s r_g}{60}$

Closed Loop System $\quad \alpha = \frac{360}{n_s}$ $\quad n_p = \frac{A_s}{\alpha} = \frac{A_s n_s}{360}$ $\quad \Delta X = \frac{pnp}{n_s} = \frac{pAs}{n_s \alpha} = \frac{pAs}{360}$

$v_t = fr = N_s p = \frac{N_m p}{r_g}$ $\quad f_p = \frac{vtns}{60p} = \frac{fr n_s}{60p}$ $\quad CR_1 = \frac{p}{n_s r_g}$ $\quad CR_2 = \frac{L}{2^B - 1}$

$CR = Max(CR_1, CR_2)$ $\quad Accuracy = \frac{CR}{2} + 3\sigma$ $\quad Repeatability = \pm 3\sigma$

Common G-words (Preparatory Word)

G-word	Function
G00	Point-to-point movement (rapid traverse) between previous point and endpoint defined in current block. Block must include x-y-z coordinates of end position.
G01	Linear interpolation movement. Block must include x-y-z coordinates of end position. Feed rate must also be specified.
G02	Circular interpolation, clockwise. Block must include either arc radius or arc center ; coordinates of end position must also be specified.
G03	Circular interpolation, counterclockwise. Block must include either arc radius or arc center ; coordinates of end position must also be specified.
G04	Dwell for a specified time.
G10	Input of the cutter offset data, followed by a P-code and an R-code.
G17	Selection of x-y plane in milling.
G18	Selection of x-z plane in milling.
G19	Selection of y-z plane in milling.
G20	Input values specified in inches.
G21	Input values specified in millimeters.
G28	Return to reference point.
G32	Thread cutting in turning.
G40	Cancel offset compensation for cutters radius (nose radius in turning).
	Cutter offset compensation, left of part surface. Cutter radius (nose radius in

Common M-words Used in Word Address Format

M-word	Function
M00	Program stop; used in the middle of program. Operator must restart machine.
M01	Optional program stop; active only when optional stop button on control panel
M02	End of program. Machine stop.
M03	Start spindle in clockwise direction for milling machine (reverse for turning machine).
M04	Start spindle in counterclockwise direction for milling machine (reverse for turning machine).
M05	Spindle stop.
M06	Execute tool change, either manually or automatically. If manually, operator must restart the machine. Does not include selection of tool, which is done by T-word if automatic, by operator if manual.
M07	Turn cutting fluid on flood.
M08	Turn cutting fluid on mist.
M09	Turn cutting fluid off.
M10	Automatic clamping of fixture, machine slides, etc.
M11	Automatic unclamping.
M13	Start spindle in clockwise direction for milling machine (reverse for turning machine) and turn on cutting fluid.
M14	Start spindle in counterclockwise direction for milling machine (reverse for turning machine) and turn on cutting fluid.
M17	Spindle and cutting fluid off.
M19	Turn spindle off at oriented position.
M30	End of program. Machine stop. Rewind tape (on tape-controlled machines).

Common Word Prefixes Used in Word Address Format

Word Prefix	Example	Function
N	N01	Sequence number; identifies block of instruction. One to four degits can be used .
G	G21	Preparatory word; prepares controller for instructions given in the block. See Table A7,2. There may be more than one G-word in a block.
X,Y,Z	X75.0	Coordinate data for three linear axes. Can be specified in either inches or millimeters. (Example defines x-axis value as 75 mm.)
U,W	U25.0	Coordinate data for incremental moves in turning in the x- and z-directions, respectively. (Example specifies an incremental move of 25 mm in the x-direction).
		Coordinate data for three rotational axes. A is the rotational axis about

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