KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE (COMPUTER ENGINEERING)

SCE 435: ROBOTS

DATE: Tuesday, 17th April, 2012 TIME: 8.00 a.m. – 10.00 a.m.

INSTRUCTIONS:

Answer question ONE and any TWO of the remaining FOUR questions
All workings should be shown in a neat and legible manner

Question 1 – Compulsory (30 marks)

a) With regard to control systems, what is the meaning of the following terms?

(i) Control inputs (1 mark)
(ii) Disturbance inputs (1 mark)

b) Give five (5) justifications for the use of robots. (5 marks)

c) Define Direct Numerical Control (DNC) (1 mark)

d) Discuss the two types of DNC systems (4 marks)

e) With the aid of a suitable block diagram, explain how speed control of a synchronous 3-phase AC servo-motor can be achieved by varying frequency of AC power supply [8 marks]

f) Starting with the equivalent circuit of a dc motor, show that the system function for an armature controlled DC servo-motor is given by

$$G(s) = \frac{\theta(s)}{E_a(s)} = \frac{K}{s[L_aJs^2 + (L_ab + R_aJ)s + R_ab + KK_b]}$$

(10 marks)

Question 2 (20 marks)

a) Define the term **work envelope** of a robot (1 mark)

b) With the aid of suitable sketches, illustrate the work envelope of a cylindrical co-ordinate robot (7 marks)

c) A double-acting hydraulic cylinder has a bore of 100 mm. The rod is 40 mm in diameter and the stroke is 200 mm. The hydraulic cylinder is required to move a load of 10000 Newtons. Given that the pump can deliver a flow rate of 30 mm^3/sec, calculate the following:

(i) System pressure needed to lift the load (3 marks)
(ii) The pulling force that the cylinder generates given the same hydraulic pressure (3 marks)
(iii) Speed of the outward stroke (2 marks)
(iv) Speed of piston retraction (2 marks)
(v) Power used in the outward stroke (2 marks)

Question 3 (20 marks)

a) Describe the nine steps of the LOTOTO procedure [4 marks]

b) Given the following coordinates, use suitable sketches to illustrate the difference between incremental and absolute machine tool positioning techniques. A(3,0), B (1,2), C(-3,-1), D(0,-5), E(5,-2). [4 marks]

c) The part drawing of a component is shown in figure 1 below. Three holes (**A, B** and **E**) of 12.5 mm diameter and two holes (**C** and **D**) of 6 mm diameter are to be drilled on the workpiece. The speed and feed rate are 592 rpm and 100 mm/min, respectively. The plate has a thickness of 50 mm. For holes A, B and E, the workpiece should be drilled through while for holes C and D, the workpiece should be drilled to 25 mm depth. Assuming that the spindle is initially at (-25, -25, 0) and absolute positioning is used, write the part program to carry out this operation. G-Codes are provided at the back. [12 marks]

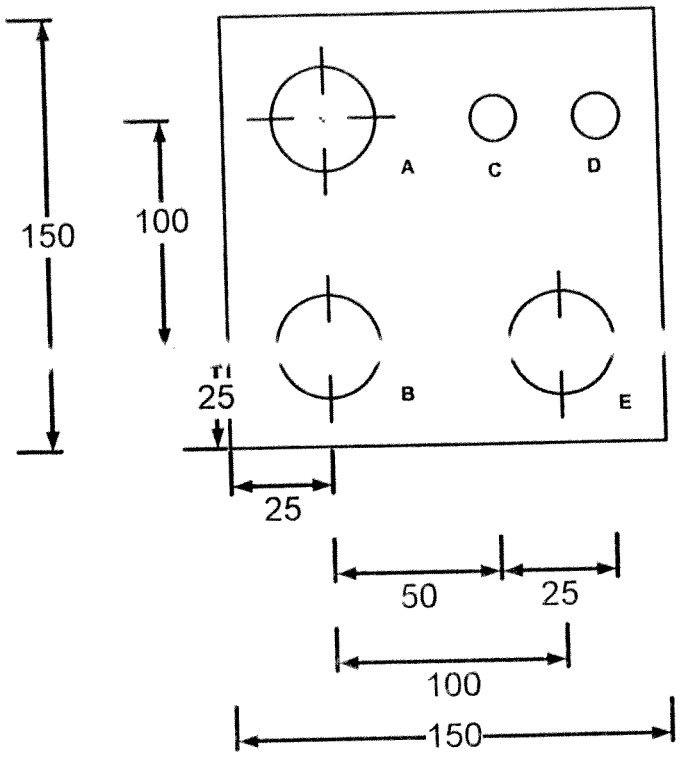


Figure 1

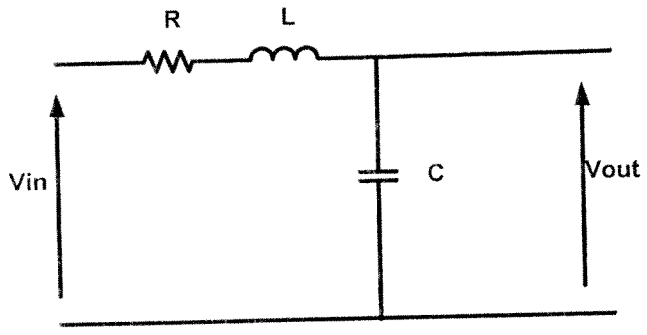
Question 4 (20 marks)

a) Sketch the response of a second order system to a unit step input for the underdamped condition. On your sketch indicate the following parameters

i. Rise time
ii. Delay time
iii. Maximum overshoot
iv. Peak time

(2 marks)

b) Part of a dynamic system can be modeled as an R-L-C network as given below.



Take v_{in} as the forcing function and v_{out} as the system response. Let **R = 100 Ω, L = 800 mH, C = 50 μF**. Determine the following:

i. The system function, H(s) [4 marks]
ii. The static sensitivity of the system [1 mark]
iii. The undamped natural frequency of the system - ω_n [3 marks]
iv. The damping ratio of the system – ξ [2 marks]
v. Maximum overshoot of the system response when the system is subjected to a unit-step input [3 marks]
vi. Rise time of the system response when the system is subjected to a unit-step input [3
vii. Peak time of the system response when the system is subjected to a unit-step input [2 marks]

Question 5 (20 marks)

a) Compare field control to armature control of dc servo-motors in terms of torque produced and speed ratios achieved (4 marks)

b) The coolant on a lathe machine should be switched on when the temperature of the work-piece reaches 40°C. An analog temperature sensor is located in the worktable to provide this information. The sensor has an output range of 0 – 10 V and operates linearly in the temperature range 0 to 100°C. The sensor needs to be interfaced to a digital controller such that the controller receives a 5 V signal whenever the temperature is greater than or equal to 40^0C and 0 V otherwise.
Design the interface circuit.
***Motivate your design.**

(5 marks)

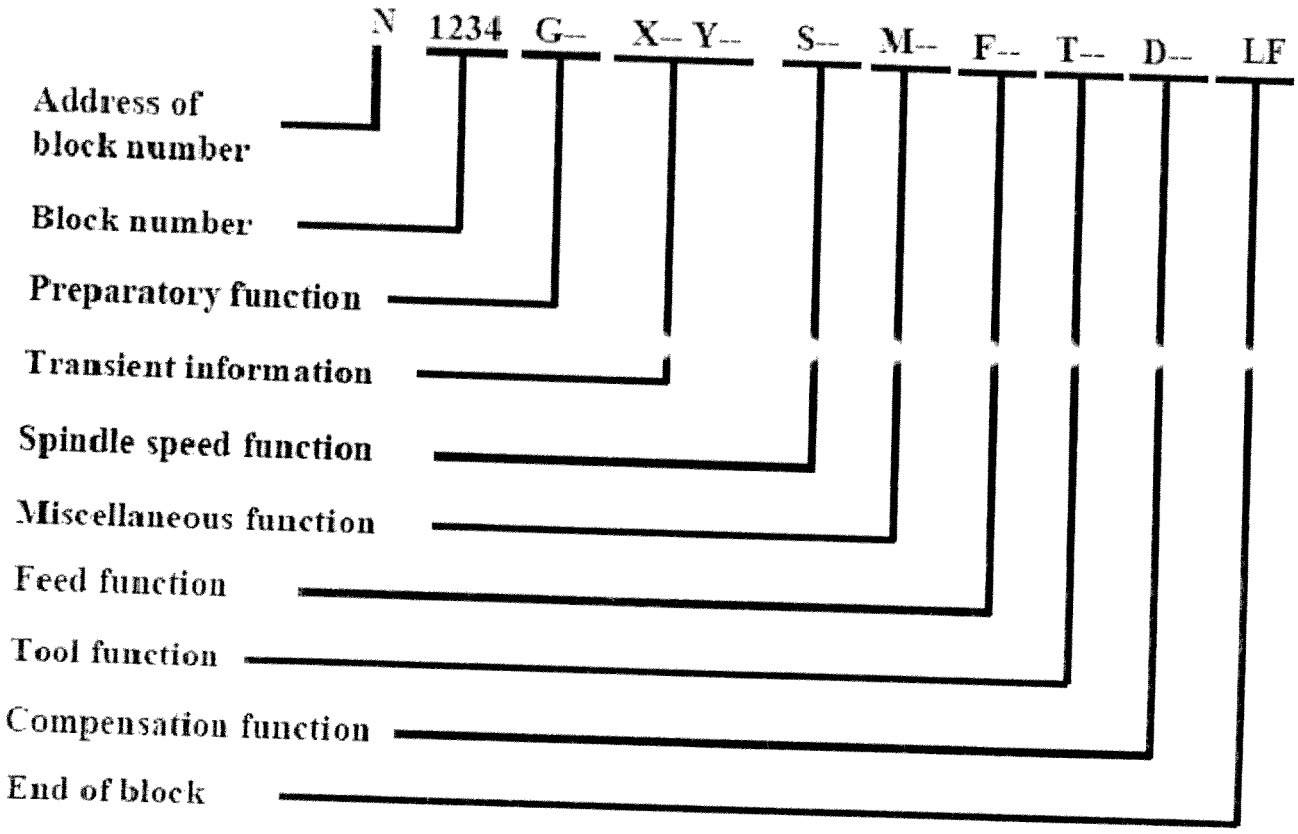
c) With the aid of suitable diagrams, show how an incremental rotary encoder can be used to detect speed and direction of rotation of a motor and therefore be able to provide feedback to a digital control system (12 marks)

A basic list of 'G' operation codes is given below. These direct motion of the tool.

G00 - Rapid move (not cutting)
G01 - Linear move
G02 - Clockwise circular motion
G03 - Counterclockwise circular motion
G04 - Dwell
G05 - Pause (for operator intervention)
G08 - Acceleration
G09 - Deceleration
G17 - x-y plane for circular interpolation
G18 - z-x plane for circular interpolation
G19 - y-z plane for circular interpolation
G20 - turning cycle or inch data specification
G21 - thread cutting cycle or metric data specification
G24 - face turning cycle
G25 - wait for input to go low
G26 - wait for input to go high
G28 - return to reference point
G29 - return from reference point
G31 - Stop on input
G33-35 - thread cutting functions
G35 - wait for input to go low
G36 - wait for input to go high
G40 - cutter compensation cancel
G41 - cutter compensation to the left
G42 - cutter compensation to the right
G43 - tool length compensation, positive
G44 - tool length compensation, negative
G50 - Preset position
G70 - set inch based units or finishing cycle
G71 - set metric units or stock removal
G72 - indicate finishing cycle
G72 - 3D circular interpolation clockwise
G73 - turning cycle contour
G73 - 3D circular interpolation counter clockwise
G74 - facing cycle contour
G74.1 - disable 360 deg arcs
G75 - pattern repeating
G75.1 - enable 360 degree arcs
G76 - deep hole drilling, cut cycle in z-axis
G77 - cut-in cycle in x-axis
G78 - multiple threading cycle
G80 - fixed cycle cancel
G81-89 - fixed cycles specified by machine tool manufacturers
G81 - drilling cycle
G82 - straight drilling cycle with dwell
G83 - drilling cycle
G83 - peck drilling cycle
G84 - taping cycle
G85 - reaming cycle
G85 - boring cycle
G86 - boring with spindle off and dwell cycle
G89 - boring cycle with dwell
G90 - absolute dimension program
G91 - incremental dimensions
G92 - Spindle speed limit
G93 - Coordinate system setting
G94 - Feed rate in ipm
G95 - Feed rate in ipr
G96 - Surface cutting speed
G97 - Rotational speed rpm
G98 - withdraw the tool to the starting point or feed per minute
G99 - withdraw the tool to a safe plane or feed per revolution
G101 - Spline interpolation

M-Codes control machine functions.

M00 - program stop
M01 - optional stop using stop button
M02 - end of program
M03 - spindle on CW
M04 - spindle on CCW
M05 - spindle off
M06 - tool change
M07 - flood with coolant
M08 - mist with coolant
M08 - turn on accessory (e.g. AC power outlet)
M09 - coolant off
M09 - turn off accessory
M10 - turn on accessory
M11 - turn off accessory or tool change
M17 - subroutine end
M20 - tailstock back
M20 - Chain to next program
M21 - tailstock forward
M22 - Write current position to data file
M25 - open chuck
M25 - set output #1 off
M26 - close chuck
M26 - set output #1 on
M30 - end of tape (rewind)
M35 - set output #2 off
M36 - set output #2 on
M38 - put stepper motors on low power standby
M47 - restart a program continuously, or a fixed number of times
M71 - puff blowing on
M72 - puff blowing off
M96 - compensate for rounded external curves
M97 - compensate for sharp external curves
M98 - subprogram call
M99 - return from subprogram, jump instruction
M101 - move x-axis home
M102 - move y-axis home
M103 - move z-axis home



Structure of a block in a part program