X028/301

NATIONAL QUALIFICATIONS 2008

TUESDAY, 10 JUNE 1.00 PM – 4.00 PM

MECHATRONICS HIGHER

100 marks are allocated to this paper.

Attempt **all** questions in Section A (50 marks).

Attempt any **two** questions from Section B (50 marks).

Use labelled diagrams and sketches to illustrate your answers where appropriate.

All calculations must be supported by working.

A PLC datasheet is included for questions 5 and 12.

A Flowchart symbol sheet is included for questions 8, 11 and 12.

Worksheets are provided for questions 1, 2, 3, 9 and 12.

SECTION A

Attempt ALL questions in this Section (50 marks).

Marks

1. (*a*) Figure Q1(*a*) illustrates the basic architecture of a microcontroller. Some elements have been identified with the letters A to D. On **Worksheet Q1(*a*)**, complete Table Q1(*a*) by entering the names of the elements labelled A to D. **2**

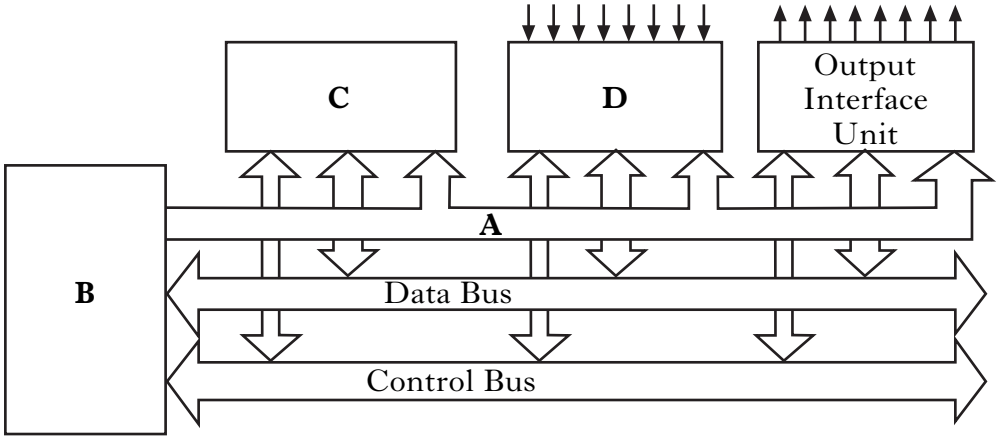


Figure Q1(*a*)

(*b*) **In your answer book**, state **two** advantages that a PC (Personal Computer) based mechatronic control system would have over a hard wired system. Assume that the application is within an industrial environment. **2**

(*c*) State the function of an "editor" within a software development environment. **1**

(5)

2. (*a*) Figure Q2 shows a labelled diagram of a polar robot. *Marks*

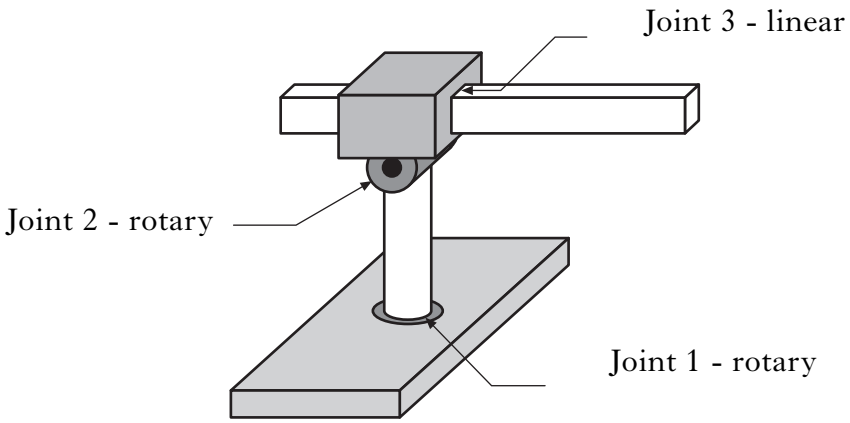


Figure Q2

Table Q2(a) identifies the movement of each joint of a robotic system as either Rotary or Linear. On **Worksheet Q2(*a*)**, complete Table Q2(a) by filling in the appropriate joint movement for the Cartesian and Revolute robots.

Robot	**Joint 1**	**Joint 2**	**Joint 3**
Polar	Rotary	Rotary	Linear
Cartesian	Linear		
Revolute	Rotary		

2

Table Q2(a)

(*b*) In your **answer book**, explain the term "work envelope" with reference to robots. **1**

(*c*) Electrical actuators are often the preferred choice of drive on small industrial robots. State **two** reasons why they would be used in preference to pneumatic actuators. **2**

(5)

[Turn over

Marks

3. (*a*) State **two** advantages of choosing a hydraulic robotic drive system over a pneumatic one. **2**

(*b*) Table Q3(b) below shows two codes used in mechatronics systems. On **Worksheet Q3(b)**, identify the missing name of the code represented and fill in each of the **four** missing code values.

Decimal	**Code Name =**	**BCD**
0	0000	0000 0000
1	0001	0000 0001
2	0010	0000 0010
3	0011	0000 0011
4	0100	
5		0000 0101
6	0110	0000 0110
7	0111	0000 0111
8	1000	0000 1000
9	1001	0000 1001
10		
11	1011	0001 0001
12	1100	0001 0010
13	1101	0001 0011
14	1110	0001 0100
15	1111	0001 0101

3

(5)

Table Q3(b)

4. (*a*) State **one** type of liquid level sensor that could be used in a mechatronic system. **1**

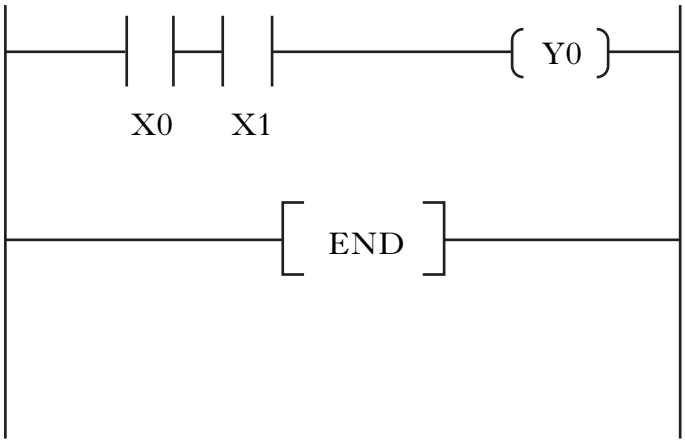
(*b*) With the aid of a simple sketch, describe the basic operation of the sensor chosen in Q4(*a*). **2**

(*c*) State an appropriate system application for the sensor chosen in Q4(*a*) and give **one** reason for your choice. **2**

(5)

Marks

5. A mechatronic control system uses a PLC.



Ladder Diagram Q5

(*a*) Describe the operation of the ladder diagram shown in Ladder Diagram Q5. **1**

(*b*) Redraw Ladder Diagram Q5 and modify it to latch the output **Y0** ON and enable the output **Y0** to be switched OFF using an additional Normally Closed (NC) contact **X2**. **2**

(*c*) Explain the operation of a Normally Closed (NC) contact in a PLC ladder diagram. **1**

(*d*) Explain the difference between a Memory/Auxiliary (M) output and an Output (Y) in a PLC system. **1**

Note: the inserted PLC Datasheet Q5, Q12 gives the PLC instruction set. **(5)**

6. (*a*) A **bi-metallic strip** and a **thermocouple** are two examples of temperature sensors. Choose **one** of these sensors and describe with the aid of a diagram:

(i) the physical properties of your selected sensor;

(ii) the principle of operation of your selected sensor. **4**

(*b*) State an application of the sensor you selected in Q6(*a*). **1**

(5)

[Turn over

7. (*a*) State how a closed loop control system generally differs from an open loop control system when applied to the same process in terms of:

(i) complexity;

(ii) accuracy. **2**

(*b*) An inkjet printer uses a stepper motor to drive the print head mechanism along the carriage.

(i) Briefly describe the operation of **one** type of stepper motor.

(ii) State why a system using a stepper motor is often classed as using open loop control. **3**

(5)

8. An automated hand dryer, shown in Figure Q8, consists of a controller, a proximity sensor, a heating element and a motorised fan. The system is designed to blow warm air for 1 minute after the proximity sensor is activated and then stop automatically. The heating element is interlocked to the motorised fan and cannot operate until the fan is running. The heating element is switched off 5 seconds before the fan is stopped.

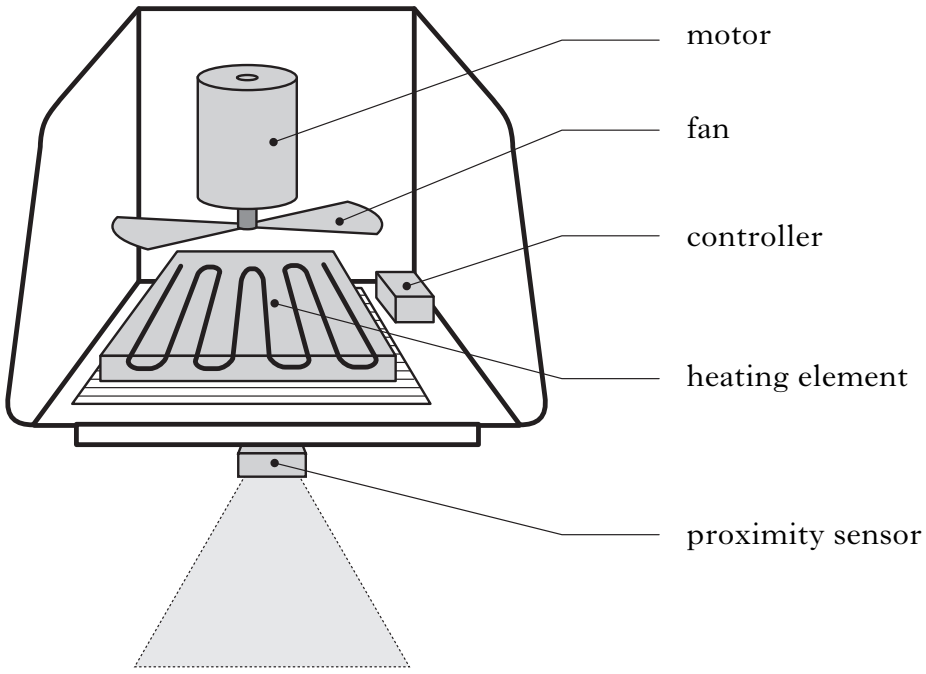


Figure Q8

Sketch a flowchart outlining the operation of the system, clearly identifying any inputs, outputs and timing events required for the correct operation. **(5)**

Note: The inserted Flowchart symbol sheet for Q8, Q11 and Q12 gives a suitable selection of Flowchart symbols.

Marks

9. A simplified schematic of a car's Anti-lock Braking System (ABS) is shown in Figure Q9. On each wheel hub there is a toothed wheel and sensor assembly.

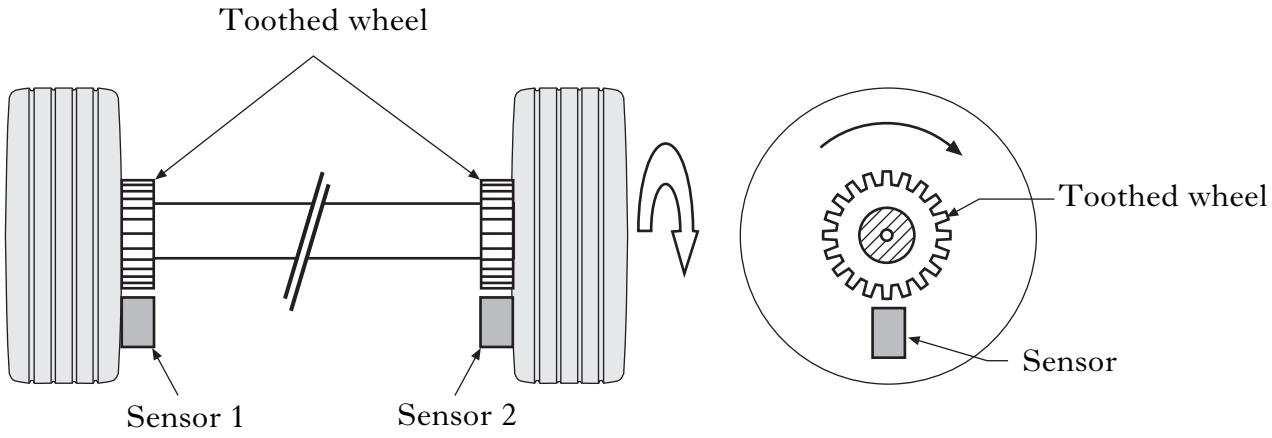


Figure Q9

(*a*) Explain how the signal from the sensor assembly could be used to calculate the rotational speed of the wheel. **2**

(*b*) On **Worksheet Q9(*b*)**, four waveform diagrams illustrate various sensor outputs when the car is moving forward in a straight line. Complete the Table Q9(*b*) to indicate the waveform that shows:

(i) constant speed;

(ii) car accelerating;

(iii) one wheel locking. **3**

(5)

[Turn over

Marks

10. A sign cutting machine has a cutting area of 800 mm x 400 mm. The machine cutting head is driven by a combination of electric motors and lead screws. Each axis has a linear encoder which uses a 12 bit binary code.

(*a*) Calculate the best resolution possible on the 400 mm axis assuming the 12 bit code is used to represent the maximum movement of 400 mm. **2**

(*b*) **One** of the three following statements describes the best resolution on the 800 mm axis. State which **one** of the following statements is true.

Statement A – the best resolution on the 800 mm axis is **the same as** the best resolution on the 400 mm axis.

Statement B – the best resolution on the 800 mm axis is **twice as good as** the best resolution on the 400 mm axis.

Statement C – the best resolution on the 800 mm axis is **only half as good as** the best resolution on the 400 mm axis. **1**

(*c*) Describe the operation of a linear encoder suitable for the above application. **2**

(5)

[*END OF SECTION A*]

[Turn over for SECTION B on *Page ten*

SECTION B

Attempt any TWO questions in this Section (50 marks).

Each question is worth 25 marks.

11. A number of businesses use a ticket based queuing system. The automatic ticket dispenser in Figure Q11 has the following main components:

- proximity sensor;
- stepper motor drive system;
- roll sensor;
- ticket sensor;
- ticket torn off sensor;
- microcontroller.

The system is supplied with a roll of 150 perforated tickets which are detected by the roll sensor. A user needs to activate the proximity sensor to let the system know a ticket is requested. The system automatically feeds **one** ticket each time the proximity sensor is activated and will **not** feed another ticket until the supplied ticket has been torn off. The diagram in Figure Q11 shows ticket a34 ready to be torn off. The "ticket torn off sensor" detects when that ticket has been torn off by the user.

The system stops if the "ticket sensor" detects that the tickets are not loaded OR the "roll sensor" does not detect a ticket roll.

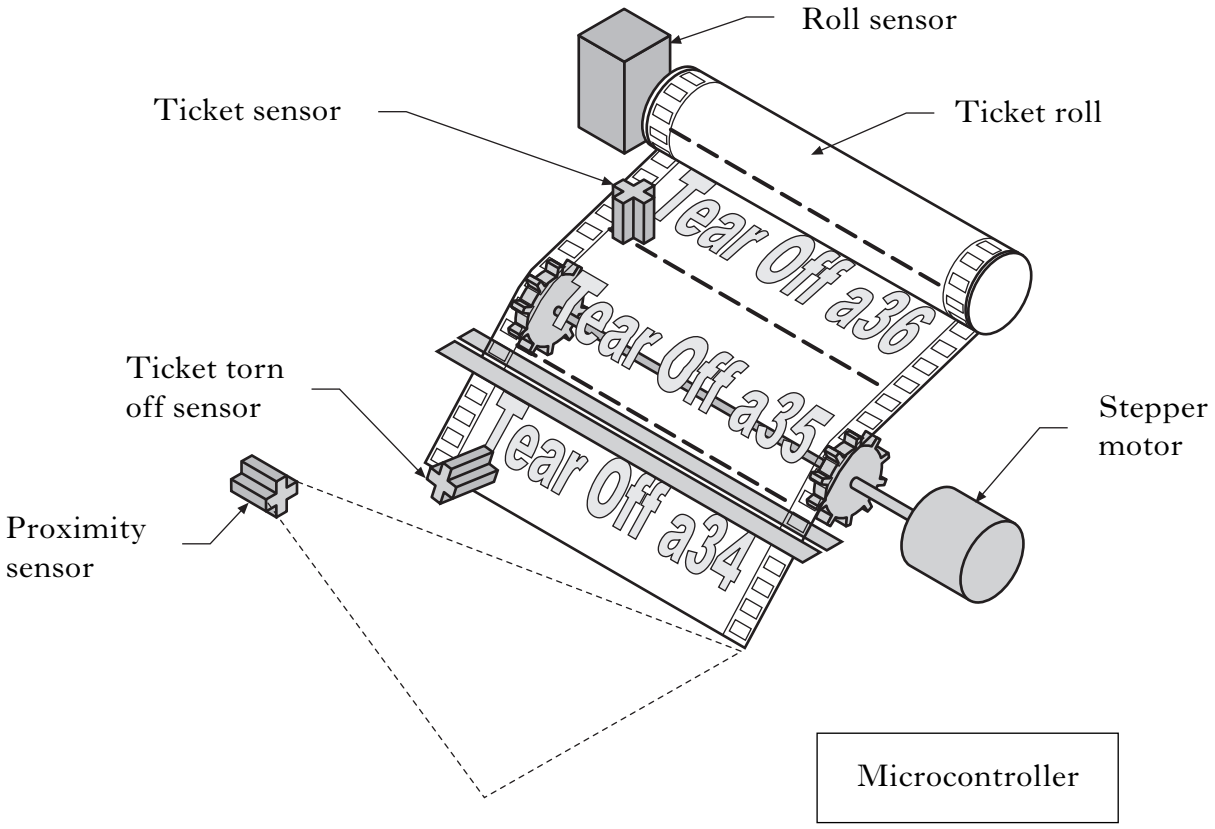


Figure Q11

Marks

11. (continued)

(*a*) The proximity sensor is connected to the microcontroller input. Select and describe a suitable sensor and describe its principle of operation. **3**

(*b*) Identify the remaining inputs to the microcontroller and suggest a suitable sensor for each. **6**

(*c*) Sketch a flowchart which describes one cycle of the system starting from when a ticket is requested through to this ticket being torn off. Your flowchart should reference the main components of the system — roll sensor, ticket sensor, ticket torn off sensor, proximity sensor and stepper motor. **6**

Note: The inserted Flowchart symbol sheet for Q8, Q11 and Q12 gives a suitable selection of Flowchart symbols.

(*d*) The system uses a 24V stepper motor to feed out the tickets. State **two** reasons why this is considered a suitable choice for the drive system. **2**

(*e*) A "Roll low" warning indicator is added to the system. Describe **one** method of detecting when there are only 10 perforated tickets remaining in the machine and then illuminating the "Roll low" warning indicator. **4**

(*f*) (i) Outline **two** safety issues which must be considered when designing a mechatronic system for this type of application.

(ii) Briefly explain how **each** of the two safety issues mentioned above could be overcome. **4**

(25)

[Turn over

12. Figure Q12 shows the layout of an automated assembly work cell.

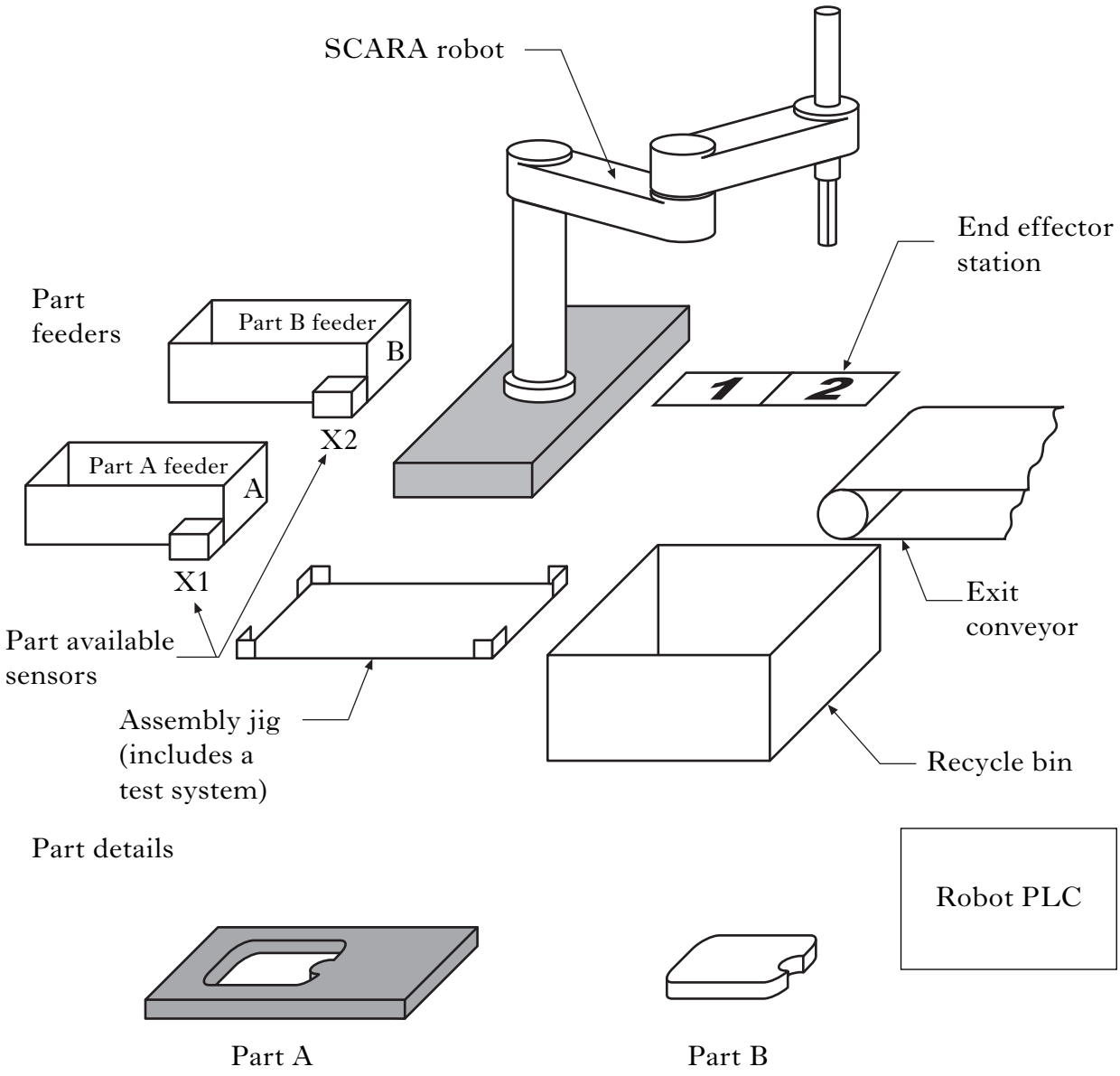


Figure Q12

The automated assembly work cell consists of the following elements.

- A SCARA robot
- Two part feeders each with a "part available" sensor
- An assembly jig (which includes a test system)
- An exit conveyor
- A recycle bin
- An end effector station that stores two different end effectors
- A robot Programmable Logic Controller (PLC)

12. (continued)

The robot has the ability to select and attach an end effector from the "end effector station" as required in the sequence below. When the robot has finished with an end effector it returns it to the end effector station.

The two "part available" sensors have Normally Open (NO) contacts. When there are no parts in the associated feeder the sensor contact closes.

The sequence of operation, controlled by the robot PLC, at the work cell is as follows. The sequence below assumes at the start of the sequence both feeders have parts available and the robot is in its home position without an end effector attached.

- Robot attaches end effector 1
- Robot picks up part A and places in the assembly jig
- Robot changes to end effector 2 and applies an adhesive to part A
- Robot changes to end effector 1
- Robot picks up part B and inserts it in part A
- Robot applies pressure to the assembly for 30 seconds to cure the adhesive
- Robot goes to its home position
- The test system checks for correct assembly
- If test is a pass – Robot picks up assembly and places on the exit conveyor
- If test is a fail – Robot picks up assembly and places in the recycle bin
- Robot returns end effector 1 to the end effector station
- Robot goes to its home position

(*a*) On **Worksheet Q12(*a*)**, complete the **Flowchart Q12(*a*)** to describe the sequence for the creation of one complete tested assembly. **6**

Note: The inserted Flowchart symbol sheet for Q8, Q11 and Q12 gives a suitable selection of Flowchart symbols.

(*b*) A "Part feeder empty" warning indicator is to be added to the system. **In your answer book**, draw a ladder diagram to show how the two "part available" sensors (X1 and X2) could be used to turn ON a "Part feeder empty" warning indicator (Y1) if **either** of the two sensors detects that a part feeder is empty. **3**

(*c*) Complete the **Ladder Diagram Q12(*c*)** on **Worksheet Q12(*c*)**. The completed ladder diagram should show a Timer (T0), activated by the robot using contact X4, that would timeout after 30 seconds. When the timer times out, Timer contact T0 then activates output Y5. **3**

Note: the inserted PLC Datasheet Q5, Q12 gives the PLC instruction set.

(*d*) **In your answer book**, sketch a suitable design for a vacuum gripper which could handle Part B **and** detect if a part was present in the gripper. **4**

(*e*) Briefly describe a suitable sensing system for testing that Part B has been correctly fitted to Part A. **3**

(*f*) Briefly describe a suitable sensing system for monitoring the pressure being applied to the assembly to cure the adhesive. **3**

(*g*) Describe **one** method by which the robot controller could detect which end effector the robot is currently using. **3**

(25)

13. A biscuit oven consists of 3 heated zones, a conveyor and an exhaust system which are all controlled by a computer.

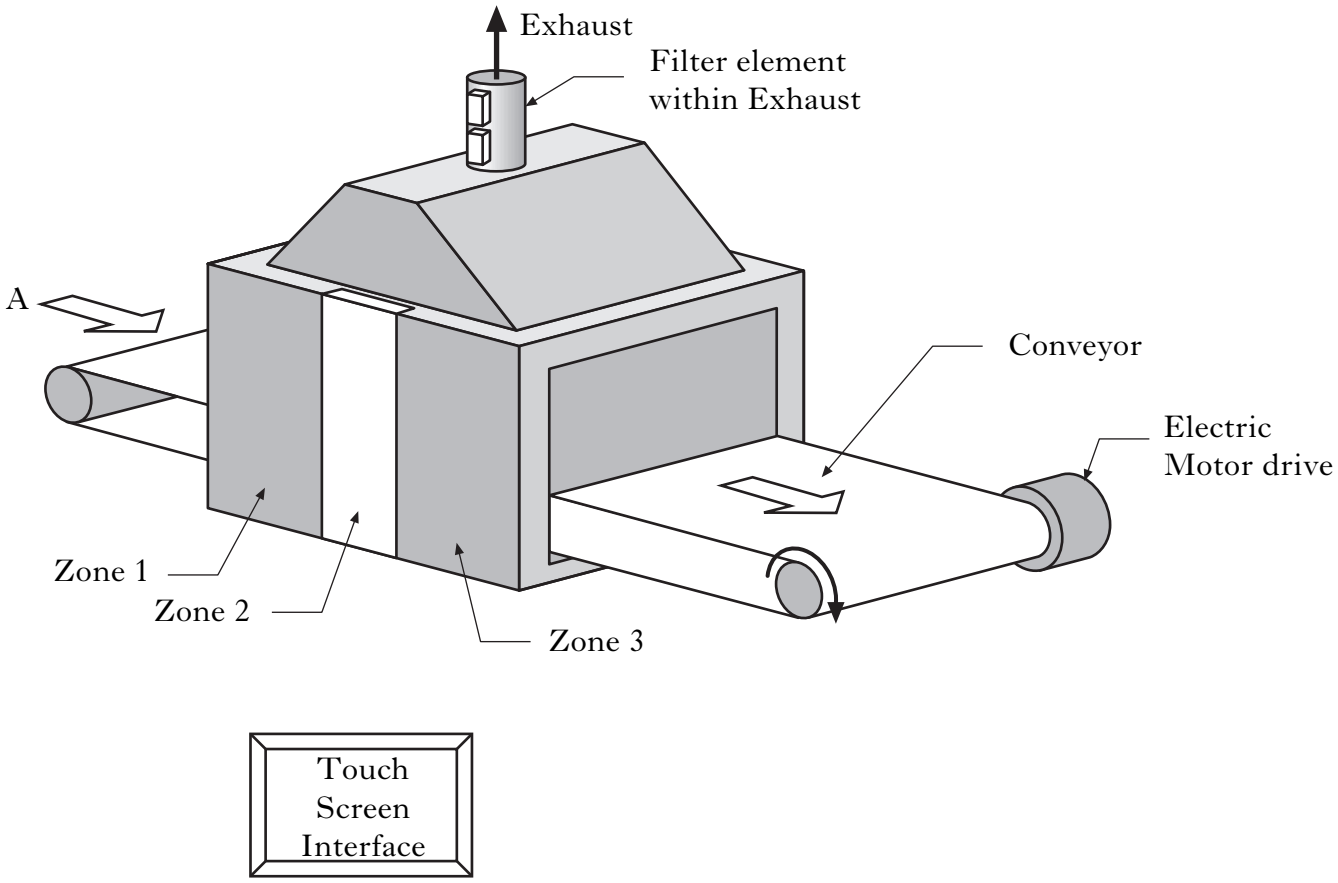


Figure Q13

Uncooked biscuits arrive at A and pass through the oven at a controlled speed. The conveyor has a variable linear speed between 1 – 5 mm/s and is driven by a large electric motor with closed loop speed control. Each oven zone can be controlled at temperatures between 120 – 400 °C. The desired speed may be selected in increments of 0·1 mm/s and the desired temperature for each zone selected in increments of 20 °C. The desired speed and zone temperatures are entered into the computer control system via the touch screen interface.

The heating elements in each zone are electronically controlled by a closed loop control system using PID control. The temperature in each zone is sensed using a thermocouple and is controlled to within ±5 °C.

The exhaust system consists of an extraction fan and a filter element. The filter element is monitored to detect and indicate its condition.

13. (continued)

(*a*) (i) Identify all the signals from the oven which require interfacing to the computer control system inputs.

(ii) Identify all the output signals from the computer control system which require interfacing to the oven. **6**

(*b*) The designer has chosen PID control as the control strategy to maintain the temperature in each zone.

(i) Give **one** reason why PID control is suitable for this system.

(ii) Briefly explain the meaning of each of the terms:

- Proportional
- Integral
- Derivative

with respect to a PID control system. **4**

(*c*) Sketch and describe a suitable sensor system for detecting the exhaust filter condition and state the nature of the output signal from your sensor. **4**

(*d*) The drive motor for the conveyor has a shaft encoder which provides a signal from which the conveyor linear speed can be calculated. Sketch and describe the operation of a suitable shaft encoder and explain how the encoder output signal may be converted into a linear value (mm/s). **6**

(*e*) Give **three** safety measures which could be included in the oven system shown in Figure Q13. **3**

(*f*) The computer control system is used to control the electric motor drive. State **two** issues associated with interfacing the computer control system to the large electric motor. **2**

(25)

[*END OF SECTION B*]

[*END OF QUESTION PAPER*]

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