Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2013

Electronics ELEC4

Unit 4 Programmable Control Systems

Thursday 6 June 2013 1.30 pm to 3.00 pm

For this paper you must have:
- a pencil and ruler
- a calculator
- a Data sheet.

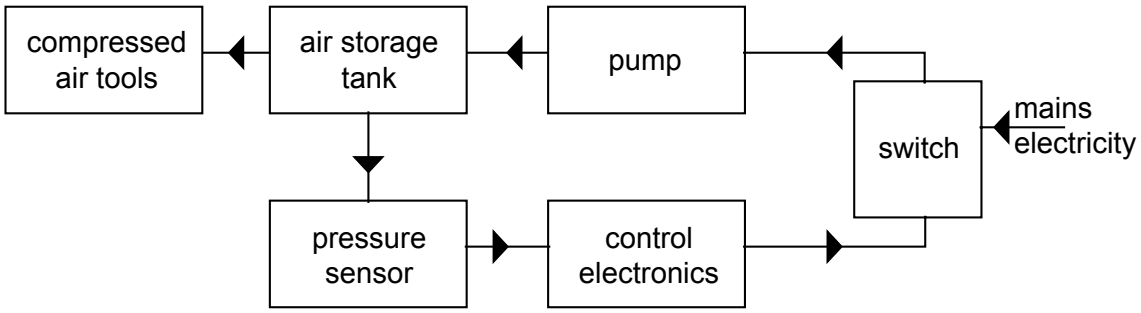
Time allowed
- 1 hour 30 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Answer **all** questions in the spaces provided.

1 A car workshop uses many tools which are powered by compressed air.
The compressed air is supplied at a steady pressure by a pump, storage tank and control system.
The system diagram is shown below.



1 (a) Explain why the system can be described as closed loop with negative feedback.

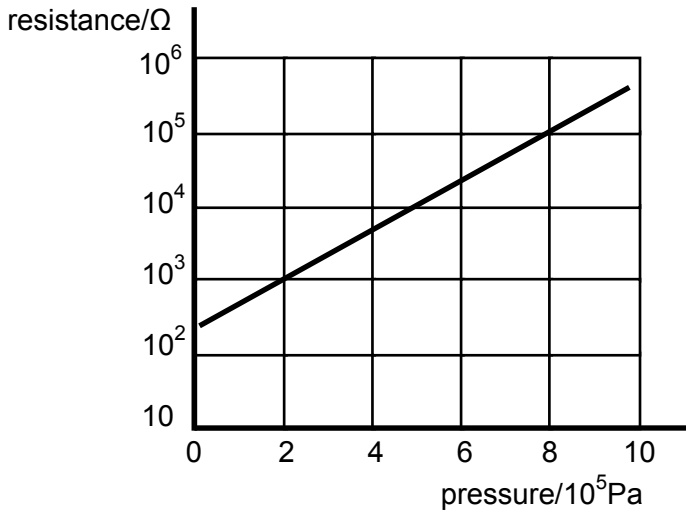
.....

.....

.....

(2 marks)

1 (b) The pressure sensor gives a varying resistance output. Its characteristic is shown below.



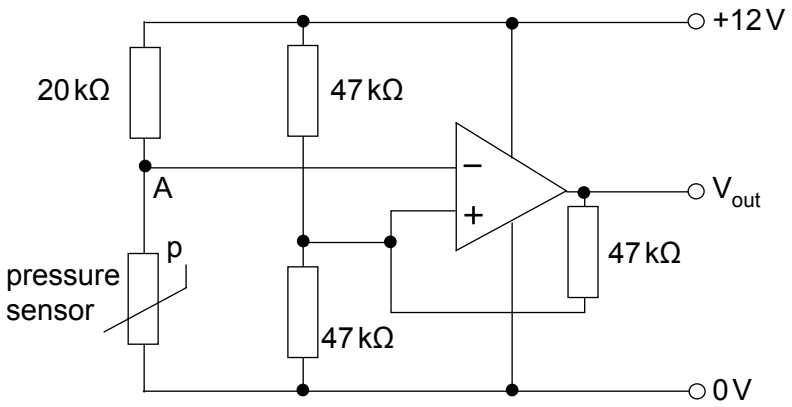
At the maximum safe operating pressure of the tank, the pressure sensor has a resistance of 100 kΩ and at the minimum operating pressure it has a resistance of 10 kΩ.
What are these two pressures?

.....

.....

(2 marks)

1 (c) The pressure sensor is connected to the circuit below.



1 (c) (i) Calculate the voltage at point A at the minimum operating pressure.

.....

.....

(2 marks)

1 (c) (ii) Show that the upper switching point of the Schmitt trigger circuit is 8 V.

.....

.....

.....

(2 marks)

1 (c) (iii) Calculate the maximum pressure that the system will produce in the storage tank.

.....

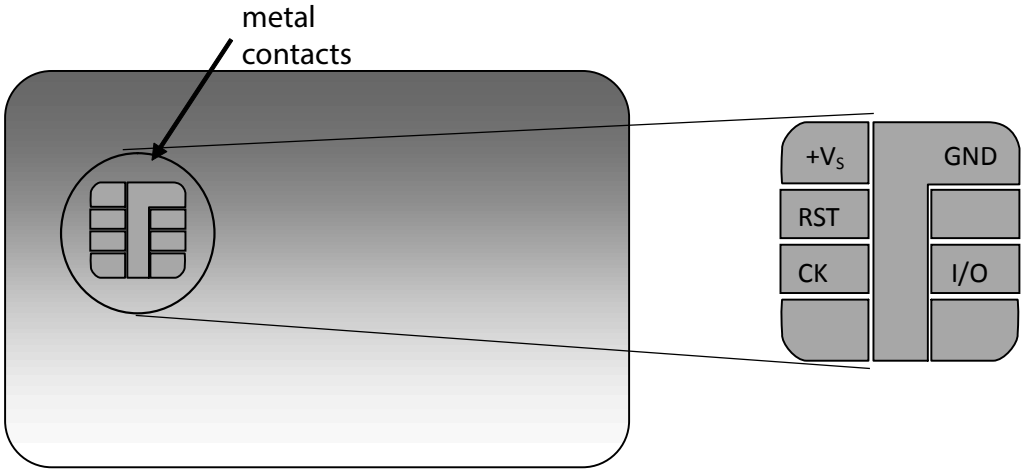
.....

(2 marks)

10

Turn over ▶

2 A smart card is a credit card size plastic card with an embedded microcontroller. The type of card shown communicates with the card reader using eight metal contacts. These contacts are wired to the enclosed microchip which contains memory and a CPU.



There are three kinds of memory in an embedded microcontroller:
read-only memory (ROM),
non-volatile memory (NVM),
random access memory (RAM).

2 (a) State the use of each type of memory in an embedded microcontroller

read-only memory

.....

non-volatile memory

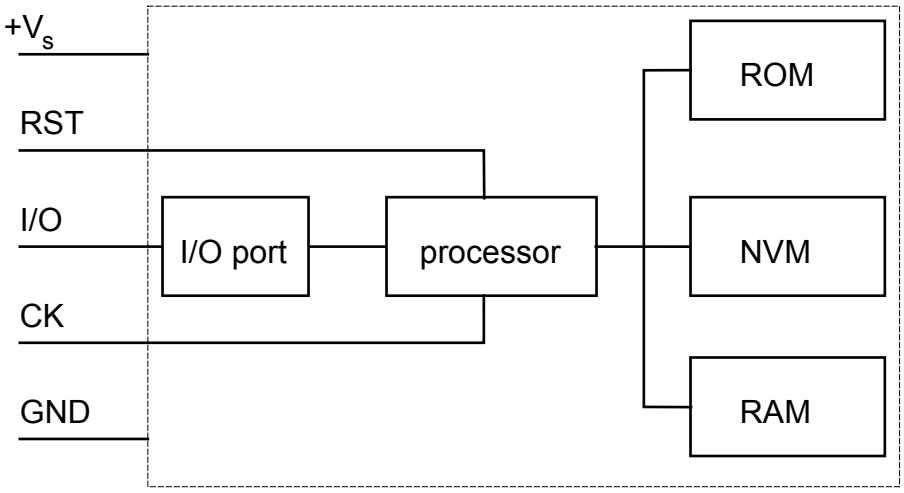
.....

random access memory.

.....

(3 marks)

2 (b) The block diagram of the smart card system is shown below.
The input/output channel on a smart card is a serial channel.
In operation, the card reader sends a command to the card and waits for a reply.



Explain the purpose of the following signals in the system:

clock (CK)

.....

reset (RST)

.....

(2 marks)

Turn over for the next question

2 (c) A smart card can be used for verifying the PIN (personal identification number) of a customer using a cash machine.
The customer's PIN is stored in encrypted form on the card and can be changed when using a cash machine.
Describe under each of the headings shown below, how each of the three types of memory is used during the verification of a PIN.

ROM

.....

.....

.....

.....

NVM

.....

.....

RAM

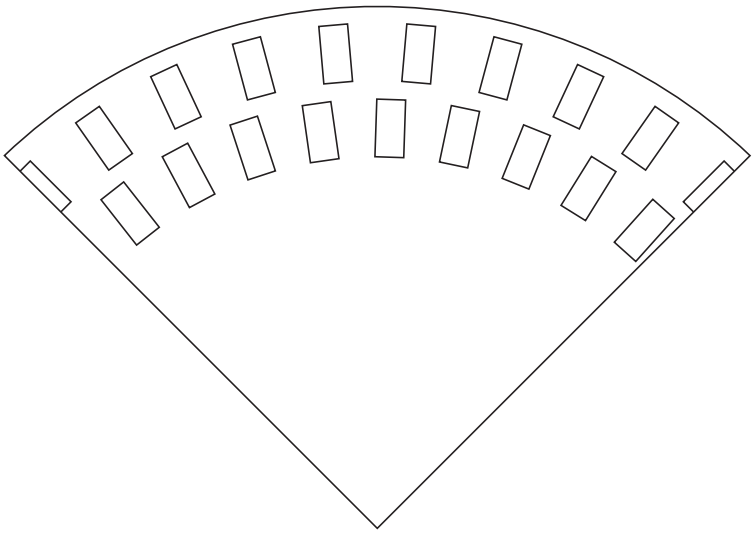
.....

.....

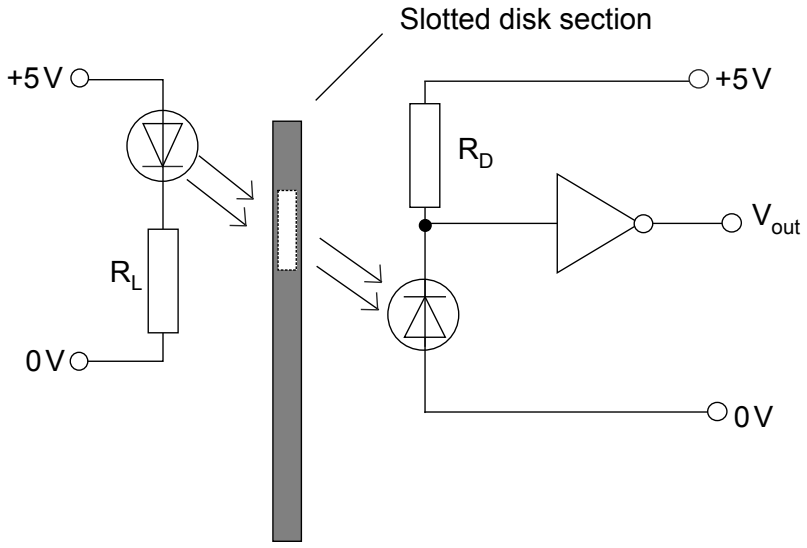
(5 marks)

10

3 Many analogue controls on equipment are now replaced with digital equivalents. One such system consists of an optical disk, a section of which is shown below.



Each circle of slots is read optically using an infra-red LED and photodiode, as shown in the diagram below.



3 (a) (i) The LED has a forward voltage of 1.4 V and needs a current of approximately 10 mA. Calculate a suitable value for R_L.

.....

.....

(2 marks)

Turn over ▶

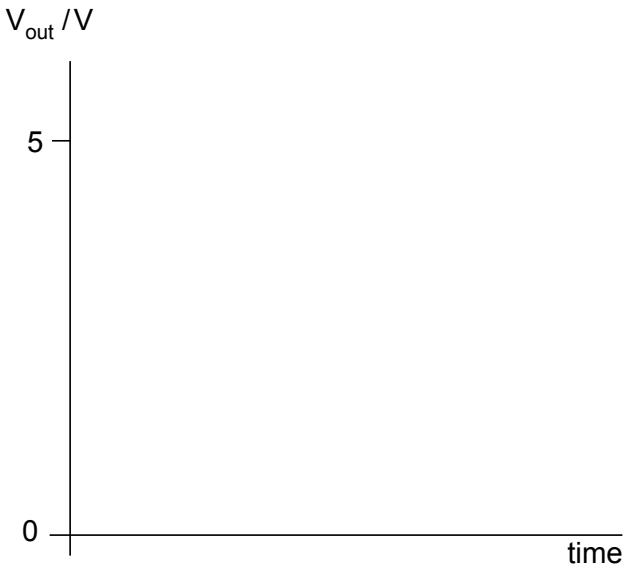
3 (a) (ii) The photodiode, when illuminated by the LED, has a reverse current of 2.5 µA and when in the dark, 0.1 µA. The NOT gate interprets an input of >2.5V as logic 1 and <2.5 V as logic 0.
Calculate a suitable value for R_D to ensure reliable operation of the NOT gate.

.....

.....

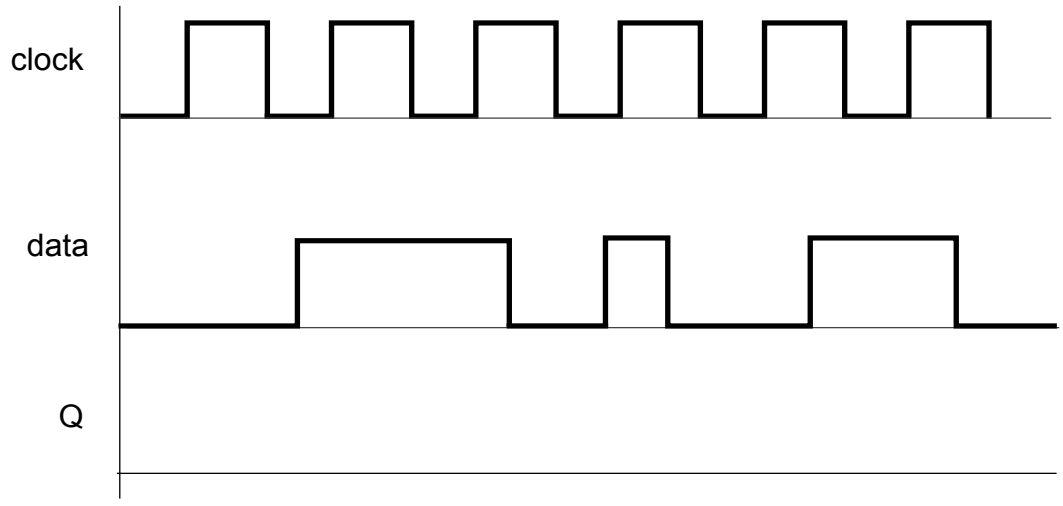
(2 marks)

3 (a) (iii) The slotted disk rotates so that a slot passes between each LED and photodiode. On the axes below, sketch how V_{out} changes as one of the slots passes in between an LED and photodiode.



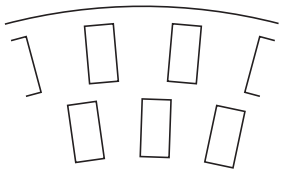
(1 mark)

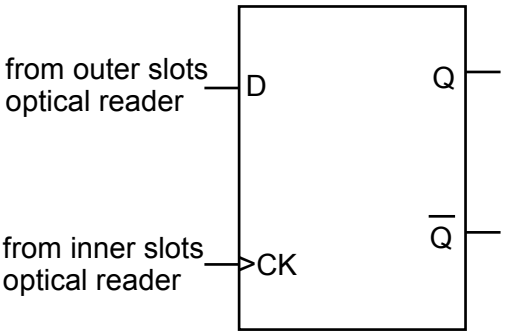
3 (b) Complete the timing diagram below to show how the output, Q, of a D-type flip-flop depends on the clock and data inputs shown below.



(2 marks)

A D-type flip-flop is used to determine the direction of rotation of the slotted disk as shown below.





3 (c) (i) The slotted disk is rotated clockwise. Explain why the Q output of the D-type flip-flop is always logic 1.

.....

.....

.....

(2 marks)

3 (c) (ii) Explain how the direction of rotation can be determined from the Q output of the D-type flip-flop.

.....

.....

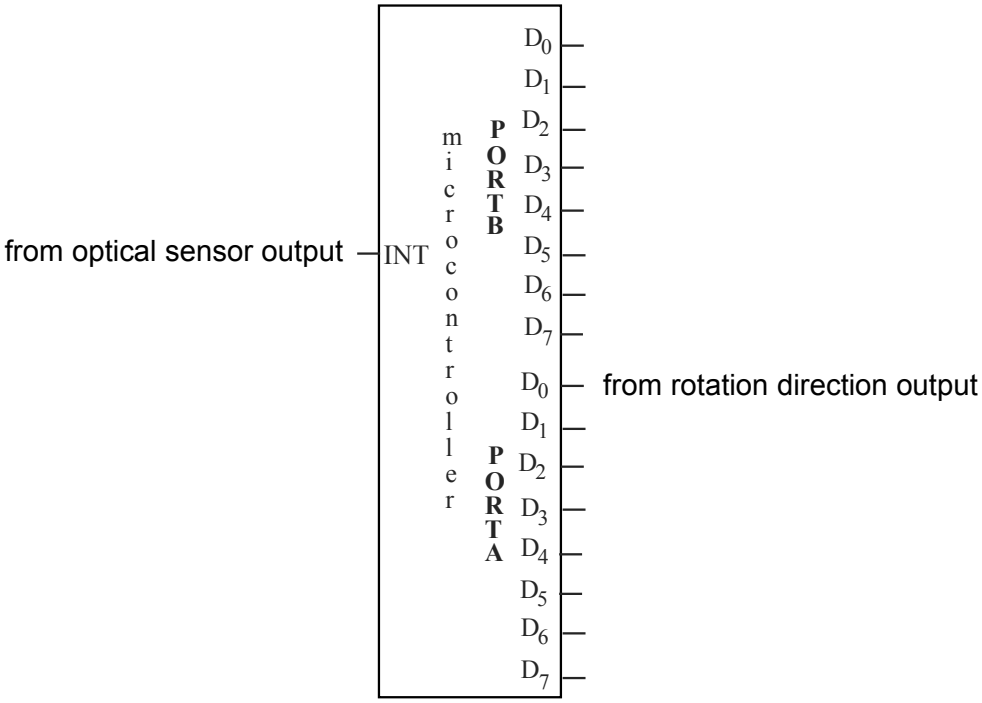
(1 mark)

10

Turn over for the next question

It is not necessary to have attempted Question 3 before answering this question.

4 Many analogue controls on equipment are now replaced with digital equivalents as in Question 3.
When a slot passes through the optical sensor a pulse is produced. The output from the optical sensor for the outer slots is connected to the Interrupt (INT) input of a microcontroller. The output from the rotation direction circuit is connected to D_0 of PORTA.
If D_0 = 1 then the rotation is anticlockwise.
If D_0 = 0 then the rotation is clockwise.



4 (a) In general terms, describe what happens within a microcontroller when it receives an interrupt request.

.....

.....

.....

.....

(3 marks)

Question 4 continues on the next page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

The flow chart for the interrupt routine is shown on the page opposite.

4 (b) If the optical disk is rotated one slot anticlockwise, what happens to the value in PORTB?

.....

.....

(2 marks)

4 (c) If the optical disk is rotated one slot clockwise, what happens to the value in PORTB?

.....

.....

(2 marks)

4 (d) Using only assembler code instructions given in the data sheet, write the instructions for the section of the flow chart in the shaded box.

.....

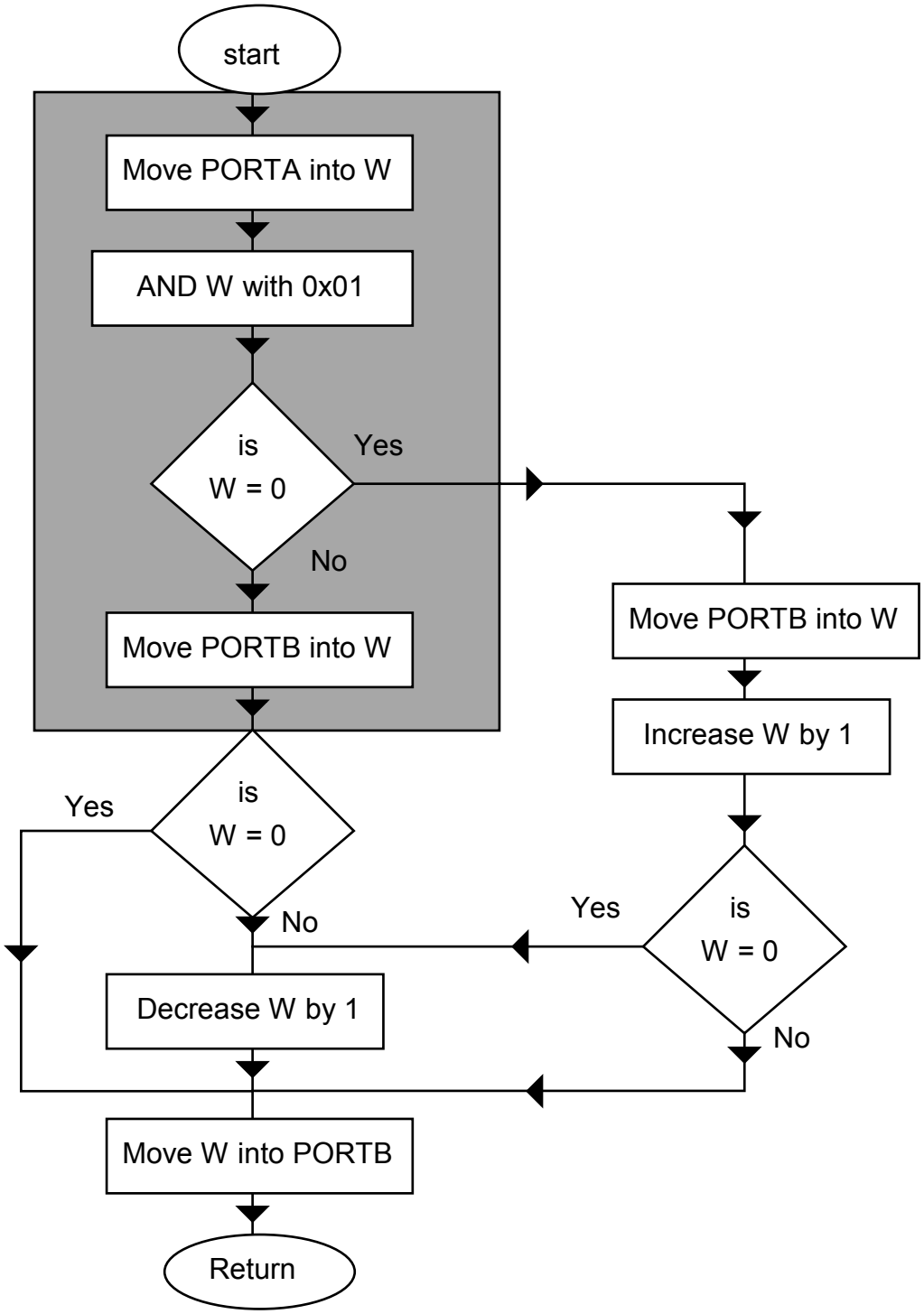
.....

.....

.....

(3 marks)

10



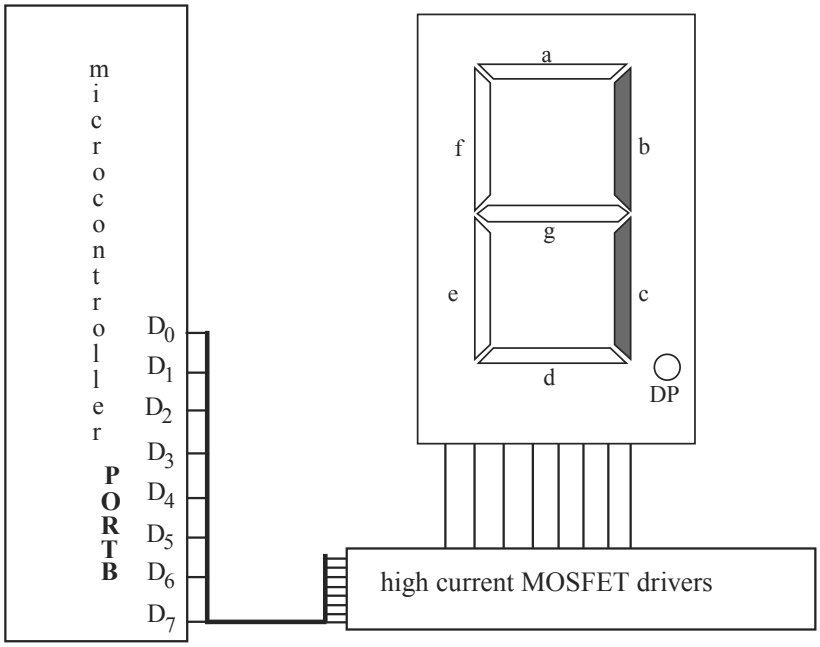
5 A busy post office needs a system which indicates to queuing customers which cashier is available. The system is microcontroller based and operates a large 7-segment display when a cashier indicates that they are available for the next customer.

5 (a) The 7-segment display is operated from PORTB of the microcontroller.
Write the assembler code to configure PORTB of the microcontroller as an output.

.....

.....

(2 marks)



5 (b) The outputs from PORTB are connected to the 7-segment display elements via the MOSFET drivers as shown below.

display	a	b	c	d	e	f	g	DP
PORTB	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7

The incomplete table below shows the value of the byte that must be sent to PORTB to illuminate the numbers. Complete the missing elements of the table.

Display	Binary	Hexadecimal
1	00000110	0x06
2		
3	01001111	0x4F
4	01100110	0x66
5		0x6D
6	01111101	0x7D
7	00000111	
8	01111111	0x7F

(4 marks)

5 (c) There are eight cashiers, each with a switch connected to one of the inputs of PORTA of the microcontroller.
When a switch is pressed the input changes from a 0 to a 1.
PORTA is 'polled' by the microcontroller to check for inputs.

Explain the meaning of the term 'polled' in this context.

.....

.....

(2 marks)

5 (d) The code for polling PORTA is

```
poll:
        MOVRW PORTA
        JPZ poll
```

If the microcontroller has a 1MHz clock, how often will PORTA be polled in the absence of an input?

.....

.....

(2 marks)

10

6 A student wants to build a fast, 6-bit analogue to digital converter (ADC) for his coursework. He researches the circuit diagram for a flash ADC and realizes that he will need to order a significant number of op-amps from his supervisor.

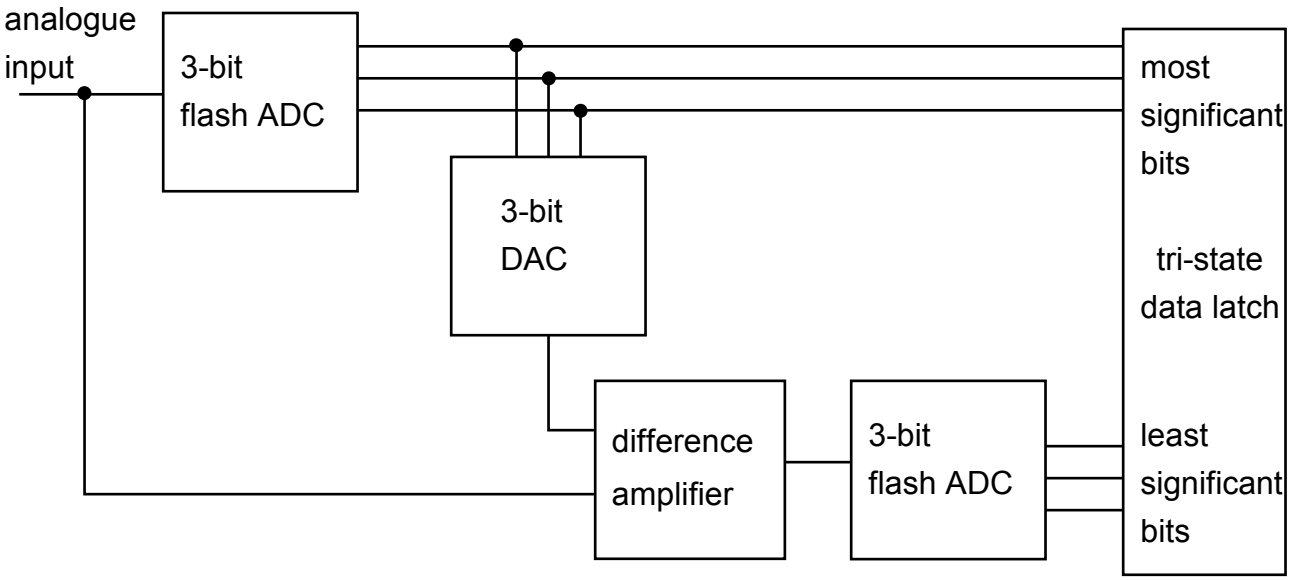
6 (a) Show, using a calculation, that 63 op-amps will be needed for a 6-bit flash ADC.

.....

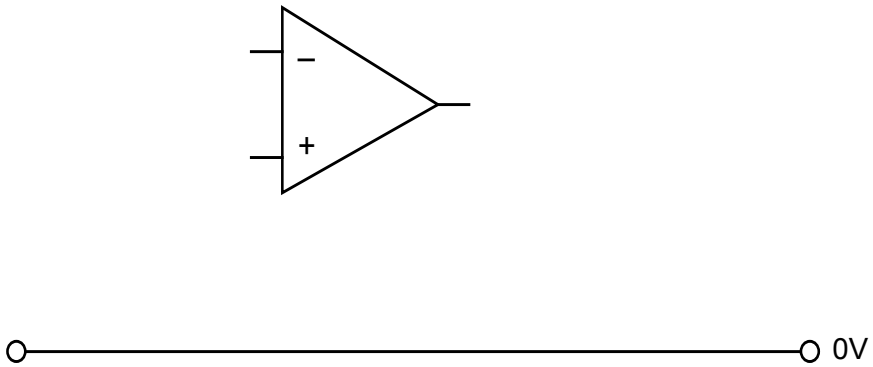
.....

(1 mark)

The supervisor rejects the idea and suggests instead that the student researches 'half flash' ADCs. The student finds the diagram below for such an ADC.

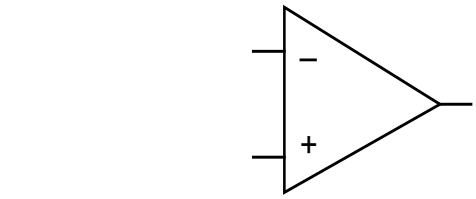


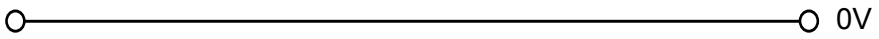
6 (b) Complete the circuit diagram below for a 3-bit summing amp DAC and give appropriate component values.



(3 marks)

6 (c) Complete the circuit diagram below for a difference amplifier and give suitable values for the circuit to have a voltage gain of 1.





(3 marks)

6 (d) Explain how this half-flash ADC works.

.....

.....

.....

.....

.....

.....

(3 marks)

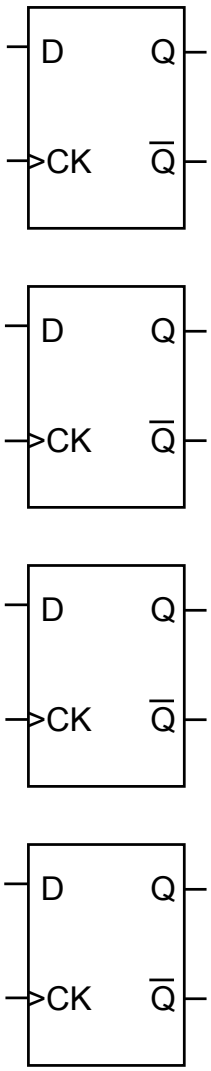
10

Turn over for the next question

It is not necessary to have attempted Question 6 before answering this question.

7 The system in Question 6 uses a tri-state data latch.

7 (a) Draw a diagram to show how four D-type flip-flops can be connected to form a 4-bit data latch. Label the data inputs, data outputs and latch enable input.



(3 marks)

7 (b) Explain what is meant by the term tri-state.

.....

.....

.....

(3 marks)

7 (c) Explain why tri-state devices are needed when information is being read by a microprocessor system.

.....

.....

.....

.....

.....

.....

.....

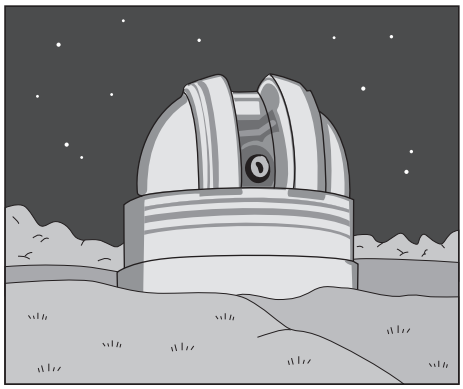
.....

(4 marks)

10

Turn over for the next question

8 Astronomical observatories are often located at the top of mountains, where there are few clouds to obscure the view of the sky. Many are not regularly manned but are effectively robotic systems.



The dome is positioned and opened using large 'mains' powered conventional motors. Stepper motors are used to position the telescope.

8 (a) Explain the choice of motors for each of these functions.

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

8 (b) The dome motor is controlled by MOSFET operated relays.
State **two** advantages of using relays instead of using semiconductors in this situation.

.....

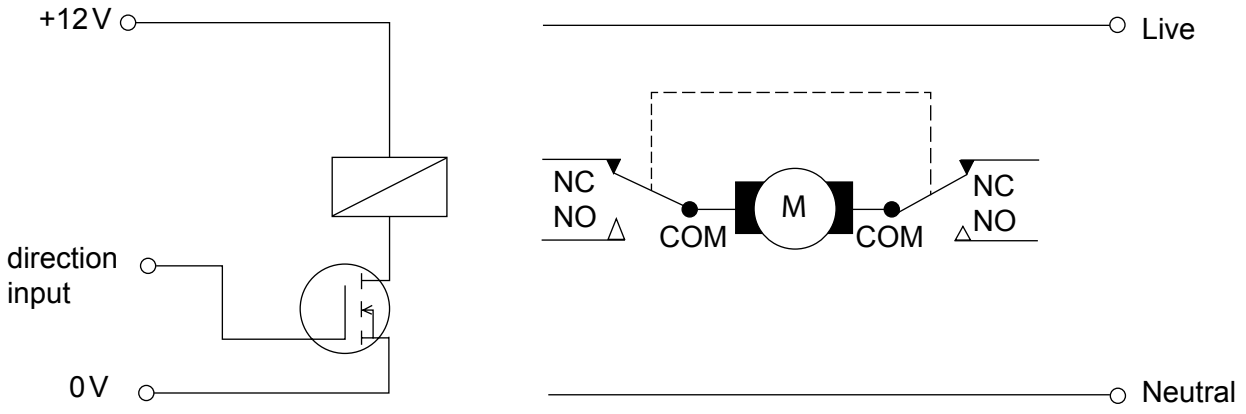
.....

(2 marks)

8 (c) Part of the direction control circuit diagram for the dome rotation motor is shown below. The direction of rotation of the dome motor can be changed by reversing its connections.

The relay has double pole double throw (DPDT) contacts and the motor is shown connected to the two common switch contacts.

Complete the circuit diagram by adding the connections to the relay contacts and any protection diodes needed.



(4 marks)

10

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED