

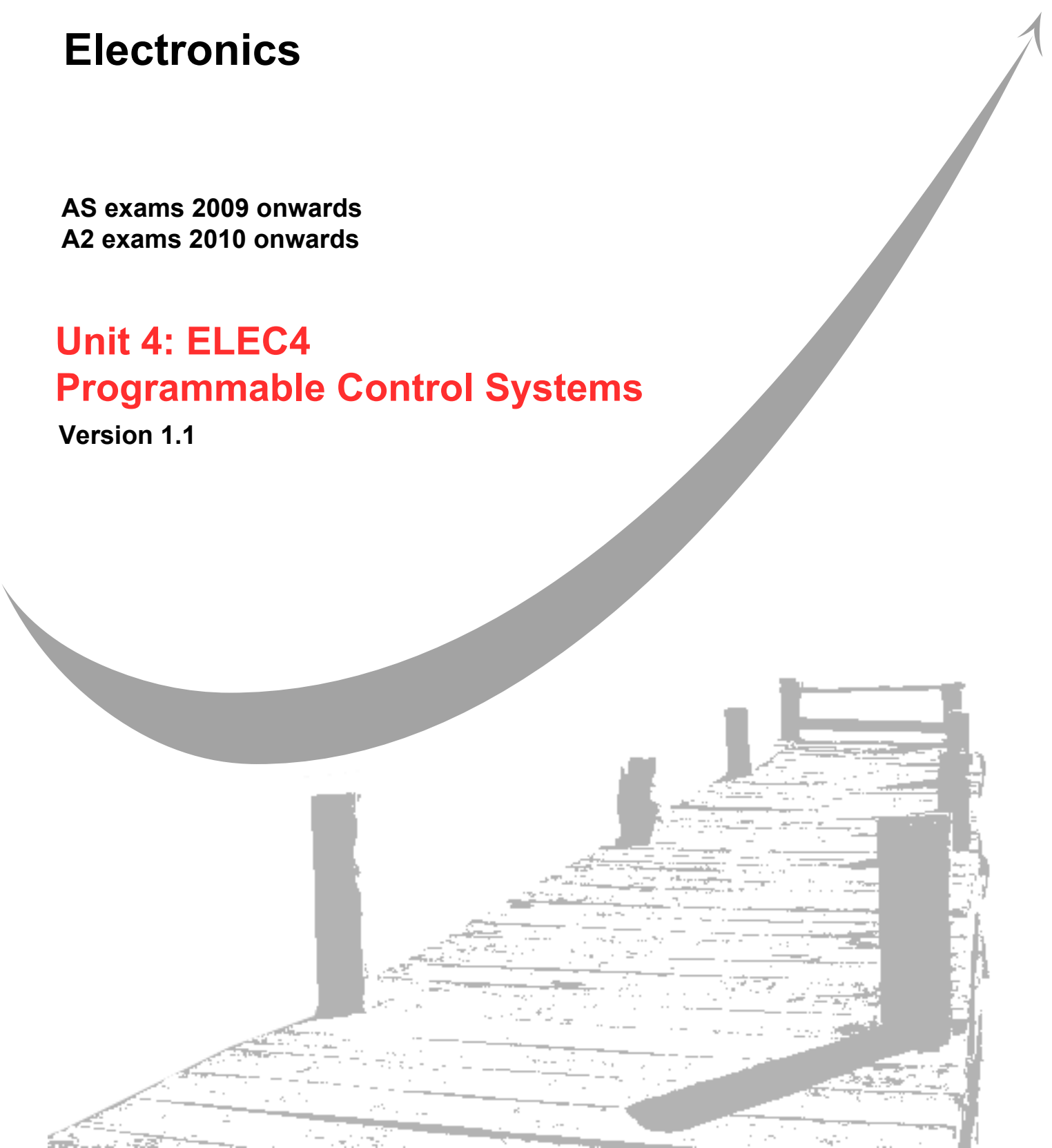
GCE
AS and A Level

Electronics

AS exams 2009 onwards
A2 exams 2010 onwards

Unit 4: ELEC4 **Programmable Control Systems**

Version 1.1



Surname					Other Names				
Centre Number					Candidate Number				
Candidate Signature									

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General Certificate of Education
Advanced Level Examination
version 0.2



ELECTRONICS
Unit 4 Programmable Control Systems

ELEC4

SPECIMEN PAPER

<p>For this paper you must have:</p> <ul style="list-style-type: none"> • a pencil and a ruler • a calculator.

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.
- Answer the questions in the space provided.
- Show the working of your calculations.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- A *Data Sheet* is provided on pages 3 and 4. Detach this perforated sheet at the start of the examination.

Information

- The maximum mark for this paper is 80.
- The marks for the questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- Any correct electronics solution will gain credit.
- You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use			
Number	Mark	Number	Mark
1		5	
2		6	
3		7	
4			
Total (Column 1)			
Total (Column 2)			
TOTAL			
Examiner's Initials			

Data Sheet

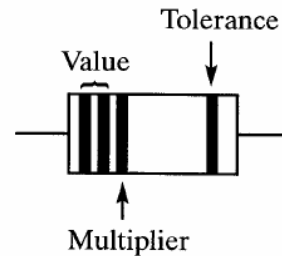
- A perforated *Data Sheet* is provided on pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- Detach this perforated sheet at the start of the examination.

Data Sheet

Resistors Preferred values for resistors (E24) series:
1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3,
4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1 ohms and multiples that are ten
times greater

Resistor Printed Code (BS 1852) This code consists of letters and numbers:
R means $\times 1$
K means $\times 1000$ (i.e. 10^3)
M means $\times 1\,000\,000$ (i.e. 10^6)
Position of the letter gives the decimal point
Tolerances are given by the letter at the end of the code,
F = $\pm 1\%$, G = $\pm 2\%$, J = $\pm 5\%$, K = $\pm 10\%$, M = $\pm 20\%$.

Resistor Colour Code	Number	Colour
	0	Black
	1	Brown
	2	Red
	3	Orange
	4	Yellow
	5	Green
	6	Blue
	7	Violet
	8	Grey
	9	White



Tolerance, gold = $\pm 5\%$, silver = $\pm 10\%$, no band = $\pm 20\%$

Silicon diode $V_F = 0.7\text{ V}$

Silicon transistor $V_{be} \approx 0.7\text{ V}$ in the on state, $V_{ce} \approx 0.2\text{ V}$ when saturated

Resistance $R_T = R_1 + R_2 + R_3$ series
 $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ parallel

Capacitance $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ series
 $C = C_1 + C_2 + C_3$ parallel

Time constant ac theory $T = CR, T_{1/2} = 0.69 CR$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

$$X_C = \frac{1}{2\pi f C}$$
 reactance

$$X_L = 2\pi f L$$
 reactance

$$f = \frac{1}{T}$$
 frequency, period

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$
 resonant frequency

Turn over ▶

Operational amplifier	$G_V = \frac{V_{out}}{V_{in}}$	voltage gain
	$G_V = -\frac{R_f}{R_1}$	inverting
	$G_V = 1 + \frac{R_f}{R_1}$	non-inverting
	$V_{out} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$	summing
	$V_{out} = (V_+ - V_-) \frac{R_f}{R_1}$	difference
555 Astable and Monstable	$T = 1.1RC$	monostable
	$t_H = 0.7 (R_A + R_B)C$	astable
	$t_L = 0.7 R_B C$	
	$f = \frac{1.44}{(R_A + 2R_B)C}$	astable frequency
Electromagnetic waves	$c = 3 \times 10^8 \text{ m s}^{-1}$	speed in vacuo

Assembler language microcontroller instructions

Mnemonic	Operands	Description	Operation	Flags	Clock cycles
NOP	none	No operation	none	none	1
CALL	K	Call subroutine	stack \leq PC PC \leq K	none	2
RET	none	Return from subroutine	PC \leq stack	none	2
INC	R	Increments the contents of R	(R) \leq (R) + 1	Z	1
DEC	R	Decrements the contents of R	(R) \leq (R) - 1	Z	1
ADDW	K	Add K to W	W \leq W + K	Z, C	1
ANDW	K	AND K with W	W \leq W • K	Z, C	1
SUBW	K	Subtract K from W	W \leq W - K	Z, C	1
ORW	K	OR K and W	W \leq W + K	Z, C	1
XORW	K	XOR K and W	W \leq W \oplus K	Z, C	1
JMP	K	Jump to K (GOTO)	PC \leq K	none	2
MOVWR	R	Move W to the contents of R	(R) \leq W	Z	1
MOVW	K, W	Move K to W	W \leq K	Z	1
MOVRW	R	Move the contents of R to W	W \leq (R)	Z	1

Turn over for the first question

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

1 Microprocessor control systems are now used to provide all of the timing and control systems for most domestic electrical and electronic goods e.g. dishwashers, washing machines etc.

1 (a) (i) State **one** way in which the architecture of a microcontroller differs from a conventional computer system.

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1 (a) (ii) Give **two** reasons why microcontrollers are now commonly used for providing the control functions for domestic goods, e.g. washing machines.

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(3 marks)

1 (b) The control functions processed by the microcontroller on a washing machine can be classified as either open or closed loop.
Explain why the functions of filling with water and heating it to the required temperature need to be closed loop.

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(2 marks)

The drum of a washing machine, which is carrying out the function of a 'slow spin', has to rotate at a steady speed of 200 revolutions per minute. To maintain this speed, negative feedback is provided to the microcontroller from a rotation sensor attached to the drum.

1 (c) (i) What is meant by the term *negative feedback*?

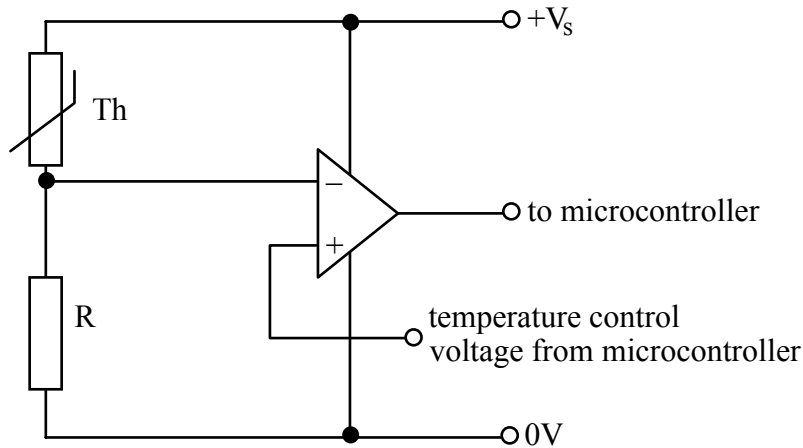
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1 (c) (ii) How does the negative feedback control the rotation speed of the drum?

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(3 marks)

The circuit diagram for the temperature sensor is shown below. The microcontroller produces a temperature control voltage dependent upon the temperature for the wash selected.



1 (d) (i) Name the function of the op-amp in the circuit.

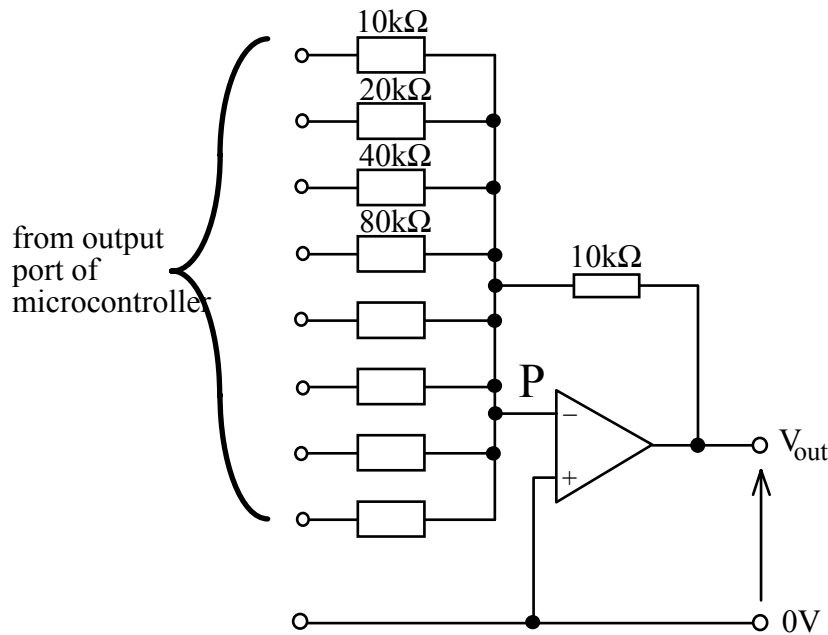
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1 (d) (ii) Explain how the temperature sensing circuit functions.

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(3 marks)

- 2 The circuit diagram shows an 8-bit DAC which is connected to the 8-bit output port of a microcontroller.



Mark on the circuit diagram

- 2 (a) (i) where you would connect the least significant bit (D₀) and the most significant bit (D₇) from the output port.

- 2 (a) (ii) the values for the unlabelled resistors.

(3 marks)

- 2 (b) Why is **P** is called a Virtual Earth point?

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(2 marks)

The decimal number 80 is written to the parallel port.

2 (c) (i) What is the value of this byte in binary?

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2 (c) (ii) Calculate the resulting output voltage from the DAC if logic 1 level is 5V and logic 0 level is 0V.

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(4 marks)

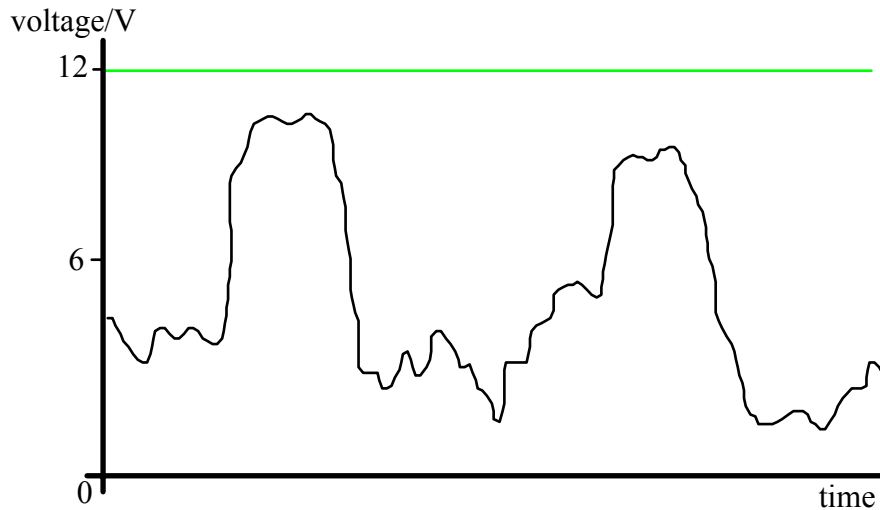
2 (d) The output of the DAC circuit is a negative voltage. Draw a diagram of a unity gain amplifier which will convert the negative voltage to a positive voltage. Give suitable component values.

(2 marks)

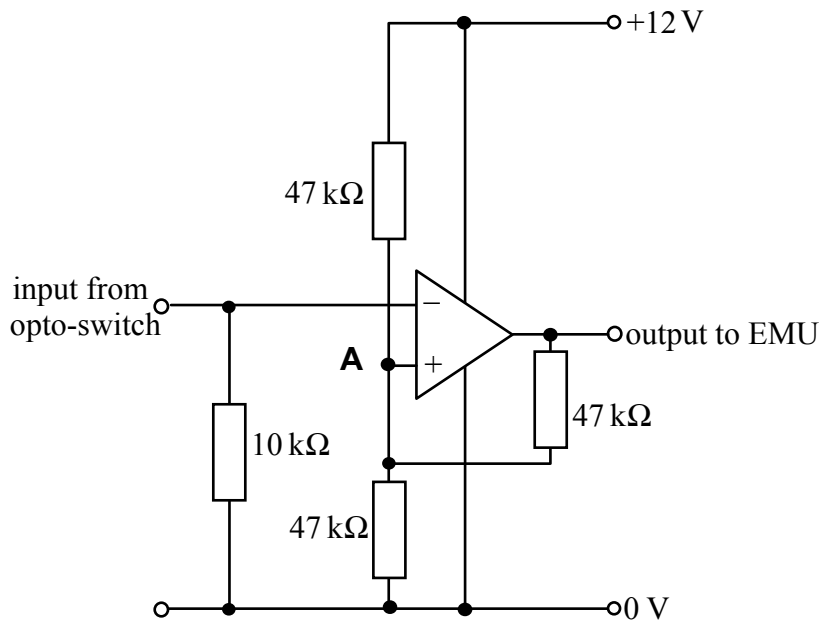
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Turn over ▶

- 3 Attached to the fly-wheel of a petrol engine is an optical shaft encoder which provides information to the Engine Management Unit (EMU) about the speed of rotation of the engine. The optical shaft encoder consists of a metal disk with 12 slots spaced every 30°. An opto-switch produces a pulse every time a slot passes by. A graph of two such pulses is shown below.



The pulses are passed through the Schmitt trigger circuit below.



- 3 (a) With reference to the graph above, explain why a Schmitt trigger is needed to interface the opto-switch to the EMU.

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(2 marks)

Assume that the op-amp output is either +12 V or 0 V.

- 3 (b) (i) Show that the voltage at point **A** in the Schmitt trigger circuit on **page 10** is 4V when the output of the op-amp is at 0V.

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- 3 (b) (ii) Calculate the voltage at point **A** in the Schmitt trigger circuit on **page 10** when the output of the op-amp is 12V.

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- 3 (b) (iii) In terms of the general properties of an op-amp explain why the voltages calculated in part (b)(i) and part (b)(ii) represent the switching voltages of the Schmitt trigger.

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(9 marks)

Turn over for the next question

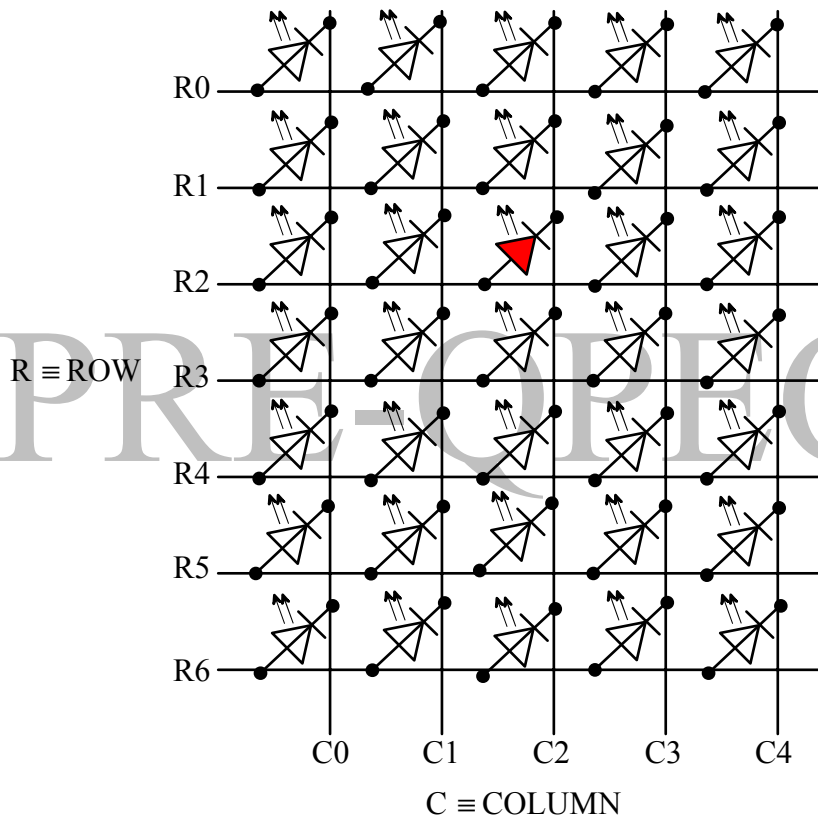
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- 4 (a) State **one** advantage and **one** disadvantage of a dot matrix display over a seven segment display.

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(2 marks)

- 4 (b) A seven by five LED matrix display is to be driven by a computer. The circuit diagram of the matrix display is shown below.

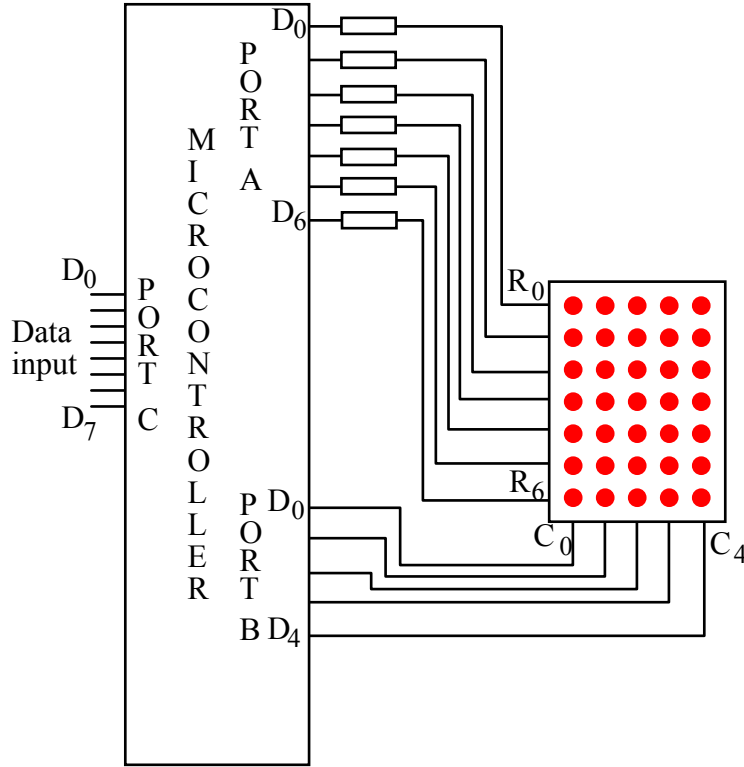


Explain how the LED shaded in the circuit diagram can be lit.

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(3 marks)

The interface circuit for the dot matrix display in part (b) is shown below. A byte of data representing a character is put onto PORT C. The microcontroller polls PORT C and any value greater than 1Fh is then displayed as the equivalent ASCII character on the display. Any value less than 20h is ignored.



4 (c) (i) How do Interrupt requests differ from polling?

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4 (c) (ii) List, in sequence, the binary values that must be written to PORT B in order for the display to be scanned once.

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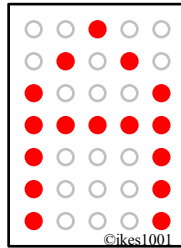
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(4 marks)

Question 4 continues on the next page

Turn over ▶

4 (d) The letter A is to be displayed on the dot matrix display as shown below.



Write down the sequence in which the binary values must be written to PORT A as the display is scanned.

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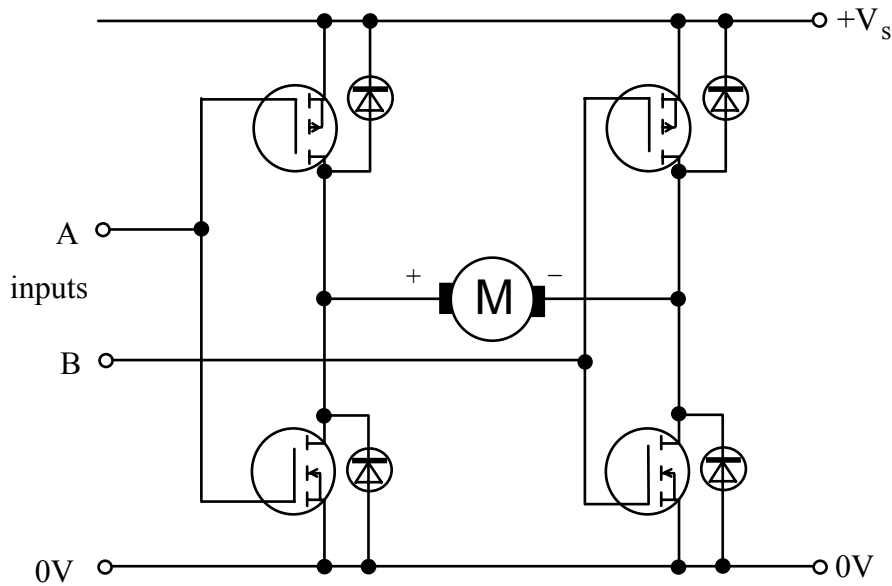
(2 marks)

11

Turn over for the next question

Turn over ▶

- 5 The circuit diagram shows an H-Bridge which is used for controlling the speed and direction of a dc conventional motor in a robot buggy.



- 5 (a) What is the function of the diodes in the circuit?
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- (2 marks)
- 5 (b) When the motor is powered so that its plus terminal is positive and its minus terminal is negative, the motor rotates clockwise. Taking logic 1 as positive and logic 0 as 0V, complete the truth table for the inputs A and B.

Input A	Input B	Motor Operation
0	0	
0	1	
1	0	
1	1	

(4 marks)

A logic subsystem is needed to connect to the inputs A and B of the H-Bridge so that it provides the functions of Stop/Go (SG) and Forward/Reverse (FR). Its truth table is shown.

SG	FR	A	B
0	0	0	0
0	1	0	0
1	0	1	0
1	1	0	1

- 5 (c) (i) State the Boolean expressions for A and B.

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- 5 (c) (ii) By adding appropriate logic gates, complete the circuit diagram for the logic subsystem.

SG ○ ———

————○ A

to H-Bridge

FR ○ ———

————○ B

(5 marks)

11

Turn over for the next question

Turn over ▶

6 The development of autonomous robotic systems is currently hampered by the lack of development of vision sensory systems and efficient power sources.

6 (a) (i) Describe the vision sensory systems that can currently be employed within robotic systems.

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6 (a) (ii) Information from a vision sensory system can be processed by an Artificial Neural Network (ANN) in order to provide shape and pattern recognition. Describe how this is achieved.

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(8 marks)

- 6 (b) Batteries provide the power sources for most current mobile robotic systems. These have a poor energy capacity to weight ratio and take a long time to charge.

Briefly analyse **two** current battery systems that are available to robot designers, identifying the advantages and disadvantages of each type considered.

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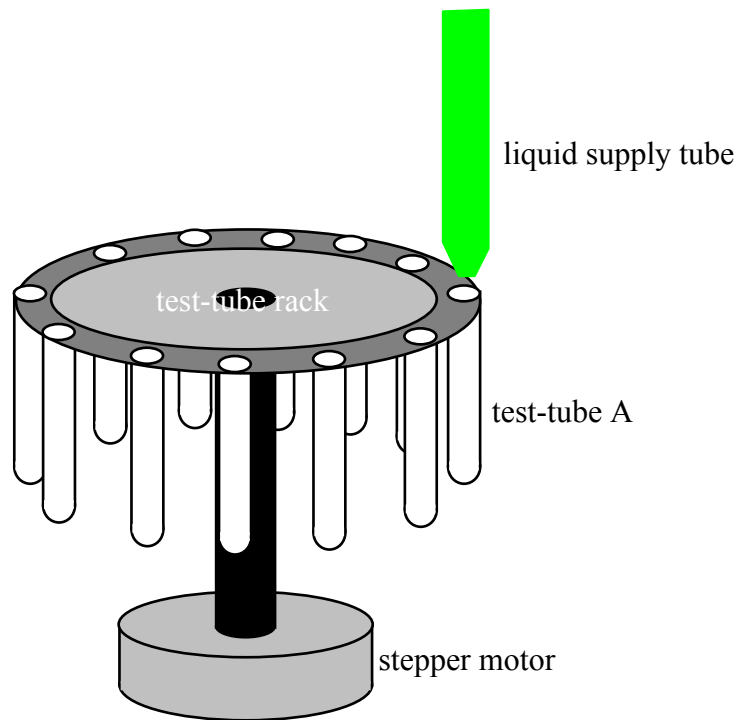
(3 marks)

11

Turn over for the next question

Turn over ▶

- 7 In a forensic laboratory, a circular rack of 12 test-tubes has to be rotated accurately so that each test-tube can be positioned beneath a tube in order that a precise amount of liquid can be added to each test-tube. The arrangement is shown below.



- 7 (a) Briefly describe the different types of electric motors and their control systems that are available to perform this task.

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(3 marks)

- 7 (b) State which motor system you would recommend and justify your recommendation.

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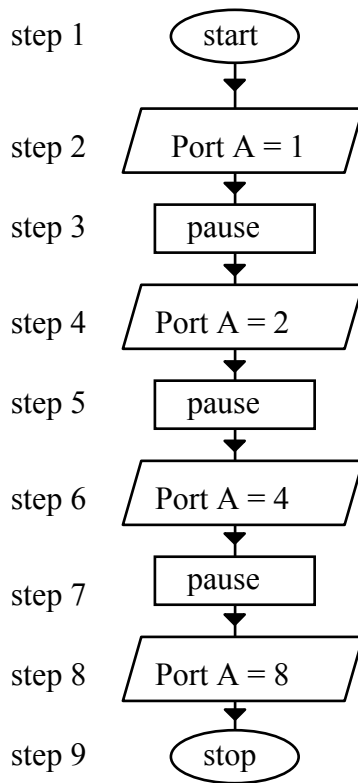
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(3 marks)

It is decided to use a 4 pole, unipolar stepper motor and a microcontroller. The coils of the stepper motor are operated by D₀, D₁, D₂, D₃ of Port A of the microcontroller. The flow diagram below makes the test-tube rack rotate clockwise to the next test-tube.



- 7 (c) What hexadecimal byte must be written to Port A's direction register so that D₀ to D₃ are outputs and D₄ to D₇ are inputs?
(Bit set = Input, Bit reset = output)

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(1 mark)

Question 7 continues on the next page

Turn over ▶

- 7 (d) The *pause* process generates a pause of 50 ms. It is implemented using the microcontroller's 8 bit timing and prescaler registers.
 The prescaler divides the 'instruction clock' pulse by a ratio from 1:2 to 1:256.
 The timing register decrements its value on each prescaler output pulse and generates an interrupt for the microcontroller when it gets to zero. If the instruction clock pulse is 1µs calculate suitable values to load into the prescaler and the timing registers.

Prescaler

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Timing

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(3 marks)

To provide a reference point for the system, an optical switch provides a logic 0 to bit 5 (D₅) of Port A when test-tube A is in line with the liquid supply tube.
 Port A is addressed at 05h and the *working register (accumulator)* of the microcontroller is W.

```
MOVRW, 0x05
ANDW, 0x10
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- 7 (e) (i) What is the purpose of the first statement?

- 7 (e) (ii) What is the purpose of the second statement?

- 7 (e) (iii) How can the program use the zero flag to check the positioning of the test tubes?

(4 marks)

END OF QUESTIONS

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