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Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
 June 2006
 Advanced Level Examination



ELECTRONICS
Unit 4 Electronic Control Systems

ELE4

Tuesday 13 June 2006 1.30 pm to 3.00 pm

For this paper you must have:

- a calculator
- a pencil and ruler

Time allowed: 1 hour 30 minutes

Instructions

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want 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 72.
- The marks for 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			

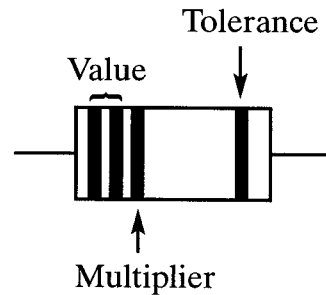
Data Sheet

- 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.

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

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

parallel

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

$$C_T = C_1 + C_2 + C_3$$

parallel

Time constant $T = CR$

A.C. theory $I_{\text{rms}} = \frac{I_o}{\sqrt{2}}$

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

$$X_C = \frac{1}{2\pi fC}$$

reactance

$$X_L = 2\pi fL$$

reactance

$$f = \frac{1}{T}$$

frequency, period

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

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

Astable and Monostable using NAND Gates $f \approx \frac{1}{2RC}$ astable

$T \approx RC$ monostable

555 Astable and Monostable $T = 1.1RC$ monostable

$t_H = 0.7(R_A + R_B)C$
 $t_L = 0.7R_B C$] astable

$f = \frac{1.44}{(R_A + 2R_B)C}$ two resistor circuit

Electromagnetic Waves $c = 3 \times 10^8 \text{ m s}^{-1}$ speed in vacuo

List of BASIC Commands

DIM variable [(subscripts)]

DO [{**WHILE** | **UNTIL**} condition]
[statement block]

LOOP

DO
[statement block]

LOOP [{**WHILE** | **UNTIL**} condition]

FOR counter = start **TO** end [**STEP** increment]
[statement block]

NEXT counter

GOSUB [label | line number]
[statement block]

RETURN

IF condition **THEN**
[statement block 1]

ELSE
[statement block 2]

INKEY\$

INP (port %)

INPUT [;] [“prompt” {;1,}] variable list (comma separated)

LPRINT [expression list] [{ ;1,}]

OUT port%, data%

PRINT [expression list] [{;1,}]

REM remark

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

1 A microcontroller system has an 8-bit data bus.

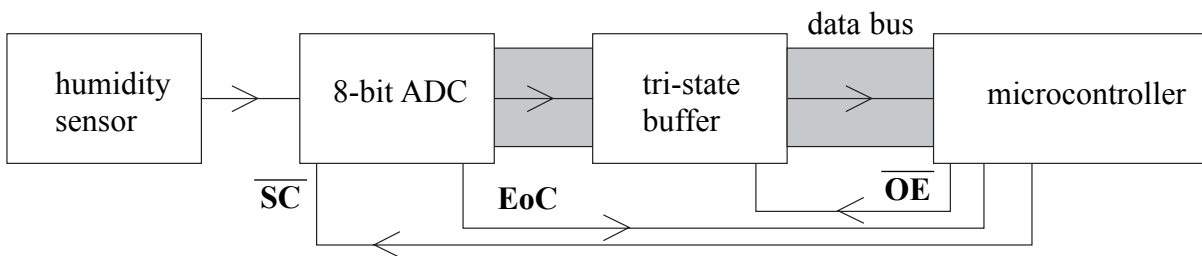
(a) Explain the meaning of the terms

(i) bit,

(ii) data bus.

(2 marks)

In order to connect an analogue humidity sensor to the microcontroller, the arrangement below is used.



SC is the Start Conversion, OE is the Output Enable and EoC is the End of Conversion.

(b) (i) What is the function of the tri-state buffer?

.....

(ii) What must the microcontroller do in order to read information from the ADC?

.....

(2 marks)

(c) (i) Why is an ADC needed in this application?

.....

(ii) What sequence of signals is required between the microcontroller and the ADC for the microcontroller to make a humidity reading?

.....

.....

.....

(4 marks)

(d) The humidity range is 0% to 100%. What is the smallest change in humidity that can be measured by this 8-bit system?

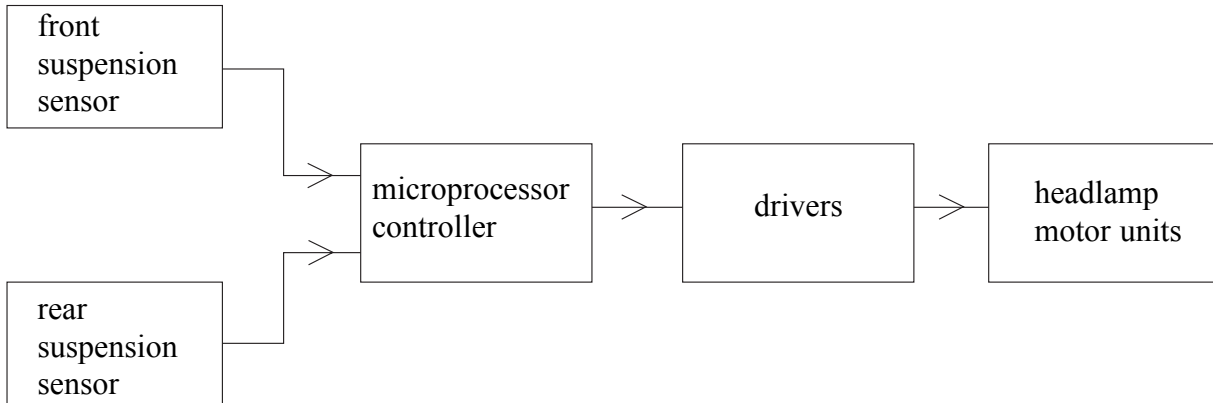
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(1 mark)

Turn over ▶

- 2 European regulations require all car manufacturers who fit HID (High Intensity Discharge) headlamps to also fit them with self-levelling systems in order to avoid glare to oncoming motorists. Information for the *levelness* of a car is obtained from sensors connected to the front and rear suspension of the car.

A simplified system diagram is shown below.



- (a) State, with a reason, whether this is an open or closed loop control system.

.....

.....

(2 marks)

The motors operating the headlamps can be stepper motors or conventional motors.

- (b) (i) What is a stepper motor?

.....

.....

- (ii) Describe the sequence of signals that must be applied to a stepper motor in order for it to rotate.

.....

.....

.....

.....

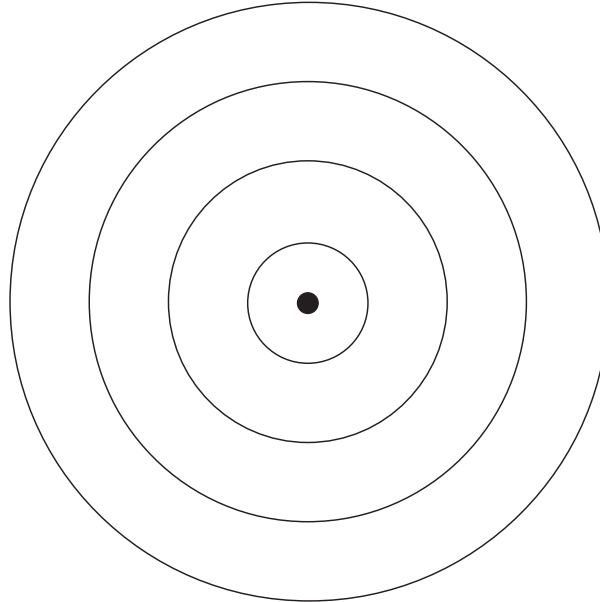
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(3 marks)

(c) In order to determine the rotation of a conventional motor an optical shaft encoder can be used.

(i) Complete the diagram of a 4-bit optical shaft encoder.



(ii) What is the smallest change in rotation that can be measured using a 4-bit optical shaft encoder?

.....

(iii) What additional information about the rotation of a motor shaft is obtainable from an optical shaft encoder that would not be so easily available from an optical slotted disk encoder?

.....

(4 marks)

9

Turn over for the next question

Turn over ▶

- 3 The Disability Discrimination Act requires all public buildings to provide easy access. This usually means that automatically opening and closing doors have to be fitted. Such a system uses a computer to control the automatic doors. A passive infrared (PIR) detector detects a person as they approach the doors and changes D_7 of the computer port &H379 from logic 0 to logic 1. A microswitch detects when the door is fully open and makes D_6 of port &H379 logic 1. A second microswitch detects when the door is fully closed and makes D_5 of port &H379 logic 1. A push switch is also available to open the door and this makes D_4 of port &H379 logic 1 when pushed. A conventional dc motor is used to operate the door and this is controlled by D_0 and D_1 of port &H378 by a suitable driver. The door is opened by writing the byte 02 to port &H378.

The input port information is summarised in the table below.

INPUT PORT &H379

	Logic 0	Logic 1
D_7	person not detected by PIR	person detected by PIR
D_6	door not fully open	door fully open
D_5	door not fully closed	door fully closed
D_4	push switch not operated	push switch operated

- (a) The following code is used to read the information from the input port:

```
A%=INP(&H379)
B%=A% AND &HF0
```

- (i) What type of variable is **A%**?

.....

- (ii) What is the function of the statement **B%=A% AND &HF0** ?

.....

.....

- (iii) State the value of **B%** when the PIR detects a person while the door is fully closed and the push switch is not pressed.

.....

(3 marks)

- (b) The door is closed and the push switch is not pressed.
In the space provided, draw a flowchart to show the process of:

the PIR detecting a person;
the door then moving to open;
the door opening fully.

Include in your flowchart the values you would expect to read from the input port and to write to the output port.

(6 marks)

9

Turn over ►

4 To improve the accuracy of predicting floods from a large river, data from wind speed and direction, date and time are fed into a neural network computer system and its predictions compared to the actual water level of the river that occurred.

(a) How does a neural network differ from a conventional PC in the following areas:

(i) processors;

.....
.....

(ii) memory;

.....
.....

(iii) programming?

.....
.....

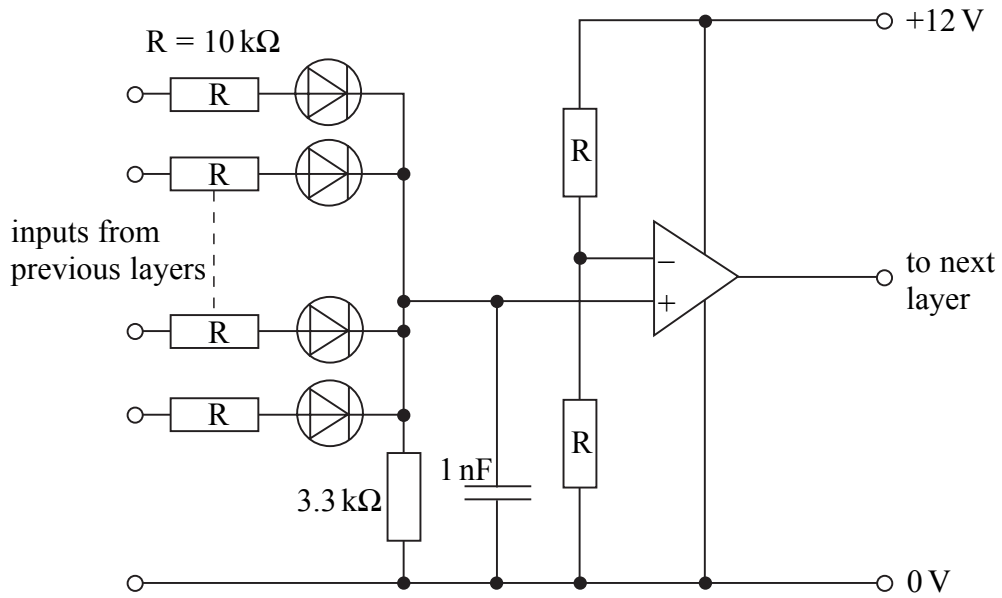
(3 marks)

(b) Explain how a neural network would be able to improve the accuracy of its predictions in comparison to a conventional computer.

.....
.....
.....
.....
.....
.....

(2 marks)

(c) The circuit diagram of a neural network processing element is shown below.



- (i) What is the function of the op-amp in this application?
.....
- (ii) What is the voltage at the inverting input of the op-amp?
.....
- (iii) Explain the input conditions necessary for the output of the op-amp to saturate at the supply voltage in this application.
.....
.....
.....
.....

(4 marks)

Turn over for the next question

Turn over ▶

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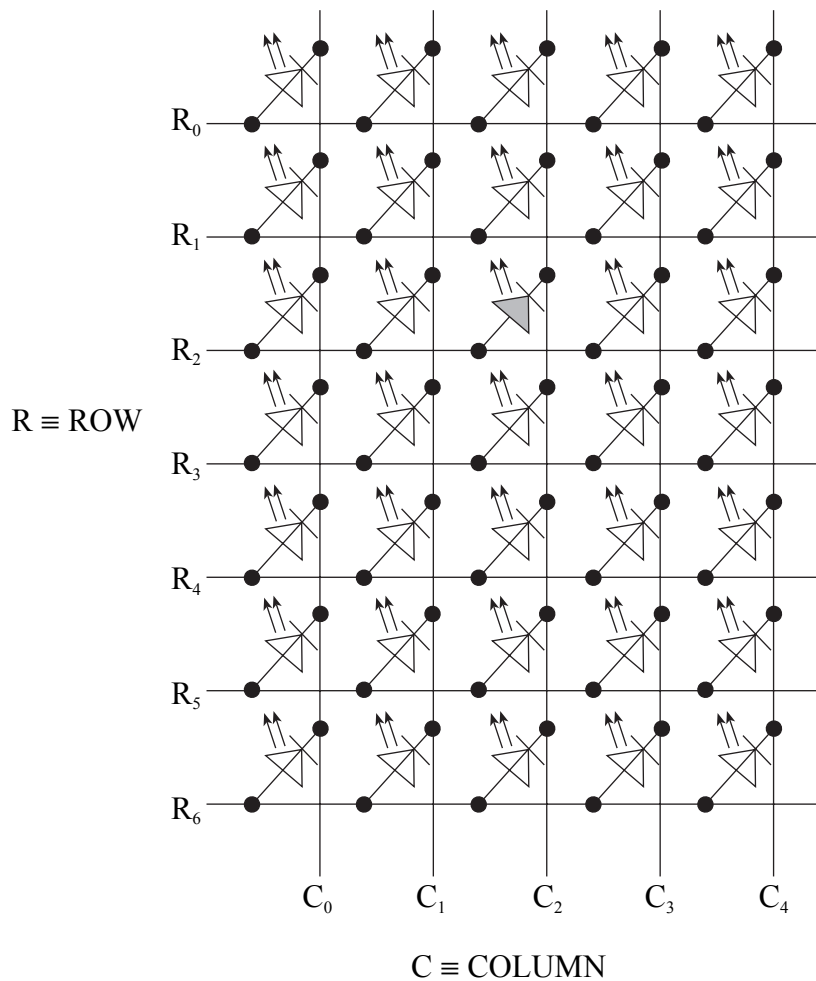
- 5 (a) Give **one** advantage and **one** disadvantage of a dot matrix display over a seven-segment display.

.....

.....

(2 marks)

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



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

.....

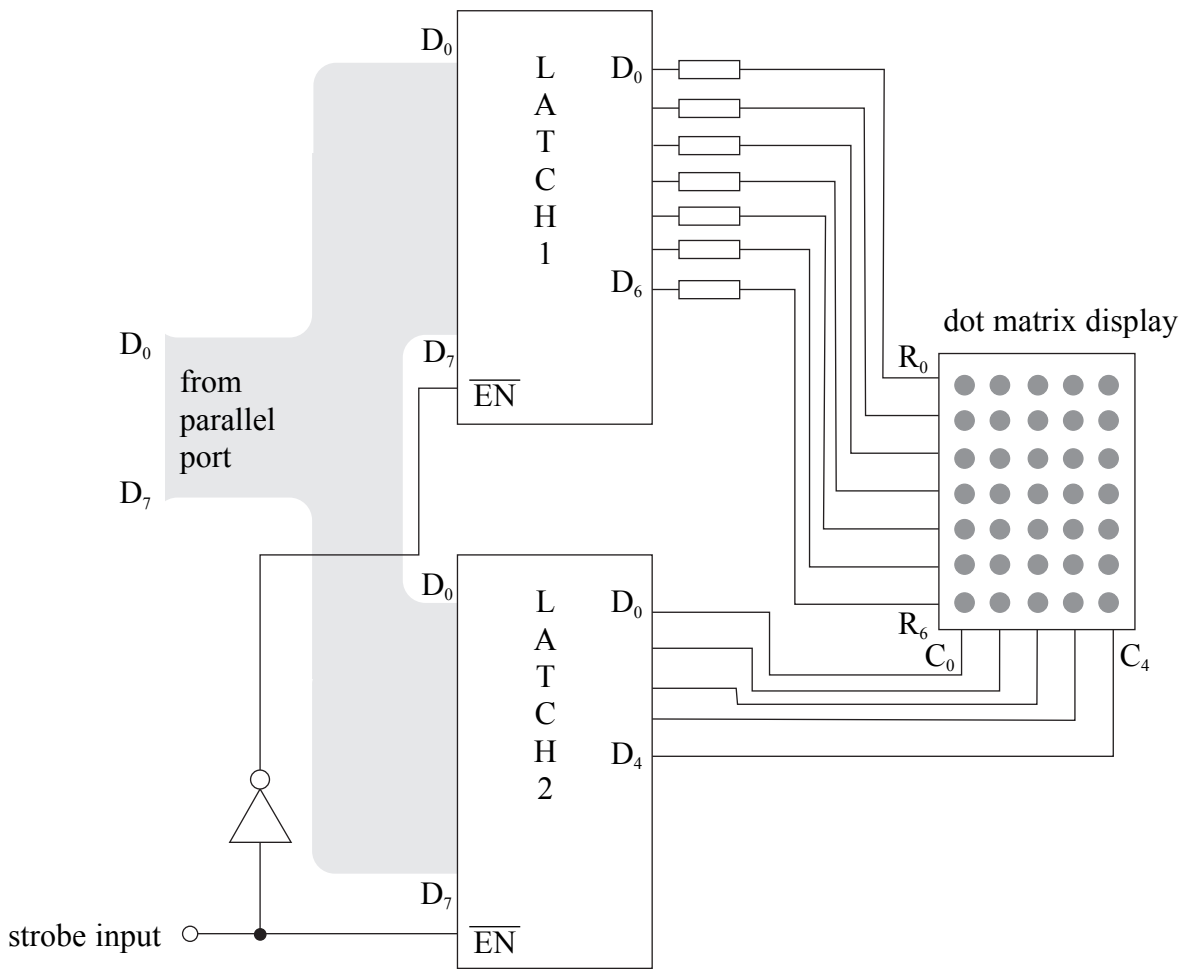
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(2 marks)

Question 5 continues on the next page

Turn over ▶

(c) The interface circuit for the dot matrix display is shown below.



(i) Explain the function of the latches used in this application.

.....

.....

.....

.....

(ii) Explain which latch is written to when the strobe input is at logic 1.

.....

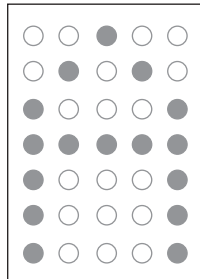
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- (iii) List, in sequence, the binary values that must be written to the COLUMN latch in order for the display to be scanned once.

.....

(3 marks)

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



List, in sequence, the binary values that must be written to the ROW latch.

.....

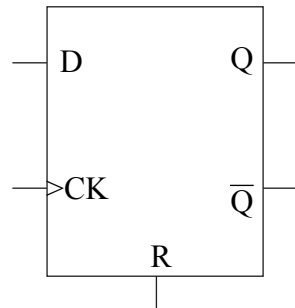
(2 marks)

Turn over for the next question

9

Turn over ▶

- 6 After completing a project using a PIC to display the frequency of an input signal onto a four-digit seven-segment display, a student is disappointed to find that the maximum frequency that it will successfully display is approximately 100 kHz. The student decides to use four D-type flip-flops to form a divide-by-10 circuit to extend the frequency range to 1 MHz. The circuit symbol for a D-type flip-flop is shown below.



- (a) Explain under what conditions the logic state of the D-input of a D-type flip-flop is transferred to the Q output.

.....
(1 mark)

- (b) Explain how the D-type flip-flop must be connected in order to make its output toggle state with each successive clock input pulse.

.....
(1 mark)

- (c) The PIC frequency meter requires an input signal with a mark to space ratio of 1:1.

- (i) Explain what is meant by the term mark to space ratio.

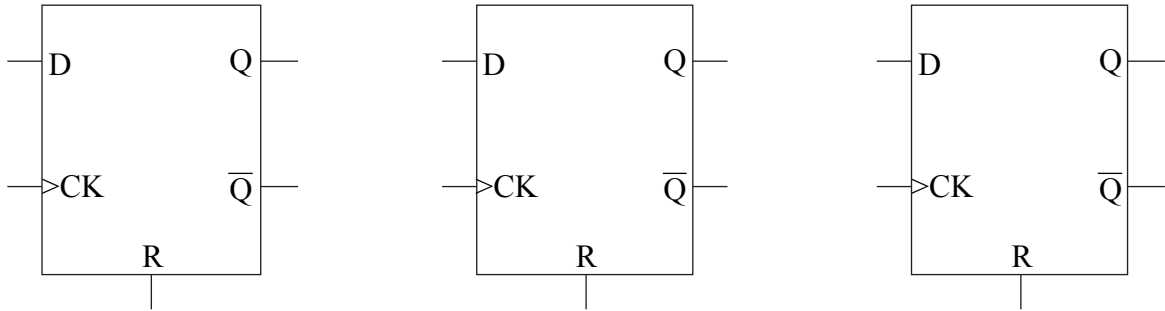
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.....

- (ii) Explain why the output from a toggled D-type flip-flop has a mark to space ratio of 1:1.

.....
.....

(2 marks)

- (d) In order to produce a divide-by-10 circuit with an output mark to space ratio of 1:1, the student arranges three D-type flip-flops as a divide-by-5 circuit and then connects the output of this circuit to a divide-by-2 circuit. Complete the circuit diagram below for a divide-by-5 counter. Add any other components that you need.



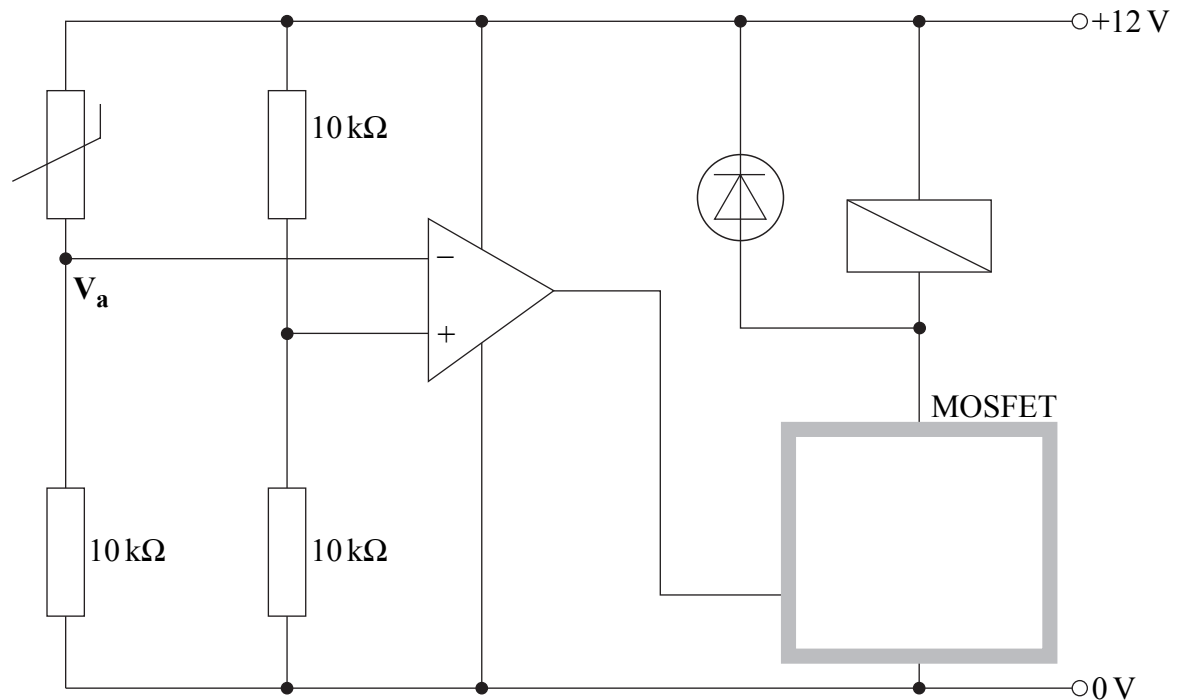
(5 marks)

9

Turn over for the next question

Turn over ▶

- 7 The circuit diagram below is of a thermostat used to maintain the temperature of a gas within an industrial process.



- (a) (i) Draw into the box labelled MOSFET a correctly connected MOSFET symbol.
 (ii) State **two** properties of a MOSFET which make it suitable for use as a buffer.

.....

 (4 marks)

- (b) What is the purpose of the diode in the circuit?

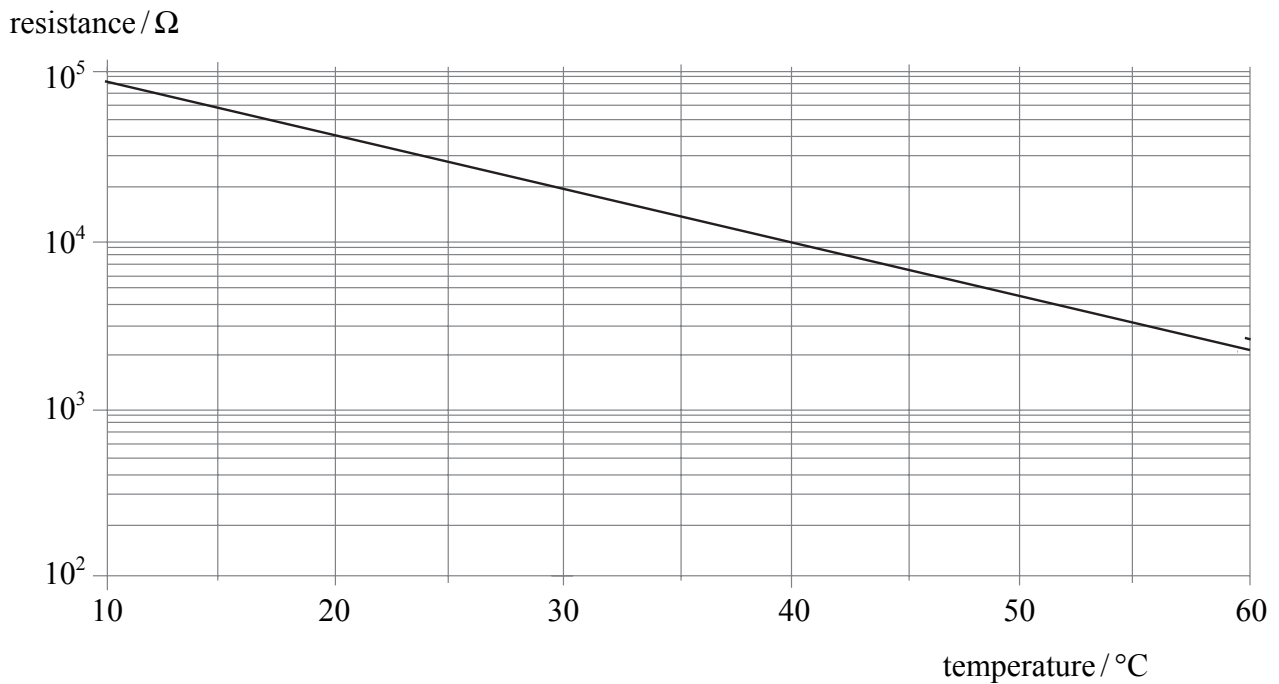
.....

 (2 marks)

- (c) For what range of voltages of V_a will the output of the op-amp be saturated at the positive supply voltage?

.....
 (2 marks)

(d) The characteristic for the thermistor is shown below.



(i) State, with a reason, the temperature the thermostat is set to maintain.

.....

(ii) State **one** way in which the thermostat could be made adjustable.

.....
 (3 marks)

(e) In operation it is found that the relay is continually switching, which causes the contacts of the relay to wear and fail.
 Explain why the relay does this.

.....

(2 marks)

Question 7 continues on the next page

Turn over ▶

(f) In order to overcome the problem of the relay continually switching, it is decided to change the op-amp circuit into a Schmitt trigger.

(i) Add to the circuit diagram on **page 18** a single resistor that will produce this change and label it **R**.

(ii) Calculate the value for **R** that will produce switching levels of 5.75 V and 6.25 V.

.....
.....
.....
.....

(iii) Explain how using a Schmitt trigger will affect the accuracy with which the temperature of the gas is maintained.

.....
.....

(5 marks)

END OF QUESTIONS