AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level
ELECTRONICS

Unit 4 Programmable Control Systems

Tuesday 14 June 2016 Morning Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:
- a pencil and a ruler
- a calculator
- Data Sheet (enclosed).

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at 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 each question are shown in brackets.
- The maximum mark for this paper is 80.

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

1 Many different subsystems and processes are present in microprocessor control systems or in microcontrollers.

Table 1 contains the names of 18 subsystems and processes.

Table 1

ADC	data latch	power supply
address bus	flag	program counter
ALU	interrupt	ROM
clock	PIC	stack
DAC	polling	tri-state buffer
data bus	port	watch dog timer

Table 2 contains 11 descriptions of subsystems and processes.

Write the correct name of each description in **Table 2** from the names given in **Table 1**. Each name may be used once, more than once or not at all. The first line has been completed for you.

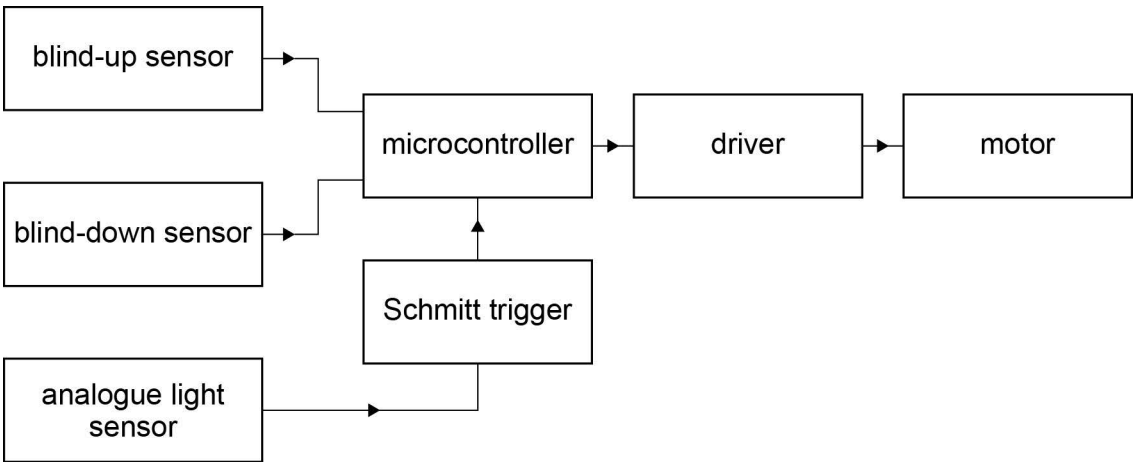
[10 marks]

Table 2

Description	Name
Interfaces a microprocessor to an analogue system.	DAC
This keeps all subsystems within a microcontroller system synchronised.	
All arithmetic and logic operations are carried out in this subsystem.	
A bi-directional bus within a microprocessor.	
A temporary store for data after being sent to an output port.	
Interfaces an analogue input signal to a microprocessor.	
Isolates an input port from a microprocessor when it is not being read.	
A process that monitors the state of an input port.	
An area of memory used by a microprocessor as temporary storage for its internal processes.	
A process by which an external system can request assistance from a microcontroller.	
The location of the control program in a microcontroller.	

2 The system diagram for an automatic window blind is shown in **Figure 1**.

Figure 1



An analogue light sensor monitors the light level outside.
When it is dark, the motor drives the blind down until it reaches the blind-down sensor.
When it is light, the motor drives the blind up until it reaches the blind-up sensor.

2 (a) (i) State why an analogue sensor cannot be connected directly to a digital input on the microcontroller.

[1 mark]

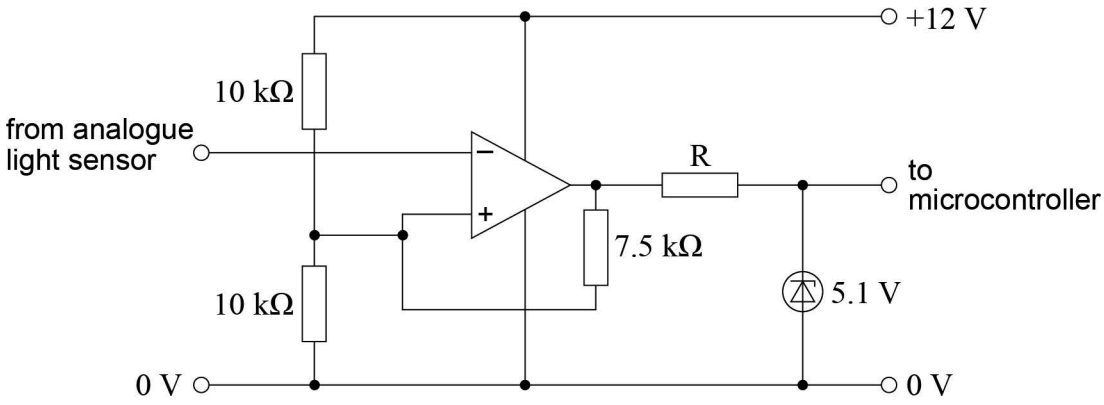
2 (a) (ii) Explain why the Schmitt trigger is used in this application rather than a comparator.

[2 marks]

Question 2 continues on the next page

2 (b) The circuit diagram of the Schmitt trigger is shown in **Figure 2**.

Figure 2



2 (b) (i) Explain the function of the resistor, R, and the Zener diode.

[2 marks]

2 (b) (ii) Show that the upper switching level of the Schmitt trigger is approximately 8.4 V.

[3 marks]

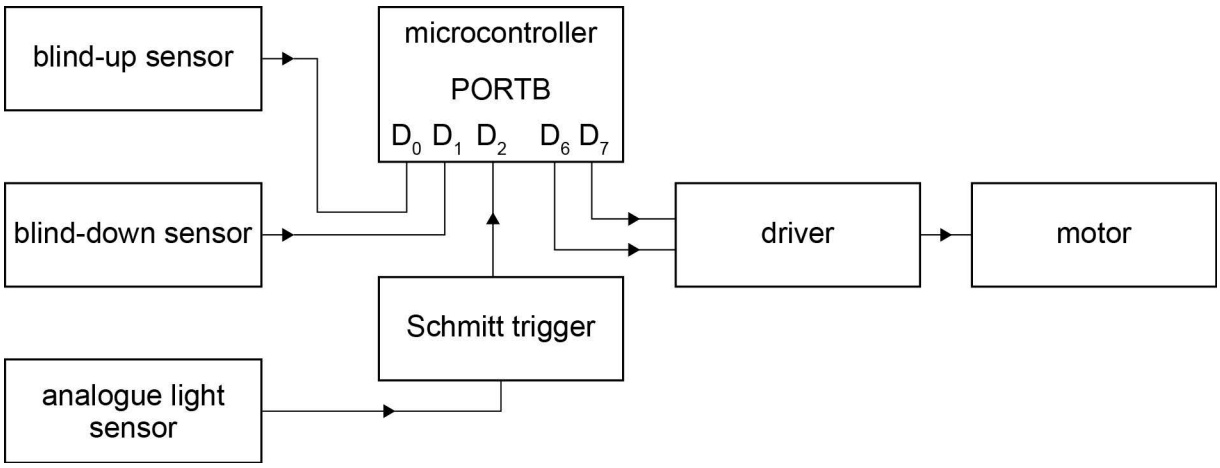
2 (b) (iii) Calculate the lower switching level of the Schmitt trigger.

[2 marks]

3 You do not need to have attempted **Question 2** before attempting this question.

The system diagram for an automatic window blind is shown in **Figure 3.**

Figure 3



An analogue light sensor monitors the light level outside.
When it is dark, the motor drives the blind down until it reaches the blind-down sensor.
When it is light, the motor drives the blind up until it reaches the blind-up sensor.

3 (a) The sensors and driver are connected to **PORTB** of the microcontroller.

State the assembly instructions needed to set bits D_0 to D_3 of **PORTB** as inputs and D_4 to D_7 as outputs.

[3 marks]

Question 3 continues on the next page

3 (b) The blind-up sensor is connected to D_0 of **PORTB**.
The sensor only gives a logic 1 when the blind is up.

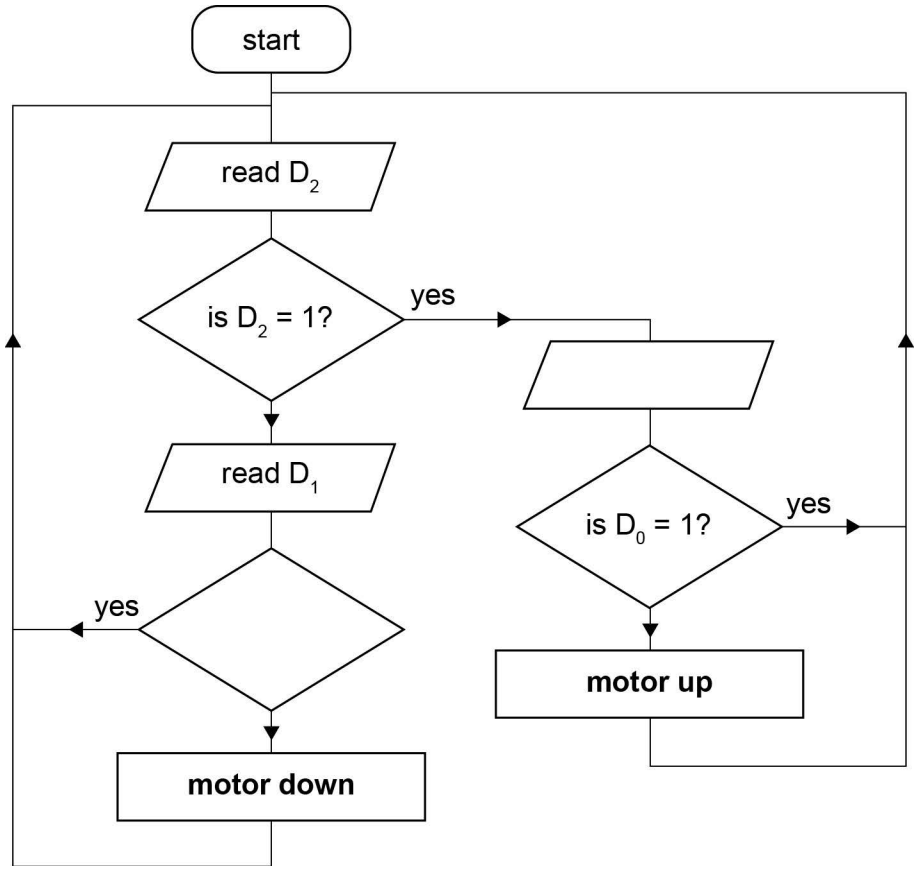
The blind-down sensor is connected to D_1 of **PORTB**.
The sensor only gives a logic 1 when the blind is down.

The Schmitt trigger is connected to D_2 of **PORTB** and gives a logic 1 output when it is light and logic 0 when it is dark.

Complete the flow chart in **Figure 4** to show how the input states are monitored and how the subroutines **motor down** and **motor up** are called as needed.

[2 marks]

Figure 4



3 (c) **Table 3** shows how the motor driver is controlled by bits D_6 and D_7 of **PORTB**.

Table 3

D_7	D_6	Motor state
0	0	off
0	1	motor moves blind down
1	0	motor moves blind up
1	1	off

3 (c) (i) Circle the number that must be written to **PORTB** to move the blind down.

[1 mark]

0x04 0x08 0x40 0x80

3 (c) (ii) Circle the number that must be written to **PORTB** to move the blind up.

[1 mark]

0x04 0x08 0x40 0x80

3 (d) When called, the **motor down** subroutine:

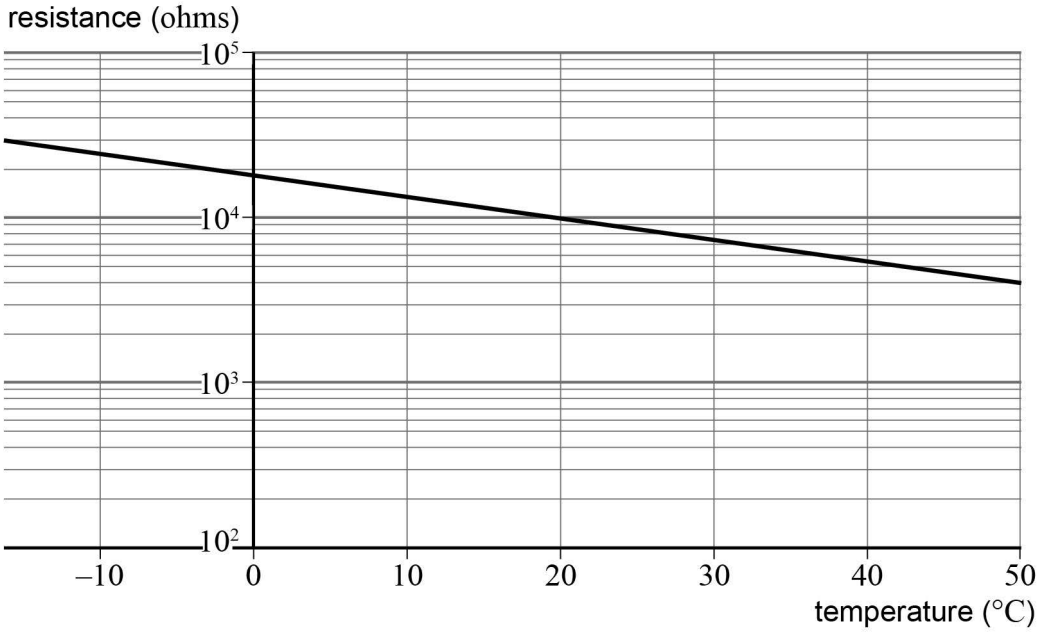
- sets **PORTB** for the motor to lower the blind
- polls the state of the blind-down sensor until it is at logic 1
- sets **PORTB** to turn the motor off
- returns.

Write the assembler code needed to poll the state of the blind-down sensor until it is at logic 1.

[3 marks]

4 A gardener wants to remotely monitor the temperature in his greenhouse from inside his home.
He decides to use a thermistor as the temperature sensor.
The characteristic of the thermistor is shown in **Figure 5**.

Figure 5



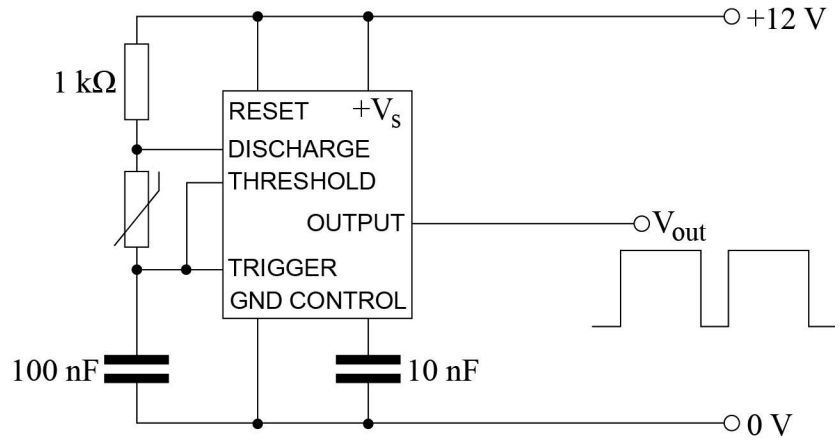
4 (a) Select from the following values the resistance of the thermistor at 0 °C.
Circle your answer.

[1 mark]

10.8 kΩ 14 kΩ 18 kΩ 22 kΩ

4 (b) The thermistor is used in the 555 astable circuit shown in **Figure 6.**

Figure 6



The resistance of the thermistor is 4 kΩ at 50 °C.

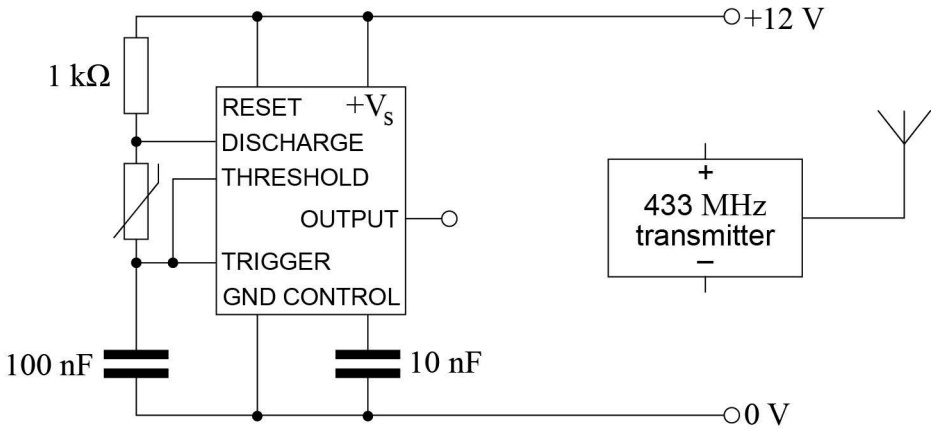
Show that the time that the output of the astable is low at this temperature is approximately 280 μs.

[2 marks]

4 (c) Complete the connections to the transmitter in **Figure 7** so that the transmitter is switched on when the output of the 555 is low.

[1 mark]

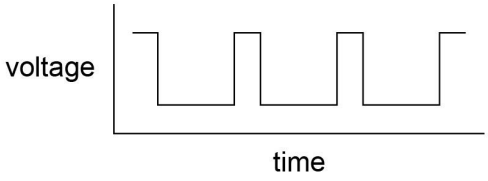
Figure 7



Question 4 continues on the next page

4 (d) The output of the receiver in the gardener's home is shown in **Figure 8**.

Figure 8



The receiver output is connected to bit D_0 of **PORTA** of a microcontroller. This port is polled by the microcontroller. The microcontroller has a $1\ \mathrm{MHz}$ clock.
The subroutine used to measure the time that the receiver output is high is:

```
label1:
        MOVW    0x00
        MOVWR   0xA0
label2:
        MOVRW   PORTA
        ANDW    0x01
        JPZ     label2
label3:
        INC     0xA0
        MOVRW   PORTA
        ANDW    0x01
        JPZ     label4
        JMP     label3
label4:
        RETURN
```

4 (d) (i) State the function of the section of code between label1 and label2.

[1 mark]

4 (d) (ii) State the function of the section of code between label2 and label3.

[1 mark]

4 (d) (iii) Describe the function of the section of code between label3 and label4.

[2 marks]

4 (e) When the temperature is $50\ °C$, the output of the receiver is high for $280\ \mu s$.

Estimate the value stored in $0xA0$ at the end of each pulse from the receiver.

[2 marks]

Turn over for the next question

5 **Figure 9** shows the top view and front view of a white-line-following robot.

Figure 9

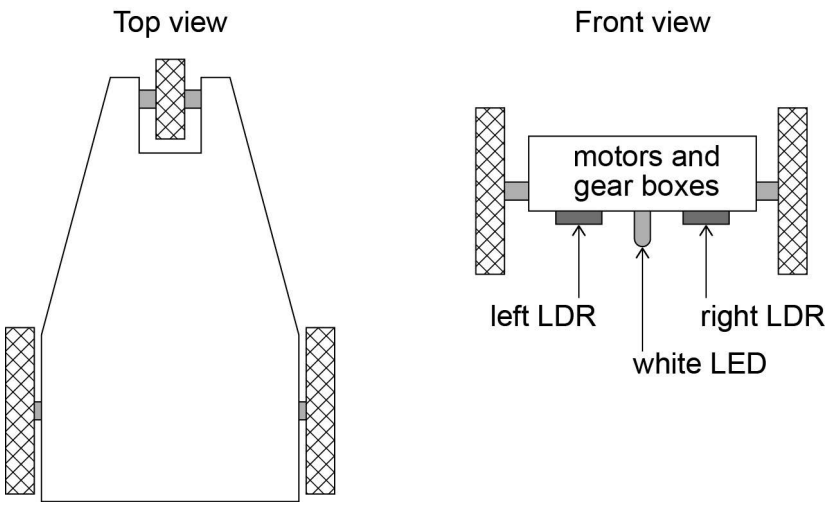
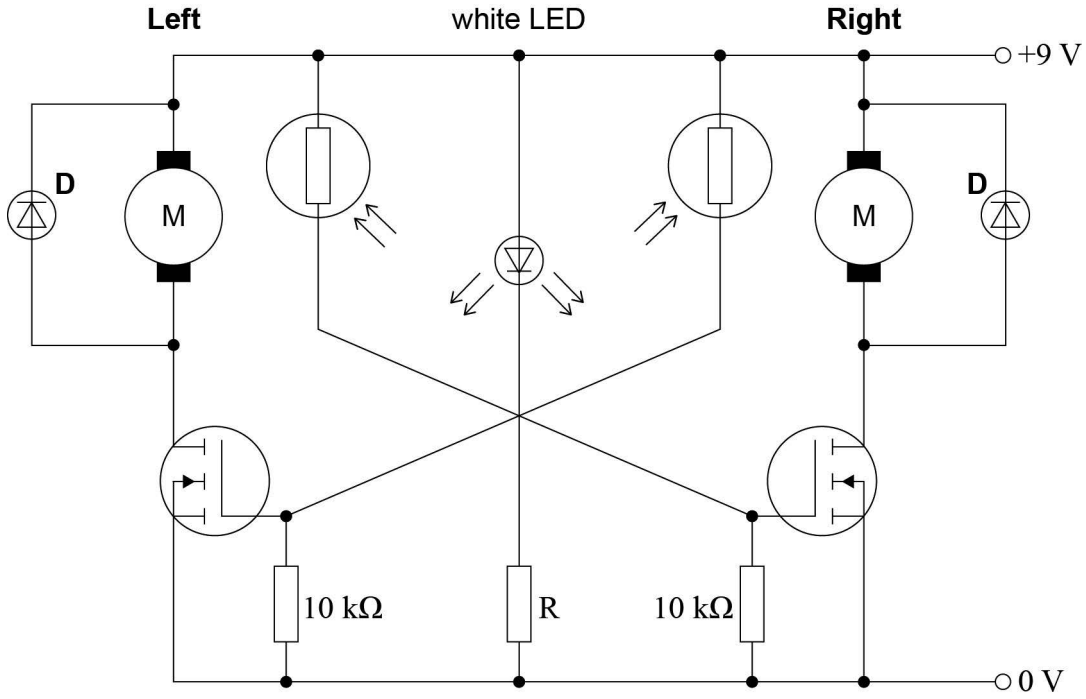


Figure 10 shows the circuit diagram of the motor control system.

Figure 10



5 (a) State the function of the two diodes labelled **D** in **Figure 10**.

[1 mark]

5 (b) The LED illuminates the white line that is being followed. The LED has a forward voltage of $3.2\ \text{V}$ and a maximum current of $30\ \text{mA}$.

Calculate a suitable value for the series resistor, R, in **Figure 10**.

[2 marks]

5 (c) The MOSFETs need a voltage from gate to source of $2.6\ \text{V}$ for them to conduct any current from drain to source.

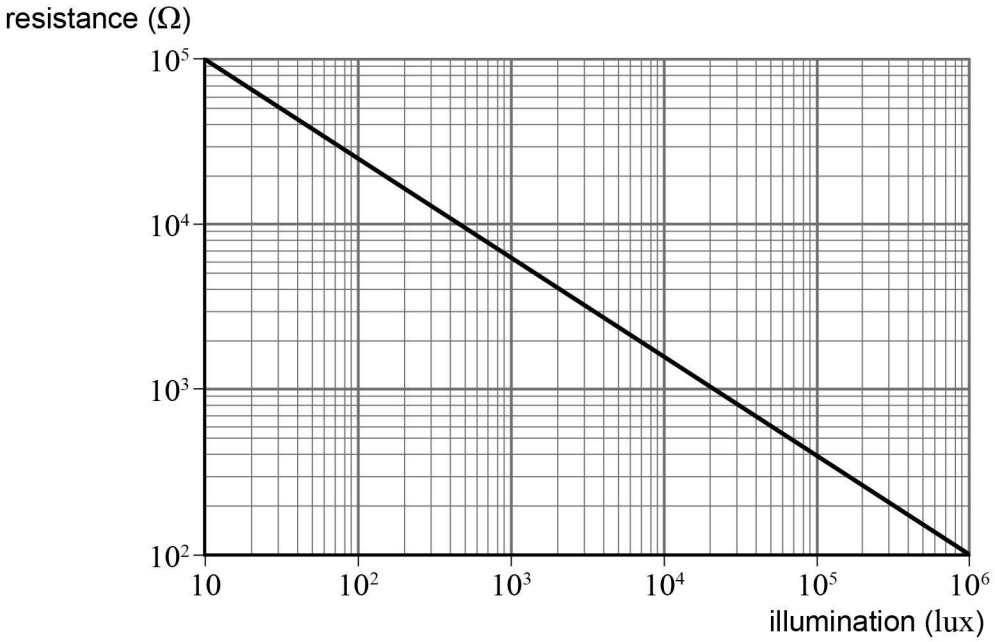
Show that the maximum resistance that the LDRs can have in order to turn on the MOSFETs is approximately $25\ \text{k}\Omega$.

[2 marks]

Question 5 continues on the next page

5 (d) **Figure 11** shows the characteristic of the LDRs.

Figure 11



State the minimum light intensity that must reach the LDRs so that the motors switch on.

[1 mark]

5 (e) Describe how the electronic circuit will control the robot as it follows a white line that turns to the right.

[2 marks]

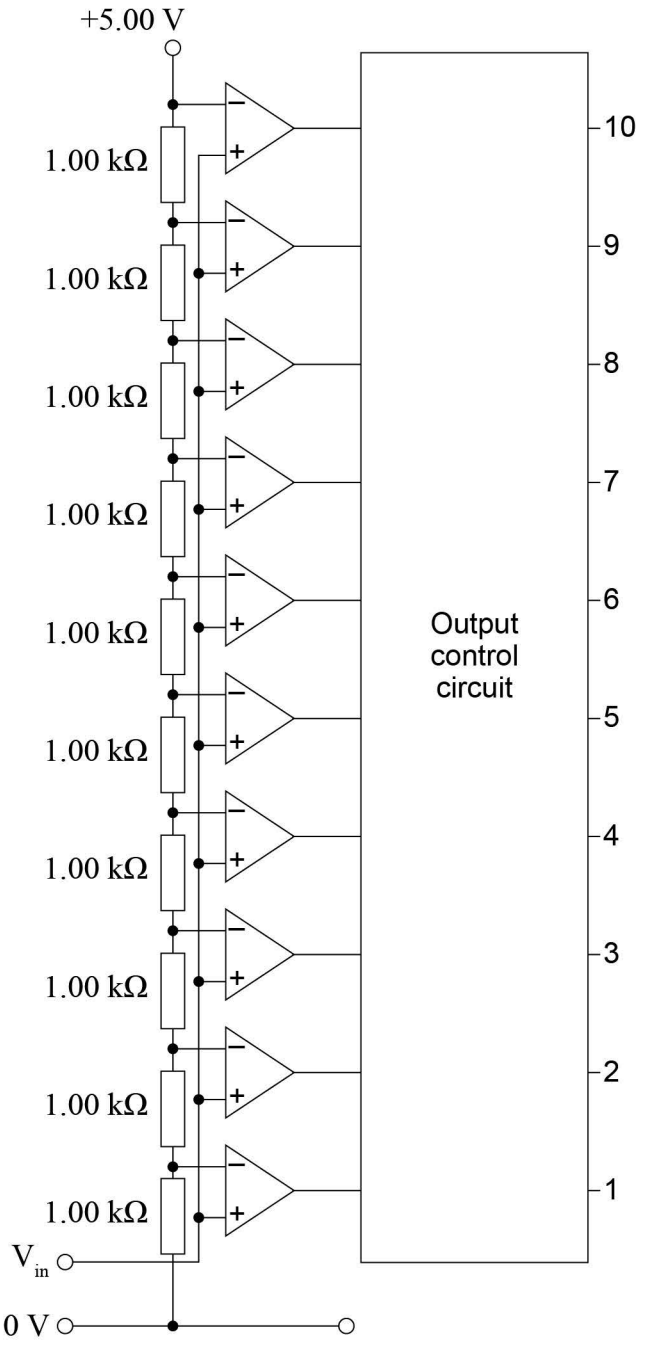
5 (f) Explain why stepper motors could not be used to replace the conventional motors shown in this circuit.

[2 marks]

Turn over for the next question

6 The LM3914 is an integrated circuit containing 10 op-amp comparators and an output control circuit to produce 10 digital outputs. This is shown in **Figure 12**.

Figure 12



6 (a) (i) State the property of an op-amp which makes it suitable for use as a comparator.

[1 mark]

6 (a) (ii) The arrangement of comparators in **Figure 12** can be used as the basis of a Flash ADC.

Calculate the resolution of an ADC based on this circuit.

[1 mark]

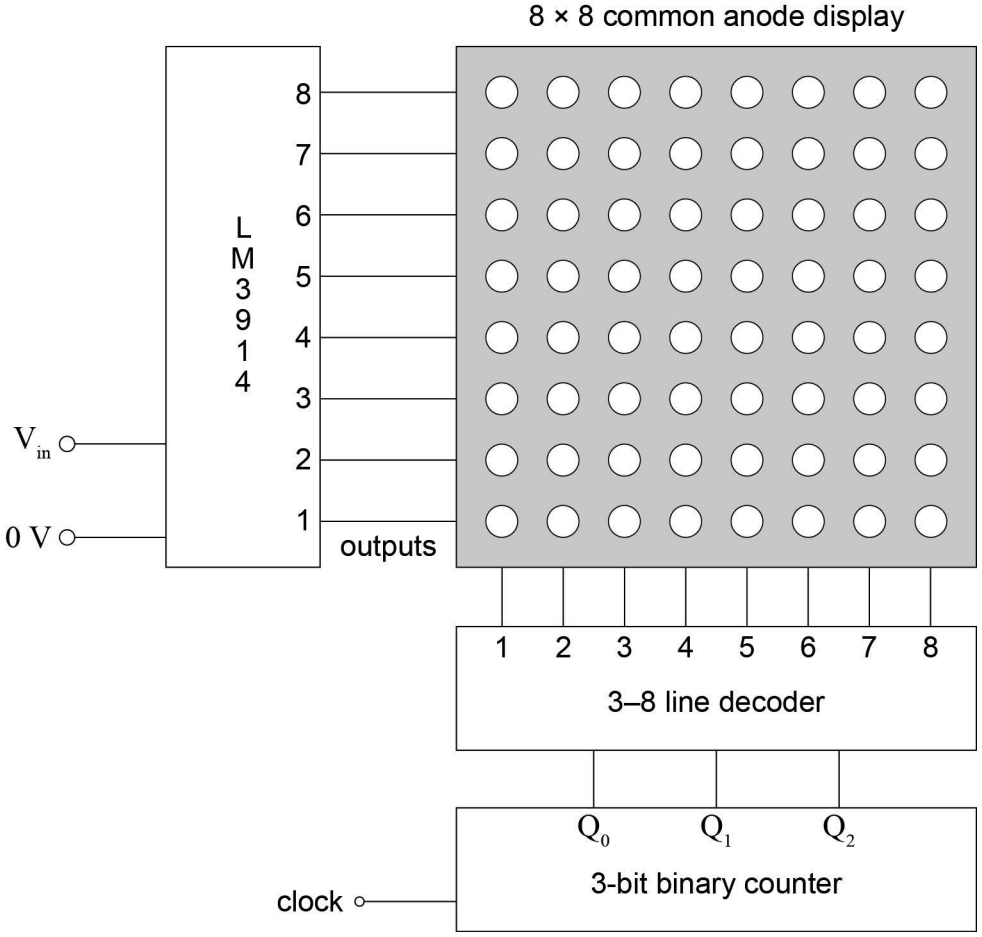
_____

_____

Question 6 continues on the next page

6 (b) A student experiments with making an LED oscilloscope using the LM3914.
He also uses an 8x8 dot matrix display, a 3-bit binary counter and a 3–8 line decoder.
The LM3914 is configured so that as V_{in} increases the most significant output goes **low**.
Only **one** output is low at any time.
In this application only the first 8 outputs are used.
The circuit diagram is shown in **Figure 13**.

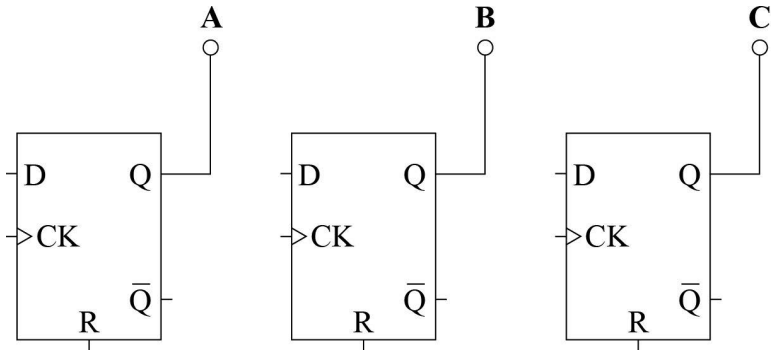
Figure 13



Complete the circuit diagram in **Figure 14** to show how three rising edge triggered D-type flip-flops can be connected to form a 3-bit binary up counter.
Label the clock input.

[4 marks]

Figure 14



6 (c) The truth table for the 3–8 line decoder is shown in **Table 4.**

Table 4

Inputs			Outputs							
C	**B**	**A**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0	0
0	1	1	0	0	0	1	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0
1	0	1	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	1

State the Boolean expression for output 6.

[1 mark]

6 (d) The input to the LM3914 is set to $2.1\ \mathrm{V}$ and the input to the 3-bit binary counter is connected to an $800\ \mathrm{Hz}$ astable.

Describe and explain what will be seen on the display.

[3 marks]

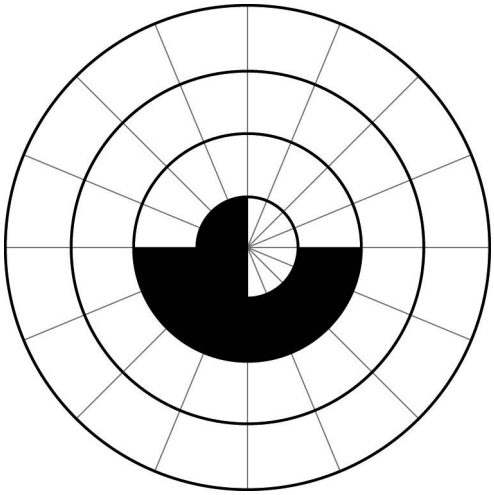
7 Shaft encoders are usually made to give either a binary coded output or a Gray coded output.

7 (a) State the advantage that a Gray coded shaft encoder has over a binary coded shaft encoder.

[1 mark]

7 (b) **Figure 15** shows a partially completed Gray coded shaft encoder.

Figure 15



Complete the diagram by shading in the correct areas.

[3 marks]

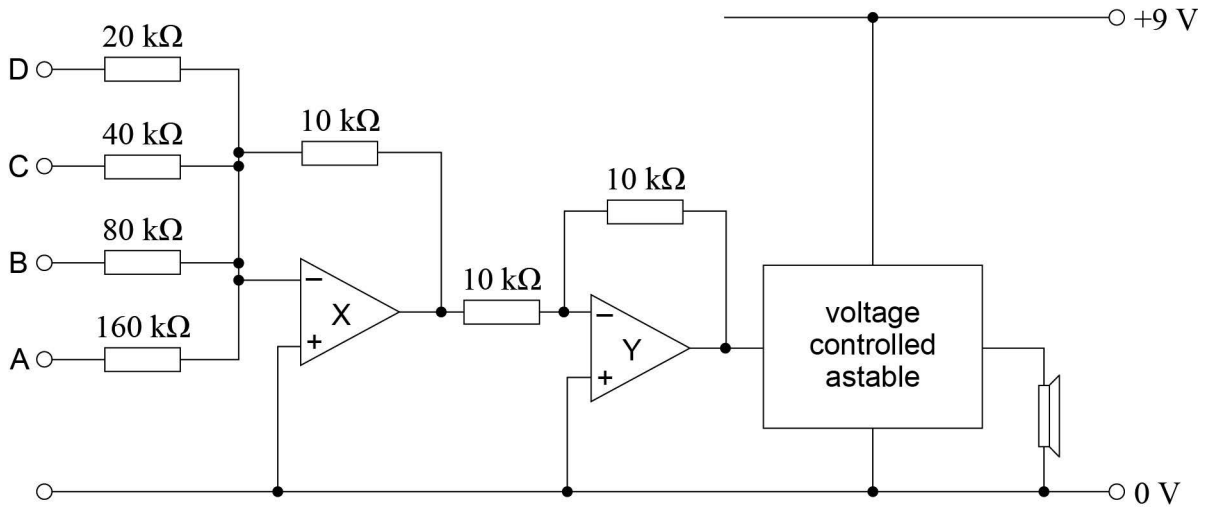
7 (c) A student fits a Gray coded shaft encoder on the wheel of a push-along toy she has been making for a young child. She uses four reflective opto-switches as sensors for the shaft encoder.

Describe a **reflective opto-switch**. You may use a diagram if you wish.

[2 marks]

7 (d) The student wants the toy to make sounds as it is pushed along.
The output from the opto-switches is connected to a Digital to Analogue Converter (DAC). The output from the DAC is connected to a voltage controlled astable as shown in **Figure 16**.

Figure 16



7 (d) (i) The op-amp power supplies are ±9 V.
The outputs from the opto-switches are either 0 V or +5 V.

Calculate the output voltage of op-amp X when all of the opto-switches are giving a logic 1 output.

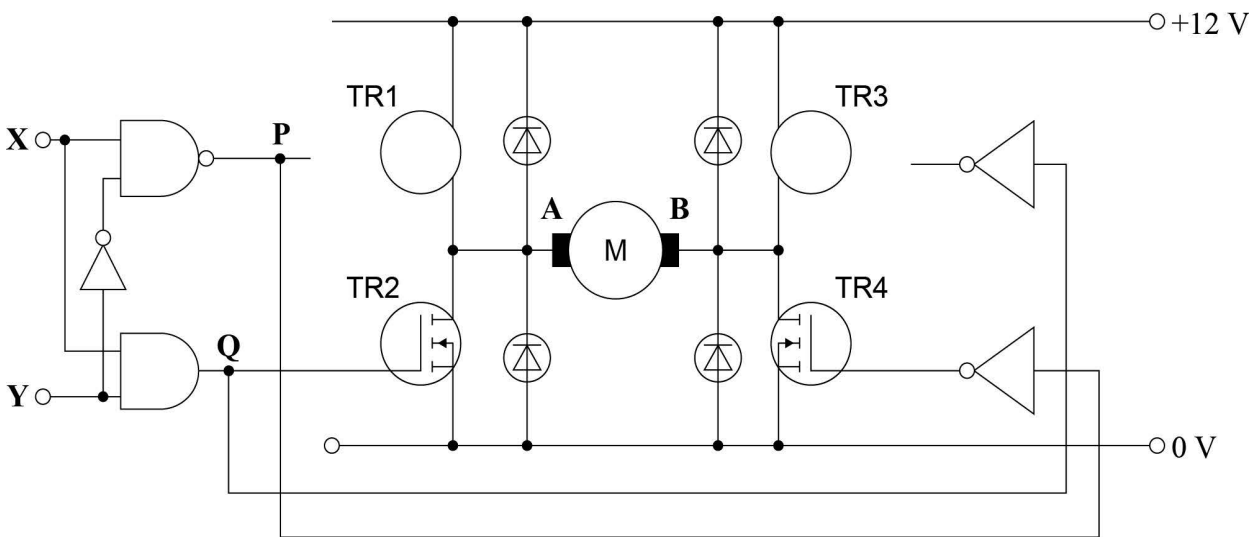
[3 marks]

7 (d) (ii) State the function of op-amp Y.

[1 mark]

8 **Figure 17** shows an incomplete circuit diagram for an H-bridge driver.

Figure 17



8 (a) (i) Complete **Figure 17** by adding the correct symbols for the **two** missing MOSFETs.

[2 marks]

8 (a) (ii) State the purpose of the diodes.

[1 mark]

8 (b) The motor is **not** powered under the following three conditions:

1. TR1 and TR3 are conducting, while TR2 and TR4 are **not** conducting.
2. TR1 and TR3 are **not** conducting, while TR2 and TR4 are conducting.
3. All MOSFETs are **not** conducting.

Describe any differences to the behaviour of the motor in these three conditions.

[2 marks]

8 (c) Referring to **Figure 17**:

when point **A** is positive and point **B** is negative, the motor rotates clockwise,
when point **B** is positive and point **A** is negative, the motor rotates anticlockwise.

Complete the truth table (**Table 5**) for the H-bridge control system shown in **Figure 17.**

[5 marks]

Table 5

X	Y	P	Q	A	B	Motor state
0	0					
0	1					
1	0					
1	1					

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED