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	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2014

Electronics ELEC4

Unit 4 Programmable Control Systems

Thursday 5 June 2014 1.30 pm to 3.00 pm

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

Time allowed
- 1 hour 30 minutes

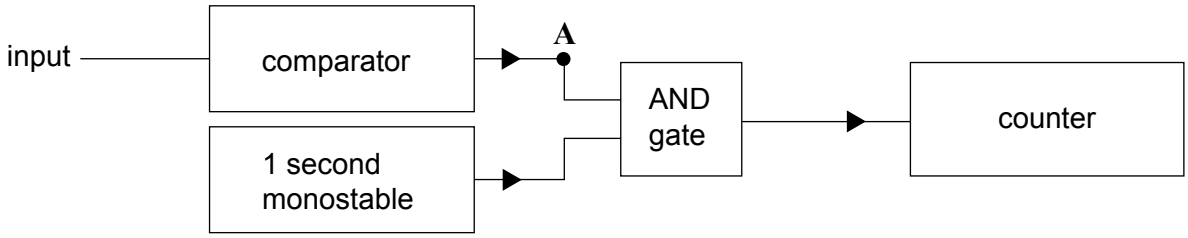
Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work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

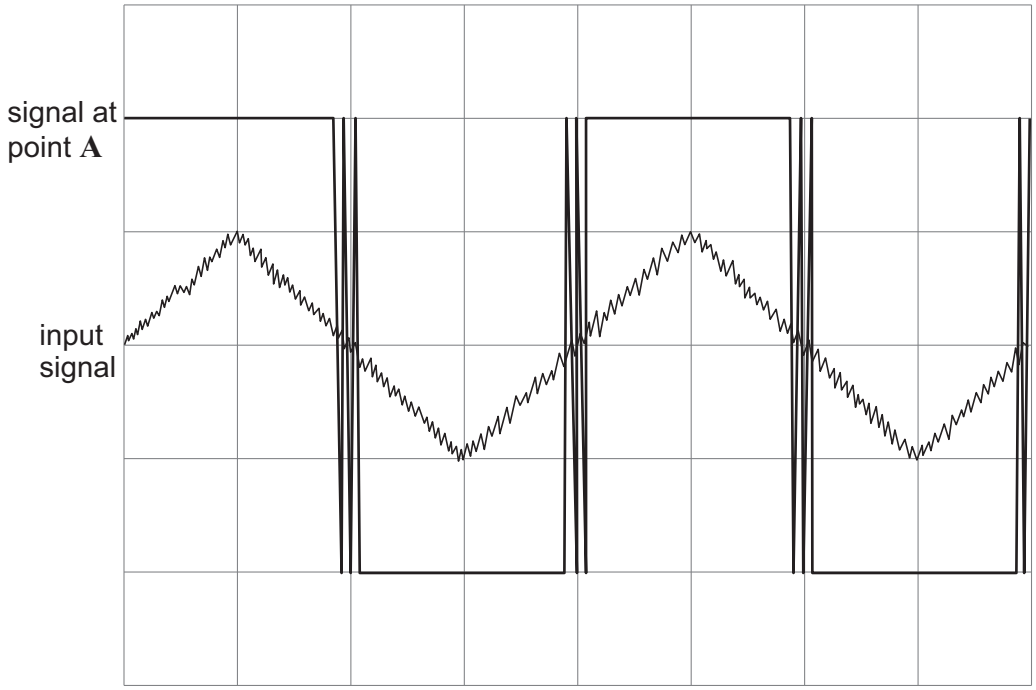
1 A student has made a frequency meter, based on the system diagram in **Figure 1**. The counter counts the number of pulses from the AND gate in 1 second.

Figure 1



When tested, it is found that the frequency shown is always too high. An oscilloscope is used to measure the input signal and the signal at point **A**, as shown in **Figure 2**.

Figure 2



1 (a) Referring to the waveform of the two signals in **Figure 2**, explain why the frequency counter reading is too high.

[2 marks]

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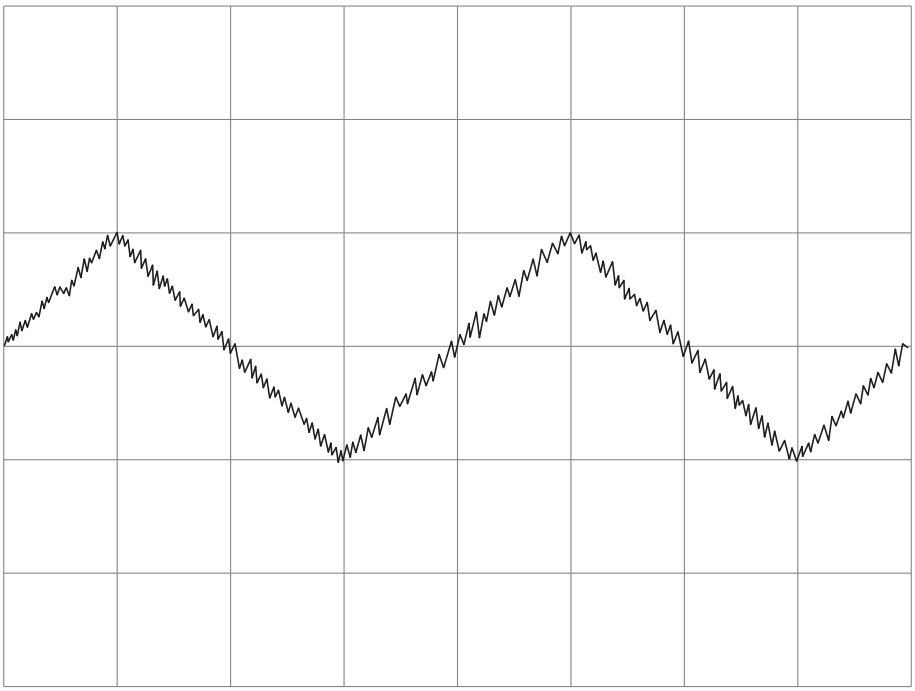
1 (b) The comparator is replaced by a Schmitt trigger. Use the graph of the input signal, which is repeated in **Figure 3**, to explain how a Schmitt trigger might improve the operation of the circuit.

[3 marks]

Figure 3



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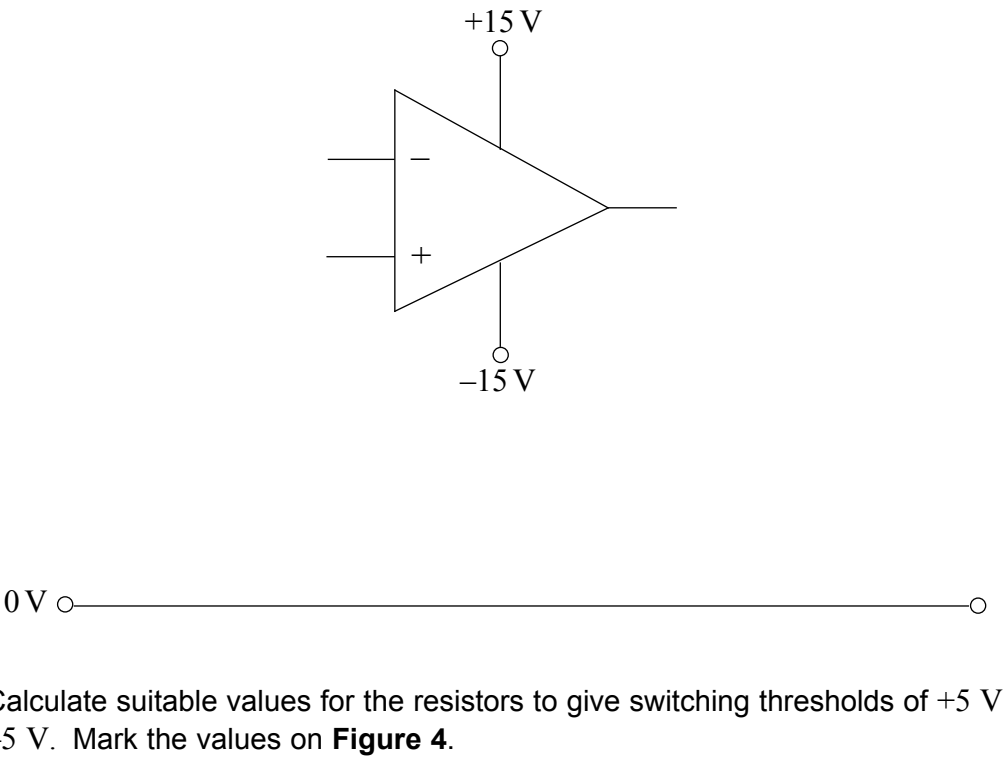
Question 1 continues on the next page

1 (c) (i) Complete the circuit diagram in **Figure 4** of an inverting Schmitt trigger. Label the input and output.

[3 marks]

Figure 4



1 (c) (ii) Calculate suitable values for the resistors to give switching thresholds of +5 V and −5 V. Mark the values on **Figure 4**.

[4 marks]

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12

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

2 To generate timing delays, the AQA microcontroller contains a prescaler. The prescaler is controlled by an inbuilt 8-bit specialist register called **PRE**.

2 (a) (i) When **PRE** is loaded with a value of 15, the prescaler will divide the clock frequency by 16. If the clock frequency of the microcontroller is 1 MHz, calculate the time period of the signal from the prescaler.

[1 mark]

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2 (a) (ii) State the assembler code necessary to load **PRE** with a value of 15.

[2 marks]

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2 (b) (i) Another specialist register is called **TMR**. It takes the output from the prescaler as a clock and counts down from a preset value to zero.
If **PRE** has a value of 15, calculate the value that must be loaded into **TMR** for it to take 4 ms to count down to zero.
Give your answer in hexadecimal.

[2 marks]

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2 (b) (ii) When **TMR** reaches zero it sets bit 1 of the Status (Flag) Register, **SR**.
Write the assembler code needed for the processor to be able to read **SR** and isolate bit 1.

[2 marks]

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2 (c) The assembler code for **PRE** and **TMR** to give a 4 ms delay is stored in a subroutine called **TIME1**, which starts its delay when called by the main program. Using this subroutine and the general purpose register with an address of **0xB0**, assembler code is needed to give a delay of approximately 1 second.

2 (c) (i) Calculate how many times **TIME1** must be called to give a delay of 1 second.

[1 mark]

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2 (c) (ii) Write the assembler code to load the register **0xB0** with this value.

[1 mark]

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2 (c) (iii) With the total number of loops initially stored in **0xB0**, write the assembler code needed to give a delay of approximately 1 second.

[3 marks]

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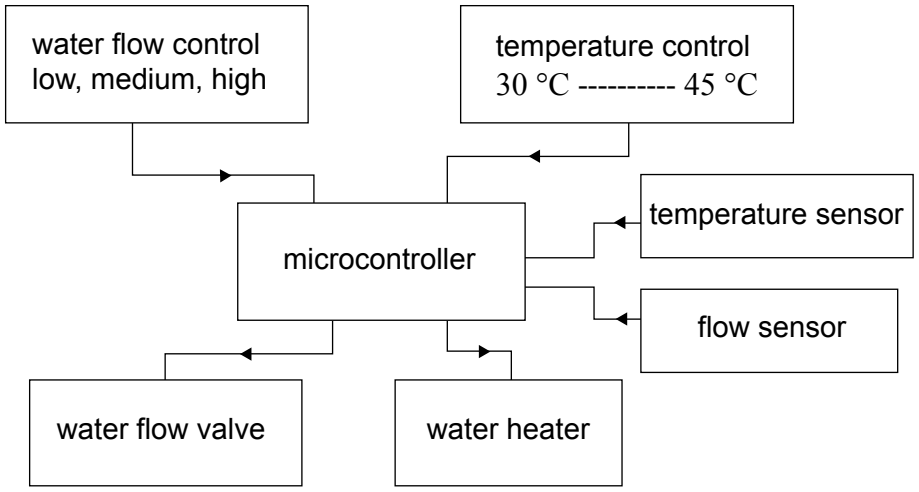
3 **Figure 5** is the system diagram for the control of an electric shower.

Figure 5



The microcontroller reads the settings of the water flow and temperature controls.
It controls the water flow rate using the water flow valve.
It controls the temperature using the water flow valve and the water heater.

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

[2 marks]

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3 (b) The temperature sensor gives an analogue output voltage, with 0 V representing 0 °C and 5 V representing 50 °C. This voltage is digitised using an 8-bit ADC.
Estimate, using a calculation, the smallest temperature change that can be detected by the microcontroller.

[2 marks]

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3 (c) The water flow valve is controlled by a two-phase bipolar stepper motor.
Explain the meaning of each of the following terms.

[3 marks]

stepper motor.....

.....

bipolar .....

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two-phase .....

.....

3 (d) Each of the coils of the stepper motor is controlled by an H-bridge driver.
Each H-bridge driver consists of two n-channel and two p-channel MOSFETs.
Draw the circuit diagram of an H-bridge driver in the space below.
Label the inputs, power supply connections and show where a stepper motor coil would be connected.

[5 marks]

12

4 A farmer, whose crops are attacked and eaten by birds, commissions students at a nearby college to design and build a robotic 'bird scarer'. It scares the birds by operating a motor, which crashes metal plates together making a sound.
The noise is produced for a short time, and there is a pause before it happens again.
The system is controlled by a microcontroller, operating from a $5\ \text{V}$ stabilised supply.

4 (a) The students decide to use a solar panel as the main power source.
In bright sunlight, the chosen solar panel behaves as a $20\ \text{V}$ voltage source connected in series with a $40\ \Omega$ resistor.

4 (a) (i) Calculate the maximum current the solar panel can supply.

[2 marks]

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4 (a) (ii) By considering how the voltage across the terminals of the panel will vary with the current supplied, estimate, using a calculation, the maximum power that can be obtained from the solar panel.

[2 marks]

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4 (b) The students decide to use an $8\ \text{V}$ Lithium Polymer (LiPo) battery to power the electronic control system and a $4.7\ \text{F}$ ultra-capacitor to power the motor.
Below is an extract from the data sheet for the battery used.

Dimensions/mm: 27 x 34 x 96
Mass: 130 g
Capacity: 2200 mAh
Max continuous discharge current: 40 A
Maximum cycle life: 2000

Use this and your knowledge of battery types to state **one** advantage and **one** disadvantage of LiPo batteries over other types in this application.

[2 marks]

Advantage.....

.....

Disadvantage.....

.....

4 (c) Assuming that the LiPo battery draws negligible current from the solar panel, estimate the time taken for the solar panel, in bright sunlight, to charge the $4.7\ \mathrm{F}$ ultra-capacitor to $12.6\ \mathrm{V}$.

[2 marks]

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4 (d) When the voltage across the capacitor reaches $12.6\ \mathrm{V}$, the control system turns on the motor. It takes the motor 1.5 seconds to discharge the capacitor to approximately $4.7\ \mathrm{V}$ at which time the control system disconnects the motor and resets the system.

4 (d) (i) Show, using a calculation, that the effective resistance of the motor is approximately $0.32\ \Omega$.

[1 mark]

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4 (d) (ii) Estimate, using a calculation, the power dissipated by the motor in making the sound.

[3 marks]

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Turn over for the next question

5 It is not necessary to have completed Question 4 before attempting this question.

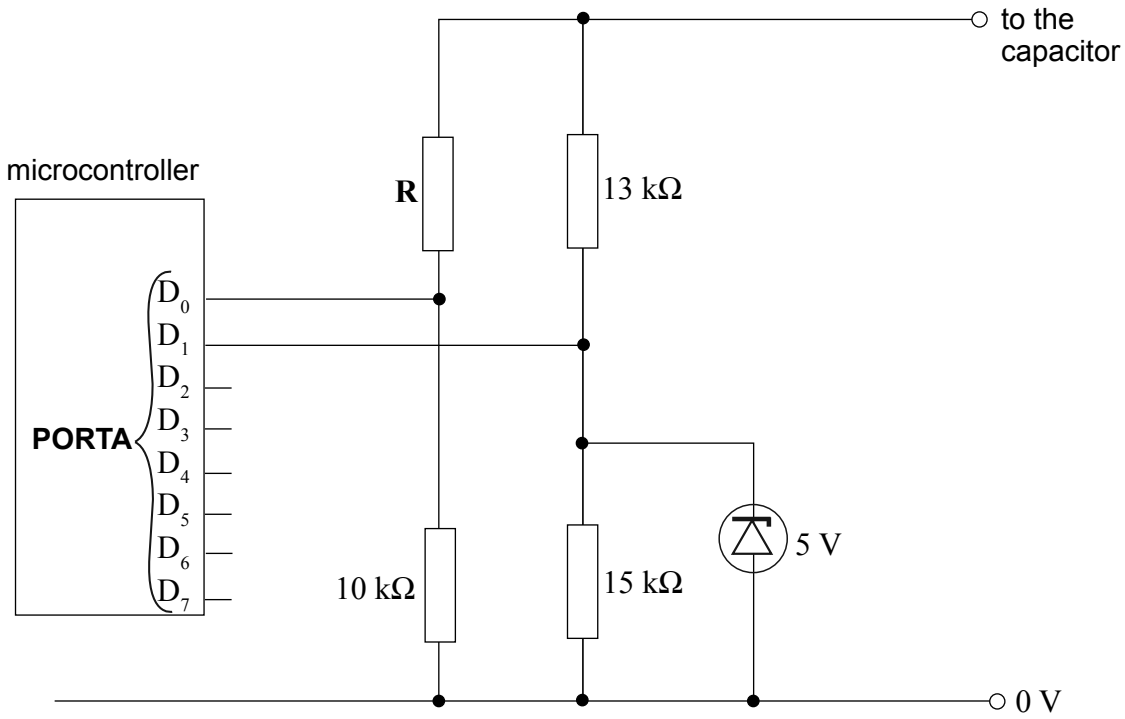
A farmer, whose crops are attacked and eaten by birds, commissions students at a nearby college to design and build a robotic 'bird scarer'.
The students decide to power the system from a solar panel, which charges a large capacitor.

A microcontroller is selected to form the control system of the bird scarer.
When the voltage across the capacitor exceeds 12.6 V, the control system switches on a motor, which is used to make a loud noise.
When the voltage across the capacitor falls below 4.7 V, the control system switches the motor off and waits until the capacitor has become charged again.

The microcontroller operates from a stabilised 5 V power supply. The bits of **PORTA** are inputs. It interprets a voltage greater than 2.5 V as logic 1 and a voltage of less than 2.5 V as logic 0.

The voltage across the capacitor is monitored using the circuit shown in **Figure 6**.

Figure 6



5 (a) Calculate the value for **R** so that when the voltage across the capacitor is $12.6\ \text{V}$, the voltage at D_0 is $2.5\ \text{V}$.

[2 marks]

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5 (b) Explain how the input D_1 can be used to test when the voltage across the capacitor has decreased to $4.7\ \text{V}$.

[2 marks]

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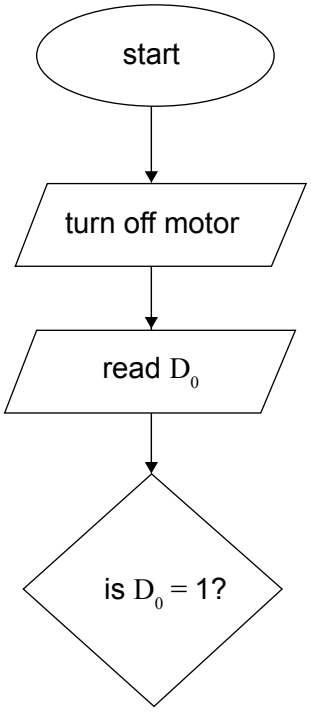
Question 5 continues on the next page

5 (c) Complete the flow chart for controlling the motor in **Figure 7**.

[6 marks]

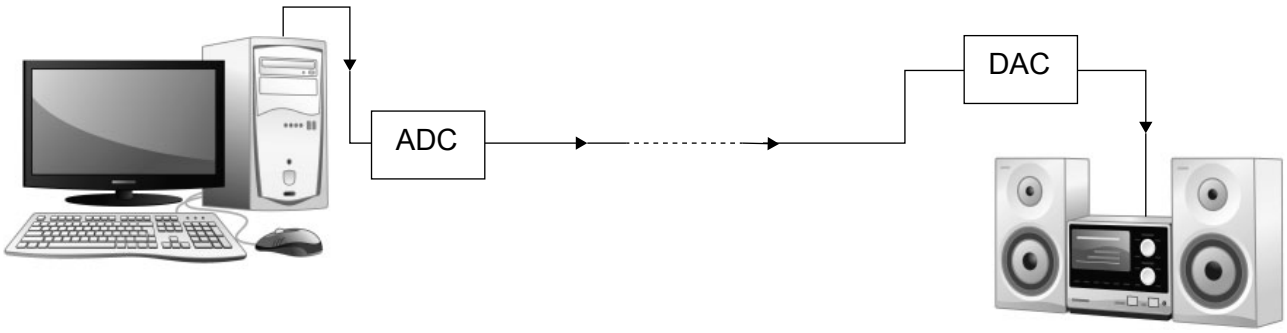
Figure 7



10

6 A student wants to connect the analogue sound output of his PC to his analogue audio system, but as this and his PC are some distance apart he decides to do this digitally to minimise noise problems. The arrangement he comes up with is shown in **Figure 8**.

Figure 8



6 (a) Explain the function of the ADC and DAC in this system.

[2 marks]

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6 (b) It is usual in audio systems to use digital signals of at least 16 bits, but he decides to use an 8-bit system so that he can build his own ADC and DAC.
Explain why an 8-bit system will not give as high quality sound as a 16-bit system.

[2 marks]

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6 (c) The student's research shows that in order to avoid distortion the audio signal must be sampled at a rate of at least $44\ \text{kHz}$. Calculate the maximum time allowable for the ADC to perform each conversion at this sampling rate.

[2 marks]

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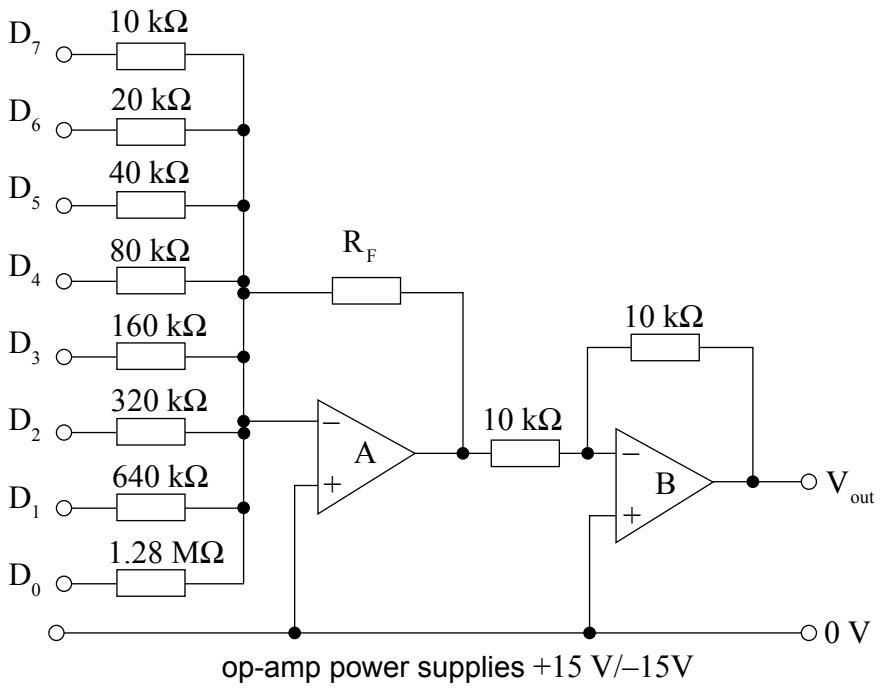
Question 6 continues on the next page

6 (d) The student bases his design for his DAC on the summing amplifier circuit diagram shown in **Figure 9**.

Figure 9



6 (d) (i) State **two** actions of the subsystem containing op-amp B.

[2 marks]

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6 (d) (ii) A logic 1 digital input is 5 V and a logic 0 input is 0 V.
Calculate the value of R_F so that for a digital input of **0x80**, the output is 5 V.

[2 marks]

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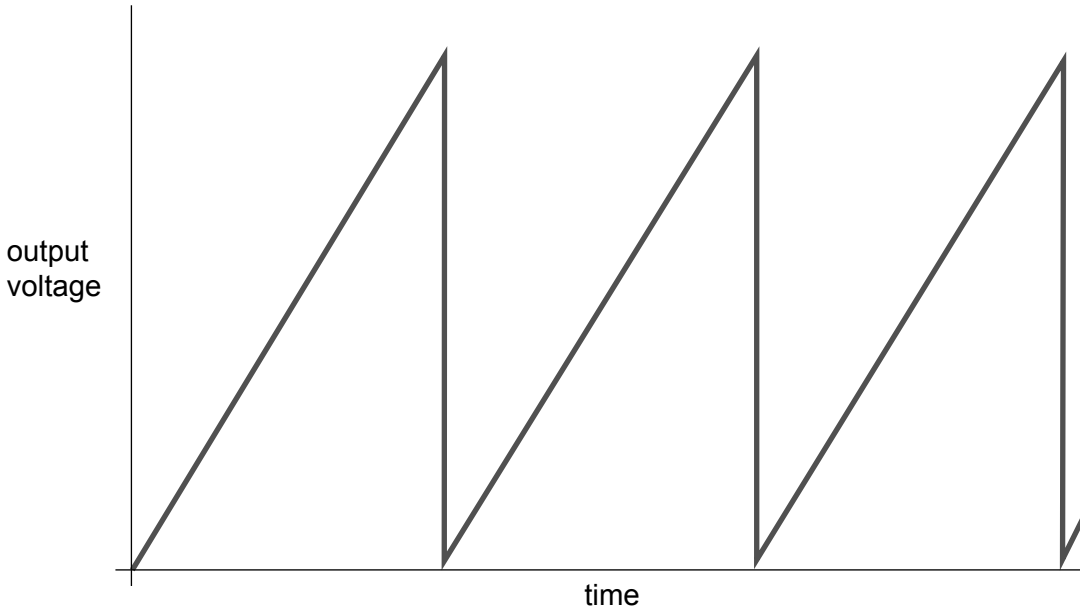
6 (e) The DAC is tested by connecting its input to the output port of a microcontroller which continuously counts from **0x00** to **0xFF**.
Figure 10 shows a graph of the output voltage.

Figure 10



Explain the shape of the graph.

[2 marks]

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12

Turn over for the next question

7 Tricolour LEDs contain a separate red, green and blue LED mounted in the same case. Varying the intensity of each LED produces different colours:

- red and green fully on and blue fully off produces a yellow colour
- all three LEDs fully on produces white.

7 (a) The intensity of each LED is set by a 2-bit binary number.
Calculate the total number of different colours that can be produced.

[2 marks]

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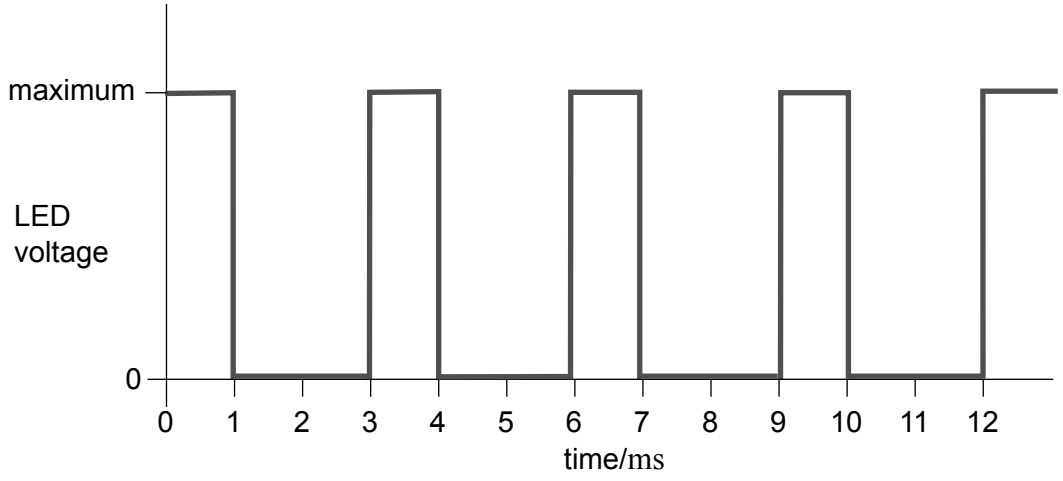
7 (b) Varying the voltage across an LED does not give a linear relationship with brightness. Better results are obtained by controlling the ratio of time that the LED is fully switched on to the time that it is fully switched off.

Figure 11 is for the red LED at a brightness setting of 01_2.

Figure 11



7 (b) (i) State, with a reason, the perceived brightness of the red LED compared with its maximum.

[2 marks]

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7 (b) (ii) Explain why the eye does not see the LED flashing under this condition.

[2 marks]

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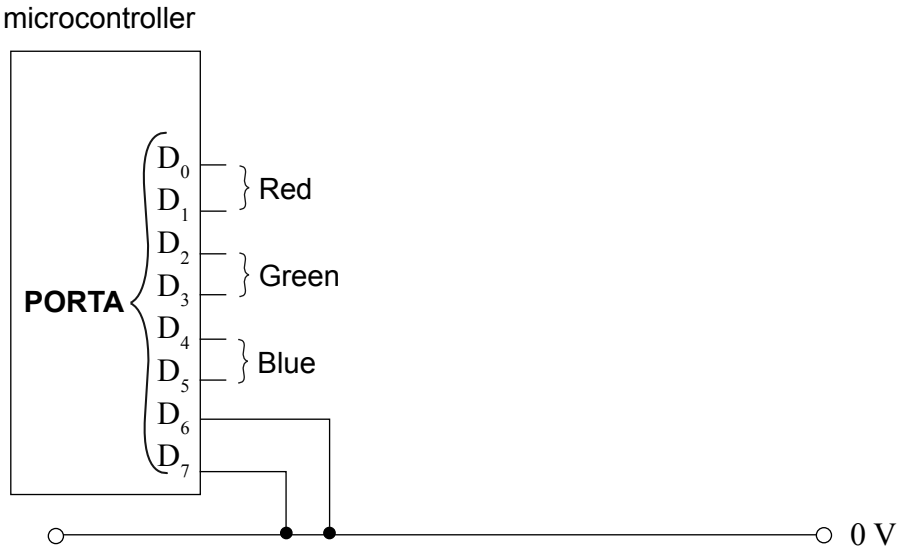
7 (c) A microcontroller is used to control the colour of the tricolour LED. The brightness data for each LED is entered onto **PORTA** as shown in **Figure 12**.

Figure 12



7 (c) (i) To produce an orange colour, the red LED must be switched on for 100% of the time, the green LED for 67% of the time and the blue LED for 33% of the time.
Determine the value of the byte that must be entered into **PORTA**, in hexadecimal.

[2 marks]

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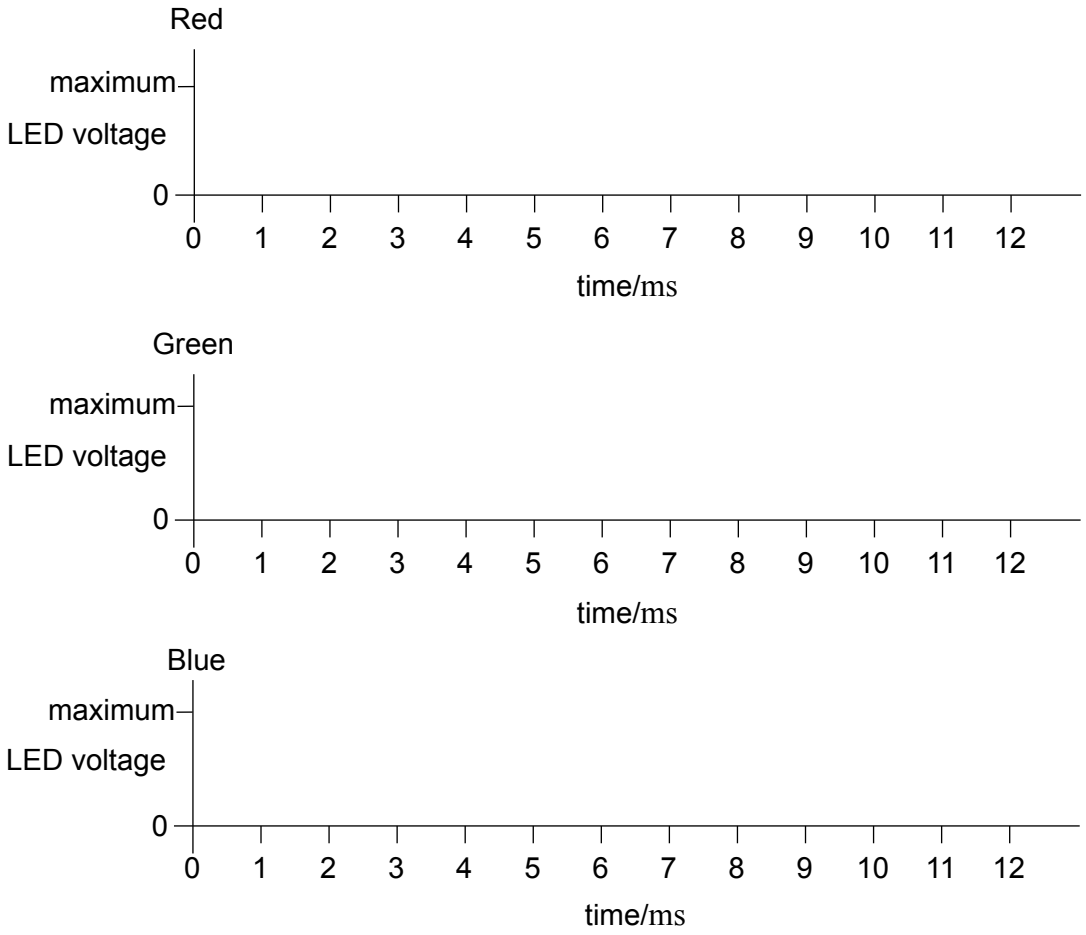
Question 7 continues on the next page

7 (c) (ii) Complete the timing diagram in **Figure 13** for the three LEDs when displaying the colour orange as defined in part **(c)(i)**.

[2 marks]

Figure 13



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END OF QUESTIONS