Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

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General Certificate of Education
June 2002
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

ELECTRONICS ELE4
Unit 4 Electronic Control Systems

Thursday 27 June 2002 Afternoon Session

In addition to this paper you will require:
- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour 30 minutes

Instructions
- Use a blue or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided. All working must be shown.
- 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.
- Mark allocations are shown in brackets.
- Any correct electronics solution will gain credit.
- The paper carries 15% of the total marks for Electronics Advanced award.
- You are reminded of the need for good English and clear presentation in your answers.

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

Data Sheet

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- Detach this sheet before you begin work.

Data Sheet

Resistors

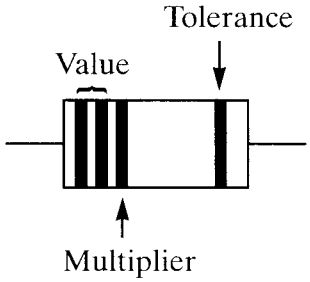
Preferred values for resistors (E24) series:
1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1 ohms and multiples that are ten times greater.

Resistor Printed Code (BS 1852)

This code consists of letters and numbers:
R means × 1
K means × 1000 (i.e. 10^3)
M means × 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 = ± 1%, G = ± 2%, J = ± 5%, K = ± 10%, M = ± 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 = ± 5%, silver = ± 10%, no band ± 20%.

Silicon diode

$V_F = 0.7\,V$

Silicon transistor

$V_{be} \approx 0.7\,V$ in the on state
$V_{ce} \approx 0.2\,V$ 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

$T = CR$

ac theory

$I_{rms} = \frac{I_o}{\sqrt{2}}$

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

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

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

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

Electromagnetic Waves

$c = 3 \times 10^8\ m\,s^{-1}$ 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) A microprocessor control system contains the following sub-systems:

an address bus, a clock, a databus, an input port, an output port, RAM, ROM.

Select the most appropriate sub-system from the list above for the following functions:

(i) carries data within the control system, ...

(ii) keeps all internal operations of the control system synchronised, ...

(iii) provides temporary storage of data, ...

(iv) is connected to a keyboard, ...

(v) carries information used to select a required memory element. .....

(5 marks)

(b) An input port is to be I/O mapped at F8 on a microprocessor control system.

(i) Explain how I/O mapping differs from memory mapping of I/O ports.

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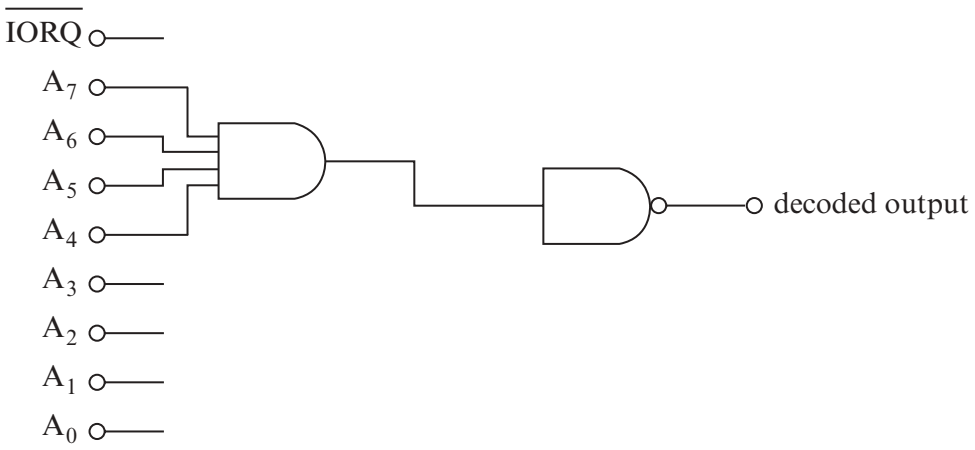
(ii) The address decoder for the input port is required to give logic 0 when the port is addressed and **$\overline{\text{IORQ}}$** is logic 0. The decoder is partly drawn below. Complete the diagram using any other logic gates that you need.



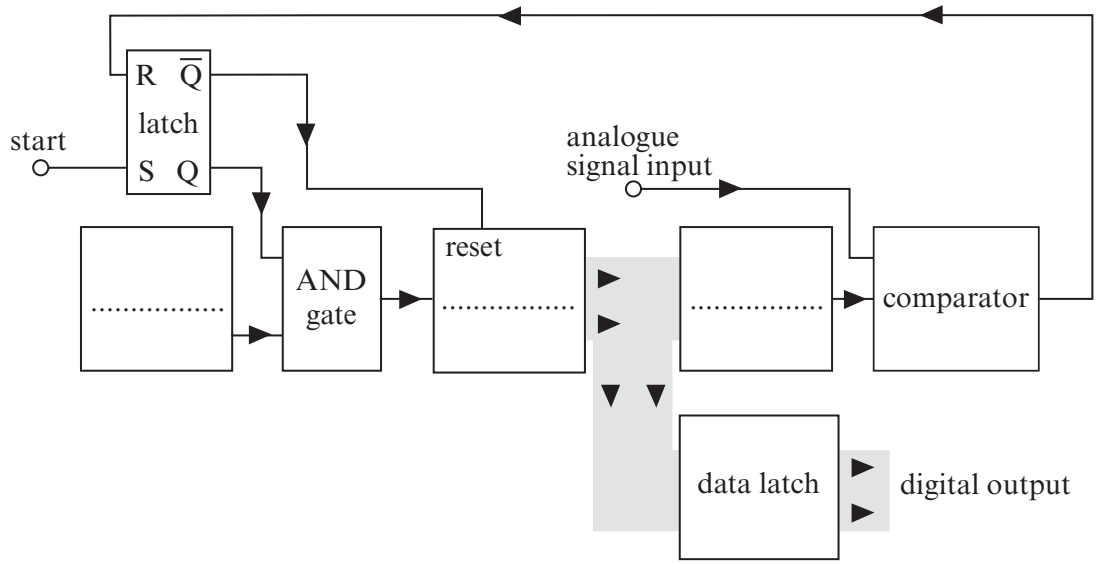
(5 marks)

10

2 A flight simulator for an aeroplane uses a computer controlled system, coupled to motors attached to the flight simulator cabin, to adjust its position and angle. The simulator program 'reads' in data from the flight controls inside the cabin via its input ports. The data is processed by the computer system which 'writes' corresponding data to the motors via its output ports.

The analogue signals from the flight controls are converted into digital data for the computer system using 8-bit digital ramp ADCs.

(a) Complete the **three** labels in the block diagram for the 8-bit digital ramp ADC shown below.



(3 marks)

(b) The comparator is required to give logic 1 output when the digitally generated ramp voltage exceeds the input voltage.

(i) State, with a reason, what component would be suitable for use as the comparator.

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(ii) Draw a circuit diagram showing how this component is connected for this application.

(4 marks)

(c) Explain why a flash ADC is **not** needed for this application.

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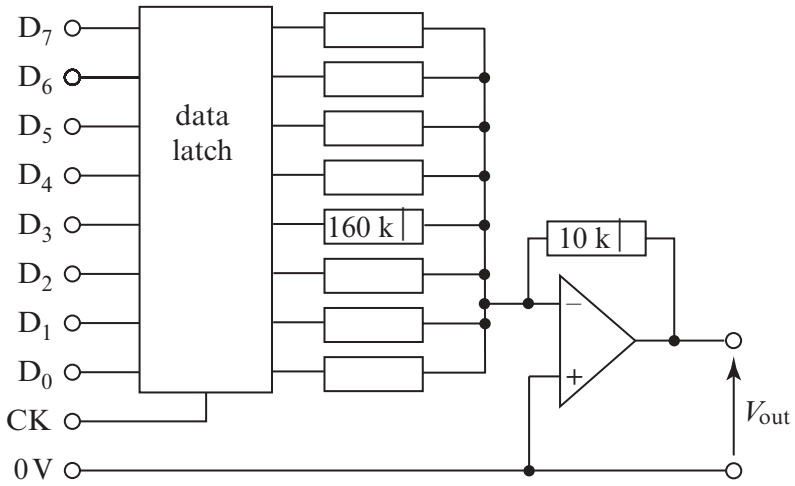
(1 mark)

8

3 In the flight simulator described in Question 2, the computer writes data to its output ports which is then converted into analogue signals using a Digital to Analogue Converter (DAC).

The circuit diagram for the 8-bit Digital to Analogue Converter (DAC) is shown below.



(a) (i) State the mode of operation of the op-amp.

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The data latch gives 5 V output for a logic 1 input and 0 V for a logic 0 input after a clock pulse.

(ii) If the input of D_3 is logic 1, and all of the other inputs are logic 0, calculate V_{out} after a clock pulse.

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(iii) Mark on the diagram above suitable values for the other input resistors.

(5 marks)

(b) Explain why a data latch is needed as the input of the DAC.

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(2 marks)

7

4 A PIC device is used to control the operation of a washing machine. The PIC device has two 8-bit I/O ports and one 4-bit output port.

(a) Give **two** advantages of using a microcomputer system to control the washing machine compared with an electromechanical timer and control system.

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(2 marks)

(b) Give **two** reasons why a PIC device may be described as a 'computer on a chip'.

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(2 marks)

(c) The main motor in the washing machine is controlled by a relay. The PIC device is unable to supply sufficient power to operate the relay. Draw a circuit diagram to show how a MOSFET can be used as a switch to control the relay.

(4 marks)

8

5 (a) A motor is required to rotate at a constant speed of 50 revolutions per second and deliver a maximum power of 500 W to a varying load. The designer can use either a stepper motor or a different type of motor.

(i) State **one** advantage of using a stepper motor in this application.

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(ii) State **one** disadvantage of using a stepper motor in this application.

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(2 marks)

(b) The designer decided not to use a stepper motor but to use a motor with an optical shaft encoder attached, to sense the speed of rotation. A microcomputer controller ensured the correct speed of rotation.

Describe what is meant by an *optical shaft encoder.* You may draw a diagram to help with your description.

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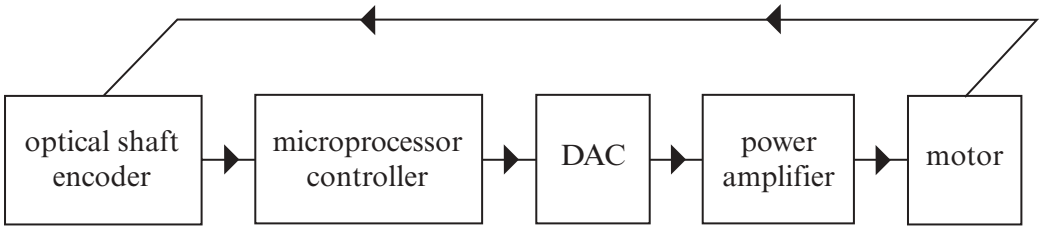
(3 marks)

(c) The block diagram for the complete system is shown below.



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

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(ii) State, with a reason, whether the system described in this question has negative or positive feedback.

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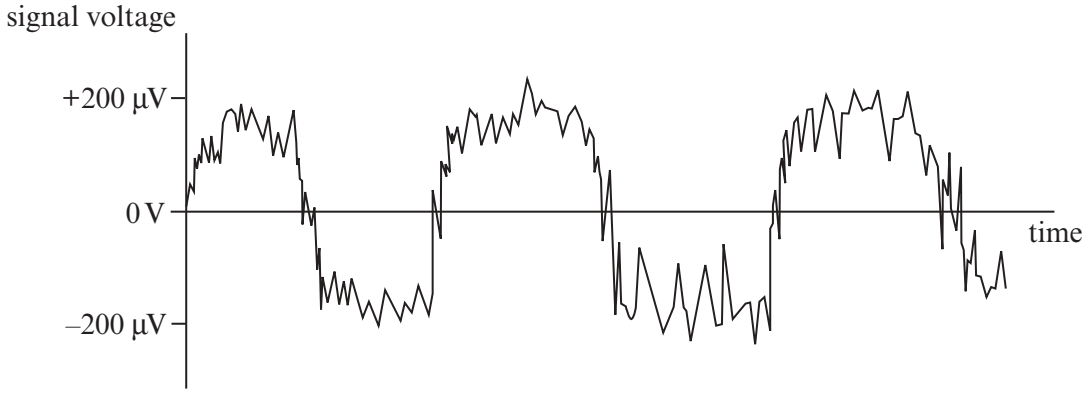
(5 marks)

10

TURN OVER FOR THE NEXT QUESTION

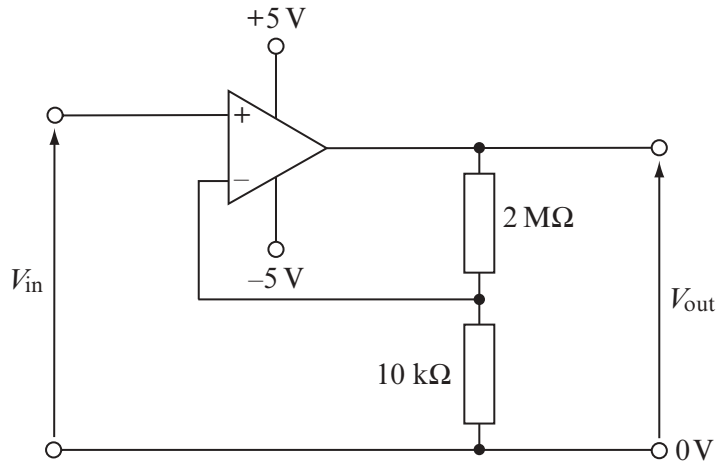
6 Information is transmitted from a remote location in a factory to a computer as a series of pulses of light. The light is received by a photosensor and produces a signal as shown in the diagram below.



(a) This signal is amplified by an inverting amplifier with an input resistance of 10 kΩ and a voltage gain of –200. In the space below, draw the circuit diagram of such an op-amp based amplifier. Mark on your diagram suitable values for the resistors.

(4 marks)

(b) The computer requires an input signal of ± 5 V and so the signal from the amplifier in part (a) is passed into the circuit below.



(i) Calculate the voltage gain of the circuit.

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(ii) Explain why the maximum output voltage is only ± 5 V.

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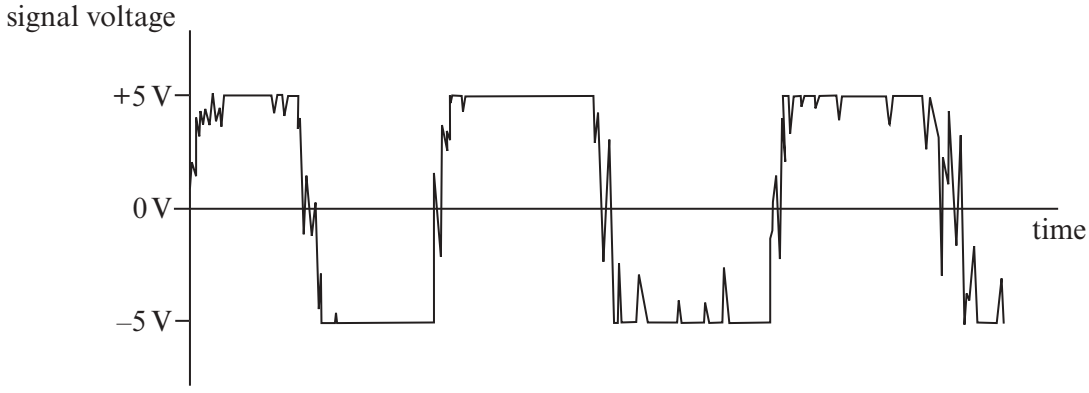
(2 marks)

(c) The output waveform from the second amplifier is shown in the diagram below.



(i) If the computer interface detects pulses by transitions from positive to negative and vice versa, why does the noise give rise to errors in the output of this system?

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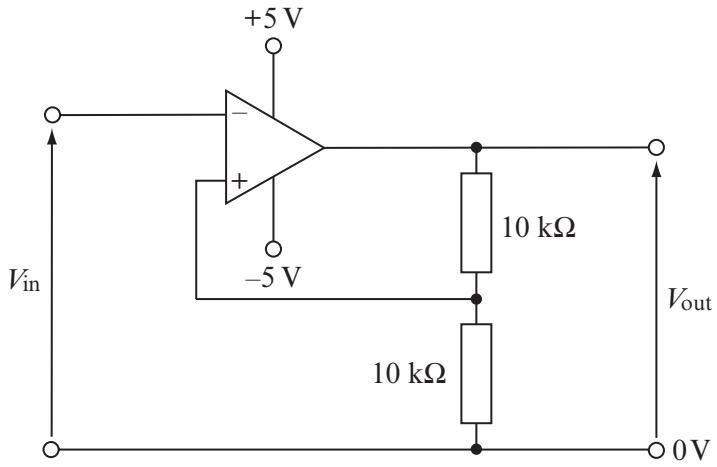
QUESTION 6 CONTINUES ON THE NEXT PAGE

Turn over ►

To overcome the errors, the second amplifier is replaced by a Schmitt trigger as shown in the diagram below.



(ii) Calculate the switching voltage levels of the circuit.

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(iii) Explain why the Schmitt trigger circuit will reduce significantly the errors in the received signal.

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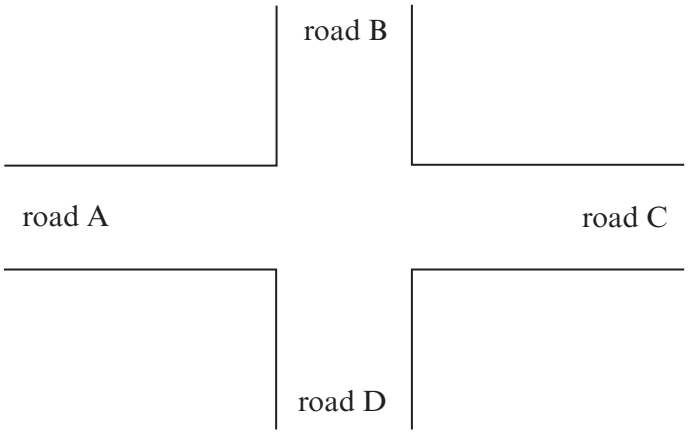
(5 marks)

11

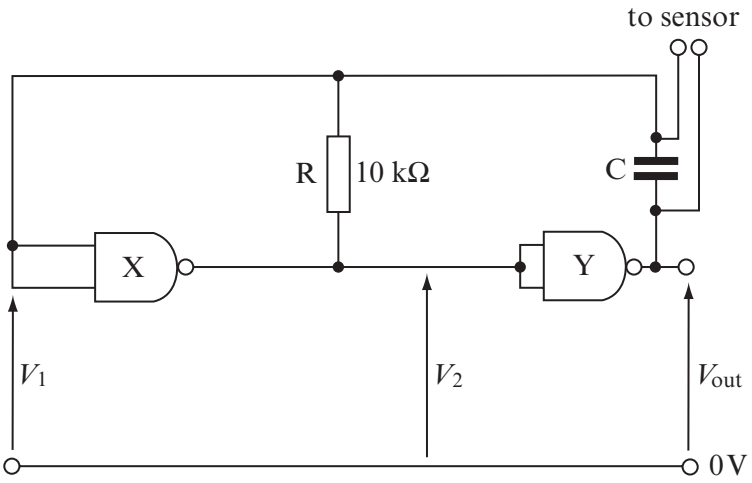
TURN OVER FOR THE NEXT QUESTION

7 The traffic at the busy road junction shown in the diagram below is controlled by traffic lights operated by a microcomputer system.



The microcomputer system is programmed to minimise the waiting time for vehicles. To detect how many cars are waiting on each road, a wire sensor is laid into the surface of each road which alters the frequency of an astable oscillator. The more vehicles that are waiting, the lower the frequency.

(a) The circuit diagram of such an astable, made from NAND gates, is shown below.



(i) Explain how a NAND gate astable functions.

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(ii) The approximate capacitance of the sensor varies from 1 nF, when there are no vehicles waiting, to 15 nF, when there are 10 vehicles waiting. If C has a capacitance of 10 nF, calculate the effective capacitance controlling the frequency of the astable when there are 10 vehicles waiting.

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(iii) Show that the frequency of the astable when there are 10 vehicles waiting is approximately 2 kHz.

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(7 marks)

(b) The outputs of the astables for the four roads A, B, C, and D are connected to D_0, D_1, D_2 and D_3 of port 379_{16} respectively. The microcomputer regularly polls the port to determine their frequency and therefore how many vehicles are waiting on each road.

Explain what is meant by *polling* and how it differs from *interrupts*.

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(2 marks)

QUESTION 7 CONTINUES ON THE NEXT PAGE

(c) The microcomputer uses the following BASIC subroutine to monitor the state of the astables connected to the input port. Before calling the subroutine a variable, X%, is loaded with a number. This number determines which astable is to be monitored.

```
START
DO
A% = INP(&H379)
A% = A% AND X%
LOOP UNTIL A% = X%
A% = A% XOR A%
RETURN
```

(i) Explain the function of each of the following BASIC lines:

A% = INP(&H379)

.....

A% = A% AND X%

.....

LOOP UNTIL A% = X%

.....

A% = A% XOR A%

.....

(ii) If X% = 4, explain which road (astable) is being monitored.

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(5 marks)

(d) In some cities the microcomputers controlling traffic lights are linked together to form a Neural Network structure.

(i) Explain briefly how the architecture of a Neural Network differs from that of a conventional computer system.

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(ii) Outline **one** beneficial social and economic effect and **one** disadvantage of such a Neural Network system.

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(4 marks)

18

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE