Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2002
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

ELECTRONICS ELE2
Unit 2 Further Electronics

Wednesday 22 May 2002 Morning 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 40% of the total marks for Electronics Advanced Subsidiary and 20% of the total marks for Advanced awards.
- 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			

SA2502/0202/ELE2 6/4/4/2245

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

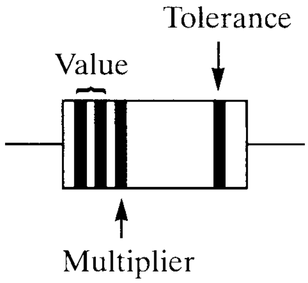
Preferred values for resistors (E24) series:
1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1 ohms and multiples that are ten times greater.

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

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

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

$X_L = 2\pi f L$ reactance

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

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

Turn over ▶

Operational amplifier	$G_V = \dfrac{V_{out}}{V_{in}}$	voltage gain
	$G_V = -\dfrac{R_f}{R_1}$	inverting
	$G_V = 1 + \dfrac{R_f}{R_1}$	non-inverting
	$V_{out} = -R_f\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3}\right)$	summing
Astable and Monostable using NAND Gates	$f \approx \dfrac{1}{2RC}$	astable
	$T \approx RC$	monostable
555 Astable and Monostable	$T = 1.1RC$	monostable
	$\left.\begin{array}{l} t_H = 0.7(R_A + R_B)C \\ t_L = 0.7R_BC \end{array}\right]$	astable
	$f = \dfrac{1.44}{(R_A + 2R_B)C}$	two resistor circuit
Electromagnetic Waves	$c = 3 \times 10^8\ \mathrm{m\,s^{-1}}$	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

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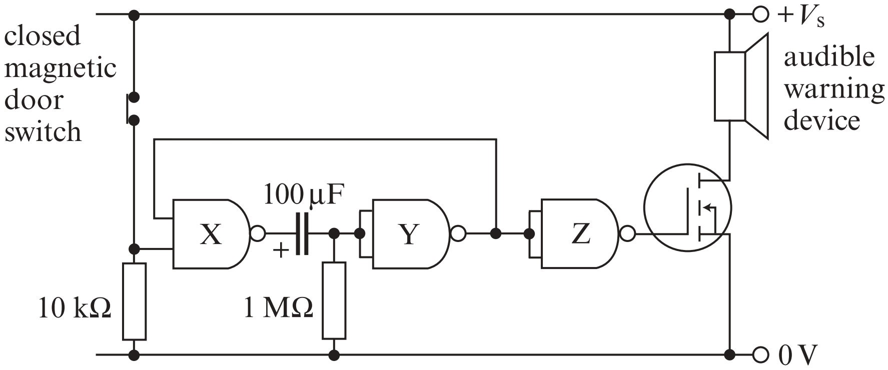
Answer **all** questions in the spaces provided.

1 An intruder alarm has the circuit diagram shown below.



(a) The two NAND gates, X and Y form a monostable. Estimate its time period.

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....

(2 marks)

(b) When the door opens the magnetic switch opens, triggering the monostable. Describe the sequence of events that occurs in the monostable circuit.

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....

....

....

....

(5 marks)

(c) State the function of

(i) NAND gate Z,

....

(ii) the MOSFET.

....

(2 marks)

9

Turn over ►

2 A specialist radio receiver requires an audio amplifier sub-system with a bandwidth of 3 kHz that will amplify an input voltage of 5 μV to an output of 2.5 V.

(a) Define the term *bandwidth*.

....

....

(2 marks)

(b) Calculate the required voltage gain of the audio amplifier sub-system.

....

....

....

(1 mark)

(c) The radio amplifier sub-system is to be built using op-amps that have a gain-bandwidth product of 10^6 Hz.

(i) Calculate the maximum voltage gain that can be achieved with a single op-amp at a frequency of 3 kHz.

....

....

(ii) How many op-amps are required to achieve the overall voltage gain?

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....

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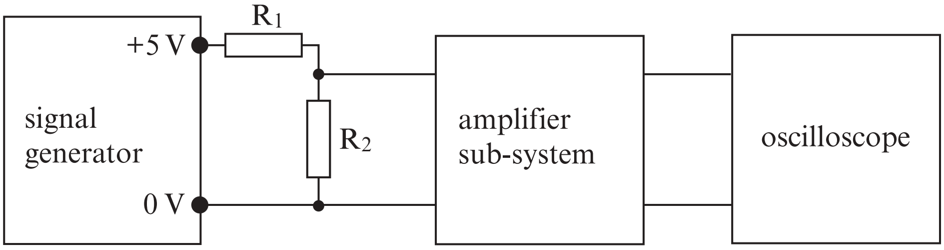
(3 marks)

(d) To test the amplifier sub-system it is necessary to generate a 5 μV signal from a normal signal generator. The test system used is shown below.



The signal generator is set to 5 V and connected to two resistors arranged as a voltage divider. If $R_1 = 1\ M\Omega$, calculate the value of R_2 so that the input signal to the amplifier is 5 μV.

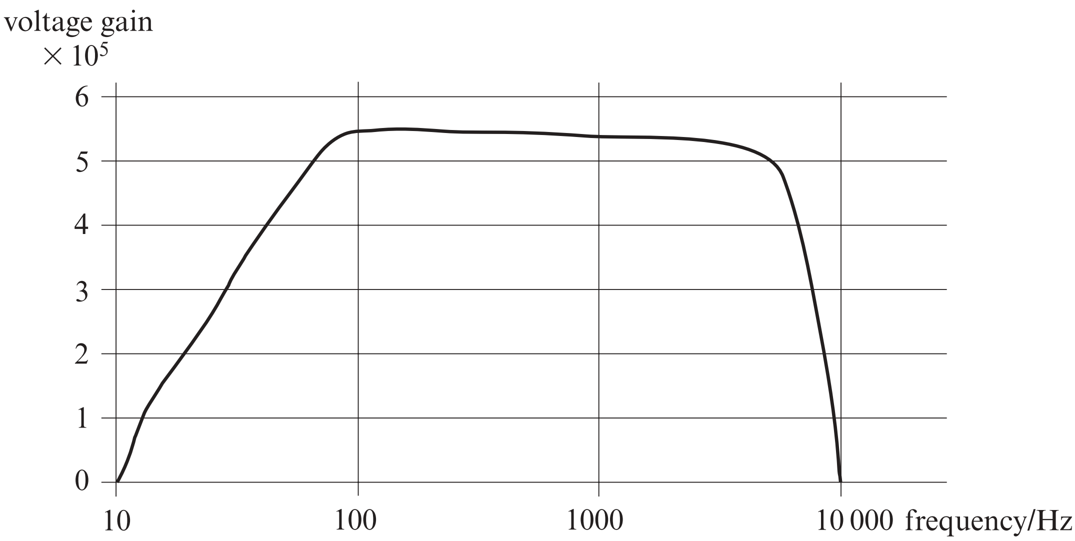
....

....

....

(2 marks)

(e) The amplifier sub-system was found to have the frequency response shown below.



Use the graph to estimate the bandwidth of the actual system.

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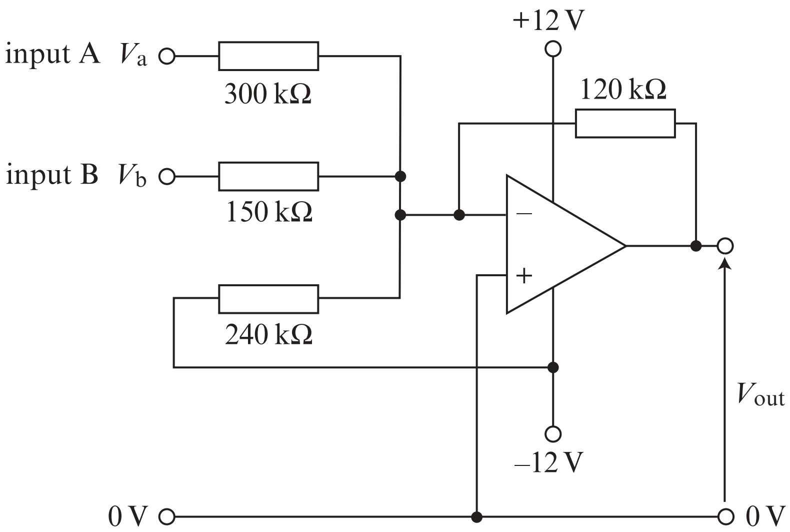
(2 marks)

10

Turn over ►

3 The circuit diagram below is a sub-system from a simple waveform generator.



(a) (i) Mark, with a P, a virtual earth point on the diagram.

(ii) Name the amplifier circuit.

....

(iii) State the input resistance of input A.

....

(3 marks)

(b) When $V_a = V_b = 0$ V, show that V_{out} is +6 V.

....

....

....

(2 marks)

(c) When $V_a = 0$ V, $V_b = +5$ V, show that V_{out} is +2 V.

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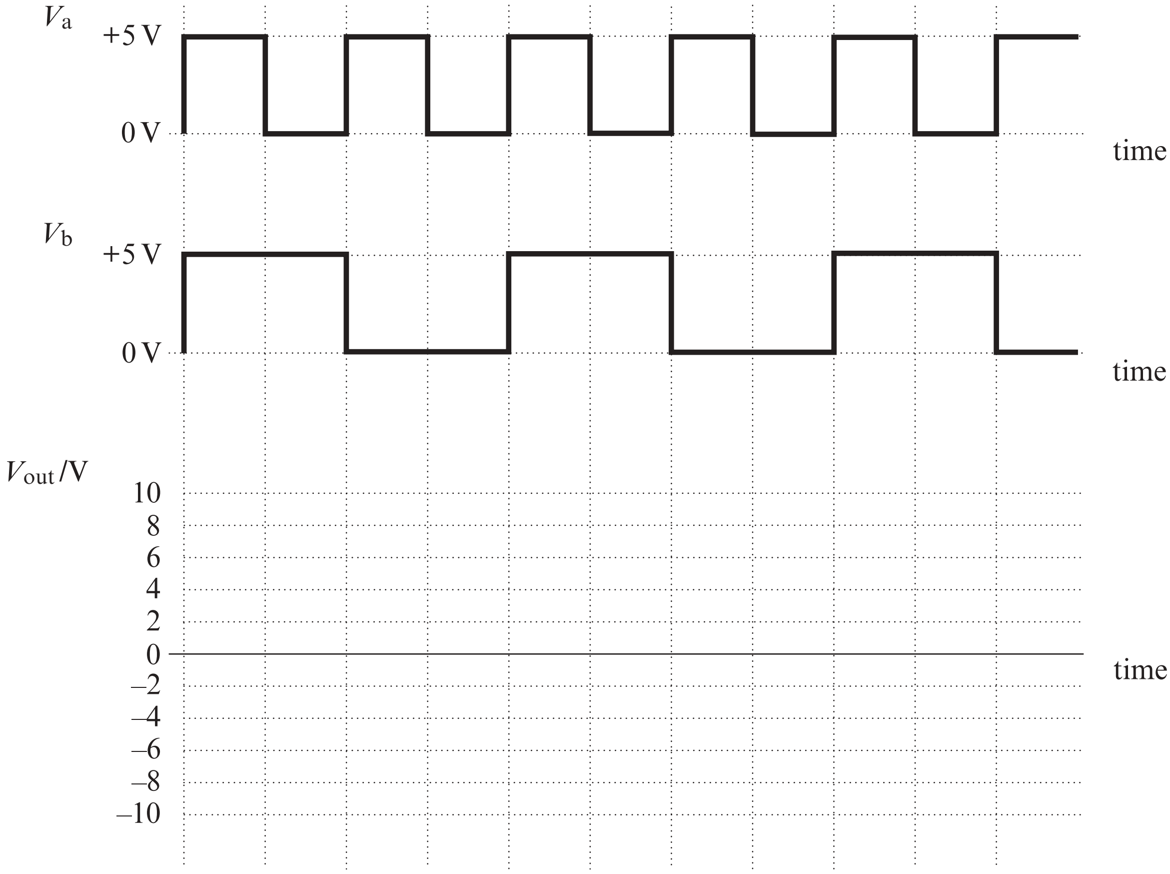
....

....

(2 marks)

LEAVE MARGIN BLANK

(d) The circuit is connected to a logic sub-system generating the waveforms shown below. Complete the diagram to show the output from the circuit.



(2 marks)

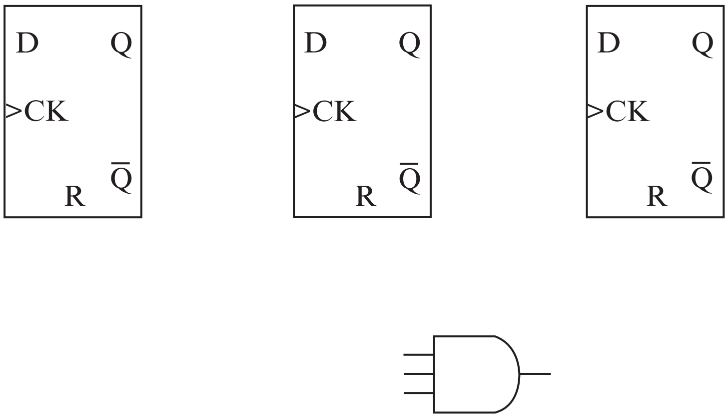
9

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

4 A signal is to be obtained by frequency dividing an approximate 28 MHz signal first by 7 and then by 2.

(a) Complete the diagram below to show how three rising edge triggered D-type flip-flops can be arranged with a three input AND gate to form the divide by 7 function.



(4 marks)

(b) Explain why dividing by 7 and then 2 produces an approximate 2 MHz signal with a 1:1 mark to space ratio whereas dividing by 14 would not.

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....

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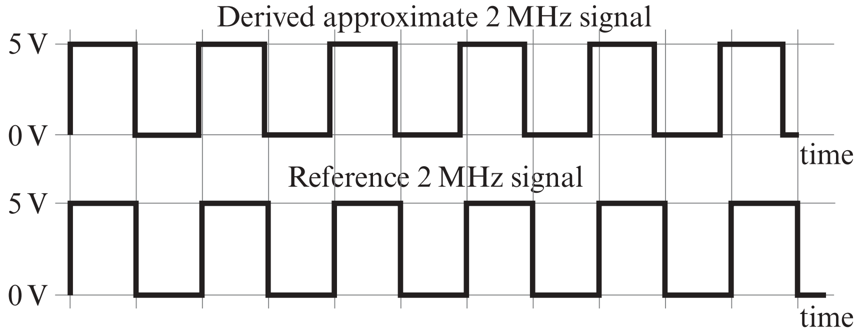
....

(2 marks)

(c) The approximate 2 MHz signal derived above is compared with a very accurate 2 MHz reference signal. The first part of the graph below shows the approximate 2 MHz signal. The second part shows the reference 2 MHz signal.



(i) What is the period of a 2 MHz signal?

....

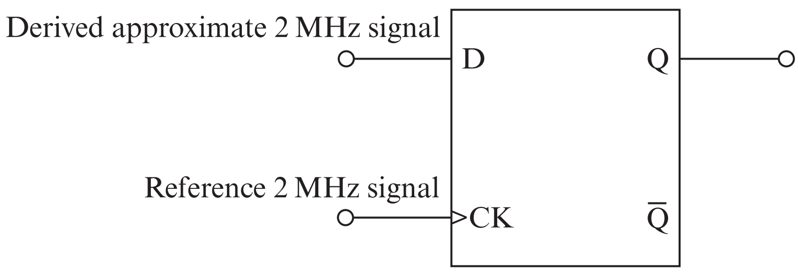
(ii) From the graph *explain* whether the approximate signal has a greater or lesser frequency than the reference signal.

....

....

(3 marks)

(d) A rising edge triggered D-type flip-flop is used to compare the reference 2 MHz signal with the derived 2 MHz signal as shown in the diagram below.



By referring to the graphs in part (c), explain why the Q output is logic 1 during the time interval of the graph.

....

....

(2 marks)

11

Turn over ►

5 Temporary traffic lights are used to control the traffic at roadworks, when one side of the road is blocked. The traffic lights have a 16 step binary sequence as shown in the table below where R ≡ red, Y ≡ yellow, G ≡ green.

D	C	B	A	TRAFFIC LIGHTS 1	TRAFFIC LIGHTS 2
0	0	0	0	R	G
0	0	0	1	R	G
0	0	1	0	R	G
0	0	1	1	R	G
0	1	0	0	R	G
0	1	0	1	R	G
0	1	1	0	R	Y
0	1	1	1	R, Y	R
1	0	0	0	G	R
1	0	0	1	G	R
1	0	1	0	G	R
1	0	1	1	G	R
1	1	0	0	G	R
1	1	0	1	G	R
1	1	1	0	Y	R
1	1	1	1	R	R, Y

(a) State the conditions, in hexadecimal, when the yellow lamp in Traffic Lights 1 is illuminated.

....

(2 marks)

(b) Explain why the Boolean expression when the green lamp of Traffic Lights 2 is illuminated is

$$\mathbf{G} = \overline{\mathbf{D}} \bullet \overline{\mathbf{C}} \bullet \overline{\mathbf{B}} \bullet \overline{\mathbf{A}} + \overline{\mathbf{D}} \bullet \overline{\mathbf{C}} \bullet \overline{\mathbf{B}} \bullet \mathbf{A} + \overline{\mathbf{D}} \bullet \overline{\mathbf{C}} \bullet \mathbf{B} \bullet \overline{\mathbf{A}} + \overline{\mathbf{D}} \bullet \overline{\mathbf{C}} \bullet \mathbf{B} \bullet \mathbf{A} + \overline{\mathbf{D}} \bullet \mathbf{C} \bullet \overline{\mathbf{B}} \bullet \overline{\mathbf{A}} + \overline{\mathbf{D}} \bullet \mathbf{C} \bullet \overline{\mathbf{B}} \bullet \mathbf{A}$$

....

....

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(3 marks)

(c) Show that the expression given in part (b) simplifies to

$$\mathbf{G} = \overline{\mathbf{D}} \bullet \overline{\mathbf{B} \bullet \mathbf{C}}$$

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....

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(3 marks)

___ / 8

TURN OVER FOR THE NEXT QUESTION

Turn over ►

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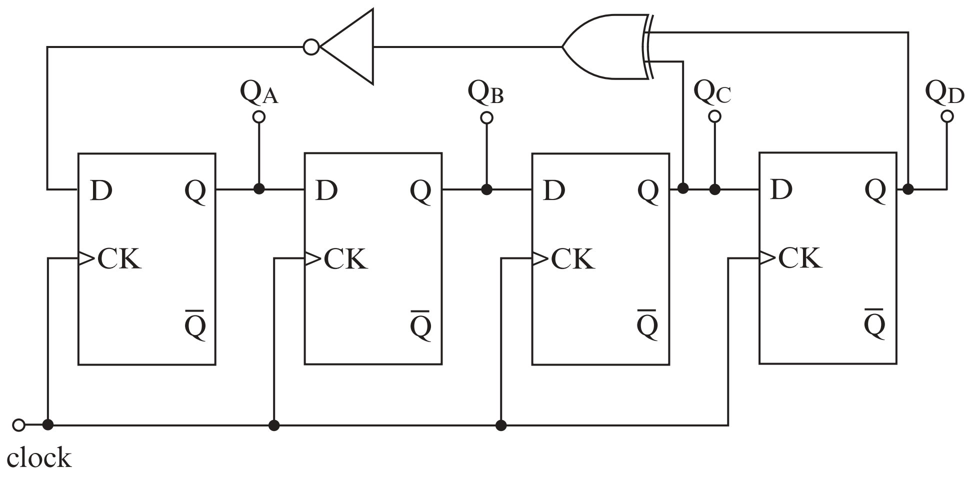
6 The circuit diagram below shows a four bit pseudo-random number generator.



(a) The four rising edge triggered D-type flip-flops form a shift register.

(i) Describe how a shift register works.

....

....

....

....

(ii) State another use of a shift register.

....

(4 marks)

LEAVE MARGIN BLANK

(b) Outputs Q_C and Q_D are EX-ORed together, inverted and then the output is connected to the D input of the first flip-flop. The truth table for the circuit is shown below. Complete the two blank lines.

Q_A	Q_B	Q_C	Q_D	D input of first flip-flop
0	0	0	0	1
1	0	0	0	1
1	1	0	0	1
1	1	1	0	0
1	0	1	1	1
1	1	0	1	0
0	1	1	0	0
0	0	1	1	1
1	0	0	1	0
0	1	0	0	1
0	1	0	1	0
0	0	1	0	0
0	0	0	1	0
0	0	0	0	1

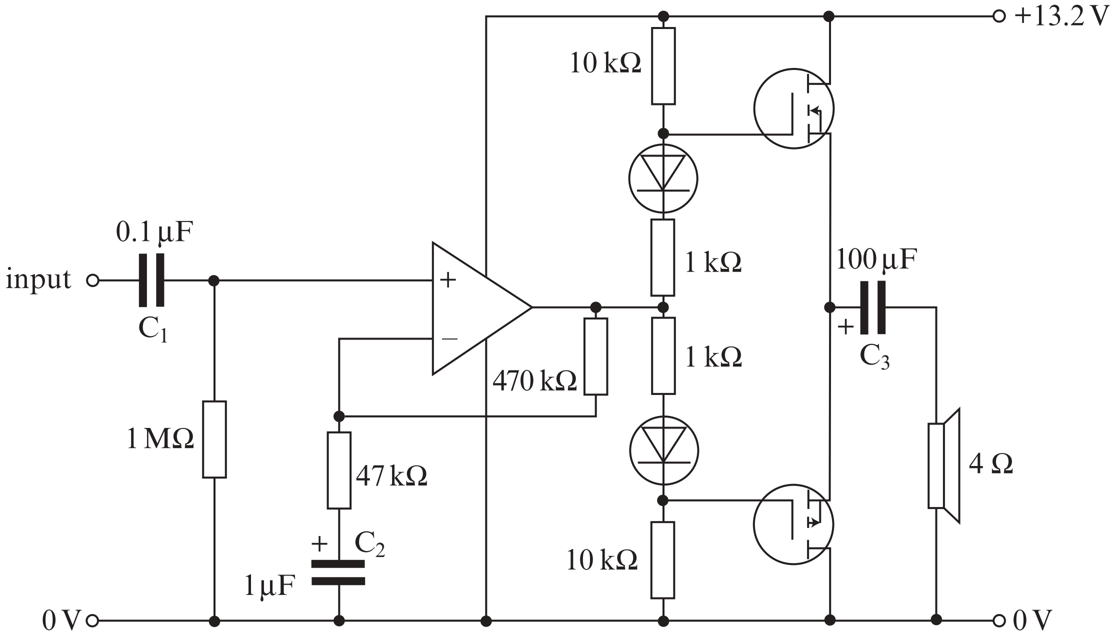
(3 marks)

7

TURN OVER FOR THE NEXT QUESTION

Turn over ►

7 A student wants to build an amplifier for a car to listen to a portable CD or MP3 player through speakers in the car. Searching the Internet, the student finds the circuit diagram, shown below, for an amplifier.



After constructing the circuit the results were disappointing. It lacked bass response, it was not very loud and it sounded distorted at low volume settings. The student discussed the problems with his electronics teacher who made several suggestions for improvements.

(a) **Poor bass response** – check the value of the output capacitor C_3.

(i) Calculate the reactance of C_3 at 20 Hz.

....

....

(ii) Suggest, with a suitable reason, a more appropriate value for C_3.

....

....

(4 marks)

LEAVE MARGIN BLANK

(b) **Not very loud** – check the overall voltage gain of the circuit.

(i) The MOSFETs are connected as source followers. State the voltage gain of a source follower.

....

(ii) Estimate the voltage gain of the op-amp sub-system, stating **one** assumption that you make.

....

....

....

(iii) If the peak output voltage from the CD or MP3 player is 200 mV, estimate, showing your calculation, the voltage gain needed to just drive the amplifier into saturation.

....

(iv) How would you modify the amplifier circuit in order to achieve this voltage gain?

....

(7 marks)

(c) **Distortion at low volume settings** – ensure that the MOSFETs are biased just into conduction, and include the output subsection into the negative feedback loop.

(i) How would you use an ammeter to determine whether the MOSFETs are correctly biased? State any results you would expect.

....

....

....

(ii) Explain how the MOSFET source followers can be included into the negative feedback loop.

....

....

(4 marks)

QUESTION 7 CONTINUES ON THE NEXT PAGE

Turn over ►

LEAVE MARGIN BLANK

(d) With all of the modifications made, the student tests the amplifer again and finds that it is much improved. However, he now finds that at maximum volume the MOSFETs become very hot. His teacher advised him to attach the MOSFETs to heat sinks.

State **three** important design features of efficient heat sinks.

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(3 marks)

18

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE