Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

ELECTRONICS ELE2
Unit 2 Further Electronics

Tuesday 22 May 2007 9.00 am to 10.30 am

For this paper you must have:
- a calculator
- a pencil and a 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 to be 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			
Question	Mark	Question	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 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 perforated sheet at the start of the examination.

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 $V_F = 0.7\,\text{V}$

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

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

$$X_C = \frac{1}{2\pi f C}$$ 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
	$t_H = 0.7(R_A + R_B)C$ $t_L = 0.7R_BC$	astable
	$f = \dfrac{1.44}{(R_A + 2R_B)C}$	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,}]

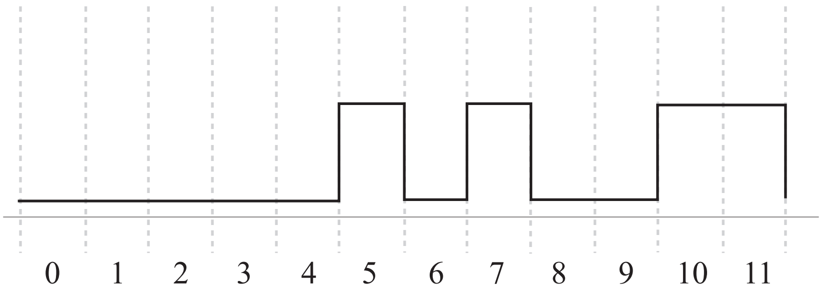
REM remark

Turn over for the first question

Turn over ▶

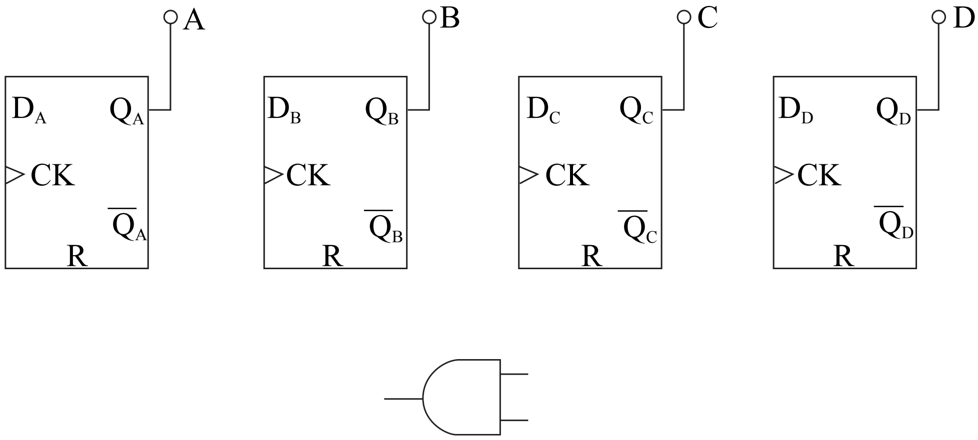
Answer **all** questions in the spaces provided.

1 In order to test the serial interface of a computer, a small team of electronics students plan to construct a piece of test equipment that will produce the sequence of pulses shown in the diagram below.



They begin by constructing a modulo-12 counter using four D-type flip-flops.

(a) Complete the circuit diagram below to show how this could be achieved.



(4 marks)

LEAVE MARGIN BLANK

(b) They next decide that they should show the sequence of pulses in a truth table which is shown below.

Step number	**Counter Output D**	**Counter Output C**	**Counter Output B**	**Counter Output A**	**Pulse**
0	0	0	0	0	0
1	0	0	0	1	0
2	0	0	1	0	0
3	0	0	1	1	0
4	0	1	0	0	0
5	0	1	0	1	1
6	0	1	1	0	0
7	0	1	1	1	1
8	1	0	0	0	0
9	1	0	0	1	0
10	1	0	1	0	1
11	1	0	1	1	1

They now devise a logic gate circuit to combine the outputs of the counter to produce the required sequence of pulses. They correctly decide that the Boolean expression for the gates is:

$$\mathbf{\overline{D}.C.\overline{B}.A + \overline{D}.C.B.A + D.\overline{C}.B.A + D.\overline{C}.B.\overline{A}}$$

(i) Explain the origin of the terms in the above expression.

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(ii) Simplify the above expression.

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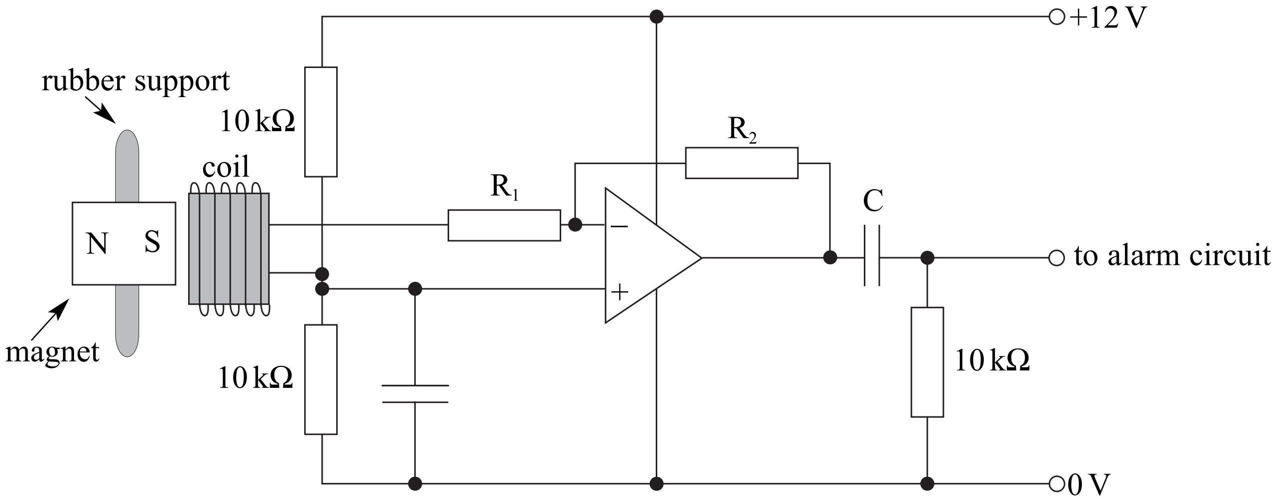
(5 marks)

9

Turn over ▶

2 The sensing element for the vibration sensor in a car alarm system consists of a small magnet mounted in a rubber support placed near to a coil of wire, as shown in the diagram below.
When there is any vibration of the car, the magnet moves relative to the coil and so a small voltage is generated by the coil. The voltage from the coil is amplified by the circuit shown below.

Vibration sensor circuit



(a) Estimate, stating your reason, the voltage at the inverting input of the op-amp when the output from the coil is zero.

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(2 marks)

(b) If $R_1 = 10\,k\Omega$ and $R_2 = 2.2\,M\Omega$, calculate the voltage gain of the amplifier circuit.

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(2 marks)

(c) If the alarm circuit requires an input of 3 V to operate, estimate the peak output signal required from the coil to trigger the alarm.

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(1 mark)

(d) In practice, it is found that the vibration sensing circuit is too sensitive. How would you modify the circuit to make the sensitivity adjustable?

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(2 marks)

(e) The value of capacitor C is chosen so that false triggering from low frequency vibrations is minimised. Calculate a value for C so that it has a reactance equal to the $10\,k\Omega$ resistor across the output at a frequency of 20 Hz.

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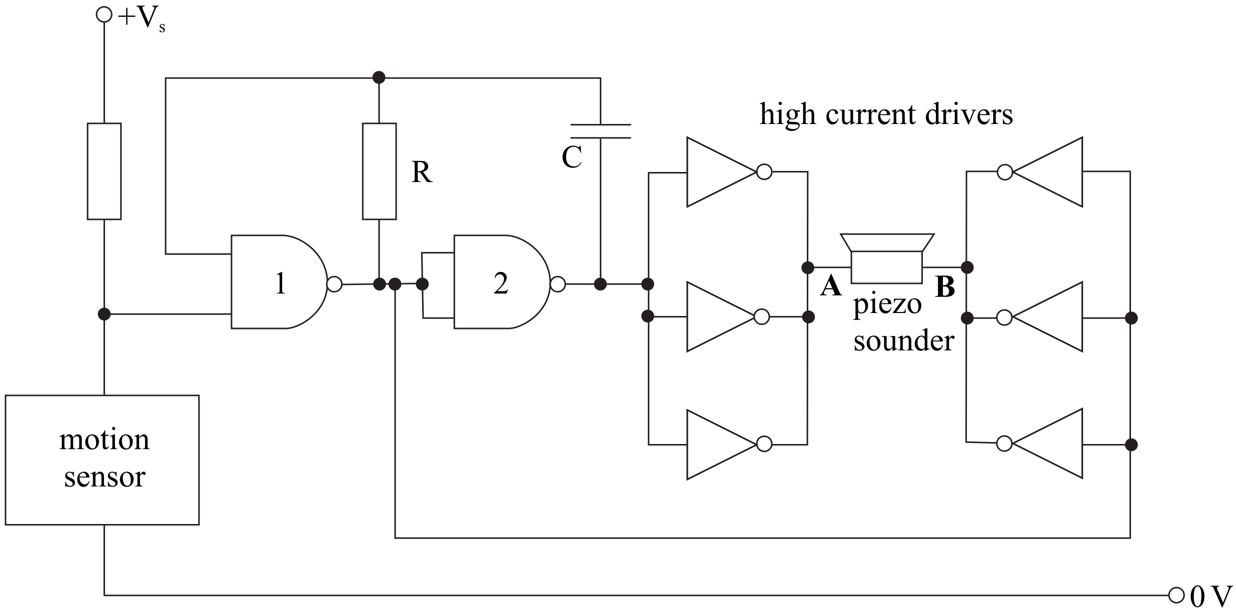
(2 marks)

9

3 Part of the circuit of a device to deter animals from a garden is shown below. When the motion sensor detects movement, it switches on the astable circuit.



(a) State what logic level is required at the output of the motion sensor to operate the astable and explain your reasoning.

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(2 marks)

(b) Explain how the astable functions when the motion sensor detects movement.

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(4 marks)

(c) Animals are particularly sensitive to sounds at 22 kHz. If R has a value of 15 kΩ, use the appropriate formula from the data sheet to calculate a value for C so that the circuit will produce an output of this frequency.

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(2 marks)

(d) Explain why point **B** is at logic 0 when point **A** is at logic 1.

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(1 mark)

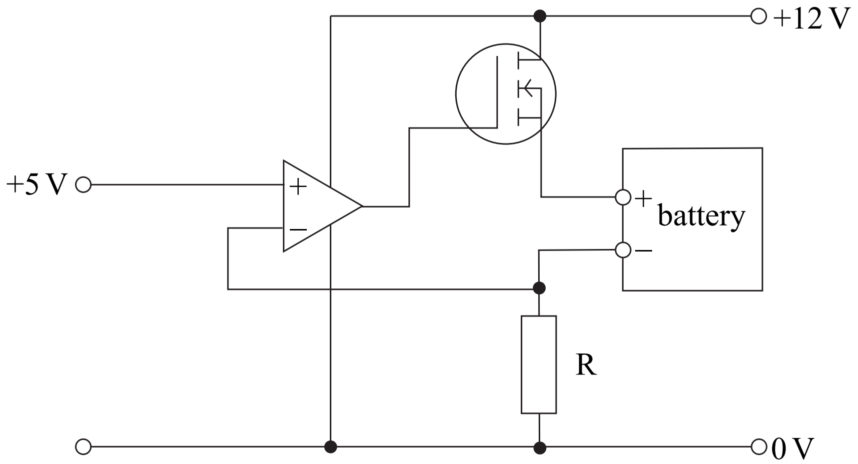
9

Turn over for the next question

LEAVE MARGIN BLANK

4 The NiMH rechargeable battery in a digital camera needs to be charged at a constant current of 200 mA.

The circuit diagram for the constant current generator is shown below.



(a) If the output of the op-amp is not saturated, explain why the voltage at the inverting input of the op-amp must be 5 V.

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(2 marks)

(b) The inverting input of the op-amp is connected to the resistor R. Calculate the value of R so that a current of 200 mA can pass through the battery.

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(2 marks)

(c) (i) What is the function of the MOSFET?

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(ii) Why is it needed in this application?

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(2 marks)

LEAVE MARGIN BLANK

(d) As the battery is charged, the voltage across its terminals rises. Explain how this circuit maintains a constant current through the battery.

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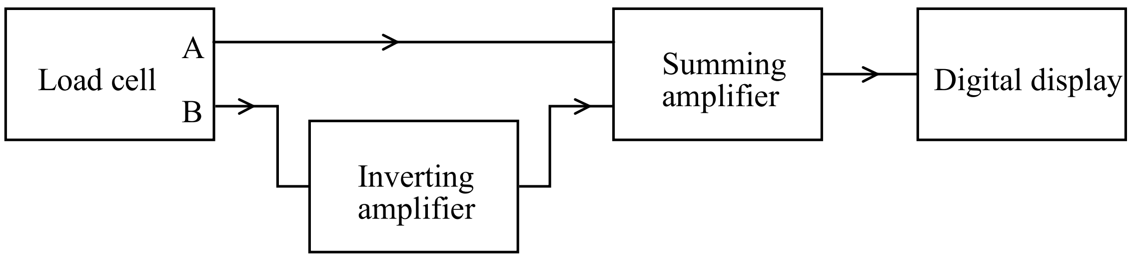
(3 marks)

9

Turn over for the next question

5 The system diagram for an electronic balance (weighing machine) is shown below. The balance is powered by a ±9 V supply.

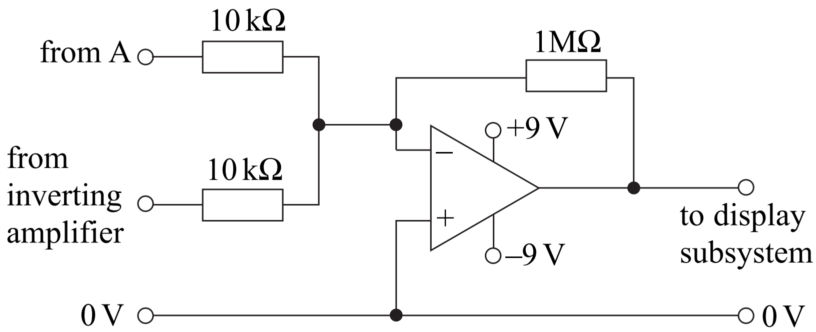


The load cell has a differential output and when there is no force on the load cell, outputs A and B are both at 0 V. When there is a force on the load cell, then output A produces an output of $-v$ and output B produces an output of $+v$, where v is a small voltage which is proportional to the force on the load cell.

(a) Output B is passed through an amplifier with a voltage gain of –1. In the space below draw the circuit diagram of an op-amp based amplifier with a voltage gain of –1 and state suitable values for any resistors that you use.

(4 marks)

(b) The circuit diagram for the summing amplifier is shown below.



(i) Label the virtual earth point on the amplifier with the letter X.

LEAVE MARGIN BLANK

(ii) Calculate the output voltage from the summing amplifier when the output voltage from the load cell is $\pm v$.

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(3 marks)

(c) The digital display is a voltmeter, with a maximum reading of 1.99 V. The output from the load cell is ±5 mV when there is a load of 1 kg.

(i) Calculate the maximum load that the weighing machine can measure and display.

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(ii) Calculate the smallest change in load that can be detected.

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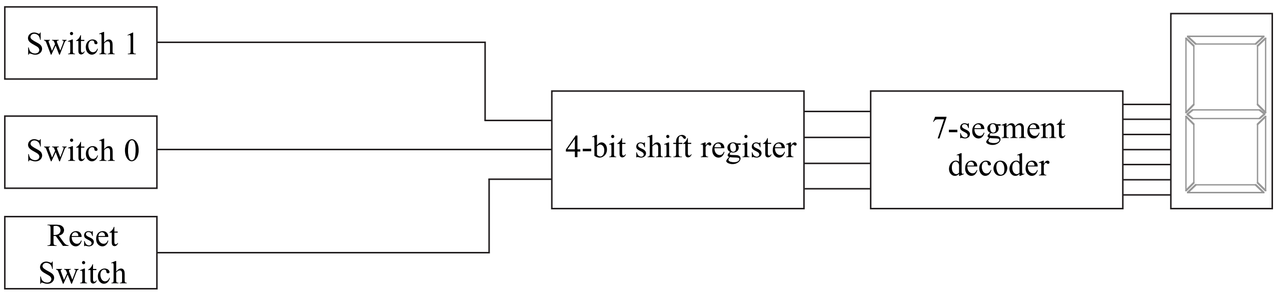
(2 marks)

9

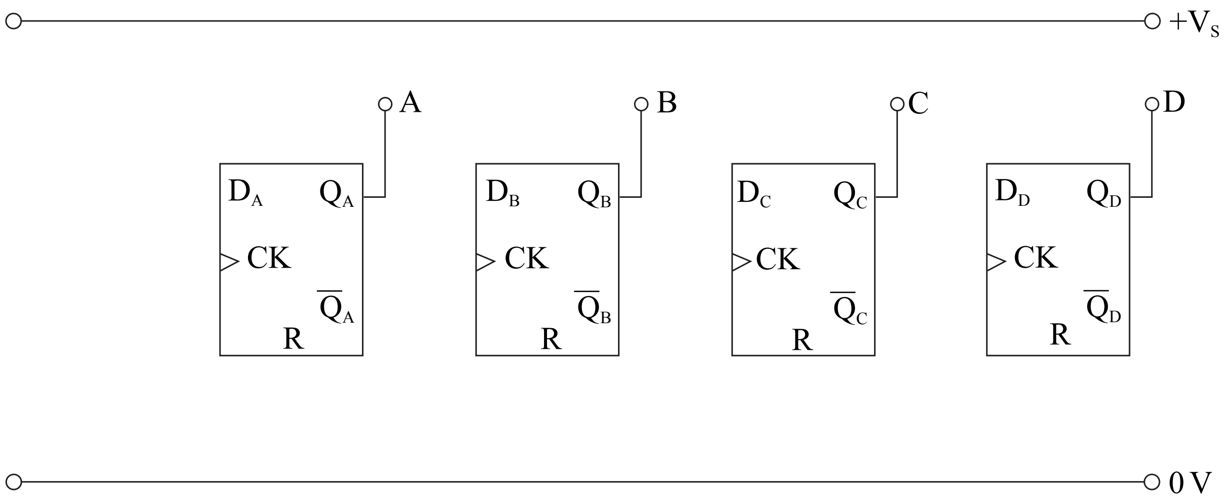
Turn over for the next question

6 An electronic system is required so that binary numbers can be entered and converted to a hexadecimal output on a 7-segment display. The system diagram is shown below.



When switch 1 is pressed, the serial input to the shift register is set to logic 1 and a clock pulse is generated to enter the logic 1 into the shift register.
When switch 0 is pressed, the serial input to the shift register is set to logic 0 and a clock pulse is generated to enter the logic 0 into the shift register.
When the reset switch is operated, the outputs of the shift register are set to logic 0.

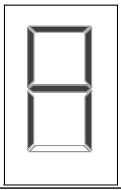
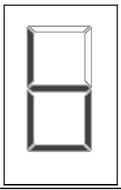
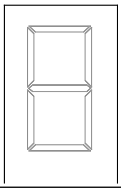
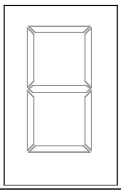
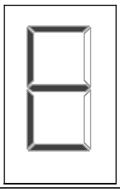
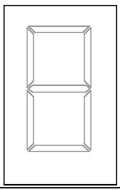
(a) (i) Complete the diagram below to show how the four D-type flip-flops should be connected to form a 4-bit shift register and clearly label the serial input.



(ii) If the reset terminals of the D-type flip-flops are active high, mark onto the diagram above where you would connect the reset switch and any other components that you need.

(6 marks)

(b) The 7-segment decoder has to be especially designed to enable the display to show the hexadecimal numbers above 9. The representation of these numbers must be completely different to the representation of the numbers from 0 to 9. Complete the table below and shade in the appropriate segments of the display to represent the hexadecimal numbers.

Binary	Decimal	Hexadecimal	Display
1010	10	A	
1011	11	B	
	12		
	13		
1110	14	E	
	15		

(3 marks)

9

7 A student wants to build a bass guitar practice amplifier.
A large 4 Ω loudspeaker and power supply are available.
The power supply provides ±15 V at a maximum current of 4 amps.
The peak output signal from the guitar is 75 mV.

(a) (i) Show that the voltage gain needed from the amplifier is approximately 200, if the amplifier just saturates on the peak signal from the guitar.

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(ii) The amplifier contains an op-amp with a voltage gain-bandwidth product of 6×10^5 Hz. Calculate, showing your working, the maximum frequency at which the amplifier will saturate when using the guitar as an input.

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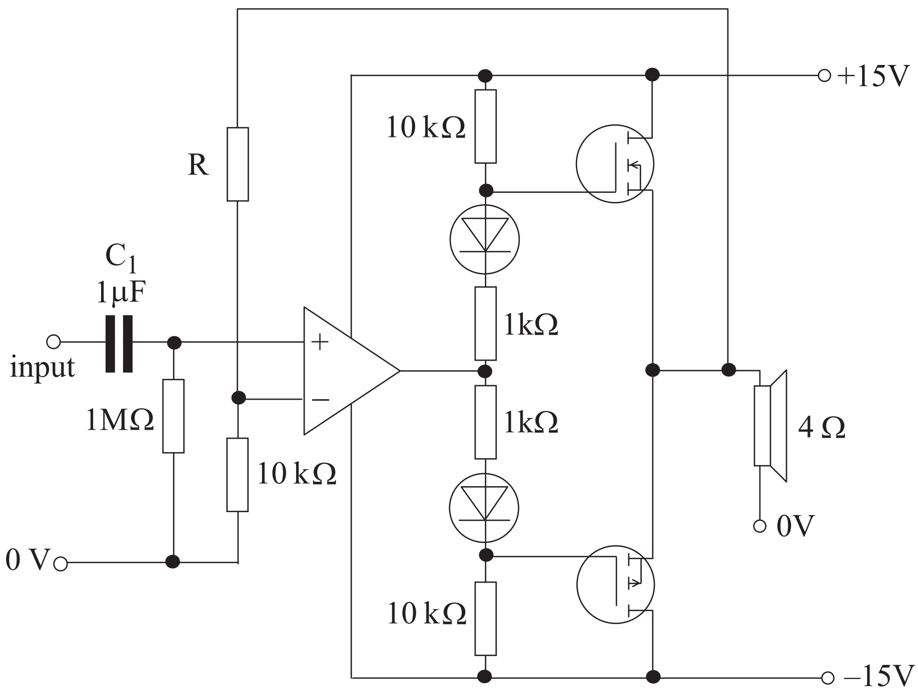
(2 marks)

The circuit diagram for the amplifier is shown below.



(b) (i) Estimate the input impedance of the amplifier circuit, stating any assumption that you make.

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(ii) Calculate a value for the feedback resistor R so that the overall amplifier circuit will have a voltage gain of 200. State any assumption that you make.

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(6 marks)

(c) When the amplifier has been constructed, the student is concerned that it should not suffer from cross-over distortion. In order to check this the current passing through the drain of the n-channel MOSFET is measured and has a value of 50 mA when there is no input signal to the amplifier.

(i) What is cross-over distortion?

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(ii) Explain whether the amplifier will suffer from cross-over distortion.

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(3 marks)

Question 7 continues on the next page

Turn over ▸

(d) (i) Show that the maximum theoretical output power of the amplifier is approximately 28W rms.

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(ii) State **two** reasons why the maximum output power is likely to be less than this in practice.

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(4 marks)

(e) In operation, the MOSFETs become very hot and so the student decides to bolt them onto heat sinks.
State **three** important design features of efficient heat sinks.

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(3 marks)

18

END OF QUESTIONS