Surname	Centre Number	Candidate Number
First name(s)		2

GCE AS

B490U10-1

S24-B490U10-1

MONDAY, 20 MAY 2024 – AFTERNOON

ELECTRONICS – AS component 1
Principles of Electronics

2 hours 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**14**	
2.	**9**	
3.	**15**	
4.	**17**	
5.	**10**	
6.	**13**	
7.	**10**	
8.	**12**	
9.	**9**	
10.	**5**	
11.	**6**	
Total	**120**	

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ADDITIONAL MATERIALS

You will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in questions **7**(a) and **11**.

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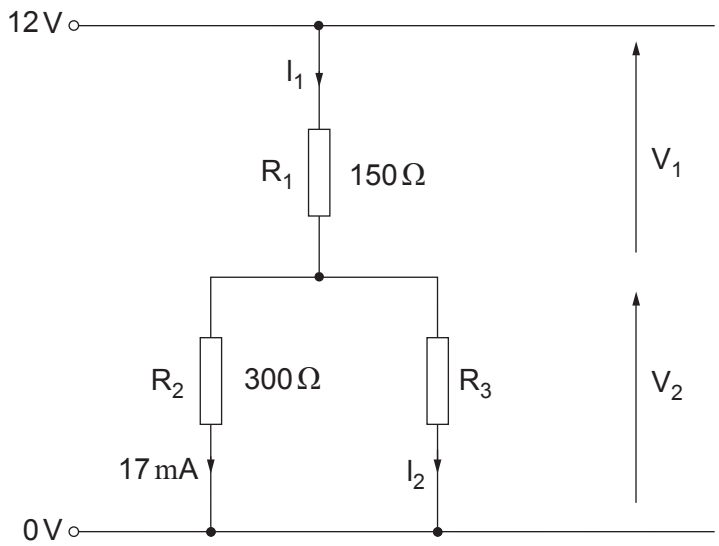
Answer **all** questions.

1. (a) Use the information given in the circuit diagram to determine the values of the quantities listed.



(i) V_2 .....

..... [1]

(ii) I_1 .....

..... [2]

(iii) I_2 .....

..... [1]

(b) The resistor R_1 has a power rating of 0.25 W.
Show by calculation whether this power rating is sufficient. [2]

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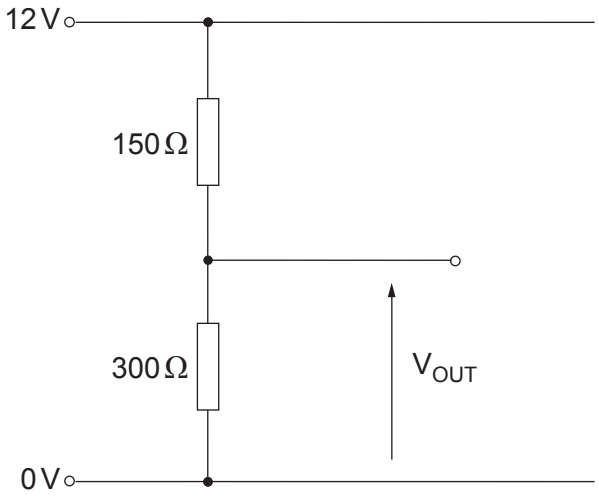
(c) The following circuit is used as a voltage source.



(i) Use Thevenin's theorem to calculate the open circuit voltage V_{OC} and the equivalent resistance, R_{eq}. [4]

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(ii) Draw and label the equivalent circuit with a load resistor connected across the output terminals. [2]

(iii) Use the equivalent circuit to calculate the voltage drop across the output terminals when the load current is 25 mA. [2]

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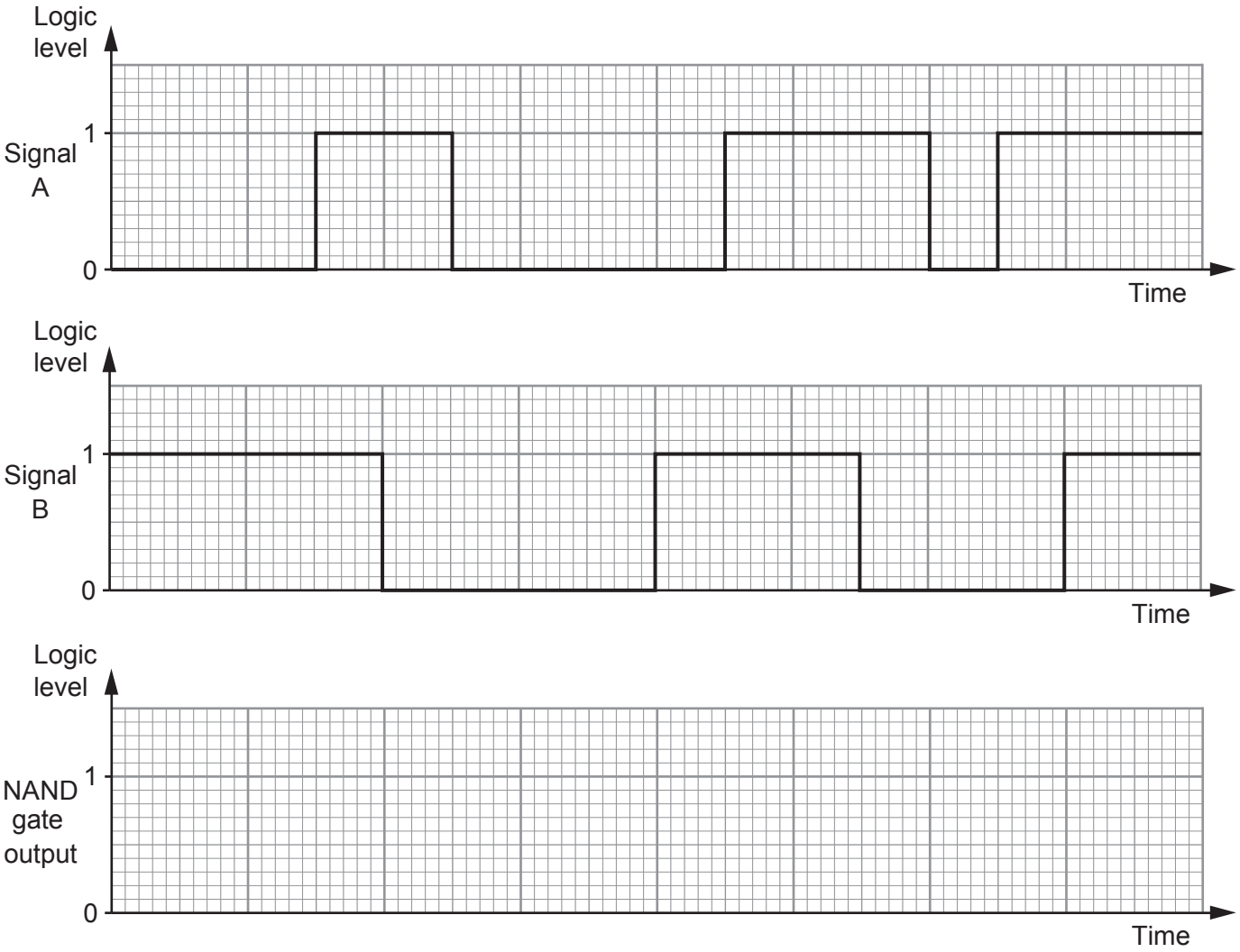
2. (a) Signals A and B are applied to the inputs of a 2-input NAND gate. Sketch the output. [2]



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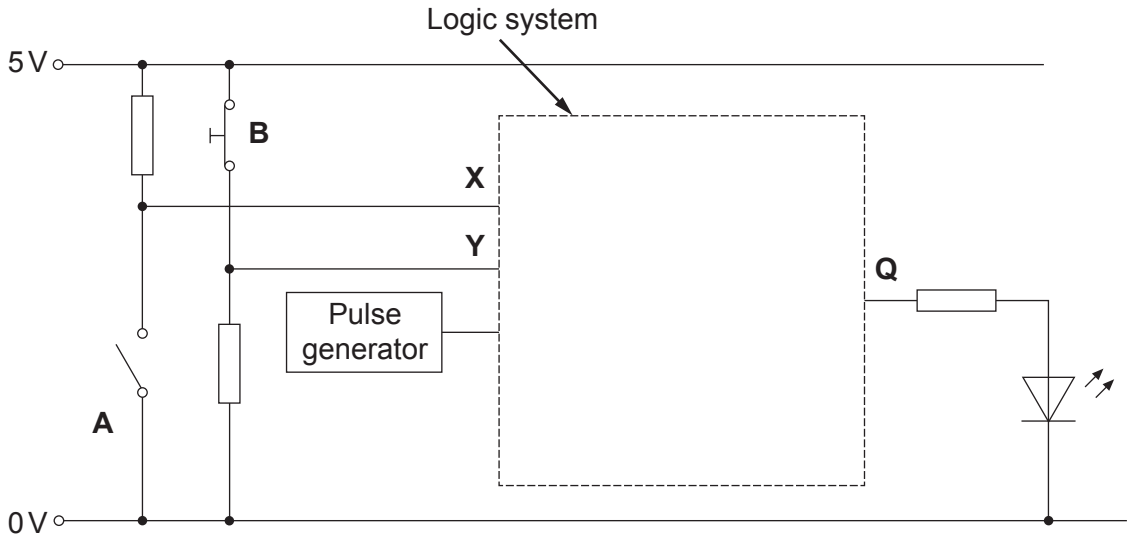
(b) The diagram shows part of an alarm system used to protect a valuable object.

- Switch **A** is **closed** to set the alarm.
- If the object is moved switch **B opens**.
- The LED flashes if the object is moved when the alarm is set.



(i) Why is a resistor needed with switch **B**? [1]

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(ii) What is the logic level at point **X** when the switch **A** is open? [1]

Logic level at **X** .....

(iii) Design a logic system, using **two 2-input** logic gates, such that the LED will flash only if the object is moved when the alarm is set. **Draw your design in the dotted box above** showing the **two** logic gates and appropriate connections. [3]

(c) When **Q** is high, it is at 5 V. The LED is rated at 2.3 V, 10 mA.
Calculate the resistance of the current limiting resistor. [2]

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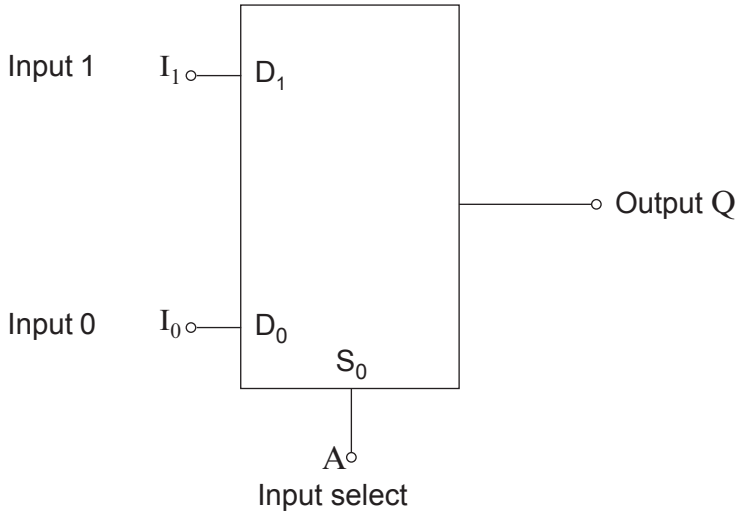
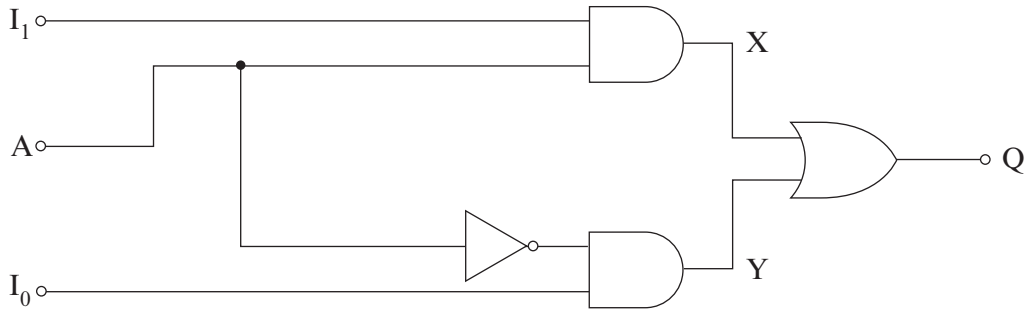
3. A 2-input multiplexer is shown below.



The multiplexer can be constructed using the logic gates shown in the following circuit diagram.



(a) Give the Boolean expression for each of the outputs X, Y and Q in terms of the inputs A, I_1 and I_0. [3]

X = ...

Y = ...

Q = ...

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(b) Complete the truth table for this system. [3]

A	I_1	I_0	X	Y	Q
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

(c) (i) Redraw the logic system shown in the diagram using NAND gates only. [3]

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(ii) **Draw lines** through all redundant gates. Identify each redundant pair. [2]

(d) Use Boolean algebra and de Morgan's theorem to simplify the following expression. [4]

$$Q = A.\overline{B} + \overline{A}.\overline{B} + \overline{A + \overline{B}}$$

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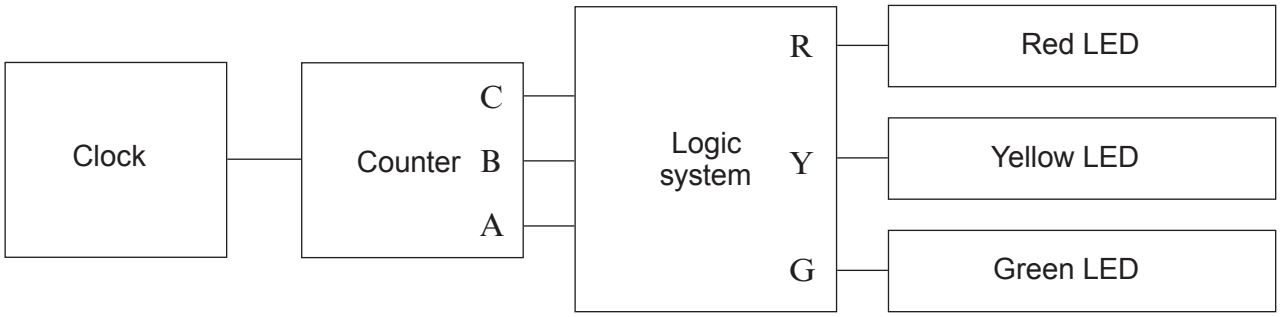
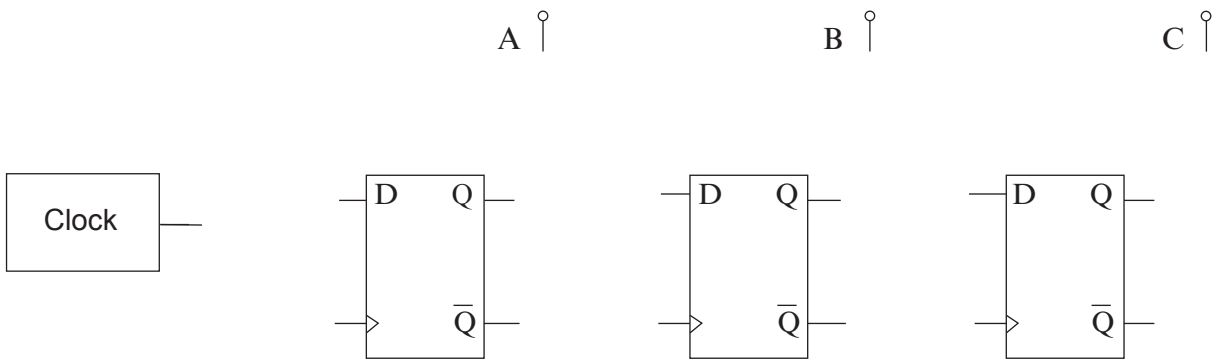
4. The following block diagram shows a design for a traffic light simulator.



(a) Complete the diagram to make a 3-bit up-counter. Each LED is activated by a logic 1 signal. [3]



(b) The following truth table shows the inputs and outputs of the logic system.

Clock pulse	C	B	A	R	Y	G
0	0	0	0	1	0	0
1	0	0	1	1	0	0
2	0	1	0	1	0	0
3	0	1	1	1	1	0
4	1	0	0	0	0	1
5	1	0	1	0	0	1
6	1	1	0	0	0	1
7	1	1	1	0	1	0

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The clock frequency is 0.1 Hz.

(i) Show by calculation that the Red LED is on for 40 s. [1]

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(ii) Use the table to write down the **simplest** Boolean equations for outputs R and Y in terms of inputs A, B and C. [2]

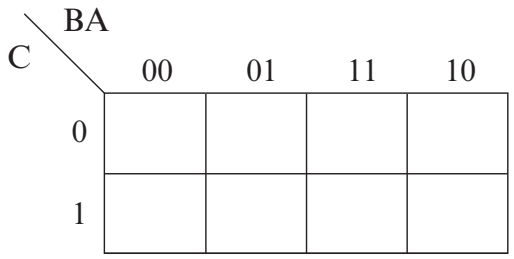
R = ...

Y = ...

(iii) I. Use the table to write down the **unsimplified** Boolean equation for output G in terms of inputs A, B and C. [1]

G = ...

II. Use the Karnaugh map to simplify the expression for output G. [3]



G = ...

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(iv) Design the logic system for the traffic light simulator on the following diagram. [3]

(c) An alternative solution for the traffic light simulator uses a microcontroller.

(i) State an advantage of using a microcontroller to produce the traffic light simulator. [1]

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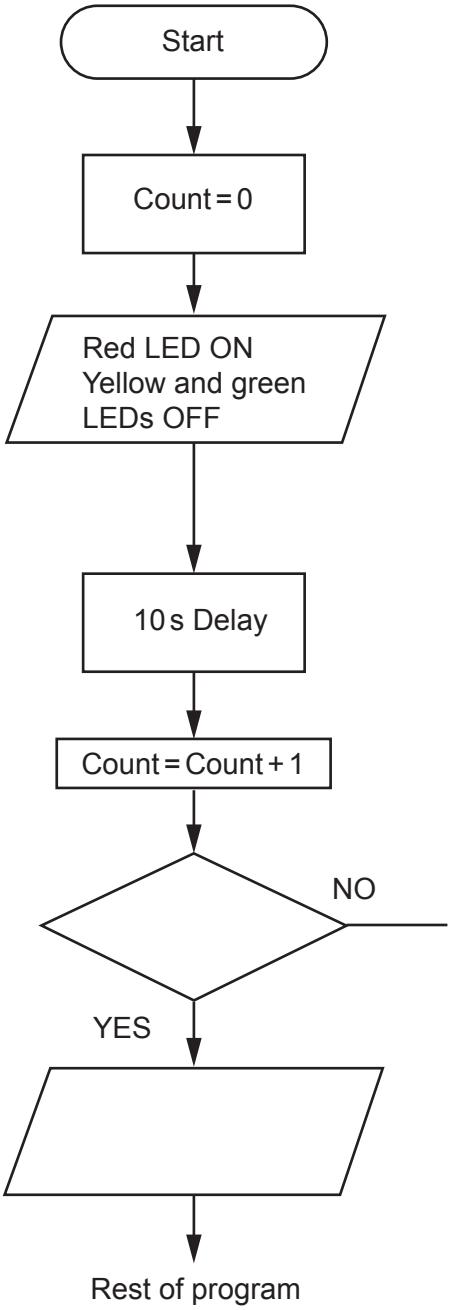
(ii) An incomplete section of the flow chart is shown below. Complete the flowchart boxes and add any flow lines needed. [3]



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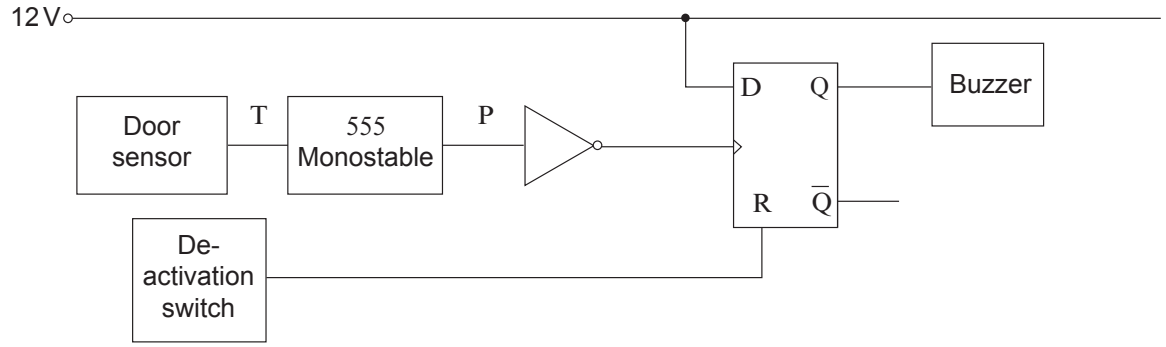
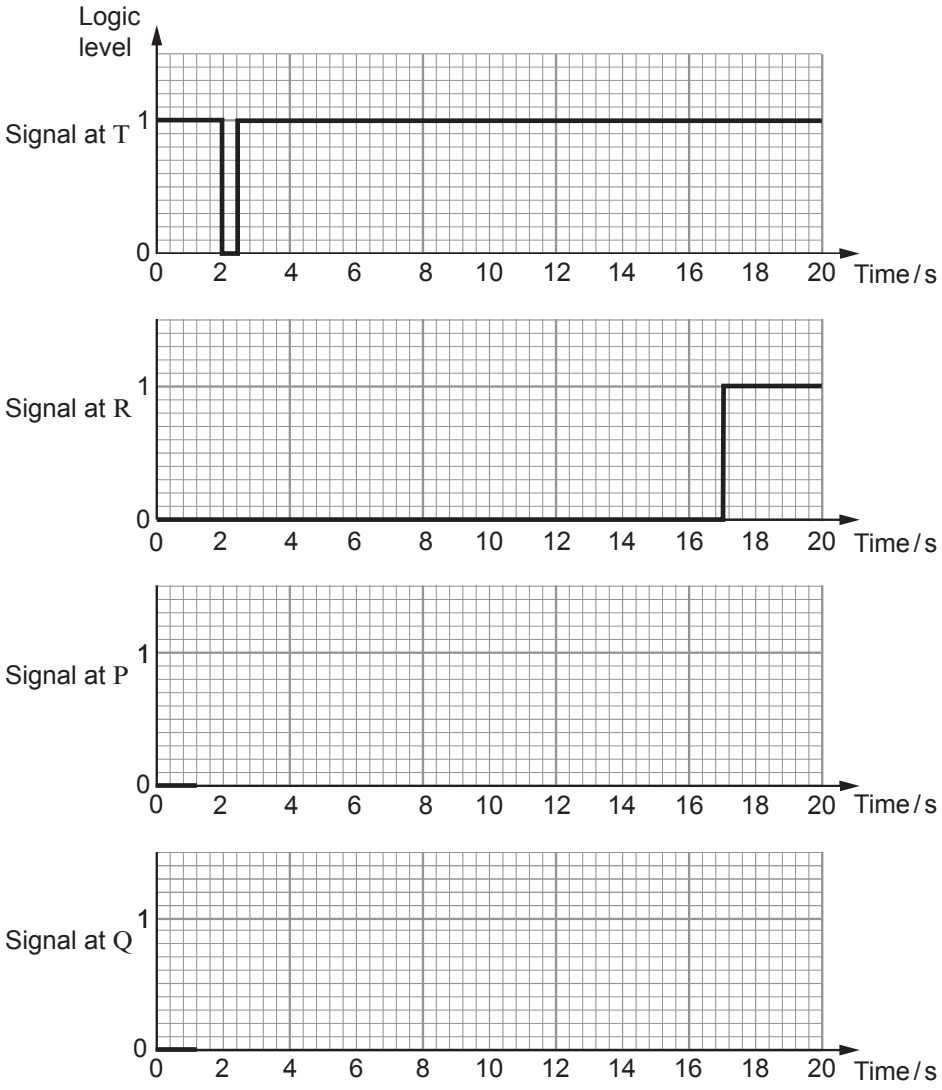
5. A student designs a prototype alarm system which sounds a buzzer 10 s after a door has been opened unless the de-activation switch has been pressed. The diagram below shows a possible solution. The D-type flip-flop is rising-edge triggered.



When the door is opened a momentary pulse is produced by the door sensor at T.

(a) The door is opened and the de-activation switch is pressed 15 s later. The timing diagram shows the signals at T and R.



Complete the timing diagram showing the signals at P and Q. [3]

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(b) Why is the NOT gate needed between the monostable and the flip-flop? [1]

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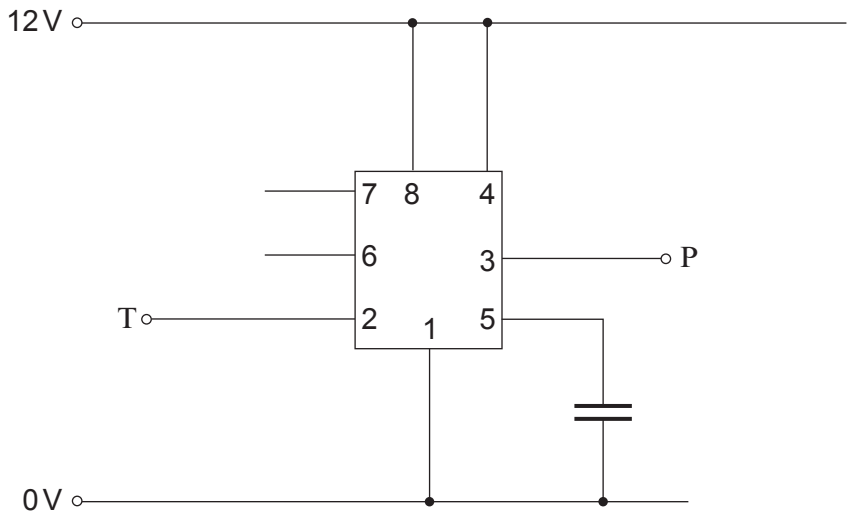
(c) (i) Complete the circuit diagram for the 555 monostable. [3]



(ii) The timing part of the circuit contains a 47 μF capacitor. Calculate the resistance required to give a time period of 10 s. [3]

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Turn over.

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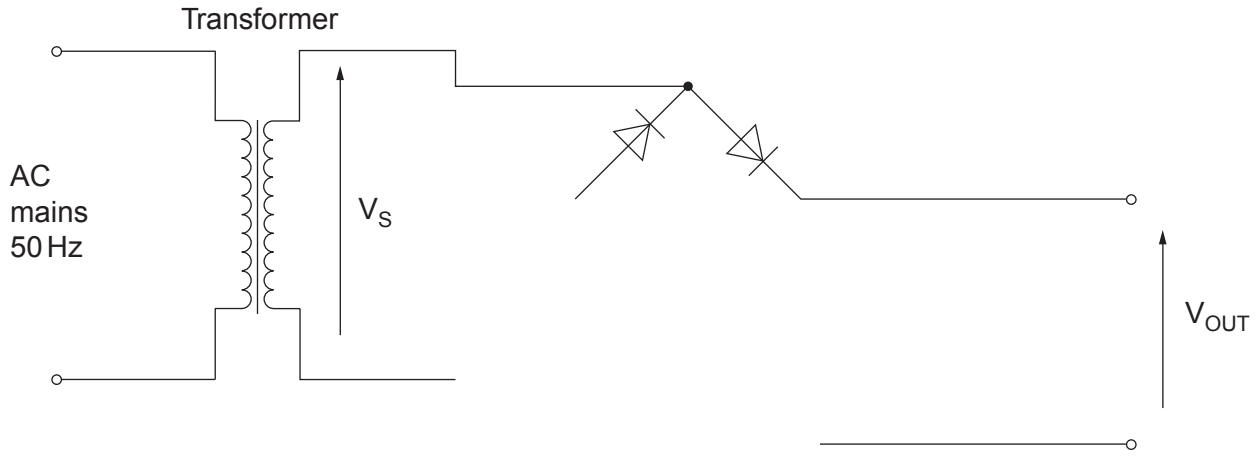
6. The following diagram shows part of the circuit of a full-wave rectified power supply.



(a) **Complete the circuit diagram** by adding: [4]

- the extra diodes needed to produce the full-wave rectification
- the circuit connections
- a 1000 μF capacitor to smooth the output
- a load resistor, R.

(b) The voltage, V_S, across the secondary windings of the transformer has a peak value of 12 V.

(i) Calculate the peak value of the voltage V_{OUT}. [1]

.....

(ii) Determine the frequency of the output ripple voltage. [1]

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(iii) Calculate the ripple voltage when a current of 400 mA is drawn by the load. [3]

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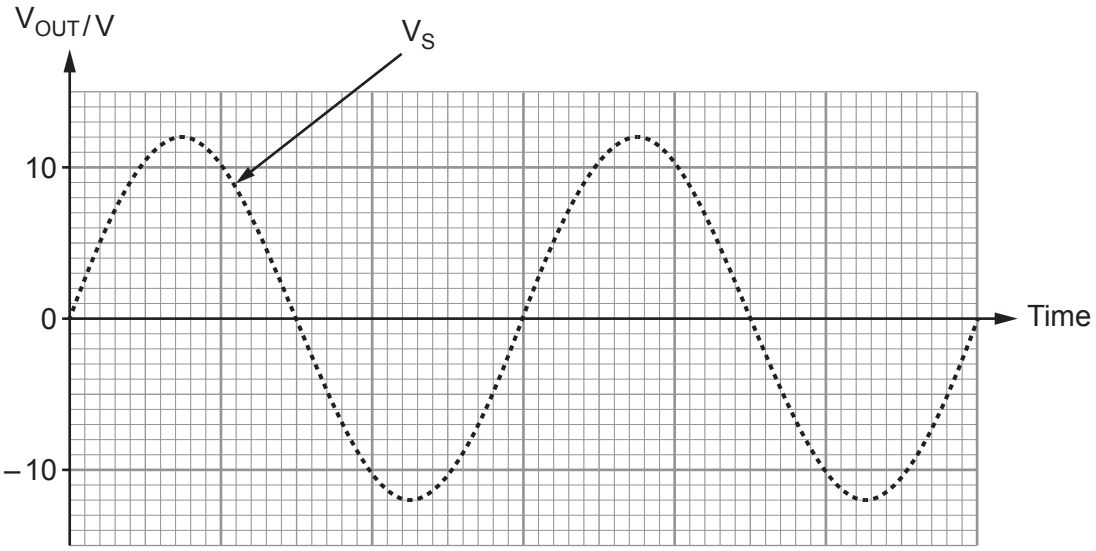
(c) In the graph below, the voltage, V_S, across the secondary windings of the transformer is shown as a dotted waveform.

On the same graph, sketch the graph to show the output voltage, V_{OUT}, when a 400 mA current flows through the load resistor R. [4]



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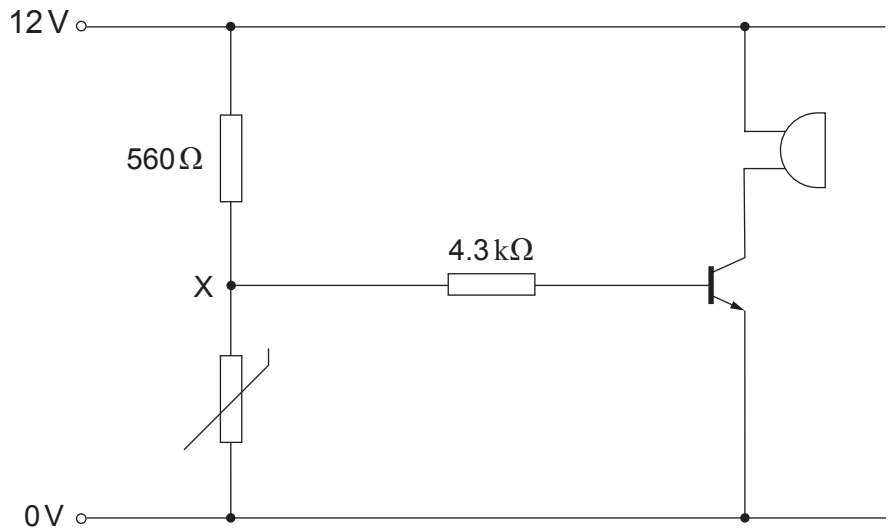
7. The following circuit has been designed as a frost alarm. The specification requires a buzzer to sound when the temperature falls below 4 °C.



Some of the component parameters are listed below:

- Buzzer 12 V, 0.16 A
- Transistor h_{FE} = 140
- Thermistor 400 Ω at 4 °C

(a) Use the information given to evaluate the design. Determine whether the circuit design meets the specification and suggest any improvements. [6 QER]

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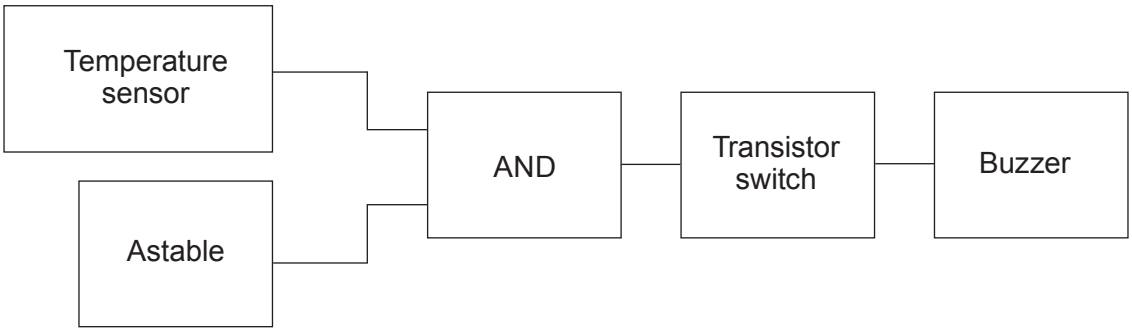
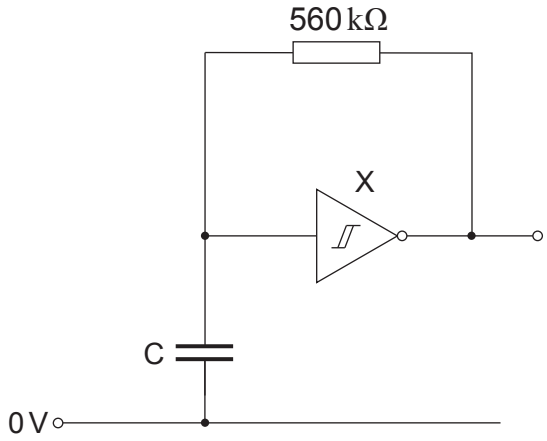
(b) The design is modified to make the buzzer pulse when the temperature falls below 4 °C.



The circuit diagram for the astable is shown below.



(i) Name the component labelled X. [1]

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(ii) Calculate a suitable value for the capacitor, C, required to produce a frequency of 0.8 Hz. [3]

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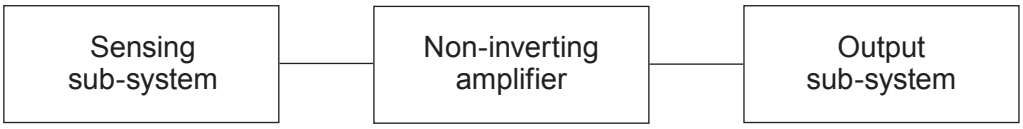
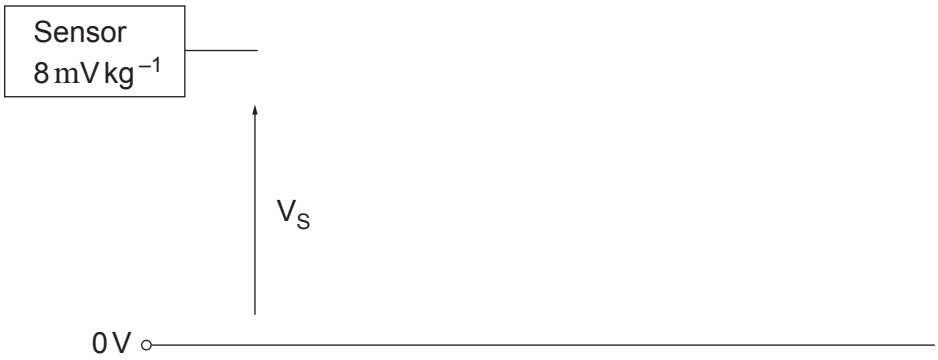
8. An electronic balance consists of three sub-systems.



The output of the sensing sub-system increases by 8 mV for each kilogram added to the balance.

(a) Design an op-amp circuit to give a voltage gain of 50. Draw a circuit diagram of your design including the connection to the sensor. Label the circuit diagram with component values. [5]



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(b) The sensing sub-system is adjusted so that the output V_S = 0 V when no load is on the balance. A 12 kg load is then placed on the balance.

(i) Calculate the voltage, V_S. [2]

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(ii) Calculate the output voltage of the amplifier. [2]

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(c) The output of the op-amp saturates at 16 V. What is the maximum load that this system can measure? [3]

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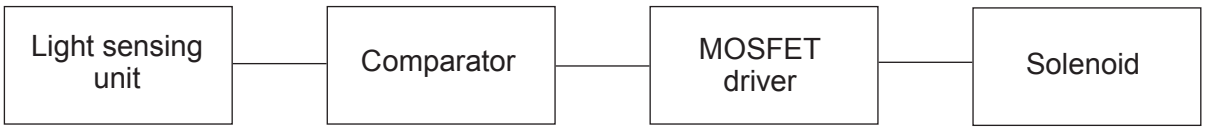
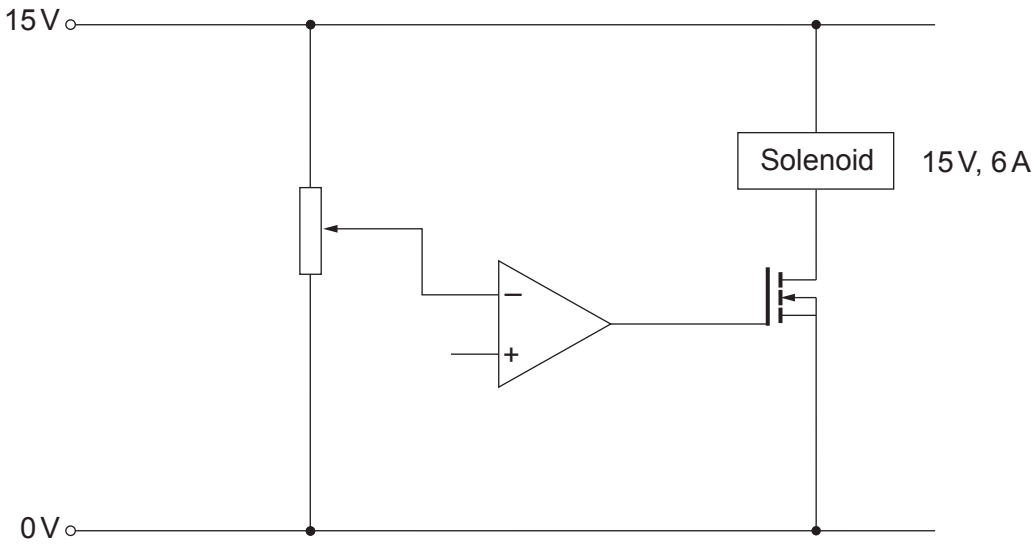
9. A student designs the following system to lock a cat-flap automatically at night.



The incomplete circuit diagram for the system is shown below.



(a) **Complete the circuit diagram** by adding:

- a light sensing sub-system to provide an input voltage to the comparator
- protection for the MOSFET when the solenoid switches off. [3]

(b) Explain the advantage of using the potentiometer in place of a voltage divider consisting of two fixed value resistors to provide the reference voltage for the comparator. [1]

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(c) An extract from the data sheet of the MOSFET is shown below.

V_{DS} / V (max)	V_{GS} / V (max)	I_D / A (max)	P_{TOT} / W (max)	g_M / S (typical)	r_{DS} / Ω (on)
50	18	30	120	0.7	0.13

(i) Calculate the minimum value of V_{GS} required to operate the solenoid at its rated current. [2]

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(ii) Calculate the power dissipated in the MOSFET when the solenoid is operating at its rated current. [2]

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(d) Identify a potential weakness in this design. [1]

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10. A 2-input NAND gate has a propagation delay of 5 ns.

(a) Explain what is meant by propagation delay. [1]

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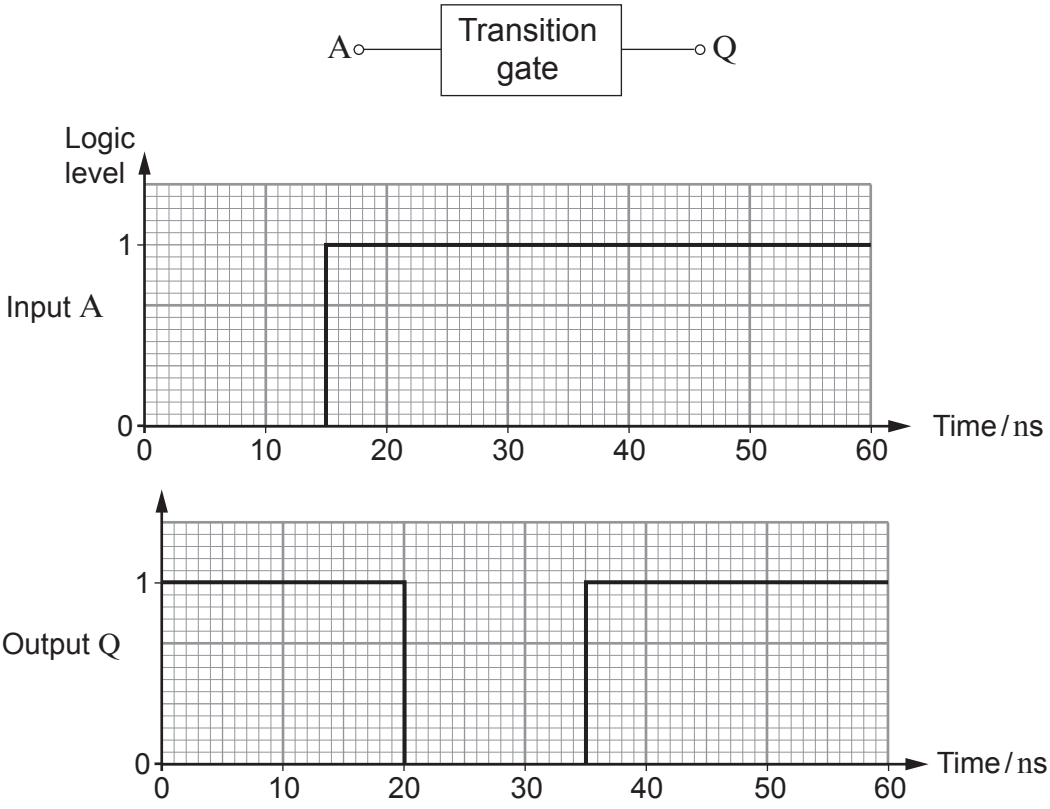
(b) A transition gate produces the output signal Q when signal A is applied to the input.



Design a suitable circuit using NAND gates with 5 ns propagation delay to produce the output Q in response to input A. [3]

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(c) What happens to the output Q when the signal at A falls from logic 1 to logic 0? [1]

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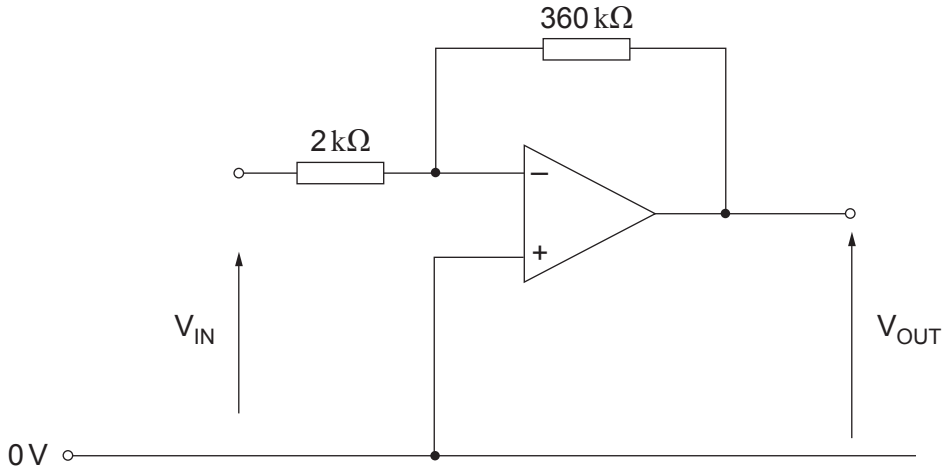
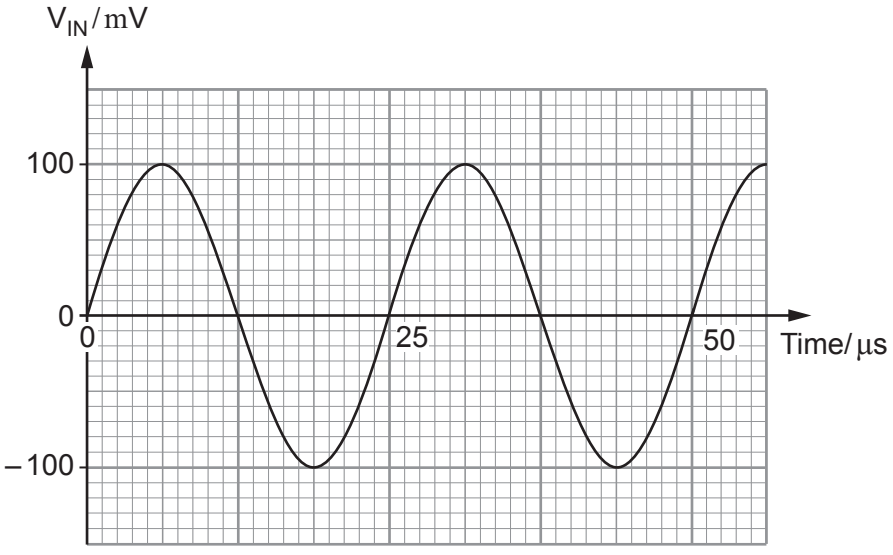
11. The following diagram shows an op-amp set up as a voltage amplifier used to amplify a 40 kHz ultrasonic signal.



An extract from the data sheet for the op-amp is given below.
The op-amp is powered from a ±16 V supply and the output saturates at ±15 V.

Parameter	Value
Open-loop gain	3.0×10^5
Input impedance	$2.0 \times 10^{12}\ \Omega$
Slew rate	$3\ \text{V}\,\mu\text{s}^{-1}$
Gain-bandwidth product	8 MHz

A 40 kHz test signal V_{IN} is applied to the input.



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Use the information given to evaluate the design of the amplifier and suggest any modifications that need to be made so that the test signal can be amplified without distortion.
[6 QER]

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