GCE A LEVEL – NEW

A490U10-1

WEDNESDAY, 5 JUNE 2019 – AFTERNOON

ELECTRONICS – A level component 1

Principles of Electronics

2 hours 45 minutes plus your additional time allowance

Surname ______________________

Other Names ______________________

Centre Number ______________________

Candidate Number 2 ______________________

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	17	
2.	14	
3.	15	
4.	13	
5.	12	
6.	10	
7.	14	
8.	10	
9.	20	
10.	15	
Total	140	

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a DATA BOOKLET.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball-point pen or your usual method.

Answer ALL questions.

Write your name, centre number and candidate number in the spaces provided on the front cover.

Write your answers in the spaces provided in this booklet.

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 2(d).

Answer ALL questions.

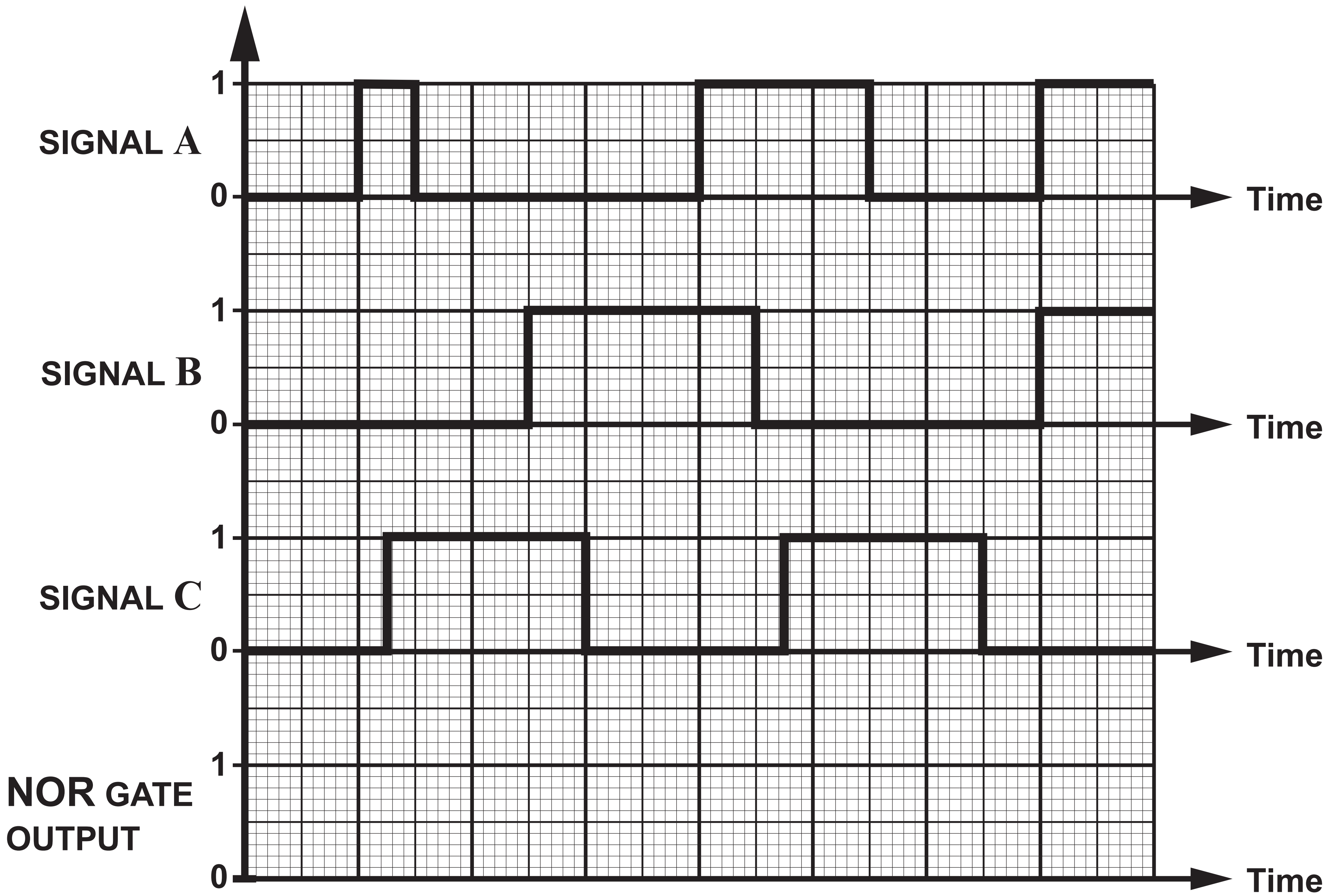
1(a) One type of logic gate is called a NOR gate.

(i) Write down a Boolean expression for the output Q of a TWO-input NOR gate in terms of its inputs A and B. [1]

(ii) Draw the circuit symbol for a THREE-input NOR gate. [1]

1(a) (iii) **On the opposite page the first three graphs show signals applied to inputs A, B and C of a THREE-input NOR gate.**

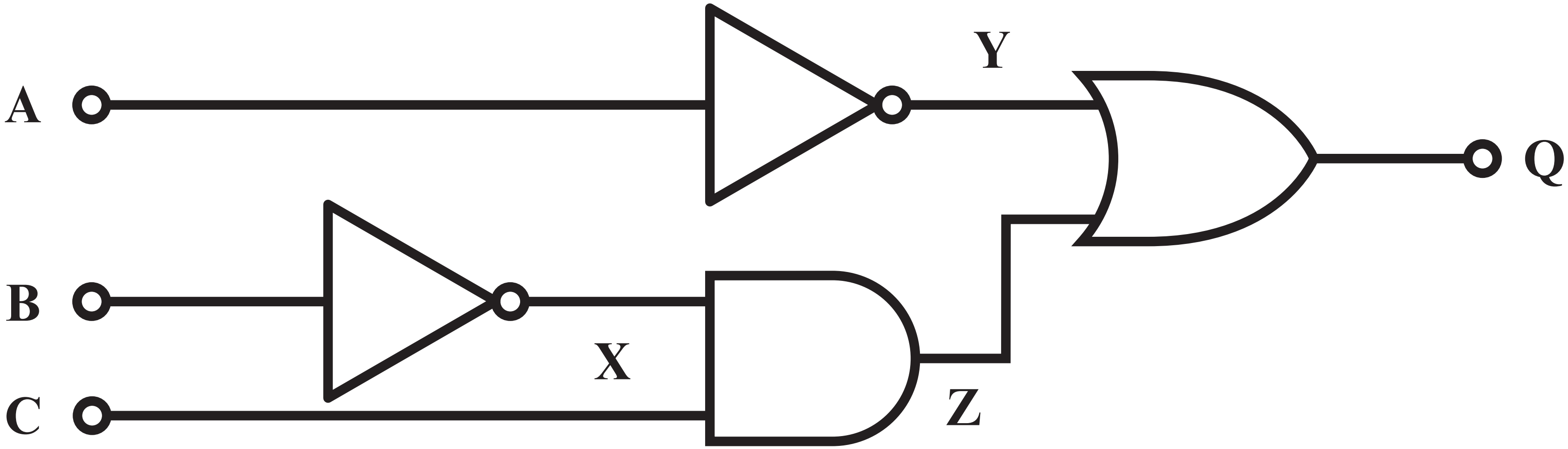
Use the axes provided to sketch the resulting output Q. [3]


SIGNAL A
SIGNAL B
SIGNAL C
NOR GATE OUTPUT
1
0
Time

1(b) The diagram opposite shows a logic system using a variety of types of logic gates.

(i) Complete the truth table for this system. [4]

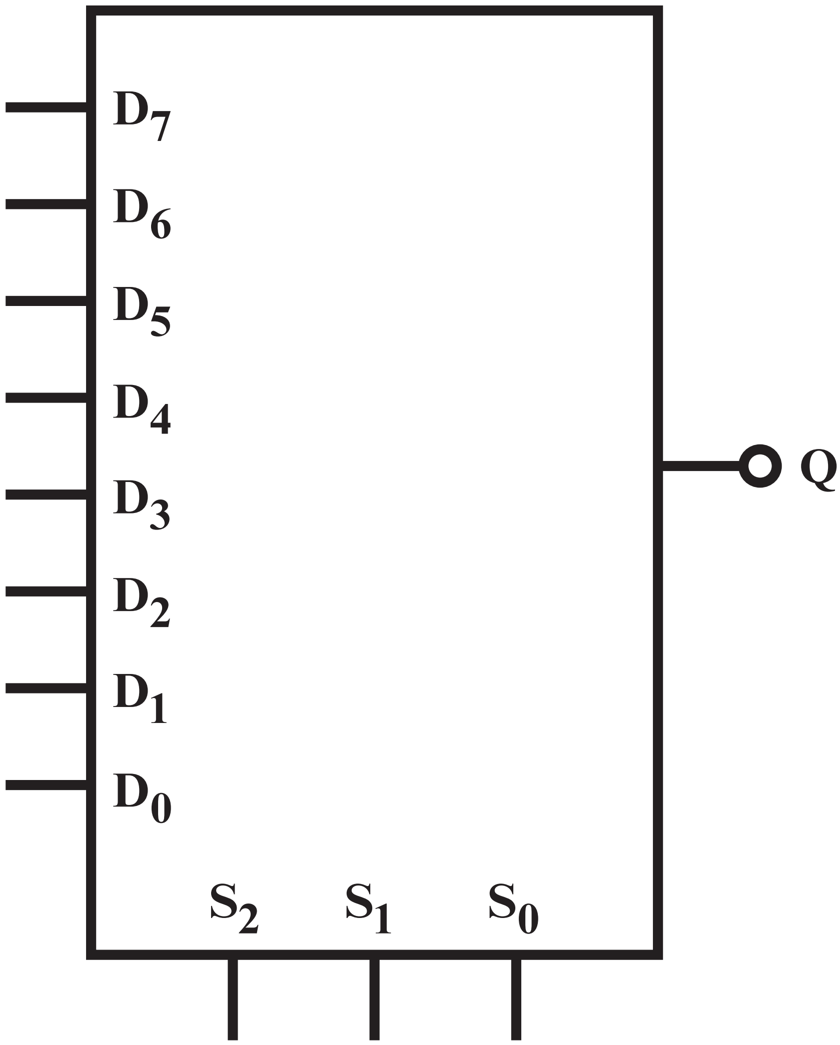
C	B	A	X	Y	Z	Q
0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				


A
B
C
X
Y
Z
Q

1(b) (ii) Draw a circuit diagram to show how the same overall logic function could be achieved using only NAND gates. [3]

(iii) Some of these NAND gates are redundant. Cross out all redundant NAND gates. [2]

1(b) (iv) Design a circuit that produces the same logic function using an 8:1 multiplexer. [3]


D_7
D_6
D_5
D_4
D_3
D_2
D_1
D_0
Q
S_2
S_1
S_0

2.(a) Simplify the following Boolean expression using the rules of Boolean algebra: [2]

$$Q = A.\,(\overline{A} + B)$$

2(b) Write down the unsimplified Boolean expression linking the output Q of the following logic system to the inputs A, B and C. [3]

C	B	A	Q
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	0

Q = ____

2(c) Simplify the following Boolean expression using a Karnaugh map [3]

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

DC \ BA	00	01	11	10
00				
01				
11				
10				

Q = ____

2(d) The logic system shown opposite has been designed to satisfy the following specification:

– When neither switch is closed, the LED is on continuously.

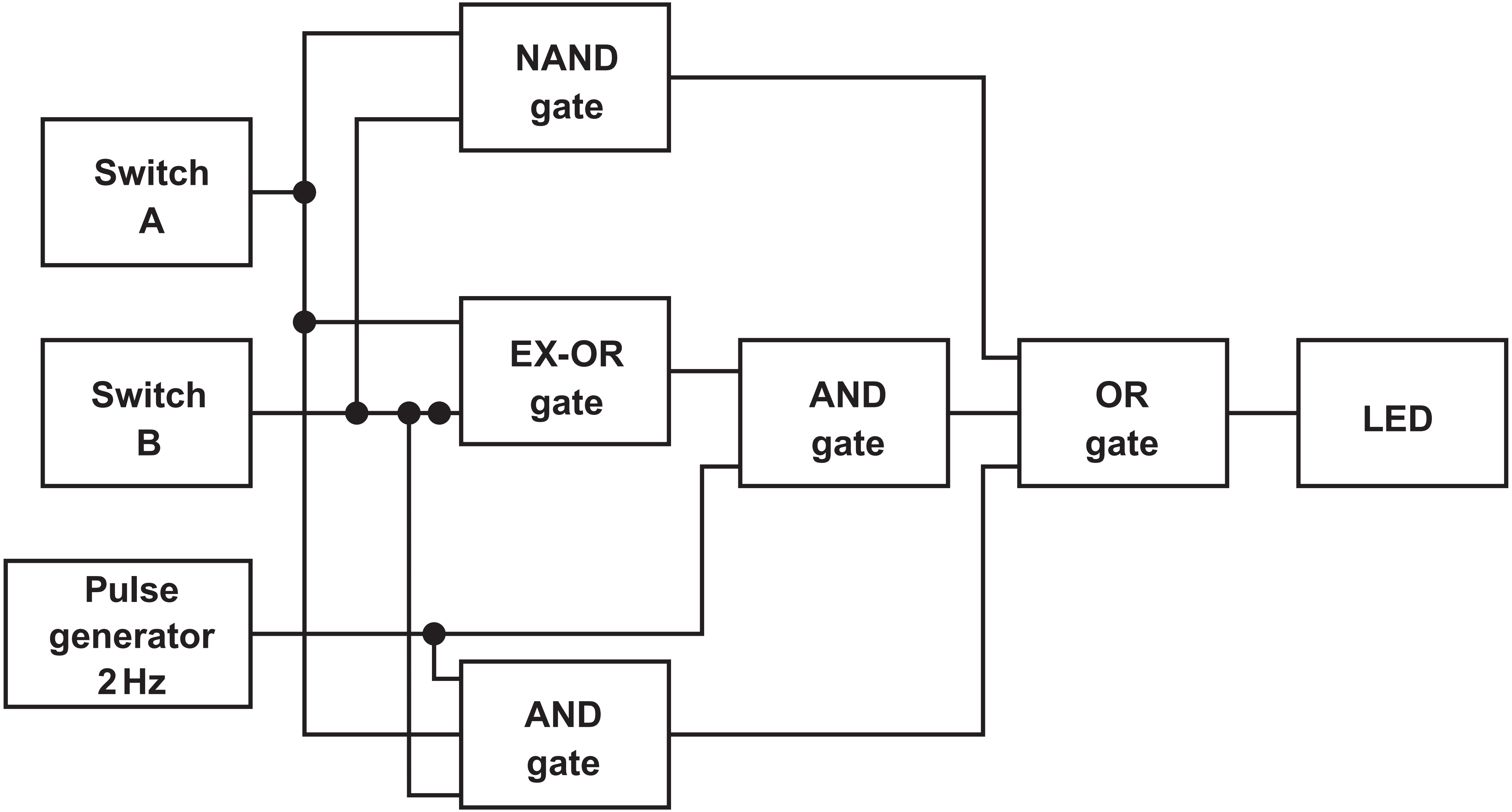
– When either switch is closed, but not both, the LED flashes at a frequency of 1 Hz.

– When both switches are closed, the LED flashes at a frequency of 2 Hz.

The switch units output a logic 1 signal when closed.

The LED requires an input signal of logic 1 to make it light.

Evaluate the logic system against the specification and suggest improvements. [6 QER]

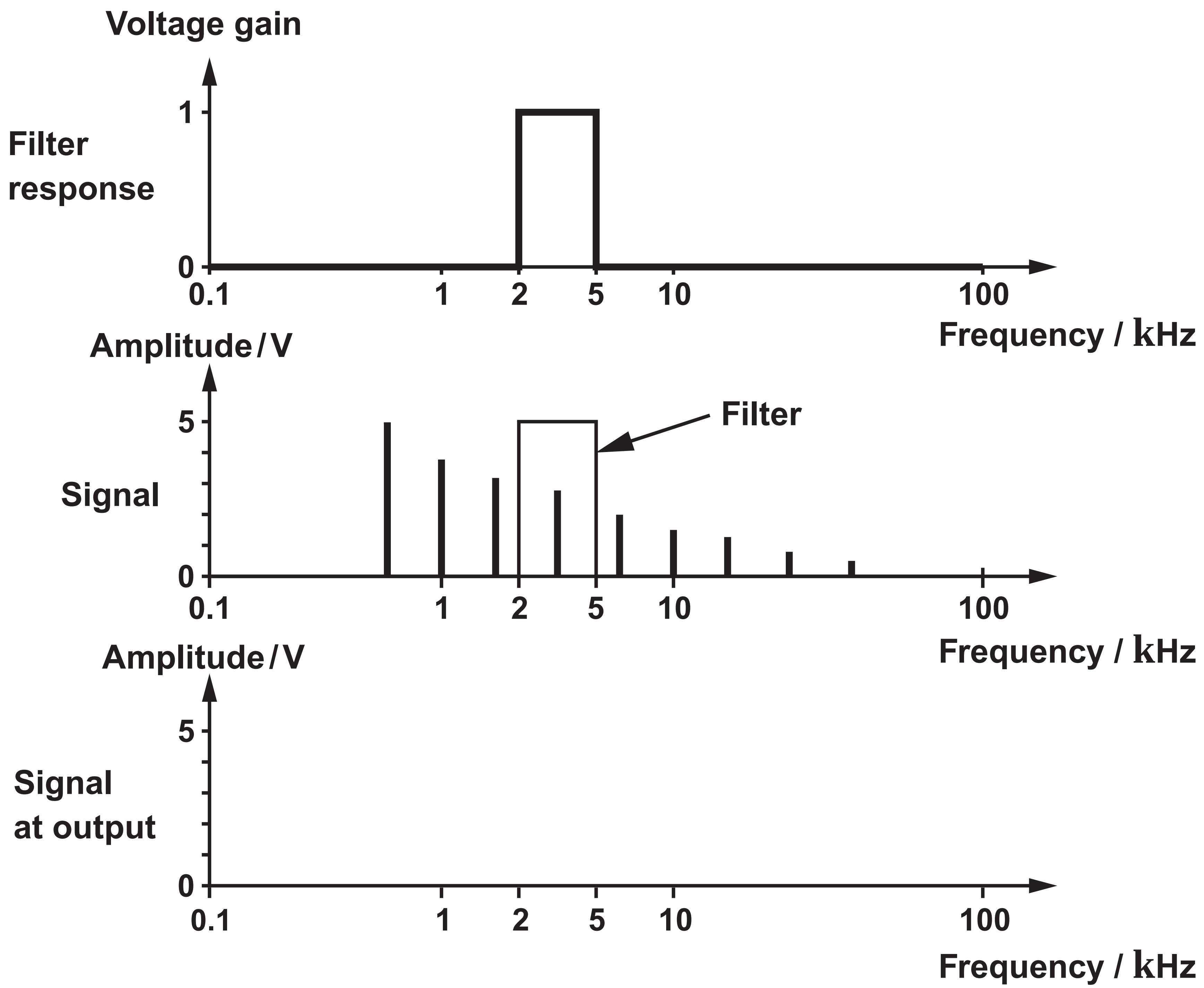

Switch A
Switch B
Pulse generator 2 Hz
NAND gate
EX-OR gate
AND gate
AND gate
OR gate
LED

3(a) (i) Distinguish between active and passive filters. [2]

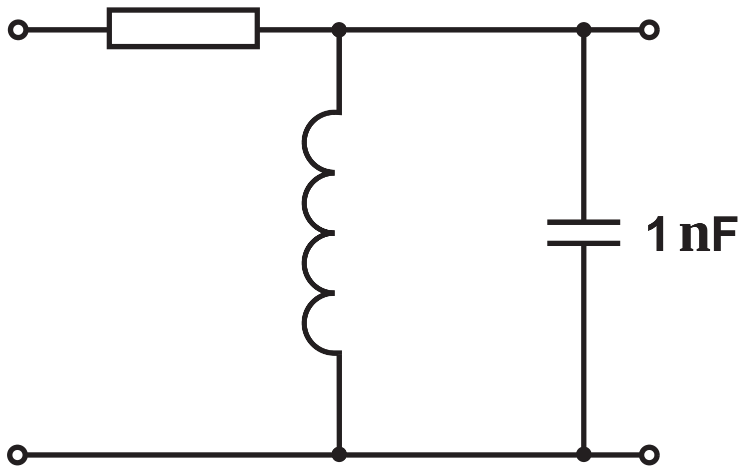
(ii) The top graph opposite shows the frequency response of an ideal band-pass passive filter.

The centre graph opposite shows the frequency spectrum of the signal applied to its input.

Use the axes provided in the bottom graph opposite to draw the frequency spectrum of the signal appearing at the output of the filter. [2]

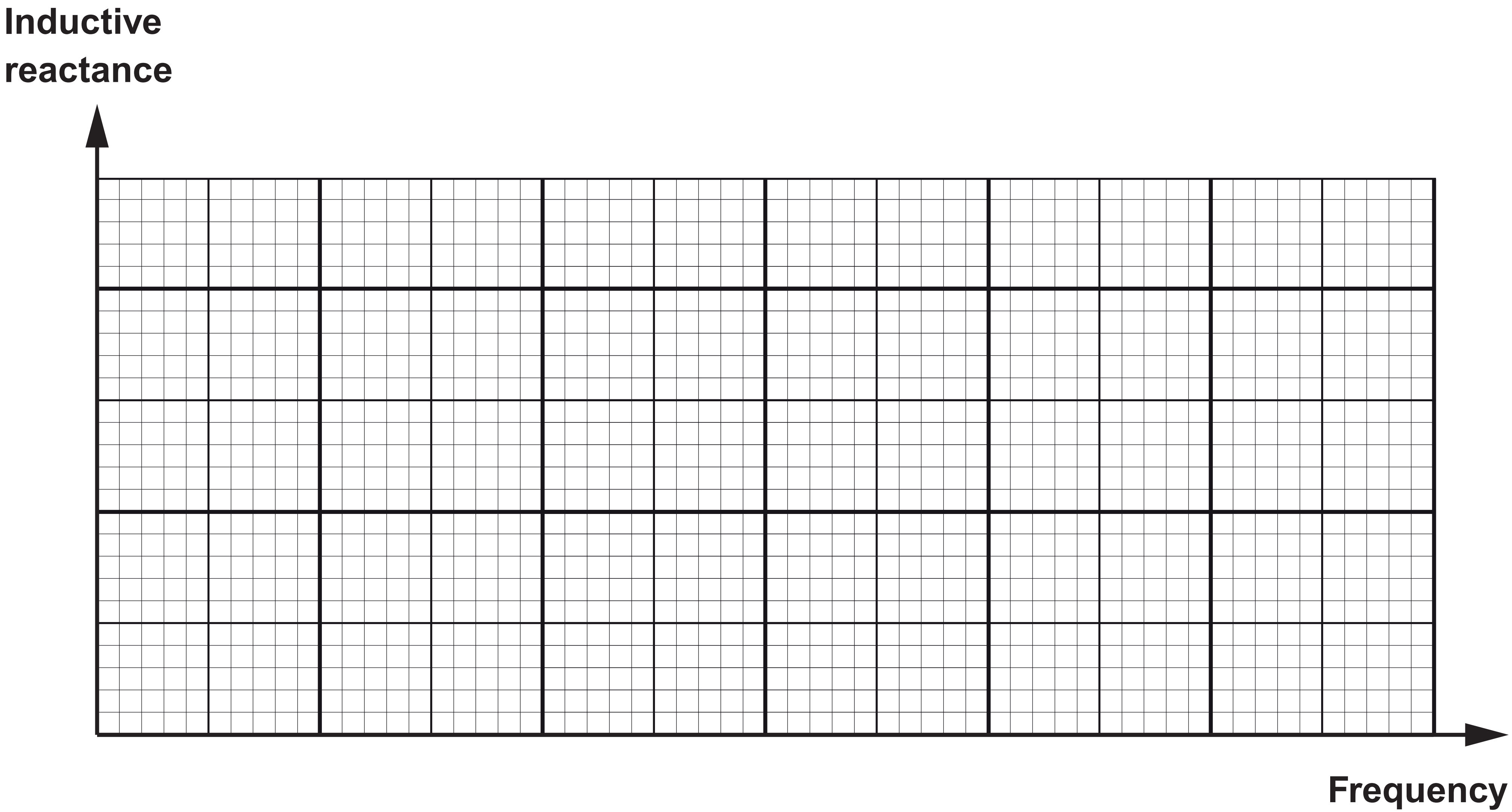

Voltage gain
1
Filter
response
0
0.1
1
2
5
10
100
Frequency / kHz
Amplitude / V
5
Filter
Signal
0
0.1
1
2
5
10
100
Frequency / kHz
Amplitude / V
5
Signal
at output
0
0.1
1
2
5
10
100
Frequency / kHz

3(b) The diagram shows one form of band-pass filter.



(i) Sketch a graph opposite to show how the reactance of the inductor changes with frequency.

[2]


Inductive
reactance
Frequency

3(b) (ii) The band-pass filter has a resonant frequency of 0.5 MHz.

At this frequency:

I. calculate the reactance of the capacitor; [2]

____

____

____

____

____

____

II. STATE the reactance of the inductor. [1]

____

3(b) (iii) The inductor has an inductance of 0.1 mH and a resistance r_L of 3Ω.

For this filter, calculate the:

I. dynamic resistance R_D; [2]

II. 'Q' factor; [2]

3(b) (iii) III. bandwidth. [2]

4(a) The graph opposite shows the frequency response of a voltage amplifier.

Use the graph opposite to estimate its bandwidth. [3]

____

____

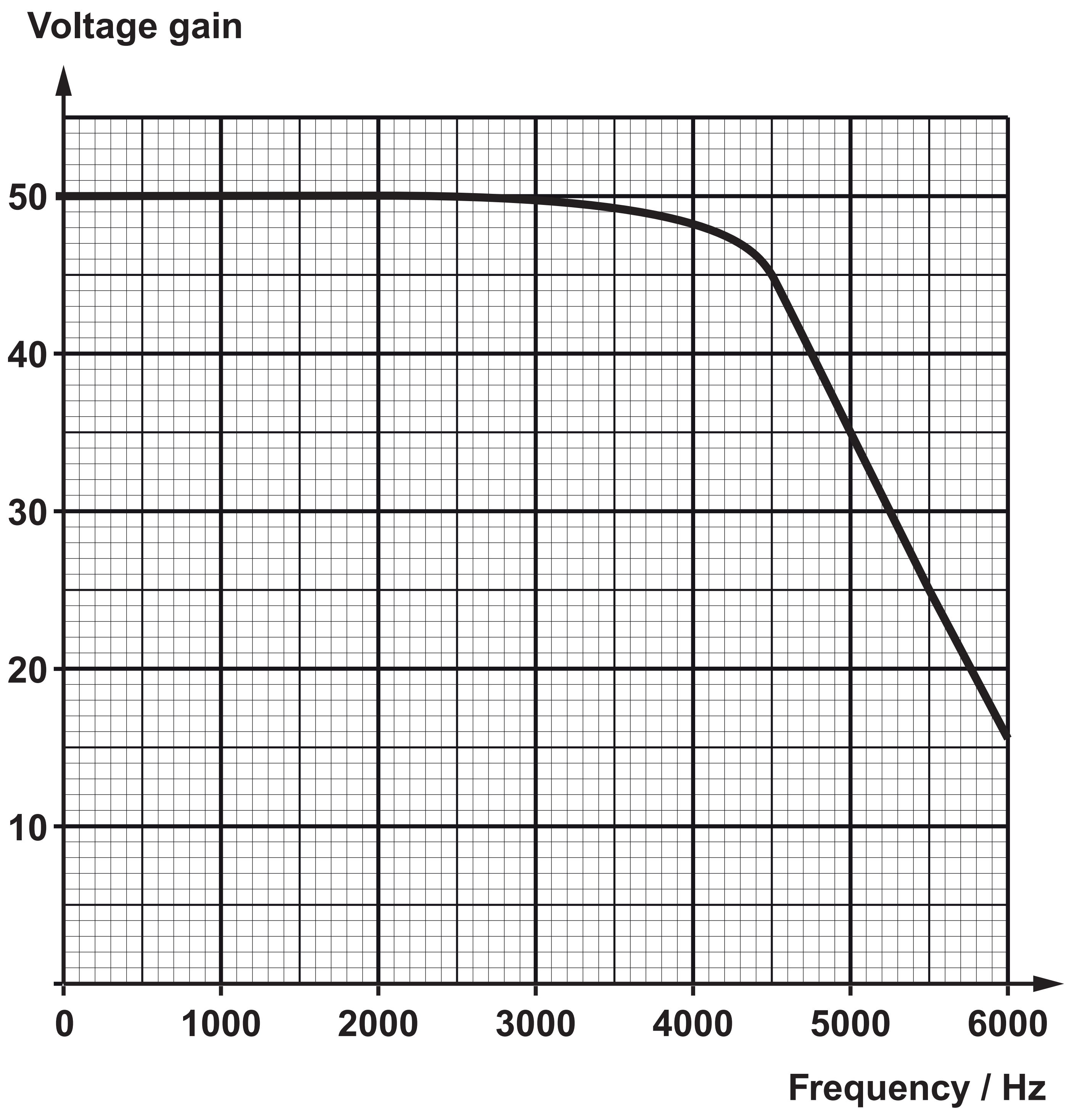
____

____

____

____

Bandwidth = ______________________________

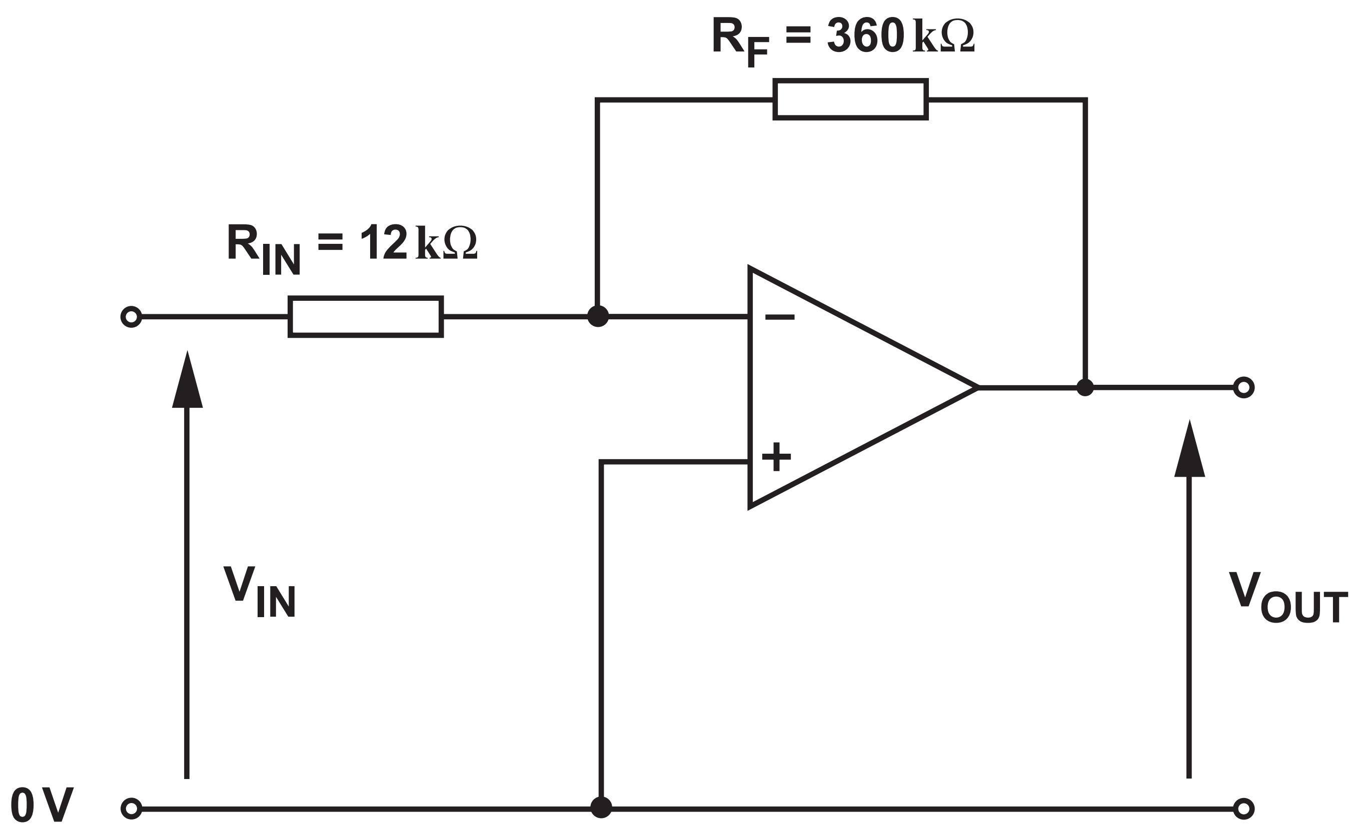

Voltage gain
50
40
30
20
10
0
1000
2000
3000
4000
5000
6000
Frequency / Hz

4(b) The circuit diagram opposite shows a voltage amplifier, using an op-amp with a slew-rate of $4\,\text{V}\,\mu\text{s}^{-1}$.

Its output has saturation voltages of +12 V and –12 V.

(i) State the input impedance of this amplifier. [1]

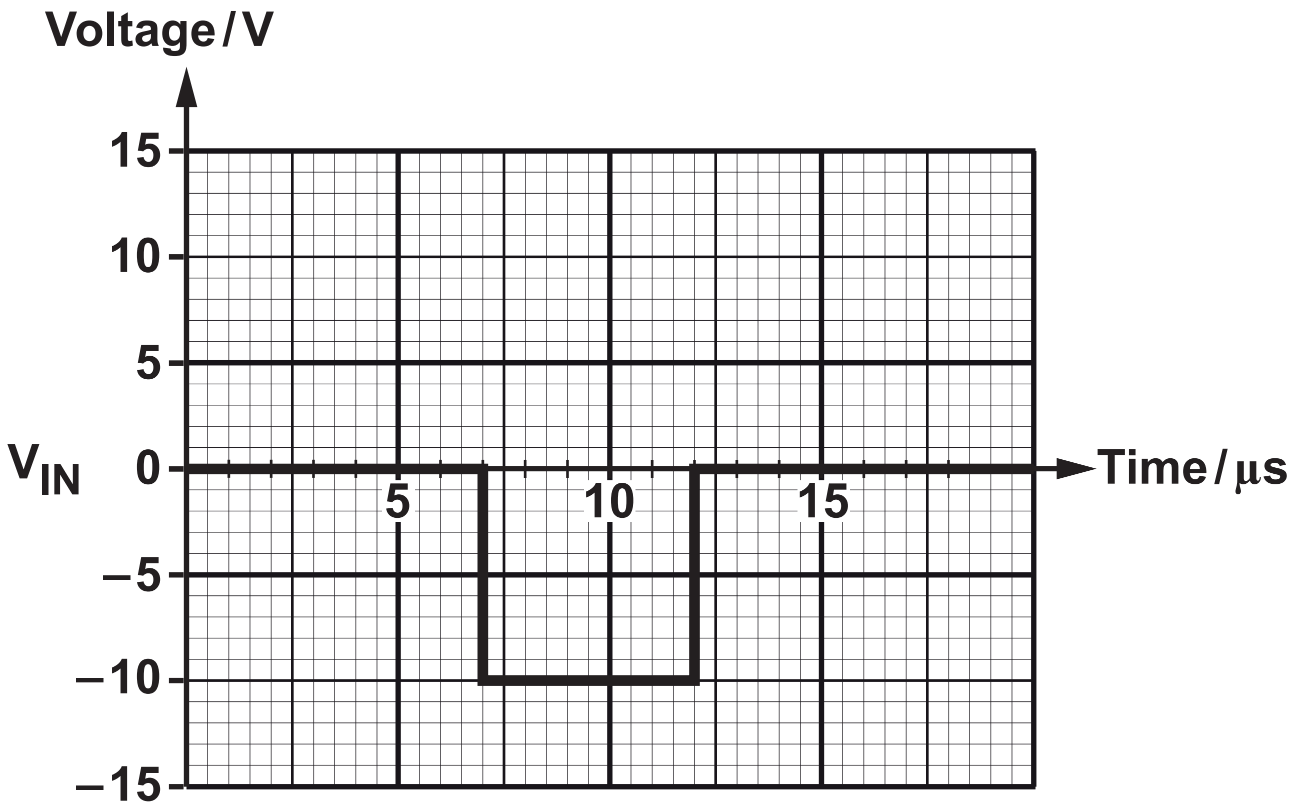
(ii) What is the maximum input voltage that avoids clipping distortion? [3]



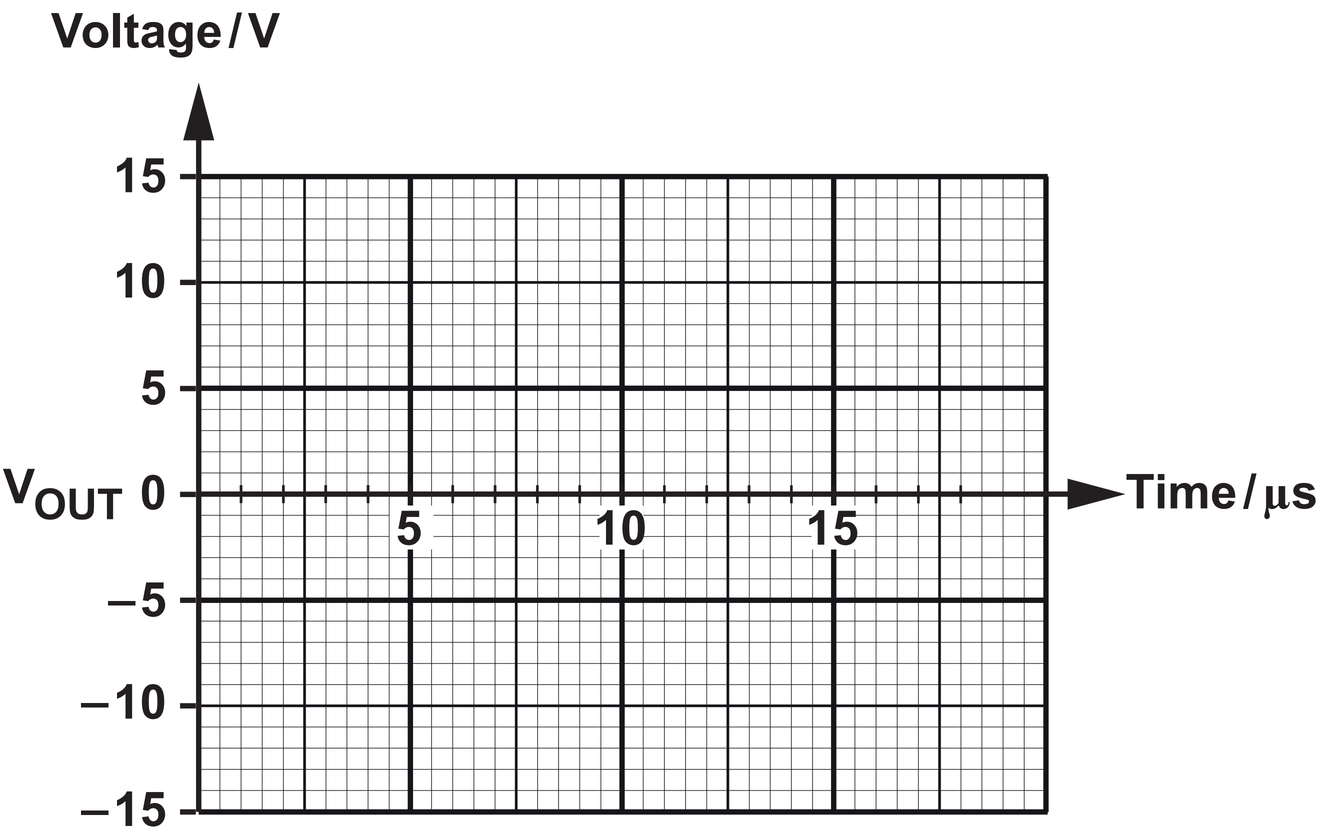
R_F = 360 kΩ
R_{IN} = 12 kΩ
−
+
V_{IN}
V_{OUT}
0 V

4(b) (iii) The signal shown in the first graph opposite is applied to the input of the amplifier.

Use the axes opposite to draw the resulting output signal. [3]



Voltage / V
15
10
5
V_{IN} 0
−5
−10
−15
5
10
15
Time / μs

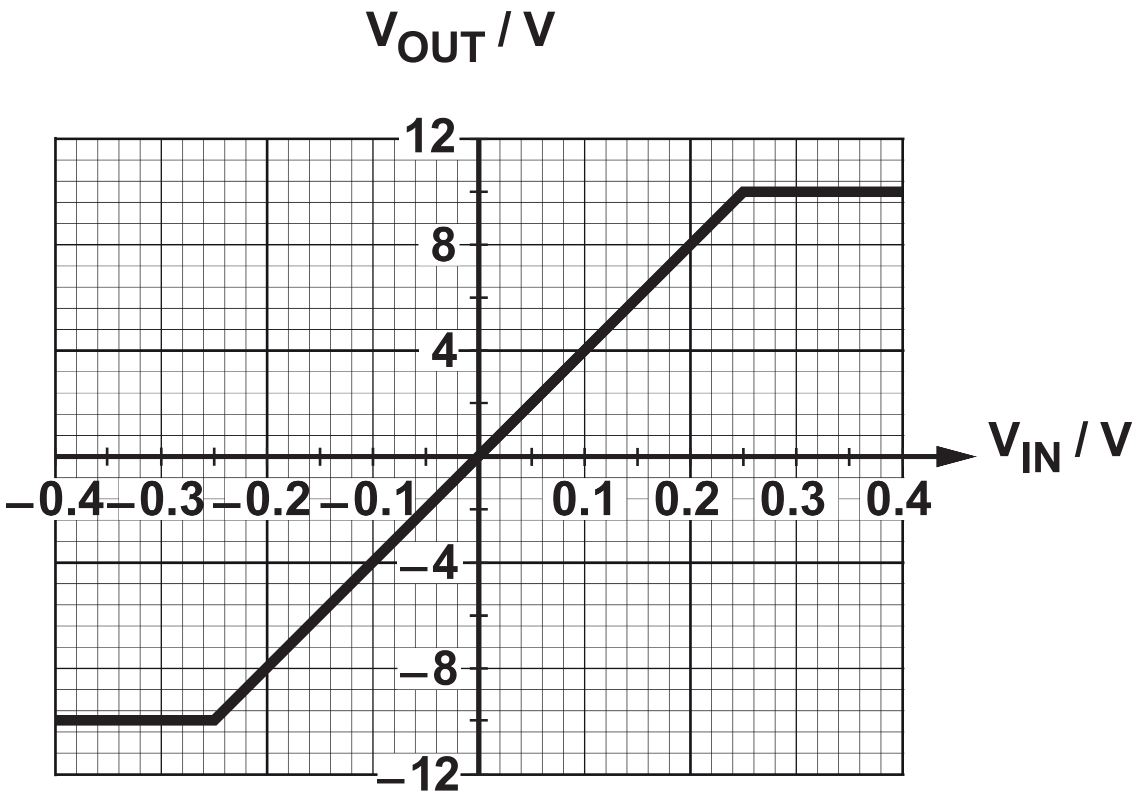


Voltage / V
15
10
5
V_{OUT} 0
−5
−10
−15
5
10
15
Time / μs

4(c) The graph opposite shows the input / output characteristics of a voltage amplifier.

Design a voltage amplifier, based on a single op-amp that has this characteristic curve opposite.

Draw a fully labelled circuit diagram to show your design, showing clearly component values. [3]



VOUT / V
12
8
4
–4
–8
–12
VIN / V
–0.4
–0.3
–0.2
–0.1
0.1
0.2
0.3
0.4

5(a) An ideal op-amp has infinite OPEN-LOOP gain.

What is the significance of the term 'open-loop' in this context? [1]

____

____

____

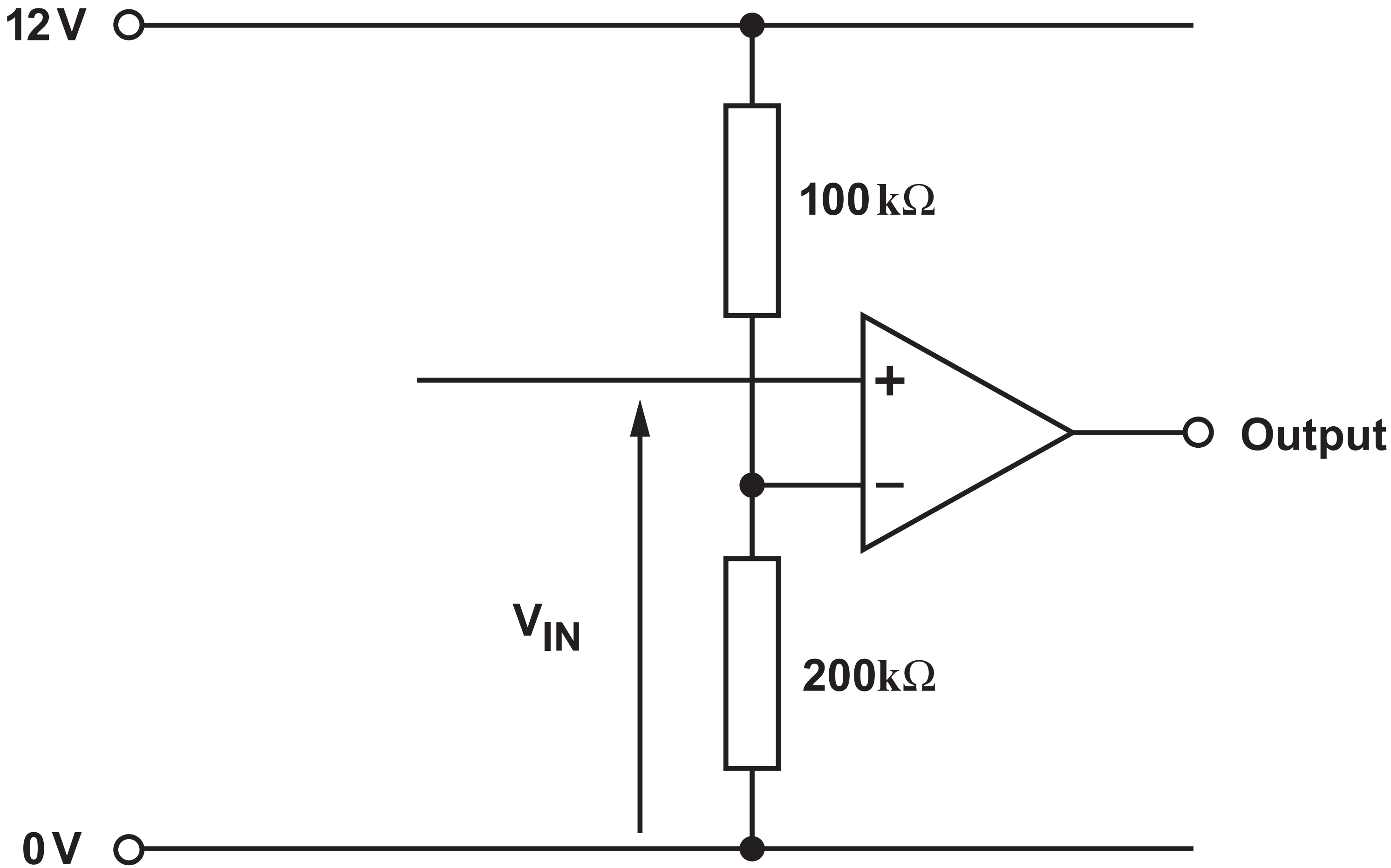
____

(b) An op-amp is used as a comparator, monitoring the output of a light sensor.

When the light level falls too far, the comparator output switches to positive saturation to turn on a lamp.

Part of the circuit is shown in the diagram opposite.

5(b) (i) Complete the circuit diagram opposite by adding the light-sensing unit, made from a LDR and another component. [2]


12 V
100 kΩ
+
–
Output
V_IN
200kΩ
0 V

5(b) (ii) At what value of input voltage, V_{IN}, does the lamp turn on? [2]

(iii) In this situation, what is the advantage of using an op-amp with a very high input impedance? [1]

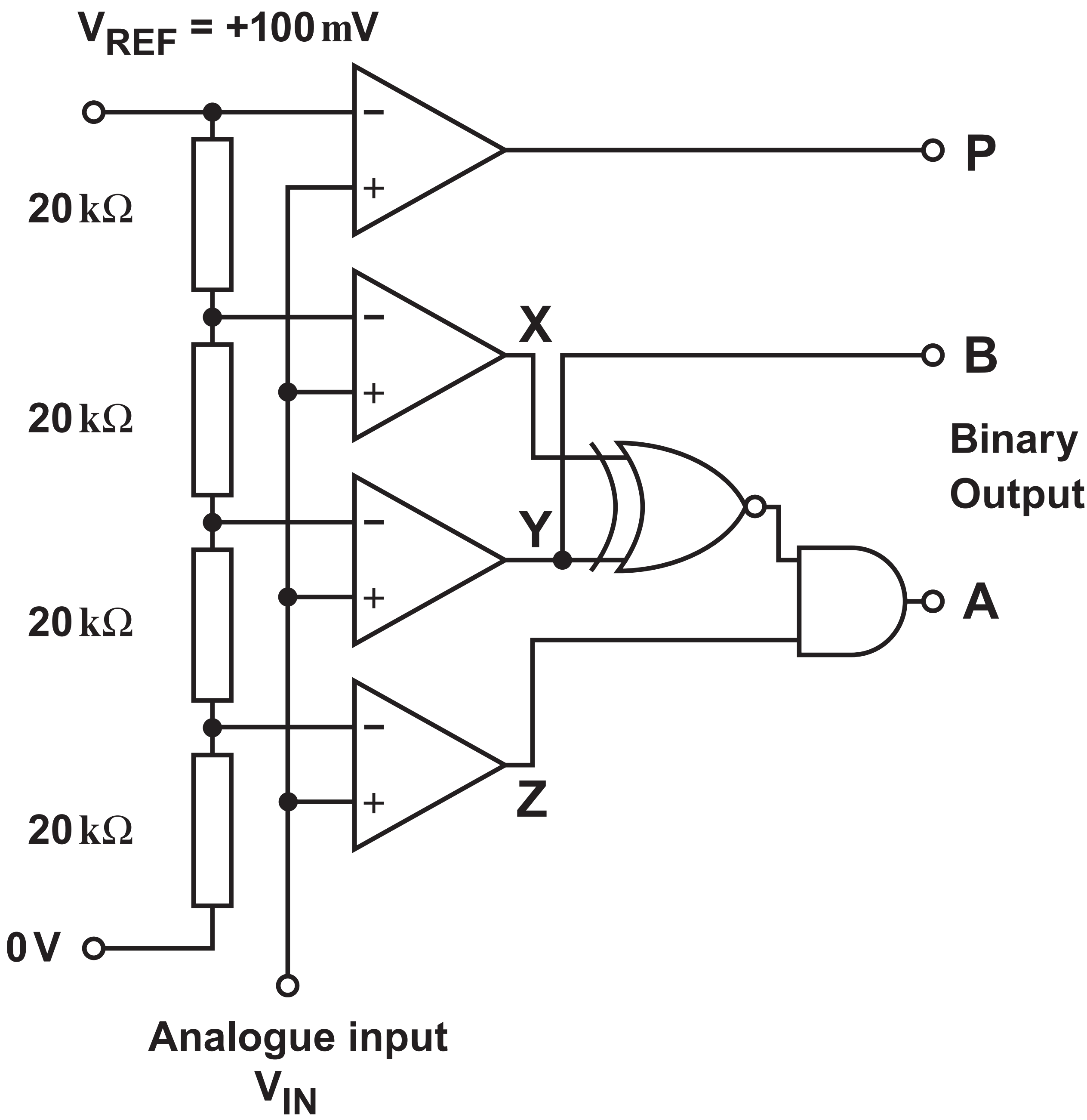
5(c) The circuit diagram opposite shows a simple flash ADC.
The logic system is used as the priority encoder.

The analogue signal is set at 60 mV.

(i) Which op-amp outputs will be in positive saturation? [1]

(ii) What is the resulting binary output BA? [1]

(iii) What is the advantage of this type of ADC over the digital ramp ADC? [1]



V_{REF} = +100 mV
20 kΩ
20 kΩ
20 kΩ
20 kΩ
0 V
Analogue input
V_{IN}
X
Y
Z
P
B
A
Binary
Output

5(d) A microcontroller is configured to have a 9-bit input port.

An 8-bit ADC is connected to the input port of the microcontroller.

(i) How many op-amps would the modified circuit need (to include overload indication)? [1]

(ii) What is the resolution of the ADC? [2]

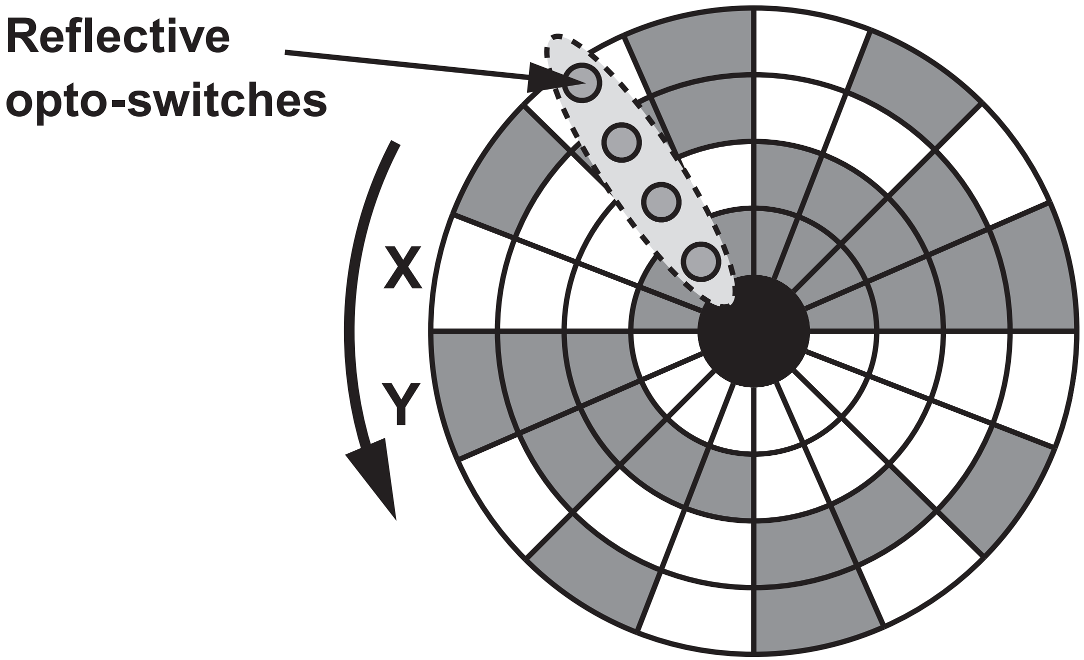
6(a) **The diagram opposite shows a binary encoded disc. As it rotates, the reflective opto-switches output signals which can be used to determine the position of the disc.**

Over white, an opto-switch outputs a logic 0 signal. Over black, it outputs logic 1.

What problem can occur as the binary disc rotates, moving the opto-switches from segment X to segment Y?

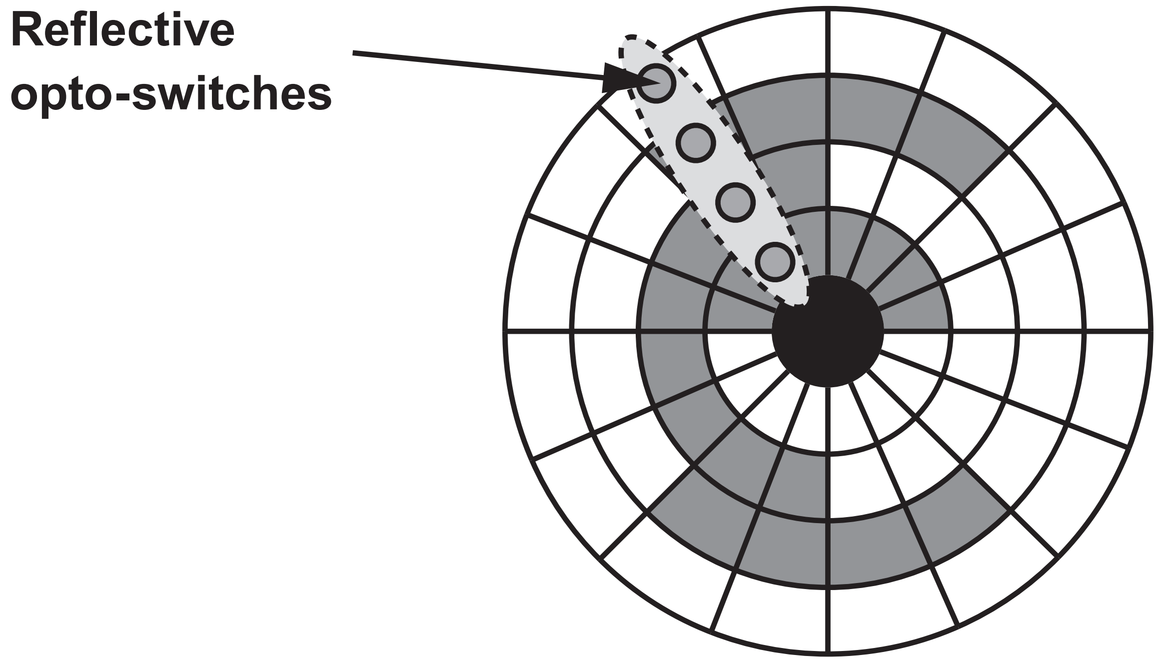
In your answer, explain the cause of the problem.

[2]


Reflective
opto-switches
X
Y

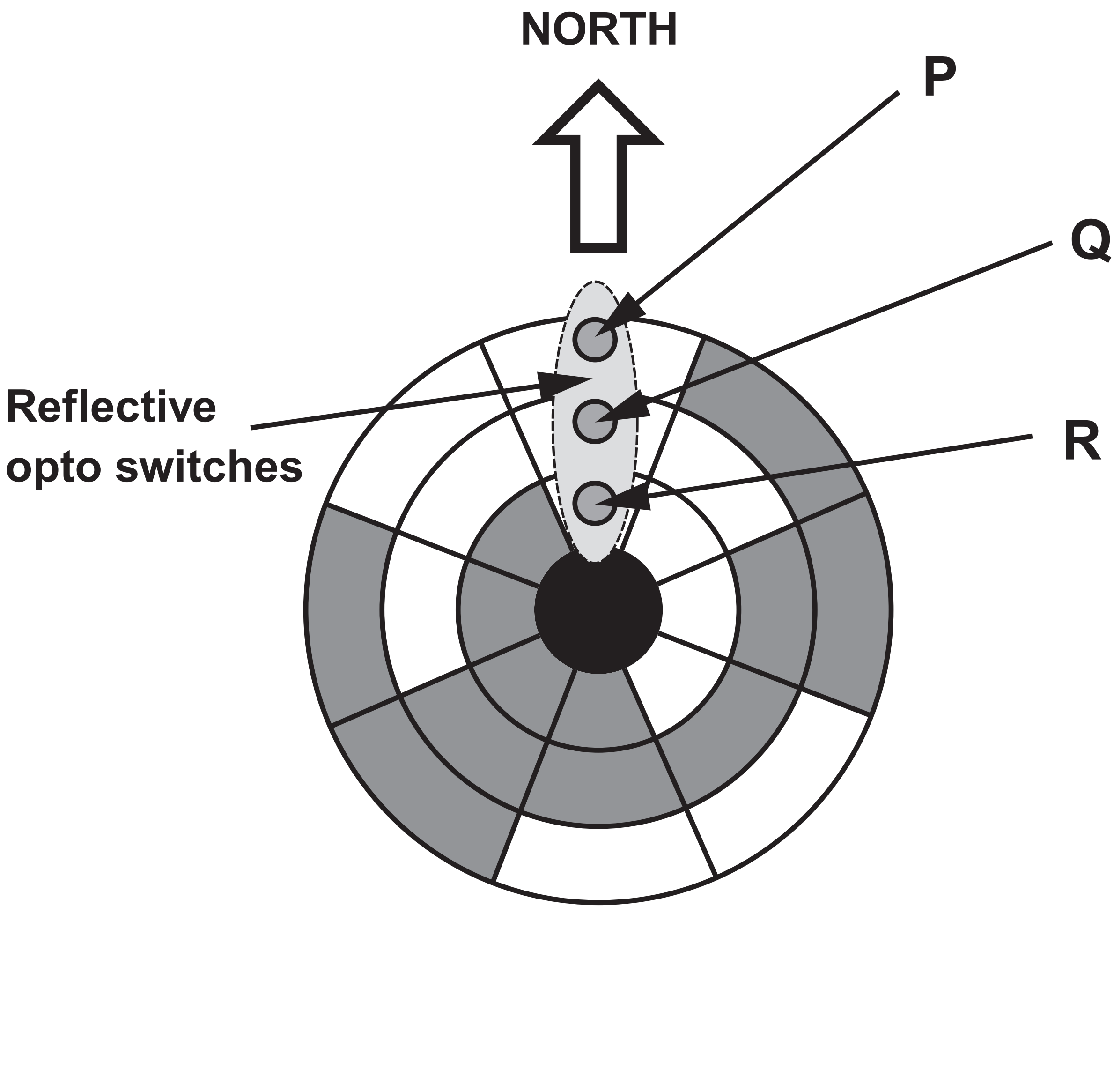
6(b) (i) Why is this not a problem for a Gray encoded disc? [1]

(ii) Complete the outer ring of the Gray code disc opposite by shading in the appropriate areas. [3]

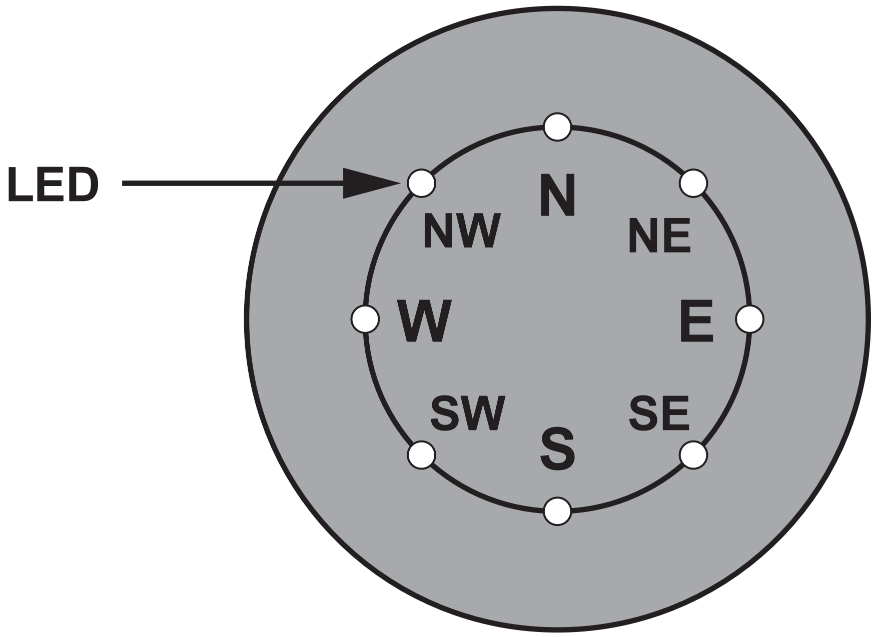

Reflective
opto-switches

6(c) An amateur yachtsman designs an electronic system to display the wind direction. A wind vane moves an arm holding three opto-switches, P, Q and R, around a three ring Gray-encoded disc.

Over white, an opto-switch outputs a logic 0 signal. Over black, it outputs logic 1.



The outputs of P, Q and R are processed to light the appropriate LED on the display shown in the following diagram.



6(c) (i) The outputs are used to address appropriate memory locations in a small memory IC. The table opposite shows the contents of the memory.

For example, when the outputs are P = 0 Q = 0 and R = 0, memory location 000 is activated. The output of that location is used to light the ‘N’ LED.

Complete the table opposite by adding the names of the LEDs lit by the contents of the other memory locations. [3]

(ii) How many different wind directions could be sensed using a five ring Gray-encoded disc? [1]

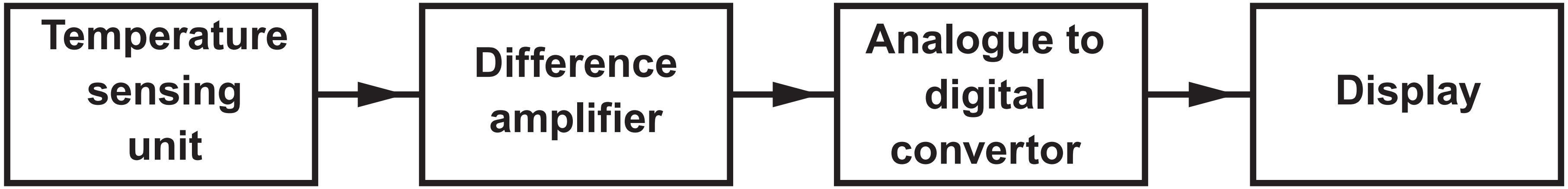
____

____

Address			Data bit								LED lit
P	Q	R	7	6	5	4	3	2	1	0	
0	0	0	1	0	0	0	0	0	0	0	N
0	0	1	0	1	0	0	0	0	0	0	
0	1	0	0	0	1	0	0	0	0	0	
0	1	1	0	0	0	1	0	0	0	0	
1	0	0	0	0	0	0	1	0	0	0	
1	0	1	0	0	0	0	0	1	0	0	
1	1	0	0	0	0	0	0	0	1	0	
1	1	1	0	0	0	0	0	0	0	1	

7. An instrumentation system monitors the temperature of a commercial freezer.

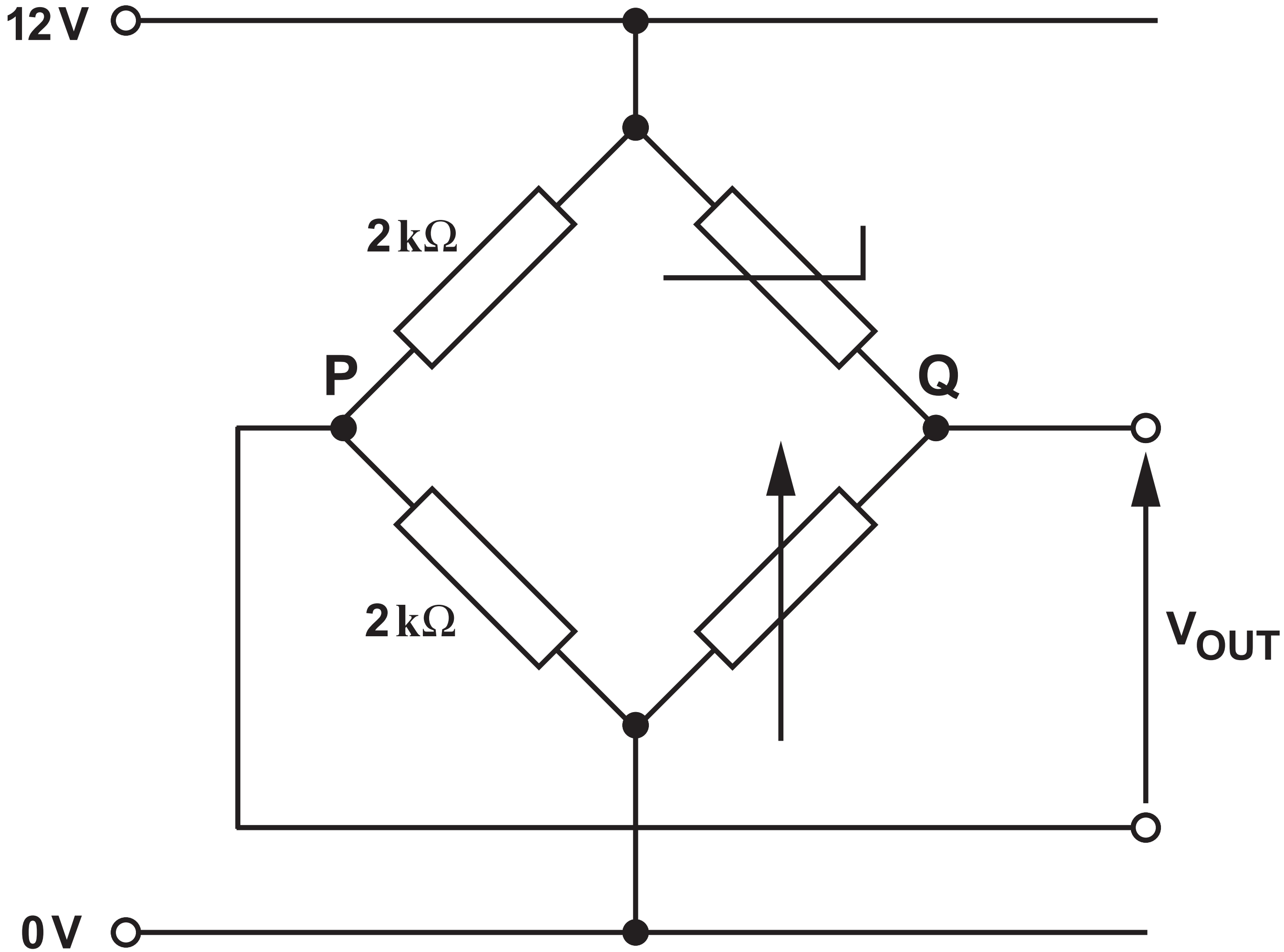
The block diagram for this system is shown opposite.


Temperature sensing unit
Difference amplifier
Analogue to digital convertor
Display

7(a) The diagram opposite shows how a ntc thermistor is used in the temperature-sensing unit.

(i) What is the name of this type of circuit? [1]

(ii) Calculate the output voltage V_{OUT} when the variable resistor is set to a resistance of 2 $k\Omega$ and the thermistor has a resistance of 1.75 $k\Omega$. [5]


12 V
0 V
2 kΩ
2 kΩ
P
Q
V_{OUT}

7(b) The output of the temperature-sensing unit is amplified by connecting points P and Q to the inputs of a difference amplifier.

(i) In some electronic circuits, it is important to keep connecting leads between sub-systems as short as possible. Why is this important? [1]

7(b) (ii) **In this circuit, that precaution is less important for the connecting leads between P, Q and the difference amplifier. Explain why this is so. [2]**

7(b) (iii) When the temperature-sensing unit output voltage V_{OUT} is –0.3 V, the output of the difference amplifier needs to be 9 V.

Design a suitable difference amplifier, based on a single op-amp.

Draw a circuit diagram showing the difference amplifier connected to the temperature-sensing unit.

Label all resistors with their values and show all necessary calculations. [5]

8(a) (i) Distinguish between NOISE and DISTORTION. [2]

(ii) Identify ONE possible source of noise. [1]

8(a) (iii) A signal with a power level of 5 mW is transmitted down a short communication link with negligible loss. However, during transmission, it is affected by a noise signal with a power level of 0.001 mW.

Calculate the signal-to-noise ratio in dB of the emerging signal. [2]

8(b) A signal is transmitted down a copper cable communications link.

The signal is ATTENUATED and subjected to noise in the copper cable.

Explain what is meant by the phrase "…the signal is attenuated…". [1]

8(c) A copper cable communication link has a bandwidth of 1.5 MHz.

It carries voice communication signals. Each voice communication channel requires a bandwidth of 3 kHz.

What is the maximum number of these voice channels that can be transmitted on this link? [2]

8(d) In most communication systems, it is advantageous to multiplex signals onto the communication link. One technique uses time-division multiplexing (TDM).

(i) Explain what is meant by time-division multiplexing. [1]

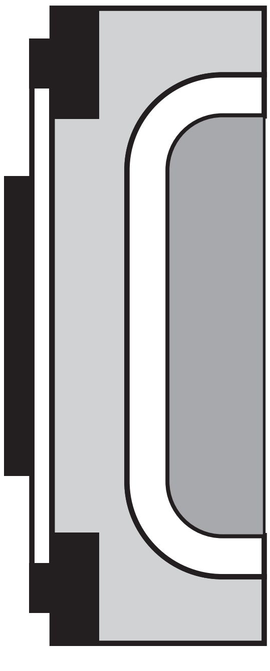
8(d) (ii) What is the advantage of using multiplexing in a communications link? [1]

9. The diagram opposite shows the structure of a n-channel MOSFET.

(a) Label:
- the n-type channel;
- the insulator;
- the gate terminal. [3]

(b) A npn bipolar transistor is described as CURRENT-CONTROLLED, whereas the MOSFET is VOLTAGE-CONTROLLED.

Explain this distinction between bipolar transistors and MOSFETs. [2]

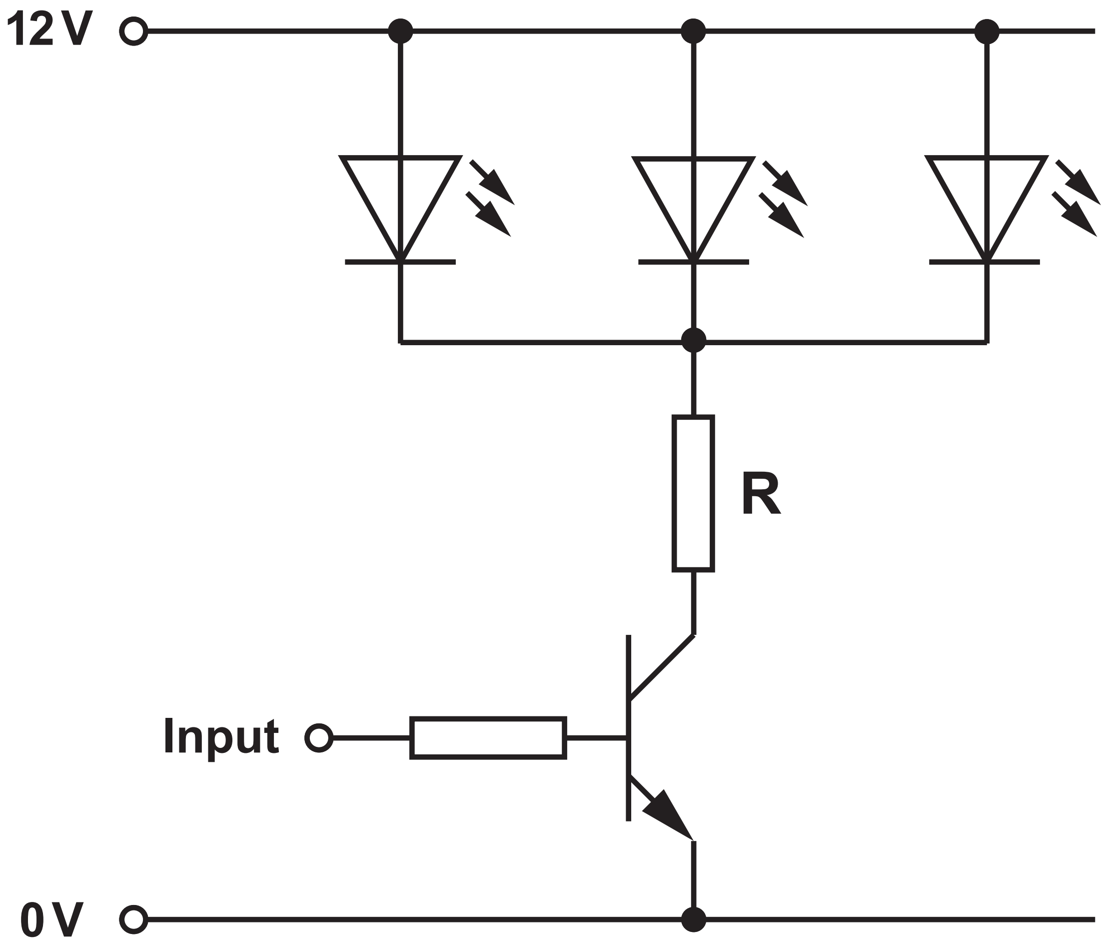


9(c) **A student designs a transistor switch sub-system to drive a set of three high-power LEDs, controlled by a logic system shown on the page opposite.**

(i) **Each LED has a forward voltage drop of 2.5 V and a maximum forward current of 250 mA when lit. Calculate the value of resistor R needed to protect the LEDs when they are fully lit. [4]**

In your answer, give both the ideal value of resistance and the actual E24 resistor value you would use.

(Assume zero collector-emitter voltage when the transistor is switched on.)


12 V
R
Input
0 V

9(c) (ii) The input of the transistor switch is connected to the output of a single logic gate, which can source currents up to 5 mA. The transistor has a current gain, h_{FE}, of 100.

Assess how well this switching sub-system will perform the task of controlling the LEDs.

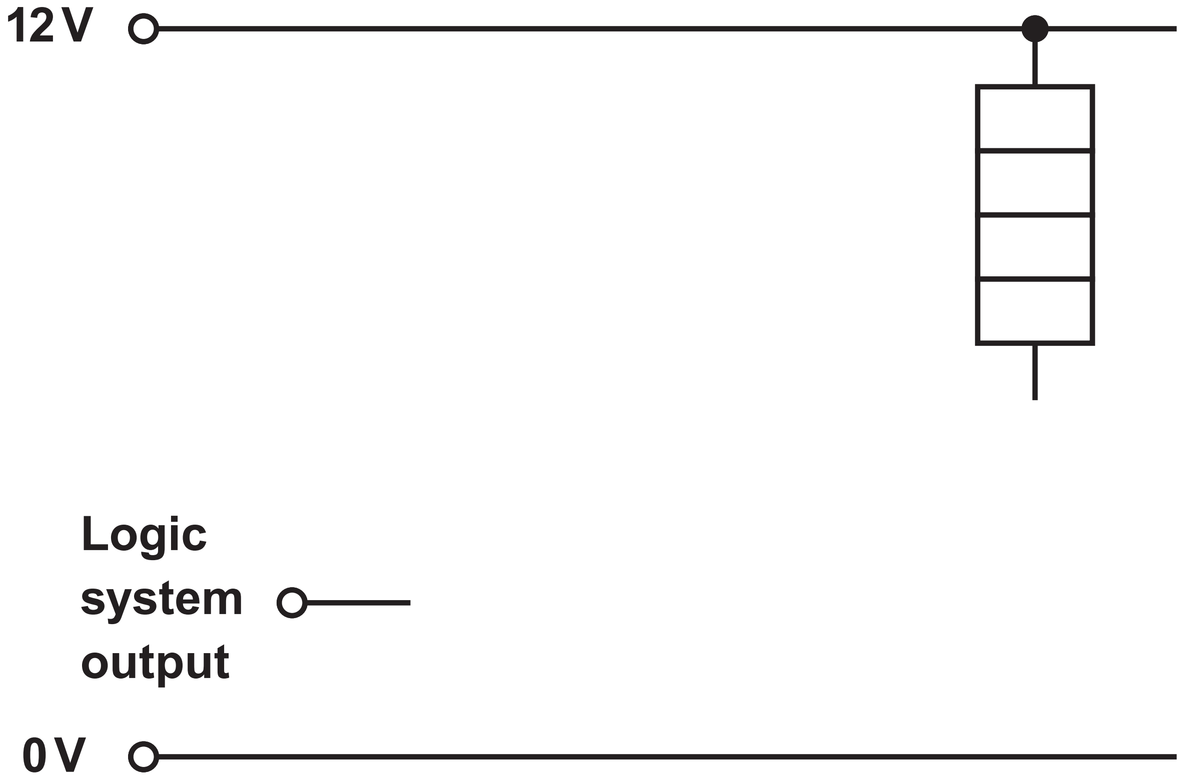
Justify your answer with appropriate calculations. [3]

9(d) **A MOSFET switching circuit, connected to the output of another logic system, controls a 12 V 60 W heater.**

(i) **A MOSFET switching circuit does not need a gate resistor.**

Explain why this is so. [1]

(ii) **Complete the circuit diagram opposite for this system. [2]**


12 V
Logic
system
output
0 V

9(d) (iii) The logic level 1 output voltage from the logic system is 10 V.
The MOSFET has an on-resistance, r_{DSON}, of 0.2 Ω

Calculate:

I. the transconductance, g_m, of the MOSFET; [2]

II. the power dissipated in the MOSFET when the heater is fully switched on. [3]

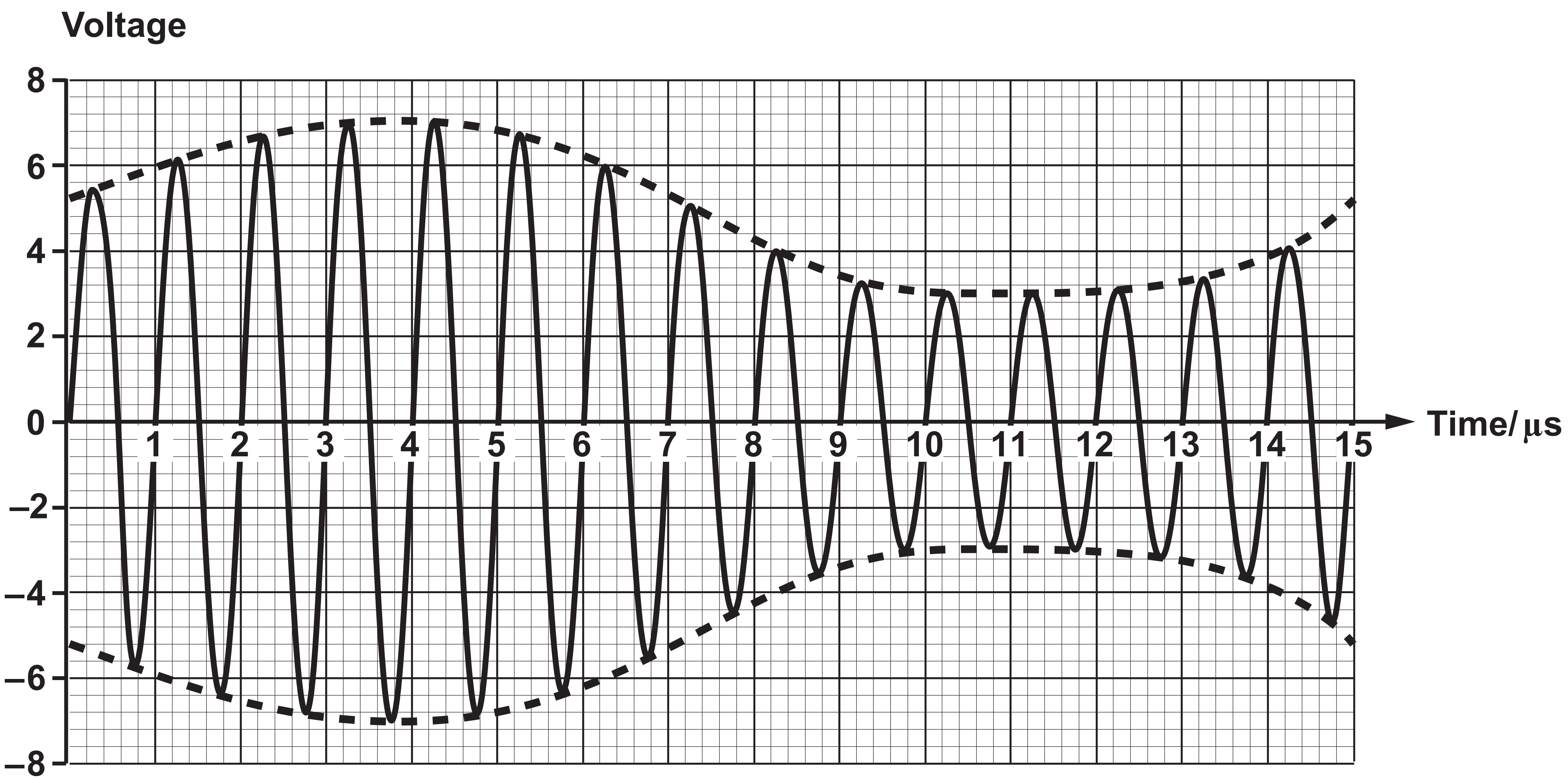
10(a) **Describe TWO advantages of using a modulated light beam for communication rather than a modulated microwave beam. [2]**

10(b) Why is frequency modulation preferable to amplitude modulation when designing a radio communications link in a region susceptible to high levels of electrical noise? [2]

10(c) The diagram opposite shows a carrier wave which has been amplitude-modulated by one cycle of a signal.

(i) What is the frequency of the carrier wave? [2]

(ii) What is the wavelength of the carrier wave, assuming that electromagnetic waves travel at 3×10^8 m s^{-1}? [2]


Voltage
8
6
4
2
0
–2
–4
–6
–8
Time/μs
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

10(c) (iii) What is the depth of modulation of the carrier wave? [2]

(iv) What is a likely consequence of over-modulation? [1]

10(d) **A 200 MHz carrier wave is frequency modulated by a 6 V peak-to-peak signal with a frequency of 10 kHz.**

The instantaneous carrier frequency varies between 199.9 and 200.1 MHz.

(i) **Calculate the modulation index. [2]**

____

____

____

____

(ii) **Calculate the signal bandwidth. [2]**

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END OF PAPER