Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A490U10-1

S23-A490U10-1

eduqas Part of WJEC

TUESDAY, 23 MAY 2023 – AFTERNOON

ELECTRONICS – A level component 1

Principles of Electronics

2 hours 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**9**	
2.	**16**	
3.	**10**	
4.	**11**	
5.	**8**	
6.	**6**	
7.	**14**	
8.	**8**	
9.	**13**	
10.	**20**	
11.	**16**	
12.	**9**	
Total	**140**	

A490U101 01

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 question **10**(a)(ii).

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BE/JS*(X22-A490U10-1)

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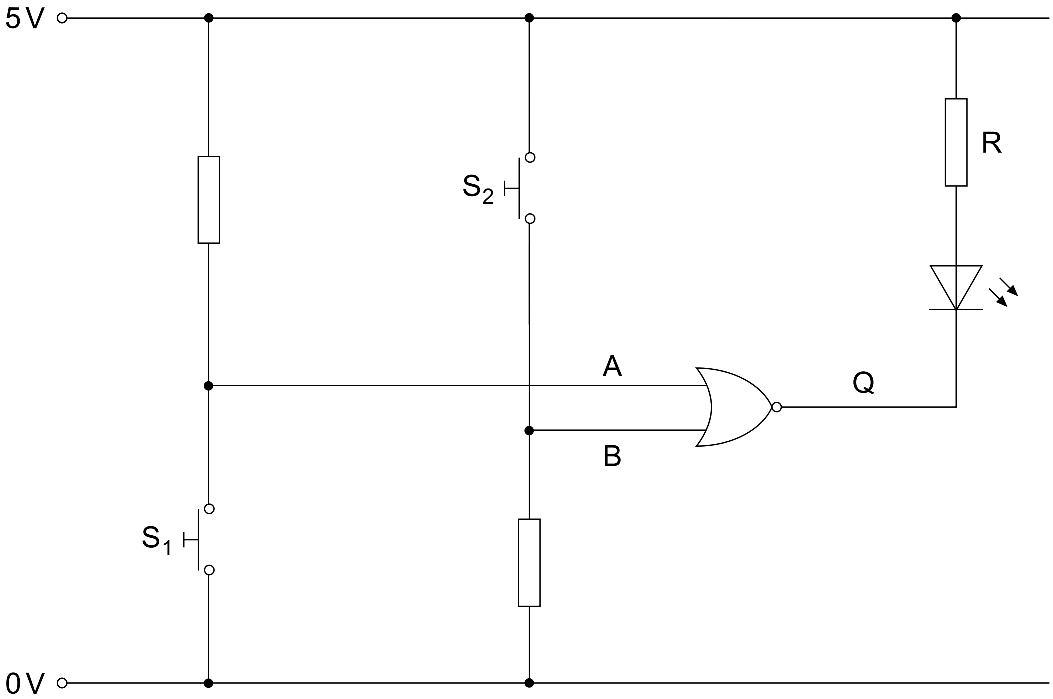
Answer **all** questions.

1. The LED in the circuit below is controlled by two switches S_1 and S_2.



(a) (i) Name the type of logic gate in the circuit. [1]

....

(ii) Complete the table for the circuit above. [4]

S_2	S_1	B (1/0)	A (1/0)	Q (1/0)	State of LED (ON/OFF)
OPEN	OPEN				
OPEN	CLOSED				
CLOSED	OPEN				
CLOSED	CLOSED				

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(b) The LED has a forward voltage drop of 2 V and a maximum current of 14 mA. The output Q of the logic gate is 5 V for a logic 1 and 0 V for a logic 0. Determine the ideal value of R required and select the most appropriate value from the E24 series. [4]

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Preferred value ....

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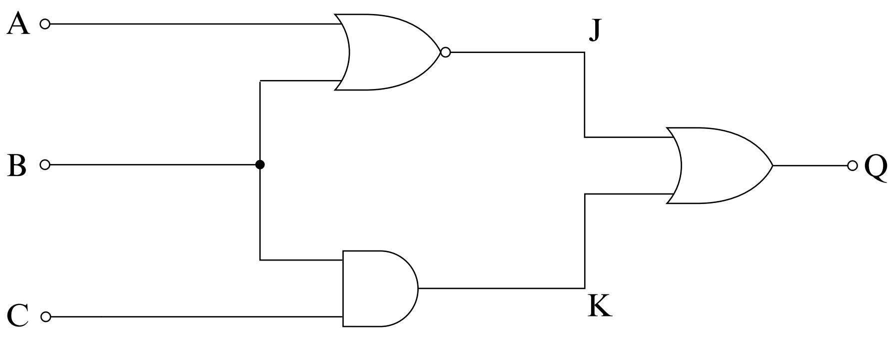
2. A logic system is shown below.



(a) (i) Give the Boolean expressions for J, K and Q in terms of inputs A, B and C. [3]

J = ...

K = ...

Q = ...

(ii) In the space below draw the equivalent logic system using NAND gates only. [3]

(iii) **Cross out all** redundant gates. [1]

(iv) Describe an advantage of converting logic systems to a NAND gate equivalent circuit. [1]

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(b) Another logic system has the following equation.

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

Apply de Morgan's theorem to the equation and then simplify the result. [3]

....

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Q = ...

(c) The truth table for a different logic system is shown below.

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

(i) Use the truth table to complete the Karnaugh map below. [2]

C \ B.A	00	01	11	10
0				
1				

(ii) Use the Karnaugh map to obtain the simplest Boolean expression for the system. [3]

Q = ...

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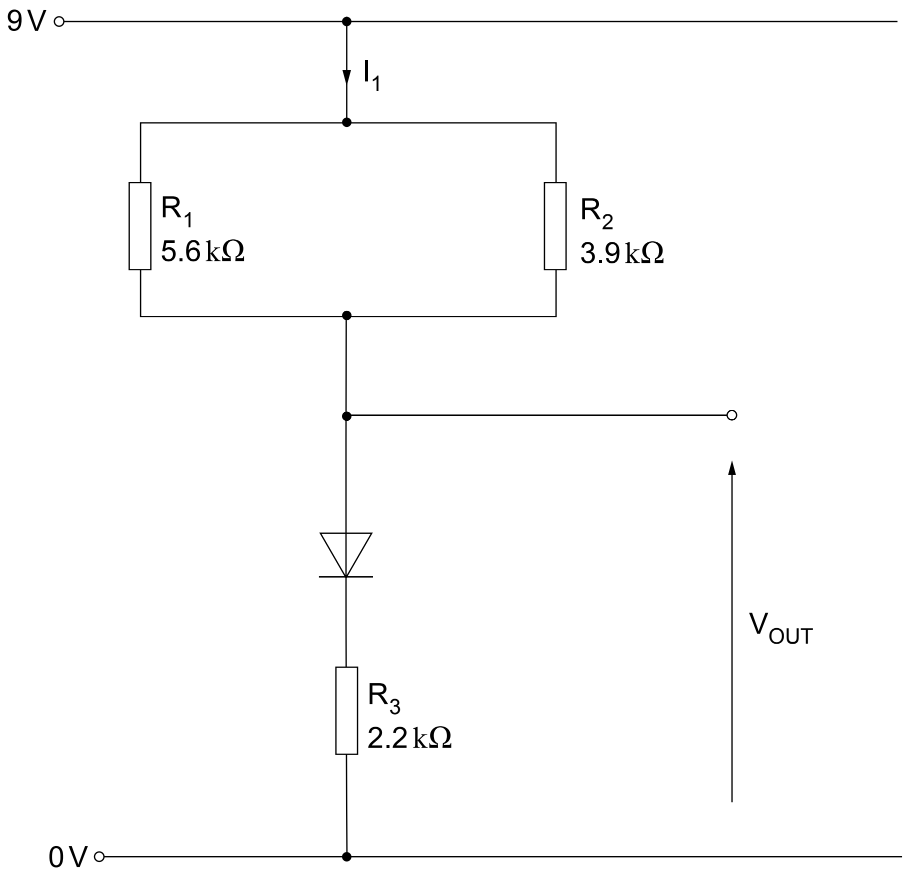
3. Use the information in the circuit diagram to answer the questions below.



(a) Calculate:

(i) the combined resistance of R_1 and R_2; [2]

....

....

(ii) the current I_1; [3]

....

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Examiner only

(iii) the voltage V_{OUT}; [2]

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....

(iv) the power dissipated in R_3. [2]

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(b) Determine the value of V_{OUT} when the diode is reversed. [1]

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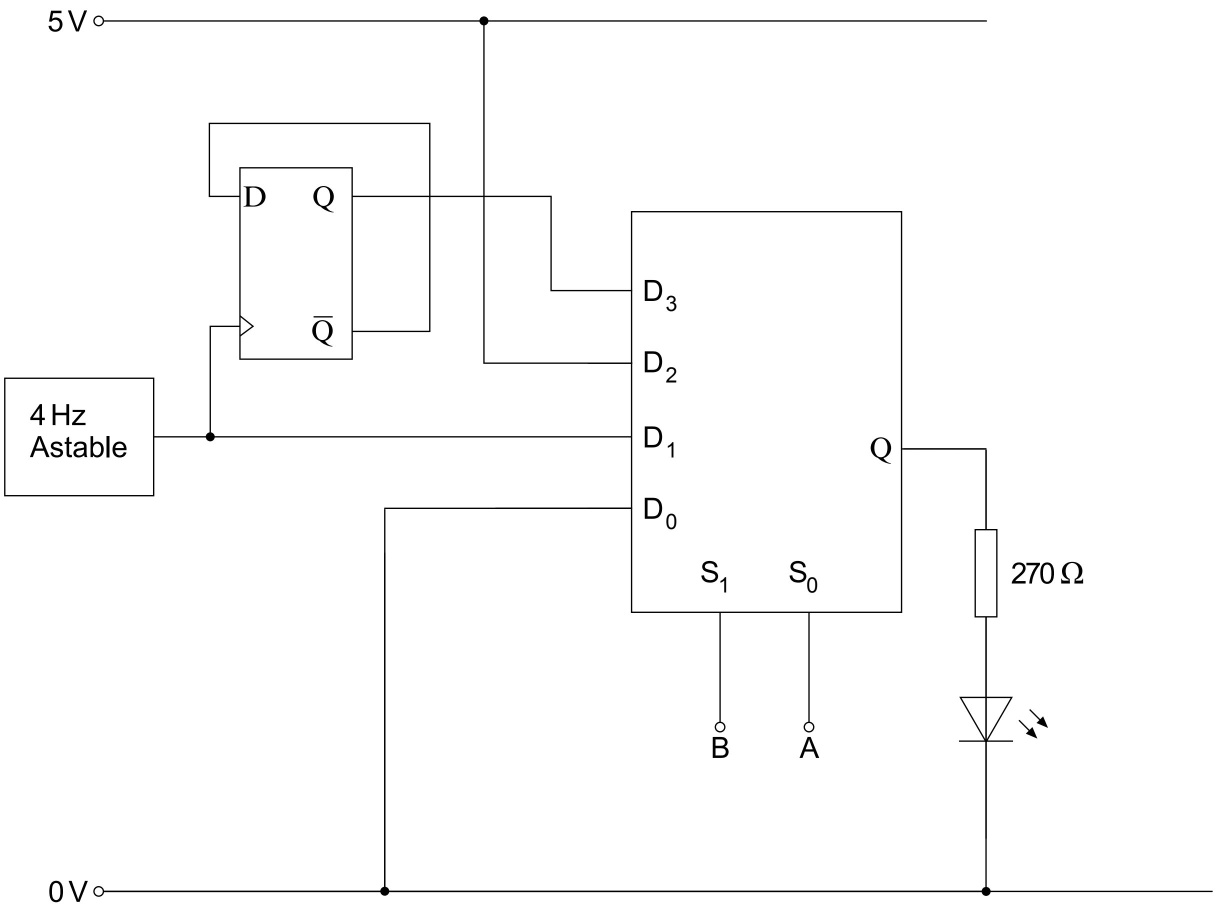
4. A multiplexer can be used in both logic and communication systems.

(a) The circuit below contains a multiplexer used in a logic system.



(i) Describe the behaviour of the LED for each of the following combinations of A and B. Indicate the frequency when applicable. [6]

B = 0, A = 0 ....

....

B = 0, A = 1 ....

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B = 1, A = 0 ....

....

B = 1, A = 1 ....

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(ii) Give an advantage of using a multiplexer in this way. [1]

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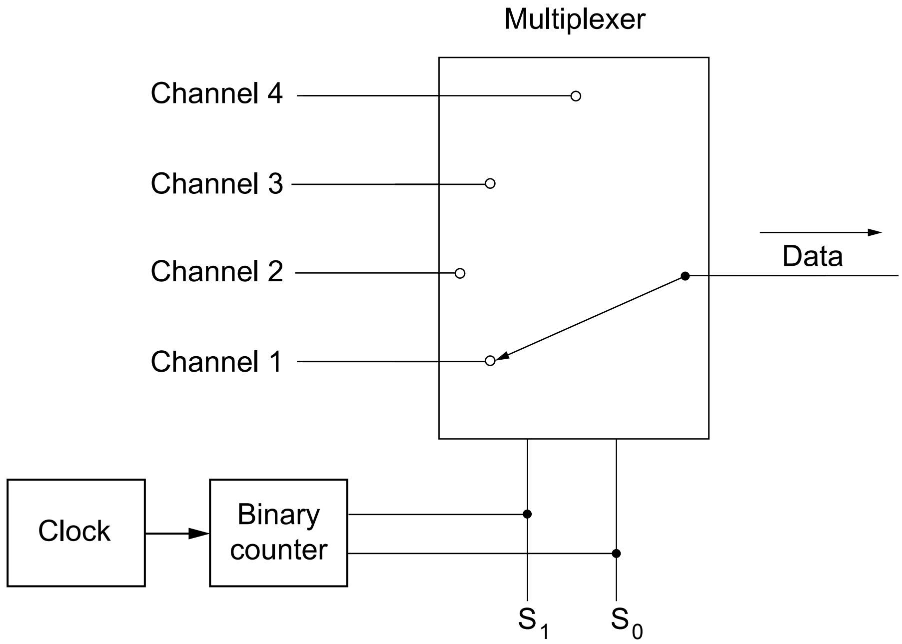
(b) The block diagram below shows the multiplexer in a TDM communication system.



(i) What does TDM stand for? [1]

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(ii) Explain how this communication system achieves TDM. [3]

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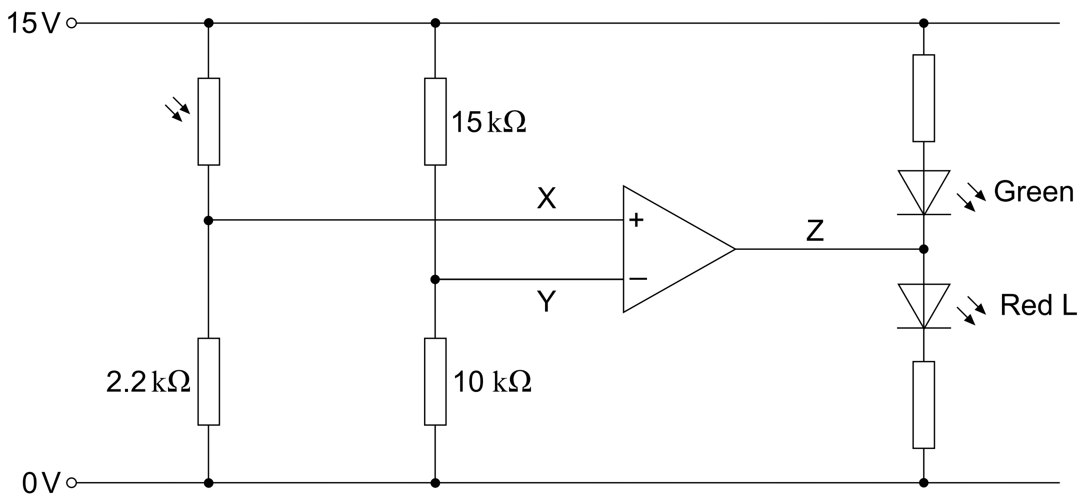
5. Below is a circuit for a light level indicator. The op-amp saturates at 0V and 15V.



(a) Calculate the voltage at Y. [2]

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(b) Calculate the resistance of the LDR that makes the output of the op-amp switch states. [3]

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(c) Describe the behaviour of both LEDs as the light level changes referring to the voltages at X, Y and Z. [3]

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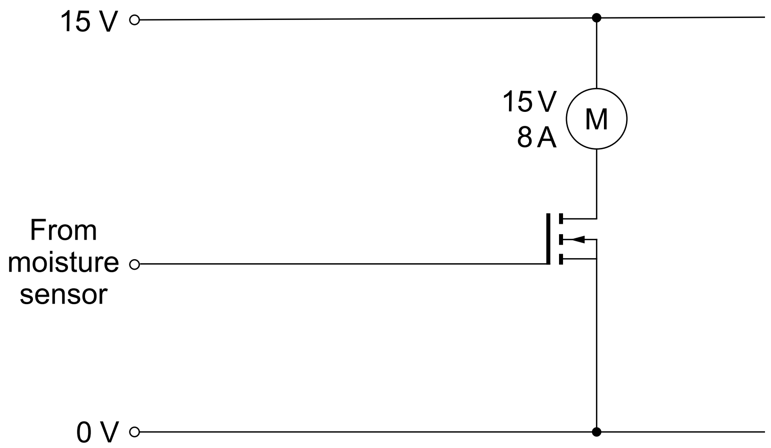
6. A MOSFET uses a signal from a moisture sensor to control a motor for a dehumidifier.



An extract from the MOSFET data sheet is shown below.

V_{DS}/V (max)	V_{GS}/V (max)	I_D/A (max)	P_{TOT}/W (max)	r_{DSon}/Ω	g_M/S (typical)
60	20	12	100	0.32	1.4

(a) **Complete the diagram** by adding a component that protects the MOSFET when the motor switches off. [1]

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

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(c) Calculate the minimum value of V_{GS} to allow the motor to operate at its rated current. [3]

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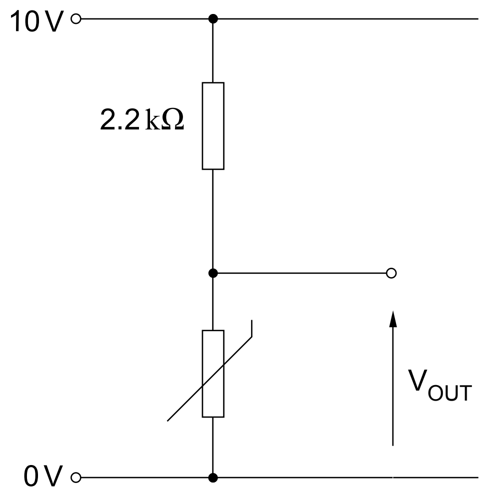
7. A small zoo requires a system to monitor and display the temperature of the environment in the reptile house.

(a) The temperature sensing circuit below is used in the system.



(i) Derive and draw the Thevenin equivalent circuit when the thermistor resistance is $2\,k\Omega$. [4]

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(ii) The circuit is connected to a display of input resistance 5.6 $k\Omega$. Draw the equivalent circuit with this load and calculate the voltage across the load. [3]

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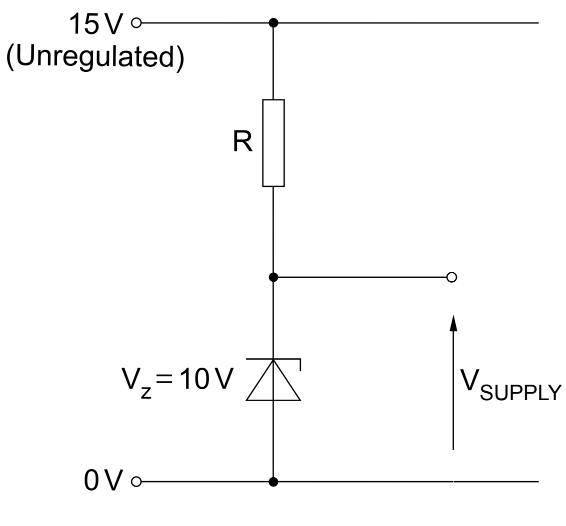
(b) The system requires a 10 V regulated supply capable of providing a maximum load current of 200 mA. The circuit design for the regulated power supply is shown below. The holding current for the zener diode is 10 mA.



Calculate the ideal value for the resistor, R. [3]

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 (A490U10-1)

Turn over.

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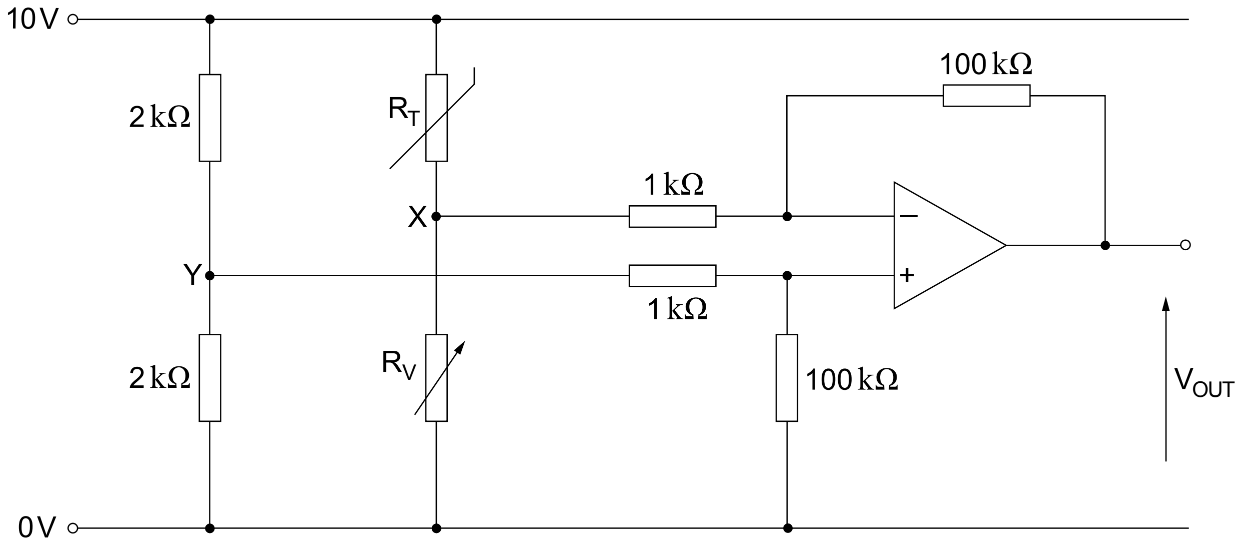
(c) The system is redesigned to enable smaller temperature changes to be detected.



Calculate the voltage V_{OUT} when:

- thermistor R_T has a resistance of 2.01 kΩ
- the variable resistor R_V has a resistance of 1.95 kΩ. [4]

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V_{OUT} = ...

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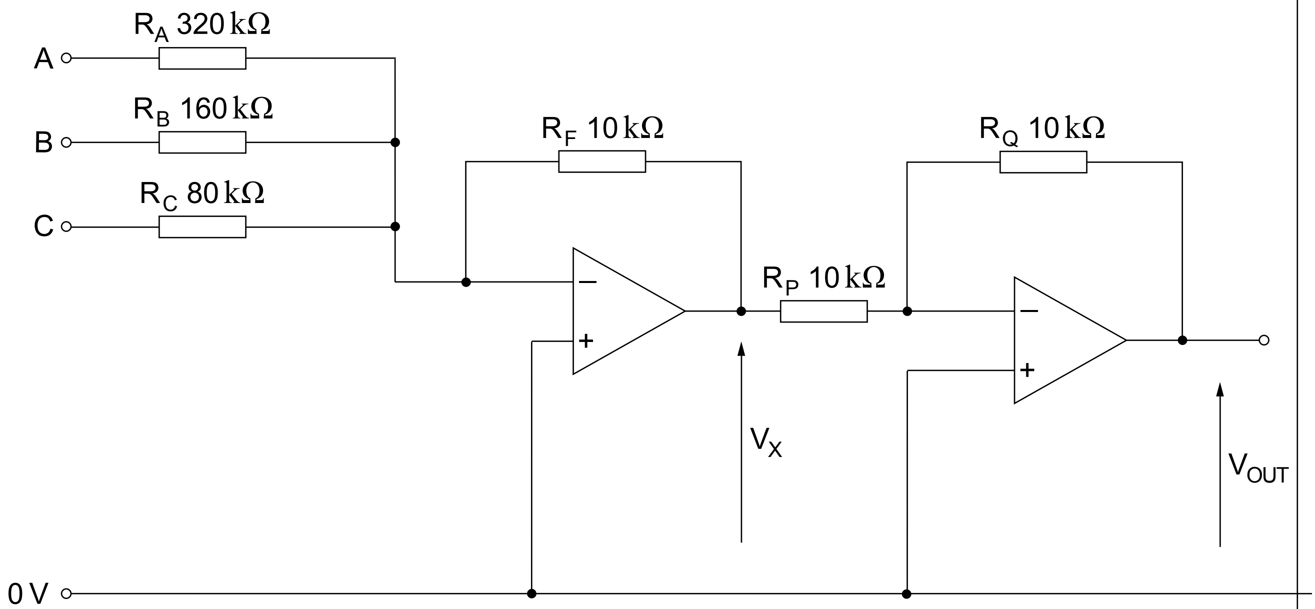
8. The diagram below shows a 3-bit digital-to-analogue converter (DAC).
The op-amps have a power supply of ±13 V and saturate at ±12 V.
Input A is the LSB.

Input logic 1 = 8 V
Input logic 0 = 0 V



(a) Calculate:

(i) the value of V_X when the binary input is 001; [2]

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....

(ii) the value of V_{OUT} when the binary input is 001; [1]

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(iii) the value of V_{OUT} when the binary input is 110. [2]

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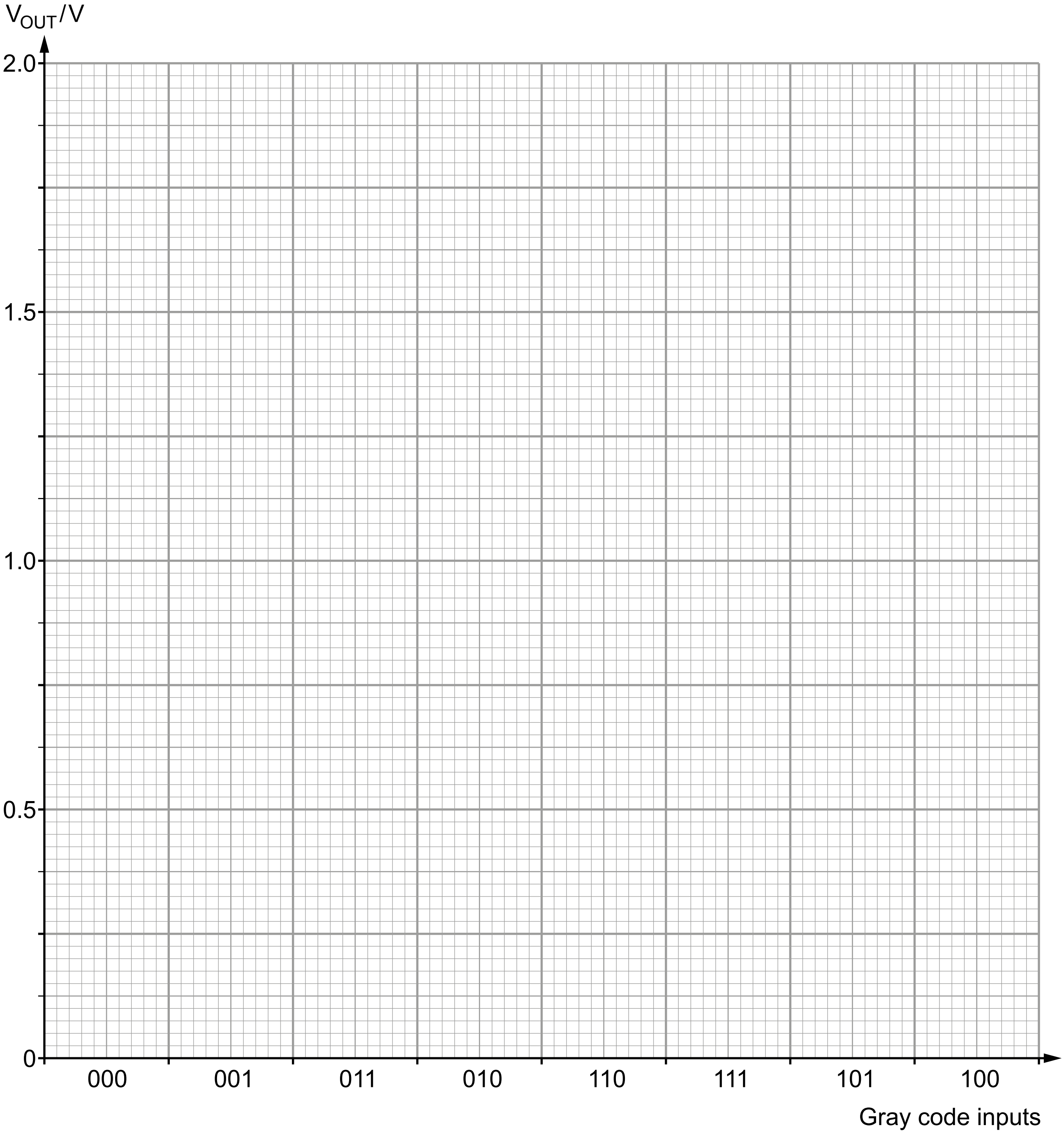
(b) A Gray code counter is connected to the DAC inputs. On the axes below draw the graph of V_{OUT} for the given Gray code inputs. [3]



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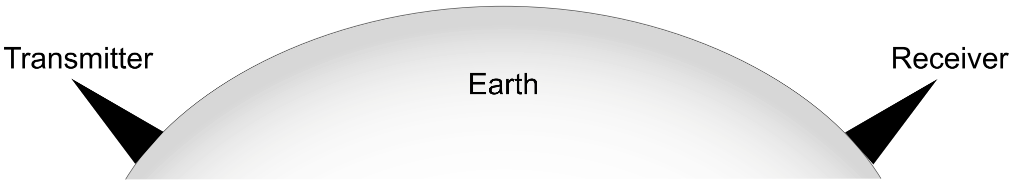
9. Radio waves can be transmitted using amplitude modulation (AM) or frequency modulation (FM).

(a) (i) Use the diagram below to illustrate the difference between surface wave propagation and space wave propagation. [2]



(ii) Calculate the wavelength of a 400 kHz surface wave travelling at $3 \times 10^8\,\text{m s}^{-1}$. [2]

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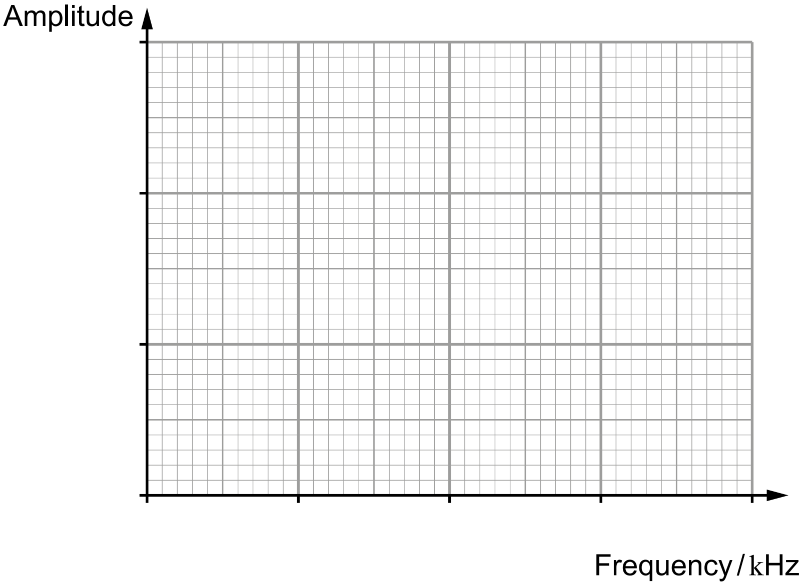
(b) A radio station uses a carrier frequency of 200 kHz to transmit an audio signal with frequencies in the range of 40 Hz to 4 kHz using AM.

(i) Using the axes below sketch the frequency spectrum for the modulated signal. Label significant frequencies. [2]



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(ii) Determine the bandwidth of this transmitted signal. [1]

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(c) A different radio station uses FM to transmit the same audio signal in the range of 40 Hz to 4 kHz on a carrier frequency of 60 MHz, with a maximum frequency deviation of 65 kHz.

(i) Calculate the modulation index. [2]

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(ii) Calculate the bandwidth of the modulated FM signal. [2]

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(d) State and describe an advantage of AM over FM. [2]

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10. (a) The table shows some of the parameters of an ideal op-amp.

Parameter	Ideal value
Input impedance	Infinite
Output impedance	....
Open loop gain	....
Slew rate	Infinite
CMRR	....
Gain-bandwidth product	Infinite

(i) **Complete the table.** [2]

(ii) Describe the procedures needed to calculate the gain-bandwidth product of an op-amp. You should include the equipment you would use, measurements you would take and how you would use your results to find the gain-bandwidth product. [6 QER]

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Examiner only

Turn over.

Examiner only

(b) A non-inverting amplifier is required to have a gain of 25.

(i) Complete the design of the circuit for this amplifier. Include all component values. [5]

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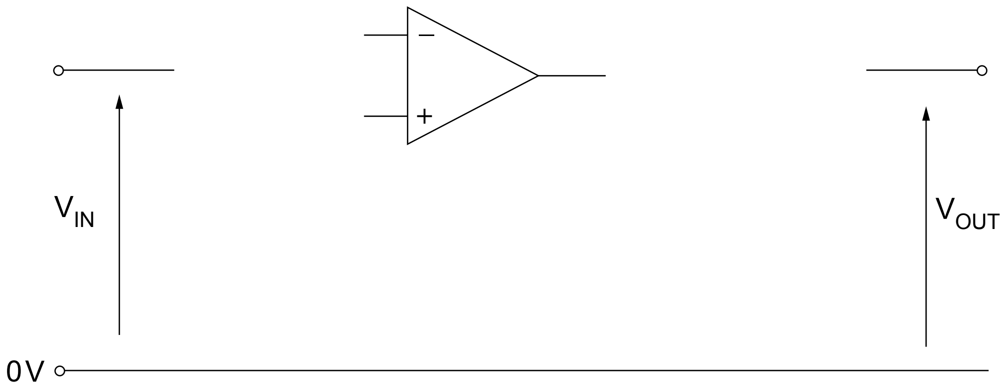

(ii) The op-amp has a power supply of ±14 V and saturates at ±13 V. Determine the maximum input voltage that avoids clipping distortion. [2]

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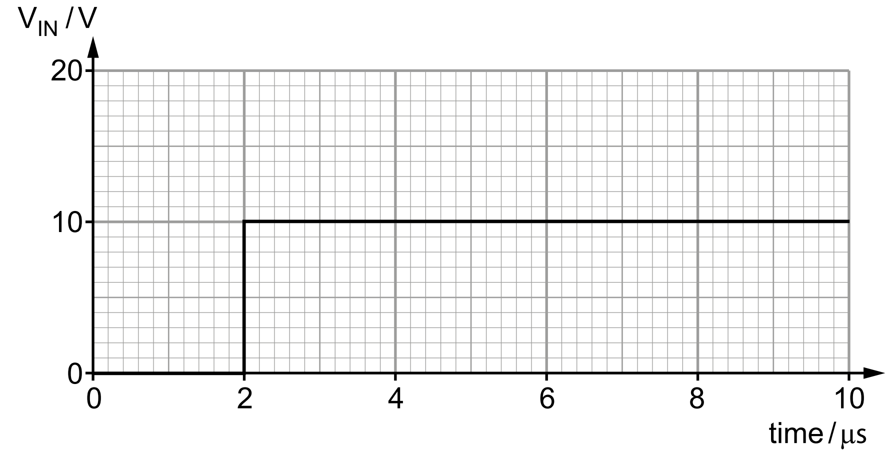
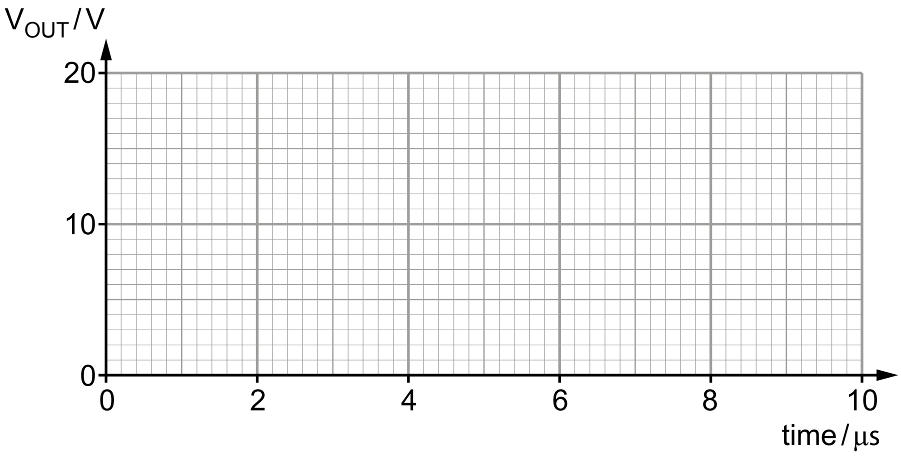
(iii) The amplifier has the following signal applied to its input. Complete the graph to show the output voltage. The op-amp has a slew rate of $5\,V\,\mu s^{-1}$. [2]





(iv) An AC signal is applied to the input of the circuit that results in a peak output voltage of 12.5 V. Determine the maximum frequency to avoid slew rate distortion. [3]

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11. A university installs a communications system for transmitting audio signals using frequency division multiplexing (FDM) on twisted-pair cables.

(a) Each channel has a signal bandwidth of 3.4 kHz and a 0.5 kHz guard band, giving a channel bandwidth of 3.9 kHz. Each twisted-pair has a bandwidth of 250 kHz.

(i) Twisted-pair cables reduce crosstalk. What is meant by crosstalk? [1]

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(ii) How many channels can be transmitted simultaneously along one twisted-pair? [2]

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(b) The noise output from the twisted-pair link is 93 μW with no signal present. What signal power is required at the output of the link if the minimum acceptable signal-to-noise ratio (SNR) is 38 dB? [5]

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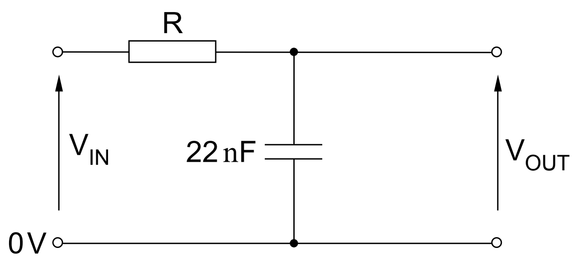
(c) Channel 1 uses a low-pass filter to meet the 3.4 kHz bandwidth requirement. The circuit below is one solution.



(i) Calculate the ideal value for R to achieve a break frequency of 3.4 kHz. [3]

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(ii) A 2 kHz sinusoidal test signal of peak value 9 V is applied to the input V_{IN}. Calculate the resulting reactance of the capacitor and the peak output voltage V_{OUT}. [5]

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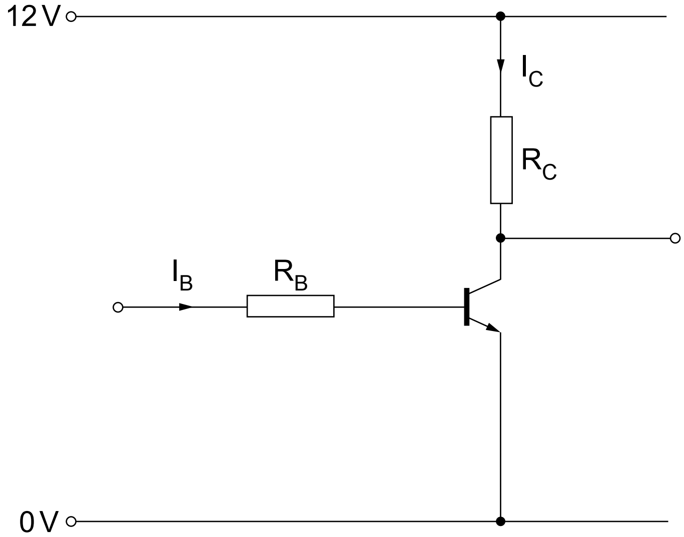
12. The following circuit was set up to determine the current gain of a transistor.



(a) To find the current gain (h_{FE}) of the transistor, values of I_B and I_C were found and are tabulated below.

I_B/mA	I_C/mA
0.06	7
0.10	12
0.22	26
0.28	34
0.34	41
0.40	48

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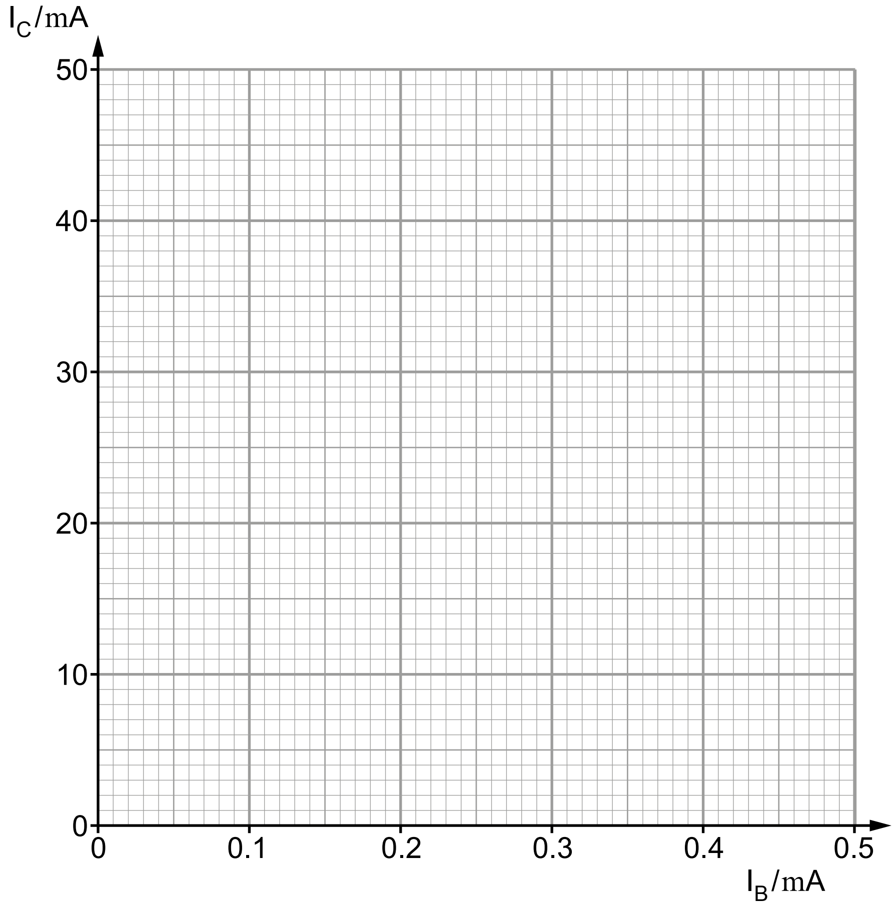
(i) Use these values to plot a graph on the axes. [2]



(ii) Use your graph to determine the current gain of the transistor. [2]

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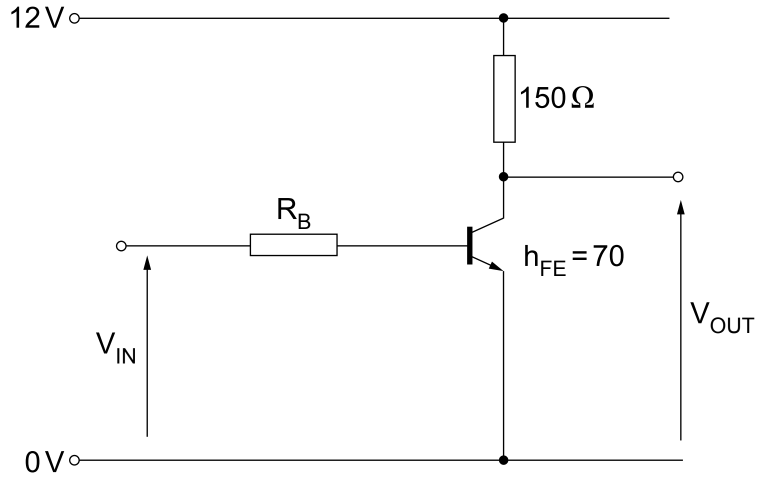
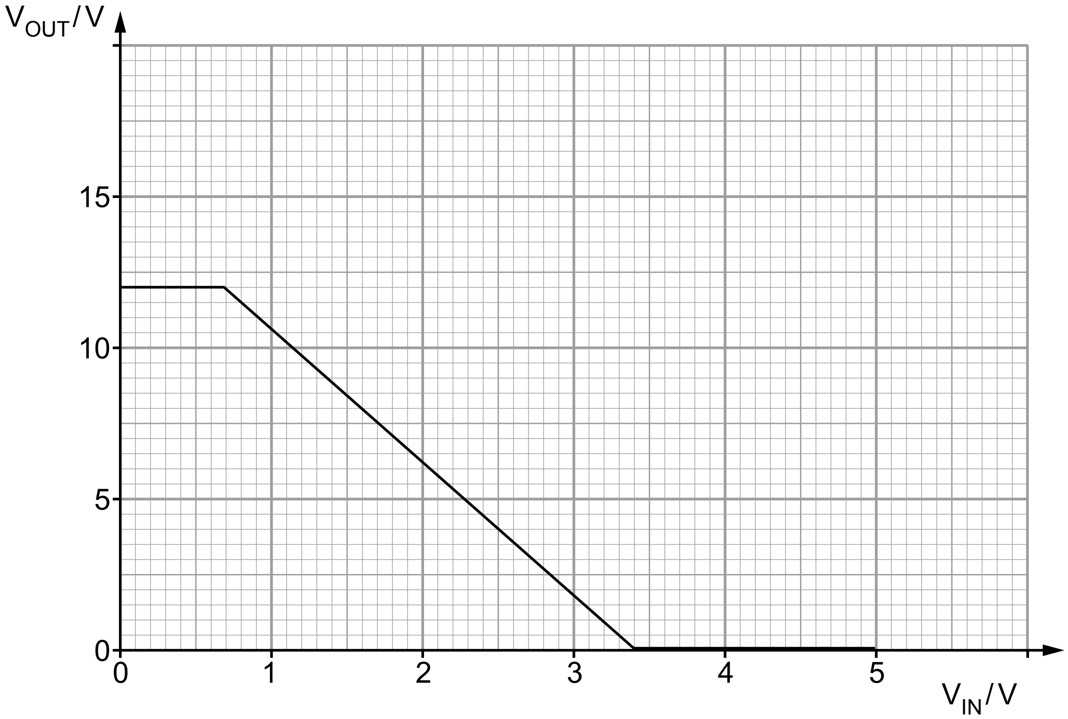
(b) A different transistor is used in the circuit below. The graph shows how V_{OUT} changes as V_{IN} is varied.





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(i) Use the graph to determine the minimum value of V_{IN} required to saturate the transistor. [1]

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(ii) Calculate the ideal value of R_B using this value of V_{IN}.
Give a suitable preferred value for R_B. [4]

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END OF PAPER

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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GCE A LEVEL

A490U10-1A

S23-A490U10-1A

TUESDAY, 23 MAY 2023 – AFTERNOON

ELECTRONICS – A level component 1
Data Booklet

A clean copy of this booklet should be issued to candidates for their use during each A Level Electronics examination.

Centres are asked to issue this booklet to candidates at the start of the A Level Electronics course to enable them to become familiar with its contents and layout.

A490U101A
01

Preferred Values for resistors

The figures shown below and their decade multiples and sub-multiples are the E24 series of preferred values.

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91.

Standard Multipliers

Prefix	Multiplier
T	$\times 10^{12}$
G	$\times 10^{9}$
M	$\times 10^{6}$
k	$\times 10^{3}$

Prefix	Multiplier
m	$\times 10^{-3}$
μ	$\times 10^{-6}$
n	$\times 10^{-9}$
p	$\times 10^{-12}$

Useful equations

$$C = \frac{Q}{V}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C = \frac{C_1 C_2}{C_1 + C_2}$$

$$C = C_1 + C_2$$

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$I_C = h_{FE} I_B$$

$$I_D = g_M (V_{GS} - 3)$$

$$P = I_D^2 r_{DSon}$$

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

$$A.B + A = A.(B + 1) = A$$

$$G = \frac{V_{OUT}}{V_{IN}}$$

$$G = 1 + \frac{R_F}{R_1}$$

$$G = -\frac{R_F}{R_{IN}}$$

$$V_{OUT} = -R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + ...\right)$$

$$V_{OUT} = V_S \text{ for } V_+ > V_-$$

$$V_{OUT} = -V_S \text{ for } V_+ < V_-$$

$$V_{OUT} = V_{IN}$$

$$\text{slew rate} = \frac{\Delta V_{OUT}}{\Delta t}$$

$$\text{slew rate} = 2\pi f V_P$$

$$\text{resolution} = \frac{\text{i/p voltage range}}{2^n}$$

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

$$X_L = 2\pi f L$$

$$Z = \sqrt{R^2 + X^2}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$R_D = \frac{L}{r_L C}$$

$$Q = \frac{f_0}{\text{bandwidth}} = \frac{2\pi f_0 L}{r_L}$$

$$N_{CH} = \frac{\text{available bandwidth}}{\text{channel bandwidth}}$$

$$\text{maximum data rate} = 2 \times \text{available bandwidth}$$

$$G_{dB} = 10\log_{10}\frac{P_{OUT}}{P_{IN}}$$

$$SNR_{dB} = 10\log_{10}\frac{P_S}{P_N} = 20\log_{10}\frac{V_S}{V_N}$$

$$m = \frac{(V_{max} - V_{min})}{(V_{max} + V_{min})} \times 100\%$$

$$\beta = \frac{\Delta f_c}{f_i}$$

$$\text{bandwidth} = 2(\Delta f_0 + f_i) = 2(1+\beta)f_i$$

$$c = f\lambda$$

$$V_{OUT} = V_{DIFF}\left(\frac{R_F}{R_1}\right)$$

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$$T = RC$$

$$V_C = V_0\left(1 - e^{-\frac{t}{RC}}\right)$$

$$V_C = V_0 e^{-\frac{t}{RC}}$$

$$t = -RC\ln\left(1 - \frac{V_C}{V_0}\right)$$

$$t = -RC\ln\left(\frac{V_C}{V_0}\right)$$

$$f \approx \frac{1}{RC}$$

$$f = \frac{1}{T}$$

$$T = 1.1RC$$

$$t_H = 0.7\left(R_1 + R_2\right)C$$

$$t_L = 0.7R_2C$$

$$f = \frac{1.44}{\left(R_1 + 2R_2\right)C}$$

$$\frac{T_{ON}}{T_{OFF}} = \frac{R_1 + R_2}{R_2}$$

$$V_r = \frac{I}{f_r C}$$

$$V_L \approx V_Z\left(1 + \frac{R_F}{R_1}\right)$$

$$\phi = \tan^{-1}\left(\frac{R}{X_C}\right)$$

$$f_b = \frac{1}{2\pi R C}$$

$$V_{OUT} \approx V_{IN} - 0.7$$

$$V_{OUT} \approx V_{IN} - 3$$

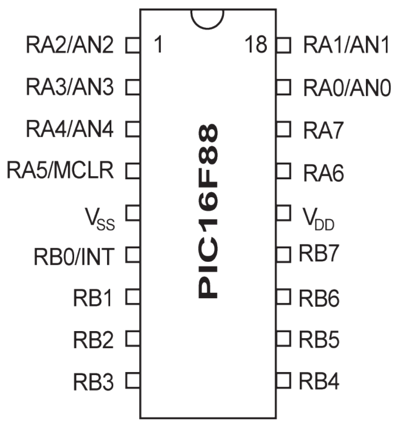
$$P_{MAX} = \frac{{V_S}^2}{8R_L}$$

PIC Information

The PIC programs include 'equate' statements that define the following labels:

Label	Description
PORTA	input / output port A
PORTB	input / output port B
TRISA	the control register for port A
TRISB	the control register for port B
STATUS	the status register
INTCON	the interrupt control register
W	Destination d = W, result stored in working register
F	Destination d = F, result stored in specified file register
RP0	the register page selection bit 0
Z	the zero flag status bit
GIE	the global interrupt controller bit
INT0IE	the external interrupt enable bit

Pinout for 16F88 PIC IC:



List of commands

Mnemonic	Operands	Description
addlw	k	Add working register to literal k
andlw	k	AND working register with literal k
bcf	f, b	Clear bit b of file register f
bsf	f, b	Set bit b of file register f
btfsc	f, b	Bit test bit b of file register f, skip if clear
btfss	f, b	Bit test bit b of file register f, skip if set
call	label	Call subroutine at label
clrf	f	Clear file register f
comf	f, d	Complement file register f
decfsz	f, d	Decrement file register f, skip if zero
goto	label	Unconditional branch to label
incf	f, d	Increment file register f
iorlw	k	Inclusive OR working register with literal
movf	f, d	Move file register f
movlw	k	Move literal to working register
movwf	f	Move working register to file register f
nop	-	No operation
retfie	-	Return from interrupt service routine and set global interrupt enable bit GIE
return	-	Return from subroutine
sublw	k	Subtract W from literal

Number system notation

Decimal	d'153'
Hex	h'99'
Binary	b'10011001'

Structure of the INTCON register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	PEIE	TMR0IE	INT0IE	RBIE	TMR0IF	INT0IF	RBIF

Structure of the STATUS register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C

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