

Please write clearly in block capitals.

Centre number

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A-level PHYSICS

Paper 3

Section B Electronics

Thursday 14 June 2018

Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

Materials

For this paper you must have:

- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do **all** rough work in this book. Cross through any work you do not want to be marked.
- Show **all** your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use

Question	Mark
1	
2	
3	
4	
5	
TOTAL	



J U N 1 8 7 4 0 8 3 B E 0 1

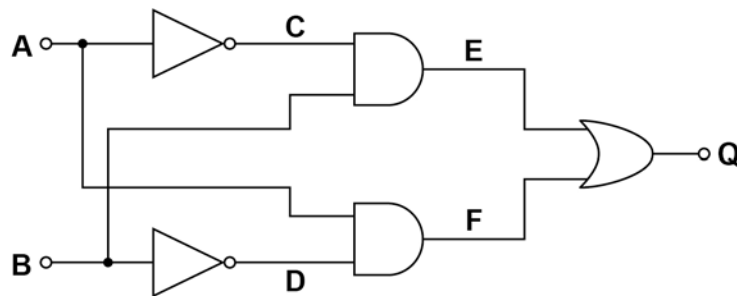
Section B

Answer **all** questions in this section.

0 1 . 1

Two logic inputs, **A** and **B**, feed into the logic circuit shown in **Figure 1**. The logic output from the circuit is **Q**.

Figure 1



Deduce the Boolean expression for the output of this logic circuit in terms of inputs **A** and **B**.

Include **all** the logic operations that take place between the inputs and the output.

[2 marks]

$$C = \bar{A}, \quad D = \bar{B}$$

$$E = C.B = \bar{A}.B, \quad F = A.D = A.\bar{B}$$

$$Q = E + F$$

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

0 1 . 2

The truth table shows some of the logic states for the logic gates in **Figure 1**.

Complete the truth table.

[2 marks]

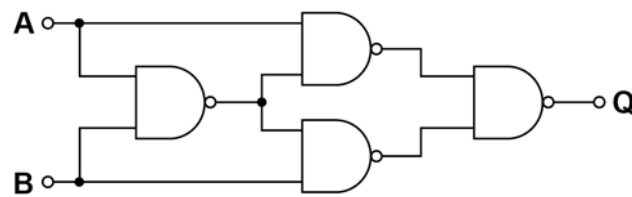
B	A	C	D	E	F	Q
0	0	1	1	0	0	0
0	1	0	1	0	1	1
1	0	1	0	1	0	1
1	1	0	0	0	0	0



0 1 . 3

Figure 2 shows a different logic circuit that produces the same logic output as that of **Figure 1**.

Figure 2



A manufacturer wants to produce a system that uses this logic function, but is undecided as to which circuit to use.

Suggest, giving reasons, **two** benefits of using the logic circuit in **Figure 2** compared to the logic circuit in **Figure 1**.

[2 marks]

It only uses one type of gate (NAND), so only one type of chip is needed, which is more economical to buy and easier to manufacture.

It needs fewer ICs (the four NAND gates fit on one chip), so it saves space on the circuit board and uses less power.

0 1 . 4

State the single logic gate that would perform the same logic function as the circuits shown in **Figure 1** and **Figure 2**.

[1 mark]

EOR (exclusive OR / XOR) gate

7

Turn over for the next question

Turn over ►



0 2 . 1

An ultrasound sensor produces an output that needs to be amplified to 3.0 V. The amplifier used has a voltage gain of 40.

Calculate the input voltage V_{in} to the amplifier from the sensor.

[1 mark]

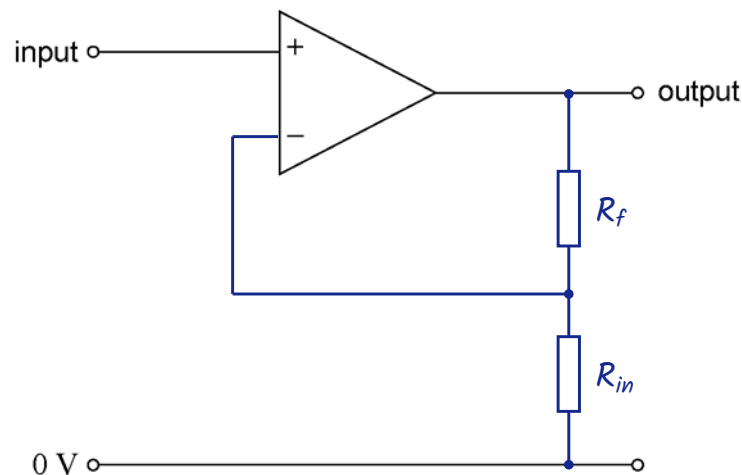
$$V_{in} = V_{out} / \text{voltage gain} = 3.0 / 40$$

$$V_{in} = \underline{0.075} \text{ V}$$

0 2 . 2

An operational amplifier in non-inverting mode is used to amplify the output of the sensor. The partially completed circuit diagram is shown in **Figure 3**.

Figure 3



Complete the circuit diagram in **Figure 3** by adding and labelling two resistors, R_{in} and R_f , so that the operational amplifier is correctly configured in its non-inverting mode.

The power lines should not be shown in the completed diagram.

[2 marks]



0 2 . 3

Determine, using resistors selected from the list below, how the voltage gain of 40 can be achieved by the non-inverting amplifier of **Figure 3**.

1 k Ω 3.6 k Ω 10 k Ω 39 k Ω 150 k Ω **[2 marks]**

$$\text{Gain} = 1 + R_f / R_{in}$$

$$40 = 1 + R_f / R_{in} \quad \text{so} \quad R_f / R_{in} = 39$$

$$\text{Using } R_{in} = 1 \text{ k}\Omega \text{ and } R_f = 39 \text{ k}\Omega \text{ gives } 1 + 39/1 = 40$$

$$R_{in} = \underline{\quad 1 \quad} \text{ k}\Omega$$

$$R_f = \underline{\quad 39 \quad} \text{ k}\Omega$$

0 2 . 4

The ultrasound frequency detected by the sensor is 50 kHz
For this operational amplifier

$$\text{gain} \times \text{bandwidth} = 1.0 \text{ MHz}$$

Discuss whether this operational amplifier is suitable for amplifying the sensor's output voltage.

[2 marks]

$$\text{Bandwidth needed with a gain of 40: gain} \times \text{bandwidth} = 40 \times 50 \text{ kHz} \\ = 2.0 \text{ MHz.}$$

$$\text{This is twice the 1.0 MHz available, so at 50 kHz the op amp can only} \\ \text{give a gain of } 1.0 \text{ MHz} / 50 \text{ kHz} = 20, \text{ half the amplification needed.}$$

So it is not suitable.

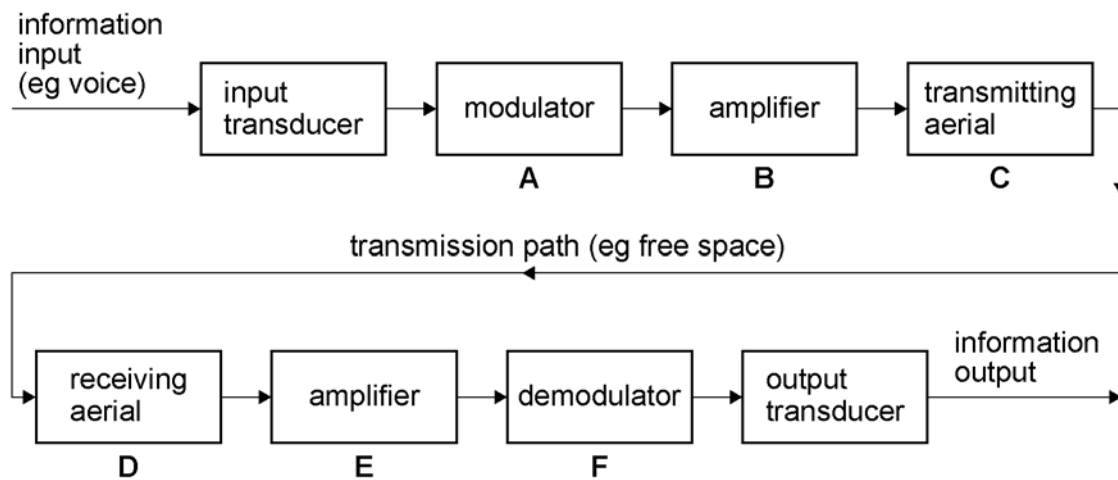
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0 3

Figure 4 shows a block (subsystem) diagram for a radio communication system.

Figure 4



0 3

1

State the letter representing the subsystem in which you might find an induced emf being generated.

[1 mark]

D

0 3

2

State the letter representing the subsystem where the audio and radio waves are combined.

[1 mark]

A

0 3

3

The signal strength at stage D must be amplified.

Explain why the signal strength at stage D is weak.

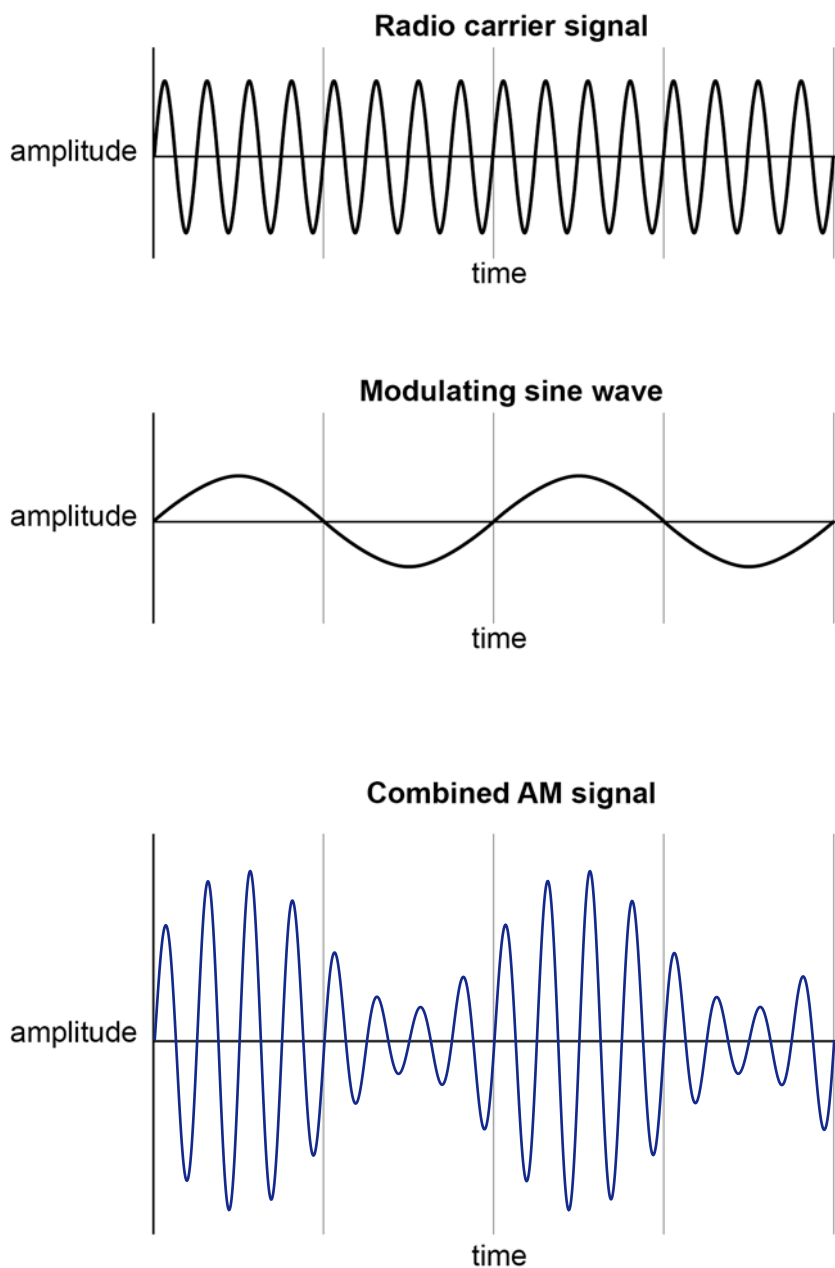
[1 mark]

The em wave is attenuated (spreads out and is absorbed) across the transmission path, so only a small fraction of the radiated energy reaches the receiving aerial.



0 3 . 4 Figure 5 shows graphs of a radio carrier signal and a modulating sine wave.

Figure 5



Complete the graph in **Figure 5** to represent the combined amplitude modulated (AM) signal.

[1 mark]

Question 3 continues on the next page

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0 3 . 5

Approximately 20 radio stations use amplitude modulation (AM) to broadcast to people living in the London area. Another 35 AM stations broadcast to people outside the London area. However, these broadcasts can still be received in London.

The allocated frequency spectrum for all these broadcasts is in the range 540 kHz to 1600 kHz

Suggest whether all these stations can broadcast hi-fi music using the full audio frequency of 20 kHz

[3 marks]

About $20 + 35 = 55$ stations can be picked up in London.

With AM, a full audio frequency of 20 kHz needs a bandwidth of $2 \times 20 = 40$ kHz for each station.

$55 \times 40 \text{ kHz} = 2200 \text{ kHz}$, but the waveband available is only $1600 - 540 = 1060 \text{ kHz}$, so about twice as much bandwidth is needed as is available.

So the stations would have to overlap, leading to crosstalk / interference, so they cannot all broadcast hi-fi music at 20 kHz.

7



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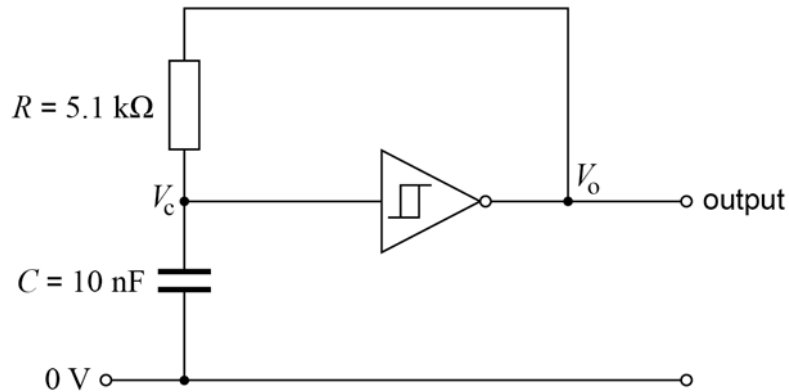
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0 4 . 1

Figure 6 shows an astable circuit based on a NOT logic gate. The symbol in the centre of the logic gate means that the output V_o changes at two different input values of V_c depending on whether the input voltage is rising or falling.

Figure 6

The pulse repetition frequency (PRF) for this particular circuit is given by:

$$\frac{1}{1.4 RC}$$

Calculate the PRF in kHz

[1 mark]

$$\begin{aligned} PRF &= 1 / (1.4RC) = 1 / (1.4 \times 5.1 \times 10^3 \times 10 \times 10^{-9}) \\ &= 1.4 \times 10^4 \text{ Hz} \end{aligned}$$

$$PRF = \underline{\quad 14 \quad} \text{ kHz}$$

0 4 . 2

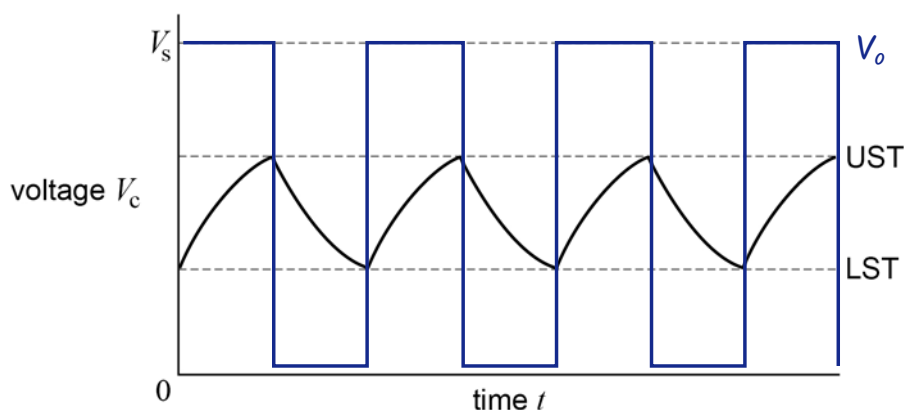
The supply voltage to the NOT gate is V_s

- When V_c increases and reaches the upper switching threshold (UST), the output of the NOT gate will switch from V_s to 0 V
- When V_c decreases and reaches the lower switching threshold (LST), the output of the NOT gate will switch from 0 V to V_s

The graph in **Figure 7** shows V_c constantly changing as the capacitor charges and discharges.



Figure 7



Draw on **Figure 7** the output voltage V_o for the astable circuit.

[1 mark]

0 4 . 3

The circuit in **Figure 6** can be modified by the addition of a resistor to vary the PRF.

The astable is to be modified so that it produces a frequency 4 times that of the original.

Calculate the value of the resistor that should be added to the circuit and explain where in the circuit this additional resistor should be placed.

[2 marks]

$PRF \propto 1/R$, so for $4 \times$ the frequency the timing resistance
must be $R/4 = 5.1 \text{ k}\Omega / 4 = 1.275 \text{ k}\Omega$

Parallel: $1/1.275 = 1/5.1 + 1/R_x$

$1/R_x = 0.784 - 0.196 = 0.588 \text{ k}\Omega^{-1}$

$R_x = 1.7 \text{ k}\Omega$

value of resistor = 1.7 k Ω

The $1.7 \text{ k}\Omega$ resistor should be placed in parallel with the original $5.1 \text{ k}\Omega$
resistor R , so that the total resistance is $1.275 \text{ k}\Omega$ and the PRF
increases by 4 times.

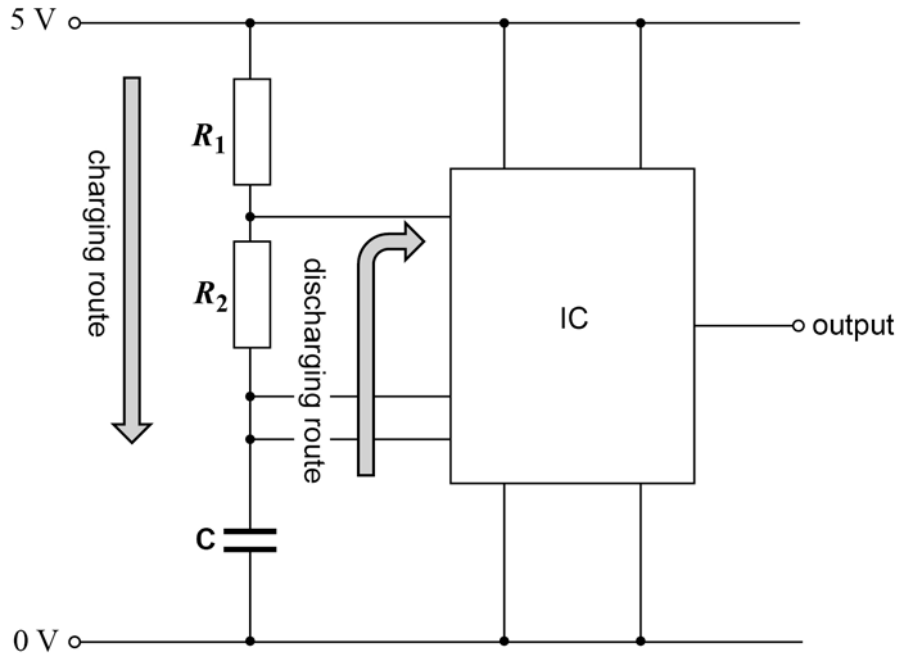
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0 4 . 4

In another astable, two resistors (R_1 and R_2) and a capacitor C form a timing chain to control the mark and space times for a square wave produced at the output of the integrated circuit (IC) shown in **Figure 8**.

Figure 8

The charging time for the capacitor C is: $t_C = 0.7 \times (R_1 + R_2) \times C$

The discharging time for the capacitor C is: $t_D = 0.7 \times R_2 \times C$

Calculate, in $k\Omega$, values for R_1 and R_2 needed to produce a 5 kHz signal with 75% duty cycle given that the capacitor C has a value of 10 nF

[2 marks]

$$T = 1/f = 1 / (5 \times 10^3) = 0.2 \text{ ms} = 200 \mu\text{s}$$

$$75\% \text{ duty cycle: } t_c = 0.75 \times 200 = 150 \mu\text{s}, \quad t_D = 0.25 \times 200 = 50 \mu\text{s}$$

$$R_2 = t_D / (0.7C) = 50 \times 10^{-6} / (0.7 \times 10 \times 10^{-9}) = 7.1 \text{ k}\Omega$$

$$R_1 + R_2 = t_c / (0.7C) = 150 \times 10^{-6} / (0.7 \times 10 \times 10^{-9}) = 21.4 \text{ k}\Omega$$

$$R_1 = 21.4 - 7.1 = 14.3 \text{ k}\Omega \quad (\text{so } R_1 = 2R_2)$$

$$R_1 = \underline{14.3} \text{ k}\Omega$$

$$R_2 = \underline{7.1} \text{ k}\Omega$$

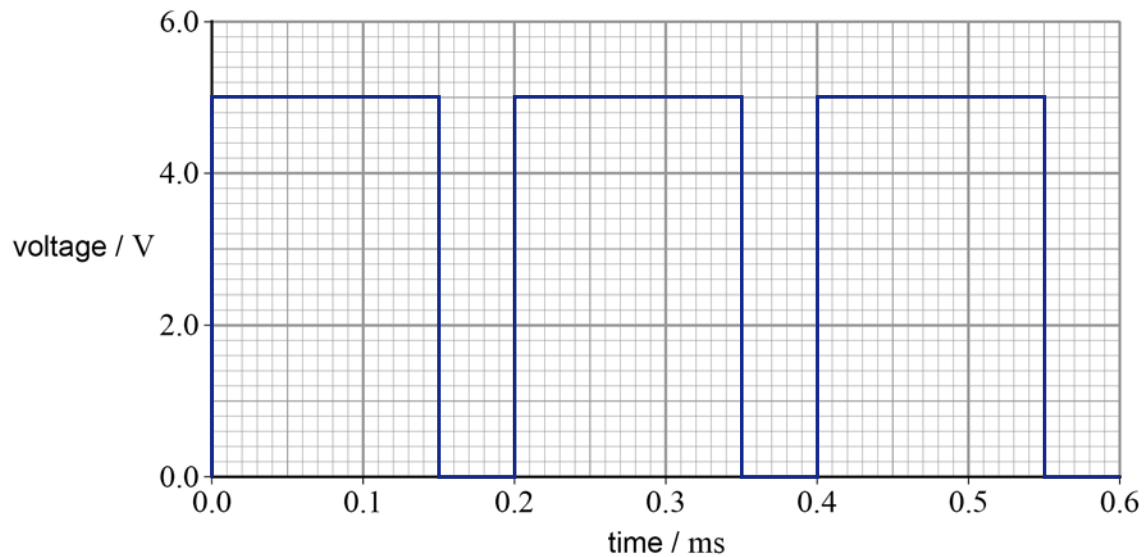


0 4 . 5

The output of the IC in **Figure 8** is 5 V during the charging period and 0 V during the discharging period.

Draw on **Figure 9** the wave pattern that represents this signal.

[2 marks]

Figure 9

high (5 V) for 0.15 ms, low (0 V) for 0.05 ms, period 0.2 ms

8

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0 5

In a recording studio the output from a microphone is an analogue signal. The equipment in the studio converts this analogue signal into a digital signal before storing it.

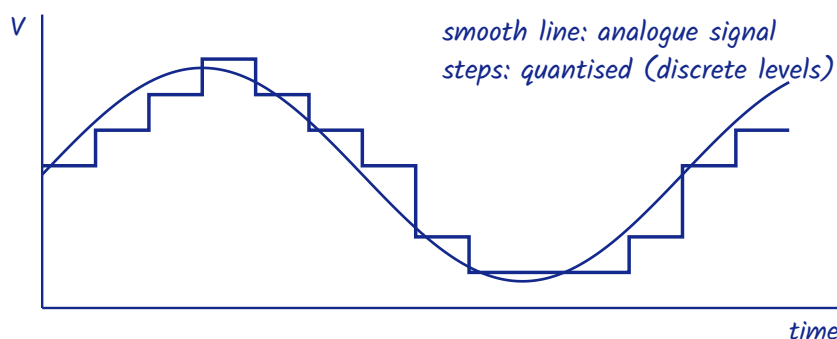
Discuss aspects of the analogue-to-digital conversion in this context.

In your answer you should include:

- what is meant by quantisation
- factors that affect the quality of the digital version of the analogue signal
- the advantages and disadvantages of digitising the analogue signal.

You may use diagrams to help make clear aspects of your answer.

[6 marks]



Quantisation is the conversion of a continuously varying voltage level from the microphone, by sampling, into a signal that only contains discrete (stepped) voltage levels; each level is then given a binary code, as in the sketch.

The quality of the digital version depends on two main factors. The first is the sampling rate: the number of times per second that the analogue signal is sampled and assigned a digital code. By the Nyquist criterion the sampling rate must be at least $2 \times$ the highest frequency component, so for audio up to 20 kHz at least 40 kHz is needed (CDs use 44.1 kHz). Under sampling causes a loss of quality (aliasing), while over sampling just produces superfluous data.

The second factor is the size of the digital code, the number of bits per sample. This determines the number of levels (2^n) and so the smallest



change in the analogue signal that can cause a change in the digital code, the resolution. The CD standard is 16 bits, giving 65 536 levels, so the quantisation error is very small.

Together these two factors determine the amount of data generated: $44.1 \text{ kHz} \times 16 \text{ bits} \times 2 \text{ channels}$ is about 1.4 Mbit every second, so the quantity of data is very large and compression techniques will probably be applied.

Advantages: digital signals have good noise immunity, since the receiver only has to tell a 1 from a 0, so noise can be removed and copies are perfect. Digital recordings do not degrade with frequent use in the way analogue recordings do (tape v CD). Digital files can be saved, edited and manipulated by computer, stored on high density devices (CD to SSD) and coded for downloading across the internet.

Disadvantages: digitising always loses some information (quantisation error) and some people think it sounds too clinical; data can become corrupt; there can be format compatibility issues; and large storage or compression is needed.

Overall, digital has become the dominant format in the recording industry, because a very good digital system is cheaper than a very good analogue one, CDs are fairly scratch resistant, and it has allowed small personal music devices and music downloads to develop.

END OF QUESTIONS



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