Sound

2.2.3 · Data · revision notes

How analogue sound is sampled and stored in binary, using the terms amplitude, sample rate, bit depth and sample interval. Expect definitions, reading samples from a graph, 'explain the effect' questions and file size expressions.

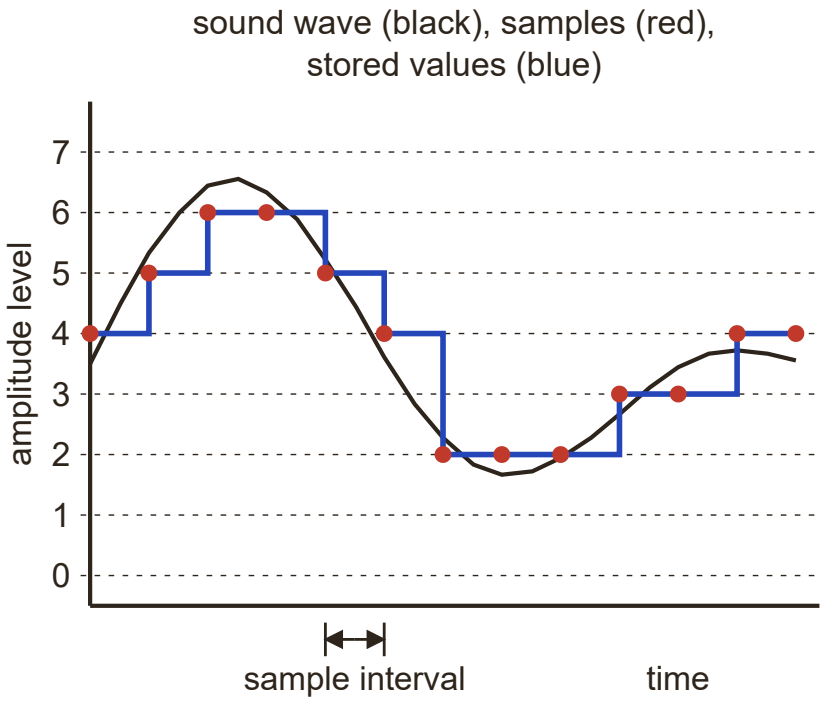
Key facts

- Sound is analogue, so it is sampled to be stored digitally
- Sample rate = samples per second, in Hz; 1 kHz = 1000 Hz
- Bit depth = bits per sample; amplitude values = $2^{\text{bit depth}}$
- Higher sample rate or bit depth: better quality, bigger file
- Sample = a measurement of the amplitude of the wave at one point in time
- Sample interval = 1 ÷ sample rate
- Sound file size in bits = sample rate × bit depth × seconds

Notes

Sampling

- Sound is an **analogue** wave: it changes continuously. Computers can only store **digital** (separate binary) values, so the sound must be sampled.
- A **sample** is a measurement of the **amplitude** (height) of the sound wave at one moment in time. Each sample is stored as a binary number.



Each sample (red dot) is the amplitude rounded to the nearest level. 3 bits give 8 levels, 0 to 7. The blue line is what is stored

- When the samples are played back they make a close copy of the original wave, but never an exact one.

Key terms

- **Sample rate**: the number of samples taken each second, measured in hertz (Hz). 44,100 Hz means 44,100 samples per second. 1 kHz = 1000 Hz.
- **Sample interval**: the time between one sample and the next. Sample interval = 1 ÷ sample rate, e.g. at 1000 Hz one sample is taken every 0.001 seconds (1 millisecond).
- **Bit depth**: the number of bits used to store each sample. n bits give 2^n possible amplitude values, e.g. 3 bits give 8 values (0 to 7).

Quality and file size

- Higher sample rate: the samples are closer together, so more of the changes in the wave are captured. Better quality, bigger file.
- Higher bit depth: more possible amplitude values, so each sample is stored more precisely, with less rounding. Better quality, bigger file.
- Lower settings give smaller files that are quicker to download or stream. Speech can be recorded at a lower sample rate than music and still be understood.

File size

- File size in bits = sample rate × bit depth × duration in seconds.
- Change minutes into seconds first (× 60), then divide by 8 for bytes, by 1024 for KiB, and so on.
- Example: 10 seconds at 8000 Hz with a bit depth of 8 bits: 8000 × 8 × 10 = 640,000 bits = 80,000 bytes.

How to answer each type of question

Define the key terms

1 mark each | Grade 4

1. Sample rate: use 'number of samples' and 'each second'.
2. Bit depth: use 'number of bits' and 'each sample'.
3. Sample interval: use 'time between' samples.

Example. (a) Define the term 'sample rate'.
(b) Define the term 'bit depth'.

Model answer.

(a) The number of samples taken each second (1)
(b) The number of bits used to store each sample (1)

Calculate the sample interval

2 marks | Grade 6

1. Divide 1 by the sample rate to get the interval in seconds.
2. Convert to the unit asked for (× 1000 for milliseconds).

Example. A sound is sampled at 2000 Hz.
Calculate the sample interval in milliseconds. (1 second = 1000 milliseconds)

Model answer.

1 ÷ 2000 = 0.0005 seconds (1)
0.0005 × 1000 = 0.5 milliseconds (1)

Explain the effect of changing a setting

2 marks | Grade 6

1. Say what happens to the quality, and why (more or fewer samples, more or fewer amplitude values).
2. Say what happens to the file size, and by how much if you can.

Example. A podcast producer reduces the bit depth used for recording from 16 bits to 8 bits.
Explain the effect of this change on the recording.

Model answer. Each sample can now have only 256 values instead of 65,536, so amplitudes are rounded more and the recording is a less accurate copy of the original (1). Each sample uses half as many bits, so the file size halves (1).

Construct an expression for the file size of a sound

2 to 3 marks | Grade 7

1. Convert the length of the recording to seconds.
2. Multiply sample rate × bit depth × seconds to get bits.
3. Divide by 8 for bytes, then by 1024 for each step up.

Example. A 3-minute song is recorded with a sample rate of 48,000 Hz and a bit depth of 16 bits. Construct an expression to calculate the file size in kibibytes (KiB). You do not need to do the calculation.

Model answer. 48,000 × 16 × 180 (3 minutes = 180 seconds) (1) ÷ 8 (1) ÷ 1024 (1)

Don’t lose marks

- Saying the sample rate is 'how often the sound is recorded' without 'number of samples per second'.
- Defining bit depth as 'the quality of the sound'. It is the number of bits used for each sample.
- Forgetting to change minutes into seconds in file size calculations.
- Writing 'colour depth' in a sound answer. Use the sound terms: sample rate and bit depth.
- Saying that higher settings give an exact copy. A sampled sound is always an approximation.

More tips

Memory tricks

- Rate = how often (samples per second); depth = how precisely (bits per sample).
- Hz means 'per second', so 44,100 Hz is 44,100 samples every second.
- Sample rate and sample interval work in opposite directions: double the rate and the interval halves.
- Size check: doubling the sample rate, the bit depth or the length of the recording doubles the file size.

Exam technique

- For 'explain the effect' questions, give the effect on quality and the effect on file size, with a reason for each.
- In expressions, show the time in seconds clearly (e.g. 3 × 60 or 180).
- Use the words amplitude, sample rate, bit depth and sample interval exactly: they are the terms examiners look for.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **State that sound is analogue**
Sound is a continuous wave, so it must be sampled before it can be stored in binary.

Grade 4 — **Define sample rate and bit depth**
Sample rate is the number of samples per second (Hz); bit depth is the number of bits per sample.

Grade 5 — **Read sample values from a graph**
Read the amplitude at each sample time and write it as a binary number.

Grade 5

Find the number of amplitude values

A bit depth of n bits gives 2^n possible amplitude values.

Grade 6

Calculate the sample interval

Sample interval = 1 ÷ sample rate: the time between one sample and the next.

Grade 6

Explain effects of sample rate and bit depth

Increasing either makes the recording a closer copy of the original, but makes the file larger.

Grade 7

Construct a file size expression for sound

sample rate × bit depth × duration in seconds gives the size in bits.

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