Sound

Computer systems (Paper 1) · revision notes

How sound is sampled and stored in binary, and how the sample rate, duration and bit depth (sample resolution) affect playback quality and file size. Expect definitions, 'explain the effect' questions and non-calculator file size calculations.

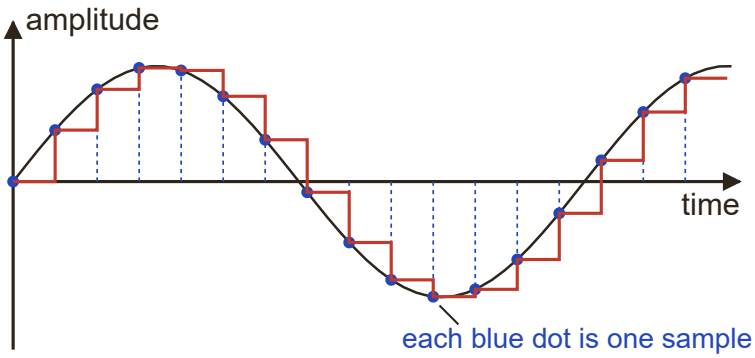
Key facts

- Sample: a measurement of the amplitude of a sound wave at one moment
- Bit depth (sample resolution): number of bits per sample
- Higher sample rate or bit depth → better quality but a larger file
- Sample rate: number of samples per second (Hz)
- File size (bits) = sample rate × bit depth × duration in seconds
- Bits ÷ 8 = bytes; minutes × 60 = seconds

Notes

Sampling sound

- Sound is an analogue wave that changes continuously. To be stored on a computer, it must be converted into digital (binary) data.
- The **amplitude** (height) of the sound wave is measured at regular intervals. Each measurement is called a **sample**.



Samples (blue) are taken at regular intervals; the stored values rebuild a stepped copy of the wave (red)

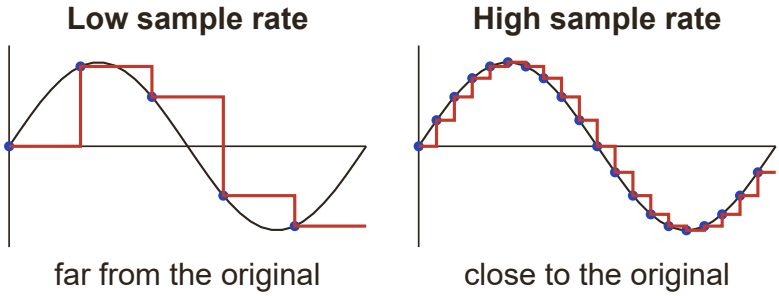
- Each sample is stored as a binary number. On playback, the samples are used to rebuild an approximation of the original wave.

Sample rate, bit depth and duration

- **Sample rate**: the number of samples taken per second, measured in hertz (Hz). E.g. 44,100 Hz means 44,100 samples every second.
- **Bit depth** (also called sample resolution): the number of bits used to store each sample. n bits give 2^n possible values, e.g. 8 bits → 256 values, 16 bits → 65,536 values.
- **Duration**: the length of the recording, in seconds.

Quality and file size

- Higher sample rate: samples are taken closer together in time, so the digital sound is closer to the original. But there are more samples to store, so the file is larger.



More samples per second: the rebuilt sound is closer to the original, but the file is larger

- Higher bit depth: more possible values for each sample, so each amplitude is recorded more accurately. But each sample uses more bits, so the file is larger.
- Longer duration: more samples in total, so a larger file (the quality is unchanged).
- File size (bits) = sample rate × bit depth × duration (s). E.g. 8000 Hz, 8 bits, 10 seconds: 8000 × 8 × 10 = 640,000 bits; ÷ 8 = 80,000 bytes = 80 KB.
- Changes multiply: doubling the sample rate and doubling the bit depth gives a file 4 times as large. Grade 8+ only

How to answer each type of question

Describe how sound is stored digitally 2 marks **Grade 4**

1. Say that the amplitude of the wave is measured (sampled).
2. Say that this happens at regular intervals.
3. Say that each sample is stored as a binary number.

Example. Describe how a sound is recorded and stored by a computer. [2]

Model answer. The amplitude (height) of the sound wave is measured / sampled at regular intervals (1). Each sample is stored as a binary number (1).

Explain the effect of changing the sample rate or bit depth

2 to 4 marks | Grade 6

1. Say what changes: more or fewer samples per second, or more or fewer bits per sample.
2. Explain the effect on quality: closer to, or further from, the original sound.
3. Explain the effect on file size: more or fewer bits to store.

Example. A musician records a song with a bit depth of 8 bits and then records it again with a bit depth of 16 bits. Explain the effect on the quality of the playback and on the file size. [4]

Model answer. With 16 bits, each sample can take many more possible values (65,536 instead of 256) (1), so each sample is closer to the real amplitude and the playback sounds more like the original (1). Each sample uses twice as many bits (1), so the file size doubles (1).

Calculate the file size of a sound recording

2 to 3 marks | Grade 7

1. Change the duration into seconds.
2. Multiply sample rate × bit depth × duration to get bits.
3. Divide by 8 for bytes, then by 1000 for KB (and again for MB) if asked.

Example. A sound is sampled at 20,000 Hz with a bit depth of 8 bits. It lasts 30 seconds. Calculate the file size in kilobytes. Use 1 KB = 1000 bytes. Show your working. [3]

Model answer.

20,000 × 8 × 30 = 4,800,000 bits (1)
4,800,000 ÷ 8 = 600,000 bytes (1)
600,000 ÷ 1000 = 600 KB (1)

Compare the file sizes of two recordings

2 marks | Grade 8

1. Find how many times bigger each factor is (sample rate, bit depth, duration).
2. Multiply the factors together.

Example. Recording A uses a sample rate of 11,025 Hz and a bit depth of 8 bits. Recording B is the same length but uses 44,100 Hz and 16 bits. Calculate how many times larger file B is than file A. [2]

Model answer. The sample rate is 4 times higher (44,100 ÷ 11,025 = 4) and the bit depth is 2 times higher (1). 4 × 2 = 8 times larger (1).

Don’t lose marks

- Saying the sample rate is 'bits per second', or that bit depth is 'how loud the sound is'.
- Using minutes instead of seconds in the formula.
- Forgetting to divide by 8 to get bytes.

- Saying a higher sample rate makes the sound louder. It makes it more accurate.
- Describing sampling without saying the samples are taken at regular intervals.

More tips

Memory tricks

- Formula order 'Rate × Depth × Time': 'Really Deep Tunes'.
- If the bit depth is 8, the number of bytes = sample rate × seconds (the 8s cancel).
- Think of a dot-to-dot picture of the wave: more dots (sample rate) and more exact dot positions (bit depth) give a truer copy.
- Hertz means 'per second'.

Exam technique

- Use the phrase 'closer to the original sound' when explaining quality.
- If asked about quality and file size, give both effects.
- Write the formula, then substitute: method marks are available.

What each grade needs

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

Grade 3 — **Describe how sound is sampled**
The amplitude of the sound wave is measured at regular intervals and each measurement is stored in binary.

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

Grade 5 — **Explain how sample rate affects quality**
More samples per second, so the digital recording is closer to the original sound.

Grade 5 — **Explain how bit depth affects quality**
More bits per sample give more possible values, so each sample is recorded more accurately.

Grade 6 — **Explain what affects the file size**
Increasing the sample rate, the bit depth or the duration increases the file size.

Grade 7 — **Calculate the file size of a recording**
Sample rate × bit depth × duration in seconds gives bits; divide by 8 for bytes.

Grade 8 — **Compare recordings using ratios**
E.g. 4 times the sample rate and 2 times the bit depth gives a file 8 times as large.

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