

# Theoretical Backgrounds of Audio & Graphics

## Digitization

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# Digital Audio

- How is analog sound/audio turned into digital sound/audio?
- How is the signal information stored and processed in a computer?

# Digital Audio

- How is analog sound/audio turned into digital sound/audio?
  - **Digitization**
- How is the signal information stored and processed in a computer?
  - **Audio Buffers**

# Digitization



# Digitization

- Digitization consists of two steps: **sampling & quantization**
- Most common method: Pulse Code Modulation (PCM)
- **Sampling:**
  - The amplitude of the analog signal is measured (in volts) at fixed time intervals determined by the **sampling rate**
- **Quantization:**
  - The sampled amplitude values are mapped onto discrete values defined by the **bit depth** or **sample size**

# Sampling

- Sampling is also called **discretization**
- The continuous signal, i.e., the time value, is converted into discrete time samples

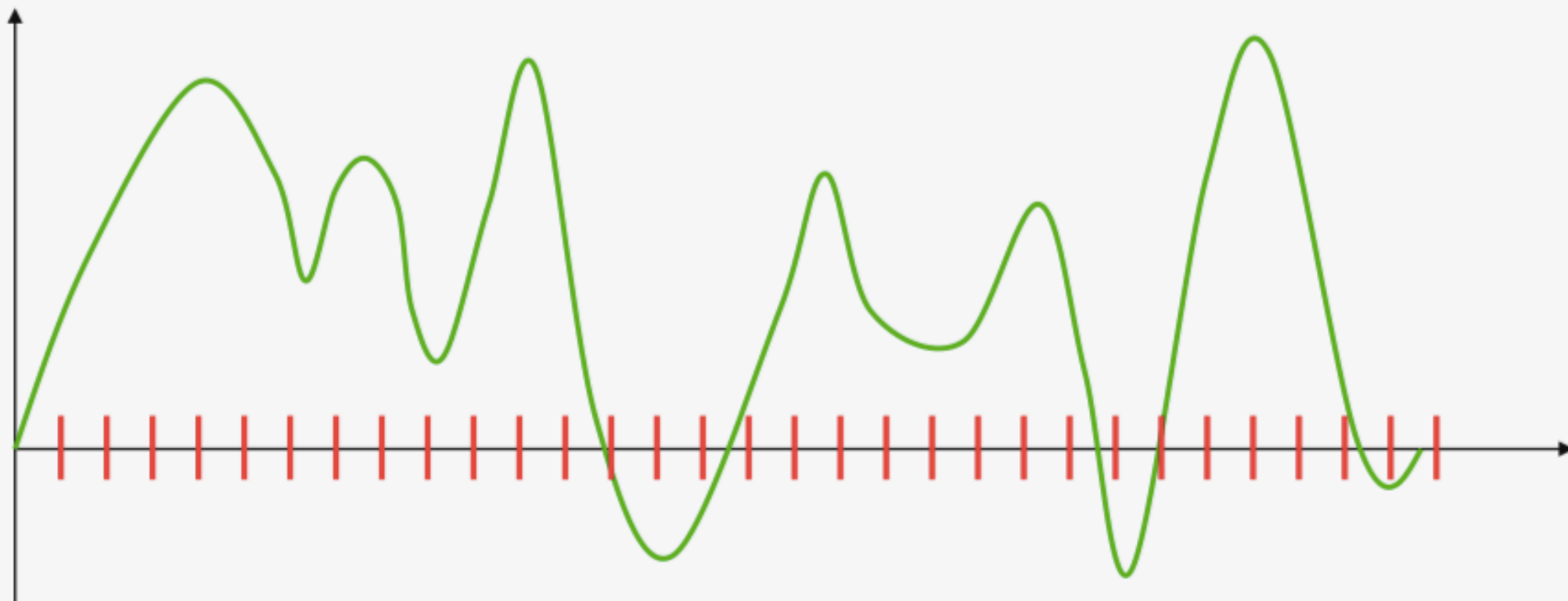


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# Sampling

- During sampling, the amplitude of the analog signal is measured at fixed time intervals determined by the **sampling rate** or **sampling frequency**
- The **sampling rate** determines how many samples are taken per second

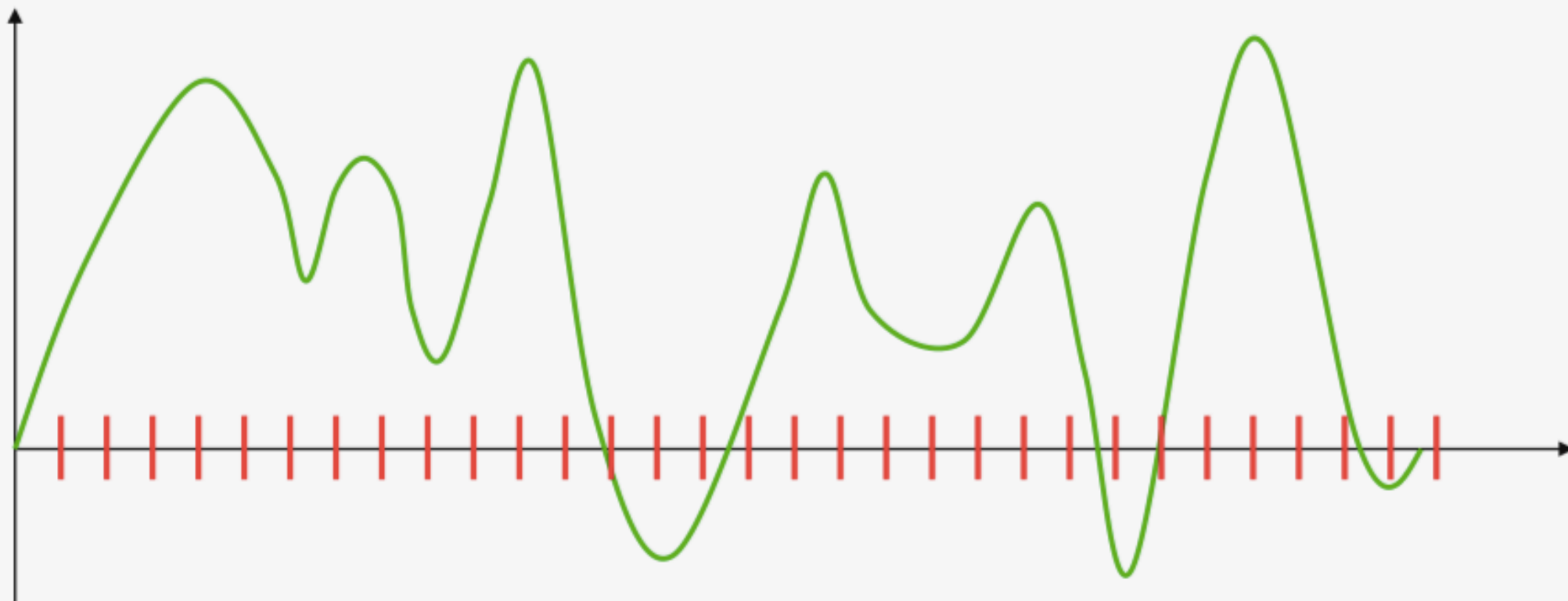


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# Sampling

- Sampling rate must be **greater than twice** the highest frequency of the original signal for proper reconstruction (Nyquist-Shannon sampling theorem) —  $f_{\text{sampled}} > 2 * f_{\text{max}}$

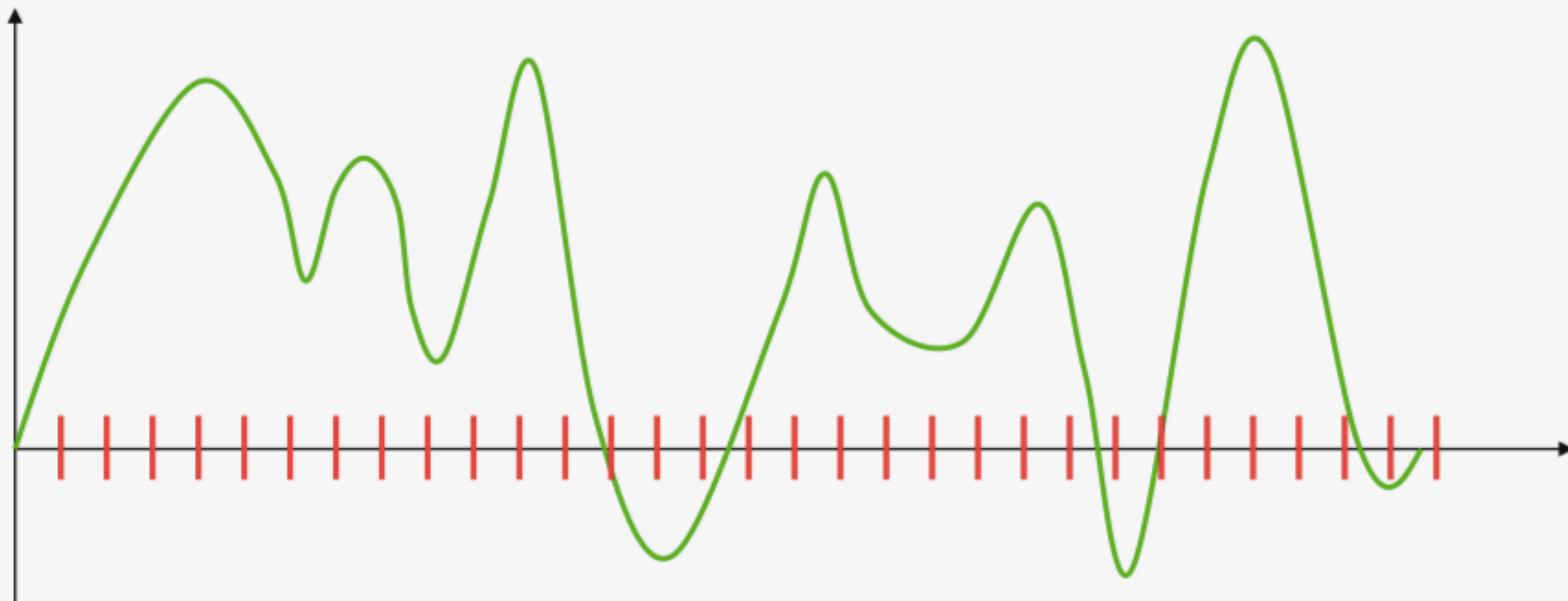


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# Sampling

- Standard sampling rate for CD quality is 44.1 kHz or 44100 Hz

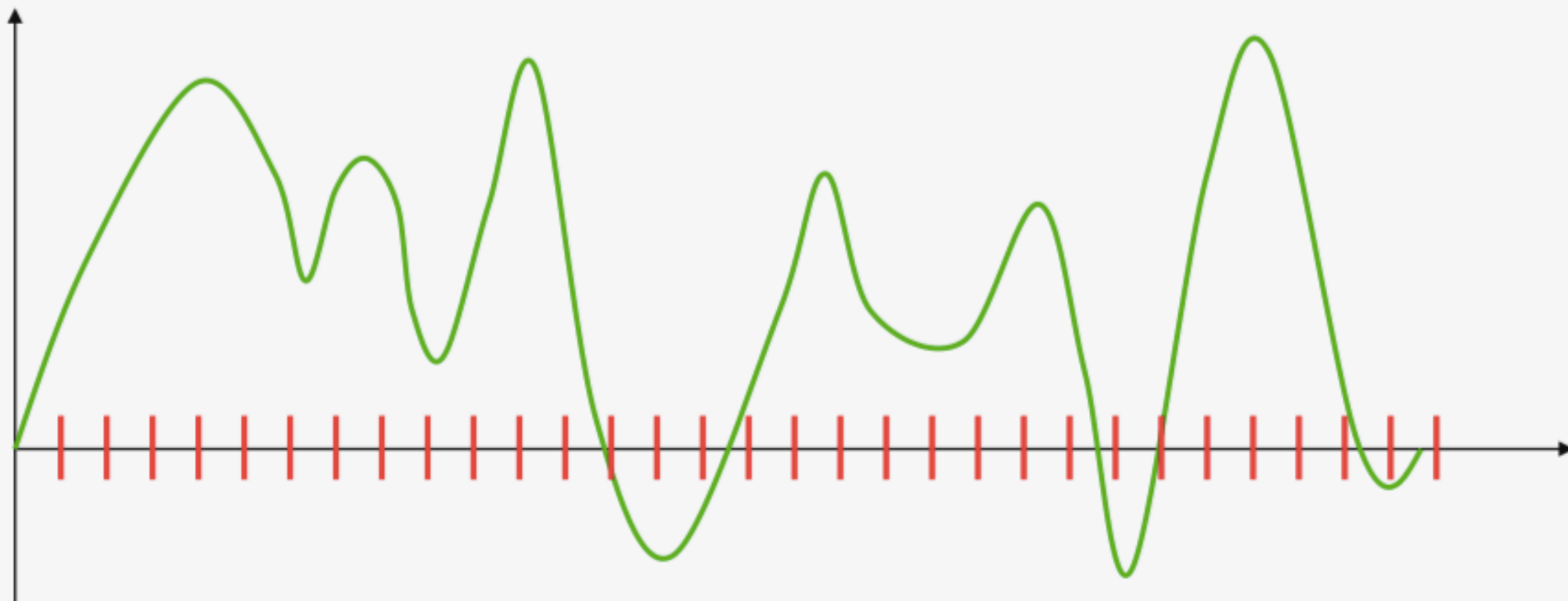


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# Sampling

- Standard sampling rate for CD quality is 44.1 kHz or 44100 Hz due to
  - Human hearing range at 20 kHz max |  $> 2 * 20 \text{ kHz}$

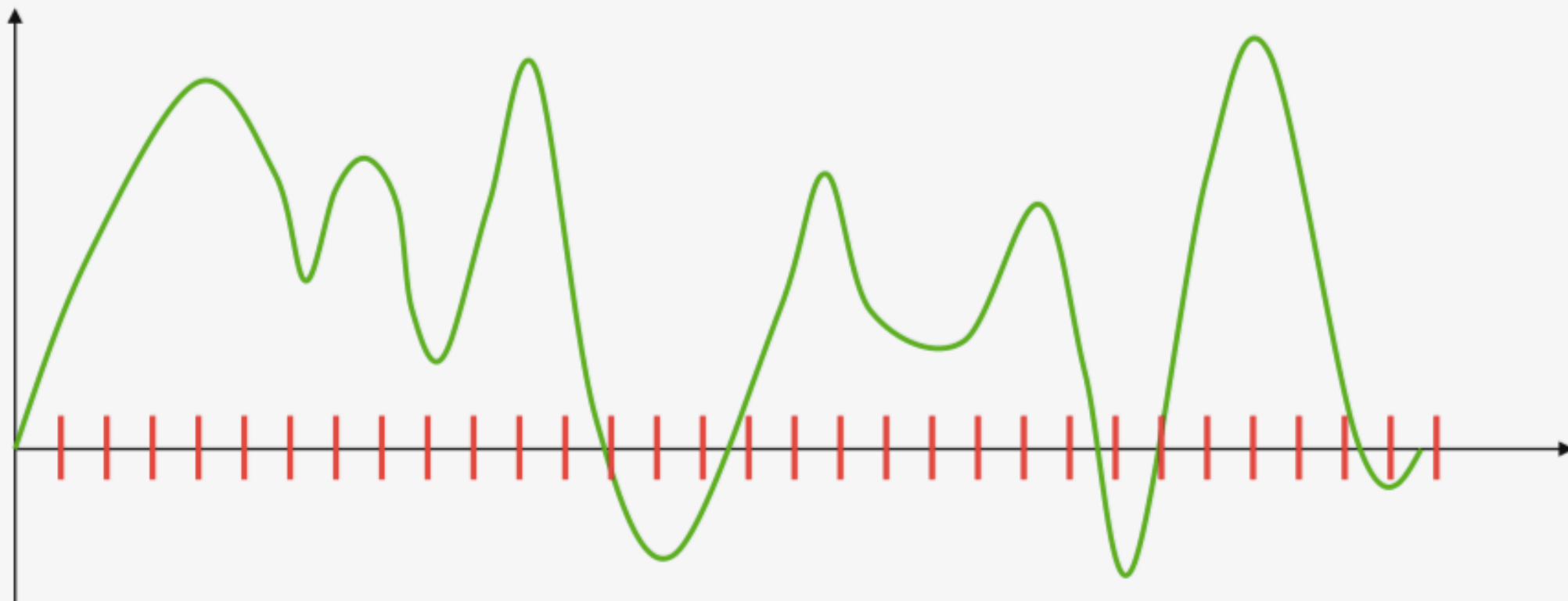


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# Quantization

- During quantization, the sampled amplitude values are quantized, i.e., mapped onto discrete values defined by the **bit depth** or **sample size**

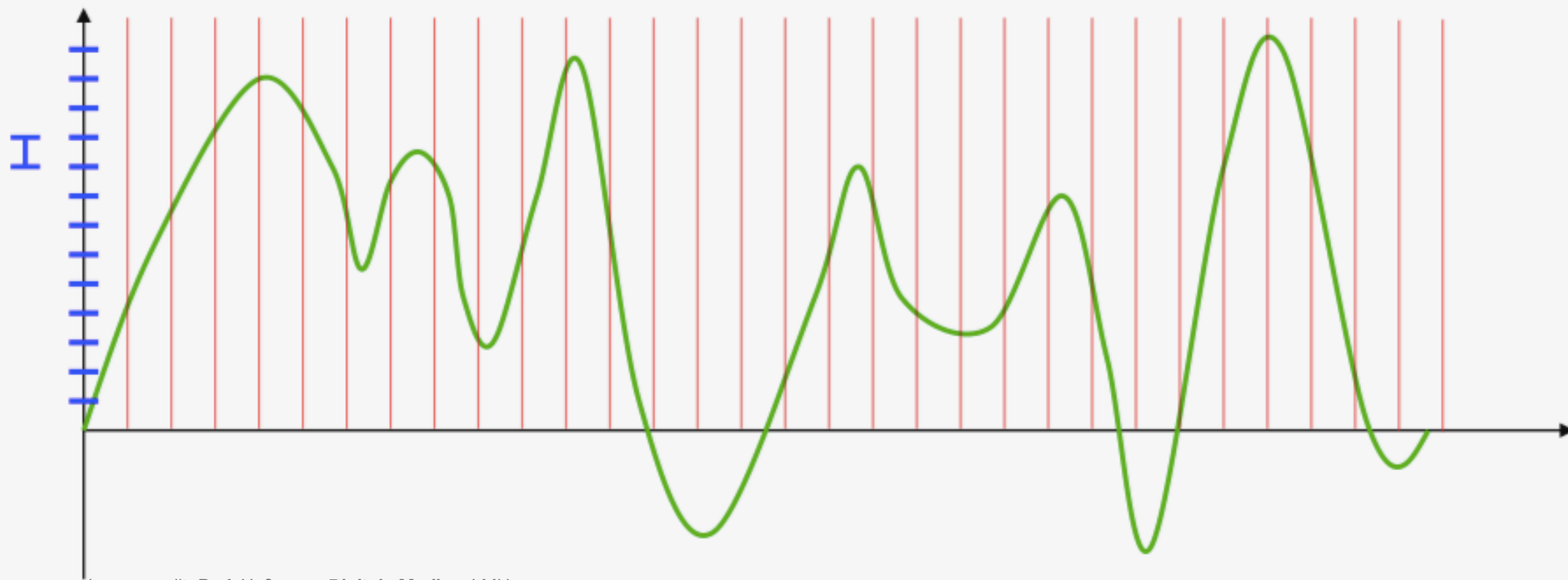


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# Quantization

- The sample size determines the difference between the softest sound and the loudest sound, i.e., the **dynamic range** of the audio application
- Numbers are usually stored as integers or floating points at 24bit

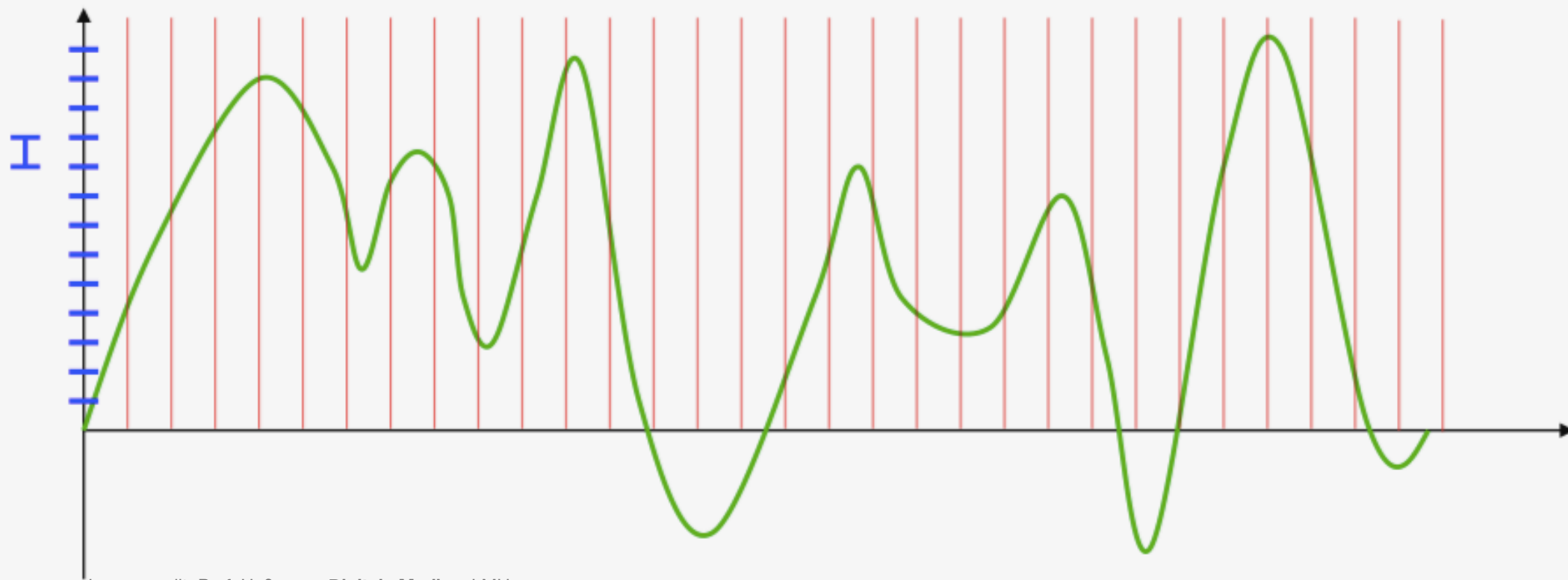


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# Quantization

- A sample size of 24 bits provides for 16 777 216 amplitude values
- Turned into decibel, a dynamic range of 144 dB can be represented
  - $144 \text{ dB} = 20 \log_{10}(16\,777\,216)$

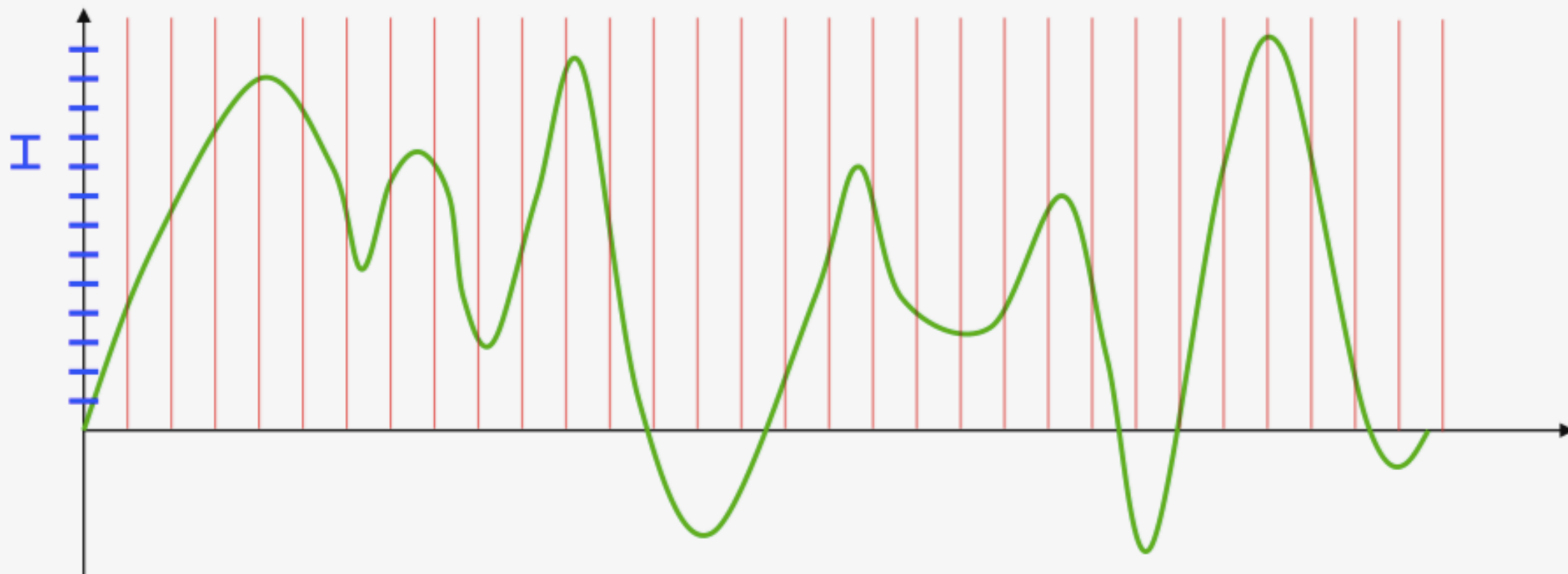


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# Digitization

- Generally, signal **quality** is controlled by sampling rate and bit depth
- Sampling & quantization always introduce a certain **digitization error**

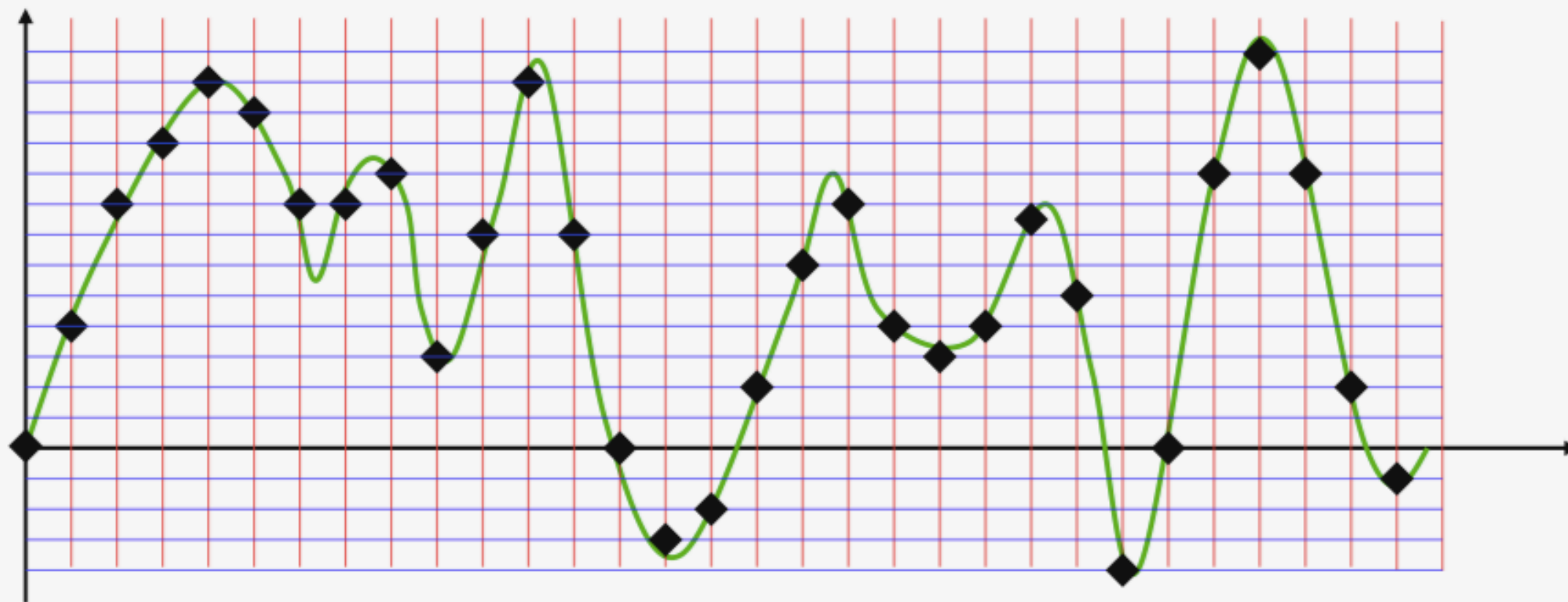


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# Digitization

- The array of numbers that is stored (or played back) is always an **approximation** of the original analog audio signal only

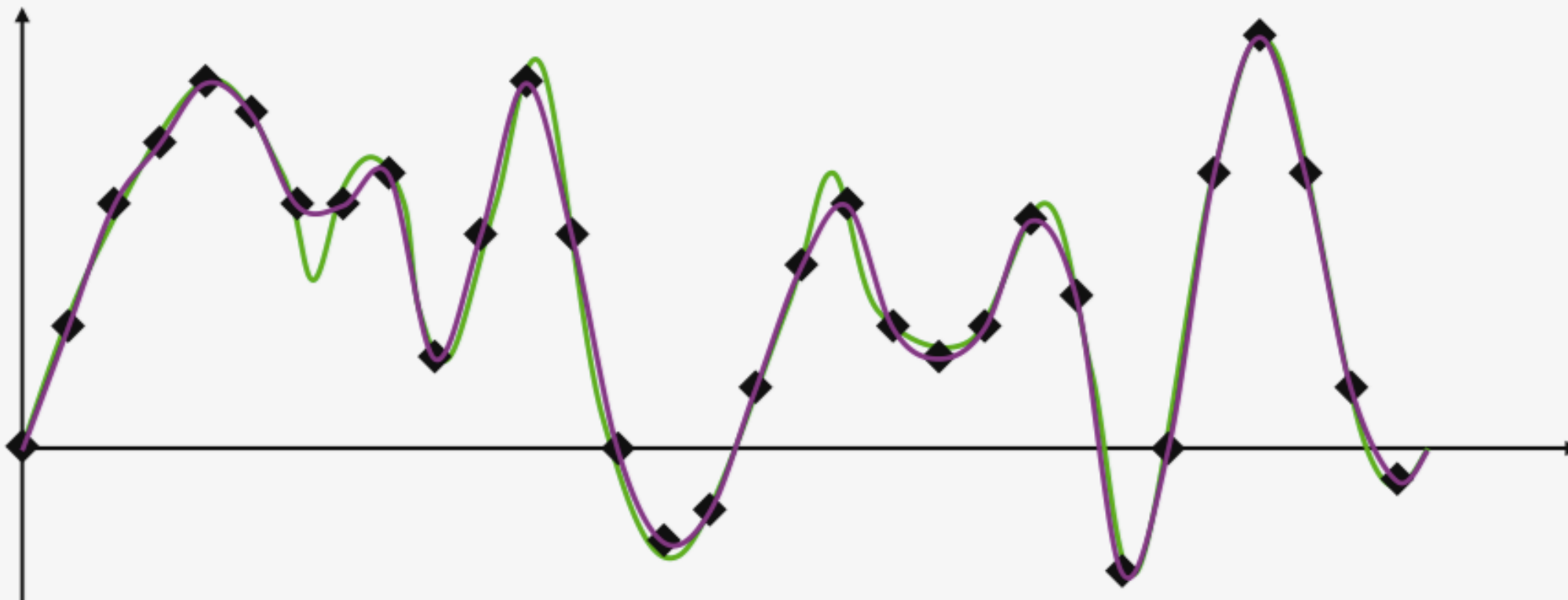


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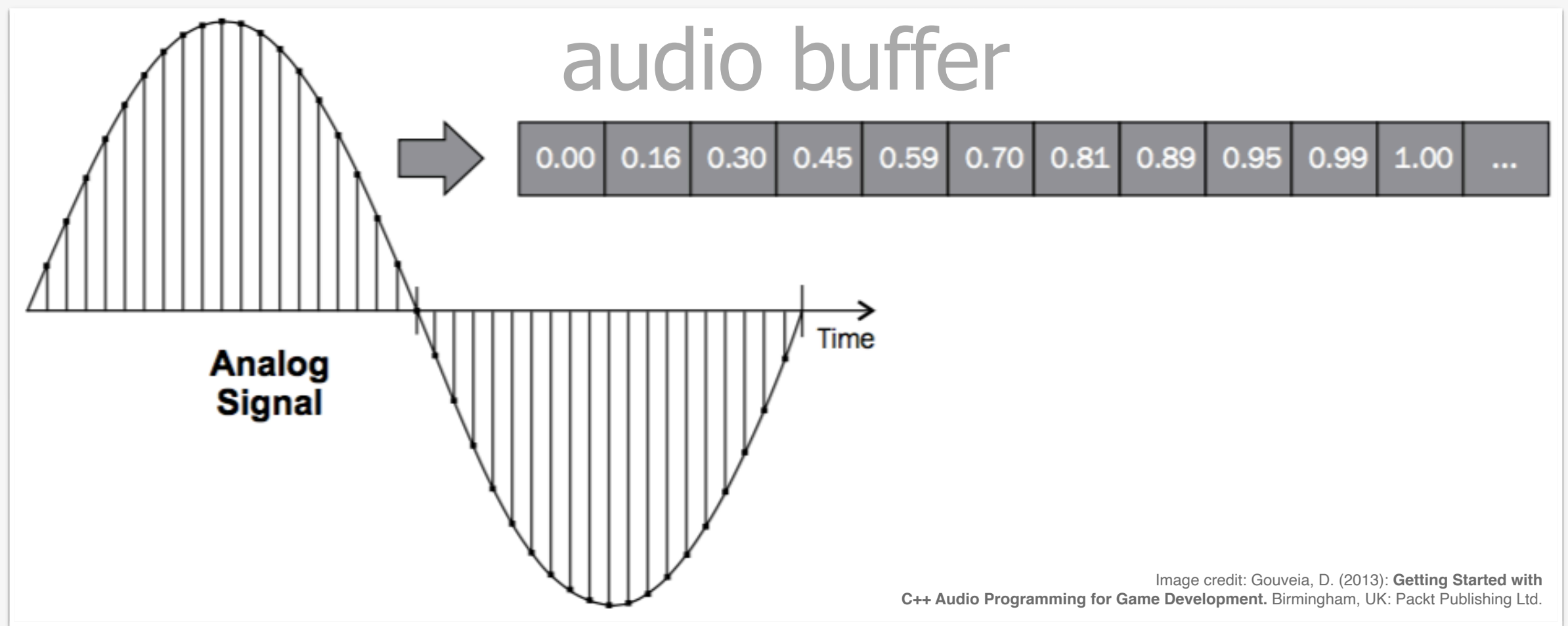
# Digital Audio Buffer





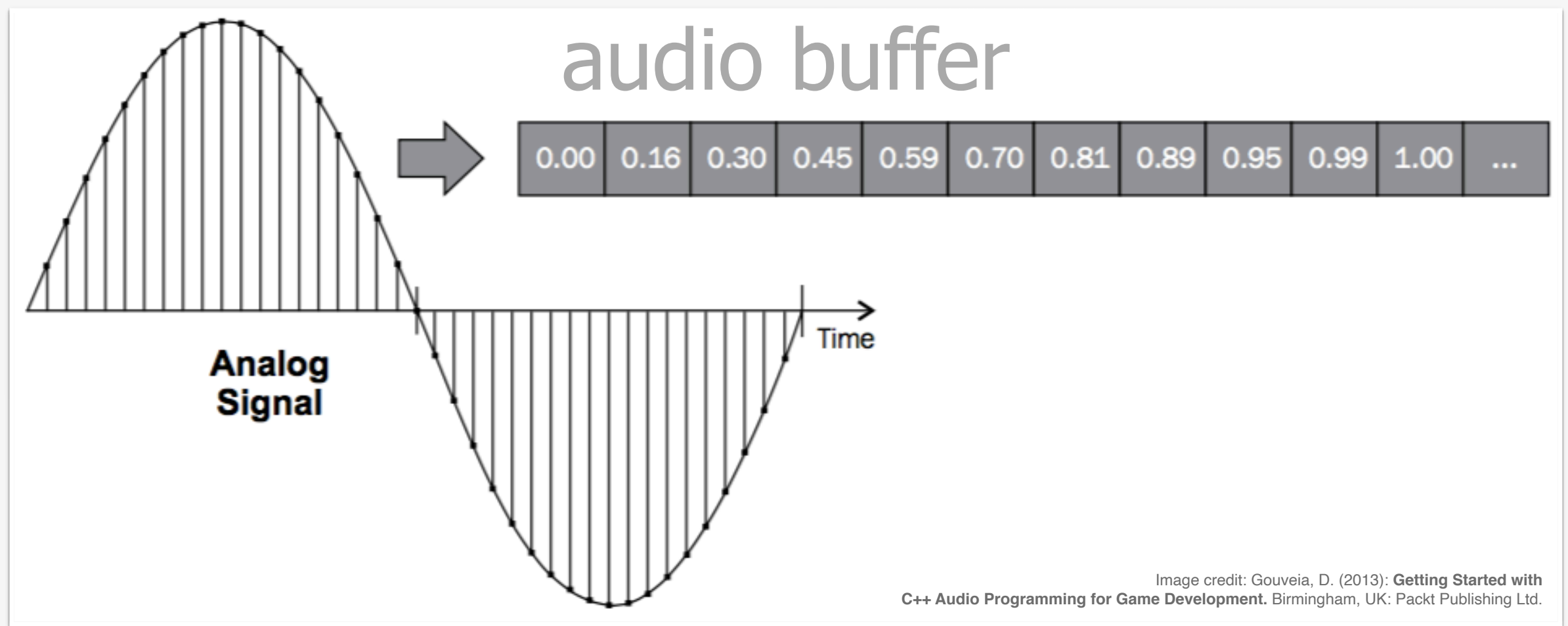
# Digital Audio

- Digital sound signal is a list of discrete numbers that represent **amplitude against time** in a buffer (array) of **value and index**



# Digital Audio

- When sound is recorded & digitized, the audio buffer is filled
- When digital sound is played back, the audio buffer is read



# Literature

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