Syllabus Content:

1.2 Multimedia Graphics

- Show understanding of how data for a bitmapped image are encoded
- Use and understand the terms: pixel, file header, image resolution, screen resolution, colour depth, bit depth
- Perform calculations to estimate the file size for a bitmap image
- Show understanding of the effects of changing elements of a bitmap image on the image quality and file size
- Use the terms: image resolution, colour depth
- Show understanding of how data for a vector graphic are encoded
- Use the terms: drawing object, property, drawing list
- Justify the use of a bitmap image or a vector graphic for a given task

Graphic images that have been processed by a computer can usually be divided into two distinct categories.

Pixels vs. Vector

Such images are either bitmap files or vector graphics. This section will cover the two main image types: **vector** and **bitmap(pixels)**, along with some compression techniques.
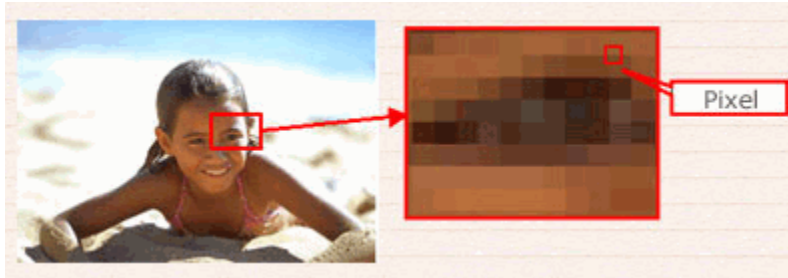
Pixel (Picture element):
The smallest possible addressable area defined by a solid color, represented as binary, in an image.

Graphics on a screen are made up of tiny blocks of pixels. The more pixels on the screen, the higher the resolution and the better the quality of the picture will be.

The higher the image resolution, the more memory is needed to store the graphic.

Image files can be either **bitmaps** or **vectors**.

Bitmap Graphics:

Bitmaps images are exactly what their name says they are: a collection of bits that form an image.

- **Bitmap images** (or raster) images are stored as a series of tiny dots called pixels.
- Each pixel is actually a very small square that is assigned a color, and then arranged in a pattern to form the image.
- The image consists of a matrix of individual dots (or pixels (picture element)) that all have their own color (described using bits, the smallest possible units of information for a computer).
- Bitmap images are organised as a grid of coloured squares called pixels (short for 'picture elements').
- When zooming in or enlarging a bitmap image, the pixels are stretched and made into larger blocks. This is why bitmap images appear as poor quality when enlarged too much.
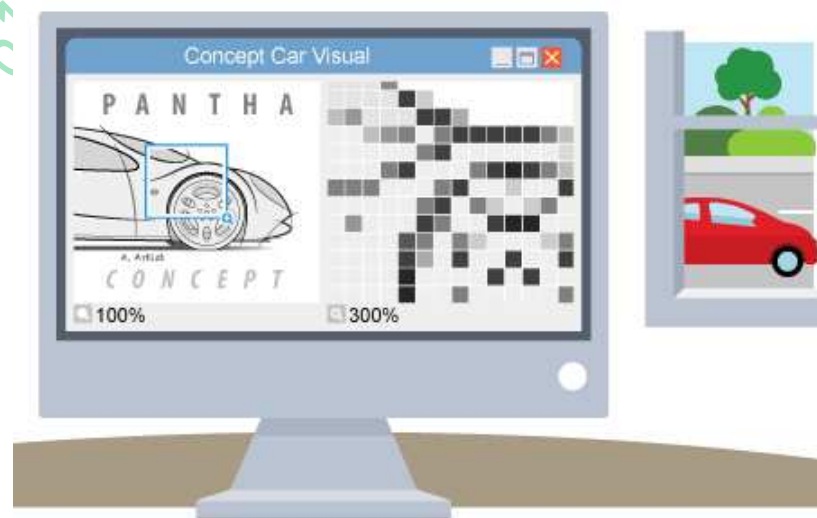
Each colour of an image is stored as a binary number. In the black-and-white image below, each pixel is either black or white. You need a binary value for each different

colour.As each pixel is either black or white, this image can be encoded with a value of 0 for white and 1 for black.
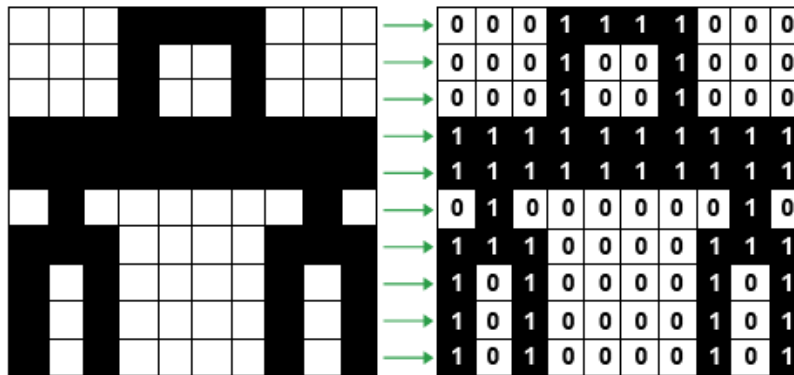
When you zoom in on a bitmap image you can see the individual pixels that make up that image. Bitmap graphics can be edited by erasing or changing the color of individual pixels using a program such as Adobe Photoshop.

Enlarged 12X
to show individual pixels
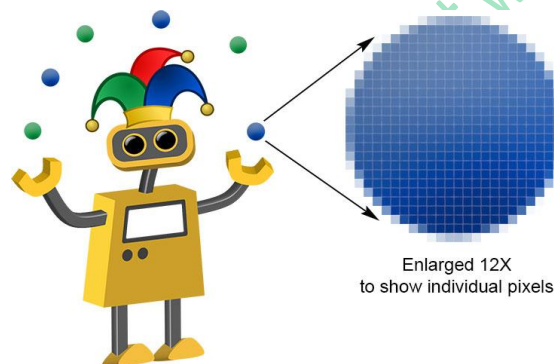
Pixel (Picture element):
The smallest possible addressable area defined by a solid color, represented as binary, in an image.

File header:
BMP, PCX, JPEG, FLI/FLC, and AVI files include headers that define the image size, number of colors, and other information needed to display the image. Fastgraph provides functions for reading the image headers and retrieving their more useful items. However, there may be times when you need additional information stored in the file header e.g.

- Confirmation that the file is a BMP
- File size
- Location/offset of image data within the file
- Dimensions of the image (in pixels) // image resolution
- Colour depth (bits per pixel, 1, 4, 8, 16, 24 or 32)
- Type of compression used, if any

Resolution:

Screen Resolution - The screen resolution tells you how many pixels your screen can display horizontally and vertically. It's written in the form 1024 x 768. In this example, the screen can show 1,024 pixels horizontally, and 768 vertically:
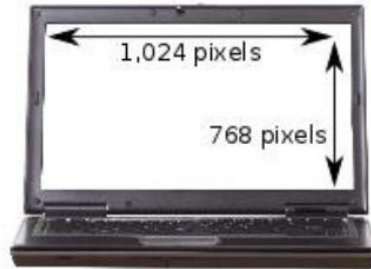
Image Resolution - how many pixels do an image contains per inch/cm? Measurements of **dots per inch (dpi)** are called image resolution.
- The number of pixels per unit measurement
- or the number of pixels in an image
- or The number of pixels wide by the number of pixels high
- or number of pixels per row by the number of rows

Resolution refers to the number of pixels in an **image**. Resolution is sometimes identified by the width and height of the **image** as well as the total number of pixels in the **image**. For example, an **image** that is 2048 pixels wide and 1536 pixels high (2048 x 1536) contains (multiply) 3,145,728 pixels (or 3.1 Megapixels).

The higher the resolution, the more pixels are available. Therefore the crisper the picture

4x6 = 1200 x 1800 pixels at 300dpi

Same photo printed at a larger size or lower resolution

Colour depth
The colour depth of an image is measured in bits. The number of bits indicates how many colours are available for each pixel. In the black and white image, only two colours are needed. This means it has a colour depth of 1 bit.

A 2-bit colour depth would allow four different values: 00, 01, 10, 11. This would allow for a range of colours such as:

Binary code	Colour
00	White
01	Light grey
10	Dark grey
11	Black

Greater the colour depth (bits per pixel), the more colours are available.

Colour depth	Available colours
1-bit	$2^1 = 2$
2-bit	$2^2 = 4$
3-bit	$2^3 = 8$
4-bit	$2^4 = 16$
5-bit	$2^5 = 32$
6-bit	$2^6 = 64$
7-bit	$2^7 = 128$
8-bit	$2^8 = 256$

Example: Calculating screen resolutions & Picture file size:

Using the diagram above we are going to work out how many pixels are required to display a single frame on a **VGA** screen.

Checking the resolution:

Height = 480 Width = 640
Area = Width x Height = Total Pixels   Area = 640 **x** 480 = 307200 pixels
Hence, it takes 307,200 pixels to display on a VGA screen!

File size = Total Pixels X Colour Depth
Coloured Images:

At least **eight bits per pixel are necessary to code a coloured image.** The number of bits per pixel is sometimes referred to as the **colour depth**.
(8 bits or 1 byte for 1 pixel in coloured image) (Computer Science Book)

Hence, it takes 307,200 pixels X 8 bits = 2457600 bits or 2457600/8 = 307200 bytes or 300KB.

Monochrome or Black & White image:

The simplest option is to use **one bit** to represent the **colour**, so that the pixel is either black or white. **(1 bit for 1 pixel in Black & White or monochrome Picture)**

Greyscale image:

Storage of the colour in **four bits** would allow simple **greyscale colouring.**

(4 bits for 1 pixel in GreyScale image)

Greyscale

Coloured Images:

At least **eight bits per pixel are necessary to code a coloured image.** The number of bits per pixel is sometimes referred to as the **colour depth**.
(8 bits or 1 byte for 1 pixel in coloured image) (Computer Science Book)

24 bits almost always uses **8 bits of each of**
RGB(Red:8 Green:8 Blue:8) 8+8+8 = 24

As of 2018 **24-bit** color depth is used by virtually every computer and phone display and the vast majority of image storage formats. (Wikipedia)

Vector graphics

It is normal for an image that is created by a drawing package or a computer-aided design (CAD) package to consist of a number of geometric objects. The outcome is then usually for the image to be stored as a **vector graphic** file

- Unlike bitmaps, vector images are not based on pixel patterns, but instead use mathematical formulas to draw lines and curves that can be combined to create an image
- Vector graphics are made from geometric objects such as circles and polygons.
- Vector images are edited by manipulating the lines and curves that make up the image using a program such as Adobe Illustrator.
- Vector images tend to be smaller than bitmap images because a bitmap image has to store color information for each individual pixel that forms the image.
- A vector image just has to store the mathematical formulas that make up the image, which take up less space.
- The three most popular image formats used on the Web (PNG, JPEG, and GIF) are bitmap formats.
- The Scalable Vector Graphics (SVG) format comes in a distant fourth due to a legacy of poor support for vector graphics in early browsers. Today however, all major browsers support the SVG (Scalable Vector Graphics) format.
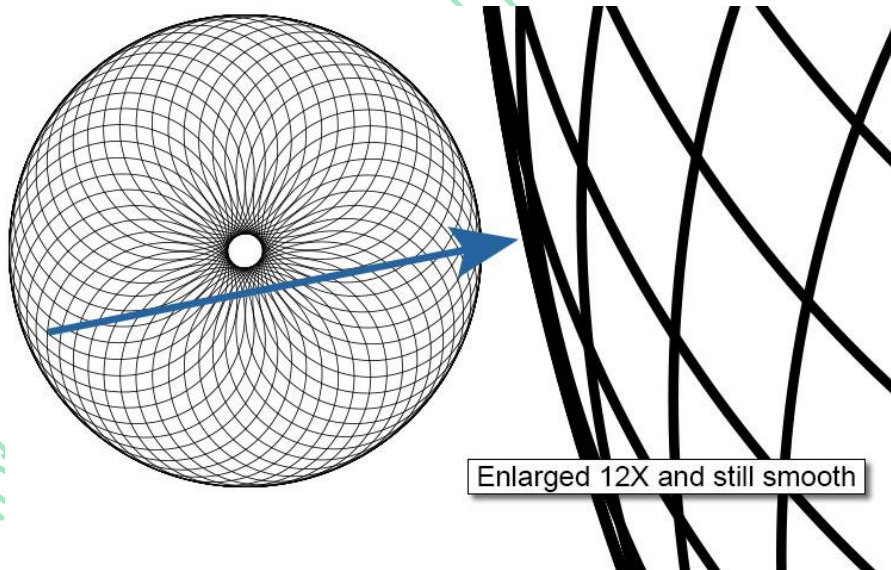- The dimensions of the vector image objects are not defined explicitly but instead are defined relative to an imaginary drawing canvas. In other words, the image is scalable.

Enlarged 12X and still smooth

Bitmap formats are best for images that need to have a wide range of color gradations, such as most photographs. Vector formats, on the other hand, are better for images that consist of a few areas of solid color. Examples of images that are well suited for the vector format include logos and type.

Vector graphic: a graphic consisting of components defined by geometric formulae and associated properties, such as line colour and style.

We do not need to consider how an image of this type would be created. We do need to consider how the data is stored after the image has been created.

Drawing list: - a set of commands used to define a vector image. A vector graphic file contains a drawing list. The list contains a command for each object included in the image.

Each command has a list of attributes that define the properties of the object.

Drawing Properties: -The properties include the basic geometric data such as, for a circle, the position of the centre and its radius. In addition properties such as the thickness and style of a line, the colour of a line and the colour that fills the shape, if that is appropriate, are defined. An example of what could be created as a vector graphic file is shown in Figure.

Vector graphics are made up of objects and their properties.

Drawing object: - is a mathematical or geometrically defined construct such as a rectangle, line or circle.

Image display
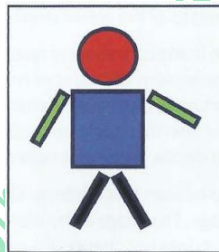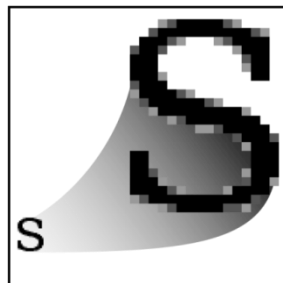When a monitor or a printer displays a vector image it is **rasterised**- converted into a grid of pixels. Regardless of the file type, an image will always be outputted onto a screen or printed in pixels.

Comparison between vector and bitmaps:

This image illustrates the difference between bitmap and vector images. The bitmap image is composed of a fixed set of dots (pixels), while the vector image is composed of

a fixed set of shapes. In the picture, scaling the bitmap reveals the pixels and scaling the vector image preserves the shapes.

- Vector images scale without file size increase / decrease
- Bitmap images scale resulting in file size increase / decrease
- Vector images scale without distortion to the image
- Bitmap images distort (pixelate) when scaling
- Bitmaps are better for photo editing
- Bitmaps require less processing power to display

One of the most common vector file formats is **scalable vector graphics (SVG)**. SVG is an open standard for vector graphics.

It is possible to edit SVG images using numbers to change the size and colour variables in HTML. This is often used for graphs and infographics in HTML5.
Vector graphics are used in:

- CAD packages
- AutoShapes in Microsoft Office
- animated movies
- encapsulated postscript (EPS)
- animation programmes such as Blender and Adobe After Effects
- image manipulation programmes such as Adobe Photoshop and GIMP
- Adobe portable document format (PDF)
- Windows meta-file (WMF)

Syllabus Content:
1.3 Sound
Candidates should be able to:
- Show understanding of how sound is represented and encoded
- Use the terms: sampling, sampling rate, sampling resolution, analogue and digital data
- Show understanding of the impact of changing the sampling rate and resolution
- Impact on file size and accuracy

(1.1.3) Sound:

Sound is an oscillation of pressure transmitted through a solid, liquid, or gas (there is no sound in outer space as space is a vacuum and there is no solid, liquid or gas to transmit sound through!). A speaker works by moving its center cone in and out; this causes the air particles to bunch together forming waves. These waves spread out from the speaker travelling at 340 m/s. If your ear is in the way, then the waves of sound particles will collide with your ear drum, vibrating it and sending a message to your brain. This is how you hear:

Natural sound consists of variations in pressure which is detected by the human ear. A typical sound contains a large number of individual waves each with a defined frequency. The result is a wave form in which the amplitude of the sound varies in a continuous but irregular pattern.

If there is a need to store sound or transmit it electronically the original analogue sound signal has to be converted to a binary code.

A sound encoder has two components.

1. Band limiting Filter
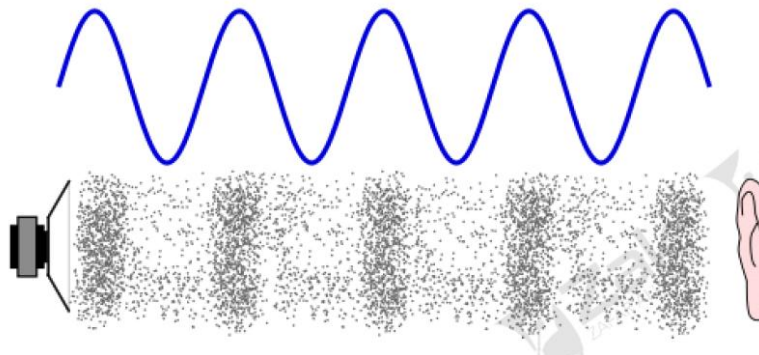2. Analogue to digital converter.

Band-limiting filter:

This is needed to remove high-frequency components. The ear would not be able to detect these and they could cause problems for the coding if not removed.

Analogue-to-digital converter (ADC).

The method of operation of the ADC is described with reference to Figure. The amplitude of the wave (the red line) has to be sampled at regular intervals. The blue vertical lines indicate the sampling times. The amplitude cannot be measured exactly; instead the amplitude is approximated by the closest of the defined amplitudes represented by the horizontal lines. In Figure 1.08, sample values 1 and 4 will be an accurate estimate of the actual amplitude because the wave is touching an amplitude line. In contrast, samples 5 and 6 will not be accurate because the actual amplitude is approximately half way between the two closest defined values.
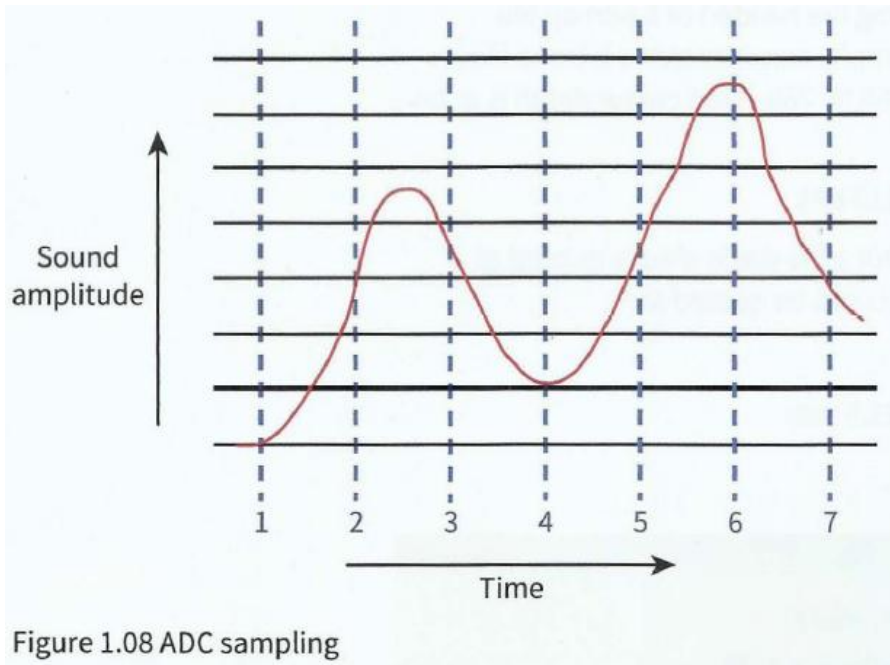
Figure 1.08 ADC sampling

Analogue and digital:

For a computer to store sound files we need to get the continuous analogue sound waves into discrete binary values:
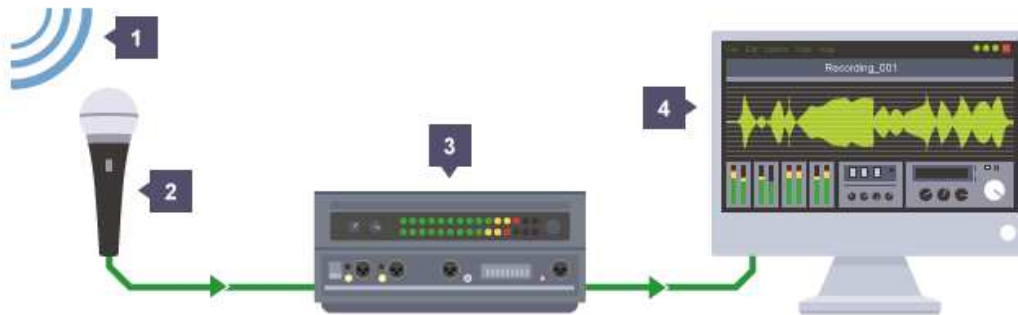
1	Microphone measures change in air pressure
2	Microphone translates air pressure into electrical voltage
3	Analogue to Digital Converter digitises the electrical voltage to bytes of information
4	Computer displays the digitised sound for manipulation

Sound input through a microphone is converted to digital for storage and manipulation

An analogue sound wave is picked up by a microphone and sent to an Analogue to Digital (ADC) converter in the form of analogue electrical signals. The ADC converts the electrical signals into digital values which can be stored on a computer.

Once in a digital format you can edit sounds with programs such as **audacity**.
To play digital audio you convert the sound from digital values into analogue electrical signals using the

DAC, these signals are then passed to a speaker that vibrating the speaker cone, moving the air to create sound waves and analogue noise.

Digital audio: Sounds created on a computer exist as digital information encoded as audio files.
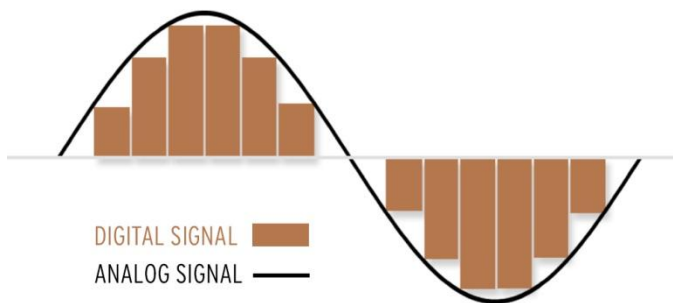

DIGITAL SIGNAL
ANALOG SIGNAL

Analogue to Digital Converter (ADC)
Converts analogue sound into digital signals that can be stored on a computer.

Digital to Analogue Converter (DAC)
Converts digital signals stored on a computer into analogue sound that can be played through devices such as speakers.

This section will cover how we record, store and transmit sound using computers.

Sound waves in nature are **continuous**, this means they have an almost infinite amount of detail that you could store for even the shortest sound. This makes them very difficult to record perfectly, as computers can only store **discrete** data, data that has a limited number of data points

Bandwidth:
Bandwidth is also the amount of data that can be transmitted in a fixed amount of time. For digital devices, the **bandwidth** is usually expressed in bits per second(bps) or bytes per second. For analog devices, the **bandwidth** is expressed in cycles per second, or Hertz (Hz).

Audio Bandwidth:

Bandwidth is the ability of a recorded signal to be reproduced at varying degrees of resolution. Think of it like enlarging a low-resolution image versus a high-resolution image. After a certain point, enlarging a lower-resolution image will become pixelated and difficult to see, where the hi-resolution image will resize clearly.

Like images, audio signals can have a limited bandwidth if recorded digitally. Once a digital recording is made, the bandwidth is set in place.

An analog recording is considered unlimited. Therefore, it can move to a higher and higher resolution without losing its original quality.

Digital sound is broken down into thousands of samples per second. Each sound sample is stored as binary data.

Digital audio quality Factors that affect the quality of digital audio include:

- **sample rate** - the number of audio samples captured every second
- **sample resolution/ bit depth:** - the number of bits assigned to each sample of sound
- **bit rate** - the number of bits used to store one second of sound

Sound Sampling:
- amplitude of sound wave taken at different points in time
- measurement of value of analogue signal at regular time intervals/a point in time
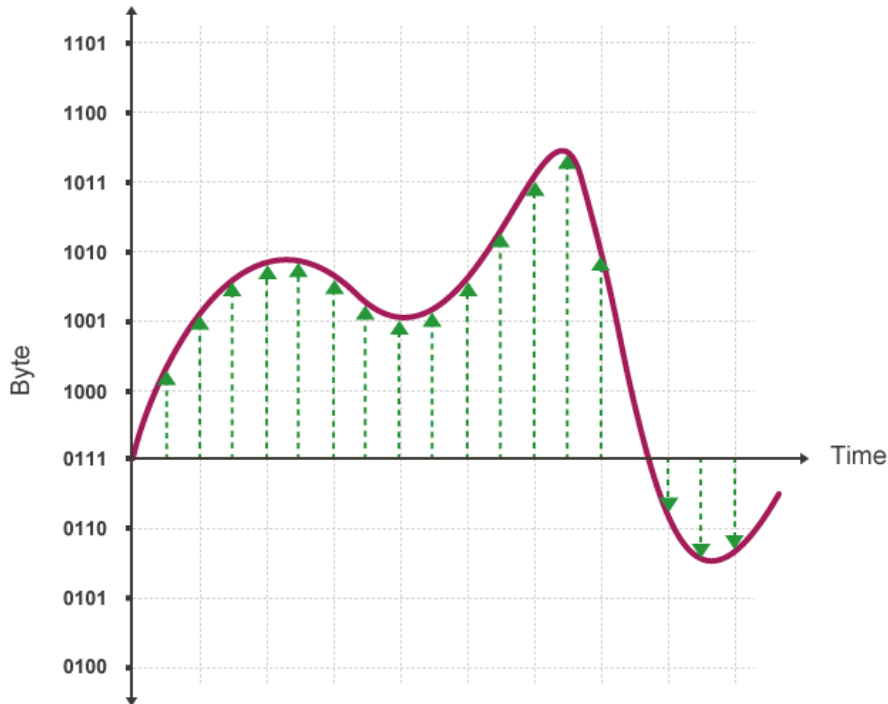
Sample rate

The **sample rate** is how many samples, or measurements, of the sound are taken each second.

The more samples that are taken, the more detail about where the waves rise and fall is recorded and the higher the quality of the audio. Also, the shape of the sound wave is captured more accurately.

Each sample represents the amplitude of the digital signal at a specific point in time. The amplitude is stored as either an **integer** or a **floating point number** and encoded as a **binary number**.

fig. 1

Conversion A-D

fig. 2

Conversion D-A

fig. 3
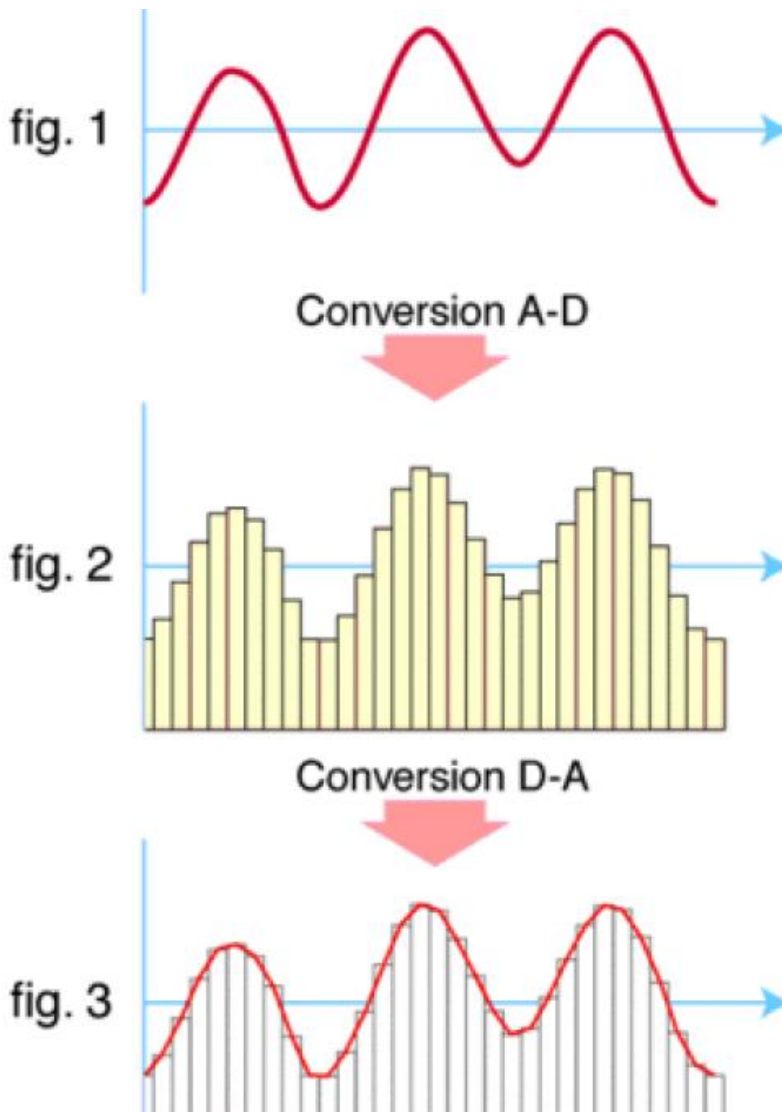
1. The original analogue sound wave is a continuous set of points
2. ADC converts sound into digital data
3. DAC converts digital data into analogue sound, the analogue wave produced may differ significantly from the original sound wave.

Sound Sampling

So we should know by now that sound waves are continuous and computers can only store discrete data. How exactly does an Analogue to Digital Converter convert a continuous sound wave into discrete digital data? To do this we need to look at how computers sample sound.

Original Sound	High sample rate	1/2 high sample rate	1/3 high sample rate	1/4 high sample rate
original continuous sound wave	digital looks like original	digital loses sharpness	loss of peaks	poor resemblance to original!
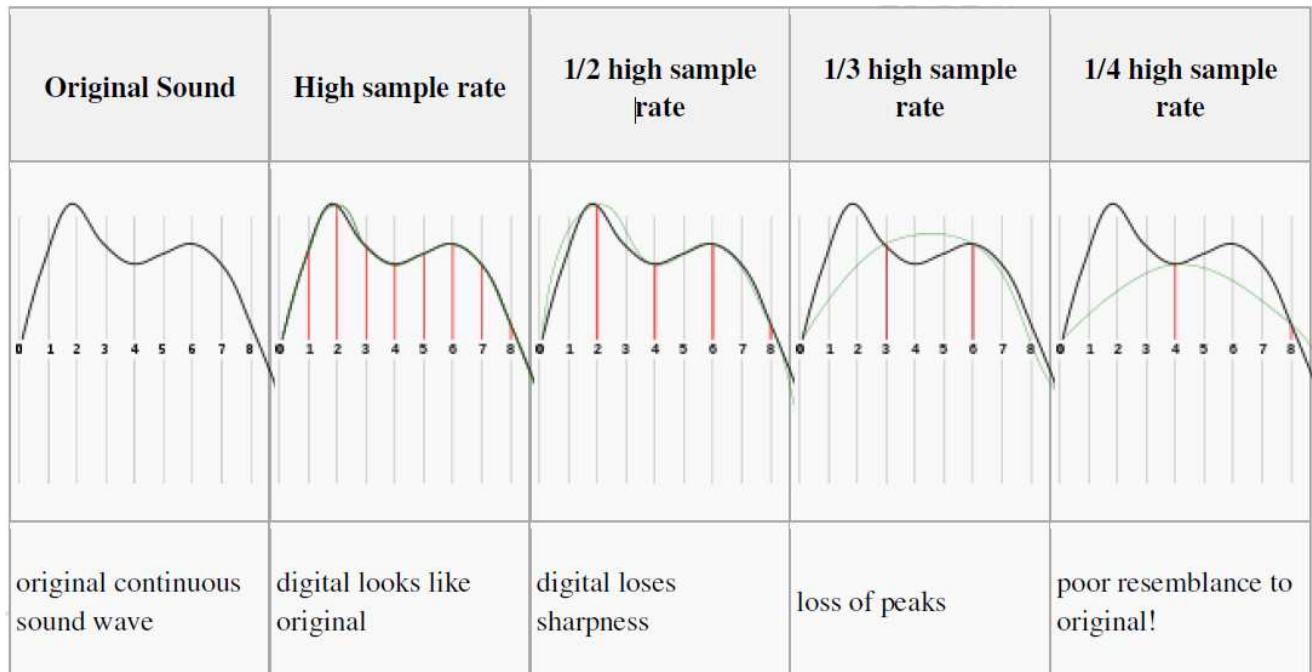
Sampling Rate - The number of samples taken per second

A higher sampling rate means the waveform will be converted from analog to digital form more accurately.

Sampling Resolution (bit depth): no. of bits assigned to each sample.
The sampling resolution allows you to set the range of volumes storable for each sample.

The quality of a sound produced using a sound sampler depends on the sampling rate and sampling resolution.

- The higher the sampling resolution (bit depth), the higher the quality of the audio.
- Higher sampling rate/resolution means larger file size

Bit depth is the number of bits available for each sample.
Sampling resolution (Bit depth) is usually 16 bits on a CD and 24 bits on a DVD.

Bit Rate: number of bits required to store 1 second of sound.

$$Bit\ Rate = Sampling\ Rate \times Sampling\ Resolution$$
$$File\ Size = Bit\ Rate \times Length\ of\ Sound$$

File Size = Sample Rate X Sample Resolution X Length of sound

Calculating bit rate

The bit rate is calculated using the formula:

Frequency × bit depth × channels = bit rate

A typical, uncompressed high-quality audio file has a sample rate of 44,100 samples per second, a sample resolution (bit depth) of 16 bits per sample and 2 channels of stereo audio. The bit rate for this file would be:

44,100 samples per second × 16 bits per sample × 2 channels = 1,411,200 bits per second (or 1,411.2 kbps)

A four-minute (240 second) song at this bit rate would create a file size of:

14,411,200 × 240 = 338,688,000 bits (or 40.37 megabytes)
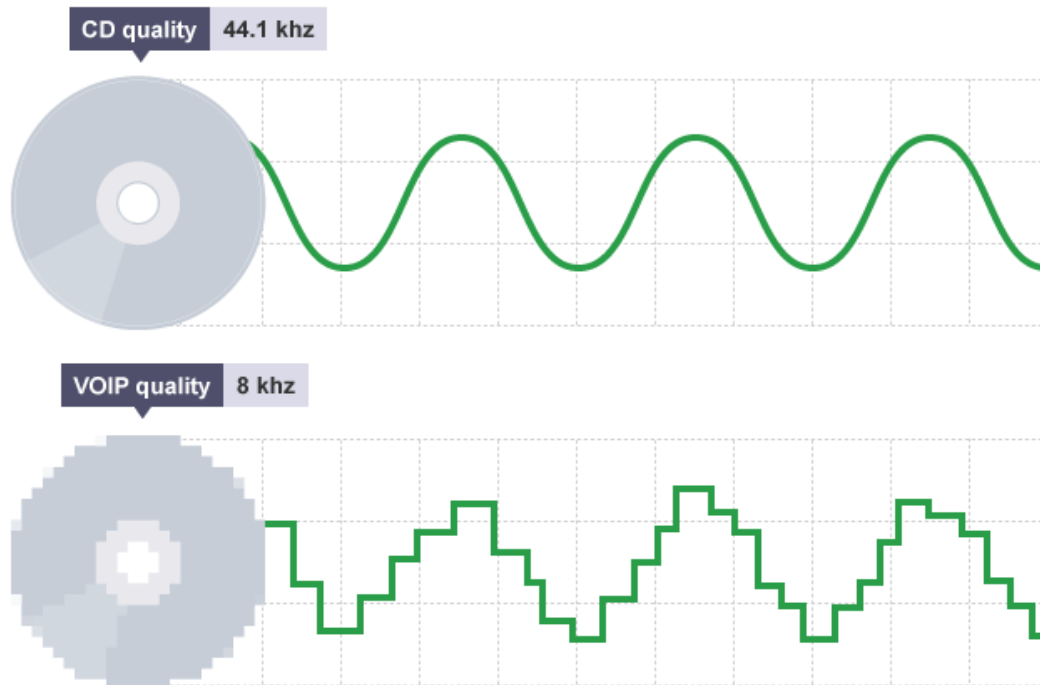
A common audio **sample rate** for music is **44,100 samples per second**. The unit for the sample rate is hertz (Hz). 44,100 samples per second is 44,100 hertz or 44.1 kilohertz (kHz).

Telephone networks and VOIP services can use a sample rate as low as 8 kHz. This uses less data to represent the audio. At 8 kHz, the human voice can still be heard clearly - but music at this sample rate would sound low quality.

Sound Editing

Simply recording sound and storing a digital representation is not enough for many applications.
Once a digital representation of the sound has been stored in a file, it can be manipulated using sound-editing software. This will typically have features for:

• combining sound from different sources
• fading in or fading out the sound
• editing the sound to remove noise and other imperfections.

If you are interested in sound editing you can start editing your own music using a program called **Audacity.**

Using Audacity you can create your own sound samples with different sample rates and sample resolutions, listening to the difference between them and noting the different file sizes.

Features
This is a list of features in Audacity, the free, open source, cross-platform audio editor.
Recording
Audacity can record live audio through a microphone or mixer, or digitize recordings from cassette tapes, records or minidiscs. With some sound cards, and on any Windows Vista, Windows 7 or Windows 8 machine,
Audacity can also capture streaming audio.

Import and Export
Import sound files, edit them, and combine them with other files or new recordings.
Export your recordings in many different file formats, including multiple files at once.

Sound Quality
Supports 16-bit, 24-bit and 32-bit (floating point) samples (the latter preserves samples in excess of full scale).
Sample rates and formats are converted using high-quality re-sampling and dithering.
Tracks with different sample rates or formats are converted automatically in real time.
Editing:
  - Easy editing with Cut, Copy, Paste and Delete.
  - Unlimited sequential Undo (and Redo) to go back any number of steps.
  - Edit and mix large numbers of tracks.
  - Multiple clips are allowed per track.
  - Label tracks with selectable Sync-Lock Tracks feature for keeping tracks and labels synchronized.
  - Draw Tool to alter individual sample points.
  - Envelope Tool to fade the volume up or down smoothly.

🎁 Automatic Crash Recovery in the event of abnormal program termination.

Accessibility

Tracks and selections can be fully manipulated using the keyboard.

🎁 Large range of keyboard shortcuts.

🎁 Excellent support for JAWS, NVDA and other screen readers on Windows, and for VoiceOver on Mac.

Effects

🎁 Change the pitch without altering the tempo (or vice-versa).

🎁 Remove static, hiss, hum or other constant background noises.

🎁 Alter frequencies with Equalization, Bass and Treble, High/Low Pass and Notch Filter effects.

🎁 Adjust volume with Compressor, Amplify, Normalize, Fade In/Fade Out and Adjustable Fade effects.

🎁 Remove Vocals from suitable stereo tracks.

🎁 Create voice-overs for podcasts or DJ sets using Auto Duck effect. Other built-in effects include:

🎁 Echo

🎁 Paulstretch (extreme stretch)

🎁 Phaser

🎁 Reverb

🎁 Reverse

🎁 Truncate Silence

🎁 Wahwah.

🎁 Run "Chains" of effects on a project or multiple files in Batch Processing mode.

Multimedia Container Formats:

🎁 Contains different types of data

🎁 Can be audio or video or both codecs

🎁 This interleaves the different type of data

🎁 The video is compressed into codecs

🎁 E.g. .avi, .mov, .mp4, .ogg, .rm

1.3 Compression

Compression is a useful tool for reducing file sizes. When images, sounds or videos are compressed, data is removed to reduce the file size. This is very helpful when streaming and downloadingfiles.

Streamed music and downloadable files, such as MP3s, are usually between 128 kbps and 320 kbps - much lower than the 1,411 kbps of an uncompressed file.

Videos are also compressed when they are streamed over a network.
Streaming HD video requires a high-speed internet connection. Without it, the user would experience buffering and regular drops in quality. HD video is usually around 3 mbps. SD is around 1,500 kbps.

Compression can be **lossy** or **lossless**.

Lossless compression:

Lossless compression means that as the file size is compressed, the audio **quality remains the same** - it does not get worse. Also, the file can be restored back to its original state. **FLAC** and **ALAC** are open source lossless compression formats. Lossless compression can reduce file sizes by up to 50% without losing quality.

Lossless Compression allows original data to be perfectly reconstructed from compression.

Run-length encoding: compression in which sequences with same data value in many consecutive values are stored as a single data value and count

E.g. **00001234111111** can be written as **(0-4)1234(1-6)**

Lossy compression:

Lossy compression permanently removes data. For example, a WAV file compressed to an **MP3** would be lossy compression. The bit rate could be set at 64 kbps, which would reduce the size and quality of the file. However, it would not be possible to recreate a 1,411 kbps quality file from a 64 kbps MP3.

With lossy compression, the original bit depth is reduced to remove data and reduce the file size. The bit depth becomes **variable**.

MP3 and **AAC** are lossy compressed audio file formats widely supported on different platforms. MP3 and AAC are both patented codecs. **Ogg Vorbis** is an open source alternative for lossy compression.

Lossy Compression is in which file accuracy is low, but file size is smaller than lossless
Perceptual coding: works by reducing certain parts of a sound which are less audible to human hearing.
Lossy Data Compression:
- These programs eliminate unnecessary bits of data
- Reduces data file size more than lossless
- Unable to get back original version

Lossless Data Compression:
- Breaks data into smaller form of transmission
- Allows recreation of original

References:
https://www.bbc.com/bitesize/guides/zqyrq6f/revision/2
https://en.wikipedia.org/wiki/Vector_graphics
https://en.wikipedia.org/wiki/File:Bitmap_VS_SVG.svg
https://www.corporate3design.com/blog/112/
http://etc.usf.edu/techease/win/images/what-is-the-difference-between-bitmap-and-vector-images/
https://www.klipsch.com/blog/digital-vs-analog-audio
https://www.bbc.com/education/guides/z7vc7ty/revision/2
http://www.globalspec.com/reference/37829/203279/5-7-spatial-and-temporal-redundancy-in-mpeg
https://robbfoxx.wordpress.com/2015/07/12/discussion-6-2-1-what-is-redundancy-temporal-redundancy-and-spatial-redundancy/
http://www.pcmag.com/encyclopedia/term/56086/spatial-redundancy
http://christmanwd.weebly.com/uploads/2/5/9/5/25956852/805063_orig.jpg
https://microscope-microscope.org/microscope-info/image-resolution/
Cambridge International AS & A level by Silvia Langfield and Dave Duddell.