LIBRARY OF CONGRESS

Choosing and Using Digitization Technologies

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Digitization is more than scanning-

A process that broadly includes:

- Selection
- Assessment
- Prioritization
- Project management and tracking
- Preparation of originals for digitizing

- Metadata collection and creation
- Digitizing
- Quality management
- Data collection and management
- Submission of digital resources to delivery systems and into repository environments
- Assessment and evaluation of the digitization effort

Digitizing Equipment –

- Still Imaging
- Audio, Video, and Motion Pictures

Still Imaging:

General Scanning, Documents, Photographs, Books, etc.-

- Digital Copy Stands
- Flatbed Scanners
- High-Speed Document Scanning
  - **Two wide-radius 90° turns**
  - **Straight path**

- Planetary Scanners
  - Scanners and more scanners
- Rare Book Scanning
- **Automated Book Scanners - Another**
- Scanning Oversized Originals
- Digital Photography of Objects and Artifacts
- Microfilm Scanners

Audio, Video, and Motion Pictures:

- •Digital Audio Workstations
- •Digitizing Video-
  - • Stand-alone Digital Video Workstations
  - • Automated Video Digitization Systems
- •Motion Picture Scanners and Workstations

Digitization Technology - Creating Better Digital Objects

Goal:

Produce digital objects-

- •Authentic
- •Consistent
- •High-quality
- •At an appropriate minimum level of information capture
- •With an appropriate complement of related metadata

Facilitate the long-term use, management, and preservation of the digital resources

Our perspective has been-

- •Standardize your digital objects, just like your metadata
- •Best to define and use consistent approaches
- •Treat large batches of images, or other digital objects, in the same way

Follow appropriate technical guidelines and specifications, based on explicit decisions relating to specific needs.

Need to collect all appropriate metadata - documenting originals and digital objects.

Digital Object Types-

- Suitability for type and nature of record / information / media
- Sustainability, usability, authenticity of digital representation and encoding method

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Digital Object Types:

Dynamic -

- Motion Pictures: time-based sequence of high resolution and high bit raster images synced to pulse code modulation sound recording
- Video: time-based sequence of raster images synced to pulse code modulation sound recording
- Audio: time-based pulse code modulation sound recording

Static -

- Still Photographs: raster image
- Textual Records: raster image

Increasing complexity for digital objects.

Static or Raster Images-

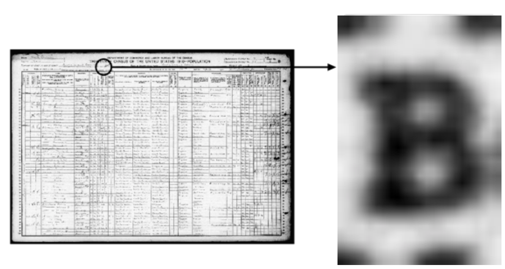
Digitizing documents, books, maps, plans, photographs, etc.

The digitization process converts an image into a series of picture elements or pixels.

Each pixel is represented by a single or series of binary digits, either “1”s or “0”s.

The pixels are arranged in a two dimensional matrix called a bitmap.

This is referred to as a raster image.



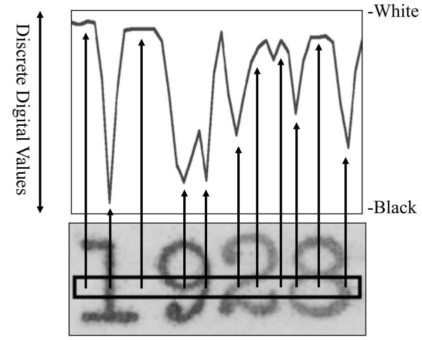
Common Digital Imaging Sensors (the "Film"):

CCD - charged coupled device
- Flatbed scanners and digital cameras

CMOS - complementary metal oxide semiconductor
- Flatbed scanners and digital cameras

PMT - photo-multiplier tube
- Drum scanners

Analog to Digital Conversion:



Signal Resolution (or Tonal Resolution):

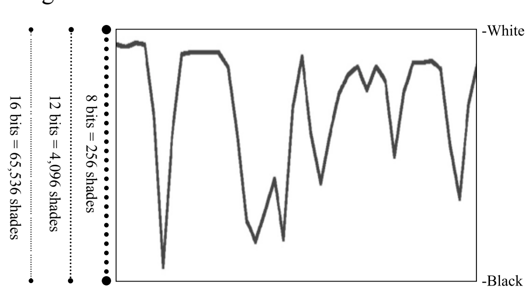
- Defines the maximum number of shades and/or colors in a digital image file, and the maximum density range that can be reproduced
- It does not define or guarantee the quality of the information
- Determined by the bit-depth or the number of binary characters (either a 0 or 1) used to represent each pixel

Bit Depth - number of bits of data representing each pixel of the image

Number of shades = 2^x
x = bit depth

1 bit = black and white	7 bits = 128 shades
2 bits = 4 shades	8 bits = 256 shades
3 bits = 8 shades	10 bits = 1,024 shades
4 bits = 16 shades	12 bits = 4,096 shades
5 bits = 32 shades	14 bits = 16,384 shades
6 bits = 64 shades	16 bits = 65,536 shades

Signal Resolution:

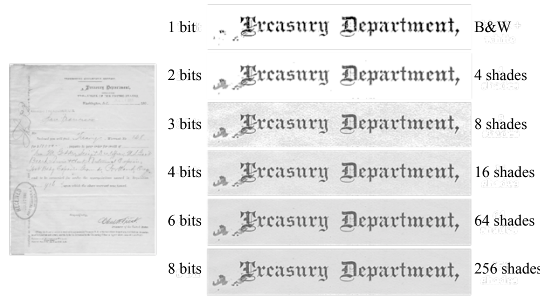


Generally, scanners sample at higher bit depths and the final digital image is sampled down to a lower bit depth.

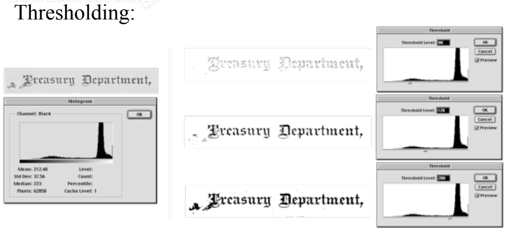
- Reduces noise
- Extends tonal scale (greater number of shades)
- Allows scanner to image larger density ranges without loss of detail

Single Channel Images:

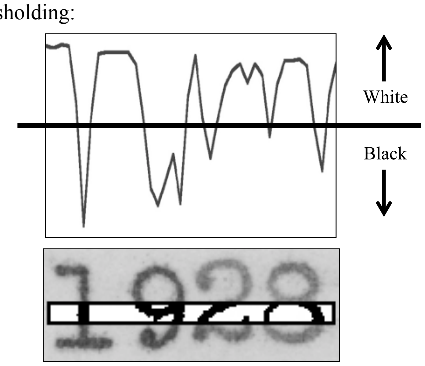
- Use one set of data, consisting of one or more bits per pixel, to define the value for each pixel



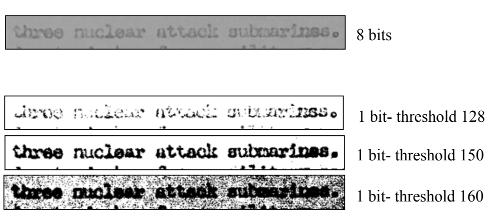
Thresholding:

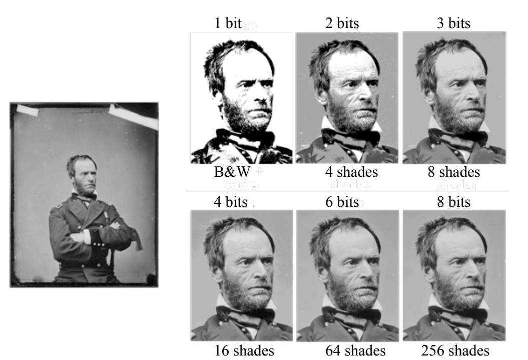


Thresholding:



Thresholding Text:





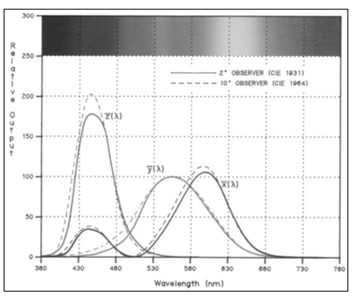
Multi Channel Files:

- •Use three or more sets of data to define lightness and color for each pixel.
- •The numeric values in the individual channels are used to calculate mathematically the final pixel values.

Color Systems - image capture and formation:

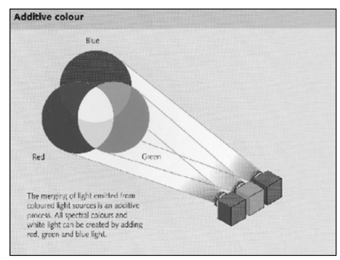
- •Additive -
  - ▪Image capture
    - •Spectral response of a scene or item is captured by recording the amount of light reflected/transmitted through red, green, and blue filters or by corresponding sensitive photographic emulsions

Light and Human Vision:



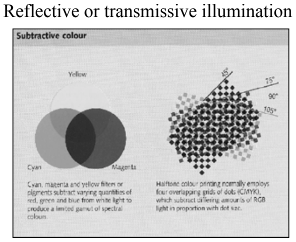
Understanding Color Communication, X-Rite

- ▪Image display with integral light source
  - •Red, green, and blue light combine to form white light



An Introduction to Digital Scanning, Agfa

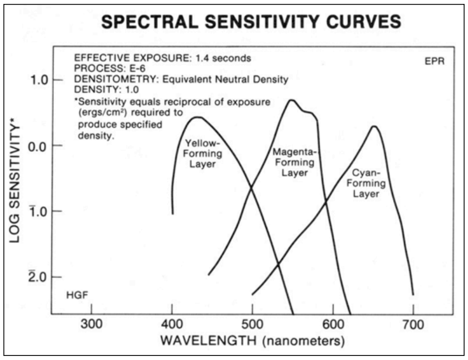
- Subtractive -
  - Hardcopy creation
    - Cyan, magenta, and yellow dyes or pigments combine to form black
    - Reflective or transmissive illumination



An Introduction to Digital Scanning, Agfa

Photographic Materials -

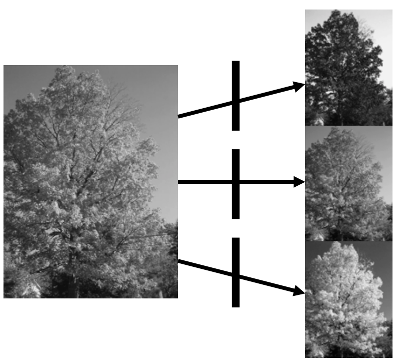
- •Have light sensitive layers that respond to the red, green, and blue portions of the visible spectrum
- •Corresponding subtractive color dyes (cyan, magenta, and yellow) are formed during development



Kodak Film Guide

Digital Image Formation -

- All scanners and digital cameras use the additive color system to create full color images
- They sample the amount of light reflected or transmitted from the original through red, green, and blue filters
- Color values are represented numerically using different color encodings



Digital Color Encoding:

- Numerical representation of color and tone -
  - Many options-
    - RGB
    - LAB
    - YCC
    - XYZ
    - CMYK

The color encoding of the stored file may be different than the encoding for the open file used within software.

This is the case for some file formats, like JFIF/JPEG and JPEG 2000.

RGB Encoding of Digital Images - three 8-bit color channels-

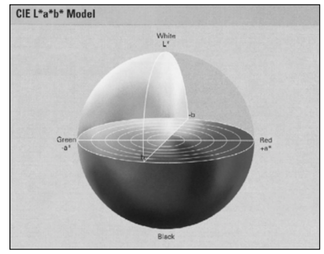
3 channels x 8-bits = 24-bit RGB color file

Monitors always display color images using RGB data, regardless of the color encoding of the image.

CIELAB model:

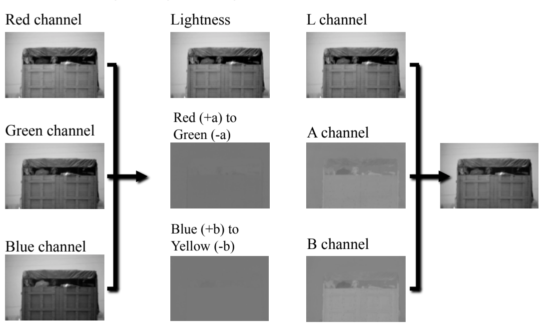
Lightness (L)
Red (+a) to Green (-a)
Blue (+b) to Yellow (-b)

Device independent color encoding.



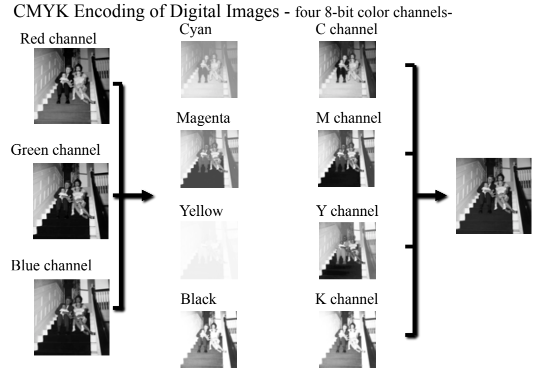
The Secrets of Color Management, Agfa

LAB Encoding of Digital Images - three 8-bit color channels-



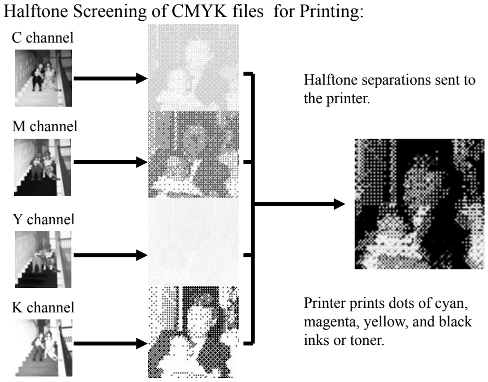
3 channels x 8-bits = 24-bit LAB color file

CMYK Encoding of Digital Images - four 8-bit color channels-



4 channels x 8-bits = 32-bit CMYK color file

Halftone Screening of CMYK files for Printing:



Halftone separations sent to the printer.

Printer prints dots of cyan, magenta, yellow, and black inks or toner.

Generally, save color images as RGB files.

Avoid CMYK for master image files, have very limited color gamut.

Digital Dynamic Range and Colors for Photographs:

•Photographs	Thousands of shades, density range- 2.0 refl. and 3.6 trans.	
•Digital-	1-bit	Bitonal, black or white
	8-bits 24-bit RGB color Density range	256 shades 16.8 million colors 2.4
	10-bits 30-bit RGB color Density range	1024 shades 1 billion colors 3.0
	12-bits 36-bit RGB color Density range	4096 shades 68.7 billion colors 3.6
	16-bits 48-bit RGB color Density range	65,536 shades 2.8 x 1014 colors 4.8

Well done 8-bits per channel imaging meets most needs. Limited ability for major corrections, transformations, and re-purposing.

12-bits to 16-bits per channel images match or exceed the shading and density range of photographic originals, better for re-purposing.

Poorly done high bit-depth imaging has no benefit.

Reformatting Comparison:

Original Document	Digital Imaging	Photographic
Printed Text (Good Condition)	1 bit / Bitonal Black and White	Microfilm / High Contrast
Low Contrast Text and Photographs	8 bit / 256 Level Greyscale	Cont. Tone Film / Low to Med. Contrast
Color Graphics / Text and Color Photos	24 bit (RGB) / 16 mil. Colors	Color Film / Low to Med. Contrast

Spatial Resolution:

- •Determines the amount of information in a raster image file in terms of the number of pixels per unit measurement
- •It does not guarantee the quality of the information
- •Defines how finely or widely spaced the individual pixels are from each other

Spatial Resolution:

- •The lower the spatial resolution, the more widely spaced and the fewer number of pixels overall
- •The higher the spatial resolution, the more finely spaced and the larger number of pixels overall

Spatial Resolution:

The number and distribution of pixels in an image can be described in a number of ways.

- PPI- pixels per inch
- DPI- dots per inch
- Pixel array

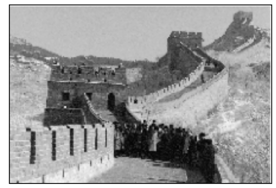
Pixel Array:

The number of pixels across both dimensions of an image.

Ex.- an 8”x10” photo scanned at 300 ppi produces a file that has 2,400 x 3,000 pixels.

Often referred to as a 3,000 line file.

Resolution:



- An 8”x10” print scanned at 300 ppi produces a file with 2,400 x 3,000 pixels
- A 4”x5” negative scanned at 600 ppi produces a file with 2,400 x 3,000 pixels
- A 35mm negative scanned at 2,100 ppi produces a file with 2,000 x 3,000 pixels
- All are 3,000 line files

Resolution: Optical vs. Interpolated

Optical is the inherent resolution of the scanner or digital camera - based on the size of the imaging array, the focal length of the lens or lenses, and the design of the optical path.

Interpolated is calculated via software. Often performed during scanning or done after scanning.

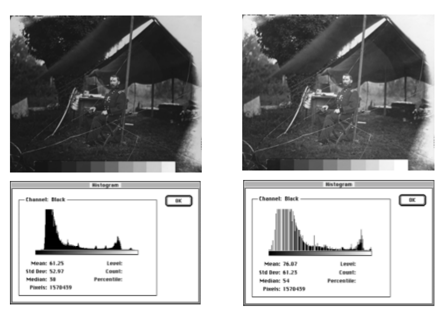
Higher optical resolution in a scanner is better than interpolated resolution.

Manufacturers’ claims for resolution can be over-rated. Often, the actual spatial resolution as measured by spatial-frequency-response (SFR) is lower than claimed.

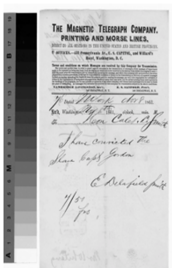
Digital Image Processing:

- It is all math - formulas or algorithms recalculate pixel values to change the appearance of the image
- Interpolation or resizing images
- Filters - sharpening, blurring, despeckling, creative effects, etc.
- Tonal and color controls - ex. levels and curves, avoid global controls like contrast, brightness, and color balance

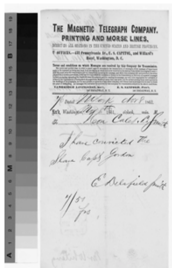
Adjusting the Tonal Scale:



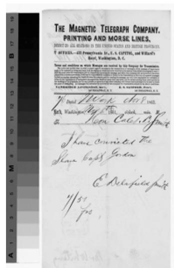
Color Imbalance:


THE MAGNETIC TELEGRAPH COMPANY.
PRINTING AND MORSE LINES.

Even tonal distribution between color channels.

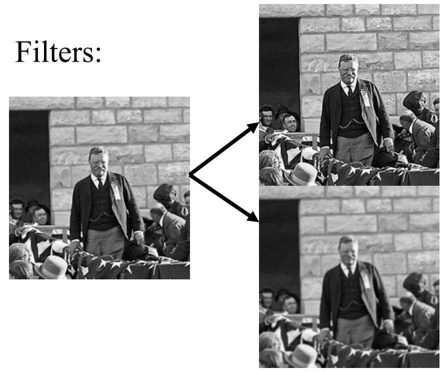

THE MAGNETIC TELEGRAPH COMPANY.
PRINTING AND MORSE LINES.

Shift in the distribution of the green channel.


THE MAGNETIC TELEGRAPH COMPANY.
PRINTING AND MORSE LINES.

Shift and clipping in the red channel.

Filters:



Sharpen

Blur

Simple Image File Structure:

Header
- A file identifier
- Image specification

Image Data
- Look-up table
- Image raster

Footer
- File terminator

"Structures and Metrics for Image Storage and Interchange", JEI, April 1993

Data Compression:

•Pro - Compress digital images prior to storage and transmission to save space and time.

•Con - Concern about compression increasing risk for corruption and/or data loss. Risk felt to be proportional to the complexity of the encoding.

Data Compression:

•Lossless - file reconstruction identical to the original image

•Lossy - a certain amount of original information discarded during compression process

"Digital Imaging and Optical Disk Technologies", Barry Roginski, NARA

File Compression:

•Saves space when files are stored by-

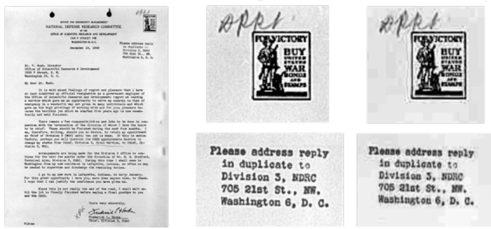
•minimizing repetitive bits within the raster data, and/or-

•eliminating image data

•Files return to original size when opened and decompressed

JPEG Compression:

Original | Uncompressed | JPEG- 1/10 orig.



Compression Comparison:

JPEG 70:1 | Wavelet 130:1 | Fractal 130:1

Choosing File Formats-

- •Suitability for the type and nature of digital object and copy types
- •Sustainability, usability, and authenticity of digital representation and encoding method

Sustainability of Digital Formats- Planning for Library of Congress Collections:

http://www.digitalpreservation.gov/formats/

- •Sustainability Factors
  - ▪Disclosure
  - ▪Adoption
  - ▪Transparency
  - ▪Self-documentation
  - ▪External dependencies
  - ▪Impact of patents
  - ▪Technical protection mechanisms
- •Format Descriptions

Digitizing guidelines exist - still work to be done:

- • Books, newspapers, and textual records - original paper records and microfilm
- • Still photographs
- • Audio recordings
- • Working on video recordings and motion pictures

Federal Agencies Digitization Guidelines Initiatives (FADGI)

http://www.digitizationguidelines.gov/

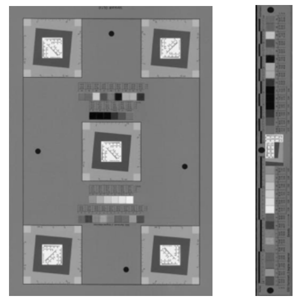
Established in 2007 and now has 18 participating agencies.

Two working groups – Still Imaging and Audio-Visual

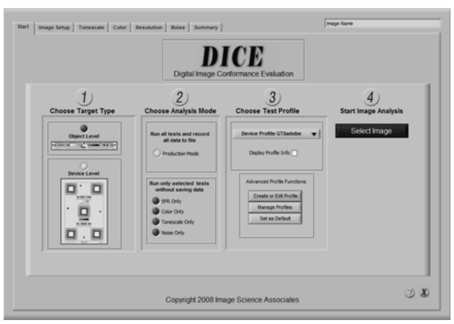
Digital Image Conformance Environment (DICE)

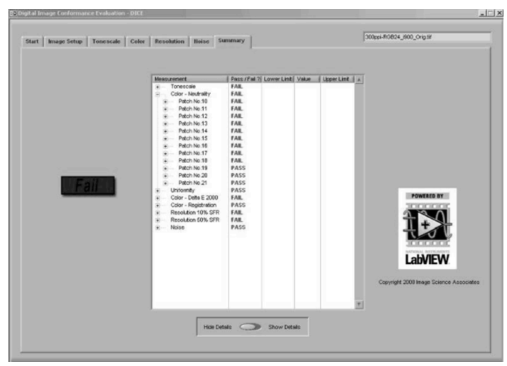
Scanner performance assessment and monitoring

Targets-



Software-





Digitizing Audio

Sound is comprised of pressure waves with the following characteristics-

- •Amplitude - change in pressure from the peak of the waveform to the trough
- •Cycle - length of time for a waveform to go from one amplitude, through all amplitude changes, to the same amplitude
- •Phase - measurement of how far through a cycle is a waveform

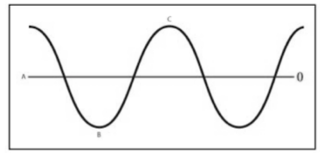
Definitions paraphrased from Adobe's "A Digital Audio Primer"

•Frequency - number of cycles per second of the waveform

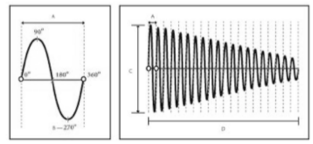
One Hertz (Hz) equals one cycle per second, 1,000 Hz goes through 1,000 cycles every second

•Wavelength - distance between two points on the waveform with the same phase

Definitions paraphrased from Adobe's "A Digital Audio Primer"



A. zero line
B. low pressure area
C. high pressure area



A. wavelength
B. degree of phase
C. Amplitude

From Adobe's "A Digital Audio Primer"

•A microphone consists of a transducer which converts the sound waves by various means into an electrical signal that varies proportionally to the sound waves

•Analog recordings convert the electrical signals into either physical grooves or magnetic signals that replicate the waveform

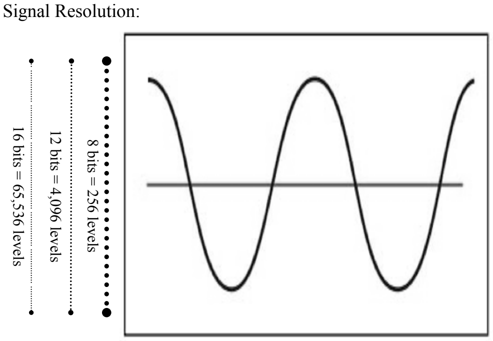
Digitizing Audio:

The analog waveform is sampled via an analog-to-digital conversion process-

•Signal or Amplitude Resolution - how finely or coarsely the amplitude of the waveform is sampled and this determines the dynamic range of the recorded signal

•Sampling Rate - how often the waveform is sampled over time and this determines the range of frequencies recorded

Signal Resolution:



From Adobe's "A Digital Audio Primer"

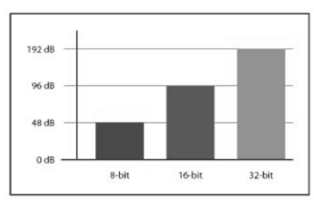
Signal Resolution:

Higher bit-depth provides higher fidelity by reproducing a larger dynamic range and having a lower noise floor.

Audio CD –
•16-bit or 65,536 levels, up to 96 dB

Human Hearing –
•120 dB

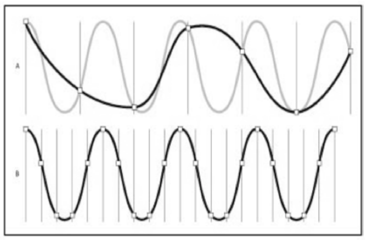
Audio DVD –
•24-bit or 16,777,216 levels, up to 144 dB



From Adobe's "A Digital Audio Primer"

Sampling Frequency:

The higher the sampling rate, the closer the shape will be to the original analog waveform.



From Adobe's "A Digital Audio Primer"

Digitizing Video

Analog video recordings synchronize a rapid sequence of images, that create the appearance of motion, with an audio track:

- •Frame Rate - the number of displayed frames per second
- •Vertical Resolution - the number of horizontal lines displayed across the vertical dimension
- •Line Display - traditionally interlaced (displaying alternate lines or fields), more recently DVDs players may use progressive (displaying every line in sequence)
- •Horizontal Resolution - depends on the video camera and the recording format

From Adobe's "A Digital Video Primer"

- •Color Encoding - luminance and two color channels (YCC), allowed backward compatibility with black-and-white TVs
- •Composite Video - the luminance and color information are transmitted together, can degrade image quality
- •S-Video - transmits luminance as one signal and the two color channels as a second signal
- •Component - transmits the luminance and the two color channels as three separate signals

From Adobe's "A Digital Video Primer"

Digital Video - video signals sampled to produce raster images and synchronized audio track:

Frame Rate –
- •30 frames per second
- •Lower frame rates used to make files smaller

Pixel Array (Resolution)
- •720 x 486
- •Smaller pixel arrays used to make files smaller

From Adobe's "A Digital Video Primer"

Bit Depth –
- •16-bits per channel and up to 4 channels is possible (YCC with an additional black)
- •8-bits per channel or 24-bit color is standard
- •Lower bit depths used to make files smaller

Color Encoding and Compression –
- •YCC
- •4:2:2, 4:1:1, and 3:3:1 used to make files smaller

Audio –
- •16-bits and 48,000 Hz
- •Lower bit-depth and sampling rates used to make files smaller

From Adobe's "A Digital Video Primer"

Compression:

- •CODEC - compression and decompression algorithm
- •If each video frame is compressed separately, this is known as “intra-frame” or “spatial” compression
- •Some compression schemes store just the differences between frames, rather than storing each frame, and this is known as “inter-frame” or “temporal” compression

From Adobe’s “A Digital Video Primer”

Digitizing Motion Pictures

35mm and 16mm digitized to produce:

- •For 35mm - 4,000 x 3,000 pixels per frame for master file, equal to 4,000 ppi. 36 MB per frame uncompressed for image only
- •For 16mm and projection/distribution - 2,000 x 1,500 pixels per frame, matched to 4th-generation film projection print quality
- •24 frames per second

Digitization technology is mature and there are many equipment choices for reformatting the variety of materials in collections.

Need to be knowledgeable users of digitization technology to achieve the goal of producing digital objects that are high-quality, consistent, and suited to institutional and patron needs.