

Digital Image Sizes

Computer storage requirements for various digitized document types (Estimates are rounded and adjusted for ease of use.) (Page 1 of 6)

Scanned Letter Size Pages

(All images are scanned 1 bit per pixel, black & white, and compressed, unless otherwise noted.)

1 scanned page (8 1/2 by 11 inches, A4) = 50 KiloBytes (KByte) (on average, black & white, CCITT G4 compressed)
 1 file cabinet (4 drawer) (10,000 pages on average) = 500 MegaBytes (MByte) = 1 CD (Compact Disc) (ROM or WORM)
 2 file cabinets = 10 cubic feet (cf) = 1,000 MegaBytes = 1 GigaByte (GByte); 10 file cabinets = 1 DVD-R (WORM) (see below)
 2,000 file cabinets = 1,000 GigaBytes = 1 TeraByte (TByte); 2,000 file cabinets = 200 DVDs
 1 box (in inches: 15 1/2 long x 12 wide x 10 deep) (400 x 300 x 250 mm) (2,500 pages) = 1 file drawer = 125 MegaBytes
 1 box (packed) = 2 linear feet (500 mm) of files (loose enough for active filing) = 25 (rounded) linear inches = 125 MegaBytes
 1 linear inch (~20 mm) = 100 pages = 5 MegaBytes; 1 thousand linear inches = 100 thousand pages = 5 GigaBytes
 1 cubic foot (cf) (~.025 cubic meter) = 2000 pages = 100 MegaBytes; 10 cubic feet (~.25 cubic meters) = 20 thousand pages = 1 GigaBytes
 8 boxes = 16 linear feet = 2 file cabinets = 1 GigaByte; 8,000 boxes = 16,000 linear feet = 1,000 GigaBytes = 1 TeraByte
 For paper and microform document imaging, see also AIIM (Association for Information and Image Management) <http://www.AIIM.org>
 For records and information management, see also ARMA (Association of Records Managers and Administrators) <http://www.ARMA.org>

Scanned Engineering Drawings / Large Format Documents

1 E size drawing (48 inches by 36 inches) (A0 size) = 16 letter size pages (8 1/2 by 11 inches, metric A4) = 800 KiloBytes To place an E size drawing in a file folder in a file cabinet drawer, the drawing must be folded in half 4 times and is then 16 sheets of paper thick when folded.
 NB: Scanning must accommodate the older, untrimmed, US paper sizes, because it is the older drawings that are digitized by scanning.

Metric Trimmed Paper Sizes					United States Paper Sizes				Storage
Metric Name	Metric Size in Millimeters	Size in Inches	Number of Square Meters	Number of A4 Size Pages	US Name	New Size (Trimmed) in Inches	Old Size (Untrimmed) in Inches	Equivalent Letter Size Pages	Digital Image Storage Requirements
A8	52 x 74	2.07 x 2.91	1 / 256	1 / 16	Business Card				5 KiloBytes
A7	74 x 105	2.91 x 4.13	1 / 128	1 / 8	3 x 5	3 x 5			10 KiloBytes
A6	105 x 148	4.13 x 5.83	1 / 64	1 / 4	Microfiche				
A5	148 x 210	5.83 x 8.27	1 / 32	1 / 2	5 x 8	5 x 8			25 KiloBytes
A4	210 x 297	8.27 x 11.69	1 / 16	1	A	8 1 / 2 x 11	9 x 12	1	50 KiloBytes
A3	297 x 420	11.69 x 16.54	1 / 8	2	B	11 x 17	12 x 18	2	100 KiloBytes
A2	420 x 594	16.54 x 23.39	1 / 4	4	C	17 x 22	18 x 24	4	200 KiloBytes
A1	594 x 841	23.39 x 33.11	1 / 2	8	D	22 x 34	24 x 36	8	400 KiloBytes
A0	841 x 1189	33.11 x 46.81	1	16	E	34 x 44	36 x 48	16	800 KiloBytes
2A0	1189 x 1682	46.81 x 66.22	2	32					1.6 MegaBytes
					F	28 x 40	varies		600 KiloBytes
					G	11 x (22 1 / 2 to 90)	varies		
					H	28 x (44 to 143)	varies		
					J	34 x (55 to 176)	varies		Sizes G, H, J, and K
					K	40 x (55 to 143)	varies		are US roll sizes

Paper size references: MIL-M9868-D, Microfilming of Engineering Documents, 35MM, Requirements for, 10-1-70 and amendments 1 and 2, 2-12-82 and 9-20-82; MIL-STD-804B Format and Coding of Aperture, Copy and Tabulating Cards Engineering Data Micro-reproduction System, 15 August, 1966; ANSI Y 14.1, 1980, Drawing Sheet Size and Format, published by ASME (American Society of Manufacturing Engineers), New York; Metric standards first published in 1922 by DIN (Deutsches Institut für Normung) (German Institute for Standards) <http://www.DIN.de> Now used worldwide as ISO 216. [See last page for ISO reference.]

Newspapers: A double truck (center fold) full broadsheet is 24 in x 36 in, equivalent to an old D size drawing in size. Because a newspaper page would be scanned at a higher resolution and contains detailed graphics, a double truck would require about 1 MegaByte and a single full broadsheet page (18 by 24 inches) would require about 1 / 2 MegaByte. See also NAA (Newspaper Association of America) <http://www.NAA.org>

Scanned Microforms

1 roll of 16 mm microfilm (100 ft, ~30 meters) (24X reduction) = 2,500 letter size images = 1 box = 1 file cabinet drawer = 125 MegaBytes
 1 roll of 35 mm microfilm (100 ft) (12X reduction, open spacing, normal scan) = 1,000 letter size images = 50 MegaBytes
 1 microfiche (105 mm film) (24X reduction) = 100 letter size images = 5 MegaBytes (average); 200 microfiche = 20,000 images = 1 GigaByte

In many record series, each microfiche contain only a few images because each fiche represents a single record in the series (e.g. one fiche per person in a personnel record series). In this case filming breaks on records, rather than being continuous. To a lesser extent this is also true for roll film. In these cases, the amount of storage required depends on the number of images on the film, not the number of microfiche or the number of rolls of film. A full, standard 24X microfiche has 7 rows of 14 letter size (8 1/2 x 11 or A4) images for a total of 98 images.

As with any microform, scanned aperture card images require the same storage as images scanned from the paper original of the document in the aperture.

Compression

All documents are stored and transmitted in compressed format. All compression formats are assumed to be lossless or used with a lossless setting, except MPEG (Moving Picture Experts Group), unless otherwise stated. Lossless or non-destructive compression (as opposed to lossy or destructive

compression) does not change the document. That is, a decompressed document is identical to the original document before compression was done. Lossless compression is often needed to meet legal requirements for document storage. The most common form of one bit (per pixel), bitonal (The two tones of color are two shades of grey which are black and white.), lossless compression, used in TIFF G4 and Adobe PDF (Portable Document Format), is the CCITT G4 (Group 4) facsimile compression format. Before using any other

form of compression, it is often useful to evaluate the cost savings of moving to the less common format. The CCITT (Comité Consultatif International pour le Télégraphe et le Téléphone) (International Telegraph and Telephone Consultative Committee) is now a part of the ITU (International Telecommunications Union) <http://www.ITU.int> The G4 ITU recommendation T.6 (11/88), Facsimile coding schemes and coding control functions for Group 4 facsimile apparatus, is on pages 48-57 of the CCITT Blue Book, Volume VII - Fascicle VII.3, Terminal Equipment and Protocols for Telematic Services, Recommendations T.0 - T.63, ISBN 92-61-03611-2

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Scanned Miscellaneous Documents

1 check (2 sided) (remittance) = 50 KiloBytes per item, 25 KiloBytes (1 sided), less if no patterns are present.

1 credit card receipt (long: 3 1/4 x 7 7/16 inches, 2 sided) (remittance) = 35 KiloBytes, short (3 1/4 x 5 in., 2 sided) = 25 KiloBytes The long size credit card receipt is the same as an 80 column punch card, which was based on the older 90 column, round hole, punched card, which in 1890 was based on the size of the old US dollar bill (before 1929). US dollar bills are now 6.14 x 2.61 inches (~156 x ~66 mm), before 1929, US dollar bills were 7.4218 x 3.125 inches (~189 x ~79 mm). [- emphasizes an approximation, rather than a precise measure.]

1 library book (average, scanned in black and white) = 10 MegaBytes; 50 books = 500 MBytes = 1 CD; 100 books = 1 GByte

Pages per Second (Internet Communications)

DSL (Digital Subscriber Line) = 1/2 to 8 Mbits (Megabits) per second = 1 to 15 pages per second (about ~ US\$ 50.00 per month)

Modem = 56 Kbit (Kilobits) per second = 3 pages per minute (about ~ US\$ 30.00 per month for a standard phone line)

ISDN (2 voice channels) = 128 Kbit per second = 10 pages per minute (~ US\$ 100.00 per month) (ISDN charge)

Cable (TV) modem = ~ 500 Kbits per second = 1 page per second (about ~ US\$ 50.00 per month)

T1 (24 voice channels, 64 Kilobits/sec each) = 1.544 Mbit (Megabit) per second = 3 pages per second (~ US\$ 1,000.00 per month)

Ethernet (CSMA/CD) = 1 Mbit per second (effective) or 10 Mbit per second (nominal) = 2 pages per second

OC3 ATM (Optical Carrier, Asynchronous Transfer Mode) = 155 Mbit per second = 300 pages per second

OC192 (SONET: Synchronous Optical Network fiber) = 10 Gbit per second = 20,000 pages (2 file cabinets) per second

Dense Wavelength Division Multiplexing (DWDM) with 32 OC192 channels = 320 Gigabits per second = 64 file cabinets per second

Dense Wavelength Division Multiplexing (DWDM) with 80 OC1536 channels = 6.4 Terabits per second = 1,600 file cabinets per second

Optical carrier frequency (1,300 nm) (dark fiber) = 230 THz (TeraHertz) (about 2,000 cycles are used for every OC1536 bit transmitted)

See also ITU (International Telecommunications Union) <http://www.ITU.int> TIA (Telecommunications Industry Association) <http://www.TIAonline.org>
The Internet Society (ISoc) <http://www.ISoc.org> The next Internet: <http://www.Internet2.edu>

(Office Color) Scanned Letter Size Pages (View-only images, 100 dpi, no OCR possible)

1 scanned page (100 dpi) (8 1/2 by 11 inches, A4) = 100 KiloBytes (KByte) (on average, office color, including grayscale, compressed)

1 file cabinet (4 drawer) (10,000 pages on average) = 1 GigaByte (GByte) = 2 CDs (ROM or WORM)

5 file cabinets = 1 DVD-R (WORM) (see below)

1,000 file cabinets = 1,000 GigaBytes = 1 TeraByte (TByte); 1,000 file cabinets = 200 DVDs

1 box (in inches: 12 wide x 15 long x 10 deep) (300 x 375 x 250 mm) (2,500 pages) = 1 file drawer = 2 linear feet (500 mm) of files = 250 MegaBytes

4 boxes = 8 linear feet = 1 file cabinets = 1 GigaByte; 4,000 boxes = 8,000 linear feet = 1,000 GigaBytes = 1 TeraByte

In general, when compressed, the digital files for document images scanned in office quality view-only-color (100 dpi) (no OCR possible) are about twice the size of document images scanned in a bi-tonal, black and white format, and then G4 compressed. In office quality color scanning, the scanned color differences aid users in reading a document and in increasing the quality of OCR (Optical Character Recognition) done at 150 dpi and higher resolutions.

Office quality view-only-color scanning is generally at a lower resolution (100 dpi) than black and white scanning (300 dpi, required for bi-tonal OCR).

Office quality grayscale-OCR-color (150 dpi) includes (has subsumed) the process of grayscale scanning which can increase OCR accuracy (at or above 150 dpi) when using low resolution scanning (lower than the 300 dpi generally required for bi-tonal OCR). Grayscale OCR is also called 3D OCR. (3 Dimensional OCR)

For the study of color (and color perception), see also CIE, the International Commission on Illumination (Commission Internationale de l'Eclairage) (Internationale Beleuchtungskommission) <http://members.eunet.at/CIE> See also SPIE, the International Society for (Photo) Optical Engineering, <http://www.SPIE.org>

(Office Color) (Includes Grayscale Scanning) Engineering Drawings / Aperture Cards

View-only-color (100 dpi, no OCR possible): 1 E size drawing (A0) (48 inches by 36 inches, with overscan) = 16 letter size pages (8 1/2 by 11 inches, A4) = 1,600 KiloBytes (1.6 MegaBytes) D size = 8 letter size pages; C size = 4 pages; B size = 2 pages; A size = 1 page

Grayscale-OCR-color (150 dpi color, including a separate 300 dpi bi-tonal image): 1 E size drawing (48 inches by 36 inches) = 8 MegaBytes

Visually-unaltered-color (150 dpi color, including a separate 300 dpi bi-tonal image): 1 E size drawing (48 inches by 36 inches) = 32 MegaBytes

Raw-color (uncompressed) (grayscale only, 400 dpi): 1 E size drawing (48 inches by 36 inches) = 320 MegaBytes

Digitized Multimedia Formats

1 hour of compressed color video = 2 GigaBytes (DVD, MPEG 2) (image quality dependent) (4 GigaBytes = 2 hour feature length movie)

1 hour of audio = 10 MegaBytes (dictation, answering machine) to 500 MBytes (a CD holds 74 minutes of music)

1 color picture = 10 KiloBytes (thumbnail) to 5 MBytes (for each of 100 photos on a 500 MByte photo CD)

The size of a compressed image file depends on the resolution (dpi: dots per inch) and the detail (information) in the photograph. The detail in a photograph is dependent on the size of the negative and the quality of the film and the camera and lens (It is not related to the print size unless the print is smaller than the negative). The resolution of the scan should be chosen to match the detail of the photograph. For most cameras, films, and formats 35mm and smaller, the 5 MByte Photo CD format (2048 by 3072 pixels) captures all the information in the image. Note that this is in dots per image rather than dots per inch. Displays are also given in dots per image (Horizontal x Vertical: e.g. 1280 x 1024), with the horizontal dimensional always being given first.

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DVD Digital Video Disc

(See also <http://www.DVDdemystified.com/dvdfaq.html>)

DVD (commonly Digital Video Disc) (A DVD is the same physical size as a CD.) DVD stands for Digital Versatile Disc, by vote of the committee that controls the trademark DVD, the DVD Forum. <http://www.DVDForum.org> All capacities are given in commercial units: e.g.: 1 GigaByte = 1 Billion Bytes; 1 MegaByte = 1 Million Bytes

NB: When you calculate the amount of storage you will need on a given CD or DVD (using the table below), be sure that the units you are using for the size (amount) of data you plan record are given in commercial rather than computer units. If you are not sure that the size (amount) of your data is given in commercial units, then add 10 (ten) percent to the size (amount) of data you plan to record. In all cases, you should leave yourself some headroom (of at least 5 percent) for last minute changes. (This can be reduced as you gain experience.) If, in addition to the normal headroom allowance, you are also uncertain of the (data size) units used, it is best to allow a total of 15 percent for headroom.

Disc Type	Acronym	Media Type	Side A Top Layer	Side A Bottom Layer	Side B Top Layer	Side B Bottom Layer	Total Storage Capacity
120 mm (4 1/4 inch) DVD	DVD-R** (SS)	DVD Recordable	4.70 GigaBytes	Not Available	Not Available	Not Available	4.70 GigaBytes
	DVD-R** (DS)	DVD Recordable	4.70 GigaBytes	Not Available	4.70 GigaBytes	Not Available	9.40 GigaBytes
	ROM (DS/DL)	Read Only Memory	4.27 GigaBytes	4.27 GigaBytes	4.27 GigaBytes	4.27 GigaBytes	17.08 GigaBytes
	RW & RAM	ReWriteable Random Access Memory	4.70 GigaBytes	Not Available	4.70 GigaBytes	Not Available	9.40 GigaBytes
80 mm (3 inch) DVD	DVD-R** (DS)	DVD Recordable	1.46 GigaBytes	Not Available	1.46 GigaBytes	Not Available	2.92 GigaBytes
	ROM (DS/DL)	Read Only Memory	1.33 GigaBytes	1.33 GigaBytes	1.33 GigaBytes	1.33 GigaBytes	5.32 GigaBytes
	RW & RAM	ReWriteable Random Access Memory	1.46 GigaBytes	Not Available	1.46 GigaBytes	Not Available	2.92 GigaBytes
HD-DVD Future: ~2006 120 mm	DVD-R** (DS)	DVD Recordable	16+ GigaBytes	Not Available	16+ GigaBytes	Not Available	32+ GigaBytes
	ROM (DS/DL)	Read Only Memory	16+ GigaBytes	16+ GigaBytes	16+ GigaBytes	16+ GigaBytes	64+ GigaBytes
120 mm CD	All (SS/SL)	All (SS/SL only)	682* MegaBytes	Not Available	Not Available	Not Available	682* MegaBytes
80 mm CD	All (SS/SL)	All (SS/SL only)	194 MegaBytes	Not Available	Not Available	Not Available	194 MegaBytes

SS (Single Sided), DS (Double Sided), SL (Single Layer), DL (Double Layer), SS/SL (Single Sided / Single Layer), DS/DL (Double Sided / Double Layer), DS/SL (Double Sided / Single Layer per side), DS/ML (Double Sided / Mixed Layer; one side 1 layer, other side 2 layer), HD (High Density); Top Layer (Layer 1), Bottom Layer (Layer 0)

* CD capacities have always been advertised as 650 MegaBytes using the older computer based MegaByte (1,048,576 Bytes) size. Using the new commercial standard units of 1 Million Bytes per MegaByte, a CD holds 682 MegaBytes. DVD capacities, however, are always stated in the new, smaller, commercial units.

** DVD-R (Recordable) and CD-R are the equivalent of WORM (Write Once, Read Many) The DVD-R capacity listed above, of 4.7 GigaBytes per side, is for discs and DVD writers that conform to the new DVD-R standard (DVD-R 2.0). The new DVD-R discs and writers are available now. The older (DVD-R 1.0) capacity of DVD-R discs is 3.95 GigaBytes per side for a total of 7.9 GigaBytes for a two sided disc.

DVD 16X

CD drives read at up to 40X speed. Music CDs are listened to at 1X. Listening to music at 2X or at an X other than 1X does not make sense, except for Alvin and the Chipmunks.

CD and DVD Xs do not always mean that the entire CD or DVD will be read at X times the normal speed. This is because CDs and DVDs are meant to be read at a Constant Linear Velocity (CLV) which means

that a CD or DVD rotates faster when reading the shorter inner tracks. Some high speed readers do not increase their rotational speed when reading the inner tracks. The rotational speed on these readers is a Constant Angular Velocity (CAV) (one rotation sweeps out an angle of 360 degrees).

A good rule of thumb is to reduce the X speed by 25 percent. A 16X DVD drive would transfer an entire DVD movie at 12X fast forward speed and would therefore read about 4 GigaBytes in about 1 / 6 hour

or 10 minutes at a data rate of about 25 GigaBytes per hour. Restoring a 250 GigaByte Database with 10 of the 16X DVD readers would require about 1 hour. In a short time the DVD drives should approach the CD drive cost of 50 US dollars each, so that 10 of the DVD drives would cost about 500 US dollars. Restoring a 2.5 TeraByte database with 10 of the 16X DVD drives would require 10 hours. A 10 TeraByte database would require 4 times as many drives (40) to restore the database in the same time (10 hours). When restoring files, some time is required to create catalog entries. For large files this is less of a problem.

DVD Multimedia

6 channel (theater quality surround sound) (5.1, Dolby AC-3) / 96 KHz audio / 24 bit audio, 8 languages tracks, 32 subtitle tracks, and about 135 minutes (long enough to accommodate 94% of all movies) of high quality video (720 horizontal pixels) on each of 4 layers. DVDs

support runtime editing so that all ratings of a movie are on the same DVD; 'R' rated scenes can be skipped, without interruption, as the DVD is played. The file format is ISO 13346 UDF (Universal Disc Format) which harmonizes all CD recording standards including ISO 9660. A future technology, 3rd generation blue lasers [sort of a blue light special, as blue light has a wavelength

about half that of red light], should yield a 64+ GigaByte DVD ROM for HDTV. [N.B. Optical disc is spelled with a 'c' as in music disc. Magnetic disk is spelled with a 'k' as in harrow disk.] [For a DVD with a two layer side, to reduce inter-layer crosstalk, the minimum pit length of both layers is increased from .40 um to .44 um. This results in longer (and therefore fewer) pits for more effective reading of the data.] See also <http://www.DVDdemystified.com/dvdfaq.html>

DVD Audio

DVDs can be used to record audio only, with no video. In addition, DVD audio includes various still images. DVD audio is different than the audio that is used as part of DVD video.

The DVD audio standard is for up to 6 channels, a sampling rate of 48, 96, or 192 KHz, and a sample size of 16, 20, or 24 bits. With 24 bit samples taken at a 192 KHz rate, this provides a 96 KHz frequency response and

a 144 dB dynamic range. DVD audio can also provide for a lossless audio compression of about 2 to 1 which would have a playing time of 120 to 140 minutes for two-channel 192 KHz / 24 bit recordings for a single layer. Each DVD disc can have up to 4 layers, 2 layers per side.

DVD audio includes various still image modes for synchronized lyrics, navigation, etc. DVD audio allows up to 16 still graphics per track (or slightly more, depending on the compression ratio) and a set of limited transitions.

The audio used in DVD video can also be used without the video. This produces a stereo, DVD quality, play time of over 55 hours at 192 Kilobits per second (compressed) for a single layer and over 200 hours for a 4 layer DVD disc. Lower quality sound can be recorded as computer files on a DVD for much longer play times. At a compressed audio rate of 16 Kilobits per second (in the low range of telephony quality), this is 9 million seconds, 150 thousand minutes, 2,500 hours, 100 days, 15 weeks, or 3 months of audio on a 4 layer DVD disc. (Each of the 24 T-1 telephony voice channels carries 64 Kilobits per second: 8 thousand 8 bit audio (sound or volume) samples per second.) See also AES (Audio Engineering Society) <http://www.AES.org>

Bit Fade and Copying

Like all storage and communications media, CD and DVD discs have the property that bits stored on them fade. Every day, some of the stored bits fade away. CDs and DVDs have an error correcting code (ECC) that can correct (replace) the lost bits. Eventually, there are too

many lost bits to be corrected. This is the basis for the estimated lifetimes of CD and DVD media. Rather than an estimate, ANSI/AIIM (Association for Information and Image Management, <http://www.AIIM.org>/American National Standards Institute) MS59-1996 media error monitoring and reporting standard, which complements the ANSI X3.131, media error hardware interface, provides a

means of directly counting the number of bad bits (the raw error rate) on a given CD or DVD. This gives a disc-by-disc reading on when to copy the data on the disc, and indicates exactly which discs will actually last (protect the data for) the disc's projected lifetime (up to 100 years). Until commercial, end user implementations of MS59 are available for checking discs, many users are following a practice of copying CDs and DVDs every five years, regardless of the nominal warranty period.

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Pixels per Image

Most document imaging resolution measures are in pixels (PICTure ELEment) per inch (or per mm - millimeter), and are commonly referred to as dpi (dots per inch) or dpmm (dots per mm). Most motion picture and still-photographic resolution measures are in pixels per image. This is most commonly seen in the 525 lines of NTSC (National Television System Committee), 625 lines for PAL (Phase Alternating Line) and SECAM (Sequential Couleur Avec Memoire or Sequential Colour with Memory), resolution of television images. No matter how physical large or small an NTSC television image is displayed, there are only 525 lines of vertical resolution (480 viewable). The computer equivalent of this is 640 by 480 pixels in a standard computer image. In pixels per image the horizontal resolution is given first. If the horizontal dimension is larger than the vertical dimension in pixels, the image or display is said to be landscape, if the horizontal is smaller, the image or display is said to be portrait. See also SMPTE (Society of Motion Picture and Television Engineers) <http://www.SMPTE.org>

The physical size of the display is an important element in the design of a document imaging workstation. A 20 or 21 inch nominal diagonal size, or exactly a $20 \pm 1/4$ inch VIS (Viewable Image Size) is most commonly used for CRTs (Cathode Ray Tubes), with an equivalent $18 \pm 1/4$ inch VIS being the most common for flat panel displays. These sizes, or larger, are especially important for extended use, or the accommodation of viewers who use bifocal glasses.

Pixels per Image: Video Image Resolutions

Computer screen resolutions are chosen to have an aspect ratio (the ratio of width to height) of 4 to 3 (the 'golden ratio' of the art world) and to have the number of pixels be an integer multiple of a power of 2. (Powers of 2 are given here as 2^{**N} for the Nth power of 2). When a prefix is added to the word pixel it can be shortened to pel (Picture Element). A 1 million pixel display is then a 1 MegaPel display. See also IEEE (The Institute of Electrical and Electronics Engineers) <http://www.IEEE.org> ACM (Association for Computing Machinery) <http://www.ACM.org> NAB (National Association of Broadcasters) <http://www.NAB.org>

IBM PC: CGA (Color Graphics Adapter) 320 x 200, EGA (Enhanced Graphics Adapter) 640 x 350, VGA (Video Graphics Array) 640 x 480.

IBM PC compatible: VGA 640 x 480 (This is the standard default screen resolution when a display card is reset to troubleshoot a problem with the display.), SVGA (Super VGA) or XGA (eXtended Graphics Array) 800 x 600, XVGA (eXtended VGA) 1024 x 768; and SXGA (Super XGA) or UVGA (Ultra VGA) 1280 x 1024 (although SVGA, SXGA, XVGA, and UVGA can mean anything that is more than the VGA's 640 x 480), UXGA (Ultra eXtended Graphics Adapter) is often 1600 x 1200. Because the meaning of IBM PC compatible acronyms is a marketing decision, no absolute meaning should be imputed to them.

The DVD NTSC resolution is 720 x 480 and the DVD PAL/SECAM resolution is 720 x 576. (Twentieth Century commercial television)

Common Display Resolutions

(An aspect ratio of [a x b] [c x d] is equal to [a * c x b * d] when expressed using matrix arithmetic.)

In all cases, the actual numeric resolutions should be used in place of an acronym. The acronyms are given here for assistance in interpreting text that does not include a numeric resolution. An acronym can be used following the numeric resolution, for reference, but the acronym may lead to extended discussions.

- 640 x 480 pixel resolution (VGA standard computer screen resolution) = $[2^{**6} \times 2^{**6}] [4 \times 3] [5 \times 5]$
- 800 x 600 (usually XGA, sometimes SVGA) = $[2^{**3} \times 2^{**3}] [4 \times 3] [25 \times 25]$
- 1024 x 768 (often XVGA, less often UVGA) = $[2^{**9} \times 2^{**9}] [4 \times 3]$
- 1152 x 900 (Sun Microsystems) 1152 x 870 (Mac) ($1152 = 2^{**4} \times 72$ typeset points per inch). Some Sun Microsystems and Apple / Mac screen resolutions were chosen so that the actual screen resolutions were 72 dpi to match the 72 points per inch used in typesetting.
- 1280 x 1024 (more often SXGA, sometimes UVGA, less often XVGA) = $[2^{**10} \times 2^{**10}] [4 \times 3]$
- 1600 x 1200 (often UXGA) (high resolution document imaging workstation) = $[2^{**4} \times 2^{**4}] [4 \times 3] [25 \times 25]$
- 1920 x 1200 (HDTV) The computer version of HDTV (High Definition TV) resolution is 1920 x 1200 (Sun Microsystems) and has the HDTV 16 to 9 aspect ratio. The 1920 x 1200 resolution is designed to match the NTSC derived HDTV video resolutions of 1920 x 1080 and old analog HDTV (NTSC derived) resolution of 1920 x 1035 and the PAL and SECAM derived analog HDTV video resolution of 1920 x 1152 ($1152 = 2 \times 576$). The current standard HDTV resolutions are 1280 x 720 and 1920 x 1080. The actual resolution of HDTV streams transmitted will usually be 1920 x 1088, because MPEG-2 requires the number of lines to be in multiples of 16 (1088 lines = 68×16).
- 1800 x 1440 (very high resolution grayscale document imaging workstation) = $[72 \times 72] [25 \times 20]$
- 2048 x 1536 (very high resolution grayscale document imaging workstation) = $[2^{**10} \times 2^{**10}] [4 \times 3]$

Pixels per Image: Single Frame (Still) Image Resolutions

See also <http://www.Kodak.com>

The Kodak PhotoCD family of resolutions: (Based on a 2 x 3 portrait aspect ration and an integer power of 2. The multiple of the base gives the number of pixels per image relative to the base image size in pixels.) A Kodak PhotoCD contains five resolution of each image: 1/16 Base through 16 Base. (The average compressed file size containing all five resolutions is about 5 MegaBytes per image.) A Kodak Pro PhotoCD contains the five resolutions for each image found on a PhotoCD plus a sixth 64 Base resolution. PhotoCD images are intended for true color, continuous tone images. 64 base Kodak Pro PhotoCD scanning does not always provide adequate resolution for 35 mm aperture card images (monotone microform images with a steep gamma curve) (nominally bi-tonal or black and white).

1/16 base (thumbnail, index print on CD cover)	.024576 megapixel image	=	128 x 192	[2 x 3]	[2^{** 6} x 2^{** 6}]
1/4 base (largest Kodak size that is smaller than 480 x 640 for display on TV)	.098304 megapixel image	=	256 x 384	[2 x 3]	[2^{** 7} x 2^{** 7}]
1 base	.393216 megapixel image	=	512 x 768	[2 x 3]	[2^{** 8} x 2^{** 8}]
4 base (largest Kodak size that is smaller than 1920 x 1152 for HDTV)	1.572864 megapixel image	=	1024 x 1536	[2 x 3]	[2^{** 9} x 2^{** 9}]
16 base (captures all the resolution on most 35 mm film images)	6.291456 megapixel image	=	2048 x 3072	[2 x 3]	[2^{**10} x 2^{**10}]
64 base (captures all the resolution for most film formats larger than 35 mm)	25.165824 megapixel image	=	4096 x 6144	[2 x 3]	[2^{**11} x 2^{**11}]

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Medical Records

1 Chest X-ray (14 x 17 inches) = 1 MegaByte: 150 dpi (dots per inch), 12 bits (compressed) (Wavlet compression, lossless mode, has FDA 510(k) approval.) (12 bits per pixel provide 4,096 shades of gray.) 150 dpi, 12 bit images are recommended by the American College of Radiology for primary reads. See also ACR (American College of Radiology) <http://www.acr.org> RSNA (Radiological Society of North America) <http://www.RSNA.org> FDA (United States Food and Drug Administration) <http://www.FDA.gov> HIMSS (Health Information Management Systems Society) <http://www.HIMSS.org>

A lossy compression, 14 x 17 Chest X-ray = 200 KiloBytes (For secondary reads: wavlet compression, lossy mode, has FDA 510(k) approval.)

X-rays that are originally recorded digitally rather than on film provide a resolution (image depth) of 16 bits per pixel which records 65,536 shades of gray per pixel. More shades of gray allow doctors to see very fine variations in the health of tissues, increasing the early detection of disease.

Aerial Photography, Digital Orthophotography, and Remote Sensing Pixel Sizes

Aerial photography uses photographs taken from the air, recording the visible electromagnetic spectrum (light), as maps of geographic areas. Remote sensing includes photographs taken from the air and from beyond the atmosphere of areas on the earth and other celestial bodies, using many segments of the electromagnetic spectrum including visible light, ultraviolet, infrared, and radar illumination. Digital orthophotography digitally rectifies the pixels of digitized aerial photographs into a continuous map, usually registered to a layer of a GIS (Geographic Information System).

For cities, 2 inch to 6 inch pixels are popular for digital orthophotography. A digital orthophotograph of a 500 square mile city using 6 inch pixels would have 4 pixels per square foot, 100 million pixels per square mile (There are approximately 25 million square feet per square mile.), for a total of 50 GigaPels (50 billion pixels). Using 8 bit uncompressed grayscale or using 24 bit color with an estimated lossless three-to-one compression, this digital orthophotographic image would require 50 GigaBytes to store. If 2 inch pixels were used, a 500 square mile city would have 9 times as many pixels or 450 GigaPels requiring 450

GigaBytes to store using the same assumptions. Using 2 inch pixels a 50 square mile city would have 45 GigaPels requiring 45 GigaBytes to store using the same compression assumptions. The metric equivalents are 50 millimeter (mm) and 100 mm pixels which are respectively 400 and 100 to the square meter. For a 1 thousand square kilometer city this would be 100 GigaPels using 100 mm pixels and would require 100 GigaBytes to store. Using 50 mm pixels for a 1 thousand square kilometer city, this would require 400 GigaPels requiring 400 GigaBytes to store. A 100 square Kilometer city, using 50 mm pixels would be imaged in 40 GigaPels which would require 40 GigaBytes to store.

In digital orthophotography, in addition to color, each pixel has an associated z axis value, the height of the pixel above sea level. When added to the x and y Cartesian coordinates of the pixel, the z values construct a digital terrain model over which the image can be mapped as a surface. This is similar to the way that images are created in virtual reality. By adding a t value, a 4 fourth dimension that represents a specific point in time, animations can be done

telling a geologic story or the developmental history of a city.

In remote sensing (satellite imagery such as weather photographs or images for crop quality assessment or storm damage / flooding), a 24 bit color image of an area 1 thousand kilometers by 1 thousand kilometers, using 100 meter pixels (pixels that are 100 meters by 100 meters), would contain 100 million pixels. Estimating a lossless three-to-one compression this would require 100 MegaBytes to store. The pixels used can be of any size. In astronomy, a single pixel can include an entire earth type planet (10 thousand kilometer pixels = 10 Mm, 10 MegaMeter pixel), a sun type star (1 million Kilometer pixels = 1 Gm, 1 Gigameter pixel), or a galaxy (100 thousand light year pixels = 1 Zm, 1 Zettameter pixel). The largest practical pixel is a 400 Ym, 400 Yottameter pixel, the diameter of the observable universe.

See also ACSM (American Congress on Surveying and Mapping) <http://www.SurvMap.org> ASPRS (American Society for Photogrammetry and Remote Sensing) <http://www.ASPRS.org> IAU (International Astronomical Union) <http://www.IAU.org>

GIS (Geographic Information System) Data Storage Requirements

GIS data, average, in city: 1 square mile = 50 MegaBytes; 20 sq. miles = 1 GigaByte, 1 square Kilometer = 20 MegaBytes, 50 sq. Kilometers = 1 GigaByte

Digital Orthophoto data, 6 inch pixels, uncompressed monochrome (or losslessly compressed color), 1 square mile = 100 MegaBytes; 10 square miles = 1 GigaByte; Using 100 mm pixels: 1 square meter = 100 Bytes, 1 square Kilometer = 100 MegaBytes, 10 square Kilometers = 1 GigaByte

Digital Orthophoto data, 2 inch pixels, uncompressed monochrome (or losslessly compressed color): 1 square mile = 1 GigaByte; Using 50 mm pixels: 1 square meter = 400 Bytes, 1 square Kilometer = 400 MegaBytes, 2.5 square Kilometers = 1 GigaByte

See also URISA (Urban and Regional Information Systems Association) <http://www.URISA.org>

Microprocessor and RAM (Random Access Memory) Design Rules (Pixel Size)

Semiconductors are made using digital photographic techniques (pixels). Recently, microprocessor production processes were improved from .25 micron (.25 um, micrometer) (250 nm, nanometer) design rules to .18 um (180 nm) design rules. This means that the pixel size for semiconductor devices is now slightly less than 1/5 micron (200 nm). A micron is one 1 millionth of a meter.

Using 200 nanometer (nm) pixels and assuming 1/25th of the area was used for active transistors, a 1 millimeter (mm) square area (about the size of the head of a pin) could hold 25 MegaPels (25 million pixels) and 1 million transistors. This is the basis for smart dust technology, developed at the University of California at Berkeley, in which remote robots called motes could be built on ultra thin 1 millimeter square

chips of silicon that float through the air and communicate with micro-lasers and micro-mirrors. Motes can remain suspended in the air for many hours, just like a cloud of dust or windblown seeds, collecting very detailed data. See also <http://robotics.eecs.Berkeley.edu/~pister/SmartDust> and International SEMATECH (Semiconductor Manufacturing Technology association) <http://www.SEMATECH.org>

The smallest practical pixel would be a pixel used as part of a halftone dot that represented the edge of the path of a sub-atomic particle, such as a neutrino. To create a smooth path in a specific color, a printed resolution of 2540 dpi (100 dpmm) would be used. Assuming a 1 ym (yoktometer) wide path, rendered as a 10 mm wide path, the width represented by each pixel

would be 1/1 thousand ym. For a superstring (2 x 10⁻³⁵ m wide), the pixel width would be 20/1 trillion ym.

Halftone dots vary in size, but their centers are on a regular grid. Halftone dots are laser printed as an array of pixels. A 16 by 16 pixel array (or macropel) can represent any one of 256 shades of gray. As the number of black pixels printed in the center of the macropel array increases, the diameter of the halftone dot increases, creating the impression of a darker gray image. For this reason, a scanner that scans 8 bits (256 shades of gray) can be said to require 256 pixels (arranged in a 16 x 16 pixel array) to reproduce each scanned pixel as a halftone dot. This is the reason a 300 dpi scanner can be represented as 4800 dpi in advertisements (4800 dpi = 300 dpi x 16).

See also GATF (Graphic Arts Technical Foundation) <http://www.GATF.lm.com>

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Units of Measure (Digital and Metric)

1 Byte (B) is defined as the set of bits used to represent 1 character. Commonly: 1 Byte (B) = 8 bits (b). (Byte & bit are best spelled out.) 8 bits can represent 256 different characters. ASCII (ANSI (American National Standards Institute) Standard Code for Information Interchange) (see <http://www.ANSI.org>) uses an 8 bit code to represent 256 characters. 1 ASCII Byte = 8 bits = 1 character 16 bits can be used to represent 65,536 different characters. Unicode uses a 16 bit code to represent 65,536 different characters (some of which are unassigned) to include most of the world's languages in the same, consistent character set. 1 Unicode Byte = 16 bits = 1 character See <http://www.Unicode.org> See also ISO (International Organization for Standardization) for the universal system of measurement known as SI (Système International d'unités). ("ISO" is not an acronym. "ISO" is a word, derived from the Greek isos, meaning "equal", which is the root of the prefix "iso-" that occurs in a host of terms, such as "isometric" (of equal measure or dimensions) and "isonomy" (equality of laws, or of people before the law).) <http://www.ISO.ch>

1 Hertz = 1 cycle per second (e.g. 1 clock cycle in a computer which corresponds roughly to the time required to execute 1 computer instruction. In these terms, a 1 GigaHertz computer executes 1 Billion instructions per second.). A 1,000 cycle per second signal or action is called a 1 KiloHertz signal or action (a 1 KHz signal), each cycle of such a signal is millisecond (ms) long. See BIPM (Bureau International des Poids et Mesures) <http://www.BIPM.fr/enus> for metric units.

1 KiloByte	= 1,000 Bytes	= 1 Thousand Bytes	(KByte)				
1 MegaByte	= 1,000 KBytes	= 1 Million Bytes	(MByte)				
1 GigaByte	= 1,000 MBytes	= 1 Billion Bytes	(GByte)	= 1 Million KiloBytes			
1 TeraByte	= 1,000 GBytes	= 1 Trillion Bytes	(TByte)	= 1 Million MegaBytes	= 1 Billion KiloBytes		
1 PetaByte	= 1,000 TBytes	= 1 Quadrillion Bytes	(PByte)	= 1 Million GigaBytes	= 1 Billion MegaBytes	= 1 Trillion KiloBytes	
1 ExaByte	= 1,000 PBytes	= 1 Quintillion Bytes	(EByte)	= 1 Million TeraBytes	= 1 Billion GigaBytes	= 1 Trillion MegaBytes	
1 ZettaByte	= 1,000 EBytes	= 1 Sextillion Bytes	(ZByte)	= 1 Million PetaBytes	= 1 Billion TeraBytes	= 1 Trillion GigaBytes	
1 YottaByte	= 1,000 ZBytes	= 1 Septillion Bytes	(YByte)	= 1 Million ExaBytes	= 1 Billion PetaBytes	= 1 Trillion TeraBytes	

1 KiloHertz	= 1,000 Hertz	= 1 Thousand Hertz	(kHz)	10**+3	1 Kilometer	= 1,000 meters	= 1 Thousand meters	(km)
1 MegaHertz	= 1,000 KHertz	= 1 Million Hertz	(MHZ)	10**+6	1 Megameter	= 1,000 Kmeters	= 1 Million meters	(Mm)
1 GigaHertz	= 1,000 MHertz	= 1 Billion Hertz	(GHZ)	10**+9	1 Gigameter	= 1,000 Gmeters	= 1 Billion meters	(Gm)
1 TeraHertz	= 1,000 GHertz	= 1 Trillion Hertz	(THz)	10**+12	1 Terameter	= 1,000 Gmeters	= 1 Trillion meters	(Tm)
1 PetaHertz	= 1,000 THertz	= 1 Quadrillion Hertz	(PHz)	10**+15	1 Petameter	= 1,000 Tmeters	= 1 Quadrillion meters	(Pm)
1 ExaHertz	= 1,000 PHertz	= 1 Quintillion Hertz	(EHZ)	10**+18	1 Exameter	= 1,000 Pmeters	= 1 Quintillion meters	(Em)
1 ZettaHertz	= 1,000 EHertz	= 1 Sextillion Hertz	(ZHz)	10**+21	1 Zettameter	= 1,000 Emeters	= 1 Sextillion meters	(Zm)
1 YottaHertz	= 1,000 ZHertz	= 1 Septillion Hertz	(YHz)	10**+24	1 Yottameter	= 1,000 Zmeters	= 1 Septillion meters	(Ym)

1 millisecond	= 1 / 1,000 second	= 1 Thousandth second	(ms)	10**-.3	1 millimeter	= 1 / 1,000 meter	= 1 Thousandth meter	(mm)
1 microsecond	= 1 / 1,000 millisecond	= 1 Millionth second	(us)	10**-.6	1 micrometer	= 1 / 1,000 millimeter	= 1 Millionth meter	(um)
1 nanosecond	= 1 / 1,000 microsecond	= 1 Billionth second	(ns)	10**-.9	1 nanometer	= 1 / 1,000 micrometer	= 1 Billionth meter	(nm)
1 picosecond	= 1 / 1,000 nanosecond	= 1 Trillionth second	(ps)	10**-.12	1 picometer	= 1 / 1,000 nanometer	= 1 Trillionth meter	(pm)
1 femtosecond	= 1 / 1,000 picosecond	= 1 Quadrillionth second	(fs)	10**-.15	1 femtometer	= 1 / 1,000 picometer	= 1 Quadrillionth meter	(fm)
1 attosecond	= 1 / 1,000 femtosecond	= 1 Quintillionth second	(as)	10**-.18	1 attometer	= 1 / 1,000 femtometer	= 1 Quintillionth meter	(am)
1 zeptosecond	= 1 / 1,000 attosecond	= 1 Sextillionth second	(zs)	10**-.21	1 zeptometer	= 1 / 1,000 attometer	= 1 Sextillionth meter	(zm)
1 yoctosecond	= 1 / 1,000 zeptosecond	= 1 Septillionth second	(ys)	10**-.24	1 yoktometer	= 1 / 1,000 zeptometer	= 1 Septillionth meter	(ym)

In the abbreviation for 1 microsecond (us), u is substituted for the symbol for the Greek letter mu.

Because light travels about 300 MegaMeters (Mm) in 1 second and has a wavelength of about 400 nm for blue light (about 700 nm for red light), the frequency of light is about 750 THz for blue light, about 430 THz for red light, and about 230 THz for the 1,300 nm light used in fiber optics). This is because speed (e.g.: C, the speed of light, which is a constant) = wavelength X frequency.

1,000 Bytes = 1 KiloByte (exactly 1 Thousand Bytes in common and legal usage) (exactly 1,024 Bytes = 2**10 = 2 to the 10th power in computer terms); 1,000 KBytes = 1 MegaByte (exactly 1 Million Bytes in common and legal usage) (exactly 1,024 KBytes = 1,048,576 Bytes = 2**20 = 2 to the 20th power in computer terms);

For marketing purposes, a given disk can hold more of the smaller commercial units than the larger computer units. For example a disk that contains 770 computer based MegaBytes (1,048,576 Bytes) sounds smaller than a disk that contains 807 of the commercial MegaBytes (1,000,000 Bytes), even though both disks hold exactly the same number of bytes of data. For both marketing purposes, and because of concern about lawsuits, only the commercial terms have been used in commercial descriptions in recent years.

Conversion from computer based terms to commercial terms. (Including the percent by which the computer terms are larger than the corresponding commercial terms.)
 1,024 Commercial Bytes = 1 Computer Based KiloByte (a difference of 2.4 percent) 1,073,741,824 Commercial Bytes = 1 Computer Based GigaByte (a difference of 7.4 percent)
 1,048,576 Commercial Bytes = 1 Computer Based MegaByte (a difference of 4.9 percent) 1,099,511,627,776 Commercial Bytes = 1 Computer Based TeraByte (a difference of 10 percent)

There are 1,048 Commercial KiloBytes in a Computer Based MegaByte, but only 1,024 Computer KiloBytes in a Computer Based MegaByte.

Computer units are given in powers of two (2**N) because the address space (size of memory, memory capacity) of a computer is determined by the number (N) of address lines available. A 32 bit computer has 32 address lines, has a 32 bit address space, and can address 2**32 (= 4,294,967,296) Bytes of RAM (Random Access Memory). The capacity of a disk or disc is determined by the number of sectors, tracks, platters, layers, and/or sides. These numbers are not based on powers of 2.

Paper, Trees, COLD Pages, Word Processor Pages, OCR Output Pages, and Commercial Scanning

1 pulp tree (loblolly pine) = 1/10th cord of wood = 10,000 pages = 1 file cabinet = 4 boxes = 1/2 GigaByte = 1 CD // 1 lumber tree (20 inch (500 mm) diameter, 110 ft (35 m) tall, 50 years old) = 1 cord = 10 pulp trees (8 in. (200 mm) diameter, 50 ft (15 meters) tall, 20 yrs old) = 1 cord = 4 ft x 4 ft x 8 ft = 128 cubic feet (3.5 cubic meters) as stacked for storage (75 cubic feet of wood, 2 cubic meters of wood) = 100,000 pages = 5 GigaBytes See also AFPA (American Forest & Paper Association) <http://www.AFandPA.org>

1 wordprocessor page, 1 office suite page, or 1 OCR'd (Optical Character Recognition) page = 5 KBytes (all pages listed above are scanned pages) For SGML (Structured Generalized Markup Language), HTML (HyperText ML), XML (Extensible ML), and CGM (Computer Graphics Metafile): see OASIS (Organization for the Advancement of Structured Information Standards) <http://www.OASIS-open.org> W3C (World Wide Web Consortium) <http://www.w3.org/XML>

1 compressed page of COLD (Computer Output to Laser Disc) or COOL (Computer Output On-Line) (including index) = 2 KiloBytes for letter size statements, 4 KiloBytes for 11 x 14 inch fanfolded greenbar computer sheet, 10 KiloBytes for All Points Addressable (APA) pages such as IBM AFP (Advanced Function Printing) and Xerox Metacode. For printing, see also Xplor International <http://www.Xplor.org>

Minimum commercial scanning cost for backfile conversion (more than 1 million pages) = about ~ 5 US cents per page

Compiled by Steve Gilheany, CRM, CDIA

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Digital Image Sizes

Note to Readers

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If you decide to divide this article into parts please print at least the updates, comments, and acknowledgements sections in each of the parts along with:

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