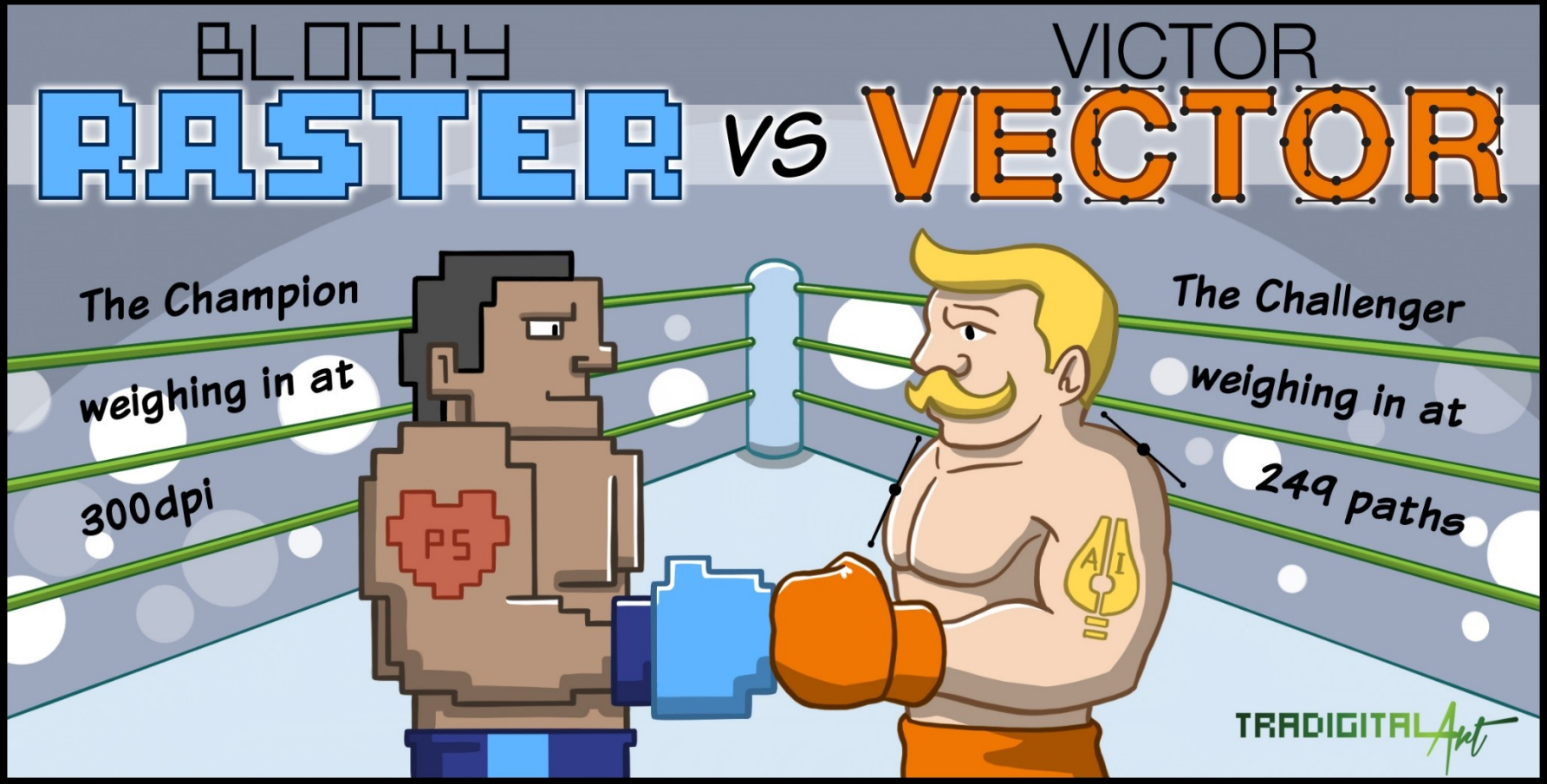
Raster image formats history and future?


BLOCKY
RASTER
VS
VICTOR
VECTOR
The Champion
weighing in at
300dpi
PS
The Challenger
weighing in at
249 paths
AI
TRADIGITALArt

Format-container / codec-compression / muxer-demuxer

Lossless / lossy compression

Display resolution

- Today
  - 8K (7680 x 4320)
  - 10/12-bit (per channel) = HDR

- SVGA – Super VGA (1988)
  - 640 x 480 – 256 colors
  - 800 x 600 – 24-bit colors
  - 1024 x 768 – 24-bit colors
  - 1280 x 1024 – 24-bit colors

VGA – Video Graphics Array (1987)

640 x 480 / 16 colors

320 x 200 / 256 colors (out of 18-bit)

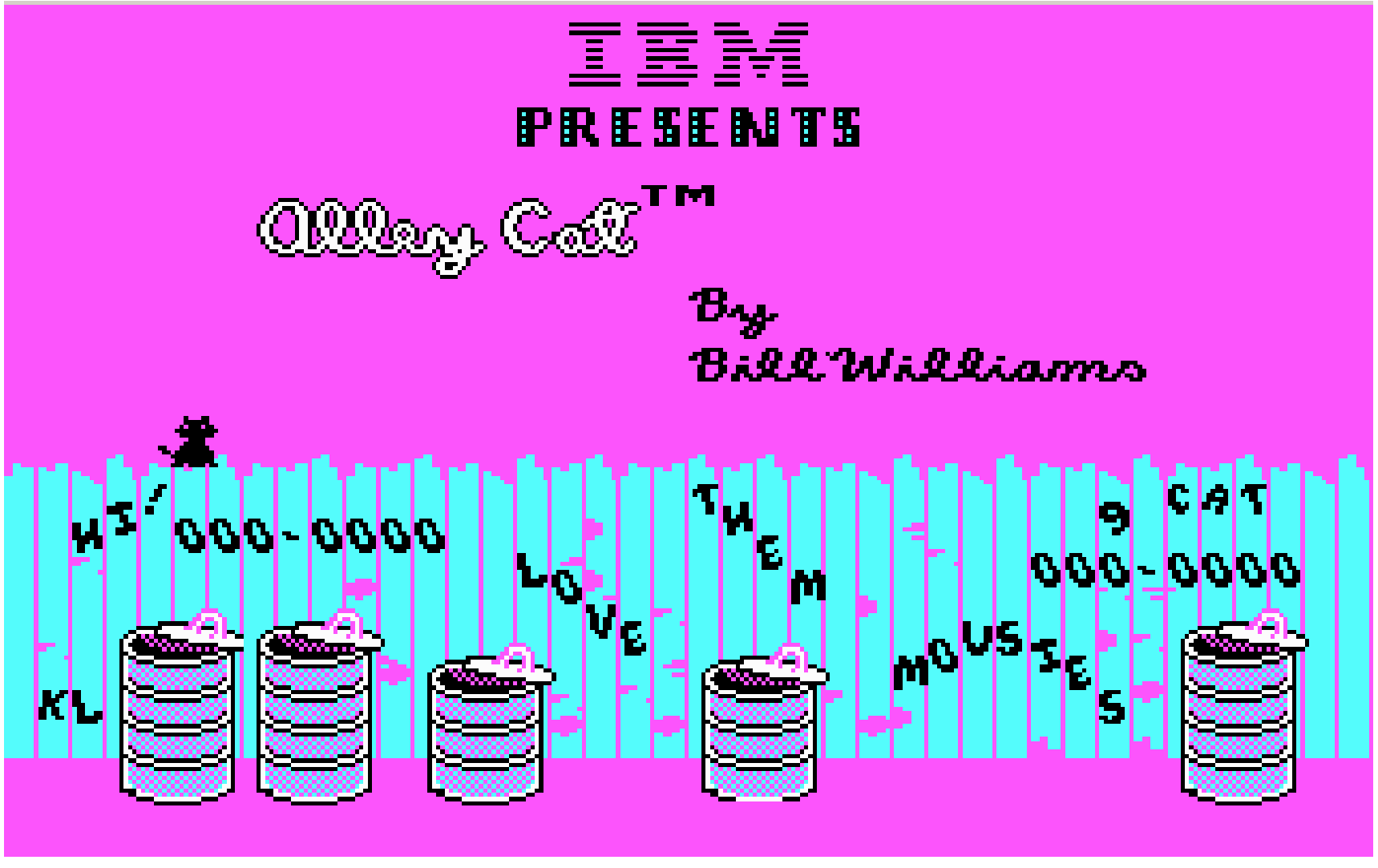
EGA – Enhanced Graphics Adapter (1984)

640 x 350 / 16 colors (out of 64)

CGA – Color Graphics Adapter (1981)

320 x 200 / 4 colors (out of 16)

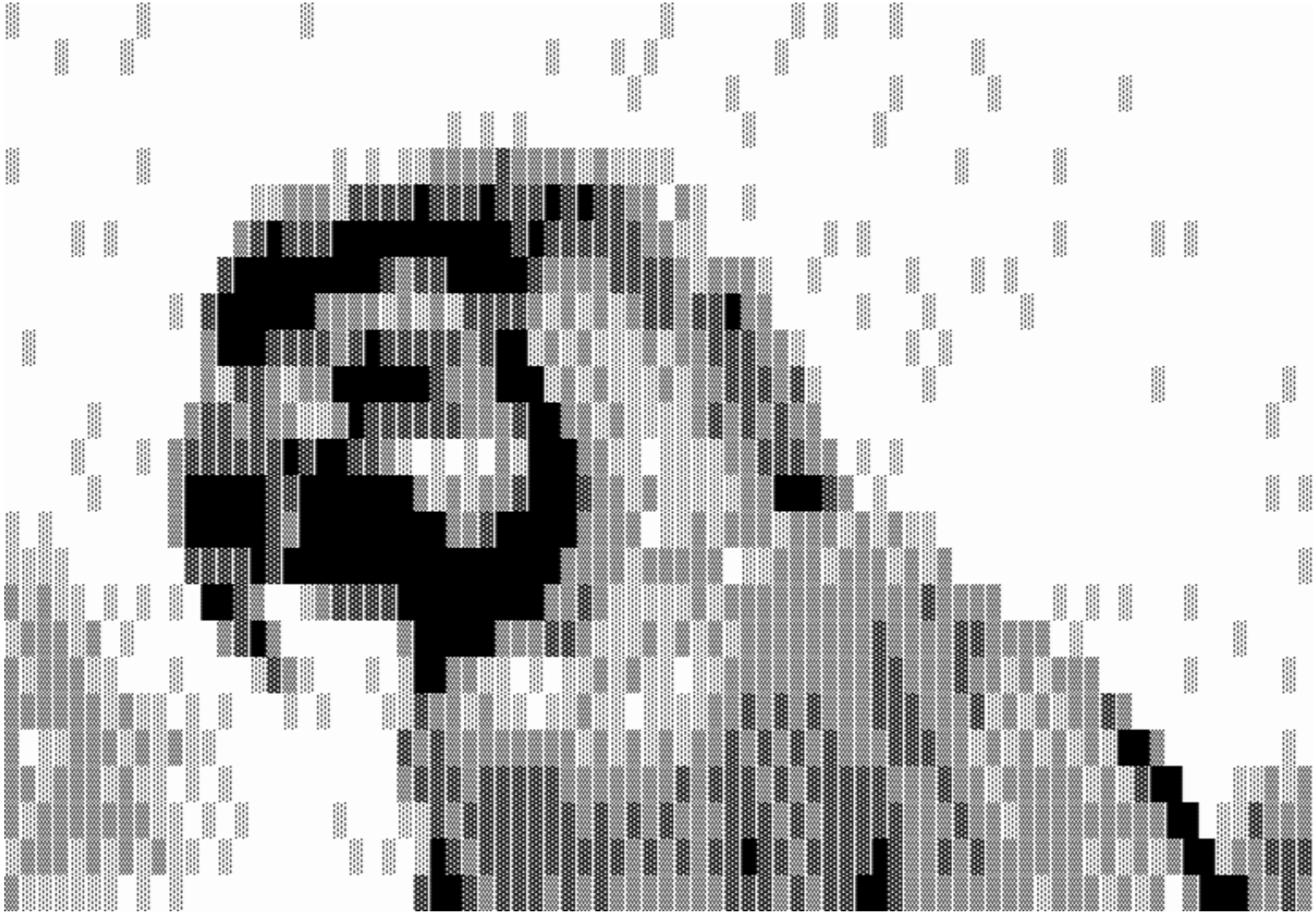
CGA – Color Graphics Adapter (1981)



HGA – Hercules Graphics Card (1982)

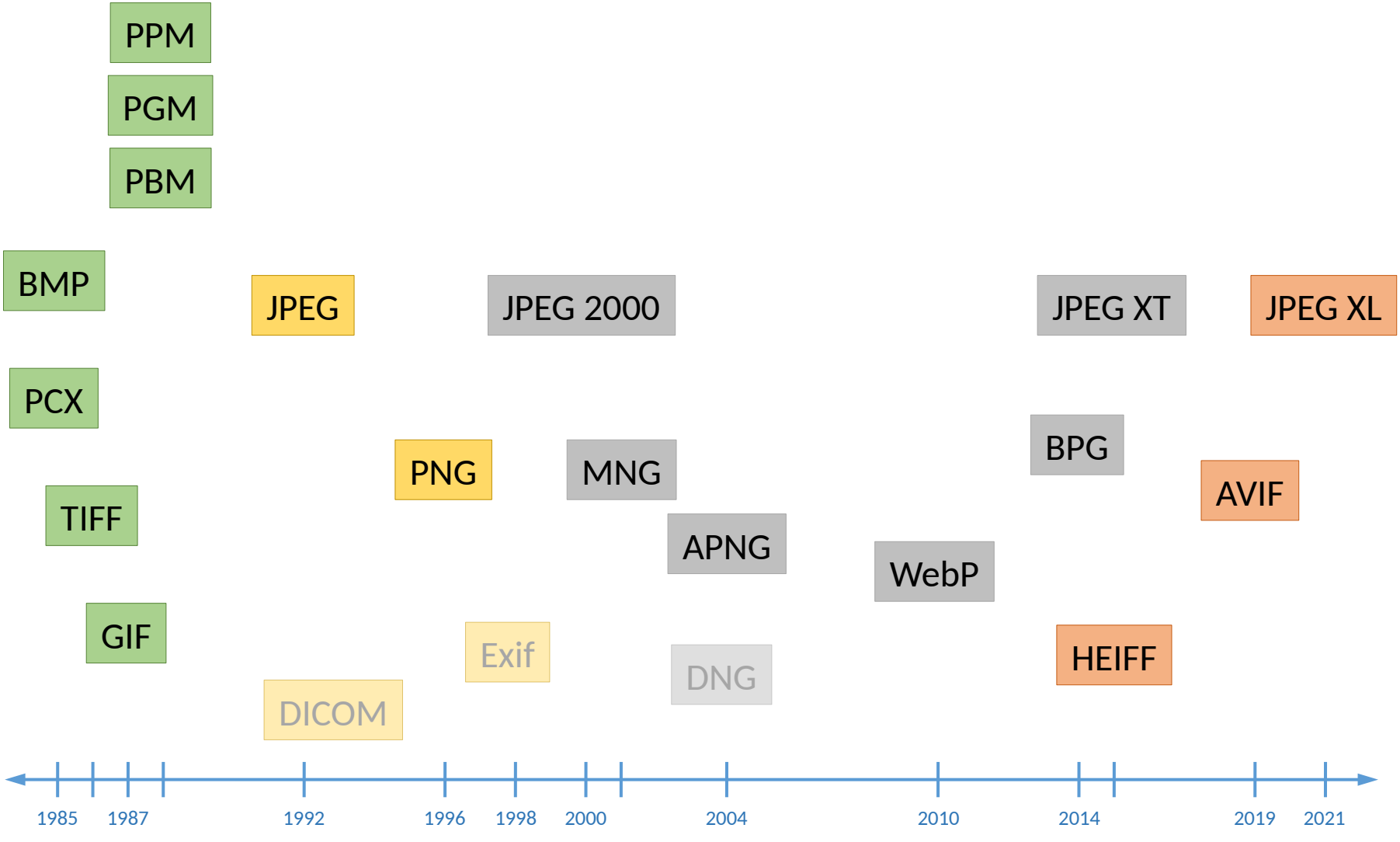
720 x 348

MDA – Monochrome Display Adapter (1981)

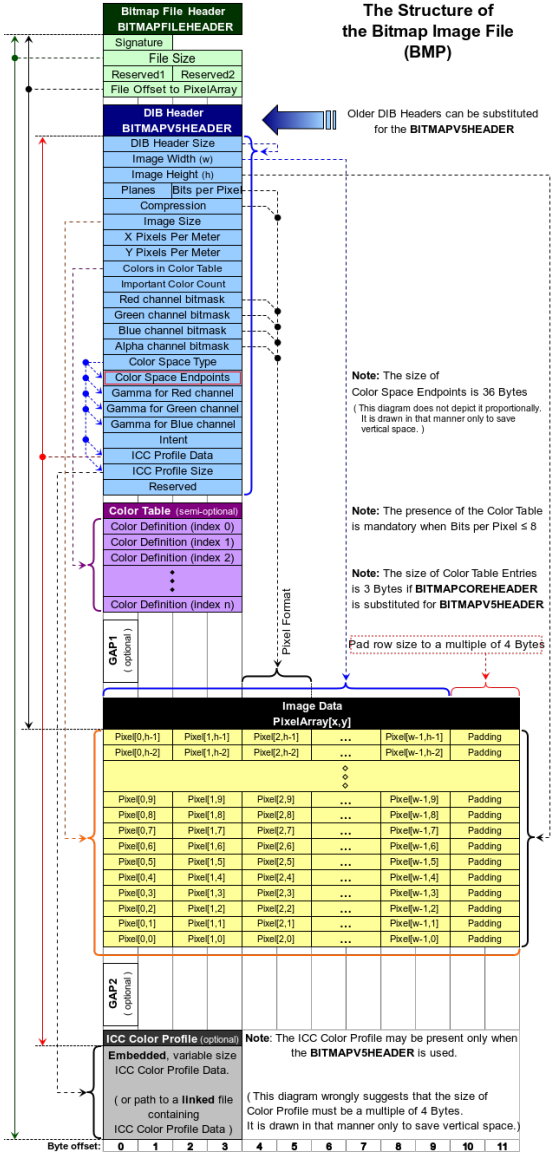


720 x 350 - text only

Image formats – timeline



BMP (DIB) + PNM



PNM = Portable aNy Map

		ASCII	Binary
PBM	Portable BitMap	P1	P4
PGM	Portable GrayMap	P2	P5
PPM	Portable PixMap	P3	P6

header = magic number, width, height

PCX (PiCture eXchange)

Offset hex	Offset dec	Size	Purpose
00	0	1 byte	The fixed header field valued at a hexadecimal `0x0A` (= 10 in decimal).
01	1	1 byte	The version number referring to the Paintbrush software release, which might be: **0** PC Paintbrush version 2.5 using a fixed EGA palette **2** PC Paintbrush version 2.8 using a modifiable EGA palette **3** PC Paintbrush version 2.8 using no palette **4** PC Paintbrush for Windows **5** PC Paintbrush version 3.0, including 24-bit images
02	2	1 byte	The method used for encoding the image data. Can be: **0** No encoding (rarely used) **1** Run-length encoding (RLE)
03	3	1 byte	The number of bits constituting one plane. Most often 1, 2, 4 or 8.
04	4	2 bytes	The minimum x co-ordinate of the image position.
06	6	2 bytes	The minimum y co-ordinate of the image position.
08	8	2 bytes	The maximum x co-ordinate of the image position.
0A	10	2 bytes	The maximum y co-ordinate of the image position.
0C	12	2 bytes	The horizontal image resolution in DPI.
0E	14	2 bytes	The vertical image resolution in DPI.
10	16	48 bytes	The EGA palette for 16-color images.
40	64	1 byte	The first reserved field, usually set to zero.
41	65	1 byte	The number of color planes constituting the pixel data. Mostly chosen to be 1, 3, or 4.
42	66	2 bytes	The number of bytes of one color plane representing a single scan line.
44	68	2 bytes	The mode in which to construe the palette: **1** The palette contains monochrome or color information **2** The palette contains grayscale information
46	70	2 bytes	The horizontal resolution of the source system's screen.
48	72	2 bytes	The vertical resolution of the source system's screen.
4A	74	54 bytes	The second reserved field, intended for future extensions, and usually set to zero bytes.

1985 – ZSoft Corporation

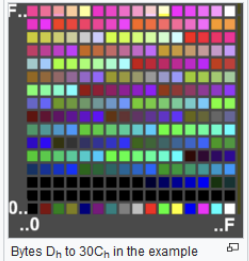
Properties:

- lossless compression (RLE)
- indexed colors (2-256)

used by PC PaintBrush

GIF (Graphics Interchange Format)

Byte # (hex)	Hexadecimal	Text or value	Meaning
0	47 49 46 38 39 61	GIF89a	Header
6	03 00	3	Logical screen width
8	05 00	5	Logical screen height
A	F7		GCT follows for 256 colors with resolution 3 × 8 bits/primary, the lowest 3 bits represent the bit depth minus 1, the highest true bit means that the GCT is present
B	00	0	Background color: index #0; #000000 black
C	00	0	Default pixel aspect ratio, 0:0
D	00 00 00	R (red) G (green) B (blue): 0 0 0	Global Color Table, color #0: #000000, black
10	80 00 00	R (red) G (green) B (blue): 128 0 0	Global Color Table, color #1: transparent bit, not used in image
...	...	...	Global Color Table extends to 30A
30A	FF FF FF	R (red) G (green) B (blue): 255 255 255	Global Color Table, color #255: #ffffff, white
30D	21 F9		Graphic Control Extension *(comment fields precede this in most files)*
30F	04	4	Amount of GCE data, 4 bytes
310	01		Transparent background color; this is a bit field, the lowest bit signifies transparency
311	00 00		Delay for animation in hundredths of a second; **not used**
313	10	16	Color number of transparent pixel in GCT
314	00		End of GCE block
315	2C		Image descriptor
316	00 00 00 00	(0, 0)	North-west corner position of image in logical screen
31A	03 00 05 00	(3, 5)	Image width and height in pixels
31E	00	0	Local color table bit, 0 means none
31F	08	8	Start of image, LZW minimum code size
320	0B	11	Amount of LZW encoded image follow, 11 bytes
321	00 51 FC 1B 28 70 A0 C1 83 01 01	<image data>	11 bytes of image data, see field 320
32C	00	0	End of image data block
32D	3B		File termination



Bytes D_h to $30C_h$ in the example define a palette of 256 colors.

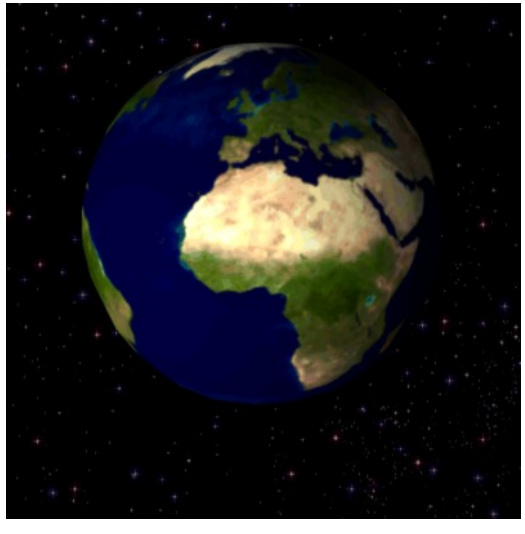
1987 – CompuServe

Properties:

- lossless compression
- indexed colors (2-256)
- animation
- transparency color

LZW (from LZ78)

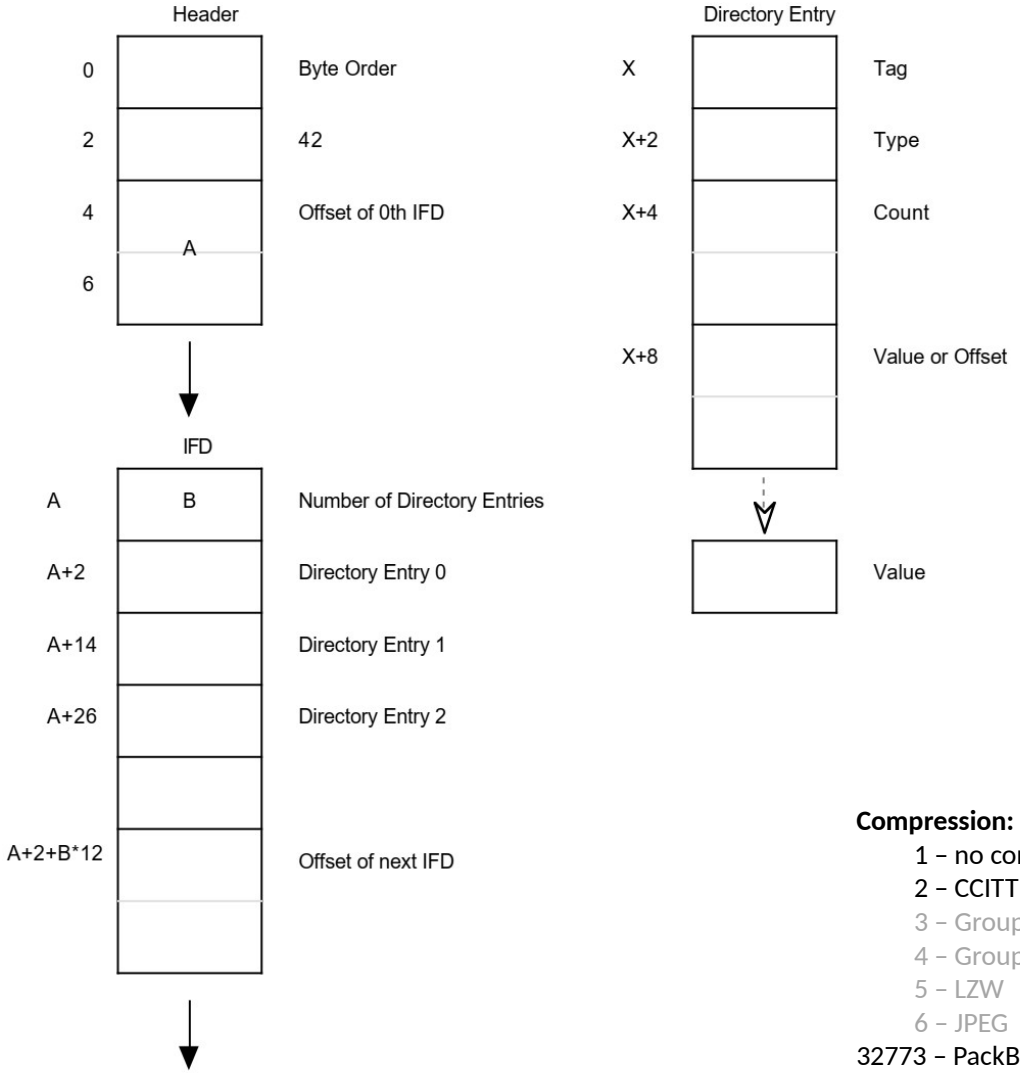
- Terry A. Welch, “A Technique for High Performance Data Compression”, IEEE Computer, vol. 17 no. 6 (June 1984)
- patent from 1986 (Welch -> Unisys)



TIFF (Tagged Image File Format)

- 1986 – Aldus Corporation (Adobe since 1994)
- initially for scanned images (B&W), later grayscale, color
- 1992 – version 6.0 (current)

TIFF (Tagged Image File Format)



1	BYTE	8-bit unsigned int
2	ASCII	zero terminated string
3	SHORT	16-bit unsigned int
4	LONG	32-bit unsigned int
5	RATIONAL	2 LONGs (nom.+denom.)
6	SBYTE	8-bit signed int
7	UNDEFINED	8-bit byte
8	SSHORT	16-bit signed int
9	SLONG	32-bit signed int
10	SRATIONAL	2 SLONGs (nom.+denom.)
11	FLOAT	single precision (4-byte)
12	DOUBLE	double precision (8-byte)

Compression:

1 – no compression
2 – CCITT Group 3 1-Dimensional Modified Huffman run-length encoding
3 – Group 3 fax
4 – Group 4 fax
5 – LZW
6 – JPEG
32773 – PackBits

TIFF (Tagged Image File Format)

TagName	Decimal	Hex	Type	Number of values
NewSubfileType	254	FE	LONG	1
SubfileType	255	FF	SHORT	1
ImageWidth	256	100	SHORT or LONG	1
ImageLength	257	101	SHORT or LONG	1
BitsPerSample	258	102	SHORT	SamplesPerPixel
Compression	259	103	SHORT	1
Uncompressed	1			
CCITT 1D	2			
Group 3 Fax	3			
Group 4 Fax	4			
LZW	5			
JPEG	6			
PackBits	32773			
PhotometricInterpretation	262	106	SHORT	1
WhiteIsZero	0			
BlackIsZero	1			
RGB	2			
RGB Palette	3			
Transparency mask	4			
CMYK	5			
YCbCr	6			
CIELab	8			
Threshholding	263	107	SHORT	1
CellWidth	264	108	SHORT	1
CellLength	265	109	SHORT	1
FillOrder	266	10A	SHORT	1
DocumentName	269	10D	ASCII	
ImageDescription	270	10E	ASCII	
Make	271	10F	ASCII	
Model	272	110	ASCII	
StripOffsets	273	111	SHORT or LONG	StripsPerImage
Orientation	274	112	SHORT	1
SamplesPerPixel	277	115	SHORT	1
RowsPerStrip	278	116	SHORT or LONG	1
StripByteCounts	279	117	LONG or SHORT	StripsPerImage
MinSampleValue	280	118	SHORT	SamplesPerPixel
MaxSampleValue	281	119	SHORT	SamplesPerPixel
XResolution	282	11A	RATIONAL	1
YResolution	283	11B	RATIONAL	1
PlanarConfiguration	284	11C	SHORT	1
PageName	285	11D	ASCII	
XPosition	286	11E	RATIONAL	
YPosition	287	11F	RATIONAL	
FreeOffsets	288	120	LONG	
FreeByteCounts	289	121	LONG	
GrayResponseUnit	290	122	SHORT	1
GrayResponseCurve	291	123	SHORT	2**BitsPerSample
T4Options	292	124	LONG	1
T6Options	293	125	LONG	1
ResolutionUnit	296	128	SHORT	1
PageNumber	297	129	SHORT	2
TransferFunction	301	12D	SHORT	{1 or SamplesPerPixel}* 2** BitsPerSample
Software	305	131	ASCII	
DateTime	306	132	ASCII	20
Artist	315	13B	ASCII	
HostComputer	316	13C	ASCII	
Predictor	317	13D	SHORT	1
WhitePoint	318	13E	RATIONAL	2
PrimaryChromaticities	319	13F	RATIONAL	6
ColorMap	320	140	SHORT	3 * (2**BitsPerSample)
HalftoneHints	321	141	SHORT	2
TileWidth	322	142	SHORT or LONG	1
TileLength	323	143	SHORT or LONG	1
TileOffsets	324	144	LONG	TilesPerImage
TileByteCounts	325	145	SHORT or LONG	TilesPerImage
InkSet	332	14C	SHORT	1
InkNames	333	14D	ASCII	total number of characters in all ink name strings, including zeros
NumberOfInks	334	14E	SHORT	1
DotRange	336	150	BYTE or SHORT	2, or 2* NumberOfInks
TargetPrinter	337	151	ASCII	any
ExtraSamples	338	152	BYTE	number of extra components per pixel
SampleFormat	339	153	SHORT	SamplesPerPixel
SMinSampleValue	340	154	Any	SamplesPerPixel
SMaxSampleValue	341	155	Any	SamplesPerPixel
TransferRange	342	156	SHORT	6
JPEGProc	512	200	SHORT	1
JPEGInterchangeFormat	513	201	LONG	1
JPEGInterchangeFormatLngth	514	202	LONG	1
JPEGRestartInterval	515	203	SHORT	1
JPEGLosslessPredictors	517	205	SHORT	SamplesPerPixel
JPEGPointTransforms	518	206	SHORT	SamplesPerPixel
JPEGQTables	519	207	LONG	SamplesPerPixel
JPEGDCTables	520	208	LONG	SamplesPerPixel
JPEGACTables	521	209	LONG	SamplesPerPixel
YCbCrCoefficients	529	211	RATIONAL	3
YCbCrSubSampling	530	212	SHORT	2
YCbCrPositioning	531	213	SHORT	1
ReferenceBlackWhite	532	214	LONG	2*SamplesPerPixel
Copyright	33432	8298	ASCII	Any

Exif (Exchangeable image file format)

based on TIFF

IFD0 contains other IFDs:

- Exif IFD (8769h)
- GPS IFD (8825h)
- Interoperability IFD (A005h)

IFD1 contains thumbnail

Tag Name	Field Name	Tag ID Dec	Tag ID Hex	Type	Count
A. Tags relating to image data structure					
Image width	ImageWidth	256	100	SHORT or LONG	1
Image height	ImageLength	257	101	SHORT or LONG	1
Number of bits per component	BitsPerSample	258	102	SHORT	3
Compression scheme	Compression	259	103	SHORT	1
Pixel composition	PhotometricInterpretation	262	106	SHORT	1
Orientation of image	Orientation	274	112	SHORT	1
Number of components	SamplesPerPixel	277	115	SHORT	1
Image data arrangement	PlanarConfiguration	284	11C	SHORT	1
Subsampling ratio of Y to C	YCbCrSubSampling	530	212	SHORT	2
Y and C positioning	YCbCrPositioning	531	213	SHORT	1
Image resolution in width direction	XResolution	282	11A	RATIONAL	1
Image resolution in height direction	YResolution	283	11B	RATIONAL	1
Unit of X and Y resolution	ResolutionUnit	296	128	SHORT	1
B. Tags relating to recording offset					
Image data location	StripOffsets	273	111	SHORT or LONG	*S
Number of rows per strip	RowsPerStrip	278	116	SHORT or LONG	1
Bytes per compressed strip	StripByteCounts	279	117	SHORT or LONG	*S
Offset to JPEG SOI	JPEGInterchangeFormat	513	201	LONG	1
Bytes of JPEG data	JPEGInterchangeFormatLength	514	202	LONG	1
C. Tags relating to image data characteristics					
Transfer function	TransferFunction	301	12D	SHORT	3 * 256
White point chromaticity	WhitePoint	318	13E	RATIONAL	2
Chromaticities of primaries	PrimaryChromaticities	319	13F	RATIONAL	6
Color space transformation matrix coefficients	YCbCrCoefficients	529	211	RATIONAL	3
Pair of black and white reference values	ReferenceBlackWhite	532	214	RATIONAL	6
D. Other tags					
File change date and time	DateTime	306	132	ASCII	20
Image title	ImageDescription	270	10E	ASCII	Any
Image input equipment manufacturer	Make	271	10F	ASCII	Any
Image input equipment model	Model	272	110	ASCII	Any
Software used	Software	305	131	ASCII	Any
Person who created the image	Artist	315	13B	ASCII	Any
Copyright holder	Copyright	33432	8298	ASCII	Any

Exif (Exchangeable image file format)

Exif IFD

Tag Name	Field Name	Tag ID Dec	Tag ID Hex	Type	Count
A. Tags Relating to Version					
Exif version	ExifVersion	36864	9000	UNDEFINED	4
Supported Flashpix version	FlashpixVersion	40960	A000	UNDEFINED	4
B. Tag Relating to Image Data Characteristics					
Color space information	ColorSpace	40961	A001	SHORT	1
Gamma	Gamma	42240	A500	RATIONAL	1
C. Tags Relating to Image Configuration					
Meaning of each component	ComponentsConfiguration	37121	9101	UNDEFINED	4
Image compression mode	CompressedBitsPerPixel	37122	9102	RATIONAL	1
Valid image width	PixelXDimension	40962	A002	SHORT or LONG	1
Valid image height	PixelYDimension	40963	A003	SHORT or LONG	1
D. Tags Relating to User Information					
Manufacturer notes	MakerNote	37500	927C	UNDEFINED	Any
User comments	UserComment	37510	9286	UNDEFINED	Any
E. Tag Relating to Related File Information					
Related audio file	RelatedSoundFile	40964	A004	ASCII	13
F. Tags Relating to Date and Time					
Date and time of original data generation	DateTimeOriginal	36867	9003	ASCII	20
Date and time of digital data generation	DateTimeDigitized	36868	9004	ASCII	20
DateTime subseconds	SubSecTime	37520	9290	ASCII	Any
DateTimeOriginal subseconds	SubSecTimeOriginal	37521	9291	ASCII	Any
DateTimeDigitized subseconds	SubSecTimeDigitized	37522	9292	ASCII	Any
G. Tags Relating to Picture-Taking Conditions					
See **Table 8**					
H. Other Tags					
Unique image ID	ImageUniqueID	42016	A420	ASCII	33
Camera Owner Name	CameraOwnerName	42032	A430	ASCII	Any
Body Serial Number	BodySerialNumber	42033	A431	ASCII	Any
Lens Specification	LensSpecification	42034	A432	RATIONAL	4
Lens Make	LensMake	42035	A433	ASCII	Any
Lens Model	LensModel	42036	A434	ASCII	Any
Lens Serial Number	LensSerialNumber	42037	A435	ASCII	Any

G. Tags Relating to Picture-Taking Conditions					
Exposure time	ExposureTime	33434	829A	RATIONAL	1
F number	FNumber	33437	829D	RATIONAL	1
Exposure program	ExposureProgram	34850	8822	SHORT	1
Spectral sensitivity	SpectralSensitivity	34852	8824	ASCII	Any
Photographic Sensitivity	PhotographicSensitivity	34855	8827	SHORT	Any
Optoelectric conversion factor	OECF	34856	8828	UNDEFINED	Any
Sensitivity Type	SensitivityType	34864	8830	SHORT	1
Standard Output Sensitivity	StandardOutputSensitivity	34865	8831	LONG	1
Recommended ExposureIndex	RecommendedExposureIndex	34866	8832	LONG	1
ISO Speed	ISOSpeed	34867	8833	LONG	1
ISO Speed Latitude yyy	ISOSpeedLatitudeyyy	34868	8834	LONG	1
ISO Speed Latitude zzz	ISOSpeedLatitudezzz	34869	8835	LONG	1
Shutter speed	ShutterSpeedValue	37377	9201	SRATIONAL	1
Aperture	ApertureValue	37378	9202	RATIONAL	1
Brightness	BrightnessValue	37379	9203	SRATIONAL	1
Exposure bias	ExposureBiasValue	37380	9204	SRATIONAL	1
Maximum lens aperture	MaxApertureValue	37381	9205	RATIONAL	1
Subject distance	SubjectDistance	37382	9206	RATIONAL	1
Metering mode	MeteringMode	37383	9207	SHORT	1
Light source	LightSource	37384	9208	SHORT	1
Flash	Flash	37385	9209	SHORT	1
Lens focal length	FocalLength	37386	920A	RATIONAL	1
Subject area	SubjectArea	37396	9214	SHORT	2 or 3 or 4
Flash energy	FlashEnergy	41483	A20B	RATIONAL	1
Spatial frequency response	SpatialFrequencyResponse	41484	A20C	UNDEFINED	Any
Focal plane X resolution	FocalPlaneXResolution	41486	A20E	RATIONAL	1
Focal plane Y resolution	FocalPlaneYResolution	41487	A20F	RATIONAL	1
Focal plane resolution unit	FocalPlaneResolutionUnit	41488	A210	SHORT	1
Subject location	SubjectLocation	41492	A214	SHORT	2
Exposure index	ExposureIndex	41493	A215	RATIONAL	1
Sensing method	SensingMethod	41495	A217	SHORT	1
File source	FileSource	41728	A300	UNDEFINED	1
Scene type	SceneType	41729	A301	UNDEFINED	1
CFA pattern	CFAPattern	41730	A302	UNDEFINED	Any
Custom image processing	CustomRendered	41985	A401	SHORT	1
Exposure mode	ExposureMode	41986	A402	SHORT	1
White balance	WhiteBalance	41987	A403	SHORT	1
Digital zoom ratio	DigitalZoomRatio	41988	A404	RATIONAL	1
Focal length in 35 mm film	FocalLengthIn35mmFilm	41989	A405	SHORT	1
Scene capture type	SceneCaptureType	41990	A406	SHORT	1
Gain control	GainControl	41991	A407	RATIONAL	1
Contrast	Contrast	41992	A408	SHORT	1
Saturation	Saturation	41993	A409	SHORT	1
Sharpness	Sharpness	41994	A40A	SHORT	1
Device settings description	DeviceSettingDescription	41995	A40B	UNDEFINED	Any
Subject distance range	SubjectDistanceRange	41996	A40C	SHORT	1

Exif (Exchangeable image file format)

GPS IFD

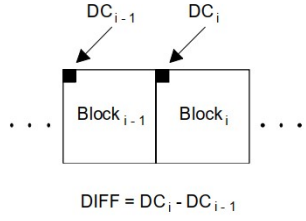
Tag Name	Field Name	Tag ID		Type	Count
		Dec	Hex		
A. Tags Relating to GPS					
GPS tag version	GPSVersionID	0	0	BYTE	4
North or South Latitude	GPSLatitudeRef	1	1	ASCII	2
Latitude	GPSLatitude	2	2	RATIONAL	3
East or West Longitude	GPSLongitudeRef	3	3	ASCII	2
Longitude	GPSLongitude	4	4	RATIONAL	3
Altitude reference	GPSAltitudeRef	5	5	BYTE	1
Altitude	GPSAltitude	6	6	RATIONAL	1
GPS time (atomic clock)	GPSTimeStamp	7	7	RATIONAL	3
GPS satellites used for measurement	GPSSatellites	8	8	ASCII	Any
GPS receiver status	GPSStatus	9	9	ASCII	2
GPS measurement mode	GPSMeasureMode	10	A	ASCII	2
Measurement precision	GPSDOP	11	B	RATIONAL	1
Speed unit	GPSSpeedRef	12	C	ASCII	2
Speed of GPS receiver	GPSSpeed	13	D	RATIONAL	1
Reference for direction of movement	GPSTrackRef	14	E	ASCII	2
Direction of movement	GPSTrack	15	F	RATIONAL	1
Reference for direction of image	GPSImgDirectionRef	16	10	ASCII	2
Direction of image	GPSImgDirection	17	11	RATIONAL	1
Geodetic survey data used	GPSMapDatum	18	12	ASCII	Any
Reference for latitude of destination	GPSDestLatitudeRef	19	13	ASCII	2
Latitude of destination	GPSDestLatitude	20	14	RATIONAL	3
Reference for longitude of destination	GPSDestLongitudeRef	21	15	ASCII	2
Longitude of destination	GPSDestLongitude	22	16	RATIONAL	3
Reference for bearing of destination	GPSDestBearingRef	23	17	ASCII	2
Bearing of destination	GPSDestBearing	24	18	RATIONAL	1
Reference for distance to destination	GPSDestDistanceRef	25	19	ASCII	2
Distance to destination	GPSDestDistance	26	1A	RATIONAL	1
Name of GPS processing method	GPSProcessingMethod	27	1B	UNDEFINED	Any
Name of GPS area	GPSAreaInformation	28	1C	UNDEFINED	Any
GPS date	GPSDateStamp	29	1D	ASCII	11
GPS differential correction	GPSDifferential	30	1E	SHORT	1
Horizontal positioning error	GPSHPositioningError	31	1F	RATIONAL	1

Tag support levels (1)

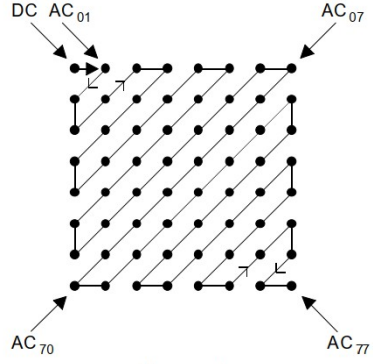
Tag Name	Field Name	Tag ID		Uncompressed			Compressed
		Dec	Hex	Chunky	Planar	YCC	
Image width	ImageWidth	256	100	M	M	M	J
Image height	ImageLength	257	101	M	M	M	J
Number of bits per component	BitsPerSample	258	102	M	M	M	J
Compression scheme	Compression	259	103	M	M	M	J
Pixel composition	PhotometricInterpretation	262	106	M	M	M	N
Image title	ImageDescription	270	10E	R	R	R	R
Manufacturer of image input equipment	Make	271	10F	R	R	R	R
Model of image input equipment	Model	272	110	R	R	R	R
Image data location	StripOffsets	273	111	M	M	M	N
Orientation of image	Orientation	274	112	R	R	R	R
Number of components	SamplesPerPixel	277	115	M	M	M	J
Number of rows per strip	RowsPerStrip	278	116	M	M	M	N
Bytes per compressed strip	StripByteCounts	279	117	M	M	M	N
Image resolution in width direction	XResolution	282	11A	M	M	M	M
Image resolution in height direction	YResolution	283	11B	M	M	M	M
Image data arrangement	PlanarConfiguration	284	11C	O	M	O	J
Unit of X and Y resolution	ResolutionUnit	296	128	M	M	M	M
Transfer function	TransferFunction	301	12D	O	O	O	O
Software used	Software	305	131	O	O	O	O
File change date and time	DateTime	306	132	R	R	R	R
Person who created the image	Artist	315	13B	O	O	O	O
White point chromaticity	WhitePoint	318	13E	O	O	O	O
Chromaticities of primaries	PrimaryChromaticities	319	13F	O	O	O	O
Offset to JPEG SOI	JPEGInterchangeFormat	513	201	N	N	N	N
Bytes of JPEG data	JPEGInterchangeFormatLength	514	202	N	N	N	N
Color space transformation matrix coefficients	YCbCrCoefficients	529	211	N	N	O	O
Subsampling ratio of Y to C	YCbCrSubSampling	530	212	N	N	M	J
Y and C positioning	YCbCrPositioning	531	213	N	N	M	M
Pair of black and white reference values	ReferenceBlackWhite	532	214	O	O	O	O
Copyright holder	Copyright	33432	8298	O	O	O	O
Exif tag	Exif IFD Pointer	34665	8769	M	M	M	M
GPS tag	GPSInfo IFD Pointer	34853	8825	O	O	O	O

JPEG (Joint Photographic Experts Group)

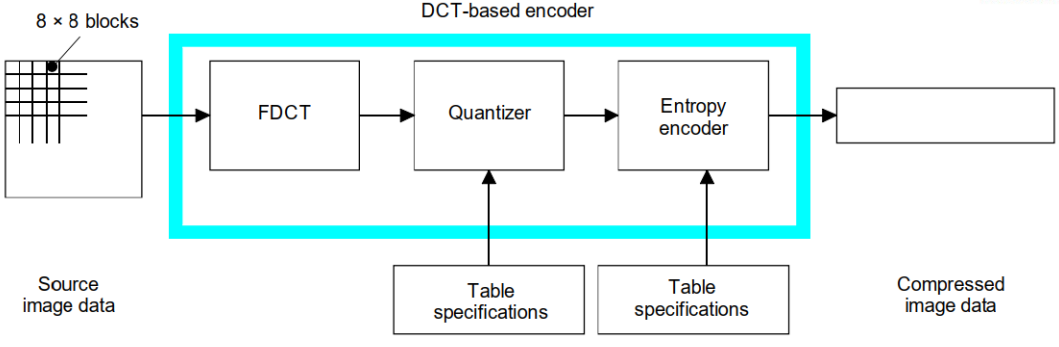
- lossy & lossless
- hierarchical & progressive modes
- Huffman & arithmetic coding
- JPEG vs JFIF (JPEG File Interchange Format)

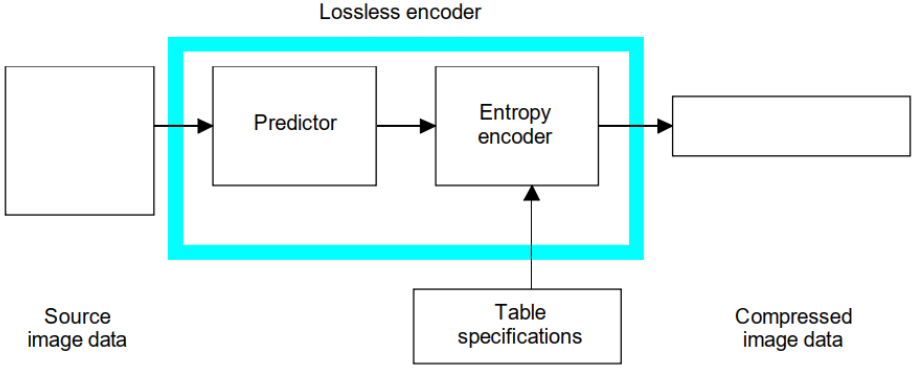


Differential DC encoding



Zig-zag order





Luminance QT

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Chrominance QT

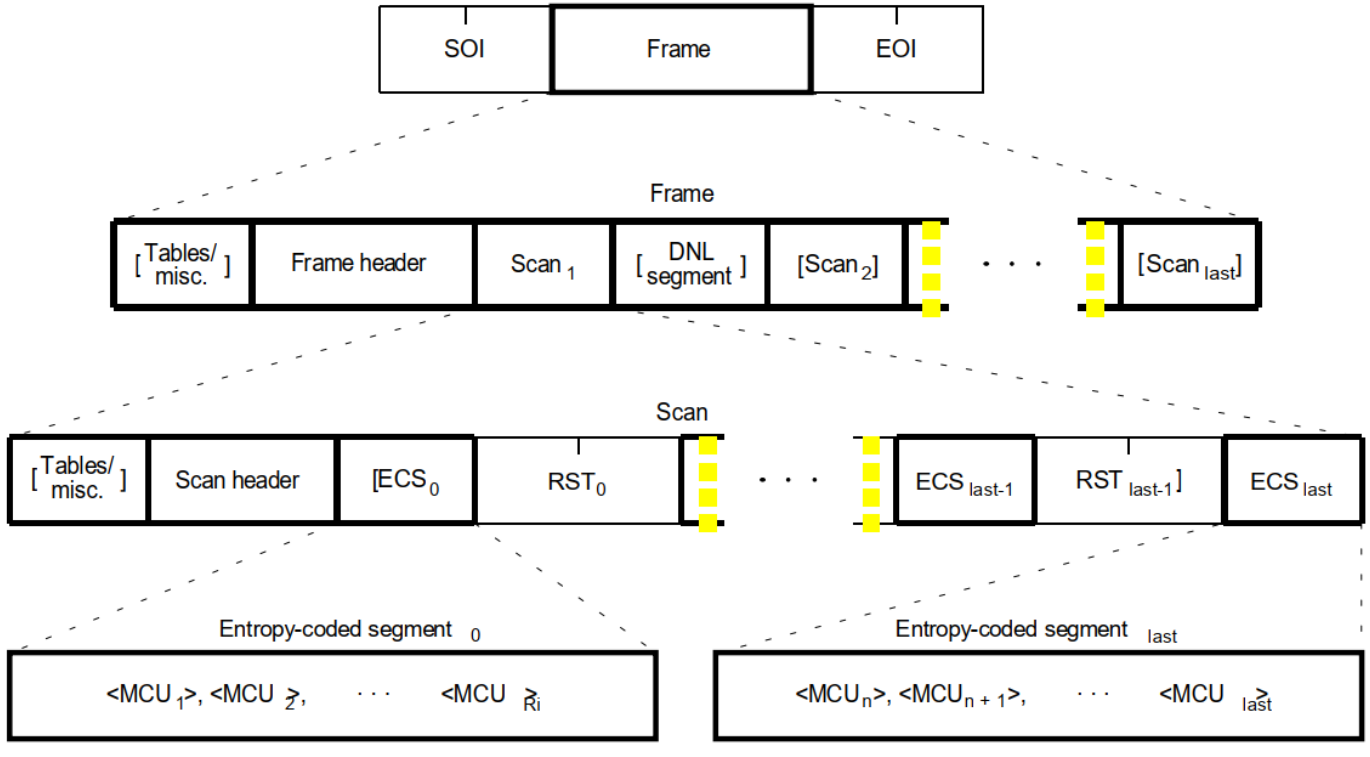
17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

JPEG (Joint Photographic Experts Group)

JFIF markers

Short name	Bytes	Payload	Name	Comments
SOI	0xFF, 0xD8	none	Start Of Image	
SOF0	0xFF, 0xC0	variable size	Start Of Frame (baseline DCT)	Indicates that this is a baseline DCT-based JPEG, and specifies the width, height, number of components, and component subsampling (e.g., 4:2:0).
SOF2	0xFF, 0xC2	variable size	Start Of Frame (progressive DCT)	Indicates that this is a progressive DCT-based JPEG, and specifies the width, height, number of components, and component subsampling (e.g., 4:2:0).
SOF3	0xFF, 0xC3	variable size	Start Of Frame (lossless)	Indicates that this is a lossless JPEG
DHT	0xFF, 0xC4	variable size	Define Huffman Table(s)	Specifies one or more Huffman tables.
DQT	0xFF, 0xDB	variable size	Define Quantization Table(s)	Specifies one or more quantization tables.
DRI	0xFF, 0xDD	4 bytes	Define Restart Interval	Specifies the interval between RSTn markers, in Minimum Coded Units (MCUs). This marker is followed by two bytes indicating the fixed size so it can be treated like any other variable size segment.
SOS	0xFF, 0xDA	variable size	Start Of Scan	Begins a top-to-bottom scan of the image. In baseline DCT JPEG images, there is generally a single scan. Progressive DCT JPEG images usually contain multiple scans. This marker specifies which slice of data it will contain, and is immediately followed by entropy-coded data.
RSTn	0xFF, 0xDn (n=0..7)	none	Restart	Inserted every r macroblocks, where r is the restart interval set by a DRI marker. Not used if there was no DRI marker. The low three bits of the marker code cycle in value from 0 to 7.
APPn	0xFF, 0xEn	variable size	Application-specific	For example, an Exif JPEG file uses an APP1 marker to store metadata, laid out in a structure based closely on TIFF.
COM	0xFF, 0xFE	variable size	Comment	Contains a text comment.
EOI	0xFF, 0xD9	none	End Of Image	

JPEG (Joint Photographic Experts Group)



PNG (Portable Network Graphics)

- motivated by patented LZW in GIF
- PING is not GIF
- 1996 – PNG Working Group
- lossless – deflate compression
- alpha transparency, 24-bit colors
- no animation (till MNG in 2001 and APNG in 2008)
- may contain Exif
- supports progressive mode

PNG (Portable Network Graphics)

PNG header

89	Has the high bit set to detect transmission systems that do not support 8-bit data and to reduce the chance that a text file is mistakenly interpreted as a PNG, or vice versa.
50 4E 47	In ASCII, the letters PNG, allowing a person to identify the format easily if it is viewed in a text editor.
0D 0A	A DOS-style line ending (CRLF) to detect DOS-Unix line ending conversion of the data.
1A	A byte that stops display of the file under DOS when the command type has been used—the end-of-file character.
0A	A Unix-style line ending (LF) to detect Unix-DOS line ending conversion.

Chunks

- length (4 bytes)
- chunk type (4 bytes)
- data (length bytes)
- CRC-32 (4 bytes)

case sensitive – critical, public, reserved, not safe to copy

IHDR – Image header

- width (4 bytes)
- height (4 bytes)
- bit depth (1 byte, values 1, 2, 4, 8, or 16)
- color type (1 byte, values 0, 2, 3, 4, or 6)
- compression method (1 byte, value 0)
- filter method (1 byte, value 0)
- interlace method (1 byte, values 0 "no interlace" or 1 "Adam7 interlace")

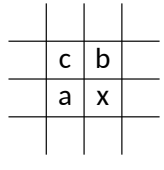
PLTE – Palette

- optional (depending on color type)

IDAT – Image data

- using deflate compression (zlib)

IEND – Image trailer



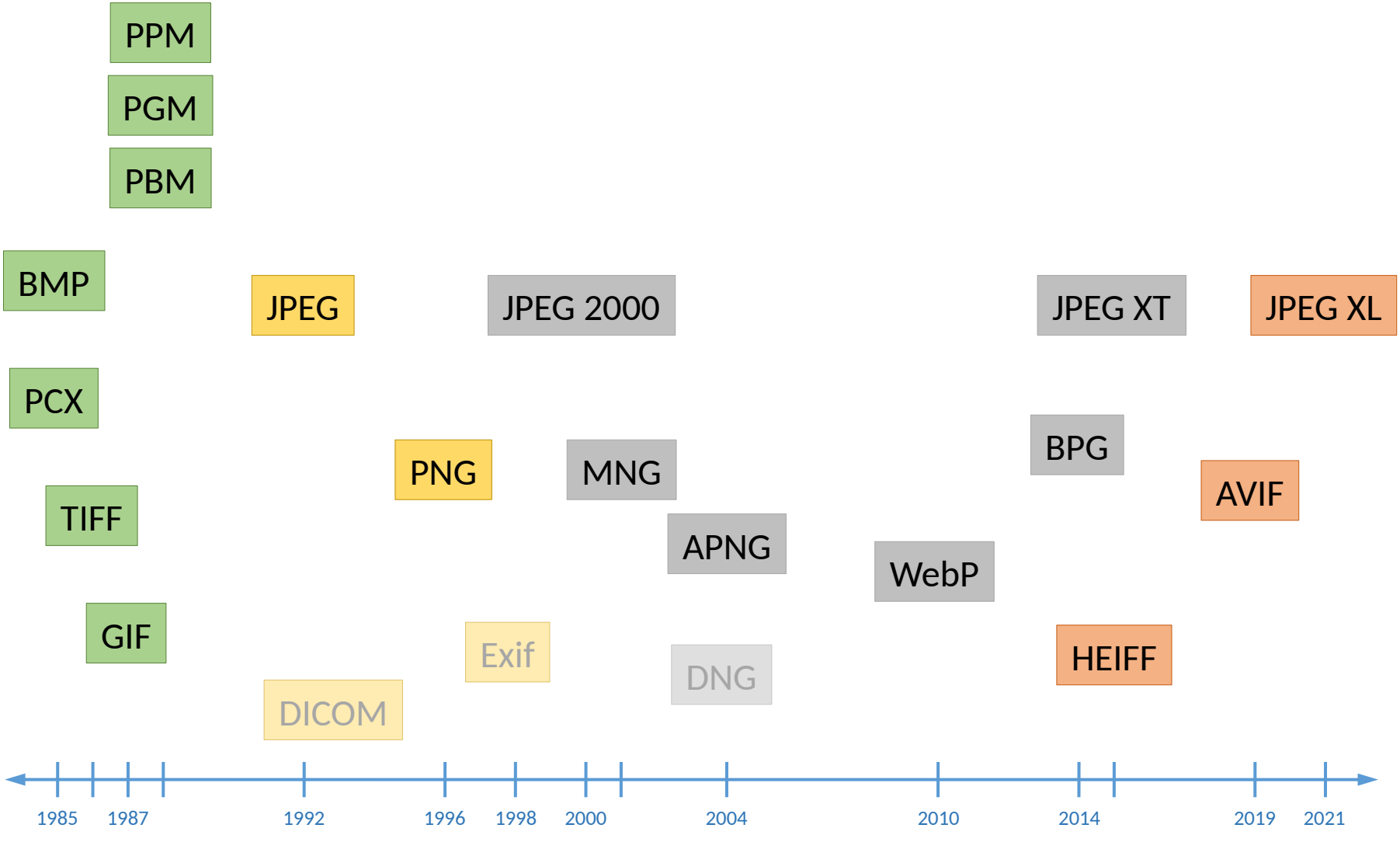
Other chunks:

tRNS	Transparency
cHRM	Primary chromaticities and white point
gAMA	Image gamma
iCCP	Embedded ICC profile
sBIT	Significant bits
sRGB	Standard RGB color space
tEXt	Textual data
zTXt	Compressed textual data
iTXt	International textual data
bKGD	Background color
hIST	Image histogram
pHYs	Physical pixel dimensions
sPLT	Suggested palette
tIME	Image last-modification time

Filter types (for each scanline):

0	None	F(x) = O(x)
1	Sub	F(x) = O(x) - O(a)
2	Up	F(x) = O(x) - O(b)
3	Average	F(x) = O(x) - floor((O(a)+O(b))/2)
4	Paeth	F(x) = O(x) - Paeth(O(a),O(b),O(c)) … min. gradient

Image formats – timeline



HEIF (High Efficiency Image File Format)

- 2015 by MPEG (Moving Picture Experts Group) – MPEG-H
- adopted by Apple in 2017 (iOS 11)
- container format based on ISOBMFF (ISO Base Media File Format)
- defaults to HEIC (HEVC), is also used by AVIF (AV1)
- supports still images, but is especially effective for sequences
- supports derived images (editing on-the-fly – cropping, rotation)
- supports other media types (audio, text)
- lossy & lossless

ISOBMFF

- generalized MP4 (MPEG)
  - based on QuickTime (Apple)
- meant for time-based media files
- sequence of objects (boxes)
- length, box type (4CC), …

ftyp						file type and compatibility
moov						container for all the metadata
	mvhd					movie header, overall declarations
	trak					container for an individual track or stream
		tkhd				track header, overall information about the track
		mdia				container for the media information in a track
			mdhd			media header, overall information about the media
			hdlr			handler, declares the media (handler) type
			minf			media information container
				dinf		data information box, container
					dref	data reference box, declares source(s) of media data in track
				stbl		sample table box, container for the time/space map
					stsd	sample descriptions (codec types, initialization etc.)
					stts	(decoding) time-to-sample
					stsc	sample-to-chunk, partial data-offset information
					stco	chunk offset, partial data-offset information
meta						metadata
	hdlr					handler, declares the metadata (handler) type

MIAF (Multi-Image Application Format) = restricted subset of HEIF

HEIF (High Efficiency Image File Format)

HEIC

Brand	Coding format	Image or sequence?	MIME Type	MIME subtype	File extension
mif1	Any	image	image	heif	.heif
msf1	Any	sequence	image	heif-sequence	.heif
heic	HEVC (Main or Main Still Picture profile)	image	image	heic	.heic
heix	HEVC (Main 10 or format range extensions profile)	image	image	heic	.heic
hevc	HEVC (Main or Main Still Picture profile)	sequence	image	heic-sequence	.heic
hevx	HEVC (Main 10 or format range extensions profile)	sequence	image	heic-sequence	.heic

AVIF

- Alliance for Open Media (Amazon, ARM, Cisco, Apple, Google, Huawei, Intel, Meta, Microsoft, Mozilla, Netflix, nVIDIA, Samsung, ...)
- open & royalty-free
- newer (2019), slightly better compression
- based on AV1 video codec

JPEG XL (JPEG Long-term)

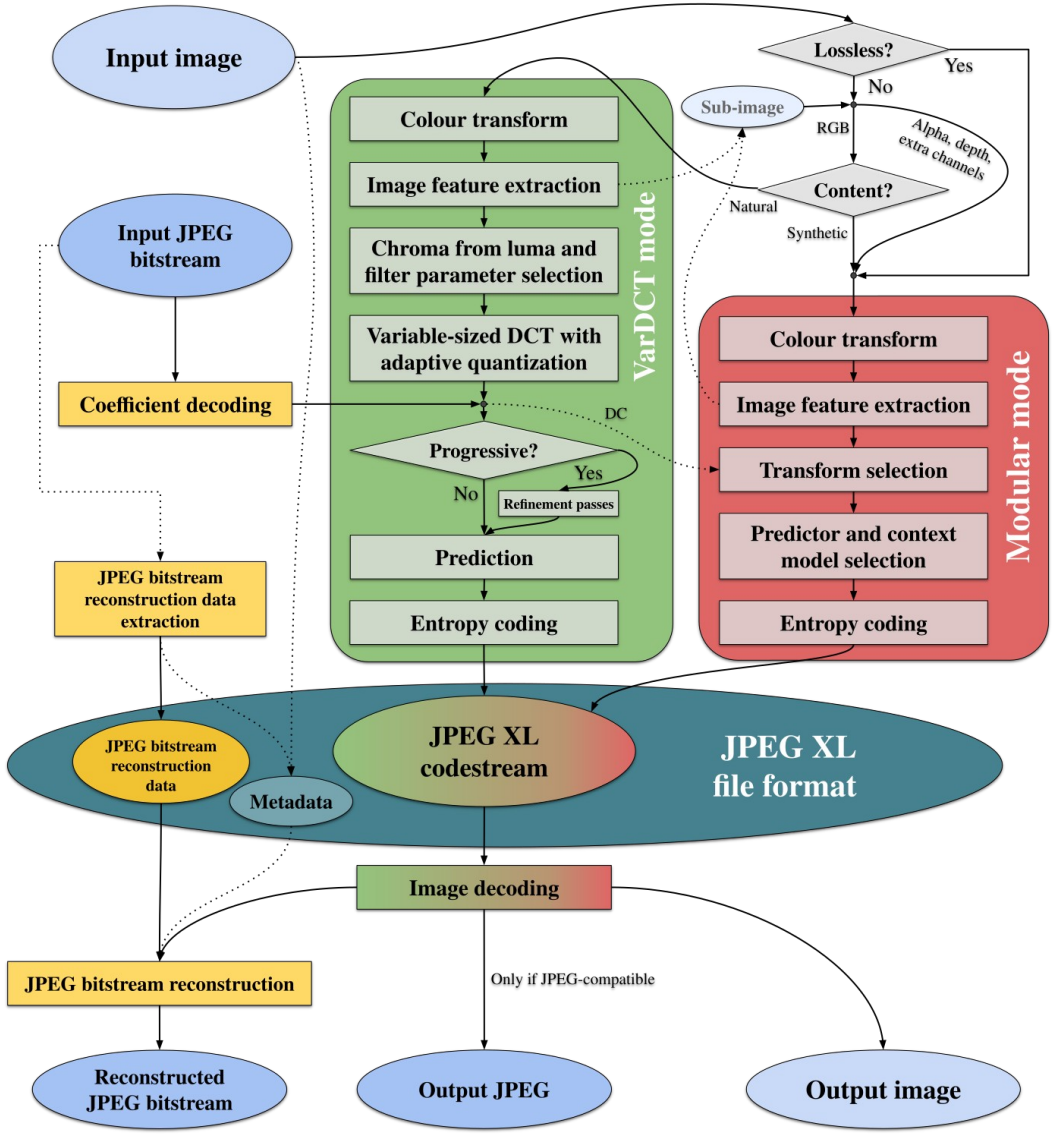
- 2021-22 by JPEG, Google, Cloudinary
- lossy & lossless
- still images of UHR (1 Tpx), 32 bpc, 4099 components
- supports alpha, animation / layers (GIF), progressive mode, HDR
- legacy JPEG transcoding (~20% reduction)
- effective for both – photographic & synthetic images (JPEG vs PNG)
- fast (similar to legacy JPEG)
- open & royalty-free
- reference implementation – libjxl (New BSD licence)

JPEG XL (JPEG Long-term)

VarDCT (Variable-blocksize DCT)
- 2x2 - 256x256 blocks
- non-square blocks (8x32, ...)
- XYB colorspace (from LMS)

Modular
- for lossless or near-lossless
- used internaly even for VarDCT
  - except for AC coefficients
- lossy – modified Haar transform
  - progressive

JPEG recompression
- exact copy
- saves space by superior EC



Modern image formats comparison

Format	Maximum Image Dimensions (in a Single Code Stream)	Maximum Bit Depth, Maximum Number of Channels
JPEG	4,294 megapixels (65,535 x 65,535)	8-bit, three channels (or four for CMYK)
HEIC	35 megapixels (8,192 x 4,320)	16-bit, three channels (alpha or depth as separate image)
AVIF	33 megapixels (7,680 x 4,320 pixels)	12-bit, three channels (alpha or depth as separate image)
JPEG XL	1,152,921,502,459 megapixels (1,073,741,823 x 1,073,741,824)	24-bit (integer) or 32-bit (float),up to 4,100 channels

Compression ratio

- difficult (impossible) to measure objectively
- AVIF slightly beats HEIC
- in low quality (<1 bpp) AVIF beats JPEG XL
- at higher quality, JPEG XL wins

So, who will be the king?