JPEG refers to a lossy compression method for images. The base file format is called JPEG Interchange Format (JIF). There are a couple of extensions to it that change the format slightly. JPEG/Exif is used in digital cameras. JPEG/JFIF is the other most common one. JPEG is a sequence of segments starting w/ 0xFF and then another byte to indicate what it is and sometimes a third and fourth byte indicating how long the segment is. Two 0xFF bytes are for padding. 0xFF followed by 0x00 indicates that the 0xFF byte if not the start of a segment.

I copied this table from Wikipedia (it was the easiest one to read that I found) with the different types of segments:

|  |
| --- |
|  |
| **Short name** | **Bytes** | **Payload** | **Name** | **Comments** |
| **SOI** | 0xFF, 0xD8 | *none* | Start Of Image |  |
| **SOF0** | 0xFF, 0xC0 | *variable size* | Start Of Frame (Baseline [DCT](http://en.wikipedia.org/wiki/Discrete_cosine_transform)) | 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). |
| **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 RST*n* markers, in macroblocks. 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. |
| **RST*n*** | 0xFF, 0xD*n*(*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 3 bits of the marker code cycle in value from 0 to 7. |
| **APP*n*** | 0xFF, 0xE*n* | *variable size* | Application-specific | For example, an [Exif](http://en.wikipedia.org/wiki/Exif) JPEG file uses an APP1 marker to store metadata, laid out in a structure based closely on [TIFF](http://en.wikipedia.org/wiki/TIFF). |
| **COM** | 0xFF, 0xFE | *variable size* | Comment | Contains a text comment. |
| **EOI** | 0xFF, 0xD9 | *none* | End Of Image |  |

JFIF improves on JPEG (using the App0 segment) and allows multiple components to have different resolutions, the encoding of resolution and aspect ratio info into the file, and which color model to use. More tables from Wikipedia:

**JFIF segment format**[[edit](http://en.wikipedia.org/w/index.php?title=JPEG_File_Interchange_Format&action=edit&section=10)]

|  |  |  |
| --- | --- | --- |
| **Field** | **Size (bytes)** | **Description** |
| APP0 marker | 2 | Always equals 0xFFE0 |
| Length | 2 | Length of segment excluding APP0 marker |
| Identifier | 5 | Always equals "JFIF" (with zero following) (0x4A46494600) |
| Version | 2 | First byte is major version (currently 0x01), Second byte is minor version (currently 0x02) |
| Density units | 1 | Units for pixel density fields   * 0 - No units, aspect ratio only specified * 1 - Pixels per inch * 2 - Pixels per centimetre |
| X density | 2 | Integer horizontal pixel density |
| Y density | 2 | Integer vertical pixel density |
| Thumbnail width (*tw*) | 1 | Horizontal size of embedded JFIF thumbnail in pixels |
| Thumbnail height (*th*) | 1 | Vertical size of embedded JFIF thumbnail in pixels |
| Thumbnail data | 3 × *tw* × *th* | Uncompressed 24 bit RGB raster thumbnail |

**JFIF extension (JFXX) segment format**[[edit](http://en.wikipedia.org/w/index.php?title=JPEG_File_Interchange_Format&action=edit&section=11)]

An optional second application segment allows a thumbnail image to be embedded using several different image formats (to save space).

|  |  |  |
| --- | --- | --- |
| **Field** | **Size (bytes)** | **Description** |
| APP0 marker | 2 | Always equals 0xFFE0 |
| Length | 2 | Length of segment excluding APP0 marker |
| Identifier | 5 | Always equals "JFXX" (with zero following) (0x4A46585800) |
| Thumbnail format | 1 | Specifies what data format is used for the thumbnail:   * 0x10 - JPEG format * 0x11 - 1 byte per pixel palettised format * 0x13 - 3 byte per pixel RGB format |
| Thumbnail data | Variable | **JPEG** Must be *JIF* format using YCbCr or just Y, and must not contain JFIF or JFXX segments.   |  |  |  | | --- | --- | --- | | **One byte per pixel** | | | | **Field** | **Size (bytes)** | **Description** | | Thumbnail width (*tw*) | 1 | Horizontal size of embedded palettised thumbnail in pixels | | Thumbnail height (*th*) | 1 | Vertical size of embedded palettised thumbnail in pixels | | Thumbnail palette | 768 | 256 palette entries giving 24-bit colour values | | Thumbnail data | *tw* × *th* | Pixel data - each value gives a position within the palette. |  |  |  |  | | --- | --- | --- | | **Three bytes per pixel** | | | | **Field** | **Size (bytes)** | **Description** | | Thumbnail width (*tw*) | 1 | Horizontal size of embedded RGB thumbnail in pixels | | Thumbnail height (*th*) | 1 | Vertical size of embedded RGB thumbnail in pixels | | Thumbnail data | 3 × *tw* × *th* | Uncompressed 24 bit RGB raster thumbnail | |

Exif uses the App1 segment. The tables I pulled out here are from <http://www.media.mit.edu/pia/Research/deepview/exif.html>

## Exif data structure

Roughly structure of Exif data (APP1) is shown as below. This is a case of "Intel" byte align and it contains JPEG format thumbnail. As described above, Exif data is starts from ASCII character "Exif" and 2bytes of 0x00, then Exif data follows. Exif uses TIFF format to store data. For more datails of TIFF format, please refer to ["TIFF6.0 specification"](http://partners.adobe.com/asn/developer/PDFS/TN/TIFF6.pdf).

|  |  |  |  |
| --- | --- | --- | --- |
| FFE1 | APP1 Marker | | |
| SSSS | APP1 Data | APP1 Data Size | |
| 45786966 0000 | Exif Header | |
| 49492A00 08000000 | TIFF Header | |
| XXXX. . . . | IFD0 (main image) | Directory |
| LLLLLLLL | Link to IFD1 |
| XXXX. . . . | Data area of IFD0 | |
| XXXX. . . . | Exif SubIFD | Directory |
| 00000000 | End of Link |
| XXXX. . . . | Data area of Exif SubIFD | |
| XXXX. . . . | IFD1(thumbnail image) | Directory |
| 00000000 | End of Link |
| XXXX. . . . | Data area of IFD1 | |
| FFD8XXXX. . . XXXXFFD9 | Thumbnail image | |

### Structure of TIFF header

First 8bytes of TIFF format are TIFF header. First 2bytes defines byte align of TIFF data. If it is 0x4949="I I", it means "Intel" type byte align. If it is 0x4d4d="MM", it means "Motorola" type byte align. For example, value '305,419,896' is noted as 0x12345678 by sixteenth system. At the Motrola align, it is stored as 0x12,0x34,0x56,0x78. If it's Intel align, it is stored as 0x78,0x56,0x34,0x12. It seems that most of digicams uses Intel align. Ricoh uses Motorola align. Sony uses Intel align except D700. Kodak DC200/210/240 use Motorola align, but DC220/260 use Intel align though they are using PowerPC! Therefore when we need the value of Exif data, we MUST check byte align every time. Though JPEG data uses Motorola align only, Exif allows both alignment. I can't understand why Exif didn't fix a byte align to Motorola.   
  
Next 2bytes are always 2bytes-length value of 0x002A. If the data uses Intel align, next 2bytes are "0x2a00". If it uses Motorola, they are "0x002a". The last 4bytes of TIFF header are an offset to the first IFD(Image File Directory, described in next chapter). Includes this offset, all the offset value used in TIFF format counts offset bytes from the first of TIFF header("I I" or "MM"). Usually the first IFD starts immediately next to TIFF header, so this offset has value '0x00000008'.

|  |  |  |
| --- | --- | --- |
| Byte align | TAG Mark | Offset to first IFD |
| "I I" or "MM" | 2A00 | 0x00000008 |

### IFD : Image file directory

Next to TIFF header, there is the first IFD:Image File Directory. It contains image information data. At the chart below, the first 2bytes('EEEE') means the number of directory entry contains in this IFD. Then directory entry (12bytes per entry) follows. After last directory entry, there is a 4bytes of data('LLLLLLLL' at the chart), it means an offset to next IFD. If its value is '0x00000000', it means this is the last IFD and there is no linked IFD.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| EEEE | | | | No. of directory entry |
| TTTT | ffff | NNNNNNNN | DDDDDDDD | Entry 0 |
| TTTT | ffff | NNNNNNNN | DDDDDDDD | Entry 1 |
| . . . . . . . . . | | | | . . . . . . |
| TTTT | ffff | NNNNNNNN | DDDDDDDD | Entry EEEE-1 |
| LLLLLLLL | | | | Offset to next IFD |

'TTTT'(2bytes) of above chart is Tag number, this shows a kind of data. 'ffff'(2bytes) is data format, 'NNNNNNNN'(4bytes) is number of components. 'DDDDDDDD'(4bytes) contains a data value or offset to data value.

### Data format

Data format ('ffff' at the above chart) is defined as below. "rational" means a fractional value, it contains 2 signed/unsigned long integer value, and the first represents the numerator, the second, the denominator.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Value | 1 | 2 | 3 | 4 | 5 | 6 |
| Format | unsigned byte | ascii strings | unsigned short | unsigned long | unsigned rational | signed byte |
| Bytes/component | 1 | 1 | 2 | 4 | 8 | 1 |
|  | | | | | | |
| Value | 7 | 8 | 9 | 10 | 11 | 12 |
| Format | undefined | signed short | signed long | signed rational | single float | double float |
| Bytes/component | 1 | 2 | 4 | 8 | 4 | 8 |

## Tag number used by Exif/TIFF

Tag numbers used by Exif/TIFF are shown as below. If the Tag has upper limit of components number, CompoNo column has numeric value. If it has no value, there is no limitation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tags used by IFD0 (main image)** | | | | |
| Tag No. | Tag Name | Format | CompoNo | Desc. |
| 0x010e | ImageDescription | ascii string |  | Describes image |
| 0x010f | Make | ascii string |  | Shows manufacturer of digicam |
| 0x0110 | Model | ascii string |  | Shows model number of digicam |
| 0x0112 | Orientation | unsigned short | 1 | The orientation of the camera relative to the scene, when the image was captured. The start point of stored data is, '1' means upper left, '3' lower right, '6' upper right, '8' lower left, '9' undefined. |
| 0x011a | XResolution | unsigned rational | 1 | Display/Print resolution of image. Large number of digicam uses 1/72inch, but it has no mean because personal computer doesn't use this value to display/print out. |
| 0x011b | YResolution | unsigned rational | 1 |
| 0x0128 | ResolutionUnit | unsigned short | 1 | Unit of XResolution(0x011a)/YResolution(0x011b). '1' means no-unit, '2' means inch, '3' means centimeter. |
| 0x0131 | Software | ascii string |  | Shows firmware(internal software of digicam) version number. |
| 0x0132 | DateTime | ascii string | 20 | Date/Time of image was last modified. Data format is "YYYY:MM:DD HH:MM:SS"+0x00, total 20bytes. In usual, it has the same value of DateTimeOriginal(0x9003) |
| 0x013e | WhitePoint | unsigned rational | 2 | Defines chromaticity of white point of the image. If the image uses CIE Standard Illumination D65(known as international standard of 'daylight'), the values are '3127/10000,3290/10000'. |
| 0x013f | PrimaryChromaticities | unsigned rational | 6 | Defines chromaticity of the primaries of the image. If the image uses CCIR Recommendation 709 primearies, values are '640/1000,330/1000,300/1000,600/1000,150/1000,0/1000'. |
| 0x0211 | YCbCrCoefficients | unsigned rational | 3 | When image format is YCbCr, this value shows a constant to translate it to RGB format. In usual, values are '0.299/0.587/0.114'. |
| 0x0213 | YCbCrPositioning | unsigned short | 1 | When image format is YCbCr and uses 'Subsampling'(cropping of chroma data, all the digicam do that), defines the chroma sample point of subsampling pixel array. '1' means the center of pixel array, '2' means the datum point. |
| 0x0214 | ReferenceBlackWhite | unsigned rational | 6 | Shows reference value of black point/white point. In case of YCbCr format, first 2 show black/white of Y, next 2 are Cb, last 2 are Cr. In case of RGB format, first 2 show black/white of R, next 2 are G, last 2 are B. |
| 0x8298 | Copyright | ascii string |  | Shows copyright information |
| 0x8769 | ExifOffset | unsigned long | 1 | Offset to Exif Sub IFD |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tags used by Exif SubIFD** | | | | |
| Tag No. | Tag Name | Format | CompoNo | Desc. |
| 0x829a | ExposureTime | unsigned rational | 1 | Exposure time (reciprocal of shutter speed). Unit is second. |
| 0x829d | FNumber | unsigned rational | 1 | The actual F-number(F-stop) of lens when the image was taken. |
| 0x8822 | ExposureProgram | unsigned short | 1 | Exposure program that the camera used when image was taken. '1' means manual control, '2' program normal, '3' aperture priority, '4' shutter priority, '5' program creative (slow program), '6' program action(high-speed program), '7' portrait mode, '8' landscape mode. |
| 0x8827 | ISOSpeedRatings | unsigned short | 2 | CCD sensitivity equivalent to Ag-Hr film speedrate. |
| 0x9000 | ExifVersion | undefined | 4 | Exif version number. Stored as 4bytes of ASCII character (like "0210") |
| 0x9003 | DateTimeOriginal | ascii string | 20 | Date/Time of original image taken. This value should not be modified by user program. |
| 0x9004 | DateTimeDigitized | ascii string | 20 | Date/Time of image digitized. Usually, it contains the same value of DateTimeOriginal(0x9003). |
| 0x9101 | ComponentConfiguration | undefined |  | Unknown. It seems value 0x00,0x01,0x02,0x03 always. |
| 0x9102 | CompressedBitsPerPixel | unsigned rational | 1 | The average compression ratio of JPEG. |
| 0x9201 | ShutterSpeedValue | signed rational | 1 | Shutter speed. To convert this value to ordinary 'Shutter Speed'; calculate this value's power of 2, then reciprocal. For example, if value is '4', shutter speed is 1/(2^4)=1/16 second. |
| 0x9202 | ApertureValue | unsigned rational | 1 | The actual aperture value of lens when the image was taken. To convert this value to ordinary F-number(F-stop), calculate this value's power of root 2 (=1.4142). For example, if value is '5', F-number is 1.4142^5 = F5.6. |
| 0x9203 | BrightnessValue | signed rational | 1 | Brightness of taken subject, unit is EV. |
| 0x9204 | ExposureBiasValue | signed rational | 1 | Exposure bias value of taking picture. Unit is EV. |
| 0x9205 | MaxApertureValue | unsigned rational | 1 | Maximum aperture value of lens. You can convert to F-number by calculating power of root 2 (same process of ApertureValue(0x9202). |
| 0x9206 | SubjectDistance | signed rational | 1 | Distance to focus point, unit is meter. |
| 0x9207 | MeteringMode | unsigned short | 1 | Exposure metering method. '1' means average, '2' center weighted average, '3' spot, '4' multi-spot, '5' multi-segment. |
| 0x9208 | LightSource | unsigned short | 1 | Light source, actually this means white balance setting. '0' means auto, '1' daylight, '2' fluorescent, '3' tungsten, '10' flash. |
| 0x9209 | Flash | unsigned short | 1 | '1' means flash was used, '0' means not used. |
| 0x920a | FocalLength | unsigned rational | 1 | Focal length of lens used to take image. Unit is millimeter. |
| 0x927c | MakerNote | undefined |  | Maker dependent internal data. Some of maker such as Olympus/Nikon/Sanyo etc. uses IFD format for this area. |
| 0x9286 | UserComment | undefined |  | Stores user comment. |
| 0xa000 | FlashPixVersion | undefined | 4 | Stores FlashPix version. Unknown but 4bytes of ASCII characters "0100"exists. |
| 0xa001 | ColorSpace | unsigned short | 1 | Unknown, value is '1'. |
| 0xa002 | ExifImageWidth | unsignedshort/long | 1 | Size of main image. |
| 0xa003 | ExifImageHeight | unsignedshort/long | 1 |
| 0xa004 | RelatedSoundFile | ascii string |  | If this digicam can record audio data with image, shows name of audio data. |
| 0xa005 | ExifInteroperabilityOffset | unsigned long | 1 | Extension of "ExifR98", detail is unknown. This value is offset to IFD format data. Currently there are 2 directory entries, first one is Tag0x0001, value is "R98", next is Tag0x0002, value is "0100". |
| 0xa20e | FocalPlaneXResolution | unsigned rational | 1 | CCD's pixel density. |
| 0xa20f | FocalPlaneYResolution | unsigned rational | 1 |
| 0xa210 | FocalPlaneResolutionUnit | unsigned short | 1 | Unit of FocalPlaneXResoluton/FocalPlaneYResolution. '1' means no-unit, '2' inch, '3' centimeter. |
| 0xa217 | SensingMethod | unsigned short | 1 | Shows type of image sensor unit. '2' means 1 chip color area sensor, most of all digicam use this type. |
| 0xa300 | FileSource | undefined | 1 | Unknown but value is '3'. |
| 0xa301 | SceneType | undefined | 1 | Unknown but value is '1'. |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tags used by IFD1 (thumbnail image)** | | | | |
| Tag No. | Tag Name | Format | CompoNo | Desc. |
| 0x0100 | ImageWidth | unsignedshort/long | 1 | Shows size of thumbnail image. |
| 0x0101 | ImageLength | unsignedshort/long | 1 |
| 0x0102 | BitsPerSample | unsigned short | 3 | When image format is no compression, this value shows the number of bits per component for each pixel. Usually this value is '8,8,8' |
| 0x0103 | Compression | unsigned short | 1 | Shows compression method. '1' means no compression, '6' means JPEG compression. |
| 0x0106 | PhotometricInterpretation | unsigned short | 1 | Shows the color space of the image data components. '1' means monochrome, '2' means RGB, '6' means YCbCr. |
| 0x0111 | StripOffsets | unsignedshort/long |  | When image format is no compression, this value shows offset to image data. In some case image data is striped and this value is plural. |
| 0x0115 | SamplesPerPixel | unsigned short | 1 | When image format is no compression, this value shows the number of components stored for each pixel. At color image, this value is '3'. |
| 0x0116 | RowsPerStrip | unsigned short/long | 1 | When image format is no compression and image has stored as strip, this value shows how many rows stored to each strip. If image has not striped, this value is the same as ImageLength(0x0101). |
| 0x0117 | StripByteConunts | unsignedshort/long |  | When image format is no compression and stored as strip, this value shows how many bytes used for each strip and this value is plural. If image has not stripped, this value is single and means whole data size of image. |
| 0x011a | XResolution | unsigned rational | 1 | Display/Print resolution of image. Large number of digicam uses 1/72inch, but it has no mean because personal computer doesn't use this value to display/print out. |
| 0x011b | YResolution | unsigned rational | 1 |
| 0x011c | PlanarConfiguration | unsigned short | 1 | When image format is no compression YCbCr, this value shows byte aligns of YCbCr data. If value is '1', Y/Cb/Cr value is chunky format, contiguous for each subsampling pixel. If value is '2', Y/Cb/Cr value is separated and stored to Y plane/Cb plane/Cr plane format. |
| 0x0128 | ResolutionUnit | unsigned short | 1 | Unit of XResolution(0x011a)/YResolution(0x011b). '1' means inch, '2' means centimeter. |
| 0x0201 | JpegIFOffset | unsigned long | 1 | When image format is JPEG, this value show offset to JPEG data stored. |
| 0x0202 | JpegIFByteCount | unsigned long | 1 | When image format is JPEG, this value shows data size of JPEG image. |
| 0x0211 | YCbCrCoefficients | unsigned rational | 3 | When image format is YCbCr, this value shows constants to translate it to RGB format. In usual, '0.299/0.587/0.114' are used. |
| 0x0212 | YCbCrSubSampling | unsigned short | 2 | When image format is YCbCr and uses subsampling(cropping of chroma data, all the digicam do that), this value shows how many chroma data subsampled. First value shows horizontal, next value shows vertical subsample rate. |
| 0x0213 | YCbCrPositioning | unsigned short | 1 | When image format is YCbCr and uses 'Subsampling'(cropping of chroma data, all the digicam do that), this value defines the chroma sample point of subsampled pixel array. '1' means the center of pixel array, '2' means the datum point(0,0). |
| 0x0214 | ReferenceBlackWhite | unsigned rational | 6 | Shows reference value of black point/white point. In case of YCbCr format, first 2 show black/white of Y, next 2 are Cb, last 2 are Cr. In case of RGB format, first 2 show black/white of R, next 2 are G, last 2 are B. |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Misc Tags** | | | | |
| Tag No. | Tag Name | Format | CompoNo | Desc. |
| 0x00fe | NewSubfileType | unsigned long | 1 |  |
| 0x00ff | SubfileType | unsigned short | 1 |  |
| 0x012d | TransferFunction | unsigned short | 3 |  |
| 0x013b | Artist | ascii string |  |  |
| 0x013d | Predictor | unsigned short | 1 |  |
| 0x0142 | TileWidth | unsigned short | 1 |  |
| 0x0143 | TileLength | unsigned short | 1 |  |
| 0x0144 | TileOffsets | unsigned long |  |  |
| 0x0145 | TileByteCounts | unsigned short |  |  |
| 0x014a | SubIFDs | unsigned long |  |  |
| 0x015b | JPEGTables | undefined |  |  |
| 0x828d | CFARepeatPatternDim | unsigned short | 2 |  |
| 0x828e | CFAPattern | unsigned byte |  |  |
| 0x828f | BatteryLevel | unsigned rational | 1 |  |
| 0x83bb | IPTC/NAA | unsigned long |  |  |
| 0x8773 | InterColorProfile | undefined |  |  |
| 0x8824 | SpectralSensitivity | ascii string |  |  |
| 0x8825 | GPSInfo | unsigned long | 1 |  |
| 0x8828 | OECF | undefined |  |  |
| 0x8829 | Interlace | unsigned short | 1 |  |
| 0x882a | TimeZoneOffset | signed short | 1 |  |
| 0x882b | SelfTimerMode | unsigned short | 1 |  |
| 0x920b | FlashEnergy | unsigned rational | 1 |  |
| 0x920c | SpatialFrequencyResponse | undefined |  |  |
| 0x920d | Noise | undefined |  |  |
| 0x9211 | ImageNumber | unsigned long | 1 |  |
| 0x9212 | SecurityClassification | ascii string | 1 |  |
| 0x9213 | ImageHistory | ascii string |  |  |
| 0x9214 | SubjectLocation | unsigned short | 4 |  |
| 0x9215 | ExposureIndex | unsigned rational | 1 |  |
| 0x9216 | TIFF/EPStandardID | unsigned byte | 4 |  |
| 0x9290 | SubSecTime | ascii string |  |  |
| 0x9291 | SubSecTimeOriginal | ascii string |  |  |
| 0x9292 | SubSecTimeDigitized | ascii string |  |  |
| 0xa20b | FlashEnergy | unsigned rational | 1 |  |
| 0xa20c | SpatialFrequencyResponse | unsigned short | 1 |  |
| 0xa214 | SubjectLocation | unsigned short | 1 |  |
| 0xa215 | ExposureIndex | unsigned rational | 1 |  |
| 0xa302 | CFAPattern | undefined | 1 |  |