



JPEG COMPRESSION

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The JPEG Still Picture Compression Standard

- Joint Photographic Experts Group
- A standards committee set up by the CCITT and the ISO.
- Tasked in the late 1980's to generate a general-purpose standard for compression of almost all continuous tone and still-image applications.
- Published Standard: “Digital Compression and Coding of Continuous-tone Still Images – Requirements and Guidelines,” ISO/IEC 10918-1:1993(E)

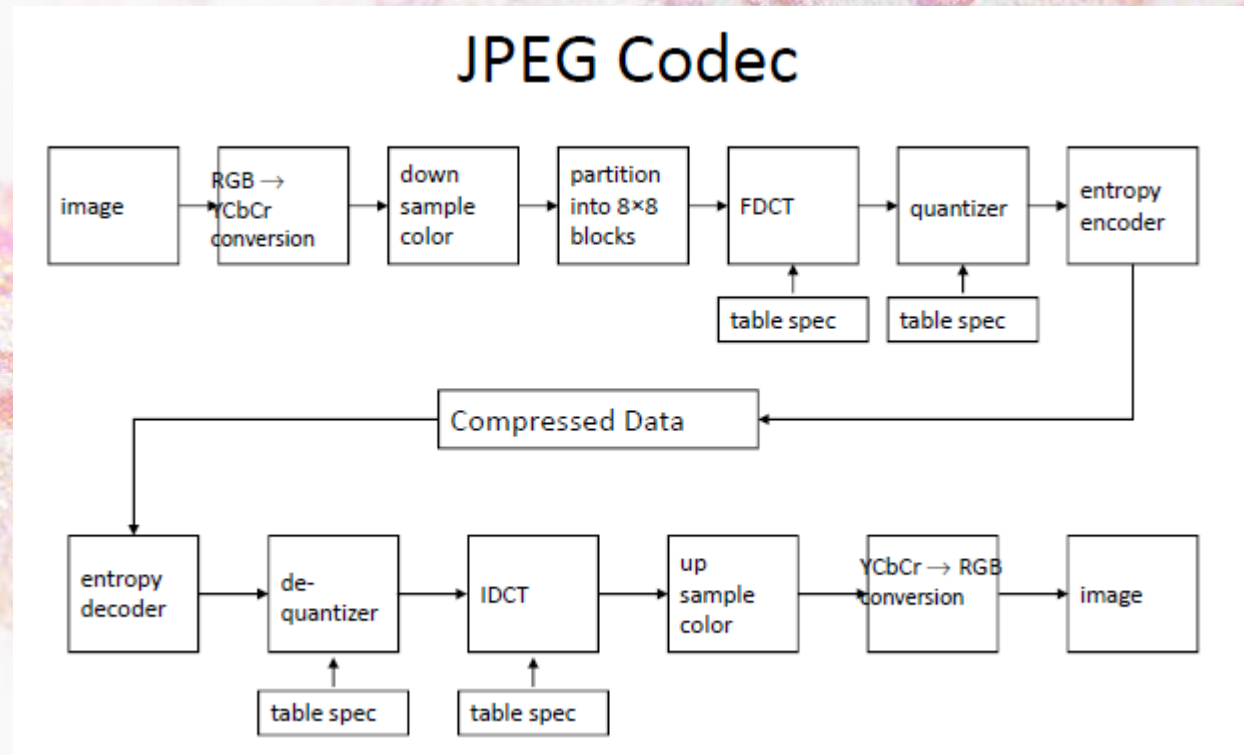
JPEG's Goals for the Standard

- Be at or near the state of the art in compression rate and image fidelity.
- User decides on the trade-off between image fidelity and compression ratio.
- Be applicable to any kind of continuous-tone digital image source (unrestricted with respect to content, complexity, color-range, statistics, etc.)
- Have tractable computational complexity for implementation on a wide range of computational hardware.

JPEG's Modes of Operation

1. **Sequential encoding:** each component (band) encoded in a single raster scan
2. **Progressive encoding:** progressive coarse-to-fine encoding and decoding of entire image
3. **Lossless encoding:** exact recovery of original image
4. **Hierarchical encoding:** multiresolution compression with independently retrievable lower-resolution versions

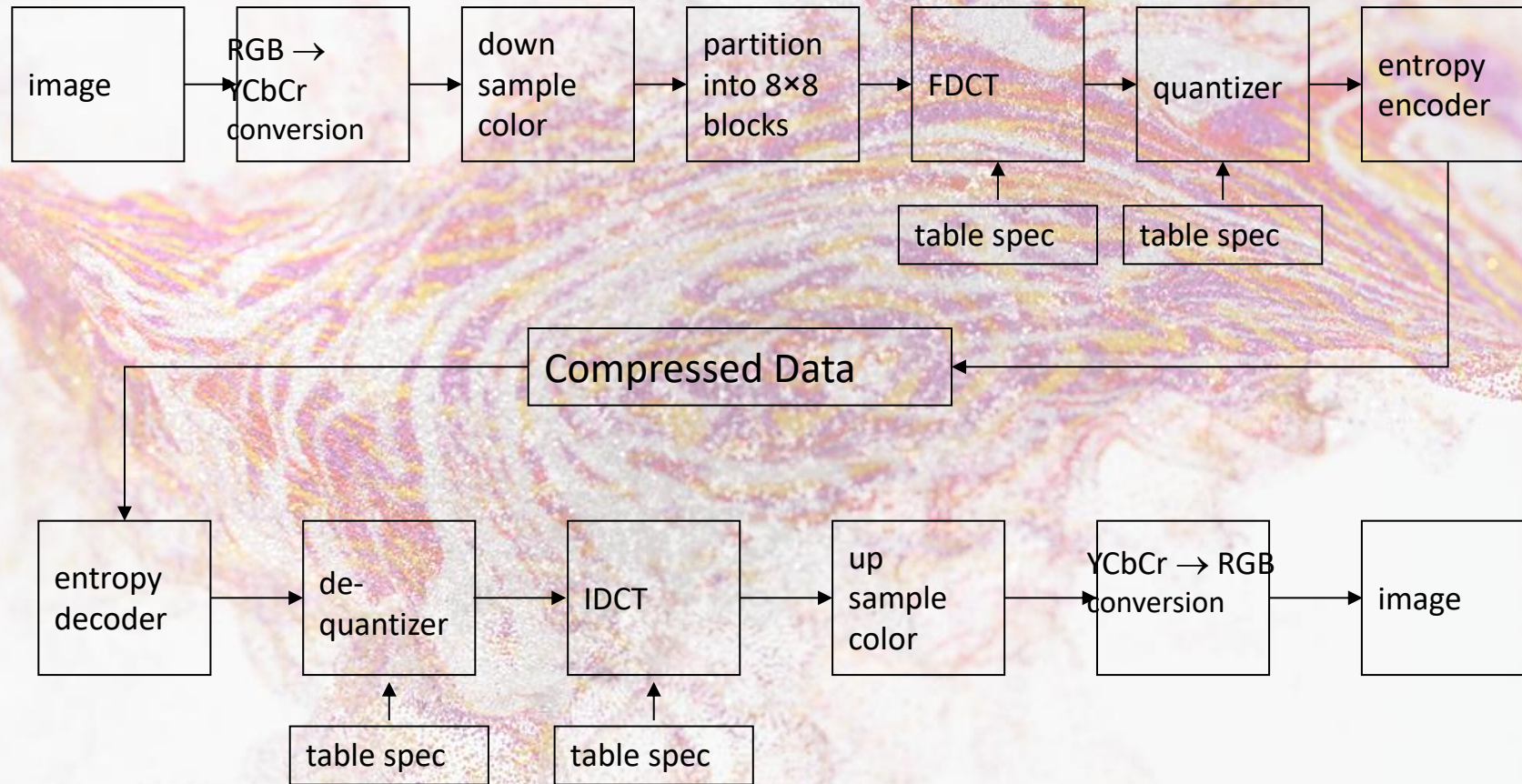
JPEG Codec



JPEG Baseline Process

- DCT-based process
- Source image: 8-bit samples within each component
- Sequential
- Huffman coding: 2 AC and 2 DC tables
- Decoders process scans with 1, 2, 3, or 4 components
- Interleaved and non-interleaved scans

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- Interleaved and non-interleaved scans

What is JPEG?

- A digital image compression standard.
- Stands for 'Joint Photographic Experts Group.'
- Widely used for compressing photographic images on the web.

JPEG Compression Process

- Lossy compression technique.
- Reduces file size by discarding some image data.
- Key steps: Color transformation, downsampling, discrete cosine transform, quantization, entropy coding.

Benefits of Using JPEG

- High compression ratio.
- Widely supported by browsers, image editors, and digital cameras.
- Adjustable compression levels (quality vs. size).

Limitations of JPEG Compression

- Lossy compression leads to quality degradation.
- Not ideal for images with transparency or sharp edges (like text).
- Limited color depth.

Visual Examples

- Show a comparison between an uncompressed image and its compressed JPEG version.
- Highlight the differences in image quality.

Comparing JPEG with PNG and GIF

- PNG: Lossless compression, ideal for graphics and transparency.
- GIF: Suitable for simple images with few colors, supports animation.
- JPEG: Best for photos with complex colors and gradients.

Common Uses of JPEG

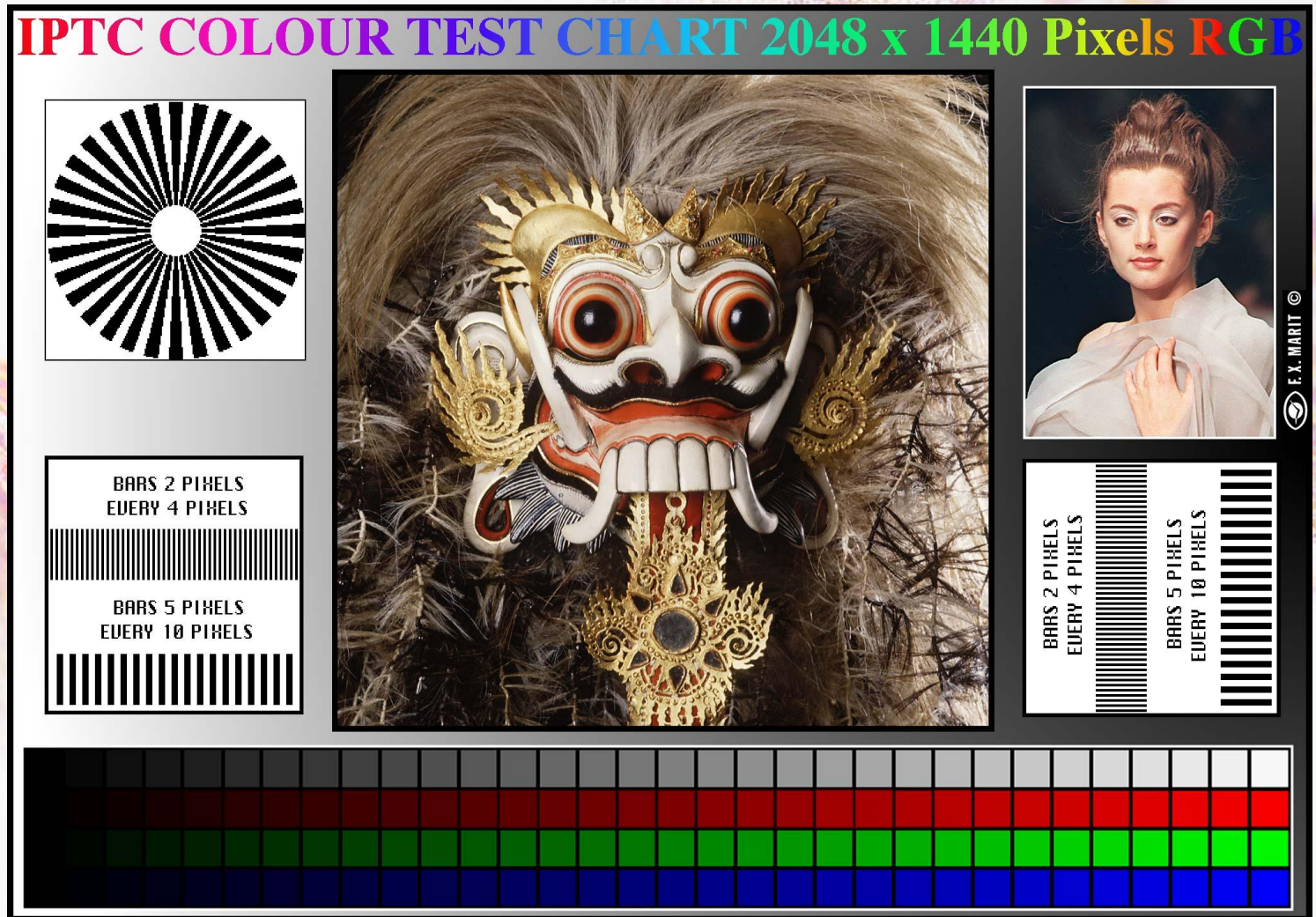
- Used for web images, digital photography, email attachments, etc.
- Supported across all platforms and devices.

Summary of JPEG

- JPEG offers efficient image compression with a trade-off in quality.
- It is the go-to format for photos on the internet and in digital media.

A Standard Color Test Chart

IPTC COLOUR TEST CHART 2048 x 1440 Pixels RGB



The chart includes several test patterns and images:

- Top Left:** A circular pattern of black and white radial lines.
- Top Center:** A detailed image of a Balinese mask with gold and white features and a large white beard.
- Top Right:** A portrait of a woman with brown hair in a bun, wearing a white garment.
- Bottom Left:** A vertical bar chart with two sections. The top section is labeled "BARS 2 PIXELS EVERY 4 PIXELS" and the bottom section is labeled "BARS 5 PIXELS EVERY 10 PIXELS".
- Bottom Center:** A horizontal bar chart with three rows of colored squares: the top row is grey, the middle row is red, and the bottom row is green.
- Bottom Right:** A vertical bar chart with two sections. The top section is labeled "BARS 2 PIXELS EVERY 4 PIXELS" and the bottom section is labeled "BARS 5 PIXELS EVERY 10 PIXELS".

© F.X. MARIT

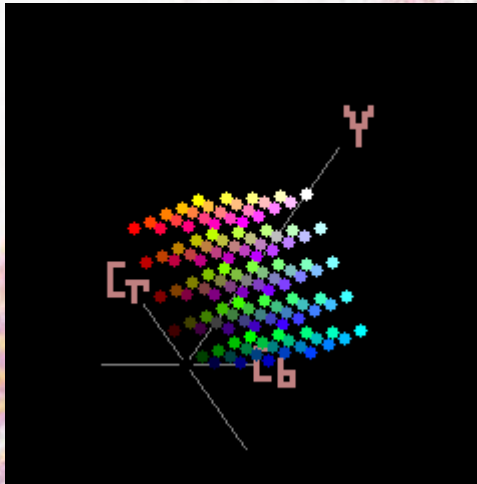
We'll use the image in some of the following slides.



Color Conversion: RGB \rightarrow YCbCr

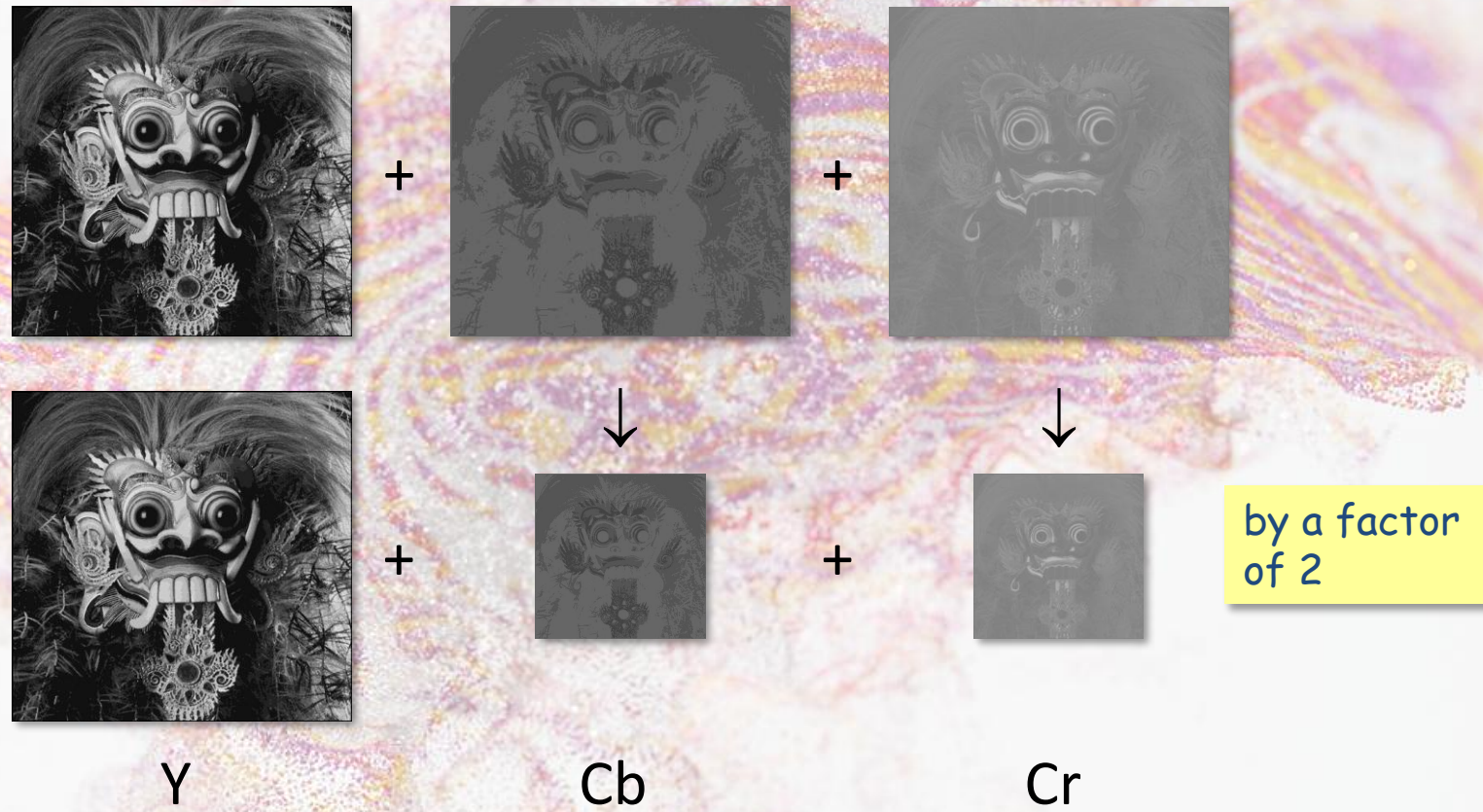


$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.25678824 & 0.50412941 & 0.09790588 \\ -0.14822290 & -0.29099279 & 0.43921596 \\ 0.43921569 & -0.36778831 & -0.07142737 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}$$

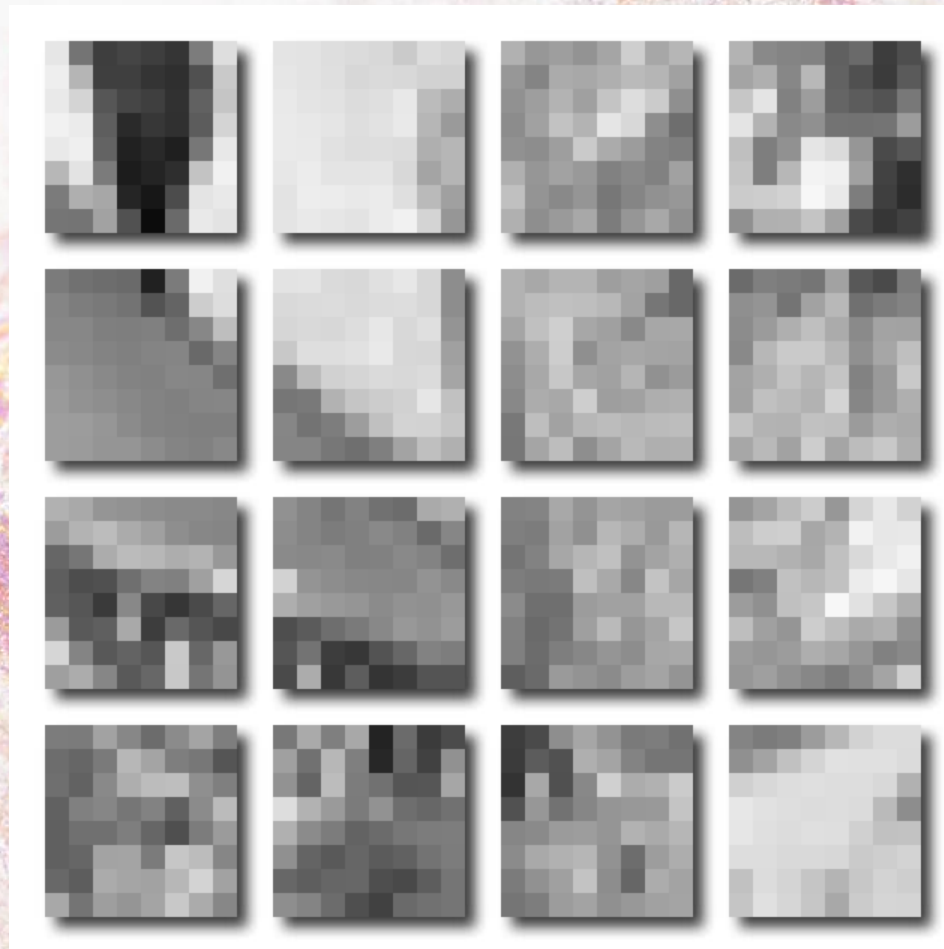


YCbCr, Y'CbCr, or Y Pb/Cb Pr/Cr, also written as $YC_B C_R$ or $Y' C_B C_R$, is a family of [color spaces](#) used as a part of the [color image pipeline](#) in [video](#) and [digital photography](#) systems. Y' is the [luma](#) component and C_B and C_R are the blue-difference and red-difference [chroma](#) components. Y' (with prime) is distinguished from Y , which is [luminance](#), meaning that light intensity is nonlinearly encoded based on [gamma corrected RGB](#) primaries.

Downsample Color Bands



Partition Each Band into 8×8 Blocks



Prep for Forward Discrete Cosine Transform

- Each image band is operated on independently.
- Each 8×8 image block is operated on independently.
- Shift all image values from $I \in [0, 2^P - 1]$ to $I \in [-2^{P-1}, 2^{P-1} - 1]$. E.g. $[0, 255] \rightarrow [-128, 127]$.
- The FDCT decomposes each block into a set of coefficients with respect to the 64 orthogonal basis functions shown on the next slide.

DCT Functions and Variables

$\mathcal{F}\{\mathbf{I}\}(v,u;r,c)$ - DCT of 8×8 block from \mathbf{I} starting at (r,c)

$L(x)$ - Normalization Factor

$\phi(v,u;r,c)$ - 2D Cosine Basis Function, (v,u)

r - image row index (vertical, increasing down)

c - image column index (horizontal, increasing right)

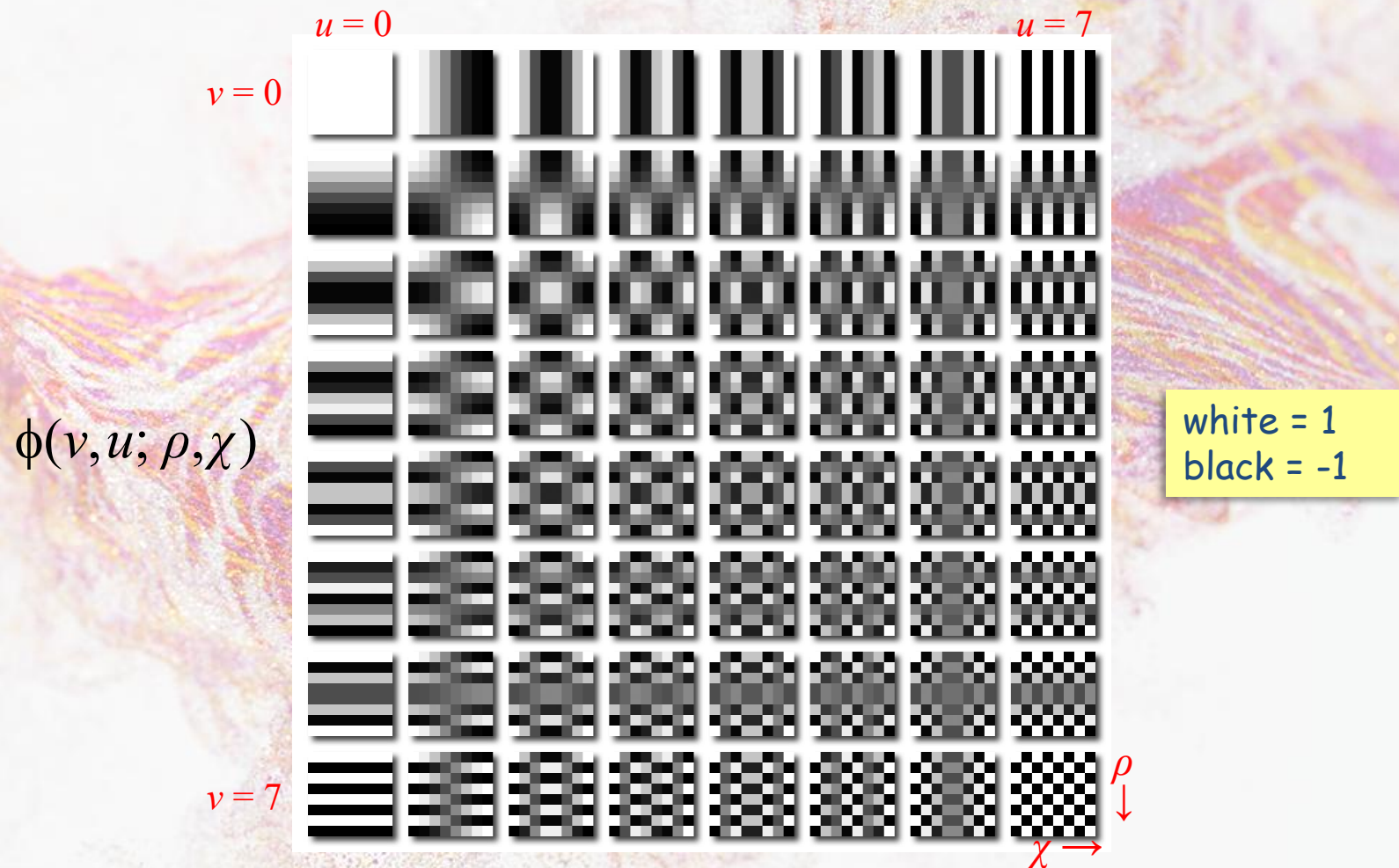
ρ - DCT row index (horizontal wave fronts, vertical propagation down)

χ - DCT column index (vertical wave fronts, horizontal propagation right)

v - DCT row frequency index (vertical, increasing down)

u - DCT column frequency index (horizontal, increasing right)

DCT Basis Functions

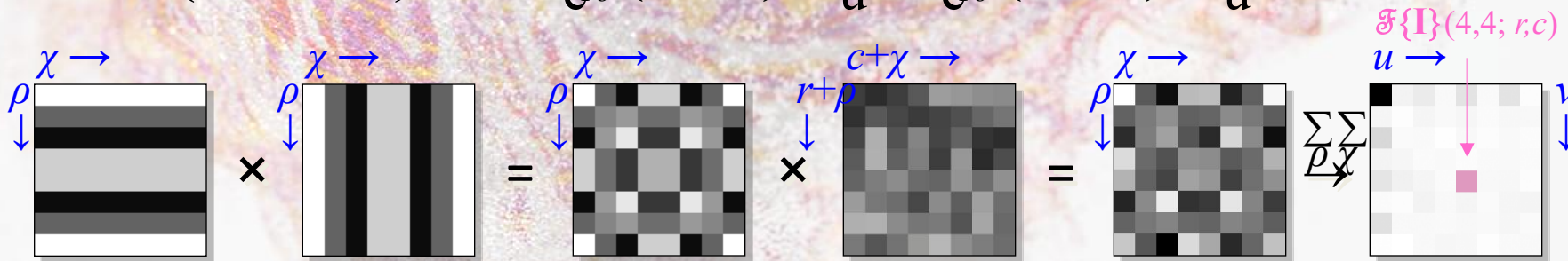


Forward Discrete Cosine Transform

$$\mathcal{F}\{\mathbf{I}\}(v,u;r,c) = \sum_{r=0}^7 \sum_{c=0}^7 \frac{1}{4} L(v)L(u)\phi(v,u;r,c) \mathbf{I}(r+c, c+c)$$

$$L(x) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for } x = 0 \\ 1 & \text{otherwise} \end{cases} \quad \begin{matrix} (r,c) \in \{0,8,16,\dots,R\} \times \{0,8,16,\dots,C\}, \\ (v,u), (\rho,\chi) \in \{0,\dots,7\} \times \{0,\dots,7\}. \end{matrix}$$

$$\phi(v,u;r,c) = \cos\left(\frac{\pi}{8}(2r+1)\rho v\right) \cos\left(\frac{\pi}{8}(2c+1)\rho u\right)$$

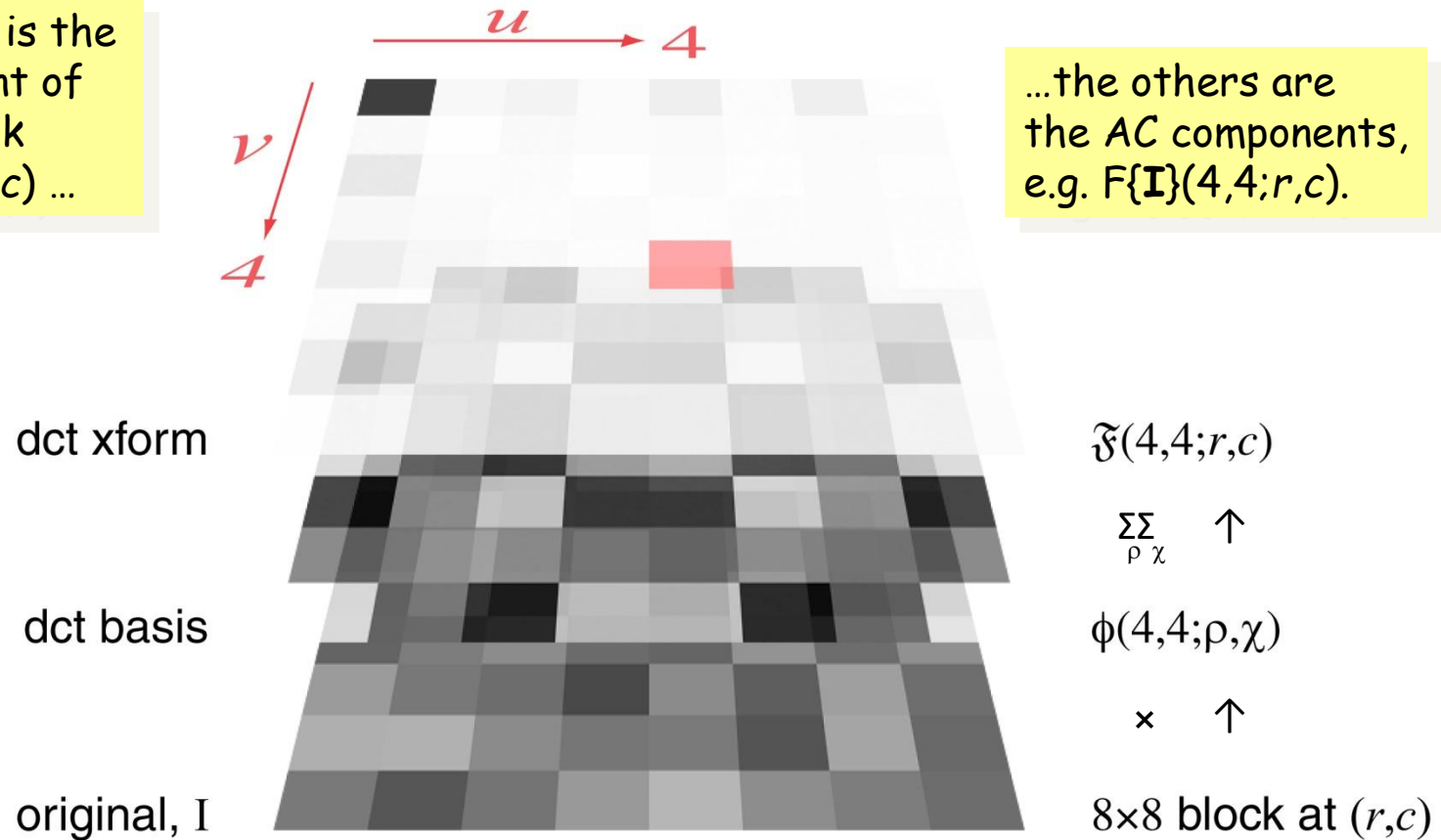


row cos: ($v=4, \rho$) col cos: ($u=4, \rho$) = col cos \times row cos \times block of \mathbf{I} @ (r, c) w. product $\mathcal{F}(v,u;r,c)$

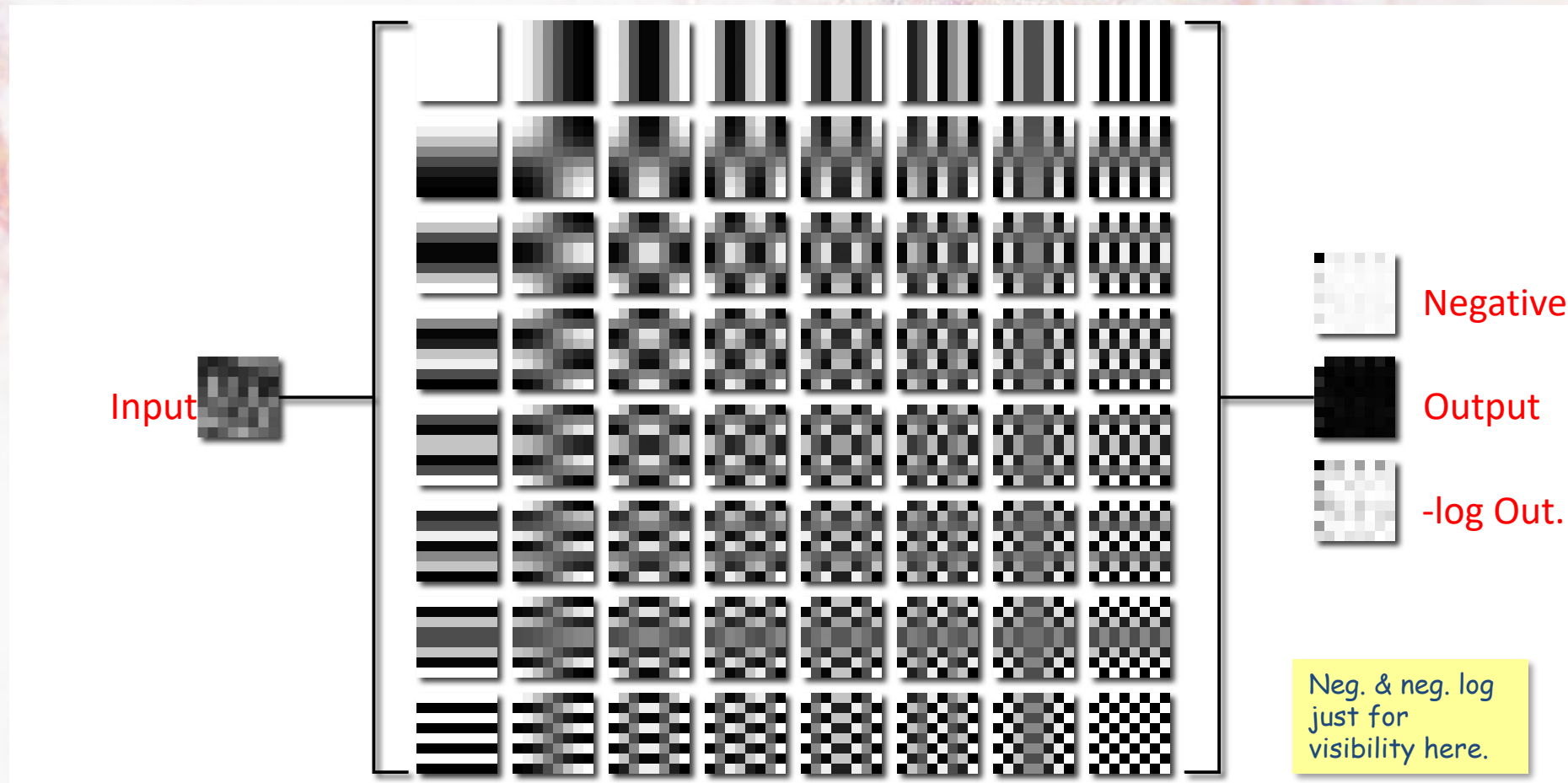
Forward Discrete Cosine Transform

$F\{\mathbf{I}\}(0,0;r,c)$ is the DC component of the 8x8 block from \mathbf{I} at (r,c) ...

...the others are the AC components, e.g. $F\{\mathbf{I}\}(4,4;r,c)$.

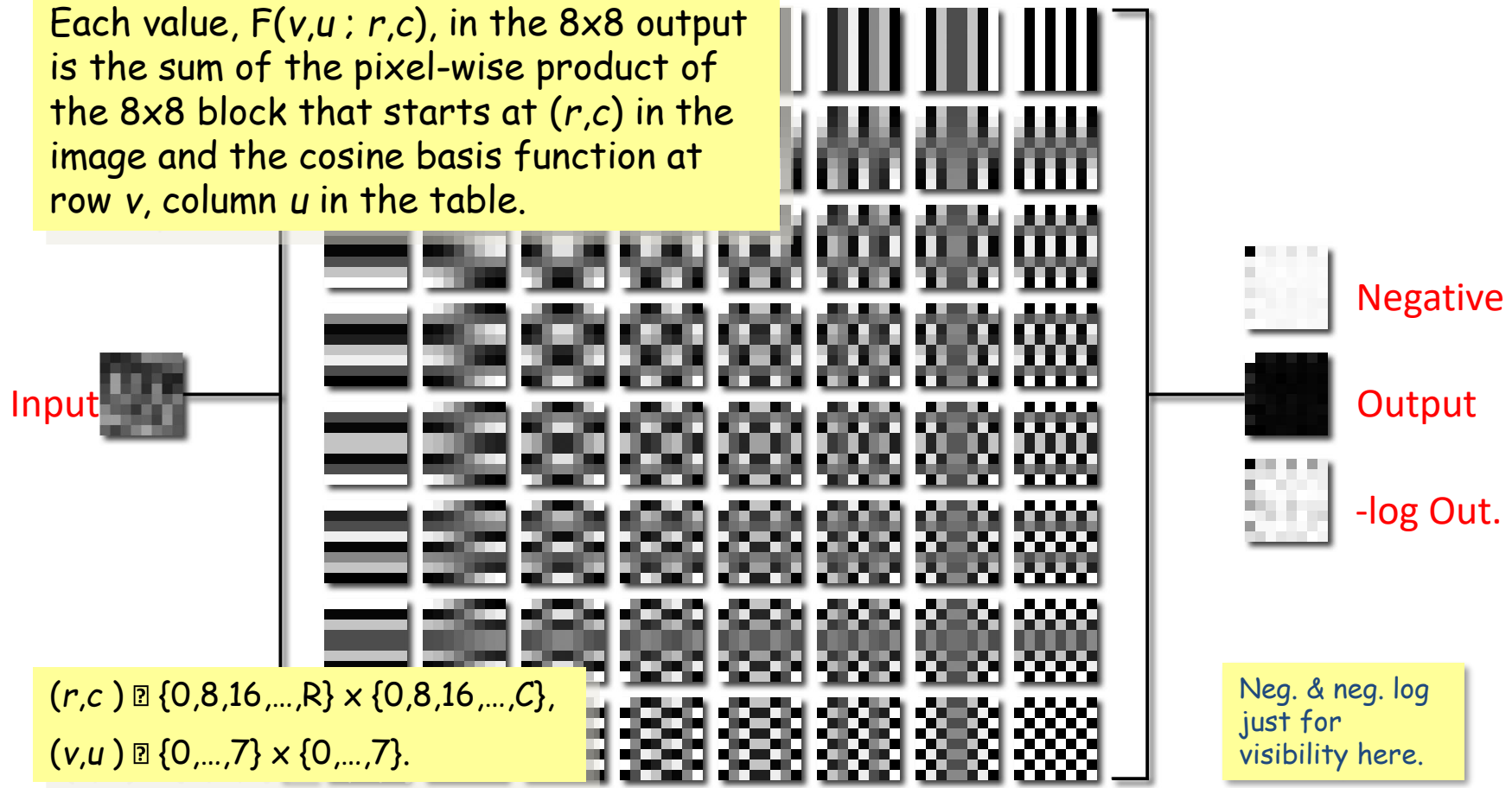


Forward Discrete Cosine Transform



Forward Discrete Cosine Transform

Each value, $F(v,u; r,c)$, in the 8x8 output is the sum of the pixel-wise product of the 8x8 block that starts at (r,c) in the image and the cosine basis function at row v , column u in the table.



Example FDCT Quantization Tables

Luminance Quantization Table

2	2	3	4	5	6	8	11
2	2	2	4	5	7	9	11
3	2	3	5	7	9	11	12
4	4	5	7	9	11	12	12
5	5	7	9	11	12	12	12
6	7	9	11	12	12	12	12
8	9	11	12	12	12	12	12
11	11	12	12	12	12	12	12

Precision: 8 bits

Approximate quality factor: 91.64

Scaling: 16.71 Variance: 22.54

Chrominance Quantization Table

3	3	7	13	15	15	15	15
3	4	7	13	14	12	12	12
7	7	13	14	12	12	12	12
13	13	14	12	12	12	12	12
15	14	12	12	12	12	12	12
15	12	12	12	12	12	12	12
15	12	12	12	12	12	12	12
15	12	12	12	12	12	12	12

Precision: 8 bits

Approximate quality factor: 92.57

Scaling: 14.85 Variance: 23.00

FDCT Quantization Procedure

255	23	34	13	44	11	44	6
19	4	19	12	18	9	16	15
58	10	11	2	14	6	12	7
22	18	9	12	7	11	12	9
42	26	19	9	23	15	16	6
9	6	23	14	20	10	19	21
48	13	13	11	15	12	18	10
3	0	13	18	16	4	11	14

Output of FDCT, $\mathcal{F}(u,v)$, at image pixel location (r,c) .

1	1	1	2	3	6	8	10
1	1	2	3	4	8	9	8
2	2	2	3	6	8	10	8
2	2	3	4	7	12	11	9
3	3	8	11	10	16	15	11
3	5	8	10	12	15	16	13
7	10	11	12	15	17	17	14
14	13	13	15	15	14	14	14

Quantization Table, $Q(u,v)$

255	23	34	7	15	2	6	1
19	4	10	4	5	1	2	2
29	5	6	1	2	1	1	1
11	9	3	3	1	1	1	1
14	9	2	1	2	1	1	1
3	1	3	1	2	1	1	2
7	1	1	1	1	1	1	1
0	0	1	1	1	0	1	1

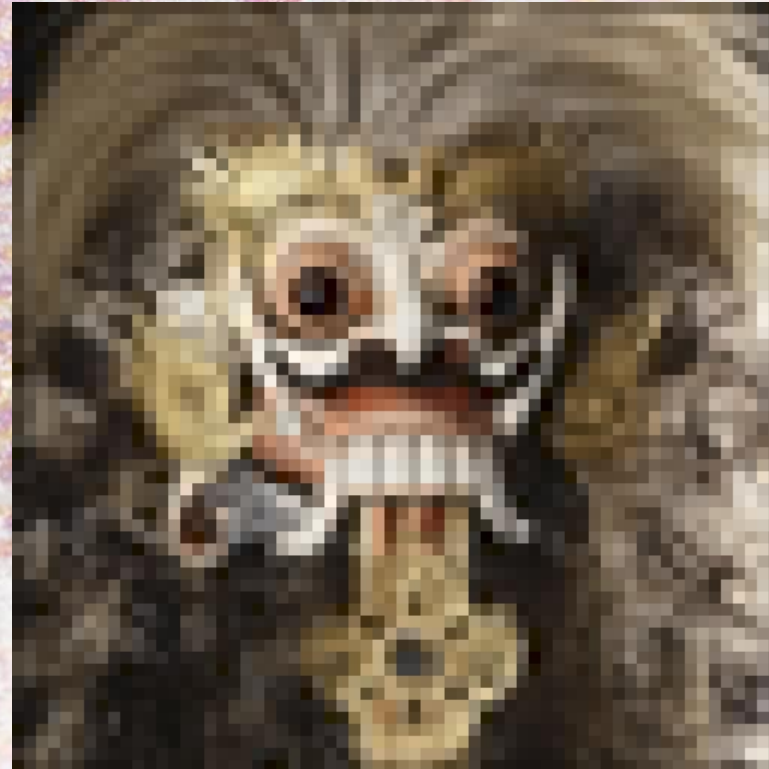
Quantized Result, $\mathcal{F}^Q(u,v)$ at image pixel location (r,c) .

$$\mathcal{F}^Q(u,v) = \text{round} \left\{ \frac{\mathcal{F}(u,v)}{Q(u,v)} \right\}$$

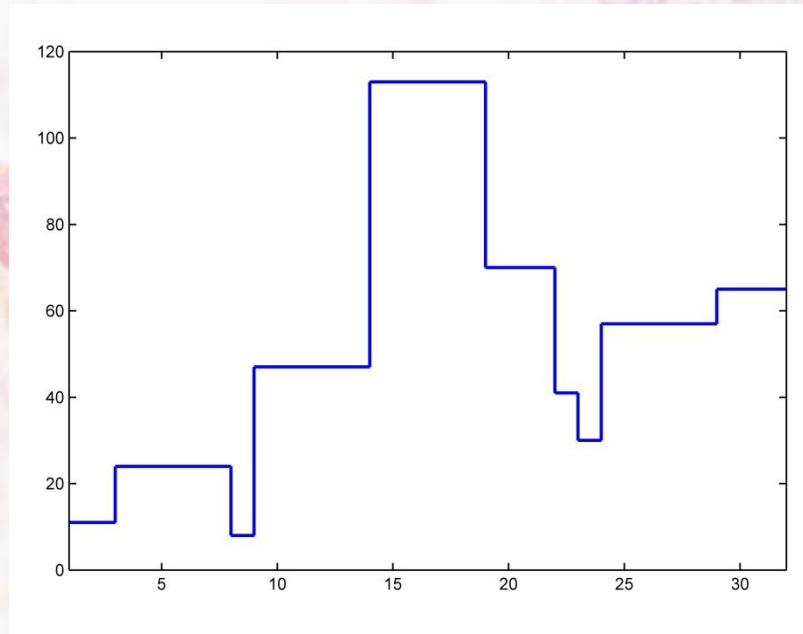
$(r,c) \in \{0,8,16,\dots,R\} \times \{0,8,16,\dots,C\}$

This $Q(u,v)$ is yet another quantization table.

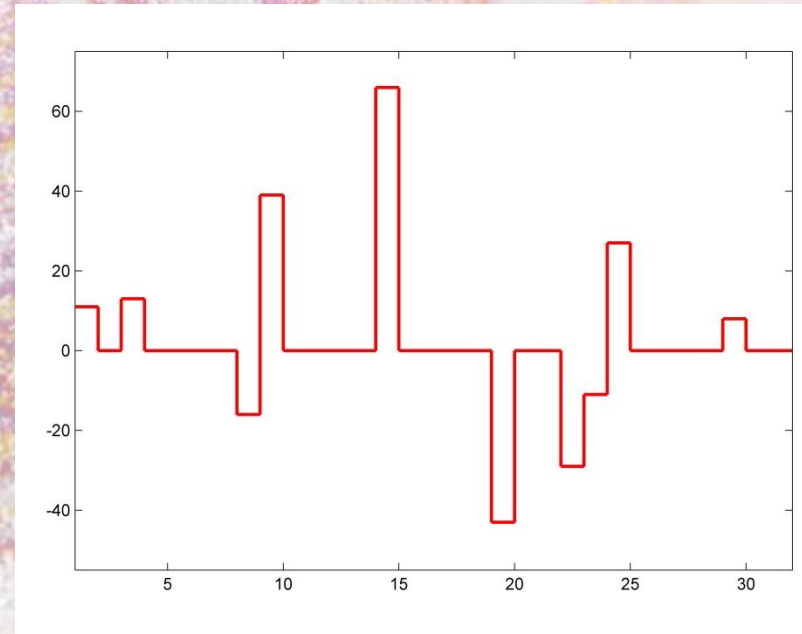
Image DC Components (8×8 constant blocks)



DC Component Coding (DPCM)



DC components from 32 blocks



Differential PCM coding of same

DC components are coded separately from the AC components.

Entropy Encoding of AC Coefficients

Two step process:

1. Convert zigzag sequence of quantized coefficients into a sequence of symbols.
2. Convert symbols to a data stream of variable length codes.

Symbol 1 = (Runlength, Size)

Symbol 2 = Amplitude

Entropy Encoding of Coefficients

Symbol 1: (Runlength, Size);

Symbol 2: Amplitude

AC:

Runlength: number of consecutive zero values (0-15)

Size: number of bits used to encode amplitude (1-10)

Amplitude: quantized value

DC:

Runlength: not included

Size: number of bits used to encode amplitude (1-11)

Amplitude: quantized value

Variable Length Entropy Encoding

size	amplitude
1	-1,1
2	-3,-2,2,3
3	-7...-4,4...7
4	-15...-8,8...15
5	-31...-16,16...31
6	-63...-32,32...63
7	-127...-64,64...128
8	-255...-128,128...255
9	-511...-256,256...511
10	-1023...-512,512...1023
DC only	11
	-2047...-1024,1024...2047

Symbol 2 Coding

Effects of Quality Settings

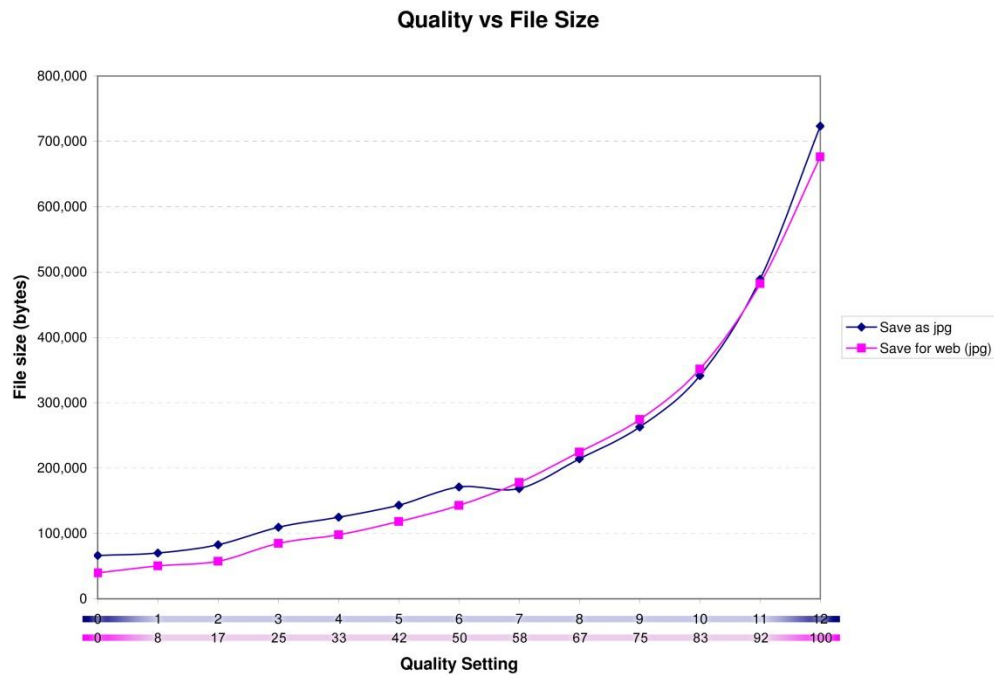


Image:

http://en.wikipedia.org/wiki/File:Quality_comparison_jpg_vs_saveforweb.jpg

JFIF Information Display Program

JPEGsnoop - JPEG File Decoding Utility
by Calvin Hass © 2010

From the web page:

Every digital photo contains a wealth of hidden information -- JPEGsnoop was written to expose these details to those who are curious. Not only can one determine the various settings that were used in the digital camera in taking the photo (EXIF metadata, IPTC), but one can also extract information that indicates the quality and nature of the JPEG image compression used by the camera in saving the file. Digital cameras specify compression quality levels, many of them wildly different, leading to the fact that some cameras produce far better JPEG images than others.

<http://www.impulseadventure.com/photo/>

Example: JPEG/JFIF Encoded Image



Keith Hamshere – Saoirse Ronan – 2007

Data Markers from the JPEG File Interchange Format (JFIF)

Short name	Code	Payload	Name	Comments
SOI	0xFFD8	none	Start Of Image	
SOF0	0xFFC0	variable size	Start Of Frame (Baseline)	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	0xFFC2	variable size	Start Of Frame (Progressive)	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	0xFFC4	variable size	Define Huffman Table(s)	Specifies one or more Huffman tables.
DQT	0xFFDB	variable size	Define Quantization Table(s)	Specifies one or more quantization tables.
DRI	0xFFDD	2 bytes	Define Restart Interval	Specifies the interval between RSTn 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	0xFFDA	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	0xFFD0...D7	none	Restart	Inserted every <i>r</i> macroblocks, where <i>r</i> 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.
APPn	0xFFEn	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	0xFFFE	variable size	Comment	Contains a text comment.
EOI	0xFFD9	none	End Of Image	

JPEG / JFIF Information (via JPEGsnoop)

```
Filename: [Saoirse Ronan - Ember.jpg]
Filesize: [3156857] Bytes

Start Offset: 0x00000000
*** Marker: SOI (xFFD8) ***
OFFSET: 0x00000000

*** Marker: APP13 (xFFE1) ***
OFFSET: 0x00000002
length      = 28
Identifier   = [Photoshop 3.0]
8BIM: [0x0404] Name=[] Len=[0x0000]
IPTC [0xFFE1:002] ? size=12392

*** Marker: APP1 (xFFE1) ***
OFFSET: 0x00000020
length      = 560
Identifier   = [http://ns.adobe.com/xap/1.0/]
XMP =

*** Marker: APP0 (xFFE0) ***
OFFSET: 0x00000252
length      = 16
identifier   = [JFIF]
version     = [1.2]
density     = 300 x 300 DPI (dots per inch)
thumbnail   = 0 x 0
```

```
*** Marker: APP2 (xFFE2) ***
OFFSET: 0x00000264
length      = 576
Identifier   = [ICC_PROFILE]
ICC Profile:
  Marker Number = 1 of 1
  Profile Size   : 560 bytes
  Preferred CMM Type      : 'ADBE' (0x41444245)
  Profile Version         : 0.2.1.0 (0x02100000)
  Profile Device/Class    : Display Device profile ('mnr' (0x6D6E7472))
  Data Colour Space       : rgbData ('RGB ' (0x52474220))
  Profile connection space (PCS) : 'XYZ ' (0x58595A20)
  Profile creation date   : 1999-06-03 00:00:00
  Profile file signature  : 'acsp' (0x61637370)
  Primary platform       : Apple Computer, Inc. ('APPL' (0x4150504C))
  Profile flags           : 0x00000000
  Profile flags           : > Profile not embedded
  Profile flags           : > Profile can't be used independently of embedded
  Device Manufacturer     : 'none' (0x6E6F6E65)
  Device Model            : '...' (0x00000000)
  Device attributes       : 0x00000000_00000000
  Device attributes       : > Reflective
  Device attributes       : > Glossy
  Device attributes       : > Media polarity = negative
  Device attributes       : > Black & white media
  Rendering intent        : Perceptual
  Profile creator          : 'ADBE' (0x41444245)
  Profile ID              : 0x00000000_00000000_00000000
```

JPEG / JFIF Information (via JPEGsnoop)

*** Marker: DQT (xFFDB) ***

Define a Quantization Table.

OFFSET: 0x000004B6

Table length = 132

Precision=8 bits

Destination ID=0 (Luminance)

DQT, Row #0: 2 2 3 4 5 6 8 11

DQT, Row #1: 2 2 2 4 5 7 9 11

DQT, Row #2: 3 2 3 5 7 9 11 12

DQT, Row #3: 4 4 5 7 9 11 12 12

DQT, Row #4: 5 5 7 9 11 12 12 12

DQT, Row #5: 6 7 9 11 12 12 12 12

DQT, Row #6: 8 9 11 12 12 12 12 12

DQT, Row #7: 11 11 12 12 12 12 12 12

Approx quality factor = 91.64 (scaling=16.71 variance=22.54)

Precision=8 bits

Destination ID=1 (Chrominance)

DQT, Row #0: 3 3 7 13 15 15 15 15

DQT, Row #1: 3 4 7 13 14 12 12 12

DQT, Row #2: 7 7 13 14 12 12 12 12

DQT, Row #3: 13 13 14 12 12 12 12 12

DQT, Row #4: 15 14 12 12 12 12 12 12

DQT, Row #5: 15 12 12 12 12 12 12 12

DQT, Row #6: 15 12 12 12 12 12 12 12

DQT, Row #7: 15 12 12 12 12 12 12 12

Approx quality factor = 92.57 (scaling=14.85 variance=23.00)

*** Marker: SOF0 (Baseline DCT) (xFFC0) ***

OFFSET: 0x0000053C

Frame header length = 17

Precision = 8

Number of Lines = 2592

Samples per Line = 3872

Image Size = 3872 x 2592

Raw Image Orientation = Landscape

Number of Img components = 3

Comp[1]: ID=0x01, Samp Fac=0x11 (Subsamp 1 x 1), Quant Tbl Sel=0x00 (Lum: Y)

Comp[2]: ID=0x02, Samp Fac=0x11 (Subsamp 1 x 1), Quant Tbl Sel=0x01 (Chrom: Cb)

Comp[3]: ID=0x03, Samp Fac=0x11 (Subsamp 1 x 1), Quant Tbl Sel=0x01 (Chrom: Cr)

*** Marker: DRI (Restart Interval) (xFFDD) ***

OFFSET: 0x0000054F

length = 4

interval = 484

JPEG / JFIF Information (via JPEGsnoop)

```
*** Marker: DHT (Define Huffman Table) (xFFC4) ***  
OFFSET: 0x00000555  
Huffman table length = 418  
----  
Destination ID = 0  
Class = 0 (DC / Lossless Table)  
Codes of length 01 bits (000 total):  
Codes of length 02 bits (000 total):  
Codes of length 03 bits (007 total): 04 05 03 02 06 01 00  
Codes of length 04 bits (001 total): 07  
Codes of length 05 bits (001 total): 08  
Codes of length 06 bits (001 total): 09  
Codes of length 07 bits (001 total): 0A  
Codes of length 08 bits (001 total): 0B  
Codes of length 09 bits (000 total):  
Codes of length 10 bits (000 total):  
Codes of length 11 bits (000 total):  
Codes of length 12 bits (000 total):  
Codes of length 13 bits (000 total):  
Codes of length 14 bits (000 total):  
Codes of length 15 bits (000 total):  
Codes of length 16 bits (000 total):  
Total number of codes: 012
```

```
----  
Destination ID = 1  
Class = 0 (DC / Lossless Table)  
Codes of length 01 bits (000 total):  
Codes of length 02 bits (002 total): 01 00  
Codes of length 03 bits (002 total): 02 03  
Codes of length 04 bits (003 total): 04 05 06  
Codes of length 05 bits (001 total): 07  
Codes of length 06 bits (001 total): 08  
Codes of length 07 bits (001 total): 09  
Codes of length 08 bits (001 total): 0A  
Codes of length 09 bits (001 total): 0B  
Codes of length 10 bits (000 total):  
Codes of length 11 bits (000 total):  
Codes of length 12 bits (000 total):  
Codes of length 13 bits (000 total):  
Codes of length 14 bits (000 total):  
Codes of length 15 bits (000 total):  
Codes of length 16 bits (000 total):  
Total number of codes: 012
```

JPEG / JFIF Information (via JPEGsnoop)

```
----
Destination ID = 0
Class = 1 (AC Table)
Codes of length 01 bits (000 total):
Codes of length 02 bits (002 total): 01 02
Codes of length 03 bits (001 total): 03
Codes of length 04 bits (003 total): 11 04 00
Codes of length 05 bits (003 total): 05 21 12
Codes of length 06 bits (002 total): 31 41
Codes of length 07 bits (004 total): 51 06 13 61
Codes of length 08 bits (002 total): 22 71
Codes of length 09 bits (006 total): 81 14 32 91 A1 07
Codes of length 10 bits (007 total): 15 B1 42 23 C1 52 D1
Codes of length 11 bits (003 total): E1 33 16
Codes of length 12 bits (004 total): 62 F0 24 72
Codes of length 13 bits (002 total): 82 F1
Codes of length 14 bits (006 total): 25 43 34 53 92 A2
Codes of length 15 bits (002 total): B2 63
Codes of length 16 bits (115 total):
  73 C2 35 44 27 93 A3 B3 36 17 54 64 74 C3 D2 E2
  08 26 83 09 0A 18 19 84 94 45 46 A4 B4 56 D3 55
  28 1A F2 E3 F3 C4 D4 E4 F4 65 75 85 95 A5 B5 C5
  D5 E5 F5 66 76 86 96 A6 B6 C6 D6 E6 F6 37 47 57
  67 77 87 97 A7 B7 C7 D7 E7 F7 38 48 58 68 78 88
  98 A8 B8 C8 D8 E8 F8 29 39 49 59 69 79 89 99 A9
  B9 C9 D9 E9 F9 2A 3A 4A 5A 6A 7A 8A 9A AA BA CA
  DA EA FA
Total number of codes: 162
```

```
----
Destination ID = 1
Class = 1 (AC Table)
Codes of length 01 bits (000 total):
Codes of length 02 bits (002 total): 01 00
Codes of length 03 bits (002 total): 02 11
Codes of length 04 bits (001 total): 03
Codes of length 05 bits (002 total): 04 21
Codes of length 06 bits (003 total): 12 31 41
Codes of length 07 bits (005 total): 05 51 13 61 22
Codes of length 08 bits (005 total): 06 71 81 91 32
Codes of length 09 bits (004 total): A1 B1 F0 14
Codes of length 10 bits (005 total): C1 D1 E1 23 42
Codes of length 11 bits (006 total): 15 52 62 72 F1 33
Codes of length 12 bits (004 total): 24 34 43 82
Codes of length 13 bits (008 total): 16 92 53 25 A2 63 B2 C2
Codes of length 14 bits (003 total): 07 73 D2
Codes of length 15 bits (003 total): 35 E2 44
Codes of length 16 bits (109 total):
  83 17 54 93 08 09 0A 18 19 26 36 45 1A 27 64 74
  55 37 F2 A3 B3 C3 28 29 D3 E3 F3 84 94 A4 B4 C4
  D4 E4 F4 65 75 85 95 A5 B5 C5 D5 E5 F5 46 56 66
  76 86 96 A6 B6 C6 D6 E6 F6 47 57 67 77 87 97 A7
  B7 C7 D7 E7 F7 38 48 58 68 78 88 98 A8 B8 C8 D8
  E8 F8 39 49 59 69 79 89 99 A9 B9 C9 D9 E9 F9 2A
  3A 4A 5A 6A 7A 8A 9A AA BA CA DA EA FA
Total number of codes: 162
```

JPEG / JFIF Information (via JPEGsnoop)

*** Marker: SOS (Start of Scan) (xFFDA) ***

OFFSET: 0x000006F9

Scan header length = 12

Number of img components = 3

Component[1]: selector=0x01, table=0x00

Component[2]: selector=0x02, table=0x11

Component[3]: selector=0x03, table=0x11

Spectral selection = 0 .. 63

Successive approximation = 0x00

*** Decoding SCAN Data ***

OFFSET: 0x00000707

Scan Decode Mode: No IDCT (DC only)

NOTE: Low-resolution DC component shown.

Scan Data encountered marker

0xFFD9 @ 0x00302B77.0

Compression stats:

Compression Ratio: 3028.43:1

Bits per pixel: 0.01:1

Huffman code histogram stats:

Huffman Table: (Dest ID: 0, Class: DC)

# codes of length 01 bits:	0 (0%)
# codes of length 02 bits:	0 (0%)
# codes of length 03 bits:	142702 (91%)
# codes of length 04 bits:	8490 (5%)
# codes of length 05 bits:	3974 (3%)
# codes of length 06 bits:	1649 (1%)
# codes of length 07 bits:	1 (0%)
# codes of length 08 bits:	0 (0%)
# codes of length 09 bits:	0 (0%)
# codes of length 10 bits:	0 (0%)
# codes of length 11 bits:	0 (0%)
# codes of length 12 bits:	0 (0%)
# codes of length 13 bits:	0 (0%)
# codes of length 14 bits:	0 (0%)
# codes of length 15 bits:	0 (0%)
# codes of length 16 bits:	0 (0%)

Huffman Table: (Dest ID: 1, Class: DC)

# codes of length 01 bits:	0 (0%)
# codes of length 02 bits:	162056 (52%)
# codes of length 03 bits:	128895 (41%)
# codes of length 04 bits:	22673 (7%)
# codes of length 05 bits:	8 (0%)
# codes of length 06 bits:	0 (0%)
# codes of length 07 bits:	0 (0%)
# codes of length 08 bits:	0 (0%)
# codes of length 09 bits:	0 (0%)
# codes of length 10 bits:	0 (0%)
# codes of length 11 bits:	0 (0%)
# codes of length 12 bits:	0 (0%)
# codes of length 13 bits:	0 (0%)
# codes of length 14 bits:	0 (0%)
# codes of length 15 bits:	0 (0%)
# codes of length 16 bits:	0 (0%)

JPEG / JFIF Information (via JPEGsnoop)

```
Huffman Table: (Dest ID: 0, Class: AC)
# codes of length 01 bits: 0 ( 0%)
# codes of length 02 bits: 2103874 ( 53%)
# codes of length 03 bits: 393151 ( 10%)
# codes of length 04 bits: 712367 ( 18%)
# codes of length 05 bits: 368952 ( 9%)
# codes of length 06 bits: 148211 ( 4%)
# codes of length 07 bits: 116694 ( 3%)
# codes of length 08 bits: 52460 ( 1%)
# codes of length 09 bits: 49772 ( 1%)
# codes of length 10 bits: 19533 ( 0%)
# codes of length 11 bits: 2118 ( 0%)
# codes of length 12 bits: 2566 ( 0%)
# codes of length 13 bits: 726 ( 0%)
# codes of length 14 bits: 367 ( 0%)
# codes of length 15 bits: 24 ( 0%)
# codes of length 16 bits: 1861 ( 0%)
```

```
Huffman Table: (Dest ID: 1, Class: AC)
# codes of length 01 bits: 0 ( 0%)
# codes of length 02 bits: 580346 ( 62%)
# codes of length 03 bits: 209085 ( 22%)
# codes of length 04 bits: 25344 ( 3%)
# codes of length 05 bits: 50682 ( 5%)
# codes of length 06 bits: 50395 ( 5%)
# codes of length 07 bits: 10862 ( 1%)
# codes of length 08 bits: 2482 ( 0%)
# codes of length 09 bits: 2378 ( 0%)
# codes of length 10 bits: 941 ( 0%)
# codes of length 11 bits: 273 ( 0%)
# codes of length 12 bits: 0 ( 0%)
# codes of length 13 bits: 1 ( 0%)
# codes of length 14 bits: 0 ( 0%)
# codes of length 15 bits: 0 ( 0%)
# codes of length 16 bits: 0 ( 0%)
```

```
YCC clipping in DC:
Y component: [<0= 0] [>255= 0]
Cb component: [<0= 0] [>255= 0]
Cr component: [<0= 0] [>255= 0]

RGB clipping in DC:
R component: [<0= 0] [>255= 0]
G component: [<0= 0] [>255= 0]
B component: [<0= 0] [>255= 0]

Average Pixel Luminance (Y):
Y=[ 86] (range: 0..255)

Brightest Pixel Search:
YCC=[ 1016, 0, 0]
RGB=[255,255,255] @ MCU[ 94, 1]

Finished Decoding SCAN Data
Number of RESTART markers decoded: 323
Next position in scan buffer:
Offset 0x00302B75.1
```

JPEG / JFIF Information (via JPEGsnoop)

*** Marker: EOI (End of Image) (xFFD9) ***

OFFSET: 0x00302B77

*** Searching Compression Signatures ***

Signature: 0166B0BC0B82C8233430BF67FA31C829
Signature (Rotated): 0166B0BC0B82C8233430BF67FA31C829
File Offset: 0 bytes
Chroma subsampling: 1x1
EXIF Make/Model: NONE
EXIF Makernotes: NONE
EXIF Software: NONE

Searching Compression Signatures: (3327 built-in, 0 user(*))

EXIF.Make / Software	EXIF.Model	Quality	Subsamp Match?

SW :[Adobe Photoshop]		[Save As 10]	

Based on the analysis of compression characteristics and EXIF metadata:

ASSESSMENT: Class 1 - Image is processed/edited

Position Marked @ MCU=[177, 52](0,0) YCC=[-468, -60, 30]