Damascus University
Faculty of information engineering
Fourth year



# MultiMedia Systems Fifth Lecture JPEG

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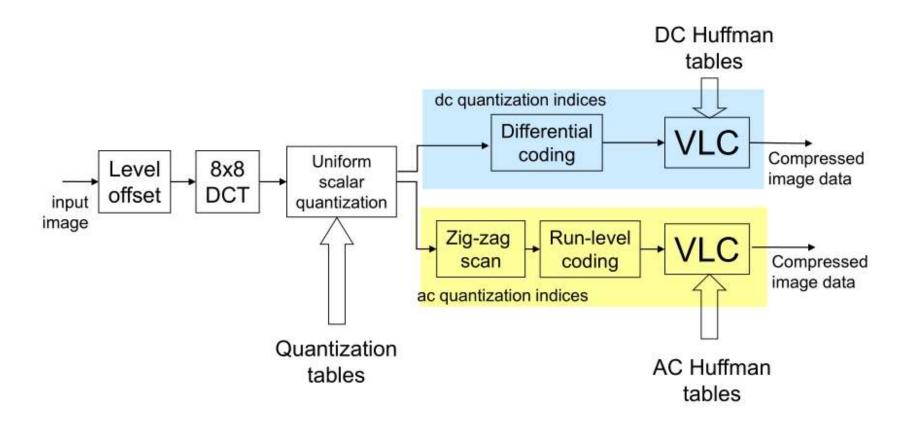
## **JPEG**

- JPEG: Joint Photographic Experts Group
- Almost 80 percents of images on web are compressed by the JPEG standards
- JPEG is a lossy image compression method (decompression the EXACTimage does NOT possible)

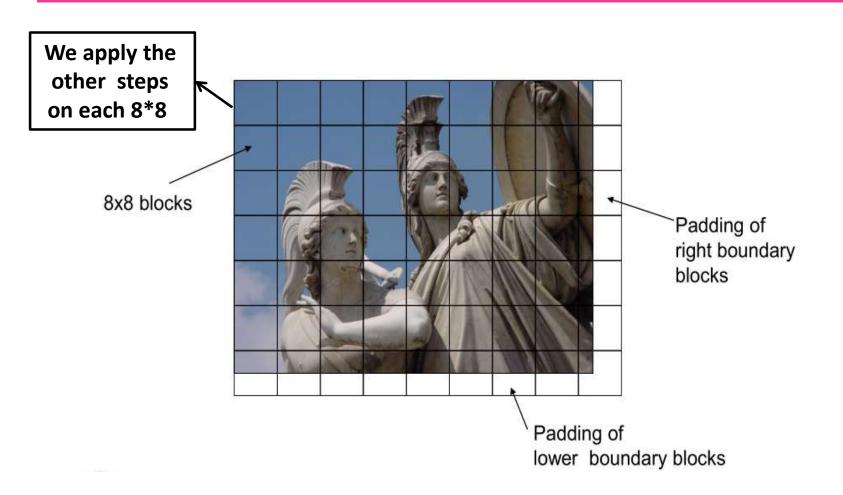
## **JPEG**

- We must convert rgb image into YCbCr
- JPEG apply on luma (Y)not chroma(CbCr)
- For croma we apply subsambling.

# JPEG main steps



# Dividision into 8\*8 blocks



## Discrete Cosine Transform

- An image block is defined to have dimension M=N=8;
- The definition of 2D DCT and its inverse IDCT are as follows:

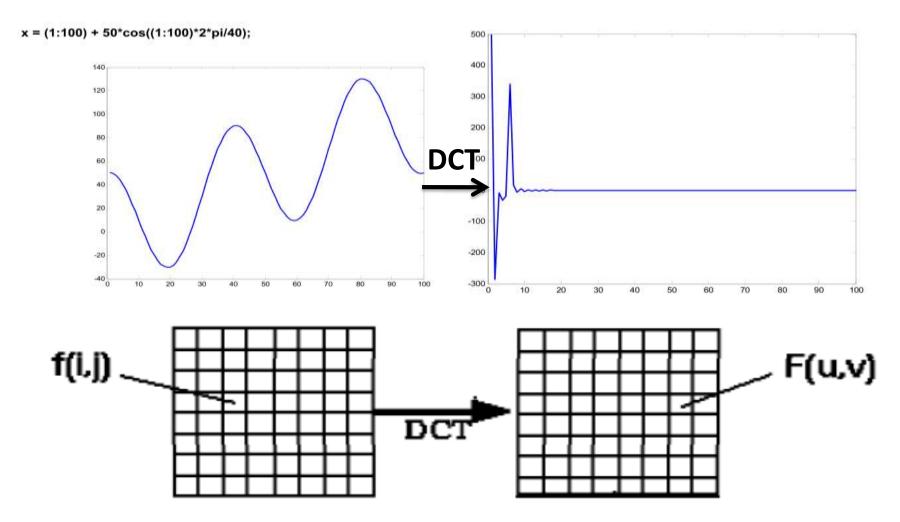
$$F(u,v) = \frac{C(u)C(v)}{4} \sum_{i=0}^{7} \sum_{j=0}^{7} \cos \frac{(2i+1)u\pi}{16} \cos \frac{(2j+1)v\pi}{16} f(i,j),$$

2D Inverse Discrete Cosine Transform(2D IDCT):

$$\widetilde{f}(i,j) = \sum_{u=0}^{7} \sum_{v=0}^{7} \frac{C(u)C(v)}{4} \cos \frac{(2i+1)u\pi}{16} \cos \frac{(2j+1)v\pi}{16} F(u,v)$$

$$C(u) = \begin{cases} \frac{\sqrt{2}}{2} & \text{if } u = 0\\ 1 & \text{else} \end{cases}$$

# Discrete Cosine Transform



# Discrete Cosine Transform

#### Suppose the output of appling DCT on (8\*8)block is

```
      20.0000
      30.5458
      -12.6501
      1.4046
      2.0000
      -5.7644
      -1.7957
      0.0331

      -48.8409
      -8.0914
      10.0495
      -1.3722
      5.5094
      0.0798
      0.4861
      2.7702

      1.2833
      -3.2701
      -8.0355
      4.7930
      1.7917
      -0.5632
      -2.1464
      -4.7514

      5.2795
      4.1426
      -3.8016
      -2.8859
      0.6881
      1.3372
      2.4971
      -2.5460

      -1.0000
      1.5931
      -1.8478
      -0.2929
      -0.5000
      -1.7569
      0.7654
      3.6796

      -2.0945
      -1.2395
      -1.4372
      3.4407
      3.0840
      3.1714
      -2.0101
      1.6248

      2.4450
      -0.0382
      2.8536
      -0.6242
      -1.5539
      1.2612
      -0.9645
      -1.7201

      0.6589
      1.3737
      1.5349
      0.9380
      -3.1680
      1.9134
      3.0202
      1.3059
```

# Quantization

Table 9.1 The Luminance Quantization Table

Table 9.2 The Chrominance Qu	uanuzauon	lable
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Ī	16	11	10	16	24	40	51	61
l	12	12	14	19	26	58	60	55
l	14	13	16	24	40	57	69	56
l	14	17	22	29	51	87	80	62
l	18	22	37	56	68	109	103	77
l	24	35	55	64	81	104	113	92
l	49	64	78	87	103	121	120	101
l	72	92	95	98	112	100	103	99
L	100000	14177-12	7000	10000001	1911/1923/5		11/4/19/2009	

This step give jpeg
The adjective(lossy algorithm)

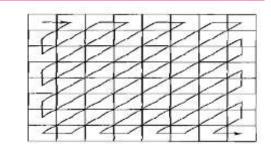
$$\hat{F}(u,v) = round \left( \frac{F(u,v)}{Q(u,v)} \right)$$

# Output of Quantization

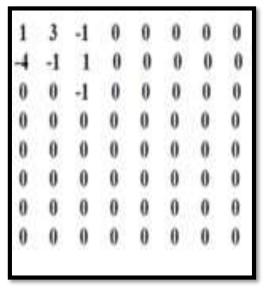
$$\hat{\mathcal{F}}(0,0) = \text{round} \frac{20}{16} = 1$$

# Zigzag

- Turns the 8×8 matrix into a 64 vector
- Concatenates long runs of zeros



Output of Quantization



The out put of zigzag

> 13-40-1-1010000-1000.....0EOB

# **DPCM on DC Coefficients**

$$d_i = DC_{i+1} - DC_i$$
$$d_0 = DC_0$$

#### for first DC Coefficient

 $Di = 1-0 = 1 = (1)_2$ 

DC reprented in huffman coding →

0111

Represent 1 in binary code

Dc code for category 1(#of bits to represent 1 in binary)

If dc=7

We write 7 in binary code 111

And we see 111 belongs which category in table ??==>3 because we use 3 bits to represent 7 in binary code → so that representation of dc in this case is 00111

# RLC(Run Length Coding)on ACs

- The 1 x 64 size vector contains long runs of zeros
- RLC (Run-length Coding):
- (skip, value)
- skip: number of zeros, value: the next nonzero value
- (0,0): the end of a block **EOB** after the last nonzero AC coefficient is reached

1 3 -4 0 -1 -1 0 1 0 0 0 0 -1 0 0 0 ..... 0 EOB

**ACs** 

## **Huffman Coding of AC Coefficient**

- (0,6):
- (0/# bits of binary 6,binary of 6)=(0/3,110)
- From the AC table we find  $0/3 \rightarrow 100$
- So coding for AC(0,6) is 100110
- The same manner we find:
- (0,-1)=000
- (0/3,011)=100011
- EOB=1010

#### JPEG default AC code

Run/ Category	Base Code	Length	Run/ Category	Base Code	Length
0/0	1010 (= EOB)	4			
0/1	00	3 4 6	8/1	11111010	9
0/2	01	4	8/2	1111111111000000	17
0/3	100	6	8/3	11111111110110111	19
0/4	1011	8	8/4	111111111110111000	20
0/5	11010	10	8/5	11111111110111001	21
0/6	111000	12	8/6	11111111110111010	22
0/7	1111000 1111116110	14 18	8/7	11111111110111011 11111111110111100	23
0/8	1111110110	18	8/8	11111111110111100	24
079	111111111110000010	3.5	0.70	111111111101111101	25
0/A	111111111110000011	26	8/A	1111111110111110	26
1/1	1100	5	9/1	111111000	10
1/2	111001	26 5 8	9/2	11111111110111111	18
1/3	1111001	10	9/3	11111111110111111 11111111111000000	19
1/4	111110110	13	974	111111111111000001	20
1/5	11111110110	16	9/5	1111111111000010 11111111111000011 111111	21
1/6	11111111110000100	22	9/6	11111111111000010 111111111111000011	22
1/7	11111111110000101	23	9/7	11111111111000100	23
1/8	11111111110000110	24	9/8	11111111111000101	24
1/9	111111111100001111	25	9/9	11111111111000110	25
1/A	11111111110001000	26	9/A	11111111111000111	26
2/1		6	A/1	11111111111000111 111111001	10
2/2		10	A/2	11111111111001000	
2/3		13	A/3	1111111111001001 11111111111001010	19
2/4	11111111110001001	20	A/4	1111111111001010	20
2/5	11111111110001010	21	A /5	111111111111001011	21
2/6	11111111110001011	22	A/6	1111111111001100	22
2/7	11111111110001100	23	A/7	11111111111001101	23

#### JPEG default DC code

Category	Base Code	Length	Category	Base Code	Length
0	010	3	6	1110	10
1	011	4	7	11110	12
2	100	5	8	111110	14
3	00	5	9	1111110	16
4	101	7	A	11111110	18
5	110	8	В	1111111110	20

#### JPEG suggested AC code for luminance

Run/ Category	Base Code	Length	Run/ Category	Base Code	Length
0/0	1010 (= EOB)	4	2000 5400	THE STREET CONTROL OF THE STREET	
0/1	00	3	8/1	11111010	9
0/2	01	4	8/2	111111111000000	17
0/3	100	6	8/3	1111111110110111	19
0/4	1011	8	8/4	1111111110111000	20
0/5	11010	10	8/5	1111111110111001	21
0/6	111000	12	8/6	1111111110111010	22
0/7	1111000	14	8/7	1111111110111011	23
0/8	1111110110	18	8/8	1111111110111100	24
0/9	11111111110000010	25	8/9	1111111110111101	25
0/A	11111111110000011	26	8/A	1111111110111110	26
1/1	1100	5	9/1	111111000	10
1/2	111001	8	9/2	1111111110111111	18
1/3	1111001	10	9/3	1111111111000000	19
1/4	111110110	13	9/4	1111111111000001	20
1/5	11111110110	16	9/5	1111111111000010	21
1/6	1111111110000100	22	9/6	1111111111000011	22
1/7	1111111110000101	23	9/7	1111111111000100	23
1/8	1111111110000110	24	9/8	1111111111000101	24
1/9	11111111100001111	25	9/9	1111111111000110	25
1/A	1111111110001000	26	9/A	11111111111000111	26
2/1	11011	6	A/1	111111001	10
2/2	11111000	10	A/2	1111111111001000	18
2/3	1111110111	13	A/3	1111111111001001	19
2/4	1111111110001001	20	A/4	1111111111001010	20
2/5	1111111110001010	21	A/5	1111111111001011	21
2/6	1111111110001011	22	A/6	1111111111001100	22
2/7	1111111110001100	23	A/7	1111111111001101	23

#### JPEG default AC code (continued...)

2/8	11111111110001101	24	A/8	1111111111001110	24
2/9	1111111110001110 11111111110001111	25	A/9	1111111111001111	25
2/A	11111111110001111	26	A/A	1111111111010000	26
3/1	111010	7	B/1	111111010	10
3/2	111 <b>010</b> 111 <b>110111</b> 111 <b>11110111</b>	11	B/2	1111111111010001	18
3/3	11111110111	14	B/3	11111111111010010	19
3/4	11111111110010000	20	B/4	11111111111010011	20
3/5	11111111110010001	21	B/5	1111111111010100 11111111111010101	21
3/6	11111111110010010	22	B/6	1111111111010101	22
3/7	1111111110010001 111111111110010010 111111	23	B/7	1111111111010110	23
3/8	11111111110010100	24	B/8	1111111111010111	24
3/9	11111111110010101	25	B/9	1111111111011000	
3/A	1111111110010100 11111111110010101 111111	26	B/A	11111111111011001	
4/1	111011	7	C/1	1111111010	11
4/2	1111111000	12	C/2	11111111111011010	18
4/3	111 <b>111110</b> 00 111 <b>11111110</b> 010111	19	C/3	1111111111011010 111111111111011011 111111	19
4/4	11111111110011000	20	C/4	11111111111011100	20
4/5	11111111110011001		C/5	1111111111011101	21
4/6	11111111110011010	22	C/6	1111111111011110	22
4/7	11111111110011011	23	C/7	11111111111011111	23
4/8	1111111110011100	24	C/8	1111111111100000	24
4/9	11111111110011101	25	C/9	1111111111100001	25
4/A		26		1111111111100010	26

#### JPEG default AC code (continued...)

5/2         1111111001         12         D/2         111111110001         18           5/3         111111110011111         19         D/3         111111110000         19           5/4         11111111000000         20         D/4         111111110000         20           5/5         11111111000000         21         D/5         1111111100010         21           5/6         11111111000001         22         D/6         111111110000         23           5/7         11111111000000         23         D/7         111111110000         23           5/8         111111110000101         25         D/9         111111110000         24           5/9         111111110000101         25         D/9         111111110001         25           5/A         111111110000         13         E/1         111111110001         25           6/1         111011         8         E/1         111111110010         13           6/2         111111110000         13         E/2         1111111110010         18           6/3         111111110010001         29         E/3         1111111110010         19           6/4         1111111110010001         21         E/	5/1	1111010	8	D/I	11111111010	12
5/3         111111110001111         19         D/3         1111111110000         19           5/4         11111111100000         20         D/4         1111111110000         20           5/5         11111111010000         21         D/5         1111111100010         21           5/6         11111111010000         22         D/6         1111111100001         22           5/7         11111111010000         23         D/7         1111111101000         23           5/8         11111111010000         24         D/8         1111111101000         24           5/9         11111111010010         25         D/9         1111111101001         25           6/1         111011         8         E/1         111111110101         25           6/1         11111110000         13         E/2         1111111101010         13           6/2         111111110000011         19         E/3         11111111101110         19           6/4         111111110010100         26         E/4         11111111100110         20           6/5         1111111110101010         21         E/5         11111111100111         21           6/6         1111111110101010         22 <td>5/2</td> <td>1111111001</td> <td>12</td> <td>10/2</td> <td>111111111100011</td> <td></td>	5/2	1111111001	12	10/2	111111111100011	
5/4         111111110100000         20         D/4         11111111100101         20           5/5         4111111110100001         21         D/5         411111111100010         21           5/6         1111111110100010         22         D/6         411111111100011         22           5/7         1111111110100000         23         D/7         41111111101000         23           5/8         111111110100000         24         D/8         41111111101000         24           5/9         111111110100010         25         D/9         41111111101010         25           5/A         1111111101000110         26         D/A         41111111101010         25           5/A         11111110000         13         E/2         41111111101010         13           6/1         411011110000         13         E/2         41111111101010         18           6/3         111111110101000         29         E/4         41111111101010         19           6/4         4111111110101000         20         E/4         411111111101010         20           6/5         4111111110101001         21         E/5         41111111110000         22           6/6         41111111	5/3	1111111110011111		12/3	IIIIIIIIIIIIIIIIIIIIII	19
5/5         111111110100001         21         D/5         1111111100010         21           5/6         111111110100000         22         D/6         11111111100000         23           5/7         111111110100000         23         D/7         1111111110000         23           5/8         111111110100000         24         D/8         11111111101000         24           5/9         111111110100010         25         D/9         1111111110101         25           5/A         11111111000010         26         D/A         1111111110101         26           6/1         111011         8         E/1         1111111101010         13           6/2         111111110000         13         E/2         1111111110100         18           6/3         111111110101001         19         E/3         11111111101010         19           6/4         111111110101001         21         E/5         11111111101011         20           6/5         1111111110101010         22         E/6         11111111110000         22           6/7         111111110101010         23         E/7         1111111110000         23           6/8         1111111110101010	5/4	IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	20	12/4	11111111111100101	20
5/7         1111111110100001         23         D/7         111111111101000         23           5/8         1111111110100000         24         D/8         111111111010001         24           5/9         1111111110100010         25         D/9         1111111110101         25           5/A         1111111101000110         26         D/A         1111111110101         26           6/1         111011         8         E/1         1111111101001         13           6/2         1111111101000         13         E/2         111111110100         18           6/3         111111110101000         20         E/4         1111111101010         19           6/4         111111110101000         26         E/4         111111111010110         20           6/5         1111111110101000         21         E/5         1111111110000         22           6/6         1111111110101000         22         E/6         11111111110000         23           6/8         1111111110101000         24         E/8         11111111110000         24           6/9         111111110000         26         E/8         11111111110000         26           7/1         11110000	5/5	111111111010XXXX	21	12/5	11111111111100110	
5/7         111111110100001         23         15/7         111111111010000         23           5/8         1111111110100100         24         15/8         111111111010001         24           5/9         1111111110100100         25         15/9         11111111101010         25           5/A         111111110100110         26         15/A         11111111101011         26           6/1         111011         8         15/1         1111111101010         13           6/2         1111111101000         13         15/2         11111111101010         18           6/3         111111110101000         29         15/4         11111111101110         19           6/4         1111111110101000         20         15/4         11111111101110         20           6/5         1111111110101000         21         15/5         11111111110000         22           6/6         1111111110101010         22         15/6         11111111110000         22           6/7         1111111110101010         24         15/8         11111111110000         23           6/8         1111111110001010         24         15/8         11111111110000         24           6/9         11	5/6	111111111010X010		D/6	1111111111100t11	
5/8         111111110100000         24         D/8         1111111100001         24           5/9         111111110100010         25         D/9         11111111101010         25           5/A         111111110100110         26         D/A         1111111101011         26           6/1         111011         8         E/1         1111111101010         13           6/2         11111110000         13         E/2         1111111101010         18           6/3         11111111010001         19         E/3         11111111101010         19           6/4         111111110101000         20         E/4         11111111101110         20           6/5         11111111010101001         21         E/5         11111111100110         20           6/5         11111111010101001         22         E/6         11111111110000         22           6/7         11111111101010101         23         E/7         11111111110000         23           6/8         11111111101010101         25         E/9         11111111110001         24           6/9         111111110001         26         E/A         1111111110001         25           6/A         111111110001	5/7	11111111110100011	23	12/7	111111111111010XXX	23
5/9         1111111101010010         25         D/9         11111111101010         25           5/A         1111111110100110         26         D/A         11111111101011         26           6/1         111011         8         E/1         1111111101010         13           6/2         1111111101010         13         E/2         11111111101010         18           6/3         11111111010100         19         E/3         1111111110110         19           6/4         111111110101000         29         E/4         11111111101110         20           6/5         111111110101010         21         E/5         111111111010110         20           6/6         1111111110101010         22         E/6         111111111110000         22           6/7         1111111110101010         23         E/7         11111111110000         23           6/8         1111111101010101         24         E/8         1111111111110001         24           6/9         111111110001010         26         E/9         1111111111111110001         25           6/A         111110001         26         E/3         1111111111110001         26           7/1         11110001	5/8	1111111110100100	24	13/8	11111111111101001	
5/A         ITITITITION         26         D/A         ITITITITION         26           6/1         ITITITION         3         E/1         ITITITION         13           6/2         ITITITION         13         E/2         ITITITION         18           6/3         ITITITION         19         E/3         ITITITION         19           6/4         ITITITION         20         E/4         ITITITION         20           6/5         ITITITION         21         E/5         ITITITION         20           6/6         ITITITION         22         E/6         ITITITION         22           6/7         ITITITION         23         E/7         ITITITION         23           6/8         ITITITION         24         E/8         ITITITION         24           6/9         ITITITION         25         E/9         ITITITION         24           6/4         ITITITION         26         E/8         ITITITION         25           6/1         ITITITION         26         E/9         ITITITION         26           6/1         ITITITION         27         ITITITION         27           7/1         ITITI	5/9	1111111110100101		D/9		25
6/2         11111111000         13         E/2         111111110100         18           6/3         1111111101000111         19         E/3         1111111101010         19           6/4         111111110101000         29         E/4         11111111010110         20           6/5         111111110101001         21         E/5         11111111100111         21           6/6         111111110101010         22         E/6         1111111110000         22           6/7         1111111110101010         23         E/7         1111111110001         23           6/8         1111111110101101         25         E/9         1111111110001         24           6/9         1111111110101101         25         E/9         1111111110001         25           6/A         111111110001         26         E/A         1111111110000         26           7/1         11111110001         13         E/1         11111111110001         17           7/3         111111111010000         20         E/3         111111111110010         18           7/4         111111110100000         20         E/3         1111111111111000         20           7/6         1111111110100000	5/A	1111111110100110		DIA	111111111111111111111111111111111111111	
6/2         11111111000         13         E/2         111111110100         18           6/3         111111110100011         19         E/3         11111111010101         19           6/4         111111110101000         20         E/4         11111111010110         20           6/5         111111110101001         21         E/5         11111111100111         21           6/6         11111111010101         22         E/6         111111111000         22           6/7         11111111010101         23         E/7         1111111110001         23           6/8         11111111010101         24         E/8         1111111110001         24           6/9         1111111101010101         25         E/9         11111111110001         25           6/A         111111110001         26         E/A         1111111110000         26           7/1         11111110001         9         E/0         11111111101010         17           7/2         11111111000001         13         E/1         111111111101010         18           7/4         111111110100000         20         E/3         11111111110110         19           7/6         111111111011001000	6/1	1111011	8	1E/1	111411110110	13
6/3         1111111101000111         19         E/3         111111111010101         19           6/4         1111111110101000         20         E/4         11111111101111         20           6/5         1111111110101001         21         E/5         11111111101111         21           6/6         1111111110101010         22         E/6         1111111110000         22           6/7         111111110101010         23         E/7         1111111110000         23           6/8         1111111110101010         24         E/8         111111111110000         24           6/9         1111111110101010         25         E/9         111111111111110100         25           6/A         111111110001         26         E/A         111111111111111110100         26           7/1         111111110001         9         F/0         111111111111111111111111111111111111	6/2	11111111000		19/2	11111111111101100	18
6/4         111111110101000         20         E/4         11111111010110         20           6/5         1111111110101001         21         E/5         1111111110101111         21           6/6         1111111110101010         22         E/6         11111111110000         22           6/7         1111111110101010         23         E/7         11111111110000         23           6/8         1111111110101010         24         E/8         11111111110001         24           6/9         1111111110101010         25         E/9         111111111110001         25           6/A         111111110001         26         E/A         111111111110000         26           7/1         111111110001         9         F/0         111111111111111110000         26           7/2         11111111100000         13         F/1         111111111111111111111111111111111111	6/3	11111111110100111	19		111111111111111111111111111111111111111	19
6/5         111111110101001         21         E/5         1111111110101111         21           6/6         1111111110101010         22         E/6         11111111111010111         22           6/7         1111111110101011         23         E/7         11111111110001         23           6/8         1111111110101101         24         E/8         11111111110010         24           6/9         1111111110101101         25         E/9         11111111111101001         25           6/A         111111111010101         26         E/A         11111111111111111110100         26           7/1         1111111110001         9         F/0         111111111111111111111111111111111111	6/4	11111111110101000	20		11111111111101110	20
6/6 1111111110101010 22 E/6 1111111111110000 22 6/7 1111111111101001 23 E/7 111111111110001 23 6/8 1111111111010101 24 E/8 1111111111110010 24 6/9 1111111111010110 25 E/9 11111111111110011 25 6/A 111111111110101 10 26 E/A 111111111111110100 26 7/1 1111111001	6/5	11111111110101001			11111111111111111111	
6/7         11111111101010101         23         E/7         1111111110001         23           6/8         11111111101010101         24         E/8         11111111110010         24           6/9         1111111110101101         25         E/9         111111111111110011         25           6/A         111111110101100         26         E/A         111111111111110100         26           7/1         1111111001         9         F/0         111111111111111111111111111111111111	6/6	1111111110101010			1111111111110000	
6/8     1111111110101101     24     E/8     111111111101010     24       6/9     1111111110101101     25     E/9     1111111111110011     25       6/A     111111110101100     26     E/A     1111111111111110100     26       7/1     11111001     9     E/0     111111111111110100     26       7/2     111111110001     9     E/0     111111111111111111111111111111111111	6/7	11111111110101011	23		1000011111111111111	23
6/9     111111110101101     25     E/9     111111111110011     25       6/A     1111111110101100     26     E/A     11111111111110100     26       7/1     11111001     9     E/0     1111111111110101     12       7/2     111111110001     13     E/1     11111111111111110101     17       7/3     111111111010000     19     E/2     111111111111111111111111111111111111	6/8	1111111110101100		15/8	11111111111110010	24
7/1         11111001         9         F/0         11111110111         12           7/2         1111111001         13         F/1         111111111111111111111111111111111111	6/9	11111111110101101		E/9	111111111111111111111111111111111111111	25
7/2     11111111001     13     171     1111111111110101     17       7/3     1111111110110000     19     172     11111111111111110110     18       7/4     1111111110110000     20     173     111111111111111111111111111111111111	MA	1111111110101110	26	EA	11111111111110100	
7/3     1111111110101111     19     14/2     111111111111111111111111111111111111	7/1	11111001	9	F/0	111111110111	
7/4     111111111111111111111111111111111111	7/2	11111111001	13	1-71	1111111111110101	17
7/5   111111110110001   21   17/4   111111111111111000   20   7/6   11111111110110010   22   17/5   111111111111111001   21	7/3	11111111110101111	19	142		
7/6 111111110110010 22 1-75 11111111111111001 21	7/4	111111110110HH0	20	F/3		
그리아가 그 이 사람들은 아이를 가려면 하는 그 그 그리고 그는 그 그 그리는 그리아를 내려가 되었다. 그리아	7/5	1111111110110801				
7/7 [11111110110011 23 176 [11111111111111010 22		1111111110110010			를 하게하다 및 시대장(BD) : [10] (PS) (BB) (BB) (BB) (BB) (BB) (BB)	
	7/7	11111111110110011	23	1-76	141111111111111111111111111111111111111	22

#### JPEG default AC code (continued...)

5/1	1111010	8	D/I	11111111010	12
5/2	1111111001	12	12/2	1111111111100011	18
5/3	1111111110011111	19	13/3	11111111111111ANICK	14
5/4	IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	20	12/4	11111111111100101	20
5/5	111111111010XXXX	21	13/5	11111111111100110	21
5/6	1111111110100000	22	12/6	11111111111100111	27
5/7	11111111110100011	23	12/7	000010111111111	23
5/X	1111111110100100	24	12/8	11111111111101001	24
5/1)	1111111110100101	25	D/9	1111111111111	25
5/A	1111111110100110	26	DIA	111111111111111111111111111111111111111	26
6/1	1111011	8	E/1	111411110110	13
0/2	11111111000	1.3	19/2	11111111111101100	18
6/3	11111111110100111	19	E/3	111111111111101	19
6/4	11111111110101000	20	E/4	11111111111101110	20
6/5	1111111110101001	21	E/5	11111111111111111111	21
6/6	1111111110101010	22	E/6	11111111111110000	22
6/7	1111111110101011	23	19/7	1511111111110001	23
6/8	1111111110101100	24	15/8	1111111111110010	24
6/9	11111111110101101	25	E/9	11111111111111111111111111111111111111	25
MA	1111111110101110	26	E/A	11111111111110100	26
7/1	11111001	9	F/O	[11111110111	12
7/2	11111111001	1.3	1-/1	1111111111111	17
7/3	11111111111111111	19	1-/2	11111111111111	ix
7/4	1111111111110H	20	F/3	111111111111111111111111111111111111111	19
7/5	TITLITITION (CAR)	21	1:/4	191111111111100ks	20)
7/6	1111111110110010	22	1-75	111111111111111111111111111111111111111	21
7/7	1111111110110011	23	1-76	141111111111111010	22

## JPEG Example

#### **Original Image Block**

124	125	122	120	122	119	117	118
121	121	120	119	119	120	120	118
126	124	123	122	121	121	120	120
124	124	125	125	126	125	124	124
127	127	128	129	130	128	127	125
143	142	143	142	140	139	139	139
150	148	152	152	152	152	150	151
156	159	158	155	158	158	157	156

### JPEG Example

## Original Image Block → DCT

#### Large values



DCT coefficients
After subtracting 128
From each pixel.

39,8750	6.5653	-2.2420	1.2203	-0.3750	-1.0874	0.7934	1.1347
-102.4388	4.5675	2.2637	1.1206	0.3581	-0.6336	-1.0530	-0.4802
37,7706	1.3144	1,7740	0.2583	-1,5095	-2.2182	-0.1010	0.2329
-5.6740	2.2421	-1.3260	-0.8132	1.4173	0.2212	-0.1393	0.1703
-3.3750	-0.7451	-1.7569	0.7764	-0.6250	-2,6597	-1.3018	0.7620
5.9894	-0.1399	-0.4595	-0.7788	1.9994	-0.2652	1.4643	0.0047
3.9733	5.5280	2.3990	-0.5588	-0.0512	-0.8476	-0.5240	-0.1301
-3.4331	0.5198	-1.0721	0.8711	0.9634	0.0903	0.3305	0.0109

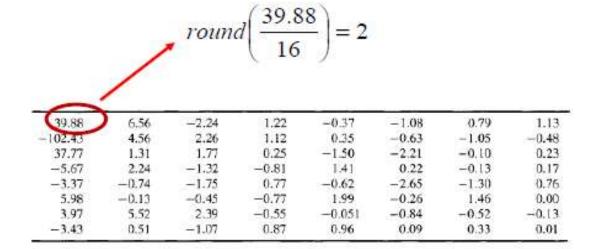
Small values

#### (The quantization table)

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

#### **QUANTIZATION**

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



DCT coefficients

#### DCT coefficients

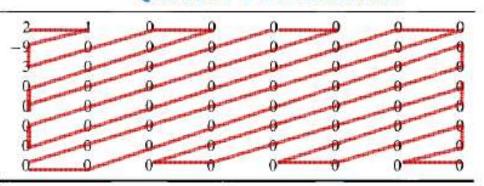
6.56	-2.24	1.22	-0.37	-1.08	0.79	1.13
4.56	2.26	1.12	0.35	-0.63	-1.05	-0.48
1.31	1.77	0.25	-1.50	-2.21	-0.10	0.23
2.24	-1.32	-0.81	1.41	0.22	-0.13	0.17
-0.74	-1.75	0.77	-0.62	-2.65	-1.30	0.76
-0.13	-0.45	-0.77	1.99	-0.26	1.46	0.00
5.52	2.39	-0.55	-0.051	-0.84	-0.52	-0.13
0.51	-1.07	0.87	0.96	0.09	0.33	0.01
	4.56 1.31 2.24 -0.74 -0.13 5.52	4.56 2.26 1.31 1.77 2.24 -1.32 -0.74 -1.75 -0.13 -0.45 5.52 2.39	4.56     2.26     1.12       1.31     1.77     0.25       2.24     -1.32     -0.81       -0.74     -1.75     0.77       -0.13     -0.45     -0.77       5.52     2.39     -0.55	4.56     2.26     1.12     0.35       1.31     1.77     0.25     -1.50       2.24     -1.32     -0.81     1.41       -0.74     -1.75     0.77     -0.62       -0.13     -0.45     -0.77     1.99       5.52     2.39     -0.55     -0.051	4.56     2.26     1.12     0.35     -0.63       1.31     1.77     0.25     -1.50     -2.21       2.24     -1.32     -0.81     1.41     0.22       -0.74     -1.75     0.77     -0.62     -2.65       -0.13     -0.45     -0.77     1.99     -0.26       5.52     2.39     -0.55     -0.051     -0.84	4.56     2.26     1.12     0.35     -0.63     -1.05       1.31     1.77     0.25     -1.50     -2.21     -0.10       2.24     -1.32     -0.81     1.41     0.22     -0.13       -0.74     -1.75     0.77     -0.62     -2.65     -1.30       -0.13     -0.45     -0.77     1.99     -0.26     1.46       5.52     2.39     -0.55     -0.051     -0.84     -0.52

#### Quantization table

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	1112	100	103	995

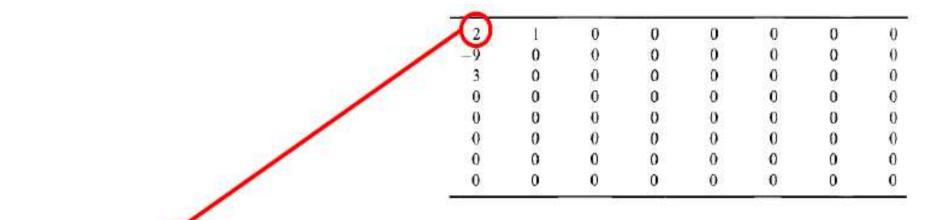


#### Quantized DCT coefficients



Zigzag

#### DCPM ON DC



DC = 2 Suppose the previous DC is -1, DIFF\_DC = 2 - (-1) = 3
3 is in Category 2 (send 100), use 2 bits (11) to specify "3"
Send 10011 5 bits

#### RLE ON ACs

#### Example (cont.)

2	I	0	0	0	0	0	0
-9	0	0	0	0	0	0	0
3	0	0	0	0	0	0	O
0	0	0	0	0	0	0	0
0	0	0	0	O	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

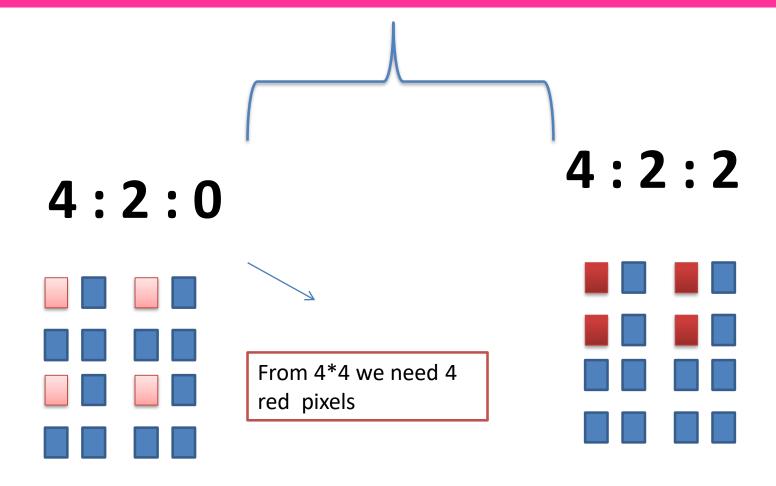
AC = (0,1), (0,-9), (0,3), EOB

**10011** 00**1** 1011 **0110** 01**11** 1010

Compression ratio=64\*8/24=21.3

Average length:24 / 64 = 0.375 bits per pixel

## Chroma subsampling



# Thanks for your attention