More Digital Representation

Discrete information is represented in binary (PandA), and "continuous" information is made discrete

Return To RGB

Images are constructed from picture elements (pixels); color uses RGB light

The RGB color intensities are specified by 3 numbers in the range (0, 255), ie 1 byte each

Black = (0, 0, 0)	0000 0000 0000 0000 0000 0000
Gray = (128,128,128)	1000 0000 1000 0000 1000 0000
White = (255,255,255)	1111 1111 1111 1111 1111 1111

White-gray-black all have same values for RGB

Colors

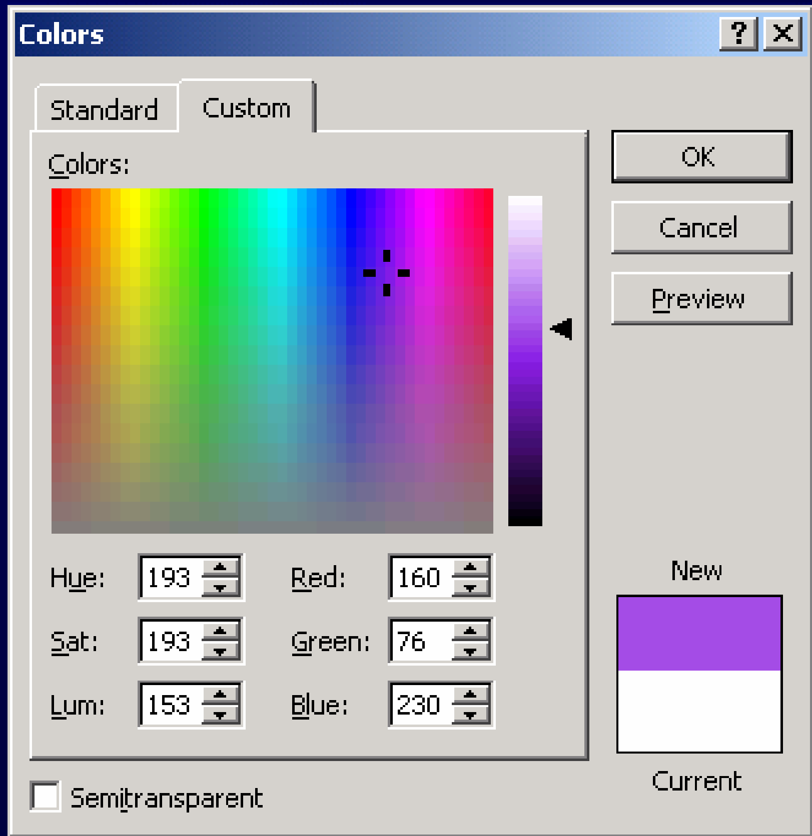
Colors use different combinations of RGB

- **Husky Purple**

Red=160

Green=76

Blue=230



Positional Notation

The RGB intensities are binary numbers

Binary numbers, like decimal numbers, use *place notation*

$$1101 = 1 \times 1000 + 1 \times 100 + 0 \times 10 + 1 \times 1$$
$$= 1 \times 10^3 + 1 \times 10^2 + 0 \times 10^1 + 1 \times 10^0$$

except that the base is 2 not 10

$$1101 = 1 \times 8 + 1 \times 4 + 0 \times 2 + 1 \times 1$$
$$= 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

Base or radix

1101 in binary is 13 in decimal

Binary Numbers

Given a binary number, add up the powers of 2 corresponding to 1s

1×2^7	$= 1 \times 128$	$= 128$
0×2^6	$= 0 \times 64$	$= 0$
1×2^5	$= 1 \times 32$	$= 32$
0×2^4	$= 0 \times 16$	$= 0$
0×2^3	$= 0 \times 8$	$= 0$
0×2^2	$= 0 \times 4$	$= 0$
0×2^1	$= 0 \times 2$	$= 0$
0×2^0	$= 0 \times 1$	$= 0$

1010 0000 $= 160$

Binary Numbers

Given a binary number, add up the powers of 2 corresponding to 1s

0×2^7	$= 0 \times 128$	$= 0$
1×2^6	$= 1 \times 64$	$= 64$
0×2^5	$= 0 \times 32$	$= 0$
0×2^4	$= 0 \times 16$	$= 0$
1×2^3	$= 1 \times 8$	$= 8$
1×2^2	$= 1 \times 4$	$= 4$
0×2^1	$= 0 \times 2$	$= 0$
0×2^0	$= 0 \times 1$	$= 0$

0100 1100 $= 76$

Binary Numbers

Given a binary number, add up the powers of 2 corresponding to 1s

1×2^7	$= 1 \times 128$	$= 128$
1×2^6	$= 1 \times 64$	$= 64$
1×2^5	$= 1 \times 32$	$= 32$
0×2^4	$= 0 \times 16$	$= 0$
0×2^3	$= 0 \times 8$	$= 0$
1×2^2	$= 1 \times 4$	$= 4$
1×2^1	$= 1 \times 2$	$= 2$
0×2^0	$= 0 \times 1$	$= 0$

1110 0110 $= 230$

Husky Purple

Recall that Husky purple is (160,76,230) which in binary is

1010 0000 0100 1100 1110 0110

160 76 230

Suppose you decide it's not "red" enough

- **Increase the red by 16 = 1 0000**

```
  1010 0000
+      1 0000
  ---------
  1011 0000
```

Adding in binary is pretty much like adding in decimal

A Redder Purple

Increase by 16 more

```
  00110 000    <------  Carries
   1011 0000
_ +   1 0000
   ---------
   1100 0000
     ↑↑
```

The rule: When the "place sum" equals the radix or more, subtract radix & carry

Find Binary From Decimal

Fill in the Table:

Num Being Converted	230	230	102	38	6	6	6	2	0
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38	6			2	0	
Binary Num	0	1	1	1	0	0	1	1	0

Find Binary From Decimal

Place number to be converted into the table; fill place value row with decimal powers of 2

Num Being Converted	230								
Place Value	256	128	64	32	16	8	4	2	1
Subtract									
Binary Num									

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230 →	230							
Place Value	256	128	64	32	16	8	4	2	1
Subtract									
Binary Num	0								

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102						
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102							
Binary Num	0	1							

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102	38					
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38						
Binary Num	0	1	1						

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102	38	6				
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38	6					
Binary Num	0	1	1	1					

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102	38	6	6			
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38	6					
Binary Num	0	1	1	1	0				

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102	38	6	6	6		
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38	6					
Binary Num	0	1	1	1	0	0			

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102	38	6	6	6	2	
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38	6			2		
Binary Num	0	1	1	1	0	0	1		

Find Binary From Decimal

Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102	38	6	6	6	2	0
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38	6			2	0	
Binary Num	0	1	1	1	0	0	1	1	

Find Binary From Decimal

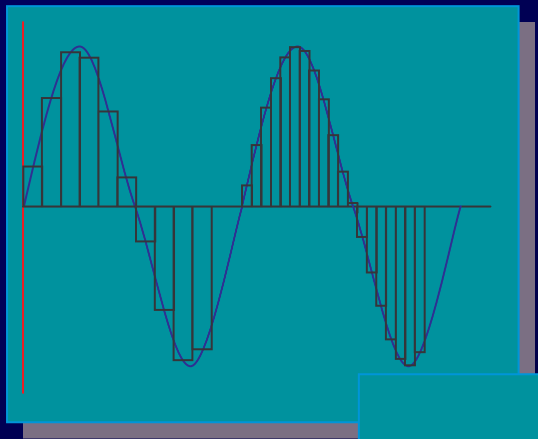
Rule: Subtract PV from the number; a positive result gives new number and "1"; otherwise, "0"

Num Being Converted	230	230	102	38	6	6	6	2	0
Place Value	256	128	64	32	16	8	4	2	1
Subtract		102	38	6			2	0	
Binary Num	0	1	1	1	0	0	1	1	0

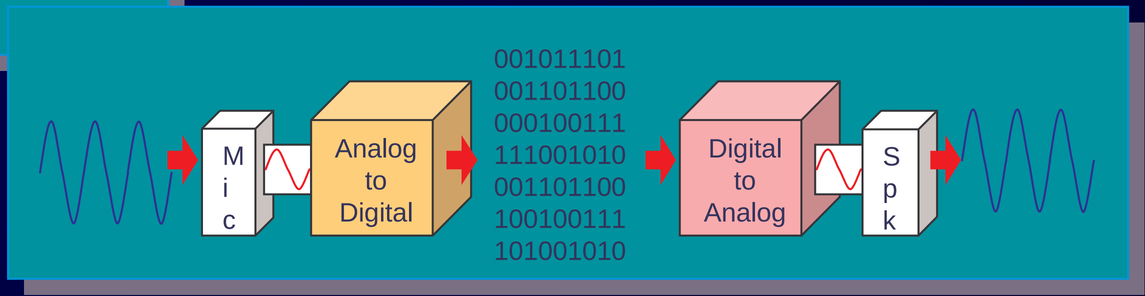
Read off the result: 0 1110 0110

Digitizing

"Continuous" information like light and sound must be made "discrete"



Digital audio uses 44,100 samples per second of 16 bits on two channels, or 10,584,000 B/min



Compression

Compression: use fewer bits

- Lossless – Recover the data
- Lossy– Lose the original data

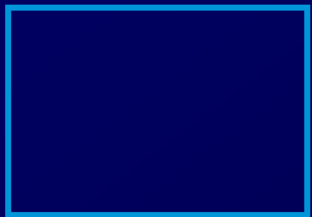
JPEG

Original

Over compressed

Run-Length Compression

Give number of 1s, number of 0s, etc.



1111111111…
1111111111…
1100000000…
1100000000…
…

(270 1s)
(270 1s)
(2 1s)(266 0s)(2 1s)
(2 1s)(266 0s)(2 1s)
…

Forget row encoding … alternate

[Size: 270x200](542)(266)(4)(266)(4)(266)(4)(266) …

Bits Are It

Bits represent information, but their interpretation gives bits meaning

0000 0000 1111 0001 0000 1000 0010 0000

- Could be a number, color, instruction, ASCII, sound samples, IP address, …

Bias-free Universal Medium Principle: Bits can represent all discrete information; bits have no inherent meaning

Summary

Bits can represent any information

* Discrete information is directly encoded using binary
* Continuous information is made discrete
* Bias-free Universal Medium Principle