

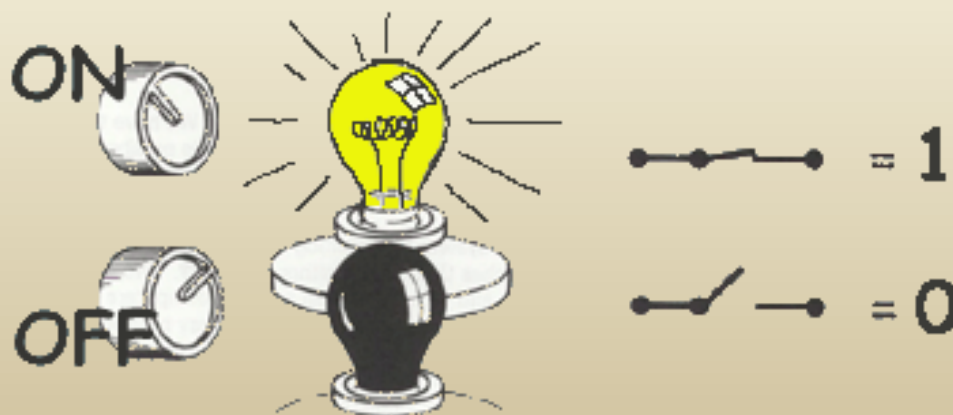


CHAPTER 1. Number Systems

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Common Number Systems

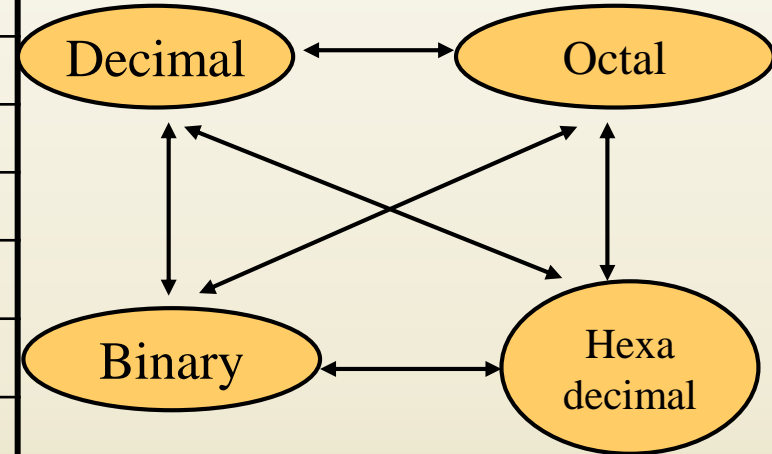
System	Base	Symbols	Used by humans?	Used in computers?
Decimal	10	0, 1, ... 9	Yes	No
Binary	2	0, 1	No	Yes
Octal	8	0, 1, ... 7	No	No
Hexa-decimal	16	0, 1, ... 9, A, B, ... F	No	No

Why Binary System?

- Computers are made of a series of switches
- Each switch has two states: ON or OFF
- Each state can be represented by a number – 1 for “ON” and 0 for “OFF”

Counting

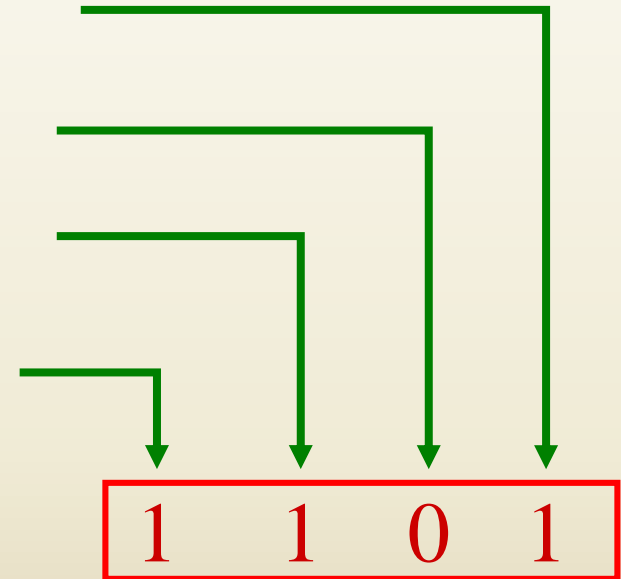
Decimal	Binary	Octal	Hexa- decimal
0	0	0	0
1	1	1	1
2	10	2	2
3	11	3	3
4	100	4	4
5	101	5	5
6	110	6	6
7	111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F



DECIMAL TO BINARY CONVERSION

Divide by 2 Process

Decimal # $13 \div 2 = 6$ remainder 1
 $6 \div 2 = 3$ remainder 0
 $3 \div 2 = 1$ remainder 1
 $1 \div 2 = 0$ remainder 1



let us convert the given decimal number 294 into a binary number.

Divide by 2	Result	Remainder
$294 \div 2$	147	0
$147 \div 2$	73	1
$73 \div 2$	36	1
$36 \div 2$	18	0
$18 \div 2$	9	0
$9 \div 2$	4	1
$4 \div 2$	2	0
$2 \div 2$	1	0
$1 \div 2$	0	1

Therefore, the binary equivalent for the given decimal number 294_{10} is 100100110_2

$$\mathbf{294_{10} = 100100110_2}$$

Example 1: Convert 160_{10} to binary Number Solution:

Given: Decimal Number = 160_{10}

Divide by 2	Result	Remainder
$160 \div 2$	80	0
$80 \div 2$	40	0
$40 \div 2$	20	0
$20 \div 2$	10	0
$10 \div 2$	5	0
$5 \div 2$	2	1
$2 \div 2$	1	0
$1 \div 2$	0	1

Therefore, $160_{10} = 10100000_2$

- **Example:** convert the number 333 to binary.

Division	Quotient	Remainder
333/2	166	1
166/2	83	0
83/2	41	1
41/2	20	1
20/2	10	0
10/2	5	0
5/2	2	1
2/2	1	0
1/2	0	1

$$333_{10} = 101001101_2$$

Successive Division by 2

2	29	Remainders
2	14	1 LSB
2	7	0
2	3	1
2	1	1
	0	1 MSB

Read the remainders from the bottom up

29 decimal = 11101 binary

2	4215	— 1	←	LSB
2	2107	— 1		
2	1053	— 1		
2	526	— 1		
2	263	— 0		
2	131	— 1		
2	65	— 1		
2	32	— 1		
2	16	— 0		
2	8	— 0		
2	4	— 0		
2	2	— 0		
2	1	— 0		
	0	— 1	←	MSB

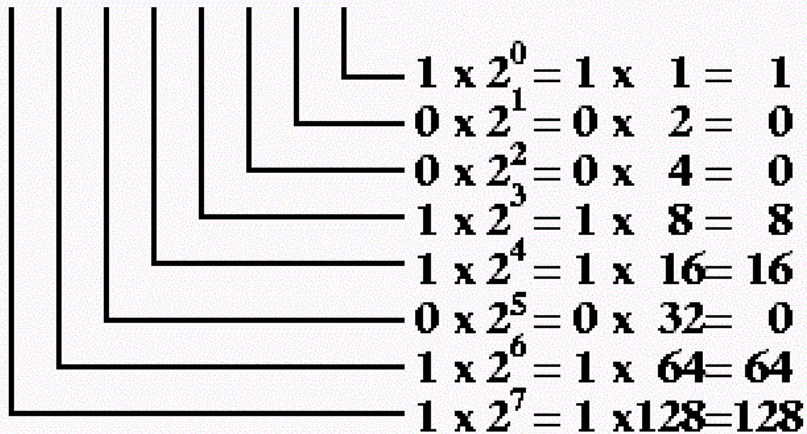
2	125	
2	62	→ 1
2	31	→ 0
2	15	→ 1
2	7	→ 1
2	3	→ 1
2	1	→ 1
	0	→ 1

BINARY TO DECIMAL CONVERSION

Convert Binary Number 10011 to a Decimal Number:

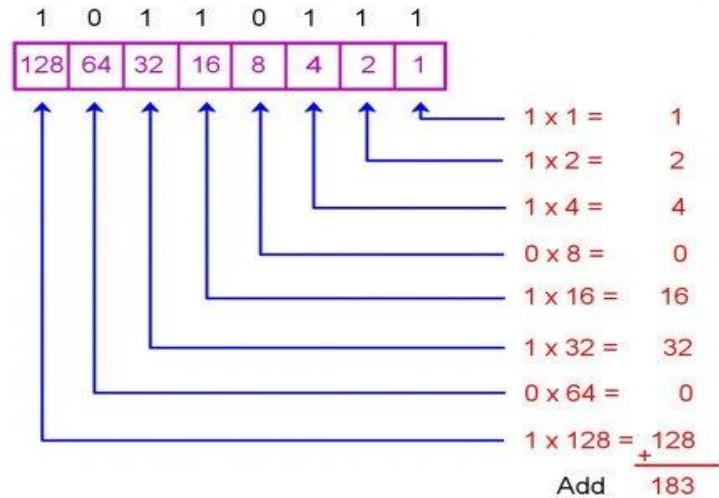
	(1	0	0	1	1) ₂
ON/OFF		ON	OFF	OFF	ON	ON	
Exponent:		2 ⁴	2³	2²	2 ¹	2 ⁰	
Calculation:		16	+ 0	+ 0	+ 2	+ 1	=
		(19)₁₀					

1 1 0 1 1 0 0 1



$1 + 8 + 16 + 64 + 128 = 217$

Convert 10110111 to Decimal



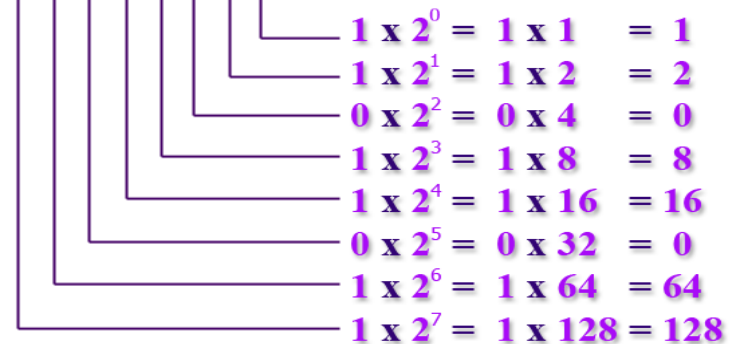
10110111 = 183 decimal

10011011



Result = 155

1 1 0 1 1 0 1 1



$1 + 2 + 8 + 16 + 64 + 128 = 219$

$(11011011)_2 = (219)_{10}$

HEXADECIMAL NUMBER SYSTEM

Uses 16 symbols -Base 16 System
0-9, A, B, C, D, E, F

<u>Decimal</u>	<u>Binary</u>	<u>Hexadecimal</u>
1	0001	1
9	1001	9
10	1010	A
15	1111	F
16	10000	10

HEXADECIMAL AND BINARY CONVERSIONS

- Hexadecimal to Binary Conversion

Hexadecimal	C	3
	↓	↓
Binary	1100	0011

- Binary to Hexadecimal Conversion

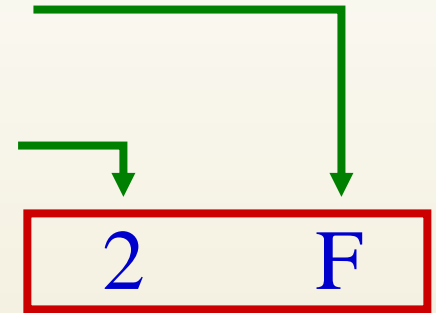
Binary	1110	1010
	↓	↓
Hexadecimal	E	A

DECIMAL TO HEXADECIMAL CONVERSION

Divide 47 by 16 Process

Decimal # $47 \div 16 = 2$ remainder 15

$2 \div 16 = 0$ remainder 2



Divide 4735 by 16 Process

4735_{10}

$$4735/16 = 295$$

$$295/16 = 18$$

$$18/16 = 1$$

$$1/16 = 0$$

$$15 = F$$

$$7 = 7$$

$$2 = 2$$

$$1 = 1$$

$$10 = A$$

$$11 = B$$

$$12 = C$$

$$13 = D$$

$$14 = E$$

$$15 = F$$

$127F_{16}$

HEXADECIMAL TO DECIMAL CONVERSION

Convert hexadecimal number **2DB** to a decimal number

Place Value	256s	16s	1s
Hexadecimal	2	D	B
	(256 x 2)	(16 x 13)	(1 x 11)
Decimal	512	+ 208	+ 11 = 731

Convert hexadecimal number **C921** to a decimal number

$C921_{16}$

$$\begin{aligned} & 1 \times 16^0 = 1 \times 1 \\ & + 2 \times 16^1 = 2 \times 16 \\ & + 9 \times 16^2 = 9 \times 256 \\ & + C \times 16^3 = C \times 4096 \end{aligned}$$

wiki How to Convert Hexadecimal to Binary or Decimal



TEST

Convert Hexadecimal number **A6** to Binary

A6 = 1010 0110 (Binary)

Convert Hexadecimal number **16** to Decimal

16 = 22 (Decimal)

Convert Decimal **63** to Hexadecimal

63 = 3F (Hexadecimal)

OCTAL NUMBERS

Uses 8 symbols -Base 8 System

0, 1, 2, 3, 4, 5, 6, 7

Decimal

Binary

Octal

1

001

1

6

110

6

7

111

7

8

001 000

10

9

001 001

11

Convert Decimal number 670 to a Octal number

$$670_{10} = 1236_8$$

$$670 \div 8 = 83 \text{ r. } 6$$

$$83 \div 8 = 10 \text{ r. } 3$$

$$10 \div 8 = 1 \text{ r. } 2$$

$$1 \div 8 = 0 \text{ r. } 1$$

Convert 120 (decimal) to its equivalent octal number.

<i>Octal number</i>	<i>Remainder</i>
8 120	
8 15	0
8 1	7
0	1

∴ the octal equivalent of 120 is 170.

Convert 460 (decimal) to its equivalent octal number.

<i>Octal number</i>	<i>Remainder</i>
8 460	
8 57	4
8 7	1
0	7

∴ the octal number = 714.

3	7	2	4	6
---	---	---	---	---

8^4 8^3 8^2 8^1 8^0

$6 \times 8^0 = 6$
 $4 \times 8^1 = 32$
 $2 \times 8^2 = 128$
 $7 \times 8^3 = 3584$
 $3 \times 8^4 = 12288$

16038

Octal = 37246

Decimal = 16038

Exercise – Convert ...

Decimal	Binary	Octal	Hexa- decimal
33			
	1110101		
		703	
			1AF

Don't use a calculator!

Skip answer

Answer

Exercise – Convert ...

Answer

Decimal	Binary	Octal	Hexa- decimal
33	100001	41	21
117	1110101	165	75
451	111000011	703	1C3
431	110101111	657	1AF



Common Powers (1 of 2)

- Base 10

Power	Preface	Symbol	Value
10^{-12}	pico	p	.000000000001
10^{-9}	nano	n	.000000001
10^{-6}	micro	μ	.000001
10^{-3}	milli	m	.001
10^3	kilo	k	1000
10^6	mega	M	1000000
10^9	giga	G	1000000000
10^{12}	tera	T	1000000000000

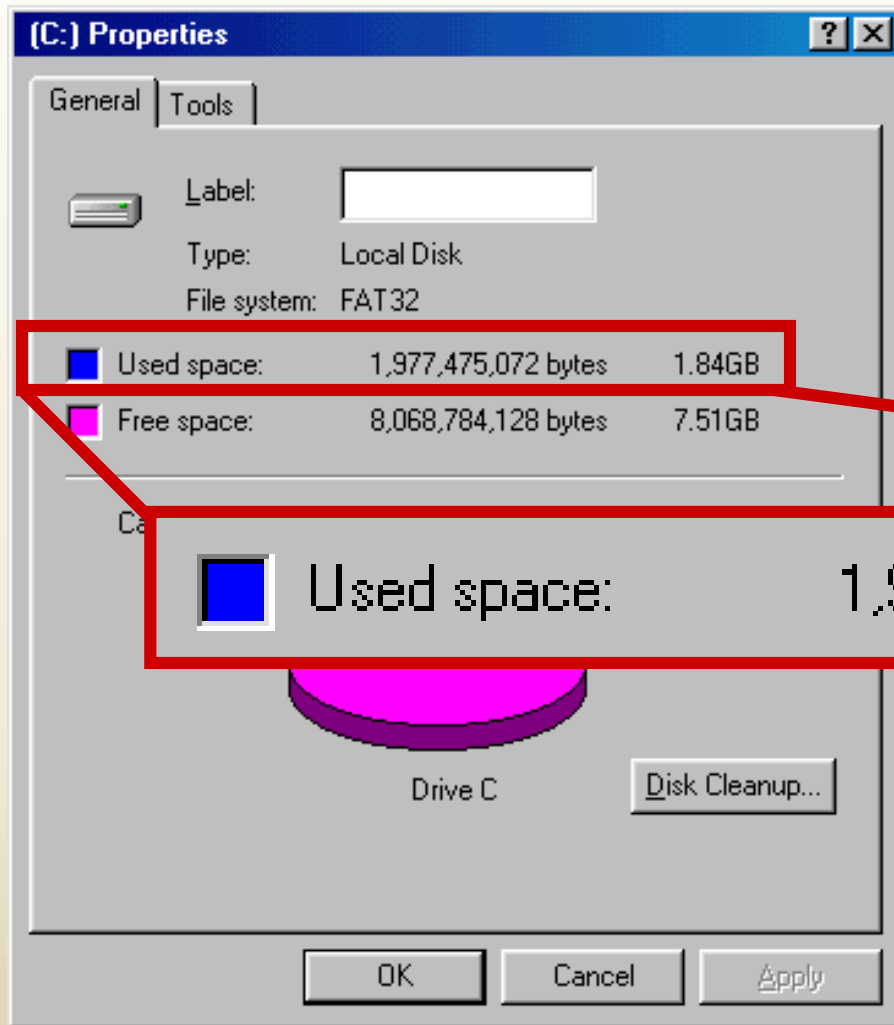
Common Powers (2 of 2)

- Base 2

Power	Preface	Symbol	Value
2^{10}	kilo	k	1024
2^{20}	mega	M	1048576
2^{30}	Giga	G	1073741824

- 1 Terab = $2^{10} * 2^{10} * 2^{10} * 2^{10}$ bytes
- 1 petabyte = $2^{10} * 2^{10} * 2^{10} * 2^{10} * 2^{10}$ bytes (2 to the 50th power)
- 1 exabyte = 2^{60}
- 1 zettabyte = 2^{70}
- 1 yottabyte = 2^{80}

Example



In the lab...

1. Double click on My Computer
2. Right click on C:
3. Click on Properties

$$/ 2^{30} =$$

Binary Addition

- Two 1-bit values

A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	10

“two”

- Two n -bit values
 - Add individual bits
 - Propagate carries
 - E.g.,

$$\begin{array}{r} \overset{1}{1}0101 \\ + 11001 \\ \hline 101110 \end{array} \qquad \begin{array}{r} 21 \\ + 25 \\ \hline 46 \end{array}$$

Multiplication

- Binary, two 1-bit values

A	B	A × B
0	0	0
0	1	0
1	0	0
1	1	1

- Binary, two n -bit values

- As with decimal values

- E.g.,

$$\begin{array}{r} 1110 \\ \times 1011 \\ \hline 1110 \\ 0000 \\ 1110 \\ \hline 10011010 \end{array}$$

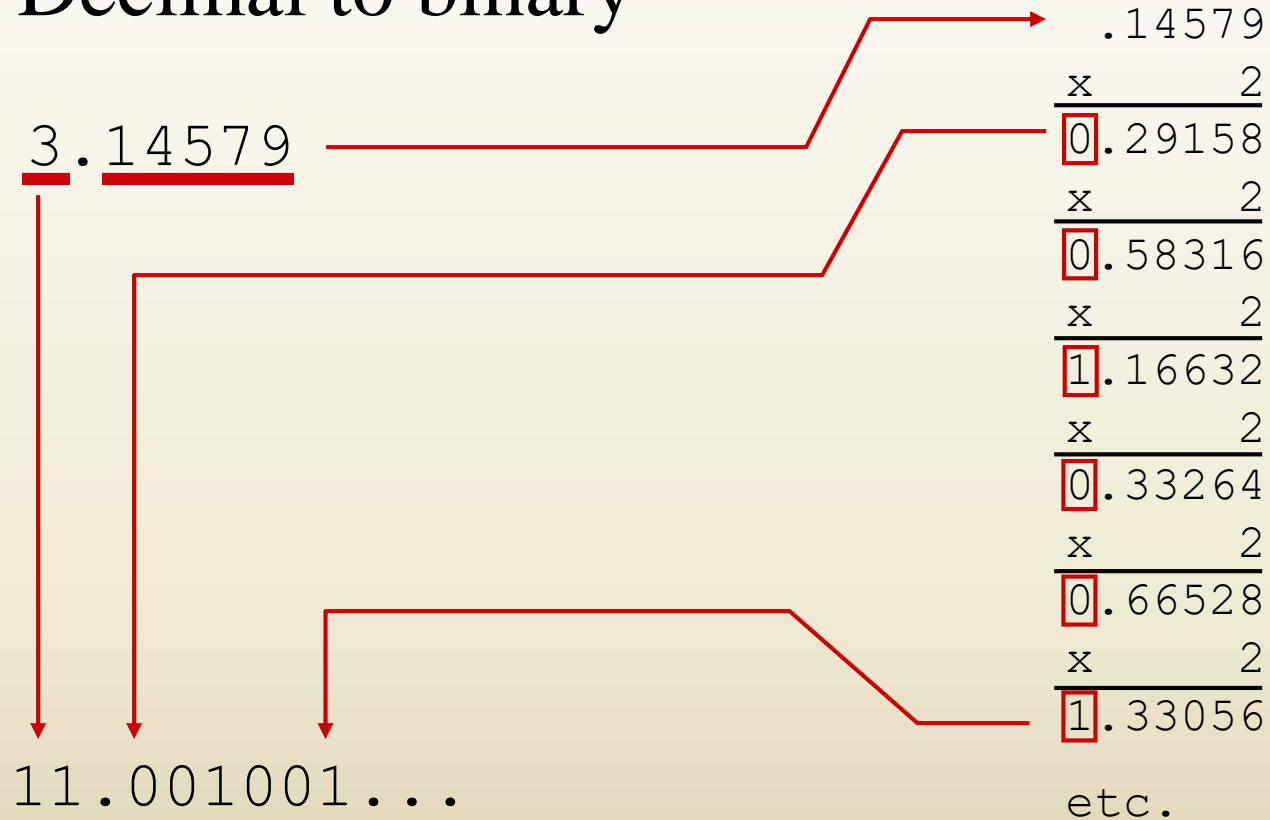
Fractions

- Binary to decimal

$$\begin{array}{r} 10.1011 \Rightarrow \\ 1 \times 2^{-4} = 0.0625 \\ 1 \times 2^{-3} = 0.125 \\ 0 \times 2^{-2} = 0.0 \\ 1 \times 2^{-1} = 0.5 \\ 0 \times 2^0 = 0.0 \\ 1 \times 2^1 = 2.0 \\ \hline 2.6875 \end{array}$$

Fractions

- Decimal to binary



Exercise – Convert ...

Decimal	Binary	Octal	Hexa- decimal
29.8			
	101.1101		
		3.07	
			C.82

Don't use a calculator!

Skip answer

Answer

Exercise – Convert ...

Answer

Decimal	Binary	Octal	Hexa- decimal
29.8	11101.110011...	35.63...	1D.CC...
5.8125	101.1101	5.64	5.D
3.109375	11.000111	3.07	3.1C
12.5078125	1100.10000010	14.404	C.82



Thank you

Next topic