

## Beyond Base 10: Non-decimal Based Number Systems

- What is the decimal based number system?
- How does the binary number system work
- Converting between decimal and binary

James Tam

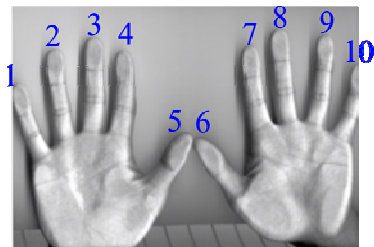
### What Is Decimal?

Base 10

- 10 unique symbols are used to represent values

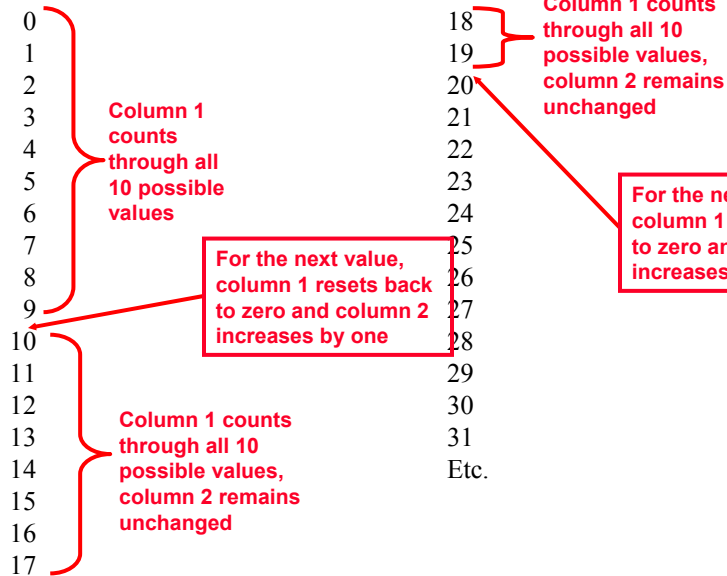
0
1
2
3
4
5
6
7
8
9
10
:

The number of digits is based on...the number of digits



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## How Does Decimal Work?



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## Decimal

Base ten

Employs ten unique symbols (0, 1, 2, 3, 4, 5, 6, 7, 8, 9)

Each digit can only take on the value from 0 – 9

- Once a column has traversed all ten values then that column resets back to zero (as does it right hand neighbours) and the column to it's immediate left increases by one.

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## **Recall: Computers Don't Do Decimal!**

Most parts of the computer work in a discrete state:

- On/off
- True/false
- Yes/No

These two states can be modeled with the binary number system

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## **Binary**

Base two

Employs two unique symbols (0 and 1)

Each digit can only take on the value 0 or the value 1

- Once a column has traversed both values then that column resets back to zero (as does it right hand neighbours) and the column to it's immediate left increases by one.

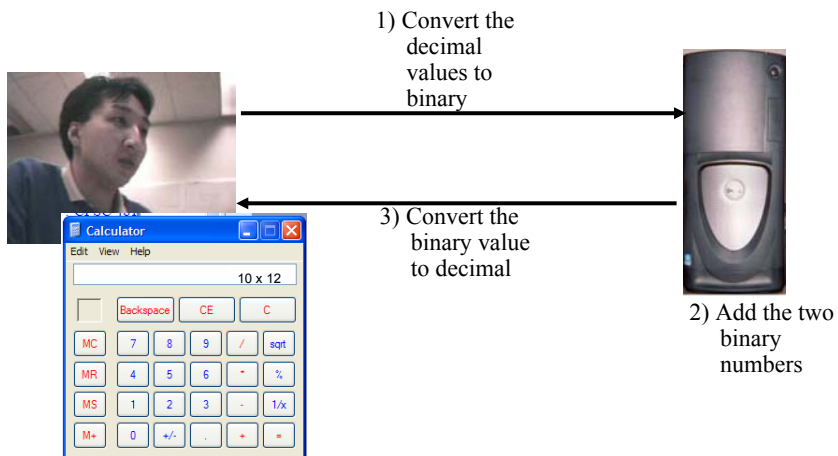
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## Counting In Binary

Decimal value	Binary value	Decimal value	Binary value
0	0000	8	1000
1	0001	9	1001
2	0010	10	1010
3	0011	11	1011
4	0100	12	1100
5	0101	13	1101
6	0110	14	1110
7	0111	15	1111

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## Computers Don't Do Decimal!



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## **Converting From Decimal To Binary**

Split up the integer and the fractional portions

- 1) For the integer portion:
  - a. Divide the integer portion of the decimal number by two.
  - b. The remainder becomes the first integer digit of the binary number (immediately left of the decimal).
  - c. The quotient becomes the new integer value.
  - d. Divide the new integer value by the target base.
  - e. The new remainder becomes the second integer digit of the binary number (second digit to the left of the decimal).
  - f. Continue dividing until the quotient is less than two (i.e., it's zero or one) and this quotient becomes the last integer digit of the binary number.

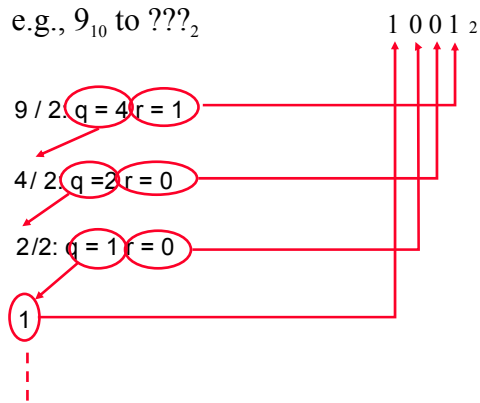
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## **Converting From Decimal To Binary (2)**

- 2) For the fractional portion:
  - a. Multiply by two.
  - b. The integer portion (if any) of the product becomes the first rational digit of the binary number (first digit to the right of the decimal).
  - c. The rational portion of the product is then multiplied by two.
  - d. The integer portion (if any) of the new product becomes the second rational digit of the binary number (second digit to the right of the decimal).
  - e. Keep multiplying by two base until:
    - a. either the resulting product equals zero,
    - b. or you have the desired number of places of precision.

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## Converting From Decimal To Binary (3)



Stop dividing! (quotient is less than two)

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## Other Example Conversions: Decimal To Binary

Decimal value	Binary value (calculate to a maximum of four fractional digits)
0.5	???
0.1	???
35.25	???

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## Converting From Binary To Decimal

Evaluate the expression: two raised to some exponent<sup>1</sup>, multiply the resulting expression by the corresponding digit and sum the resulting products.

### Example:

1 0 <sup>-1</sup> ← Position of digits  
 1 1. 0<sub>2</sub> ← Number to be converted

$$\text{Value in decimal} = (1 \times 2^1) + (1 \times 2^0) + (0 \times 2^{-1}) = (1 \times 2) + (1 \times 1) + 0 = 3$$

### General formula:

3 2 1 0 -1 -2 -3 ← Position of digits  
 d7 d6 d5 d4. d3 d2 d1<sub>b</sub> ← Number to be converted

$$\text{Value in decimal} = (\text{digit}7 \times 2^3) + (\text{digit}6 \times 2^2) + (\text{digit}5 \times 2^1) + (\text{digit}4 \times 2^0) + (\text{digit}3 \times 2^{-1}) + (\text{digit}2 \times 2^{-2}) + (\text{digit}1 \times 2^{-3})$$

<sup>1</sup> The value of this exponent will be determined by the position of the digit (superscript)

## Other Example Conversions: Binary To Decimal

Binary value	Decimal value
0.1	???
0.01	???
10000	???
01111	???
10001	???

## **You Should Now Know**

- What is meant by a number base.
- How the binary works what role it plays in the computer.
- How to convert to/from binary and decimal.