The language of the computers

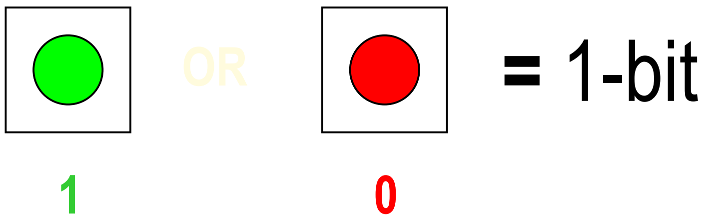
CMPT -2!X

The Language of the Computers

Computer (binary) arithmetic

Digital computers use two states

- 0 and 1 = Binary System
- Bi in Latin is 2



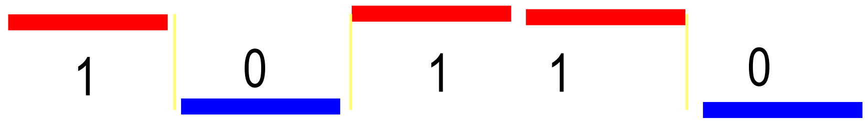
Binary system

- 0 and 1 = Binary System

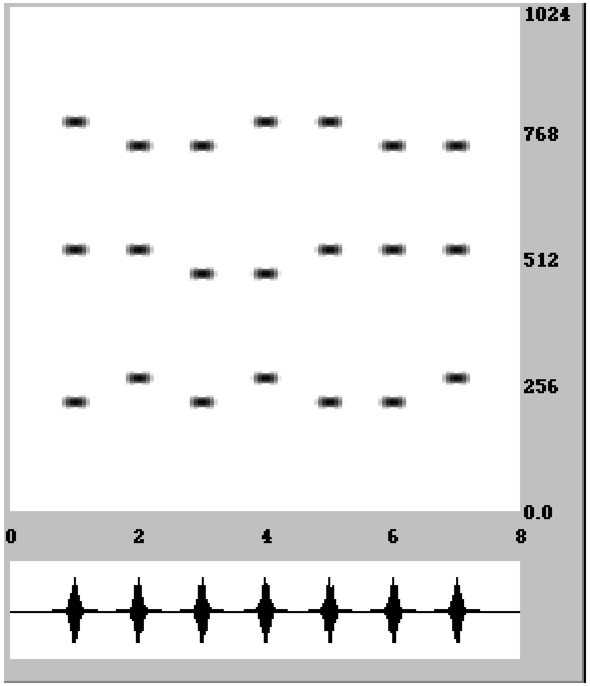
➢ 0 = OFF,   1 = ON

➢ 0 = Down,   1 = Up

➢ 0 = 0 volts, 1 = 5 volts

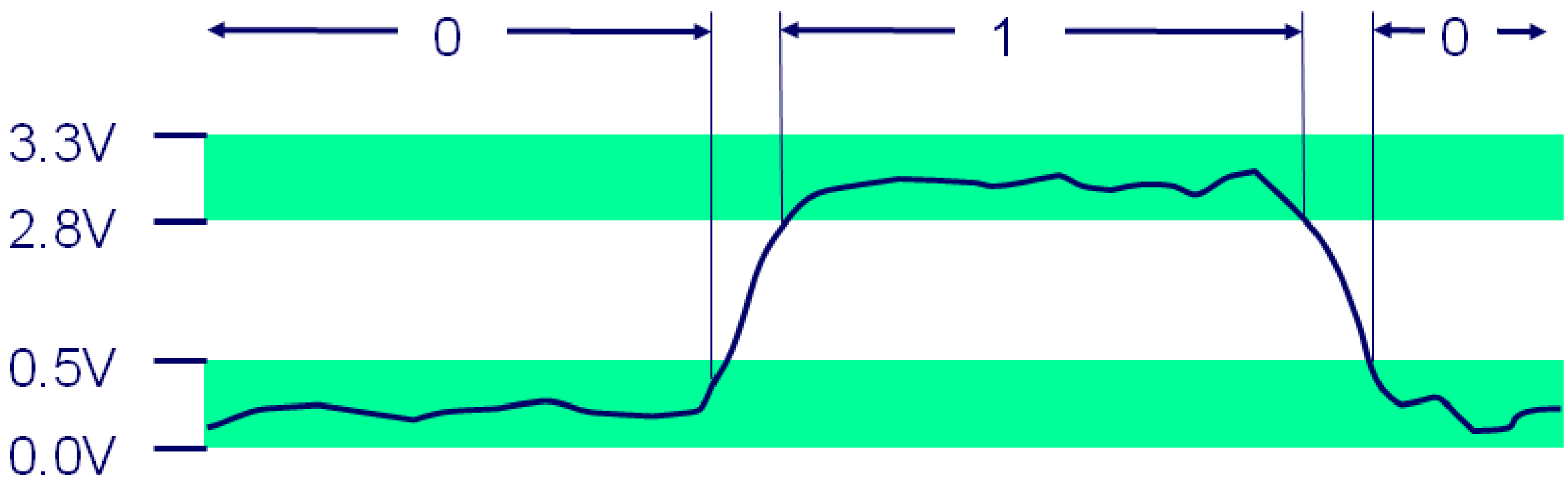


Actual Binary signal or sequence

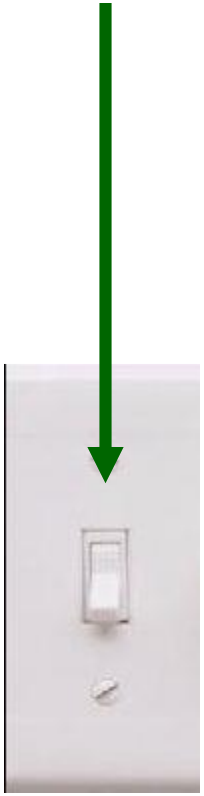


http://www.uwec.edu

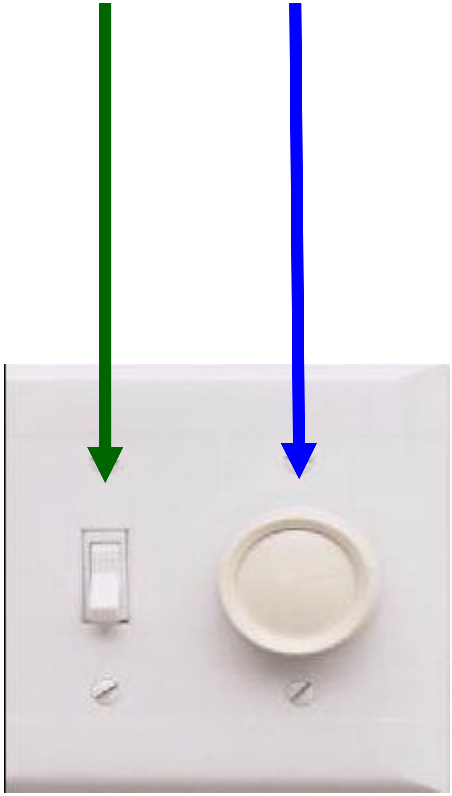
It is all voltage … electricity



Digital … Binary



Digital & Analog … analogy



Number systems

- Decimal
- Binary
- Octal
- Hexadecimal.

Binary System

- Binary numbers: $base_2$

  $\{0, 1\}$

Octal System

- Binary numbers: $base_2$

  {0, 1}

- Octal numbers: $base_8$

  {0 1 2 3 4 5 6 7}

Hex System

- Binary numbers: $base_2$

  {0, 1}

- Octal numbers: $base_8$

  {0 1 2 3 4 5 6 7}

- Hexadecimal numbers: $base_{16}$

  {0 1 2 3 4 5 6 7 8 9 A B C D E F}

Binary 1…0…1

00100111101111011111111111100000
10101111101111110000000000010100
10101111101001000000000000100000
10101111101001010000000000100100
10101111101000000000000000011000
10101111101000000000000000011100
10001111101011100000000000011100
10001111101110000000000000011000
00000001110011100000000000011001
00100101110010000000000000000001
00101001000000010000000001100101
10101111101010000000000000011100
00000000000000000111100000010010
00000011000011111100100000100001
00010100001000001111111111110111
10101111101110010000000000011000
00111100000001000001000000000000
10001111101001010000000000011000
00001100000100000000000011101100
00100100100001000000010000110000

Decimal (Base-10) ... Binary (Base-2)

Decimal (Base 10)	Binary (Base 2)
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
1000	1111101000

Number conversions

- Our aim is to learn how to convert:
- Decimal numbers to Binary numbers and back
- $(xxxx)_{10} \Longleftrightarrow (yyyy)_2$

Number with Base-10 (Decimal)

- $NumberWithBase_{10}$
  - $(\ 9 \quad 5 \quad 3\ )_{10}$

    $= 900 \quad +50 \quad +3$

    $= 9*100 \quad +5*10 \quad +3*1$

    $= 9*10^2 \quad +5*10^1 \quad +3*10^0$

Multiply by the proper power of 10

- NumberWithBase$_{10}$
  - $(\ 9 \quad 5 \quad 3\ )_{10}$

$= 900 \quad +50 \quad +3$

$= 9*100 \quad +5*10 \quad +3*1$

$= 9*10^2 \quad +5*10^1 \quad +3*10^0$

We multiply each digit by the appropriate power of 10

Convert binary number to decimal number

- NumberWithBase$_{10}$
  - $(953)_{10}$

    $= 9 * 10^2 + 5 * 10^1 + 3 * 10^0$

- Convert: From base-2 to base-10
  - $(1\ 1\ 1\ 0)_2 = (\ ?\ )_{10}$

Convert binary number to decimal number

- NumberWithBase$_{10}$
  - $(953)_{10}$

    $= 9 * 10^2 + 5 * 10^1 + 3 * 10^0$

- Convert: From base-2 to base-10
  - $(1\ 1\ 1\ 0)_2 = (\ ?\ )_{10}$

    $= 1 * 2^3 \quad + \quad 1 * 2^2 \quad + \quad 1 * 2^1 \quad + \quad 0 * 2^0$

We multiply each binary digit by the appropriate power of 2

Perform the simple arithmetic operations

- $NumberWithBase_{10}$
  - $(953)_{10}$

    $= 9 * 10^2 + 5 * 10^1 + 3 * 10^0$

- Convert: From base-2 to base-10
  - $(1\ 1\ 1\ 0)_2 = (\ ?\ )_{10}$

$$= 1 * 2^3 + 1 * 2^2 + 1 * 2^1 + 0 * 2^0$$
$$= 8 + 4 + 2 + 0$$
$$= 12 + 2$$
$$= (14)_{10}$$

The result

The result

- $(1\ 1\ 1\ 0)_2 = (14)_{10}$

Another view

$$(1\ 1\ 1\ 0)_2$$

$$0 * 2^0 = 0$$

$$1 * 2^1 = 2$$

$$1 * 2^2 = 4$$

$$1 * 2^3 = 8$$

$$(14)_{10}$$

Another example

Convert: From $base_2$ to $base_{10}$

- $(1\ 1\ 0\ 1\ 1)_2$

  $= 1 * 2^4 + 1 * 2^3 + 0 * 2^2 + 1 * 2^1 + 1 * 2^0$

  $= 16 + 8 + 0 + 2 + 1$

  $= (27)_{10}$

- Therefore the result is: $(1\ 1\ 0\ 1\ 1)_2 = (27)_{10}$

One more example

- $(\ 1\ 0\ 1\ 1\ )_2 = (\ ?\ )_{10}$

  $= 1*2^3 + 0*2^2 + 1*2^1 + 1*2^0$

  $= 8 + 0 + 2 + 1$

  $= (11)_{10}$

- Therefore the result is: $(\ 1\ 0\ 1\ 1\ )_2 = (\ 11\ )_{10}$

Convert: From base-10 ⇨ base-2

The inverse …

Binary to Decimal, use multiplications
Decimal to Binary, use divisions

Convert: From base-10 ⇨ base-2

- $(2\ 7)_{10} = (?)_2$
- Divide decimal 27 by 2
  - 27 / 2 = 13 remainder 1
  - 13 / 2 = 6 remainder 1
  - 6 / 2 = 3 remainder 0
  - 3 / 2 = 1 remainder 1
  - 1 / 2 = 0 remainder 1

When the result of the division is ZERO. We stop

The result …

- $(2\ 7)_{10} = (?)_2$
- Divide decimal 27 by 2
  - 27 / 2 = 13 remainder 1
  - 13 / 2 = 6 remainder 1
  - 6 / 2 = 3 remainder 0
  - 3 / 2 = 1 remainder 1
  - 1 / 2 = 0 remainder 1

Write remainders of division (bottom to top)

The result …

- $(2\ 7)_{10} = (?)_2$

Write remainders of division (bottom to top)

- Divide decimal 27 by 2
  - 27 / 2 = 13 remainder 1
  - 13 / 2 = 6 remainder 1
  - 6 / 2 = 3 remainder 0
  - 3 / 2 = 1 remainder 1
  - 1 / 2 = 0 remainder 1

1 1 0 1 1

The result

- $(2\ 7)_{10} = (11011)_2$

Another example

- $(2\ 8)_{10} = (?)_2$
- Divide decimal 28 by 2
  - 28 / 2 = 14 remainder 0
  - 14 / 2 = 7 remainder 0
  - 7 / 2 = 3 remainder 1
  - 3 / 2 = 1 remainder 1
  - 1 / 2 = 0 remainder 1

When the result of the division is ZERO. We stop

Another example …

Write remainders of division (bottom to top)

- $(2\ 8)_{10} = (?)_2$
- Divide decimal 28 by 2
  - 28 / 2 = 14 remainder 0
  - 14 / 2 = 7 remainder 0
  - 7 / 2 = 3 remainder 1
  - 3 / 2 = 1 remainder 1
  - 1 / 2 = 0 remainder 1

1 1 1 0 0

The result

- $(2\ 8)_{10} = (11100)_2$

Conclusion: Binary and Decimal conversion

1. Converting a binary (base-2) to decimal (base-10), form the appropriate sum of powers in base "2"

2. Converting a decimal integer (base-10) to binary (base-2), divide by "2", use the remainders as coefficients. Collect the coefficients bottom-top.