High Level View Of A Computer

- Input
- Processor
- Output
- Storage
- Memory

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Getting Data In

Input

Others?

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Getting Data Out

Others?

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Unit of Storage

Memory

• ___
  – ____________
  – Smallest unit of measurement

Storage

Two possible values
  on  OR  off

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How Data Is Stored

- ___: a group of 8 bits; $2^8=256$ possibilities – 00000000, 00000001, 00000010, 00000011, ...
  , 11111111

- ____________: long sequence of locations, each large enough to hold one byte, numbered 0, 1, 2, 3, ...

- ____________: The number of the location
How Data Is Stored

- Contents of a location can change
  - e.g. 01011010 can become 11100001
- Use consecutive locations to store longer sequences
  - e.g. 4 bytes = 1 word

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Binary Numbers

• Base Ten Numbers (Integers)
  – characters
    • 0 1 2 3 4 5 6 7 8 9
  – 5401 is \(5 \times 10^3 + 4 \times 10^2 + 0 \times 10^1 + 1 \times 10^0\)

• Binary numbers are the same
  – characters
    • 0 1
  – 1011 is \(1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0\)
Converting Binary to Base 10

• $2^3 = 8$
• $2^2 = 4$
• $2^1 = 2$
• $2^0 = 1$

1. $1001_2 = \underline{____} _{10} =$
2. $1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 =$
3. $1 \times 8 + 0 \times 4 + 0 \times 2 + 1 \times 1 =$
4. $8 + 0 + 0 + 1 =$
5. $9_{10}$

• $0110_2 = \underline{____} _{10}$ (Try yourself)
• $0110_2 = 6_{10}$
Converting Base 10 to Binary

- \(2^8 = 256\)
- \(2^7 = 128\)
- \(2^6 = 64\)
- \(2^5 = 32\)
- \(2^4 = 16\)
- \(2^3 = 8\)
- \(2^2 = 4\)
- \(2^1 = 2\)
- \(2^0 = 1\)

\[388_{10} = \_\_\_\_2\]

- \(388 - 256 \cdot 2^8 = 132\)
- \(132 - 128 \cdot 2^7 = 4\)
- \(4 - 4 \cdot 2^2 = 0\)

\[2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0 = 110000100\]

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Converting Base 10 to Binary

- \(388_{10} = \_\_\_2\)
- \(388_{10} / 2 = 194_{10}\) Remainder \(0\)
- \(194_{10} / 2 = 97_{10}\) Remainder \(0\)
- \(97_{10} / 2 = 48_{10}\) Remainder \(1\)
- \(48_{10} / 2 = 24_{10}\) Remainder \(0\)
- \(24_{10} / 2 = 12_{10}\) Remainder \(0\)
- \(12_{10} / 2 = 6_{10}\) Remainder \(0\)
- \(6_{10} / 2 = 3_{10}\) Remainder \(0\)
- \(3_{10} / 2 = 1_{10}\) Remainder \(1\)
- \(1_{10} / 2 = 0_{10}\) Remainder \(1\)

\[2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0\]

\[1 1 0 0 0 0 1 0 0\]

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Other common number representations

- _____________ Numbers
  - characters
    - 0 1 2 3 4 5 6 7 8
    - 7820 is $7 \times 8^3 + 8 \times 8^2 + 2 \times 8^1 + 0 \times 8^0$

- _____________ Numbers
  - characters
    - 0 1 2 3 4 5 6 7 8 9 A B C D E F
    - 2FD6 is $2 \times 16^3 + F \times 16^2 + D \times 16^1 + 6 \times 16^0$
________ Numbers

• Can we store a __________ sign?
• What can we do?
  – Use a ____
• Most common is ____________________
Representing __________ Numbers

- ____________________________
  - flip all the bits
    - change 0 to 1 and 1 to zero
  - add 1
  - if the leftmost bit is __, the number is ___ or _____________
  - if the leftmost bit is __, the number is _____________
• What is -9?
  – 9 is 00001001 in binary
  – flip the bits → 11110110
  – add 1 → 11110111

• Addition and Subtraction are easy
  – always addition
• Addition
  – $13 - 9 = 4$
  – $13 + (-9) = 4$
  – $00001101 + 11110111 = ?$

This bit is lost

\[\begin{array}{c}
00001101 \\
+ 11110111 \\
\hline
111110111
\end{array}\]

But that doesn’t matter since we get the correct answer anyway

\[000001000 = 4\]

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Real (_____________) numbers

• Break the bits used into parts

011010100000000011

Sign bits

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Limitations of Finite Data Encodings

• _____________ - number is too large
  – suppose 1 byte stores integers in base 2, from 0 (00000000) to 255 (11111111) (note: this is not ________________ although it would have the same problem)
  – if the byte holds 255, then adding 1 to it results in __, not _____
Limitations of Finite Data Exchange

• ___________ Error
  – Insufficient ___________ (size of word)
    • ex. Try to store 1/8, which is 0.001 in binary, with only two bits
  – ______________ expansions in current base
    • ex. Try to store 1/3 in base 10, which is 0.3333...
  – ______________ expansions in every base
    • ex. Irrational numbers such as π