Computers

Question:
Today, the fastest PCs run at roughly 1.5 GHz. Someday, computers may run at 1,000,000 GHz. Compared to present computers, those high-speed ones would have to be
1. much larger.
2. much smaller.
3. about the same size.

Observations About Computers
- They respond to inputs with various outputs
- They handle all kinds of information
- Information is measured in bits and bytes
- Some information is lost when power fails
- Computers work extremely quickly
- They follow instructions perfectly

Analog Representation
- A number is represented by a physical quantity
  - Current
  - Voltage
  - Magnetization
- Number is proportional to the physical quantity
- Precision is determined by the quantity itself

Digital Representation
- A number is represented by physical quantities
- Physical quantities take on discrete values
- These values represent pieces of the number
- Precision is determined by number of quantities

Binary Representation
- Each physical quantity has two values
  - One value is defined as a “1”
  - The other value is defined as a “0”
- Each quantity represents one information bit
- A number is represented by several bits
- The more bits, the more precision
- Bits are relatively immune to noise
Example: 19
- Five bits can represent number from 0 to 31
- 19 is represented by the bits: 10011
- Each bit represents a power of 2
- \(1 \cdot 2^4 + 0 \cdot 2^3 + 0 \cdot 2^2 + 1 \cdot 2^1 + 1 \cdot 2^0 = 19\)

Representing Non-Numbers
- Bits or groups of bits are assigned to objects
  - Characters
  - Colors
  - Days of the week
- 8 bits (a byte) can distinguish 256 objects
- Two bytes can distinguish 65,536 objects

Quantities Representing Bits
- Current
- Magnetization
- Charge
- Optical properties
- Light
- Radio Waves
- Sound

Computers & Bits
- Computation: currents
- Memory: charge
- Disk Drives: magnetization
- CDROM/DVDROM: optical properties

Computing
- Computers perform logical operations with bits
- Complicated operations based on simple ones
- Simplest operations: inversion & not-and
- Any function can be realized from these two

Inverter
- Takes one input bit, provides one output bit
- Output bit is inverse of input bit
Not-And (NAND)
- Takes two input bits, provides one output bit
- Output is inverse of logical “and” of input bits
- Example truth table:

<table>
<thead>
<tr>
<th>Input 1</th>
<th>Input 2</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

CMOS Logic
- Bits are represented by charge
- “1” is represented by positive charge
- “0” is represented by negative or no charge
- Logic is built from n-channel and p-channel MOSFETs in complementary pairs

CMOS Inverter
- Input charge delivered to two complementary MOSFETs
- Positive charge on input delivers negative charge to output
- Vice Versa

CMOS NAND
- Positive on both inputs delivers negative charge to output
- Negative on either input delivers positive charge to output

Personal Computers
- Use CMOS logic for computations
- Use charge-based memory for fast storage
- Use magnetization or optical for slow storage
- Use light, radio, current, or sound for network

Speed Limits
- Bits move no faster than the speed of light
- Speed of light is 1 foot per nanosecond
- During one PC cycle, bits can move 1 foot
- Processors can’t be bigger than 1 foot
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