Computer Abstractions

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Everything is bits

- Bottom-Up description of a computer:
  - "an organized collection of bits"
- Bit: anything that can take on either one of values 1 or 0.
  - an element of the set {0,1}

An abstraction!

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Why Bits?

- Humans usually deal with more complex abstractions, for example:
  - using *digits* to communicate mathematical quantities.
  - using *letters* from some alphabet to communicate in written language.
  - using *words* and *expressions* to communication in spoken language.

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Machines

- Many mechanical addition machines were based on decimal.
- It is feasible to build an electronic machine that could work in decimal:
  - 10 different voltage levels, one for each digit.
  - 10 different current levels, …

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Simple ≈ Best ?

- It is much simpler to build an electronic machine based on only 2 distinct *quantities*.
- Question: if we use 10 possible values, is that more powerful than using 2 ?

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Consider This

- Make up any set of symbols (of any cardinality).
- I can show you how to *encode* each of your symbols using only 1s and 0s.
- Any machine that can perform all possible operations on 1s and 0s can simulate a machine that can perform operations on the elements of your set.

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Sequences of Bits

- numbers (integer and floating point)
- addresses (can think of as numbers)
- characters from some language (ASCII)
- instructions (can think of as characters from some machine language!)
- control signals (turn on/off various devices in the computer)

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Binary vs. Hexadecimal

- Humans can easily deal with more complex entities (we *think* in base 10, right?).
- Base 10 is not convenient – it is not easy to convert from binary <-> base 10.
- It is easy to convert from binary to base 2, 4, 16, etc (any power of 2).

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4 bits is 1 Hexadecimal digit

0000	0	1000	8
0001	1	1001	9
0010	2	1010	A (10)
0011	3	1011	B (11)
0100	4	1100	C (12)
0101	5	1101	D (13)
0110	6	1110	E (14)
0111	7	1111	F (15)

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Conversion of sequence of bits

- Chop in to groups of 4 bits.
- Replace each group of 4 bits with the corresponding hex digit.
- If we are talking about numbers – the result is in base 16.

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Example: **01111110**

0*128 + 1*64 + 1*32 + 1*16 + 1*8 + 1*4 + 1*2 + 0*1

In Decimal this is the quantity **126**

01111110
7 E

In Hex this is the quantity **7E**

7*16 + E*1

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32 Bits as Hex

00110101101100100100101001110000
3 5 B 2 4 A 7 0

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Integer lengths

10 bits : integer values from 0 – 1,023
1,024 different values. 1K
10 bits is *about* 1,000

20 bits : integer values from 0 – 1,048,575
1,048,576 different values. 1M (Mega)
20 bits is *about* 1,000,000

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Quiz

- How many integers can I represent using 11 bits?
- How about 22 bits?

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ASCII

- sequences of bits are used to represent everything (not just positive integers).
- ASCII uses 8 bits to represent (encode) 256 different characters.

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ASCII and you shall receivey

Binary	HEX	Decimal	Character
00100000	**20**	**32**	*space*
01000001	**41**	**65**	**'A'**
01011001	**59**	**89**	**'Y'**
01100001	**61**	**97**	**'a'**
01111001	**79**	**121**	**'y'**

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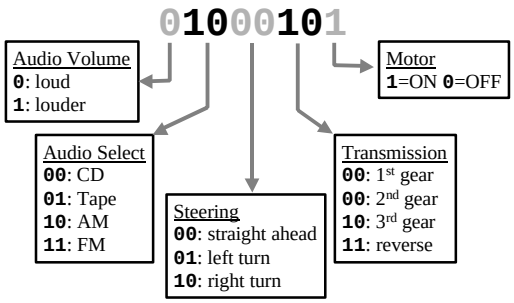
Bits as controls



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Top-Down Description of Computers

- Break the computer in to components.
- Describe each component by breaking it down in to smaller components.
- …
- eventually get to "bits"

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Five Classic Components

- Control
- Datapath
- Memory
- Input
- Output

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Control and Datapath

- *Processor* or *Central Processing Unit*
- The Control *tells* the datapath, memory, I/O what to do and when (via on/off signals).
- The datapath includes movement of bits from one place to another, and arithmetic and logic operations.

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Memory

- Place to store sequence of bits.
- Organized in to groups of bits (typically bytes).
- Each byte (word) has a unique *address*.

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Types of Memory

- Primary Memory
  - RAM: Random Access Memory
  - Constant time lookup
  - Volatile
- Secondary Memory
  - Disk, Tape, CD, …
  - nonvolatile (does not require power to maintain state)

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RAM and Performance

For many years the size, speed (and cost) of primary memory was a limiting factor in computer performance.

Still a very important factor, but memory has caught up to other components (now the CPU and I/O can be limiting factors).

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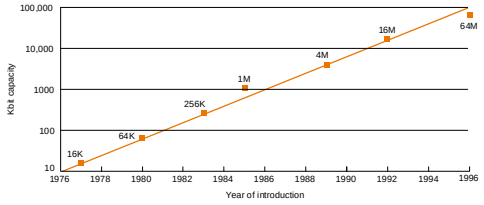
DRAM Capacity over time



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I/O

Keyboard
Mouse
Screen
Audio (in and out)
Network
Disks
Printers
…

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Fallacies & Pitfalls

Computer organization has not changed much over the years, so something completely different is needed to increase performance.

stuck in a rut?

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Maybe not yet?

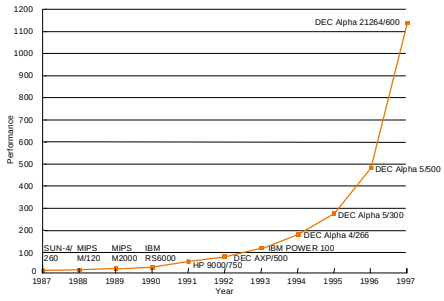

Figure 1.20 from the book: Workstation Performance based on specint_92

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