Computer hardware

computers, transistors, how does computer work?

Computer

- general purpose device that can be programmed to carry out a set of arithmetic or logical operations
  - *(Examples: cameras, phones)*
- Two main parts of computer:
  - Hardware refers to the physical parts of the computer
    - *Example: piano is a hardware*
- Software refers to the code that runs on the computer
  - *Example: the music is the software*

"Computer" word's history

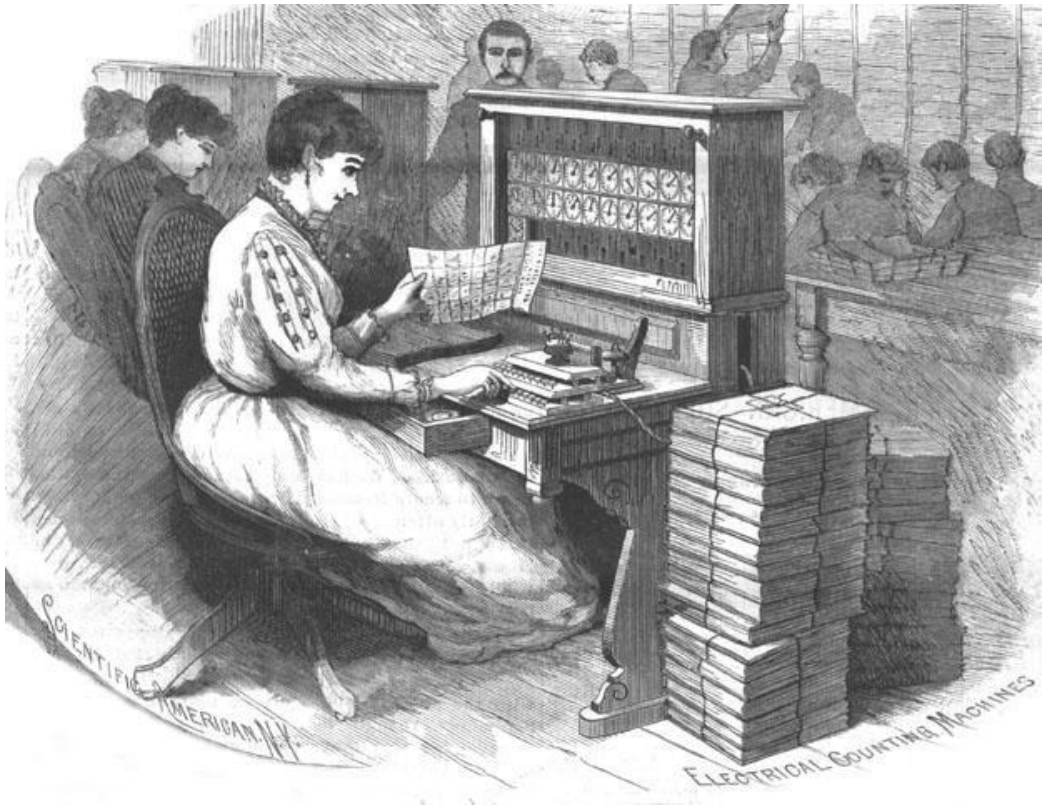
The term "computer", in use from the early 17th century , meant **"one who computes"**: a person performing mathematical calculations, before electronic computers became commercially available.

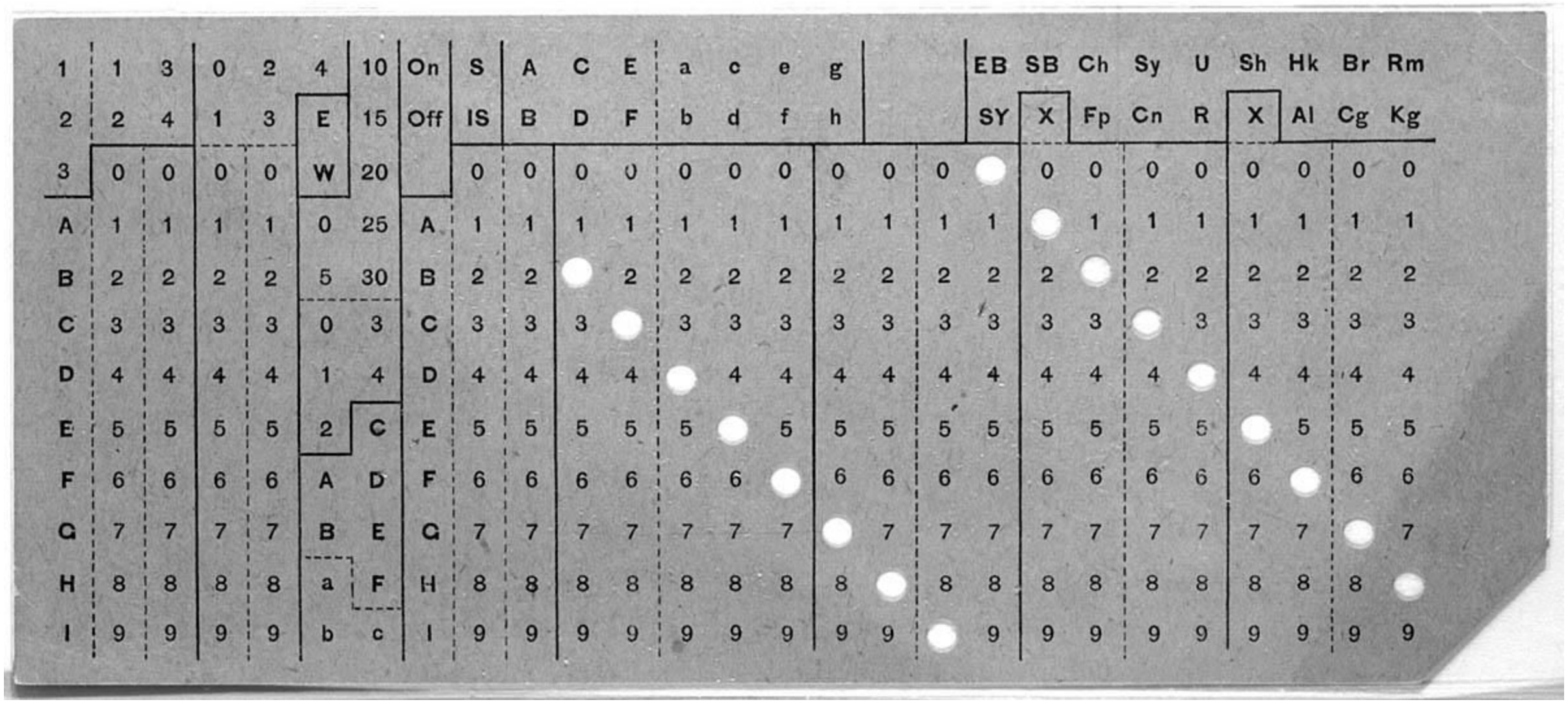
"The human computer is supposed to be following fixed rules; he has no authority to deviate from them in any detail."

US Census 1890

US Census 1880 has taken 8 years to summarize data.

Hollerith invented **"Tabulating machine"** electromechanical machine that was made for summarization of census




1 1 3 0 2 4 10 On S A C E a c e g EB SB Ch Sy U Sh Hk Br Rm
2 2 4 1 3 E 15 Off IS B D F b d f h SY X Fp Cn R X Al Cg Kg
3 0 0 0 0 W 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
A 1 1 1 1 0 25 A 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
B 2 2 2 2 5 30 B 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
C 3 3 3 3 0 3 C 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
D 4 4 4 4 1 4 D 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
E 5 5 5 5 2 C E 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
F 6 6 6 6 A D F 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
G 7 7 7 7 B E G 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7
H 8 8 8 8 a F H 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
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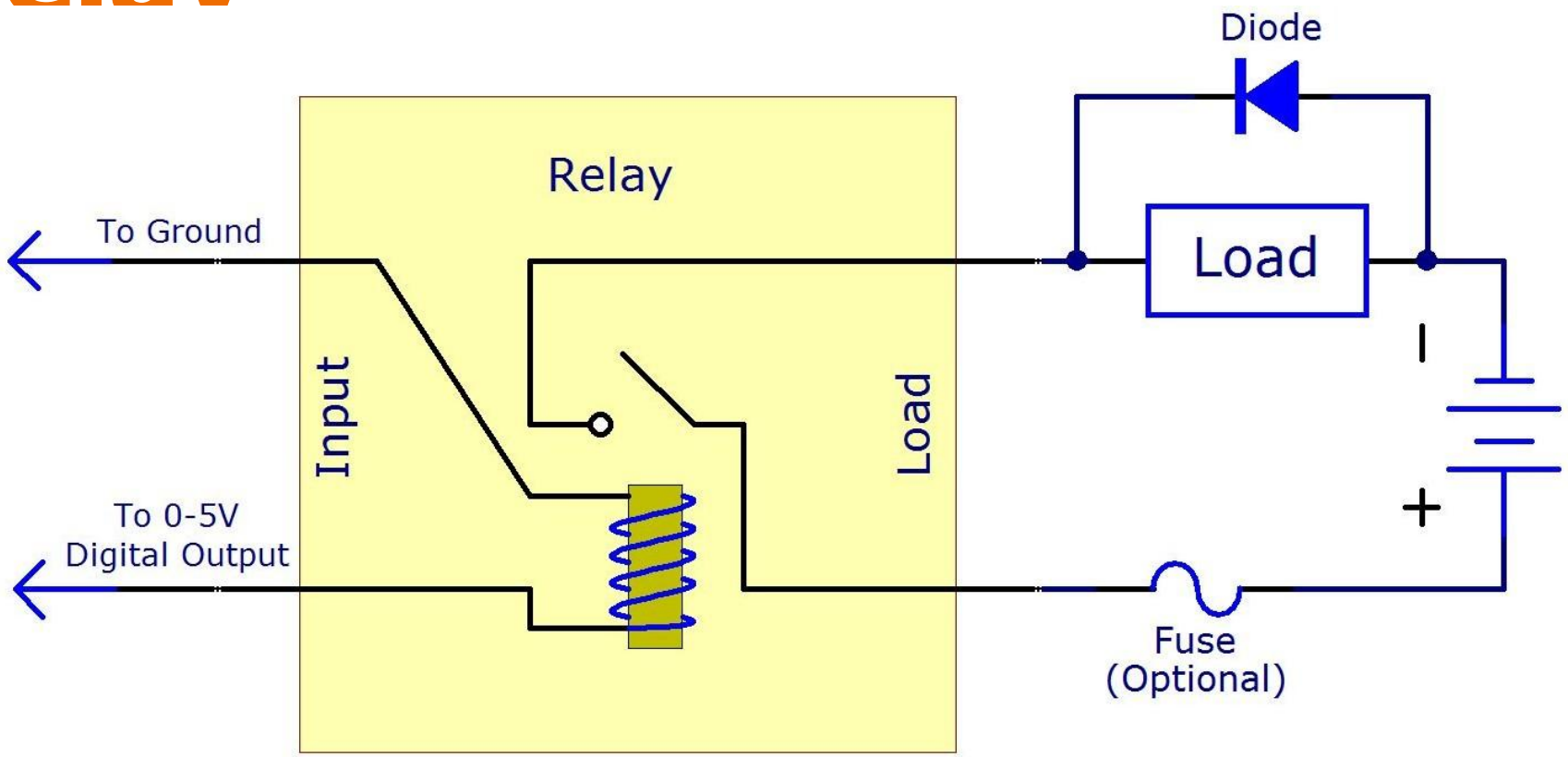
Mechanical relay

Light turns on if coil was turned on



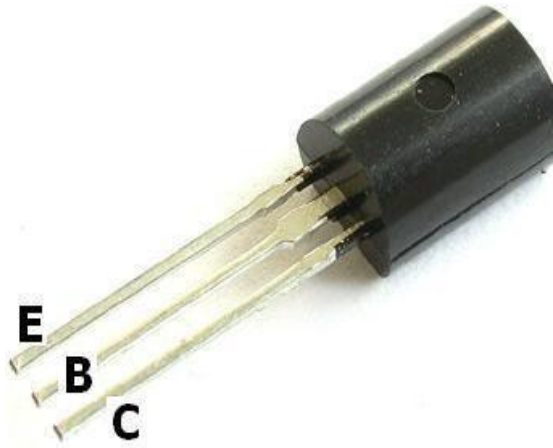
Before transistors

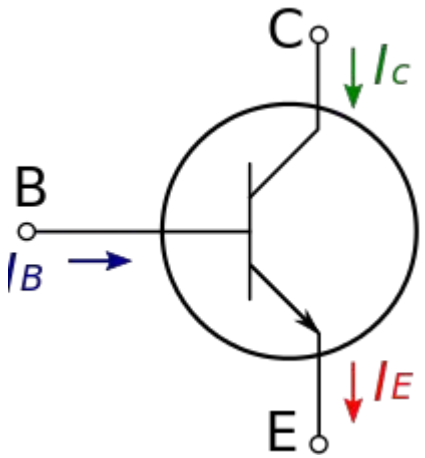
Vacuum tubes:

Transistors

Transistor is a “solid state” device, meaning it has no moving parts

- works as a sort of amplifying valve for a flow of electrons
- It is a basic building block used to construct more complex electronic components
- Nowadays transistors are made of silicon
  - silicone (rubber) and silicon (chips, кремний) are different

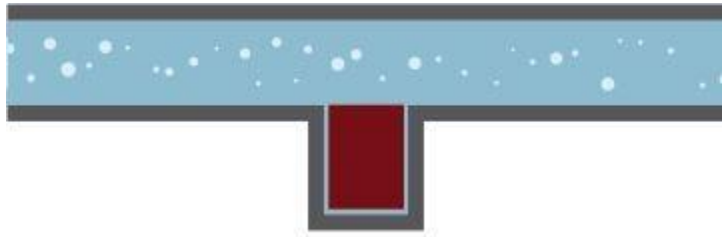




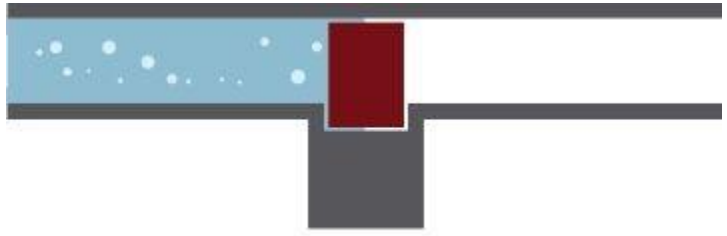
When B is **ON** current goes through C to E

When B is **OFF** current doesn't go through C to E

Water analogy



Transistor On

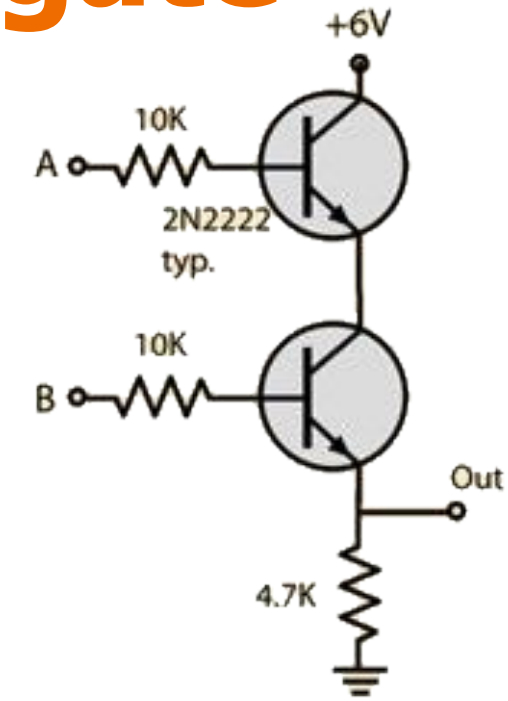


Transistor Off

We can apply water tube analogy to transistors

What we can do with transistors?

AND gate



When A is OFF and B is OFF current can’t pass A gate, Out is OFF

When A is OFF and B is ON current can’t pass A gate, Out is OFF

When A is ON and B is OFF current pass A gate, but can’t pass B gate, Out is OFF

When A is ON and B is ON current pass A gate, and B gate, Out is ON

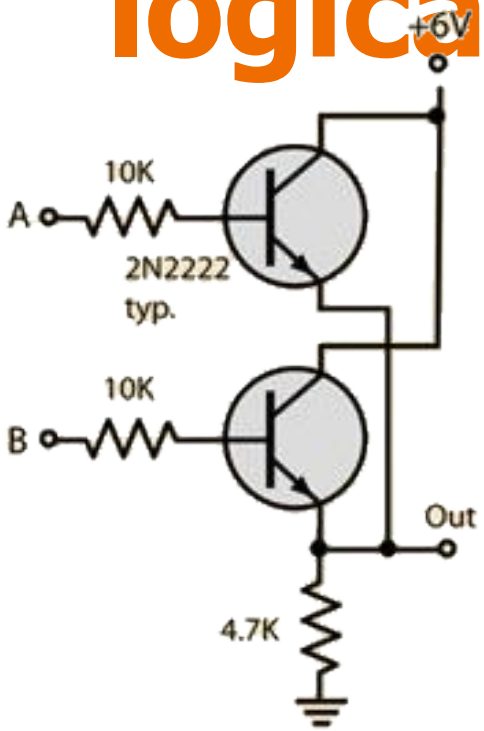
AND logic

Gate A	Gate B	Output
OFF	OFF	OFF
OFF	ON	OFF
ON	OFF	OFF
ON	ON	ON

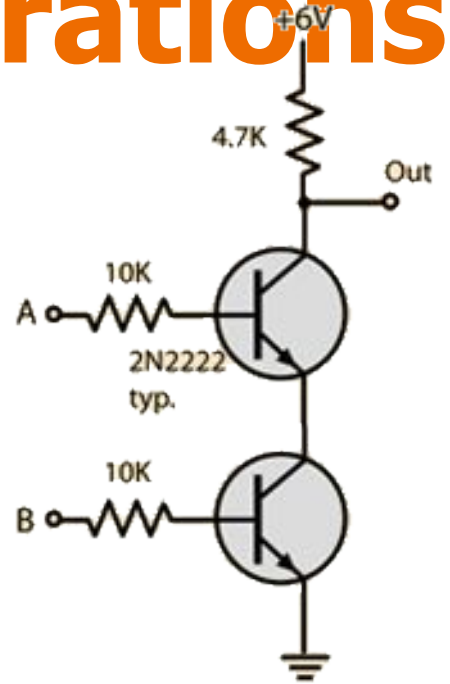
Instead of OFF we can use FALSE

Instead of ON we can use TRUE

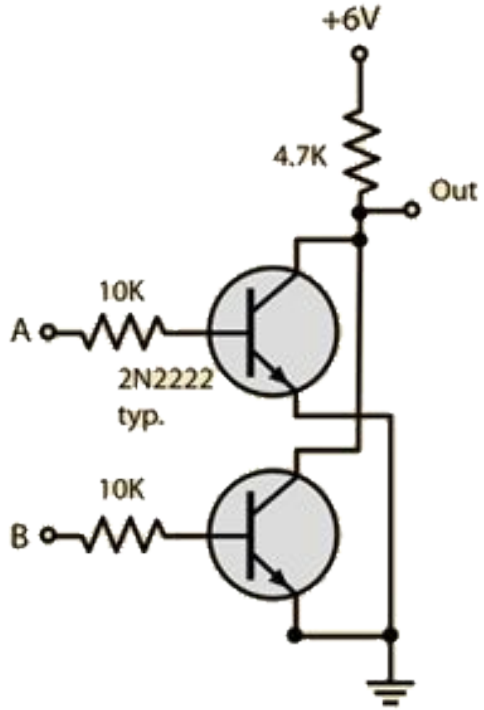
Schemes that perform logical operations



OR

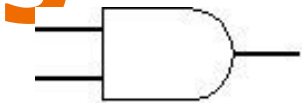


NAND



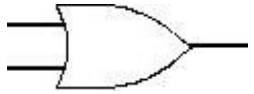
NOR

Basic Logic gates



AND

A	B	OUT
F	F	F
F	T	F
T	F	F
T	T	T



OR

A	B	OUT
F	F	F
F	T	T
T	F	T
T	T	T

XOR

A	B	OUT
F	F	F
F	T	T
T	F	T
T	T	F

NOT

A	OUT
F	T
T	F

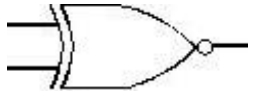
Basic Logic gates (2)

NAND

A	B	OUT
F	F	T
F	T	F
T	F	F
T	T	F

NOR

A	B	OUT
F	F	T
F	T	T
T	F	T
T	T	F



XNOR

A	B	OUT
F	F	T
F	T	F
T	F	F
T	T	T

How to add two numbers by logic gates

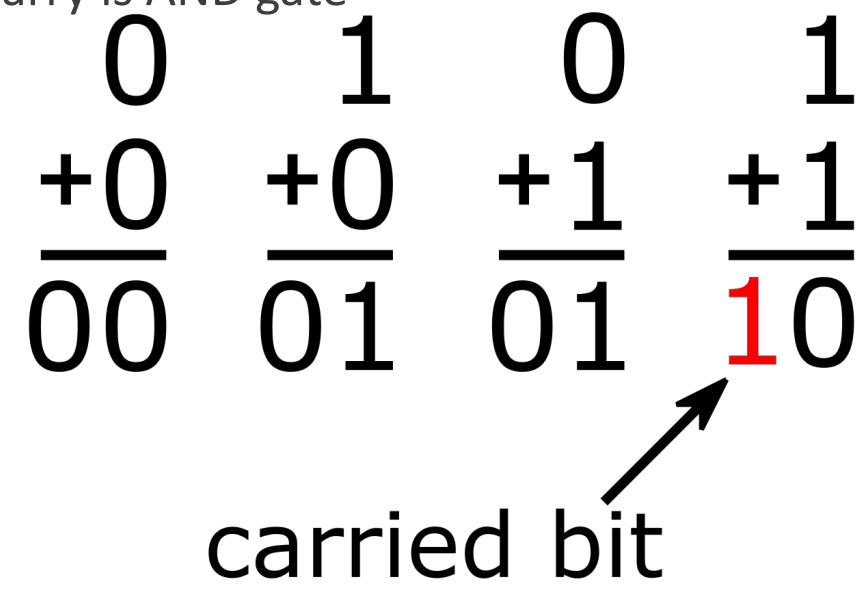
Let's create simplest ever calculator It adds two binary numbers

So let's find what should it output, on specific inputs

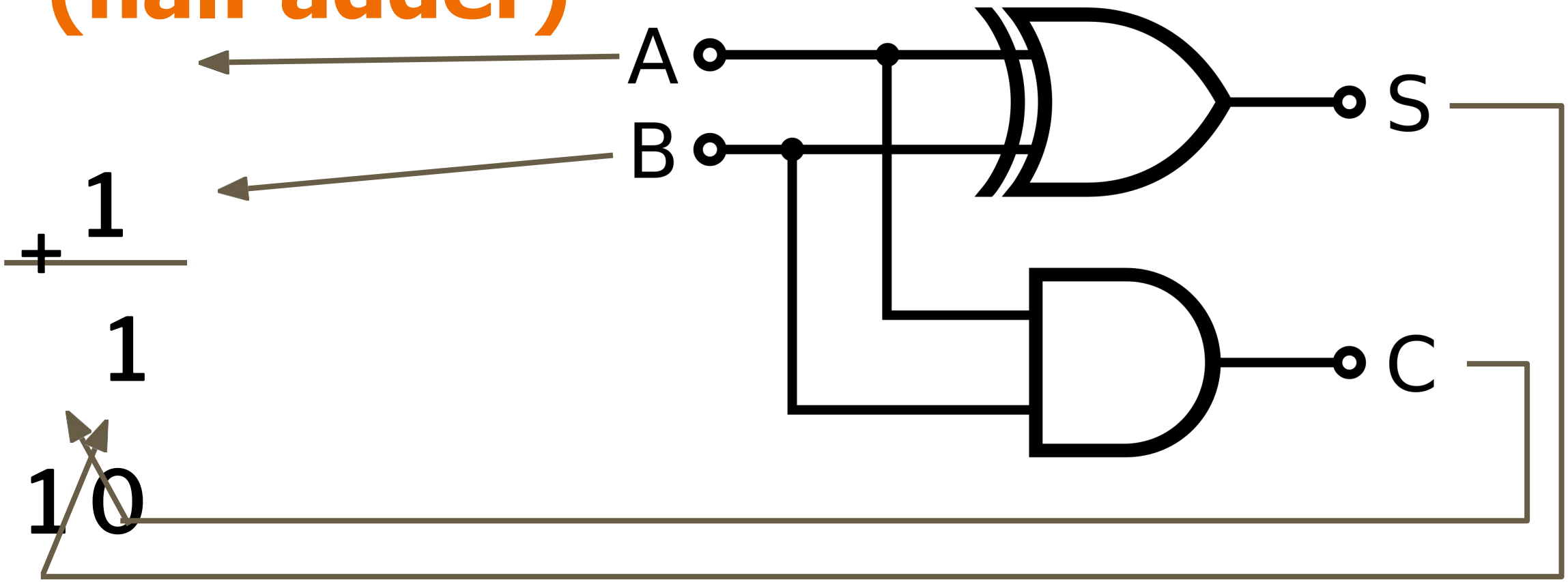
Output is XOR gates, and Carry is AND gate

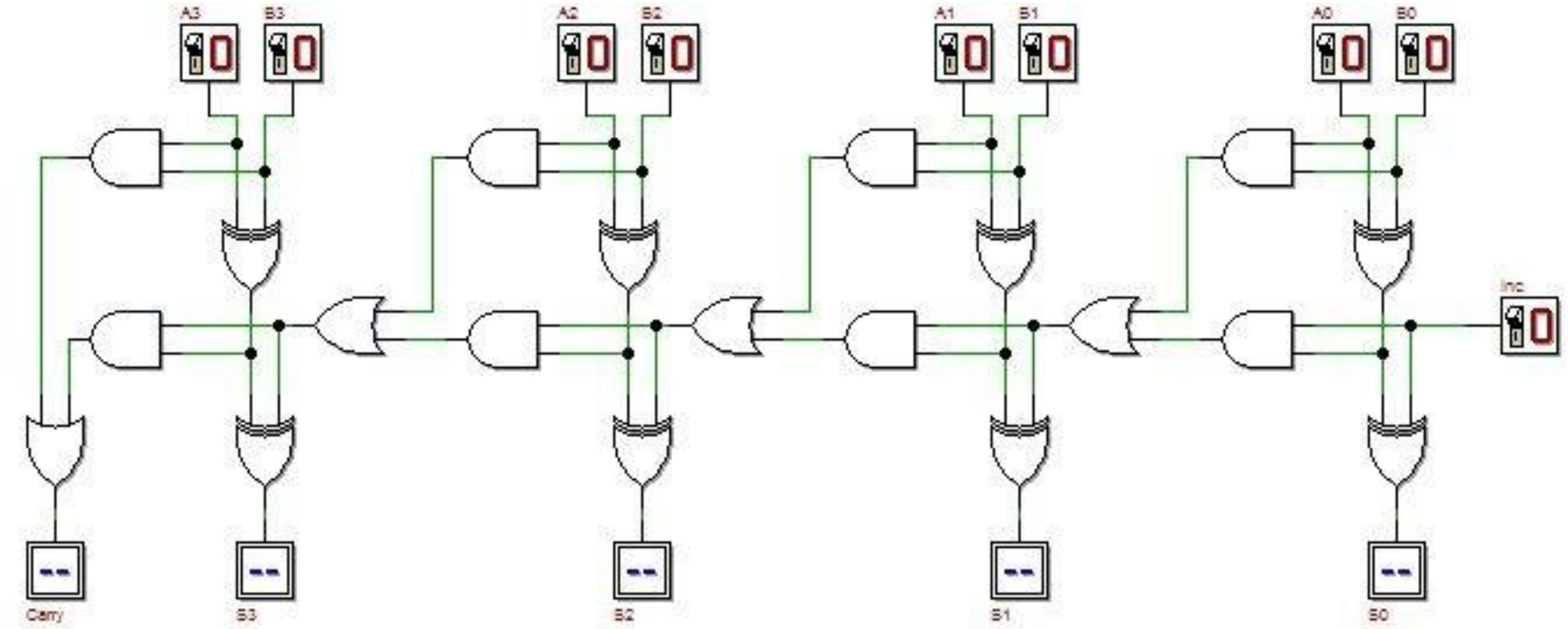
Input	Output
0+0	0
0+1	1
1+0	1
1+1	10

A	B	Carry	Output
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0



Binary adder (half adder)





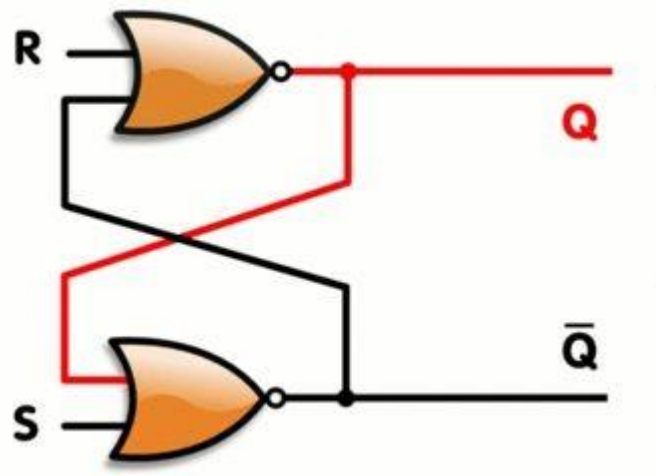
Scheme for adding two 4-bit numbers, input switches are A3, A2, A1, A0 and B3, B2, B1, B0, sum is outputted into S3, S2, S1, S0

Full adder

What does this scheme do?

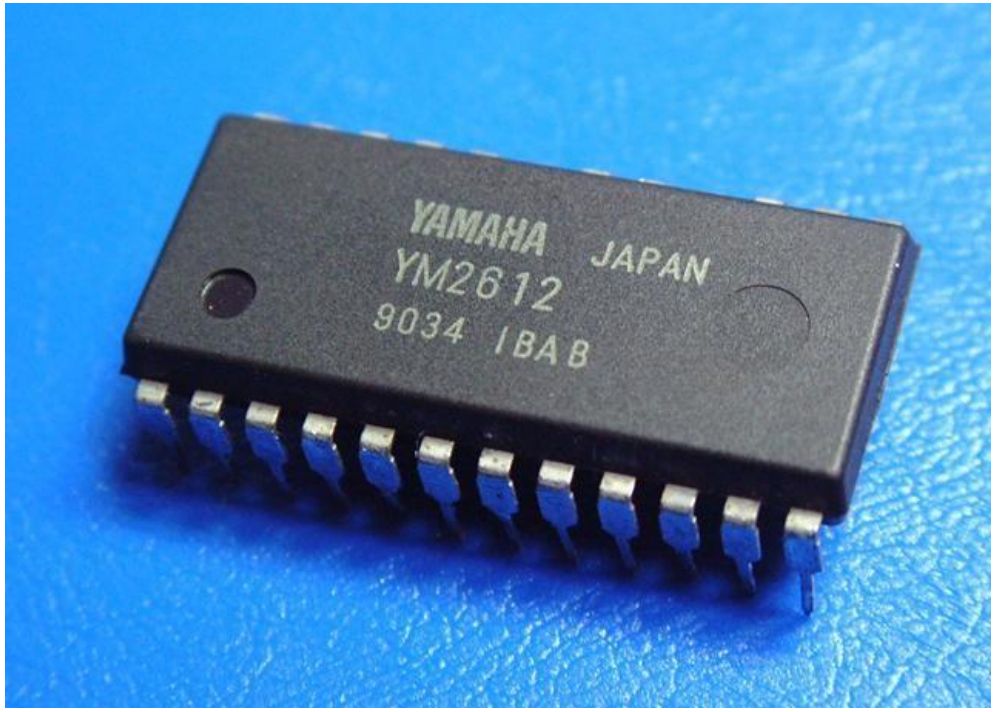
Memory using logic gates

Flip-flops are used to save information, when S is 1, Q is equal to R, when S



Chips

- Computer contains millions of chips
- Chip- fingernail sized silicon
- Chip can contain billions of transistors
- Chips in plastic package with metal pins
- CPU chips , memory chips, flash chips



Whole picture

Transistors are switches

Logic gates are created from Transistors

Logical and arithmetical units are created from Logic gates

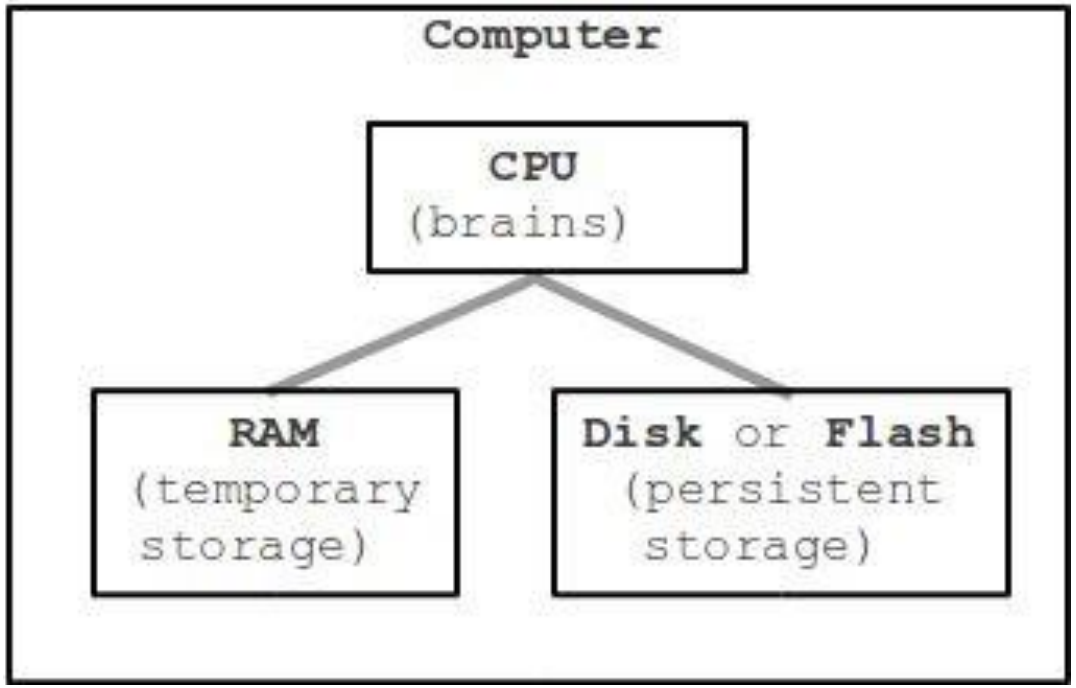
Chips consist of many logical and arithmetical units

Moore’s law

- Transistors get smaller about every 18-24 months
- Can fit twice as many per chip
- **It is observation, not law**
- In effect, transistors/computers get cheaper (powerful)
- Why computers are now in cars, thermostats
- $50 MP3 player bigger every couple years: 2GB, 4GB, 8GB
- Exponential - 10 doublings, about 1000 x
- Moore's law ... computers cheap, everywhere

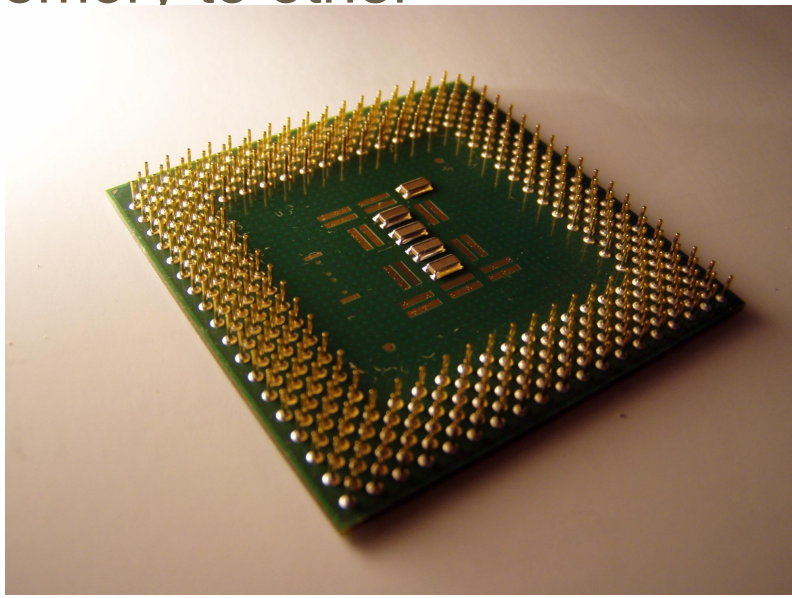
Computer hardware

There are 3 major parts that make up a computer: CPU, RAM, Persistent Storage



CPU

- CPU- Central Processing Unit
- CPU is big chip with many different logical and arithmetical units
- The brains of computer
- Performs simple operations
  - e.g. Add two numbers, copies data from one memory to other
- Run button… code “runs” on the CPU



RAM - (Random Access Memory)

RAM- Memory, Random Access Memory

It is called Random Access, because any needed memory can be accessed immediately, whereas in magnetic hard disk, it takes time to rotate disc to specified place Temporary, working storage bytes

e.g. typing text in MS Word before saving document, text is stored in RAM

e.g. while playing game, the units location and life is stored in RAM RAM is “volatile”, not “persistent”,..gone when power goes out

What does RAM do?

"In simple terms, RAM is to Disk Memory as Pockets is to your bag. When you are going about your usual day(processing) you keep things needed frequently to you in your pocket and the remaining stuff in your bag. The reason you do this is you can access your pockets with less time compared to opening your bag and getting things out of it.
The computer does the same thing with memory. It has everything it needs in the Disk Space but accessing that memory takes a lot of time. So it keeps the most frequently used data(currently and predictably) in the RAM which is constructed using a transistor and a capacitor connected in a matrix of word and bit lines, as it is faster to access compared to the drive which is a spinning physical disk."

Quora (Akshay Sharma)

Persistent Storage: Hard Drive, Flash Drive

Hard Drive

- Stores bytes as a magnetic pattern on a spinning disk
- Fragrant
- Heavy

Flash Drive

- Stores bytes as electrons in a chip
- No moving parts
- More expensive
- Uses less power
  - e.g. usb key, SD card in camera, flash chips built into a phone or tablet

Persistent Storage, Hard drive, Flash drive

Nowadays most laptops use hard drive, the only reason for using hard drive is they are cheap.

But flash drive’s cost is got cheap, from year to year, and it is expected in next 5 years that most laptop will contain flash drives instead of hard drives.

Whole picture

Any program makes arithmetic and logical operations with some data. Data that needs to be saved for long time is stored in hard drive

Data that is operated by CPU and is used very frequently is stored RAM

Measurements

- Hertz - operations per second
  - Hz is abbreviation of Hertz
  - CPU’s performance is measured in hertzes
- Bit - is measurement of memory. Bit’s value can be 1 or 0.
  - Byte consists of 8 bits
  - Hard drive’s, flash drive’s and RAM’s are measured by bits
- Kilo - 10^3
- Mega - 10^6
- Giga - 10^9
- Tera - 10^12
- Peta - 10^15

Question???

You have written code for strategy game. Any warrior has 10 different values presenting his skills, abilities, life and etc. All of them are saved in int typed variable. Each int variable takes 12 bytes in memory. If you have created an army of 100000 warriors.

- What is the minimum size of necessary RAM memory?

You type some document of size 10000 symbols. Each symbol takes 1 byte of memory.

- What is the minimum size of necessary hard drive’s memory?

Arduino

- Arduino is programmable microcontroller
  - You can program it
  - It receives input signals processes it and output signals
- You can design your own gadgets
- Lots of compatible devices and sensors
- Costs ~20$

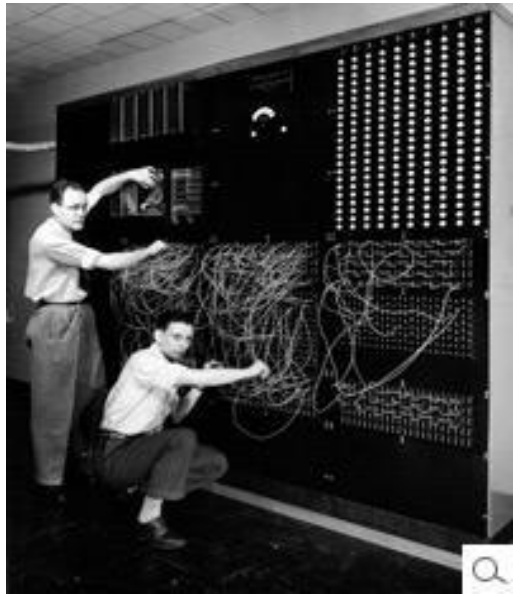
Arduino: what can we do?

http://www.makeuseof.com/tag/arduino-technology-explained/ :

> *it's like a little computer you can program to do things, and it interacts with the world through electronic sensors, lights, and motors. In essence, it makes some truly hardcore electronics projects accessible to anyone – so artists and creative types can concentrate on making their ideas a reality. It's the ultimate tinkering tool*

Evolution of computers

- 1940 - 1945: computers used mostly for deciphering messages
  - Took place of 100 square meters or more
- 1946 ENIAC computer has been completed
  - Speed: 5,000 operations per second (5 kHz)
  - Input/output: cards, lights, switches, plugs
  - Floor space: 1000 square feet (about 100 square meters)
- 1951 UNIVAC. First commercial computer
  - Speed: 1,905 operations per second (2 kHz)
  - Input/output: magnetic tape, unityper, printer
  - Memory: 1,000 12-digit words. (1.5 KB) (delay lines, magnetic tape)
  - Floor space: 26 cubic meters
  - Cost: F.O.B. factory $750,000 plus $185,000 for a high speed printer



Evolution of computers (2)

- 1956 first computer build with transistors
- 1950s - 1970s beginning of commercial computers' era
  - computers were bought by companies, universities and army
  - They become small and more productive
- 1977 first personal computers were sold. Whose main characteristics were:
  - Price: 600$
  - 4 kilobytes of memory
  - cassette storage
- 1984 apple's Macintosh computer (http://www.youtube.com/watch?v=2B-XwPjn9YY)
  - Price: 2500$
  - **Graphical interface**
  - **Mouse**

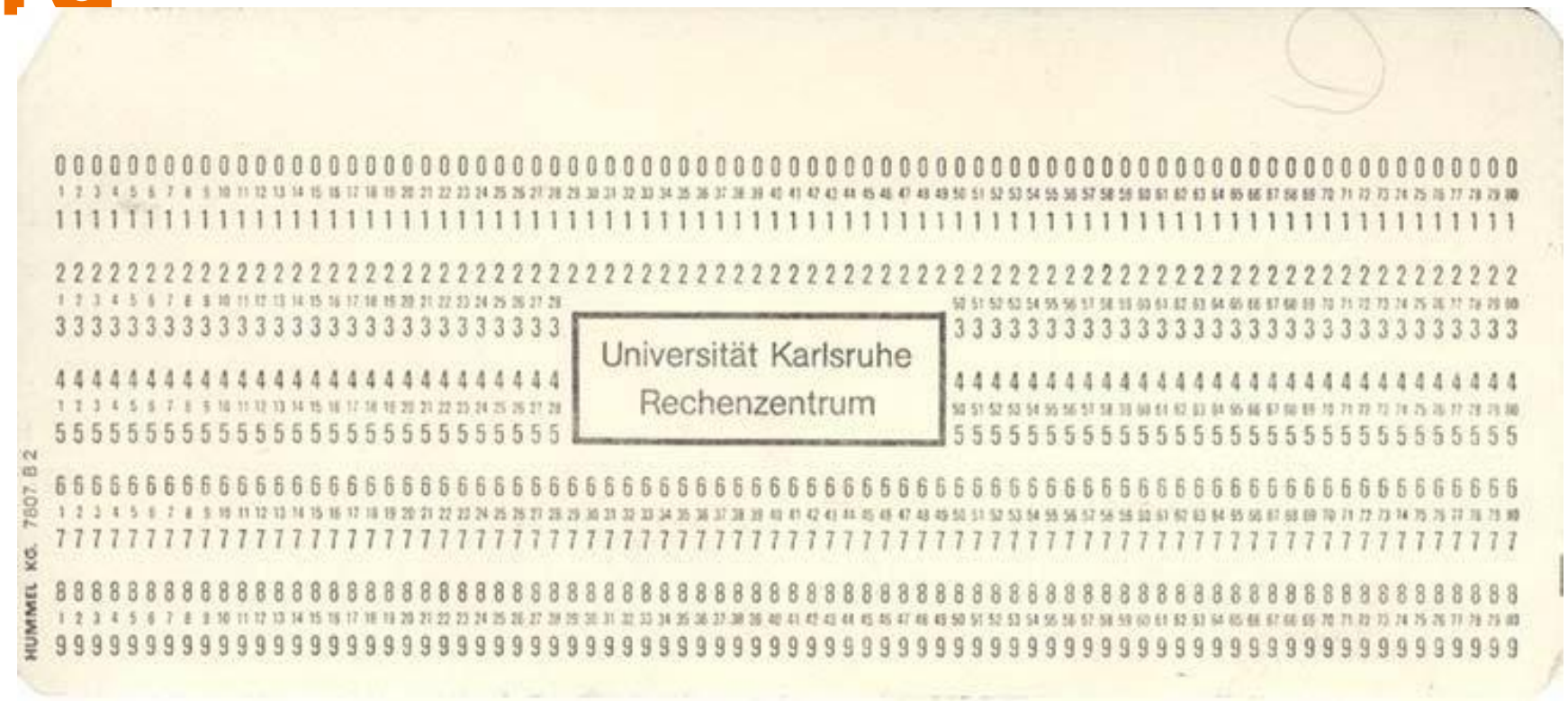
Evolution of computers (3)

- 1990s - 2000s: Era of personal computers
- 2000s - 2008s:Laptops, get smaller and cheaper
- 2004 - now: Phones got smarter
- 2008 - now: Tablets get more popular
- in 2012 tablets and smartphones were sold more than personal computers

Evolution of input devices

- switches
- punched cards (перфокарты)
- keyboard
- mouse
- screen

Punch card



https://www.youtube.com/watch?v=KG2M4ttzBnY

Evolution of output devices

- Punched cards
- Printer
- Monitor

Evolution of storage devices

- Magnetic tapes
- Magnetic disks
  - 1961 IBM’s magnetic disk
  - Capacity 28 million characters (28 MB)
  - cost: $2100 per month, or purchased for $115000
- 1994: Floppy disks
  - size: 1.4 MB
- Optical CD
- Blu-ray disks
- Flash storage

The 350 Disk Storage Unit consisted of the magnetic disk memory unit with its access mechanism, the electronic and pneumatic controls for the access mechanism, and a small air compressor. Assembled with covers, the 350 was 60 inches long, 68 inches high and 29 inches deep. It was configured with 50 magnetic disks containing 50,000 sectors, each of which held 100 alphanumeric characters, for a capacity of 5 million characters.

Disks rotated at 1,200 rpm, tracks (20 to the inch) were recorded at up to 100 bits per inch, and typical head-to-disk spacing was 800 microinches. The execution of a "seek" instruction positioned a read-write head to the track that contained the desired sector and selected the sector for a later read or write operation. Seek time averaged about 600 milliseconds.

With storage capacities of 5 million and 10 million digits, and the capability to be installed either singly or in pairs, the 350 provided the 305 system with storage capacities of 5, 10, 15 or 20 million characters.

An IBM RAMAC 305 with a 350 disk storage unit leased for about $3,200 per month back in 1957. Over a thousand of the 305 systems (one of IBM's last vacuum tube units) were manufactured before production ended in 1961, and the 305 was withdrawn in 1969.

Evolution of computer usage

First generation - science, army needs; Arithmetical calculations

Second generation - government, big business needs; Storing data

Third generation - small and medium business needs; Useful Input and Output, smaller size

Fourth generation - personal computers.

Extra information

- http://www.stanford.edu/class/cs101/hardware-1.html
- http://www.youtube.com/watch?v=IcrBqCFLHIY

Further learning

Basic Circuit Theory (2nd course I semester) - The flow of current in circuit, simple electrical circuits.

Digital Design (2nd course II semester) - Logic gates constructed from transistors, creating schemes that perform some logical operations on inputs

Advanced Digital Electronics (3rd course I semesters) - create more complex schemes from chips that are constructed from logic gates.