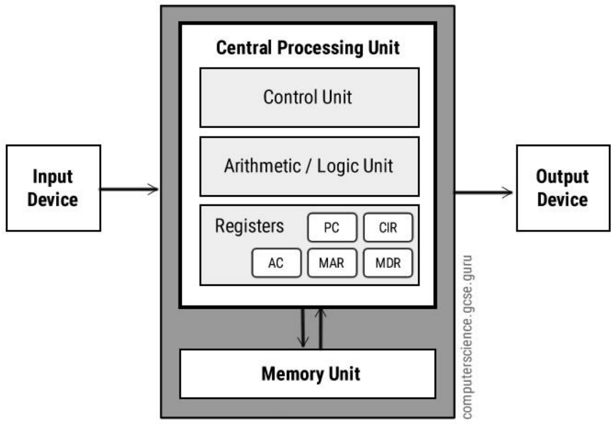
Computer Architecture



The von Neumann architecture

Also known as von Neumann model or Princeton architecture.

Component of a CPU (Central Processing Unit):

CU = Control Unit (Controls and monitors all computer operations among other things)

ALU = Arithmetic and Logic Unit (allows arithmetic = add, subtract etc and logic = AND, OR, NOT etc operations)

Registers = High speed storage areas in the CPU. All data must be stored in a register before it can be processed.

PC = Program counter CIR = Current Instruction Register

AC = Accumulator MAR = Memory Address Register MDR = Memory Data Register

Cache = L1, L2, L3. (Closer to further from the CU) Very fast memory for the CPU only.

Memory Unit = RAM (temporary), random access memory or ROM (permanent), read only memory.

CPU Cycle

1. Read data from RAM > 2. Decode data (understand instruction) > 3. Execute operation > 4. Return result in RAM

CPU Classifications

Measured in cycles per seconds. MegaHertz (MHz = 10^6 Hz) or GigaHertz (GHz = 10^9 Hz).

Difference in word size: 16, 32, 64 bits. 64 bits can access 8 bytes at a time. Also consider the number of cores.

GPU (Graphical Processing Unit)

Is a co-processor for the CPU, dedicated to graphics. An integrated GPU means that it is part of the CPU.

GPUs have thousands of cores meaning they can parallelize operations. Useful for machine/deep learning.

Secondary storage

HDD = Hard Disk Drive, information in binary, head magnetizes the surface (north/south, 1/0), mechanical so slow.

SDD = Solid State Drive, NandFlash keeps information when powered off, can lose their state after a long time.

RAID (Redundant Array of Independent Disks)

RAID 1: 2 hard drives, you write the same data to both. So, if one fails the other can provide the data. Data is never lost, you have backup = fault-tolerance. Writing is slow because your write the same thing in two places.

RAID 0: Improving Speed. Striping, data is divided between HDD. Writing and reading is fast. You read in parallel from both disks.

Moore's law

Hardware capacity doubles every 18 months, this trend is expected to end in 2020 to 2025. Formulated in 1965.

Computer representation of image

RGB = Red Green Blue. Every pixel is a mixture of these three colours. 256 shades of each colour = 2^8

About 16,8 million colour options. (2^24). Image of size 800x600 = 480.000 = 0,48 megapixel

Number System

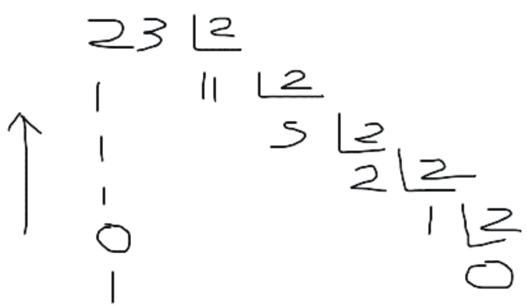
Every program that executes on PC understands binary code. All instructions in a program are in binary format.

Binary numbers are 0,1 (on, off).

<u>Binary to decimal</u>

Binary	1	0	1	1	0	1		*Binary number to convert*
Decimal	1*2^5	0*2^4	1*2^3	1*2^2	0*2^1	1*2^0		*Binary value x 2 to the power of the digit*
Decimal	32	0	8	4	0	1	= 45	*Add all separate decimal values*

<u>Decimal to binary</u>



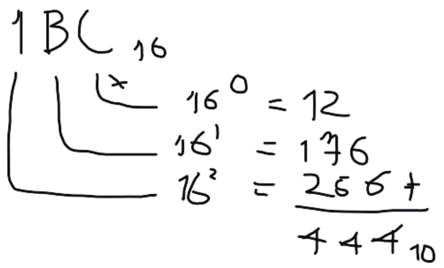
Divide by two each step, if there is a remainder (0.5) then the binary value will be one.

Afterwards you read form the bottom to the top.

Here:

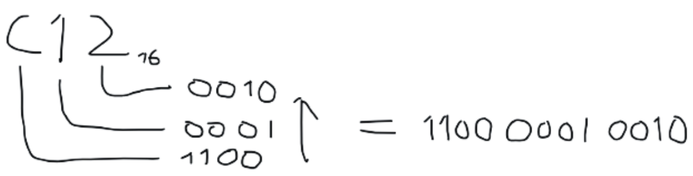
10111

<u>Hexadecimal to decimal</u>



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

<u>Hexadecimal to binary</u>



<u>Decimal to hexadecimal</u>

921 to hex	921/16 = 57, answer must be integer	remainder = (57.5625-57)*16 = 9 hex
	57/16 = 3	remainder = (3.5625-3)*16 = 9 hex
	3/16 = 0	remainder = (0.1875-0)*16 = 3 hex

Answer is read bottom to top = **399**

<u>Why is hexadecimal relevant?</u> 1.000.000.000.000 requires 13 chars to be display in decimal = 13 bytes. In hex = E8D4A51000 requires 10 chars to be displayed = 10 bytes. Difference is trivial but adds up in millions of operations.

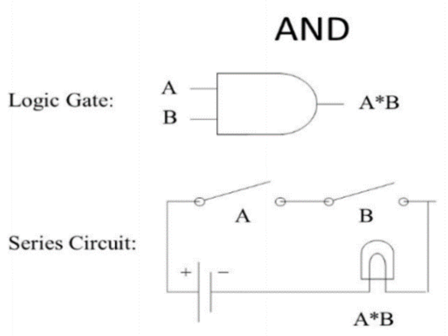
Boolean Algebra

Computing truth: terms of truth values 0 and 1.

<u>Operators</u>

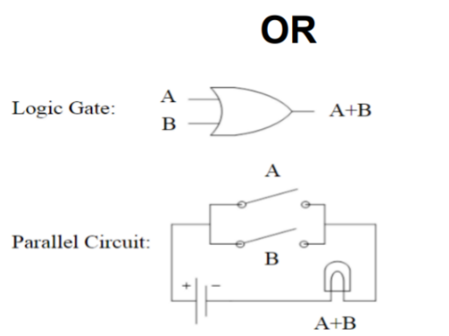
- AND - limiter (Cats AND Dogs) — To build a conjunction — Symbol = ∧
- OR - expander (Cats OR Dogs) — To build a disjunction — Symbol = ∨
- NOT - limiter (Cats NOT Dogs) — To negate — Symbol = ¬

<u>Logic gates</u>



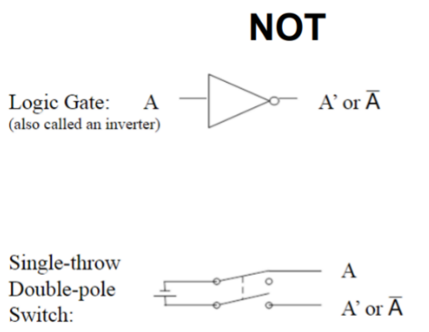
Truth Table:

A	B	A*B
0	0	0
0	1	0
1	0	0
1	1	1



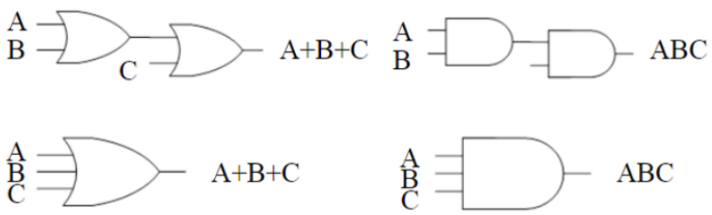
Truth Table:

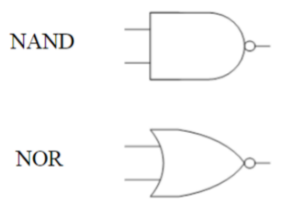
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1



Truth Table:

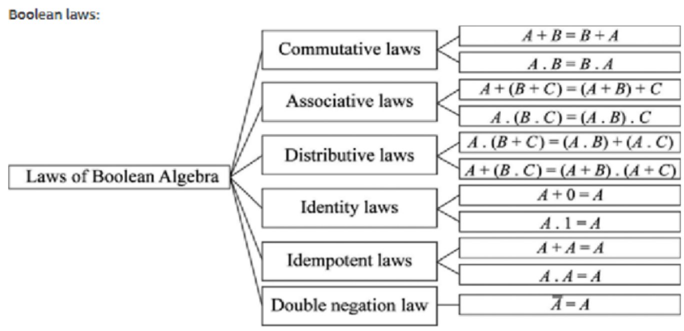
A	Ā
0	1
1	0





A	B	A↑B
0	0	1
0	1	1
1	0	1
1	1	0

A	B	A↓B
0	0	1
0	1	0
1	0	0
1	1	0



<u>Laws</u>

Absorptive Law:

A+AB = A, A.(A+B) = A

A AND B = A.B = A*B = AB

De Morgan Laws:

¬(p ∨ q) = ¬p ∧ ¬ q

¬(p ∧ q) = ¬p ∨ ¬ q

Double Negation Law:

¬¬p = p

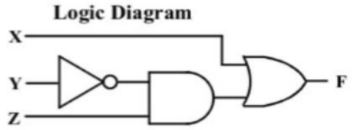
Truth Table

X Y Z	$F = X + \overline{Y} \cdot Z$
0 0 0	0
0 0 1	1
0 1 0	0
0 1 1	0
1 0 0	1
1 0 1	1
1 1 0	1
1 1 1	1

Logic Equation

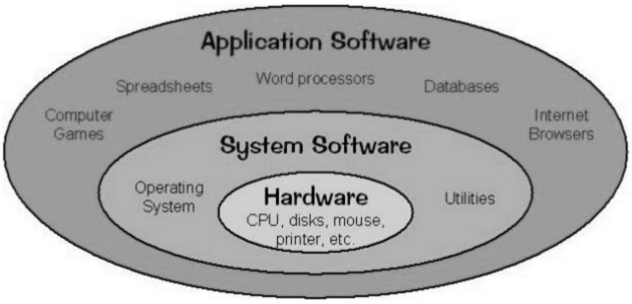
$$F = X + \overline{Y}Z$$

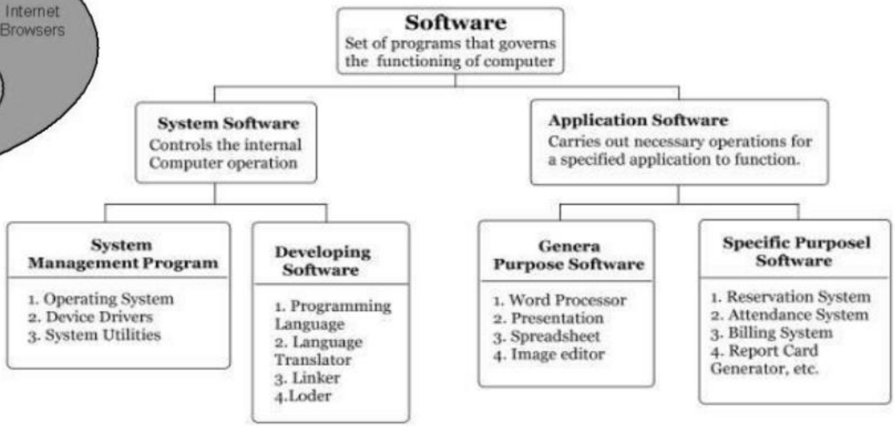
Logic Diagram



Software Side

Taxonomy of software





Programming

The process of writing computer programs. The process of taking an algorithm and encoding it into a notation, a programming language, so that it can be executed by a computer.

Lower-level programming languages: if you want to do hardware programming.

Higher-level programming: if you want to data manipulation.

Binary code > Machine code > Assembly language > High/middle languages > Scripted languages

Variable = a cell of RAM, in hexadecimal

Loop = repeat a set of instructions until a condition is met.

The process of building software (software engineering):

Requirement Analysis > Design > Implementation (20 %) - Writing the code > Testing > Deployment > Maintenance

IDE = Intergatated Development Environment.

COTS = Commercial off the shelf (Office, Chrome, Photoshop)

Algorithm

A set of well-defined, ordered, simple and finite steps that solve a specific computational problem.

A computational problem specifies an input-output relationship. *Input > Finite, ordered list of steps > Output*

Flowcharts

Symbol	Name	Function
	Start/end	An oval represents a start or end point
	Arrows	A line is a connector that shows relationships between the representative shapes
	Input/Output	A parallelogram represents input or output
	Process	A rectangle represents a process
	Decision	A diamond indicates a decision

Operating Systems

OS roles

Interface between computer user and hardware, manages the CPU, manages the memory and storage, manages hardware and peripheral devices, and provides file management.

Arbitration

Manages access to shared hardware resources, enables the multiple applications to share the same hardware.

Abstraction

Hiding the details of different hardware configurations. Without abstraction developers would write the same program for each hardware configuration.

Developers "talk" with the OS via a API (Application Programming Interface).

Processes

The OS mangeges many different processes of different applications at the same time. Making it seem that those all operate simultantiously. A process is an active entity and a program is a passive entity.

CPU Mangement

Measuring the time with respect to a process

Arrival Time =Time at which the process arrives in the ready queue.

Completion Time =Time at which process completes its execution.

Burst Time = Time required by a process for CPU execution.

Turn Around Time = Completion Time – Arrival Time

Waiting Time = Turn Around Time – Burst Time

Basic algorithms

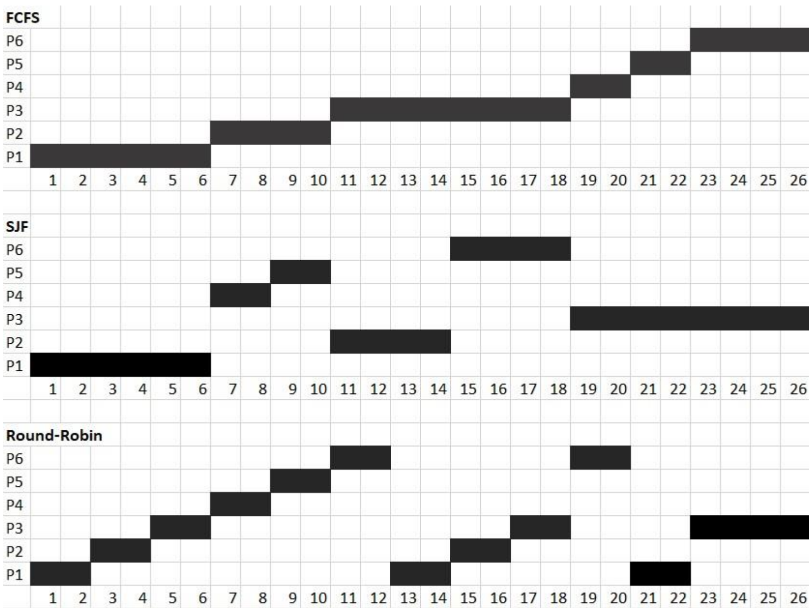
FCFS = First Come First Server — *Starts with the process that arrives first, doesn't continue until it's done.*

SJN = Shortest Job Next — *Starts with the process that has the lowest execution time, continues in order.*

RR = Round Robin (quantum) — Handles all process in equal time slices (quantums), gives no priorities.

Example calculating process times for algorithms

Process	Exec time	Arrival time
P1	6	0
P2	4	1
P3	8	2
P4	2	3
P5	2	5
P6	4	5



File paths

```
f
├──f1
│  └──f10
├──f2
│  └──f6
│     └──f8
├──f3
│  └──f7
├──f4
│  └──f9
└──f5
```

f to f5 (your work directory is f) =	Absolute = f/f5
	Relative = f5
f10 to f8 (your work directory is f10) =	Absolute = f\f2\f6\f8
	Relative = ..\..\f2\f6\f8
f9 to f10 (your work directory is f9) =	Absolute = f\f1\f10
	Relative = ..\..\f1\f10

Computer Networks

Types

PAN = Personal Area Network:

Your phone connected to the computer.

Your smartwatch connected to your phone.

LAN = Local Area Network:

Computers connected with each other at home/university.

Computer often share the same physical space.

MAN = Metropolitan Area Network:

Computers in a specific city.

WAN = Wide Area Network:

LANs connected with each other.

Also based on management method (Client/Server, Peer-to-Peer) or topology (Ring, Bus, Star)

Elements

Every device connected to a network is referred to as a node. Every node is connected to a network using a transmission media. TM establish links between the node and the network.

NIC = Network Interface Card.

MAC-address = Media Access Control, 6 bytes long. 2^48 possible addresses.

Bandwidth = Amount of information that can move through the transformation media in a given amount of time.

LAN

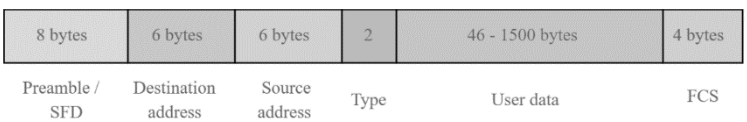
Most common connection type is ethernet (at first coaxial cable, now twisted pair or fibre optics).

You want to send data from computer A to B, A sends first a special set of bits to check whether it can start sending (preamble). This to clear the channel otherwise you have collisions. If nodes send the preamble at the same time, solved by a wait time. This time is random otherwise they would collide again.

Data is divided into chunks:

Ethernet frames.

8 bytes:	Preamble / SFD	Indicating start of frame
6 bytes	Destination adress	MAC Adress of B
6 bytes	Source adress	MAC Adress of A
2 bytes	Type	Length of data (in 2^16 bits)
46-1500 bytes	Actual data (payload)	
4 bytes	FCS (used for checksum)	Saves amount of bits in payload, if equal that means the data is not corrupted



Computer Networks

WAN

Most common type is Internet (Network of networks)

Collisions in a WAN are solved by the router:

The router has a routing table identifying networks over the internet, it routes data.

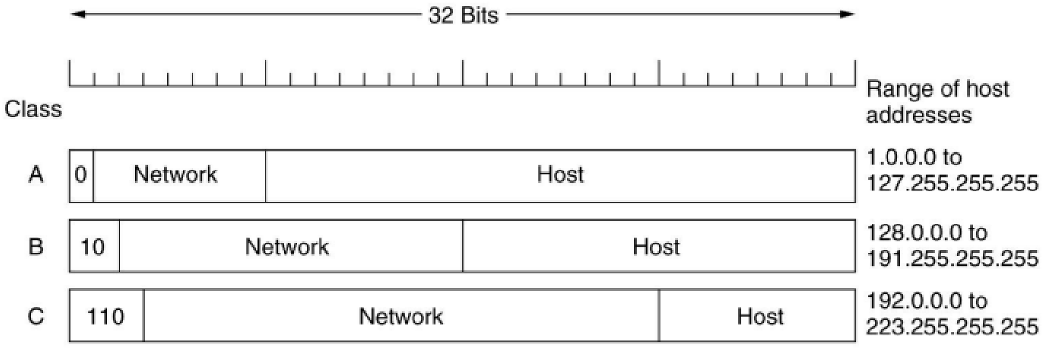
You need a network ID and host ID = IP Address

Not using MAC addresses because they are not hierarchical!

Device A 00:00:00 can be in the NL but device B 00:00:01 can be in the UK

If they wanted to use them you would need a very very large routing table. IP Adresses are therefore used.

WAN Classes



Class A allows for 127 netid and 16 M hosts.

Class B allows for 16 K netid and 64 K hosts.

Class C allows for 2 M netid and 256 hosts.

IP Adress

4 bytes long, byte.byte.byte.byte   00000000.00000000.00000000.00000000 > 0.0.0.0

Max adresses = 2^32   11111111.11111111.11111111.11111111 > 255.255.255.255

Subnets

Consider the following IP address: 195.167.174.0 = class C network

and the mask: 255.255.255.248
11111111.11111111.11111111.11111000

How many subnets with this mask?   *Five bits of value 1 can be used for the subnets. 2^5 = 32 subnets.*

How many hosts per subnet?   *Three bits of value 0 can be used for hosts. 2^3 = 6 subnets per host.*

An organization has IP Address: 153.117.0.0 = class B network

You want to create subnets with 120 hosts each.

120 = 1111000 = 7 bits. You need to dedicate 7 bits of 16 bits for the hosts.

16 – 7 bits leaves 9 bits for the subnets.

Subnet mask will be the max ip - the bits you needed for the hosts (7 here) set these to zero =

11111111.11111111.11111111.10000000 = 255.255.255.128

Computer Networks

If a packet is sent to the address 153.117.122.63, which subnet should the router forward it to?

Address in decimal	153.117.122.63	
Address in binary	10011001.01110101.01111010.00111111	AND - operation
Mask in binary	11111111.11111111.11111111.10000000	
Subnet in binary	10011001.01110101.01111010.00000000	
Subnet in decimal	153.117.122.0	

Problems with IPs

Shortage of IPs solved with NAT (Network Address Translations)

Inside a network: private address, outside network: public address.

Technology Trends

GDPR = General Data Protection Regulation

Data Protection Principles

Fair and lawful (legitimate)	If a company is gathering personal data, they need a legal ground to do that.
Purpose	Organization needs to be open about why they are gathering the data.
Adequacy	Data collected should be reasonable for the purpose.
Accuracy	Data collected should be accurate, and up to date.
Retention	Don't keep data for longer than needed (unless agreed upon).
Rights of Individuals	People need to be able to see their data, edit it and delete it (right to be forgotten).
Security	The systems used to keep personal data need to be secure.
International	Data can go overseas if the target country has an equal data protection level.

Data science

Data Surfing	Look at data that is relevant for the research
Data Wrangling	Collect, gather, clean and transform the data, make connections with other data
Data Mining	Choose a algorithm to interpret the data, test it and fine tune it for your application
Data Artistry	Show the conclusions and other useful data in a visual or clear way.

Machine Learning

Traditional programming	Data + Program > Computer > Output
Machine learning	Data + Output > Computer > Program

Cyber Security

CIA requirements: C = Confidentiality I = Integrity (data correctness) A = Availabilty