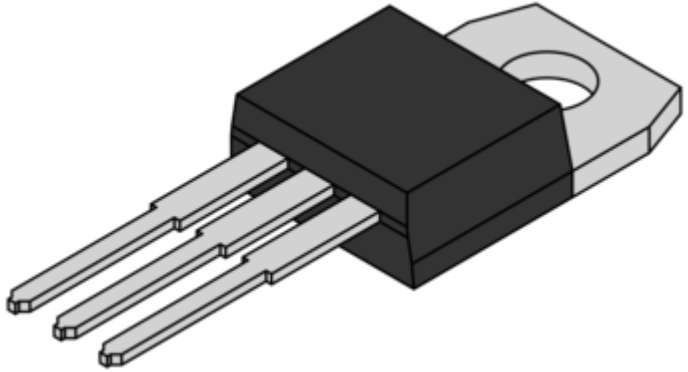
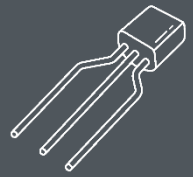

The greatest invention
starting in 5:00
Dr. Goran Soldar
Dr. Khuong An Nguyen

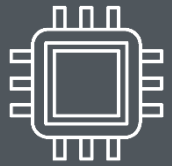
The greatest invention ?

The greatest invention

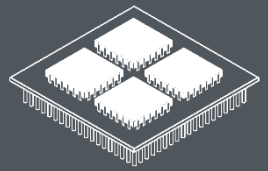




Transistor



CPU

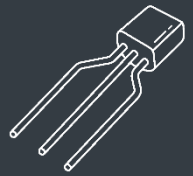


Parallel processing

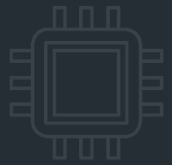
1 | What is the role of transistor ?

2 | Central Processing Unit

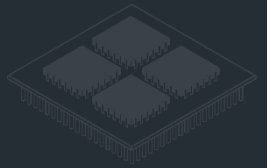
3 | Parallel processing



Transistor

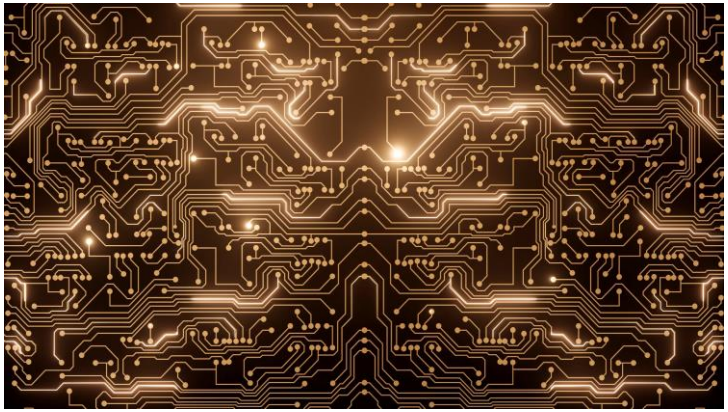


CPU

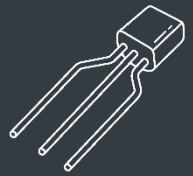


Parallel processing

Electricity



How to control the flow of electric current ?

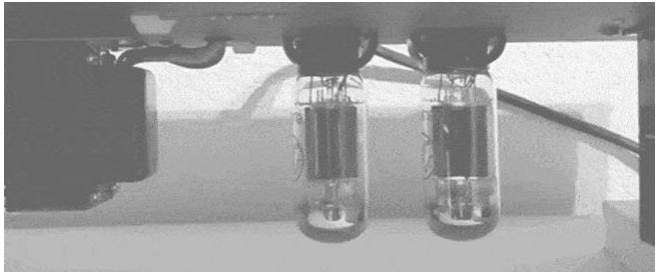


Transistor

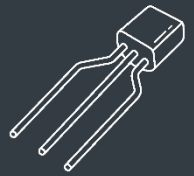
CPU

Parallel processing

Vacuum tube

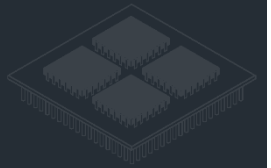


1. Bulky.
2. Unreliable.
3. High energy consumption.



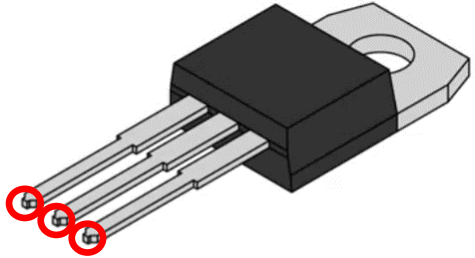
Transistor

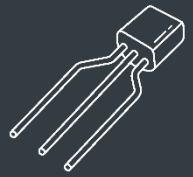
CPU



Parallel processing

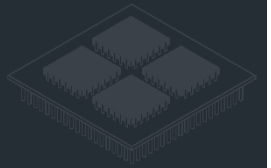
Transistor





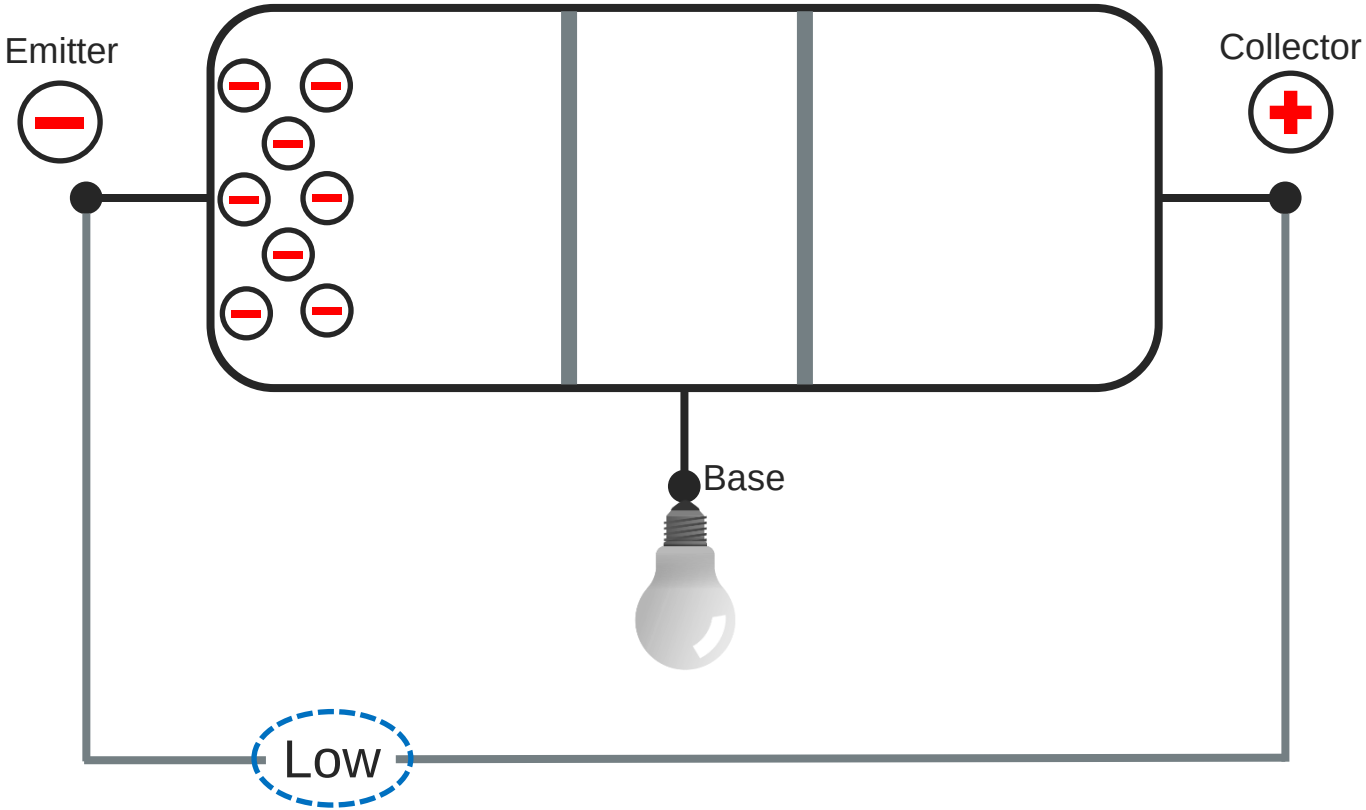
Transistor

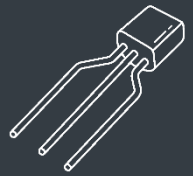
CPU



Multicore processing

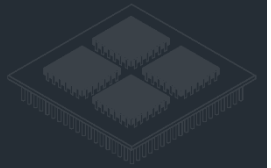
Transistor (low voltage)





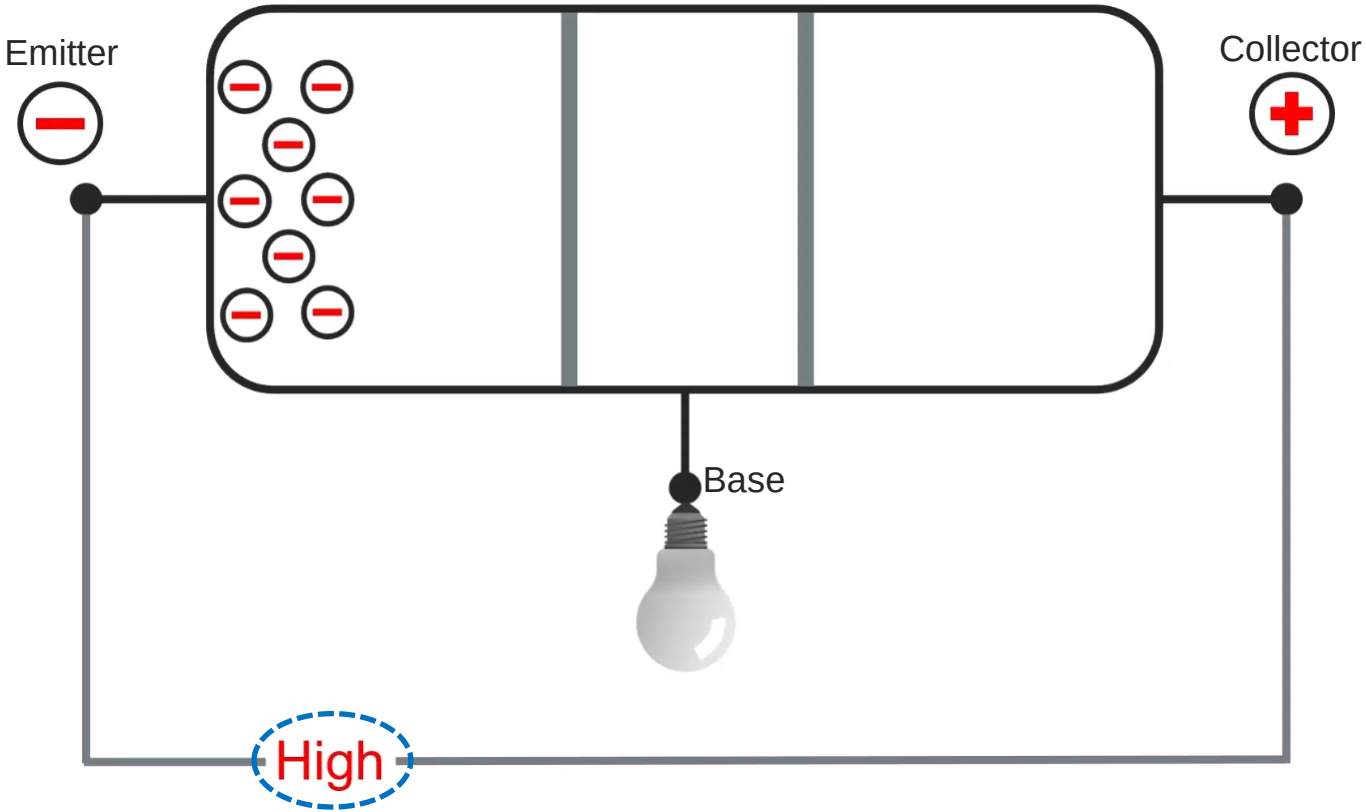
Transistor

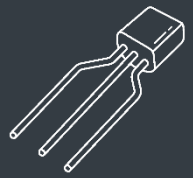
CPU



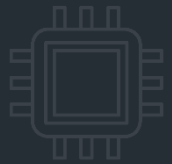
Parallel processing

Transistor (high voltage)

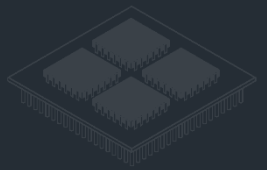




Transistor

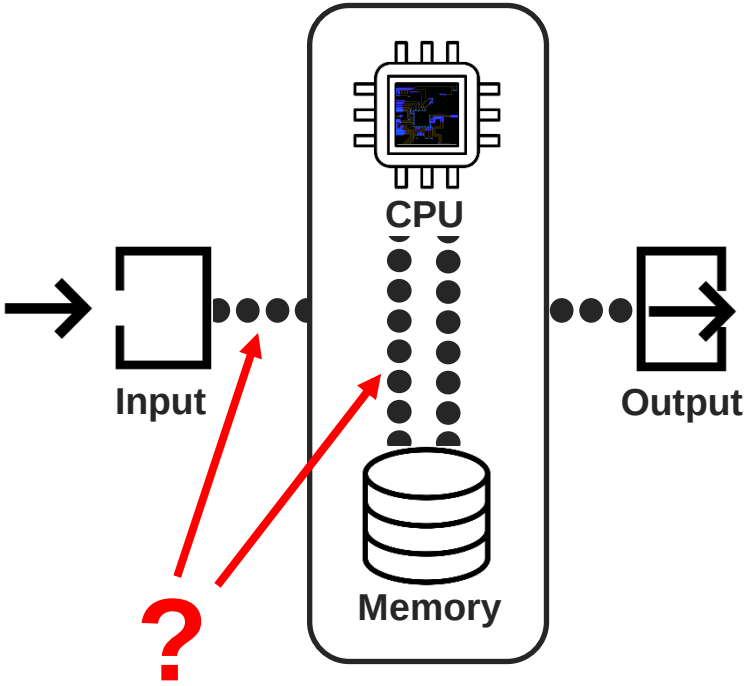


CPU

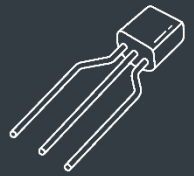


Parallel processing

Four components of a computer



1. **The input** takes outside information.
2. **The memory** stores the information.
3. **The CPU** processes the information.
4. **The output** returns the processed information to the outside world.



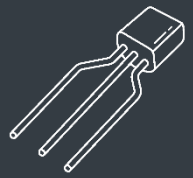
Transistor

CPU

Parallel processing

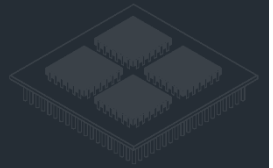
Representing binary

“ There are only **10** types of people in the world: those who understand binary, and those who don’t.”



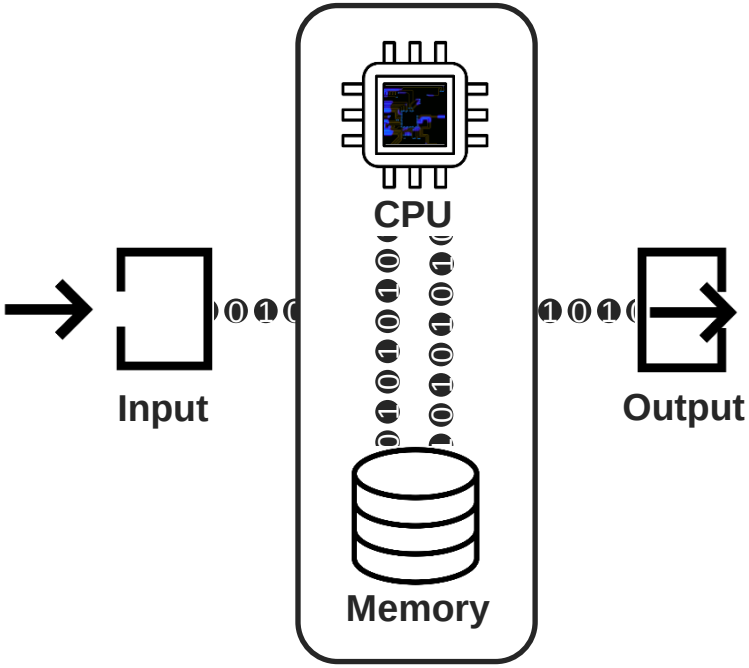
Transistor

CPU



Parallel processing

Four components of a computer



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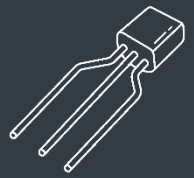
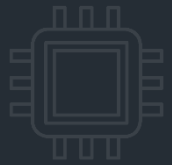
Why binary ? (0 1)

Why not base-10 ? (0 1 2 3 4 5 6 7 8 9)



Transistor

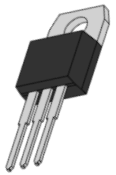


CPU

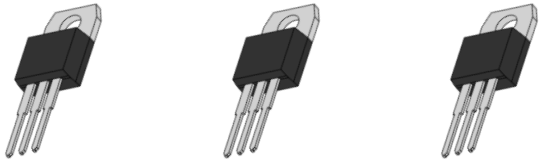
Parallel processing

Representing binary

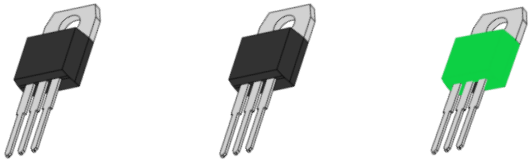
smallest unit



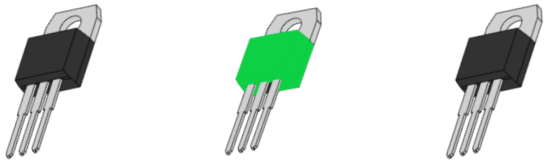
= bit (Binary digit) = 0 , 1



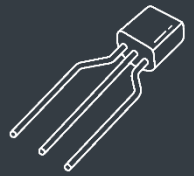
= 0



= 1



= 2



Transistor

CPU

Parallel processing

Representing binary

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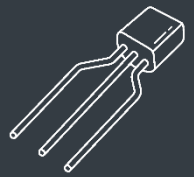


Transistor

CPU

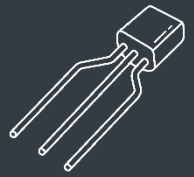
Parallel processing

ASCII code

1. American Standard Code for Information Interchange

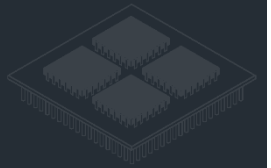
2. A mapping system from binary number to letter.

Letter	ASCII Code	Binary	Letter	ASCII Code	Binary
a	097	01100001	A	065	01000001
b	098	01100010	B	066	01000010
c	099	01100011	C	067	01000011
d	100	01100100	D	068	01000100
e	101	01100101	E	069	01000101
f	102	01100110	F	070	01000110
g	103	01100111	G	071	01000111
h	104	01101000	H	072	01001000
i	105	01101001	I	073	01001001
j	106	01101010	J	074	01001010
k	107	01101011	K	075	01001011
l	108	01101100	L	076	01001100
m	109	01101101	M	077	01001101
n	110	01101110	N	078	01001110
o	111	01101111	O	079	01001111
p	112	01110000	P	080	01010000
q	113	01110001	Q	081	01010001
r	114	01110010	R	082	01010010
s	115	01110011	S	083	01010011
t	116	01110100	T	084	01010100
u	117	01110101	U	085	01010101
v	118	01110110	V	086	01010110
w	119	01110111	W	087	01010111
x	120	01111000	X	088	01011000
y	121	01111001	Y	089	01011001
z	122	01111010	Z	090	01011010



Transistor

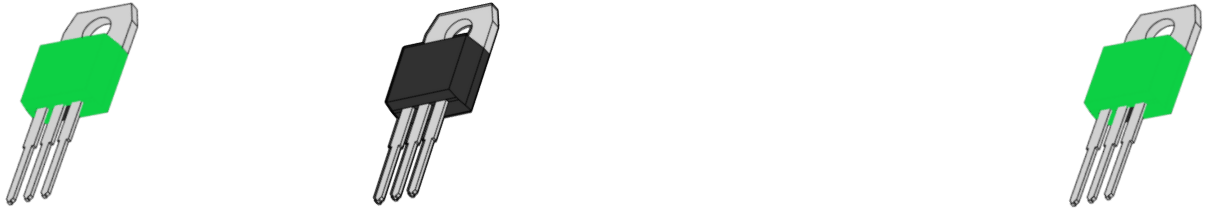
CPU



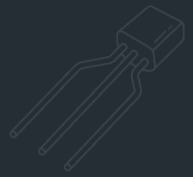
Parallel processing

A byte

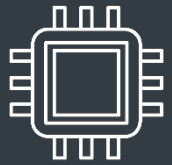
Letter : **A**
ASCII code : **65**
Binary : **01000001**



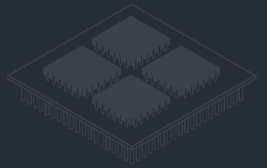
0 1 0 0 0 0 0 1



Transistor



CPU



Parallel processing

Inside a CPU

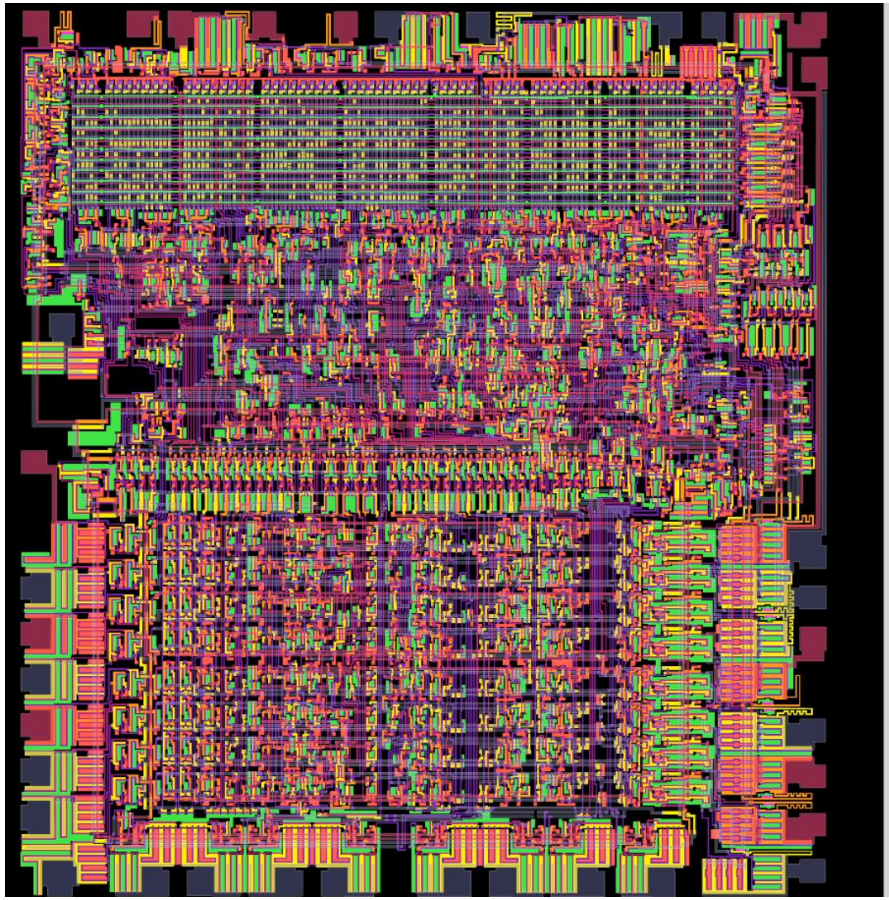
(ASML)

Transistor

CPU

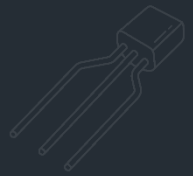
Parallel processing

CPU clock

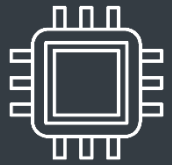


http://visual6502.org

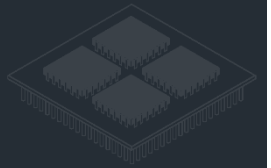
```
halfcyc:4068 phi0:0 AB:0015 D:69 RnW:1
PC:0015 A:d8 X:49 Y:b7 SP:fb Nv-BdIzc
Hz: 17.5
0000: a9 00 20 10 00 4c 02 00 00 00 00 00 00 00 89
0010: e8 88 e6 0f 38 69 02 60 00 00 00 00 00 00 00
0020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0030: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0040: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0050: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0060: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0070: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0080: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0090: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00a0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00b0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00f0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0100: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0110: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0120: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0130: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0140: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0150: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0160: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0170: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0180: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0190: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01a0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01b0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01f0: 00 00 00 00 00 00 00 00 00 00 00 00 04 00 00 00
```



Transistor

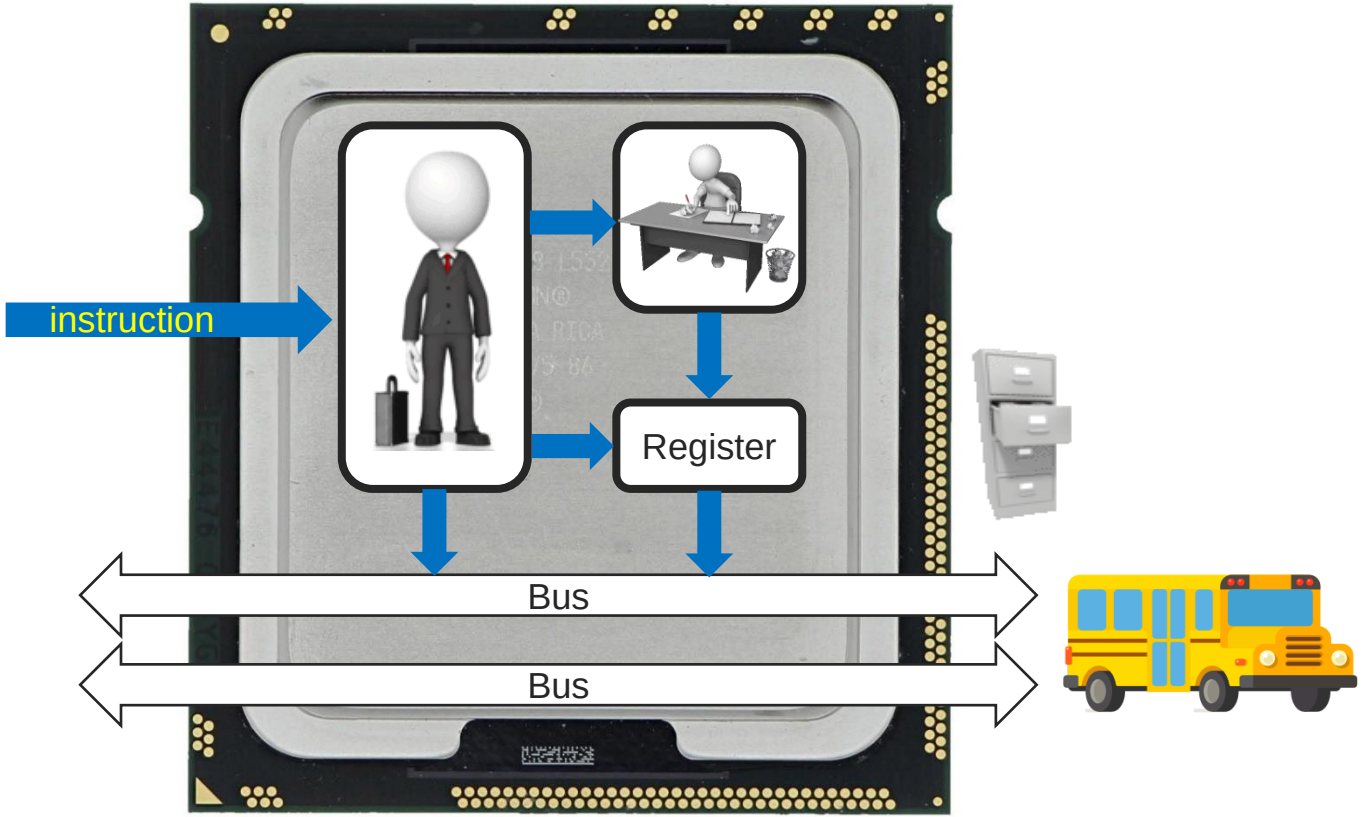


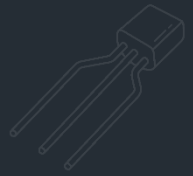
CPU



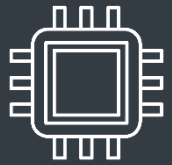
Parallel processing

CPU components





Transistor



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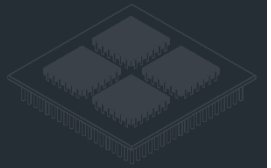
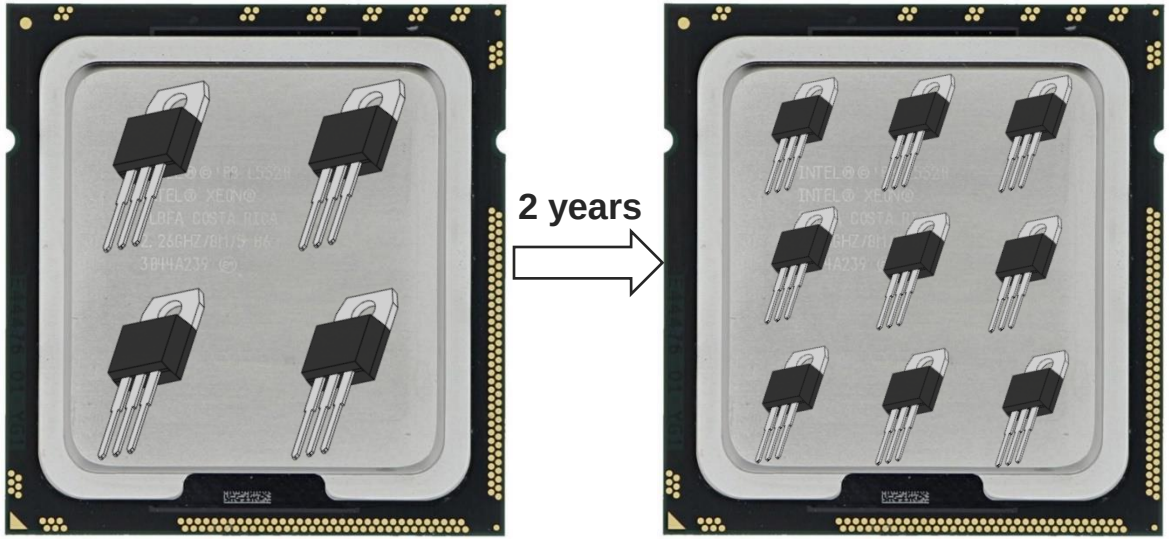


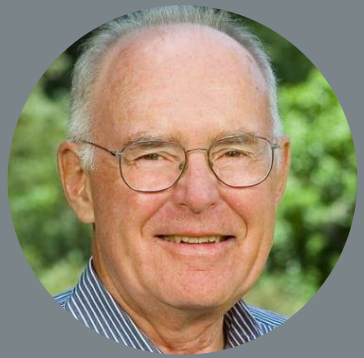
Parallel processing

Moore’s law



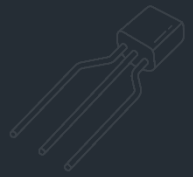
“The number of transistors in an integrated circuit will double every two years, while the cost halves”

- Gordon Moore, 1965

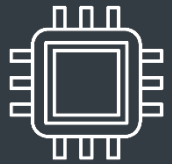


Further reading

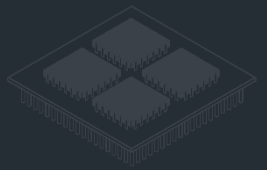
“Cramming more components onto integrated circuits”. Electronics Magazine, Gordon Moore, 1965.



Transistor

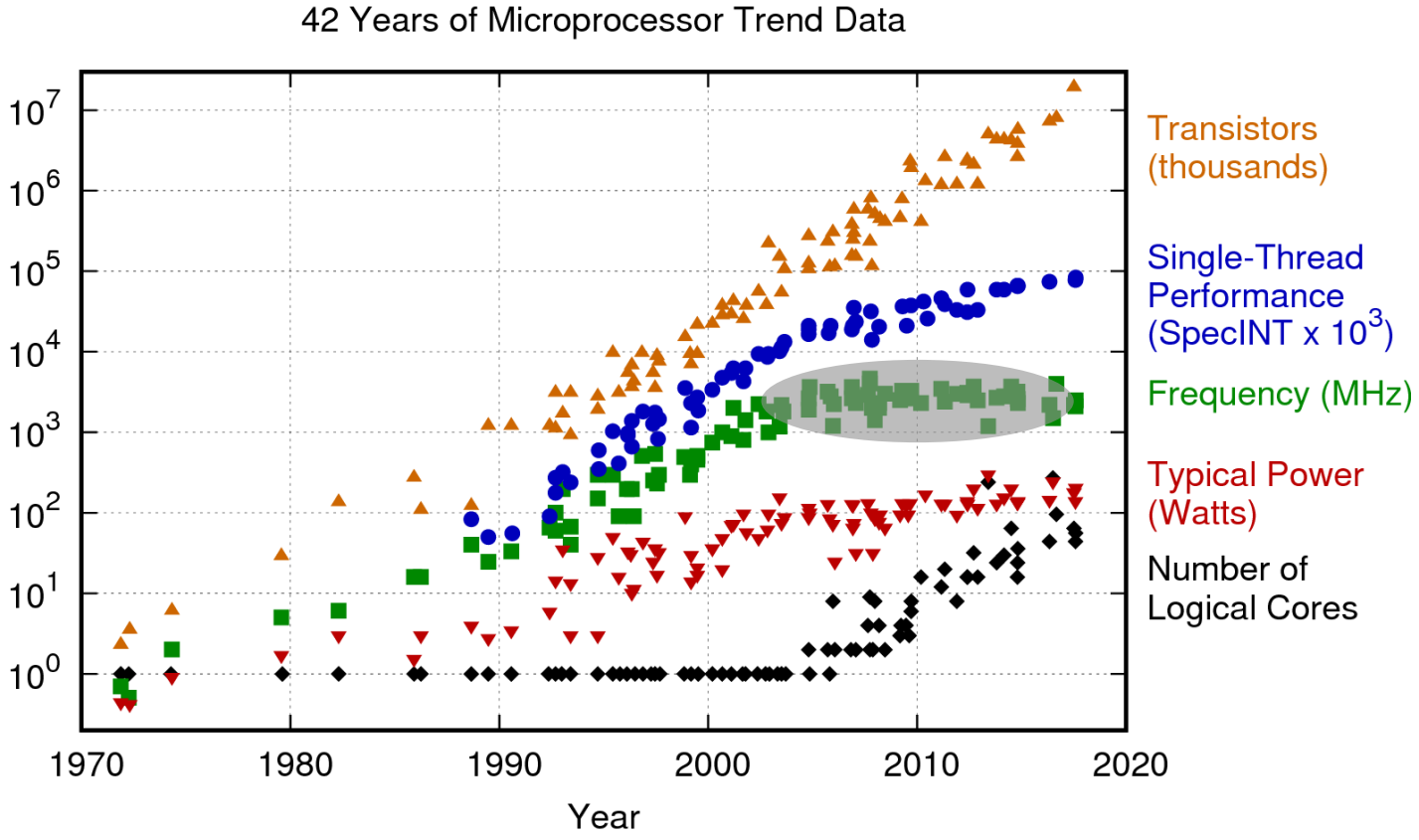


CPU

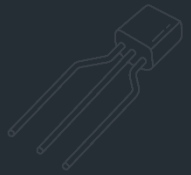


Parallel processing

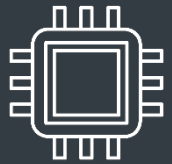
Moore's law



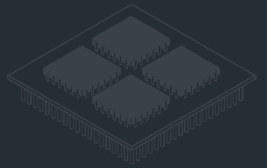
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp



Transistor



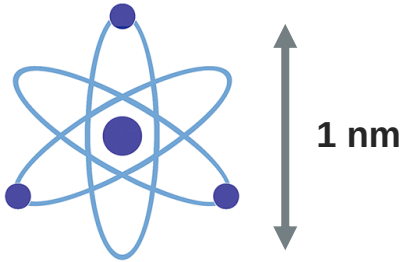
CPU



Parallel processing

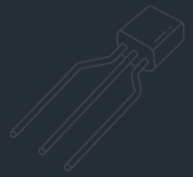
Issues with Moore's law (size)

1. Cannot get physically smaller than an atom (1 nm in diameter).
2. 7 nm chip achieved in 2020.

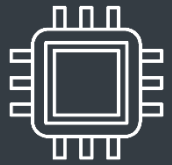


"The fact that materials are made of atoms is the fundamental limitation, and it's not that far away."

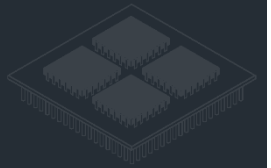
- Gordon Moore, 2007



Transistor



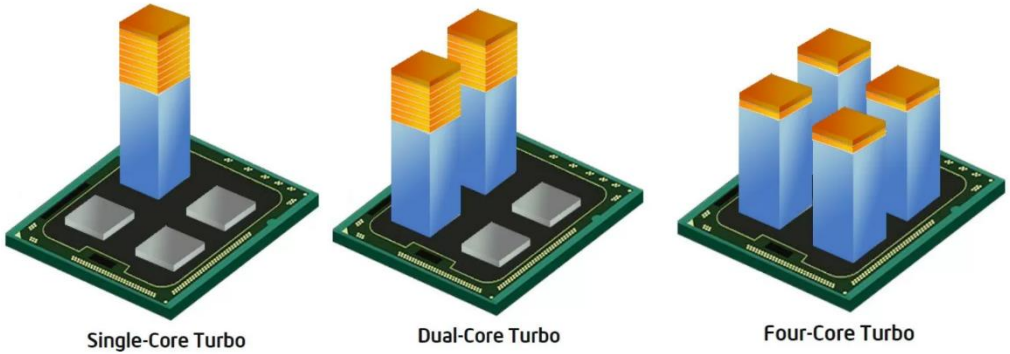
CPU

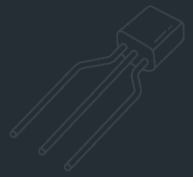


Parallel processing

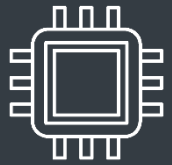
Issues with Moore’s law (thermal)

1. Transistor becomes leaky.
2. Heat dissipation.
3. Better to focus on improving design ?





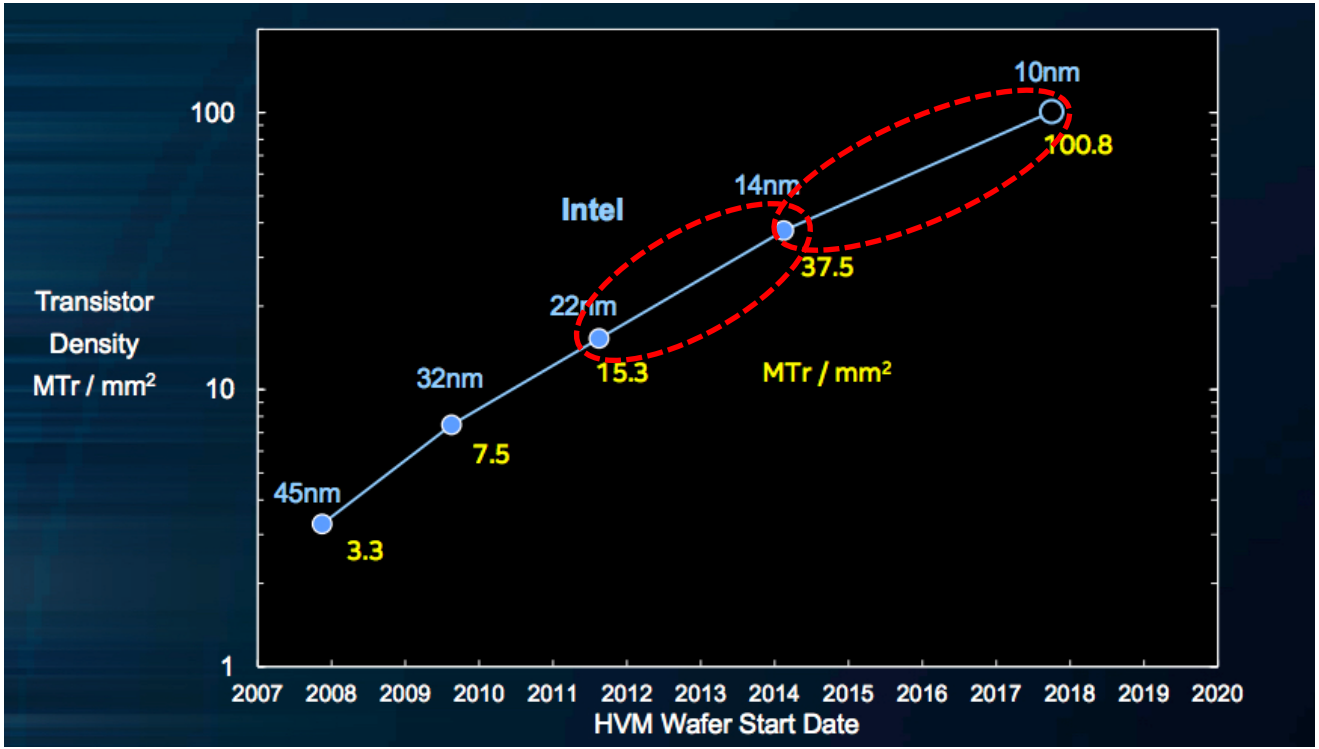
Transistor

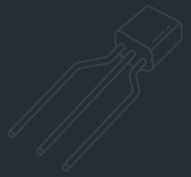


CPU

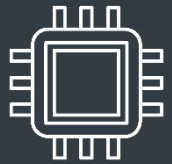
Parallel processing

Issues with Moore's law (cost)

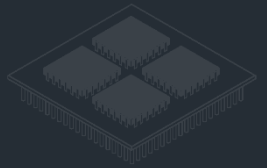




Transistor

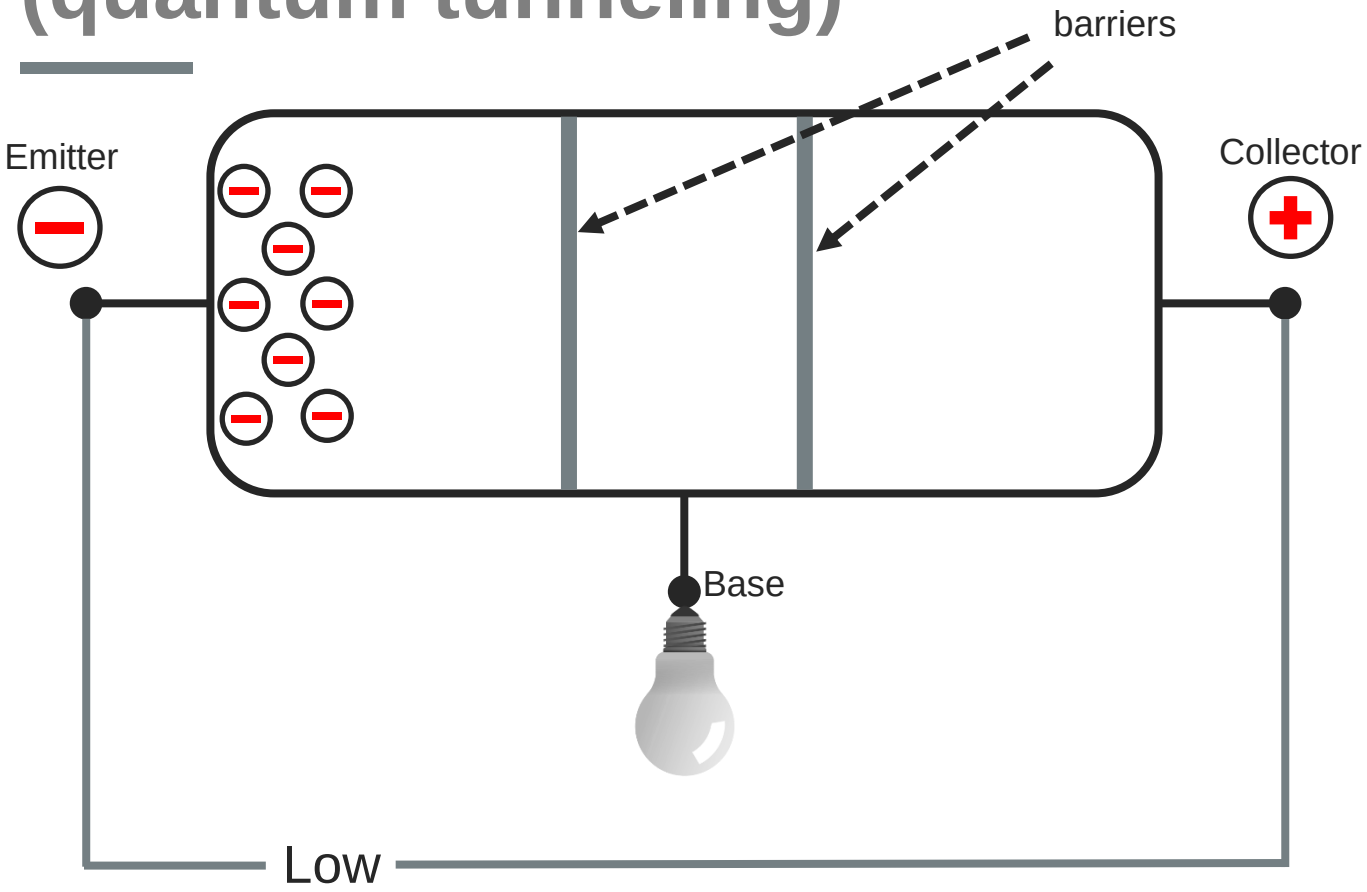


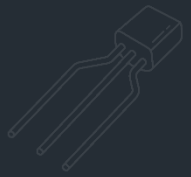
CPU



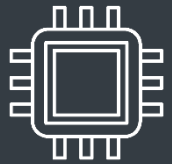
Parallel processing

Issues with Moore's law (quantum tunneling)

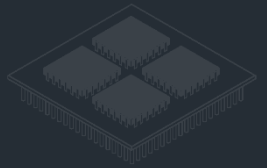




Transistor

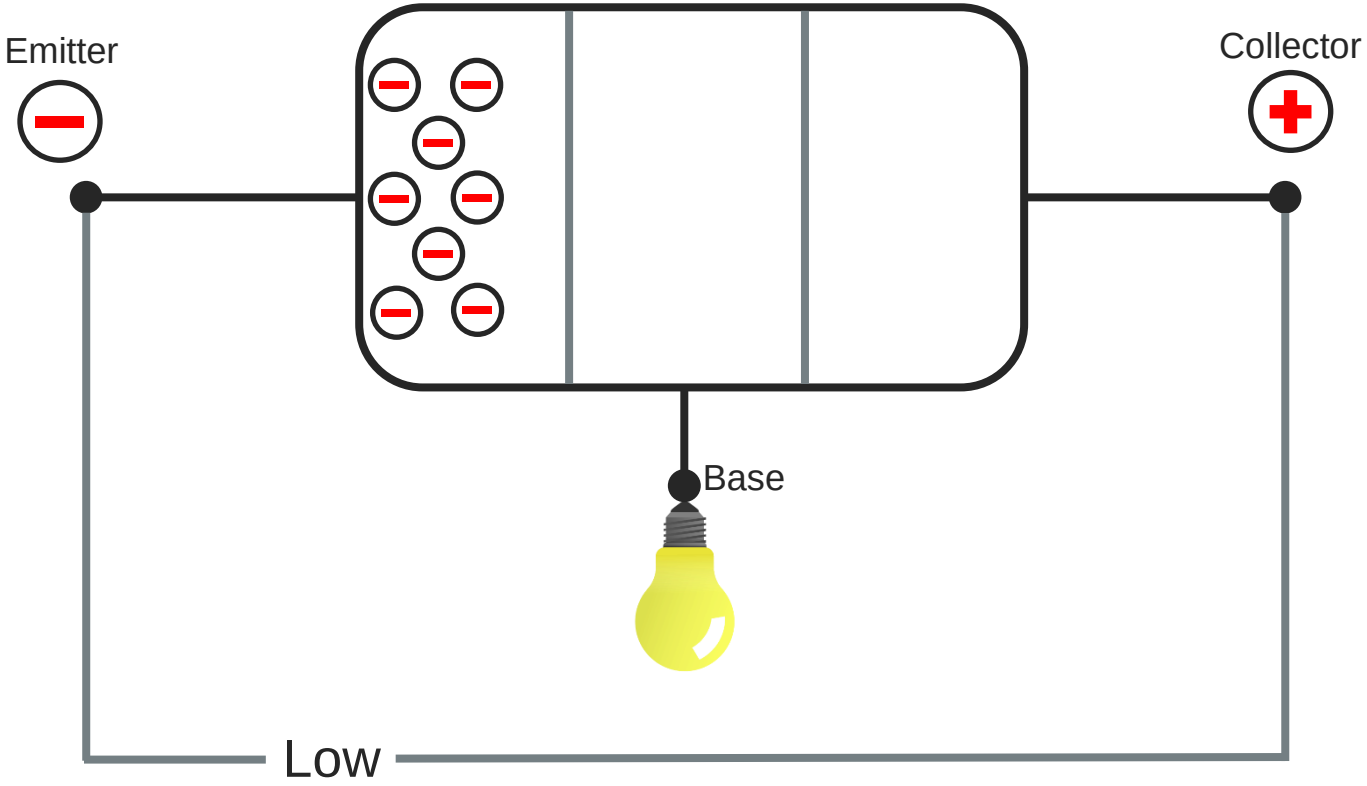


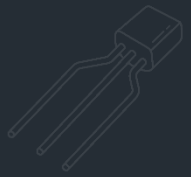
CPU



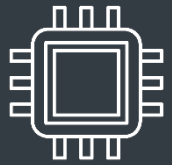
Parallel processing

Issues with Moore's law (quantum tunneling)

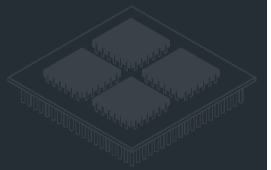




Transistor

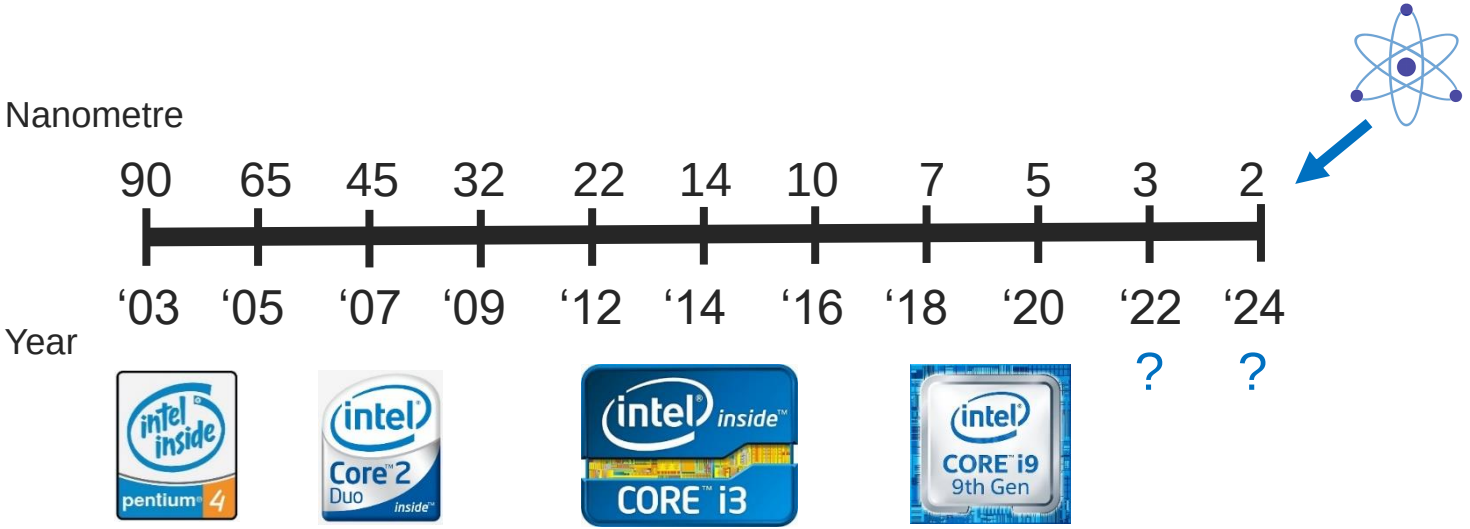


CPU



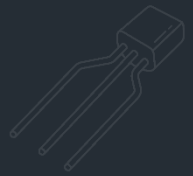
Parallel processing

Chip size

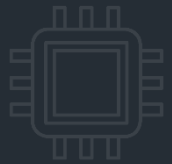


Further reading

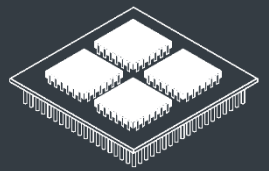
“Design of ion-implanted MOSFET's with very small physical dimensions”. IEEE Journal of Solid-State Circuits, RH Dennard et al., 1974.



Transistor

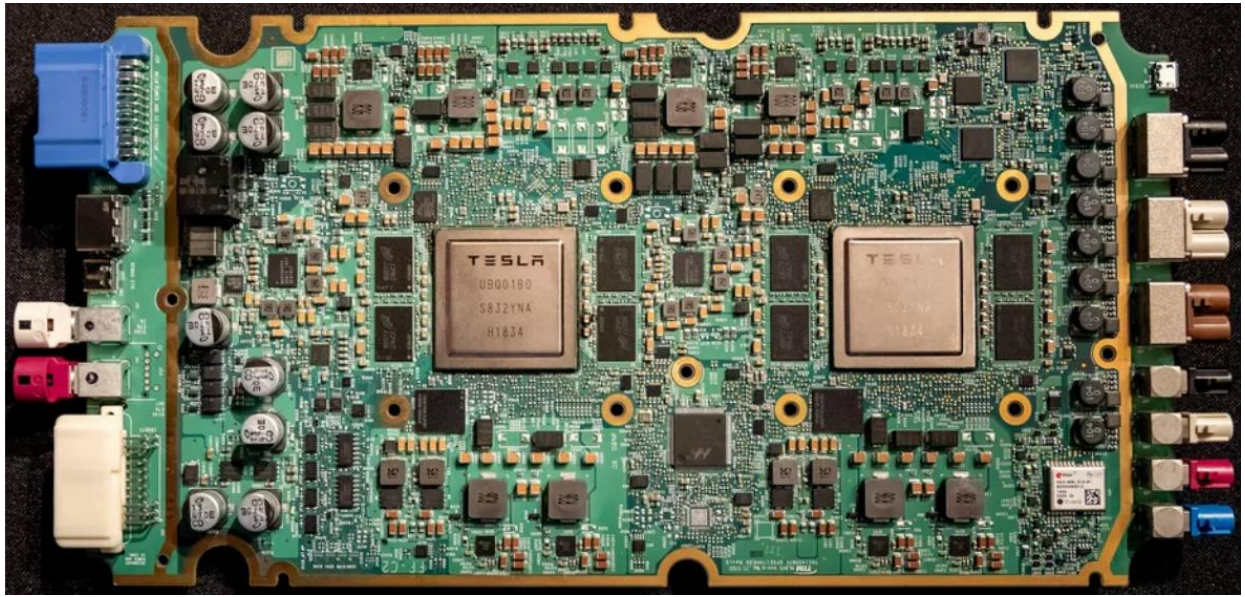


CPU

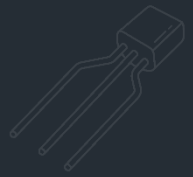


Parallel processing

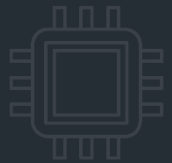
Parallel processing



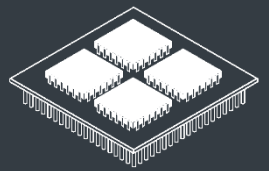
Tesla self-driving car’s board



Transistor

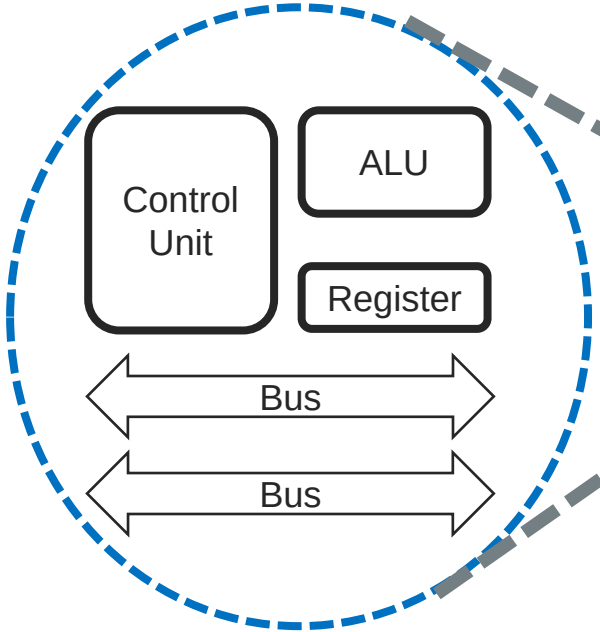


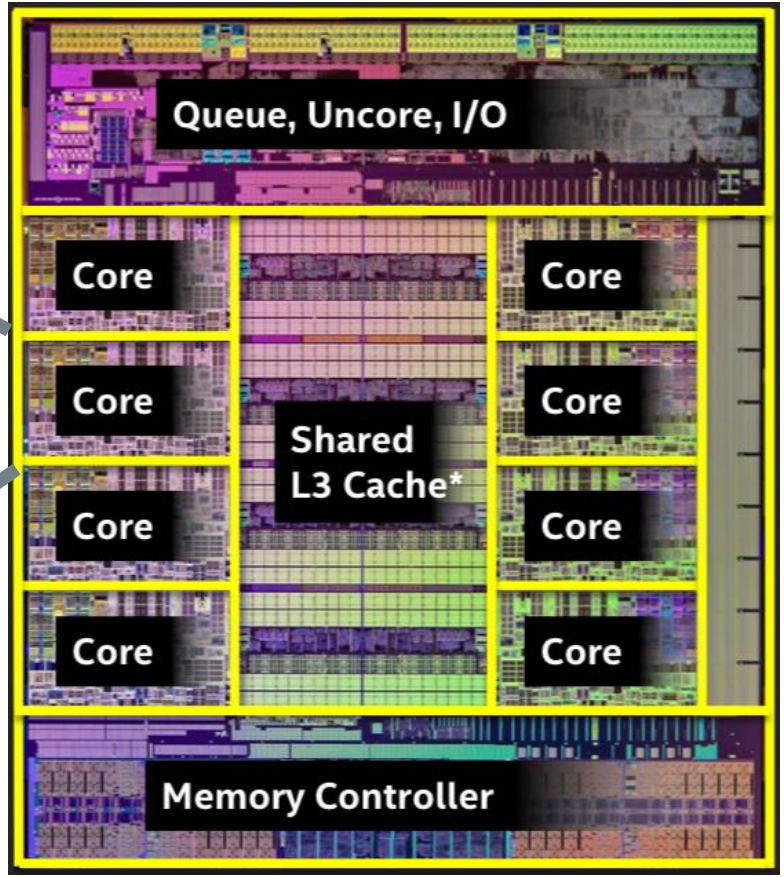
CPU

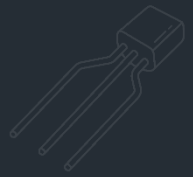


Multicore processing

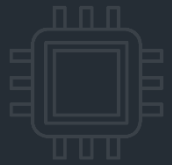
Multicore CPU



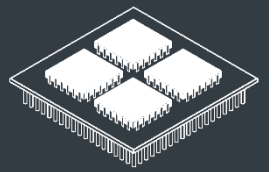




Transistor

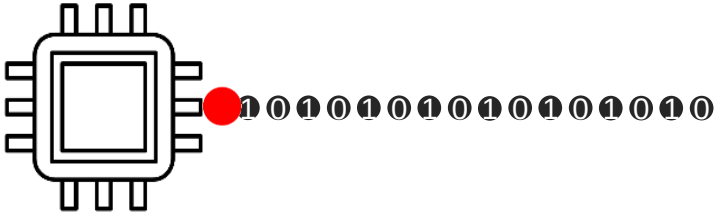


CPU

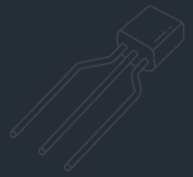


Parallel processing

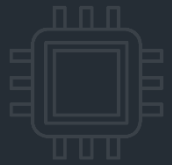
Sequential, parallel processing



Sequential processing
(1 job)



Transistor



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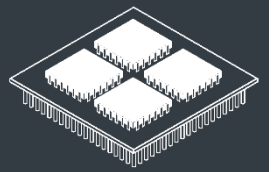
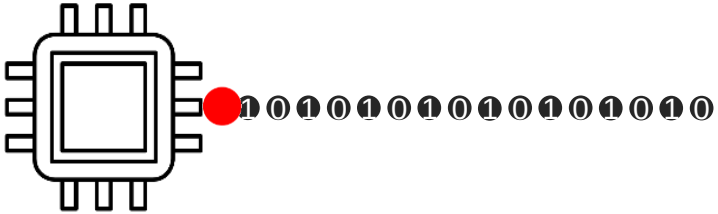
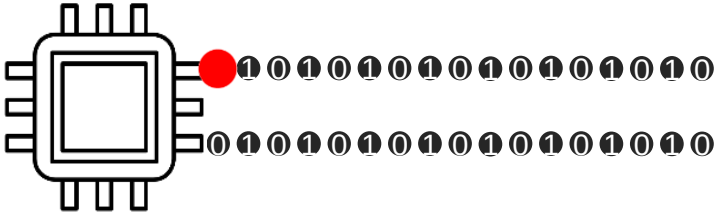


Parallel processing

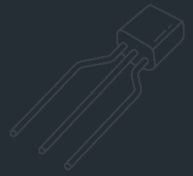
Sequential, parallel processing



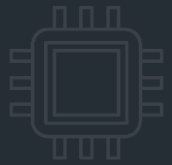
Sequential processing
(1 job)



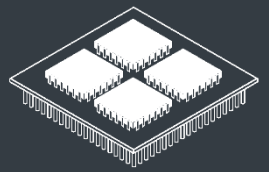
Sequential processing
(2 jobs)



Transistor

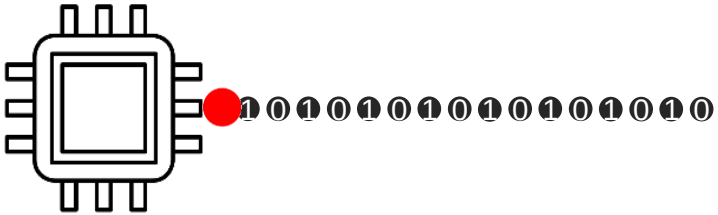


CPU

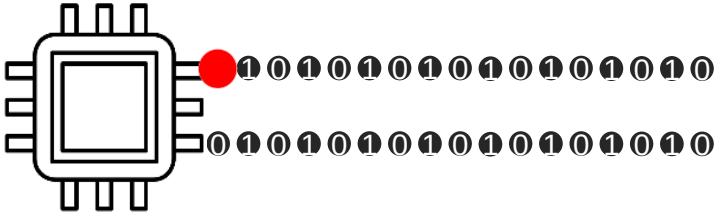


Parallel processing

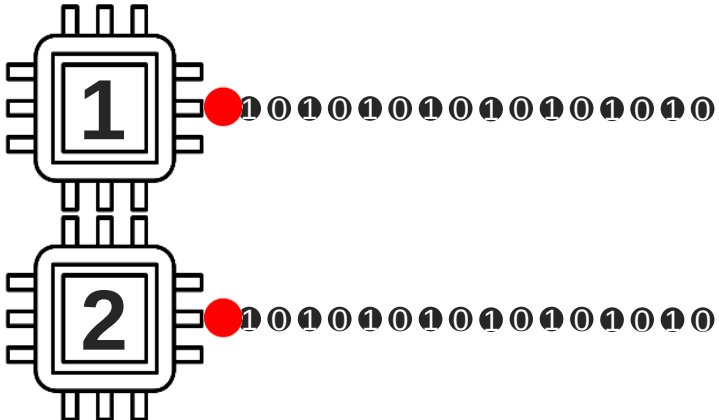
Sequential, parallel processing



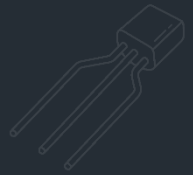
Sequential processing
(1 job)



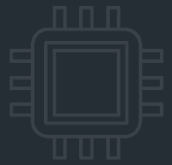
Sequential processing
(2 jobs)



Parallel processing
(2 jobs)



Transistor



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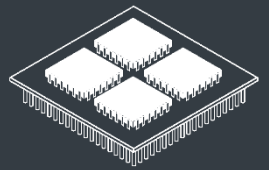
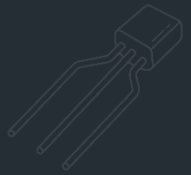


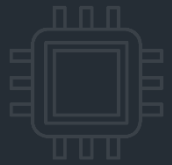
Parallel processing

Issue 1 : Non-parallel task

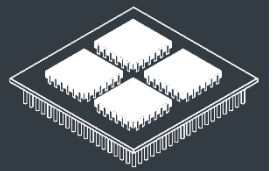
Day 1 Day 2 Day 3 Day 4



Transistor



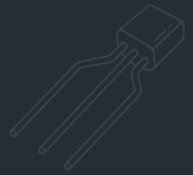
CPU



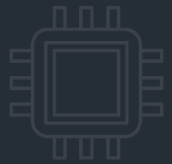
Parallel processing

Issue 2 : Software support

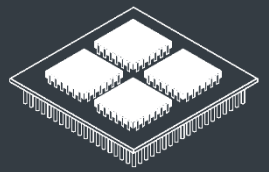
1. Code optimisation.
2. Core co-ordinations.
3. Work sharing amongst cores.



Transistor



CPU

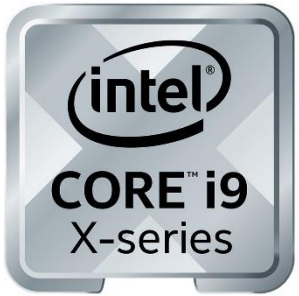


Parallel processing

Issue 3 : Cost

1. More cores = more expensive.
2. Non-scalable performance gain.

10980XE (**18** cores)
£950



10980XE (**14** cores)
£743

10900X (**10** cores)
£580

Questions, feedback

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