Hard and Soft Ware

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Some pics provided by Wikimedia Commons

Agenda

Definitions

Chips and their building blocks

Processors and instructions

Layers of software

Conclusion

Hard and soft ware?

Hardware?

- Physical
- Electronic chips: electricity in, electricity out

Software?

- Programs, frameworks, libraries, files, code, data
- Numbers, bits stored on media and memory
- Voltages inside chips: on and off

Numbers


```
0000000    2123    622f    6e69    622f    7361    0a68    230a    4320
0000010    7268    6d6f    7569    206d    616c    6e75    6863    7265
0000020    0a0a    2023    7541    6874    726f    3a73    230a    2020
0000030    6843    6461    4d20    6c69    656c    2072    633c    6168
0000040    2e64    696d    6c6c    7265    6340    6e61    6e6f    6369
0000050    6c61    632e    6d6f    0a3e    2023    4620    6261    6569
0000060    206e    6154    7373    6e69    3c20    7466    4061    6f73
0000070    6166    6172    6177    2e79    726f    3e67    230a    4c20
0000080    6369    6e65    6573    203a    5047    764c    2032    726f
0000090    6c20    7461    7265    0a0a    2023    7845    6c70    6369
00000a0    7469    796c    7320    7465    7420    6568    5020    5441
00000b0    2048    6f74    7420    6168    2074    666f    4520    564e
00000c0    535f    5055    5441    2048    6e69    2f20    7465    2f63
00000d0    6f6c    6967    2e6e    6564    7366    6120    646e    7520
00000e0    736e    7465    230a    7620    7261    6f69    7375    6f20
00000f0    6874    7265    7620    7261    6169    6c62    7365    202e
0000100    4c28    3a50    2320    3031    3534    3839    2936    202e
0000110    6854    7369    6320    6e61    6220    2065    6572    6f6d
0000120    6576    2064    6e6f    6563    4120    7070    7241    6f6d
0000130    0a72    2023    7573    7070    726f    7374    6520    766e
0000140    7269    6e6f    656d    746e    6620    6c69    6574    6972
0000150    676e    2820    504c    203a    3123    3430    3935    3538
0000160    0a29    7865    6f70    7472    5020    5441    3d48    752f
0000170    7273    6c2f    636f    6c61    732f    6962    3a6e    752f
```

The beginning of the *Chromium* browser on my machine

The transistor
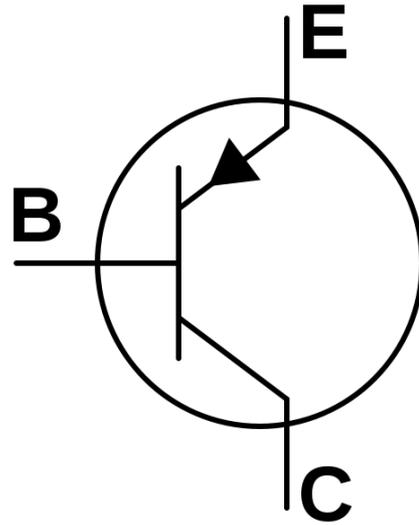
Electronic amplifier or switch, here of the bipolar junction (BJT) type: emitter, base and collector

The transistor
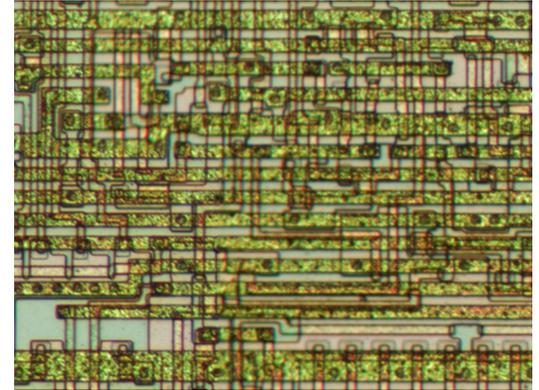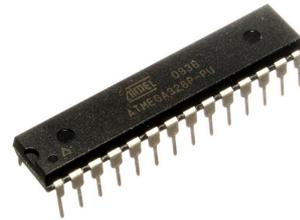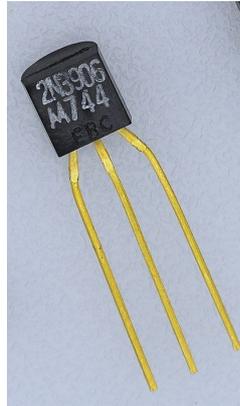
Vacuum tube (1906), single transistor and integrated circuit

The Transistor

Transistors can be combined to form *gates*

Logical operations NOT, AND, OR, XOR, NAND and more

Gates can be combined to achieve higher-level operations

A modern processor contains milliards (billions) of transistors

Let's see a *ripple carry adder*:
https://www.multisim.com/content/r4ardeyWfW4ZzstFt9BjWS/3-bit-ripple-carry-adder/
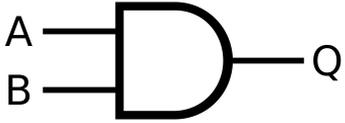
A full processor (CPU)

Combination of different blocks responsible for different kinds of operations:

- Decoding
- Calculations (ALU)
- Branching (CU)
- Input and output
- And more

Let's see a simple(ish) example: 6502 SVG Schematic

Instructions

The CPU executes *instructions*

Numbers that dictate what happens next: add, subtract, compare, jump, read from memory, write to memory, ...

The *instruction decoder* decides where the instruction goes

An instruction may also contain data to be processed with it

Let's see an example of how they are: Online assembler

Different layers

Today's platforms consist of different layers

- Hardware
- Operating system kernel and drivers
- System services
- Libraries and frameworks
  - They too have different levels
- Applications

On old or embedded systems less or effectively no layers

Different layers
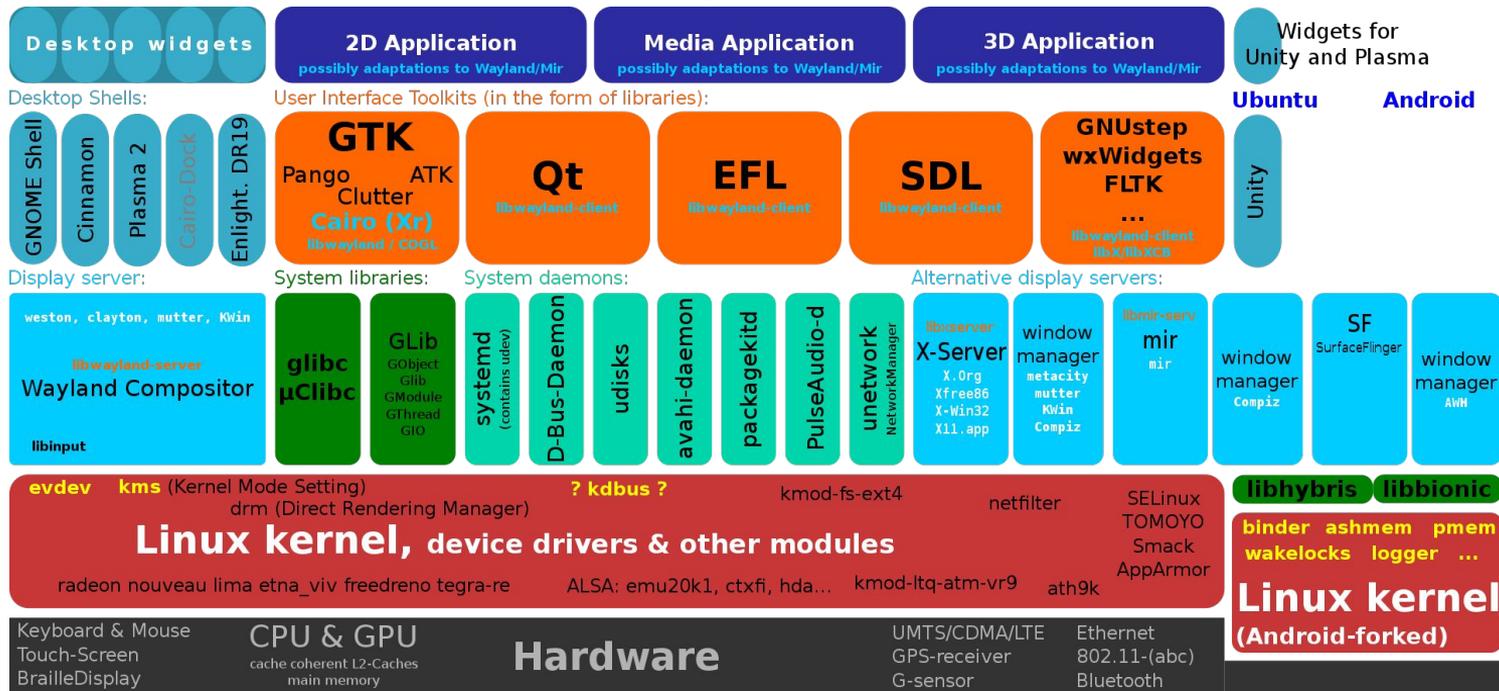
Linux software layers (by Shmuel Csaba Otto Traian, CC)

Gray areas

Usually it's clear which is which, but some technologies blend the border between software and hardware

Emulators and *virtual machines* – software pretending to be hardware

Field-Programmable Gate Arrays (FPGA) – (re)configurable chips

Microcode – very low-level instructions describing how normal instructions are processed, can be modified

Conclusion

Stuff to remember:

- Software is numbers – instructions – executed by a processor
  - At the end of the day, voltages on and off
- Transistors are the basic building blocks of computers
  - Combined into higher-level blocks
  - A CPU consists of multiple such blocks
- The layered software model