What is computer hardware?

1 PC Internals

Motherboard:

- CPU Socket
- RAM Slots (Memory, temporary storage)
- Northbridge Chipset - Communication between fast components (CPU, Graphics, RAM)
- Southbridge Chipset - Communication between slow components (USB, audio, soundcards)
- CPU - Pins on bottom transfer voltage and so information
- SATA Connectors - Storage
- PCI Slots - Expansion (GPU etc)
- ATX Power Connector
- CPU Power Connector

There have been some changes over the years but nothing really significant

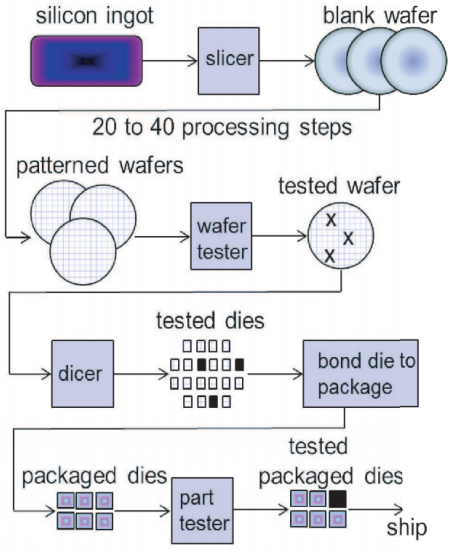
Communication within the CPU is undertaken using a variety of buses

2 Silicon Chips

A silicon chip/CPU/Processor is an integrated circuit

- Millions (Modern Billions) of transistors interconnected by microscopic wires within 1 cm^2 footprint
- Transistors building blocks of circuits

Initially hundreds of copies of the same IC are etched on a wafer of silicon, each called a die
Dies are tested and each error-free die is cut and mounted in a package with the die's pads connected to the package pins. High error rate which is the reason for the high cost of chips.



Multi core processor:

- Multiple independent cores are manufactured on the same IC
- They have billions of transistors

Higher core count processors are designed for more specific operations

3 Moore's law

"Transistor capacity doubles every 18-24 months" - new law based on transistor density
Debate as to how long this will keep going as things get smaller and smaller
Problems of more transistors:

- Power dissipation from higher number of transistors
- Size of a silicon atom

Power $\propto$ Number of transistors switched $\times$ frequency of switching

4 Transistors

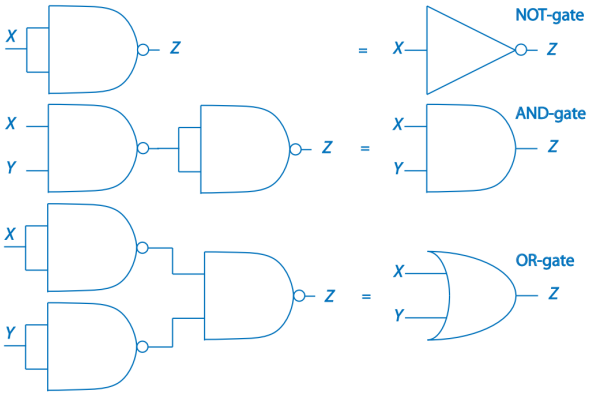
A transistor is a semiconductor device used to amplify and switch electronic signals

5 Gates

We use transistors to build gates with take binary inputs of 0 and 1
Three fundamental gates **Remember to later add the circuits for this**

- NOT - Inverse output and input
- AND - Output only 1 if both inputs are 1
- OR - Output 1 if one or both inputs are 1

NAND gate is a combined AND and NOT - can make any of 3 fundamental gates using NAND gates
So a silicon chip is a massively complex system of gates and wires connecting them
See below for how NAND gates can be used to create the 3 fundamental logic gates



6 A binary world

If we are given any function $f(X_1, X_2, X_3 ... X_N) : 0, 1^n \rightarrow 0, 1$ then using AND, OR and NOT gates we can build a circuit that computes f
For example we can build a circuit that takes two binary inputs and outputs the addition of these two numbers

X_3	X_2	X_1		0	1	1
Y_3	Y_2	Y_1		1	1	0
Z_4	Z_3	Z_2	Z_1	1	0	0	1

Half adder diagram

Delay in half adder from out of the not gate. May cause timing errors.

Half adders can be combined to have more inputs, creating a full adder, the carrys connect.

Full adders can then be connected together to give as many inputs as needed.

Ripple adder has a cascade of full adders, need to wait for carrys from previous sum.

7 Integrated Circuit Design not on test

8 Micro architecture

8.1 Pentium 4

Insert diagram from slides

Datapath - Performs the data processing operations

- Includes the ALU
- A small amount of memory in the form of **registers**

Control - Tells the datapath, memory and I/O devices what to do
Cache - Small, fast, relatively expensive on chip memory

8.2 von Neumann architecture

The von Neumann arhcitecture is a fundamental computer architecture.

- Stored program and data both held in memory
- Allows for self modifying programs as the processor has access to memory

The von Neumann bottleneck is the limitation of the data transfer rate between the CPU and memory. This resulted in the use of CPU caches on chip to reduce this bottleneck.

Harvard Architecture - Data memory and instruction memory and separated, each with their own buses.

8.3 Memory

Closer it is to the CPU, the faster, but more expensive.
Memory - Pigeon holes containing data.

Each pigeon hole has a unique address and holds 1 byte of storage.

64 bit processors have a "word length" of 64 bits, and so can retrieve 64 bits at a time

3 different buses:

- Address Bus
  - Determines location in memory
  - Width determines size of addressable memory (e.g. 4gb ram limit for 32 bit)
- Data Bus
  - Carries Contents of memory
  - Width determines bus size

Comparison of different types of memory:

- Hard Disk - cheap to produce but slow. Permanent, so no data loss
- RAM
  - dynamic RAM (DRAM) - data stored by transistor/capacitor, slow
- Cache - expensive used to store rapidly accessed data items

9 Putting it all together

Register - On chip memory locations (limited in number according to a hardware design decision) and are at the top of the memory heirarchy
Accumulator - Register that acts as a calculator **Program counter** - Holds the address where the next instruction is found **More from slides**

1. CPU outputs the value of program counter on address bus
2.
3. Finds what instruction wants us to do
4. What data does it want to operate on
5. Look for data in memory over data bus - find what inputs needed
6. Execute the operation on the ALU
7. Answer stored in accumulator
8. Program counter updated
9. (Optional) Write the data back into memory