Course Overview

Computer Organization

TÉCNICO LISBOA

The Computer Revolution

- Progress in computer technology
  - Reinforced by Moore's Law
- Makes novel applications feasible
  - Computers in automobiles
  - Cell phones
  - Human genome project
  - World Wide Web
  - Search Engines
- Computers are pervasive

Classes of Computers

- Desktop
  - single user, general purpose, with a typical set up of display, keyboard, and mouse

    Critical: cost, performance

Desktop Computer

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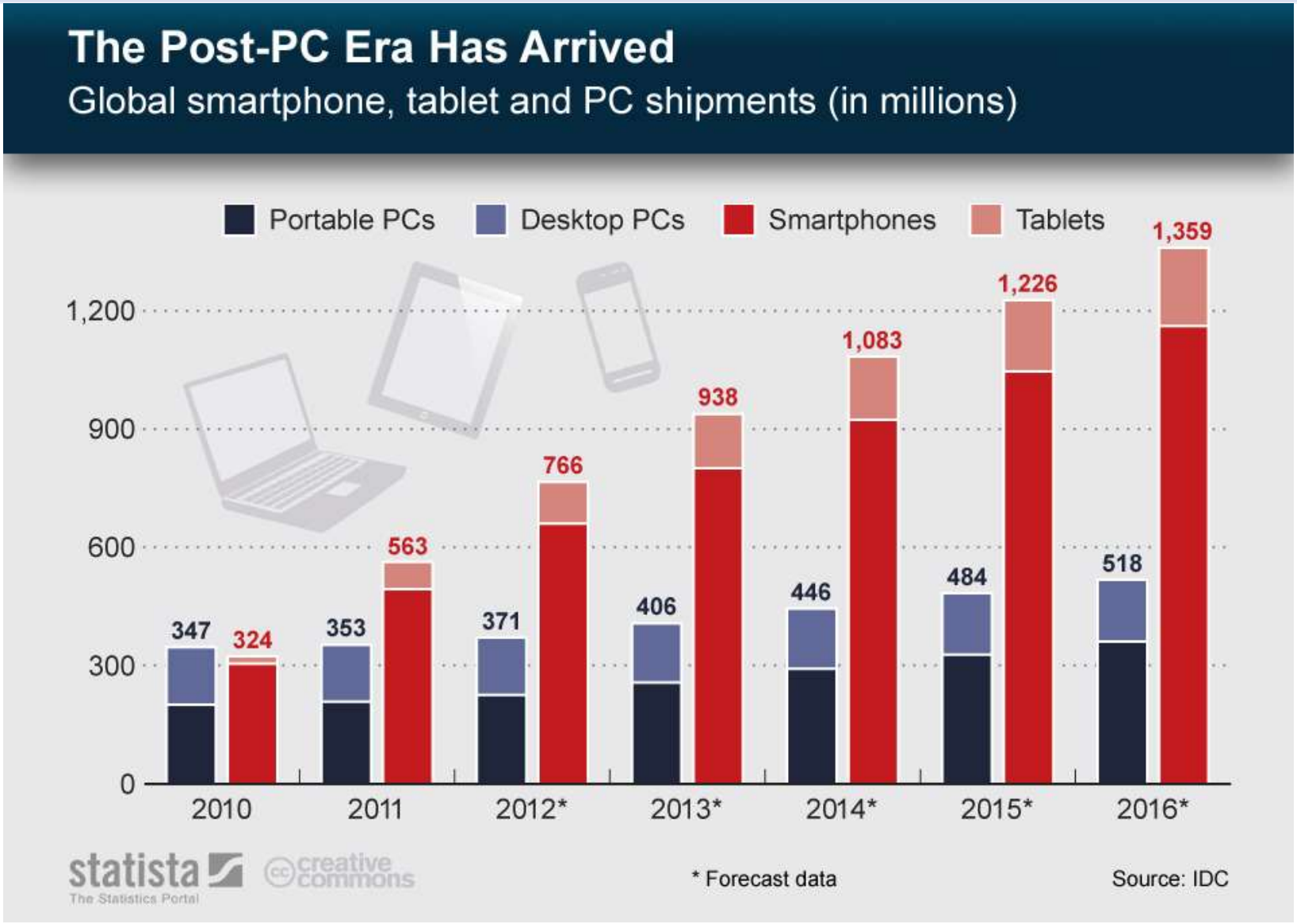
- Personal Mobile Device (PMD)
  - single user, general purpose, small-size touchscreen

    Critical: power, cost

The Post-PC Era



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- Servers
  - run larger programs in parallel for multiple users, typically accessed remotely

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Server

Server

Rack

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  - clusters with hundreds to thousands of processors, terabytes of memory and petabytes of storage

    Critical: performance, capacity, expandability

Supercomputer

Frontier,
Oak Ridge National Laboratory and the USA Department of Energy @ Tennessee, United States

Currently the world's most powerful supercomputer with 606,208 cores
9,472 AMD Epyc 7A53s each with 64 core @ 2 GHz and 37,888 Radeon GPUs
with a peak performance of **1.685 exaFLOPS** power consumption of **21 MW**
the current lowest power supercomputer with **62.68 gigaflops/watt**

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  - hidden component of a system, running a predefined program
    Critical: cost, power, performance

Embedded Computers

Over 99% of processor sales are for embedded systems!

Issues in Embedded Systems

Specific issues when programming embedded systems:

- Real-time requirements
  - Often worst-case is more important than average-case
- Resource constraints
  - Power and memory
- Reliability
  - Safety critical systems
  - Difficult access
- Diversity
  - Heterogeneity of computing architectures
  - Diverse set of input/output devices

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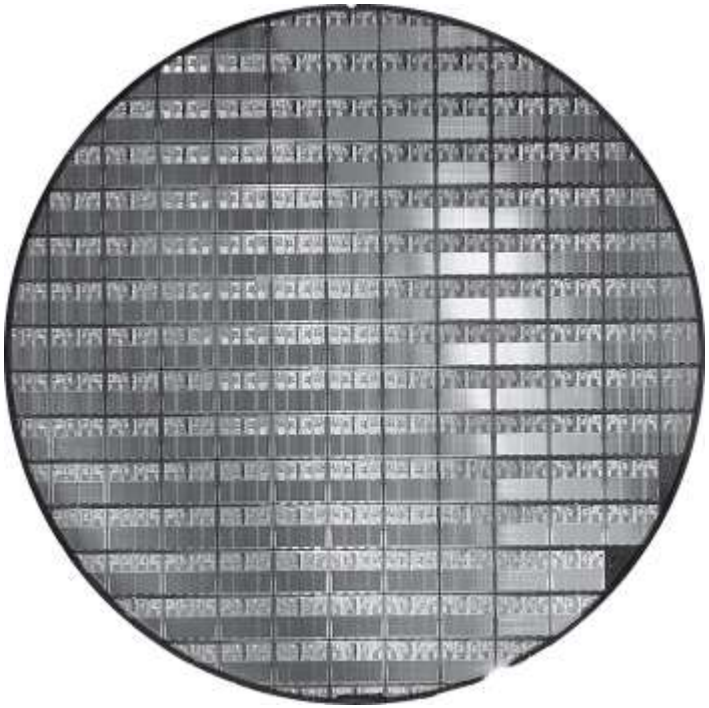
Technology Trends

- The transistor density increases about 35% per year.
- The circuits area increases about 10% to 20% per year.
- The number of transistors per circuit increases about 55% per year.

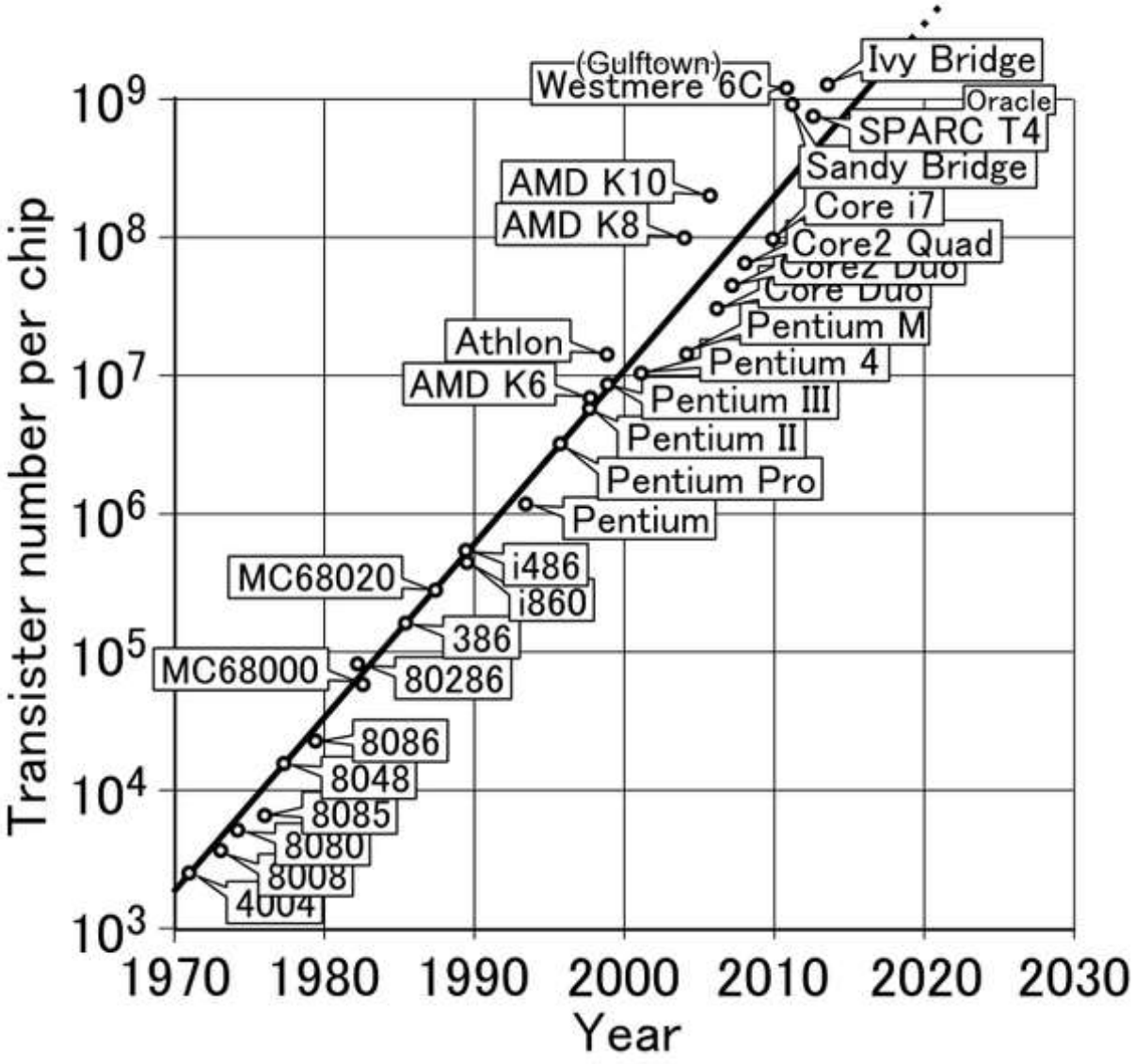


Moore's Law (1965):

"The number of transistors per square-centimeter of integrated circuit doubles every 18 months."

- In practice, the density increased about 1,000,000x in the last 45 years!

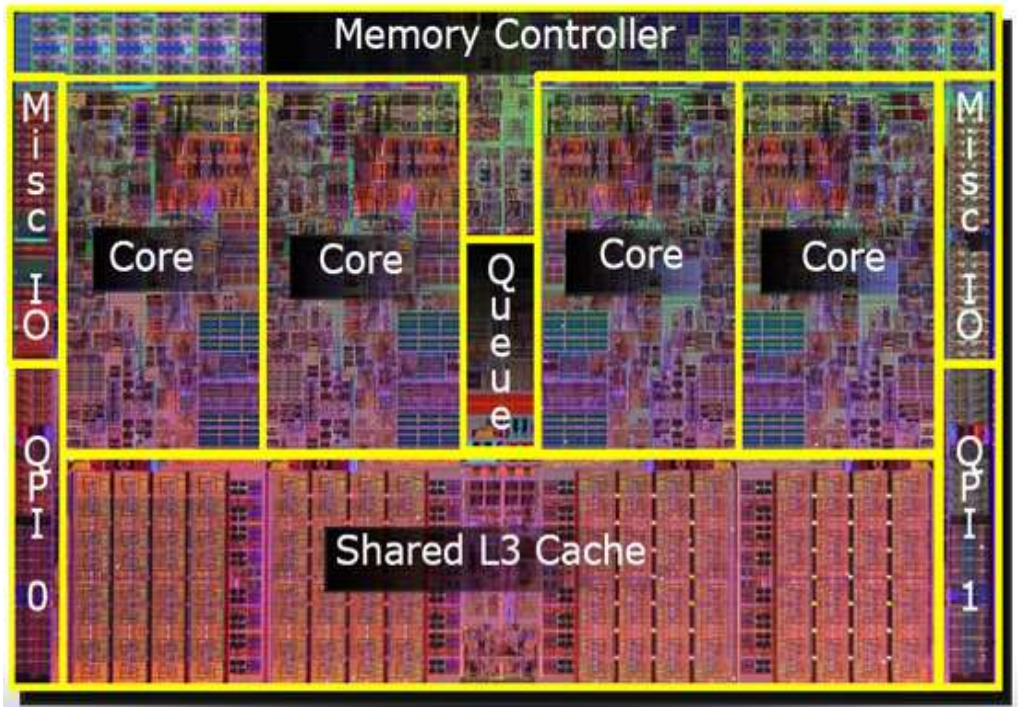
Moore's Law in Practice



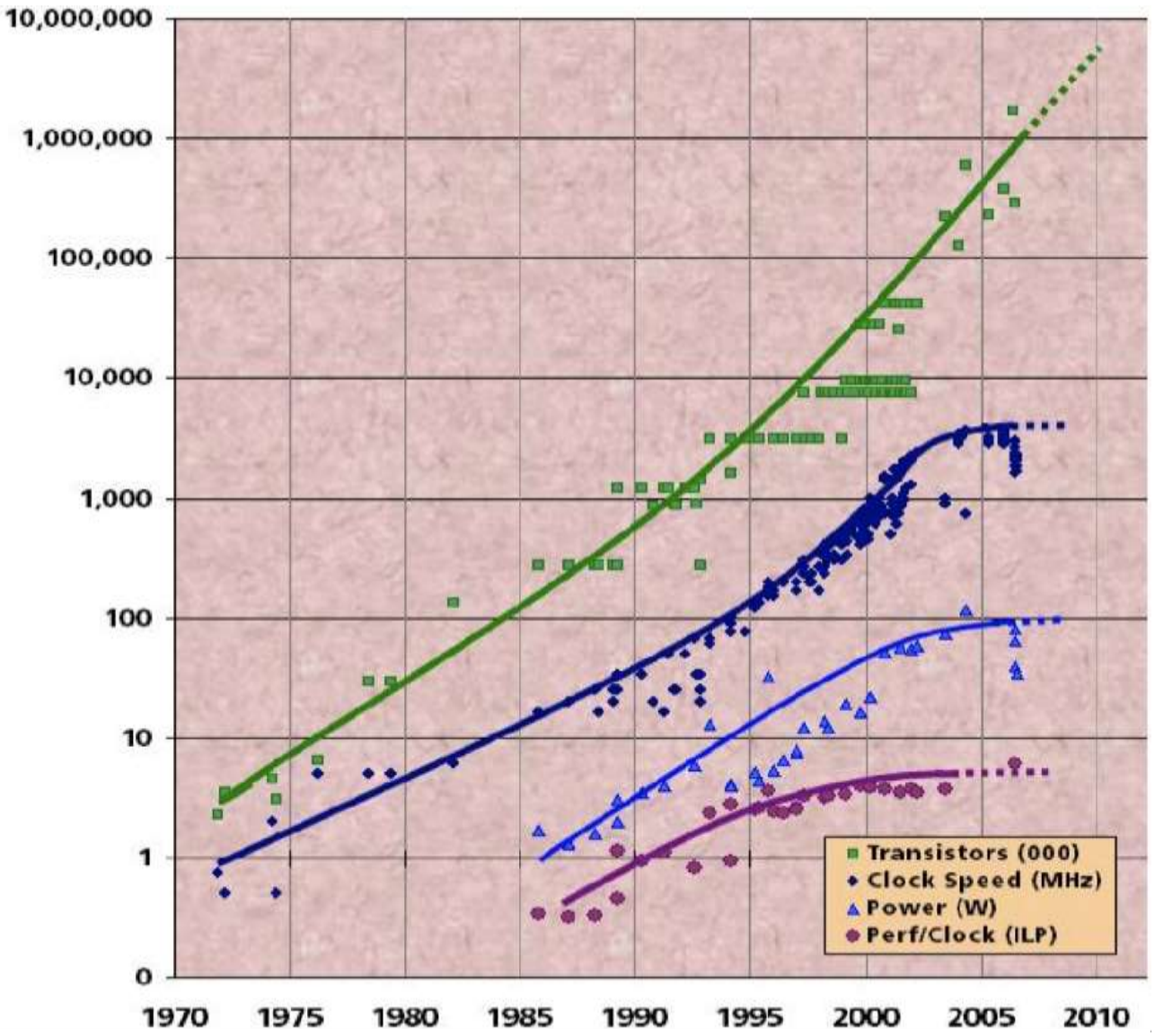
Inside the Processor

Intel Core i7:

4 processor cores, 1.3×10^9 transistors



Technology Trends

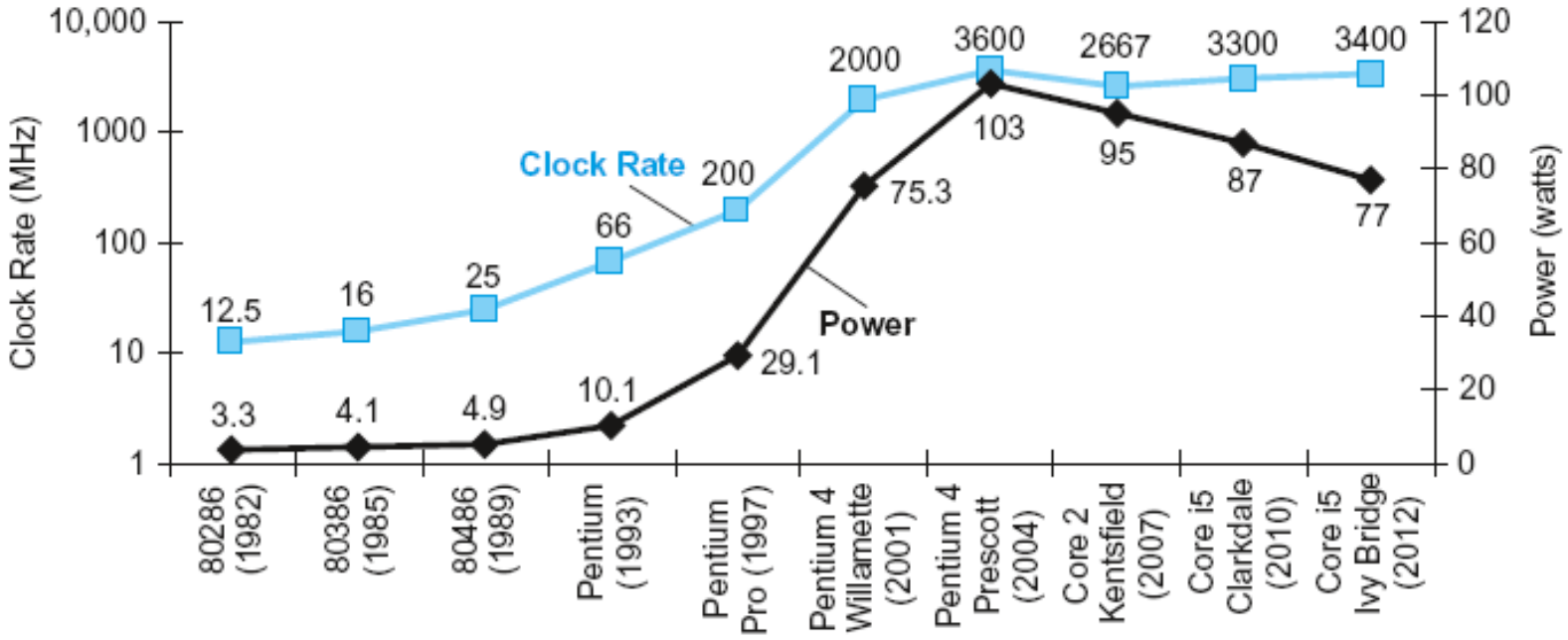


Power Trends

In CMOS IC technology

$$\text{Power} = \text{Capacitive load} \times \text{Voltage}^2 \times \text{Frequency}$$

×30 | 5V → 1V | ×1000



The power wall!

Multiprocessors

The power wall:

- can't reduce voltage further
- can't remove more heat

How else can we improve performance?

➥ Multicore microprocessors

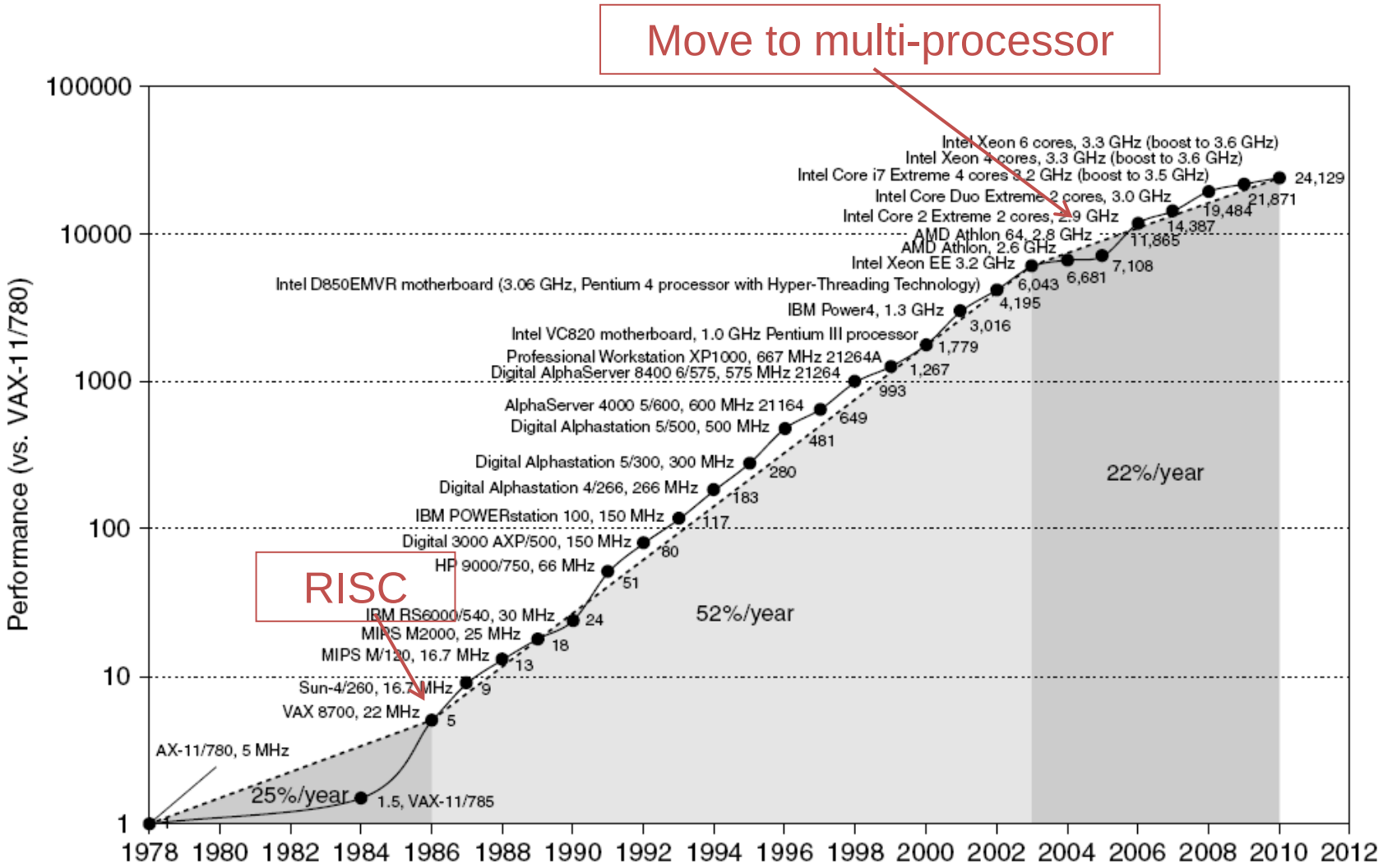
- More than one processor per chip

New paradigm!

Requires explicitly parallel programming:

- Compare with instruction level parallelism
  - Hardware executes multiple instructions at once
  - Hidden from the programmer
- Hard to do
  - Programming for performance
  - Load balancing
  - Optimizing communication and synchronization

Processor Performance



Check@home: Trends in Technology

- Integrated circuit technology
  - Transistor density: 35%/year
  - Die size: 10-20%/year
  - Integration overall: 40-55%/year
- DRAM capacity: 25-40%/year (slowing)
- Flash capacity: 50-60%/year
  - 15-20X cheaper/bit than DRAM
- Magnetic disk technology: 40%/year
  - 15-25X cheaper/bit then Flash
  - 300-500X cheaper/bit than DRAM

Check@home: Bandwidth and Latency

- Bandwidth or throughput
  - Total work done in a given time
  - 10,000-25,000X improvement for processors
  - 300-1200X improvement for memory and disks
- Latency or response time
  - Time between start and completion of an event
  - 30-80X improvement for processors
  - 6-8X improvement for memory and disks

What You Will Learn

- Architecture of current processors
  - **Performance metrics**
- Integrated view of the computer system
  - Memory hierarchy
  - Input/Output system
- **How to improve program performance**
- **What is parallel processing**
- **What are embedded systems**
- Future trends

Teaching Staff

Senior Lecturer:

Taguspark → Alberto Cunha,
alberto.cunha@tecnico.ulisboa.pt
Subject: [OC] …

All relevant information published on **Fénix**.

Check it frequently (daily).

Grade assessment

- Final grade = 70%.max{[max (MAP45_a, Ex_a)
  + max(MAP45_b, Ex_b)]/2, EE} + 30%.L

- MAP1+MAP2 or Recov. Exam , Min. grade = 7.5
- Labs = (L1 + L2 + L3) , Min. grade = 8

MAP (45 min test):

- mini-Test […, memory]: September 25 @ 18:00 (week 3)
- mini-Test]memory, …] : October 16 @ 18:00 (week 6)

Recov. Exam:

- Recovery Exam: November 7 @ 15:30 (week 9)
  - Two part recovery (MAP_a and/or MAP_b]memory, end])
- **No** 2nd exam (“época de recurso”)

Grade assessment

Labs (30%)

- 3 labs
- groups of 3 elements, from the same registration slot
- lab grade defined individually at the oral discussions
- can be reused - grade from labs submitted in the last 2 years (from 2022/2023)
- Report / Code to be submitted at the beginning of the demo class

- **Important dates (weeks):**
  - **Publication Lab1 (cache simulator) : week 1**
  - **Publication Lab2 (cache profiling) : week 2**
  - **Delivery & Demo of Lab 1 : week 3**
  - **Publication Lab3 (pileline) : week 3**
  - **Delivery & demo of Lab 2 : week5**
  - **Delivery & demo of Lab 3 : week 6**
  - **Oral evaluation : week 7 (- 8)**

Grade assessment

Labs 1

- Cache simulator to be written in C code
- Basic simulator and tests are provided
- To submit:
  - 2 page report describing what you did
  - Code (with comments)
  - Results (given the provided Memory times)

Labs 2 and 3

- Guided work
  - PAPI
  - WinMIPS
- To submit:
  - Report pages with results

Bibliography

Main book:

Computer Organization and Design: The Hardware/Software Interface
D. Patterson, J. Hennessy
Morgan Kaufmann, 5th Edition, 2014, ISBN: 978-0-12-407726-3

Secondary Bibliography:

- *Structured Computer Organization*
  A. Tanenbaum, T. Austin
  Prentice-Hall, 6th Edition, 2013, ISBN: 978-0273769248

- *Embedded Computing: A VLIW Approach to Architecture, Compilers and Tools*
  J. Fisher, P. Faraboschi, C. Young
  Morgan Kaufmann, 4th Edition, 2005, ISBN: 978-1558607668

- *Computer Architecture: A Quantitative Approach*
  J. Hennessy, D. Patterson
  Morgan Kaufmann, 5th Edition, 2011, ISBN: 978-0123838728

Next Class

- Review of basic concepts on computer architecture
- Performance metrics

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