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

Output device

Network cable

Input device

Input device

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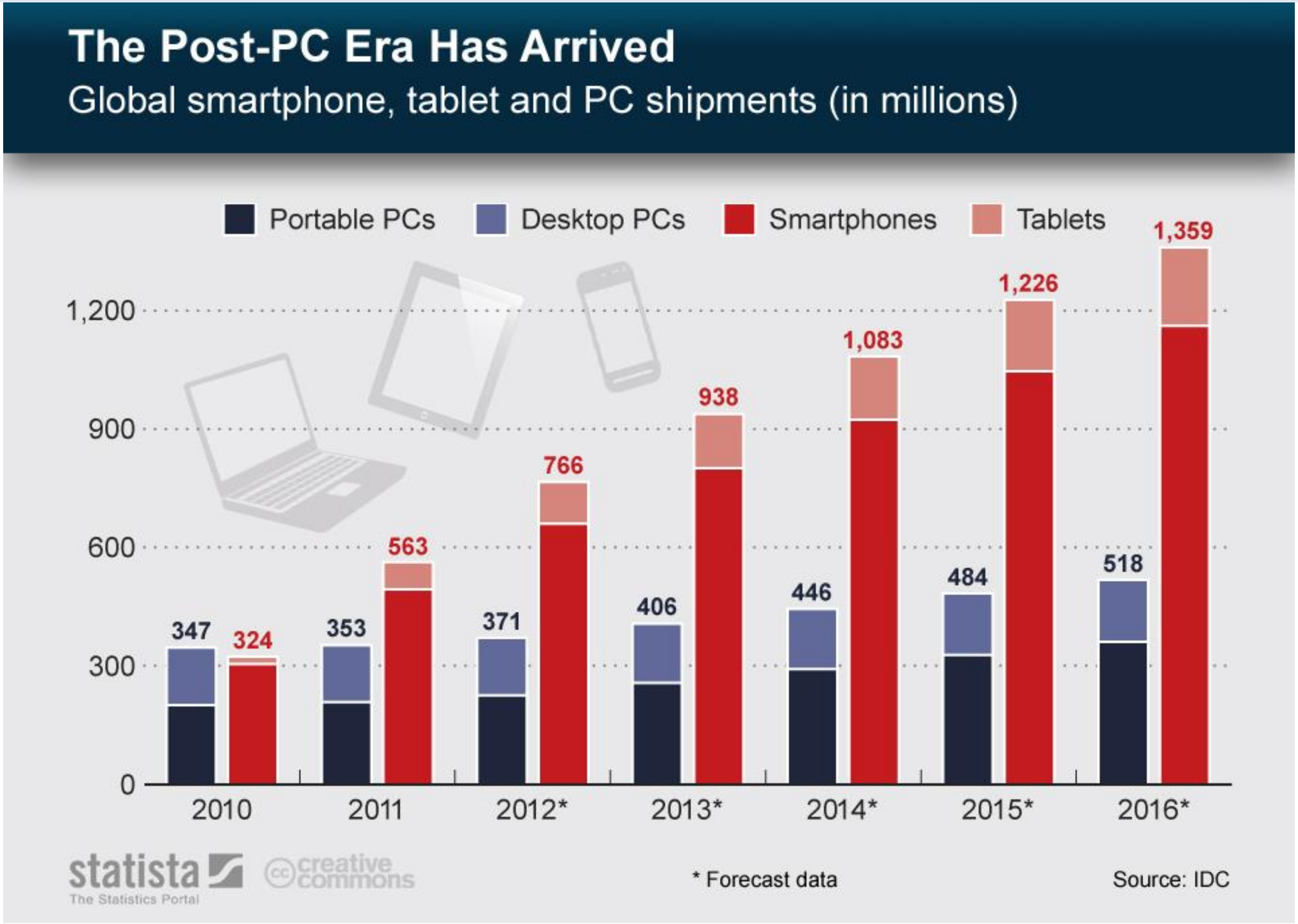
- Personal Mobile Device (PMD)
  - single user, general purpose, small-size touchscreen

    Critical: power, cost

The Post-PC Era



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

    Critical: performance, capacity, security, reliability

Server

Server

Rack

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- Supercomputers
  - 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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- Embedded
  - hidden component of a system, running a predefined program

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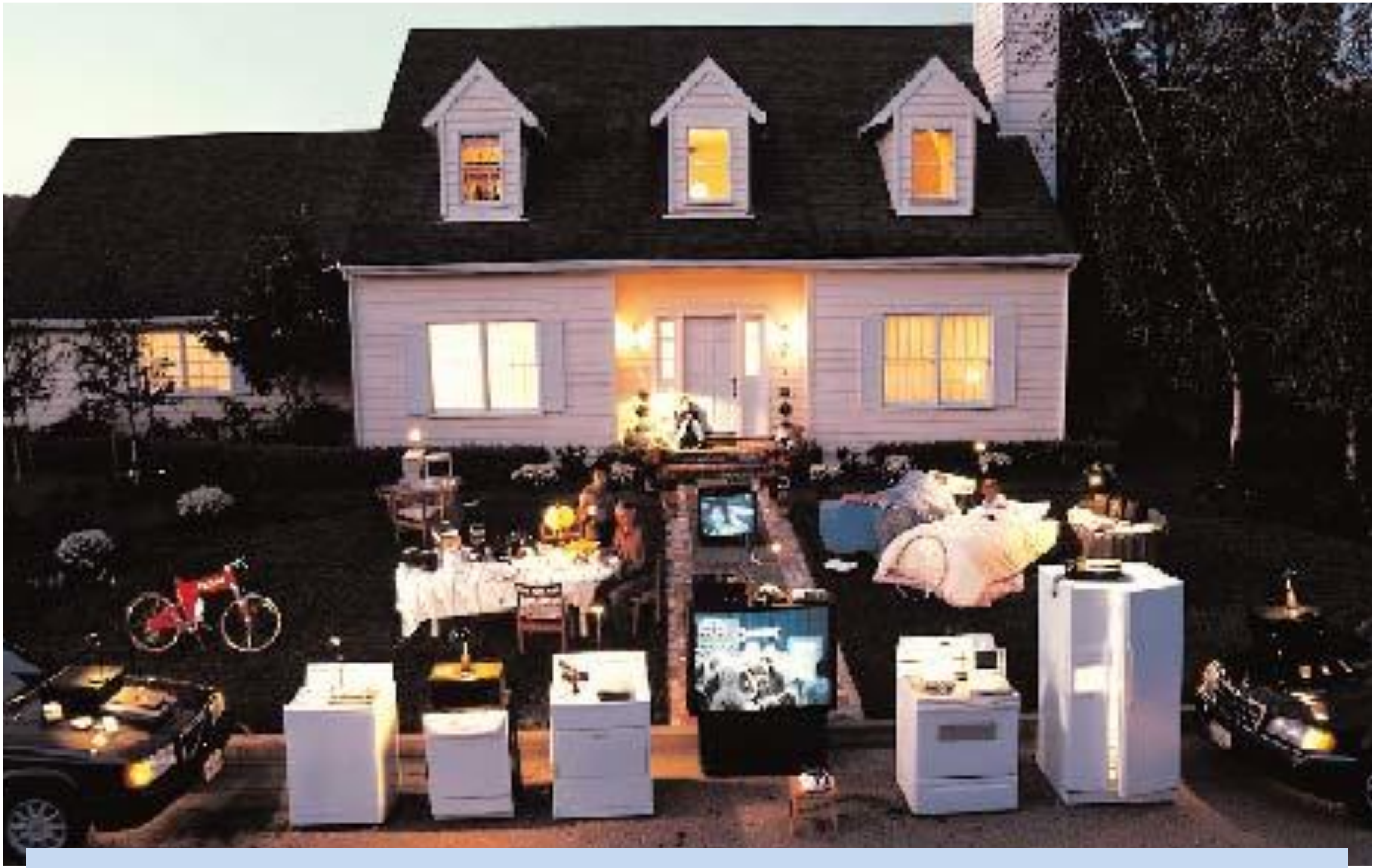
Embedded Computers



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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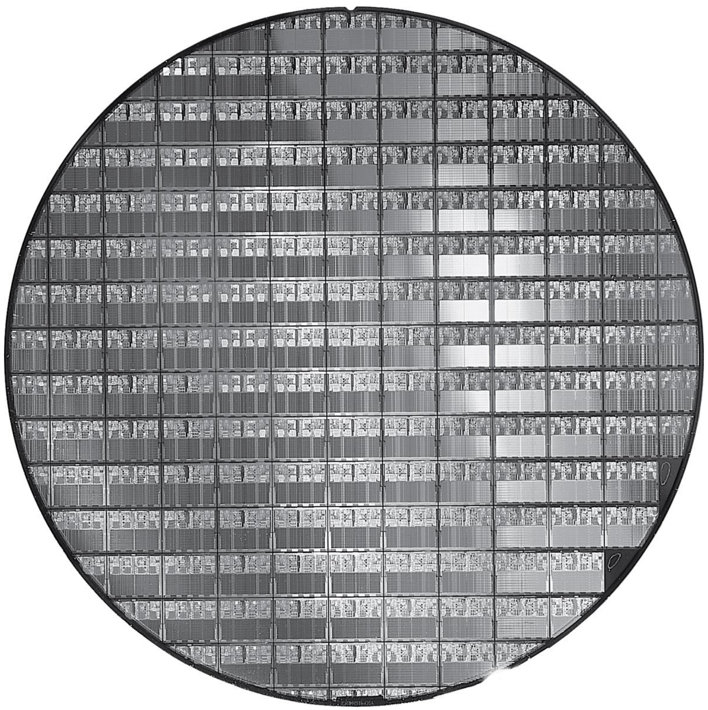
Technology Trends

- 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.

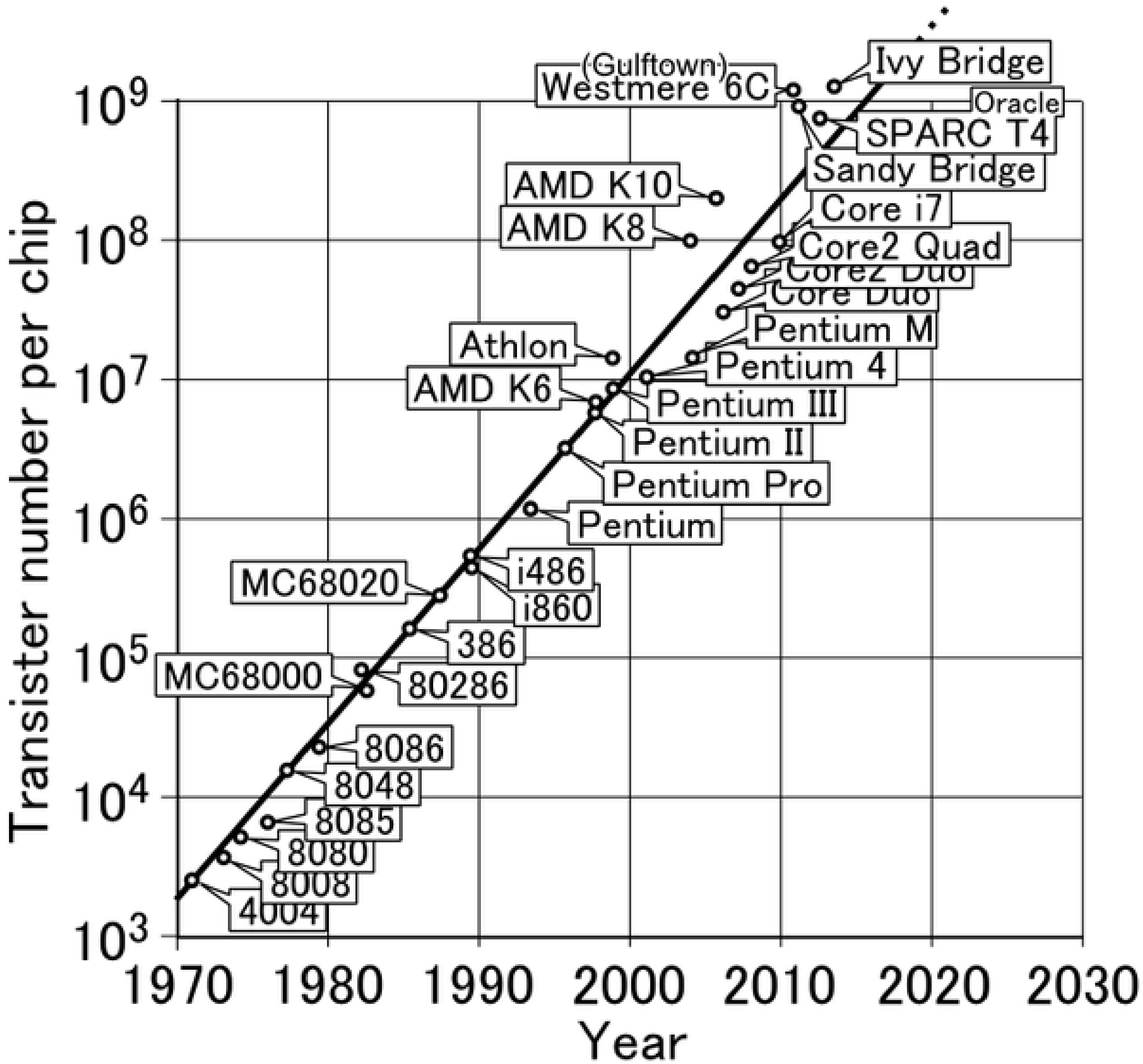


Moore's Law (1965):

"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!

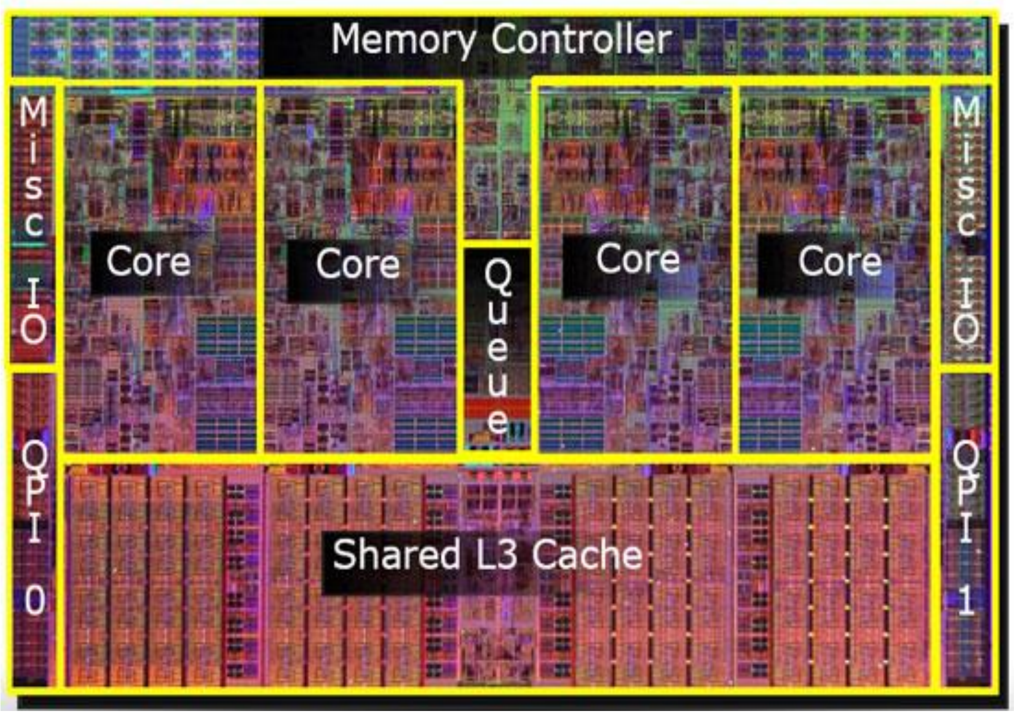
Moore's Law in Practice



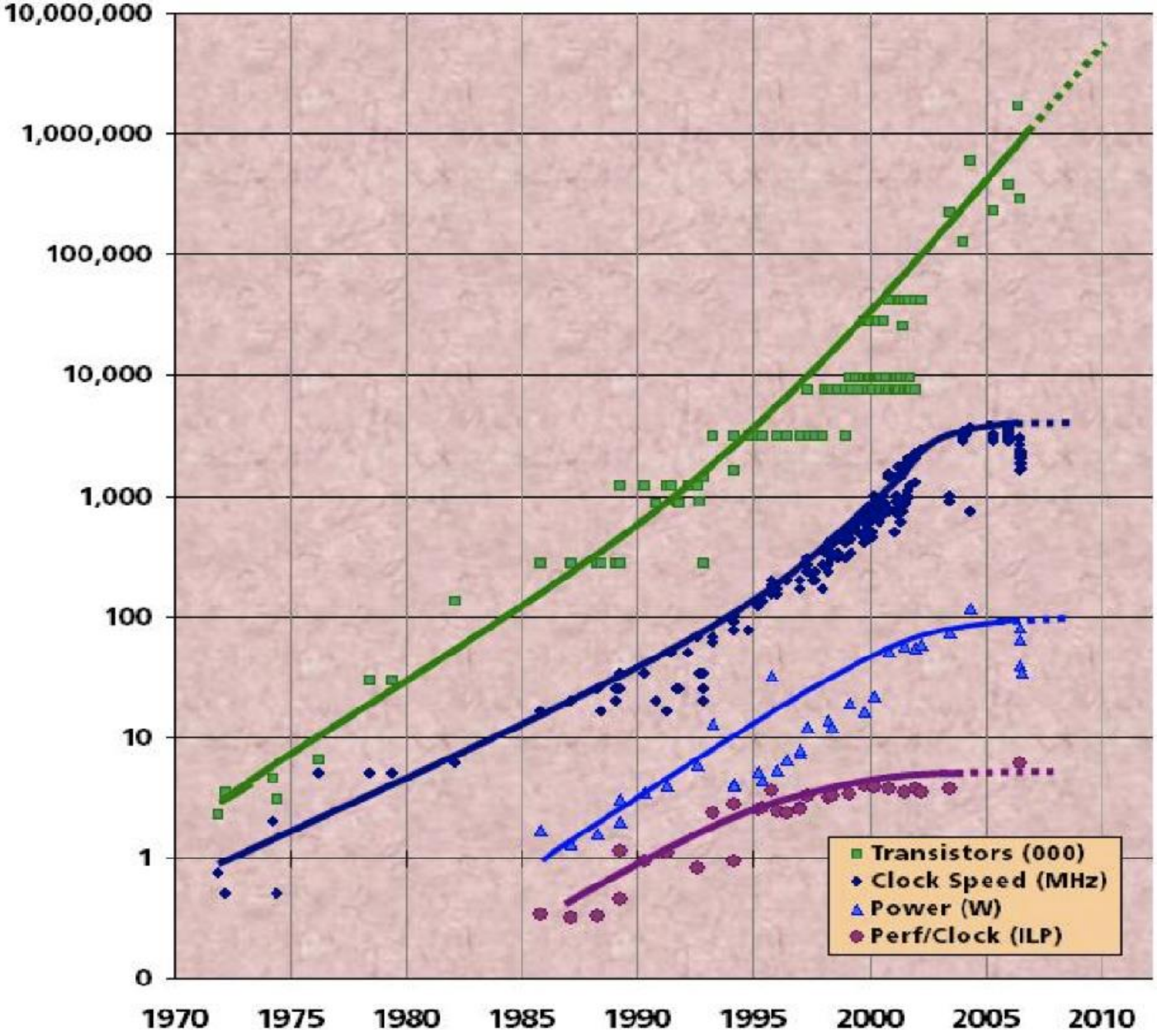
Inside the Processor

Intel Core i7:

- 4 processor cores, 1.3×10^9 transistors



Technology Trends



Power Trends

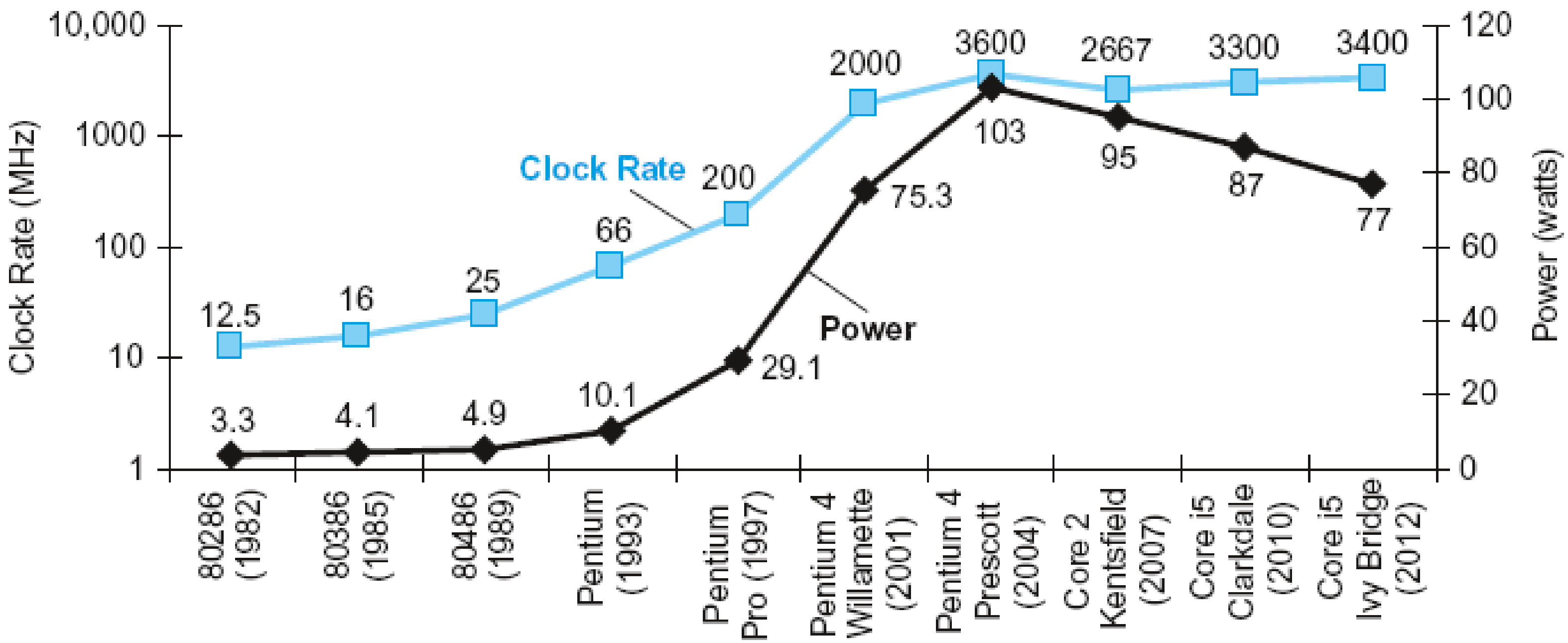
In CMOS IC technology

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

×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?

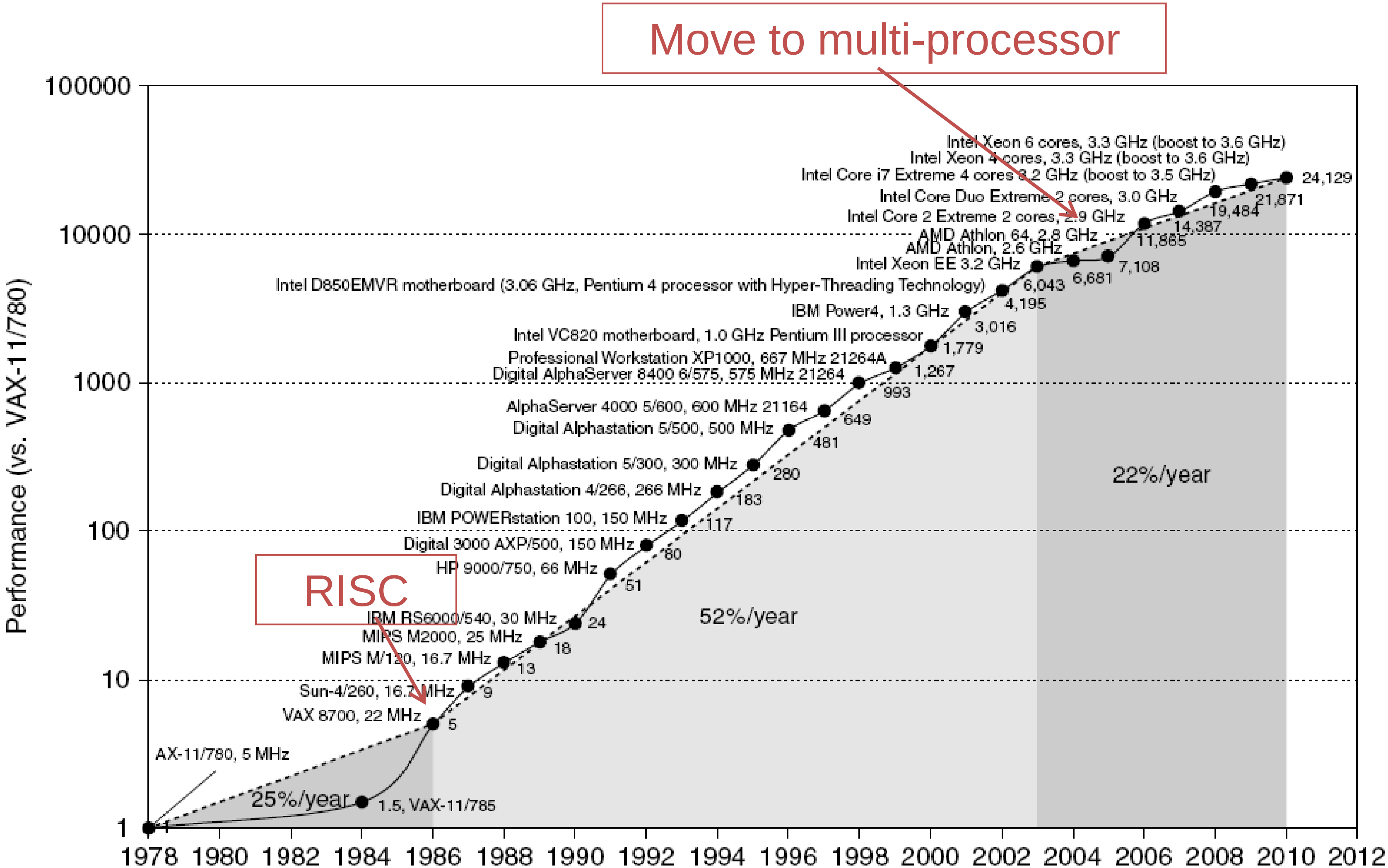
➥ Multicore microprocessors
- More than one processor per chip

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
- Features related to embedded systems
- What is parallel processing
- Future trends

Teaching Staff

Senior Lecturers:

Alameda → Ricardo Chaves @INESC-ID

Taguspark → Alberto Cunha

All relevant information published on **Fénix**.

Check it frequently.

Couse email:

Alameda → oc-a-leic@tecnico.ulisboa.pt Sub:[OC] …

Taguspark → oc-t-leic@tecnico.ulisboa.pt Sub:[OC] …

Teaching Staff

Teaching assistants:

- Diogo Cardoso
- Afonso Fernandes
- Inês Pissarra
- Catarina Bento
- David Valente
- Diogo Dinis
- Hugo Mantinhas
- Vasco Correia
- Guilherme Baracho

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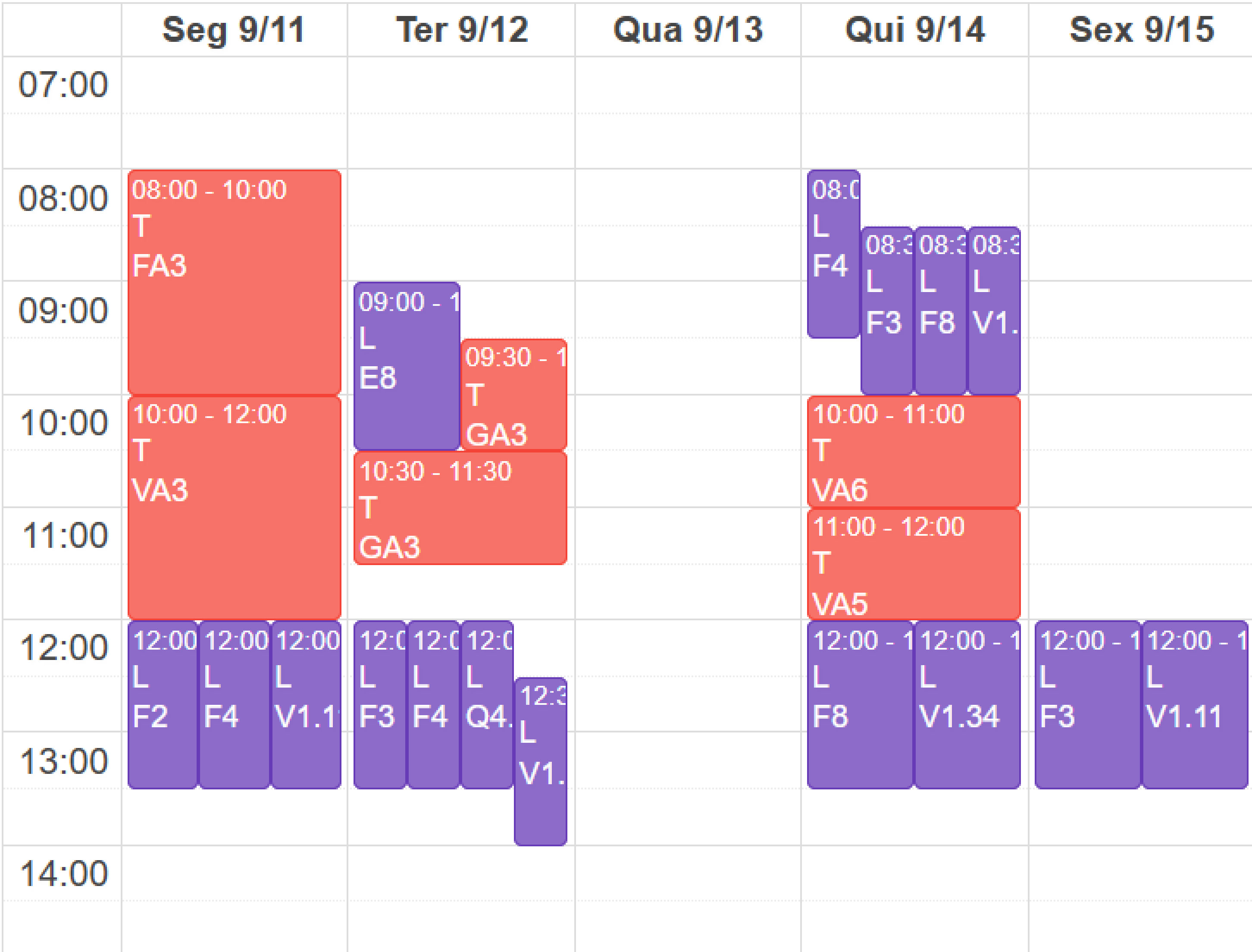
Class Schedule



Grade assessment

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

- MAP1+2 or Recov. Exam , Min. grade = 7.5
- Labs = (L1 + L2 + L3) , Min. grade = 8

MAP (45 min test):

– mini-Test: October 6 @ 18:00
– mini-Test: October 25 @ 18:00

Recov. Exam:

– Recov. Exam: November 9 @ 15:30
  - Two part recovery (MAP_a and/or MAP_b)

Grade assessment

Labs (30%)

- 2 + 1 labs, 15% + 15%
- 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 (2021/2022)
- Report / Code to be submitted at the beginning on the second practical class of the respective week.

- **Important dates (weeks):**
  - **Publication Lab1 : Sep 11 week**
  - **Publication Lab2 : Sep 18 week**
  - **Delivery & Demo of Lab 1 : Sep 25 week**
  - **Publication Lab3 : Sep 25 week**
  - **Delivery of Lab 2 : Oct 9 week**
  - **Delivery of Lab 3 : Oct 16 week**
  - **Oral evaluation : Oct 23 and Oct 30 Weeks**

Grade assessment

Labs 1 and 3 (15%)

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

Labs 2 (15%)

- 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)

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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