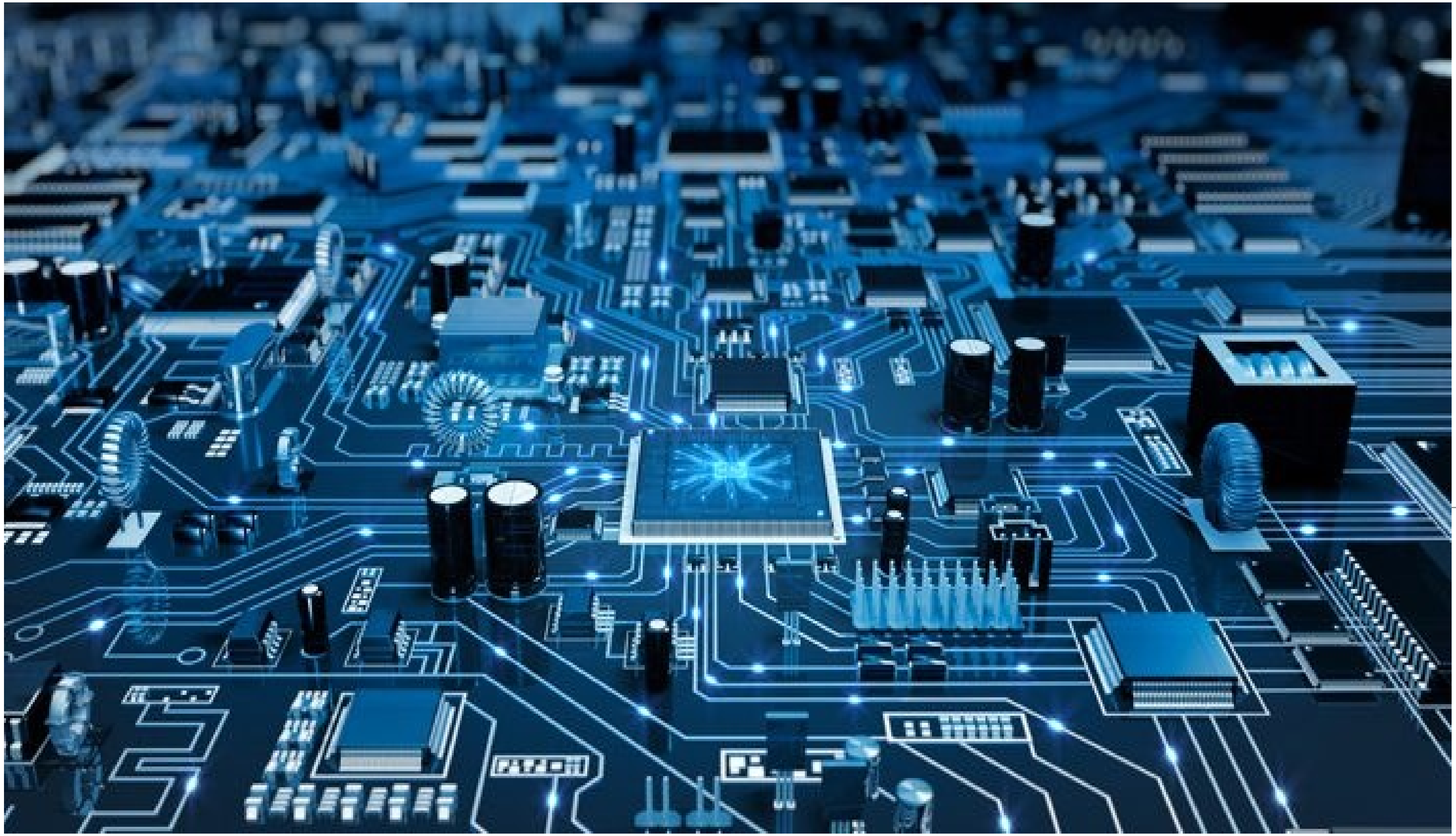
Introduction to Embedded Systems



Yogesh M Iggalore

Agenda

Embedded systems - Overview

Embedded is everywhere

Embedded Systems – Architecture, segments & roles

Moore's Law – Transistor trend

Embedded Systems Market - Career & Opportunities

Some more insight to Embedded systems

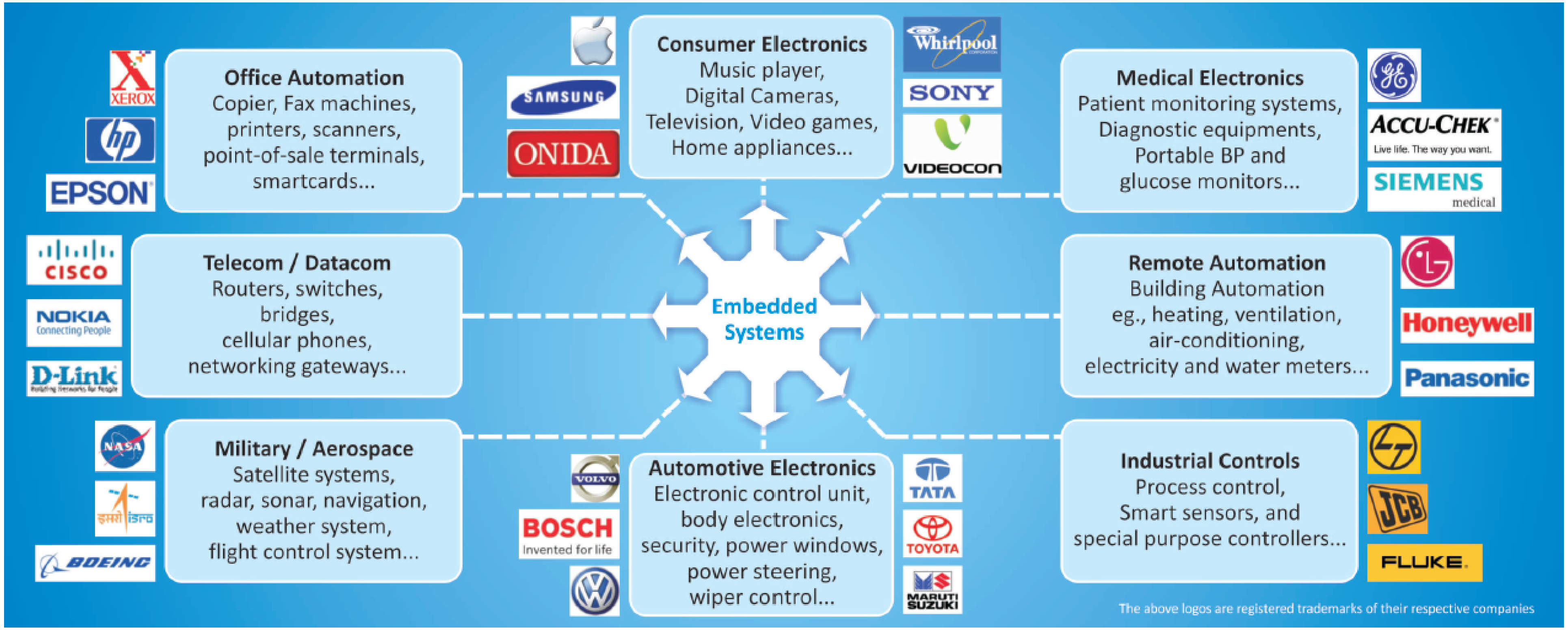
Embedded Systems

A system built to perform its duty, completely or partially independent of human intervention.

Specially designed to perform a few tasks in the most efficient way.

Interacts with physical elements in our environment, viz. sensing temperature, controlling and driving a motor etc.,

Embedded is everywhere…



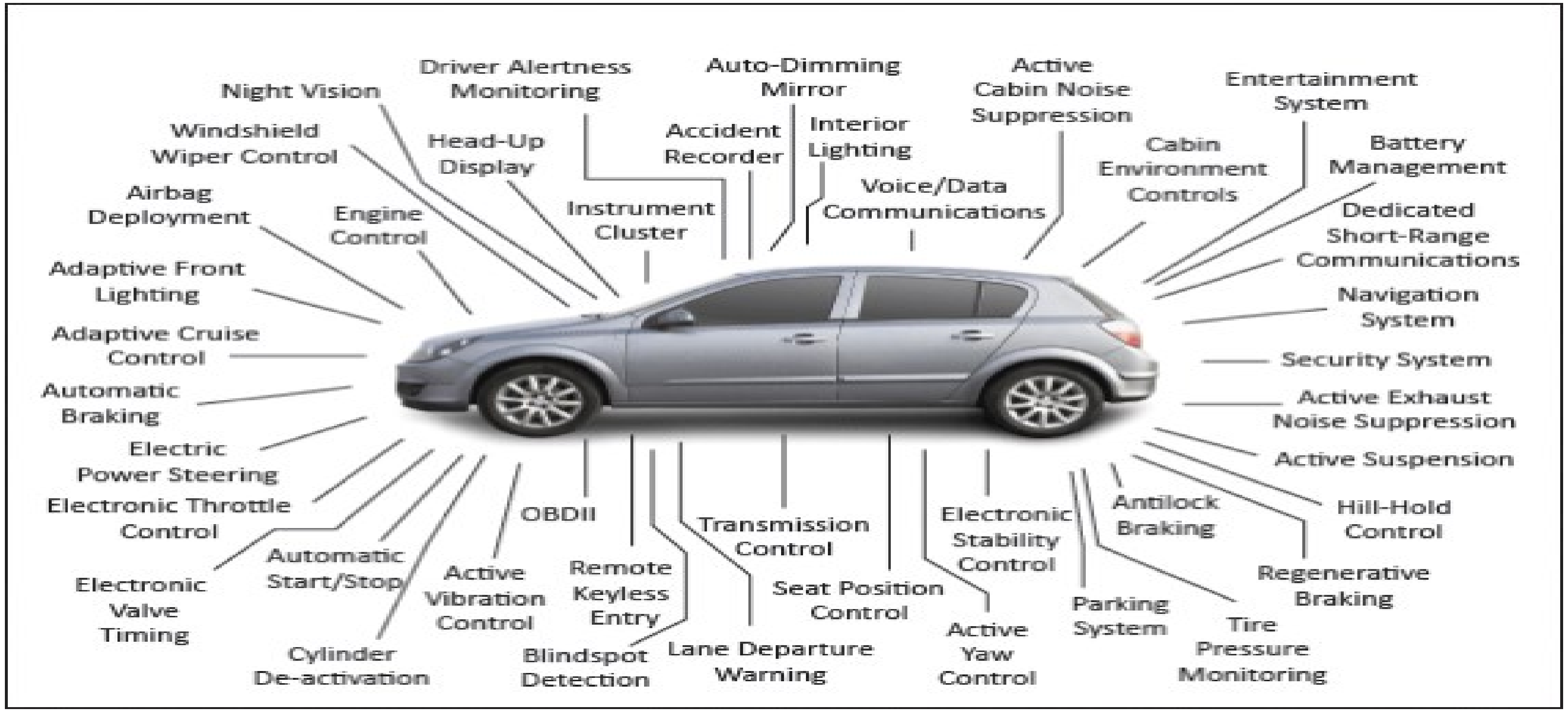
Embedded is everwhere

Example: Automotive Electronics

BMW 745i

Modern cars: Around 50 microcontrollers run complex software

- Engine and emissions control, stability and traction control, diagnostics, gearless automatic transmission and more
- http://www.howstuffworks.com/car-computer.htm



- 2 million lines of code
- 53 8-bit μC
- 11 32-bit μC
- 7 16-bit μC
- Multiple comm. networks

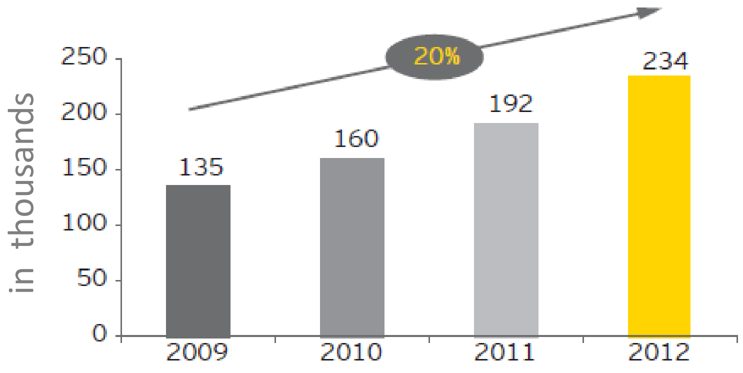
Embedded Systems – Growth potential

The Embedded systems field is poised for a huge growth throughout the world

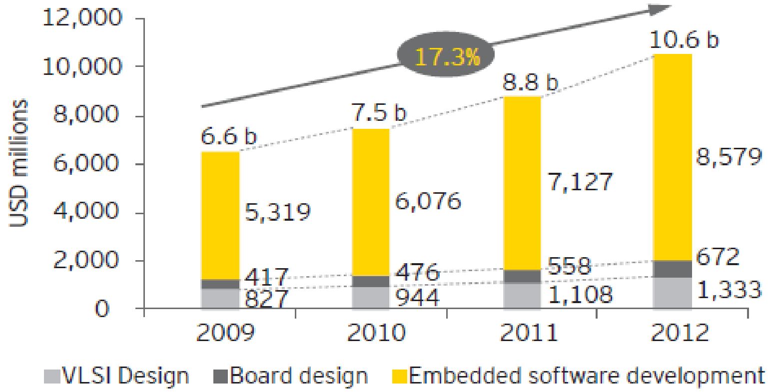
In consumer segment alone, there are 2 billion embedded devices hitting the market every year

The worldwide R&D in the field of Embedded Systems is expected to double over the next 10 years

Professionals trained in embedded systems are a rare commodity in the recruitment market place.



Installed talent pool in India



Indian semiconductor design industry

Source: ISA

India's new electronic policy targets $400 billion

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THE ECONOMIC TIMES

Kapil Sibal aims to boost domestic electronics manufacturing with new draft policy

The Economic Times: October 04, 2011

New Delhi: India aims to achieve a turnover of $400 billion from domestic electronics manufacturing by 2020. The government will take a series of initiatives to attract $100-billion investment in this sector, communication minister Kapil Sibal said on Monday.

Unveiling the draft electronics manufacturing policy, Sibal pointed out that domestic manufacturing in the current scenario could cater to only $100 billion worth of products by 2020 against a $400 million and the rest of the requirements would therefore have to be met by imports.

"This aggregates to a demand supply gap of nearly $300 billion by 2020. Unless the situation is corrected, it is likely that by 2020 the electronics import may far exceed oil imports," Sibal said.

"The National Policy of Electronics-2011 envisions creating a globally competitive electronics systems design and manufacturing (ESDM) industry, including nano-electronics, to meet the country's needs and serve the international market," he added. The minister said that the policy help generate 28 million jobs and would be finalised by the year-end.

http://mit.gov.in/sites/upload_files/dit/files/Draft-NationalPolicyonElectronics2011_4102011(2).pdf

Embedded Systems Market

- The global market for embedded systems is expected to increase from $101.6 billion in 2009 to an estimated $158.6 billion by the end of 2015, a compound annual growth rate (CAGR) of 7%
  - Embedded hardware was worth $108.8 billion in 2010 and is expected to grow at a CAGR of 7% to reach $152.4 billion in 2015
  - Embedded software generated $4.2 billion in 2010. This should increase to $6.1 billion in 2015, for a CAGR of 7.8%
  - http://www.bccresearch.com/report/embedded-systems-technologies-markets-ift016d.html (published Jan 2012)

Embedded Systems Market - Contd….

More than 5 billion ARM-based processors sold in 2010 alone (Intel has sold close to 4 billion processors during its entire history!)

In consumer segment alone, there are 2 billion embedded devices hitting the market every year

The worldwide R&D in the field of Embedded Systems is expected to double over the next 10 years

The average person (mostly unknowingly) uses around 100 embedded microcontrollers in his/her day-to-day life

Professionals trained in embedded systems are a rare commodity in the recruitment market place.

GOI is coming out with a plan to grow Indian electronic industry to $400 billion.

Moore’s Prediction in 1965 – His law

The number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years

Cramming more components onto integrated circuits

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

By Gordon E. Moore
Director, Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

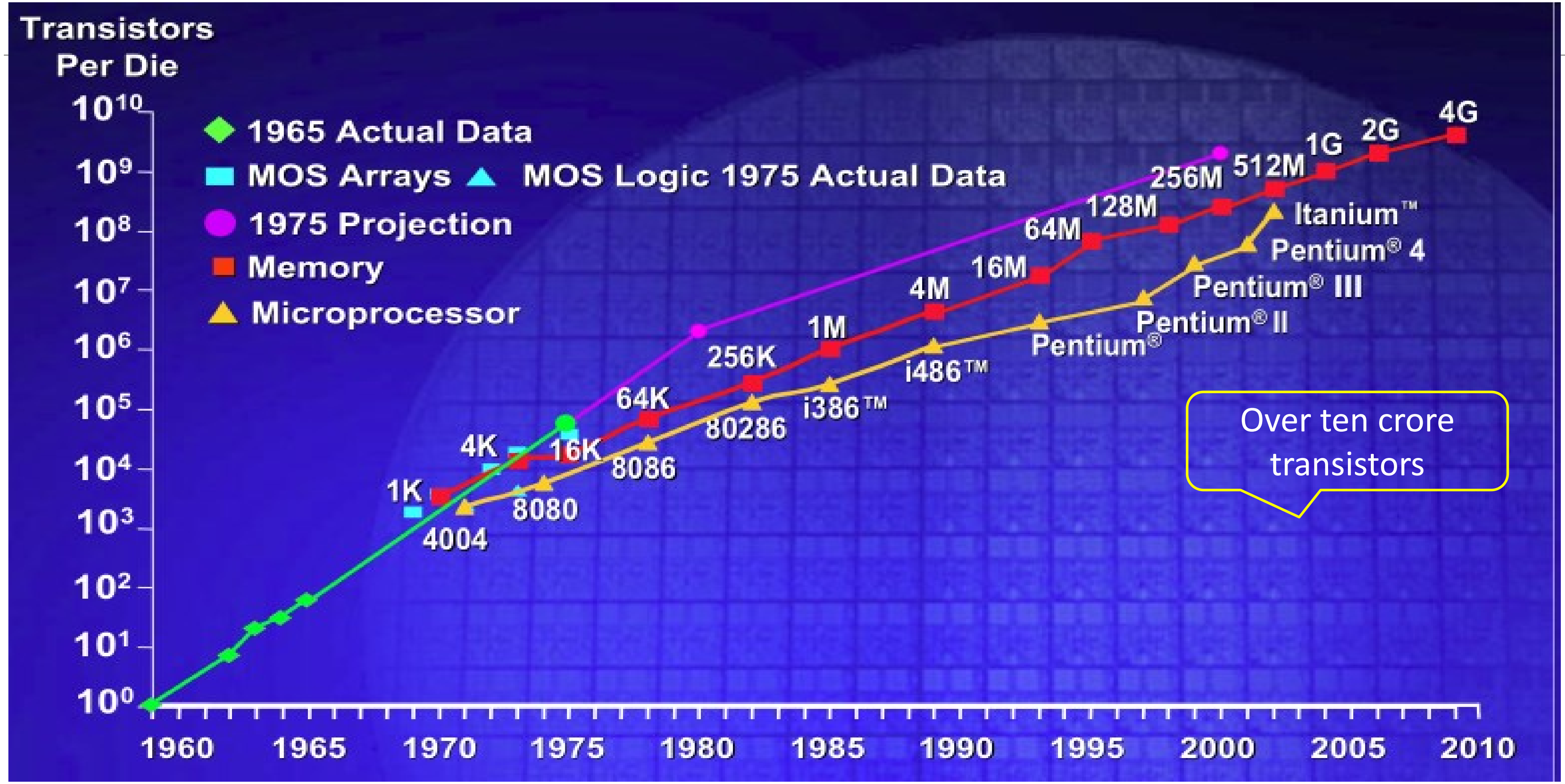
Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.

machine instead of being concentrated in a central unit. In addition, the improved reliability made possible by integrated circuits will allow the construction of larger processing units. Machines similar to those in existence today will be built at lower costs and with faster turn-around.

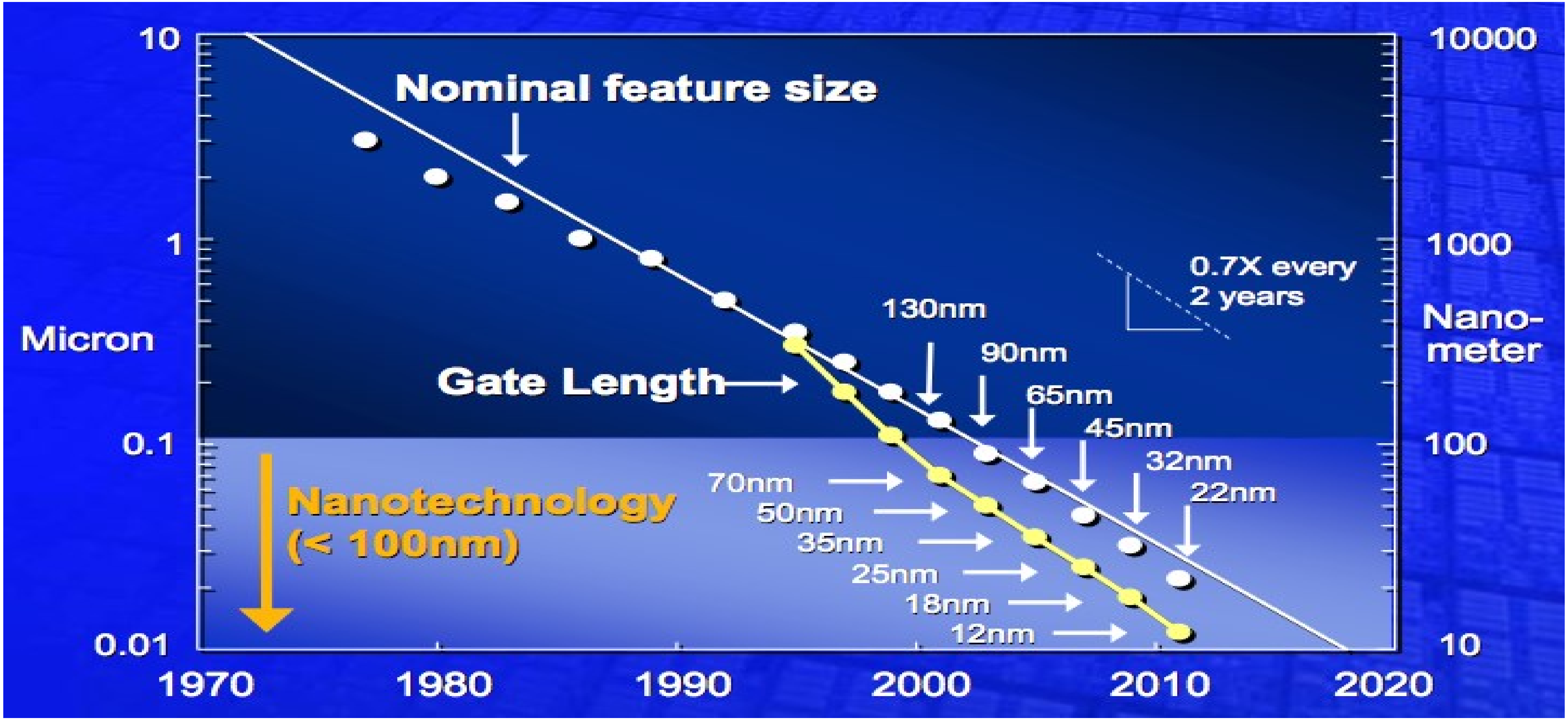
Present and future

By integrated electronics, I mean all the various technologies which are referred to as microelectronics today as

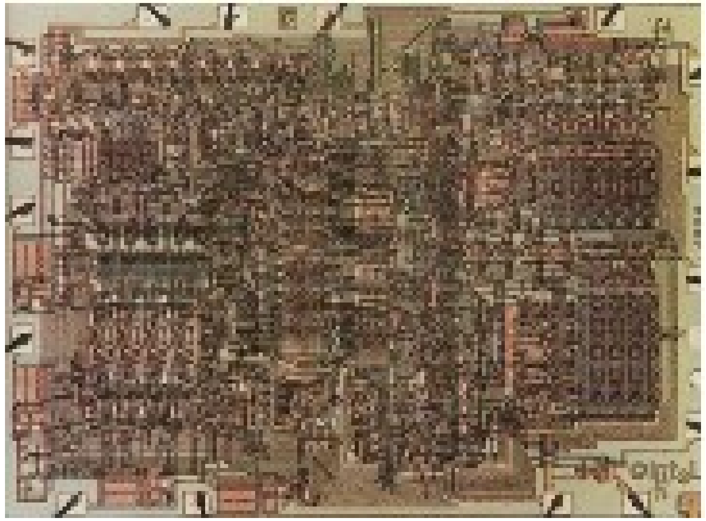
Moore’s Law


Transistors Per Die
1965 Actual Data
MOS Arrays
MOS Logic 1975 Actual Data
1975 Projection
Memory
Microprocessor
10^10
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
1K
4K
16K
64K
256K
1M
4M
16M
64M
128M
256M
512M
1G
2G
4G
4004
8080
8086
80286
i386™
i486™
Pentium®
Pentium® II
Pentium® III
Pentium® 4
Itanium™
Over ten crore transistors

The Shrinking Transistor

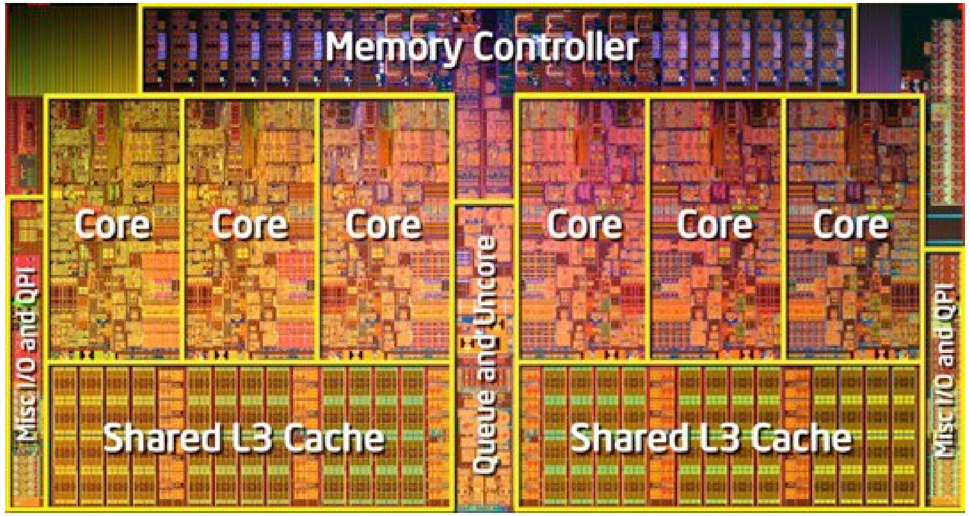


Chip of 1971 vs. Chip of 2010



Intel 4004 (first microprocessor)

- 2300 transistors
- 10 µm feature size
- 12 mm^2 die area



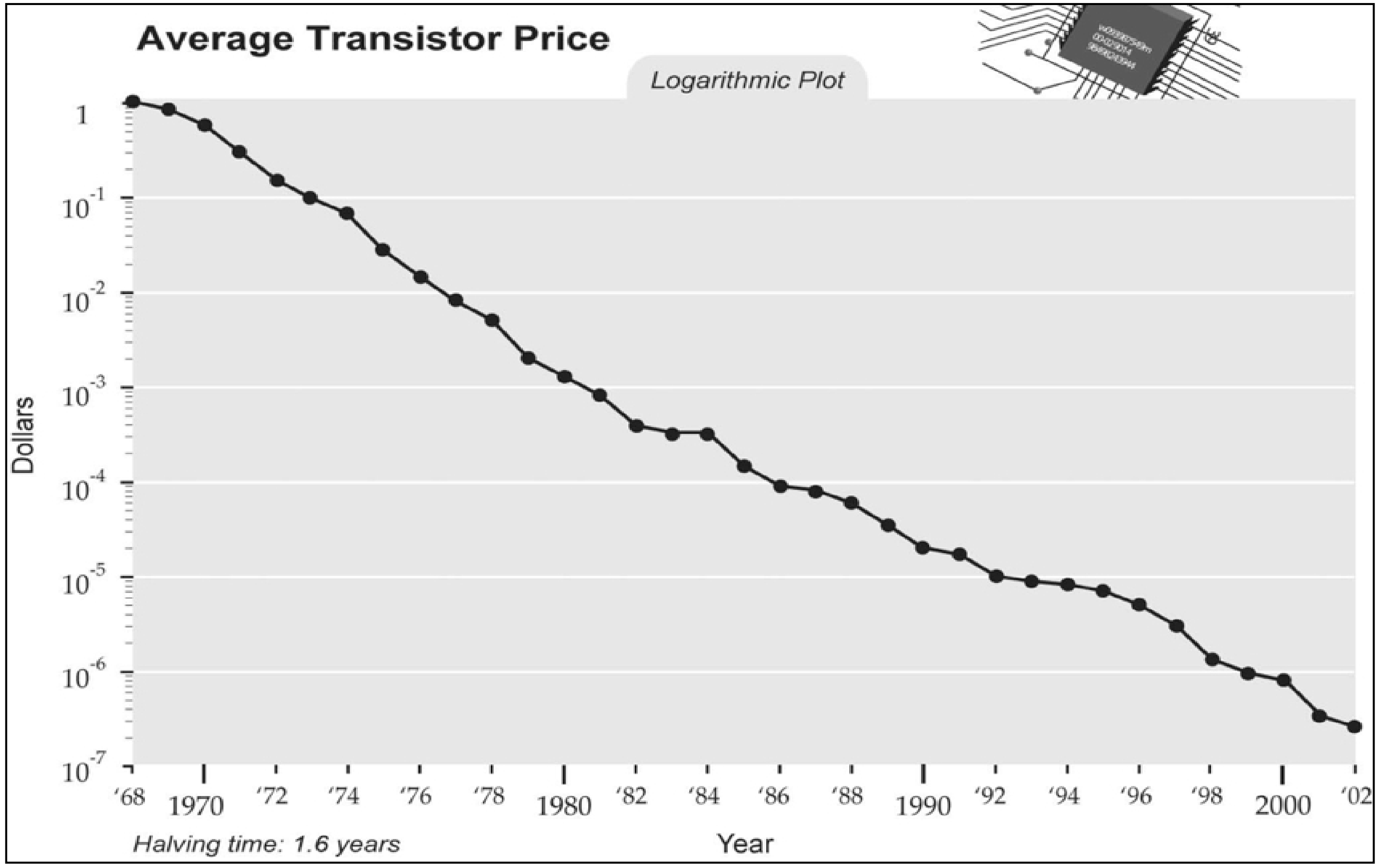
Intel Core i7-980X (Gulftown)

- 1.17 billion transistors
- 32 nm feature size
- 248 mm^2 die area

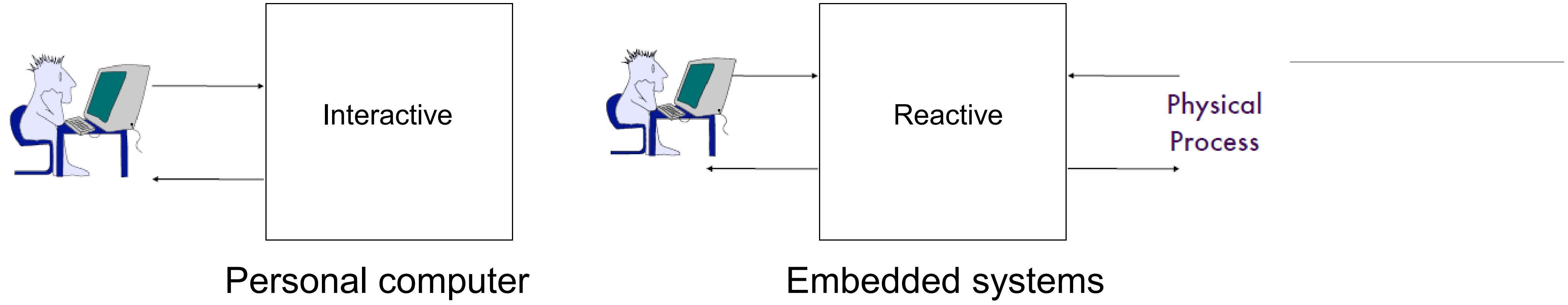
Decreasing Cost per Transistor

Average cost of a transistor halves every 1.6 years

- Note that the transistor also gets faster, so you can do more with it
- Rough price of a transistor now = one printed newspaper character.



Reactive Operation



Computation is in response to external events, as opposed to operations in interactive systems
- Need to deal with a mix of periodic and aperiodic events

Interaction with environment causes problems
- Indeterminacy in execution
  - e.g., waiting for events from multiple sources
- Physical environment is delay intolerant
  - can't put it on wait with an hour glass icon!

Handling timing constraints crucial to the design of embedded systems

What is Real-Time?

Time is a major discriminator relative to general purpose computing

- Time: correctness of system depends not only on the logical result of the computation, but also on the time at which the results are produced
- Real: reaction of the system to external events must occur during their evolution

Real-time != Fast

- Fast is relative, and does not capture the “real” constraint
- Concept of time is not an inherent property of an embedded system. Rather, it is strictly related to environment in which the system operates

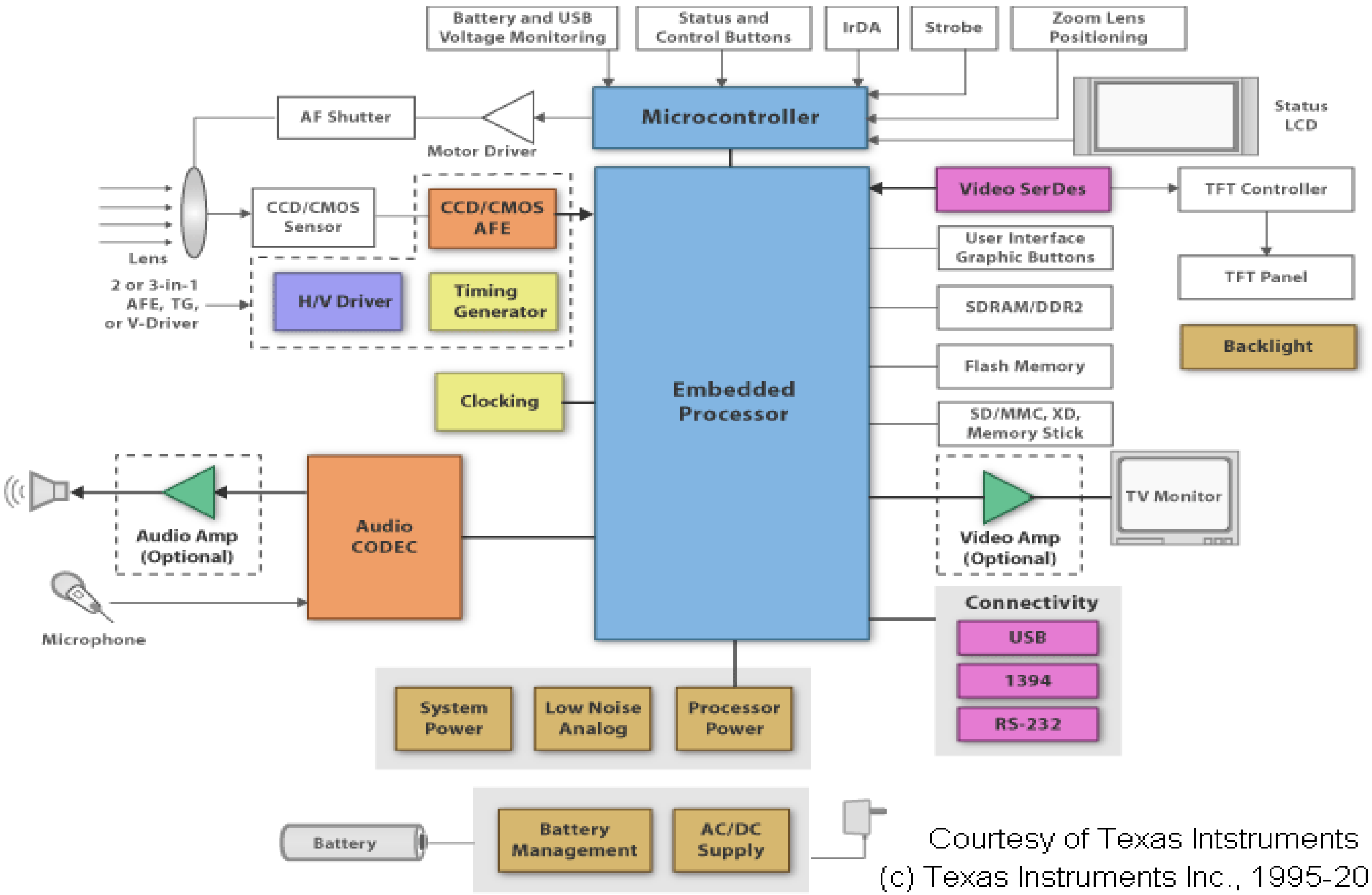
Erroneous belief: faster hardware will solve the problem

- Faster hardware improves throughput but does not imply that individual timing constraints will be met

Fast vs. predictable: Just because a system is fast, cannot guarantee that individual timing requirements will be met under all circumstances

- Worst case performance is often the issue

Modern Embedded Systems



Courtesy of Texas Intstruments

Embedded HW Considerations

Processor
- energy, computation

Network interface
- wired, RF, acoustic, optical
- energy, range, bandwidth, interference-robustness

Energy supply
- wired, battery, scavenging
- lifetime, size

User interface
- type, energy, complexity

Sensing
- type, energy, range, accuracy, resolution, frequency, reliability

Actuation
- type, energy, range

Storage
- energy, capacity, bandwidth

Packaging
- form-factor, weight, weather-proof

Overall cost

Processing Choices

- Microprocessors
- Domain-specific processors
  - DSPs
  - Network processors
  - Microcontrollers
- Reconfigurable SoC (PSoC...)
- FPGA
- ASIC

Hardware vs. Software

Hardware = functionality implemented via a custom architecture

- e.g., datapath + controller (Finite State Machine - FSM)

Software = functionality implemented on a programmable processor

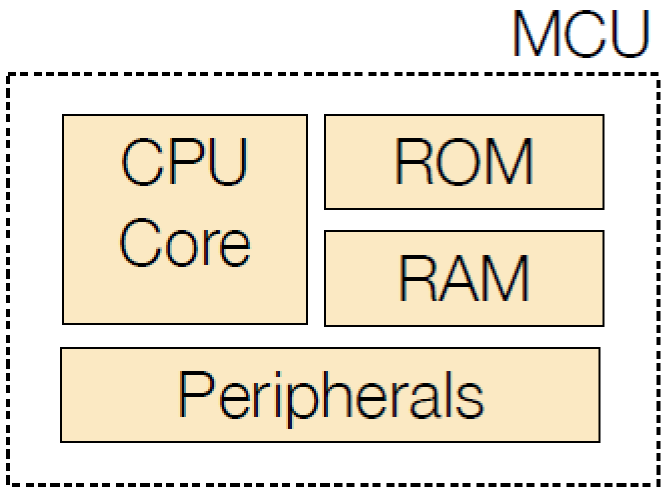
Key differences:

- Multiplexing
  - software modules multiplexed with others on a processor
  - hardware modules are typically mapped individually on dedicated hardware
- Concurrency
  - processors usually have one “thread of control”
  - dedicated hardware often has concurrent datapaths

Microcontrollers (MCU)

Chip vendors either develop own CPU core or license IP

Specific chips usually targeted toward a small set of applications (unlike PSoC, which targets multiple applications)



Microcontrollers

Different from your regular desktop CPU

- Smaller in size
- Reduced instruction set
- Less power consumption
- Lower frequencies

Within microcontrollers, there is a large variation (typical variations are represented below)

Bus Width	CPU Speeds	RAM	ROM
8-bit	1-8 MHz	128-1K	512 to 10K
16-bit	4-25 MHz	1K to 10K	10K to 128K
32-bit	10-1000 MHz	10K to 512M	128K to 512M

Communication Interfaces

Communication is an important aspect of embedded systems

Often contain specialized communication chips

Wired

- Interfacing with sensors and other system components (like comm. chips)
  - I2C
  - SPI
  - UART
  - USB
  - CAN
- Communication with other embedded systems
  - Ethernet
  - RS485

Wireless

- Becoming more and more important because of ease of installation
- Many different standards for short, mid, and long range communication

Wireless Technologies

Short Range
- IEEE 802.15.4, ZigBee Alliance
  - Home automation
  - Sensor Networks
- z-Wave
  - Home automation
- Bluetooth
  - Short range communication
  - Audio headsets
- Proprietary (Eg:CyFi)

Mid Range
- 802.11

Wide Area Networks
- GSM/CDMA
- Satellite
- Proprietary point to point links

Programming techniques

Microcontroller's flash are programmed in different ways

- ISSP - In-system serial programming
- JTAG - Joint Test Action Group is an IEEE standard
- Boot loading

One Possible Taxonomy

Signal processing systems

- E.g., Radar, sonar, real-time video, set-top boxes, DVD players, medical equipment, residential gateways
- Key challenge: Need for high computational power

Mission critical systems

- E.g., Avionics, space-craft control, nuclear plant control
- Key challenge: Need for extreme reliability

Distributed control

- E.g., Smart grid, mass transit systems, elevators in buildings
- Key challenge: Need to deal with distributed nature of system

Small systems

- E.g., Cellular phones, pagers, home appliances, toys, smart cards, MP3 players, PDAs, digital cameras and camcorders, sensors, smart badges
- Key challenge: Deal with stringent resource constraints

Several embedded systems fall into more than one category

Typical Characteristics

Physically coupled

- Interact (sense, manipulate) with physical world processes and phenomena
- Hybrid dynamics (mix of continuous-state and discrete-state)

Passage of time is extremely important

- Correctness of results also depends on time at which they are produced
- Operation is almost always time constrained: latency, throughput

HW and SW do application-specific function – not general purpose

- Application is typically known a priori
- Some degree of re-programmability is essential (upgrading, bug fixing, product differentiation, customization)

Inherently concurrent

Never terminate (ideally)

Various constraints: computation, memory, bandwidth, power, size, weight, heat, reliability, cost, etc.

Key Recent Trends

Increasing computation demands

- e.g., multimedia processing in set-top boxes, HDTV

Increasingly networked

- e.g., embedded web servers, cameras, disks, etc., that sit directly on networks

Increasing need for flexibility

- Time-to-market under ever changing standards! This is where PSoC comes into picture

Increasing share of SW development in terms of cost

Embedded Product Development Process

9 Production
8 Final Integration and testing
7 Hardware and Firmware testing
6 Firmware architecture and development
5 Design of Preliminary hardware (Schematic and board design)
4 Component selection
3 Project scheduling
2 Develop design specifications
1 Market Research & Feasibility study

Thank You

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