EMBEDDED SYSTEM BASICS AND APPLICATION

TOPICS TO BE DISCUSSED

- System
- Embedded System
- Components
- Classifications
- Processors
- Other Hardware
- Software
- Applications

INTRODUCTION

What is a system?

A system is a way of working, organizing or doing one or many tasks according to a fixed plan, program or set of rules.

A system is also an arrangement in which all its units assemble and work together according to the plan or program.

SYSTEM EXAMPLES

WATCH

It is a time display SYSTEM

Parts: Hardware, Needles, Battery, Dial, Chassis and Strap

Rules

1.All needles move clockwise only

2.A thin needle rotates every second

3.A long needle rotates every minute

4.A short needle rotates every hour

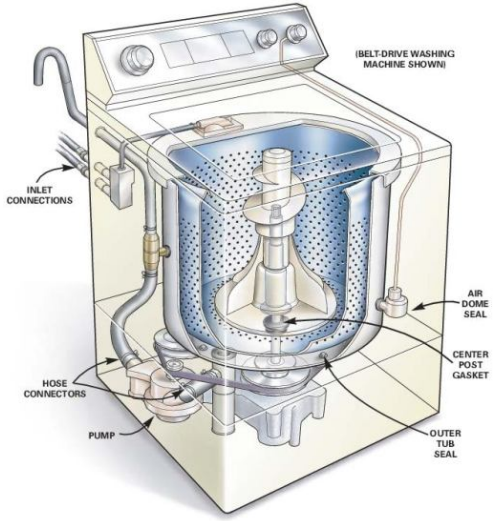
5.All needles return to the original position after 12 hours

SYSTEM EXAMPLES

WASHING MACHINE

It is an automatic clothes washing SYSTEM

Parts: Status display panel, Switches & Dials, Motor, Power supply & control unit, Inner water level sensor and solenoid valve.



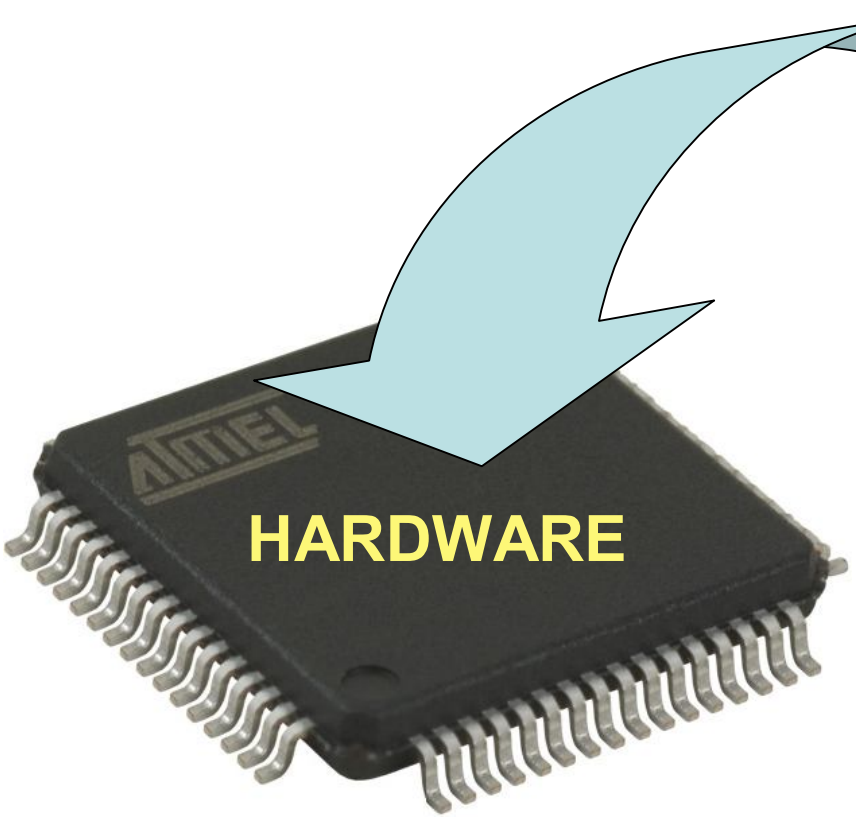
Rules

1.Wash by spinning
2.Rinse
3.Drying
4.Wash over by blinking
5.Each step display the process stage
6.In case interruption, execute only the remaining

EMBEDDED SYSTEM

Definition: An Embedded System is one that has computer hardware with software embedded in it as one of its important components.

Its software embeds in ROM (Read Only Memory). It does not need secondary memories as in a computer



SOFTWARE PROGRAM

```
#include <16f876a.h>
#use delay (clock=20000000)
#byte PORTB=6
main()
{
set_tris_b(0);
portb=255;        //decimal
delay_ms(1000);
portb=0x55;       //hexadecimal
delay_ms(1000);
portb=0b10101010;  //binary
delay_ms(500);
}
```

COMPUTER HARDWARE

A Microprocessor

A Large Memory
(Primary and Secondary)
(RAM, ROM and caches)

Input Units
(Keyboard, Mouse, Scanner, etc.)

Output Units
(Monitor, printer, etc.)

Networking Units
(Ethernet Card, Drivers, etc.)

I/O Units
(Modem, Fax cum Modem, etc.)

COMPONENTS OF EMBEDDED SYSTEM

- **It has Hardware**

  Processor, Timers, Interrupt controller, I/O Devices, Memories, Ports, etc.

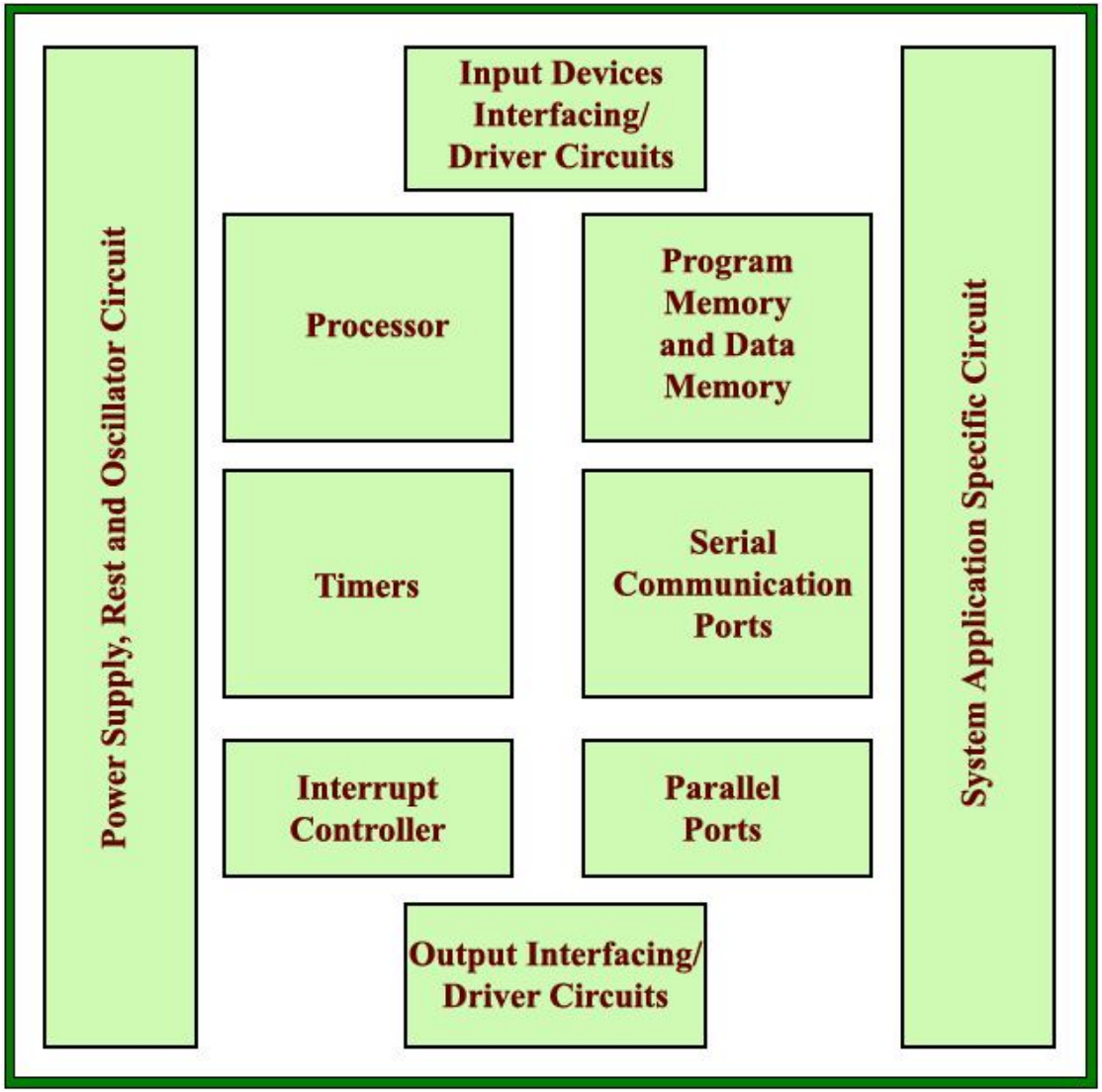
- **It has main Application Software**

  Which may perform concurrently the series of tasks or multiple tasks.

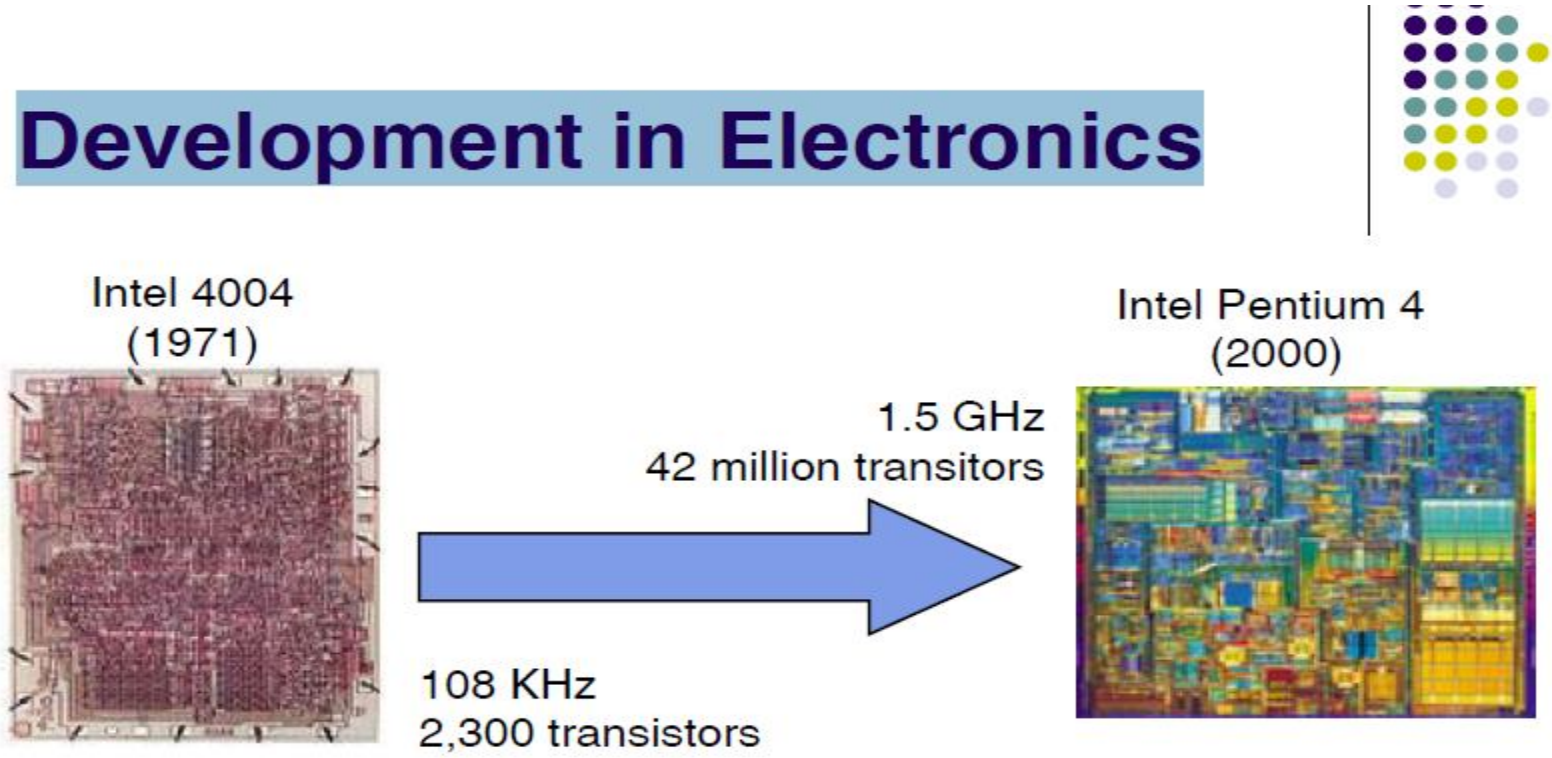
- **It has Real Time Operating System (RTOS)**

  RTOS defines the way the system work. Which supervise the application software. It sets the rules during the execution of the application program. A small scale embedded system may not need an RTOS.

EMBEDDED SYSTEM HARDWARE



Development in Electronics



If automobile speed had increased similarly over the same period, we could now drive from San Francisco to New York in about 13 seconds (Intel).

EMBEDDED SYSTEM CONSTRAINTS

An embedded system is software designed to keep in view three constraints:

- **Available system memory**
- **Available processor speed**
- **The need to limit the power dissipation**

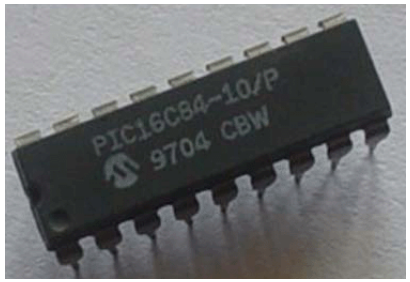
When running the system continuously in cycles of wait for events, run, stop and wakeup.

What makes embedded systems different?

- Real-time operation
- size
- cost
- time
- reliability
- safety
- energy
- security

CLASSIFICATIONS OF EMBEDDED SYSTEM

1. Small Scale Embedded System

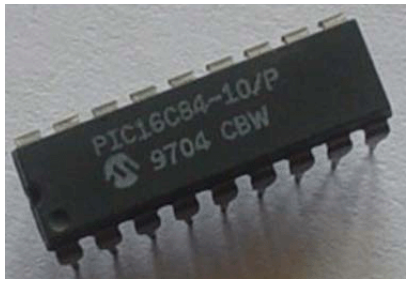


2. Medium Scale Embedded System

3. Sophisticated Embedded System

SMALL SCALE EMBEDDED SYSTEM

- Single 8 bit or 16bit Microcontroller.
- Little hardware and software complexity.
- They May even be battery operated.



- Usually “C” is used for developing these system.
- The need to limit power dissipation when system is running continuously.

Programming tools:

Editor, Assembler and Cross Assembler

MEDIUM SCALE EMBEDDED SYSTEM

- **Single or few 16 or 32 bit microcontrollers or Digital Signal Processors (DSP) or Reduced Instructions Set Computers (RISC).**

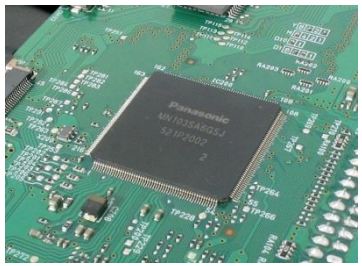
- **Both hardware and software complexity.**

Programming tools:

RTOS, Source code Engineering Tool, Simulator, Debugger and Integrated Development Environment (IDE).

SOPHISTICATED EMBEDDED SYSTEM

- **Enormous hardware and software complexity**
- **Which may need scalable processor or configurable processor and programming logic arrays.**
- **Constrained by the processing speed available in their hardware units.**



Programming Tools:

For these systems may not be readily available at a reasonable cost or may not be available at all. A compiler or retargetable compiler might have to be developed for this.

PROCESSOR

- A Processor is the heart of the Embedded System.

- For an embedded system designer knowledge of microprocessor and microcontroller is a must.

Two Essential Units:

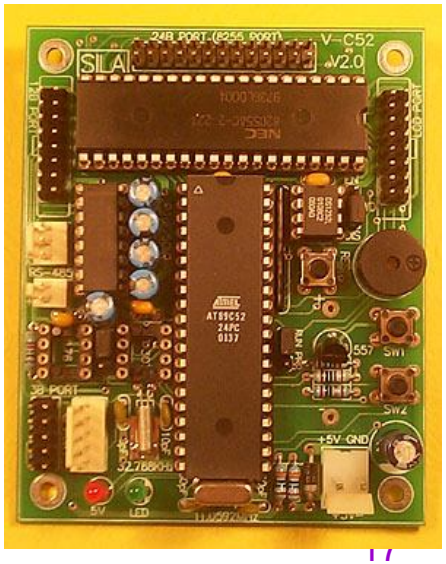
Control Unit (CU),

Execution Unit (EU)

<u>Operations</u>

Fetch

Execute



VARIOUS PROCESSOR

1. General Purpose processor (GPP)

- Microprocessor
- Microcontroller
- Embedded Processor
- Digital signal Processor

2. Application Specific System Processor (ASSP)

3. Multi Processor System using GPPs

MICROPROCESSOR

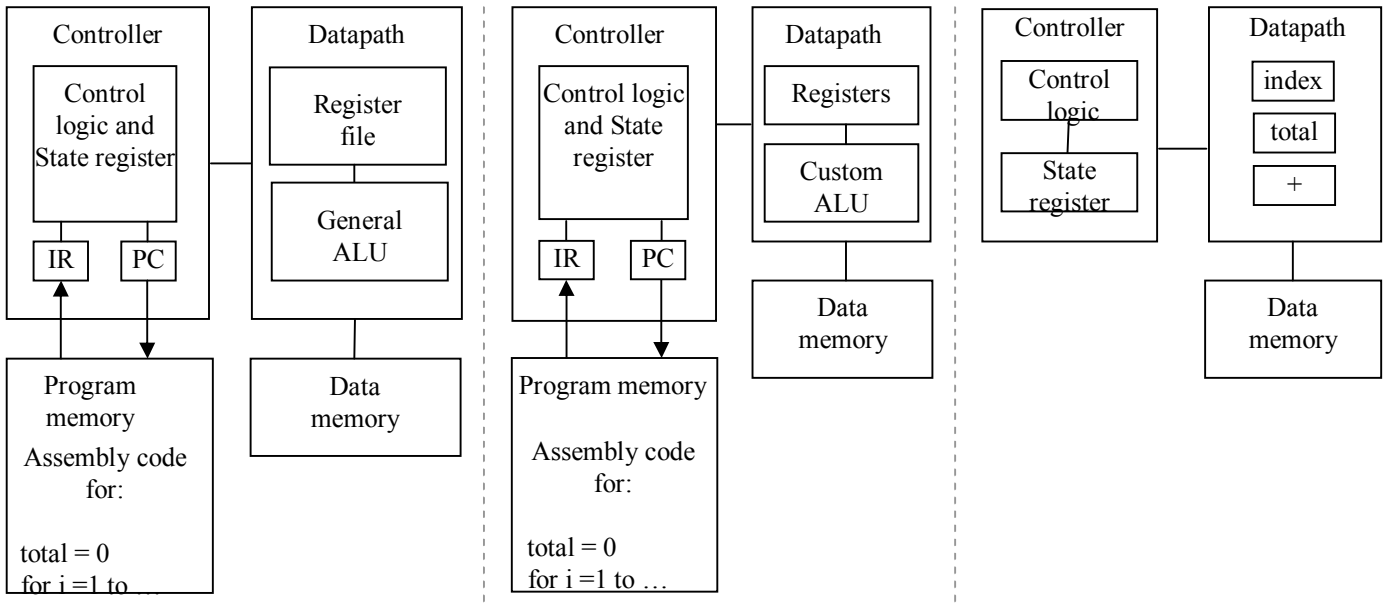
- A microprocessor is a single chip semi conductor device also which is a computer on chip, but not a complete computer.

- Its CPU contains an ALU, a program counter, a stack pointer, some working register, a clock timing circuit and interrupt circuit on a single chip.

- To make complete micro computer, one must add memory usually ROM and RAM, memory decoder, an oscillator and a number of serial and parallel ports.

Processor technology

- The architecture of the computation engine used to implement a system's desired functionality
- Processor does not have to be programmable
  - "Processor" *not* equal to general-purpose processor



Processor technology

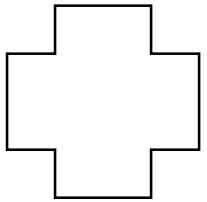
- Processors vary in their customization for the problem at hand

Desired functionality

```
total = 0
for i = 1 to N  loop
   total += M[i]
end loop
```

General-purpose processor

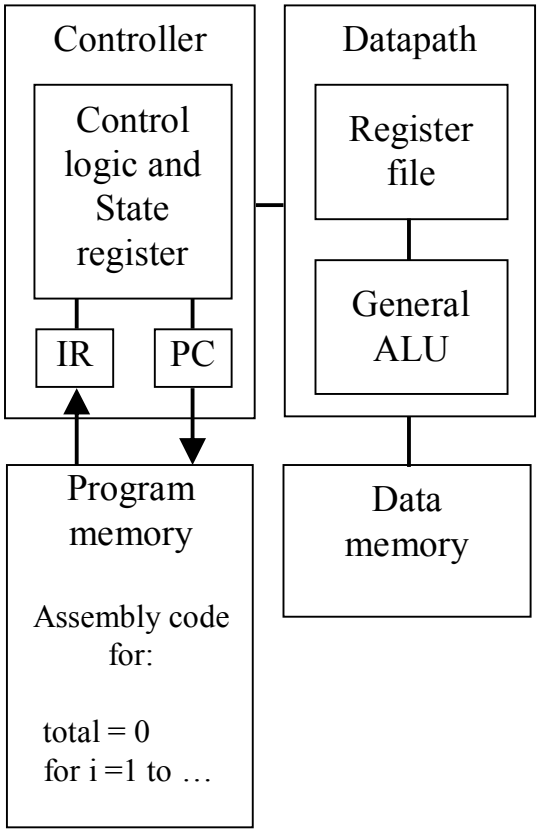
Application-specific processor



Single-purpose processor

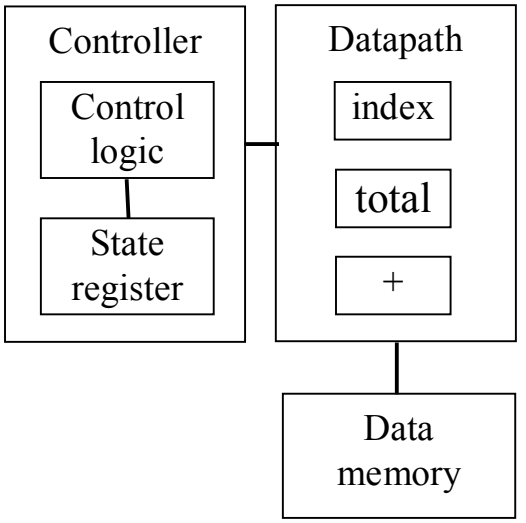
General-purpose processors

- Programmable device used in a variety of applications
  - Also known as “microprocessor”
- Features
  - Program memory
  - General datapath with large register file and general ALU
- User benefits
  - Low time-to-market and NRE costs
  - High flexibility
- “Pentium” the most well-known, but there are hundreds of others



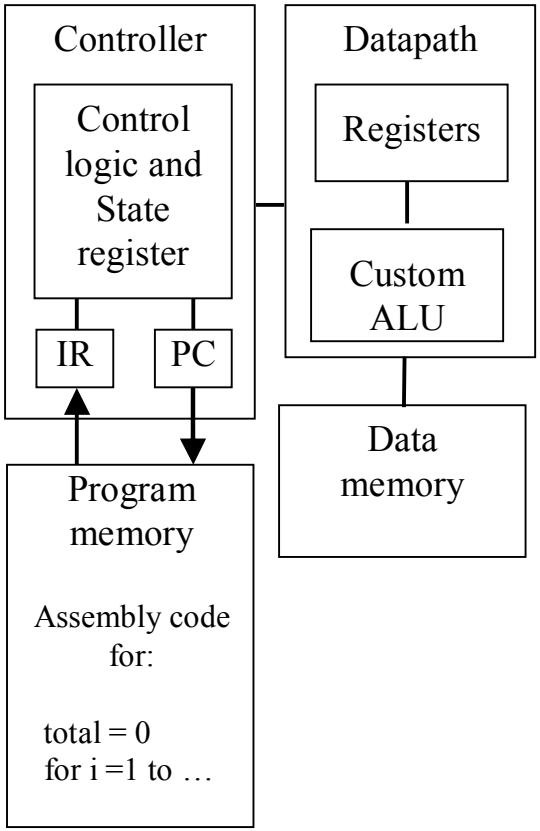
Single-purpose processors

- Digital circuit designed to execute exactly one program
  - a.k.a. coprocessor, accelerator or peripheral
- Features
  - Contains only the components needed to execute a single program
  - No program memory
- Benefits
  - Fast
  - Low power
  - Small size



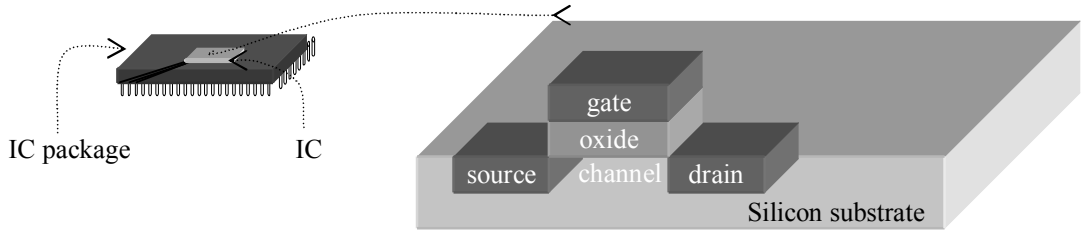
Application-specific processors

- Programmable processor optimized for a particular class of applications having common characteristics
  - Compromise between general-purpose and single-purpose processors
- Features
  - Program memory
  - Optimized datapath
  - Special functional units
- Benefits
  - Some flexibility, good performance, size and power



IC technology

- The manner in which a digital (gate-level) implementation is mapped onto an IC
  - IC: Integrated circuit, or “chip”
  - IC technologies differ in their customization to a design
  - IC’s consist of numerous layers (perhaps 10 or more)
    - IC technologies differ with respect to who builds each layer and when



IC technology

- Three types of IC technologies
  - Full-custom/VLSI
  - Semi-custom ASIC (gate array and standard cell)
  - PLD (Programmable Logic Device)

Full-custom/VLSI

- All layers are optimized for an embedded system's particular digital implementation
  - Placing transistors
  - Sizing transistors
  - Routing wires
- Benefits
  - Excellent performance, small size, low power
- Drawbacks
  - High NRE cost (e.g., $300k), long time-to-market

Semi-custom

- Lower layers are fully or partially built
  - Designers are left with routing of wires and maybe placing some blocks
- Benefits
  - Good performance, good size, less NRE cost than a full-custom implementation (perhaps $10k to $100k)
- Drawbacks
  - Still require weeks to months to develop

PLD (Programmable Logic Device)

- All layers already exist
  - Designers can purchase an IC
  - Connections on the IC are either created or destroyed to implement desired functionality
  - Field-Programmable Gate Array (FPGA) very popular
- Benefits
  - Low NRE costs, almost instant IC availability
- Drawbacks
  - Bigger, expensive (perhaps $30 per unit), power hungry, slower

MICROCONTROLLER

- A **microcontroller** is a functional computer system-on-a-chip. It contains a processor, memory, and programmable input/output peripherals.

- Microcontrollers include an integrated CPU, memory (a small amount of RAM, program memory, or both) and peripherals capable of input and output.

VARIOUS MICROCONTROLLERS

INTEL

8031,8032,8051,8052,8751,8752

PIC

8-bit PIC16, PIC18,

16-bit DSPIC33 / PIC24,

PIC16C7x

Motorola

MC68HC11

MICROPROCESSOR Vs MICROCONTROLLER

MICROPROCESSOR	MICROCONTROLLER
The functional blocks are ALU, registers, timing & control units	It includes functional blocks of microprocessors & in addition has timer, parallel i/o, RAM, EPROM, ADC & DAC
Bit handling instruction is less, One or two type only	Many type of bit handling instruction
Rapid movements of code and data between external memory & MP	Rapid movements of code and data within MC
It is used for designing general purpose digital computers system	They are used for designing application specific dedicated systems

EMBEDDED PROCESSOR

- Special microprocessors & microcontrollers often called, Embedded processors.

- An embedded processor is used when fast processing fast context-switching & atomic ALU operations are needed.

Examples : ARM 7, INTEL i960, AMD 29050.

DIGITAL SIGNAL PROCESSOR

- DSP as a GPP is a single chip VLSI unit.
- It includes the computational capabilities of microprocessor and multiply & accumulate units (MAC).
- DSP has large number of applications such as image processing, audio, video & telecommunication processing systems.
- It is used when signal processing functions are to be processed fast.

Examples : TMS320Cxx, SHARC, Motorola 5600xx

APPLICATION SPECIFIC SYSTEM PROCESSOR (ASSP)

- **ASSP is dedicated to specific tasks and provides a faster solution.**

- **An ASSP is used as an additional processing unit for running the application in place of using embedded software.**

Examples : IIM7100, W3100A

MULTI PROCESSOR SYSTEM USING GPPs

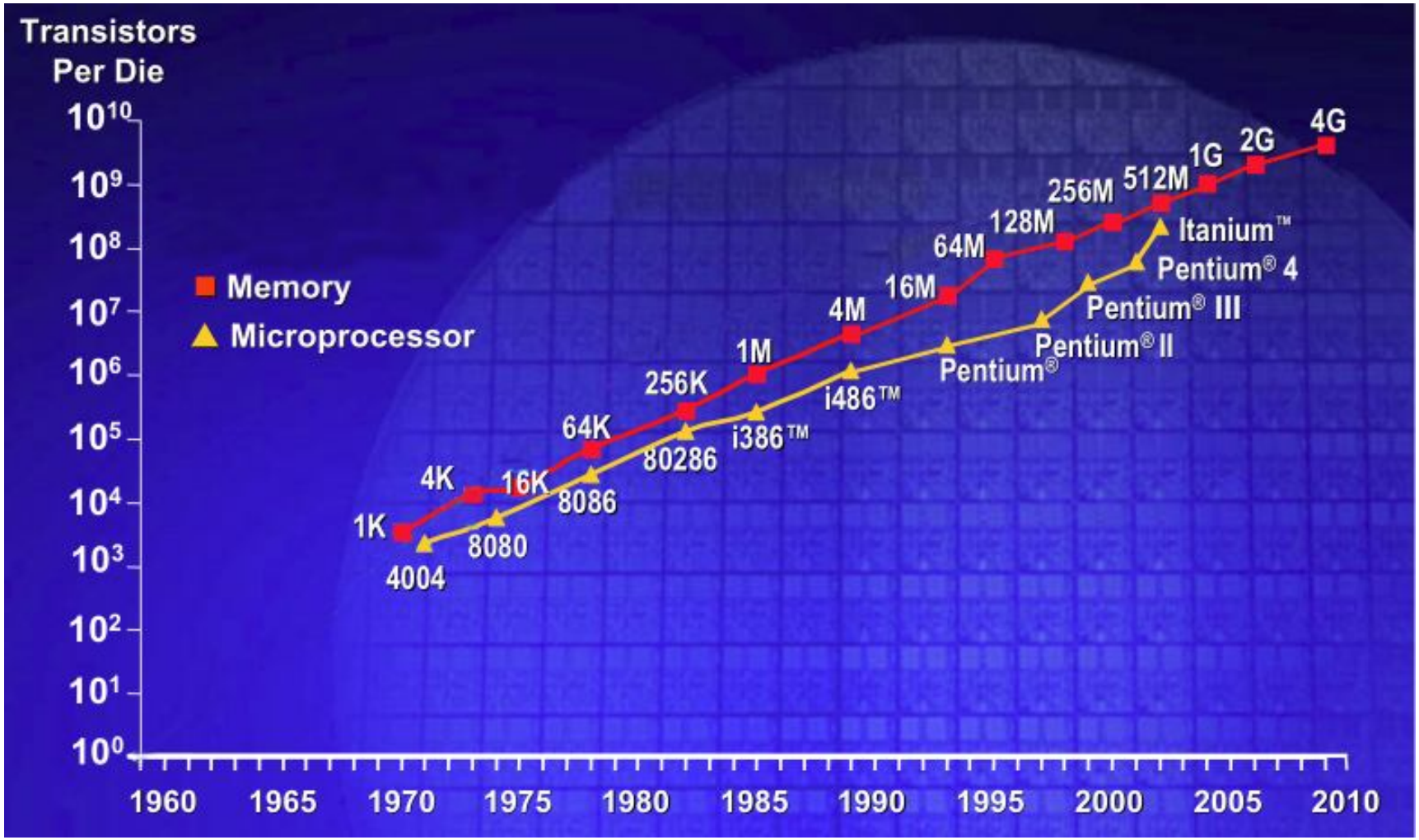
- Multiple processors are used when a single processor does not meet the needs of different task.

- The operations of all the processors are synchronized to obtain an optimum performance.

Moore’s Law

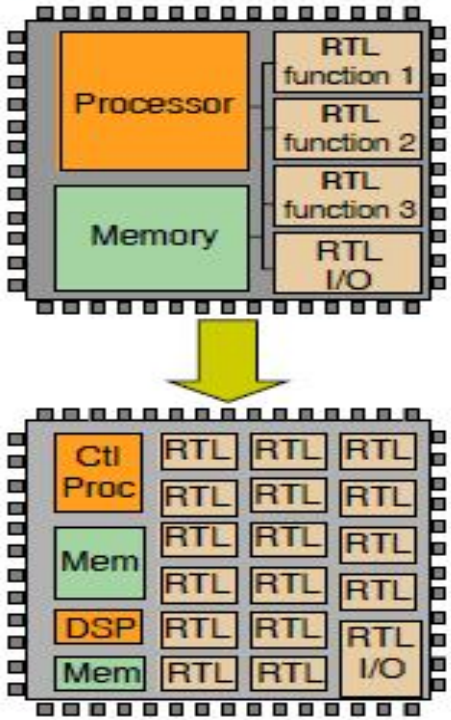
- **Moore's law describes a long-term trend in the history of computing hardware.**
- **Since the invention of the integrated circuit in 1958, the number of transistors that can be placed inexpensively on an integrated circuit has increased exponentially, doubling approximately every two years.**
- **The trend was first observed by Intel co-founder Gordon E. Moore in 1965.**
- **Almost every measure of the capabilities of digital electronic devices is linked to Moore's law: processing speed, memory capacity, etc.**

Moore's law


Transistors
Per Die
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
Memory
Microprocessor
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™
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Moore's Law drives the development of System-in-Chip Architectures

The growing number of transistors on an SOC drives the trend towards more RTL blocks on the chip



Yesterday's SOC

Today's SOC

Source: Leibson (DAC2004)

OTHER HARDWARE

- Power Source
- Clock Oscillator
- Real Time Clock (RTC)
- Reset Circuit, Power-up Reset and watchdog timer Reset
- Memory
- I/O Ports, I/O Buses
- Interrupt Handler
- DAC and ADC
- LCD and LED Display
- Keypad/Keyboard

SOFTWARE

SOFTWARE

C
C++
Dot Net

SIMULATOR

Masm

COMPILER

RIDE
KEIL

APPLICATIONS

- Household appliances:
  - Microwave ovens, Television, DVD Players & Recorders
- Audio players
- Integrated systems in aircrafts and missiles
- Cellular telephones
- Electric and Electronic Motor controllers
- Engine controllers in automobiles
- Calculators
- Medical equipments
- Videogames
- Digital musical instruments, etc.

TELEVISION

REMOT CONTROL

REFRIGERATORS

ELEVATORS

VIDEO GAMES

SET-TOP BOX

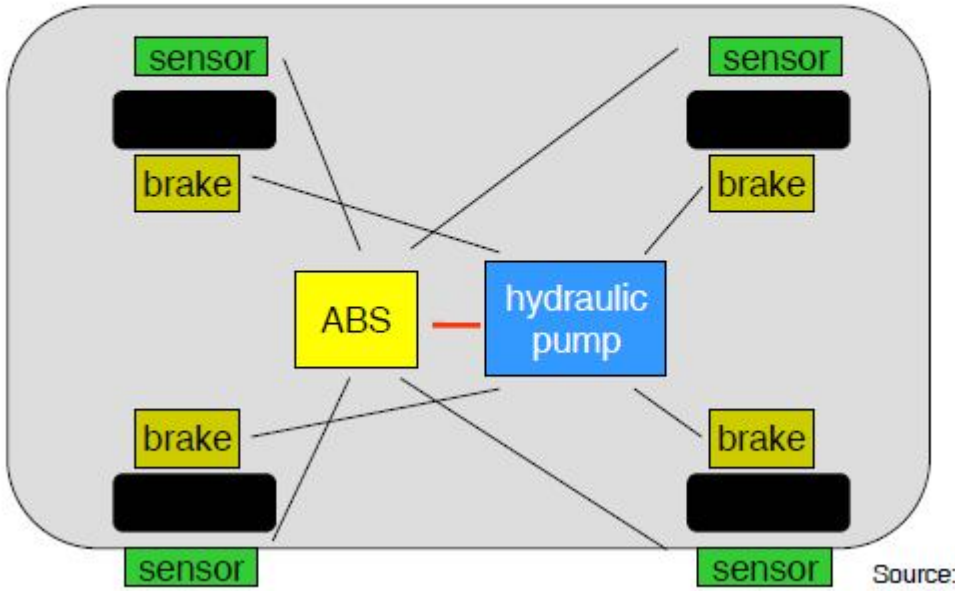
PLANES

CARS

BMW 850i brake and stability control system

- Anti-lock brake system (ABS): pumps brakes to reduce skidding.
- Automatic stability control (ASC+T): controls engine to improve stability.
- ABS and ASC+T communicate.
  - ABS was introduced first---needed to interface to existing ABS module

BMW 850i, cont'd.

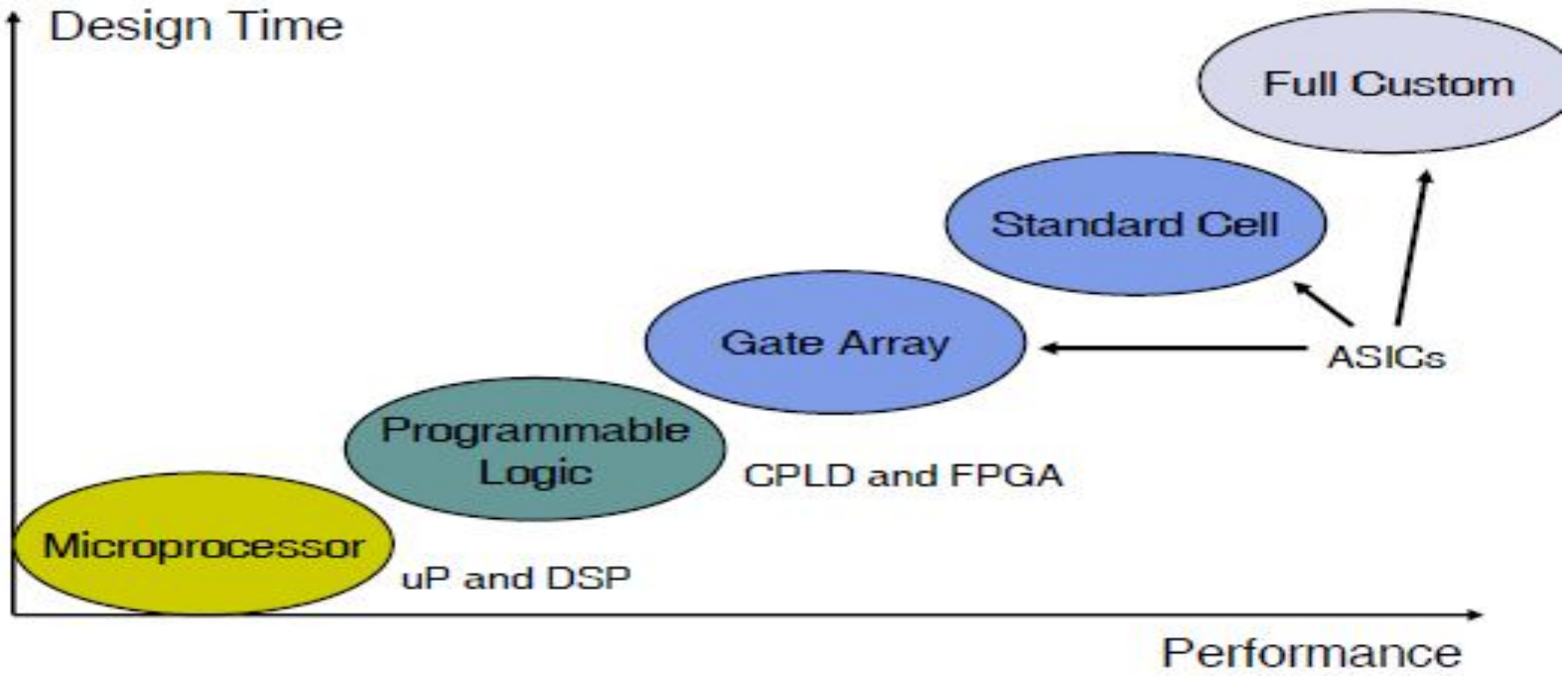


Source: Wolf 2000,
© 2000 Morgan Kaufmar

- **Automotive embedded**
- **systems**
- Today’s high-end automobile may have 100
- microprocessors:
- 4-bit microcontroller checks seat belt;
- microcontrollers run dashboard devices;
- 16/32-bit microprocessor controls engine.
- Source:

- **Embedded Systems...**
- □ react on the environment at the speed of the
- environment
- □ often real-time requirements
- □ are designed for one single task
- □ have often to be power-efficient
- □ are mass products and have to be cheap
- □ must be reliable

Alternatives mean longer design time, but allow higher performance



- **Thus ...**
- Microprocessors are used
- As key components in an embedded design
- Programmable Logic and ASICs are used
- for critical parts in a design
- An obective for an embedded system designer is to
- find the cheapest solution that meets the requirements
- Do not use a Pentium, when you
- only want to control a freezer...

- **Challenges in embedded system design**
- How much hardware do we need?
- How big is the CPU? Memory?
- How do we meet our deadlines?
- Faster hardware or cleverer software?
- How do we minimize power?
- Turn off unnecessary logic? Reduce memory accesses?

- **Challenges, etc.**
- Does it really work?
- Is the specification correct?
- Does the implementation meet the spec?
- How do we test for real-time characteristics?
- How do we test on real data?
- How do we work on the system?
- Observability, controllability?
- What is our development platform?

Learn by Doing

Excel Thru Experimentation

Lead by Example

Acquire skills and get employed

Update skills and stay employed

THANK YOU