Topic 1

Introduction to Digital Electronic Systems

Department of Electronics

Academic Year 13/14

(ver 10-07-2013)

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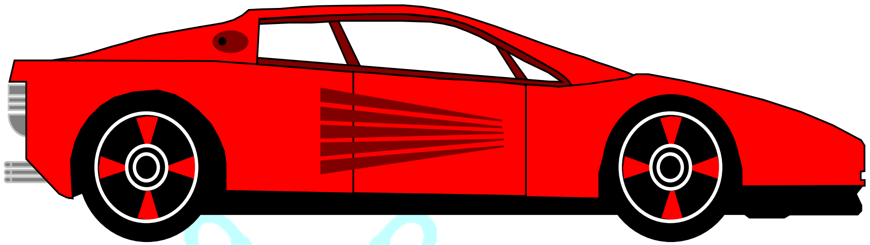
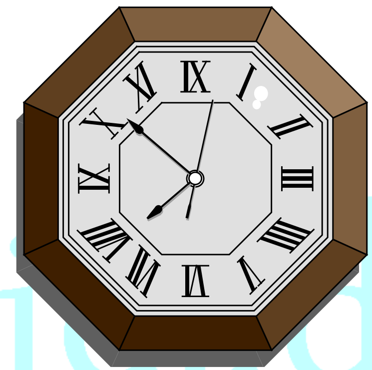
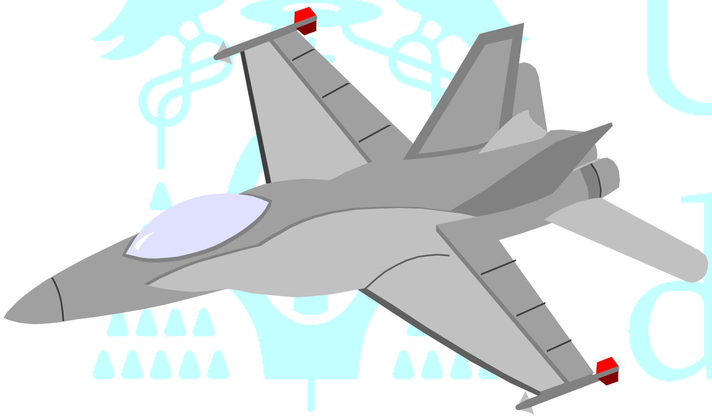
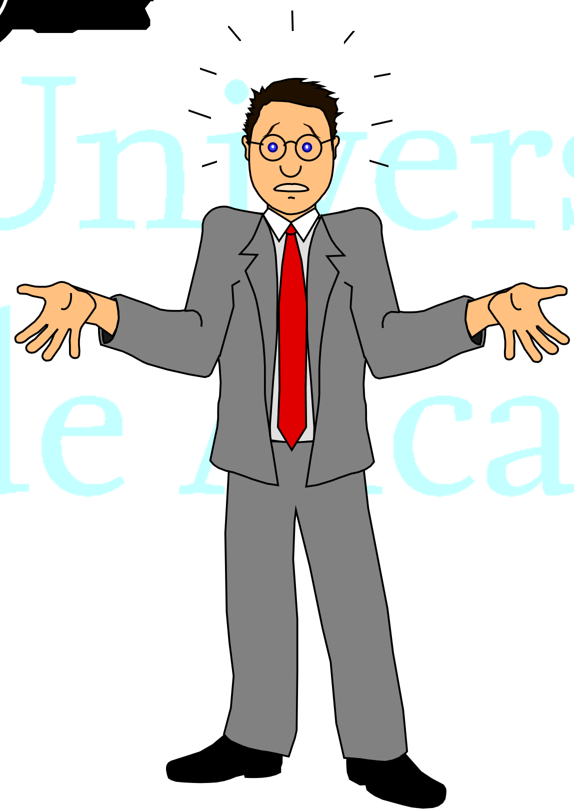
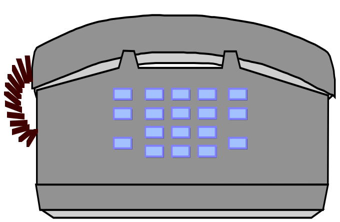
1.1. Introduction: What is a system?











1.1. Introduction

- Interacts with the environment
- Is divided into three stages:
  1. Input
  2. Processing
  3. Output
- The processing is based on:
  - Combinational logic and sequential circuits
  - Microprocessors
  - Microcontrollers
  - Digital Signal Processor (DSP)
  - Programmable logic circuits
  - Programmable Logic Controllers (PLC’s)

1.1. Introduction: processing system classification

	DO NOT CONTROL	DO CONTROL / REAL TIME
NOT EMBEDDED	Supercomputers Servers Workstations Personal computers Calculator *Scientific calculation* *Management (accounting, etc.)* *Databases*	Specific computers Personal Computers+ I/O boards PLCs Digital regulators *Industrial Control* *Flight simulators* *Robotics*
EMBEDDED		Microprocessors-based boards + I/O boards + VME bus PC's + I/O boards + ISA bus Microcontrollers *Appliances* *Aeronautics* *Mobile robotics* *Mobile phones*

1.2. Embedded Systems

- Based on programmable devices
  (e.g. microcontrollers, DSPs….)
- In general, they are real-time reactive systems:
  - They react to external events
  - They keep continuous interaction
  - They are continuously running
  - Their work is subjected to external time constraints
- They do concurrently several tasks

1.2. Embedded Systems

◆ Embedded system examples

- Consumer electronics
  - CD players, HIFI, television, ...
  - Washer machines, fridges, dishwashers, ...
- Automotive
  - Speed control, air conditioning, etc.
  - ABS, ASR, Electronic fuel injection
- Telecommunications
  - Mobile phone
- Avionics, Space
  - Flying computers
  - Path-finder
- Defense
  - Bombs and intelligent missiles
  - Vehicles, ...
- Instrumentation

1.2. Embbeded Systems: Features

- **Concurrency**
  - All the tasks carried out by the system under control work simultaneously
  - The control system has to generate simultaneously the control actions
  - If there is only on processing unit: multiprocessing techniques are required, by using real time operating systems
  - It there are several processing units, we are speaking about a multiprocessor solution
- **Reliability and safety**
  - A fault in a control system can drive the controlled system to behave dangerously or uneconomical
  - It is important to guarantee that if the control system fails, the system remains in a safe controlled state: to anticipate potential design errors and exceptions

1.2. Embbeded Systems: Features

- Low power
  - Many of these systems are powered by batteries.
  - Less consumption => greater autonomy
  - In many cases low voltage (3V) is needed
- Low weight
  - Desirable feature in portable systems
  - It not only depends on the onboard computer and its periphery but also on the sup
- Low prices
  - Related to consumer electronics and other devices with very competitive markets
- Small size
  - The dimensions of an embedded system depend not only on itself but also on the space available on the system that controls and / or monitors

1.3. Design of Digital Systems

- Combinational/Sequential integrated circuits
  - Big space, delays, difficult redesign.
- Full-custom circuits
  - Very expensive design, slow process of debugging
- Semi-custom circuits
  - ASIC (Application Specific Integrated Circuit)
  - Created from standard cells from the library, for a specific application.
  - Easy design modification.

1.3. Design of Digital Systems

- Standard circuits
  - ASSP circuits (Application Specific Standard Part).
  - Originally designed for a client and then offered to the general public
  - Microcontrollers and Microprocessors
    - Generic processor with embedded devices for specific applications…
  - DSPs
    - Device for Digital Signal Processing
    - It has been designed for carrying out a small set of operations with a large amount of data.

1.4. The Microprocessor

- From the wired machine to the programmed one
  - WIRED:
    - Mainly simple logic gates
    - According to the inputs it is deterministic, very rigid with constant output
  - The technology was introducing more complex logic functions
    - Hard its implementation
    - A huge amount of integrated circuits is needed (multiplication, division, n order roots)

✌ At the early 70 the PROGRAMMED MACHINE became only one electronic circuit: the MICROPROCESSOR

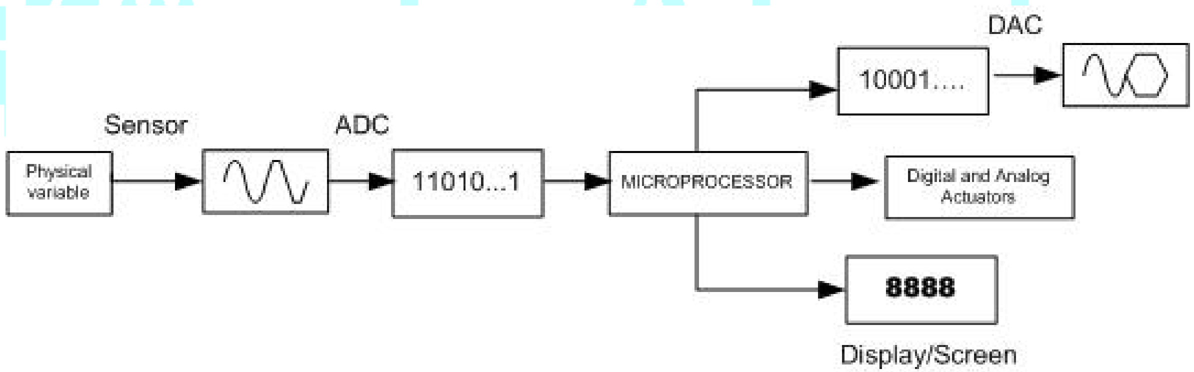
1.4. The Microprocessor

- General purpose circuit
  - It is a very versatile chip, easy to adapt a multiple applications, limited by the designer:
    - Logic functions (AND, OR,...)
    - If a specific function is not implemented, it can be obtained by the combination of the existing ones
- Programmable: it works by means of a set of basic steps
  - Each step is called instruction
  - Each information element is called data
  - Program: it is a structured set of instructions

If the program is changed, the functionality changes accordingly

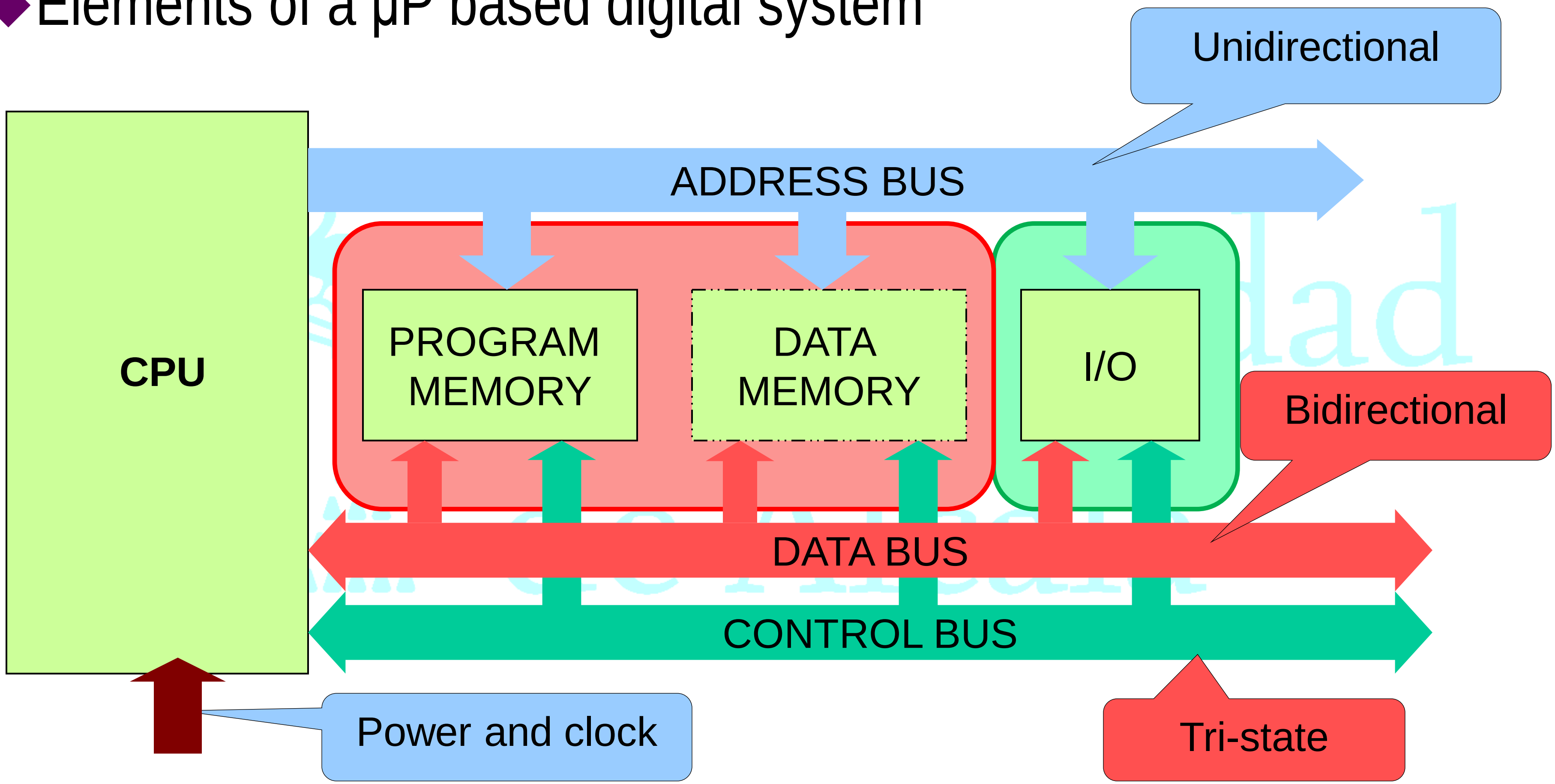
1.4. The Microprocessor

- Advantages of the microprocessor (uP)
  - By changing the program a new function is obtained. In wired systems it is required to change the design, and some electronic circuits
    - Much easier to debug and to optimize applications
    - Easy to update versions
    - Easy to adapt the design to a different application
    - Easy to design digital electronic circuits
  - It is possible to work with analog signals by using A/D and D/A converters



1.4. The Microprocessor

◆ Elements of a µP based digital system



1.4. The Microprocessor

- The µP needs memory enough to store both instructions and data (variables and constants) of a program
  - Instructions and constant data are stored in non-volatile memories (their contents are preserved without power). Called program memory, it can only be read or programmed (not written)
  - Variable data are stored in volatile memories (their contents are lost with power down). Called data memory, it can be read and written

1.4. The Microprocessor: Differences with the Microcontroller

- A **microcontroller (µC) is a chip** that includes:
  - the processor (µP, CPU)
  - different types and amounts of memory and
  - various input/output interfaces and peripherals
  - All of them interconnected by uni/bidirectional busses
- **The main difference between µP and µC:**
  - The µC includes in a single chip all elements needed in a digital system, therefore achieving more integration and lower price.

1.4. The Microprocessor: Differences with the Microcontroller

- More differences between **μP** and **μC** :
  - Lower time to marked when implementing a project in a μC
  - In former μC all operations in the ALU where developed using an accumulator
    - The accumulator output is connected to one of the ALU's inputs, being always therefore one of the operands
    - Instructions with a single operand (clear, increment, decrement, invert) operate with the accumulator

1.5. Inputs / Outputs

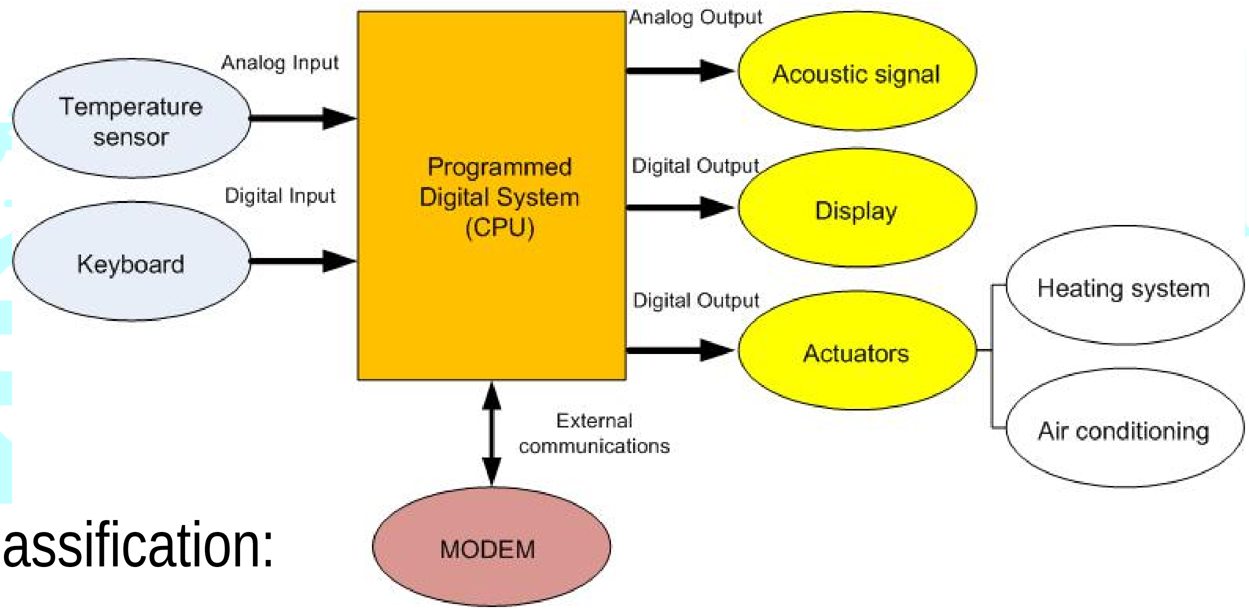
Inputs / Outputs(I/O)

- The reference for the interchange of information is the CPU.
  - I/O: the data or information that is passed into or out of a CPU
  - CPU takes an external data from the external system *Input operation*
  - CPU gives the data to the external system *Output operation*
- µP external access are carried out through the buses
  - I/O devices can be connected to the main system buses
  - Or can be a special subsystem depending on the main system.

1.5. Inputs / Outputs

Example: domestic heating system

- µP external access are carried out through the buses



- I/O classification:
  - *Directly with the environment under control (analog or digital I/O)*
  - *With the user (analog or digital I/O)*
  - *With other digital systems* (this improves the capabilities of the whole system)

Devices classification

- Output
  - Capability of holding data. Example: Latch
- Input
  - They need tri-state outputs
- Bidirectional
  - Both features in the same device

1.5. Inputs / Outputs. Interface structure

- Interface circuits
  - They make possible transition between two different systems
- Interface structure
  - In general, there are two options for the design.
    - General purpose circuits (standard circuits such as logic gates, latches, …)
    - Special circuits designed for a specific function (e.g. USB adapter)
  - The CPU "sees" the interface circuits as a group of registers located (mapped) in specific addresses.

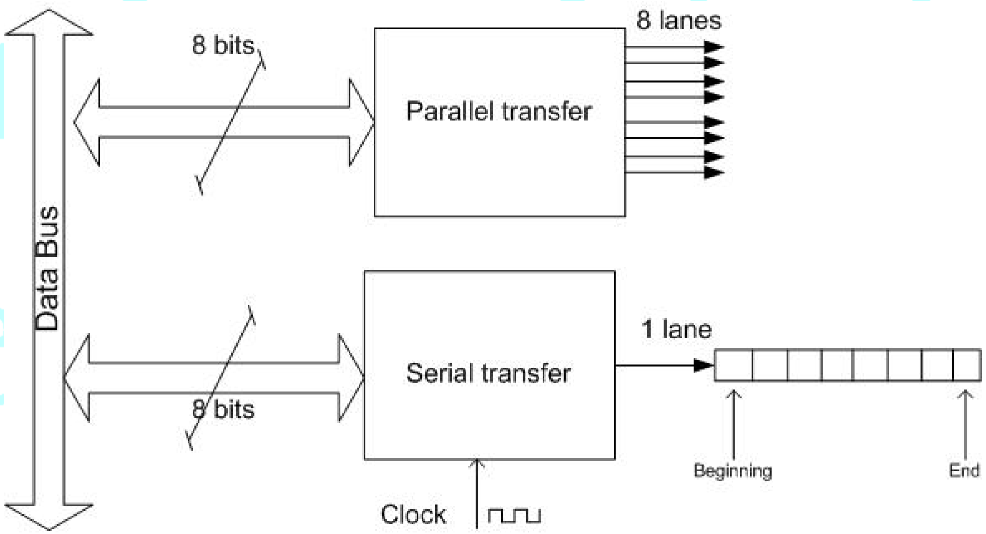
1.5. Inputs / Outputs. Interface structure

Digital Interfaces

- They only manage digital information.
- In general, there are two kinds for transferring information:
  - **Parallel data transfer**:

    A group of *n* bits are transferred simultaneously.
  - **Serial data transfer**:

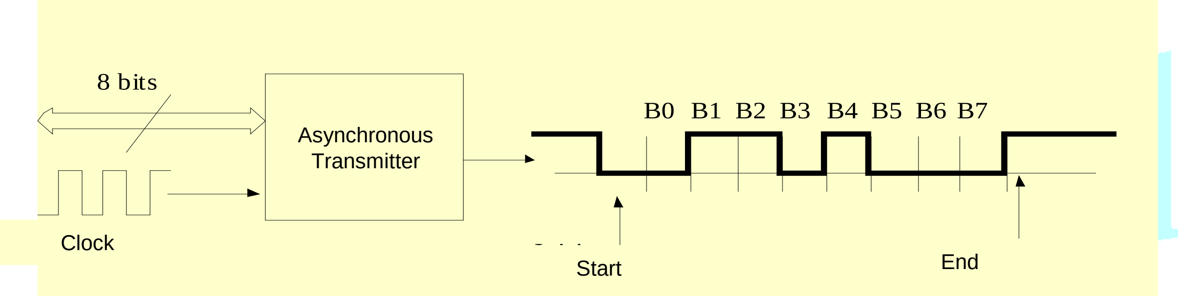
    The bits are transferred one by one. It is needed time or synchronism information for understanding the data without errors..



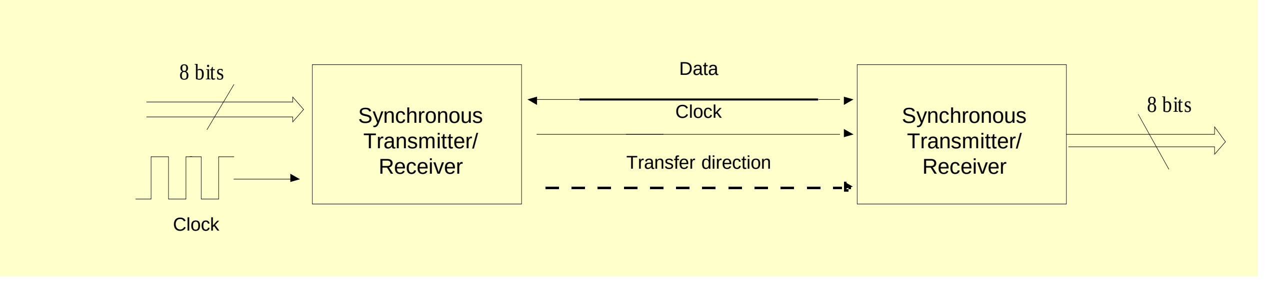
Advantages and disadvantages?

Digital interfaces

- Asynchronous serial:



- Synchronous serial:



1.5. Inputs / Outputs. Interface structure

Analog interfaces

- They are circuits that facilitate the conversion between numerical codes (related to the digital system) and the multiplicity of instant values of the analog signals
  - Circuits: Digital/Analog Converter (DAC, D/A) and Analog/Digital Converter (ADC, A/D)
- An important parameter related to A/D and D/A is the number of bits of resolution and the sample frequency

1.5. Inputs / Outputs. Interface structure

I/O Interface and peripherals addressing

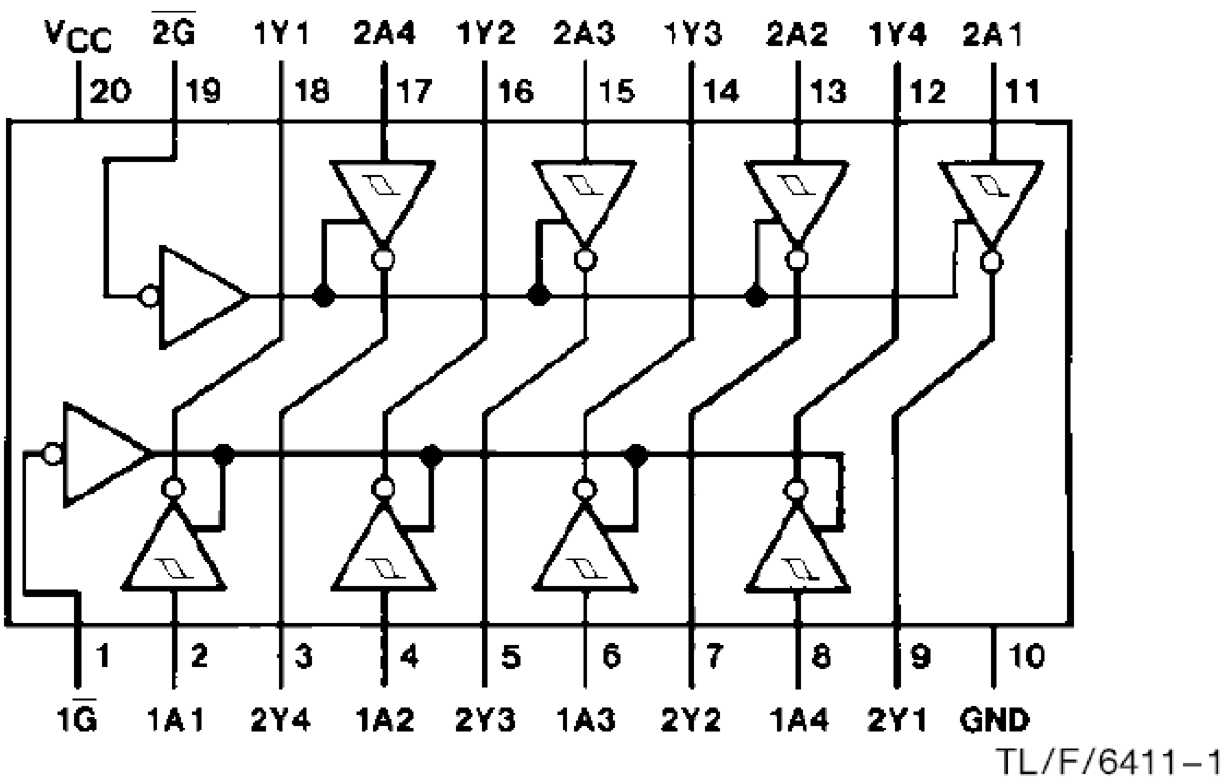
- For the microprocessor the interface is a group of “registers”
- For working with the interface, it is needed to read or write the registers
- Depending on the microprocessor, Inputs and Outputs can be:
  - mapped in memory (standard accesses to the registers)
  - Out of the memory map (special instructions for accessing)

1.5. Inputs / Outputs. Interface structure

◆ Buses accessing

- Interconnection electrical problems
  - Unidirectional Buses. (fan-out, fan-in)
  - Bidirectional Buses. It is needed arbitrations techniques to prevent conflicts (who is using the bus and when).
- Two or more devices connected to the same bus never can transfer simultaneously information through the bus. Solutions*:*
  - Integrated circuits with high impedance controlled by the selection of the chip (CS, *chip select signal*) or output enable (OE = *Output Enable Signal*).
  - Devices without high impedance outputs can use additional tri-state buffers with enable logic. .

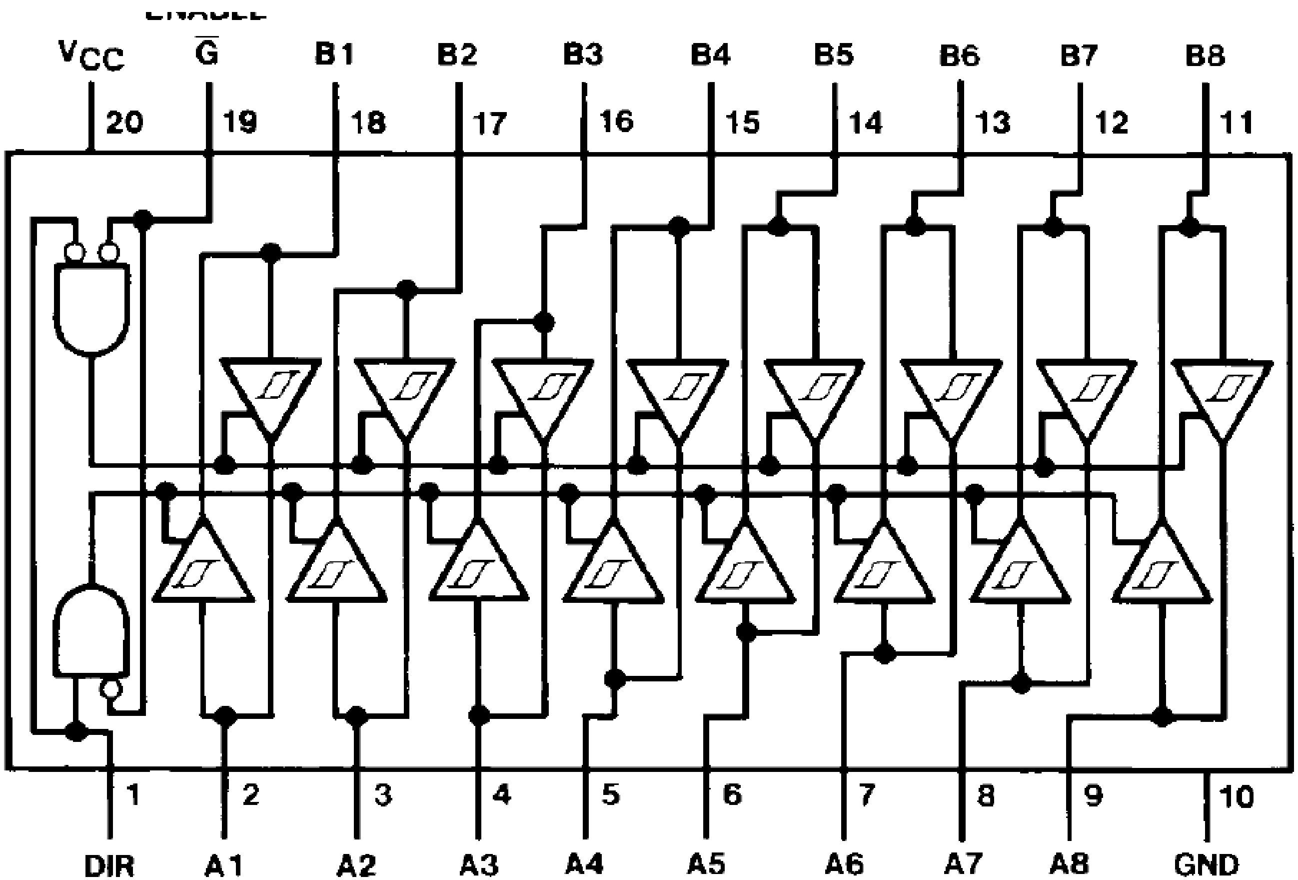
◆Circuits



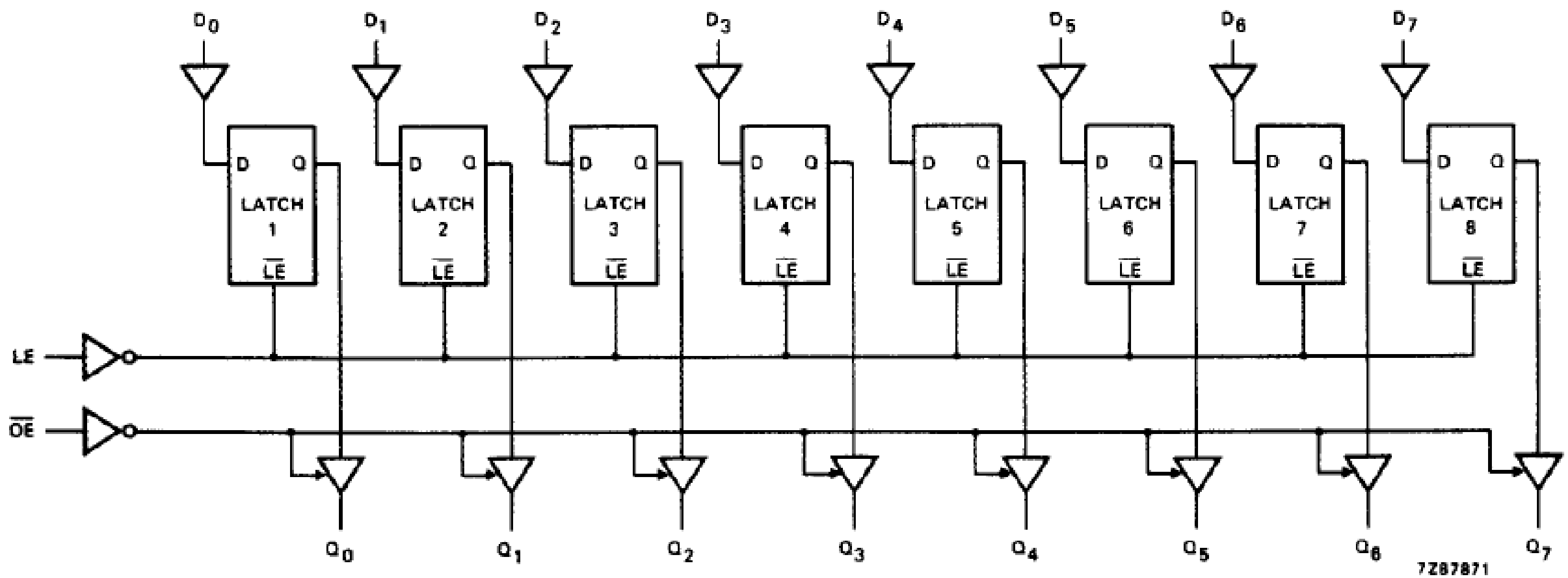
VCC
2G
1Y1
2A4
1Y2
2A3
1Y3
2A2
1Y4
2A1
20
19
18
17
16
15
14
13
12
11
1
2
3
4
5
6
7
8
9
10
1G
1A1
2Y4
1A2
2Y3
1A3
2Y2
1A4
2Y1
GND
TL/F/6411–1

1.5. Inputs / Outputs. Interface structure

◆Circuits



◆Circuits


D0
D1
D2
D3
D4
D5
D6
D7
D Q
LATCH 1
LATCH 2
LATCH 3
LATCH 4
LATCH 5
LATCH 6
LATCH 7
LATCH 8
LE
OE
Q0
Q1
Q2
Q3
Q4
Q5
Q6
Q7
7Z87871

1.6. Microprocessor Evolution

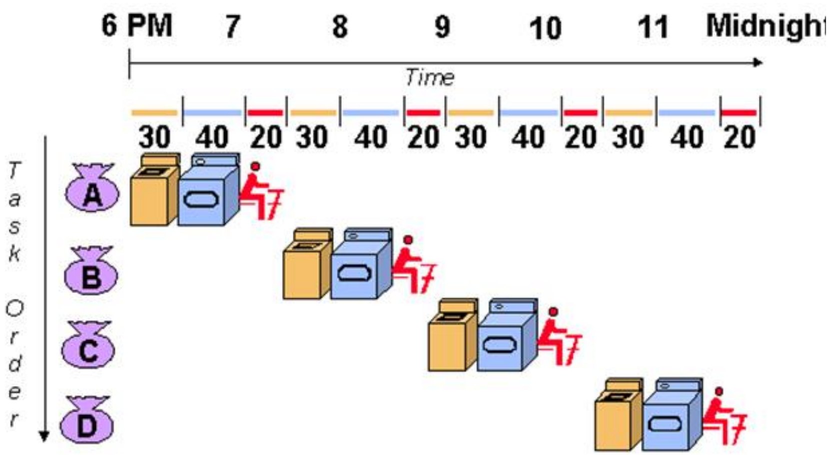
- Evolution based on ideas, and not only on the technology
  - At the beginning the evolution depended only on the technology
    - Goal: to increase the clock frequency
  - Efficiency is affected for more parameters:
    - Memory accesses (bottleneck)
    - Input/Output operations
    - Compilation
    - Operating System Overload
    - CPU

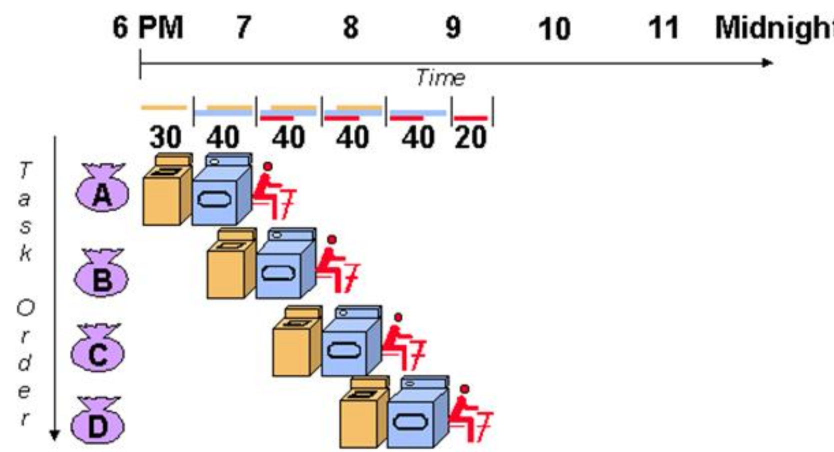
1.6. Microprocessor Evolution

- Von Neumann's machine had a single functional unit
- CISC processors:
  - Complex Instruction Set Computer
  - Short programs with complex instructions (each instruction does many things)
  - Very sophisticated operations:
    It reduces the gap between “High level” and ASM programming
  - A few number of instructions, but a lot of machine cycles
  - More complex functional units, based on microcode
  - Memory Operations (LOAD/STORE): Few internal registers
  - Simple compilers

1.6. Microprocessor Evolution

- Segmentation
  - Without finishing one instruction, another starts to be processed





1.6. Microprocessor Evolution

- New philosophy
  - New compilers
  - Machine cycles as fast as technology permits
  - More operations in one machine cycle
  - The simple decoding and the segmented execution are more important than the code size (only one instruction format)
  - New words appear in the processor design:
    - Super-segmentation and superscalar architectures
    - Goal: to increase the number of simultaneous operation (PARALELISM)

1.6. Microprocessor Evolution

- RISC processors:
  - Reduced Instruction Set Computer
  - Long programs
  - Simple CPU
  - Small execution time of the instructions
  - Easily Pipelining / Segmenting (PARALELISM)

1.7. Developing Tools

- Simulator
  - It is a software that permits to simulate the behavior of a program. It imitates the behavior of a microprocessor or a microcontroller.
  - It permits to visualize and modify the registers and the memory content
  - Real-time functionalities are not available
  - In general, physical and time aspects are no considered
  - The running speed is lower than the one with the real device

1.7. Developing Tools

- On-chip debugging
  - It is needed a special software running in the device, and a communication port for connecting with a computer.
  - Specific ports for this task:
    - JTAG (Joint Test Action Group) is a method of accessing memory and CPU resources without having an application running on the target
    - BDM or background debugging mode also achieves this objective
  - The debugging application slows down the program
  - It is easy to visualize the real content of the memory, registers, etc.
  - Other features: step-by-step execution, break points, etc.