Distributed & Embedded Real-Time Systems
(0640751)

Lecture (2)

Classification of Real-Time Systems

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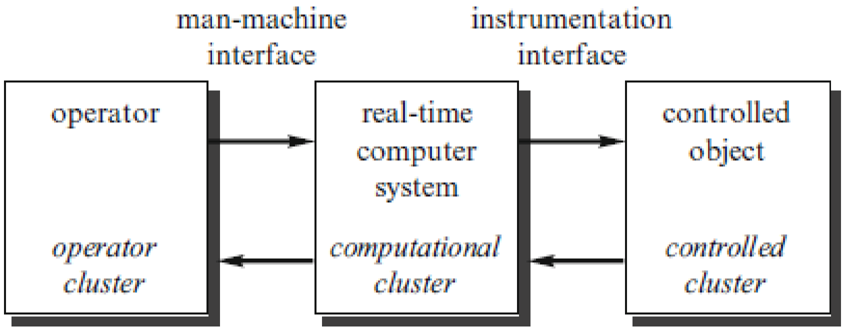
Lecture Outline:

- Historical background.
- Definition: Real- time System, Distributed system, Embedded systems?
- Elements of a real-time system.
- Classification of real-time systems.
- Characteristics of Distributed and Embedded real-time systems.

What is a Real-Time System?

➢ According to Oxford dictionary :

"Any system in which the O/P is produced is significant."



➢ Alternative definitions :

- A RTS reads I/Ps from the plant and sends control signals to the plant at times determined by plant operational C/Cs.
- RTSs are those which must produce correct responses within a definite time limit.
- A RTS is any information processing system that has to respond to externally generated signal within a finite and specified period.
- A RTS is a computer system where the correctness of the system behavior depends not only on the logical results of the computations, but also on the physical time when these results are produced.

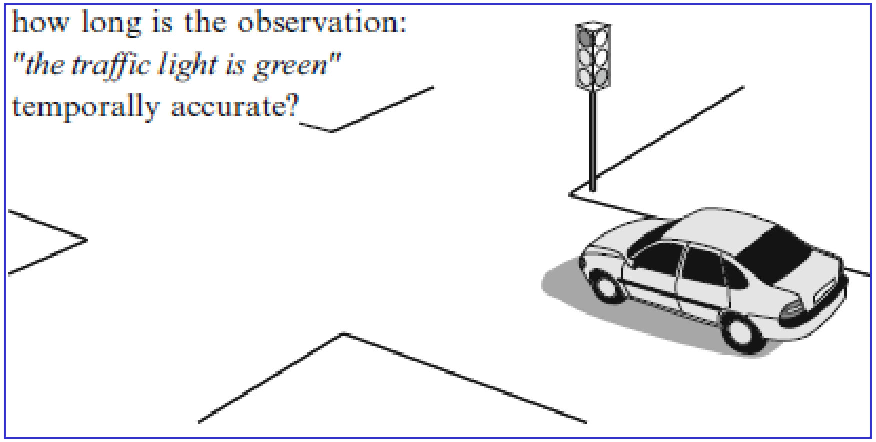
- A system, where correct timing behavior is strongly related to functionality, performance and reliability
- A computer system is a real-time one if it explicitly manages resources in order to meet timing constraints.
- A system that is synchronous with the interacting environment.
- In real-time systems:
- **Timing of actions is essential:** Compare with table tennis, air bag, engine control and music.
- **Age of data is essential:** Compare with a weather report: sample data, compute, actuate - when does the data stop to be valid?

Notes:

- Different consequences depending on context!
- Different types of timing requirements
- Delays need to be controlled!

Requirements on a real-time system:

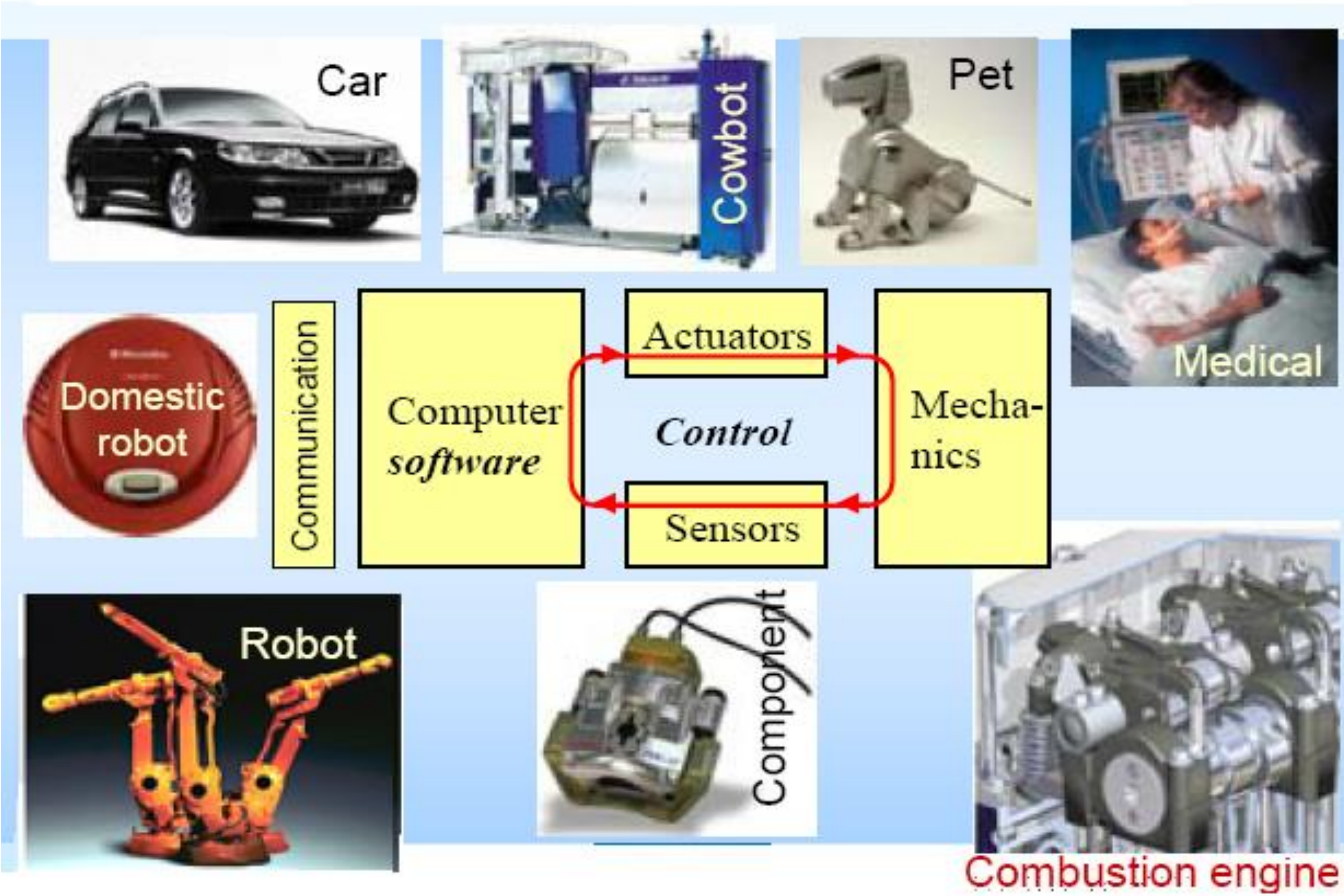
1. Sufficiently fast.
2. Predictable resource sharing and timing!



Historical Background:

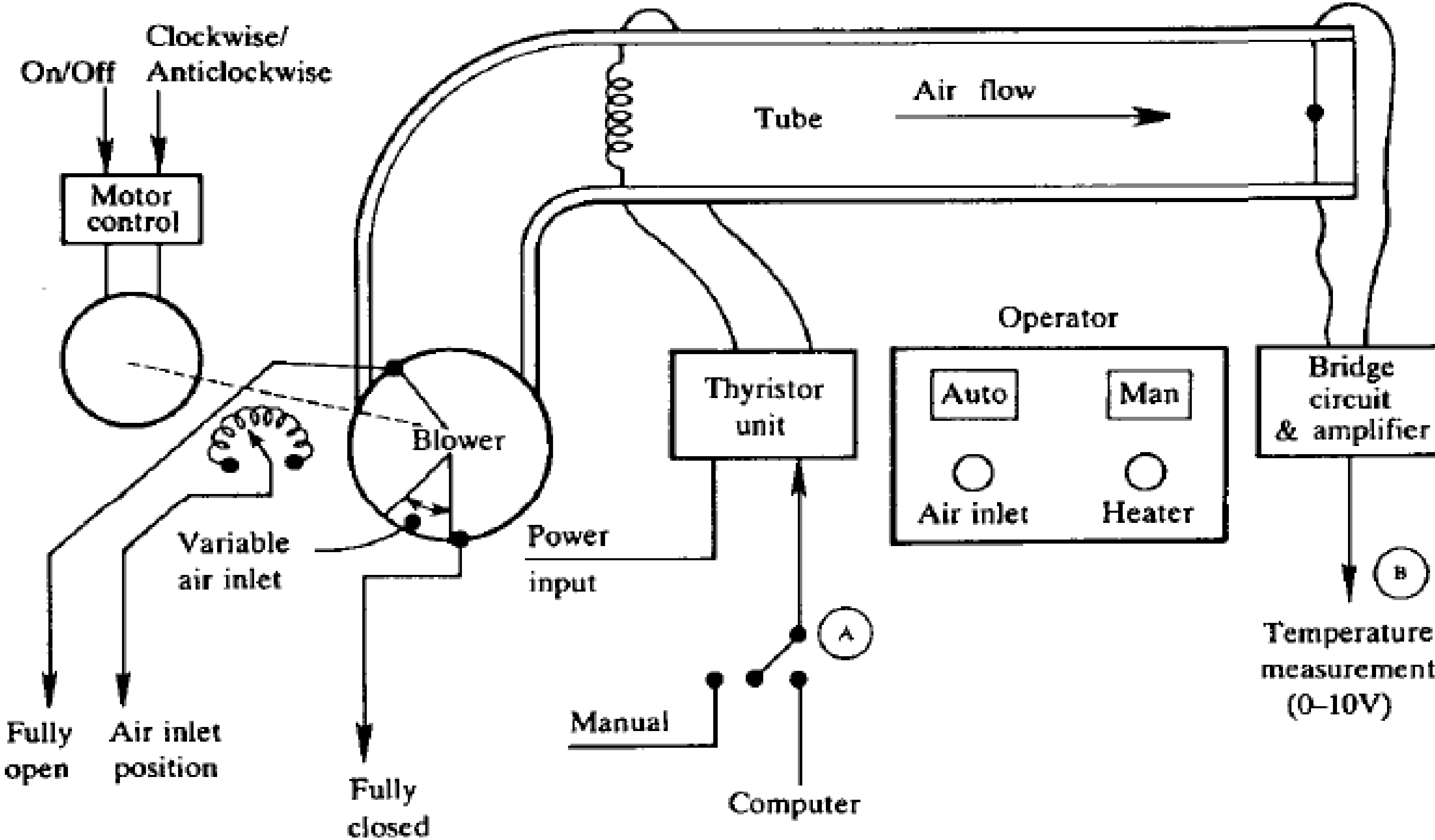
- Brown and Campbell (1950) : (in paper only)
- Using a computer operating in real-time as part of a control system . (analog computing elements)
- The 1st digital computers developed specifically for R.T.S. were for airborne operating. in 1954 a digital computer was successfully used to provide an automatic flight and weapons control system .
- The 1st industrial installation of a computer system was in September, 1958 for plant monitoring at power station in sterling , Louisiana .
- The 1st industrial computer control installation was mad by the Texaco company who installed an RW-300 system at their port Arthur refinery in Texas on 15/03/1959
- The 1st DDC computer system was the Ferranti Argus 200 system installed in November, 1962 at the ICI, Lancashire, UK. It has 120 control loops and 256 measurements .
- The advent of the Microprocessor in 1974 made economically possible the use of DDC and distributed computer control systems.

Real-Time Systems



Elements of a Real-Time System:

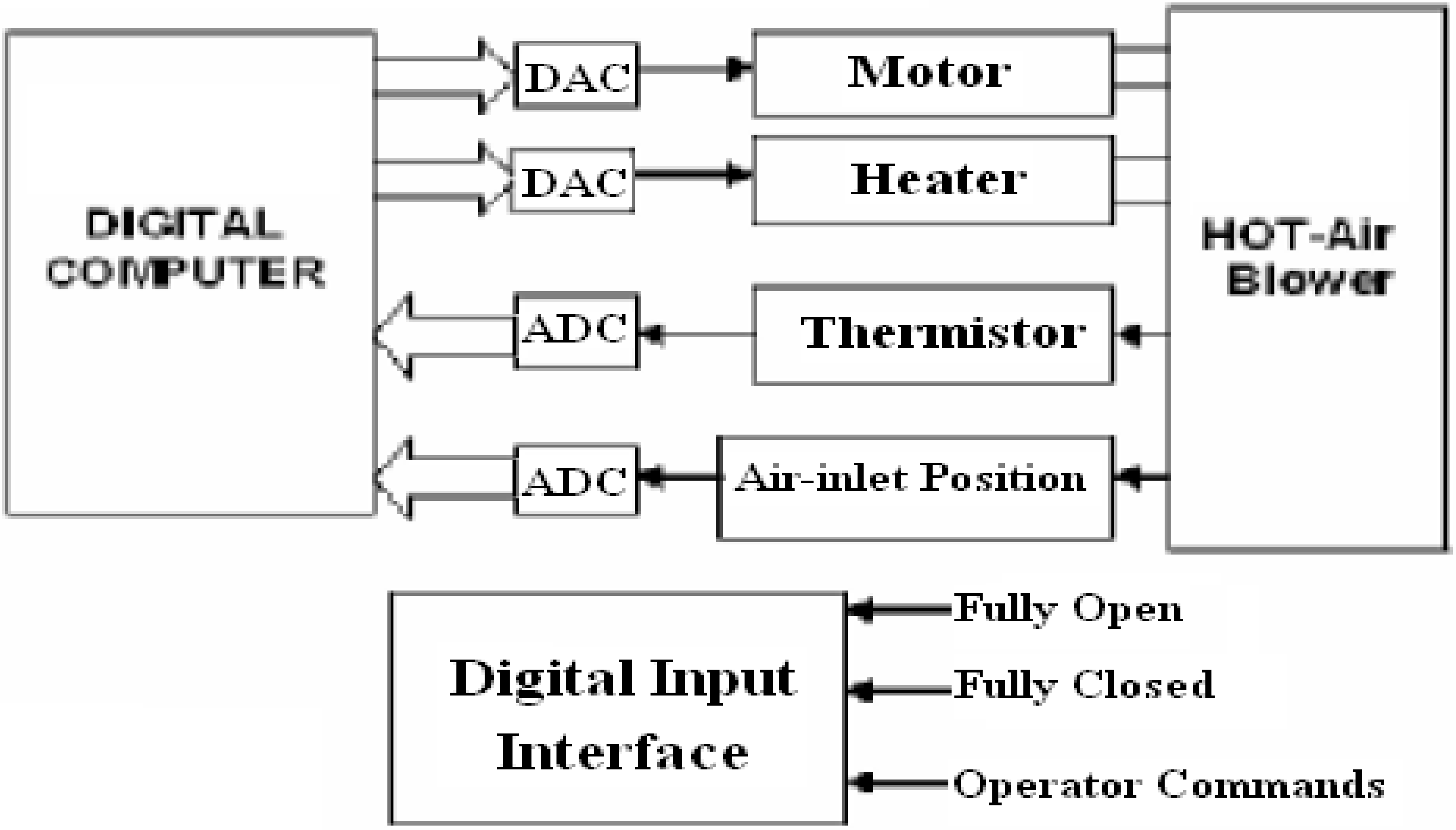
A simple plant – a hot-air blower.

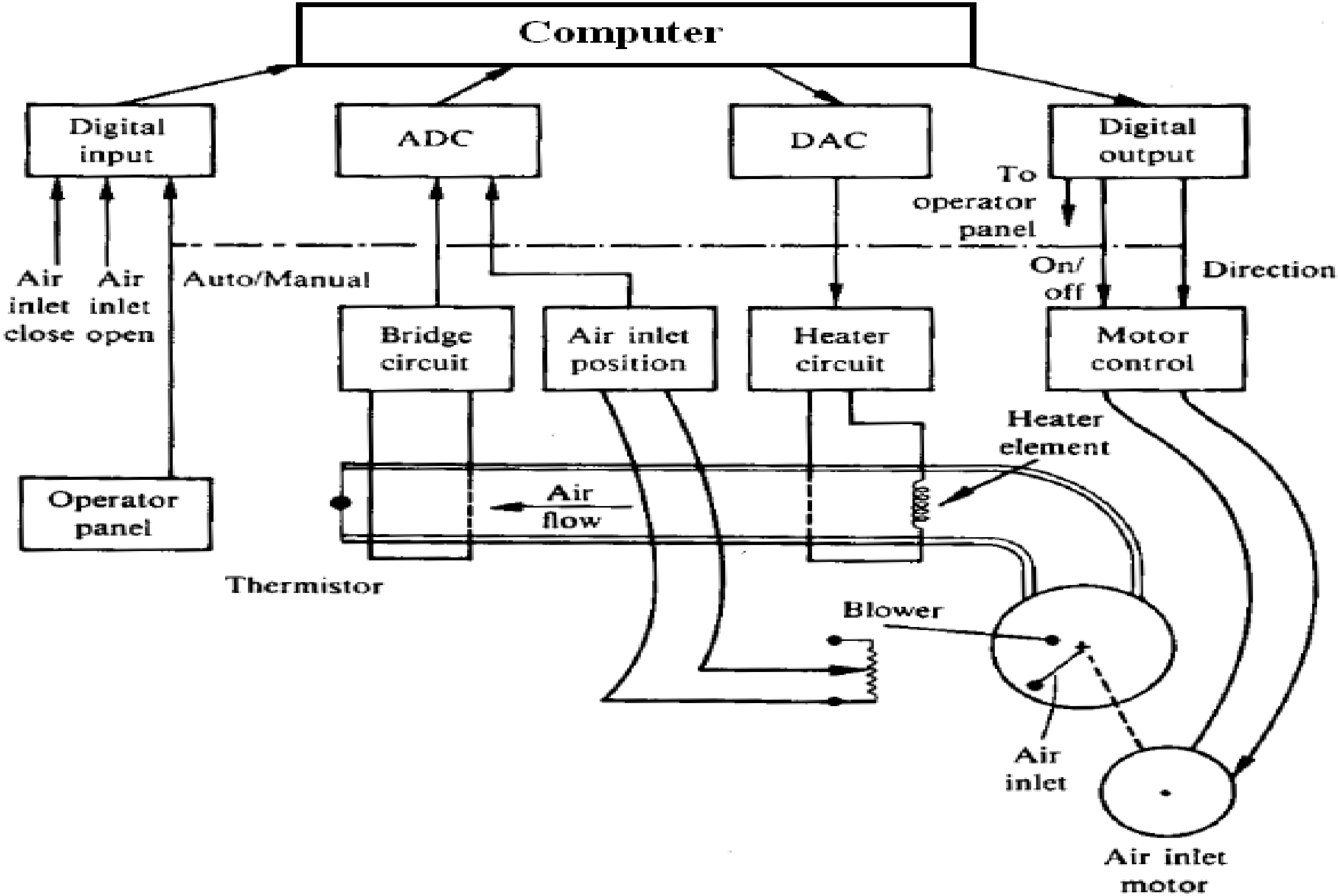


Direct Digital Control (DDC):

- A centrifugal fan blows air over a heating element and into a tube.
- A thermostat is used to detect the temp.
- The position of the air-inlet cover to the fan is adjusted by a reversible DC motor (constant speed).
- A potentiometer is attached to the air-inlet cover .
- Two 8-switches are used to detect when the cover is fully open or fully closed .
- The operator is provided with a panel from which the control system can be switched from automatic to manual control panel. Lights indicate: Fan ON, Heater ON, Cover fully-open, Cover fully-closed, Auto/Manual status.
- The information is available from the plant instrument in the following two forms:
  - Analog signals : Air Temp., Fan-inlet cover position .
  - Digital signals : Fan-inlet cover position (Fully-open, Fully-closed)
  - Status signals : Auto/Manual , Fan motor ON, Heater ON

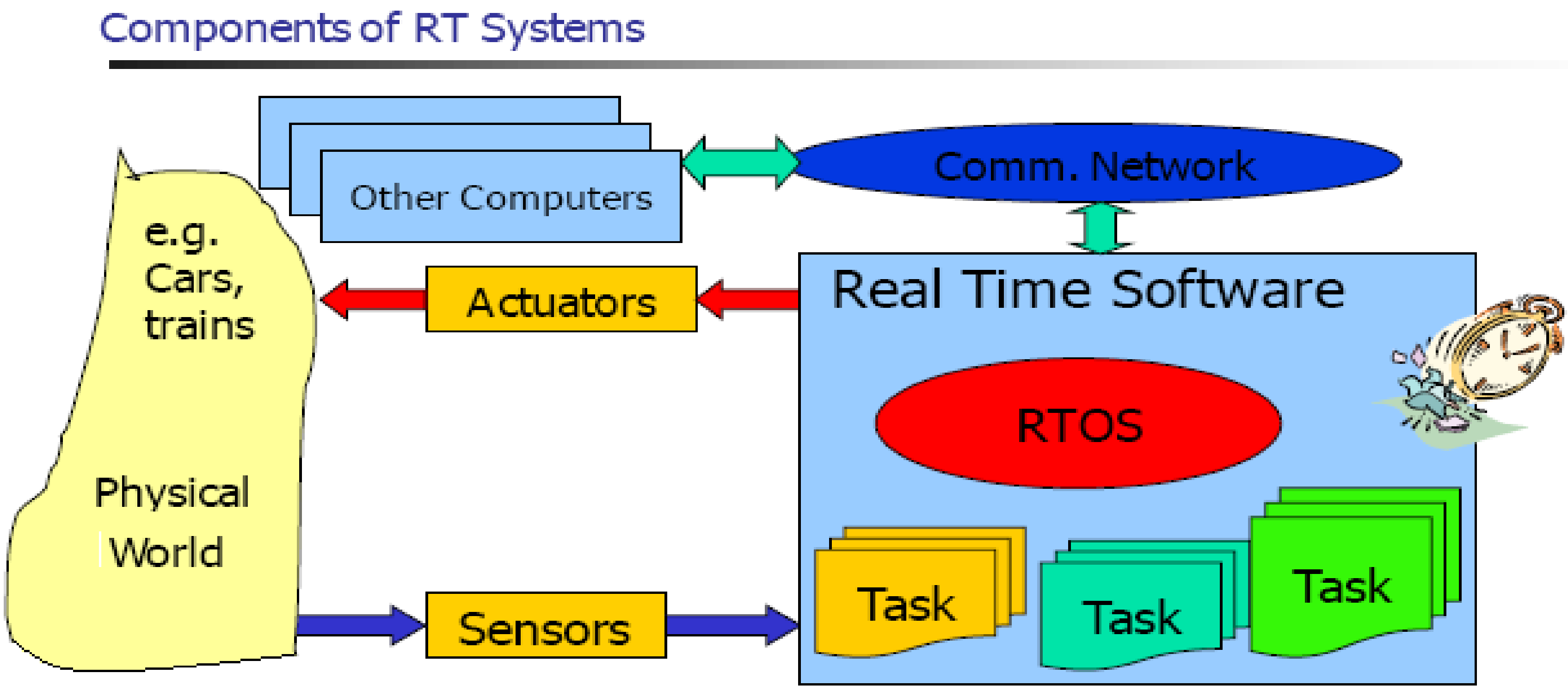
Computer Control Of a Hot-air Blower :




Computer
Digital input
ADC
DAC
Digital output
To operator panel
Air inlet close
Air inlet open
Auto/Manual
On/off
Direction
Bridge circuit
Air inlet position
Heater circuit
Motor control
Heater element
Operator panel
Air flow
Thermistor
Blower
Air inlet
Air inlet motor

Overall Structure of RT Systems:

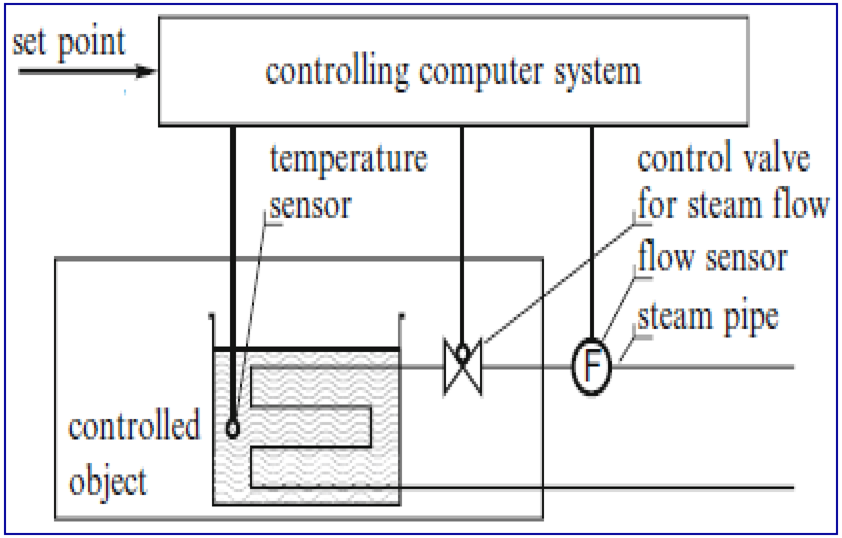
- Hardware (CPU, I/O devices, memory… etc)
  - Single CPU or more.
  - Clock selection.
- A real time Operating System: function as standard OS, with predictable behavior and well-defined functionality.
- A collection of RT tasks/processes (share resources, communicate/synchronize with each other and the environment)

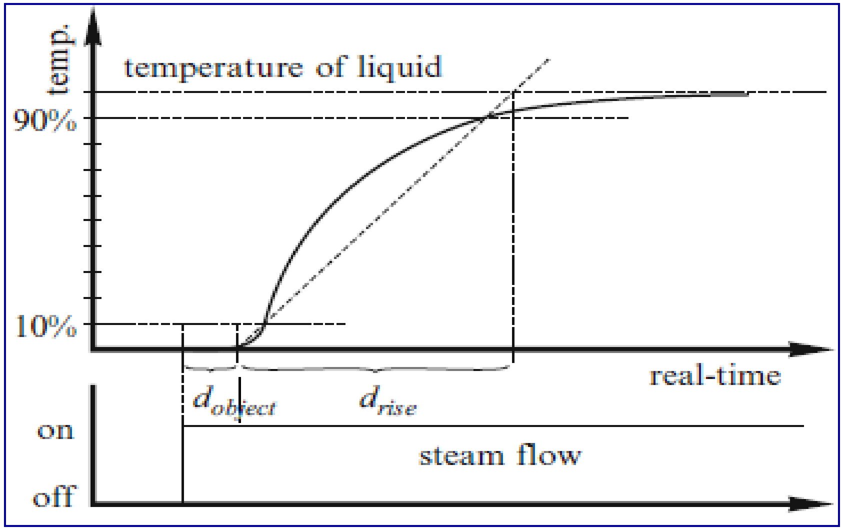


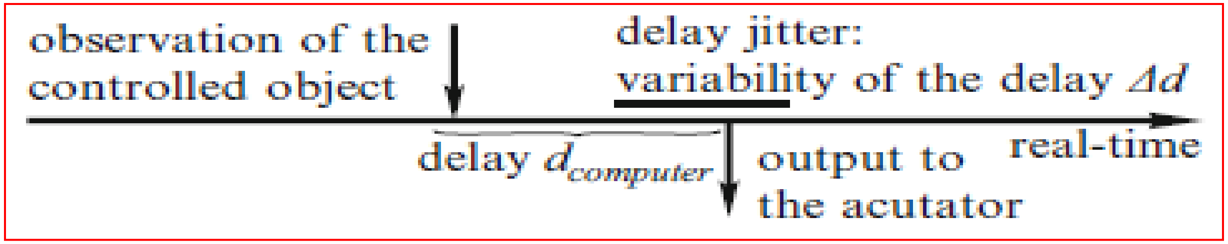
Design Requirements in RTS:

Example: (Heat exchanger connected to a steam pipe**)**

The objective of the computer is to control the valve determining the flow of steam such that the temperature of the liquid remains around the set point selected by the operator.







Dependability Requirements:

1. Reliability (R(t)): It is the probability that a system will provide the specified service until time t.

The probability that a system will fail in a given interval of time is expressed by the failure rate, measured in FITs (Failure In Time).

If a system has a constant failure rate of ƛ failures/h, then the reliability at time t is given by:

$$R(t) = \exp(-\lambda(t - t_o))$$

where (t-to) is given in hours. The inverse of the failure rate (1/ ƛ) is called the Mean-Time-To-Failure MTTF (in hours).

For Example: If the failure rate of a system is required to be in the order of (10^-9) failures/h or lower, then we speak of a system with an ultrahigh reliability requirement.

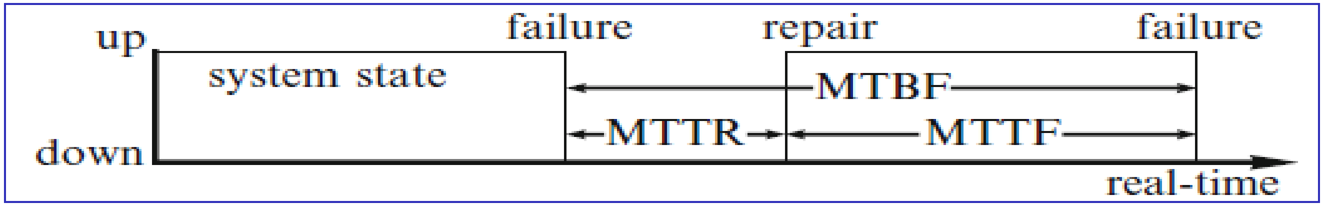
2. Safety: It is reliability regarding critical failure modes.

Note: In many cases the design of a safety-critical real-time system must be approved by an independent certification agency.

3. Maintainability: It is a measure of the time interval required to repair a system after the occurrence of a benign failure. Maintainability is measured by the probability M (d) that the system is restored within a time interval (d) after the failure.

4. Availability: It is a measure of the delivery of correct service with respect to the alternation of correct and incorrect service. It is measured by the fraction of time that the system is ready to provide the service.
In systems with constant failure and repair rates, the reliability (MTTF), maintainability(MTTR), and availability (A) measures are related by:

$$A = MTTF/(MTTF + MTTR)$$



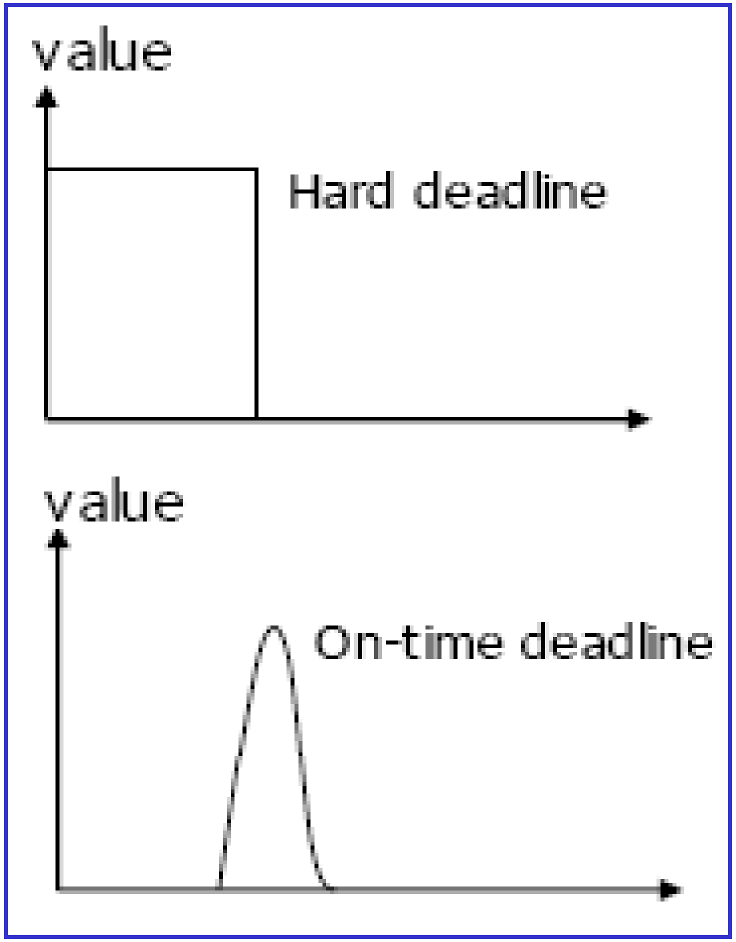
5. Security: It is concerned with the authenticity and integrity of information, and the ability of a system to prevent unauthorized access to information or services.

Classification of RTSs:

Real-Time systems can be classified as:

1. HARD REAL-TIME SYSTEM:

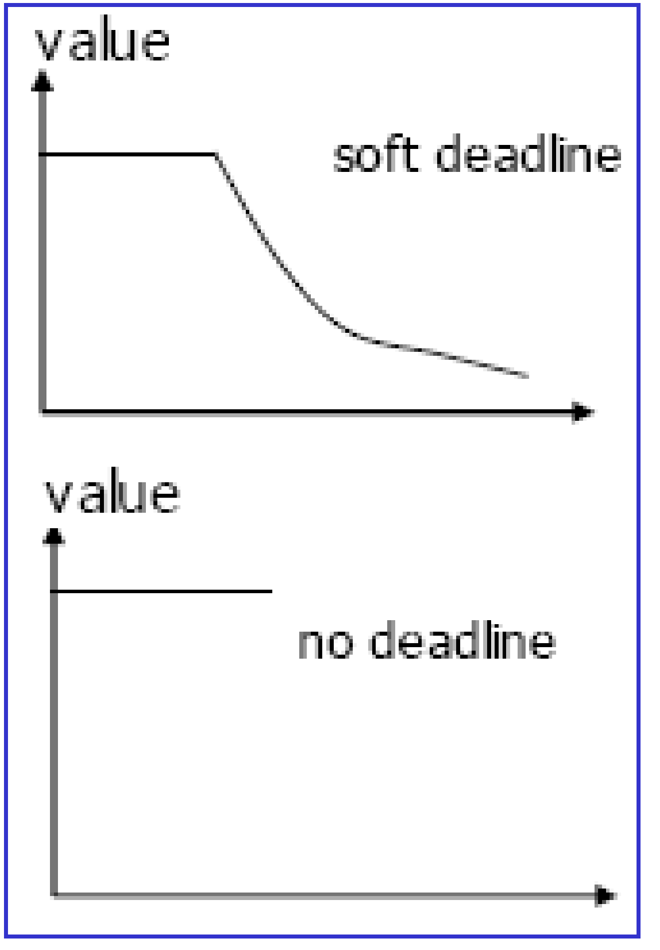
- A system that produces the results at the correct instant.
- System response occur within a specified deadline. Failure to meet such a timing requirement can have catastrophic consequences.
- Systems where it is absolutely imperative that responses occur within the required deadline. Example: Flight control systems, automotive systems, robotics etc.



Classification of RTSs: (Cont)

2. SOFT REAL-TIME SYSTEMS:

- A system whose operation is incorrect if results are not produced according to the timing constraints. Catastrophic results will happen then.
- The response times are important but not critical to the operation of the system . Failure to meet the timing requirements would not impair the system.
- Systems where deadlines are important but which will still function correctly if deadlines are occasionally missed. Example: Banking system, multimedia etc.



Hard real-time versus soft real-time systems

Characteristic	Hard real-time	Soft real-time (on-line)
Response time	Hard-required	Soft-desired
Peak-load performance	Predictable	Degraded
Control of pace	Environment	Computer
Safety	Often critical	Non-critical
Size of data files	Small/medium	Large
Redundancy type	Active	Checkpoint–recovery
Data integrity	Short-term	Long-term
Error detection	Autonomous	User assisted

Time-Triggered & Event-Triggered Systems:

- Synchronization between the external processes and internal actions (tasks) carried out by the computer may be defined in terms of the passage of time, or the actual time of day, in which case the system is said to be **"Time-Triggered system"** or it may be defined in terms of events, and the system is said to be **"Event-Triggered system"**.
- If the relationship between the actions in the computer and the system is much more loosely defined, then the system is said to be **"interactive system".**

Classification of RTSs :

Real-Time systems can be classified as:

1. Time-Triggered Tasks: (Cyclic and Periodic):

- The completion of the operations within the specified time is dependent on the number of operations to be performed and the speed of the computer .
- Synchronization is usually obtained by adding a clock to the computer system , and using a signal from this clock to interrupt the operation of the computer at predetermined fixed time interval .

Plant time constant → Sampling time (Ts) → Interrupt

2. Event-Triggered Tasks: (Aperiodic):

- Action are to be performed not at particular times or time intervals but in response to some event . The system must respond within a given max. time to a particular event .
- Events occur at non-deterministic intervals and event-based tasks are referred to as “a periodic” task.

Classification of Programs:

- A real-time program is defined as a program for which the correctness of operation depends on the logical results of the computation and the time at which the results are produced.

In general there are three types of programming:

1. **Sequential**: Actions are ordered as a time sequence , the program behavior depends only on the effects of the individual actions and their order .
2. **Multi-tasking**: Actions are not necessarily disjoint in time , it may be necessary for several actions to be performed in parallel .
3. **Real-Time**: Actions are not necessarily disjoint in time , and the sequence of some of program actions is not determined by the designer but the environment (by events occurring in the outside world which occur in real-time and without reference to the internal operations of the computer).

- A real-time program can be divided into a number of tasks but communication between the tasks can not necessarily wait for a synchronization signal. The environment task can not be delayed.
- In RT programs, the actual time taken by an action is an essential factor in the process of verification .

NOTES:

- RTSs have to carry out both periodic and aperiodic activities .
- RTSs have to satisfy time constraints that can be either:

  -A hard constraint , or

  -A soft (average value) constraint.
- RT software is more difficult to specify, design and construct than non real-time software .

Characteristics of a RTS:

- **Large and complex:** vary from a few hundred lines of assembler or C to 20 million lines of Ada estimated for the Space Station Freedom.
- **Concurrent control of separate system components:** devices operate in parallel in the real-world; better to model this parallelism by concurrent entities in the program.
- **Facilities to interact with special purpose hardware:** need to be able to program devices in a reliable and abstract way.
- **Mixture of Hardware/Software:** some modules implemented in hardware, even whole systems, SoC.
- **Extreme reliability and safety:** real-time systems typically control the environment in which they operate; failure to control can result in loss of life, damage to environment or economic loss
- **Guaranteed response times:** we need to be able to predict with confidence the worst case response times for systems; efficiency is important but predictability is essential

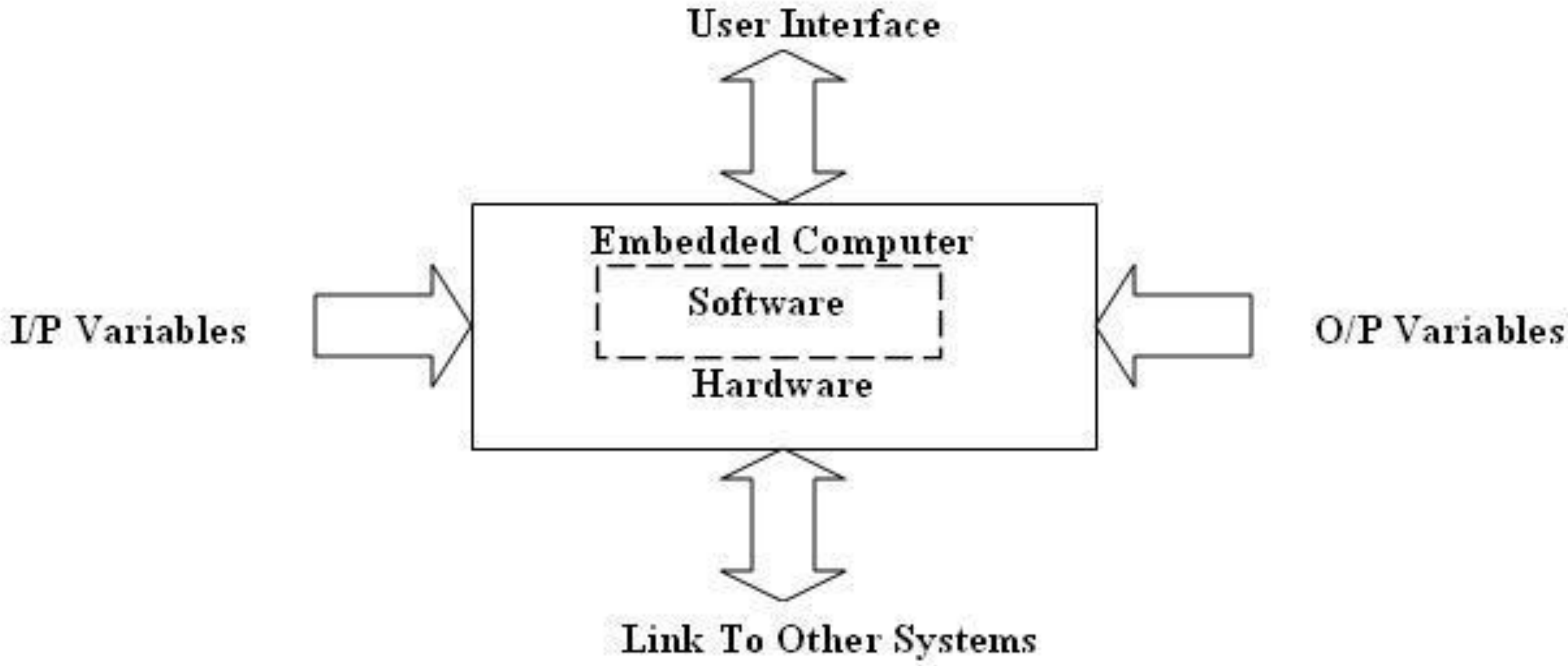
Embedded Real-Time Systems:

- Embedded system (ES) is a system whose principal function is controlled by **a computer embedded within it**.
- The word embedded implies that:

  - It lies inside the overall system, hidden from view forming an integral part of a greater whole.
  - The user may be unaware of the computer existence.
  - The computer is usually purpose designed, on at least customized, for the single function of controlling its system.

- *According to this definition: a P.C. is not an embedded system !!*
- An embedded real-time computer system is always part of a well-specified larger system, which we call an intelligent product. An intelligent product consists of a physical subsystem; the controlling embedded computer, and, most often, a man–machine interface.

- Embedded systems are found across industry and commerce, in machine control, factory automation, robotics, most modern domestic applications such as washing machines, dishwashers, ovens, central heating….
  The list has almost no end and it continues to grow.



Classification of Embedded Systems

E.S.s can be classified into 3 types:

1. **Small –Scale E.S.s:** These systems are designed with little h/w & s/w complexities and involve board-level design.
   - ✓ They use a single 8-bit, or 16-bit microcontroller.
   - ✓ They may even be battery operated.
   - ✓ An editor & assembler specific to the µC are used.
   - ✓ C– language is used for developing these systems.
   - ✓ Commonly used microcontrollers: PIC 16F8X, 8051, 6805.

2. **Medium Scale Embedded Systems:** These systems are designed with a single or few 16-bit or 32-bit microcontroller or DSPs or RISCs.

- ✓ They have both h/w& s/w complexities.
- ✓ Programming tools: RTOS, source code eng. Tool, simulator, debugger & Integrated Development Environment (IDE).
- ✓ Commonly used microcontrollers: 80X86, 68HC11XX.

3. **Sophisticated Embedded Systems:** These systems have enormous h/w & s/w complexities and may need scalable processors or configurable processors & PLAs.

- ✓ They are used for applications that need h/w & s/w co-design & integration in the final system.
- ✓ Development tools may not be available at a reasonable cist or may not be available at all. In some cases, a compiler might have to be developed for these systems.
- ✓ Commonly used microcontrollers: Intel80960, ARM7, MPC604.

Characteristics of Embedded Systems:

1. Mass Production: many embedded systems are designed for a mass market and consequently for mass production in highly automated assembly plants.
2. Static Structure: the computer system is embedded in an intelligent product of given functionality and rigid structure.
3. Man–Machine Interface: it must be specifically designed for the stated purpose and must be easy to operate.
4. Minimization of the Mechanical Subsystem: to reduce the manufacturing cost and to increase the reliability of the intelligent product, the complexity of the mechanical subsystem is minimized.
5. Functionality determined by software in Read-Only Memory (ROM), since it is not possible to modify the software in a ROM after its release, the quality standards for this software are high.
6. Maintenance Strategy: many intelligent products are designed to be non maintainable, because the partitioning of the product into replaceable units is too expensive.

7. Ability to communicate: many intelligent products are required to interconnect with some larger system or the Internet. Security is of utmost concern when there is an Internet access to the system..
8. Limited amount of energy: Many mobile embedded devices are powered by a battery. The lifetime of a battery load is a critical parameter for the utility of a system.

What is a distributed real-time system?

It is a system in which components located on networked computers communicate and coordinate their actions in real-time by way of a communication mechanism. The components interact with each other in order to achieve a common goal.

Questions to be Answered?

Page: 27, there are 21 questions to be answered within a week!