Real-Time Systems
(0630581)

Lecture: 9

Design of Real-Time Systems

General Approach

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Course Objectives:

The main objective of this unit are:

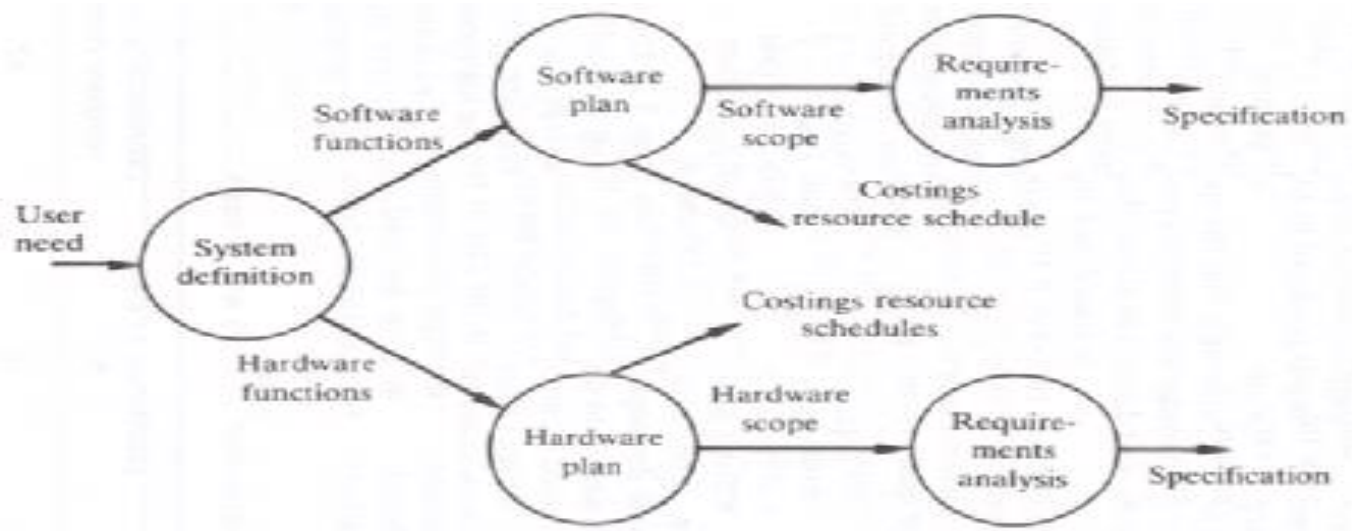
- To give an outline of a general approach to the design of computer-based real-time systems.
- To consider three approaches in designing the software of real-time systems, these are:
  - Single-program approach.
  - Foreground/background approach.
  - Multi-tasking approach.
- To show how to approach the planning and design of a real-time system.
- To illustrate the basic approaches for the top-level design of real-time software.

Real-Time Systems Design:

- The approach to the design of RTSs is no different in outline from that required for any computer-based system. The work can be divided into two main sections:
  - The planning phase, and
  - The development phase.

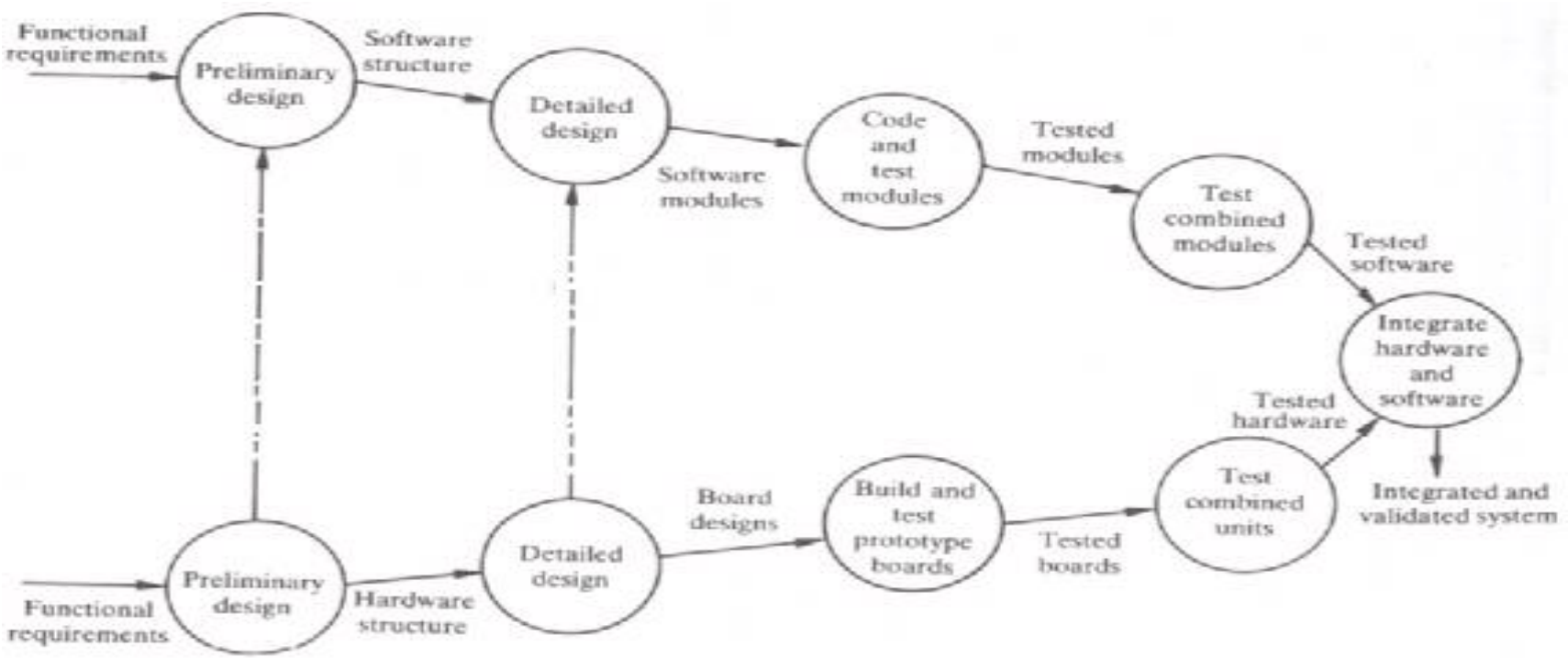
Planning Phase:

- It is concerned with interpreting user requirements to produce a detailed specification of the system to be developed and outline plan of the resources, people, time, equipment and costs.
- At this stage preliminary decisions regarding the division of functions between hardware and software will be made.



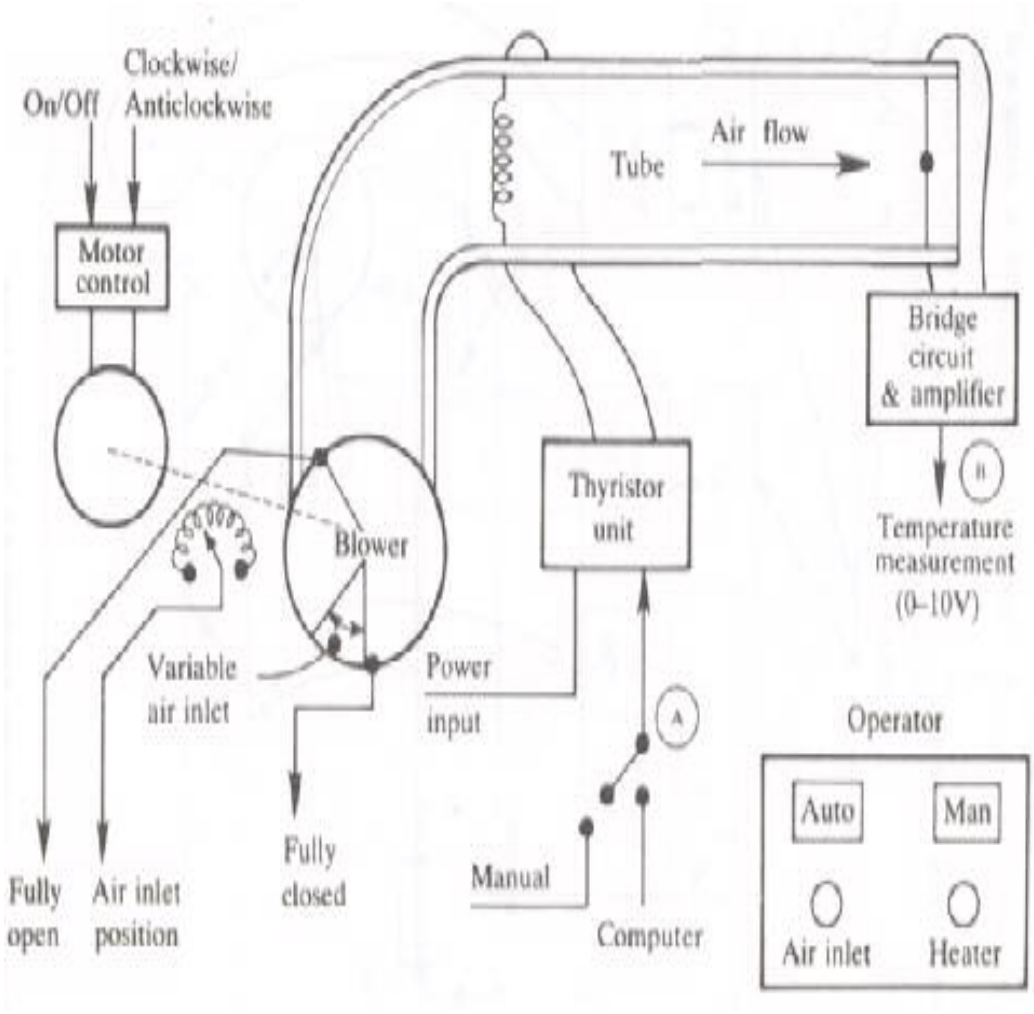
Development Phase:

- The aim of preliminary design stage is to decompose the system into a set of specific sub-tasks. The inputs to this stage are the HL specifications. During this stage extensive liaison between hardware and software designers is needed.
- The detailed design is usually broken down into two stages;
  - Decomposition into modules, and
  - Module internal design.



Specification Document:

Example: Hot-air blowers.



Display

The operator display is as shown below:

Set temperature	:nn.n °C	Date	:dd/mm/yyyy
Actual temperature	:nn.n °C	Time	:hh.mm
Error	:nn.n °C		
Heater output	:nn% FS	Sampling	
		Interval	:nn ms
Controller settings			
Proportional gain	:nn.n		
Integral action	:nn.nn s		
Derivative action	:nn.nn s		

The values on the display will be updated every 5 seconds.

Operator input

1. Set temperature = nn.n	2. Proportional gain = nn.n
3. Integral action = nn.nn	4. Derivative action = nn.nn
5. Sampling interval = nn	6. Management information
7. Accept entries	

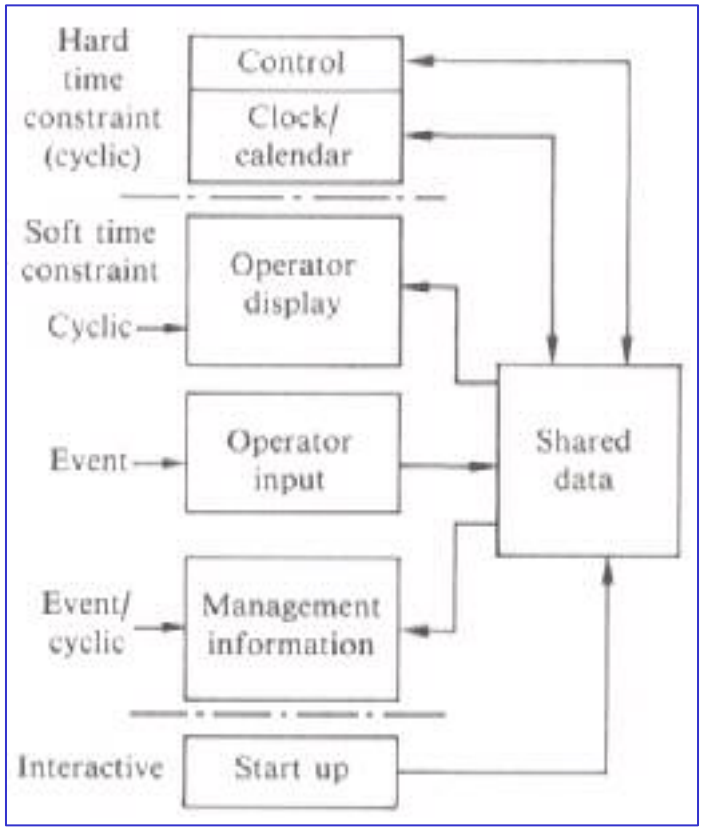
Select menu number to change

Preliminary Design:

Hardware Design: to be discussed in lecture.

Software Design:

- The required software must perform several functions:
  - DDC for temperature control.
  - Operator display.
  - Operator input.
  - Management information.
  - System start-up and shut-down.
  - Clock/calendar function.
- The control module has a hard constraint, it must run every 40 msec.
- The clock/calendar module must run every 20 msec.
- The operator display has a hard constraint in that an update interval of 5 sec is given.
- Soft constraints are adequate for operator i/p and for the management information.



Software Design:

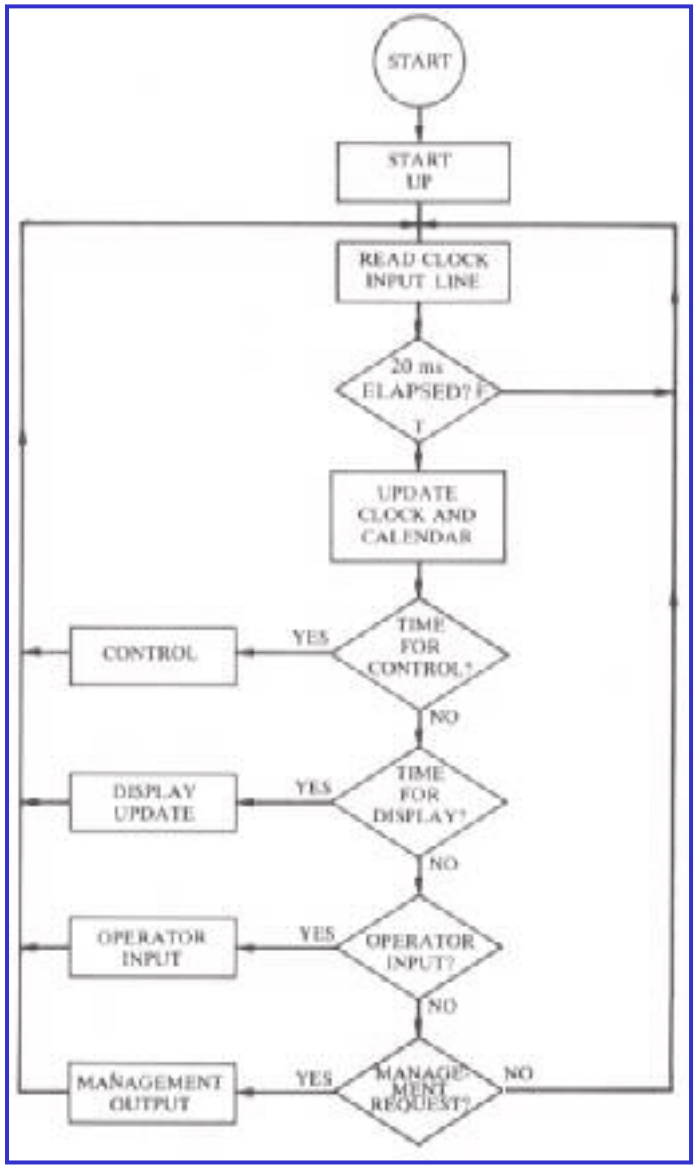
- There are several different activities which can be divided into sub-problems. The sub-problems will have to share information. To achieve this, there are three approaches:

1. Single-Program Approach:

- The modules are treated as procedures or subroutines of a single program.
- This structure is easy to program, however, it imposes the most severe of the time constraints.

Example: for the system to work the clock/calendar module and any one of the other modules must complete their operations within T. t_1, t_2, t_3, t_4 and t_5 are the maximum execution times for the given modules, then a requirement for the system to work is;

$$t_1 + \max(t_2, t_3, t_4, t_5) \angle T$$

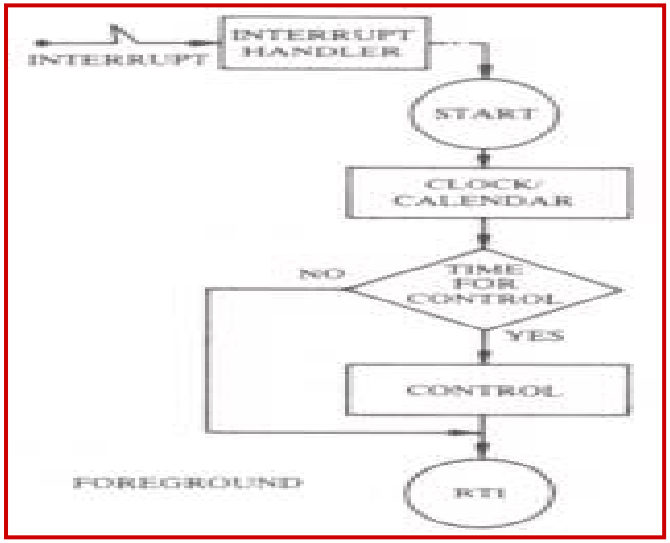


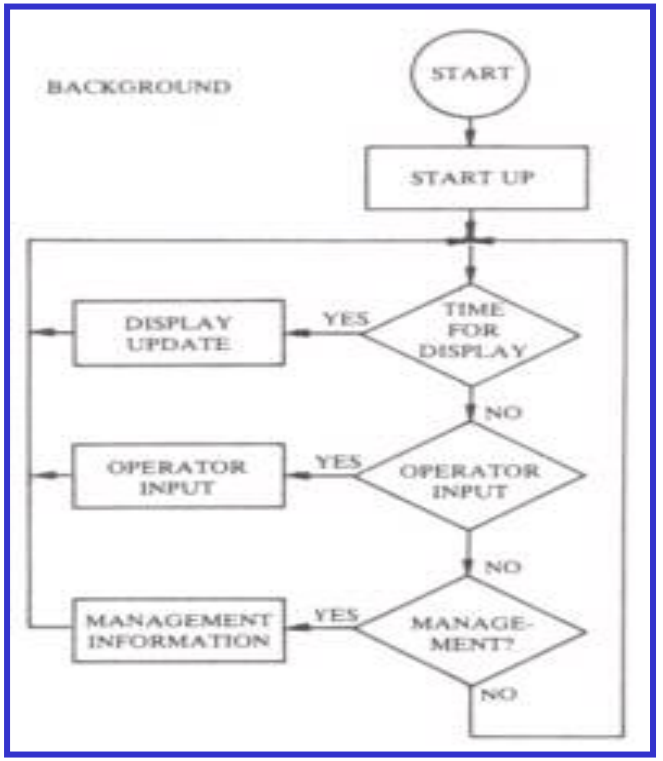
2. Foreground/Background System:

- There are advantages (less time constraints) if the modules with hard time can be separated from, and handled independently of, the modules with soft time constraints or on constraints.
- The modules with hard time constraints are run in "foreground" and the modules with soft constraints (or no constraints) are run in the "background".
- The partitioning into foreground and background usually requires the support of a real-time OS.
- A requirement for the foreground part to work is that:

$$t_1 + t_2 \angle T$$

- A requirement for the background part to work is that;
- max(t_3, t_4, t_5) is less than 10 sec.
- Display module runs on average every 5 sec, and
- Operator input responds in less than 10 sec.



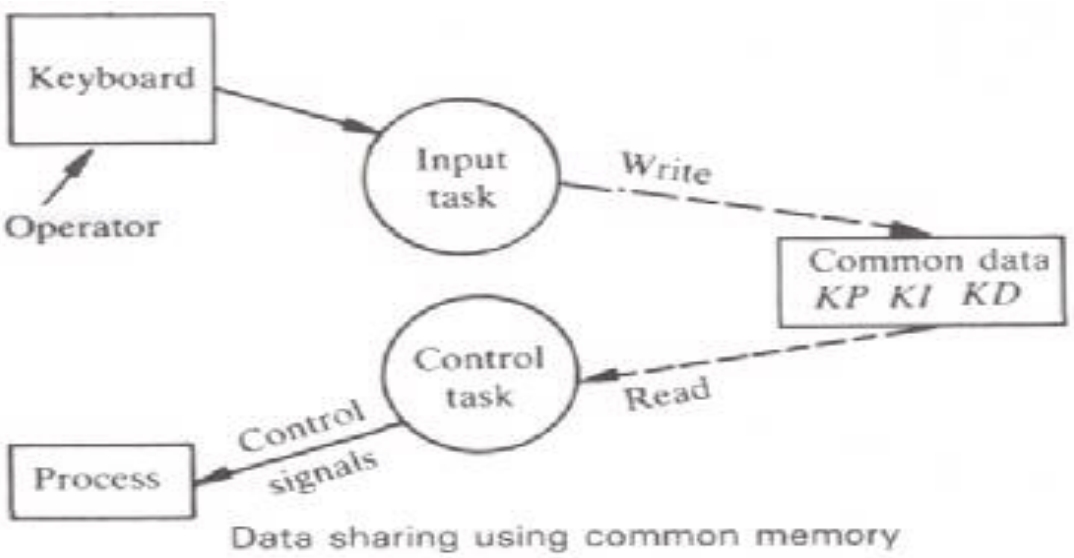


Multi-Tasking Approach:

- The design and programming of large RT systems is eased if the foreground/background partitioning can be extended into multiple partitions to allow the concept of many active tasks each can be carried out in parallel.
- The implementation of a multi-tasking system requires the ability to;
  - Create separate tasks.
  - Schedule running of the tasks on a priority basis.
  - Share data between tasks.
  - Synchronize tasks with each other and with external events.
  - Prevent tasks corrupting each other.
  - Control the starting and stopping of tasks.
- The facilities to perform the above actions are typically provided by a RTOS or a combination of RTOS and a real-time programming language.

Mutual Exclusion:

- Consider the transfer of information from i/p task to a control task. The i/p task gets the values for the controller i/p parameters (gain, Ti and Td). From these it computes the controller parameters (KP, KI, and KD) and these are transferred to the CONTROL task.
- A simple method is to hold the parameters values in an area of memory (common data area) and hence is accessible to both tasks.



Data sharing using common memory

For more information:

1. http://www.cs.ou.edu/~fagg/umass/classes/377f02/lectures.html
2. http://www.cs.umbc.edu/~younis/Real-Time/CMSC691S.htm#D