Real-Time Operating Systems (0_KRI)
Operating System Architecture

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Outline

What is a Real-Time System?

Definition

A real-time system is an information processing system which has to respond to external events both correctly and within a finite, specified period of time.

- The correctness and usefulness of the system depends not only on the logical results of its computations, but also on the time at which they are produced.
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Embedded Systems

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In a real-time system, the computer is often embedded into, and interfaced directly to, some physical equipment, and controls or monitors its operation.

- The computer receives stimuli coming from the environment, and acts on the environment by means of dedicated I/O devices: sensors and actuators.
- The reaction must take place within a time frame dictated by the characteristics of the environment itself.
- The consequences of a late or missing reaction also depend on the environment.
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Hard, Firm, Soft Real-Time

Hard Real-Time

It is imperative that reactions occur within the specified deadline, because they are useless when late and missing a deadline leads to a catastrophe. Example: pacemaker.

Soft Real-Time

Response times are still important, but it is acceptable to occasionally miss a deadline (with a low probability). The value of a result decreases as its lateness increases. Example: video streaming.

Firm Real-Time

It is acceptable to occasionally miss a deadline, but there is no benefit from late delivery of a result. Example: financial applications.

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Real-World Systems

- Often, real-world systems have both soft and hard real-time requirements.
- For example, the reaction to some warning event may have both an optimal, soft deadline which should be met most of the times, and a longer, hard deadline which guarantees that no damage takes place.
- Moreover, the term "soft" deadline encompasses several different properties, for example:
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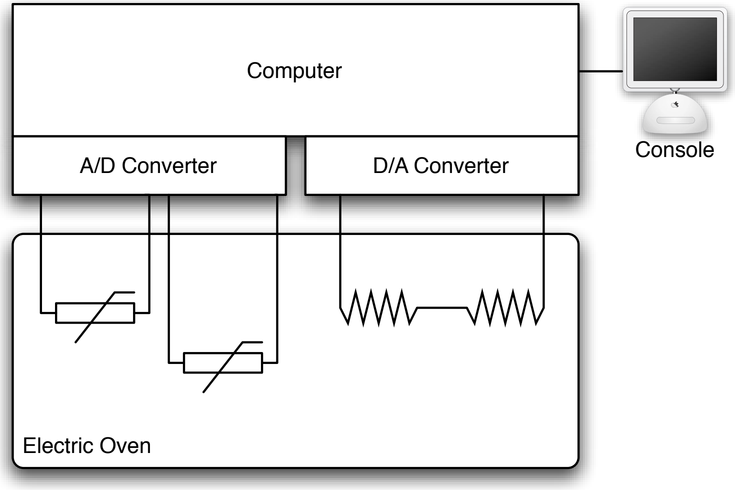
An Example of Real-Time System



A computer can control the temperature of an electric oven.

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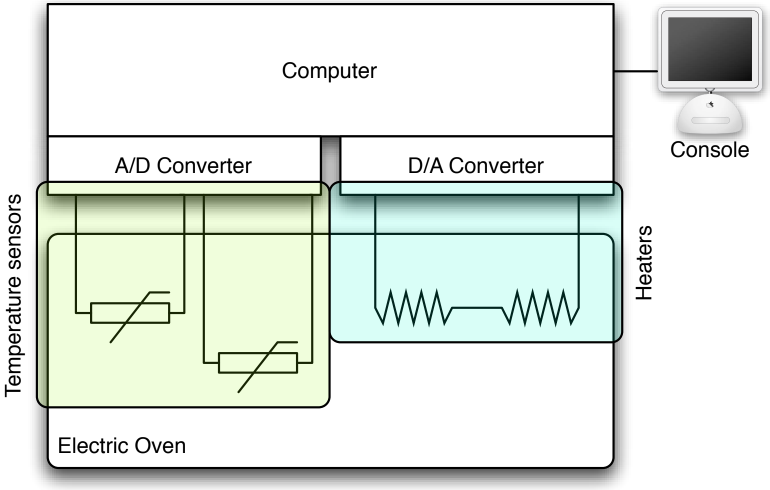

It interacts with the environment by means of sensors and actuators (heaters in this case).

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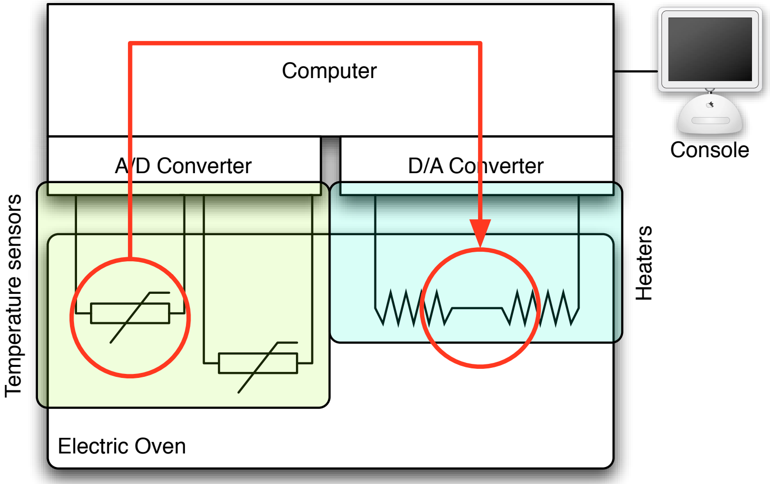

It must react to any change of temperature by properly regulating the heaters within a specified deadline.

Characteristics of a Real-Time System

- Real-time systems are often complex, because they must respond to the changing requirements of the real world and therefore undergo continuous maintenance and extension.
- Real-world elements naturally operate in parallel and the computer must interact with them.

The Concurrent Programming Role

For both reasons, a major (and important) problem is how to express concurrency in a program, and how to solve the resulting synchronization and communication problems. This is the goal of concurrent programming.

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- Language and run-time support is required to enable the processes to synchronize with time itself, for example to specify times at which actions are to be performed.
- Since real-time systems are often time-critical, efficiency of implementation will be more important than in other systems. Programmers must be concerned with the cost of using a particular language or operating system feature.
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What is an Operating System?

Operating systems perform two, mostly unrelated, functions: extending the machine and managing resources.

1. The architecture of most computers is quite primitive and difficult to program, especially for I/O. On the other hand, programmers do not like to get involved with its details and want to deal with a simpler, higher-level and hardware-independent set of services instead.
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Operating System Structure

Monolithic systems: It was the most common "non-structure" of older operating systems, and it is still widespread. The operating system is written as an unstructured collection of procedures, which can freely call each other.

Layered systems: The operating system is organized as a hierarchy of layers, each one constructed upon the one below it.

Microkernel: The operating system is a set of processes, which are independent of each other and cooperate to realize the operating system functions. They communicate by means of a microkernel that, ideally, only transports messages between processes.

Virtual machines: Multiprogramming is provided by several virtual machines that are an exact copy of the bare hardware. Each of them runs its own operating system.

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- To build the operating system executable image, all the procedures are first compiled individually and then bound together by the linker.
- There is essentially no information hiding, because every procedure is visible to every other procedure.
- It is possible to have a little structure by informally dividing the procedures into three groups, or levels:
  - A main procedure, that intercepts the system calls and invokes the requested service procedure.
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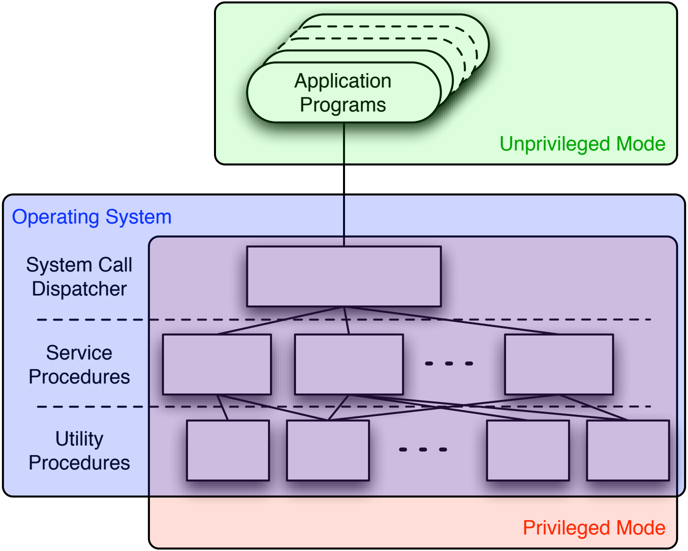

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- ...even if this is not strictly necessary.
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Further Generalization of Layering (Multics)

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- Instead of layers, the MULTICS operating system had a series of concentric rings. The inner rings were more privileged than outer ones.
- When a procedure in an outer ring wanted to call a procedure in an inner ring, it had to perform the equivalent of a system call, whose parameters were carefully checked for validity before proceeding.
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- The only purpose of the microkernel is to handle the communications among user and system processes.
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Microkernels and I/O

Some operating system functions, for example interacting with physical I/O devices, are difficult or impossible to do from an unprivileged process, because they inherently require the execution of privileged instructions.

There are two ways to deal with this problem:

1. Make some system processes run in privileged mode, so that they have complete access to the hardware, but still communicate with other processes as usual, in order to keep the system structure intact.
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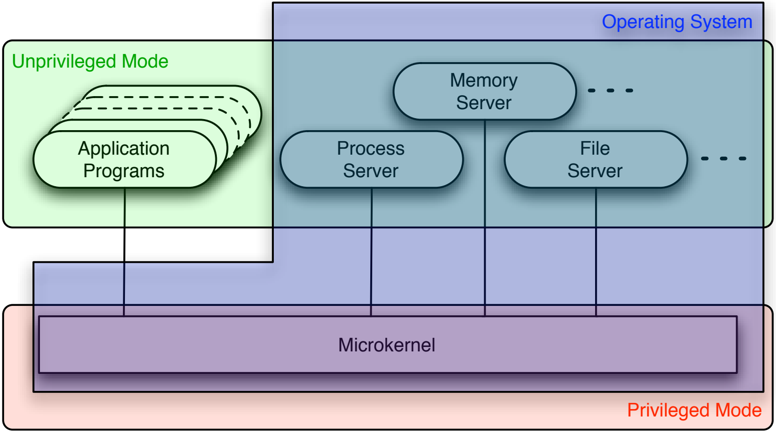

Microkernel Pros and Cons

+ Better modularity: the operating system is split up into simpler modules that communicate in a well-defined way.
+ Greater reliability: if a system process crashes or must be replaced, it can be stopped and restarted without rebooting the whole machine.
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Virtual Machines (VM/370)

Observation

A timesharing system provides:

1. multiprogramming;
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VM/370 completely separates these two functions:

1. A virtual machine monitor runs on the bare hardware and provides (through multiprogramming) several virtual machines, that are exact copies of the bare hardware.
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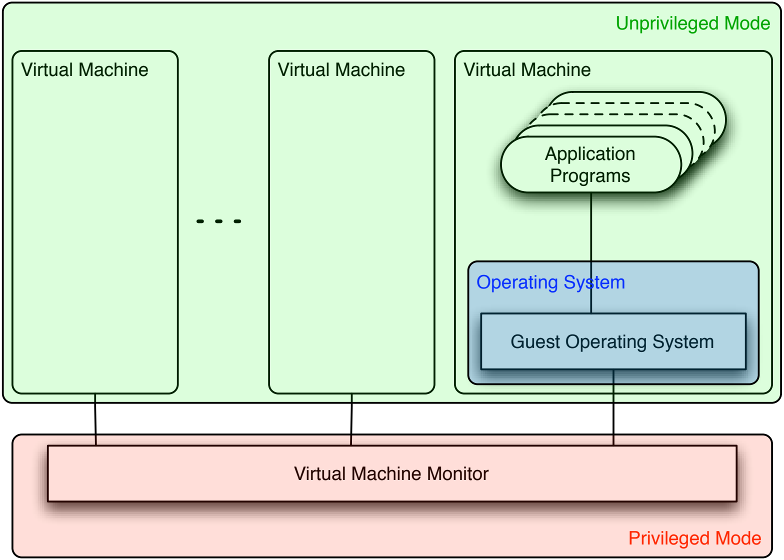

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- Terminate the invoking process.
- Wait for another process to terminate.
- Low-level, dynamic memory allocation.

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- The library procedure, often written in assembly language, takes the system call parameters from the location into which the compiler placed them for the function call (usually the stack), puts them into the place where the operating system expects them for the system call, and executes the system call instruction.
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- The trap switches the processor from unprivileged to privileged mode and starts executing within then kernel at the trap handler address, where there the system call dispatcher resides.
- The system call dispatcher saves the unprivileged execution context, determines which system call has been requested, and dispatches to the right system call handler.
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