Introduction to Real Time Operating System

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Outline

- Courses
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  - Scheduling
  - FreeRTOS
- Labs
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  - Part 2- Espressif Framework
  - Part 3- FreeRTOS Labs
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    - 2- Message Queue & Interrupt service
    - 3- Semaphore & Mutex
    - 4- Direct task notification
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Why using an Operating System ?

- Human-machine direct interaction
- Easy access all the features of the computer
  - Processors
  - Memories
  - Storage, files
  - Peripherals (screen, mouse, printer …)
  - Network …
- Hides the complexity of the operations (files, peripherals …)
- Allows access to privileged resources without having special rights (could be dangerous)

Variety of OS

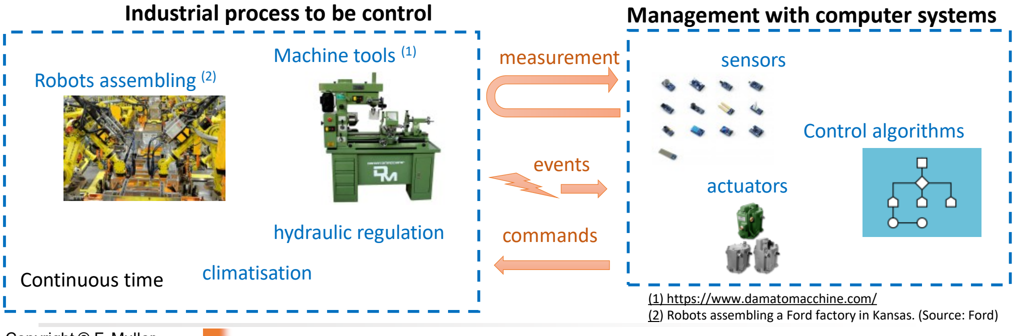
- According to the context of use, an OS can be
  - Single/multi user
  - Mono/multi tasks (cooperative/premptive scheduler)
  - Distributed (managing the resources of multiprocessor systems)
  - Embedded
  - Realtime
- Can be
  - Generalist (often based on time sharing)
  - Specialized (developed for a limited domain of applications)

Examples of OS

- Generalist
  - Windows, Linux
- Embedded
  - uCLinux, Windows CE
- Embedded & Real time
  - Amazon-FreeRTOS
  - RTLinux (Linux + path PREEMPT-TR)
- Embedded & Distributed & Real time
  - RTEMS, VxWorks
- Specialized
  - Android, iOS
  - OSEK/VDX (automotive)

Why using an Real Time Operating System ? - Example

- The behavior of a computer system is called real-time when the operation is subject to the dynamic evolution of an industrial process connected to it.
- The process is controlled, managed or supervised by the system that reacts to the state changes of the process.



(1) https://www.damatomacchine.com/
(2) Robots assembling a Ford factory in Kansas. (Source: Ford)

Why using an Real Time Operating System ?

- Simple cases
  - Writing good embedded software without the use of a kernel
- Complex cases
  - Using a kernel is preferable
  - Task prioritization can help ensure an application meets its processing deadlines
  - But other less obvious benefits

Why using an Real Time Operating System ?

- Abstracting away timing information
  - Responsible for execution timing
  - Time-related API
  - Allows code to be simpler and the code size to be smaller
- Maintainability/Extensibility
  - Fewer interdependencies between modules
  - Allows the software to evolve in a controlled and predictable way
  - application performance is less dependent of the hardware
- Modularity
  - Tasks are independent modules
  - Each of tasks has a well-defined purpose

Why using an Real Time Operating System ?

- Team development
  - Tasks have well-defined interfaces
  - Allows easier development by teams
- Easier testing
  - If tasks are well-defined independent modules with clean interfaces, they can be tested in isolation (non-regression tests)
- Portability / Code reuse
  - Application can be easily performed on differents boards
  - Greater modularity and fewer interdependencies results in code that can be reused with less effort

Why using an Real Time Operating System ?

- Improved efficiency
  - Kernel allows software to be completely event-driven
  - No processing time is wasted by polling for events
  - Code executes only when there is something that must be done
  - The need to process the RTOS tick interrupt and to switch execution from one task to another
- Idle time, for what ?
  - Idle task is created automatically when the scheduler is started
  - To measure spare processing capacity
  - To perform background checks
  - To place the processor into a low-power mode

Why using an Real Time Operating System ?

- Power Management
  - RTOS allows the processor to spend more time in a low power mode
- Flexible interrupt handling
  - Interrupt handlers can be kept very short by deferring processing to either a task or the daemon task
- Mixed processing requirements
  - Mix of periodic, continuous and event-driven processing/tasks within an application
  - Hard & Soft real-time requirements can be met by selecting appropriate task and interrupt priorities

Real-time is NOT equal to go fast

- Examples
  - Need a short reaction time (10 ms) to control an airplane
  - Need for a shorter reaction time (1s) for an HMI (Human-Machine Interface)
  - Need for a shorter reaction time (1 min) for the control of a production line
  - Need a shorter reaction time (1h) to control a chemical reaction
  - Need a time latency of a few hours for the establishment of a weather forecast
- The important thing is to respect the deadline
- A fair result after the deadline may be unusable and considered a fault

Services

- Activity management
  - Create
  - Suspend
  - Destroy
- Time management
  - Clock, Tick
  - Timers
- Communication & Synchronization
  - Message queue
  - Shared memory
  - Semaphore, mutex, conditional variable

Services

- Notification
  - Interrupt, signal
  - event
- Memory management
  - Virtual memory
  - Memory lock
  - Memory protection
- Inputs/Outputs
  - Open, Read, Write
  - (Asynchronous) Direct I/O
- Network management

POSIX Standard

- Portable Operating System Interface = POSIX
- Standards specified by the IEEE
- Compatible with variants of the Unix operating system (although the standard can apply to any operating system)
- Portability: a compliant POSIX application should be ported on several systems
- RTOS compliant with POSIX
  - VxWorks, FreeRTOS (partially)
  - QNX, RTEMS, RTAI
  - RTLinux (partially)
  - …

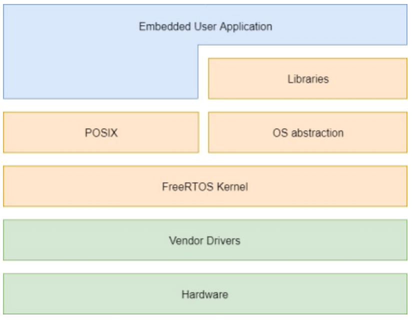
POSIX Overview

POSIX.1 Core Services IEEE Std 1003.1	Process Creation and Control, Signals, Timers ...	Define API with the RTOS
POSIX.1b Real-time extensions IEEE Std 1003.1b	Priority Scheduling, Real-Time Signals, Clocks and Timers, Semaphores, Message Passing …	Define the extensions for real-time
POSIX.1c Threads extensions IEEE Std 1003.1c	Thread Creation, Control, and Cleanup; Thread Scheduling …	Define the API for the threads management

FreeRTOS Example

- Implement partially the IEEE STD 1003.1-2017
- Use of a wrapper

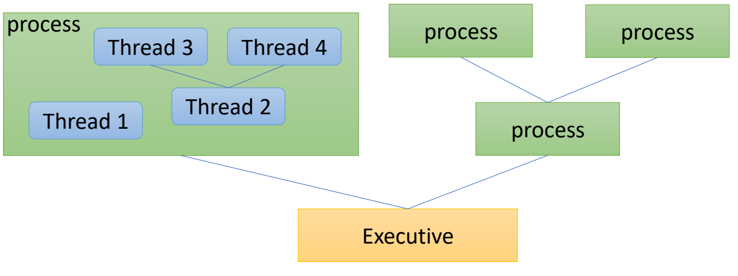
- Open source
- Royalty free



https://www.freertos.org/FreeRTOS-Plus/FreeRTOS_Plus_POSIX/index.html

Process & Thread - POSIX

- Process
  - Entity with its own memory
- Thread
  - Internal entity of a process.
  - The threads of a process share the memory



Conclusion

- Lot of RTOS
- POSIX standard or not
- Control of scheduling is essential in the design of real-time applications
  - Sharing of the CPU between the different tasks
  - Management of dependencies between tasks (sharing of exclusive resources)
  - Management of overload situations
- In addition to functionalities of a classic OS, a RTOS allows
  - to set up the scheduling algorithms
  - to synchronize tasks
  - to communicate and exchange data between tasks