

ECE445M/ECE380L.12 Embedded and Real-Time Systems/ Real-Time Operating Systems

Lecture 12: Commercial RTOS, Final Exam, Review

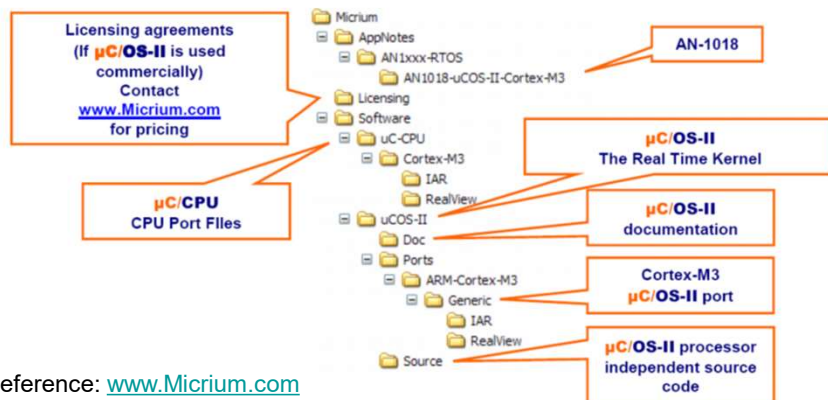
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Putting it All Together

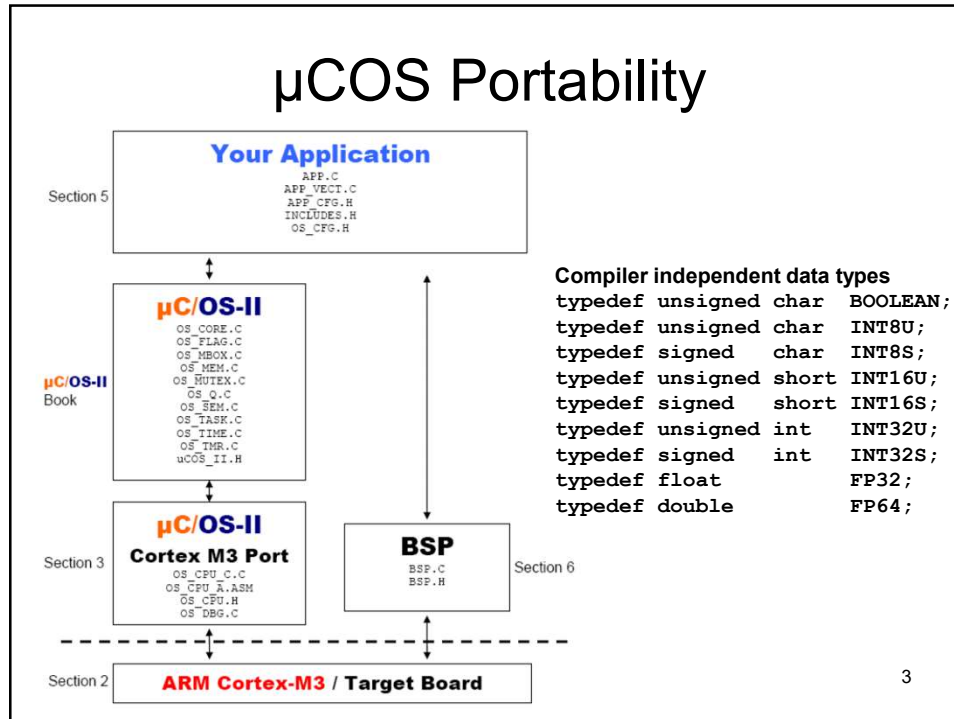
- Micrium μ COS-II



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Hooks

- Run user supplied code at strategic places
- Allows you to
 - Extend the OS
 - Implement debugging
 - Implement performance testing
 - Implement black box recording
- Collect run-time performance data

μCOS Runs with PSP

```

OS_CPU_PendSVHandler
  CPSID   I           ; Prevent interruption during context switch
  MRS    R0, PSP      ; PSP is process stack pointer
  CBZ    R0, OS_CPU_PendSVHandler_nosave ; Skip save the
                                           ; first time

  SUBS   R0, R0, #0x20 ; Save remaining regs r4-11
                                           ; on process stack

  STM    R0, {R4-R11}

  LDR    R1, =OSTCBCur ; OSTCBCur->OSTCBStkPtr = SP;
  LDR    R1, [R1]
  STR    R0, [R1]      ; R0 is SP of process being
                                           ; switched out

  ...

```

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User Can Hook into μCOS

```

... (context switch continued)
  PUSH   {R14}        ; Save LR exc_return value
  LDR    R0, =OSTaskSwHook ; OSTaskSwHook();
  BLX   R0
  POP   {R14}

```

Many hooks provided:

```

OSInitHookBegin()
OSInitHookEnd()
OSTaskCreateHook()
OSTaskDelHook()
OSTaskIdleHook()
OSTaskStatHook()
OSTaskStkInit()
OSTaskSwHook()
OSTCBInitHook()
OSTimeTickHook()

```

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Board Support Package (BSP)

- Hardware abstraction layer (HAL)
 - I/O abstraction for anything OS needs
 - Encapsulate functionality of target hardware
 - Timer initialization
 - ISR Handlers
 - LED control functions
 - Reading switches
 - Setting up the interrupt controller
 - Setting up communication channel
 - CAN, I2C, ADC, DAC, SPI, serial, graphics

```
void LED_Init(void);
void LED_On(CPU_INT08U led_id);
void LED_Off(CPU_INT08U led_id);
void LED_Toggle(CPU_INT08U led_id);
```

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μCOS Synchronization

- Message mail box
- Message queue
- Semaphores
- Flags (software events)
 - Groups of flags
 - Names
 - pend/post, and/or

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μCOS Mutex

```

/* Description: This function waits for a mutual exclusion semaphore.
Arguments  : pevent pointer to event control block associated with mutex.
             timeout optional timeout period (in clock ticks).
             If non-zero, your task will wait up to the specified time
             If you specify 0, however, will wait forever for resource
perr      pointer to where an error message will be deposited.
           OS_ERR_NONE           successful and your task owns the mutex
           OS_ERR_TIMEOUT       not available within the 'timeout'.
           OS_ERR_PEND_ABORT    mutex was aborted.
           OS_ERR_EVENT_TYPE    If you didn't pass a pointer to a mutex
           OS_ERR_PEVENT_NULL  'pevent' is a NULL pointer
           OS_ERR_PEND_ISR     called from an ISR
           OS_ERR_PIP_LOWER     task priority that owns is HIGHER
           OS_ERR_PEND_LOCKED  called when the scheduler is locked

* Returns   : none
* Note(s)1) The task that owns the Mutex MUST NOT pend on any other event while it
*            owns the mutex.
*            2) You MUST NOT change the priority of the task that owns the mutex
*/
void OSMutexPend (OS_EVENT *pevent, INT16U timeout, INT8U *perr)
INT8U OSMutexPost (OS_EVENT *pevent)

```

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Other μCOS Features

- Memory manager
- Time delay (sleep)
- Priority resolution table
- Debugger aware

Reference: www.Micrium.com
 μC/OS-II and μC/OS-III books by Jean J. Labrosse

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Final Exam

- Friday, May 4, 8am-10am, ECJ 1.312
 - Open book, open notes, open web
 - No electronic devices other than laptop
 - No communication, all phones off
- Comprehensive (see Study Guide)
 - Book Chapters 1-9
 - Lectures 1-12
 - Labs 1-7

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Lab Topics

- Lab 1
 - Interrupts, Cortex M architecture, FIFOs, serial port, ADC
- Lab 2
 - Real time OS, semaphores, critical sections, synchronization, communication
- Lab 3
 - Priority scheduling, blocking semaphores, debugging
- Lab 4
 - File system, SPI, SD cards
- Lab 5
 - Memory & process management, process loading & linking
- Lab 6
 - Interfaces, CAN/Ethernet, TCP/IP, networking, distributed systems
- Lab 7
 - Applications, abstractions, sensing, actuating and control

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Topics Not in Labs

- DMA
- PID and ~~Fuzzy logic~~ control
- Ethernet (vs. CAN), TCP/IP
- Virtual Memory, Paging
- Synchronization & Communication
 - Monitors
 - KPNs
 - Design and implementation of thread flags
OS_Wait_Event_Or, OS_Wait_Event_And,
OS_Trigger_Event(Thread)

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General Topics

- Software development
 - Data flow graphs, call graphs
- I/O
 - Device drivers
 - CPU bound, I/O bound
- Debugging
 - Intrusiveness, stabilization, profiling, dumps, monitors
- SPI/SSI, disk/flash concepts
 - Synchronization, Bandwidth, Protocol
- Networking fundamentals
 - How does CAN/Ethernet and TCP/IP work
- Memory management
 - Virtual memory, paging, page table, TLB

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General OS Concepts

- Kernel, Hooks
- Deadlock (detection, prevention)
- Aging, Starvation
- Race condition, Critical Section
- Reentrancy, Mutual exclusion, Atomic
- Bounded waiting
- ROMable, Portability, Scalability
- CPU utilization, latency, jitter
- FIFO queue/pipe implementation, usage

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OS Design & Implementation

- Interrupts
 - Arm, enable
 - Protocol, interrupt processing on TM4C123
 - Interrupt priority
- Context switch
 - PSP/MSP, Stack
- Scheduling
 - Round robin, priority based, rate monotonic
 - Linked list, TCB

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Synchronization

- Semaphores
 - Binary, counting
 - Spin lock, Blocking
- Mailbox, FIFO
- Monitors
- Path expression
- Implementation, applications
 - Little book of semaphores
 - Study lecture examples, old exams

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High-Speed I/O

- Hardware FIFOs
- Dual-port, banked memory
- DMA Concepts
 - DMA controller
 - Cycle steal, Burst
 - Single address, dual address
 - Latency, Bandwidth

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File Systems

- SD card interface
 - Bandwidth
 - DMA
- Internal/external fragmentation
- Free space management
- Disk block allocation
 - Contiguous, linked, indexed
 - First fit, best fit, worst fit
 - Directory
- Linked, Indexed, FAT

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Memory & Process Management

- Heap, Heap Manager
 - Dynamic memory allocation, malloc/free
- Processes (vs. threads)
 - Creation, termination, PCB
- Loading, linking, relocation
 - ELF files
 - Position-independence, dynamic linking, SVC
- Protection
- Virtual memory
 - Address translation
 - MMU, paging, swapping, TLB

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Networking

- Framing and Messaging
- Layering
- CAN & Ethernet concepts
 - Message protocol, arbitration
 - Bandwidth, stuff bits
 - Error detection
- TCP/IP
- IoT, Application-layer protocols

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Sensing

- Timed input capture (fundamentals)
- Measuring delay
- Measuring frequency
- Measuring pulse width
- Measuring period
 - Precision
 - Resolution
 - Range

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Actuating, Control

- PWM
 - Range, resolution, precision
- Motor interface
 - H bridge
- PID control
 - Show how controller is run within the RTOS
- ~~Fuzzy logic control~~

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Old Exams (See Study Guide)

- All Since Spring 2014
 - TM4C, excluding filter questions
- Spring 2013, Spring 2012, Spring 2011
 - All but filters relevant, change LM3S to TM4C
- Spring 2010
 - Change STM32 to LM4C
- Older exam topics no longer covered
 - 9S12 ports, interface, software, paging
 - Memory interfacing, Timing diagrams

<http://www.ece.utexas.edu/~valvano/EE345Moldquiz/>

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