



## TI3 - Cortex M4 Texas Instruments Implementation and Ti-RTOS

### Objectifs

- Although the Cortex-M4 seems to be a simple 32-bit core, it supports sophisticated mechanisms, such as exception pre-emption, internal bus matrix and debug units
- Through a tutorial, the Cortex-M4 low level programming is explained, particularly the ARM linker parameterizing and some tricky assembly instructions
- Discover the concepts of real time multitasking
  - Determinism
  - Preemption
  - Interrupts
- Understand the structure of a TI-RTOS
- Discover the various TI-RTOS services and APIs
- Learn how to develop TI-RTOS applications
- Learn how to debug TI-RTOS applications

### Course Environment

- Code Composer Studio (CCS) v9.0.1
- LAUNCHXL-CC1352P1(CC1352P microcontroller) Texas Instruments board

### Target Audience

- Any embedded systems engineer or technician with the above prerequisites.

## Course Outline

### Prerequisites

- Basic Knowledge on C language and microcontrollers

### First Day

#### Introduction to ARM CORTEX-M4/M4F

- ARM Cortex-M4 processor macrocell
- Programmer's model
- Instruction pipeline
- Fixed memory map
- Privilege, modes and stacks
- Memory Protection Unit
- Interrupt handling
- Nested Vectored Interrupt Controller [NVIC]
- Power management
- Debug

#### ARM CORTEX-M4 CORE

- Special purpose registers
- Datapath and pipeline

- Write buffer
- System timer
- State, privilege and stacks
- System control block
- EXCEPTIONS

## Exception behavior, exception return

- Non-maskable exceptions
- Privilege, modes and stacks
- Fault escalation
- Priority boosting
- Vector table

## Interrupts

- Basic interrupt operation, micro-coded interrupt mechanism
- Interrupt entry / exit, timing diagrams
- Interrupt stack
- Tail chaining
- Interrupt response, pre-emption
- Interrupt prioritization
- Interrupt handlers

**Exercise:** Interruption Management on Cortex-M4

## Second Day

### Elements of a real time system

- Tasks and task descriptors
  - Content of the task descriptor
  - Lists of task descriptors
- Context switch
- Task scheduling and preemption
  - Tick based or tickless scheduling
- Scheduling systems and schedulability proofs
  - Fixed priority scheduling
  - RMA and EDF scheduling
  - Adaptive scheduling
- Synchronization primitives
  - Waiting and waking up tasks
  - Semaphores
  - Mutual exclusion
  - The priority inversion problem
  - Priority inheritance (the automagic answer)
  - Priority ceiling (the design centric answer)
  - Mutexes and condition variables
  - Mailboxes

### Introduction to TI-RTOS

- What is TI-RTOS ?
- Overview of TI-RTOS Components
- SYS/BIOS: The TI-RTOS Kernel
- TI-RTOS Networking and Networking Services
- TI-RTOS Drivers

## Third Day

### SYS/BIOS

- SYS/BIOS Packages
- SYS/BIOS and XDC Tools
- TI-RTOS Startup Sequence
- Configuring SYS/BIOS Using XDCTools
- Overview of Threading Modules
- Thread Characteristics
- Choosing the right Thread
- Thread Priorities preemption and yielding
- Introduction to Hooks

### Memory management

- Memory Map
- Placing sections into Memory Segments
- Stacks
- Cache configuration
- Dynamic Memory Allocation
- Heap implementations

### Hardware Interrupt Threads (Hwis)

- Introduction to Hwis
- Creating Hwi Objects
- Hwi APIs
- Hwi Interrupt Nesting and System Stack Size
- Hwi Hooks

**Exercise:** Configuring Hwis

**Exercise:** Configuring Hwis dynamically

### Software Interrupt Threads (Swis)

- Introduction to Swis
- Creating Swi objects
- SWI interrupts nesting
- Using Swi object trigger variables

**Exercise:** Configuring Swis

**Exercise:** Configuring Swis dynamically

## Fourth Day

### Task Threads

- Introduction to Task Threads
- Creating Tasks
- Task Execution states and scheduling
- Task Stacks
- Testing for stack overflow
- Task Hooks
- Task Yielding for time-slice scheduling
- Idle Loop

**Exercise:** Hwi, Swi, Task and Idle Threads

## Synchronization modules

- Semaphores
- Event Module
- Gates
- Mailboxes
- Queues

**Exercise:** Synchronization Primitives (Semaphore, Gates and Events)

**Exercise:** Reader / Writers (Mailboxes)

## Timing Services

- Clock
- Timer Module
- Seconds Module
- Timestamp

**Exercise:** Clock and Timer Threads

## Instrumentation

- Introduction
- Load Module
- Error Handling
- Instrumentation Tools in Code Composer studio
- Performance optimization

**Exercise:** Threads statistics (Hwi Global, Swi Global and Tasks)

## Timing Benchmarks

- Timing Benchmarks
- Interrupt Latency
- Hwi-Hardware Interrupt
- Swi-Software Interrupt Benchmarks
- Task Benchmarks
- Semaphore Benchmarks