



RT5 - Zephyr RTOS Programming

Comprehensive Zephyr OS training from Theory to Practice

Objectives

- Learn how to develop, configure, debug and trace Zephyr applications
- Devicetree and Kconfig usage and development
- Using west and writing west manifest
- Zephyr real time multitasking overview
- Understand the Zephyr kernel Services and ecosystem
- Learn communication and synchronization mechanisms
- Understand Zephyr memory management and data structures
- Understand User mode and kernel mode
- Writing a device tree, and driver
- Using common subsystems

Course Environment

- Theoretical course
 - PDF course material (in English) supplemented by a printed version.
 - The trainer answers trainees' questions during the training and provide technical and pedagogical assistance.
- Practical activities
 - Practical activities represent from 40% to 50% of course duration.
 - Code examples, exercises and solutions
 - One PC (Linux ou Windows) for the practical activities with, if appropriate, a target board.
 - ▶ One PC for two trainees when there are more than 6 trainees.
 - For onsite trainings:
 - ▶ An installation and test manual is provided to allow preinstallation of the needed software.
 - ▶ The trainer come with target boards if needed during the practical activities (and bring them back at the end of the course).
- Downloadable preconfigured virtual machine for post-course practical activities
- At the start of each session the trainer will interact with the trainees to ensure the course fits their expectations and correct if needed

Prerequisites

- Good C programming skills (see our [L2 - C language for Embedded MCU](#) course)

Duration

- Total: 5 days
- From 40% to 50% of training time is devoted to practical activities
- Some Labs may be completed between sessions and are checked by the trainer on the next session

Target Audience

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

Evaluation modalities

- The prerequisites indicated above are assessed before the training by the technical supervision of the trainee in his company, or by the trainee himself in the exceptional case of an individual trainee.
- Trainee progress is assessed in two different ways, depending on the course:
 - For courses lending themselves to practical exercises, the results of the exercises are checked by the trainer while, if necessary, helping trainees to carry them out by providing additional details.
 - Quizzes are offered at the end of sections that do not include practical exercises to verify that the trainees have assimilated the points presented
- At the end of the training, each trainee receives a certificate attesting that they have successfully completed the course.
 - In the event of a problem, discovered during the course, due to a lack of prerequisites by the trainee a different or additional training is offered to them, generally to reinforce their prerequisites, in agreement with their company manager if applicable.

Plan

First Day

Introduction to Zephyr

- Zephyr Project
- Zephyr Ecosystem
- Why use Zephyr
- Install and use Zephyr
- Build and Configuration Systems
 - West
 - CMake
 - Zephyr SDK
- Application components and structure
- West manifest

Configure Zephyr

- Overview
- Kconfig
 - Default configuration
 - Interactive configuration tools
 - Config fragments
- Devicetree
 - Syntax
 - Standard properties
 - Initial devicetree source
 - Access devicetree from source code
 - Best practices

Exercise: Write a device tree overlay

Zephyr Without Threads

- Operation without Threads
- GPIO subsystem
- Utilities
 - Container_of
 - For_each
- Data Structures
 - Single-linked List
 - Double-linked List
 - Ring Buffers

Exercise: Hello World from Zephyr, configure and blink LEDs using Zephyr

Exercise: Manage Zephyr linked list and understand container_of macro

Second Day

Thread Management

- Thread Fundamentals
 - Thread Control Block
 - Creating Threads
 - Threads Priorities
 - Changing Thread Priority
 - Thread States
- Main and Idle Threads
- Delays
- Suspending Threads
- Kernel Structures
 - Simple linked-list ready queue
 - Red/black tree ready queue
 - Traditional multi-queue ready queue
- Thread Custom Data

Exercise: Create and manage threads

Exercise: Create periodic threads

Tracing and logging

- Runtime Statistics
- Scheduling Traces
 - User-Defined Tracing
 - Percepio Tracealyzer

Exercise: Create config fragment for visual trace diagnostics using Tracealyzer

Memory Management in Zephyr

- Memory Managers
- Dynamic memory managers
 - K_heap
 - System heap
 - Memory Slabs
 - Memory Blocks
- Heap Listeners
- Thread Resource Pools
- RAM/ROM reports
- Stack information
 - Stack Overflow detection
 - Stack analysis

Exercise: Understand dynamic memory allocation in Zephyr

Exercise: Display threads information and detect stack overflow

Third Day

User Mode

- Overview
- Memory Domains
 - Partitions
 - Logical apps
- Syscalls
 - Kernel objects
 - Permissions

Resource Management and Synchronization

- Mutual Exclusion
- Mutexes
- Gatekeeper threads
- Critical Sections
- Atomic
- SpinLocks
- Semaphores
- Events
- Polling

Exercise: The producer-consumer problem, synchronize and avoid concurrent access problems

Exercise: Understanding event bit group by synchronizing several threads

Data Passing

- Message Queues
- Queues
 - FIFOs
 - LIFOs
- Mailboxes
- Pipes
- Stacks
- Zephyr Bus (Zbus)
 - Zbus overview
 - Elements
 - Usage

Exercise: Create a print gatekeeper thread using message queue

Exercise: Synchronous communication using mailboxes

Fourth Day

Interrupt Management

- Threads and Interrupts
- Interrupts in zephyr
- Interrupts on ARM Cortex-M
- Handler thread
- Queue within an ISR
- Workqueue Threads

Exercise: Understand how to wait on multiple events and interrupt safe APIs

Exercise: Understand how to pass data using Queues from an interrupt to a thread

Exercise: Create and submit work items from interrupts to custom WorkQueue

Software Timers

- Timers
 - Defining a Timer
 - Using a Timer Expiry Function
- Timer types
 - One-shot timers
 - Auto-reload timers
- Timer Commands

Exercise: Understand the use of one-shot and auto-reload timers

Modules

- Why to use modules?

- Module structure
- Out-of-tree module
- YAML files
- Module CMakeLists.txt

Exercise: Create a simple hello world module

Kconfig

- Advantages
- Kconfig Options in Zephyr RTOS
- Configuration System
- Writing custom Kconfig Options
- Kconfig extension
- Using Kconfigs

Exercise: Create a module that uses custom Kconfig options

Fifth Day

Zephyr device driver model

- Introduction to Device Drivers
- Overview of the Zephyr device driver model
- Standard Drivers
- The struct device
- Subsystems
- API Extensions
- Initialization Levels
- Dependencies between device drivers
- Define devices programmatically

Exercise: Create a driver that respects the Zephyr Device Driver Model and define devices

Device Trees in Zephyr

- Overview of Device Tree (DT) and its role in Zephyr
- Device Tree VS Kconfig
- Device Tree node structure
- Device Tree bindings
- Overlay and yaml files
- APIs to access device tree properties
- Write device drivers using device tree APIs
- Device Tree in Zephyr VS Linux
- Adding In-Tree Code to Zephyr Source Code
- Common properties
 - compatible
 - reg
 - interrupts

Exercise: Create a driver that uses custom device tree and Kconfig

Exercise: Writing in-tree drivers

Power Management

- Overview
- System Power Management
- Device Power Management
 - System-Managed
 - Runtime
- Power domains

Exercise: Write a driver compatible with power management subsystem

Renseignements pratiques

Inquiry : 5 days