



## STR8 - STM32MP15 Implementation

*This course describes the STM32MP15x SoC*

### Objectifs

- This course details the hardware implementation of the STM32MP15x SoC
- The course focuses on the boot sequence, the clocking and the power management strategies
- The course explains all parameters that affect the performance of the system in order to easily perform the final tuning
- An overview of the Cortex-A7MP core helps to understand issues caused by MMU, cache and snooping
- An overview of the Cortex-M4F with MPU is included to understand the microcontroller side of the STM32MP15 implementation
- To become more familiar with the synchronization features of the STM32MP15x implementation labs are proposed
- Note that this course has been designed from the architecture of STM32MP15x-series devices, the STM32MP157C
- The peripherals overview presented in this course can be detailed upon request ([STR9 - STM32 Peripherals](#)course)

### Prerequisites and Related Courses

- Familiarity with C concepts and programming targeting the embedded world
- Basic knowledge of embedded processors
- The following courses could be of interest:
  - [RA4 - Cortex-A7 implementation](#)course
  - [RM3 - Cortex-M4 / Cortex-M4F implementation](#)course
  - [STR9 - STM32 Peripherals](#)course
  - [OS3 - FreeRTOS Programming](#)course
  - [D1S - Embedded Linux with Ac6 System Workbench](#)course
  - [DIY - Embedded Linux with Yocto](#)course

### Course environment

- Convenient course material
- Example code, labs and solutions

### Target Audience

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

## Course Outline

### First Day

#### Cortex M4 Architecture Overview

- V7-M Architecture Overview
- Core Architecture
  - Harvard Architecture, I-Code, D-Code and System Bus
  - Write Buffer
  - Registers (Two stacks pointers)
  - States
  - Different Running-modes and Privileged Levels
  - System Control Block

- SysTick Timer
- MPU Overview
- Programming
  - Alignment and Endianness
  - CMSIS Library
- Exception/ Interrupt Mechanism Overview
  - Vector Table
  - Interrupt entry and return Overview
  - Tail-Chaining
  - Pre-emption (Nesting)
  - NVIC Integrated Interrupt Controller
  - Exception Priority Management
  - Fault escalation
- Debug Interface

**Exercise:** Becoming familiar with the IDE and Clarifying the boot sequence

**Exercise:** Cortex-M4 Mode Privilege

**Exercise:** Cortex-M4 Exception Management

**Exercise:** Cortex-M4 MPU

## The ARM Cortex-A7MP Architecture Overview

- V7-A Architecture Overview
- Cortex A7 Overview
  - Cortex-A7 Architecture
  - Hardware Cache Coherency
  - Cortex-A7 Main Features
- System Features
  - Multi-processing
  - Cache Maintenance
  - Cache Coherency Hardware
  - Interrupt Distribution
  - Power saving Modes
  - Memory System Hierarchy
  - Software Storage and Upload
- Memory Management Unit
- Generic Interrupt Controller
- Multicore operation
- TrustZone
- Virtualization Extension

## Second Day

### STM32MP15 Architecture Overview

- ARM Core Based Architecture
- Description of STM32MP15 SoC architecture
- Clarifying the internal data and instruction paths:
  - Bus Architecture
  - NIC-400 Network Interconnect AXI-based
  - Multi-Layer AHB Interconnect
- Memory Organization
  - Embedded Memories: (ROM, SYSRAM, MCU SRAM, Retention RAM)
  - External Memories: (DDR3/LPDDR2, FMC, QUADSPI, SDMMCx)
- SoC mapping
- Boot Configuration

## Boot, Security and One time programmable (OTP) control (BSEC)

- Introduction
- BSE Block diagram
- Interface to OTP
- OTP security Mode
- OTP operations
  - OTP read
  - OTP programming
  - OTP permanent write lock
- Scratch registers and Transport key (TK) access
- OTP Mapping

## Reset, Power and Clocking

- Power Control
  - Power control overview
  - Power supplies
  - Power supply supervision
  - Power management
  - Low-Power Modes
  - Power control interrupts
  - Power Control and TrustZone capability
- RCC Reset and Clock
  - RCC overview
  - RCC Block diagram
  - RCC Reset
  - RCC Clock
  - RCC interrupts
  - Handling dynamic Clock switching
  - PLL Programming
  - Configuring the sub-system clock
  - Clock calibrations using timers

**Exercise:** Configure the system to measure the current consumption in different low-power modes (Cortex-M4)

**Exercise:** RTC wakeup timer event / interrupt (Cortex-M4)

**Exercise:** Configure the system Clock (SYSCLK) and modify the clock settings in Run Mode (Cortex-M4)

## Synchronizations mechanisms

- Hardware Semaphore (HSEM)
  - HSEM Overview
  - Lock procedures
  - Clear Procedures
  - Interrupts
- Inter-Processor Communication Controller (IPCC)
  - IPCC Overview
  - Simplex Channel and Half-Duplex channel modes
  - IPCC interrupts

## Third Day

### Hardware Implementation

- Power pins
- Pinout
  - Pin Muxing, alternate functions

- GPIO Module
  - Configuring a GPIO
  - Speed selection
  - Locking mechanism
  - Analog function
  - Integrated pull-up / pull-down
  - I/O pin multiplexer and mapping
  - TrustZone security
- System Configuration Controller
  - I/O compensation cell
  - Ethernet Clock source
- Interrupts
  - Nested Vectored Interrupt Controllers (NVIC)
  - Global interrupt Controller (GIC)
  - Extended Interrupt and event controller (EXTI)

**Exercise:** How to configure the external interrupt lines

## Internal Interconnect

- Bus Matrix
- DMA

**Exercise:** DMA FIFO mode

## Security and Integrity

- Extended TrustZone Protection Controller
  - Extended Trustzone architecture and ETZPC
  - STM32P15x Security Architecture
  - STM32P15x MCU resource isolation
- True Random number generator (RNG)
- Hash processor (HASH)
- Cryptographic Processor (CRYP)

**Exercise:** CRC User Defined Polynomial

**Exercise:** How to use HASH peripheral to hash data with SHA-1 and MD5 algorithms

**Exercise:** How to use the Cryptographic Processor

## Memory Features

- DDR3/LPDDR2/LPDDR3 Controller (DDRCTRL)
  - DDRCTRL Architecture overview
  - Transaction Service Control and QoS
  - Power saving
  - Address mapper
  - DRAM timing parameters
  - SDRAM initialization sequence
  - Refresh controls
  - DDRCTRL Configuration
  - TrustZone Address Space Controller for DDR
- DDR physical Interface Control (DDRPHYC)
- DDR performance monitor (DDRPERFM)
- Master Direct Memory Access (MDMA) Controller
- Flexible Memory Controller (FMC)
- Quad-SPI interface
- Delay Block

**Exercise:** Configuring the FSMC controller to access the SRAM memory

**Exercise:** QSPI Read Write IT

## Fourth Day

### Asymmetric Multiprocessing Communication

- Open AMP-Overview
- Components in OpenAMP
- Connection between OpenAMP and Libmetal
- How to write a simple OpenAMP application
- CoProSync APIs

**Exercise:** Creating rpmsg channel between Cortex-M4 and Cortex-A7MP (Cortex-M4 side)

### Analog modules

- Analog-to-Digital (ADC)
- Digital-to-Analog Converter (DAC)
- Digital filter for sigma delta modulators (DFSDM)
- Temperature sensor (TDS)

**Exercise:** ADC Single Conversion Trigger Timer DMA

## Fifth Day

### Watchdogs and Real-time clock (RTC)

- Independent Watchdogs (IWDG)
- Window Watchdog
- RTC
  - Overview
  - Functional Description
  - RTC low power-modes

**Exercise:** MCU WWDG reset

**Exercise:** RTC Alarm

### Connectivity and communication

- SPI
- USART/UART
- I2C
- Serial audio interface & SPDIF receiver interface
- Management data input/output (MDIOS)
- Secure Digital input/output MultiMediaCard Interface
- FDCAN
- USB OTG
- USB HS PHY controller
- USB EHCI/USB\_OHCI
- HDMI-CEC
- Ethernet

**Exercise:** How to handle I2C data buffer Tx/Rx between two boards via DMA

### Debug Support

- Debug block diagram
- Debug power and clocking
- Security
- Chip Level TAP controller
- Serial wire and JTAG debug port (SWJ-DP)
- Access port

- Cortex-A7 debug
- Cortex-M4 debug