

## RM3 - Cortex-M4 / Cortex-M4F implementation

This course covers both Cortex-M4 and Cortex-M4F (with FPU) ARM core

### Objectives

- This course is split into 3 important parts:
  - Cortex-M4 architecture
  - Cortex-M4 software implementation and debug
  - Cortex-M4 hardware implementation.
- 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.
- The course also indicates how to use new DSP and FPU instructions to boost DSP algorithm implementation.
- Note that attendees can replay these labs after the training.
- The course also details the hardware implementation and provides some guidelines to design a SoC based on Cortex-M4, taking benefit of concurrent AHB transactions.
- An overview of the Coresight specification is provided prior to describing the debug related units.

*A more detailed course description is available on request at [formation@ac6-formation.com](mailto:formation@ac6-formation.com)*

### Prerequisites

- A basic understanding of microprocessors and microcontrollers.

### Course Environment

- Theoretical course
  - PDF course material (in English) supplemented by a printed version for face-to-face courses.
  - Online courses are dispensed using the Teams video-conferencing system.
  - The trainer answers trainees' questions during the training and provide technical and pedagogical assistance.
- At the start of each session the trainer will interact with the trainees to ensure the course fits their expectations and correct if needed

### 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 by quizzes offered at the end of various sections 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 - ARCHITECTURE

#### **INTRODUCTION TO ARM CORTEX-M4**

- 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
- Bit-banding
- System timer
- State, privilege and stacks
- System control block

#### **ARCHITECTURE OF A SOC BASED ON CORTEX-M4**

- Internal bus matrix
- External bus matrix to support DMA masters
- Connecting peripherals
- Sharing resources between Cortex-M4 and other CPUs
- Connection to Power Manager Controller

### SECOND DAY - PROGRAMMING

#### **EMBEDDED SOFTWARE DEVELOPMENT WITH CORTEX-M4**

- Application startup
- Placing code, data, stack and heap in the memory map, scatterloading
- Reset and initialisation
- Placing a minimal vector table
- Further memory map considerations, 8-byte stack alignment in handlers

#### **THUMB-2 INSTRUCTION SET**

- General points on syntax
- Data processing instructions
- Branch and control flow instructions
- Memory access instructions
- Exception generating instructions
- If&then conditional blocks
- Stack in operation
- Exclusive load and store instructions, implementing atomic sequences

- Memory barriers and synchronization

## CORTEX-M4 DSP INSTRUCTION SET

- Multiply instructions
- Packing / unpacking instructions
- V6 ARM SIMD packed add / sub instructions
- SIMD combined add/sub instructions, implementing canonical complex operations
- Multiply and multiply accumulate instructions
- SIMD sum absolute difference instructions
- SIMD select instruction
- Saturation instructions

## FLOATING POINT UNIT

- Introduction to IEEE754
- Floating point arithmetic
- Cortex-M4F single precision FPU
- Register bank
- Enabling the FPU
- FPU performance, fused MAC
- Improving the performance by selection flush-to-zero mode and default NaN mode
- Extension of AAPCS to include FP registers

## C/C++ COMPILER HINTS AND TIPS FOR Cortex-M4

- Mixing C/C++ and assembly
- Coding with ARM compiler
- Measuring stack usage
- Unaligned accesses
- Local and global data issues, alignment of structures
- Further optimisations, linker feedback

## THIRD DAY - EXCEPTIONS, DEBUG

### 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

### EXCEPTIONS

- Exception behavior, exception return
- Non-maskable exceptions
- Privilege, modes and stacks
- Fault escalation
- Priority boosting
- Vector table

### MEMORY PROTECTION UNIT

- Memory types
- Access order
- Memory barriers, self-modifying code

- Memory protection overview, ARM v7 PMSA
- Cortex-M4 MPU and bus faults
- Fault status and address registers
- Region overview, memory type and access control, sub-regions
- Region overlapping

## **INVASIVE DEBUG**

- Coresight debug infrastructure
- Halt mode
- Vector catching
- Debug event sources
- Flash patch and breakpoint features
- Data watchpoint and trace
- ARM debug interface specification
- Coresight components
- AHB-Access Port
- Possible DP implementations: Serial Wire JTAG Debug Port [SWJ-DP] or SW-DP

## **NON-INVASIVE DEBUG**

- Basic ETM operation
- Instruction trace principles
- Instrumentation trace macrocell
- ITM stimulus port registers
- DWT trace packets
- Hardware event types
- Instruction tracing
- Synchronization packets
- Interface between on-chip trace data from ETM and Instrumentation Trace Macrocell [ITM]
- TPIU components
- Serial Wire connection

## **FOURTH DAY HARDWARE IMPLEMENTATION**

### **AMBA3.0 INTERCONNECT SPECIFICATION**

- Purpose of this specification
- Example of SoC based on AMBA specification
- Differences between AMBA2.0 and AMBA3.0

### **AHB - ADVANCED HIGH PERFORMANCE BUS**

- Centralized address decoding
- Address gating logic
- Arbitration, bus parking
- Indivisible transactions
- Single-data transactions
- Address pipelining
- Sequential transfers
- AHB-lite specification
- Parameterizing the AHB core provided by ARM

### **APB - ADVANCED PERIPHERAL BUS**

- Second-level address decoding
- Read timing diagram
- Write timing diagram
- Operation of the AHB-to-APB bridge

- APB3.0 new features

## **AHB CORTEX-M4 HARDWARE IMPLEMENTATION**

- Clocking and reset, power management
- Using an external Wake-up Interrupt Controller (WIC)
- Bus interfaces: Icode memory interface, Dcode memory interface, System interface and External Private Peripheral Bus interface
- AMBA-3 compliance
- Unifying the code buses
- Unaligned access management
- Debug interface
- Connection to the TPIU
- AHB Trace Macrocell (HTM)

## **Renseignements pratiques**

**Inquiry : 4 days**