

## This course covers the Cortex-M33 ARMv8 core

### Course objectives

- This course is split into 3 parts:
  - Cortex-M33 architecture
  - Cortex-M33 software implementation and debug
  - Cortex-M33 DSP programming.
- The Cortex-M33, although a 32-bit core, is one of the first ARMv8-M cores proposed by ARM and includes several advanced features.
- The Cortex-M33 low level programming is explained, particularly the ARM linker parameterizing and some tricky assembly instructions.
- The course also indicates how to use the DSP and FPU instructions to boost DSP algorithm implementation.
- The various Coresight debug elements implemented in the Cortex-M33 are also presented

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

### Prerequisites

- Basic understanding of microprocessors and microcontrollers

### Course Environment

- Labs will be executed on an ARMv8 simulator.
- Printed training material is given to attendees during training.
- Precise and easy to use, it can be used as a reference afterwards.

### Environnement du cours

- Cours théorique
  - Support de cours au format PDF (en anglais) et une version imprimée lors des sessions en présentiel
  - Cours dispensé via le système de visioconférence Teams (si à distance)
  - Le formateur répond aux questions des stagiaires en direct pendant la formation et fournit une assistance technique et pédagogique
- Au début de chaque demi-journée une période est réservée à une interaction avec les stagiaires pour s'assurer que le cours répond à leurs attentes et l'adapter si nécessaire

### Audience visée

- Tout ingénieur ou technicien en systèmes embarqués possédant les prérequis ci-dessus.

### Modalités d'évaluation

- Les prérequis indiqués ci-dessus sont évalués avant la formation par l'encadrement technique du stagiaire dans son entreprise, ou par le stagiaire lui-même dans le cas exceptionnel d'un stagiaire individuel.
- Les progrès des stagiaires sont évalués par des quizz proposés en fin des sections pour vérifier que les stagiaires ont assimilé les points présentés
- En fin de formation, une attestation et un certificat attestant que le stagiaire a suivi le cours avec succès.
  - En cas de problème dû à un manque de prérequis de la part du stagiaire, constaté lors de la formation, une formation différente ou complémentaire lui est proposée, en général pour conforter ses prérequis, en accord avec son responsable en

- o entreprise le cas échéant.

## Plan

### First Day

#### **Introduction to ARMv8-M Architecture**

- ARM Cortex-M33 processor macrocell
- ARMv8-M Programmer's model
- Instruction pipeline
- Fixed memory map
- Privilege, modes and stacks
- Memory Protection Unit
- Security extensions
- Interrupt handling
- Nested Vectored Interrupt Controller [NVIC]
- Power management
- Debug

#### **ARM Cortex-M33 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-M33**

- 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

#### **Embedded Software Development with Cortex-M33**

- 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

#### **The T32 Instruction Set variant supported on ARMv8M**

- 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
- Stack limit registers
- Exclusive load and store instructions, implementing atomic sequences
- Memory barriers and synchronization

## **Synchronization and Semaphores**

- Exclusive access instructions
- The Local, Global and External monitors
- Interaction with exclusive access instructions
- Load Exclusive and Store Exclusive usage and constraints

## **Cortex-M 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

## **Third day**

## **CMSIS DSP support**

- The CMSIS library framework
- The CMSIS DSP intrinsic functions
- The optimized CMSIS data-processing functions

## **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-M33**

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

## **Exceptions**

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

## **Fourth day**

### **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
- The Nested Vectored Interrupt Controller (NVIC)

### **The Security Extension**

- Security states
- Register banking between security states
- Stacks and security states
- Security Extension and exceptions
- Secure state address protection
- Secure and Non-Secure states interactions
  - Secure state transitions
  - Function calls from Non-Secure to Secure state
  - Returning from Secure state
- Exceptions and the Security Extension
  - Handling Secure Exceptions
  - Handling Non-Secure Exceptions while in the Secure state
  - Returning from a Non-Secure exception to the Secure state
- The Security Attribution Unit
- The Implementation Defined Attribution Unit

### **Memory Protection Unit**

- Memory types
- Access order
- Memory barriers, self-modifying code
- Memory protection overview, ARM v8 PMSA
- Cortex-M33 MPU and bus faults
- Fault status and address registers
- Region overview, memory type and access control
- Setting up the MPU

### **Debugging features**

- 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

## Renseignements pratiques

**Renseignements : 4 jours**