



## Designing with STM32L4 Family

### Course Description

Designing with STM32L4 is a 3 days ST official course.

The course provides all necessary theoretical and practical know-how for start developing platforms based on STM32L4 family.

The course begins with an introduction to STM32L Ultra Low Power (ULP) microcontroller families and focuses on Cortex-M4 architecture in STM32L4.

The course continues with an in-depth study of the Cube tool, memory organization, reset unit, interrupts handling, low power modes, security, and all the SoC peripherals such as Flash, PWR, RCC, EXTI, SYS, GPIO, DMA, CRC, USART, SPI, I2C, CAN, LPUART, RTC, IWDG, WWDG, TIM, LPTIM, ADC, DAC, COMP, OAMP, TOUCH, LCD, DFSDM, SAI, RNG, AES, QSPI, FIREWALL, SWPMI, FMC, and USB

The course also employs hardware and software design tools, and combines 50% theory with 50% practical work in every meeting.

### Course Duration

3 days



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## Goals

1. Become familiar with STM32L families
2. Become familiar with ARM Cortex-M4 architecture
3. Become familiar with STM32L4 peripherals
4. Become familiar with hardware and software design tools
5. Build a new project using the development tools
6. Work with Firmware libraries
7. Control efficiently low power modes
8. Configure and work with STM32L4 peripherals

## Target Audience

Software and hardware engineers who would like start developing with STM32L4 microcontrollers

## Prerequisites

- Computer architecture background
- Experience in C programming
- Experience in developing embedded systems

## Course Material

- STMCube
- ST Discovery Eval board
- Course book (including labs)

## Agenda



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## Day #1

- **STM32L4 MCU Series**
  - STM32L4 highlights
  - STM32L ULP offer
  - STM32L4 main features
  - STM32L4 block diagram
  - Safety and security
  - STM32 product series
  
- **STM32L4 ARM Core**
  - Cortex-M processors overview
  - ARM Cortex-M4 core
  - Cortex-M4 processor microarchitecture
  - Cortex-M feature set comparison
  - NVIC
    - Nested vectored interrupt controller overview
    - Key features
    - Exception entry and return
    - Tail chaining and late arriving optimizations
    - NVIC hints and tips
  - Single cycle MAC unit
  - Saturated arithmetic
  - Single cycle SIMD instructions
  - DSP and non-DSP instructions
  - Packed data types
  - DSP performance for control application
  - DSP lib
  - Tools
  - Main DSP operations (FIR, IIR, FFT)
  - Assembly or C?
  - Optimization strategies
  - FIR filter example
    - Cortex-M inner loop
    - Loop unrolling
    - Apply SIMD
    - CMSIS files
    - Data organization with caching
  - Floating point unit

- FPU usage
  - Benefits of a FPU
  - Rounding issues
  - C example
  - IEEE 754
  - Floating point operations
  - Floating point format conversion
  - Exceptions
  - ARM FPv4-SP single precision FPU
  - FPU instructions
  - Exception handling
- **STM32CubeMX Development Tool**
    - STM32CubeMX introduction
    - Key features
    - Prerequisites and settings
    - Updater
    - MCU selector
    - Pin assignment
    - Clock configuration
    - Peripheral and middleware configuration
    - NVIC configuration panel
    - DMA configuration panel
    - GPIO settings panel
    - Code generation
    - Power consumption calculator (PCC)
    - General PCC parameters
    - Building a sequence
    - Power consumption step definition
    - Sequence consumption profile display
    - Output and generating report
  - **STM32Cube Hardware Abstraction Layer & Low Layer Drivers**
    - STM32Cube HAL introduction
    - STM32CubeL4 package key features
    - Low layer drivers
    - Firmware architecture
    - STM32CubeL4 package structure
  - **STM32L4 Interconnect Matrix**



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- Interconnect Matrix overview
- Interconnect Matrix key features
- Sources and destinations
- Low-power modes
- Application examples
  
- **STM32L4 Debug**
  - Debug overview
  - Debug key features
  - Flash patch and breakpoint unit (FPB)
  - Data watchpoint trigger (DWT)
  - Instrumentation trace macrocell (ITM)
  - Embedded trace macrocell (ETM)
  - Trace port interface unit (TPIU)
  - Flexible SWJ-DP pin assignment
  - Low-power modes
  
- **STM32L4 Flash**
  - Overview
  - Key features
  - Flash organization
  - Flash dual bank
  - Dual bank boot
  - ECC
  - Programming/erase time
  - Row fast programming
  - Standard versus fast programming modes
  - Flash retention
  - Flash read access
  - Adaptive real-time memory accelerator (ART Accelerator)
  - ART basics
  - Flash memory protection
  - User option bytes
  - Interrupts
  - Low power modes
  - Flash performance
  - Related peripherals
  
- **STM32L4 Power Control**



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- FlexPowerControl overview
  - Key features
  - Power schemes
  - Peripheral voltage monitor
  - Power supply supervisor
  - Voltage regulators
  - Run mode: range1, range 2
  - Low power run mode
  - Power optimization versus frequency
  - Sleep and low power sleep modes
  - Batch Acquisition Mode (BAM)
  - Stop 1 and Stop 2 modes
  - Standby mode
  - Standby mode with SRAM2
  - Shutdown mode
  - Low power modes summary
  - Low power modes transitions
  - VBAT backup domain
  - VBAT mode
  - Option bytes
  - Debug information
  - Related peripherals
- 
- **Reset and Clock Controller**
    - RCC overview
    - Reset key features
    - Reset sources
    - Clock key features
    - Multi-Speed Internal (MSI) clock
    - High-Speed Internal (HIS) clock
    - HIS vs MSI characteristics
    - High-Speed External (HSE) clock
    - Low-Speed Internal (LSI) clock
    - Low-Speed External (LSE) clock
    - 3 PLL clocks
    - System clock
    - Clock tree block diagram
    - Clock-out capability
    - Clock gating

- Interrupts
- Related peripherals
  
- **EXTI – Extended Interrupts & Events Controller**
  - EXTI overview
  - EXTI key features
  - Low power modes
  
- **SYSCFG – System Configuration Controller**
  - SYSCFG overview
  - Memory mapping
  - Memory remap
  - Bus matrix
  - Boot modes
  - Bootloader
  - SRAM2 features
  - SYSCFG safety & robustness features
  - Performance
  - Related peripherals
  
- **GPIO – General Purpose I/O Interface**
  - GPIO overview
  - GPIO key features
  - Operating modes
  - Alternate functions
  - Independent  $V_{DDIO2}$  supply
  - Special considerations for I/O pins
  - Special considerations for HSE/LSI pins
  - Analog switch control register
  - Multi-supply I/O pins
  - Low power modes
  
- **Lab #1: System Configuration and using EXTI**
- **Lab #2: Low Power Modes**

## Day #2

- **STM32L4 DMA**
  - DMA overview
  - DMA key features
  - Individual channel flexibility
  - Channel transfer management
  - STM32L4 instances
  - DMA1 requests mapping
  - DMA2 requests mapping
  - Interrupts
  - DMA in low-power modes
  
- **STM32L4 CRC**
  - CRC overview
  - CRC key features
  - CRC block diagram
  - Input and output format
  - Performance
  - Low-power modes
  
- **STM32L4 USART**
  - USART overview
  - USART key features
  - USART block diagram
  - Dual clock domain
  - Oversampling
  - Data format – asynchronous mode
  - Idle/break character
  - Full/half duplex modes
  - RS-232 hardware flow control
  - RS-485 hardware flow control
  - Multi-processor communication
  - Synchronous mode
  - ISO/IEC 7816 mode
  - IrDA SIR encoder decoder



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- Auto baudrate detection
  - Receiver timeout
  - Wake up from stop mode
  - Interrupts
  - Interrupts and DMA
  - Error interrupts
  - Low-power modes
  - STM32L4 USART instances features
  - Related peripherals
- **STM32L4 SPI**
    - SPI overview
    - SPI key features
    - SPI block diagram
    - Interconnection of SPI nodes
      - Full duplex
      - Simplex
      - Half-duplex
      - Multi-slave: star topology
      - Multi-slave: circular topology
      - Multi-master
    - Data frame format
    - Data packing, FIFO access
    - 32-bit Rx and Tx FIFOs
    - FIFO threshold and CRC control
    - Standard NSS modes
    - Specific NSS modes
    - Interrupts and DMA
    - Low-power modes
    - Performance
    - Application tips and tricks
    - STM32L4 instances features
    - SPI related peripherals
  - **STM32L4 I2C**
    - I2C overview
    - I2C key features
    - I2C block diagram
    - I2C SDA and SCL noise filters
    - I2C programmable timings

- I2C master clock generation
  - Slave addressing mode
  - Wakeup from Stop mode on address match
  - Simple master mode management
  - Easy to use event management
  - Slave mode
  - SMBUS
  - SMBus Packet Error Checking (PEC)
  - Interrupts and DMA
  - Error interrupts
  - Low-power modes
  - Debug information
  - STM32L4 instances features
  - Related peripherals
- **STM32L4 CAN**
    - CAN overview
    - CAN features
    - BxCAN features
    - BxCAN operating modes
    - BxCAN test modes
    - BxCAN block diagram
    - Interrupts
    - Low-power modes
    - Related peripherals
- **STM32L4 LPUART**
    - LPUART overview
    - LPUART key features
    - LPUART block diagram
    - Dual clock domain
    - Data format
    - Idle/break character
    - Full/half duplex modes
    - RS-232 hardware flow control
    - RS-485 hardware flow control
    - Multi-processor communication
    - Wakeup from Stop mode
    - Interrupts



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- Error interrupts and DMA
  - Low-power modes
  - STM32L4 LPUART vs USART
  - Related peripherals
- **Lab #3:** Using DMA, SPI, UART and LPUART
- **STM32L4 RTC**
    - RTC overview
    - RTC key features
    - RTC block diagram
    - RTC register write protection
    - RTC calendar
    - Smooth digital calibration
    - RTC programmable alarm
    - Periodic auto-wakeup
    - Tamper detection
    - Interrupts
    - Low-power modes
    - Debug information
    - Related peripherals
- **STM32L4 IWDG**
    - IWDG overview
    - IWDG key features
    - IWDG block diagram
    - Configuring IWDG hardware start
    - Configuring IWDG software start
    - IWDG settings and reset flag
    - Debug information
    - Low-power modes
- **STM32L4 WWDG**
    - WWDG overview
    - WWDG key features
    - WWDG block diagram
    - WWDG functional description
    - WWDG settings and reset flag

- Interrupts
- Low-power modes
- Debug information
  
- **STM32L4 Timers**
  - Timers overview
  - Timers key features
  - TIM block diagram
  - Timer clocking schemes
  - Counting period management
  - Counting mode
  - Timer as internal timing resource
  - Input capture
  - Advanced capture options
  - Output compare
  - One pulse mode
  - PWM modes
  - Advanced PWM modes
  - Cascading timers
  - Example of synchronized operation
  - Motor control features
  - Deadtime insertion
  - 6-step / block commutation
  - Break function
  - Bidirectional break inputs
  - ADC triggering
  - ADC synchronization example
  - Interrupts and DMA
  - DMA burst mode
  - Low-power modes
  - Debug
  - Application tips and tricks
  - Related peripherals
  - STM32L4 instances features
  
- **STM32L4 LPTIM**
  - LPTIM overview



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- LPTIM key features
  - LPTIM block diagram
  - Up to 3 configurable waveforms
  - Encoder mode
  - Interrupts
  - Low-power modes
- **STM32L4 IRTIM**
    - IRTIM overview
    - IRTIM key features
    - IRTIM block diagram
    - Carrier frequency generator
    - Modulation waveform generator
    - IRTIM modulator
    - IR\_OUT pin
    - Interrupts
    - Low-power modes
    - Related peripherals
- **Lab #4: Using WWDG, TIM, RTC and LPTIM**

## Day #3

- **STM32L4 ADC**
  - ADC overview
  - ADC key features
  - ADC block diagram
  - Low-power features
  - High performance features
  - ADC conversion speeds
  - Sampling times
  - ADC clocks
  - ADC conversion modes
  - Hardware oversampling
  - Analog watchdog
  - Data transfers

- Injected conversions
  - Interrupts and DMA
  - Low-power modes
  - Performance
  - Related peripherals
  - Features for each individual ADC
- **STM32L4 DAC**
    - DAC overview
    - DAC key features
    - DAC block diagram
    - DAC with output buffer
    - DAC data formats
    - DAC conversion triggers
    - Sample and hold features
    - Noise and triangle wave generation
    - DAC with DMA
    - Interrupts and DMA
    - Low-power modes
    - Performance
    - Related peripherals
- **STM32L4 Comparator**
    - COMP overview
    - COMP key features
    - COMP block diagram
    - COMP low power features
    - Interrupts
    - Low-power modes
    - Performance and power consumption
    - COMP window mode
    - COMP break signal generation
    - COMP blanking
    - STM32L4 COMP differences
    - Related peripherals
- **STM32L4 OP-AMP**
    - OP-AMP overview



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- OP-AMP key features
  - OP-AMP block diagram
  - Internal follower mode
  - PGA mode
  - Transimpedance amplifier
  - Low-power modes
  - Performance
  - Related peripherals
- **STM32L4 Touch Sensing Controller (TSC)**
    - TSC overview
    - TSC key features
    - TSC block diagram
    - Charge transfer acquisition overview
    - Charge transfer measuring circuit
    - Charge transfer acquisition sequence
    - I/O configuration
    - Acquisition modes
    - GPIO analog switch and hysteresis control
    - Interrupts
    - Low-power modes
    - Number of capacitive sensing channels
    - Application tips and tricks
    - STM32Cube Touch sensing library features
    - Related peripherals
- **Lab #5: Using ADC and DAC**
- **STM32L4 LCD**
    - LCD overview
    - LCD principle
    - LCD key features
    - LCD block diagram
    - Frequency generator
    - Frame format
    - LCD contrast compensation
    - LCD contrast level
    - LCD dual drive capability
    - LCD low power output buffers

- LCD RAM arrangement
- Interrupts
- Low-power modes
- Related peripherals
  
- **STM32L4 Digital Filter for Sigma-Delta Modulators (DFSDM)**
  - DFSDM typical usage
  - DFSDM overview
  - DFSDM key features
  - DFSDM block diagram
  - Serial transceivers
  - Parallel transceivers
  - Sincx/x digital filter
  - Integrator unit
  - Output data unit
  - Analog watchdog
  - Short circuit detector
  - Extremes detector
  - Conversion type selection
  - MEMS microphone support (PDM)
  - Interrupts
  - DMA
  - Low-power modes
  - Performance
  - Application examples
  - Related peripherals
  
- **STM32L4 Serial Audio Interface (SAI)**
  - SAI overview
  - SAI key features
  - SAI block diagram
  - SAI in the circuit
  - Free protocol modes
  - SPDIF protocol
  - AC97 protocol
  - Interrupts and DMA
  - Low-power modes
  - Application examples
  
- **STM32L4 Random Number Generator (RNG)**



- RNG overview
- RNG key features
- RNG block diagram
- Application examples
- Related peripherals
  
- **STM32L4 AES Hardware Accelerator**
  - AES overview
  - AES key features
  - AES block diagram
  - AES processing time
  - Interrupts and DMA
  - Low-power modes
  - Application examples
  - Related peripherals
  
- **STM32L4 Device Electronic Signature**
  - Device electronic signature overview
  - UID key features
  - Unique device ID register
  
- **STM32L4 QSPI Memory Interface**
  - QSPI overview
  - QSPI key features
  - Frame format
  - Indirect operating mode
  - Status-polling mode
  - Memory-mapped mode
  - Delayed data sampling
  - Interrupts and DMA
  - Low-power modes
  - Performance & power consumption
  - Energy
  - Coremark scores
  - Application examples
  - Related peripherals
  
- **STM32L4 Firewall**



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- Firewall overview
  - Firewall key features
  - Firewall states
  - Call gate function
  - Access to protected segments
  - Interrupt and DMA
  - Complementary protections
  - Related peripherals
- **STM32L4 Single Wire Protocol Master Interface (SWPMI)**
    - SWPMI overview
    - SWPMI key features
    - SWPMI principle
    - Class B and class C
    - S1 signal
    - S2 signal
    - SWP frame structure
    - SWP frame handling by SWPMI
    - SWP bus states
    - SWPMI block diagram with internal/external transceiver
    - No Software Buffer mode (NSB)
    - Software Single Buffer mode (SSB)
    - Software Multi Buffer mode (SMB)
    - Interrupts
    - DMA
    - Low-power modes
    - Related peripherals
- **STM32L4 Flexible Static memory Controller (FSMC)**
    - FSMC overview
    - FSMC key features
    - Supported devices
    - Bank memory mapping
    - NOR/PSRAM address mapping
    - NOR/PSRAM interface signals
    - NOR/PSRAM timing configuration
    - NAND address mapping
    - NAND interface signals
    - NAND configuration
    - NAND timing configuration

- Interrupts
- Low-power modes
  
- **STM32L4 USB Interface**
  - USB overview
  - USB key features
  - USB block diagram
  - Operating modes
  - Interrupts
  - Low-power modes
  - Debug information
  
- **Lab #6: Using USB CDC and USB HID**



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