COEN-4720 Embedded Systems

Lecture 4
STM32CubeIDE, HAL

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BE THE DIFFERENCE.

Outline

- STM32CubeIDE
- ST HAL
- CMSIS
- STM32CubeMX

New Project in STM32CubeIDE

- When a new project is created in STM32CubeIDE, it downloads the corresponding Cube Firmware Package for the selected Nucleo board
- This includes several components, including:
  - Complete HAL for given STM32 family: Hardware Abstraction Layer (HAL)
    - Set of libraries that allow to drive the microcontroller peripherals and core features without dealing with the details of the given MCU
  - Additional Middleware packages
  - Examples projects for development boards

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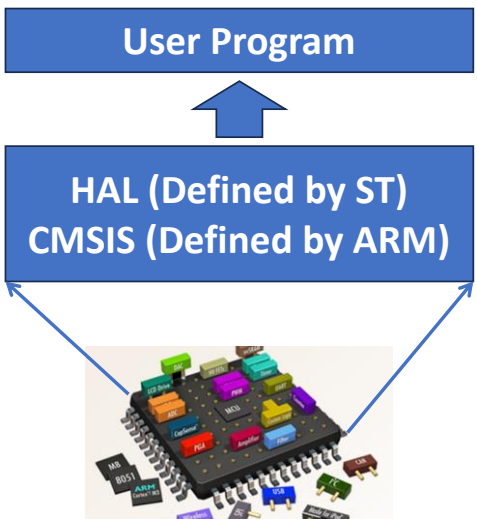
Hardware Abstraction Layer (HAL)




```
97  while (1)
98  {
99    /* USER CODE END WHILE */
100   /* USER CODE BEGIN 3 */
101   HAL_GPIO_TogglePin(LD2_GPIO_Port, LD2_Pin);
102   HAL_Delay(500);
103 }
```

```
74  /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
75  HAL_Init();

81  /* Configure the system clock */
82  SystemClock_Config();
```

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Cortex Microcontroller Software Interface Standard (CMSIS)

- ARM - actively working on a way to standardize the software infrastructure among MCUs vendors
- This is an evolving effort
- Cortex Microcontroller Software Interface Standard (CMSIS) is a vendor-independent hardware abstraction layer for Cortex-M processors
- CMSIS consists of many components, including:
  - CMSIS-CORE: API for the Cortex-M processor core and peripherals
  - CMSIS-Driver: Defines generic peripheral driver interfaces for middleware
  - CMSIS-RTOS API: Common API for Real-Time Operating Systems
  - ... many more

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Cortex Microcontroller Software Interface Standard (CMSIS)

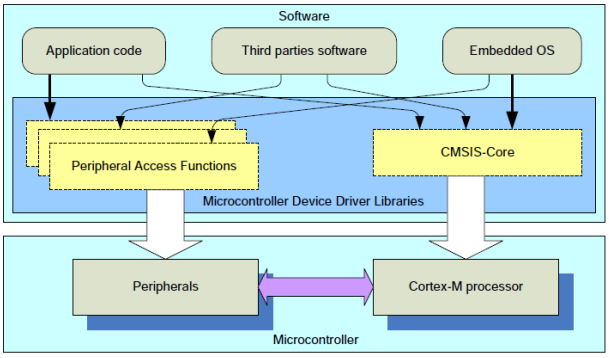

Figure 3.17
CMSIS-CORE provides standardized access functions for processor features.

- **CMSIS contains definitions for the various registers**
- **Allows easy access to MCU's registers**
  - **One can then implement his/her own HAL**
- **CMSIS is defined by ARM and not ST**
  - **Greatly aids in portability**
- **HAL may have more bugs**
  - **CMSIS cleaner and more stable**
- **One can code by using HAL and CMSIS**

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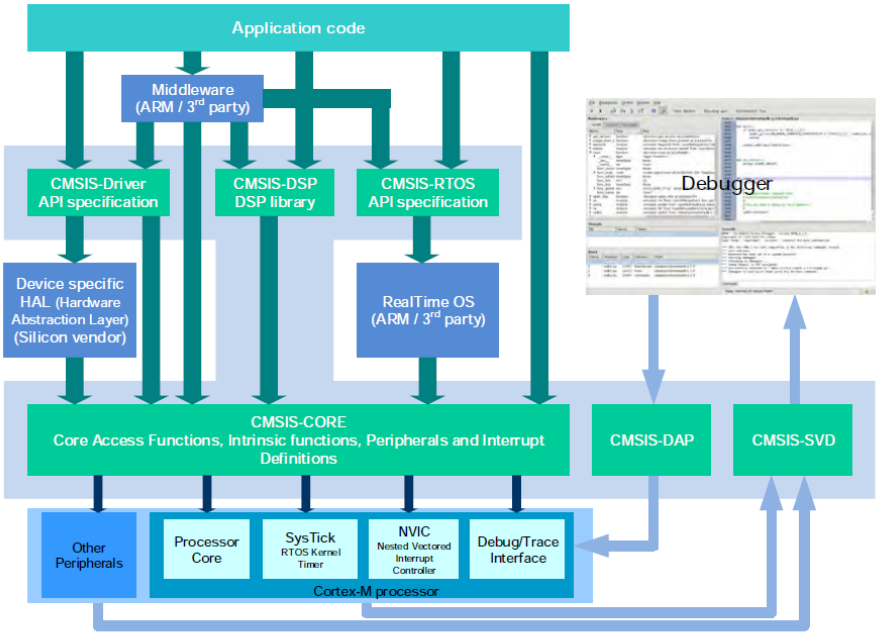

Figure 3.18
Interactions between different CMSIS projects.

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STM32CubeMX Tool

- A fundamental tool integrated inside STM32CubeIDE.
- Upon creation of new project, it can be used for Peripheral Configurations.
  - It makes it easy for programmers; otherwise, one needs to dig into datasheets and user manuals
  - Programmer can ignore specific implementation details underlying a peripheral configuration
- Used both to:
  1. Choose the right hardware connections
  2. Generate the code necessary to configure the ST HAL

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STM32CubeMX Tool

- Once a new project has been created, STM32CubeIDE automatically opens a file in the project folder named <project-name>.ioc
- This file is the CubeMX main project file, containing all the configurations performed in CubeMX
- Starting from them, CubeMX will generate the corresponding project structure, with all source files and libraries needed to use the selected peripherals and Middleware components

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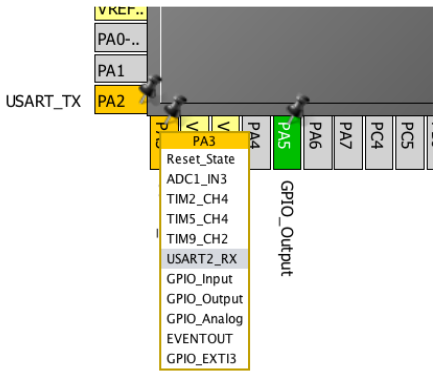
STM32CubeMX Tool

- Example of usage:
  - Most of MCU pins can have alternate functionalities
  - CubeMX can be used to select desired functionality for a pin



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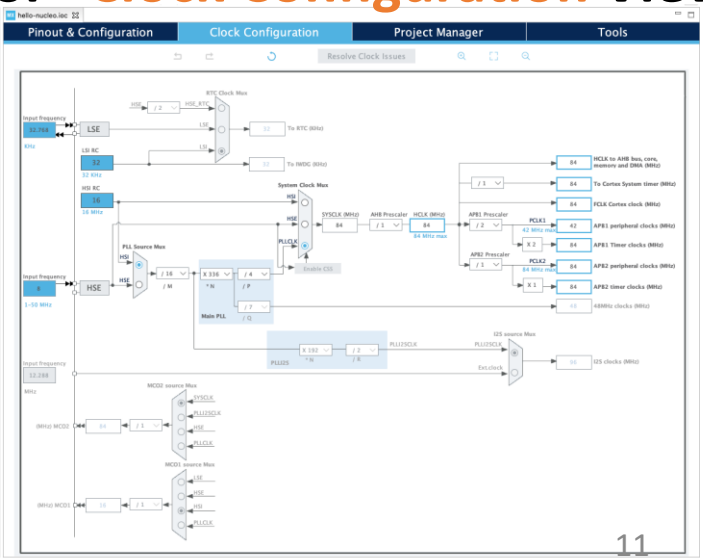
STM32CubeMX Tool - Clock Configuration View

- Clock Configuration view is the pane where all configurations related to clocks management take place



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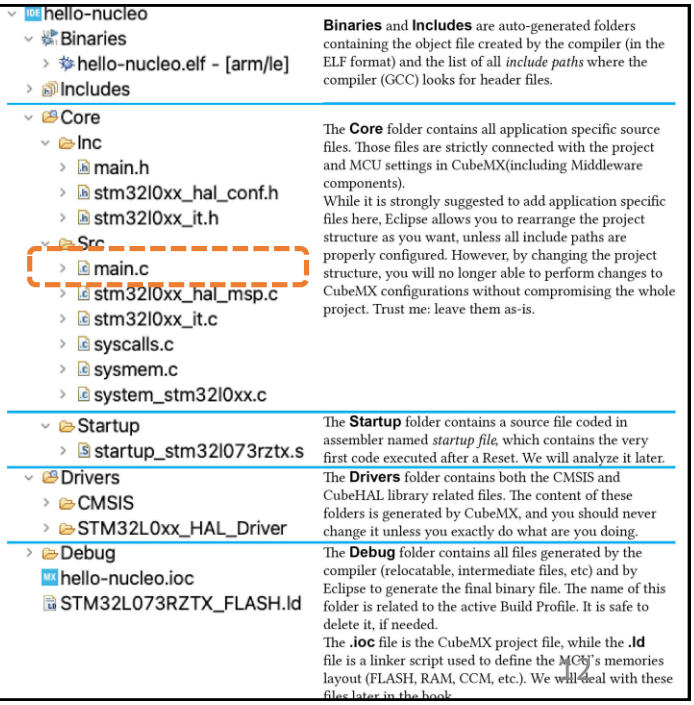
Project Structure

- After all configurations with CubeMX are done, the <project-name>.ioc file is saved and the skeleton files for the project are created. Including main.c



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main.c Automatically Created

- The project generated by CubeIDE automatically contains all the necessary code to build a self-consistent application
- main.c includes already a template, which includes code that takes care of default configurations
  - One can then add code to this file to implement desired functionality
  - For example, the blink LED example needs just a few additional lines of code

```
97    while (1)
98    {
99      /* USER CODE END WHILE */
100     /* USER CODE BEGIN 3 */
101     HAL_GPIO_TogglePin(LD2_GPIO_Port, LD2_Pin);
102     HAL_Delay(500);
103   }
```

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main.c

- **HAL_Init()**
  - Initializes the CubeHAL framework.
  - Responsible of the very first MCU initialization.
- **SystemClock_Config()**
  - Configures the MCU to work with one of the possible clock sources.
- **MX_GPIO_Init()**
  - Initializes I/O pins, according to the graphical configuration done in STM32CubeMX.
- **MX_USART2_UART_Init()**
  - Initializes the UART2 peripheral, which is wired to the ST-LINK interface in all Nucleo boards.

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Blink LD2 LED Example

- HAL_GPIO_TogglePin() function inverts the logical state of the PIN connected to the LD2 LED (corresponds to PIN 5 of the GPIO port A in all Nucleo-64 boards)
- HAL_Delay() introduces a delay of 500ms (LD2 will blink at 1HZ rate)
- PA5 is shorthand for PIN5 of GPIO port A, which is the standard way to indicate a GPIO in STM32 world.
- STM32CubeMX automatically defines the macro LD2_GPIO_Port and LD2_Pin so that their expansion corresponds to GPIOA port and PIN5.

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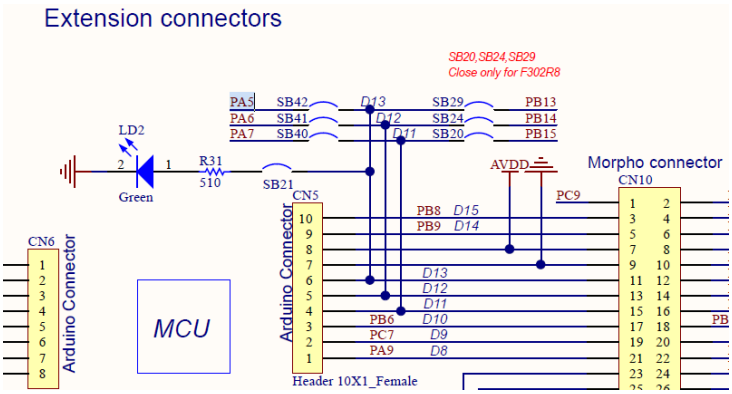
Schematic Diagram of Board

- See Schematic Diagram of Nucleo board to check connection of PA5:



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Core/Inc/stm32XXxx_hal_conf.h

- File where HAL configurations are translated into C code, using several macros.
- These macros are used to "instruct" the HAL about enabled MCU functionalities.
- They are used to selectively include HAL modules at compile time.
- When you need a module, you can simply uncomment the corresponding macro.

Filename: Core/Inc/stm32XXxx_hal_conf.h

```
55  #define HAL_UART_MODULE_ENABLED
56  /*#define HAL_USART_MODULE_ENABLED   */
57  /*#define HAL_IRDA_MODULE_ENABLED    */
58  /*#define HAL_SMARTCARD_MODULE_ENABLED   */
59  /*#define HAL_SMBUS_MODULE_ENABLED   */
60  /*#define HAL_WWDG_MODULE_ENABLED    */
61  /*#define HAL_PCD_MODULE_ENABLED     */
62  #define HAL_GPIO_MODULE_ENABLED
63  #define HAL_EXTI_MODULE_ENABLED
64  #define HAL_DMA_MODULE_ENABLED
65  #define HAL_I2C_MODULE_ENABLED
66  #define HAL_RCC_MODULE_ENABLED
67  #define HAL_FLASH_MODULE_ENABLED
68  #define HAL_PWR_MODULE_ENABLED
69  #define HAL_CORTEX_MODULE_ENABLED
```

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Core/Inc/stm32XXxx_it.h and Core/Src/stm32XXxx_it.c

- Where all the Interrupt Service Routines (ISR) generated by CubeMX are stored
- For example: the case of Blink LED LD2 project:
  - void SysTick_Handler(void)
  - This function is the ISR of the SysTick timer - the routine invoked when the SysTick timer reaches 0. But where is this ISR invoked?
  - A: Nested Vectored Interrupt Controller (NVIC)
  - Cortex-M defines the SysTick_Handler to be the fifteenth exception in the NVIC vector array. But where is this array defined?
  - A: Inside the Core/Startup folder, a special assembly file: **Core/Startup/startup_stmXXxx.s**

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startup_stm32l053r8tx.s

```
118 ******************************************************************************/
119   .section  .isr_vector,"a",%progbits
120   .type  g_pfnVectors, %object
121   .size  g_pfnVectors, .-g_pfnVectors
122
123
124 g_pfnVectors:
125   .word  _estack
126   .word  Reset_Handler
127   .word  NMI_Handler
128   .word  HardFault_Handler
129   .word  0
130   .word  0
131   .word  0
132   .word  0
133   .word  0
134   .word  0
135   .word  0
136   .word  SVC_Handler
137   .word  0
138   .word  0
139   .word  PendSV_Handler
140   .word  SysTick_Handler
141   .word     WWDG_IRQHandler                   /* Window WatchDog              */
142   .word     PVD_IRQHandler                    /* PVD through EXTI Line detection */
```

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Core/Src/stm32XXxx_hal_msp.c

- "MSP" stands for MCU Support Package
- Defines all initialization functions used to configure the on-chip peripherals according to the user configuration
  - PIN allocation
  - Enabling of clock
  - Use of DMA and Interrupts

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- Example: A peripheral is essentially composed of two things:
  1. the peripheral itself (for example, the SPI2 interface)
  2. the hardware pins associated with this peripheral
  - ST HAL is designed so that the SPI module of the HAL is generic and abstracted from the specific I/O settings - which may differ due to the MCU package and the user-defined hardware configuration
  - ST developers left to the user the responsibility to "fill" this piece of the HAL with the code necessary to configure the peripheral - using a sort of **callback** routines.
    - This code resides inside Core/Src/stm32XXxx_hal_msp.c

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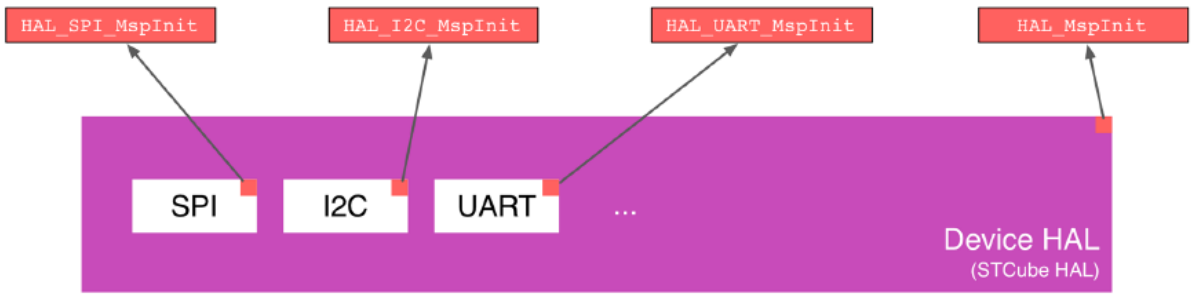

Figure 4.15: The relation between MSP files and the HAL

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main.c | stm32l0xx_hal_msp.c

```
85 void HAL_UART_MspInit(UART_HandleTypeDef* huart)
86 {
87   GPIO_InitTypeDef GPIO_InitStruct = {0};
88   if(huart->Instance==USART2)
89   {
90   /* USER CODE BEGIN USART2_MspInit 0 */
91
92   /* USER CODE END USART2_MspInit 0 */
93     /* Peripheral clock enable */
94     __HAL_RCC_USART2_CLK_ENABLE();
95
96     __HAL_RCC_GPIOA_CLK_ENABLE();
97     /**USART2 GPIO Configuration
98     PA2     ------> USART2_TX
99     PA3     ------> USART2_RX
100    */
101    GPIO_InitStruct.Pin = GPIO_PIN_2|GPIO_PIN_3;
102    GPIO_InitStruct.Mode = GPIO_MODE_AF_PP;
103    GPIO_InitStruct.Pull = GPIO_NOPULL;
104    GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_VERY_HIGH;
105    GPIO_InitStruct.Alternate = GPIO_AF4_USART2;
106    HAL_GPIO_Init(GPIOA, &GPIO_InitStruct);
107
108  /* USER CODE BEGIN USART2_MspInit 1 */
109
110  /* USER CODE END USART2_MspInit 1 */
111  }
112
113 }
```

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Call Hierarchy

- main.c → MX_USART2_UART_Init() → HAL_UART_Init() → HAL_UART_MspInit()

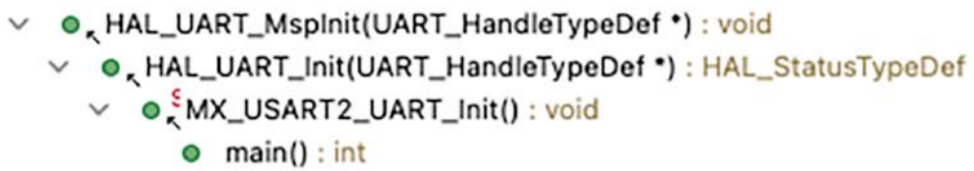

Figure 4.16: The Call Hierarchy of the function HAL_UART_MspInit()

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