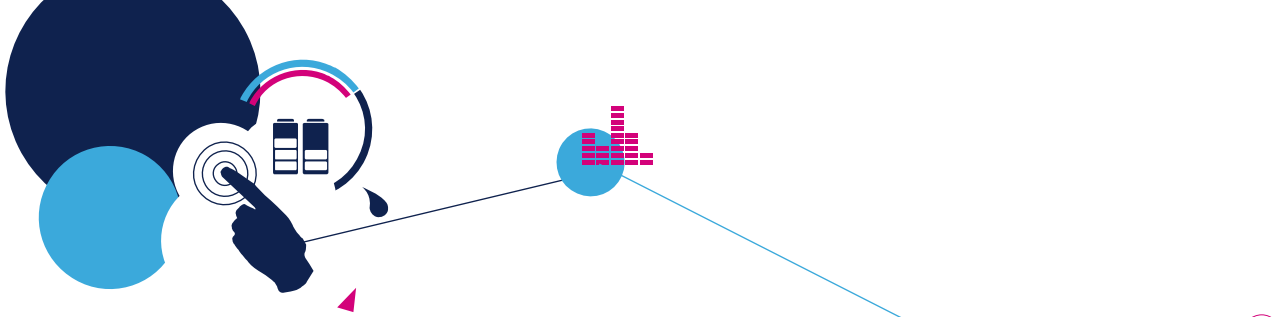

STM32L4 – Putting All Together

STM32L4 Workshop

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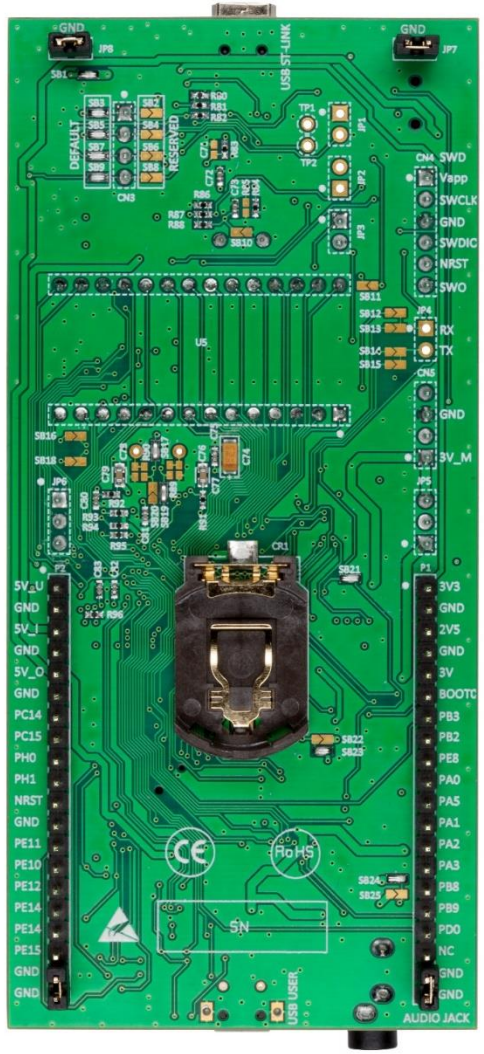
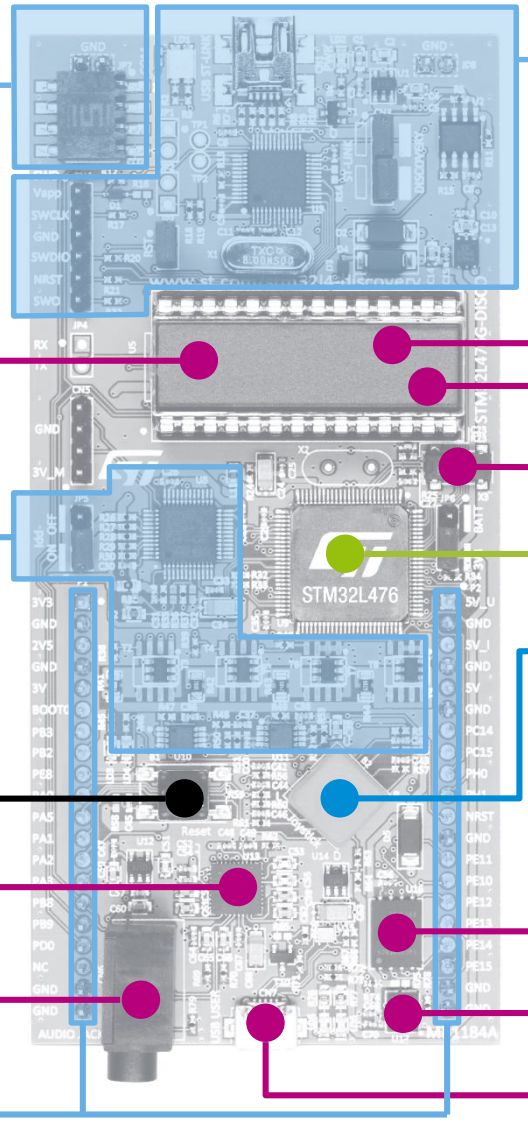
Goal of this part

- Get some basic knowledge about advanced topics
- Practice a little bit with STM32CubeMX
- Understand the structure of prepared demo application
- Have some fun!

STM32L476 Discovery



STM32L476 Discovery



APC connector
(for Apple connector – I²C)

Glass LCD (96 segments)

MFX
(for I_{DD} measurement)

Reset Button

Audio Codec

Audio Out (3.5mm jack)

GPIO access

Integrated ST-Link/V2-1
(for programming and debugging)

Accelerometer + Magnetometer (3-axis)

Gyro (3-axis)

32.768kHz crystal

STM32L476VG
1MB FLASH
LQFP100

Joystick (Push Buttons)

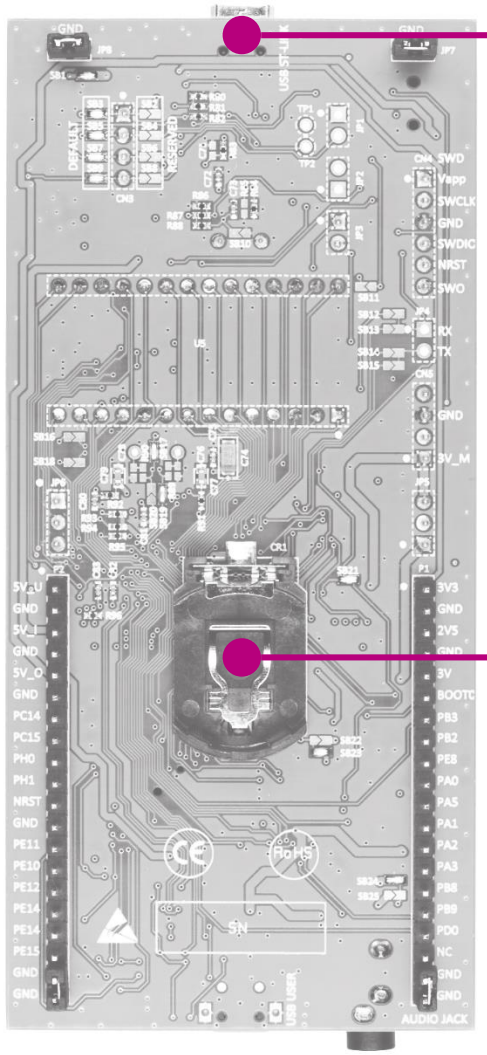
QUADSPI NOR Flash (16MB)

MEMS Microphone

USB OTG connector

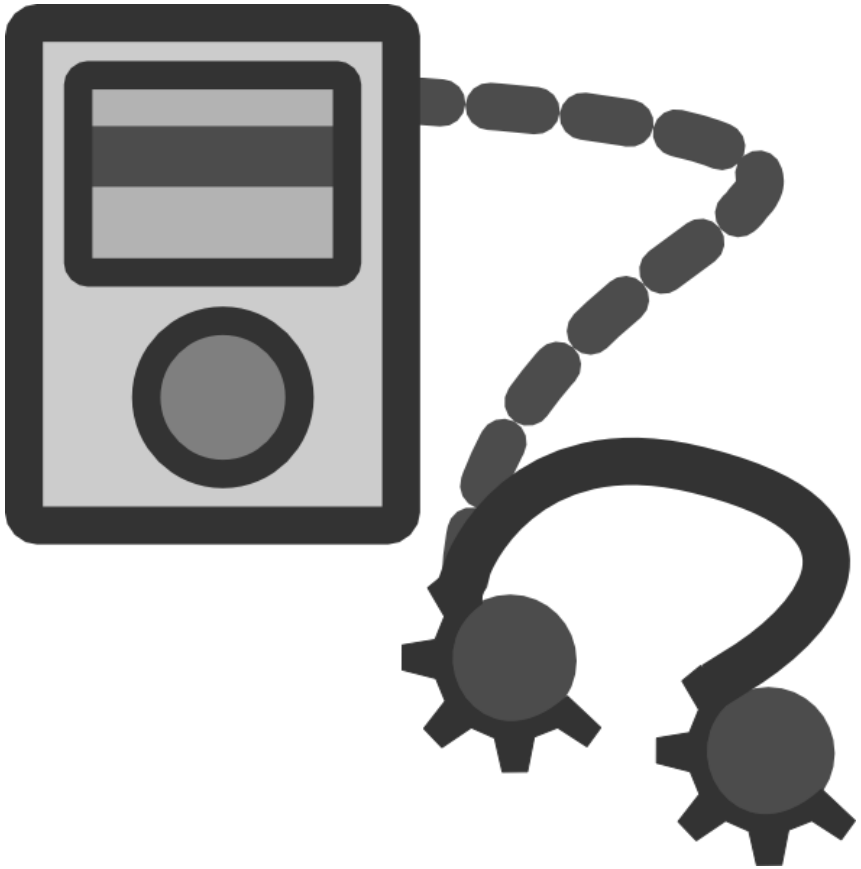
STM32L476 Discovery

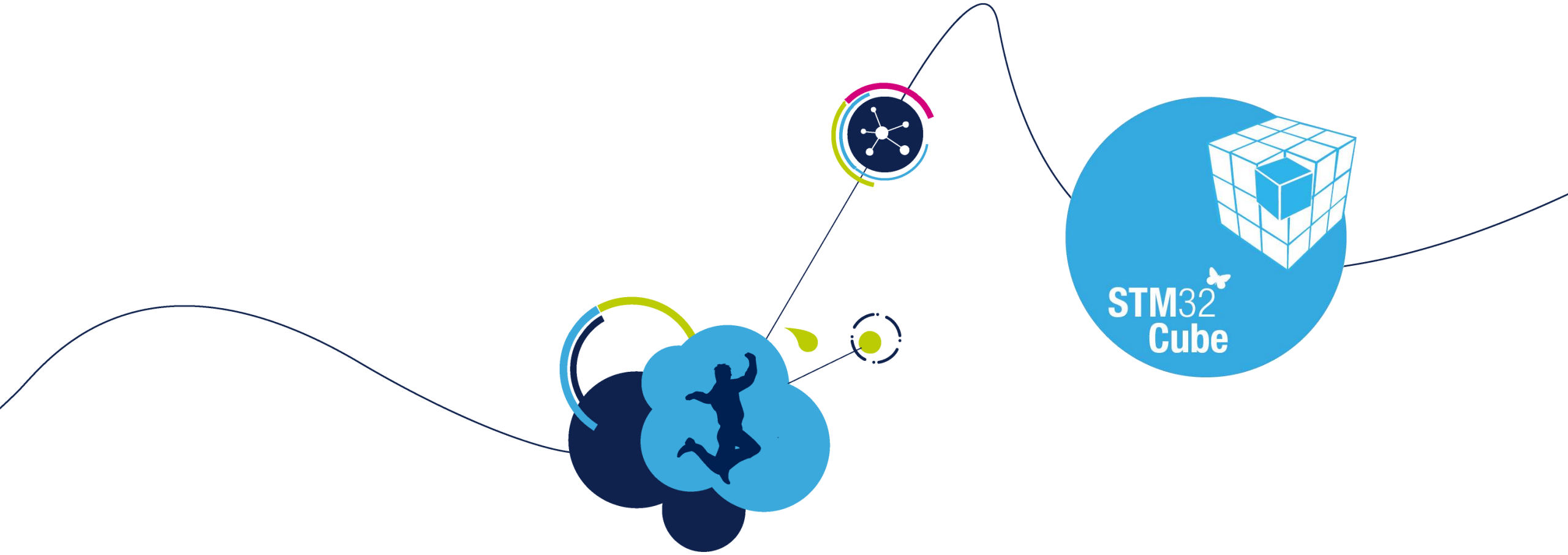
Flexible board power supply



Application idea

- Create simple Audio Player





Let’s start to work!

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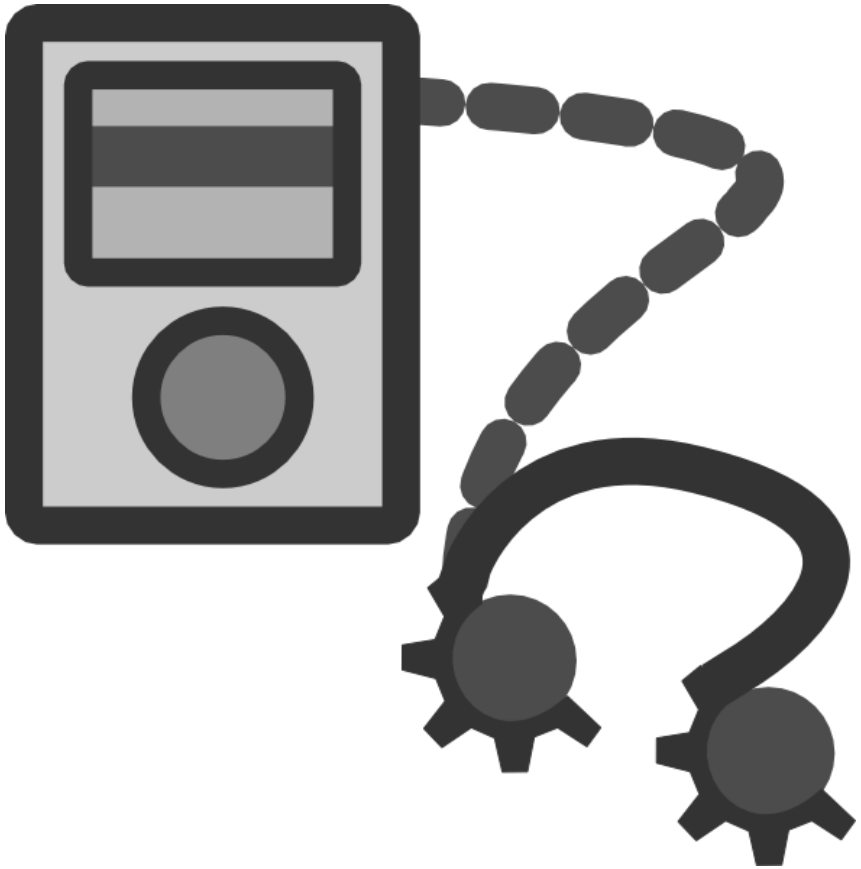
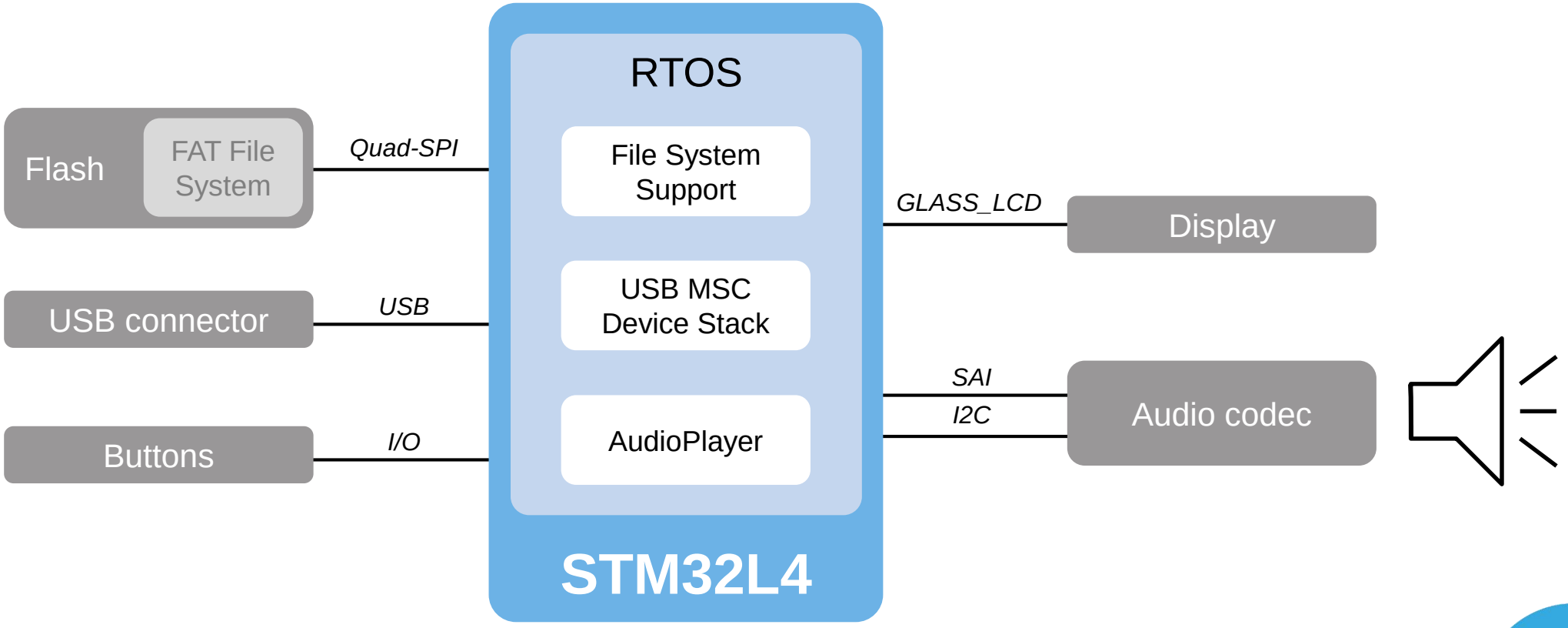
Application idea

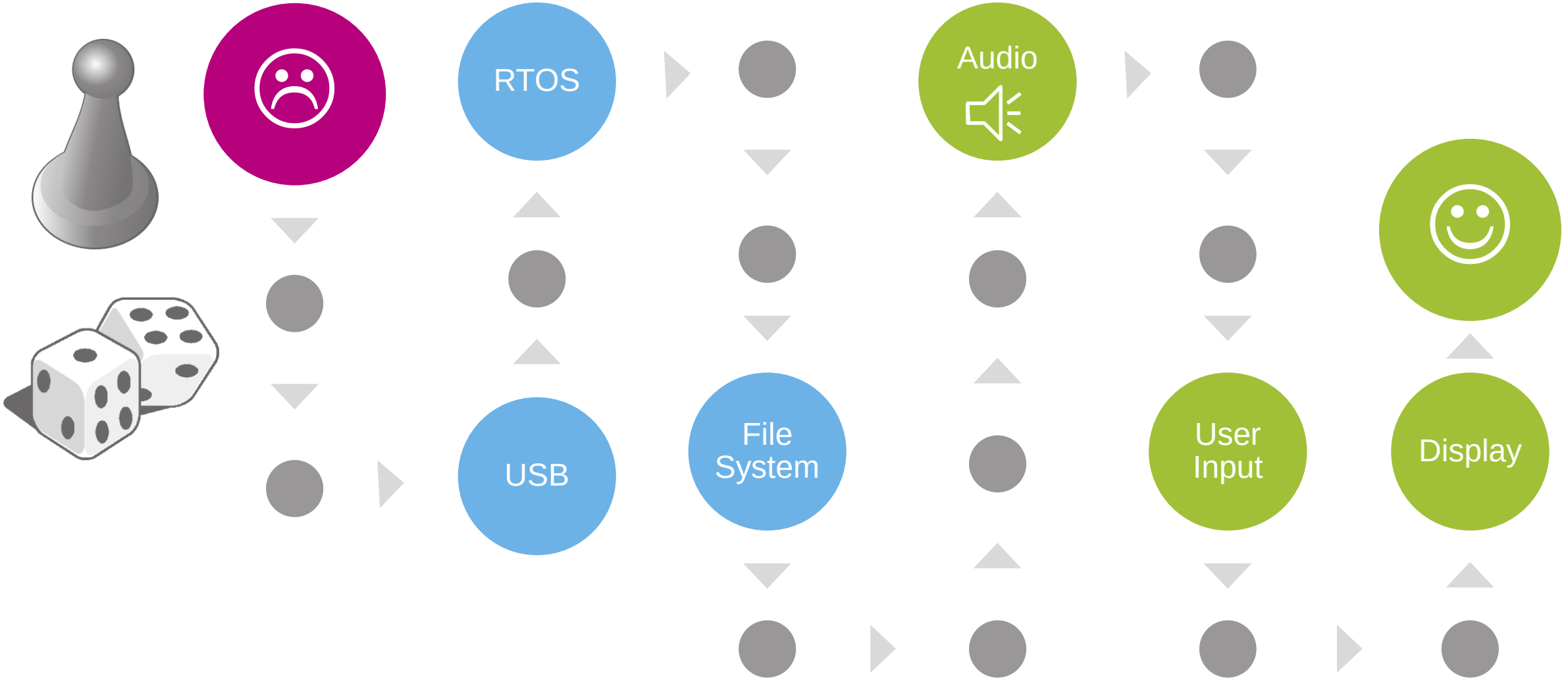
- Create simple Audio Player



Simplified target block diagram



„Game“ flow



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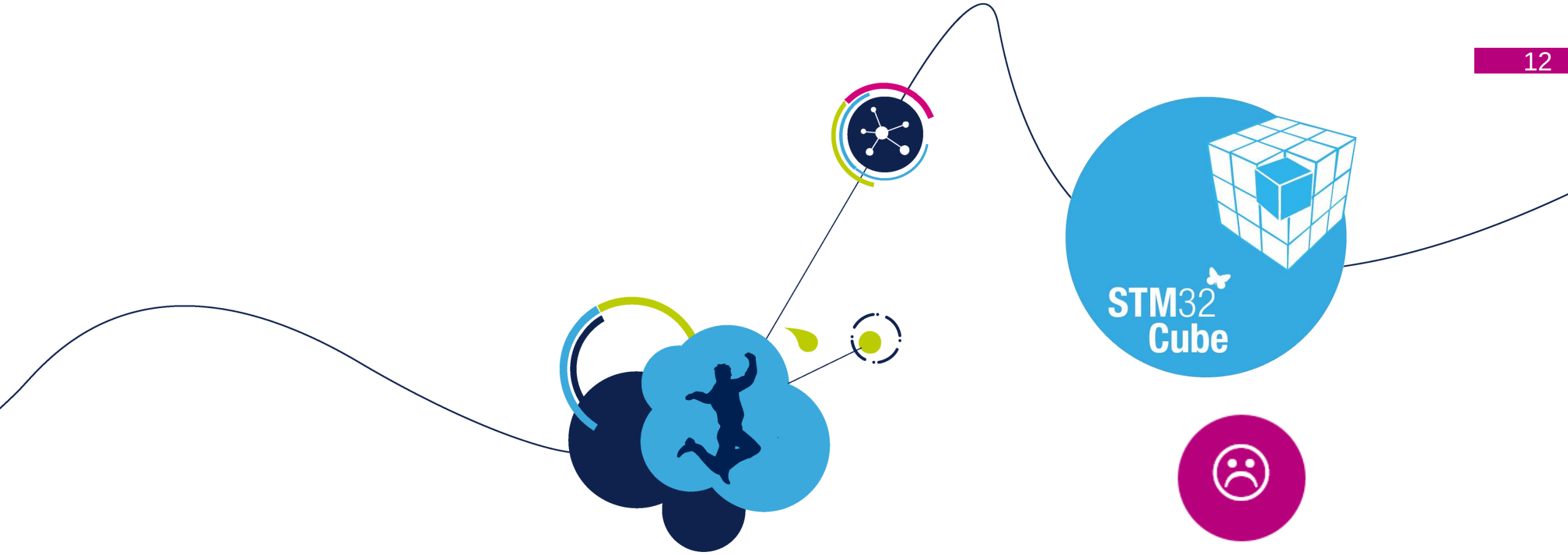
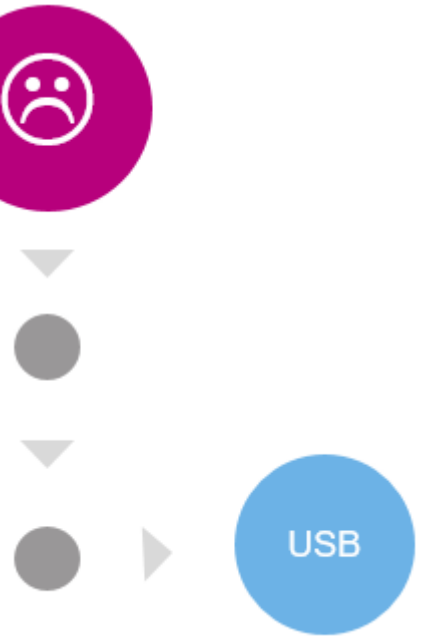
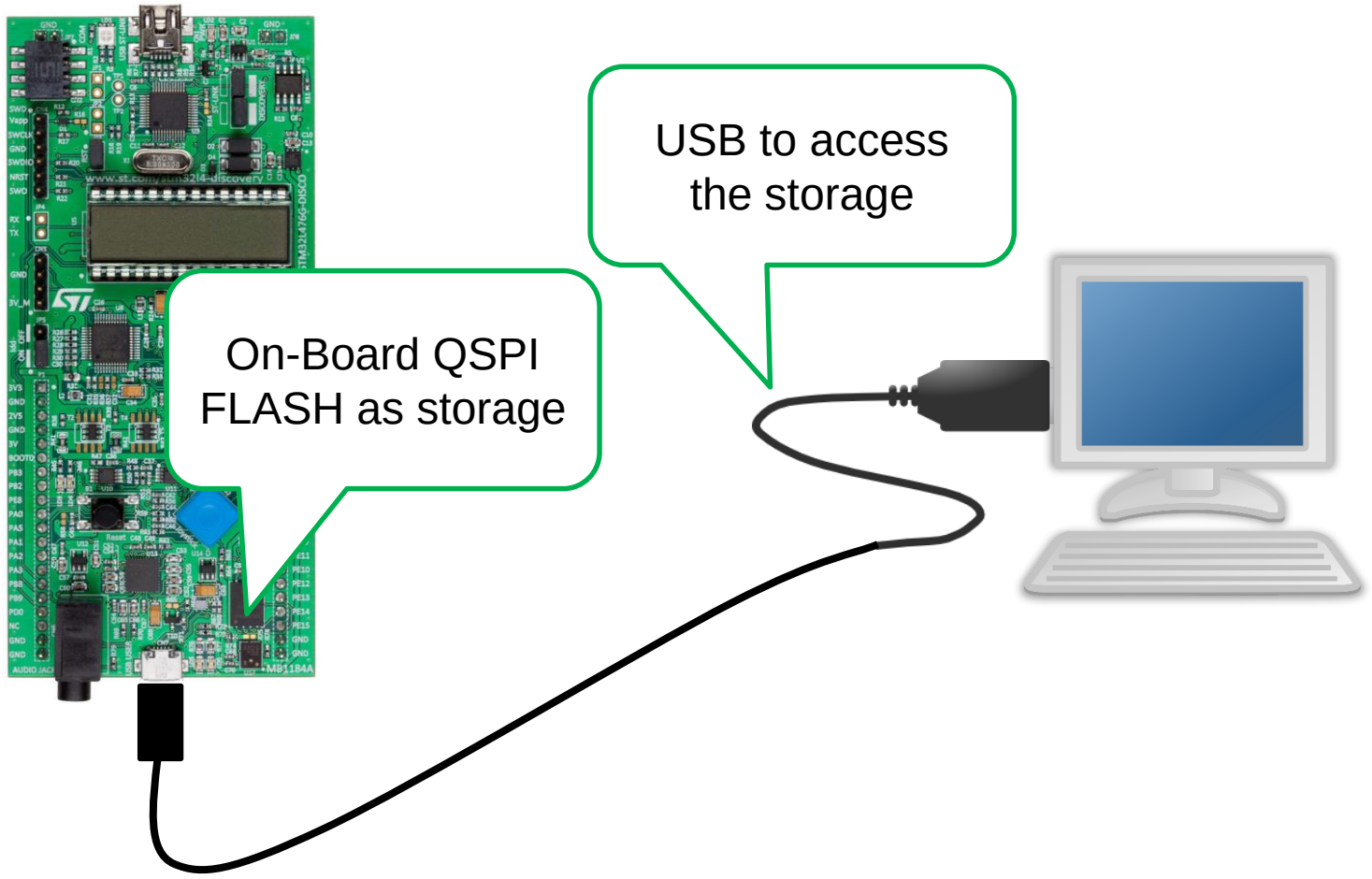


STEP1 – USB MSC Device



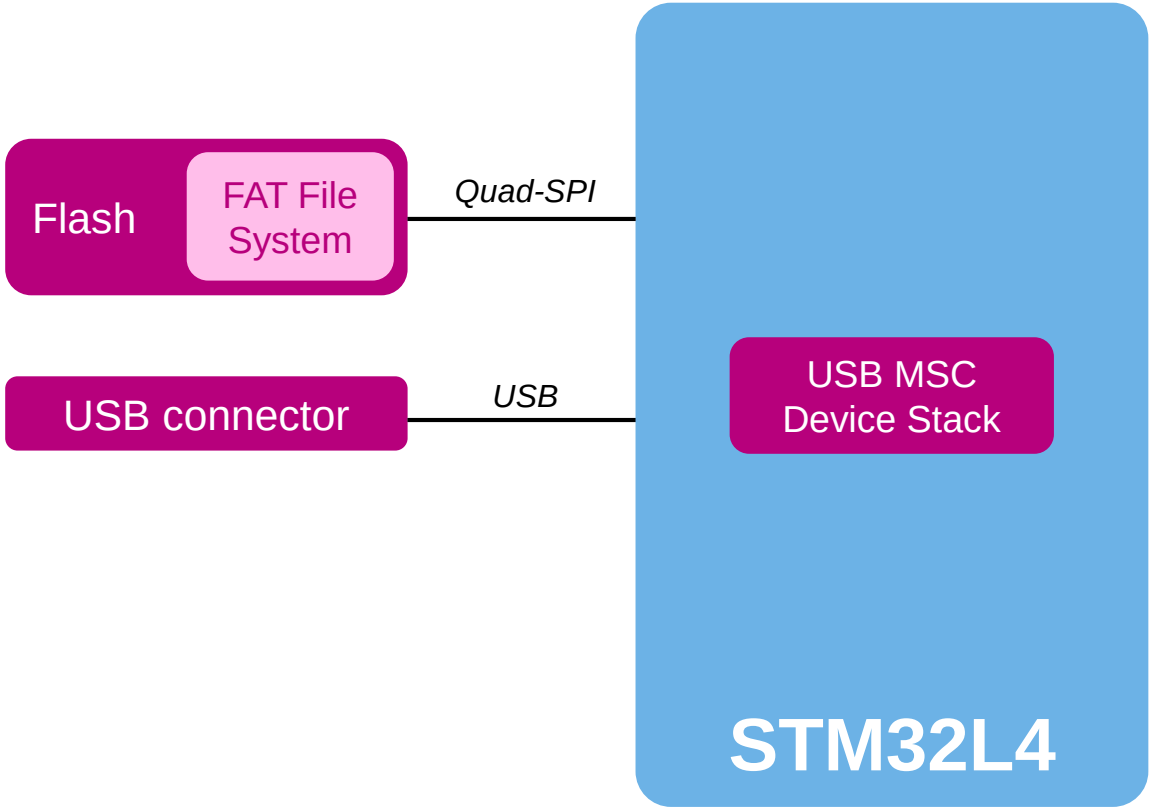
1 USB MSC Device with QUADSPI

- We need storage for our audio files!



1 Adding USB MSC Device functionality

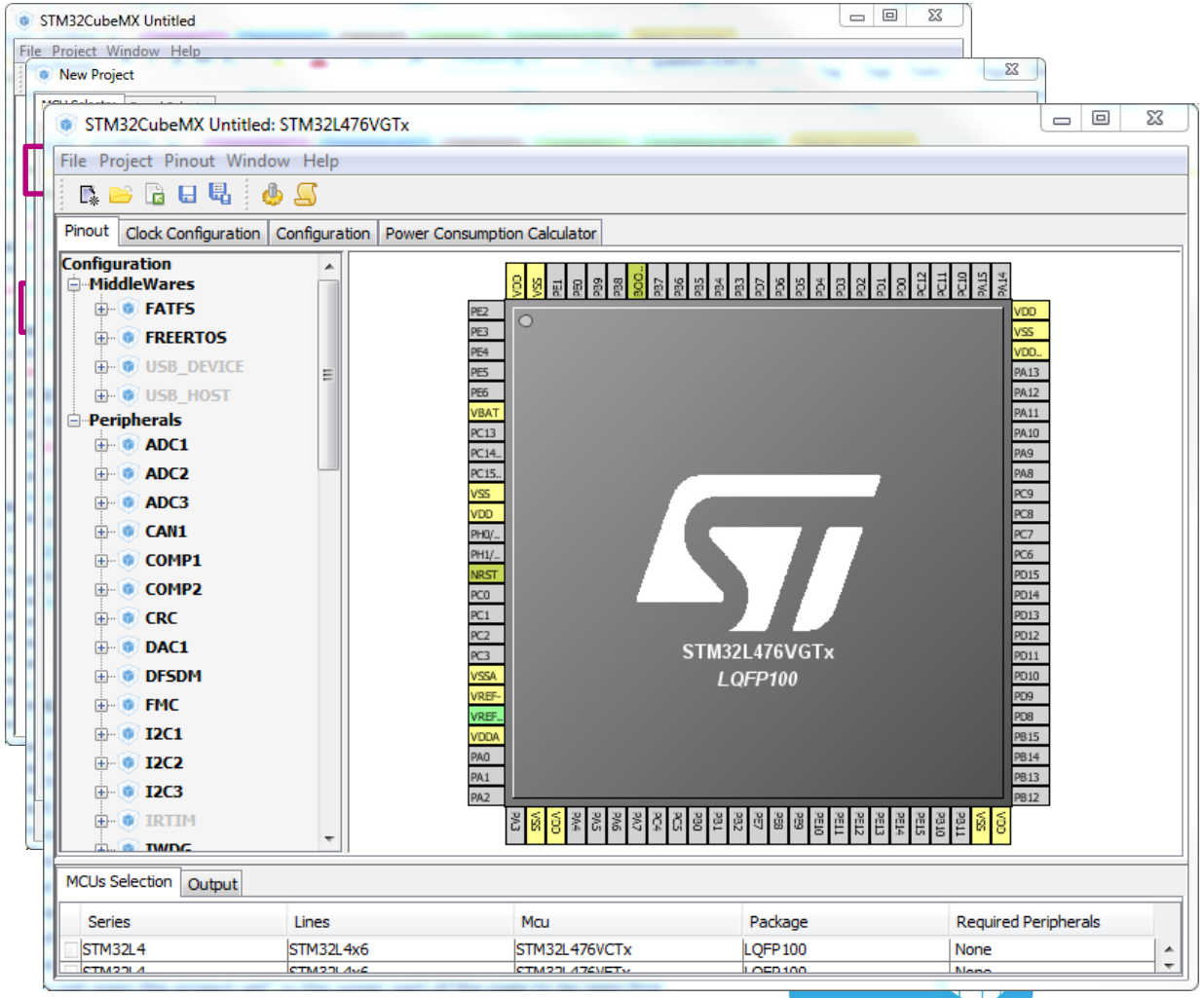
- We need storage for our audio files!



1

Create new project

- Run CubeMX tool
- Menu->File->New Project
- Filter:
  - Series STM32L4
  - Line STM32L4x6
  - Package LQFP100
- Select STM32L476VGTx



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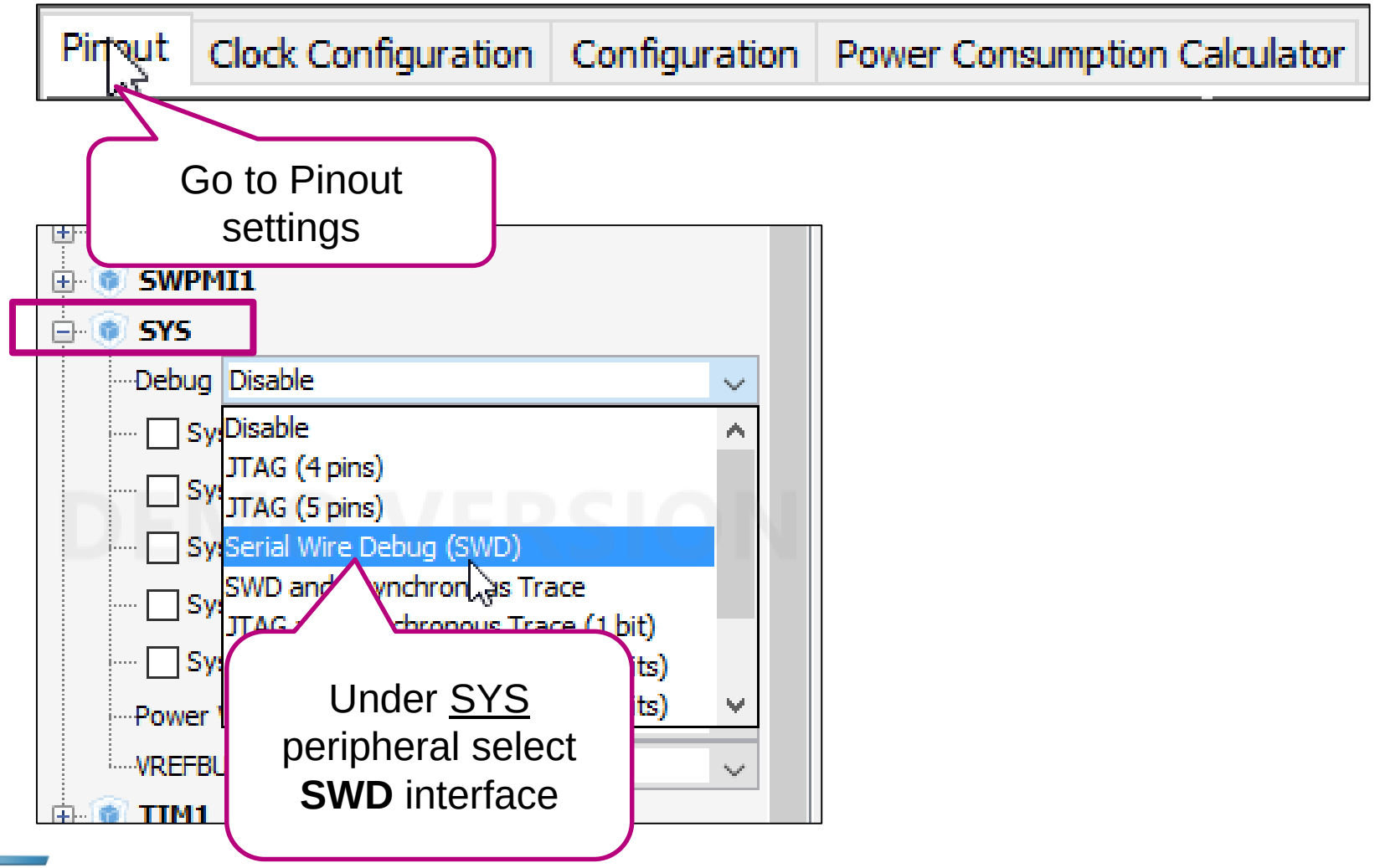
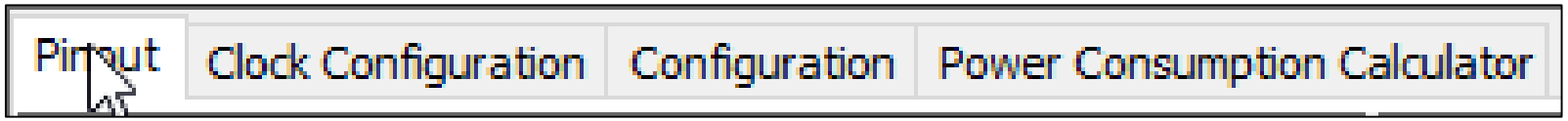
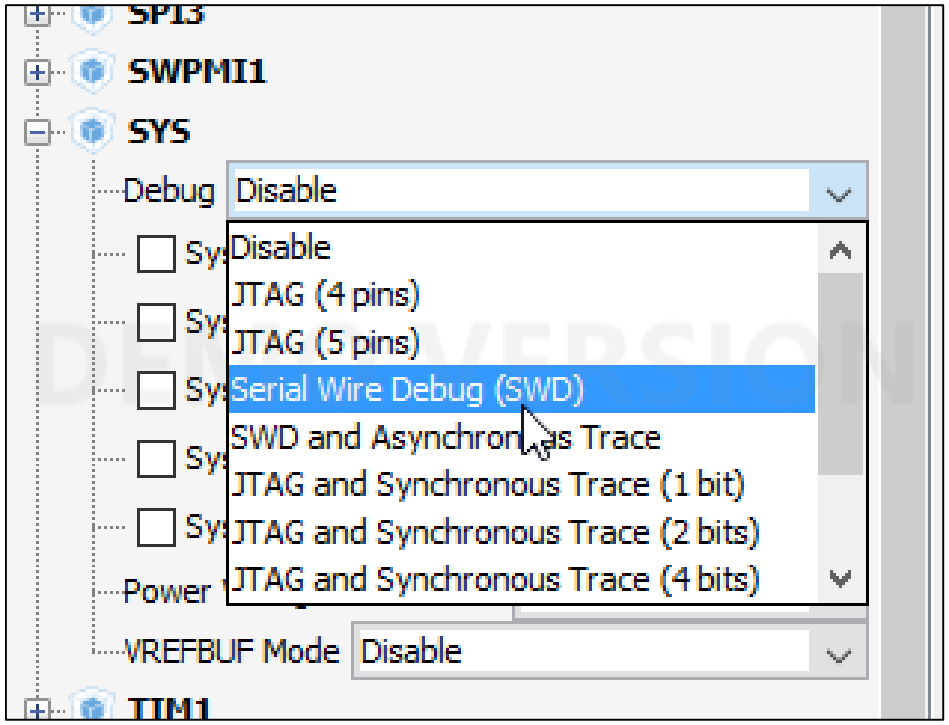
STM32 Cube

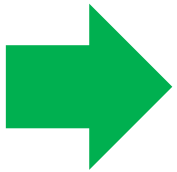
1 Configure debug interface

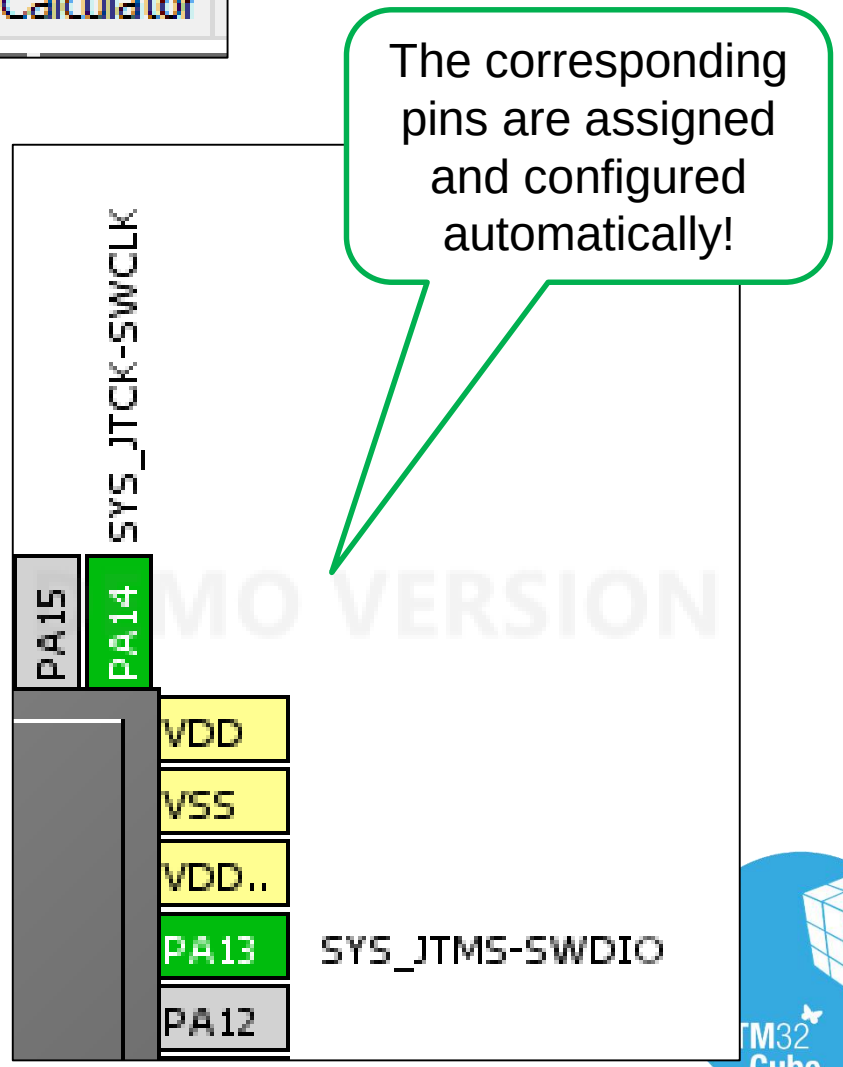


1 Configure debug interface

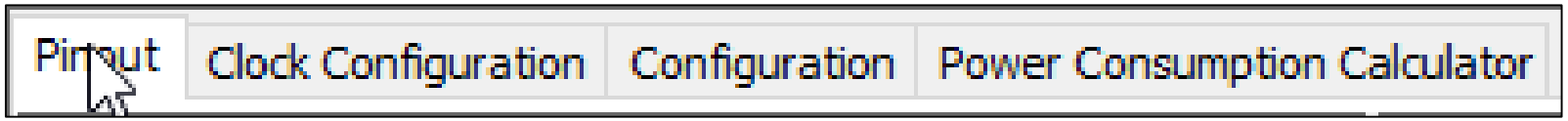


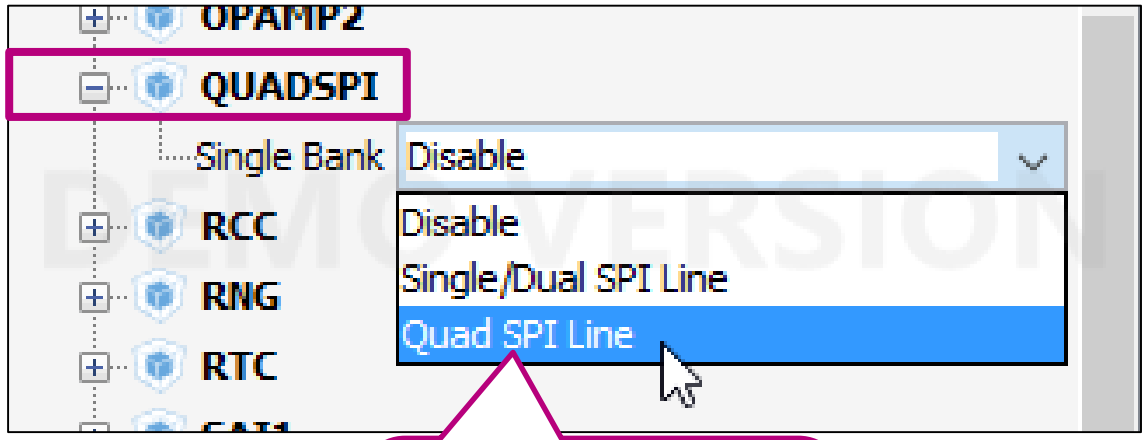




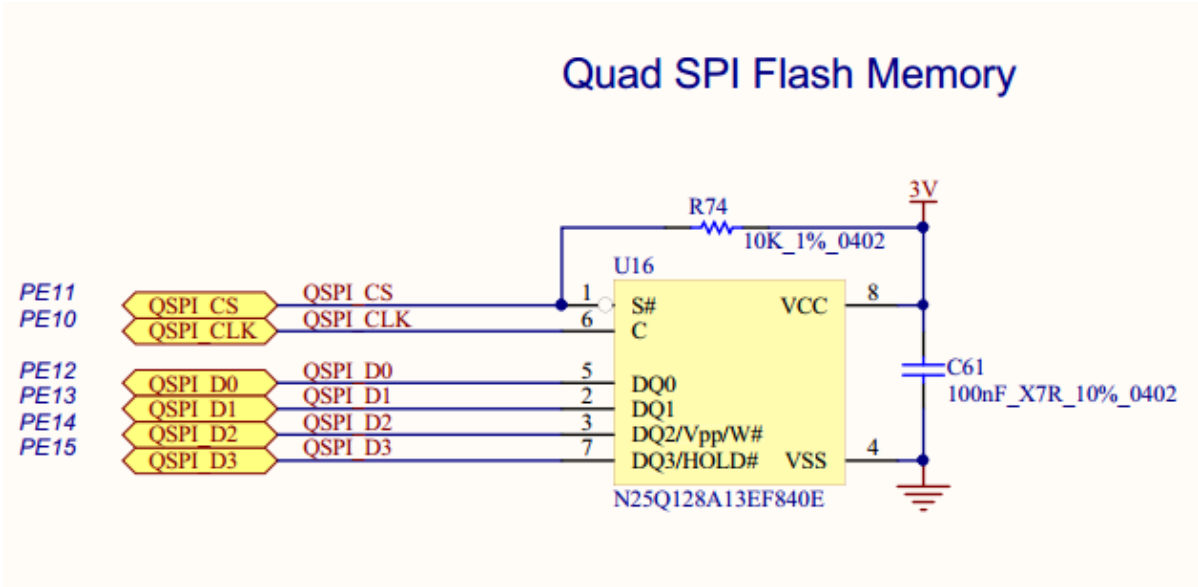


1 Configure QUADSPI interface

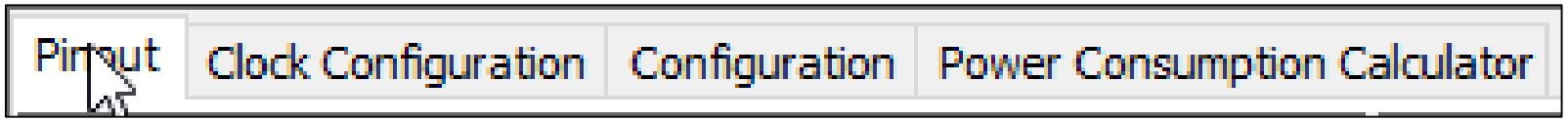




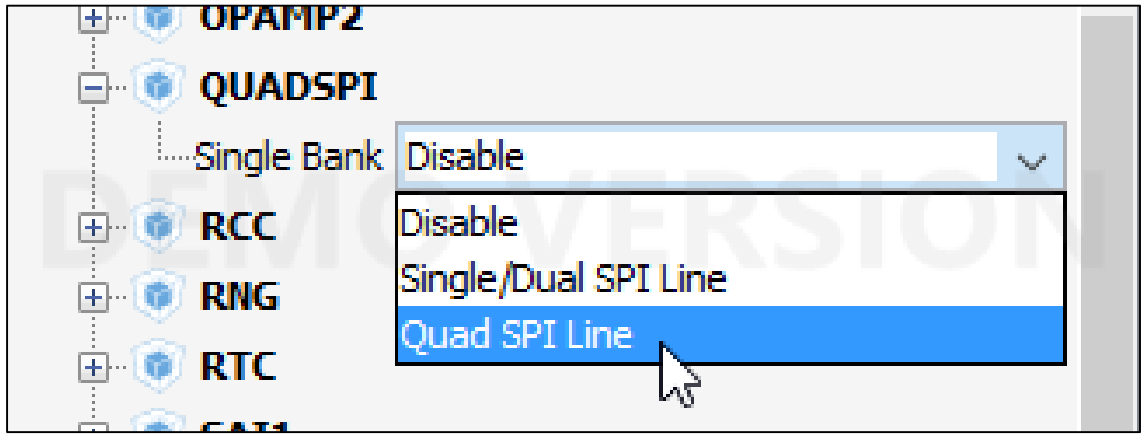
Under QUADSPI peripheral select **Quad SPI Line** configuration

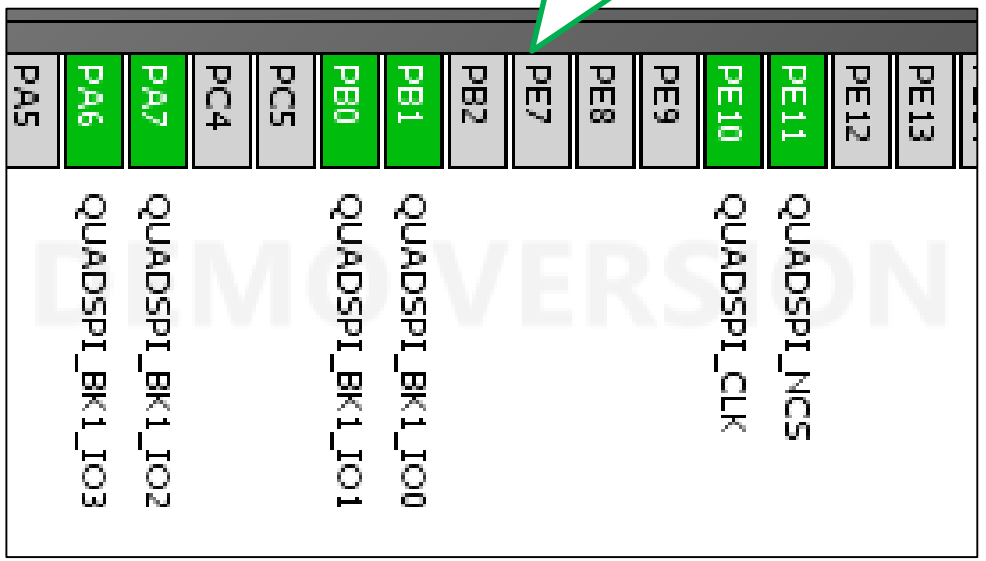


1 Configure QUADSPI interface



The corresponding pins are assigned and configured automatically!





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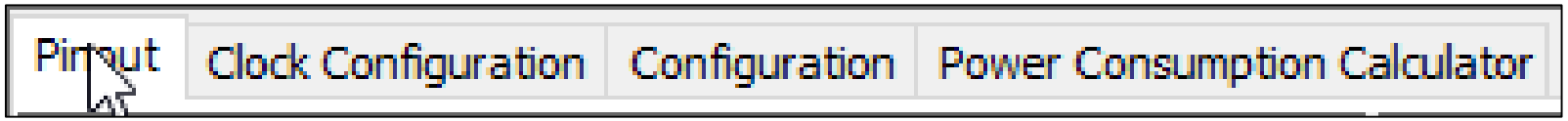
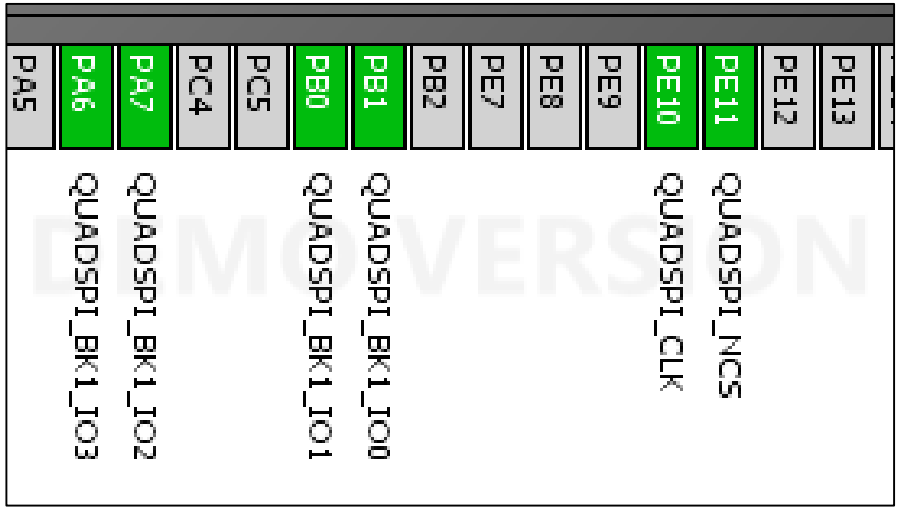
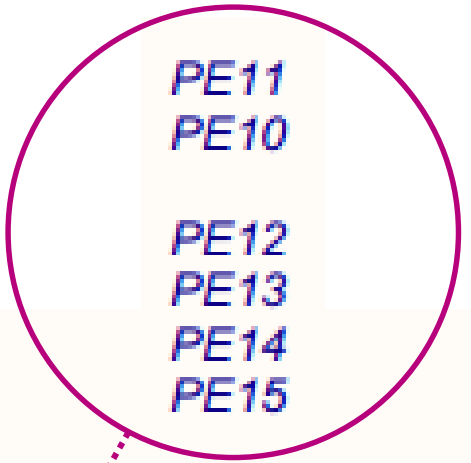
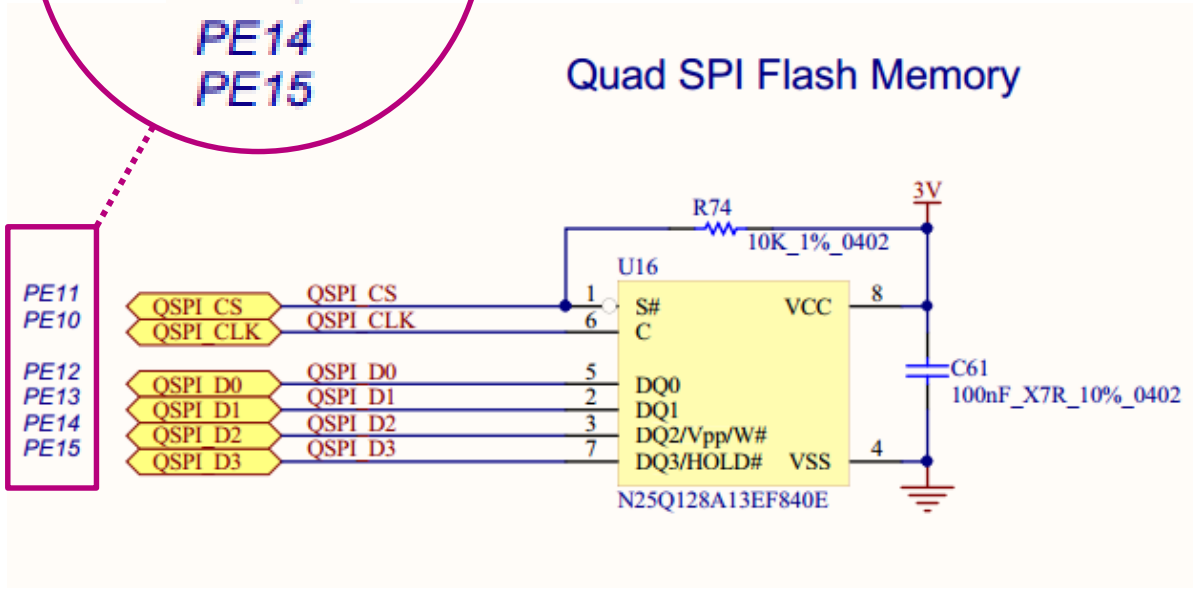
STM32 Cube

1 QUADSPI interface pins remapping

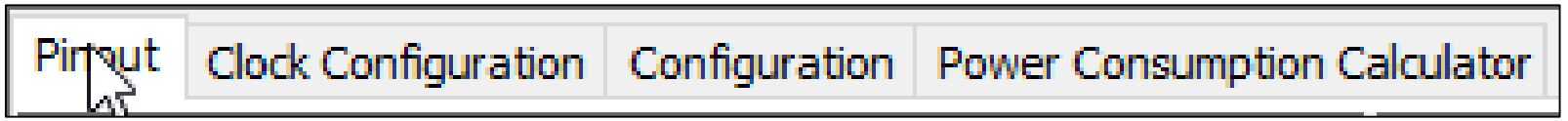


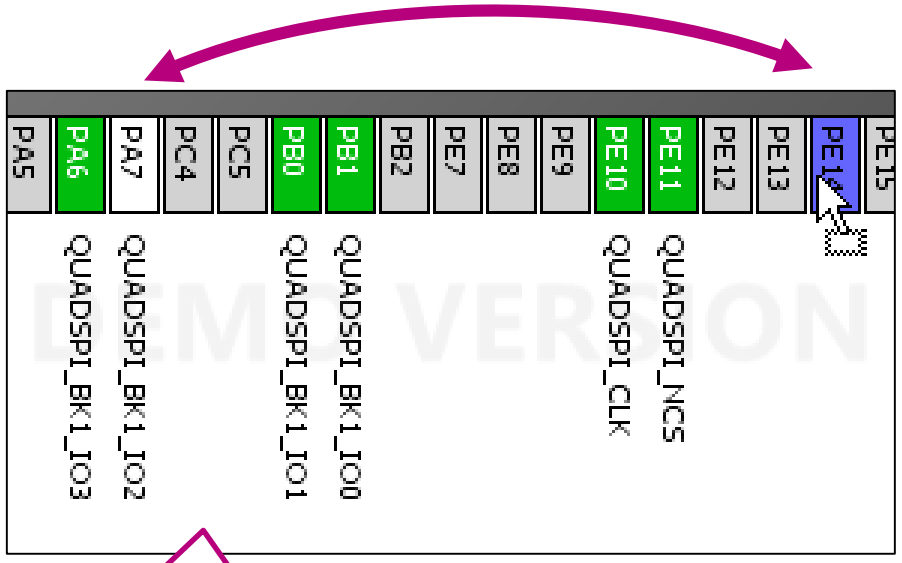






1 QUADSPI interface pins remapping





Hold CTRL key → click on the pin → move it to the other possible configuration

PA7 → PE14
PA6 → PE15
PB0 → PE13
PB1 → PE12

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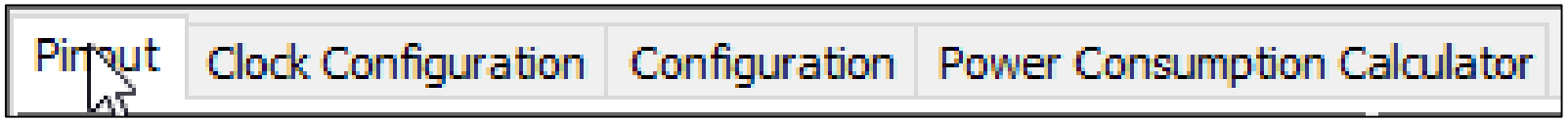
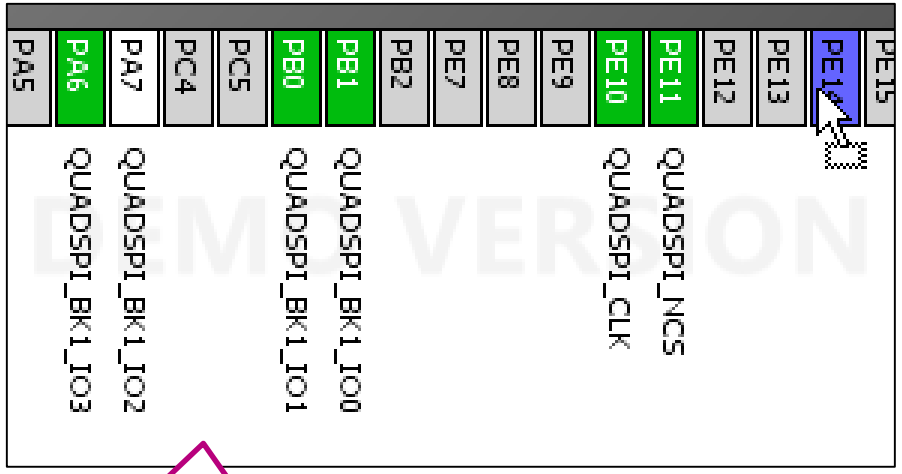
STM32 Cube

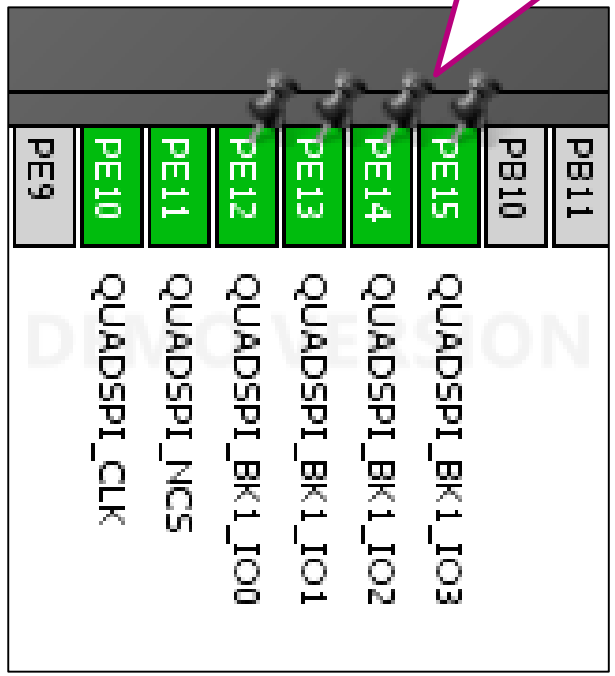
1 QUADSPI interface pins remapping





Hold CTRL key → click on the pin → move it to the other possible configuration

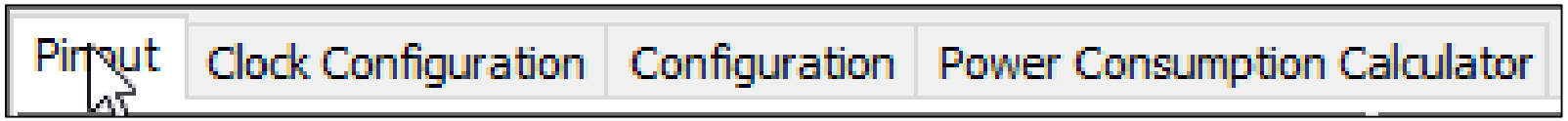
Desired configuration

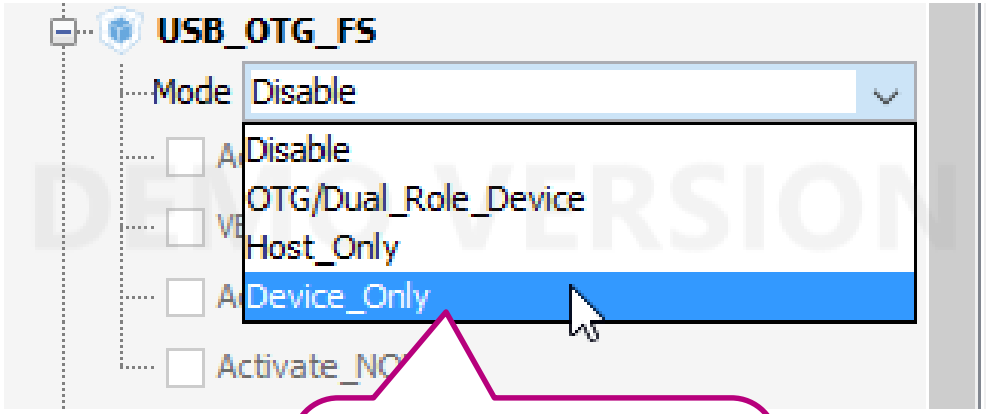


life.augmented

STM32 Cube

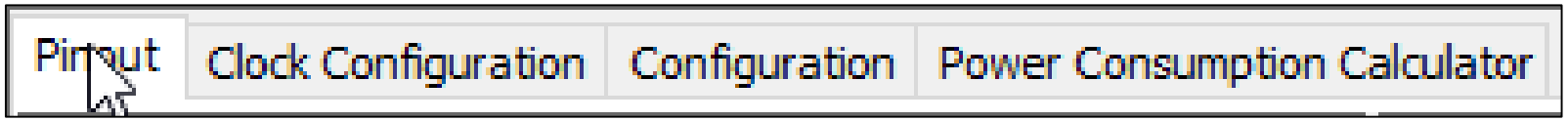
1 Configure USB_OTG_FS interface

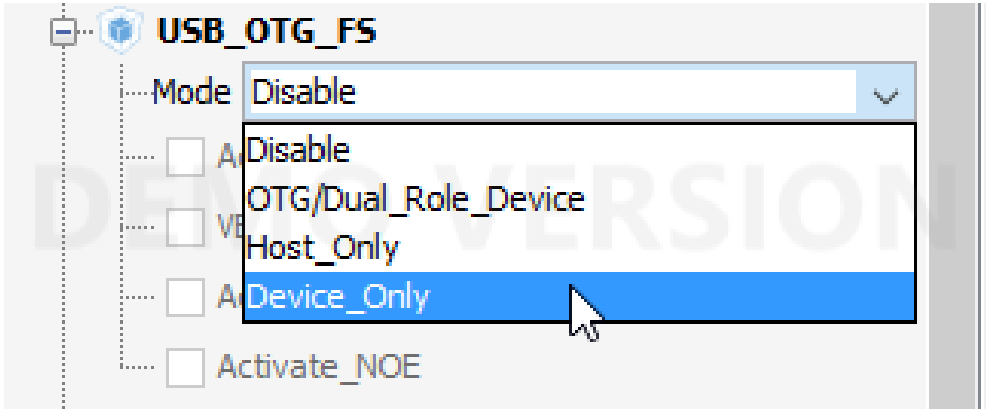




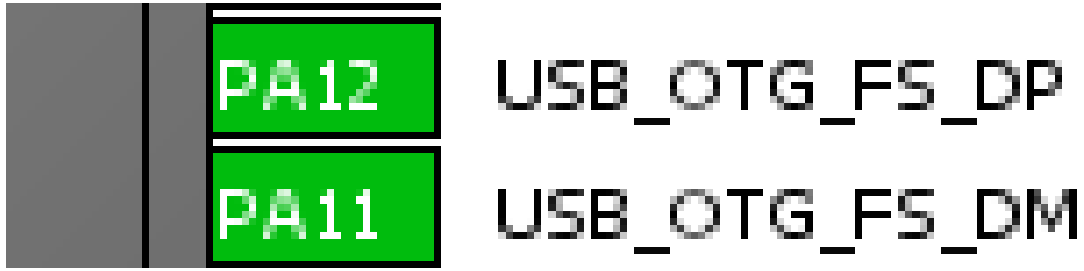
Under USB_OTG_FS peripheral select **Device_Only**

1 Configure USB_OTG_FS interface





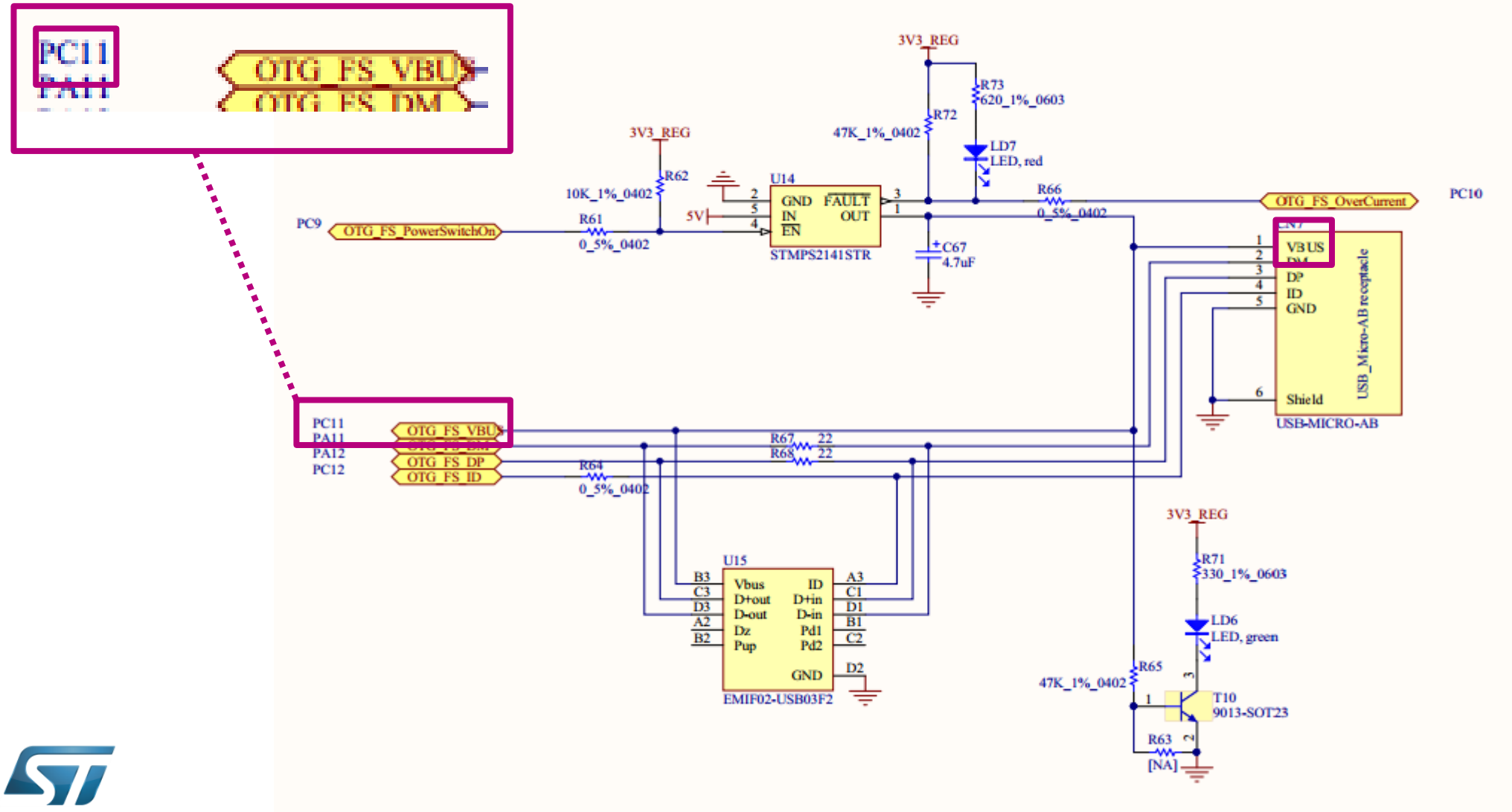
The corresponding pins are assigned and configured automatically!



life.augmented

STM32 Cube

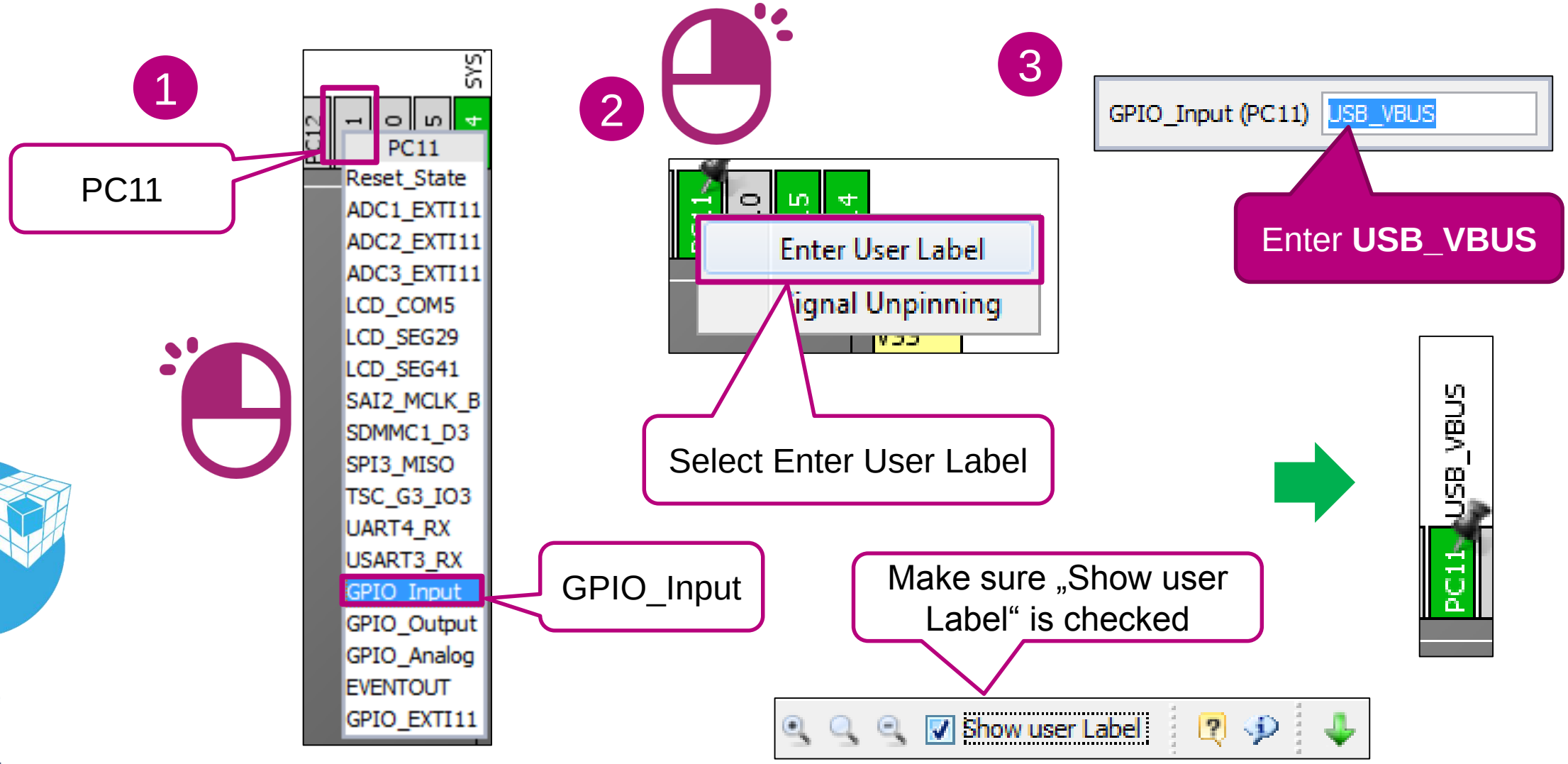
1 Configure USB_OTG_FS interface



life.augmented

STM32 Cube

1 Configure USB_OTG_FS interface



STM32 Cube

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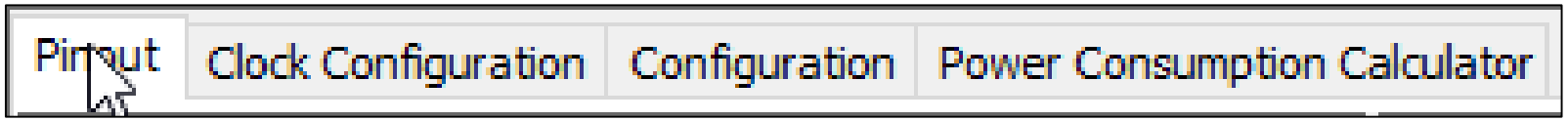
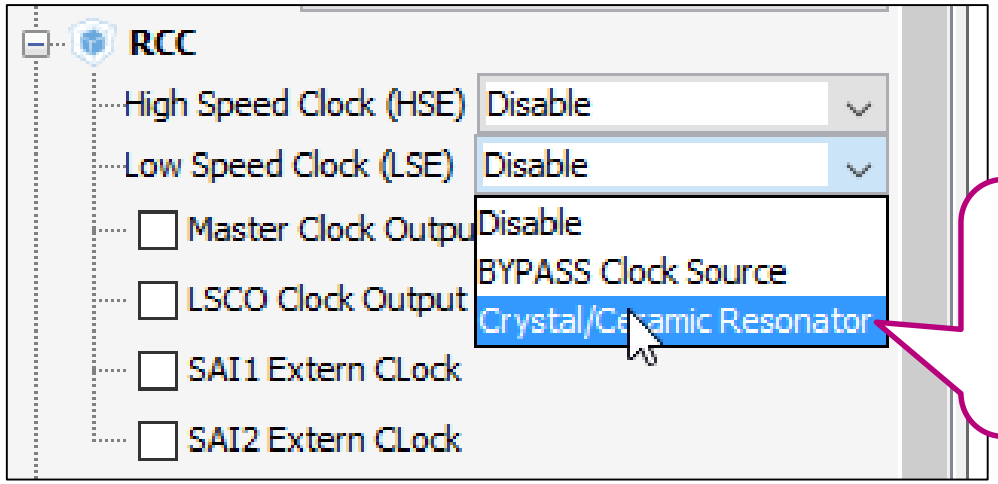
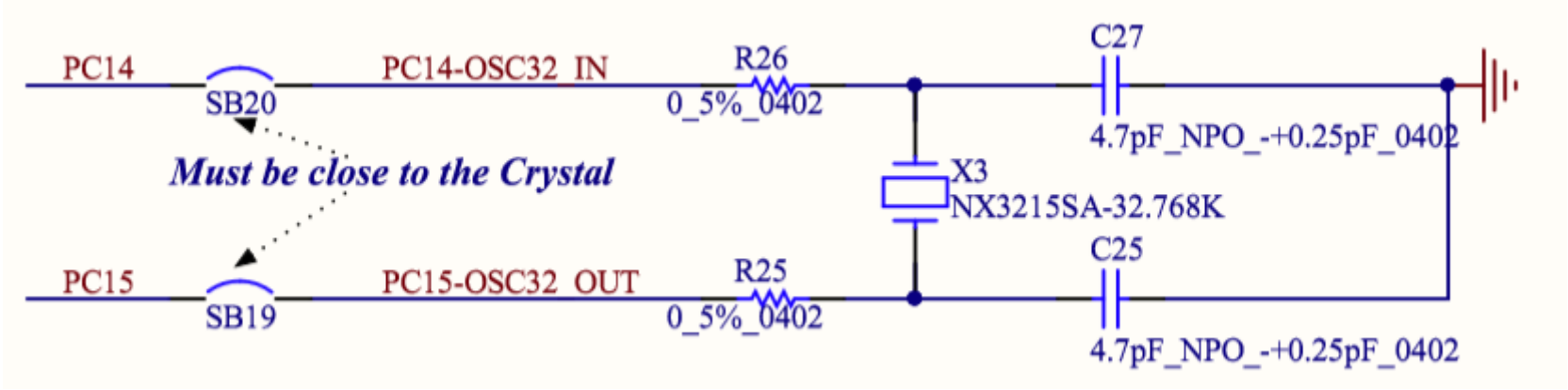
1 Configure LSE oscillator

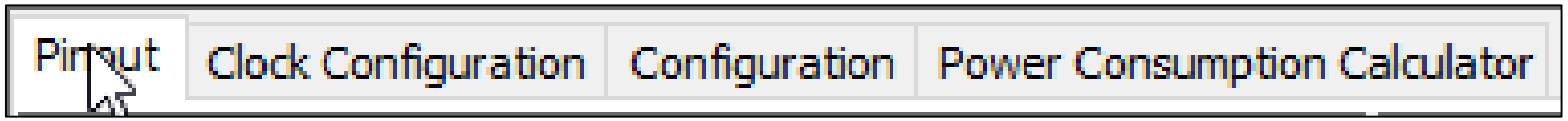


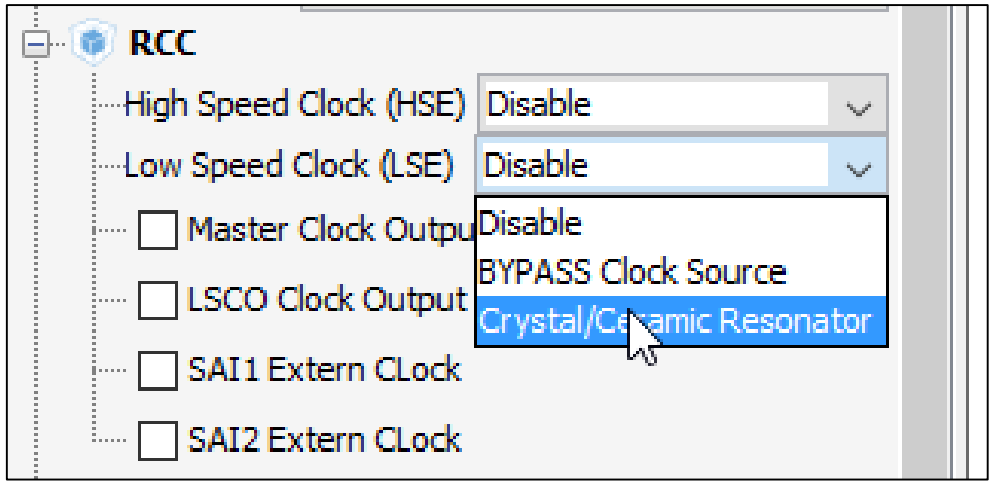


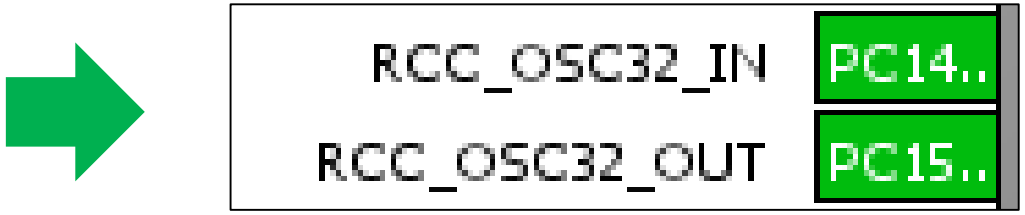
Under RCC Low Speed Clock (LSE)
select **Crystal/Ceramic Resonator**

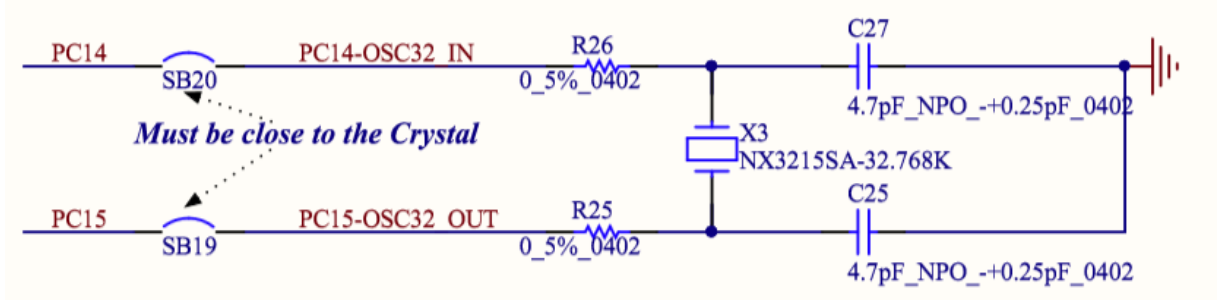


1 Configure LSE oscillator





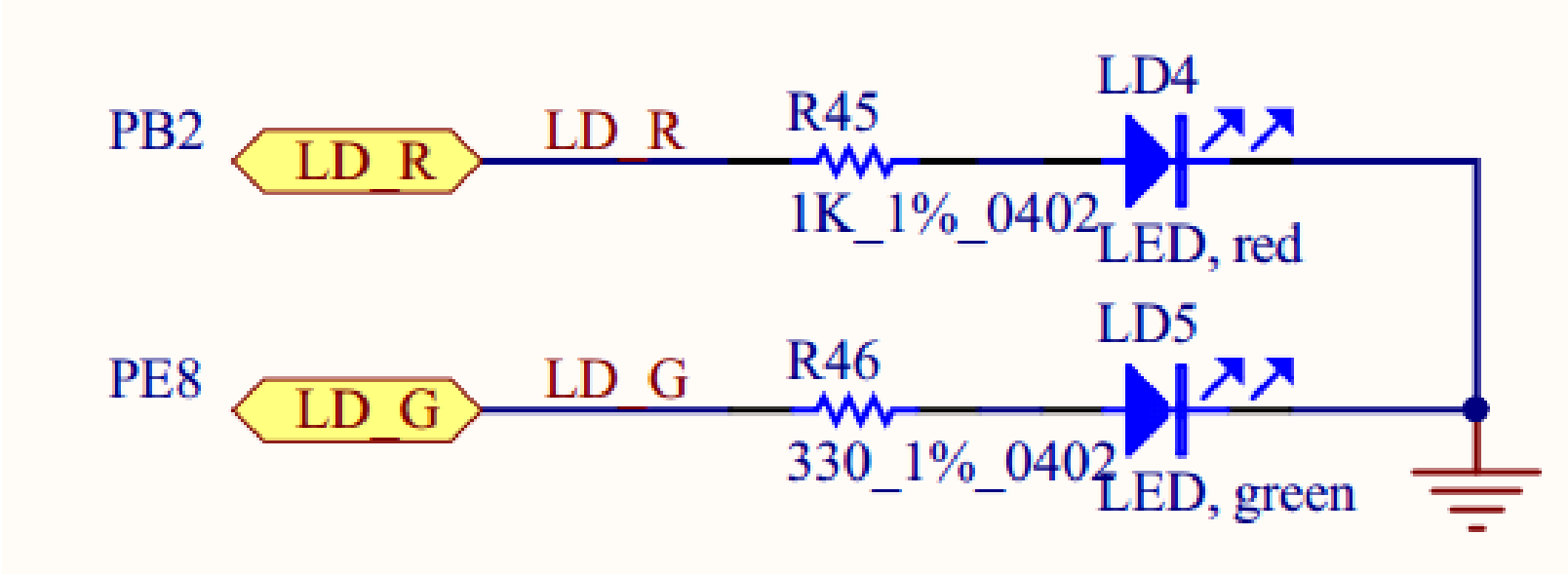




The corresponding pins are assigned and configured automatically!

life.augmented

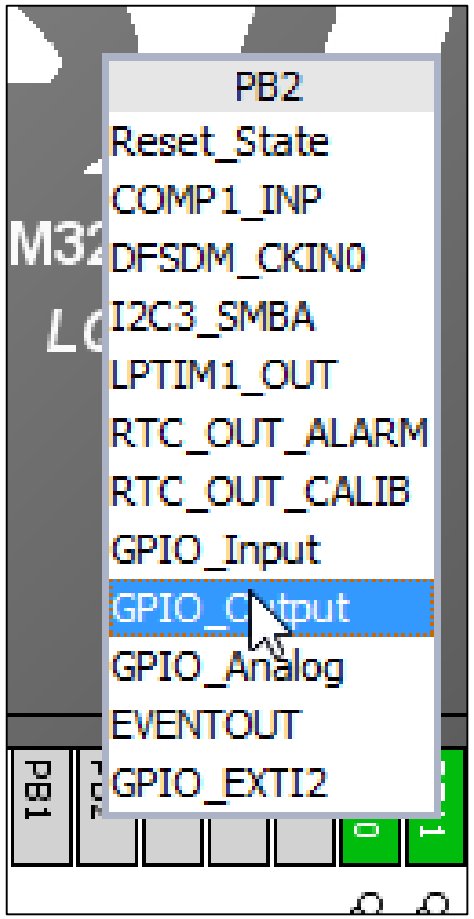
1 Configure LED pins



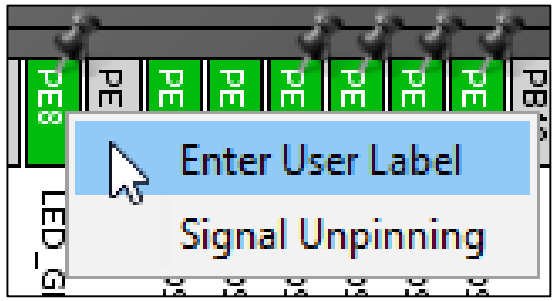
1

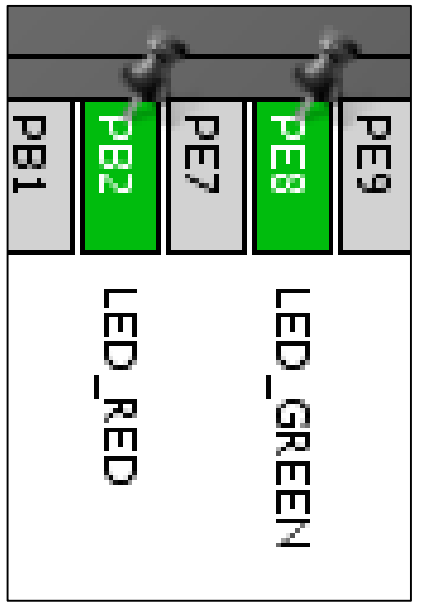
Configure LED pins

1

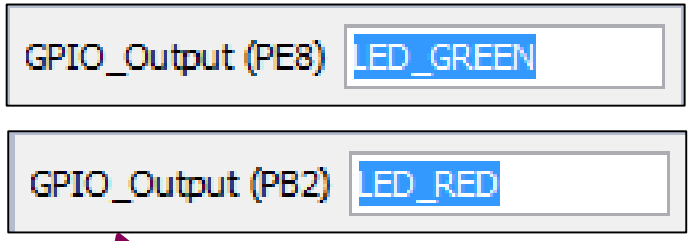


2

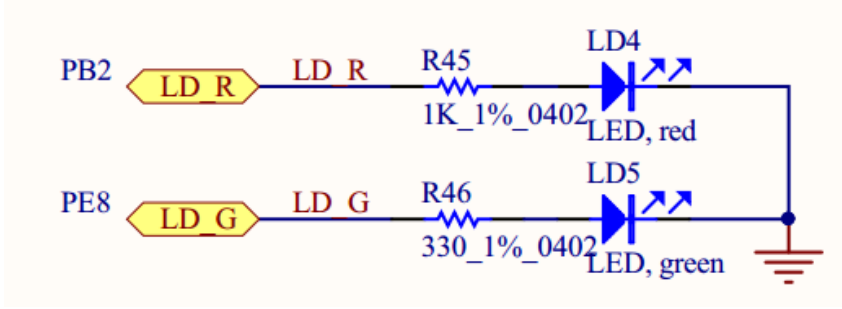




3



LED_GREEN for PE8
LED_RED for PB2



Checkpoint #1

1

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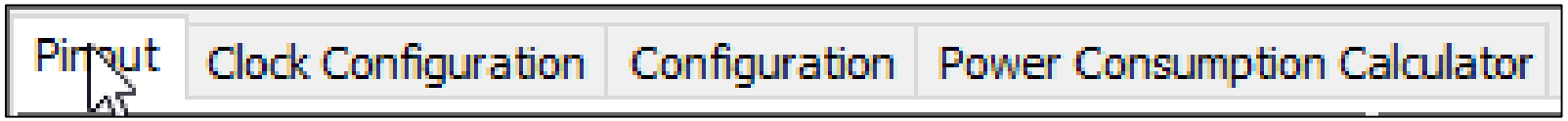
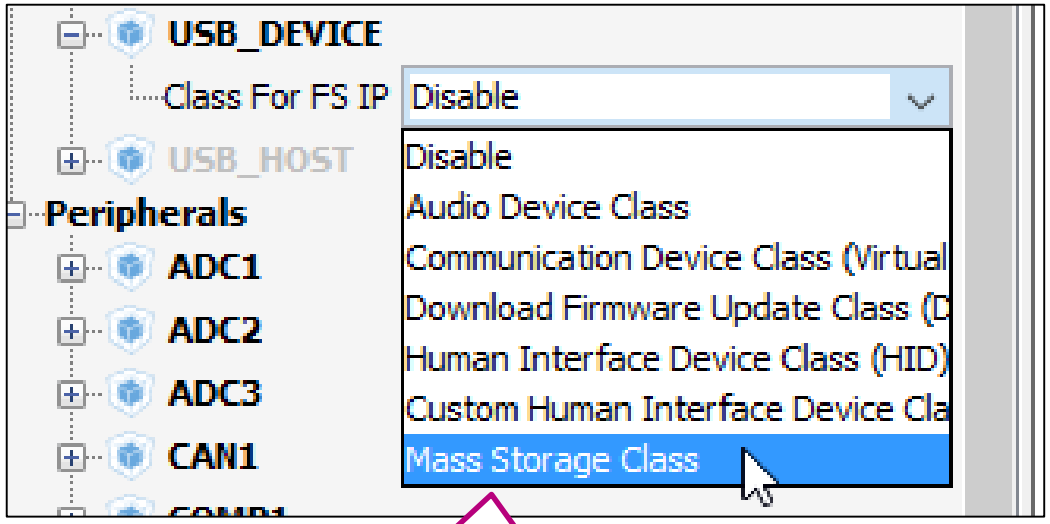
STM32 Cube

1 Configure USB_DEVICE stack





Under USB_DEVICE MiddleWare select **Mass Storage Class**

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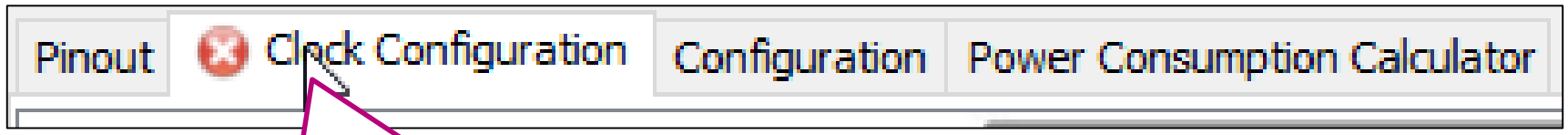
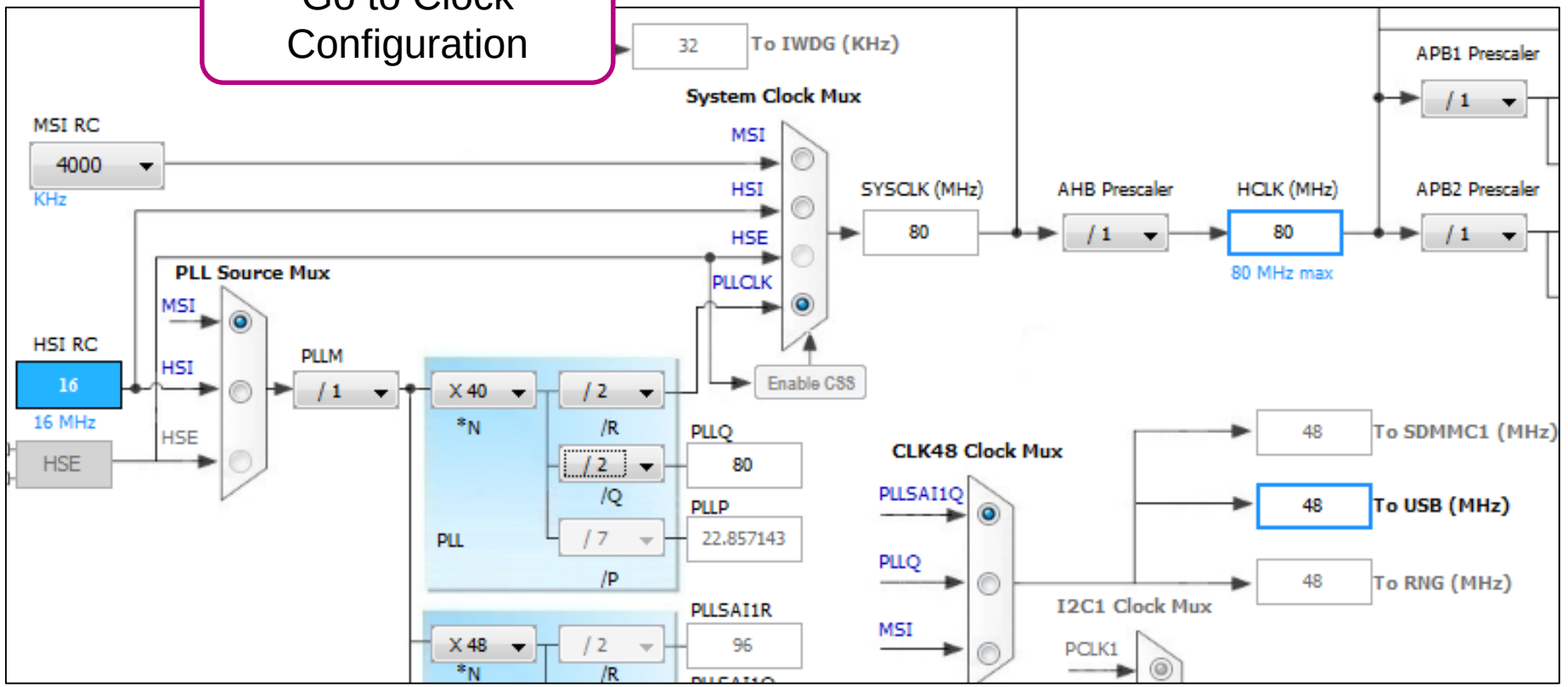
STM32 Cube

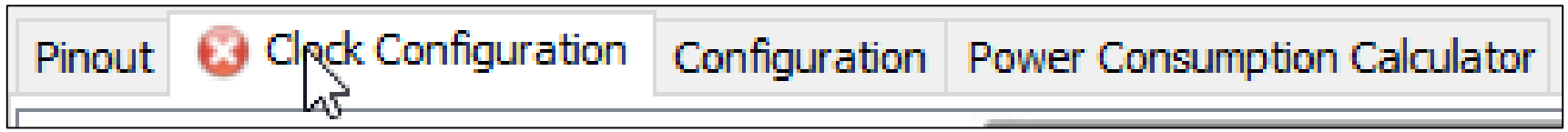
System Clock Configuration



Go to Clock Configuration



System Clock Configuration



4000 kHz
(MSI RC)

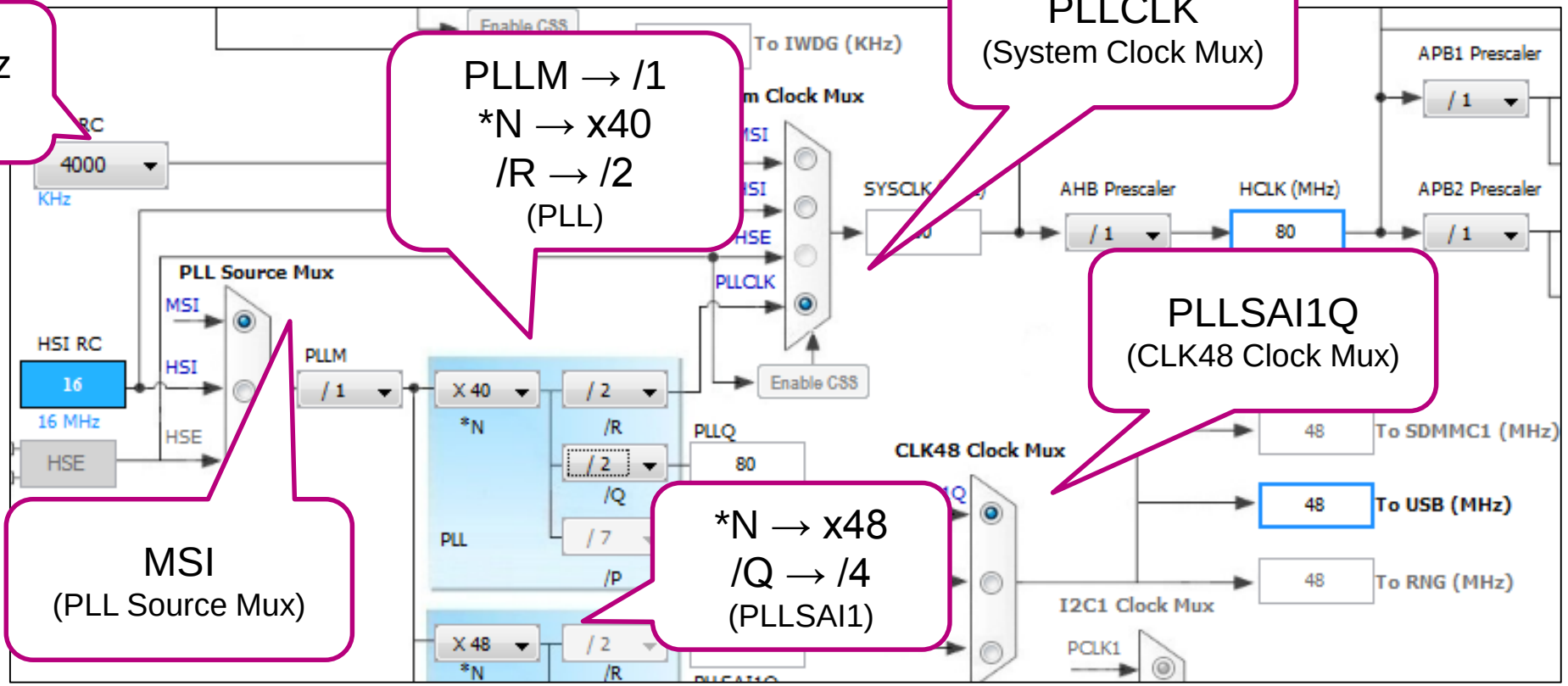
PLLM → /1
*N → x40
/R → /2
(PLL)

PLLCLK
(System Clock Mux)

PLLSAI1Q
(CLK48 Clock Mux)

MSI
(PLL Source Mux)

*N → x48
/Q → /4
(PLLSAI1)



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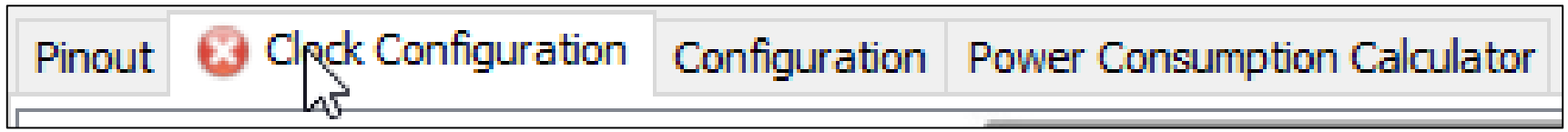
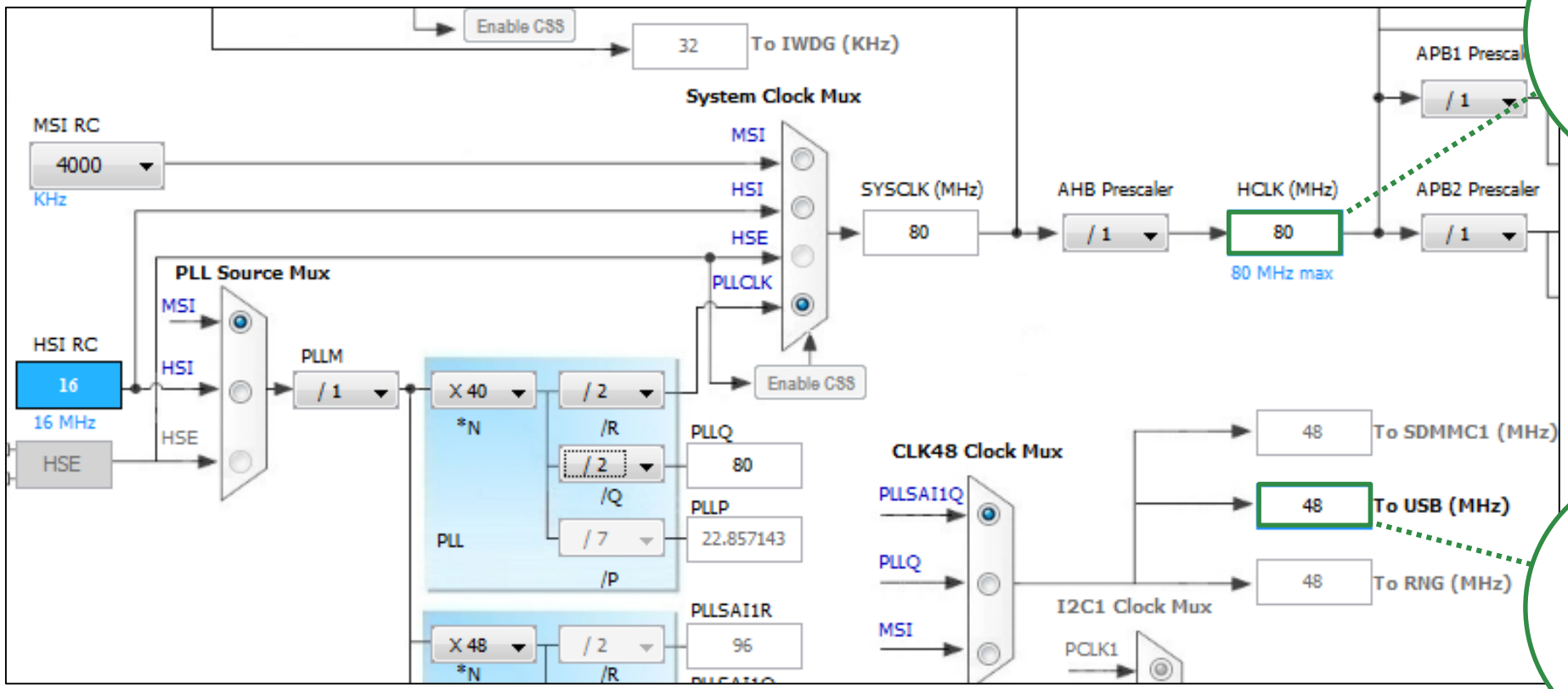
STM32 Cube

Checkpoint #2



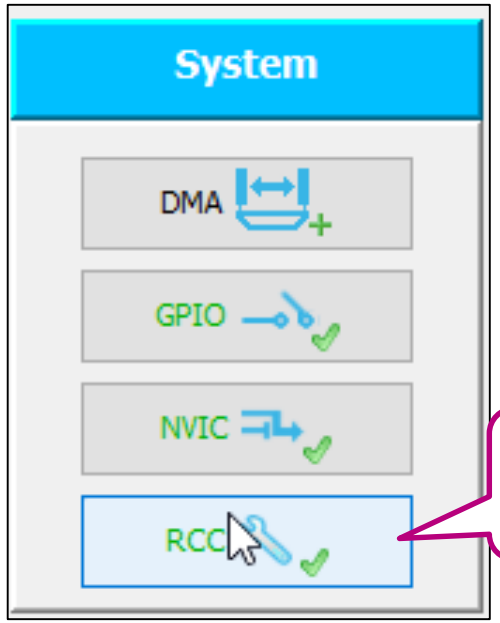


80MHz
(HCLK)

48MHz
(To USB)

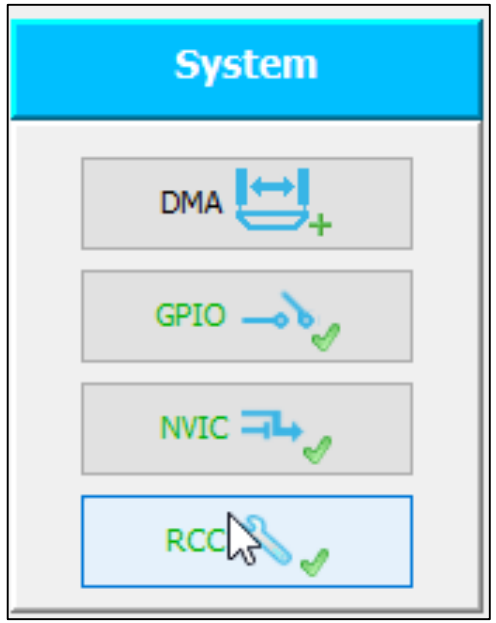
1 RCC Configuration check

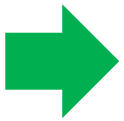
Go to Configuration

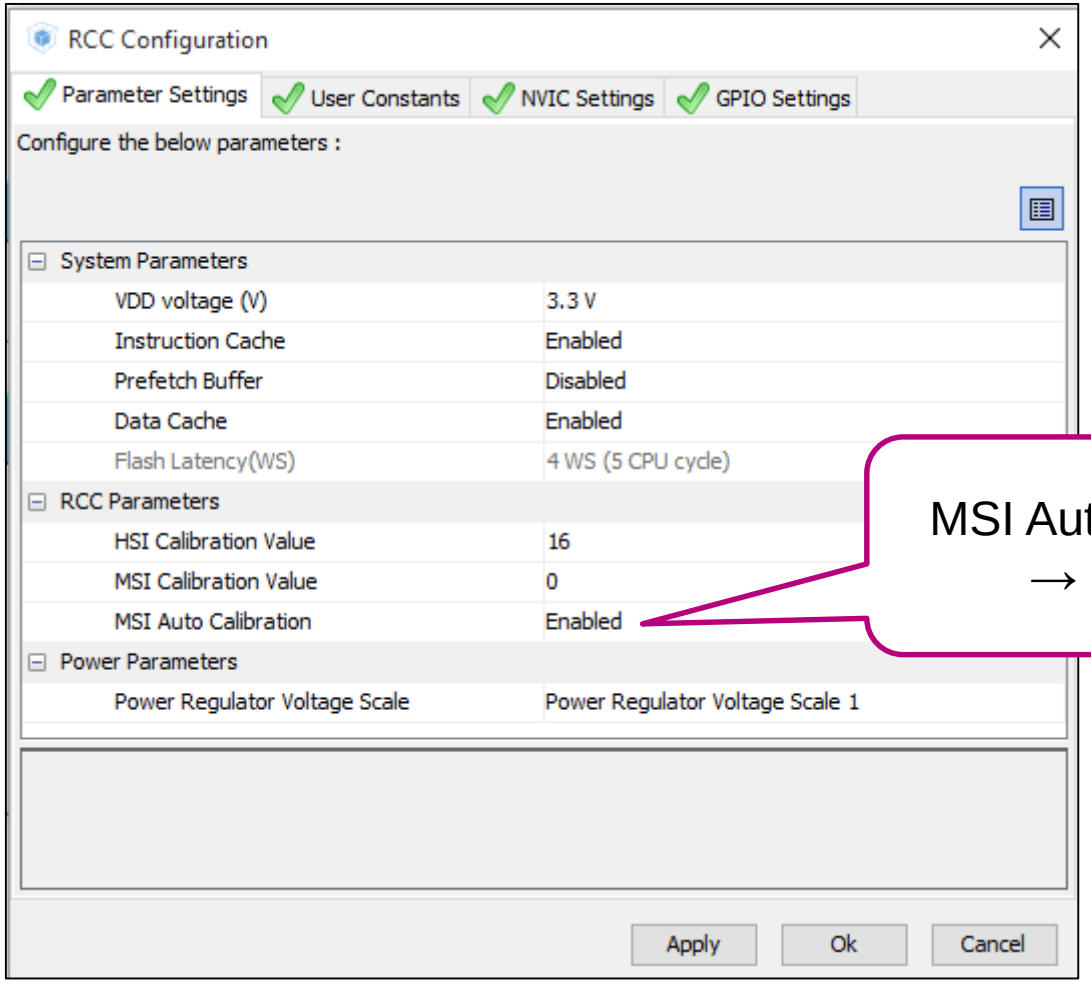


RCC in System

RCC Configuration check







MSI Auto Calibration
→ Enabled

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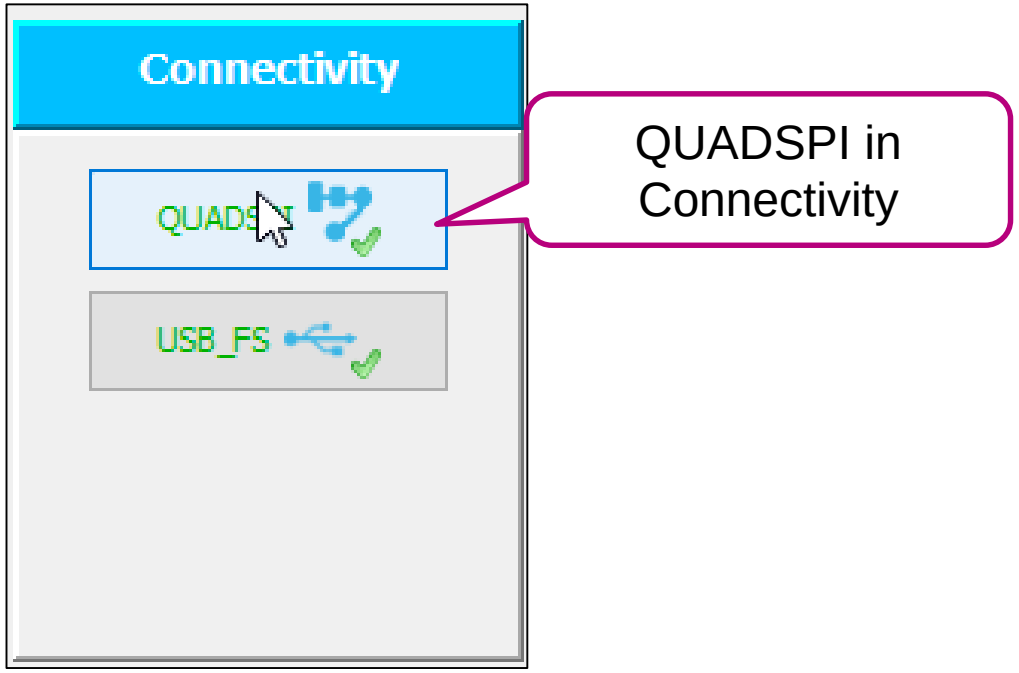
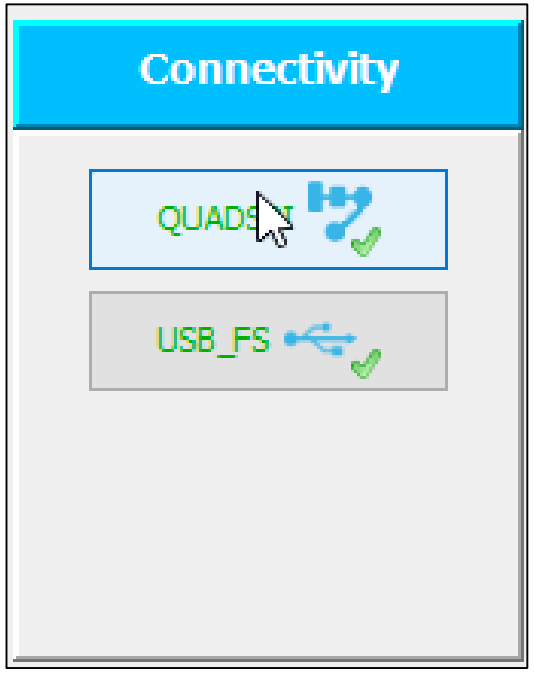
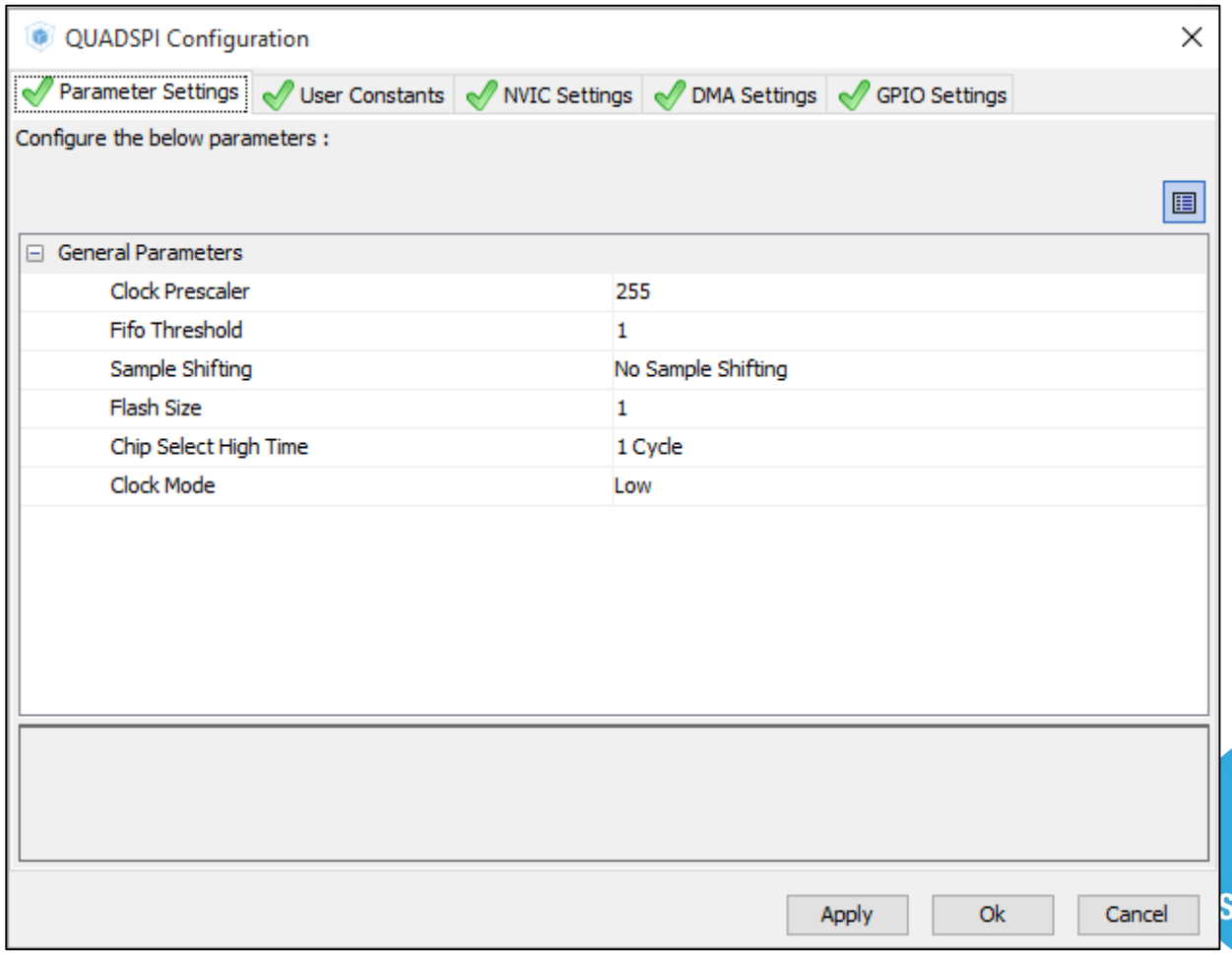
STM32 Cube

1 QUADSPI Configuration



QUADSPI Configuration





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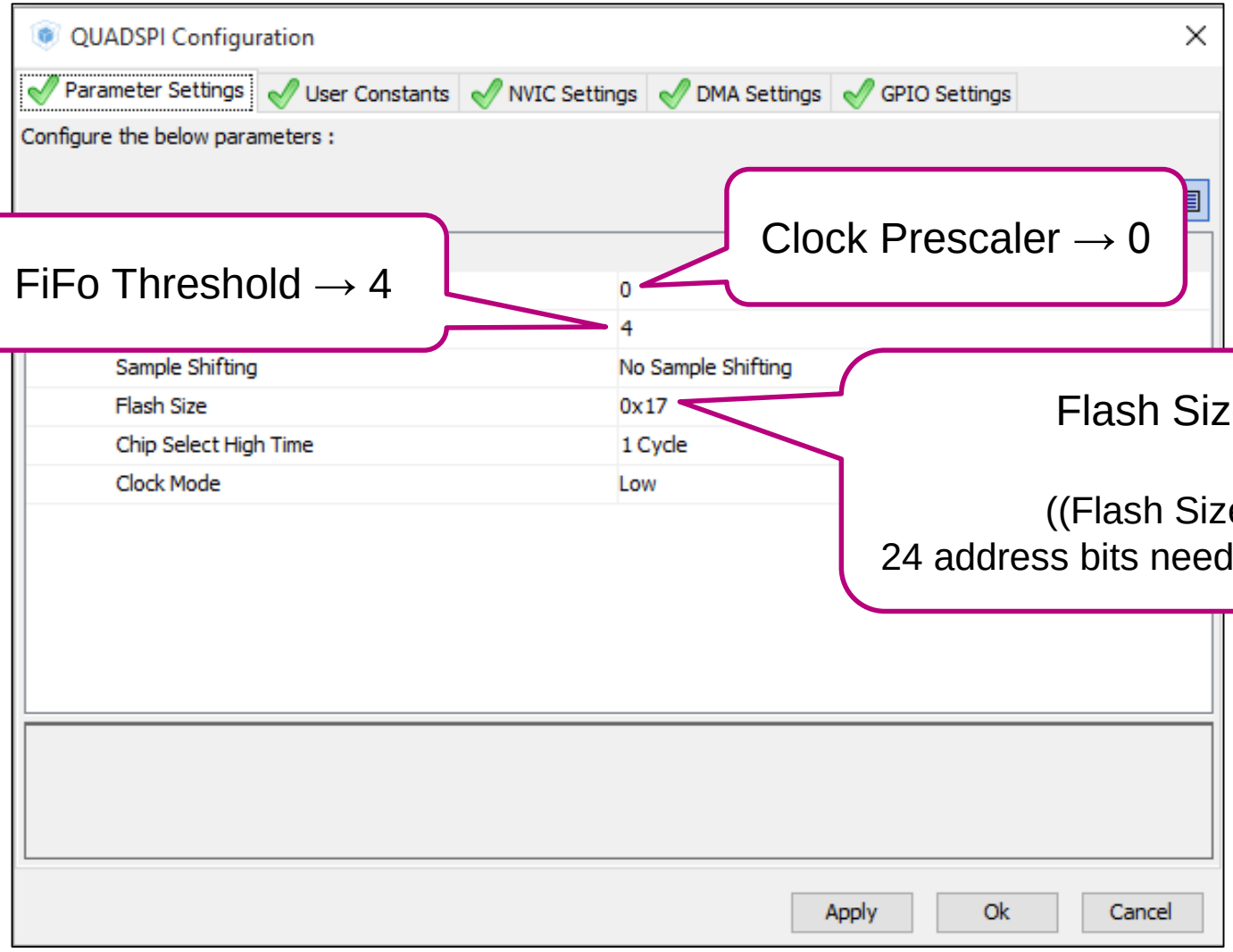
STM32 Cube

QUADSPI Configuration



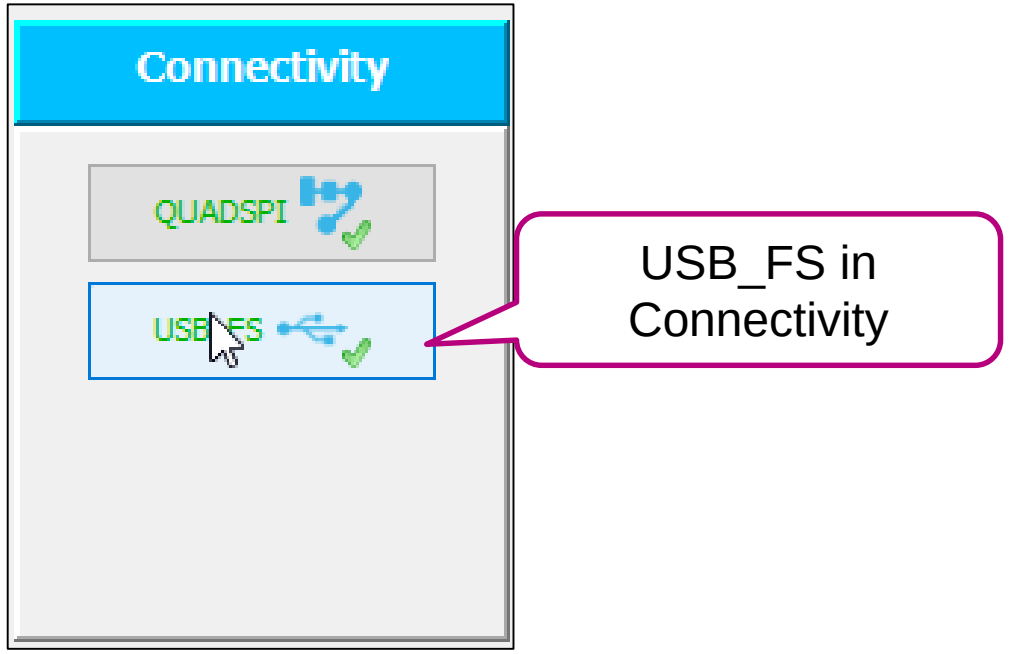
FiFo Threshold → 4

Clock Prescaler → 0

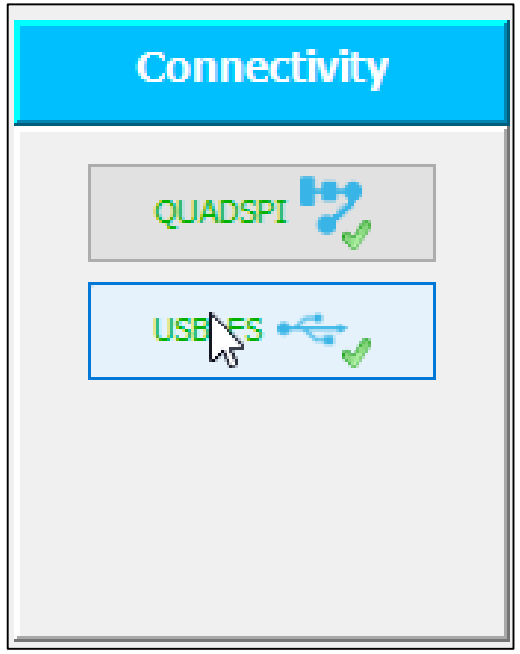
Flash Size → 0x17

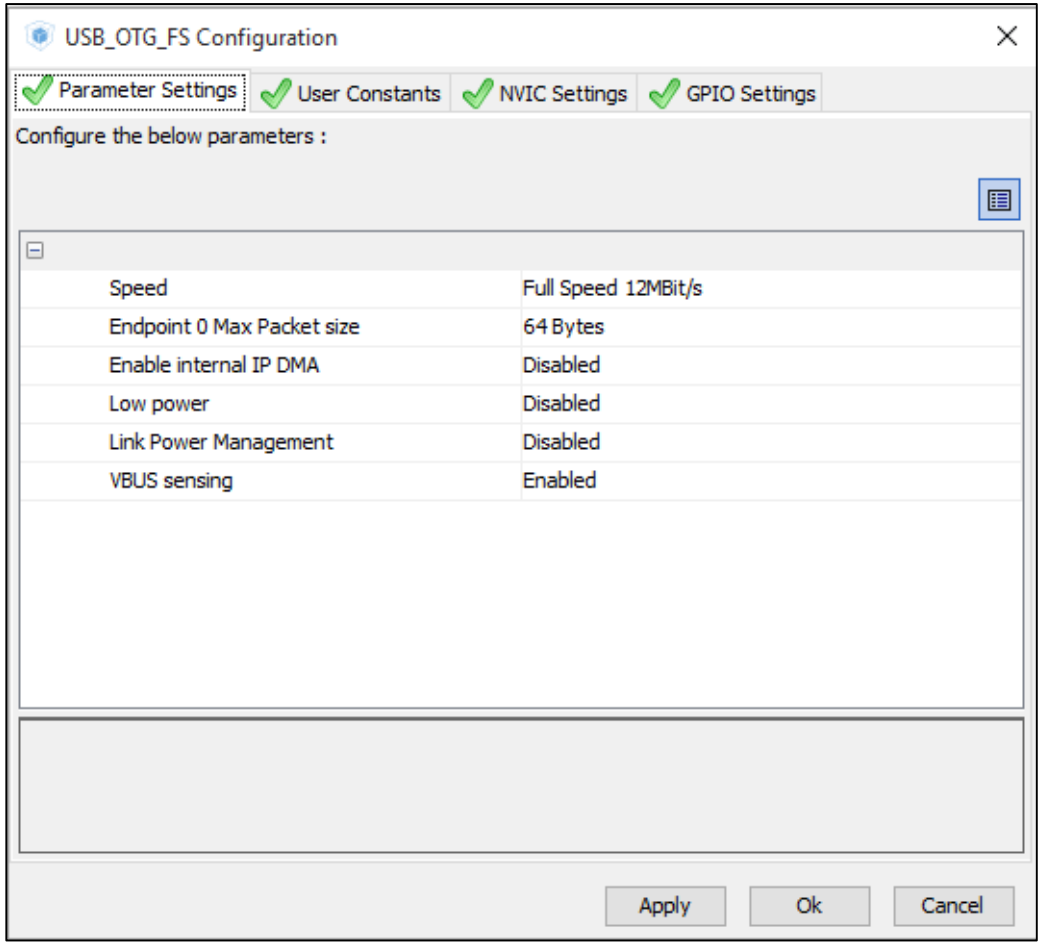
((Flash Size) + 1) = 24
24 address bits needed for 16MB memory

1 USB_OTF_FS Configuration



1 USB_OTF_FS Configuration





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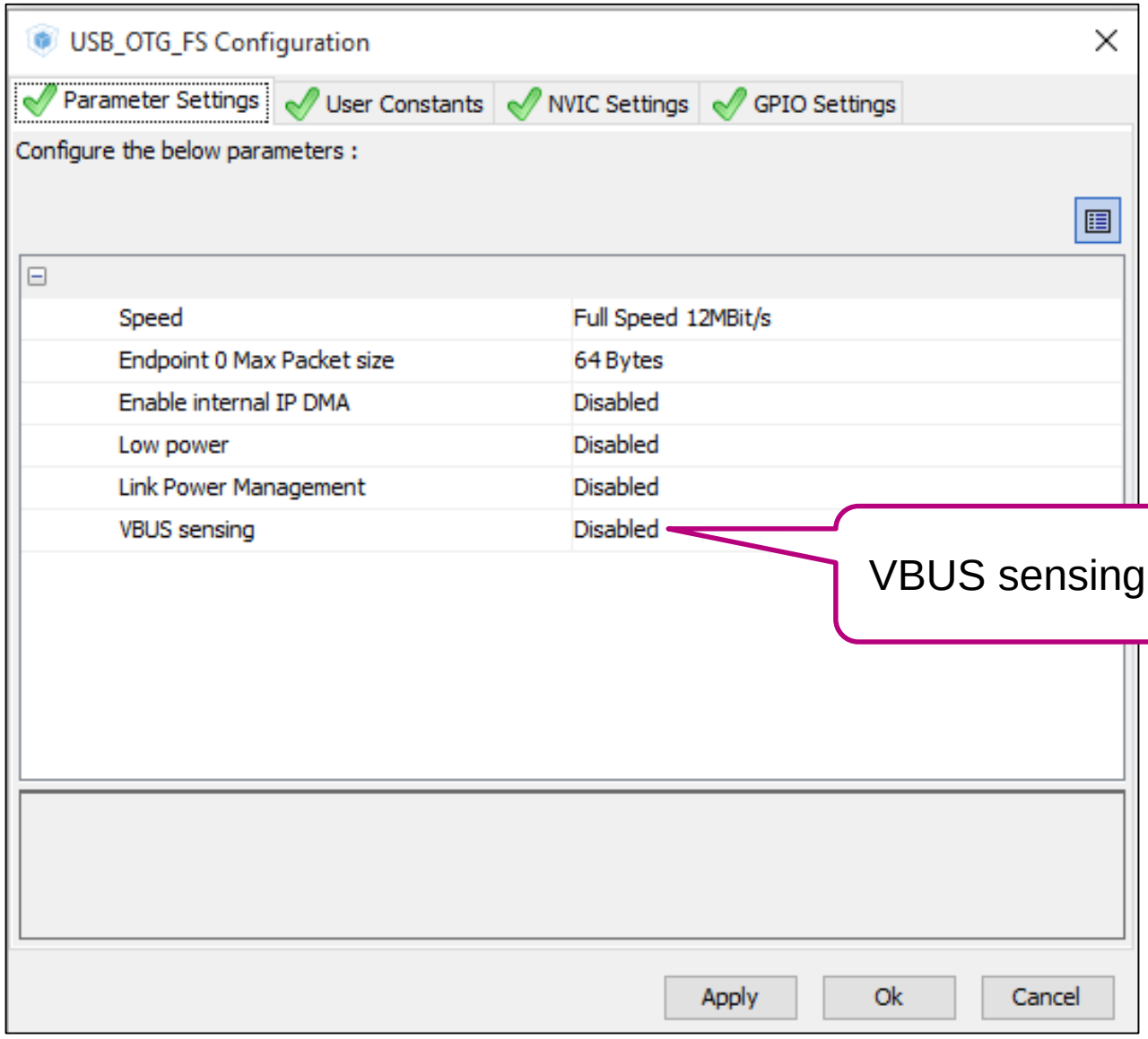
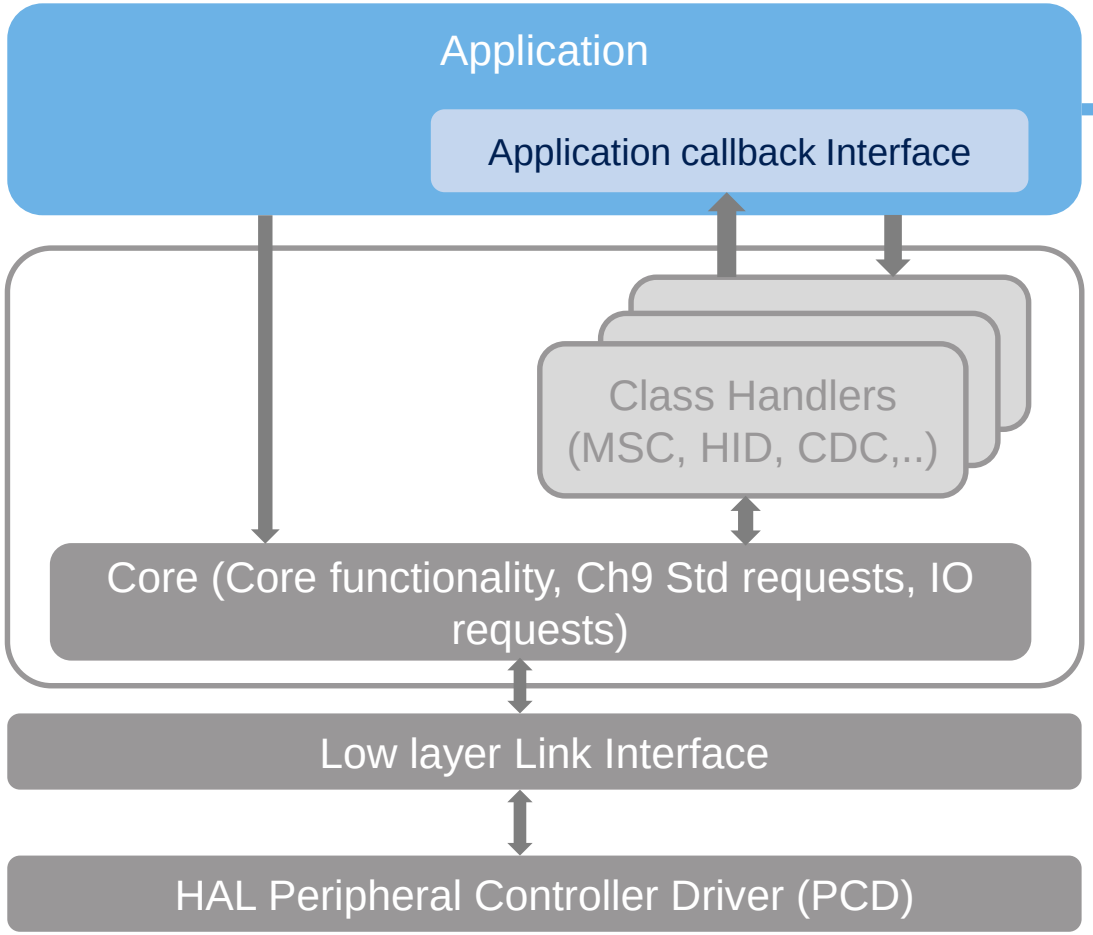
STM32 Cube

USB_OTG_FS configuration



VBUS sensing → Disabled

1 USB Mass Storage Class Basics



- USB wrapper for SCSI commands

SCSI = Small Computer System Interface

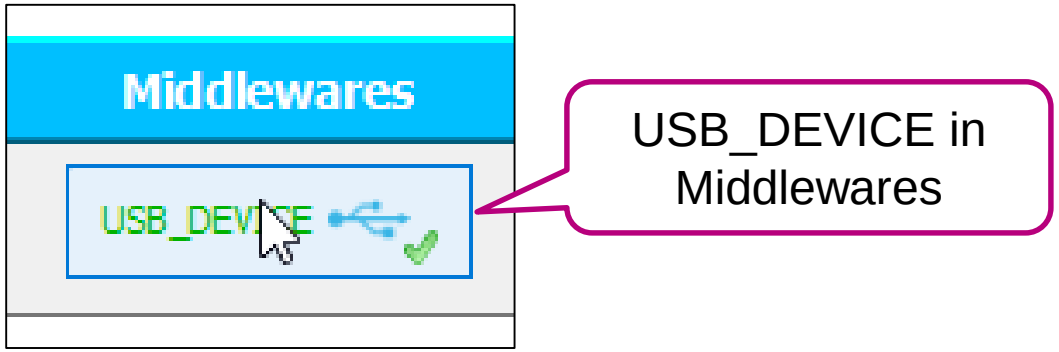
SCSI command subset for USB

- Init
- Read
- Write
- Is Ready
- Get Capacity
- Get Max LUN
- Is Write Protected

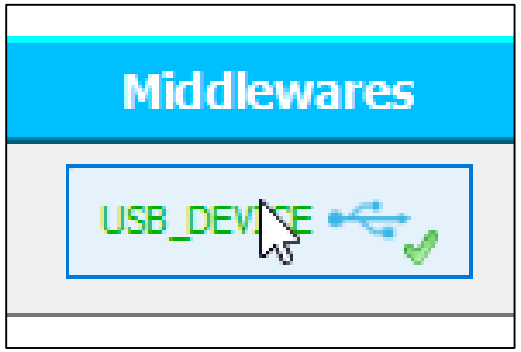
life.augmented 15y since Windows Me® (2000), Linux kernel 2.4 (2001), Mac OS 9/X® (2000)

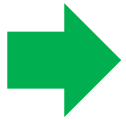
STM32 Cube

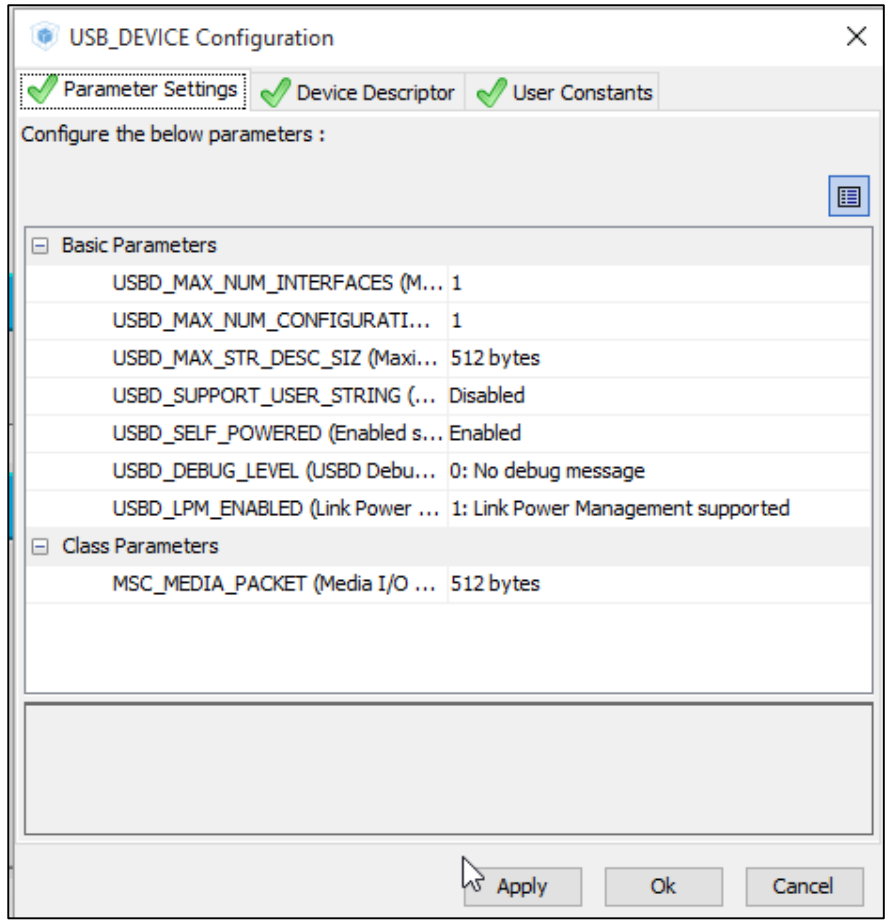
1 USB_DEVICE MiddleWare configuration



1 USB_DEVICE MiddleWare configuration







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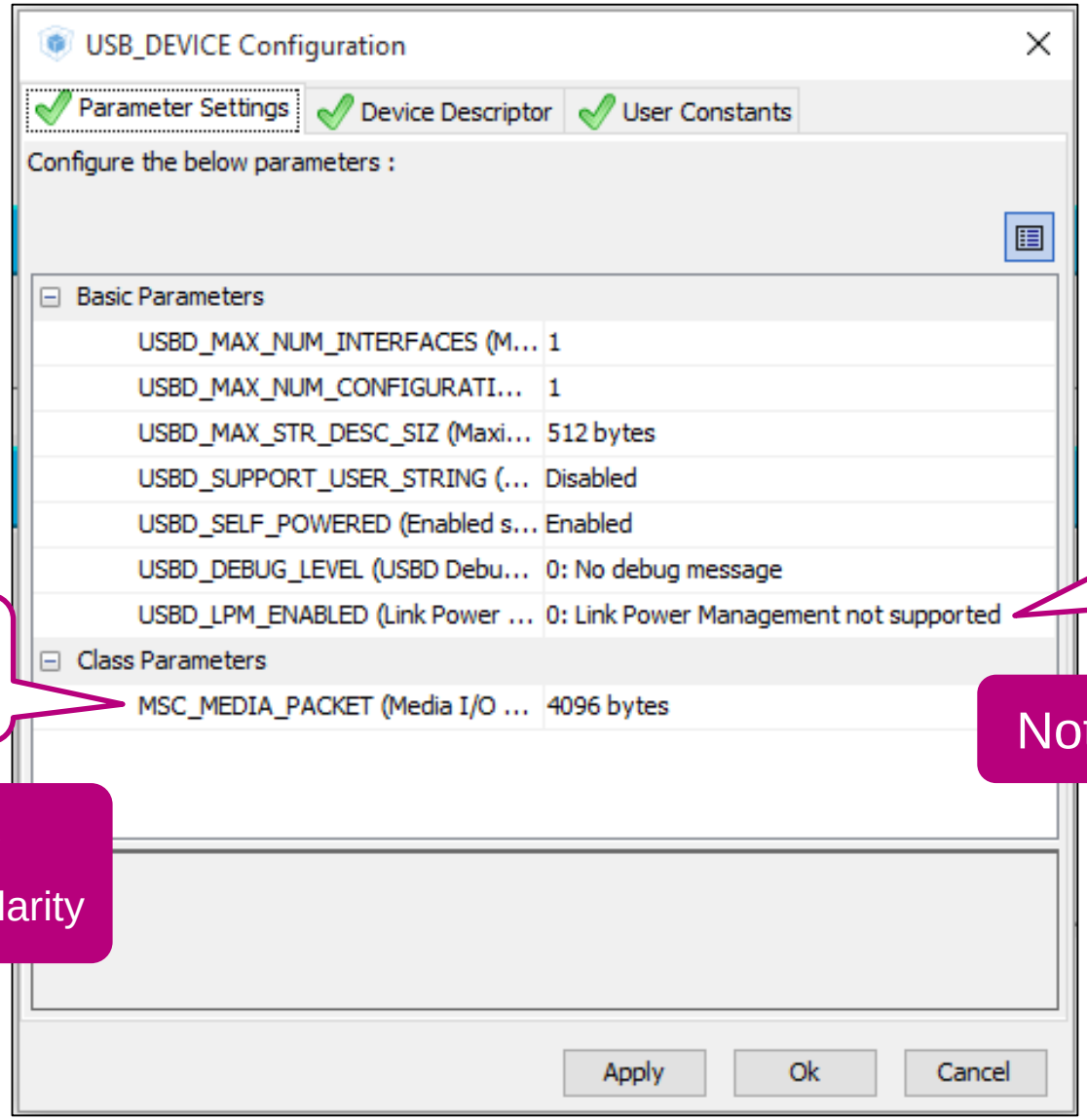
STM32 Cube

1 USB_DEVICE MiddleWare configuration



MSC_MEDIA_PACKET
→ 4096 bytes

N25Q128A memory
4kB Sub-Sector Erase Granularity

USBD_LPM_ENABLED
→ 0

Not used in this demo app

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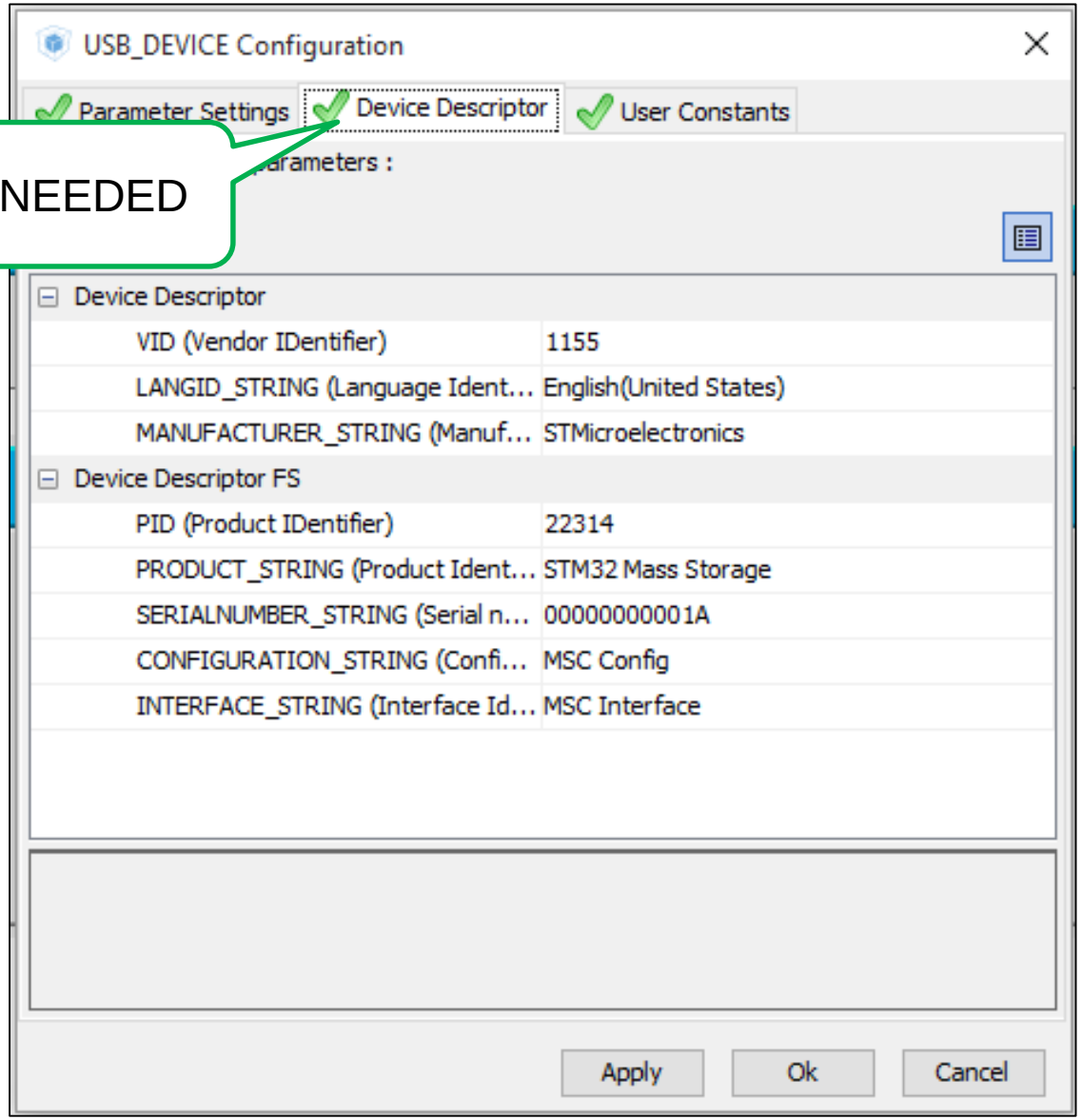
STM32 Cube

1 USB_DEVICE MiddleWare configuration

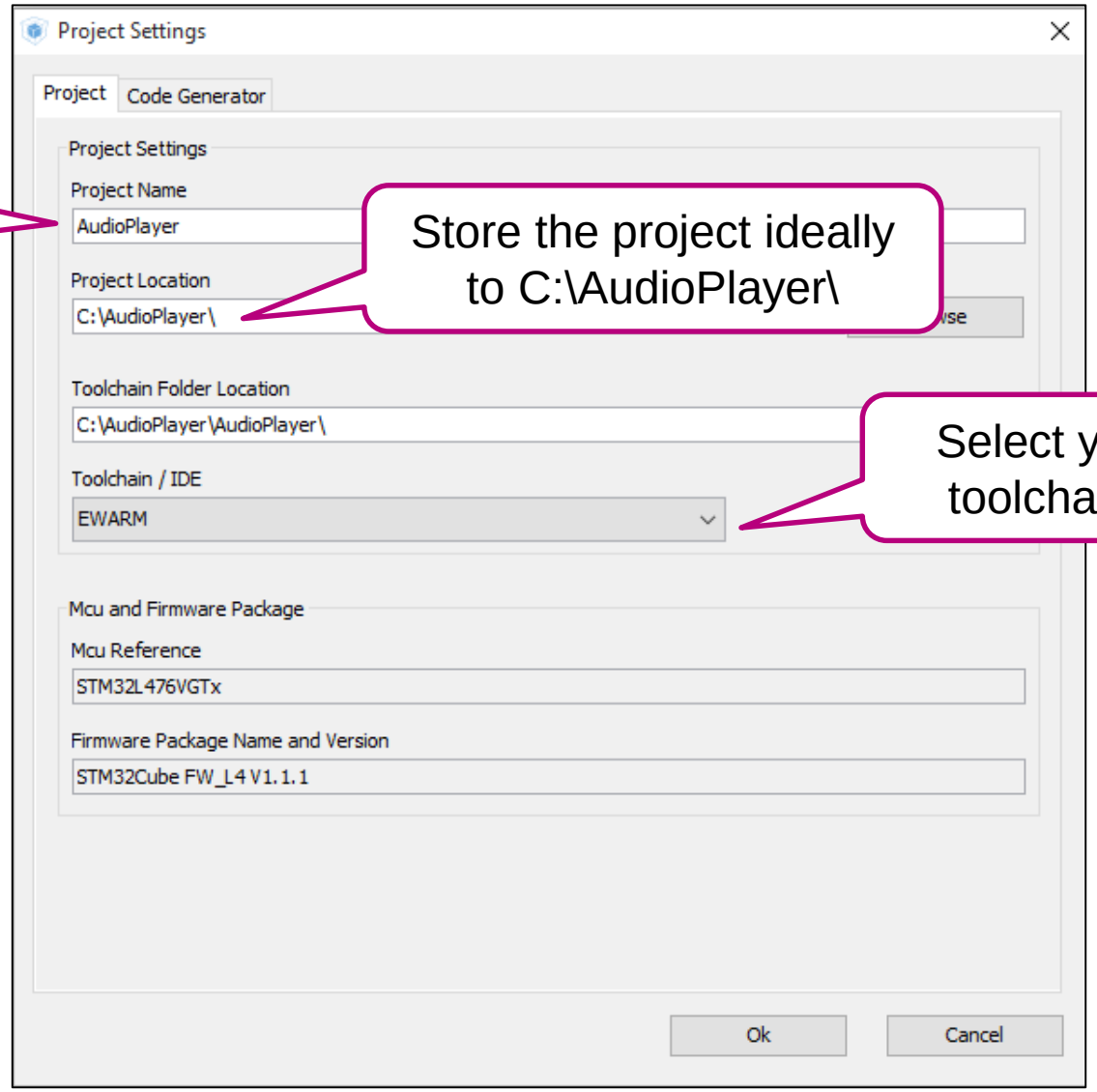
NO CHANGE NEEDED



1

Project Settings

Project Name
→ AudioPlayer



Store the project ideally to C:\AudioPlayer\

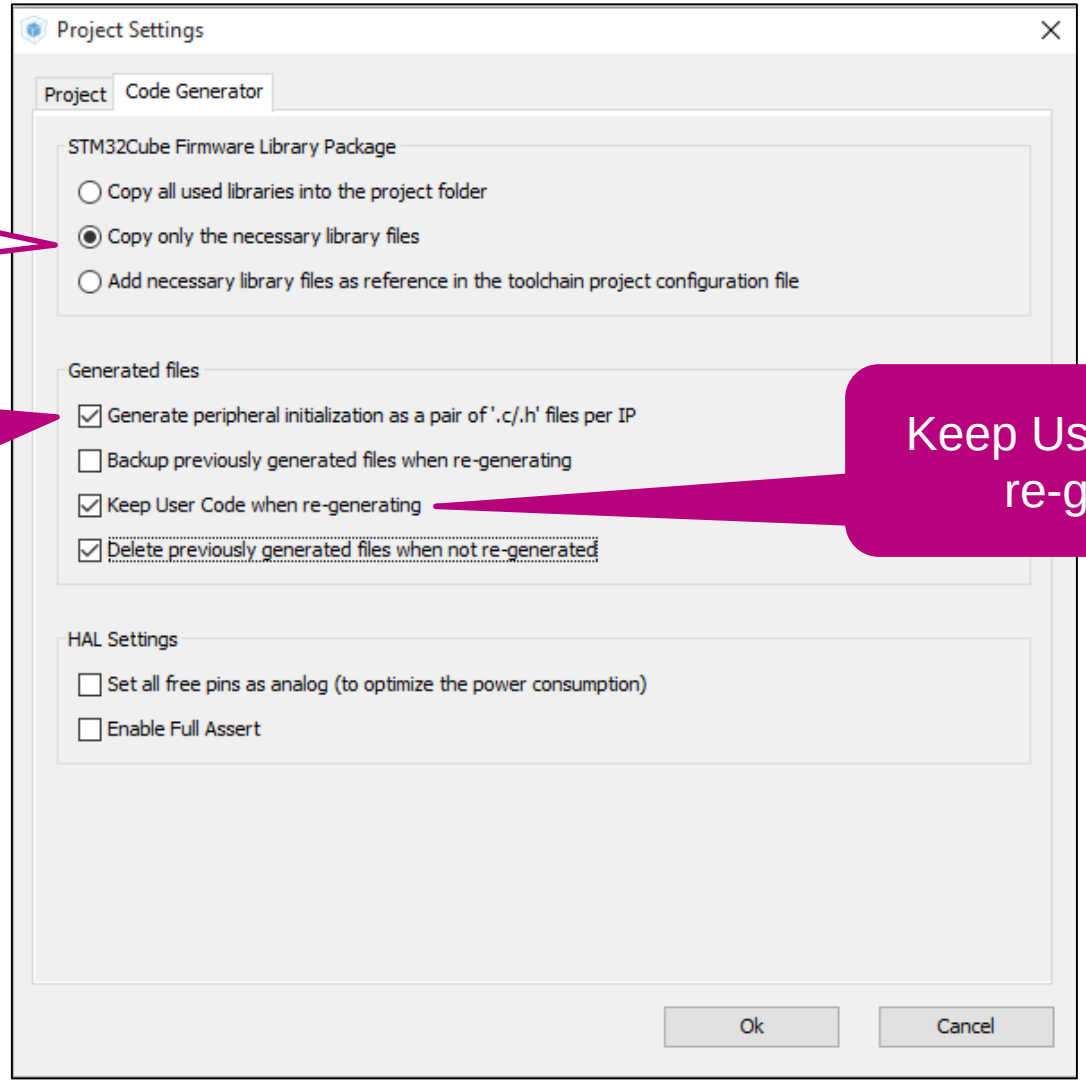
Select your preffered toolchain (EWARM)

Project Settings

Copy only the necessary library files

Generate peripheral initialization as a pair of .c/.h files per IP

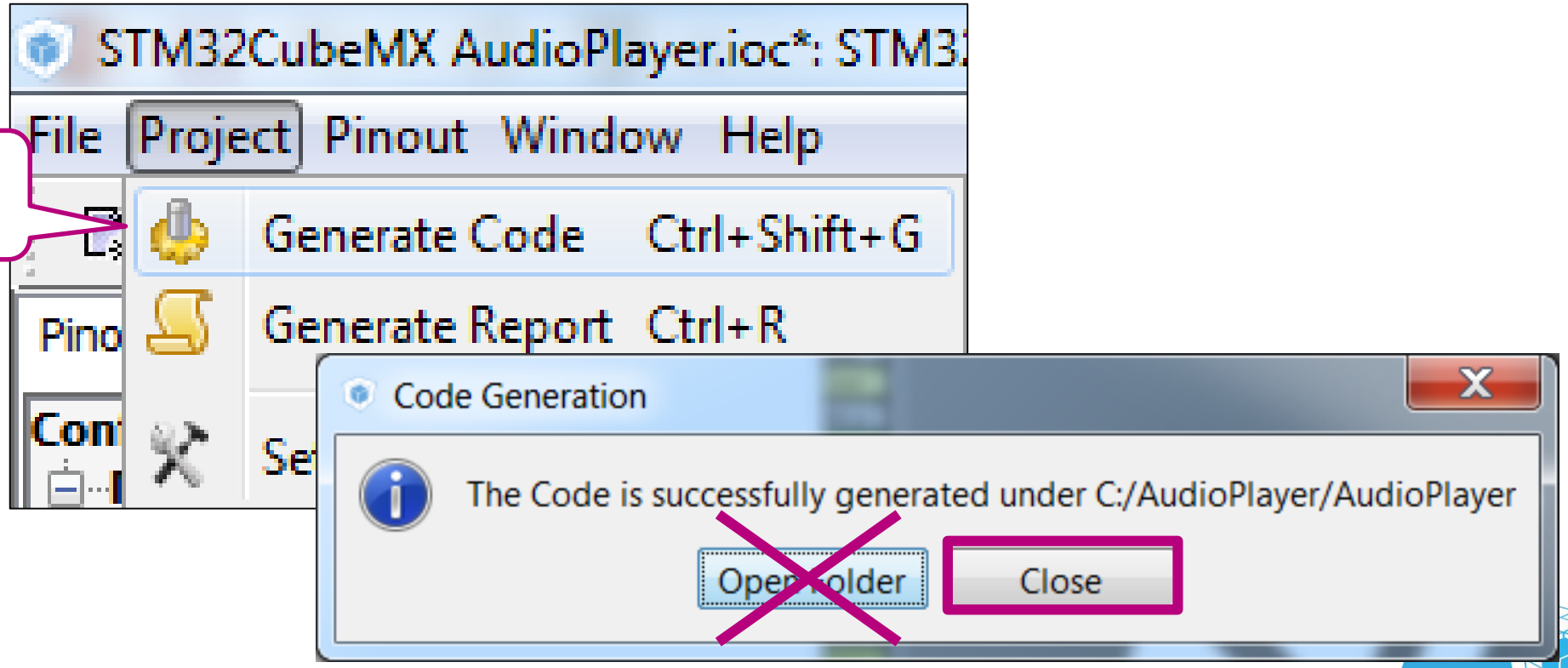
Keep User Code when re-generating



1 Save and generate the project

Do not open the project yet

Generate Code
(Ctrl+Shift+G)



1 Apply small patch

- Apply patch from folder

  C:\STM32L4_Workshop\HandsOn\2_Putting_All_Together\Patch\STEP1_USB_MSC_Device

  to project folder

  (C:\AudioPlayer\AudioPlayer\)

- It contains the following files:

  .\Inc\

  quadspi.h

  n25q128a.h

  .\Src\

  usbd_storage_if.c

  quadspi.c

This operation is STM32CubeMX non-intrusive. You can re-generate the project later and the modifications will be retained.

These files contains the main needed source code the user has to add to have the USB MSC device running together with QSPI FLASH storage

1 quadspi.c added content

- quadspi.c

QSPI_Init(void)
QSPI_DeInit(void)
} Initialization

QSPI_Read(…)
QSPI_Write(…)
} Read / Write access

QSPI_Erase_Block (…)
QSPI_Erase_Sector(…)
QSPI_Erase_Chip(void)
} Erase operations

QSPI_GetStatus(void)
QSPI_GetInfo(…)
} QUADSPI memory info / status

Based on BSP driver in STM32CubeL4 HAL

1 usbd_storage_if.c added content

- usbd_storage_if.c
  - STORAGE_Init_FS (…)
  - STORAGE_Read_FS (…)
  - STORAGE_Write_FS (…)
  - STORAGE_IsReady_FS (…)
  - STORAGE_GetCapacity_FS (…)

Most important and implemented
Support for 4kB sector size only
(due to 4kB block erase feature of used memory)

- STORAGE_GetMaxLun_FS (void)
- STORAGE_IsWriteProtected_FS (…)

Not so important

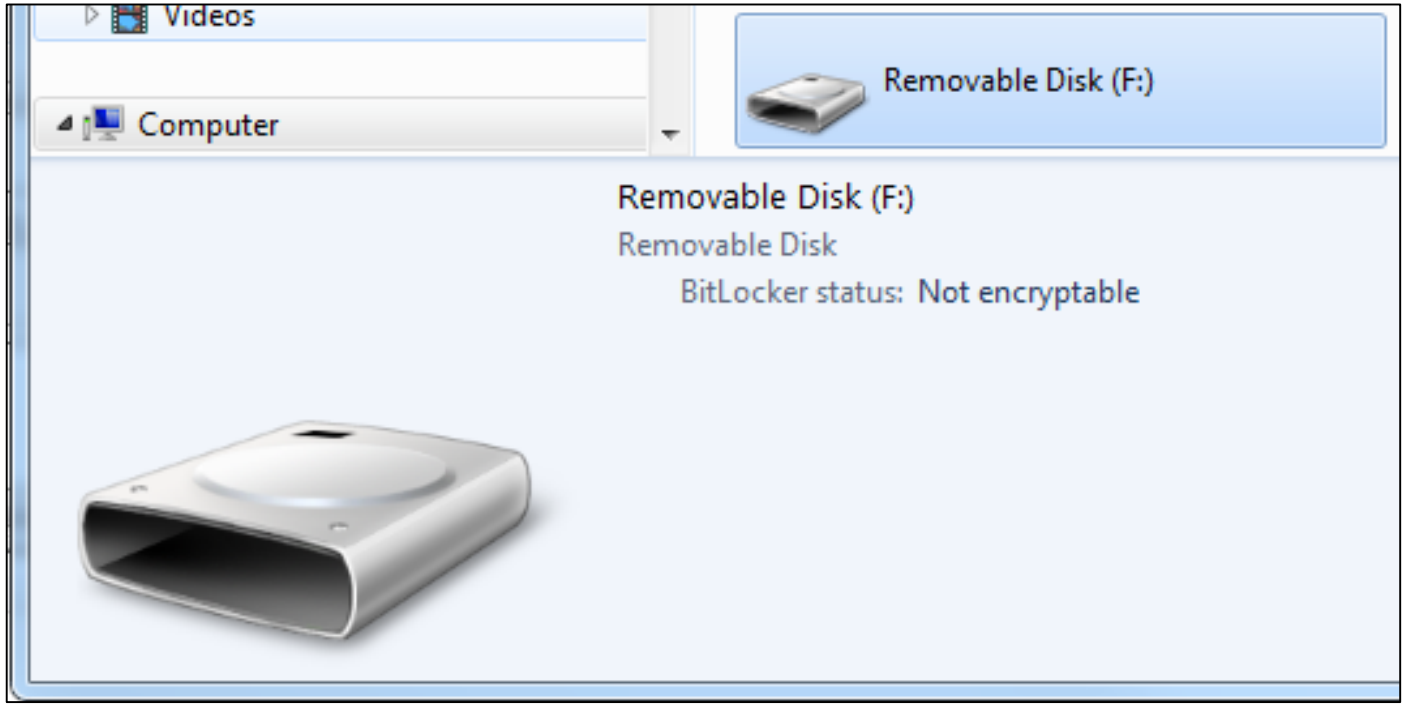
Templates generated by STM32CubeMX, just the bodies of the functions were implemented.

1 Let’s try it out

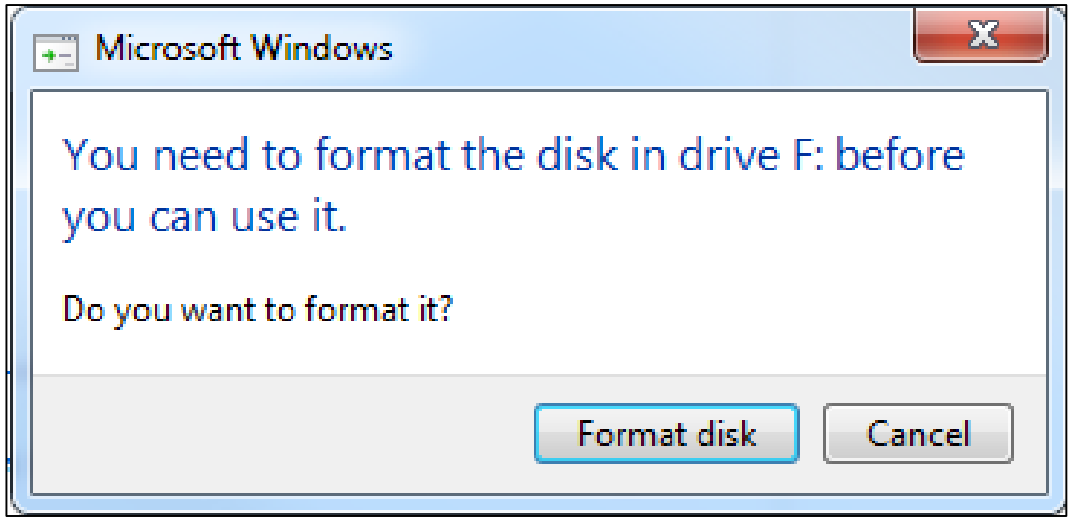
1. Open the project
2. Connect discovery kit over miniUSB cable (ST-Link)
3. Compile and download
4. Press the reset button on discovery once download has finished

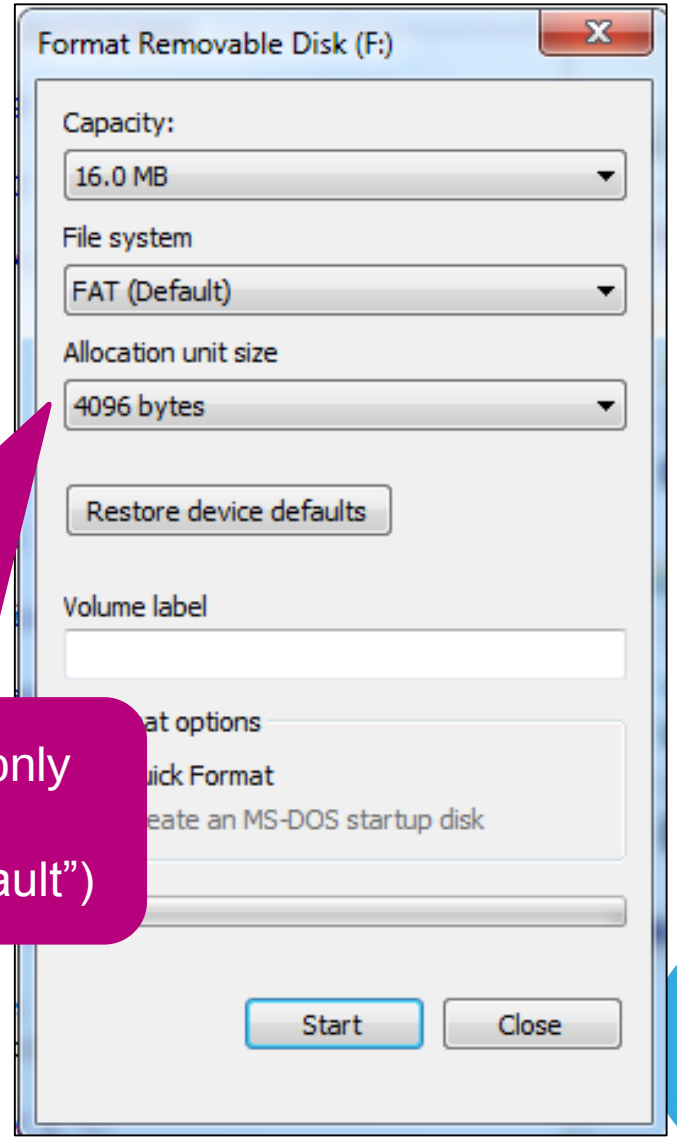
1 Connect the new “FLASH stick”

- Plug-In microUSB cable
- Check if new Mass Storage Class device appeared



Storage formatting





Actual tiny implementation supports only native 4kB sector size
(Windows 10 users should select “default”)

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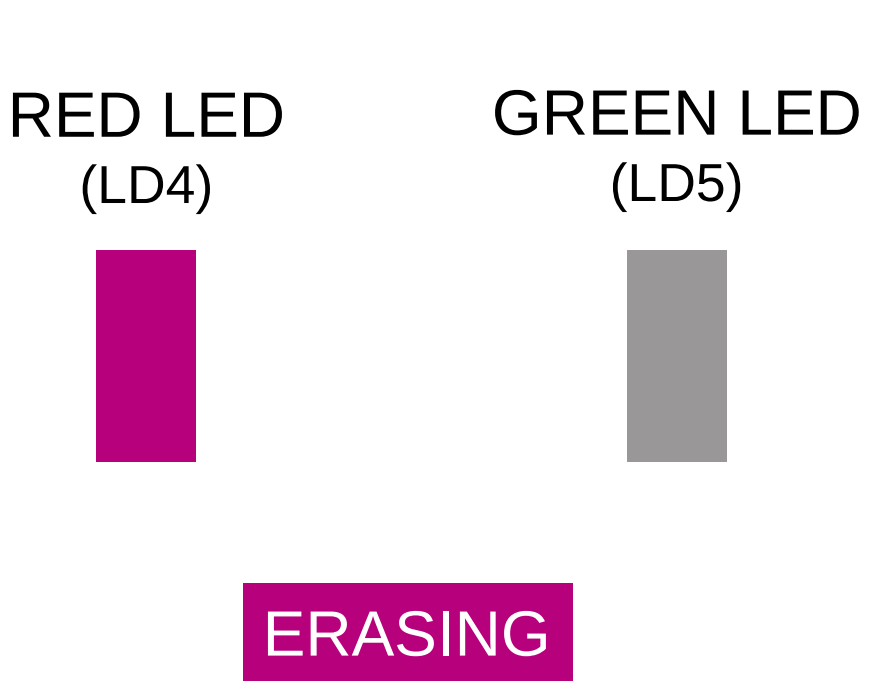
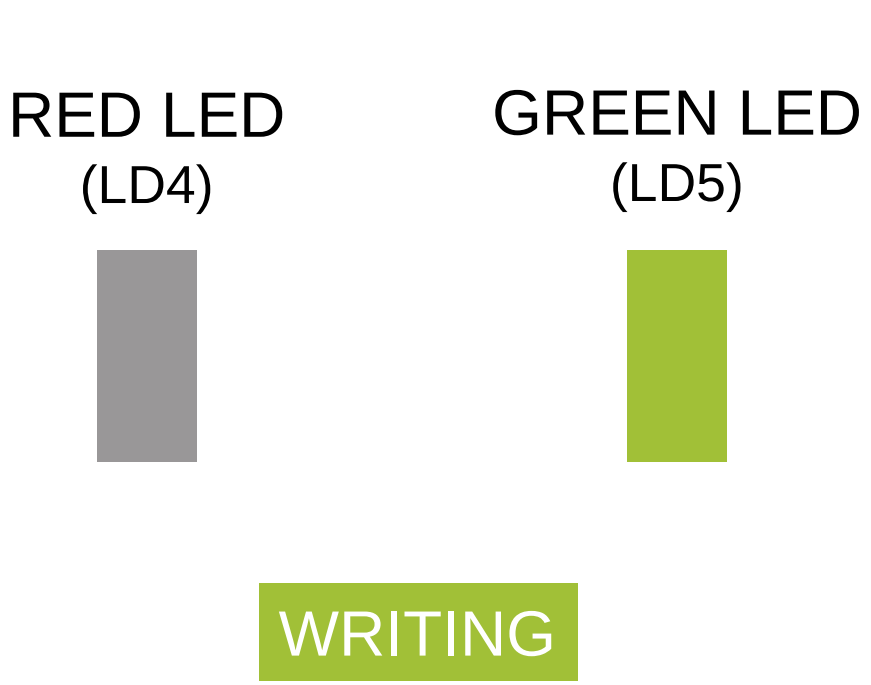
STM32 Cube

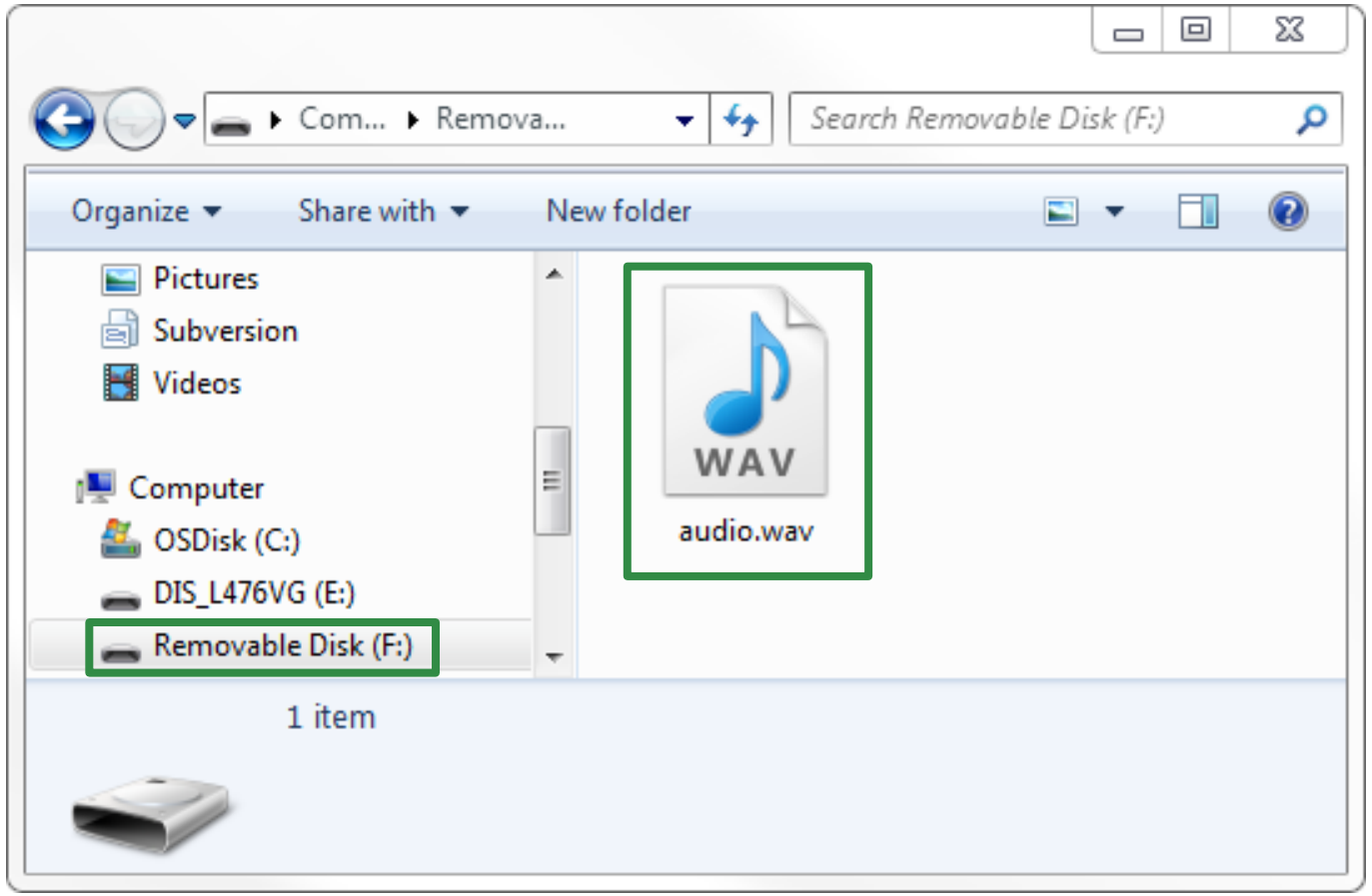
1 Test the functionality

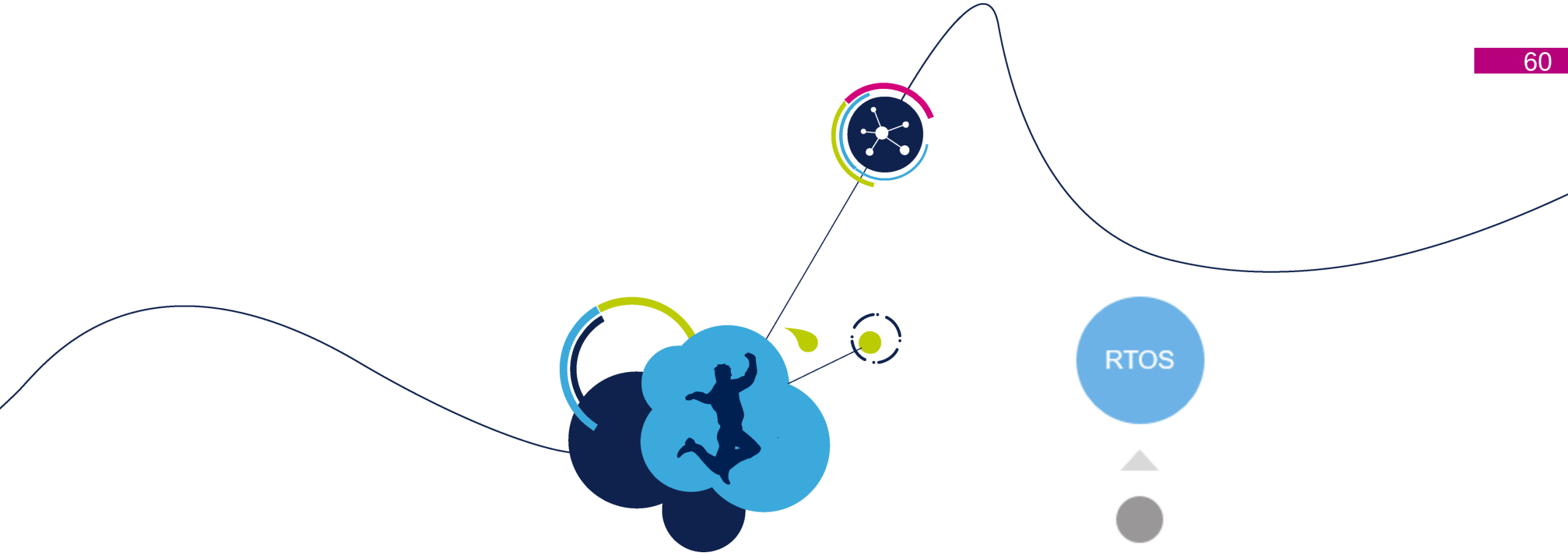
- Now try to copy the **audio.wav** file from the package to the new





Checkpoint #3

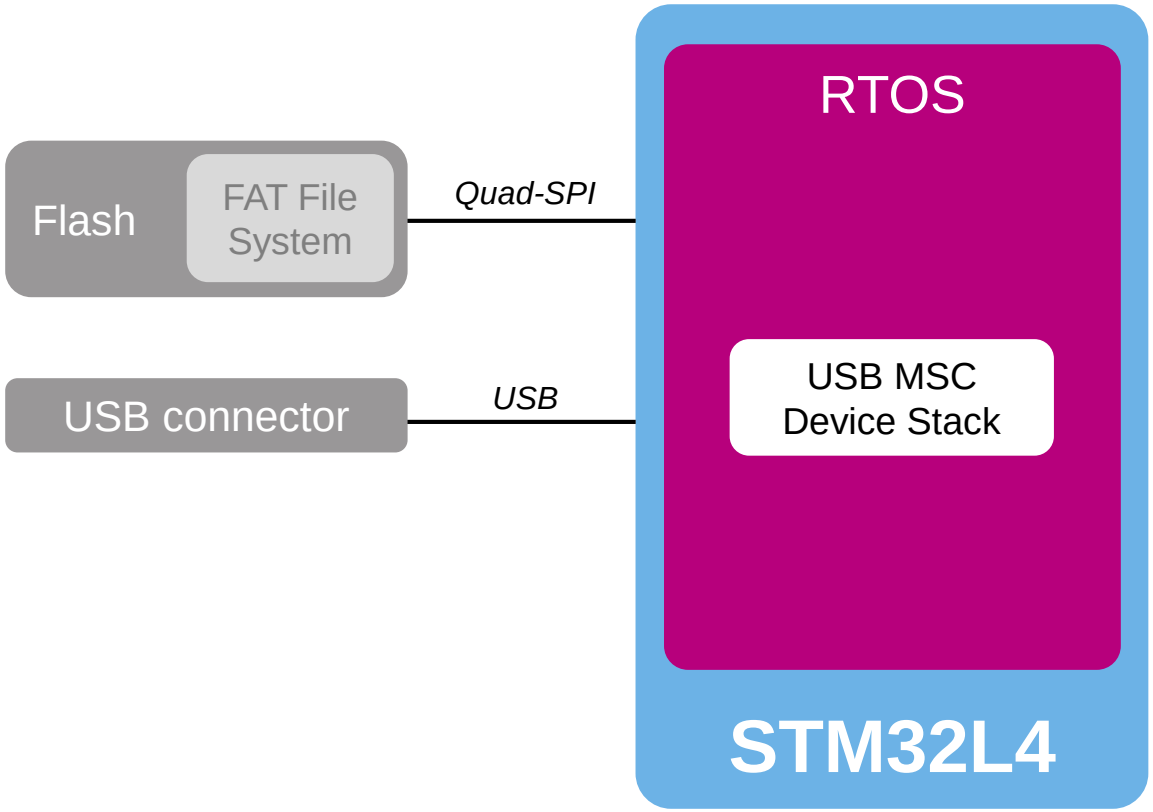




STEP2 – RTOS

Adding RTOS

- We want to have the application running on RTOS



2 Why RTOS?

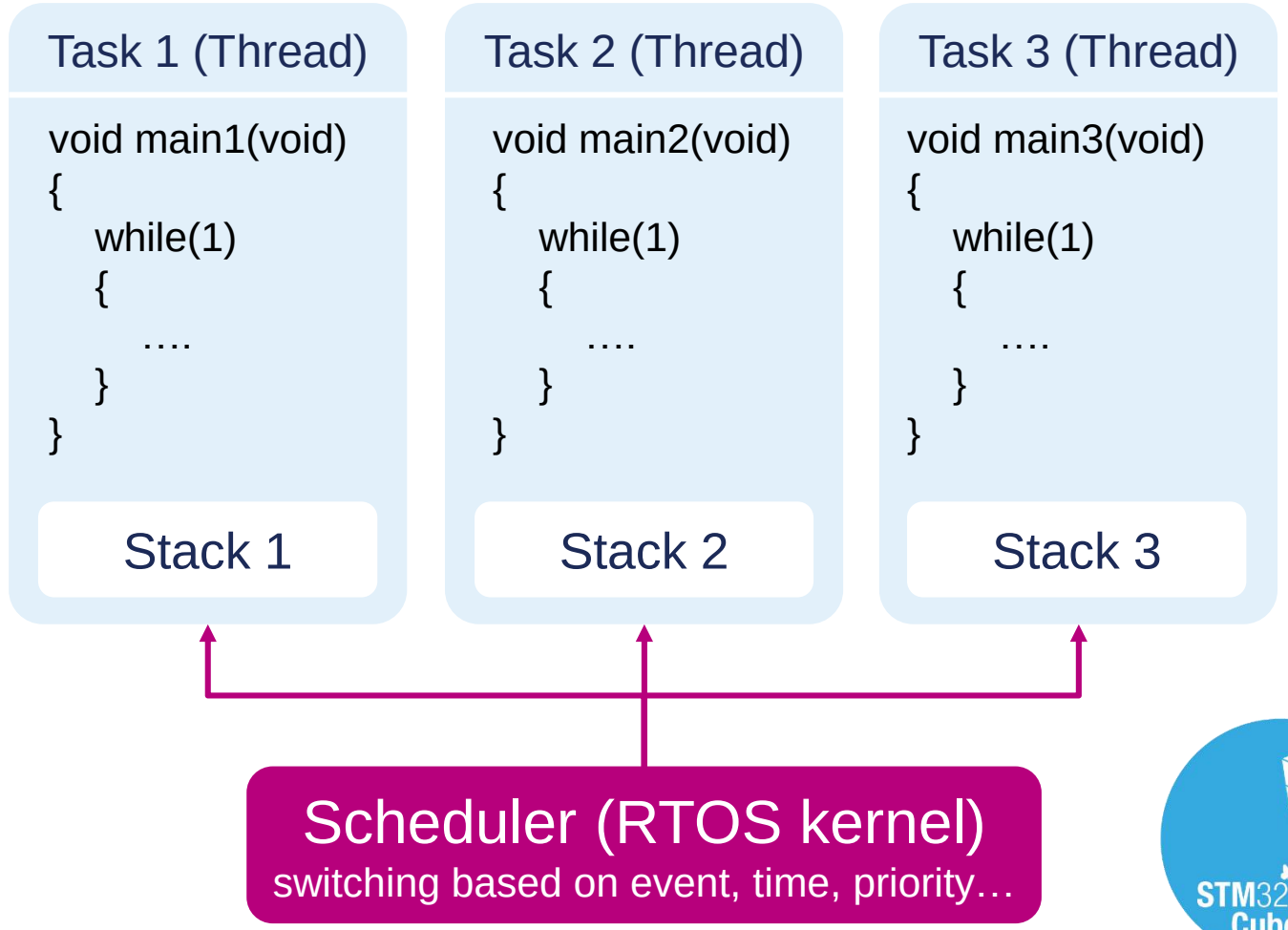
- To have the application modular (design not closed yet)
  - add/remove functionality easily
- We want to implement application with multiple functionality quickly
  - we don’t want to care about the operations synchronization and flow management
- Because we can
  - far more than enough flash, RAM, performance
  - don’t need to limit ourselves

RTOS basics

Conventional app

```
void main(void)
{
   while(1)
   {
      switch task {
      case 1:
         ….
         break;
      case 2:
         ….
         break;
      case 3:
         ….
         break;
      }
   }
}
```

RTOS app



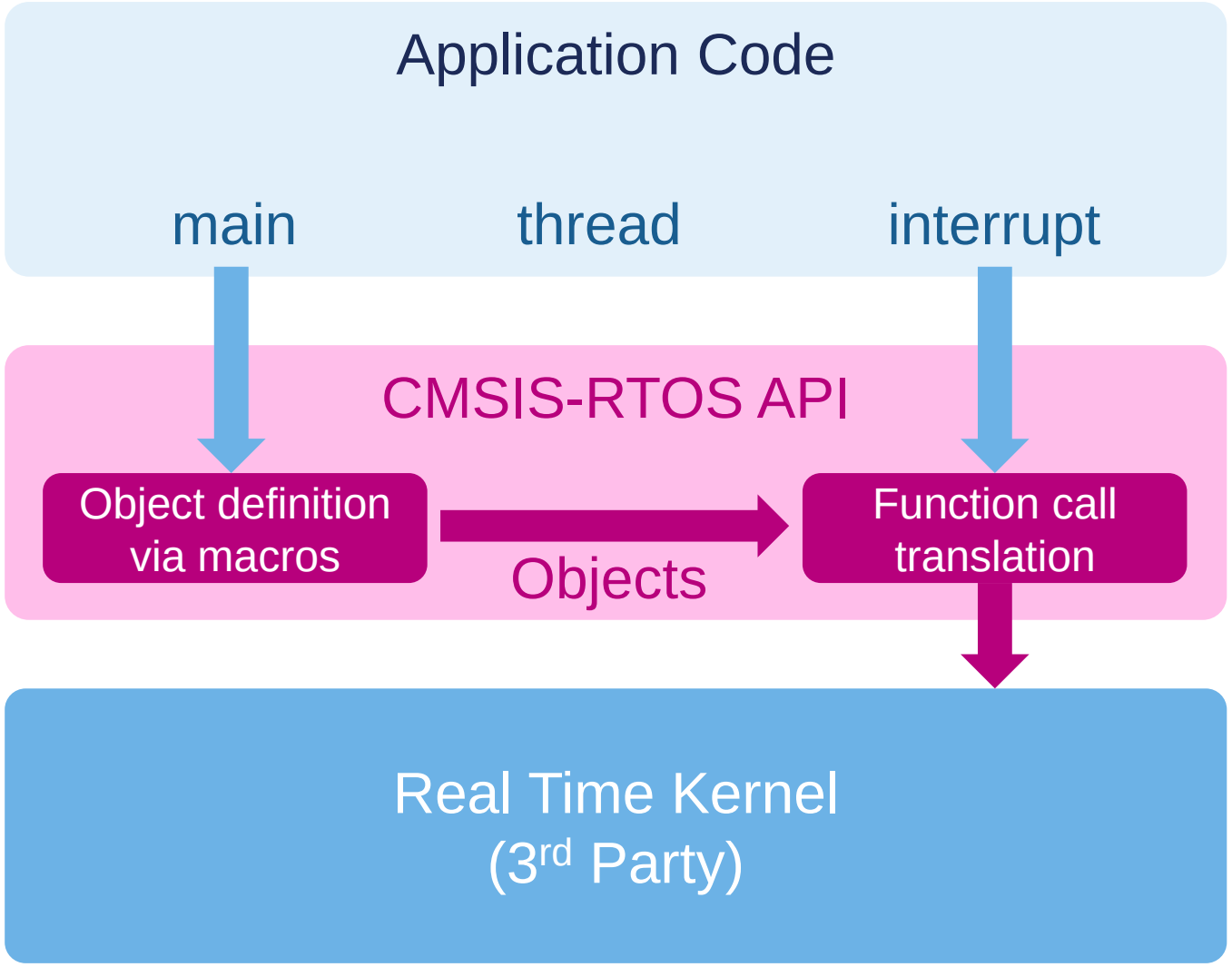
CPU time and scheduling

- A timeout parameter is incorporated in RTOS functions to avoid system lockup
- When a timeout is specified the system waits until a resource is available or event occurs
- While waiting, other threads are scheduled
- osDelay function puts a thread into the state WAITING for a specified period of time

Threads and ISR communication

- Signal
  - flag that may be used to signal specific condition to a thread
  - can be modified in an ISR or set from other threads.
- Message
  - 32-bit value that can be sent to a thread or an ISR
  - buffered in a queue, type and queue size defined in a descriptor
- Mail
  - fixed-size memory block that can be sent to a thread or an ISR
  - buffered in a queue and memory allocation is provided
  - type and queue size are defined in a descriptor.

CMSIS-RTOS introduction



FreeRTOS

2 Where to find more information?

- UM1722 – Developing Applications on STM32Cube with RTOS

  http://www.st.com/st-web-ui/static/active/en/resource/technical/document/user_manual/DM00105262.pdf

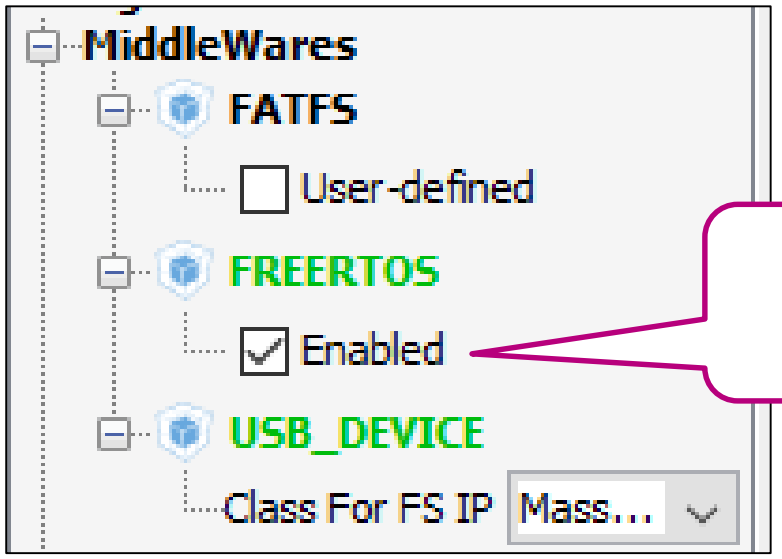
- http://www.freertos.org

- Using The FreeRTOS Real Time Kernel - Cortex-M3 edition

  http://shop.freertos.org/FreeRTOS_Tutorial_Book_Generic_Cortex_M3_Edition_p/pdf_cortex-m3_tutorial_book.htm

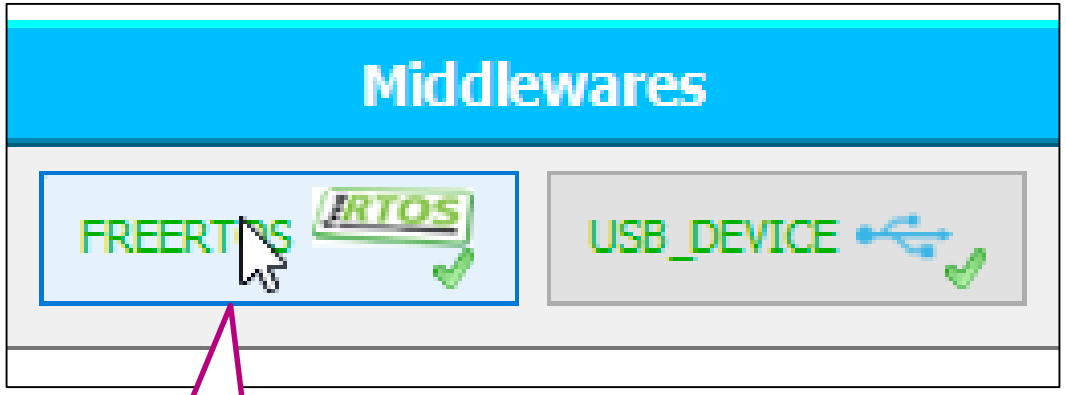
2 FreeRTOS Configuration

Go to Configuration



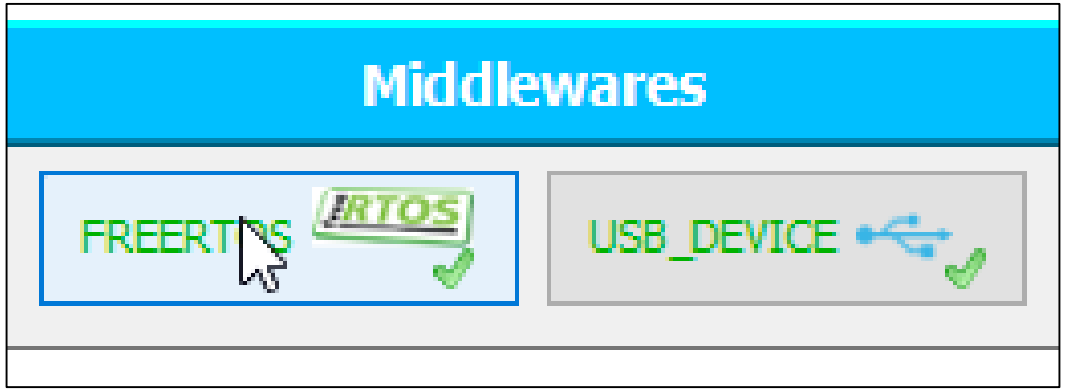
Enable FreeRTOS

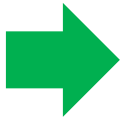
2 FreeRTOS Configuration

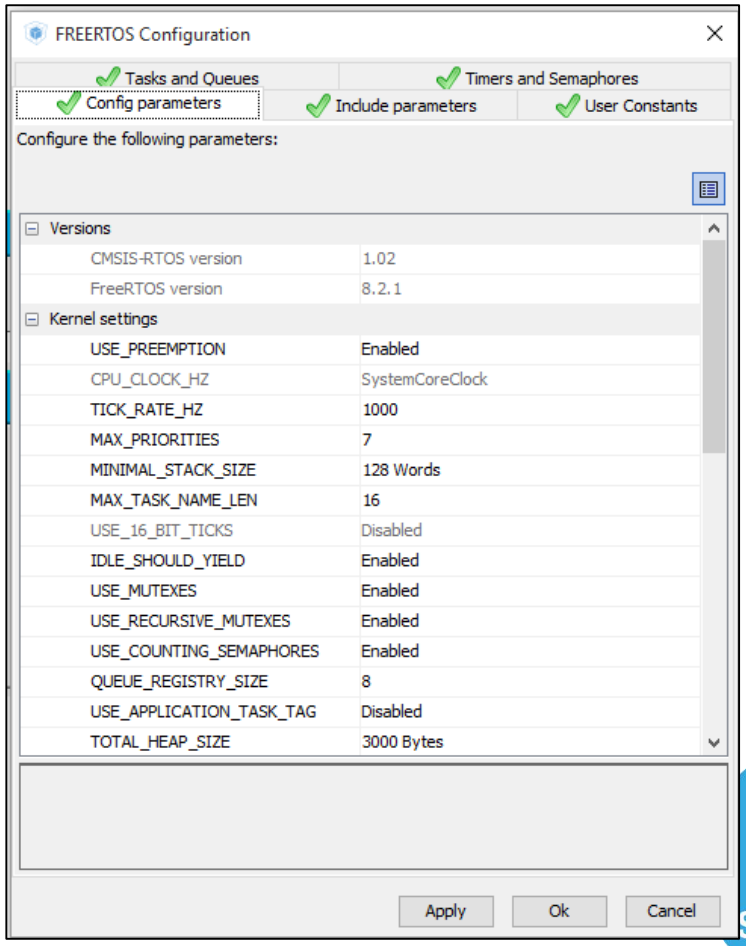


FREERTOS in Middlewares

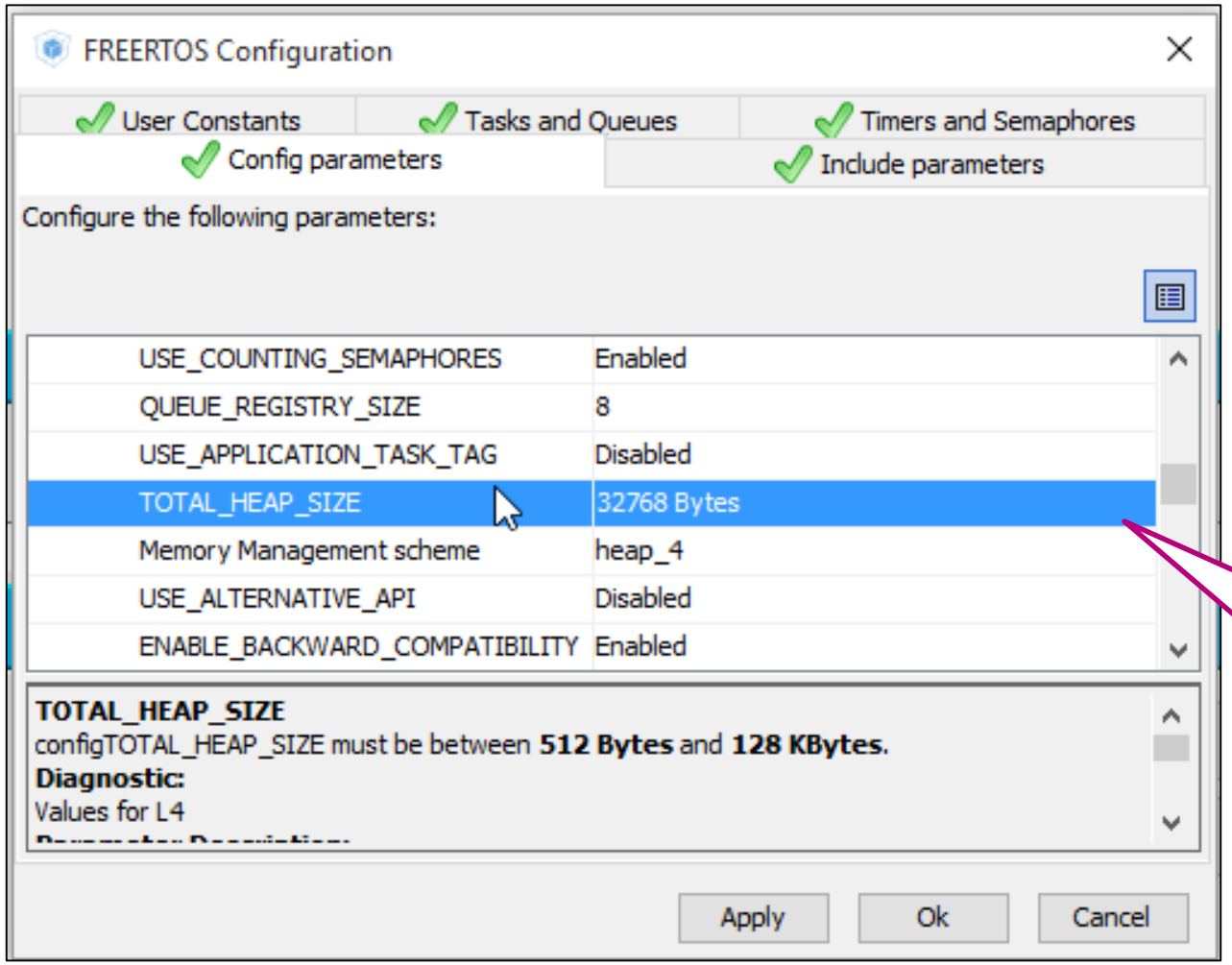
FreeRTOS Configuration







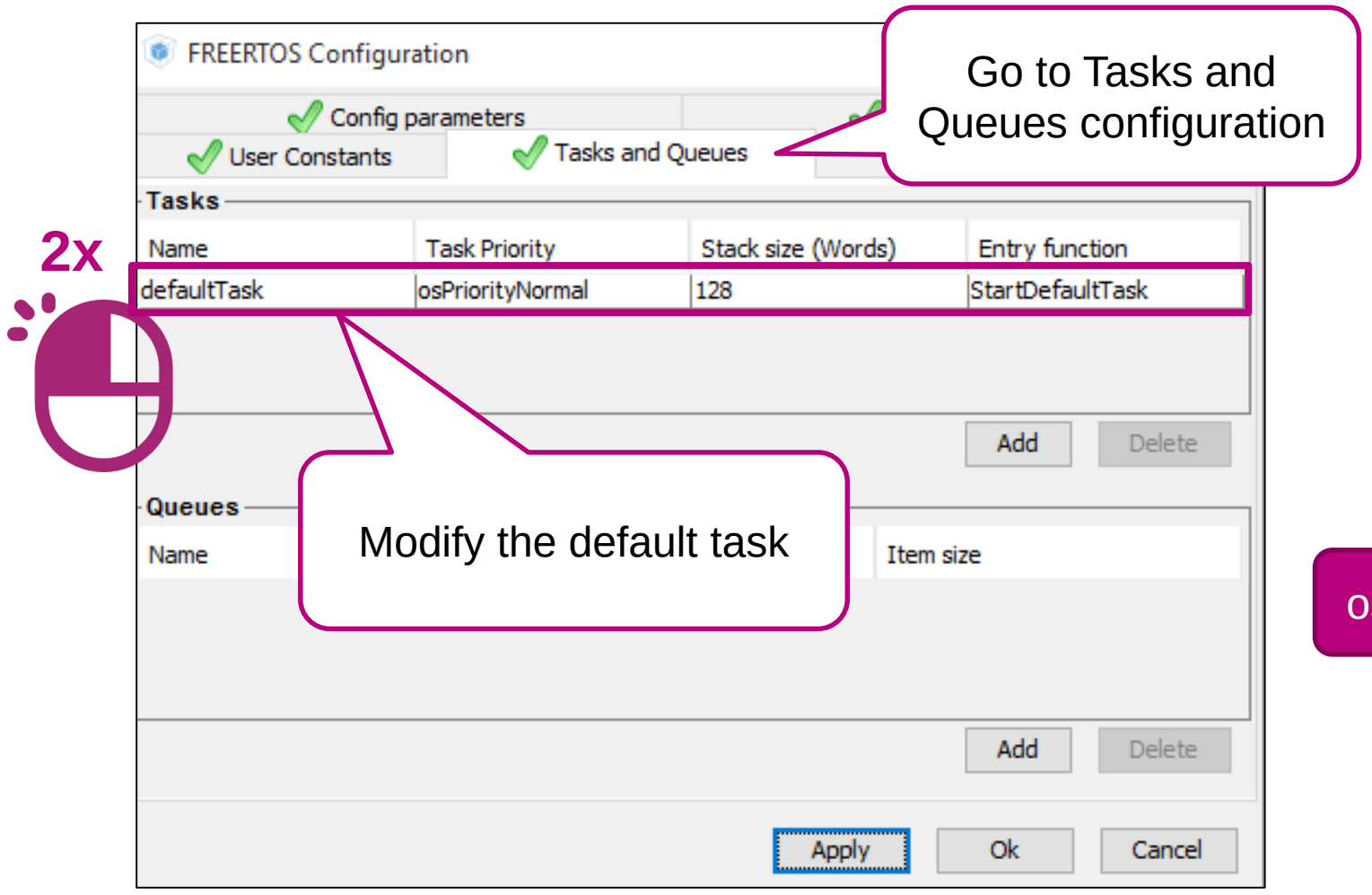
FreeRTOS Configuration

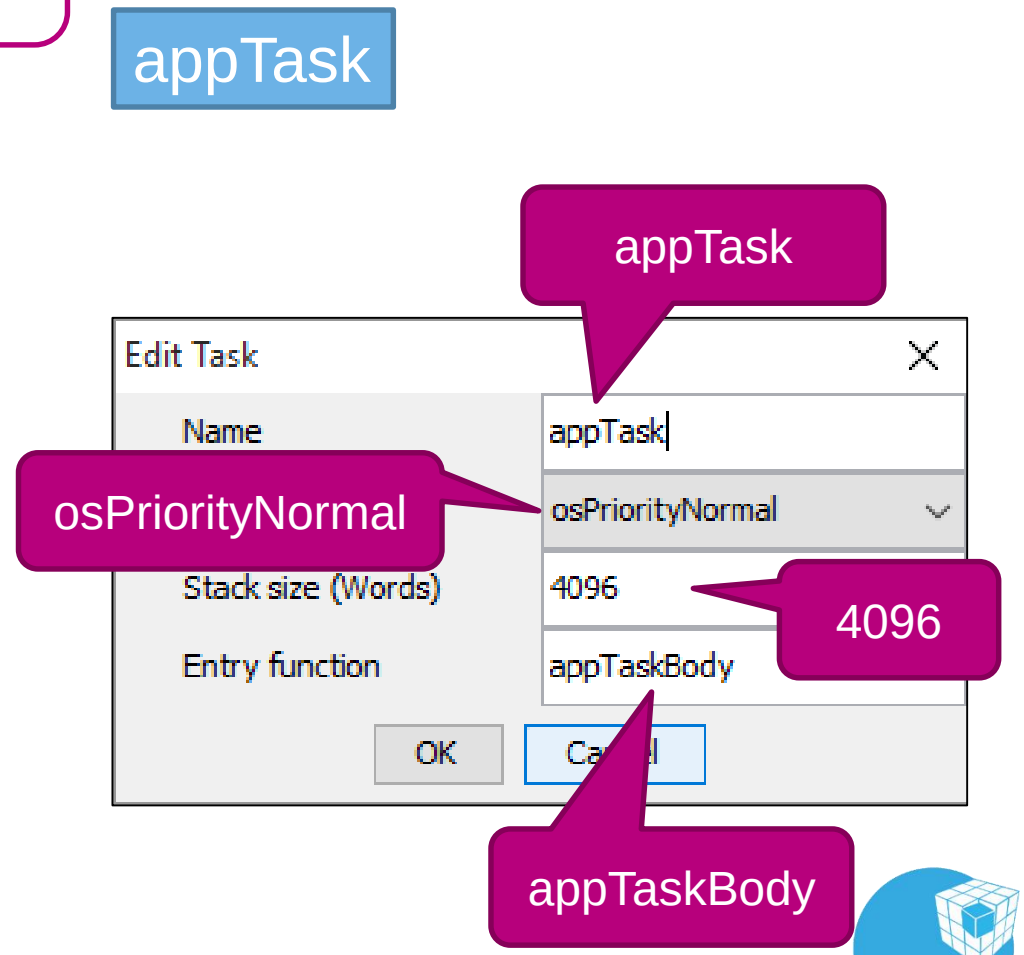


TOTAL_HEAP_SIZE
→ 32768 bytes

(to have some reserve)

2 FreeRTOS Configuration

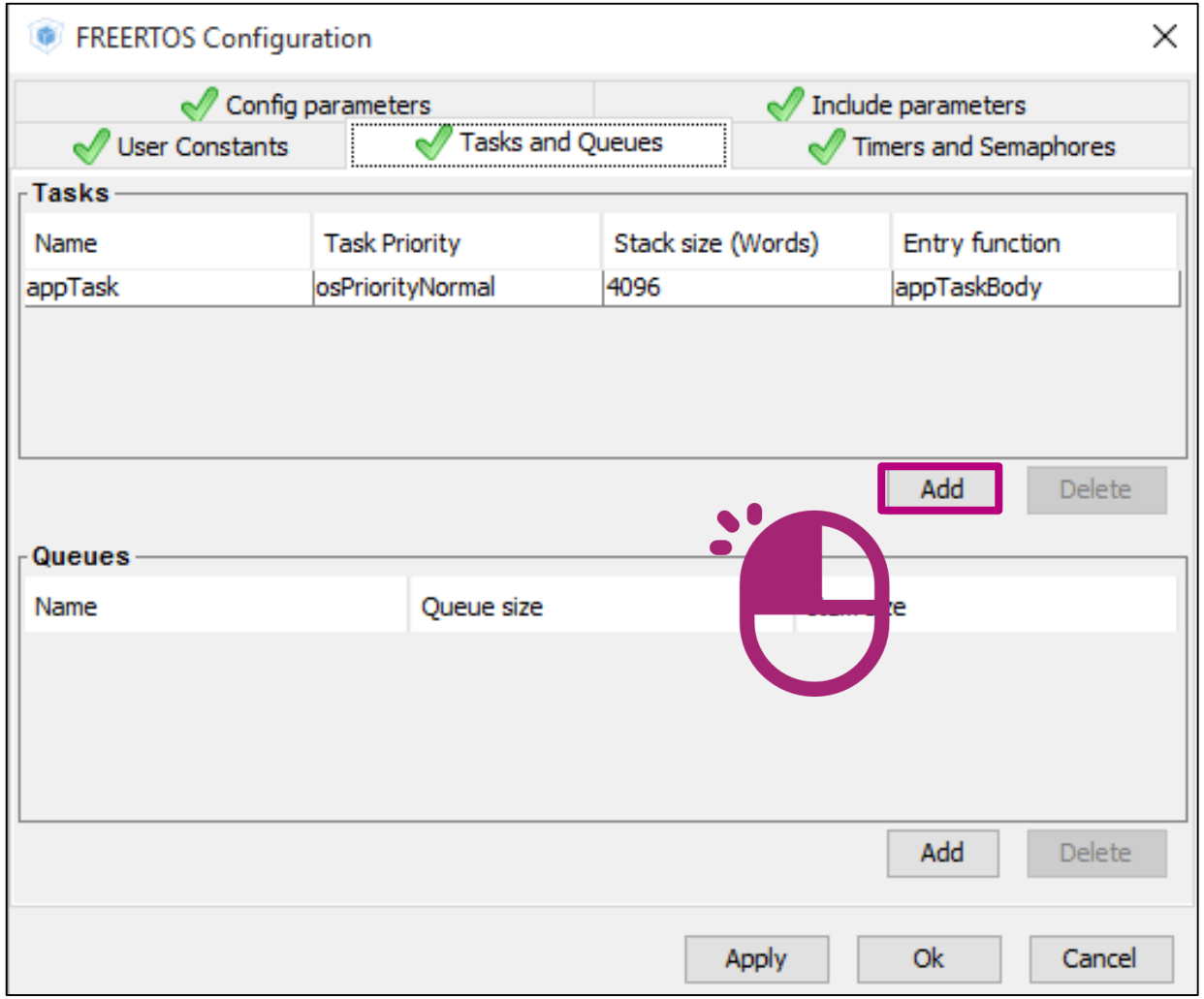




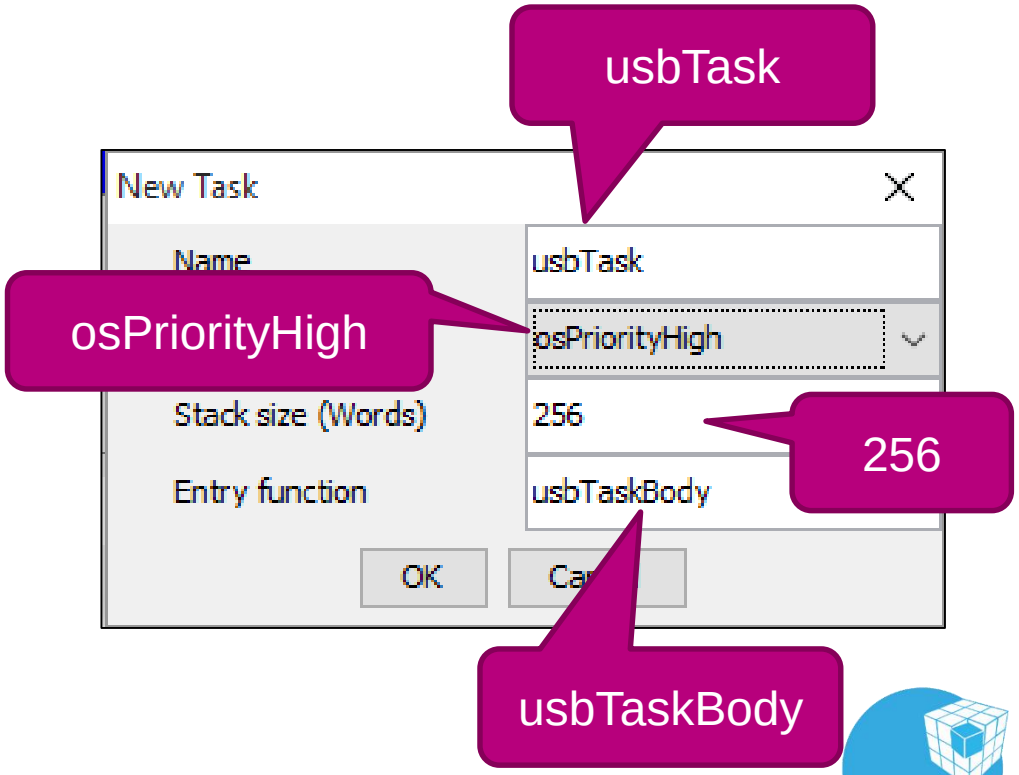
life.augmented

STM32 Cube

2 FreeRTOS Configuration

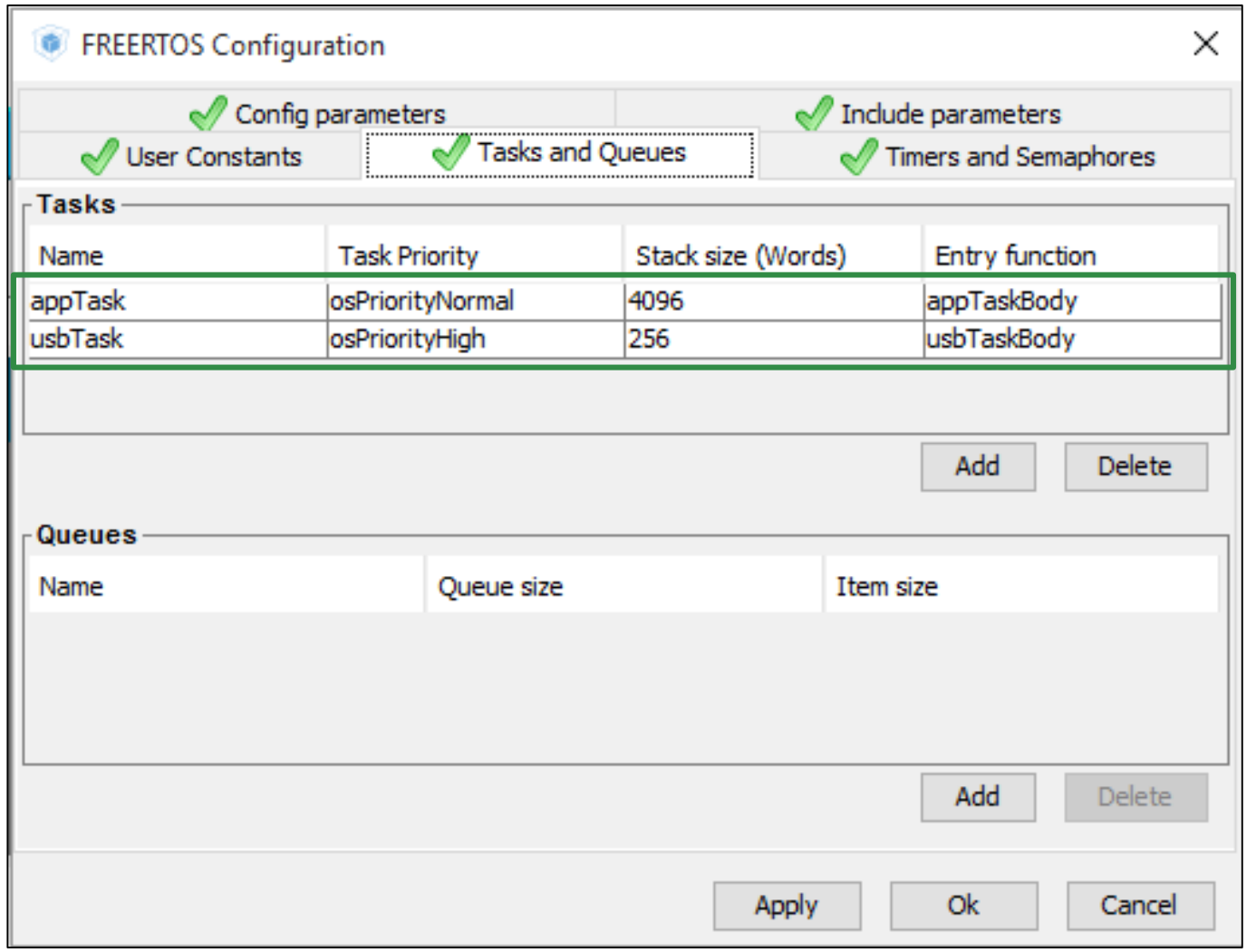


usbTask



Checkpoint #4

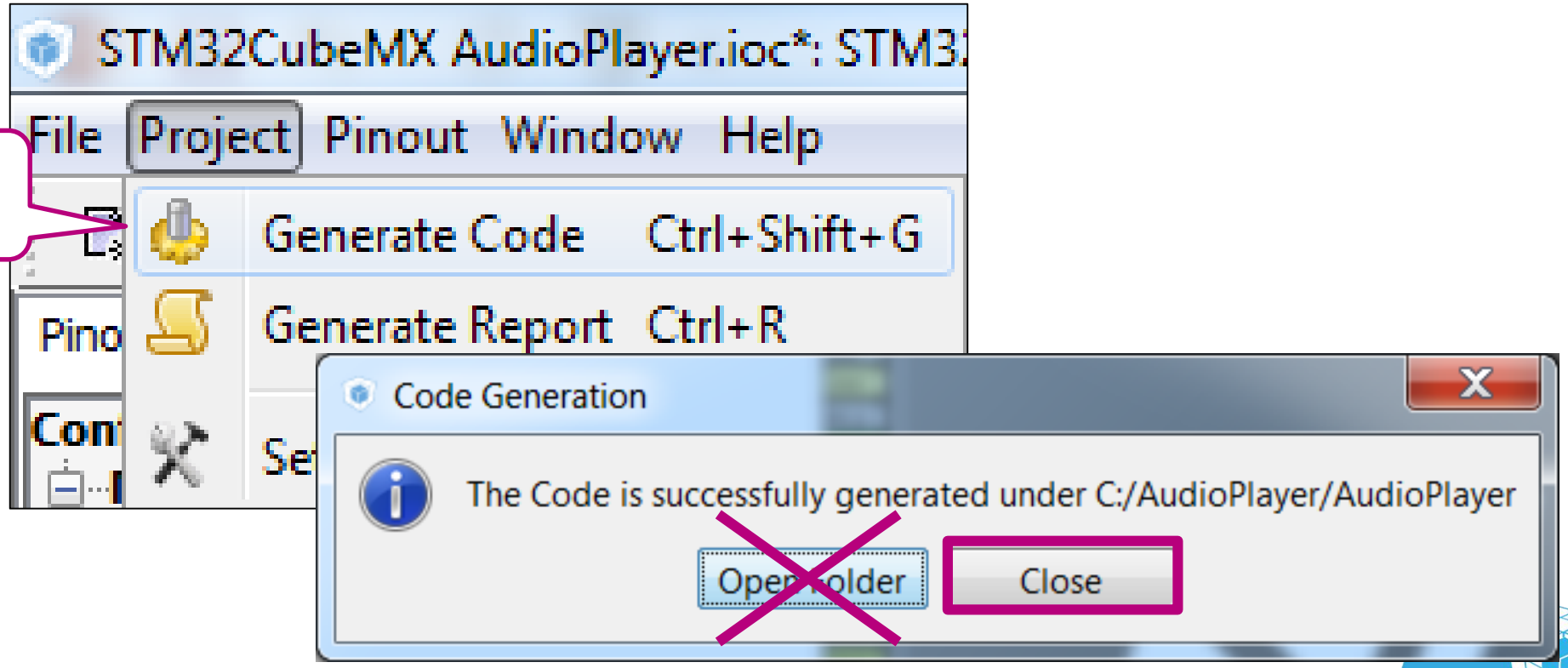
USB



2 Save and generate the project

Do not open the project yet

Generate Code
(Ctrl+Shift+G)



2 Apply small patch

- Apply patch from folder
  C:\STM32L4_Workshop\HandsOn\2_Putting_All_Together\Patch\STEP2_RTOS
  to root folder of your project
  (C:\AudioPlayer\AudioPlayer\)

This operation is STM32CubeMX non-intrusive. You can re-generate the project later and the modifications will be retained.

- It contains the following files:
  .\Src\
  freertos.c
  usbd_storage_if.c

- usbd_storage_if.c – change in LEDs use, we need them for other pur[illegible]e

2

Let’s try it out

1. Open the project

2. Compile and download

3. Press the reset button on discovery once download has finished

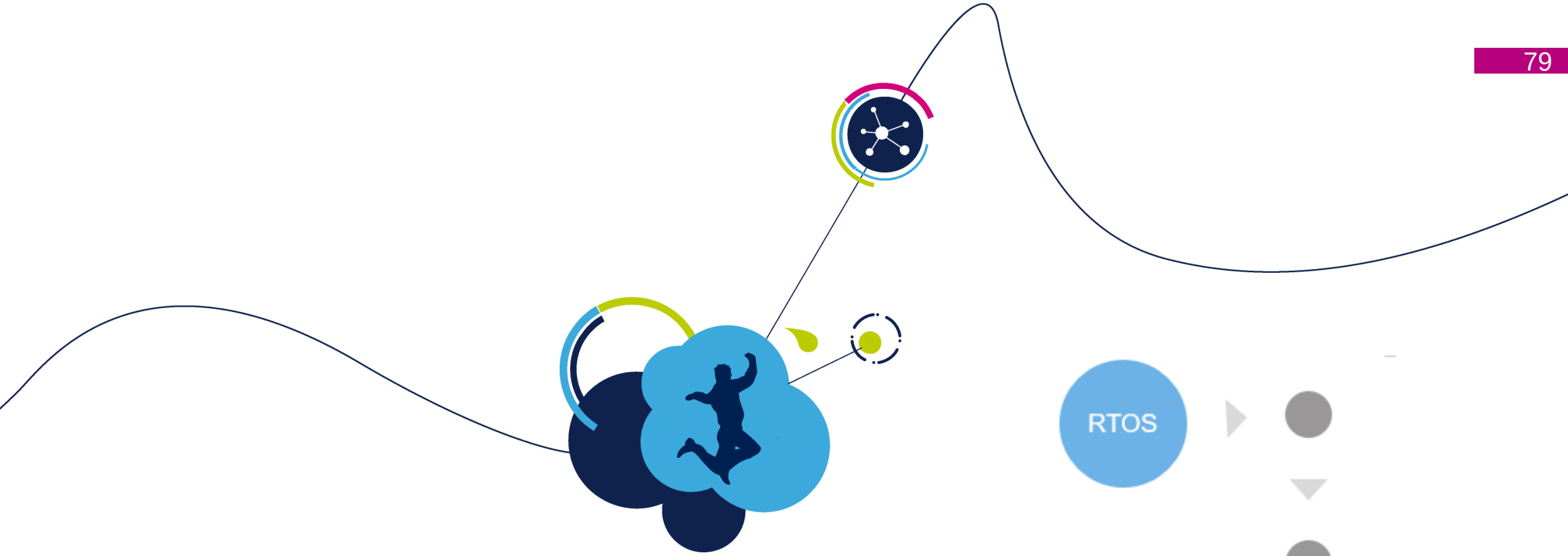
2

Checkpoint #5

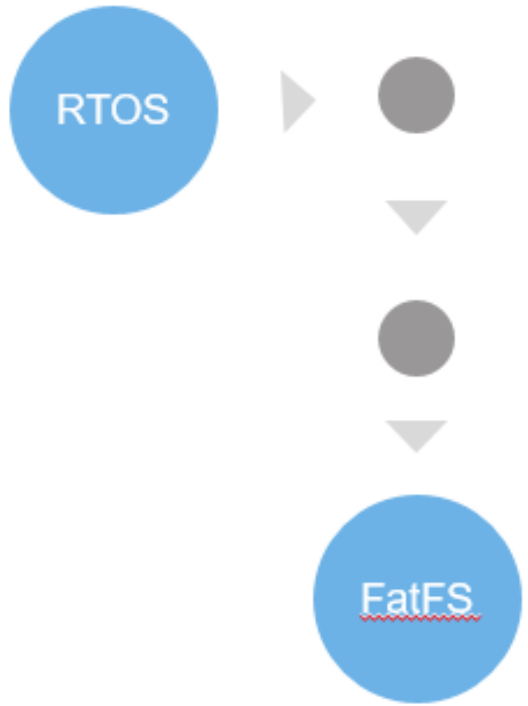
- appTask – GREEN LED blinking
- usbTask – USB connected → RED LED ON
- usbTask – USB connected → RED LED OFF

life.augmented

STM32 Cube

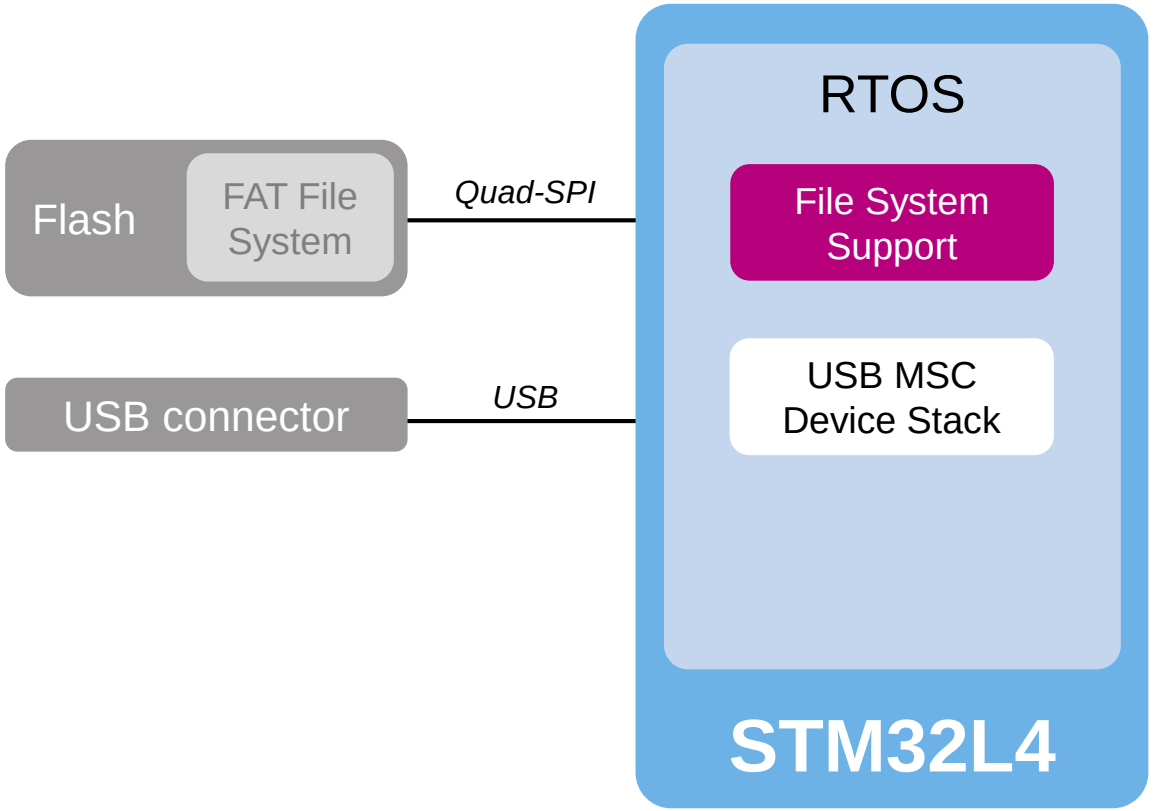


STEP3 – File System



3 Adding File System support

- We want to have the access to our “audio.wav” file from RTOS



3 File System Support Basics

PC application in C language	MCU application in C language

C standard libraries (stdio.h)

- fopen(…) – opens a file
- fclose(…) – closes a file
- fread(…) – reads from a file
- fwrite(…) – writes to a file
- fprintf(…) – formatted output to a file
- fscanf(…) – formatted input from a file

C standard libraries (stdio.h)

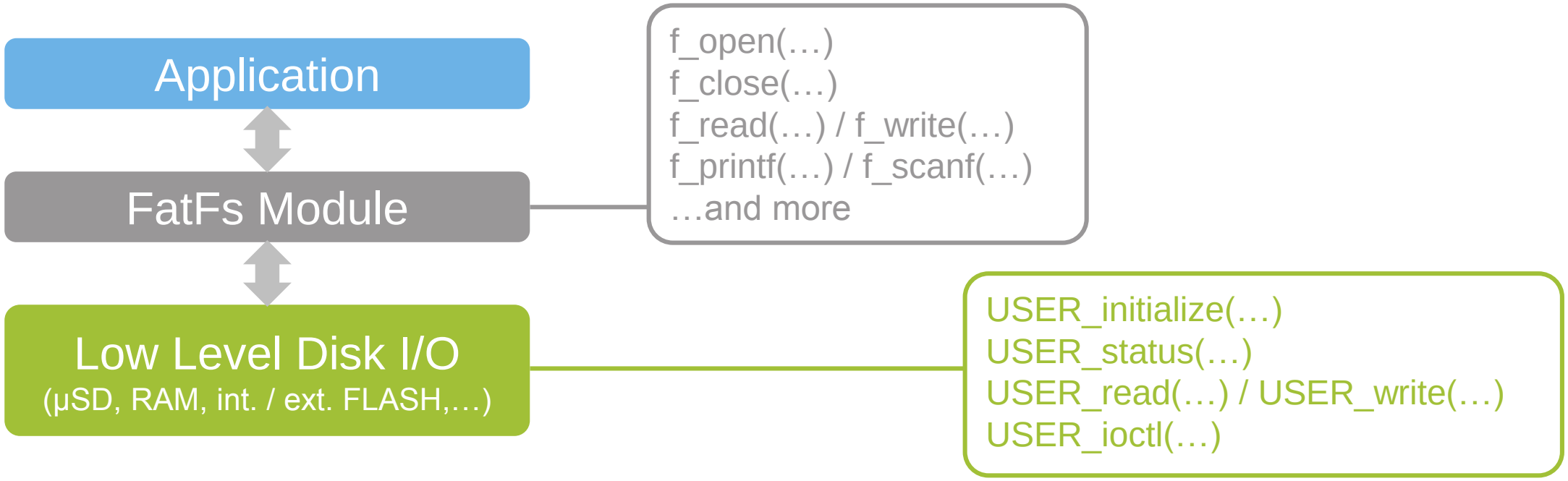
- ~~fopen(…) – opens a file~~
- ~~fclose(…) – closes a file~~
- ~~fread(…) – reads from a file~~
- ~~fwrite(…) – writes to a file~~
- ~~fprintf(…) – formatted output to a file~~
- ~~fscanf(…) – formatted input from a file~~

No OS + No standard File System = No native support by C standard IO library

Let's add "special" library to support that

FatFs Module Basics

- Windows compatible FAT file system support



UM1721 – Developing Applications on STM32Cube with FatFs
http://www.st.com/st-web-ui/static/active/en/resource/technical/document/user_manual/DM00105259.pdf

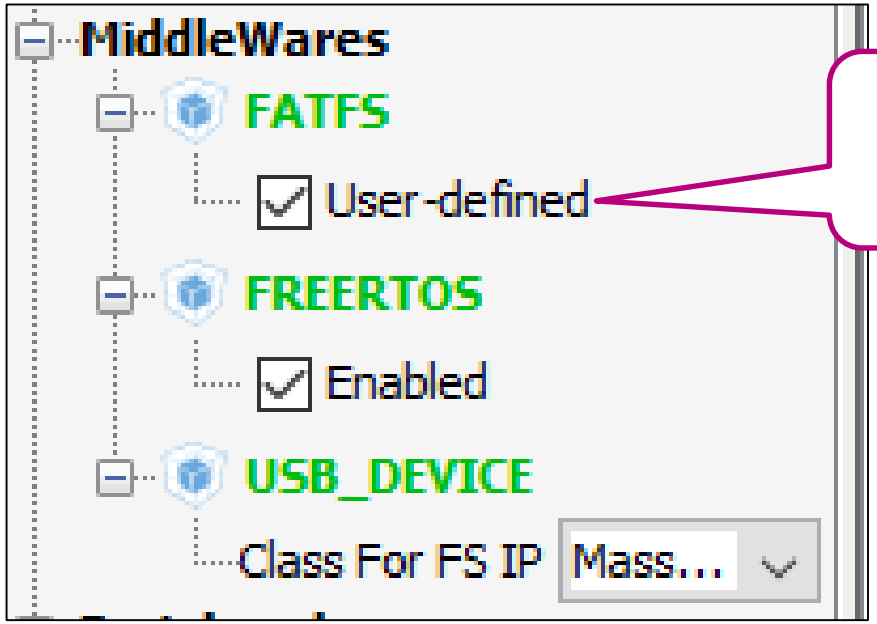
FatFs project home page
http://elm-chan.org/fsw/ff/00index_e.html

life.augmented

STM32 Cube

3 FatFs Configuration

Go to Configuration

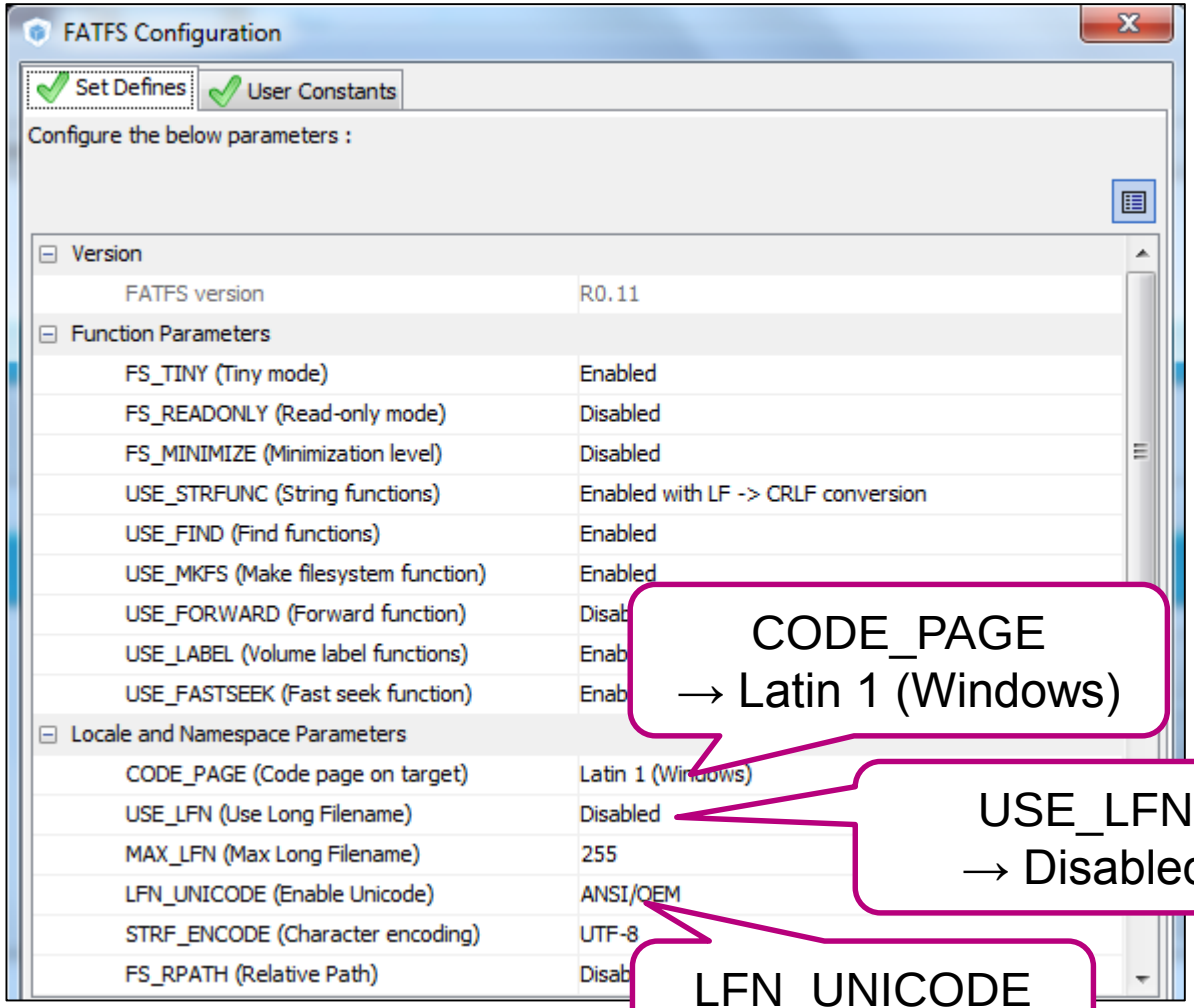


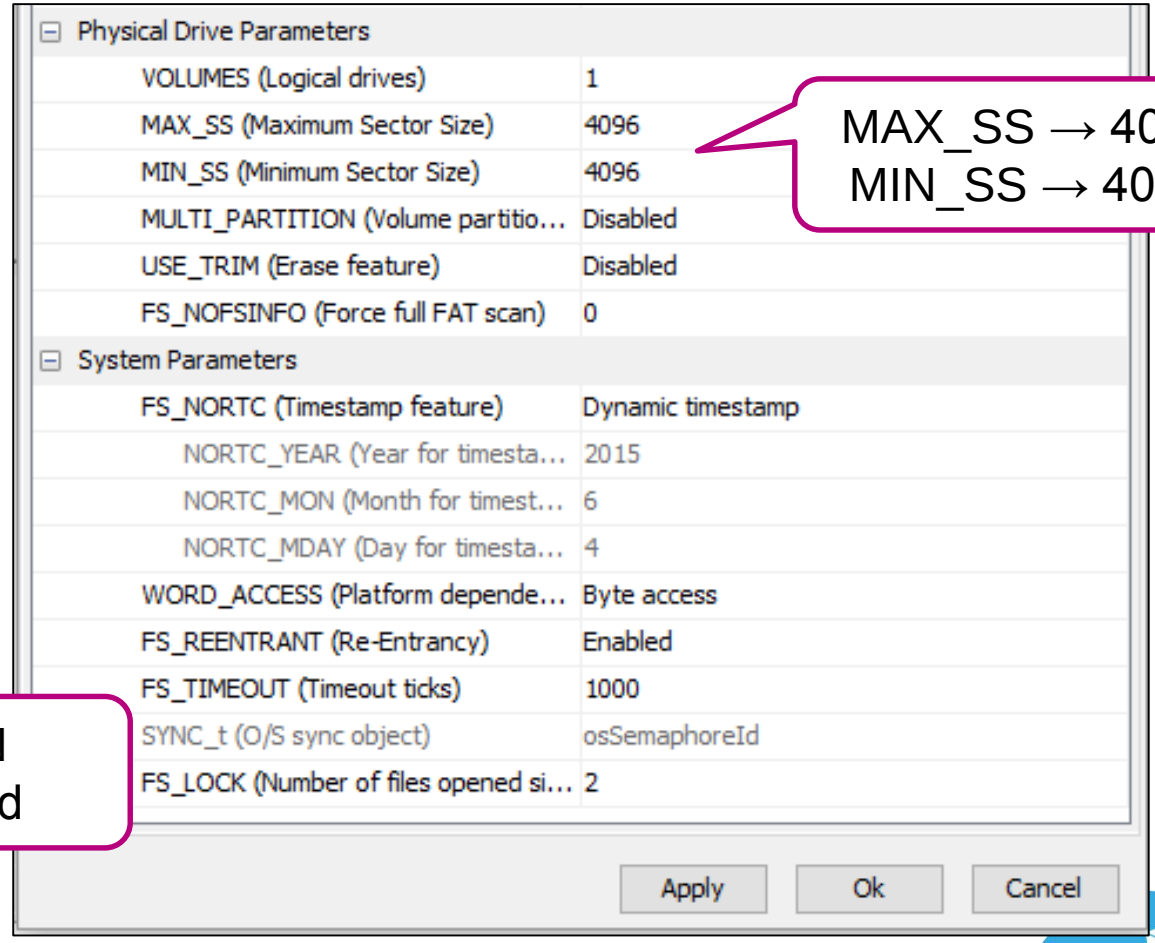
Enable User-defined FatFs

3 FatFs Configuration

FATFS in Middlewares

FatFs Configuration





MAX_SS → 4096
MIN_SS → 4096

CODE_PAGE
→ Latin 1 (Windows)

USE_LFN
→ Disabled

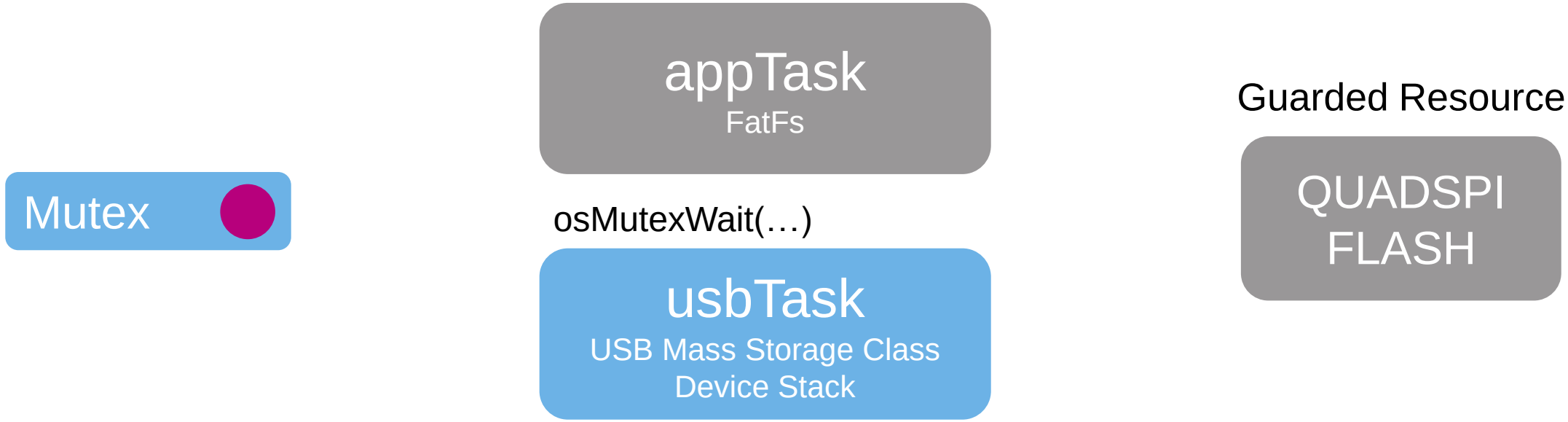
LFN_UNICODE
→ ANSI/OEM

life.augmented

STM32 Cube

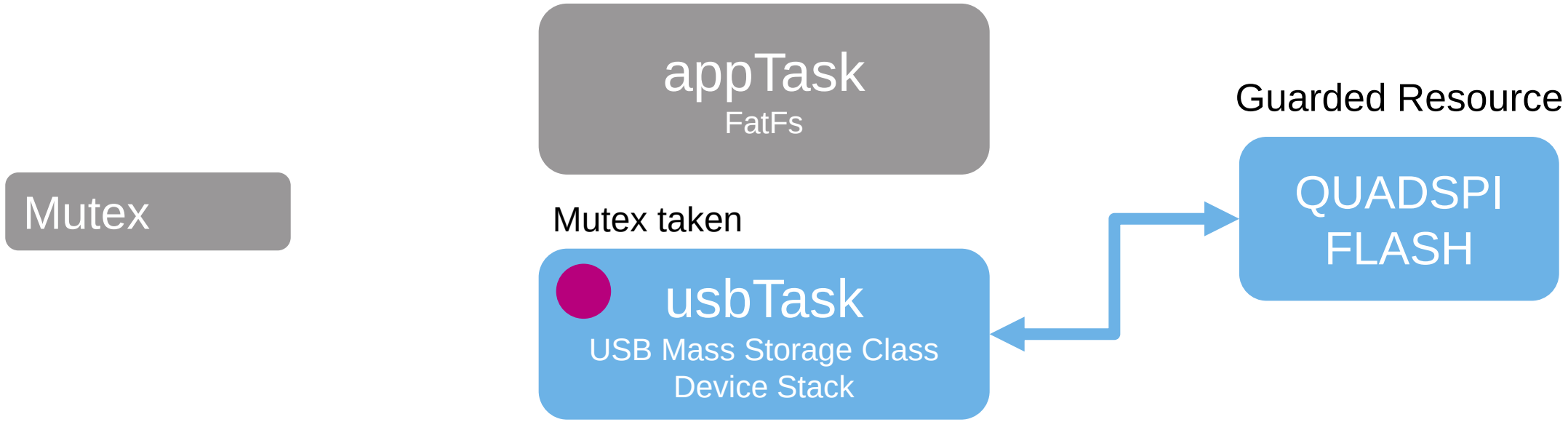
Mutex

- Mutex needed as we can’t have concurrent access to the QSPI FLASH



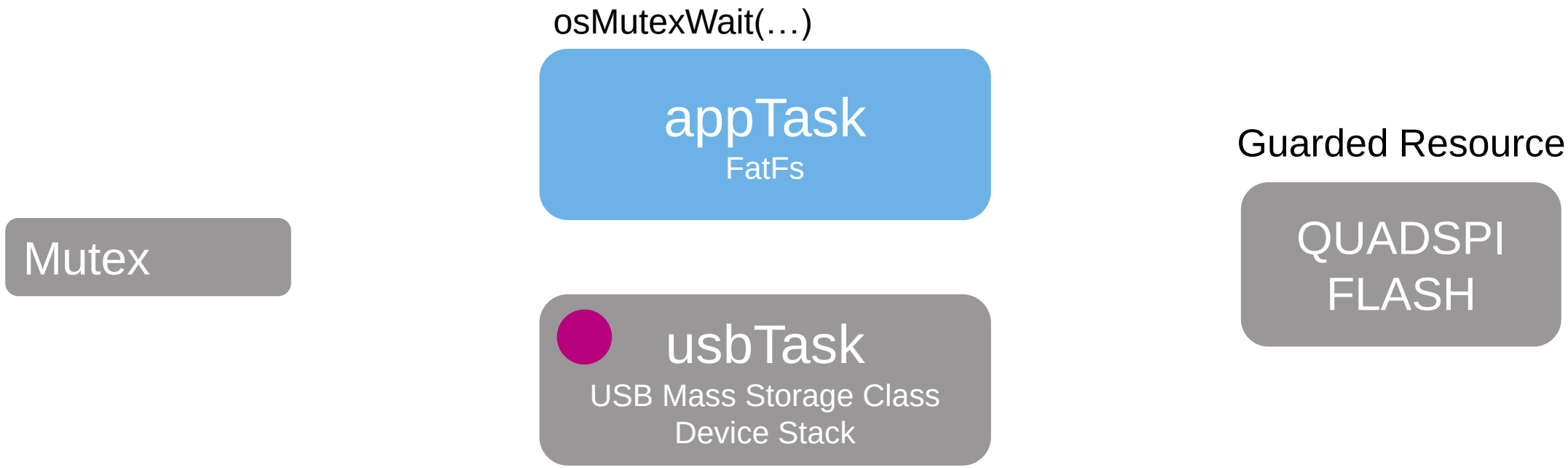
Mutex

- Mutex needed as we can’t have concurrent access to the QSPI FLASH



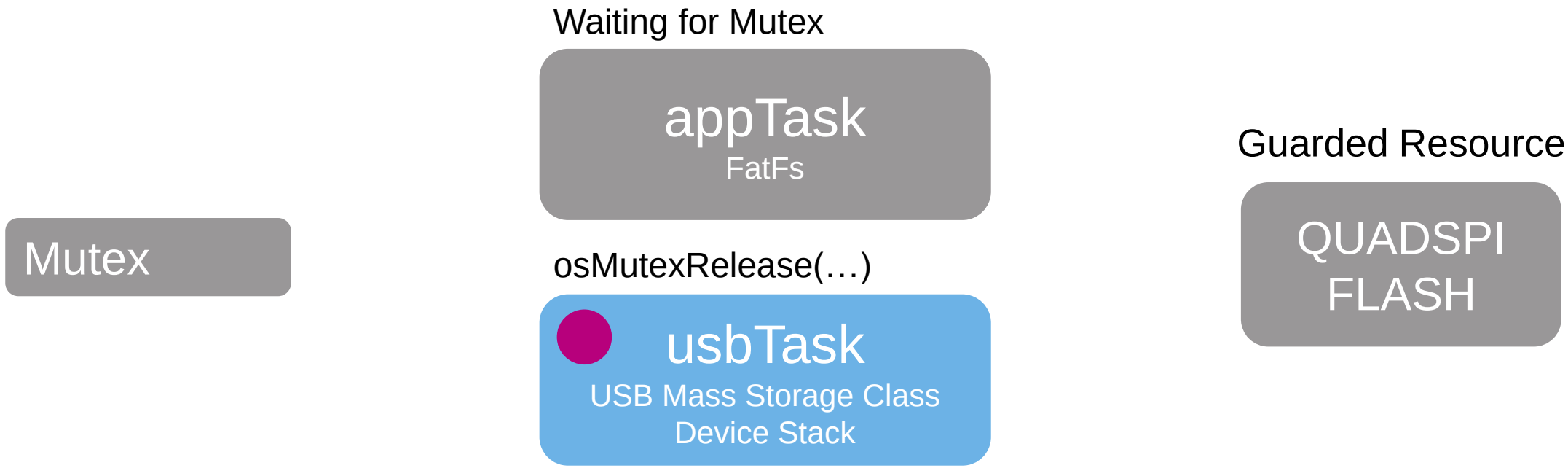
Mutex

- Mutex needed as we can’t have concurrent access to the QSPI FLASH



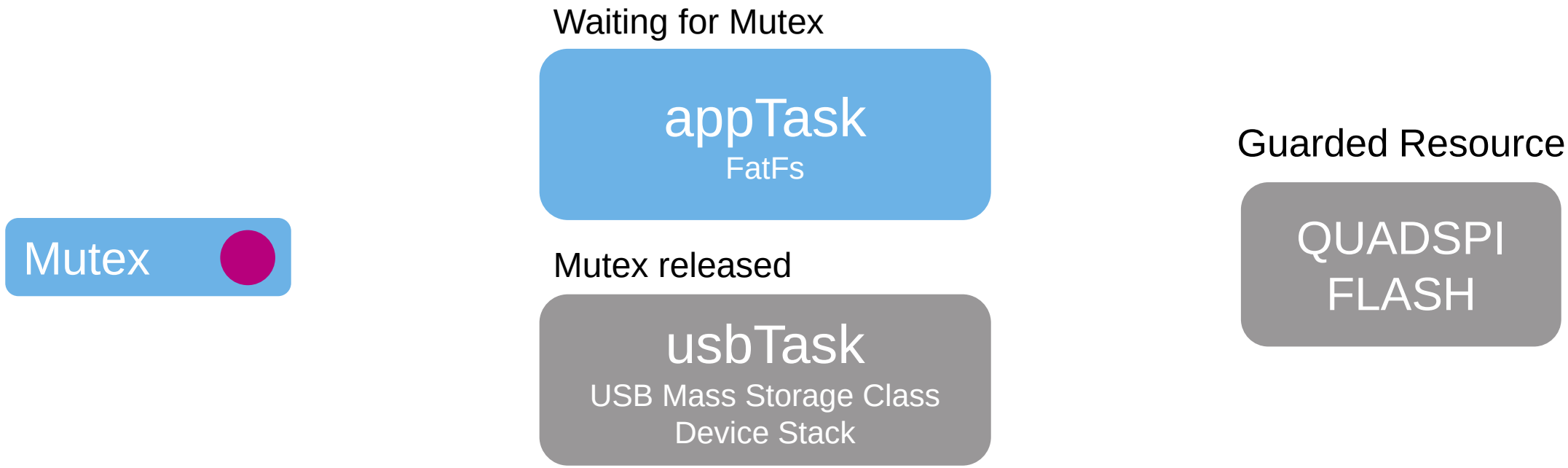
Mutex

- Mutex needed as we can’t have concurrent access to the QSPI FLASH



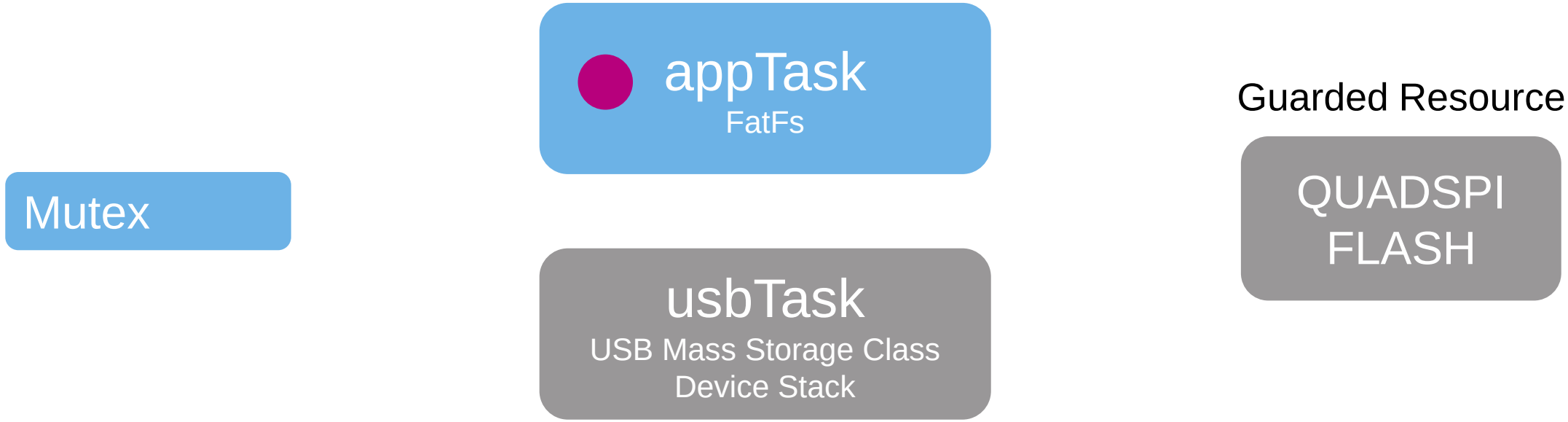
Mutex

- Mutex needed as we can’t have concurrent access to the QSPI FLASH



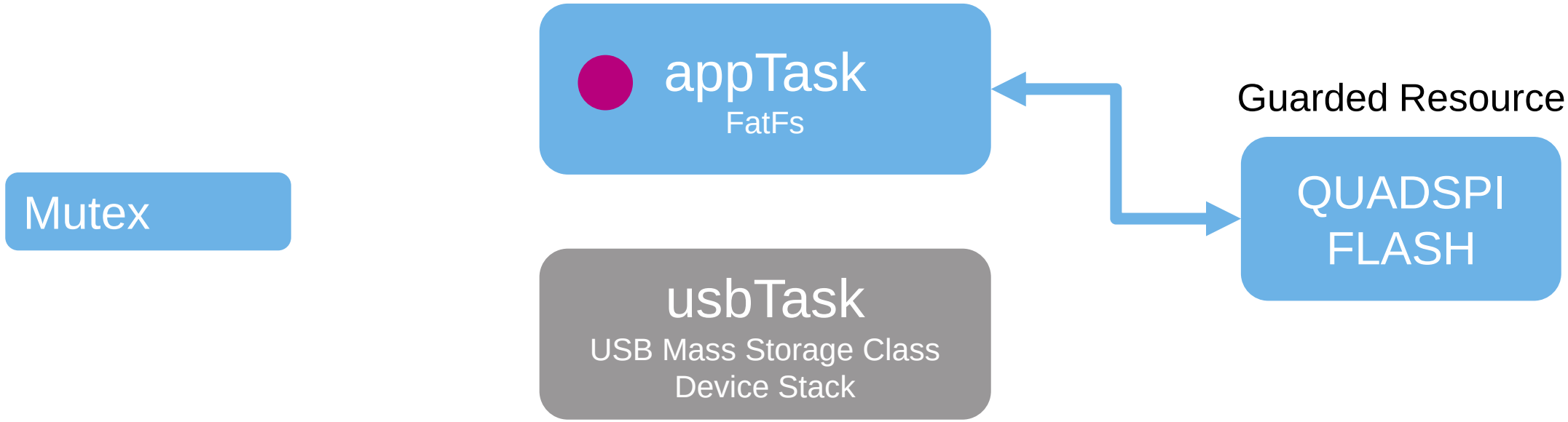
Mutex

- Mutex needed as we can’t have concurrent access to the QSPI FLASH



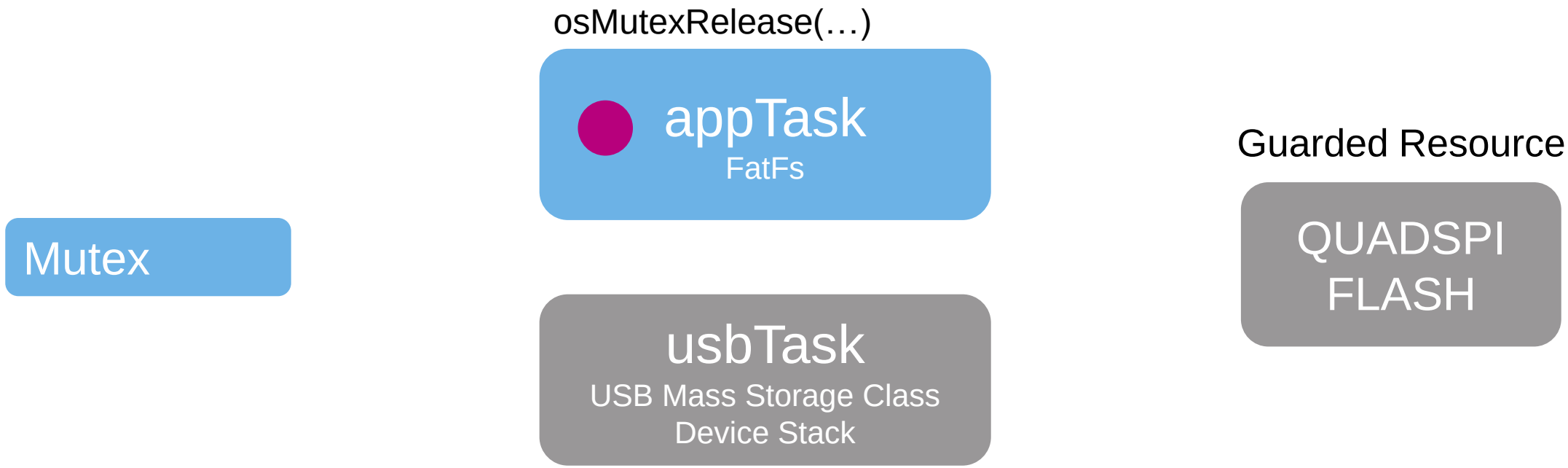
Mutex

- Mutex needed as we can’t have concurrent access to the QSPI FLASH



Mutex

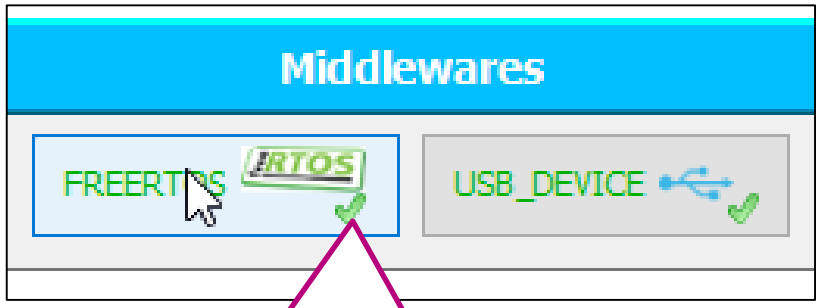
- Mutex needed as we can’t have concurrent access to the QSPI FLASH

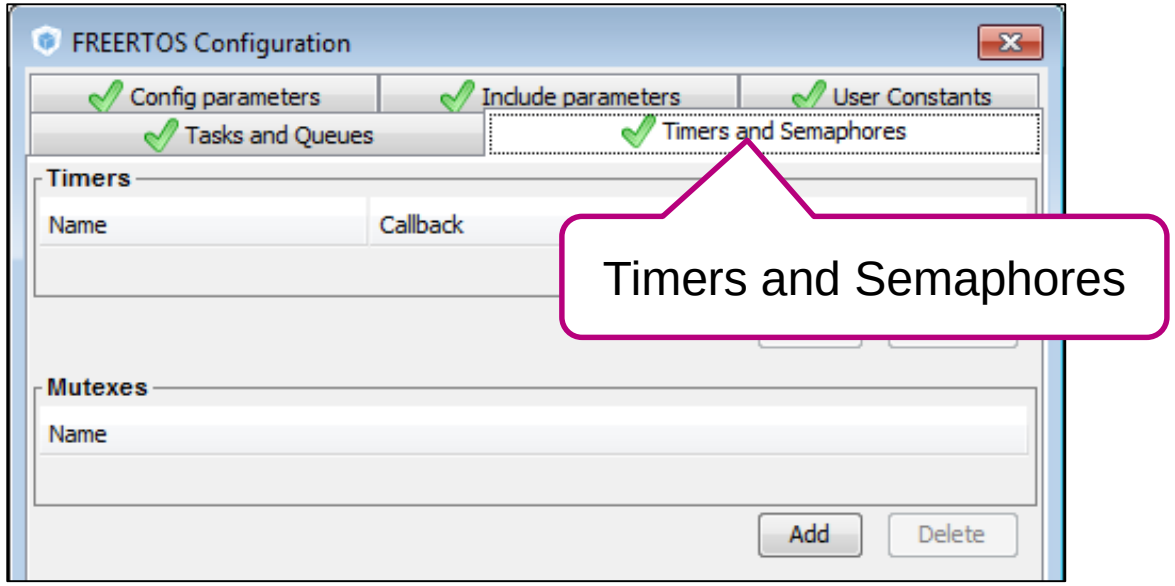


Mutex

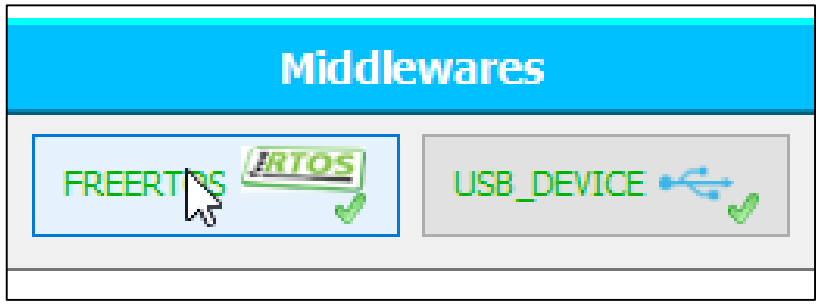
- Mutex needed as we can’t have concurrent access to the QSPI FLASH

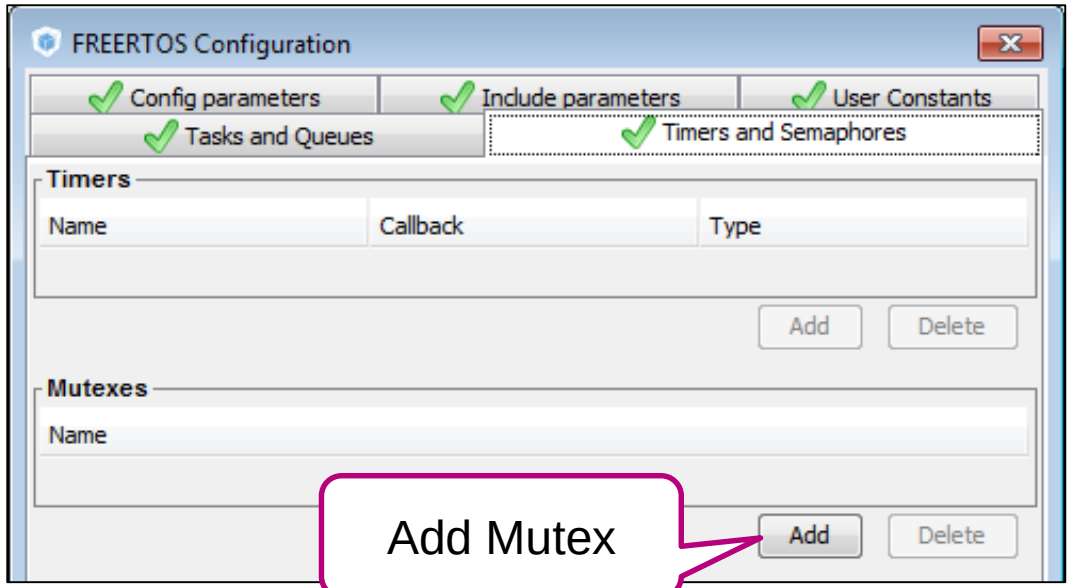
3 FreeRTOS Configuration Change





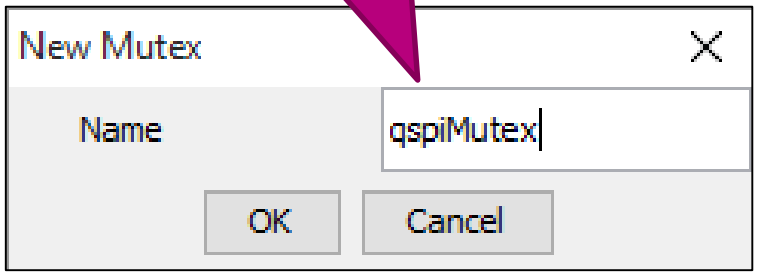
3 FreeRTOS Configuration Change





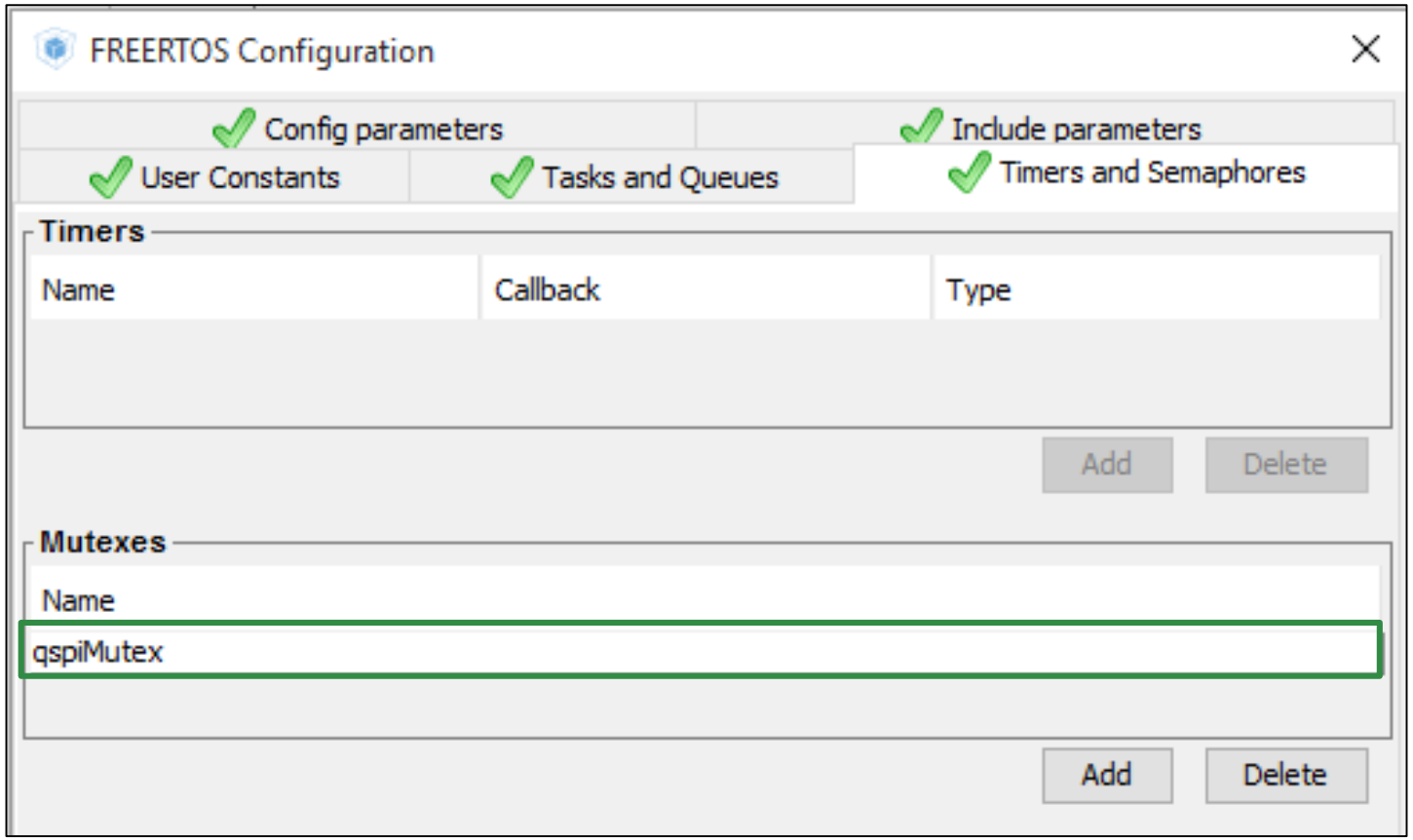
Add Mutex

Name → qspiMutex



Checkpoint #6

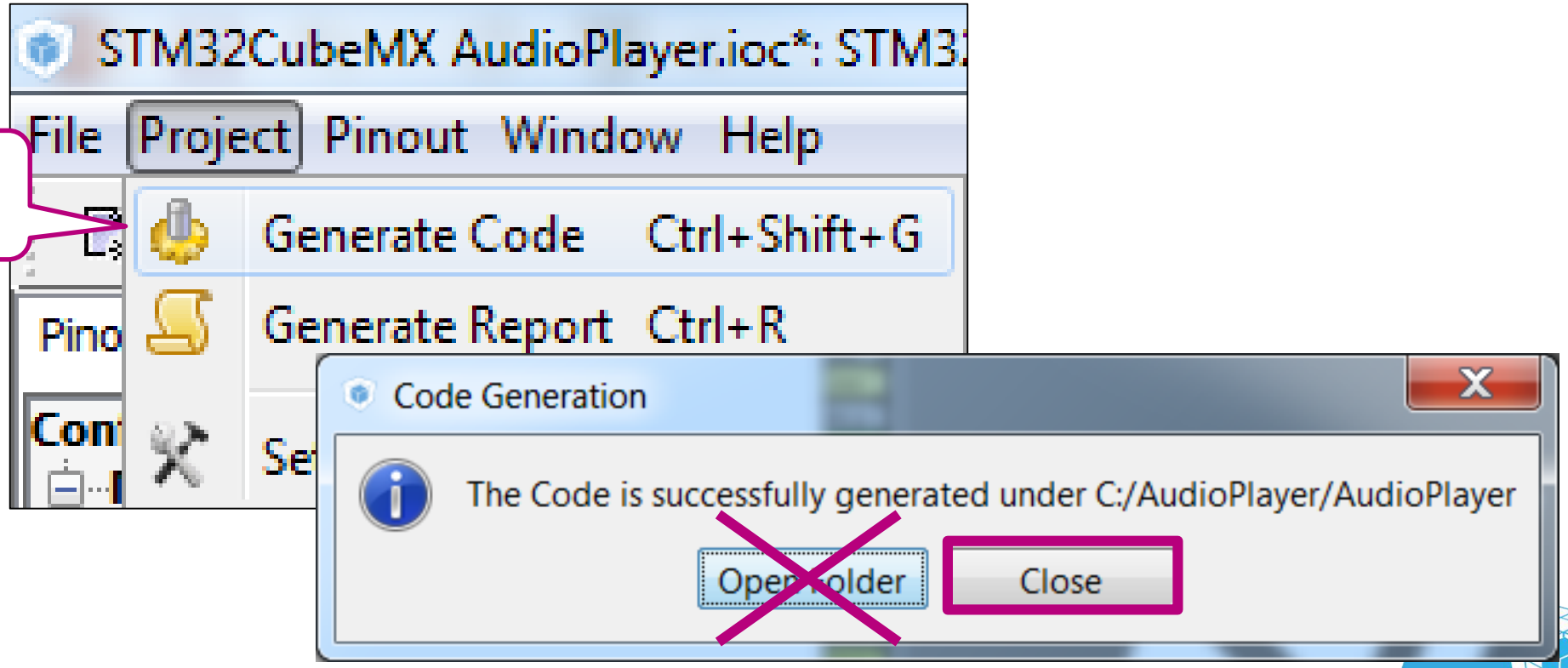
RTOS



3 Save and generate the project

Do not open the project yet

Generate Code
(Ctrl+Shift+G)



3 Apply small patch

- Apply patch from folder
  C:\STM32L4_Workshop\HandsOn\2_Putting_All_Together\Patch\STEP3_FileSystem
  to root folder of your project
  (C:\AudioPlayer\AudioPlayer\)

- It contains the following files:
  .\Src\
    freertos.c
    user_diskio.c

This operation is STM32CubeMX non-intrusive. You can re-generate the project later and the modifications will be retained.

- These files contains the main needed source code the user has to add to have the FatFS working together with QSPI FLASH storage

3 user_diskio.c added content

- user_diskio.c

USER_initialize (…)
USER_status (…)
} Storage initialization and Status info

USER_read (…)
USER_write (…)
} Read / Write operations

USER_ioctl (…)
} IO control

Based on BSP driver in STM32CubeL4 HAL

3 FatFS test flow

- f_mount(…) – mount the storage
  - f_mkfs(…) – create filesystem if not existing
- f_open(…) – open/create file with name FATFSOK
- f_printf(…) – write “FatFS is working properly.“ into FATFSOK file
- f_close(…) – close the file, no more needed

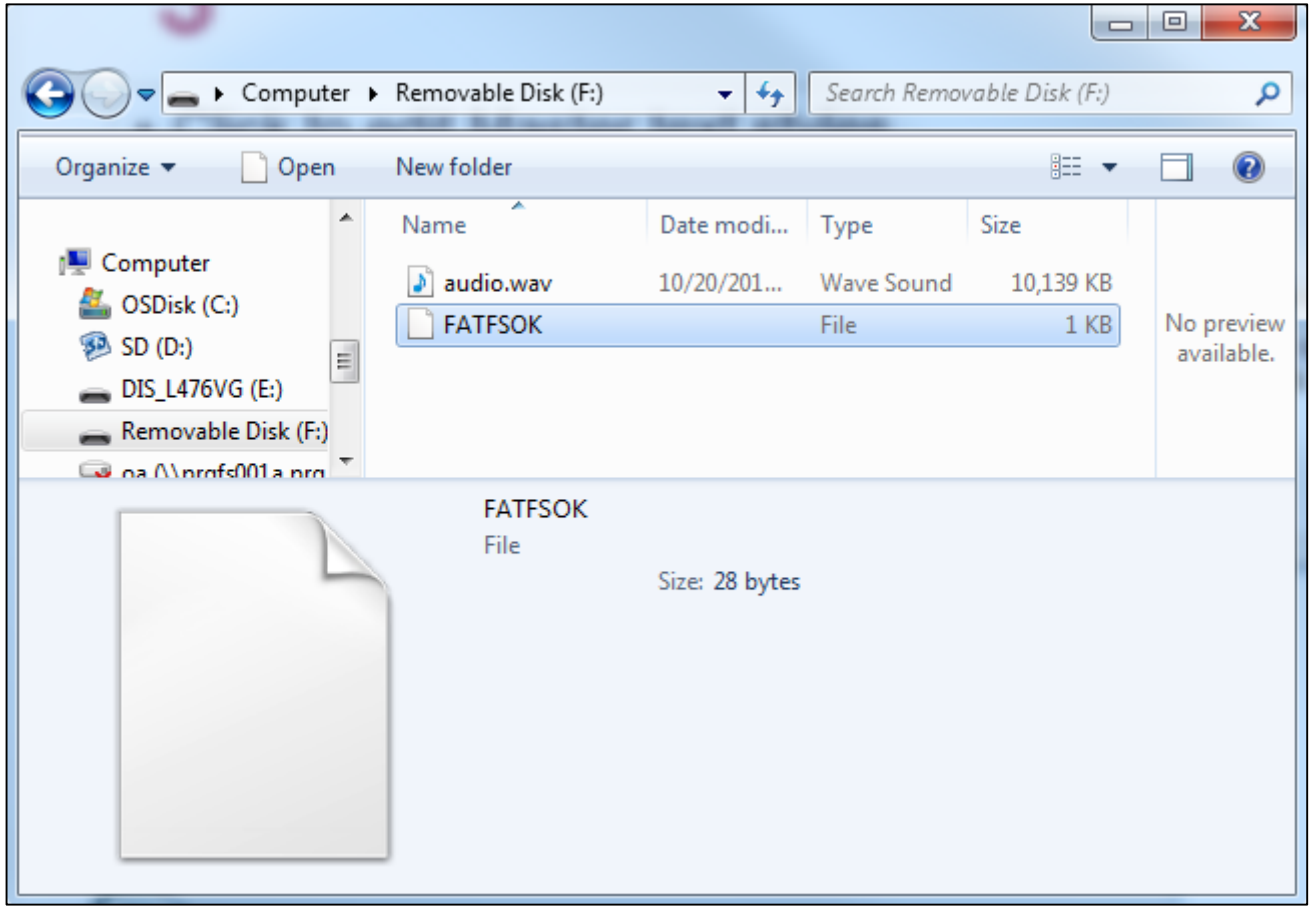
FATFSOK file in the root of the connected storage
Content should be (FatFS is working properly.)

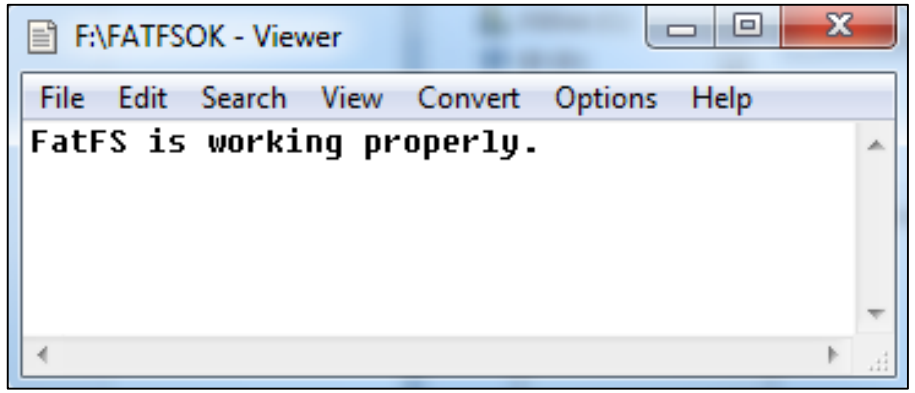
3

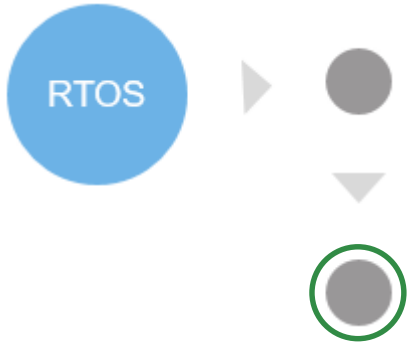
Let’s try it out

1. Open the project
2. Compile and download
3. Press the reset button on discovery once download has finished
4. Try to connect microUSB to PC

Checkpoint #7





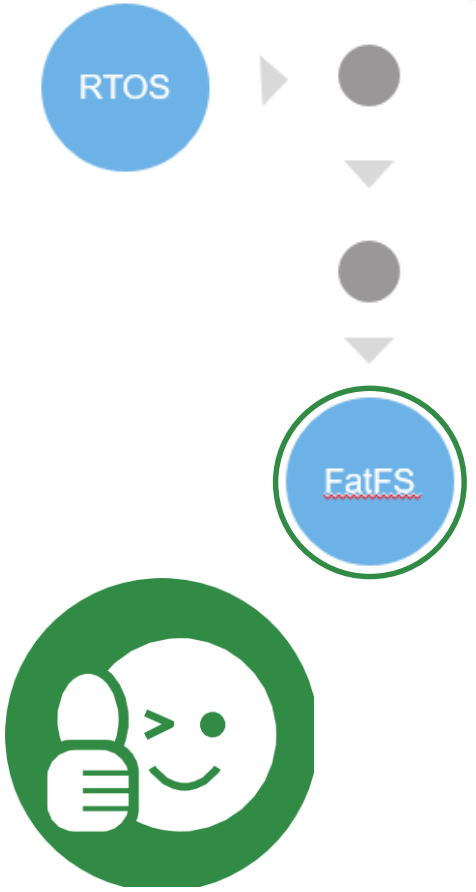


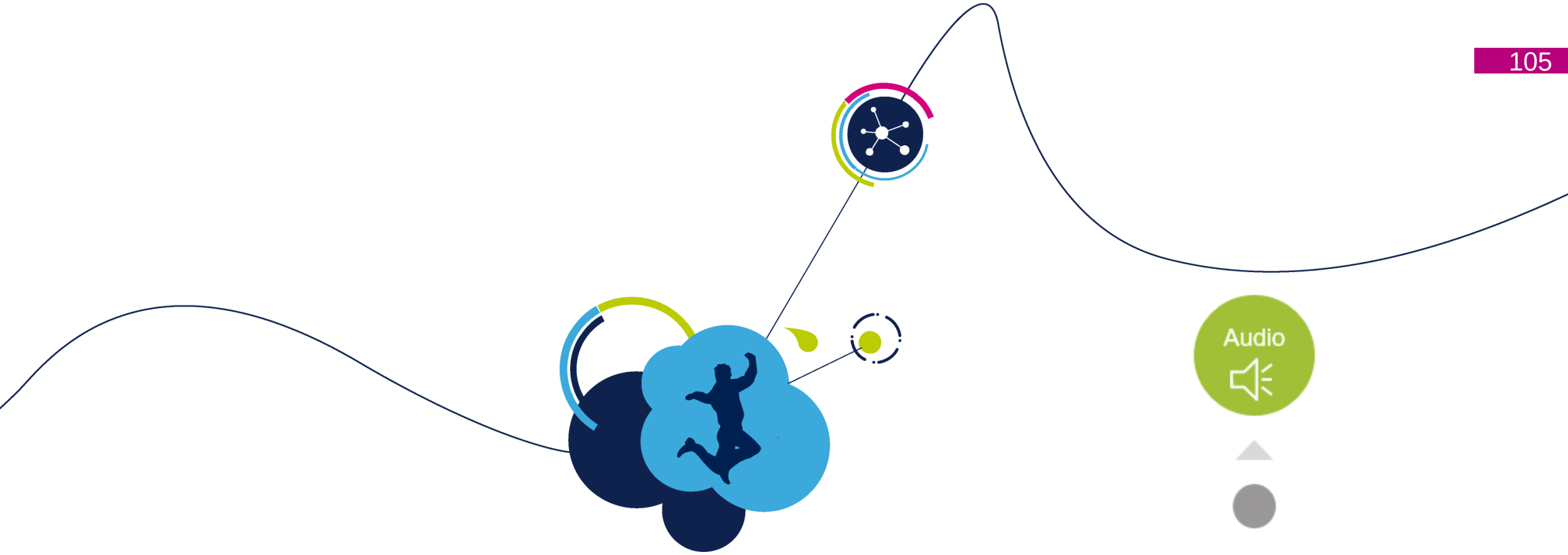
life.augmented

STM32 Cube

Checkpoint #8

- LED_GREEN ON before qspiMutex take in appTask
- LED_GREEN OFF after qspiMutex release in appTask
- LED_RED ON on qspiMutex take in usbTask
- LED_RED OFF on qspiMutex release in usbTask

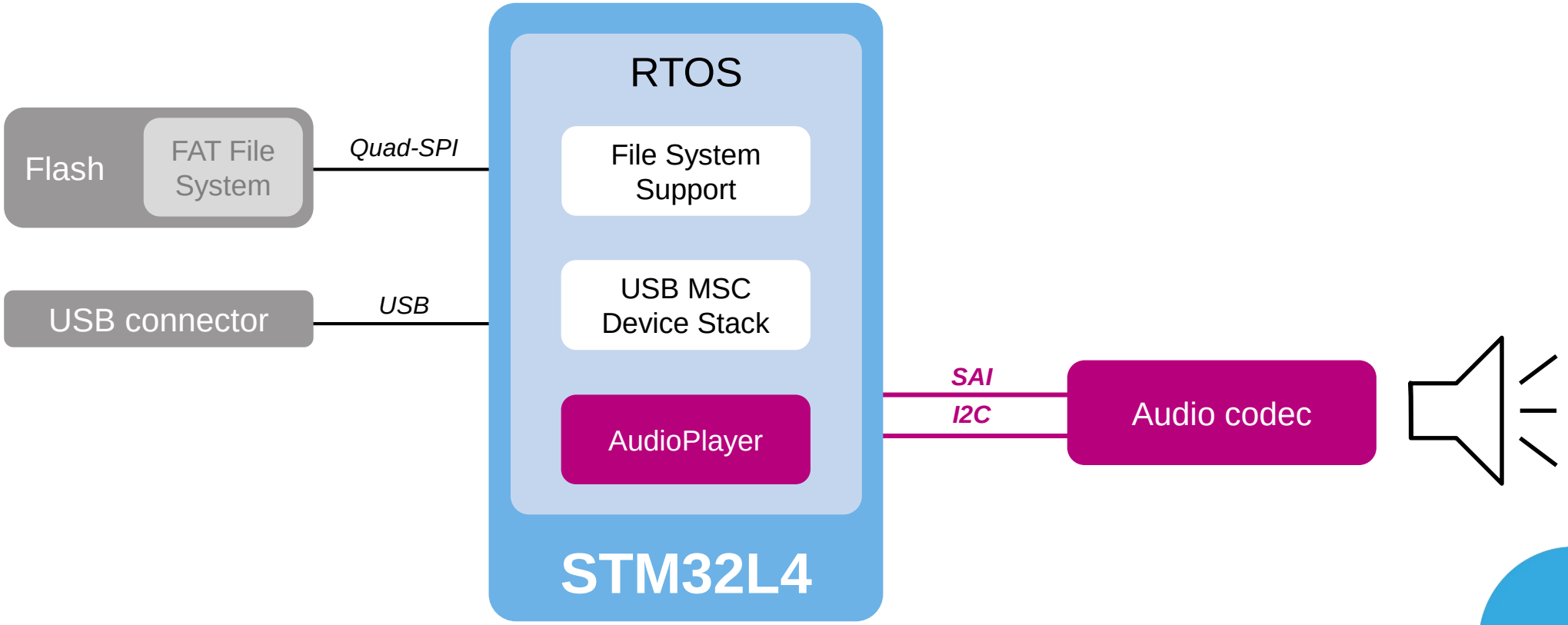


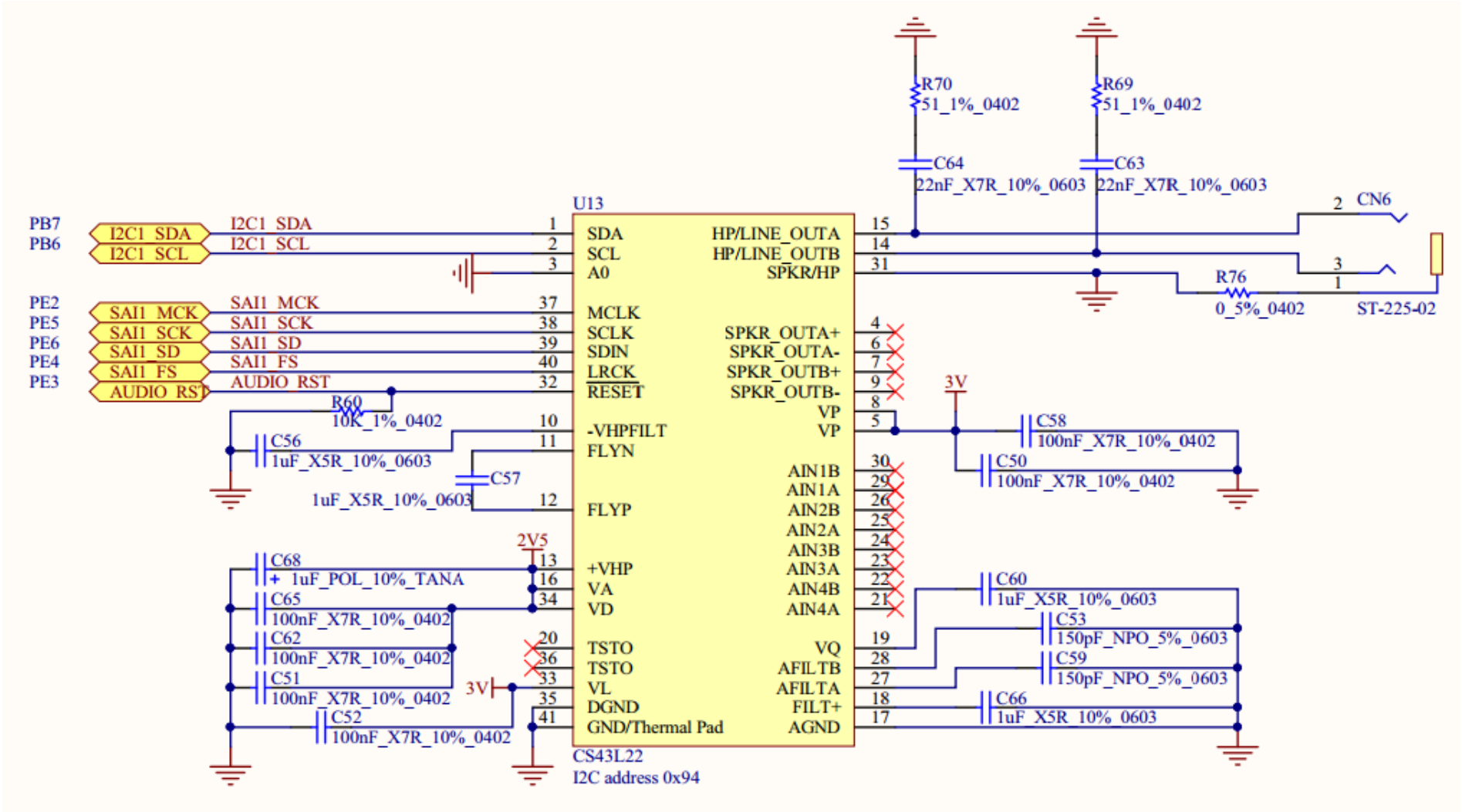


STEP4 – Audio

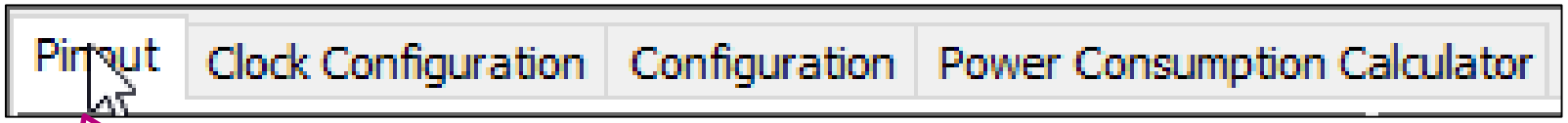
4 Adding “playback” functionality

- We want to hear our “audio.wav” file in headphones

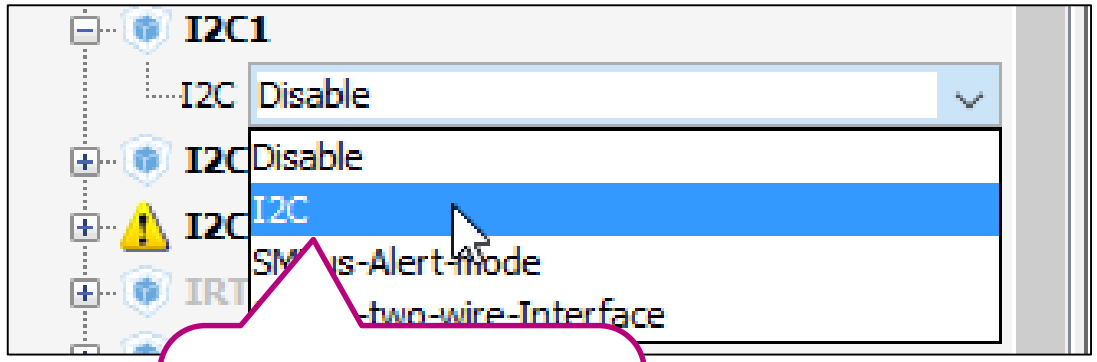



U13
CS43L22
I2C address 0x94
SDA
SCL
A0
MCLK
SCLK
SDIN
LRCK
RESET
-VHPFILT
FLYN
FLYP
+VHP
VA
VD
TSTO
TSTO
VL
DGND
GND/Thermal Pad
HP/LINE_OUTA
HP/LINE_OUTB
SPKR/HP
SPKR_OUTA+
SPKR_OUTA-
SPKR_OUTB+
SPKR_OUTB-
VP
VP
AIN1B
AIN1A
AIN2B
AIN2A
AIN3B
AIN3A
AIN4B
AIN4A
VQ
AFILTB
AFILTA
FILT+
AGND
PB7
PB6
I2C1_SDA
I2C1_SCL
PE2
PE5
PE6
PE4
PE3
SAI1_MCK
SAI1_SCK
SAI1_SD
SAI1_FS
AUDIO_RST
R70
51_1%_0402
R69
51_1%_0402
C64
22nF_X7R_10%_0603
C63
22nF_X7R_10%_0603
CN6
R76
0_5%_0402
ST-225-02
3V
C58
100nF_X7R_10%_0402
C50
100nF_X7R_10%_0402
R60
10K_1%_0402
C56
1uF_X5R_10%_0603
C57
1uF_X5R_10%_0603
2V5
C68
1uF_POL_10%_TANA
C65
100nF_X7R_10%_0402
C62
100nF_X7R_10%_0402
C51
100nF_X7R_10%_0402
C52
100nF_X7R_10%_0402
C60
1uF_X5R_10%_0603
C53
150pF_NPO_5%_0603
C59
150pF_NPO_5%_0603
C66
1uF_X5R_10%_0603

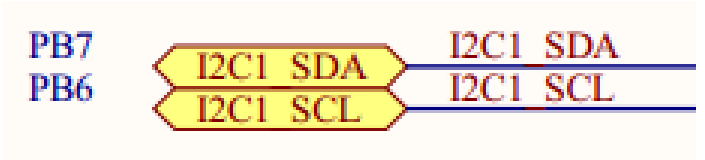
4 Audio Configuration



Go to Pinout



Under I2C1 peripheral select **I2C** interface



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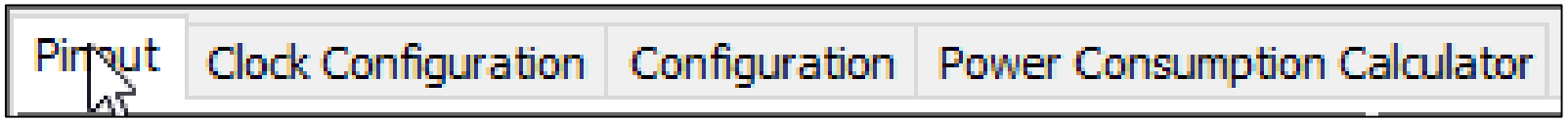
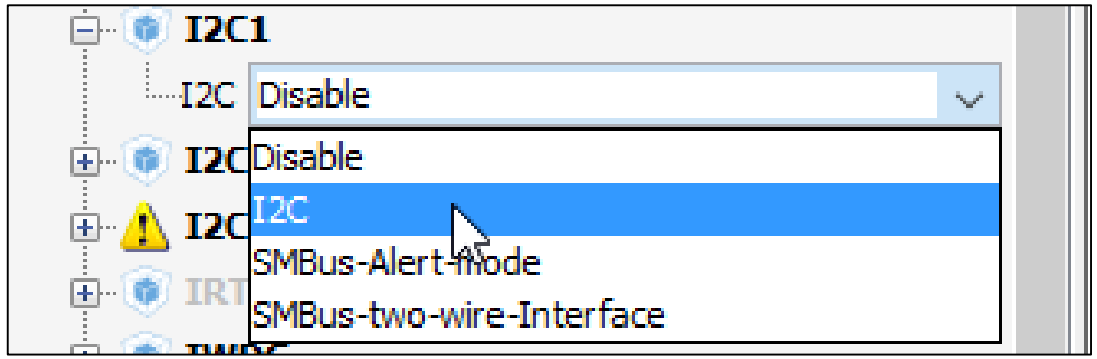
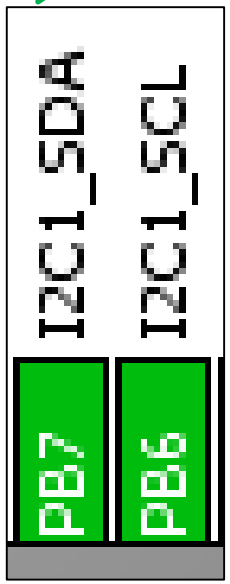
STM32 Cube

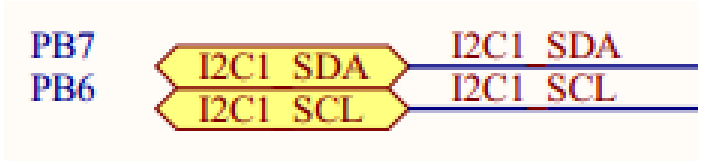
Audio Configuration





The corresponding pins are assigned and configured automatically!

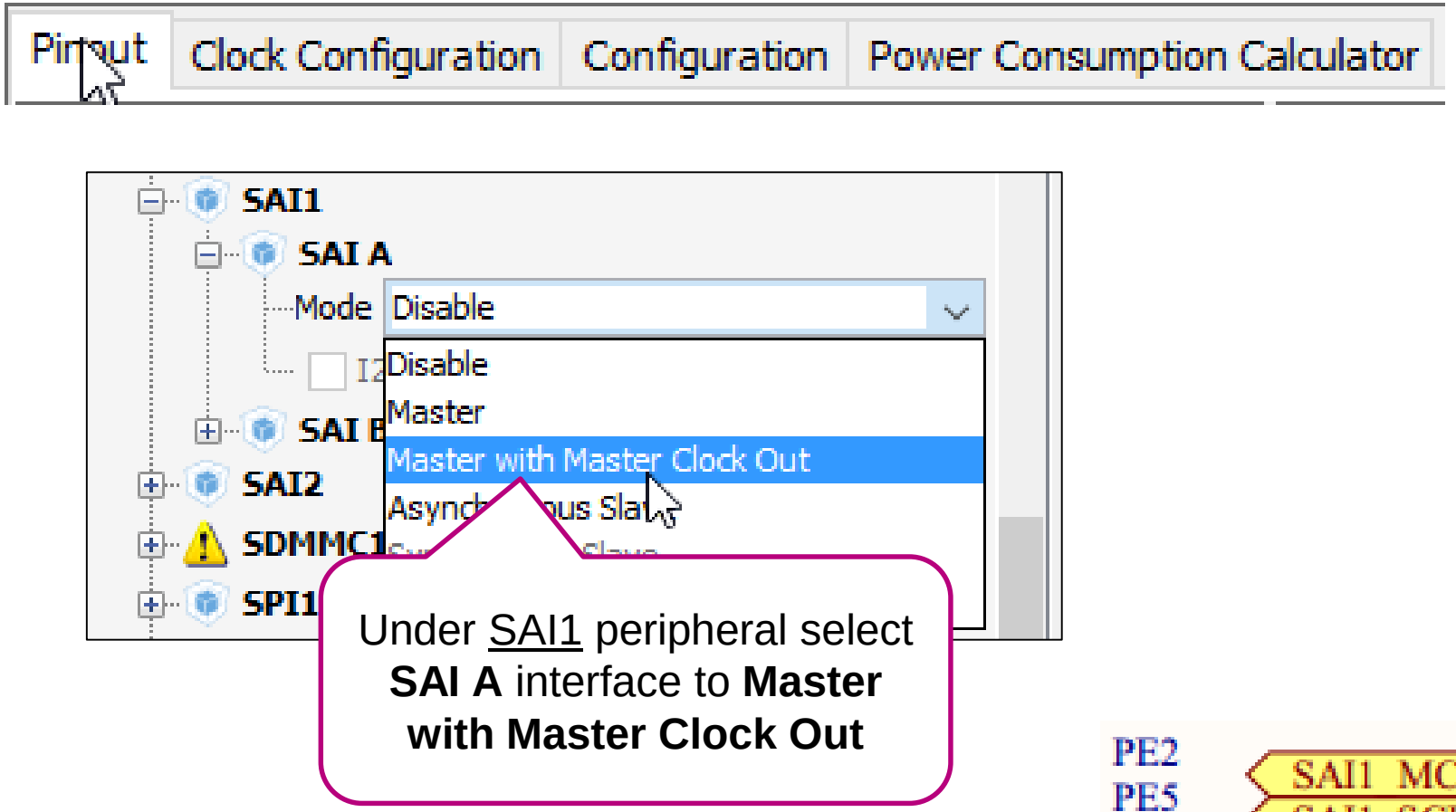


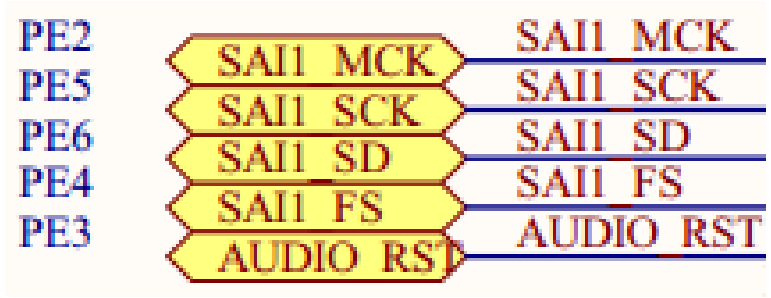


life.augmented

STM32 Cube

Audio Configuration

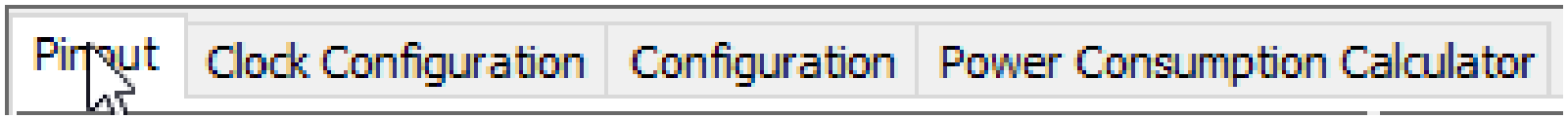


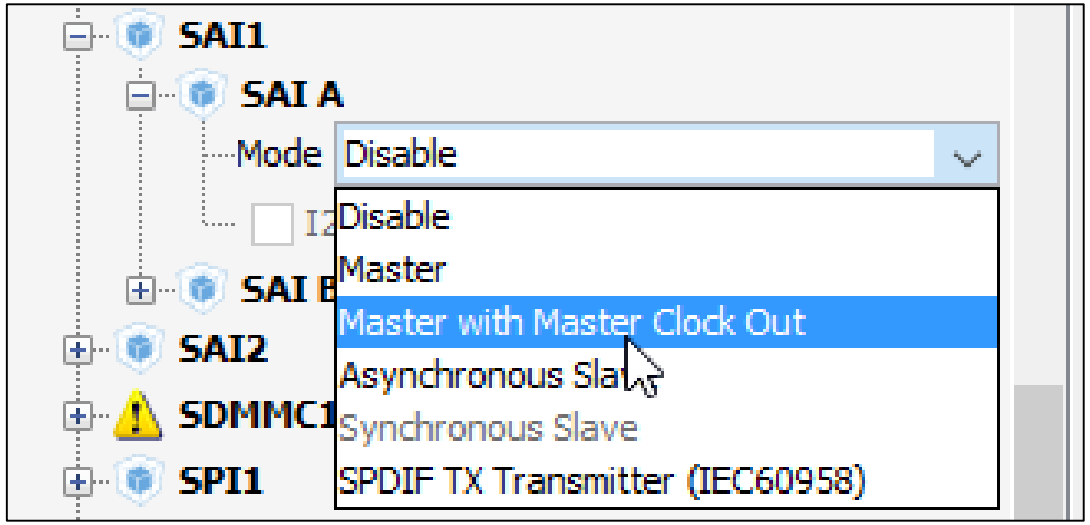


life.augmented

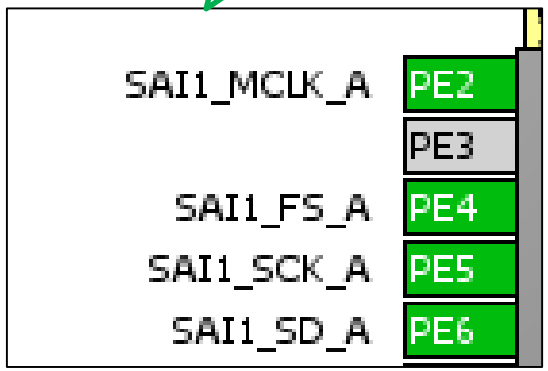
STM32 Cube

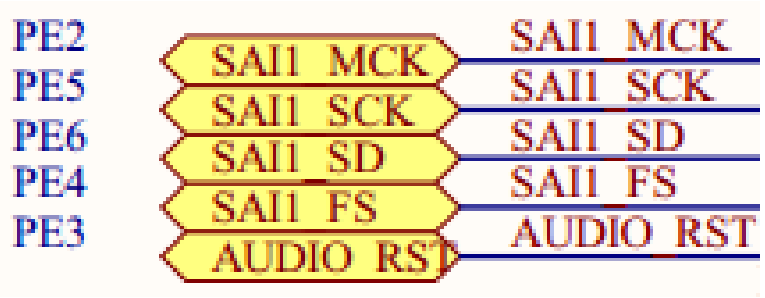
Audio Configuration





The corresponding pins are assigned and configured automatically!

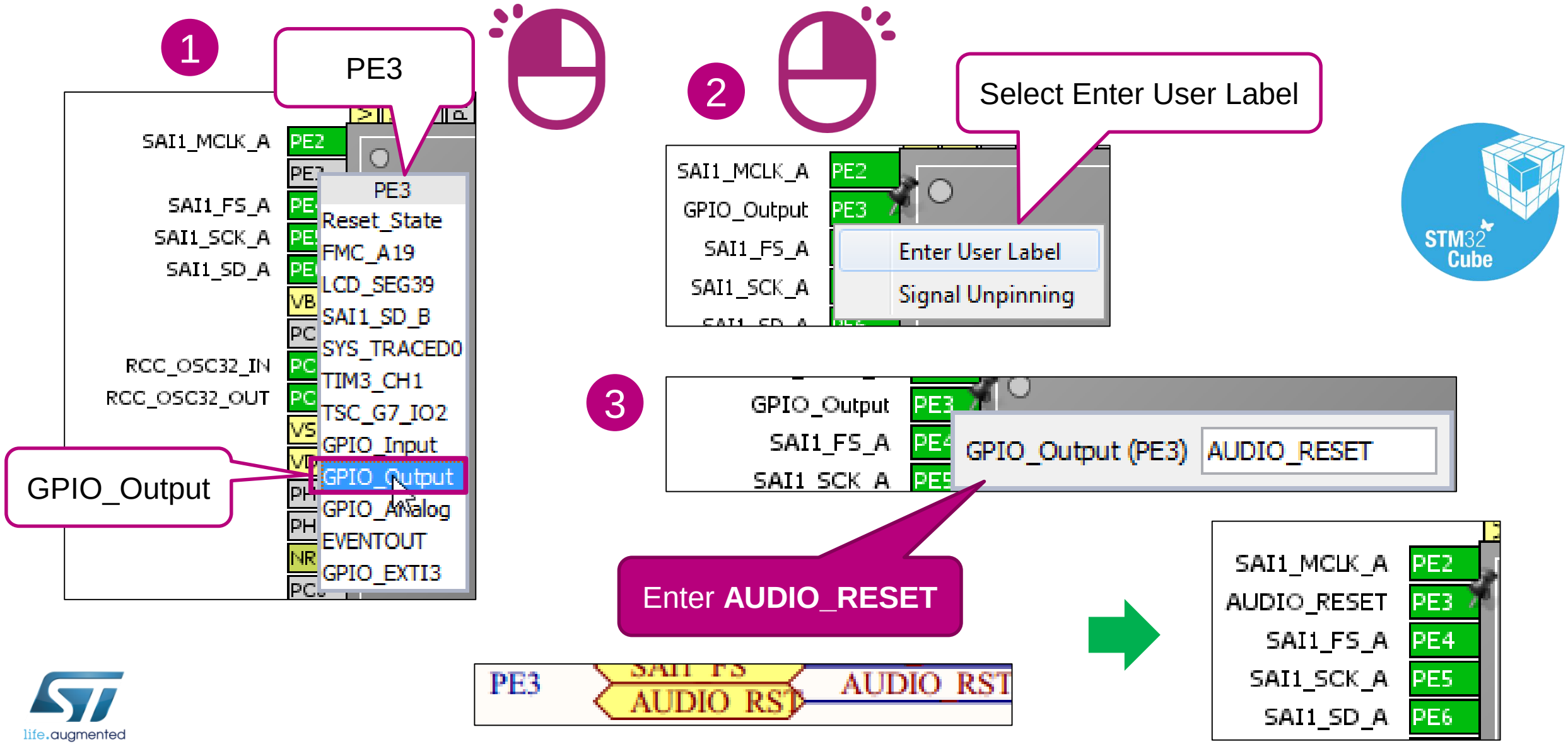




life.augmented

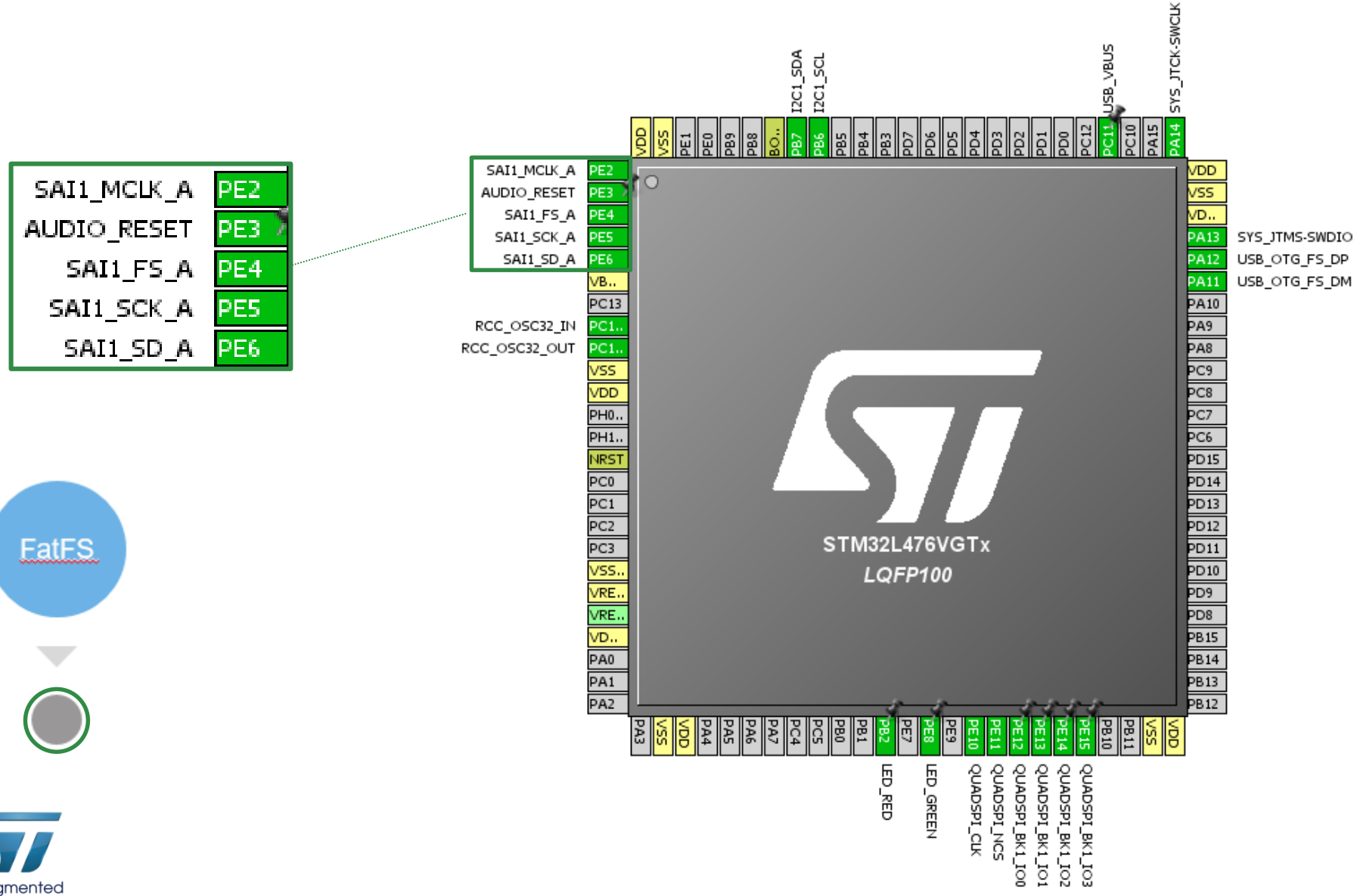
STM32 Cube

4 Audio Configuration



life.augmented

Checkpoint #9



life.augmented

STM32 Cube

Audio Configuration

SAI MCLK configuration

audio.wav	
WAVE Information	
Length	00:58
Compression	PCM
Bitrate (bps)	16
Frequency (Hz)	44 100
Mode	Stereo

CIRRUS LOGIC

CS43L22

4.6 Serial Port Clocking

The CS43L22 serial audio interface port operates either as a slave or master, determined by the M/$\overline{S}$ bit. It accepts externally generated clocks in Slave Mode and will generate synchronous clocks derived from an input master clock (MCLK) in Master Mode. Refer to the tables below for the required setting in register 05h and 06h associated with a given MCLK and sample rate.

Referenced Control	Register Location
M/$\overline{S}$	"Master/Slave Mode" on page 40
Register 05h	"Clocking Control (Address 05h)" on page 38
Register 06h	"Interface Control 1 (Address 06h)" on page 40

MCLK (MHz)	Sample Rate, Fs (kHz)	SPEED[1:0] (AUTO='0'b)	32kGROUP	VIDEOCLK	RATIO[1:0]	MCLKDIV2
12.2880	8.0000	11	1	0	00	0
	12.0000	11	0	0	00	0
	16.0000	10	1	0	00	0
	24.0000	10	0	0	00	0
	32.0000	01	1	0	00	0
	48.0000	01	0	0	00	0
	96.0000	00	0	0	00	0
11.2896	11.0250	11	0	0	00	0
	22.0500	10	0	0	00	0
	44.1000	01	0	0	00	0
	88.2000	00	0	0	00	0

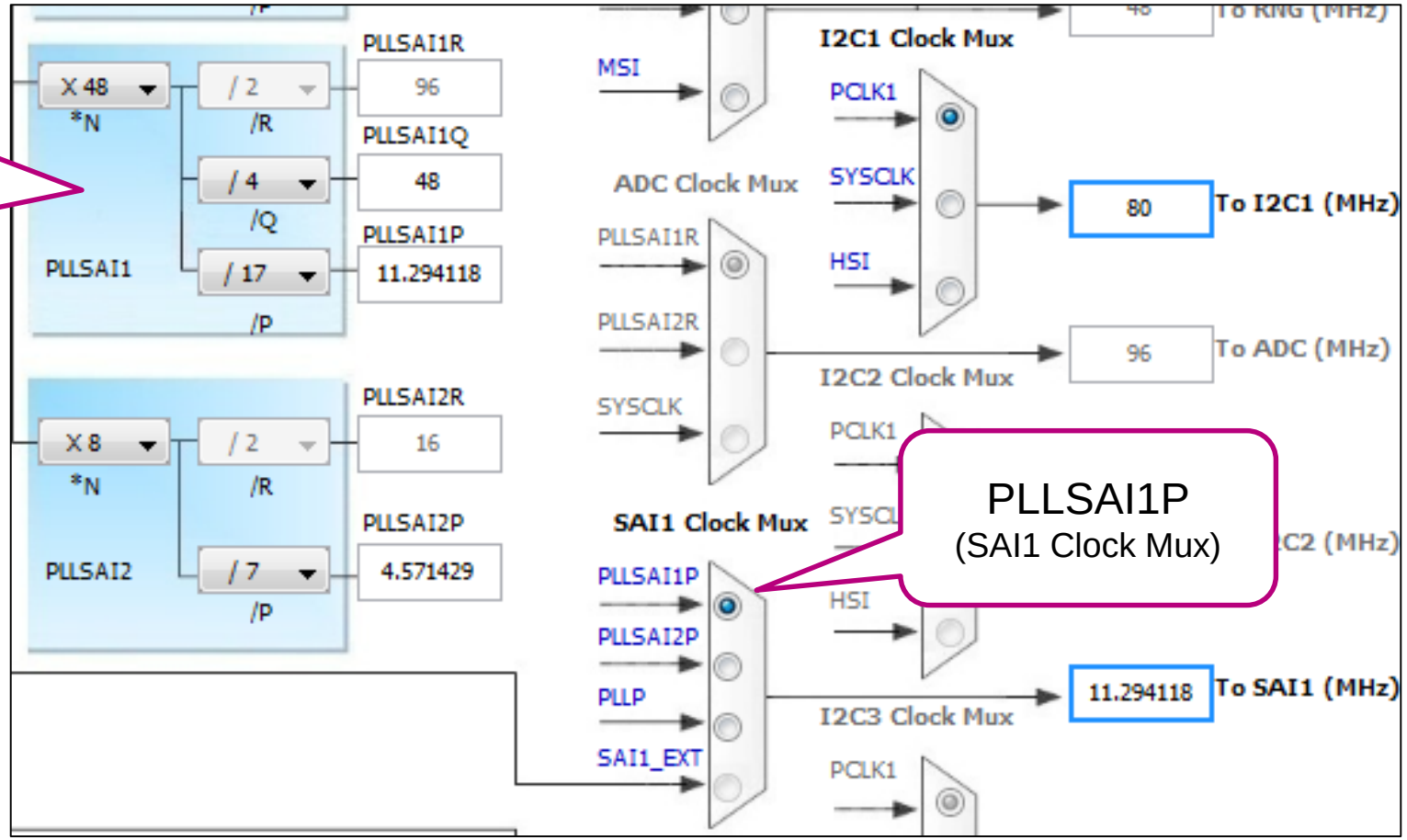
life.augmented

STM32 Cube

Audio Configuration

Pinout | Clock Configuration | Configuration | Power Consumption Calculator

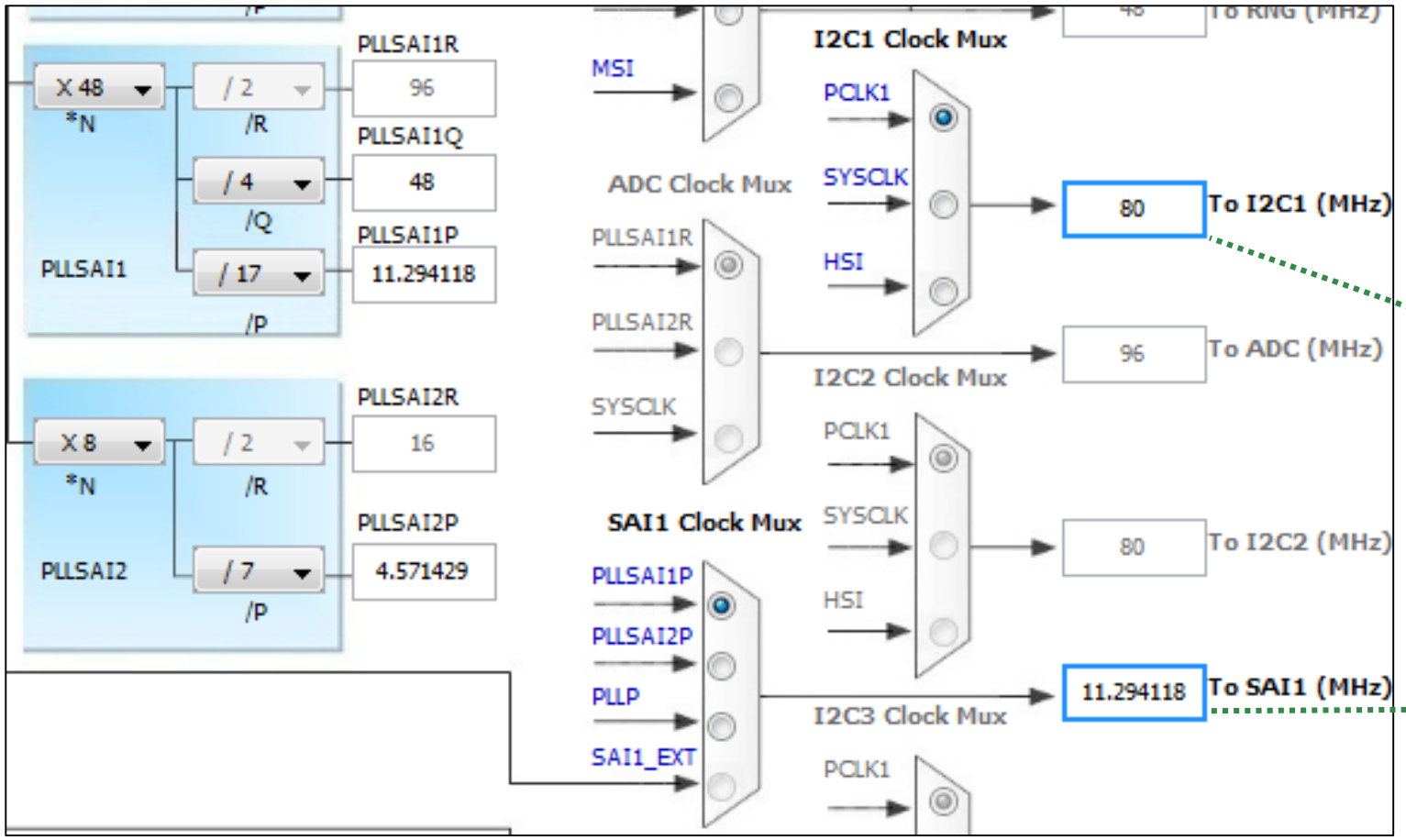
*N → x48
/Q → /4
/P → /17
(PLLSAI1)



PLLSAI1P
(SAI1 Clock Mux)

Checkpoint #10

FatFS

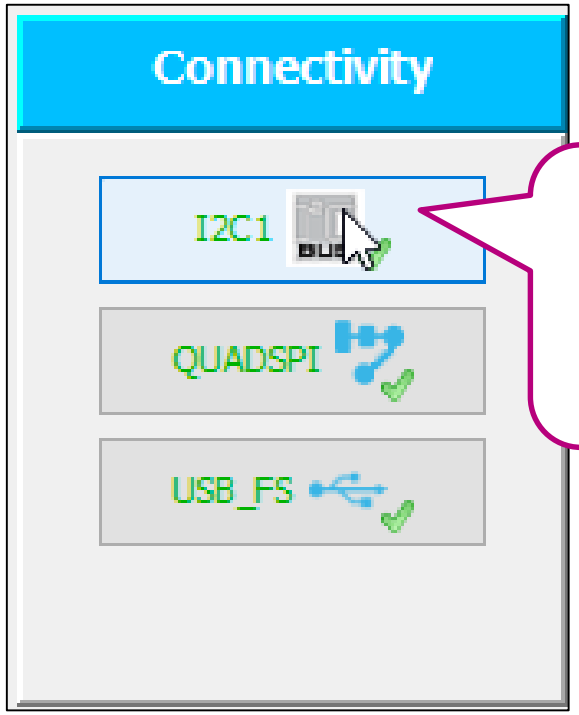


80MHz
(To I2C1)

11.294118
MHz
(To SAI1)

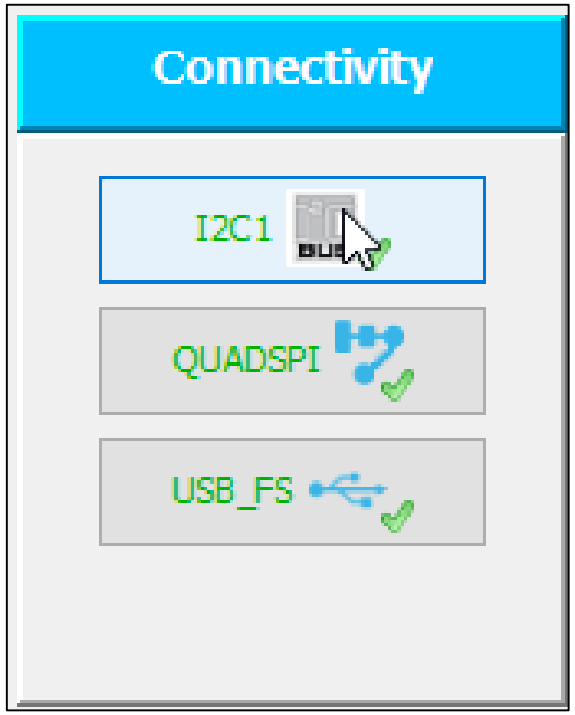
Audio Configuration

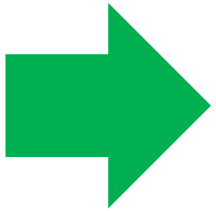
Go to Configuration

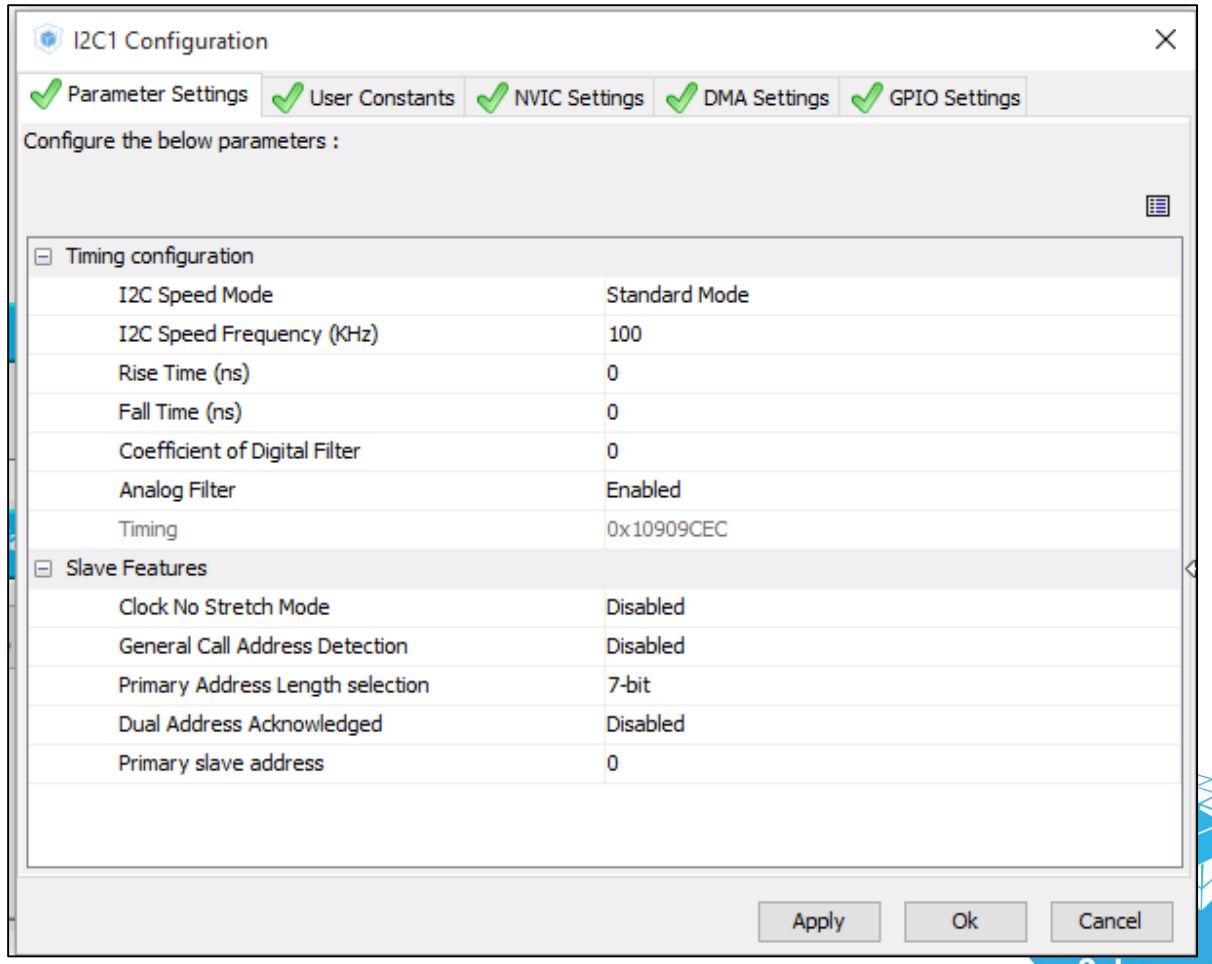


I2C1 in Connectivity

Audio Configuration







CIRRUS LOGIC®

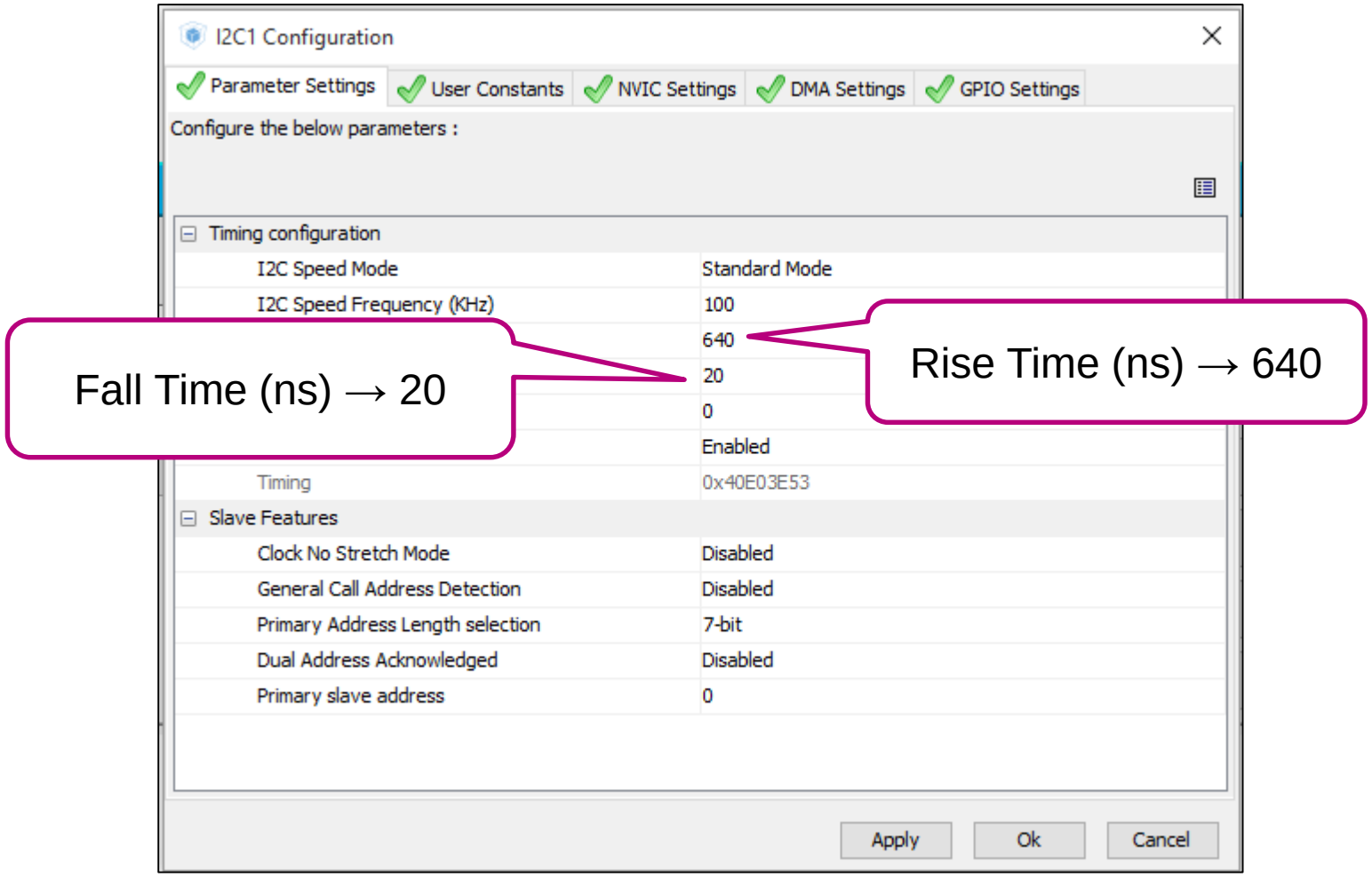
CS43L22

SWITCHING SPECIFICATIONS - I²C CONTROL PORT

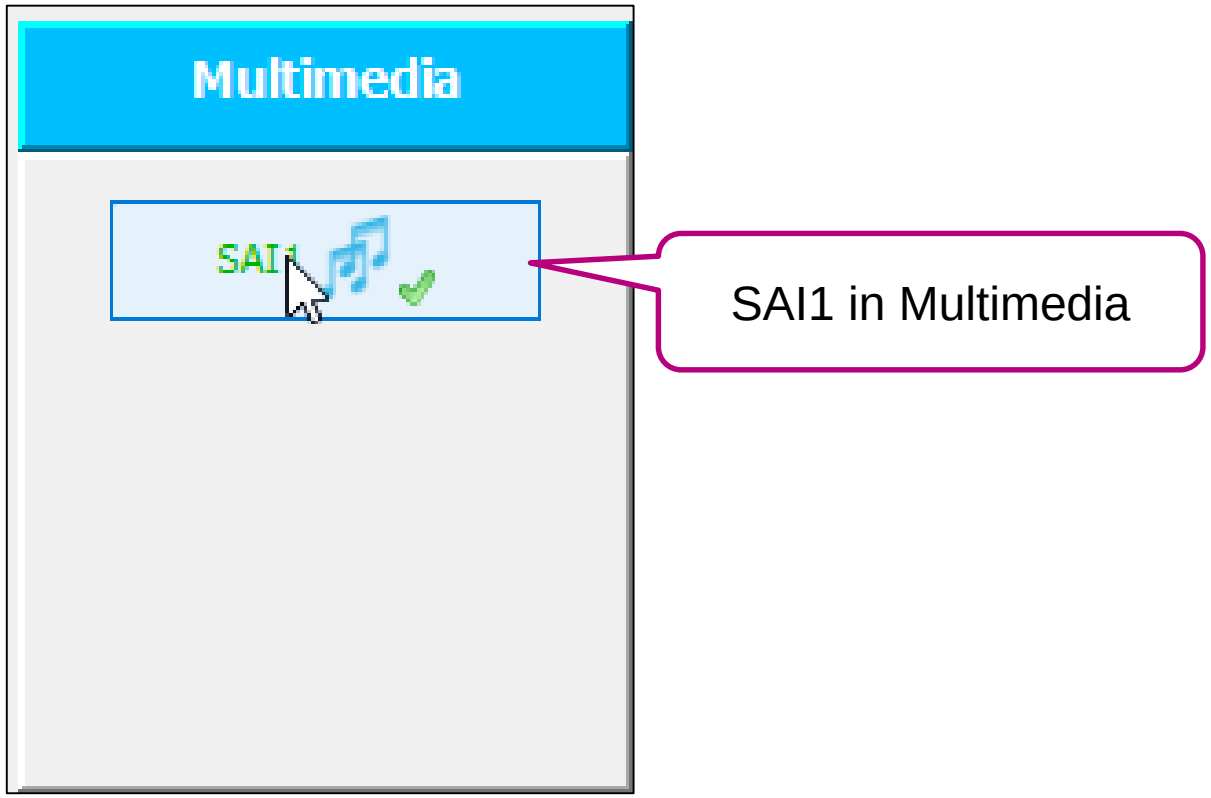
Inputs: Logic 0 = DGND; Logic 1 = V; SDA C_L = 30 pF.

Parameters	Symbol	Min	Max	Unit
SCL Clock Frequency	f_{scl}	-	100	kHz
RESET Rising Edge to Start	t_{irs}	550	-	ns
Bus Free Time Between Transmissions	t_{buf}	4.7	-	µs
Start Condition Hold Time (prior to first clock pulse)	t_{hdst}	4.0	-	µs
Clock Low time	t_{low}	4.7	-	µs
Clock High Time	t_{high}	4.0	-	µs
Setup Time for Repeated Start Condition	t_{sust}	4.7	-	µs
SDA Hold Time from SCL Falling (Note 13)	t_{hdd}	0	-	µs
SDA Setup time to SCL Rising	t_{sud}	250	-	ns
Rise Time of SCL and SDA	t_{rc}	-	1	µs
Fall Time SCL and SDA	t_{fc}	-	300	ns
Setup Time for Stop Condition	t_{susp}	4.7	-	µs
Acknowledge Delay from SCL Falling	t_{ack}	300	1000	ns

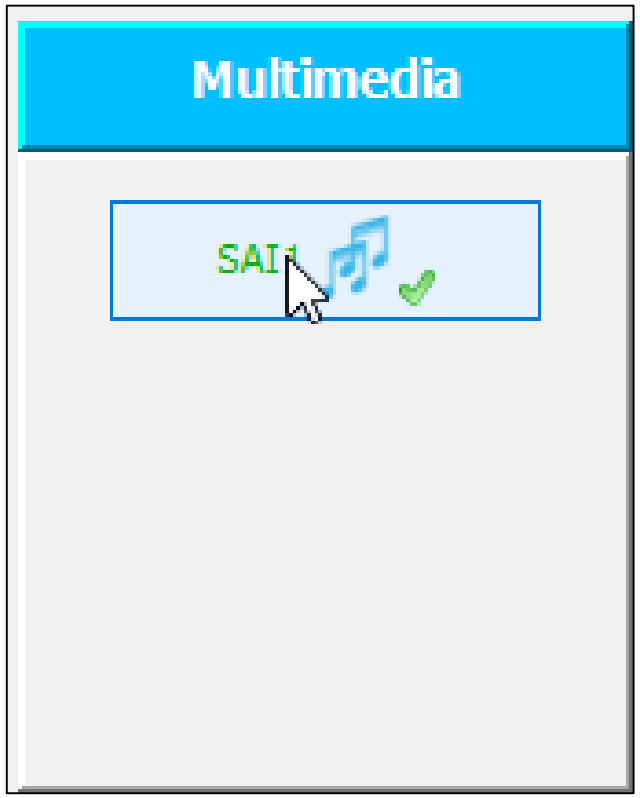
Audio Configuration

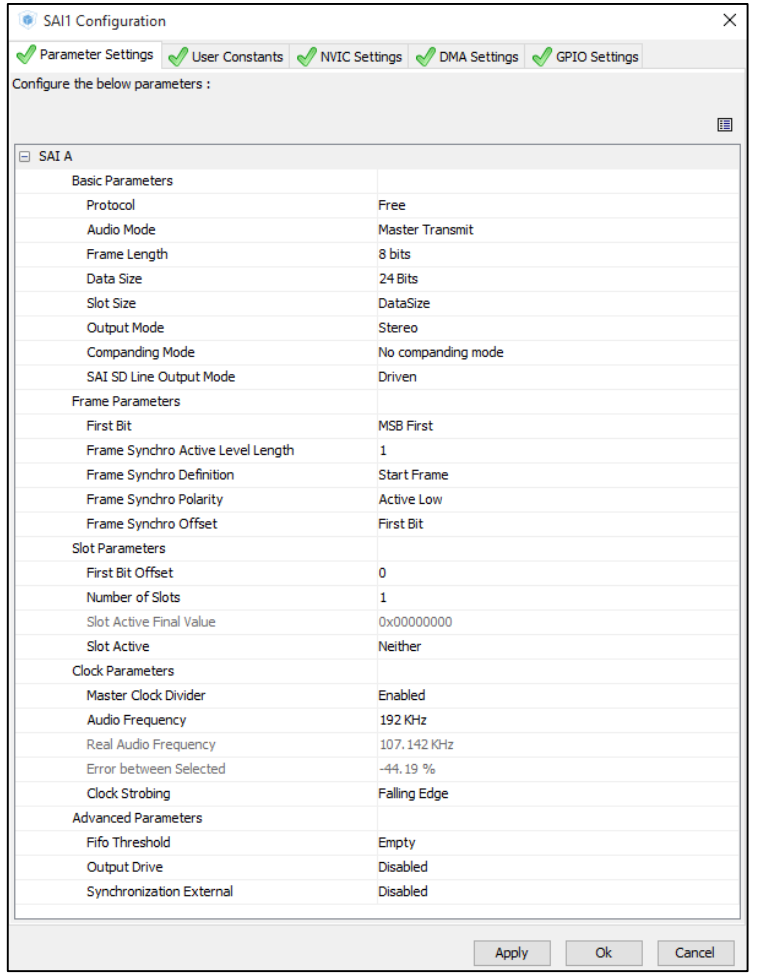


Audio Configuration

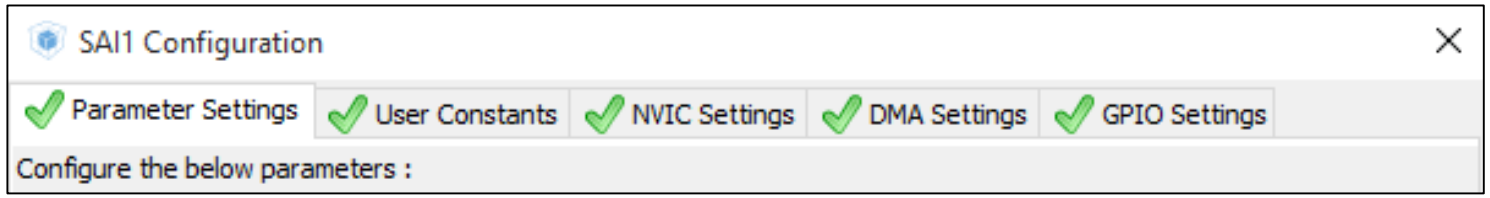


Audio Configuration

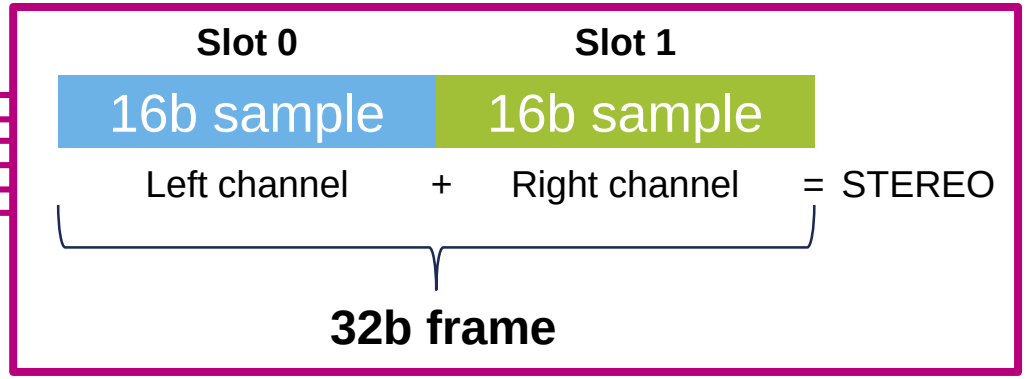




Audio Configuration



1	Frame Length	32 bits
2	Data Size	16 Bits
3	Frame Synchro Active Level Length	16
4	Frame Synchro Offset	Before First Bit
5	Number of Slots (only Even Values)	2
6	Frame Synchro Definition	Channel Identification
	Slot Active	User Setting
	Slot 0 Active	☑
	Slot 1 Active	☑
	Audio Frequency	44.1 KHz
	Clock Strobing	Rising Edge
	Fifo Threshold	One Quarter Full
	Output Drive	Enabled



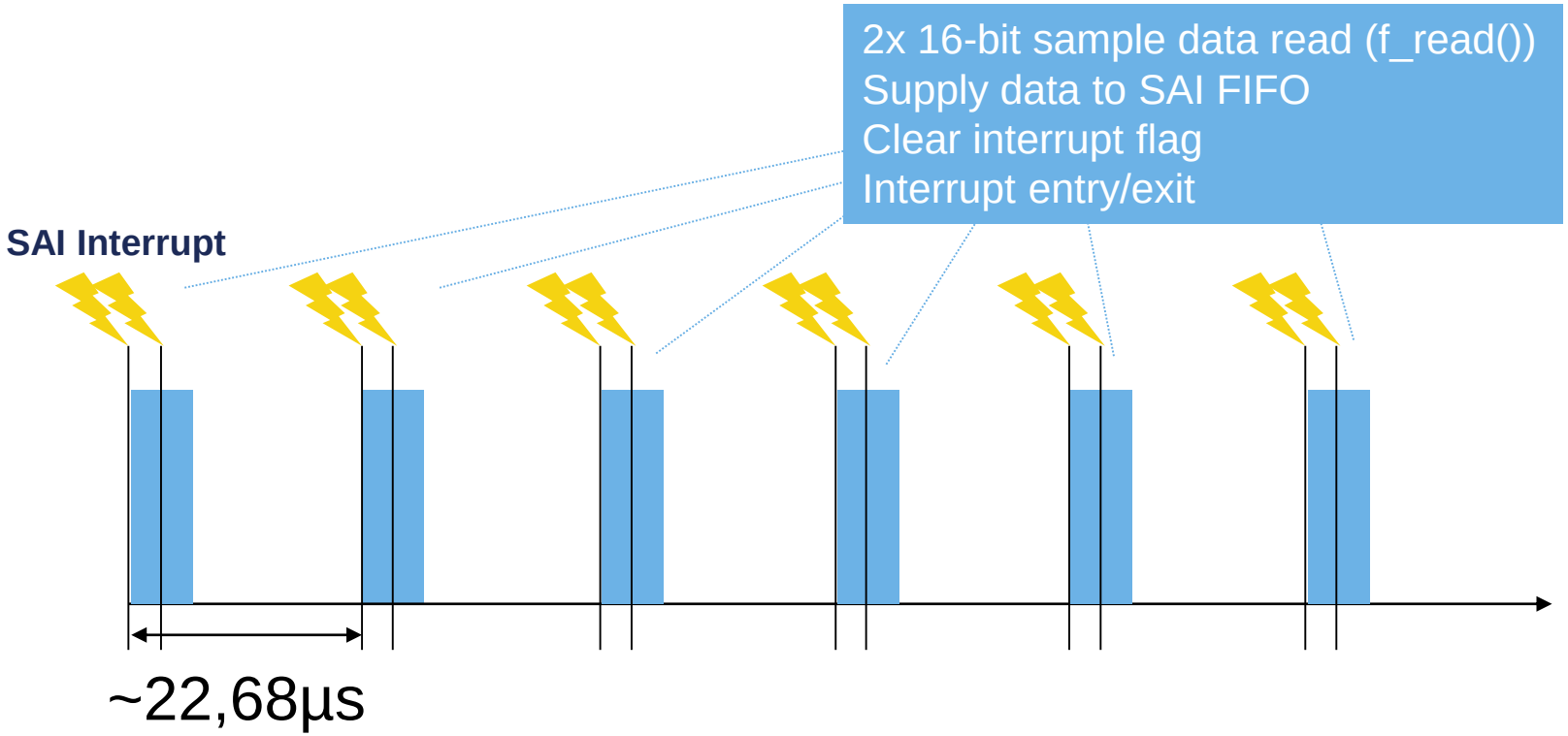
audio.wav	
WAVE Information	
Length	00:58
Compression	PCM
Bitrate (bps)	16
Frequency (Hz)	44 100
Mode	Stereo

life.augmented

STM32 Cube

4 How to supply audio data to SAI

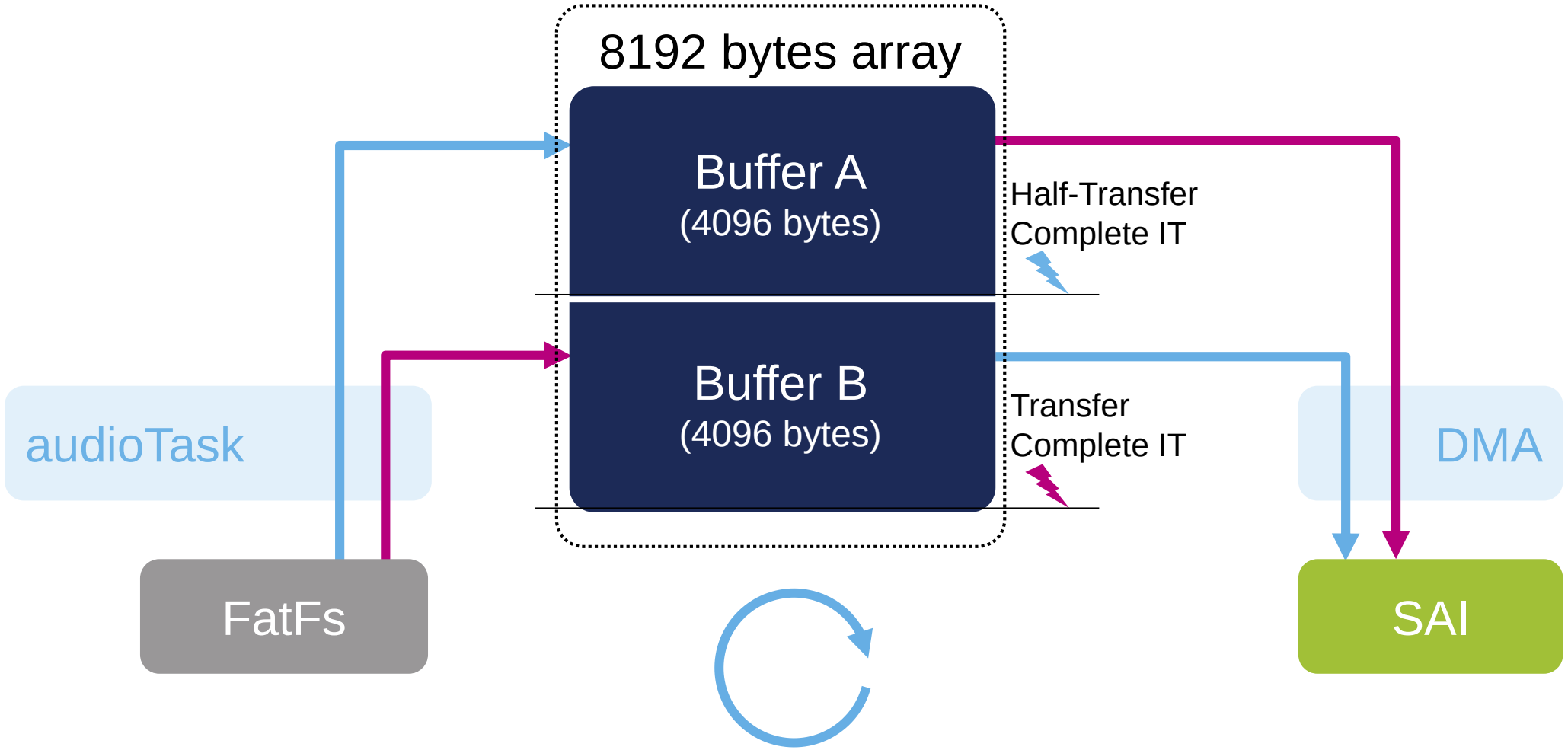
audio.wav	
WAVE Information	
Length	00:58
Compression	PCM
Bitrate (bps)	16
Frequency (Hz)	44 100
Mode	Stereo



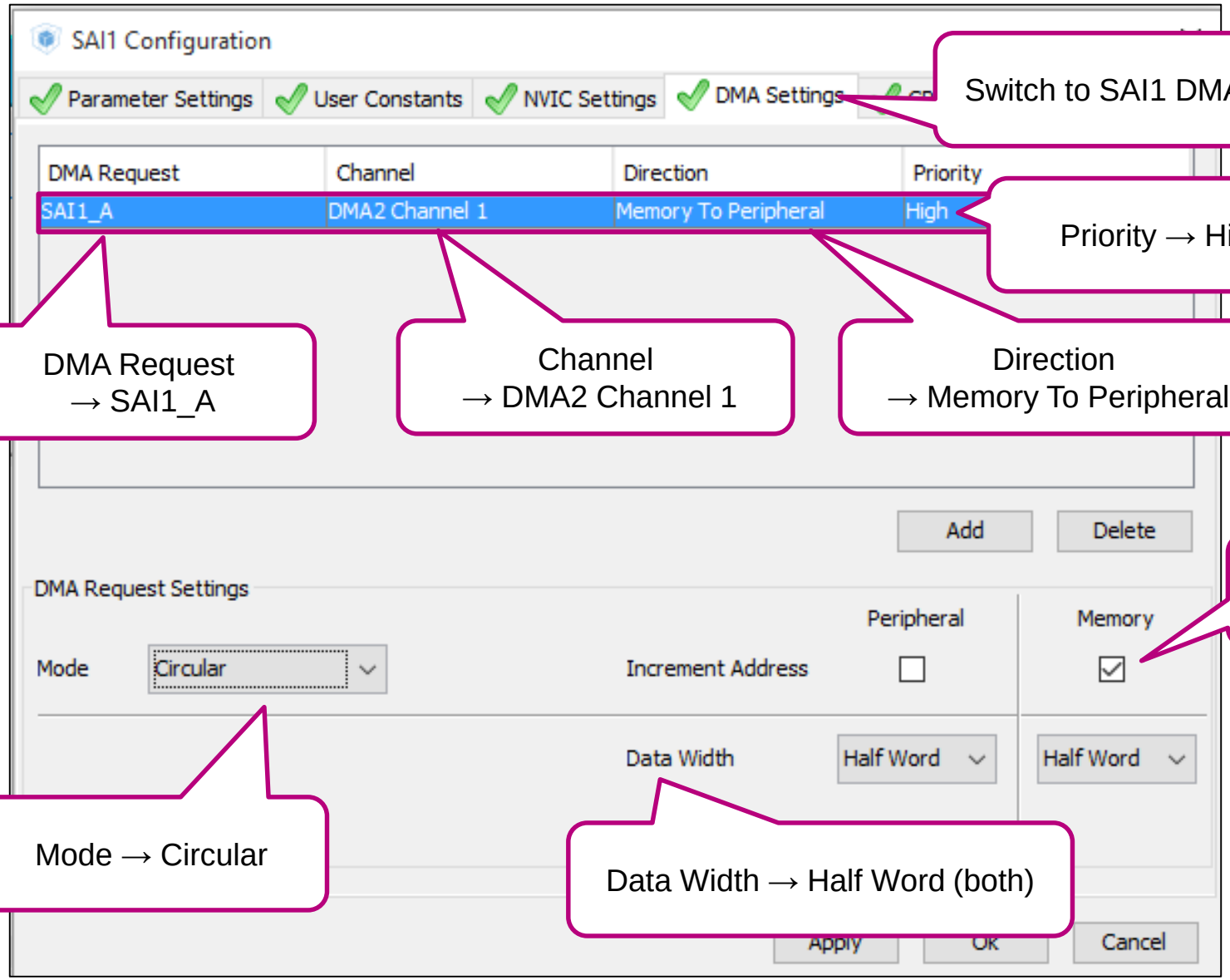
~1814 clk cycles @80 MHz → **far enough for the task**

But, is it “best practices” implementation of such task? NO!

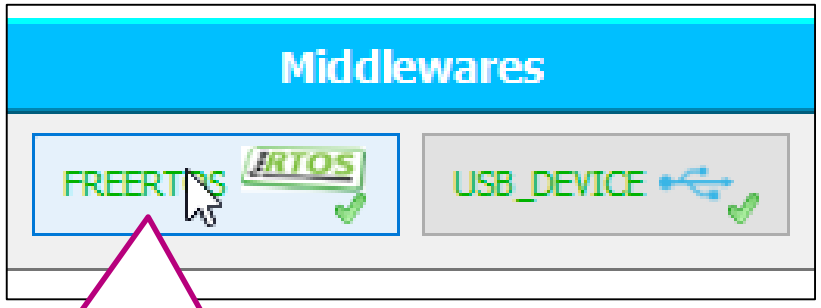
4 Audio data Dual-Buffer with DMA



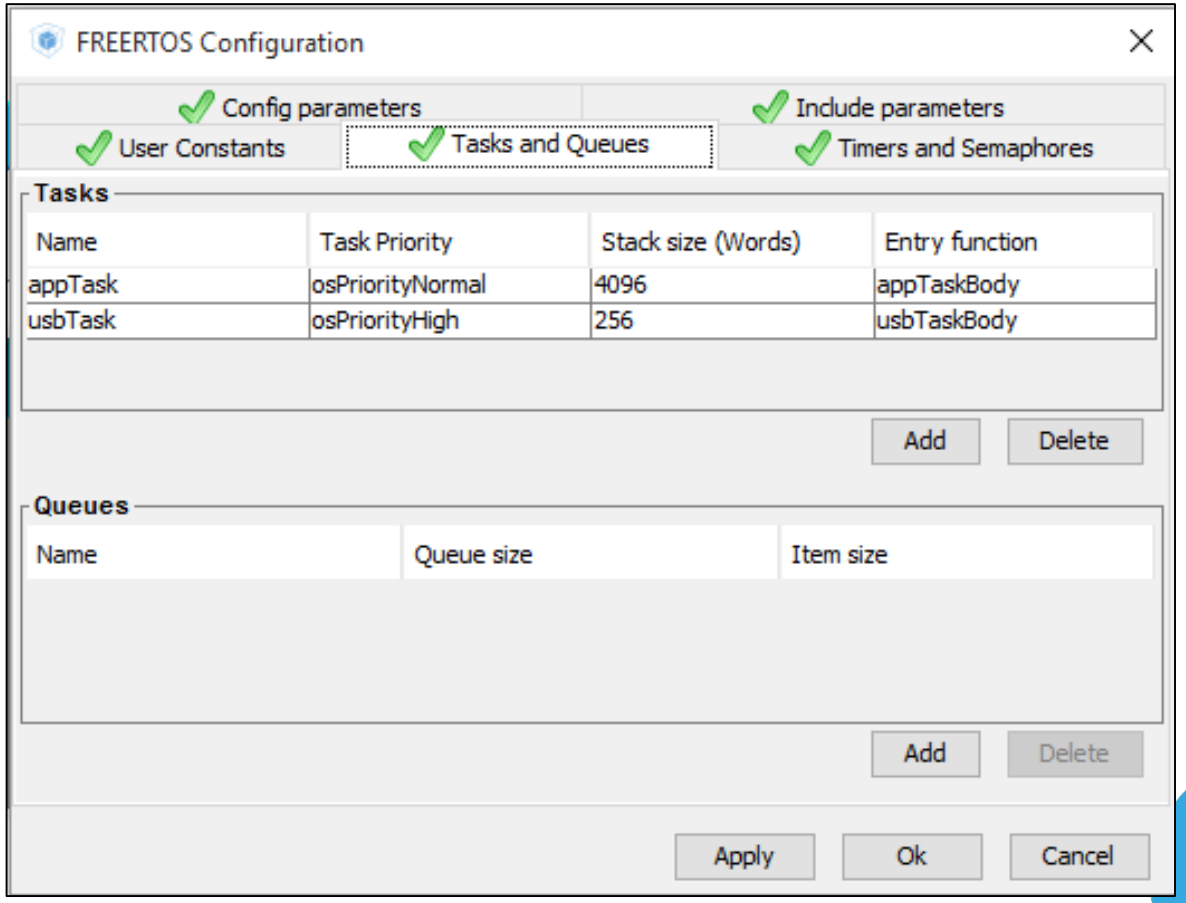
Audio Configuration



4 FreeRTOS Configuration Change



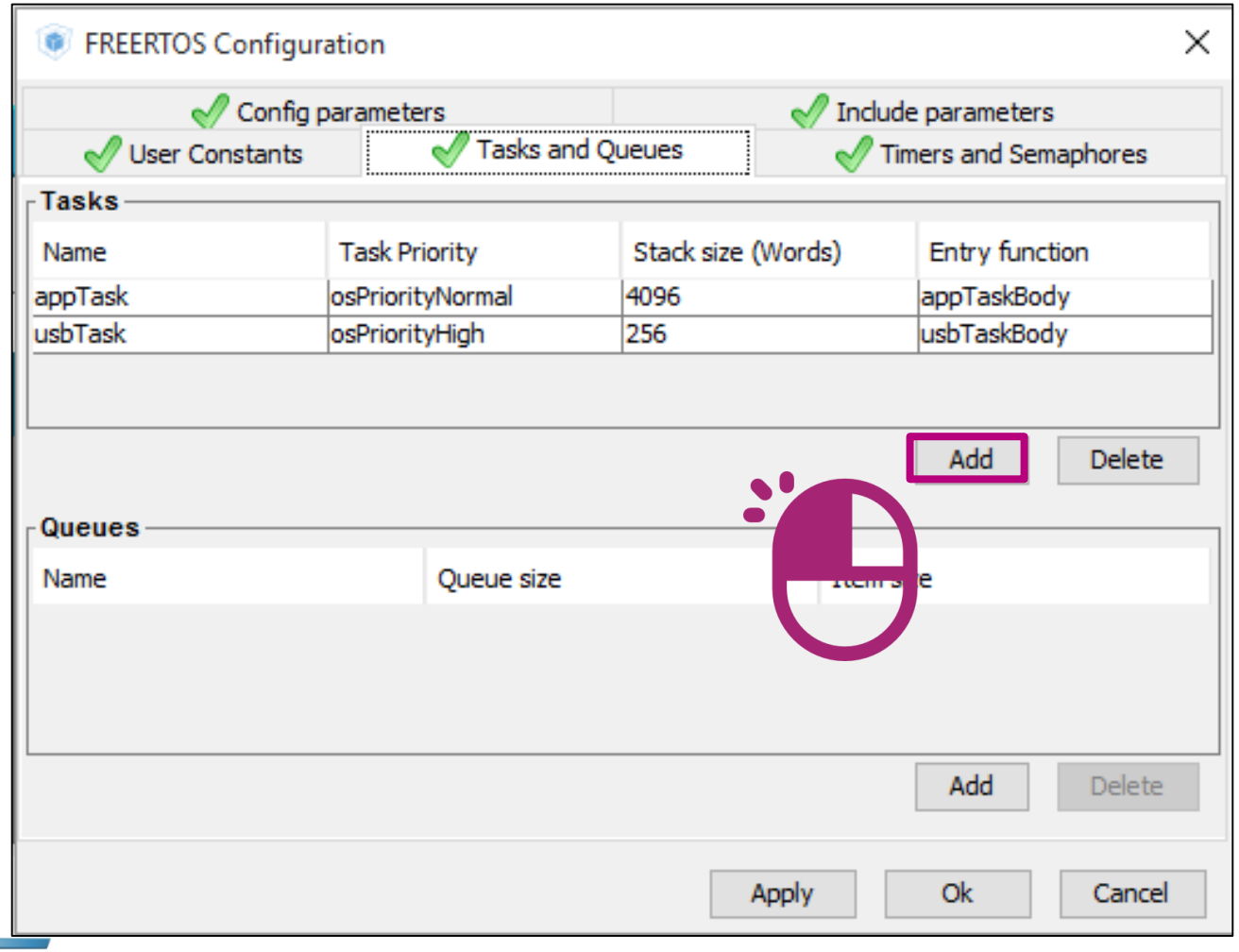
FREERTOS in Middlewares



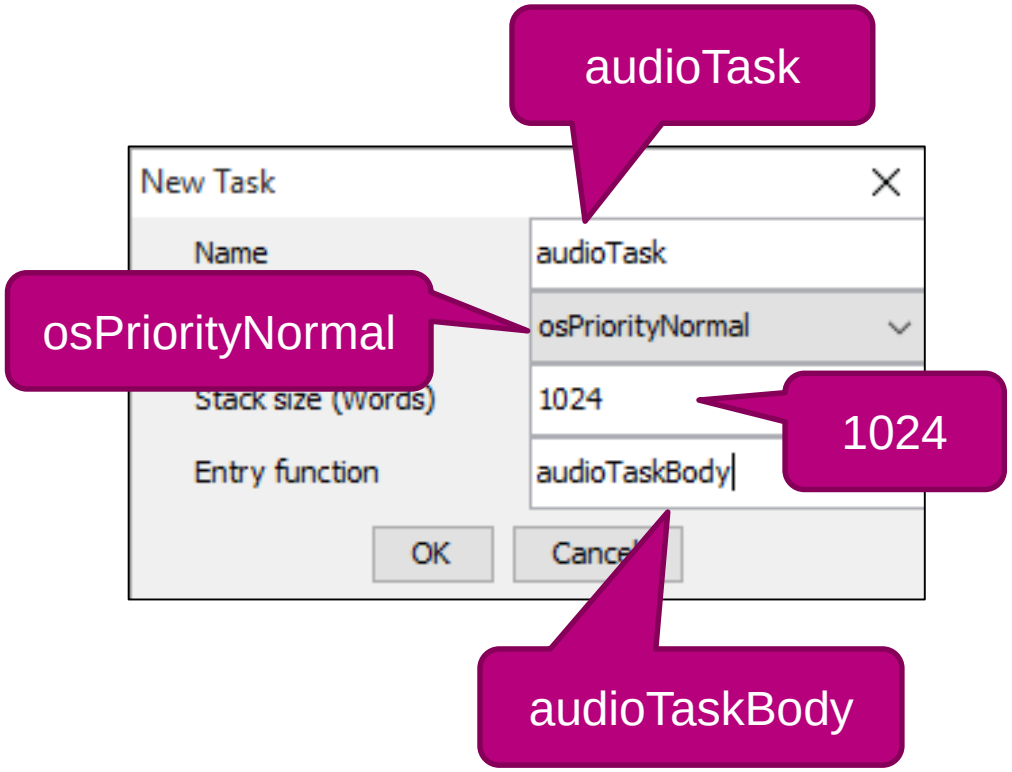
life.augmented

STM32 Cube

4 Audio Configuration



audioTask



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Checkpoint #11

FatFS

FREERTOS Configuration

Config parameters | Include parameters | User Constants | Tasks and Queues | Timers and Semaphores

Tasks

Name	Task Priority	Stack size (Words)	Entry function
appTask	osPriorityNormal	4096	appTaskBody
usbTask	osPriorityHigh	256	usbTaskBody
audioTask	osPriorityNormal	1024	audioTaskBody

Add | Delete

Queues

Name	Queue size	Item size

Add | Delete

Apply | Ok | Cancel

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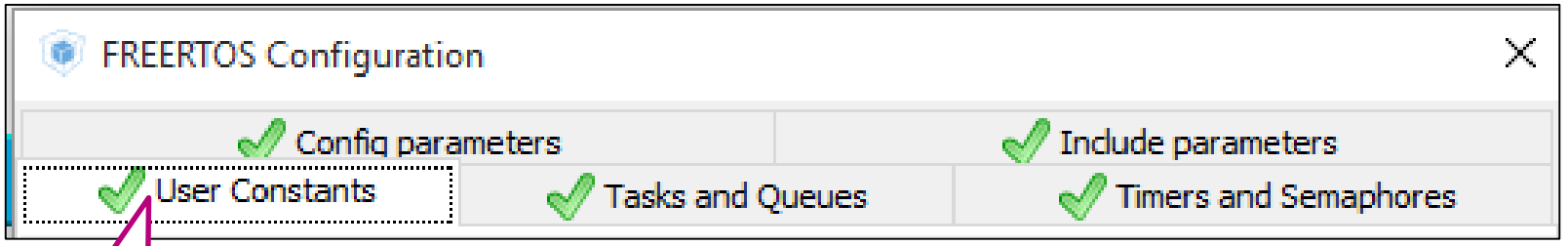
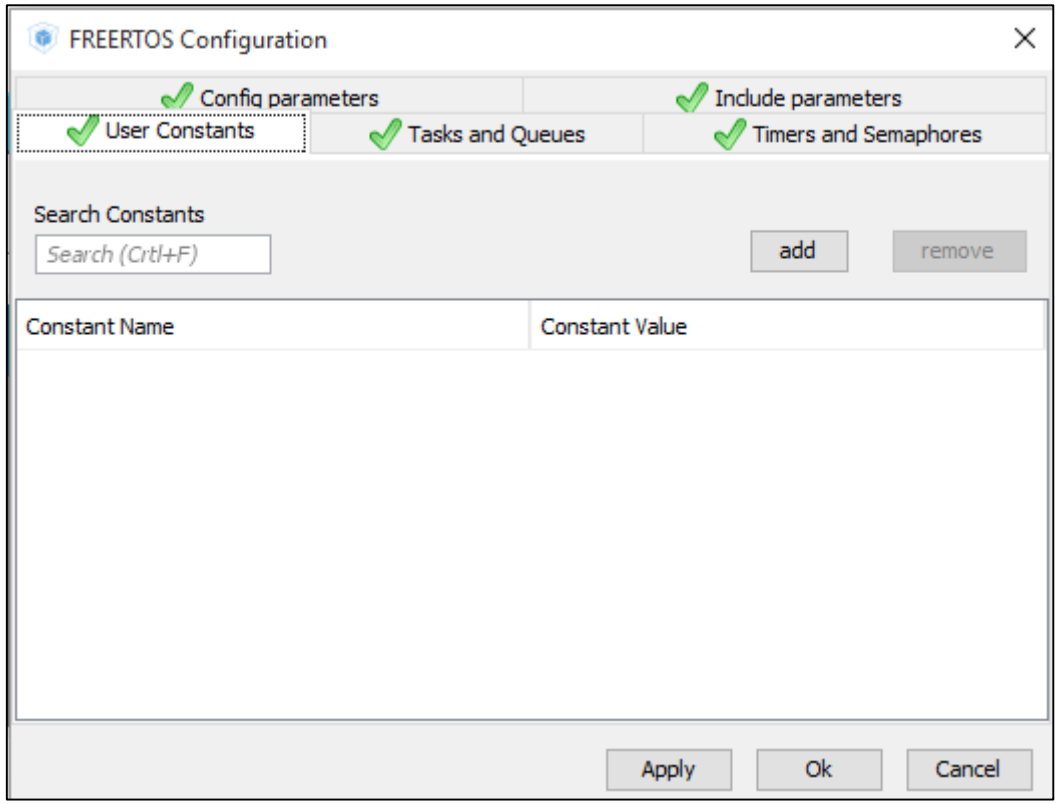
STM32 Cube

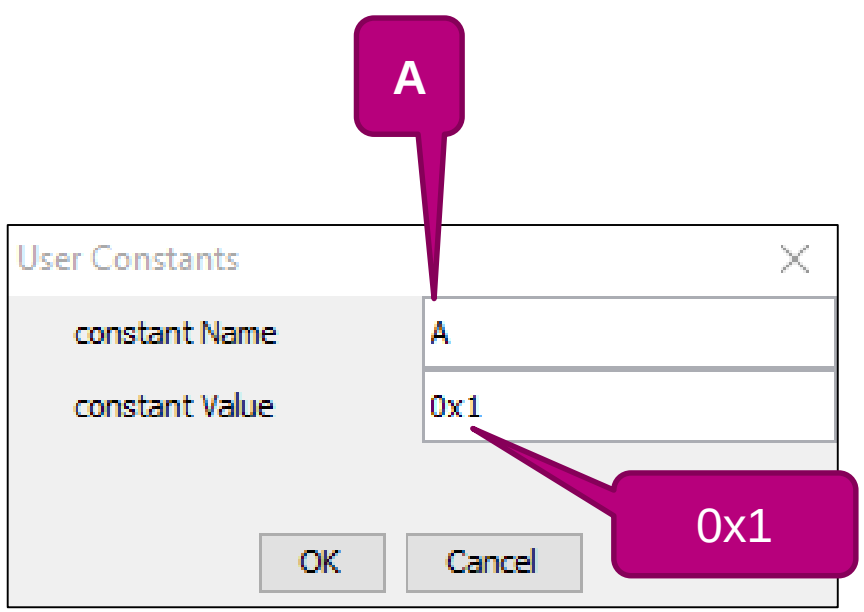
4 FreeRTOS Configuration Change

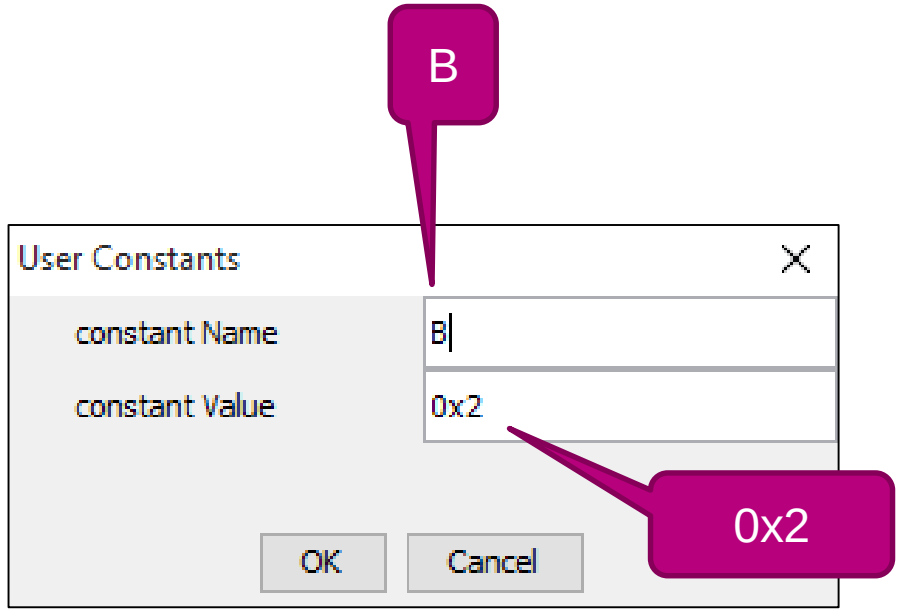


Go to User Constants in FreeRTOS Configuration

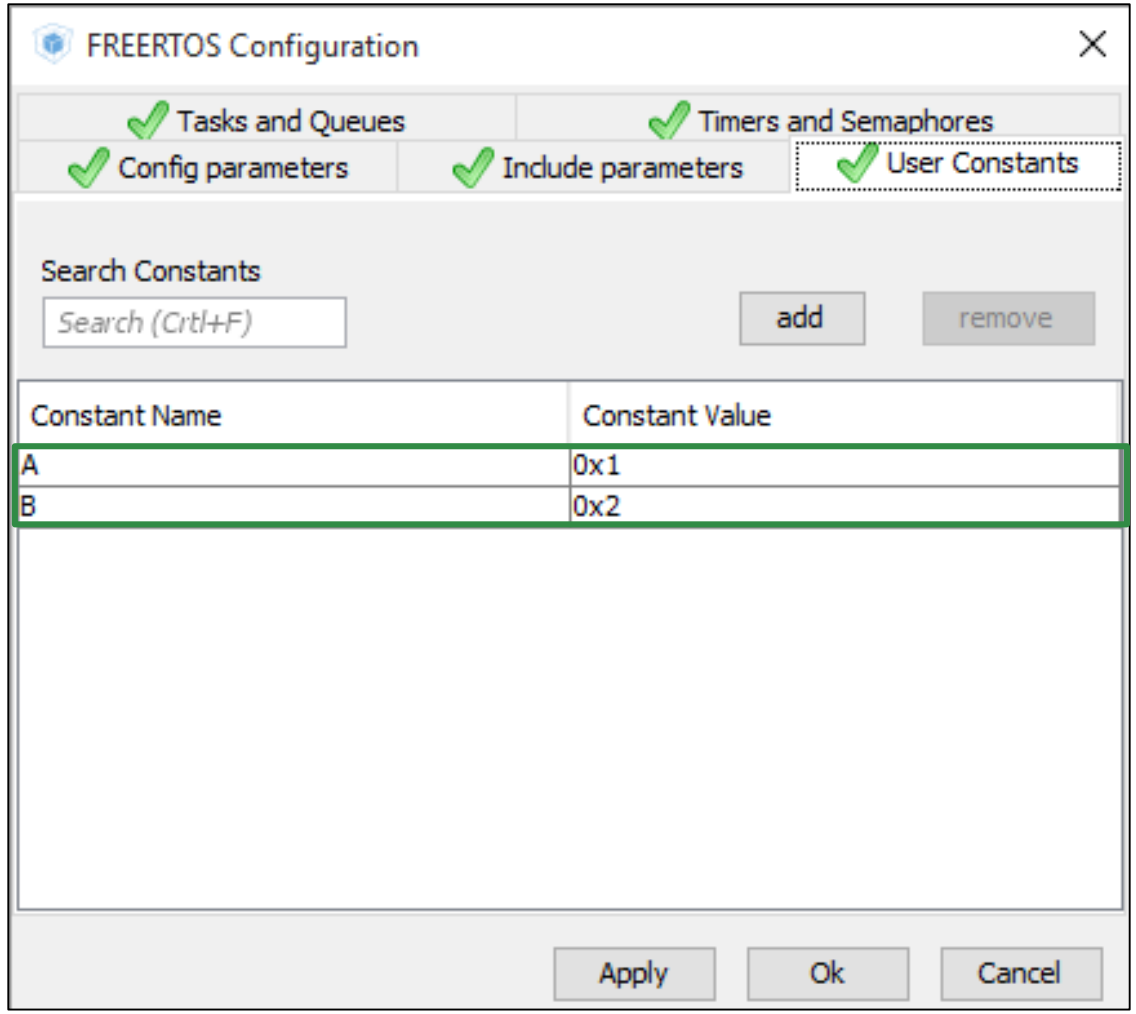


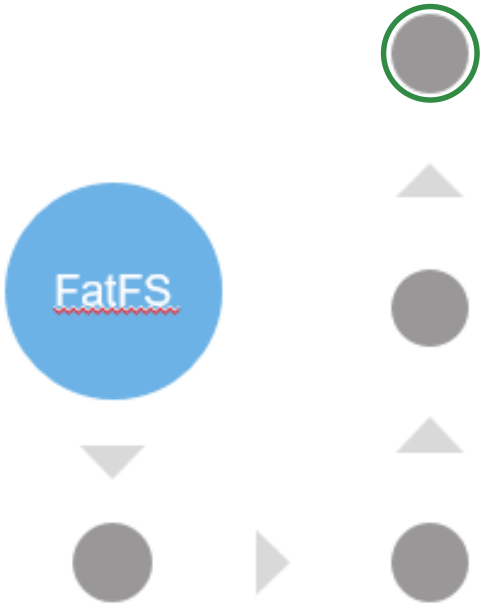
4 FreeRTOS Configuration Change





Checkpoint #12





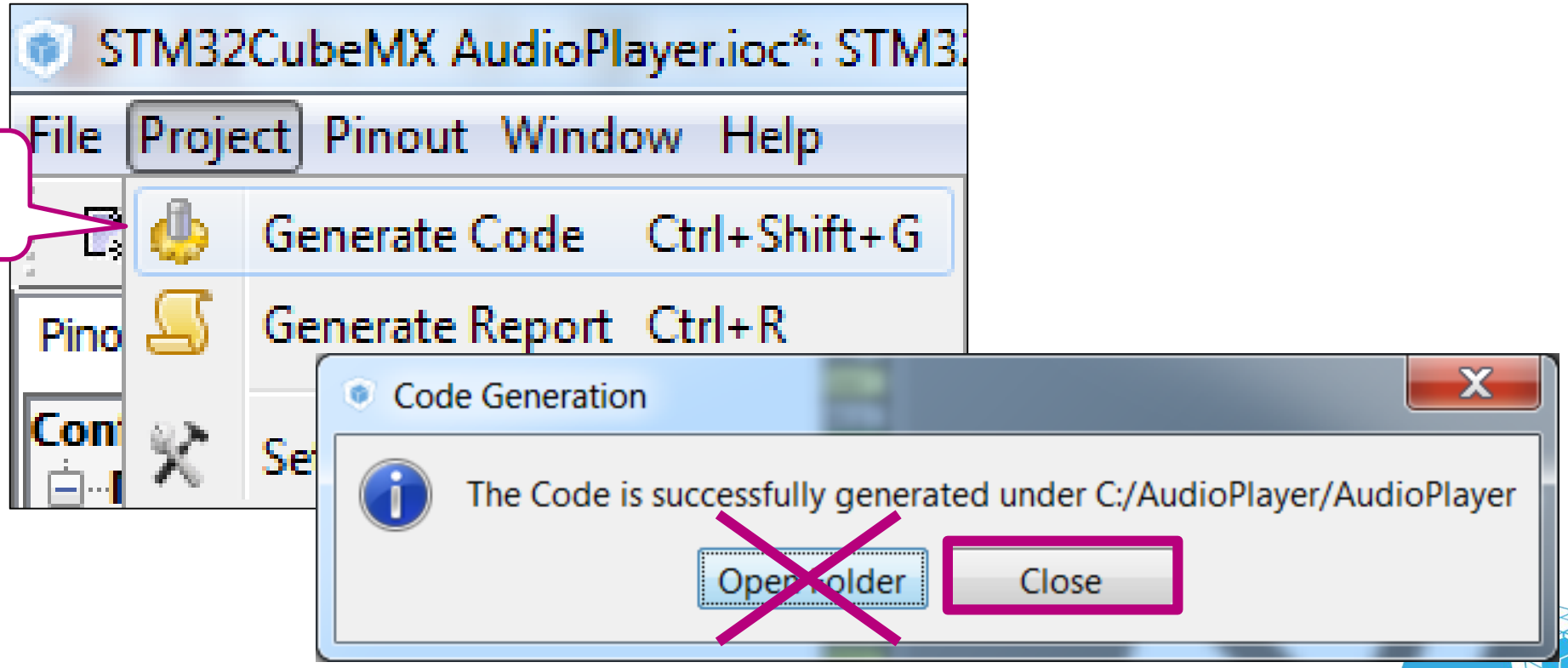
life.augmented

STM32 Cube

4 Save and generate the project

Do not open the project yet

Generate Code
(Ctrl+Shift+G)



4 Apply small patch

- Apply patch from folder
  C:\STM32L4_Workshop\HandsOn\2_Putting_All_Together\Patch\STEP4_Audio
  to root folder of your project (C:\AudioPlayer\AudioPlayer\)

- It contains the following files:

  .\Inc\

  cs43l22.h

  i2c.h

  .\Src\

  freertos.c

  i2c.c

This operation is STM32CubeMX non-intrusive. You can re-generate the project later and the modifications will be retained.

- These files contains the main needed source code the user has to add to be able to work with the external audio codec (cd43l22)

4 i2c.c added content

- i2c.c
  - AUDIO_Init(…)
  - AUDIO_DeInit(void)
  - AUDIO_ReadID(…)
  - AUDIO_Play(…)
  - AUDIO_Pause(…)
  - AUDIO_Resume(…)
  - AUDIO_Stop(…)
  - AUDIO_SetVolume(…)
  - AUDIO_SetFrequency(…)
  - AUDIO_SetMute(…)
  - AUDIO_SetOutputMode(…)

Based on BSP driver in STM32CubeL4 HAL

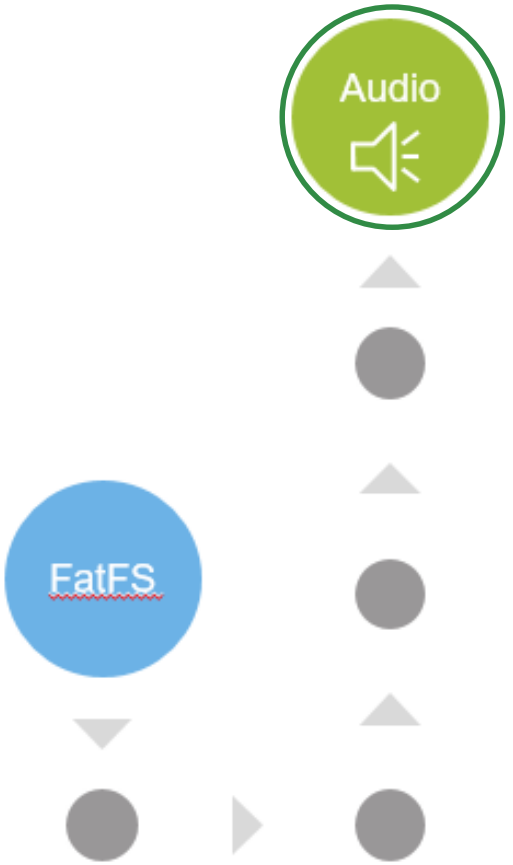
4 Let’s try it out

1. Open the project
2. Compile and download
3. Press the reset button to restart the application

4

Checkpoint #13

- Connect headphones
- Do you hear music?
- LED_GREEN being toggled when playing audio file

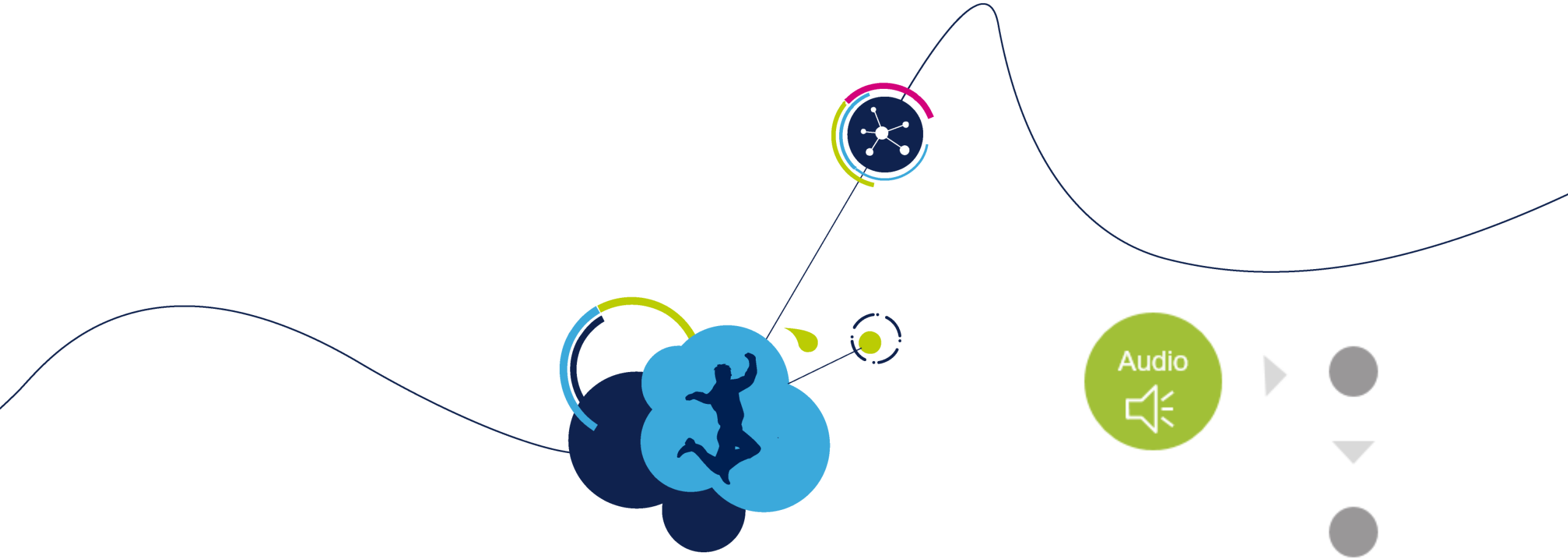


Why Signal?

Synchronization of the dual buffer filling mechanism:

- if both at the same time → error, we are not fast enough maybe

- “Low cost” => fast management by Scheduler, 0 memory usage

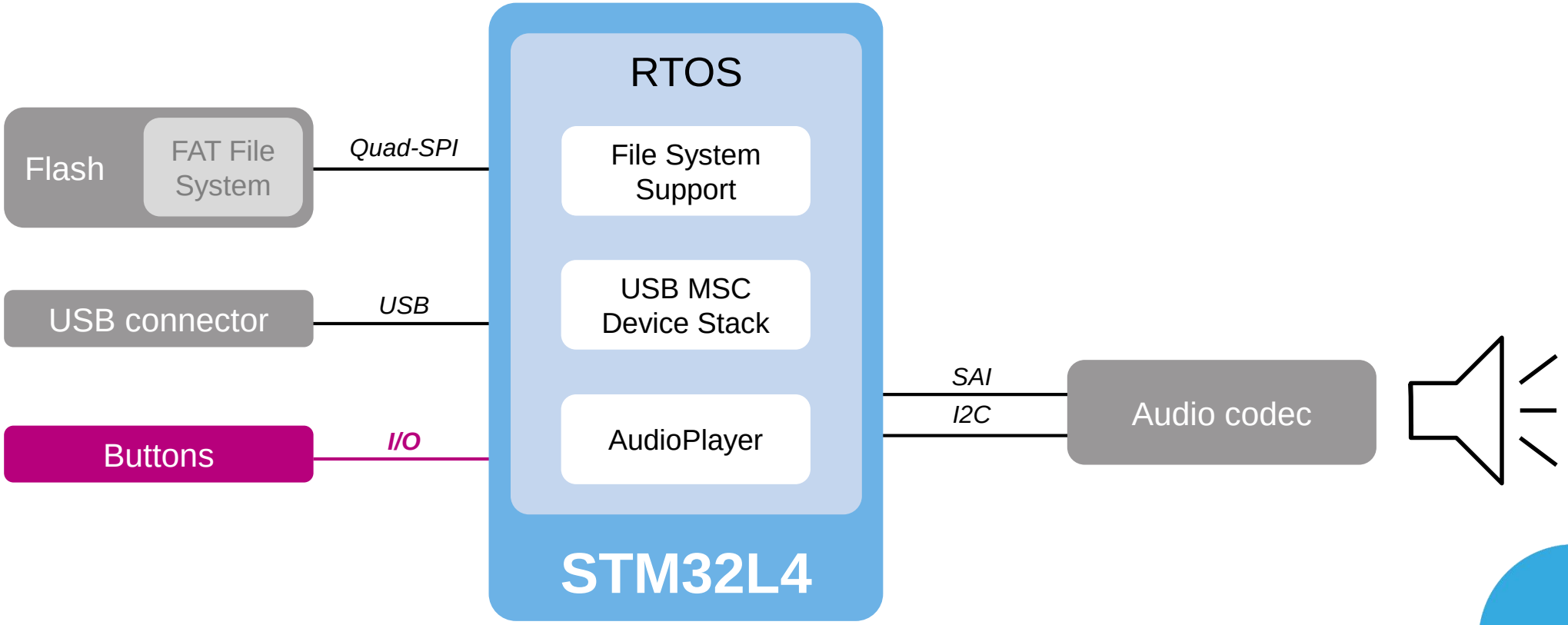


STEP5 – Joystick Input

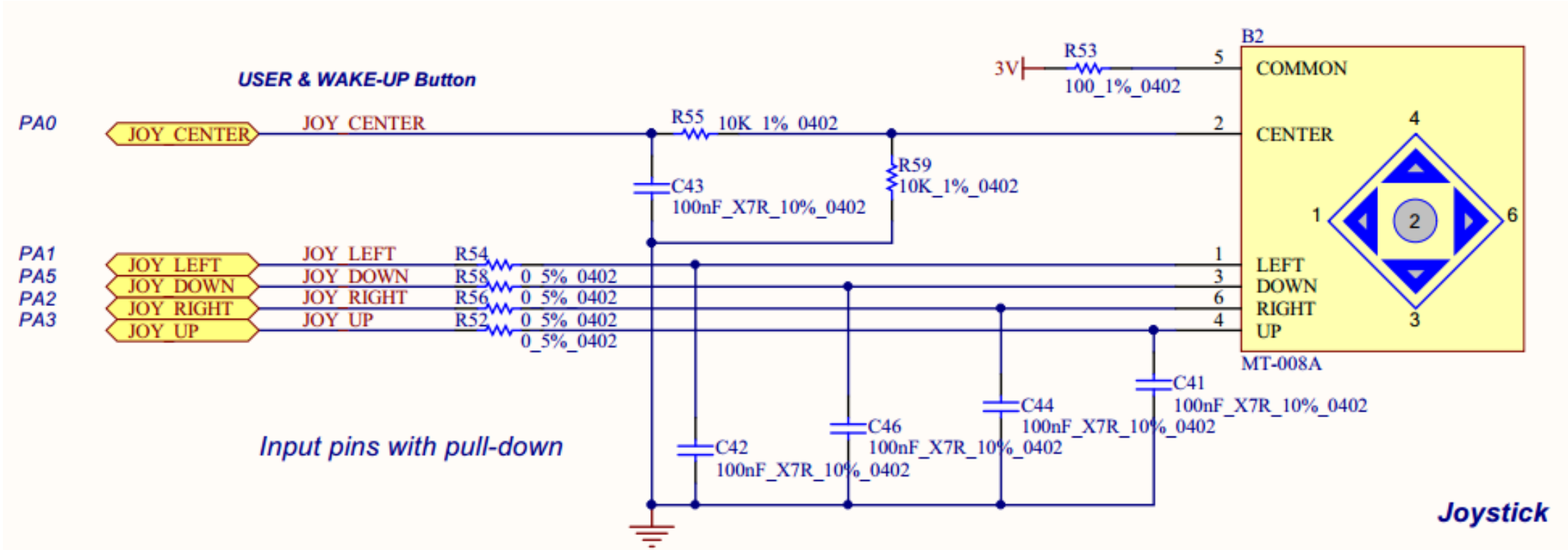
life.augmented

5 Adding Control Input functionality

- We want to control our application state
  - like “play”, “stop”, “pause” commands



Joystick Configuration



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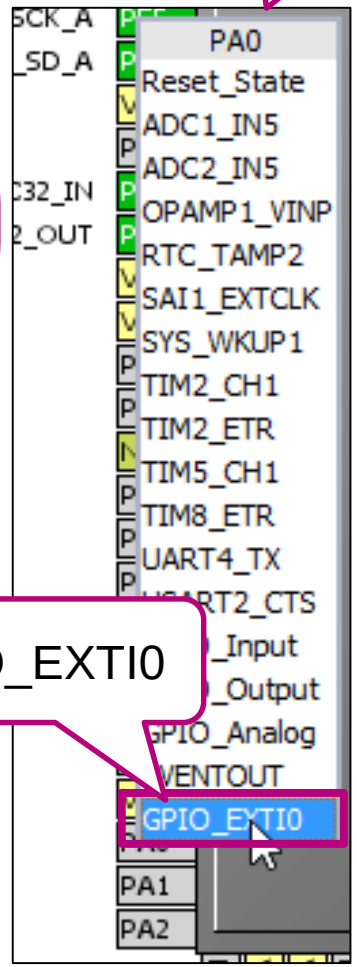
STM32 Cube

Joystick Configuration

5

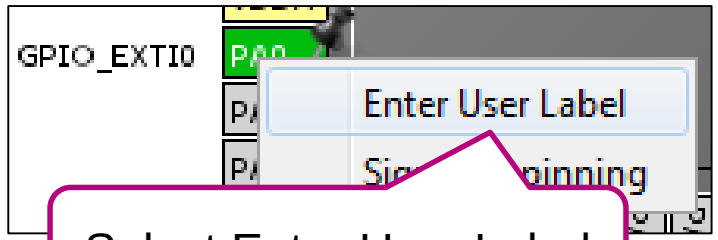
PA0

1



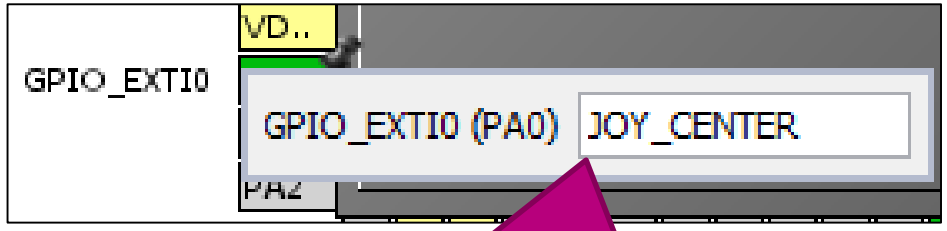
GPIO_EXTI0

2



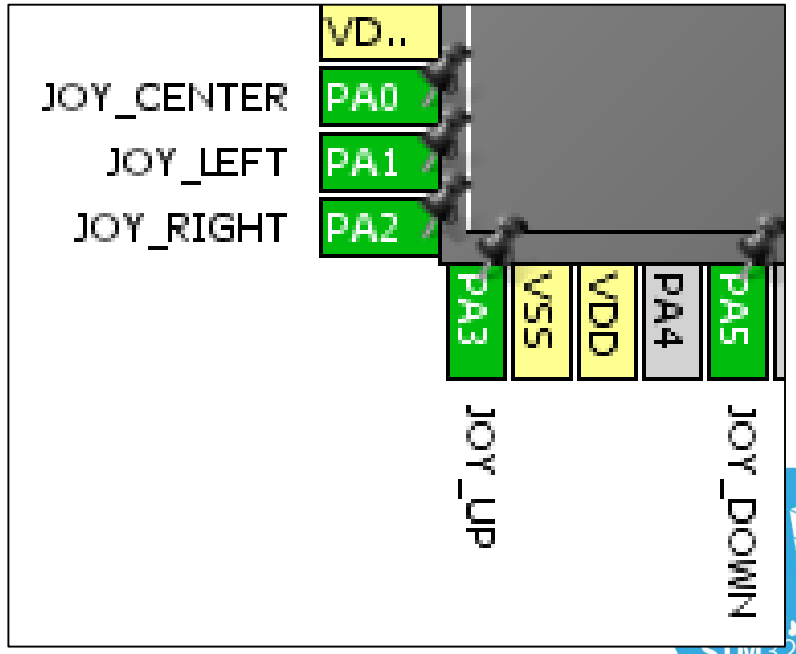
Select Enter User Label

3



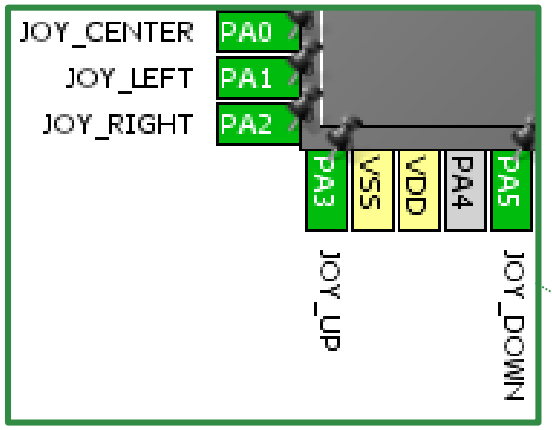
Enter **JOY_CENTER**

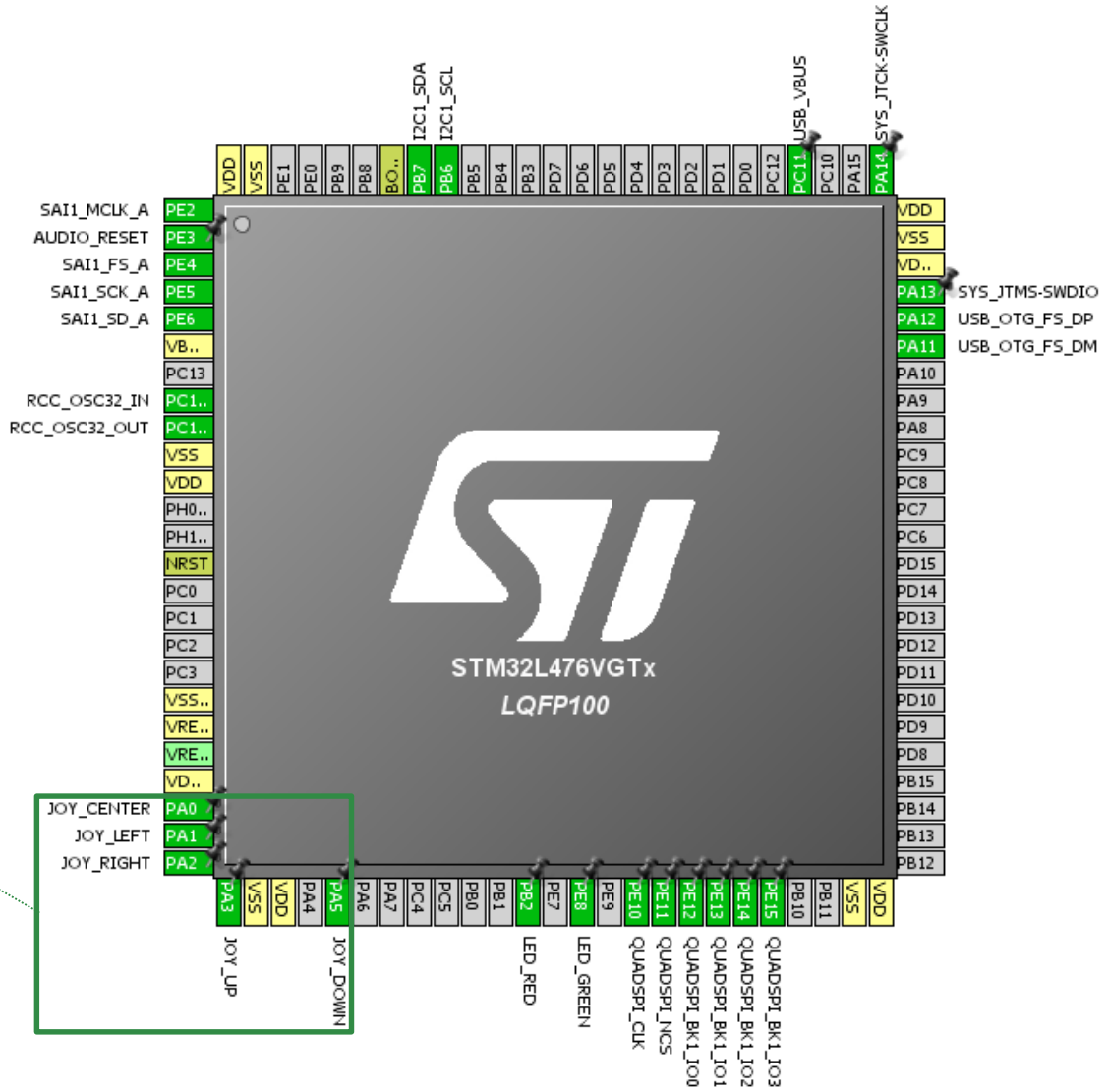
PA0 → JOY_CENTER
PA1 → JOY_LEFT
PA2 → JOY_RIGHT
PA3 → JOY_UP
PA5 → JOY_DOWN



life.augmented

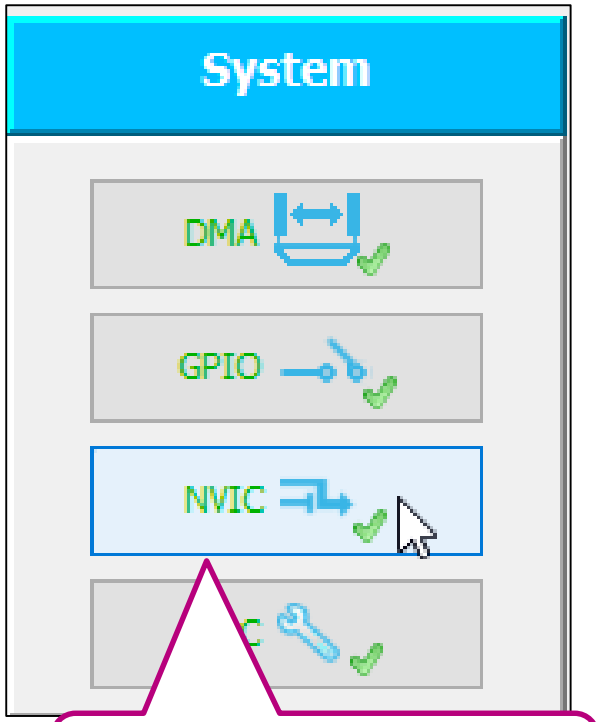
Checkpoint #14





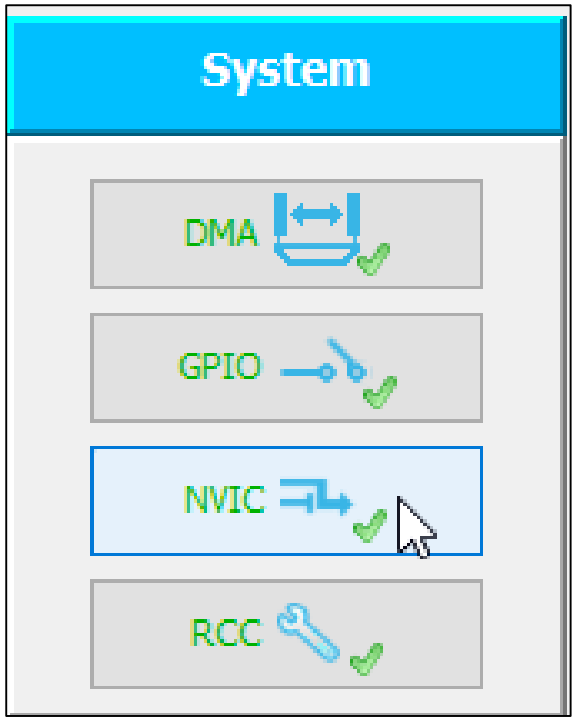
Joystick Configuration

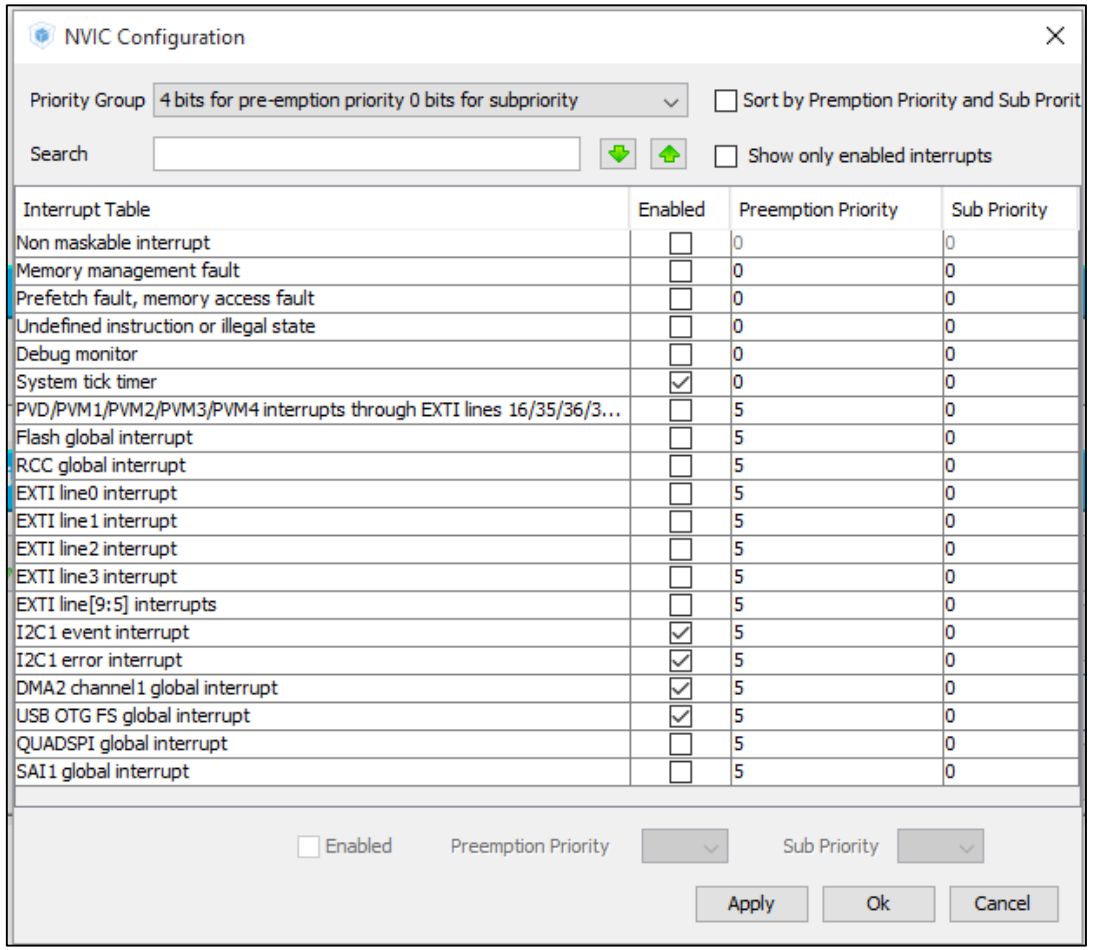
Go to Configuration



NVIC in System

Joystick Configuration

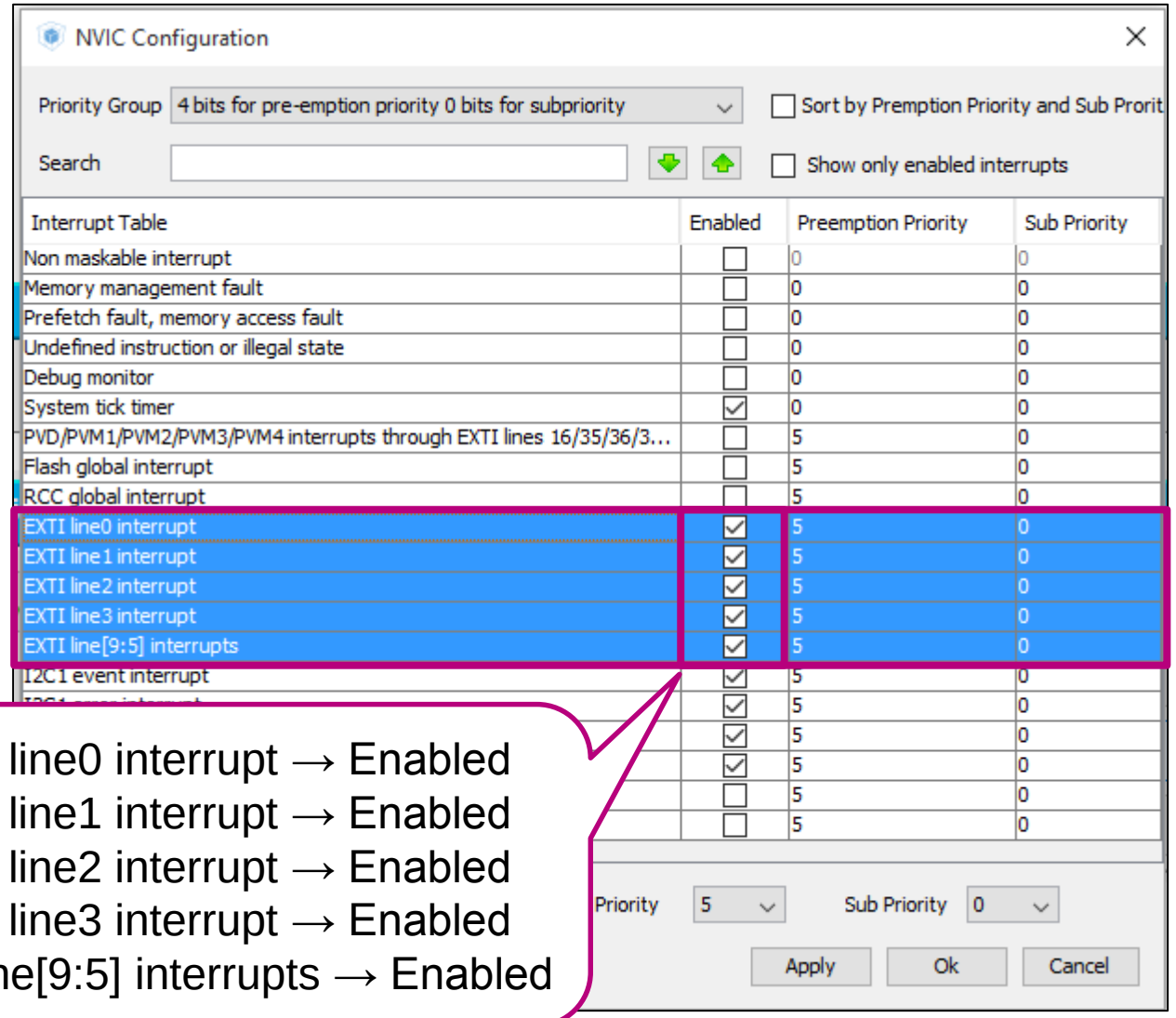




life.augmented

STM32 Cube

Joystick Configuration

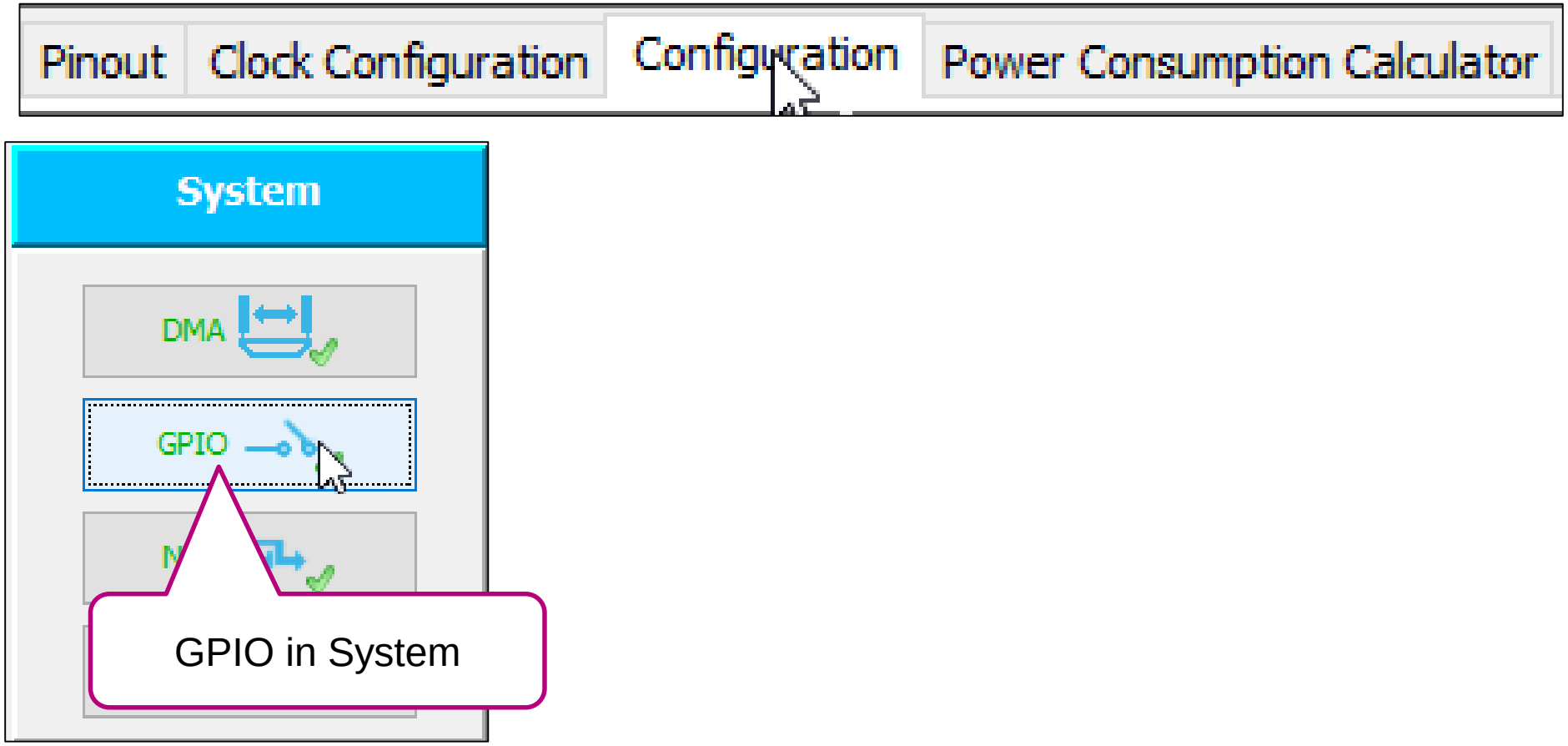


EXTI line0 interrupt → Enabled
EXTI line1 interrupt → Enabled
EXTI line2 interrupt → Enabled
EXTI line3 interrupt → Enabled
EXTI line[9:5] interrupts → Enabled

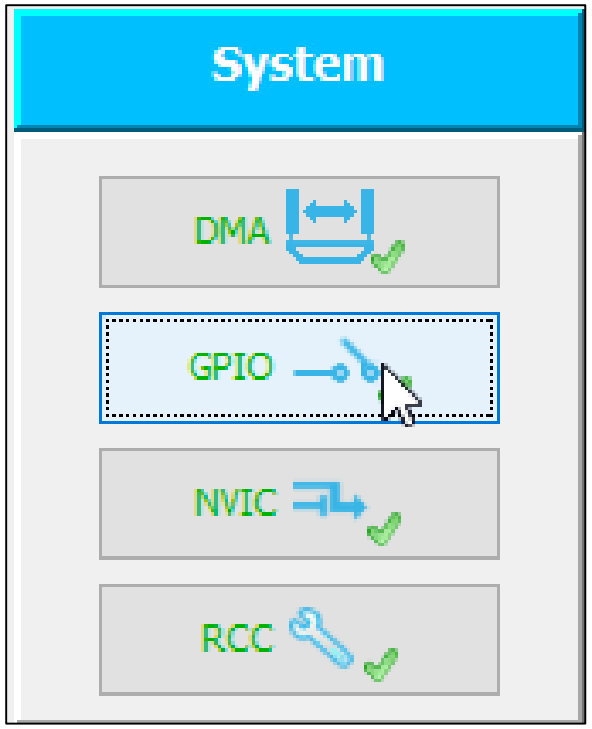
life.augmented

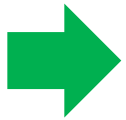
STM32 Cube

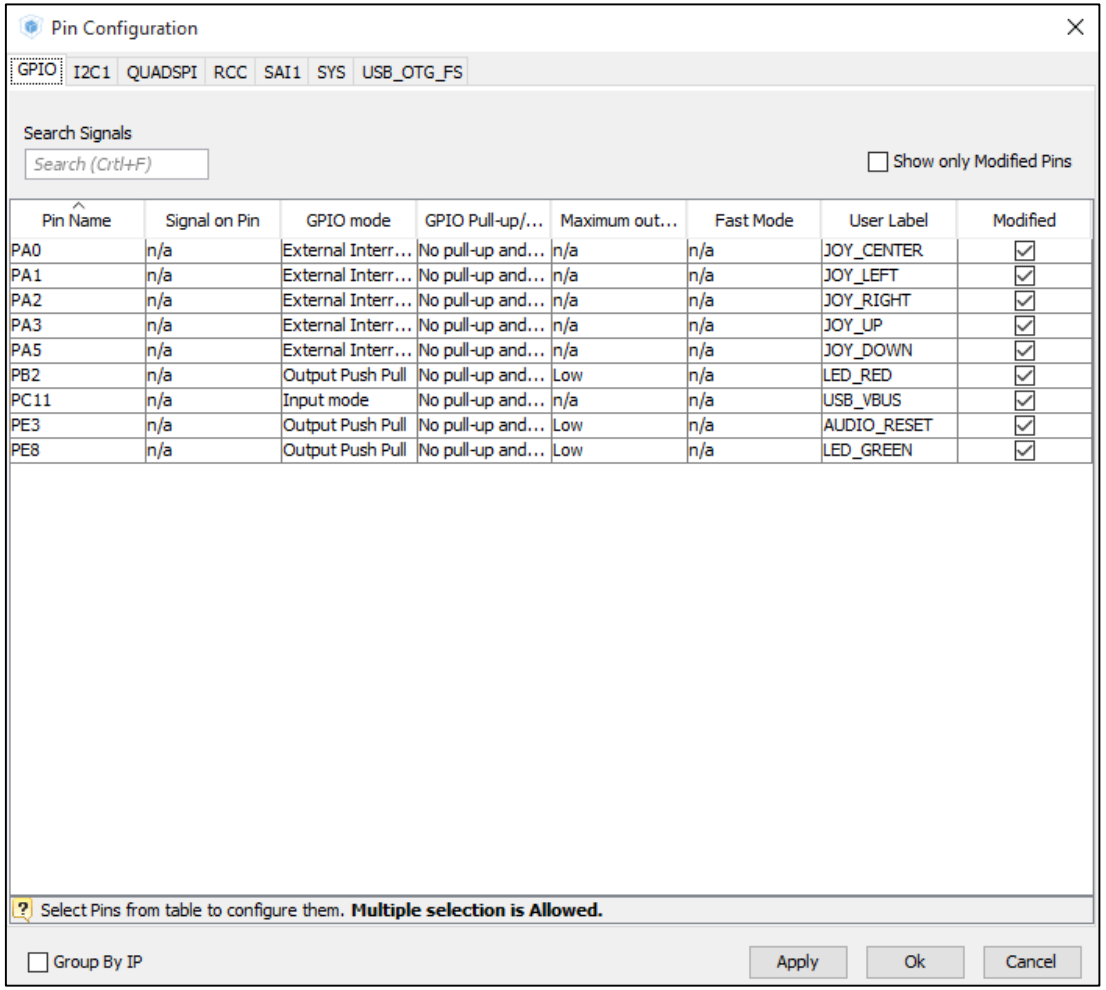
Joystick Configuration



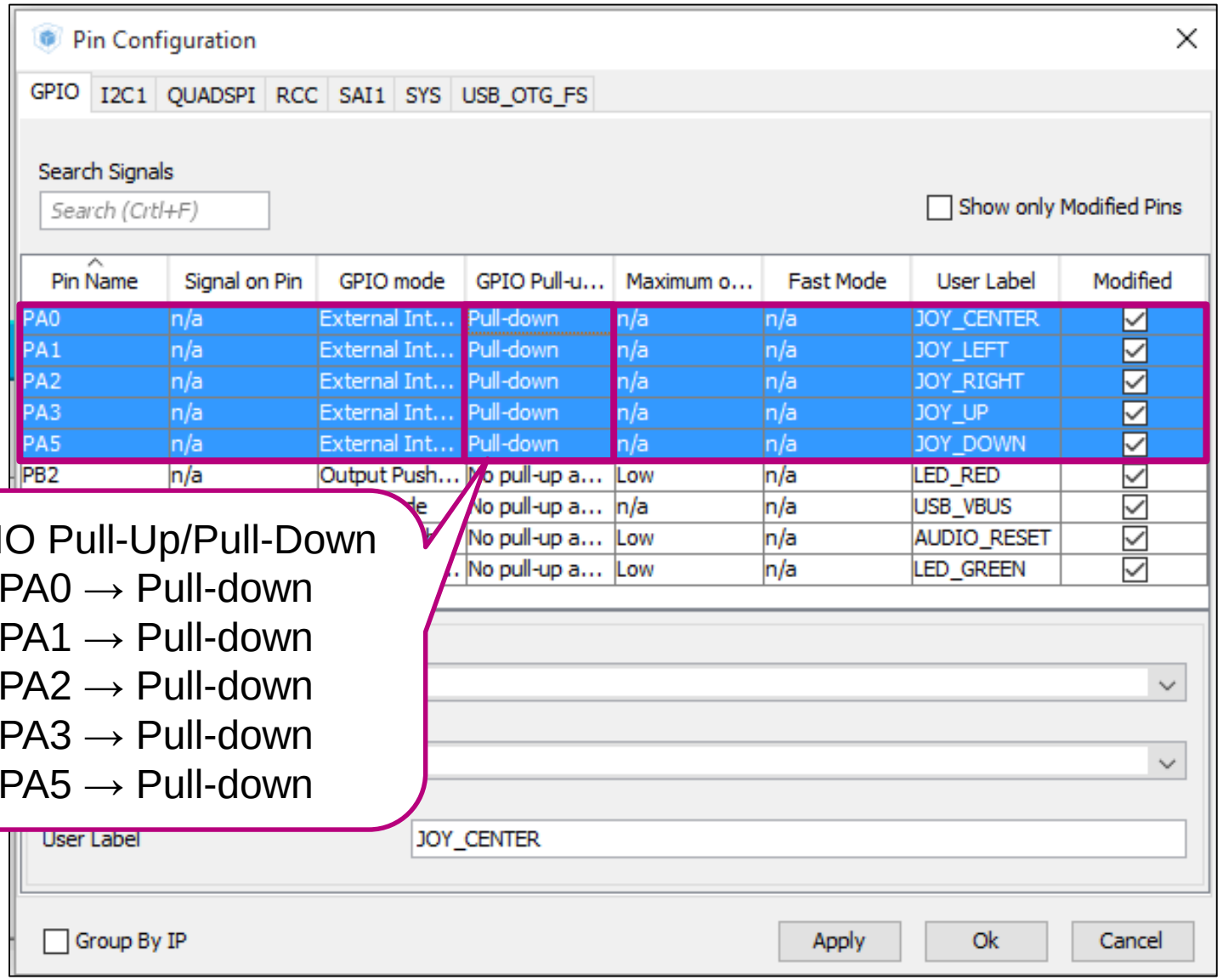
Joystick Configuration







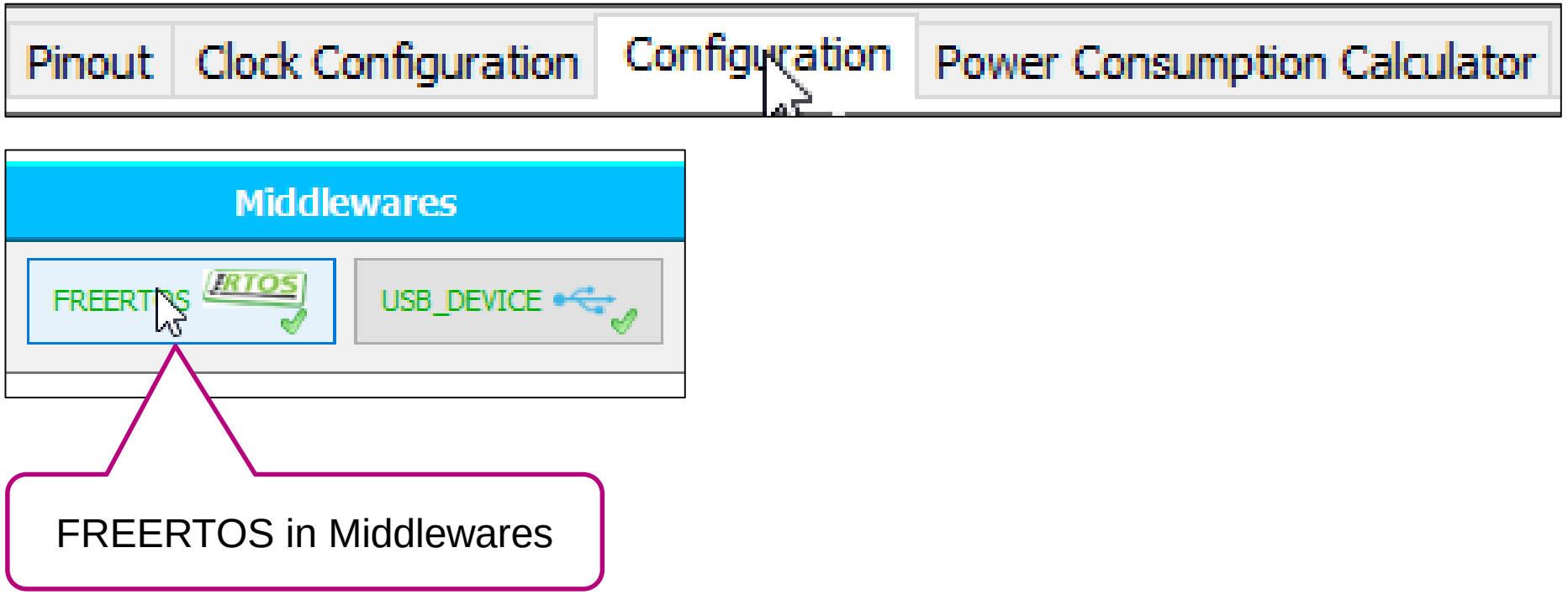
Joystick Configuration



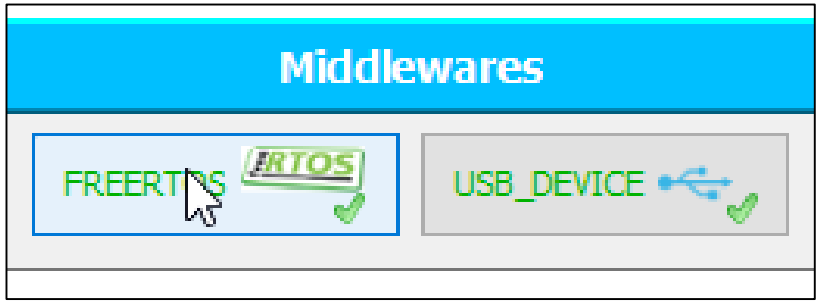
GPIO Pull-Up/Pull-Down

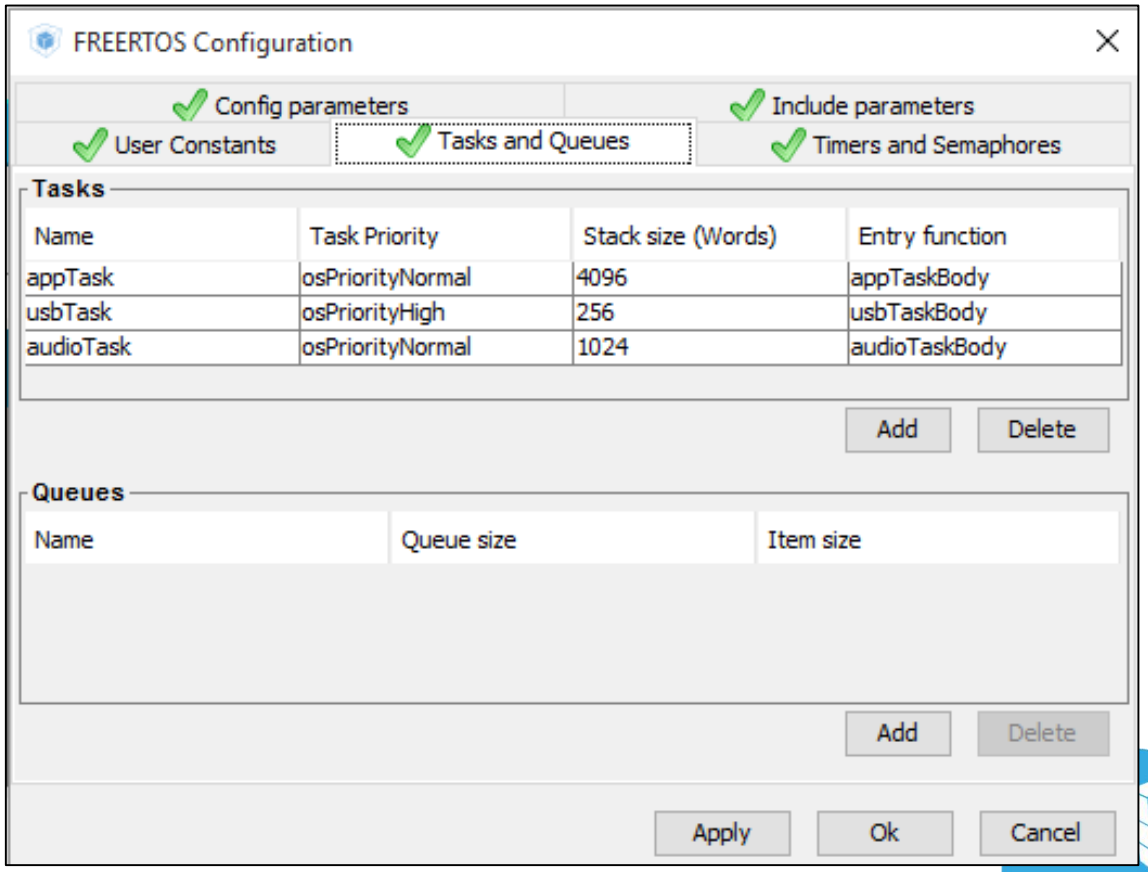
- PA0 → Pull-down
- PA1 → Pull-down
- PA2 → Pull-down
- PA3 → Pull-down
- PA5 → Pull-down

5 Joystick Configuration



Joystick Configuration

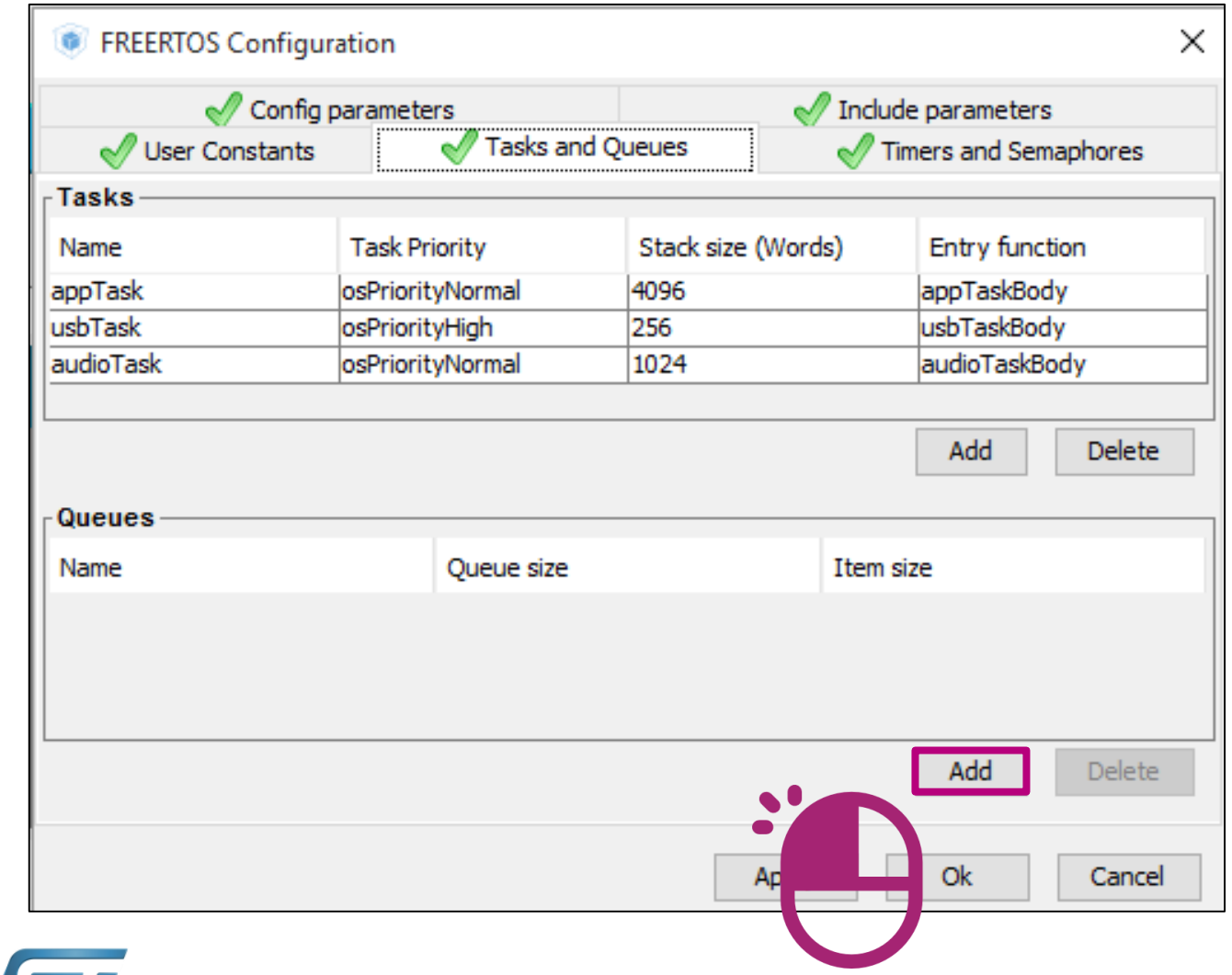


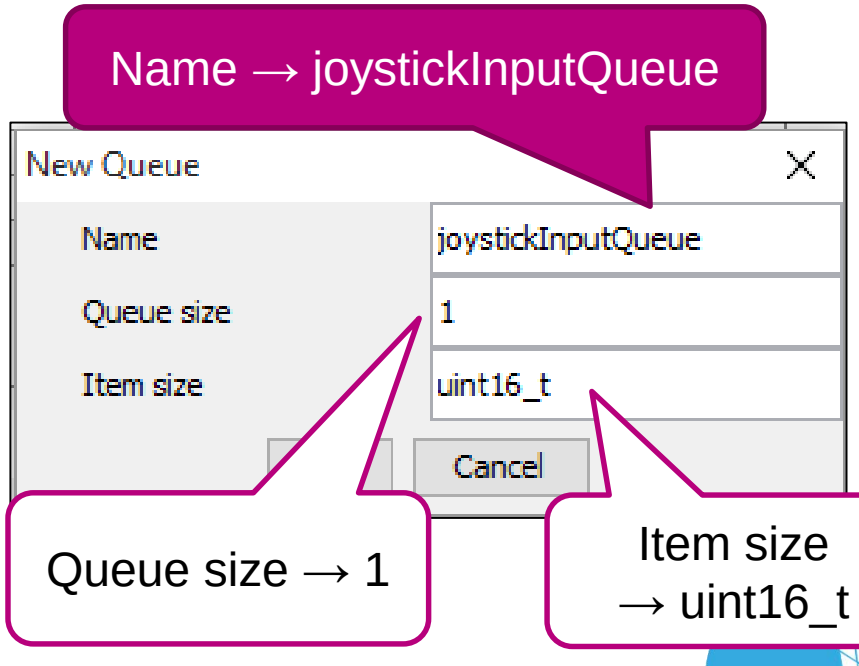


life.augmented

STM32 Cube

Joystick Configuration

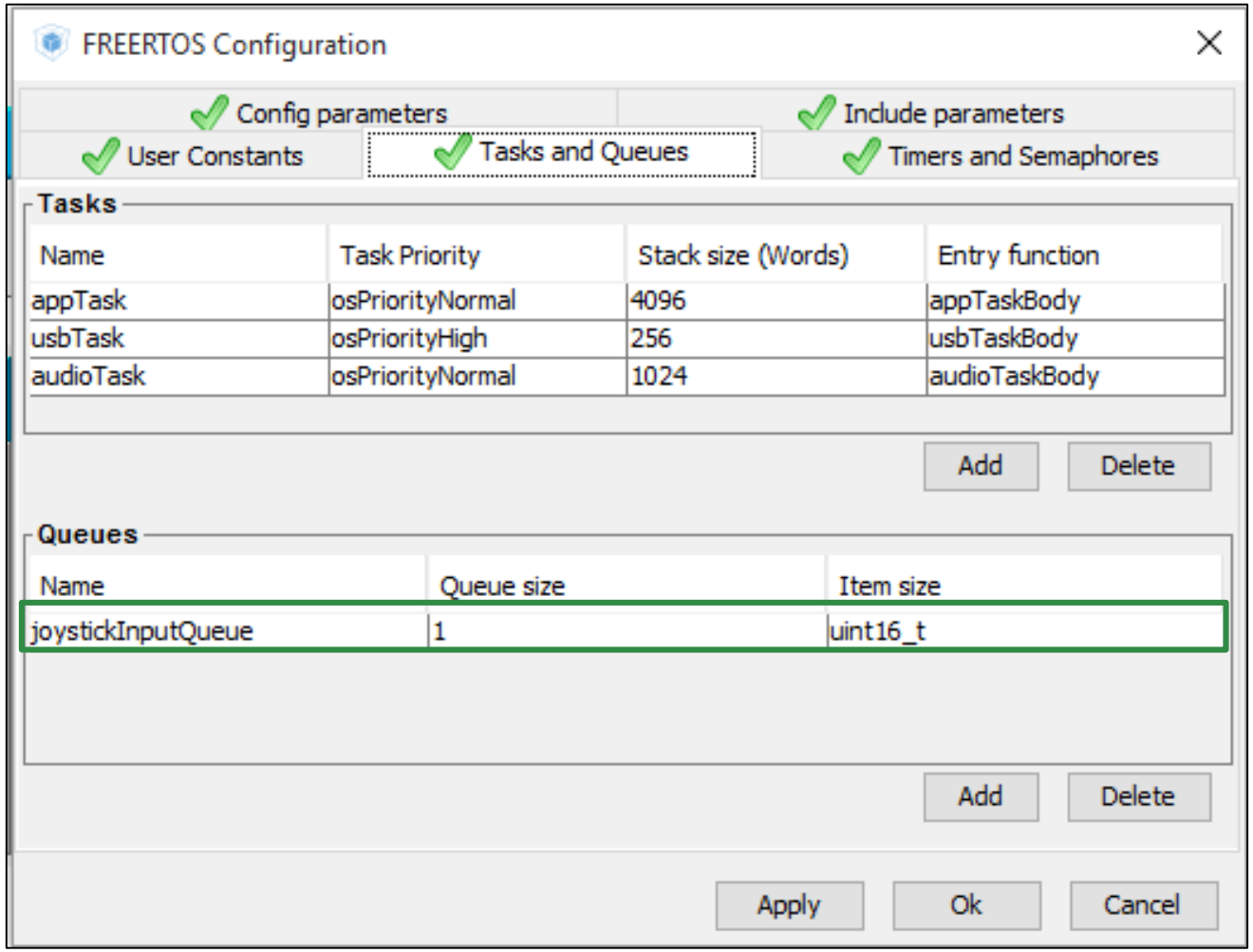


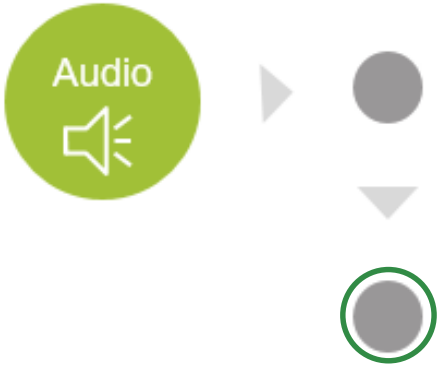


life.augmented

STM32 Cube

Checkpoint #15





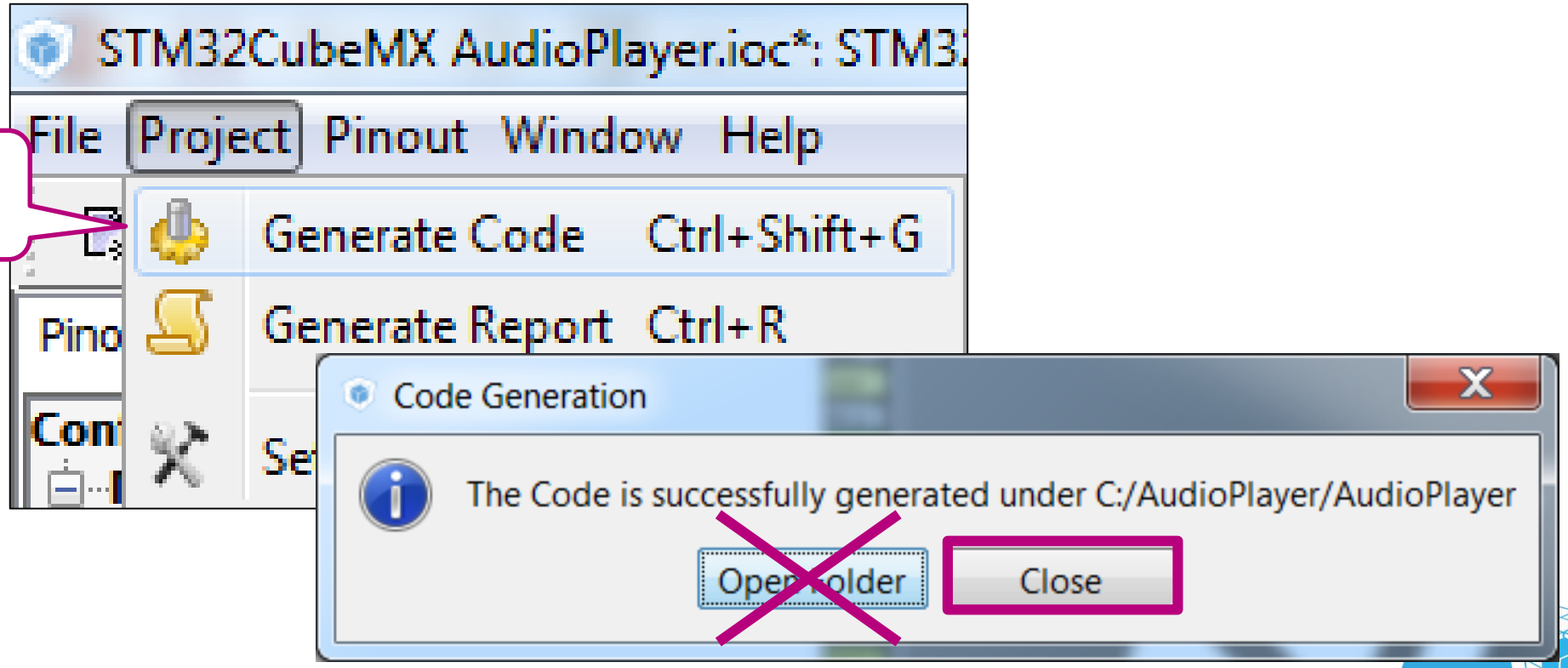
life.augmented

STM32 Cube

5 Save and generate the project

Do not open the project yet

Generate Code
(Ctrl+Shift+G)



5 Apply small patch

- Apply patch from folder
  C:\STM32L4_Workshop\HandsOn\2_Putting_All_Together\Patch\STEP5_ControlInput
  to root folder of your project

  (C:\AudioPlayer\AudioPlayer\)

- It contains the following files:

  .\Src\

  freertos.c

This operation is STM32CubeMX non-intrusive. You can re-generate the project later and the modifications will be retained.

- This operation is STM32CubeMX non-intrusive. You can re-generate the project later and the modifications will be retained.

5

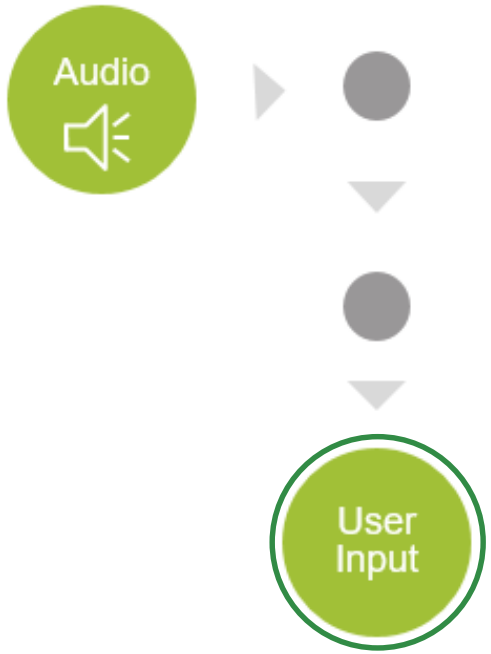
Let’s try it out

1. Open the project

2. Compile and download

3. Press the reset button on discovery once download has finished

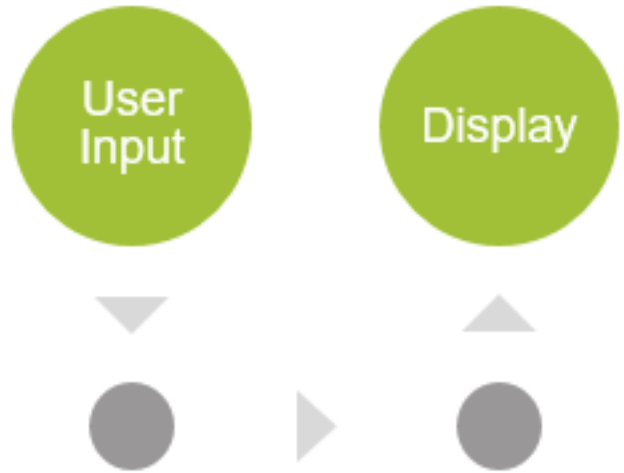
Checkpoint #16



Why Queue?

- Because we want to process just one input event at a time
- We are passing the command (queue item) from the EXTI ISR
- Why not signal?
  - Multiple signals can be set at a time

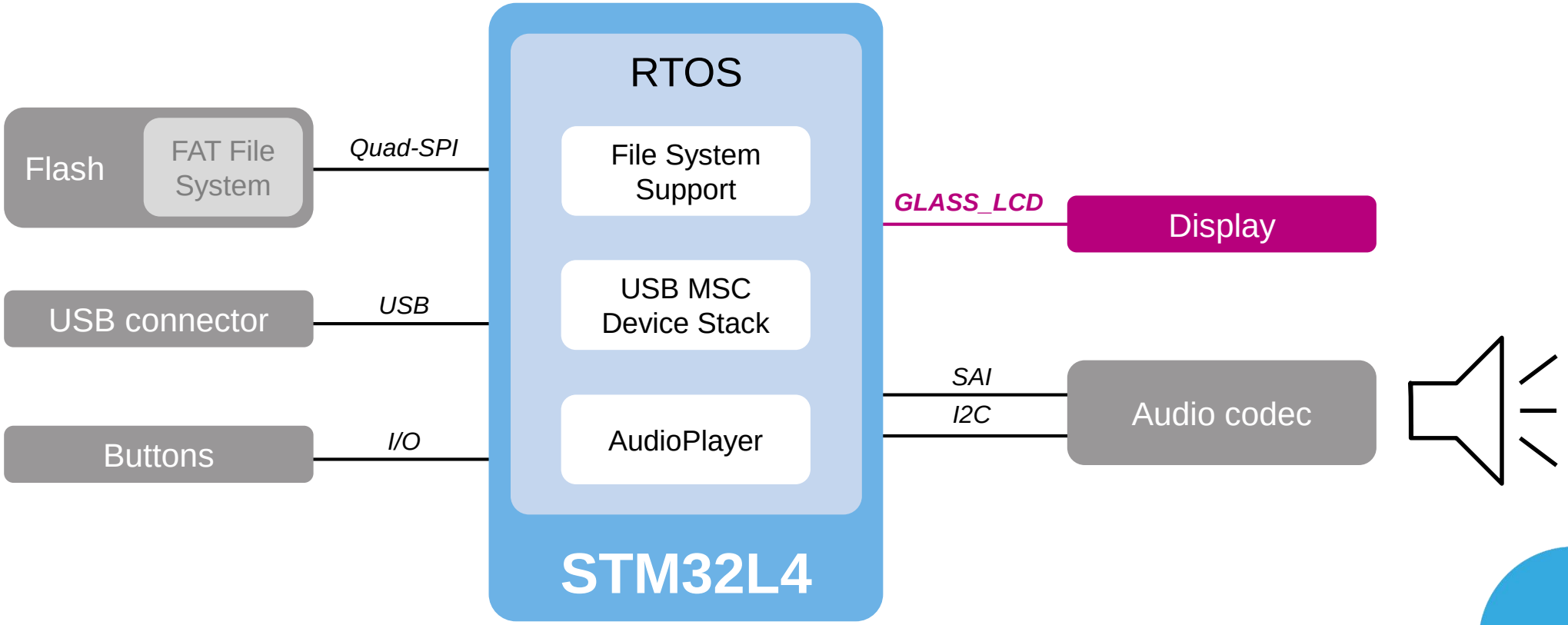
STEP6 – LCD



life.augmented

Adding Display functionality

- We want to see the actual application state
  - like “PLAYING”, “STOPPED”, “PAUSED”

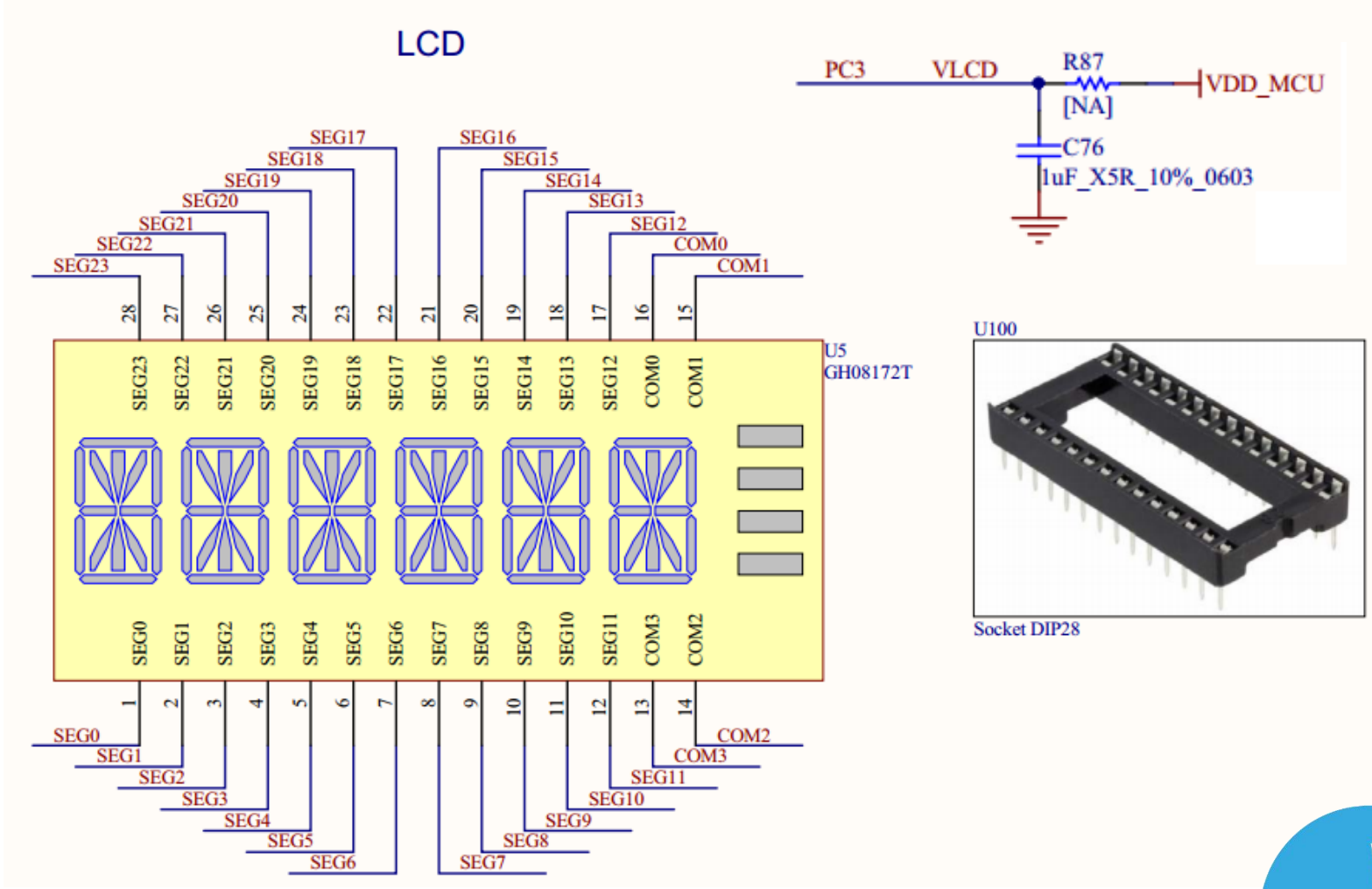


LCD Configuration

PA8	COM0
PA9	COM1
PA10	COM2
PB9	COM3

PA7	SEG0
PC5	SEG1
PB1	SEG2
PB13	SEG3
PB15	SEG4
PD9	SEG5
PD11	SEG6
PD13	SEG7
PD15	SEG8
PC7	SEG9
PA15	SEG10
PB4	SEG11
PB5	SEG12

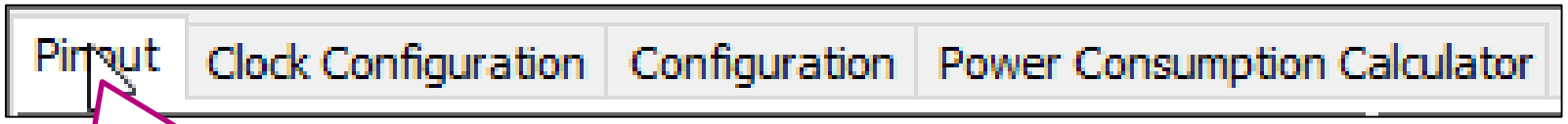
PC8	SEG13
PC6	SEG14
PD14	SEG15
PD12	SEG16
PD10	SEG17
PD8	SEG18
PB14	SEG19
PB12	SEG20
PB0	SEG21
PC4	SEG22
PA6	SEG23



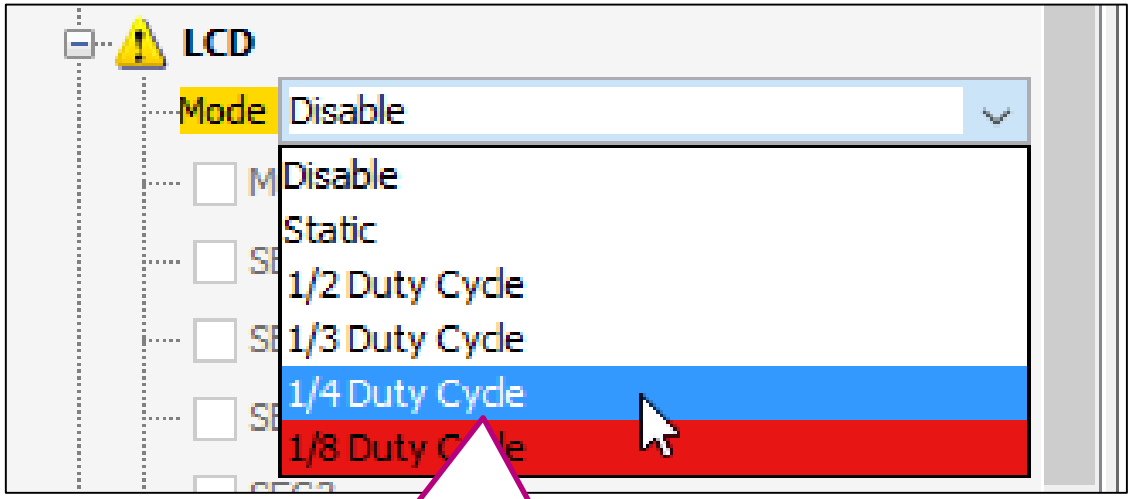
life.augmented

STM32 Cube

6 LCD Configuration

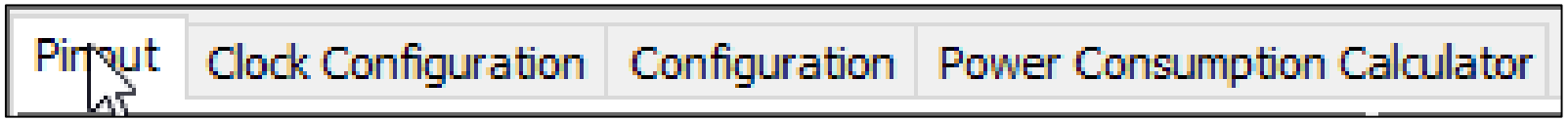


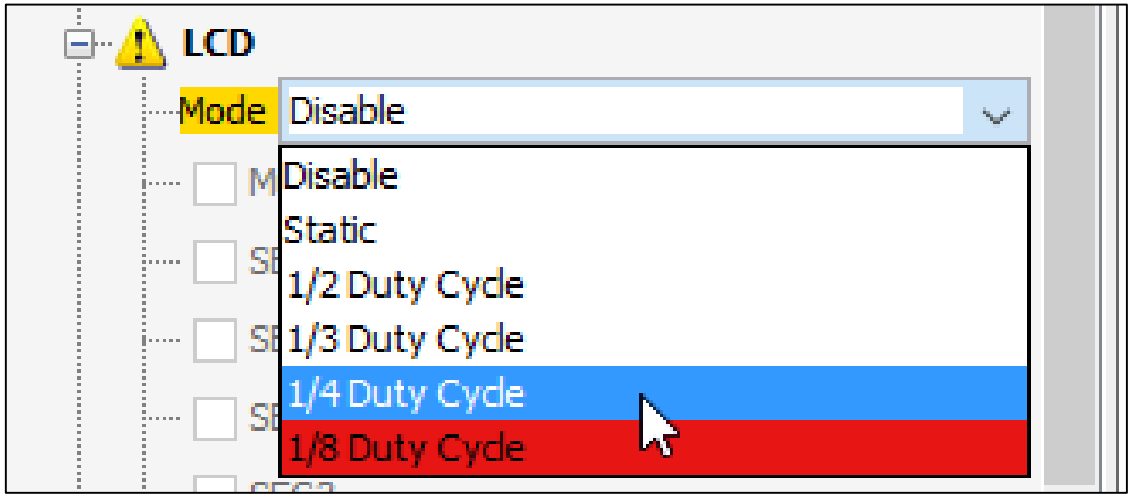
Go to Pinout

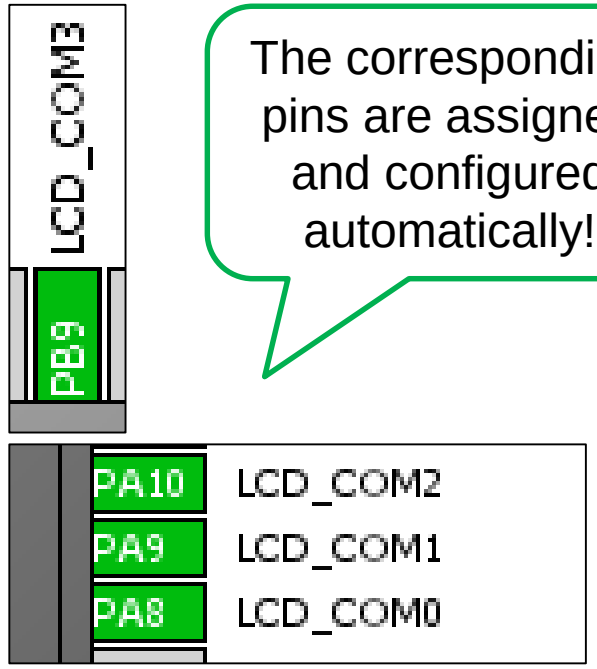


Under LCD peripheral select **1/4 Duty Cycle** mode

6 LCD Configuration







The corresponding pins are assigned and configured automatically!

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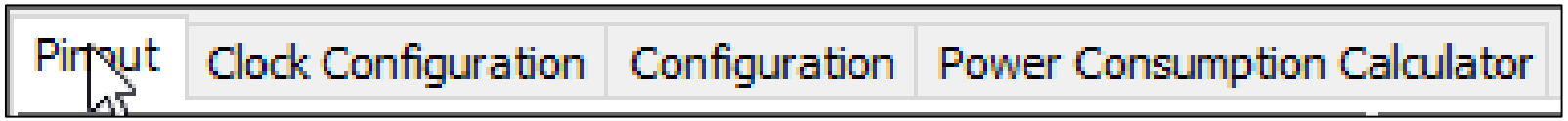
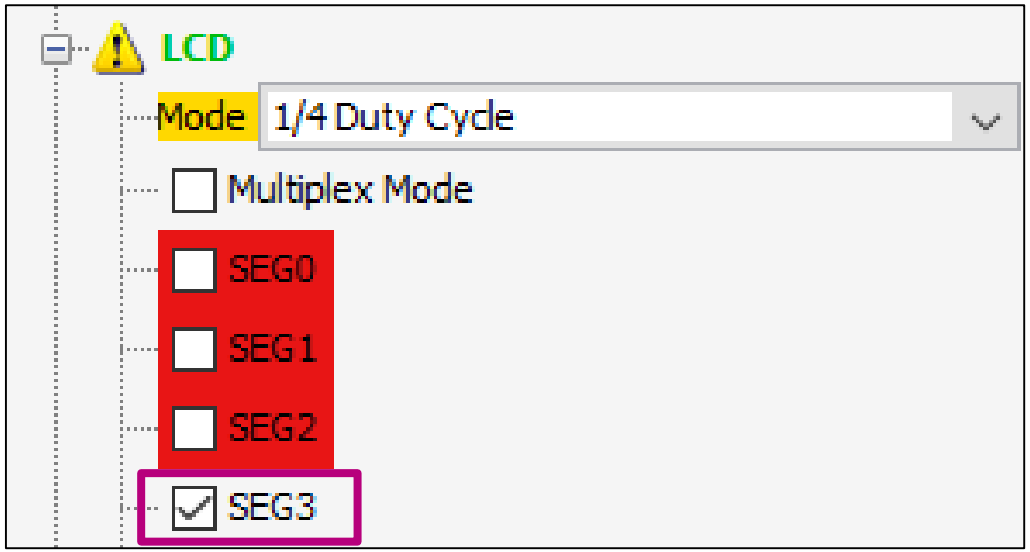
STM32 Cube

6 LCD Configuration





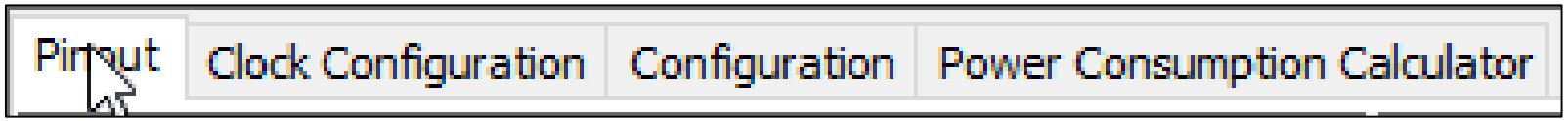
x	3	4	5	6	8	9	12	13	14	15	17	22
	23	24	25	26	28	29	30	31	32	33	34	35

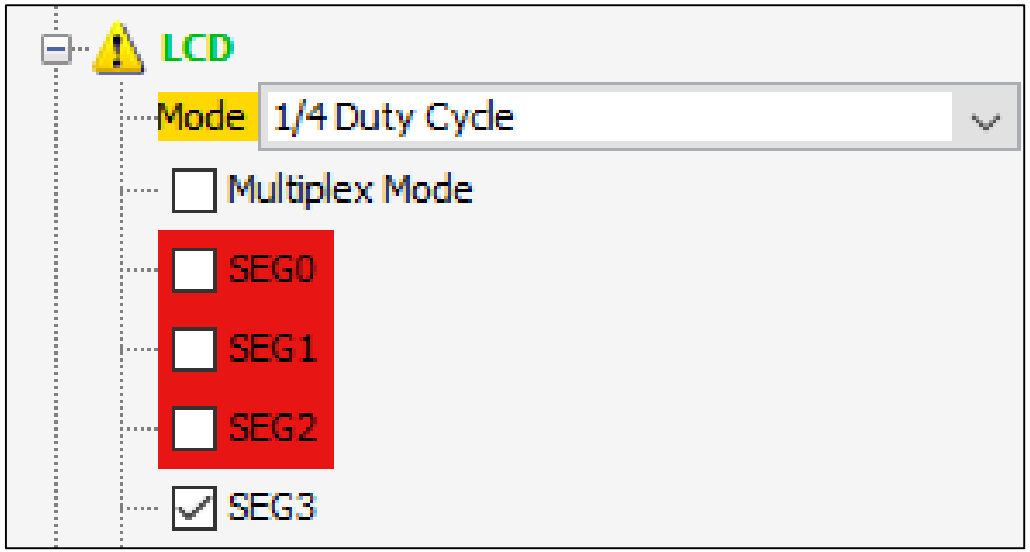
Under LCD peripheral check all the above **SEGx**

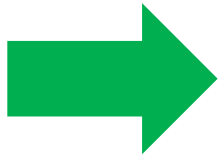
life.augmented

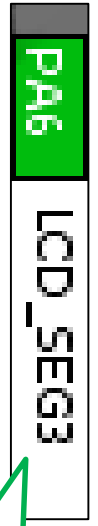
STM32 Cube

LCD Configuration









x	3	4	5	6	8	9	12	13	14	15	17	22
	23	24	25	26	28	29	30	31	32	33	34	35

The corresponding pins are assigned and configured automatically!

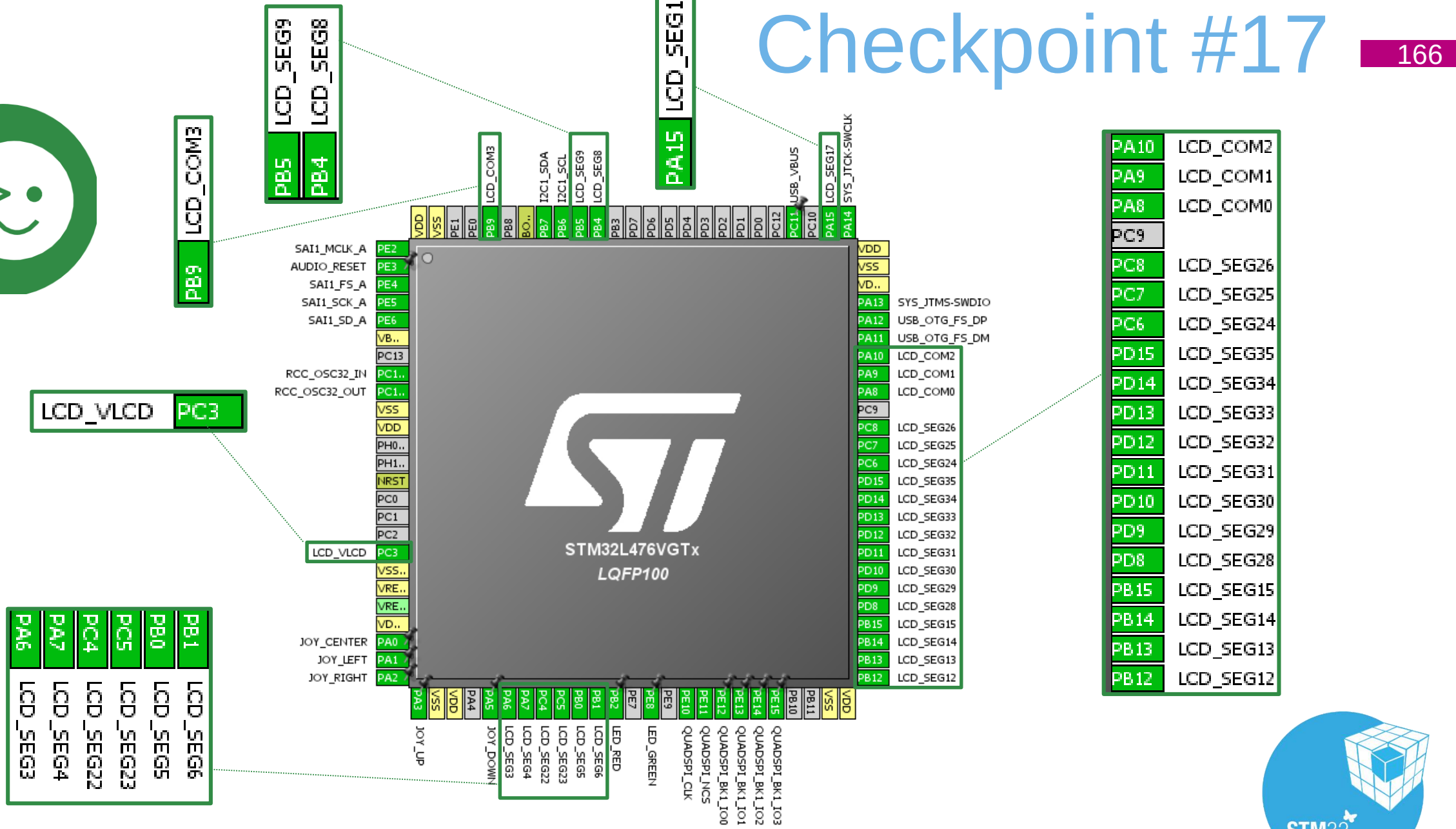
life.augmented

STM32 Cube

6

Checkpoint #17

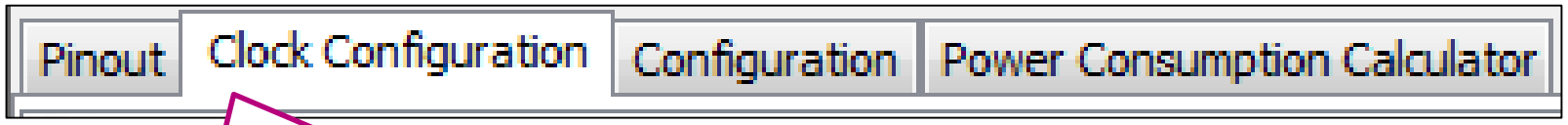
User Input



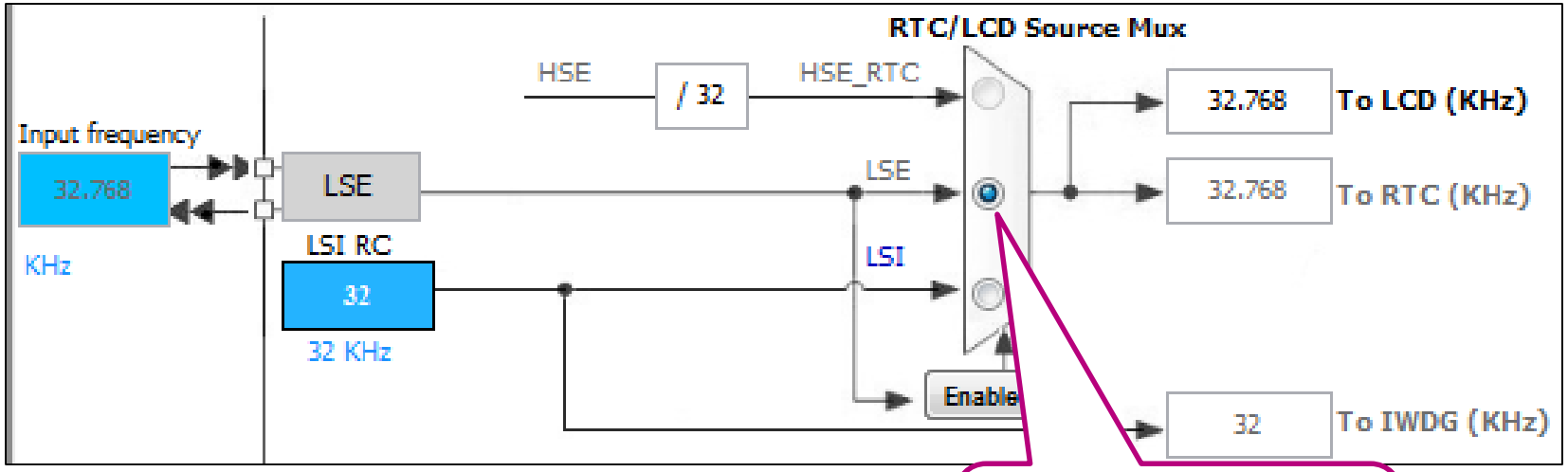
life.augmented

STM32 Cube

LCD Configuration

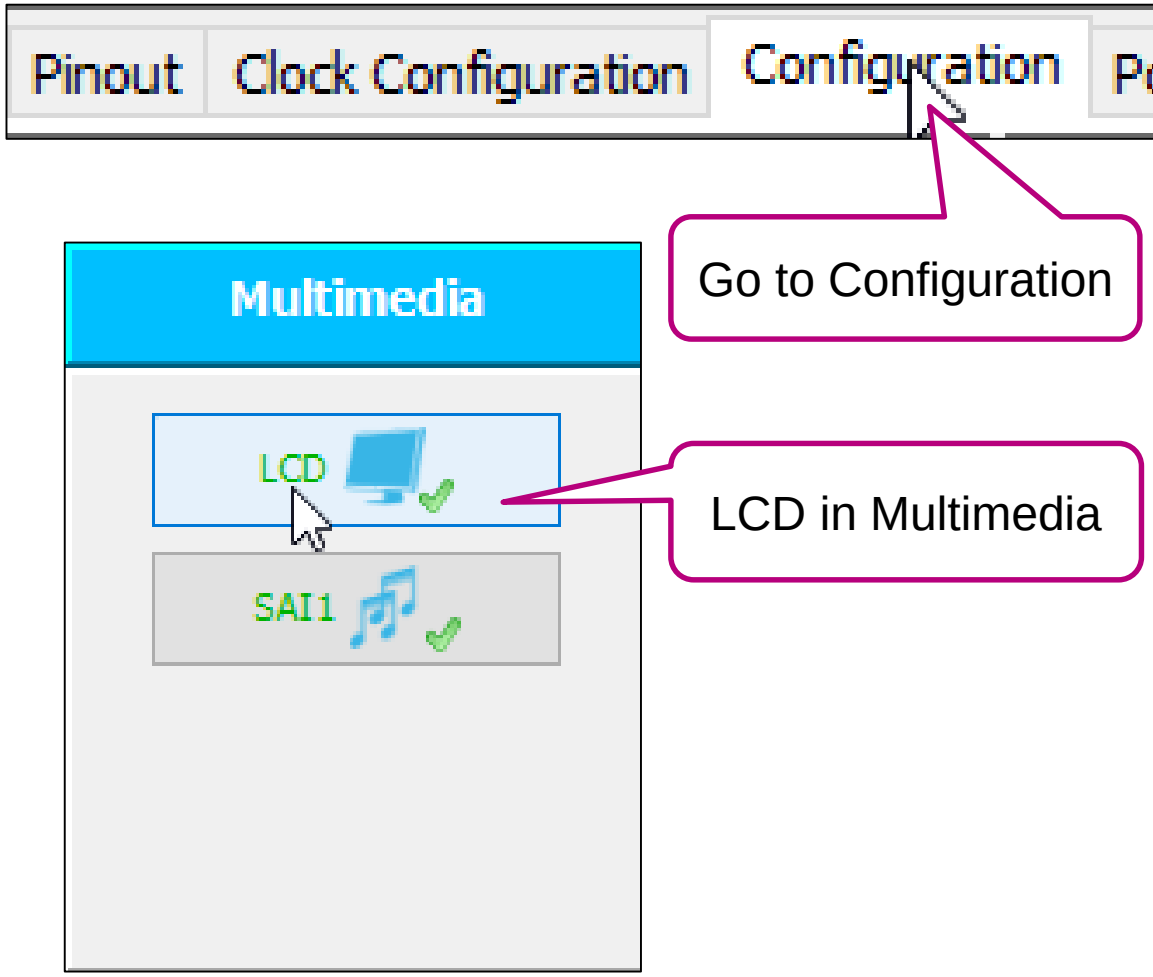


Go to Clock Configuration

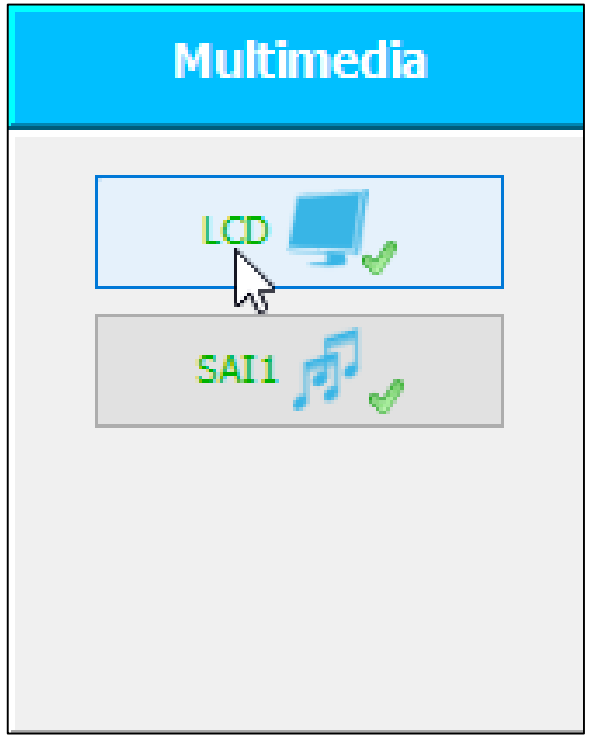


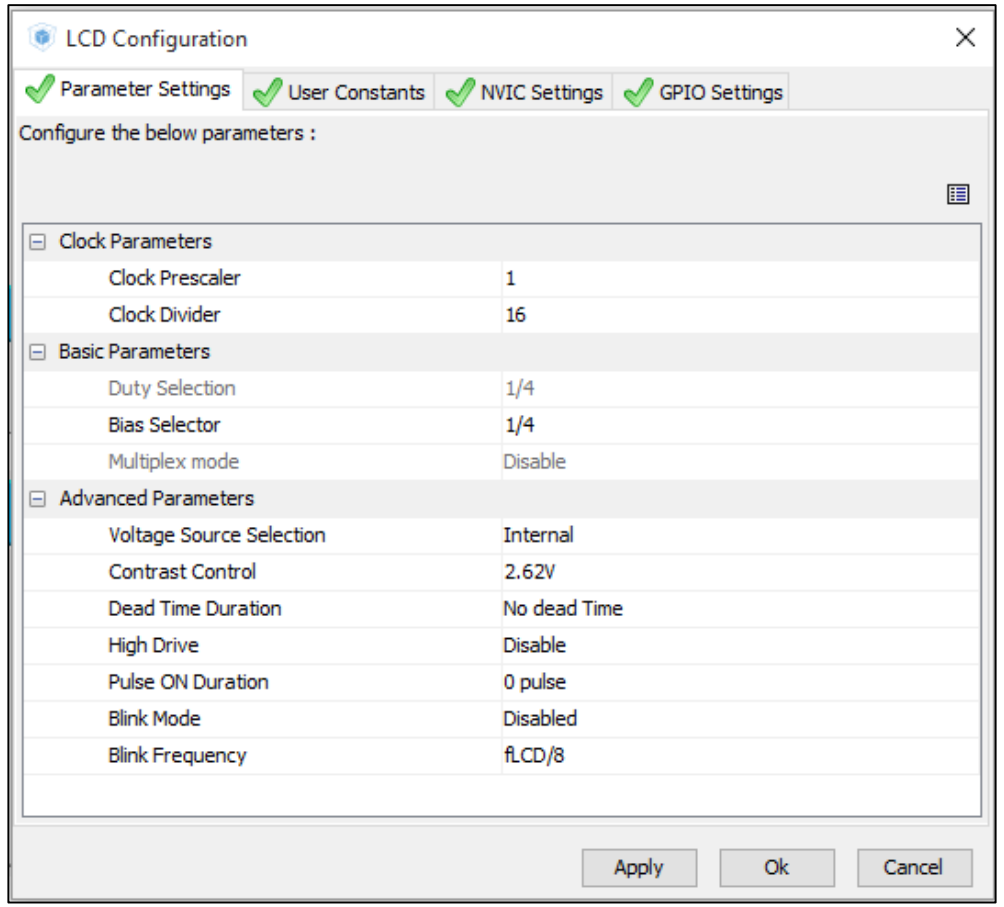
LSE
(RTC/LCD Source Mux)

LCD Configuration



LCD Configuration

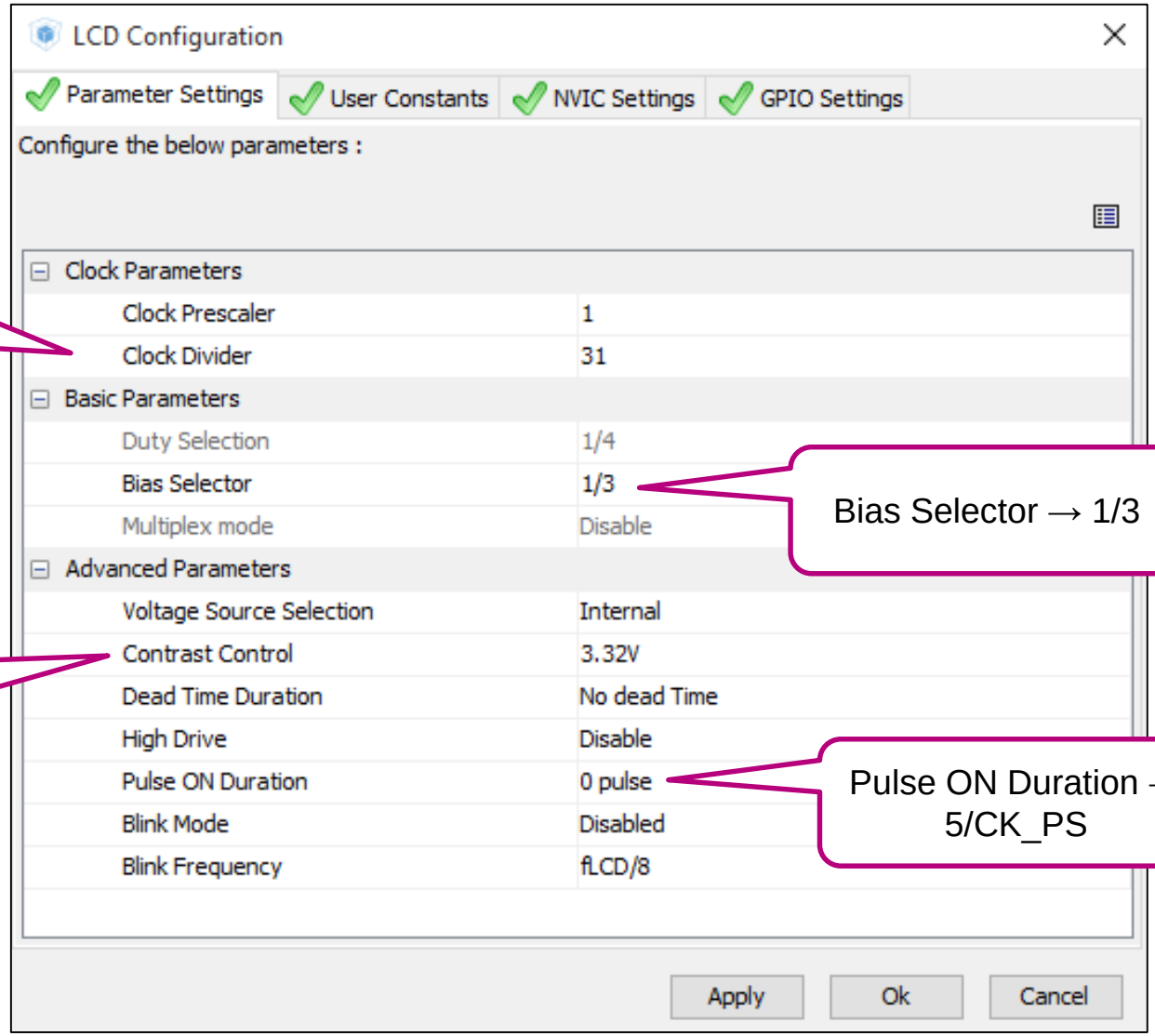




life.augmented

STM32 Cube

LCD Configuration



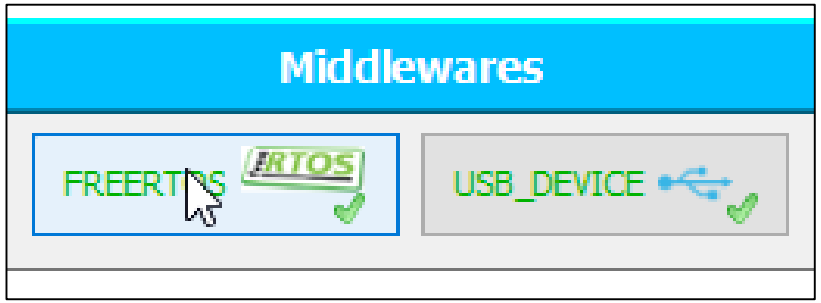
Clock Divider → 31

Contrast Control → 3.32V

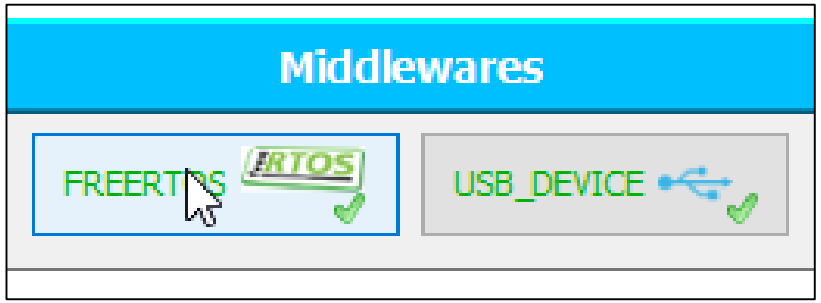
Bias Selector → 1/3

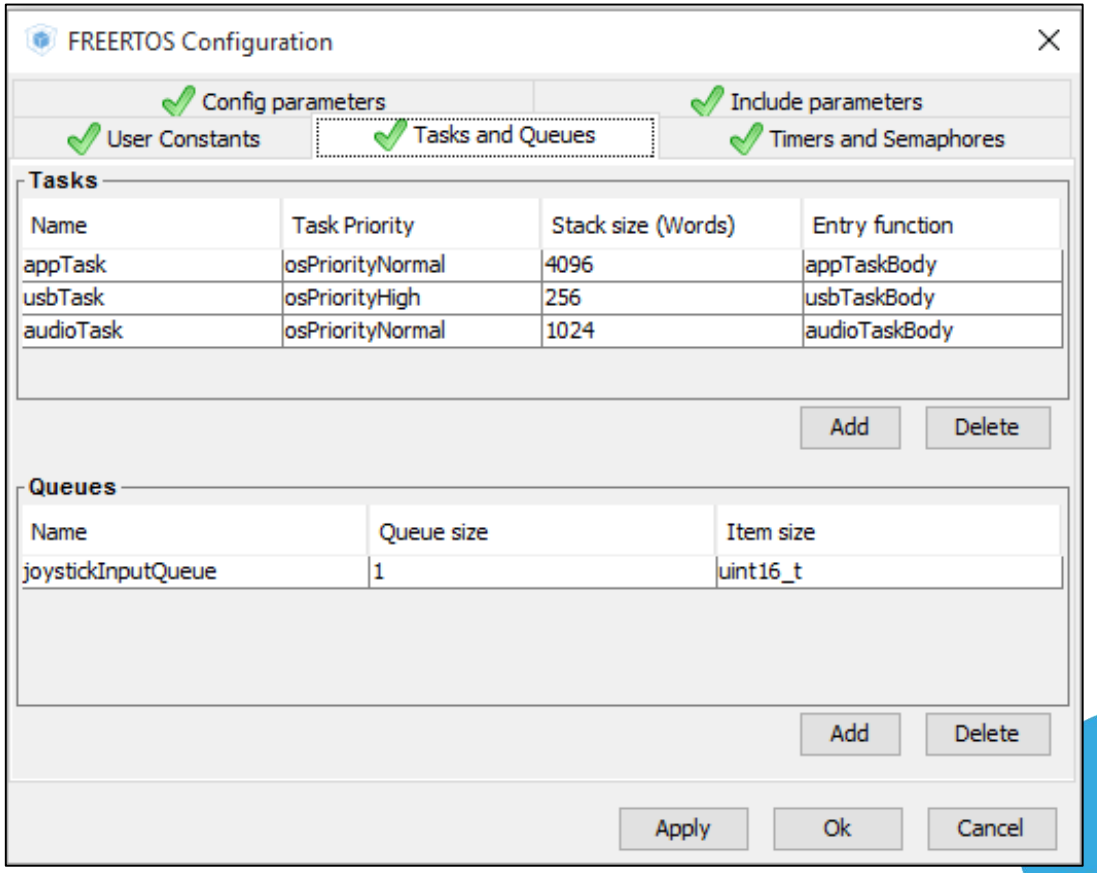
Pulse ON Duration → 5/CK_PS

LCD Configuration

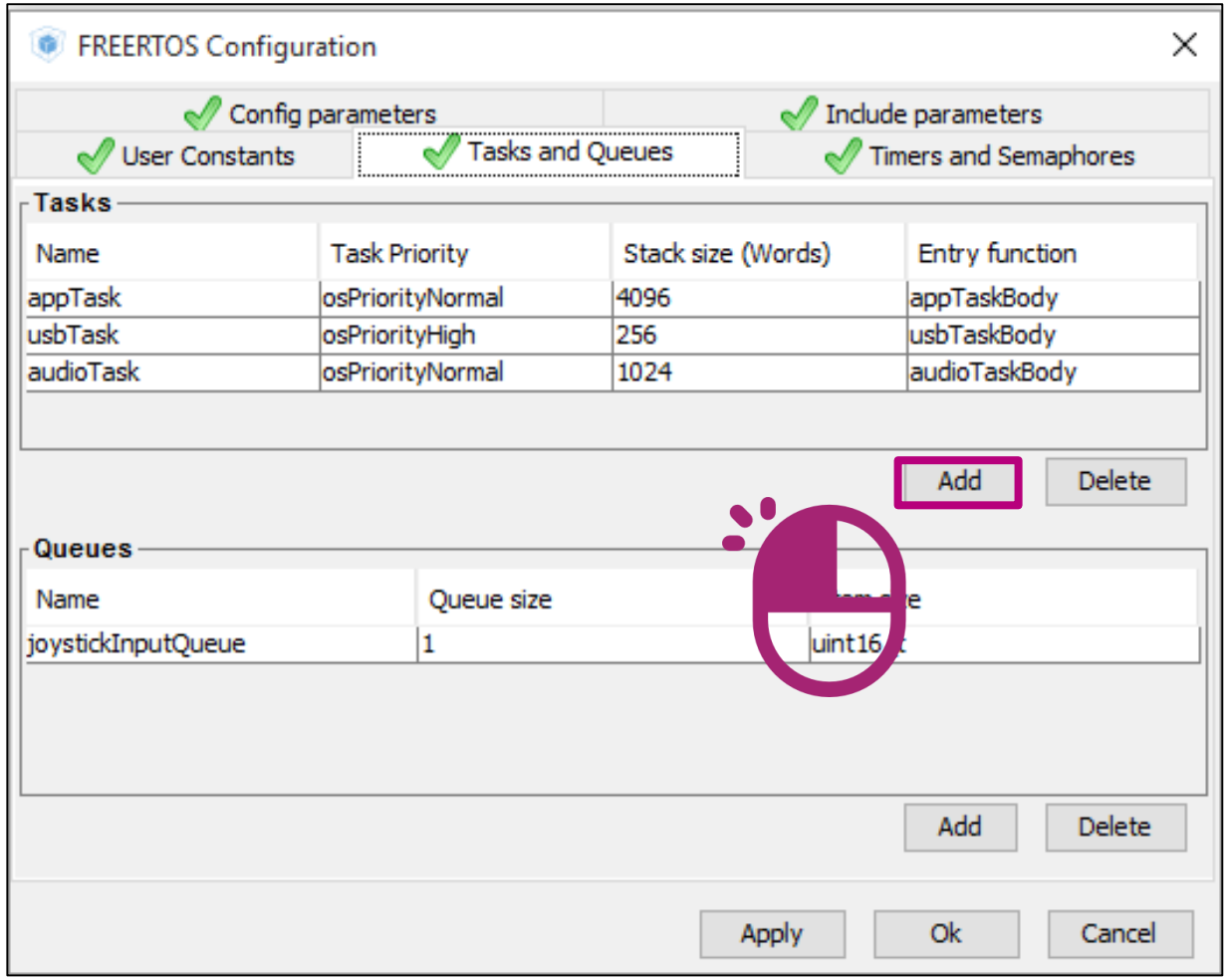


LCD Configuration

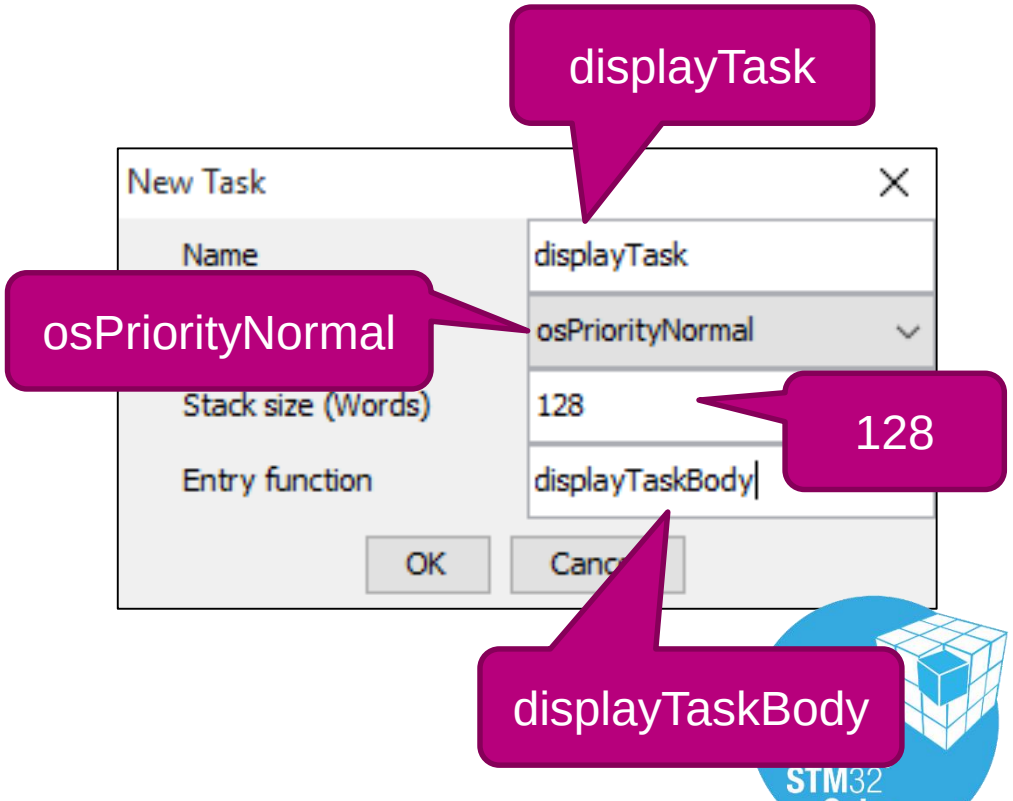




LCD Configuration

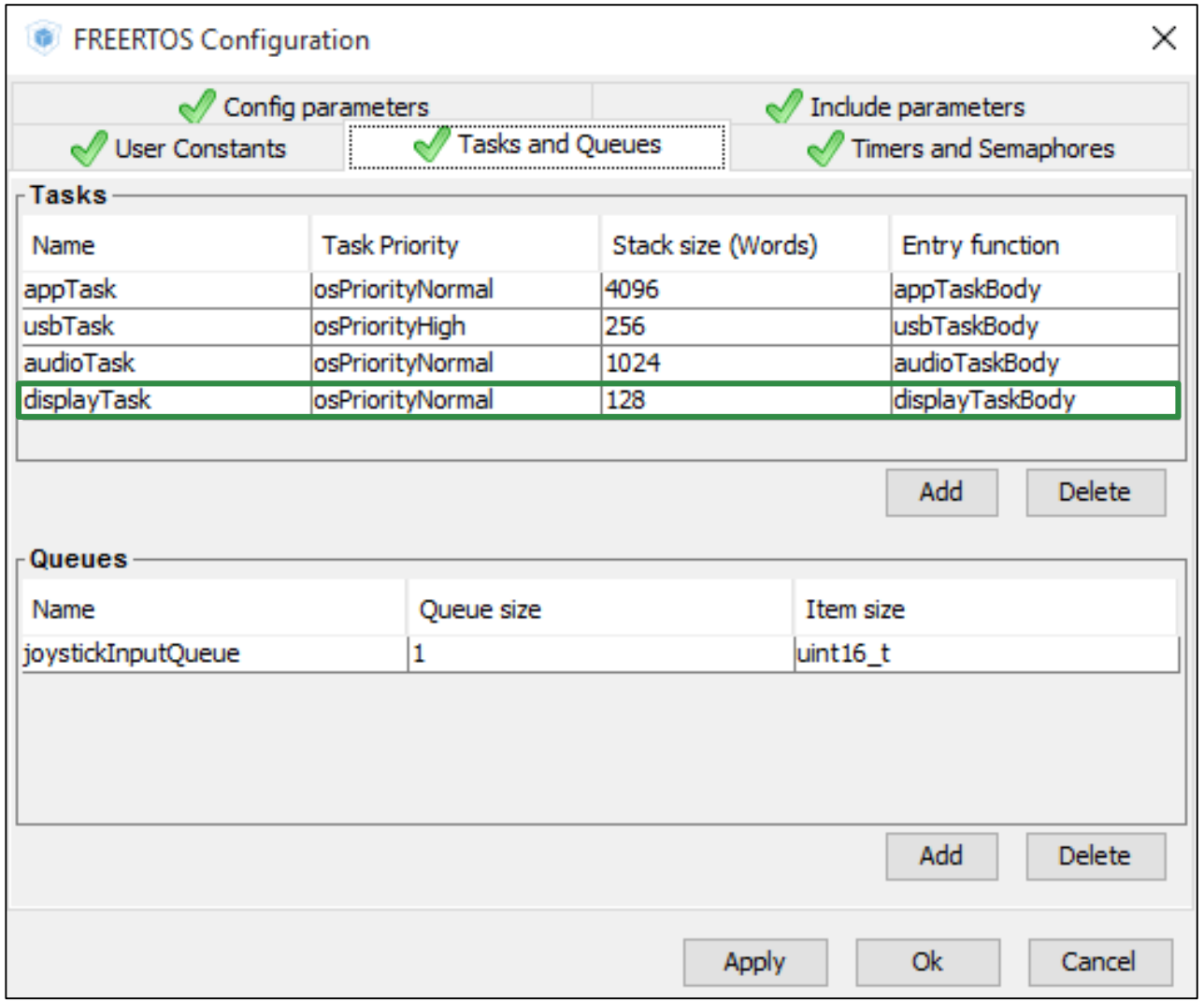


displayTask



Checkpoint #18

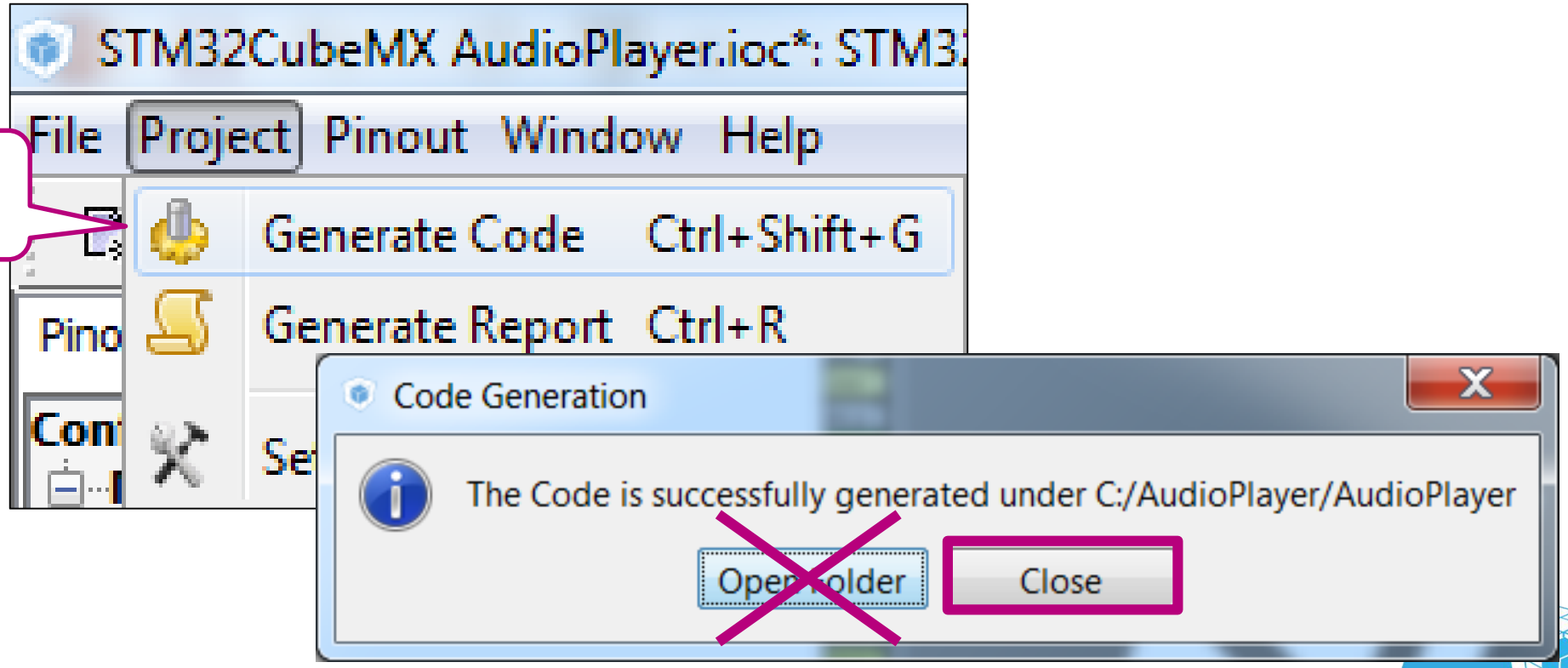
User Input



6 Save and generate the project

Do not open the project yet

Generate Code
(Ctrl+Shift+G)



6 Apply small patch

- Apply patch from folder
  C:\STM32L4_Workshop\HandsOn\2_Putting_All_Together\Patch\STEP6_Display
  to root folder of your project

  (C:\AudioPlayer\AudioPlayer\)

- It contains the following files:

  .\Inc\

  lcd.h

  .\Src\

  freertos.c

  lcd.c

This operation is STM32CubeMX non-intrusive. You can re-generate the project later and the modifications will be retained.

- These files contains the main needed source code the user has to add to work with the particular glass LCD available on the STM32L4 discovery kits

lcd.c content

- lcd.c

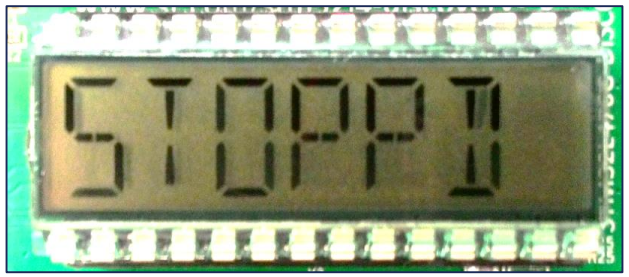
```
LCD_GLASS_Clear(void);
LCD_GLASS_DisplayString(…);
```

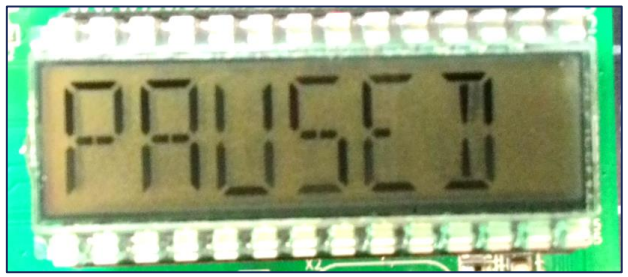

Based on BSP driver in STM32CubeL4 HAL

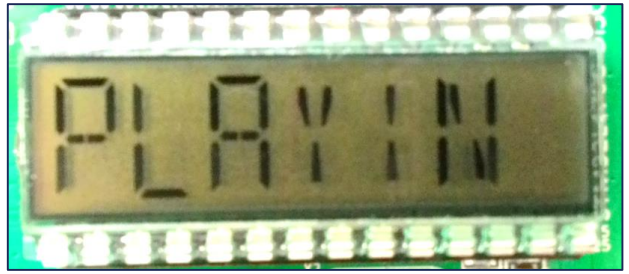
6 Let’s try it out

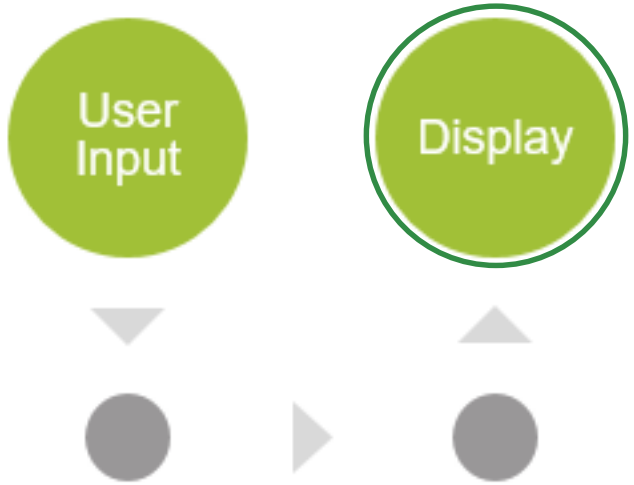
1. Open the project
2. Compile and download
3. Press the reset button on discovery once download has finished

Checkpoint #19









Why new Thread?

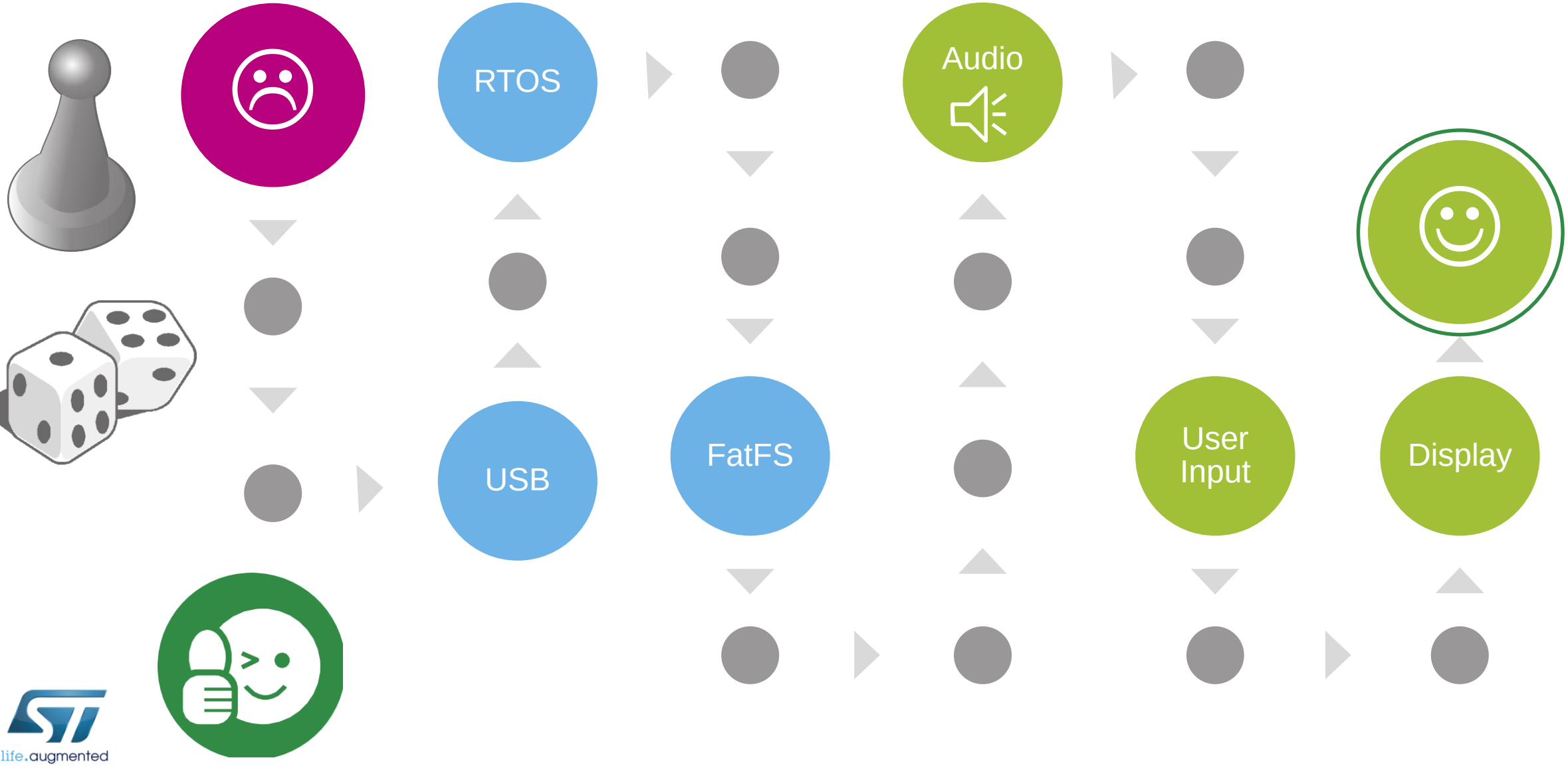
Because it can run completely independent on the other threads in the application

- You can implement previous state change checking mechanism

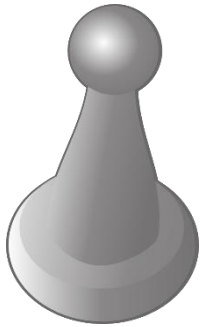
EXAMPLE USE-CASE

You may want to add animations or blinking segments with changing refresh rate related to the timeout variable used as argument of the osDelay(…) call.

Finish



What you have learned?



RTOS

USB

FatFS

Audio

User Input

Display

life.augmented

Enjoy!

www.st.com/stm32l4