

# *FreeRTOS for STM32*

## *Step 1*

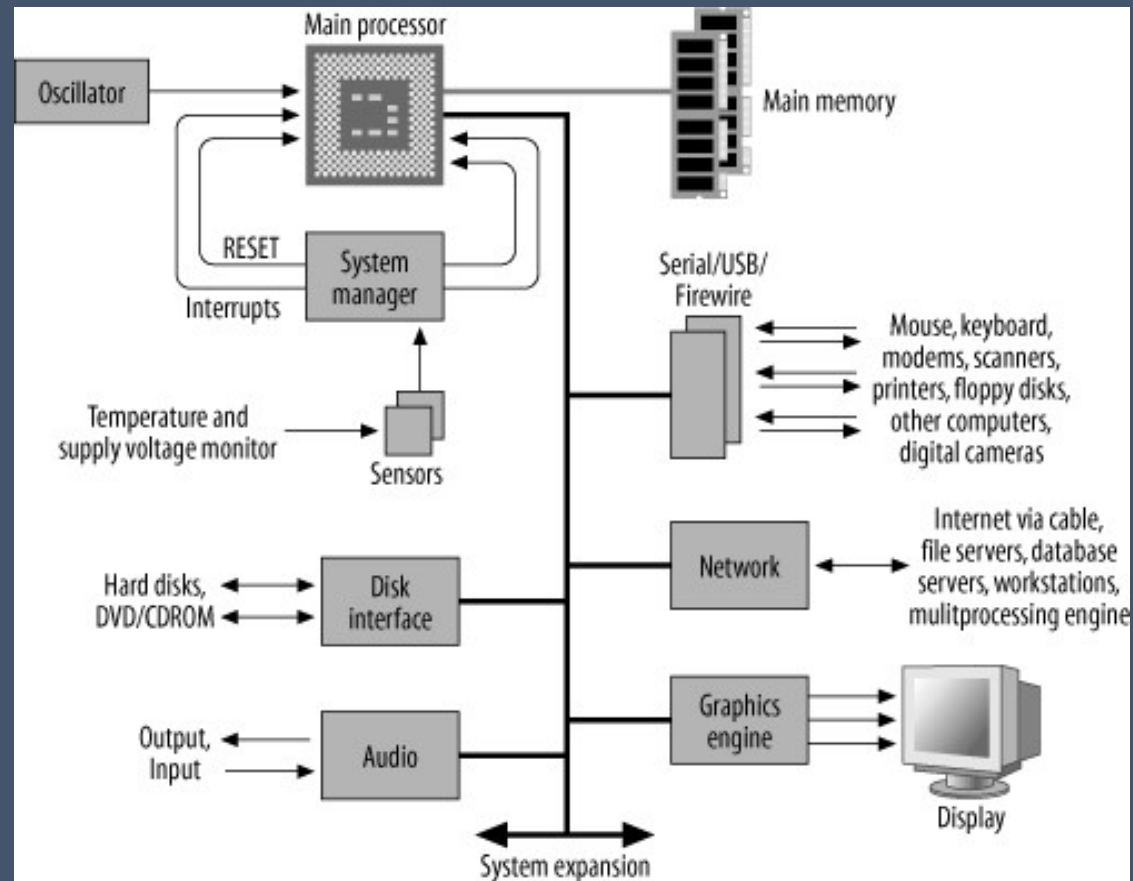
회사소개

CodeZoo

[www.CodeZoo.co.kr](http://www.CodeZoo.co.kr)

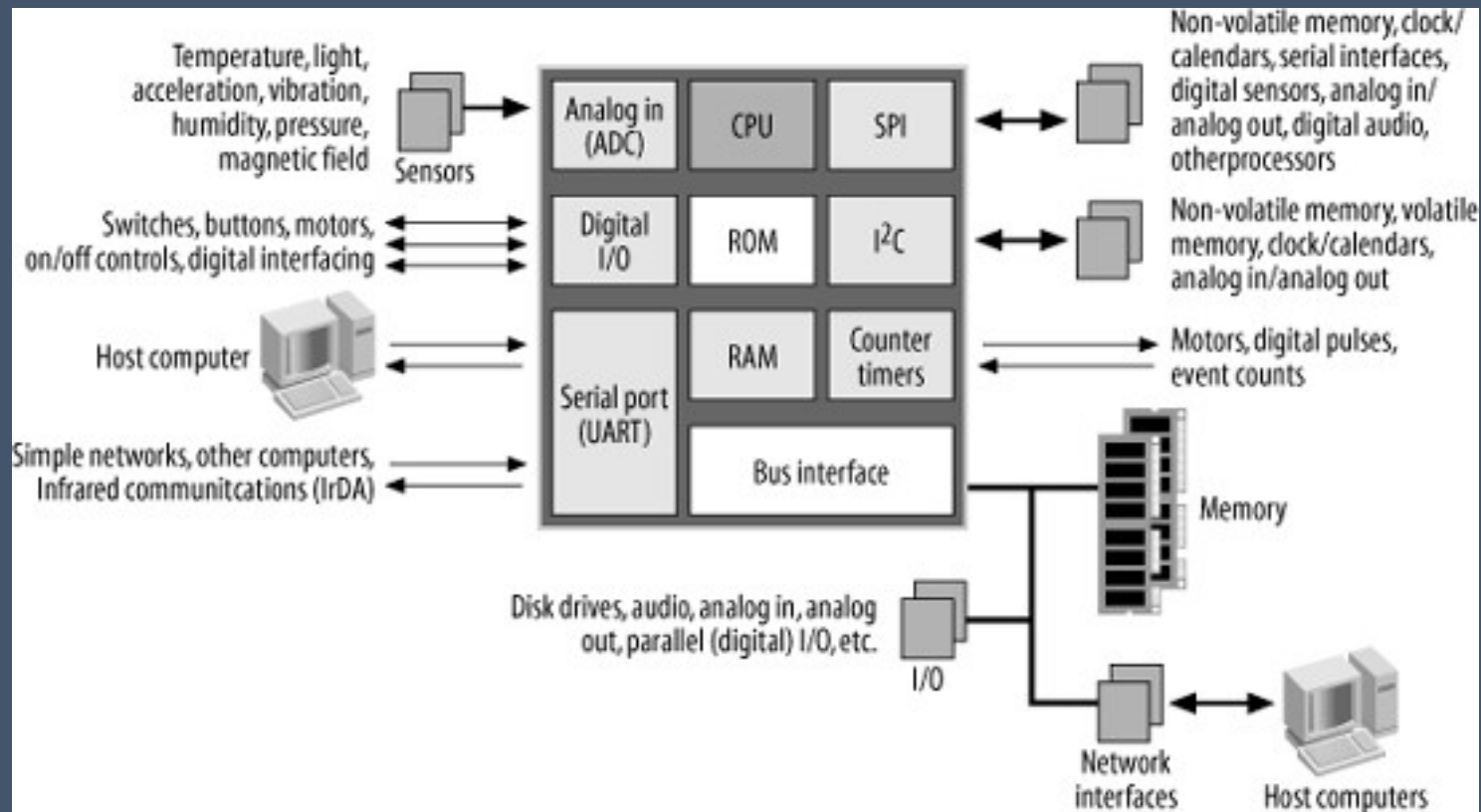
# PC 하드웨어

PC(Personal Computer)



# 임베디드 시스템 하드웨어

## Embedded System



# ARM

## ARM Holdings

영국의 반도체 회사

- 프로세서를 설계하고 라이선싱
- 소프트웨어 개발 도구 설계 및 판매(케일 등)

## ARM Architecture

RISC 프로세서

Joint venture between  
Acorn Computers and Apple



1990

Designed into first mobile  
phones and then smartphones



1993 onwards

Now all electronic devices can  
use smart Arm technology



Today

# ARM Core

## Cortex-A

Highest performance

Optimized for  
high-level operating  
systems



## Cortex-R

Fast response

Optimized for  
high performance,  
hard real-time  
applications



## Cortex-M

Smallest/lowest power

Optimized for  
discrete processing  
and  
microcontrollers





# ARM Core

## ARM TRUSTZONE

System Security

## ARM ARTISAN

Physical IP

## ARM MALI

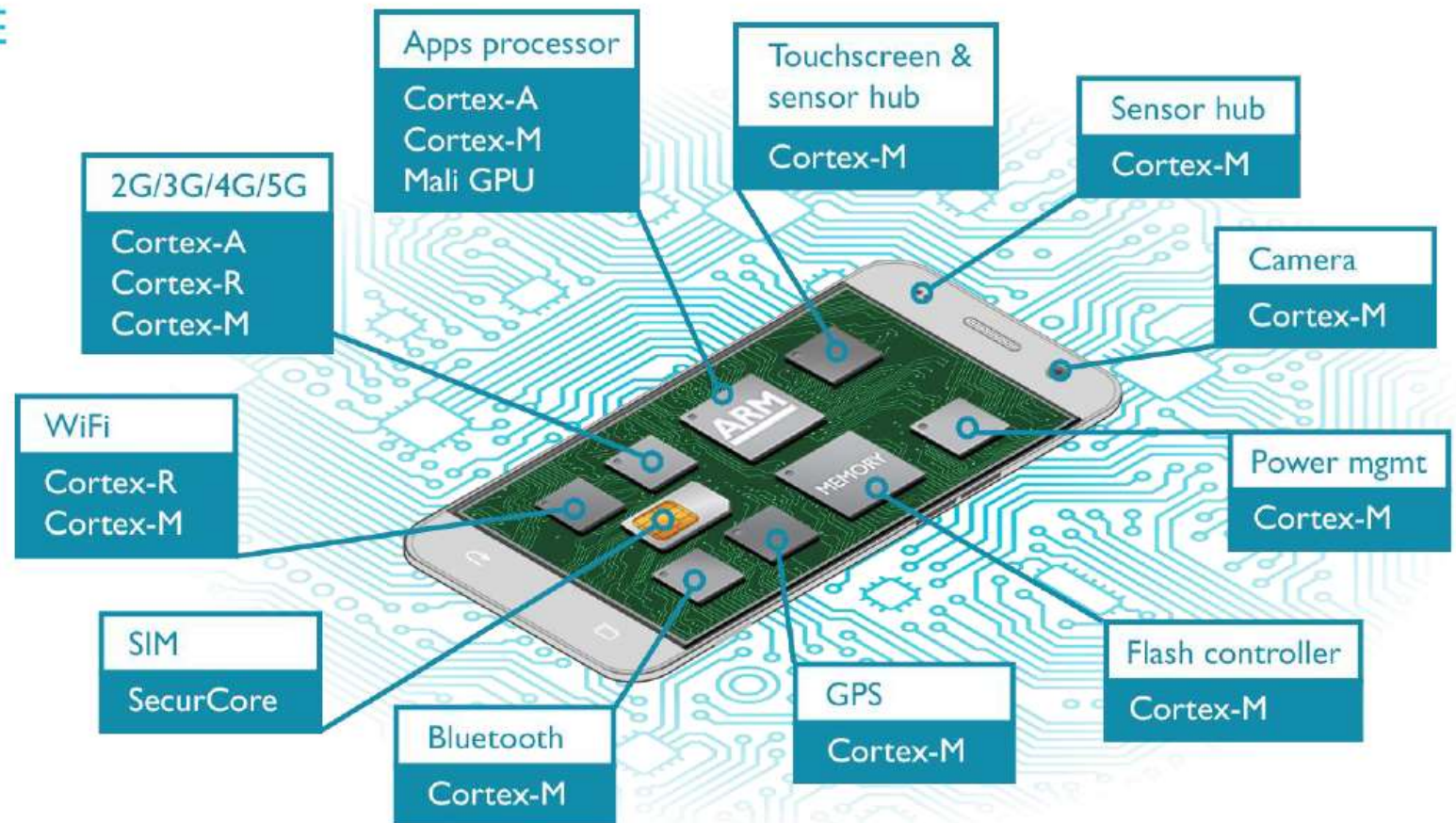
Visual Technology

## ARM CORTEX

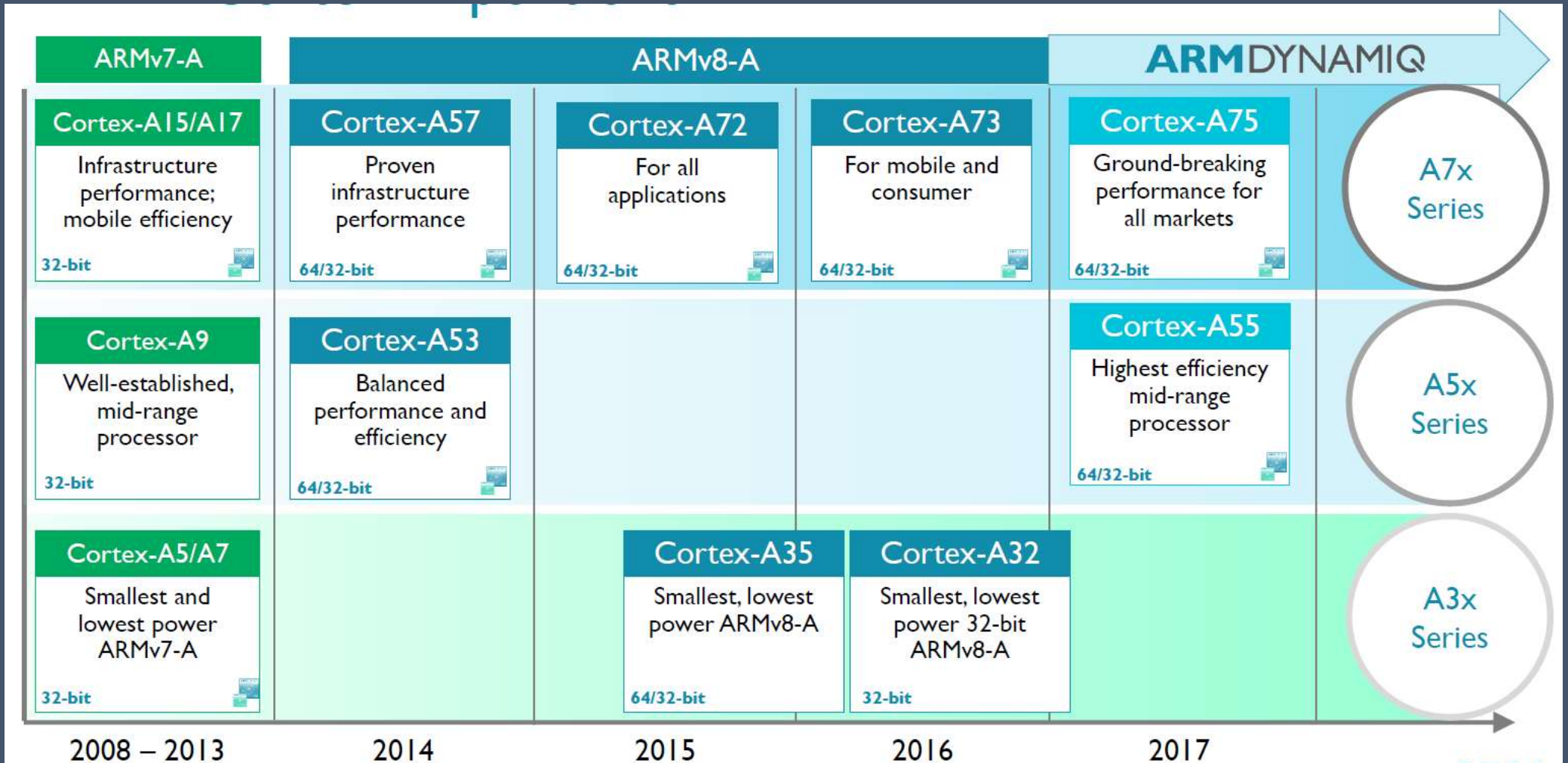
Processor Technology

## ARM CORELINK

Processor System IP

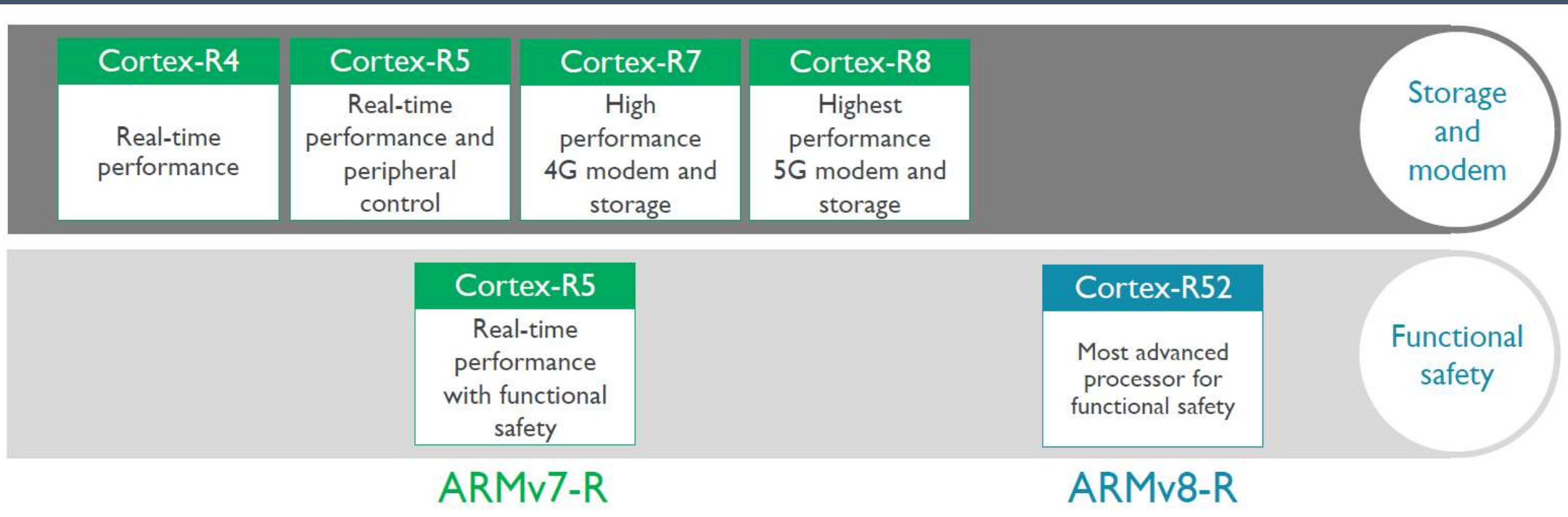


# ARM Core

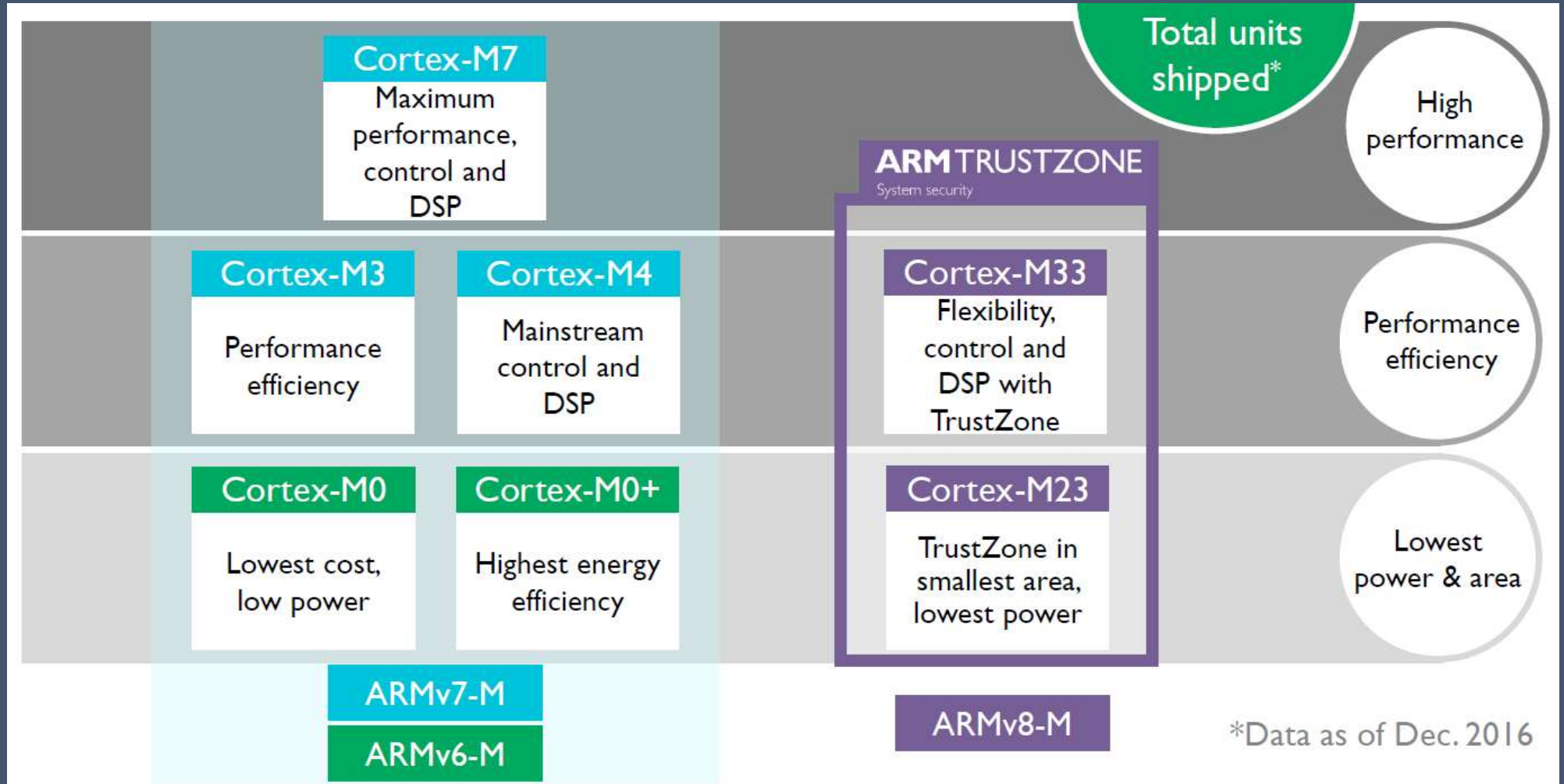




# ARM Core



# ARM Core



# ARM Core

	Cortex-A	Cortex-R	Cortex-M
설계	고주파 클럭, 긴 파이프 라인, 고성능, 멀티 미디어 지원 (NEON 명령어 세트 확장)	고주파 클럭, 중간에서 긴 길이의 파이프 라인, 확정적 (저지연 인터럽트)	보통 더 짧은 파이프라인, 초저전력, 확정적 (저지연 인터럽트)
시스템 기능	메모리 관리 장치(MMU), 캐시 메모리, ARM TrustZone 보안 확장	메모리 보호 장치(MPU), 캐시 메모리, 밀착 결합 메모리(Tightly Coupled Memory)	메모리 보호 장치(MPU), 중첩 벡터형 인터럽트 컨트롤러(NVIC), 웨이크업 인터럽트 컨트롤러(WIC), 최신 ARM TrustZone 보안 기능 확장
용도	모바일 컴퓨팅, 스마트폰, 에너지 효율 서버, 하이엔드 마이크로프로세서	산업용 마이크로컨트롤러, 자동차, 하드디스크 컨트롤러, 베이스밴드 모뎀	마이크로컨트롤러, 심층 임베디드(Deeply embedded) 시스템 (예: 센서, MEMS, 혼합 신호 IC), 사물인터넷 (IoT)

# Cortex-M

프로세스	설 명
Cortex-M0	저비용, 초저전력 마이크로컨트롤러 및 고도의 임베디드 애플리케이션용 초소형 프로세서(12K 게이트에서 시작)
Cortex-M0+	소형 임베디드 시스템을 위한 최고 수준의 에너지 효율 프로세서. Cortex-M0 프로세서와 비슷한 크기와 프로그래머 모델이지만 단일 사이클 I/O 인터페이스와 벡터 테이블 재배치등 추가 기능이 포함되어 있다.
Cortex-M1	FPGA 설계에 최적화된 소형 프로세서 설계이며 FPGA의 메모리 블록을 통해 밀착 결합 메모리(Tightly Coupled Memory)를 구현한다. Cortex-M0과 동일한 명령어 세트
Cortex-M3	복잡한 작업을 보다 신속하게 처리할 수 있도록 많은 명령어가 설정된 저전력 마이크로 컨트롤러를 위한 작지만 강력한 임베디드 프로세서. 하드웨어 디바이더(Hardware Divider)와 Multiply-Accumulate(MAC) 명령어를 탑재하고 있다. 이와 함께 소프트웨어 개발자가 애플리케이션을 더 빠르게 개발할 수 있도록 포괄적인 디버그 및 추적 기능을 지원한다.
Cortex-M4	이 프로세서는 Cortex-M3의 모든 기능을 제공하며, Single Instruction Multiple Data(SIMD)와 보다 빠른 단일 사이클 MAC 연산과 같은 디지털 신호 처리(Digital Signal Processing) 작업에서 추가 명령어 대상을 제공한다. 또한 IEEE 754 부동 소수점 표준을 지원하는 단정도(Single Precision) 부동 소수점 유닛 (옵션)도 제공한다.
Cortex-M7	하이엔드 마이크로컨트롤러 및 프로세싱 집약적인 애플리케이션용 고성능 프로세서. Cortex-M4에서 사용할 수 있는 모든 ISA 기능과 캐시 및 밀착 결합 메모리(Tightly Coupled Memory)와 같은 추가 메모리 기능뿐만 아니라 배정도(double precision) 부동 소수점을 위한 추가 지원을 제공한다.
Cortex-M23	초저전력과 저비용 설계용으로 설계된 소형 프로세서로 Cortex-M0+ 프로세서와 비슷하지만 명령어 세트 및 시스템 수준의 기능이 다양하게 향상됐다. 이와 함께 TrustZone 보안 기능 확장을 지원한다.
Cortex-M33	기존 Cortex-M3및 Cortex-M4 프로세서와 비슷하지만 더욱 향상된 유연성을 갖춘 시스템 설계와 보다 나은 에너지 효율성과 성능을 제공하는 주류 프로세서 설계. 또한 이 프로세서는 TrustZone 보안 확장을 지원한다.

# Cortex-M

Architecture	설 명
ARMv6-M	Cortex-M0, Cortex-M0+ 및 Cortex-M1 프로세서용.
ARMv7-M	Cortex-M3, Cortex-M4 및 Cortex-M7 프로세서용. DSP 유형의 명령어 (예: SIMD)를 지원하기 위한 ARMv7-M의 확장은 ARMv7E-M으로 명명된다.
ARMv8-M	이 아키텍처 릴리스는 다음과 같이 나뉘어진다. Cortex-M23 프로세서용 Baseline 서브 프로파일 Cortex-M33 프로세서용 Mainline 서브 프로파일

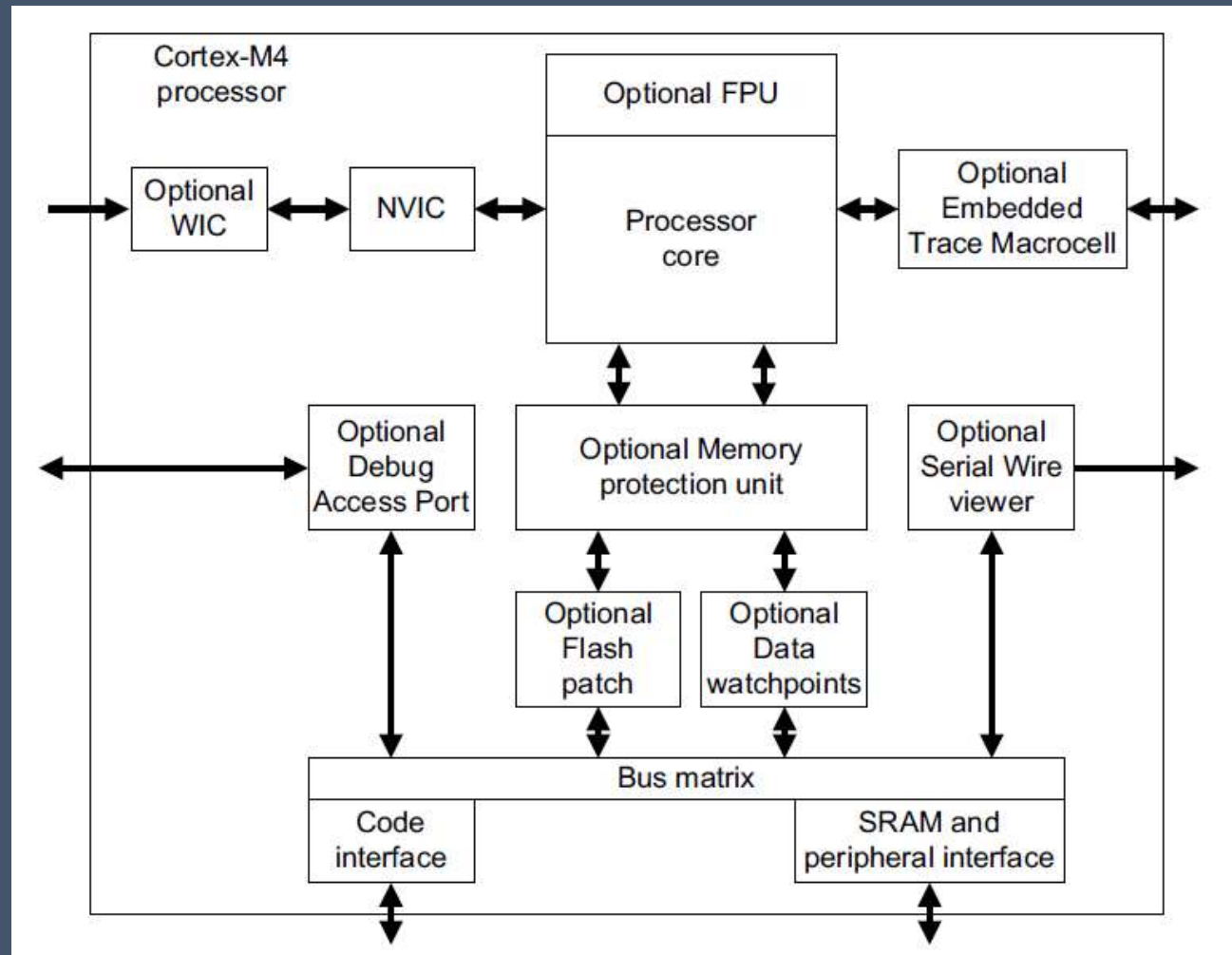




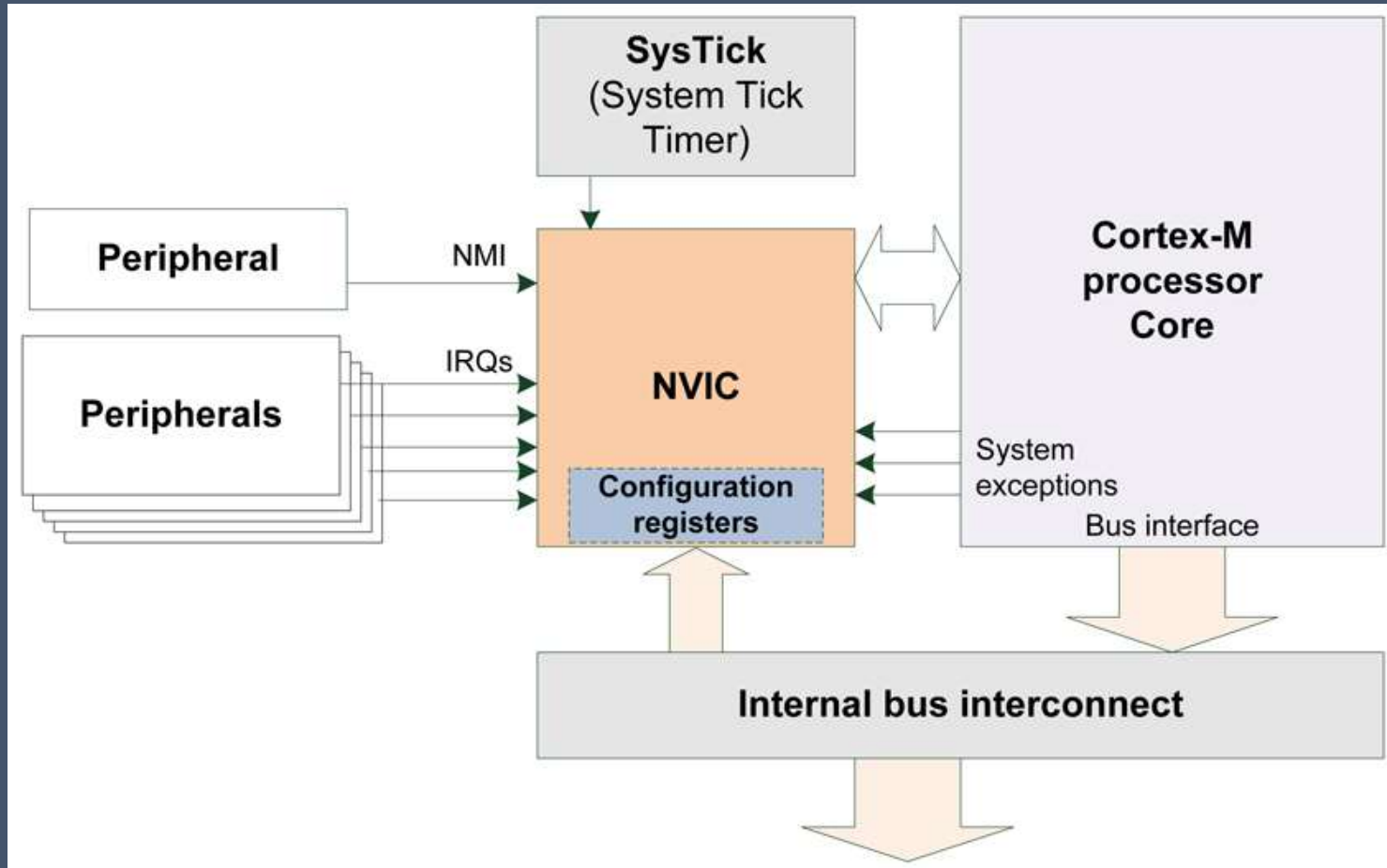
## Command Set



# Cortex-M



# Cortex-M



# Cortex-M

Exception Type	ARMv6-M (Cortex-M0/M0+/M1)	ARMv7-M (Cortex-M3/M4/M7)	ARMv8-M Baseline (Cortex-M23)	ARMv8-M Mainline (Cortex-M33)	Vector Table	Vector address offset (initial)
495		Not supported in Cortex-M3/M4/M7	Not supported in Cortex-M23		Interrupt#479 vector	1 0x000007BC
256						
255					Interrupt#239 vector	1 0x000003FC
				Device Specific Interrupts		
31	Device Specific Interrupts	Device Specific Interrupts	Device Specific Interrupts		Interrupt#31 vector	1 0x000000BC
17						
16					Interrupt#1 vector	1 0x00000044
15	SysTick	SysTick	SysTick	SysTick	Interrupt#0 vector	1 0x00000040
14	PendSV	PendSV	PendSV	PendSV	SysTick vector	1 0x0000003C
13	Not used	Not used	Not used	Not used	PendSV vector	1 0x00000038
12		Debug Monitor		Debug Monitor	Not used	0x00000034
11	SVC	SVC	SVC	SVC	Debug Monitor vector	1 0x00000030
10					SVC vector	1 0x0000002C
9		Not used		Not used	Not used	0x00000028
8					Not used	0x00000024
7	Not used		Not used	SecureFault	Not used	0x00000020
6		Usage Fault		Usage Fault	SecureFault (ARMv8-M Mainline)	1 0x0000001C
5		Bus Fault		Bus Fault	Usage Fault vector	1 0x00000018
4		MemManage (fault)		MemManage (fault)	Bus Fault vector	1 0x00000014
3	HardFault	HardFault	HardFault	HardFault	MemManage vector	1 0x00000010
2	NMI	NMI	NMI	NMI	HardFault vector	1 0x0000000C
1					NMI vector	1 0x00000008
0					Reset vector	1 0x00000004
					MSP initial value	0x00000000



# Cortex-M



# STM32

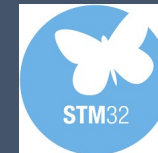
## STMicroelectronics

스위스 제네바에 본사를 둔 전자제품과 반도체를 생산하는 기업







## STM32

32-bit ARM Cortex-m processor core를 사용하는 STMicroelectronics에서 생산하는 Microcontroller 제품군






# STM32





## High-performance

STM32H7 series – High performance with DSP, Double-precision FPU, JPEG Codec and Chrom-ART Accelerator™										
400 MHz Cortex-M7 L1-Cache	Up to 2-Mbyte dual-bank Flash	Up to 1-Mbyte SRAM	2x USB 2.0 OTG FS/HS	2x 16-bit advanced MC timer HR timer	DFSDM HDMI-CEC Ethernet S/PDIF	Quad-SPI FMC MDIO Camera IF SDIO	Crypto-hash TRNG	4x SAI 3x I <sup>2</sup> S 2x FDCAN LCD-TFT	3x 16-bit ADC Op-amps comp.	
STM32F7 series – High performance with DSP, FPU, ART Accelerator™ and Chrom-ART Accelerator™										
216 MHz Cortex-M7 L1-Cache	Up to 2-Mbyte dual-bank Flash	Up to 512-Kbyte SRAM	2x USB 2.0 OTG FS/HS	2x 16-bit advanced MC timer	DFSDM HDMI-CEC Ethernet S/PDIF	Quad-SPI FMC MDIO Camera IF SDIO	Crypto-hash TRNG	2x SAI 2x I <sup>2</sup> S LCD-TFT Up to 3x CAN	MIPI-DSI	
STM32F4 series – High performance with DSP, FPU, ART Accelerator™ and Chrom-ART Accelerator™										
Up to 180 MHz Cortex-M4	Up to 2-Mbyte dual-bank Flash	Up to 384-Kbyte SRAM	2x USB 2.0 OTG FS/HS	2x 16-bit advanced MC timer	DFSDM HDMI-CEC Ethernet S/PDIF	Quad-SPI FMC MDIO Camera IF SDIO	Crypto-hash TRNG	2x SAI 5x I <sup>2</sup> S LCD-TFT Up to 2x CAN	MIPI-DSI	
STM32F2 series – High performance with ART Accelerator™										
120 MHz Cortex-M3 CPU	Up to 1-Mbyte Flash	Up to 128-Kbyte SRAM	2x USB 2.0 OTG FS/HS	2x 16-bit advanced MC timer	Ethernet	FSMC Camera IF SDIO	Crypto-hash TRNG	2x I <sup>2</sup> S Up to 2x CAN		


## Mainstream

STM32F3 series – Mixed-signal with DSP and FPU									
72 MHz Cortex-M4	Up to 512-Kbyte Flash	Up to 80-Kbyte SRAM CCM-RAM	USB 2.0 FS	3x 16-bit advanced MC timer	3x DAC 7x comp. 4x PGA	FSMC CAN	HR-Timer	ADC 3x 16-bit $\Sigma\Delta$ 4x 12-bit (5 MSPS)	
STM32F1 series – Mainstream									
Up to 72 MHz Cortex-M3 CPU	Up to 1-Mbyte Flash	Up to 96-Kbyte SRAM	USB 2.0 OTG FS	2x 16-bit advanced MC timer	HDMI-CEC Ethernet	FSMC SDIO	2x I <sup>2</sup> S 2x CAN		
STM32F0 series – Entry-level									
48 MHz Cortex-M0 CPU	Up to 256-Kbyte Flash	Up to 32-Kbyte SRAM 20-byte backup data	USB 2.0 FS device Crystal less	Comp. HDMI-CEC	CAN DAC				

## Ultra-Low-Power

STM32L4+ series – Ultra-Low-Power and more Performance with DSP, FPU, ART Accelerator™ and Chrom-ART Accelerator™										
120 MHz Cortex-M4 CPU	Up to 2-Mbyte dual-bank Flash	Up to 640-Kbyte SRAM	USB 2.0 OTG Crystal less	2x 16-bit advanced MC timer	DFSDM Op-amps comp.	2x Octo-SPI FSMC SDIO 2x SAI	SHA-256 AES-256 TRNG CAN	MIPI-DSI LCD-TFT Chrom-GRC™		
STM32L4 series – Ultra-Low-Power and Performance with DSP, FPU, ART Accelerator™ and Chrom-ART Accelerator™										
80 MHz Cortex-M4 CPU	Up to 1-Mbyte dual-bank Flash	Up to 320-Kbyte SRAM	USB 2.0 OTG FS	2x 16-bit advanced MC timer	DFSDM Op-amps comp.	Quad-SPI FSMC SDIO 2x SAI	SHA-256 AES-256 TRNG 2x CAN	Up to LCD 8x40		
STM32L1 series – Ultra-Low-Power										
32 MHz Cortex-M3 CPU	Up to 512-Kbyte Flash	Up to 80-Kbyte SRAM	Up to 16-Kbyte EEPROM	USB 2.0 FS Device	Op-amps comp.	FSMC SDIO	AES-128	Up to LCD 8x40		
STM32L0 series – Ultra-Low-Power										
32 MHz Cortex-M0+ CPU	Up to 192-Kbyte SRAM	Up to 20-Kbyte SRAM	Up to 6-Kbyte EEPROM	USB 2.0 FS device Crystal less	DAC comp.	LP ADC 12-/16-bit	TRNG AES-128	LCD 8x48 / 4x52		

## Wireless

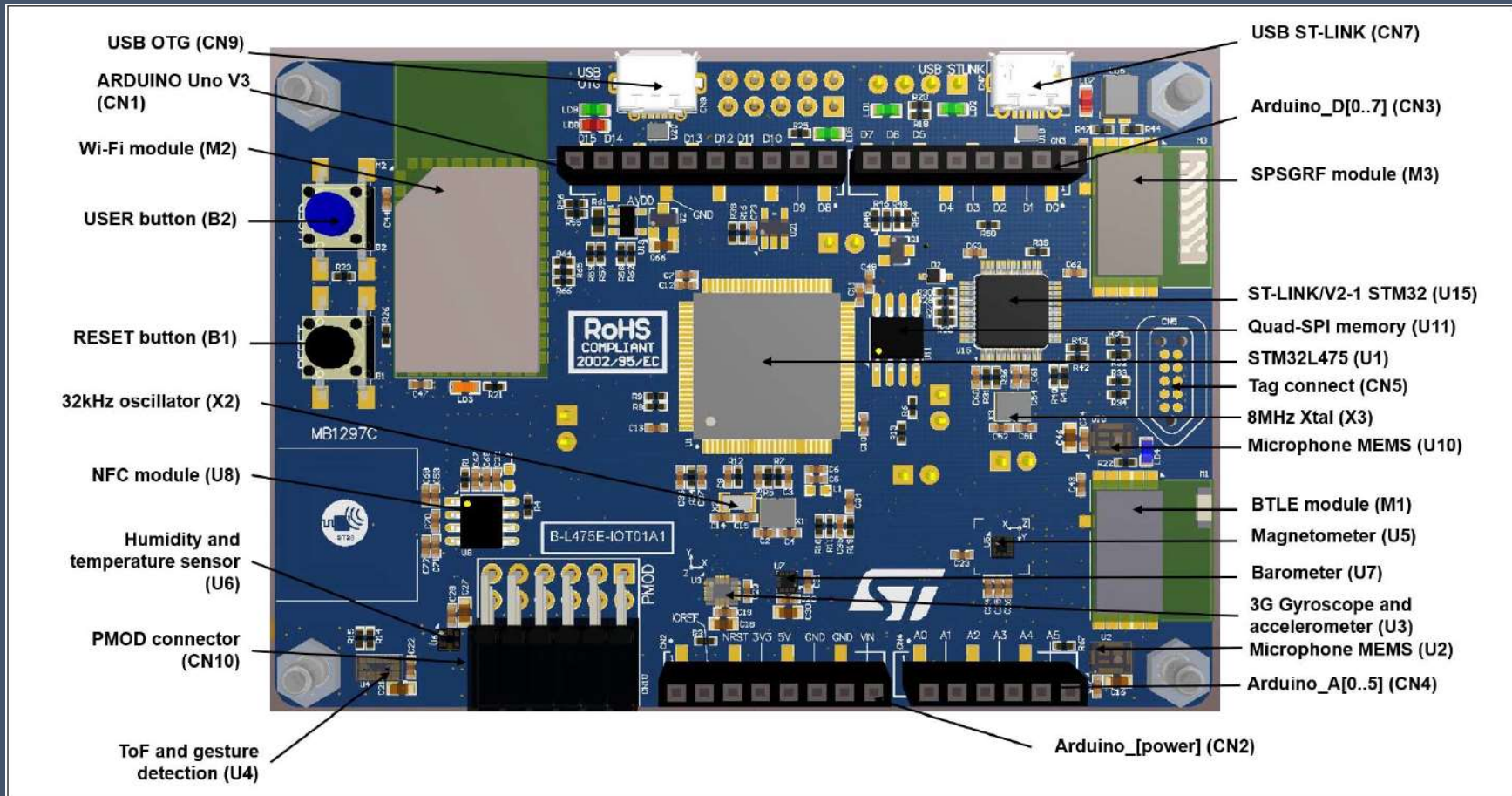
STM32WB series – Multiprotocol and ultra-low-power 2.4 GHz radio with DSP, FPU, ART Accelerator™ and IP Protection										
64 MHz Cortex-M4 CPU	Up to 1-Mbyte Flash	Up to 256-Kbyte SRAM	USB 2.0 FS Crystal less BCD / LPM	1x 16-bit advanced MC timer	Cortex-M0+ BLE 5.0 802.15.4 Concurrent	LP ADC 12x-16bit 2x comp.	Quad-SPI 1x SAI (2ch)	PKA AES-256 TRNG CKS*	LCD 8x40 4x44	

\* Customer Key Storage



# 실습보드

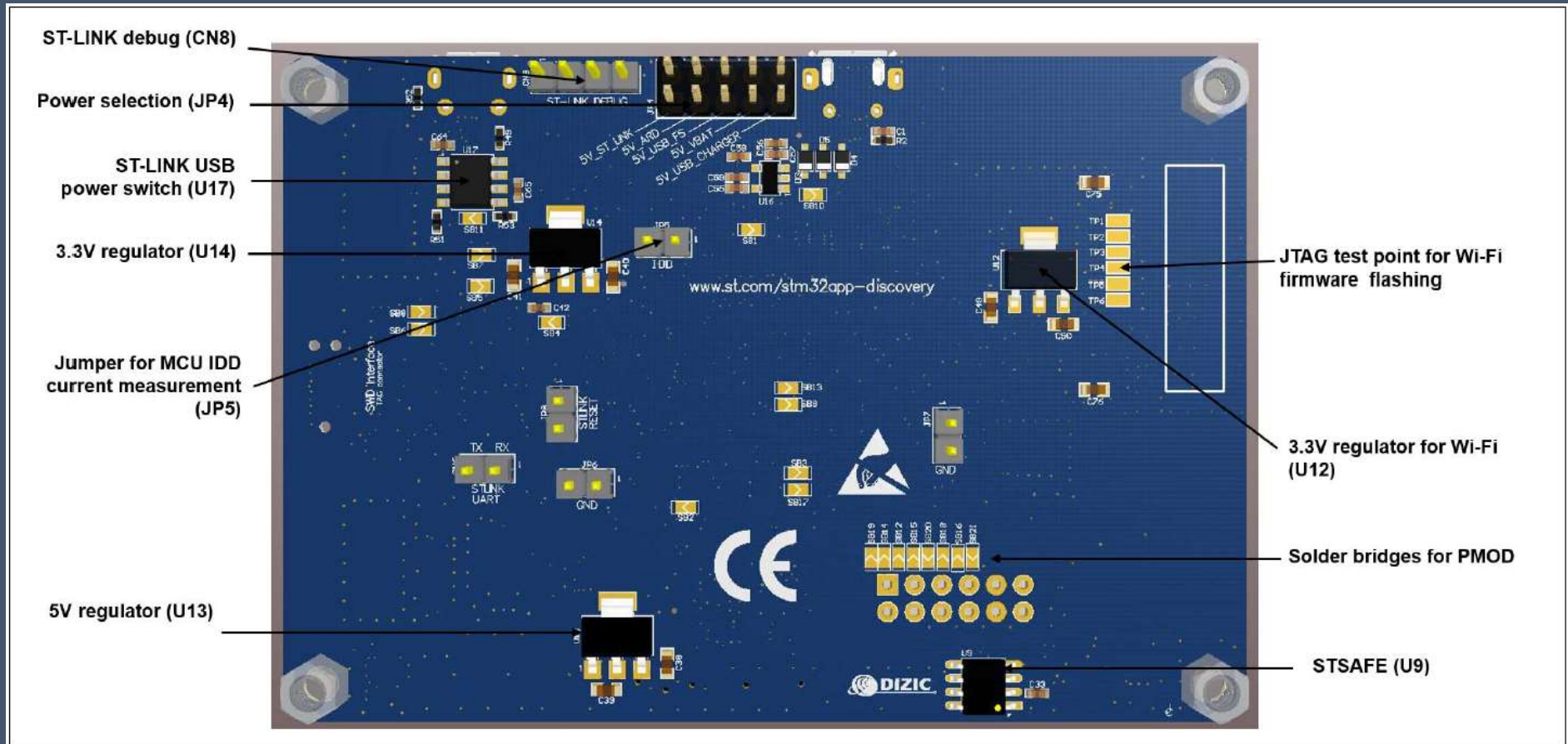
## B-L475E-IOT01A





# 실습보드

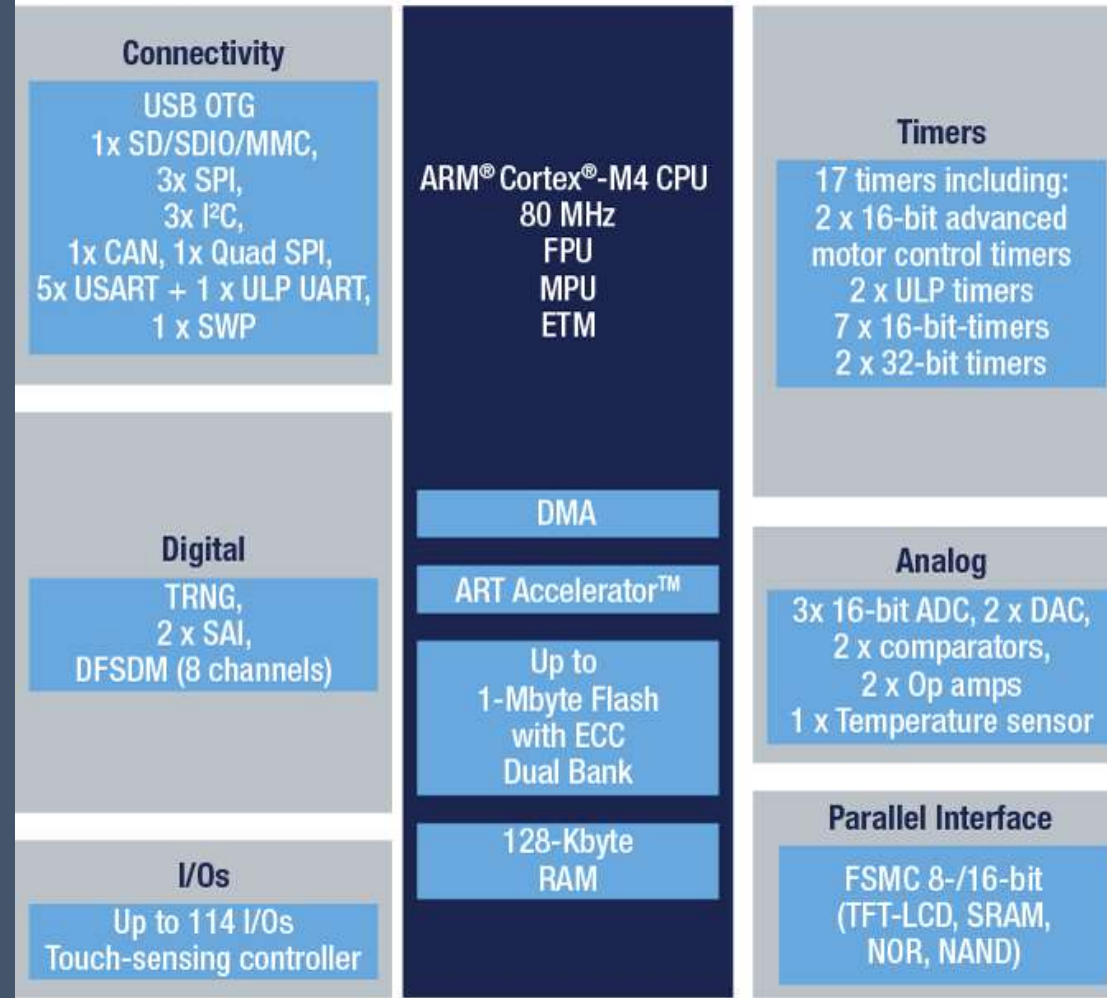
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## STM32L475

### STM32L475



# 개발환경 구축

## STM32CubeMX 설치

다운로드 <https://www.st.com/en/development-tools/stm32cubemx.html>

GET SOFTWARE				
Part Number	Software Version	Marketing Status	Supplier	Download
STM32CubeMX	5.0.0	Active	ST	<a href="#">Get Software</a>

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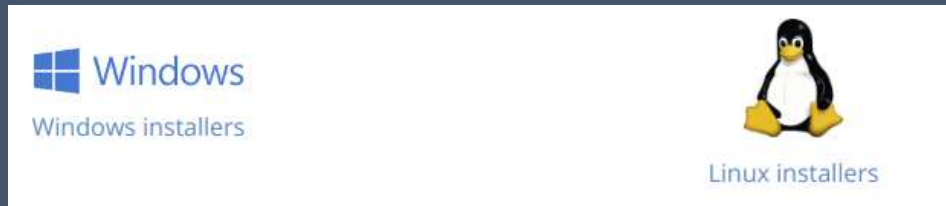
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# 개발환경 구축

## TrueSTUDIO 설치

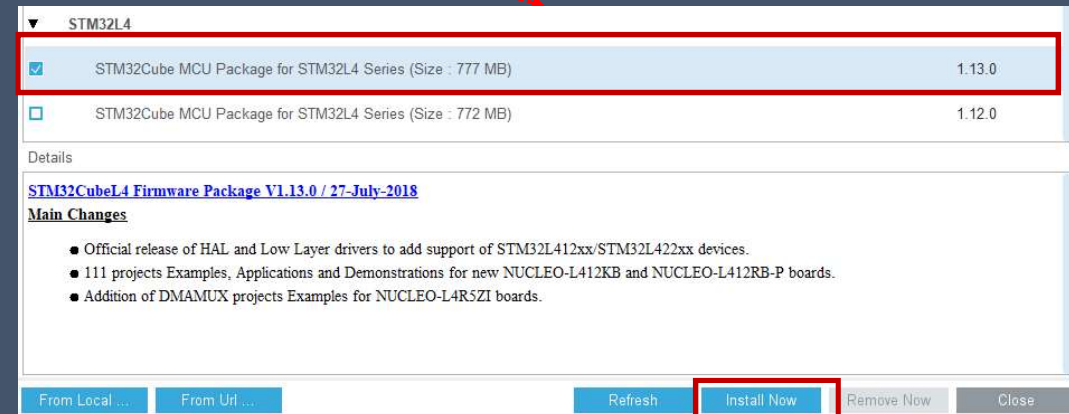
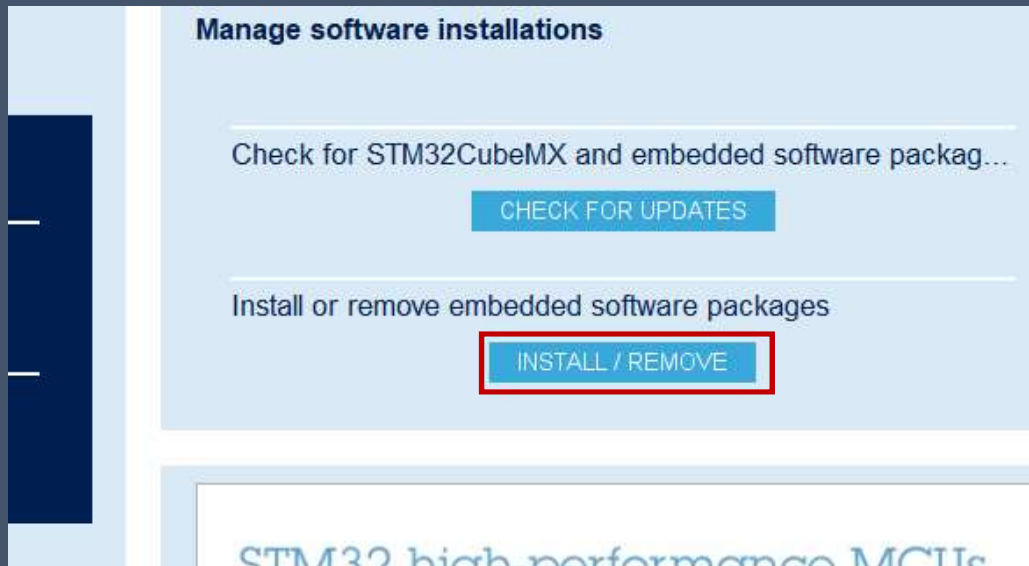
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# 개발환경 구축

## STM32L4 Library 설치



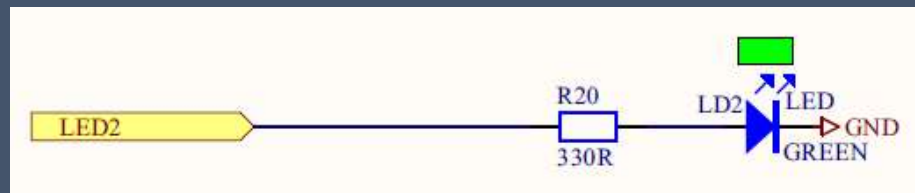
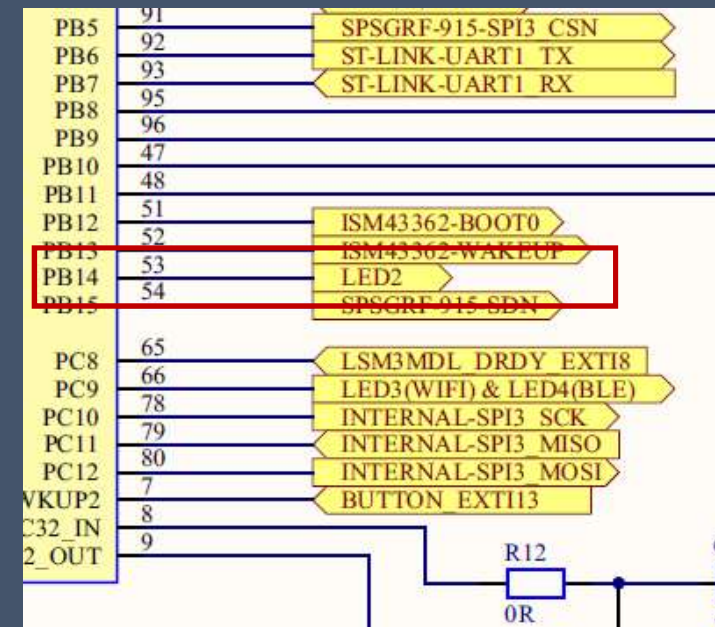
# 기본 firmware 실습

## LED Blinky

LED 회로

Table 2. Button and LED control port

Reference	Color	Name	Comment
B1	black	Reset	-
B2	blue	Wake-up	Alternate function Wake-up
LD1	green	LED1	PA5 (alternate with ARD.D13)
LD2	green	LED2	PB14
LD3	yellow	LED3 (Wi-Fi)	PC9, Wi-Fi activity
LD4	blue	LED4 (BLE)	PC9, Bluetooth activity
LD5	green	5V Power	5 V available
LD6	Bicolor (red and green)	ST-LINK COM	green when communication
LD7	red	Fault Power	Current upper than 750 mA
LD8	red	V <sub>BUS</sub> OCRCR	PE3
LD9	green	V <sub>BUS</sub> OK	5 V USB available

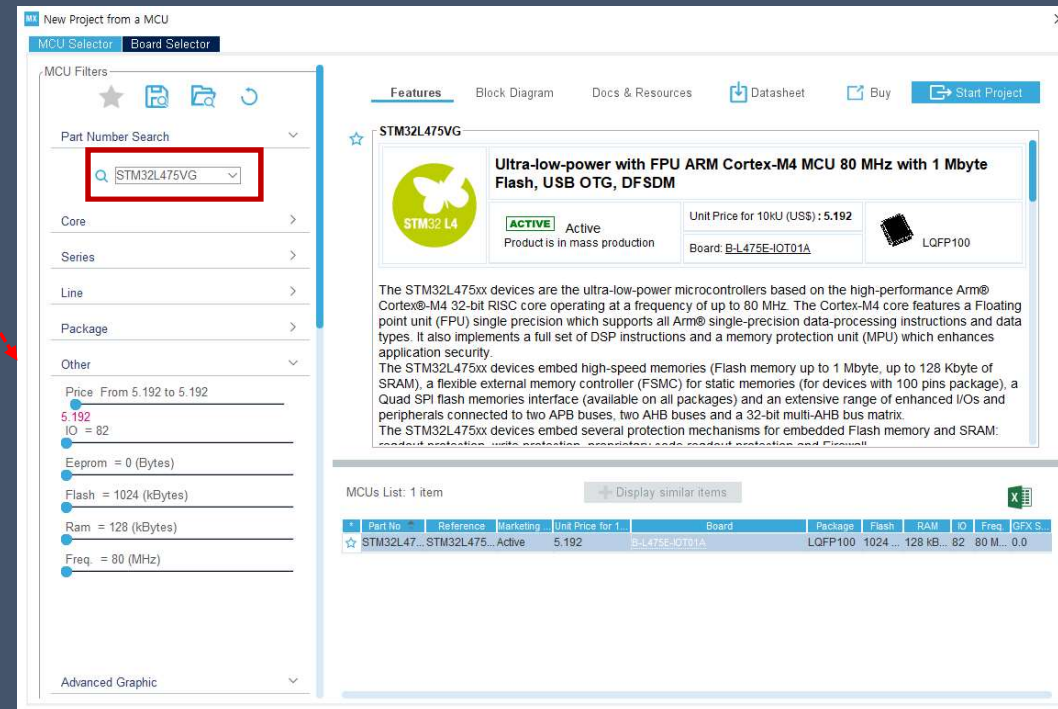
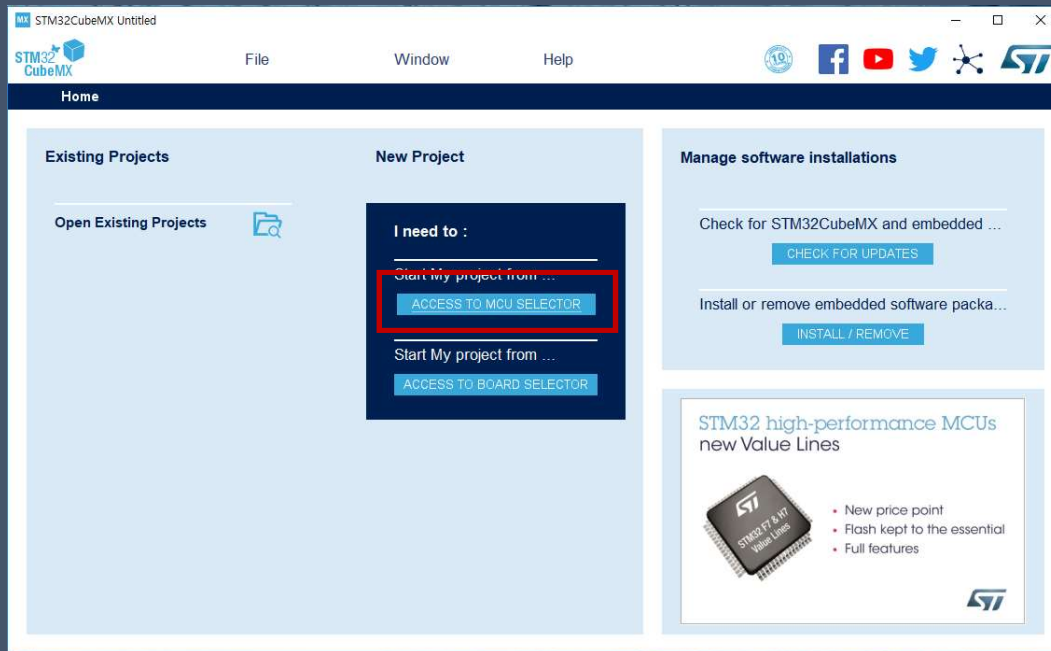




# 기본 firmware 실습

## LED Blinky

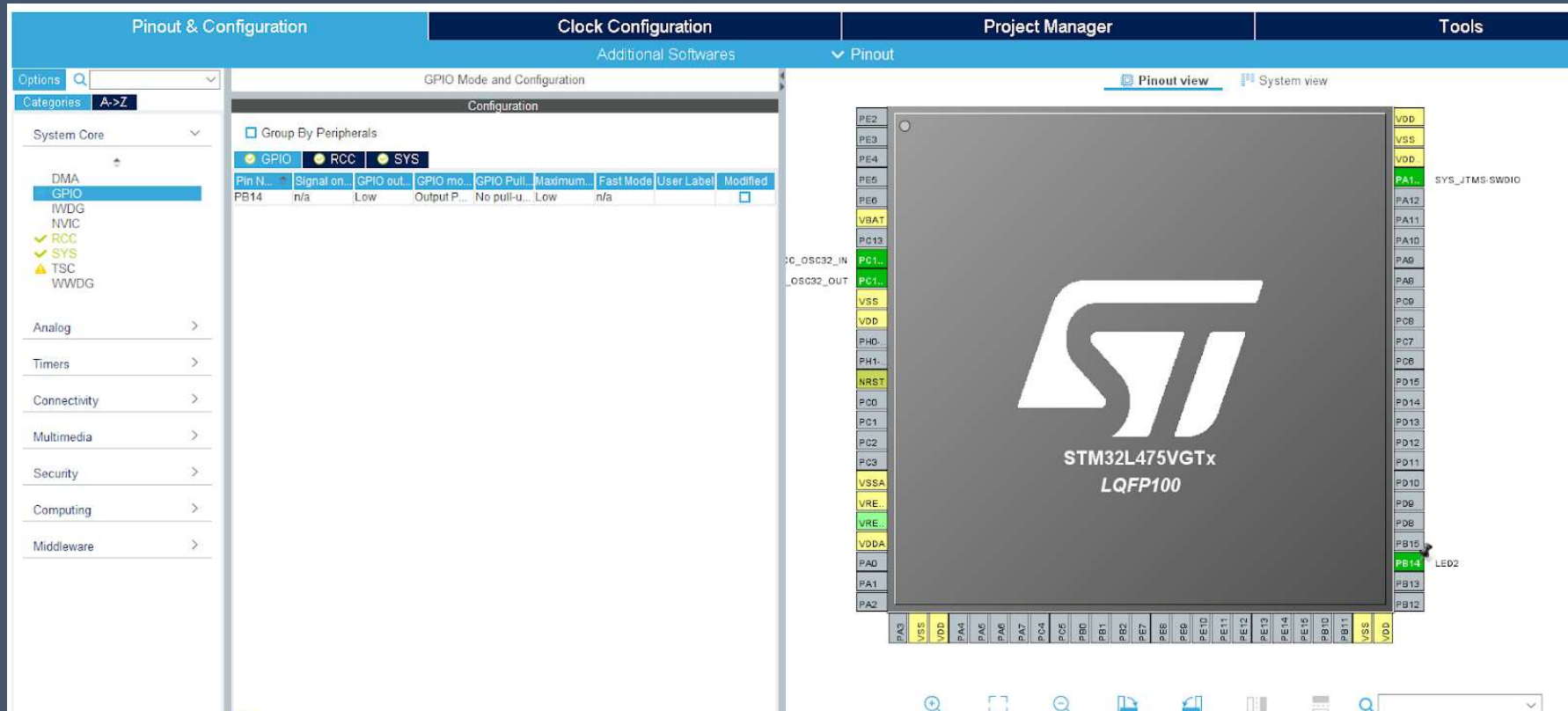
CubeMX로 코드생성



# 기본 *firmware* 실습

## LED Blinky

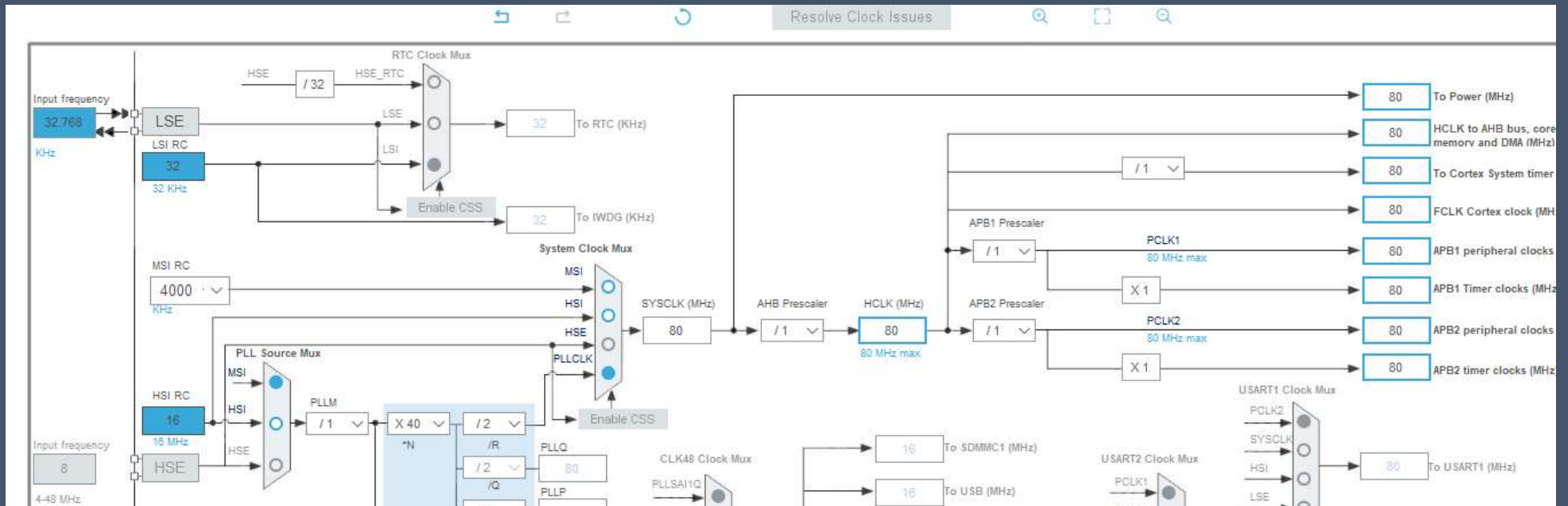
CubeMX로 코드생성



# 기본 *firmware* 실습

## LED Blinky

CubeMX로 코드생성



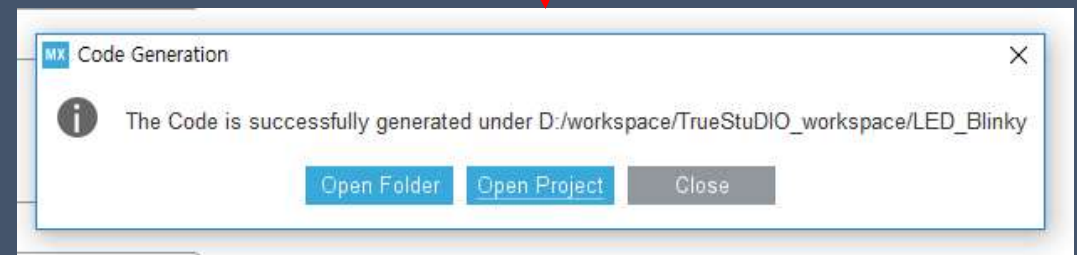
# 기본 *firmware* 실습

## LED Blinky

CubeMX로 코드생성

The screenshot shows the 'Pinout & Configuration' tab in STM32CubeMX. The left sidebar has four categories: 'Project', 'Code Generator', 'Advanced Settings', and 'Mcu and Firmware Package'. The 'Project' category is selected, showing the following settings:

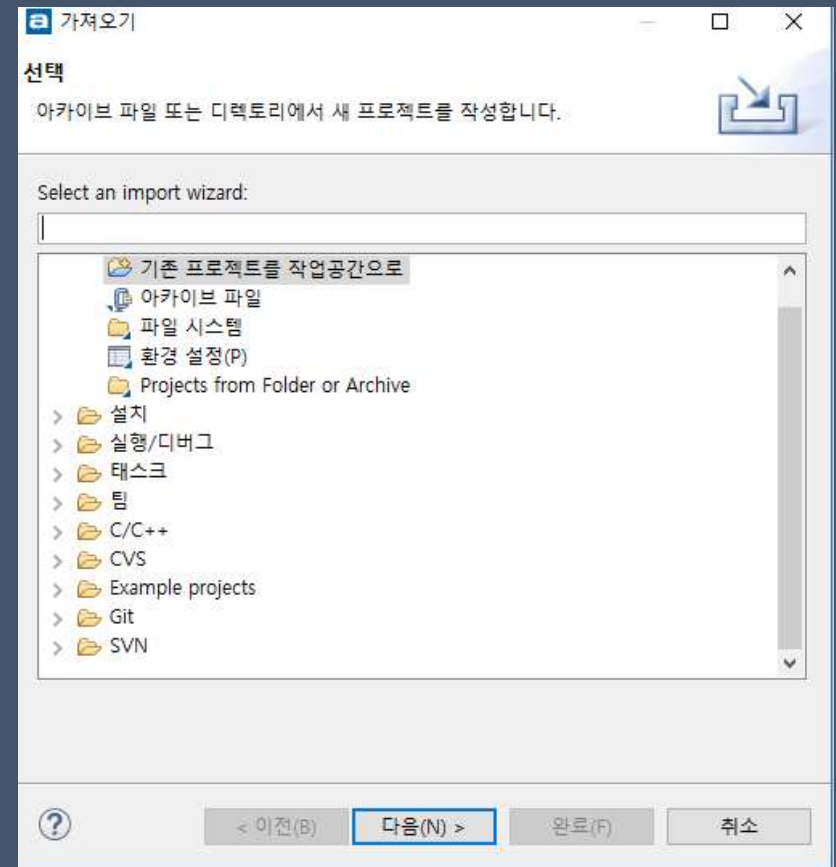
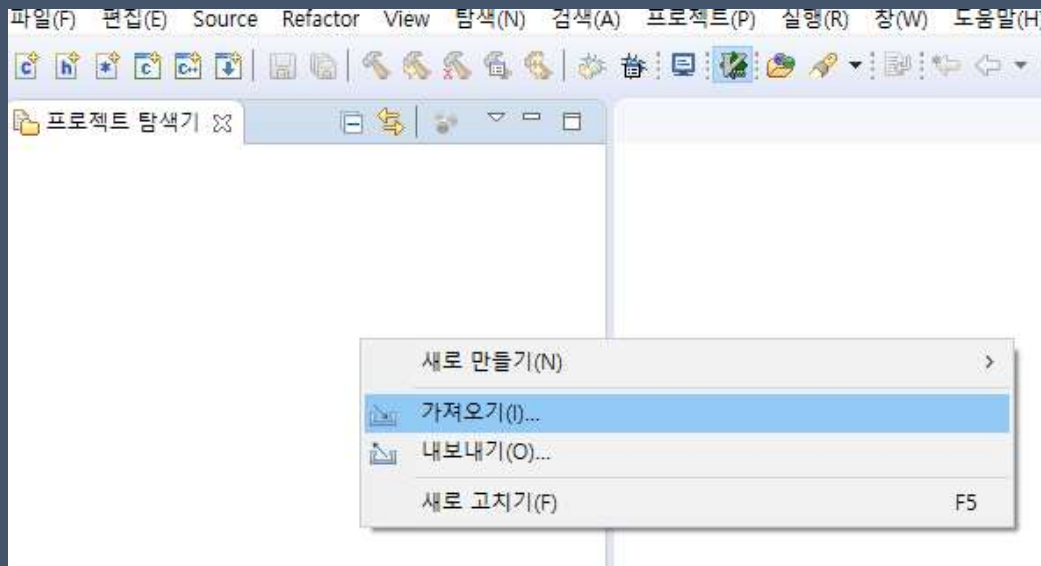
- Project Settings**
  - Project Name: LED\_Blinky
  - Project Location: D:\workspace\TrueStuDIO\_workspace (with a 'Browse' button)
  - Application Structure: Basic (dropdown menu) with a checkbox 'Do not generate the main()' which is unchecked.
  - Toolchain Folder Location: D:\workspace\TrueStuDIO\_workspace\LED\_Blinky\ (with a 'Browse' button)
  - Toolchain / IDE: TrueSTUDIO (dropdown menu) with a checkbox 'Generate Under Root' which is checked.
- Linker Settings**
  - Minimum Heap Size: 0x200
  - Minimum Stack Size: 0x400
- Mcu and Firmware Package**
  - Mcu Reference: STM32L475VGTX
  - Firmware Package Name and Version: STM32Cube FW\_L4 V1.13.0
  - Use Default Firmware Location: checked (checkbox)
  - Path: D:/STM32Cube/Repository/STM32Cube\_FW\_L4\_V1.13.0 (with a 'Browse' button)



# 기본 *firmware* 실습

## LED Blinky

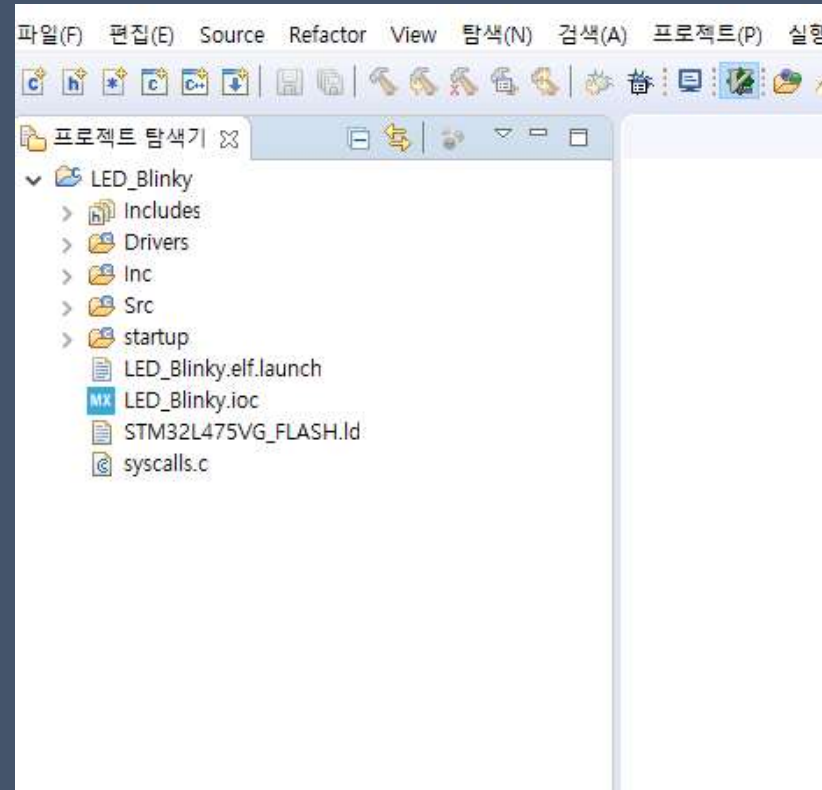
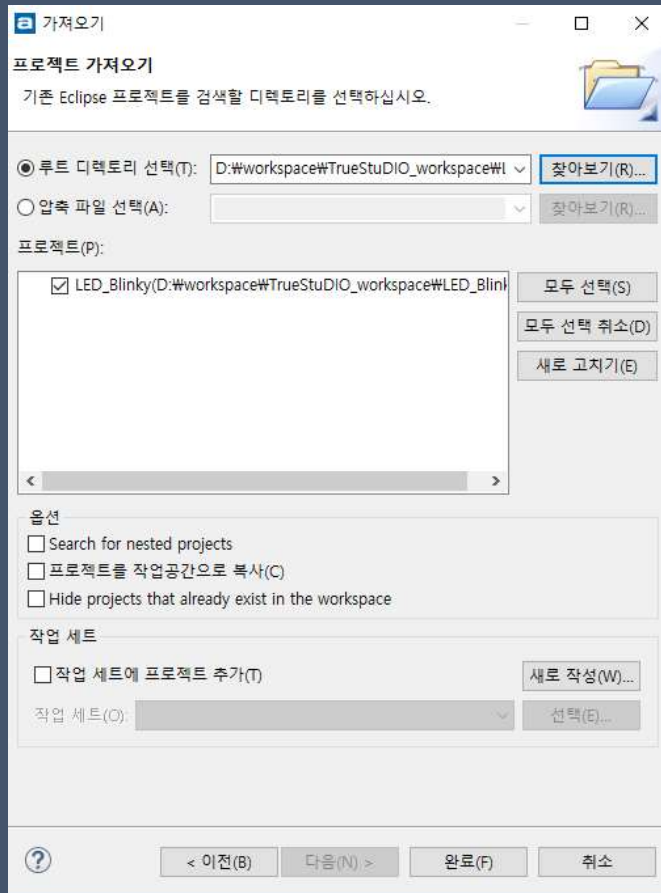
TrueSTUDIO code Import



# 기본 *firmware* 실습

## LED Blinky

TrueSTUDIO code Import



# 기본 *firmware* 실습

LED Blinky - Example



# 기본 *firmware* 실습

## UART (Universal Asynchronous serial Receiver and Transmitter)

1 대 1통신

비동기 통신 - 동기를 위한 클럭신호를 사용하지 않음

- Baud Rate
- 데이터 전송 속도로 Bit-per-Second(bps)단위로 표시

## 데이터 구조

- start bit: 통신의 시작을 의미하며 한 비트 시간 길이 만큼 유지한다. 지금 부터 정해진 약속에 따라 통신을 시작한다.
- data bit: 5~8비트의 데이터 전송을 한다. 몇 비트를 사용할 것인지는 해당 레지스터 설정에 따라 결정된다.
- Parity bit: 오류 검증을 하기 위한 패리티 값을 생성하여 송신하고 수신쪽에 오류 판단한다. 사용안함, 짝수, 홀수 패리티 등의 세가지 옵션으로 해당 레지스터 설정에 따라 선택할 수 있다. '사용안함'을 선택하면 이 비트가 제거된다.
- Stop bit: 통신 종료를 알린다. 세가지의 정해진 비트 만큼 유지해야 한다. 1, 1.5, 2비트로 해당 레지스터 설정에 따라 결정된다.

비트 수	1	2	3	4	5	6	7	8	9	10	11
	시작 비트 (Start bit)	5-8 데이터 비트								패리티 비트 (parity bit)	종료 비트 (Stop bit(s))
	Start	Data 0	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Parity	Stop

# 기본 *firmware* 실습

## UART (Universal Asynchronous serial Receiver and Transmitter)

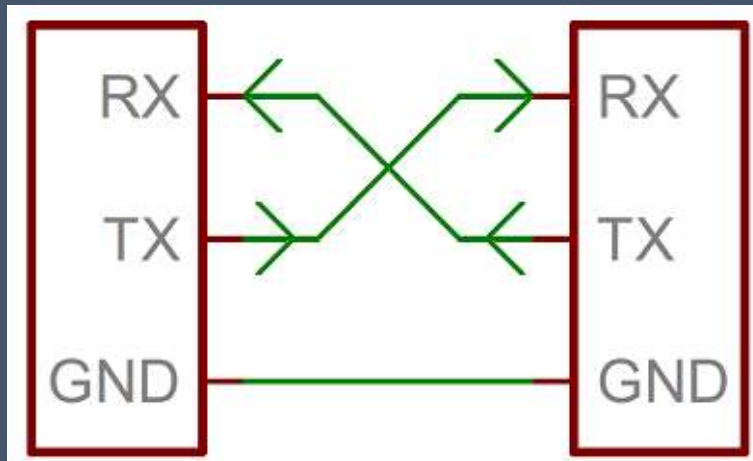
통신 속도 예)

9600 8N1 : 9600 baud rates, 8 data bits, no parity, 1 stop bit

9600 bps 속도로 보내므로 각 비트는  $1/(9600 \text{ pbs}) = 104\mu\text{s}$ 이고

8bit 전송시 start bit, stop bit를 더해 10bit 패킷을 사용하므로 초당 960byte를 전송할 수 있다.

## UART 회선 연결 방법

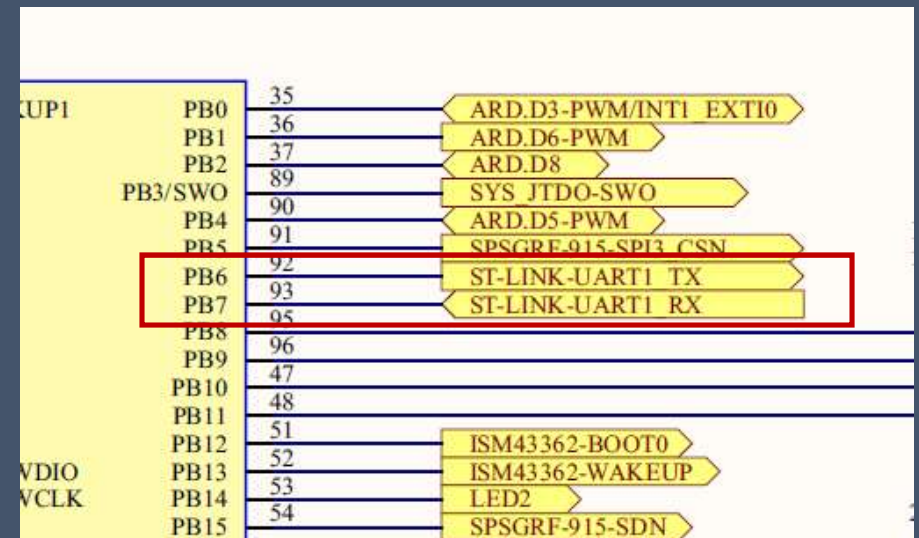
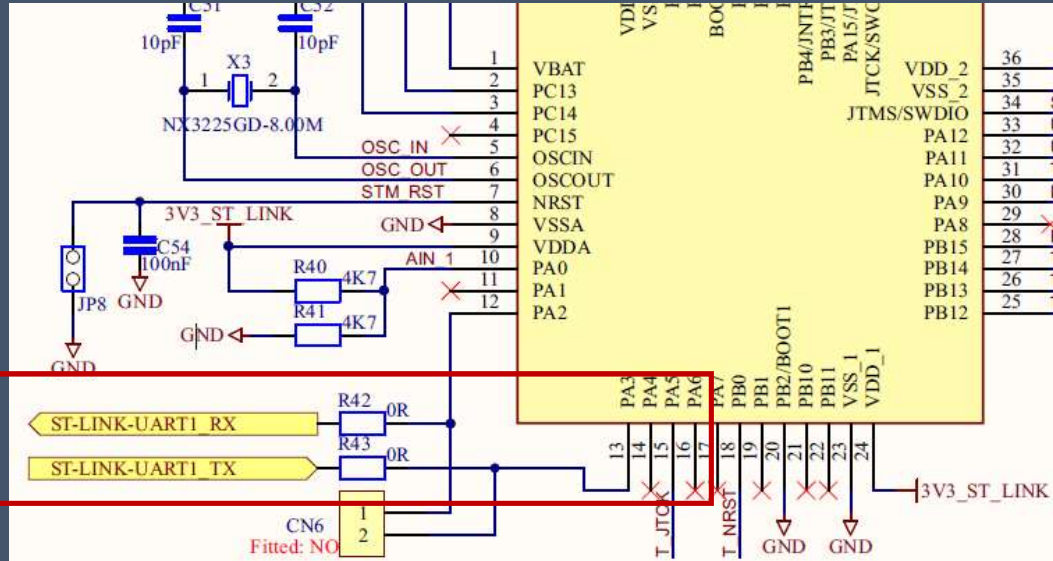


# 기본 firmware 실습

## UART (Universal Asynchronous serial Receiver and Transmitter)

Debug Uart 회로

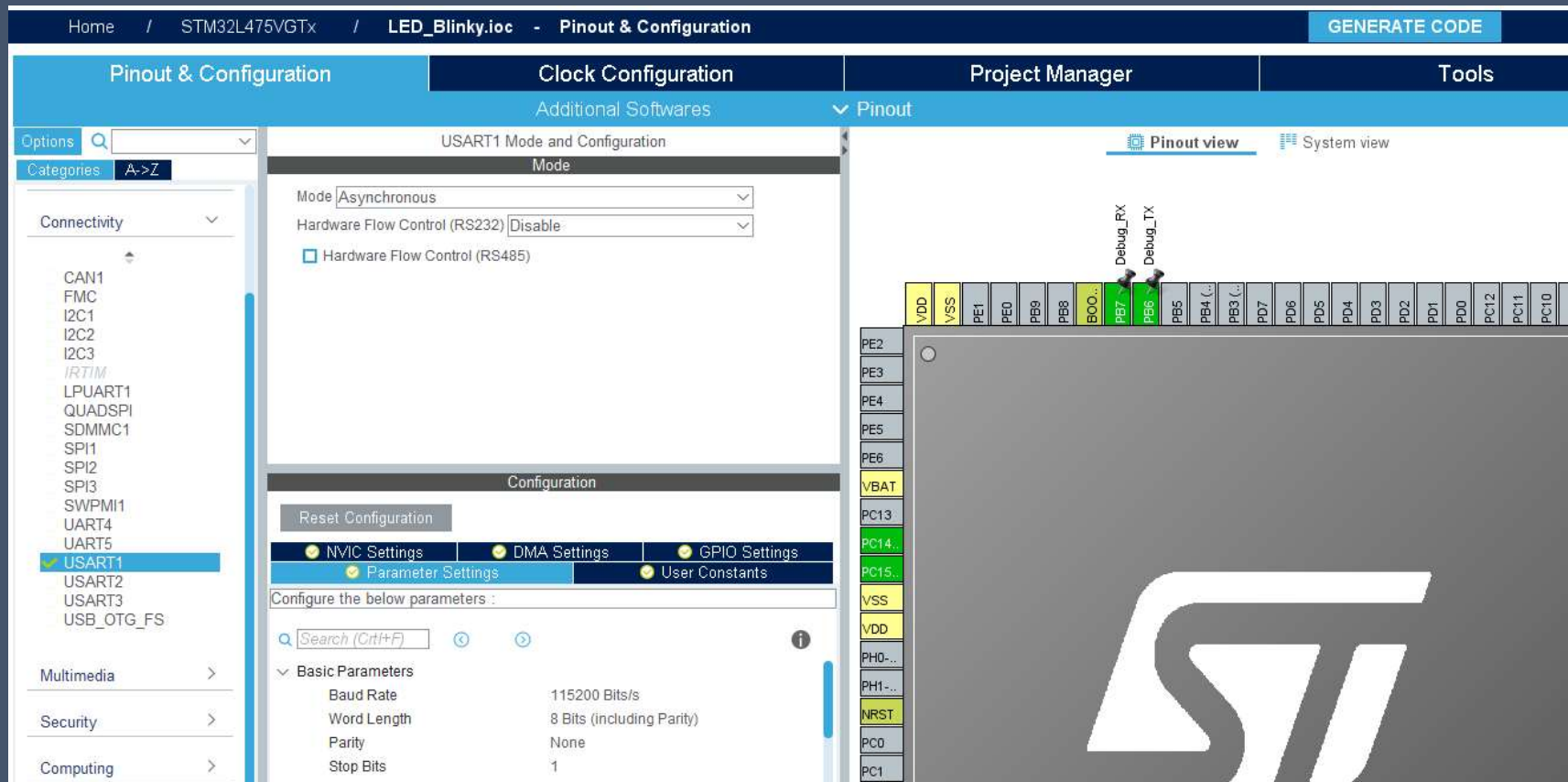
90	PB4	TIM3_CH1	ARD.D5-PWM
91	PB5	GPIO_Output	SPSGRF-915-SPI3_CSN
92	PB6	USART1_TX	ST-LINK-UART1_TX
93	PB7	USART1_RX	ST-LINK-UART1_RX
94	BOOT0	Boot	BOOT0



# 기본 *firmware* 실습

## UART (Universal Asynchronous serial Receiver and Transmitter)

CubeMX를 이용해서 Uart code 추가



# 기본 *firmware* 실습

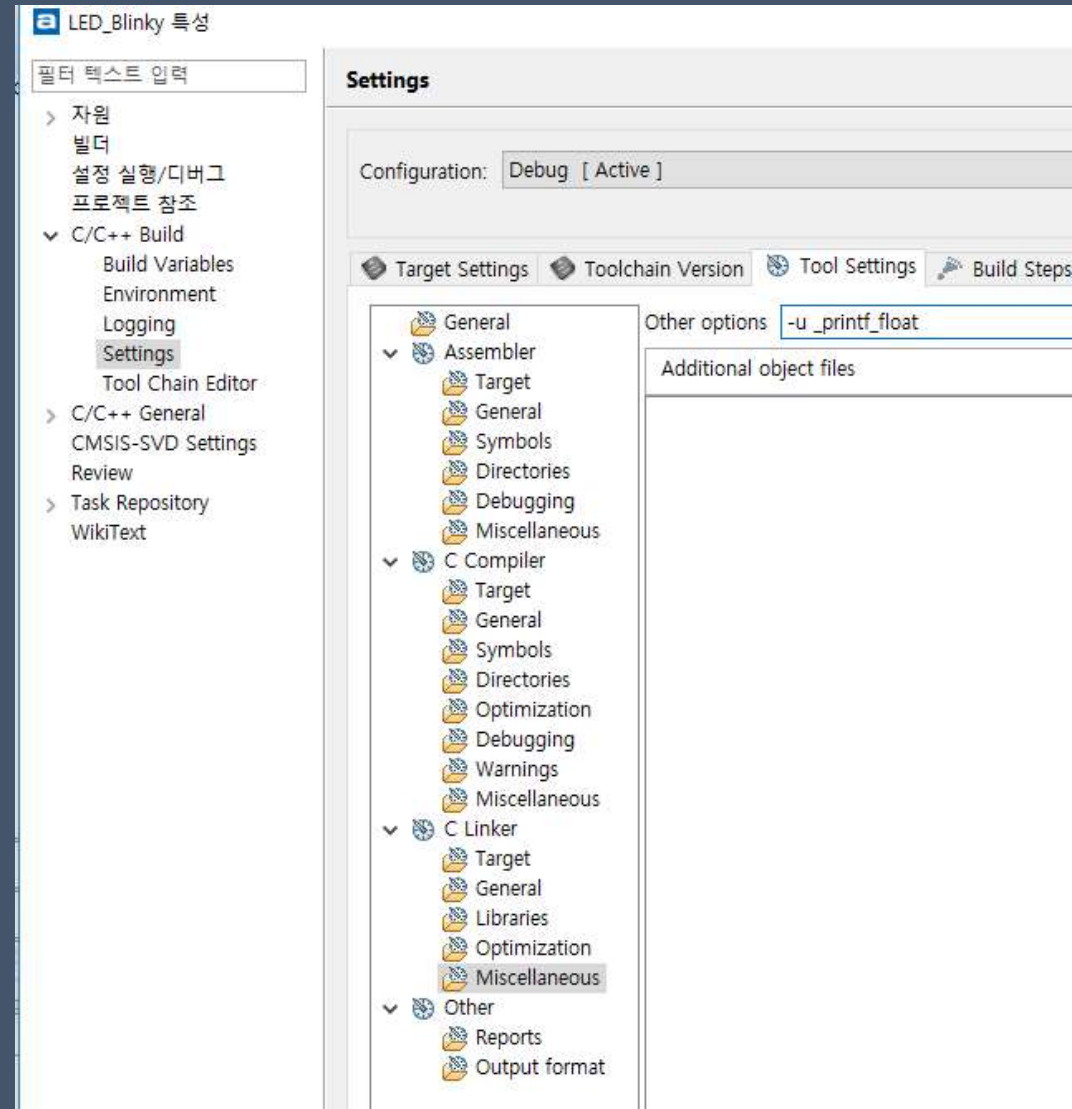
## UART - Example

printf() 함수 출력

# 기본 *firmware* 실습

## TrueSTUDIO

printf()에서 float 출력 설정



*감사합니다.*