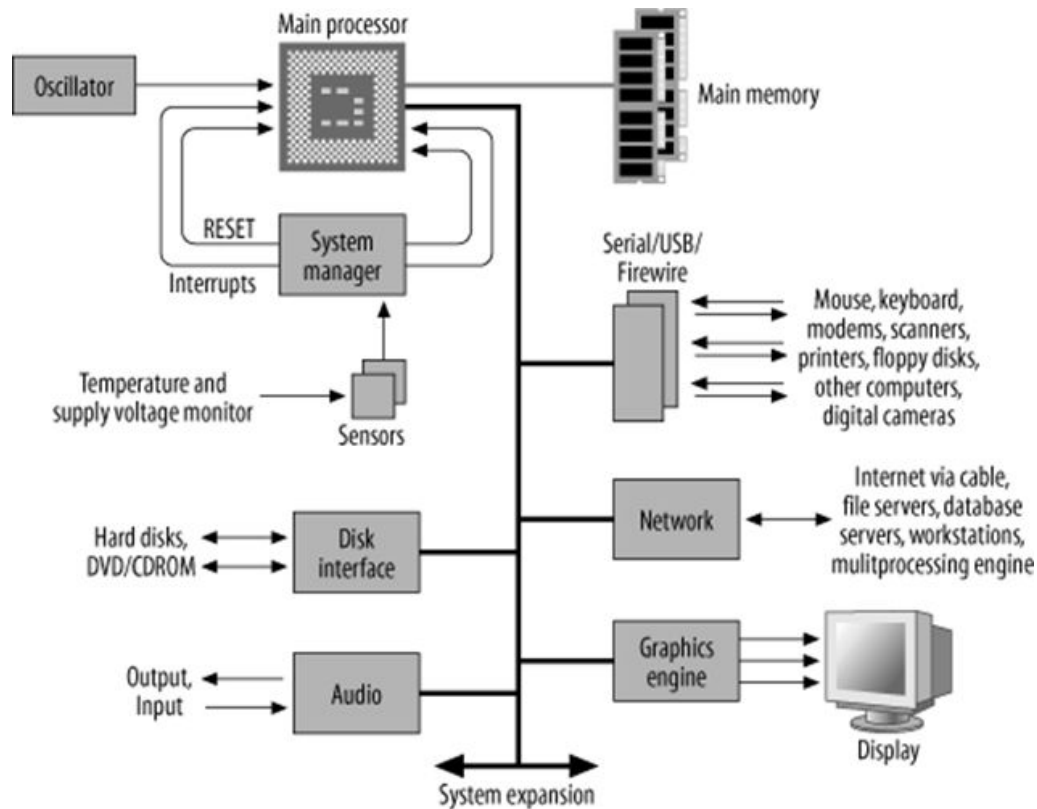


STM32를 활용한 FreeRTOS입문

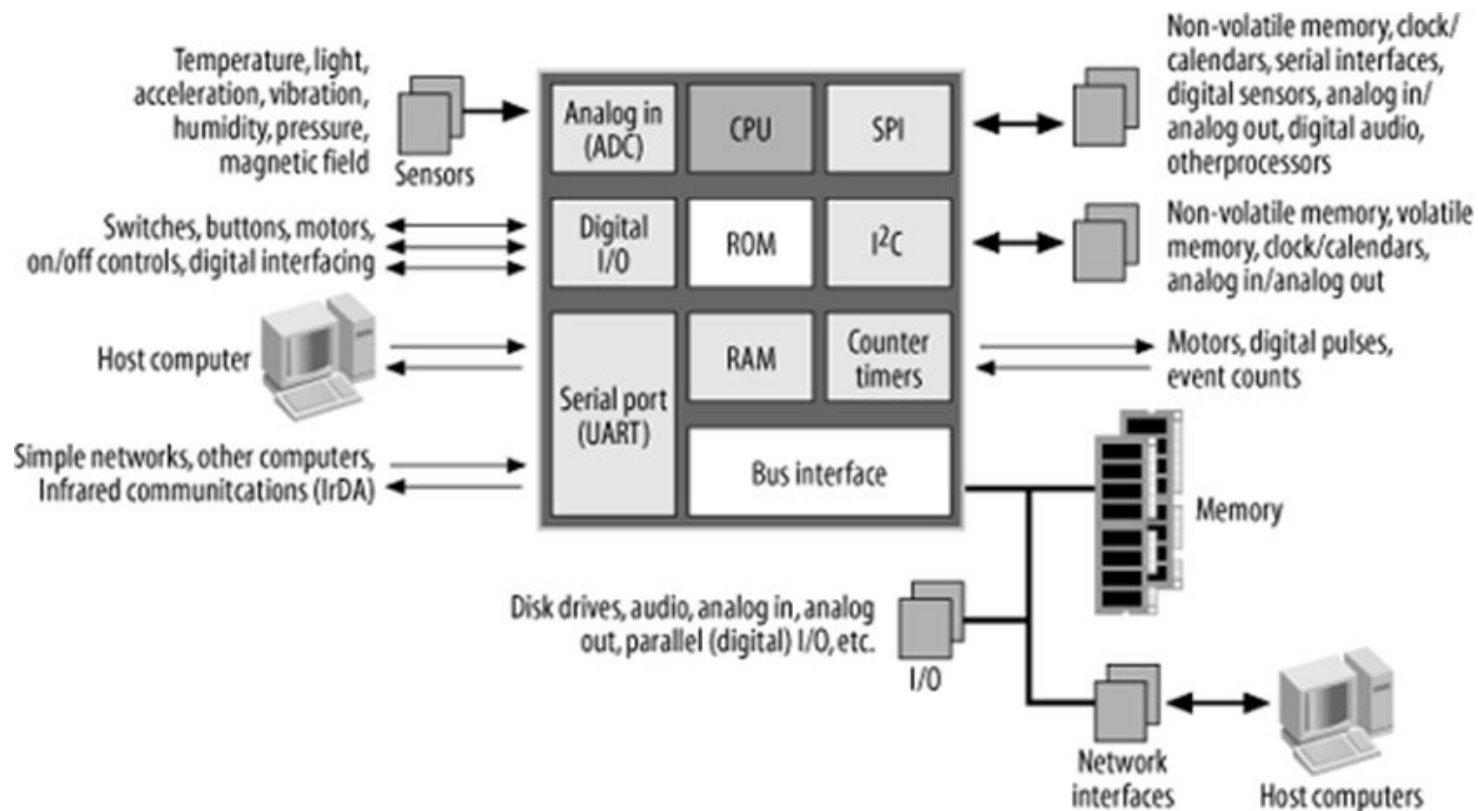
회사소개

<http://www.codezoo.co.kr/>

PC 하드웨어



임베디드 시스템 하드웨어



ARM

ARM Holdings

영국의 반도체 회사

- 프로세서를 설계하고 라이선싱
- 소프트웨어 개발 도구 설계 및 판매

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

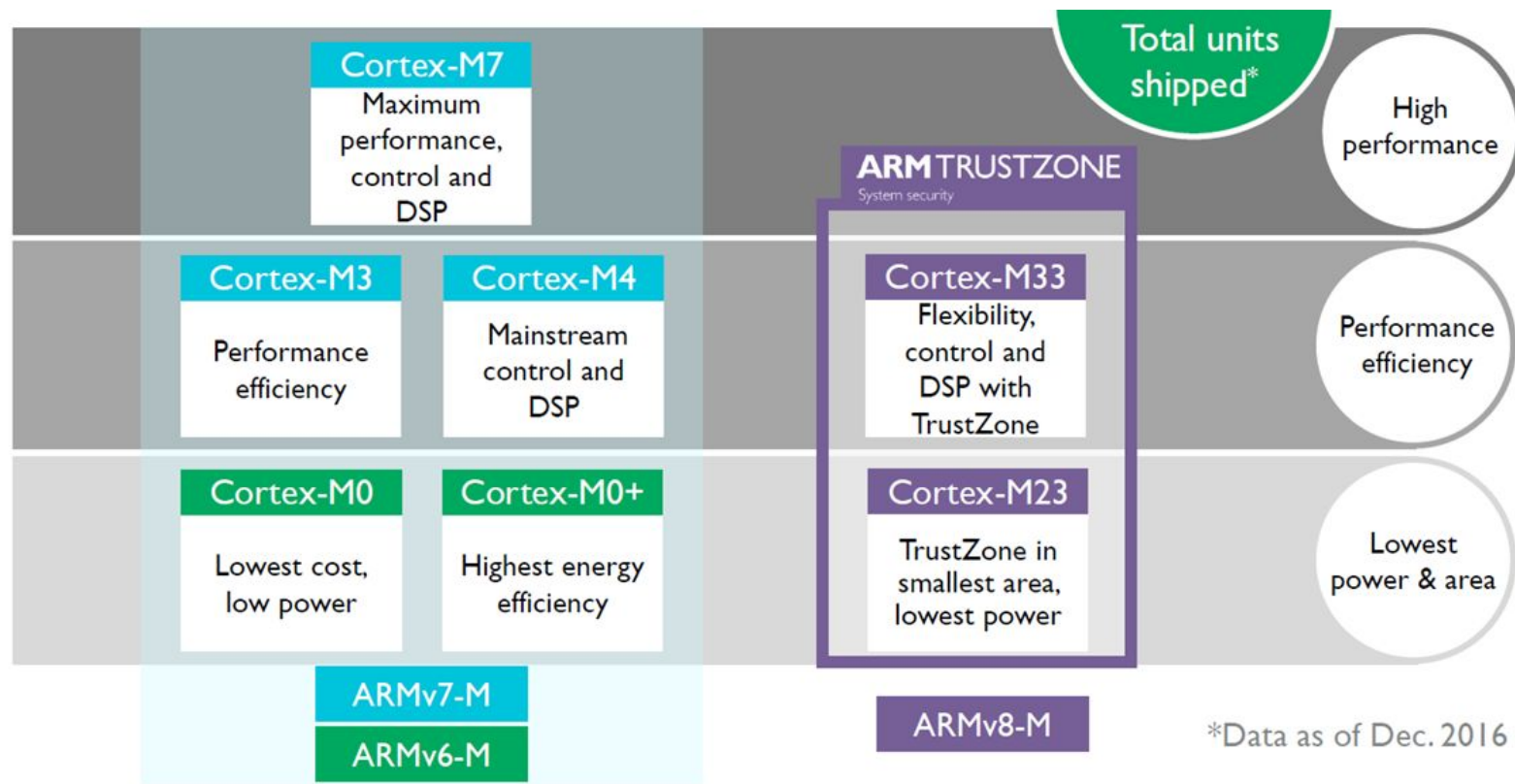
Optimized for
discrete processing
and
microcontrollers



ARM Core

	Cortex-A	Cortex-R	Cortex-M
설계	고주파 클럭, 긴 파이프 라인, 고성능, 멀티미디어 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)

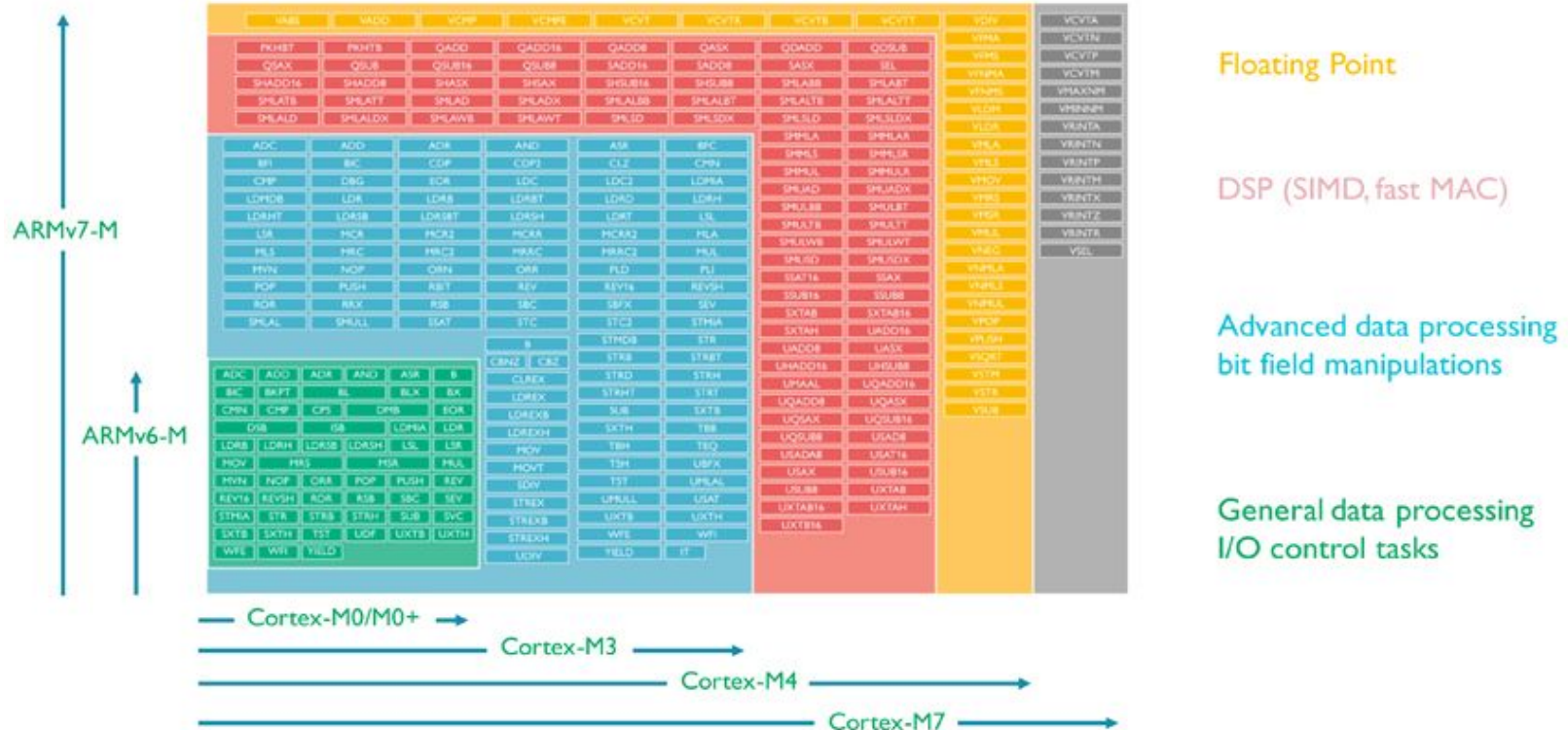
Cortex-M



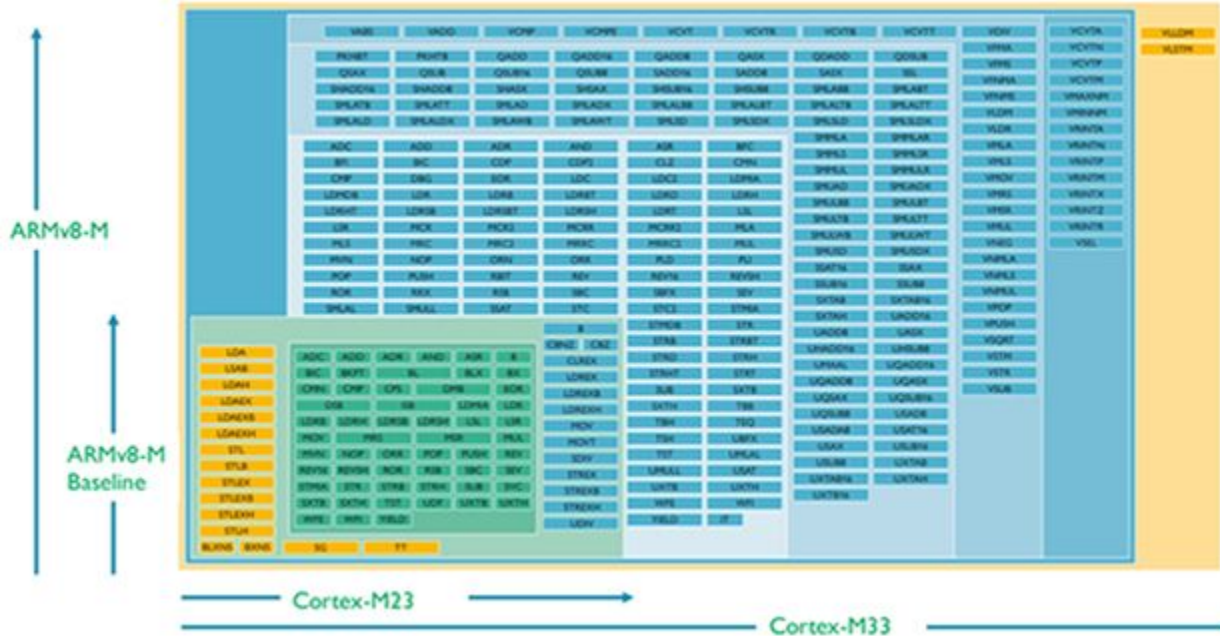
Cortex-M

프로세스	설명
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 Command Set



Cortex-M Command Set



Cortex-M Command Set

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

Cortex-M 생산 회사



STM32

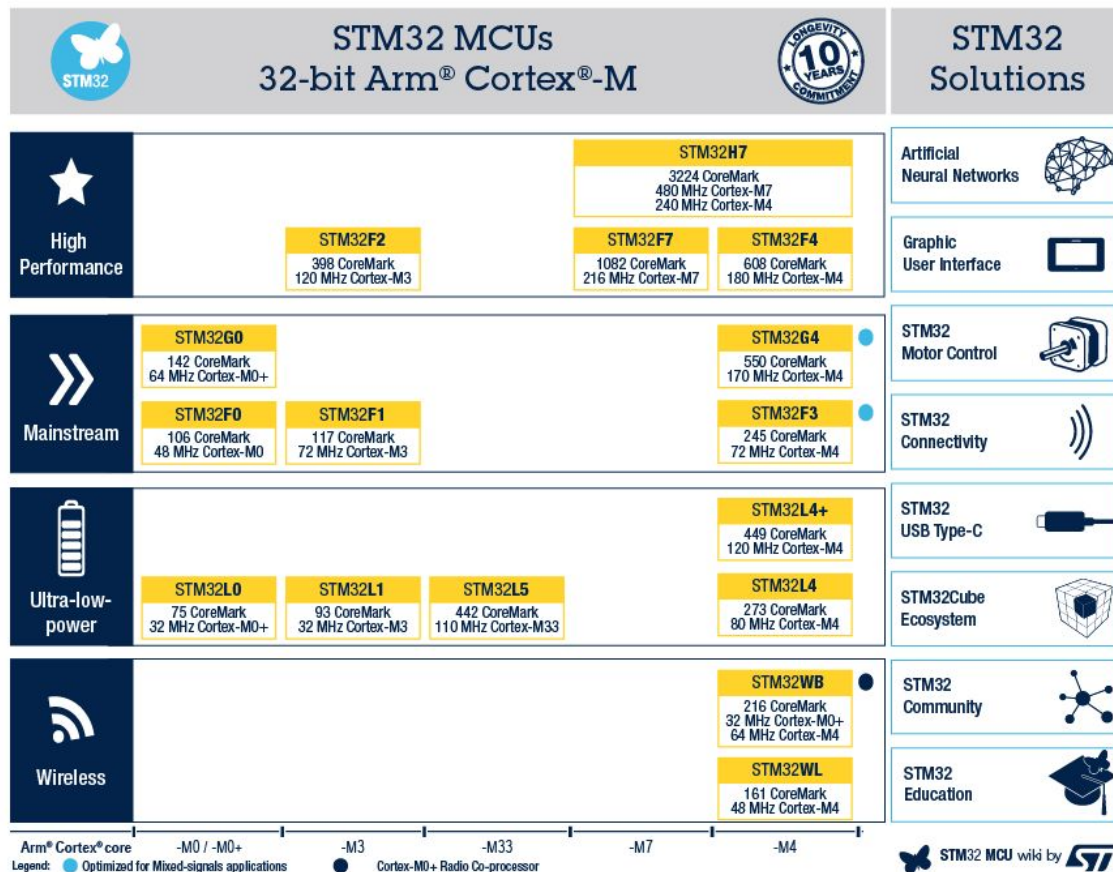
STMicroelectronics

스위스 제네바에 본사를 둔 전자제품과 반도체를 생산하는 기업

STM32

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

STM32



STM32 S/W Tools



STM32 Software Development Tools



STM32
CubeProgrammer

STM32
CubeMonitor

MCU
Finder
ST

STM32
CubeMX

STM32
CubeIDE

Configure
& Generate Code

Compile and Debug
IDEs

Monitor, Program
& Utilities

Performance and debuggers ▶

Programmers ▶

Utilities ▶

STM32CubeIDE

Eclipse 기반의 STM32 개발을 위한 통합 IDE

STM32CubeIDE

All-in-one STM32 development tool

TrueSTUDIO[®] for STM32

+

STM32
CubeMX



STM32
CubeIDE

STM32CubeIDE 다운로드

<https://www.st.com/en/development-tools/stm32cubeide.html>

Get Software

Part Number ▲	General Description	Software Version	Download	Previous versions
+ STM32CubeIDE-DEB	STM32CubeIDE Debian Linux Installer	1.3.0	Get Software	Select version ▼
+ STM32CubeIDE-Lnx	STM32CubeIDE Generic Linux Installer	1.3.0	Get Software	Select version ▼
+ STM32CubeIDE-Mac	STM32CubeIDE macOS Installer	1.3.0	Get Software	Select version ▼
+ STM32CubeIDE-RPM	STM32CubeIDE RPM Linux Installer	1.3.0	Get Software	Select version ▼
+ STM32CubeIDE-Win	STM32CubeIDE Windows Installer	1.3.0	Get Software	Select version ▼

STM32CubeIDE 다운로드

License Agreement

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Get Software

If you have an account on my.st.com, login and download the software without any further validation steps.

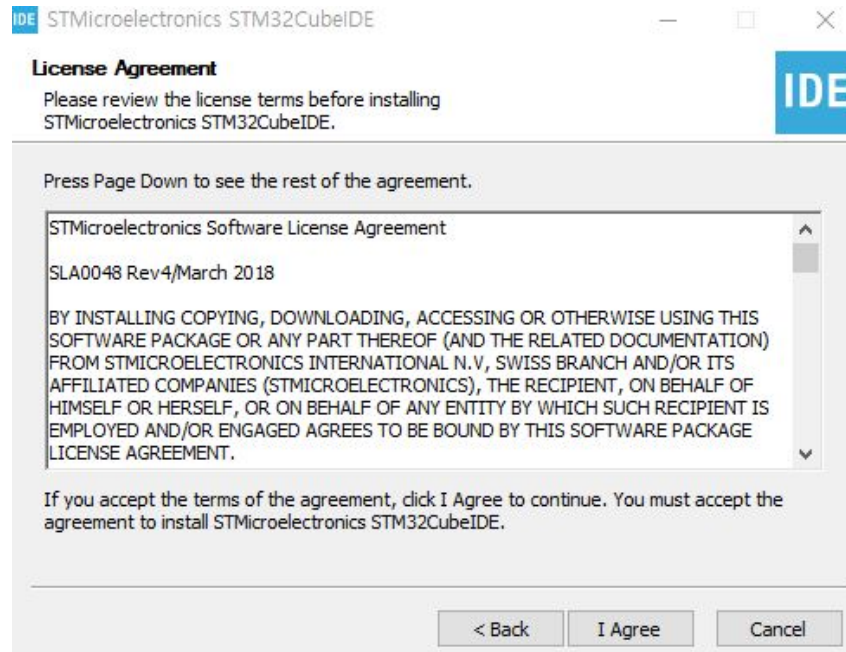
Login/Register

If you don't want to login now, you can download the software by simply providing your name and e-mail address in the form below and validating it.

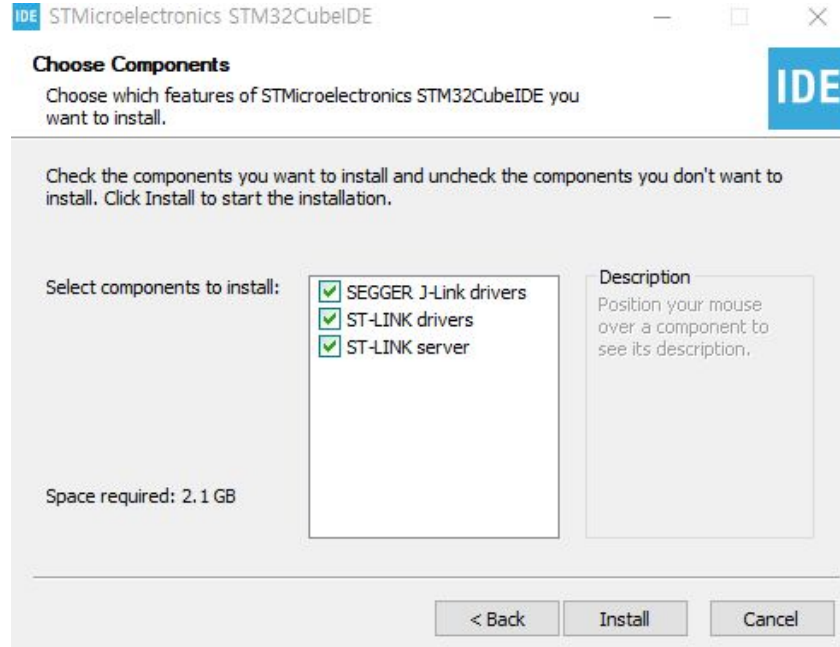
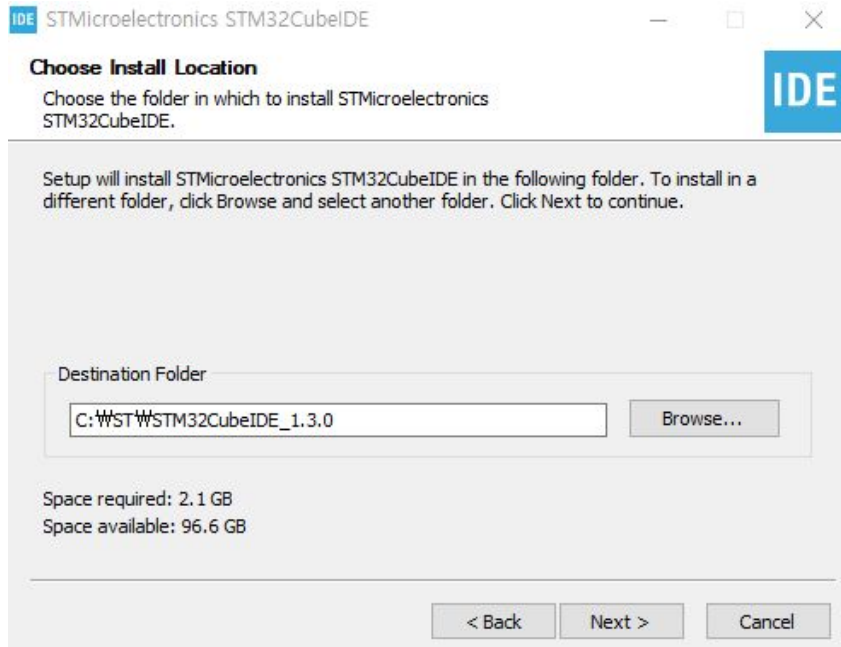
This allows us to stay in contact and inform you about updates of this software.

For subsequent downloads this step will not be required for most of our software.

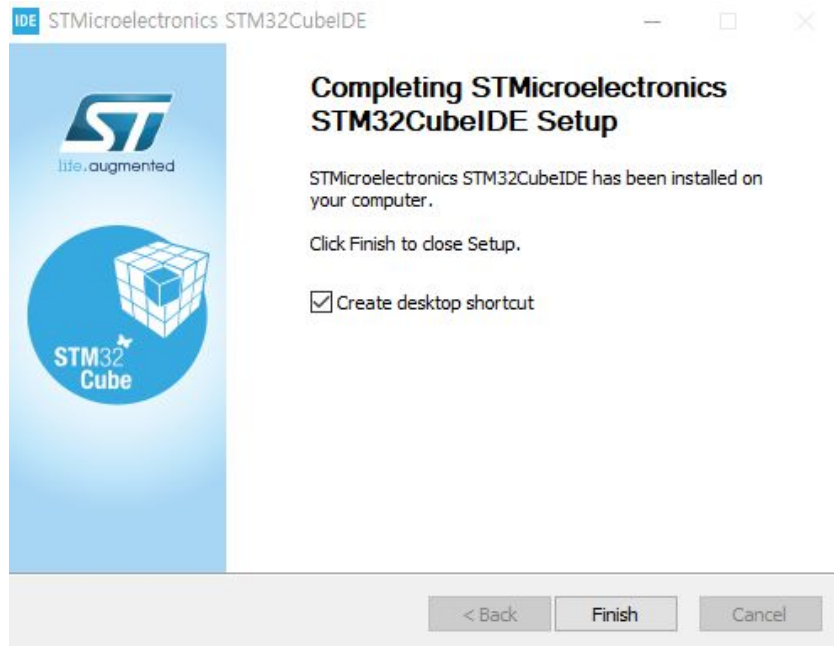
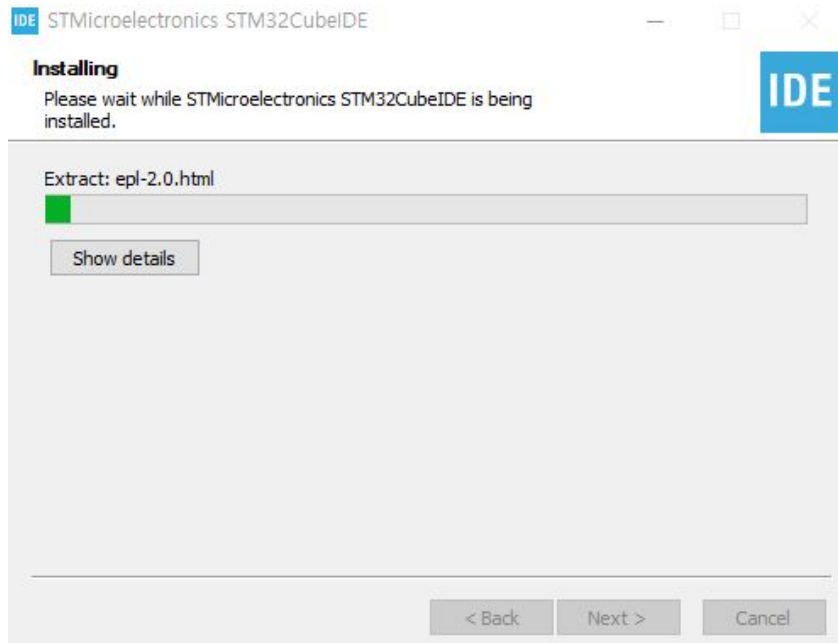
STM32CubeIDE 설치



STM32CubeIDE 설치



STM32CubeIDE 설치



STM32CubeIDE 실행

STM32CubeIDE Launcher

Select a directory as workspace

STM32CubeIDE uses the workspace directory to store its preferences and development artifacts.

Workspace: C:\Users\wgauib\STM32CubeIDE\workspace_1.3.0

Browse...

☐ Use this as the default and do not ask again

Launch

Cancel

STM32CubeIDE

File Edit View Navigate Search Project Run Window Help

IDE Home

Welcome to STM32CubeIDE

Start a project



Start new
STM32
project



Start new project
from
STM32CubeMX
.ioc file



Import
SW4STM32 or
TrueSTUDIO
project

Quick links



Read STM32CubeIDE Documentation



Getting Started with STM32CubeIDE



Explore What's New in STM32CubeIDE

Support & Community

Twitter

Facebook

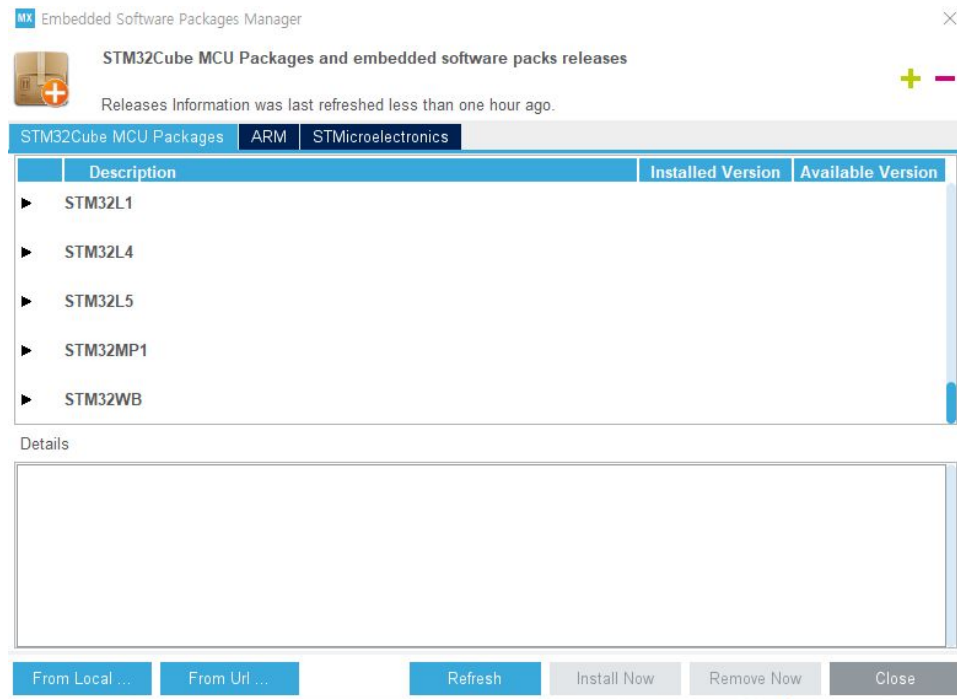
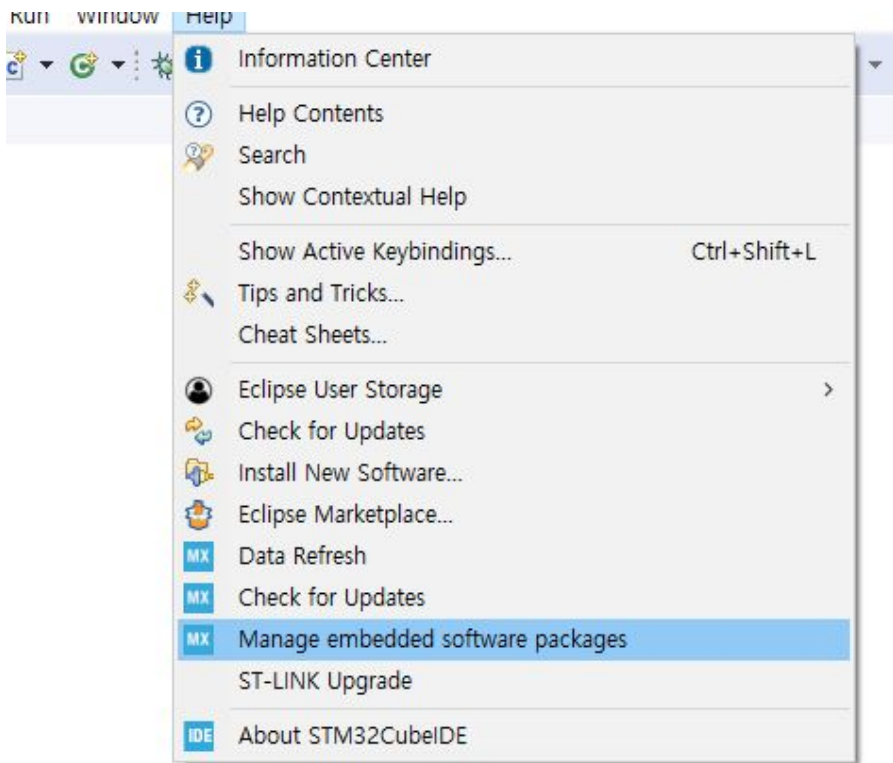
Youtube

ST Home

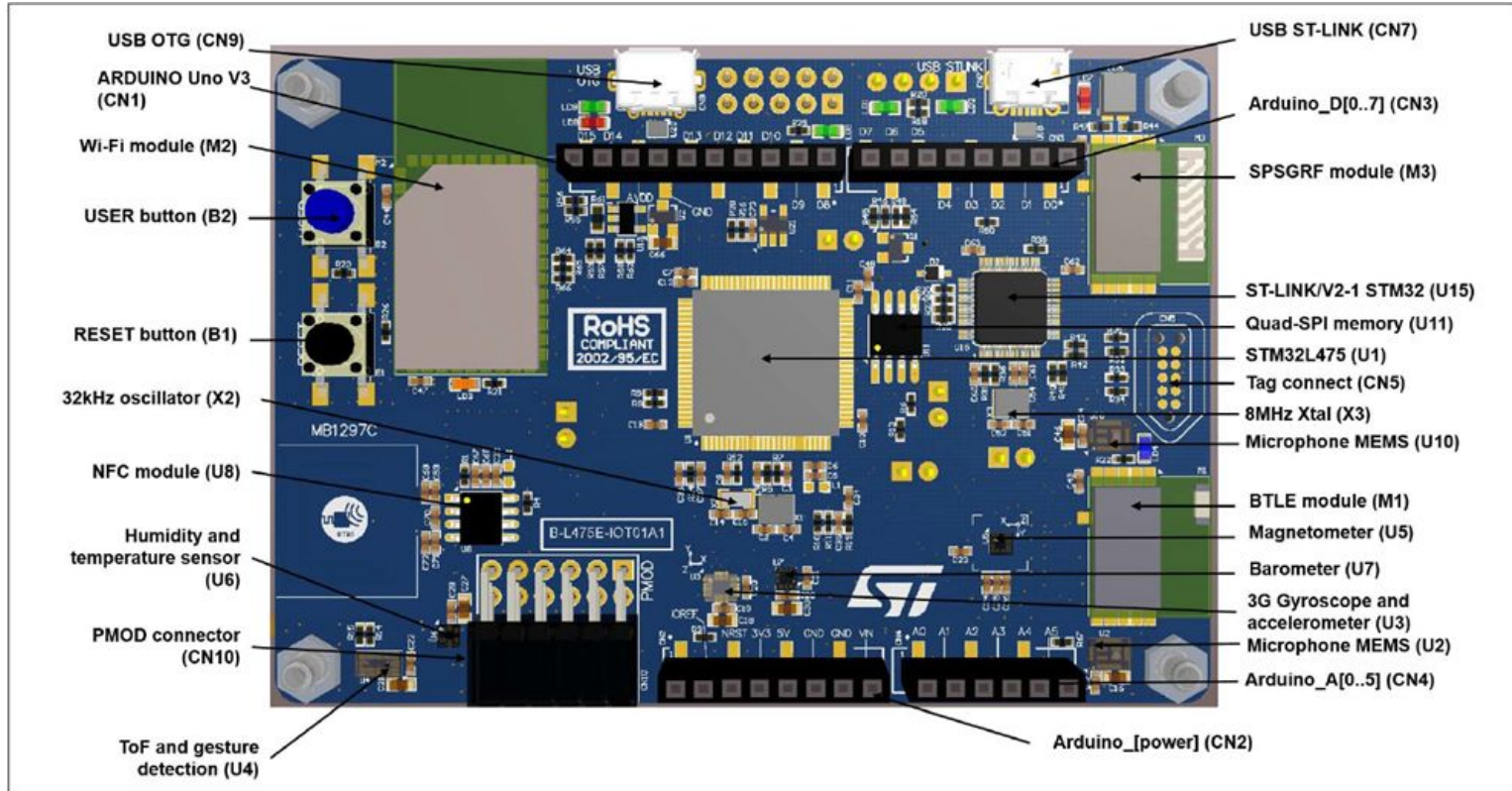
ST Community

ST Longevity Commitment

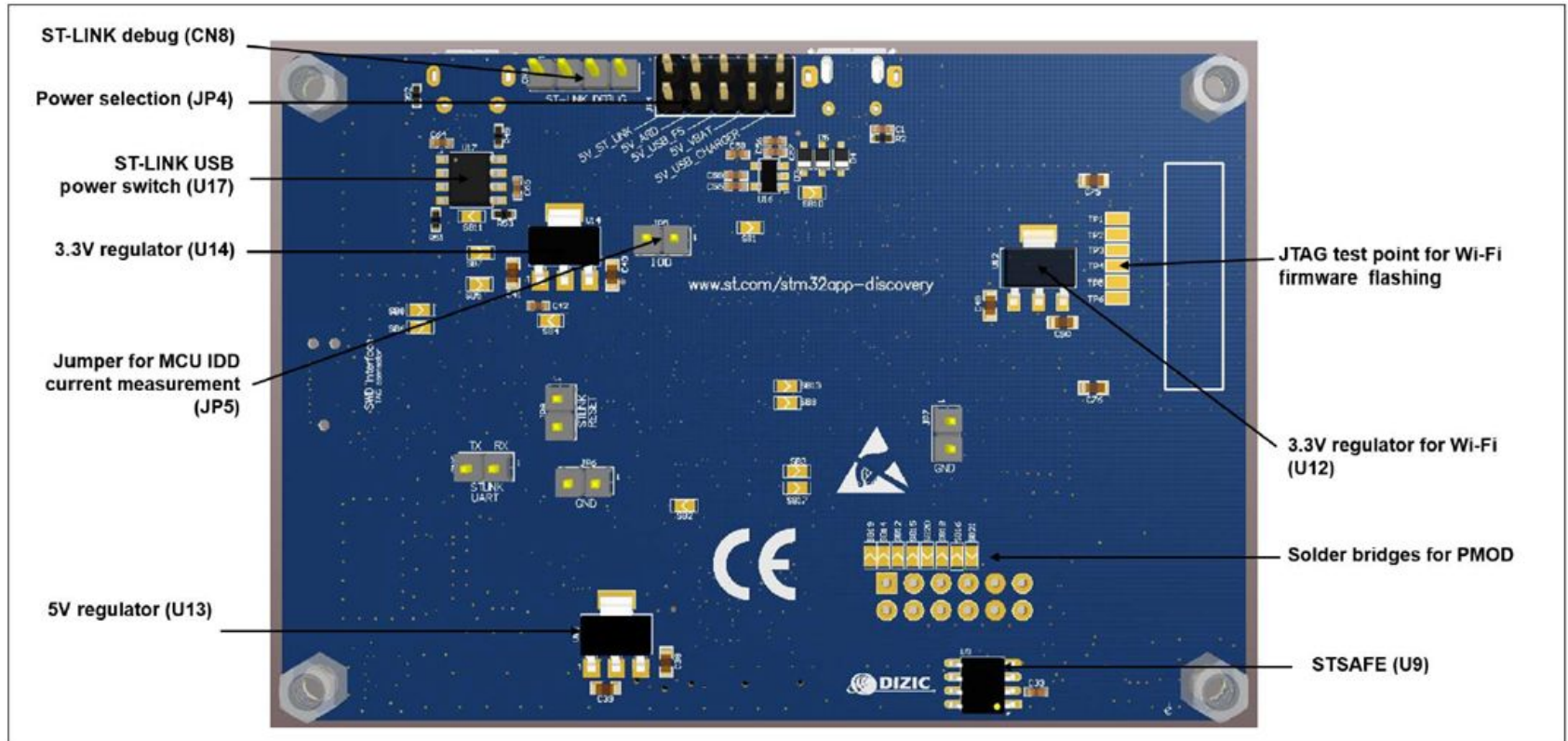
STM32CubeIDE s/w package 관리



실습보드(B-L475E-IOT01A)

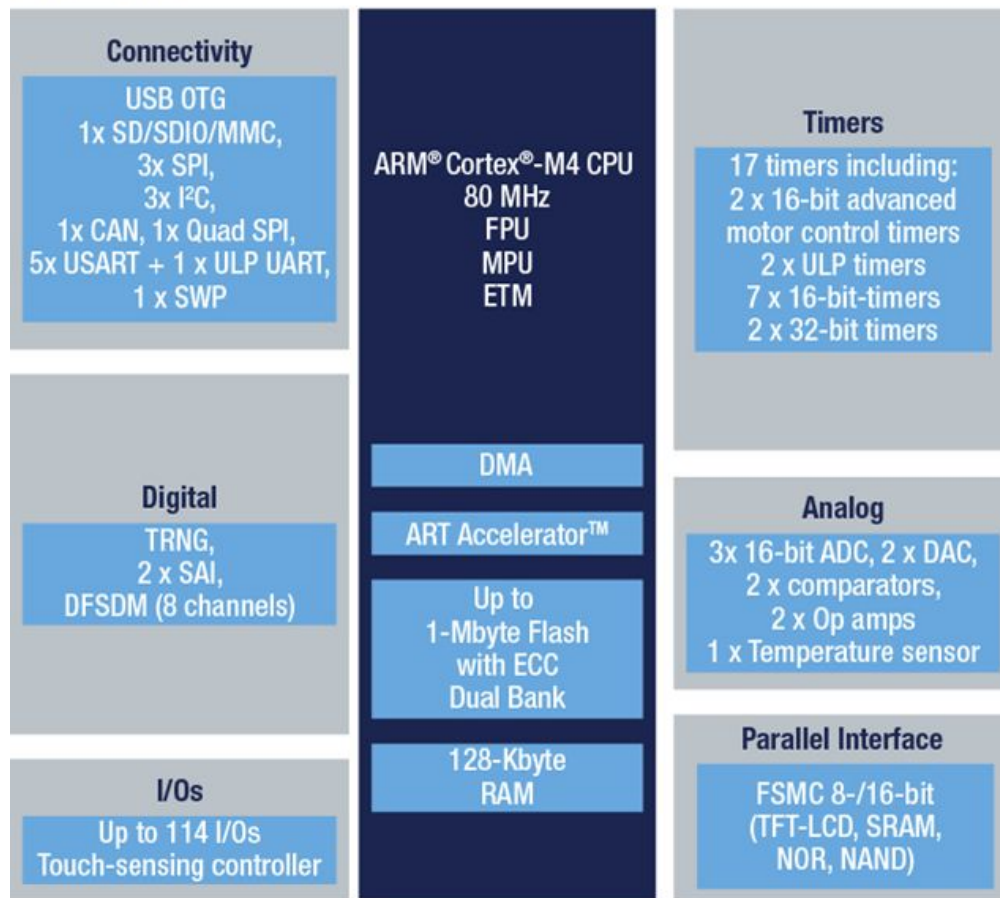


실습보드(B-L475E-IOT01A)

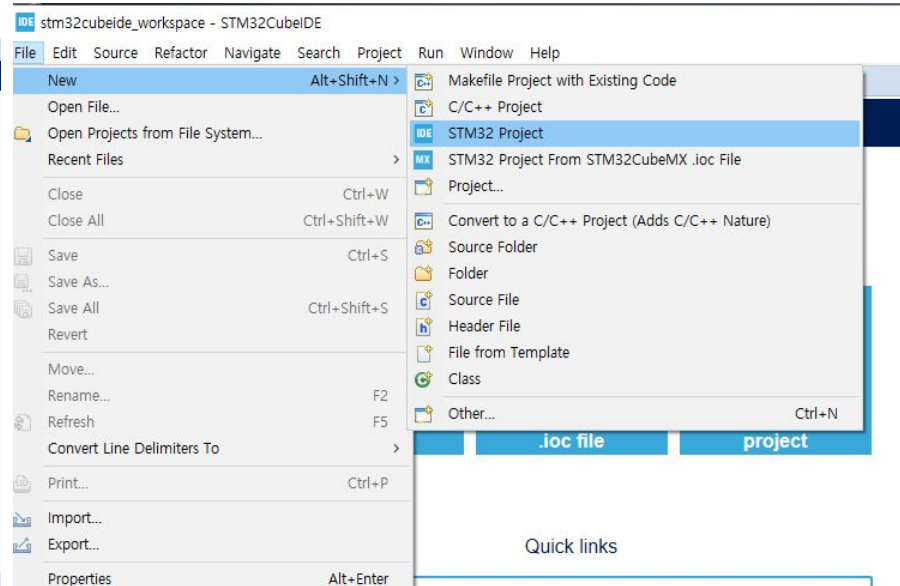
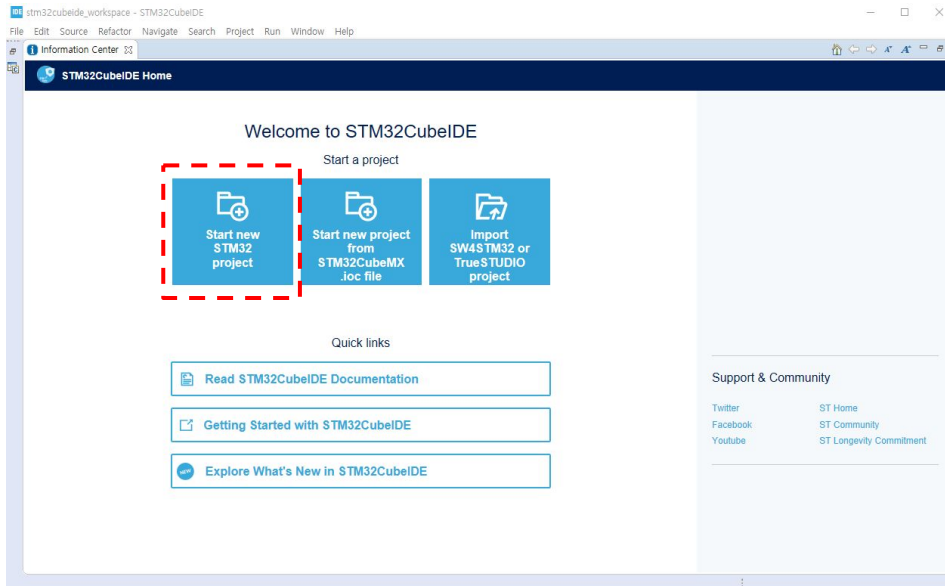


실습보드

STM32L475



STM32CubeIDE Project 생성



STM32CubeIDE Project 생성

MCU/MPU Selector

STM32 Project

Target Selection
Select STM32 target

MCU/MPU Selector Board Selector Cross Selector

MCU/MPU Filters

Part Number Search

Core >

Series >

Line >

Package >

Other >

Price From 0.0 to 9.54

IO From 11 to 176

Eeprom From 0 to 16384 (Bytes)

Flash From 0 to 2048 (kBytes)

Ram From 2 to 1184 (kBytes)

Features Block Diagram Docs & Resources Datasheet

STM32Cube embedded software now available on GitHub

MCUs/MPUs List: 1641 items

Part No.	Reference	Marketing St.	Unit Price for 10kU	Board	Package	Flash	RAM	IO	Freq
☆ STM32F030C6	STM32F030C6Tx	Active	0.597		LQFP48	32 kBytes	4 kBytes	39	48 MHz
☆ STM32F030C8	STM32F030C8Tx	Active	0.722		LQFP48	64 kBytes	8 kBytes	39	48 MHz
☆ STM32F030CC	STM32F030CCTx	Active	1.1		LQFP48	256 kBytes	32 kBytes	37	48 MHz
☆ STM32F030F4	STM32F030F4Px	Active	0.424		TSSOP20	16 kBytes	4 kBytes	15	48 MHz
☆ STM32F030K6	STM32F030K6Tx	Active	0.518		LQFP32	32 kBytes	4 kBytes	25	48 MHz
☆ STM32F030R8	STM32F030R8Tx	Active	0.754	N_3...	LQFP64	64 kBytes	8 kBytes	55	48 MHz
☆ STM32F030RC	STM32F030RCTx	Active	1.21		LQFP64	256 kBytes	32 kBytes	51	48 MHz
☆ STM32F031C4	STM32F031C4Tx	Active	0.97		LQFP48	16 kBytes	4 kBytes	39	48 MHz
☆ STM32F031C6	STM32F031C6Tx	Active	1.013		LQFP48	32 kBytes	4 kBytes	39	48 MHz

< Back Next > Finish Cancel

STM32CubeIDE Project 생성

Board Selector

The screenshot shows the STM32CubeIDE interface with the 'Board Selector' window open. The window has a 'Target Selection' header and a 'Select STM32 target' sub-header. The 'Board Selector' tab is selected, showing a list of boards. The left sidebar contains filters for Board Filters, Part Number Search, Vendor, Type, MCU/MPU Series, Other, Price, Oscillator Freq., and Peripheral. The main area displays a banner for STM32Cube embedded software on GitHub and a table of boards.

Board Filters

- Part Number Search
- Vendor
- Type
- MCU/MPU Series
- Other
- Price: From 0.0 to 560.0
- Oscillator Freq.: From 0 to 25 (MHz)
- Peripheral

Boards List: 145 items

	Overview	Part No.	Type	Marketing Status	Unit Price (US\$)	Mounted Device
☆		32F0308DISCOVERY	Discovery kit	NRND	8.9	STM32F0308Tx
☆		32F072BDISCOVERY	Discovery kit	Active	10.4	STM32F072RBTx

Navigation buttons: < Back, Next >, Finish, Cancel

STM32CubeIDE Project 생성

사용할 MCU의

Part Number 선택

The screenshot displays the STM32CubeIDE MCU/MPU Selector window. The interface is divided into three main sections: MCU/MPU Filters, Features, and Block Diagram. The MCU/MPU Filters section on the left allows for searching and filtering components. The Features section on the right provides detailed information about the selected component, including its name, description, and specifications. The Block Diagram section at the bottom shows a list of selected components.

MCU/MPU Selector | Board Selector | Cross Selector

MCU/MPU Filters

- Part Number Search: STM32L475VG
- Core: >
- Series: >
- Line: >
- Package: >
- Other: >

Price = 4.529
IO = 82
Eeprom = 0 (Bytes)
Flash = 1024 (kBytes)
Ram = 128 (kBytes)
Freq. = 80 (MHz)

Features | Block Diagram | Docs & Resources | Datasheet

STM32L475VG

Ultra-low-power with FPU ARM Cortex-M4 MCU 80 MHz with 1 Mbyte Flash, USB OTG, DFSDM

STM32 L4

ACTIVE Active
Product is in mass production

Unit Price for 10kU (US\$): **4.529**

Board: [B-L475E-IOT01A](#)

LQFP100

The STM32L475xx devices are the ultra-low-power microcontrollers based on the high-performance Arm® Cortex®-M4 32-bit RISC core operating at a frequency of up to 80 MHz. The Cortex-M4 core features a Floating point unit (FPU) single precision which supports all Arm® single-precision data-

MCUs/MPUs List: 1 item

Display similar items

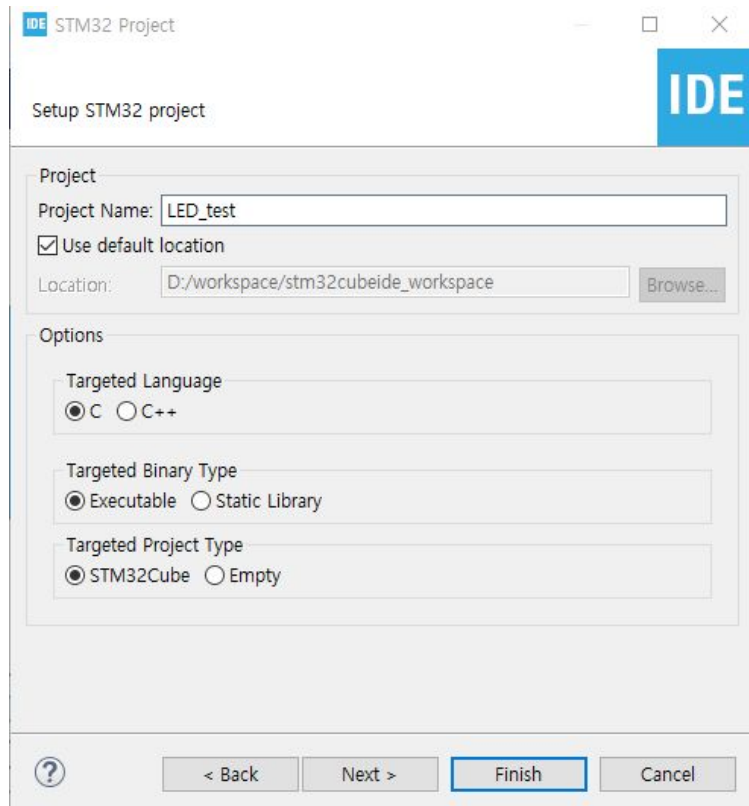
Export

* Part No *	Reference	Marketing Sta	Unit Price for 10kU (Board	Package	Flash	RAM	IO	Freq
☆ STM32L475VG	STM32L475VGtx	Active	4.529	B-L4	LQFP100	1024 kBy...	128 kBytes	82	80 MHz

< Back | **Next >** | Finish | Cancel

STM32CubeIDE Project 생성

Project
이름설정



IDE STM32 Project

Setup STM32 project

Project

Project Name:

☒ Use default location

Location:

Options

Targeted Language

☒ C ☐ C++

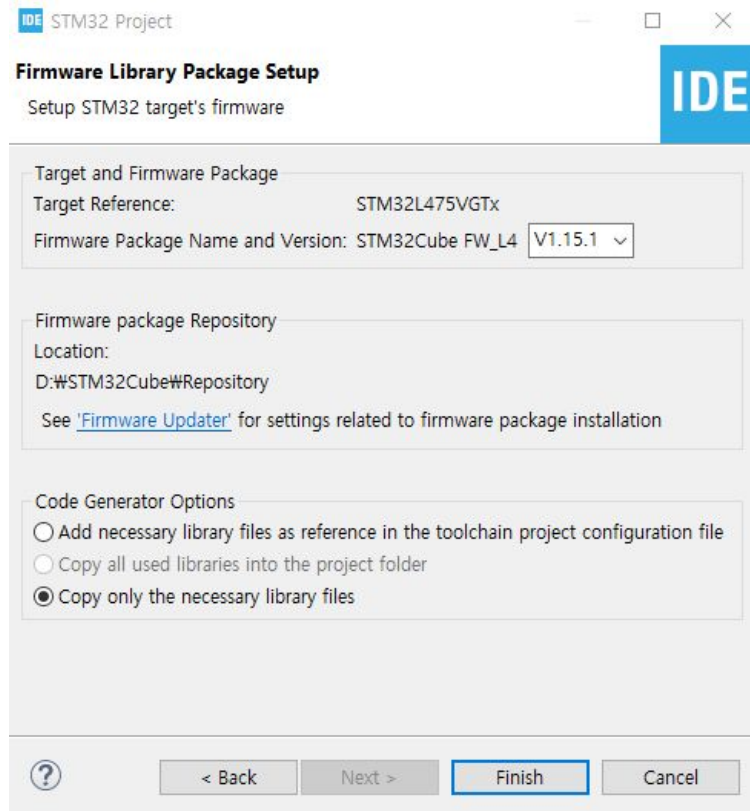
Targeted Binary Type

☒ Executable ☐ Static Library

Targeted Project Type

☒ STM32Cube ☐ Empty

S/W
package
설정



IDE STM32 Project

Firmware Library Package Setup

Setup STM32 target's firmware

Target and Firmware Package

Target Reference: STM32L475VGTx

Firmware Package Name and Version: STM32Cube FW_L4

Firmware package Repository

Location: D:#STM32Cube#Repository

See '[Firmware Updater](#)' for settings related to firmware package installation

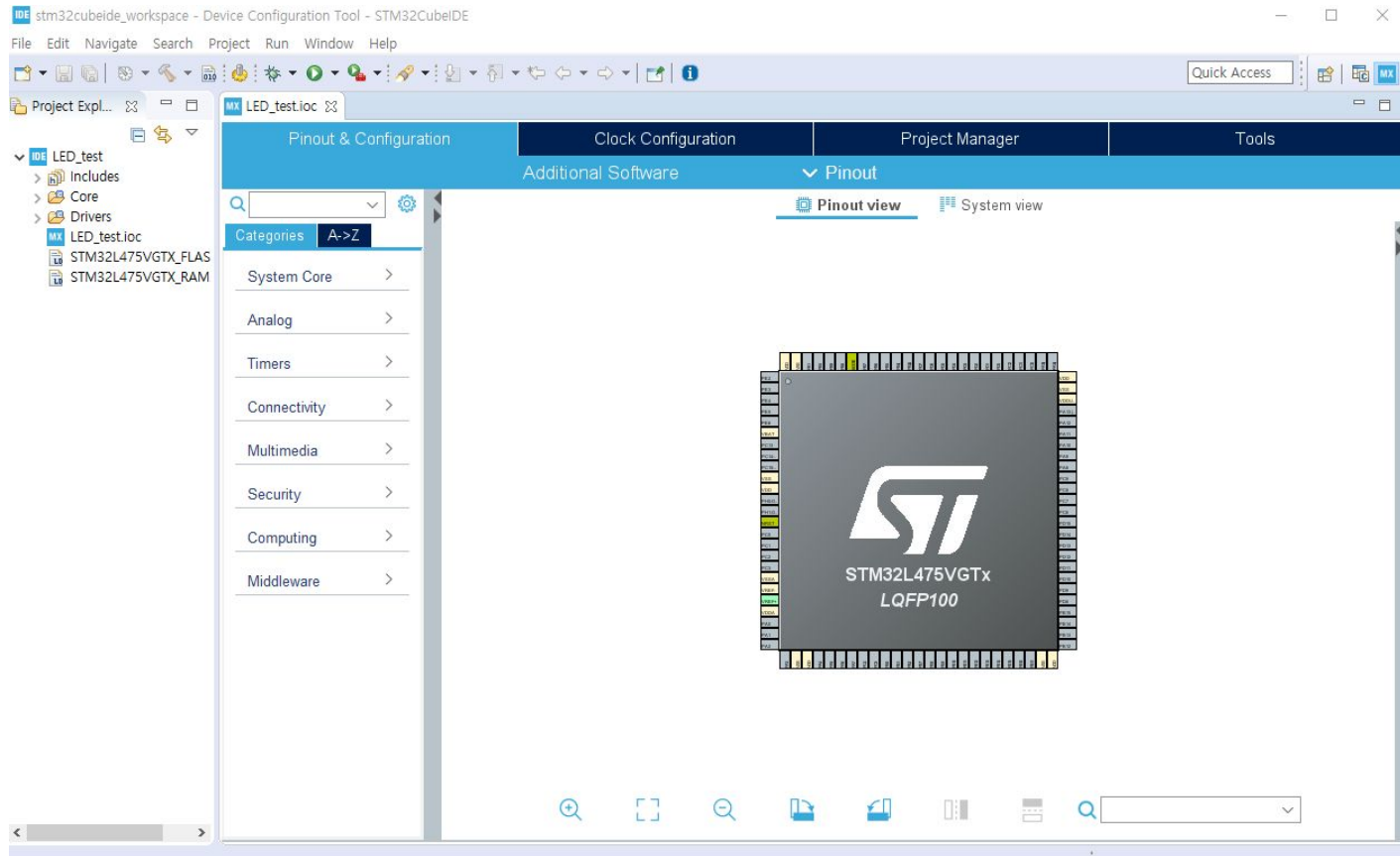
Code Generator Options

☐ Add necessary library files as reference in the toolchain project configuration file

☐ Copy all used libraries into the project folder

☒ Copy only the necessary library files

STM32CubeIDE Project 생성



Firmware

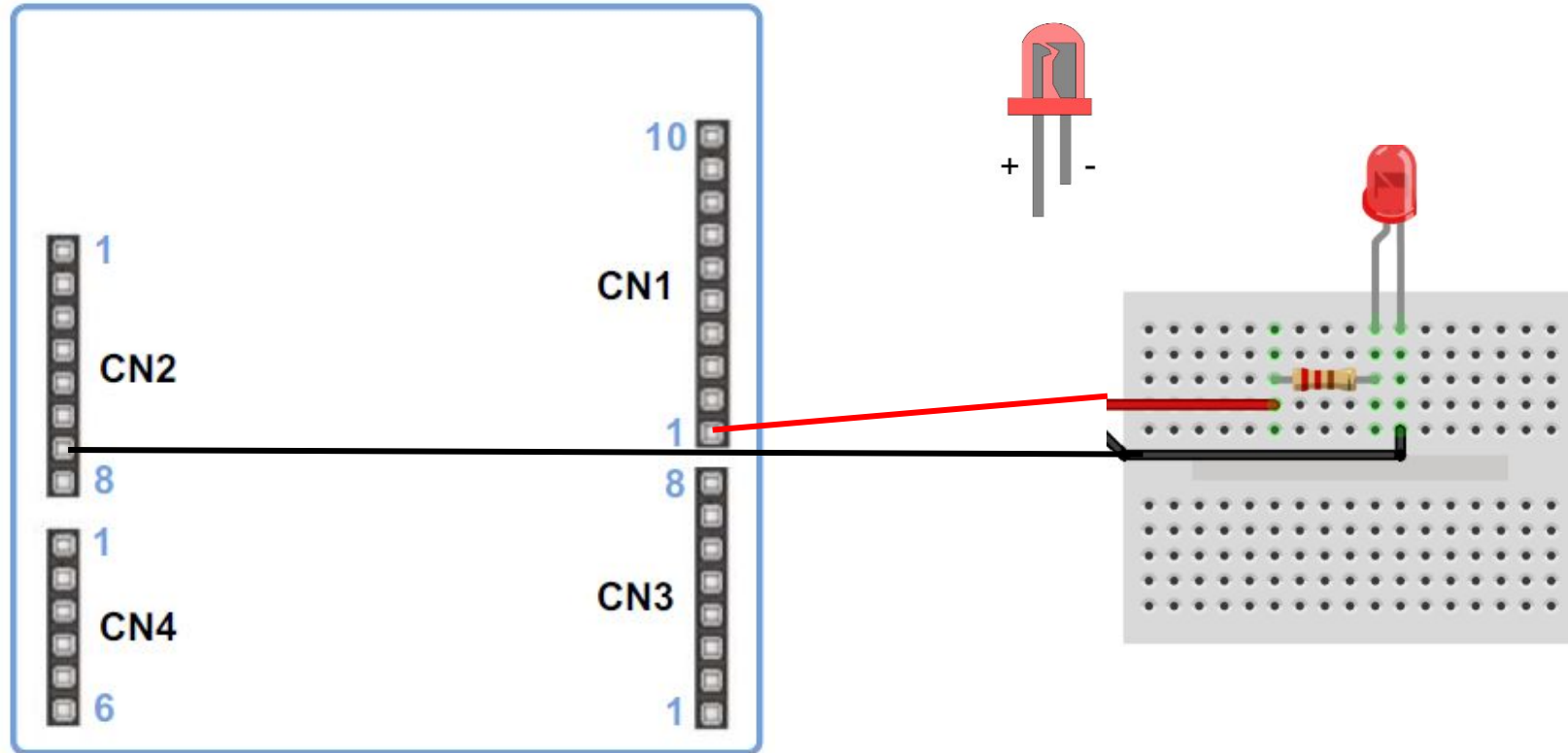
Firmware

컴퓨팅과 공학 분야에서 특정 하드웨어 장치에 포함된 소프트웨어, 소프트웨어를 읽어 실행하거나, 수정되는 것도 가능한 장치를 뜻한다. 펌웨어는 ROM이나 PROM에 저장되며, 하드웨어보다는 교환하기가 쉽지만, 소프트웨어보다는 어렵다.

인용 : 위키백과 (<https://ko.wikipedia.org/wiki/%ED%8E%8C%EC%9B%A8%EC%96%B4>)

Firmware : 임베디드 하드웨어를 동작시키며 특정 기능의 수행을 목표로하는 프로그램

LED Blinky



LED Blinky

Connector	Pin number	Pin name	Signal name	STM32 pin	Function
CN2	1	NC	-	-	-
	2	IOREF	-	-	3.3 V reference
	3	NRST	STM_NRST	NRST	Reset
	4	3.3 V	-	-	3.3 V input/output
	5	5V	-	-	5V
	6	GND	-	-	GND
	7	GND	-	-	GND
	8	VIN	-	-	Power input
CN4	1	A0	ARD.A0-ADC	PC5	ADC
	2	A1	ARD.A1-ADC	PC4	ADC
	3	A2	ARD.A2-ADC	PC3	ADC
	4	A3	ARD.A3-ADC	PC2	ADC
	5	A4	ARD.A4-ADC	PC1	ADC / I2C3_SDA
	6	A5	ARD.A5-ADC	PC0	ADC / I2C3_SCL

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CN1	10	SCL/D15	ARD.D15-I2C1_SCL	PB8	I2C1_SCL
	9	SDA/D14	ARD.D14-I2C1_SDA	PB9	I2C1_SDA
	8	AVDD	VDDA	-	VDDA
	7	GND	GND	-	Ground
	6	SCK/D13	ARD.D13-SPI1_SCK/LED1	PA5	SPI1_SCK / LED1
	5	MISO/D12	ARD.D12-SPI1_MISO	PA6	SPI1_MISO
	4	PWM/MOSI/D11	ARD.D11-SPI1_MISO/PWM	PA7	SPI1_MOSI / TIMxx
	3	PWM/CS/D10	ARD.D10-SPI_SSN/PWM	PA2	TIM2_CH3
	2	PWM/D9	ARD.D9-PWM	PA15	TIM2_CH1
	1	D8	ARD.D8	PB2	GPIO
CN3	8	D7	ARD.D7	PA4	GPIO
	7	PWM/D6	ARD.D6-PWM	PB1	TIM3_CH4
	6	PWM/D5	ARD.D5-PWM	PB4	TIM3_CH1
	5	D4	ARD.D4	PA3	TIMxx
	4	PWM/D3	ARD.D3-PWM/INT1_EXTI0	PB0	TIM3_CH3 / EXTI0
	3	D2	ARD.D2-INT0_EXTI14	PD14	EXTI14
	2	TX/D1	ARD.D1-UART4_TX	PA0	UART4_TX
	1	RX/D0	ARD.D0-UART4_RX	PA1	UART4_RX

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Debug Pin 설정

The screenshot displays the STM32CubeMX Pinout & Configuration window. The top navigation bar includes 'Pinout & Configuration', 'Clock Configuration', and 'Project Manager'. Below this, a secondary bar shows 'Additional Software' and a dropdown for 'Pinout'. The left sidebar contains a search bar and a 'Categories' section with a list of system components: DMA, GPIO, IWDG, NVIC, RCC, **SYS** (selected), TSC, and WWDG. Below this are expandable sections for Analog, Timers, Connectivity, and Multimedia. The main area is titled 'SYS Mode and Configuration' and contains a 'Mode' section with a 'Debug' dropdown set to 'Serial Wire'. Below this are five checkboxes for 'System Wake-Up' (1-5), all of which are unchecked. Further down are three dropdown menus: 'Power Voltage Detector In' set to 'Disable', 'VREFBUF Mode' set to 'Disable', and 'Timebase Source' set to 'SysTick'. On the right side of the main area, there is a 'Pinout view' tab and a diagram of the pinout. The diagram shows a row of pins: PD2, PD1, PD0, PC12, PC11, PC10, PA15, and PA14. The PA14 pin is highlighted in green. To the right of the pinout diagram, there is a vertical stack of labels: VDD, VSS, VDD.., PA13.., PA12, and PA11. The PA13.. label is highlighted in green. The text 'SYS_JTCK-S1' is written vertically next to the pinout diagram, and 'SYS_JTMS-S1' is written next to the PA13.. label.

Pinout & Configuration | Clock Configuration | Project Manager

Additional Software | Pinout

Search | Categories | A-Z

System Core

- DMA
- GPIO
- IWDG
- NVIC
- RCC
- SYS**
- TSC
- WWDG

Analog >

Timers >

Connectivity >

Multimedia >

SYS Mode and Configuration

Mode

Debug: Serial Wire

- ☐ System Wake-Up 1
- ☐ System Wake-Up 2
- ☐ System Wake-Up 3
- ☐ System Wake-Up 4
- ☐ System Wake-Up 5

Power Voltage Detector In: Disable

VREFBUF Mode: Disable

Timebase Source: SysTick

Pinout view

PD2 PD1 PD0 PC12 PC11 PC10 PA15 PA14

SYS_JTCK-S1

VDD VSS VDD.. PA13.. PA12 PA11

SYS_JTMS-S1

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LED pin 설정

The screenshot shows the STM32CubeIDE Pinout Configuration window. The left sidebar lists system components, with 'SYS' selected. The main area displays the 'GPIO Mode and Configuration' for pin PB2. The pin is configured as an output (Out...). A context menu is open over the pin, showing various peripheral functions, with 'GPIO_Output' highlighted.

GPIO Mode and Configuration

Group By Peripherals

GPIO SYS

Search Signals

Search (Ctrl+F) ☐ Show only Modified Pins

	Sig...	GPI...	GPI...	GPI...	Ma...	Fas...	Use...	Mo...
PB2	n/a	Low	Out...	No ...	Low	n/a		<input type="checkbox"/>

Select Pins from table to configure them. **Multiple selection is Allowed.**

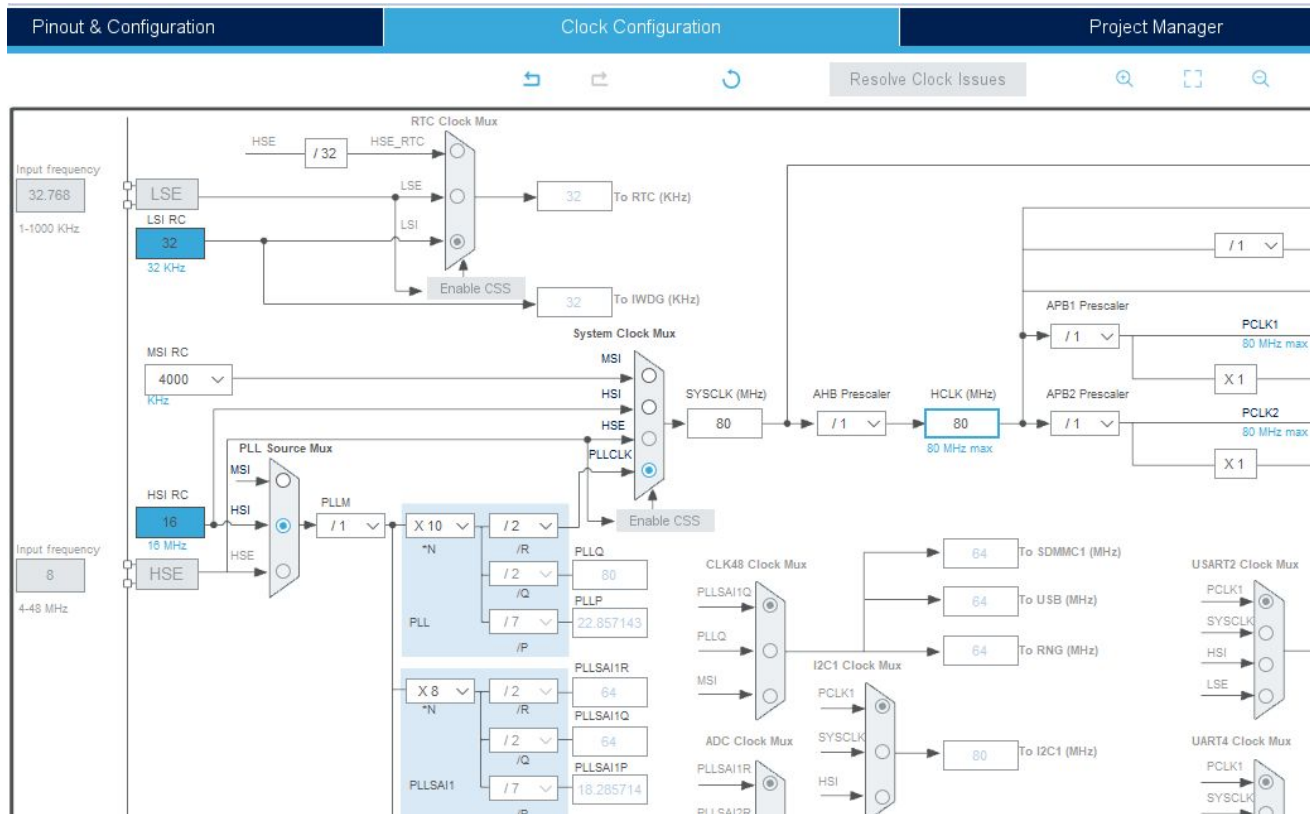
Pinout view System view

PC5 PB0 PB1 PB2 PB8 PB9 PE10 PE11 PE12

Reset_State
COMP1_INP
DFSDM1_CKIN0
I2C3_SMBA
LPTIM1_OUT
RTC_OUT_ALARM
RTC_OUT_CALIB
GPIO_Input
GPIO_Output
GPIO_Analog
EVENTOUT
GPIO_EXTI2

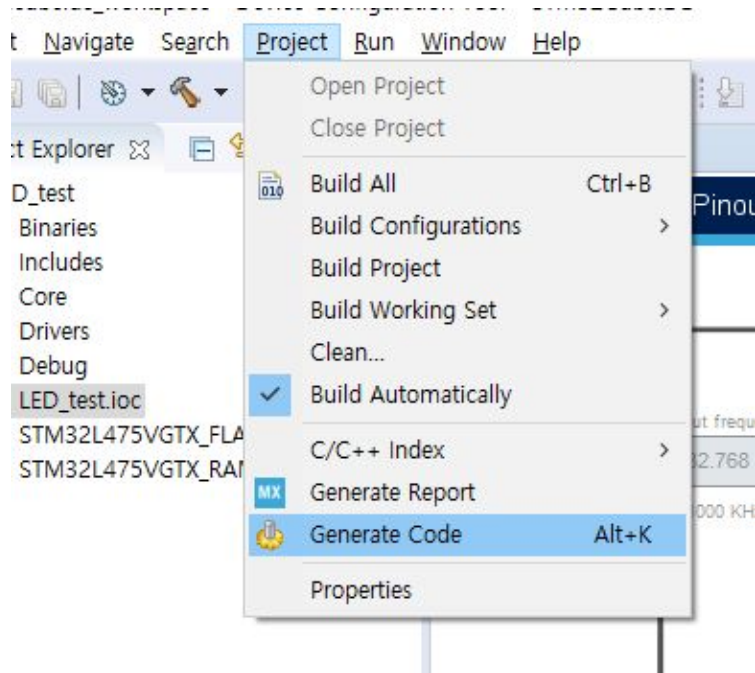
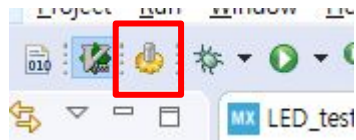
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Clock 설정



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코드 생성



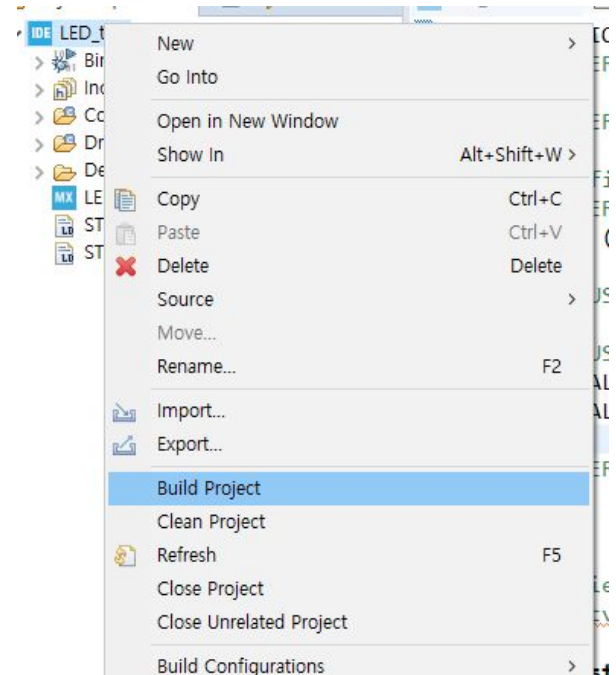
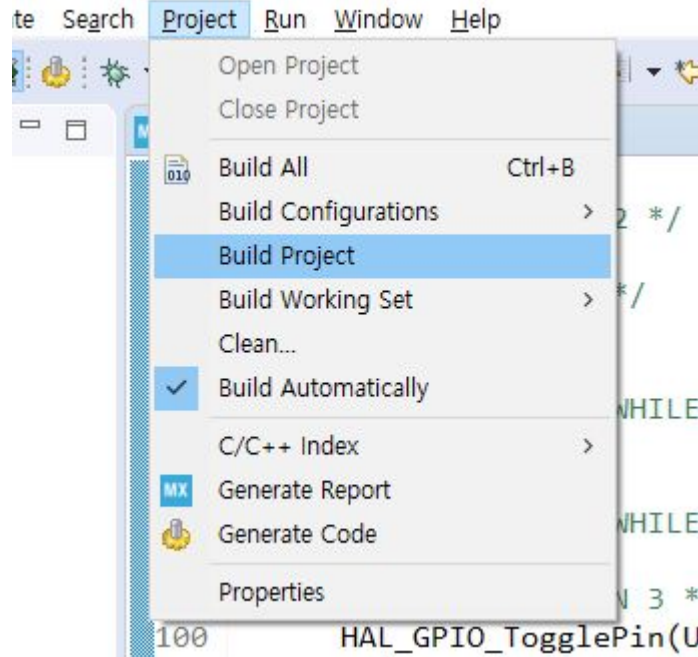
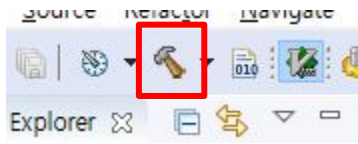
LED Blinky

User code 작성

```
90
91  /* USER CODE END 2 */
92
93  /* Infinite loop */
94  /* USER CODE BEGIN WHILE */
95  while (1)
96  {
97      /* USER CODE END WHILE */
98
99      /* USER CODE BEGIN 3 */
00      HAL_GPIO_TogglePin(USER_LED_GPIO_Port, USER_LED_Pin);
01      HAL_Delay(500);
02  }
03  /* USER CODE END 3 */
04 }
05
```

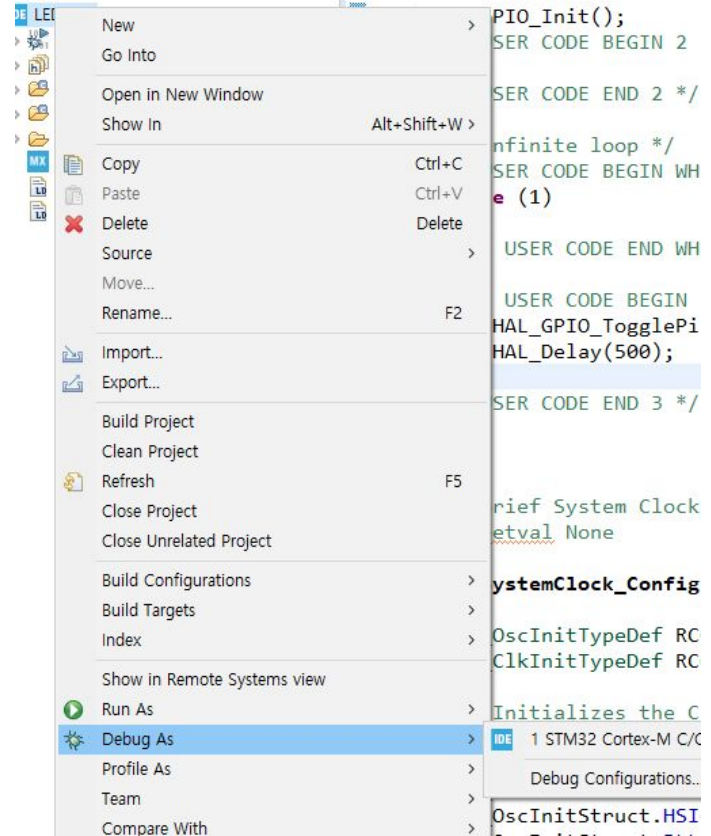
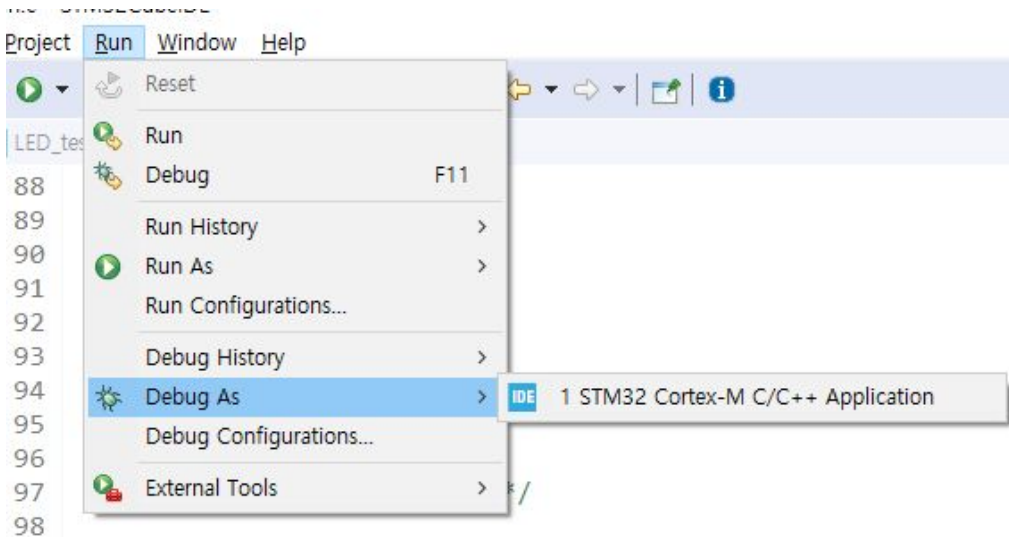
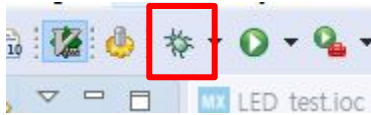
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Build Project



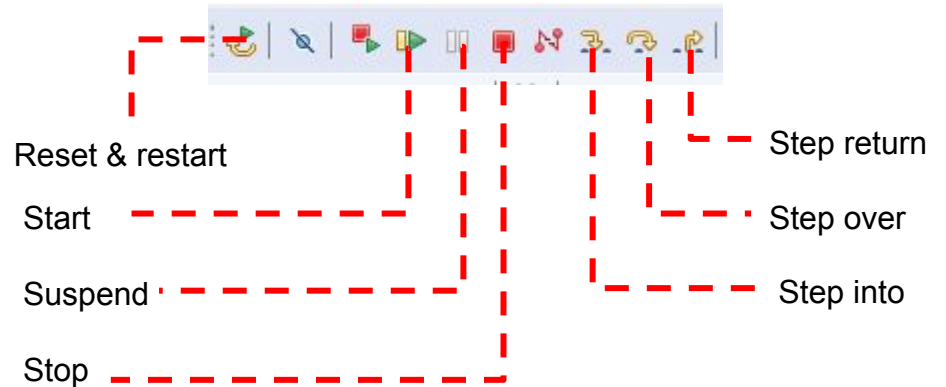
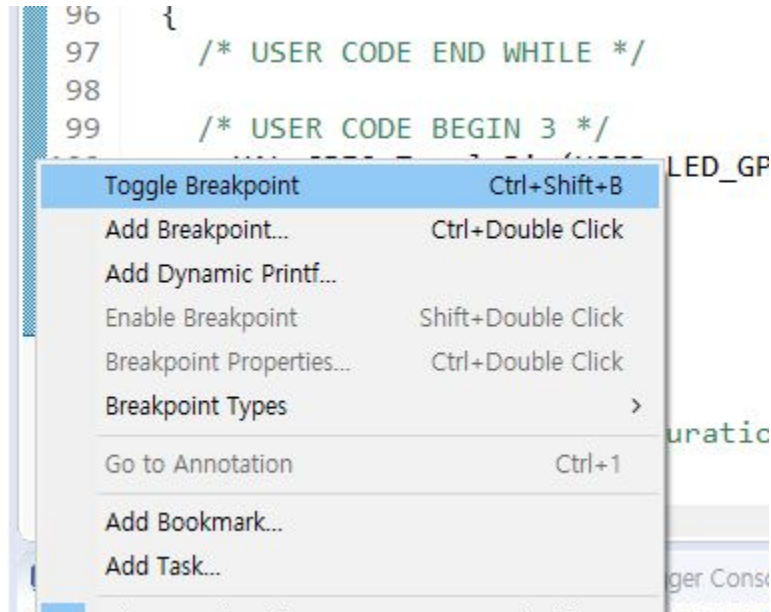
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Debug



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Debugging



Firmware 흐름(NO-RTOS)

START UP

```
int main(void)
/* USER CODE BEGIN 1 */

/* USER CODE END 1 */

/* MCU Configuration-----

/* Reset of all peripherals, Init
HAL_Init();

/* USER CODE BEGIN Init */

/* USER CODE END Init */

/* Configure the system clock */
SystemClock_Config();

/* USER CODE BEGIN SysInit */

/* USER CODE END SysInit */

/* Initialize all configured peri
/* USER CODE BEGIN 2 */

/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{
/* USER CODE END WHILE */

/* USER CODE BEGIN 3 */

/* USER CODE END 3 */
}
}
```

실습

LED Blinky

- LED 2개를 연결하고 LED1 500ms, LED2 700ms로 설정

감사합니다.