

Lab 1

A/D and D/A Converter



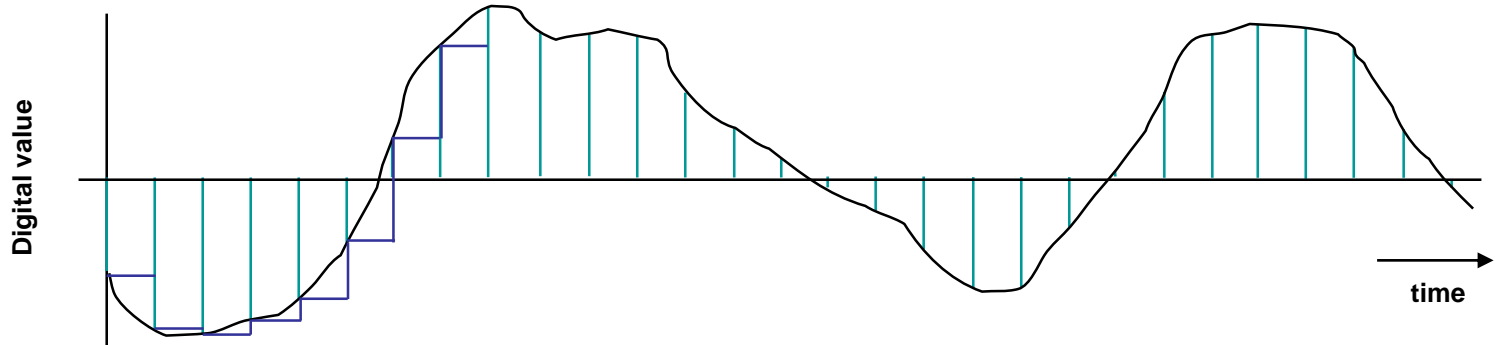
Analog and Digital



- CD digital audio encoding:
2-channel signed 16-bit
Linear PCM sampled at
44,100 Hz.



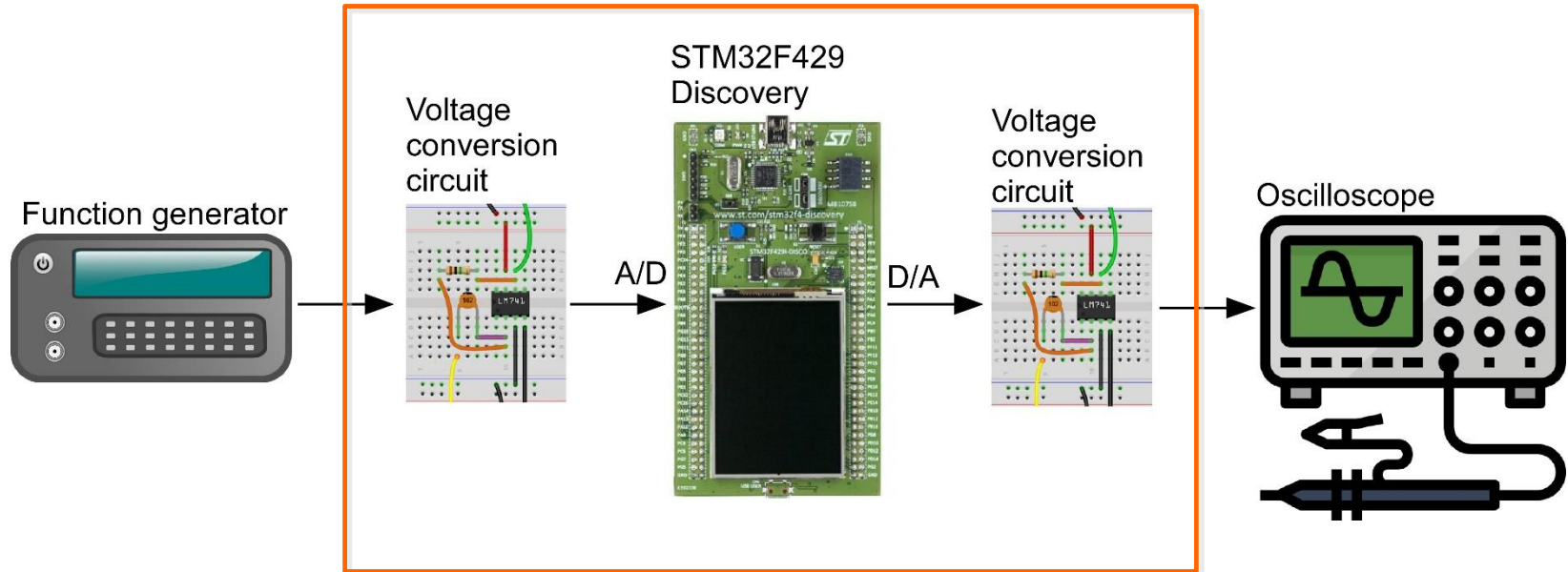
Waveform Sampling and Quantization



- A waveform is **sampled** at a constant rate – every Δ_t
 - Each such sample represents the instantaneous amplitude at the instant of sampling
 - “At 37 ms, the input is 1.91341914513451451234311... V”
 - Sampling converts a **continuous time** signal to a **discrete time** signal
- The sample can now be **quantized** (converted) into a digital value
 - Quantization represents a **continuous** (analog) value with the closest **discrete** (digital) value
 - “The sampled input voltage of 1.91341914513451451234311... V is best represented by the code 0x018, since it is in the range of 1.901 to 1.9980 V which corresponds to code 0x018.”

Lab Setup

Base Board



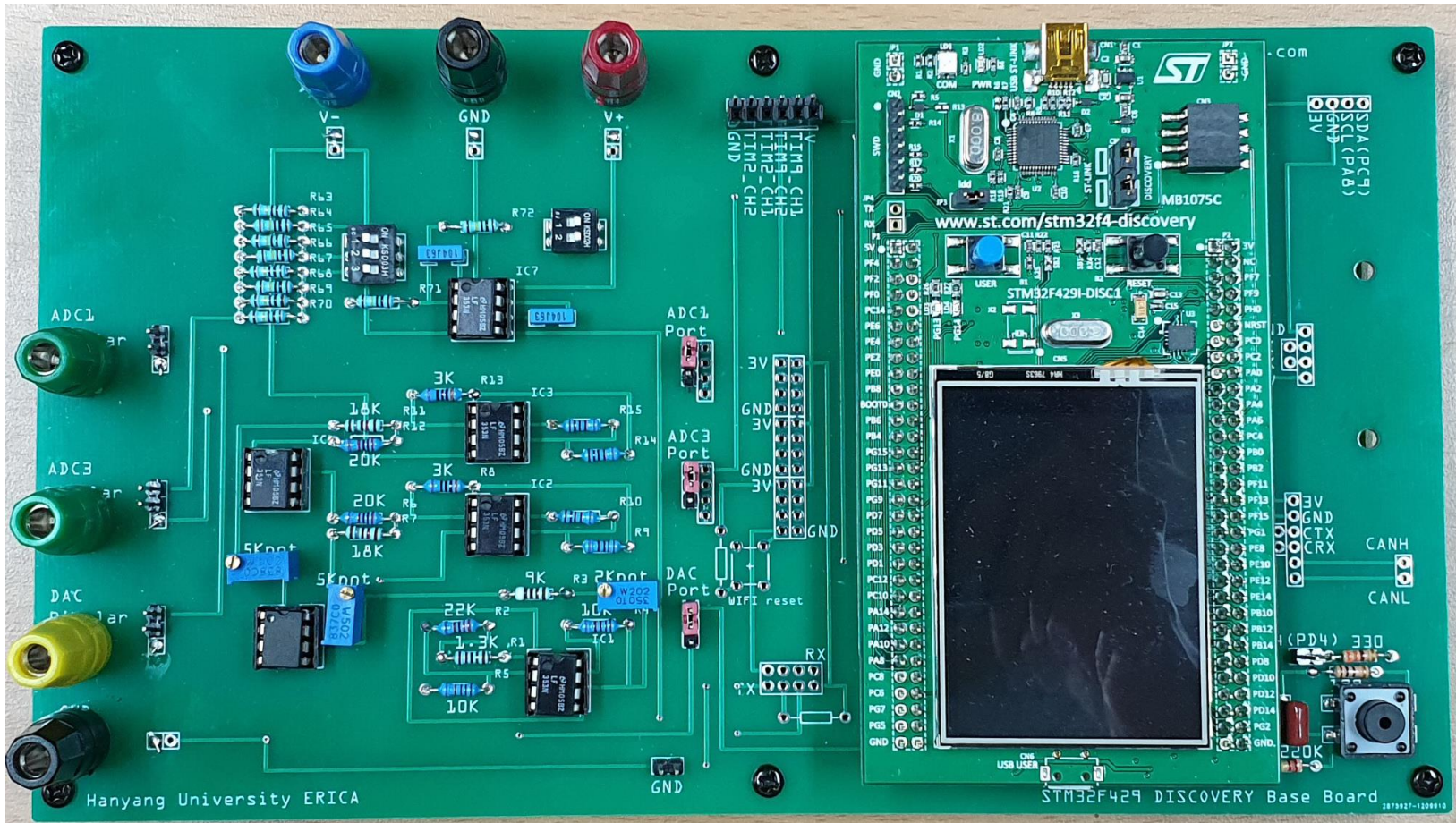
STM32F429 Discovery Board

-15V GND +15V

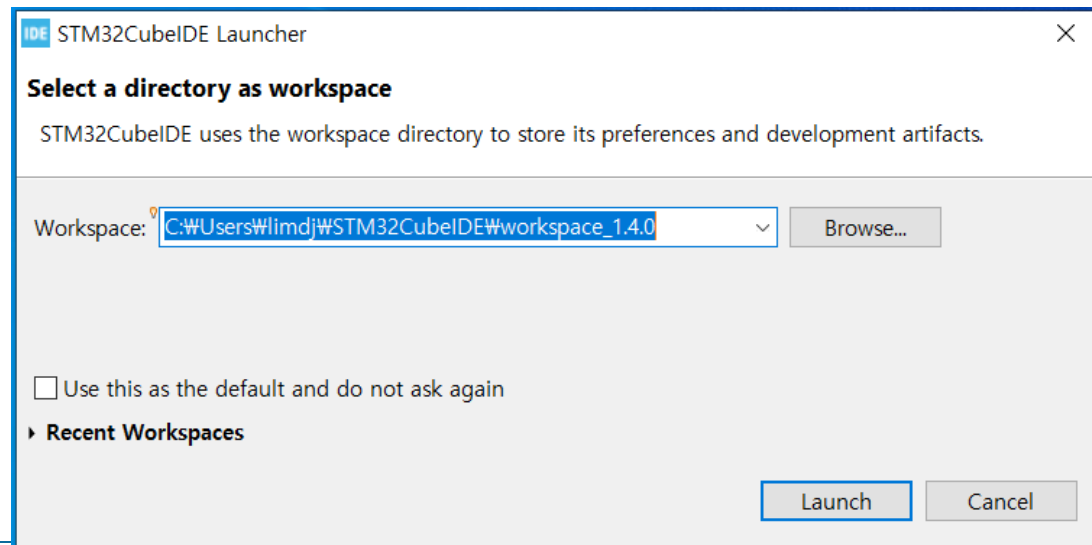
Mini USB: To PC

ADC
input

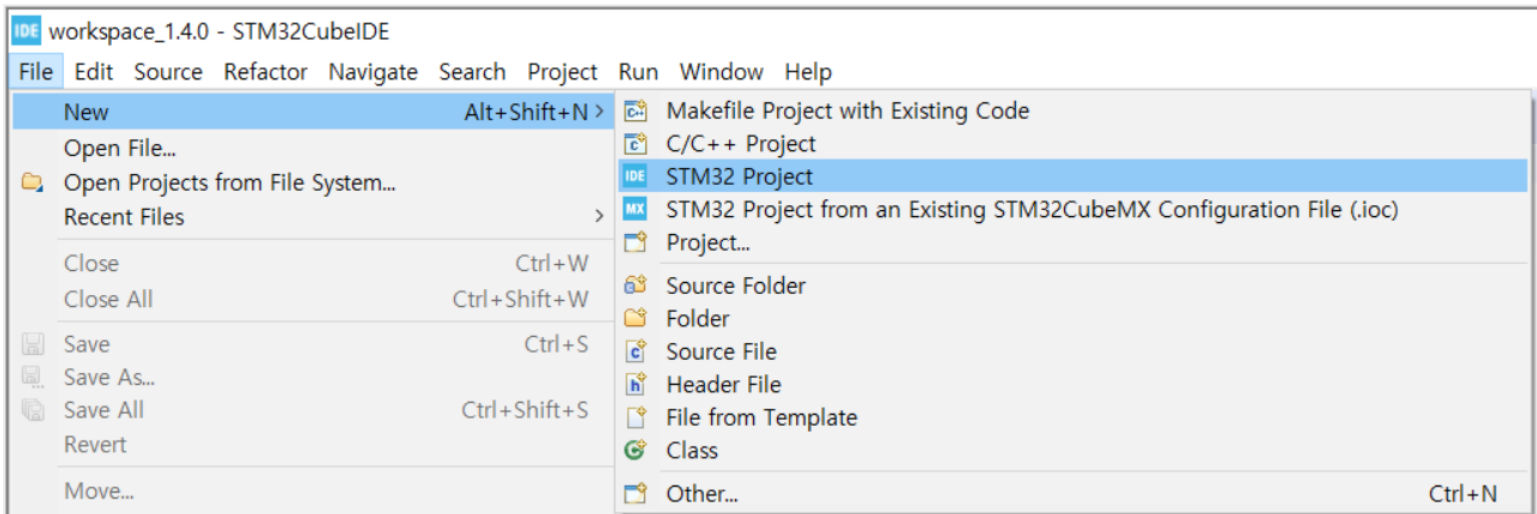
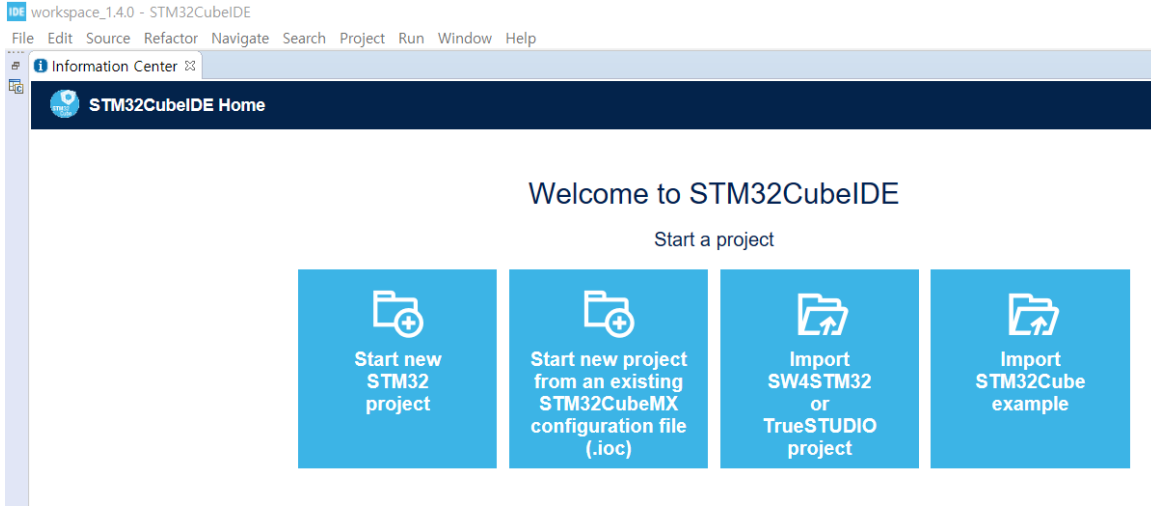
DAC
output
GND



Start STM32CubeIDE



Start New STM32 Project



Board Selector

- Select STM32F-429I-DISC1
- Click Next

The screenshot shows the 'Board Selector' interface within the STM32 Project IDE. The interface is titled 'Target Selection' and includes a search bar for 'STM32F4 Series'. Below the search bar, there is a 'Boards List' with 7 items. The board 'STM32F429I-DISC1' is highlighted in blue. The interface also includes filters for 'Commercial Part Number', 'Vendor', and 'Type', and a list of 'MCU/MPU Series'.

Board Filters

Commercial Part Number: [Dropdown]

Vendor: [Dropdown]

Type: [Dropdown]

Check/Uncheck All

Discovery Kit

Evaluation Board

Evaluation Kit

Nucleo USB Dongle

Nucleo-144

Nucleo-32

Nucleo-64

Nucleo-RF Kit

MCU/MPU Series: [Dropdown]

Check/Uncheck All

STM32F0

STM32F1

STM32F2

STM32F3

STM32F4

STM32F7

Boards List: 7 items

	Overview	Commercial Part No	Type	Marketing Status	Unit Price (US\$)	Mounted Device
☆		STM32F407G-DISC1	Discovery Kit	Active	19.89	STM32F407VGTx
☆		STM32F411E-DISCO	Discovery Kit	Active	15.0	STM32F411VETx
☆		STM32F412G-DISCO	Discovery Kit	Active	35.0	STM32F412ZGTx
☆		STM32F413H-DISCO	Discovery Kit	Active	70.0	STM32F413ZHTx
☆		STM32F429I-DISC1	Discovery Kit	Active	29.9	STM32F429ZITx
☆		STM32F469I-DISCO	Discovery Kit	Active	59.0	STM32F469NHTx

Setup Project

- Project Name:ADDA

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

IDE Board Project Options

Initialize all peripherals with their default Mode ?

The screenshot displays the STM32CubeIDE interface for configuring a project. The top menu bar includes File, Edit, Source, Refactor, Navigate, Search, Project, Run, Window, and Help. Below the menu is a toolbar with various icons for file operations and development tools.

The Project Explorer on the left shows the project structure for 'ADDA'. The main workspace is divided into several panes:

- Pinout & Configuration**: Contains a search bar and a 'Mode and Configuration' section with a 'Mode' dropdown.
- Software Packs**: A section for managing software packs, currently showing 'Pinout'.
- Project Manager**: A section for managing project settings.
- Tools**: A section for additional tools.

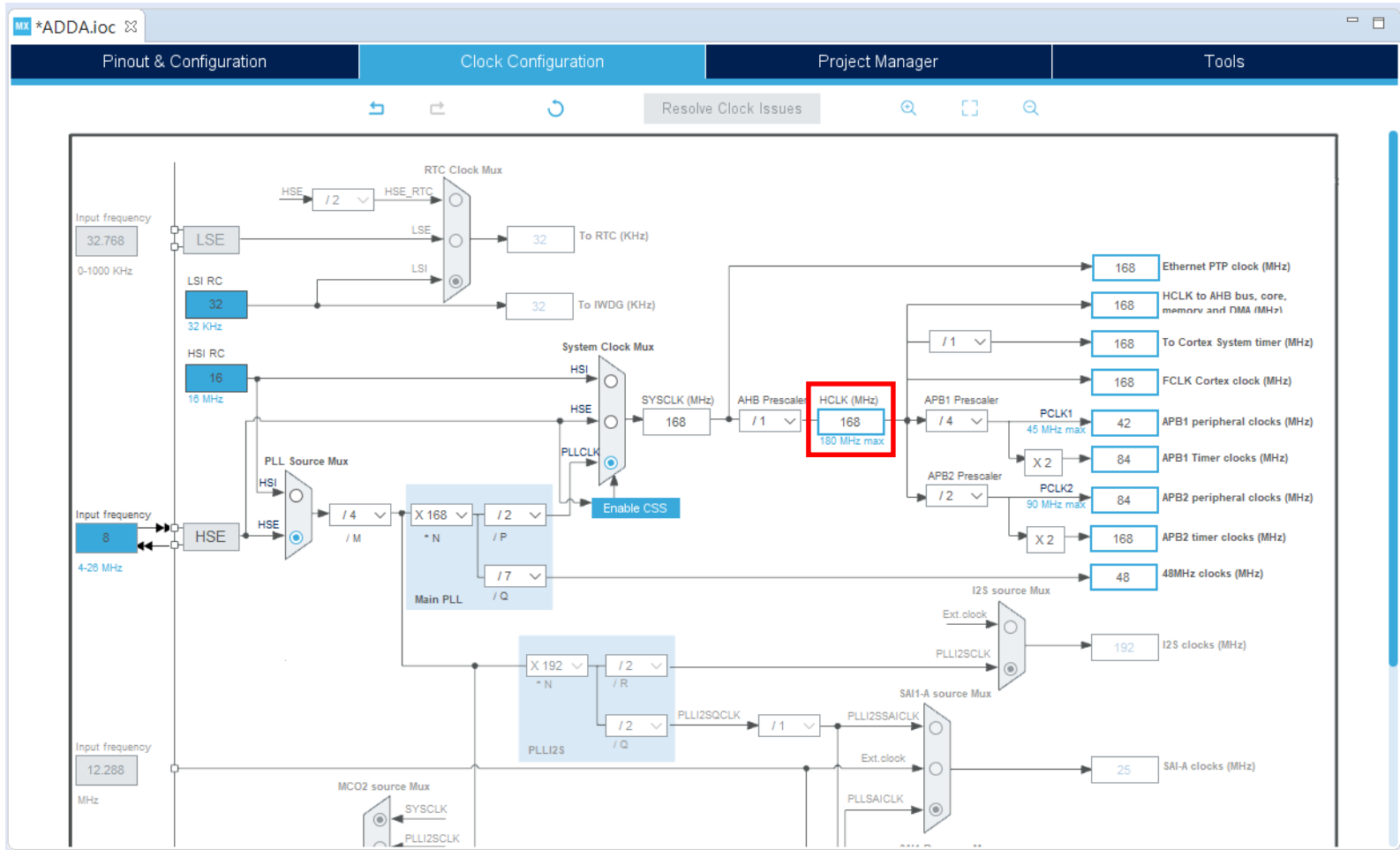
The 'Mode and Configuration' pane is expanded to show a list of categories and their configurations:

- System Core >
- Analog >
- Timers >
- Connectivity >
- Multimedia >
- Security >
- Computing >
- Middleware >
 - FATFS
 - ✓ FREERTOS
 - LIBJPEG
 - LWIP
 - MBEDTLS
 - PDM2PCM
 - USB_DEVICE
 - ✓ USB_HOST

The right side of the workspace shows a detailed pinout diagram for the STM32F429ZITx LQFP144 package. The diagram features the ST logo and the device name. The pins are color-coded: green for I/O pins, yellow for power pins, and grey for other pins. The pinout is labeled with names such as PC10, PC11, PC12, PC13, PC14, PC15, PC16, PC17, PC18, PC19, PC20, PC21, PC22, PC23, PC24, PC25, PC26, PC27, PC28, PC29, PC30, PC31, PC32, PC33, PC34, PC35, PC36, PC37, PC38, PC39, PC40, PC41, PC42, PC43, PC44, PC45, PC46, PC47, PC48, PC49, PC50, PC51, PC52, PC53, PC54, PC55, PC56, PC57, PC58, PC59, PC60, PC61, PC62, PC63, PC64, PC65, PC66, PC67, PC68, PC69, PC70, PC71, PC72, PC73, PC74, PC75, PC76, PC77, PC78, PC79, PC80, PC81, PC82, PC83, PC84, PC85, PC86, PC87, PC88, PC89, PC90, PC91, PC92, PC93, PC94, PC95, PC96, PC97, PC98, PC99, PC100, PC101, PC102, PC103, PC104, PC105, PC106, PC107, PC108, PC109, PC110, PC111, PC112, PC113, PC114, PC115, PC116, PC117, PC118, PC119, PC120, PC121, PC122, PC123, PC124, PC125, PC126, PC127, PC128, PC129, PC130, PC131, PC132, PC133, PC134, PC135, PC136, PC137, PC138, PC139, PC140, PC141, PC142, PC143, PC144, PC145, PC146, PC147, PC148, PC149, PC150, PC151, PC152, PC153, PC154, PC155, PC156, PC157, PC158, PC159, 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PC2140, PC2141, PC2142, PC2143, PC2144, PC2145, PC2146, PC2147, PC2148, PC2149, PC2150, PC2151, PC2152, PC2153, PC2154, PC2155, PC2156,

Clock Configuration

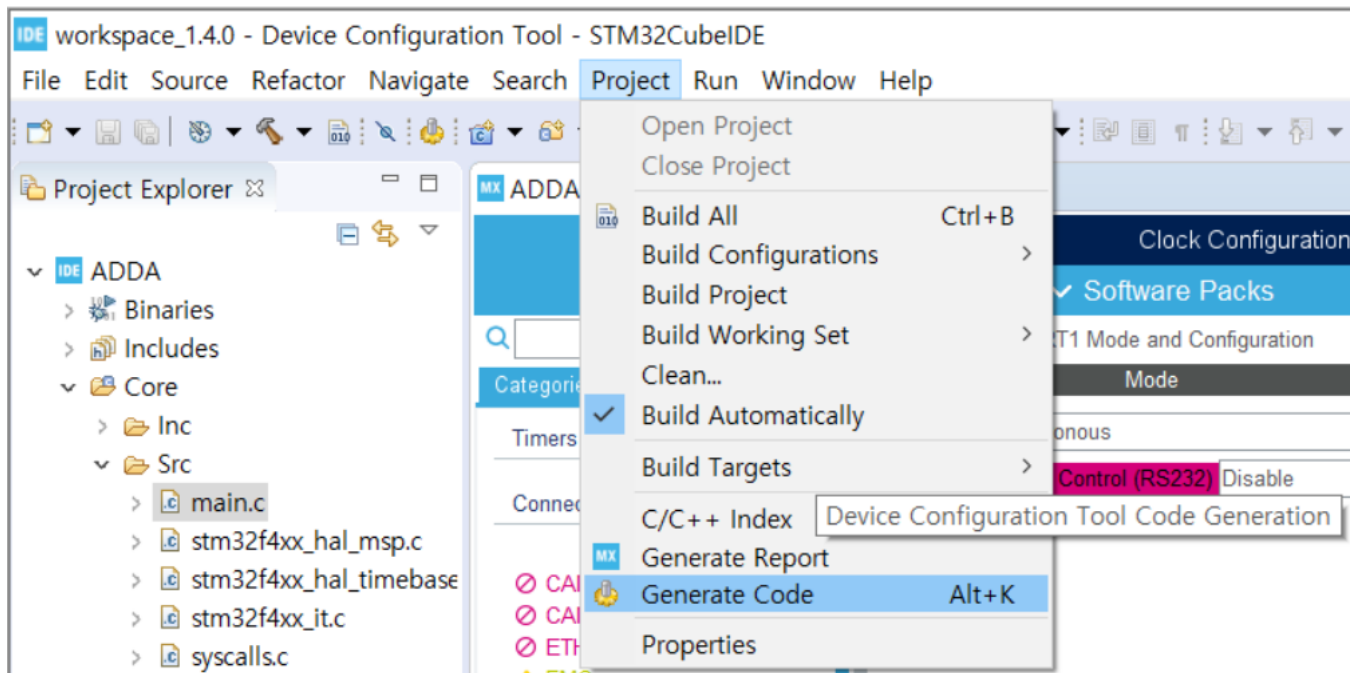
- HCLK (MHZ): 168



Disable FREERTOS



Generate Code



```

1  /* USER CODE BEGIN Header */
2  /**
3   *
4   * @file          : main.c
5   * @brief         : Main program body
6   *
7   * @attention
8   *
9   * <h2><center>&copy; Copyright (c) 2020 STMicroelectronics.
10  * All rights reserved.</center></h2>
11  *
12  * This software component is licensed by ST under Ultimate Liberty license
13  * SLA0044, the "License"; You may not use this file except in compliance with
14  * the License. You may obtain a copy of the License at:
15  *
16  *                               www.st.com/SLA0044
17  *
18  */
19 /* USER CODE END Header */
20 /* Includes -----*/
21 #include "main.h"
22 #include "usb_host.h"
23
24 /* Private includes -----*/
25 /* USER CODE BEGIN Includes */
26 #include "stdio.h"
27 /* USER CODE END Includes */

```

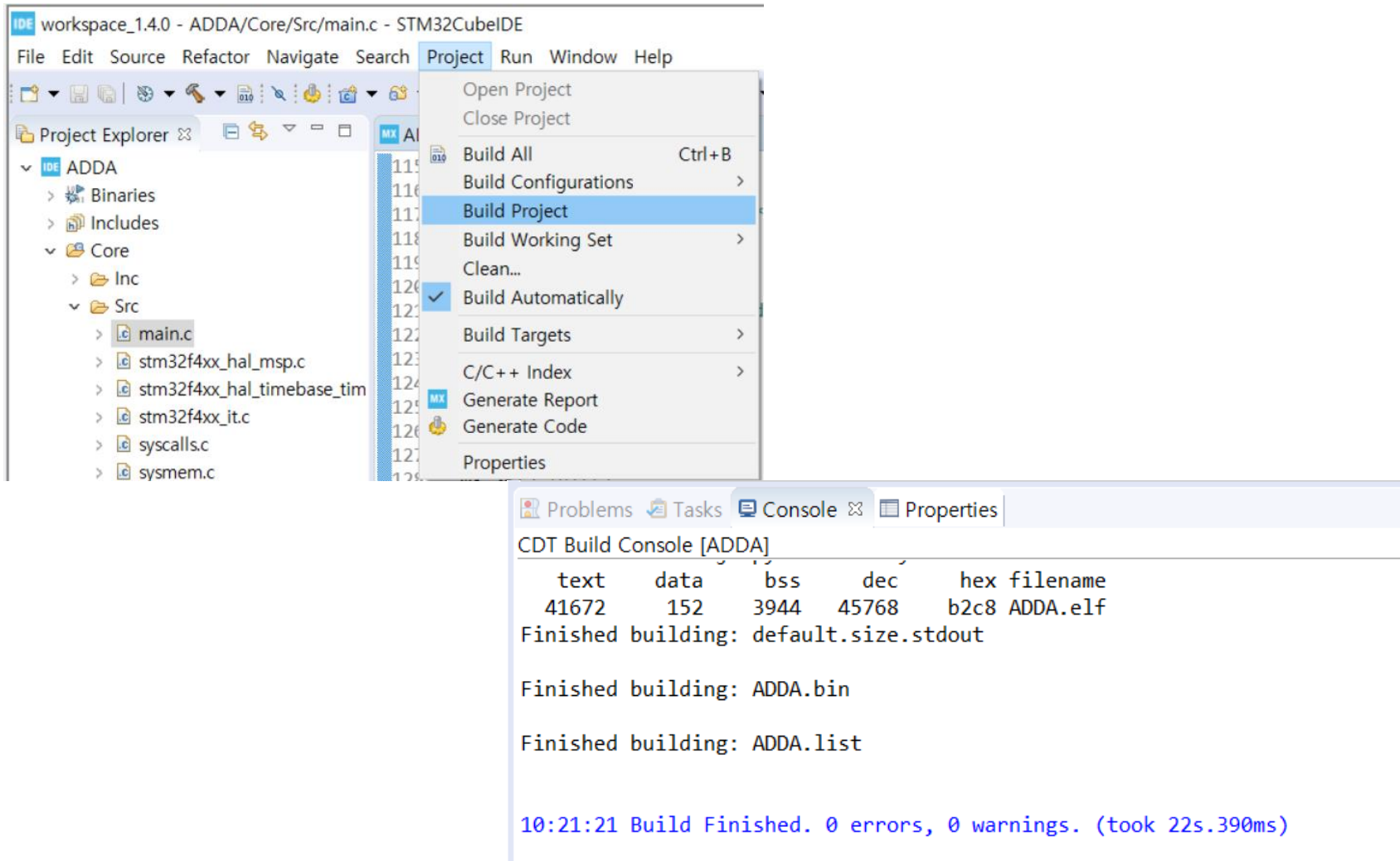

printf

```
/* USER CODE BEGIN Includes */
#include "stdio.h"
/* USER CODE END Includes */

/* USER CODE BEGIN 0 */
#ifdef __GNUC__
#define PUTCHAR_PROTOTYPE int __io_putchar(int ch)
#else
#define PUTCHAR_PROTOTYPE int fputc(int ch, FILE *f)
#endif /* __GNUC__ */
PUTCHAR_PROTOTYPE
{
    HAL_UART_Transmit(&huart1, (uint8_t *)&ch, 1, 0xFFFF);
    return ch;
}
/* USER CODE END 0 */

/* USER CODE BEGIN 2 */
printf("Hello World\r\n");
/* USER CODE END 2 */
```

Build Project



The screenshot shows the STM32CubeIDE interface. The 'Project' menu is open, with 'Build Project' selected. The Project Explorer on the left shows the project structure for 'ADDA', including 'Core' and 'Src' folders. The CDT Build Console on the right displays the output of the build process.

```
workspace_1.4.0 - ADDA/Core/Src/main.c - STM32CubeIDE
File Edit Source Refactor Navigate Search Project Run Window Help
Project Explorer
IDE ADDA
  Binaries
  Includes
  Core
  Inc
  Src
    main.c
    stm32f4xx_hal_msp.c
    stm32f4xx_hal_timebase_tim
    stm32f4xx_it.c
    syscalls.c
    systemem.c

Project menu:
Open Project
Close Project
Build All (Ctrl+B)
Build Configurations
Build Project
Build Working Set
Clean...
Build Automatically (checked)
Build Targets
C/C++ Index
Generate Report
Generate Code
Properties

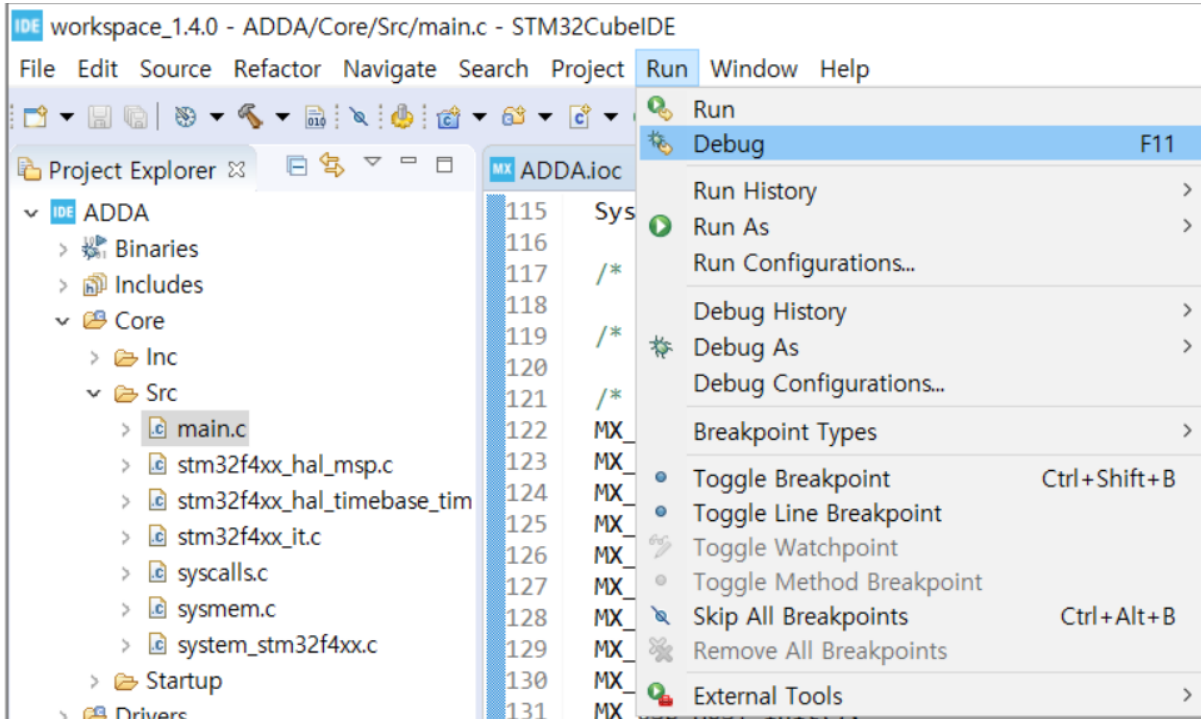
CDT Build Console [ADDA]
text  data  bss  dec  hex filename
41672  152   3944  45768  b2c8 ADDA.elf
Finished building: default.size.stdout

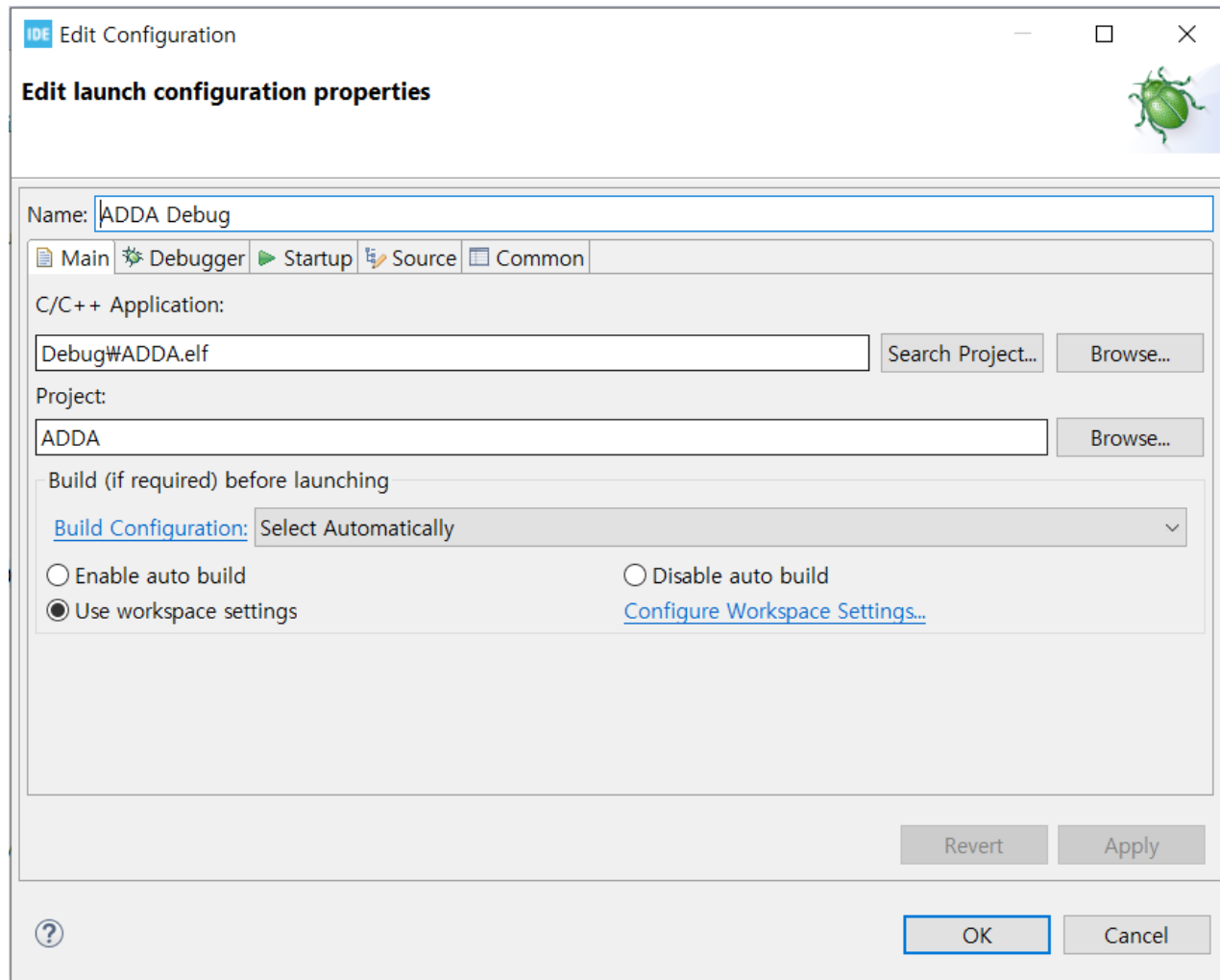
Finished building: ADDA.bin

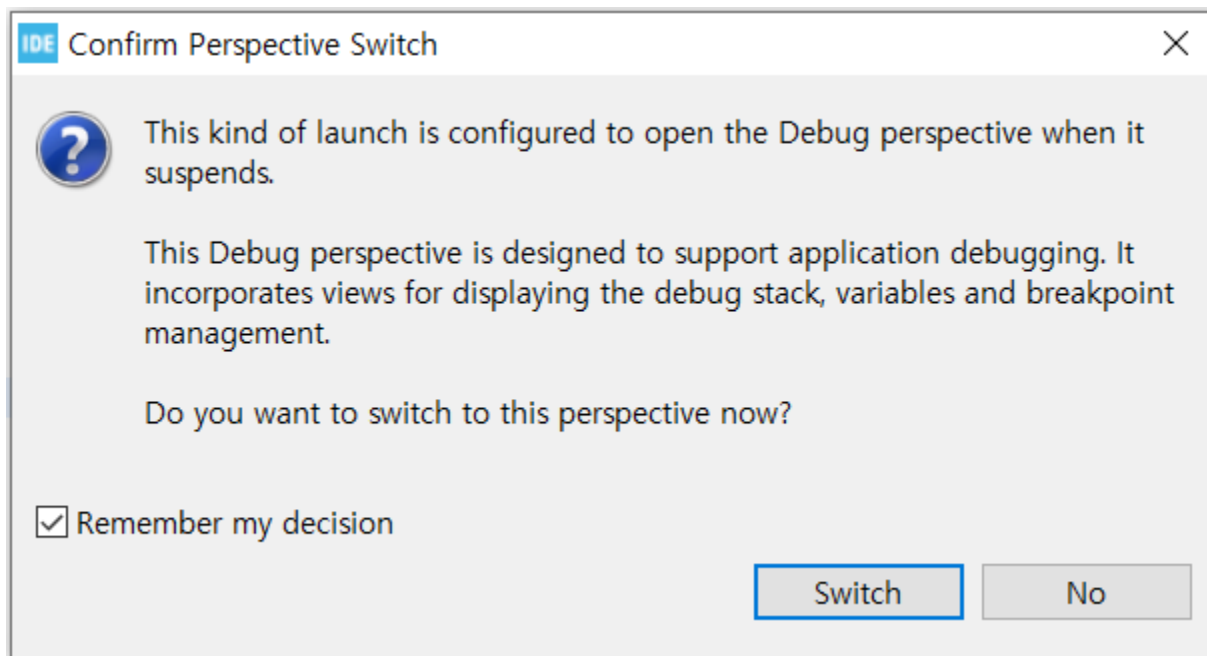
Finished building: ADDA.list

10:21:21 Build Finished. 0 errors, 0 warnings. (took 22s.390ms)
```

Start Debug







Debugging Screen

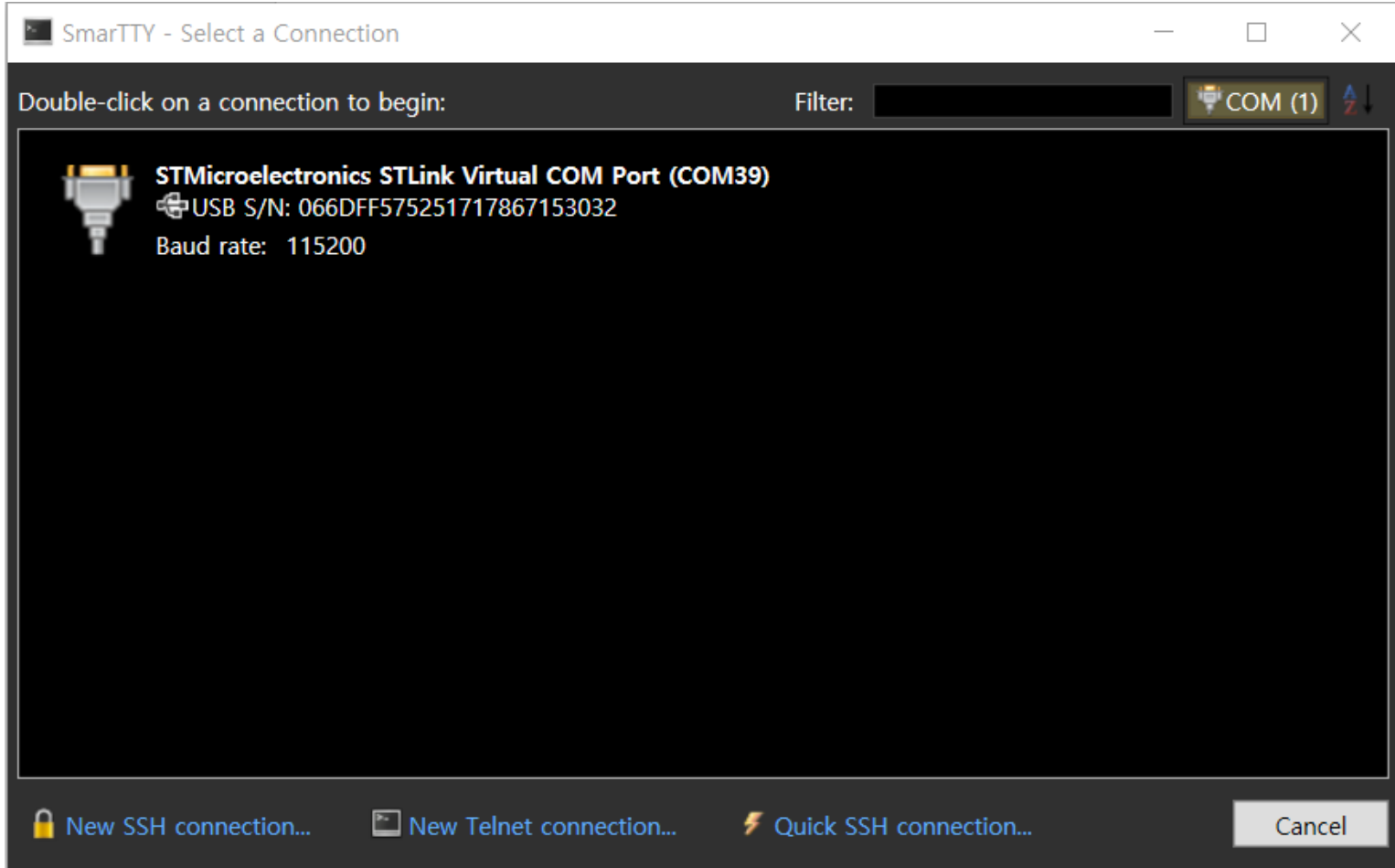
The screenshot displays an IDE window titled "workspace_1.4.0 - ADDA/Core/Src/main.c - STM32CubeIDE". The interface includes a menu bar (File, Edit, Source, Refactor, Navigate, Search, Project, Run, Window, Help), a toolbar, and a Project Explorer on the left. The Project Explorer shows the project structure: "ADDA Debug [STM32 Cortex-M C/C++ Application]" containing "ADDA.elf [cores: 0]" and "Thread #1 [main] 1 [core: 0] (Suspended : Breakpoint)" with a sub-entry for "main() at main.c:108 0x8000514".

The main editor window shows the source code for "main.c". The code is as follows:

```
98  */
99  int main(void)
100 {
101  /* USER CODE BEGIN 1 */
102
103  /* USER CODE END 1 */
104
105  /* MCU Configuration-----*/
106
107  /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
108  HAL_Init();
109
110  /* USER CODE BEGIN Init */
111
112  /* USER CODE END Init */
113
114  /* Configure the system clock */
115  SystemClock_Config();
116
117  /* USER CODE BEGIN SysInit */
118
119  /* USER CODE END SysInit */
120
121  /* Initialize all configured peripherals */
122  MX_GPIO_Init();
123  MX_CRC_Init();
124  MX_DMA2D_Init();
125  MX_FMC_Init();
126  MX_I2C3_Init();
127  MX_LTDC_Init();
128  MX_SPI5_Init();
129
```

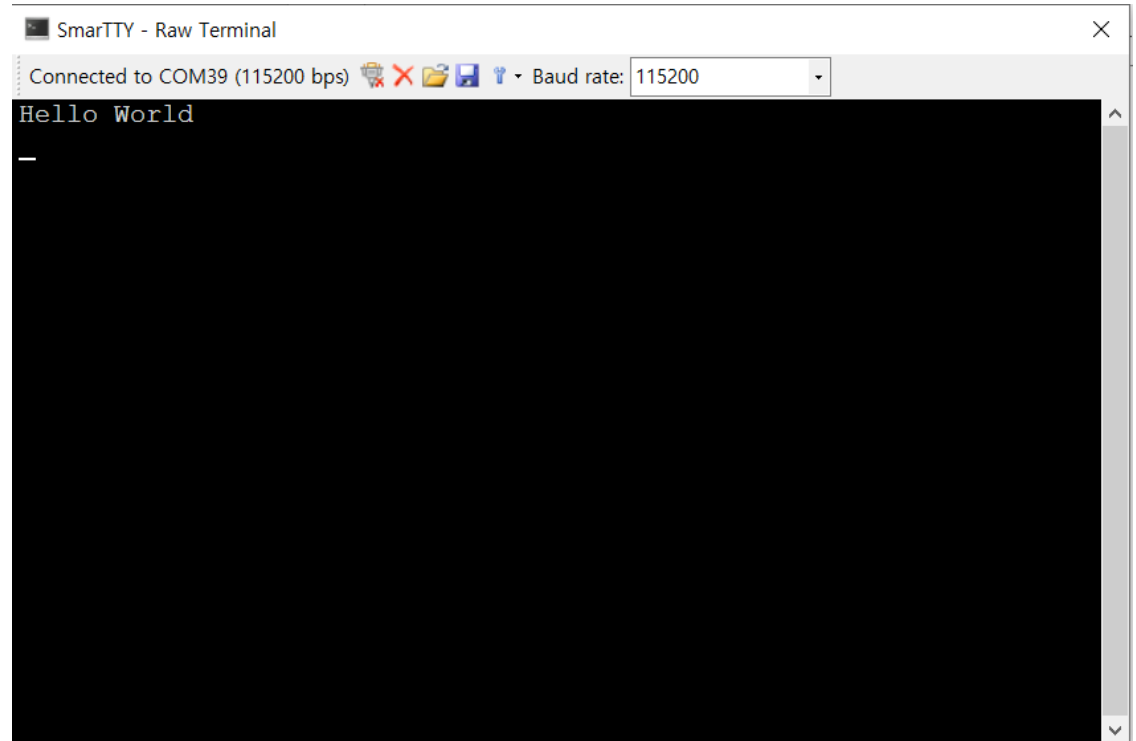
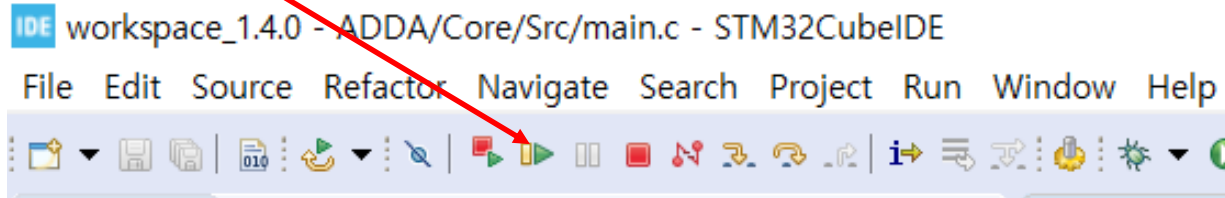
The line "HAL_Init();" at line 108 is highlighted in blue, indicating the current execution point. Below the code editor, the "Console" tab is active, displaying the message "Download verified successfully". Other tabs include "Problems", "Executables", "Debugger Console", and "Memory".

Open Terminal Program: SmarTTY



Resume

- Green Arrow: Resume
- Red Square: Stop Debugging



ADC1

MX *ADDA.ioc main.c startup_stm32f429zitx.s

Pinout & Configuration Clock Configuration Proj

Software Packs Pinout

ADC1 Mode and Configuration

Mode

- IN10
- IN11
- IN12
- IN13
- IN14
- IN15

Temperature Sensor Channel

Vrefint Channel

Vbat Channel

Configuration

Reset Configuration

DMA Settings GPIO Settings

Parameter Settings User Constants NVIC Settings

Search (Ctrl+F)

ADCs_Common_Settings

Mode Independent mode

DAC

The screenshot displays the STM32CubeMX configuration tool. The top tabs include 'Pinout & Configuration', 'Clock Configuration', and 'Project'. The 'Pinout & Configuration' tab is active, showing a search bar and a 'Categories' list on the left. The 'DAC' category is selected and highlighted in blue. The main configuration area is titled 'DAC Mode and Configuration' and is divided into two sections: 'Mode' and 'Configuration'. In the 'Mode' section, 'OUT1 Configuration' is unchecked, 'OUT2 Configuration' is checked, and 'External Trigger' is unchecked. The 'Configuration' section includes a 'Reset Configuration' button and several checked options: 'DMA Settings', 'GPIO Settings', 'Parameter Settings', 'User Constants', and 'NVIC Settings'. Below these options is a 'Search Signals' input field. At the bottom, a table lists the pin configuration for PA5.

Pin Name	Signal on Pin	GPIO output...	GPIO mode	GPIO Pull-
PA5	DAC_OUT2	n/a	Analog mode	No pull-up a

Timer10

- $168,000,000 / (840 * 200) = 1000$

MX ADDA.ioc

Pinout & Configuration | Clock Configuration

Software Packs | Pinout

Search []

Categories: A->Z

- System Core >
- Analog >
- Timers >
 - RTC
 - ⚠ TIM1
 - ⚠ TIM2
 - ⚠ TIM3
 - ⚠ TIM4
 - ⚠ TIM5
 - TIM6
 - TIM7
 - ⚠ TIM8
 - TIM9
 - ✓ TIM10
 - TIM11
 - ⚠ TIM12
 - TIM13
 - TIM14

TIM10 Mode and Configuration

Mode

- Activated
- Channel1: Disable
- One Pulse Mode

Configuration

Reset Configuration

Parameter Settings | User Constants | NVIC Settings

Configure the below parameters :

Search (Ctrl+F)

Parameter	Value
Prescaler (PSC - 16 bits value)	839
Counter Mode	Up
Counter Period (AutoReload Register - 16 bits value)	199
Internal Clock Division (CKD)	No Division
auto-reload preload	Disable

Timer10 Interrupt

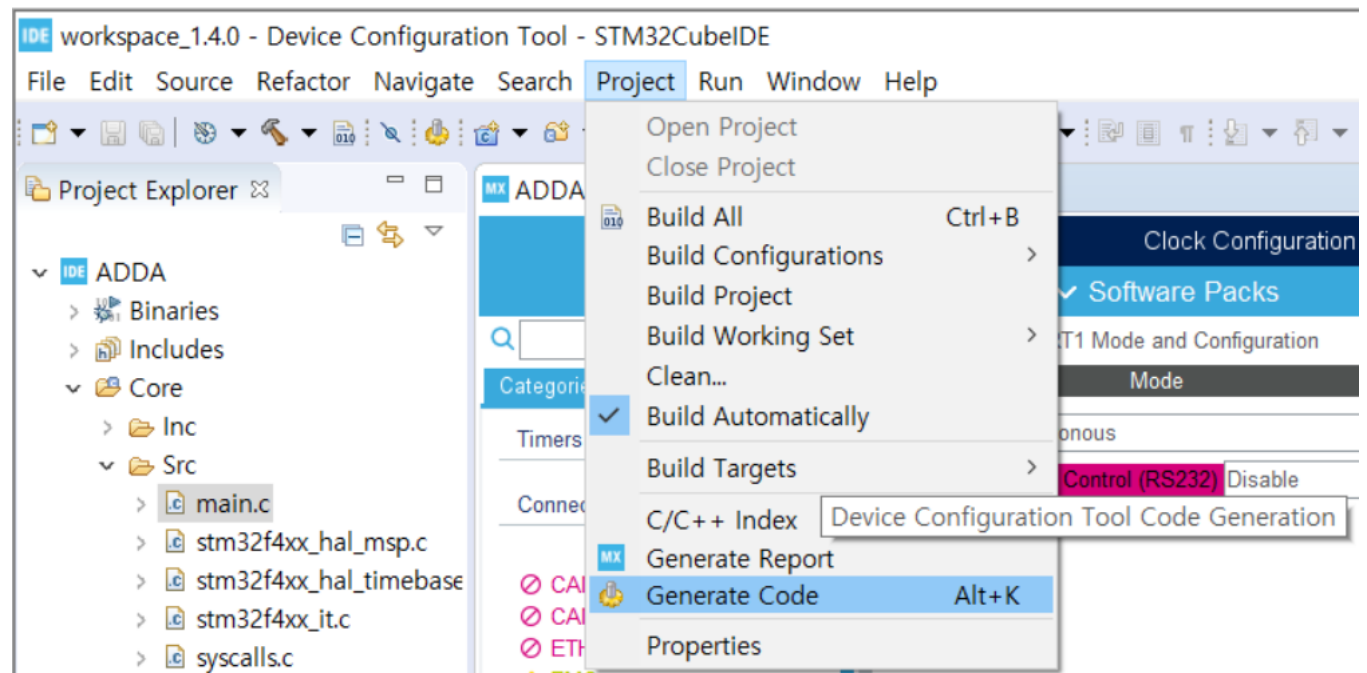
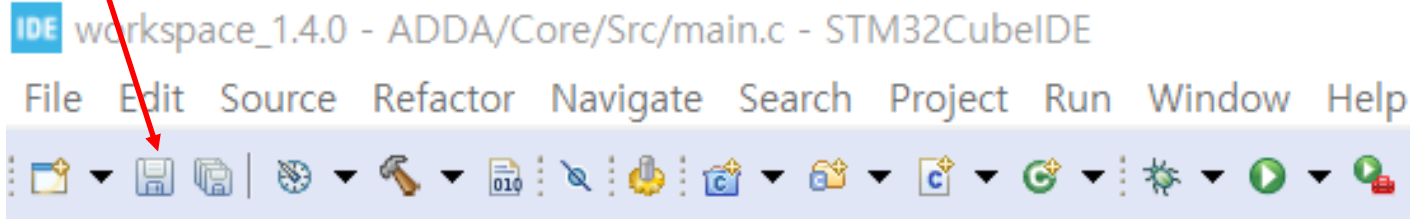
The screenshot shows the STM32CubeMX IDE interface for configuring the TIM10 timer. The top navigation bar includes 'Pinout & Configuration', 'Clock Configuration', and 'Project'. Below this, there are tabs for 'Software Packs' and 'Pinout'. The main configuration area is titled 'TIM10 Mode and Configuration' and is divided into two sections: 'Mode' and 'Configuration'.

In the 'Mode' section, the 'Activated' checkbox is checked. The 'Channel1' dropdown menu is set to 'Disable', and the 'One Pulse Mode' checkbox is unchecked.

In the 'Configuration' section, there is a 'Reset Configuration' button and three tabs: 'Parameter Settings', 'User Constants', and 'NVIC Settings'. The 'NVIC Settings' tab is active, showing the 'NVIC Interrupt Table'.

NVIC Interrupt Table	Enabled	Preemption Priority	Sub Priority
TIM1 update interrupt and TIM10 global interrupt	<input checked="" type="checkbox"/>	0	0

Save and Generate Code



A/D D/A Code

```
/* USER CODE BEGIN Includes */
#include "stdio.h"
/* USER CODE END Includes */

/* USER CODE BEGIN 0 */
#ifdef __GNUC__
#define PUTCHAR_PROTOTYPE int __io_putchar(int ch)
#else
#define PUTCHAR_PROTOTYPE int fputc(int ch, FILE *f)
#endif /* __GNUC__ */
PUTCHAR_PROTOTYPE
{
    HAL_UART_Transmit(&huart1, (uint8_t *)&ch, 1, 0xFFFF);
    return ch;
}
/* USER CODE END 0 */

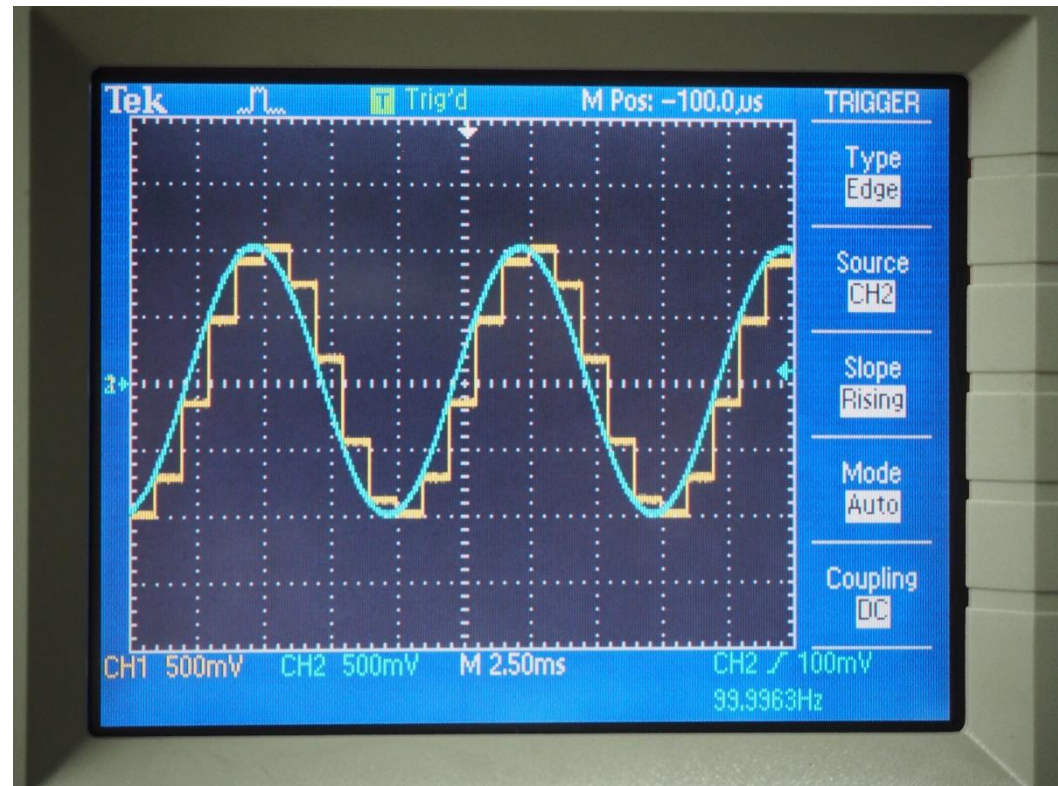
/* USER CODE BEGIN 2 */
printf("Hello World\r\n");
HAL_TIM_Base_Start_IT(&htim10);
HAL_DAC_Start(&hdac, DAC_CHANNEL_2);
/* USER CODE END 2 */
```

A/D D/A Code

```
/* USER CODE BEGIN Callback 0 */
int da_value,ad_value;
if (htim->Instance == TIM10) {
    HAL_ADC_Start(&hadc1);
    if (HAL_ADC_PollForConversion(&hadc1, 10000) == HAL_OK) {
        ad_value = HAL_ADC_GetValue(&hadc1);
    }
    da_value = ad_value;
    HAL_DAC_SetValue(&hdac, DAC_CHANNEL_2, DAC_ALIGN_12B_R, (uint32_t)(da_value));
}
/* USER CODE END Callback 0 */
```

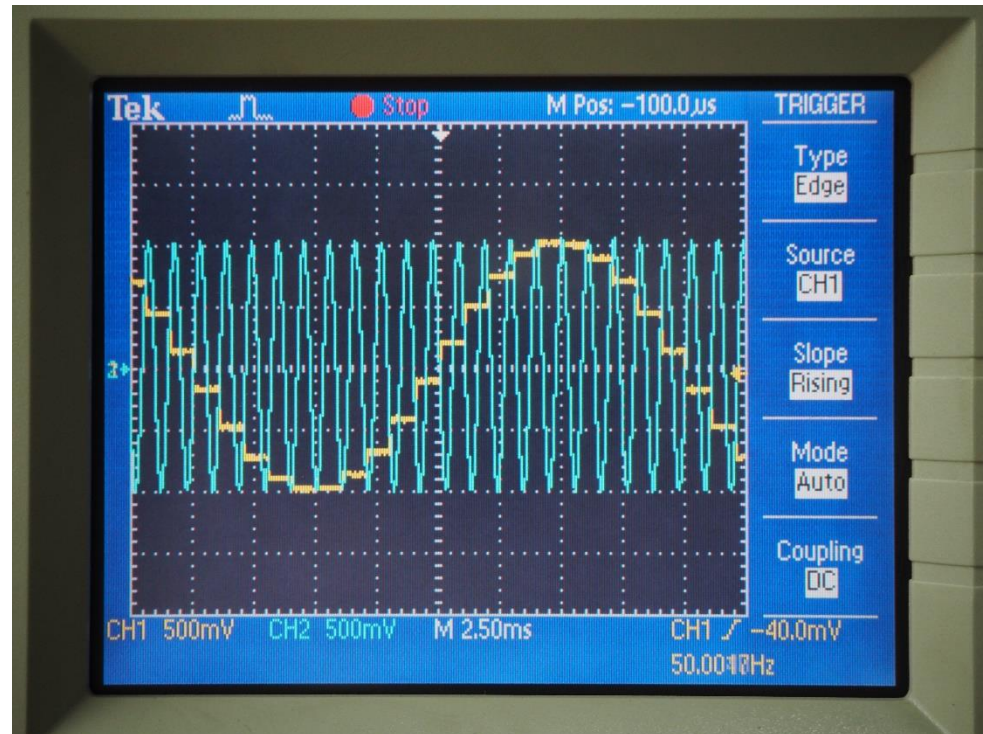
A/D Sampling

- Build and Run
- Function Generator
 - ▶ Sine wave
 - ▶ 2V peak-to-peak
 - ▶ 100 Hz



Aliasing

- Change function generator frequency to:
 - ▶ 1KHz=1000Hz
 - ▶ 1020Hz, 1030Hz, 1040Hz, 1050Hz
 - ▶ 980Hz, 970,Hz,960Hz,950Hz
- Find the frequencies of the DA output signal (Trigger source DA output signal)



Aliasing

- Change function generator frequency to:
 - ▶ 2KHz=2000Hz
 - ▶ 2020Hz, 2030Hz, 2040Hz, 2050Hz
 - ▶ 1980Hz, 1970,Hz,1960Hz,1950Hz
- Find the frequencies of the DA output signal (Trigger source DA output signal)

Nyquist Shannon Sampling Theorem

- Anti-aliasing filter

