Application Note

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Adaptive Lattice Filter on STM32H7 Devices

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StorAIge www:
https://storaige.eu/

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https://zs.utia.cas.cz/index.php?ids=projects/storaige

1 Introduction

This application note and the accompanying evaluation package describe implementation of adaptive recursive least square Lattice filters on STM32H7 microcontrollers. Lattuce filter serves for adaptive estimation of an acoustic channel. It can be used for active noice cancellation. In ultrasound based hand gesture GUI applications, the Lattice filter can be used as part of an electronic detector of presence of hand and improves quality of hand distance measurement by removing of acustic reflections from static distant objects.

1.1 Objective of this Application Note and Evaluation Package

We describe:

- Installation STM32CubeIDE and STM32CubeMX tools on Win 11 Pro PC.
- Installation, compile and test adaptive lattice filter test applications for several STM32H7 Nucleo 144 boards:
  - NUCLEO-H723ZG,
  - NUCLEO-H743ZI2,
  - NUCLEO-H7A3ZI-Q,
  - NUCLEO-H755ZI-Q.
- Installation and use of Scilab package for generation of test data, execution of adaptive lattice filter and cration of reference results for STM32H7 projects.

2 Installation of STM Development Tools on PC

2.1 Installation of STM32CubeIDE

Go to:

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

Install the latest release of the Integrated Development Environment for STM32:

STM32CubeIDE
Version: 1.14.1
Build: 20064_20240111_1413 (UTC)
(C) 2024 STMicroelectronics ALL RIGHTS RESERVED

2.2 Installation of STM32CubeMX

Go to:

https://www.st.com/content/st_com/en/stm32cubemx.html

Install the latest release of the STM32Cube initialization code generator

STM32CubeMX
Version: 6.10.0

2.3 Install Adaptive Latice Test Projects for STM32H7 boards

Copy and unzip content of directories with projects from evaluation package

STM32Cube_FW_H7_V1.11.1\Projects\ NUCLEO-H723ZG\

STM32Cube_FW_H7_V1.11.1\Projects\ NUCLEO-H743ZI\

STM32Cube_FW_H7_V1.11.1\Projects\ NUCLEO-H745ZI-Q\

STM32Cube_FW_H7_V1.11.1\Projects\ NUCLEO-H7A3ZI-Q\

to

<install_path>\STM32Cube\Repository\STM32Cube_FW_H5_V1.1.1\Projects\

Copy directory with support drivers from evaluation package

STM32Cube_FW_H7_V1.11.1\Drivers\Adafruit_Shield\

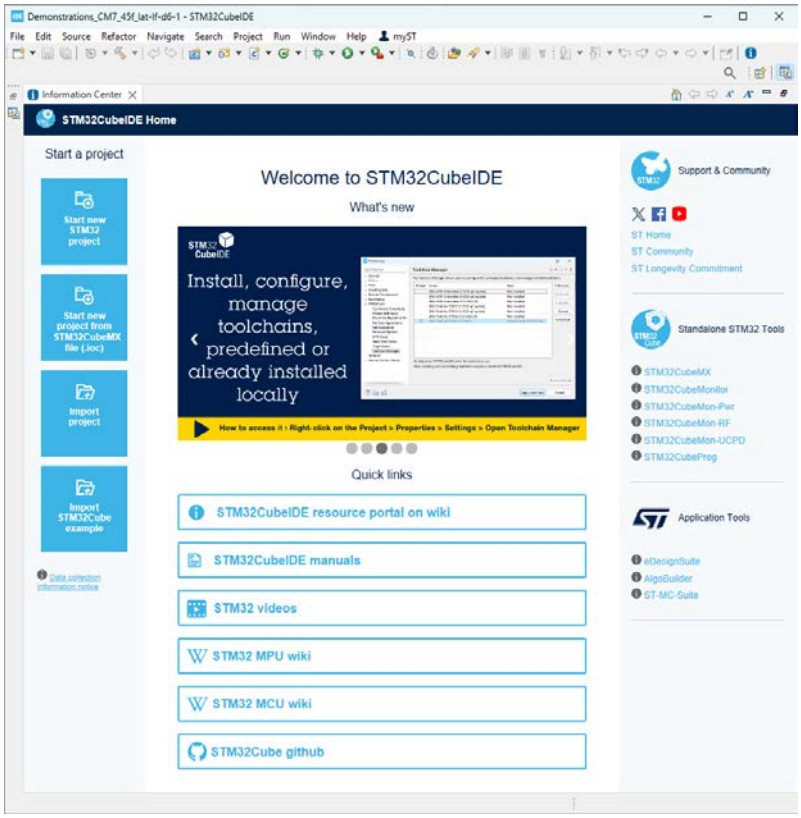
to

<install_path>\STM32Cube\Repository\STM32Cube_FW_H5_V1.1.1\Drivers\ Adafruit_Shield

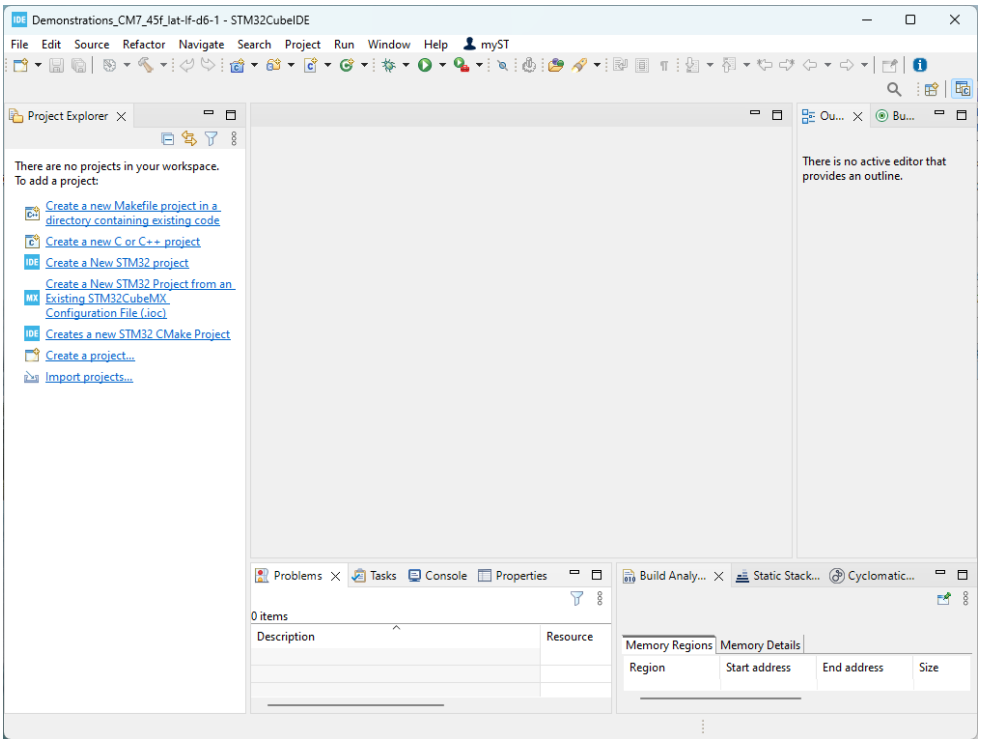
2.4 Import Adaptive Lattice Test Project to STM32CubeIDE

Open STM32CubeIDE tool and select es workspace the directory

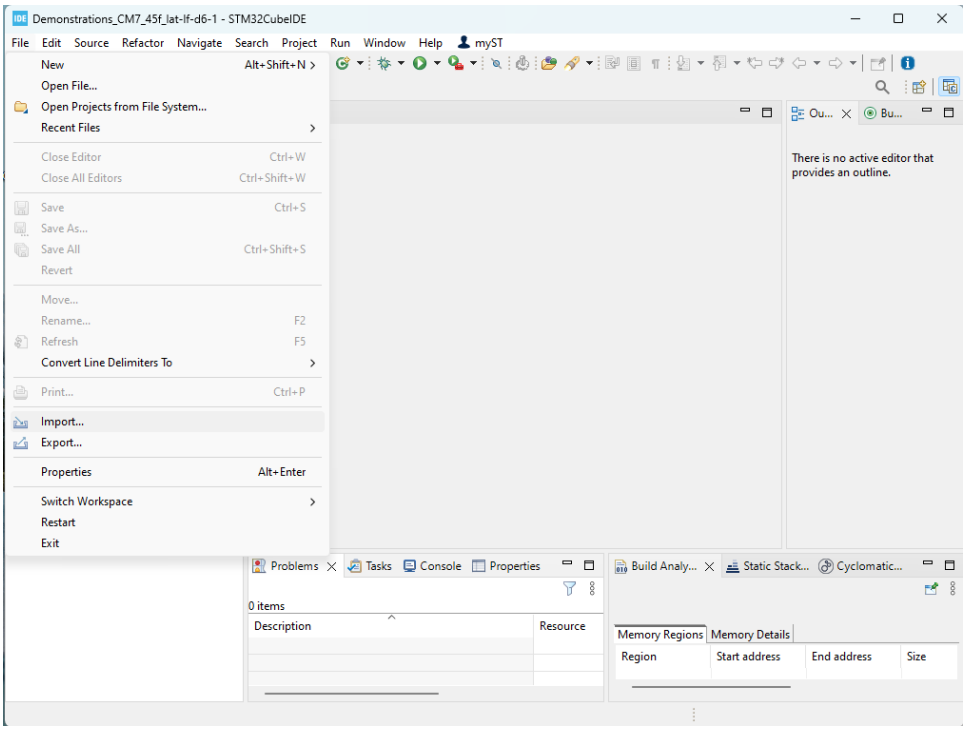
<install_path>\STM32Cube\Repository\STM32Cube_FW_H7_V1.11.1\Projects\NUCLEO-H723ZG\Demonstrations_CM7_45f_lat-lf-d6-1

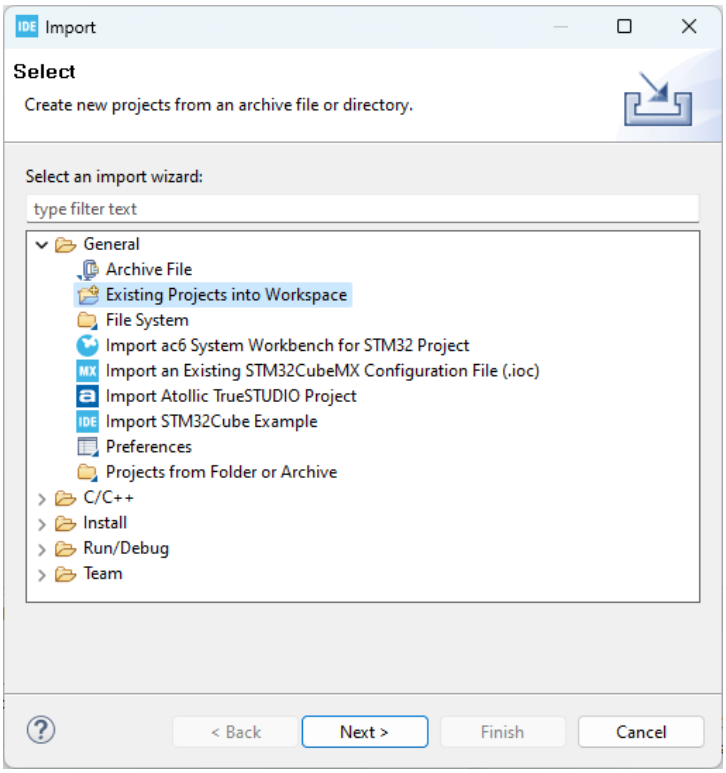


Close velcome page.

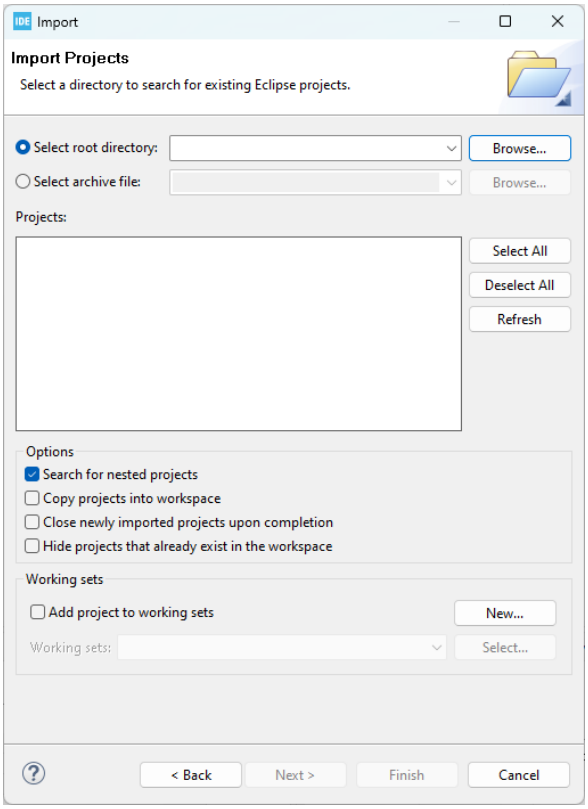


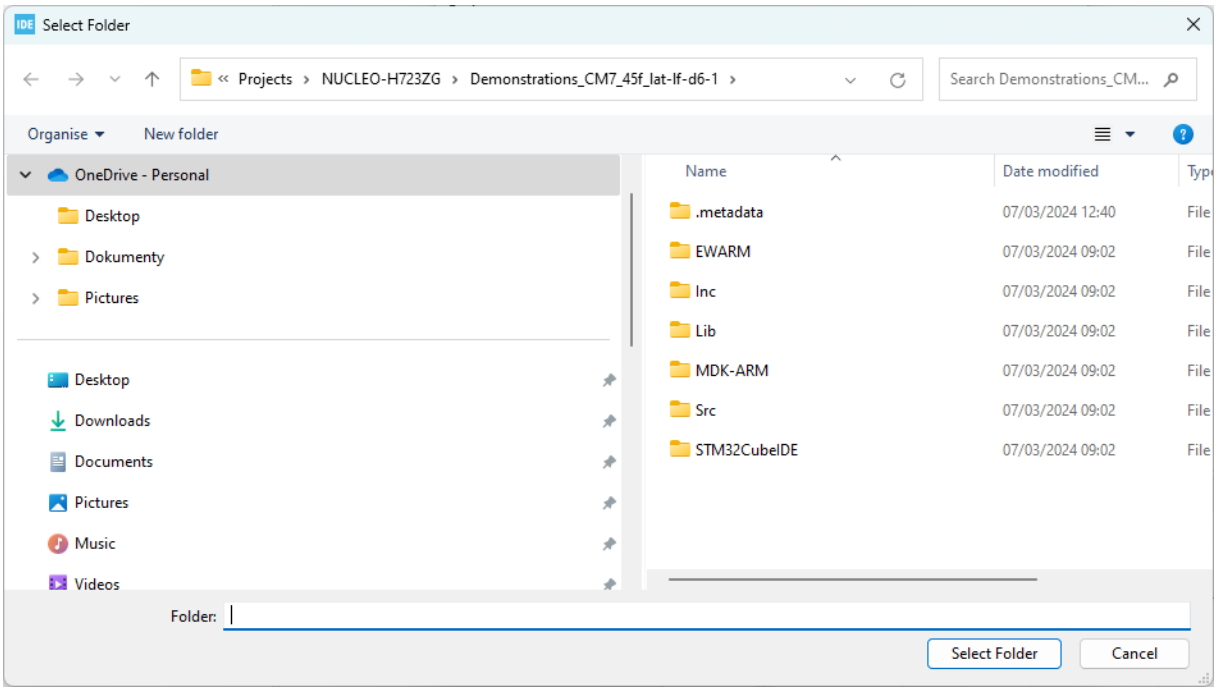
Select: `File` → `Import` → `Existing Projects into Workspace`
Click on `Next`



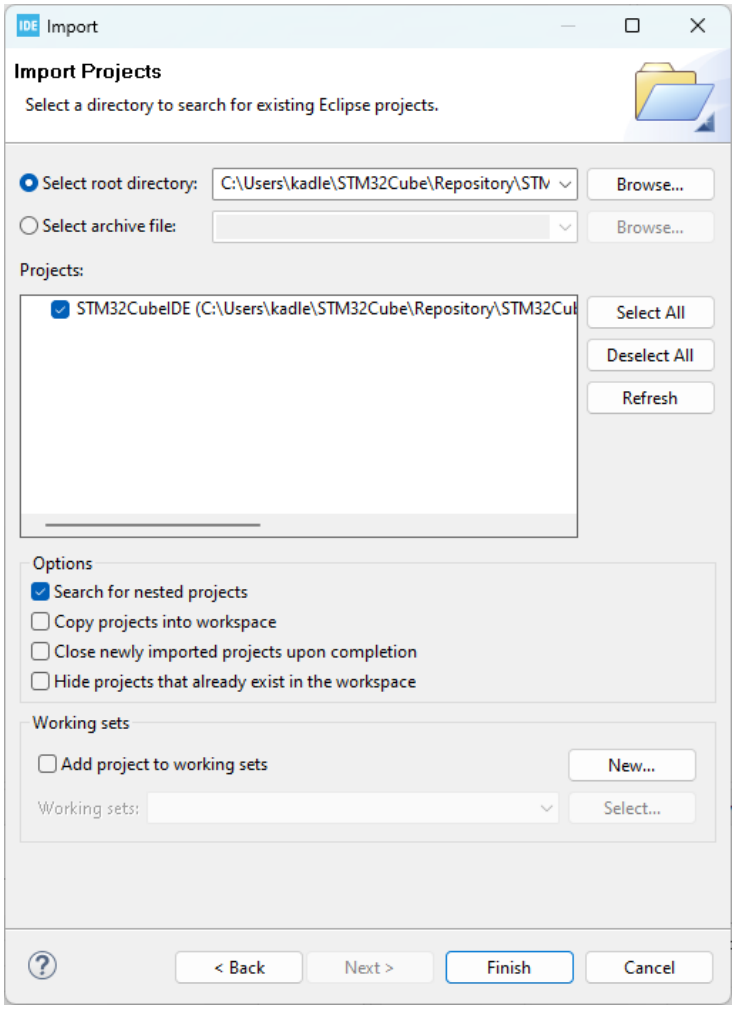


Click on `Next.` → Click on `Browse.` → Click on `Select Folder`





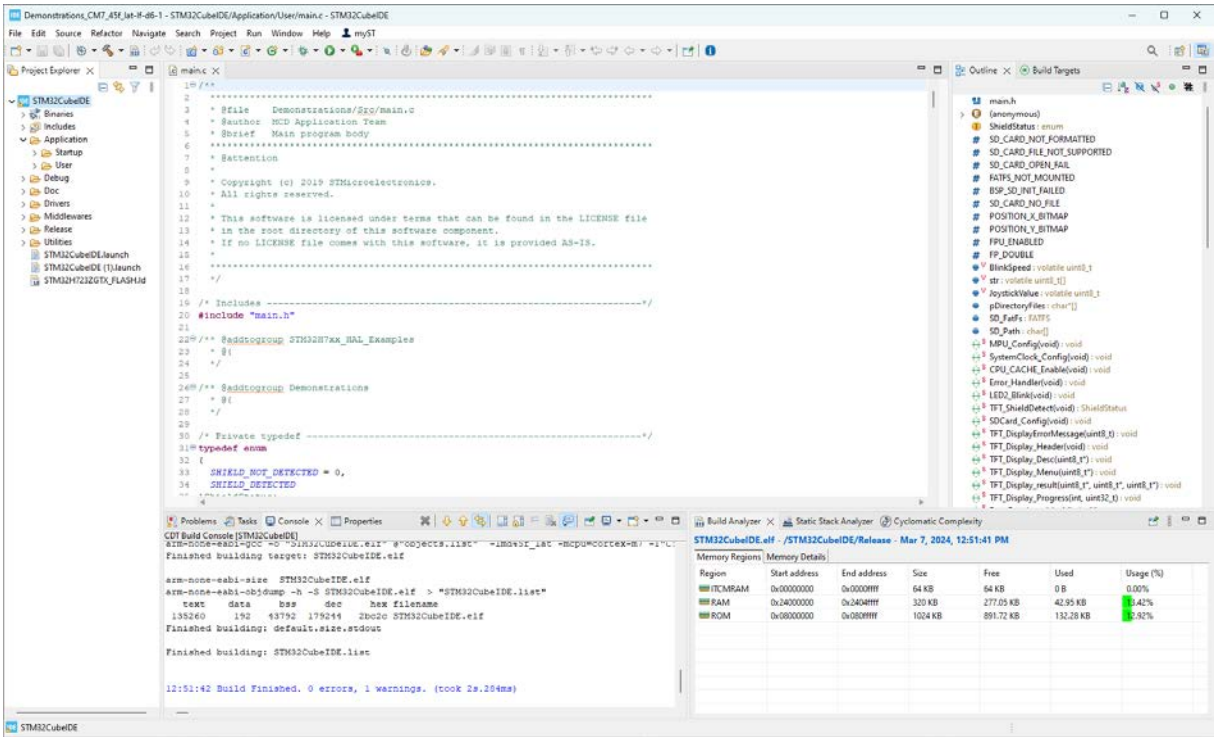
Click on `Finish`



Inported project

Reference project is created.

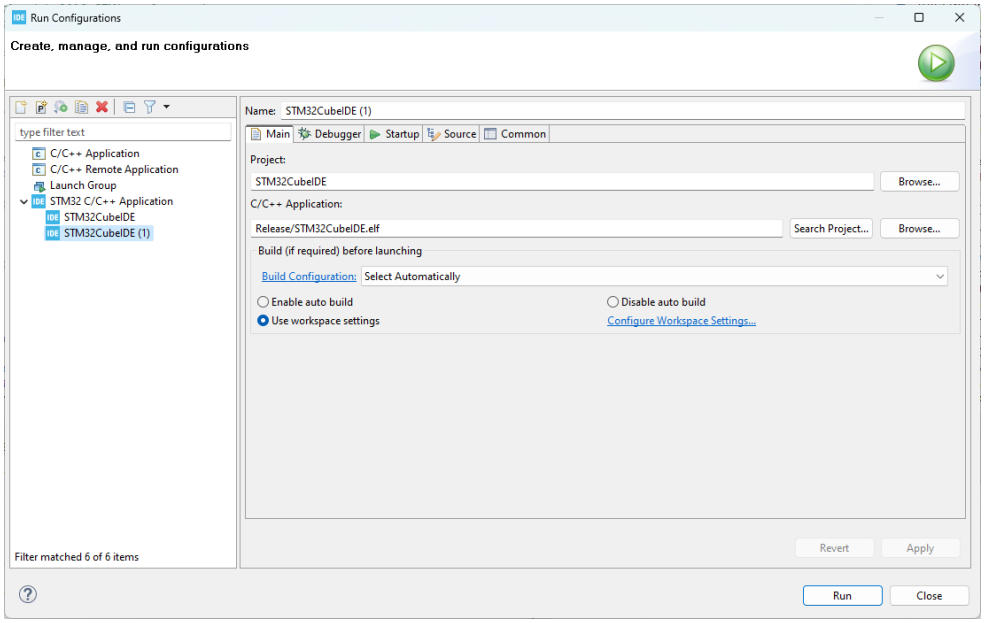
Select `release` target. → Select `Compile`.



Compiled project

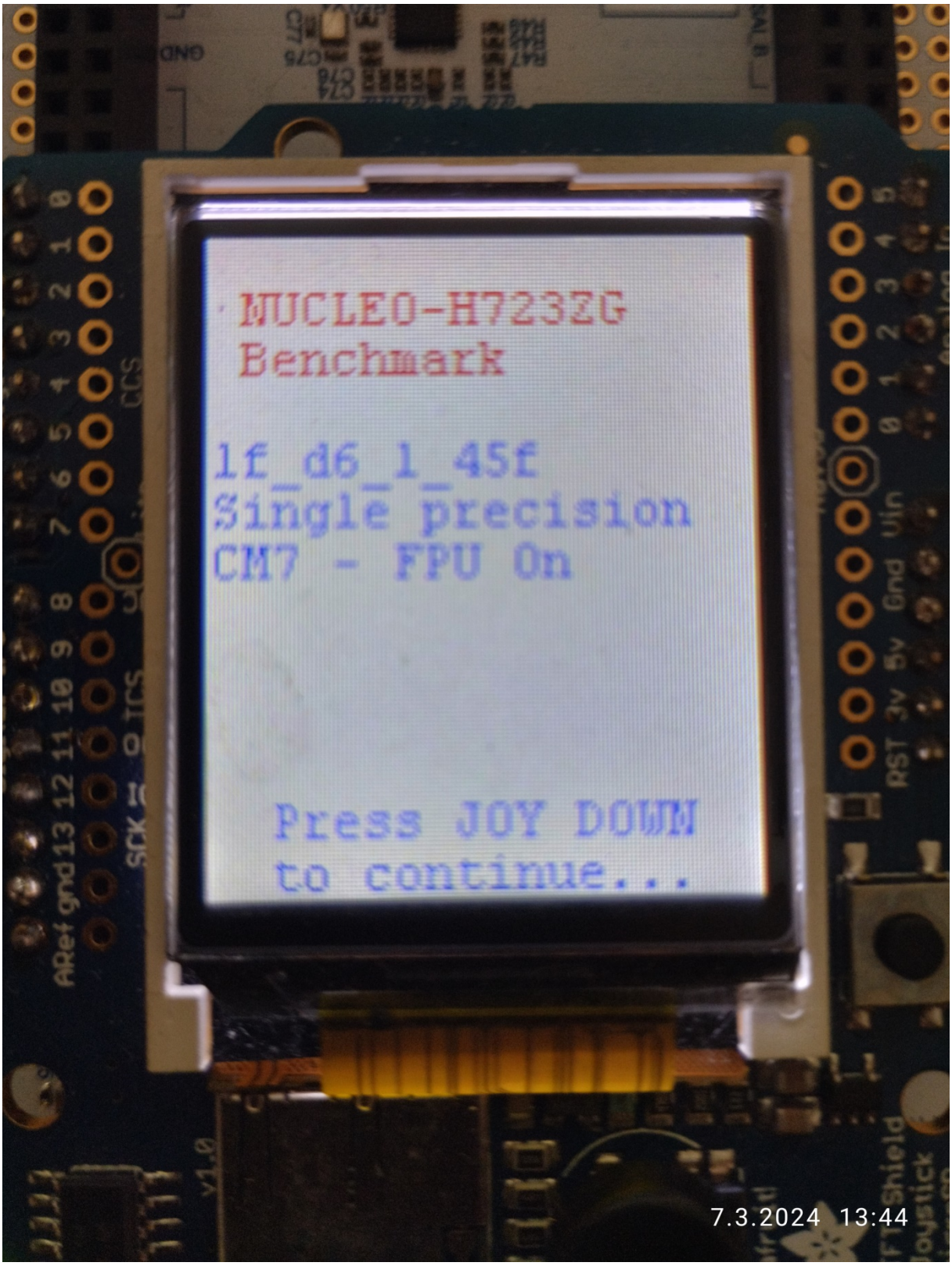
2.5 Flash the STM32H723ZI board

Connect STM32H723ZI board STLINK connector to PC by USB cable.



Flash to STM32H7 board

ttttt

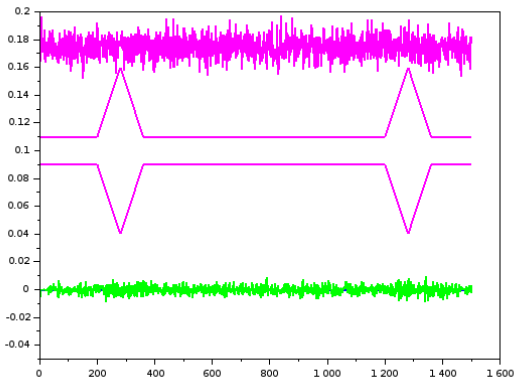
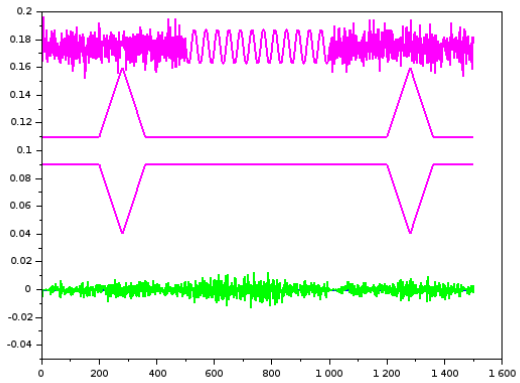
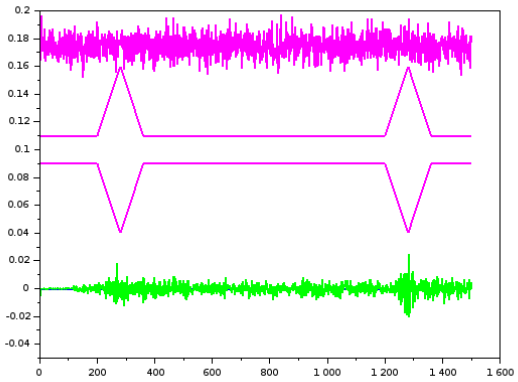
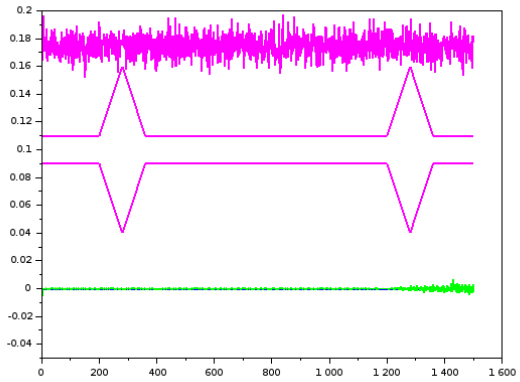
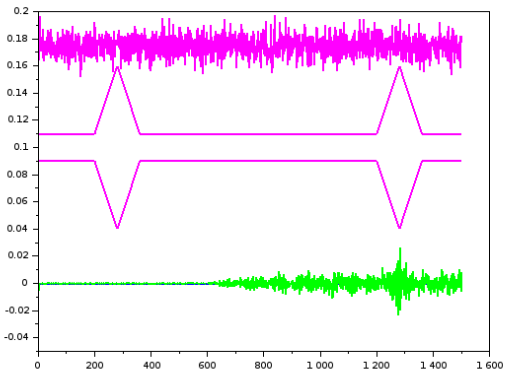
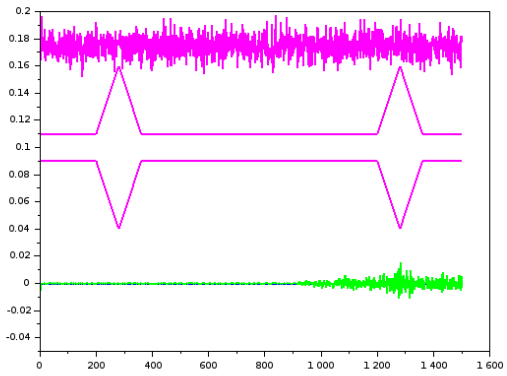


Initial display on STM32H723ZI board

FA

Final display on STM32H723ZI board

The display presents the measured performance of implemented Lattice filter.
The message PASSED or FAILED indicates if the Lattice filter results computed on the board is identical with reference PC Scilab data.

Demonstrations_CM7_45f_lat-lf-d1-1	Demonstrations_CM7_45f_lat-lf-d1-3
Demonstrations_CM7_45f_lat-lf-d3-1	Demonstrations_CM7_45f_lat-lf-d4-1
Demonstrations_CM7_45f_lat-lf-d5-1	Demonstrations_CM7_45f_lat-lf-d6-1

Defined projects

Evaluation data contain 1500 samples of system input and reference Lattice filter output generated in PC Scilab framework. Time variable stochastic discrete system is modelled by time variable FIR filter. Two time variable parameters are displayed parameters.

- Pinq top signal is modelled system input.
- Green bottom signal is filtration error produced by adaptive recursive Lattice filter.

Demonstrations_CM7_45f_lat-lf-d1-1
Project performs adaptive recursive identification by Lattice filter with order N=3 and persistent input (white noice on input).

Demonstrations_CM7_45f_lat-lf-d1-3
Project performs adaptive recursive identification of Lattice filter with order N=3 and peripd from steps 501 to step 1000 with non-persistent excitacion (sinus on input).

Demonstrations_CM7_45f_lat-lf-d3-1
Project performs adaptive recursive identification by Lattice filter with order N=23 and persistent input (white noice on input).

Demonstrations_CM7_45f_lat-lf-d4-1
Project performs adaptive recursive identification by Lattice filter with order N=1024 and persistent input (white noice on input).

Demonstrations_CM7_45f_lat-lf-d5-1
Project performs adaptive recursive identification by Lattice filter with order N=512 and persistent input (white noice on input).

Demonstrations_CM7_45f_lat-lf-d6-1
Project performs adaptive recursive identification by Lattice filter with order N=768 and persistent input (white noice on input).

Setup and compilation of Demonstrations_CM7_45f_lat-lf-d6-1 project has been described in detail for the target board STM32H723ZI. It can be repeated for all data sets

2.6 Performance Lattice Demonstrations_CM7_45f_lat-lf-d6-1

Table compares performance of STM32H7 devices for Demonstrations_CM7_45f_lat-lf-d6-1 project.

STM32 Nucleo144 evaluation boards. Power was measured on Vdd pin of the device.			
Lattice N=256, Lattice N=768	MFLOPS	POWER [W]	MFLOPS/W
STM32H743, 400 MHz CM7	59.19	0.452	130.9
STM32H723, 520 MHz CM7	80.64	0.498	161.9
STM32H7A3, 280 MHz CM7	42.84	0.174	246.1
STM32H755, 200 MHz CM4	23.62	0.349	67.5

Measured performance of STM32H7 devices

3 Scilab Reference Simulations

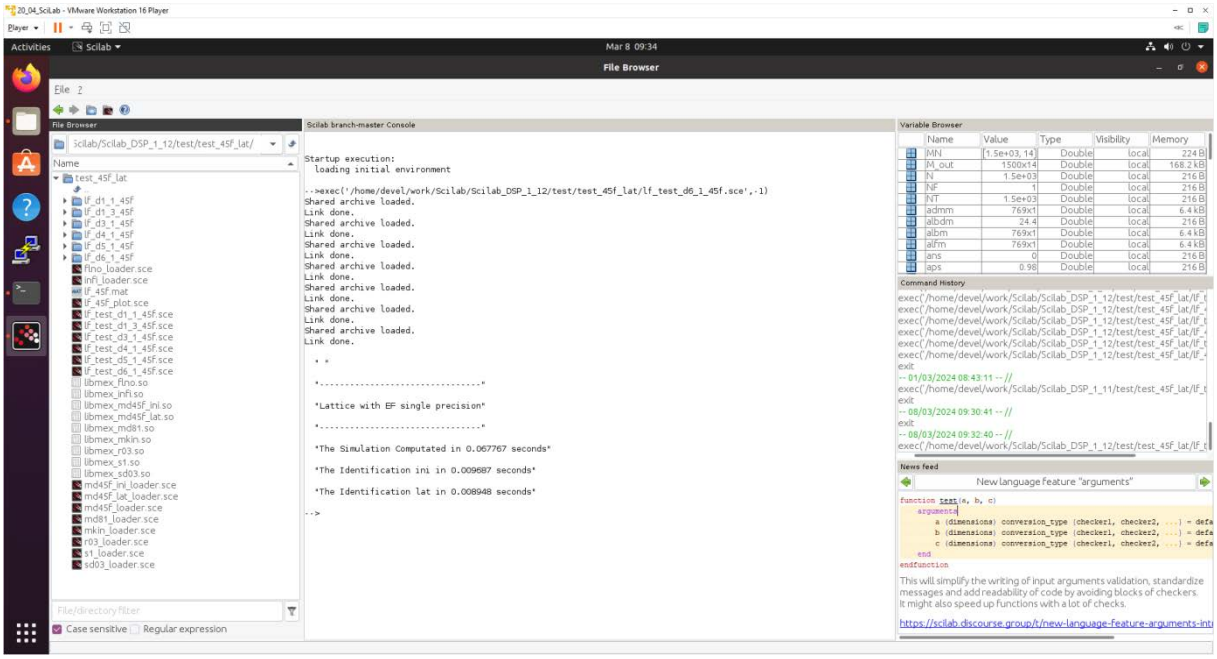
The reference time variable stochastic system, input data, the adaptive recursive Latttice filter and output data are modelled in Scilab.

https://www.scilab.org/

3.1 Lattice reference in Scilab

The simulation can be configured by parameters in Scilab scripts.

The Lattice filter is implemented in C and compiled into shared object library. This library is called from scripts interpreted in Scilab 6.1. Scilab 6.1 is a major new release of Scilab, the open-source platform for numerical computation.



Scilab 6.1

Scilab scripts generate input and output data for the files STM32H7 projects in form of header files. These data header files can be copied into STM32CubeIDE projects.
Projects are recompiled in STM32CubeIDE tool and flashed to the supported STM32H7 boards.

The accompanying evaluation package is packed in the directory

```
Scilab_DSP_1_12
```

It includes Scilab scripts and several shared object libraries with precompiled C code compatible with Scilab tool installed in Ubuntu 20.04.6 LTS. Data vectors and matrices defined in Scilab are stired in double precision floating point format.

The precompiled C code Lattice algorithm includes input and output conversion to single precision floating point data representation. All Lattice filter computation is performed in single precision floating point.

Scilab tool is called from user terminal in Ubuntu 20.04.6 LTS

```
MESA_GL_VERSION_OVERRIDE=3.0 scilab &
```

The define `MESA_GL_VERSION_OVERRIDE=3.0` is needed to support rendering of plots generated by Scilab running on Ubuntu 20.04.6 LTS.

Result of simulation in Scilab can be displayed on the Ubuntu 20.04.6 LTS desktop.