STM32-MAT/TARGET

Hands On

Rev 2.5

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Table of Contents

Objectives

- Hands-on workshop to show you the steps needed to quickly develop STM32 applications using MATLAB® Simulink graphical environment.
- Know tools installations and settings to be able to start development.
- Know Simulation and «C» Code Generation possibility
- Know how to develop application from scratch
- Know where to obtain additional technical support

Systems Check

- Mandatory Software
  - From Mathworks
    - MATLAB®, Simulink and Embedded Coder 
  - From STMicroelectronics
    - STM32CubeMX 
  - One of following Toolchain
    - EWARM from IAR 
    - MDK-ARM from Keil 
    - TrueSTUDIO® for STM32 from  
    - SW4STM32 from STMicroelectronics 
    - STM32CubeIDE from STMicroelectronics
  - STM32-MAT/TARGET toolkit to develop STM32 applications

- Hardware
  - Any electronic application board with STM32 and SWD/JTAG connection.
  - STLinkV2 or 3rd parties dongle if not integrated to STM32 application board.
  - USB to Serial adapter.

Pre-requisites

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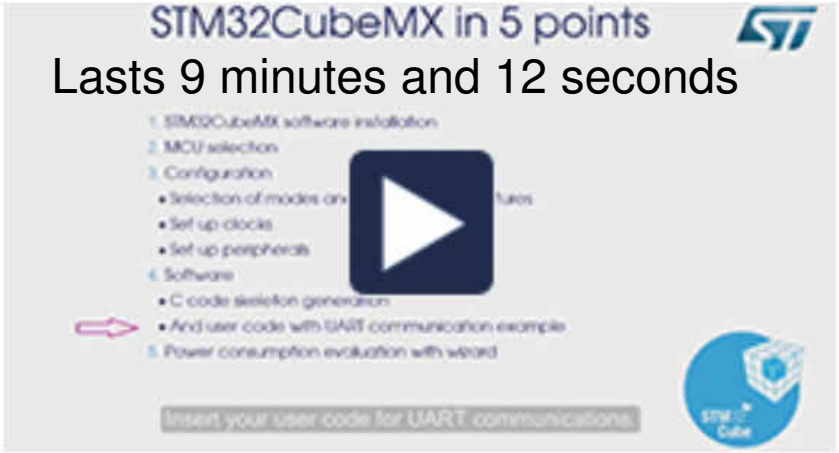
Pre-requisites

- STM32CubeMX
  - Have a look to STM32CubeMX videos to know how using this powerful tool.

FEATURED VIDEOS

See All



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Pre-requisites

- Toolchain
  - You must be comfortable with one of following toolchain.
  - Ewarm from IAR

    Embedded **W**orkbench for **Arm** (Ewarm)

  - µVision from Keil

  - TrueSTUDIO® for STM32 from

  - SW4STM32 from

  - STM32CubeIDE from STMicroelectronics

Hardware setup

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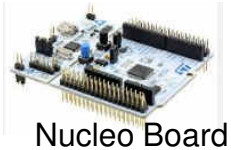
Step #1 – Hardware selection

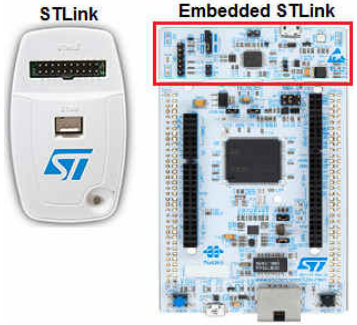
- Use one of STM32 boards including STLink
  - Nucleo, Discovery, EvaluationBoard etc…
  - STM32F3348-DISCO and STM32F429i-DISCO

  will be used during examples.


Nucleo Board


Discovery Board


Evaluation Board



- Or STM32 application board connected to SWD (Single Wire Debug)/JTAG dongle.
  - STLink, ULink2, JLink etc..


STLink

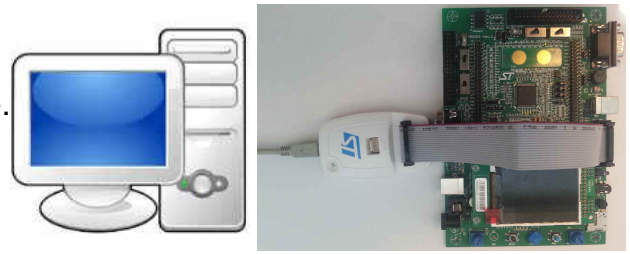
ULink2


JLink

Step #2 – Hardware connection

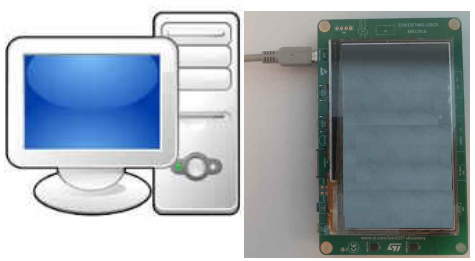
- Connect USB dongle port to PC USB port
  - And connect STM32 HE10 20 pins dongle connector to STM32 target board

Example: Connect STLink dongle USB to PC on one side.



Example:
Connect HE10 20 pins STLink dongle connector to HE10 20 pins connector of
STM32 Evaluation Board on the other side.

- Or connect PC USB port to embedded STLink



Example: Connect USB PC port to STLink USB port embedded in STM32 board.

Usually, all ST recent boards embed STLink tool.

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Step #3 – Hardware connection

- As soon as you are using ST-LINK
  - look at http://www.st.com/web/catalog/tools/FM146/CL1984/SC720/SS1450/PF251168?s_searchtype=partnumber
  - «Related Tools and Software» section to check or update firmware

SOFTWARE DEVELOPMENT TOOLS

Picture	Part number	Manufacturer	Description
	ST-LINK-SERVER	ST	ST-LINK server software module
	STM32CubeProg	ST	STM32CubeProgrammer software for all STM32
	STSW-LINK004	ST	STM32 ST-LINK utility
	STSW-LINK007	ST	ST-LINK, ST-LINK/V2, ST-LINK/V2-1, STLINK-V3 boards firmware upgrade
	STSW-LINK009	ST	ST-LINK, ST-LINK/V2, ST-LINK/V2-1 USB driver signed for Windows7, Windows8, Windows10

Software setup

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Quick description of tools

MathWorks

MATLAB® — High level language for complex calculation

Simulink — Graphical development environment
Complete environment of simulation and implementation of embedded systems.

Embedded Coder — C code generation for embedded system.
Embedded system interface

STM32Cube Embedded Software — Collection of embedded software components, highly portable from one STM32 to another

STM32CubeMX — Configuration software tool on the PC, able to generate initialization C code versus user choices

Toolchain

One toolchain from partners or ST is required to compile and link C code generated by Embedded Coder, STM32CubeMX and STM32Cube embedded software

IAR SYSTEMS

KEIL Tools by ARM

atollic

STM32

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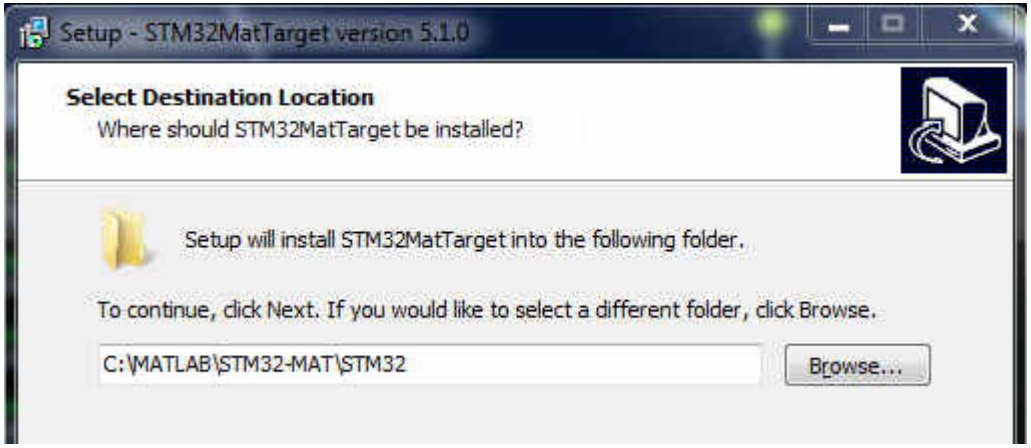
Step #1 – Software installation

- Install MathWorks software (R2018b or later)
  - MATLAB®, Simulink, Embedded Coder are mandatory
  - Add-ons : SimPowerSystems, Simscape and Stateflow for motor control applications if needed.
  - http://www.mathworks.com
- Install STM32CubeMX
  - Download and documents available from : *www.st.com/microxplorer*
- Install toolchain (Cf Slide 3 : «Systems Check»)
  - Cf Slide 3 «Systems Check» to get link to supported 3rd parties download area.

Step #2 – Software installation

- Install STM32-MAT/TARGET
  - STM32 embedded target for MATLAB® and Simulink
  - This toolkit is mandatory to integrate STM32 to MathWorks tools.
  - Download and documents available from : click here
  - Unzip «`stm32-mat_target.zip`»
  - Run «`STM32MatTarget_5.6.0_setup.exe`»
  - Default installation path is «`C:\MATLAB\STM32-MAT`» repository



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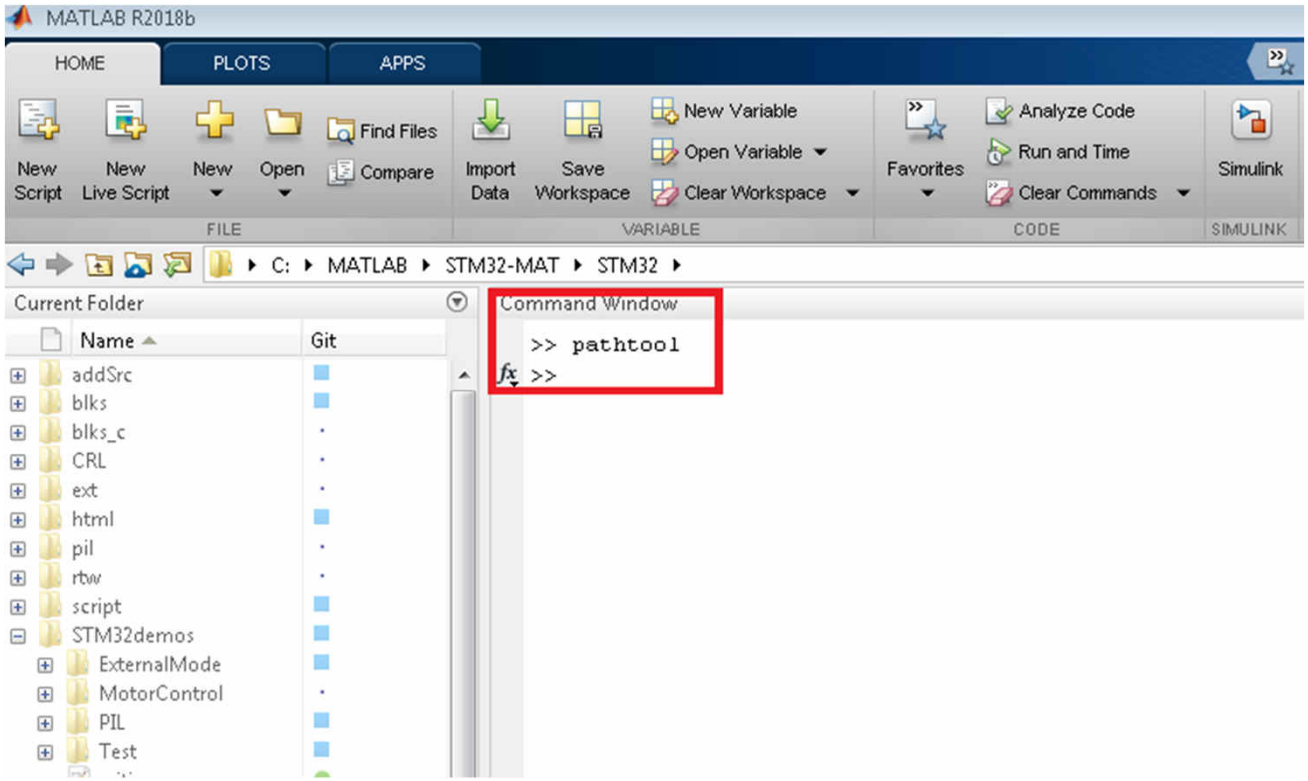
Step #3 – STM32-MAT/TARGET integration

- Integrate STM32-MAT/TARGET to MathWorks flow
  1. Open MATLAB®
  2. Enter «`pathtool`» command from Command Window



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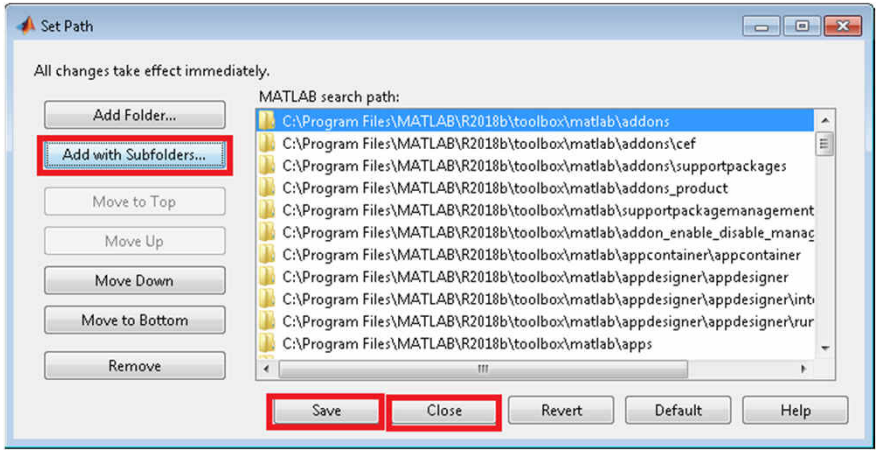
Step #4 – STM32-MAT/TARGET integration

3. Click «Add with Subfolders…» button on «Set path» window.
4. Select STM32 installed path
   - Default path: `C:\MATLAB\STM32-MAT\STM32`

5. Click «Save» then «Close» button.



6. Simulink is then ready to design STM32 applications.

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Scenarios and Tools usage

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Simulation / PIL / Code Generation

- Step 1: Pure simulation
  - Everything done on the PC. Only MATLAB® and Simulink are needed

MATLAB®/ Simulink

- Step 2: Processor-in-the-loop (PIL)
  - Algorithm fully executed on STM32
  - Data (Input or output) exchanged between MATLAB®/Simulink and STM32 via UART

MATLAB®/ Simulink

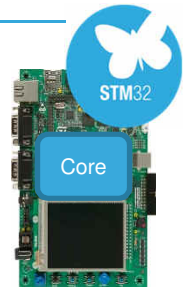
Embedded Coder

STM32Cube Embedded Software

STM32CubeMX

*: used only for UART

Toolchain



- Step 3: Everything on STM32
  - Data (input or output) obtained within STM32 through its peripherals (ADC, Timers, …) and algorithm fully executed on STM32

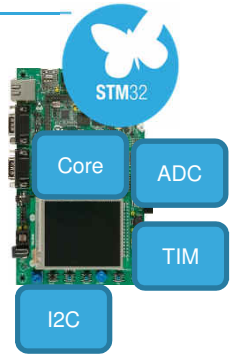
MATLAB®/ Simulink

Embedded Coder

STM32Cube Embedded Software

STM32CubeMX

Toolchain



- Scenarios are independent and can be done individually

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Scenarios

- Simulink applications can :
  - Be Simulated on PC.
    - MATLAB® and Simulink needed only.
  - Process Simulink data on STM32 target
    - MATLAB®, Simulink, STM32CubeMX, one toolchain and STM32-MAT/TARGET must have been installed.
  - Generate C code project for this application
    - MATLAB®, Simulink, STM32CubeMX, one toolchain and STM32-MAT/TARGET must have been installed.
  - External Mode
    - MATLAB®, Simulink, STM32CubeMX, one toolchain and STM32-MAT/TARGET must have been installed.

- Simulink model must be created and configured to be able to develop STM32 applications.

Simulink model setting

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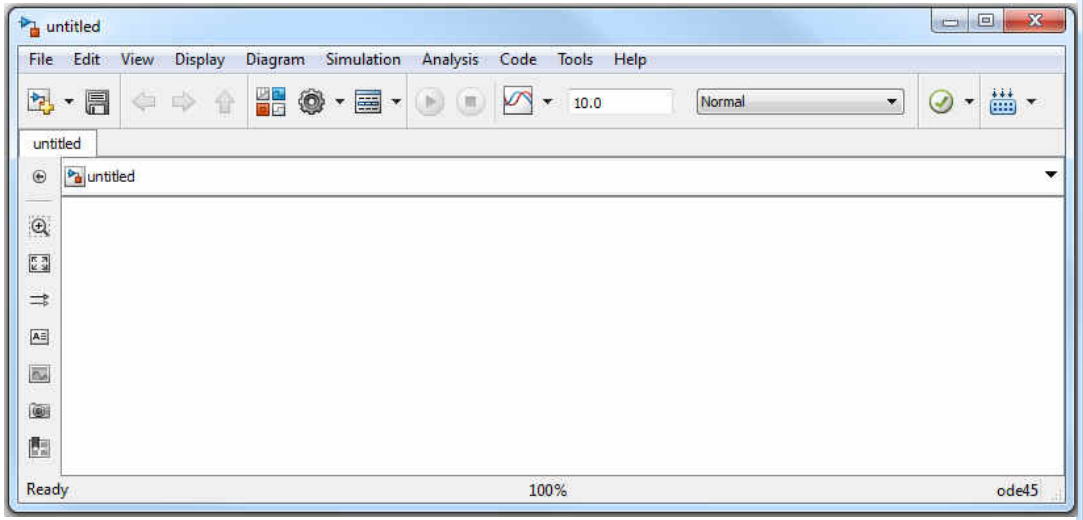
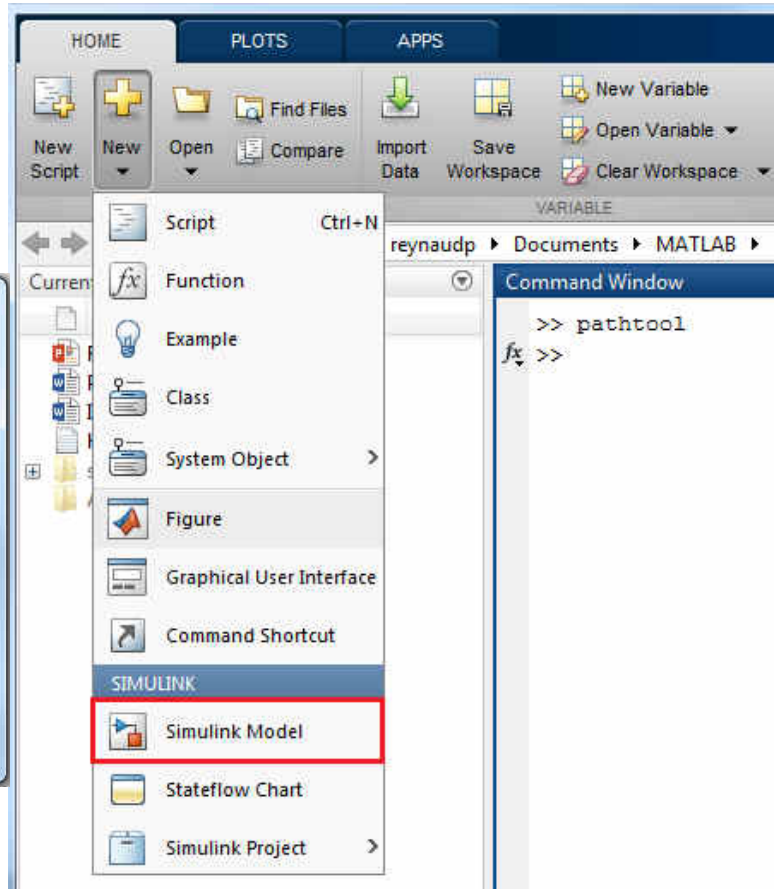
Simulink Model Setting 1/5

- From MATLAB® IDE click New>Simulink Model to open a new Simulink graphical application model.

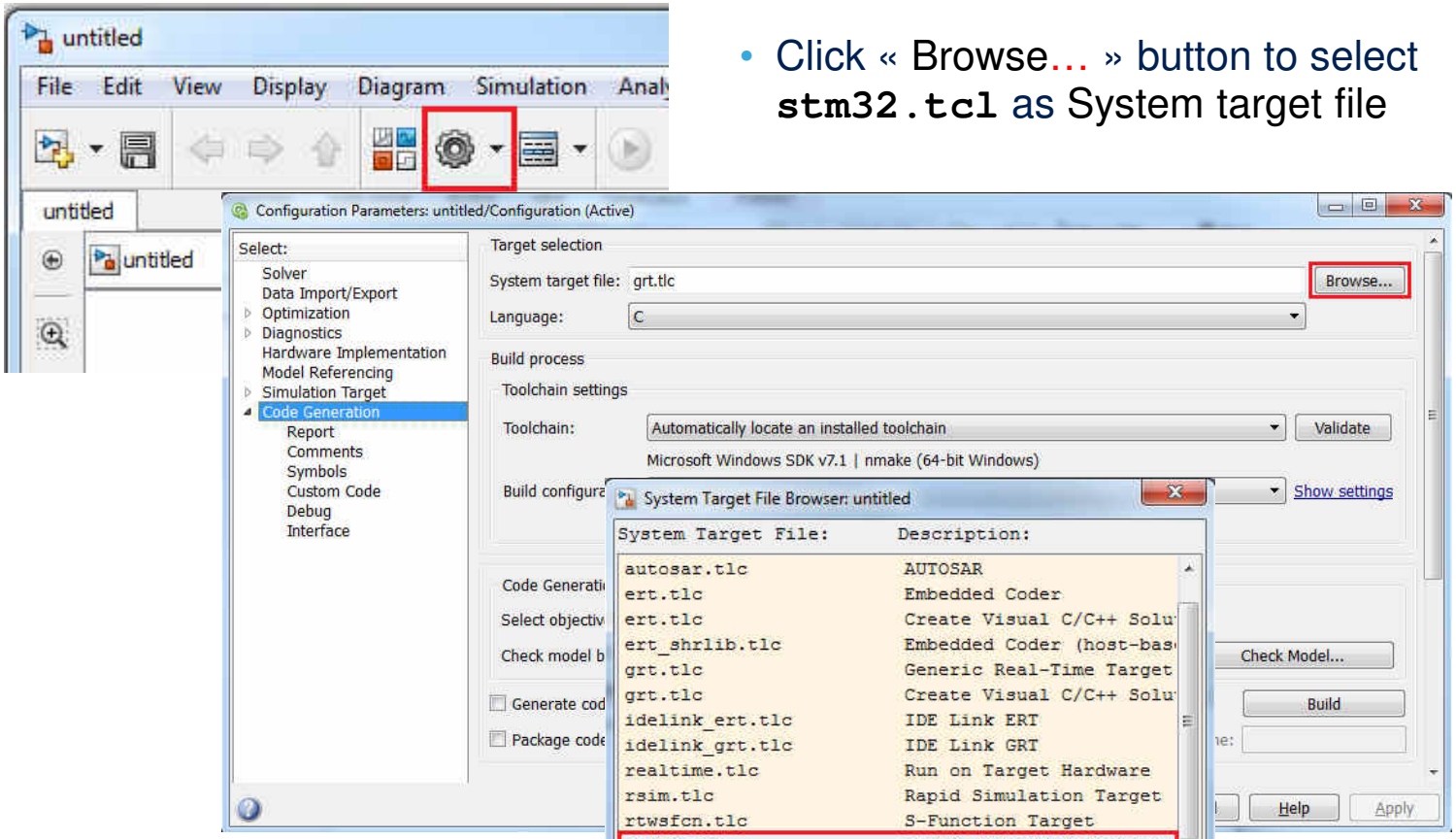




- Then application parameters must be set for STM32 target…..

Simulink Model Setting 2/5

- Open Configuration Parameters window and select Code Generation



- Click « Browse… » button to select **`stm32.tcl`** as System target file

- Click « OK» button

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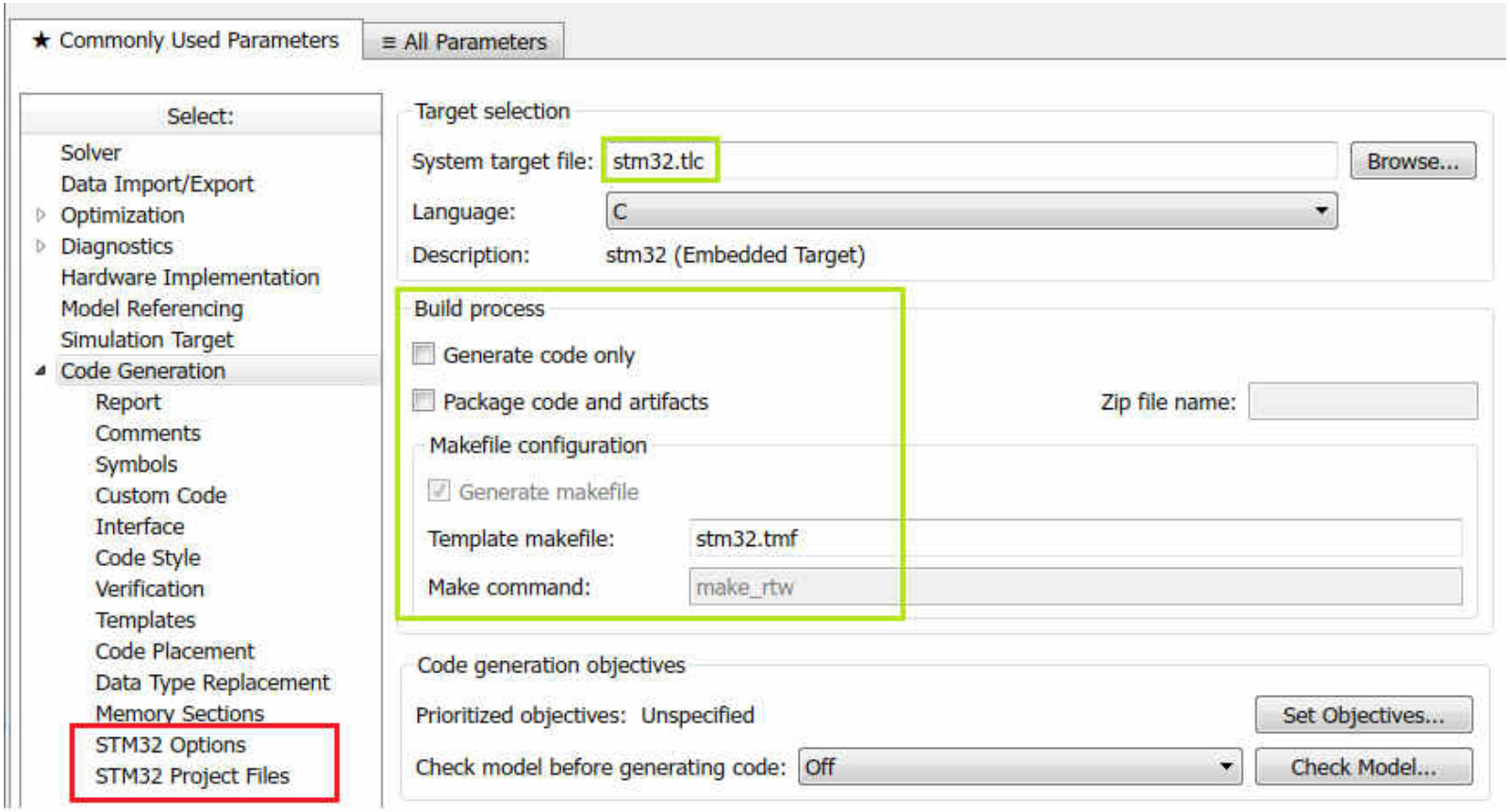
Simulink Model Setting 3/5

- **`stm32.tlc`** has been selected, Build process parameters have changed
  - Select STM32 Options (mandatory) and STM32 Project Files



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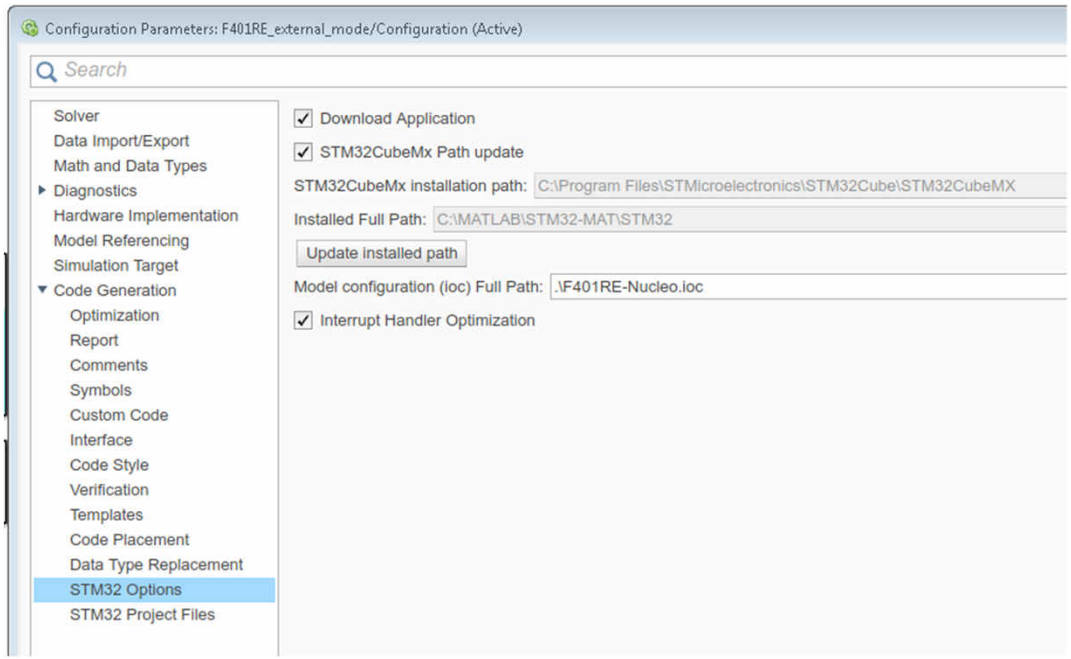
Simulink Model Setting 4/5

- STM32CubeMX Path update is used to automatically update STM32CubeMX installation path.
  - Path selected during STM32CubeMX installation
- Download Application is used to start STM32CubeMX to generate project.
  - Uncheck for code generation only
- Installed Full path is STM32-MAT/TARGET installation path.
  - Default path: `C:\MATLAB\STM32-MAT\STM32`
- Update installed path to update path when it has changed
- Model configuration (`*.ioc`) Full path is configuration file path created using STM32CubeMX for this Simulink application
  - Read only, updated from STM32_Config block.



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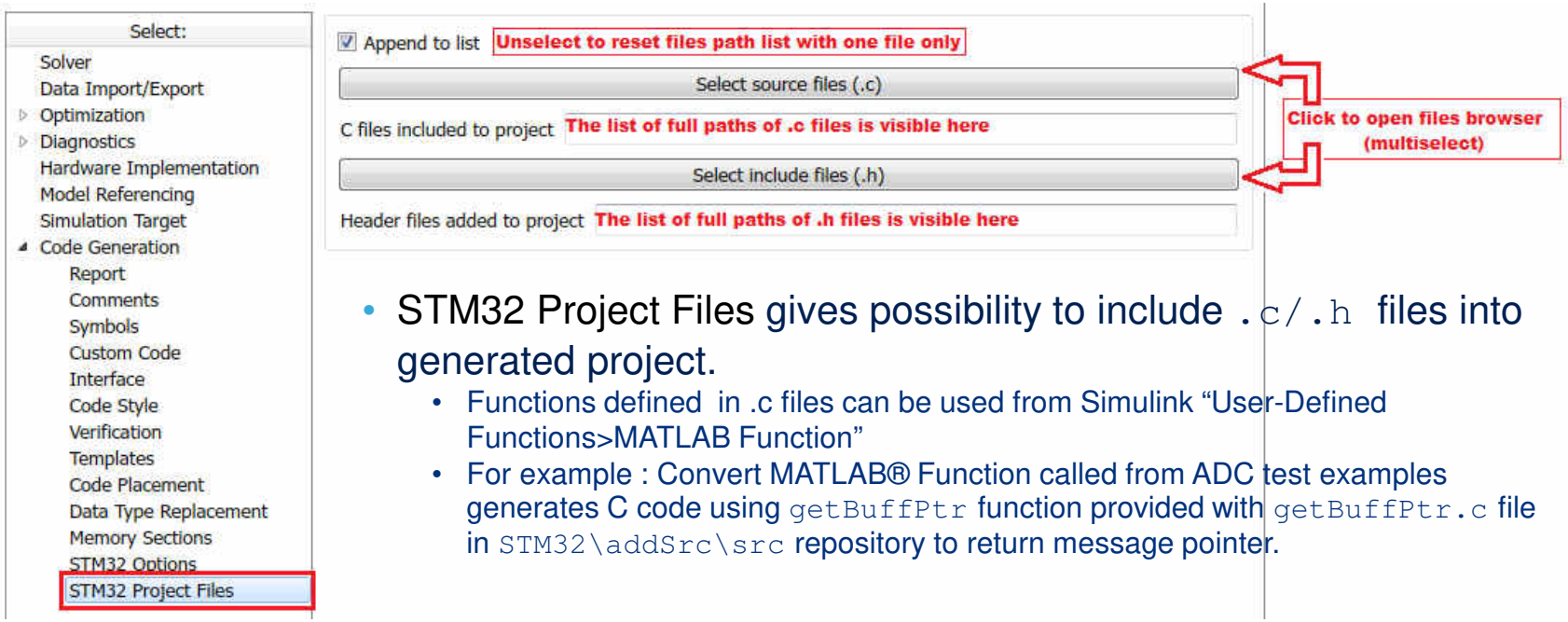
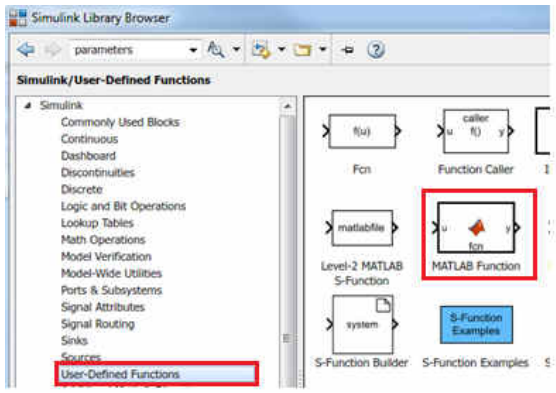
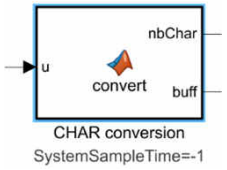
Simulink Model Setting 5/5



- STM32 Project Files gives possibility to include `.c/.h` files into generated project.
  - Functions defined in .c files can be used from Simulink “User-Defined Functions>MATLAB Function”
  - For example : Convert MATLAB® Function called from ADC test examples generates C code using `getBuffPtr` function provided with `getBuffPtr.c` file in `STM32\addSrc\src` repository to return message pointer.






```
function [nbChar, buff] = convert(u)
if coder.target('Sfun')
    % Executing in MATLAB, Buff is null
    buff = uint32(0);
    nbChar = uint16(0);
else
    coder.cinclude('stdio.h');
    coder.cinclude('main.h');
    coder.cinclude('getBuffPtr.h');

    % Executing in the generated code.
    string = char(zeros(1,20));
    stringSize = uint16(size(string,2));
    stringFormat = char(['%08x-%5.2f V',13,10,0]);
    tick = uint32(0);
    tick = coder.ceval('HAL_GetTick');
    coder.ceval('snprintf',coder.wref(string),stringSize,coder.rref(stringFormat),tick,u);

    buff = coder.ceval('getBuffPtr',coder.rref(string));
    nbChar = stringSize;
end
end
```

getBuffPtr.c

PC pure simulation

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Tools usage

- Step 1: Pure simulation
  - Everything done on the PC

- Step 2: Processor-in-the-loop (PIL)
  - Algorithm fully executed on STM32
  - Data (Input or output) exchanged between MATLAB®/Simulink and STM32 via UART

- Step 3: Everything on STM32
  - Data (input or output) obtained within STM32 through its peripherals (ADC, Timers, ...) and algorithm fully executed on STM32

MATLAB® & Simulink

- Not a subject for this HandsOn
- General purpose for MATLAB®/Simulink
- Doesn’t need STM32-MAT/TARGET toolkit.
- Contact MathWorks for MATLAB®, Simulink trainings

Processor in The Loop (PIL)

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Tools usage

- Step 1: Pure simulation
  - Everything done on the PC

MATLAB®/ Simulink

- **Step 2: Processor-in-the-loop (PIL)**
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MATLAB®/ Simulink

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STM32CubeMX

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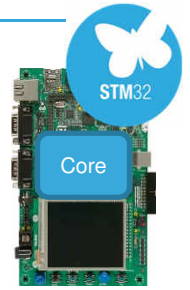

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MATLAB®/ Simulink

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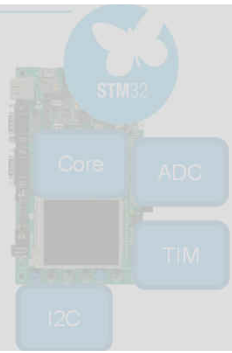
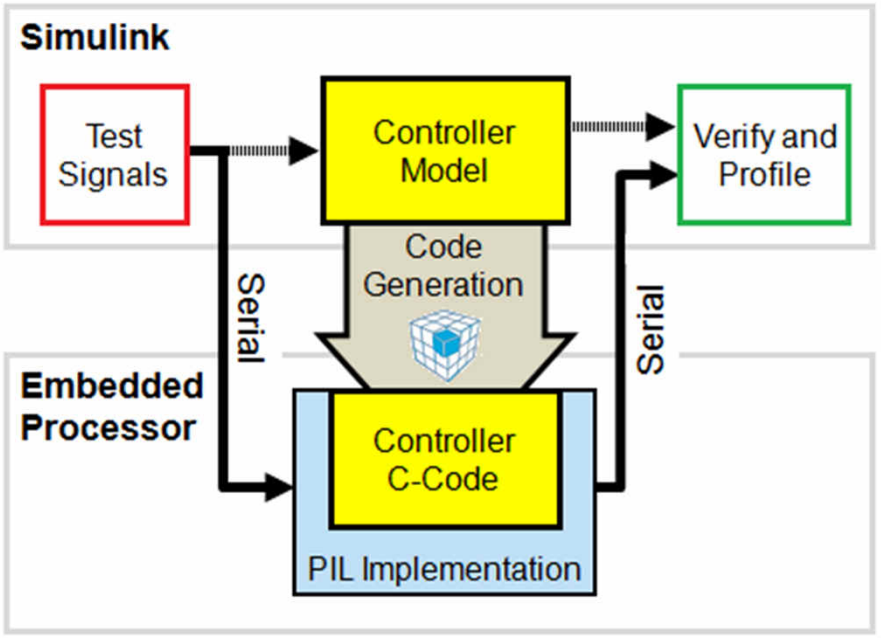


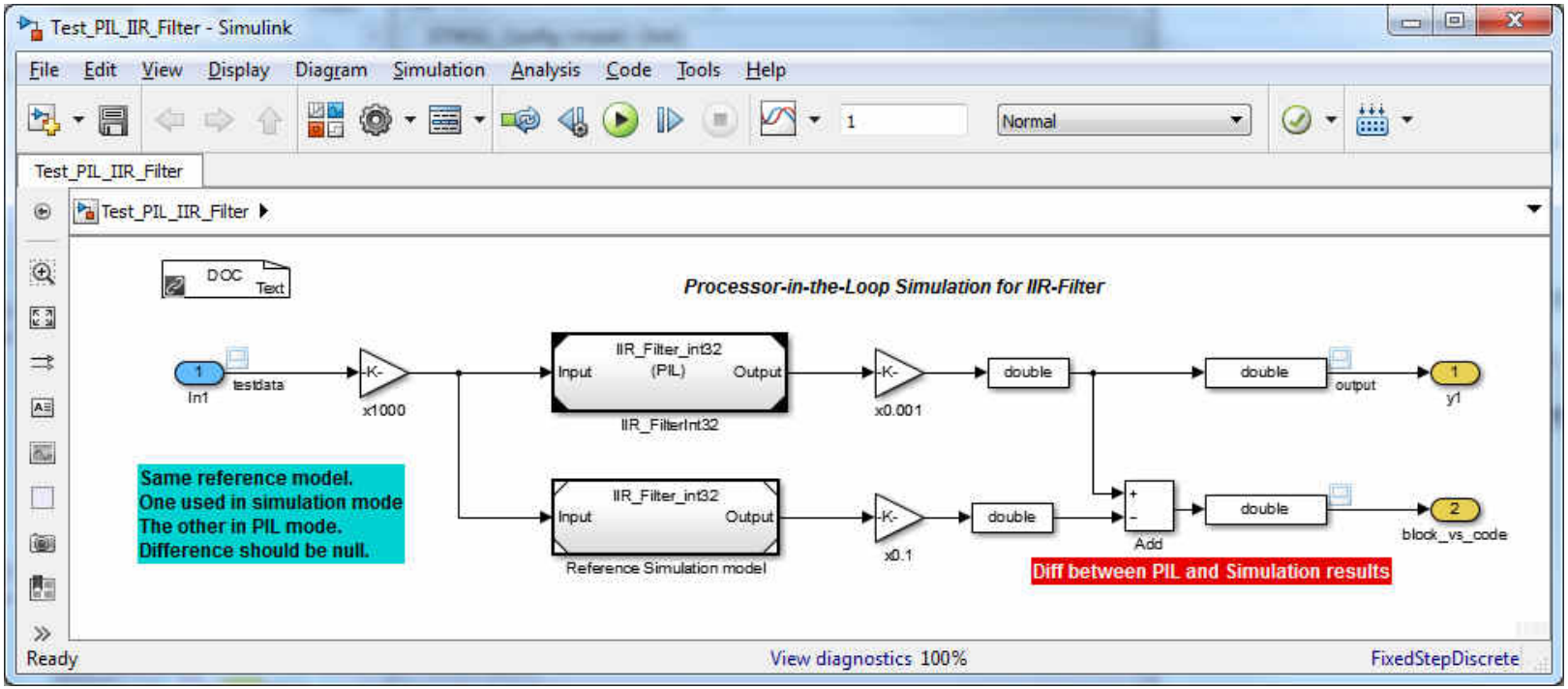
PIL Overview

- PIL is used to run MATLAB® algorithm on STM32 device
  - To see if STM32's computational results are numerically equivalent to PC-based simulation results.
  - To measure directly the time to execute the Simulink model steps (**profiling**)
- PIL simulation uses serial port to send data from Simulink to STM32 and receive Simulink processed data back from STM32
- PIL simulation doesn't run in «real-time»
  - Simulink is «master» sending asynchronously data to STM32 through serial port.
  - STM32 device waits for data from Simulink, process data (in real-time) and sends result back to Simulink through serial-port.
- PIL simulation doesn't process real data from STM32 peripherals.
  - STM32 peripherals (ADC etc…) are not used.
  - Only STM32 USART peripheral is used to communicate with Simulink.



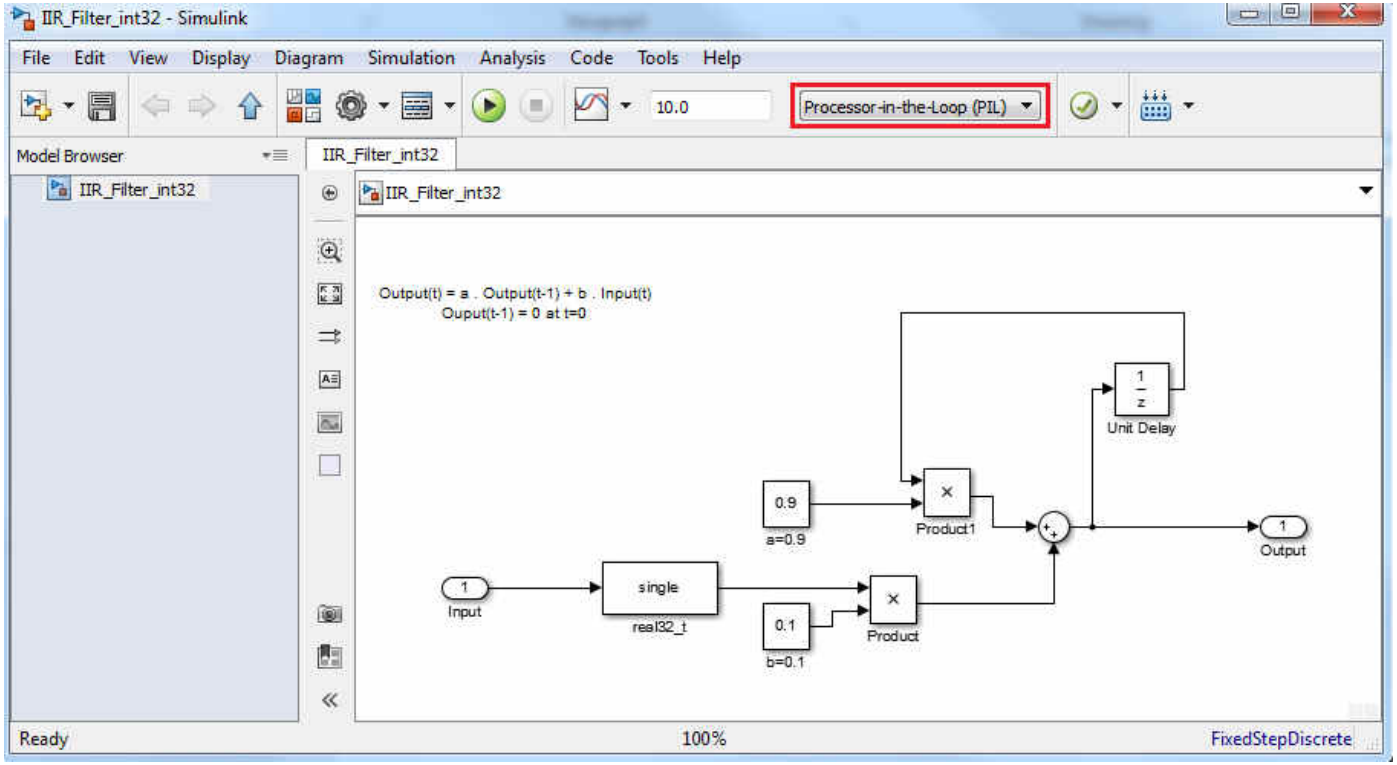
PIL Example

- IIR Filter example
  - Open `Test_PIL_IIR_Filter.mdl` model example from `C:\MATLAB\STM32-MAT\STM32\STM32demos\PIL\Filter` (Default STM32-MAT/TARGET installation path)



Reference Model for PIL

- It uses `IIR_Filter_int32.mdl` as reference model.
- `IIR_Filter_int32.mdl` is a simple algorithm for one order filtering.
- `IIR_Filter_int32.mdl` is set to be used for Processor-in-the-loop (PIL)



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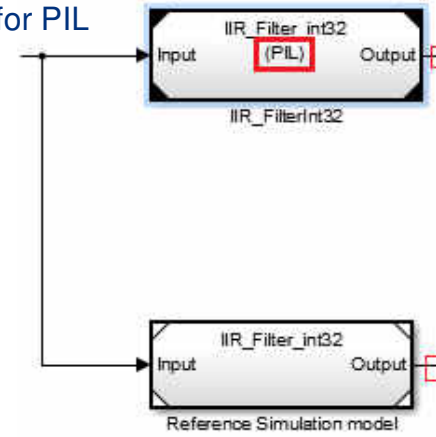
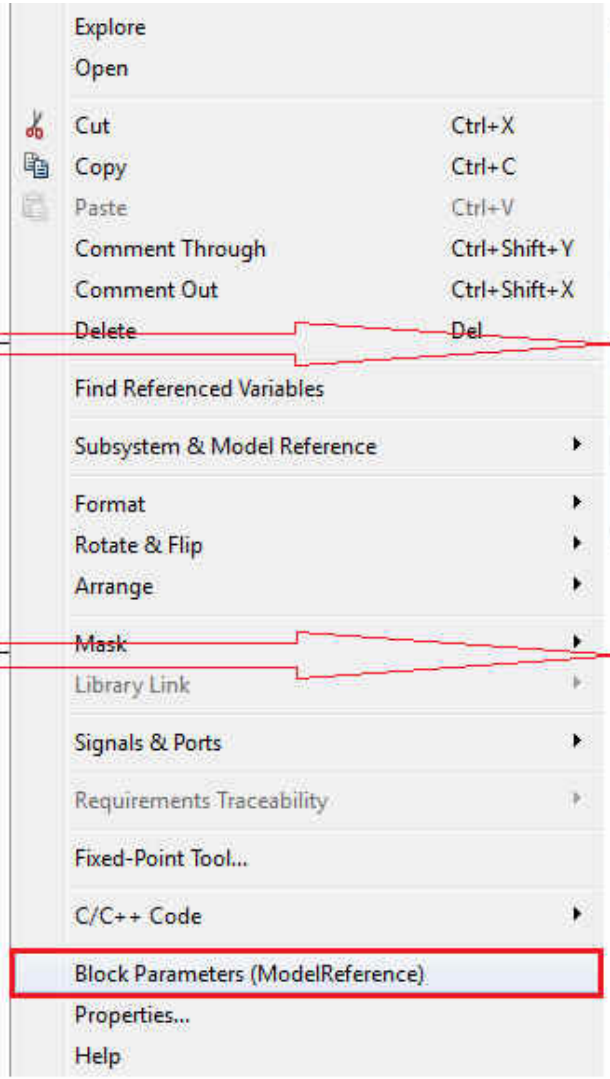
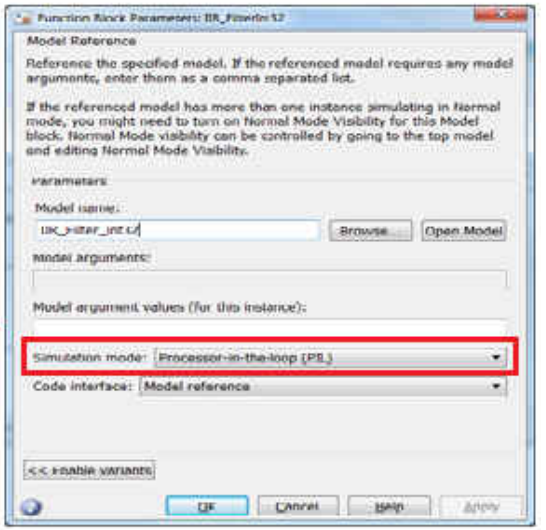
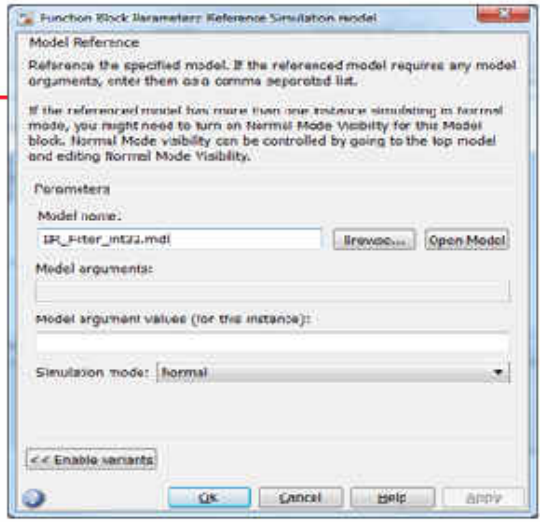
PIL setting vs Simulation

- `IIR_filter_int32` model is used twice:
- One is set for PIL
- One is set for simulation model (Normal)
- Click right mouse button on each reference model to open select Block Parameters









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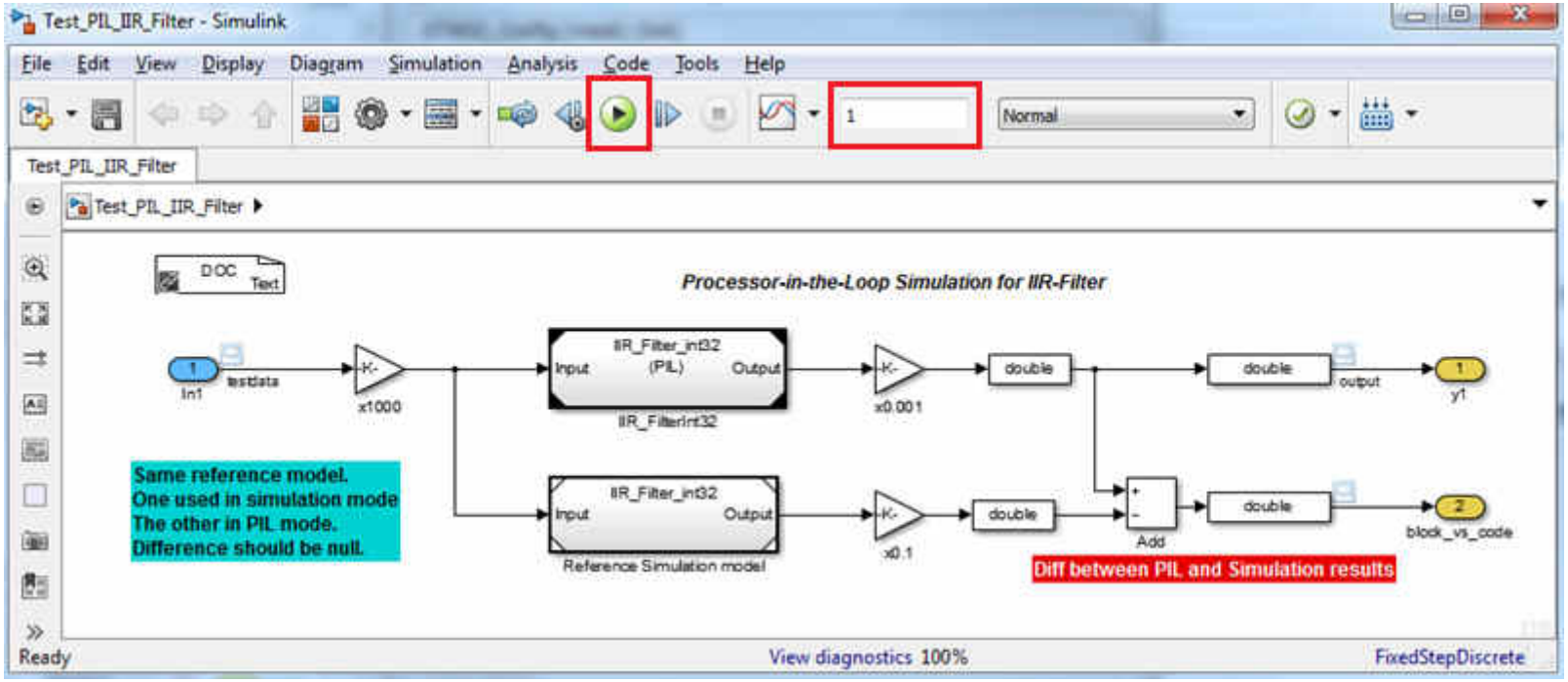
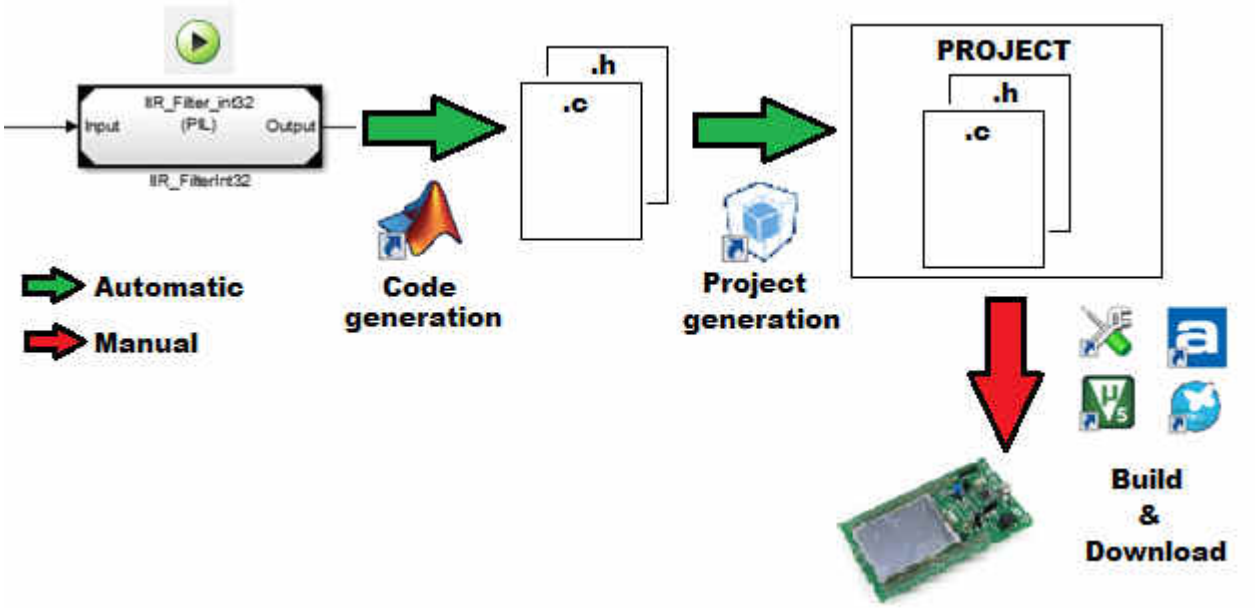
Simulink PIL start

- Set simulation duration time and click run simulation green button
  - Example: Simulate 1 second (given 1000 values from `testdata`, one for each 1 ms)



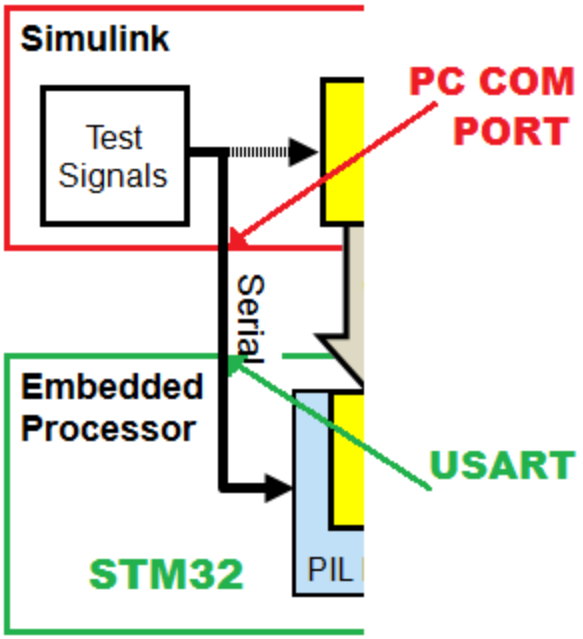
Code generation overview

- PIL referenced model runs into STM32 target while the simulation model runs on PC
  - Automatic conversion of PIL model to `.c/.h` files
  - Automatic call to STM32CubeMX to create project
  - Manually build and download project to STM32 target from selected IDE



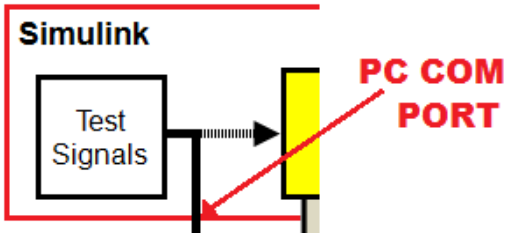
PC/STM32 communication overview

- Some parameters are requested when you start PIL
  - STM32 Target
    - STM32 device that will run the application
  - PC Communication Port
    - COMx
      - Default parameters : 115200bds, 8b, no parity, 1 stop
  - STM32 Communication Port
    - USARTx
      - USARTx, Port and Pins for Rx/Tx
      - Same parameters as PC COM Port selection

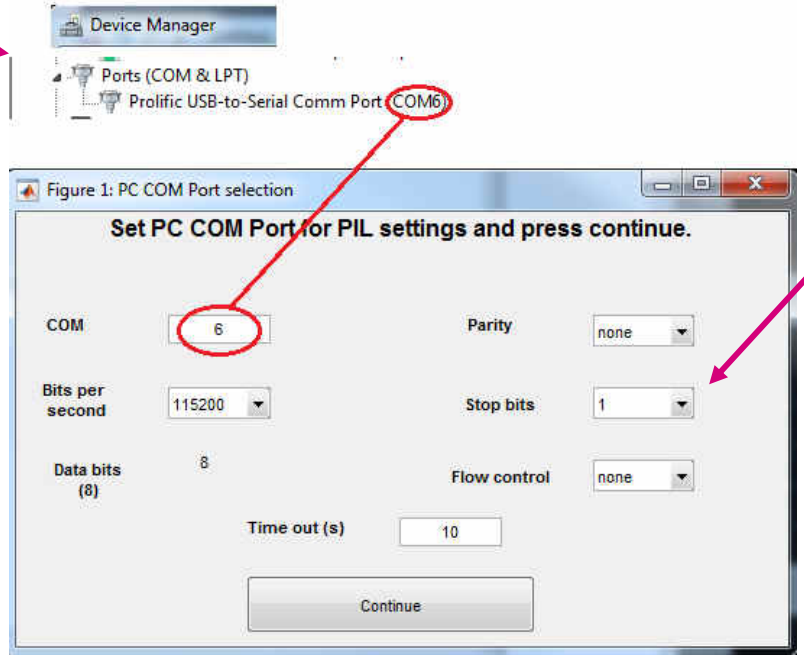


PIL Processing 1/5

- PC COM Port from Device Manager
  - 8b is fixed, other parameters can be changed
  - Time Out: Simulink message error after 10 seconds without communication.



Look at Windows «Device Manager» to find PC COM Port



Set parameters

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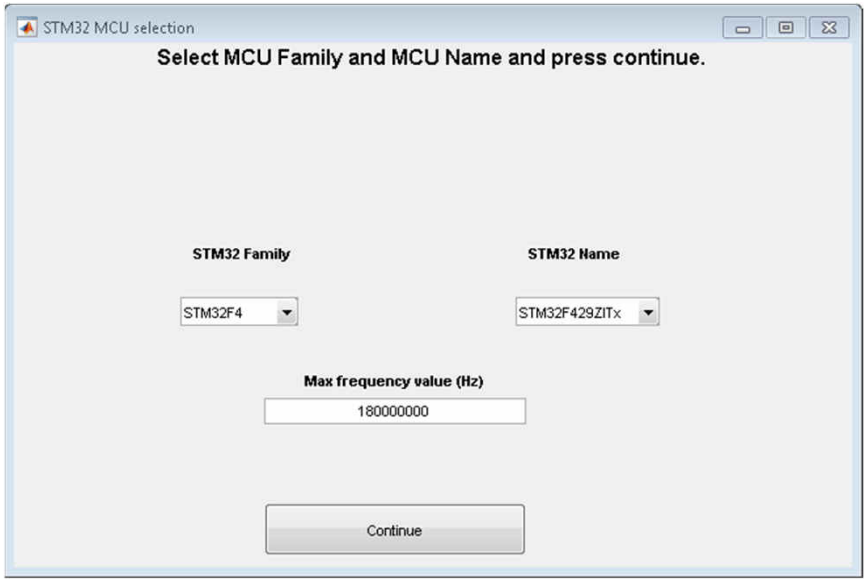
PIL Processing 2/5

- STM32 Selection
  - Example with STM32F429i-DISCO board
    - Family: STM32F4
    - Name: STM32F429ZITx
    - Frequency:180MHz (by default STM32max speed is selected)

Frequency value is used as unit for Profiling.

To compute STM32 processing time.



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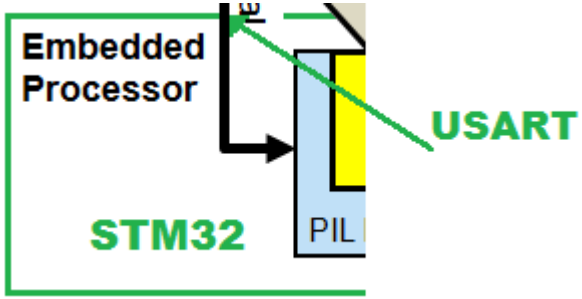
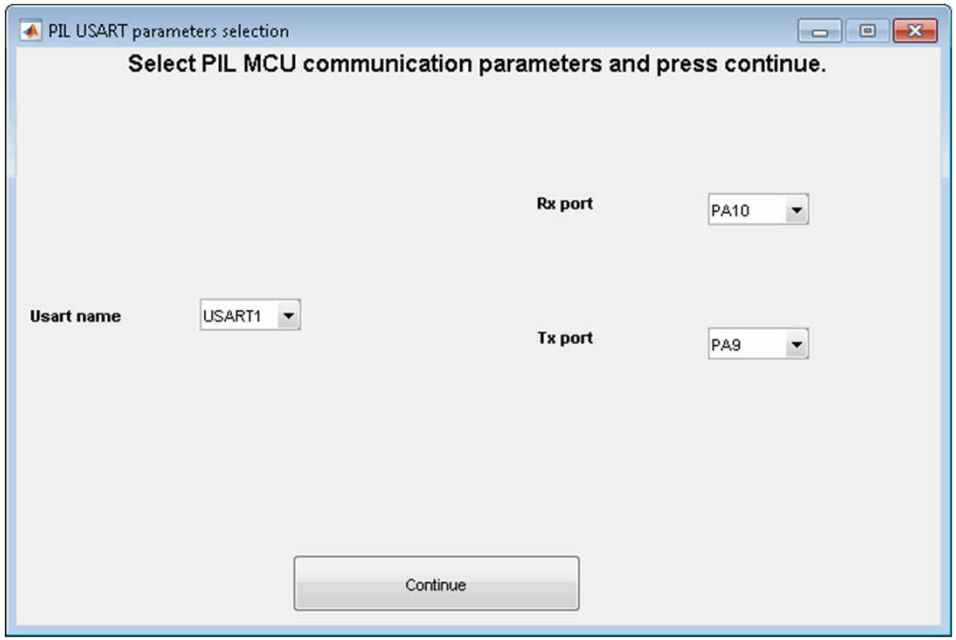
PIL Processing 3/5

- STM32 COM Port
  - Example
    - USART1
    - Rx: PA10 & Tx: PA9





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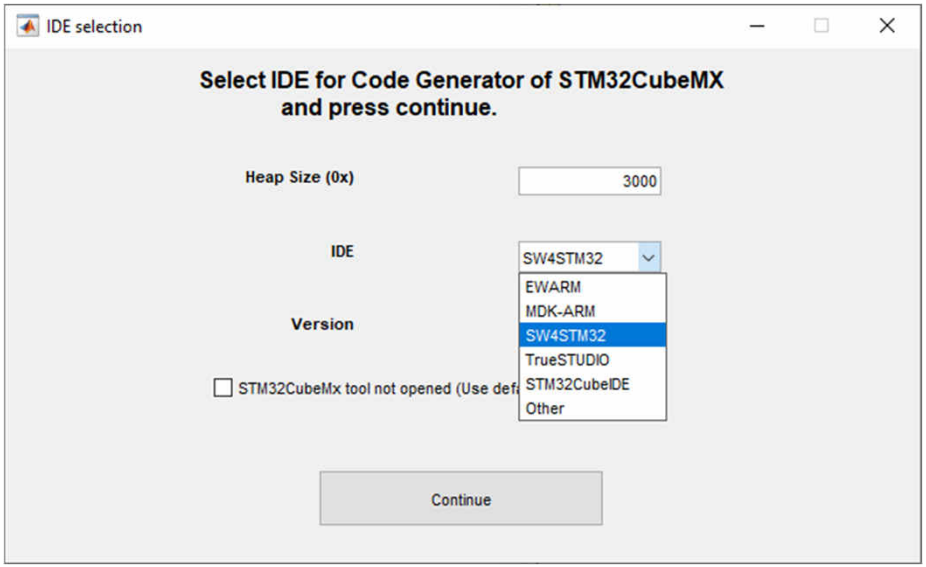
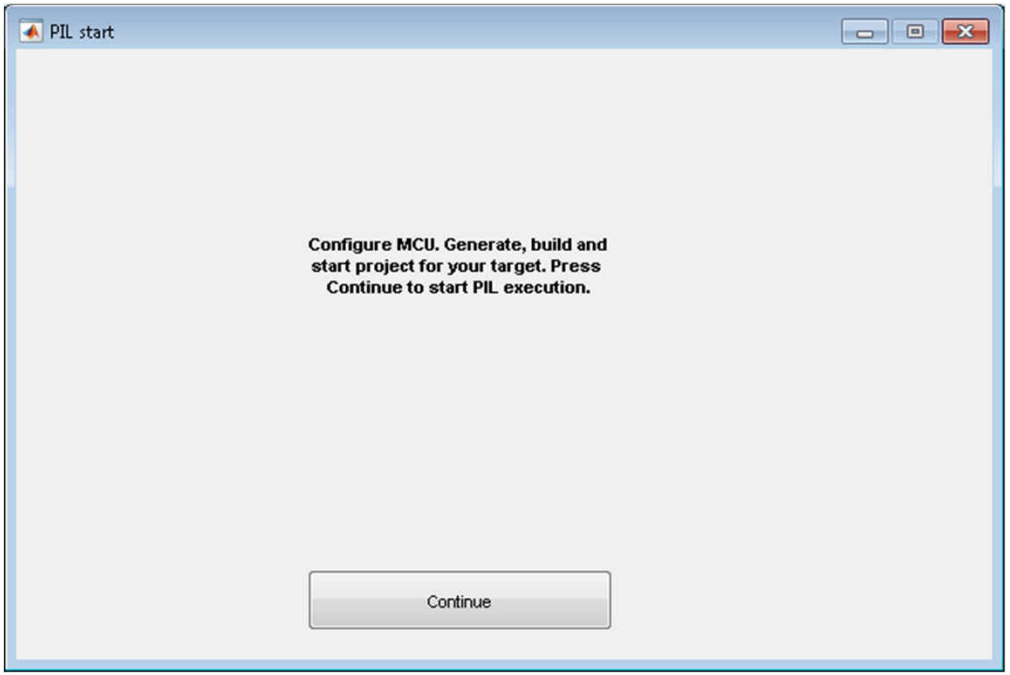
PIL Processing 4/5

- Toolchain Selection
  - Select IDE from list of proposals
  - Hide STM32CubeMx tool call
    - By default STM32CubeMX is opened in order to set/verify clock configuration.
    - Set «Hide STM32CubeMx» to automatically generate an IDE project using the default clock settings of the STM32CubeMX tool.



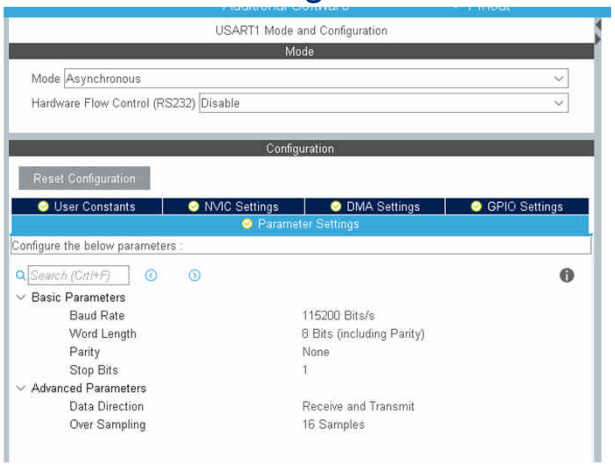
PIL Processing 5/5

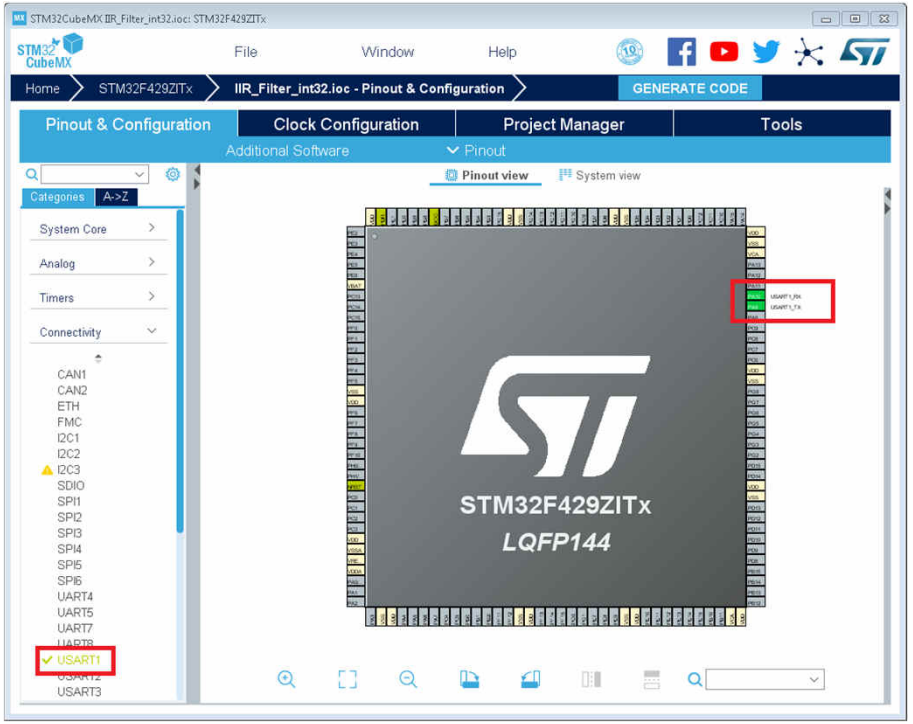
- It is an asynchronous process.
  - Simulink is waiting.
  - Simulink must send data through COM port, only when project is built, downloaded and running on the STM32 target.
  - Then, you will press « Continue » button to start data flow between the PC and the STM32 device.
  - STM32CubeMX is automatically opened and you can verify or modify STM32 settings.



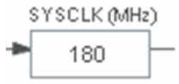
STM32CubeMX & PIL 1/2

- STM32CubeMX settings
  - Pinout :
    - Usart1 , Rx/Tx
  - USART1 Configuration





- STM32CubeMX settings
  - Clock Configuration
    - Reference value already selected for Profiling



    - Clock setting : Enter 180 and return if needed
      - Then Clock tree is automatically updated

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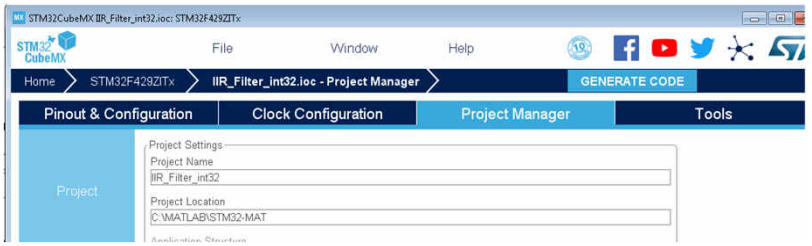
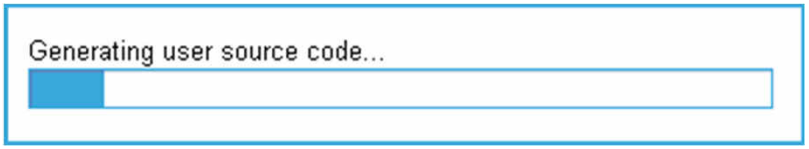
STM32CubeMX & PIL 2/2

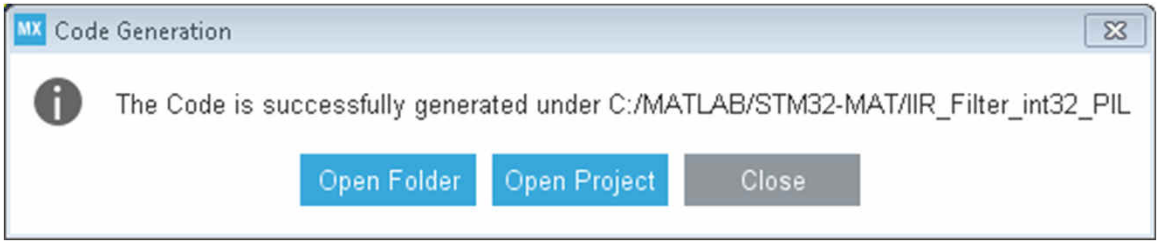
- STM32CubeMX project generation
  - Generate source code based on user settings



  - Generate Project



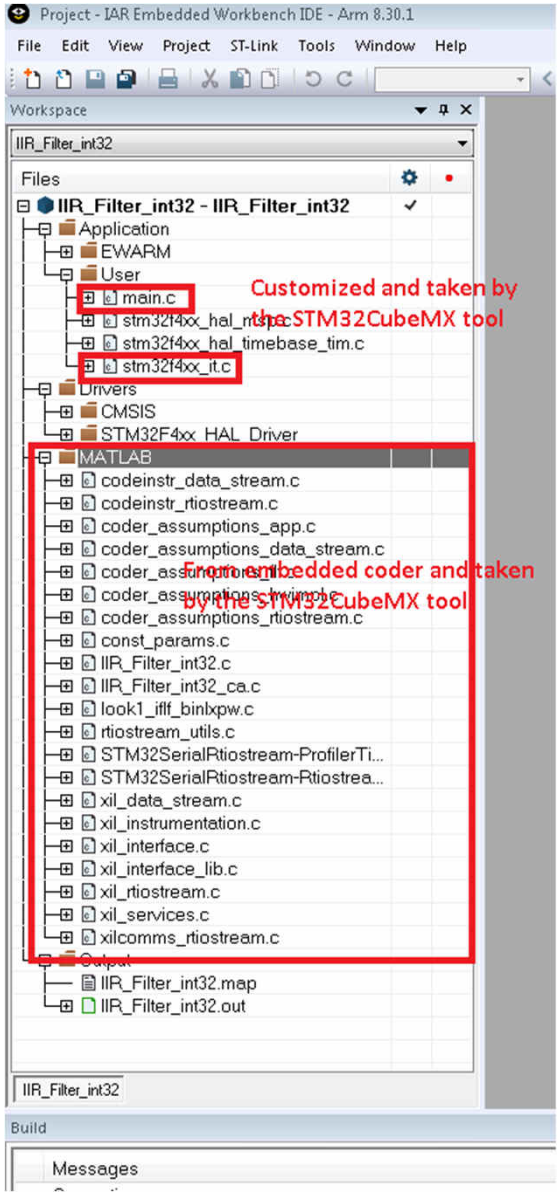
  - Open Project



  - Close STM32CubeMX

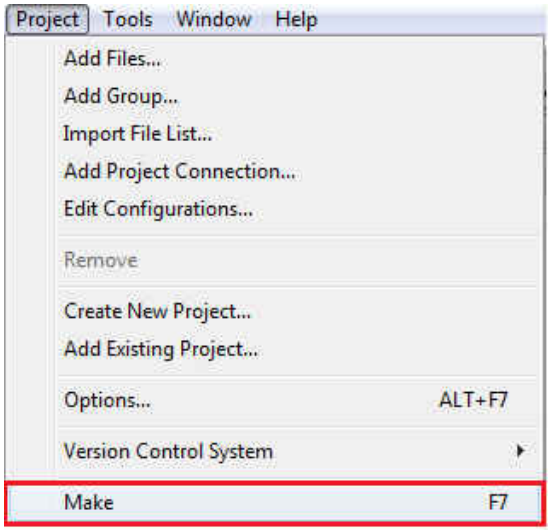
IDE & PIL 1/2

- IDE project
  - Generated by the STM32CubeMX tool
  - Includes
    - Application files generated from MATLAB® and Simulink
    - `main.c` generated from MATLAB® and modified by the STM32CubeMX tool
    - HAL mandatory peripherals drivers



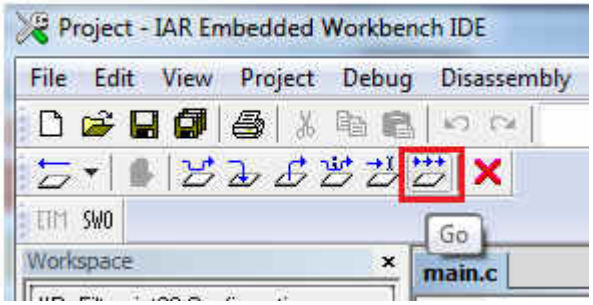
Toolchain & PIL 2/2

- Build Toolchain project
  - Make (F7)



IAR EWARM toolchain used for this example

- Download project



- Run project
  - Then, STM32 is running and waits for data from Simulink.

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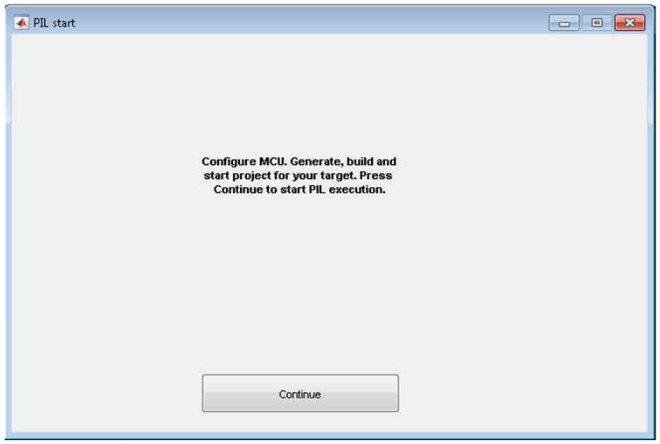
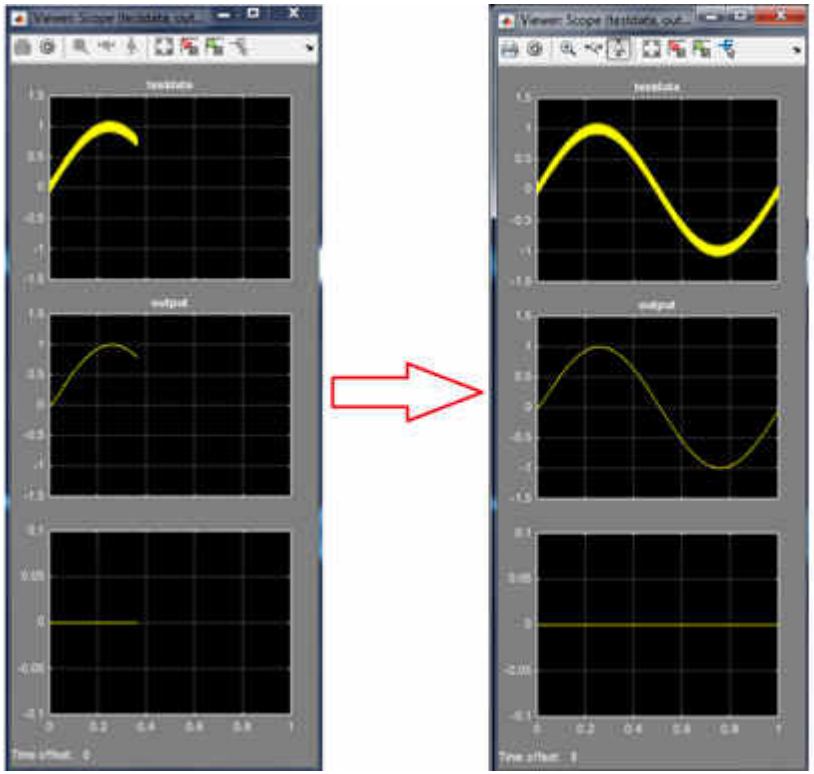
Running PIL

- Start Simulink data flow
  - « Continue » button of PIL start window



- PIL results



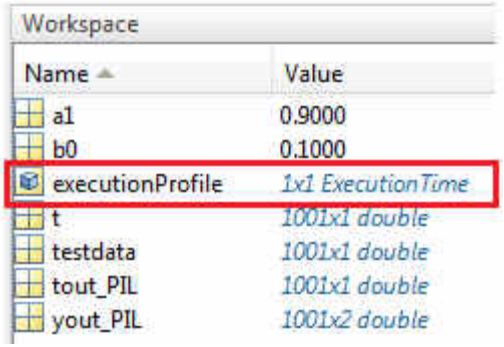
Input signal

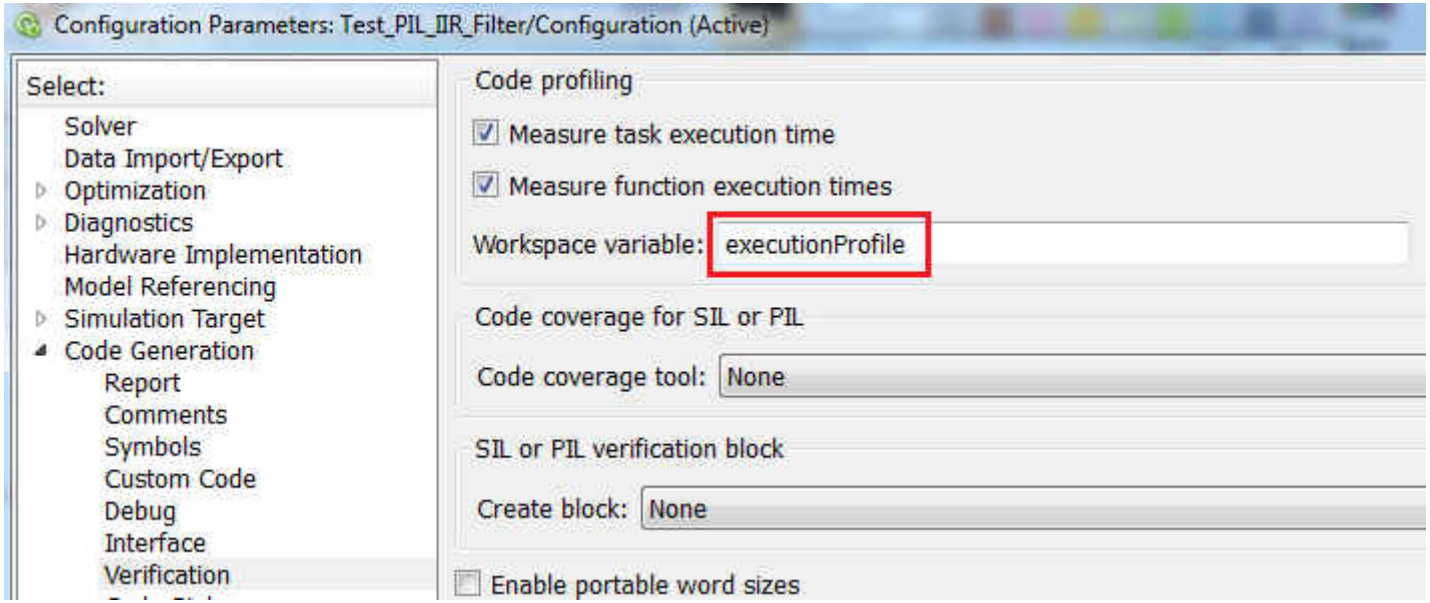
STM32 filtered signal

Difference between PC & STM32 filters

PIL Profiling 1/3

- Profiling = PIL Timing analysis
  - `executionProfile` has been generated in MATLAB® Workspace
  - « `executionProfile` » default Workspace variable name
    - Can be modified from « Configuration Parameters » window Code Generation > Verification of the model.





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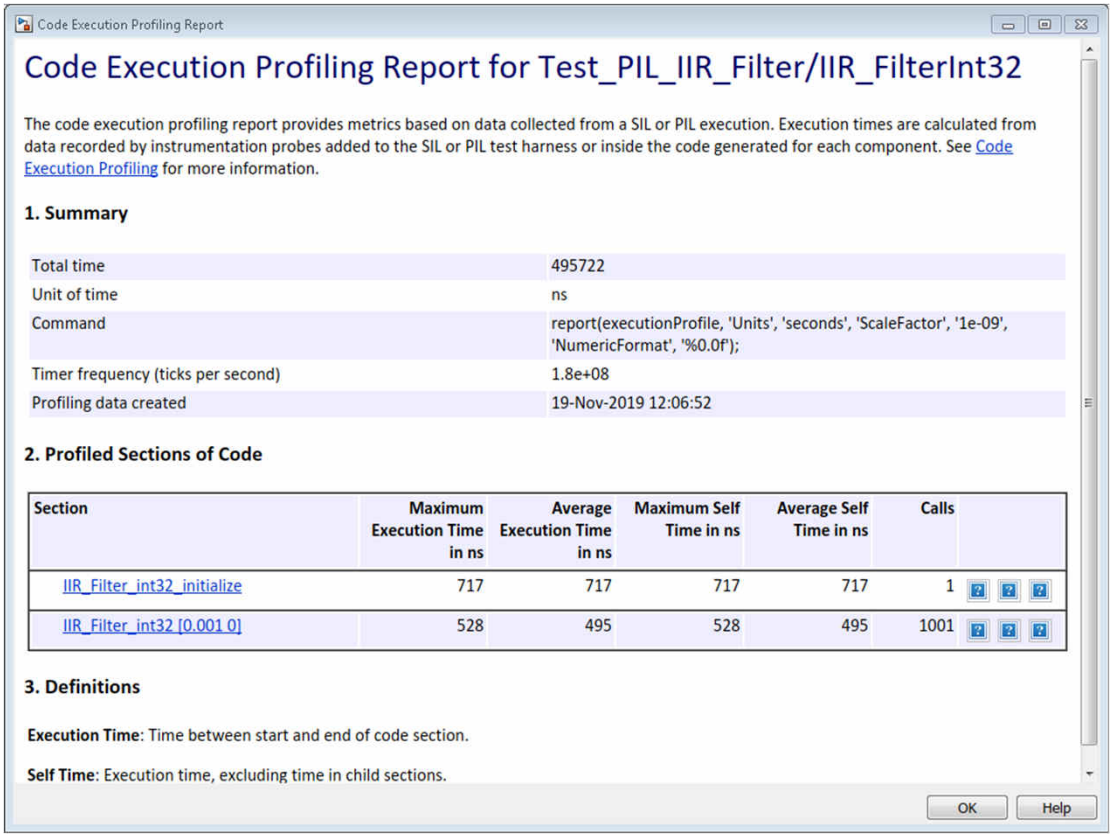
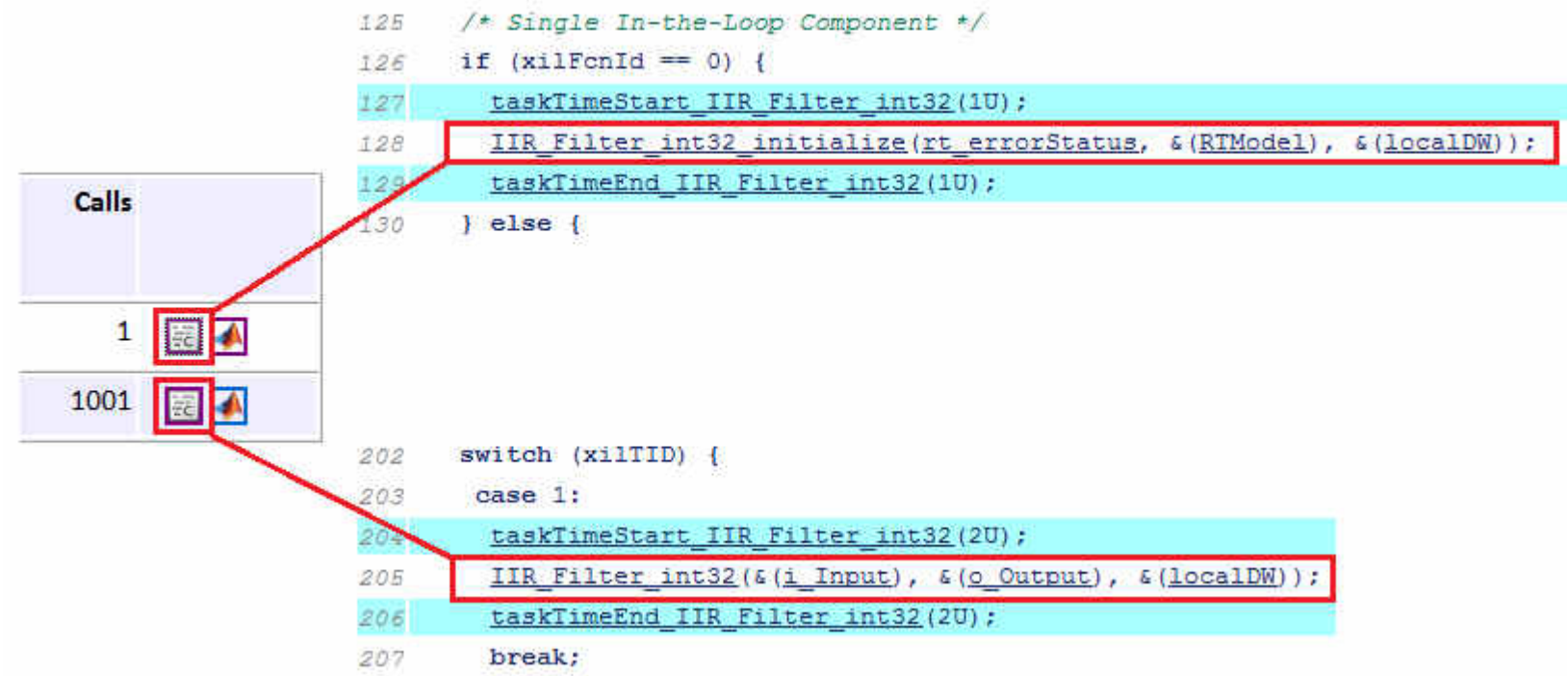
PIL Profiling 2/3

- Enter «`executionProfile.report`» on MATLAB® command window to open profiling report window to know
  - STM32 processing time at selected frequency
  - Execution time and number of calls per function



PIL Profiling 3/3

- Click on C code generated
  - To see MATLAB® generated code for STM32
  - or profiled sections



Application Code Generation

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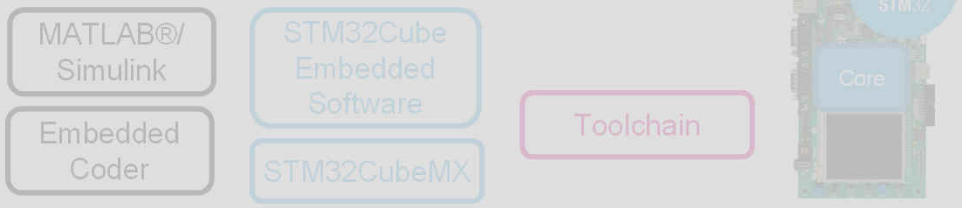
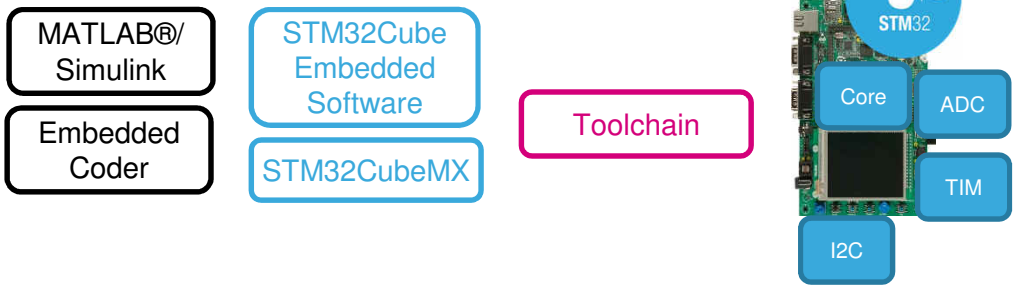
Tools usage

- Step 1: Pure simulation
  - Everything done on the PC

- Step 2: Processor-in-the-loop (PIL)
  - Algorithm fully executed on STM32
  - Data (Input or output) exchanged between MATLAB®/Simulink and STM32 via UART



- Step 3: Everything on STM32
  - Data (input or output) obtained within STM32 through its peripherals (ADC, Timers, …) and algorithm fully executed on STM32



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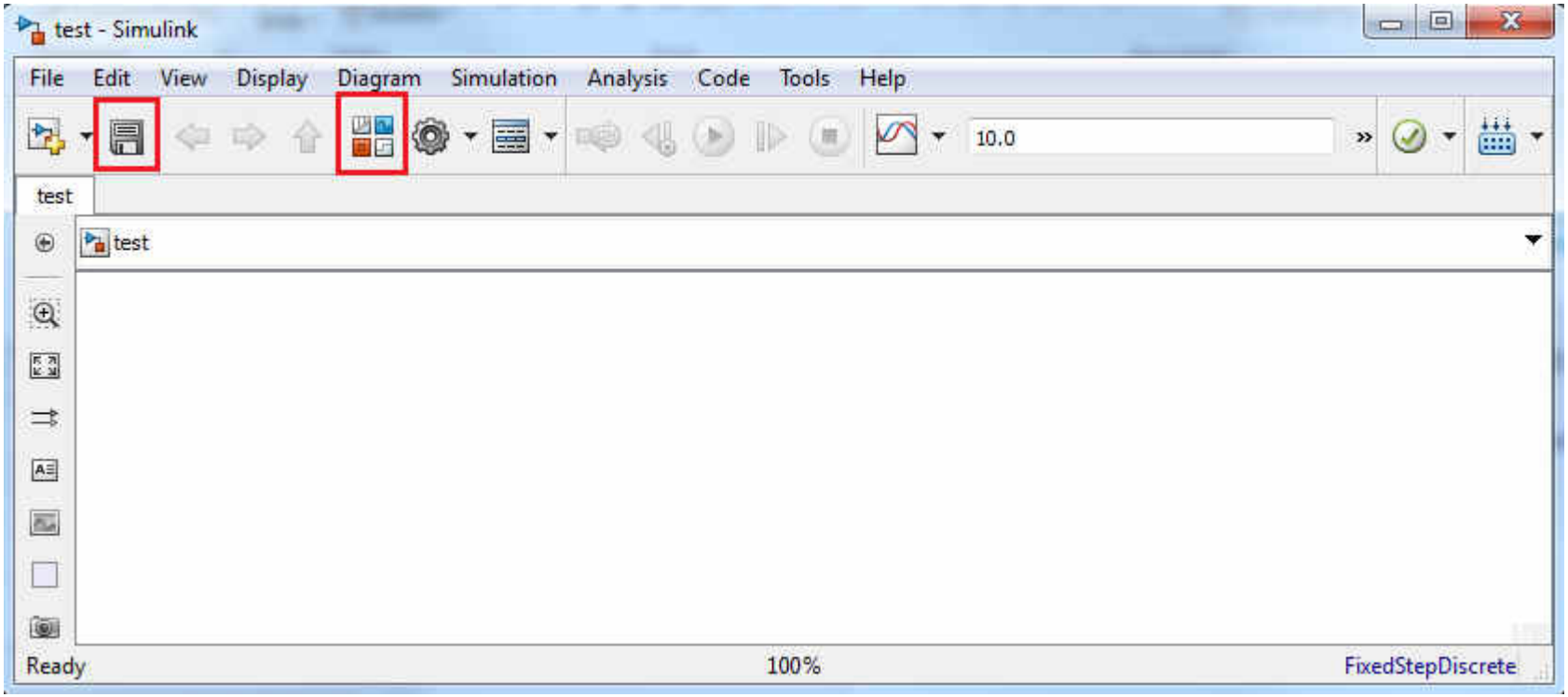
Simulink application development

- Look at Simulink model Setting 1/4 to 4/4 to open and configure new model.
- Save Simulink model and open Library Browser
  - For example: Save model as `test.slx` into `C:\TEMP\test` repository



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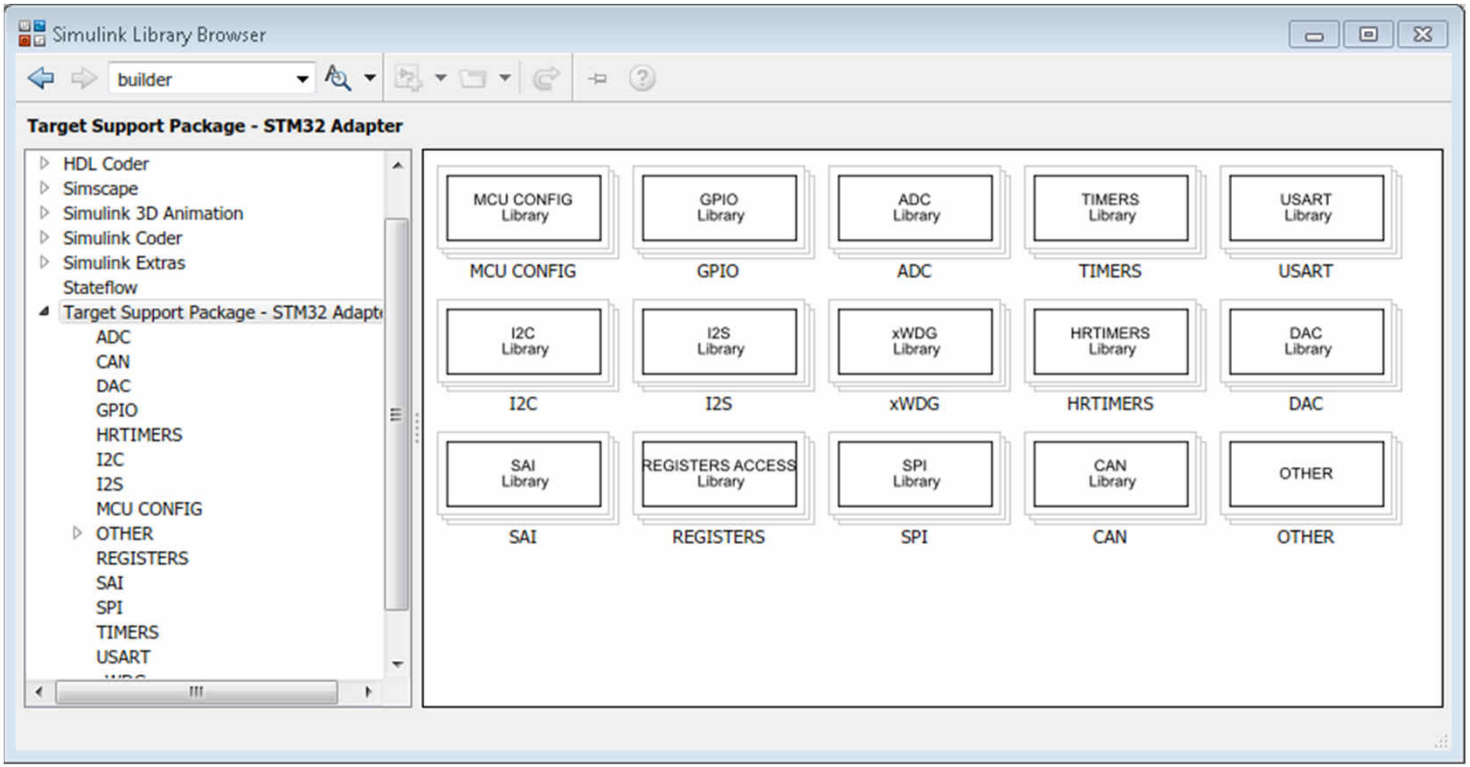
STM32 Configuration 1/3

- STM32 Drivers Library
  - Several STM32 peripheral drivers are available.

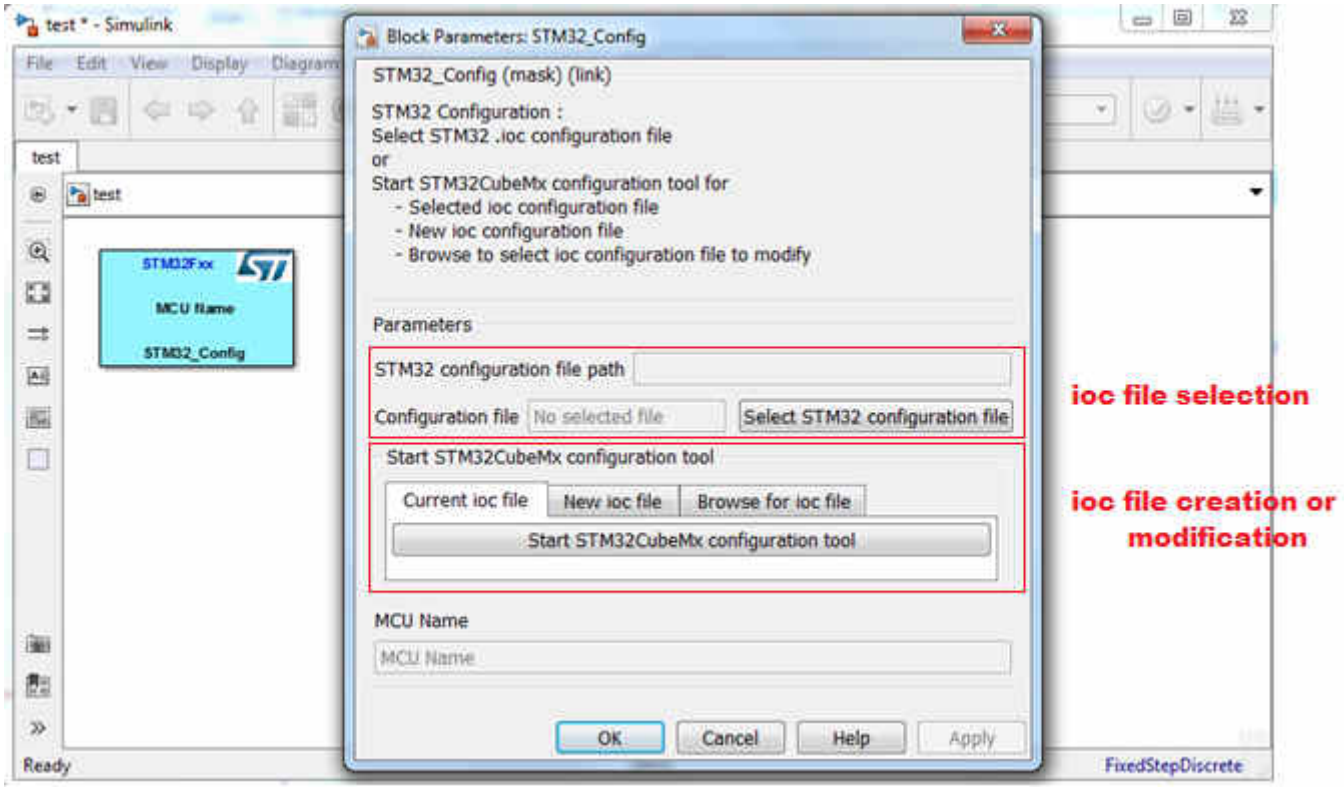
- MCU Configuration
  - «MCU CONFIG» is the first library to open and use
  - Drag & Drop STM32_Config block to your Simulink model.
  - STM32_Config is used to select STM32 configuration through STM32CubeMX configuration file (`*.ioc`).



STM32 Configuration 2/3

- IOC file selection
  - `.ioc` file is a text file created and used by STM32CubeMX as STM32 descriptor.
  - `.ioc` file contains STM32 configuration (pinout, peripheral selection & configuration)
  - Double click STM32_Config to open block parameters window

- Select ioc file describing STM32 you want to use for your application with «Select STM32 configuration file»
  - It is the only and mandatory way to select .ioc file for the Simulink application.
- You can also modify ioc file or create a new one and the STM32CubeMX tool is automatically opened.



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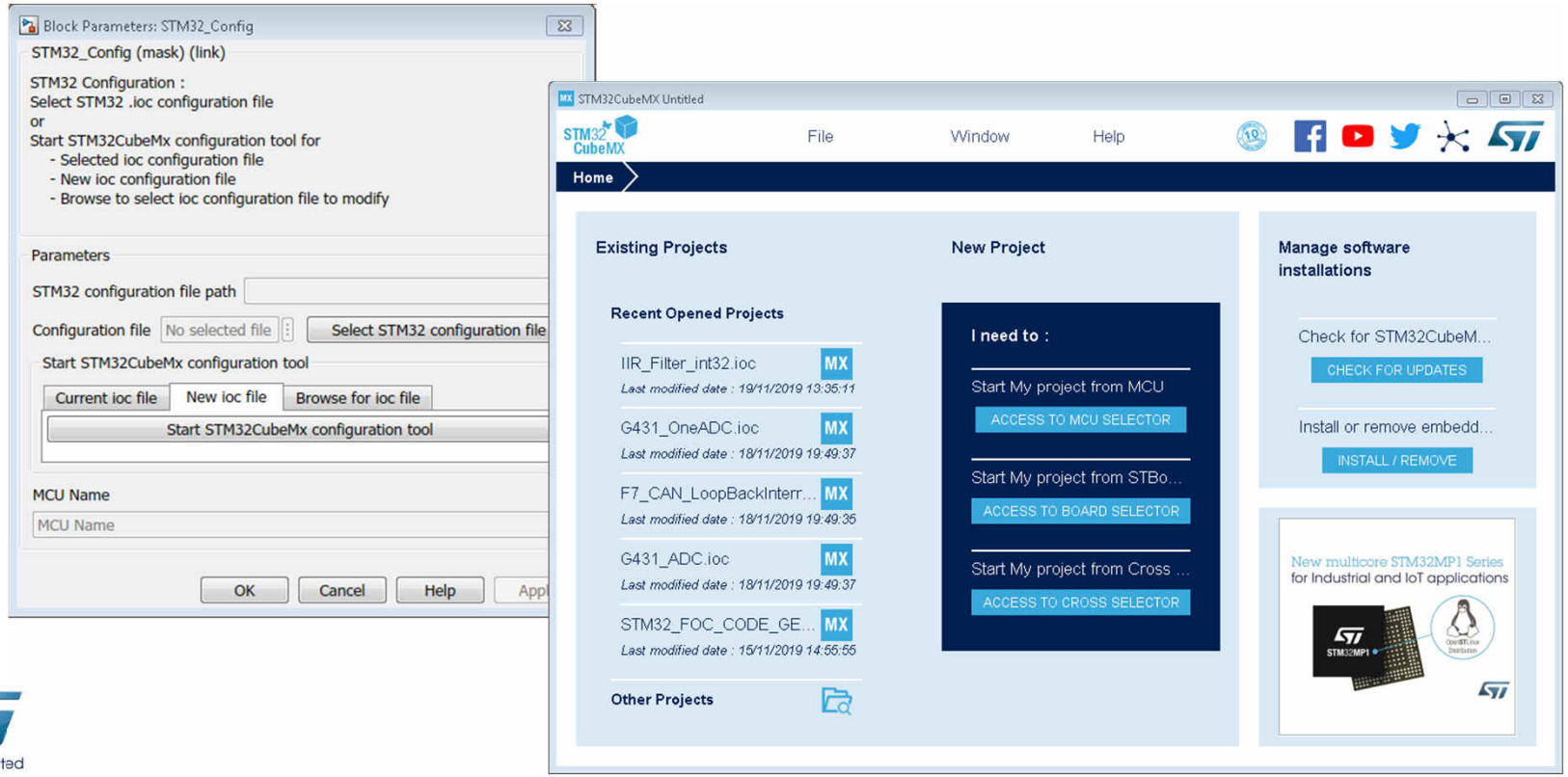
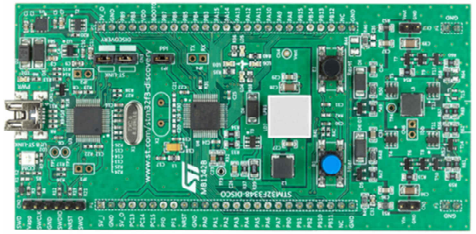
STM32 Configuration 3/3

- IOC file creation
  - Select «New ioc file» and click «Start STM32CubeMx configuration tool» button.
  - STM32CubeMX opens.
  - Look at http://www.st.com/web/catalog/tools/FM147/CL1794/SC961/SS1533/PF259242?s_searchtype=partnumber to get the STM32CubeMX User Manual.
  - Save the STM32CubeMX ioc configuration file and select it using «Select STM32 configuration file» button.
    - ioc file is not automatically selected for Simulink application from STM32CubeMX



Simulink application example

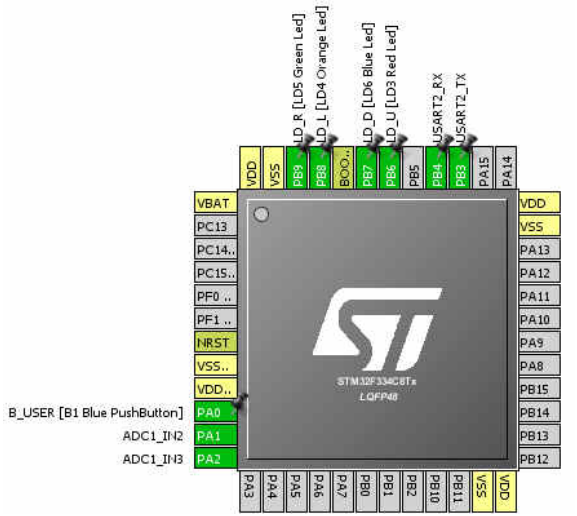
- Hardware :
  - Example based on STM32F3348-DISCO
  - Configuration :
    - Leds (LED3/4/5/6)
    - Push Button (User blue button)
    - USART2 Virtual Com Port (SB14&SB16 soldered)
    - ADC1
    - TIM1 & TIM6



- Software application :
  - Use TIM1 to blink LED3 at 1Hz
  - Use TIM6 to blink LED4 at 2Hz
  - Use TIM6 to trig ADC1 channels 2&3 conversion
  - Blink Led6 when user push button is pressed
  - Send the values of ADC1 channel 3 on USART2 when the user push button is pressed

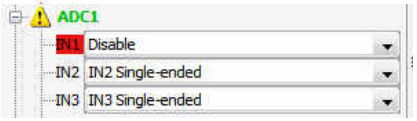
STM32CubeMX STM32F3348 Pinout

- Hardware pinout configuration
  - PA0 : GPIO_EXTI0
  - PA1 : ADC1_IN1
  - PA2 : ADC1_IN2
  - PB3 : Usart2_Tx
  - PB4 : Usart2_Rx
  - PB6 to PB9 : GPIO_Output

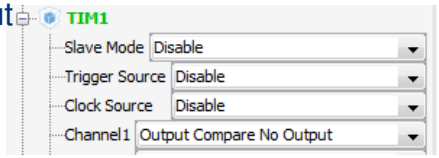


- Hardware setting
  - USART2 is Asynchronous

  - ADC1 IN2 & IN3 Single-ended



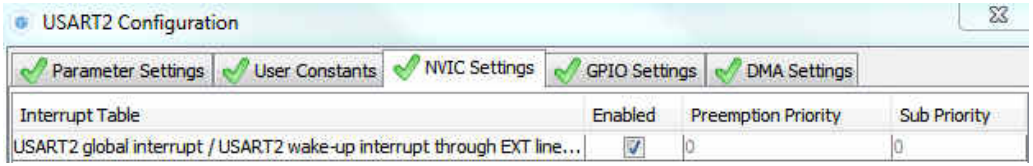
  - TIM1 Channel1 as Output Compare No output

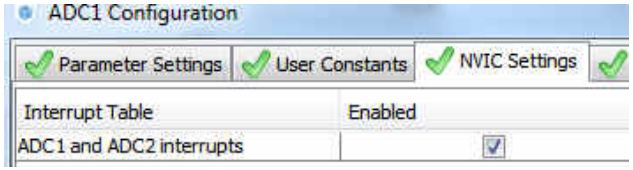


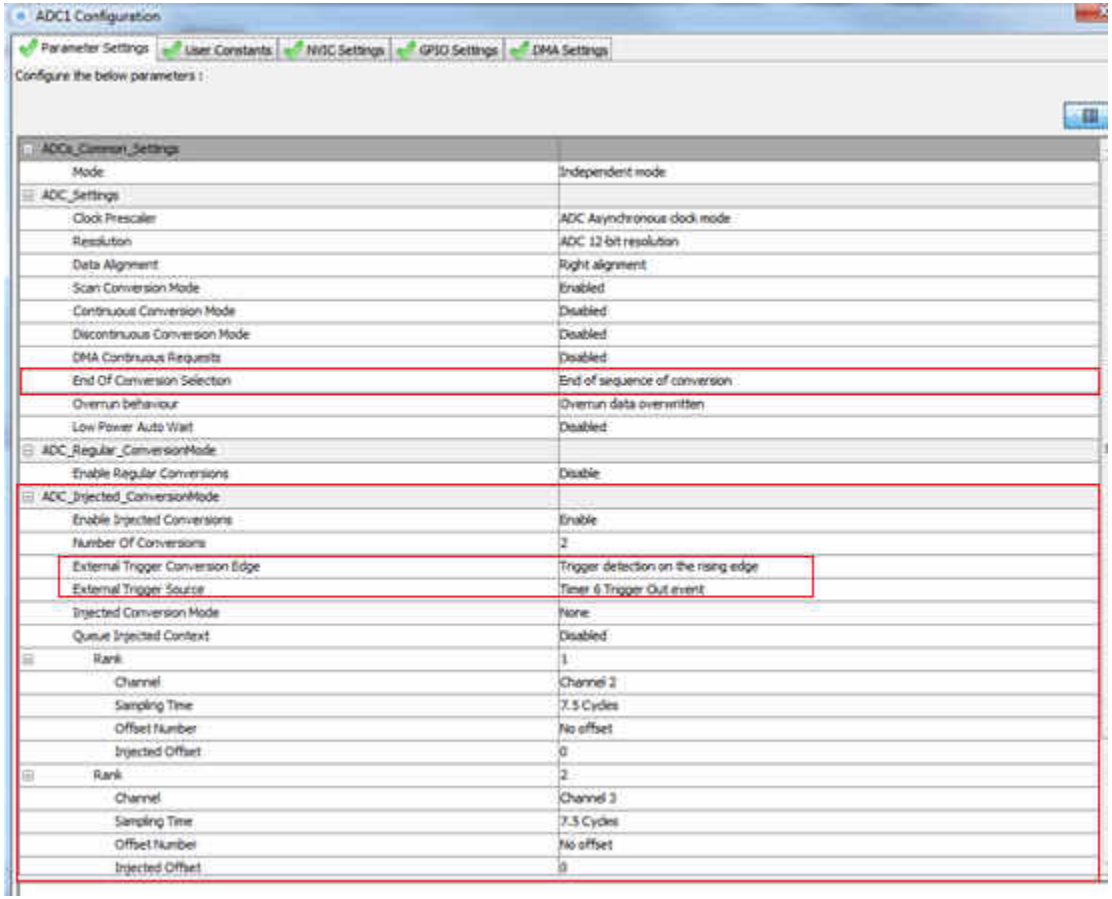
  - TIM6 Activated (No Output)

STM32CubeMX Peripheral settings 1/2

- Peripheral configuration :
  - USART2
    - Baud Rate : 115200
    - Word Length: 8 Bits
    - Parity: None
    - Stop Bits: 1
    - Enable global interrupt
  - ADC1
    - Injected Channels 2&3
    - Interrupt at end of sequence of conversion
    - Conversion triggered from Timer6
    - Interrupt Enabled







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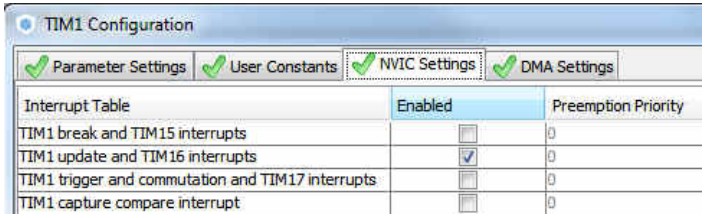
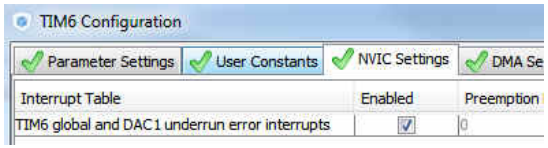
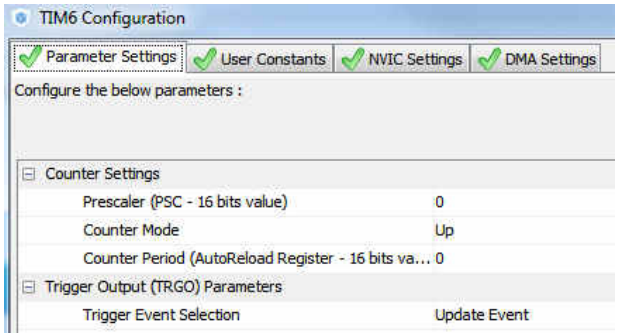
STM32CubeMX Peripheral settings 2/2

- Peripheral configuration :
  - TIM1
    - Default configuration
    - TIM1 Update interrupt enabled

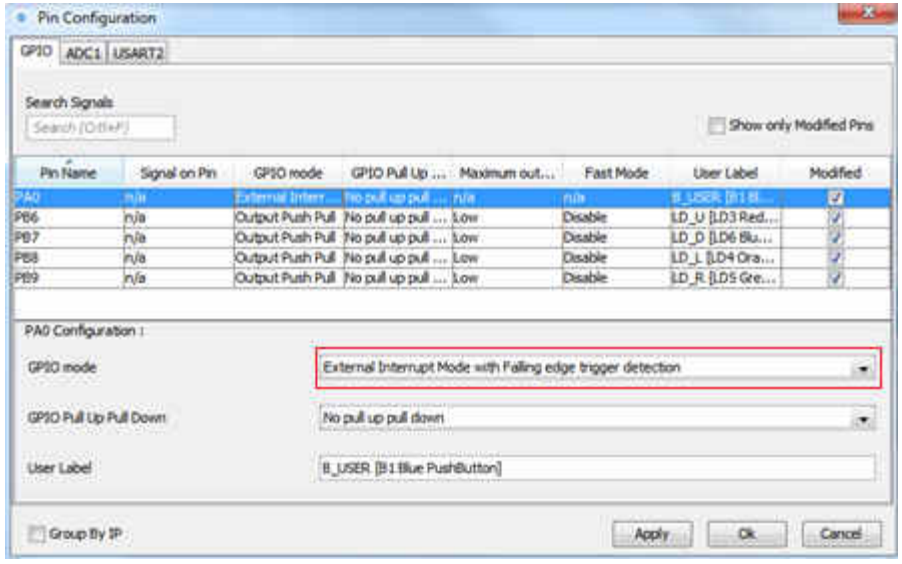


  - TIM6
    - Trigger event :Update Event
    - TIM6 global interrupt enabled





  - GPIO External interrupt
    - External Interrupt Mode with Falling edge trigger detection



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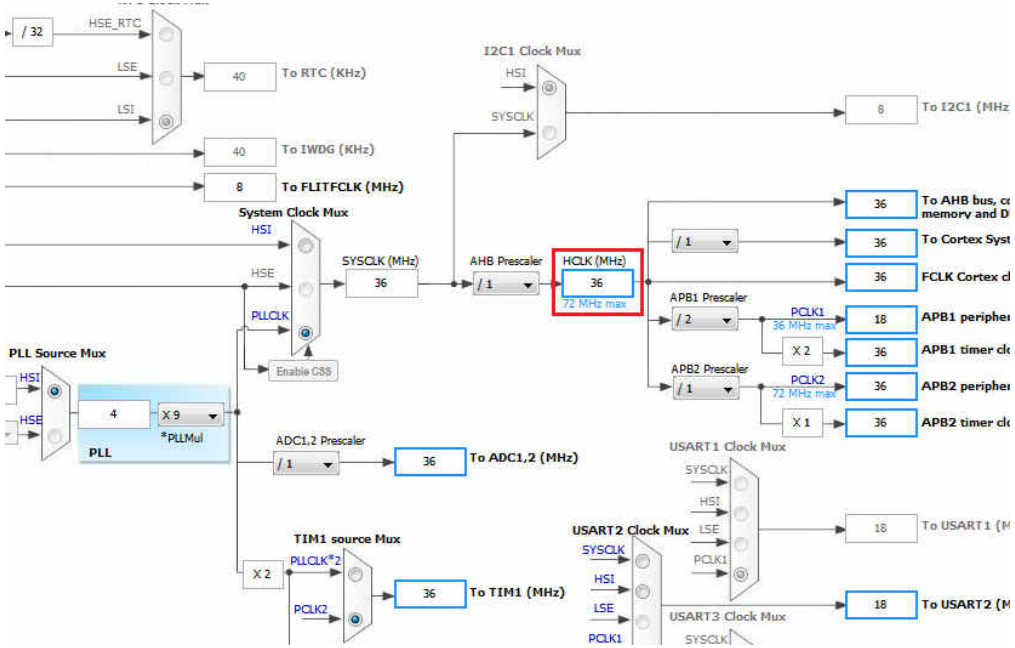
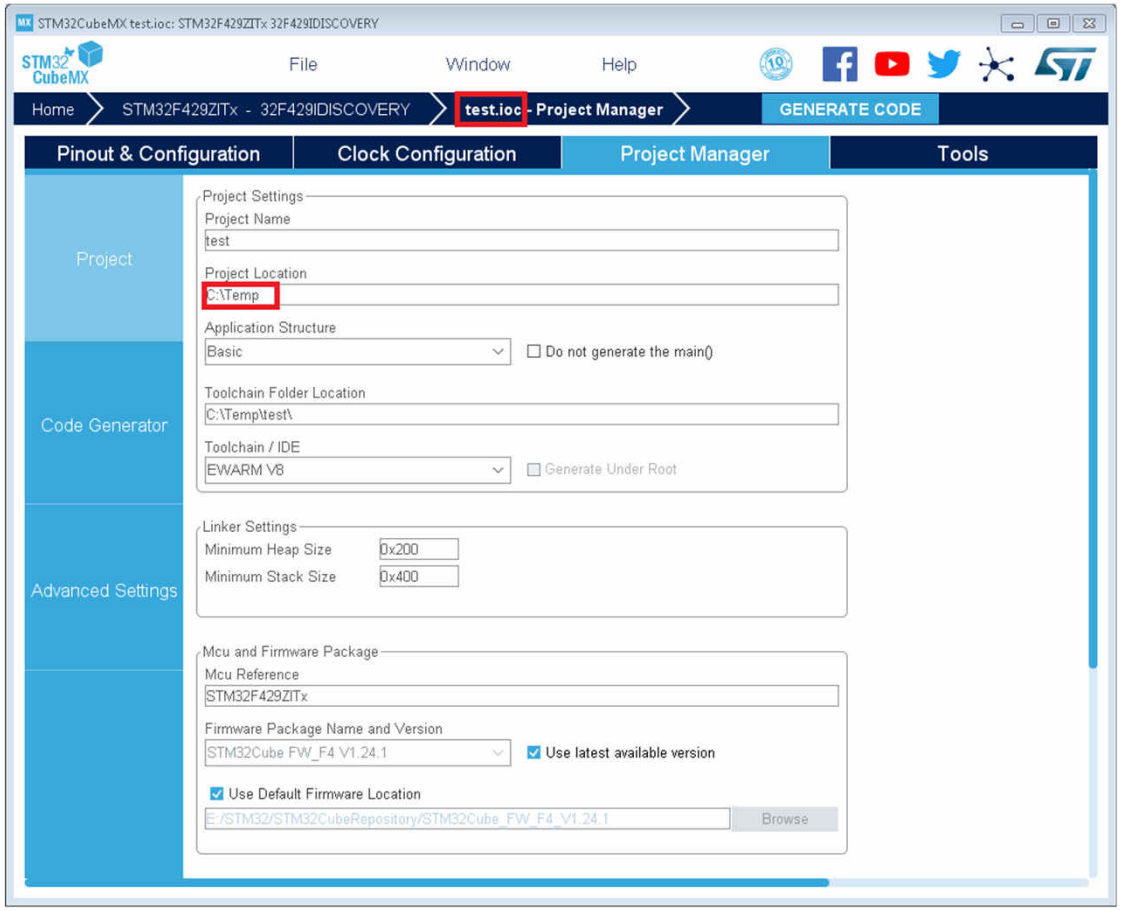
STM32CubeMX Clock Configuration

- Clock Default Configuration:
  - 16 MHz
- Modification not mandatory
  - Can be 36 MHz for example



STM32CubeMX project Settings

- Project Name:
  - «`test`» for this example
- Project Location :
  - `C:\TEMP` for this example
- Save the current project
  - `test.ioc` file is available from `c:\TEMP\test` repository



- You can save **`ioc`** file anywhere.
- It is preferable to save **`ioc`** file in same repository as model that will use it. Repository and **`ioc`** file must have same name.

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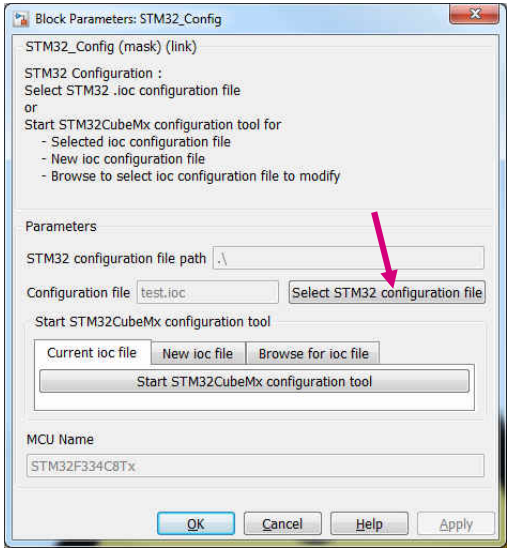
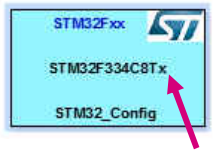
Simulink application IOC file selection

- IOC file selection
  - `.ioc` file has been created and can be selected
  - Open (double click) STM32_Config block parameters window
  - STM32 configuration path is related to model
    - `.\` because `test.ioc` and `test.slx` are in the same repository

Double click



«Select STM32 configuration file »
Browse and select `test.ioc` file



Simulink application for
STM32F334C8Tx MCU

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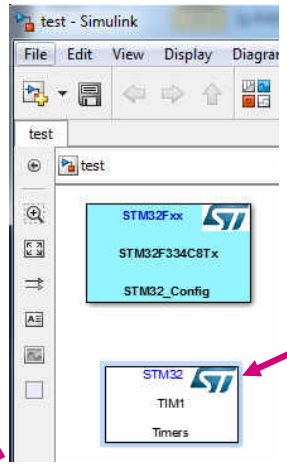
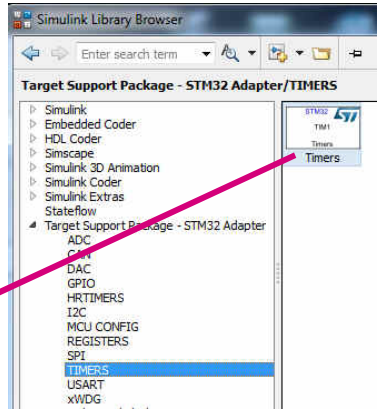
USE TIM1 to Blink LED3 at 1Hz

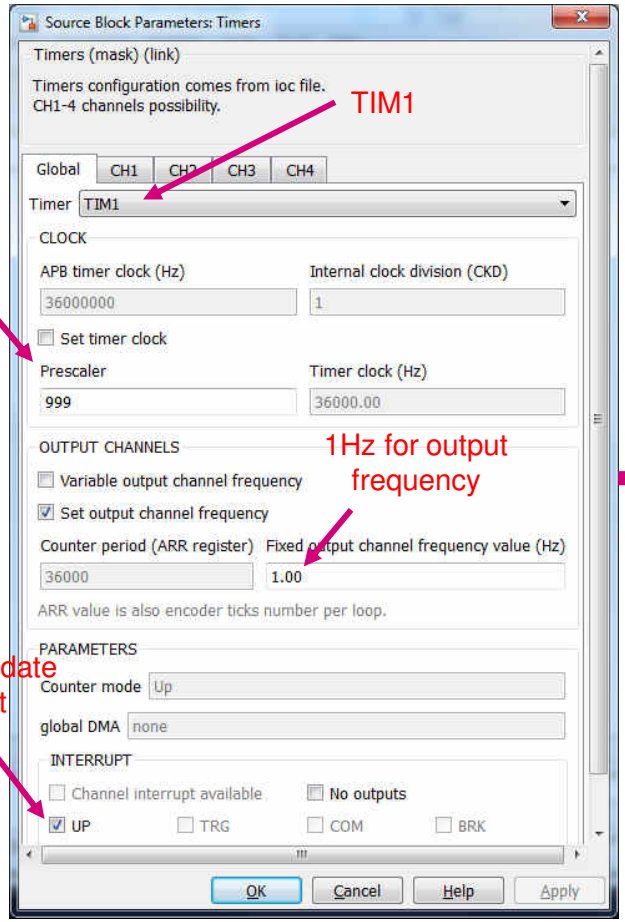
- Software application example:
  - **Use TIM1 to blink LED3 at 1Hz**
  - Use TIM6 to blink LED4 at 2Hz
  - Use TIM6 to trig ADC1 channels 2&3 conversion
  - Blink Led6 when user push button is pressed
  - Send the values of ADC1 channel 3 on USART2 when the user push button is pressed

TIM1 Selection & Configuration

- TIM1 Selection
  - Drag&Drop Timers block from Simulink Library Browser
- TIM1 Configuration
  - Open (double click) Timers block parameters window
  - Select TIM1 and set parameters

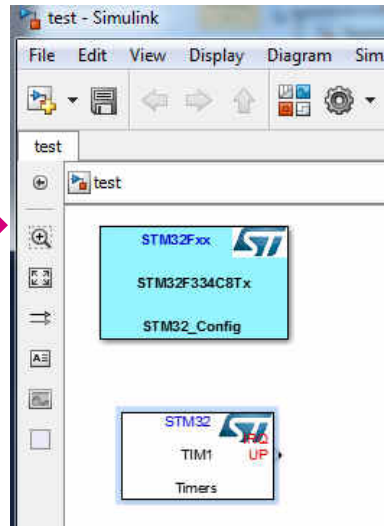






Prescaler or Timer Clock

Validate Update interrupt



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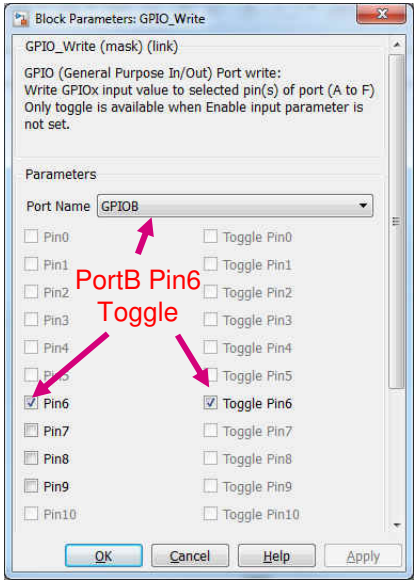
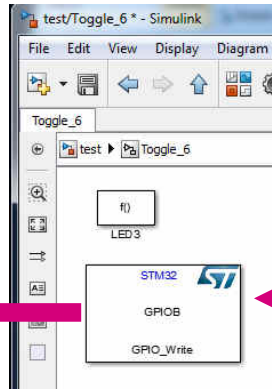
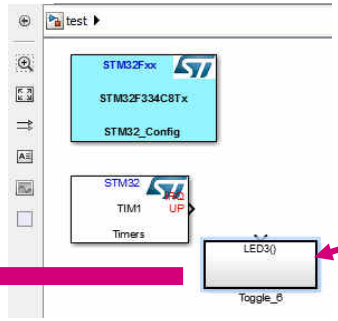
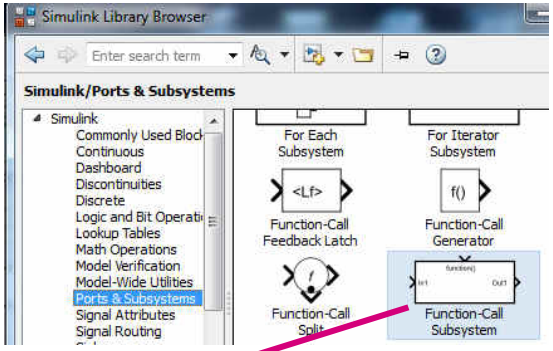
TIM1 Application

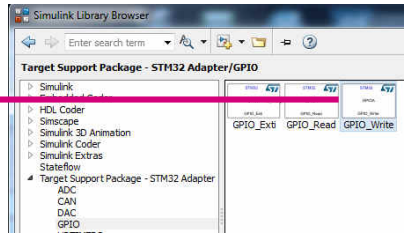
- TIM1 toggle LED3 at 1Hz
  - Drag&Drop Function-Call Subsystem from Simulink Library Browser (Simulink>Ports & Subsystems)
  - Open (double click) Function-Call block and Drag&Drop GPIO_Write block
  - Open (double click) GPIO_Write block parameters window and select Pin6 (LED3 is connected to Pin6)

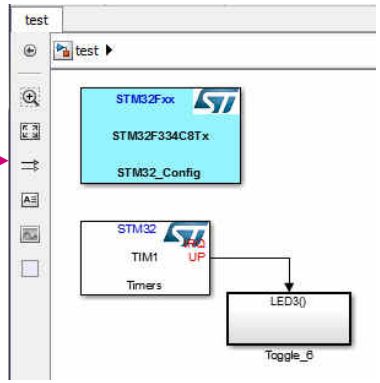












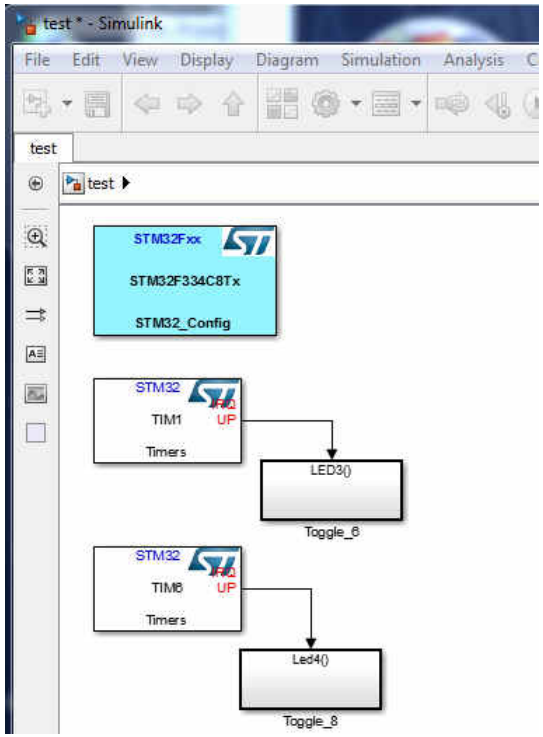
LED3 will blink when TIM1 update interrupt occurs. Every second at 1Hz

USE TIM6 to Blink LED4 at 2Hz

- Software application example:
  - Use TIM1 to blink LED3 at 1Hz
  - **Use TIM6 to blink LED4 at 2Hz**
  - Use TIM6 to trig ADC1 channels 2&3 conversion
  - Blink Led6 when user push button is pressed
  - Send the values of ADC1 channel 3 on USART2 when the user push button is pressed

TIM6 Application

- TIM6 toggle LED4 at 2Hz
  - Make the same thing as for TIM1 but frequency is 2Hz and PortB Pin8 toggle as it is connected to Led4



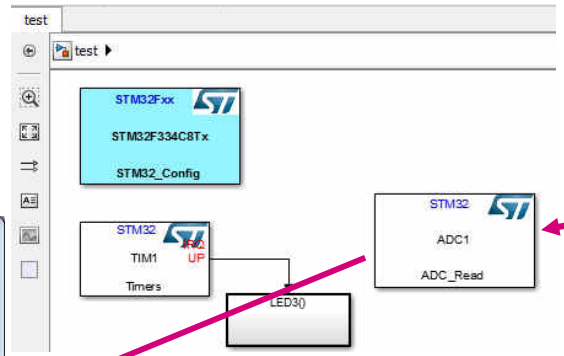
LED4 will blink when TIM6 update interrupt occurs. Every 0.5 second at 2Hz

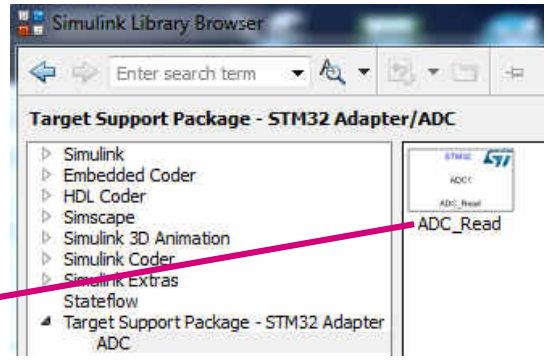
USE TIM6 to trig ADC1 channels 2&3

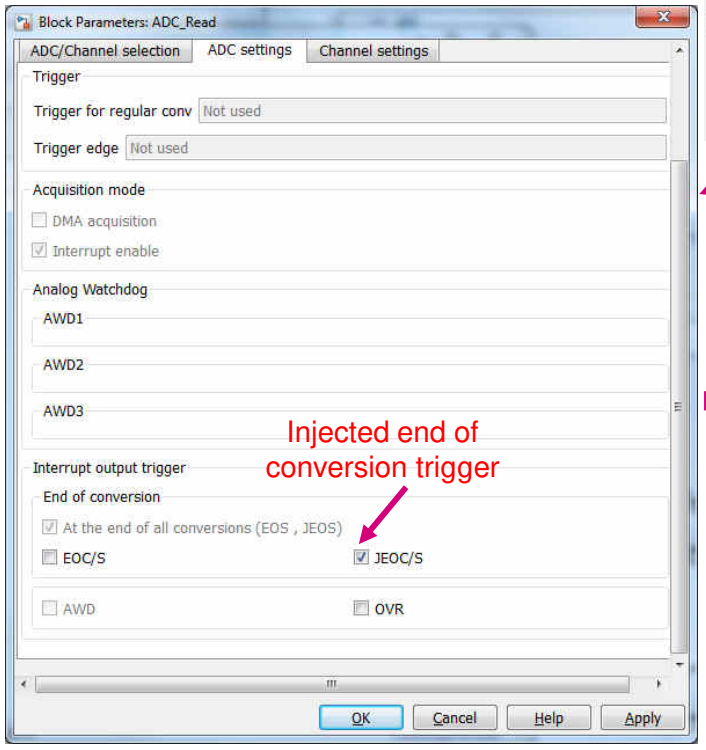
- Software application example:
  - Use TIM1 to blink LED3 at 1Hz
  - Use TIM6 to blink LED4 at 2Hz
  - **Use TIM6 to trig ADC1 channels 2&3 conversion**
  - Blink Led6 when user push button is pressed
  - Send the values of ADC1 channel 3 on USART2 when the user push button is pressed

ADC1 Selection & Configuration

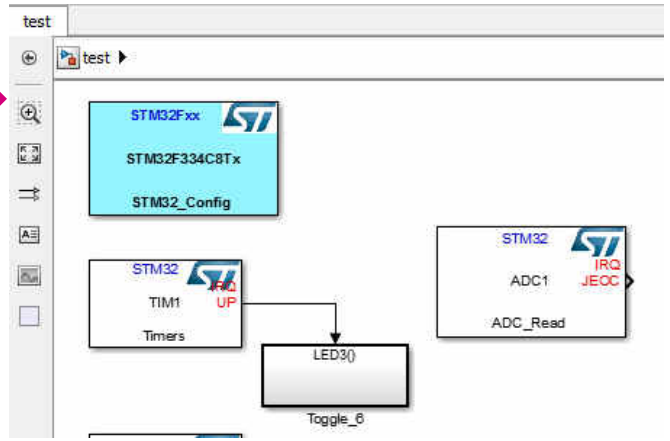
- ADC1 Selection
  - Drag&Drop ADC_Read block from Simulink Library Browser
- ADC1 Configuration
  - We don't need ADC values
  - Select JEOC/S as interrupt output trigger







Injected end of conversion trigger



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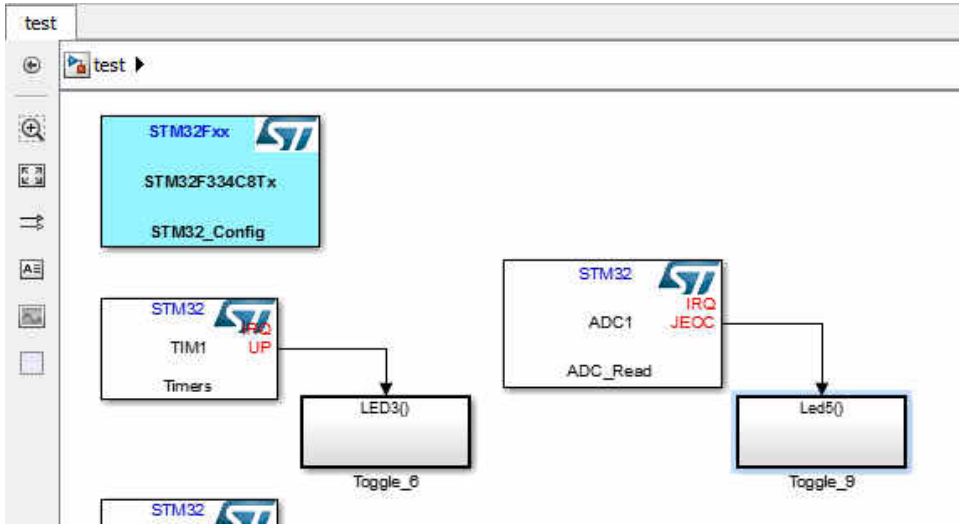
ADC1 Application

- TIM6 trig ADC1 channels conversion
  - Blink LED5 at end of ADC1 conversion to verify that TIM6 has triggered it.
  - Drag&Drop Function-Call Subsystem from Simulink Library Browser (Simulink>Ports & Subsystems) and add GPIO_Write block in.
  - Set GPIO_Write block parameters window to toggle Pin9 (LED5 is connected to Pin9)



LED5 will blink when ADC1 injected channels 2&3 has been converted.

Start of Conversion is triggered from TIM6

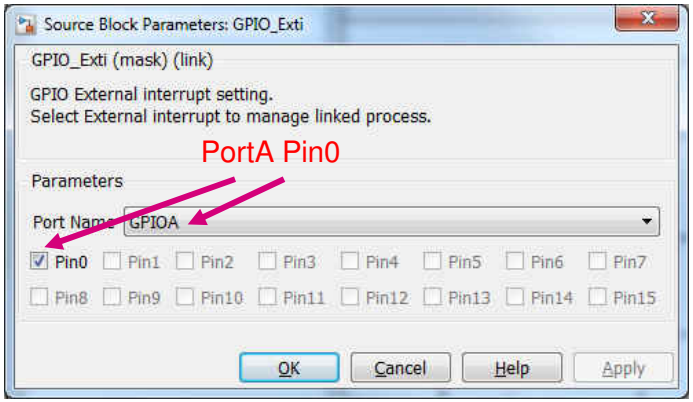
Channels 2&3 values are available at the end of conversion

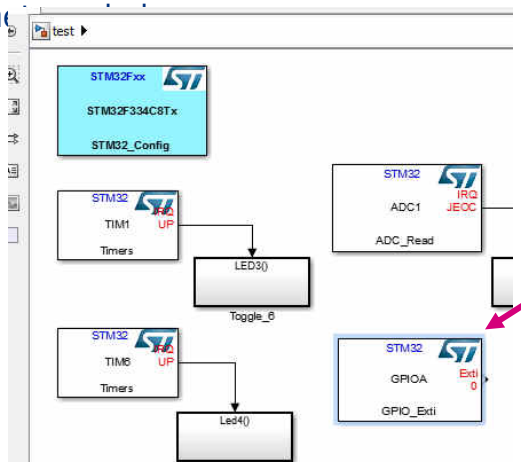
Push Button functions

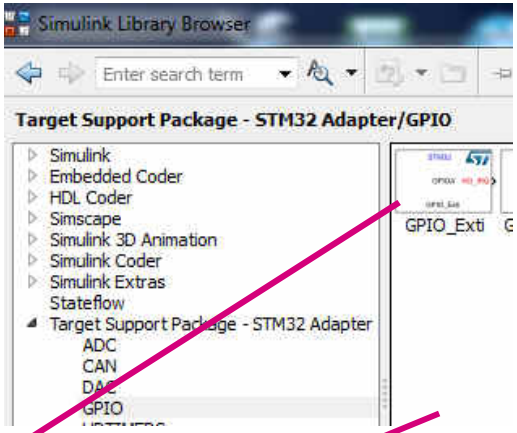
- Software application example:
  - Use TIM1 to blink LED3 at 1Hz
  - Use TIM6 to blink LED4 at 2Hz
  - Use TIM6 to trig ADC1 channels 2&3 conversion
  - **Blink Led6 when user push button is pressed**
  - **Send the values of ADC1 channel 3 on USART2 when the user push button is pressed**

EXTI0 Selection & Configuration

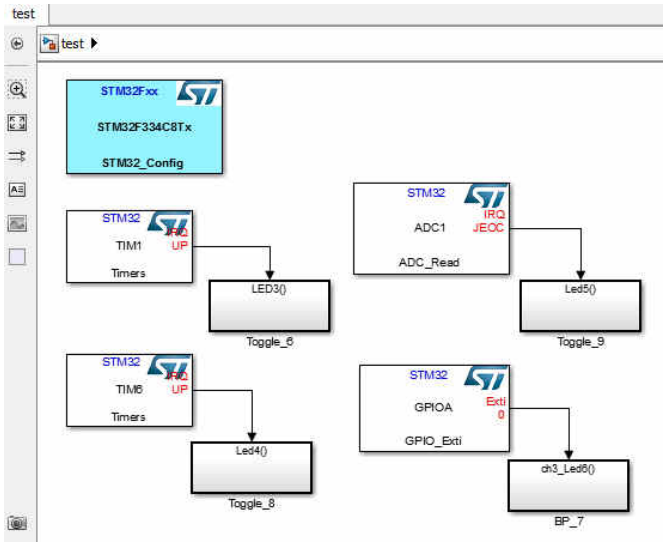
- EXTI0 Selection
  - Push Button is connected to External Interrupt 0 on PA0
  - Drag & Drop GPIO_Exti block from Simulink Library Browser
  - Open (double click) GPIO_Exti block parame[illegible] and select GPIOA pin0







- Drag&Drop Function-Call Subsystem from Simulink Library Browser (Simulink>Ports & Subsystems) and connect it to Exti0 output



Every models in Function-Call connected to GPIO_Exti output will be executed for every action on push button.

We want to blink LED6 and send ADC1 ch3 value on USART2

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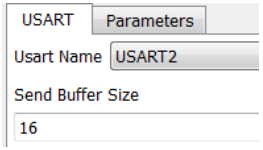
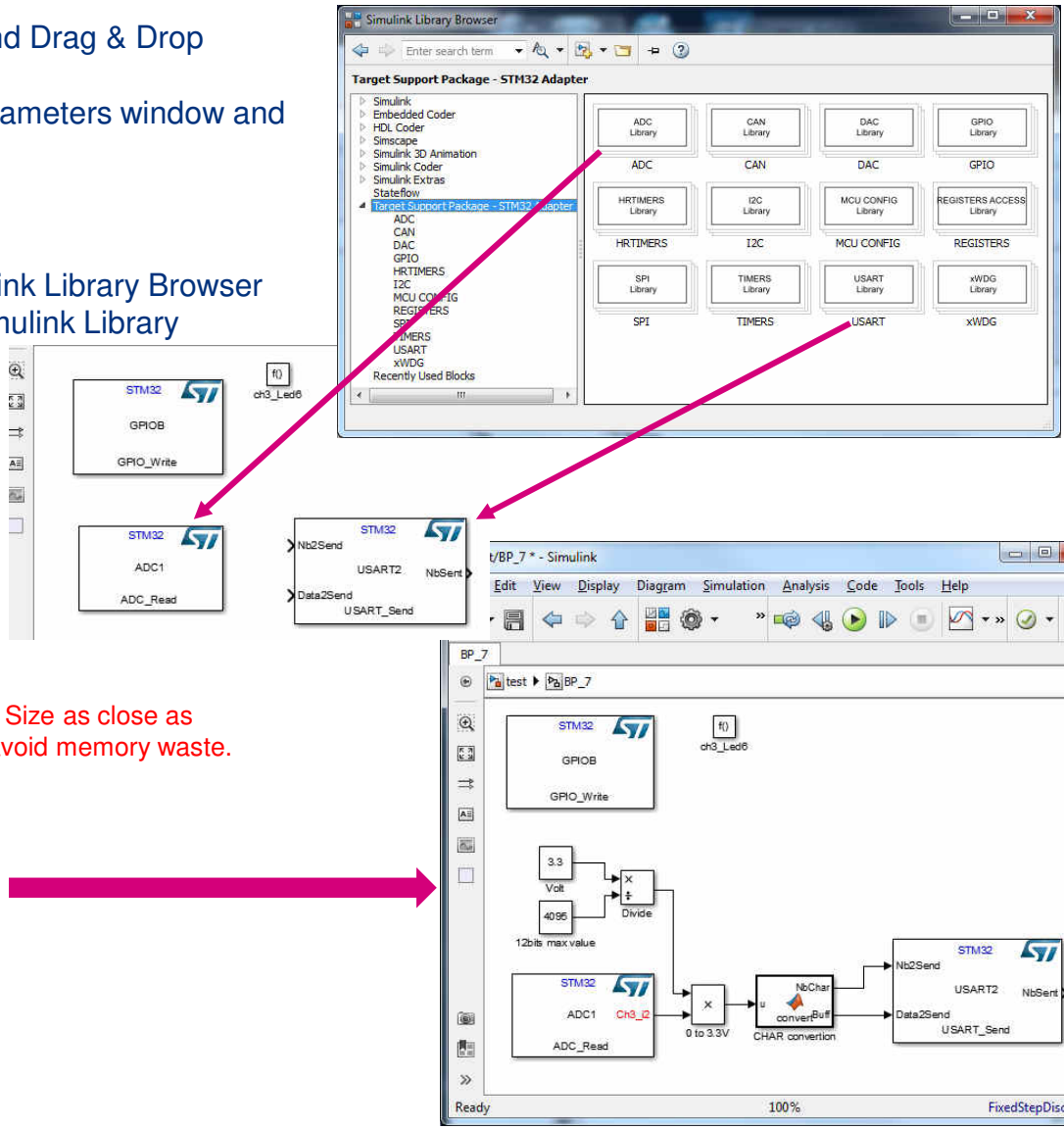
Push Button Action 1/2

- Blink LED6
  - Open (double click) Function-Call block and Drag & Drop GPIO_Write block
  - Open (double click) GPIO_Write block parameters window and select Pin7 (LED6 is connected to Pin7)
- Send ADC1 Ch3 value on USART2
  - Drag & Drop ADC_Read block from Simulink Library Browser
  - Drag & Drop USART_Send block from Simulink Library Browser
- ADC1 Settings
  - Open (double click) ADC_Read block parameters window and select ADC1 Ch3
- USART2 Settings
  - Open (double click) USART2_Send block parameters window and set buffer size.



It is mandatory to set Buffer Size as close as messages sent in order to avoid memory waste.

- Add signal processing.
- MATLAB® code can be added in « MATLAB Function » from Simulink Library Browser>User-Defined Functions>MATLAB Function



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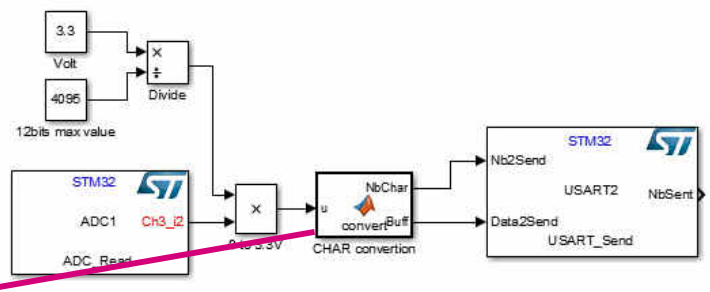
Push Button Action 2/2

- MATLAB Function
  - Add MATLAB® code to convert ADC1 Ch3 value to Buffer of characters
  - MATLAB® function is converted to C code and integrated to generated project during « build » process.



Function convert : 1 input and 2 outputs

BP_7/CHAR convertion

```
1   function [NbChar, Buff] = convert(u)
2   if coder.target('Sfun')
3       % Executing in MATLAB, Buff is null
4       Buff = uint32(0);
5       NbChar = uint16(0);
6   else
7       % Executing in the generated code.
8       buffer = zeros(1,15,'uint8');
9       coder.ceval('sprintf',coder.wref(buffer),['%2.2f',0],u);
10      tmp = uint8('Volt');
11      y = [buffer(1:4), tmp, 13, 10, 0];
12      Buff = coder.ceval('getBuffPtr',coder.ref(y));
13      NbChar = uint16(size(y,2));
14  end
15  end
```

Nothing to do for Simulation

« xx.x Volt » Buffer to send through USART2

«`getBuffPtr`» is a C function provided with STM32-MAT/TARGET that converts MATLAB® array to C pointer.

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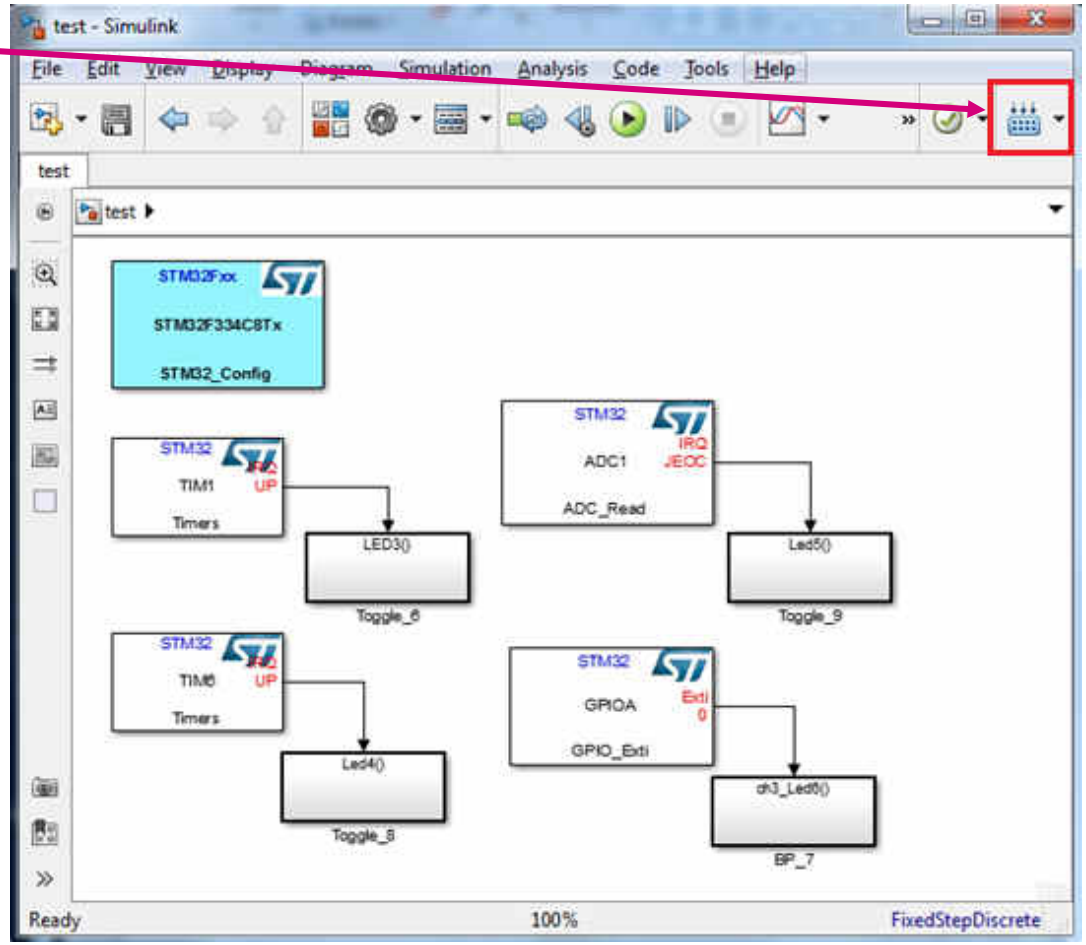
Build Application

- Generate code for the Simulink application
  - Press «Build Model» to automatically generate C code and IDE project.

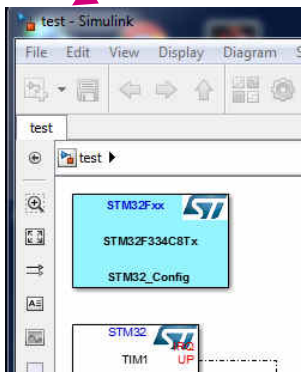


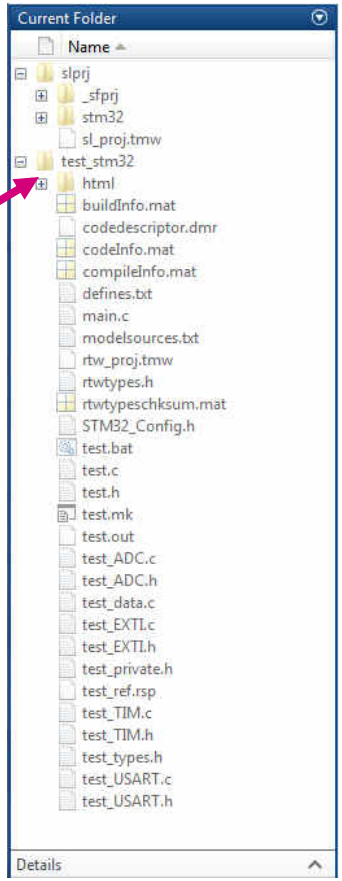
MATLAB® Code Generation 1/2

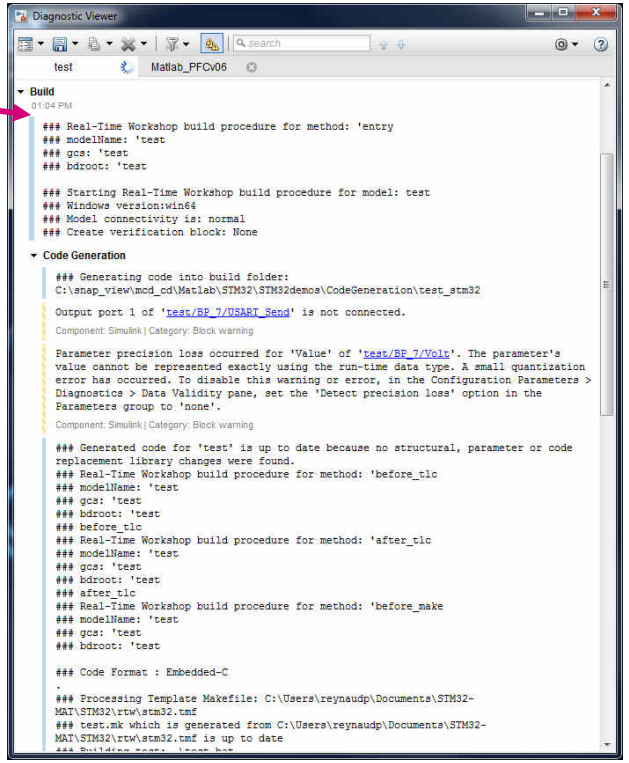
- Diagnostic Viewer
  - Diagnostic Viewer window appears when you click on «View diagnostics» at the bottom of built model. It gives «Code Generation» information about Simulink build process.

- Generated Code
  - MATLAB® generates C code corresponding to Simulink model in selected Current Folder

  - STM32 code is generated in repository which name is created using name of Simulink model with « `_stm32`»







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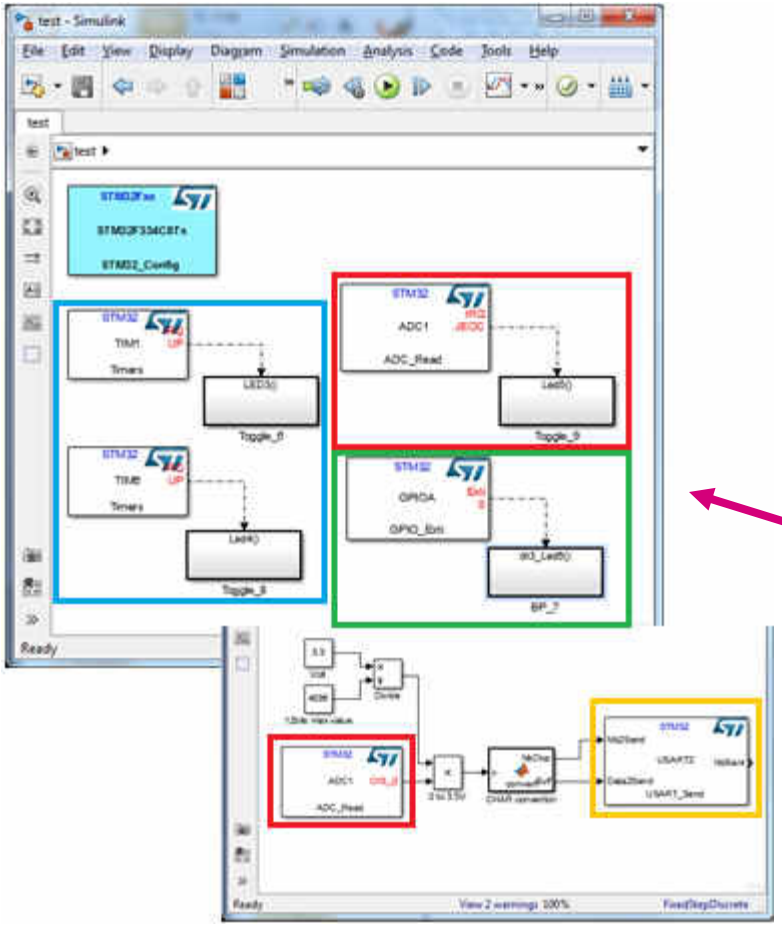
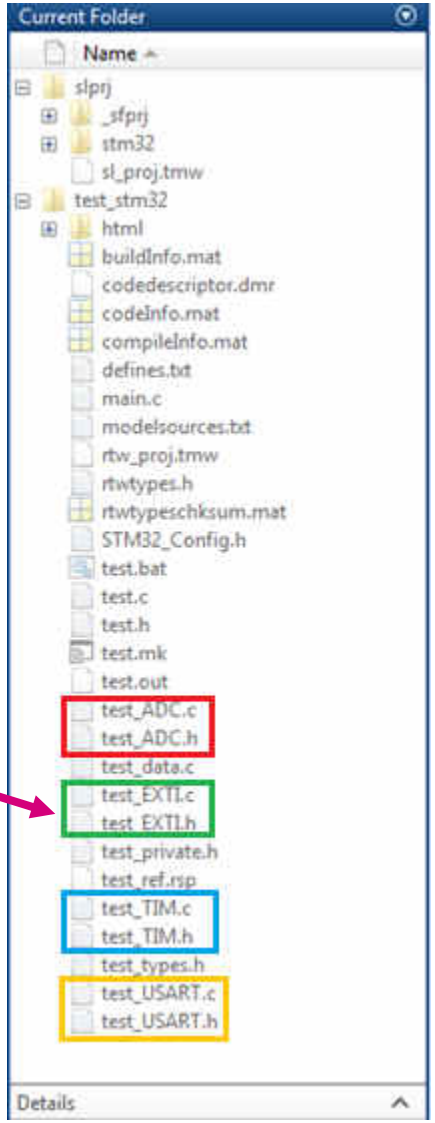
MATLAB® Code Generation 2/2

- STM32 peripherals driver code is generated in `.c/.h` files which name is created using name of Simulink model and peripheral name.





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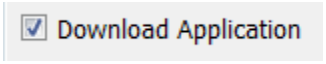
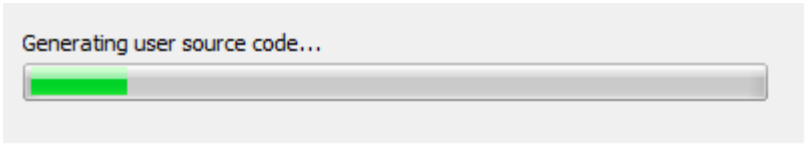
STM32CubeMX Code Generation 1/2

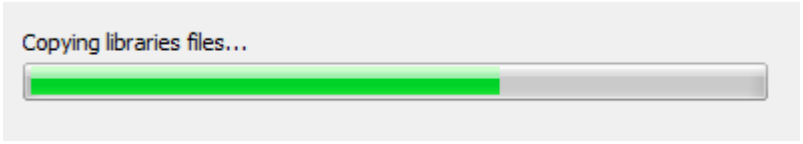
- STM32CubeMX process
  - STM32CubeMX is automatically called from MATLAB® when «Download Application» has been selected from the Model Configuration window.



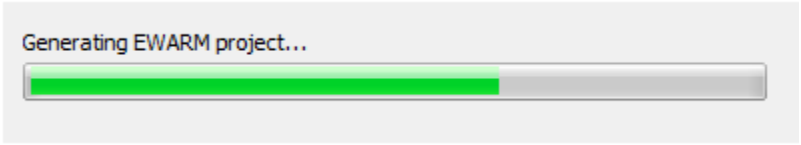
  - STM32CubeMX generates configuration code.



  - STM32CubeMX adds necessary library files. .c/.h library files from HAL STM32 libraries.

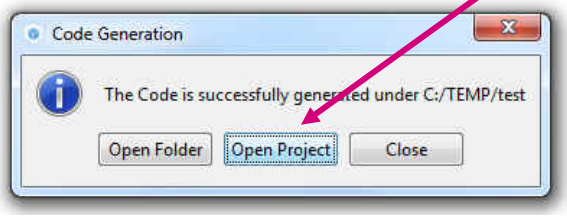


  - STM32CubeMX generates toolchain project including files generated from MATLAB®



  - The project generated by STM32CubeMX can be opened

Click « Open Project » to automatically open project using selected toolchain.



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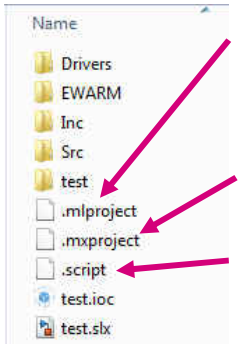
STM32CubeMX Code Generation 2/2

- STM32CubeMX project generation
  - Project is generated in same repository as ioc file. (Example with Simulink « test » project)

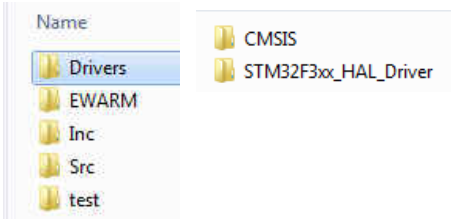


`.mlproject` : Generated from MATLAB®. Contains information about .c/.h files to add to project from MATLAB®

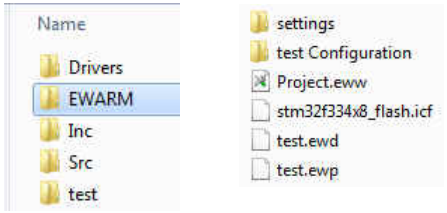
`.mxproject` : Generated from STM32CubeMX. Contains information about .c/.h files generated from STM32CubeMX

`.script` : Generated from MATLAB®. Contains STM32CubeMX command to generate project.

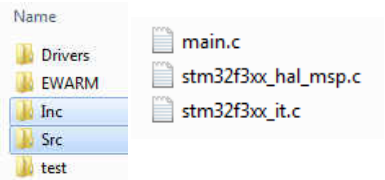
- STM32CubeMX project contains
  - Drivers : Contains STM32 selected library and CMSI files



  - EWARM: Contains toolchain project files (IAR for example)

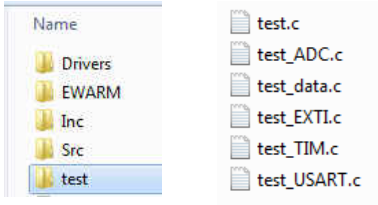


- `Inc` & `Src`: Contains STM32CubeMX generated or modified files.



`main.c` : Generated from MATLAB®. It has been modified by STM32CubeMX to add project configuration.
`_hal_msp.c`: Peripherals configuration
`_it.c` : Interrupt handlers for configured interrupt only.

- test (Simulink project name): Contains all .c/h files generated from MATLAB®



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It is required to know toolchain functionalities.

Toolchain Project

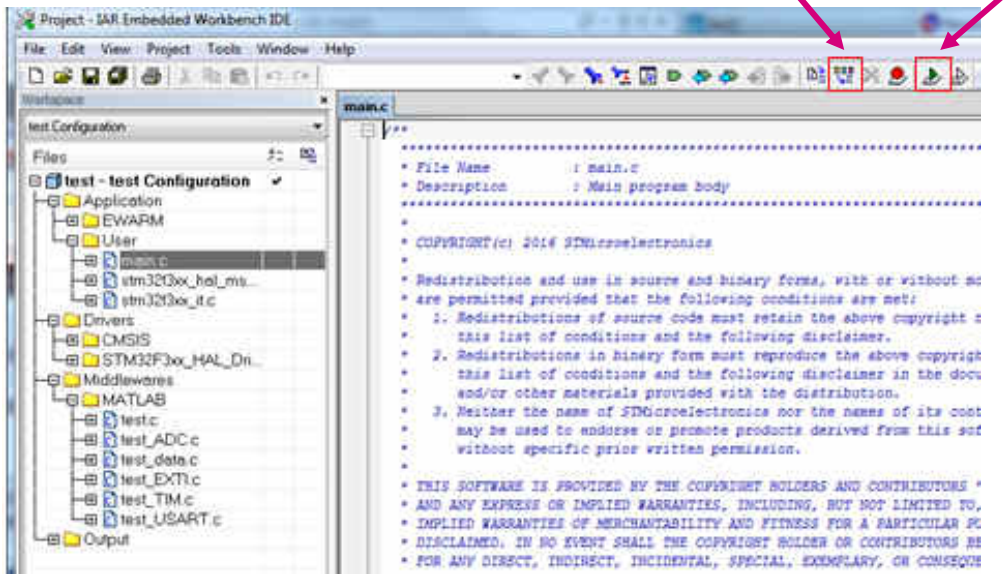
- Toolchain settings
  - STM32CubeMX has automatically generated project including mandatory settings. It is exactly same project at it should be generated « by hand ». Possibility to tune all settings.

Example using EWARM (IAR) toolchain for Simulink test project

- Toolchain Actions
  - Build project
  - Download and Debug project

BUILD project

Download & Debug project



STM32 board must be connected to PC when you click «Download & Debug»

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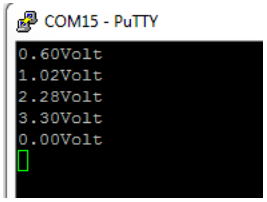
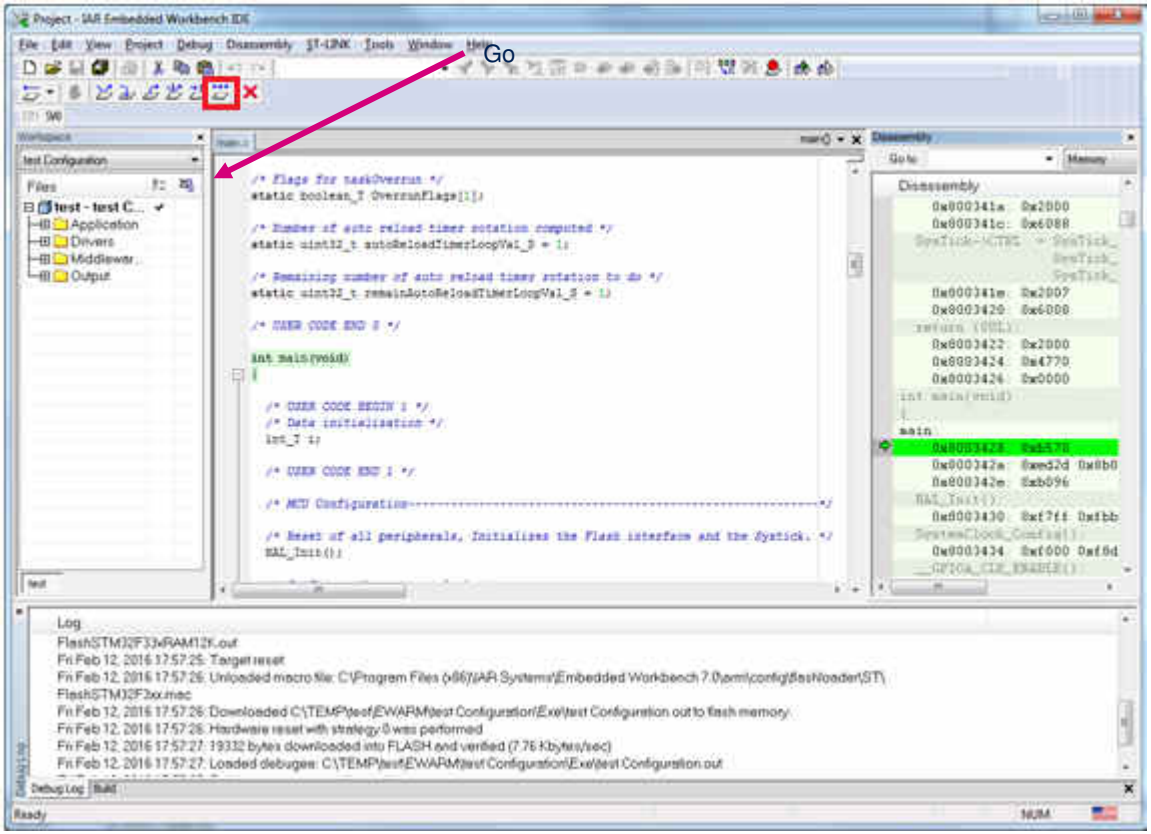
It is required to know toolchain functionalities.

Run Project

- Simulink «test» example results
  - Project is started and waits at 1st main instruction.
  - Click «Go»
  - LD3/LD4/LD5 are blinking
  - LD6 is alternatively ON and OFF when you press User button. ADC value set on PA2 (ADC1 Ch3) is sent to PC through USART.
    You can see ADC value on PC using PuTTY for example.



Example using EWARM (IAR) toolchain for Simulink test project



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External Mode

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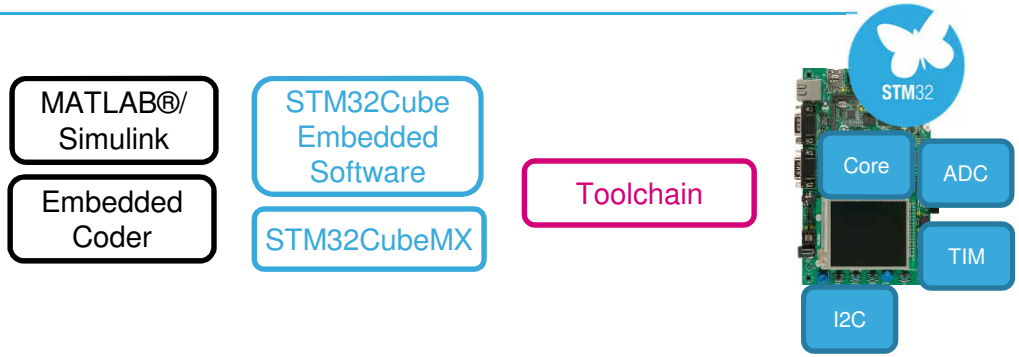
Tools usage

- Step 1: Pure simulation
  - Everything done on the PC

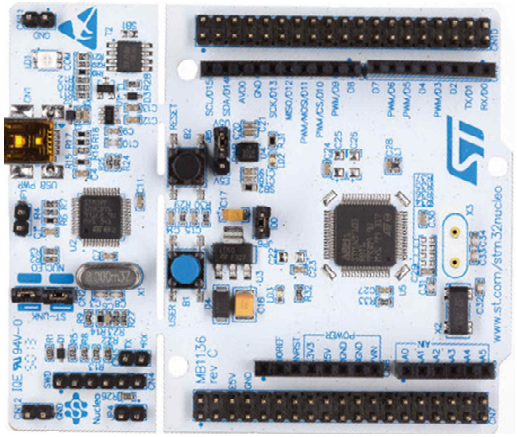
- Step 2: Processor-in-the-loop (PIL)
  - Algorithm fully executed on STM32
  - Data (Input or output) exchanged between MATLAB®/Simulink and STM32 via UART

- External Mode
  - Data (input or output) obtained within STM32 through its peripherals (ADC, Timers, …) and algorithm fully executed on STM32.
  - Data monitoring from Simulink via UART
  - Not possible to modify STM32 configuration during External Mode.



External mode example

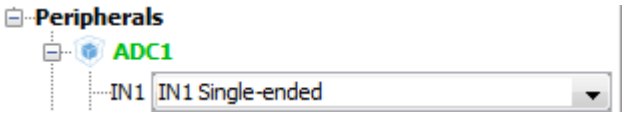
- Hardware :
  - Example based on NUCLEO-F302R8
  - Configuration :
    - ADC1 : IN1

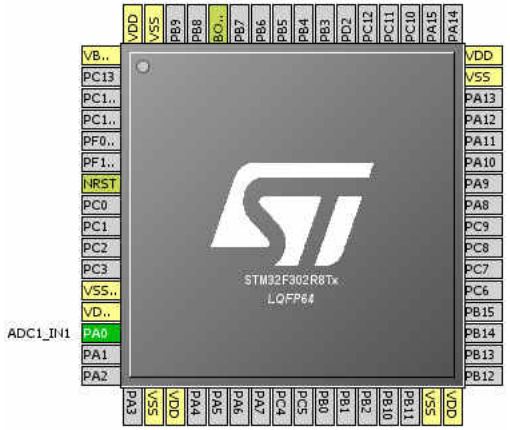


- Software application :
  - Read ADC1 IN1 value from Simulink

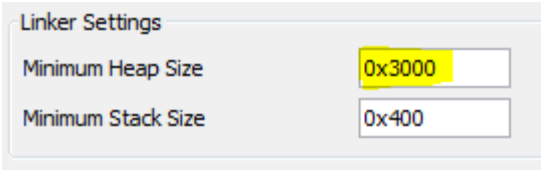
STM32CubeMX STM32F302R8 configuration

- Open STM32CubeMX tool and select STM302R8Tx
- Hardware setting
  - PA0: ADC1 IN1 Single-ended





- Project configuration
  - Heap Size : 0x3000



Because of communication flow between Simulink and the STM32 device , the Heap Size must be higher as possible.

- Clock configuration
  - Set to Max : 64MHz if HSI used

- Save project

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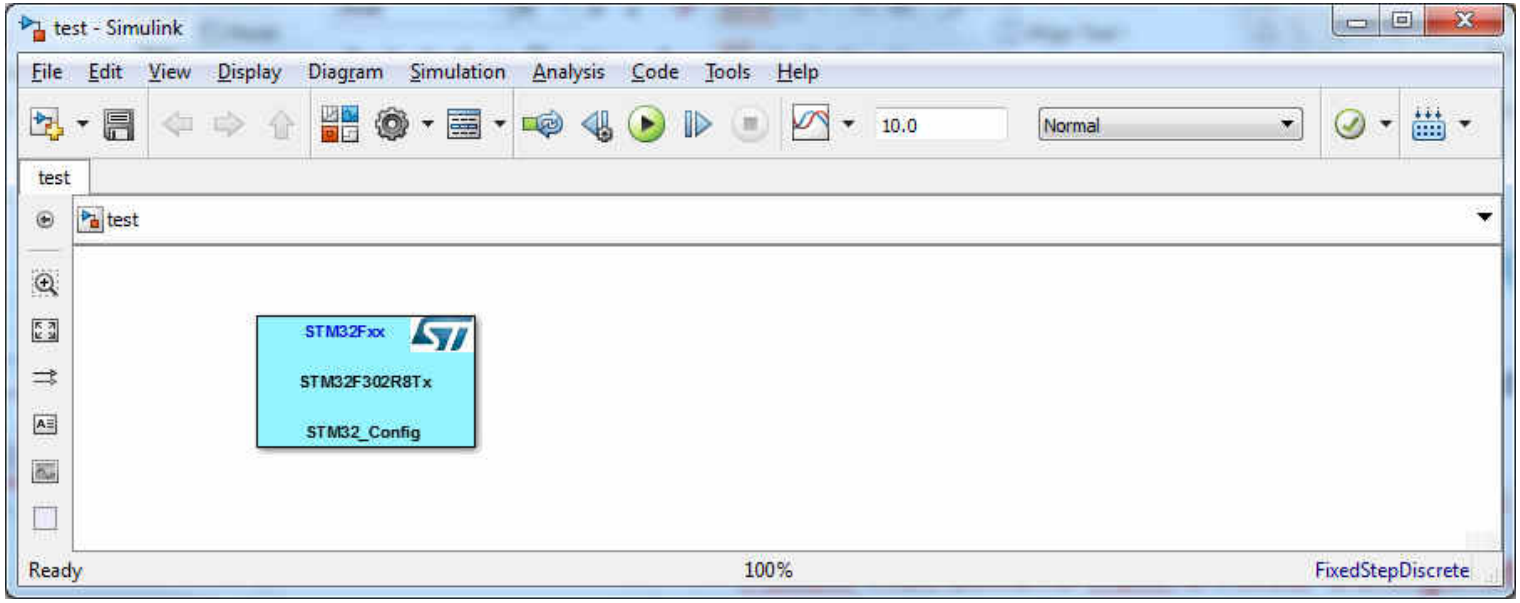
Simulink External Mode

- Look at Simulink model Setting 1/4 to 4/4 to open and configure new model.
- Save Simulink model and open Library Browser
  - For example: Save model as `test.slx` into `C:\TEMP\test` repository
- Follow instructions from STM32 Configuration 1/3 to 3/3 in order to select IOC configuration file you saved for STM302R8.



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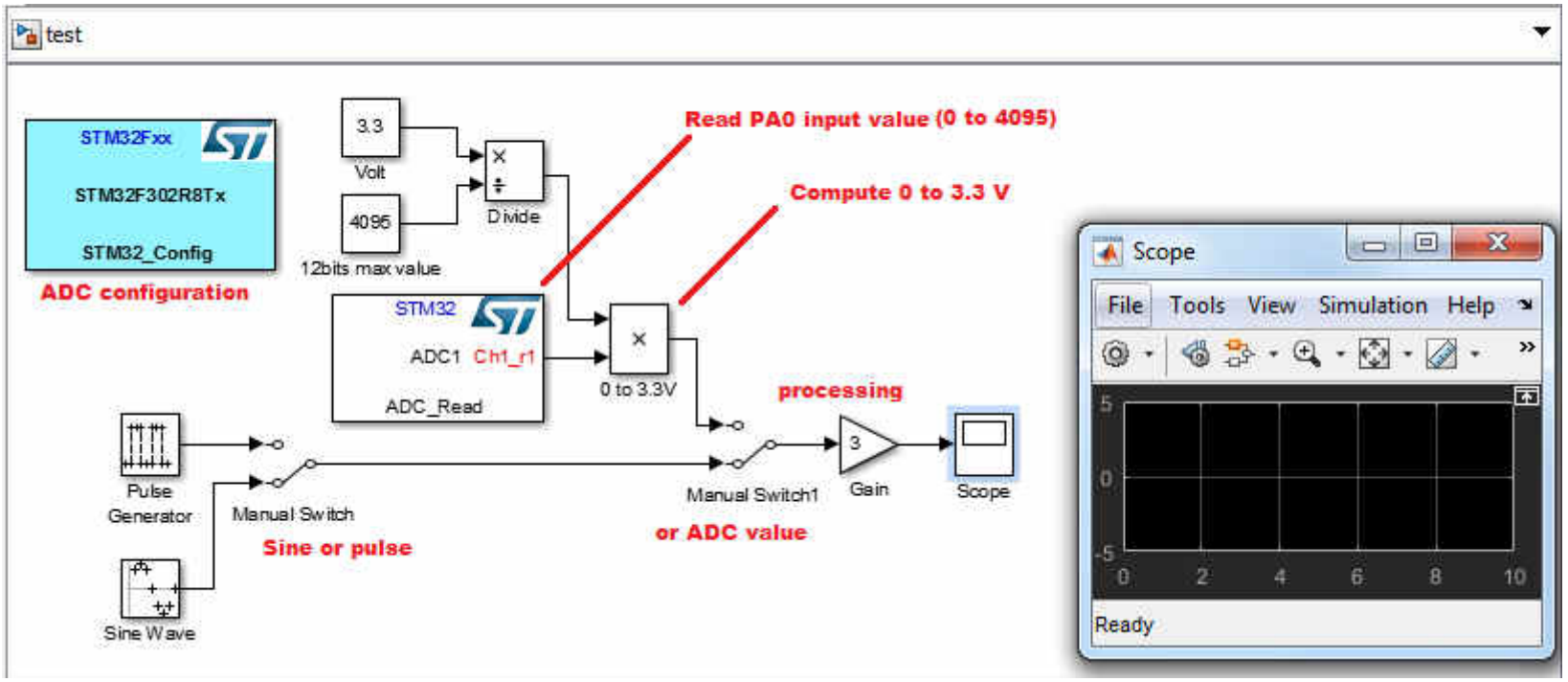
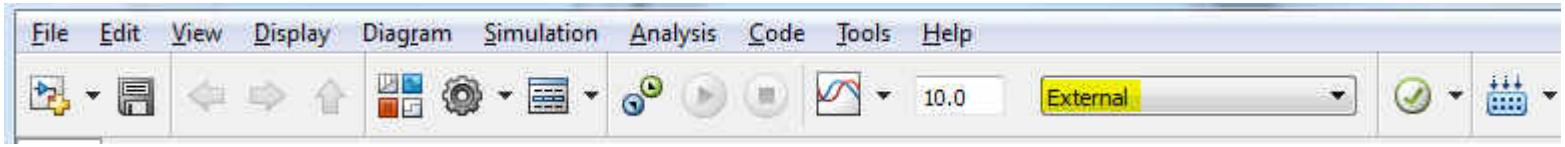
Simulink External Mode

- PULSE or SIN or ADC value
  - Select source to scope on Simulink.
  - It can be Sine Wave or square pulses depending on Switch position or STM32 ADC1 PA0 input value depending on Switch1 position.

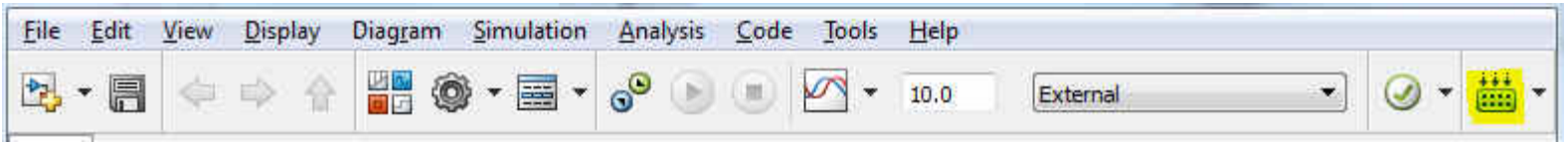


Simulink External Mode

- Select External to enable the External Mode

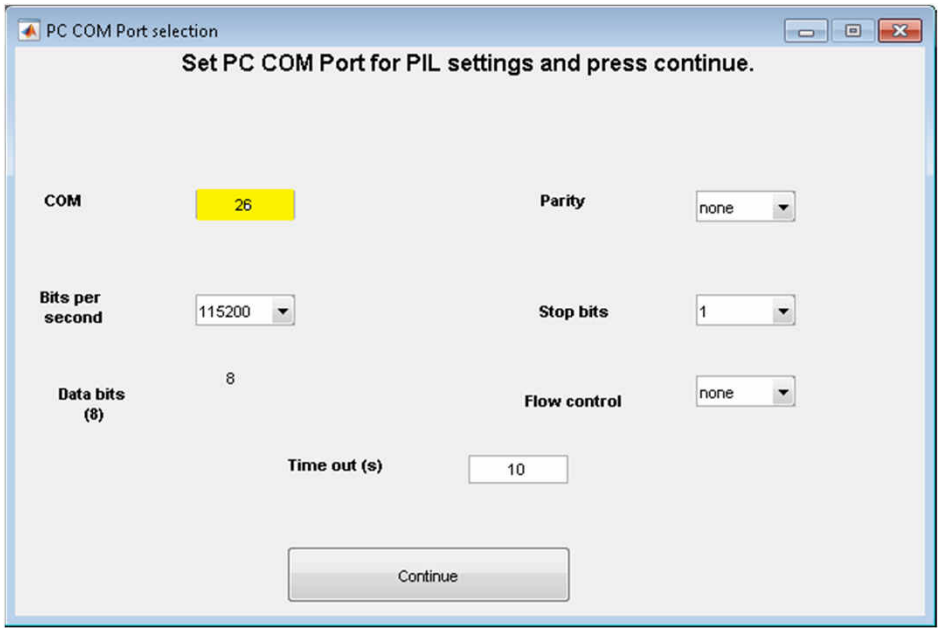


- Generate code for created application
  - Press «Build Model» to automatically generate the C code and the IDE project.



Simulink External Mode

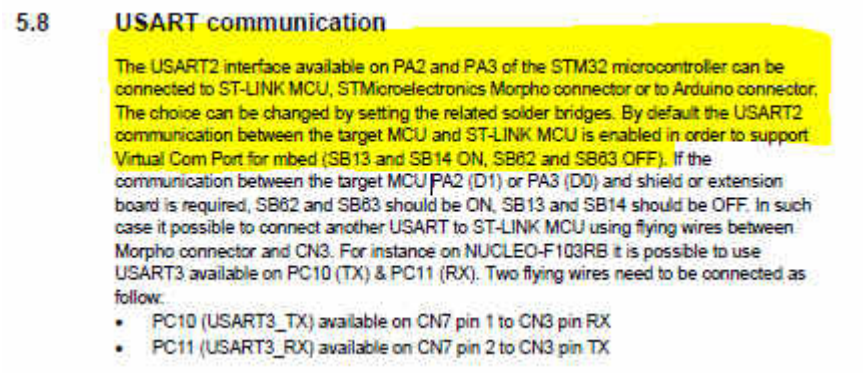
- PC COM Port selection
  - COM port number is given from Device manager



UART speed Baud Rate only is configurable.

Simulink External Mode

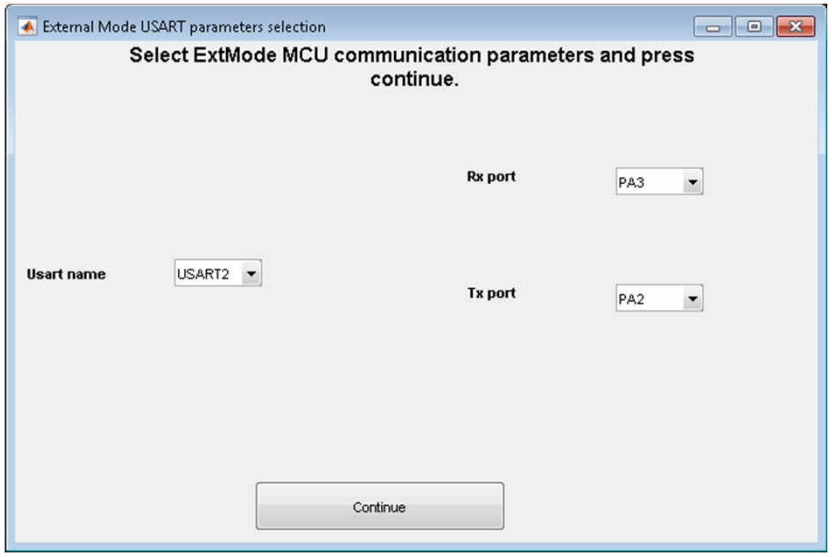
- STM32 UART selection
  - Selected UART depends on Virtual Com Port (VCP) configuration.
  - Look at User manual of used board
  - NUCLEO-F302R8 example:



5.8 **USART communication**

The USART2 interface available on PA2 and PA3 of the STM32 microcontroller can be connected to ST-LINK MCU, STMicroelectronics Morpho connector or to Arduino connector. The choice can be changed by setting the related solder bridges. By default the USART2 communication between the target MCU and ST-LINK MCU is enabled in order to support Virtual Com Port for mbed (SB13 and SB14 ON, SB62 and SB63 OFF). If the communication between the target MCU PA2 (D1) or PA3 (D0) and shield or extension board is required, SB62 and SB63 should be ON, SB13 and SB14 should be OFF. In such case it possible to connect another USART to ST-LINK MCU using flying wires between Morpho connector and CN3. For instance on NUCLEO-F103RB it is possible to use USART3 available on PC10 (TX) & PC11 (RX). Two flying wires need to be connected as follow:

- PC10 (USART3_TX) available on CN7 pin 1 to CN3 pin RX
- PC11 (USART3_RX) available on CN7 pin 2 to CN3 pin TX



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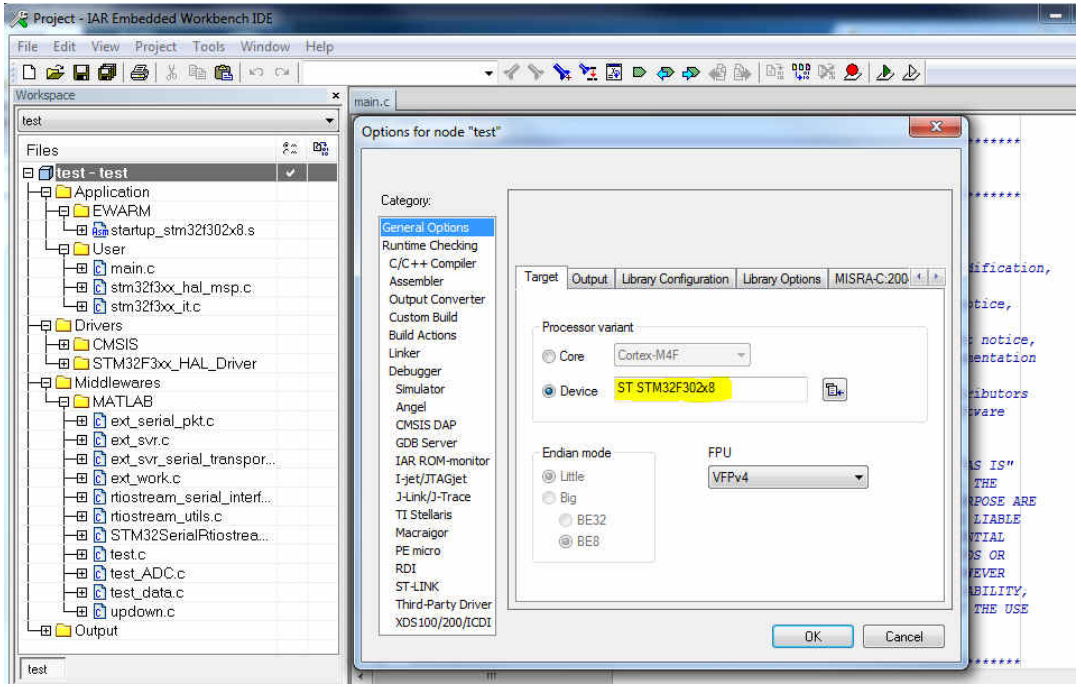
Simulink External Mode

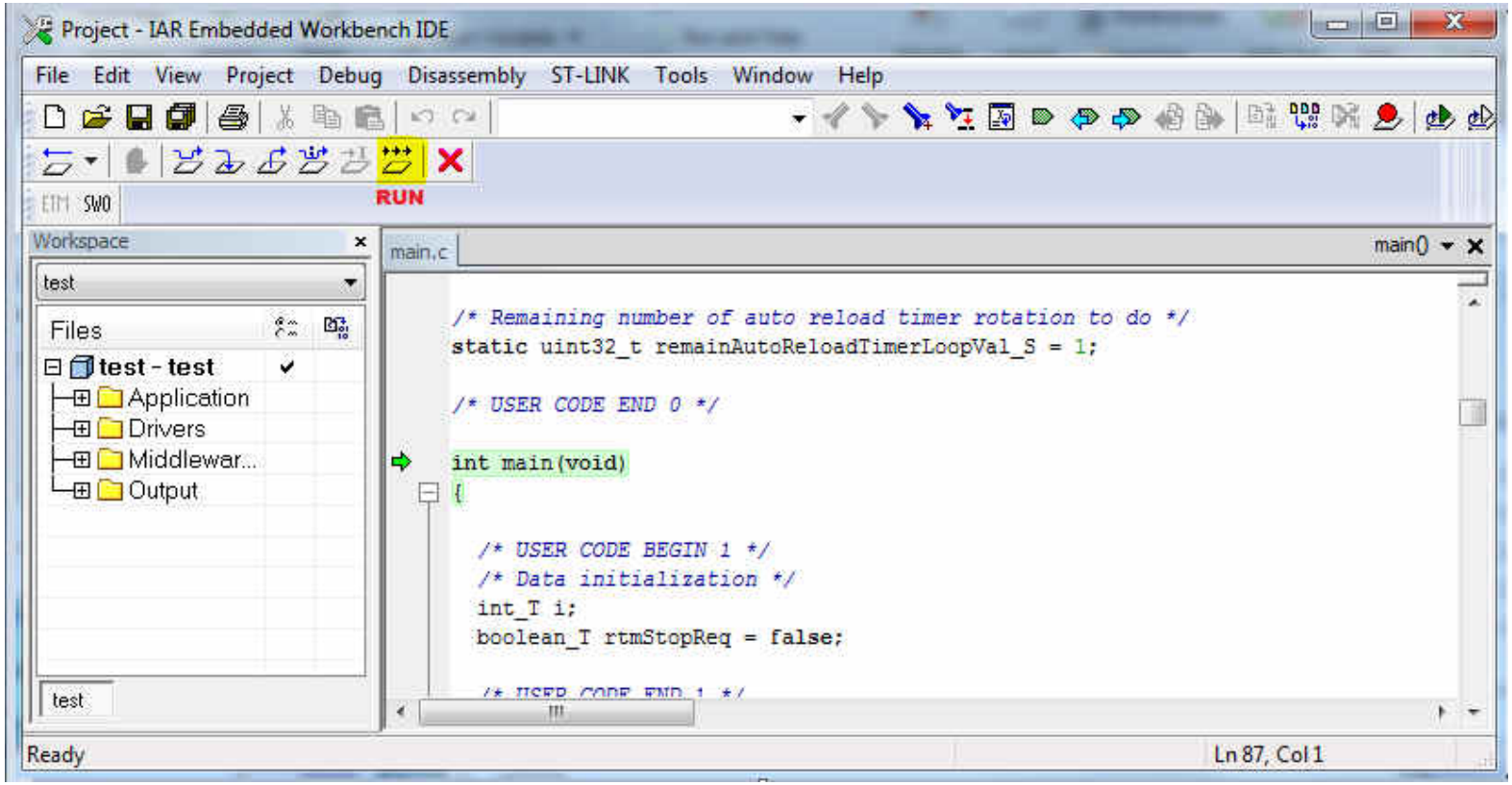
- Project Generation
  - STM32CubeMX generates project as for Build Project Process.

  - Click Open Project and verify Project Setting



Simulink External Mode

- Build, Download and Run project
  - STM32 target must run project before connection with Simulink is done.



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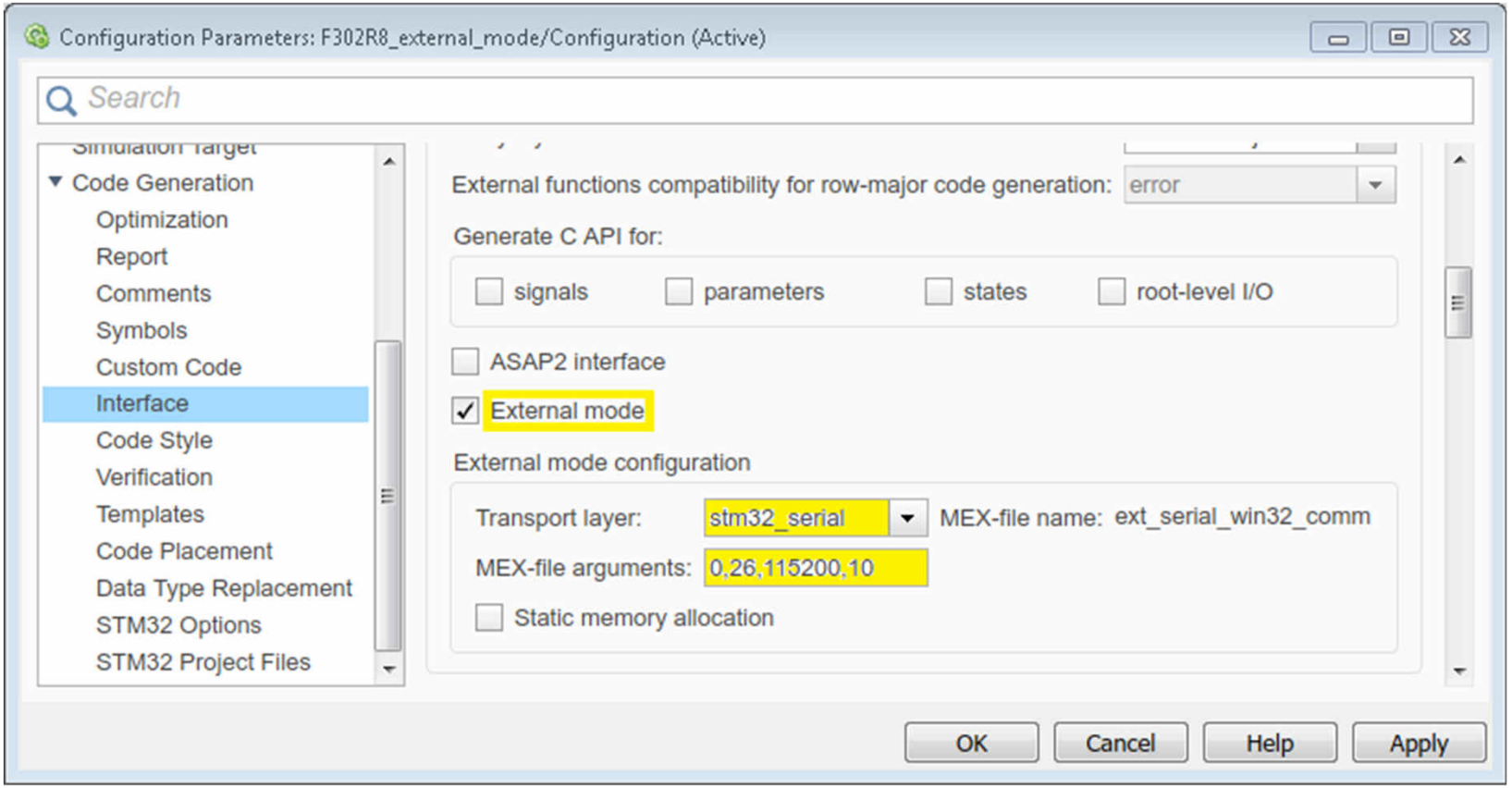
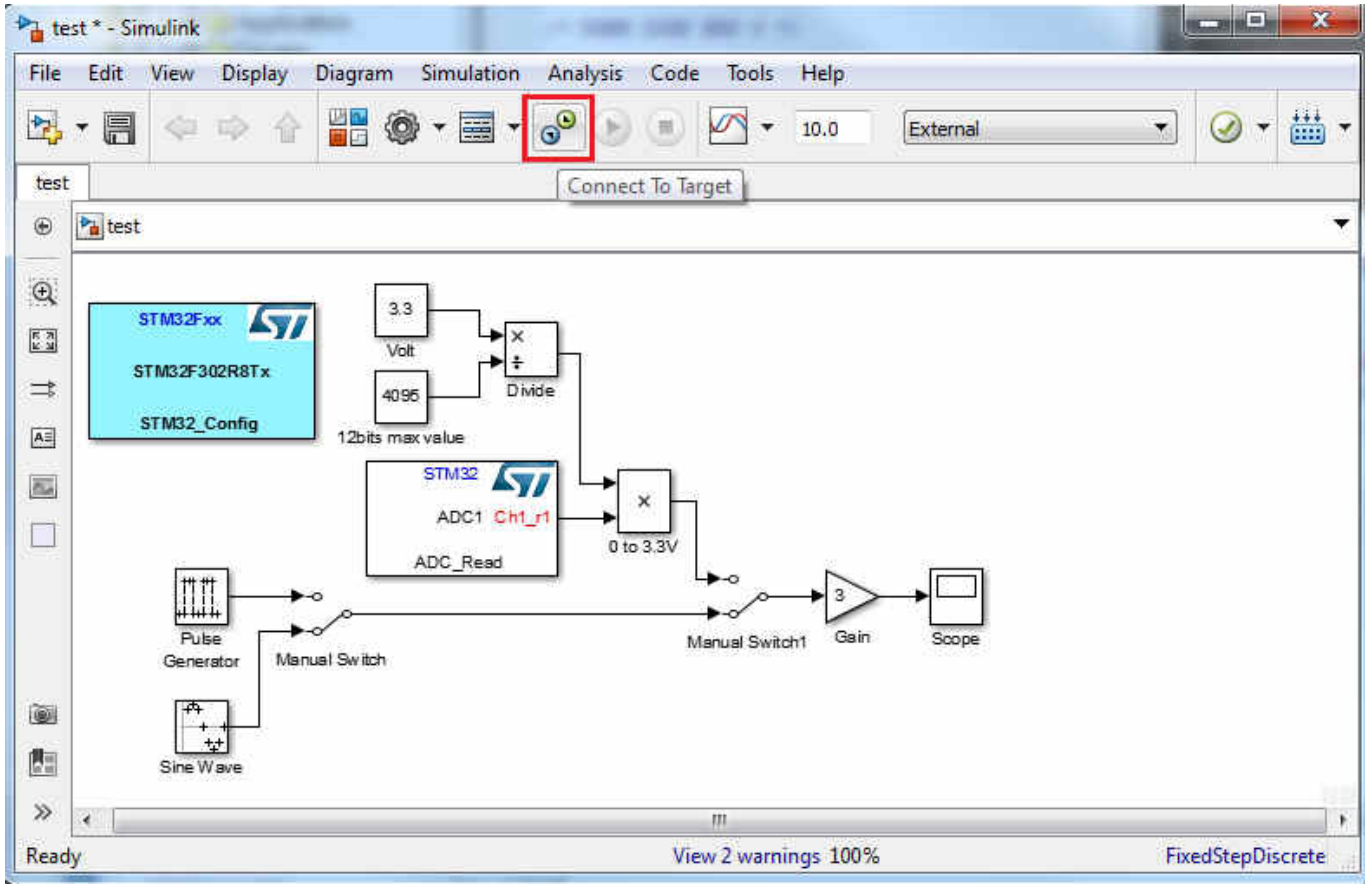
Simulink External Mode

- Simulink External Mode settings
  - Verify Simulink model Configuration parameters window



Simulink External Mode

- STM32 – Simulink Connection
  - Click Connect To Target



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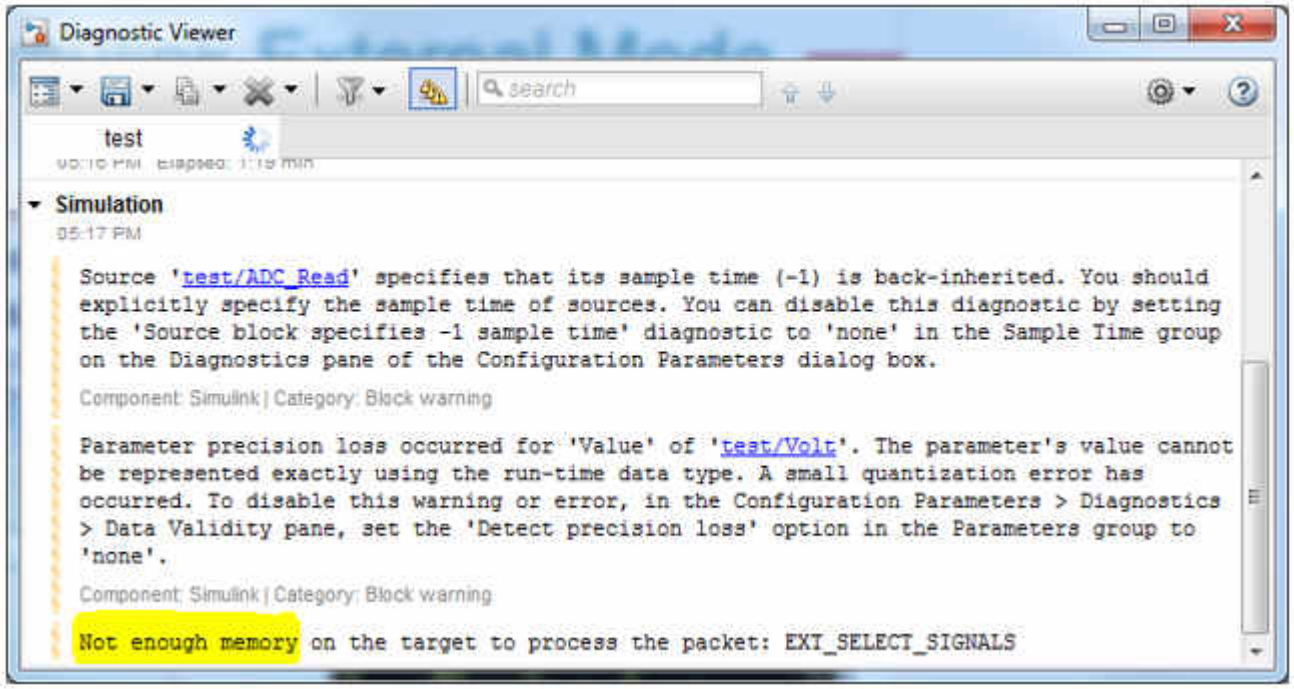
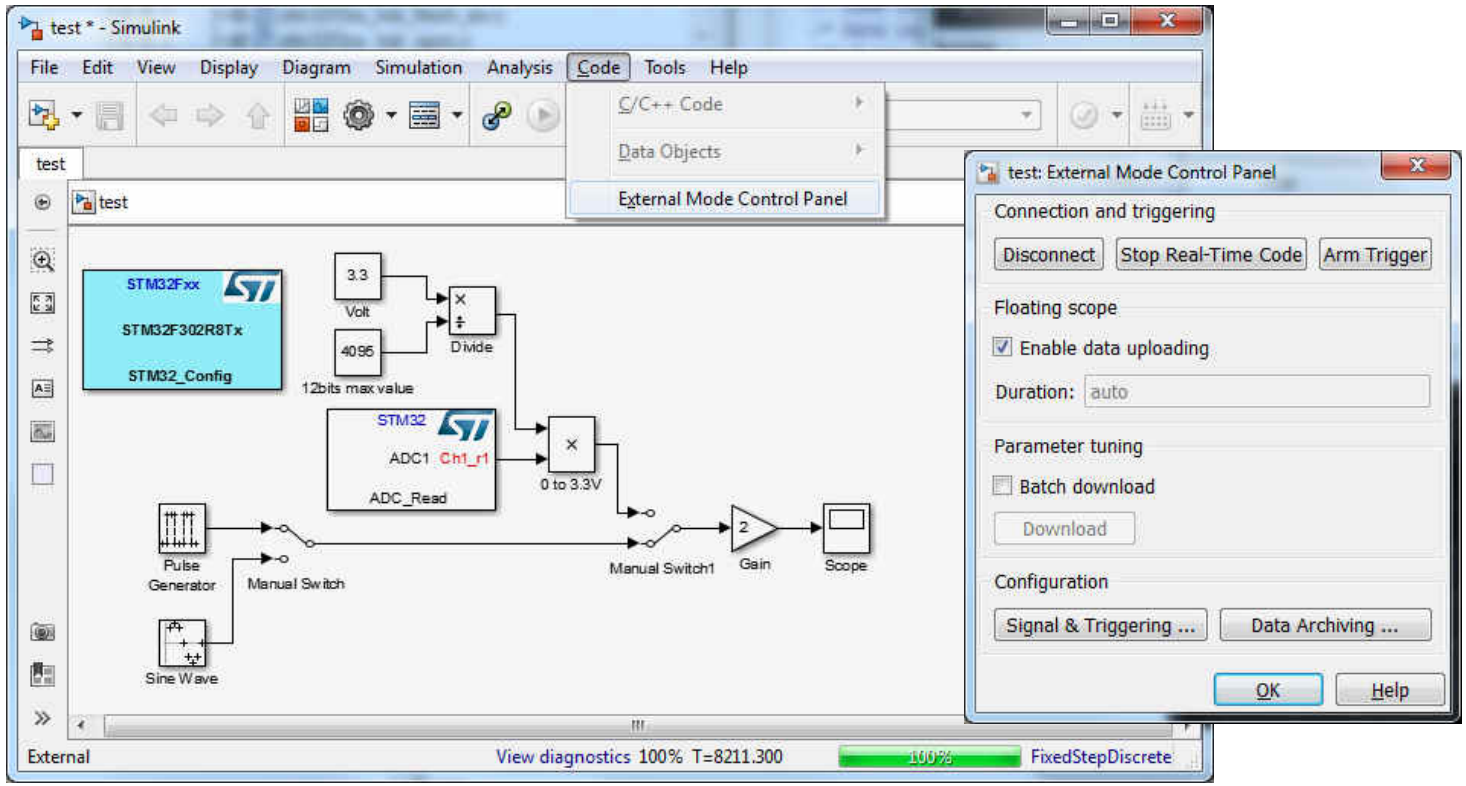
Simulink External Mode

- Memory configuration
  - Connection can be done but no signal visible from scope.



Simulink External Mode

- Memory configuration
  - Increase Heap Size from STM32CubeMX configuration if possible
  - Or configure Signal & Triggering from External Mode Control Panel



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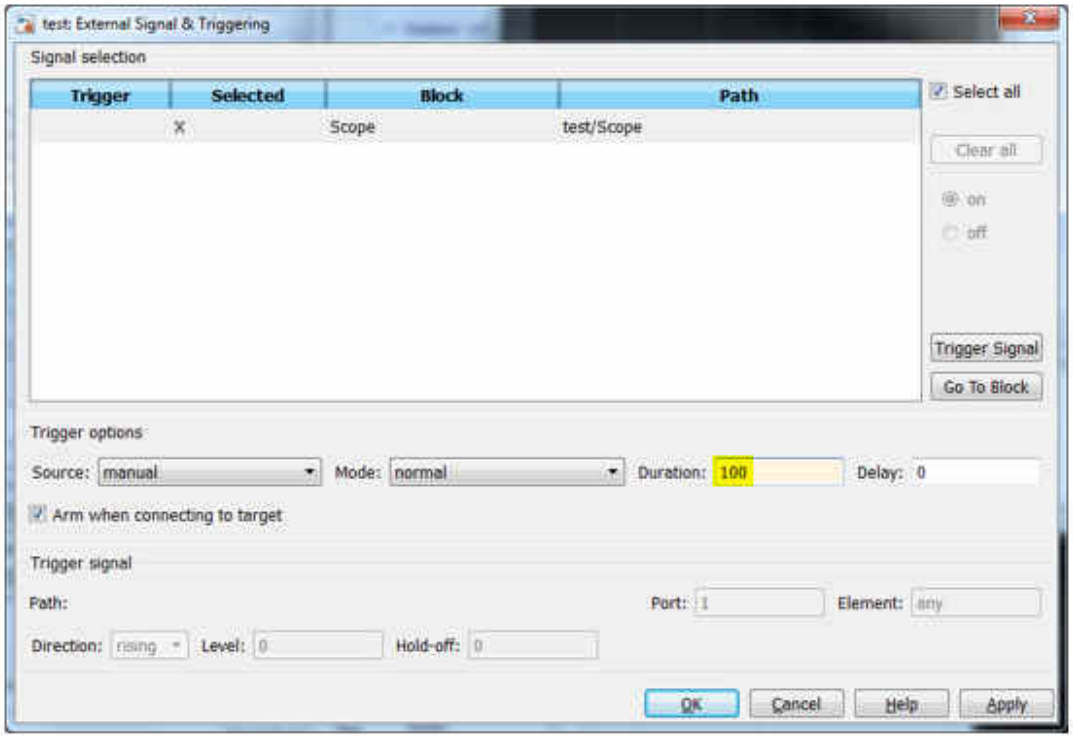
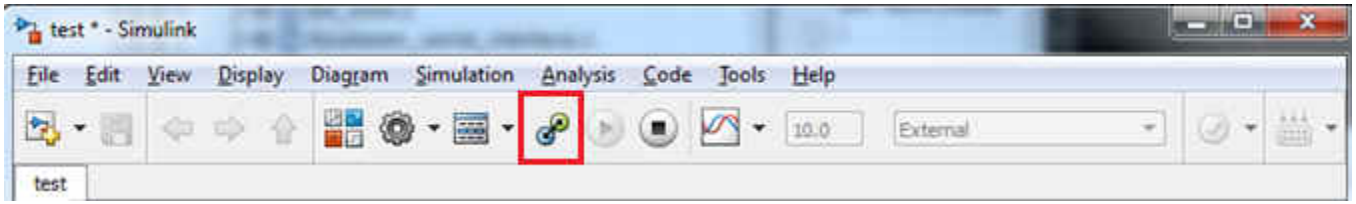
Simulink External Mode

- Memory Configuration
  - Change Scope duration to 100



  - Connect To Target again



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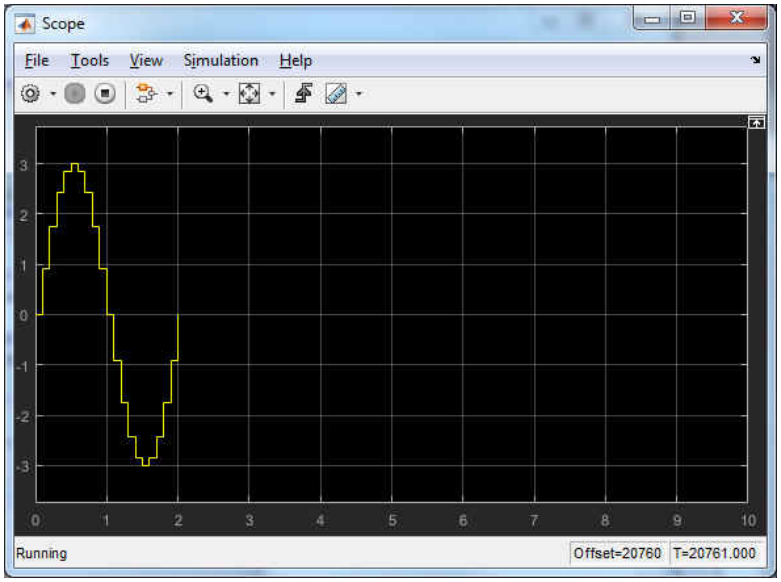
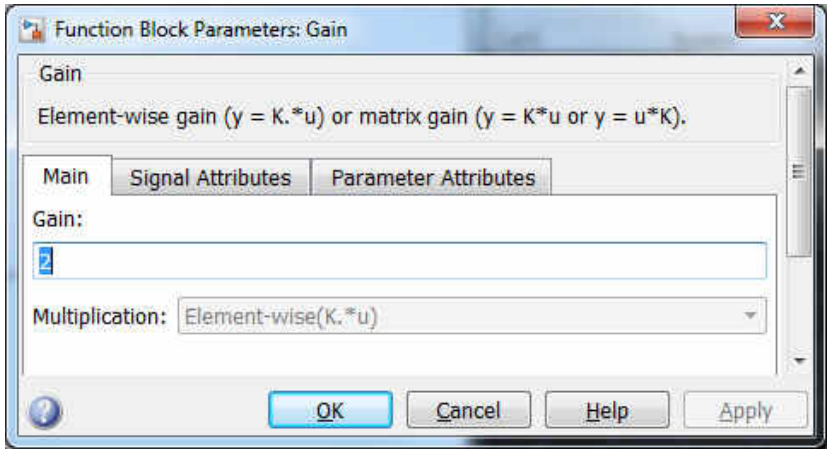
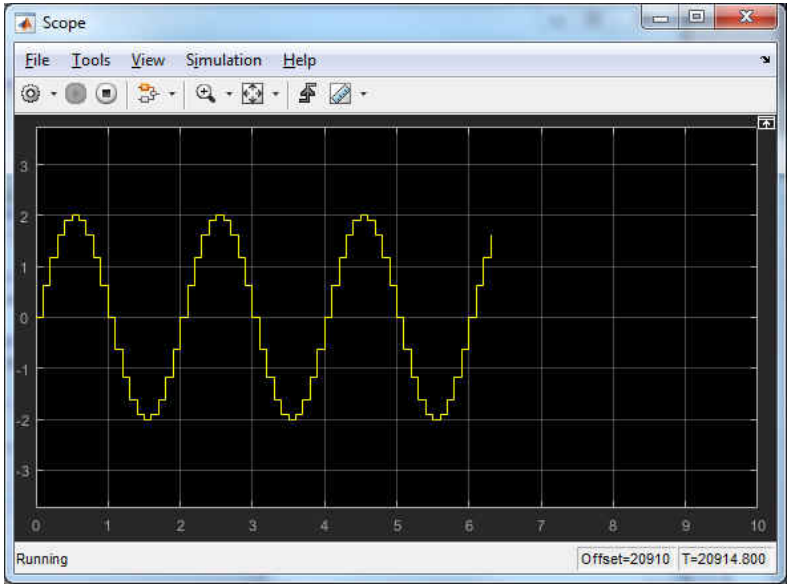
Simulink External Mode

- Signal modification
  - Sine is selected (-3 to 3)





  - Change Gain from 3 to 2



  - Sine signal amplitude is now from -2 to 2

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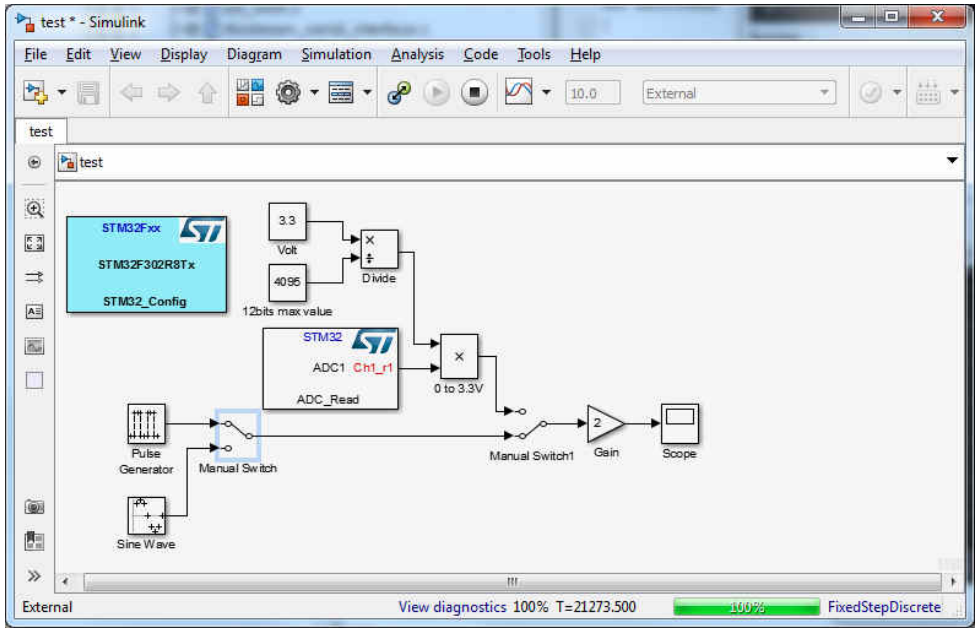
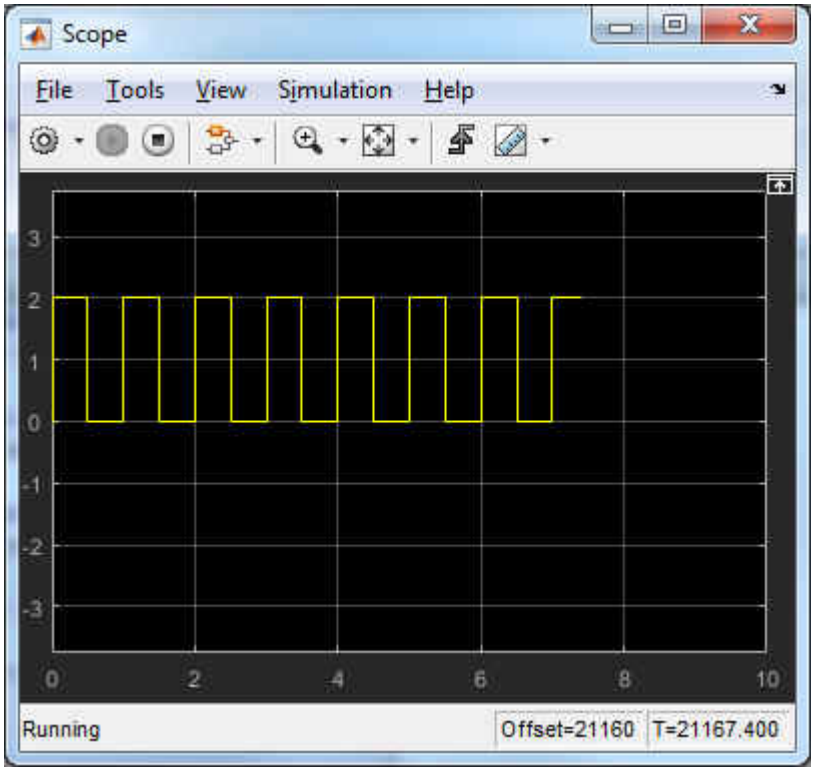
Simulink External Mode

- Signal Selection
  - Double click Switch to select pulse generation





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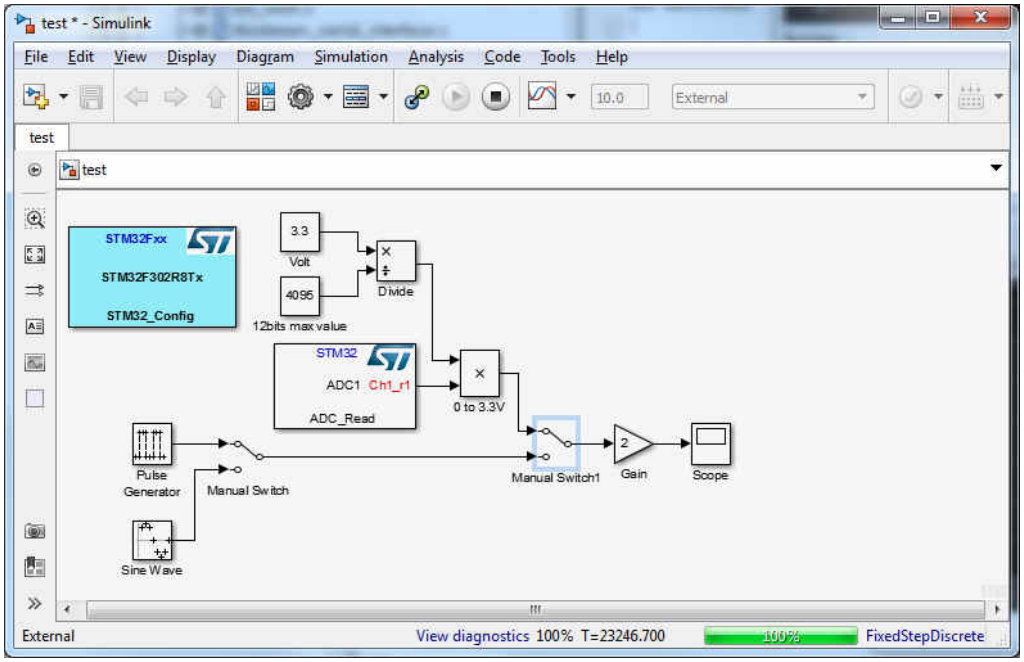
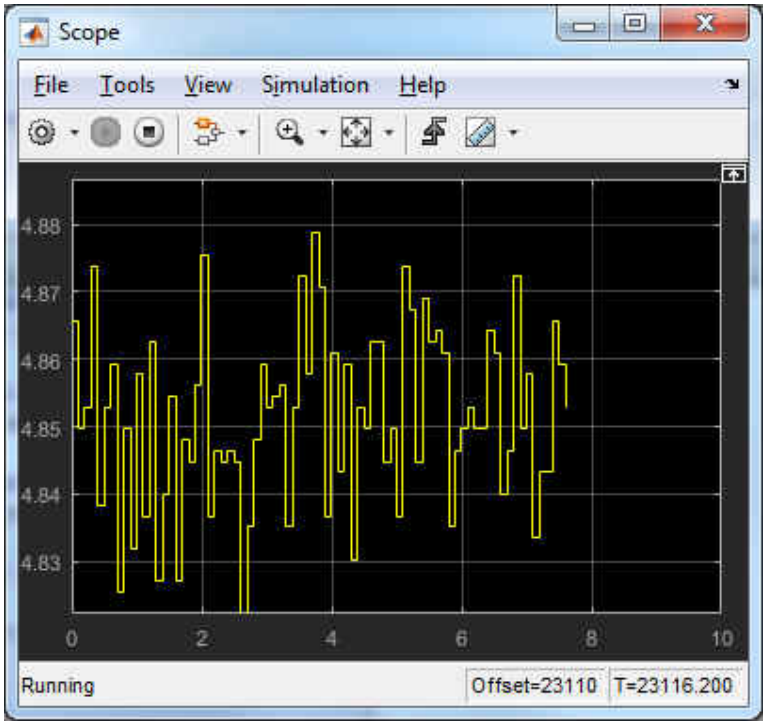
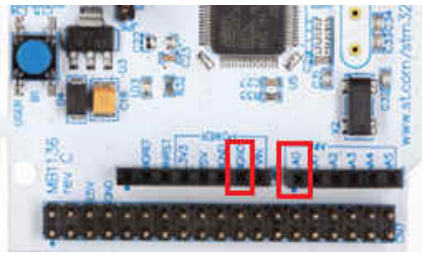
Simulink External Mode

- Signal Selection
  - Double click Switch1 to select signal from ADC1 PA0





NUCLEO AN-A0 Pin (connected to ADC1 IN1) and GND must be connected to a power supply (or voltage generator) max 3.3V.



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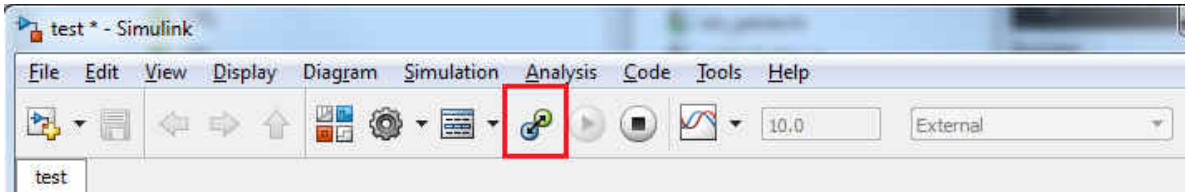
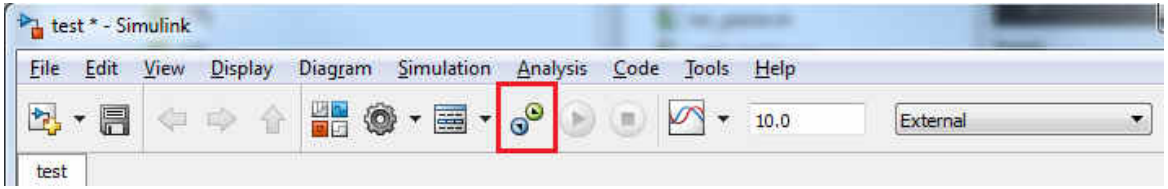
Simulink External Mode

- Connected / Not connected
  - As long as STM32 application is running, you can connect or un-connect Simulink model.
  - Connected

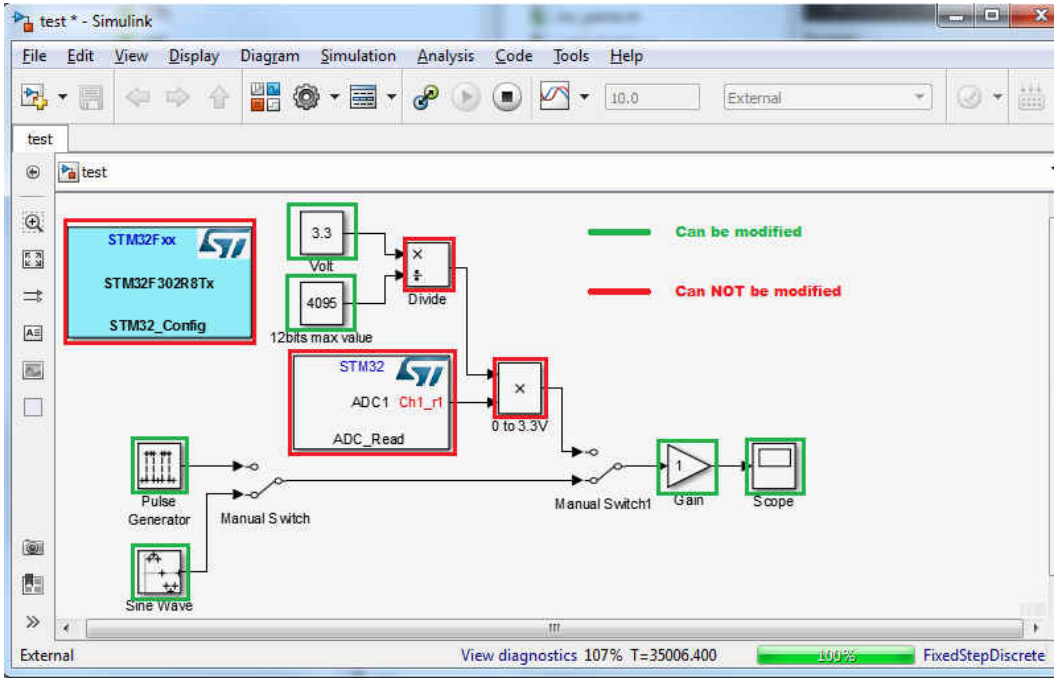


  - Not connected



Simulink External Mode

- Monitoring
  - As long as STM32 application is running, you can modify Simulink model parameters.



Monitoring means that only parameters can be modified. C generated code can't be modified. For example, it is not possible to replace x with + as x C code function has been generated.

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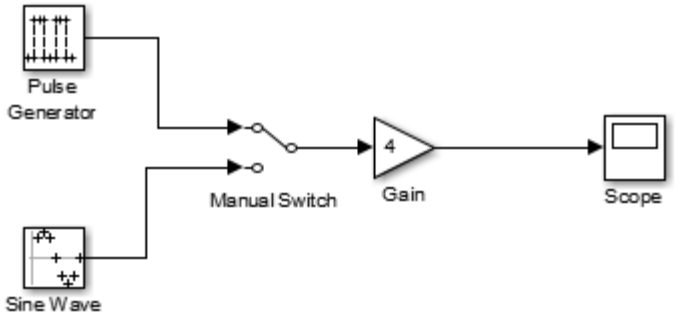
Simulink External Mode

- External Mode without `ioc` file selection.
  - It is possible to do STM32 External Mode for Simulink model without any STM32 driver used.
  - MCU used for External Mode is then selected using MCU selection window as PC port and STM32 USART for External Mode communication
  - IOC file is generated including selected STM32 MCU and USART for communication with Simulink.
  - STM32CubeMX generates code and project.
  - Process is same as process using STM32 drivers.



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