Code generation for STM32 MCUs using MATLAB® and simulink®

March 2020

Systems check

- Mandatory Software
  - From Mathworks
    - MATLAB®, Simulink and Embedded Coder (2018B)
  - From STMicroelectronics
    - STM32CubeMX  (5.6.0)
    - STM32-MAT/TARGET toolkit to develop STM32 applications (STM32MatTarget_5.6.0_setup.zip)
  - One of following Toolchain
    - EWARM from IAR  (8.32.3)
    - MDK-ARM from Keil  (5.29.0)
    - STM32CubeIDE from STMicroelectronics  (1.3.0)
- Hardware
  - Any STM32 based electronic application board with SWD/JTAG connection.
  - STLinkV2/V3 or 3rd party debug probe
  - Virtual Com Port implemented between STM32 and Computer

Key information

- Arm®/ST/MathWorks initiative
  - Optimized Cortex-M code for Embedded Coder based on Arm's CMSIS DSP SW library
  - Simulink Peripheral blockset provided by ST based on STM32Cube abstraction layers supporting most of STM32 portfolio
  - Compiler / IDE integration for MATLAB, based on Arm Keil  IAR  and STM32CubeIDE 
- Enables Model-Based Design Workflow for STM32 MCUs
  - Create executable models
  - Generate code automatically
  - Automate software integration
- Reduces cost and time, improves quality
  - ~33% cost & time reduction in ECU development
  - ~50% fewer specification errors

Why matlab/simulink on STM32 ?

- Simulation maybe of interest when creating a mathematical algorithm
- Matlab/Simulink enable STM32 simulation and on chip algorithm execution
- The algorithm can use the actual STM32 peripherals, ending up with a complete processing 100% done in the MCU, with no written lines of code and a complete model-driven approach, less error prone

Quick description of tools

MathWorks

Matlab	High level language for complex calculations
Simulink	Graphical development environment Complete environment of simulation and implementation of embedded systems.
Embedded Coder	C code generation for embedded systems. 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 based on user choices

Toolchain

A toolchain from one of our partners is required to compile and link C code generated by Embedded Coder, STM32CubeMX and STM32Cube embedded software

Using scenarios and tools

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

MATLAB/ Simulink

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

MATLAB/ Simulink

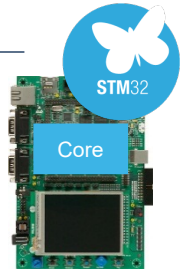
Embedded Coder

STM32Cube Embedded Software

STM32CubeMX

*: used only for UART

Toolchain



- **Step 3: Everything on STM32**
  - Data (input or output) gathered from STM32 peripherals (ADC, Timers, …) and algorithm fully executed on STM32

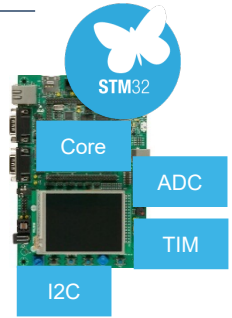
MATLAB/ Simulink

Embedded Coder

STM32Cube Embedded Software

STM32CubeMX

Toolchain



- **Step 4: External mode**
  - Same behavior than step 3. Data monitoring from Simulink via UART. Not possible to modify STM32 configuration during External Mode.

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Step 1: pure simulation

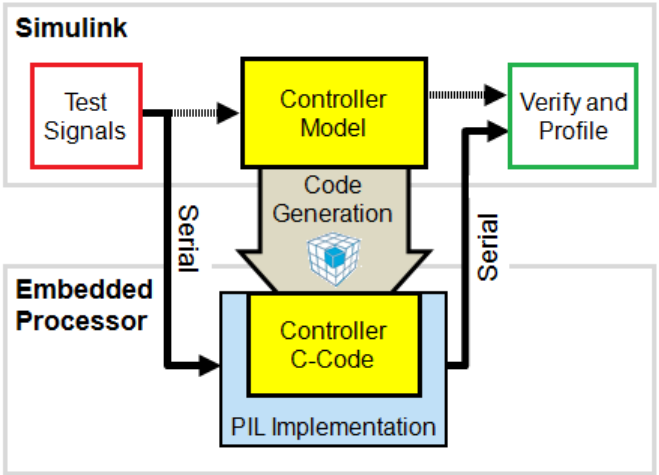
MATLAB® & simulink

- Not a subject for this presentation : You do your model ready, simulate and test it on the PC.
- General purpose for MATLAB®/Simulink
- Doesn’t need STM32-MAT/TARGET toolkit.
- Contact MathWorks for MATLAB®, Simulink trainings

Step 2: processor-in-the-loop

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.



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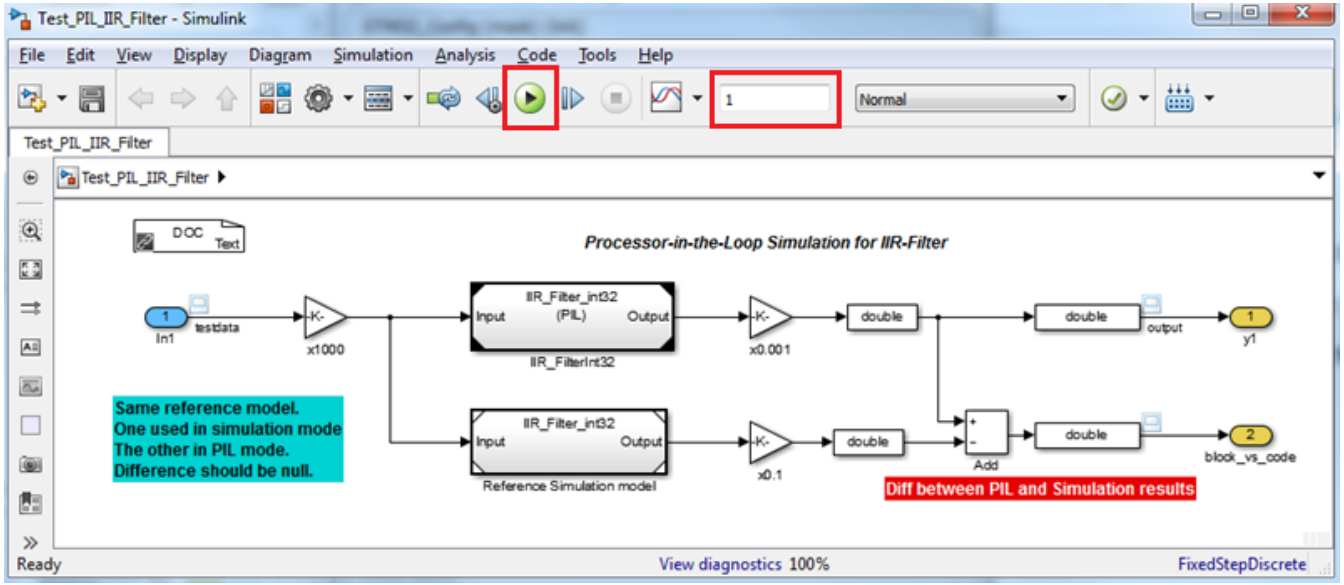
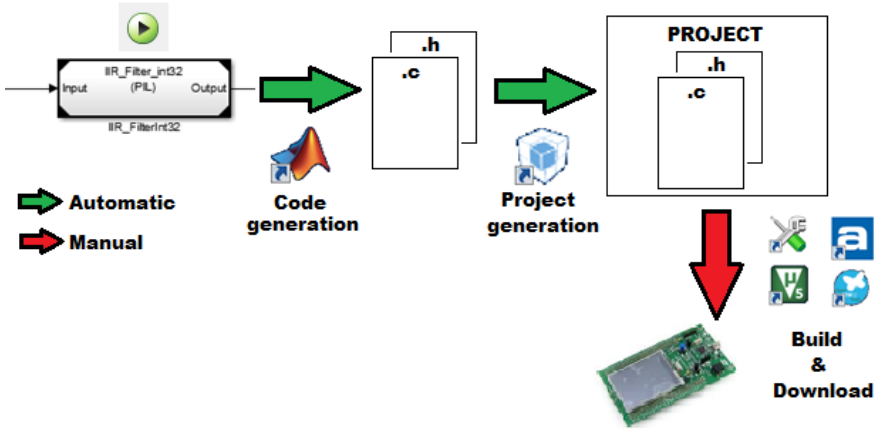
Simulink PIL start

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



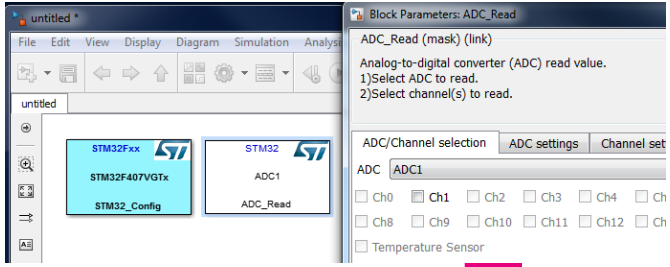
Code generation overview

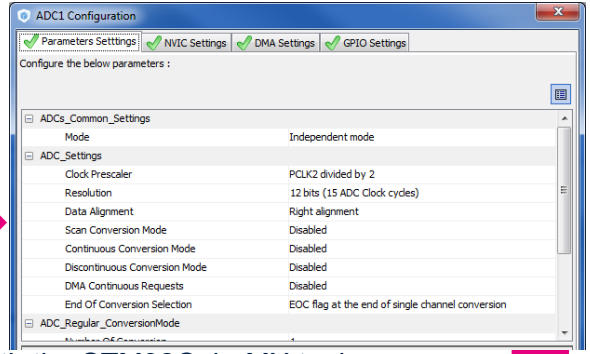
- PIL referenced model runs into STM32 target while the simulation model runs on PC
  - Automatic conversion of PIL model to .c/.h files
  - Automatic call to STM32CubeMX to create project
  - Manually build and download project to STM32 target from selected IDE

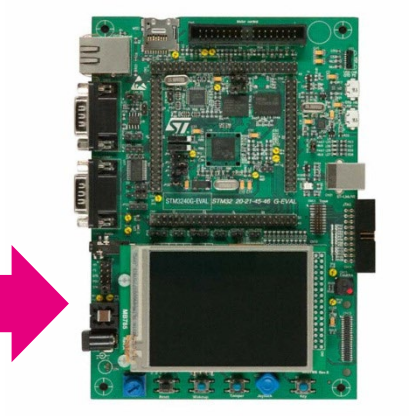


Step 3: everything on STM32

Handle data through real peripherals







- Configure your peripherals through a bridge with the STM32CubeMX tool
- Flash your device and run !
- More info at www.st.com/stm32-mat-target

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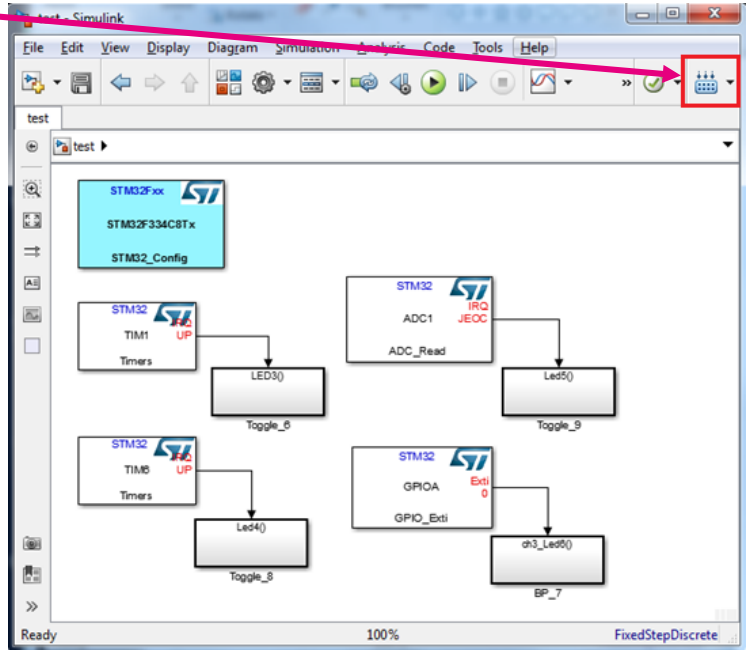
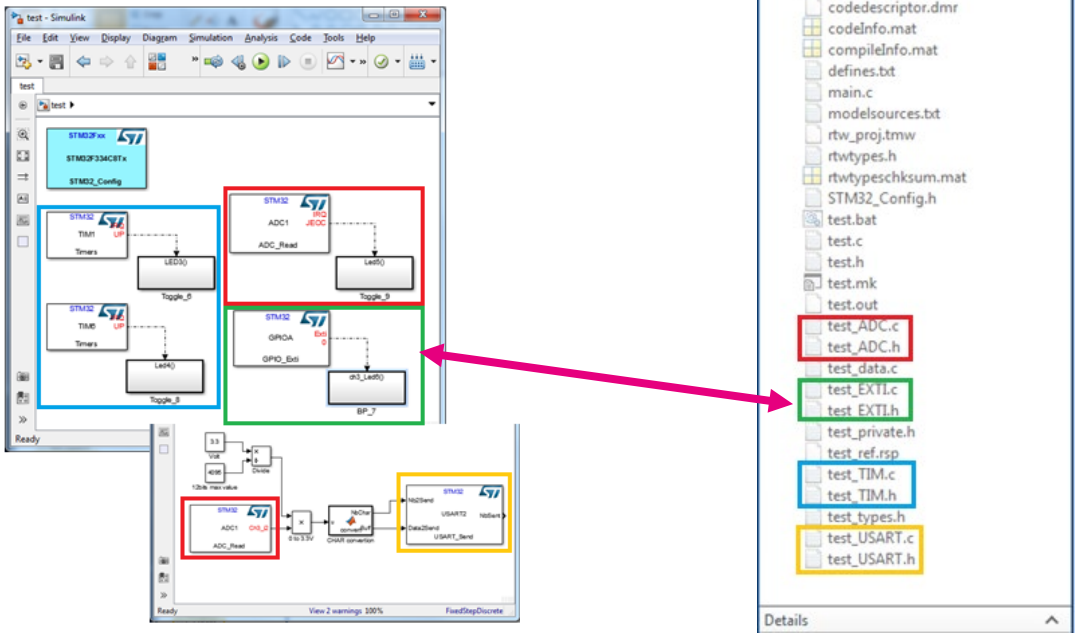
Build application

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



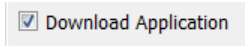
MATLAB® code generation

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

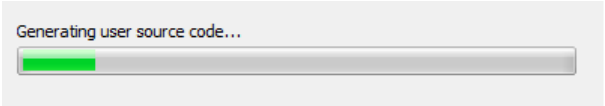


STM32CubeMX code generation

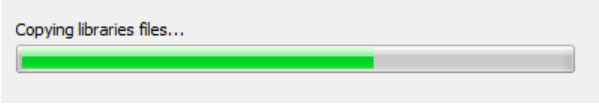
- STM32CubeMX process
  - STM32CubeMX is automatically called from MATLAB® when «Download Application» has been selected from the Model Configuration window.



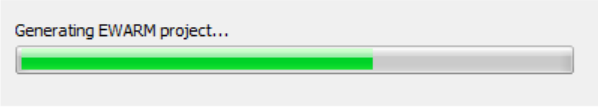
  - STM32CubeMX generates configuration code.



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

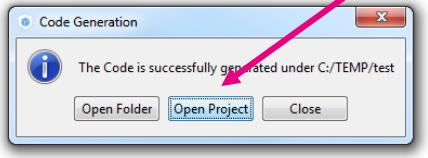


  - STM32CubeMX generates toolchain project including files generated from MATLAB®



  - The project generated by STM32CubeMX can be opened

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



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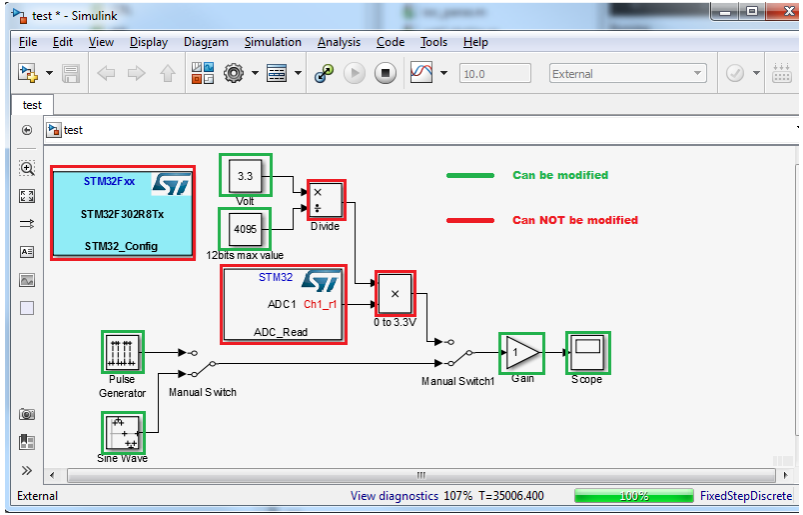
Step 4: external mode

Simulink external mode

- Monitoring
  - As long as STM32 application is running, Simulink model parameters can be edited



  - 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.

Summary

- New Support Package for MATLAB, Simulink, and Embedded Coder
  - Generate optimized code
  - Automate build, integration and verification steps
- Now with ST and MathWorks you can:
  - Accelerate time to market
  - Reduce development costs
  - Improve product quality
- …Join the Design Community

Thank you

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