



# ***Documentation***

***X2C® v6.6.4477  
Free Edition***

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# Part I

## Installation

### 1 Software versions

Following software versions were tested for full X2C<sup>®</sup> functionality:

| Software                                                            | Version                                      |
|---------------------------------------------------------------------|----------------------------------------------|
| <i>Required:</i>                                                    |                                              |
| Scilab ( <a href="http://www.scilab.org">www.scilab.org</a> )       | 6.1.1                                        |
| <i>Optional (for standalone operation):</i>                         |                                              |
| Java Runtime Environment                                            | Java SE 8 / <a href="#">ojdkbuild 13 JRE</a> |
| <i>Optional (for documentation):</i>                                |                                              |
| MiKTeX ( <a href="http://www.miktex.org">www.miktex.org</a> )       | 2.9                                          |
| Doxygen ( <a href="http://www.doxygen.org">www.doxygen.org</a> )    | 1.9.0                                        |
| Graphviz ( <a href="http://www.graphviz.org">www.graphviz.org</a> ) | 2.38                                         |
| <i>Optional (for programming):</i>                                  |                                              |
| TI Code Composer Studio                                             | 11.x                                         |
| TI Code Generation Tools                                            | c2000_16.9.5.LTS / arm_16.9.4.LTS            |
| TI TivaWare                                                         | TivaWare_C_Series-2.x.x.xxx                  |
| ST STM32CubeIDE                                                     | 1.15.x                                       |
| Infineon DAVE IDE                                                   | 4.x.x                                        |
| Microchip MPLAB <sup>®</sup> X                                      | 6.xx                                         |
| Microchip XC16                                                      | 1.xx                                         |

Different versions of these programs may work but without warranty.

### 2 Setup with Scilab & Xcos support

#### 2.1 Installation

1. Open *Scilab* and with the *File Browser* navigate to <X2C\_ROOT>\System\Scilab\Scripts. Right click on **setup.sce** and click *Execute in Scilab*.
2. Restart *Scilab*
3. The setup command creates a X2C configuration file which will automatically load X2C libraries and palettes at startup of *Scilab*.

#### 2.2 Uninstallation

1. Open *Scilab* and execute the command `initX2C(%f)` in the *Scilab* console.
2. Restart *Scilab*
3. Once above command was executed, the X2C configuration file is deleted and *Scilab* will not load any X2C libraries or palettes anymore.

For the unlikely event that Scilab freezes at startup and remains in a deadlock state, the deinstallation can be done manually by deleting the file **scilab.ini** located in the Scilab home directory (for Windows typically C:\Users\<your user name>\AppData\Roaming\Scilab\scilab-6.x.x).

## 3 Configuration of *Code Composer Studio*

### 3.1 Install the TI v16.9.5 compiler

It is necessary to use the compiler version TI v16.9.5 in *Code Composer Studio* in combination with X2C. Navigate to **Project** → **Properties** click **General** and in the **Advanced settings** area see what compiler versions are available. It is necessary to use the compiler version **TI v16.9.5**. If this version is not selectable go to **Help** → **Install new Software** and in the **Work with** drop down menu choose **Code Generation Tools Update**. In the section **TI Compiler Updates** find *C2800 Compiler Tools Version 16.9.5* and mark it as seen in Figure 1. Click **Next** and install the update. Now go back to the Project Properties and change the compiler.

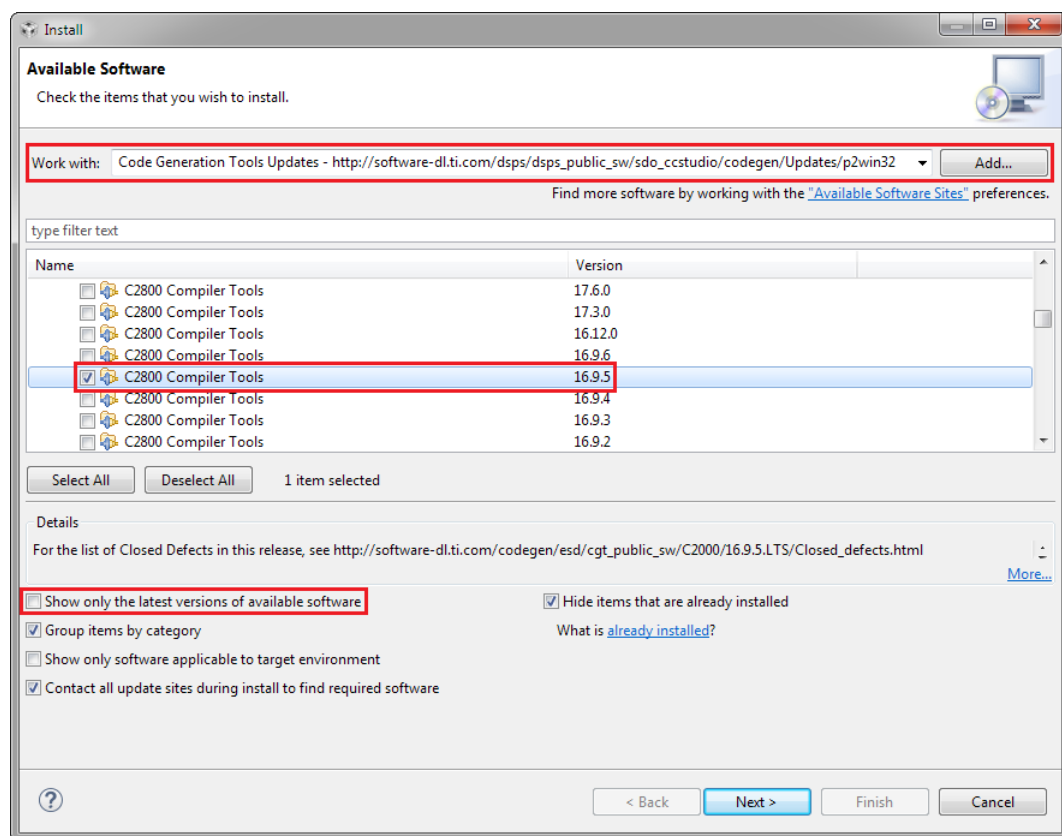


Figure 1: *Code Composer Studio* Compiler Download

### 3.2 *Texas Instruments* target processor types

#### 3.2.1 Supported processors families

Currently the following *Texas Instruments* processor families are supported by X2C.

- TI C28x 32-Bit CPU
- TI TM4C12x 32-Bit CPU (ARM Cortex-M4 core)



### 3.2.2 Change target processor in *Code Composer Studio*

In the following section file names may vary with different processor types.

1. Import the *Blinky* demo application in *Code Composer Studio* (see Section 17 for more information).
2. Change the *Predefined symbols* (see Section 3.3) suitable for the used processor type.
3. With the OS file browser navigate to the *controlSUITE* subdirectory *device\_support* and search for your processor type (e.g. C:\ti\controlSUITE\device\_support\f2806x\v130\F2806x\_headers).
4. Copy the folders *cmd*, *include* and *source* into the project directory <PROJECT\_DIRECTORY>\TexasInstruments and replace the existing folders from the processor used in the *Blinkdy* demo application.
5. In *Code Composer Studio* open the **F28xxx\_Device.h** file in the folder <PROJECT\_DIRECTORY>\TexasInstruments\include. In the section *User To Select Target Device* search for your processor and change the 0 to TARGET. An example is shown in Figure 2.

```
57 #define DSP28_28067P      0
58 #define DSP28_28067UP    0
59 #define DSP28_28067PZ    0
60 #define DSP28_28067UPZ   0
61
62 #define DSP28_28068P      0
63 #define DSP28_28068UP    0
64 #define DSP28_28068PZ    0
65 #define DSP28_28068UPZ   0
66
67 #define DSP28_28069P      0
68 #define DSP28_28069UP    0
69 #define DSP28_28069PZ    0
70 #define DSP28_28069UPZ   TARGET
```

Figure 2: Change processor type in the *device.h* file

6. In *Code Composer Studio* open the files *Hardware.h* and *X2cDataTypes.h* and adapt the file names in the *include* directives for the *F28xxx\_Device.h* file.

### 3.3 Change predefined Symbols

The X2C project uses predefined symbols to give the preprocessor information before compiling the project. Navigate to **Project** → **Properties** open **Build** → **C2000 Compiler** → **Predefined Symbols**.

Currently three different processor families can be chosen

- `__GENERIC_TI_C28X__` for *Texas Instruments* Processors
- `__GENERIC_ARM_ARMV7__` for *ARM* Processors
- `__GENERIC_MICROCHIP_DSPIC__` for *Microchip* Processors

The definition

- `__CUSTOM_DATATYPE_DEFINITIONS__`

is needed to avoid compiler warnings caused by multiple *typedefs*.

In addition the definition

- `SCOPE_SIZE=8000`

like seen in Figure 3 needs to be made. The value of *Scope Size* is changeable and depends on the intended application and the used target processor. In the *Blinky* demo applications these values are already defined.

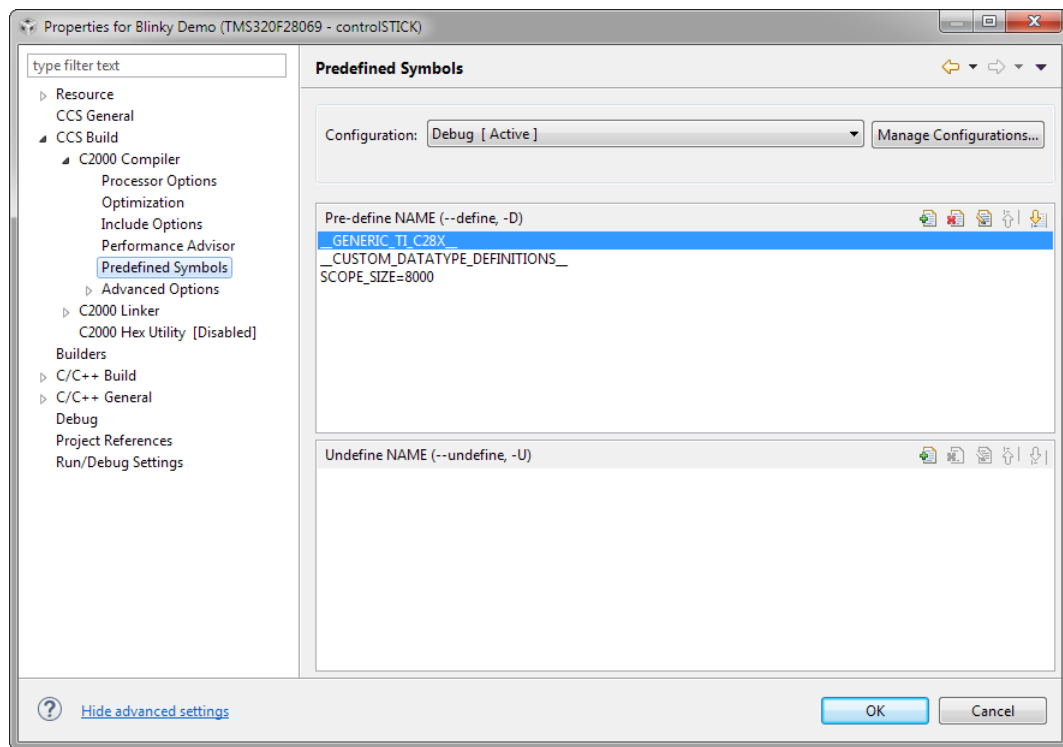


Figure 3: Predefined symbols for generic processor type in *Code Composer Studio*

## 4 Configuration of *MPLAB*<sup>®</sup> X

### 4.1 Install the XC16 compiler

When working with *MPLAB X* the compiler to build the project has to be installed manually. Which compiler is needed depends on the used processor type. In the demo application *Blinky* the *xc 16 v1.21* compiler from the *Microchip* web page ([http://www.microchip.com/pagehandler/en\\_us/devtools/mplabxc/](http://www.microchip.com/pagehandler/en_us/devtools/mplabxc/)) can be used.

### 4.2 *Microchip* target processor types

#### 4.2.1 Supported processors families

Currently the following *Microchip* processor families are supported by *X2C*.

- dsPIC 16-Bit CPU

#### 4.2.2 Change target processor in *MPLAB X*

Right click on the **Project** → **Properties**. In the *Configuration* area *Devices* can be picked in the drop down menu. Click **OK** to save the changes.

### 4.3 Change predefined Symbols

The *X2C* project uses *predefined Symbols* to give the preprocessor information before compiling the project. In the the sample project these symbols are already defined. Right click on the **Projectname** → **Properties** → **XC16 Global Options** → **xc16-gcc** to eventually change them. In the section *Define C macros* a list of defines is available as seen in Figure 4. Depending on the used target processor three different processor families can be choosen

- `__GENERIC_TI_C28X__` for *Texas Instruments* Processors
- `__GENERIC_ARM_ARMV7__` for *ARM* Processors
- `__GENERIC_MICROCHIP_DSPIC__` for *Microchip* Processors

In addition the definition

- `SCOPE_SIZE=5000`

like seen in Figure 4 needs to be made. The value of *Scope Size* is changeable and depends on the intended application and the used target processor. In the *Blinky* demo applications these values are already defined.

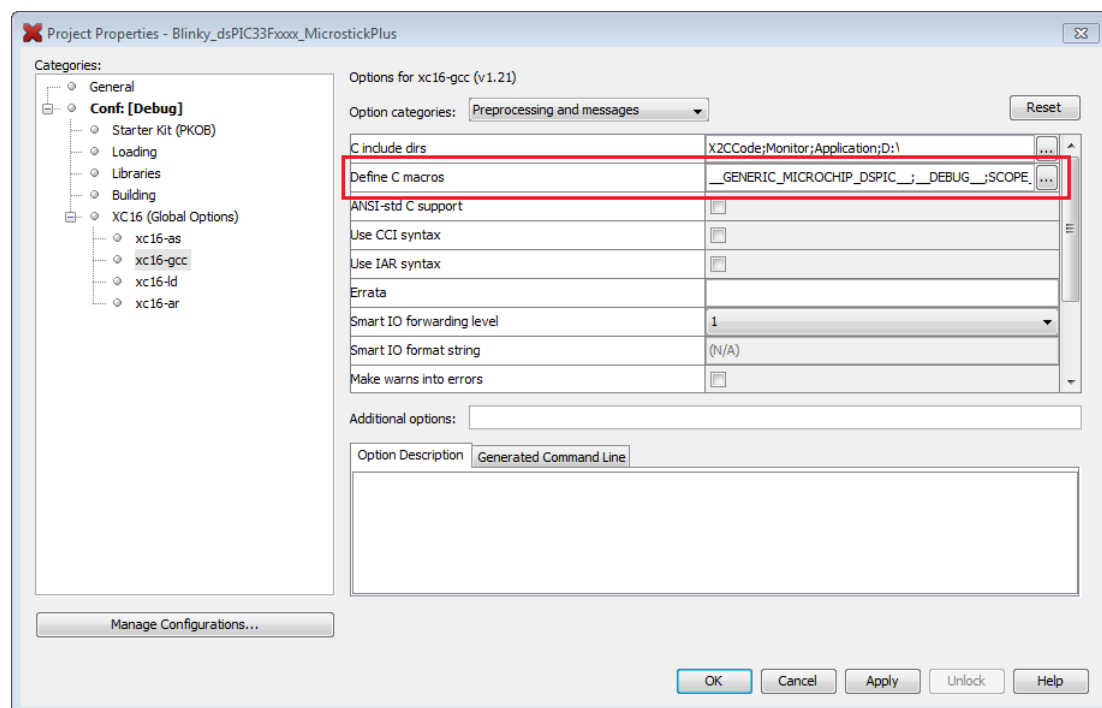


Figure 4: Predefined Symbols in *MPLAB X*

## Part II

# General

## 5 Introduction to X2C<sup>®</sup>

### 5.1 General structure of X2C

X2C can be seen as a two layer application, as it is depicted in figure 5.

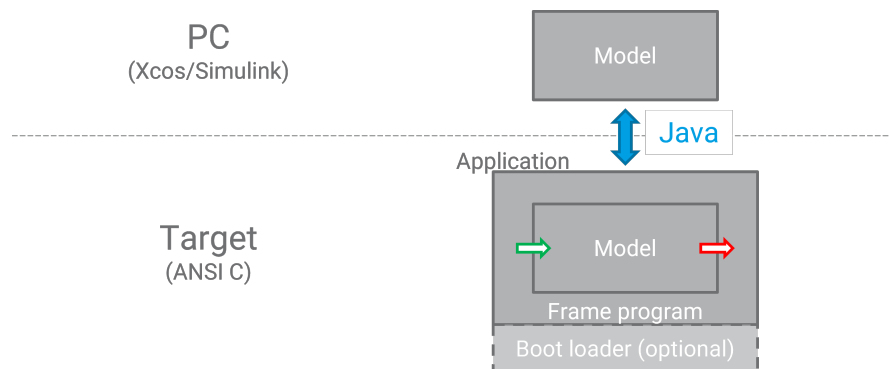


Figure 5: General X2C structure

The top layer is the abstraction layer located on the PC. Either in Xcos or in Simulink the model-based development takes place. This means the user designs the control algorithm graphically.

Based on the graphical model X2C generates C-code with its java tool Communicator. The generated C-code together with the so called frame program form the application. Since the model-based design is independent of hardware, the generated model code is (more or less) too. The model code is called from the frame program, which is manually coded and handles the initialization and configuration of the hardware peripherals and provides the hardware signals for the application.

In the commercial version a bootloader is available. With this bootloader programming of the target can be executed over Serial/CAN/Ethernet interface, so no programming device is needed.

### 5.2 Connection between frame program and model

As already mentioned in the previous section, the generated code from the model is embedded in the manually coded frame program. For the most minimalist application imaginable (no communication between target and PC, no hardware peripherals used by the target), the frame program consists of only two function calls:

- X2C\_Init() once at startup
- X2C\_Update() cyclically with the sample time defined in the model

The schematic structure of such a minimal frame program can be seen in figure 6a, where the generated code by X2C is marked in light blue.

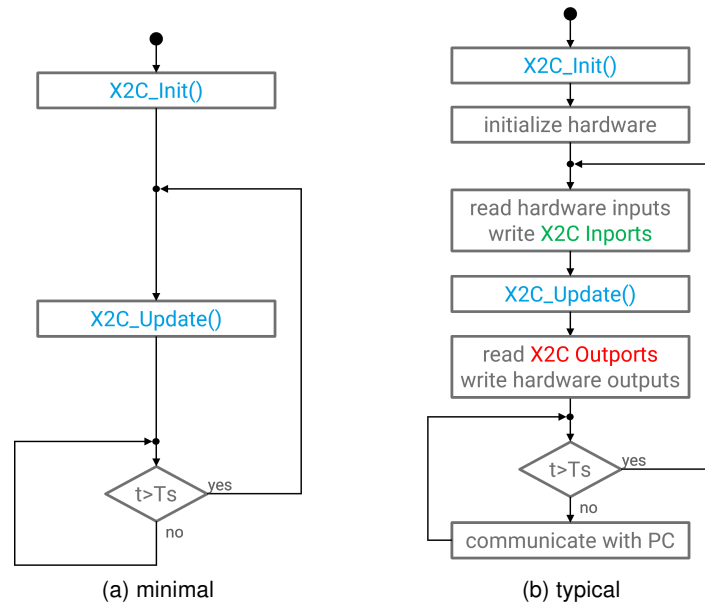


Figure 6: Frame program structure

However, in real life applications hardware peripherals will be used, and in most cases an X2C communication should be possible. Therefore, the startup process will be enhanced with an initialization routine of the target's peripherals, such as ADC, Timer, Interrupt, PWM, etc. and communication interfaces such as UART, CAN, Ethernet, etc.

The cyclic part of the frame program will be enhanced too. Before the `X2C_Update()` function will be called, the hardware inputs are read, and the values are assigned to the corresponding X2C Inports. For example, given an X2C Inport labelled as *AnIn1* in the model and the analog-to-digital conversion result available as `ADCResult[0]` variable in the frame program, the code would be:

```
x2cModel.inports.bAnIn1 = ADCResult[0];
```

After the `X2C_Update()` function call the computed X2C Outports are read and the values put to the corresponding hardware outputs. For example, given an X2C Outport labelled *LED1* and the target's name for port A hardware register is *GPADAT* the code for controlling a LED connected to pin 4 of hardware port A could be:

```
if (*x2cModel.outports.bLED1 != 0) {
    GPADAT |= 0x0008;
} else {
    GPADAT &= 0xFFFF7;
}
```

While the target waits for the next cycle the X2C communication can be executed. It enables online parameter tuning and signal monitoring with X2C Communicator and Scope.

These enhancements are depicted in figure 6b.

Typically, the cyclic part is handled in a high priority interrupt service routine and the communication with the host PC is handled in a low priority task, e.g. the `while(1)` loop.

### 5.3 Boolean data representation

Boolean data is based on the header `stdbool.h` introduced in C99 in the C Standard Library for the C programming language.

| <b>Bool</b>         |           |
|---------------------|-----------|
| Implementation type | Boolean   |
| Format              | C99       |
| Minimum value       | 0 (false) |
| Maximum value       | 1 (true)  |

## 5.4 Fixed point data representation

### 5.4.1 Standard signals

Standard signals are symmetrically scaled about zero and their scaling range is  $]-1...1[$ . In a case of an overflow the signal will be limited to 1 (or -1 respectively). For example a subtraction of a signal with value 0.5 from a signal with value -0.7 will lead to a signal with value -1.

Depending on the chosen implementation the values are handled in one of the following formats:

| <b>FiP8</b>         |                   |
|---------------------|-------------------|
| Implementation type | 8-bit fixed point |
| Format              | Q7                |
| Minimum value       | -0.992 187 500    |
| Maximum value       | 0.992 187 500     |
| Resolution          | 0.007 812 500     |

| <b>FiP16</b>        |                        |
|---------------------|------------------------|
| Implementation type | 16-bit fixed point     |
| Format              | Q15                    |
| Minimum value       | -0.999 969 482 421 875 |
| Maximum value       | 0.999 969 482 421 875  |
| Resolution          | 0.000 030 517 578 125  |

| <b>FiP32</b>        |                        |
|---------------------|------------------------|
| Implementation type | 32-bit fixed point     |
| Format              | Q31                    |
| Minimum value       | -0.999 999 999 534 339 |
| Maximum value       | 0.999 999 999 534 339  |
| Resolution          | 0.000 000 000 465 661  |

### 5.4.2 Unlimited/Unbalanced signals

The scaling of unlimited/unbalanced signals is  $[-1...1]$ . While the standard signals omit one value to achieve a symmetrical value range, the unlimited (or also called unbalanced) signals utilize the full value range which leads to a slightly unbalanced value range. As the name implies unlimited signals won't be limited. In fact unlimited signals utilize wrapping/overflow functions of the DSP. For example a subtraction of a signal with value 0.5 from a signal with value -0.7 will lead to a signal with value 0.8.

So the primary use of the unlimited signal is as angular signal where  $(-1...1)$  corresponds to  $(-\pi... \pi)$ .

Depending on the chosen implementation the values are handled in one of the following formats:

| FiP8                |                   |
|---------------------|-------------------|
| Implementation type | 8-bit fixed point |
| Format              | Q7                |
| Minimum value       | -1.000 000 000    |
| Maximum value       | 0.992 187 500     |
| Resolution          | 0.007 812 500     |

| FiP16               |                        |
|---------------------|------------------------|
| Implementation type | 16-bit fixed point     |
| Format              | Q15                    |
| Minimum value       | -1.000 000 000 000 000 |
| Maximum value       | 0.999 969 482 421 875  |
| Resolution          | 0.000 030 517 578 125  |

| FiP32               |                        |
|---------------------|------------------------|
| Implementation type | 32-bit fixed point     |
| Format              | Q31                    |
| Minimum value       | -1.000 000 000 000 000 |
| Maximum value       | 0.999 999 999 534 339  |
| Resolution          | 0.000 000 000 465 661  |

## 5.5 Floating point data representation

### 5.5.1 Standard signals

The standard signals in floating point format are not restricted, the full value range according to the IEEE 754 standard is available.

| Float32             |                                                            |
|---------------------|------------------------------------------------------------|
| Implementation type | 32-bit floating point                                      |
| Format              | IEEE 754                                                   |
| Minimum value       | $-3.4028234663852885981170418348452e + 38$                 |
| Maximum value       | $3.4028234663852885981170418348452e + 38$                  |
| Resolution          | $\pm 1.1754943508222875079687365372222e - 38$ (normalized) |

| Float64             |                                                             |
|---------------------|-------------------------------------------------------------|
| Implementation type | 64-bit floating point                                       |
| Format              | IEEE 754                                                    |
| Minimum value       | $-1.797693134862315708145274237317e + 308$                  |
| Maximum value       | $1.797693134862315708145274237317e + 308$                   |
| Resolution          | $\pm 2.2250738585072013830902327173324e - 308$ (normalized) |

### 5.5.2 Unlimited/Unbalanced signals

Contrary to their names the unlimited/unbalanced signals in floating point format are limited to  $[-\pi, +\pi]$ . All other properties are similar to the unlimited signals in fixed point format.

| Float32             |                                                            |
|---------------------|------------------------------------------------------------|
| Implementation type | 32-bit floating point                                      |
| Format              | IEEE 754                                                   |
| Minimum value       | $-3.1415926535897932384626433832795$                       |
| Maximum value       | $3.1415926535897932384626433832795$                        |
| Resolution          | $\pm 1.1754943508222875079687365372222e - 38$ (normalized) |

| Float64             |                                                             |
|---------------------|-------------------------------------------------------------|
| Implementation type | 64-bit floating point                                       |
| Format              | IEEE 754                                                    |
| Minimum value       | $-3.1415926535897932384626433832795$                        |
| Maximum value       | $3.1415926535897932384626433832795$                         |
| Resolution          | $\pm 2.2250738585072013830902327173324e - 308$ (normalized) |

## 5.6 Angular Signals

The unlimited/unbalanced signals are typically used for angular signals, especially in the proprietary *X2C MotorControl* library. An angular signal is needed for the field oriented control of permanent magnet synchronous motors. For such a case, the zero value has to be defined.



For the X2C *MotorControl* library the zero value is the angle where the Back-EMF voltage of the first motor phase has its negative zero-crossing (see figure 7).

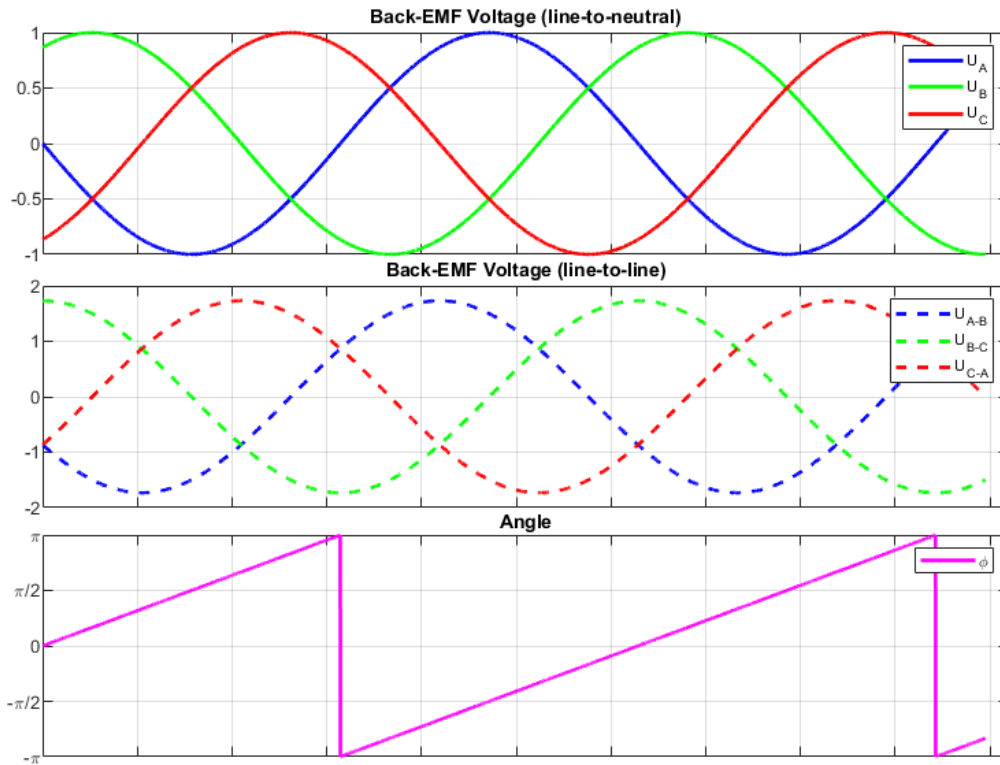


Figure 7: Angle in respect to Back-EMF voltage

## 5.7 Simulation

It is possible to simulate a X2C-model in Xcos . All blocks except hardware dependent ones (e.g. Inport, Outport) contain glue code which are linked with the corresponding source code of the X2C-block. This enables a simulation of a X2C-model in Xcos . Hence testing of DSP control algorithms is possible without the need for a DSP connected to the simulation PC.

## 5.8 Restrictions

### 5.8.1 Algebraic loops

Algebraic loops as depicted in Figure 8a are not possible due to a execution order problem. Therefore a block is required which breaks the loop at a specific position. This can be achieved by inserting a block with no direct feedthrough functionality, e.g. [Block: LoopBreaker](#) from the X2C *General* library (see Figure 8b).

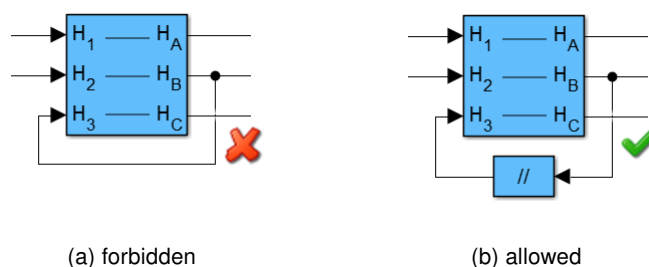


Figure 8: Algebraic loops

### 5.8.2 Connection of blocks with different implementations

Though blocks with different implementations are allowed (and computed correctly) in the same model, connections of ports with different datatypes are not permitted. The conversion blocks [Block: TypeConv](#), [Block: Int2Real](#) and [Block: Real2Int](#) can be used to resolve datatype incompatibilities.

## 5.9 Model Identifier

The Model identifier is an 32-bit value to uniquely identify an X2C Model based on its

- Blocks and the used Implementation
- Block connections
- Block label names
- Block Parameter identifiers

However, the initial Block parameter values are *\*NOT\** part of the Model identifier. So, if you only change the initial Block parameters, the Model identifier will not change. The Model identifier is added to the generated X2C files and may be used by the user application as well.

### 5.9.1 Communicator and LNet services

The X2C Communicator is able to check the Model Identifier on the target against the currently loaded X2C Model in the Communicator itself. To enable this feature, the user application must implement the LNet Model Identifier services. Once these services are available on the target, the Communicator checks the Model Identifiers on every connect. In case of a Model Identifier mismatch, the Communicator outputs a warning in the log window and shows a warning dialog. The latter can be disabled in the Communicator settings. If the target does not support the Model Identifier feature, the Communicator outputs a warning in the log window as well.

### 5.9.2 Method

The Model Identifier uses a CRC-32 checksum.

To add the elements in the correct order, the following steps are required:

1. Update the Parameter Identifiers of all Blocks in the Model so that each Block has a valid Parameter ID
2. Sort all Blocks ascending by the Parameter ID
3. Repeat the following sequence for each block
  - (a) Get the unique Block label (containing all parent sub-systems) and add the ASCII value of each character to the checksum, starting with the first character
  - (b) Get the 16-bit Block Implementation identifier and add the value as 2 8-bit values, LSB first
  - (c) Get the 16-bit Parameter ID and add the value as 2 8-bit values, LSB first
  - (d) Get the Parameter ID of the Blocks connected to each Inport, starting with the first Inport, and add each 16-bit Parameter ID as 2 8-bit values, LSB first

## 6 Basic structure of the C Code

When setting up a new project with X2C code generation it is necessary to configure the hardware on the target system. The following section provides basic information how the *Blinky* demo applications are structured. With this understanding one should be able to adapt hardware configuration for further projects.

In the following the *Blinky* demo application in combination with the *TI Piccolo F28069 ControlSTICK* and the *TMS320F28069* Processor is used for demonstration.

**Info:** The \*.c files listed below need to be updated in case of changes in the *Xcos* model configuration.

### 6.1 Main.c

- **initInterruptVector()** defined in *Hardware.c* configures the target specific interrupts.
- **initSerial()** defined in *Hardware.c* initializes the serial interface.
- **initHardware()** defined in *Hardware.c* here the peripheral devices such as *Watchdog*, *GPIO Ports*, *ADCs*, *Timers* and others are defined.
- **X2C\_init()** defined in *X2C.c* calls the initialization functions of the X2C blocks.
- The **while(1)** loop is mainly used for the serial communication.
- The **mainTask()** function is the key structure of the project. Here the connection between *Outports* and *Inports* are defined and the *X2C\_Update()* function (defined in *X2C.c*) is called. The basic structure of the *mainTask()* is
  1. Assign Inports
  2. Call *X2C\_Update()*
  3. Update Outports

The *mainTask()* function is usually called by an *Interrupt Service Routine (Isr)* which can be triggered by multiple sources.

**Example:** In the *Blinky Demo Application* after each *ADC* conversion cycle the *ADCIsr* calls the *mainTask()* function.

- **KICK\_DOG** resets the *Watchdog* timer periodically. During operation this timer continuously counts a certain time span (configured in *Hardware.c*). If the application has an unexpected failure *KICK\_DOG* can not be called and the *Watchdog* timer exceeds its limit and therefore the target reboots. If the operation executes as expected the *Watchdog* timer is within the limit and can be reseted by *KICK\_DOG* without any further actions.

### 6.2 Hardware.c

In this file all connections and peripheral device settings should be made.

- In **initHardware()** all peripheral function should be initialized.
  - Watchdog timer
  - GPIO Ports
  - Interrupt initialization
  - ADC, Timer, PWM and all the other peripheral devices
- **initSerial()** initializes the serial interface on the target. The settings made here should match with the setting made in the *Communicator* described in Section 11.

## 7 Testing

### 7.1 JUnit tests

To minimize the risk of software bugs most parts of X2C are tested. The Java core of X2C is tested with JUnit tests.

### 7.2 CUnit tests

Much care is also taken of testing the C-code of the blocks. These so called CUnit tests are conducted directly on the target. In Figure 9 the test setting can be seen.

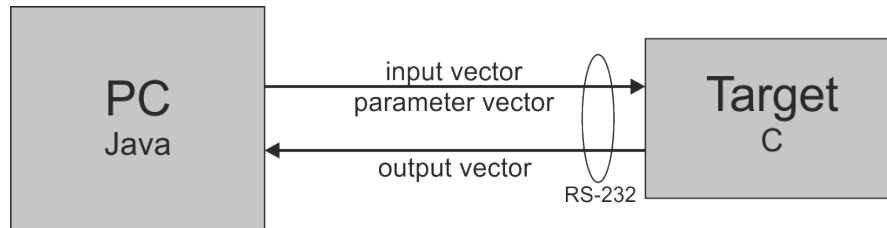


Figure 9: CUnit test setting

In the test environment on the PC a input vector and a parameter vector, if necessary, are defined and sent to the target via serial interface. On the target the update function of the block under test is executed. The resulting output vector is transferred back to the PC where it is compared with a reference output vector. If the difference between the actual and the reference output vector is below a specified limit the test is marked as passed. Otherwise an error is reported.

Basically, the generation of the test vectors are done with one or a combination of these methods:

**Equivalence class testing** To reduce the number of test items they are grouped into classes with same behavior. Only one member of each equivalence class is used as entry for the test vector. Two simple equivalence classes could be positive and negative numbers.

**Boundary testing** The entries for the test vectors are chosen in such a way that they lie below and above critical boundaries. For example, typical values for a FiP16 implementation would be -32768, -32767, -1, 0, 1, 32767.

**Back-to-back testing** For complex blocks this method is used. The vectors are generated by simulating a block or model with the same functionality in Simulink or Xcos.

Several different targets are used for testing. The test reports can be found in the library documentation *Library.source.pdf* in the directory `<X2C_ROOT>\Library`.

## 8 Coding Conventions

### 8.1 Language

The native language of X2C is English. Hence all documentation, file names, variables, comments in source files, etc. should be in English.

### 8.2 General naming conventions

- Unless otherwise stated, all names should use the camel case notation. A definition of camel case can be found on <http://en.wikipedia.org/wiki/CamelCase>. The type of camel case (upper or lower) depends on the type of name, see sections below.

Examples: `ThisIsUpperCamelCasing.java`, `showLowerCamelCaseExample()`

- Only meaningful names should be used. Abbreviations should be avoided, unless they are widely used.
- Non-ASCII characters should be avoided. Also the space character should not be used.
- Due to a character limitation in Scilab 5, names with more than 27 characters should be avoided.
- Names should not start with a number.
- [Hungarian notation](#) should not be used.

### 8.3 Naming of files

In general files should have a meaningful name. If abbreviations are used, easy understandable ones should be used. Upper camel case is recommended.

Examples: `Hardware.c`, `SystemControl.c`, `GlobalDefines.h`

### 8.4 Naming of functions and methods

Function and method names should contain a verb to describe the action of the function. The verb is placed first and is in lower case and subsequent nouns start with a capital letter (lower camel case).

Examples: `readADC()`, `setPWM()`

### 8.5 Naming of macros

Macros should be written in capital letters. Macro names which contain multiple words should use an underscore as separator (screaming [snake case](#)).

Examples: `DISABLE_PWM`, `NO_ERROR`

### 8.6 Naming of variables

Based on the proposed convention from Sun Microsystems following guidelines should be considered:

*"Variables are in mixed case with a lowercase first letter. Internal words start with capital letters. Variable names should be short yet meaningful. The choice of a variable name should be mnemonic- that is, designed to indicate to the casual observer the intent of its use. One-character variable names should be avoided except for temporary "throwaway"*

variables. Common names for temporary variables are *i, j, k, m, and n* for integers; *c, d, and e* for characters."

Examples: `int16_t i; float32_t myWidth;`

## 8.7 Naming of type definitions

Type definitions as well as structure definitions should be written in upper camel case to distinguish them from variables.

Example:

```
typedef uint16_t MyType;

struct MyStruct
{
    uint16_t member1;
    int32_t member2;
};

struct MyStruct myStruct1;
struct MyStruct myStruct2;
```

## 8.8 Naming of model parameters

Parameter and variable names in Matlab or Scilab should follow lower [snake case](#) notation. This means the first word can either start with a lower or upper case letter, all subsequent words have to start with a lower case letter, and the words are separated by underscores.

Examples: `i_ref`, `n_max`, `k_T`, `U_dc_max`

## 8.9 Naming of X2C blocks

Block and Subsystem/Superblock names in Matlab or Scilab should follow upper camel case notation. Exceptions are words with abbreviations, then a underscore character as separator is allowed to increase readability.

Examples: `CurrentController`, `OffsetAngle`, `AnIn1`, `DigOut1`, `i_Phase1`, `m_Phase1`, `iq_Ref`

## 8.10 Formatting

### 8.10.1 Intending

For code intending **four spaces** should be used, tabs should be avoided.

### 8.10.2 Braces

Braces should be placed according to the [Allman style](#). *"This style puts the brace associated with a control statement on the next line, indented to the same level as the control statement. Statements within the braces are indented to the next level."*

Though braces in separate lines increase the line count they have some advantages in terms of identification of code blocks, selecting statements by pre-processor macros, commenting out statements without breaking the code, etc.

An exception is the do-while loop, where the braces should be on the same line as the statements to make it easy to see that the while statement belongs to the loop.

### 8.10.3 Spaces

Between a statement and its opening parentheses a space should be inserted.

A space is also suggested after the comma between two function parameters, variables, array elements, etc.

Before and after an operator, relation symbol, etc. a space should be inserted.

### 8.10.4 Return statement

The return argument shall be enclosed in parentheses.

### 8.10.5 Example

Listing 1: Formatting example

```
/* *
 * @brief Function to read ADC results .
 *
 * @param result Array with ADC results
 * @param method Variable which averaging method information
 * @return Number of iterations
 */
int16_t readInputs(uint16_t result[], int8_t method)
{
    int16_t x = 0, i = 0;

    if (method < 0)
    {
        readADC(result[0], result[1]);
    }
    else if (method > 0)
    {
        readADC(result[2], result[3]);
    }
    else
    {
        /* Do nothing in the else branch */
    }

    for (i = 0; i < MAX_SIZE; i++)
    {
        x++;
    }

    while (x < 0)
    {
        x = x + 2;
    }

    do {
        x = x - i;
    } while (x > 0);

    return (x);
}
```

## 8.11 Source and header files

Every \*.c source file should have a corresponding \*.h header file. A minimalistic header with prototype definitions is sufficient.

Due to MISRA rule 8.1 (see [MISRA-C 2004 compliance](#)) it is required to have prototypes for every function, including static ones. To avoid conflicts between global and static function prototypes when including header files, the following rule shall apply:

- Global function prototypes should be located in its header file
- Static function prototypes should be located at the beginning of its source file

## 8.12 File headers

X2C developers should use following headers in the source files.

Listing 2: \*.c header template

```
/*
 * $Revision: 4131 $
 * $Date:: 2026-03-16 17:20:39 +0100#$
 *
 * ===== CONFIDENTIAL =====
 * The content of this file is confidential according to the X2C
 * Licence Terms and Conditions.
 *
 * Copyright (c) 2026, Linz Center of Mechatronics GmbH (LCM), web:
 * www.lcm.at
 * All rights reserved.
 */
```

Listing 3: \*.h header template

```
/**
 * @file
 * @brief Enter here a brief description
 */
/*
 * $Revision: 4131 $
 * $Date:: 2026-03-16 17:20:39 +0100#$
 *
 * ===== CONFIDENTIAL =====
 * The content of this file is confidential according to the X2C
 * Licence Terms and Conditions.
 *
 * Copyright (c) 2026, Linz Center of Mechatronics GmbH (LCM), web:
 * www.lcm.at
 * All rights reserved.
 */
```

## 8.13 Global definitions

Definition of macros which are used in more than one source file should be placed in GlobalDefines.h. Macros only used in one file should be defined in the source file in which they are used.

Globally needed variables should be defined in GlobalDefines.c and declared in GlobalDefines.h. This way all global variables are at one place and can be referenced from every file which has the GlobalDefines.h header file included. Exceptions are global



variables used in firmware modules/drivers which can not be substituted without major drawbacks.

Example:

Listing 4: GlobalDefines.c

```
#include "GlobalDefines.h"

/* ***** */
/* Global Variables */
/* ***** */
uint16_t errorState = NO_ERROR; /* Error Message */
uint32_t moduleState = NO_ERROR; /* Module Status */
FIStates fiState = RESET_STATE; /* State of frequency inverter */
```

Listing 5: GlobalDefines.h

```
#ifndef GLOBALDEFINES_H
#define GLOBALDEFINES_H

#include "Target.h"
#include "X2C.h"

/* ***** */
/* Global Variables */
/* ***** */
extern uint16_t errorState; /* Error Message */
extern uint32_t moduleState; /* Module Status */
extern FIStates fiState; /* State of frequency inverter */

#endif
```

## 8.14 Template files

For an easy orientation standard file names should be used in X2C projects:

- Config.h: Basic configuration settings for frame program.
- Main.c: Frame program main file.
- Hardware.c: Hardware configuration and initialization.
- GlobalDefines.\*: Files with globally needed definitions and variables.
- SystemControl.c: File with startup sequence of power electronics and error handling.
- InterruptControl.c: Interrupt handling, especially interrupt vector table and interrupt service routines.
- InputControl.c: Handling of analog and digital inputs.
- OutputControl.c: Handling of analog and digital outputs.
- CANControl.c: Configuration, initialization and functions of a CAN interface.

Of course, if files contain a lot of code it is recommended to split the file into several ones to maintain comprehensibility.

Example: Splitting of InputControl.c in AnalogInputControl.c, DigitalInputControl.c and HallSensorControl.c

## 8.15 Include order of header files

To avoid conflicts and missing dependencies header files should be included in following order:

1. System headers
2. Application headers
3. Header of current source file

Example:

Listing 6: Main.c

```
#include "VersionInfo.h"
#include "GlobalDefines.h"
#include "Hardware.h"
#include "SystemControl.h"
#include "InputControl.h"
#include "OutputControl.h"
#include "Main.h"
```

## 8.16 Hardware registers

To maintain comprehensibility and to allow interchangeability of source files hardware (DSP) registers should be accessed via macros.

Example:

```
#define SET_LED      (GPBSET = 0x00000004U)

/* some code */
SET_LED;
/* some more code */
```

instead of

```
/* some code */
GPBSET = 0x00000004;
/* some more code */
```

## 8.17 Doxygen documentation

The C source code should be documented with doxygen commands so that a documentation can be easily created. Javadoc style is advised, this means a comment block starts with two `/*`s, like this

```
/**
 * some documentation text
 */
```

Additionally, the Javadoc style `@` character should be used for doxygen tags.

Examples: `@brief`, `@param[in,out]`, `@return`, etc.

To enable documentation, the line

```
/** @file */
```

must be in the file containing the code to be documented, preferable in the `*.h` header file.

## 8.18 List of commonly used abbreviations

| Abbreviations |                                                     |
|---------------|-----------------------------------------------------|
| AC            | Alternate Current                                   |
| ADC           | Analog to Digital Converter                         |
| CAN           | Controller Area Network                             |
| DC            | Direct Current                                      |
| DSP           | Digital Signal Processor                            |
| EEPROM        | Electrically Erasable Programmable Read-Only Memory |
| FOC           | Field Oriented Control                              |
| I2C           | Inter-Integrated Circuit                            |
| PWM           | Pulse Width Modulation                              |
| RAM           | Random Access Memory                                |
| ROM           | Read-Only Memory                                    |
| SPI           | Serial Peripheral Interface                         |
| UART          | Universal Asynchronous Receiver / Transmitter       |
| USB           | Universal Serial Bus                                |

## 9 MISRA-C 2004 compliance

The rules of the Motor Industry Software Reliability Association [MISRA](#) should be followed as much as possible. Some major rules are:

- **MISRA-C:2004 2.2/R:** Source code shall only use `/* ... */` style comments.
- **MISRA-C:2004 19.4/R:** C macros shall only expand to a braced initialiser, a constant, a string literal, a parenthesised expression, a type qualifier, a storage class specifier, or a do-while-zero construct.
- **MISRA-C:2004 8.12/R:** When an array is declared with external linkage, its size shall be stated explicitly or defined implicitly by initialisation.
- **MISRA-C:2004 18.4/R:** Unions shall not be used.
- **MISRA-C:2004 16.3/R:** Identifiers shall be given for all of the parameters in a function prototype declaration.
- **MISRA-C:2004 19.15/R:** Precautions shall be taken in order to prevent the contents of a header file being included twice.
- **MISRA-C:2004 19.1/A:** `#include` statements in a file should only be preceded by other preprocessor directives or comments.
- **MISRA-C:2004 8.1/R:** Functions shall have prototype declarations and the prototype shall be visible at both the function definition and call.

### 9.1 Applied rules

```
1  /* Enable MISRA-C:2004 checking (all rules) */
2  --check_misra="all"
3
4  /* Rule violation handling */
5  --misra_advisory="warning"
6  --misra_required="warning"
7
8  /* Exceptions */
9  --check_misra="-1.1" /* (MISRA-C:2004 1.1/R) Ensure strict ANSI C mode (-ps)
   is enabled */
10 --check_misra="-12.7" /* (MISRA-C:2004 12.7/R) Bitwise operators shall not be
   applied to operands whose underlying type is signed */
11 --check_misra="-19.7" /* (MISRA-C:2004 19.7/A) A function should be used in
   preference to a function-like macro */
12 --check_misra="-5.7" /* (MISRA-C:2004 5.7/A) No identifier name should be
   reused */
```

Listing 7: MISRA.opt

## 10 *Scilab* & *Xcos* user notes

### 10.1 *Xcos* Diagram

Only blocks from the X2C *Xcos* libraries can be used to construct an X2C model. *Xcos* native blocks are permitted on the left side (input) of an X2C inport block and on the right side (output) of an X2C outport block for simulation purposes.

This limitation does not apply for the following *Xcos* event handling blocks since these are required for the X2C sample time and for X2C blocks that have an event input:

- CLOCK\_c to define a base sample time for the X2C model and time dependent X2C blocks
- freq\_div to define a different sample time derived from the base sample time for time dependent X2C blocks
- CLKFROM and CLKGOTO to simplify event signal routing

There are several additional exceptions for *Xcos* elements that can be used with or within X2C blocks.

#### **Structural element exceptions**

- Super block

#### **Simulation element exceptions**

- SCOPE elements from the Sinks palette

## Part III

# Utilities

### 11 Communicator

The *Communicator* is the interface between the target system and the model in *Xcos* . It is used to generate the C code files out of the model. Furthermore it is used to transfer data between the computer and the target. When started the *Communicator* is connected with the model via *RMI* interface and via serial interface with the target (DSP).

#### 11.1 *Xcos Communicator start*

As described in Section 16 the *Communicator* is started out of an open *Xcos* model with the buttons *start Communicator*. The button *Transform model and push to Communicator* loads the model file (.xml) into the *Communicator*. Changes in the model structure can be made and pushed to the *Communicator* by double clicking on the button *Transform model and push to Communicator*.

#### 11.2 Standalone *Communicator start*

If there are no intended changes in the model structure it is possible to start the *Communicator* without *Xcos* . In <X2C\_ROOT>\System\Java double click on **Communicator.jar**. In the open *Communicator* go to **Model** → **Load Model** and browse to your project directory. In the *X2CCode* folder choose the model (.xml) file and open it. In the *Status* tab check the *Log* area if the model has been loaded successfully.

#### 11.3 Basic functions of the *Communicator*

The *Communicator* is structured into the menu bar (1) the toolbar (2) and four main tabs (3).

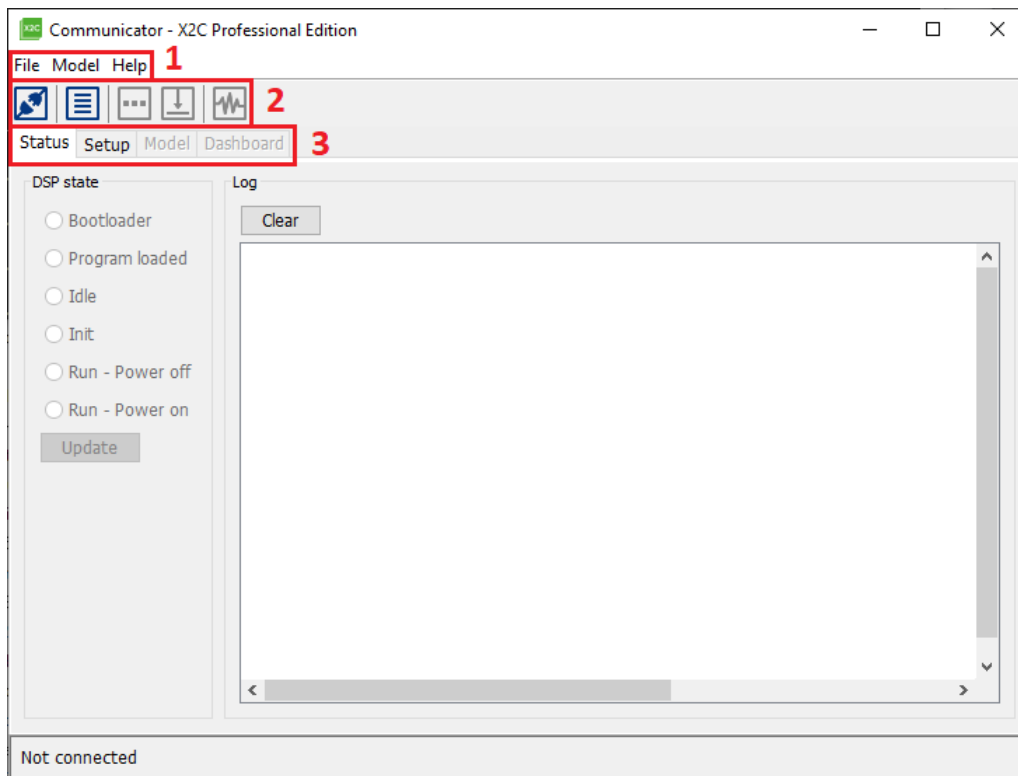


Figure 10: Basic structure of the *Communicator*

### 1. Menu bar

- In the **File** menu the settings can be modified, loaded and saved.
- In the **Model** menu a new *.xml* file can be loaded and saved.

### 2. Toolbar

- With the button **Connect to Target** the *Communicator* can be connected respectively disconnected from the target.
- **Create Code** generates the *X2C* C code files out of the *X2C* model. Changes in the *Model* tab like *Sample time* require new code creation.
- **Create RTOS Code** was moved to *Settings*. See [11.4](#) for details.
- In the **Download settings** the *Binary* and *MAP* files can be selected. These files are usually generated during the build process and are used by the *Communicator* for the following purposes:
  - (a) The binary is required to download an application to the target system. This feature is not available in the free edition.
  - (b) The MAP file is optional and is required only to view global variables in the *X2C Scope*. See [12](#) for details.
- The **Download application to target** function is only available in the Professional edition of *X2C*. This function provides application download functionality without any use of external programming devices.
- The **Scope** button starts an oscilloscope like environment for plotting signals and variables of the running target. For more information see [Section 12](#).

### 3. Tabs

- In the **Status** tab there are two main areas as seen in [Figure 11](#). In *DSP state* the current status of the connected target is shown. The following states are possible:

- The **Bootloader** state indicates that no valid/working application is present on the target system. Bootloader and Application download are available in the Professional edition only.
- The **Program loaded** state indicates an application is present and running.
- In the **Idle** state only the communication between target and computer is active. All controller functions are inactive furthermore the *Outports* values are static.
- The **Init** state calls the initialization functions of all *X2C* blocks. In this state all signals and variables are reset to their initial values.
- **Run - Power off** means the application is running normally but the power supply of the power electronics (e.g. frequency converter) is off.
- In **Run - Power on** the system is fully active.

**Info:** In the *Blinky* demo application the last four states cannot be changed because they are only useful for engine control applications.

The *Log* area shows status updates and error messages and can be cleared with the *Clear* button.

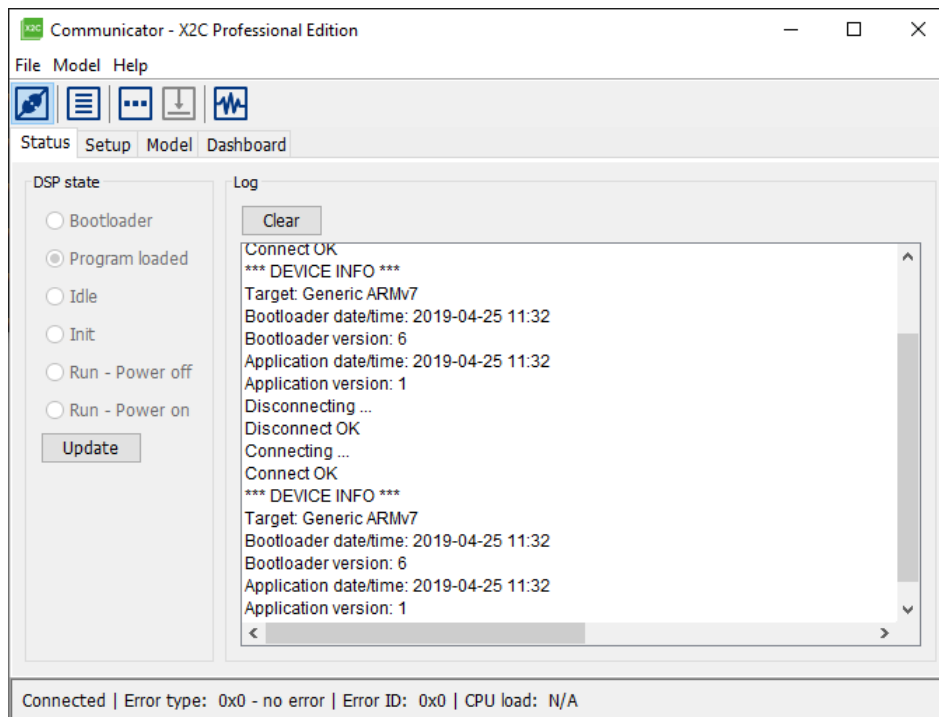


Figure 11: *Communicator* status

- The **Setup** tab is for the interface configuration. To change the settings the *Communicator* needs to be disconnected from the target. There are a few ways to connect with the target. One can choose between *Serial*, *USB* and *PCAN* interface. The setting made here need to be compatible with the target configurations. In the *Protocol* area the *LNet Node ID* can be set. By default this value is set to 1. Since the *Communicator* can be used with more than one target each target is defined with an unique *LNet Node ID*.



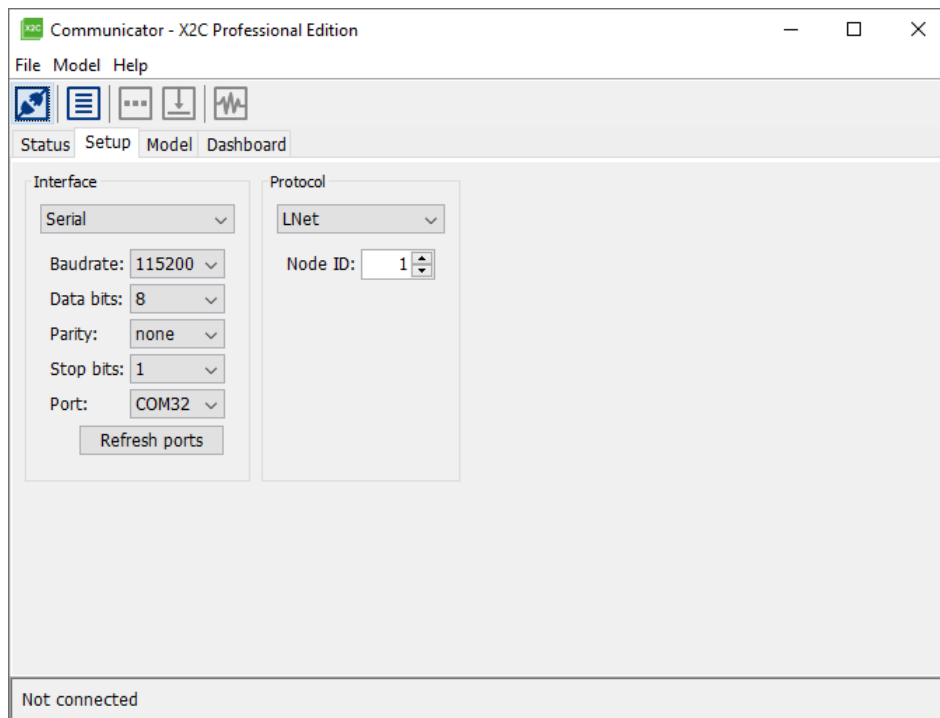


Figure 12: *Communicator* setup

- In the **Model** tab the *Model structure* area provides a list of the used blocks in the *Scilab* model. Jump to Section 11.5 to see how variables can be changed through the *Model structure* settings.

The *Model properties* settings need to be made before code generation.

- The *Sample time* can be changed in the *Xcos* model by changing the values in the *CLOCK* block. After double clicking on *transform model and push to Communicator* the sample time in the *Communicator* is updated. After clicking on *Analyze* the sample in the *Communicator* is updated.

**Note:** Changes of the sample time made in the model need to be compatible with the defined sample time on the target.

- *Use Scope* was moved to *Settings*. See 11.4 for details.
- *Use Parameter ID for block data transfer* was moved to *Settings*. See 11.4 for details.

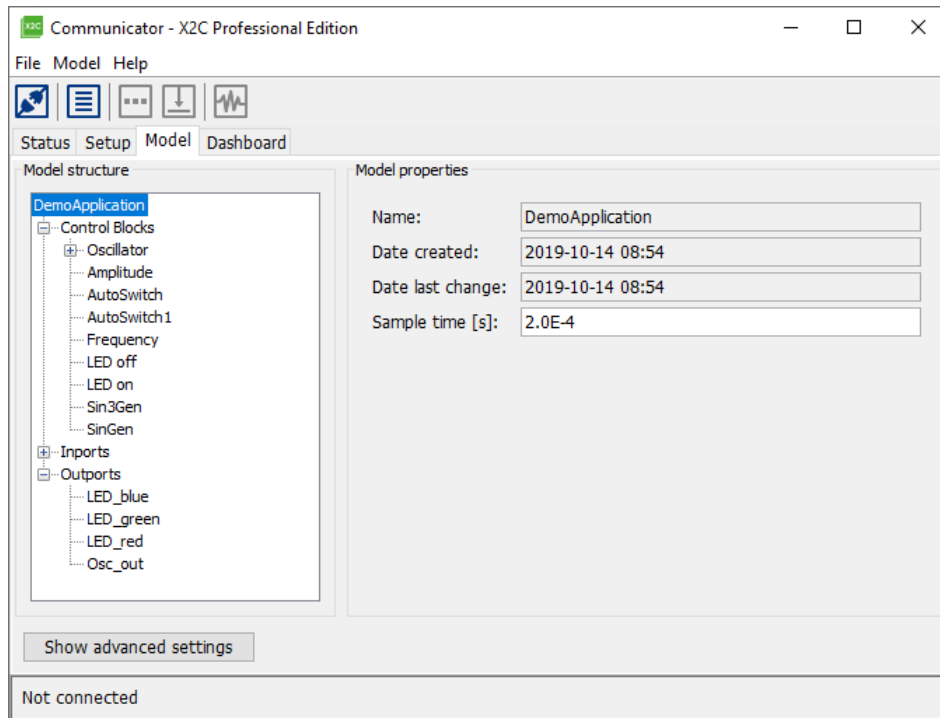


Figure 13: *Communicator Model*

## 11.4 Settings

The Settings can be found in the *File* menu. The Settings view is divided into 4 tabs.

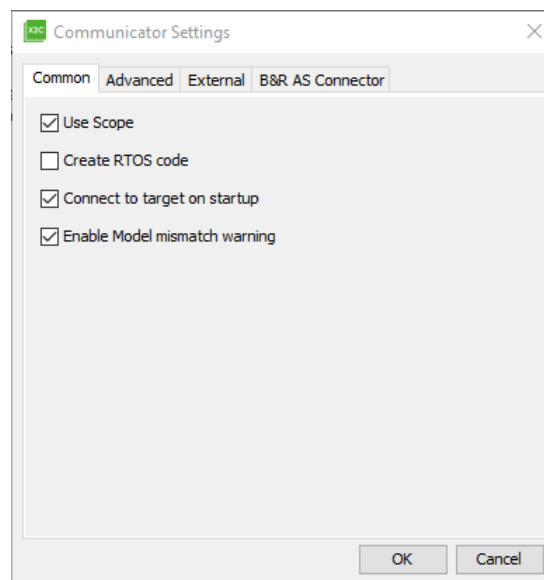


Figure 14: *Communicator Settings*

### Common

- **Use Scope** [enabled]

*Use Scope* defines if the scope application (see Section 12) can be used when connected with the target. When disabled the target processor is relieved due to less communication effort.

- **Create RTOS code** [disabled]  
Generates code which is optimized for real time operations.
- **Connect to target on startup** [enabled]  
Tries to connect to the target when the Communicator starts. If this option is enabled, the previously used communication setup is being used.
- **Enable Model mismatch warning** [enabled]  
If this option is enabled, a warning dialog is shown if the target Model ID differs from the Communicator Model ID. If the Model ID feature is not supported by the target or if no Model is present in the Communicator, this option is ignored.

## Advanced

- **Create Signals code** [disabled]  
Creates a file containing lists with internal X2C signals. These signals are Inports, Outports and Block Outports.
- **Create & compile HotInt code** [disabled]  
Generates HotInt specific files. After successful generation, the HotInt project (Microsoft®Visual Studio) is being compiled. The latest version being found is used for compilation. Supported Visual Studio versions:
  - Visual Studio 2013
  - Visual Studio 2012
- **Enable Code For Speed Optimizer** [disabled]  
Allows the usage of the Code For Speed Optimizer. Refer to [14](#) for details.

## External

Allows to select executables which are executed

- before code generation (Pre-Generate)
- after code generation (Post-Generate)

## B&R AS Connector

This tab allows to configure the X2C Connector for *B&R Automation Studio*. Refer to [22](#) for details.

## 11.5 Change parameters on the target with the *Communicator*

If all connection are set up properly there are two ways of changing the parameter values on the running target.

1. In the *Communicator* click on **Model**. In the Model structure area all the Block properties are listed and can be changed by double clicking on them.
2. In the *Xcos* model double click on the blocks and change the values.

## 12 Scope

The *Scope* application is a very useful device for monitoring signals and variables on the running target. It allows an easy observation in an oscilloscope like environment. The *Scope* is structured into four main areas as seen in Figure 15.

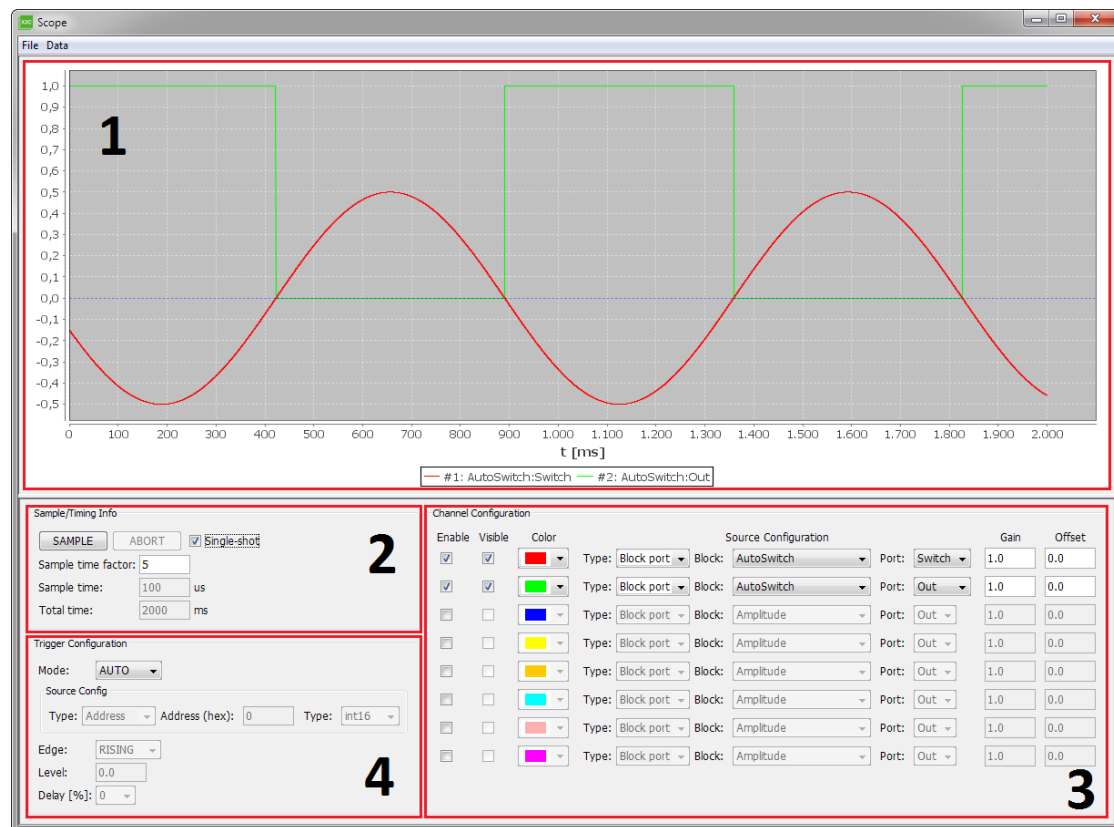


Figure 15: Communicator Scope

1. The **Plot area** shows the selected values at a time based abscissa (x-coordinate) in milliseconds and scaled from  $-1.0$  to  $1.0$  at the ordinate (y-coordinate). Furthermore there is a legend at the bottom of the plot area showing the color of each channel.
2. In the **Sample/Timing Info** section options of the time axis can be made. The oscilloscope is started with the button *SAMPLE*. When the option *Single-shot* is marked only one time period (see *Total time*) is shown in the plot area. When unmarked the plot area continuously plots the received values from the target. Due to time delay in data transfer it is possible that there are missing values between two plot cycles. The plot process can be stopped with the button *ABORT*.  
With the option *Sample time factor* the time axis can be scaled. Factor 1 means every value (Time between two values is *Sample Time*) is plotted in the plot area. As example factor 5 means every fifth value is used, therefore a longer time span can be plotted at the time axis.
3. The **Channel Configuration** configures which signal is shown at the plot area. There are eight channels that can be plotted simultaneously. Mark *Enable* to configure one channel. In the *Type* menu *Address*, *Block Port* and *I/O port* can be chosen. *I/O ports* are the links between the target peripheries and the *X2C* model. The *Block Port* are

signals used in the *X2C* model.

When fixed point data representation is selected all signal are scaled to values between  $-1.0$  and  $1.0$ , therefore one might use the option *Gain* or *Offset* to plot the signal in real scale.

4. The **Trigger Configuration** is divided in the options *NORMAL* and *AUTO*. When option *AUTO* is chosen no specific trigger is set. In this configuration signal values are continuously transfer and plotted. This can lead to moving graphs especially when periodic signals are observed.

Choose *NORMAL* to set up a trigger.

- (a) In *Source Config* choose a signal which should work as trigger source.
- (b) With *Edge* the trigger only checks rising respectively falling edges of the source signal.
- (c) The *Level* and *Delay* options move the trigger point in vertical and time direction.

**Example:** Trigger the harmonic sine wave  $u$  from a *SinGen* block.

As trigger source the signal itself is used. When the trigger is delayed in time a vertical marker indicates the position. The effect of the settings *Level* with a value of  $0.2$  and *Edge* for *FALLING* can be seen in Figure 16.

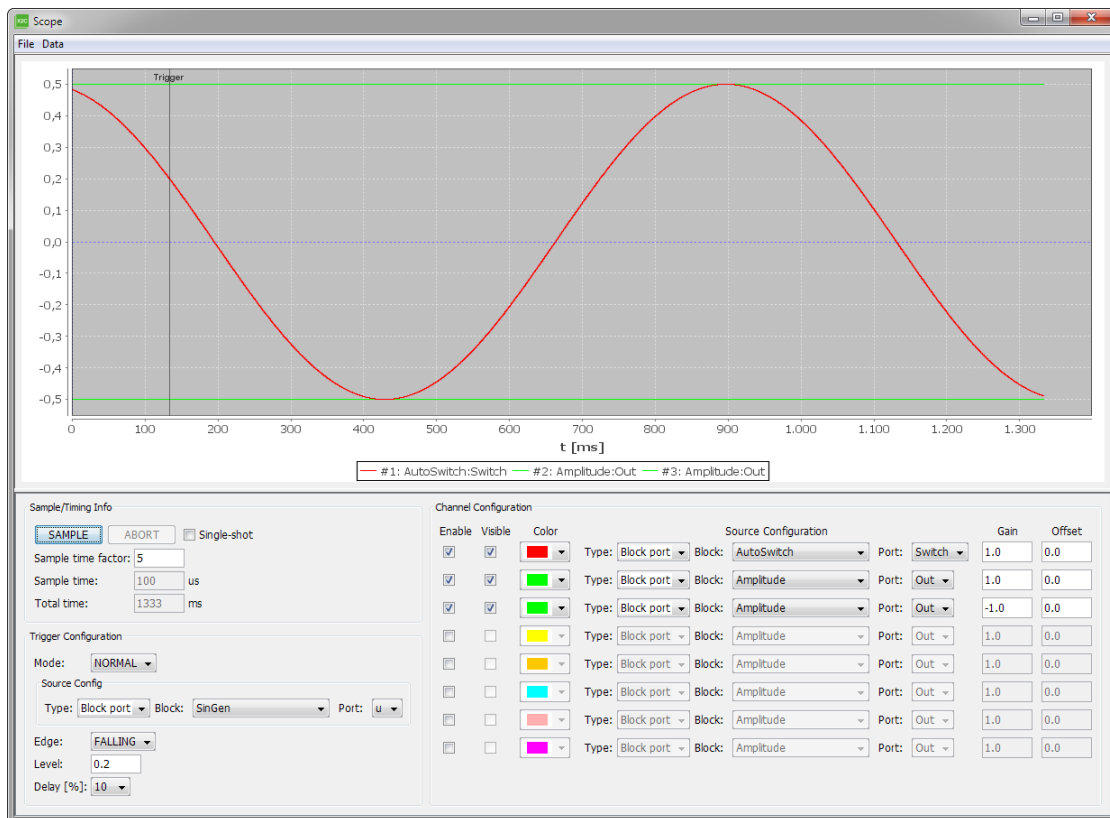


Figure 16: Scope Trigger using Example

## 13 Block Generator

The Block Generator is used to create new blocks, load and/or edit previously saved blocks. The following, essential parameters define the block function:

### 13.1 Block properties

#### Name

Each block within a library must have a unique name.

#### Library type

The library type selection is done via the 'Change configuration' button.

An internal library block will be stored within the X2C structure where only the library name is required. The internal library name can be selected via a dropdown menu.

When the block is saved, the files will be automatically saved into the correct directories.

An external (or project specific) block is stored within its project structure and requires the user to enter a library name and pre-namespace identifier. Both, the library name & pre-namespace, is entered via text fields.

When the block is saved, a window will appear, which allows to select the project directory for this project specific block (only directory selection is possible) The Block Generator tries to save the files in the following structure (directories will be created automatically if they don't exist):

<selected directory>\Library\<library name>\

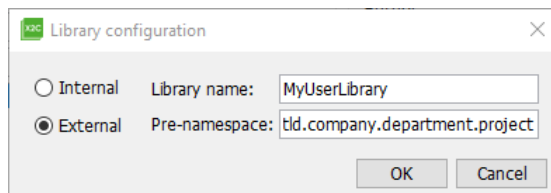


Figure 17: *Block Generator* External library settings

#### Identifier

Every block needs a unique identifier (ID) across all libraries to ensure proper functionality if a project uses blocks from different libraries. *ID* must not exceed 4095 and should be a value  $< 4000$  for internal blocks and a value  $\geq 4000$  for external blocks.

#### Additional $\LaTeX$ information file

In case of having a  $\LaTeX$  file with additional block information the name of the file can be set.

#### Mask In- & Outports

Every block can have several inports & outports. Each in-/outport must have a unique name.

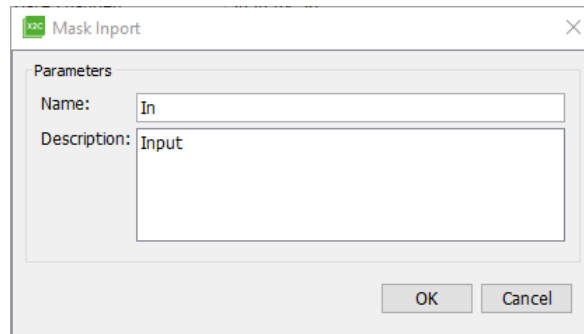


Figure 18: *Block Generator* Mask Inport

## Mask Parameters

Every block can have several mask parameters. Each mask parameter must have a unique name. *Prompt* will be displayed next to the value input of this parameter. *Data type* decides between an input field for type *Double* or a dropdown menu for type *ComboBox*.

In case of type *Double* you can select the *Default value* for this parameter.

Type *ComboBox* lets you add/remove items which can be selected by the user if this parameter value should be changed. The default value is defined by selecting one out of the entries.

*Visible* makes this parameter visible, *Changeable* en- or disables this parameter.

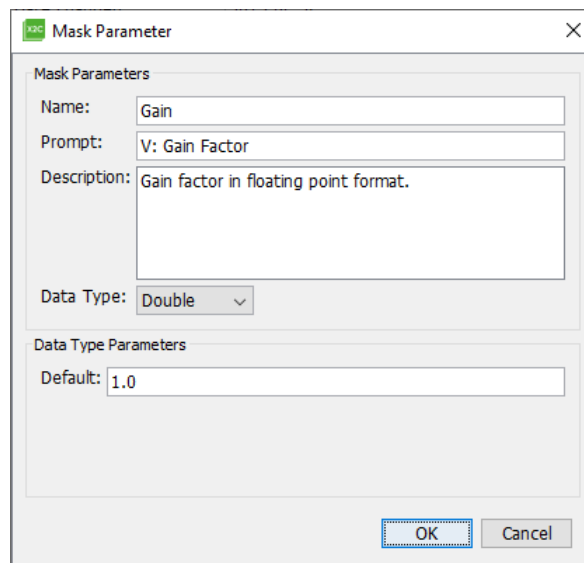


Figure 19: *Block Generator* Mask Parameter

## Visualizations

*Visualizations* are used to represent the block within a model. *Command* contains the language specific commands to represent the block.

## 13.2 Implementation properties

Every block must have at least 1 Implementation. Each Implementation has its Init-, Update-, Save- and Load functions (C) and Conversion functions (Java/Python/JavaScript).

### Name

Each implementation must have a unique name within a block. The Implementation name is used for C- & Java code file name.

### Controller In- & Outports

The Controller In- & Outport names can be selected but not edited. The names are defined by the block's Mask In- & Outports. Only the data type must be selected for each In-/Outport.

### Controller Parameter

Each Controller Parameter must have a unique name within its Implementation. The data type and default value can be selected. Also the ability to download/upload the parameter can be defined by using *Load & Save Enable* checkbox.

The *Array* option allows the Parameter to contain a data array instead of a scalar value. Two array configurations are possible:

- **Modifiable**  
Enabled by setting the *Array* checkbox and *Array size*. This type of array has a fixed size and is located in volatile memory. Due to volatile nature the data can be up- and downloaded.
- **Fixed**  
Enabled by setting both, the *Array* and *Array in flash memory* checkboxes. The size of this type of array is not fixed because it is generated on Model generation. It is located in non-volatile memory and therefore cannot be up- and downloaded.

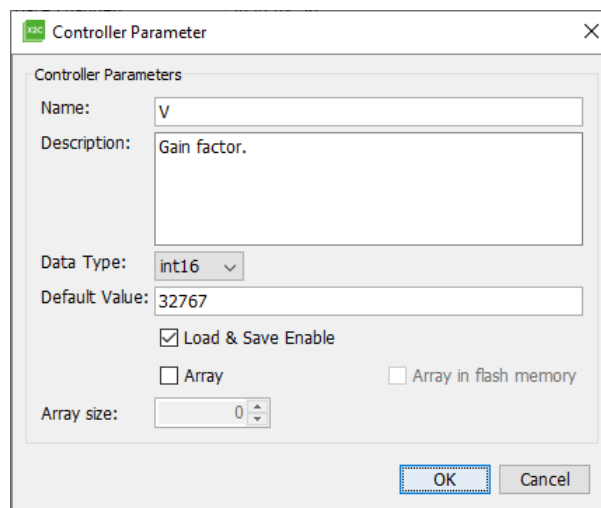


Figure 20: Block Generator Controller Parameter



## Conversion function type

The Conversion function type can be selected by using the dropdown menu. If *Java*, *Python* or *JavaScript* is selected, the Block Generator will generate a conversion function template file for this block which needs to be manually filled with block-specific conversion calculations, otherwise no conversion function file will be created.

### 13.2.1 Advanced Implementation Settings

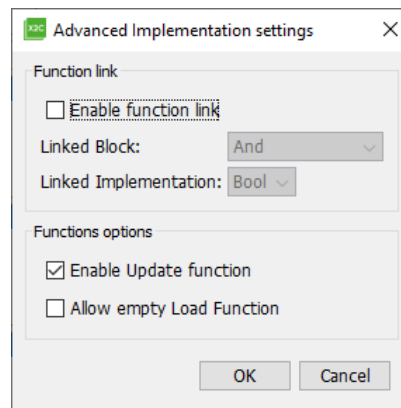


Figure 21: *Block Generator* Advanced Implementation Settings

## Function Link

If this option is enabled, the *Init*-, *Update*-, *Load*- and *Save* Block functions are used from an other Block Implementation. A Block within the same *X2C* library may be selected as link source.

## Update Function

This option is enabled by default. If disabled, the Implementation does not have a (cyclic) Update function.

## Allow empty Load function

Forces the Block Generator to create a *Load* function even if the Implementation doesn't contain any transmittable parameters. The user customizable part of the *Load* function may be used to change the *Load* functions' default behaviour.

## 13.3 Save or load a block

Saving & loading is done via the *File* menu in the menu bar.

### Saving

If the selected block is member of an internal library, the Block Generator automatically uses the correct library root directory.

In case of an external library block type, the user is prompted a directory selection window, in which the project directory can be selected. The library root directory is now located in: <user directory selection>\<Library>\<library name>.

Each library is organized in this structure:

- Controller: Directory with the C-code source files (\*.c, \*.h).
- Conversion: Directory with the Java, Python or JavaScript conversion files.
- Doc: Directory with files needed for the (auto-generated) documentation.
- Scilab: This directory contains the *Xcos* library files as well as the interfaces functions and the files need for simulation in *Xcos* .
- XML: Configuration files (\*.xml) contain all block parameters and are located in this directory.

## Part IV

# Add-Ons

### 14 Code For Speed Optimizer (CFSO)

The CFSO allows the optimization of the X2C Update function(s) to decrease the execution time. TO achieve this, the CFSO, if activated, replaces the X2C Block function calls by the X2C Block Update code itself to remove the overhead of C function calls. The optimizer collects the required information from the Block-Implementation C source code. It can be enabled in the Advanced *Communicator* settings tab.

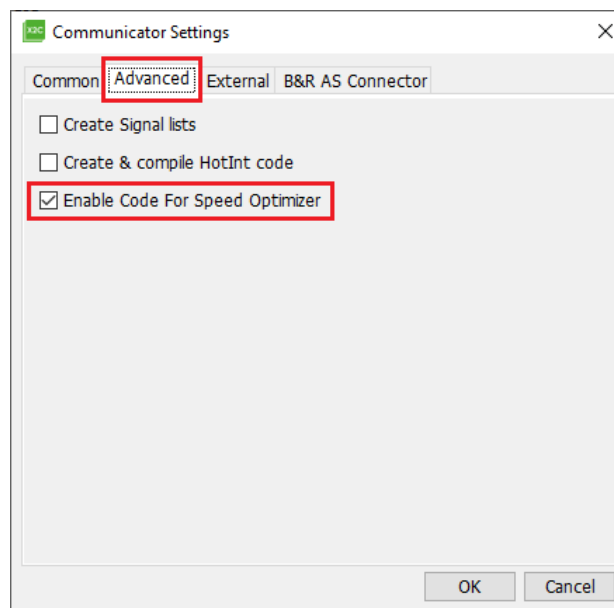


Figure 22: CFSO in Advanced *Communicator* settings

This feature is only available in editions **Plus** and **Professional**.

#### 14.1 Data Collection

The CFSO collects the data from the C source for each Block-Implementation type. If the source is not available, the Implementation is tagged to use the usual Update function call instead and the next Implementation type is processed. Otherwise the following Implementation specific elements are extracted from the C source:

- Preprocessor code
- Includes
- Define names
- Update function code

During data extraction, every occurrence of the Implementation Pointer variable is replaced by a placeholder. The data collection procedure is repeated for every Implementation type in the Model. In the further course the X2C Code Generator will replace the placeholder by the current Block variable.

### 14.1.1 Implementations using a function link

This kind of Implementation shares the Update function code with an other Implementation. In this case the Preprocessor code, Includes and Define names from both Implementations are merged. The Update function code is retrieved from the linked Implementation.

## 14.2 Code Generation

Once all the Implementation information is collected, the *X2C* Code Generator replaces every Update function call, except for the Implementations of which the sources are not available. Following elements are added at the beginning of the generated *X2C* C file:

- An informational line beyond the header to inform the user that the CFSO is active
- All collected Implementation C Includes

For each Update function the following content is added in the following order:

1. Preprocessor code
2. Implementation Update function
3. Undefine C macros (`#undef`) for all possible defined C macros

The placeholders, which were set during the data collection procedure, are replaced by the appropriate Block Implementation variable. In case of an Implementation with unavailable C source, the usual Update function call is used. A comment is added above the relevant Update function call for information.

## 15 Dashboard

The Dashboard allows the user to view and modify selected elements. Each element features various, configurable properties for a user friendly representation of each data value. The elements can be uploaded or downloaded - depending on the respective type.

A download can be done for each individual, editable entry by changing its value or for all editable values by using the 'Download Editable Values' button.

The upload procedure is started by the 'Start Update' button and uploads ALL uploadable values at a defined interval.

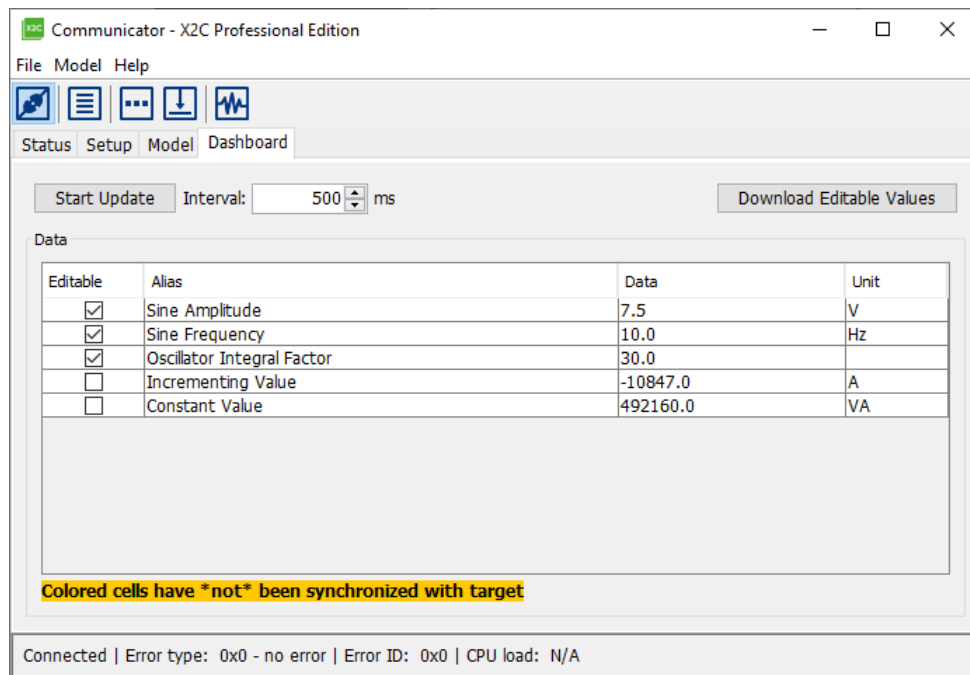


Figure 23: Communicator Dashboard View

This feature is only available in editions **Plus** and **Professional**.

### 15.1 Configuration File

The Dashboard configuration is stored in a properties file. Currently there is no GUI support to setup a Dashboard configuration. Instead, the user has to setup the file.

Configuration file templates are available to make the configuration process easier. These templates can be found in directory /Templates/Dashboard.

A Dashboard configuration can be loaded or cleared via the Communicator menus. Two options are available to either load a new configuration or clear the current configuration.

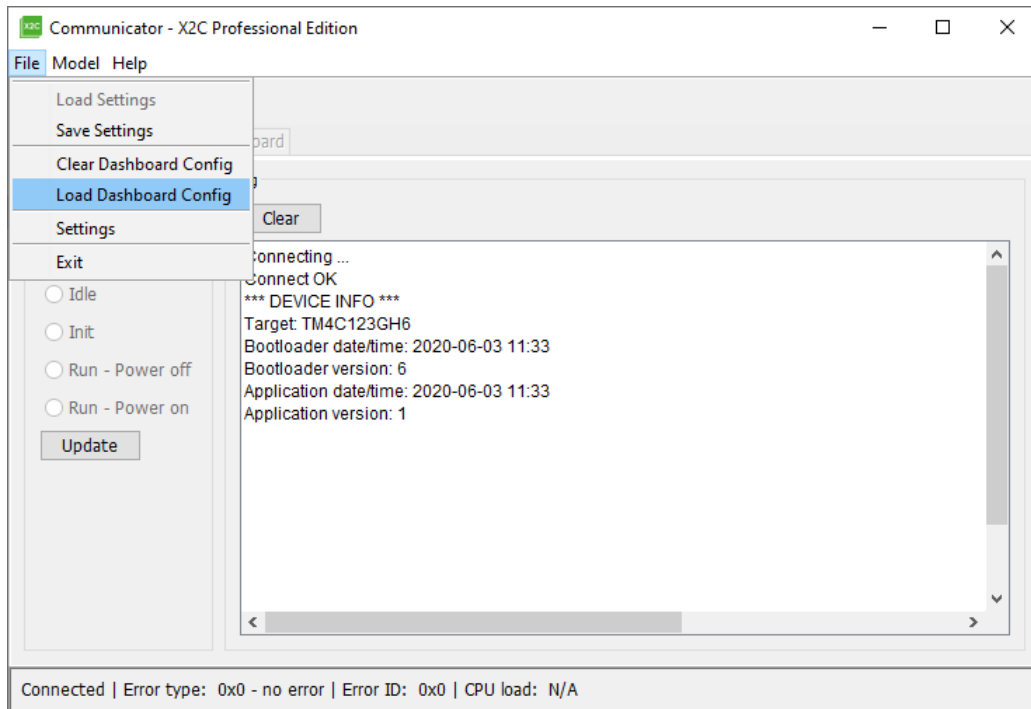


Figure 24: Communicator Dashboard configuration

These elements are usually contained in a configuration file:

### Property

A property is defined by a key and value. The syntax is  
KEY=VALUE

Example:

MODEL=MyModel.xml

### Comment

The hash symbol # introduces a comment line. Every line starting with a hash symbol is ignored by the configuration file parser. Example:

# This line is a comment

## 15.2 Common properties

Each Dashboard element does have common properties independent of its type.

### Alias name

If this property is set, the alias name will be displayed instead of the element name. Otherwise the element name is shown.

Property name: ALIAS

Example:

ALIAS=Show this text instead

## Offset & Gain

Applies Offset and Gain factors. This allows, for example, the transformation between physical unit and raw value. If one or both values are not set, the appropriate default value is used. The default for GAIN is 1.0, the default for OFFSET is 0.0.

Property name: OFFSET, GAIN

Example:

OFFSET=0.5

GAIN=2.0

ATTENTION:

The Offset and Gain calculation depends on the transfer direction (UPLOAD or DOWNLOAD).

DOWNLOAD (data is transferred from Dashboard to the target):

$$TargetValue = DashboardValue * GAIN + OFFSET$$

UPLOAD (data is transferred from the target to the Dashboard):

$$DashboardValue = (TargetValue - OFFSET) / GAIN$$

## Unit

Defines a physical unit. If this property is not set, no unit will be used.

Property name: UNIT

Example:

UNIT=MyUnitName

## 15.3 Element types

### 15.3.1 Block-Parameter

Allows to define an X2C Block and one of its Mask Parameters to be downloaded to the target. Following additional properties have to be set to identify the selected X2C Block:

- BLOCK  
X2C Block name
- PARAMETER  
Mask Parameter name of X2C Block
- MIN  
Defines the lower limit for the value  
If this value is not defined or empty, no lower limit is active.
- MAX  
Defines the upper limit for the value  
If this value is not defined or empty, no upper limit is active.
- VALUE  
Sets the initial Dashboard value  
If this value is not defined, the current Mask Parameter from the Block is used

This element type can currently be used for **download only**.

A complete example for a Block-Parameter element. This first 5 properties are Block-Parameter-type specific, the rest are common properties.

```
BLOCK=MyConstant  
PARAMETER=Value  
VALUE=5.0  
MIN=1.0  
MAX=12.0  
ALIAS=Voltage  
UNIT=V  
GAIN=300.0  
OFFSET=10.0
```

### 15.3.2 Variables

Allows to define a global symbol (variable) to be uploaded from the target and displayed in the Dashboard. Following additional properties have to be set:

- VARIABLE  
Variable name
- TYPE  
Data type of the variable

The data type can be one out of the following values:

int8, uint8, int16, uint16, int32, uint32, int64, uint64

The Boolean type is currently not supported. This element type can currently be used for **upload only**.

#### ATTENTION:

This feature requires a MAP file to be loaded in the Communicator because the target memory addresses for each global variable is extracted from the MAP file generated by the vendors' toolchain. If no MAP file is loaded, the variables will be displayed in the Dashboard View but the 'Start Update' button will remain inactive. If one or more invalid variable names are encountered in the Dashboard configuration file, an error message is shown in the Communicator log for every invalid variable name. Trying to use the 'Start Update' button will result in an error message showing the first invalid variable name.

A complete example for a Variable element. The first 2 properties are Variable-type specific, the rest are common properties.

```
VARIABLE=MyGlobalVar  
TYPE=int16  
ALIAS=Current  
UNIT=A  
GAIN=100.0  
OFFSET=0.0
```



## 15.4 Model Override

This property allows the Communicator to replace the currently loaded X2C Model or load a new Model at all. The property is optional and can be omitted if not used but must be defined at the beginning of the Dashboard configuration file if used. The value can be a filename or a fully qualified file name containing the complete path.

Property name: MODEL

Example:

MODEL=MyModelFile.xml

MODEL=C:\MyProject\Dashboard.txt

The Communicator log window displays a message if loading the Model from the configuration file was successful.

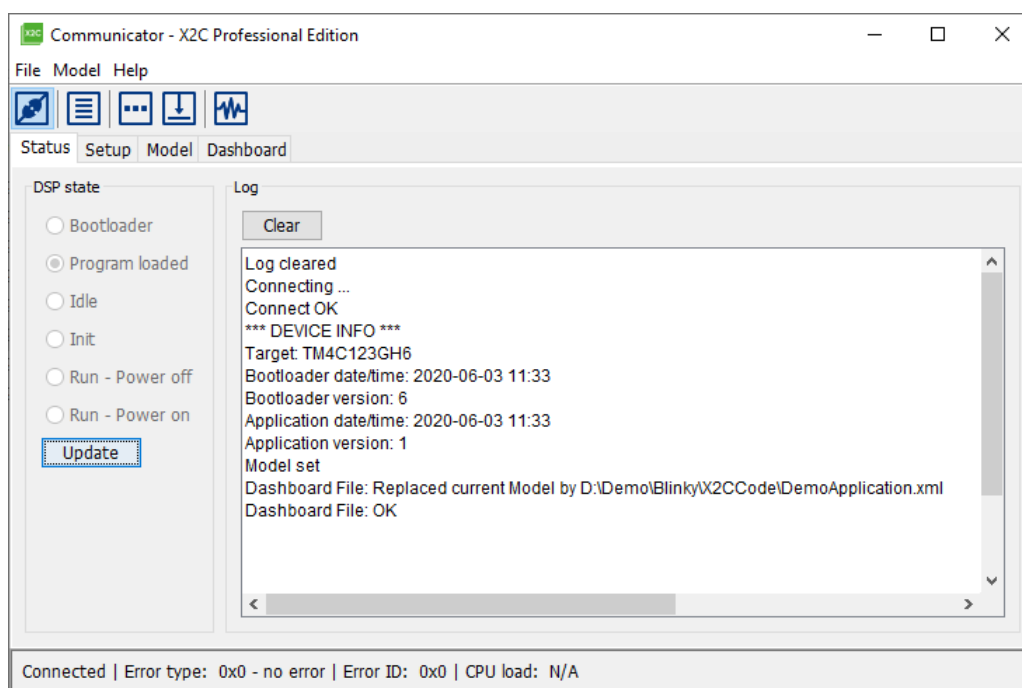


Figure 25: Communicator Dashboard Model log entry

## Part V

# How-To

## 16 X2C<sup>®</sup> code generation with Scilab

The following section describes *X2C* code generation of a *Xcos* model based on the *Blinky* demo application.

1. Open *Scilab* and in the file browser navigate to your project directory (e.g. <X2C\_ROOT>\DemoApplication\Blinky\_TI\_TMS320F28069\_controlSTICK\X2CCode).
2. Double click on **DemoApplication.zcos**. The example project contains a few blocks used to demonstrate the basic function of *X2C* (see Figure 26). The *Inport* and *Outport* blocks define the interface between the generated *X2C* code and the peripheral functions (e.g. ADC or GPIO Pins) on the target. For details about each block function read *X2Copen.Doc.pdf* in the documentation folder of the *X2C* directory.

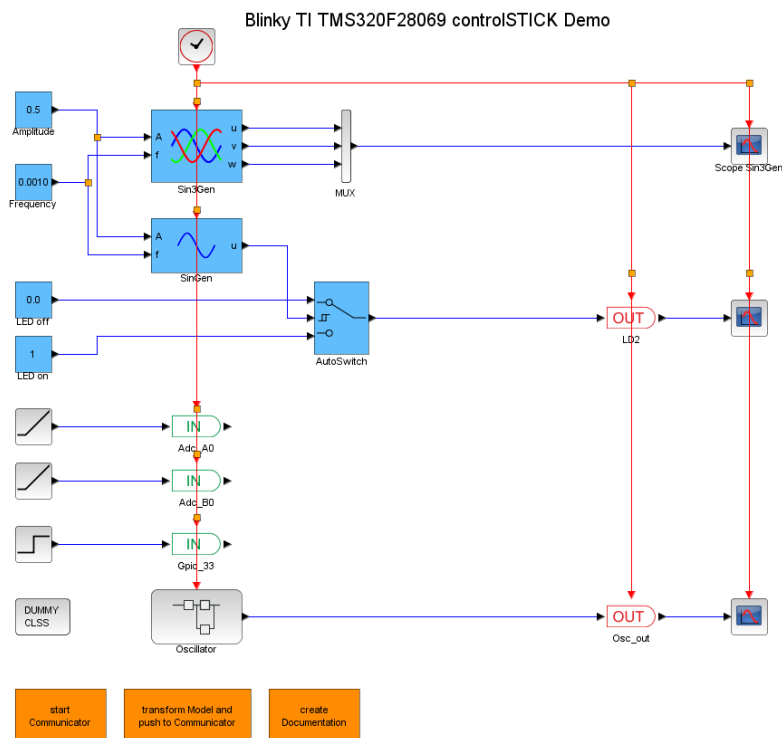


Figure 26: *Blinky* demo application in *Scilab*

3. Double click on **start Communicator** (for more information about the *Communicator* see Section 11). Some details of the current actions of the *Communicator* are shown in the *Log* area of the *Communicator* window and the *Scilab* command line:

```
1 Starting Communicator
2 done
3 Successfully connected to Communicator
```

- Double click on **Transform model and push to Communicator** and check the pop-up window for the end of the transformation process.

5. Click **Create Code** in the *Communicator*. Now the files *X2C.h* and *X2C.c* are generated in the <PROJECT\_ROOT>\X2CCode directory and the Log screen should contain the lines:

```
1  [...]
2  Model updated
3  Model XML file write: OK
4  Create code successful.
```

6. The *C* code for the *X2C* application has been created. Depending on the used target start the programming tool (e.g. *Code Composer Studio* , *STM32CubeIDE* or *MPLAB X* ) and import the *Blinky* demo application project as described in Section [17](#), or [18](#) respectively. Follow the instructions on how to configure and download the application to the target.

## 17 Loading and building the demo application Blinky in Code Composer Studio

The demo application *Blinky* is intended to be used with a *TI F28069 Piccolo controlSTICK*.

1. Connect the *TI F28069 Piccolo controlSTICK* to the computer.
2. Open *Code Composer Studio* (choose workspace directory as you like). Now click **Project** → **Import Existing CCS Eclipse Project**. Browse to the location of the *Blinky* project (<X2C\_ROOT>\DemoApplication\Blinky\_TI\_TMS320F28069\_controlSTICK). Click **Finish** to import the project.
3. In the *Code Composer Studio* file structure of the *Blinky* demo project there are two virtual folders *Blocks* and *Core*, which should be linked directly to the X2C directory. To ensure this go to **Project** → **Properties** drop down **Resource** and click **Linked Resources**. Double click on folder **X2C\_ROOT** and set the correct link to your X2C installation directory (<X2C\_ROOT>). After hitting **OK** two times there should not be any warning signs (like shown in Figure 27) at the icons for the linked files in the *Blocks* and *Core* folders.

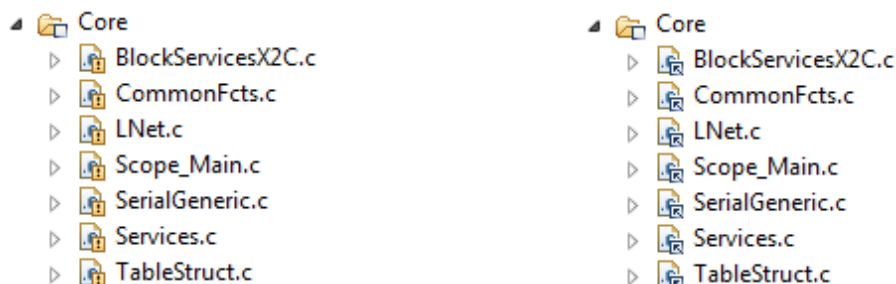


Figure 27: *Code Composer Studio* invalid (left) and valid (right) X2C root directory

4. The generated code from X2C is located in the folder <X2C\_ROOT>\DemoApplication\Blinky\_TI\_TMS320F28069\_controlSTICK\X2CCode. To check if code generation went fine go to the X2CCode folder and open *X2C.c*. Make sure time and date of code generation is plausible.
5. Build the project in *Code Composer Studio* by clicking **Project** → **Build all** or by clicking on the **Hammer** symbol as seen in Figure 28 at the top of the screen. Check for errors while building in the console at the bottom of the screen.



Figure 28: *Code Composer Studio* build and debug buttons

6. If your target is connected to the computer click **Run** → **Debug** or click on the *Bug* symbol as seen in Figure 28 at the top. The program is now transferred to the target and can be started with the **green arrow** button at the top.
7. After starting the program the on-board LED of the *TI F28069 Piccolo controlSTICK* should be blinking!

## 18 Loading and building the demo application Blinky in MPLAB<sup>®</sup> X

The demo application *Blinky* is build for the combination of the *Microstick II* with the *dsPIC33FJ128MC802* processor and the *MicrostickPlus* developer board (for details see [www.microstick.com](http://www.microstick.com)).

**Info:** To download a new application only the *Microstick II* needs to be connected with the computer.

1. Connect the *Microstick II* with the computer.
2. Open *MPLAB X* and click **File** → **Open Project**. Browse to the location of the *Blinky* demo application in the *X2C* directory <X2C\_ROOT>\DemoApplication\... \Blinky\_Microchip\_dsPIC33Fxxxx\_MicrostickPlus. Click **Open Project**.
3. In the case the demo application is copied/moved to a different location, the include paths have to be adapted. To ensure the compiler uses the correct path variables right click on the **Projectname** → **Properties** → **XC16 Global Options** → **xc16-gcc**. In the drop down menu **Option categories** choose **Preprocessing and messages**. Click on the dots beside *C include dirs*. There are relative paths to the needed include files listed as seen in Figure 29. Correct the links by double clicking on the path variables.  
**Info:** Only the links to the *Library* and *Controller* path need to be updated.

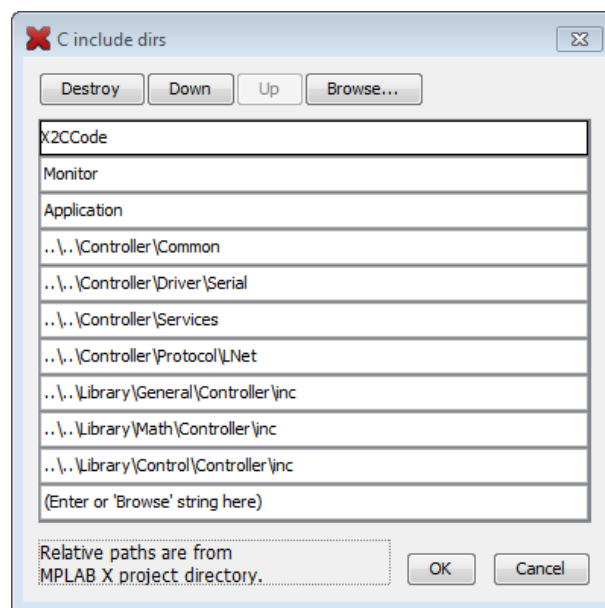


Figure 29: Default path variables for the include files

4. Go to **Run** → **Clean and Build Main Project** or click the *hammer with brush* button as seen in Figure 30. After building there should be a message BUILD SUCCESSFUL in the message area at the bottom of the screen.



Figure 30: MPLAB X Clean and Build Main Project button

5. If the build process was successful go to **Run** → **Run Main Project** or click the *Green*

*Arrow* button as seen in Figure 30. If there is a message similar to *MICROSTICK not Found* try to select the *Starter Kits (PKOB)* item which represents your board.

6. After starting the program the LED (RB12) on the *MicrostickPlus Board* should be blinking!

## 19 Loading and building the demo application Blinky in *STM32CubeIDE*

The demo application *Blinky* is intended to be used with the *ST STM32F072RB Nucleo* or the *ST STM32G474RE Nucleo* kit.

1. Connect the ST development kit with the computer. You may have to install the ST-Link USB driver (available on [www.stm.com](http://www.stm.com)) to get the board recognized by your operating system.
2. Open *STM32CubeIDE* and click **File** → **Import...** Select **General/Existing Projects into Workspace** and click **Next**. Select the root directory of the *Blinky* project (either <X2C\_ROOT>\DemoApplication\Blinky\_ST\_STM32F072RB\_Nucleo or <X2C\_ROOT>\DemoApplication\Blinky\_ST\_STM32G474RE\_Nucleo). Click **Finish** to import the project.
3. In the *STM32CubeIDE* file structure of the *Blinky* demo project are two virtual folders *X2C-Blocks* and *X2C-Core*, which are linked relatively to the *X2C* directory. If the *Blinky* demo project is copied/moved to a different location, the resource property *X2C\_ROOT* as seen in Figure 31 and the build variable *X2CDirPath* as seen in Figure 32 have to be adapted.

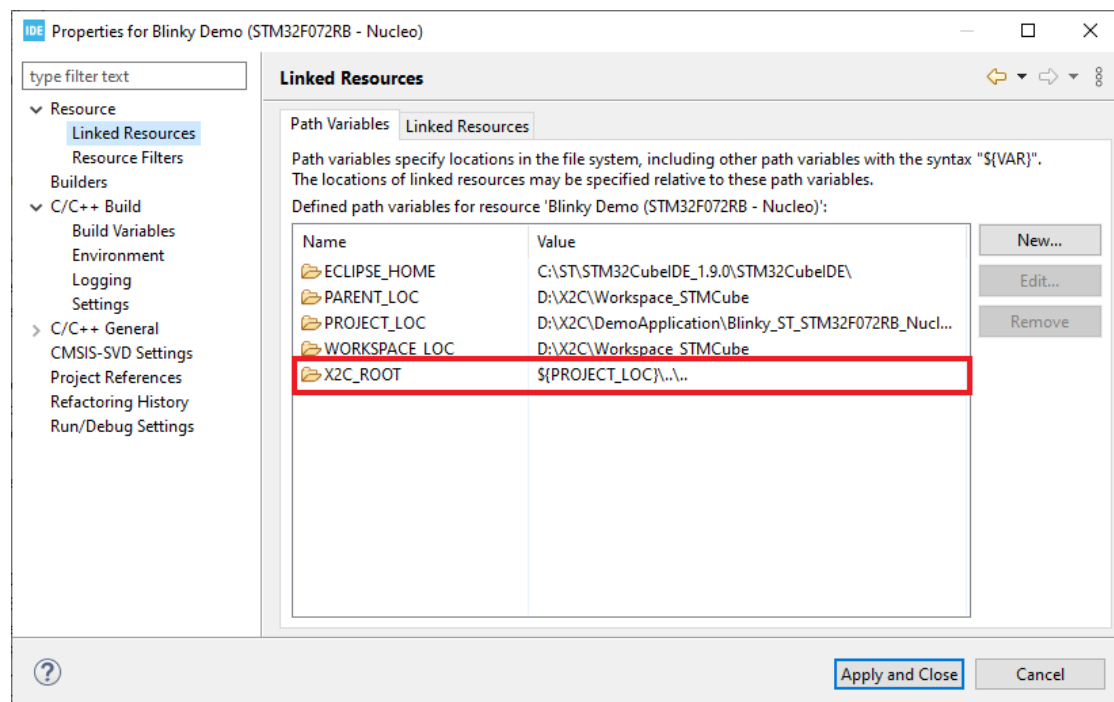


Figure 31: *STM32CubeIDE* resources settings

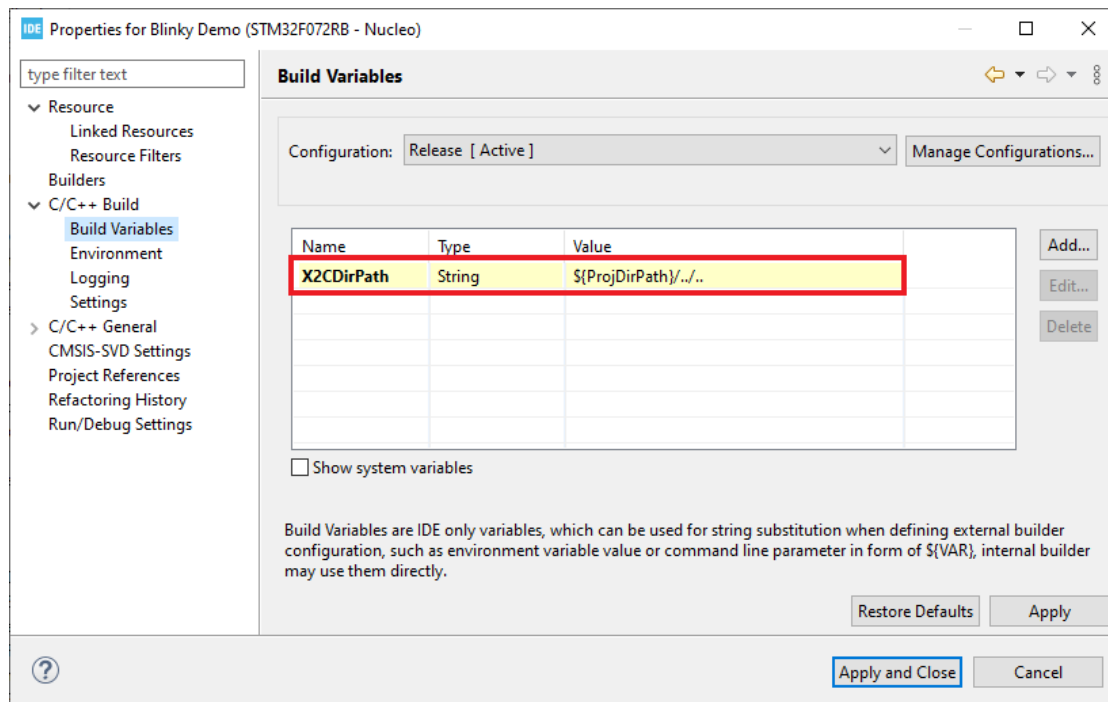


Figure 32: STM32CubeIDE build variables setting

To open shown windows go to **Project** → **Properties**.

4. The generated code from X2C is located in the X2CCode folder (eg. <X2C\_ROOT>\DemoApplication\Blinky\_ST\_STM32F072RB\_Nucleo\X2CCode). To check if code generation went fine go to the X2CCode folder and open X2C.c. Make sure time and date of code generation are plausible.
5. Before building the project the first time some hardware specific code has to be generated. Open the STM32CubeMX configuration window with a double-click on the \*.ioc file in STM32CubeIDE's project explorer. Then the code can be generated with **Project** → **Generate Code** or by clicking on the *Code Generation* icon as seen in Figure 33.



Figure 33: STM32CubeIDE menu icons - Code Generation

6. Build the project in STM32CubeIDE by clicking **Project** → **Build Project** or by clicking on the *Build* icon as seen in Figure 34. Check for errors while building in the console at the bottom of the screen.



Figure 34: STM32CubeIDE menu icons - Build

7. If your target is connected to the computer click **Run** → **Run** or click on the *Run* icon as seen in Figure 35. The program is now transferred to the target and is automatically started.



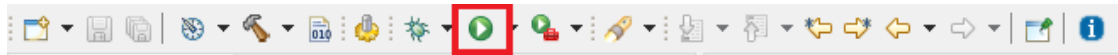


Figure 35: *STM32CubeIDE* menu icons - Run

8. After starting the program the green on-board LED of the ST development kit should be blinking!

## 20 Loading and building the demo application Blinky in *DAVE IDE*

The demo application *Blinky* is intended to be used with the *Infineon XMC4700 Relax Kit*.

1. Connect the Infineon development kit with the computer. Use a Micro-USB cable to connect the USB port of the computer with the USB port labeled X101 on the kit.
2. Open *DAVE IDE* and click **File** → **Import....** Select **General/Existing Projects into Workspace** and clickt **Next**. Select the root directory of the *Blinky* project (<X2C\_ROOT>\DemoApplication\Blinky\_Infineon\_XMC4700\_RelaxKit). Click **Finish** to import the project.
3. In the *DAVE IDE* file structure of the *Blinky* demo project are two virtual folders *X2C-Blocks* and *X2C-Core*, which are linked relatively to the *X2C* directory. If the *Blinky* demo project is copied/moved to a different location, the resource property *X2C\_ROOT* as seen in Figure 36 and the build variable *X2CDirPath* as seen in Figure 37 have to be adapted.

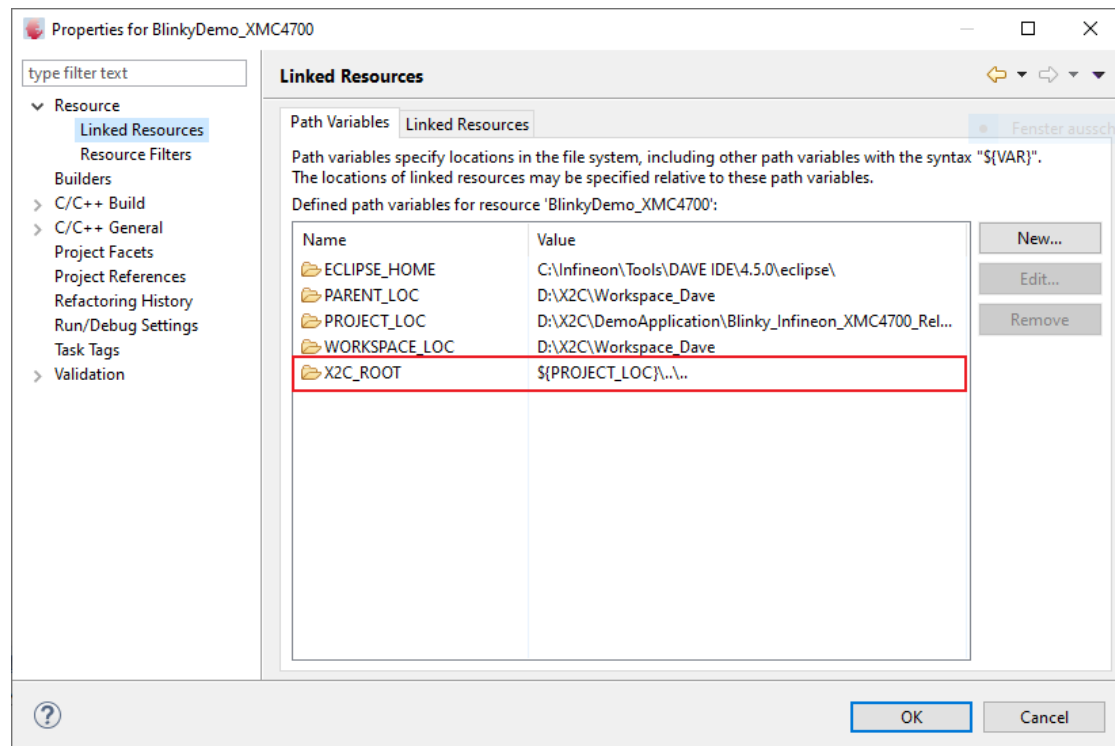


Figure 36: *DAVE IDE* resources settings

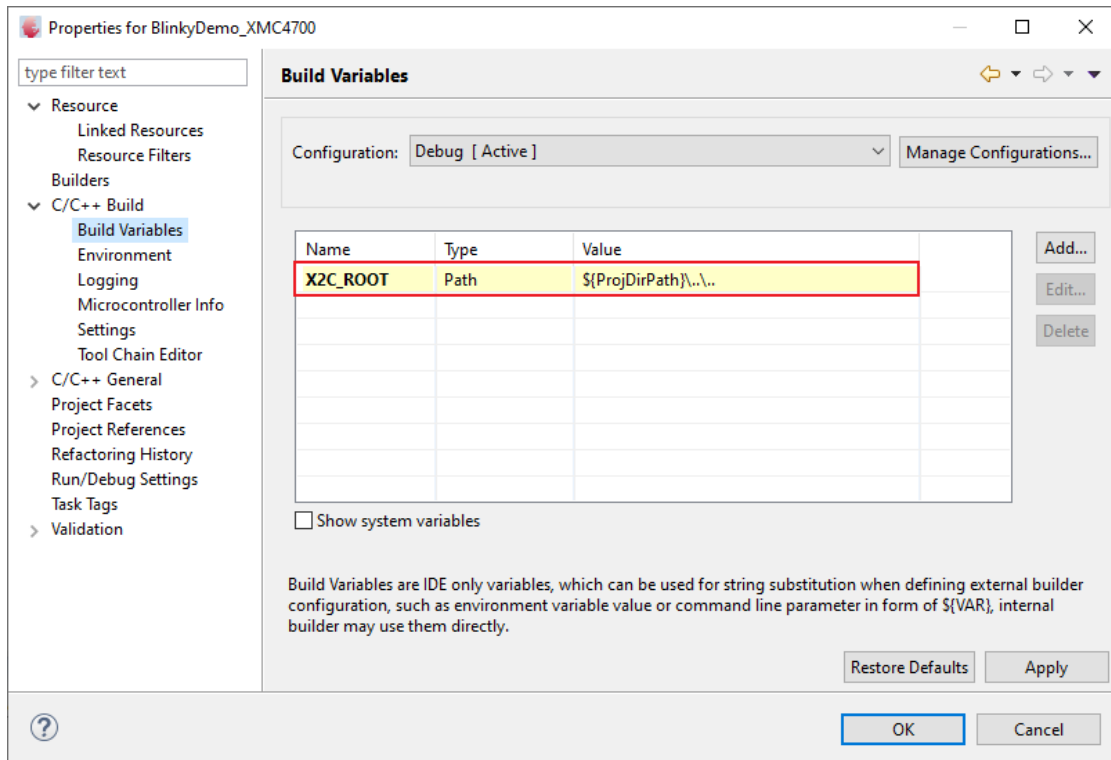


Figure 37: DAVE IDE build variables setting

To open shown windows go to **Project** → **Properties**.

- The generated code from X2C is located in the X2CCode folder (eg. <X2C\_ROOT>\DemoApplication\Blinky\_Infineon\_XMC4700\_RelaxKit). To check if code generation went fine go to the X2CCode folder and open X2C.c. Make sure time and date of code generation are plausible.
- Before building the project the first time some hardware specific code has to be generated. Right-click on the project name in the project tree to open the context menu and select **Set Active Project**. This activates the menu icons which are needed for code generation and project building.

The hardware specific code can be generated with **DAVE** → **Generate Code** or by clicking on the *Generate Code* icon as seen in Figure 38.



Figure 38: DAVE IDE menu icons - Code Generation

- Build the project in DAVE IDE by clicking **Project** → **Build Active Project** or by clicking on the *Build Active Project* icon as seen in Figure 39. Check for errors while building in the console at the bottom of the screen.



Figure 39: DAVE IDE menu icons - Build

- If your target is connected to the computer click on the *Debug* icon as seen in Figure 40.



Figure 40: *DAVE IDE* menu icons - Debug

When the debug session is started for the first time a *Debug Configurations* window will open. Double-click on the *GDB SEGGER J-Link Debugging* entry on the left hand side. This will create a debug configuration as depicted in Figure 41.

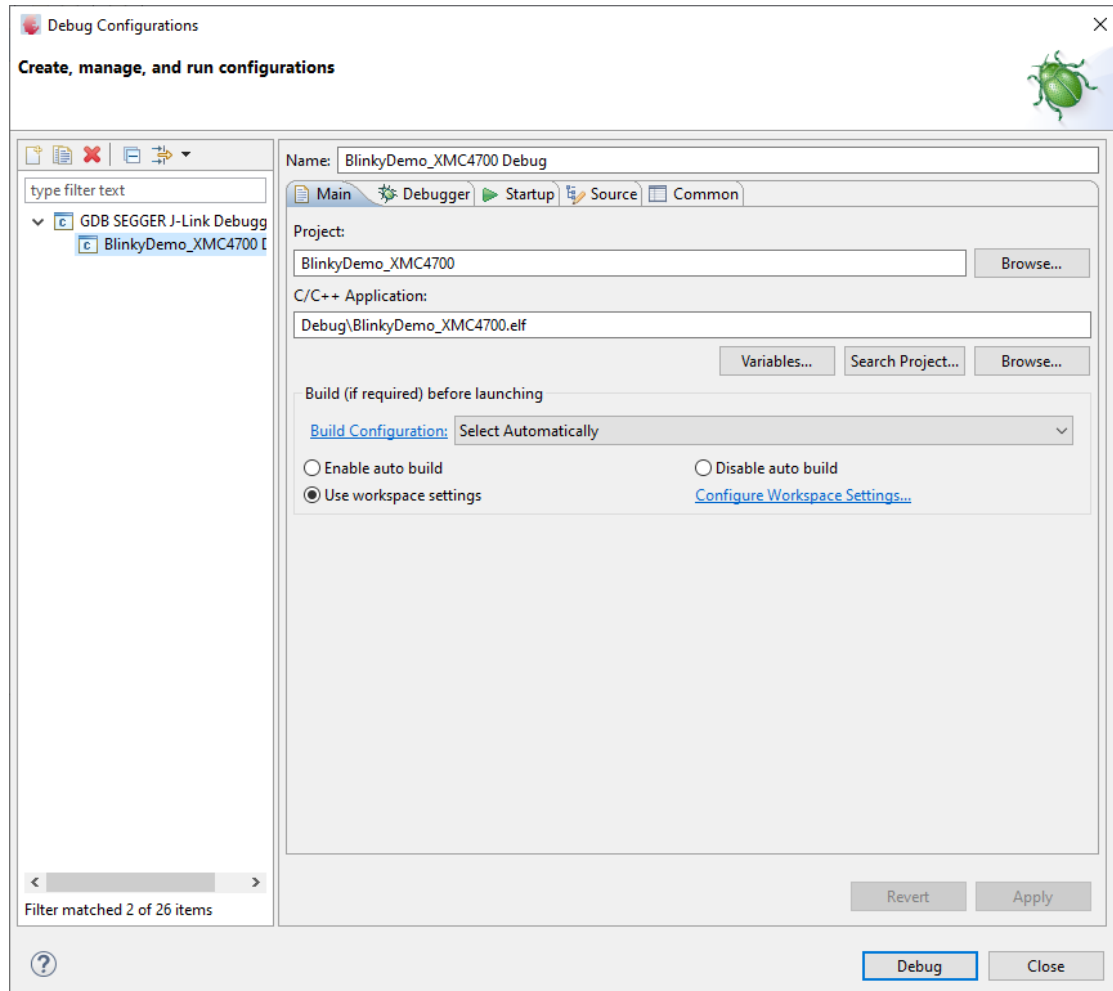


Figure 41: *DAVE IDE* Debug configuration

A click on **Debug** will start the debug session. This means the application will be transferred to the target and *DAVE IDE* will switch to the debug perspective.

8. To start the execution of the application press **F8** or click on the *Resume* icon as seen in Figure 42.

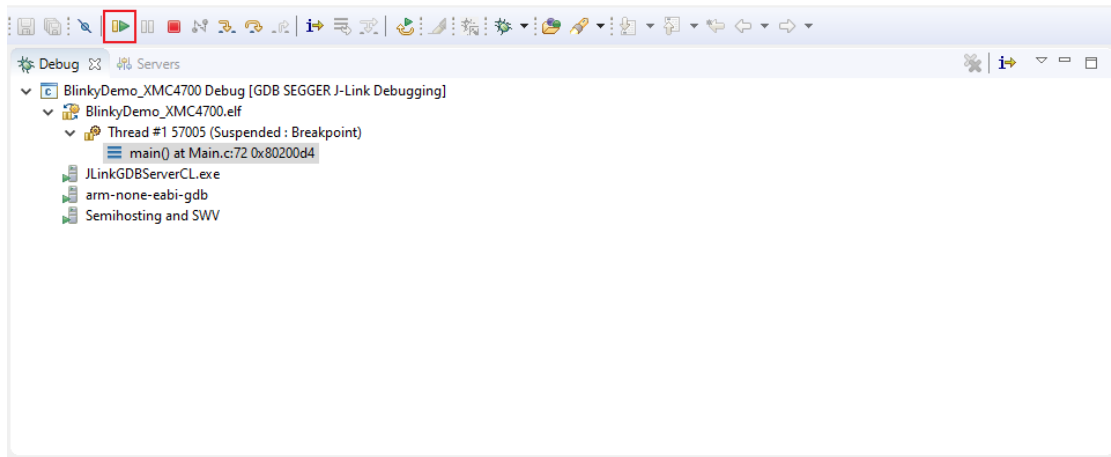


Figure 42: *DAVE IDE* Debug view

9. After starting the program the red on-board LED1 of the Infineon Relax Kit should be blinking!

## 21 The creation of an external project-specific X2C<sup>®</sup> block

The creation of an external project-specific X2C block is summarized in four steps by the subsequent four subsections.

The last two subsections explain what has to be considered when using a project-specific block.

### 21.1 The creation of the basic structure

The first step in the creation of an external project-specific X2C block is the creation of its basic structure using *X2C Block Generator* previously described in Section 13. *X2C Block Generator* can be initiated by executing the `BlockGenerator.jar` file located in `<X2CRoot>\System\Java\`. Once executed, *X2C Block Generator* opens up in the form of the GUI shown in Figure 43 whose options are described hereafter.

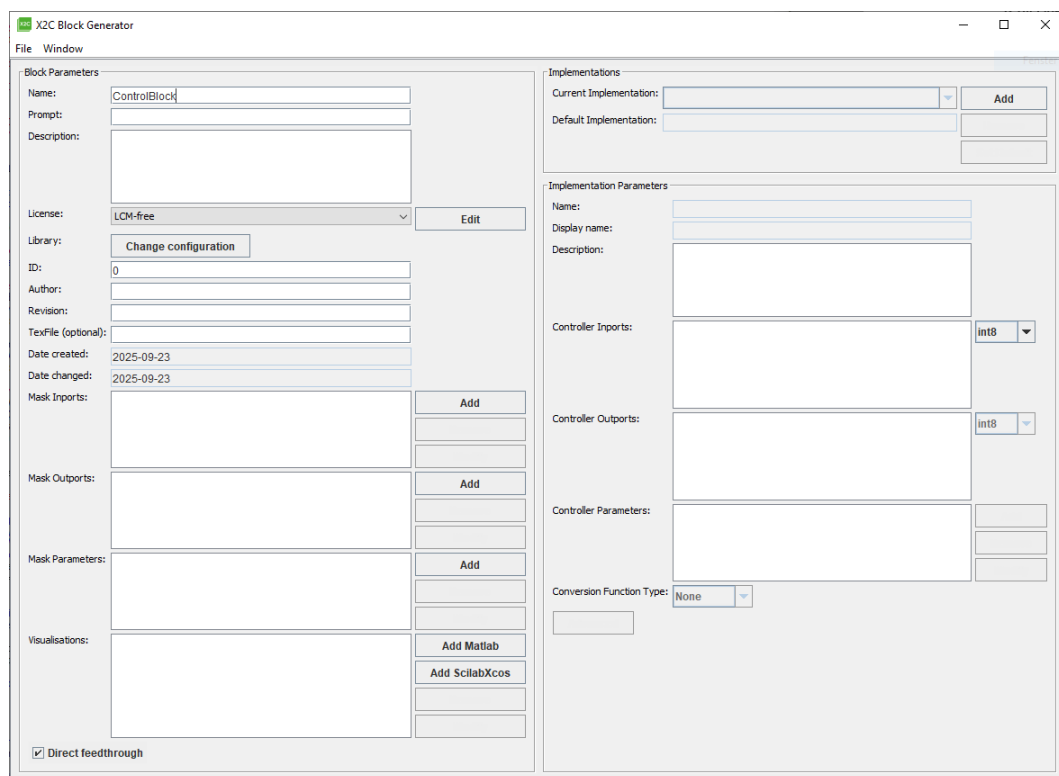


Figure 43: The initial appearance of the *X2C Block Generator* GUI

#### Block Parameters

- **Name** of the block needs to be uniquely specified for the unambiguous identification of the block in the library and the Simulink or Scilab Xcos model.
- **Prompt** is displayed in the help of the block in Scilab Xcos.
- **Description** of the block is displayed in the dialog window of the block in both Simulink and Scilab Xcos and should describe the purpose of the block.
- **License** can be selected from the drop-down menu that contains various options or it can be manually defined by clicking on the **Edit** push-button.
- **Library** needs to be specified by clicking on the **Change Configuration** push-button that opens up the *Library Configuration* window in which the **External** radio-button should be selected. By doing so, the **Library Name** and **Pre-Namespace** text-fields

become available. It is mandatory to save the library in the `<ProjectRoot>` folder (i.e. the folder that contains the `X2CCode` folder).

- **Library Name** should be uniquely specified.
  - **Pre-Namespace** is used for Java conversion functions and can be arbitrarily selected. For example the library name can be entered here as well.
- **ID** needs to be an unique integer number between 4000 and 4095, including those two limits.
- **Author** of the block should be specified.
- **Revision** should be specified to enable the distinction between different software versions of the block.
- **TeX File** containing a description of the block in the  $\text{\LaTeX}$  format that can be optionally created for the documentation of the block. When writing display math, it is advisable not to use environments provided by the `amsmath` package. Instead, `displaymath`, `equation`, `array`, and `eqnarray` should be used for consistent rendering of display equations by  $\text{\JLaTeX}$  in the generated `.html` file. The name of the `.tex` file should differ from the name of the block. (Internal convention is `<BlockName>_Info.tex`).
- **Date Created** is automatically specified upon the creation of the block.
- **Date Changed** is automatically specified every time the block is changed.
- **Mask Inports** are user interfaces that need to be defined for all inputs of the block by clicking on the **Add** push-button that opens up the *Mask Inport* window in which the **Name** and **Description** text-fields under the **Parameters** section become available. Every mask input can also be removed or edited by clicking on the **Remove** or **Modify** push-button, respectively.
  - **Parameters**
    - \* **Name** is displayed in the documentation of the block.
    - \* **Description** is displayed in the documentation of the block.
- **Mask Outports** are user interfaces that need to be defined for all outputs of the block by clicking on the **Add** push-button that opens up the *Mask Outport* window in which the **Name** and **Description** text-fields under the **Parameters** section become available. Every mask output can also be removed or edited by clicking on the **Remove** or **Modify** push-button, respectively.
  - **Parameters**
    - \* **Name** is displayed in the documentation of the block.
    - \* **Description** is displayed in the documentation of the block.
- **Mask Parameters** are user interfaces that need to be defined for all parameters of the block by clicking on the **Add** push-button that opens up the *Mask Parameter* window in which the **Name**, **Prompt**, and **Description** text-fields together with the **Data Type** drop-down menu under the **Parameters** section become available. Every mask parameter can also be removed or edited by clicking on the **Remove** or **Modify** push-button, respectively.
  - **Parameters**
    - \* **Name** is displayed in the documentation of the block.
    - \* **Prompt** is displayed in the dialog window of the block in both Simulink and Scilab Xcos.

- \* **Description** is displayed in the documentation of the block and the dialog window of the block in both Simulink and Scilab Xcos.
- \* **Data Type** can be selected from the drop-down menu to be either **Double** or **ComboBox** as well as **Visible** and/or **Changeable** by the available check-boxes.
- **Data Type Parameters**
  - \* **Default** value of the parameter needs to be specified in the case of **Data Type: Double**.
  - \* **Add** or **Remove** push-buttons become available for adding items in the case of **Data Type: ComboBox**.
- **Visualizations** of the block can be separately defined for Simulink by clicking on the **Add Matlab** push-button as well as for Scilab Xcos by clicking on the **Add ScilabXcos** push-button.
  - **Visualization Parameters** for Simulink
    - \* **Command** can contain labels of the block and its input(s) and output(s) that can be defined as:
 

```
disp('\fontsize12<BlockLabel>', 'texmode', 'on')
port_label('input', '<InputNumber>', '<InputLabel>',
'texmode', 'on')
port_label('output', '<OutputNumber>', '<OutputLabel>',
'texmode', 'on')
```
  - **Visualization Parameters** for Scilab Xcos
    - \* **Define Section** defines options of the block in the `x2c_<BlockName>.sci` script between `// ++ BlockGenerator: Define Section` and `// - BlockGenerator: Define Section`.
    - \* **Block Icon Default Size** defines the size of the block in Scilab Xcos units in the `x2c_<BlockName>.sci` script between `// ++ BlockGenerator: BlockIconDefaultSize` and `// - BlockGenerator: BlockIconDefaultSize`.
    - \* **Plot Section** defines options of the block in the `x2c_<BlockName>.sci` script between `// ++ BlockGenerator: Style` and `// - BlockGenerator: Style`.
    - \* **Style** defines options of the block in the `starter.sce` script between `// ++ BlockGenerator: Plot Section` and `// - BlockGenerator: Plot Section`.
- **Direct Feedthrough** should be generally checked. It should be unchecked when the block serves as a breaker of an algebraic loop.

## Implementations

- **Current Implementation** serves as an identifier of the current implementation and can be arbitrarily named, whereby multiple implementations are possible. The internal naming convention of LCM defines **Bool** (Boolean), **FiP8** (8 Bit Fixed Point), **FiP16** (16 Bit Fixed Point), **FiP32** (32 Bit Fixed Point), **Float32** (32 Bit Floating Point), and **Float64** (64 Bit Floating Point) as implementations. A new implementation can be defined by clicking on the **Add** push-button as well as removed by clicking on the **Remove** button.
- **Default Implementation** can be selected by choosing the desired implementation from the **Current Implementation** drop-down menu (if multiple available) and clicking on the **Set Default** push-button.



## Implementation Parameters

- **Name** is automatically taken from the **Current Implementation** drop-down menu and every change in the text-field directly renames the selected implementation in the **Current Implementation** drop-down menu. The internal naming convention of LCM defines **Bool**, **FiP8**, **FiP16**, **FiP32**, **Float32**, and **Float64** as names.
- **Display Name** of the current implementation is displayed in the dialog window of the block in the **Used Implementation** drop-down menu. The internal naming convention of LCM defines **Boolean**, **8 Bit Fixed Point**, **16 Bit Fixed Point**, **32 Bit Fixed Point**, **32 Bit Floating Point**, and **64 Bit Floating Point** as display names. This name is used for naming of the corresponding C and Java files.
- **Description** of the current implementation in the documentation of the block. The internal naming convention of LCM defines **Boolean Implementation**, **8 Bit Fixed Point Implementation**, **16 Bit Fixed Point Implementation**, **32 Bit Fixed Point Implementation**, **32 Bit Floating Point Implementation**, or **64 Bit Floating Point Implementation** as descriptions.
- **Controller Inputs** of the current implementation need to be defined with respect to **Mask Inputs**, whereby the data type can be selected from the drop-down menu.
- **Controller Outputs** of the current implementation need to be defined with respect to **Mask Outputs**, whereby the data type can be selected from the drop-down menu.
- **Controller Parameters** of the current implementation need to be defined with respect to **Mask Outputs** together with any additional internal parameter can also be defined) by clicking on the **Add** push-button that opens up the *Controller Parameter* window in which the **Name**, **Description**, and **Default Value** text-fields together with the **Data Type** drop-down menu and the **Load & Save Enable** and **Array** check-boxes under the **Controller Parameters** section become available. Every controller parameter can also be removed or edited by clicking on the **Remove** or **Modify** push-button, respectively.

### – Controller Parameters

- \* **Name** is displayed in the dialog window of the block in both Simulink and Scilab Xcos and denotes a parameter of the block.
  - \* **Description** is displayed in the dialog window of the block in both Simulink and Scilab Xcos and should describe the parameter of the block.
  - \* **Data Type** determines the data type that is to be used on the target.
  - \* **Default Value** sets the default value of the parameter.
- **Conversion Function Type** can be selected from the drop-down menu between **Java**, **Python**, and **JavaScript**. After selecting the conversion function type, a template of the conversion function used for the conversion of mask parameters, which are of the type `double`, into the data type of the current implementation is generated. The template needs to be manually adapted. If there are no mask parameters, no conversion function is necessary.

## 21.2 Coding the source file

The functionality of the block needs to be manually implemented in the automatically generated `<BlockName>_<Implementation>.c` source file located in `<ProjectRoot>\Library\<LibraryName>\Controller\src\`. In that source file, everything between each pair of the comment tags `/* USERCODE-BEGIN: ... */` and `/* USERCODE-END: ... */` stays

unchanged even if the source file is regenerated by *X2C Block Generator*. Between the first pair of such comments, namely `/* USERCODE-BEGIN:Description */` and `/* USERCODE-END:Description */`, a short description of the block can be written in the form of comments. The definitions of the input(s) and the output(s) as well as parameters, variables, constants, and if necessary, the inclusions of header files should be defined between the PreProcessor-tags as

```
/* USERCODE-BEGIN:PreProcessor */
#include "<HeaderFile>.h"
#define <INPUT>      (* block-><InportName>)
#define <OUTPUT>     (block-><OutportName>)
#define <PARAMETER> (block-><ParameterName>)
#define <VARIABLE>  (block-><ParameterName>)
#define <CONSTANT>  <HexadecimalValue>
/* USERCODE-END:PreProcessor */
```

The functionality of the block should be defined between the UpdateFnc-tags and can be demonstrated by an example in a FiP16 implementation as

```
/* USERCODE-BEGIN:UpdateFnc */
int32_t <Result>;
<Result> = (int32_t)<INPUT> * (int32_t)<VARIABLE>;
<Result> >= <PARAMETER>;
<Result> += (int32_t)<CONSTANT>;
if (<Result> > INT16_MAX)
{
    <Result> = INT16_MAX;
}
else
{
    if (<Result> < -INT16_MAX)
    {
        <Result> = -INT16_MAX;
    }
}
<OUTPUT> = (int16_t)<Result>;
/* USERCODE-END:UpdateFnc */
```

The initial values of used variables can be specified between the InitFnc-tags as

```
/* USERCODE-BEGIN:InitFnc */
<Variable> = 0;
/* USERCODE-END:InitFnc */
```

Between `/* USERCODE-BEGIN:LoadFnc */` and `/* USERCODE-END:LoadFnc */` and between `/* USERCODE-BEGIN:SaveFnc */` and `/* USERCODE-END:SaveFnc */` the user can insert code which is executed when the save-function of the block (download of the implementation parameters from the host to the target) or the load-function of the block (upload of the implementation parameters to the host from the target) is called. Usually these sections are left empty.

### 21.3 Coding the conversion function

If the block uses mask parameters, the conversion function, which converts the mask parameters into controller parameters, has to be implemented in the corresponding programming language as well. The template of the conversion function is located in `<ProjectRoot>\Library\<LibraryName>\Conversion\<ConversionType>\`.

### 21.3.1 A conversion function in Java

In the case of Java, the conversion function of the block needs to be manually implemented in the automatically generated `ConvFnc_<BlockName>_<Implementation>.java` file located in `<ProjectRoot>\Library\<LibraryName>\Conversion\Java\src\...` Furthermore, **Eclipse** needs to be installed on the system and the project imported into the workspace via the menu bar as **File**  $\Rightarrow$  **Import...**  $\Rightarrow$  **General**  $\Rightarrow$  **Existing Project**. Under **Project**  $\Rightarrow$  **Build Automatically** needs to be enabled and by right-clicking on the project in the project tree, under **Properties**  $\Rightarrow$  **Java Compiler**  $\Rightarrow$  **Compiler Compliance Level** needs to be set to **1.6**. In the above mentioned file, everything between each pair of the comments `// USERCODE-BEGIN:` and `// USERCODE-END:` stays unchanged even if the source file is regenerated by *X2C Block Generator*. User-defined Java classes like

```
// USERCODE-BEGIN:Imports
import at.lcm.x2c.utils.QFormat;
// USERCODE-END:Imports
```

can be loaded between the Imports-tags, while the conversion of the controller parameters from the mask into the designated implementation needs to be written between the `ConvMaskToImplementation`-tags and can be demonstrated by an example in a `FiP16` implementation as

```
// USERCODE-BEGIN:ConvMaskToImplementation
double <ControlParameter>;
final int BITS = 16;

// Getting the value of the mask parameter:
<ControlParameter> =
    Double.valueOf(<MaskParameter>MaskVal.getValue());

// Calculating the shift factor:
<ShiftFactor>CtrVal.setReal(0, 0,
    Double.valueOf(QFormat.getQFormat(<ControlParameter>, BITS,
    true)));

// Calculating the Q-value:
<ControlParameter>CtrVal.setReal(0, 0,
    Double.valueOf(QFormat.getQValue(<ControlParameter>,
    (int)<ShiftFactor>CtrVal.getReal(0, 0), BITS, true)));
// USERCODE-END:ConvMaskToImplementation
```

The conversion of the controller parameters from the designated implementation into the mask needs to be written between the `ConvImplementationToMask`-tags as

```
// USERCODE-BEGIN:ConvImplementationToMask
double <ControlParameter>, <ShiftFactor>;
final int BITS = 16;

// Getting the Q-value:
<ControlParameter> = <ControlParameter>CtrVal.getReal(0, 0);

// Getting the shift factor:
<ShiftFactor> = <ShiftFactor>CtrVal.getReal(0, 0);

// Calculating the value of the mask parameter:
<MaskParameter>MaskData.setReal(0, 0,
    QFormat.getDecValue((long)<ControlParameter>,
    (int)<ShiftFactor>, BITS, true));
// USERCODE-END:ConvImplementationToMask
```

Eventually a JAR file has to be created to make the conversion function available in Scilab/Xcos. There are multiple ways to create a JAR file. One could work with \*.jardesc files in Eclipse, use Apache Ant tasks or simply build the JAR file on the command line. Taking the command line approach as example, one has to change into the <LibraryDirectory>\Conversion\Java\bin directory and execute following command:

```
jar cf ..\<LibraryName>.jar .\
```

### 21.3.2 A conversion function in JavaScript

In the case of JavaScript, two JavaScript script files are automatically generated in <ProjectRoot>\Library\<LibraryName>\Conversion\JavaScript\src\..., where one is used for the conversion of the mask parameters to the implementation parameters, while the other one is used for the conversion of the implementation parameters to the mask parameters. The conversion of the mask parameters to the implementation parameters needs to be manually implemented in ConvertMask2Imp\_<BlockName>\_<Implementation>.js, while the conversion of the implementation parameters to the mask parameters needs to be implemented in ConvertImp2Mask\_<BlockName>\_<Implementation>.js. Both files contain /\* USERCODE-BEGIN:Description \*/ and /\* USERCODE-END:Description \*/ as well as /\* USERCODE-BEGIN:ExternalModules \*/ and /\* USERCODE-END:ExternalModules \*/, where between the first pair a short description of the conversion function can be written, while between the second pair external modules can be imported. The conversion of the mask parameters to the implementation parameters comes between /\* USERCODE-BEGIN:Convert \*/ and /\* USERCODE-END:Convert \*/ in the first file, while the conversion of the implementation parameters to the mask parameters comes between /\* USERCODE-BEGIN:Revert \*/ and /\* USERCODE-END:Revert \*/ in the second file.

### 21.3.3 A conversion function in Python

Similar to the case of JavaScript, in the case of Python, two Python scripts are automatically generated in <ProjectRoot>\Library\<LibraryName>\Conversion\Python\src\..., where the ConvertMask2Imp\_<BlockName>\_<Implementation>.py script is used for the conversion of the mask parameters to the implementation parameters, while the ConvertImp2Mask\_<BlockName>\_<Implementation>.py script is used for the conversion of the implementation parameters to the mask parameters. The scripts are structurally identical to the above described JavaScript script files containing # USERCODE-BEGIN: ... and # USERCODE-END: ... sections, where the only difference is the scripting language.

### 21.3.4 A conversion on target function (CoT) in C

If it should be possible to convert the blocks mask parameters on the target directly, the CoT (Conversion on Target) conversion function has to be coded as well. The template for the CoT conversion function is located in <ProjectRoot>\Library\<LibraryName>\Conversion\C\src\.

The conversion of the mask parameters to the controller parameters of the designated implementation needs to be written between the Conversion-tags, see following example for the Gain\_FiP16 implementation.

```
/* USERCODE-BEGIN:Conversion */
/* Calculating the shift factor: */
impParam->sfr = getQFormat(maskParam->Gain, 16);
/* Calculating the Q-value: */
impParam->V = getQx16Value(maskParam->Gain, impParam->sfr);
/* USERCODE-END:Conversion */
```

## 21.4 Finalizing the block in Scilab

In Scilab execute the command

```
createXcosBlock('<LibraryName>', '<BlockName>', '<ProjectRoot>')
```

## 21.5 The block in an Xcos model

When the project-specific block is used in an Xcos project, the corresponding palette has to be loaded prior opening the Xcos model. To simplify this task, the script `initProject.sce` can be used.

Please follow these steps when working with Scilab/Xcos:

1. Start Scilab.
2. Change into the `<ProjectRoot>\X2CCode` directory.
3. Execute the `initProject.sce` script for loading project-specific palettes. If not present, copy the file from any of the X2C demo applications located in `<X2CRoot>\DemoApplication`.
4. Open the projects Xcos model, the project-specific library should be visible in the palette browser now.

## 21.6 The block in Code Composer Studio

After including the project in Code Composer Studio, the library should be listed in the project tree. Before compiling, it is necessary to exclude the **Matlab** and **Conversion** folders from the build.

## 22 Setup X2C® for use in a B&R® Automation Studio® project

X2C allows the user to modify an already created *Automation Studio* project for use with X2C and generate the corresponding code. Therefore several configuration parameters have to be set.

### 22.1 Configuration

- Setup a new *Automation Studio* project or use an existing one
- Head to the Communicator settings and configure the the *Automation Studio* specific parts
  1. Enable the "Create Automation Studio code" option
  2. Select the project APJ file. After a valid project is selected, the configuration menu is updated and contains all project configurations. Further Settings elements will be enabled and updated.
  3. Select a configuration, a CPU module and a Application task class. This becomes the task in which the X2C Update function is called.
  4. Enable the Communication option in case TCP/IP communication should be used for online X2C Block parameter updates or Scope usage. After enabling, the task class for the X2C communication task and the TCP port can be selected.
  5. The "Use library" option allows you to use X2C as *Automation Studio* library block.
  6. Sets the X2C Scope buffer size. This buffer is used to cache the sampled data if the Scope feature is used.

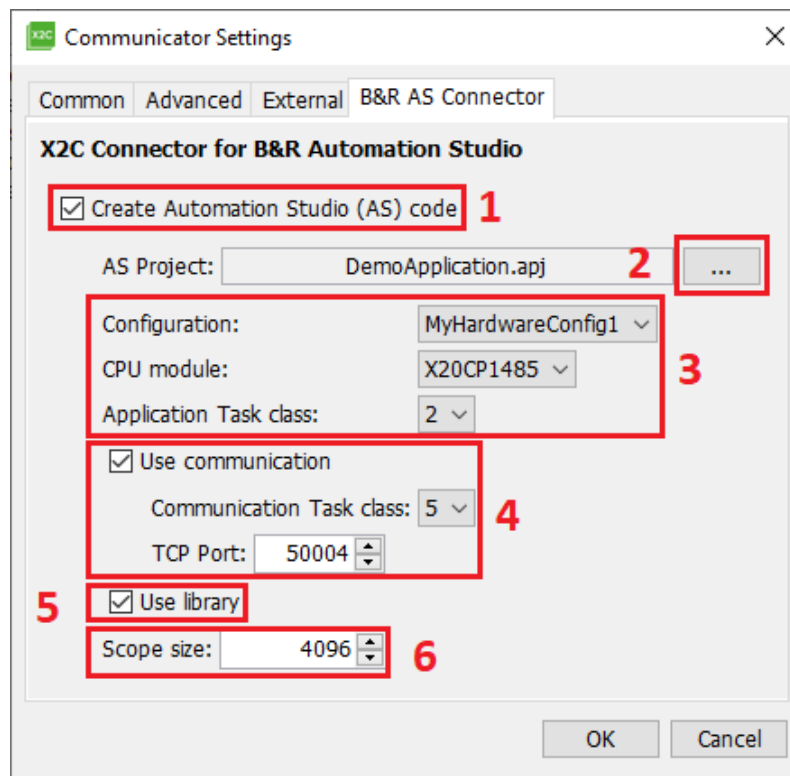


Figure 44: X2C Connector for *B&R Automation Studio* settings

- Confirm the changes by pressing the OK button

- Generate the *X2C* code as usual

All required *X2C* and *Automation Studio* files will be created. The Automation Studio configuration files are being updated to include the newly generated *X2C* code.

## 22.2 Logical View

Now we can head over to *Automation Studio* to check the modifications and build the project. *Automation Studio* may ask you to reload changed components.

The "Logical View" should have been updated by X2C content as well as the Software configuration file in the "Configuration View". In case of enabled Communication, the B&R library "AsTCP", required for TCP/IP communications, is added to your project libraries.

Therefore your *Automation Studio* project may look like this:

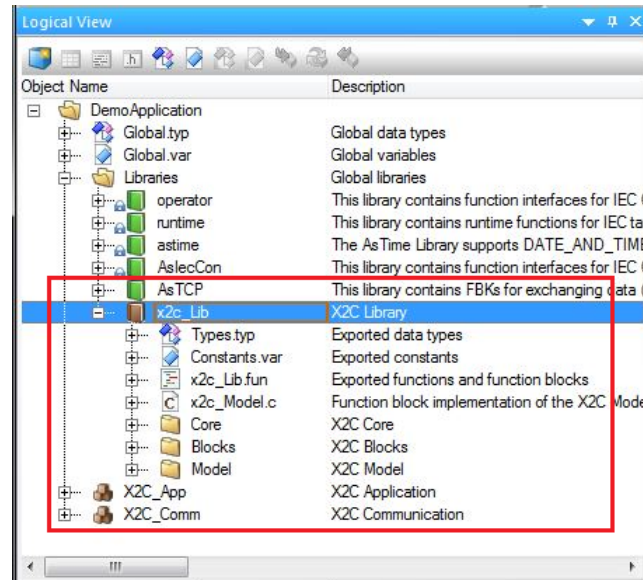


Figure 45: *Automation Studio* Logical View

This example shows the added

- B&R AsTCP library
- X2C as *Automation Studio* library
- X2C application program package
- X2C communication program package



## 22.3 Software Configuration

The software configuration file shows the newly added programs and libraries.

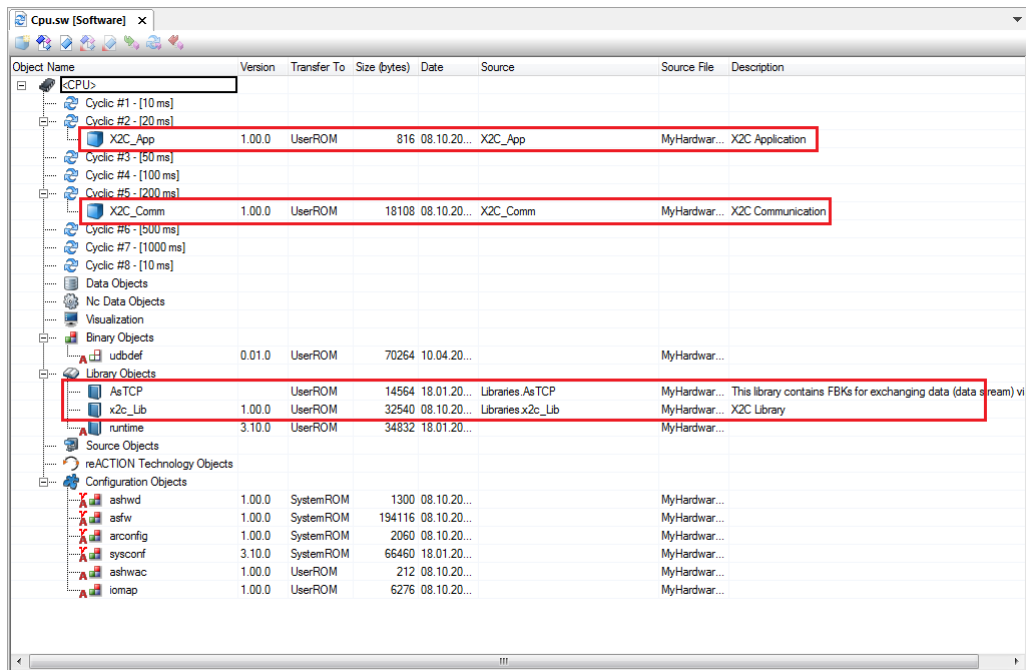


Figure 46: Automation Studio Software Configuration

## 22.4 Communication configuration

In case of enabled communication don't forget to configure the Ethernet and TCP/IP settings for your hardware in *Automation Studio*.

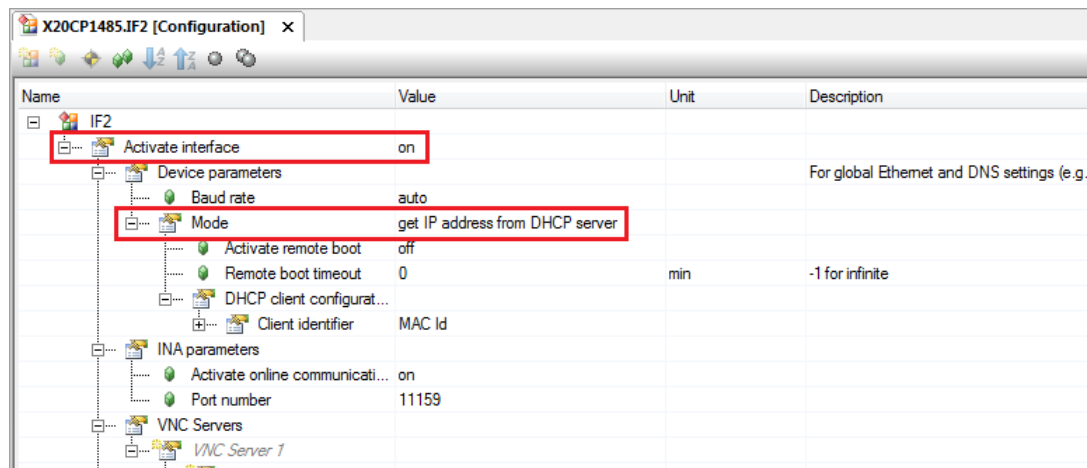


Figure 47: Automation Studio Ethernet configuration using DHCP (X20CP1485)

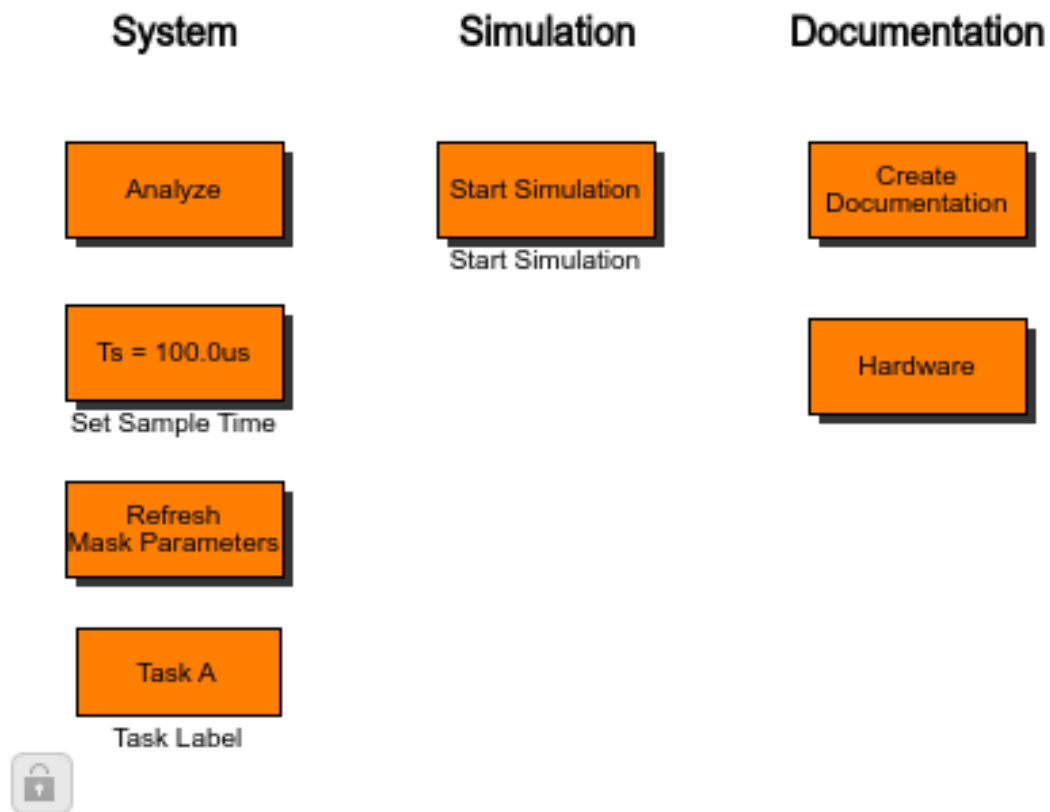
The X2C integration is now complete and the *Automation Studio* project is ready to be built.

## Part VI

# Libraries

### 23 Basic

Virtual blocks to configure basic code generation, simulation and help generation settings.



## Block: CommunicatorStart (Xcos only)

---

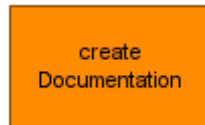


### Description:

With a double-click on this block, the X2C Communicator will start. The Communicator will connect to Scilab via Java Remote Method Invocation (Java RMI) to enable data exchange between Scilab and X2C.

## Block: CreateDocumentation

---



### Description:

With a double-click on this block, a documentation with all relevant information about the current X2C project can be created. The document will be created in `<ProjectDir>\Doc` and will be called `ProjectDocumentation_<NameOfModel>.pdf`.

### Parameters

**User documentation:** It is possible to add user specific documentation to the project documentation. When creating the project documentation, the `X2CCode` directory is scanned for the specified tex file (`UserDoc.tex` by default). If the file is present, it will be included in the documentation.

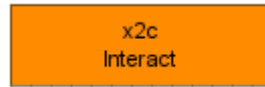
**Test reports:** If the checkbox `Add test reports` is selected, test reports of the C-Unit tests of the used X2C blocks are added to the project documentation.

### Requirements

In order to generate a documentation in PDF-format a TeX-compiler (e.g. `MiKTeX`) has to be installed. The software tools `Doxygen` and `Graphviz` are recommended to get documentation of the C-code.

## Block: Interact (Xcos only)

---



### Description:

When double-clicked, the block executes the Scilab script *doInteraction.sci*, if available. By customizing the script, the user can execute simple tasks, e.g. setting block parameters, read parameter values, display status information, etc., repeatedly and effortlessly.

## Block: ModelTransformation (Xcos only)

---



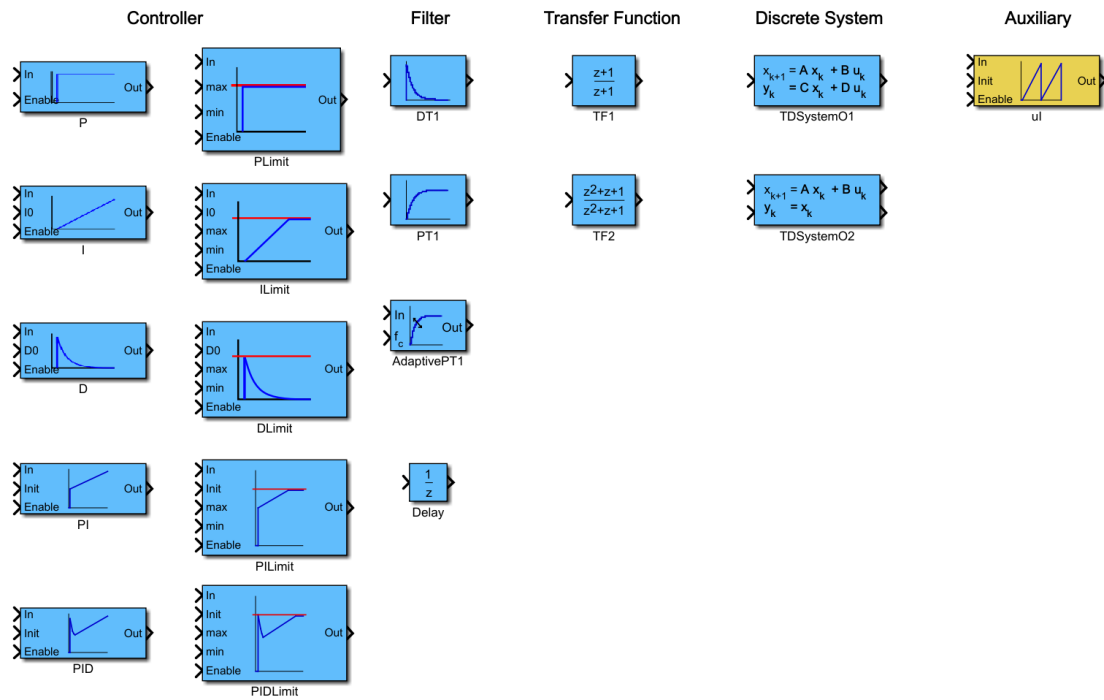
transform Model and  
push to Communicator

### Description:

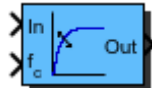
With a double-click on this block, the Xcos model will be analyzed. All relevant information for code generation are gathered, transfered to the Communicator and written to the model XML file.

## 24 Control

This library contains blocks for building control algorithms.



## Block: AdaptivePT1



First order low pass with adaptive cut off frequency:

$$G(s) = V/(s/(2\pi fc) + 1)$$

### Inports

|    |                  |
|----|------------------|
| In | Input In(k)      |
| fc | Cutoff frequency |

### Outports

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

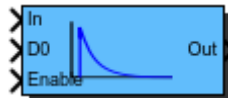
| Name    | ID | Description                                                            |
|---------|----|------------------------------------------------------------------------|
| V       | 1  | Gain                                                                   |
| fmax    | 2  | Maximum frequency [Hz]<br>(not used in floating point implementations) |
| ts_fact | 3  | Multiplication factor of base sampling time (in integer format)        |
| method  | 4  | Discretization method                                                  |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: D



D Controller:

$$G(s) = K_d \cdot s / (s / (2 \cdot \pi \cdot f_c) + 1)$$

| Inports |                                                                                                                                   |
|---------|-----------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                               |
| D0      | Derivational value which is loaded during initialization. (Usually this inport is connect to the In inport.)                      |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable 0->1: Preload of derivational part<br>Enable == 1: Activation of block |

| Outports |               |
|----------|---------------|
| Out      | Control value |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Kd              | 1  | Derivative Factor                                               |
| fc              | 2  | Cutoff frequency of realization low pass                        |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Delay

---



Output delay by one sample time interval.

| Inports |             |
|---------|-------------|
| In      | Input In(k) |

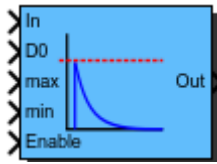
| Outputs |                       |
|---------|-----------------------|
| Out     | Output Out(k)=In(k-1) |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| ts_fact         | 1  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Integration                  |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: DLimit



D Controller with Output Limitation:

$$G(s) = K_d \cdot s / (s / (2 \cdot \pi \cdot f_c) + 1)$$

| Inports |                                                                                                              |
|---------|--------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                          |
| D0      | Derivational value which is loaded during initialization. (Usually this inport is connect to the In inport.) |
| max     | Maximum output value                                                                                         |
| min     | Minimum output value                                                                                         |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable == 1: Activation of block                         |

| Outports |               |
|----------|---------------|
| Out      | Control value |

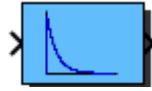
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Kd              | 1  | Derivative Factor                                               |
| fc              | 2  | Cutoff frequency of realization low pass                        |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: DT1

---



First order high pass:

$$G(s) = V \cdot s / (s/w + 1)$$

| Inports |             |
|---------|-------------|
| In      | Input In(k) |

| Outports |               |
|----------|---------------|
| Out      | Output Out(k) |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| V               | 1  | Gain                                                            |
| fc              | 2  | Cut off frequency of low pass filter                            |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |
| method          | 4  | Discretization method                                           |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: I

---



I controller:

$$G(s) = K_i/s = 1/(T_i*s)$$

| Inports |                                                                                                                               |
|---------|-------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                           |
| I0      | Integral value which is loaded at initialization function call                                                                |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable 0->1: Preload of integral part<br>Enable == 1: Activation of block |

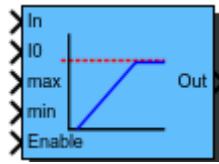
| Outports |               |
|----------|---------------|
| Out      | Control value |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Ki              | 1  | Integral Factor                                                 |
| ts_fact         | 2  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: ILimit



I controller with output limitation:

$$G(s) = Ki/s = 1/(Ti*s)$$

| Inports |                                                                                                                               |
|---------|-------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                           |
| I0      | Integral value which is loaded at initialization function call                                                                |
| max     | Maximum output value                                                                                                          |
| min     | Minimum output value                                                                                                          |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable 0->1: Preload of integral part<br>Enable == 1: Activation of block |

| Outports |               |
|----------|---------------|
| Out      | Control value |

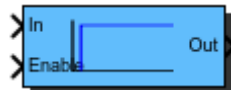
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Ki              | 1  | Integral Factor                                                 |
| ts_fact         | 2  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: P

---



P controller:

$$G(s) = K_p$$

| Inports |                                                                                      |
|---------|--------------------------------------------------------------------------------------|
| In      | Control error input                                                                  |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable == 1: Activation of block |

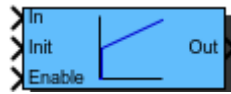
| Outports |               |
|----------|---------------|
| Out      | Control value |

| Mask Parameters |    |                     |
|-----------------|----|---------------------|
| Name            | ID | Description         |
| Kp              | 1  | Proportional Factor |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: PI



PI controller:  
 $G(s) = K_p + K_i/s$

| Inports |                                                                                                                               |
|---------|-------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                           |
| Init    | Initial value of output Out when enabled                                                                                      |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable 0->1: Preload of integral part<br>Enable == 1: Activation of block |

| Outputs |               |
|---------|---------------|
| Out     | Control value |

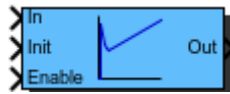
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Kp              | 1  | Proportional Factor                                             |
| Ki              | 2  | Integral Factor                                                 |
| initHandling    | 3  | Determines what the signal provided on Init input is used for   |
| ts_fact         | 4  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: PID



PID controller:

$$G(s) = K_p + K_i/s + K_d*s/(s/(2*\pi*fc) + 1)$$

| Inports |                                                                                                                               |
|---------|-------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                           |
| Init    | Initial value of output Out when enabled                                                                                      |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable 0->1: Preload of integral part<br>Enable == 1: Activation of block |

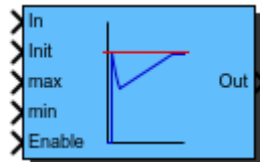
| Outputs |               |
|---------|---------------|
| Out     | Control value |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Kp              | 1  | Proportional Factor                                             |
| Ki              | 2  | Integral Factor                                                 |
| Kd              | 3  | Derivative Factor                                               |
| fc              | 4  | Cutoff frequency of realization low pass                        |
| initHandling    | 5  | Determines what the signal provided on Init input is used for   |
| ts_fact         | 6  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: PIDLimit



PID Controller with Output Limitation and anti wind-up method clamping:

$$G(s) = K_p + K_i/s + K_d*s/(s/(2*\pi*fc) + 1)$$

| Inports |                                                                                                                               |
|---------|-------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                           |
| Init    | Initial value of output Out when enabled                                                                                      |
| max     | Maximum output value                                                                                                          |
| min     | Minimum output value                                                                                                          |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable 0->1: Preload of integral part<br>Enable == 1: Activation of block |

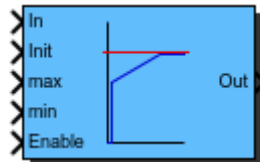
| Outports |               |
|----------|---------------|
| Out      | Control value |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Kp              | 1  | Proportional Factor                                             |
| Ki              | 2  | Integral Factor                                                 |
| Kd              | 3  | Derivative Factor                                               |
| fc              | 4  | Cutoff frequency of realization low pass                        |
| initHandling    | 5  | Determines what the signal provided on Init input is used for   |
| ts_fact         | 6  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: PILimit



PI controller with output limitation and anti wind-up method clamping:

$$G(s) = K_p + K_i/s$$

| Inports |                                                                                                                               |
|---------|-------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                           |
| Init    | Initial value of output Out when enabled                                                                                      |
| max     | Maximum output value                                                                                                          |
| min     | Minimum output value                                                                                                          |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable 0->1: Preload of integral part<br>Enable == 1: Activation of block |

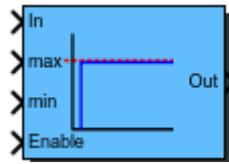
| Outports |               |
|----------|---------------|
| Out      | Control value |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Kp              | 1  | Proportional Factor                                             |
| Ki              | 2  | Integral Factor                                                 |
| initHandling    | 3  | Determines what the signal provided on Init input is used for   |
| ts_fact         | 4  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: PLimit



P controller with output limitation:

$$G(s) = K_p$$

| Inports |                                                                                      |
|---------|--------------------------------------------------------------------------------------|
| In      | Control error input                                                                  |
| max     | Maximum output value                                                                 |
| min     | Minimum output value                                                                 |
| Enable  | Enable == 0: Deactivation of block; Out set to 0<br>Enable == 1: Activation of block |

| Outports |               |
|----------|---------------|
| Out      | Control value |

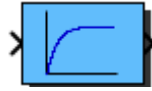
| Mask Parameters |    |                     |
|-----------------|----|---------------------|
| Name            | ID | Description         |
| Kp              | 1  | Proportional Factor |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: PT1

---



First order low pass:

$$G(s) = V/(s/w + 1)$$

| Inports |             |
|---------|-------------|
| In      | Input In(k) |

| Outports |               |
|----------|---------------|
| Out      | Output Out(k) |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| V               | 1  | Gain                                                            |
| fc              | 2  | Cut off frequency of low pass filter                            |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |
| method          | 4  | Discretization method                                           |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: TDSysSystemO1

---

$$\begin{cases} x_{k+1} = A x_k + B u_k \\ y_k = C x_k + D u_k \end{cases}$$

1st order time discrete system with one input and one output.

| Inports |          |
|---------|----------|
| In      | Input #1 |

| Outports |           |
|----------|-----------|
| Out      | Output #1 |

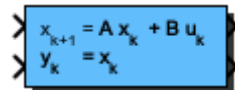
| Mask Parameters |    |                      |
|-----------------|----|----------------------|
| Name            | ID | Description          |
| A               | 1  | State matrix A       |
| B               | 2  | Input matrix B       |
| C               | 3  | Output matrix C      |
| D               | 4  | Feedthrough matrix D |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: TDSysSystemO2

---


$$\begin{aligned}x_{k+1} &= A x_k + B u_k \\ y_k &= x_k\end{aligned}$$

2nd order time discrete system with two inputs and two outputs.

| Inports |          |
|---------|----------|
| In1     | Input #1 |
| In2     | Input #2 |

| Outports |           |
|----------|-----------|
| Out1     | Output #1 |
| Out2     | Output #2 |

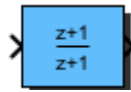
| Mask Parameters |    |                |
|-----------------|----|----------------|
| Name            | ID | Description    |
| A               | 1  | State matrix A |
| B               | 2  | Input matrix B |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: TF1

---



First order transfer function:

$$G(z) = (b1.z + b0) / (z + a0)$$

| Inports |             |
|---------|-------------|
| In      | Input In(k) |

| Outports |               |
|----------|---------------|
| Out      | Output Out(k) |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| b1              | 1  | b1                                                              |
| b0              | 2  | b0                                                              |
| a0              | 3  | a0                                                              |
| ts_fact         | 4  | Multiplication factor of base sampling time (in integer format) |

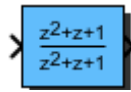
### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: TF2

---



Second order transfer function:

$$G(z) = (b_2 \cdot z^2 + b_1 \cdot z + b_0) / (z^2 + a_1 \cdot z + a_0)$$

| Inports |             |
|---------|-------------|
| In      | Input In(k) |

| Outports |               |
|----------|---------------|
| Out      | Output Out(k) |

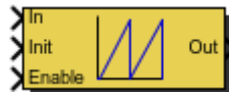
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| b2              | 1  | b2                                                              |
| b1              | 2  | b1                                                              |
| b0              | 3  | b0                                                              |
| a1              | 4  | a1                                                              |
| a0              | 5  | a0                                                              |
| ts_fact         | 6  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: ul

---



Integrator for angle signals:

$$G(s) = K_i/s = 1/(T_i \cdot s)$$

| Inports |                                                                                                                                    |
|---------|------------------------------------------------------------------------------------------------------------------------------------|
| In      | Control error input                                                                                                                |
| Init    | Value which is loaded at initialization function call                                                                              |
| Enable  | Enable == 0: Deactivation of block; Out is set to 0.<br>Enable 0->1: Preload of integral part.<br>Enable == 1: Activation of block |

| Outputs |                   |
|---------|-------------------|
| Out     | Integrator output |

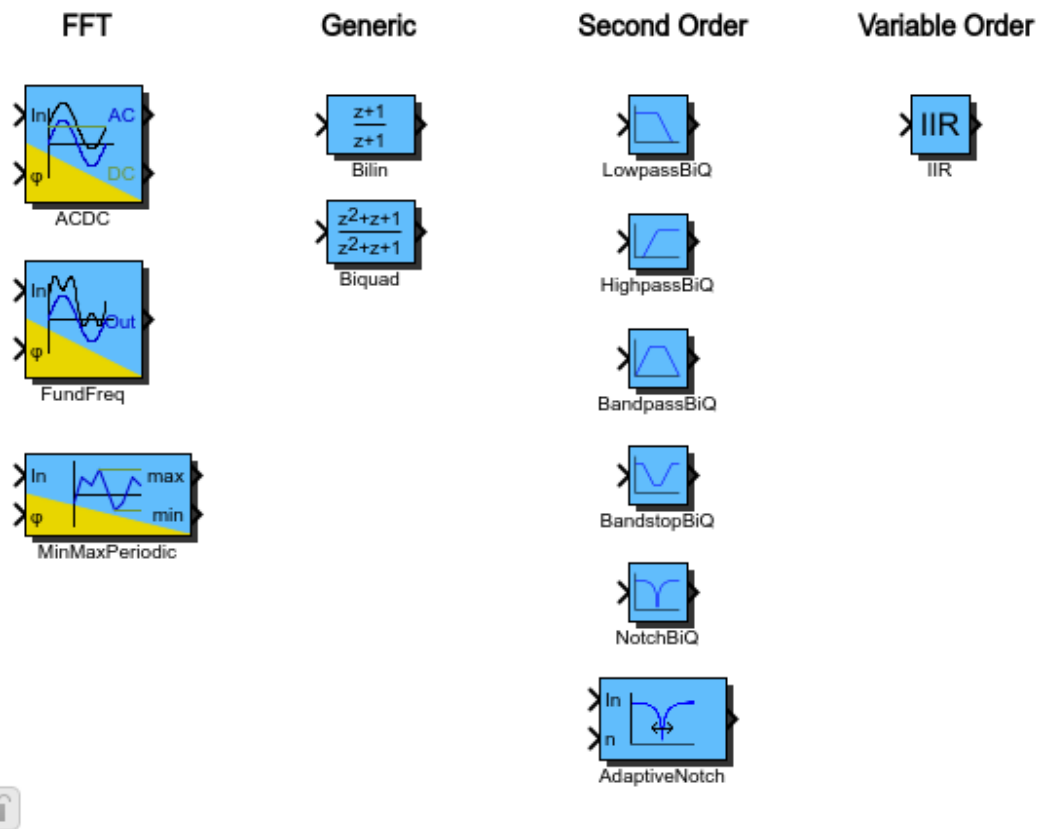
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Ki              | 1  | Integral Factor                                                 |
| ts_fact         | 2  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

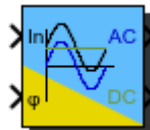
## 25 Filter

Library with various kinds of digital filter blocks.



## Block: ACDC

---



Calculation of AC and DC part of input signal.

| Inports |              |
|---------|--------------|
| In      | Input signal |
| phi     | Angle signal |

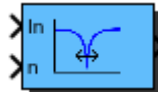
| Outports |                         |
|----------|-------------------------|
| AC       | AC part of input signal |
| DC       | DC part of input signal |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| ts_fact         | 1  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: AdaptiveNotch



Notch filter with variable notch frequency

| Inports |                               |
|---------|-------------------------------|
| In      | Input signal                  |
| n       | Speed input = notch frequency |

| Outputs |                        |
|---------|------------------------|
| Out     | Filtered output signal |

| Mask Parameters |    |                                                                                |
|-----------------|----|--------------------------------------------------------------------------------|
| Name            | ID | Description                                                                    |
| Q               | 1  | Q-Factor of the notch filter                                                   |
| n_thresh        | 2  | Speed threshold for activating the filter                                      |
| n_max           | 3  | Maximum revolutions per minute<br>(Not used in floating point implementations) |
| p               | 4  | Number of pole pairs                                                           |
| ts_fact         | 5  | Multiplication factor of base sampling time (in integer format)                |
| method          | 6  | Discretization method                                                          |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: BandpassBiQ

---



Calculates the filter coefficients for a second order bandpass and performs filtering on input signal.

Second order transfer function used:

$$H(z) = (b0.z^2 + b1.z + b2) / (z^2 + a1.z + a2)$$

### Inports

|    |             |
|----|-------------|
| In | Input In(k) |
|----|-------------|

### Outports

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

| Name           | ID | Description                                                            |
|----------------|----|------------------------------------------------------------------------|
| characteristic | 1  | The filter characteristic is one of Butterworth (=Bessel) or Chebyshev |
| fc1            | 2  | Lower cut-off frequency in Hz                                          |
| fc2            | 3  | Upper cut-off frequency in Hz                                          |
| rc             | 4  | Attenuation at cut-off frequencies                                     |
| ts_fact        | 5  | Multiplication factor of base sampling time (in integer format)        |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: BandstopBiQ

---



Calculates the filter coefficients for a second order bandstop and performs filtering on input signal.

Second order transfer function used:

$$H(z) = (b0.z^2 + b1.z + b2) / (z^2 + a1.z + a2)$$

### Inports

|    |             |
|----|-------------|
| In | Input In(k) |
|----|-------------|

### Outports

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

| Name           | ID | Description                                                            |
|----------------|----|------------------------------------------------------------------------|
| characteristic | 1  | The filter characteristic is one of Butterworth (=Bessel) or Chebyshev |
| fc1            | 2  | Lower cut-off frequency in Hz                                          |
| fc2            | 3  | Upper cut-off frequency in Hz                                          |
| rc             | 4  | Attenuation at cut-off frequencies                                     |
| ts_fact        | 5  | Multiplication factor of base sampling time (in integer format)        |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Bilin

---



First order transfer function:

$$H(z) = (b_0.z + b_1) / (a_0.z + a_1)$$

### Inports

|    |             |
|----|-------------|
| In | Input In(k) |
|----|-------------|

### Outputs

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

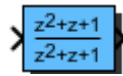
| Name    | ID | Description                                                     |
|---------|----|-----------------------------------------------------------------|
| b0      | 1  | Filter coefficient b0                                           |
| b1      | 2  | Filter coefficient b1                                           |
| a0      | 3  | Filter coefficient a0                                           |
| a1      | 4  | Filter coefficient a1                                           |
| ts_fact | 5  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: Biquad



Second order transfer function:

$$H(z) = (b_0.z^2 + b_1.z + b_2) / (a_0.z^2 + a_1.z + a_2)$$

### Inports

|    |             |
|----|-------------|
| In | Input In(k) |
|----|-------------|

### Outports

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

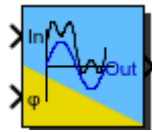
| Name    | ID | Description                                                     |
|---------|----|-----------------------------------------------------------------|
| b0      | 1  | Filter coefficient b0                                           |
| b1      | 2  | Filter coefficient b1                                           |
| b2      | 3  | Filter coefficient b2                                           |
| a0      | 4  | Filter coefficient a0                                           |
| a1      | 5  | Filter coefficient a1                                           |
| a2      | 6  | Filter coefficient a2                                           |
| ts_fact | 7  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: FundFreq

---



Calculation of the first harmonic (fundamental frequency) of the input signal.

| Inports |              |
|---------|--------------|
| In      | Input signal |
| phi     | Angle signal |

| Outports |                |
|----------|----------------|
| Out      | First harmonic |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| ts_fact         | 1  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: HighpassBiQ



Calculates the filter coefficients for a second order highpass and performs filtering on input signal.

Second order transfer function used:

$$H(z) = (b0.z^2 + b1.z + b2) / (z^2 + a1.z + a2)$$

### Inports

|    |             |
|----|-------------|
| In | Input In(k) |
|----|-------------|

### Outports

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

| Name           | ID | Description                                                                                                            |
|----------------|----|------------------------------------------------------------------------------------------------------------------------|
| characteristic | 1  | The filter characteristic is one of Butterworth, Chebyshev I, Chebyshev II (also known as inverse Chebyshev) or Bessel |
| fc             | 2  | Cut-off frequency in Hz                                                                                                |
| rp             | 3  | The passband ripple is only used and verified with 'Chebyshev I' filters.<br>Must be a positive number                 |
| rs             | 4  | The stopband ripple is only used and verified with 'Chebyshev II' filters.<br>Must be a positive number                |
| ts_fact        | 5  | Multiplication factor of base sampling time (in integer format)                                                        |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: IIR

---



Transfer function:

$$H(z) = (b_0.z^n + b_1.z + \dots + b_n) / (a_0.z^n + a_1.z + \dots + a_n)$$

The maximum filter order is 32.

The order of the denominator has to be greater than or equal to the order of the numerator.

### Inports

|    |             |
|----|-------------|
| In | Input In(k) |
|----|-------------|

### Outports

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

| Name    | ID | Description                                                     |
|---------|----|-----------------------------------------------------------------|
| CoeffB  | 1  | Array with filter coefficients of numerator                     |
| CoeffA  | 2  | Array with filter coefficients of denominator                   |
| ts_fact | 3  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: LowpassBiQ



Calculates the filter coefficients for a second order lowpass and performs filtering on input signal.

Second order transfer function used:

$$H(z) = (b0.z^2 + b1.z + b2) / (z^2 + a1.z + a2)$$

| Inports |             |
|---------|-------------|
| In      | Input In(k) |

| Outports |               |
|----------|---------------|
| Out      | Output Out(k) |

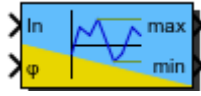
| Mask Parameters |    |                                                                                                                        |
|-----------------|----|------------------------------------------------------------------------------------------------------------------------|
| Name            | ID | Description                                                                                                            |
| characteristic  | 1  | The filter characteristic is one of Butterworth, Chebyshev I, Chebyshev II (also known as inverse Chebyshev) or Bessel |
| fc              | 2  | Cut-off frequency in Hz                                                                                                |
| rp              | 3  | The passband ripple is only used and verified with 'Chebyshev I' filters.<br>Must be a positive number                 |
| rs              | 4  | The stopband ripple is only used and verified with 'Chebyshev II' filters.<br>Must be a positive number                |
| ts_fact         | 5  | Multiplication factor of base sampling time (in integer format)                                                        |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: MinMaxPeriodic

---



Outputs the minimum and maximum of the input signal over one period of the (angle) signal phi.

| Inports |              |
|---------|--------------|
| In      | Input signal |
| phi     | Angle signal |

| Outports |                         |
|----------|-------------------------|
| max      | Maximum of input signal |
| min      | Minimum of input signal |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: NotchBiQ



Calculates the filter coefficients for a second order notch filter and performs filtering on input signal.

Second order transfer function used:

$$H(z) = (b0.z^2 + b1.z + b2) / (z^2 + a1.z + a2)$$

### Inports

|    |             |
|----|-------------|
| In | Input In(k) |
|----|-------------|

### Outports

|     |               |
|-----|---------------|
| Out | Output Out(k) |
|-----|---------------|

### Mask Parameters

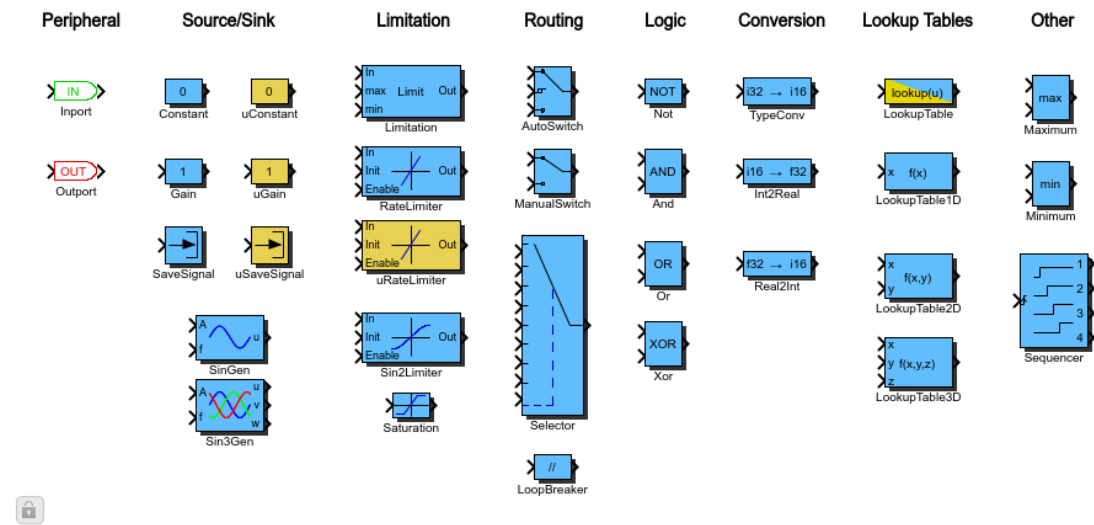
| Name    | ID | Description                                                              |
|---------|----|--------------------------------------------------------------------------|
| method  | 1  | Selection between bilinear and matched Z-transform discretization method |
| fn      | 2  | Notching frequency in Hz                                                 |
| Q       | 3  | Defines a quality factor of the filter                                   |
| ts_fact | 4  | Multiplication factor of base sampling time (in integer format)          |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## 26 General

Library with general purpose blocks.





## Block: And

---



Logical AND block.

| Inports |  |
|---------|--|
| In1     |  |
| In2     |  |

| Outports |  |
|----------|--|
| Out      |  |

### Implementations:

**Bool**    Boolean Implementation

## Block: AutoSwitch

---



Switch between In1 and In3 dependent on Switch signal:

Switch signal rising: Switch  $\geq$  Threshold up  $\rightarrow$  Out = In1

Switch signal falling: Switch  $<$  Threshold down  $\rightarrow$  Out = In3

| Inports |                            |
|---------|----------------------------|
| In1     | Input #1                   |
| Switch  | Input #2: Threshold signal |
| In3     | Input #3                   |

| Outputs |                                                                     |
|---------|---------------------------------------------------------------------|
| Out     | Either value of input #1 or input #3 dependent on value of input #2 |

| Mask Parameters |    |                                           |
|-----------------|----|-------------------------------------------|
| Name            | ID | Description                               |
| Thresh_up       | 1  | Threshold level for rising switch signal  |
| Thresh_down     | 2  | Threshold level for falling switch signal |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Constant

---



Constant value.

| Outputs |                 |
|---------|-----------------|
| Out     | Constant output |

| Mask Parameters |    |                 |
|-----------------|----|-----------------|
| Name            | ID | Description     |
| Value           | 1  | Constant factor |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Implementation               |
| <b>Int8</b>    | 8 Bit Integer Implementation         |
| <b>Int16</b>   | 16 Bit Integer Implementation        |
| <b>Int32</b>   | 32 Bit Integer Implementation        |
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Gain

---



Amplification of input by gain factor.

| Inports |       |
|---------|-------|
| In      | Input |

| Outports |                 |
|----------|-----------------|
| Out      | Amplified input |

| Mask Parameters |    |                                      |
|-----------------|----|--------------------------------------|
| Name            | ID | Description                          |
| Gain            | 1  | Gain factor in floating point format |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Inport



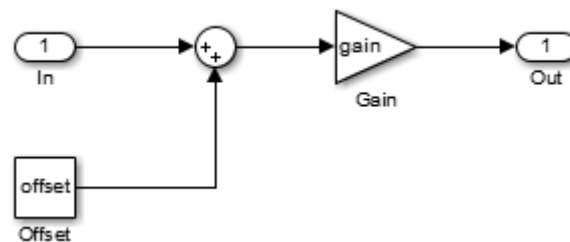
| Inports |                           |
|---------|---------------------------|
| IN      | Signal from frame program |

| Mask Parameters |                                                                 |
|-----------------|-----------------------------------------------------------------|
| ts_fact         | Multiplication factor of base sampling time (in integer format) |
| Gain            | Gain value used in simulation                                   |
| Offset          | Offset value used in simulation                                 |

### Description:

Serves as interface to the frame program. The input of this block is intended for simulation purposes and can be left unconnected if not used. Also the parameters *Gain* and *Offset* are only used during simulation. The schematic for simulation can be seen in the figure below.

**Note:** Currently, *Gain* and *Offset* parameters are only available in Matlab/Simulink.

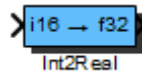


### Data Types:

|                |                       |
|----------------|-----------------------|
| <b>bool</b>    | Boolean               |
| <b>int8</b>    | 8 Bit Fixed Point     |
| <b>int16</b>   | 16 Bit Fixed Point    |
| <b>int32</b>   | 32 Bit Fixed Point    |
| <b>float32</b> | 32 Bit Floating Point |
| <b>float64</b> | 64 Bit Floating Point |

## Block: Int2Real

---



Conversion block from integer (fixed point) datatypes to real (floating point) datatypes.

$\text{Out} = \text{In} * \text{Scale}$

| Inports |               |
|---------|---------------|
| In      | Integer input |

| Outports |             |
|----------|-------------|
| Out      | Real output |

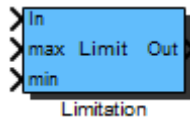
| Mask Parameters |    |                                     |
|-----------------|----|-------------------------------------|
| Name            | ID | Description                         |
| Scale           | 1  | Scaling factor from integer to real |

### Implementations:

|                      |                                                            |
|----------------------|------------------------------------------------------------|
| <b>FiP8_Float32</b>  | 8 Bit Fixed Point to 32 Bit Floating Point Implementation  |
| <b>FiP16_Float32</b> | 16 Bit Fixed Point to 32 Bit Floating Point Implementation |
| <b>FiP32_Float32</b> | 32 Bit Fixed Point to 32 Bit Floating Point Implementation |
| <b>FiP8_Float64</b>  | 8 Bit Fixed Point to 64 Bit Floating Point Implementation  |
| <b>FiP16_Float64</b> | 16 Bit Fixed Point to 64 Bit Floating Point Implementation |
| <b>FiP32_Float64</b> | 32 Bit Fixed Point to 64 Bit Floating Point Implementation |
| <b>Bool_Float32</b>  | Boolean to 32 Bit Floating Point Implementation            |
| <b>Bool_Float64</b>  | Boolean to 64 Bit Floating Point Implementation            |

## Block: Limitation

---



Limits the input signal to min and max\_sci.

Caution: For correct computation the upper limit max has to be greater than the lower limit min!

| Inports |              |
|---------|--------------|
| In      | Input signal |
| max     | Upper limit  |
| min     | Lower limit  |

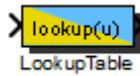
| Outports |                      |
|----------|----------------------|
| Out      | Limited input signal |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: LookupTable

---



Look-up Table with 256+1 values.

Note: 257th value is used for preventing index overflow during interpolation.

-> for periodic signals the 257th value should be set equal to 1st value

-> for non-periodic signals the 257th value should be set equal to 256th value

| Inports |             |
|---------|-------------|
| In      | Table index |

| Outports |              |
|----------|--------------|
| Out      | Table output |

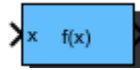
| Mask Parameters |    |               |
|-----------------|----|---------------|
| Name            | ID | Description   |
| Lookup          | 1  | Look-up Table |

### Implementations:

- FiP8** 8 Bit Fixed Point Implementation
- FiP16** 16 Bit Fixed Point Implementation
- FiP32** 32 Bit Fixed Point Implementation



## Block: LookupTable1D



One dimensional look-up table with selectable number of data points.

Table data must be an array of size DimX. If one of the RAM implementations is used, DimX must not exceed 257.

If input is out of specified range, output will be cut off (no extrapolation).

| Inports |                            |
|---------|----------------------------|
| x       | Table index in x direction |

| Outports |              |
|----------|--------------|
| Out      | Table output |

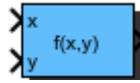
| Mask Parameters |    |                                                      |
|-----------------|----|------------------------------------------------------|
| Name            | ID | Description                                          |
| TableData       | 1  | Look-up table data                                   |
| DimX            | 2  | Number of data points in x-direction                 |
| x_min           | 3  | Minimum input value of x-dimension for look-up table |
| x_max           | 4  | Maximum input value of x-dimension for look-up table |

### Implementations:

|                    |                                                                                 |
|--------------------|---------------------------------------------------------------------------------|
| <b>FiP16</b>       | 64 Bit Floating Point Implementation with look-up table located in RAM          |
| <b>FiP32</b>       | 32 Bit Fixed Point Implementation with look-up table located in Flash memory    |
| <b>Float32</b>     | 32 Bit Floating Point Implementation with look-up table located in Flash memory |
| <b>Float64</b>     | 64 Bit Floating Point Implementation with look-up table located in Flash memory |
| <b>FiP16_RAM</b>   | 16 Bit Fixed Point Implementation with look-up table located in RAM             |
| <b>FiP32_RAM</b>   | 32 Bit Fixed Point Implementation with look-up table located in RAM             |
| <b>Float32_RAM</b> | 32 Bit Floating Point Implementation with look-up table located in RAM          |
| <b>Float64_RAM</b> | 64 Bit Floating Point Implementation with look-up table located in RAM          |

## Block: LookupTable2D

---



Two dimensional look-up table with selectable number of data points.

Table data must be an array of size DimX\*DimY.

If input is out of specified range, output will be cut off (no extrapolation).

| Inports |                            |
|---------|----------------------------|
| x       | Table index in x direction |
| y       | Table index in y direction |

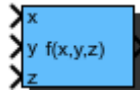
| Outports |              |
|----------|--------------|
| Out      | Table output |

| Mask Parameters |    |                                                      |
|-----------------|----|------------------------------------------------------|
| Name            | ID | Description                                          |
| TableData       | 1  | Look-up table data                                   |
| DimX            | 2  | Number of data points in x-direction                 |
| x_min           | 3  | Minimum input value of x-dimension for look-up table |
| x_max           | 4  | Maximum input value of x-dimension for look-up table |
| DimY            | 5  | Number of data points in y-direction                 |
| y_min           | 6  | Minimum input value of y-dimension for look-up table |
| y_max           | 7  | Maximum input value of y-dimension for look-up table |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: LookupTable3D



Three dimensional look-up table with selectable number of data points.

Table data must be an array of size DimX\*DimY\*DimZ.

If input is out of specified range, output will be cut off (no extrapolation).

| Inports |                            |
|---------|----------------------------|
| x       | Table index in x direction |
| y       | Table index in y direction |
| z       | Table index in z direction |

| Outputs |              |
|---------|--------------|
| Out     | Table output |

| Mask Parameters |    |                                                      |
|-----------------|----|------------------------------------------------------|
| Name            | ID | Description                                          |
| TableData       | 1  | Look-up table data                                   |
| DimX            | 2  | Number of data points in x-direction                 |
| x_min           | 3  | Minimum input value of x-dimension for look-up table |
| x_max           | 4  | Maximum input value of x-dimension for look-up table |
| DimY            | 5  | Number of data points in y-direction                 |
| y_max           | 6  | Maximum input value of y-dimension for look-up table |
| y_min           | 7  | Minimum input value of y-dimension for look-up table |
| DimZ            | 8  | Number of data points in z-direction                 |
| z_min           | 9  | Minimum input value of z-dimension for look-up table |
| z_max           | 10 | Maximum input value of z-dimension for look-up table |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: LoopBreaker

---



Block to break algebraic loops.

| Inports  |                       |
|----------|-----------------------|
| In       | Input In(k)           |
| Outports |                       |
| Out      | Output Out(k)=In(k-1) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Integration                  |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: ManualSwitch

---



Toggling between inputs by double-clicking on block.

| Inports |          |
|---------|----------|
| In1     | Input #1 |
| In2     | Input #2 |

| Outports |  |
|----------|--|
| Out      |  |

| Mask Parameters |    |             |
|-----------------|----|-------------|
| Name            | ID | Description |
| Toggle          | 1  | Toggle      |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Implementation               |
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Maximum

---



Outputs the greater value of the two input signals.

| Inports |          |
|---------|----------|
| In1     | Input #1 |
| In2     | Input #2 |

| Outports |                                  |
|----------|----------------------------------|
| Out      | Maximum of Input #1 and Input #2 |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Minimum

---



Outputs the lesser value of the two input signals.

| Inports |          |
|---------|----------|
| In1     | Input #1 |
| In2     | Input #2 |

| Outports |                                  |
|----------|----------------------------------|
| Out      | Minimum of Input #1 and Input #2 |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Not

---



Logical inverter block.

| Inports  |  |
|----------|--|
| In       |  |
| Outports |  |
| Out      |  |

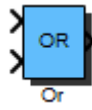
### Implementations:

**Bool**    Boolean Implementation



## Block: Or

---



Logical OR block.

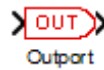
| Inports |  |
|---------|--|
| In1     |  |
| In2     |  |

| Outports |  |
|----------|--|
| Out      |  |

### Implementations:

**Bool**    Boolean Implementation

## Block: Output



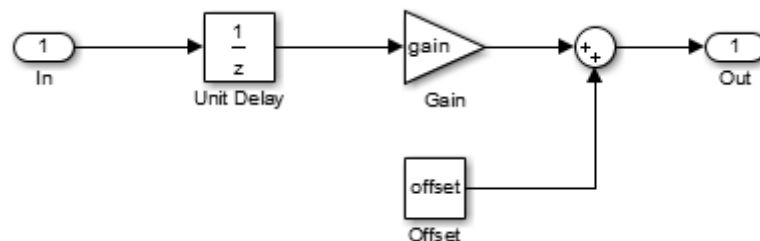
| Outputs |                         |
|---------|-------------------------|
| OUT     | Signal to frame program |

| Mask Parameters |                                                                 |
|-----------------|-----------------------------------------------------------------|
| ts_fact         | Multiplication factor of base sampling time (in integer format) |
| Gain            | Gain value used in simulation                                   |
| Offset          | Offset value used in simulation                                 |

### Description:

Serves as interface to the frame program. The output of this block is intended for simulation purposes and can be left unconnected if not used. Also the parameters *Gain*, and *Offset* are only used during simulation. The schematic for simulation can be seen in the figure below. The Unit Delay block is only used during simulation and should reflect the time delay caused by a discrete controller.

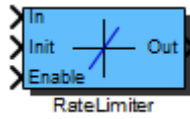
**Note:** Currently, *Gain* and *Offset* parameters are only available in Matlab/Simulink.



### Data Types:

|                |                       |
|----------------|-----------------------|
| <b>bool</b>    | Boolean               |
| <b>int8</b>    | 8 Bit Fixed Point     |
| <b>int16</b>   | 16 Bit Fixed Point    |
| <b>int32</b>   | 32 Bit Fixed Point    |
| <b>float32</b> | 32 Bit Floating Point |
| <b>float64</b> | 64 Bit Floating Point |

## Block: RateLimiter



Limitation of rising and falling rate.

Function of Enable:

0: rate limiting disabled, signal is passed through

1: rate limiting enabled, signal is rate limited

0->1: preload of output with value from init input

| Inports |                                                                                                                                                                                         |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| In      |                                                                                                                                                                                         |
| Init    | Value which is loaded at rising flanke of enable signal                                                                                                                                 |
| Enable  | Enable == 0: Deactivation of block; Out is set to In.<br>Enable != 0: Activation of block; Out is rate limited.<br>Enable 0->1: Preloading of output; Out is set to value of Init input |

| Outports |  |
|----------|--|
| Out      |  |

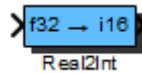
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Tr              | 1  | Rising time in seconds. Slew rate will be $1/Tr$                |
| Tf              | 2  | Falling time in seconds. Slew rate will be $1/Tf$               |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Real2Int

---



Conversion block from real (floating point) datatypes to integer (fixed point) datatypes.

$\text{Out} = \text{In} / \text{Scale}$

| Inports |            |
|---------|------------|
| In      | Real input |

| Outports |                |
|----------|----------------|
| Out      | Integer output |

| Mask Parameters |    |                                     |
|-----------------|----|-------------------------------------|
| Name            | ID | Description                         |
| Scale           | 1  | Scaling factor from real to integer |

### Implementations:

|                      |                                                        |
|----------------------|--------------------------------------------------------|
| <b>Float32_FiP8</b>  | 32 Floating Point to 8 Bit Fixed Point Implementation  |
| <b>Float32_FiP16</b> | 32 Floating Point to 16 Bit Fixed Point Implementation |
| <b>Float32_FiP32</b> | 32 Floating Point to 32 Bit Fixed Point Implementation |
| <b>Float64_FiP8</b>  | 64 Floating Point to 8 Bit Fixed Point Implementation  |
| <b>Float64_FiP16</b> | 64 Floating Point to 16 Bit Fixed Point Implementation |
| <b>Float64_FiP32</b> | 64 Floating Point to 32 Bit Fixed Point Implementation |
| <b>Float32_Bool</b>  | 32 Floating Point to Boolean Implementation            |
| <b>Float64_Bool</b>  | 64 Floating Point to Boolean Implementation            |

## Block: Saturation

---



Saturation of output to adjustable upper and lower limit.

| Inports |       |
|---------|-------|
| In      | Input |

| Outports |                |
|----------|----------------|
| Out      | Limited output |

| Mask Parameters |    |             |
|-----------------|----|-------------|
| Name            | ID | Description |
| max             | 1  | Upper Limit |
| min             | 2  | Lower Limit |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: SaveSignal

---



Makes the incoming signal accessible for reading with parameter numbers.

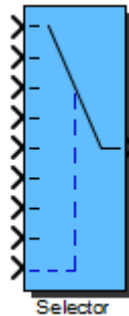
| Inports |                          |
|---------|--------------------------|
| In      | Input signal to be saved |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Implementation               |
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Selector

---



Passing through of input signal selected by the select inport:

Select = 0 (DSP): Out = In0

Select = 1 (DSP): Out = In1

...

Select = 7 (DSP): Out = In7

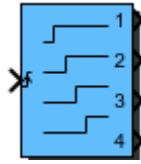
| Inports |              |
|---------|--------------|
| In0     | Input #0     |
| In1     | Input #1     |
| In2     | Input #2     |
| In3     | Input #3     |
| In4     | Input #4     |
| In5     | Input #5     |
| In6     | Input #6     |
| In7     | Input #7     |
| Select  | Input select |

| Outports |                       |
|----------|-----------------------|
| Out      | Selected input signal |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Sequencer



Generation of time delayed (enable) sequence.

| Inports |                                              |
|---------|----------------------------------------------|
| Start   | Start signal. Rising flank triggers sequence |

| Outputs |           |
|---------|-----------|
| Out1    | Output #1 |
| Out2    | Output #2 |
| Out3    | Output #3 |
| Out4    | Output #4 |

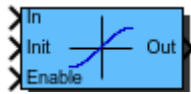
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Delay1          | 1  | Time delay for output 1                                         |
| Delay2          | 2  | Time delay for output 2                                         |
| Delay3          | 3  | Time delay for output 3                                         |
| Delay4          | 4  | Time delay for output 4                                         |
| ts_fact         | 5  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Implementation               |
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: Sin2Limiter



Limitation of rising and falling rate with  $\sin^2$  characteristic.

Note: A running limitation process can not be interrupted!

Function of Enable:

0: rate limiting disabled, signal is set to zero

1: rate limiting enabled, signal is rate limited

0->1: preload of output with value from init input

| Inports |                                                                                                                                                                                           |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| In      |                                                                                                                                                                                           |
| Init    | Value which is loaded at rising flanke of enable signal                                                                                                                                   |
| Enable  | Enable == 0: Deactivation of block; Out is set to zero.<br>Enable != 0: Activation of block; Out is rate limited.<br>Enable 0->1: Preloading of output; Out is set to value of Init input |

| Outports |  |
|----------|--|
| Out      |  |

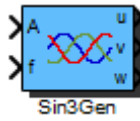
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Tr              | 1  | Rising time in seconds. Slew rate will be $1/Tr$                |
| Tf              | 2  | Falling time in seconds. Slew rate will be $1/Tf$               |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Sin3Gen

---



Generation of a 3 sine waves with amplitude (A) and frequency (f).

| Inports |           |
|---------|-----------|
| A       | Amplitude |
| f       | Frequency |

| Outports |                          |
|----------|--------------------------|
| u        | Sine wave output phase u |
| v        | Sine wave output phase v |
| w        | Sine wave output phase w |

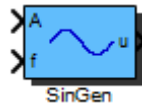
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| fmax            | 1  | Maximum Frequency in Hz                                         |
| Offset          | 2  | Offset                                                          |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: SinGen

---



Generation of a sine wave with amplitude (A) and frequency (f).

| Inports |           |
|---------|-----------|
| A       | Amplitude |
| f       | Frequency |

| Outputs |                  |
|---------|------------------|
| u       | Sine wave output |

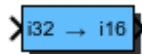
| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| fmax            | 1  | Maximum Frequency in Hz                                         |
| Offset          | 2  | Offset                                                          |
| Phase           | 3  | Phase [-Pi..Pi]                                                 |
| ts_fact         | 4  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: TypeConv

---



Data Type Conversion

| Inports  |  |
|----------|--|
| In       |  |
| Outports |  |
| Out      |  |

### Implementations:

|                   |                                              |
|-------------------|----------------------------------------------|
| <b>FiP8_16</b>    | 8 to 16 Bit Fixed Point Implementation       |
| <b>FiP8_32</b>    | 8 to 32 Bit Fixed Point Implementation       |
| <b>FiP16_8</b>    | 16 to 8 Bit Fixed Point Implementation       |
| <b>FiP16_32</b>   | 16 to 32 Bit Fixed Point Implementation      |
| <b>FiP32_8</b>    | 32 to 8 Bit Fixed Point Implementation       |
| <b>FiP32_16</b>   | 32 to 16 Bit Fixed Point Implementation      |
| <b>Bool_FiP16</b> | Boolean to 16 Bit Fixed Point Implementation |
| <b>Bool_FiP32</b> | Boolean to 32 Bit Fixed Point Implementation |
| <b>FiP16_Bool</b> | 16 Bit Fixed Point to Boolean Implementation |
| <b>FiP32_Bool</b> | 32 Bit Fixed Point to Boolean Implementation |

## Block: uConstant

---



Constant value.

| Outputs |                 |
|---------|-----------------|
| Out     | Constant output |

| Mask Parameters |    |                 |
|-----------------|----|-----------------|
| Name            | ID | Description     |
| Value           | 1  | Constant factor |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Integration                  |
| <b>Int8</b>    | 8 Bit Integer Implementation         |
| <b>Int16</b>   | 16 Bit Integer Implementation        |
| <b>Int32</b>   | 32 Bit Integer Implementation        |
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: uGain

---



Amplification of input by gain factor with output wrapping.

| Inports |       |
|---------|-------|
| In      | Input |

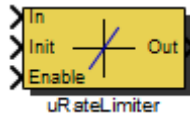
| Outports |                 |
|----------|-----------------|
| Out      | Amplified input |

| Mask Parameters |    |                                      |
|-----------------|----|--------------------------------------|
| Name            | ID | Description                          |
| Gain            | 1  | Gain factor in floating point format |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: uRateLimiter



Limitation of rising and falling rate.

Function of Enable:

0: rate limiting disabled, signal is passed through

1: rate limiting enabled, signal is rate limited

0->1: preload of output with value from init input

| Inports |                                                                                                                                                                                         |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| In      |                                                                                                                                                                                         |
| Init    | Value which is loaded at rising flanke of enable signal                                                                                                                                 |
| Enable  | Enable == 0: Deactivation of block; Out is set to In.<br>Enable != 0: Activation of block; Out is rate limited.<br>Enable 0->1: Preloading of output; Out is set to value of Init input |

| Outports |  |
|----------|--|
| Out      |  |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| Tr              | 1  | Rising time in seconds. Slew rate will be $1/Tr$                |
| Tf              | 2  | Falling time in seconds. Slew rate will be $1/Tf$               |
| ts_fact         | 3  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: uSaveSignal

---



Makes the incoming signal accessible for reading with parameter numbers.

| Inports |                          |
|---------|--------------------------|
| In      | Input signal to be saved |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>Bool</b>    | Boolean Implementation               |
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: Xor

---



Logical XOR block.

| Inports |  |
|---------|--|
| In1     |  |
| In2     |  |

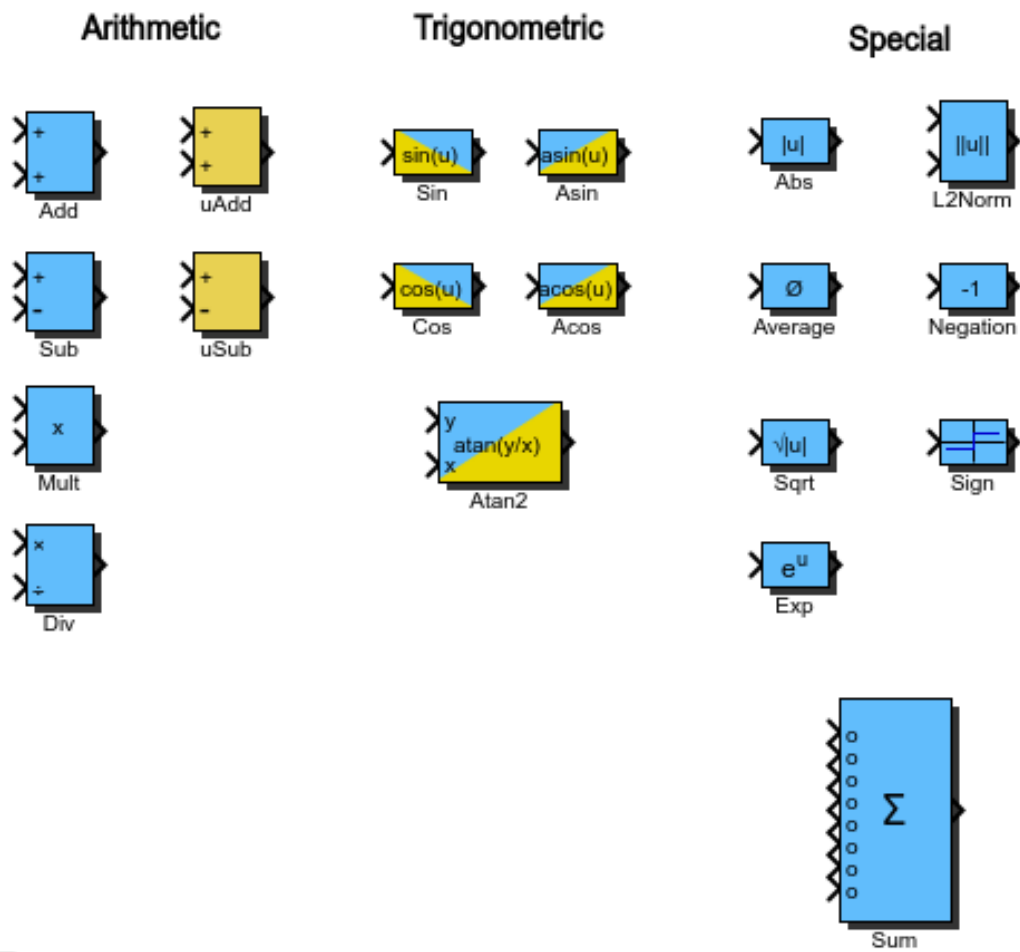
| Outports |  |
|----------|--|
| Out      |  |

### Implementations:

**Bool**    Boolean Implementation

## 27 Math

This library contains blocks for computation of common mathematical functions.



## Block: Abs

---



Calculation of absolute value of input.

| Inports |         |
|---------|---------|
| In      | Input u |

| Outports |                     |
|----------|---------------------|
| Out      | Absolute value of u |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Acos

---



Arccosine computation of input value.

| Inports  |                  |
|----------|------------------|
| In       | Input u          |
| Outports |                  |
| Out      | Result of sin(u) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Add

---



Addition of input 1 and input 2.

| Inports |          |
|---------|----------|
| In1     | Addend 1 |
| In2     | Addend 2 |

| Outports |     |
|----------|-----|
| Out      | Sum |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Asin

---



Arcsine computation of input value.

| Inports  |                  |
|----------|------------------|
| In       | Input u          |
| Outports |                  |
| Out      | Result of sin(u) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Atan2

---



Computation of the angle between the inputs x and y.

| Inports |  |
|---------|--|
| y       |  |
| x       |  |

| Outports |                      |
|----------|----------------------|
| Out      | Result of atan2(y/x) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Average

---



Calculation of moving average value over n numbers.

| Inports |             |
|---------|-------------|
| In      | Input value |

| Outports |                |
|----------|----------------|
| Out      | Averaged value |

| Mask Parameters |    |                                                                 |
|-----------------|----|-----------------------------------------------------------------|
| Name            | ID | Description                                                     |
| n               | 1  | Number of points to be averaged over                            |
| ts_fact         | 2  | Multiplication factor of base sampling time (in integer format) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: Cos

---



Cosine computation of input value.

| Inports  |                  |
|----------|------------------|
| In       | Input u          |
| Outports |                  |
| Out      | Result of cos(u) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Div

---



Division of input Num by input Den.

| Inports |                       |
|---------|-----------------------|
| Num     | Dividend (Numerator)  |
| Den     | Divisor (Denominator) |

| Outports |          |
|----------|----------|
| Out      | Quotient |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Exp

---



Computation of the exponential of the input.

| Inports |         |
|---------|---------|
| In      | Input u |

| Outports |                     |
|----------|---------------------|
| Out      | Result of $\exp(u)$ |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: L2Norm

---



Calculation of L2-norm (euclidean norm).

| Inports |          |
|---------|----------|
| u1      | Input u1 |
| u2      | Input u2 |

| Outports |                             |
|----------|-----------------------------|
| Out      | Euclidean norm of u1 and u2 |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Mult

---



Multiplication of input 1 with input 2.

| Inports |                |
|---------|----------------|
| In1     | Multiplicand 1 |
| In2     | Multiplicand 2 |

| Outports |         |
|----------|---------|
| Out      | Product |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Negation

---



Negation of input signal.

| Inports |       |
|---------|-------|
| In      | Input |

| Outports |                     |
|----------|---------------------|
| Out      | Negated input value |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Sign

---



Signum function.

| Inports  |                                  |
|----------|----------------------------------|
| In       | Input u                          |
| Outports |                                  |
| Out      | Value corresponding to sign of u |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Sin

---



Sine computation of input value.

| Inports  |                  |
|----------|------------------|
| In       | Input u          |
| Outports |                  |
| Out      | Result of sin(u) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |



## Block: Sqrt

---



Square root computation of absolute input value.

| Inports |         |
|---------|---------|
| In      | Input u |

| Outports |                     |
|----------|---------------------|
| Out      | Result of sqrt( u ) |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Sub

---



Subtraction of input Minus from input Plus.

| Inports |            |
|---------|------------|
| Plus    | Minuend    |
| Minus   | Subtrahend |

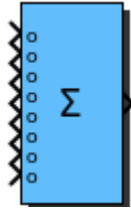
| Outports |            |
|----------|------------|
| Out      | Difference |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: Sum

---



Sum of inputs:

+ ... Input will be added to result.

- ... Input will be subtracted from result.

0 ... Input will be ignored.

| Inports |          |
|---------|----------|
| In1     | Input #1 |
| In2     | Input #2 |
| In3     | Input #3 |
| In4     | Input #4 |
| In5     | Input #5 |
| In6     | Input #6 |
| In7     | Input #7 |
| In8     | Input #8 |

| Outports |        |
|----------|--------|
| Out      | Result |

| Mask Parameters |    |             |
|-----------------|----|-------------|
| Name            | ID | Description |
| In1             | 1  | Input #1    |
| In2             | 2  | Input #2    |
| In3             | 3  | Input #3    |
| In4             | 4  | Input #4    |
| In5             | 5  | Input #5    |
| In6             | 6  | Input #6    |
| In7             | 7  | Input #7    |
| In8             | 8  | Input #8    |

**Implementations:**

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: uAdd

---



Addition of input 1 and input 2 with output wrapping.

| Inports |          |
|---------|----------|
| In1     | Addend 1 |
| In2     | Addend 2 |

| Outports |     |
|----------|-----|
| Out      | Sum |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |

## Block: uSub

---



Subtraction of input Minus from input Plus with output wrapping.

| Inports |            |
|---------|------------|
| Plus    | Minuend    |
| Minus   | Subtrahend |

| Outports |            |
|----------|------------|
| Out      | Difference |

### Implementations:

|                |                                      |
|----------------|--------------------------------------|
| <b>FiP8</b>    | 8 Bit Fixed Point Implementation     |
| <b>FiP16</b>   | 16 Bit Fixed Point Implementation    |
| <b>FiP32</b>   | 32 Bit Fixed Point Implementation    |
| <b>Float32</b> | 32 Bit Floating Point Implementation |
| <b>Float64</b> | 64 Bit Floating Point Implementation |