



Project Documentation DemoApplication

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Not	31
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Part I

X2C Model

1 Version Information

1.1 X2C

- X2C Development: Version 6.5.3260

1.2 Operating System

- OS: Windows 10 10.0

1.3 Scilab

- Scilab: Version 6.1.1.1626343451
- Java: Version 1.8.0_292

2 Model Structure

2.1 Xcos Model

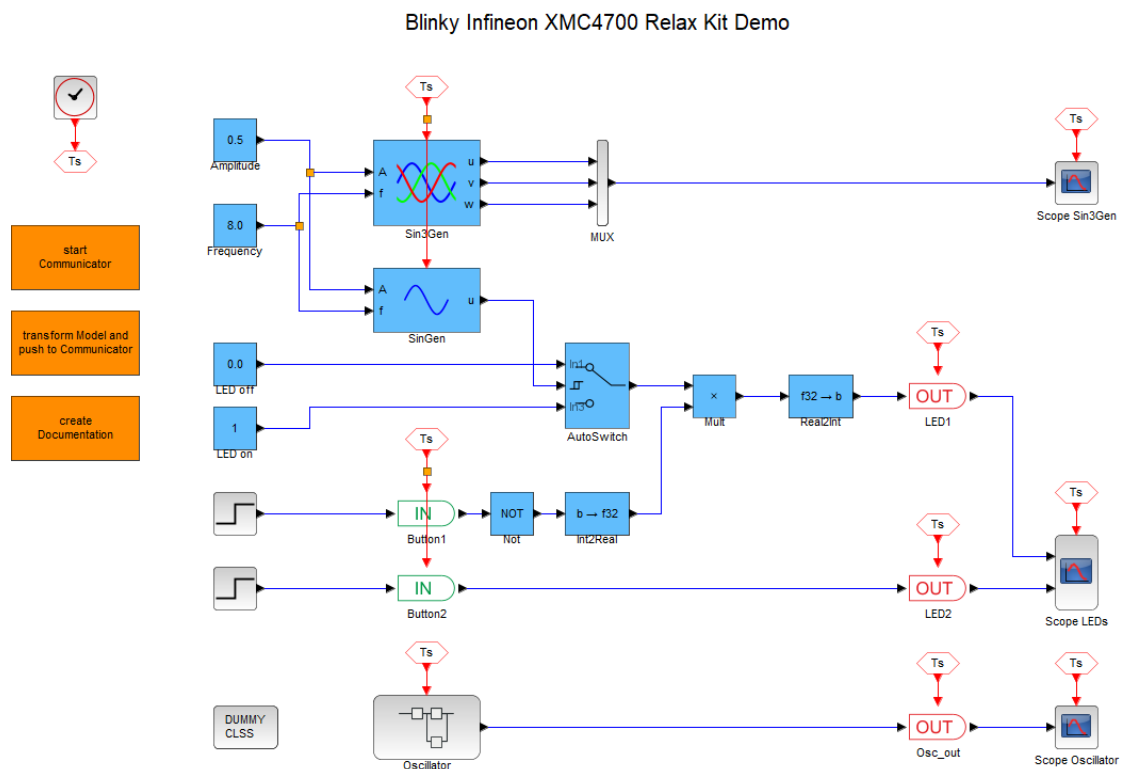


Figure 1: DemoApplication

2.2 Subsystems

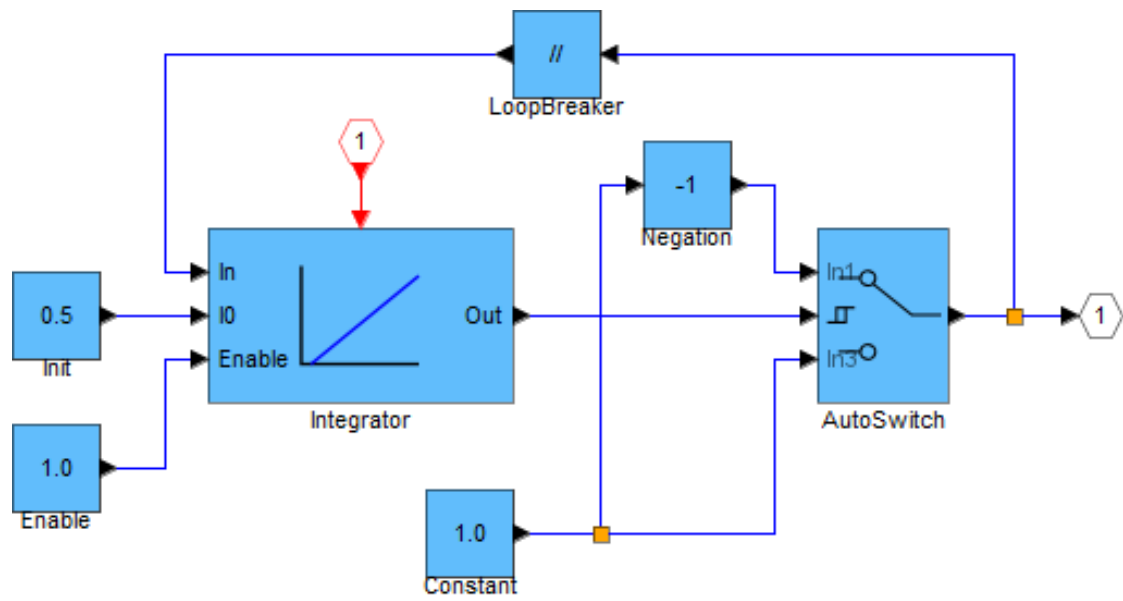


Figure 2: Oscillator

3 Model Parameter

3.1 Sample Time

Sample Time	
T_S	$100\mu s$

3.2 Scilab Parameter

```
1 // File with parameter and scaling factor information.
2
3 // $LastChangedRevision: 2386 $
4 // $LastChangedDate:: 2021-12-03 12:52:37 +0100#$
5 //
6 // This file is part of X2C. https://x2c.lcm.at/
7 //
8 // Copyright (c) 2024, Linz Center of Mechatronics GmbH (LCM) https://www.lcm.at/
9 // All rights reserved.
10
11
12 //-----
13 // Model update period
14 //-----
15 X2C_sampleTime = 100e-6;
```

Listing 1: ModelParameter.sce

4 Mask Parameter

4.1 Inports

4.1.1 Inports with auto generated ID

Button1	
Block Type	Inport - bool
ts_fact	1.0
Simulation Gain	1.0
Simulation Offset	0.0

Button2	
Block Type	Inport - bool
ts_fact	1.0
Simulation Gain	1.0
Simulation Offset	0.0

4.2 Outports

4.2.1 Outports with auto generated ID

LED1	
Block Type	Outport - bool
ts_fact	1.0
Simulation Gain	1.0
Simulation Offset	0.0

LED2	
Block Type	Outport - bool
ts_fact	1.0
Simulation Gain	1.0
Simulation Offset	0.0

Osc_out	
Block Type	Outport - int16
ts_fact	1.0
Simulation Gain	1.0
Simulation Offset	0.0

4.3 Blocks

4.3.1 Blocks with auto generated ID

Amplitude	
Block Type	Constant - Float32
Value	0.5

AutoSwitch	
Block Type	AutoSwitch - Float32
Thresh_up	0.0
Thresh_down	0.0

Frequency	
Block Type	Constant - Float32
Value	8.0

Int2Real	
Block Type	Int2Real - Bool_Float32
Scale	1.0

LED off	
Block Type	Constant - Float32
Value	0.0

LED on	
Block Type	Constant - Float32
Value	1.0

Mult	
Block Type	Mult - Float32

Not	
Block Type	Not - Bool

Oscillator/AutoSwitch	
Block Type	AutoSwitch - FiP16
Thresh_up	0.5
Thresh_down	-0.5

Oscillator/Constant	
Block Type	Constant - FiP16
Value	1.0

Oscillator/Enable	
Block Type	Constant - Bool
Value	1.0

Oscillator/Init	
Block Type	Constant - FiP16
Value	0.5

Oscillator/Integrator	
Block Type	I - FiP16
Ki	50.0
ts_fact	1.0

Oscillator/LoopBreaker	
Block Type	LoopBreaker - FiP16

Oscillator/Negation	
Block Type	Negation - FiP16

Real2Int	
Block Type	Real2Int - Float32_Bool
Scale	1.0

Sin3Gen	
Block Type	Sin3Gen - Float32
fmax	1000.0
Offset	0.2
ts_fact	1.0

SinGen	
Block Type	SinGen - Float32
fmax	1000.0
Offset	0.0
Phase	0.0
ts_fact	1.0

Part II

Frame Program Documentation

5 File Index

5.1 File List

Here is a list of all documented files with brief descriptions:

<code>inc/GlobalDefines.h</code>	
Global definitions	9
<code>inc/Hardware.h</code>	
Hardware initialization	9
<code>inc/InterruptControl.h</code>	
Interrupt control	11
<code>inc/Main.h</code>	
Main function	11

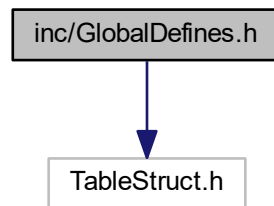
6 File Documentation

6.1 `inc/GlobalDefines.h` File Reference

Global definitions.

```
#include "TableStruct.h"
```

Include dependency graph for `GlobalDefines.h`:



6.1.1 Detailed Description

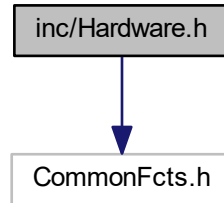
Global definitions.

6.2 `inc/Hardware.h` File Reference

Hardware initialization.

```
#include "CommonFcts.h"
```

Include dependency graph for Hardware.h:



Functions

- void **initHardware** (void)
Initialization of hardware.
- void **initSerial** (tSerial *serialXMC, const UART_t *interface)
Initialization of serial interface.
- void **linkSerial** (tProtocol *lnkProtocol, tSerial *serialXMC)
Linking of serial interface with LNet protocol.

6.2.1 Detailed Description

Hardware initialization.

6.2.2 Function Documentation

6.2.2.1 void initHardware (void)

Initialization of hardware.

- Configuration of IO ports
- Start of watchdog timer
- Start of timer for X2C update

6.2.2.2 void initSerial (tSerial * **serialXMC**, const UART_t * **interface**)

Initialization of serial interface.

Parameters

serialXMC	Serial object
------------------	---------------

<i>UART_t</i>	UART interface
---------------	----------------

6.2.2.3 void linkSerial (tProtocol * *InkProtocol*, tSerial * *serialXMC*)

Linking of serial interface with LNet protocol.

Parameters

<i>tProtocol</i>	Protocol object
<i>serialXMC</i>	Serial object

6.3 inc/InterruptControl.h File Reference

Interrupt control.

6.3.1 Detailed Description

Interrupt control.

6.4 inc/Main.h File Reference

Main function.

Functions

- void [mainTask](#) (void)
Main control task.

6.4.1 Detailed Description

Main function.

6.4.2 Function Documentation

6.4.2.1 void mainTask (void)

Main control task.

The main control task is called by the ADC interrupt service routine with a frequency of 10kHz.

- Assign inports
- Update X2C
- Update outputs

Part III

Used X2C-Blocks

7 Project Specific Blocks

8 Internal Library Blocks

Block: AutoSwitch



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

Outports	
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

Description:

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

Implementations:

FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: FiP16

16 Bit Fixed Point Implementation

Inports Data Type	
In1	int16
Switch	int16
In3	int16

Outports Data Type	
Out	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Inports Data Type	
In1	int32
Switch	int32
In3	int32

Outports Data Type	
Out	int32

Implementation: Float32

32 Bit Floating Point Implementation

Inports Data Type	
In1	float32
Switch	float32
In3	float32

Outports Data Type	
Out	float32

Implementation: Float64

64 Bit Floating Point Implementation

Inports Data Type	
In1	float64
Switch	float64
In3	float64

Outports Data Type	
Out	float64

Block: Constant



Outputs	
Out	Constant output

Mask Parameters		
Name	ID	Description
Value	1	Constant factor

Description:

Constant value.

Implementations:

Bool	Boolean Implementation
Int8	8 Bit Integer Implementation
Int16	16 Bit Integer Implementation
Int32	32 Bit Integer Implementation
FiP8	8 Bit Fixed Point Implementation
FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: Bool

Boolean Implementation

Outputs Data Type	
Out	bool

Implementation: Int8

8 Bit Integer Implementation

Outputs Data Type	
Out	int8

Implementation: Int16

16 Bit Integer Implementation

Outports Data Type	
Out	int16

Implementation: Int32

32 Bit Integer Implementation

Outports Data Type	
Out	int32

Implementation: FiP8

8 Bit Fixed Point Implementation

Outports Data Type	
Out	int8

Implementation: FiP16

16 Bit Fixed Point Implementation

Outports Data Type	
Out	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Outports Data Type	
Out	int32

Implementation: Float32

32 Bit Floating Point Implementation

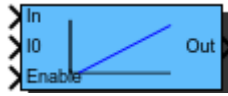
Outports Data Type	
Out	float32

Implementation: Float64

64 Bit Floating Point Implementation

Outports Data Type	
Out	float64

Block: I



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 Enable 0->1: Preload of integral part Enable == 1: Activation of block

Outputs	
Out	Control value

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

Description:

I controller:

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

Each fixed point implementation uses the next higher integer datatype for the integrational value storage variable.

A rising flank at the *Enable* input will preload the integrational part with the value present on the *Init* input.

Transfer function (zero-order hold discretization method):

$$G(z) = K_i T_s \frac{1}{z - 1}$$

8.0.0.1 Developer note:

The source code of block *ILimit* is used.

Implementations:

FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: FiP16

16 Bit Fixed Point Implementation

Inports Data Type	
In	int16
I0	int16
Enable	bool

Outports Data Type	
Out	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Inports Data Type	
In	int32
I0	int32
Enable	bool

Outports Data Type	
Out	int32

Implementation: Float32

32 Bit Floating Point Implementation

Inports Data Type	
In	float32
I0	float32
Enable	bool

Outports Data Type	
Out	float32

Implementation: Float64

64 Bit Floating Point Implementation

Inports Data Type	
In	float64
I0	float32
Enable	bool

Outports Data Type	
Out	float64

Block: Inport



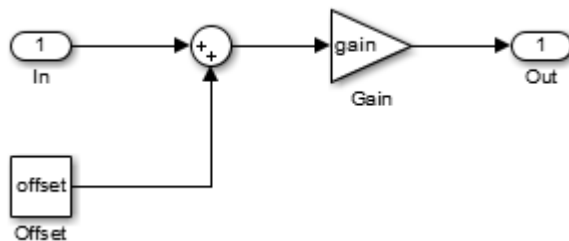
Inports	
IN	Signal from frame program

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.

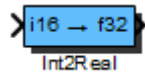
Note: Currently, *Gain* and *Offset* parameters are only available in Matlab/Simulink.



Data Types:

bool	Boolean
int8	8 Bit Fixed Point
int16	16 Bit Fixed Point
int32	32 Bit Fixed Point
float32	32 Bit Floating Point
float64	64 Bit Floating Point

Block: Int2Real



Inports	
In	Integer input

Outports	
Out	Real output

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

Description:

Conversion block from integer (fixed point) datatypes to real (floating point) datatypes.
 $\text{Out} = \text{In} * \text{Scale}$

Implementations:

FiP8_Float32	8 Bit Fixed Point to 32 Bit Floating Point Implementation
FiP16_Float32	16 Bit Fixed Point to 32 Bit Floating Point Implementation
FiP32_Float32	32 Bit Fixed Point to 32 Bit Floating Point Implementation
FiP8_Float64	8 Bit Fixed Point to 64 Bit Floating Point Implementation
FiP16_Float64	16 Bit Fixed Point to 64 Bit Floating Point Implementation
FiP32_Float64	32 Bit Fixed Point to 64 Bit Floating Point Implementation
Bool_Float32	Boolean to 32 Bit Floating Point Implementation
Bool_Float64	Boolean to 64 Bit Floating Point Implementation

Implementation: FiP8_Float32

8 Bit Fixed Point to 32 Bit Floating Point Implementation

Inports Data Type	
In	int8

Outports Data Type	
Out	float32

Implementation: FiP16_Float32

16 Bit Fixed Point to 32 Bit Floating Point Implementation

Inports Data Type	
In	int16
Outports Data Type	
Out	float32

Implementation: FiP32_Float32

32 Bit Fixed Point to 32 Bit Floating Point Implementation

Inports Data Type	
In	int32
Outports Data Type	
Out	float32

Implementation: FiP8_Float64

8 Bit Fixed Point to 64 Bit Floating Point Implementation

Inports Data Type	
In	int8
Outports Data Type	
Out	float64

Implementation: FiP16_Float64

16 Bit Fixed Point to 64 Bit Floating Point Implementation

Inports Data Type	
In	int16
Outports Data Type	
Out	float64

Implementation: FiP32_Float64

32 Bit Fixed Point to 64 Bit Floating Point Implementation

Inports Data Type	
In	int32

Outports Data Type	
Out	float64

Implementation: Bool_Float32

Boolean to 32 Bit Floating Point Implementation

Inports Data Type	
In	bool

Outports Data Type	
Out	float32

Implementation: Bool_Float64

Boolean to 64 Bit Floating Point Implementation

Inports Data Type	
In	bool

Outports Data Type	
Out	float64

Block: LoopBreaker



Inports	
In	Input In(k)

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

Description:

Block to break algebraic loops.

Implementations:

Bool	Boolean Integration
FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: Bool

Boolean Integration

Inports Data Type	
In	bool

Outports Data Type	
Out	bool

Implementation: FiP16

16 Bit Fixed Point Implementation

Inports Data Type	
In	int16

Outports Data Type	
Out	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Inports Data Type	
In	int32

Outports Data Type	
Out	int32

Implementation: Float32

32 Bit Floating Point Implementation

Inports Data Type	
In	float32

Outports Data Type	
Out	float32

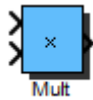
Implementation: Float64

64 Bit Floating Point Implementation

Inports Data Type	
In	float64

Outports Data Type	
Out	float64

Block: Mult



Inports	
In1	Multiplicand 1
In2	Multiplicand 2

Outports	
Out	Product

Description:

Multiplication of input 1 with input 2.

Calculation:

$$\text{Out} = \text{In}_1 \cdot \text{In}_2$$

Implementations:

FiP8	8 Bit Fixed Point Implementation
FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: FiP8

8 Bit Fixed Point Implementation

Inports Data Type	
In1	int8
In2	int8

Outports Data Type	
Out	int8

Implementation: FiP16

16 Bit Fixed Point Implementation

Inports Data Type	
In1	int16
In2	int16

Outports Data Type	
Out	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Inports Data Type	
In1	int32
In2	int32

Outports Data Type	
Out	int32

Implementation: Float32

32 Bit Floating Point Implementation

Inports Data Type	
In1	float32
In2	float32

Outports Data Type	
Out	float32

Implementation: Float64

64 Bit Floating Point Implementation

Inports Data Type	
In1	float64
In2	float64

Outports Data Type	
Out	float64

Block: Negation



Inports	
In	Input

Outputs	
Out	Negated input value

Description:

Negation of input signal.

Calculation:

$$\text{Out} = -\text{In}$$

Implementations:

FiP8	8 Bit Fixed Point Implementation
FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: FiP8

8 Bit Fixed Point Implementation

Inports Data Type	
In	int8

Outputs Data Type	
Out	int8

Implementation: FiP16

16 Bit Fixed Point Implementation

Inports Data Type	
In	int16

Outputs Data Type	
Out	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Inports Data Type	
In	int32

Outputs Data Type	
Out	int32

Implementation: Float32

32 Bit Floating Point Implementation

Inports Data Type	
In	float32

Outputs Data Type	
Out	float32

Implementation: Float64

64 Bit Floating Point Implementation

Inports Data Type	
In	float64

Outputs Data Type	
Out	float64

Block: Not



Inports	
In	

Outports	
Out	

Description:

Logical inverter block.

Implementations:

Bool Boolean Implementation

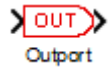
Implementation: Bool

Boolean Implementation

Inports Data Type	
In	bool

Outports Data Type	
Out	bool

Block: Output



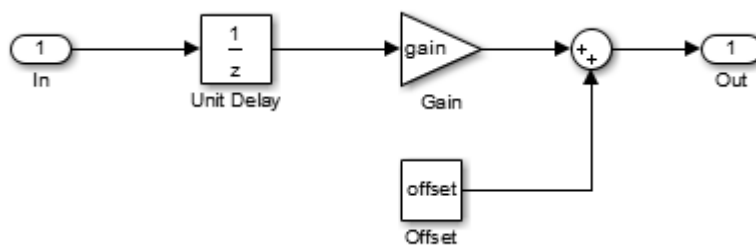
Outputs	
OUT	Signal to frame program

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.

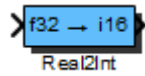
Note: Currently, *Gain* and *Offset* parameters are only available in Matlab/Simulink.



Data Types:

bool	Boolean
int8	8 Bit Fixed Point
int16	16 Bit Fixed Point
int32	32 Bit Fixed Point
float32	32 Bit Floating Point
float64	64 Bit Floating Point

Block: Real2Int



Inports	
In	Real input

Outports	
Out	Integer output

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

Description:

Conversion block from real (floating point) datatypes to integer (fixed point) datatypes.
 $Out = In / Scale$

Implementations:

Float32_FiP8	32 Floating Point to 8 Bit Fixed Point Implementation
Float32_FiP16	32 Floating Point to 16 Bit Fixed Point Implementation
Float32_FiP32	32 Floating Point to 32 Bit Fixed Point Implementation
Float64_FiP8	64 Floating Point to 8 Bit Fixed Point Implementation
Float64_FiP16	64 Floating Point to 16 Bit Fixed Point Implementation
Float64_FiP32	64 Floating Point to 32 Bit Fixed Point Implementation
Float32_Bool	32 Floating Point to Boolean Implementation
Float64_Bool	64 Floating Point to Boolean Implementation

Implementation: Float32_FiP8

32 Floating Point to 8 Bit Fixed Point Implementation

Inports Data Type	
In	float32

Outports Data Type	
Out	int8

Implementation: Float32_FiP16

32 Floating Point to 16 Bit Fixed Point Implementation

Inports Data Type	
In	float32

Outports Data Type	
Out	int16

Implementation: Float32_FiP32

32 Floating Point to 32 Bit Fixed Point Implementation

Inports Data Type	
In	float32

Outports Data Type	
Out	int32

Implementation: Float64_FiP8

64 Floating Point to 8 Bit Fixed Point Implementation

Inports Data Type	
In	float64

Outports Data Type	
Out	int8

Implementation: Float64_FiP16

64 Floating Point to 16 Bit Fixed Point Implementation

Inports Data Type	
In	float64

Outports Data Type	
Out	int16

Implementation: Float64_FiP32

64 Floating Point to 32 Bit Fixed Point Implementation

Inports Data Type	
In	float64

Outports Data Type	
Out	int32

Implementation: Float32_Bool

32 Floating Point to Boolean Implementation

Inports Data Type	
In	float32

Outports Data Type	
Out	bool

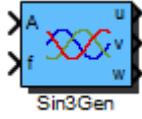
Implementation: Float64_Bool

64 Floating Point to Boolean Implementation

Inports Data Type	
In	float64

Outports Data Type	
Out	bool

Block: Sin3Gen



Inports	
A	Amplitude
f	Frequency

Outputs	
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)

Description:

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

Calculation fixed point implementation:

$$\begin{aligned}
 u_k &= A_k \sin(2f_k f_{\max} kT_s) + A_{\text{offset}} \\
 v_k &= A_k \sin\left(2f_k f_{\max} kT_s - \frac{2\pi}{3}\right) + A_{\text{offset}} \\
 w_k &= A_k \sin\left(2f_k f_{\max} kT_s + \frac{2\pi}{3}\right) + A_{\text{offset}}
 \end{aligned}$$

For sine calculation a lookup table with 256 entries is used. This results in a short computation time but with the downside of reduced accuracy for the FiP32 implementation.

Calculation floating point implementation (parameter $f_{\max}$ is ignored):

$$\begin{aligned}
 u_k &= A_k \sin(2\pi f_k kT_s) + A_{\text{offset}} \\
 v_k &= A_k \sin\left(2\pi f_k kT_s - \frac{2\pi}{3}\right) + A_{\text{offset}} \\
 w_k &= A_k \sin\left(2\pi f_k kT_s + \frac{2\pi}{3}\right) + A_{\text{offset}}
 \end{aligned}$$

Implementations:

FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: FiP16

16 Bit Fixed Point Implementation

Inports Data Type	
A	int16
f	int16

Outports Data Type	
u	int16
v	int16
w	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Inports Data Type	
A	int32
f	int32

Outports Data Type	
u	int32
v	int32
w	int32

Implementation: Float32

32 Bit Floating Point Implementation

Inports Data Type	
A	float32
f	float32

Outports Data Type	
u	float32
v	float32
w	float32

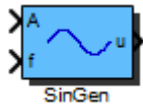
Implementation: Float64

64 Bit Floating Point Implementation

Inports Data Type	
A	float64
f	float64

Outports Data Type	
u	float64
v	float64
w	float64

Block: SinGen



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)

Description:

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

Calculation fixed point implementation:

$$u_k = A_k \sin(2f_k f_{\max} k T_s + \phi_{\text{phase}}) + A_{\text{offset}}$$

For sine calculation a lookup table with 256 entries is used. This results in a short computation time but with the downside of reduced accuracy for the FiP32 implementation.

Calculation floating point implementation (parameter $f_{\max}$ is ignored):

$$u_k = A_k \sin(2\pi f_k k T_s + \phi_{\text{phase}}) + A_{\text{offset}}$$

Implementations:

FiP16	16 Bit Fixed Point Implementation
FiP32	32 Bit Fixed Point Implementation
Float32	32 Bit Floating Point Implementation
Float64	64 Bit Floating Point Implementation

Implementation: FiP16

16 Bit Fixed Point Implementation

Inports Data Type	
A	int16
f	int16

Outports Data Type	
u	int16

Implementation: FiP32

32 Bit Fixed Point Implementation

Inports Data Type	
A	int32
f	int32

Outports Data Type	
u	int32

Implementation: Float32

32 Bit Floating Point Implementation

Inports Data Type	
A	float32
f	float32

Outports Data Type	
u	float32

Implementation: Float64

64 Bit Floating Point Implementation

Inports Data Type	
A	float64
f	float64

Outports Data Type	
u	float64