

**Simulink®**

Modeling Guidelines for Code Generation



**MATLAB® & SIMULINK®**

R2022a



# How to Contact MathWorks



Latest news: [www.mathworks.com](http://www.mathworks.com)  
Sales and services: [www.mathworks.com/sales\\_and\\_services](http://www.mathworks.com/sales_and_services)  
User community: [www.mathworks.com/matlabcentral](http://www.mathworks.com/matlabcentral)  
Technical support: [www.mathworks.com/support/contact\\_us](http://www.mathworks.com/support/contact_us)



Phone: 508-647-7000



The MathWorks, Inc.  
1 Apple Hill Drive  
Natick, MA 01760-2098

## *Modeling Guidelines for Code Generation*

© COPYRIGHT 2010–2022 by The MathWorks, Inc.

The software described in this document is furnished under a license agreement. The software may be used or copied only under the terms of the license agreement. No part of this manual may be photocopied or reproduced in any form without prior written consent from The MathWorks, Inc.

FEDERAL ACQUISITION: This provision applies to all acquisitions of the Program and Documentation by, for, or through the federal government of the United States. By accepting delivery of the Program or Documentation, the government hereby agrees that this software or documentation qualifies as commercial computer software or commercial computer software documentation as such terms are used or defined in FAR 12.212, DFARS Part 227.72, and DFARS 252.227-7014. Accordingly, the terms and conditions of this Agreement and only those rights specified in this Agreement, shall pertain to and govern the use, modification, reproduction, release, performance, display, and disclosure of the Program and Documentation by the federal government (or other entity acquiring for or through the federal government) and shall supersede any conflicting contractual terms or conditions. If this License fails to meet the government's needs or is inconsistent in any respect with federal procurement law, the government agrees to return the Program and Documentation, unused, to The MathWorks, Inc.

### **Trademarks**

MATLAB and Simulink are registered trademarks of The MathWorks, Inc. See [www.mathworks.com/trademarks](http://www.mathworks.com/trademarks) for a list of additional trademarks. Other product or brand names may be trademarks or registered trademarks of their respective holders.

### **Patents**

MathWorks products are protected by one or more U.S. patents. Please see [www.mathworks.com/patents](http://www.mathworks.com/patents) for more information.

### **Revision History**

September 2010	Online only	New for Version 1.0 (Release 2010b)
April 2011	Online only	Revised for Version 1.1 (Release 2011a)
September 2011	Online only	Revised for Version 1.2 (Release 2011b)
March 2012	Online only	Revised for Version 1.3 (Release 2012a)
September 2012	Online only	Revised for Version 1.4 (Release 2012b)
March 2013	Online only	Revised for Version 1.5 (Release 2013a)
September 2013	Online only	Revised for Version 1.6 (Release 2013b)
March 2014	Online only	Revised for Version 1.7 (Release 2014a)
October 2014	Online only	Revised for Version 1.8 (Release 2014b)
March 2015	Online only	Revised for Version 1.9 (Release 2015a)
September 2015	Online only	Revised for Version 1.10 (Release 2015b)
March 2016	Online only	Revised for Version 1.11 (Release 2016a)
September 2016	Online only	Revised for Version 1.12 (Release 2016b)
March 2017	Online only	Revised for Version 1.13 (Release 2017a)
September 2017	Online only	Revised for Version 1.14 (Release 2017b)
March 2018	Online only	Revised for Version 1.15 (Release 2018a)
September 2018	Online only	Revised for Version 1.16 (Release 2018b)
March 2019	Online only	Revised for Version 1.17 (Release 2019a)
September 2019	Online only	Revised for Version 1.18 (Release 2019b)
March 2020	Online only	Revised for Version 1.19 (Release 2020a)
September 2020	Online only	Revised for Version 1.20 (Release 2020b)
March 2021	Online only	Revised for Version 1.21 (Release 2021a)
September 2021	Online only	Revised for Version 1.22 (Release 2021b)
March 2022	Online only	Revised for Version 1.23 (Release 2022a)

	<b>Introduction</b>	
<b>1</b>		
	<b>Motivation</b> .....	<b>1-2</b>
	<b>Guideline Template</b> .....	<b>1-3</b>
	<b>Block Considerations</b>	
<b>2</b>		
	<b>cgsl_0101: Zero-based indexing</b> .....	<b>2-2</b>
	<b>cgsl_0102: Evenly spaced breakpoints in lookup tables</b> .....	<b>2-3</b>
	<b>cgsl_0103: Precalculated signals and parameters</b> .....	<b>2-4</b>
	<b>cgsl_0104: Modeling global shared memory using data stores</b> .....	<b>2-7</b>
	<b>cgsl_0105: Modeling local shared memory using data stores</b> .....	<b>2-10</b>
	<b>Modeling Pattern Considerations</b>	
<b>3</b>		
	<b>cgsl_0201: Redundant Unit Delay and Memory blocks</b> .....	<b>3-2</b>
	<b>cgsl_0202: Usage of For, While, and For Each subsystems with vector signals</b> .....	<b>3-6</b>
	<b>cgsl_0204: Vector and bus signals crossing into atomic subsystems or Model blocks</b> .....	<b>3-7</b>
	<b>cgsl_0205: Signal handling for multirate models</b> .....	<b>3-12</b>
	<b>cgsl_0206: Data integrity and determinism in multitasking models</b> ...	<b>3-14</b>

## Configuration Parameter Considerations

### 4

<b>cgsl_0301: Prioritization of code generation objectives for code efficiency</b> .....	<b>4-2</b>
<b>cgsl_0302: Diagnostic settings for multirate and multitasking models</b> .....	<b>4-3</b>

# Introduction

---

- “Motivation” on page 1-2
- “Guideline Template” on page 1-3

## Motivation

MathWorks intends the guidelines for engineers developing models and generating code for embedded systems using Model-Based Design with MathWorks products. The guidelines provide recommendations for model settings, block usage, and block parameters that impact simulation behavior or code generated by the Embedded Coder® product.

The guidelines do not address model style or development processes. For more information about creating models in a way that improves consistency, clarity, and readability, see the “MAB Modeling Guidelines”. Development process guidance and additional information for specific standards is available with the IEC Certification Kit (for ISO 26262 and IEC 61508) and DO Qualification Kit (for DO-178) products.

---

**Disclaimer** While adhering to the recommendations in the guidelines will reduce the risk that an error is introduced during development and not be detected, it is not a guarantee that the system being developed will be safe. Conversely, if some of the recommendations in the guidelines are not followed, it does not mean that the system being developed will be unsafe.

---

## Guideline Template

Guideline descriptions are documented, using the following template. Companies that want to create additional guidelines are encouraged to use the same template.

<b>ID: Title</b>	<i>XX_nnnn</i> : Title of the guideline (unique, short)
<b>Description</b>	Description of the guideline
<b>Prerequisites</b>	Links to guidelines that are prerequisites to this guideline (ID: Title)
<b>Notes</b>	Notes for using the guideline
<b>Rationale</b>	Rationale for providing the guideline
<b>Model Advisor Check</b>	Title of and link to the corresponding Model Advisor check, if a check exists
<b>References</b>	References to standards that apply to guideline
<b>See Also</b>	Links to additional information
<b>Last Changed</b>	Version number of last change
<b>Examples</b>	Guideline examples



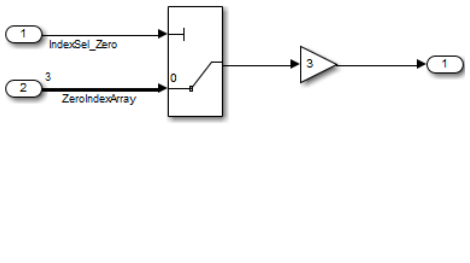
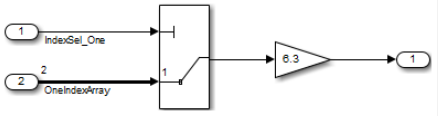


# Block Considerations

---

- “cgsl\_0101: Zero-based indexing” on page 2-2
- “cgsl\_0102: Evenly spaced breakpoints in lookup tables” on page 2-3
- “cgsl\_0103: Precalculated signals and parameters” on page 2-4
- “cgsl\_0104: Modeling global shared memory using data stores” on page 2-7
- “cgsl\_0105: Modeling local shared memory using data stores” on page 2-10

## cgsl\_0101: Zero-based indexing

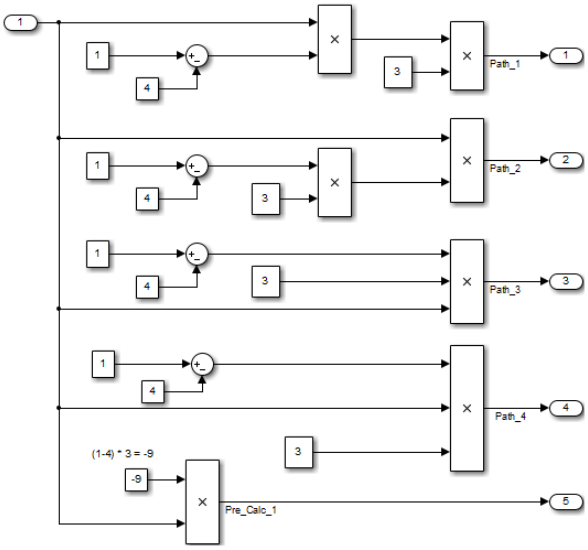
ID: Title	cgsl_0101: Zero-based indexing	
Description	Use zero-based indexing for blocks that require indexing. To set up zero-based indexing, do one of the following:	
	A	For the Index Vector block parameter <b>Data port order</b> , select <b>Zero-based contiguous</b> .
	B	Set block parameter <b>Index mode</b> to Zero-based for the following blocks: <ul style="list-style-type: none"> <li>• Assignment</li> <li>• Selector</li> <li>• For Iterator</li> <li>• Find Nonzero Elements</li> </ul>
Notes	The C language uses zero-based indexing.	
Rationale	A, B	Use zero-based indexing for compatibility with integrated C code.
	A, B	Results in more efficient C code execution. One-based indexing requires a subtraction operation in generated code.
See Also	"hisl_0021: Consistent vector indexing method"	
Last Changed	R2011b	
Examples	 <p><b>Recommended</b></p> <pre>void ZeroIndex(void) {     Y.Out5 = 3.0 * ZeroIndexArray[IndexSel_Zero]; }</pre>	
	 <p><b>Not Recommended</b></p> <pre>void OneIndex(void) {     Y.Out1 = OneIndexArray[IndexSel_One - 1] * 6.3; }</pre>	

## cgsl\_0102: Evenly spaced breakpoints in lookup tables

ID: Title	cgsl_0102: Evenly spaced breakpoints in lookup tables	
Description	When you use Lookup Table and Prelookup blocks,	
	A	With <i>non-fixed-point data types</i> , use evenly spaced data breakpoints for the input axis
	B	With <i>fixed-point data types</i> , use power of two spaced breakpoints for the input axis
Notes	Evenly spaced breakpoints can prevent generated code from including division operations, resulting in faster execution.	
Rationale	A	Improve ROM usage and execution speed.
	B	<p>Improve execution speed.</p> <p>When compared to unevenly spaced data, power-of-two data can</p> <ul style="list-style-type: none"> <li>• Increase data RAM usage if you require a finer step size</li> <li>• Reduce accuracy if you use a coarser step size</li> </ul> <p>Compared to an evenly spaced data set, there should be minimal cost in memory or accuracy.</p>
Model Advisor Checks	<b>By Product &gt; Embedded Coder &gt; Identify questionable fixed-point operations</b>	
	For check details, see “Identify questionable fixed-point operations” (Embedded Coder).	
See Also	“Formulation of Evenly Spaced Breakpoints”	
Last Changed	R2010b	

## cgsl\_0103: Precalculated signals and parameters

ID: Title	cgsl_0103: Precalculated signals and parameters	
Description	Precalculate invariant parameters and signals by doing one of the following:	
	A	Manually precalculate the values
	B	Set these configuration parameters: <ul style="list-style-type: none"> <li>• Set <b>Default parameter behavior</b> to Inlined</li> <li>• Select <b>Inline invariant signals</b></li> </ul>
Notes	Precalculating variables can reduce local and global memory usage and improve execution speed. If you set <b>Default parameter behavior</b> to Inlined and enable <b>Inline invariant signals</b> , the code generator minimizes the number of run-time calculations by maximizing the number calculations completed before run time. In some cases, this can lead to a reduction in the number of parameters stored. However, the algorithms the code generator uses have limitations. In some cases, the code is more compact if you calculate the values outside of the Simulink environment. This can improve model efficiency, but can reduce model readability.	
Rationale	A, B	Precalculate data, outside of the Simulink environment, to reduce memory requirements of a system and improve run-time execution.
Last Changed	R2012b	

ID: Title	cgs1_0103: Precalculated signals and parameters
Examples	<p>In the following model, the four paths are mathematically equivalent. However, due to algorithm limitations, the number of run-time calculations for the paths differs.</p>  <pre> Path_1 = InputSignal * -3.0 * 3.0;  /* Product: '&lt;Root&gt;/Product4' incorporates:  * Inport: '&lt;Root&gt;/In1'  */ Path_2 = InputSignal * -9.0;  /* Product: '&lt;Root&gt;/Product2' incorporates:  * Constant: '&lt;Root&gt;/Constant2'  * Inport: '&lt;Root&gt;/In1'  */ Path_3 = -9.0 * InputSignal;  /* Product: '&lt;Root&gt;/Product5' incorporates:  * Constant: '&lt;Root&gt;/Constant2'  * Inport: '&lt;Root&gt;/In1'  */ Path_4 = -3.0 * InputSignal * 3.0;  /* Product: '&lt;Root&gt;/Product6' incorporates:  * Constant: '&lt;Root&gt;/Constant3'  * Inport: '&lt;Root&gt;/In1'  */ Pre_Calc_1 = -9.0 * InputSignal; </pre> <p>To maximize automatic precalculation, add signals at the end of the set of equations.</p> <p>Inlining data reduces the ability to tune model parameters. You should define parameters that require calibration to allow calibration. For more</p>

<b>ID: Title</b>	<b>cgsI_0103: Precalculated signals and parameters</b>
	information, see “Create Tunable Calibration Parameter in the Generated Code” (Simulink Coder).

## cgsl\_0104: Modeling global shared memory using data stores

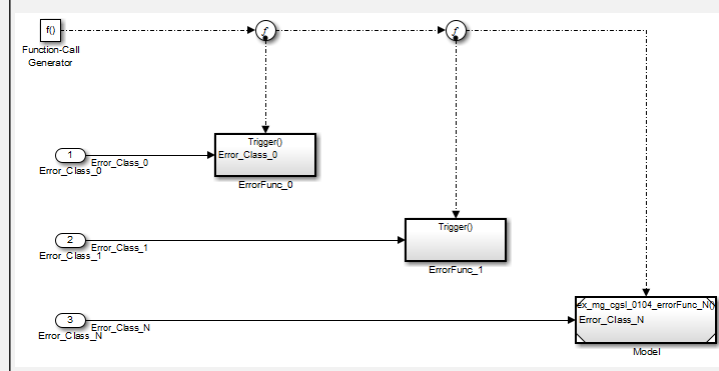
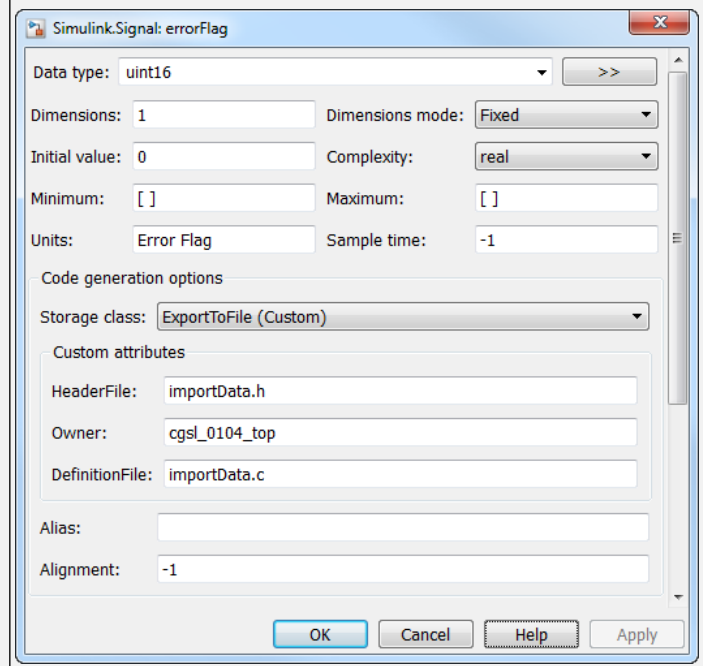
ID: Title	cgsl_0104: Modeling global shared memory using data stores	
Description	When using data store blocks to model shared memory across multiple models:	
	A	Set configuration parameters <b>Duplicate data store names to error</b> for models in the hierarchy.
	B	Define the data store using a Simulink Signal or MPT Signal object.
	C	Do not use Data Store Memory blocks in the model.
Notes	<p>If multiple Data Store blocks use the same data store name within a model, then Simulink interprets each instance of the data store as having a unique local scope.</p> <p>Use <b>Duplicate data store names</b> to help detect unintended identifier reuse. For models intentionally using local data stores, set the diagnostic to warning. Verify that only intentional data stores are included.</p> <p>Merge blocks, used in conjunction with subsystems operating in a mutually exclusive manor, provide a second method of modeling global data across multiple models.</p>	
Rationale	A, B, C	Promotes a modeling pattern where a single consistent data store is used across models and a single global instance is created in the generated code.
See Also	<ul style="list-style-type: none"> <li>• “hisl_0013: Usage of data store blocks”</li> <li>• “hisl_0015: Usage of Merge blocks”</li> <li>• “cgsl_0302: Diagnostic settings for multirate and multitasking models” on page 4-3</li> <li>• “cgsl_0105: Modeling local shared memory using data stores” on page 2-10</li> </ul>	
Last Changed	R2011b	

**ID: Title** **cgsl\_0104: Modeling global shared memory using data stores**

Examples

The following examples illustrate the use of data stores as global shared memory. The data store is used to model a global fault flag. A data store is required because the flag can be set in multiple functions and used in the same execution step.

The top model contains three subsystems, each utilizing a data store memory. The data store is defined using a signal data object.

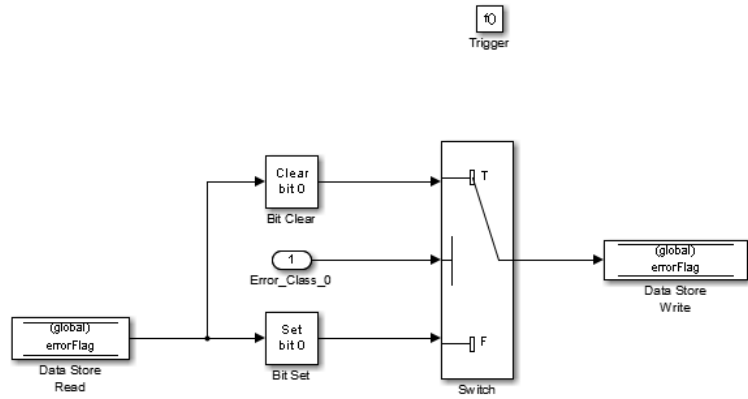


**Recommended**

In this example, there are no Data Store Memory blocks. The resulting code uses the same global variable for the full model.



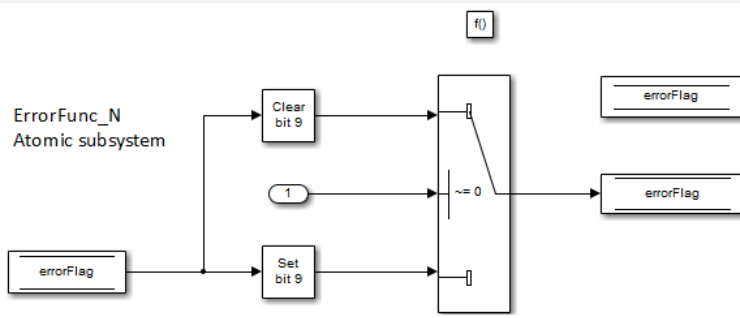
**ID: Title** cgsl\_0104: Modeling global shared memory using data stores



```
void cgsl_0104_top_ErrorFunc_0(void)
{
  if (Error_Class_0) {
    errorFlag = (uint16_T) (~((uint16_T) ((uint16_T) (~errorFlag) | ((uint16_T) 1U))));
  } else {
    errorFlag = (uint16_T) (errorFlag | ((uint16_T) 1U));
  }
}
```

**Not Recommended**

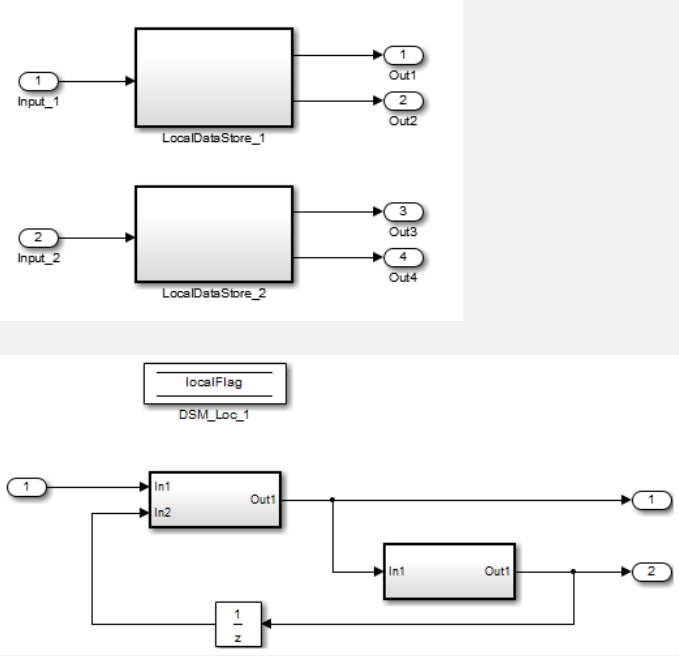
In this example, a Data Store Memory block is added into the Model block subsystem. The model subsystem uses a local version of the data store. The Atomic Subsystem use a different version.



```
rtMdlrefDWorK_mr_cgsl_0104_errro_mr_cgsl_0104_errorF_MdlrefDWorK;
void mr_cgsl_0104_errorFunc_N_UseDSM(const boolean_T *rtu_Error_Class_N)
{
  rtDW_mr_cgsl_0104_errorFunc_N_U *localDW =
  &(mr_cgsl_0104_errorF_MdlrefDWorK.rtdw);
  if (*rtu_Error_Class_N) {
    localDW->errorFlag = (uint16_T) (~((uint16_T) ((uint16_T) (~localDW->errorFlag)
    | ((uint16_T) 512U))));
  } else {
    localDW->errorFlag = (uint16_T) (localDW->errorFlag | ((uint16_T) 512U));
  }
}
```

## cgsl\_0105: Modeling local shared memory using data stores

ID: Title	cgsl_0105: Modeling local shared memory using data stores	
Description	When using data store blocks as local shared memory:	
	A	Explicitly create the data store using a Data Store Memory block.
	B	Clear block parameter <b>Data store name must resolve to Simulink signal object.</b>
	C	Consider following a naming convention for local Data Store Memory blocks.
Notes	<p>Use configuration parameter <b>Duplicate data store names</b> to help detect unintended identifier reuse. For models intentionally using local data stores, set the diagnostic to warning. Verify that only intentional data stores are included.</p> <p>Data store blocks are realized as global memory in the generated code. If they are not assigned a specific storage class, they are included in the DWork structure. In the model, the data store is scoped to the defining subsystem and below. In the generated code, the data store has file scope.</p>	
Rationale	A, B	Data store block is treated as a local instance of the data store
	C	Provides graphical feedback that the data store is local
See Also	<ul style="list-style-type: none"> <li>• “cgsl_0104: Modeling global shared memory using data stores” on page 2-7</li> <li>• “cgsl_0302: Diagnostic settings for multirate and multitasking models” on page 4-3</li> <li>• “hisl_0013: Usage of data store blocks”</li> </ul>	
Last Changed	R2011b	

ID: Title	cgsl_0105: Modeling local shared memory using data stores
Examples	<p>In some instances, such as a library function, reuse of a local data store is required. In this example, the local data store is defined in two subsystems.</p>  <p>The diagram illustrates the reuse of a local data store. At the top, two separate subsystems are shown: 'LocalDataStore_1' and 'LocalDataStore_2'. 'LocalDataStore_1' has an input 'Input_1' (labeled '1') and two outputs 'Out1' (labeled '1') and 'Out2' (labeled '2'). 'LocalDataStore_2' has an input 'Input_2' (labeled '2') and two outputs 'Out3' (labeled '3') and 'Out4' (labeled '4'). Below this, a larger subsystem is shown containing a data store 'localFlag' (DSM_Loc_1). This subsystem has two input blocks, 'In1' and 'In2', and two output blocks, 'Out1' and 'Out2'. The 'localFlag' data store is connected to the 'In1' and 'In2' inputs. The 'Out1' output of the first block is connected to the 'In1' input of the second block. The 'Out2' output of the second block is connected to the 'In2' input of the first block. A feedback loop is shown with a block containing '1/z' that receives input from the 'Out1' of the second block and feeds back into the 'In2' of the first block.</p> <p>The instance of localFlag is in scope within the subsystem LocalDataStore_1 and its subsystems.</p> <pre data-bbox="584 1197 1291 1312"> /* Block signals and states (auto storage) for system '&lt;Root&gt;' */ typedef struct {     real_T localFlag;           /* '&lt;S2&gt;/DSM_Loc_2' */     real_T localFlag_k;       /* '&lt;S1&gt;/DSM_Loc_1' */ } D_Work_cgsl_0105;     </pre> <p>In the generated code, the data stores are part of the global DWork structure for the model. Embedded Coder automatically assigns them unique names during the code generation process.</p>

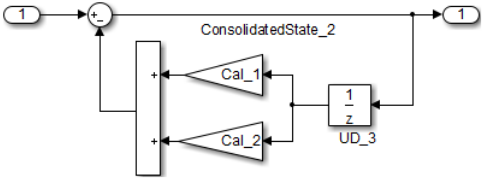
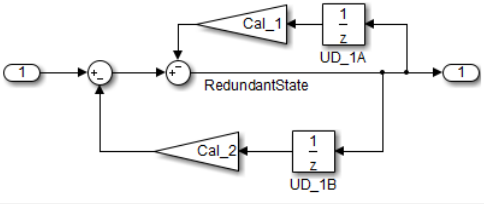


# Modeling Pattern Considerations

---

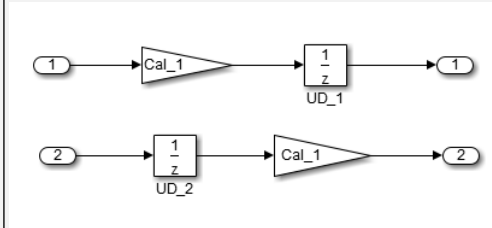
- “cgsl\_0201: Redundant Unit Delay and Memory blocks” on page 3-2
- “cgsl\_0202: Usage of For, While, and For Each subsystems with vector signals” on page 3-6
- “cgsl\_0204: Vector and bus signals crossing into atomic subsystems or Model blocks” on page 3-7
- “cgsl\_0205: Signal handling for multirate models” on page 3-12
- “cgsl\_0206: Data integrity and determinism in multitasking models” on page 3-14

## cgsl\_0201: Redundant Unit Delay and Memory blocks

ID: Title	cgsl_0201: Redundant Unit Delay and Memory blocks	
Description	When preparing a model for code generation, A Remove redundant Unit Delay and Memory blocks.	
Rationale	A	Redundant Unit Delay and Memory blocks use additional global memory. Removing the redundancies from a model reduces memory usage without impacting model behavior.
Last Changed	R2013a	
Example	 <p><b>Recommended: Consolidated Unit Delays</b></p> <pre data-bbox="354 882 1136 997"> void Reduced(void) {     ConsolidatedState_2 = Matrix_UD_Test - (Cal_1 * DWork.UD_3_DSTATE + Cal_2 *         DWork.UD_3_DSTATE);     DWork.UD_3_DSTATE = ConsolidatedState_2; } </pre>	
	 <p><b>Not Recommended: Redundant Unit Delays</b></p> <pre data-bbox="354 1302 1104 1438"> void Redundant(void) {     RedundantState = (Matrix_UD_Test - Cal_2 * DWork.UD_1B_DSTATE) - Cal_1 *         DWork.UD_1A_DSTATE;     DWork.UD_1B_DSTATE = RedundantState;     DWork.UD_1A_DSTATE = RedundantState; } </pre>	

**ID: Title** cgsl\_0201: Redundant Unit Delay and Memory blocks

Unit Delay and Memory blocks exhibit commutative and distributive algebraic properties. When the blocks are part of an equation with one driving signal, you can move the Unit Delay and Memory blocks to a new position in the equation without changing the result.



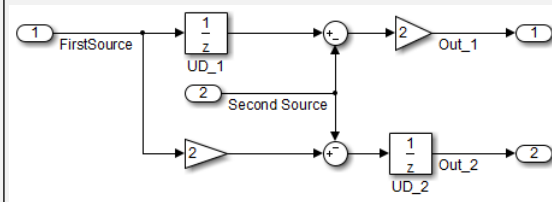
For the top path in the preceding example, the equations for the blocks are:

- 1  $Out\_1(t) = UD\_1(t)$
- 2  $UD\_1(t) = In\_1(t-1) * Cal\_1$

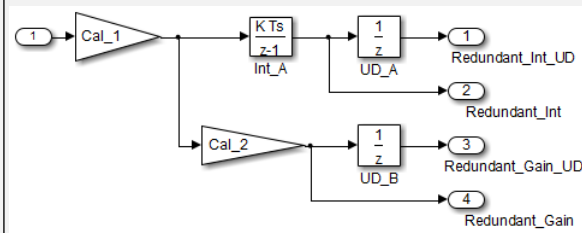
For the bottom path, the equations are:

- 1  $Out\_2(t) = UD\_2(t) * Cal\_1$
- 2  $UD\_2(t) = In\_2(t-1)$

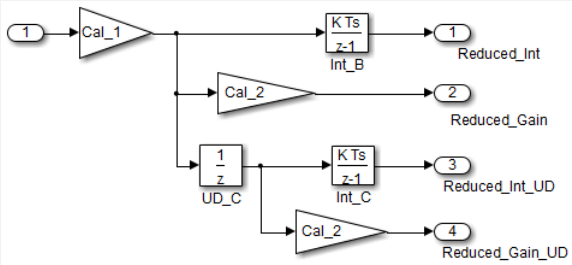
In contrast, if you add a secondary signal to the equations, the location of the Unit Delay block impacts the result. As the following example shows, the location of the Unit Delay block impacts the results due to the skewing of the time sample between the top and bottom paths.



In cases with a single source and multiple destinations, the comparison is more complex. For example, in the following model, you can refactor the two Unit Delay blocks into a single unit delay.



**ID: Title** **cgsl\_0201: Redundant Unit Delay and Memory blocks**



From a black box perspective, the two models are equivalent. However, from a memory and computation perspective, differences exist between the two models.

```

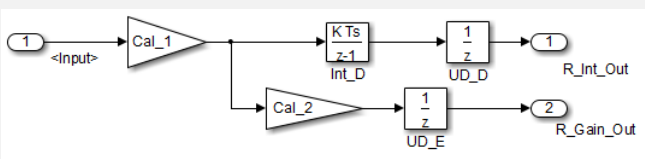
{
  real_T rtb_Gain4;
  rtb_Gain4 = Cal_1 * Redundant;
  Y.Redundant_Gain = Cal_2 * rtb_Gain4;
  Y.Redundant_Int = DWork.Int_A;
  Y.Redundant_Int_UD = DWork.UD_A;
  Y.Redundant_Gain_UD = DWork.UD_B;
  DWork.Int_A = 0.01 * rtb_Gain4 + DWork.Int_A;
  DWork.UD_A = Y.Redundant_Int;
  DWork.UD_B = Y.Redundant_Gain;
}

{
  real_T rtb_Gain1;
  real_T rtb_UD_C;
  rtb_Gain1 = Cal_1 * Reduced;
  rtb_UD_C = DWork.UD_C;
  Y.Reduced_Gain_UD = Cal_2 * DWork.UD_C;
  Y.Reduced_Gain = Cal_2 * rtb_Gain1;
  Y.Reduced_Int = DWork.Int_B;
  Y.Reduced_Int_UD = DWork.Int_C;
  DWork.UD_C = rtb_Gain1;
  DWork.Int_B = 0.01 * rtb_Gain1 + DWork.Int_B;
  DWork.Int_C = 0.01 * rtb_UD_C + DWork.Int_C;
}

```

In this case, the original model is more efficient. In the first code example, there are three global variables, two from the Unit Delay blocks (DWork.UD\_A and DWork.UD\_B) and one from the discrete time integrator (DWork.Int\_A). The second code example shows a reduction to one global variable generated by the unit delays (Dwork.UD\_C), but there are two global variables due to the redundant Discrete Time Integrator blocks (DWork.Int\_B and DWork.Int\_C). The Discrete Time Integrator block path introduces an additional local variable (rtb\_UD\_C) and two additional computations.

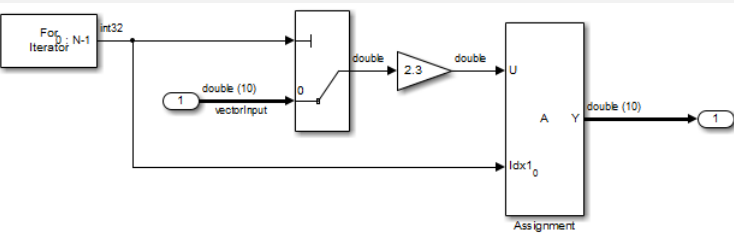
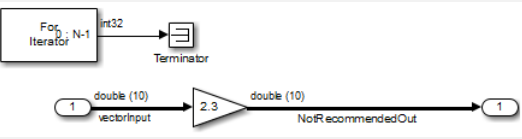
By contrast, the refactored model (second) below is more efficient.





ID: Title	cgs1_0201: Redundant Unit Delay and Memory blocks
	<pre> {   real_T rtb_Gain4_f;   real_T rtb_Int_D;   rtb_Gain4_f = Cal_1 * U.Input;   rtb_Int_D = DWork.Int_D;   Y.R_Int_Out = DWork.UD_D;   Y.R_Gain_Out = DWork.UD_E;   DWork.Int_D = 0.01 * rtb_Gain4_f + DWork.Int_D;   DWork.UD_D = rtb_Int_D;   DWork.UD_E = Cal_2 * rtb_Gain4_f; }  {   real_T rtb_UD_F;   rtb_UD_F = DWork.UD_F;   Y.Gain_Out = Cal_2 * DWork.UD_F;   Y.Int_Out = DWork.Int_E;   DWork.UD_F = Cal_1 * U.Input;   DWork.Int_E = 0.01 * rtb_UD_F + DWork.Int_E; } </pre> <p>The code for the refactored model is more efficient because the branches from the root signal do not have a redundant unit delay.</p>

## cgsl\_0202: Usage of For, While, and For Each subsystems with vector signals

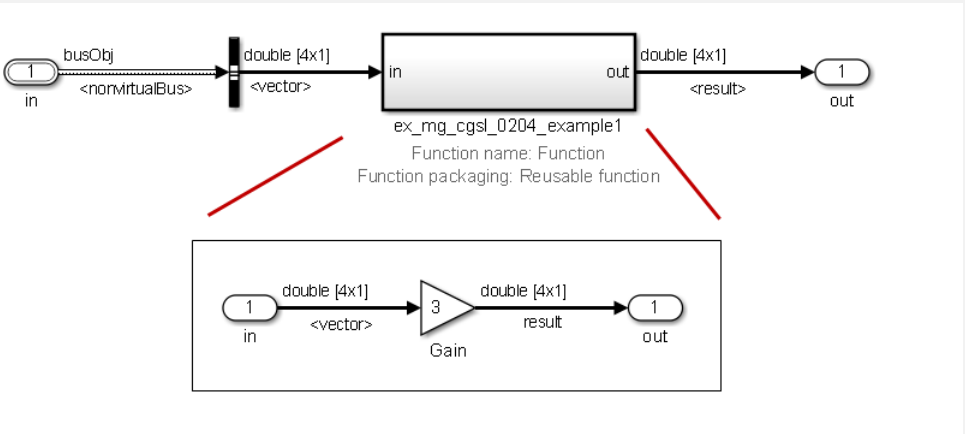
ID: Title	cgsl_0202: Usage of For, While, and For Each subsystems with vector signals	
Description	A	Use For, While, and For Each subsystems for calculations that require iterative behavior or operate on a subset (frame) of data.
	B	Avoid using For, While, or For Each subsystems for basic vector operations.
Rationale	A, B	Avoid redundant loops.
See Also	<ul style="list-style-type: none"> <li>“Loop unrolling threshold” (Simulink Coder) in the Simulink documentation</li> </ul>	
Last Changed	R2010b	
Examples	<p>The recommended method for preceding calculation is to place the Gain block outside the For Subsystem. If the calculations are required as part of a larger algorithm, you can avoid the nesting of for loops by using Index Vector and Assignment blocks.</p>	
	 <p><b>Recommended</b></p> <pre>for (s1_iter = 0; s1_iter &lt; 10; s1_iter++) {     RecommendedOut[s1_iter] = 2.3 * vectorInput[s1_iter]; }</pre> <p>A common mistake is to embed basic vector operations in a For, While, or For Each subsystem. The following example includes a simple vector gain inside a For subsystem, which results in unnecessary nested for loops.</p>  <p><b>Not Recommended</b></p> <pre>for (s1_iter = 0; s1_iter &lt; 10; s1_iter++) {     for (i = 0; i &lt; 10; i++) {         NotRecommendedOut[i] = 2.3 * vectorInput[i];     } }</pre>	

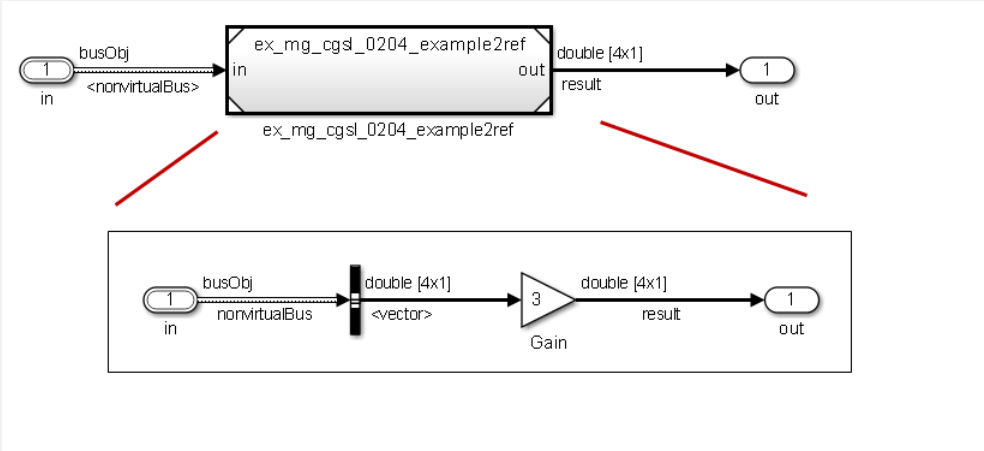
## cgsi\_0204: Vector and bus signals crossing into atomic subsystems or Model blocks

ID: Title	cgsi_0204: Vector and bus signals crossing into atomic subsystems or Model blocks																																					
Description	When working with vector or bus signals and some of the signal elements are in an atomic subsystem or a referenced model, use the following information to determine how to select signal elements to minimize memory usage.																																					
	A	<p><b>Bus or vector entering an atomic subsystem:</b></p> <table border="1" data-bbox="555 617 1474 1058"> <thead> <tr> <th colspan="3" data-bbox="555 617 1474 667"><b>Function packaging:</b> Non-reusable function</th> </tr> <tr> <th colspan="3" data-bbox="555 667 1474 718"><b>Function interface:</b> void_void</th> </tr> <tr> <th data-bbox="555 718 857 827"></th> <th data-bbox="857 718 1170 827"><b>Signals selected outside subsystem results in...</b></th> <th data-bbox="1170 718 1474 827"><b>Signal selected inside subsystem results in...</b></th> </tr> </thead> <tbody> <tr> <td data-bbox="555 827 857 869"><b>Virtual Bus</b></td> <td data-bbox="857 827 1170 869">No data copies.</td> <td data-bbox="1170 827 1474 869">No data copies.</td> </tr> <tr> <td data-bbox="555 869 857 911"><b>Nonvirtual Bus</b></td> <td data-bbox="857 869 1170 911">No data copies.</td> <td data-bbox="1170 869 1474 911">No data copies.</td> </tr> <tr> <td data-bbox="555 911 857 1058"><b>Vector</b></td> <td data-bbox="857 911 1170 1058">A copy of the selected signals in global block I/O structure that is used in the function.</td> <td data-bbox="1170 911 1474 1058">No data copies.</td> </tr> </tbody> </table> <table border="1" data-bbox="555 1058 1474 1661"> <thead> <tr> <th colspan="3" data-bbox="555 1058 1474 1108"><b>Function packaging:</b> Non-reusable function</th> </tr> <tr> <th colspan="3" data-bbox="555 1108 1474 1159"><b>Function interface:</b> Allow arguments (Optimized)</th> </tr> <tr> <th data-bbox="555 1159 857 1268"></th> <th data-bbox="857 1159 1170 1268"><b>Signals selected outside subsystem results in</b></th> <th data-bbox="1170 1159 1474 1268"><b>Signal selected inside subsystem results in</b></th> </tr> </thead> <tbody> <tr> <td data-bbox="555 1268 857 1415"><b>Virtual Bus</b></td> <td data-bbox="857 1268 1170 1415">No data copies. Only the selected signals are passed to the function.</td> <td data-bbox="1170 1268 1474 1415">No data copies. Only the selected signals are passed to the function.</td> </tr> <tr> <td data-bbox="555 1415 857 1524"><b>Nonvirtual Bus</b></td> <td data-bbox="857 1415 1170 1524">No data copies. Only the selected signals are passed to the function.</td> <td data-bbox="1170 1415 1474 1524">No data copies. The whole bus is passed to the function.</td> </tr> <tr> <td data-bbox="555 1524 857 1661"><b>Vector</b></td> <td data-bbox="857 1524 1170 1661">A copy of the selected signals in a local variable that is passed to the function.</td> <td data-bbox="1170 1524 1474 1661">No data copies. The whole vector is passed to the function.</td> </tr> </tbody> </table>		<b>Function packaging:</b> Non-reusable function			<b>Function interface:</b> void_void				<b>Signals selected outside subsystem results in...</b>	<b>Signal selected inside subsystem results in...</b>	<b>Virtual Bus</b>	No data copies.	No data copies.	<b>Nonvirtual Bus</b>	No data copies.	No data copies.	<b>Vector</b>	A copy of the selected signals in global block I/O structure that is used in the function.	No data copies.	<b>Function packaging:</b> Non-reusable function			<b>Function interface:</b> Allow arguments (Optimized)				<b>Signals selected outside subsystem results in</b>	<b>Signal selected inside subsystem results in</b>	<b>Virtual Bus</b>	No data copies. Only the selected signals are passed to the function.	No data copies. Only the selected signals are passed to the function.	<b>Nonvirtual Bus</b>	No data copies. Only the selected signals are passed to the function.	No data copies. The whole bus is passed to the function.	<b>Vector</b>	A copy of the selected signals in a local variable that is passed to the function.
<b>Function packaging:</b> Non-reusable function																																						
<b>Function interface:</b> void_void																																						
	<b>Signals selected outside subsystem results in...</b>	<b>Signal selected inside subsystem results in...</b>																																				
<b>Virtual Bus</b>	No data copies.	No data copies.																																				
<b>Nonvirtual Bus</b>	No data copies.	No data copies.																																				
<b>Vector</b>	A copy of the selected signals in global block I/O structure that is used in the function.	No data copies.																																				
<b>Function packaging:</b> Non-reusable function																																						
<b>Function interface:</b> Allow arguments (Optimized)																																						
	<b>Signals selected outside subsystem results in</b>	<b>Signal selected inside subsystem results in</b>																																				
<b>Virtual Bus</b>	No data copies. Only the selected signals are passed to the function.	No data copies. Only the selected signals are passed to the function.																																				
<b>Nonvirtual Bus</b>	No data copies. Only the selected signals are passed to the function.	No data copies. The whole bus is passed to the function.																																				
<b>Vector</b>	A copy of the selected signals in a local variable that is passed to the function.	No data copies. The whole vector is passed to the function.																																				

ID: Title	cgsl_0204: Vector and bus signals crossing into atomic subsystems or Model blocks		
	<b>Function packaging:</b> Reusable function		
		<b>Signals selected outside subsystem results in</b>	<b>Signal selected inside the subsystem results in</b>
	<b>Virtual Bus</b>	No data copies. Only the selected signals are passed to the function.	No data copies. Only the selected signals are passed to the function.
	<b>Nonvirtual Bus</b>	No data copies. Only the selected signals are passed to the function. See example 1.	No data copies. The whole bus is passed to the function.
	<b>Vector</b>	A copy of the selected signals in a local variable that is passed to the function.	No data copies. The whole vector is passed to the function.

ID: Title		cgsi_0204: Vector and bus signals crossing into atomic subsystems or Model blocks													
	B	<b>Bus or vector entering a Model block:</b>													
			<table border="1"> <thead> <tr> <th></th> <th>Signals selected outside Model block results in...</th> <th>Signal selected inside Model block results in...</th> </tr> </thead> <tbody> <tr> <td><b>Virtual Bus</b></td> <td>No data copies. Only selected signals are passed to the function.</td> <td> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is selected, then there are no data copies. Only the selected signals are passed to the function.</p> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is cleared, then a copy of the whole bus is passed to the function.</p> </td> </tr> <tr> <td><b>Nonvirtual Bus</b></td> <td>No data copies. Only the selected signals are passed to the function.</td> <td> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is selected, then there are no data copies. Only the selected signals are passed to the function.</p> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is cleared, then a copy of the whole bus is passed to the function. See example 2.</p> </td> </tr> <tr> <td><b>Vector</b></td> <td>A copy of the selected signals in a local variable that is passed to the function.</td> <td>No data copies. The whole vector is passed to the function.</td> </tr> </tbody> </table>		Signals selected outside Model block results in...	Signal selected inside Model block results in...	<b>Virtual Bus</b>	No data copies. Only selected signals are passed to the function.	<p>If Inport block parameter <b>Output as nonvirtual bus</b> is selected, then there are no data copies. Only the selected signals are passed to the function.</p> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is cleared, then a copy of the whole bus is passed to the function.</p>	<b>Nonvirtual Bus</b>	No data copies. Only the selected signals are passed to the function.	<p>If Inport block parameter <b>Output as nonvirtual bus</b> is selected, then there are no data copies. Only the selected signals are passed to the function.</p> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is cleared, then a copy of the whole bus is passed to the function. See example 2.</p>	<b>Vector</b>	A copy of the selected signals in a local variable that is passed to the function.	No data copies. The whole vector is passed to the function.
			Signals selected outside Model block results in...	Signal selected inside Model block results in...											
		<b>Virtual Bus</b>	No data copies. Only selected signals are passed to the function.	<p>If Inport block parameter <b>Output as nonvirtual bus</b> is selected, then there are no data copies. Only the selected signals are passed to the function.</p> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is cleared, then a copy of the whole bus is passed to the function.</p>											
<b>Nonvirtual Bus</b>	No data copies. Only the selected signals are passed to the function.	<p>If Inport block parameter <b>Output as nonvirtual bus</b> is selected, then there are no data copies. Only the selected signals are passed to the function.</p> <p>If Inport block parameter <b>Output as nonvirtual bus</b> is cleared, then a copy of the whole bus is passed to the function. See example 2.</p>													
<b>Vector</b>	A copy of the selected signals in a local variable that is passed to the function.	No data copies. The whole vector is passed to the function.													
Notes	<ul style="list-style-type: none"> <li>Depending on Embedded Coder settings (e.g. optimizations), predecessor blocks and signal storage classes, actual results might differ from the tables.</li> <li>Virtual busses do not support global data.</li> <li>If the subsystem is set to <code>InLine</code>, data copies do not occur.</li> </ul>														
Rationale	A, B	Minimize RAM, ROM, and stack usage													
Last Changed	R2016a														

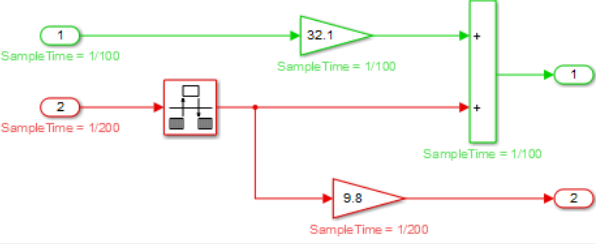
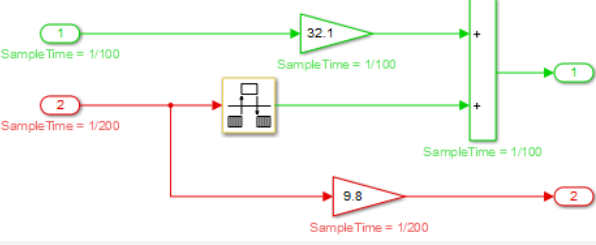
ID: Title	cgs1_0204: Vector and bus signals crossing into atomic subsystems or Model blocks
Examples	<p><b>Example 1:</b> Nonvirtual bus entering an atomic subsystem</p> <ul style="list-style-type: none"> <li>• <b>Function packaging:</b> Reusable function</li> <li>• Selection: Subsignal selected outside the subsystem</li> </ul>  <p>Only the selected signals are passed to the function:</p> <pre data-bbox="446 987 1136 1270"> 6 void Function(const real_T rtu_in[4], real_T rty_out[4]) 7 { 8     rty_out[0] = 3.0 * rtu_in[0]; 9     rty_out[1] = 3.0 * rtu_in[1]; 10    rty_out[2] = 3.0 * rtu_in[2]; 11    rty_out[3] = 3.0 * rtu_in[3]; 12 } 13 14 void ex_mg_cgs1_0204_example1_step(void) 15 { 16     Function(&amp;nonvirtualBus.vector[0], Y.Out1); 17 } </pre>

ID: Title	cgs1_0204: Vector and bus signals crossing into atomic subsystems or Model blocks
	<p><b>Example 2:</b> Nonvirtual bus entering a model block</p> <ul style="list-style-type: none"> <li>• <b>Total number of instances allowed per top model:</b> Multiple</li> <li>• Selection: Subsignal selected inside the referenced model</li> </ul>  <p>There are no data copies in the code for the main model. The whole bus is passed to the model reference function.</p> <pre data-bbox="444 1045 1338 1140"> 6 void ex_mg_cgs1_0204_example2_step(void) 7 { 8   ex_mg_cgs1_0204_example2ref(&amp;ex_mg_cgs1_0204_example2_U.nonvirtualBus, 9     &amp;ex_mg_cgs1_0204_example2_Y.Out1[0]); </pre> <p>Code for the model reference function:</p> <pre data-bbox="444 1241 1338 1402"> 4 void ex_mg_cgs1_0204_example2ref(const busObj *rtu_in, real_T rty_out[4]) 5 { 6   rty_out[0] = 3.0 * rtu_in-&gt;vector[0]; 7   rty_out[1] = 3.0 * rtu_in-&gt;vector[1]; 8   rty_out[2] = 3.0 * rtu_in-&gt;vector[2]; 9   rty_out[3] = 3.0 * rtu_in-&gt;vector[3]; 10 } </pre>

## cgsl\_0205: Signal handling for multirate models

ID: Title	cgsl_0205: Signal handling for multirate models	
Description	For multirate models, handle the change in operation rate in one of two ways:	
	A	At the destination block, Insert a Rate Transition.
	B	Set configuration parameter <b>Automatically handle rate transition for data transfer</b> to <i>Always</i> or <i>Whenever possible</i> .
Rationale	A,B	Following this guideline supports the handling of data operating at different rates.
Note	<p>Setting <b>Automatically handle rate transition for data transfer</b> to <i>Whenever possible</i> requires you to insert a Rate Transition block in locations indicated by Simulink.</p> <p>Setting <b>Automatically handle rate transition for data transfer</b> to <i>Always</i> allows Simulink to automatically handle rate transitions by inserting a Rate Transition block. The following exceptions apply:</p> <ul style="list-style-type: none"> <li>• The insertion of a Rate Transition block requires rewiring the block diagram.</li> <li>• Multiple Rate Transition blocks are required: <ul style="list-style-type: none"> <li>• The blocks' sample times are not integer multiples of each other</li> <li>• The blocks use different sample time offsets</li> <li>• One of the rates is asynchronous</li> </ul> </li> <li>• An inserted Rate Transition block can have multiple valid configurations.</li> </ul> <p>For these cases, manually insert a Rate Transition block or blocks.</p> <p>MathWorks does not recommend using Unit Delay and Zero Order Hold blocks for handling rate transitions.</p>	
Last Changed	R2011a	



ID: Title	cgsl_0205: Signal handling for multirate models
Examples	<p><b>Not Recommended:</b></p> <p>In this example, the Rate Transition block is inserted at the source, not at the destination of the signal. The model fails to update because the two destination blocks (Gain and Sum) run at different rates. To fix this error, insert Rate Transition blocks at the signal destinations and remove Rate Transition blocks from the signal sources. Failure to remove the Rate Transition blocks is a common modeling pattern that might result in errors and inefficient code.</p>  <p><b>Recommended:</b></p> <p>In this example, the rate transition is inserted at the destination of the signal.</p> 

## cgsl\_0206: Data integrity and determinism in multitasking models

ID: Title	cgsl_0206: Data integrity and determinism in multitasking models	
Description	For multitasking models that are deployed with a preemptive (interruptible) operating system, protect the integrity of selected signals by doing one of the following:	
	A	Select the Rate Transition block parameter <b>Ensure data integrity during data transfer</b> .
	B	For Inport blocks in Function Called subsystems, select the block parameter <b>Latch input for feedback signals of function-call subsystem outputs</b> .
	To protect selected signal determinism, do one of the following:	
	C	Select the Rate Transition block parameter <b>Ensure deterministic data transfer (maximum delay)</b> .
D	<ul style="list-style-type: none"> <li>• Select the configuration parameter <b>Automatically handle rate transition for data transfer</b>.</li> <li>• Set configuration parameter <b>Deterministic data transfer</b> to Whenever possible or Always.</li> </ul>	
Prerequisites	cgsl_0205:Signal handling for multirate models on page 3-12	
Rationale	A,B, C,D	Following this guideline protects data against possible corruption of preemptive (interruptible) operating systems.
Note	<p>Multitasking systems with a non-preemptive operating system do not require data integrity or determinism protection. In this case, clear these parameters:</p> <ul style="list-style-type: none"> <li>• Rate Transition block parameter <b>Ensure data integrity during data transfer</b></li> <li>• Configuration parameter <b>Ensure deterministic data transfer (maximum delay)</b></li> </ul> <p>Ensuring data integrity and determinism requires additional memory and execution time. To reduce this additional expense, evaluate signals to determine the level of protection that they require.</p>	
See Also	<ul style="list-style-type: none"> <li>• Rate Transition</li> <li>• “Data Transfer Problems” (Simulink Coder)</li> </ul>	
Last Changed	R2011a	

# Configuration Parameter Considerations

---

- “cgsl\_0301: Prioritization of code generation objectives for code efficiency” on page 4-2
- “cgsl\_0302: Diagnostic settings for multirate and multitasking models” on page 4-3

## cgsl\_0301: Prioritization of code generation objectives for code efficiency

ID: Title	cgsl_0301: Prioritization of code generation objectives for code efficiency	
Description	Prioritize code generation objectives for code efficiency by using the Code Generation Advisor.	
	A	Assign priorities to code (ROM, RAM, and Execution efficiency) efficiency objectives.
	B	Select the relative order of ROM, RAM, and Execution efficiency based on application requirements.
	C	Configure the Code Generation Advisor to run before generating code by setting the <b>Check model before generating code</b> configuration parameter to On (proceed with warnings) or On (stop for warnings).
Notes	<p>A model's configuration parameters provide control over many aspects of generated code. The prioritization of objectives specifies how configuration parameters are set when conflicts between objectives occur.</p> <p>Prioritizing code efficiency objectives above safety objectives may remove initialization or run-time protection code (for example, saturation range checking for signals out of representable range). Review the resulting parameter configurations to verify that safety requirements are met.</p>	
Rationale	A, B, C	When you use the Code Generation Advisor, configuration parameters conform to the objectives that you want and they are consistently enforced.
See also	<ul style="list-style-type: none"> <li>• “Application Objectives Using Code Generation Advisor” (Simulink Coder)</li> <li>• “Manage Configuration Sets for a Model”</li> </ul>	
Last Changed	R2015b	

## cgsl\_0302: Diagnostic settings for multirate and multitasking models

ID: Title	cgsl_0302: Diagnostic settings for multirate and multitasking models
Description	<p>For multirate models using either <b>single tasking</b> or <b>multitasking</b>, set these configuration parameters to warning or error:</p> <ul style="list-style-type: none"> <li>• <b>Single task rate transition</b></li> <li>• <b>Enforce sample time specified by Signal Specification blocks</b></li> <li>• <b>Detect multiple driving blocks executing at the same time step</b></li> </ul> <p>For <b>multitasking</b> models, set these configuration parameters to warning or error:</p> <ul style="list-style-type: none"> <li>• <b>Multitask task rate transition</b></li> <li>• <b>Multitask conditionally executed subsystem</b></li> <li>• <b>Tasks with equal priority</b></li> </ul> <p>If the model contains Data Store Memory blocks, set these configuration parameters to Enable all as warnings or Enable all as errors:</p> <ul style="list-style-type: none"> <li>• <b>Detect read before write</b></li> <li>• <b>Detect write after read</b></li> <li>• <b>Detect write after write</b></li> <li>• <b>Multitask data store</b></li> </ul>
Rationale	Setting diagnostic configuration parameters improves run-time detection of rate and tasking errors.
See Also	<ul style="list-style-type: none"> <li>• “Model Configuration Parameters: Diagnostics”</li> <li>• “hisl_0013: Usage of data store blocks”</li> <li>• “hisl_0044: Configuration Parameters &gt; Diagnostics &gt; Sample Time”</li> <li>• “hisl_0303: Configuration Parameters &gt; Diagnostics &gt; Data Validity &gt; Merge blocks”</li> </ul>
Last Changed	2016a

