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A Comparison of Three Code Generators for Models Created in Simulink

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Purpose

- Compare
  - Real-Time Workshop Embedded Coder from MathWorks
  - TargetLink from dSPACE
  - SCADE Drive from Esterel Technologies
- with respect to
  - code quality
  - integration with other software and hardware
  - relevant standards
  - functionality
- Generate code from a Simulink ABS-brake model provided by Volvo Technology and examine the outcome

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Method

Functionality
- Block support
- Optimisation
- Customisation
- Scheduling and integration with RTOS

Metrics
- ABS-system from Volvo Technology
- Programming Research's QA C 4.4.2

Standards and guidelines
- DO-178B
- IEC 61508
- MISRA C

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Factors to compare

- **Environment**
- **Fixed-point arithmetic**
- **Verification and validation**
- **RTOS**
- **Customisation**
- **Optimisation**
- **Block support**
- **Standards**
- **Comparison of the generated code with QA C**

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The Environment

Real-Time Workshop Embedded Coder

Doesn't need a conversion

TargetLink

Models need to be converted
Uses the Simulink environment
User friendly
All options collected in one place

SCADE

Models need to be converted
May need manual settings to get a conversion into SCADE
Has its own design environment totally independent of Simulink

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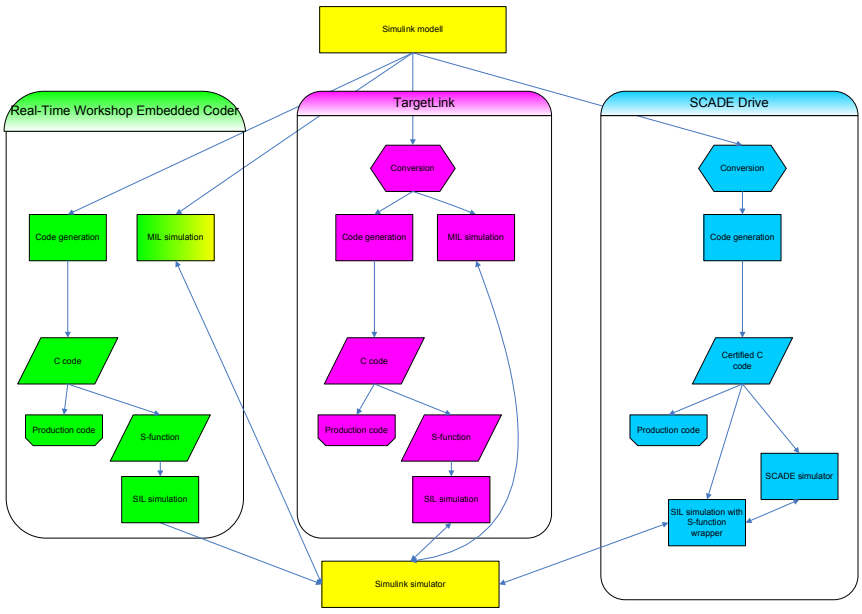

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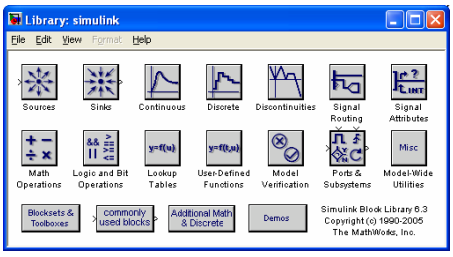
Block support



217 block i Simulink library
~190 relevant

Not suited for code generation
Continuous
Display, source

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Block support

Real-Time Workshop Embedded Coder

Support for almost all of the blocks

TargetLink

Support for more then 50% of the blocks relevant for code generation
Limitations associated with many blocks

SCADE

Support for about 40% of the blocks relevant for code generation
Subsystem – Nodes
When converting many options get hard-coded

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Scheduling and integration with RTOS

Real-Time Workshop Embedded Coder

Automatic or manual insertion of 'rate transition' blocks
OSEK/VDX blocks available through additional toolbox

TargetLink

Manual insertion of 'rate transition' blocks
OSEK/VDX block included

SCADE

No support for managing messages between tasks
Multi Task, generated separately from different nodes
RTOS wrapper for OSEK and MicroC/OS-II

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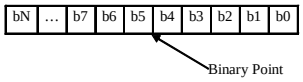
Fixed-point arithmetic

Allow representation of real numbers
Faster operations than with floating-point



Auto-scaling
- Worst-case scenario
- Simulation scenario

$$W \approx \hat{W} = S * Q + B$$

$$S = F * 2^{-E}$$

W: Real-world value
Ŵ: Approximate value
S: Slope
Q: Quantization value (stored in memory)
B: Bias (binary-only scaling B=0)
F: Fraction (binary-only scaling F=1)
E: Binary point

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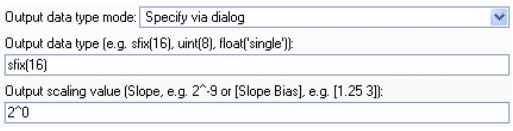
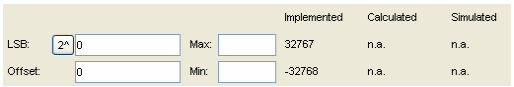
Fixed-point arithmetic

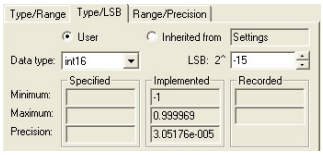
Real-Time Workshop Embedded Coder
- Simulation
- Integer 1-128 bits



TargetLink
- Worst-case and Simulation
- User-friendly



SCADE
- Worst-case and Simulation



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Guiding principles and standards

- **DO-178B/ED-12B**
  - Supported by SCADE
- **MISRA C**
  - Supported by Real-Time Workshop Embedded Coder
  - Supported by TargetLink
  - Supported by SCADE
- **IEC 61508**
  - Supported by SCADE

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Verification and validation

- **Model coverage, Code coverage**
- **Signal verification**
- **MIL, SIL, PIL**

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Customisation

- **Custom code**
- **Create functions from subsystems and nodes**
- **Representation of signals and variables**
- **Assigning variables to a memory section**
- **Target Language Compiler**

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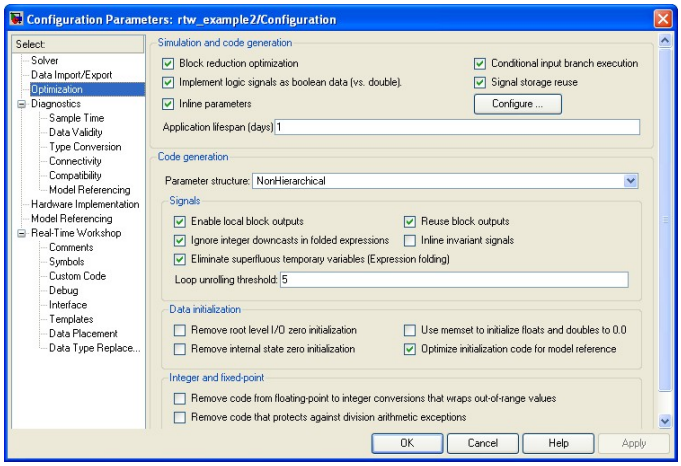
Real-Time Workshop Embedded Coder



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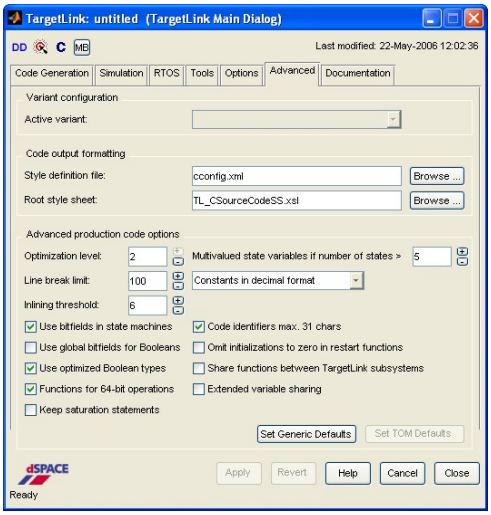
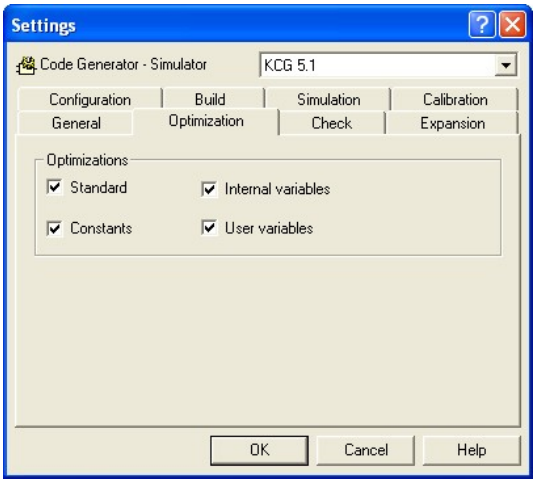
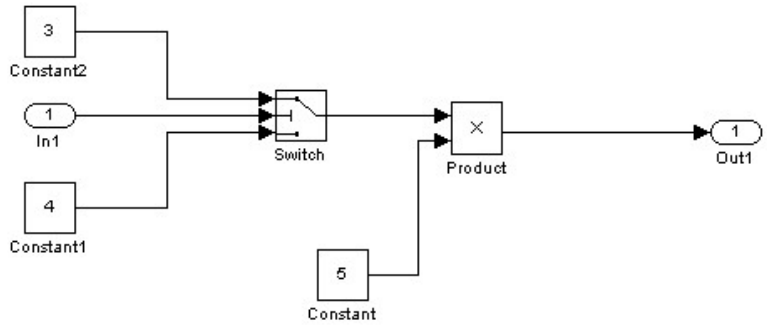
TargetLink Main Dialog



SCADE Drive



Example



Code example

RTW-EC

```
/* Model step function */
void cp_step(void)
{

  /* local block i/o variables*/
  real_T rtb_Switch;

  /* Switch: '<Root>/Switch' incorporates:
   *  Inport: '<Root>/In1'
   */
  if(cp_U.In1 >= 0.0) {
    rtb_Switch = 3.0;
  } else {
    rtb_Switch = 4.0;
  }

  /* Outport: '<Root>/Out1' incorporates:
   *  Product: '<Root>/Product'
   */
  cp_Y.Out1 = rtb_Switch * 5.0;
}
```

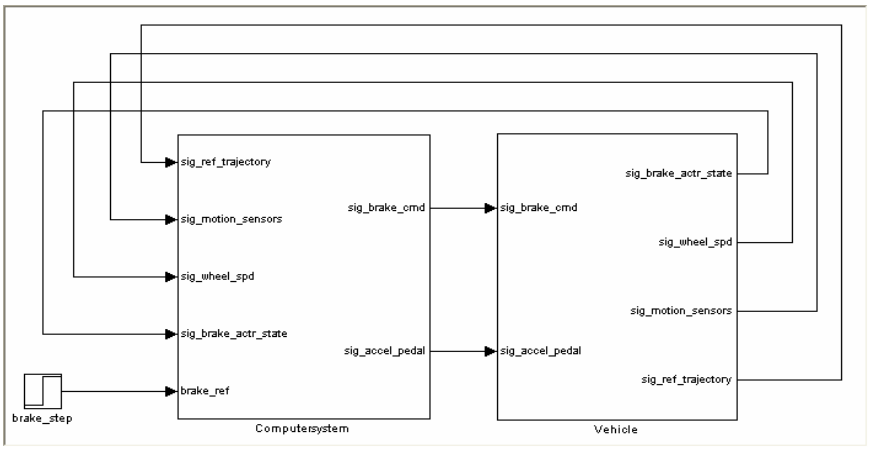
TargetLink

```
Void Subsystem(Void)
{
  /* SLLocal: Default storage class for local
variables | Width: 16 */
  Int16 Sa1_Switch;

  /* SwitchSubsystem/Switch */
  if (Sa1_InPort >= 0.F) {
    Sa1_Switch = 3 /* 3. */;
  }
  else {
    Sa1_Switch = 4 /* 4. */;
  }

  /* Outport: Subsystem/out.
     # combined # Product:
Subsystem/Product */
  Sa1_OutPort = (Float32) (Int16) (((UInt8)
Sa1_Switch) * 5);
}
```

SCADE

```
void Node1(_C_Node1 * _C_)
{
   real _L0_Node1;
/*#code for node Node1 */
   if (((_C_->_I0_Input1) >= (real) 0.0)) {
                _L0_Node1 = (real) 3.0;
   } else {
                _L0_Node1 = (real) 4.0;
   }
   (_C_->_O0_Output1)  =  (_L0_Node1  *
(real) 5.0);
/*#end code for node Node1 */
}
```

ABS-Model



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Metrics from ABS-model

Programming Research QA C 4.4.2

1. Lines of Executable Code
   Lines of code excluding declarations, blank lines and comment lines

2. Cyclomatic Complexity
   Number of independent paths through the flow graph

3. Halstead's Program Difficulty
   Indicates if the program uses a rich vocabulary and therefore is potentially difficult to understand.

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Metric Result

	Real-Time Workshop Embedded Coder	TargetLink	SCADE
Lines of code, executable	45 (56)	77 (61)	144 (248)
Cyclomatic Complexity	12 (14)	20 (14*)	21 (21)
Program Difficulty (maximum of the generated files)	11.12 (13.44)	18.55 (21.38)	19.99 (24.46**)
	Unscaled (scaled) *: saturation function defined elsewhere **: combination of files to get representative value		

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Summary

	Simulink support	User-friendliness	Customization options	Standard compliance	Verification tools	Fixed-Point	Purchase Price
RTW-EC	**High**	**Medium**	**High**	**Low-Medium**	**Medium**	**Low-Medium**	**High**
TargetLink	**Medium**	**High**	**Medium-High**	**Low-Medium**	**Medium**	**High**	**Medium**
SCADE	**Low-Medium**	**Medium**	**Low**	**High**	**High**	**Medium-High**	**Low**

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Conclusions

- Real-Time Workshop Embedded Coder and TargetLink are quite alike
- SCADE use a different environment which complicates conversion and requires training to manage
- To fully be able to compare the three tools, the benefits of SCADE's certification to DO178B and IEC61508 has to be evaluated
- The savings made from using a certified code generator could motivate the high price of SCADE.
  Real-Time Workshop Embedded Coder

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The End

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