Real-Time Workshop Embedded Coder Release Notes

The "Real-Time Workshop Embedded Coder 3.2.1 Release Notes" on page 1-1 describe changes included in the latest version of the Real-Time Workshop Embedded Coder, Version 3.2.1. The release notes discuss the following topics:

- "New Features" on page 1-2
- "Major Bug Fixes" on page 1-4
- "Known Software and Documentation Problems" on page 1-5

Note Real-Time Workshop Embedded Coder 3.2.1 requires R13SP1.

If you are upgrading from a version earlier than Version 3.2, you should also see these sections:

- "Real-Time Workshop Embedded Coder 3.2 Release Notes" on page 2-1
- "Real-Time Workshop Embedded Coder 3.1 Release Notes" on page 3-1
- "Real-Time Workshop Embedded Coder 3.0.1 Release Notes" on page 4-1
- "Real-Time Workshop Embedded Coder 3.0 Release Notes" on page 5-1
- "Real-Time Workshop Embedded Coder 2.0 Release Notes" on page 6-1

Printing the Release Notes

If you would like to print the Release Notes, you can link to a PDF version.

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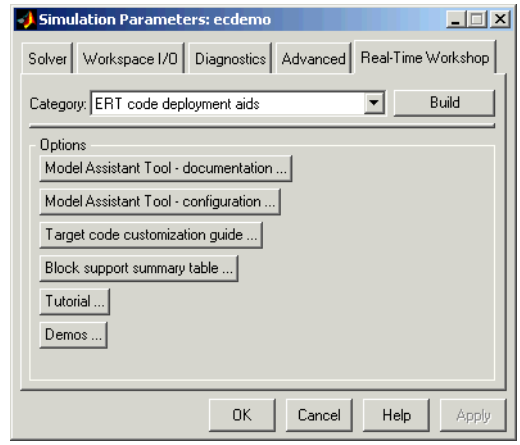
New Features

This section summarizes the new features and enhancements introduced in the Real-Time Workshop Embedded Coder 3.2.1.

ERT Code Deployment Aids Added to GUI

A new group of buttons has been added to the Embedded Real-Time (ERT) target options in the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box. To access these buttons, select `ERT code deployment aids` from **Category** menu, as shown in the figure below.



The `ERT code deployment aids` buttons provide quick access to features and information that can help you to optimize your generated code. The buttons are:

- **Model Assistant Tool - documentation**: Click this button to view online help for the Model Assistant Tool in the MATLAB Help browser. You can also view this help by typing the MATLAB command

  ```
  modelassistant('help')
  ```

- **Model Assistant Tool - configuration**: Click this button to open the Model Assistant Tool for configuration of options.
- **Target code customization guide**: Click this button to view the "Advanced Code Generation Features," chapter of the Real-Time Workshop Embedded

Coder online documentation. The chapter documents useful code generation, optimization, and customization techniques for the ERT target. Most of the features described were introduced in the Real-Time Workshop Embedded Coder 3.2 (see Chapter 2, "Real-Time Workshop Embedded Coder 3.2 Release Notes" for a summary).

- **Block summary support table**: Click this button to view the Simulink Block Data Type Support Table in the MATLAB Help Browser. The table describes the data types that are supported by the blocks in the main Simulink and Fixed-Point libraries. The table also identifies blocks that are suitable for production code generation. You can also view the table by typing the MATLAB command

  ```
  showblockdatatypetable
  ```

- **Tutorial**: Click this button to open an interactive Real-Time Workshop Embedded Coder tutorial demo in the in the MATLAB Help Browser. You can also view the tutorial demo by typing the MATLAB command

  ```
  ecodertutorial
  ```

- **Demos**: Click this button to open the Real-Time Workshop Embedded Coder demo suite. You can also view the demos by typing the MATLAB command

  ```
  ecoderdemos
  ```

Major Bug Fixes

Real-Time Workshop Embedded Coder 3.2.1 includes important bug fixes made since Version 3.2.

If you are viewing these Release Notes in PDF form, please refer to the HTML form of the Release Notes, using either the Help browser or the MathWorks Web site and use the link provided.

If you are upgrading from a release earlier than Version 3.1, then you should also see “Major Bug Fixes” on page 3-7 of the Real-Time Workshop Embedded Coder 3.0.1 Release Notes.

Known Software and Documentation Problems

This section includes a link to a description of known software and documentation problems in Version 3.2.1 and prior.

If you are viewing these Release Notes in PDF form, please refer to the HTML form of the Release Notes, using either the Help browser or the MathWorks Web site and use the link provided.

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New Features

This section summarizes the new features and enhancements introduced in the Real-Time Workshop Embedded Coder 3.2.

Advanced Code Generation Techniques Documented

A new chapter, "Advanced Code Generation Features," has been added to the the Real-Time Workshop Embedded Coder User's Guide. This chapter contains complete information on the new features that are summarized in these release notes. In addition, the chapter documents useful code generation, optimization, and customization techniques that have not received wide exposure in previous releases. These include

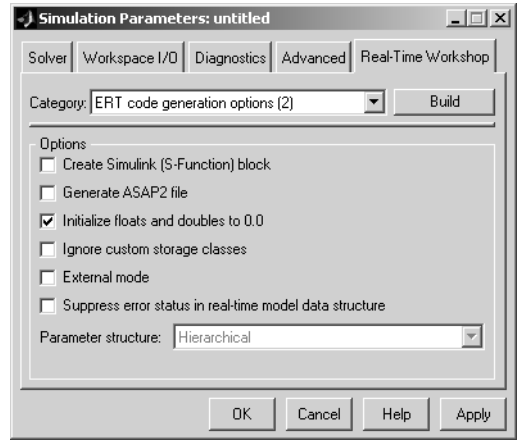
- How to specify target characteristics (such as word sizes for C data types) for the build process, so that generated code is correct for deployment on target hardware
- A general hook file mechanism for adding target-specific customizations to the build process

New Code Generation Options

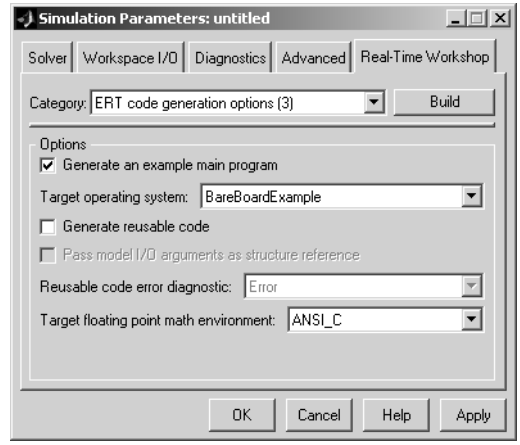
Several new code generation options have been added, and some changes have been made to the layout of Embedded Real-Time (ERT) target code generation options in the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box.

Options Layout Changes and Additions

The **Suppress error status in real-time model data structure** option has been relocated to the `ERT code generation options (2)` category, as shown in this figure.

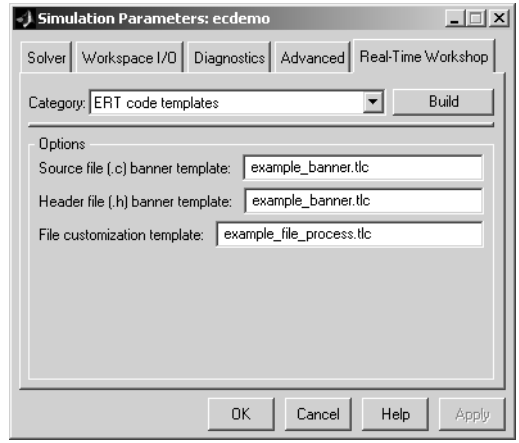


A new code generation option, **Pass model I/O arguments as structure reference**, is now available in the `ERT code generation options (3)` category, as shown below. This option is described in "Passing Model I/O Arguments to the model_step Function" on page 2-6.



A new group of options supporting use of *code templates*, a powerful and simple technique for customizing generated code, has been added. These options are available in the `ERT code templates` category of the **Real-Time Workshop** pane of the **Simulation Parameters** dialog (see the figure below). Code

templates are summarized in "Code Templates for Customizing Generated Code" on page 2-5.



Auto-Configuration of Models for Code Generation

The Real-Time Workshop Embedded Coder now supports automated configuration of all (or selected) model parameters during the code generation process. By automatically configuring a model in this way, you can avoid manually configuring models. This saves time and eliminates potential errors.

Auto-configuration is performed by executing an M-file (referred to as a *hook file*) that is executed as part of the the target build process. Therefore, auto-configuration becomes a function of the target that invokes the hook file. You can direct the automatic configuration process to save existing model settings before code generation and restore them afterwards, so that the user's manually chosen options are not disturbed.

The automatic configuration process, and utilities provided to support auto-configuration, are described in the "Advanced Code Generation Features" chapter of the Real-Time Workshop Embedded Coder User's Guide.

Optimized ERT Targets for Fixed-Point and Floating-Point Code Generation

To make it easier for you to customize a hook file that is optimized for your target hardware, Real-Time Workshop Embedded Coder provides two variants of the ERT target:

- `RTW Embedded Coder (auto configures for optimized fixed-point code)`: To optimize for fixed-point code generation, select this target from the System Target File Browser.
- `RTW Embedded Coder (auto configures for optimized floating-point code)`: To optimize for floating-point code generation, select this target from the System Target File Browser.

The use of these targets is detailed in the "Advanced Code Generation Features" chapter of the Real-Time Workshop Embedded Coder User's Guide.

Code Templates for Customizing Generated Code

The ERT target now supports use of *custom file processing templates* (CFP templates).

A CFP template is a Target Language Compiler (TLC) file that calls a high-level applications programming interface (API), referred to as the *code template* API. The code template API simplifies generation of custom source code by letting you

- Generate virtually any type of source (`.c`) or header (`.h`) file. A CFP template can emit code to the standard generated model files (e.g., `model.c`, `model.h`, etc.) or generate files that are independent of model code.
- Organize generated code into sections (such as includes, typedefs, functions, and more). Your CFP template can emit code (e.g., functions), directives (such as `#define` or `#include` statements), or comments into each section as required.
- Generate code to call model functions such as `model_initialize`, `model_step`, etc.
- Generate code to read and write model inputs and outputs.
- Generate a main program module.
- Obtain information about the model and the files being generated from it.

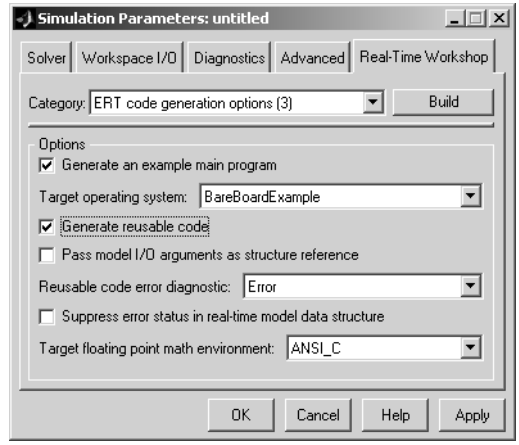
CFP templates are described in the "Advanced Code Generation Features" chapter of the Real-Time Workshop Embedded Coder User's Guide.

Custom File Banner Generation

The ERT target now supports use of *banner templates* during code generation. A banner template is a TLC file that specifies banner and trailer comments that are emitted to generated source (`.c`) and header (`.h`) files. Banner templates are described in the "Advanced Code Generation Features" chapter of the Real-Time Workshop Embedded Coder User's Guide.

Passing Model I/O Arguments to the model_step Function

A new code generation option, **Pass model I/O arguments as structure reference**, lets you control how model inputs and outputs at the root level of the model are passed in to the `model_step` function. This option is available in the `ERT code generation options (3)` category of the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box. When **Generate reusable code** is selected, **Pass model I/O arguments as structure reference** is enabled, as shown in this figure.



When **Pass model I/O arguments as structure reference** is deselected (the default), each root-level model input and output is passed to `model_step` as a separate argument. When this option is selected, all root-level inputs are

packed into a `struct` that is passed to `model_step` as an argument. Likewise, all root-level outputs are packed into a `struct` that is also passed to `model_step` as an argument. Selecting **Pass model I/O arguments as structure reference** can reduce the number of arguments passed in to `model_step`.

See the "Code Generation Options and Optimizations" chapter of the Real-Time Workshop Embedded Coder User's Guide documentation for further details.

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New Features

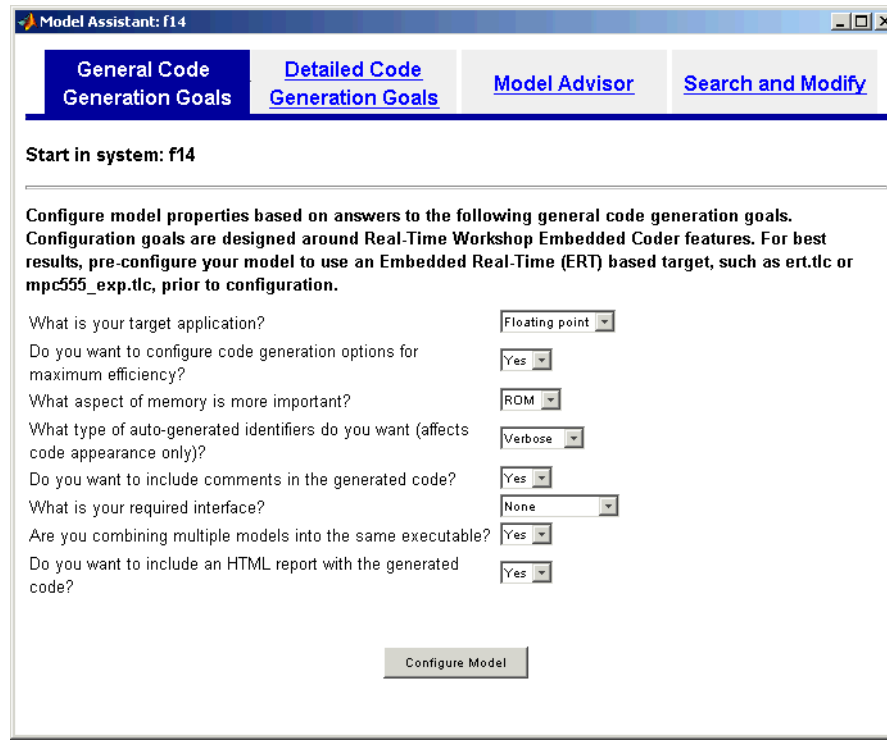
This section summarizes the new features and enhancements introduced in the Real-Time Workshop Embedded Coder 3.1.

Model Assistant Tool

The Model Assistant Tool is a utility that lets you configure a model for code generation quickly. The Model Assistant Tool also helps you to identify aspects of your model that impede production deployment or limit code efficiency. You can use the Model Assistant Tool at any point in your design cycle, as it is completely independent from the code generation process.

The Model Assistant Tool is designed primarily for use with Real-Time Workshop Embedded Coder. It works most effectively with the Embedded Real-Time (ERT) target and with ERT-based targets (such as the Embedded Target for Motorola MPC555). It will also operate with other targets.

The figure below shows the top-level window of the Model Assistant Tool.



Four main components of the Model Assistant Tool provide a powerful and centralized interface for configuring settings for Simulink blocks, Stateflow charts, models and subsystems. You select these components via the four buttons at the top of the Model Assistant display:

- **General Code Generation Goals**
- **Detailed Code Generation Goals**
- **Model Advisor**
- **Search and Modify**

These components are summarized in the next sections.

General Code Generation Goals

This component lets you quickly configure code generation settings based on specific goals, such as whether to optimize for RAM or ROM usage. Once you have decided the overall optimization and trade-offs for your application, the Model Assistant Tool will select the model settings that best suit your goals.

Detailed Code Generation Goals

This component presents a centralized interface to the available code generation options. Options are grouped by category, and are applied across products.

Model Advisor

The Model Advisor component is is particularly useful early in the design cycle. It provides an analysis of your model to ensure that you best utilize Real-Time Workshop Embedded Coder. You can check selected aspects of your model settings (for example, to identify possible inefficiencies such as blocks that generate saturation and rounding code) or choose **Select All** for a comprehensive analysis.

Search and Modify

This component is a powerful model search and modify engine. It reduces the effort of configuring a model block by block. The search feature helps you find attributes of blocks, lines, input ports, output ports, and annotations quickly. The modify feature lets you perform rapid batch operations on the search results. Frequently performed tasks are packaged conveniently into a single button click.

The **Search and Modify** component includes the following features:

- The **Frequent tasks** page lets you quickly perform common actions.
- The **Simulink object search** page lets you specify a general Simulink object search and modify action. This search mechanism is useful when you know the specific names of underlying attributes.

- The **Stateflow object search** page lets you quickly configure the Stateflow data in your model. This is particularly useful for converting data from floating point to fixed-point types.
- The **Search and replace Simulink text** page lets you quickly modify text for objects in Simulink. For example, you can change all occurrences of `'K1'` to `'K2'`. The semantics of the search and replace are the same as for the Stateflow search and replace tool that ships with Stateflow.
- Two **Parameter name search** mechanisms are provided:
  - Search and modify parameters using prompt strings. This search mechanism is useful when you know the parameter by its dialog prompt string, but you don't know the name of the underlying attribute.
  - "Fuzzy" search using property and/or value pairs. This search mechanism is useful for isolating the name of an underlying attribute.

Using the Model Assistant Tool

You run Model Assistant Tool from the MATLAB command line, via the `modelassistant` command. Before invoking the Model Assistant Tool, make sure that the desired target (such as the ERT target) is selected in the **Target Configuration** section of the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box.

The following examples illustrate the `modelassistant` command syntax and its possible arguments.

To obtain detailed help on the Model Assistant Tool, type

```
modelassistant('help')
```

To invoke the Model Assistant Tool for the root system of a model, type

```
modelassistant('model_name')
```

where `model_name` is the name of the model.

To invoke the Model Assistant Tool for a particular system in a model, type

```
modelassistant('system_name')
```

where `systen_name` is the name of the system.

You can also invoke the Model Assistant Tool for models and systems using the built-in Simulink `bdroot`, `gcb`, and `gcs` commands. For example:

```
modelassistant(gcs)
```

Further Help and Demos

The above sections have summarized the main features of the Model Assistant Tool. To obtain full online documentation on the Model Assistant Tool, type

```
modelassistant('help')
```

There are also three demo models available for the Model Assistant Tool: `advisordemo1`, `advisordemo2`, and `advisordemo3`.

Major Bug Fixes

Real-Time Workshop Embedded Coder 3.1 includes several important bug fixes made since Version 3.0.

If you are viewing these Release Notes in PDF form, please refer to the HTML form of the Release Notes, using either the Help browser or the MathWorks Web site and use the link provided.

If you are upgrading from a version earlier than Version 3.0.1, then you should also see “Major Bug Fixes” on page 4-2 of the Real-Time Embedded Coder 3.0.1 Release Notes.

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Real-Time Workshop Embedded Coder 3.0.1 Release Notes

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Major Bug Fixes

Real-Time Workshop Embedded Coder 3.0.1 includes several important bug fixes made since Version 3.0.

If you are viewing these Release Notes in PDF form, please refer to the HTML form of the Release Notes, using either the Help browser or the MathWorks Web site and use the link provided.

If you are upgrading from a release earlier than Release 13, then you should also see “Major Bug Fixes” on page 5-13 of the Real-Time Embedded Coder 3.0 Release Notes.

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New Features

This section summarizes the new features and enhancements introduced in the Real-Time Workshop Embedded Coder 3.0.

If you are upgrading from a release earlier than Release 12.1, then you should see the Real-Time Workshop Embedded Coder 2.0 "Release Summary" on page 6-2. For an introduction to the Real-Time Workshop Embedded Coder and for information about demos for the product, see the "Product Overview" section of the Real-Time Workshop Embedded Coder User's Guide.

New User's Guide

The Real-Time Workshop Embedded Coder is now documented in a separate manual, the Real-Time Workshop Embedded Coder User's Guide. The new manual includes and updates the information about the Real-Time Workshop Embedded Coder that was formerly included in the Real-Time Workshop documentation.

The new manual also includes an appendix on generating ASAP2 files.

Auto-Generated Main Program

The new **Generate an example main program** option lets you generate a fully commented, model-specific example main program module, `ert_main.c`. The code requires minimal modification for deployment in your environment. You can generate the example main program as either

- A bare-board program designed to run under control of a real-time clock, without a real-time operating system
- An example showing how to deploy the code under the VxWorks real-time operating system

By default, **Generate an example main program** is on. Note that once you have generated and customized the main program, you should take care to avoid overwriting your customized version.

See the "Data Structures and Program Execution" section of the section of the Real-Time Workshop Embedded Coder User's Guide for further information about the operation of the main program module.

The Real-Time Workshop Embedded Coder continues to provide a static (non-generated) version of `ert_main.c` as a template example for developing embedded applications. To use the static version of `ert_main.c` (or continue using a customized version):

- Turn **Generate an example main program** off.
- Read the next section, "Modifying the Static Main Program Module" and make changes to `ert_main.c` as required by your application.

Modifying the Static Main Program Module

This section describes modifications you may need to make to use the static version of `ert_main.c` (or continue using a customized version):

- The multi-rate scheduling code that was in `ert_main.c` is now generated with the model code. Therefore, if your model has multiple rates, note that multi-rate systems will not operate correctly unless:
  - The multirate scheduling code is removed. The relevant code is tagged with the keyword `REMOVE` in comments. (See also the Version 3.0 comments in `ert_main.c`.)
  - Use the `MODEL_SETEVENTS` macro (defined in `ert_main.c`) to set the event flags instead of accessing the flags directly. The relevant code is tagged with the keyword `REPLACE` in comments.
- Remove old `#include ertformat.h` directives. `ertformat.h` is no longer required, and will be obsoleted in a future release. The following macros, formerly defined in `ertformat.h`, are now defined within `ert_main.c`:

```
EXPAND_CONCAT
CONCAT
MODEL_INITIALIZE
MODEL_STEP
MODEL_TERMINATE
MODEL_SETEVENTS
RT_OBJ
```

- If applicable, follow comments in the code regarding where to add code for reading/writing model I/O and saving/restoring FPU context.
- When the **Generate code only** and **Generate an example main program** options are off, the Real-Time Workshop Embedded Coder generates the file `autobuild.h` to provide an interface between the main module and

generated model code. If you create your own static main program module, you would normally include `autobuild.h`.

Alternatively, you can suppress generation of `autobuild.h`, and include *`model`*`.h` directly in your main module. To suppress generation of `autobuild.h`, use the following statement in your system target file:

```
%assign AutoBuildProcedure = 0
```

- If you have cleared the **Terminate function required** option, remove or comment out the following in your production version of `ert_main.c`:
  - The `#if TERMFCN...` compile-time error check
  - The call to `MODEL_TERMINATE`
- If you do *not* want to combine output and update functions, clear the **Single output/update function** option and make the following changes in your production version of `ert_main.c`:
  - Replace calls to `MODEL_STEP` with calls to `MODEL_OUTPUT` and `MODEL_UPDATE`.
  - Remove the `#if ONESTEPFCN...` error check.
- The static `ert_main.c` module does not support the **Generate Reusable Code** option. Use this option only if you are generating a main program. The following error check will raise a compile-time error if **Generate Reusable Code** is used illegally:

  ```
  #if MULTI_INSTANCE_CODE==1
  ```

- The static `ert_main.c` module does not support the **External Mode** option. Use this option only if you are generating a main program. The following error check will raise a compile-time error if **External Mode** is used illegally:

  ```
  #ifdef EXT_MODE
  ```

Code Generation Options

This section describes new Real-Time Workshop Embedded Coder code generation options. These options are available via the **ERT code generation options** menus of the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box.

External Mode

Select this option to generate external mode communications support code in the target program. See also “External Mode Support” on page 5-7.

Generate an Example Main Program

This option lets you generate a model-specific example main program module. See “Auto-Generated Main Program” on page 5-2.

Generate Reusable Code

When this option is selected, the Real-Time Workshop Embedded Coder generates reusable, reentrant code for the model. See “Reusable Code Generation” on page 5-9.

Parameter Structure

See “Hierarchical Parameter Structures” on page 5-8

Suppress Error Status in Real-Time Model Data Structure

If you do not need to log or monitor error status in your application, select this option.

By default, the real-time model data structure (`rtM`) includes an error status field (data type string). This field lets you log and monitor error messages via macros provided for this purpose (see *`model`*`.h`). The error status field is initialized to `NULL`. If **Suppress error status in real-time model data structure** is selected, the error status field is not included in `rtM`. Selecting this option may also cause the real-time model data structure to disappear completely from the generated code.

When generating code for multiple models that will be integrated together, make sure that the **Suppress error status in real-time model data structure** option is set the same for all of the models. Otherwise, the integrated application may exhibit unexpected behavior. For example, if the option is selected in one model but not in another, the error status may or may not be registered by the integrated application.

Do not select **Suppress error status in real-time model data structure** if the **MAT-file logging** option is also selected. The two options are incompatible.

Target Floating Point Math Environment

The Target Floating Point Math Environment pop-up menu provides two options. If you select the `ANSI_C` option (the default), the Real-Time Workshop Embedded Coder generates calls to the ANSI C (ANSI X3.159-1989) math library for floating point functions. If you select the `ISO_C` option, Real-Time Workshop Embedded Coder generates calls to the ISO C (ISO/IEC 9899:1999) math library wherever possible.

If your target compiler supports the ISO C (ISO/IEC 9899:1999) math library, we recommend selecting the `ISO_C` option and setting your compiler's ISO C option. This will generate calls to the ISO C functions wherever possible (for example, `sqrtf()` instead of `sqrt()` for single precision data) and ensure that you obtain the best performance your target compiler offers.

If your target compiler does not support ISO C math library functions, use the `ANSI_C` option.

ECRobot Target Example

The ECRobot (Embedded Coder Robot) target is a simple example of a custom target based on the Real-Time Workshop Embedded Coder. The ECRobot target was originally developed as a training example for use in classes offered to Real-Time Workshop Embedded Coder users. In this release, the ECRobot target is available to all Real-Time Workshop Embedded Coder users as an example and demonstration.

The ECRobot target files are automatically installed with the Real-Time Workshop Embedded Coder. Source code files, control files, demonstration models, and documentation for the target are installed in the directory

```
matlabroot/toolbox/rtw/targets/ECRobot
```

Note The ECRobot target requires an operating system kernel, a cross-compiler and support utilities that are available on the Web. For instructions on how to obtain and install these utilities, see the file `readme.html` in the `ECRobot/documentation` directory.

Note that the ECRobot target uses a Windows-based cross-compiler and other utilities; it is therefore hosted on Windows 2000 or Windows XP. A UNIX configuration is not planned.

Programs generated by the ECRobot target run on the Command System (RCX™) module of the LEGO® MINDSTORMS™ Robotics Invention System 2.0™. This platform affords an inexpensive and simple way to study concepts and techniques essential to developing a custom embedded target, and to develop, run and observe generated programs.

The files included with the target illustrate typical approaches to problems encountered in custom target development, including:

- Interfacing a Real-Time Workshop Embedded Coder generated program to an external real-time operating system (RTOS) or kernel
- Implementing device drivers, via wrapper S-functions, for use in simulation and inlined code generation
- Customizing a system target file by adding code generation options and adding the target to the System Target File Browser
- Customizing a template makefile to use a target specific cross compiler and download generated code to the target hardware

External Mode Support

The Real-Time Workshop Embedded Coder now includes full support for all features of Simulink external mode. External mode lets you use your Simulink block diagram as a front end for a target program that runs on external hardware or in a separate process on your host computer. External mode allows you to tune parameters and view or log signals as the target program executes.

The **External mode** option is available via the **ERT code generation options (2)** category of the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box.

See the “External Mode” section of the Real-Time Workshop User’s Guide for further information.

GetSet Custom Storage Class for Data Store Memory

A new custom storage class, `GetSet`, has been added to provide acessor methods for memory associated with Data Store Memory blocks. This custom storage class is used in conjunction with Data Store Memory blocks. The purpose of the `GetSet` class is to generate code that reads (gets) and writes (sets) data via functions.

See the "Custom Storage Classes" section of the Real-Time Workshop Embedded Coder User's Guide for detailed documentation of the GetSet class.

Hierarchical Parameter Structures

The **Parameter structure** menu lets you control how parameter data is generated for reusable subsystems. (If you are not familiar with reusable subsystem code generation, see "Nonvirtual Subsystem Code Generation Options" in the Real-Time Workshop User's Guide for further information.)

The **Parameter structure** menu is available via the **ERT code generation options (3)** menu item of the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box.

The **Parameter structure** menu is enabled when the **Inline parameters** option is on. The menu lets you select the following options:

- `Hierarchical`: This option is the default. When the `Hierarchical` option is selected, the Real-Time Workshop Embedded Coder generates a separate header file, defining an independent parameter structure, for each subsystem that meets the following conditions:
  - The `Reusable function` option is selected in the subsystem's **RTW system code** pop-up menu, and the subsystem meets all conditions for generation of reusable subsystem code.
  - The subsystem does not access any parameters other than its own (such as parameters of the root-level model).

  When the `Hierarchical` option is selected, each generated subsystem parameter structure is referenced as a substructure of the root-level parameter data structure, which is therefore called a hierarchical data structure.

- `Non-hierarchical`: When this option is selected, the Real-Time Workshop Embedded Coder generates a single parameter data structure. This is a flat data structure; subsystem parameters are defined as fields within this structure.

Real-Time Model Structure Replaces Real-Time Object and Logging Object

The Real-Time Workshop Embedded Coder now encapsulates information about the root model in the *real-time model* data structure. We refer to the real-time model data structure as `rtM`.

`rtM` replaces the real-time object (`RT_OBJ`) and the logging object, which were used in previous releases. If your code accesses these objects through the macros provided with previous releases, it will continue to work.

See the "Data Structures and Code Modules" section of the Real-Time Workshop Embedded Coder User's Guide for further information.

Reusable Code Generation

The **Generate reusable code** option lets you generate reusable, reentrant code from a model or subsystem. When this option is selected, data structures such as block states, parameters, external outputs, etc. are passed in (by reference) as arguments to *`model`*`_step` and other generated model functions. These data structures are also exported via *`model`*`.h`.

In some cases, the Real-Time Workshop Embedded Coder may generate code that will compile but is not reentrant (although it may still be acceptable for your application). For example, if a signal or parameter has a storage class other than `Auto`, the generated code is not reentrant, because the code must access the global data directly. To handle such cases, the **Reusable code error diagnostic** menu is enabled when **Generate reusable code** is selected. This menu offers a choice of three severity levels for diagnostics to be displayed in such cases:

- `None`: build proceeds without displaying a diagnostic message
- `Warn`: build proceeds after displaying a warning message
- `Error`: build aborts after displaying an error message

In some cases, the Real-Time Workshop Embedded Coder is unable to generate valid and compilable code. For example, if the model contains any of the following, the code generated would be invalid:

- A Stateflow chart that outputs function-call events
- An S-Function that is not code-reuse compliant
- A subsystem triggered by a wide function call trigger

In these cases, the build will terminate after reporting the problem.

When **Generate reusable code** option is not selected (the default), model data structures are statically allocated and accessed directly in the model code. Therefore the model code is neither reusable nor reentrant.

Revised Packaging of Generated Code Files

The packaging of generated code into `.c` and `.h` files has changed. The following table summarizes the structure of source code generated by the Real-Time Workshop Embedded Coder. All code modules described are written to the build directory.

Note The file packaging of the Real-Time Workshop Embedded Coder differs slightly (but significantly) from the file packaging employed by the GRT, GRT malloc, and other non-embedded targets. See the Real-Time Workshop User's Guide for further information.

Real-Time Workshop Embedded Coder File Packaging

File	Description
model`.c`	Contains entry points for all code implementing the model algorithm (*model*`_step`, *model*`_initialize`, *model*`_terminate`, *model*`_SetEventsForThisBaseStep`).
model`_private.h`	Contains local defines and local data that are required by the model and subsystems. This file is included by the generated source files in the model. You do not need to include *model*`_private.h` when interfacing hand-written code to a model.

Real-Time Workshop Embedded Coder File Packaging (Continued)

File	Description
model.h	Defines model data structures and a public interface to the model entry points and data structures. Also provides an interface to the real-time model data structure (*model*_rtM) via accessor macros. *model*.h is included by subsystem .c files in the model. If you are interfacing your hand-written code to generated code for one or more models, you should include *model*.h for each model to which you want to interface.
*model*_data.c (conditional)	*model*_data.c is conditionally generated. It contains the declarations for the parameters data structure and the constant block I/O data structure. If these data structures are not used in the model, *model*_data.c is not generated. Note that these structures are declared extern in *model*.h.
*model*_types.h	Provides forward declarations for the real-time model data structure and the parameters data structure. These may be needed by function declarations of reusable functions. *model*_types.h is included by all the generated header files in the model.
ert_main.c (optional)	This file is generated only if the **Generate an example main program** option is on. (This option is on by default). See "Auto-Generated Main Program" on page 5-2.
autobuild.h (optional)	This file is generated only if the **Generate code only** and **Generate an example main program** options are off. See "Auto-Generated Main Program" on page 5-2. autobuild.h contains #include directives required by the static version of the ert_main.c main program module. Since the static ert_main.c is not created at code generation time, it includes autobuild.h to access model-specific data structures and entry points.

Real-Time Workshop Embedded Coder File Packaging (Continued)

File	Description
`model_pt.c` (optional)	Provides data structures that enable a running program to access model parameters without use of external mode. To learn how to generate and use the `model_pt.c` file, see "C API for Parameter Tuning" in the Real-Time Workshop documentation.
`model_bio.c` (optional)	Provides data structures that enable your code to access block outputs. To learn how to generate and use the `model_bio.c` file, see "Signal Monitoring via Block Outputs" in the Real-Time Workshop documentation.

If you have interfaced hand-written code to code generated by previous releases of the Real-Time Workshop Embedded Coder, you may need to remove dependencies on header files that are no longer generated. Use `#include` *`model`*`.h` directives, and remove `#include` directives referencing any of the following:

- *`model`*`_common.h` (replaced by *`model`*`_types.h` and *`model`*`_private.h`)
- *`model`*`_export.h` (replaced by *`model`*`.h`)
- *`model`*`_prm.h` (replaced by *`model`*`_data.c`)
- *`model`*`_reg.h` (subsumed by *`model`*`_.c`)

See also "Code Modules" in the Real-Time Workshop Embedded Coder documentation.

Template Makefile for Tornado

We have provided a simplified version of the Tornado target template makefile support deployment of Real-Time Workshop Embedded Coder code on the VxWorks operating system. See *`matlabroot`*`/rtw/c/ert/ert_tornado.tmf` for details.

Major Bug Fixes

Fixed Incorrect Effects of Expression Folding for Action Subsystems

With expression folding enabled, models containing action subsystems (such as For Iterator Subsystems or While Iterator Subsystems) could generate invalid or inefficient code. This problem has been fixed.

Removed License Restriction on Loading Objects with Custom Storage Classes

In Release 12, the Real-Time Workshop Embedded Coder license was checked when loading Simulink data objects that contained custom storage classes. This license dependency has been removed; the license is now checked only when you generate code with data containing custom storage classes.

If you have created your own subclasses of Simulink data objects that contain custom storage classes, you should reload your classes into theSimulink Data Class Designer and regenerate them to remove the license dependency.

Upgrading from an Earlier Release

This section describes the upgrade issues involved in moving from the Real-Time Workshop Embedded Coder 2.0 to Version 3.0.

Changes to Main Program Module (ert_main.c)

In this release, the Real-Time Workshop Embedded Coder generates a model-specific example main program module by default. For backwards compatibility, we continue to provide a static (nongenerated) version of `ert_main.c`.

To use the static version of `ert_main.c` , (or continue using a previously customized version), note that certain modifications to `ert_main.c` may be required. See "Modifying the Static Main Program Module" on page 5-3 for modification guidelines.

HTML Code Generation Report Changes

In prior releases, the **Generate HTML report** option was available only for the Real-Time Workshop Embedded Coder. In the current release, a limited report is available for all targets (except the S-Function target and the Rapid Simulation target), while the Real-Time Workshop Embedded Coder continues to generate a more extensive report.

The **Generate HTML report** option is now located in the **General code generation options** category of the **Real-Time Workshop** pane of the **Simulation Parameters** dialog box. The option is on by default.

See "Generating a Code Generation Report" in the Real-Time Workshop Embedded Coder User's Guide for further information.

Include Model Name in Exported Structures Option Superseded

The **Include model name in exported structures** option has been superseded by the more general **Prefix model name to global identifiers** option. When this option is on, the Real-Time Workshop prefixes subsystem function names with the name of the model (*`model_`*). In addition, the model name is prefixed to the names of functions and data structures at the model level. This is useful in cases where you want to compile and link code from two or more models into a single executable, without name clashes.

Prefix model name to global identifiers is on by default. The option is located in the **General code appearance options** category of the Real-Time Workshop pane of the **Simulation Parameters** dialog box.

Replace Obsolete Header File #includes

Generated code is packaged into different files in this release (see "Revised Packaging of Generated Code Files" on page 5-10). If you have interfaced your hand-written code to code generated by previous releases of Real-Time Workshop Embedded Coder, you may need to remove dependencies on header files that are no longer generated.

Use `#include` *`model`*`.h` directives, and remove `#include` directives referencing any of the following:

- *`model`*`_common.h`
- *`model`*`_export.h`
- *`model`*`_prm.h`
- *`model`*`_reg.h`

Update Your Custom System Target Files

The Real-Time Workshop Embedded Coder template makefile, `ert.tmf`, now contains additional identifiers that were not defined in release 12.1 or earlier releases. If you are using an older system target file (such as a custom target file based on an earlier version of `ert.tlc`) with the new `ert.tmf` file, you should update the system target file to make sure that no make options are missing.

All missing makefile options are reported on the MATLAB window during the build process, so that you can easily update your custom system target files.

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Real-Time Workshop Embedded Coder 2.0 Release Notes

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Release Summary

Release 2.0 of the Real-Time Workshop Embedded Coder is a major upgrade, incorporating

- Significant improvements in efficiency and readability of generated code.

  Many improvements in Real-Time Workshop code generation technology are especially applicable to embedded systems development. These include expression folding and buffer optimizations. For further information on these features, see the Real-Time Workshop 4.1 Release Notes.
- Custom storage classes for signal, state, and parameter objects, for embedded systems development
- Additional and enhanced code generation options
- Improved HTML code generation report

New Features

This section introduces the new features and enhancements added in the Real-Time Workshop Embedded Coder 2.0, since the Real-Time Workshop Embedded Coder 1.0.

Custom Storage Classes for Data Objects

The Real-Time Workshop Embedded Coder 2.0 implements a number of predefined custom storage classes that are useful in embedded systems development. These classes extend the built-in storage classes provided by the Real-Time Workshop. The built-in classes provide limited control over the form of the code generated for references signals, parameters, and other types of data. These storage classes are suitable for a simulation or rapid prototyping environment, but embedded system designers often require greater control over the representation of data.

Using Real-Time Workshop Embedded Coder custom storage classes, you can define and generate constructs such as bit fields or structs from your model, and easily interface data structures to externally written code.

See "Custom Storage Classes" in the Real-Time Workshop Embedded Coder User's Guide for further information.

Note To create Simulink data objects with custom storage classes from M-code, you must have a Real-Time Workshop Embedded Coder license. To share data objects of this type with users who do not have the required license, save the objects in a MAT-file, which the users can load into the MATLAB workspace.

Enhanced Code Generation Options

Initialize Floats and Doubles to 0.0

This option lets you control how internal storage for floats and doubles is initialized. You can initialize floats and doubles to the integer bit pattern `0` (all bits off) or set float and double storage explicitly to the value `0.0`.

See “Initialize Floats and Doubles to 0.0” in the Real-Time Workshop Embedded Coder User’s Guide for further information.

MAT-File Logging Off by Default

In prior releases, the **MAT-file logging** option was on by default. In Real-Time Workshop Embedded Coder 2.0, the **MAT-file logging** option is off by default. We recommend this setting because it eliminates the extra code and memory usage required to maintain logging variables.

Virtualized Output Ports Optimization

The virtualized output ports optimization lets you eliminate code and data storage associated with root output ports under certain conditions.

See “Virtualized Output Ports Optimization” in the Real-Time Workshop Embedded Coder User’s Guide for further information.

Improved HTML Code Generation Report

The format of the Real-Time Workshop Embedded Coder code generation report has been enhanced for readability. The “Optimizations” section lists additional options that will better optimize your code. Links from the report to the online Real-Time Workshop Embedded Coder documentation have been expanded.

See “Generating a Code Generation Report” in the Real-Time Workshop Embedded Coder User’s Guide for further information.