8051 RTOS

GU0102 (v1.2) January 20, 2004

Table of Contents

Manual Purpose and Structure

Manual Purpose

This manual aims to provide you with the necessary information to build real−time applications using the RTOS (Real Time Operating System) micro kernel delivered with the toolchain.

After reading the document, you should:

- know how to build real−time RTOS applications using.
- understand the benefits of using the RTOS.
- be able to customize the RTOS to your project needs.
- be familiar with the most relevant RTOS concepts.
- know how to debug RTOS applications.

This manual assumes that you have already read the User's Manual of the toolchain documentation. The manual leads you through the hottest topics of configuring and building RTOS applications, overview of the functionality, design hints, debugging facilities and performance.

This manual expects you to have gone through the main topics of the online OSEK/VDX standard documents. These documents should be, in fact, a constant reference during the reading of this manual.

Short Table of Contents

Chapter 9: Interrupts

Describes how you can declare ISR objects in the application OIL file in order to optimize the interrupt configuration

Chapter 10: Interprocess Communication

Describes why the communication services offer you a robust and reliable way of data exchange between tasks and/or interrupt service routines and how you can declare MESSAGE and COM objects in the application OIL file.

Chapter 11: Error Handling

Helps you to understand the available debug facilities and error checking posibilities. Describes which services and mechanisms are available to handle errors in the system and how you can interfere with them by means of customizing certain Hook Routines.

Chapter 12: Debugging an RTOS Application

Explains how you can easily debug RTOS information with the Cross View Debugger and describes in detail all the information that you can obtain.

Appendix A: Implementation Parameters

The implementation parameters provide detailed information concerning the functionality, performance and memory demand. From the implementation parameters you can obtain valuable information about the impact of the RTOS on your application.

Appendix B: Stack Overflow

Describes how you can avoid problems caused by stack overflow.

1 Introduction to the RTOS kernel

Summary

This chapter provides an introduction to the RTOS real−time multitasking kernel. It discusses the choice of making the RTOS compliant with the OSEK standard. Additionally, this chapter provides a high−level introduction to real−time concepts.

1.1 Real−time Applications

A real−time system is used when there are rigid time requirements on the operations of a processor to perform certain tasks. There are two flavors of real−time systems. A *hard real−time* system must guarantee that critical tasks complete on time. Processing must be done within the defined constraints or the system will fail. A *soft real−time* system is less restrictive; a critical task gets priority over other tasks and retains that priority until a point of rescheduling. In a soft real−time system, failure to produce the correct response at the correct time is also undesirable but not fatal.

In reality most applications consist of tasks with both hard and soft real−time constraints. If these tasks are single purposed they could be implemented as semi−independent program segments. Still the programmer needs to embed the processor allocation logic inside the application tasks. Implementations of this kind typically take the form of a control loop that continually checks for tasks to execute. Such techniques suffer from numerous problems and represent no solutions for regular applications. Besides they complicate the maintenance and reusability of the software.

An RTOS (Real Time Operating System) is a dedicated operating system fully compromised to overcome the time constraints of a real−time system. An RTOS provides, like any other operating system, an environment in which a user can execute programs in a convenient and structured manner but at no risk of failing with the real−time constraints. The benefits of using an RTOS are:

- An RTOS eliminates the need for processor allocation in the application software.
- Modifications, and even additions of completely new tasks can be made in the application software without affecting critical system response requirements.
- Besides managing task execution most real−time operating systems also provide facilities that include task communication, task synchronization, timers, memory management etc.
- An RTOS hides the underlying hardware specific concerns to the user offering a runtime environment that is completely independent of the target processor.
- Easy migration to other targets (provided that the RTOS vendor offers support for these other processor families).

1.2 What is OSEK/VDX

In May 1993 OSEK was founded as a joint project in the German automotive industry aiming at an industry standard for an open−ended architecture for distributed control units in vehicles. OSEK is an abbreviation for the German term ”Offene Systeme und deren Schnittstellen für die Elektronik im Kraftfahrzeug” (”Open Systems and the Corresponding Interfaces for Automotive Electronics”). Meanwhile in France, PSA and Renault were developing a similar system called VDX, or “Vehicle Distributed eXecutive”. The two projects merged in 1994, and a year later OSEK/VDX was presented.

Although the OSEK/VDX standards were originally developed for the automotive industry, the resulting specifications describe a small, real−time OS ideal for most embedded systems that are statically defined, i.e. with no dynamic (run−time) allocation of memory.

The OSEK/VDX specification consists of five normative documents:

- OS − operating system
- COM − communication
- NM − network monitoring (not discussed in this manual)
- OIL − osek implementation language
- ORTI − osek/vdx real−time interface

An *OSEK/VDX implementation* refers to a particular implementation of one or more of the standards. These standards tend to define the minimum requirements for a compliant system but individual implementations can vary because of different processor requirements and/or capabilities.

An *OSEK/VDX application* refers to an application that was developed using a particular OSEK/VDX implementation.

OSEK/VDX operating system (OS)

The specification of the OSEK/VDX OS covers a pool of services and processing mechanisms. The operating system controls the real−time execution in concurrent executing applications and provides you with a dedicated programming environment. The architecture of the OSEK/VDX OS distinguishes three processing levels: an interrupt level, a logical level for operating system activities and a task level. The interrupt level is assigned higher priorities than the task level.

In addition to the management of the processing levels, the operating system offers also *system services* to manage tasks, events, resources, counters, alarms, and to handle errors. You can consider system services as library functions in C.

The OSEK/VDX standards do not explicitly cover I/O.

OSEK/VDX communication (COM)

The communication specification provides interfaces for the transfer of data within vehicle networks systems. This communication takes place between and within network stations (CPUs). This specification defines an interaction layer and requirements to the underlying network layer and/or data link layer. The interaction layer provides the *application programming interface* (API) of OSEK/VDX COM to support the transfer of messages within and between network stations. For network communication, the interaction layer uses services provided by the lower layers. CPU−internal communication is handled by the interaction layer only.

OSEK/VDX Implementation Language (OIL)

To reach the original goal of the OSEK/VDX project in having portable software, a way of describing an OSEK/VDX system is defined. This is the motivation for the definition of a standardised *OSEK/VDX Implementation Language*, abbreviated OIL.

OSEK/VDX Run Time Interface (ORTI)

To provide debugging support on the level of OSEK objects, it is necessary to have debuggers that are capable of displaying and debugging OSEK components. The ORTI specification provides an interface for debugging and monitoring tools to access OSEK objects in target memory. Tools can evaluate internal data structures of OSEK objects and their location in memory. ORTI consists of a language to describe kernel objects (KOIL: *Kernel Object Interface Language*) and a description of OSEK specific objects and attributes.

1.3 The OSEK/VDX Documentation

Information about the OSEK/VDX organization (including all the standards) is available online at www.osek−vdx.org.

Currently the Altium RTOS is implemented to follow:

- Operating System (OS) Version 2.2.1
- Communication (COM) Version 3.0.1
- OSEK Implementation Language (OIL) Version 2.4.1
- OSEK/VDX Run Time Interface (ORTI) Version 2.1

1.4 The Altium RTOS

The Altium RTOS is a real−time, preemptive, multitasking kernel, designed for time−critical embedded applications and is developed by Altium.

The future plans of Altium (in parallel to OSEK plans) aim to certify the Altium RTOS according to the Specification Binding SB5 following the certification plans in the Certification Binding CB5 of the OSEK industry standard.

In the first release of the RTOS only a subset (internal communication) of COM3.0 is supported. This subset of standards is included as online documentation. The standards are copyright protected.

The RTOS is written in ANSI C and assembly and delivered as source code.

For every RTOS application the RTOS source code is compiled (after some mandatory configurational input from the application developer) to generate a customized RTOS library. The RTOS image is actually this generated library. The application source code must be linked with this RTOS library in order to build the final application object.

1.5 Why Using the Altium RTOS?

The benefits of using the RTOS to build embedded applications (a natural consequence of its future conformance with OSEK/VDX products) are listed below:

- High degree of modularity and ability for flexible configurations.
- Focusing on the time−critical aspects, the dynamic generation of system objects is left out. Instead, generation of system objects is done in the system *generation* phase. The user statically specifies the number of tasks, resources, and services required statically.
- Error inquiries within the operating system are obviated to a large extent in order to not affect the speed of the overall system unnecessarily. A system version with extended error inquiries has been defined. It is intended for the test phase and/or for less time−critical applications
- The interface between the application software and the operating system is defined by system services (in an ISO/ANSI−C−like syntax) with well defined functionality. The interface is identical for all implementations of the operating system on various processor families.
- For better portability of application software, the OSEK standard defines a language for a standardised configuration information. This language ”OIL” (OSEK Implementation Language) supports a portable description of all OSEK specific objects such as ”tasks” and ”alarms”.

Ideal applications are compact, real−time system that fit within minimum resources (8 to 512 kB of ROM and 1 to 32 kB of RAM).

2 Getting Started

Summary

This chapter gives an overview of the files (and their interrelations) involved in an RTOS application and includes a self explanatory diagram of the development process as a whole. It also guides you through the process of building your very first RTOS application.

2.1 What is an RTOS Project?

This chapter first discusses in detail the files that are involved in an RTOS project. In the remaining sections an example project is created.

The basic ideas of an RTOS project are listed below:

1. An RTOS project is a “normal” DXP project where you must add a file written in the OSEK Implementation Language (OIL) to the project members. This file has the extension `.oil` and contains the specific details of the system configuration. We refer to it as the *application OIL file*.

See Chapter 3, *OIL Language*

2. One and only one of the project members can have the extension `.oil`. The application OIL file first includes a target specific *implementation OIL file* (`#include <osek/osek.oil>`) which is delivered with the product, followed by a user defined part with all details for the configuration of your RTOS application.
3. By adding an OIL file to the list of project members, an extra project dependency is created in the project makefile. The makefile now contains the rules to generate a special RTOS library from the OIL file.

In fact, the makefile calls the *Tasking OIL Compiler* (TOC) which preprocesses the application OIL file. The TOC compiler outputs a number of configurational files, written in C source code. These files are used to build a dedicated RTOS library with the same name as the `.oil` file. This library is then built together with the rest of the application. The compiler and assembly options of the project prevail while building the RTOS library (only some compiler optimizations may change).

The RTOS library is only rebuilt upon changes in the OIL file since it constitutes its only dependency. Changes in the application software will not affect the RTOS library.

4. In your application source code files you must include the OSEK/VDX standard OS and COM interfaces (`osek.h`) to compile.

When you use the Notification Flag mechanism, you must also include the file `flag.h` in your application source code files.

5. The RTOS system services used in the application software are extracted from the RTOS library during the linking phase.

The following table lists the files involved in an RTOS project:

Extension	Description
Application source files	
*.c / *.h / *.asm	C source files, header include files and optional hand coded assembly files are used to write the application code. These files must be members of your (DXP) project and are used to build application objects.
mytypes.h	You need to write `mytypes.h` when using messages with non basic CDATATYPE attributes.
The application OIL file and the configurational files	
user.oil	You must write exactly one *application OIL file* to configure the RTOS library. It is the only `.oil` member of the project and contains the input for the Tasking OIL Compiler (TOC).
g_conf.c g_conf.h g_conf_types.h g_isrframe.c flag.h orti.txt	These configurational files are intermediate files (ANSI C) generated by the TOC compiler after processing the OIL file. The files *g_** are compiled together with the RTOS source files to build the RTOS library of the project. The file '*flag.h*' is an extra interface for the application software. The file '*orti.txt*' is the runtime debug interface. They are rebuilt when you change your OIL file.
RTOS source files	
c_*.c c_*.h t_*.c t_*.h	The source code files of the RTOS are located in `$(PRODDIR)/c51/osek/` They are used by all the RTOS projects to build their RTOS libraries. They should never be removed or modified.
osek.h	The RTOS application interface `osek.h` is located in `$(PRODDIR)/c51/include/osek` and constitutes the only interface for your code as an RTOS user.
Implementation OIL file	
osek.oil	The *implementation OIL file*, which is located in `$(PRODDIR)/c51/include/osek`, must be included from the OIL files of all RTOS applications. It imposes how and what can be configured in this current RTOS release. It should never be removed or modified.

Table 2–1: Project files

The next figure shows the relation between the files in an RTOS project and the development process.

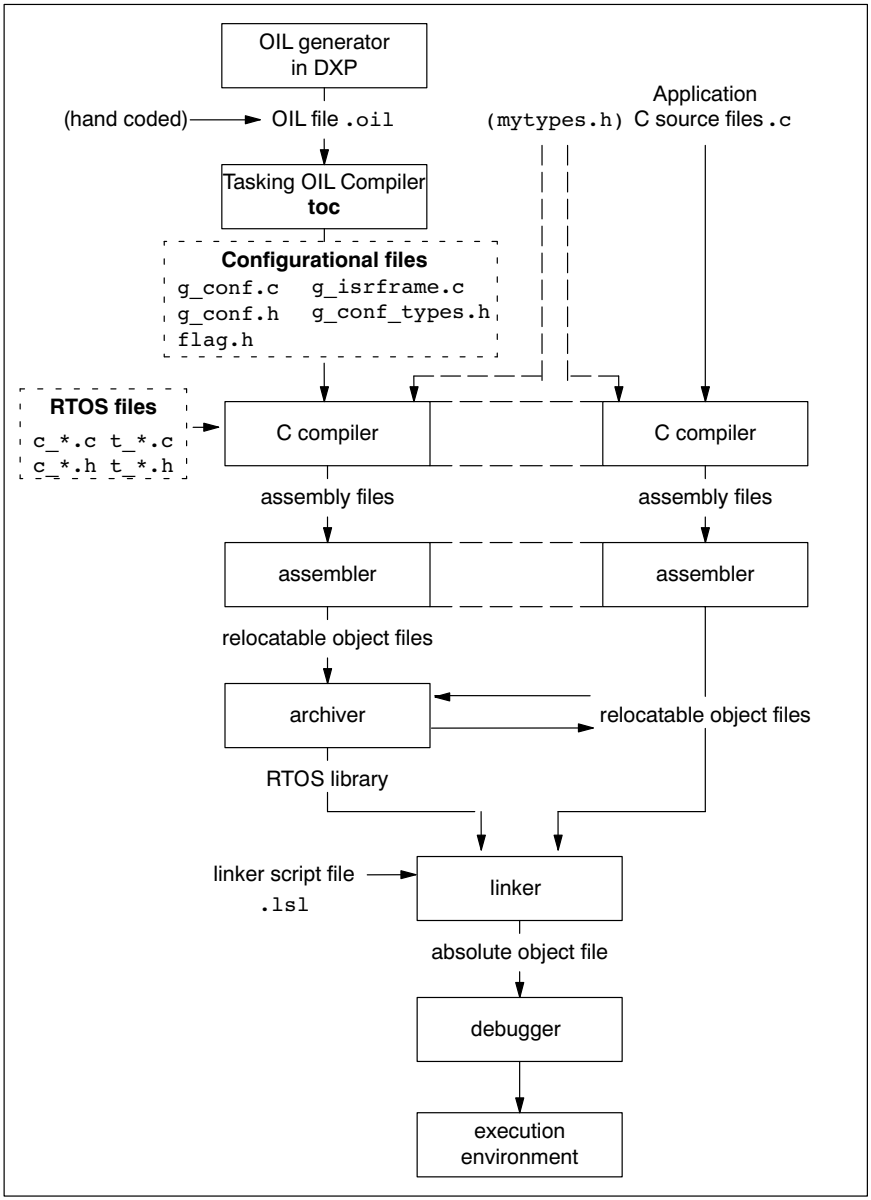


Figure 2-1: Development process

2.2 The Design Environment ”DXP”

Design Environment

DXP is a Windows application that facilitates working with the tools in the toolchain and also offers project management and an integrated editor.

DXP has three main functions: *Edit / Project management*, *Build* and *Debug*. The figure below shows how these main functionalities relate to each other and how the RTOS system is integrated.

With DXP you can write, compile, assemble, link, locate and finally debug RTOS applications.

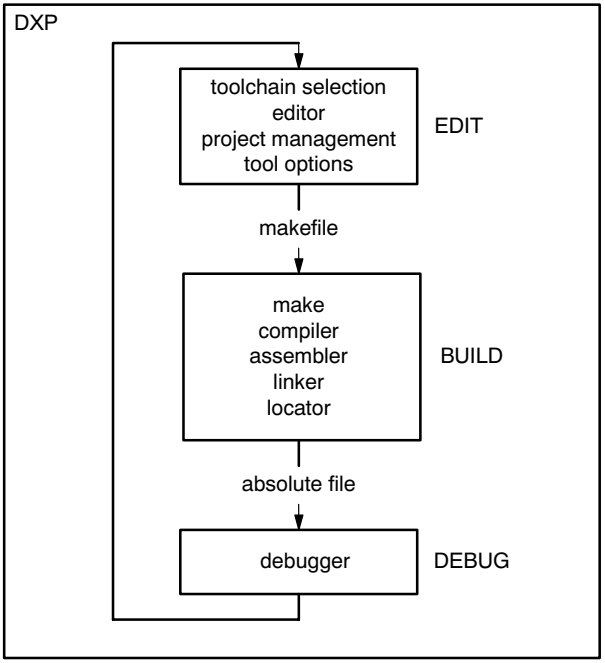


Figure 2–2: Altium RTOS integrated in DXP

In the **Edit** part you make all your changes:

- Create and maintain a project and add a file *user*.oil to it
- Edit the source files in a project
- Edit the *user*.oil file
- Set the options for each tool in the toolchain

In the **Build** part you build your files:

- A makefile (created by the Edit part) is used to invoke the needed toolchain components, resulting in an absolute object file. The makefile rebuilds the RTOS library if the OIL file has changed.

In the **Debug** part you can debug your project:

- Call the TASKING debugger with the generated absolute object file. The debugger uses a special ORTI file (OSEK Run−time Interface) to retrieve information. This file is automatically generated by the TOC compiler

This next sections will guide you step−by−step through the most important steps of building a simple RTOS application.

2.3 Create a new Project Space for the MYRTOS Project

Before you create your own RTOS application you need to create an embedded software project.

Create a new embedded software project

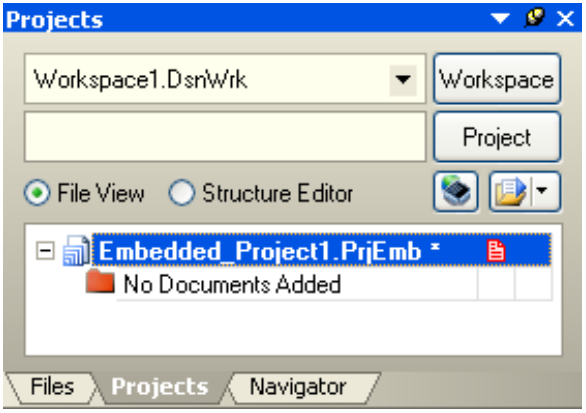
1. Start DXP.

   *DXP opens. Look for the **Pick a task** section on your screen.*

2. From the **Pick a task** section, select **Embedded Software Development**.

3. Click on **New Blank Embedded Software Project**

*The **Projects** panel opens. The new project file "Embedded Project1.PrjEmb" is shown. No documents are added to the project yet.*



Now save your project. You are free to choose a name and a location for the project but you can also follow this example:

4. From the **File** menu, select **Save Project As...**

   The Save [Embedded Project1.PrjEmb] As... dialog appears.

   - In this dialog, browse to the folder `.../Altium2004/Examples/Embedded`.
   - Create a new folder with the name `firstrtos`.
   - Browse to this folder.
   - Enter the file name for your project: `myrtos.PrjEmb` and make sure it is saved as type `Embedded Software Project (*.PrjEmb)`.

5. Click on the **Save** button.

Add new files to the project

Now you can add files you want to be part of your project. You can either add existing files, or create and add new files. In this example, two new files are needed: `main.c` and `myrtos.oil`:

6. In the **Projects** panel, right–click on your project `myrtos.PrjEmb` and select **Add New to Project** » **C File**.

   A new empty file with the name Source1.C is added to your project and opened.

7. From the **File** menu, select **Save As...**

   The Save [Source1.C] As... dialog appears. Save your file as main.c.
   Repeat steps 6 and 7 for the file 'myrtos.oil'. Add this file as type 'text document'.

   The new project is now ready to be edited.

   DXP automatically creates a *makefile* for the project (in this case `myrtos.mak`.). This file contains the rules to build your application. DXP updates the makefile every time you modify your project settings.

Note that because DXP detected the presence of an `.oil` file, the makefile contains rules to generate also the RTOS library from the file `myrtos.oil`. You can check this for yourself by opening the file `myrtos.mak`.

2.4 Edit the Application Files

In order to get a working rtos project, you must edit `main.c` and `myrtos.oil`. It is not necessary to pay attention to the exact contents of the files at this moment.

Edit the user source code

1. As an example, type the following C source in the `main.c` document window:

```
#include <osek/osek.h>

DeclareTask(task0);
DeclareTask(task1);
DeclareTask(task2);
DeclareEvent(E1);
DeclareEvent(E2);
DeclareAppMode(AP1);

int main(int argc)
{
    (void)argc;
    StartOS(AP1);
    return 1;
}

TASK (task0)
{
    EventMaskType event;
    ActivateTask(task1);
    while(1)
    {
        WaitEvent(E1 | E2);
        GetEvent(task0,&event);
        if (event & E1)
        {
            ActivateTask(task2);
        }
        else if (event & E2)
        {
            ActivateTask(task1);
        }
        ClearEvent(E1 | E2);
    }
}
```

```
TASK (task1)
{
    SetEvent(task0,E1);
    TerminateTask();
}

TASK (task2)
{
    SetEvent(task0,E2);
    TerminateTask();
}
```

2. Click on the **Save Active Document <Ctrl+S>** button to save this file.

Edit the user OIL file

1. Edit the `myrtos.oil` file with the following text:

```
#include <osek/osek.oil>

CPU myRTOS
{
    OS StdOS
    {
        STATUS              = EXTENDED;
        STARTUPHOOK         = FALSE;
        ERRORHOOK           = FALSE;
        SHUTDOWNHOOK        = FALSE;
        PRETASKHOOK         = FALSE;
        POSTTASKHOOK        = FALSE;
        USEGETSERVICEID     = FALSE;
        USEPARAMETERACCESS  = FALSE;
        USERESSCHEDULER     = FALSE;
        CORE                = TSK51A;
        USERTOSTIMER        = FALSE;
    };

    EVENT E1;
    EVENT E2;
    APPMODE AP1;
```

```
    TASK task0
    {
        PRIORITY   = 5;
        SCHEDULE   = FULL;
        ACTIVATION = 1;
        AUTOSTART  = TRUE {APPMODE=AP1;};
        EVENT      = E1;
        EVENT      = E2;
    };

    TASK task1
    {
        PRIORITY   = 5;
        SCHEDULE   = FULL;
        ACTIVATION = 1;
        AUTOSTART  = FALSE;
    };

    TASK task2
    {   PRIORITY   = 5;
        SCHEDULE   = FULL;
        ACTIVATION = 1;
        AUTOSTART  = FALSE;
    };
};
```

2. Click on the **Save Active Document <Ctrl+S>** button to save this file.

2.5 Build Your Application

If you have modified and saved the project files, you can actually build your first RTOS application. This results in an absolute object file which is ready to be debugged. You can build this project with default project options.

Build your Application

To build the currently active project:

- Right–click on your project `myrtos.PrjEmb` and select **Compile Embedded Project myrtos.PrjEmb**.

  The OIL file is compiled and the RTOS library is built. All files together are compiled, assembled, linked and located. The resulting file is `myrtos.abs`.

After you application has been built, you can check the following for yourself:

- in your project folder, a dedicated folder with the name `myrtos.rtos` has been created
- the TOC tool has placed the generational files `g_conf.c`, `g_isrframe.c`, `g_conf_types.h` and `g_conf.h` in this directory
- the TOC tool has placed the generational files `orti.txt` and `flag.h` in the project folder
- a library `osek.lib` has been created in the folder `myrtos.rtos` and it has been copied to your project folder with the name `myrtos.lib`.

You can compare the contents of this directory to the files shown in figure 2–1.

2.6 Debug Your Application

The application `myrtos.abs` is the final result, ready for execution and/or debugging. Since the RTOS environmennt supports ORTI files, you can easily gain access to RTOS information during the simulation of your application.

Make sure that `main.c` is the active file.

1. From the **Debug** menu, select **Simulate**
2. From the **View** menu, select **Workspace Panels** » **Embedded** » **RTOS**

   The RTOS panel opens. In this panel you can easily obtain RTOS information.

3. From the **Debug** menu, select **RTOS** » **System Status** (repeat this step for **Tasks** and/or **Resources**)

3 The OSEK/VDX Implementation Language (OIL)

Summary

This chapter describes how you can configure your application with a file written in OIL (Osek Implementation Language) language (which needs to be added to the project as a project member). The chapter ends with a working example of an OIL file.

3.1 Why an OIL Language

Purpose of the OIL language

The OSEK/VDX Implementation Language (OIL) language is used to configure the RTOS library. An OIL configuration file contains the definition of the application. The usage of OIL to configure OSEK/VDX systems enhances the portability of RTOS applications among different target processors.

Hand-coded or generated

Depending on the OSEK/VDX implementation you must either write the OIL file manually or you can use a graphical user interface which helps you create the OIL file.

3.2 What are the OIL System Objects?

Every version of OIL language defines syntactically and semantically a set of *OIL system objects.* These objects are defined in the OSEK standard. One of the system objects is CPU. This serves as a container for all other objects. Objects are defined by their attributes.

Refer to http://www.osek-vdx.org/mirror/oil241.pdf for detailed information.

3.2.1 Standard and Non-Standard Attributes

Every OIL system object has attributes that can hold values. According to the OIL standard, each object has at least a minimum mandatory set of attributes, called the *standard attributes*. Besides the standard attributes, an OSEK/VDX implementation may define additional attributes (*non-standard attributes*) for any OIL system object.

To configure a system for an specific OSEK/VDX implementation you need to instantiate and/or define OIL objects and assign values to their attributes.

An OSEK/VDX implementation can limit the given set of values for object attributes.

Since the *non–standard* attributes are OSEK/VDX implementation specific they are not portable. However, there are two reasons to justify non–standard attributes:

- they can address platform specific features
- they can provide extra configuration possibilities for a certain target

3.2.2 Overview of System Objects and Attributes

The next table shows the list of system objects with their standard attributes as defined by OIL2.4.1 and the non–standard attributes for the 8051. The non–standard attributes are marked italic.

Because the Altium RTOS supports only internal communication, the IPDU object and some standard attributes of other objects are not included in the list.

In addition to the attributes listed in the table below, there are a number of non–standard attributes which are not included in this table. These extra attributes all start with the keyword WITH_AUTO and take AUTO as their default value (you can search for them in the file `osek.oil`). This subset of attributes can be considered as internals of the implementation and are not user configurable. Instead, the TOC tool initializes them.

OIL system object	**Description**	**Standard Attributes** ***Non Standard Attributes***
CPU	The CPU on which the application runs under the RTOS control. Container of all the other objects.	
OS	The OS that runs on the CPU. All system objects are controlled by OS.	STATUS STARTUPHOOK ERRORHOOK SHUTDOWNHOOK PRETASKHOOK POSTTASKHOOK USEGETSERVICEID USEPARAMETERACCESS USERESSCHEDULER *CORE* *EXTDATASIZE* *LONGMSG* *MAXNESTEDISR* *MULTISTART* *SMAINSTACK* *STACKMONITOR* *USERTOSTIMER* *VISRSTACK*
APPMODE	Defines different modes of operation for the application.	

OIL system object	**Description**	**Standard Attributes** ***Non Standard Attributes***
ISR	Interrupt service routines supported by OS.	CATEGORY RESOURCE [ ] MESSAGE [ ] *ENBIT* *LEVEL*
RESOURCE	The resource that can be occupied by a task.	RESOURCEPROPERTY
TASK	The task handled by the OS.	PRIORITY SCHEDULE ACTIVATION AUTOSTART RESOURCE [ ] EVENT [ ] MESSAGE [ ] *SSTACK* *VSTACK*
COUNTER	The counter represents hardware/software tick source for alarms.	MAXALLOWEDVALUE TICKSPERBASE MINCYCLE
EVENT	The event on which tasks may react.	MASK
ALARM	The alarm is based on a counter and can either activate a task or set an event or activate an alarm−callback routine.	COUNTER ACTION AUTOSTART
MESSAGE	The message is defined in OSEK COM and defines a mechanism for data exchange between different entities (tasks or ISRs)	MESSAGEPROPERTY NOTIFICATION
COM	The communication subsystem. The COM object has standard attributes to define general properties for the interaction layer.	COMERRORHOOK COMERRORGETSERVICEID COMUSEPARAMETERACCESS COMSTARTCOMEXTENSION COMAPPMODE [ ] COMSTATUS
NM	The network management subsystem.	

Table 3−1: OIL objects and their standard and non−standard attributes

3.2.3 Non–Standard Attributes for the 8051

This section describes the non–standard attributes, which are specific for the 8051.

Please refer to the OSEK/VDX OIL documentation for the semantics of all standard attributes.

OS object

CORE

The CORE attribute specifies the Processor Definition of the project. The type of this attribute is ENUM and has one of the following values:

TSK51A, TSK52A, TSK52B

The default value is TSK51A.

EXTDATASIZE

The EXTDATASIZE attribute indicates the maximum size (in bytes) of the extended data section. The extended data section resides in the internal data area and it is used for extra register allocation. You define the maximum size of this area with the compiler option **–x** (default is 4 bytes). Since this area is shared by all tasks, the RTOS needs to save/restore it during context switch (it is part of the context of the task). The type of this attribute us UINT32 and the default value is 4 bytes.

You need to update this attribute everytime you change the option **–x** of the compiler.

LONGMSG

The LONGMSG boolean attribute determines whether Category 2 ISRS are suspended during the copy of messages from the RTOS buffers to the application or vise versa. If set to TRUE, the RTOS expects long messages, so the interrupts will not be suspended. This is at the costs of extra handling. The default value is FALSE.

See section 5.4, *The Priority of a Task*, in Chapter *Task Management*.

MULTISTART

The MULTISTART boolean attribute specifies whether the system is allowed to start the RTOS more than once (undergoing application resets via the usage of `ShutdownOS()`). It has a default value of TRUE.

See section 4.5, *The Shut–Down Process* in chapter Startup Process.

MAXNESTEDISR

The MAXNESTEDISR attribute specifies the maximum number of nested ISRs. The type of this attribute is UINT32 and the possible values range from 1 to 8. The default value is 2.

SMAINSTACK

The SMAINSTACK attribute specifies the maximum usage (in bytes) of the system stack before the application starts the RTOS with the system service *StartOS*. The RTOS allocates a dedicated buffer to save these bytes. You can easily find the best value by comparing the value of the system stack pointer after `main` and before the call to *StartOS*.
The type of this attribute is UINT32. It has no default value.

STACKMONITOR

With the STACKMONITOR attribute you can request the RTOS to monitor continuously possible stack overflows for you. Although expensive in run–time performance, the RTOS will inform you as soon as possible with the precise cause of the stack overflow. The default value is FALSE.

See Appendix B, *Stack Overflow*, for an extensive description of this attribute.

USERTOSTIMER

The USERTOSTIMER is a parametrized boolean attribute which determines whether ALARM OIL objects based on the system counter have been configured in the system.

If set to TRUE, the RTOS provides the interrupt framework for the timer unit and the application provides its initialization. In this case, you must set the parameter RTOSTIMERLEVEL with the entry of the timer unit in the Interrupt Vector Table. The type of RTOSTIMERLEVEL is UINT32. It has no default value.

The default value for USERTOSTIMER is FALSE.

VISRSTACK

The RTOS allocates a dedicated buffer for the run–time virtual stacks of the interrupts. The VISRSTACK attribute specifies the size of this buffer (in bytes). You should consider the worst case scenario (maximum nested number) and the RTOS contribution (see Appendix A, *Implementation Parameters*).
The type of this attribute is UINT32. The default value is 100 bytes.

ISR object

ENBIT

The ENBIT attribute specifies the SFR register bit that enables/disables the ISR. The type of this attribute is STRING. It has no default value.

Check the `.sfr` files in `$(PRODDIR)/c51/include` to find the appropiate `.sfr` file name.

LEVEL

The LEVEL attrribute specifies the entry in the Vector Interrupt Table.
The RTOS source code uses this value as argument for the `__interrupt` function qualifier. The type of this attribute is UINT32. It has no default value.

TASK object

SSTACK

The SSTACK attribute specifies the contribution of the task to the system stack (in bytes). The type of this attribute is UINT32. The default value is 30.


Section 5.7.2, *The System Stack*, in Chapter *Task Management*.

VSTACK

The VSTACK attribute specifies the contribution of the task to the virtual stack (in bytes). The type of this attribute is UINT32. The default value is 30.


Section 5.7.3, *The Virtual Stack*, in Chapter *Task Management*.

3.3 The Structure of an OIL File

The complete OIL configuration consists of two parts (files):

- *Implementation Part*: Definition of the OIL system objects with their standard and implementation specific features (the standard and non–standard attributes). The implementation part is delivered with the product as a separate *system OIL file* which you must include before the application part. The file is named `osek.oil` and should never be modified. It is located in the general include directory of the toolchain.
- *Application Part*: Defines the structure of the application located on the particular CPU. For every RTOS application, you must write an application part (or: *user OIL file*). In this file you instantiate objects that are defined in the implementation part. The user OIL file must therefore include the system OIL file, like you include header files in a C source.

The Application Part is slaved to the Implementation Part. In object oriented terminology we would say that the Implementation Part contains the “class definitions” of all OIL objects for all projects. In a specific project the “classes” are instantiated in the Application Part of the OIL configuration file.

For example: In the Implementation Part an OIL object `TASK` exists which defines `PRIORITY` as one of its attributes. In the Application Part you must now instantiate classes of the kind `TASK` and give values to their `PRIORITY` attributes.

Restrictions

- At least one CPU object must be defined in the Application Part and it must be defined first since it is the container object for all other objects defined in the configuration. All the other objects are defined inside the CPU object.
- One and only one OS object can reside in each CPU container since it defines global characteristics for the system (CPU speed, RTOS hardware resources etc. are typical). OSEK/VDX implementations usually add many non–standard attributes in this object.
- One and only one COM object can reside in each CPU container.

With an OIL generator tool, a friendly GUI interface will guide you in the process of configuring the Application Part of the OIL file and it will output a syntactically correct OIL configuration file for you. Without such a tool you must hand–code the Application Part (taking care of its grammatical correctness) of the OIL file.

3.3.1 Implementation Part

The Implementation part of the OIL file is delivered with the product in the file `osek.oil`. You can find this file in the general include directory of the toolchain. This file, the *Implementation OIL file*, represents a mandatory interface for the Application OIL part in the OIL file of all projects.

3.3.2 Application Part

The Application OIL part contains all instances of OIL objects for a given application. Below you will find an example of how an OIL file may look like.

You must select proper names for the OIL objects since they become variables with global scope (and with type ObjectType). For instance, if you define in the OIL file an EVENT object *download,* you cannot define a function with such a name in your source code (the least you can expect is link errors).

```
#include <osek/osek.oil>

CPU Sample_CPU1
{
    OS StdOS
    {
        STATUS              = EXTENDED;
        STARTUPHOOK         = TRUE;
        ERRORHOOK           = TRUE;
        SHUTDOWNHOOK        = TRUE;
        PRETASKHOOK         = TRUE;
        POSTTASKHOOK        = TRUE;
        USEGETSERVICEID     = TRUE;
        USEPARAMETERACCESS  = TRUE;
        USERESSCHEDULER     = TRUE;
        CORE                = TSK51A;
        USERTOSTIMER        = TRUE
                              { RTOSTIMERLEVEL = 1; };
        MULTISTART          = TRUE;
        EXTDATASIZE         = 12;
    };

    EVENT intervaldelay;

    TASK init
    {
        PRIORITY    = 7;
        SCHEDULE    = FULL;
        ACTIVATION  = 1;
        RESOURCE    = sem_out;
        AUTOSTART   = TRUE
        {
            APPMODE=AUTOSTART;
            APPMODE=NONAUTOSTART;
        };
        VSTACK      = 100;
        SSTACK      = 40;
    };
```

```
TASK monitor
{
    PRIORITY   = 9;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = FALSE;
    MESSAGE    = sendHandler1;
    MESSAGE    = sendHandler2;
    MESSAGE    = sendHandler3;
    MESSAGE    = recCommand;
    VSTACK     = 100;
    SSTACK     = 40;
};

ISR MonitorISR
{
    CATEGORY = 2;
    LEVEL    = 4;
    ENBIT    = "ES";
    MESSAGE  = sendCommand;
};

MESSAGE sendCommand
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE = "myCommand";
        RECEIVER  = recCommand;
    };
};

MESSAGE recCommand
{
    MESSAGEPROPERTY = RECEIVE_QUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendCommand;
        QUEUESIZE      = 5;
    };
    NOTIFICATION    = ACTIVATETASK
    {
        TASK = monitor;
    };
};

APPMODE AUTOSTART {};
APPMODE NONAUTOSTART {};

EVENT internaldelay;
```

```
TASK bounce1
{
    PRIORITY   = 5;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = TRUE { APPMODE=AUTOSTART; };
    EVENT      = intervaldelay;
    MESSAGE    = recHandler1;
    RESOURCE   = sem_printf;
    VSTACK     = 100;
    SSTACK     = 40;
};

TASK bounce2
{
    PRIORITY   = 5;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = TRUE { APPMODE=AUTOSTART; };
    EVENT      = intervaldelay;
    MESSAGE    = recHandler2;
    RESOURCE   = sem_printf;
    VSTACK     = 100;
    SSTACK     = 40;
};

TASK bounce3
{
    PRIORITY   = 5;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = TRUE { APPMODE=AUTOSTART; };
    EVENT      = intervaldelay;
    MESSAGE    = recHandler3;
    RESOURCE   = sem_printf;
    VSTACK     = 100;
    SSTACK     = 40;
};
```

```
TASK trsi
{
    PRIORITY   = 11;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = FALSE;
    RESOURCE   = sem_out;
    VSTACK     = 80;
    SSTACK     = 40;
};

COUNTER crsi
{
    MAXALLOWEDVALUE = 500;
    TICKSPERBASE    = 1;
    MINCYCLE        = 3;
};

ALARM arsi
{
    COUNTER   = crsi;
    ACTION    = ACTIVATETASK { TASK = trsi; };
    AUTOSTART = TRUE
    {
        CYCLETIME = 200;
        APPMODE   = AUTOSTART;
        ALARMTIME = 200;
    };
};

ALARM ainterval1
{
    COUNTER   = SYS_TIMER;
    ACTION    = SETEVENT
    {
        TASK      = bounce1;
        EVENT     = intervaldelay;
    };
    AUTOSTART = FALSE;
};
```

```
ALARM ainterval2
{
    COUNTER   = SYS_TIMER;
    ACTION    = SETEVENT
    {
        TASK      = bounce2;
        EVENT     = intervaldelay;
    };
    AUTOSTART = FALSE;
};

ALARM ainterval3
{
    COUNTER   = SYS_TIMER;
    ACTION    = SETEVENT
    {
        TASK      = bounce3;
        EVENT     = intervaldelay;
    };
    AUTOSTART = FALSE;
};

MESSAGE sendHandler1
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
         CDATATYPE = ”int”;
         RECEIVER  = recHandler1;
    };
};

RESOURCE sem_printf
{
    RESOURCEPROPERTY = STANDARD;
};

RESOURCE sem_out
{
    RESOURCEPROPERTY = STANDARD;
};
```

```
MESSAGE sendHandler2
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE = ”int”;
        RECEIVER  = recHandler2;
    };
};

MESSAGE sendHandler3
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE = ”int”;
        RECEIVER  = recHandler3;
    };
};

MESSAGE recHandler1
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendHandler1;
        INITIALVALUE   = 3 ;
    };
};

MESSAGE recHandler2
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendHandler2;
        INITIALVALUE   = 3;
    };
};

MESSAGE recHandler3
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendHandler3;
        INITIALVALUE   = 3;
    };
};
```

```
    COM Com
    {
        COMERRORHOOK           = TRUE;
        COMUSEGETSERVICEID     = TRUE;
        COMUSEPARAMETERACCESS  = TRUE;
        COMSTARTCOMEXTENSION   = TRUE;
        COMSTATUS              = COMEXTENDED;
    };
}: "CPU Sample application";
```

3.4 Preprocessor Commands

The OIL preprocessor allows the following preprocessor commands:

- `#include "file"` or `#include <file>`
- `#ifdef A`
- `#ifndef A`
- `#else`
- `#endif`

It is highly recommended to divide the functionality of the OIL file into separated files. The syntax is the same as in ISO/ANSI–C.

The OIL preprocessor accepts C++ –style comments (`/* */` and `//`). C++ rules apply.

4 The startup process

Summary

This chapter explains what happens inside the system from application reset until the first application task is scheduled and describes how you can interfere with the start–up process by customizing certain Hook Routines.

4.1 Introduction

This chapter details the various phases the system undergoes from CPU reset until the first application task is scheduled. You can intervene in this process via the *Hook Routines* and the *Application Modes*.

Please refer to the OSEK/VDX OIL documentation for details about the Hook Routines and Application Modes.

The startup process includes the following phases:

1. System boot
2. C entry point `main()`
3. StartOS
4. RTOS initialization phase: Hook Routines

After the startup process the first task is scheduled.

4.2 System Boot

When the processor first starts up, it always looks at the same place in the system ROM memory area for the start of the system boot program. The boot code runs sequentially until it reaches the point where it jumps to the label `main`. This code runs, of course, in the absence of the operating system.

In general, embedded systems differ so much from each other that the boot code tends to be almost unique for each system. You can create the system boot in two ways:

1. Reuse the standard startup code provided by the toolchain and enhance it (if necessary) to suit the specific needs of your hardware. The standard startup code merely contains what is necessary to get the system running. It is easy configurable via **Project Options** in the **Project** menu.
2. You may decide to create the system boot code if some board specific actions need to be taken at a very early stage. Some of the most common actions are:
   - Initialization of critical microprocessor registers (including standard pointers like the stack pointer).
   - Initialization of specific peripheral registers for your unique hardware design.
   - Initialization of all static variables (using the delivered `_init` routine).
   - Distinguish the source of processor reset (hard or soft reset, power−on reset, watchdog, ...).
   - Addition of some power−on tests.
   - Call the label `main()` to start the application.

4.3 The Main() Module

At the moment of entering `main()` only minimal controller initialization has occurred. At this point the application can run extra (application–specific) initialization routines before the RTOS starts. This code cannot call an RTOS system service.

The OSEK/VDX standard defines a service to start the operating system:

```
void StartOS(AppModeType);
```

4.3.1 What are Application Modes?

Application Modes allow you (as a matter of speaking) to have “multiple” applications in one single image. Application Modes allow application images to structure the software running in the processor depending on external conditions. These conditions must be tested by the application software upon system reset. The difference in functionality between applications that start in different modes is determined by:

- Which tasks and which alarms automatically start after the RTOS initialization.
- Mode–specific code (the mode can be detected at run time by using the system service *GetActiveApplicationMode).*

You define (and set all these dependencies) in the OIL file of the project. The OSEK/VDX does not set a limit for the number of Application Mode objects. See Appendix A, *Implementation Paramaters*, for the maximum number of application modes in this implementation.

4.3.2 Defining Application Modes

The application modes are strongly related to the decissions you take at system architecture level. The following example of an ATM (Automated Teller Machine) illustrates this dependency.

Let us assume an ATM which must meet the following system requirement: “The ATM software shall be upgraded locally at high speed and being service affecting”.

How could we implement a solution for such a scenario? The software can be designed in such a way, it has two mutually exclusive modes: a download mode and mode for normal operation. In this example, an external pin must be read before the RTOS starts (after reset) to distinguish between the modes: if the pin is not asserted, the image starts in ’normal mode’, if asserted the image starts in ’download mode’.

The download process takes place locally: to download a new image, an operator must go to the ATM location. The operator must, in order, (1) open the ATM box, (2) assert the pin, (3) reset the machine to start it in download mode, (4) download the image from a notebook, (5) deassert the pin, (6) reset the machine to start it in normal operation mode, (7) close the ATM box. Obviously while downloading a new image, the ATM is out of service.

In the OIL file you would define two APPMODE objects like:

```
APPMODE NORMAL {};

APPMODE DOWNLOAD {};
```

In NORMAL operation mode the ATM machine is ready to address customer queries. A task is started that offers, for example, a tactile–graphical interface waiting for customer queries, another task maintains a link with a bank database to update the customer latest data a third task interfaces with the paper money repository.

In DOWNLOAD operation mode, the ATM machine starts a task to process download messages over a fast serial line. Another task flashes the image to the target read only memory. The system is entirely dedicated to download purposes.

Code example

OIL file

You define application modes in the OIL file like:

```
APPMODE NORMAL {};
APPMODE DOWNLOAD {};
```

C source file

In the application source code, like with all other OIL objects, you need to declare the application mode before using it:

The example assumes that the system boot code passes the type of reset that has occurred as `argc`. The application is designed so that the execution flow returns to the boot code when the RTOS shuts down.

```
DeclareAppMode(mode);

AppModeType GetAppMode(void)
{    AppModeType mode;
     /* check if the pin has been asserted */
     if (PinIsAsserted())
     {    /* 'StartOS' shall start in DOWNLOAD mode */
          mode = DOWNLOAD; }
     else
     {   /* 'StartOS' shall start in NORMAL mode */
          mode = NORMAL;   }
return mode;
}
```

```
int main(int argc)
{
     ResetType reset = argc;
     AppModeType mode;
        /* common initialization for all modes */
     InitInCLevel();
        /* different action depending on reset type */
     InitSystem(reset);
        /* find out the run time current mode */
     mode = GetAppMode();
        /* start the OS for current mode */
     StartOS(mode);
     ...
     return 1;
}
```

`StartOS()` is the one and only method defined by the OSEK/VDX standard in which you can define the Application Mode for the current system environment. To change modes, the application must first shutdown and then the RTOS must restart using a the new mode.

4.3.3 Changing Application Modes: Application Reset.

Since sending operators across the whole ATM network is inefficient and costly, a new system requirement could arise: “The ATM software shall be upgraded remotely at high speed and being service affecting”.

Identically two mutually exclusive modes keep coexisting but no operator is needed (on location). How do we implement such a solution?

The ATM software can receive a command to change its mode (the system shuts down and starts again with the other mode). In order to download the following steps, in order, are necessary: an operator in the bank headquarters issues remotely a command to enter download mode, the ATM software undergoes an application reset and starts up again the link in download mode, the operator sends download commands over the link and when the new image has been downloaded, a command to enter normal mode is issued. The ATM undergoes a second application reset and starts the new image in normal mode.

You should then implement a function like `ChangeMode()` in order to change the mode:

```
void ChangeMode(AppModeType mode)
{    if (mode != GetActiveApplicationMode() )
     /* GetActiveApplicationMode returns the current application mode */
     {
          CurrentMode = mode;
          ShutdownOS(E_OK);
     }
     return;
}
```

In NORMAL mode, the application calls this routine when it has been signaled remotely to start downloading an image. First a global variable is updated to indicate the desired next mode and then the system shuts down with the system service `ShutdownOS()`. The implementation makes sure that after the execution of this system service the system effectively returns from the API that started the RTOS, thus from `StartOS()`.

The `main()` code should now be changed to:

```
static AppModeType CurrentMode = NORMAL;

int main(int argc)
{
     ResetType reset = argc;
     InitInCLevel();
     InitSystem(reset);
     while (1)
     {
          StartOS(CurrentMode);
     }
     return 1;
}
```

The non–standard attribute MULTISTART of the OS object must be defined as TRUE in the OIL file because `StartOS()` can be called more than once. Only in systems where application resets will never occur, the value of the MULTISTART attribute can be set as FALSE. This saves code and data size.

Dependency on the System Requirements

An ATM machine could enter temporarily the download mode, “out of service”, without causing great disaster (at most some customers will be bothered to try other ATMs nearby). But could a telecommunication router stop performing its normal traffic operation because it is upgrading remotely its software? This depends strongly on the system requirements.

Let us assume then a system requirement: ”The ATM software shall be upgraded remotely at low speed and being non–service affecting”.

Downloading is performed in the background, mingled with the other components, in normal operation. In such system there is no “download” mode.

4.3.4 Non–mutually exclusive application modes

So far we think of application modes as performing mutually exclusive tasks. Although this describes well the general case it should not be taken as a dogma. Let us think what happens in the following mental example.

Imagine a rack system composed of three identical boards where functionality depends on their position in the rack. If the functionality is very different we would possibly maintain three software images.

But what happens if their functionality is almost identical? It would be then convenient to distinguish three modes (for each position) and determine at run time which code to execute (the system service *GetActiveApplicationMode* will specify the current position in the rack).

The benefits are obvious: it eases the factory programming process (only one software image) and the boards will become interchangeable.

4.4 The RTOS Initialization

This section shows what happens inside the system from the moment that you call `StartOS()` until the first application task is scheduled and explains how you can intervene in this process.

The RTOS performs the following actions during the initialization process:

1. The RTOS initializes some internal data structures on the basis of what is stated in the OIL file. In particular, it prepares autostarting tasks and alarms to start running.
2. The RTOS hardware timer is initialized.

   Not all applications need a system counter (only those with ALARM OIL objects based on the system counter). You determine this with the non–standard attribute USERTOSTIMER.

   When USERTOSTIMER is set to TRUE:

   - The RTOS builds the framework for the system counter interrupt.
   - Due to the amount of derivatives/systems it must still be you who actually initializes the hardware clock. In fact, you must provide a definition for the Interface:

   ```
   void InitRTOSTimer(void);
   ```

   If the USERTOSTIMER attribute in the OIL file is set but you do not define the InitRTOSTimer routine in your source, the linking phase fails because it encounters unresolved externals.

See section 8.4. Initialization of the RTOS Timer.

You can always set alarms to be based on the SYSTEM_TIMER counter which has this hardware timer as a source.

3. The RTOS calls the hook routine `StartupHook` (provided that you have assigned the value TRUE to the STARTUPHOOK attribute of the OS object in the OIL file):

```
void StartupHook(void);
```

If the STARTUPHOOK attribute in the OIL file is set but you do not define the `StartupHook` routine in your source, the linking phase fails because it encounters unresolved externals.

During the lifetime of the `StartupHook` routine all the system interrupts are disabled and you have only restricted access to system services. The only available services are `GetActiveApplicationMode()` and `ShutdownOS()`.

You should use this hook routine to add initialization code which strongly relies on the current selected Application Mode.

```
void StartupHook(void)
{
    AppModeType mode = GetActiveApplicationMode();
    switch (mode)
    {
        case NORMAL:
            InitLinkBankDriver();
            break;
        case DOWNLOAD:
            InitLinkServerDriver();
            InitFlashDriver();
            break;
        default:
            ShutdownOS(E_OK);
            break;
    }
    return;
}
```

4. The RTOS enables all system interrupts
5. The RTOS executes the highest priority task ready to execute.

If you define the AUTOSTART attribute as FALSE for all TASK objects in the OIL file, the system enters directly into an RTOS–defined idle state. The system then waits for external events.

4.5 The Shut–down Process

The OSEK/VDX standard defines a service to shut–down the operating system:

```
void ShutdownOS(StatusType);
```

1. You can directly request the `ShutdownOS` routine. In this case, you must define your own set of shut–down reasons: error codes.

   ```
   #define E_APP_ERROR1     64
   #define E_APP_ERROR2     65
   ...
   ...
   #define E_APP_ERROR192   255
   ```

   (0–63 are reserved for the RTOS code)

   As soon as your application encounters error *N*, the `ShutdownOS` routine must be called with E_APP_ERRORN as parameter:

   ```
   ShutdownOS(E_APP_ERRORN);
   ```

2. The `ShutdownOS` routine can also be reached internally by the operating system in case the RTOS encounters an internal fatal error.

   The possible RTOS error codes then are:

   ```
   E_OS_SYS_ERROR      : In case of a fatal internal error
   E_OS_SYS_SSTACK     : In case of a stack overflows
   E_OS_SYS_VSTACK
   E_OS_SYS_STACK
   E_OS_SYS_ISRSTACK
   ```

The RTOS error codes are defined in `types.h`.

In (the body of) `ShutdownOS()` the RTOS calls the hook routine `ShutdownHook` (provided that you have assigned the value TRUE to the SHUTDOWNHOOK attribute of the OS object in the OIL file)

```
void ShutdownHook(StatusType);
```

If the SHUTDOWNHOOK attribute in the OIL file is set but you do not define the `ShutdownHook` routine in your source, the linking phase fails because it encounters unresolved externals.

During the lifetime of the `ShutdownHook` routine all system interrupts are disabled and the only available service is `GetActiveApplicationMode()`.

The OSEK/VDX standard allows you to define any system behaviour in this routine, including no return from the routine. Typical actions would be:

- Use a logging mechanism to study the reason for shutdown (you must always check both application and RTOS error codes).
- Just return if E_OK.

See also section 4.3.3, *Changing Application Modes: Application Reset*

- If a severe error is encountered you can force the system to shut down.

In case you decide to return from `ShutdownHook`, the RTOS cleans up all opened objects and returns from the previous call to `StartOS()`. The control is given back to the application in `main()`.

Example of a Shut-Down

The next example illustrates how a typical `ShutdownOS` hook routine can look like.

```
/* counts number of resets */
static int no_resets = 0;

/* switch off the system */
extern void SwitchOff(void);

/* handles error N */
extern void HandlerErrorN(void);

void ShutdownHook (StatusType Error)
{
    TaskType task;

    switch(Error)
    {
        case E_OK:
        /* Example of "good" application reset */
        break;

        case E_OS_SYS_VSTACK:
        case E_OS_SYS_SSTACK:
        case E_OS_SYS_STACK:
        case E_OS_SYS_ISRSTACK:
        case E_OS_SYS_ERROR:
```

```
        /* RTOS has detected a stack overflow
         * or a fatal internal error.
         * We allow the system three errors like
         * these before switching the system off */
        if (++no_resets==3)
        {
            SwitchOff();
        }
        break;

        case E_APP_ERRORN:
        /* application handler for Error N */
        HandlerErrorN();
        break;

        default:
        /* no idea what has happened */
        SwitchOff();
        break;
    }

    /* After returning, the RTOS will clean up all
     * opened objects and return from the previous
     * call to StartOS().
     * The control will be normally given back to
     * the application in main().
     */
    return;
}
```

5 Task management

Summary

This chapter explains how the RTOS manages tasks (scheduling policies, tasks states, ..) and describes how you can declare TASK objects in the OIL file in order to optimize your task configuration.

5.1 What is a Task?

A task is a semi−independent program segment with a dedicated purpose. Most modern real−time applications require multiple tasks. A task provides the framework for the execution of functions. The RTOS provides concurrent and asynchronous execution of tasks. The scheduler organises the sequence of task execution including a mechanism which is active when no other system or application function is active: the *idle−mechanism*.

ECC2 OSEK/VDX Conformance CLASS

The concept of task is obviously the most important concept in the OSEK/VDX OS standard. In the standard, a task is either *basic* or *extended*, has a well defined static priority, is or not preemptable, can or cannot enter the *waiting* state, is or not the only owner of a priority level, and so on. All possible definitions of these attributes and their interrelation define four different conformance class levels: BCC1, BCC2, ECC1, ECC2.

This OSEK/VDX implementation is ECC2 compliant. The reason to choose this conformance class is simple: it includes all the others (any task developed for a BCCx−level can be used in a ECCx−level and any task written for an xCC1−level can be used in a xCC2−level). As a consequence of being ECC2 compliant:

- The number of task activations can be larger than one.
- The number of tasks occupying a particular priority level can be larger than one.
- Basic tasks are supported.
- Extended tasks are supported.

5.2 Defining a Task in the C Source

To configure a task, you must declare a specific TASK object in the user OIL file of the project and assign values to all of its attributes. Please refer to the OSEK/VDX documentation for detailed information about all possible attributes of a task and how to use them.

With the macro `TASK` you can define a task in your application. The name of the TASK object in the OIL file is passed as parameter to the macro.

You must always end the code of a task with the system service `TerminateTask` or `ChainTask` (regardless of whether the RTOS defines a resistant default behaviour in case the task reaches a (forbidden) RET instruction). For example, to define the task *mytask*:

```
TASK(mytask)
{
      .
      . code for task 'mytask'
      .
      TerminateTask();
}
```

The OSEK/VDX implementation uses this macro to encapsulate the implementation-specific formatting of the task definition (*mytask* is the identity of the task and is of the type `TaskType`). During preprocessing, the C name of the function that correspond to the task is created by adding the prefix '*_os_u_*' to the task name. You can then view the function with the debugger using the mingled name: '*_os_u_mytask* '.

5.3 The States of a Task

A task goes through several different states during its lifetime. A processor can only execute one instruction at a time so, even when several tasks are competing for the processor at the same time, only one task is actually running. The RTOS is responsible of saving and restoring the context of the tasks when they undergo such state transitions

A task can be in one of the following states:

Task state	Description
running	The CPU is now assigned to the task and it is executing the tesk. Only one task can be in this state at any point in time.
ready	All functional prerequisites for a transition into the *running* state exist, and the task only waits for allocation of the processor. The scheduler decides which ready task is executed next.
waiting	A task cannot continue execution because it has to wait for at least one event (extended tasks only)
suspended	In the suspended state the task is passive and can be activated.

Table 5–1: Task States

5.3.1 Basic Tasks

A basic task runs to completion unless preempted by a higher priority task. Basic tasks can only exist in one of three states

- *suspended*
- *ready*
- *runnig*

So, a basic state cannot be in the *waiting* state.
A basic task can undergo only these next four transitions:

- *activation* (from *suspended* to *ready*).
- *start* (from *ready* to *running*).
- *preempted* (from *running* to *ready*).
- *terminate* (from *running* to *suspended*).

When the RTOS is started with `StartOS()` a basic task is either in the *suspended* or *ready* state (depending on whether you set the AUTOSTART attribute of the TASK object in the OIL file to FALSE or TRUE). Based on later events, the basic task can flow through any of the four transitions.

Below is the OIL configuration for a basic non–autostarting task:

```
TASK NotActTask
{
    PRIORITY   = 5;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = FALSE;
};
```

The OIL configuration for an auto–starting task is:

```
TASK InitTask
{
    PRIORITY   = 9;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = TRUE { APPMODE = NORMAL; };
};
```

5.3.2 Extended Tasks

Extended tasks have one additional state, *waiting.* In this state the *extended* task waits for an event to occur to resume execution. While in this state, a task cannot be scheduled since it is not ready to run. Extended tasks can undergo two more transitions (additional to the transitions of basic states):

- *wait* (from *running* to *waiting*)
- *trigger* (from *waiting* to *ready*)

Because extended tasks are intrinsically related to *events* it is very easy to define in the OIL file whether a task is *basic* or *extended*. If the optional attribute EVENT exists for the TASK object, the task will be an *extended* task. Otherwise it is a *basic* task.

Below is the OIL configuration for an *extended* auto–starting task:

```
EVENT MonitorReadEvent;
TASK Monitor
{
    PRIORITY   = 7;
    SCHEDULE   = FULL;
    ACTIVATION = 1;
    AUTOSTART  = TRUE { APPMODE = DOWNLOAD; };
    EVENT      = MonitorReadEvent;
};
```

5.4 The Priority of a Task

The scheduler decides on the basis of the task priority (precedence) which is the next of the *ready* tasks to be transferred into the *running* state. The value 0 is defined as the lowest priority of a task and it is reserved for the *idle* task.

To enhance efficiency, a dynamic priority management is not supported. Accordingly the priority of a task is defined statically: you cannot change it during execution.

In special cases the operating system can treat tasks with a lower priority as tasks with a higher priority. See Section 7.3, *The Ceiling Priority Protocol*, in Chapter *Resource Management*.

Since this OSEK/VDX implementation is ECC2 compliant, more than one task with the same priority can execute. The implementation uses a first in, first out (FIFO) queue for each priority level containing all the *ready* tasks within that priority. Some facts about the *ready–queues* are listed below:

- Every *ready–queue* corresponds to a priority level.
- Tasks are queued, in activation order, in the *ready–queue* that corresponds to their static priority.
- All the tasks that are queued must be in the *ready* state.
- Since the *waiting* tasks are not in any *ready* queue, they do not block the start of subsequent tasks with identical priority.
- The *system priority* corresponds to the highest priority among all the non–empty *ready–queues*.
- The *running* task is the first task in the *ready–queue* with the *system priority*.
- A task being released from the *waiting* state is treated like the newest task in the *ready–queue* of its priority.
- The following fundamental steps are necessary to determine the next task to be processed:

  1. The scheduler searches for all tasks in the *ready*/*running* state
  2. From the set of tasks in the *ready*/*running* state, the scheduler determines the set of tasks with the highest priority.
  3. Within the set of tasks in the *ready*/*running* state and of highest priority, the scheduler finds the oldest task.

5.4.1 Virtual versus Physical Priorities

We define *virtual priority* of a task as ”the priority of a task as it is given in the application OIL file”. We define *physical priority* of a task as ”the real run–time priority of the task”.

Let us think of an application OIL file with three TASK OIL objects defined such that:

```
TASK T1 { PRIORITY = 6; .. };
TASK T2 { PRIORITY = 4; .. };
TASK T3 { PRIORITY = 4; .. };
```

The ”ready–to–run” array comprises all the ready queues of the system. In such a system there will be two ”ready–queues” in the ”ready–to–run” array, one per priority level.

The next figure shows the ”ready–to–run” array where T1 is running and tasks T2 and T3 are ready (T2 being the oldest).

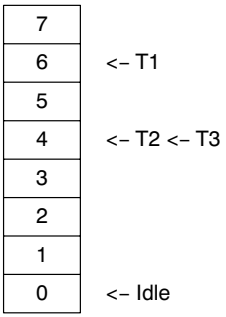


Figure 5–1: Virtual ready–to–run array

Now, what would, in terms of functionality, be the differences between this configuration and the next systems?

System A

```
TASK T1 { PRIORITY = 3; .. };
TASK T2 { PRIORITY = 1; .. };
TASK T3 { PRIORITY = 1; .. };
```

System B

```
TASK T1 { PRIORITY = 17;.. };
TASK T2 { PRIORITY = 9; .. };
TASK T3 { PRIORITY = 9; .. };
```

The equivalent ”ready–to–run” arrays of such systems would then be:

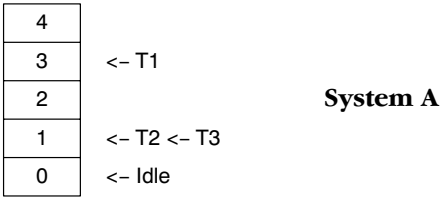


Figure 5–2: Virtual ready–to–run array for System A

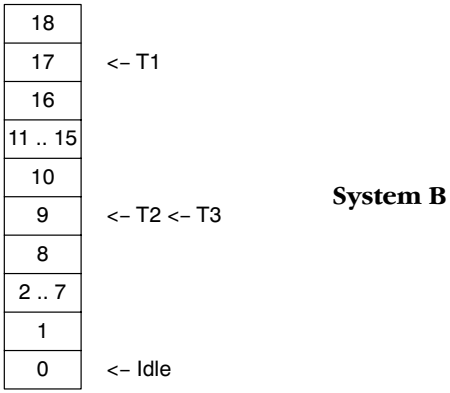


Figure 5–3: Virtual ready–to–run array for System B

There are no functional differences. As soon as T1 undergoes the *wait* or *terminate* transition, T2 is scheduled. T2 can only be preempted by T1. T3 only runs after T2 undergoes a *wait* or *terminate* transition.

However, it is easy to infer from the diagrams that system A has the better run–time response of the system. In system B, for instance, there are 15 ”useless” priority levels defined in the system. Besides these levels can never hold a ready task, the scheduler also wastes CPU cycles in checking them. And RAM area has been allocated for them. In a hard real–time system, these unnecessary checks must be avoided.

Since all this information can be interpreted beforehand by the RTOS code, all these configurations will end up in the same physical ”ready–to–run” array:

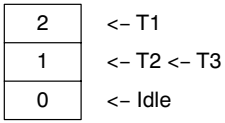


Figure 5–4: Virtual ready–to–run array for System A and System B

Internally, the RTOS code deals always with ”physical priorities”. The maximum size of the ”ready–to–run” array determines the upper limit for the number of physical priorities.

See Appendix A, *Implementation Parameters*, to find out the maximum possible number of physical priority levels in the system.

5.4.2 Fast Scheduling

Every physical priority level holds a ”ready−queue”. You can define multiple tasks with the same priority. However, if you define only one task per priority level, the scheduler becomes faster. In this situation the RTOS software does not have to deal with ”ready−queues” but merely with pointers to the task control blocks.

Whenever possible, you should try to define only one TASK OIL object with the same value for its PRIORITY standard attribute. You will benefit not only from better run−time responses but also from smaller RAM and ROM sizes.

5.5 Activating and Terminating a Task

Tasks must be properly activated and terminated.

You can activate tasks directly from a task or interrupt level, or from the `StartupHook()` routine. To activate a task, use the system service

```
StatusType ActivateTask(TaskType task);
```

Example

```
DeclareTask(myTask);

ISR (myISR)
{
     ActivateTask(myTask);
}

TASK (myOtherTask)
{
     .
     .    code
     .
     ActivateTask(myTask);
     TerminateTask();
}

void StartupHook(void)
{
     ActivateTask(myTask);
}
```

Although allowed, activating a task from the `StartupHook()` routine is less preferable than declaring the task as AUTOSTART in your OIL file.

A task is activated by the RTOS code when:

- An alarm expires (with its attribute ACTION set to ACTIVATETASK).
- A message has been sent (with its attribute NOTIFICATION set to ACTIVATETASK).
- You configured a task to be activated during the RTOS startup. You must set the attribute AUTOSTART to TRUE and indicate under which application mode(s) the task must autostart.

```
APPMODE AppMode1;
TASK autoT
{
     AUTOSTART = TRUE { APPMODE = AppMode1; };
};
```

And the RTOS needs to be started in your C source:

```
DeclareAppMode(AppMode1);

int main(int argc)
{
     StartOS(AppMode1);
     return;
}
```

After activation, the task is ready to execute from the first statement. The RTOS does not support C–like parameter passing when starting a task. Those parameters should be passed by message communication or by global variables.


See Chapter 10, *Interprocess Communication*.

Since this implementation is ECC2 compliant, a task can be activated once or multiple times (maximum number of requests in parallel is defined at system generation with the attribute ACTIVATE of the TASK object).

If the task is in *suspended* mode, the system service moves the task into the *ready* state.

If the task is not in the *suspended* mode and maximum number of multiple requests has not been reached yet, the request is queued by the RTOS for later processing.

Example of Activating a Task

OIL file:

```
TASK Init { PRIORITY = 2; };
TASK activate
{
     PRIORITY    = 1;
     ACTIVATION  = 5
};
```

C source file:

```
TASK (activate) { TerminateTask();   }
TASK (Init)
{
    /* 'activate' task is set to ready */
    ActivateTask(activate);
    /* log new requests */
    for (i=1;i<5;i++)
    {
        if(E_OK != ActivateTask(activate))
        {
            /* never here - always E_OK -*/
            while(1);
        }
    }
    for (i=0;i<5;i++)
    {
        if (E_OS_LIMIT != ActivateTask(activate))
        {
            /* never here - always E_OS_LIMIT - */
            while(1);
         }
    }
    TerminateTask();
    /* Now 'activate' task will run five times */
    return;
}
```

Terminating a task

You must explicitly terminate a task with one of the system services:

```
void TerminateTask(void);
```

or:

```
void ChainTask(TaskType);
```

The OSEK/VDX standard has an undefined behaviour if the return instruction is encountered at task level.

Situations like demonstrated in the example should be avoided:

```
TASK (myTask)
{
     unsigned char var = readPulse();
     switch (var)
     {
          case READY:
               sendSignal();
               TerminateTask();
               break;
          case NONREADY:
               TerminateTask();
               break;
          default:
               break;
     }
     return;
}
```

Although apparently innocuous, the behaviour of the whole system is completely undefined if `var` does not equal to READY or NONREADY. In that case the switch reaches `default` where the function is not properly terminated.

Be aware that calling `TerminateTask` from interrupts or from hook routines can bring the system to a complete undefined state. You should terminate tasks only from task level.

5.6 Scheduling a Task

A task can be scheduled with one of the following scheduling policies: *full−preemtable* and *non−preemptable* scheduling. You must assign a scheduling policy to every task in your application OIL file, setting the attribute SCHEDULE to either FULL or NON.

5.6.1 Full−preemptive Tasks

Full−preemptive scheduling means that the *running* task can be rescheduled at any moment by the occurrence of trigger conditions pre−set by the operating system. The *running* task enters the ready state, as soon as a higher−priority task becomes *ready*.

The rescheduling points for full−preemptive scheduling are:

- Successful termination of a task.
- Successful termination of a task with activation of a successor task.
- Activating a task at task level.
- Explicit wait call if a transition into the *waiting* state takes place.
- Setting an event to a *waiting* task at task level.
- Release of resource at task level.
- Return from interrupt level to task level.

If the tasks in the system are all *full−preemptive*, the scheduling policy of the system as whole is fully preemptive. During interrupt service routines no rescheduling is performed.

5.6.2 Non−preemptive Tasks

Non−preemptive scheduling means that task switching is only performed via an explicitly defined system services.

The explicit rescheduling points for non−preemptive tasks are:

- Successful termination of a task.
- Successful termination of a task with explicit activation of a successor task.
- Explicit call of the scheduler.
- A transition into the *waiting* state.

If the tasks in the system are all *non−preemptive*, the scheduling policy of the system as whole is said to be non−preemptive.

Be aware of the special constraints that non−preemptive scheduling imposes on possible timing requirements while designing your TASK objects. A non−preemptable task prevents all other tasks from CPU time so their execution time should be extremely short.

5.6.3 Scheduling Policy

In the most general case, the system runs with the so−called *mixed preemptive* scheduling policy (full−preemptable and non−preemptable tasks are mixed). The current scheduling policy depends on the preemption properties of the running task: non−preemptable or full−preemptive. If the *running* task has its SCHEDULE attribute set to FULL in the OIL file, the scheduling policy is fully preemptive. Otherwise the scheduling policy will be non−preemptive.

Typically an application will operate in mixed preemptive mode where most of the tasks can be safely preempted while the non−preemptable tasks constitute only a small subset among all tasks.

The code belows shows the behaviour of the system with a *mixed−preemptive* policy.

OIL file

```
EVENT  eT2−nP1;

TASK  T1
{
     SCHEDULE = FULL;
     PRIORITY = 4;
};

TASK  T2
{
     SCHEDULE = FULL;
     PRIORITY = 2;
};

TASK  nP1
{
     SCHEDULE = NONE;
     PRIORITY = 3;
     EVENT    = eT2−nP1;
     AUTOSTART = TRUE { APPMODE = default; };
};

TASK  nP2
{
     SCHEDULE = FULL;
     PRIORITY = 4;
};
```

C source file

```
/* Like all other OIL objects you need to declare
  the tasks before you can use them in your code */
DeclareTask(T1);
DeclareTask(T2);
DeclareTask(nP1);
DeclareTask(nP2);

TASK(T1)
{
     TerminateTask();
}

TASK(T2)
{
     SetEvent(nP1,eT2-nP1)
     TerminateTask();
}

TASK(nP2)
{
     TerminateTask();
}

TASK(nP1)
{
    /* T1,T2, nP2 are activated but they cannot preempt the running task */
     ActivateTask(T1);
     ActivateTask(T2);
     ActivateTask(nP2);
     /* ... */

     /* This call allows CPU scheduling to tasks with higher priority */
     Schedule();
     /* 1. T1 runs first and terminates */
     /* 2. nP2 runs and terminates */
     /* 3. nP1 resumes execution */
     /* <--- An ISR activates T1 */
     /* ... */

     WaitEvent(eT2-nP1);
     /* 1. T1 runs next and terminates */
     /* 2. Finally T2 runs. It sets 'eT2-nP1' to trigger again 'nP1' */
     /* ... */

     TerminateTask();
     /* T2 terminates */
}
```

5.7 The Stack of Task

The memory usage becomes a crucial discussion point for small embedded applications. Thus, you need to know in great detail how the RTOS allocates memory for each of its tasks. You also need to know, as far as possible, how you can customize the process to the needs of a particular application. In particular, since this architecture offers no stack overflow protection mechanisms, you should take special care to avoid run−time stack overflows.

See Appendix B, *Stack Overflow*, for an extensive discussion.

5.7.1 The Memory Model

The RTOS code is compiled with the *reentrant* model. This model favours context switching techniques since almost no copying needs to be done while saving/restoring the task.

You can still compile some parts of the application with the *large* memory model or the *mixed* memory model:

- You can compile a task with this model if none of its code and/or data is shared with other tasks.
- You can, in very exceptional cases, define an interrupt handler with the function qualifier `__interrupt` and compile it with the large model.

  Since this piece of code runs beyond the scope of the RTOS, you must make sure that it executes always with the highest priority to prevent it from being preempted by an RTOS interrupt. Obviously, this handler cannot share neither code nor data with other routines or call system services.

  These must be considered as extremely rare situations, under normal and desirable circumstances you will compile all code with the reentrant model.

With the reentrant model you make use of two stacks: the *system stack* and the *virtual stack*.

5.7.2 The System Stack

The system stack is used (using direct internal RAM) for return addresses only. The stack is allocated in the indirect addressable internal RAM segment (together with the IDATA segments) and grows upwards.

Since every task must save its return addresses history at context switch, the RTOS saves and restores the system stack to a dedicated area in external RAM. You configure the size of this dedicated area per task with the non−standard attribute of the TASK OIL object SSTACK. Thus, you need to estimate the highest possible number of nested calls for every task.

Since tasks normally use RTOS system services, the contribution of the RTOS code to the system stack growth must be considered. The value of the maximum penetration depth of the RTOS code in the system stack (in bytes) is defined as `_os_RTOS_STSTACK` bytes. As a result, the value of the attribute SSTACK of a task that uses system services must be always higher than `_os_RTOS_STSTACK`. How much higher depends on the usage of the system stack by the code of that particular task.

See also Appendix A*, Implementation Parameters*.

The dynamic size of the system stack influences the context switch time. To minimize this effect, you must avoid excessive use of nested function calls in your code.

5.7.2.1 The Run–Time System Stack

Since in this architecture an interrupt service routine also stores the return addresses in the same system stack, you must consider this contribution to avoid run–time system stack overflows, thus corrupting other internal data.

The RTOS code contributes to the system stack depth with `_os_RTOS_SISR1STACK` bytes for an interrupt service routine where no system services are used (Category 1), and with `_os_RTOS_SISR2STACK` bytes for an interrupt where system services are called (Category 2).

See section 9.4, *The Category of an ISR object*, in Chapter *Interrupts* to learn what Category 1 and Category 2 interrupts are.

A final contribution for the system stack comes from the processor context (which is pushed on this stack before context switching). The size of the context is given (in bytes) by `_os_CONTEXTSIZE`.

See also Appendix A*, Implementation Parameters*.

In the next figure you can see the worst case scenario of the usage of the system stack for a system where *m* Category 2 ISRs and *n* Category 1 ISRs can be nested.

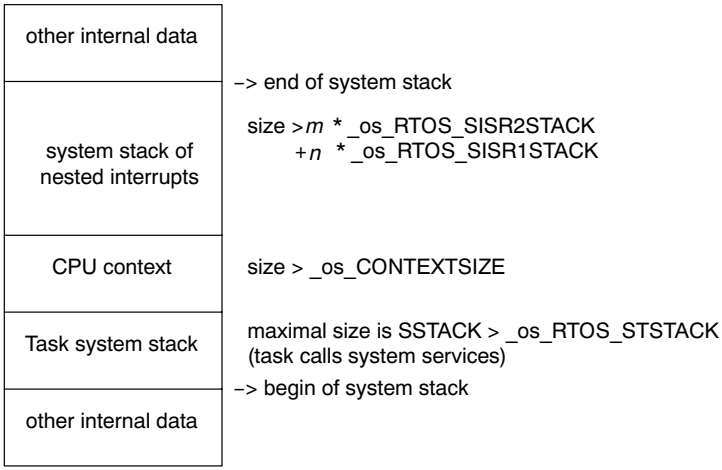


Figure 5–5: System stack use: worst case

You configure the maximum run–time size for the system stack in the linker options of the project.

5.7.2.2 Saving the System Stack

The RTOS saves the system stack of the preempted task in a dedicated location in external memory. The memory reserved to save the system stack for every task is:

```
SSTACK + _os_CONTEXTSIZE.
```

This memory is allocated statically at compile time.

5.7.3 The Virtual Stack

The RTOS code is compiled in *reentrant* model. In this model, automatics and parameters are all accessed using a virtual stack pointer register, allocated as a 16–bit pointer in direct addressable internal RAM (label `__SP`). The virtual stack must be located in external RAM and grows downwards.

A task tracks the history of its automatics and parameters in a dedicated area in external data reserved by the RTOS, therefore having a virtual stack on its own. Context switching, for automatics and parameters, is as easy as changing the value of the virtual stack pointer. You can configure the size of these dedicated areas per task with the attribute VSTACK of the TASK OIL object.

Since tasks normally use RTOS system services, the contribution of the RTOS code to the virtual stack growth must be considered. The value of the maximum penetration depth of the RTOS code in the virtual stack (in bytes) is defined as `_os_RTOS_VTSTACK` bytes. As a result, the value of the attribute VSTACK of a task that uses system services must be always higher than `_os_RTOS_VTSTACK`. How much higher depends on the usage of the virtual stack by that particular task.

See also Appendix A, *Implementation Parameters*.

5.7.3.1 The Run−Time Virtual Stack

Since an interrupt service routine also uses the virtual stack, you must measure this contribution to avoid run−time virtual stack overflows, thus corrupting other external data areas. The RTOS changes the value of the virtual stack pointer register upon entering an interrupt at first nesting level so that the automatics and parameters of the interrupt routines are pushed and popped in a dedicated area. The value is restored upon leaving an interrupt at first nesting level.

You configure the maximum contribution (in bytes) to the run−time virtual stack of the interrupts with the non−standard attribute VISRSTACK of the OS object. When you give values to this non−standard attribute, be aware that the RTOS code contributes to the system stack depth with `_os_RTOS_VISR1STACK` bytes for an interrupt service routine where no system services are used (Category 1), and with `_os_RTOS_VISR2STACK` bytes for an interrupt where system services are called (Category 2).

See section 9.4, *The Category of an ISR object*, in Chapter *Interrupts* to learn what Category 1 and Category 2 interrupts are.

See also Appendix A*, Implementation Parameters*.

The RTOS allocates then VISRSTACK bytes for the interrupt routines and VSTACK bytes for every task. These areas are allocated statically at compile time. If your application does not use ISR objects, you would define the VISRSTACK attribute as zero.

The figure below shows the run−time virtual stack:

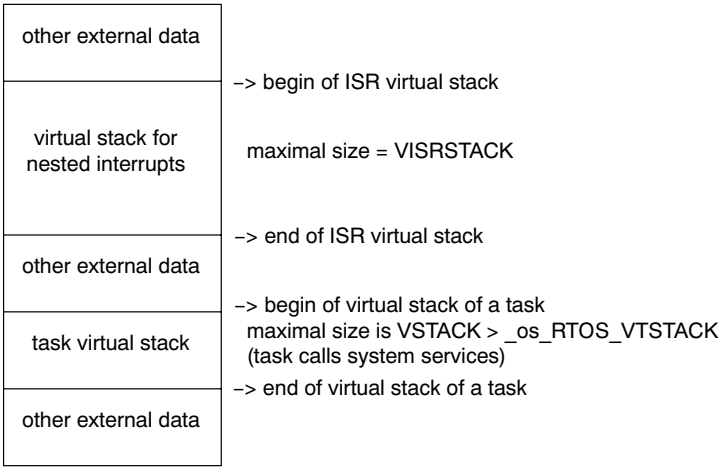


Figure 5−6: Virtual stack

5.8 The C Interface for Tasks

You can use the following data types, constants and system services in your C sources to deal with task related issues.

Element	C Interface
Data Types	TaskType TaskRefType TaskStateType TaskStateRefType
Constants	RUNNING WAITING READY SUSPENDED INVALID_TASK
System Services	DeclareTask ActivateTask TerminateTask ChainTask Schedule GetTaskID GetTaskState

Table 5–2: C Interface for Tasks

Please refer to the OSEK/VDX documentation for an extensive description.

6 Events

Summary

This chapter explains how the RTOS may synchronize tasks via events and describes how you can declare EVENT objects in the OIL file in order to optimize your event configuration.

6.1 Introduction

The OSEK/VDX provides you with events as a synchronization method between tasks. They differentiate basic from extended tasks. Basically, every extended task has a private array of binary semaphores. The array index corresponds with a bit position in an event mask. Thus, waiting on an event mask implies a wait operation on multiple semaphores at a time.

Most hook routines and interrupt service routines can set and check events, however only an extended task owning the event can wait for it and/or clear it.

Since this implementation does not deal with external communication the scope of the events limits to one application.

6.2 Configuring Events

To configure an EVENT, you must declare a specific EVENT object in the application OIL file of the project:

```
EVENT myEvent;
```

You do not need to define values for the standard attribute MASK of the EVENT OIL object. The RTOS will always calculate this value internally.

In this example, *myEvent* becomes the identity of the event, a specific bit value in a mask.

In Appendix A, *Implementation Parameters* you can find the maximum number of events supported by this implementation. If you define more EVENT OIL objects in your application OIL file than the maximum number supported, the system behaviour would be, at least, unpredictable.

6.3 The Usage of Events

1. An extended task might enter the *waiting* state and allow other tasks the CPU time until a certain event occurs. Thus events form the criteria for the transition of tasks from the *running* state into the *waiting* state. The transition is performed with the system service:

   ```
   StatusType WaitEvent(EventMaskType);
   ```

2. A task can undergo such a transition only if it owns that specific event. Or equivalently, the event must belong to the event list of the multiple attribute EVENT of the task.

The following OIL configuration specifies that task *myTask* can only wait for *myEvent1* and *myEvent2*:

OIL file

```
EVENT myEvent1;
EVENT myEvent2;
EVENT myEvent3;

TASK myTask
{
    EVENT = myEvent1;
    EVENT = myEvent2;
}
```

If task *myTask* attempts to wait on another event than *myEvent1* or *myEvent2*, the system service `WaitEvent` fails:

C source file

```
TASK(myTask)
{   /* TASK waits on an allowed event */
    if (E_OK != WaitEvent(myEvent1))
    {
        LogError(WAITEVENT);
        TerminateTask();
    }

    /* CPU has been given to other tasks            */

    /* From another task/ISR the event 'myEvent1'   *
     * has been  set for this task. Now 'myTask'    *
     * can resume execution.                        */

    /* TASK attempts to wait on a 'forbidden' event.*/
```

```
    if (E_OK != WaitEvent(myEvent3))
    {   /* 'myEvent' is not owned by 'myTask' */
        LogError(WAITEVENT);
        TerminateTask();
    }
    ...
    TerminateTask();
    return;
}
```

When the scheduler moves the task from the *ready* to the *running* state, the task resumes execution at the following immediate instruction.

3. A task can wait for several events at a time:

   ```
   WaitEvent(myEvent1 | myEvent2 | ...);
   ```

   The task does not undergo the transition if just one of the events has occurred. In this case the service immediately returns and the task remains in the *running* state. Only when all the events are cleared for the calling task, the invoking task is put into the *waiting* state.

4. `WaitEvent()` can only be invoked from the task level of an extended task, never from interrupt level or a hook routine.

5. You can set an event (equivalent to "an event occurs") to a specific task directly with the system service:

   ```
   StatusType SetEvent(TaskType,EventMaskType);
   ```

6. If you need to trigger an event for more than one task you need to call `SetEvent()` for each combination of task and event.

7. An event can be set indirectly by the RTOS code upon expiration of an alarm (provided that its ACTION attribute is set to SETEVENT in the OIL file) or when a message is transmitted (provided that its NOTIFICATION attribute is set to SETEVENT).

8. An event can be triggered from interrupt level (common situation).

9. You cannot set events to suspended tasks.

10. You can set several events at a time for a *waiting* task or *ready* task:

    ```
    SetEvent( myTask, myEvent1 | myEvent2 | ...)
    ```

    If *myTask* is waiting for any of the triggered events it will enter the *ready* state. If the task is *ready,* the events shall remain set waiting for evaluation in the next call to `WaitEvent()`.

11. You can check which events have been set for a given task with the system service:

    ```
    StatusType GetEvent(TaskType,EventMaskRefType);
    ```

    You can call this service to distinguish which event triggered the task and then take the corresponding action. This service can be called from a hook routine or from interrupt level.

```
TASK(myTask)
{
     EventMaskType event;
     /* Wait for any of three events */
     WaitEvent(myEvent1 | myEvent2 | myEvent3);
     /* Which one occurred? */
     GetEvent(myTask,&event);
     /* take actions */
     if (event | myEvent1)
     {
         Action1();
     }
     if (event | myEvent2)
     {
         Action2();
     }
     if (event | myEvent3)
     {
         Action3();
     }
     TerminateTask();
     return;
}
```

Every time *myTask* gets activated (events are all cleared) it waits for one of the three events. When running again, it uses `GetEvent()` to find out which events have triggered the task.

12. You can clear events yourself with the system service:

```
StatusType ClearEvent(EventMaskType);
```

13. You can call this service only from an extended task level, never from a hook routine, a basic task or an interrupt.

    Adding this service to the previous example you can build a simplified version of an event handler task:

```
TASK(eventHandler)
{
    EventMaskType event;
    while(1)
    {
        /* Wait for any of three events */
        WaitEvent(myEvent1 | myEvent2 | myEvent3);
        /* Which one occurred? */
        GetEvent(eventHandler,&event);
        /* Clear events */
        ClearEvents(myEvent1 | myEvent2 | myEvent3);
        /* take actions */
       if (event | myEvent1)
       {
           Action1();
       }
       if (event | myEvent2)
       {
           Action2();
       }
       if (event | myEvent3)
       {
           Action3();
       }
    }
    TerminateTask();
    return;
}
```

14. Like all other OIL objects you need to declare the event before using it in your source in order to compile your module:

```
DeclareEvent(myEvent);

TASK (task)
{
     ...
     WaitEvent(myEvent);
}
```

6.4 The C Interface for Events

You can use the following data types and system services in your C sources to deal with event related issues.

Element	C Interface
Data Types	EventMaskType EventMaskRefType
Constants	–
System Services	DeclareEvent SetEvent ClearEvent GetEvent WaitEvent

Table 6–1: The C Interface for Events

Please refer to the OSEK/VDX documentation for an extensive description.

7 Resource Management

Summary

This chapter explains how the RTOS performs resource management and describes how you can declare RESOURCE objects in the OIL file in order to optimize your resource configuration.

7.1 Key Concepts

Below a number of key concepts are explained.

Critical code

A critical code section is a piece of software that must be executed atomically to preserve data integrity and hardware integrity. Critical code sections handle for example:

- access to shared variables.
- most manipulations of linked lists.
- code that increment counters

An example of critical code is:

```
i = i + 1;
```

If **i** is initially set to zero and two processes both execute this code, as a result the value of **i** should be incremented to 2. If Process A executes the code and then Process B does, the result will be correct. However, if A executes and, during the increment instruction, process B also executes the same code, **i** may only be incremented to 1.

Mutex

A software entity that prevents multiple tasks from entering the critical section. Acquiring mutexes guarantees serialized access to critical regions of code and protects the calling task from being preempted in favor of another task (which also attempts to access the same critical section), until the mutex is dropped.

Priority inversion

A lower priority task preempts a higher priority task while it has acquired a lock. (See also section 7.3.1, *Priority Inversion*.)

Deadlock

The impossibility of task execution due to infinite waiting for mutually locked resources. (See also section 7.3.2, *Deadlocks*.)

Since OSEK/VDX OS is meant to operate in a critical environment (like the automobile industry) both priority inversion and deadlocks are unacceptable.

7.2 What is a Resource?

The OSEK/VDX standard defines the use of *resources* to coordinate concurrent access of several tasks with different priorities to shared resources. During these processes, the RTOS guarantees that two tasks or interrupt routines do not occupy the same resource at the same time.

A *resource* is the OSEK/VDX version of what the literature commonly refers to as *semaphores* or *mutexes*.

In OSEK context, *resources* are an abstract mechanism for protecting data accesses by multiple tasks or ISRs. A resource request effectively locks the corresponding data against concurrent access by another task. This is usually called a *mutex lock*.
In OSEK it is implemented by temporarily raising the priority of the calling process so that possible other contending lock requests cannot actually happen during the duration of the lock. This mechanism is also known as the *Priority Ceiling Protocol* (see section 7.3, *Priority Ceiling Protocol*).
The important aspect of this particular mutex implementation is that the resource request never waits. This makes it specially suitable for ISRs. In this regard, the priority levels are internally expanded to include all maskable interrupt levels on top of the highest real priority level.

Some general ideas are listed below:

1. You must define resources for critical sections that you encounter in the system which are liable to concurrency problems.
2. You configure resources in your OIL file like:

```
RESOURCE myResource
{
    RESOURCEPROPERTY = STANDARD;
};
```

3. It is useless to define a resource without defining its occupiers. In the OIL file you can configure a task or an interrupt service routine to own a resource (a task or an interrupt service routine *owning* a resource means that they can occupy and release the resource).

Example

Let us assume that *myTask1*, *myTask2* and an asynchronous interrupt service routine named *myISR,* need to update the same global counter *no_counter*. In your OIL file you must configure a new RESOURCE object and define *myTask1, myTask2* and *myISR* as owners of the resource.

OIL file

```
TASK myTask1
{   ...
    RESOURCE = myResource;
};

TASK myTask2
{   ...
    RESOURCE = myResource;
};

ISR myIsr
{   ...
    RESOURCE = myResource;
};
```

The following source code makes sure that the counter update does not suffer from concurrency problems.

C source file

```
TASK (myTask1)
{   ...
    GetResource(myResource);
    no_counter--;
    ReleaseResource(myResource);
    ...
}

TASK (myTask2)
{   GetResource(myResource);
    no_counter--;
    ReleaseResource(myResource);
}

ISR (myIsr)
{   GetResource(myResource);
    no_counter++;
    ReleaseResource(myResource);
}
```

4. Try to avoid superfluous resource definitions. A resource that is owned by only one task is useless. It decreases the performance of the system because:
   - Memory is allocated with the configuration data for a useless resource.
   - Execution speed decreases because of useless system services around not even real critical code.
   - Longer internal searches of the RTOS.

   So, a resource should be owned by at least two tasks, by a task and an interrupt service routine or by two interrupt service routines.

5. You should define only one RESOURCE object for all the critical sections accessed by the same occupiers.

   Let us assume that a second counter *so_counter* needs to be updated globally by these three actors. There is no need yet to change the OIL file.

```
TASK (myTask1)
{
    GetResource(myResource);
    so_counter--;
    ReleaseResource(myResource);
    ...
    GetResource(myResource);
    no_counter--;
    ReleaseResource(myResource);
    ...
}

TASK (myTask2)
{
    GetResource(myResource);
    no_counter--;
    so_counter--;
    ReleaseResource(myResource);
}

ISR (myIsr)
{
    GetResource(myResource);
    no_counter++;
    so_counter++;
    ReleaseResource(myResource);
}
```

But in case this second global counter needs to be updated by a third task *myTask3* and a second ISR *myOtherIsr* then

OIL file

```
TASK myTask1
{
    RESOURCE = myResS;
    RESOURCE = myResN;
};

TASK myTask2
{
    RESOURCE = myResS;
    RESOURCE = myResN;
};

ISR myIsr
{
    RESOURCE = myResS;
    RESOURCE = myResN;
};

TASK myTask3
{
    RESOURCE = myResN;
};

ISR myOtherIsr
{
    RESOURCE = myResN;
};
```

C source file

```
TASK (myTask1)
{   ...
    GetResource(myResS);
    so_counter--;
    ReleaseResource(myResS);
    ...
    GetResource(myResN);
    no_counter--;
    ReleaseResource(myResN);
    ...
}
```

```
TASK (myTask2)
{   ...
    GetResource(myResN);
    no_counter--;
    ReleaseResource(myResN);
    GetResource(myResS);
    so_counter--;
    ReleaseResource(myResS);
    ...
}

TASK (myTask3)
{   ...
    GetResource(myResN);
    so_counter--;
    ReleaseResource(myResN);
    ...
}

ISR (myIsr)
{   ...
    GetResource(myResN);
    no_counter--;
    ReleaseResource(myResN);
    GetResource(myResS);
    so_counter--;
    ReleaseResource(myResS);
    ...
}

ISR (myOtherIsr)
{   ...
    GetResource(myResN);
    so_counter--;
    ReleaseResource(myResN);
    ...
}
```

6. You can not use the system services `TerminateTask`, `ChainTask`, `Schedule`, and/or `WaitEvent` while a resource is being occupied. The task will not leave the *running* state under that condition.

```
ISR (myTask)
{   ...
    GetResource(myRes);
    no_counter--;
    /* This is forbidden - even if myEvent is
       owned by myTask */
    WaitEvent(myEvent);
    ReleaseResource(myRes);
    ...
}
```

7. The RTOS assures you that an interrupt service routine is only processed under the condition that all resources that might be needed by that interrupt service routine are released.

```
TASK (myTask2)
{   ...
    GetResource(myResN);
    /* myIsr and myOtherIsr disabled  */
    no_counter++;
    ReleaseResource(myResN);
    GetResource(myResS);
    /* myIsr disabled */
    so_counter--;
    ReleaseResource(myResS);
    ...
}
```

8. Make sure that resources are not still ocuppied at task termination or interrupt completion since this scenario can lead the system to undefined behaviour. You should always encapsulate the access of a resource by the calls `GetResource` and `ReleaseResource`. Avoid code like:

```
GetResource(R1);
...
switch ( condition )
{
     case CASE_1 :
          do_something1();
          ReleaseResource(R1);
          break;
     case CASE_2 : /* WRONG: no release here! */
          do_something2();
          break;
     default:
          do_something3();
     ReleaseResource(R1);
}
```

The resource can be locked forever, rejecting all further attempts to access the resource.

9. You should use the system services `GetResource` and `ReleaseResource` from the same functional call level. Even when the function `foo` is corrected concerning the LIFO order of resource occupation like:

```
void foo( void )
{
     ReleaseResource( R1 );
     GetResource( R2 );
     /* some code accessing resource R2 */
     ...
     ReleaseResource( R2 );
}
```

there still can be a problem because `ReleaseResource(R1)` is called from another level than `GetResource(R1)`. Calling the system services from different call levels can cause problems.

10. You should not define RESOURCE objects to protect critical code which can only be accessed by tasks with the same priority. The reason is simple: If we join (6) with the idea that VDX/OSEK systems do not allow round–robbin scheduling of tasks at the same priority level, we can conclude that two (or more) tasks, with same priority, accessing critical code will not suffer concurrency problems.

This is the basic idea behind the concept of the *ceiling priority protocol*.

11. Be careful using nested resources since the occupation must be performed in strict last–in–first–out (LIFO) order (the resources have to be released in the reversed order of their occupation order).

OIL file

```
TASK myTask
{
    RESOURCE = myRes1;
    RESOURCE = myRes2;
};
```

C source file

```
TASK(myTask)
{
    GetResource(myRes1);
    ...
    GetResource(myRes2);
    ...
    ReleaseResource(myRes2);
    ReleaseResource(myRes1);
}
```

The below code sequence is incorrect because function `foo` is not allowed to release resource R1:

```
TASK(incorrect)
{
    GetResource( R1 );
    /* some code accessing resource R1 */
    ...
    foo();
    ...
    ReleaseResource( R2 );
}

void foo()
{
    GetResource( R2 );
    /* code accessing resource res_2 */
    ...
    ReleaseResource( R1 );
}
```

12. The RTOS forbids nested access to the same resource. In the rare cases where you need nested access to the very same resource, it is recommended to use a second resource with the same behaviour (so–called *linked resources*).

    You can configure linked resources in your OIL file like:

```
RESOURCE myResS
{
    RESOURCEPROPERTY = STANDARD;
};

RESOURCE myResL
{
    RESOURCEPROPERTY = LINKED
    {
        LINKEDRESOURCE = myResS;
    };
};
```

7.3 The Ceiling Priority Protocol

The OSEK/VDX standard defines the *ceiling priority protocol* in order to eliminate priority inversion and deadlocks.

7.3.1 Priority Inversion

A typical problem of common synchronization mechanisms is *priority inversion.* This means that a lower–priority task delays the execution of higher–priority task.

Let us assume three tasks T1, T2 and T3 with increasing priorities (T1 has the lowest priority and T3 the highest). T1 is running and the otthers are suspended. All tasks are fully preemptable.

Let us assume that T1 and T3 share resource R. Theoretically, the longest time that T3 can be delayed should be the maximum time that T1 locks the resource R.

However let us see what happens in the following time sequence:

1. T1 occupies the resource R.
2. T2 and T3 are activated.
3. T3 preempts T1 and inmediatly requests R.
4. As R is occupied T3 enters the *waiting* state.
5. The scheduler selects T2 as the running task.
6. T1 waits till T2 terminates or enters the *waiting* state.
7. T1 runs again and releases R.
8. T3 immediately preempts T1 and runs again.

Although T2 does not use resource R, it is in fact delaying T3 during its lifetime. So a task with high priority sharing a resource with a task with low priority can be delayed by tasks with intermediate priorities. That should not happen.

7.3.2 Deadlocks

Deadlocks are even more serious when locking resources causes a conflict between two tasks. Each task can lock a resource that the other task needs and neither of the two is allowed to complete.

Imagine what would happen in the following scenario:

1. Task T1 occupies the resource R1.
2. Task T2 preempts T1.
3. Task T2 occupies resource R2.
4. Task T2 attempts to occupy resource R1 and enters the *waiting* state.
5. Task T1 resumes, attempts to occupy resource R2 and enters the *waiting* state.
6. This results in a *deadlock*. T1 and T2 wait forever.

With a properly designed application you can avoid deadlocks but this requires strict programming techniques. The only real safe method of eliminating deadlocks is inherent to the RTOS itself. This RTOS offers the priority ceiling protocol to avoid priority inversion and deadlocks.

7.3.3 Description of The Priority Ceiling Protocol

The principles of the ceiling priority protocol can be summarized as follows:

- At system generation, the RTOS assigns to each resource a ceiling priority. The ceiling priority is set at least to the highest priority of all tasks that access a resource or any of the resources linked to this resource. The ceiling priority must be lower than the lowest priority of all tasks that do not access the resource, and which have priorities higher than the highest priority of all tasks that access the resource.
- If a task requires a resource, and its current priority is lower than the ceiling priority of the resource, the priority of the task will be raised to the ceiling priority of the resource.
- If the task releases the resource, the priority of this task will be reset to its original (rescheduling point).

The problem of priority inversion is eliminated since only one task is actually capable of locking a resource. Refering to the example in the previous section:

1. T1 gets the resource and the RTOS raises its priority to the ceiling priority of the resource R.
2. T3 is activated and shall remain in the *ready* state (at least while T1 locks resource R) since its priority is never higher than the current priority of the system. Remember that T1 can neither terminate nor wait for an event at this phase.
3. T2 is also activated and remains in the *ready* state.

4. T1 finally releases the resource. The RTOS revers its priority to its normal static level. This is a point of rescheduling: T3 starts *running*.
5. T3 terminates and T2 starts *running*.
6. T2 terminates and T1 resumes *running*.

The only drawback is that T2 is inhibited by a lower priority task, T1. But this occurs only during the locking time which can be calculated and/or minimized. The latency time in this scenario for T2 is far less than for T3 in the previous case.

Deadlock is also easily eliminated because T2 cannot preempt T1. T1 must occupy and release (LIFO) R1 and R2 before T2 attempts to take R2.

Ceiling Priority Protocol at Interrupt levels

The extension of the ceiling priority protocol to interrupt levels is also simple in this implementation:

Suppose that a resource R is owned by the interrupt service routines ISR_1...ISR_N and tasks T_1 .. T_N. Let P be the maximum interrupt priority level of these ISRs.

When task T_j occupies R, T_j behaves as a non−preemptable task and all the ISR interrupts with priority P (and lower) are temporarily disabled (all R owners included). Thus, while T_j owns the resource, it can only be preempted by interrupts with a priority higher than P. Since T_j runs as non−preemptable, even if high priority tasks are activated from an ISR_2 interrupt with higher priority than P, they will not be scheduled until T_j releases resource R.

When the task T_j releases R, the priority of this task is reset to its original (rescheduling point). Possible pending interrupts (with priority P or lower) and/or higher priority ready tasks (activated by interrupts with priority higher than P) are now allowed to execute.

When the interrupt service routine ISR_j gets resource R, all other ISR interrupts with priority P (and lower) are temporarily disabled (this includes all other R owners) until R is released. The RTOS must handle possible nested accesses to resources at different priority levels

7.3.4 Calculating the Ceiling Priority

This RTOS implementation adds a non−standard attribute to the RESOURCE object:

```
UINT32 WITH_AUTO [0..255] CEILING=AUTO;
```

where the ceiling priority is calculated for every resource. Although you can assign your own value for this attribute (overwriting the generated RTOS value) in the OIL file, you should always let the RTOS generate the value for you!

See Chapter 12, *Debugging an RTOS Application*, for a description about how to check that value with the debugger.

Consider the following OIL file configuration:

```
RESOURCE R1 {RESOURCEPROPERTY = STANDARD;};
RESOURCE R2 {RESOURCEPROPERTY = STANDARD;};
RESOURCE R3 {RESOURCEPROPERTY = STANDARD;};
RESOURCE R4 {RESOURCEPROPERTY = STANDARD;};

TASK T
{   PRIORITY = 5;
    RESOURCE = R1;
    RESOURCE = R2;
    RESOURCE = R3;
};

TASK T1
{   PRIORITY = 6;
    RESOURCE = R1;
};

TASK T2
{   PRIORITY = 7;
    RESOURCE = R2;
    RESOURCE = R4;
};

TASK T3
{   PRIORITY = 8;
    RESOURCE = R3;
};

TASK T4
{   PRIORITY = 10;
    RESOURCE = R4;
};

TASK T5
{   PRIORITY = 9;
    RESOURCE = R2;
};

TASK T6
{   PRIORITY = 8;
    RESOURCE = R4;
    RESOURCE = R3;
};
```

The generated CEILING attributes are:

```
RESOURCE R1 {CEILING = 6; };
RESOURCE R2 {CEILING = 9; };
RESOURCE R3 {CEILING = 8; };
RESOURCE R4 {CEILING = 10;};
```

If we assume a fully preemptive policy:

```
TASK (T)
{   /* priority 5: all tasks can preempt */
    GetResource(R1);
    /* priority 6: all tasks, but T1, can preempt */
    GetResource(R2);
    /* priority 9: only T4 can preempt */
    GetResource(R3);
    ReleaseResource(R3);
    ReleaseResource(R2);
    /* priority 6 */
    ReleaseResource(R3);
    /*priority 5 */
    TerminateTask();
}
```

In the example below the priorities become different:

```
TASK (T)
{   /* priority 5: all tasks can preempt */
    GetResource(R1);
    /* priority 6: all tasks, but T1, can preempt */
    GetResource(R3);
    /* priority 8: T4 and T5 can preempt */
    GetResource(R2);
    /* priority 9: only T4 can preempt */
    ReleaseResource(R2);
    /* priority 8 */
    ReleaseResource(R3);
    /* priority 6 */
    ReleaseResource(R3);
    /*priority 5 */
    TerminateTask();
}
```

7.4 Grouping Tasks

What is a group of Tasks?

The RTOS allows tasks to combine aspects of preemptive and non−preemptive scheduling by defining groups of tasks.

For tasks which have the same or lower priority as the highest priority within a group, the tasks within the group behave like non−preemptable tasks. For tasks with a higher priority than the highest priority within the group, tasks within the group behave like preemptable tasks.

How to group Tasks

You can use an internal resource to define explicitely a group of tasks (or equivalently: a group of tasks is defined as the set of tasks which own the same internal resource).

```
RESOURCE resInt
{
    RESOURCEPROPERTY = INTERNAL;
};
```

The RTOS automatically takes the internal resource when an owner task enters the *running* state (not when the task is activated). As a result, the priority of the task is automatically changed to the ceiling priority of the resource. At the points of rescheduling the internal resource is automatically released (the priority of the task is set back to the original).

In the following configuration all the tasks are initially suspended. An event triggers the task *infirst* to activate. The idle task is preempted and the task *infirst* will start execution. Because it owns the internal resource *resInt*, the task starts running with the ceiling priority of *resInt* (3) instead of with its static priority (1). This is the starting point in next example.

Example

OIL file

```
TASK infirst
{   PRIORITY = 1;
    RESOURCE = resInt; };

TASK insecond
{   PRIORITY = 2;
    RESOURCE = resInt; };

TASK inthird
{   PRIORITY = 3;
    RESOURCE = resInt; };

TASK outfirst
{   PRIORITY = 2; };

TASK outsecond
{   PRIORITY = 4; };
```

C source file

```
TASK (outfirst)
{
     TerminateTask();
}

TASK (inthird)
{
     TerminateTask();
}

TASK (outsecond)
{
     TerminateTask();
}

TASK (infirst)
{
    Activate(outfirst);
    /* infirst runs; outfirst is ready */
    ActivateTask(inthird);
    /* infirst runs: inthird is ready */
    ActivateTask(outsecond);
    /* outsecond has run */
    /* infirst resumes execution */
    Schedule();
    /* inthird and outfirst have run */
    TerminateTask();
}
```

Features of internal resources are:

- A task can belong exclusively to a one group of tasks therefore owning a maximum of one internal resource.
- Internal resources cannot be occupied and/or released in the standard way by the software application but they are managed strictly internally within a clearly defined set of system functions.

Determining the most appropiate range for the priorities of tasks owning an internal resource, becomes a key factor in the design. In most cases, this range of priorities should be reserved exlusively for the members of the group. Otherwise, low priority tasks in the group could delay tasks outside the group with higher priority. This is exactly what has happened in the previous example: *outfirst* was delayed by *infirst*.

7.5 The Scheduler as a Special Resource

The scheduler can be considered as a special resource that can be locked by the running task. As a result, while the running task has locked the scheduler, it behaves like a non–preemptive task (with the same re–scheduling points).

If you plan to use the scheduler as a resource, you must first set the attribute USERESSCHEDULER to TRUE in the OS object of your OIL file. C source code then can look as follows:

```
TASK(myTask)
{   ...
    /* preemptable */
    GetResource(RES_SCHEDULER);
    /* I am non-preemptable */
    ReleaseResource(RES_SCHEDULER);
    /* preemptable */
    ...
}
```

- You can neither define nor configure this resource in the user OIL file. It is a system resource generated by the RTOS and already present in this OSEK/VDX implementation.
- You do not need to add it to the resource list of any task.
- Interrupts are received and processed irrespective of the state of the resource.

Declaring a resource

Like all other OIL objects you need to declare the resource before using it in your C source:

```
DeclareResource(myResource);

TASK (myTask)
{
    GetResource(myResource)
    ...
}
```

7.6 The C Interface for Resources

You can use the following data types, constants and system services in your C sources to deal with resource related issues.

Element	C Interface
Data Types	ResourceType
Constants	RES_SCHEDULER
System Services	DeclareResource GetResource ReleaseResource

Table 7–1: C Interface for Resources

Please refer to the OSEK/VDX documentation for an extensive description.

8 Alarms

Summary

This chapter describes how the RTOS offers alarms mechanisms based on counting specific recurring events and describes how you can declare these objects in the OIL file in order to optimize your alarm configuration.

8.1 Introduction

The RTOS provides services for processing recurring events. A recurring event is an abstract entity which has been defined in the scope of a particular application. Each application monitors its events, therefore, differently. A ”wheel has rotated five more degrees” or ”routine `f` has been called” could be examples of recurring events.

Each of these recurring events must be registered in a dedicated counter (a COUNTER OIL object). You must increment this counter each time the associated event occurs. In the ’wheel’ example, you probably increment the counter in an interrupt service routine. In the ’routine’ example, you increment the counter in the body of `f`.

Based on these counters, you can install *alarms*. ”Activation of a specific task every time the wheel rotates 180 degrees” or ”setting an event when routine `f` has been called ten times” are examples of such alarms.

We say that an alarm expires when the counter reaches a preset value. You can bind specific actions to alarms and the RTOS execute these actions upon expiration of the alarms.

8.2 Counters

8.2.1 What is a Counter?

A counter is an abstract entity directly associated with a recurring event. The counter registers happenings of its event (ticks) in a counter value (which must be incremented every time the event takes place).

The OSEK/VDX standard does not provide you with means to interact with a counter object at run time.

Let us assume that your application needs to monitor the rotation of a wheel. Your application software, project agreement, works with one degree as the atomic unit in the system. You must define a COUNTER object in your OIL file to represent the rotated angle:

```
COUNTER sensorC
{   MAXALLOWEDVALUE = 359;
    MINCYCLE        = 5;   };
```

MAXALLOWEDVALUE is set to 359 since this corresponds to one complete full turn (360 degrees is equivalent to 0 degrees).

MINCYCLE depends on the application sensibility and/or the hardware itself. In this example, your application cannot log any action that happens before the wheel has rotated five degrees.

You build the application regardless of the hardware interface that shall, eventually, monitor the wheel rotation. Ideally the dependency on such a device should be minimized.

Suppose three different sensors S1, S2, S3 are candidates for the hardware interface. They all interface equally with your chip (the pulse is converted into an external IO hardware interrupt). But they send the pulses at different rates, S1 every quarter of a degree, S2 every half a degree and S3 every degree.

The impact of this on your application is minimal. You only need to modify the TICKSPERBASE attribute of your OIL file. This attribute defines how many ticks are requested to increase the counter unit by one. Hence, the value for the attribute must be 4 (if S1), 2 (if S2) and 1 (if S3).

If we select S2, the OIL file would look as follows:

```
COUNTER sensorC
{
    MAXALLOWEDVALUE = 100;
    TICKSPERBASE    = 2;
    MINCYCLE        = 5;

};
```

After processing the OIL file, the OSEK/VDX implementation defines the following constants for you:

```
OSMAXALLOWEDVALUE_sensorC : 100
OSTICKSPERBASE_sensorC    : 2
OSMINCYCLE_sensorC        : 5
```

If the counter demands hardware or software initialization, you can use the `StartUpHook()` routine to place the initialization code.

You are responsible for detecting the recurring events of your own counters and, as a follow–up, notifying the RTOS. You must inform the RTOS about the arrival of a new sensor tick with the system service:

```
StatusType IncrementCounter(CounterType);
```

In this example you must increment the counter in the handler of the IO hardware interrupt connected to the sensor:

```
ISR (sensorHandler)
{
    IncrementCounter(sensorC);
    ...
}
```

See section 9.3, *Defining an Interrupt in the C Source*, in Chapter *Interrupts*.

Some other OSEK/VDX implementations might offer you extra API services to set the counter internal value, to reset it, and so on. This implementation exclusively adds the necessary `IncrementCounter()` API to the standard.

8.2.2 The RTOS System Counter

The implementation always offers one counter that is derived from a hardware timer. This counter is known as the *system counter*. The unit of time is the *system tick* (as the interval between two consecutive hardware clock interrupts).

The implementation parameter OSTICKDURATIONINMSCS defines the length (in miliseconds) of the system tick. The OSEK/VDX standard does not provide you with the concept of a timer interface. If you want to time certain actions in your application, you must declare an alarm with the system timer as a counter:

```
ALARM myAlarm
{
    COUNTER = SYSTEM_TIMER;
};
```

If you plan to use the system counter, i.e. if you define ALARM OIL objects that are based on the system_counter, you first need to set the non-standard attribute of the OS OIL object USERTOSTIMER to TRUE.

```
OS myOS
{
    USERTOSTIMER = TRUE { RTOSTIMERLEVEL = 1; };
};
```

The RTOSTIMERLEVEL sub-attribute declares the entry of the timer interrupt in the Interrupt Vector Table. The RTOS needs this information to build the interrupt framework. The timer interrupt behaves as a Category 2 ISR (See section 9.4, *The Category of an ISR object*, in Chapter *Interrupts* to learn what Category 1 and Category 2 interrupts are).

When the USERTOSTIMER attribute is set to TRUE, the RTOS code calls the following routine to initialize the system counter during the start–up process:

```
extern void InitRTOSTimer(void);
```

You are responsible for providing a definition for the routine. Otherwise, the linking phase will fail due to unresolved externals.

The advantages of this method are listed below:

- You decide exactly which hardware resources are taken by the system counter.
- You decide how these resources are used.
- A general method, for all hardware systems and derivatives, is extremely hard to define.

And the constraints:

- The interarrival time of the clock hardware interrupt must be OSTICKDURATIONINMSCS mscs. (See Appendix A, *Implementation Parameters*.)
- You cannot handle application code in the clock interrupt.
- You cannot define an interrupt handler at entry RTOSTIMERLEVEL in Vector Table.

Besides, you need to define three extra routines:

1. `void DisableRTOSTimer(void);`

   Disables the clock maskable interrupt associated with the system counter.

2. `void EnableRTOSTimer(void);`

   Enables the clock maskable interrupt associated with the system counter.

3. `void ReloadRTOSTimer(void);`

   Reloads, if not auto–reload, the associated timer registers (otherwise, empty). To be called from the interrupt framework.

A failure to define any of these three routines will be detected at linking phase.

As the RES_SCHEDULER object, you can neither define nor configure this counter (the SYSTEM_TIMER object) in the OIL file. It is a counter already generated by the RTOS and already present in this OSEK/VDX implementation.

Following the same discussion you cannot call the `IncrementCounter()` system service with SYSTEM_TIMER as parameter.

The OSEK/VDX implementation defines the following system constants related to the system timer:

- OSMAXALLOWEDVALUE
  This value determines the upper limit for the timer value unit.
- OSTICKSPERBASE
  This value determines how many clock ticks constitute a timer unit.
- OSMINCYCLE
  This value represents an absolute minimum for the possible expiring times of system alarms. You can set alarms which actions are meant to happen after OSMINCYCLE time units.
- OSTICKDURATION
  The timer duration in nanoseconds.
- OSTICKDURATIONINMSCS
  The timer tick duration in miliseconds.

The values for these parameters depend on the RTOS implementation. You can look them up in Appendix A, *Implementation Parameters*.

8.3 What is an Alarm?

An alarm is a counter based mechanism to provide services to activate tasks, set events or call specific routines when the alarm expires. When you set an alarm, you basically state two things: (1) a preset value for the counter and (2) the action to be triggered when the counter reaches that value.

1. You must attach an alarm to only one counter (although it is possible to attach multiple alarms to the same counter). In the OIL file this looks like follows:

```
COUNTER sensorC
{   MAXALLOWEDVALUE = 100;
    TICKSPERBASE    = 2;
    MINCYCLE        = 1;   };

ALARM sensorAE
{   COUNTER = sensorC;  };

ALARM sensorAA
{   COUNTER = sensorC;  };
```

2. In the OIL file you must configure the action to be performed when the alarm expires. This information is permanent: it is not possible to change the associated action to an alarm at runtime.

3. You can configure an alarm to set a specific event when the alarm expires. In that case, you must specify which event is set and to which task.

```
ALARM sensorAE
{
    COUNTER = sensorC;
    ACTION  = SETEVENT
    {
        TASK  = sensorT;
        EVENT = sensorE;
    };
};
```

   When the alarm reaches the preset value, the RTOS code sets event *sensorE* to task *sensorT*'. If task *sensorT* waits for such an event (normal case) this becomes a point of rescheduling.

4. You can configure an alarm to activate a certain task when it expires:

```
ALARM sensorAA
{
    COUNTER = sensorC;
    ACTION  = ACTIVATETASK
    {
        TASK  = sensorT;
    };
};
```

When the alarm reaches the preset value, the RTOS code will try to activate task *sensorT*. If task *sensorT* is in the *suspended* state, this becomes a point of rescheduling.

5. You can configure an alarm to run a *callback* routine when it expires.

```
ALARM sensorAC
{
    COUNTER = sensorC;
    ACTION  = ALARMCALLBACK
    {
        CALLBACK  = ”myCallBack”;
    };
};
```

A callback must be defined in the application source like:

```
ALARMCALLBACK(myCallBack)
{
    /* application processing */
}
```

The processing level of a callback would be an Interrupt Service Routine. Besides, the OSEK/VDX standard forbids preemption during the routine execution by means of suspending Category 2 interrupts. Therefore this implementation expects very short code for the callback routines.

6. You can use the system service `SetRelAlarm()` to predefine a counter value for an alarm to expire relative to the actual counter value:

```
StatusType SetRelAlarm(AlarmType alarm,
                  TickType increment, TickType cycle);
```

When this sytem service is invoked, the alarm is set to expire at the current value of the counter plus an *increment* (if the alarm is not in use, obviously). The increment value must be, in all cases, at least equal to the MINCYCLE attribute of the associated counter.

The *cycle* parameter determines whether the alarm is periodic or not. If not zero, the alarm is restarted upon expiration with *cycle* as a new timeout interval (at least equal to the MINCYCLE attribute of the associated counter). If *cycle* equals to zero, the alarm will not be restarted.

This service can be called at task or interrupt level but not from hook routine level. Below you will find an example of how to install an alarm that will activate task *sensorT* every 90 degrees:

```
SetRelAlarm(sensorAA,90,90);
```

7. You can use the system service `SetAbsAlarm()` to predefine a counter value for an alarm to expire in absolute terms:

```
Type SetAbsAlarm(AlarmType alarm,TickType increment, TickType cycle);
```

When this sytem service is invoked the alarm is set to expire at an specific absolute value of the counter (if the alarm is not in use, obviously). The *cycle* determines whether the alarm is periodic or not. If not zero, the alarm is restarted upon expiration with *cycle* as a new timeout interval. If *cycle* equals to zero,k the alarm will not be restarted.

This service can be called at task or interrupt level but not from hook routine level.

Below you find an example of how to install an alarm that sets event *sensorE* to task *sensorT* exactly when the wheel angle is 0 or 180 degrees:

```
SetAbsAlarm(sensorAE,0,180);
```

8. You can configure an alarm to run at startup. Normally, these are periodic alarms carrying out periodic actions required by the application. Even before the first tasks have been scheduled, the alarm is already running to expiration.

   You must set the attribute AUTOSTART to TRUE. The subattributes ALARMTIME and CYCLETIME behave the same as *increment* and *cycle* for the `SetRelAlarm()` system service. You must indicate also under which application modes the alarm should autostart.

   The next example counts the total number of turns:

   OIL file

```
APPMODE AppModeA;
ALARM sensorAC
{
    COUNTER = sensorC;
    ACTION  = ALARMCALLBACK
    {
        CALLBACK  = ”myCallBack”;
    };
    AUTOSTART = TRUE
    {
        CYCLETIME = 359;
        APPMODE   = AppModeA;
        ALARMTIME = 359;
    };
};
```

   The alarm will autostart if the environment is correct:

   C source file

```
DeclareAppMode(AppModeA);

int no_turns = 0;

int main(int argc)
{
    StartOS(AppModeA);
    return;
}
```

```
ALARMCALLBACK(myCallBack)
{
    no_turns++;
}
```

9. You can use a combination of the system services `GetAlarm()` and `CancelAlarm()` to set timeouts associated to actions.

   ```
   StatusType GetAlarm(AlarmType, TickRefType);
   ```

   ```
   StatusType CancelAlarm(AlarmType)
   ```

   With the `GetAlarm()` routine you can check whether the alarm has already expired or not. With the `CancelAlarm()` routine you actually cancel a running alarm.

   The next example shows how to set a timeout associated with an action:

   ```
   TASK(sensorT)
   {
       TickType tick;
       ...
       /* start alarm */
       setRelAlarm(sensorAE,90,0);
       /* indicate I am waiting Action */
       WaitAction();
       /* wait for the event: It is set when the action
          has completed or by the alarm */
       WaitEvent(sensorE);
       /* the event has been set */
       GetAlarm(sensorAE,&tick);
       if (tick)
       {
           /* Action was completed */
           CancelAlarm(sensorAE);
       }
       else
       {
           /* Timeout */
       }
       ...
       TerminateTask();
   }
   ```

10. You can use the system counter as a generator for software timers. A software timer basically guarantees the application that a certain action will occur after a certain period. If (1) the action is short enough to be the body of a callback function and (2) the time period in which the action must occur is 500 milisecs, and (3) assuming that an alarm *SoftwareTimer* has been already declared, the next system call will take care of executing the callback code in exactly 500 miliseconds.

    ```
    SetRelAlarm(SoftwareTimer,(500/OSTICKDURATIONINMSCS),0);
    ```

11. You can use `SetRelAlarm()`, `WaitEvent()` and `ClearEvent()` to workaround an OSEK/VDX version of an standard *delay s*ervice.

OIL file

```
EVENT delayE;
TASK myTask
{
    EVENT = delayE;
};

ALARM delayA
{
    COUNTER = SYSTEM_TIMER;
    ACTION  = SETEVENT
    {
         TASK = myTask;
         EVENT = delayE;
    };
};
```

C source file

```
TASK(myTask)
{ ...
  /* delay the system one sc */
  SetRelAlarm(delayA,(1000)/(OSTICKDURATIONINMSCS),0);
  WaitEvent(delayE);
  ClearEvent(delayE);
  ...
  TerminateTask();
}
```

Declaring an alarm

Like all other OIL objects you need to declare the task before using it in your source in order to compile your module:

```
DeclareAlarm(myAlarm);

TASK (myTask)
{
    CancelAlarm(myAlarm)
    ...
}
```

8.4 The C Interface for Alarms

You can use the following data types and system services in your C sources to deal with alarm related issues.

Element	C Interface
Data Types	TickType TickRefType AlarmBaseType AlarmBaseRefType AlarmType
Constants	OSMAXALLOWEDVALUE_x ('x' is a counter name) OSTICKSPERBASE_x ('x' is a counter name) OSMINCYCLE_x ('x' is a counter name) OSMAXALLOWEDVALUE OSTICKSPERBASE OSMINCYCLE OSTICKDURATION OSTICKDURATIONINMSCS SYS_TIMER
System Services	DeclareAlarm DeclareCounter GetAlarmBase GetAlarm IncrementCounter SetRelAlarm SetAbsAlarm CancelAlarm

Table 8–1: The C Interface for Alarms

Please refer to the OSEK/VDX documentation for an extensive description.

9 Interrupts

Summary

This chapter describes how you can declare ISR objects in the application OIL file in order to optimize the interrupt configuration.

9.1 Introduction

An interrupt is a mechanism for providing immediate response to an external or internal event. When an interrupt occurs, the processor suspends the current path of execution and transfers control to the appropriate Interrupt Service Routine (ISR). The exact operation of an interrupt is so inherently processor−specific that they may constitute a major bottleneck when porting applications to other targets.

In most of the embedded applications the interrupts constitute a critical interface with external events (where the response time often is crucial).

9.2 The ISR Object

Among the typical events that cause interrupts are:

- Overflow of hardware timers
- Reception/Transmission of Serial Character
- External Events
- Reset

Please check the documentation of your core to find out the interrupt sources of the core you are using.

Every interrupt has to be associated with a piece of code called *Interrupt Service Routine* (or: ISR). The architecture defines a specific *code address* for each ISR, which is stored in the, *Interrupt vector Table* (IVT).

The interrupt execution steps are listed below:

1. CPU finishes the instruction it is currently executing and stores the PC on the system stack
2. CPU saves the current status of all interrupts internally
3. Fetches the ISR address for the interrupt from IVT and jumps to that address
4. Executes the ISR until it reaches the RETI instruction
5. Upon RETI, the CPU pops back the old PC from the stack and continues with whatever it was doing before the interrupt occurred.

Defining an ISR object in the OIL file

Should your application make use, for example, of an external interrupt, you define one ISR OIL object in your OIL file:

```
ISR isrExternal
{
...
};
```

The RTOS software continously needs to enable/disable particular interrupts to avoid fatal preemptions. Each of the 8051 interrupts has its own enable/disable bit in a Special Function Register. (Check beforehand the manual of your core and/or the `.sfr` files in the `$(PRODDIR)/c51/include` directory.)
The RTOS enables the interrupt by setting the corresponding bit.

You provide the RTOS with this information as a non−standard attribute of the ISR OIL object. See also the next section 9.2.1, *The ISR Non−Standard Attributes*.

Depending on the used core, different levels of interrupt priority levels are offered. The RTOS does not modify the priority level of any interrupt at run−time (except from possible extensions of the Ceiling Priority Protocol to interrupt level).

You normally place the initialization code for the ISR objects in the `StartupHook` routine (where they are also normally enabled). However, in specific applications, you might want to do this (if at all) later.

9.2.1 The ISR Non–Standard Attributes

This implementation defines two non–standard attributes for the ISR OIL objects:

LEVEL
ENBIT

They help the RTOS to configure the interrupt.

LEVEL

Determines the entry in the vector table. The type of the LEVEL attribute is UINT32 and the possible values range from 0 to 31. LEVEL has no default value.

ENBIT

The ENBIT attribute specifies the SFR register bit that enables/disables the ISR. The type of this attribute is STRING. It has no default value.

The example below shows an OIL configuration example for a system with an external interrupt:

```
ISR isrExternal
{
    LEVEL = 0;
    ENBIT = EX0;
};
```

The following situations are prohibited by the implementation:

- Define two ISRs objects with the same value for their LEVEL attribute. The link phase shall fail since two routines become equal candidate for the same interrupt handler.
- Define two ISR objects with the same value for their ENBIT attribute. This is a more dangerous situation since the program compiles, links and builds.
- Define a name for the ENBIT attribute which is not defined in the `.sfr` include file. The compiler phase then already fails.
- Build your interrupt framework outside the RTOS scope. You cannot use the function qualifier `_interrupt()` to declare an interrupt since the RTOS would not have any control of it.

9.3 Defining an Interrupt in the C Source

To define an interrupt service routine, you must use the macro `ISR` in your application software. You must pass the name of the related ISR object in the OIL file as parameter to the macro:

```
ISR(isrTimer)
{
     ... code ...
     return;
}
```

The OSEK/VDX implementation uses this macro to encapsulate the implementation–specific formatting of the routine definition (*isrTimer* is the identity of the ISR related object and has *IsrType* type). The C name of the function that correspond to the interrupt service routine is created by prepending the tag *_os_u_*. The function can then be viewed with the debugger using the mingled name: *_os_u_isrTimer*.

The OSEK/VDX standard, focusing on portability, internally hides all the intrinsic details of the target. Migration to another platform should have almost no impact on your application source code. You remain unaware of how internally the interrupt framework is built, i.e. how the RTOS dispatches the execution flow to *_os_u_isrTimer()* when a timer interrupt is generated.

9.4 The Category of an ISR Object

OSEK/VDX defines two types of interrupts by ISR category: 1 and 2.

Category 1

These ISRs cannot use system services. The internal status of the RTOS before and after the interrupt always prevails. After the ISR has finished, processing continues exactly at the same instruction where the interrupt occurred.

ISRs of this category have the least overhead and since they can always run concurrently with the RTOS code, they are hardly disabled. They execute normally at high priorities and have small handlers.

An example could be a serial interrupt that provides `printf` functionality.

```
ISR isrSerial
{
    CATEGORY = 1;
    LEVEL    = 4;
    ENBIT    = ES;
};
```

Category 2

These ISRs can use a subset of system services. Thus the internal status of the RTOS might have been altered after the ISR has been served. Now, after the ISR's handler, processing may (or may not) continue exactly at the same instruction where the interrupt did occur. If no other interrupt is active and the preempted task does not have the highest priority among the tasks in the "ready–to–run array" anymore, rescheduling will take place instead.

ISRs of this category have the most overhead and because they cannot always run concurrently with the RTOS code (they access internals of the RTOS via their system services), they are constantly enabled/disabled.

An example could be a serial interrupt receiving characters and storing them in a buffer. When a 'end–of–frame' character is received, a message is sent to a task in order to process the new frame.

```
ISR isrSerial
{
    CATEGORY    = 2;
    LEVEL       = 4;
    ENBIT       = ES;
};
```

These interrupts typically require a task to be activated, an event to be set, or a message to be sent. The list of available system services follows:

```
ActivateTask                GetTaskID
GetTaskState                GetResource
ReleaseResource             SetEvent
GetEvent                    GetAlarmBase
GetAlarm                    SetRelAlarm
SetAbsAlarm                 CancelAlarm
GetActiveApplicationMode    ShutdowOS
```

Category 2 ISRs can establish, for instance, run–time differences in functionality with the `GetApplicationMode` system service.

9.5 Nested ISRs

The peripheral IO interrupts are maskable interrupts. They can be preempted if:

- the incoming ISR has a higher PRIORITY value.
- the incoming ISR has the same PRIORITY value but higher harware priority (check your chipset manual).

The attribute MAXNESTEDISR of the OS object configures the maximum run−time depth of nested interrupt levels.

You may encounter problems when interrupts of different categories are nested. The premises are:

- All interrupts must be processed before returning to task level.
- Rescheduling takes place on termination of an ISR of category 2 but only at first nesting level.

What happens then if a Category 2 ISR2 interrupts a category 1 ISR1?

No rescheduling takes place in *ISR2* because it is a nested interrupt, but also not when *ISR1* is falling back to task level. Therefore having high priority tasks activated or events set from interrupt level in *ISR2* has caused no rescheduling and the system has returned to task level at the very same point. Thus any activities corresponding to the calls of the operating system in the interrupting *ISR2* are unbounded delayed until the next rescheduling point.

You can solve this situation by configuring all the Category 1 ISRs so that they can never be preempted by any Category 2 ISR. Thus the highest priority among all Category 2 ISRs should be lower than the lowest priority among all category 1 ISRs.

9.6 ISRs and Resources

In Chapter 7, *Resource Management*, it was described how we can use resources to avoid concurrency problems when several tasks and/or isrs have access to the same critical code section. If your ISR demands manipulation of a certain critical section, which access is controlled by resource R, you need to add R to the list of resources owned by the ISR.

The OSEK/VDX standard offers you the standard attribute RESOURCE (a multiple reference of type RESOURCE_TYPE) to add resources to the list of resources owned by the ISR.

Category 1 ISRs cannot own resources.

If *isrUART1* and *isrUART0* are ISR OIL objects that update the same counter (increased by one unit in *isrUART1* and decreased by one unit in *isrUART0*) in their handlers, they must own the same resource R. A task *printNetto* can also be activated to output the value.

OIL file

```
ISR isrUART0
{
    CATEGORY = 2;
    RESOURCE = R;
};

ISR isrUART1
{
    CATEGORY = 2;
    RESOURCE = R;
};

TASK printNetto
{
    RESOURCE = R;
    ...
};
```

C source file

```
DeclareResource(R);

ISR(isrUartTx)
{
    GetResource(R);
    netto_counter--;
    ReleaseResource(R);
}
```

```
ISR(isrUartRx)
{
    GetResource(R);
    netto_counter++;
    ReleaseResource(R);
}

TASK(printNetto)
{
    int netto;
    GetResource(R);
    netto = netto_counter;
    ReleaseResource(R);
    printf("%d",netto);
}
```

9.7 ISRs and Messages

In Chapter 10, *Interprocess Communication*, it will be described how an ISR object might be defined as a sender and/or a receiver of messages. In both cases the ISR object must own the message. Messages are used to pass information between interrupt service routines, like you pass arguments to a function.

The OSEK/VDX standard offers you the standard attribute MESSAGE (a multiple reference of type MESSAGE_TYPE) to add messages to the list of messages owned by the ISR.

Let us suppose that an ISR object *isrSender* sends a message to another ISR object *isrRec*. Your application OIL file and C source file now look like follows.

OIL file

```
MESSAGE recMsg
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {
         SENDINGMESSAGE = sendMsg;
         INITIALVALUE   = 1;
    };
};

MESSAGE sendMsg
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
         CDATATYPE = "int";
    };
};
```

C source file

```
DeclareMessage(sendMsg);
DeclareMessage(recMsg)

ISR(isrSender)
{
    int data = GetData();
    SendMessage(sendMsg,&data);
    ...
    return;
}

ISR(isrRec)
{
    int data;
    ReceiveMessage(recMsg,&data);
    ProcessData(data);
    ...
    return;
}
```

9.8 Fast Disable/Enable API Services

The OSEK/VDX standard provides you with a number of fast disable/enable API functions. The implementation hides all the internal target details for you. These services come always in pairs.

9.8.1 Disable/Enable All Interrupts

You can use the following system services to disable/enable all maskable interrupts:

```
void DisableAllInterrupts(void);

void EnableAllInterrupts(void);
```

The `DisableAllInterrupts()` service clears the global interrupt enable bit and saves the current state.

The `EnableAllInterrupts()` service does the opposite, it restores the saved state in the previous routine.

You can call these services from Category 1 ISR and Category 2 ISR and from the task level, but not from hook routines.

These services are intended to encapsulate a critical section of the code (no maskable interrupts means no scheduling which in its turn means no concurrency). It is a much faster and costless alternative to the `GetResource/ReleaseResource` routines.

```
TASK(myTask)
{
    ...
    DisableAllInterrupts();
    /* critical code section */
    EnableAllInterrupts();
    ...
}
```

The critical area should be extremely short though, since the system as a whole is on hold (even Category 1 ISRs are disabled!). `DisableAllInterrupts()` must always precede the critical section and immediately after the section, `EnableAllInterrupts()` must follow.

Avoid situations situations like below:

```
ISR(isr)
{
    DisableAllInterrupts();
    if (A)
    {
        EnableAllInterrupts();
        doSth();
    }
    else
    {
    ...
    }
    return;
}
```

This causes the system to be outbalanced when returning from *isr* if A is zero.

Also, no API service calls are allowed within this critical section. You must avoid code like below:

```
TASK(myTask)
{
    ...
    DisableAllInterrupts();

    /* critical code section */
    SetEvent(task,event);           /* not allowed */

    EnableAllInterrupts();
    ...
}
```

You should be careful when building library functions which are potential users of of these services, since nested calls are never allowed. Avoid situations like below:

```
static void f(void)
{
    DisableAllInterrupts();
    otherThings();
    EnableAllInterrupts();
    return;
}
```

```
TASK(myTask)
{
    ...
    DisableAllInterrupts();
    someThings();
    f();
    EnableAllInterrupts();
    ...
    return;
}
```

As a rule of thumb you should try to avoid function calls while in the critical section.

9.8.2 Suspend/Resume All Interrupts

You can use the following system services to suspend/resume all maskable interrupts:

```
void SuspendAllInterrupts(void);

void ResumeAllInterrupts(void);
```

They enhance the previous pair `Disable/EnableAllInterrupts()` in order to allow nesting. In case of nesting pairs of calls, the interrupt recognition status saved by the first call of `SuspendAllInterrupts()` is restored by the last call of the `ResumeAllInterrupts()` service.

```
static void f(void)
{
    /* nothing happens with the status */
    SuspendAllInterrupts();
    otherThings();
    /* status is not yet restored */
    ResumeAllInterrupts();
    return;
}

TASK(myTask)
{   ...
    /* status is saved now */
    SuspendAllInterrupts();
    someThings();
    f();
    /* status is restored now */
    ResumeAllInterrupts();
    ...
    return;
}
```

The considerations for the pair `DisableAllInterrupts` / `EnableAllInterrupts` apply here too.

9.8.3 Suspend/Resume OS Interrupts

The previous pairs disabled all maskable interrupts, including your Category 1 ISRs, while in the critical code section. However, theoretically there is no need to disable the Category 1 ISRs in order to prevent concurrency problems (they are never a rescheduling point).

If you do not want to disable a Category 1 ISR while executing certain critical code, you can use the following pair to encapsulate the section instead:

```
void SuspendOSInterrupts(void);

void ResumeOSInterrupts(void);
```

This pair saves and restores the status of only the Category 2 ISRs. The overhead in code is bigger since they must go through the interrupt enable bits for all Category 2 ISRs to save/restore their priority levels .

OIL file

```
ISR myISR1
{
    CATEGORY = 1;
};

ISR myISR2
{
    CATEGORY = 2;
};
```

C source file

```
TASK(myTask)
{   ...
    SuspendOSInterrupts();
    /* critical code */
    /* myISR1 is enabled */
    /* myISR2 is disabled */
    ResumeOSInterrupts();
    ...
    return;
}
```

The considerations for the pair `DisableAllInterrupts` / `EnableAllInterrupts` apply here too. Like the pair `SuspendAllInterrupts` / `ResumeAllInterrupts`, nesting is allowed.

9.9 The C Interface for Interrupts

You can use the following data types and system services in your C sources to deal with interrupt related issues.

Element	C Interface
Data Types	–
Constants	–
System Services	EnableAllInterrupts DisableAllInterrupts ResumeAllInterrupts SuspendAllInterrupts ResumeOSInterrupts SuspendOSInterrupts

Table 9–1: The C Interface for Interrupts

Please refer to the OSEK/VDX documentation for an extensive description.

10 Interprocess Communication

Summary

This chapter describes why the communication services offer you a robust and reliable way of data exchange between tasks and/or interrupt service routines and how you can declare MESSAGE and COM objects in the application OIL file.

10.1 Introduction

The OSEK/VDX COM normative document provides interfaces for the transfer of data within networks systems.

Although the COM and OS standards could be mutually exclusive, this implementation combines them both. The implementation OIL file (see section 3.3.1, *Implementation Part*, in Chapter *OIL Language*) already defines two COM OIL objects: the MESSAGE and COM objects. So in the application OIL file you configure both the OS and the COM. Both the OS and the COM APIs are included in the system header file `osek.h`. You must include this header file in your C source to compile your application.

As was stated in Chapter 1, *Introduction to the RTOS Kernel*, this implementation supports only a subset (internal communication) of COM3.0. In internal communication the interprocess communication is limited to a single microcontroller where a physical network does not exist.

This COM implementation provides all the features defined by the OSEK/DVX standard for the Communication Conformance Class CCCB.

Without the benefit of communication services, the only possibility for tasks and interrupt service routines to share data is the usage of global data. Although this mechanism might be extremely effective in some cases, it fails to satisfy the most general case. The communication services offer you a robust and reliable way to exchange data.

The conformance class CCCB

The main purpose of conformance classes is to ensure that applications that were built for a particular conformance class are portable across different OSEK/VDX COM implementations and CPUs featuring the same level of conformance class. The CCCB conformance class

- Does not offer support for external communication.
- Supports both unqueued/queued messages.

- Supports SendMessage/ReceiveMessage routines.
- Incorporates Notification Mechanisms (only Class 1).
- Supports `GetMessageStatus()` API.

Within this conformance class only the interaction layer is implemented and not the network and/or data link layers. This implementation allows you the transfer of data between tasks and/or interrupt service routines within the same CPU.

10.2 Basic Concepts

This section presents some basic concepts and definitions.

One sender sends a message to one or more receivers

This is the leading principle of the communication mechanism. Throughout the whole OSEK/VDX documentation, source code examples, etc. you will find sentences like “the task *TaskA* sends message *M* to tasks *TaskB* and *TaskC* and to the interrupt service routine *ISRA*”. In this case, for the message *M*, *TaskA* is the sender and *TaskB*, *TaskC* and *ISRA* are the receivers. This situation is taken as an example for the rest of this section.

Message

The message is the physical application data that is exchanged between a sender and its receivers. A message can have zero (or more) senders and zero (or more) receivers.

Messages are equal to data, i.e. bits. It has no direct OIL representation. The set ’sender(s) of a message’, ’message data’ and ’receiver(s) of a message’ represents a closed unit of communication. On both the sender and receiver sides there must be an agreement about the type of the exchange message data.

Sender of a message

A TASK (or an ISR) OIL object can be allowed to send a particular message. The sender qualifier relates to a *specific* message. A TASK (or an ISR) OIL object, for example, can be a sender for message *M1*, a receiver for message *M2*, and none of both for message *M3*.

In the example, *TaskA* prepares the data and uses the system service `SendMessage()` to starts the transmission to the receivers.

Receiver of a message

A TASK (or an ISR) OIL object can be allowed to receive a particular message. Like the sender, the receiver qualifier relates to a *specific* message. A TASK (or an ISR) OIL object, for example, can be a receiver for message *M1*, a sender for message *M2*, and none of both for message *M3*.

In the example, *TaskB*, *TaskC* and *ISRA* use the system service `ReceiveMessage()` to receive the data sent by *TaskA*.

Unqueued Receive Message

On the receiving side an *unqueued* message is not consumed by reading; it returns the last received value each time it is read.

If in the example the message *M* is unqueued for *TaskB* and *ISRA*, both will read from the same buffer on the receive side when using `ReceiveMessage()`. The buffer is overwritten for both *TaskB* and *ISRA* only when *TaskA* sends new data (`ReceiveMessage()` keeps reading the same value meanwhile). More than one receiver can read from the same unqueued buffer.

Queued Receive Message

On the receiving side a *queued* message can only be read once (the read operation removes the oldest message from the queue).

If in the example the message *M* is queued for *TaskC*, there will be a dedicated receive queue buffering the messages for *TaskC* (every queued receiver has its own receive queue). The queue size for a particular message is specified per receiver. If a receive queue is full and a new message arrives, the message is lost for this receiver. Obviously to prevent this situation, the average processing time of a message should be shorter than the average message interarrival time.

Send Message Object

The *send message object* is the internal container where the data is stored on the sending side, every time that a sender of the message attempts to send the message.

In the example there will be only one send message object for *TaskA*.

Receive Message Object

The *receive message object* is the internal container where the data is stored on the receiving side. The message object is available for an arbitrary number of receivers if the message is unqueued, or for only one receiver when queued.

In the example there will be two receive message objects, one for *TaskB* and *ISRA* (which size is the size of the transmitted data) and a second one for *TaskC* (which size is the size of the transmitted data times the size of the queue).

Symbolic Name

A symbolic name is the application identification for a message object (*send* or *receive*).

A symbolic name identifies either a send message object or a received message object for an unqueued receive message or a received message object for a queued receive message. In fact, the symbolic name becomes an alias for the container.

10.3 Configuring Messages

For every message you must define one symbolic name on the sending side. On the receiver side you must define one symbolic name for all the receivers that do not queue the message. Or you must define one extra symbolic name for every receiver that does queue the message.

The phases of message configuration are shown below, with help of the example in the previous section.

1. Isolate all the messages in the system.

   M has been identified as the only messages for the system.

2. Identify the Send Message Object for every message.

   M has one Send Message Object, let us call it *sendM*.

3. Configure the Send Message Objects in the application OIL file

   You configure a send message object by defining a MESSAGE OIL object with the value for its MESSAGEPROPERTY set to SEND_STATIC_INTERNAL.

   In this case (and assuming that the type of the transmitted data is the built−in type integer):

```
MESSAGE sendM
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE=”int”;
    };
};
```

4. Configure the senders of the messages.

   The senders of the message *M* are those TASK and/or ISR OIL objects that can use the system service `SendMessage()` to send the message *M* to its receivers (if any).

   The OSEK/VDX standard offers you the standard attribute MESSAGE (a multiple reference of type MESSAGE_TYPE) in the TASK/ISR OIL objects to add messages to the list of messages owned by the TASK or ISR.

   In order to define the TASK *TaskA* as a sender of message *M* you only need to add *sendM* to the message list of the *TaskA* object:

```
TASK TaskA
{
    MESSAGE =  sendM;
};
```

5. Identify the Receive Message Objects for every message.

   M has two receive message objects. Let us call them *recMU* and *recMQTaskC*.

6. Configure the Receive Message Objects in the application OIL file.

   You configure an unqueued receive message object by defining a MESSAGE OIL object with its value for its MESSAGEPROPERTY set to RECEIVE_UNQUEUED_INTERNAL.

   You configure a queued receive message object by defining a MESSAGE OIL object with its value for its MESSAGEPROPERTY set to RECEIVE_QUEUED_INTERNAL. The subattribute QUEUESIZE defines the length of the receive queue.

   In both cases, the subattribute SENDINGMESSAGE defines which is the related Send Message Object. In our example:

```
MESSAGE recMU
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL;
    {
        SENDINGMESSAGE = sendM;
    };
};

MESSAGE recMQTaskC
{
    MESSAGEPROPERTY = RECEIVE_QUEUED_INTERNAL;
    {
        SENDINGMESSAGE = sendM;
        QUEUESIZE      = 5;
    };
};
```

7. Configure the receivers of the messages.

   The receivers of the message *M* are those TASK and/or ISR OIL objects which can use the system service `ReceiveMessage()` to read the transmitted data of message *M*.

   The OSEK/VDX standard offers you the standard attribute MESSAGE (a multiple reference of type MESSAGE_TYPE) in the TASK/ISR OIL objects to add messages to the list of messages owned by the TASK or ISR.

   To define the TASK *TaskB* and the ISR *ISRA* as unqueud receivers for message *M* you need to add *recMU* to the message list of the *TaskB* and *ISRA* objects. And to define the TASK *TaskC* as a queued receiver for message *M* you need to add *recMQTaskC* to the message list of the *TaskC*' object:

```
TASK TaskB
{
    MESSAGE =  recMU;
};
```

```
TASK ISRA
{
    MESSAGE =  recMU;
};

TASK TaskC
{
    MESSAGE =  recMQTaskC;
};
```

10.4 Message Transmission

10.4.1 Sending a Message

Sending a message requires the transfer of the application message *data* to all the receiving message objects. This process is done automatically for internal communication.

You now can use the following system service to send a message:

```
StatusType sendMessage(SymbolicName msg,
                       ApplicationDataRef DataRef);
```

msg a Send Message Object in your file with value SEND_STATIC_INTERNAL for its MESSAGEPROPERTY attribute. *msg* must belongs to the MESSAGE list of the sender.

DataRef points to the application data to be transmitted (the type of `ApplicationDataRef` is a pointer to void).

In our example this could lead to the following C source code:

```
DeclareMessage(sendM);

TASK (TaskA)
{
    int data = getData();
    ...
    data = getData();
    SendMessage(sendM,&data);
    ...
    TerminateTask();
}
```

When you return from the `SendMessage()` system service, the data has already been transmitted (i.e. copied) into the receive message objects.

10.4.2 How to Define the Data Type of a Message

When the value of the subattribute CDATATYPE for a SEND_STATIC_INTERNAL message does not correspond to a basic type, you need to add an extra header file in the project that contains the type definition (the RTOS software needs this information to build its internal buffers). The name of the file is hard coded in the RTOS code as `mytypes.h` and its location must be the project folder.

Let us assume that you want to send a message whose layout can be divided into a header (first byte), payload (next 20 bytes), and crc (last byte). You must edit the file `mytypes.h` with the type definitions:

```
#ifndef _MYTYPES_H
#define _MYTYPES_H

#define PAYLOADSIZE 20
typedef struct mystruct myStruct;

struct mystruct
{
    unsigned char header;
    unsigned char payload[PAYLOADSIZE];
    unsigned char crc;
};

#endif
```

If you configure a MESSAGE OIL object like:

```
MESSAGE sendM
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE=”myStruct”;
    };
};
```

but you fail to provide the type definition for *myStruct* in the `mytypes.h` file, the RTOS code will not compile.

At system generation time, the attribute LENGTH of a MESSAGE OIL object stores the size in bytes of the indicated CDATATYPE attribute (`sizeof(myStruct)`). This is done automatically by the RTOS tools. Thus, since the LENGTH of the message is known by the RTOS, a call to `SendMessage()` copies LENGTH number of bytes into the receive objects (starting at `DataRef`).

In our example:

```
#include ”mytypes.h”

DeclareMessage(sendM);
```

```
TASK (TaskA)
{
    myStruct st;
    /* prepare the message */
    st.header = 0x12;
    for (i=0;i<PAYLOADSIZE;i++)
    {
        st.payload[i] = 0;
    }
    st.crc = 0xFF;
    /* send message to receive objects */
    SendMessage(sendM,&st);
    ...
    TerminateTask();
}
```

10.4.3 Receiving a Message

To receive a message, use the following system service:

```
StatusType ReceiveMessage(SymbolicName msg, ApplicationDataRef DataRef);
```

msg a Receive Message Object in your file which MESSAGEPROPERTY attribute has either RECEIVE_UNQUEUED_INTERNAL or RECEIVE_QUEUED_INTERNAL as value. *msg* must belong to the MESSAGE list of the receiver.

DataRef points to the application data to be transmitted (the type of `ApplicationDataRef` is a pointer to void).

When the application calls the `ReceiveMessage()` system service, the message object's data are copied to the application buffer pointed to by *DataRef*.

Queued messages

If the MESSAGEPROPERTY of *msg* is RECEIVE_QUEUED_INTERNAL, *msg* refers to a queue receive message object (queued message).

A *queued message* behaves like a FIFO (first–in first–out) queue. When the queue is empty, no message data will be provided to the application. When the queue is not empty and the application receives the message, the application is provided with the oldest message data and removes this message data from the queue. If new message data arrives and the queue is not full, this new message is stored in the queue. If new message data arrives and queue is full, this message is lost and the next `ReceiveMessage` call on this message object returns the information that a message has been lost.

```
TASK (TaskC)
{
    myStruct st;
    StatusType ret;
    ...
    ret = ReceiveMessage(recMQTaskC,&st);
    if (ret == E_COM_NOMSG)
    {
        /* Queue is empty: no new messages */
        /* st contains no valid data       */
        return;
    }
    /* st contains valid data */
    if (ret == E_COM_LIMIT)
    {
        /* A message has been lost */
    }
    else
    {
        /* Everything is okey */
    }

    processMsg(&st);

    ...
    TerminateTask();
}
```

A separate queue is supported for each receiver and messages from these queues are consumed independently. The OIL configuration below is erroneous since a second receiver cannot access the same queue receive message object.

```
TASK TaskD
{
    MESSAGE =  recMQTaskC;
};

TASK TaskC
{
    MESSAGE =  recMQTaskC;
};
```

Should our sender *TaskA* transmit the message to a new queue receiver *TaskD*, a new queue receive message object must be added to the OIL file:

```
TASK TaskD
{
    MESSAGE =  recMQTaskD;
};

MESSAGE recMQTaskD
{
    MESSAGEPROPERTY = RECEIVE_QUEUED_INTERNAL;
    {
        SENDINGMESSAGE = sendM;
        QUEUESIZE      = 5;
    };
};
```

Unqueued messages

If the MESSAGEPROPERTY of *msg* is RECEIVE_UNQUEUED_INTERNAL, 'msg' refers to a unqueue receive message object (unqueued message).

Unqueued messages do not use the FIFO mechanism. The application does not consume the message during reception of message data but a message can be read multiple times by an application once it has been received. If no message has been received since the application started, the application receives the message value set at initialization. Unqueued messages are overwritten by new messages that arrive.

```
TASK (TaskB)
{
    myStruct st;
    ...
    if (E_OK != ReceiveMessage(recMU,&st);
    {
        /* an error occurred */
    }
    else
    {
        /* message has been read */
        processMsg(&st);
    }
    ...
    TerminateTask();
}
```

Contrary to queue receive message objects, the addition of new receivers for an unqueued message is straightforward. You only need to add the *recMU* message object to the MESSAGE list of the new receivers in the OIL file:

```
TASK TaskD
{
    MESSAGE =  recMU;
};
```

However, a receiver can never own more than one symbolic name per message (a maximum of one queue and/or unqueue receive message objects per message per receiver). The configuration below is therefore erroneous:

```
TASK TaskC
{
    MESSAGE =  recMQTaskC;
    MESSAGE =  recMU;
};
```

10.4.4 Initializing Unqueued Messages

Since the OSEK/VDX COM standard allows only the senders to send messages, the initial value of messages theoretically could only be set by a TASK/ISR sender of the message. Consequently, every attempt to receive a message before the application actually sent the message will contain indeterminated data.

For a queued message this is not a problem since a returned value of `ReceiveMessage()` equal to E_COM_NOMSG indicates that no message has arrived yet to the queue.

You should consistently check the returned status when receiving queued messages.

For an unqueued message, none of the possible returned values indicate this situation and the application probably continues with erroneous data.

There is a workaround for it which uses Notification Mechanisms. See section 10.5.3, *Notification Example: Flag*. A better practice is to initialize the unqueued receive message object before any receiver tries to read it.

The OSEK/VDX standard provides you with the following ways to initialize unqueued messages:

1. Assign a value to the INITIALVALUE subattribute in the MESSAGE OIL object:

```
MESSAGE sendM
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE=”int”;
    };
};
```

```
MESSAGE recMU
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendM;
        INITIALVALUE = 3;
     };
};
```

To guarantee that *recMU*' cannot be received before its container has been initialized with the value 3, this initialization is performed in the `StartCOM()` routine.

See section 10.6.1, *Starting the COM*, for more information regarding the com hook routine `StartCOM()`.

However, note that OIL only allows the specification of a limited range of unsigned integer initialization values. This means that OIL can only be used to initialize messages that correspond to unsigned integer types within OIL's range of values. Thus the OIL configuration below makes no sense:

```
MESSAGE sendM
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE="myStruct";
    };
};

MESSAGE recMU
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendM;
        INITIALVALUE   = 3;
    };
};
```

2. Let the `StartCOM()` routine initialize the unqueued message with the default value zero. Again this applies only when the messages correspond to unsigned integer types within OIL's range of values.
3. You can always use the following system service to initialize messages that are too large or too complex for their initial value to be specified in the OIL file:

   ```
   StatusType InitMessage(SymbolicName msg, ApplicationDataRef DataRef);
   ```

   Although you can call the `InitMessage()` routine at any point in the application's execution, the safest practice is to initialize all unqueued messages in the hook routine `StartCOMExtension()`.

See section 10.6.2, *Starting the COM Extension*, for more information regarding the com hook routine `StartCOMExtension()`.

```
StatusType StartCOMExtension(void);
{
    myStruct st;
    /* prepare the default message */
    st.header = 0x12;
    for (i=0;i<PAYLOADSIZE;i++)
    {
        st.payload[i] = 0;
    }
    st.crc = 0xFF;
    /* initialize the receive message object recMU */
    InitMessage(recMU,&st);
    ...
    TerminateTask();
}
```

You can also use `InitMessage()` to reset your unqueued messages at any moment (after you have called `StartCOM()` and before you call `StopCOM()`).

10.4.5 Long versus Short Messages

Sending a message involves the copying of data from an application buffer into (at least one) receive message objects. Reversely, receiving a message involves the copying of data from a receive message object into an application buffer.

Concurrency problems to protect critical data are resolved inside the RTOS code by means of temporarily suspending all Category 2 ISRs (and the system timer).

While copying to/from unqueue receive message objects we need always protection against concurrency, thus Category 2 ISRs must be always disabled during the copy process. As a simple mental exercise, imagine what would happen if a *SendMessage* call is preempted by another *SendMessage*. After the two calls, the buffer data are corrupted (a mix of both messages).

While copying to/from queue receive message objects, concurrency problems can be avoided without real need to disable Category 2 ISRs (implementing locks in every member of the message queue). So, keeping interrupts enabled while copying the messages is certainly possible. Extra software is needed to handle locks in the queue. If the messages to be copied are very long, you simply cannot allow interrupts to be disabled during the whole copy process. However, if messages are so short that interrupts can be easily disabled during the copy process, this extra handling should be best avoided.

If you set the non−standard attribute LONGMSG to TRUE, Category 2 ISRs are disabled while the copy process of queued messages and extra software (i.e. run−time performance) is needed. If set to FALSE, Category 2 ISRs are enabled but no extra software is needed.

10.5 Message Notification

So far you know how to send and receive messages. The question that still remains is: how does the receiver know that the sender has just sent a new message?

For queued messages the receiver can survive by constantly checking the receive queue. For unqueued messages the receivers have no means to know whether a new message has arrived or whether it is still the old one. There must exist ways to synchronize senders and receivers.

The OSEK/VDX standard defines standard notification mechanisms as a follow up of the transmition and/or reception of a message. For internal communication only Notification Class 1 is supported which means that as soon as the message has been stored in the receive message object, a notification mechanism is invoked automatically.

Check the OSEK/VDX COM documentation for more information about other Notification Classes. They do not apply, however, to internal communication since internal transmission is always performed before returning from the `SendMessage()` system service and without loss of data.

The following notification mechanisms are provided:

Callback routine
A callback routine provided by the application is called.

Flag
A flag is set. The application can check the flag with the `ReadFlag` API service. Resetting the flag is performed by the application with the `ResetFlag` API service. Additionally, calls to `ReceiveMessage` reset also the flag

Task
An application task is activated.

Event
An event for an application task is set.

The notification mechanism can be defined only for a receiver message object. With these mechanisms you can synchronize the copy of data into the receive message object with the receiver.

Since Notifications occur before returning from `SendMessage()`, this system service becomes a rescheduling point for the RTOS. Thus the application may or may not return immediately from the system service (imagine what happens if a higher priority task is activated).

10.5.1 Notification Example: Activate Task

Imagine an application with a serial line command handler. The race condition for the reception of the command is the arrival of a line feed. At that moment the serial ISR object *serialRx* must send a message to a TASK object called *commandHandler* with the new command. The task *commandHandler* interpretates the given commands and has the highest priority.

A possible OIL configuration for this system is shown below:

```
ISR SerialRx
{   MESSAGE = sendCommand; };

TASK commandHandler
{
    MESSAGE = recCommand;
    ACTIVATION = 3;
};

MESSAGE sendCommand
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {   CDATATYPE="myCommand"; };
};

MESSAGE recCommand
{
    MESSAGEPROPERTY = RECEIVE_QUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendCommand;
        QUEUESIZE = 3;
    };
    NOTIFICATION = ACTIVATETASK
    {   TASK = commandHandler; };
};
```

The sender message object of the command message is *sendCommand*. The only owner of the sender object is *SerialRx*, it is the only sender. When the race condition is met, the command message is sent with the last buffered command from the ISR code. The command is copied to all the receiver objects, in this case only *recCommand*. And since there is a Notification mechanism defined for this receive object, the task *commandHandler* is also activated. Upon return from the ISR code the *commandHandler* task is running. This tasks receives the oldest message of the *recCommand* queue message object and interpretates it.

This method is safe. The only problem that could arise would be an overrun in the ISR receive buffer in case the execution time in the ISR code `SendMessage()` exceeds the minimal interarrival time between two consecutive interrupts.

10.5.2 Notification Example: Set Event

Consider the OIL configuration below:

```
ISR SerialRx
{
    MESSAGE = sendCommand;
};

EVENT commandEvent;

TASK commandHandler
{
    MESSAGE     = recCommand;
    ACTIVATION  = 3;
    EVENT       = commandEvent;
};

MESSAGE sendCommand
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {   CDATATYPE="myCommand"; };
};

MESSAGE recCommand
{
    MESSAGEPROPERTY = RECEIVE_QUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendCommand;
        QUEUESIZE      = 3;
    };
    NOTIFICATION = SETEVENT
    {
        TASK  = commandHandler;
        EVENT = commandEvent;
    };
};
```

In this solution the *commandHandler* task is never in the *suspended* state, it remains most of the time *waiting* for event *commandEvent*. The Notification mechanism for *recCommand* sets now *commandEvent* immediately after that the command message was copied to the receive object in the ISR code. Upon return from the ISR, the task *commandHandler* resumes execution, clears the event *commandEvent*, receives and interpretates the message before waiting again for the event.

This method is far less safe than the previous one. Apart from the previous problem there is a second drawback. If the cycle “clear event, receive message, interpretate message, wait event” is longer than the minimum time between the arrival of two consecutive serial commands, events could sometimes get lost and some commands would not be processed.

10.5.3 Notification Example: Flag

Associated with a receive message object, a flag will be set when a new message overwrites the container. It remains set until the application explicitely resets the flag or calls `ReceiveMessage()`.

Although theoretically available for all messages, the Notification Flag mechanism normally applies only to unqueued messages. The drawback is that when the flag is set, all you know is that at least one message arrived since the `ReceiveMessage()` call. But you never can tell how many messages you might have lost in between. But it does solve the problem of uninitialized unqueued messages.

Next you will find another configuration for the previous problem:

```
ISR SerialRx
{
    MESSAGE = sendCommand;
};

TASK commandHandler
{
    MESSAGE = recCommand;
};

MESSAGE sendCommand
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {   CDATATYPE = "myCommand"; };
};

MESSAGE recCommand
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {   SENDINGMESSAGE = sendCommand; };
    NOTIFICATION = FLAG
    {   FLAGNAME = "FlgComm";          };
};
```

In the C source below, the task *commandHandler* checks every POLLMSCS, the flag associated with the receive object *recCommand*. If the flag is set, the task receives the message, otherwise it enters again the *waiting* state for the next POLLMSCS.

You can check the status of the Flag with the following API:

```
FlagValue ReadFlag_FlgComm(void);
```

If the returned value is COM_TRUE, the Flag was set: a new message has been received.

```
#include ”flag.h”
#include ”mytypes.h”

DeclareMessage(recCommand);

TASK (commandHandler)
{
    myStruct st;
    while(1)
    {
        if (COM_TRUE == ReadFlag_FlgComm())
        {
            ReceiveMessage(recCommand,&st);
            processMsg(&st);
        }
        else
        {
            SetRelAlarm(alarm,
                 (POLLMSCS)/(OSTICKDURATIONINMSCS),0);
            WaitEvent(event);
            ClearEvent(event);
        }
    }
    TerminateTask();
    return;
}
```

You must always include the file `flag.h` when using Flag Notification Mechanisms. Otherwise your application will not compile.

This solution is even less safe. It assumes that the minimum average interarrival time between two consecutive commands is at least greater than POLLMSCS plus the code execution overhead in the while loop.

10.5.4 Notification Example: Callback

A COM Callback must be defined in your application source as follows:

```
COMCallOut (myCallOut)
{
     ...
     return COM_TRUE;
}
```

The return type for a `COMCallout` routine is `CalloutReturnType`.

In the previous example:

```
ISR SerialRx
{
    MESSAGE = sendCommand;
};

MESSAGE sendCommand
{
    MESSAGEPROPERTY = SEND_STATIC_INTERNAL
    {
        CDATATYPE=”myCommand”;
    };
};

MESSAGE recCommand
{
    MESSAGEPROPERTY = RECEIVE_UNQUEUED_INTERNAL
    {
        SENDINGMESSAGE = sendCommand;
    };
    NOTIFICATION    = COMCALLBACK
    {
        CALLBACKROUTINENAME = ”myCallOut”;
    };
};
```

10.6 Starting and Ending the COM

10.6.1 Starting the COM

The OSEK/VDX COM standard provides you with the following service to start the communication component:

```
StatusType StartCOM(COMApplicationModeType mode);
```

For internal communication this service performs little: basically it sets some internal variables and, if applicable, it initializes all the unqueued receive message objects with the value of their standard attribute INITIALVALUE.

The `StartCOM()` routine supports the possibility of starting the communication in different configurations with the parameter *mode* (like the application modes and `StartOS()`). You can define different modes with the multiple standard attribute COMAPPMODE in the COM OIL object. The type of this multiple attribute is STRING.

The OSEK/VDX implementation forces you to call the routine `StartCOM()` from task level. Be carefull: `StartCOM()` must be called before any COM activity takes places in the system.

A good practice could be the use of an autostarting task performing some possible extra OS initialization plus calling `StartCOM()`. This task becomes the only “real” autostarting task in the configuration, the “old” other autostarting tasks will be activated directly from this task (which runs non–preemptable).

OIL file

```
TASK Init
{
    SCHEDULE = NON;
    ACTIVATION = 1;
    AUTOSTART = TRUE { APPMODE=validMode; };
};

COM myCOM
{
    COMAPPMODE = ”COMMODE”;
};
```

C source file

```
DeclareComAppMode(COMMODE);

TASK(Init)
{   /* Whatever is left to initialize */
    InitOS();
    /* if other tasks need to run at startup */
    ActivateTask(autoT1);
    ...
    ActivateTask(autoTN);

    StartCOM(COMMODE);
    TerminateTask();
}
```

10.6.2 Starting the COM Extension

If in the OIL file the standard attribute COMSTARTCOMEXTENSION of the COM OIL object is set to TRUE, the `StartCOM` routine calls a user–supplied function called `StartCOMExtension` to interfere with the start–up process.

See section 10.4.4, *Initializing Unqueued Messages* to learn about how to use this com hook routine in order to initialize messages that are too large or too complex for their initial value to be specified in the OIL file.

10.6.3 Stopping the COM

The OSEK/VDX COM standard provides you with the following service to stop the communication component:

```
StatusType StopCOM(COMShutdownModeType mode);
```

If the given parameter *mode* equals to COM_SHUTDOWN_IMMEDIATE, the service shuts down the communication component immediately. This implementation does not define any other additional shutdown mode for the COM component. Thus, you should always call this service with COM_SHUTDOWN_IMMEDIATE as parameter.

`StopCOM()` sets the system ready for a new call to `StartCOM()`.

10.7 The C Interface for Messages

You can use the following data types and system services in your C sources to deal with message related issues.

Element	C Interface
Data Types	SymbolicName ApplicationDataRef FlagValue COMApplicationModeType COMShutdownModeType COMServiceIdType LengthRef CalloutReturnType
Constants	COM_SHUTDOWN_IMMEDIATE E_COM_ID E_COM_LENGTH E_COM_LIMIT E_COM_NOMSG
System Services	StartCOM StopCOM GetCOMApplicationMode InitMessage SendMessage ReceiveMessage GetMessageStatus ResetFlag_*Flag* ReadFlag_*Flag* COMErrorGetServiceId

Table 10–1: The C Interface for Messages

Please refer to the OSEK/VDX documentation for an extensive description.

11 Error Handling

Summary

This chapter helps you to understand the available debug facilities and error checking posibilities. Describes which services and mechanisms are available to handle errors in the system and how you can interfere with them by means of customizing certain Hook Routines.

11.1 Introduction

This chapter helps you to understand the available debug facilities and error checking posibilities of an OSEK/VDX system.

All these techniques should constitute the “debug module” which is included in the application during the development phase.

11.2 Error Handling

11.2.1 Standard Versus Extended Status

Most of the system services have a `StatusType` return type. All services return E_OK when no error occurs. However the number of possible return values for each system service depends on the error status mode that you configure in the application OIL file: STANDARD or EXTENDED. In both cases a return value from a system service not equal to E_OK means that an error has occurred.

It is recommended to select extended status while your are developing the system. In this mode the system services perform extra routinary integrity checks like:

- Service calls from legal location (many services are forbidden at interrupt level or at hook routines).
- Integrity of objects (they must be defined in the OIL file)
- Validity of ranges (passed values might have limited ranges, like you cannot set an alarm to expire after zero cycles)
- Consistency in configuration (a task must own a resource if it attempts to take it, or own a message if it attempts to send/receive it)

All these extra return codes can be tested only in extended error mode. To run in extended mode you must set the attribute STATUS of the OS object in the OIL file to EXTENDED.

When you finished debugging and the application is ready to be released, you should enable the standard mode. Since these tests will not be included in the program you will benefit from smaller images and faster programs. You must then set the attribute STATUS of the OS object in the OIL file to STANDARD.

Be aware that you cannot test on extended error codes while running in standard mode.

So far we have referred to OSEK/VDX OS, but in an equivalent manner the OSEK/VDX COM defines also standard and extended error checking modes for the system services of the OSEK/VDX COM module. You can define this error checking mode for the COM routines by setting the COMSTATUS attribute of the COM object to COMSTANDARD or COMEXTENDED.

Fatal Errors

So far we have been speaking about application errors: the RTOS cannot perform the service request correctly but assumes the correctness of its internal data.

If the RTOS cannot assume the correctness of its internal data, it will not return from the system services. The RTOS will call the `ShutdownHook` instead (provided that the standard attribute SHUTDOWNHOOK of the OS OIL object is TRUE). These are *Fatal Errors*.

See also section 4.5, *The Shutdown Process*.

11.2.2 The ErrorHook Routine

In both *standard* and *extended* modes, when a system service returns a `StatusType` value not equal to E_OK, the RTOS calls the `ErrorHook()` routine (provided that you set the ERRORHOOK attribute of the OS object to TRUE):

```
void ErrorHook(StatusType);
```

If ERRORHOOK is set but you fail to define the `ErrorHook()` routine in your code, the linking phase will fail due to unresolved externals.

`ErrorHook()` is called at the end of the system service and immediately before returning to the calling function.

The RTOS does not call `ErrorHook` if the failing system service is called from the `ErrorHook` itself (recursive calls never occur). Therefore you can only detect possible errors in OS system services in the `ErrorHook` itself by evaluating directly their return value.

Macro services inside ErrorHook()

Once inside the `ErrorHook()` routine, the RTOS provides you with mechanisms to access valuable information. With these mechanisms you can check which system service has failed and what its parameters were. You can use the macro services listed in the next table for this purpose.

Macro Service	Description
OSErrorGetServiceId()	Provides the system service identifier where the error occurred. The return value of the macro is a service identifier of type `OSServiceIdType` and its possible values are: OSServiceID_GetResource OSServiceID_ReleaseResource OSServiceID_GetTaskID OSServiceID_StartOS OSServiceID_ActivateTask OSServiceID_TerminateTask OSServiceID_GetTaskState OSServiceID_Schedule OSServiceID_GetActiveApplicationMode OSServiceID_GetSystemTime OSServiceID_GetAlarmBase OSServiceID_GetAlarm OSServiceID_SetRelAlarm OSServiceID_SetAbsAlarm OSServiceID_CancelAlarm OSServiceID_SetEvent OSServiceID_GetEvent OSServiceID_WaitEvent OSServiceID_ClearEvent OSServiceID_ShutdownOS OSServiceID_IncrementCounter The value of the standard attribute of the OS object USEGETSERVICEID must be set to TRUE.
In all cases below the standard attribute of the OS object USEPARAMETERACCESS must be set to TRUE.	
OSError_GetResource_ResID()	Returns the value of parameter *ResID* of the failing system service *GetResource*.
OSError_ReleaseResource_ResID()	Returns the value of parameter *ResID* of the failing system service *ReleaseResource*.
OSError_StartOS_Mode()	Returns the value of parameter *Mode* of the failing system service *StartOS*.
OSError_ActivateTask_TaskID()	Returns the value of parameter *TaskID* of the failing system service *ActivateTask*.
OSError_ChainTask_TaskID()	Returns the value of parameter *TaskID* of the failing system service *ChainTask*.
OSError_GetTaskState_TaskID()	Returns the value of parameter *TaskID* of the failing system service *GetTaskState*.
OSError_GetTaskState_State()	Returns the value of parameter *State* of the failing system service *GetTaskState*.
OSError_GetAlarmBase_AlarmID()	Returns the value of parameter *AlarmID* of the failing system service *GetAlarmBase*.
OSError_GetAlarmBase_Info()	Returns the value of parameter *Info* of the failing system service *GetAlarmBase*.

Macro Service	Description
OSError_SetRelAlarm_AlarmID()	Returns the value of parameter *AlarmID* of the failing system service *SetRelAlarm*.
OSError_SetRelAlarm_increment()	Returns the value of parameter *increment* of the failing system service *SetRelAlarm*.
OSError_SetRelAlarm_cycle()	Returns the value of parameter *cycle* of the failing system service *SetRelAlarm*.
OSError_SetAbsAlarm_AlarmID()	Returns the value of parameter *AlarmID* of the failing system service *SetAbsAlarm*.
OSError_SetAbsAlarm_start()	Returns the value of parameter *start* of the failing system service *SetAbsAlarm*.
OSError_SetAbsAlarm_cycle()	Returns the value of parameter *cycle* of the failing system service *SetAbsAlarm*.
OSError_CancelAlarm_AlarmID()	Returns the value of parameter *AlarmID* of the failing system service *CancelAlarm*.
OSError_GetAlarm_AlarmID()	Returns the value of parameter *AlarmID* of the failing system service *GetAlarm*.
OSError_GetAlarm_Tick()	Returns the value of parameter *Tick* of the failing system service *GetAlarm*.
OSError_SetEvent_TaskID()	Returns the value of parameter *TaskID* of the failing system service *SetEvent*.
OSError_SetEvent_Mask()	Returns the value of parameter *Mask* of the failing system service *SetEvent*.
OSError_GetEvent_TaskID()	Returns the value of parameter *TaskID* of the failing system service *GetEvent*.
OSError_GetEvent_Event()	Returns the value of parameter *Event* of the failing system service *GetEvent*.
OSError_WaitEvent_Mask()	Returns the value of parameter *Mask* of the failing system service *WaitEvent*.
OSError_ClearEvent_Mask()	Returns the value of parameter *Mask* of the failing system service *ClearEvent*.
OSError_IncrementCounter_CounterID()	Returns the value of parameter *CounterID* of the failing system service *IncrementCounter*.

Table 11–1: Error Management macro services

Example of ErrorHook definition

The body of the `ErrorHook` routine could look like:

```
void ErrorHook (StatusType Error )
{
    int Param1,Param2,Param3,sys;
    switch(OSErrorGetServiceId())
    {
    case OSServiceID_SetRelAlarm:
            Param1 =  OSError_SetRelAlarm_AlarmID();
            Param2 =  OSError_SetRelAlarm_increment();
            Param3 =  OSError_SetRelAlarm_cycle();
            #define   SETRELALARM   1
            sys    =  SETRELALARM;
            break;
        case OSServiceID_GetEvent:
            Param1 =  OSError_GetEvent_TaskID();
            Param2 =  OSError_GetEvent_Event();
            #define   GETEVENT   2
            sys    =  GETEVENT;
            break;
        /* all other cases
           ...
        default:
            break;
    }
    /* log error in a circular buffer with
       the last 10 errors*/
    errorLog->Param1 = Param1;
    errorLog->Paran2 = Param2;
    errorLog->Param3 = Param3;
    errorLog->Error  = Error;
    errorLog->sys    = sys;
    errorLog++;
    if (errorLog > startLog + sizeof(startLog))
    {   errorLog = startLog; }
    return;
}
```

11.2.3 The COMErrorHook Routine

In both *comstandard* and *comextended* modes, when a system service returns a `StatusType` value not equal to E_OK the RTOS calls the `COMErrorHook()` routine (provided that you set the COMERRORHOOK attribute of the COM object to TRUE in your OIL file):

```
void COMErrorHook(StatusType);
```

If COMERRORHOOK is set but you fail to define the `COMErrorHook()` routine in your code, the linking phase will fail due to unresolved externals.

`COMErrorHook()` is called at the end of the system service and immediately before returning to the calling function.

The RTOS does not call `COMErrorHook` if the failing system service is called from the `COMErrorHook` itself (recursive calls never occur). Therefore you can only detect possible error in COM system services in the `COMErrorHook` itself by evaluating directly their return value.

Once inside the `COMErrorHook()` routine, the RTOS provides you with mechanisms to access valuable information. With these mechanisms you can check which COM system service has failed and what its parameters were. You can use the macro services listed in the next table for this purpose.

Macro services inside ComErrorHook()

Macro Service	Description
COMErrorGetServiceId()	Provides the system service identifier where the error has been arisen. The return value of the macro is a service identifier of type *COMServiceIdType* and its possible values are: COMServiceID_StartCOM COMServiceID_StopCOM COMServiceID_GetCOMApplicationMode COMServiceID_InitMessage COMServiceID_SendMessage COMServiceID_ReceiveMessage COMServiceID_GetMessageStatus The value of the standard attribute of the COM object COMERRORGETSERVICEID must be set to TRUE
In all cases below the standard attribute of the COM object COMUSEPARAMETERACCESS must be set to TRUE.	
COMError_StartCOM_Mode()	Returns the value of parameter *Mode* of the failing system service *StartCOM*.
COMError_StopCOM_Mode()	Returns the value of parameter *Mode* of the failing system service *StopCOM*.
COMError_InitMessage_Message()	Returns the value of parameter *Message* of the failing system service *InitMessage*.
COMError_InitMessage_DataRef()	Returns the value of parameter *DataRef* of the failing system service *InitMessage*.
COMError_SendMessage_Message()	Returns the value of parameter *Message* of the failing system service *SendMessage*.

Macro Service	Description
COMError_SendMessage_DataRef()	Returns the value of parameter *DataRef* of the failing system service *SendMessage*.
COMError_ReceiveMessage_Message()	Returns the value of parameter *Message* of the failing system service *ReceiveMessage*.
COMError_ReceiveMessage_DataRef()	Returns the value of parameter *DataRef* of the failing system service *ReceiveMessage*.
COMError_GetMessageStatus_Message( )	Returns the value of parameter *Message* of the failing system service *GetMessageStatus*.

Table 11–2: Error Management COM macro services

Example of COMErrorHook definition

The body of the `COMErrorHook()` routine could look like:

```
void COMErrorHook(StatusType Error)
{
    int Param1,Param2,sys;
    switch(COMErrorGetServiceId())
    {
    case COMServiceID_InitMessage :
        Param1 = COMError_InitMessage_Message();
        #define INITMESSAGE 1
        sys = INITMESSAGE;
        break;
    case COMServiceID_SendMessage:
        Param1 = COMError_SendMessage_Message();
        Param2 = COMError_SendMessage_DataRef();
        #define SENDMESSAGE 2
        sys = SENDMESSAGE;
        break;
    default:        /* all other cases */
        break;
    }

     /* log errors in a circular buffer containing the
        last ten errors */
        errorLog->Param1 = Param1;
        errorLog->Paran2 = Param2;
        errorLog->Error  = Error;
        errorLog->sys    = sys;
        errorLog++;
        if (errorLog > startLog + sizeof(startLog))
        { errorLog = startLog; }
    return;
}
```

11.3 Debug Routines

The RTOS calls two other hook routines, `PreTaskHook` and `PostTaskHook` to enhance your debugging facilities (if in the OIL file you set the attributes PRETASKHOOK and POSTTASKHOOK of the OS object to TRUE).

```
void PreTaskHook(void);

void PostTaskHook(void);
```

If PRETASKHOOK/POSTTASKHOOK is set but you fail to define the `PreTaskHook()` or `PostTaskHook()` routine in your code, the linking phase will fail due to unresolved externals.

`PreTaskHook()` is called by the RTOS after it has switched tasks but before passing control of the CPU to the new task. This allows you to determine which task is about to run.

`PostTaskHook()` is called after the RTOS determines that a switch is to occur but always before the switch actually occurs. This allows you to determine which task has just completed or has been preempted.

You can use `PreTaskHook()` and `PostTaskHook()` to perform, for instance, some time measurements (CPU task usage etc...).

In both cases there is still (already) a task in the *running* state so that you can determine which task is about to be preempted or scheduled with the OS system service `GetTaskId()`.

The body of the `PreTaskHook()` routine could look like:

```
void PreTaskHook (void)
{
    TaskType task;
    TaskStateType state;
    GetTaskID(&task);
    if (task== INVALID_TASK)
    {   /* i cannot be here */
        while(1); }
    if ( RUNNING != GetTaskState(task,&state) )
    {   /* i cannot be here */
        while(1); }
    /* debug code */
    return;
}
```

11.4 OIL Examples

To enjoy maximum debug facilities you must configure your OIL file as follows:

```
OS StdOS
{   STATUS              = EXTENDED;
    STARTUPHOOK         = TRUE;
    ERRORHOOK           = TRUE;
    SHUTDOWNHOOK        = TRUE;
    PRETASKHOOK         = TRUE;
    POSTTASKHOOK        = TRUE;
    USEGETSERVICEID     = TRUE;
    USEPARAMETERACCESS  = TRUE;
}

COM Com
{   COMERRORHOOK           = TRUE;
    COMUSEGETSERVICEID     = TRUE;
    COMUSEPARAMETERACCESS  = TRUE;
    COMSTARTCOMEXTENSION   = TRUE;
    COMSTATUS              = COMEXTENDED;
};
```

To cut out all debug facilities when releasing the product you must configure your OIL file as follows:

```
OS StdOS
{   STATUS              = STANDARD;
    STARTUPHOOK         = FALSE;
    ERRORHOOK           = FALSE;
    SHUTDOWNHOOK        = FALSE;
    PRETASKHOOK         = FALSE;
    POSTTASKHOOK        = FALSE;
    USEGETSERVICEID     = FALSE;
    USEPARAMETERACCESS  = FALSE;
}

COM Com
{   COMERRORHOOK           = FALSE;
    COMUSEGETSERVICEID     = FALSE;
    COMUSEPARAMETERACCESS  = FALSE;
    COMSTARTCOMEXTENSION   = FALSE;
    COMSTATUS              = COMSTANDARD;
};
```

If the size of your image becomes critical you can notably reduce the ROM area size of your application by choosing this configuration. The real–time responses of the system are also enhanced since many run time checks are not performed.

12 Debugging an RTOS Application

Summary

This chapter explains how you can easily debug RTOS information with the Cross View Debugger and describes in detail all the information that you can obtain.

12.1 Introduction

This chapter describes how the debugger can help you to debug your OSEK/VDX application.

Often while debugging, you will find situations where having access to certain RTOS information becomes crucial. For instance:

- if you are running code that is shared by many tasks, you may need to know which task is executing at that moment.
- you may need to know the state of your tasks
- you may need to know which event a task is waiting for
- you may need to know what the priority of the system is once the task has got a resource

To provide debug information, the OSEK/VDX standard proposes a universal interface for development tools: the OSEK Run Time Interface (ORTI). An ORTI file clearly specifies to the debugger what information to access, how to access it and how to present it.

The toolchain generates at system generation time an ORTI file with rules for the debugger to display valuable kernel information at run time. Every time you make changes in the OIL file, a new ORTI file is generated.

You need to start the debugger every time a new ORTI file is created.

The information provided by the ORTI file (and displayed by the debugger) must be extremely precise and well documented. This information can be both dynamic (stacks, current task, last error) and static (added to help you comprehend the run−time environment).

12.2 How to Debug the System Status

Before you start debugging, make sure that:

- The following options are set in the debugger options of your project

  ```
  --orti=orti.txt --radm=osek_radm
  ```

  Otherwise the debugger does not load the ORTI file.

- The system runs in *extended* mode (the attribute STATUS of the OS object must be set to EXTENDED and the COMSTATUS of the COM object must be set to COMEXTENDED) if you aim for a maximum of information. If you need to debug your application in standard mode, you must be aware of the fact that some of the information will be indeterminated.

Every time you stop the debugger you can have a first look at the current status of the system via some general information. This information intends to provide a global and fast description of the system.

1. From the **OSEK/ORTI** menu select **MYOSEK** and **System Status.**

   A window pops up showing values for some global status properties. The status properties are described in the next table.

Status Debug Property	Description
RUNNINGTASK	Specifies which task is currently *running*. RUNNINGTASK is set to IDLE when none of the application tasks is in *running* state.
RUNNINGRESOURCE	Specifies the resource (if any) which is currently locked by the *running* task.
RUNNINGTASKPRIORITY	Current priority of the task referred by RUNNINGTASK (it can be different from its static priority due to the Ceiling Priority Protocol).
RUNNINGISR2	Specifies which Category 2 ISR is running (if current code executes in a Category 2 ISR). RUNNINGISR2 is set to NO_ISR in case current code does not execute in a Category 2 ISR2.
LASTERROR	Last error code detected. At start-up the error code is initialised with E_OK. (only if running with *extended* mode)
SYSLASTERROR	System service where LASTERROR did occur. (only if running with *extended* mode)
CURRENTAPPMODE	Current application mode.

Table 12-1: Status Debug Properties

12.3 How to Debug Tasks

The debugger can display relevant information about all the tasks in the system.

1. From the **OSEK/ORTI** menu select **MYOSEK** and **Tasks**

   A window pops up showing a list with all the tasks in the system. Every task is described with a set of properties. The debugger displays the values of these properties. The task properties are described in the next table.

Task Debug Property	Description
PRIORITY	Current priority of the task (it can be different from the static task priority due to the Ceiling Priority Protocol).
STATE	Current state of the task (SUSPENDED, READY, RUNNING or WAITING).
CURRACT	Number of current activations for the task.
vs_Sched	Scheduling policy of the task (NON or FULL).
vs_Ev_Wait	“wait mask” of the task: a mask of all the events that the task is waiting for (if any).
vs_Ev_Set	“set mask” for the TASK object: a mask of all the events that are already set for the task.
vs_Resource	Resource locked by the task if running through critical code.
vs_Group	Internal Resource identifying the group to which this task belongs (if any).
vs_StackUsed	Indicates the number of bytes currently in use for the Virtual Stack of the task.
vs_StackAvailable	Indicates the number of bytes still available for the Virtual Stack of the task.
vs_SystemStackPtr	Points at the last saved byte in the system stack at task level. From here you can do stack tracing (System stack stores return addresses. Only for *ready* and *waiting* tasks).
vs_VirtualStackPtr	Points at the last saved byte in the virtual stack at task level. (Only for *ready* and *waiting* tasks).

Table 12–2: Task Debug Properties

12.4 How to Debug Resources

The debugger can display relevant information about all the resources in the system.

1. From the **OSEK/ORTI** menu select **MYOSEK** and **Resources**

   A window pops up showing a list with all the resources in the system. Every resource is described with a set of properties. The debugger displays the values of these properties. The resource properties are described in the next table.

Resource Debug Property	Description
STATE	Represents the state of a resource (LOCKED/UNLOCKED). (only if running in *extended* mode)
PRIORITY	Ceiling priority of the resource.
vs_property	Property of the resource (STANDARD,INTERNAL or LINKED).

Table 12–3: Resource Debug Properties

12.5 How to Debug Alarms

The debugger can display relevant information about all the alarms in the system.

1. From the **OSEK/ORTI** menu select **MYOSEK** and **Alarms**

   A window pops up showing a list with all the alarms in the system. Every alarm is described with a set of properties. The debugger displays the values of these properties. The alarm properties are described in the next table.

Alarm Debug Property	Description
ALARMTIME	Time left untill the alarm expires next.
CYCLETIME	Cycle time for cyclic alarms. The value is 0 for non−cyclic alarms.
STATE	Specifies whether the alarm is RUNNING, STOPPED or INPROCESS (the time has expired but the RTOS has not finished processing yet).
COUNTER	Counter on which the alarm is based.
ACTION	Action (ACTIVATETASK, SETEVENT or ALARMCALLBACK) that will be performed by the alarm when expiring.
vs_task	Task that is activated by the alarm (if ACTION is ACTIVATETASK) or the task receiver of the event (if ACTION is SETEVENT).
vs_event	Event that is set when ACTION is SETEVENT.
vs_callback	Physical address of callback function when ACTION is ALARMCALLBACK. Otherwise a 0 value is given.

Table 12−4: Alarm Debug Properties

12.6 How to Debug ISRs

The debugger can display information about all the ISRs in the system.

1. From the **OSEK**/**ORTI** menu select **MYOSEK** and **ISRs**

   A window pops up showing a list with all the ISRs in the system. Every ISR is described with a set of properties. The debugger displays the values of these properties. The ISR properties are described in the next table.

ISR Debug Property	Description
vs_Level	Entry in the Vector Interrupt Table.
vs_Category	Category of the ISR
vs_Resource	Resource locked by the isr if running through critical code.
vs_Status	Indicates whether the ISR is disabled/enabled (ON/OFF).

Table 12–5: ISR Debug Properties

12.7 How to Debug Messages

The debugger can display information only about the receive message objects in the system (since the send messages are routed directly to the receiving side).

1. From the **OSEK/ORTI** menu select **MYOSEK** and **Messages**

   A window pops up showing a list with all the messages in the system. Every message is described with a set of properties. The debugger displays the values of these properties. The message properties are described in the next table.

Message Debug Property	Description
TYPE	Indicates the message type: RECEIVE_UNQUEUED_INTERNAL or RECEIVE_QUEUED_INTERNAL.
SENDINGMESSAGE	Symbolic name of the sender.
vs_LENGTH	Indicates the length of the message data.
vs_DATAPTR	Pointer to the receive message object (for queued messages, vs_DATAPTR points at the next available element of the queue, if non empty).
vs_QueueUsed	Number of non−read messages already in the queue. If vs_QueueUsed equals to 0, the queue is empty. (only for queue messages)
vs_QueueAvailable	Number of messages that still might be received without suffering from overflow. If vs_QueueAvailable equals to 0, the queue is full. (only for queue messages)

Table 12−6: Message Debug Properties

A Implementation Parameters

Summary

The implementation parameters provide detailed information concerning the functionality, performance and memory demand. From the implementation parameters you can obtain valuable information about the impact of the RTOS on your application.

1 Introduction

The OS OSEK/VDX normative documents state that "*The operating system vendor provides a list of parameters specifying the implementation. Detailed information is required concerning the functionality, performance and memory demand*"

From the implementation parameters you can obtain valuable information regarding the impact of the RTOS on your application. There are three kinds of implementation parameters:

- *Functionality Implementation Parameters*. They relate to the configuration of the system. You should always take them into account when writing your application OIL file.
- *Hardware Resources Implementation Parameters*. They evaluate the impact of having a RTOS on the hardware resources of the system (RAM, ROM, interrupts, times, etc).
- *Performance Implementation Parameters*. They measure the real time response of the RTOS. The basic conditions to reproduce the measurement of those parameters are mentioned.

2 Functionality Implementation Parameters

Parameter	Description	Implementation
MAX_NO_TASK	Maximum number of tasks. Limits the total number of TASK OIL objects in the OIL file.	
MAX_NO_ACTIVE_TASK	Maximum number of active tasks (i.e. not suspended) in the system.	The most general scenario is when all tasks can be 'active' at any given time, thus all having a stack of their own. If this Parameter equals to 1, only one task can be active at a time and the same stack can be shared by all tasks.
MAX_NO_PRIO_LEVEL	Maximum number of physical priority levels. Limits the total number of TASK OIL objects with different PRIORITY value.	The total number of physical priority levels is calculated by the TOC tool after processing the application OIL file.
MAX_TASK_PER_LEVEL	Maximum number of tasks per priority level.	The implementation supports the general case, thus allowing many ready task in the same priority level. However, better performance is achieved when no more than one task is assigned statically to the same priority level (smaller context switch latency times).
MIN_PRIO_LEVEL	Lowest priority level used by the user. No TASK OIL object can be defined with lower priority.	
MAX_PRIO_LEVEL	Highest priority level used by the user.	No limits. Virtual priority values have no limits.
MAX_NO_ACTIVATIONS	Upper limit for the number of task activations.	
MAX_NO_EVENTS	Maximum number of events objects (per system/per task). Limits the number of EVENT OIL objects that can be defined in the appl. OIL file.	
MAX_NO_COUNTER	Maximum number of counter objects (per system / per task). Limits the number of COUNTER OIL objects that can be defined in the application OIL file.	

Parameter	Description	Implementation
MAX_NO_ALARM	Maximum number of alarm objects (per system / per task). Limits the number of ALARM OIL objects that can be defined in the appl. OIL file.	
MAX_NO_APPMODE	Maximum number of application modes. Limits the number of APPMODE objects that can be defined in the appl. OIL file.	
MAX_NO_RESOURCE	Maximum number of resource objects (per system / per task). Limits the number of RESOURCE OIL objects that can be defined in the application OIL file.	
MAX_QUEUE_SIZE	Maximum size for the queues in QUEUE MESSAGE objects.	
MAX_DATA_LENGTH	Maximum length of the data in a message (in bytes).	
OSTICKDURATIONINMSCS	Time (in ms) between two consecutive ticks of the hardware system clock.	10
OSTICKDURATION	Time (in nano– seconds) between two consecutive ticks of the hardware system clock.	10 000 000
OSMINCYCLE	Absolute minimum log expiring time (in timer units).	1
OSTICKSPERBASE	Number of clock ticks per timer unit.	1
OSMAXALLOWEDVALUE	This value determines the upper limit for the timer value unit.	65535
MAX_TIMEOUT	Maximum timeout for an alarm based on the system counter.	

3 Hardware Resource Implementation Parameters

This section tries to help you understand the impact of the RTOS on the total size of the application. The contributions of the RTOS to the total size fall roughly into two categories:

- *ROM usage by system services*: The main idea is that there is a direct relation between the ROM size and the number of different system services your application uses (the more system services your application uses, the larger the code area).

  The implementation reserves one module (object) per system service in the RTOS library. The linker will extract only the modules for the system services that are used in the application code. All these modules contribute mainly to code area.

- *ROM/RAM usage by OIL objects*: Each added OIL object takes both data area (external) and code area.

The next subsections present some experimental results regarding memory usage. While obtaining these results:

- STARTUPHOOK , ERRORHOOK, SHUTDOWNHOOK, PRETASKHOOK, POSTTASKHOOK, USEGETSERVICEID, USEPARAMETERACCESS, USERESSCHEDULER, STACKMONITOR, COMERRORHOOK, COMUSEGETSERVICEID, COMUSEPARAMETERACCESS and COMSTARTCOMEXTENSION were set to FALSE.
- Default compiler options were used.

The tables distinguishes the following cases:

- *EXTENDED*: The STATUS standard attribute of OS OIL object is set as EXTENDED and the COMSTATUS standard attribute of COM OIL object is set as COMEXTENDED.
- *STANDARD*: The STATUS standard attribute of OS OIL object is set as STANDARD and the COMSTATUS standard attribute of COM OIL object is set as COMEXTENDED.

These results have been taken with a specific configuration and built with specific options. They will differ for each application and configuration. This table is provided to give inside in how the usage of system services and OIL objects affect the total size of your application.

3.1 The ROM Usage by System Services

System Service	ROM size (bytes): EXTENDED	ROM size (bytes): STANDARD
ActivateTask	0xA9	0x92
CancelAlarm	0xC6	0xBF
ChainTask	0x18A	0xF2
ClearEvent	0xA5	0x6D
GetAlarm	0x82	0x67
GetAlarmBase	0xAE	0x8B
GetApplicationMode	0x8	0x8
GetCOMApplicationMode	0x8	0x8
GetEvent	0x71	0x4E
GetMessageStatus	0x9E	0x79
GetResource	0x15B	0xBC
GetTaskID	0x52	0x3E
GetTaskState	0x5C	0x4A
IncrementCounter	0x48	0x40
InitMessage	0x96	0x64
ReceiveMessage	0x1C3	0x176
ReleaseResource	0x132	0x8C
Schedule	0x1C0	0x6C
SendMessage	0x47C	0x3D1
SetAbsAlarm	0x23A	0x1AB
SetEvent	0x102	0xD7
SetRelAlarm	0x159	0x8E
ShutdownOS	0x5	0x5
StartCOM	0xD2	0xA6
StartOS	0x14C8	0x1438
StopCOM	0x3A	0x12
TerminateTask	0xCC	0x76
WaitEvent	0x12A	0xCE

The smallest possible application uses at least the `StartOS` system service (0x2b bytes in code area). Each system service you add to your application, increases code size with at least the value as given in the table. For example, given an application with the following system services:

```
ActivateTask  TerminateTask   SetEvent
WaitEvent     ClearEvent
```

The contribution of the system services modules to the final code size of the application is approximately:

```
14C8 + A9 + CC + 102 + 12A + A5 = 190E  (EXTENDED mode)
1438 + 92 + 76 + d7  + CE  + 6D = 1752  (STANDARD mode)
```

The OIL file used to obtain these results is very similar to the OIL file example in section 3.3.2, *Application Part* in Chapter *OIL Language*.

3.2 The ROM/RAM Usage of OIL Objects

Every time you add an OIL object to you application system, this takes a certain amount of memory. The table below helps you to estimate the memory costs of adding new OIL objects to the application. The first row shows data for the most basic RTOS configuration (just one TASK object); the remaining rows give the increase in memory per added OIL objects.

Please be aware that the costs of adding OIL objects are independent of whether your application accesses them or not with system services. The measurements below have been obtained with a minimum application, i.e. empty application labels and using only one system service `StartOS`.

While obtaining the results below:

- All reference lists in OIL objects are empty (bigger usage of both code and data area otherwise).
- VSTACK and SSTACK are both 10 and AUTOSTART is FALSE for TASK OIL objects.
- TASK objects have different PRIORITY values.
- EXTDATASIZE is 8.
- CDATATYPE is 'char' and QUEUESIZE is 5 for MESSAGE OIL objects.
- AUTOSTART is FALSE and ACTION is ACTIVATETASK for ALARM OIL objects.
- The CATEGORY value for the ISR objects is 2.

OIL object	RAM size (bytes) EXTENDED	ROM size (bytes) EXTENDED	RAM size (bytes) STANDARD	ROM size (bytes) STANDARD
MINIMUM (1 TASK)	162	A44	162	9EB
1st TASK	5D	1C	5D	19
2st TASK	5D	1	5D	1
3st TASK	5D	1	5D	1
1st ISR	5	1DB	5	1D3
2st ISR	7	97	7	97
3st ISR	7	87	7	87
1st ALARM (sys cntr)	1	6B4	1	686
2st ALARM (sys cntr)	19	0	19	0
3st ALARM (sys cntr)	19	0	19	0
1st ALARM (app cntr) *	17	0	17	0
2st ALARM (app cntr) *	17	0	19	0
3st ALARM (app cntr) *	17	0	19	0
1st EVENT	4	95	4	95
2st EVENT	10	0	10	0
3st EVENT	10	0	10	0
1st RESOURCE	9	64	9	64
2st RESOURCE	A	0	A	0
3st RESOURCE	A	0	A	0
1st MESSAGE	1	0	1	0
2st MESSAGE	1E	0	1E	0
3st MESSAGE	1E	0	1E	0

*) System counter based ALARMS and application counter based ALARMS, share a lot of code. Therefor, if an system counter based ALARM is already present, it takes only little extra code when an application based ALARM is added. The values for application counter based ALARMS are only valid if an system counter based ALARM is already present.

3.3 Miscellaneous

Timer units reserved for the OS.	None
Interrupts, traps and other hardware resources occupied by the operating system.	None

B Stack Overflow

Summary

This appendix describes how you can avoid problems caused by stack overflow.

1 Introduction

For many years, microprocessors have been included on–chip memory management units (MMU) that enable individual tasks to run in hardware–protected address spaces. But many commercial real–time operating systems never enable the MMU, even if such hardware is present in the system. This is the case with OSEK/VDX systems: all tasks share the same memory space. It is easy to understand how a single errant pointer in one task can easily bring down the entire system, or at least cause it to behave unexpectedly. Apart from errant pointers, the most common way to suffer from data corruption in an OSEK/VDX system is due to a stack overflow. Stack overflow is defined as an error condition which results from attempting to push more items onto a stack than space has been allocated for.

Often, stack overflow will simply overwrite the adjacent memory locations causing bugs that are hard to trace. A task could unintentionally corrupt the data or stack of another task. A misbehaved task could even corrupt the RTOS's own code or internal data structures.

In our OSEK/VDX implementation, a static stack area is allocated for every task. The user configures the size of the stack in the OIL file. The stack area of a task normally tracks the history of return addresses, automatics and parameters of every task.

The RTOS statically allocates buffers for all the stacks at compile time in the generated file `g_conf.c`. These buffers occupy contiguous positions in data area. If you set the size of stack for task *T* to 40 bytes, the following code for task T would invariantly lead to data corruption:

```
TASK(T)
{
    char local[41];
    ...
}
```

This stack overflow example would cause serious problems. Since the whole memory area is accessible, there has been data corruption. The corruption will affect the RTOS's internal data, to the stack of another task or to application data. (Both are possible). Later, when this corrupted data is used by the application, the system will fail to perform correctly. Finding the cause of the problem can be extremely difficult since the failure might occur at a time after the moment when the stack actually suffered the overflow.

In order to avoid stack overflow, you could over allocate memory to the stack of each task, thus providing a safety margin. However, in embedded applications, RAM is often the most precious resource and over allocating extra memory for all stacks could severely increase the final cost of the product.

Some optimizations can be achieved by sharing stack areas between tasks that can never preempt each other. For instance, basic tasks with the same priority level, non−preemptable basic tasks or tasks owning the same internal resource (group of tasks).

With the help of a Stack Analyzer you could even predict beforehand the maximum size of the stack for a given task. A Stack Analyzer inspects the call graph of a task and calculates the stack usage for a worst−case scenario. With these results you can set new sizes for the stacks in the OIL file and (without any other change in the source code) build a new image.

The next section presents mechanisms to detect stack overflows at run−time.

2 Run-time Stack Monitoring

2.1 IsStackInRange

You can call the following service to detect possible stack overflows at run-time:

```
StatusType IsStackInRange(void);
```

This service compares current values of stack pointers with their absolute limits. Checking the return value of this service helps you determine whether conditions of overflow exist at the moment of the call.

StatusType	Description
E_OK	No present conditions for stack overflow.
E_OS_SYS_VSTACK	The VSP pointer is currently out of range (task level). You must increase the value of the non-standard VSTACK attribute in the corresponding TASK OIL object.
E_OS_SYS_STACK	The SP pointer is currently out of range. You must increase the value of the stack size in the linker/locator options.
E_OS_SYS_ISRSTACK	The VSP pointer is currently out of range (interrupt level). You must increase the value of the non-standard VISRSTACK attribute of the OS OIL object.

You must be aware that a E_OK return value does not imply that no data corruption exists in the system. A E_OK return value only means that the stack pointers are all in range at the moment of the call; it tells you nothing about previous out of range situations.

2.2 Stack Monitor

You can request the RTOS to continuously monitor possible stack overflows. Although expensive in run-time performance, the RTOS will inform you as soon as possible with the precise cause of the stack overflow.

A non-standard attribute (STACKMONITOR) is offered in the OS OIL object to request these tests. When this attribute is set to TRUE, the RTOS code performs internal stack overflow tests after every task run, thus in every context switch. If reasons for stack overflow have been encountered during the last task run, the RTOS code calls the service `ShutdownOS`. The value of the call parameter will help you determining the precise cause of the overflow. The possible values are listed in the table below. The default value of STACKMONITOR is TRUE (less run-time overhead).

This method leaves almost no chance to the system to either hang or crash since the corrupted data would normally belong to another task (which has had still no chance to run).

It is recommended to run every application at least once with STACKMONITOR set to TRUE during the debugging phase.

StatusType	Description
E_OK	No conditions for stack overflow have been detected.
E_OS_SYS_VSTACK	Conditions for a stack overflow in the virtual stack buffer of the exiting task have been detected. You must increase the value of the non−standard VSTACK attribute in the corresponding TASK OIL object.
E_OS_SYS_SSTACK	Conditions for a stack overflow in the system stack buffer of the exiting task have been detected. You must increase the value of the non−standard SSTACK attribute in the corresponding TASK OIL object.
E_OS_SYS_STACK	Conditions for a stack overflow in the system stack have been detected. You must increase the value of the stack size in the linker/locator options.
E_OS_SYS_ISRSTACK	Conditions for a stack overflow in the virtual stack of the interrupt frames have been detected. You must increase the value of the non−standard VISRSTACK attribute of the OS OIL object.

You can now study the body of the hook routine `ShutdownHook` to find the reason for the overflow. Obviously, the SHUTDOWNHOOK standard attribute of the OS OIL object must have been set to TRUE:

```
OS StdOS
{   SHUTDOWNHOOK = TRUE;
    STACKMONITOR = TRUE; } ;
```

The `ShutdownHook` routine could look like follows:

```
void ShutdownHook ( StatusType Error)
{
    switch(Error)
    {
        case E_OK: break;
        case E_OS_SYS_VSTACK: case E_OS_SYS_SSTACK:
        case E_OS_SYS_STACK:  case E_OS_SYS_ISRSTACK:
        Log("STACK OVERFLOW\n");
        StackHandler(Error);
        default: break;
    }
    return;
}
```

And the a `StackHandler` routine could look like follows:

```
void StackHandler(StatusType Error)
{
    TaskType task;
    GetTaskID(&task);
    switch(Error)
    {
        case E_OS_SYS_STACK:
             Log(”T: %d Err: S”,task);break;
        case E_OS_SYS_ISRSTACK:
             Log(”T: %d Err: ISR”,task);break;
        case E_OS_SYS_VSTACK:
             Log(”T: %d Err: VT”,task);break;
        case E_OS_SYS_SSTACK:
             Log(”T: %d Err: ST”,task);break;
        default: break;
    }

    /* Freeze everything. The application needs
       to be rebuilt with right stack configuration */
    DisableAllInterrupts();
    while(1);
    return;
}
```

Index