embOS

Real-Time
Operating System

CPU-independent

User & reference guide

Software version 3.60
Document revision 0
Date: January 28, 2008

A product of SEGGER Microcontroller GmbH & Co. KG

www.segger.com

Disclaimer

Copyright notice

Trademarks

Registration

Register the software via email. This way we can make sure you will receive updates or notifications of updates as soon as they become available. For registration, provide the following information:
Company name and address

- Your name
- Your job title
- Your email address and telephone number
- Name and version of the product

Send this information to: register@segger.com

Contact address

SEGGER Microcontroller GmbH & Co. KG

Heinrich-Hertz-Str. 5
D-40721 Hilden
Germany
Tel.+49 2103-2878-0
Fax.+49 2103-2878-28
Email: support@segger.com
Internet: http://www.segger.com

Software and manual versions

This manual describes the current software version. If any error occurs, inform us and we will try to assist you as soon as possible.
Contact us for further information on topics or routines not yet specified.

Print date: January 28, 2008

Software	Manual	Date	By	Description
3.60	0	080117	OO	General updates. Chapter "System tick" added.
3.52	1	071026	AW	Chapter "Task routines": Added OS_SetTaskName().
3.52	0	070824	OO	Chapter "Task routines": Added OS_ExtendTaskContext(). Chapter "Interrupts": Updated, added OS_CallISR() and OS_CallNestableISR().
3.50c	0	070814	AW	Chapter "List of libraries" updated, XR library type added.
3.40C	3	070716	OO	Chapter "Performance and resource usage" updated,
3.40C	2	070625	SK	Chapter "Debugging", error codes updated: - OS_ERR_ISR_INDEX added. - OS_ERR_ISR_VECTOR added. - OS_ERR_RESOURCE_OWNER added. - OS_ERR_CSEMA_OVERFLOW added. Chapter "Task routines": - OS_Yield() added. Chapter "Counting semaphores" updated. - OS_SignalCSema(), additional information adjusted. Chapter "Performance and resource usage" updated: - Minor changes in wording.
3.40A	1	070608	SK	Chapter "Counting semaphores" updated. - OS_SetCSemaValue() added. - OS_CreateCSema(): Data type of parameter InitValue changed from unsigned char to unsigned int. - OS_SignalCSemaMax(): Data type of parameter MaxValue changed from unsigned char to unsigned int. - OS_SignalCSema(): Additional information updated.
3.40	0	070516	SK	Chapter "Performance and resource usage" added. Chapter "Configuration of your target system (RTOSInit.c)" renamed to "Configuration of your target system". Chapter "STOP\WAIT\IDLE modes" moved into chapter "Configuration of your target system". Chapter "time-related routines" renamed to "Time measurement".
3.32o	9	070422	SK	Chapter 4: OS_CREATETIMER_EX(), additional information corrected.
3.32m	8	070402	AW	Chapter 4: Extended timer added. Chapter 8: API overview corrected, OS_Q_GetMessageCount()
3.32j	7	070216	AW	Chapter 6: OS_CSemaRequest() function added.
3.32e	6	061220	SK	About: Company description added. Some minor formating changes.
3.32e	5	061107	AW	Chapter 7: OS_GetMessageCnt() return value corrected to unsigned int.
3.32d	4	061106	AW	Chapter 8: OS_Q_GetPtrTimed() function added.
3.32a	3	061012	AW	Chapter 3: OS_CreateTaskEx() function, description of parameter pContext corrected. Chapter 3: OS_CreateTaskEx() function, type of parameter TimeSlice corrected. Chapter 3: OS_CreateTask() function, type of parameter TimeSlice corrected. Chapter 9: OS_GetEventsOccured() renamed to OS_GetEventsOccurred(). Chapter 10: OS_EVENT_WaitTimed() added.
3.32a	2	060804	AW	Chapter 3: OS_CREATETASK_EX() function added. Chapter 3: OS_CreateTaskEx() function added.
3.32	1	060717	OO	Event objects introduced. Chapter 10 inserted which describes event objects. Previous chapter "Events" renamed to "Task events"
3.30	1	060519	OO	New software version.

Software	Manual	Date	By	Description
3.28	5	060223	OO	All chapters: Added API tables. Some minor changes.
3.28	4	051109	AW	Chapter 7: OS_SignalCSemaMax() function added. Chapter 14: Explanation of interrupt latencies and high / low priorities added.
3.28	3	050926	AW	Chapter 6: OS_DeleteRSema() function added.
3.28	2	050707	AW	Chapter 4: OS_GetSuspendCnt() function added.
3.28	1	050425	AW	Version number changed to 3.28 to fit to current ombOS version. Chapter 18.1.2: Type of return value of OS GetTime32() corrected
3.26		050209	AW	Chapter 4: OS_Terminate() modified due to new features of version 3.26. Chapter 24: Source code version: additional compile time switches and build process of libraries explained more in detail.
3.24		041115	AW	Chapter 6: Some prototype declarations showed in OS_SEMA instead of OS_RSEMA. Corrected.
3.22	1	040816	AW	Chapter 8: New Mailbox functions added OS_PutMailFront() OS_PutMailFront1() OS_PutMailFrontCond() OS_PutMailFrontCond1()
3.20	5	040621	RS AW	Software timers: Maximum timeout values and OS_TIMER_MAX_TIME described. Chapter 14: Description of rules for interrupt handlers revised. OS_LeaveNestableInterruptNoSwitch() added which was not described before.
3.20	4	040329	AW	OS_CreateCSema() prototype declaration corrected. Return type is void. OS_Q_GetMessageCnt() prototype declaration corrected. OS_Q_Clear() function description added. OS_MEMF_FreeBlock() prototype declaration corrected.
3.20	2	031128	AW	OS_CREATEMB() Range for parameter MaxnofMsg corrected. Upper limit is 65535, but was declared 65536 in previous manuals.
3.	1	040831	AW	Code samples modified: Task stacks defined as array of int, because most CPUs require alignment of stack on integer aligned addresses.

Software	Manual	Date	By	Description
3.20	1	031016	AW	Chapter 4: Type of task priority parameter corrected to unsigned char. Chapter 4: OS_DelayUntil(): Sample program modified. Chapter 4: OS_Suspend() added. Chapter 4: OS_Resume() added. Chapter 5: OS_GetTimerValue(): Range of return value corrected. Chapter 6: Sample program for usage of resource semaphores modified. Chapter 6: OS_GetResourceOwner(): Type of return value corrected. Chapter 8: OS_CREATEMB(): Types and valid range of parameter corrected. Chapter 8: OS_WaitMail() added Chapter 10: OS_WaitEventTimed(): Range of timeout value specified.
3.12	1	021015	AW	Chapter 8: OS_GetMailTimed() added Chapter 11 (Heap type memory management) inserted Chapter 12 (Fixed block size memory pools) inserted
3.10	3	020926 020924 020910	KG KG KG	Index and glossary revised. Section 16.3 (Example) added to Chapter 16 (Time-related routines). Revised for language/grammar. Version control table added. Screenshots added: superloop, cooperative/preemptive multitasking, nested interrupts, low-res and hi-res measurement. Section 1.3 (Typographic conventions) changed to table. Section 3.2 added (Single-task system). Section 3.8 merged with section 3.9 (How the OS gains control). Chapter 4 (Configuration for your target system) moved to after Chapter 15 (System variables). Chapter 16 (Time-related routines) added.

About this document

Assumptions

This document assumes that you already have a solid knowledge of the following:

- The software tools used for building your application (assembler, linker, C compiler)
- The C programming language
- The target processor

- DOS command line.

If you feel that your knowledge of C is not sufficient, we recommend The C Programming Language by Kernighan and Richie (ISBN 0-13-1103628), which describes the standard in C-programming and, in newer editions, also covers the ANSI C standard.

How to use this manual

The intention of this manual is to give you a CPU- and compiler-independent introduction to embOS and to be a reference for all embOS API functions.

For a quick and easy startup with embOS, refer to Chapter 2 in the *CPU & Compiler Specifics manual* of embOS documentation, which includes a step-by-step introduction to using embOS.

Typographic conventions for syntax

This manual uses the following typographic conventions:

Style	Used for
Body	Body text.
`Keyword`	Text that you enter at the command-prompt or that appears on the display (that is system functions, file- or pathnames).
`Parameter`	Parameters in API functions.
`Sample`	Sample code in program examples.
Reference	Reference to chapters, tables and figures or other documents.
GUIElement	Buttons, dialog boxes, menu names, menu commands.
Emphasis	Very important sections

Table 1.1: Typographic conventions

SEGGER Microcontroller GmbH & Co. KG develops and distributes software development tools and ANSI C software components (middleware) for embedded systems in several industries such as telecom, medical technology, consumer electronics, automotive industry and industrial automation.

SEGGER's intention is to cut software development-time for embedded applications by offering compact flexible and easy to use middleware, allowing developers to concentrate on their application.

Our most popular products are emWin, a universal graphic software package for embedded applications, and embOS, a small yet efficent real-time kernel. emWin, written entirely in ANSI C, can easily be used on any CPU and most any display. It is complemented by the available PC tools: Bitmap Converter, Font Converter, Simulator and Viewer. embOS supports most 8/16/32-bit CPUs. Its small memory footprint makes it suitable for single-chip applications.

Apart from its main focus on software tools, SEGGER developes and produces programming tools for flash microcontrollers, as well as J-Link, a JTAG emulator to assist in development, debugging and production, which has rapidly become the industry standard for debug access to ARM cores.

Corporate Office:
http://www.segger.com

United States Office:
http://www.segger-us.com

EMBEDDED SOFTWARE (Middleware)

emWin
Graphics software and GUI
emWin is designed to provide an efficient, processor- and display controller-independent graphical user interface (GUI) for any application that operates with a graphical display. Starterkits, eval- and trial-versions are available.

embOS
Real Time Operating System
embOS is an RTOS designed to offer the benefits of a complete multitasking system for hard real time applications with minimal resources. The profiling PC tool embOSView is included.

emFile
File system
emFile is an embedded file system with FAT12, FAT16 and FAT32 support. emFile has been optimized for minimum memory consumption in RAM and ROM while maintaining high speed. Various Device drivers, e.g. for NAND and NOR flashes, SD/MMC and CompactFlash cards, are available.

USB-Stack
USB device stack
A USB stack designed to work on any embedded system with a USB client controller. Bulk communication and most standard device classes are supported.

SEGGER TOOLS

Flasher
Flash programmer
Flash Programming tool primarily for microcontrollers.

J-Link
JTAG emulator for ARM cores
USB driven JTAG interface for ARM cores.

J-Trace
JTAG emulator with trace
USB driven JTAG interface for ARM cores with Trace memory. supporting the ARM ETM (Embedded Trace Macrocell).

J-Link / J-Trace Related Software
Add-on software to be used with SEGGER's industry standard JTAG emulator, this includes flash programming software and flash breakpoints.

Table of Contents

Chapter 1

Introduction to embOS

1.1 What is embOS

embOS is a priority-controlled multitasking system, designed to be used as an embedded operating system for the development of real-time applications for a variety of microcontrollers.

embOS is a high-performance tool that has been optimized for minimum memory consumption in both RAM and ROM, as well as high speed and versatility.

1.2 Features

Throughout the development process of embOS, the limited resources of microcontrollers have always been kept in mind. The internal structure of the realtime operating system (RTOS) has been optimized in a variety of applications with different customers, to fit the needs of the industry. Fully source-compatible RTOS are available for a variety of microcontrollers, making it well worth the time and effort to learn how to structure real-time programs with real-time operating systems.

embOS is highly modular. This means that only those functions that are needed are linked, keeping the ROM size very small. The minimum memory consumption is little more than 1 Kbyte of ROM and about 30 bytes of RAM (plus memory for stacks). A couple of files are supplied in source code to make sure that you do not loose any flexibility by using embOS and that you can customize the system to fully fit your needs.

The tasks you create can easily and safely communicate with each other using a complete palette of communication mechanisms such as semaphores, mailboxes, and events.

Some features of embOS include:

- Preemptive scheduling:
  Guarantees that of all tasks in READY state the one with the highest priority executes, except for situations where priority inversion applies.
- Round-robin scheduling for tasks with identical priorities.
- Preemptions can be disabled for entire tasks or for sections of a program.
- Up to 255 priorities.
- Every task can have an individual priority => the response of tasks can be precisely defined according to the requirements of the application.
- Unlimited number of tasks
  (limited only by the amount of available memory).
- Unlimited number of semaphores
  (limited only by the amount of available memory).
- 2 types of semaphores: resource and counting.
- Unlimited number of mailboxes
  (limited only by the amount of available memory).
- Size and number of messages can be freely defined when initializing mailboxes.
- Unlimited number of software timers
  (limited only by the amount of available memory).
- 8-bit events for every task.
- Time resolution can be freely selected (default is 1ms).
- Easily accessible time variable.
- Power management.
- Unused calculation time can automatically be spent in halt mode .
  power-consumption is minimized.
- Full interrupt support:
  Interrupts can call any function except those that require waiting for data,
  as well as create, delete or change the priority of a task.
  Interrupts can wake up or suspend tasks and directly communicate with tasks using all available communication instances (mailboxes, semaphores, events).
- Very short interrupt disable-time => short interrupt latency time.
- Nested interrupts are permitted.
- embOS has its own interrupt stack (usage optional).
- Frame application for an easy start.
- Debug version performs runtime checks, simplifying development.
- Profiling and stack check may be implemented by choosing specified libraries.
- Monitoring during runtime via UART available (embOSView).
- Very fast and efficient, yet small code.
- Minimum RAM usage.
- Core written in assembly language.
- Interfaces C and/or assembly.
- Initialization of microcontroller hardware as sources.

Chapter 2

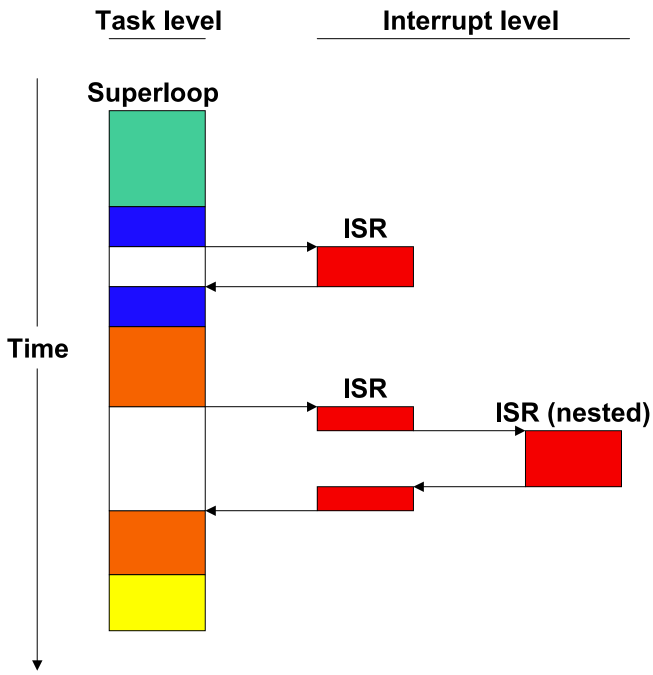
Basic concepts

2.1 Tasks

In this context, a task is a program running on the CPU core of a microcontroller. Without a multitasking kernel (an RTOS), only one task can be executed by the CPU at a time. This is called a single-task system. A real-time operating system allows the execution of multiple tasks on a single CPU. All tasks execute as if they completely "owned" the entire CPU. The tasks are scheduled, meaning that the RTOS can activate and deactivate every task.

2.2 Single-task systems (superloop)

A superloop application is basically a program that runs in an endless loop, calling OS functions to execute the appropriate operations (task level). No real-time kernel is used, so interrupt service routines (ISRs) must be used for real-time parts of the software or critical operations (interrupt level). This type of system is typically used in small, uncomplex systems or if real-time behavior is not critical.



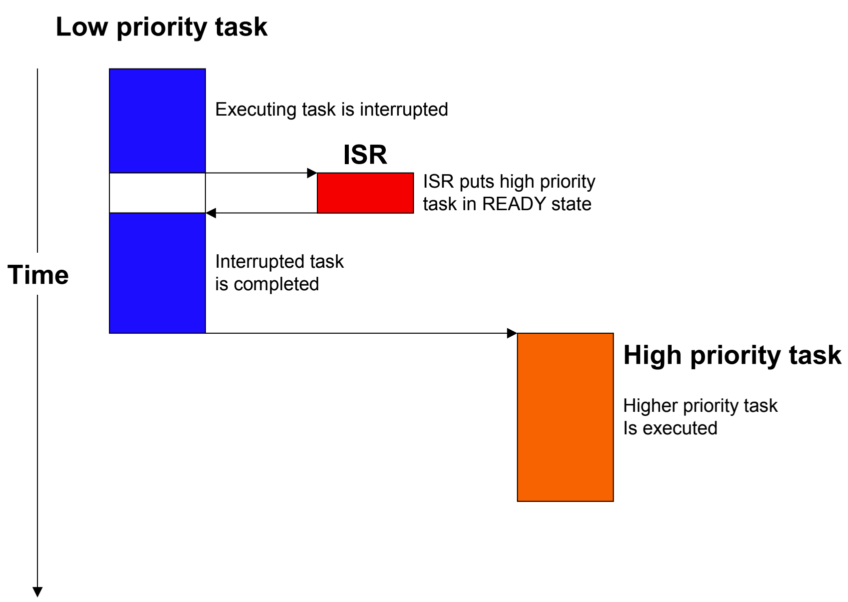
Of course, there are fewer preemption and synchronization problems with a superloop application. Also, because no real-time kernel is used, only one stack exists in ROM, meaning that ROM size is smaller and less RAM is used up for stacks. However, superloops can become difficult to maintain if the program becomes too large. Because one software component cannot be interrupted by another component (only by ISRs), the reaction time of one component depends on the execution time of all other components in the system. Real-time behavior is therefore poor.

2.3 Multitasking systems

In a multitasking system, there are different scheduling systems in which the calculation power of the CPU can be distributed among tasks.

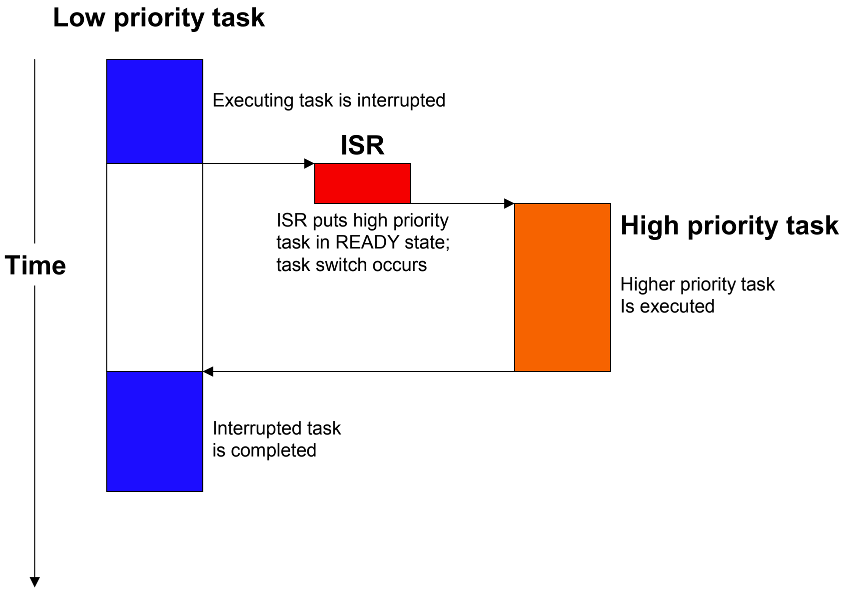
2.3.1 Cooperative multitasking

Cooperative multitasking expects cooperation of all tasks. Tasks can only be suspended by calling a function of the operating system. If they do not, the system "hangs", which means that other tasks have no chance of being executed by the CPU while the first task is being carried out. This is illustrated in the diagram below. Even if an ISR makes a higher-priority task ready to run, the interrupted task will be returned to and finished before the task switch is made.



2.3.2 Preemptives multitasking

Real-time systems like embOS operate with preemptive multitasking only. A real-time operating system needs a regular timer-interrupt to interrupt tasks at defined times and to perform task-switches if necessary. The highest-priority task in the READY state is therefore always executed, whether it is an interrupted task or not. If an ISR makes a higher priority task ready, a task switch will occur and the task will be executed before the interrupted task is returned to.

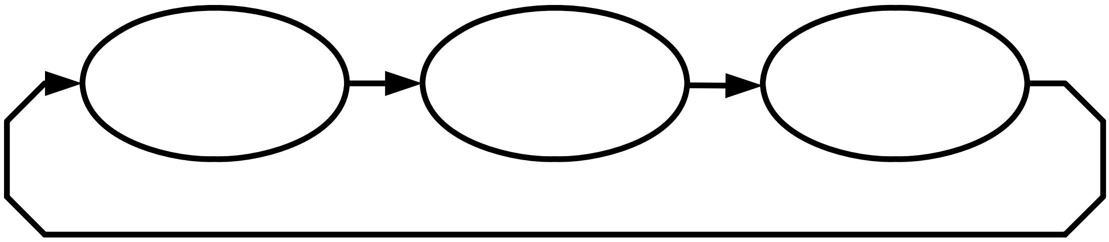


2.4 Scheduling

There are different algorithms that determine which task to execute, called schedulers. All schedulers have one thing in common: they distinguish between tasks that are ready to be executed (in the READY state) and the other tasks that are suspended for any reason (delay, waiting for mailbox, waiting for semaphore, waiting for event, and so on). The scheduler selects one of the tasks in the READY state and activates it (executes the program of this task). The task which is currently executing is referred to as the active task. The main difference between schedulers is in how they distribute the computation time between the tasks in READY state.

2.4.1 Round-robin scheduling algorithm

With round-robin scheduling, the scheduler has a list of tasks and, when deactivating the active task, activates the next task that is in the READY state. Round-robin can be used with either preemptive or cooperative multitasking. It works well if you do not need to guarantee response time, if the response time is not an issue, or if all tasks have the same priority. Round-robin scheduling can be illustrated as follows:



All tasks are on the same level; the possession of the CPU changes periodically after a predefined execution time. This time is called timeslice, and may be defined individually for every task.

2.4.2 Priority-controlled scheduling algorithm

In real-world applications, different tasks require different response times. For example, in an application that controls a motor, a keyboard, and a display, the motor usually requires faster reaction time than the keyboard and display. While the display is being updated, the motor needs to be controlled. This makes preemptive multitasking a must. Round-robin might work, but because it cannot guarantee a specific reaction time, an improved algorithm should be used.

In priority-controlled scheduling, every task is assigned a priority. The order of execution depends on this priority. The rule is very simple:

Note: The scheduler activates the task that has the highest priority of all tasks in the READY state.

This means that every time a task with higher priority than the active task gets ready, it immediately becomes the active task. However, the scheduler can be switched off in sections of a program where task switches are prohibited, known as critical regions.

embOS uses a priority-controlled scheduling algorithm with round-robin between tasks of identical priority. One hint at this point: round-robin scheduling is a nice feature because you do not have to think about whether one task is more important than another. Tasks with identical priority cannot block each other for longer than their timeslices. But round-robin scheduling also costs time if two or more tasks of identical priority are ready and no task of higher priority is ready, because it will constantly switch between the identical-priority tasks. It is more efficient to assign a different priority to each task, which will avoid unnecessary task switches.

2.4.3 Priority inversion

The rule to go by for the scheduler is:

Activate the task that has the highest priority of all tasks in the READY state.

But what happens if the highest-priority task is blocked because it is waiting for a resource owned by a lower-priority task? According to the above rule, it would wait until the low-priority-task becomes active again and releases the resource.

The other rule is: No rule without exception.

To avoid this kind of situation, the low-priority task that is blocking the highest-priority task gets assigned the highest priority until it releases the resource, unblocking the task which originally had highest priority. This is known as priority inversion.

2.5 Communication between tasks

In a multitasking (multithreaded) program, multiple tasks work completely separately. Because they all work in the same application, it will sometimes be necessary for them to exchange information with each other.

2.5.1 Global variables

The easiest way to do this is by using global variables. In certain situations, it can make sense for tasks to communicate via global variables, but most of the time this method has various disadvantages.

For example, if you want to synchronize a task to start when the value of a global variable changes, you have to poll this variable, wasting precious calculation time and power, and the reaction time depends on how often you poll.

2.5.2 Communication mechanisms

When multiple tasks work with one another, they often have to:

- exchange data,
- synchronize with another task, or
- make sure that a resource is used by no more than one task at a time.

For these purposes embOS offers mailboxes, queues, semaphores and events.

2.5.3 Mailboxes and queues

A mailbox is basically a data buffer managed by the RTOS and is used for sending a message to a task. It works without conflicts even if multiple tasks and interrupts try to access it simultaneously. embOS also automatically activates any task that is waiting for a message in a mailbox the moment it receives new data and, if necessary, automatically switches to this task.

A queue works in a similar manner, but handle larger messages than mailboxes, and every message may have a individual size.
For more information, see the Chapter *Mailboxes* on page 111 and Chapter *Queues* on page 129.

2.5.4 Semaphores

Two types of semaphores are used for synchronizing tasks and to manage resources. The most common are resource semaphores, although counting semaphores are also used. For details and samples, refer to the Chapter *Resource semaphores* on page 85 and Chapter *Counting Semaphores* on page 97. Samples can also be found on our website at www.segger.com.

2.5.5 Events

A task can wait for a particular event without using any calculation time. The idea is as simple as it is convincing; there is no sense in polling if we can simply activate a task the moment the event that it is waiting for occurs. This saves a great deal of calculation power and ensures that the task can respond to the event without delay. Typical applications for events are those where a task waits for data, a pressed key, a received command or character, or the pulse of an external real-time clock.
For further details, refer to the Chapter *Task events* on page 141 and Chapter *Event objects* on page 151.

2.6 How task-switching works

A real-time multitasking system lets multiple tasks run like multiple single-task programs, quasi-simultaneously, on a single CPU. A task consists of three parts in the multitasking world:

- The program code, which usually resides in ROM (though it does not have to)
- A stack, residing in a RAM area that can be accessed by the stack pointer
- A task control block, residing in RAM.

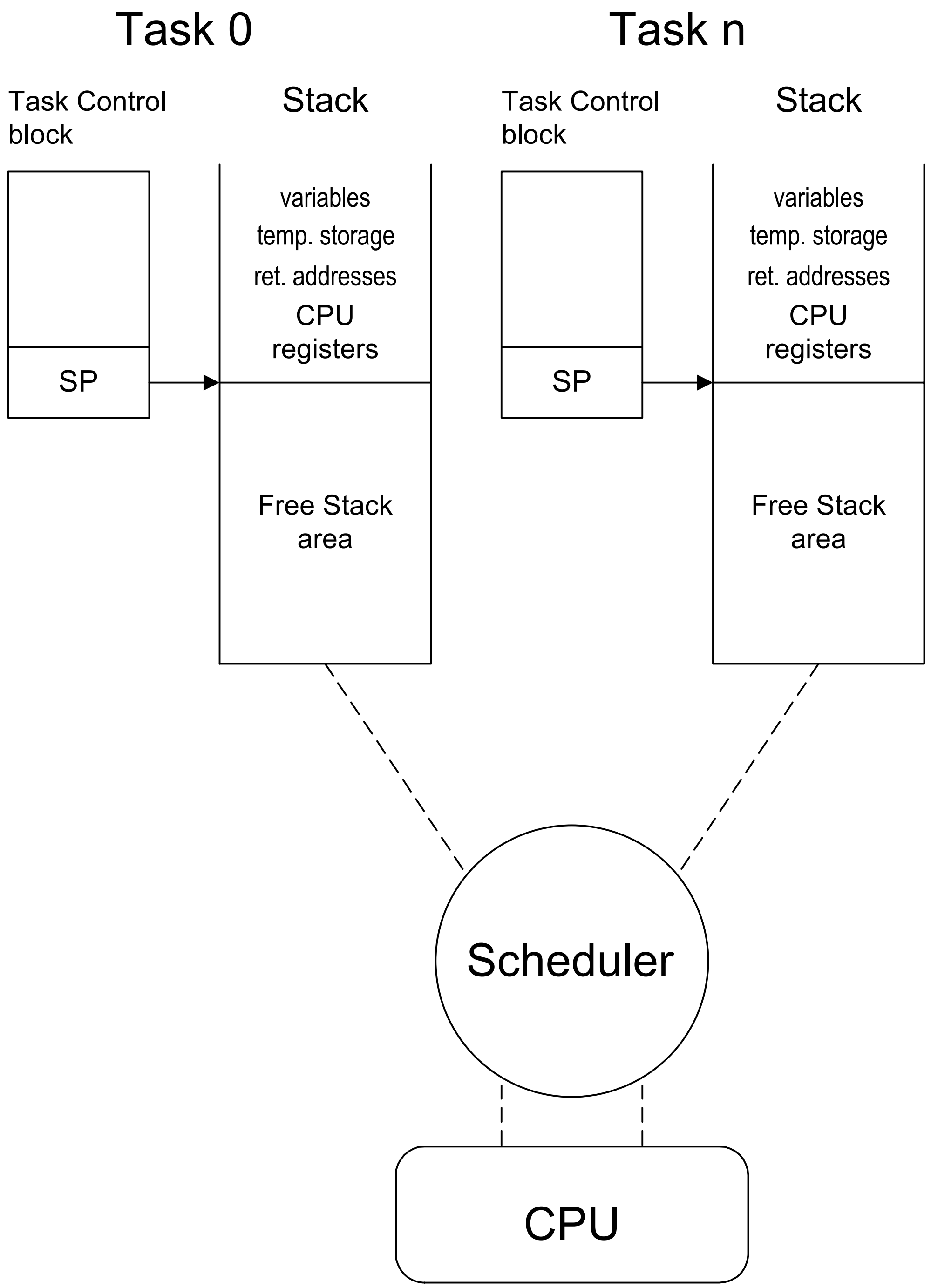
The stack has the same function as in a single-task system: storage of return addresses of function calls, parameters and local variables, and temporary storage of intermediate calculation results and register values. Each task can have a different stack size. More information can be found in chapter *Stacks* on page 183.

The task control block (TCB) is a data structure assigned to a task when it is created. It contains status information of the task, including the stack pointer, task priority, current task status (ready, waiting, reason for suspension) and other management data. This information allows an interrupted task to continue execution exactly where it left off. TCBs are only accessed by the RTOS.

2.7 Switching stacks

The following diagram demonstrates the process of switching from one stack to another.

The scheduler deactivates the task to be suspended (Task 0) by saving the processor registers on its stack. It then activates the higher-priority task (Task n) by loading the stack pointer (SP) and the processor registers from the values stored on Task n's stack.



2.8 Change of task status

A task may be in one of several states at any given time. When a task is created, it is automatically put into the READY state (TS_READY).

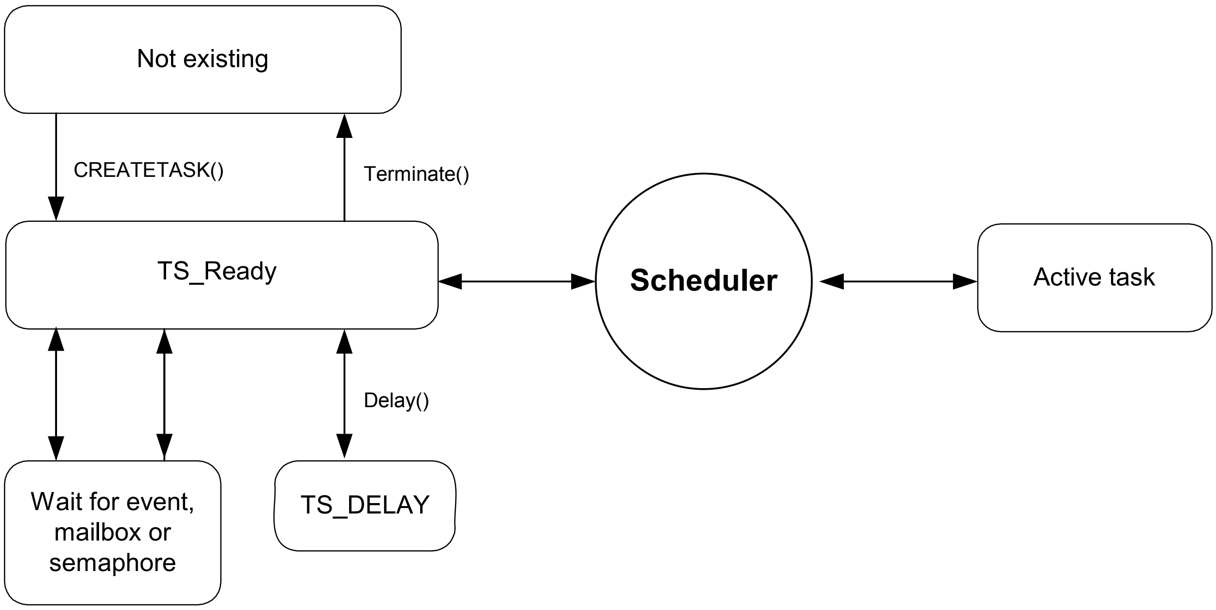
A task in the READY state is activated as soon as there is no other READY task with higher priority. Only one task may be active at a time. If a task with higher priority becomes READY, this higher priority task is activated and the preempted task remains in the the READY state.

The active task may be delayed for or until a specified time; in this case it is put into the DELAY state (TS_DELAY) and the next highest priority task in the READY state is activated.

The active task may also have to wait for an event (or semaphore, mailbox, or queue). If the event has not yet occurred, the task is put into the waiting state and the next highest priority task in the READY state is activated.

A non-existent task is one that is not yet available to embOS; it has either not been created yet or it has been terminated.

The following illustration shows all possible task states and transitions between them.



2.9 How the OS gains control

When the CPU is reset, the special-function registers are set to their respective values. After reset, program execution begins. The PC register is set to the start address defined by the start vector or start address (depending on the CPU). This start address is usually in a startup module shipped with the C compiler, and is sometimes part of the standard library.

The startup code performs the following:

- Loads the stack pointers with the default values, which is for most CPUs the end of the defined stack segment(s)
- Initializes all data segments to their respective values
- Calls the `main()` routine.

In a single-task-program, the `main()` routine is part of your program which takes control immediately after the C startup. Normally, embOS works with the standard C startup module without any modification. If there are any changes required, they are documented in the startup file which is shipped with embOS.

The `main()` routine is still part of your application program. Basically, `main()` creates one or more tasks and then starts multitasking by calling `OS_Start()`. From then on, the scheduler controls which task is executed.

The `main()` routine will not be interrupted by any of the created tasks, because those tasks are executed only after the call to `OS_Start()`. It is therefore usually recommended to create all or most of your tasks here, as well as your control structures such as mailboxes and semaphores. A good practice is to write software in the form of modules which are (up to a point) reusable. These modules usually have an initialization routine, which creates the required task(s) and/or control structures.
A typical `main()` looks similar to the following example:

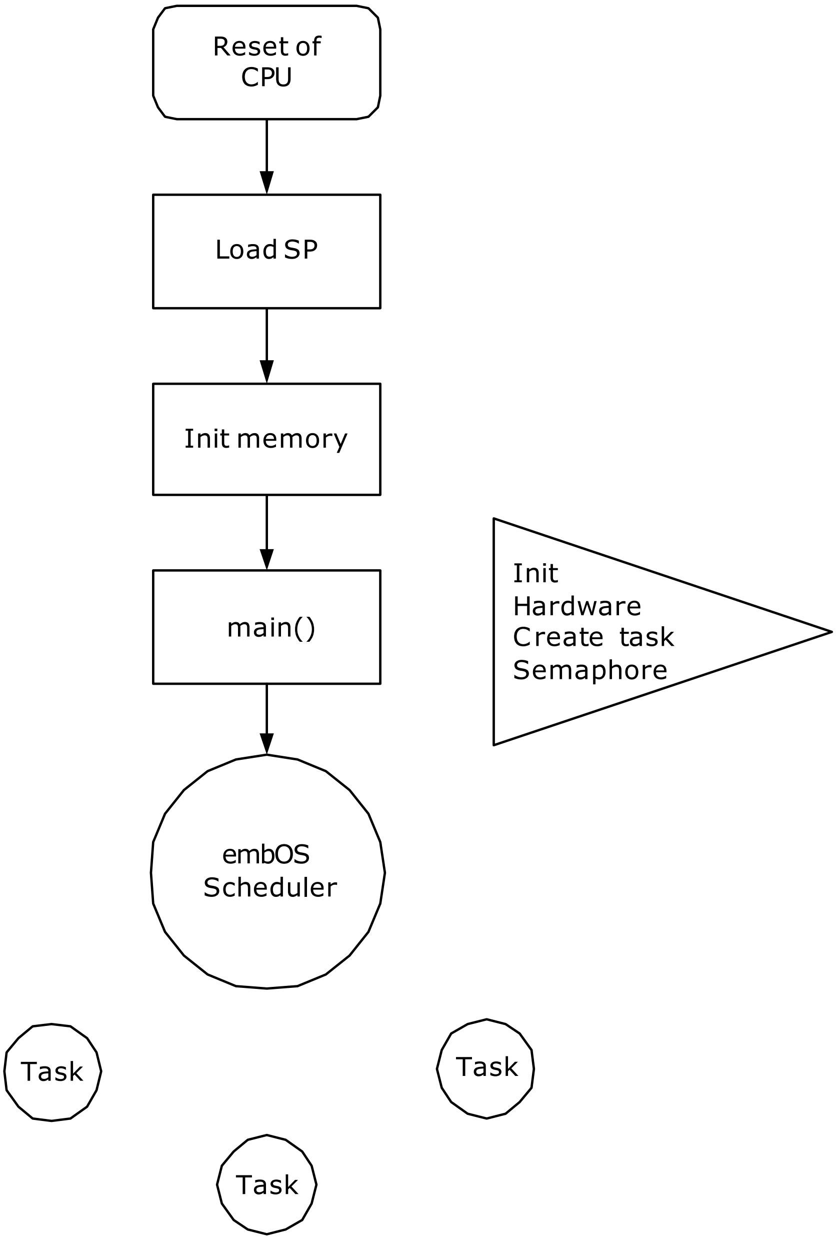
Example

```
/*********************************************************************
*
*                    main
*
**********************************************************************
*/

void main(void) {
  OS_InitKern();        /* Initialize OS (should be first !)          */
  OS_InitHW();          /* Initialize Hardware for OS (in RtosInit.c) */
  /* Call Init routines of all program modules which in turn will create
  the tasks they need ... (Order of creation may be important) */
  MODULE1_Init();
  MODULE2_Init();
  MODULE3_Init();
  MODULE4_Init();
  MODULE5_Init();
  OS_Start();           /* Start multitasking */
}
```

With the call to `OS_Start()`, the scheduler starts the highest-priority task that has been created in `main()`.

Note that `OS_Start()` is called only once during the startup process and does not return.

The flowchart below illustrates the starting procedure:



2.10 Different builds of embOS

embOS comes in different builds, or versions of the libraries. The reason for different builds is that requirements vary during development. While developing software, the performance (and resource usage) is not as important as in the final version which usually goes as release version into the product. But during development, even small programming errors should be caught by use of assertions. These assertions are compiled into the debug version of the embOS libraries and make the code a bit bigger (about 50%) and also slightly slower than the release or stack check version used for the final product.

This concept gives you the best of both worlds: a compact and very efficient build for your final product (release or stack check versions of the libraries), and a safer (though bigger and slower) version for development which will catch most of the common application programming errors. Of course, you may also use the release version of embOS during development, but it will not catch these errors.

2.10.1 Profiling

embOS supports profiling in profiling builds. Profiling makes precise information available about the execution time of individual tasks. You may always use the profiling libraries, but they induce certain overhead such as bigger task control blocks, additional ROM (approximately 200 bytes) and additional runtime overhead. This overhead is usually acceptable, but for best performance you may want to use non-profiling builds of embOS if you do not use this feature.

2.10.2 List of libraries

In your application program, you need to let the compiler know which build of embOS you are using. This is done by defining a single identifier prior to including `RTOS.h`.

Build	Define	Description
XR: Extreme Release	`OS_LIBMODE_XR`	Smallest fastest build. Does not support round robin scheduling and task names.
R: Release	`OS_LIBMODE_R`	Small, fast build, normally used for release version of application
S: Stack check	`OS_LIBMODE_S`	Same as release, plus stack checking
SP: Stack check plus profiling	`OS_LIBMODE_SP`	Same as stack check, plus profiling
D: Debug	`OS_LIBMODE_D`	Maximum runtime checking
DP: Debug plus profiling	`OS_LIBMODE_DP`	Maximum runtime checking, plus profiling
DT: Debug including trace, profiling	`OS_LIBMODE_DT`	Maximum runtime checking, plus tracing API calls and profiling

Table 2.1: List of libraries

Chapter 3

Task routines

A task that should run under embOS needs a task control block (TCB), a stack, and a normal routine written in C. The following rules apply to task routines:

- The task routine cannot take parameters.
- The task routine must never be called directly from your application.
- The task routine must not return.
- The task routine should be implemented as an endless loop, or it must terminate itself (see examples below).
- The task routine needs to be started from the scheduler, after the task is created and `OS_Start()` is called.

Example of task routine as an endless loop:

```
/*  Example of a task routine as an endless loop */
void Task1(void) {
  while(1) {
    DoSomething()               /* Do something  */
    OS_Delay(1);    /* Give other tasks a chance */
  }
}
```

Example of task routine that terminates itself

```
/*  Example of a task routine that terminates       */
void Task2(void) {
  char DoSomeMore;
  do {
    DoSomeMore = DoSomethingElse() /* Do something  */
    OS_Delay(1);       /* Give other tasks a chance */
  } while(DoSomeMore);
  OS_Terminate(0);     /* Terminate yourself        */
}
```

There are different ways to create a task; embOS offers a simple macro that makes this easy and which is fully sufficient in most cases. However, if you are dynamically creating and deleting tasks, a routine is available allowing "fine-tuning" of all parameters. For most applications, at least initially, using the macro as in the sample start project works fine.

3.1 Task routine API function overview

Routine	Description
OS_CREATETASK()	Creates a task.
OS_CreateTask()	Creates a task.
OS_CREATETASK_EX()	Creates a task with parameter.
OS_CreateTaskEx()	Creates a task with parameter.
OS_Delay()	Suspends the calling task for a specified period of time.
OS_DelayUntil()	Suspends the calling task until a specified time.
OS_ExtendTaskContext()	Make global variables or processor registers task specific.
OS_GetpCurrentTask()	Returns a pointer to the task control block structure of the currently running task.
OS_GetPriority()	Returns the priority of a specified task
OS_GetSuspendCnt()	Returns the suspension count.
OS_GetTaskID()	Returns the ID of the currently running task.
OS_IsTask()	Determines whether a task control block actually belongs to a valid task.
OS_Resume()	Decrements the suspend count of specified task and resumes the task, if the suspend count reaches zero.
OS_SetPriority()	Assigns a specified priority to a specified task.
OS_SetTaskName()	Allows modification of a task name at runtime.
OS_SetTimeSlice()	Assigns a specified timeslice value to a specified task.
OS_Suspend()	Suspends the specified task.
OS_Terminate()	Ends (terminates) a task.
OS_WakeTask()	Ends delay of a task immediately.
OS_Yield()	Calls the scheduler to force a task switch.

Table 3.1: Task routine API list

3.1.1 OS_CREATETASK()

Description

Creates a task.

Prototype

```
void  OS_CREATETASK (OS_TASK*      pTask,
                     char*         pName,
                     void*         pRoutine,
                     unsigned char Priority,
                     void*         pStack);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which will be used as task control block (and reference) for this task.
pName	Pointer to the name of the task. Can be NULL (or 0) if not used.
pRoutine	Pointer to a routine that should run as a task
Priority	Priority of the task. Must be within the following range: 1 <= Priority <=255 Higher values indicate higher priorities.
pStack	Pointer to an area of memory in RAM that will serve as stack area for the task. The size of this block of memory determines the size of the stack area.

Table 3.2: OS_CREATETASK() parameter list

Additional Information

OS_CREATETASK() is a macro calling an OS library function. It creates a task and makes it ready for execution by putting it in the READY state. The newly created task will be activated by the scheduler as soon as there is no other task with higher priority in the READY state. If there is another task with the same priority, the new task will be placed right before it. This macro is normally used for creating a task instead of the function call OS_CreateTask(), because it has fewer parameters and is therefore easier to use.

OS_CREATETASK() can be called at any time, either from main() during initialization or from any other task. The recommended strategy is to create all tasks during initialization in main() to keep the structure of your tasks easy to understand.
The absolute value of Priority is of no importance, only the value in comparison to the priorities of other tasks.

OS_CREATETASK() determines the size of the stack automatically, using sizeof. This is possible only if the memory area has been defined at compile time.

Important

The stack that you define has to reside in an area that the CPU can actually use as stack. Most CPUs cannot use the entire memory area as stack.Most CPUs require alignment of stack in multiples of bytes. This is automatically done, when the task stack is defined as an array of integers.

Example

```
OS_STACKPTR int UserStack[150]; /* Stack-space */
OS_TASK UserTCB;          /* Task-control-blocks */

void UserTask(void) {
  while (1) {
    Delay (100);
  }
}

void InitTask(void) {
  OS_CREATETASK(&UserTCB, "UserTask", UserTask, 100, UserStack);
}
```


3.1.2 OS_CreateTask()

Description

Creates a task.

Prototype

```
void OS_CreateTask (OS_TASK*       pTask,
                    char*          pName,
                    unsigned char  Priority,
                    voidRoutine*   pRoutine,
                    void*          pStack,
                    unsigned       StackSize,
                    unsigned char  TimeSlice);)
```

Parameter	Description
pTask	Pointer to a data structure of type `OS_TASK` which will be used as the task control block (and reference) for this task.
pName	Pointer to the name of the task. Can be `NULL` (or 0) if not used.
Priority	Priority of the task. Must be within the following range: 1 <= Priority <=255 Higher values indicate higher priorities.
pRoutine	Pointer to a routine that should run as task
pStack	Pointer to an area of memory in RAM that will serve as stack area for the task. The size of this block of memory determines the size of the stack area.
StackSize	Size of the Stack
TimeSlice	Time slice value for round-robin scheduling. Has an effect only if other tasks are running at the same priority.TimeSlice denotes the time in embOS timer ticks that the task will run until it suspends; thus enabling another task with the same priority. This parameter has no effect on some ports of embOS for efficiency reasons.

Table 3.3: OS_CreateTask() parameter list

Additional Information

This function works the same way as `OS_CREATETASK()`, except that all parameters of the task can be specified.
The task can be dynamically created because the stack size is not calculated automatically as it is with the macro.

Important

The stack that you define has to reside in an area that the CPU can actually use as stack. Most CPUs cannot use the entire memory area as stack.
Most CPUs require alignment of stack in multiples of bytes. This is automatically done, when the task stack is defined as an array of integers.

Example

```
/* Demo-program to illustrate the use of OS_CreateTask */

OS_STACKPTR int StackMain[100], StackClock[50];
OS_TASK TaskMain,TaskClock;
OS_SEMA SemaLCD;

void Clock(void) {
  while(1) {
    /* Code to update the clock */
  }
}

void Main(void) {
  while (1) {
    /* Your code  */
  }
}

void InitTask(void) {
  OS_CreateTask(&TaskMain,  NULL, 50, Main,  StackMain, sizeof(StackMain), 2);
  OS_CreateTask(&TaskClock, NULL, 100, Clock,StackClock,sizeof(StackClock),2);
}
```


3.1.3 OS_CREATETASK_EX()

Description

Creates a task and passes a parameter to the task.

Prototype

```
void  OS_CREATETASK_EX (OS_TASK*       pTask,
                        char*          pName,
                        void*          pRoutine,
                        unsigned char  Priority,
                        void*          pStack,
                        void*          pContext);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which will be used as task control block (and reference) for this task.
pName	Pointer to the name of the task. Can be NULL (or 0) if not used.
pRoutine	Pointer to a routine that should run as a task.
Priority	Priority of the task. Must be within the following range: 1 <= Priority <=255 Higher values indicate higher priorities.
pStack	Pointer to an area of memory in RAM that will serve as stack area for the task. The size of this block of memory determines the size of the stack area.
pContext	Parameter passed to the created task function.

Table 3.4: OS_CREATETASK_EX() parameter list

Additional Information

OS_CREATETASK_EX() is a macro calling an embOS library function. It works like OS_CREATETASK(), but allows passing a parameter to the task.
Using a void pointer as additional parameter gives the flexibility to pass any kind of data to the task function.

Example

The following example is delivered in the Samples folder of embOS.

```
/*-------------------------------------------------------------------
File    : Main_TaskEx.c
Purpose : Sample program for embOS using OC_CREATETASK_EX
--------- END-OF-HEADER --------------------------------------------*/

#include "RTOS.h"
OS_STACKPTR int StackHP[128], StackLP[128];          /* Task stacks */
OS_TASK TCBHP, TCBLP;                        /* Task-control-blocks */
/********************************************************************/
static void TaskEx(void* pData) {
  while (1) {
    OS_Delay ((OS_TIME) pData);
  }
}
/*********************************************************************
*
*       main
*
*********************************************************************/
int main(void) {
  OS_IncDI();                      /* Initially disable interrupts  */
  OS_InitKern();                   /* initialize OS                 */
  OS_InitHW();                     /* initialize Hardware for OS    */
  /* You need to create at least one task before calling OS_Start() */
  OS_CREATETASK_EX(&TCBHP, "HP Task", TaskEx, 100, StackHP, (void*) 50);
  OS_CREATETASK_EX(&TCBLP, "LP Task", TaskEx,  50, StackLP, (void*) 200);
  OS_SendString("Start project will start multitasking !\n");
  OS_Start();                      /* Start multitasking            */
  return 0;
}
```

3.1.4 OS_CreateTaskEx()

Description

Creates a task and passes a parameter to the task.

Prototype

```
void OS_CreateTaskEx (OS_TASK*      pTask,
                      char*         pName,
                      unsigned char Priority,
                      voidRoutine*  pRoutine,
                      void*         pStack,
                      unsigned      StackSize,
                      unsigned char TimeSlice,
                      void*         pContext);)
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which will be used as the task control block (and reference) for this task.
pName	Pointer to the name of the task. Can be NULL (or 0) if not used.
Priority	Priority of the task. Must be within the following range: 1 <= Priority <=255 Higher values indicate higher priorities.
pRoutine	Pointer to a routine that should run as task.
pStack	Pointer to an area of memory in RAM that will serve as stack area for the task. The size of this block of memory determines the size of the stack area.
StackSize	Size of the Stack
Timeslice	Time slice value for round-robin scheduling. Has an effect only if other tasks are running at the same priority.TimeSlice denotes the time in embOS timer ticks that the task will run until it suspends; thus enabling another task with the same priority. This parameter has no effect on some ports of embOS for efficiency reasons.
pContext	Parameter passed to the created task.

Table 3.5: OS_Create_Task_Ex() parameter list

Additional Information

This function works the same way as `OS_CreateTask()`, except that a parameter is passed to the task function.
An example of parameter passing to tasks is shown under `OS_CREATETASK_EX()`.

3.1.5 OS_Delay()

Description

Suspends the calling task for a specified period of time.

Prototype

```
void OS_Delay (int ms);
```

Parameter	Description
ms	Time interval to delay. Must be within the following range: 1 <= ms <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= ms <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 3.6: OS_Delay() parameter list

Additional Information

The calling task will be put into the TS_DELAY state for the period of time specified. The task will stay in the delayed state until the specified time has expired. The parameter ms specifies the precise interval during which the task has to be suspended given in basic time intervals (usually 1/1000 sec). The actual delay (in basic time intervals) will be in the following range: ms - 1 <= delay <= ms, depending on when the interrupt for the scheduler will occur.
After the expiration of a delay, the task is made ready again and activated according to the rules of the scheduler. A delay can be ended prematurely by another task or by an interrupt handler calling `OS_WakeTask()`.

Example

```
void Hello() {
  printf("Hello");
  printf("The next output will occur in 5 seconds");
  OS_Delay (5000);
  printf("Delay is over");
}
```

3.1.6 OS_DelayUntil()

Description

Suspends the calling task until a specified time.

Prototype

```
void OS_DelayUntil (int t);
```

Parameter	Description
t	Time to delay until. Must be within the following range: 1 <= (t - OS_Time) <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= (t - OS_Time) <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 3.7: OS_DelayUntil() parameter list

Additional Information

The calling task will be put into the TS_DELAY state until the time specified.
The OS_DelayUntil() function delays until the value of the time-variable OS_Time has reached a certain value. It is very useful if you have to avoid accumulating delays.

Example

```
int sec,min;

void TaskShowTime() {
  int t0 = OS_GetTime();
  while (1) {
    ShowTime();                     /* Routine to display time */
    OS_DelayUntil (t0 += 1000);
    if (sec < 59) sec++;
    else {
      sec=0;
      min++;
    }
  }
}
```

In the example above, the use of OS_Delay() could lead to accumulating delays and would cause the simple "clock" to be slow.

3.1.7 OS_ExtendTaskContext()

Description

The function may be used for a varity of purposes. Typical applications include, but are not limited to:

- global variables such as "errno" in the "C"-library, making the C-lib functions thread-safe.
- additional, optional CPU / registers such as MAC / EMAC registers (mutliply and accumulate unit) if they are not saved in the task context per default.
- Co-processor registers such as registers of a VFP (floating point coprocessor).
- Data registers of an add. hardware unit such as a CRC calculation unit

This allows the user to extend the task context as required by his system. A major advantage is that the task extension is task specific. This means that the additional information (such as floating point registers) needs to be saved only by tasks that actually use these registers. The advatange is that the task switing time of the other tasks is not affected. The same thing is true for the required stack space: Add. stack space is required only for the tasks which actually save the add. registers.

Prototype

```
void OS_ExtendTaskContext(const OS_EXTEND_TASK_CONTEXT * pExtendContext);
```

Parameter	Description
pExtendContext	Pointer to the OS_EXTEND_TASK_CONTEXT structure which contains the addresses of the specific save and restore functions which save and restore the extended task context during task switches.

Table 3.8: OS_ExtendTaskContext() parameter list

Additional Information

The OS_EXTEND_TASK_CONTEXT structure is defined as follows:

```
typedef struct OS_EXTEND_TASK_CONTEXT {
  void (*pfSave)    (      void * pStack);
  void (*pfRestore)(const void * pStack);
} OS_EXTEND_TASK_CONTEXT;
```

The save and restore functions have to be declared according the function type used in the structure.
The sample below shows, how the task stack has to be addressed to save and restore the extended task context.

OS_ExtendTaskContext() is not available in the XR libraries.

Example

The following example is delivered in the Samples folder of embOS.

```
----------------------------------------------------------------------
File : ExtendTaskContext.c
Purpose : Sample program for embOS demonstrating how to dynamically
extend the task context.
This example adds a global variable to the task context of
certain tasks.
-------- END-OF-HEADER -----------------------------------------------
*/
#include "RTOS.h"


OS_STACKPTR int StackHP[128], StackLP[128];          /* Task stacks */
OS_TASK TCBHP, TCBLP;                        /* Task-control-blocks */
int GlobalVar;
```

```
/*********************************************************************
*
*       _Restore
*       _Save
*
*  Function description
*    This function pair saves and restores an extended task context.
*    In this case, the extended task context consists of just a single
*    member, which is a global variable.
*/

typedef struct {
  int GlobalVar;
} CONTEXT_EXTENSION;

static void _Save(void * pStack) {
  CONTEXT_EXTENSION * p;
  p = ((CONTEXT_EXTENSION*)pStack) - (1 - OS_STACK_AT_BOTTOM);  // Create pointer
  //
  // Save all members of the structure
  //
  p->GlobalVar = GlobalVar;
}

static void _Restore(const void * pStack) {
  CONTEXT_EXTENSION * p;
  p = ((CONTEXT_EXTENSION*)pStack) - (1 - OS_STACK_AT_BOTTOM);  // Create pointer
  //
  // Restore all members of the structure
  //
  GlobalVar = p->GlobalVar;
}


/*********************************************************************
*
*       Global variable which holds the function pointers
*       to save and restore the task context.
*/
const OS_EXTEND_TASK_CONTEXT _SaveRestore = {
  _Save,
  _Restore
};


/********************************************************************/


/*********************************************************************
*
*       HPTask
*
*  Function description
*    During the execution of this function, the thread-specific
*    global variable has always the same value of 1.
*/
static void HPTask(void) {
  OS_ExtendTaskContext(&_SaveRestore);
  GlobalVar = 1;
  while (1) {
    OS_Delay (10);
  }
}

/*********************************************************************
*
*       LPTask
*
*  Function description
*    During the execution of this function, the thread-specific
*    global variable has always the same value of 2.
*/
static void LPTask(void) {
  OS_ExtendTaskContext(&_SaveRestore);
  GlobalVar = 2;
  while (1) {
    OS_Delay (50);
  }
}
```



```
/*********************************************************************
*
*       main
*/
int main(void) {
  OS_IncDI();                      /* Initially disable interrupts  */
  OS_InitKern();                   /* initialize OS                 */
  OS_InitHW();                     /* initialize Hardware for OS    */
  /* You need to create at least one task here !                    */
  OS_CREATETASK(&TCBHP, "HP Task", HPTask, 100, StackHP);
  OS_CREATETASK(&TCBLP, "LP Task", LPTask,  50, StackLP);
  OS_Start();                      /* Start multitasking            */
  return 0;
}
```


3.1.8 OS_GetpCurrentTask()

Description

Returns a pointer to the task control block structure of the currently running task.

Prototype

```
OS_TASK* OS_GetpCurrentTask (void);
```

Return value

`OS_TASK*`: A pointer to the task control block structure.

Additional Information

This function may be used for determining which task is executing. This may be helpful if the reaction of any function depends on the currently running task.

3.1.9 OS_GetPriority()

Description

Returns the priority of a specified task.

Prototype

```
unsigned char OS_GetPriority (OS_TASK* pTask);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK.

Table 3.9: OS_GetPriority() parameter list

Return value

Priority of the specified task as an "unsigned character" (range 1 to 255).

Additional Information

If pTask is the NULL pointer, the function returns the priority of the currently running task. If pTask does not specify a valid task, the debug version of embOS calls OS_Error(). The release version of embOS cannot check the validity of pTask and may therefore return invalid values if pTask does not specify a valid task.

Important

This function may not be called from within an interrupt handler.

3.1.10 OS_GetSuspendCnt()

Description

The function returns the suspension count and thus suspension state of the specified task. This function may be used for examining whether a task is suspended by previous calls of `OS_Suspend()`.

Prototype

```
unsigned char OS_GetSuspendCnt (OS_TASK* pTask);
```

Parameter	Description
pTask	Pointer to a data structure of type `OS_TASK`.

Table 3.10: OS_GetSuspendCnt() parameter list

Return value

Suspension count of the specified task as unsigned character value.
0: Task is not suspended.
>0: Task is suspended by at least one call of `OS_Suspend()`.

Additional Information

If `pTask` does not specify a valid task, the debug version of embOS calls `OS_Error()`. The release version of embOS can not check the validity of `pTask` and may therefore return invalid values if `pTask` does not specify a valid task. When tasks are created and terminated dynamically, `OS_IsTask()` may be called prior calling OS_GetSuspendCnt() to examine whether the task is valid. The remturned value can be used for resuming a suspended task by calling `OS_Resume()` as often as indicated by the returned value.

Example

```
/* Demo-function to illustrate the use of OS_GetSuspendCnt() */

void ResumeTask(OS_TASK* pTask) {
  unsigned char SuspendCnt;
  SuspendCnt = OS_GetSuspendCnt(pTask);
  while(SuspendCnt > 0) {
    OS_Resume(pTask); /* May cause a task switch */
    SuspendCnt--;
  }
}
```


3.1.11 OS_GetTaskID()

Description

Returns the ID of the currently running task.

Prototype

```
OS_TASKID OS_GetTaskID (void);
```

Return value

`OS_TASKID`: A pointer to the task control block. A value of 0 (`NULL`) indicates that no task is executing.

Additional Information

This function may be used for determining which task is executing. This may be helpful if the reaction of any function depends on the currently running task.

3.1.12 OS_IsTask()

Description

Determines whether a task control block actually belongs to a valid task.

Prototype

```
char OS_IsTask (OS_TASK* pTask);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which is used as task control block (and reference) for this task.

Table 3.11: OS_IsTask() parameter list

Return value

Character value:
0: TCB is not used by any task
1: TCB is used by a task

Additional Information

This function checks if the specified task is still in the internal task list. If the task was terminated, it is removed from the internal task list. This function may be useful to determine whether the task control block and stack for the task may be reused for another task in applications that create and terminate tasks dynamically.

3.1.13 OS_Resume()

Description

Decrements the suspend count of the specified task and resumes it, if the suspend count reaches zero.

Prototype

```
void OS_Resume (OS_TASK* pTask);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which is used as task control block (and reference) for the task that should be suspended.

Table 3.12: OS_Resume() parameter list

Additional Information

The specified task's suspend count is decremented. If the resulting value is 0, the execution of the specified task is resumed.
If the task is not blocked by other task blocking mechanisms, the task will be set back in ready state and continues operation according to the rules of the scheduler.
In debug versions of embOS, the OS_Resume() function checks the suspend count of the specified task. If the suspend count is 0 when OS_Resume() is called, the specified task is not currently suspended and OS_Error() is called with error OS_ERR_RESUME_BEFORE_SUSPEND.

3.1.14 OS_SetPriority()

Description

Assigns a specified priority to a specified task.

Prototype

```
void OS_SetPriority (OS_TASK* pTask,
                     unsigned char Priority);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK.
Priority	Priority of the task. Must be within the following range: 1 <= Priority <= 255 Higher values indicate higher priorities.

Table 3.13: OS_SetPriority() parameter list

Additional Information

Can be called at any time from any task or software timer. Calling this function might lead to an immediate task switch.

Important

This function may not be called from within an interrupt handler.

3.1.15 OS_SetTaskName()

Description

Allows modification of a task name at runtime.

Prototype

```
void OS_SetTaskNamePriority (OS_TASK* pTask,
                             const char* s);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK.
s	Pointer to a zero terminated string which is used as task name.

Table 3.14: OS_SetTaskName() parameter list

Additional Information

Can be called at any time from any task or software timer.
When pTask is the NULL pointer, the name of the currently running task is modified.

3.1.16 OS_SetTimeSlice()

Description

Assigns a specified timeslice value to a specified task.

Prototype

```
unsigned char OS_SetTimeSlice (OS_TASK*      pTask,
                               unsigned char TimeSlice);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK.
TimeSlice	New timeslice value for the task. Must be within the following range: 1 <= TimeSlice <= 255.

Table 3.15: OS_SetTimeSlice() parameter list

Return value

Previous timeslice value of the task as unsigned char.

Additional Information

Can be called at any time from any task or software timer. Setting the timeslice value only affects the tasks running in round-robin mode. This means another task with the same priority must exist.
The new timeslice value is interpreted as reload value. It is used after the next activation of the task. It does not affect the remaining timeslice of a running task.

3.1.17 OS_Suspend()

Description

Suspends the specified task.

Prototype

```
void OS_Suspend (OS_TASK* pTask);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which is used as task control block (and reference) for the task that should be suspended.

Table 3.16: OS_Suspend() parameter list

Additional Information

If pTask is the NULL pointer, the current task suspends.
If the function succeeds, execution of the specified task is suspended and the task's suspend count is incremented. The specified task will be suspended immediately. It can only be restarted by a call of OS_Resume().
Every task has a suspend count with a maximum value of OS_MAX_SUSPEND_CNT. If the suspend count is greater than zero, the task is suspended.
In debug versions of embOS, calling OS_Suspend() more often than OS_MAX_SUSPEND_CNT times without calling OS_Resume(), the task's internal suspend count is not incremented and OS_Error() is called with error OS_ERR_SUSPEND_TOO_OFTEN.

3.1.18 OS_Terminate()

Description

Ends (terminates) a task.

Prototype

```
void OS_Terminate (OS_TASK* pTask);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which is used as task control block (and reference) for this task.

Table 3.17: OS_Terminate() parameter list

Additional Information

If pTask is the NULL pointer, the current task terminates. The specified task will terminate immediately. The memory used for stack and task control block can be reassigned.

Since version 3.26 of embOS, all resources which are held by the terminated task are released. Any task may be terminated regardless of its state. This functionality is default for any 16-bit or 32-bit CPU and may be changed by recompiling embOS sources. On 8-bit CPUs, terminating tasks that hold any resources is prohibited. To enable safe termination, the embOS sources have to be recompiled with the compile time switch OS_SUPPORT_CLEANUP_ON_TERMINATE activated.

Important

This function may not be called from within an interrupt handler.

3.1.19 OS_WakeTask()

Description

Ends delay of a task immediately.

Prototype

```
void OS_WakeTask (OS_TASK* pTask);
```

Parameter	Description
pTask	Pointer to a data structure of type OS_TASK which is used as task control block (and reference) for this task.

Table 3.18: OS_WakeTask() parameter list

Additional Information

Puts the specified task, which is already suspended for a certain amount of time with OS_Delay() or OS_DelayUntil() back to the state TS_READY (ready for execution). The specified task will be activated immediately if it has a higher priority than the priority of the task that had the highest priority before. If the specified task is not in the state TS_DELAY (because it has already been activated, or the delay has already expired, or for some other reason), this command is ignored.

3.1.20 OS_Yield()

Description

Calls the scheduler to force a task switch.

Prototype

```
void OS_Yield (void);
```

Additional Information

If the task is running on round-robin, it will be suspended if there is an other task with the same priority ready for execution.

Chapter 4

Software timers

A software timer is an object that calls a user-specified routine after a specified delay. A basically unlimited number of software timers can be defined with the macro `OS_CREATETIMER()`.

Timers can be stopped, started and retriggered much like hardware timers. When defining a timer, you specify any routine that is to be called after the expiration of the delay. Timer routines are similar to interrupt routines; they have a priority higher than the priority of all tasks. For that reason they should be kept short just like interrupt routines.

Software timers are called by embOS with interrupts enabled, so they can be interrupted by any hardware interrupt. Generally, timers run in single-shot mode, which means they expire only once and call their callback routine only once. By calling `OS_RetriggerTimer()` from within the callback routine, the timer is restarted with its initial delay time and therefore works just as a free-running timer.

The state of timers can be checked by the functions `OS_GetTimerStatus()`, `OS_GetTimerValue()`, and `OS_GetTimerPeriod()`.

Maximum timeout / period

The timeout value is stored as an integer, thus a 16-bit value on 8/16-bit CPUs, a 32-bit value on 32-bit CPUs. The comparisons are done as signed comparisons, (because expired time-outs are permitted). This means that only 15-bits can be used on 8/16 bit CPUs, 31-bits on 32-bit CPUs. Another factor to take into account is the maximum time spent in critical regions. During critical regions timers may expire, but because the timer routine can not be called from a critical region (timers are "put on hold"), the maximum time that the system spends at once in a critical region needs to be deducted. In most systems, this is no more than a single tick. However, to be safe, we have assumed that your system spends no more than up to 255 ticks in a row in a critical region and defined a macro which defines the maximum timeout value. It is normally `0x7F00` for 8/16-bit systems or `0x7FFFFF00` for 32-bit Systems and defined in `RTOS.h` as `OS_TIMER_MAX_TIME`. If your system spends more than 255 ticks without break in a critical section (effectively disabling the scheduler during this time ... not recommended), you have to make sure your application uses shorter timeouts.

Extended software timers

Sometimes it may be useful to pass a paramter to the timer callback function. This allows usage of one callback function for different software timers.
Since version 3.32m of embOS, the extended timer structure and related extended timer functions were implemented to allow parameter passing to the callback function.
Except the different callback function with parameter passing, extended timers behave exactly the same as normal embOS software timers and may be used in parallel with normal software timers.

4.1 Software timers API function overview

Routine	Description
OS_CREATETIMER()	Macro that creates and starts a software-timer.
OS_CreateTimer()	Creates a software timer without starting it.
OS_StartTimer()	Starts a software timer.
OS_StopTimer()	Stops a software timer.
OS_RetriggerTimer()	Restarts a software timer with its initial time value.
OS_SetTimerPeriod()	Sets a new timer reload value for a software timer.
OS_DeleteTimer()	Stops and deletes a software timer.
OS_GetTimerPeriod()	Returns the current reload value of a software timer.
OS_GetTimerValue()	Returns the remaining timer value of a software timer.
OS_GetTimerStatus()	Returns the current timer status of a software timer.
OS_GetpCurrentTimer()	Returns a pointer to the data structure of the timer that just expired.
OS_CREATETIMER_EX()	Macro that creates and starts an extended software-timer.
OS_CreateTimer_Ex()	Creates an extended software timer without starting it.
OS_StartTimer_Ex()	Starts an extended timer.
OS_StopTimer_Ex()	Stops an extended timer.
OS_RetriggerTimer_Ex()	Restarts an extended timer with its initial time value.
OS_SetTimerPeriod_Ex()	Sets a new timer reload value for an extended timer.
OS_DeleteTimer_Ex()	Stops and deletes an extended timer.
OS_GetTimerPeriod_Ex()	Returns the current reload value of an extended timer.
OS_GetTimerValue_Ex()	Returns the remaining timer value of an extended timer.
OS_GetTimerStatus_Ex()	Returns the current timer status of an extended timer.
OS_GetpCurrentTimerEx()	Returns a pointer to the data structure of the extended timer that just expired.

Table 4.1: Software timers API

4.1.1 OS_CREATETIMER()

Description

Macro that creates and starts a software timer.

Prototype

```
void OS_CREATETIMER (OS_TIMER*         pTimer,
                     OS_TIMERROUTINE* Callback,
                     OS_TIME Timeout););
```

Parameter	Description
pTimer	Pointer to the `OS_TIMER` data structure which contains the data of the timer.
Callback	Pointer to the callback routine to be called from the RTOS after expiration of the delay. The callback function hast to be a void function which does not take any parameter and does not return any value.
Timeout	Initial timeout in basic embOS time units (nominal ms): The data type `OS_TIME` is defined as an integer, therefore valid values are 1 <= `Timeout` <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= `Timeout` <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 4.2: OS_CREATETIMER() parameter list

Additional Information

embOS keeps track of the timers by using a linked list. Once the timeout is expired, the callback routine will be called immediately (unless the current task is in a critical region or has interrupts disabled).
This macro uses the functions `OS_CreateTimer()` and `OS_StartTimer()`. It is supplied for backward compatibility; in newer applications these routines should be called directly instead.
`OS_TIMERROUTINE` is defined in `RTOS.h` as follows:

```
typedef void OS_TIMERROUTINE(void);
```

```
Source of the macro (in RTOS.h):

#define OS_CREATETIMER(pTimer,c,d)   \
        OS_CreateTimer(pTimer,c,d); \
        OS_StartTimer(pTimer);
```

Example

```
OS_TIMER TIMER100;

void Timer100(void) {
  LED = LED ? 0 : 1;              /* Toggle LED   */
  OS_RetriggerTimer(&TIMER100);   /* Make timer periodical */
}

void InitTask(void) {
  /* Create and start Timer100   */
  OS_CREATETIMER(&TIMER100, Timer100, 100);
}
```


4.1.2 OS_CreateTimer()

Description

Creates a software timer (but does not start it).

Prototype

```
void OS_CreateTimer (OS_TIMER*         pTimer,
                     OS_TIMERROUTINE* Callback,
                     OS_TIME Timeout););
```

Parameter	Description
pTimer	Pointer to the OS_TIMER data structure which contains the data of the timer.
Callback	Pointer to the callback routine to be called from the RTOS after expiration of the delay.
Timeout	Initial timeout in basic embOS time units (nominal ms): The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 4.3: OS_CreateTimer() parameter list

Additional Information

embOS keeps track of the timers by using a linked list. Once the timeout is expired, the callback routine will be called immediately (unless the current task is in a critical region or has interrupts disabled). The timer is not automatically started. This has to be done explicitly by a call of OS_StartTimer() or OS_RetriggerTimer().
OS_TIMERROUTINE is defined in RTOS.h as follows:

```
typedef void OS_TIMERROUTINE(void);
```

Example

```
OS_TIMER TIMER100;

void Timer100(void) {
  LED = LED ? 0 : 1;            /* Toggle LED  */
  OS_RetriggerTimer(&TIMER100);  /* Make timer periodical */
}

void InitTask(void) {
  /* Create Timer100, start it elsewhere */
  OS_CreateTimer(&TIMER100, Timer100, 100);
}
```

4.1.3 OS_StartTimer()

Description

Starts a software timer.

Prototype

```
void OS_StartTimer (OS_TIMER* pTimer);
```

Parameter	Description
pTimer	Pointer to the `OS_TIMER` data structure which contains the data of the timer.

Table 4.4: OS_StartTimer() parameter list

Additional Information

`OS_StartTimer()` is used for the following reasons:

- Start a timer which was created by `OS_CreateTimer()`. The timer will start with its initial timer value.
- Restart a timer which was stopped by calling `OS_StopTimer()`. In this case, the timer will continue with the remaining time value which was preserved by stopping the timer.

Important

This function has no effect on running timers. It also has no effect on timers that are not running, but have expired. Use `OS_RetriggerTimer()` to restart those timers.

4.1.4 OS_StopTimer()

Description

Stops a software timer.

Prototype

```
void OS_StopTimer (OS_TIMER* pTimer);
```

Parameter	Description
pTimer	Pointer to the OS_TIMER data structure which contains the data of the timer.

Table 4.5: OS_StopTimer() parameter list

Additional Information

The actual value of the timer (the time until expiration) is kept until OS_StartTimer() lets the timer continue.

4.1.5 OS_RetriggerTimer()

Description

Restarts a software timer with its initial time value.

Prototype

```
void OS_RetriggerTimer (OS_TIMER* pTimer);
```

Parameter	Description
pTimer	Pointer to the OS_TIMER data structure which contains the data of the timer.

Table 4.6: OS_RetriggerTimer() parameter list

Additional Information

OS_RetriggerTimer() restarts the timer using the initial time value programmed at creation of the timer or with the function OS_SetTimerPeriod().

Example

```
OS_TIMER TIMERCursor;
BOOL CursorOn;

void TimerCursor(void) {
  if (CursorOn) ToggleCursor();     /* Invert character at cursor-position */
  OS_RetriggerTimer(&TIMERCursor); /* Make timer periodical */
}

void InitTask(void) {
  /* Create and start TimerCursor  */
  OS_CREATETIMER(&TIMERCursor, TimerCursor, 500);
}
```


4.1.6 OS_SetTimerPeriod()

Description

Sets a new timer reload value for a software timer.

Prototype

```
void OS_SetTimerPeriod (OS_TIMER* pTimer,
                        OS_TIME   Period);
```

Parameter	Description
pTimer	Pointer to the OS_TIMER data structure which contains the data of the timer.
Period	Timer period in basic embOS time units (nominal ms): The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 4.7: OS_SetTimerPeriod() parameter list

Additional Information

OS_SetTimerPeriod() sets the initial time value of the specified timer. Period is the reload value of the timer to be used as initial value when the timer is retriggered by OS_RetriggerTimer().

Example

```
OS_TIMER TIMERPulse;
BOOL CursorOn;

void TimerPulse(void) {
  if TogglePulseOutput();           /* Toggle output */
  OS_RetriggerTimer(&TIMERCursor); /* Make timer periodical */
}

void InitTask(void) {
  /* Create and start Pulse Timer with first pulse = 500ms */
  OS_CREATETIMER(&TIMERPulse, TimerPulse, 500);
  /* Set timer period to 200 ms for further pulses */
  OS_SetTimerPeriod(&TIMERPulse, 200);
}
```


4.1.7 OS_DeleteTimer()

Description

Stops and deletes a software timer.

Prototype

```
void OS_DeleteTimer (OS_TIMER* pTimer);
```

Parameter	Description
pTimer	Pointer to the OS_TIMER data structure which contains the data of the timer.

Table 4.8: OS_DeleteTimer() parameter list

Additional Information

The timer is stopped and therefore removed out of the linked list of running timers. In debug builds of embOS, the timer is also marked as invalid.

4.1.8 OS_GetTimerPeriod()

Description

Returns the current reload value of a software timer.

Prototype

```
OS_TIME OS_GetTimerPeriod (OS_TIMER* pTimer);
```

Parameter	Description
pTimer	Pointer to the OS_TIMER data structure which contains the data of the timer.

Table 4.9: OS_GetTimerPeriod() parameter list

Return value

Type OS_TIME, which is defined as an integer between
1 and 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs and as an integer between
1 and <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs, which is the permitted range of timer values.

Additional Information

The period returned is the reload value of the timer set as initial value when the timer is retriggered by OS_RetriggerTimer().

4.1.9 OS_GetTimerValue()

Description

Returns the remaining timer value of a software timer.

Prototype

```
OS_TIME OS_GetTimerValue (OS_TIMER* pTimer);
```

Parameter	Description
pTimer	Pointer to the OS_TIMER data structure which contains the data of the timer.

Table 4.10: OS_GetTimerValue() parameter list

Return value

Type OS_TIME, which is defined as an integer between
1 and 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs and as an integer between
1 and <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs, which is the permitted range of timer values.
The returned time value is the remaining timer time in embOS tick units until expiration of the timer.

4.1.10 OS_GetTimerStatus()

Description

Returns the current timer status of a software timer.

Prototype

```
unsigned char OS_GetTimerStatus (OS_TIMER* pTimer);
```

Parameter	Description
pTimer	Pointer to the `OS_TIMER` data structure which contains the data of the timer.

Table 4.11: OS_GetTimerStatus parameter list

Return value

`Unsigned character`, denoting whether the specified timer is running or not:
0: timer has stopped
! = 0: timer is running.

4.1.11 OS_GetpCurrentTimer()

Description

Returns a pointer to the data structure of the timer that just expired.

Prototype

```
OS_TIMER* OS_GetpCurrentTimer (void);
```

Return value

`OS_TIMER*`: A pointer to the control structure of a timer.

Additional Information

The return value of `OS_GetpCurrentTimer()` is valid during execution of a timer callback function; otherwise it is undetermined. If only one callback function should be used for multiple timers, this function can be used for examining the timer that expired.
The example below shows one usage of `OS_GetpCurrentTimer()`. Since version 3.32m of embOS, the extended timer structure and functions which come with embOS may be used to generate and use software timer with individual parameter for the callback function.

Example

```
#include "RTOS.H"

/*********************************************************
*
*       Types
*/
typedef struct {    /* Timer object with its own user data */
  OS_TIMER Timer;
  void*    pUser;
} TIMER_EX;

/*********************************************************
*
*       Variables
*/

TIMER_EX Timer_User;
int a;

/*********************************************************
*
*       Local Functions
*/

void CreateTimer(TIMER_EX* timer, OS_TIMERROUTINE* Callback, OS_UINT Timeout,
                 void* pUser) {
  timer->pUser = pUser;
  OS_CreateTimer((OS_TIMER*) timer, Callback, Timeout);
}

void cb(void) { /* Timer callback function for multiple timers  */
  TIMER_EX* p = (TIMER_EX*)OS_GetpCurrentTimer();
  void* pUser = p->pUser;          /* Examine user data */
  OS_RetriggerTimer(&p->Timer);    /* Retrigger timer   */
}

/*********************************************************
*
*       main
*/
int main(void) {
  OS_InitKern();         /* Initialize OS */
  OS_InitHW();           /* Initialize Hardware for OS */
  CreateTimer(&Timer_User, cb, 100, &a);
  OS_Start();            /* Start multitasking */
  return 0;
}
```


4.1.12 OS_CREATETIMER_EX()

Description

Macro that creates and starts an extended software timer.

Prototype

```
void OS_CREATETIMER_EX (OS_TIMER_EX*          pTimerEx,
                        OS_TIMER_EX_ROUTINE* Callback,
                        OS_TIME               Timeout
                        void*                 pData)
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended software timer.
Callback	Pointer to the callback routine to be called from the RTOS after expiration of the delay. The callback function hast to be of type OS_TIMER_EX_ROUTINE which takes a void pointer as parameter and does not return any value.
Timeout	Initial timeout in basic embOS time units (nominal ms): The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs
pData	A void pointer which is used as parameter for the extended timer callback function.

Table 4.12: OS_CREATETIMER_EX() parameter list

Additional Information

embOS keeps track of the timers by using a linked list. Once the timeout is expired, the callback routine will be called immediately (unless the current task is in a critical region or has interrupts disabled).
This macro uses the functions OS_CreateTimerEx() and OS_StartTimerEx(). OS_TIMER_EX_ROUTINE is defined in RTOS.h as follows:

```
typedef void OS_TIMER_EX_ROUTINE(void *);
```

```
Source of the macro (in RTOS.h):

#define OS_CREATETIMER_EX(pTimerEx,cb,Timeout,pData)   \
        OS_CreateTimerEx(pTimerEx,cb,Timeout,pData);   \
        OS_StartTimerEx(pTimerEx)
```

Example

```
OS_TIMER TIMER100;
OS_TASK  TCB_HP;

void Timer100(void* pTask) {
  LED = LED ? 0 : 1;                /* Toggle LED  */
  if (pTask != NULL) {
    OS_SignalEvent(0x01, (OS_TASK*)pTask);
  }
  OS_RetriggerTimerEx(&TIMER100);   /* Make timer periodical */
}

void InitTask(void) {
  /* Create and start Timer100  */
  OS_CREATETIMER_EX(&TIMER100, Timer100, 100, (void*) &TCB_HP);
}
```

4.1.13 OS_CreateTimerEx()

Description

Creates an extended software timer (but does not start it).

Prototype

```
void OS_CreateTimerEx (OS_TIMER_EX*          pTimerEx,
                       OS_TIMER_EX_ROUTINE* Callback,
                       OS_TIME               Timeout,
                       void*                 pData)
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended software timer.
Callback	Pointer to the callback routine of type OS_TIMER_EX_ROUTINE to be called from the RTOS after expiration of the timer.
Timeout	Initial timeout in basic embOS time units (nominal ms): The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs
pData	A void pointer which is used as parameter for the extended timer callback function.

Table 4.13: OS_CreateTimerEx() parameter list

Additional Information

embOS keeps track of the timers by using a linked list. Once the timeout has expired, the callback routine will be called immediately (unless the current task is in a critical region or has interrupts disabled).
The extended software timer is not automatically started. This has to be done explicitly by a call of `OS_StartTimerEx()` or `OS_RetriggerTimerEx()`.

`OS_TIMER_EX_ROUTINE` is defined in `RTOS.h` as follows:

```
typedef void OS_TIMER_EX_ROUTINE(void*);
```

Example

```
OS_TIMER TIMER100;
OS_TASK  TCB_HP;

void Timer100(void* pTask) {
  LED = LED ? 0 : 1;               /* Toggle LED  */
  if (pTask != NULL) {
    OS_SignalEvent(0x01, (OS_TASK*) pTask);
  }
  OS_RetriggerTimerEx(&TIMER100);  /* Make timer periodical */
}

void InitTask(void) {
  /* Create Timer100, start it elsewhere later on*/
  OS_CreateTimerEx(&TIMER100, Timer100, 100, (void*) & TCB_HP);
}
```


4.1.14 OS_StartTimerEx()

Description

Starts an extended software timer.

Prototype

```
void OS_StartTimerEx (OS_TIMER_EX* pTimerEx);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended software timer.

Table 4.14: OS_StartTimereEx() parameter list

Additional Information

OS_StartTimerEx() is used for the following reasons:

- Start an extended software timer which was created by OS_CreateTimerEx(). The timer will start with its initial timer value.
- Restart a timer which was stopped by calling OS_StopTimerEx(). In this case, the timer will continue with the remaining time value which was preserved by stopping the timer.

Important

This function has no effect on running timers. It also has no effect on timers that are not running, but have expired. Use OS_RetriggerTimerEx() to restart those timers.

4.1.15 OS_StopTimerEx()

Description

Stops an extended software timer.

Prototype

```
void OS_StopTimerEx (OS_TIMER_EX* pTimerEx);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended software timer.

Table 4.15: OS_StopTimerEx() parameter list

Additional Information

The actual time value of the extended software timer (the time until expiration) is kept until OS_StartTimerEx() lets the timer continue.

4.1.16 OS_RetriggerTimerEx()

Description

Restarts an extended software timer with its initial time value.

Prototype

```
void OS_RetriggerTimerEx (OS_TIMER_EX* pTimerEx);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended software timer.

Table 4.16: OS_RetriggerTimerEx() parameter list

Additional Information

OS_RetriggerTimerEx() restarts the extended software timer using the initial time value which was programmed at creation of the timer or which was set using the function OS_SetTimerPeriodEx().

Example

```
OS_TIMER TIMERCursor;
OS_TASK TCB_HP;
BOOL CursorOn;

void TimerCursor(void* pTask) {
  if (CursorOn != 0) ToggleCursor(); /* Invert character at cursor-position */
  OS_SignalEvent(0x01, (OS_TASK*) pTask);
  OS_RetriggerTimerEx(&TIMERCursor); /* Make timer periodical */
}

void InitTask(void) {
  /* Create and start TimerCursor  */
  OS_CREATETIMER_EX(&TIMERCursor, TimerCursor, 500, (void*)&TCB_HP);
}
```

4.1.17 OS_SetTimerPeriodEx()

Description

Sets a new timer reload value for an extended software timer.

Prototype

```
void OS_SetTimerPeriodEx (OS_TIMER_EX* pTimerEx,
                          OS_TIME      Period);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended software timer.
Period	Timer period in basic embOS time units (nominal ms): The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 4.17: OS_SetTimerPeriodEx() parameter list

Additional Information

OS_SetTimerPeriodEx() sets the initial time value of the specified extended software timer. Period is the reload value of the timer to be used as initial value when the timer is retriggered the next time by OS_RetriggerTimerEx().
A call of OS_SetTimerPeriodEx() does not affect the remaining time period of an extended software timer.

Example

```
OS_TIMER_EX TIMERPulse;
OS_TASK TCB_HP;

void TimerPulse(void* pTask) {
 OS_SignalEvent(0x01, (OS_TASK*) pTask);
 OS_RetriggerTimerEx(&TIMERPulse); /* Make timer periodical */
}

void InitTask(void) {
  /* Create and start Pulse Timer with first pulse == 500ms */
  OS_CREATETIMER_EX(&TIMERPulse, TimerPulse, 500, (void*)&TCB_HP);
  /* Set timer period to 200 ms for further pulses */
  OS_SetTimerPeriodEx(&TIMERPulse, 200);
}
```


4.1.18 OS_DeleteTimerEx()

Description

Stops and deletes an extended software timer.

Prototype

```
void OS_DeleteTimerEx(OS_TIMER_EX* pTimerEx);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the timer.

Table 4.18: OS_DeleteTimerEx() parameter list

Additional Information

The extended software timer is stopped and therefore removed out of the linked list of running timers. In debug builds of embOS, the timer is also marked as invalid.

4.1.19 OS_GetTimerPeriodEx()

Description

Returns the current reload value of an extended software timer.

Prototype

```
OS_TIME OS_GetTimerPeriodEx (OS_TIMER_EX* pTimerEx);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended timer.

Table 4.19: OS_GetTimerPeriodEx() parameter list

Return value

Type OS_TIME, which is defined as an integer between
1 and 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs and as an integer between
1 and <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs, which is the permitted range of timer values.

Additional Information

The period returned is the reload value of the timer which was set as initial value when the timer was created or which was modified by a call of OS_SetTimerPeriodEx(). This reload value will be used as time period when the timer is is retriggered by OS_RetriggerTimerEx().

4.1.20 OS_GetTimerValueEx()

Description

Returns the remaining timer value of an extended software timer.

Prototype

```
OS_TIME OS_GetTimerValueEx(OS_TIMER_EX* pTimerEx);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the timer.

Table 4.20: OS_GetTimerValueEx() parameter list

Return value

Type OS_TIME, which is defined as an integer between
1 and 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs and as an integer between
1 and <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs, which is the permitted range of timer values.
The returned time value is the remaining timer time in embOS tick units until expiration of the extended software timer.

4.1.21 OS_GetTimerStatusEx()

Description

Returns the current timer status of an extended software timer.

Prototype

```
unsigned char OS_GetTimerStatusEx (OS_TIMER_EX* pTimerEx);
```

Parameter	Description
pTimerEx	Pointer to the OS_TIMER_EX data structure which contains the data of the extended timer.

Table 4.21: OS_GetTimerStatusEx parameter list

Return value

Unsigned character, denoting whether the specified timer is running or not:
0: timer has stopped
! = 0: timer is running.

4.1.22 OS_GetpCurrentTimerEx()

Description

Returns a pointer to the data structure of the extended timer that just expired.

Prototype

```
OS_TIMER_EX* OS_GetpCurrentTimerEx (void);
```

Return value

`OS_TIMER_EX*`: A pointer to the control structure of an extended software timer.

Additional Information

The return value of `OS_GetpCurrentTimerEx()` is valid during execution of a timer callback function; otherwise it is undetermined. If one callback function should be used for multiple extended timers, this function can be used for examining the timer that expired.
Example

```
#include "RTOS.H"


OS_TIMER_EX MyTimerEx;


/*********************************************************
*
*       Local Functions
*/

void cbTimerEx(void* pData) {  /* Timer callback function for multiple timers  */
  OS_TIMER_EX* pTimerEx;

  pTimerEx = OS_GetpCurrentTimerEx();
  OS_SignalEvent(0x01, (OS_TASK*) pData);
  OS_RetriggerTimer(pTimerEx); /* Retrigger timer   */
}
```

Chapter 5

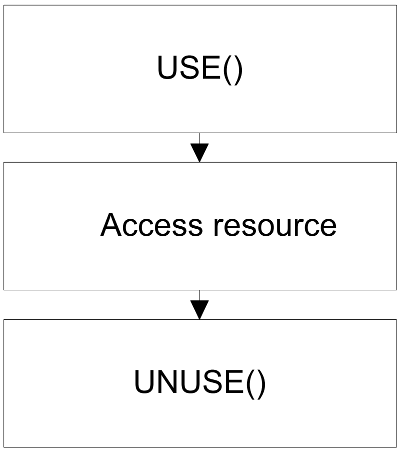
Resource semaphores

Resource semaphores are used for managing resources by avoiding conflicts caused by simultaneous use of a resource. The resource managed can be of any kind: a part of the program that is not reentrant, a piece of hardware like the display, a flash prom that can only be written to by a single task at a time, a motor in a CNC control that can only be controlled by one task at a time, and a lot more.

The basic procedure is as follows:

Any task that uses a resource first claims it calling the `OS_Use()` or `OS_Request()` routines of embOS. If the resource is available, the program execution of the task continues, but the resource is blocked for other tasks. If a second task now tries to use the same resource while it is in use by the first task, this second task is suspended until the first task releases the resource. However, if the first task that uses the resource calls `OS_Use()` again for that resource, it is not suspended because the resource is blocked only for other tasks.

The following diagram illustrates the process of using a resource:



A resource semaphore contains a counter that keeps track of how many times the resource has been claimed by calling `OS_Request()` or `OS_Use()` by a particular task. It is released when that counter reaches 0, which means the `OS_Unuse()` routine has to be called exactly the same number of times as `OS_Use()` or `OS_Request()`. If it is not, the resource remains blocked for other tasks.

On the other hand, a task cannot release a resource that it does not own by calling `OS_Unuse()`. In the debug version of embOS, a call of `OS_Unuse()` for a semaphore that is not owned by this task will result in a call to the error handler `OS_Error()`.

Example of using resource semaphores

Here, two tasks access an LC display completely independently from each other. The LCD is a resource that needs to be protected with a resource semaphore. One task may not interrupt another task which is writing to the LCD, because otherwise the following might occur:

- Task A positions the cursor
- Task B interrupts Task A and repositions the cursor
- Task A writes to the wrong place in the LCD' s memory.

To avoid this type of situation, every the LCD must be accessed by a task, it is first claimed by a call to `OS_Use()` (and is automatically waited for if the resource is blocked). After the LCD has been written to, it is released by a call to `OS_Unuse()`.


```
/*
*  demo program to illustrate the use of resource semaphores
*/
OS_STACKPTR int StackMain[100], StackClock[50];
OS_TASK TaskMain,TaskClock;
OS_SEMA SemaLCD;

void TaskClock(void) {
  char t=-1;
  char s[] = "00:00";
  while(1) {
    while (TimeSec==t) Delay(10);
    t= TimeSec;
    s[4] = TimeSec%10+'0';
    s[3] = TimeSec/10+'0';
    s[1] = TimeMin%10+'0';
    s[0] = TimeMin/10+'0';
    OS_Use(&SemaLCD);        /* Make sure nobody else uses LCD */
    LCD_Write(10,0,s);
    OS_Unuse(&SemaLCD);      /* Release LCD  */
  }
}

void TaskMain(void) {
  signed char pos ;
  LCD_Write(0,0,"Software tools by Segger !    ") ;
  OS_Delay(2000);
  while (1) {
    for ( pos=14 ; pos >=0 ; pos-- ) {
      OS_Use(&SemaLCD);            /* Make sure nobody else uses LCD  */
      LCD_Write(pos,1,"train ");   /* Draw train   */
      OS_Unuse(&SemaLCD);          /* Release LCD  */
      OS_Delay(500);
    }
    OS_Use(&SemaLCD);              /* Make sure nobody else uses LCD  */
    LCD_Write(0,1,"     ") ;
    OS_Unuse(&SemaLCD);            /* Release LCD  */
  }
}

void InitTask(void) {
  OS_CREATERSEMA(&SemaLCD);   /* Creates resource semaphore  */
  OS_CREATETASK(&TaskMain,  0, Main,   50, StackMain);
  OS_CREATETASK(&TaskClock, 0, Clock, 100, StackClock);
}
```

In most applications, the routines that access a resource should automatically call `OS_Use()` and `OS_Unuse()` so that when using the resource you do not have to worry about it and can use it just as you would in a single-task system. The following is an example of how to implement a resource into the routines that actually access the display:

```
/*
*  Simple example when accessing single line dot matrix LCD
*/
OS_RSEMA RDisp;       /* Define resource semaphore  */

void UseDisp() {      /* Simple routine to be called before using display */
  OS_Use(&RDisp);
}

void UnuseDisp() {    /* Simple routine to be called after using display  */
  OS_Unuse(&RDisp);
}

void DispCharAt(char c, char x) {
  UseDisp();
  LCDGoto(x, y);
  LCDWrite1(ASCII2LCD(c));
  UnuseDisp();
}

void DISPInit(void) {
  OS_CREATERSEMA(&RDisp);
}
```

5.1 Resource semaphores API function overview

Routine	Description
OS_CREATERSEMA()	Macro that creates a resource semaphore.
OS_Use()	Claims a resource and blocks it for other tasks.
OS_Unuse()	Releases a semaphore currently in use by a task.
OS_Request()	Requests a specified semaphore, blocks it for other tasks if it is available. Continues execution in any case.
OS_GetSemaValue()	Returns the value of the usage counter of a specified resource semaphore.
OS_GetResourceOwner()	Returns a pointer to the task that is currently using (blocking) a resource.
OS_DeleteRSema()	Deletes a specified resource semaphore.

Table 5.1: Resource semaphore API overview

5.1.1 OS_CREATERSEMA()

Description

Macro that creates a resource semaphore.

Prototype

```
void OS_CREATERSEMA (OS_RSEMA* pRSema);
```

Parameter	Description
pRSema	Pointer to the data structure for a resource semaphore.

Table 5.2: OS_CREATESEMA() parameter list

Additional Information

After creation, the resource is not blocked; the value of the counter is 0.

5.1.2 OS_Use()

Description

Claims a resource and blocks it for other tasks.

Prototype

```
int OS_Use (OS_RSEMA* pRSema);
```

Parameter	Description
pRSema	Pointer to the data structure for a resource semaphore.

Table 5.3: OS_Use() parameter list

Return value

The counter value of the semaphore.

A value larger than 1 means the resource was already locked by the calling task.

Additional Information

The following situations are possible:

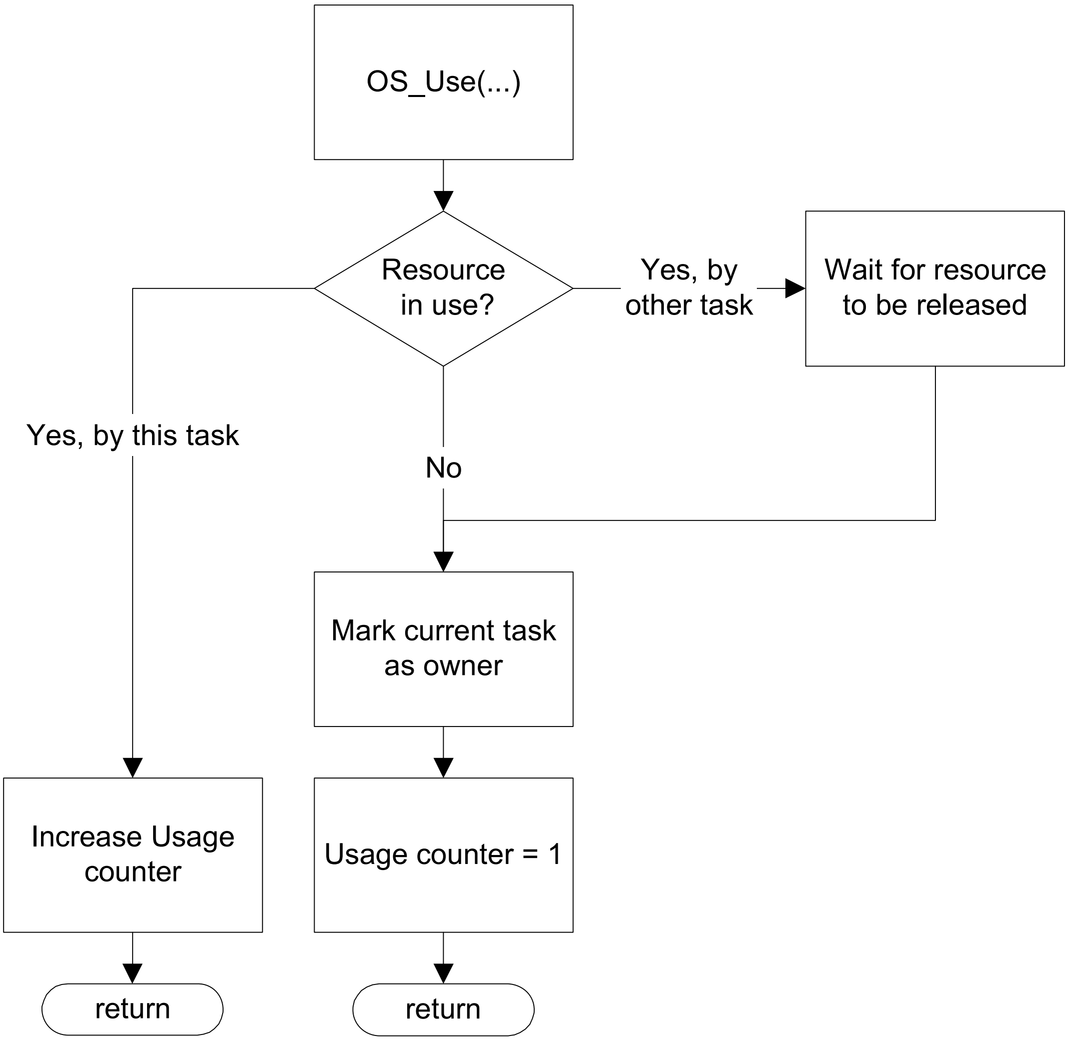
- Case A: The resource is not in use.
  If the resource is not used by a task, which means the counter of the semaphore is 0, the resource will be blocked for other tasks by incrementing the counter and writing a unique code for the task that uses it into the semahore.
- Case B: The resource is used by this task.
  The counter of the semaphore is simply incremented. The program continues without a break.
- Case C: The resource is being used by another task.
  The execution of this task is suspended until the resource semaphore is released. In the meantime if the task blocked by the resource semaphore has a higher priority than the task blocking the semaphore, the blocking task is assigned the priority of the task requesting the resource semaphore. This is called priority inversion. Priority inversion can only temporarily increase the priority of a task, never reduce it.

An unlimited number of tasks can wait for a resource semaphore. According to the rules of the scheduler, of all the tasks waiting for the resource, the task with the highest priority will get access to the resource and can continue program execution.

Important

This function may not be called from within an interrupt handler.

The following diagram illustrates how the `OS_Use()` routine works:



5.1.3 OS_Unuse()

Description

Releases a semaphore currently in use by a task.

Prototype

```
void OS_Unuse (OS_RSEMA* pRSema)
```

Parameter	Description
pRSema	Pointer to the data structure for a resource semaphore.

Table 5.4: OS_Unuse() parameter list

Additional Information

OS_Unuse() may be used on a resource semaphore only after that semaphore has been used by calling OS_Use() or OS_Request(). OS_Unuse() decrements the usage counter of the semaphore which must never become negative. If this counter becomes negative, the debug version will call the embOS error handler OS_Error() with error code OS_ERR_UNUSE_BEFORE_USE. In the debug version OS_Error() will also be called, if OS_Unuse() is called from a task which does not own the resource. The error code in this case is OS_ERR_RESOURCE_OWNER.

Important

This function may not be called from within an interrupt handler.

5.1.4 OS_Request()

Description

Requests a specified semaphore and blocks it for other tasks if it is available. Continues execution in any case.

Prototype

```
char OS_Request (OS_RSEMA* pRSema);
```

Parameter	Description
pRSema	Pointer to the data structure for a resource semaphore.

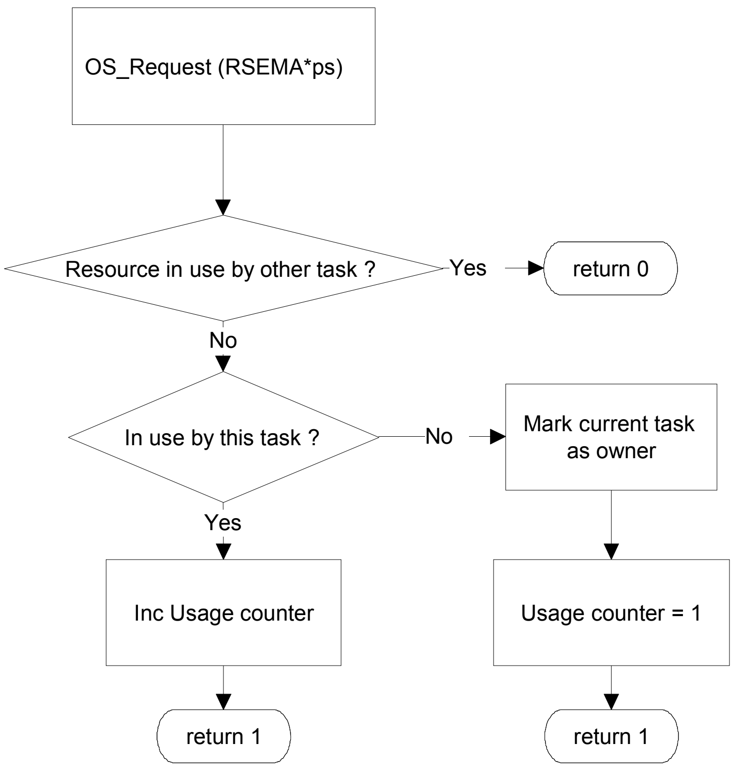
Table 5.5: OS-Request() parameter list

Return value

1: Resource was available, now in use by calling task
0: Resource was not available.

Additional Information

The following diagram illustrates how `OS_Request()` works:



Example

```
if (!OS_Request(&RSEMA_LCD) ) {
  LED_LCDBUSY = 1;              /* Indicate that task is waiting for    */
                                /* resource                             */
  OS_Use(&RSEMA_LCD);           /* Wait for resource                    */
  LED_LCDBUSY = 0;              /* Indicate task is no longer waiting   */
}
  DispTime();                   /* Access the resource LCD              */
  OS_Unuse(&RSEMA_LCD);         /* Resource LCD is no longer needed     */
```


5.1.5 OS_GetSemaValue()

Description

Returns the value of the usage counter of a specified resource semaphore.

Prototype

```
int OS_GetSemaValue (OS_SEMA* pSema);
```

Parameter	Description
pRSema	Pointer to the data structure for a resource semaphore.

Table 5.6: OS_GetSemaValue() parameter list

Return value

The counter of the semaphore.
A value of 0 means the resource is available.

5.1.6 OS_GetResourceOwner()

Description

Returns a pointer to the task that is currently using (blocking) a resource.

Prototype

```
OS_TASK* OS_GetResourceOwner (OS_RSEMA* pSema);
```

Parameter	Description
pRSema	Pointer to the data structure for a resource semaphore.

Table 5.7: OS_GetResourceOwner() parameter list

Return value

Pointer to the task that is blocking the resource.
A value of 0 means the resource is available.

5.1.7 OS_DeleteRSema()

Description

Deletes a specified resource semaphore. The memory of that semaphore may be reused for other purposes or may be used for creating another resources semaphore using the same memory.

Prototype

```
void OS_DeleteRSema (OS_RSEMA* pRSema);
```

Parameter	Description
pRSema	Pointer to a data structure of type OS_RSEMA.

Table 5.8: OS_DeleteRSema parameter list

Additional Information

Before deleting a resource semaphore, make sure that no task is claiming the resources semaphore. The debug version of embOS will call `OS_Error()`, if a resources semaphore is deleted when it is already used. In systems with dynamic creation of resource semaphores, it is required to delete a resource semaphore, before re-creating it. Otherwise the semaphore handling will not work correctly.

Chapter 6

Counting Semaphores

Counting semaphores are counters that are managed by embOS. They are not as widely used as resource semaphores, events or mailboxes, but they can be very useful sometimes. They are used in situations where a task needs to wait for something that can be signaled one or more times. The semaphores can be accessed from any point, any task, or any interrupt in any way.

Example of using counting semaphores

```
OS_STACKPTR int Stack0[96], Stack1[64];              /* Task stacks */
OS_TASK TCB0, TCB1;   /* Data-area for tasks (task-control-blocks)  */
OS_CSEMA SEMALCD;

void Task0(void) {
Loop:
  Disp("Task0 will wait for task 1 to signal");
  OS_WaitCSema(&SEMALCD);
  Disp("Task1 has signaled !!");
  OS_Delay(100);
  goto Loop;
}

void Task1(void) {
Loop:
  OS_Delay(5000);
  OS_SignalCSema(&SEMALCD);
  goto Loop;
}

void InitTask(void) {
  OS_CREATECSEMA(&SEMALCD);                        /* Create Semaphore  */
  OS_CREATETASK(&TCB0, NULL, Task0, 100, Stack0);  /* Create Task0      */
  OS_CREATETASK(&TCB1, NULL, Task1,  50, Stack1);  /* Create Task1      */
}
```


6.1 Counting semaphores API function overview

Routine	Description
OS_CREATECSEMA()	Macro that creates a counting semaphore with an initial count value of zero.
OS_CreateCSema()	Creates a counting semaphore with a specified initial count value.
OS_SignalCSema()	Increments the counter of a semaphore.
OS_SignalCSemaMax	Increments the counter of a semaphore up to a specified maximum value.
OS_WaitCSema()	Decrements the counter of a semaphore.
OS_CSemaRequest()	Decrements the counter of a semaphore, if available.
OS_WaitCSemaTimed	Decrements a semaphore counter if the semaphore is available within a specified time.
OS_GetCSemaValue()	Returns the counter value of a specified semaphore.
OS_SetCSemaValue()	Sets the counter value of a specified semaphore.
OS_DeleteCSema()	Deletes a specified semaphore.

Table 6.1: Counting semaphores API overview

6.1.1 OS_CREATECSEMA()

Description

Macro that creates a counting semaphore with an initial count value of zero.

Prototype

```
void OS_CREATECSEMA (OS_CSEMA* pCSema);
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.

Table 6.2: OS_CREATECSEMA() parameter list

Additional Information

To create a counting semaphore, a data structure of the type OS_CSEMA needs to be defined in memory and initialized using OS_CREATECSEMA(). The value of a semaphore created using this macro is zero. If, for any reason, you have to create a semaphore with an initial counting value above zero, use the function OS_CreateCSema().

6.1.2 OS_CreateCSema()

Description

Creates a counting semaphore with a specified initial count value.

Prototype

```
void OS_CreateCSema (OS_CSEMA*     pCSema,
                     OS_UINT       InitValue);
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.
InitValue	Initial count value of the semaphore: 0 <= InitValue <= 2^{16} = 0xFFFF for 8/16-bit CPUs 0 <= InitValue <= 2^{32} = 0xFFFFFFFF for 32-bit CPUs

Table 6.3: OS_CreateCSema() parameter list

Additional Information

To create a counting semaphore, a data structure of the type OS_CSEMA needs to be defined in memory and initialized using OS_CreateCSema(). If the value of the created semaphore should be zero, the macro OS_CREATECSEMA() should be used.

6.1.3 OS_SignalCSema()

Description

Increments the counter of a semaphore.

Prototype

```
void OS_SignalCSema (OS_CSEMA * pCSema);
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.

Table 6.4: OS_SignalCSema() parameter list

Additional Information

OS_SignalCSema() signals an event to a semaphore by incrementing its counter. If one or more tasks are waiting for an event to be signaled to this semaphore, the task that has the highest priority will become the active task. The counter can have a maximum value of 0xFFFF for 8/16-bit CPUs / 0xFFFFFFFF for 32-bit CPUs. It is the responsibility of the application to make sure that this limit will not be exceeded. The debug version of embOS detects an counter overflow and calls OS_Error() with error code OS_ERR_CSEMA_OVERFLOW, if an overflow occurs.

6.1.4 OS_SignalCSemaMax()

Description

Increments the counter of a semaphore up to a specified maximum value.

Prototype

```
void OS_SignalCSemaMax (OS_CSEMA*     pCSema,
                        OS_UINT       MaxValue );
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.
MaxValue	Limit of semaphore count value. 1 <= MaxValue <= 2^{16} = 0xFFFF for 8/16-bit CPUs 1 <= MaxValue <= 2^{32} = 0xFFFFFFFF for 32-bit CPUs

Table 6.5: OS_SignalCSemaMax() parameter list

Additional Information

As long as current value of the semaphore counter is below the specified maximum value, OS_SignalCSemaMax() signals an event to a semaphore by incrementing its counter. If one or more tasks are waiting for an event to be signaled to this semaphore, the tasks are put into ready state and the task that has the highest priority will become the active task. Calling OS_SignalCSemaMax() with a MaxValue of 1 handles a counting semaphore as a binary semaphore.

6.1.5 OS_WaitCSema()

Description

Decrements the counter of a semaphore.

Prototype

```
void OS_WaitCSema (OS_CSEMA* pCSema);
```

Parameter	Description
pCSema	Pointer to a data structure of type `OS_CSEMA`.

Table 6.6: OS_WaitCSema() parameter list

Additional Information

If the counter of the semaphore is not 0, the counter is decremented and program execution continues.
If the counter is 0, `WaitCSema()` waits until the counter is incremented by another task, a timer or an interrupt handler via a call to `OS_SignalCSema()`. The counter is then decremented and program execution continues.
An unlimited number of tasks can wait for a semaphore. According to the rules of the scheduler, of all the tasks waiting for the semaphore, the task with the highest priority will continue program execution.

Important

This function may not be called from within an interrupt handler.

6.1.6 OS_WaitCSemaTimed()

Description

Decrements a semaphore counter if the semaphore is available within a specified time.

Prototype

```
int OS_WaitCSemaTimed (OS_CSEMA* pCSema,
                       OS_TIME   TimeOut);
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.
TimeOut	Maximum time until semaphore should be available

Table 6.7: OS_WaitCSemaTimed parameter list

Return value

Integer value:
0: Failed, semaphore not available before timeout.
1: OK, semaphore was available and counter decremented.

Additional Information

If the counter of the semaphore is not 0, the counter is decremented and program execution continues. If the counter is 0, WaitCSemaTimed() waits until the semaphore is signaled by another task, a timer, or an interrupt handler via a call to OS_SignalCSema(). The counter is then decremented and program execution continues. If the semaphore was not signaled within the specified time, the program execution continues but returns a value of 0. An unlimited number of tasks can wait for a semaphore. According to the rules of the scheduler, of all the tasks waiting for the semaphore, the task with the highest priority will continue program execution.

Important

This function may not be called from within an interrupt handler.

6.1.7 OS_CSemaRequest()

Description

Decrements the counter of a semaphore, if it is signaled.

Prototype

```
char OS_CSemaRequest (OS_CSEMA* pCSema);
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.

Table 6.8: OS_CSemaRequest() parameter list

Return value

Integer value:
0: Failed, semaphore was not signaled.
1: OK, semaphore was available and counter was decremented once.

Additional Information

If the counter of the semaphore is not 0, the counter is decremented and program execution continues.
If the counter is 0, OS_CSemaRequest() does not wait and does not modify the semaphore counter. The function returns with error state.
Because this function never blocks a calling task, this function may be called from an interrupt handler.

6.1.8 OS_GetCSemaValue()

Description

Returns the counter value of a specified semaphore.

Prototype

```
int OS_GetCSemaValue (OS_SEMA* pCSema);
```

Parameter	Description
pCSema	Pointer to a data structure of type `OS_CSEMA`.

Table 6.9: OS_GetCSemaValue() parameter list

Return value

The counter value of the semaphore.

6.1.9 OS_SetCSemaValue()

Description

Sets the counter value of a specified semaphore.

Prototype

```
OS_U8 OS_SetCSemaValue (OS_SEMA*   pCSema,
                        OS_UINT    Value);
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.
Value	Count value of the semaphore: 0 <= InitValue <= 2^{16} = 0xFFFF for 8/16-bit CPUs 0 <= InitValue <= 2^{32} = 0xFFFFFFFF for 32-bit CPUs

Table 6.10: OS_SetCSemaValue() parameter list

Return value

0: If the value could be set.
!= 0: In case of error.

6.1.10 OS_DeleteCSema()

Description

Returns the counter value of a specified semaphore.

Prototype

```
void OS_DeleteCSema (OS_CSEMA* pCSema);
```

Parameter	Description
pCSema	Pointer to a data structure of type OS_CSEMA.

Table 6.11: OS_DeleteCSema() parameter list

Additional Information

Before deleting a semaphore, make sure that no task is waiting for it and that no task will signal that semaphore at a later point.
The debug version of embOS will reflect an error if a deleted semaphore is signaled.

Chapter 7

Mailboxes

7.1 Why mailboxes?

In the preceding chapters, task synchronization by the use of semaphores was described. Unfortunately, semaphores cannot transfer data from one task to another. If we need to transfer data between tasks via a buffer for example, we could use a resource semaphore every time we accessed the buffer. But doing so would make the program less efficient. Another major disadvantage would be that we could not access the buffer from an interrupt handler, because the interrupt handler is not allowed to wait for the resource semaphore.

One way out would be the usage of global variables. In this case we would have to disable interrupts every time and in every place that we accessed these variables. This is possible, but it is a path full of pitfalls. It is also not easy for a task to wait for a character to be placed in a buffer without polling the global variable that contains the number of characters in the buffer. Again, there is a way out - the task could be notified by an event signaled to the task every time a character is placed in the buffer. That is why there is an easier way to do this with a real-time OS:
The use of mailboxes.

7.2 Basics

A mailbox is a buffer that is managed by the real-time operating system. The buffer behaves like a normal buffer; you can put something (called a message) in and retrieve it later. Mailboxes usually work as FIFO: first in, first out. So a message that is put in first will usually be retrieved first. "Message" might sound abstract, but very simply just means "item of data". It will become clearer in the typical applications explained in the following section.

The number of mailboxes is limited only by the amount of available memory.
Message size: 1 <= x <= 127 bytes.
Number of messages: 1 <= x <= 32767.
These limitations have been placed on mailboxes to guarantee efficient coding and also to ensure efficient management. The limitations are normally not a problem.
For handling messages larger than 127 bytes, you may use queues. For more information, refer to the Chapter *Queues* on page 129.

7.3 Typical applications

A keyboard buffer

In most programs, you use either a task, a software timer or an interrupt handler to check the keyboard. When detected that a key has been pressed, that key is put into a mailbox that is used as a keyboard buffer. The message is then retrieved by the task that handles the keyboard input. The message in this case is typically a single byte that holds the key code; the message size is therefore 1 byte.

The advantage of a keyboard buffer is that management is very efficient; you do not have to worry about it, because it is reliable, proven code and you have a type-ahead buffer at no extra cost. On top of that, a task can easily wait for a key to be pressed without having to poll the buffer. It simply calls the `OS_GetMail()` routine for that particular mailbox. The number of keys that can be stored in the type-ahead buffer depends only on the size of the mailbox buffer, which you define when creating the mailbox.

A buffer for serial I/O

In most cases, serial I/O is done with the help of interrupt handlers. The communication to these interrupt handlers is very easy with mailboxes. Both your task programs and your interrupt handlers store or retrieve data to/from the same mailboxes. As with a keyboard buffer, the message size is 1 character.

For interrupt-driven sending, the task places the character(s) in the mailbox using `OS_PutMail()` or `OS_PutMailCond()`; the interrupt handler that is activated when a new character can be sent retrieves this character with `OS_GetMailCond()`.

For interrupt-driven receiving, the interrupt handler that is activated when a new character is received puts it in the mailbox using `OS_PutMailCond()`; the task receives it using `OS_GetMail()` or `OS_GetMailCond()`.

A buffer for commands sent to a task

Assume you have one task controlling a motor, as you might have in applications that control a machine. A simple way to give commands to this task would be to define a structure for commands. The message size would then be the size of this structure.

7.4 Single-byte mailbox functions

In many (if not the most) situations, mailboxes are used simply to hold and transfer single-byte messages. This is the case, for example, with a mailbox that takes the character received or sent via serial interface, or normally with a mailbox used as keyboard buffer. In some of these cases, time is very critical, especially if a lot of data is transferred in short periods of time.

To minimize the overhead caused by the mailbox management of embOS, variations on some mailbox functions are available for single-byte mailboxes. The general functions `OS_PutMail()`, `OS_PutMailCond()`, `OS_GetMail()`, and `OS_GetMailCond()` can transfer messages of sizes between 1 and 127 bytes each. Their single-byte equivalents `OS_PutMail1()`, `OS_PutMailCond1()`, `OS_GetMail1()`, and `OS_GetMailCond1()` work the same way with the exception that they execute much faster because management is simpler. It is recommended to use the single-byte versions if you transfer a lot of single byte-data via mailboxes.

The routines `OS_PutMail1()`, `OS_PutMailCond1()`, `OS_GetMail1()`, and `OS_GetMailCond1()` work exactly the same way as their more universal equivalents and are therefore not described separately. The only difference is that they can only be used for single-byte mailboxes.

7.5 Mailboxes API function overview

Routine	Explanation
OS_CREATEMB()	Macro that creates a new mailbox.
OS_PutMail()	Stores a new message of a predefined size in a mailbox.
OS_PutMail1()	Stores a new message of a predefined size in a mailbox.
OS_PutMailCond()	Stores a new message of a predefined size in a mailbox, if the mailbox is able to accept one more message.
OS_PutMailCond1()	Stores a new message of a predefined size in a mailbox, if the mailbox is able to accept one more message.
OS_PutMailFront()	Stores a new message of a predefined size into a mailbox in front of all other messages. This new message will be retrieved first.
OS_PutMailFront1()	Stores a new message of a predefined size into a mailbox in front of all other messages. This new message will be retrieved first.
OS_PutMailFrontCond()	Stores a new message of a predefined size into a mailbox in front of all other messages, if the mailbox is able to accept one more message.
OS_PutMailFrontCond1()	Stores a new message of a predefined size into a mailbox in front of all other messages, if the mailbox is able to accept one more message.
OS_GetMail()	Retrieves a new message of a predefined size from a mailbox.
OS_GetMail1()	Retrieves a new message of a predefined size from a mailbox.
OS_GetMailCond()	Retrieves a new message of a predefined size from a mailbox, if a message is available.
OS_GetMailCond1()	Retrieves a new message of a predefined size from a mailbox, if a message is available.
OS_GetMailTimed()	Retrieves a new message of a predefined size from a mailbox, if a message is available within a given time.
OS_WaitMail()	Waits until a mail is available, but does not retrieve the message from the mailbox.
OS_ClearMB()	Clears all messages in a specified mailbox.
OS_GetMessageCnt()	Returns number of messages currently in a specified mailbox.
OS_DeleteMB()	Deletes a specified mailbox.

Table 7.1: Mailboxes API overview

7.5.1 OS_CREATEMB()

Description

Macro that creates a new mailbox.

Prototype

```
void OS_CREATEMB (OS_MAILBOX*    pMB,
                  unsigned char sizeofMsg,
                  unsigned int  maxnofMsg,
                  void*         pMsg););
```

Parameter	Description
pMB	Pointer to a data structure of type OS_MAILBOX reserved for managing the mailbox.
sizeofMsg	Size of a message in bytes. (1 <= sizeofMsg <= 127)
maxnoMsg	Maximum number of messages. (1 <= MaxnofMsg <= 65535)
pMsg	Pointer to a memory area used as buffer. The buffer has to be big enough to hold the given number of messages of the specified size: sizeofMsg * maxnoMsg bytes.

Table 7.2: OS_CREATEMB() parameter list

Example

Mailbox used as keyboard buffer:

```
OS_MAILBOX MBKey;
char MBKeyBuffer[6];

void InitKeyMan(void) {
  /* Create mailbox, functioning as type ahead buffer */
  OS_CREATEMB(&MBKey, 1, sizeof(MBKeyBuffer), &MBKeyBuffer);
}
```

Mailbox used for transfering complex commands from one task to another:

```
/*
* Example of mailbox used for transfering commands to a task
* that controls 2 motors
*/
typedef struct {
  char Cmd;
  int Speed[2];
  int Position[2];
} MOTORCMD ;

OS_MAILBOX MBMotor;

#define MOTORCMD_SIZE 4

char BufferMotor[sizeof(MOTORCMD)*MOTORCMD_SIZE];

void MOTOR_Init(void) {
  /* Create mailbox that holds commands messages */
  OS_CREATEMB(&MBMotor, sizeof(MOTORCMD), MOTORCMD_SIZE, &BufferMotor);
}
```

7.5.2 OS_PutMail() / OS_PutMail1()

Description

Stores a new message of a predefined size in a mailbox.

Prototype

```
void OS_PutMail  (OS_MAILBOX* pMB,
                  void*       pMail);
void OS_PutMail1 (OS_MAILBOX* pMB,
                  const char* pMail);
```

Parameter	Description
pMB	Pointer to the mailbox.
pMail	Pointer to the message to store.

Table 7.3: OS_PutMail() / OS_PutMail1() parameter list

Additional Information

If the mailbox is full, the calling task is suspended.
Because this routine might require a suspension, it must not be called from an interrupt routine. Use `OS_PutMailCond()`/`OS_PutMailCond1()` instead if you have to store data in a mailbox from within an ISR.

Important

This function may not be called from within an interrupt handler.

Example

Single-byte mailbox as keyboard buffer:

```
OS_MAILBOX MBKey;
char MBKeyBuffer[6];

void KEYMAN_StoreKey(char k) {
  OS_PutMail1(&MBKey, &k);  /* Store key, wait if no space in buffer */
}

void KEYMAN_Init(void) {
  /* Create mailbox functioning as type ahead buffer */
  OS_CREATEMB(&MBKey, 1, sizeof(MBKeyBuffer), &MBKeyBuffer);
}
```


7.5.3 OS_PutMailCond() / OS_PutMailCond1()

Description

Stores a new message of a predefined size in a mailbox, if the mailbox is able to accept one more message.

Prototype

```
char OS_PutMailCond  (OS_MAILBOX* pMB,
                      void*       pMail);
char OS_PutMailCond1 (OS_MAILBOX* pMB,
                      const char* pMail););
```

Parameter	Description
pMB	Pointer to the mailbox.
pMail	Pointer to the message to store.

Table 7.4: OS_PutMailCond() / OS_PutMailCond1() overview

Return value

0: Success; message stored.
1: Message could not be stored (mailbox is full).

Additional Information

If the mailbox is full, the message is not stored.
This function never suspends the calling task. It may therefore be called from an interrupt routine.

Example

```
OS_MAILBOX MBKey;
char MBKeyBuffer[6];

char KEYMAN_StoreCond(char k) {
  return OS_PutMailCond1(&MBKey, &k); /* Store key if space in buffer */
}
```

This example can be used with the sample program shown earlier to handle a mailbox as keyboard buffer.

7.5.4 OS_PutMailFront() / OS_PutMailFront1()

Description

Stores a new message of a predefined size at the beginning of a mailbox in front of all other messages. This new message will be retrieved first.

Prototype

```
void OS_PutMailFront  (OS_MAILBOX* pMB,
                        void*       pMail);
void OS_PutMailFront1 (OS_MAILBOX* pMB,
                        const char* pMail);
```

Parameter	Description
pMB	Pointer to the mailbox.
pMail	Pointer to the message to store.

Table 7.5: OS_PutMailFront() / OS_PutMailFront1() parameter list

Additional Information

If the mailbox is full, the calling task is suspended. Because this routine might require a suspension, it must not be called from an interrupt routine. Use `OS_PutMailFrontCond()`/`OS_PutMailFrontCond1()` instead if you have to store data in a mailbox from within an ISR.
This function is useful to store "emergency" messages into a mailbox which have to be handled quick.
It may also be used in general instead of `OS_PutMail()` to change the FIFO structure of a mailbox into a LIFO structure.

Important

This function may not be called from within an interrupt handler.

Example

Single-byte mailbox as keyboard buffer:

```
OS_MAILBOX MBCmd;
char MBCmdBuffer[6];

void KEYMAN_StoreCommand(char k) {
  OS_PutMailFront1(&MBCmd, &k); /* Store command, wait if no space in buffer*/
}

void KEYMAN_Init(void) {
  /* Create mailbox for command buffer */
  OS_CREATEMB(&MBCmd, 1, sizeof(MBCmdBuffer), &MBCmdBuffer);
}
```


7.5.5 OS_PutMailFrontCond() / OS_PutMailFrontCond1()

Description

Stores a new message of a predefined size into a mailbox in front of all other messages, if the mailbox is able to accept one more message. The new message will be retrieved first.

Prototype

```
char OS_PutMailFrontCond  (OS_MAILBOX* pMB,
                           void*       pMail);
char OS_PutMailFrontCond1 (OS_MAILBOX* pMB,
                           const char* pMail);)
```

Parameter	Description
pMB	Pointer to the mailbox.
pMail	Pointer to the message to store.

Table 7.6: OS_PutMailFrontCond() / OS_PutMailFrontCond1() parameter list

Return value

0: Success; message stored.
1: Message could not be stored (mailbox is full).

Additional Information

If the mailbox is full, the message is not stored. This function never suspends the calling task. It may therefore be called from an interrupt routine. This function is useful to store "emergency" messages into a mailbox which have to be handled quick. It may also be used in general instead of `OS_PutMail()` to change the FIFO structure of a mailbox into a LIFO structure.

7.5.6 OS_GetMail() / OS_GetMail1()

Description

Retrieves a new message of a predefined size from a mailbox.

Prototype

```
void OS_GetMail  (OS_MAILBOX* pMB,
                  void*       pDest);
void OS_GetMail1 (OS_MAILBOX* pMB,
                  char* pDest);
```

Parameter	Description
pMB	Pointer to the mailbox.
pDest	Pointer to the memory area that the message should be stored at. Make sure that it points to a valid memory area and that there is sufficient space for an entire message. The message size (in bytes) was defined when the mailbox was created.

Table 7.7: OS_GetMail() / OS_GetMail1() parameter list

Additional Information

If the mailbox is empty, the task is suspended until the mailbox receives a new message. Because this routine might require a suspension, it may not be called from an interrupt routine. Use `OS_GetMailCond`/`OS_GetMailCond1` instead if you have to retrieve data from a mailbox from within an ISR.

Important

This function may not be called from within an interrupt handler.

Example

```
OS_MAILBOX MBKey;
char MBKeyBuffer[6];

char WaitKey(void) {
  char c;
  OS_GetMail1(&MBKey, &c);
  return c;
}
```


7.5.7 OS_GetMailCond() / OS_GetMailCond1()

Description

Retrieves a new message of a predefined size from a mailbox, if a message is available.

Prototype

```
char OS_GetMailCond  (OS_MAILBOX * pMB,
                      void* pDest);
char OS_GetMailCond1 (OS_MAILBOX * pMB,
                      char* pDest);
```

Parameter	Description
pMB	Pointer to the mailbox.
pDest	Pointer to the memory area that the message should be stored at. Make sure that it points to a valid memory area and that there is sufficient space for an entire message. The message size (in bytes) was defined when the mailbox was created.

Table 7.8: OS_GetMailCond() / OS_GetMailCond1() parameter list

Return value

0: Success; message retrieved.
1: Message could not be retrieved (mailbox is empty); destination remains unchanged.

Additional Information

If the mailbox is empty, no message is retrieved, but the program execution continues.
This function never suspends the calling task. It may therefore also be called from an interrupt routine.

Important

This function may not be called from within an interrupt handler.

Example

```
OS_MAILBOX MBKey;
char MBKeyBuffer[6];

/*
* If a key has been pressed, it is taken out of the mailbox and returned to
* caller.
* Otherwise, 0 is returned.
*/
char GetKey(void) {
  char c =0;
  OS_GetMailCond1(&MBKey, &c)
  return c;
}
```


7.5.8 OS_GetMailTimed()

Description

Retrieves a new message of a predefined size from a mailbox, if a message is available within a given time.

Prototype

```
char OS_GetMailTimed (OS_MAILBOX* pMB,
                      void* pDest,
                      OS_TIME Timeout);
```

Parameter	Description
pMB	Pointer to the mailbox.
pDest	Pointer to the memory area that the message should be stored at. Make sure that it points to a valid memory area and that there is sufficient space for an entire message. The message size (in bytes) has been defined upon creation of the mailbox.
Timeout	Maximum time in timer ticks until the requested mail has to be available. The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 7.9: OS_GetMailTimed() parameter list

Return value

0: Success; message retrieved.
1: Message could not be retrieved (mailbox is empty); destination remains unchanged.

Additional Information

If the mailbox is empty, no message is retrieved, the task is suspended for the given timeout. The task continues execution, according to the rules of the scheduler, as soon as a mail is available within the given timeout, or after the timeout value has expired.

Important

This function may not be called from within an interrupt handler.

Example

```
OS_MAILBOX MBKey;
char MBKeyBuffer[6];

/*
* If a key has been pressed, it is taken out of the mailbox and returned to
* caller.
* Otherwise, 0 is returned.
*/
char GetKey(void) {
  char c =0;
  OS_GetMailTimed(&MBKey, &c, 10) /* Wait for 10 timer ticks */
  return c;
}
```


7.5.9 OS_WaitMail()

Description

Waits until a mail is available, but does not retrieve the message from the mailbox.

Prototype

```
void OS_WaitMail (OS_MAILBOX* pMB);
```

Parameter	Description
pMB	Pointer to the mailbox.

Table 7.10: OS_WaitMail() parameter list

Additional Information

If the mailbox is empty, the task is suspended until a mail is available, otherwise the task continues.
The task continues execution, according to the rules of the scheduler, as soon as a mail is available, but the mail is not retrieved from the mailbox.

Important

This function may not be called from within an interrupt handler.

7.5.10 OS_ClearMB()

Description

Clears all messages in a specified mailbox.

Prototype

```
void OS_ClearMB (OS_MAILBOX* pMB);
```

Parameter	Description
pMB	Pointer to the mailbox.

Table 7.11: OS_ClearMB() parameter list

Example

```
OS_MAILBOX MBKey;
char MBKeyBuffer[6];

/*
* Clear keyboard type ahead buffer
*/
void ClearKeyBuffer(void) {
  OS_ClearMB(&MBKey);
}
```


7.5.11 OS_GetMessageCnt()

Description

Returns the number of messages currently available in a specified mailbox.

Prototype

```
unsigned int OS_GetMessageCnt (OS_MAILBOX* pMB);
```

Parameter	Description
pMB	Pointer to the mailbox.

Table 7.12: OS_GetMessageCnt() parameter list

Return value

The number of messages in the mailbox.

Example

```
char GetKey(void) {
  if (OS_GetMessageCnt(&MBKey)) return WaitKey();
  return 0;
}
```


7.5.12 OS_DeleteMB()

Description

Deletes a specified mailbox.

Prototype

```
void OS_DeleteMB (OS_MAILBOX* pMB);
```

Parameter	Description
pMB	Pointer to the mailbox.

Table 7.13: OS_DeleteMB() parameter list

Additional Information

To keep the system fully dynamic, it is essential that mailboxes can be created dynamically. This also means there has to be a way to delete a mailbox when it is no longer needed. The memory that has been used by the mailbox for the control structure and the buffer can then be reused or reallocated.
It is the programmer's responsibility to:

- make sure that the program no longer uses the mailbox to be deleted
- make sure that the mailbox to be deleted actually exists (i.e. has been created first).

Example

```
OS_MAILBOX MBSerIn;
char MBSerInBuffer[6];

void Cleanup(void) {
  OS_DeleteMB(MBSerIn);
  return 0;
}
```


Chapter 8

Queues

8.1 Why queues?

In the preceding chapter, intertask communication using mailboxes was described. Mailboxes can handle small messages with fixed data size only.
Queues enable intertask communication with larger messages or with messages of various sizes.

8.2 Basics

A queue consists of a data buffer and a control structure that is managed by the real-time operating system. The queue behaves like a normal buffer; you can put something (called a message) in and retrieve it later. Queues work as FIFO: first in, first out. So a message that is put in first will be retrieved first.
There are three major differences between queues and mailboxes:

1. Queues accept messages of various size. When putting a message into a queue, the message size is passed as a parameter.
2. Retrieving a message from the queue does not copy the message, but returns a pointer to the message and its size. This enhances performance because the data is copied only once, when the message is written into the queue.
3. The retrieving function has to delete every message after processing it.

Both the number and size of queues is limited only by the amount of available memory. Any data structure can be written into a queue. The message size is not fixed.

8.3 Queues API function overview

Routine	Description
OS_Q_Create()	Creates and initializes a message queue.
OS_Q_Put()	Stores a new message of given size in a queue.
OS_Q_GetPtr()	Retrieves a message from a queue.
OS_Q_GetPtrCond()	Retrieves a message from a queue, if one message is available or returns without suspension.
OS_Q_GetPtrTimed()	Retrieves a message from a queue within a specified time, if one message is available.
OS_Q_Purge()	Deletes the last retrieved message in a queue.
OS_Q_Clear()	Deletes all message in a queue.
OS_Q_GetMessageCnt()	Returns the number of messages currently in a queue.

Table 8.1: Queues API

8.3.1 OS_Q_Create()

Description

Creates and initializes a message queue.

Prototype

```
void OS_Q_Create (OS_Q* pQ,
                  void*pData,
                  OS_UINT Size);
```

Parameter	Description
pQ	Pointer to a data structure of type OS_Q reserved for the management of the message queue.
pData	Pointer to a memory area used as data buffer for the queue.
Size	Size in bytes of the data buffer.

Table 8.2: OS_Q_Create() parameter list

Example

```
#define MEMORY_QSIZE 10000;
static OS_Q   _MemoryQ;
static char   _acMemQBuffer[MEMORY_QSIZE];

void MEMORY_Init(void) {
  OS_Q_Create(&_MemoryQ, &_acMemQBuffer, sizeof(_acMemQBuffer));
}
```


8.3.2 OS_Q_Put()

Description

Stores a new message of given size in a queue.

Prototype

```
int OS_Q_Put (OS_Q* pQ,
              const void* pSrc,
              OS_UINT Size);
```

Parameter	Description
pQ	Pointer to a data structure of type `OS_Q` reserved for the management of the message queue.
pSrc	Pointer to the message to store
Size	Size of the message to store

Table 8.3: OS_Q_Put() parameter list

Return value

0: Success; message stored.
1: Message could not be stored (queue is full).

Additional Information

If the queue is full, the function returns a value unequal to 0.
This routine never suspends the calling task. It may therefore also be called from an interrupt routine.

Example

```
char MEMORY_Write(char* pData, int Len) {
  return OS_Q_Put(&_MemoryQ, pData, Len));
}
```


8.3.3 OS_Q_GetPtr()

Description

Retrieves a message from a queue.

Prototype

```
int OS_Q_GetPtr (OS_Q*  pQ,
                 void** ppData);
```

Parameter	Description
pQ	Pointer to the queue.
ppData	Address of pointer to the message to be retrieved from queue.

Table 8.4: OS_Q_GetPtr() parameter list

Return value

The size of the retrieved message.
Sets the pointer to the message that should be retrieved.

Additional Information

If the queue is empty, the calling task is suspended until the queue receives a new message. Because this routine might require a suspension, it must not be called from an interrupt routine. Use `OS_GetPtrCond()` instead. The retrieved message is not removed from the queue. This has to be done by a call of `OS_Q_Purge()` after the message was processed.

Example

```
static void MemoryTask(void) {
  char MemoryEvent;
  int Len;
  char* pData;

  while (1) {
    Len = OS_Q_GetPtr(&_MemoryQ, &pData);             /* Get message     */
    Memory_WritePacket(*(U32*)pData, pData+4, Len);   /* Process message */
    OS_Q_Purge(&_MemoryQ);                            /* Delete message  */
  }
}
```

8.3.4 OS_Q_GetPtrCond()

Description

Retrieves a message from a queue, if one message is available.

Prototype

```
int OS_Q_GetPtrCond (OS_Q*  pQ,
                     void** ppData);
```

Parameter	Description
pQ	Pointer to the queue.
ppData	Address of pointer to the message to be retrieved from queue.

Table 8.5: OS_Q_GetPtrCond() parameter list

Return value

0: No message available in queue.
>0: Size of message that was retrieved from queue.

Additional Information

If the queue is empty, the function returns 0. The value of ppData is undefined. This function never suspends the calling task. It may therefore also be called from an interrupt routine. If a message could be retrieved, it is not removed from the queue. This has to be done by a call of `OS_Q_Purge()` after the message was processed.

Example

```
static void MemoryTask(void) {
  char MemoryEvent;
  int Len;
  char* pData;
  while (1) {
    Len = OS_Q_GetPtrCond(&_MemoryQ, &pData);          /* Check message   */
    if (Len > 0) {
      Memory_WritePacket(*(U32*)pData, pData+4, Len);  /* Process message */
      OS_Q_Purge(&_MemoryQ);                           /* Delete message  */
    } else {
      DoSomethingElse();
    }
  }
}
```

8.3.5 OS_Q_GetPtrTimed()

Description

Retrieves a message from a queue within a specified time if a message is available.

Prototype

```
int OS_Q_GetPtrTimed (OS_Q*   pQ,
                      void** ppData,
                      OS_TIME Timeout);
```

Parameter	Description
pQ	Pointer to the queue.
ppData	Address of pointer to the message to be retrieved from queue.
Timeout	Maximum time in timer ticks until the requested message has to be available. The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 8.6: OS_Q_GetPtrCond() parameter list

Return value

0: No message available in queue.
>0: Size of message that was retrieved from queue.

Additional Information

If the queue is empty, no message is retrieved, the task is suspended for the given timeout. The task continues execution, according to the rules of the scheduler, as soon as a message is available within the given timeout, or after the timeout value has expired.

Example

```
static void MemoryTask(void) {
  char MemoryEvent;
  int Len;
  char* pData;
  while (1) {
    Len = OS_Q_GetPtrTimed(&_MemoryQ, &pData, 10);      /* Check message   */
    if (Len > 0) {
      Memory_WritePacket(*(U32*)pData, pData+4, Len);   /* Process message */
      OS_Q_Purge(&_MemoryQ);                            /* Delete message  */
    } else {                                            /* Timeout         */
      DoSomethingElse();
    }
  }
}
```


8.3.6 OS_Q_Purge()

Description

Deletes the last retrieved message in a queue.

Prototype

```
void OS_Q_Purge (OS_Q* pQ);
```

Parameter	Description
pQ	Pointer to the queue.

Table 8.7: OS_Q_Purge() parameter list

Additional Information

This routine should be called by the task that retrieved the last message from the queue, after the message is processed.

Example

```
static void MemoryTask(void) {
  char MemoryEvent;
  int Len;
  char* pData;

  while (1) {
    Len = OS_Q_GetPtr(&_MemoryQ, &pData);            /* Get message     */
    Memory_WritePacket(*(U32*)pData, pData+4, Len);  /* Process message */
    OS_Q_Purge(&_MemoryQ);                           /* Delete message  */
  }
}
```


8.3.7 OS_Q_Clear()

Description

Deletes all message in a queue.

Prototype

```
void OS_Q_Clear (OS_Q* pQ);
```

Parameter	Description
pQ	Pointer to the queue.

Table 8.8: OS_Q_Clear() parameter list

8.3.8 OS_Q_GetMessageCnt()

Description

Returns the number of messages currently in a queue.

Prototype

```
int OS_Q_GetMessageCnt (OS_Q* pQ);
```

Parameter	Description
pQ	Pointer to the queue.

Table 8.9: OS_Q_GetMessageCnt() parameter list

Return value

The number of messages in the queue.

Chapter 9

Task events

Task events are another way of communication between tasks. In contrast to semaphores and mailboxes, task events are messages to a single, specified recipient. In other words, a task event is sent to a specified task.

The purpose of a task event is to enable a task to wait for a particular event (or for one of several events) to occur. This task can be kept inactive until the event is signaled by another task, a S/W timer or an interrupt handler. The event can consist of anything that the software has been made aware of in any way. For example, the change of an input signal, the expiration of a timer, a key press, the reception of a character, or a complete command.

Every task has a 1-byte (8-bit) mask, which means that 8 different events can be signaled to and distinguished by every task. By calling `OS_WaitEvent()`, a task waits for one of the events specified as a bitmask. As soon as one of the events occurs, this task must be signaled by calling `OS_SignalEvent()`. The waiting task will then be put in the READY state immediately. It will be activated according to the rules of the scheduler as soon as it becomes the task with the highest priority of all the tasks in the READY state.

9.1 Events API function overview

Routine	Description
OS_WaitEvent()	Waits for one of the events specified in the bitmask and clears the event memory after an event occurs.
OS_WaitSingleEvent()	Waits for one of the events specified as bitmask and clears only that event after it occurs.
OS_WaitEventTimed()	Waits for the specified events for a given time, and clears the event memory after an event occurs.
OS_WaitSingleEventTimed()	Waits for the specified events for a given time; after an event occurs, only that event is cleared.
OS_SignalEvent()	Signals event(s) to a specified task.
OS_GetEventsOccurred()	Returns a list of events that have occurred for a specified task.
OS_ClearEvents()	Returns the actual state of events and then clears the events of a specified task.

Table 9.1: Events API overview

9.1.1 OS_WaitEvent()

Description

Waits for one of the events specified in the bitmask and clears the event memory after an event occurs.

Prototype

```
char OS_WaitEvent (char EventMask);
```

Parameter	Description
EventMask	The events that the task will be waiting for.

Table 9.2: OS_WaitEvent() parameter list

Return value

All events that have actually occurred.

Additional Information

If none of the specified events are signaled, the task is suspended. The first of the specified events will wake the task. These events are signaled by another task, a S/W timer or an interrupt handler. Any bit in the 8-bit event mask may enable the corresponding event.

Example

```
OS_WaitEvent(3);          /* Wait for event 1 or 2 to be signaled */
```

For a further example, see `OS_SignalEvent()`.

9.1.2 OS_WaitSingleEvent()

Description

Waits for one of the events specified by the bitmask and clears only that event after it occurs.

Prototype

```
char OS_WaitSingleEvent (char EventMask);
```

Parameter	Description
EventMask	The events that the task will be waiting for.

Table 9.3: OS_WaitSingleEvent() parameter list

Return value

All masked events that have actually occurred.

Additional Information

If none of the specified events are signaled, the task is suspended. The first of the specified events will wake the task. These events are signaled by another task, a S/W timer, or an interrupt handler. Any bit in the 8-bit event mask may enable the corresponding event. All unmasked events remain unchanged.

Example

```
OS_WaitSingleEvent(3);        /* Wait for event 1 or 2 to be signaled */
```

9.1.3 OS_WaitEventTimed()

Description

Waits for the specified events for a given time, and clears the event memory after an event occurs.

Prototype

```
char OS_WaitEventTimed (char EventMask,
                        OS_TIME TimeOut);
```

Parameter	Description
EventMask	The events that the task will be waiting for.
Timeout	Maximum time in timer ticks until the events have to be signaled. The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 9.4: OS_WaitEventTimed() parameter list

Return value

The events that have actually occurred within the specified time.
0 if no events were signaled in time.

Additional Information

If none of the specified events are available, the task is suspended for the given time. The first of the specified events will wake the task if the event is signaled by another task, a S/W timer, or an interrupt handler within the specified TimeOut time.

If no event is signaled, the task is activated after the specified timeout and all actual events are returned and then cleared. Any bit in the 8-bit event mask may enable the corresponding event.

Example

```
OS_WaitEventTimed(3, 10); /* Wait for event 1 or 2 to be signaled within 10 ms */
```

9.1.4 OS_WaitSingleEventTimed()

Description

Waits for the specified events for a given time; after an event occurs, only that event is cleared.

Prototype

```
char OS_WaitSingleEventTimed (char EventMask,
                              OS_TIME TimeOut);
```

Parameter	Description
EventMask	The events that the task will be waiting for.
Timeout	Maximum time in timer ticks until the events have to be signaled. The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 9.5: OS_WaitSingleEventTimed() parameter list

Return value

The masked events that have actually occurred within the specified time.
0 if no masked events were signaled in time.

Additional Information

If none of the specified events are available, the task is suspended for the given time. The first of the specified events will wake the task if the event is signaled by another task, a S/W timer or an interrupt handler within the specified TimeOut time. If no event is signaled, the task is activated after the specified timeout and the function returns zero. Any bit in the 8-bit event mask may enable the corresponding event. All unmasked events remain unchanged.

Example

```
OS_WaitSingleEventTimed(3, 10); /* Wait for event 1 or 2 to be
                                   signaled within 10 ms */
```

9.1.5 OS_SignalEvent()

Description

Signals event(s) to a specified task.

Prototype

```
void OS_SignalEvent (char Event,
                        OS_TASK* pTask);
```

Parameter	Description
Event	The event(s) to signal: 1 means event 1 2 means event 2 4 means event 3 ... 128 means event 8. Multiple events can be signaled as the sum of the single events (for example, 6 will signal events 2 & 3).
pTask	Task that the events are sent to.

Table 9.6: OS_SignalEvent() parameter list

Additional Information

If the specified task is waiting for one of these events, it will be put in the READY state and activated according to the rules of the scheduler.

Example

The task that handles the serial input and the keyboard waits for a character to be received either via the keyboard (EVENT_KEYPRESSED) or serial interface (EVENT_SERIN):

```
/*
* Just a small demo for events
*/

#define EVENT_KEYPRESSED (1)
#define EVENT_SERIN (2)

OS_STACKPTR int Stack0[96], Stack1[64];                      /* Task stacks */
OS_TASK TCB0, TCB1;           /* Data area for tasks (task control blocks) */

void Task0(void) {
  OS_U8 MyEvent;
  while(1)
    MyEvent = OS_WaitEvent(EVENT_KEYPRESSED | EVENT_SERIN)
    if (MyEvent & EVENT_KEYPRESSED) {
      /* handle key press        */
    }
    if (MyEvent & EVENT_SERIN) {
      /* Handle serial reception  */
    }
  }
}

void TimerKey(void) {
 /* More code to find out if key has been pressed  */
  OS_SignalEvent(EVENT_SERIN, &TCB0); /* Notify Task that key was pressed */
}

void InitTask(void) {
  OS_CREATETASK(&TCB0, 0, Task0, 100, Stack0);            /* Create Task0 */
}
```

If the task was only waiting for a key to be pressed, OS_GetMail() could simply be called. The task would then be deactivated until a key is pressed. If the task has to handle multiple mailboxes, as in this case, events are a good option.

9.1.6 OS_GetEventsOccurred()

Description

Returns a list of events that have occurred for a specified task.

Prototype

```
char OS_GetEventsOccurred (OS_TASK* pTask);
```

Parameter	Description
pTask	The task who's event mask is to be returned, NULL means current task.

Table 9.7: OS_getEventsOccured() parameter list

Return value

The event mask of the events that have actually occurred.

Additional Information

By calling this function, the actual events remain signaled. The event memory is not cleared. This is one way for a task to find out which events have been signaled. The task is not suspended if no events are available.

9.1.7 OS_ClearEvents()

Description

Returns the actual state of events and then clears the events of a specified task.

Prototype

```
char OS_ClearEvents (OS_TASK* pTask);
```

Parameter	Description
pTask	The task who's event mask is to be returned, NULL means current task.

Table 9.8: OS_ClearEvents() parameter list

Return value

The events that were actually signaled before clearing.

Chapter 10

Event objects

Event objects are another type of communication and synchronization objects. In contrast to task-events, event objects are standalone objects which are not owned by any task.

The purpose of an event object is to enable one or multiple tasks to wait for a particular event to occur. The tasks can be kept suspended until the event is set by another task, a S/W timer, or an interrupt handler. The event can be anything that the software is made aware of in any way. Examples include the change of an input signal, the expiration of a timer, a key press, the reception of a character, or a complete command.

Compared to a task event, the signalling function does not need to know which task is waiting for the event to occur.

10.1 Event object API function overview

Routine	Description
OS_EVENT_Create()	Creates an event object. Has to be called before the event object can be used.
OS_EVENT_Wait()	Waits for an event and resets the event after it occurs.
OS_EVENT_WaitTimed()	Waits for an event with timeout and resets the event after it occurs.
OS_EVENT_Set()	Sets the events, or resumes waiting tasks.
OS_EVENT_Reset()	Clears for example resets the event to un-signaled state.
OS_EVENT_Pulse()	Sets the event, resumes waiting tasks, if any, and then resets the event.
OS_EVENT_Get()	Returns the state of an event object.
OS_EVENT_Delete()	Deletes the specified event object.

Table 10.1: Event object API overview

10.1.1 OS_EVENT_Create()

Description

Creates an event object and resets the event.

Prototype

```
void OS_EVENT_Create (OS_EVENT* pEvent)
```

Parameter	Description
pEvent	Pointer to an event object data structure.

Table 10.2: OS_EVENT_Create() parameter list

Additional Information

Before the event object can be used, it has to be created once by a call of `OS_EVENT_Create()`. On creation, the event is set in non-signaled state, and the list of waiting tasks is deleted. Therefore, `OS_EVENT_Create()` must not be called for an event object which was already created before. The debug version of embOS checks whether the specified event object was already created and calls `OS_Error()` with error code `OS_ERR_2USE_EVENTOBJ`, if the event object was already created before the call of `OS_EVENT_Create()`.

Example

```
OS_EVENT _HW_Event;
OS_EVENT_Create(&HW_Event);           /* Create and initialize event object */
```


10.1.2 OS_EVENT_Wait()

Description

Waits for an event and suspends the calling task as long as the event is not signaled.

Prototype

```
void OS_EVENT_Wait (OS_EVENT* pEvent)
```

Parameter	Description
pEvent	Pointer to the event object that the task will be waiting for.

Table 10.3: OS_EVENT_Wait() parameter list

Additional Information

If the specified event object is already set, the calling task resets the event and continues operation. If the specified event object is not set, the calling task is suspended until the event object becomes signaled. pEvent has to address an existing event object, which has to be created before the call of OS_EVENT_Wait(). The debug version of embOS will check whether pEvent addresses a valid event object and will call OS_Error() with error code OS_ERR_EVENT_INVALID in case of an error.

Important

This function may not be called from within an interrupt handler or software timer.

Example

```
OS_EVENT_Wait(&_HW_Event);        /* Wait for event object */
```

10.1.3 OS_EVENT_WaitTimed()

Description

Waits for an event and suspends the calling task for a specified time as long as the event is not signaled.

Prototype

```
char OS_EVENT_WaitTimed (OS_EVENT* pEvent, OS_TIME Timeout)
```

Parameter	Description
pEvent	Pointer to the event object that the task will be waiting for.
Timeout	Maximum time in timer ticks until the event have to be signaled. The data type OS_TIME is defined as an integer, therefore valid values are 1 <= Timeout <= 2^{15}-1 = 0x7FFF = 32767 for 8/16-bit CPUs 1 <= Timeout <= 2^{31}-1 = 0x7FFFFFFF for 32-bit CPUs

Table 10.4: OS_EVENT_Wait() parameter list

Return value

0 success, the event was signaled within the specified time.
1 if the event was not signaled and a timeout occured.

Additional Information

If the specified event object is already set, the calling task resets the event and continues operation. If the specified event object is not set, the calling task is suspended until the event object becomes signaled or the timeout time has expired.
pEvent has to address an existing event object, which has to be created before the call of OS_EVENT_WaitTimed(). The debug version of embOS will check whether pEvent addresses a valid event object and will call OS_Error() with error code OS_ERR_EVENT_INVALID in case of an error.

Important

This function may not be called from within an interrupt handler or software timer.

Example

```
if (OS_EVENT_WaitTimed(&_HW_Event, 10) == 0) {
  /* event was signaled within tim out time, handle event */
  ...
} else {
  /* event was not signaled within tim out time, handle timeout */
  ...
}
```


10.1.4 OS_EVENT_Set()

Description

Sets an event object to signaled state, or resumes tasks which are waiting at the event object.

Prototype

```
void OS_EVENT_Set (OS_EVENT* pEvent)
```

Parameter	Description
pEvent	Pointer to the event object which should be set to signaled state.

Table 10.5: OS_EVENT_Set() parameter list

Additional Information

If no tasks are waiting at the event object, the event object is set to signaled state. If at least one task is already waiting at the event object, all waiting tasks are resumed and the event object is not set to the signaled state. pEvent has to address an existing event object, which has to be created before by a call of of OS_EVENT_Create(). The debug version of embOS will check whether pEvent addresses a valid event object and will call OS_Error() with error code OS_ERR_EVENT_INVALID in case of an error.

Example

The following printout shows an example using event objects to synchronize tasks to a hardware initilization function. This sample application can be found in MAIN_Event.c, which is delivered in the Samples subdirectory of the embOS Start folder.

```
/*********************************************************************
* SEGGER MICROCONTROLLER SYSTEME GmbH
* Solutions for real time microcontroller applications
**********************************************************************
File    : Main_EVENT.c
Purpose : Sample program for embOS using EVENT object
--------- END-OF-HEADER --------------------------------------------*/

#include "RTOS.h"

OS_STACKPTR int StackHP[128], StackLP[128];          /* Task stacks */
OS_TASK TCBHP, TCBLP;                        /* Task-control-blocks */

/********************************************************************/

/****** Interface to HW module **************************************/

void HW_Wait(void);
void HW_Free(void);
void HW_Init(void);

/********************************************************************/

/****** HW module ***************************************************/

OS_STACKPTR int _StackHW[128];                       /* Task stack  */
OS_TASK _TCBHW;                              /* Task-control-block  */

/****** local data **************************************************/
static OS_EVENT _HW_Event;

/****** local functions *********************************************/
static void _HWTask(void) {
  /* Initialize HW functionallity    */
```

```
  OS_Delay(100);
  /* Init done, send broadcast to waiting tasks */
  HW_Free();
  while (1) {
    OS_Delay (40);
  }
}

/****** global functions *******************************************/
void HW_Wait(void) {
  OS_EVENT_Wait(&_HW_Event);
}

void HW_Free(void) {
  OS_EVENT_Set(&_HW_Event);
}

void HW_Init(void) {
  OS_CREATETASK(&_TCBHW, "HWTask", _HWTask, 25, _StackHW);
  OS_EVENT_Create(&_HW_Event);
}

/********************************************************************/

/********************************************************************/

static void HPTask(void) {
  HW_Wait();                    /* Wait until HW module is set up */
  while (1) {
    OS_Delay (50);
  }
}

static void LPTask(void) {
  HW_Wait();                    /* Wait until HW module is set up */
  while (1) {
    OS_Delay (200);
  }
}

/*********************************************************************
*
*       main
**********************************************************************/

int main(void) {
  OS_IncDI();                    /* Initially disable interrupts  */
  OS_InitKern();                 /* Initialize OS                 */
  OS_InitHW();                   /* Initialize Hardware for OS    */
  HW_Init();                     /* Initialize HW module          */
  /* You need to create at least one task before calling OS_Start() */
  OS_CREATETASK(&TCBHP, "HP Task", HPTask, 100, StackHP);
  OS_CREATETASK(&TCBLP, "LP Task", LPTask,  50, StackLP);
  OS_SendString("Start project will start multitasking !\n");
  OS_Start();                    /* Start multitasking            */
  return 0;
}
```


10.1.5 OS_EVENT_Reset()

Description

Resets the specified event object to non-signaled state.

Prototype

```
void OS_EVENT_Reset (OS_EVENT* pEvent)
```

Parameter	Description
pEvent	Pointer to the event object which should be reset to non-signaled state.

Table 10.6: OS_EVENT_Reset() parameter list

Additional Information

pEvent has to address an existing event object, which has been created before by a call of OS_EVENT_Create(). The debug version of embOS will check whether pEvent addresses a valid event object and will call OS_Error() with the error code OS_ERR_EVENT_INVALID in case of an error.

Example

```
OS_EVENT_Reset(&_HW_Event); /* Reset event object to non-signaled state */
```

10.1.6 OS_EVENT_Pulse()

Description

Signals an event object and resumes waiting tasks, then resets the event object to non-signaled state.

Prototype

```
void OS_EVENT_Pulse (OS_EVENT* pEvent);
```

Parameter	Description
pEvent	Pointer to the event object which should be pulsed.

Table 10.7: OS_EVENT_Pulse() parameter list

Additional Information

If any tasks are waiting at the event object, the tasks are resumed. The event object remains unsignaled. The debug version of embOS will check whether `pEvent` addresses a valid event object and will call `OS_Error()` with the error code `OS_ERR_EVENT_INVALID` in case of an error.

10.1.7 OS_EVENT_Get()

Description

Returns the state of an event object.

Prototype

```
unsigned char OS_EVENT_Get (OS_EVENT* pEvent);
```

Parameter	Description
pEvent	Pointer to an event object who’s state should be examined.

Table 10.8: OS_EVENT_Get() parameter list

Return value

0: Event object is not set to signaled state
1: Event object is set to signaled state.

Additional Information

By calling this function, the actual state of the event object remains unchanged. pEvent has to address an existing event object, which has been created before by a call of OS_EVENT_Create(). The debug version of embOS will check whether pEvent addresses a valid event object and will call OS_Error() with error code OS_ERR_EVENT_INVALID in case of an error.

10.1.8 OS_EVENT_Delete()

Description

Deletes an event object.

Prototype

```
void OS_EVENT_Delete (OS_EVENT* pEvent);
```

Parameter	Description
pEvent	Pointer to an event object which should be deleted.

Table 10.9: OS_EVENT_Delete() parameter list

Additional Information

To keep the system fully dynamic, it is essential that event objects can be created dynamically. This also means there has to be a way to delete an event object when it is no longer needed. The memory that has been used by the event object's control structure can then be reused or reallocated.
It is your responsibility to make sure that:

- the program no longer uses the event object to be deleted
- the event object to be deleted actually exists (has been created first)
- no tasks are waiting at the event object when it is deleted.

pEvent has to address an existing event object, which has been created before by a call of OS_EVENT_Create(). The debug version of embOS will check whether pEvent addresses a valid event object and will call OS_Error() with error code OS_ERR_EVENT_INVALID in case of an error. If any task is waiting at the event object which is deleted, the debug version of embOS calls OS_Error() with error code OS_ERR_EVENT_DELETE. To avoid any problems, an event object should not be deleted in a normal application.

Chapter 11

Heap type memory management

ANSI C offers some basic dynamic memory management functions. These are `malloc`, `free`, and `realloc`.
Unfortunately, these routines are not thread-safe, unless a special thread-safe implementation exists in the compiler specific runtime libraries; they can only be used from one task or by multiple tasks if they are called sequentially. Therefore, embOS offer task-safe variants of these routines. These variants have the same names as their ANSI counterparts, but are prefixed `OS_`; they are called `OS_malloc()`, `OS_free()`, `OS_realloc()`. The thread-safe variants that embOS offers use the standard ANSI routines, but they guarantee that the calls are serialized using a resource semaphore.
If heap memory management is not supported by the standard C-libraries for a specific CPU, embOS heap memory management is not implemented.

Heap type memory management is part of the embOS libraries. It does not use any resources if it is not referenced by the application (that is, if the application does not use any memory management API function).

Note that another aspect of these routines may still be a problem: the memory used for the functions (known as heap) may fragment. This can lead to a situation where the total amount of memory is sufficient, but there is not enough memory available in a single block to satisfy an allocation request.

11.1 Heap type memory manager API reference

API routine	Description
OS_malloc()	Allocates a block of memory on the heap.
OS_free()	Frees a block of memory previously allocated.
OS_realloc()	Changes allocation size.

Table 11.1: Heap type memory manager API overview

Chapter 12

Fixed block size memory pools

Fixed block size memory pools contain a specific number of fixed-size blocks of memory. The location in memory of the pool, the size of each block, and the number of blocks are set at runtime by the application via a call to the `OS_MEMF_CREATE()` function. The advantage of fixed memory pools is that a block of memory can be allocated from within any task in a very short, determined period of time.

12.1 Memory pools API reference overview

All API functions for fixed block size memory pools are prefixed OS_MEMF_.

API routine	Description
Create / Delete	
OS_MEMF_Create	Creates fixed block memory pool.
OS_MEMF_Delete	Deletes fixed block memory pool.
Allocation	
OS_MEMF_Alloc	Allocates memory block from a given memory pool. Wait indefinitely if no block is available.
OS_MEMF_AllocTimed	Allocates memory block from a given memory pool. Wait no longer than given timelimit if no block is available.
OS_MEMF_Request	Allocates block from a given memory pool, if available. Non-blocking.
Release	
OS_MEMF_Release	Releases memory block from a given memory pool.
OS_MEMF_FreeBlock	Releases memory block from any pool.
Info	
OS_MEMF_GetNumFreeBlocks	Returns the number of available blocks in a pool.
OS_MEMF_IsInPool	Returns !=0 if block is in memory pool.
OS_MEMF_GetMaxUsed	Returns the maximum number of blocks in a pool which have been used at a time.
OS_MEMF_GetNumBlocks	Returns the number of blocks in a pool.
OS_MEMF_GetBlockSize	Returns the size of one block of a given pool.

Table 12.1: Memory pools API overview

12.1.1 OS_MEMF_Create()

Description

Creates and initializes a fixed block size memory pool.

Prototype

```
void OS_MEMF_Create (OS_MEMF* pMEMF,
                     void* pPool,
                     OS_U16 NumBlocks,
                     OS_U16 BlockSize);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.
pPool	Pointer to memory to be used for the memory pool. Required size is: NumBlocks * (BlockSize + OS_MEMF_SIZEOF_BLOCKCONTROL).
NumBlocks	Pointer to memory to be used for the memory pool. Required size is: NumBlocks * (BlockSize + OS_MEMF_SIZEOF_BLOCKCONTROL).
BlockSize	Size in bytes of one block.

Table 12.2: OS_MEMF_Create() parameter list

Additional Information

OS_MEMF_SIZEOF_BLOCKCONTROL gives the number of bytes used for control and debug purposes. It is guaranteed to be 0 in release or stack check builds. Before using any memory pool, it has to be created. The debug version of libraries keeps track of created and deleted memory pools. The release and stack check versions do not.

12.1.2 OS_MEMF_Delete()

Description

Deletes a fixed block size memory pool. After deletion, the memory pool and memory blocks inside this pool can no longer be used.

Prototype

```
void OS_MEMF_Delete (OS_MEMF* pMEMF);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.

Table 12.3: OS_MEMF_Delete() parameter list

Additional Information

This routine is provided for completeness. It is not used in the majority of applications because there is no need to dynamically create/delete memory pools.
For most applications it is preferred to have a static memory pool design; memory pools are created at startup (before calling `OS_Start()`) and will never be deleted.
The debug version of libraries mark the memory pool as deleted.

12.1.3 OS_MEMF_Alloc()

Description

Requests allocation of a memory block. Waits until a block of memory is available.

Prototype

```
void* OS_MEMF_Alloc (OS_MEMF* pMEMF,
                     int      Purpose);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.
Purpose	This is a parameter which is used for debugging purpose only. Its value has no effect on program execution, but may be remembered in debug builds to allow runtime analysis of memory allocation problems.

Table 12.4: OS_MEMF_Alloc() parameter list

Return value

Pointer to the allocated block.

Additional Information

If there is no free memory block in the pool, the calling task is suspended until a memory block becomes available. The retrieved pointer must be delivered to `OS_MEMF_Release()` as a parameter to free the memory block. The pointer must not be modified.

12.1.4 OS_MEMF_AllocTimed()

Description

Requests allocation of a memory block. Waits until a block of memory is available or the timeout has expired.

Prototype

```
void* OS_MEMF_AllocTimed (OS_MEMF* pMEMF,
                          int Timeout,
                          int Purpose);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.
Timeout	Timelimit before timeout, given in ticks. 0 or negative values are permitted.
Purpose	This is a parameter which is used for debugging purpose only. Its value has no effect on program execution, but may be remembered in debug builds to allow runtime analysis of memory allocation problems.

Table 12.5: OS_MEMF_Alloc_Timed()

Return value

`!=NULL` pointer to the allocated block
`NULL` if no block has been allocated.

Additional Information

If there is no free memory block in the pool, the calling task is suspended until a memory block becomes available or the timeout has expired. The retrieved pointer must be delivered to `OS_MEMF_Release()` as parameter to free the memory block. The pointer must not be modified.

12.1.5 OS_MEMF_Request()

Description

Requests allocation of a memory block. Continues execution in any case.

Prototype

```
void* OS_MEMF_Request (OS_MEMF* pMEMF,
                       int      Purpose);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.
Purpose	This is a parameter which is used for debugging purpose only. Its value has no effect on program execution, but may be remembered in debug builds to allow runtime analysis of memory allocation problems.

Table 12.6: OS_MEMF_Request() parameter list

Return value

`!=NULL` pointer to the allocated block
`NULL` if no block has been allocated.

Additional Information

The calling task is never suspended by calling `OS_MEMF_Request()`. The retrieved pointer must be delivered to `OS_MEMF_Release()` as parameter to free the memory block. The pointer must not be modified.

12.1.6 OS_MEMF_Release()

Description

Releases a memory block that was previously allocated.

Prototype

```
void OS_MEMF_Release (OS_MEMF* pMEMF,
                      void*    pMemBlock);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.
pMemBlock	Pointer to the memory block to free.

Table 12.7: OS_MEMF_Release() parameter list

Additional Information

The pMemBlock pointer has to be the one that was delivered form any retrival function described above. The pointer must not be modified between allocation and release. The memory block becomes available for other tasks waiting for a memory block from the pool. If any task is waiting for a fixed memory block, it is activated according to the rules of the scheduler.

12.1.7 OS_MEMF_FreeBlock()

Description

Releases a memory block that was previously allocated. The memory pool does not need to be denoted.

Prototype

```
void OS_MEMF_FreeBlock (void* pMemBlock);
```

Parameter	Description
pMemBlock	Pointer to the memory block to free.

Table 12.8: OS_MEMF_FreeBlock() parameter list

Additional Information

The pMemBlock pointer has to be the one that was delivered form any retrieval function described above. The pointer must not be modified between allocation and release. This function may be used instead of OS_MEMF_Release(). It has the advantage that only one parameter is needed. embOS itself will find the associated memory pool. The memory block becomes available for other tasks waiting for a memory block from the pool. If any task is waiting for a fixed memory block, it is activated according to the rules of the scheduler.

12.1.8 OS_MEMF_GetNumBlocks()

Description

Information routine to examine the total number of available memory blocks in the pool.

Prototype

```
int OS_MEMF_GetNumFreeBlocks (OS_MEMF* pMEMF);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.

Table 12.9: OS_MEMF_GetNumBlocks() parameter list

Return value

Returns the number of blocks in the specified memory pool. This is the value that was given as parameter during creation of the memory pool.

12.1.9 OS_MEMF_GetBlockSize()

Description

Information routine to examine the size of one memory block in the pool.

Prototype

```
int OS_MEMF_GetBlockSize (OS_MEMF* pMEMF);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.

Table 12.10: OS_MEMF_GetBlockSize() parameter list

Return value

Size in bytes of one memory block in the specified memory pool. This is the value of the parameter when the memory pool was created.

12.1.10 OS_MEMF_GetNumFreeBlocks()

Description

Information routine to examine the number of free memory blocks in the pool.

Prototype

```
int OS_MEMF_GetNumFreeBlocks (OS_MEMF* pMEMF);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.

Table 12.11: OS_MEMF_GetNumFreeBlocks() parameter list

Return value

The number of free blocks actually available in the specified memory pool.

12.1.11 OS_MEMF_GetMaxUsed()

Description

Information routine to examine the amount of memory blocks in the pool that were used concurrently since creation of the pool.

Prototype

```
int OS_MEMF_GetMaxUsed (OS_MEMF* pMEMF);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.

Table 12.12: OS_MEMF_GetMaxUsed() parameter list

Return value

Maximum number of blocks in the specified memory pool that were used concurrently since the pool was created.

12.1.12 OS_MEMF_IsInPool()

Description

Information routine to examine whether a memory block reference pointer belongs to the specified memory pool.

Prototype

```
char OS_MEMF_IsInPool (OS_MEMF* pMEMF,
                       void* pMemBlock);
```

Parameter	Description
pMEMF	Pointer to the control data structure of memory pool.
pMemBlock	Pointer to a memory block that should be checked

Table 12.13: OS_MEMF_IsInPool() parameter list

Return value

0: Pointer does not belong to memory pool.
1: Pointer belongs to the pool.

Chapter 13

Stacks

The stack is the memory area used for storing the return address of function calls, parameters, and local variables, as well as for temporary storage. Interrupt routines also use the stack to save the return address and flag registers, except in cases where the CPU has a separate stack for interrupt functions. Refer to the *CPU & Compiler Specifics manual* of embOS documentation for details on your processor's stack. A "normal" single-task program needs exactly one stack. In a multitasking system, every task has to have its own stack.

The stack needs to have a minimum size which is determined by the sum of the stack usage of the routines in the worst-case nesting. If the stack is too small, a section of the memory that is not reserved for the stack will be overwritten, and a serious program failure is most likely to occur. embOS monitors the stack size (and, if available, also interrupt stack size in the debug version), and calls the failure routine `OS_Error()` if it detects a stack overflow. However, embOS cannot reliably detect a stack overflow.

A stack that has been defined larger than necessary does not hurt; it is only a waist of memory. To detect a stack overflow, the debug and stack check builds of embOS fill the stack with control characters when it is created and check these characters every time the task is deactivated. If an overflow is detected, `OS_Error()` is called.

13.1 System stack

Before embOS takes over control (before the call to `OS_Start()`), a program does use the so-called system stack. This is the same stack that a non-embOS program for this CPU would use. After transferring control to the embOS scheduler by calling `OS_Start()`, the system stack is used only when no task is executed for the following:

- embOS scheduler
- embOS software timers (and the callback).

For details regarding required size of your system stack, refer to the *CPU & Compiler Specifics manual* of embOS documentation.

13.2 Task stack

Each embOS task has a separate stack. The location and size of this stack is defined when creating the task. The minimum size of a task stack pretty much depends on the CPU and the compiler. For details, see the *CPU & Compiler Specifics manual* of embOS documentation.

13.3 Interrupt stack

To reduce stack size in a multitasking environment, some processors use a specific stack area for interrupt service routines (called a hardware interrupt stack). If there is no interrupt stack, you will have to add stack requirements of your interrupt service routines to each task stack.
Even if the CPU does not support a hardware interrupt stack, embOS may support a separate stack for interrupts by calling the function `OS_EnterIntStack()` at beginning of an interrupt service routine and `OS_LeaveIntStack()` at its very end. In case the CPU already supports hardware interrupt stacks or if a separate interrupt stack is not supported at all, these function calls are implemented as empty macros.
We recommend using `OS_EnterIntStack()` and `OS_LeaveIntStack()` even if there is currently no additional benefit for your specific CPU, because code that uses them might reduce stack size on another CPU or a new version of embOS with support for an interrupt stack for your CPU. For details about interrupt stacks, see the *CPU & Compiler Specifics manual* of embOS documentation.

13.4 Stacks API function overview

Routine	Description
OS_GetStackBase()	Returns the base address of a task stack.
OS_GetStackSize()	Returns the size of a task stack.
OS_GetStackSpace()	Returns the unused portion of a task stack.
OS_GetStackUsed()	Returns the used portion of a task stack.

Table 13.1: Stacks API overview

13.4.1 OS_GetStackBase()

Description

Returns a pointer to the base of a task stack.

Prototype

```
OS_STACKPTR* OS_GetStackBase (OS_TASK* pTask);
```

Parameter	Description
pTask	The task who's stack base has to be returned. NULL means current task.

Table 13.2: OS_GetStackBase() parameter list

Return value

The pointer to the base address of the task stack.

Additional Information

This function is only available in the debug and stack check builds of embOS, because only these builds initialize the stack space used for the tasks.

Example

```
void CheckSpace(void) {
  printf("Addr Stack[0]  %x", OS_GetStackBase(&TCB[0]);
  OS_Delay(1000);
  printf("Addr Stack[1]  %x", OS_GetStackBase(&TCB[1]);
  OS_Delay(1000);
}
```


13.4.2 OS_GetStackSize()

Description

Returns the size of a task stack.

Prototype

```
int OS_GetStackSize (OS_TASK* pTask);
```

Parameter	Description
pTask	The task who's stack size should be checked. NULL means current task.

Table 13.3: OS_GetStackSize() parameter list

Return value

The size of the task stack in bytes.

Additional Information

This function is only available in the debug and stack check builds of embOS, because only these builds initialize the stack space used for the tasks.

Example

```
void CheckSpace(void) {
  printf("Size Stack[0]  %d", OS_GetStackSize(&TCB[0]);
  OS_Delay(1000);
  printf("Size Stack[1]  %d", OS_GetStackSize(&TCB[1]);
  OS_Delay(1000);
}
```


13.4.3 OS_GetStackSpace()

Description

Returns the unused portion of a task stack.

Prototype

```
int OS_GetStackSpace (OS_TASK* pTask);
```

Parameter	Description
pTask	The task who's stack space has to be checked. NULL means current task.

Table 13.4: OS_GetStackSpace() parameter list

Return value

The unused portion of the task stack in bytes.

Additional Information

In most cases, the stack size required by a task cannot be easily calculated, because it takes quite some time to calculate the worst-case nesting and the calculation itself is difficult.
However, the required stack size can be calculated using the function OS_GetStackSpace(), which returns the number of unused bytes on the stack. If there is a lot of space left, you can reduce the size of this stack and vice versa.
This function is only available in the debug and stack check builds of embOS, because only these builds initialize the stack space used for the tasks.

Important

This routine does not reliably detect the amount of stack space left, because it can only detect modified bytes on the stack. Unfortunately, space used for register storage or local variables is not always modified. In most cases, this routine will detect the correct amount of stack bytes, but in case of doubt, be generous with your stack space or use other means to verify that the allocated stack space is sufficient.

Example

```
void CheckSpace(void) {
  printf("Unused Stack[0]  %d", OS_GetStackSpace(&TCB[0]);
  OS_Delay(1000);
  printf("Unused Stack[1]  %d", OS_GetStackSpace(&TCB[1]);
  OS_Delay(1000);
}
```

13.4.4 OS_GetStackUsed()

Description

Returns the used portion of a task stack.

Prototype

```
int OS_GetStackUsed (OS_TASK* pTask);
```

Parameter	Description
pTask	The task who's stack usage has to be checked. NULL means current task.

Table 13.5: OS_GetStackUsed() parameter list

Return value

The used portion of the task stack in bytes.

Additional Information

In most cases, the stack size required by a task cannot be easily calculated, because it takes quite some time to calculate the worst-case nesting and the calculation itself is difficult.
However, the required stack size can be calculated using the function `OS_GetStackUsed()`, which returns the number of used bytes on the stack. If there is a lot of space left, you can reduce the size of this stack and vice versa.
This function is only available in the debug and stack check builds of embOS, because only these builds initialize the stack space used for the tasks.

Important

This routine does not reliably detect the amount of stack space used, because it can only detect modified bytes on the stack. Unfortunately, space used for register storage or local variables is not always modified. In most cases, this routine will detect the correct amount of stack bytes, but in case of doubt, be generous with your stack space or use other means to verify that the allocated stack space is sufficient.

Example

```
void CheckSpace(void) {
  printf("Used Stack[0]  %d", OS_GetStackUsed(&TCB[0]);
  OS_Delay(1000);
  printf("Used Stack[1]  %d", OS_GetStackUsed(&TCB[1]);
  OS_Delay(1000);
}
```


Chapter 14

Interrupts

In this chapter, you will find a very basic description about using interrupt service routines (ISRs) in cooperation with embOS. Specific details for your CPU and compiler may be found in the *CPU & Compiler Specifics manual* of the embOS documentation.

Interrupts are interruptions of a program caused by hardware. When an interrupt occurs, the CPU saves its registers and executes a subroutine called an interrupt service routine, or ISR. After the ISR is completed, the program returns to the highest-priority task in the READY state. Normal interrupts are maskable; they can occur at any time unless they are disabled with the CPU's "disable interrupt" instruction. ISRs are also nestable - they can be recognized and executed within other ISRs.

There are several good reasons for using interrupt routines. They can respond very quickly to external events such as the status change on an input, the expiration of a hardware timer, reception or completion of transmission of a character via serial interface, or other types of events. Interrupts effectively allow events to be processed as they occur.

14.1 Interrupt latency

Interrupt latency is the time between an interrupt request and the execution of the first instruction of the interrupt service routine.
Every computer system has an interrupt latency. The latency depends on various factors and differs even on the same computer system. The value that one is typically interested in is the worst case interrupt latency.
The interrupt latency is the sum of a lot of different smaller delays explained below.

14.1.1 Causes of interrupt latencies

- The first delay is typically in the hardware: The interrupt request signal needs to be synchronized to the CPU clock. Depending on the synchronization logic, typically up to 3 CPU cycles can be lost before the interrupt request has reached the CPU core.
- The CPU will typically complete the current instruction. This instruction can take a lot of cycles; on most systems, divide, push-multiple, or memory-copy instructions are the instructions which require most clock cycles. On top of the cycles required by the CPU, there are in most cases additional cycles required for memory access. In an ARM7 system, the instruction `STMDB SP!,{R0-R11,LR};` (Push parameters and perm. register) is typically the worst case instruction. It stores 13 32-bit registers on the stack. The CPU requires 15 clock cycles.
- The memory system may require additional cycles for wait states.
- After the current instruction is completet, the CPU performs a mode switch or pushes registers (typically, PC and flag registers) on the stack. In general, modern CPUs (such as ARM) perform a mode switch, which requires less CPU cycles than saving registers.
- Pipeline fill
  Most modern CPUs are pipelined. Execution of an instruction happens in various stages of the pipeline. An instruction is executed when it has reached its final stage of the pipeline. Because the mode switch has flushed the pipeline, a few extra cycles are required to refill the pipeline.

14.1.2 Additional causes for interrupt latencies

There can be additional causes for interrupt latencies.
These depend on the type of system used, but we list a few of them.

- Latencies caused by cache line fill.
  If the memory system has one or multiple caches, these may not contain the required data. In this case, not only the required data is loaded from memory, but in a lot of cases a complete line fill needs to be performed, reading multiple words from memory.
- Latencies caused by cache write back.
  A cache miss may cause a line to be replaced. If this line is marked as dirty, it needs to be written back to main memory, causing an additional delay.
- Latencies caused by MMU translation table walks.
  Translation table walks can take a considerable amount of time, especially as they involve potentially slow main memory accesses. In real-time interrupt handlers, translation table walks caused by the TLB not containing translations for the handler and/or the data it accesses can increase interrupt latency significantly.
- Application program.
  Of course, the application program can cause additional latencies by disabling interrupts. This can make sense in some situations, but of course causes add. latencies.
- Interrupt routines.
  On most systems, one interrupt disables further interrupts. Even if the interrupts are re-enabled in the ISR, this takes a few instructions, causing add. latency.
- RTOS (Real-time Operating system).
  An RTOS also needs to temporarily disable the interrupts which can call API-functions of the RTOS. Some RTOSes disable all interrupts, effectively increasing

interrupt latencies for all interrupts, some (like embOS) disable only low-priority interrupts and do thereby not affect the latency of high priority interrupts.

14.2 Zero interrupt latency

Zero interrupt latency in the strict sense is not possible as explained above. What we mean when we say "Zero interrupt latency" is that the latency of high-priority interrupts is not affected by the RTOS; a system using embOS will have the same worst-case interrupt latency for high priority interrupts as a system running without embOS.

14.3 High / low priority interrupts

Most CPUs support interrupts with different priorities. Different priorities have two effects:

- If different interrupts occur simultaneously, the interrupt with higher priority takes precedence and its ISR is executed first.
- Interrupts can never be interrupted by other interrupts of the same or lower level of priority.

How many different levels of interrupts there are depend on the CPU and the interrupt controller. Details are explained in the CPU/MCU/SOC manuals and the *CPU & Compiler Specifics manual* of embOS. embOS distinguishes two different levels of interrupts: High / Low priority interrupts. The embOS port specific documentation explains where "the line is drawn", which interrupts are considered high and which interrupts are considered low priority. In general, the differences are:

Low priority interrupts

- May call embOS API functions
- Latencies caused by embOS

High priority interrupts

- May not call embOS API functions
- No Latencies caused by embOS (Zero latency)

Example of different interrupt priority levels

M16C CPUs support 8 interrupt priority levels. With embOS, the 3 highest priority levels are treated as “High priority interrupts”. ARM CPUs support normal interrupts (IRQ) and fast interrupt (FIQ). Using embOS, the FIQ is treated as “High priority interrupt”.

14.4 Rules for interrupt handlers

14.4.1 General rules

There are some general rules for interrupt handlers. These rules apply to both single-task programming as well as to multitask programming using embOS.

- Interrupt handlers preserve all registers.
  Interrupt handlers must restore the environment of a task completely. This environment normally consists of the registers only, so the ISR has to make sure that all registers modified during interrupt execution are saved at the beginning and restored at the end of the interrupt routine
- Interrupt handlers have to be finished quickly.
  Intensive calculations should be kept out of interrupt handlers. An interrupt handler should only be used for storing a received value or to trigger an operation in the regular program (task). It should not wait in any form or perform a polling operation.

14.4.2 Additional rules for preemptive multitasking

A preemptive multitasking system like embOS needs to know if the program that is executing is part of the current task or an interrupt handler. This is because embOS cannot perform a task switch during the execution of an interrupt handler; it can only do so at the end of an interrupt handler.

If a task switch were to occur during the execution of an ISR, the ISR would continue as soon as the interrupted task became the current task again. This is not a problem for interrupt handlers that do not allow further interruptions (which do not enable interrupts) and that do not call any embOS functions.

This leads us to the following rule:

- Interrupt functions that re-enable interrupts or use any embOS function need to call `OS_EnterInterrupt()` at the beginning, before executing any other command, and before they return, call either `OS_LeaveInterrupt()` or `OS_LeaveInterruptNoSwitch()` as last command.

If a higher priority task is made ready by the ISR, the task switch then occurs in the routine `OS_LeaveInterrupt()`. The end of the ISR is executed at a later point, when the interrupted task is made ready again. If you debug an interrupt routine, do not be confused. This has proven to be the most efficient way of initiating a task switch from within an interrupt service routine.

If fast task-activation at the end of an interrupt service routine is not required, `OS_LeaveInterruptNoSwitch()` can be used instead.

14.5 Calling embOS routines from within an ISR

Before calling any embOS function from within an ISR, embOS has to be informed that an interrupt service routine is running.

14.5.1 Interrupts API function overview

Routine	Description
OS_CallISR()	Interrupt entry function.
OS_CallNestableISR()	Interrupt entry function supporting estable interrupts.
OS_EnterInterrupt()	Informs embOS that interrupt code is executing.
OS_LeaveInterrupt()	Informs embOS that the end of the interrupt routine has been reached; executes task switching within ISR.
OS_LeaveInterruptNoSwitch()	Informs embOS that the end of the interrupt routine has been reached but does not execute task switching within ISR.
OS_IncDI()	Increments the interrupt disable counter (OS_DICnt) and disables interrupts.
OS_DecRI()	Decrements the counter and enables interrupts if the counter reaches 0.
OS_DI()	Disables interrupts. Does not change the interrupt disable counter.
OS_EI()	Unconditionally enables Interrupt.
OS_RestoreI()	Restores the status of the interrupt flag, based on the interrupt disable counter.
OS_EnterNestableInterrupt()	Re-enables interrupts and increments the embOS internal critical region counter, thus disabling further task switches.
OS_LeaveNestableInterrupt()	Disables further interrupts.
OS_LeaveNestableInterruptNoSwitch()	Disables further interrupts, informs embOS that the end of ISR is reached, but does not perform a task switch.

Table 14.1: Interrupt API overview

14.5.2 OS_CallISR()

Description

Entry function for use in an embOS interrupt handler. Nestable interrupts disabled.

Prototype

```
void  OS_CallISR (void (*pRoutine)(void));
```

Parameter	Description
pRoutine	Pointer to a routine that should run on interrupt.

Table 14.2: OS_CallISR() parameter list

Additional Information

`OS_CallISR()` can be used as entry function in an embOS interrupt handler, when the corresponding interrupt should not be interrupted by another embOS interrupt. `OS_CallISR()` sets the interrupt priority of the CPU to the user definable 'fast' interrupt priority level, thus locking any other embOS interrupt.
Fast interrupts are not disabled.

Note: For some specific CPUs `OS_CallISR()` has to be used to call an interrupt handler because `OS_EnterInterrupt()` / `OS_LeaveInterrupt()` may not be available.
Refer to the CPU specific manual.

Example

```
#pragma interrupt void OS_ISR_Tick(void) {
  OS_CallISR(_IsrTickHandler);
}
```


14.5.3 OS_CallNestableISR()

Description

Entry function for use in an embOS interrupt handler. Nestable interrupts enabled.

Prototype

```
void  OS_CallNestableISR (void (*pRoutine)(void));
```

Parameter	Description
pRoutine	Pointer to a routine that should run on interrupt.

Table 14.3: OS_CallNestableISR() parameter list

Additional Information

`OS_CallNestableISR()` can be used as entry function in an embOS interrupt handler, when interruption by higher prioritized embOS interrupts should be allowed. `OS_CallNestableISR()` does not alter the interrupt priority of the CPU, thus keeping all interrupts with higher priority enabled.

Note: For some specific CPUs `OS_CallNestableISR()` has to be used to call an interrupt handler because `OS_EnterNestableInterrupt()` / `OS_LeaveNestableInterrupt()` may not be available.
Refer to the CPU specific manual.

Example

```
#pragma interrupt void OS_ISR_Tick(void) {
  OS_CallNestableISR(_IsrTickHandler);
}
```

14.5.4 OS_EnterInterrupt()

Note: This function may not be available in all ports.

Description

Informs embOS that interrupt code is executing.

Prototype

```
void OS_EnterInterrupt (void);
```

Additional Information

If `OS_EnterInterrupt()` is used, it should be the first function to be called in the interrupt handler. It must be used with either `OS_LeaveInterrupt()` or `OS_LeaveInterruptNoSwitch()` as the last function called.
The use of this function has the following effects, it:

- disables task switches
- keeps interrupts in internal routines disabled.

14.5.5 OS_LeaveInterrupt()

Note: This function may not be available in all ports.

Description

Informs embOS that the end of the interrupt routine has been reached; executes task switching within ISR.

Prototype

```
void OS_LeaveInterrupt (void);
```

Additional Information

If `OS_LeaveInterrupt()` is used, it should be the last function to be called in the interrupt handler. If the interrupt has caused a task switch, it will be executed (unless the program which was interrupted was in a critical region).

14.5.6 OS_LeaveInterruptNoSwitch()

Note: This function may not be available in all ports.

Description

Informs embOS that the end of the interrupt routine has been reached but does not execute task switching within ISR.

Prototype

```
void OS_LeaveInterruptNoSwitch (void);
```

Additional Information

If `OS_LeaveInterruptNoSwitch()` is used, it should be the last function to be called in the interrupt handler. If the interrupt has caused a task switch, it is not executed from within the ISR, but at the next possible occasion. This will be the next call of an embOS function or the scheduler interrupt if the program is not in a critical region.

14.5.7 Example using OS_EnterInterrupt()/OS_LeaveInterrupt()

Interrupt routine using `OS_EnterInterrupt()`/`OS_LeaveInterrupt()`:

```
__interrupt void ISR_Timer(void) {
  OS_EnterInterrupt();
  OS_SignalEvent(1,&Task);/* Any functionality could be here */
  OS_LeaveInterrupt();
}
```


14.6 Enabling / disabling interrupts from C

During the execution of a task, maskable interrupts are normally enabled. In certain sections of the program, however, it can be necessary to disable interrupts for short periods of time to make a section of the program an atomic operation that cannot be interrupted. An example would be the access to a global volatile variable of type `long` on an 8/16-bit CPU. To make sure that the value does not change between the two or more accesses that are needed, the interrupts have to be temporarily disabled:

Bad example:

```
volatile long lvar;

void routine (void) {
  lvar ++;
}
```

The problem with disabling and re-enabling interrupts is that functions that disable/ enable the interrupt cannot be nested.

Your C compiler offers two intrinsic functions for enabling and disabling interrupts. These functions can still be used, but it is recommended to use the functions that embOS offers (to be precise, they only look like functions, but are macros in reality). If you do not use these recommended embOS functions, you may run into a problem if routines which require a portion of the code to run with disabled interrupts are nested or call an OS routine.

We recommend disabling interrupts only for short periods of time, if possible. Also, you should not call routines when interrupts are disabled, because this could lead to long interrupt latency times (the longer interrupts are disabled, the higher the interrupt latency). As long as you only call embOS functions with interrupts enabled, you may also safely use the compiler-provided intrinsics to disable interrupts.

14.6.1 OS_IncDI() / OS_DecRI()

The following functions are actually macros defined in RTOS.h, so they execute very quickly and are very efficient. It is important that they are used as a pair: first OS_IncDI(), then OS_DecRI().

OS_IncDI()

Short for **Increment and Disable Interrupts**. Increments the interrupt disable counter (OS_DICnt) and disables interrupts.

OS_DecRI()

Short for **Decrement and Restore Interrupts**. Decrements the counter and enables interrupts if the counter reaches 0.

Example

```
volatile long lvar;

void routine (void) {
  OS_IncDI();
  lvar ++;
  OS_DecRI();
}
```

OS_IncDI() increments the interrupt disable counter which is used for the entire OS and is therefore consistent with the rest of the program in that any routine can be called and the interrupts will not be switched on before the matching OS_DecRI() has been executed.

If you need to disable interrupts for a short moment only where no routine is called, as in the example above, you could also use the pair OS_DI() and OS_RestoreI(). These are a bit more efficient because the interrupt disable counter OS_DICnt is not modified twice, but only checked once. They have the disadvantage that they do not work with routines because the status of OS_DICnt is not actually changed, and they should therefore be used with great care. In case of doubt, use OS_IncDI() and OS_DecRI().

14.6.2 OS_DI() / OS_EI() / OS_RestoreI()

OS_DI()

Short for **Disable Interrupts**. Disables interrupts. Does not change the interrupt disable counter.

OS_EI()

Short for **Enable Interrupts**. Refrain from using this function directly unless you are sure that the interrupt enable count has the value zero, because it does not take the interrupt disable counter into account.

OS_RestoreI()

Short for **Restore Interrupts**. Restores the status of the interrupt flag, based on the interrupt disable counter.

Example

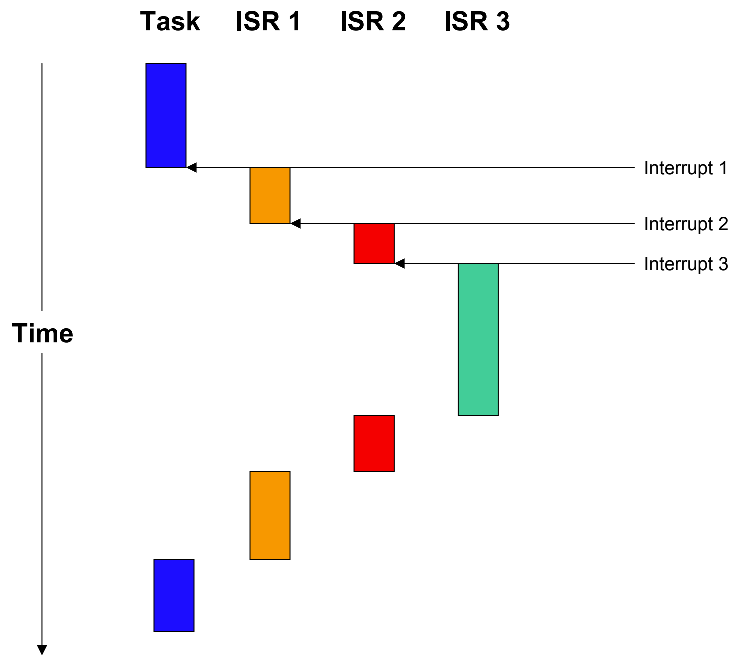
```
volatile long lvar;

void routine (void) {
  OS_DI();
  lvar++;
  OS_RestoreI();
}
```

14.7 Definitions of interrupt control macros (in RTOS.h)

```
#define OS_IncDI()        { OS_ASSERT_DICnt(); OS_DI(); OS_DICnt++; }
#define OS_DecRI()        { OS_ASSERT_DICnt(); if (--OS_DICnt==0) OS_EI(); }
#define OS_RestoreI()     { OS_ASSERT_DICnt(); if (OS_DICnt==0)   OS_EI(); }
```


14.8 Nesting interrupt routines

By default, interrupts are disabled in an ISR because the CPU disables interrupts with the execution of the interrupt handler. Re-enabling interrupts in an interrupt handler allows the execution of further interrupts with equal or higher priority than that of the current interrupt. These are known as nested interrupts, illustrated in the diagram below:



For applications requiring short interrupt latency, you may re-enable interrupts inside an ISR by using `OS_EnterNestableInterrupt()` and `OS_LeaveNestableInterrupt()` within the interrupt handler.

Nested interrupts can lead to problems that are difficult to track; therefore it is not really recommended to enable interrupts within an interrupt handler. As it is important that embOS keeps track of the status of the interrupt enable/disable flag, the enabling and disabling of interrupts from within an ISR has to be done using the functions that embOS offers for this purpose.

The routine `OS_EnterNestableInterrupt()` enables interrupts within an ISR and prevents further task switches; `OS_LeaveNestableInterrupt()` disables interrupts right before ending the interrupt routine again, thus restores the default condition. Re-enabling interrupts will make it possible for an embOS scheduler interrupt to shortly interrupt this ISR. In this case, embOS needs to know that another ISR is still active and that it may not perform a task switch.

14.8.1 OS_EnterNestableInterrupt()

Note: This function may not be available in all ports.

Description

Re-enables interrupts and increments the embOS internal critical region counter, thus disabling further task switches.

Prototype

```
void OS_EnterNestableInterrupt (void);
```

Additional Information

This function should be the first call inside an interrupt handler when nested interrupts are required. The function `OS_EnterNestableInterrupt()` is implemented as a macro and offers the same functionality as `OS_EnterInterrupt()` in combination with `OS_DecRI()`, but is more efficient, resulting in smaller and faster code.

Example

Refer to the example for `OS_LeaveNestableInterrupt()`.

14.8.2 OS_LeaveNestableInterrupt()

Note: This function may not be available in all ports.

Description

Disables further interrupts, then decrements the embOS internal critical region count, thus re-enabling task switches if the counter has reached zero again.

Prototype

```
void OS_LeaveNestableInterrupt (void);
```

Additional Information

This function is the counterpart of `OS_EnterNestableInterrupt()`, and has to be the last function call inside an interrupt handler when nested interrupts have earlier been enabled by `OS_EnterNestableInterrupt()`.
The function `OS_LeaveNestableInterrupt()` is implemented as a macro and offers the same functionality as `OS_LeaveInterrupt()` in combination with `OS_IncDI()`, but is more efficient, resulting in smaller and faster code.

14.8.3 OS_LeaveNestableInterruptNoSwitch()

Note: This function may not be available in all ports.

Description

Disables further interrupts, informs embOS that the end of the ISR is reached, but does not perform a task switch.

Prototype

```
void OS_LeaveNestableInterruptNoSwitch (void);
```

Additional Information

If `OS_LeaveNestableInterruptNoSwitch()` is used, it should be the last function to be called in the interrupt handler. If the interrupt has caused a task switch, it is not executed from within the ISR, but at the next possible occasion. This will be the next call of an embOS function or the scheduler interrupt if the program is not in a critical region.

Example

```
__interrupt void ISR_Timer(void) {
  OS_EnterNestableInterrupt(); /* Enable interrupts, but disable task switch*/
  /*
  * Any code legal for interrupt-routines can be placed here
  */
  IntHandler();
  OS_LeaveNestableInterrupt();  /* Disable interrupts, allow task switch    */
}
```


14.9 Non-maskable interrupts (NMIs)

embOS performs atomic operations by disabling interrupts. However, a non-maskable interrupt (NMI) cannot be disabled, meaning it can interrupt these atomic operations. Therefore, NMIs should be used with great care and may under no circumstances call any embOS routines.

Chapter 15

Critical Regions

Critical regions are program sections during which the scheduler is switched off, meaning that no task switch and no execution of software timers are allowed except in situations where the active task has to wait. Effectively, preemptions are switched off.

A typical example for a critical region would be the execution of a program section that handles a time-critical hardware access (for example writing multiple bytes into an EEPROM where the bytes have to be written in a certain amount of time), or a section that writes data into global variables used by a different task and therefore needs to make sure the data is consistent.

A critical region can be defined anywhere during the execution of a task. Critical regions can be nested; the scheduler will be switched on again after the outermost loop is left. Interrupts are still legal in a critical region. Software timers and interrupts are executed as critical regions anyhow, so it does not hurt but does not do any good either to declare them as such. If a task switch becomes due during the execution of a critical region, it will be performed right after the region is left.

15.1 Critical regions API function overview

Routine	Description
OS_EnterRegion()	Indicates to the OS the beginning of a critical region.
OS_LeaveRegion()	Indicates to the OS the end of a critical region.

Table 15.1: Critical regions API overview

15.1.1 OS_EnterRegion()

Description

Indicates to the OS the beginning of a critical region.

Prototype

```
void OS_EnterRegion (void);
```

Additional Information

`OS_EnterRegion()` is not actually a function but a macro. However, it behaves very much like a function but is much more efficient. Using the macro indicates to embOS the beginning of a critical region. A critical region counter (`OS_RegionCnt`), which is 0 by default, is incremented so that the routine can be nested. The counter will be decremented by a call to the routine `OS_LeaveRegion()`. If this counter reaches 0 again, the critical region ends. Interrupts are not disabled using `OS_EnterRegion()`; however, disabling interrupts will disable preemptive task switches.

Example

```
void SubRoutine(void) {
  OS_EnterRegion();
  /* this code will not be interrupted by the OS  */
  OS_LeaveRegion();
}
```


15.1.2 OS_LeaveRegion()

Description

Indicates to the OS the end of a critical region.

Prototype

```
void OS_LeaveRegion (void);
```

Additional Information

`OS_LeaveRegion()` is not actually a function but a macro. However, it behaves very much like a function but is much more efficient. Usage of the macro indicates to embOS the end of a critical region. A critical region counter (`OS_RegionCnt`), which is 0 by default, is decremented. If this counter reaches 0 again, the critical region ends.

Example

Refer to the example for `OS_EnterRegion()`.

Chapter 16

Time measurement

embOS supports 2 types of time measurement:

- Low resolution (using a time variable)
- High resolution (using a hardware timer)

Both are explained in this chapter.

Overview

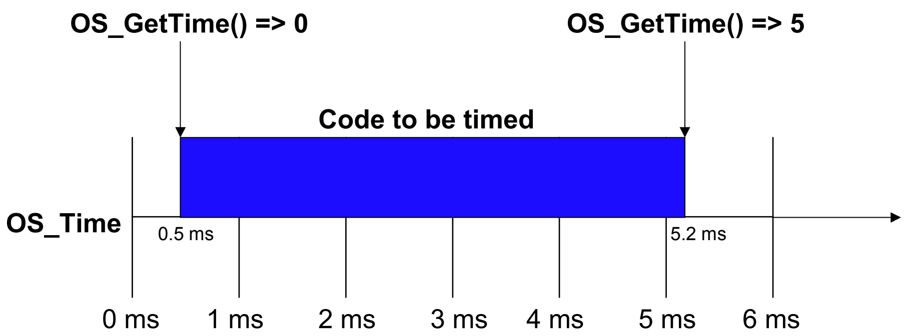
embOS supports two basic types of run-time measurement which may be used for calculating the execution time of any section of user code. Low-resolution measurements use a time base of ticks, while high-resolution measurements are based on a time unit called a cycle. The length of a cycle depends on the timer clock frequency.

16.1 Low-resolution measurement

The system time variable OS_Time is measured in ticks, or ms. The low-resolution functions OS_GetTime() and OS_GetTime32() are used for returning the current contents of this variable. The basic idea behind low-resolution measurement is quite simple: The system time is returned once before the section of code to be timed and once after, and the first value is subtracted from the second to obtain the time it took for the code to execute.

The term low-resolution is used because the time values returned are measured in completed ticks. Consider the following: with a normal tick of 1 ms, the variable OS_Time is incremented with every tick-interrupt, or once every ms. This means that the actual system time can potentially be more than what a low-resolution function will return (for example, if an interrupt actually occurs at 1.4 ticks, the system will still have measured only 1 tick as having elapsed). The problem becomes even greater with runtime measurement, because the system time must be measured twice. Each measurement can potentially be up to 1 tick less than the actual time, so the difference between two measurements could theoretically be inaccurate by up to two ticks.

The following diagram illustrates how low-resolution measurement works. We can see that the section of code actually begins at 0.5 ms and ends at 5.2 ms, which means that its actual execution time is (5.2 - 0.5) = 4.7 ms. However with a tick of 1 ms, the first call to OS_GetTime() returns 0, and the second call returns 5. The measured execution time of the code would therefore result in (5 - 0) = 5 ms.



For many applications, low-resolution measurement may be fully sufficient for your needs. In some cases, it may be more desirable than high-resolution measurement due to its ease of use and faster computation time.

16.2 Low-resolution measurement API function overview

Routine	Description
OS_GetTime()	Returns the current system time in ticks.
OS_GetTime32()	Returns the current system time in ticks as a 32-bit value.

Table 16.1: Low-resolution measurement API overview

16.2.1 OS_GetTime()

Description

Returns the current system time in ticks.

Prototype

```
int OS_GetTime (void);
```

Return value

The system variable `OS_Time` as a 16- or 32-bit integer value.

Additional Information

This function returns the system time as a 16-bit value on 8/16-bit CPUs, and as a 32-bit value on 32-bit CPUs. The `OS_Time` variable is a 32-bit value. Therefore, if the return value is 32-bit, it is simply the entire contents of the `OS_Time` variable. If the return value is 16-bit, it is the lower 16 bits of the `OS_Time` variable.

16.2.2 OS_GetTime32()

Description

Returns the current system time in ticks as a 32-bit value.

Prototype

```
U32 OS_GetTime32 (void);
```

Return value

The system variable `OS_Time` as a 32-bit integer value.

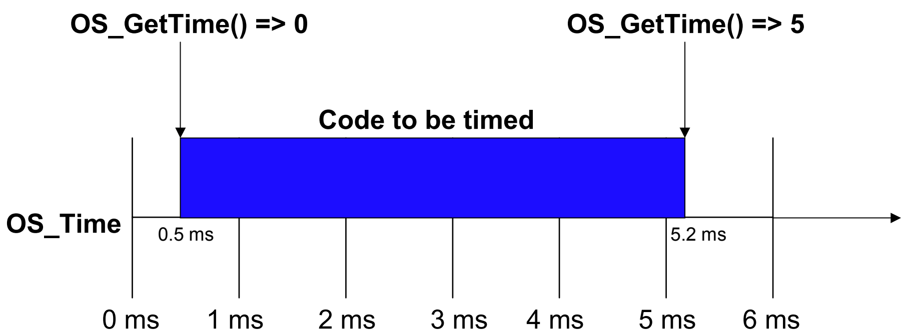
Additional Information

This function always returns the system time as a 32-bit value. Because the `OS_Time` variable is also a 32-bit value, the return value is simply the entire contents of the `OS_Time` variable.

16.3 High-resolution measurement

High-resolution measurement uses the same routines as those used in profiling builds of embOS, allowing for fine-tuning of time measurement. While system resolution depends on the CPU used, it is typically about 1 µs, making high-resolution measurement about 1000 times more accurate than low-resolution calculations.

Instead of measuring the number of completed ticks at a given time, an internal count is kept of the number of cycles that have been completed. Look at the illustration below, which measures the execution time of the same code used in the low-resolution calculation. For this example, we assume that the CPU has a timer running at 10 MHz and is counting up. The number of cycles per tick is therefore (10 MHz / 1 kHz) = 10,000. This means that with each tick-interrupt, the timer restarts at 0 and counts up to 10,000.



The call to `OS_Timing_Start()` calculates the starting value at 5,000 cycles, while the call to `OS_Timing_End()` calculates the ending value at 52,000 cycles (both values are kept track of internally). The measured execution time of the code in this example would therefore be (52,000 - 5,000) = 47,000 cycles, which corresponds to 4.7 ms.

Although the function `OS_Timing_GetCycles()` may be used for returning the execution time in cycles as above, it is typically more common to use the function `OS_Timing_Getus()`, which returns the value in microseconds (µs). In the above example, the return value would be 4,700 µs.

Data structure

All high-resolution routines take as parameter a pointer to a data structure of type `OS_TIMING`, defined as follows:

```
#define OS_TIMING OS_U32
```


16.4 High-resolution measurement API function overview

Routine	Description
OS_TimingStart()	Marks the beginning of a code section to be timed.
OS_TimingEnd()	Marks the end of a code section to be timed.
OS_Timing_Getus()	Returns the execution time of the code between OS_Timing_Start() and OS_Timing_End() in microseconds.
OS_Timing_GetCycles()	Returns the execution time of the code between OS_Timing_Start() and OS_Timing_End() in cycles.

Table 16.2: High-resolution measurement API overview

16.4.1 OS_Timing_Start()

Description

Marks the beginning of a section of code to be timed.

Prototype

```
void OS_Timing_Start (OS_TIMING* pCycle);
```

Parameter	Description
pCycle	Pointer to a data structure of type OS_TIMING.

Table 16.3: OS_TimingStart() parameter list

Additional Information

This function must be used with OS_Timing_End().

16.4.2 OS_Timing_End()

Description

Marks the end of a section of code to be timed.

Prototype

```
void OS_Timing_End (OS_TIMING* pCycle);
```

Parameter	Description
pCycle	Pointer to a data structure of type OS_TIMING.

Table 16.4: OS_TimingEnd() parameter list

Additional Information

This function must be used with OS_Timing_Start().

16.4.3 OS_Timing_Getus()

Description

Returns the execution time of the code between `OS_Timing_Start()` and `OS_Timing_End()` in microseconds.

Prototype

```
OS_U32 OS_Timing_Getus (OS_TIMING* pCycle);
```

Parameter	Description
pCycle	Pointer to a data structure of type `OS_TIMING`.

Table 16.5: OS_Timing_Getus() parameter list

Additional Information

The execution time in microseconds (µs) as a 32-bit integer value.

16.4.4 OS_Timing_GetCycles()

Description

Returns the execution time of the code between `OS_Timing_Start()` and `OS_Timing_End()` in cycles.

Prototype

```
OS_U32 OS_Timing_GetCycles (OS_TIMING* pCycle);
```

Parameter	Description
pCycle	Pointer to a data structure of type `OS_TIMING`.

Table 16.6: OS_Timing_GetCycles() parameter list

Return value

The execution time in cycles as a 32-bit integer.

Additional Information

Cycle length depends on the timer clock frequency.

16.5 Example

The following sample demonstrates the use of low-resolution and high-resolution measurement to return the execution time of a section of code:

```
/*********************************************************
*        SEGGER MICROCONTROLLER SYSTEME GmbH
*  Solutions for real time microcontroller applications
**********************************************************
File        : SampleHiRes.c
Purpose     : Demonstration of embOS Hires Timer
--------------END-OF-HEADER------------------------------*/

#include "RTOS.H"
#include <stdio.h>

OS_STACKPTR int Stack[1000]; /* Task stacks */
OS_TASK TCB;                 /* Task-control-blocks */

volatile int Dummy;
void UserCode(void) {
  for (Dummy=0; Dummy < 11000; Dummy++);  /* Burn some time  */
}

/*
* Measure the execution time with low resolution and return it in ms (ticks)
*/
int BenchmarkLoRes(void) {
  int t;
  t = OS_GetTime();
  UserCode();           /* Execute the user code to be benchmarked */
  t = OS_GetTime() - t;
  return t;
}

/*
* Measure the execution time with hi resolution and return it in us
*/
OS_U32 BenchmarkHiRes(void) {
  OS_U32 t;
  OS_Timing_Start(&t);
  UserCode();           /* Execute the user code to be benchmarked */
  OS_Timing_End(&t);
  return OS_Timing_Getus(&t);
}

void Task(void) {
  int tLo;
  OS_U32 tHi;
  char ac[80];
  while (1) {
    tLo = BenchmarkLoRes();
    tHi = BenchmarkHiRes();
    sprintf(ac, "LoRes: %d ms\n", tLo);
    OS_SendString(ac);
    sprintf(ac, "HiRes: %d us\n", tHi);
    OS_SendString(ac);
  }
}

/*********************************************************
*
*                    main
*
*********************************************************/

void main(void) {
  OS_InitKern();        /* Initialize OS                  */
  OS_InitHW();          /* Initialize Hardware for OS     */
  /* You need to create at least one task here !          */
  OS_CREATETASK(&TCB, "HP Task", Task, 100, Stack);
  OS_Start();           /* Start multitasking             */
}
```


The output of the sample is as follows:

```
LoRes: 7 ms
HiRes: 6641 us
LoRes: 7 ms
HiRes: 6641 us
LoRes: 6 ms
```

Chapter 17

System variables

The system variables are described here for a deeper understanding of how the OS works and to make debugging easier.

Note: Do not change the value of any system variables.

These variables are accessible and are not declared constant, but they should only be altered by functions of embOS. However, some of these variables can be very useful, especially the time variables.

17.1 Time variables

17.1.1 OS_Time

Description

This is the time variable which contains the current system time in ticks (usually equivalent to ms).

Prototyp

```
extern volatile OS_I32 OS_Time;
```

Additional Information

The time variable has a resolution of one time unit, which is normally 1/1000 sec (1 ms) and is normally the time between two successive calls to the embOS interrupt handler. Instead of accessing this variable directly, use `OS_GetTime()` or `OS_GetTime32()` as explained in the Chapter *Time measurement* on page 223.

17.1.2 OS_TimeDex

Basically, for internal use only. Contains the time at which the next task switch or timer activation is due. If `((int)(OS_Time - OS_TimeDex)) >= 0`, the task list and timer list will be checked for a task or timer to activate. After activation, `OS_TimeDex` will be assigned the time stamp of the next task or timer to be activated.

17.2 OS internal variables and data-structures

embOS internal variables are not explained here as they are in no way required to use embOS. Your application should not rely on any of the internal variables, as only the documented API functions are guaranteed to remain unchanged in future versions of embOS.

Important

Do not alter any system variables.

Chapter 18

System tick

This chapter explains the concept of the system tick, generated by a hardware timer and all options available for it.

Overview

Typically a hardware timer generates periodic interrupts used as a time base. embOS offers tick handlers with different functionality as well as a way to call a hook function from within the system tick handler.
The hardware timer will normally be initialized in the `OS_InitHW()` function which is delivered with the BSP.
The BSP also includes the interrupt handler which will be called by the hardware timer interrupt. This interrupt handler has to call one of the embOS system tick handler functions which are explained in this chapter.

18.1 Tickhandler

Routine	Description
OS_HandleTick()	Standard embOS tick handler.
OS_HandleTick_Ex()	Extended embOS tick handler.

Table 18.1: Tickhandlers

18.1.1 OS_HandleTick()

Description

The default embOS timer tick handler which is typically called by the hardware timer interrupt handler.

Prototype

```
void OS_HandleTick (void);
```

Additional Information

The embOS tick handler must not be called by the application, it has to be called from an interrupt handler.
`OS_EnterInterrupt()`, or `OS_EnterNestableInterrupt()` has to be called, before calling the embOS tick handler

Example

```
/*  Example of a timer interrupt handler */
__interrupt void OS_ISR_Tick(void) {
  OS_EnterNestableInterrupt();
  OS_HandleTick();
  OS_LeaveNestableInterrupt();
}
```

18.1.2 OS_HandleTick_Ex()

Description

An alternate tick handler which may be used instead of the standard tick handler. It can be used in situations where the basic timer-interrupt interval (tick) is a multiple of 1 ms and the time values used as parameter for delays still should use 1 ms as the time base.

Prototype

```
void OS_HandleTick_Ex (void);
```

Additional Information

The embOS tick handler must not be called by the application, it has to be called from an interrupt handler.
`OS_EnterInterrupt()`, or `OS_EnterNestableInterrupt()` has to be called, before calling the embOS tick handler.
`OS_HandleTick_Ex()` incremets the embOS internal time variable by an amount which is stored in the variable `OS_IntMSInc` which has to be initialized accordingly.

Example

```
/*  Example of a timer interrupt handler using OS_HandleTick_Ex */
__interrupt void OS_ISR_Tick(void) {
  OS_EnterNestableInterrupt();
  OS_HandleTick_Ex();
  OS_LeaveNestableInterrupt();
}
```

Assuming the hardware timer runs at a frequency of 500Hz, thus interrupting the system every 2ms, the embOS internal variable `OS_IntMSInc` should be initialized with a value of two.
This should be done during `OS_IntHW()`, before the embOS timer is started.

18.2 Hooking into the system tick

Routine	Description
OS_AddTickHook()	Adds a tick hook handler.
OS_RemoveTickHook()	Removes a tick hook handler.

Table 18.2: Tick hook functions API

There are various situations in which it can be desireable to call a function from the tick handler. Some examples are:

- Watchdog update
- Periodic status check
- Periodic I/O update

The same functionality can be achieved with a high-priority task or a software timer with 1 tick period time.

Advantage of using a hook function

Using a hook function is much faster than performing a task switch or activating a software timer, because the hook function is directly called from the embOS timer interrupt handler.

18.2.1 OS_AddTickHook()

Description

Adds a tick hook handler.

Prototype

```
void OS_AddTickHook (OS_TICK_HOOK* pHook,
                     OS_TICK_HOOK_ROUTINE * pfUser);
```

Parameter	Description
pHook	Pointer to a structure of OS_TICK_HOOK.
pfUser	Pointer to an OS_TICK_HOOK_ROUTINE function.

Table 18.3: OS_AddTickHook() parameter list

Additional Information

The hook function is called driectly from the interrupt handler.
The function therefore should execute as fast as possible.
The function called by the tick hook must not re-enable interrupts.

18.2.2 OS_RemoveTickHook()

Description

Removes a tick hook handler.

Prototype

```
void OS_RemoveTickHook (OS_TICK_HOOK* pHook);
```

Parameter	Description
pHook	Pointer to a structure of OS_TICK_HOOK.

Table 18.4: OS_RemoveTickHook() parameter list

Additional Information

The function may be called to dynamically remove a tick hook function which was installed by a call of OS_AddTickHook().

Chapter 19

Configuration of target system (BSP)

This chapter explains the target system specific parts of ***embOS***, also called BSP (board support package).
If the system is up and running on your target system, there is no need to read this chapter.

Overview

You do not have to configure anything to get started with embOS. The start project supplied will execute on your system. Small changes in the configuration will be necessary at a later point for system frequency or for the UART used for communication with the optional embOSView.

The file `RTOSInit.c` is provided in source code and can be modified to match your target hardware needs. It is compiled and linked with your application program.

19.1 Hardware-specific routines

Routine	Description
OS_InitHW()	Initializes the hardware timer used for generating interrupts. embOS needs a timer-interrupt to determine when to activate tasks that wait for the expiration of a delay, when to call a software timer, and to keep the time variable up-to-date.
OS_Idle()	The idle loop is always executed whenever no other task (and no interrupt service routine) is ready for execution.
OS_GetTime_Cycles()	Reads the timestamp in cycles. Cycle length depends on the system. This function is used for system information sent to embOSView.
OS_ConvertCycles2us()	Converts cycles into µs (used with profiling only).
OS_COM_Init()	Initializes communication for embOSView (used with embOSView only).
OS_ISR_Tick()	The embOS timer-interrupt handler. When using a different timer, always check the specified interrupt vector.
OS_ISR_rx()	Rx Interrupt service handler for embOSView (used with embOSView only).
OS_ISR_tx()	Tx Interrupt service handler for embOSView (used with embOSView only).
OS_COM_Send1()	Send 1 byte via a UART (used with embOSView only). Do not call this function from your application.

Table 19.1: Hardware specific routines

19.2 Configuration defines

For most embedded systems, configuration is done by simply modifying the following defines, located at the top of the `RTOSInit.c` file:

Define	Description
OS_FSYS	System frequency (in Hz). Example: 20000000 for 20MHz.
OS_UART	Selection of UART to be used with embOSView (-1 will disable communication),
OS_BAUDRATE	Selection of baudrate for communication with embOSView.

Table 19.2: Configuration defines overview

19.3 How to change settings

The only file which you may need to change is `RTOSInit.c`. This file contains all hardware-specific routines. The one exception is that some ports of embOS require an additional interrupt vector table file (details can be found in the *CPU & Compiler Specifics manual* of embOS documentation).

19.3.1 Setting the system frequency OS_FSYS

Relevant defines

`OS_FSYS`

Relevant routines

`OS_ConvertCycles2us()` (used with profiling only)

For most systems it should be sufficient to change the `OS_FSYS` define at the top of `RTOSInit.c`. When using profiling, certain values may require a change in `OS_ConvertCycles2us()`. The `RTOSInit.c` file contains more information about in which cases this is necessary and what needs to be done.

19.3.2 Using a different timer to generate the tick-interrupts for embOS

Relevant routines

`OS_ InitHW()`

embOS usually generates 1 interrupt per ms, making the timer-interrupt, or tick, normally equal to 1 ms. This is done by a timer initialized in the routine `OS_InitHW()`. If you have to use a different timer for your application, you must modify `OS_InitHW()` to initialize the appropriate timer. For details about initialization, read the comments in `RTOSInit.c`.

19.3.3 Using a different UART or baudrate for embOSView

Relevant defines

```
OS_UART
OS_BAUDRATE
```

Relevant routines:

```
OS_COM_Init()
OS_COM_Send1()
OS_ISR_rx()
OS_ISR_tx()
```

In some cases, this is done by simply changing the define `OS_UART`. Refer to the contents of the `RTOSInit.c` file for more information about which UARTS that are supported for your CPU.

19.3.4 Changing the tick frequency

Relevant defines

`OS_FSYS`

As noted above, embOS usually generates 1 interrupt per ms. `OS_FSYS` defines the clock frequency of your system in Hz (times per second). The value of `OS_FSYS` is used for calculating the desired reload counter value for the system timer for 1000 interrupts/sec. The interrupt frequency is therefore normally 1 kHz.

Different (lower or higher) interrupt rates are possible. If you choose an interrupt frequency different from 1 kHz, the value of the time variable `OS_Time` will no longer be equivalent to multiples of 1 ms. However, if you use a multiple of 1 ms as tick time, the basic time unit can be made 1 ms by using the (optional) configuration macro `OS_CONFIG()` (see µbelow). The basic time unit does not have to be 1 ms; it might just as well be 100 µs or 10 ms or any other value. For most applications, 1 ms is an appropriate value.

19.4 STOP / HALT / IDLE modes

Most CPUs support power-saving STOP, HALT, or IDLE modes. Using these types of modes is one possible way to save power consumption during idle times. As long as the timer-interrupt will wake up the system with every embOS tick, or as long as other interrupts will activate tasks, these modes may be used for saving power consumption.

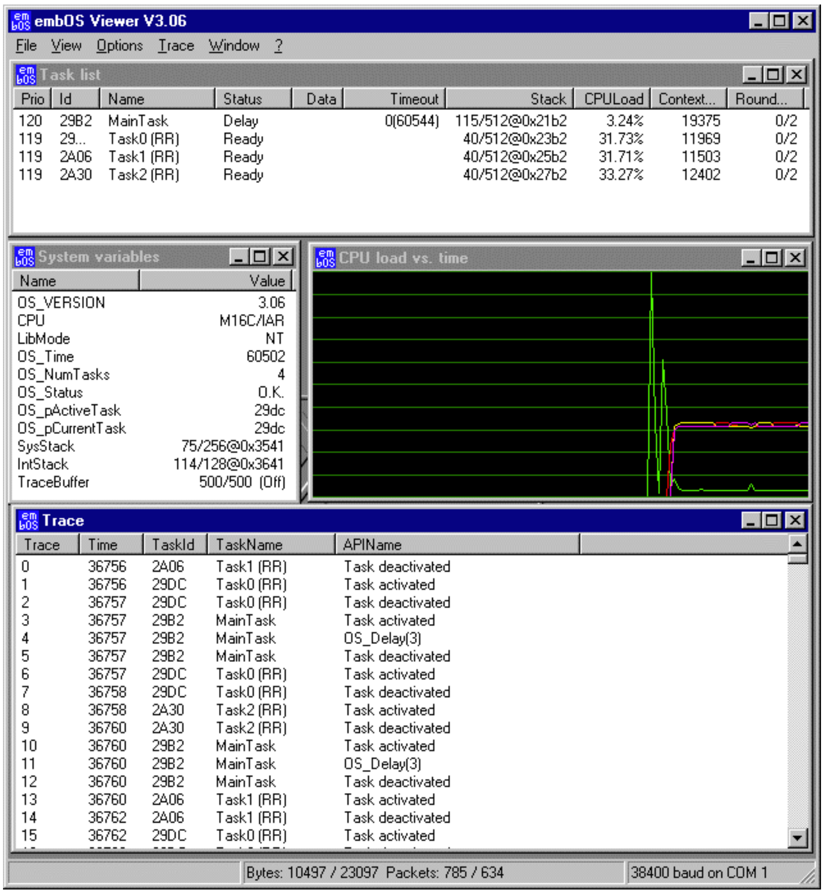
If required, you may modify the `OS_Idle()` routine, which is part of the hardware-dependant module `RTOSInit.c`, to switch the CPU to power-saving mode during idle times. Refer to the *CPU & Compiler Specifics manual* of embOS documentation for details about your processor.

Chapter 20

embOSView: Profiling and analyzing

20.1 Overview

embOSView displays the state of a running application using embOS. A serial interface (UART) is normally used for communication with the target. The hardware-dependent routines and defines and defines available for communication with embOSView are located in `RTOSInit.c`. This file has to be configured properly. For details on how to configure this file, refer the *CPU & Compiler Specifics manual* of embOS documentation. The embOSView utility is shipped as `embOSView.exe` with embOS and runs under Windows 9x / NT / 2000. The latest version is available on our website at www.segger.com



embOSView is a very helpful tool for analysis of the running target application.

20.2 Task list window

embOSView shows the state of every created task of the target application in the **Task list window**. The information shown depends on the library used in your application.

Item	Description	Builds
Prio	Current priority of task.	All
Id	Task ID, which is the address of the task control block.	All
Name	Name assigned during creation.	All
Status	Current state of task (ready, executing, delay, reson for suspension).	All
Data	Depends on status.	All
Timeout	Time of next activation.	All
Stack	Used stack size/max. stack size/stack location.	S, SP, D, DP, DT
CPULoad	Percentage CPU load caused by task.	SP, DP, DT
Context Switches	Number of activations since reset.	SP, DP, DT

Table 20.1: Task list window overview

The **Task list window** is helpful in analysis of stack usage and CPU load for every running task.

20.3 System variables window

embOSView shows the actual state of major system variables in the **System variables window**. The information shown also depends on the library used in your application:

Item	Description	Builds
OS_VERSION	Current version of embOS.	All
CPU	Target CPU and compiler.	All
LibMode	Library mode used for target application.	All
OS_Time	Current system time in timer ticks.	All
OS_NUM_TASKS	Current number of defined tasks.	All
OS_Status	Current error code (or O.K.).	All
OS_pActiveTask	Active task that should be running.	SP, D, DP, DT
OS_pCurrentTask	Actual currently running task.	SP, D, DP, DT
SysStack	Used size/max. size/location of system stack.	SP, DP, DT
IntStack	Used size/max. size/location of interrupt stack.	SP, DP, DT
TraceBuffer	Current count/maximum size and current state of trace buffer.	All trace builds

Table 20.2: System variables window overview

20.4 Sharing the SIO for terminal I/O

The serial input/output (SIO) used by embOSView may also be used by the application at the same time for both input and output. This can be very helpful. Terminal input is often used as keyboard input, where terminal output may be used for outputting debug messages. Input and output is done via the **Terminal window**, which can be shown by selecting **View/Terminal** from the menu.

To ensure communication via the **Terminal window** in parallel with the viewer functions, the application uses the function `OS_SendString()` for sending a string to the **Terminal window** and the function `OS_SetRxCallback()` to hook a reception routine that receives one byte.

20.4.1 Shared SIO API function overview

Routine	Description
OS_SendString()	Sends a string over SIO to the **Terminal window**.
OS_SetRxCallback()	Sets a callback hook to a routine for receiving one character.

Table 20.3: Shared SIO API overview

20.4.2 OS_SendString()

Description

Sends a string over SIO to the **Terminal window**.

Prototype

```
void OS_SendString (const char* s);
```

Parameter	Description
s	Pointer to a zero-terminated string that should be sent to the **Terminal window**.

Table 20.4: OS_SendString() parameter list

Additional Information

This function uses `OS_COM_Send1()` which is defined in `RTOSInit.c`.

20.4.3 OS_SetRxCallback()

Description

Sets a callback hook to a routine for receiving one character.

Prototype

```
typedef void OS_RX_CALLBACK (OS_U8 Data)
OS_RX_CALLBACK* OS_SetRxCallback (OS_RX_CALLBACK* cb);
```

Parameter	Description
cb	Pointer to the application routine that should be called when one character is received over the serial interface.

Table 20.5: OS_SetRxCallback() parameter list

Return value

`OS_RX_CALLBACK*` as described above. This is the pointer to the callback function that was hooked before the call.

Additional Information

The user function is called from embOS. The received character is passed as parameter. See the example below.

Example

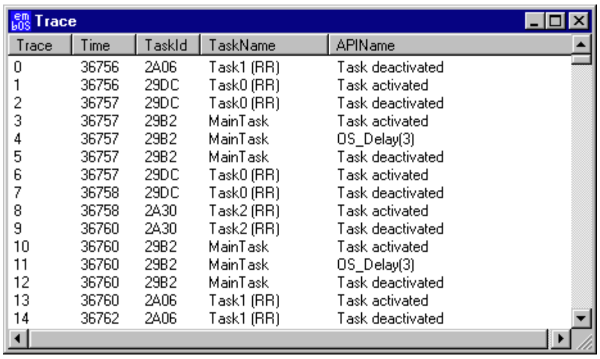
```
void GUI_X_OnRx(OS_U8 Data); /* Callback ... called from Rx-interrupt */

void GUI_X_Init(void) {
  OS_SetRxCallback( &GUI_X_OnRx);
}
```


20.5 Using the API trace

embOS versions 3.06 or higher contain a trace feature for API calls. This requires the use of the trace build libraries in the target application.

The trace build libraries implement a buffer for 100 trace entries. Tracing of API calls can be started and stopped from embOSView via the **Trace menu**, or from within the application by using the functions `OS_TraceEnable()` and `OS_TraceDiasable()`. Individual filters may be defined to determine which API calls should be traced for different tasks or from within interrupt or timer routines.

Once the trace is started, the API calls are recorded in the trace buffer, which is periodically read by embOSView. The result is shown in the **Trace window**:



Trace

Trace	Time	TaskId	TaskName	APIName
0	36756	2A06	Task1 (RR)	Task deactivated
1	36756	29DC	Task0 (RR)	Task activated
2	36757	29DC	Task0 (RR)	Task deactivated
3	36757	29B2	MainTask	Task activated
4	36757	29B2	MainTask	OS_Delay(3)
5	36757	29B2	MainTask	Task deactivated
6	36757	29DC	Task0 (RR)	Task activated
7	36758	29DC	Task0 (RR)	Task deactivated
8	36758	2A30	Task2 (RR)	Task activated
9	36760	2A30	Task2 (RR)	Task deactivated
10	36760	29B2	MainTask	Task activated
11	36760	29B2	MainTask	OS_Delay(3)
12	36760	29B2	MainTask	Task deactivated
13	36760	2A06	Task1 (RR)	Task activated
14	36762	2A06	Task1 (RR)	Task deactivated

Every entry in the **Trace list** is recorded with the actual system time. In case of calls or events from tasks, the task ID (**TaskId**) and task name (**TaskName**) (limited to 15 characters) are also recorded. Parameters of API calls are recorded if possible, and are shown as part of the **APIName** column. In the example above, this can be seen with `OS_Delay(3)`. Once the trace buffer is full, trace is automatically stopped. The **Trace list** and buffer can be cleared from embOSView.

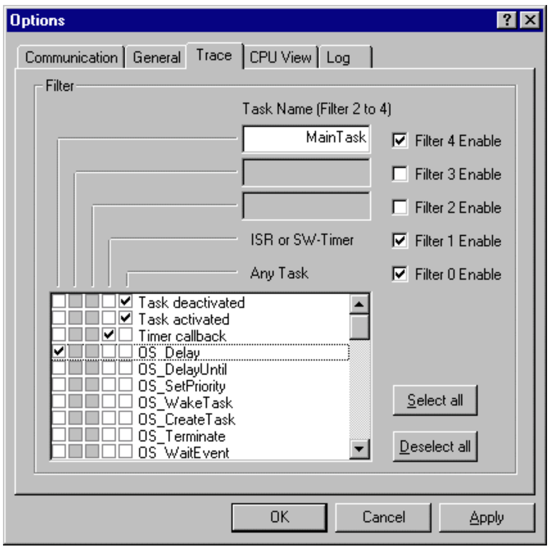
Setting up trace from embOSView

Three different kinds of trace filters are defined for tracing. These filters can be set up from embOSView via the menu **Options/Setup/Trace**.

Filter 0 is not task-specific and records all specified events regardless of the task. As the Idle loop is not a task, calls from within the idle loop are not traced.

Filter 1 is specific for interrupt service routines, software timers and all calls that occur outside a running task. These calls may come from the idle loop or during startup when no task is running.

Filters 2 to 4 allow trace of API calls from named tasks.



To enable or disable a filter, simply check or uncheck the corresponding checkboxes labeled **Filter 4 Enable** to **Filter 0 Enable**.

For any of these five filters, individual API functions can be enabled or disabled by checking or unchecking the corresponding checkboxes in the list. To speed up the process, there are two buttons available:

- **Select all** - enables trace of all API functions for the currently enabled (checked) filters.
- **Deselect all** - disables trace of all API functions for the currently enabled (checked) filters.

Filter 2, **Filter 3**, and **Filter 4** allow tracing of task-specific API calls. A task name can therefore be specified for each of these filters. In the example above, **Filter 4** is configured to trace calls of `OS_Delay()` from the task called `MainTask`. After the settings are saved (via the **Apply** or **OK** button), the new settings are sent to the target application.

20.6 Trace filter setup functions

Tracing of API or user function calls can be started or stopped from embOSView. By default, trace is initially disabled in an application program. It may be very helpful to control the recording of trace events directly from the application, using the following functions.

20.7 Trace filter API functions

Routine	Description
OS_TraceEnable()	Enables tracing of filtered API calls.
OS_TraceDisable()	Disables tracing of API and user function calls.
OS_TraceEnableAll()	Sets up Filter 0 (any task), enables tracing of all API calls and then enables the trace function.
OS_TraceDisableAll()	Sets up Filter 0 (any task), disables tracing of all API calls and also disables trace.
OS_TraceEnableId()	Sets the specified ID value in Filter 0 (any task), thus enabling trace of the specified function, but does not start trace.
OS_TraceDisableId()	Resets the specified ID value in Filter 0 (any task), thus disabling trace of the specified function, but does not stop trace.
OS_TraceEnableFilterId()	Sets the specified ID value in the specified trace filter, thus enabling trace of the specified function, but does not start trace.
OS_TraceDisableFilterId()	Resets the specified ID value in the specified trace filter, thus disabling trace of the specified function, but does not stop trace.

Table 20.6: Trace filter API overview

20.7.1 OS_TraceEnable()

Description

Enables tracing of filtered API calls.

Prototype

```
void OS_TraceEnable (void);
```

Additional Information

The trace filter conditions should have been set up before calling this function. This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.7.2 OS_TraceDisable()

Description

Disables tracing of API and user function calls.

Prototype

```
void OS_TraceDisable (void);
```

Additional Information

This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.7.3 OS_TraceEnableAll()

Description

Sets up Filter 0 (any task), enables tracing of all API calls and then enables the trace function.

Prototype

```
void OS_TraceEnableAll (void);
```

Additional Information

The trace filter conditions of all the other trace filters are not affected.
This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.7.4 OS_TraceDisableAll()

Description

Sets up Filter 0 (any task), disables tracing of all API calls and also disables trace.

Prototype

```
void OS_TraceDisableAll (void);
```

Additional Information

The trace filter conditions of all the other trace filters are not affected, but tracing is stopped.
This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.7.5 OS_TraceEnableId()

Description

Sets the specified ID value in Filter 0 (any task), thus enabling trace of the specified function, but does not start trace.

Prototype

```
void OS_TraceEnableId (OS_U8 Id);
```

Parameter	Description
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.

Table 20.7: OS_TraceEnabled() parameter list

Additional Information

To enable trace of a specific embOS API function, you must use the correct Id value. These values are defined as symbolic constants in RTOS.h.
This function may also enable trace of your own functions.
This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.7.6 OS_TraceDisableId()

Description

Resets the specified ID value in Filter 0 (any task), thus disabling trace of the specified function, but does not stop trace.

Prototype

```
void OS_TraceDisableId (OS_U8 Id);
```

Parameter	Description
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.

Table 20.8: OS_TraceDisabledId() parameter list

Additional Information

To disable trace of a specific embOS API function, you must use the correct `Id` value. These values are defined as symbolic constants in `RTOS.h`.
This function may also be used for disabling trace of your own functions.
This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.7.7 OS_TraceEnableFilterId()

Description

Sets the specified ID value in the specified trace filter, thus enabling trace of the specified function, but does not start trace.

Prototype

```
void OS_TraceEnableFilterId (OS_U8 FilterIndex,
                             OS_U8 Id)
```

Parameter	Description
FilterIndex	Index of the filter that should be affected: 0 <= FilterIndex <= 4 0 affects Filter 0 (any task) and so on.
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.

Table 20.9: OS_TraceEnabledFilterId() parameter list

Additional Information

To enable trace of a specific embOS API function, you must use the correct Id value. These values are defined as symbolic constants in RTOS.h.
This function may also be used for enabling trace of your own functions.
This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.7.8 OS_TraceDisableFilterId()

Description

Resets the specified ID value in the specified trace filter, thus disabling trace of the specified function, but does not stop trace.

Prototype

```
void OS_TraceDisableFilterId (OS_U8 FilterIndex,
                              OS_U8 Id)
```

Parameter	Description
FilterIndex	Index of the filter that should be affected: 0 <= FilterIndex <= 4 0 affects Filter 0 (any task) and so on.
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.

Table 20.10: OS_TraceDisableFilterId() parameter list

Additional Information

To disable trace of a specific embOS API function, you must use the correct Id value. These values are defined as symbolic constants in `RTOS.h`.
This function may also be used for disabling trace of your own functions.
This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.8 Trace record functions

The following functions are used for writing (recording) data into the trace buffer. As long as only embOS API calls should be recorded, these functions are used internally by the trace build libraries. If, for some reason, you want to trace your own functions with your own parameters, you may call one of these routines.

All of these functions have the following points in common:

- To record data, trace must be enabled.
- An ID value in the range from 100 to 127 must be used as the Id parameter. ID values from 0 to 99 are internally reserved for embOS.
- The events specified as Id have to be enabled in any of the trace filters.
- Active system time and the current task are automatically recorded together with the specified event.

20.9 Trace record API function overview

Routine	Description
OS_TraceVoid()	Writes an entry identified only by its ID into the trace buffer.
OS_TracePtr()	Writes an entry with ID and a pointer as parameter into the trace buffer.
OS_TraceData()	Writes an entry with ID and an integer as parameter into the trace buffer.
OS_TraceDataPtr()	Writes an entry with ID, an integer, and a pointer as parameter into the trace buffer.
OS_TraceU32Ptr()	Writes an entry with ID, a 32-bit unsigned integer, and a pointer as parameter into the trace buffer.

Table 20.11: Trace record API overview

20.9.1 OS_TraceVoid()

Description

Writes an entry identified only by its ID into the trace buffer.

Prototype

```
void OS_TraceVoid (OS_U8 Id);
```

Parameter	Description
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.

Table 20.12: OS_TraceVoid() parameter list

Additional Information

This functionality is available in trace builds only, and the API call is not removed by the preprocessor.

20.9.2 OS_TracePtr()

Description

Writes an entry with ID and a pointer as parameter into the trace buffer.

Prototype

```
void OS_TracePtr (OS_U8 Id,
                  void* p);
```

Parameter	Description
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.
p	Any void pointer that should be recorded as parameter.

Table 20.13: OS_TracePtr() parameter list

Additional Information

The pointer passed as parameter will be displayed in the trace list window of embOSView. This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.9.3 OS_TraceData()

Description

Writes an entry with ID and an integer as parameter into the trace buffer.

Prototype

```
void OS_TraceData (OS_U8 Id,
                   int   v);
```

Parameter	Description
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.
v	Any integer value that should be recorded as parameter.

Table 20.14: OS_TraceData() parameter list

Additional Information

The value passed as parameter will be displayed in the trace list window of embOSView.This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.9.4 OS_TraceDataPtr()

Description

Writes an entry with ID, an integer, and a pointer as parameter into the trace buffer.

Prototype

```
void OS_TraceDataPtr (OS_U8 Id,
                      int   v,
                      void* p);
```

Parameter	Description
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.
v	Any integer value that should be recorded as parameter.
p	Any void pointer that should be recorded as parameter.

Table 20.15: OS_TraceDataPtr() parameter list

Additional Information

The values passed as parameters will be displayed in the trace list window of embOS-View. This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.9.5 OS_TraceU32Ptr()

Description

Writes an entry with ID, a 32-bit unsigned integer, and a pointer as parameter into the trace buffer.

Prototype

```
void OS_TraceU32Ptr (OS_U8  Id,
                     OS_U32 p0,
                     void*  p1);
```

Parameter	Description
Id	ID value of API call that should be enabled for trace: 0 <= Id <= 127 Values from 0 to 99 are reserved for embOS.
p0	Any unsigned 32-bit value that should be recorded as parameter.
p1	Any void pointer that should be recorded as parameter.

Table 20.16: OS_TraceU32Ptr() parameter list

Additional Information

This function may be used for recording two pointers. The values passed as parameters will be displayed in the trace list window of embOSView. This functionality is available in trace builds only. In non-trace builds, the API call is removed by the preprocessor.

20.10 Application-controlled trace example

As described in the previous section, the user application can enable and set up the trace conditions without a connection or command from embOSView. The trace record functions can also be called from any user function to write data into the trace buffer, using ID numbers from 100 to 127.

Controlling trace from the application can be very helpful for tracing API and user functions just after starting the application, when the communication to embOSView is not yet available or when the embOSView setup is not complete.

The example below shows how a trace filter can be set up by the application. The function `OS_TraceEnableID()` sets the trace filter 0 which affects calls from any running task. Therefore, the first call to `SetState()` in the example would not be traced because there is no task running at that moment. The additional filter setup routine `OS_TraceEnableFilterId()` is called with filter 1, which results in tracing calls from outside running tasks.

Example code

```
#include "RTOS.h"

#ifndef OS_TRACE_FROM_START
  #define OS_TRACE_FROM_START 1
#endif

/*  Application specific trace id numbers   */
#define APP_TRACE_ID_SETSTATE  100

char MainState;

/*  Sample of application routine with trace   */

void SetState(char* pState, char Value) {
  #if OS_TRACE
    OS_TraceDataPtr(APP_TRACE_ID_SETSTATE, Value, pState);
  #endif
  * pState = Value;
}

/*  Sample main routine, that enables and setup API and function call trace
    from start  */
void main(void) {
  OS_InitKern();
  OS_InitHW();
  #if (OS_TRACE && OS_TRACE_FROM_START)
    /*  OS_TRACE is defined in trace builds of the library          */
    OS_TraceDisableAll();        /*  Disable all API trace calls    */
    OS_TraceEnableId(APP_TRACE_ID_SETSTATE);        /*  User trace  */
    OS_TraceEnableFilterId(APP_TRACE_ID_SETSTATE);  /*  User trace  */
    OS_TraceEnable();
  #endif

  /*  Application specific initilisation  */
  SetState(&MainState, 1);
  OS_CREATETASK(&TCBMain, "MainTask", MainTask, PRIO_MAIN, MainStack);
  OS_Start();   /* Start multitasking  -> MainTask() */
}
```

By default, embOSView lists all user function traces in the trace list window as Routine, followed by the specified ID and two parameters as hexadecimal values. The example above would result in the following:

```
Routine100(0xabcd, 0x01)
```

where `0xabcd` is the pointer address and `0x01` is the parameter recorded from `OS_TraceDataPtr()`.

20.11 User-defined functions

To use the built-in trace (available in trace builds of embOS) for application program user functions, embOSView can be customized. This customization is done in the setup file `embOS.ini`.

This setup file is parsed at the startup of embOSView. It is optional; you will not see an error message if it cannot be found.

To enable trace setup for user functions, embOSView needs to know an ID number, the function name and the type of two optional parameters that can be traced. The format is explained in the following sample `embOS.ini` file:

Example code

```
# File: embOS.ini
#
# embOSView Setup file
#
# embOSView loads this file at startup. It has to reside in the same
# directory as the execuatble itself.
#
# Note: The file is not required to run embOSView. You will not get
# an error message if it is not found. However, you will get an error message
# if the contents of the file are invalid.


#
# Define add. API functions.
# Syntax: API( <Index>, <Routinename> [parameters])
# Index: Integer, between 100 and 127
# Routinename: Identifier for the routine. Should be no more than 32 characters
# parameters: Optional paramters. A max. of 2 parameters can be specified.
#             Valid parameters are:
#               int
#               ptr
#            Every parameter has to be preceeded by a colon.
#
API( 100, "Routine100")
API( 101, "Routine101", int)
API( 102, "Routine102", int, ptr)
```


Chapter 21

Debugging

21.1 Runtime errors

Some error conditions can be detected during runtime. These are:

- Usage of uninitialized data structures
- Invalid pointers
- Unused resource that has not been used by this task before
- `OS_LeaveRegion()` called more often than `OS_EnterRegion()`
- Stack overflow (this feature is not available for some processors)

Which runtime errors that can be detected depend on how much checking is performed. Unfortunately, additional checking costs memory and speed (it is not that significant, but there is a difference). If embOS detects a runtime error, it calls the following routine:

```
void OS_Error(int ErrCode);
```

This routine is shipped as source code as part of the module `OS_Error.c`. It simply disables further task switches and then, after re-enabling interrupts, loops forever as follows:

Example

```
/*
   Run time error reaction
*/
void OS_Error(int ErrCode) {
  OS_EnterRegion();      /* Avoid further task switches */
  OS_DICnt =0;           /* Allow interrupts so we can communicate */
  OS_EI();
  OS_Status = ErrCode;
  while (OS_Status);
}
```

If you are using embOSView, you can see the value and meaning of `OS_Status` in the system variable window.

When using an emulator, you should set a breakpoint at the beginning of this routine or simply stop the program after a failure. The error code is passed to the function as parameter.

You can modify the routine to accommodate your own hardware; this could mean that your target hardware sets an error-indicating LED or shows a little message on the display.

Note: When modifying the OS_Error() routine, the first statement needs to be the disabling of scheduler via OS_EnterRegion(); the last statement needs to be the infinite loop.

If you look at the `OS_Error()` routine, you will see that it is more complicated than necessary. The actual error code is assigned to the global variable `OS_Status`. The program then waits for this variable to be reset. Simply reset this variable to 0 using your in circuit-emulator, and you can easily step back to the program sequence causing the problem. Most of the time, looking at this part of the program will make the problem clear.

21.2 List of error codes

Value	Define	Explanation
100	OS_ERR_ISR_INDEX	Index value out of bounds during interrupt controller initilization or interrupt installation.
101	OS_ERR_ISR_VECTOR	Default interrupt handler called, but interrupt vector not initialized.
120	OS_ERR_STACK	Stack overflow or invalid stack.
121	OS_ERR_CSEMA_OVERFLOW	Counting semaphore overflow.
128	OS_ERR_INV_TASK	Task control block invalid, not initialized or overwritten.
129	OS_ERR_INV_TIMER	Timer control block invalid, not initialized or overwritten.
130	OS_ERR_INV_MAILBOX	Mailbox control block invalid, not initialized or overwritten.
132	OS_ERR_INV_CSEMA	Control block for counting semaphore invalid, not initialized or overwritten.
133	OS_ERR_INV_RSEMA	Control block for resource semaphore invalid, not initialized or overwritten.
135	OS_ERR_MAILBOX_NOT1	One of the following 1-byte mailbox functions has been used on a multi-byte mailbox: OS_PutMail1() OS_PutMailCond1 ()OS_GetMail1() OS_GetMailCond1().
136	OS_ERR_MAILBOX_DELETE	OS_DeleteMB() was called on a mailbox with waiting tasks.
137	OS_ERR_CSEMA_DELETE	OS_DeleteCSema() was called on a counting semaphore with waiting tasks.
138	OS_ERR_RSEMA_DELETE	OS_DeleteRSema() was called on a resource semaphore which is claimed by a task.
140	OS_ERR_MAILBOX_NOT_IN_LIST	The mailbox is not in the list of mailboxes as expected. Possible reasons may be that one mailbox data structure was overwritten.
142	OS_ERR_TASKLIST_CORRUPT	The OS internal tasklist is destroyed.
150	OS_ERR_UNUSE_BEFORE_USE	OS_Unuse() has been called before OS_Use().
151	OS_ERR_LEAVEREGION_BEFORE_ENTERREGION	OS_LeaveRegion() has been called before OS_EnterRegion().
152	OS_ERR_LEAVEINT	Error in OS_LeaveInterrupt().
153	OS_ERR_DICNT	The interrupt disable counter (OS_DICnt) is out of range (0-15). The counter is affected by the following API calls: OS_IncDI() OS_DecRI() OS_EnterInterrupt() OS_LeaveInterrupt()
154	OS_ERR_INTERRUPT_DISABLED	OS_Delay() or OS_DelayUntil() called from inside a critical region with interrupts disabled.

Table 21.1: Error code list

Value	Define	Explanation
156	OS_ERR_RESOURCE_OWNER	OS_Unuse() has been called from a task which does not own the resource.
160	OS_ERR_ILLEGAL_IN_ISR	Illegal function call in an interrupt service routine:A routine that may not be called from within an ISR has been called from within an ISR.
161	OS_ERR_ILLEGAL_IN_TIMER	Illegal function call in an interrupt service routine:A routine that may not be called from within a software timer has been called from within a timer.
162	OS_ERR_ILLEGAL_OUT_ISR	embOS timer tick handler or UART handler for embOSView was called without a call of OS_EnterInterrupt().
170	OS_ERR_2USE_TASK	Task control block has been initialized by calling a create function twice.
171	OS_ERR_2USE_TIMER	Timer control block has been initialized by calling a create function twice.
172	OS_ERR_2USE_MAILBOX	Mailbox control block has been initialized by calling a create function twice.
173	OS_ERR_2USE_BSEMA	Binary semaphore has been initialized by calling a create function twice.
174	OS_ERR_2USE_CSEMA	Counting semaphore has been initialized by calling a create function twice.
175	OS_ERR_2USE_RSEMA	Resource semaphore has been initialized by calling a create function twice.
176	OS_ERR_2USE_MEMF	Fixed size memory pool has been initialized by calling a create function twice.
180	OS_ERR_NESTED_RX_INT	OS_Rx interrupt handler for embOSView is nested. Disable nestable interrupts.
190	OS_ERR_MEMF_INV	Fixed size memory block control structure not created before use.
191	OS_ERR_MEMF_INV_PTR	Pointer to memory block does not belong to memory pool on Release
192	OS_ERR_MEMF_PTR_FREE	Pointer to memory block is already free when calling OS_MEMF_Release(). Possibly, same pointer was released twice.
193	OS_ERR_MEMF_RELEASE	OS_MEMF_Release() was called for a memory pool, that had no memory block allocated (all available blocks were already free before).
194	OS_ERR_POOLADDR	OS_MEMF_Create() was called with a memory pool base address which is not located at a word aligned base address
195	OS_ERR_BLOCKSIZE	OS_MEMF_Create() was called with a data block size which is not a multiple of processors word size.
200	OS_ERR_SUSPEND_TOO_OFTEN	Nested call of OS_Suspend() exceeded OS_MAX_SUSPEND_CNT
201	OS_ERR_RESUME_BEFORE_SUSPEND	OS_Resume() called on a task that was not suspended.

Table 21.1: Error code list (Continued)

Value	Define	Explanation
202	OS_ERR_TASK_PRIORITY	OS_CreateTask() was called with a task priority which is already assigned to another task. This error can only occur when embOS was compiled without round robin support.
210	OS_ERR_EVENT_INVALID	An OS_EVENT object was used before it was created.
211	OS_ERR_2USE_EVENTOBJ	An OS_EVENT object was created twice.
212	OS_ERR_EVENT_DELETE	An OS_EVENT object was deleted with waiting tasks

Table 21.1: Error code list (Continued)

The latest version of the defined error table is part of the comment just before the OS_Error() function declaration in the source file OS_Error.c.

Chapter 22

Performance and resource usage

This chapter covers the performance and resource usage of embOS. It explains how to benchmark embOS and contains information about the memory requirements in typical systems which can be used to obtain sufficient estimates for most target systems.

22.1 Introduction

High performance combined with low resource usage has always been a major design consideration. embOS runs on 8/16/32-bit CPUs. Depending on which features are being used, even single-chip systems with less than 2 Kbytes ROM and 1 Kbyte RAM can be supported by embOS. The actual performance and resource usage depends on many factors (CPU, compiler, memory model, optimization, configuration, etc.).

22.2 Memory requirements

The memory requirements of embOS (RAM and ROM) differs depending on the used features of the library. The following table shows the memory requirements for the different modules.

Module	Memory type	Memory requirements
embOS kernel	ROM	1100 - 1600 bytes *
embOS kernel	RAM	18 - 25 bytes *
Mailbox	RAM	9 - 15 bytes *
Binary and counting semaphores	RAM	3 bytes
Recource semaphore	RAM	4 - 5 bytes *
Timer	RAM	9 - 11 bytes *
Event	RAM	0 bytes

Table 22.1: embOS memory requirements

* Depends on CPU, compiler, and library model used

22.3 Performance

The following section shows how to benchmark embOS with the supplied example programs.

22.4 Benchmarking

embOS is designed to perform fast context switches. This section describes two different methods to calculate the execution time of a context switch from a task with lower priority to a task with a higher priority.

The first method uses port pins and requires an oscilloscope. The second method uses the high-resolution measurement functions. Example programs for both methods are supplied in the `\Sample` directory of your embOS shipment.

Segger uses these programs to benchmark the embOS performance. You can use these examples to evaluate the benchmark results. Note, that the actual performance depends on many factors (CPU, clock speed, toolchain, memory model, optimization, configuration, etc.).

The following table gives an overview about the variations of the context switch time depending on the memory type and the CPU mode:

Target	OS version	Memory	CPU mode	Time
ATMEL AT91SAM7S256	3.50b	Flash	Thumb	7.562us
ATMEL AT91SAM7S256	3.50b	Flash	ARM	7.875us
ATMEL AT91SAM7S256	3.50b	RAM	ARM	5.896us
ATMEL AT91SAM7S256	3.50b	RAM	Thumb	6.187us

Table 22.2: embOS context switch times

All named example performance values in the following section are determined with the following system configuration:

ATMEL AT91SAM7S256 running with 48 MHz clock speed. All sources are compiled with IAR Embedded Workbench version 4.40A using thumb or arm mode with high optimization level.

22.4.1 Measurement with port pins and oscilloscope

The example file `MeasureCST_Scope.c` uses the `LED.c` module to set and clear a port pin. This allows measuring the context switch time with an oscilloscope.

The following source code is excerpt from `MeasureCST_Scope.c`:

```
#include "RTOS.h"
#include "LED.h"

static OS_STACKPTR int StackHP[128], StackLP[128];  // Task stacks
static OS_TASK TCBHP, TCBLP;                        // Task-control-blocks

/*********************************************************************
*
*       HPTask
*/
static void HPTask(void) {
  while (1) {
    OS_Suspend(NULL);   // Suspend high priority task
    LED_ClrLED0();      // Stop measurement
  }
}

/*********************************************************************
*
*       LPTask
*/
static void LPTask(void) {
  while (1) {
    OS_Delay(100);     // Syncronize to tick to avoid jitter
    //
    // Display measurement overhead
    //
    LED_SetLED0();
    LED_ClrLED0();
    //
    // Perform measurement
    //
    LED_SetLED0();     // Start measurement
    OS_Resume(&TCBHP); // Resume high priority task to force task switch
  }
}

/*********************************************************************
*
*       main
*/
int main(void) {
  OS_IncDI();                      // Initially disable interrupts
  OS_InitKern();                   // Initialize OS
  OS_InitHW();                     // Initialize Hardware for OS
  LED_Init();                      // Initialize LED ports
  OS_CREATETASK(&TCBHP, "HP Task", HPTask, 100, StackHP);
  OS_CREATETASK(&TCBLP, "LP Task", LPTask,  99, StackLP);
  OS_Start();                      // Start multitasking
  return 0;
}
```


22.4.1.1 Oscilloscope analysis

The context switch time is the time between switching the LED on and off. If the LED is switched on with an active high signal, the context switch time is the time between rising and falling edge of the signal. If the LED is switched on with an active low signal, the signal polarity is reversed.

The real context switch time is shorter, because the signal also contains the overhead of switching the LED on and off. The time of this overhead is also displayed on the oscilloscope as a small peak right before the task switch time display and has to be subtracted from the displayed context switch time. The picture below shows a simplified oscilloscope signal with an active-low LED signal (low means LED is illuminated). There are switching points to determine:

- A = LED is switched on for overhead measurement
- B = LED is switched off for overhead measurement
- C = LED is switched on right before context switch in low-prio task
- D = LED is switched off right after context switch in high-prio task

The time needed to switch the LED on and off in subroutines is marked as time t_{AB}. The time needed for a complete context switch including the time needed to switch the LED on and off in subroutines is marked as time t_{CD}.

The context switching time t_{CS} is calculated as follows:

$t_{CS} = t_{CD} - t_{AB}$

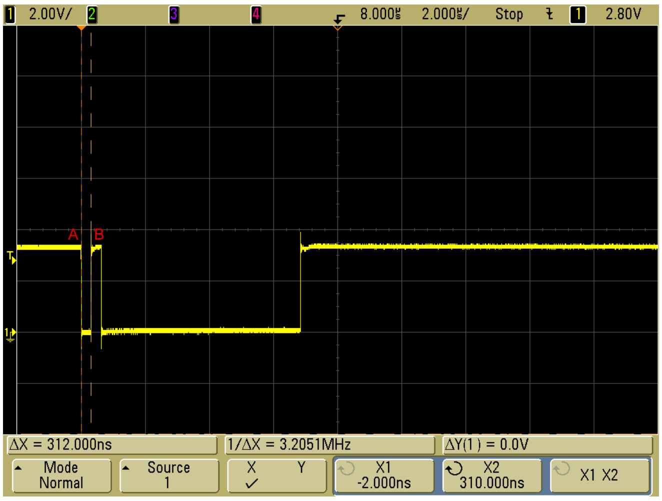
22.4.1.2 Example measurements AT91SAM7S, ARM code in RAM

Task switching time has been measured with the pararmeters listed below:

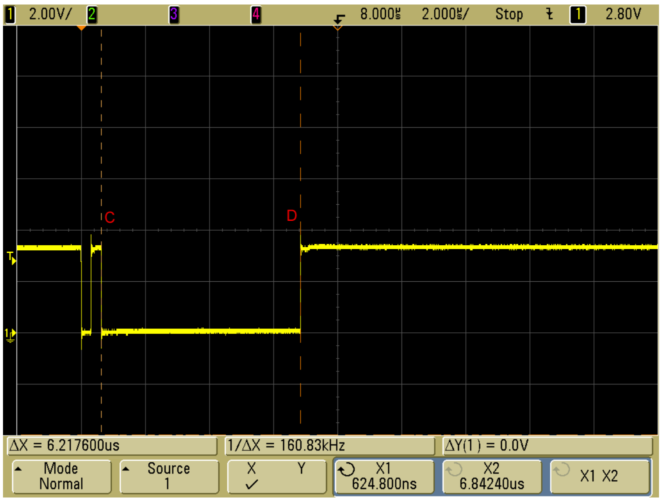
embOS Version V3.50b
Application program: `MeasureCST_Scope.c`
`Hardware:` AT91SAM7S256 processor with 48MHz
Program is executing in RAM
ARM mode is used
Compiler used: IAR V4.40A
CPU frequency (f_{CPU}): `47.9232MHz`
CPU clock cycle (t_{Cycle}): $t_{Cycle} = 1 / f_{CPU} = 1 / 47.9232MHz = 20,866ns$

Measuring t_{AB} and t_{CD}

t_{AB} is measured as 312ns.
The number of cycles calculates as follows:
$Cycles_{AB} = t_{AB} / t_{Cycle}$
$=312ns / 20.866ns$
$= 14.952Cycles$
$=> 15Cycles$



t_{CD} is measured as 6217.6ns.
The number of cycles calculates as follows:
$Cycles_{CD} = t_{CD} / t_{Cycle}$
$= 6217.6ns / 20.866ns$
$= 297.977Cycles$
$=> 298Cycles$



Resulting context switching time and number of cycles

The time which is required for the pure context switch is:
$t_{CS} = t_{CD} - t_{AB} = 298Cycles - 15Cycles = 283Cycles$
=> **283Cycles (5.9us @48MHz)**.

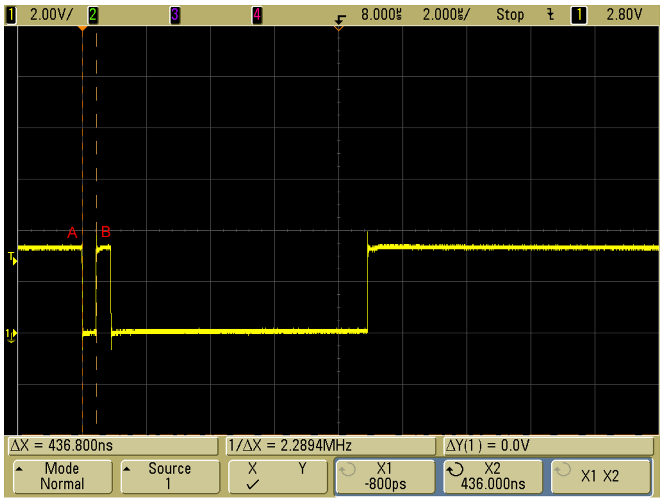
22.4.1.3 Example measurements AT91SAM7S, Thumb code in FLASH

Task switching time has been measured with the pararmeters listed below:

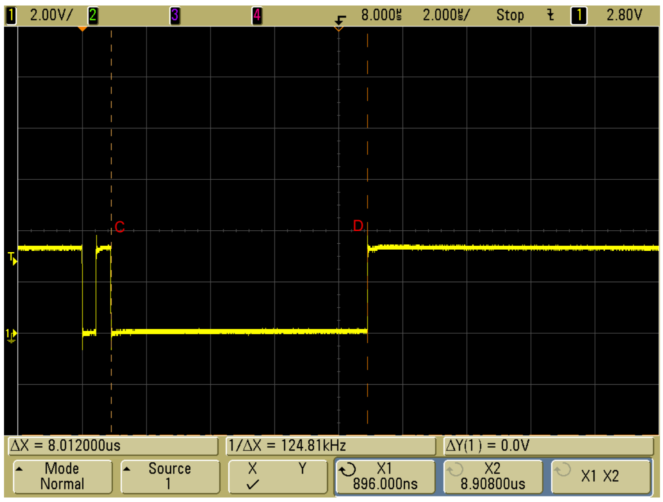
embOS Version V3.50b
Application program: `MeasureCST_Scope.c`
`Hardware:` AT91SAM7S256 processor with 48MHz
Program is executing in FLASH
Thumb mode is used
Compiler used: IAR V4.40A
CPU frequency (f_{CPU}): `47.9232MHz`
CPU clock cycle (t_{Cycle}): $t_{Cycle} = 1 / f_{CPU} = 1 / 47.9232MHz = 20,866ns$

Measuring t_{AB} and t_{CD}

t_{AB} is measured as 436.8ns.
The number of cycles calculates as follows:
$Cycles_{AB} = t_{AB} / t_{Cycle}$
=436.8ns / 20.866ns
= 20.933Cycles
=> 21Cycles



t_{CD} is measured as 8012ns.
The number of cycles calculates as follows:
$Cycles_{CD} = t_{CD} / t_{Cycle}$
= 8012ns / 20.866ns
= 383.973Cycles
=> 384Cycles



Resulting context switching time and number of cycles

The time which is required for the pure context switch is:
$t_{CS} = t_{CD} - t_{AB}$ = 384Cycles - 21Cycles = 363Cycles
=> **363Cycles (7.56us @48MHz)**.

22.4.1.4 Measurement with high-resolution timer

The context switch time may be measured with the high-resolution timer. Refer to section *High-resolution measurement* on page 229 for detailed information about the embOS high-resolution measurement.

The example `MeasureCST_HRTimer_embOSView.c` uses a high resolution timer to measure the context switch time from a low priority task to a high priority task and displays the results on embOSView.

```
#include "RTOS.h"
#include "stdio.h"

static OS_STACKPTR int StackHP[128], StackLP[128];  // Task stacks
static OS_TASK TCBHP, TCBLP;                        // Task-control-blocks
static OS_U32 _Time;                                // Timer values

/*********************************************************************
*
*       HPTask
*/
static void HPTask(void) {
  while (1) {
    OS_Suspend(NULL);                   // Suspend high priority task
    OS_Timing_End(&_Time);              // Stop measurement
  }
}

/*********************************************************************
*
*       LPTask
*/
static void LPTask(void) {
  char   acBuffer[100];                 // Output buffer
  OS_U32 MeasureOverhead;               // Time for Measure Overhead
  OS_U32 v;

  //
  // Measure Overhead for time measurement so we can take
  // this into account by subtracting it
  //
  OS_Timing_Start(&MeasureOverhead);
  OS_Timing_End(&MeasureOverhead);
  //
  // Perform measurements in endless loop
  //
  while (1) {
    OS_Delay(100);                   // Sync. to tick to avoid jitter
    OS_Timing_Start(&_Time);         // Start measurement
    OS_Resume(&TCBHP);               // Resume high priority task to force task switch
    v = OS_Timing_GetCycles(&_Time) - OS_Timing_GetCycles(&MeasureOverhead);
    v = OS_ConvertCycles2us(1000 * v);  // Convert cycles to nano-seconds
    sprintf(acBuffer, "Context switch time: %u.%.3u usec\r", v / 1000, v % 1000);
    OS_SendString(acBuffer);
  }
}
```

The example program calculates and subtracts the measurement overhead itself, so there is no need to do this. The results will be transmitted to embOSView, so the example runs on every target that supports UART communication to embOSView.

The example program `MeasureCST_HRTimer_Printf.c` is equal to the example program `MeasureCST_HRTimer_embOSView.c` but displays the results with the `printf()` function for those debuggers which support terminal output emulation.

Chapter 23

Supported development tools

embOS has been developed with and for a specific C compiler version for the selected target processor. Check the file RELEASE.HTML for details. It works with the specified C compiler only, because other compilers may use different calling conventions (incompatible object file formats) and therefore might be incompatible. However, if you prefer to use a different C compiler, contact us and we will do our best to satisfy your needs in the shortest possible time.

Reentrance

All routines that can be used from different tasks at the same time have to be fully reentrant. A routine is in use from the moment it is called until it returns or the task that has called it is terminated.

All routines supplied with your real-time operating system are fully reentrant. If for some reason you need to have non-reentrant routines in your program that can be used from more than one task, it is recommended to use a resource semaphore to avoid this kind of problem.

C routines and reentrance

Normally, the C compiler generates code that is fully reentrant. However, the compiler may have options that force it to generate non-reentrant code. It is recommended not to use these options, although it is possible to do so under certain circumstances.

Assembly routines and reentrance

As long as assembly functions access local variables and parameters only, they are fully reentrant. Everything else has to be thought about carefully.

Chapter 24

Limitations

The following limitations exist for embOS:

Max. no. of tasks:	limited by available RAM only
Max. no. of priorities:	255
Max. no. of semaphores:	limited by available RAM only
Max. no. of mailboxes:	limited by available RAM only
Max. no. of queues:	limited by available RAM only
Max. size. of queues:	limited by available RAM only
Max. no. of timers	limited by available RAM only
Task specific Event flags :	8 bits / task

We appreciate your feedback regarding possible additional functions and we will do our best to implement these functions if they fit into the concept.

Do not hesitate to contact us. If you need to make changes to embOS, the full source code is available.

Chapter 25

Source code of kernel and library

embOS is available in two versions:

1. Object version: Object code + hardware initialization source.
2. Full source version: Complete source code.

Because this document describes the object version, the internal data structures are not explained in detail. The object version offers the full functionality of embOS including all supported memory models of the compiler, the debug libraries as described and the source code for idle task and hardware initialization. However, the object version does not allow source-level debugging of the library routines and the kernel.

The full source version gives you the ultimate options: embOS can be recompiled for different data sizes; different compile options give you full control of the generated code, making it possible to optimize the system for versatility or minimum memory requirements. You can debug the entire system and even modify it for new memory models or other CPUs.

The source code distribution of embOS contains the following additional files:

- The `CPU` folder contains all CPU and compiler specific source code and header files used for building the embOS libraries. It also contains the sample start project, workspace, and source files for the embOS demo project delivered in the Start folder. Normally, you should not modify any of the files in the `CPU` folder.
- The `GenOSSrc` folder contains all embOS sources and a batch file used for compiling all of them in batch mode as described in the following section.

25.1 Building embOS libraries

The embOS libraries can only be built if you have purchased a source code version of embOS.

In the root path of embOS, you will find a DOS batch file `PREP.BAT`, which needs to be modified to match the installation directory of your C compiler. Once this is done, you can call the batch file `M.BAT` to build all embOS libraries for your CPU.

Note: Rebuilding the embOS libraries using the M.bat file will delete and rebuild the entire Start folder. If you made any modifications or built own projects in the Start folder, make a copy of your start folder before rebuilding embOS.

The build process should run without any error or warning message. If the build process reports any problem, check the following:

- Are you using the same compiler version as mentioned in the file `RELEASE.HTML`?
- Can you compile a simple test file after running `PREP.BAT` and does it really use the compiler version you have specified?
- Is there anything mentioned about possible compiler warnings in the `RELEASE.HTML`?

If you still have a problem, let us know.

The whole build process is controlled with a few amount of batch files which are located in the root directory of your source code distribution:

- `Prep.bat`: Sets up the environment for the compiler, assembler, and linker. Ensure, that this file sets the path and additional include directories which are needed for your compiler. Normally, this batch file is the only one which might have to be modified to build the embOS libraries. Normally, this file is called from `M.bat` during the build process of all libraries.
- `Clean.bat`: Deletes the whole output of the embOS library build process. It is called automatically during the build process, before new libraries are generated. Normally it deletes the `Start` folder. Therefore, be careful not to call this batch file accidentally. Normally, this file is called initially by `M.bat` during the build process of all libraries.
- `cc.bat`: This batch file calls the compiler and is used for compiling one embOS source file without debug information output. Most compiler options are defined in this file and should normally not be modified. For your purposes, you might activate debug output and may also modify the optimization level. All modifications should be done with care. Normally, this file is called from the embOS internal batch file `CC_OS.bat` and can not be called directly.
- `ccd.bat`: This batch file calls the compiler and is used for compiling `OS_Global.c` which contains all global variables. All compiler settings are equal to those used in `cc.bat`, except debug output is activated to enable debugging of global variables when using embOS libraries. Normally, this file is called from the embOS internal batch file `CC_OS.bat` and can not be called directly.
- `asm.bat`: This batch file calls the assembler and is used for assembling the assembly part of embOS which normally contains the task switch functionality. Normally this file is called from the embOS internal batch file `CC_OS.bat` and can not be called directly.
- `MakeH.bat`: Builds the embOS header file `RTOS.h` which is composed from the CPU/compiler-specific part `OS_Chip.h` and the generic part `OS_RAW.h`. Normally, `RTOS.h` is output in the subfolder `Start\Inc`.
- `M1.bat`: This batch file is called from `M.bat` and is used for building one specific embOS library, it can not be called directly.
- `M.bat`: This batch file has to be called to generate all embOS libraries. It initially calls `Clean.bat` and therefore deletes the whole `Start` folder. The generated libraries are then placed in a new `Start` folder which contains start projects, libraries, header, and sample start programs.

25.2 Major compile time switches

Many features of embOS may be modified by compile-time switches. All of them are predefined to reasonable values in the distribution of embOS. The compile-time switches must not be changed in `RTOS.h`. When the compile-time switches should be modified to alter any of the embOS features, the modification has to be done in `OS_RAW.h` or has to be passed as parameters during the library build process. embOS sources have to be recompiled and `RTOS.h` has to be rebuilt with the modified switches.

25.2.1 OS_RR_SUPPORTED

This switch defines whether round robin scheduling algorithm is supported. All embOS versions enable round robin scheduling by default. If you never use round robin scheduling and all of your tasks run on different individual priorities, you may disable round robin scheduling by defining this switch to 0. This will save RAM and ROM and will also speed up the task-switching process. Ensure that none of your tasks ever run on the same priority when you disable round robin scheduling. This compile time switch must not be modified in `RTOS.h`. It has to be modified in `OS_RAW.h` before embOS libraries are rebuilt.

25.2.2 OS_SUPPORT_CLEANUP_ON_TERMINATE

This compile time switch is new since version 3.26 of embOS. If enabled, it allows termination of tasks which are claiming resource semaphores or are suspended on any synchronization object.

Note: By default, this switch is activated for 16- and 32-bit CPUs. For 8-bit CPUs it is disabled.

Even though the overhead is minimal and execution time is not affected significantly, you may define this switch to zero when you do not terminate tasks in your application, or if your application ensures, that tasks are never suspended on any synchronization object or claim any resource semaphores when they are terminated.

Disabling this switch will save some RAM in the task control structure and will also speed up the wait functions for synchronization objects.

When using an 8-bit CPU, you have to enable this switch (define it to be unequal to 0) to enable termination of tasks which are suspended on synchronization objects or claim resource semaphores.

This compile time switch must not be modified in `RTOS.h`. It can only be modified in `OS_RAW.h` or has to be passed as `define` during the build process when embOS libraries are rebuilt.

Chapter 26

Additional modules

26.1 Keyboard manager: KEYMAN.C

Keyboard driver module supplied in C. It serves both as an example and as a module that can actually be used in your application. The module can be used in most applications with only little changes to the hardware-specific portion. It needs to be initialized on startup and creates a task that checks the keyboard 50 times per second.

Changes required for your hardware

```
void ReadKeys(void);
```

Example of how to implement into your program

```
void main(void) {
  OS_InitKern();        /* Initialize OS (should be first !)          */
  OS_InitHW();          /* Initialize Hardware for OS (see RtosInit.c)*/
  /* You need to create at least one task here ! */
  OS_CREATETASK(&TCB0, "HP Task", Task0, 100, Stack0); /* Create Task0*/
  OS_CREATETASK(&TCB1, "LP Task", Task1,  50, Stack1); / *Create Task1*/
  InitKeyMan();         /* Initialize keyboard manager                */
  OS_Start();
}
```


26.2 Additional libraries and modules

For all embOS-compatible real-time operating systems, there are additional libraries and modules available. However, these modules can also be used without embOS or with a different operating system. Because these libraries are written in ANSI C, they can be used on any target CPU for which an ANSI C compiler exists. In general, these modules are highly optimized for both low memory consumption (especially in RAM) and high speed.

The modules can be scaled for optimum performance at minimum memory consumption using compile-time switches. Unused portions of the modules are not even compiled; your program stays lean and fast.

emWin	The complete solution for graphical LCDs. A fully scaleable graphical user interface featuring: • different fonts (from 4*6 to 16*32) • line drawing, bitmap drawing • advanced drawing (for example circles) • display routines for strings, dec/hex/bin values, multiple windows • ultra-fast, yet still very compact (typically between 8 and 20 Kbytes ROM) Everything you need for graphic displays! Any LCD * Any LCD controller * Any CPU Both monochrome and color versions available, as well as bitmapconverter, font converter, PC simulation and viewer. Check out our website!
emLoad	Boot-loader software

Chapter 27

FAQ (frequently asked questions)

Q: Can I implement different priority scheduling algorithms ?
A: Yes, the system is fully dynamic, which means that task priorities can be changed while the system is running (using `OS_SetPriority()`). This feature can be used for changing priorities in a way so that basically every desired algorithm can be implemented. One way would be to have a task control task with a priority higher than that of all other tasks that dynamically changes priorities. Normally, the priority-controlled round-robin algorithm is perfect for real-time applications.

Q: Can I use a different interrupt source for embOS ?
A: Yes, any periodical signal can be used, that is any internal timer, but it could also be an external signal.

Q: What interrupt priorities can I use for the interrupts my program uses?
A: Any.

Chapter 28

Glossary

Active task	Only one task can execute at any given time. The task that is currently executing is called the active task.
Cooperative multitasking	A scheduling system in which each task is allowed to run until it gives up the CPU; an ISR can make a higher priority task ready, but the interrupted task will be returned to and finished first.
Counting semaphore	A type of semaphore that keeps track of multiple resources. Used when a task must wait for something that can be signaled more than once.
CPU	Central Processing Unit. The "brain" of a microcontroller; the part of a processor that carries out instructions.
Critical region	A section of code which must be executed without interruption.
Event	A message sent to a single, specified task that something has occurred. The task then becomes ready.
ISR	Interrupt Service Routine. The routine is called automatically by the processor when an interrupt is acknowledged. ISRs must preserve the entire context of a task (all registers).
Mailbox	A data buffer managed by the RTOS, used for sending messages to a task or interrupt handler.
Message	An item of data (sent to a mailbox, queue, or other container for data).
Multitasking	The execution of multiple software routines independently of one another. The OS divides the processor's time so that the different routines (tasks) appear to be happening simultaneously.
NMI	Non-Maskable Interrupt. An interrupt that cannot be masked (disabled) by software. Example: Watchdog timer-interrupt.
Preemptive multitasking	A scheduling system in which the highest priority task that is ready will always be executed. If an ISR makes a higher priority task ready, that task will be executed before the interrupted task is returned to.
Processor	Short for microprocessor. The CPU core of a controller
Priority	The relative importance of one task to another. Every task in an RTOS has a priority.
Priority inversion	A situation in which a high priority task is delayed while it waits for access to a shared resource which is in use by a lower priority task. The lower priority task temporarily gets the highest priority until it releases the resource.

Queue	Like a mailbox, but used for sending larger messages, or messages of individual size, to a task or an interrupt handler.
Resource	Anything in the computer system with limited availability (for example memory, timers, computation time). Essentially, anything used by a task.
Resource semaphore	A type of semaphore used for managing resources by ensuring that only one task has access to a resource at a time.
RTOS	Real-time Operating System.
Scheduler	The program section of an RTOS that selects the active task, based on which tasks are ready to run, their relative priorities, and the scheduling system being used.
Semaphore	A data structure used for synchronizing tasks.
Software timer	A data structure which calls a user-specified routine after a specified delay.
Stack	An area of memory with LIFO storage of parameters, automatic variables, return addresses, and other information that needs to be maintained across function calls. In multitasking systems, each task normally has its own stack.
Superloop	A program that runs in an infinite loop and uses no real-time kernel. ISRs are used for real-time parts of the software.
Task	A program running on a processor. A multitasking system allows multiple tasks to execute independently from one another.
Tick	The OS timer interrupt. Usually equals 1 ms.
Timeslice	The time (number of ticks) for which a task will be executed until a round-robin task change may occur.

Index