embOS

Real-Time
Operating System

CPU & Compiler
specifics for 8051using
IAR

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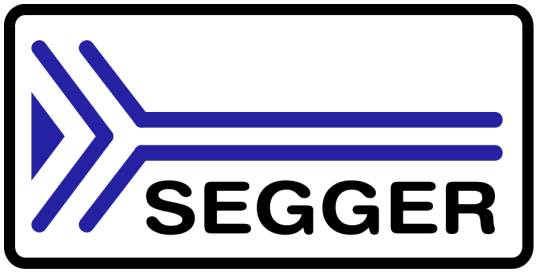
Date: August 4, 2014



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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: August 4, 2014

Software	Revision	Date	By	Description
4.00a	0	140804	TS	First version.

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

This manual explains all the functions and macros that the product offers. It assumes you have a working knowledge of the C language. Knowledge of assembly programming is not required.

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.
`Sample comment`	Comments in programm examples.
Reference	Reference to chapters, sections, tables and figures or other documents.
GUIElement	Buttons, dialog boxes, menu names, menu commands.
Emphasis	Very important sections.

Table 2.1: 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 efficient 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 develops and produces programming tools for flash micro controllers, 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.

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.

embOS/IP
TCP/IP stack
embOS/IP a high-performance TCP/IP stack that has been optimized for speed, versatility and a small memory footprint.

emFile
File system
emFile is an embedded file system with FAT12, FAT16 and FAT32 support. Various Device drivers, e.g. for NAND and NOR flashes, SD/MMC and CompactFlash cards, are available.

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

SEGGER TOOLS

Flasher
Flash programmer
Flash Programming tool primarily for micro controllers.

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

Using embOS for 8051

This chapter describes how to start with and use embOS for 8051 cores and the IAR compiler. You should follow these steps to become familiar with embOS.

1.1 Installation

embOS is shipped on CD-ROM or as a zip-file in electronic form.

To install it, proceed as follows:

If you received a CD, copy the entire contents to your hard-drive into any folder of your choice. When copying, keep all files in their respective sub directories. Make sure the files are not read only after copying. If you received a zip-file, extract it to any folder of your choice, preserving the directory structure of the zip-file.

Assuming that you are using the IAR Embedded Workbench project manager to develop your application, no further installation steps are required. You will find a lot of prepared sample start projects, which you should use and modify to write your application. So follow the instructions of section “First steps” on page 11.

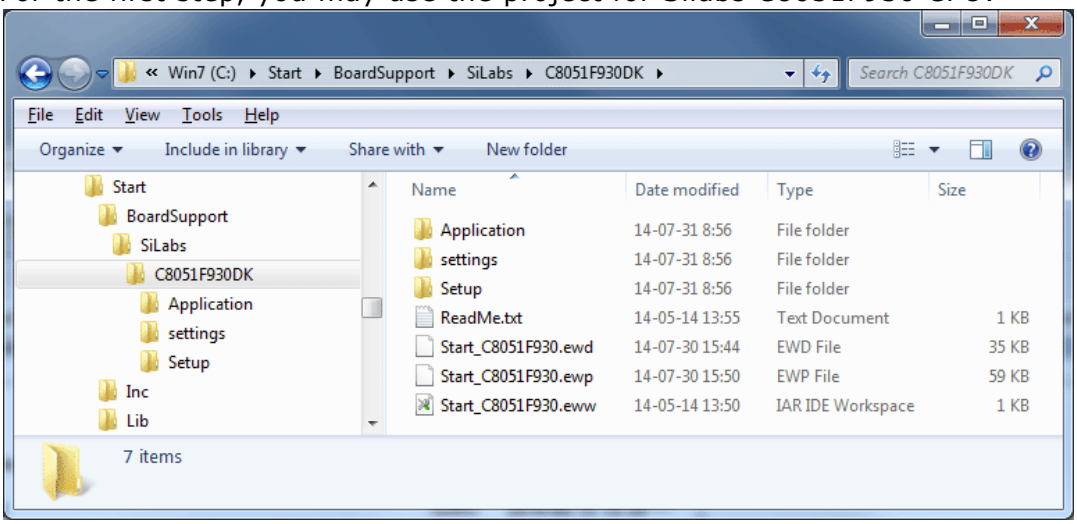
You should do this even if you do not intend to use the project manager for your application development to become familiar with embOS.

If you will not work with the embedded workbench, you should: Copy either all or only the library-file that you need to your work-directory. This has the advantage that when you switch to an updated version of embOS later in a project, you do not affect older projects that use embOS also. embOS does in no way rely on the IAR Embedded Workbench project manager, it may be used without the project manager using batch files or a make utility without any problem.

1.2 First steps

After installation of embOS you can create your first multitasking application. You received several ready to go sample start workspaces and projects and every other files needed in the subfolder **Start**. It is a good idea to use one of them as a starting point for all of your applications. The subfolder **BoardSupport** contains the workspaces and projects which are located in manufacturer- and CPU-specific subfolders.

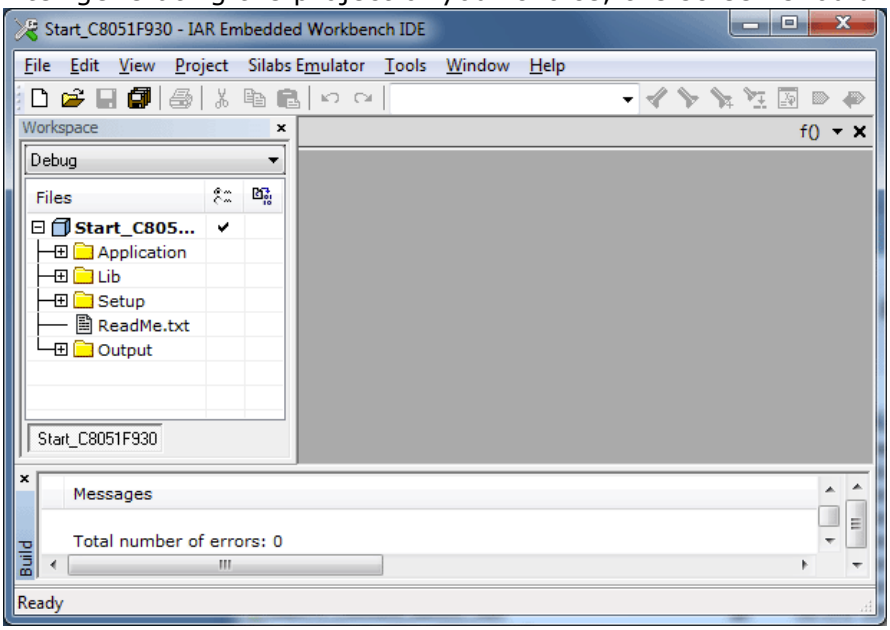
For the first step, you may use the project for Silabs C8051F930 CPU:



To get your new application running, you should proceed as follows:

- Create a work directory for your application, for example `c:\work`.
- Copy the whole folder **Start** which is part of your embOS distribution into your work directory.
- Clear the read-only attribute of all files in the new **Start** folder.
- Open the sample workspace **Start\BoardSupport\Silabs\C8051F930DK** with the IAR Embedded Workbench project manager (for example, by double clicking it).
- Build the project. It should be build without any error or warning messages.

After generating the project of your choice, the screen should look like this:



For additional information you should open the `ReadMe.txt` file which is part of every specific project. The ReadMe file describes the different configurations of the project and gives additional information about specific hardware settings of the supported eval boards, if required.

1.3 The example application Start_2Tasks.c

The following is a printout of the example application `Start_2Tasks.c`. It is a good starting point for your application. (Note that the file actually shipped with your port of embOS may look slightly different from this one.)

What happens is easy to see:

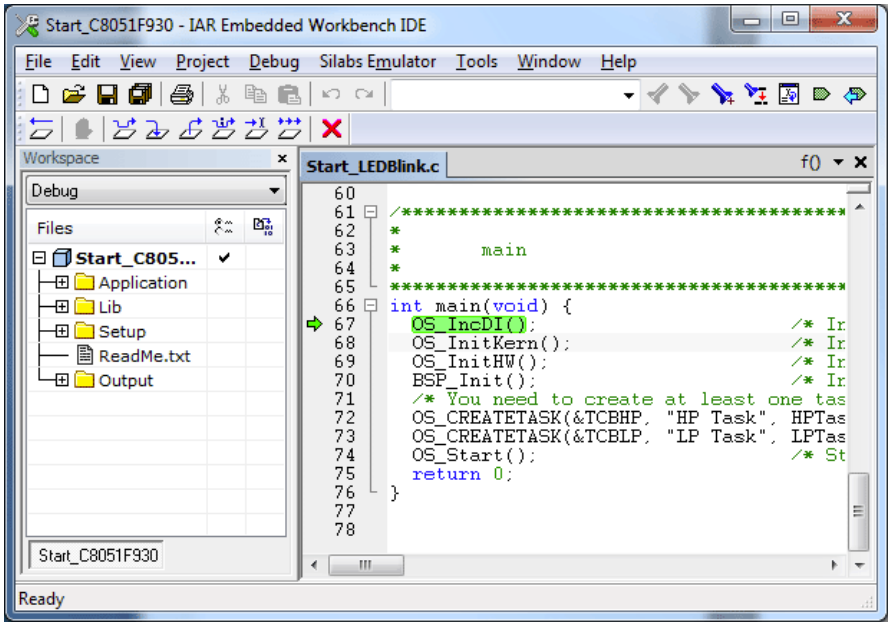
After initialization of embOS; two tasks are created and started.
The two tasks are activated and execute until they run into the delay, then suspend for the specified time and continue execution.

```
/*********************************************************
* SEGGER MICROCONTROLLER SYSTEME GmbH & Co.KG
* Solutions for real time microcontroller applications
**********************************************************
File    : Start2Tasks.c
Purpose : Skeleton program for embOS
--------- END-OF-HEADER ---------------------------------*/

#include "RTOS.h"

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

void HPTask(void) {
  while (1) {
    OS_Delay (10);
  }
}

void LPTask(void) {
  while (1) {
    OS_Delay (50);
  }
}

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

void 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;
}
```

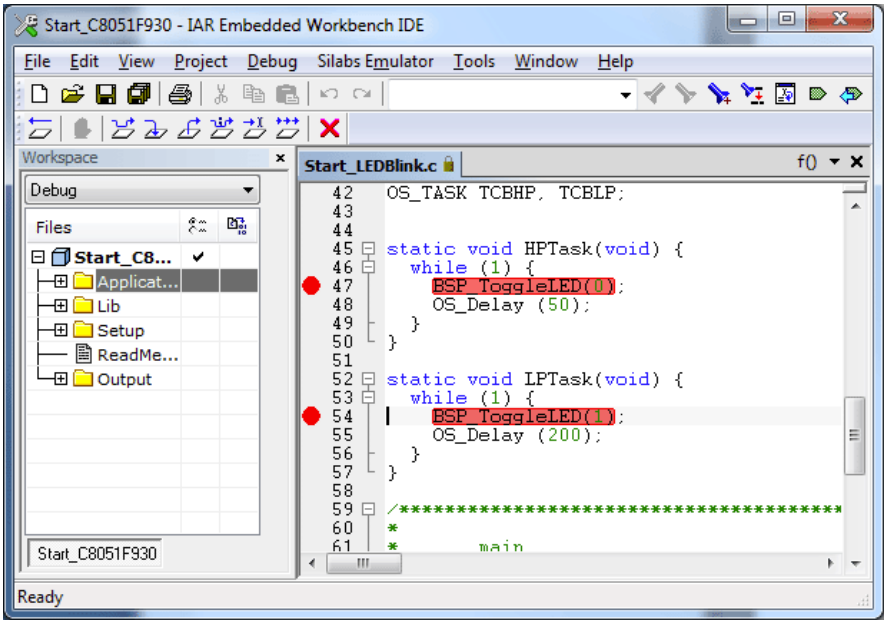

1.4 Stepping through the sample application

When starting the debugger, you will see the `main` function (see example screenshot below). The `main` function appears as long as the C-SPY option **Run to main** is selected, which it is by default. Now you can step through the program. `OS_IncDI()` initially disables interrupts.
`OS_InitKern()` is part of the embOS library and written in assembler; you can therefore only step into it in disassembly mode. It initializes the relevant OS variables. Because of the previous call of `OS_IncDI()`, interrupts are not enabled during execution of `OS_InitKern()`.
`OS_InitHW()` is part of `RTOSInit_*.c` and therefore part of your application. Its primary purpose is to initialize the hardware required to generate the timer-tick-interrupt for embOS. Step through it to see what is done.

`OS_Start()` should be the last line in main, because it starts multitasking and does not return.

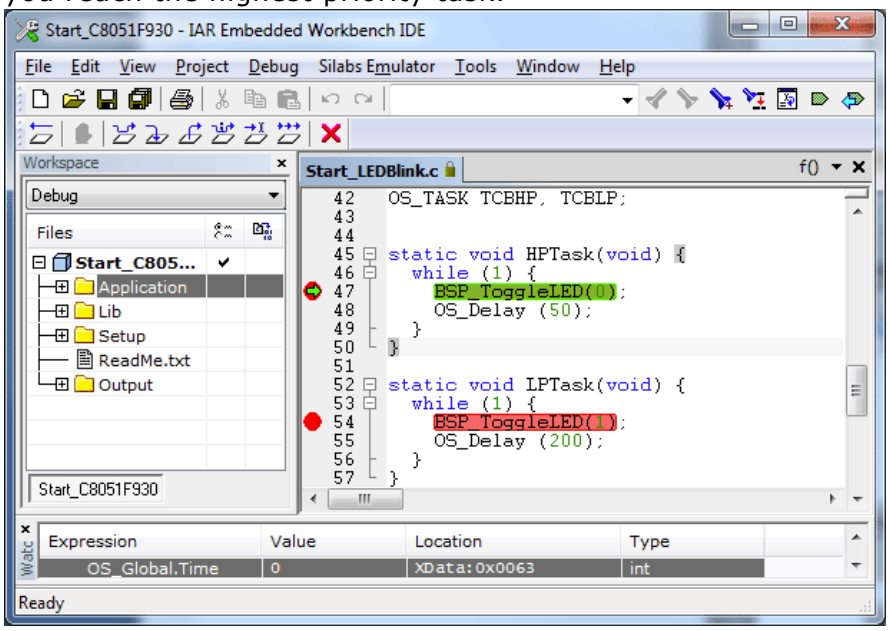


Before you step into `OS_Start()`, you should set two breakpoints in the two tasks as shown below.

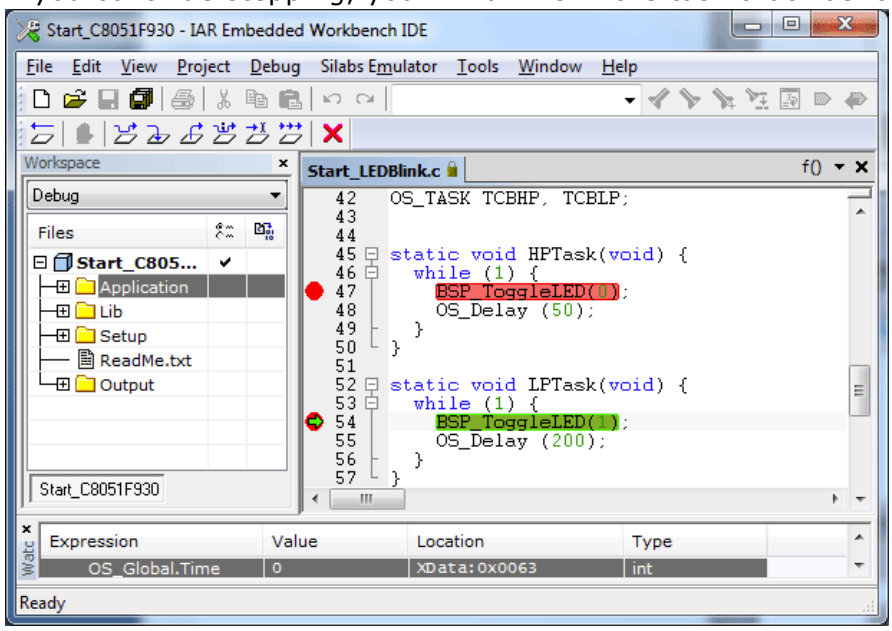


As `OS_Start()` is part of the embOS library, you can step through it in disassembly mode only.

Click **GO**, step over `OS_Start()`, or step into `OS_Start()` in disassembly mode until you reach the highest priority task.

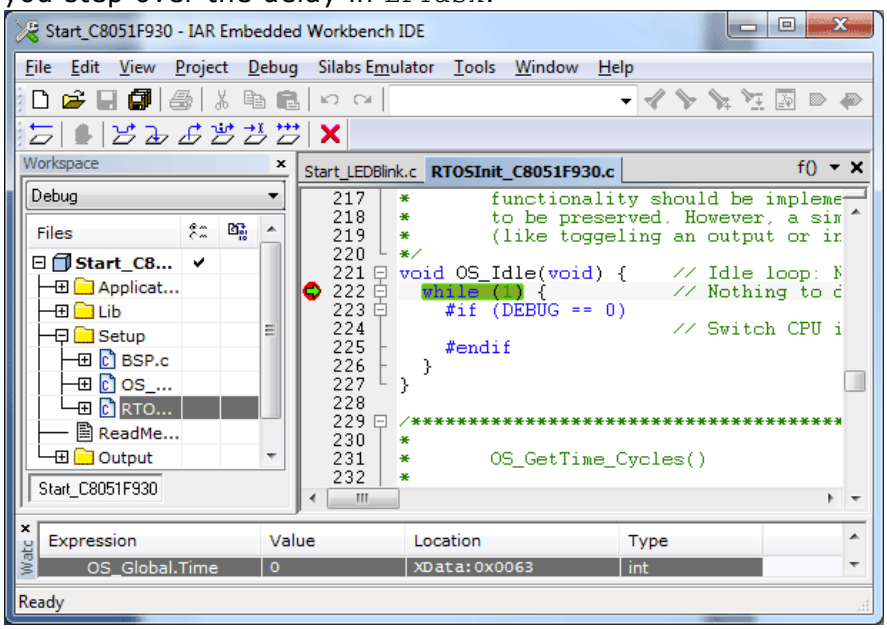


If you continue stepping, you will arrive in the task that has lower priority:



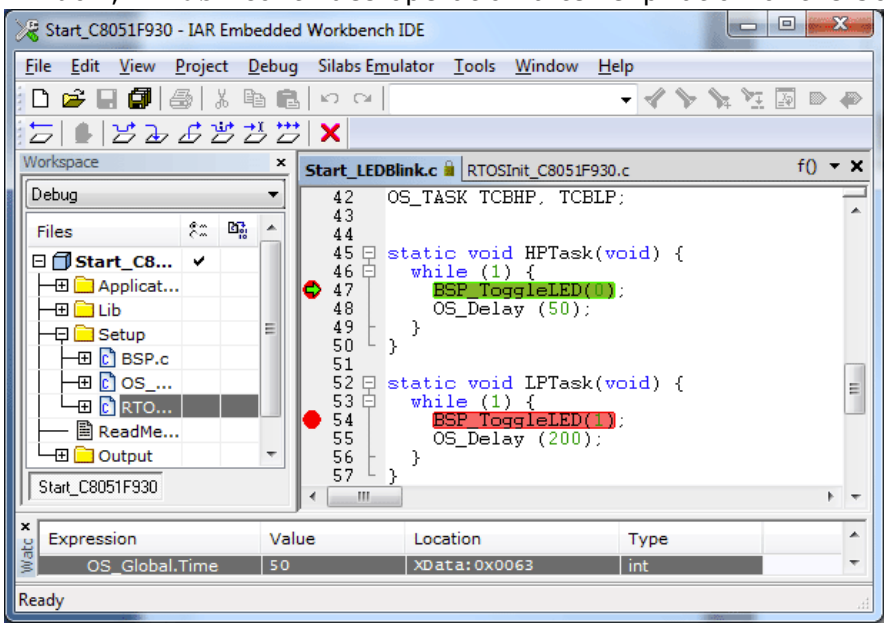
Continue to step through the program, there is no other task ready for execution. embOS will therefore start the idle-loop, which is an endless loop which is always executed if there is nothing else to do (no task is ready, no interrupt routine or timer executing).

You will arrive there when you step into the `OS_Delay()` function in disassembly mode. `OS_Idle()` is part of `RTOSInit*.c`. You may also set a breakpoint there before you step over the delay in `LPTask`.



If you set a breakpoint in one or both of our tasks, you will see that they continue execution after the given delay.

As can be seen by the value of embOS timer variable OS_Time, shown in the Watch window, `HPTask` continues operation after expiration of the 50 ms delay.



Chapter 2

Build your own application

This chapter provides all information to setup your own embOS project.

2.1 Introduction

To build your own application, you should always start with one of the supplied sample workspaces and projects. Therefore, select an embOS workspace as described in First steps on page 9 and modify the project to fit your needs. Using a sample project as starting point has the advantage that all necessary files are included and all settings for the project are already done.

2.2 Required files for an embOS for 8051

To build an application using embOS, the following files from your embOS distribution are required and have to be included in your project:

- `RTOS.h` from subfolder `Inc\`.
  This header file declares all embOS API functions and data types and has to be included in any source file using embOS functions.
- RTOSInit_*.c from one target specific **BoardSupport\<Manufacturer>\<MCU>** subfolder.
  It contains hardware-dependent initialization code for embOS. It initializes the system timer, timer interrupt and optional communication for embOSView via UART or JTAG.
- One embOS library from the subfolder `Lib\`.
- OS_Error.c from one target specific subfolder **BoardSupport\<Manufacturer>\<MCU>**.
  The error handler is used if any library other than Release build library is used in your project.
- Additional low level init code may be required according to CPU.

When you decide to write your own startup code or use a `__low_level_init()` function, ensure that non-initialized variables are initialized with zero, according to C standard. This is required for some embOS internal variables.
Also ensure, that `main()` is called with the CPU running in supervisor or system mode.
Your `main()` function has to initialize embOS by a call of `OS_InitKern()` and `OS_InitHW()` prior any other embOS embOS functions are called.
You should then modify or replace the `Start_2Task.c` source file in the subfolder `Application\`.

2.3 Change library mode

For your application you might want to choose another library. For debugging and program development you should use an embOS-debug library. For your final application you may wish to use an embOS-release library or a stack check library.

Therefore you have to select or replace the embOS library in your project or target:

- If your selected library is already available in your project, just select the appropriate configuration.
- To add a library, you may add a new `Lib` group to your project and add this library to the new group. Exclude all other library groups from build, delete unused `Lib` groups or remove them from the configuration.
- Check and set the appropriate `OS_LIBMODE_*` define as preprocessor option and/or modify the OS_Config.h file accordingly.

2.4 Select another CPU

embOS contains CPU-specific code for various 8051 CPUs. Manufacturer- and CPU specific sample start workspaces and projects are located in the subfolders of the **BoardSupport** folder. To select a CPU which is already supported, just select the appropriate workspace from a CPU specific folder.

If your 8051 CPU is currently not supported, examine all `RTOSInit` files in the CPU-specific subfolders and select one which almost fits your CPU. You may have to modify `OS_InitHW()`, `OS_COM_Init()`, and the interrupt service routines for embOS timer tick and communication to embOSView and `__low_level_init()`.

Chapter 3

8051 specifics

3.1 CPU modes

embOS for 8051 supports only the Near code and Large data model with XDATA stack reentrant calling convention.

3.2 Available libraries

embOS for 8051 and IAR compiler comes with 7 different libraries, one for each library mode combination.

3.2.1 Naming conventions for prebuilt libraries

embOS 8051 for the IAR Embedded Workbench is shipped with different prebuilt libraries with different combinations of the following features:

- Library mode - `LibMode`

The libraries are named as follows:

`os8051_<Libmode>.r51`

Parameter	Meaning	Values
`LibMode`	Specifies the library mode	XR: Extreme Release
		R: Release
		S: Stack check
		SP: Stack check + profiling
		D: Debug
		DP: Debug + profiling
		DT: Debug + profiling + trace

Example

os8051_DP.r51 is the library for a project using a 8051 core with debug and profiling support.

Chapter 4

Compiler specifics

4.1 Standard system libraries

embOS for 8051 and IAR may be used with IAR standard libraries.
If non thread-safe functions are used from different tasks, embOS functions may be used to encapsulate these functions and guarantee mutual exclusion.

Chapter 5

Stacks

5.1 Task stack for 8051

Each task uses its individual stack. The stack poiter is initialized and set every time a task is activated by the scheduler. The stack-size required for a task is the sum of the stack-size of all routines plus a basic stack size plus size used by exceptions.

The basic stack size is the size of memory required to store the registers of the CPU plus the stack size required by calling embOS-routines.

The IAR compiler uses a software stack pointer which points to the XDATA memory. This software stack pointer is initialized by embOS to the end of the task stack and grows to lower addresses. The hardware stack pointer is initialized to the start of the task stack and grows to higher addresses. Thus the task stack is divided into two parts with the same size, one part for the hardware stack in IDATA and the other part for the software stack in XDATA. With each task switch the the used task stack is copied from XDATA to a fixed address in IDATA and copied back to XDATA with the next task switch. This fixed address can be changed with the embOS source version with the define `IDATA_STACK_BASE_ADDR`. The default address is 0x80 in IDATA RAM. Thus the maximum IDATA task stack size is 128 bytes and the maximum complete task stack size is 256 bytes.

For the 8051 CPUs, this minimum basic task stack size is about 30 bytes. Because any function call uses some amount of stack and every exception also pushes at least 2 bytes onto the current stack, the task stack size has to be large enough to handle one exception too. We recommend at least 256 bytes stack as a start.

5.2 System stack for 8051

The minimum system stack size required by embOS is about 20 bytes (stack check & profiling build) However, since the system stack is also used by the application before the start of multitasking (the call to OS_Start()), the actual stack requirements depend on the application.

We recommend a minimum stack size of 80 bytes for the ISTACK.

5.3 Interrupt stack for 8051

The 8051 core has no separate interrupt stack pointer. If an interrupt occurs, the 8051 core saves the return address on the current stack which could be a task stack or the ISTACK.

Chapter 6

Interrupts

The 8051 core comes with an built in vectored interrupt controller. The number of interrupt sources depends on the specific target CPU.

6.1 What happens when an interrupt occurs?

- The CPU-core receives an interrupt request form the interrupt controller.
- As soon as the interrupts are enabled, the interrupt is accepted and executed.
- The CPU pushes the return address onto the current stack.
- The CPU jumps to the vector address.
- The interrupt handler is processed.
- The interrupt handler ends with a return from interrupt instruction
- The CPU returns to the address from the stack and continues the interrupted function.

6.2 Defining interrupt handlers in C

Interrupt handlers for 8051 cores are written as normal C-functions which do not take parameters and do not return any value. Interrupt handler which call an embOS function need a prolog and epilog function as described in the generic manual and in the examples below. Interrupt handlers needs the `#pragma` statement with the interrut vector number and the `__interrupt` keyword.

Example

Simple interrupt routine:

```
#pragma vector = 0x2B
__interrupt void OS_ISR_Tick (void);
__interrupt void OS_ISR_Tick (void) {
  TMR2CN &= ~TMR2_TF2H_MASK;
  OS_EnterNestableInterrupt();
  OS_TICK_Handle();
  OS_LeaveNestableInterrupt();
}
```

6.3 Zero latency interrupts

6.3.1 Zero latency interrupts with 8051

The 8051 CPU does not support execution priority thus embOS has to disables all interrupts for internal operations. Therefore zero latency interrupts are not supported.

6.4 Interrupt priorities

The 8051 CPU has two interrupt priorities, low and high. Each interrupt can be initialized with low or high priority.
Interrupt routines with high priority must not call any embOS API functions.

6.5 Interrupt nesting

The 8051 CPU uses a priority controlled interrupt scheduling which allows nesting of interrupts per default. Any interrupt with high interrupt priority may interrupt an interrupt handler running on the low interrupt priority. An interrupt handler calling embOS functions has to start with an embOS prolog function that informs embOS that an interrupt handler is running. For any interrupt handler, the user may decide individually whether this interrupt handler may be preempted or not by choosing the prolog function.

6.5.1 OS_EnterInterrupt()

Description

OS_EnterInterrupt(), disables nesting

Prototype

```
void OS_EnterInterrupt(void)
```

Return value

None.

Additional Information

OS_EnterInterrupt() has to be used as prolog function, when the interrupt handler should not be preempted by any other interrupt handler that runs on a priority below the fast interrupt priority. An interrupt handler that starts with OS_EnterInterrupt() has to end with the epilog function OS_LeaveInterrupt().

Example

Interrupt-routine that can not be preempted by other interrupts

```
#pragma vector = 0x2B
__interrupt void OS_ISR_Tick (void);
__interrupt void OS_ISR_Tick (void) {
  TMR2CN &= ~TMR2_TF2H_MASK;
  OS_EnterInterrupt();
  OS_TICK_Handle();
  OS_LeaveInterrupt();
}
```

6.5.2 OS_EnterNestableInterrupt()

Description

OS_EnterNestableInterrupt(), enables nesting

Prototype

```
void OS_EnterNestableInterrupt(void)
```

Return value

None.

Additional Information

OS_EnterNestableInterrupt(), allow nesting. OS_EnterNestableInterrupt() may be be used as prolog function, when the interrupt handler may be preempted by any other interrupt handler that runs on a higher interrupt priority. An interrupt handler that starts with OS_EnterNestableInterrupt() has to end with the epilog function OS_LeaveNestableInterrupt().

Example

Interrupt-routine that can be preempted by other interrupts

```
#pragma vector = 0x2B
__interrupt void OS_ISR_Tick (void);
__interrupt void OS_ISR_Tick (void) {
  TMR2CN &= ~TMR2_TF2H_MASK;
  OS_EnterInterrupt();
  OS_TICK_Handle();
  OS_LeaveInterrupt();
}
```


Chapter 7

STOP / WAIT Mode

7.1 Introduction

In case your controller does support some kind of power saving mode, it should be possible to use it also with embOS, as long as the timer keeps working and timer interrupts are processed. To enter that mode, you usually have to implement some special sequence in the function `OS_Idle()`, which you can find in embOS module `RTOSInit.c`.
Per default, the `wfi` instruction is executed in `OS_Idle()` to put the CPU into a low power mode.

Chapter 8

Technical data

8.1 Memory requirements

These values are neither precise nor guaranteed but they give you a good idea of the memory-requirements. They vary depending on the current version of embOS. The minimum ROM requirement for the kernel itself is about 2.500 bytes.

In the table below, which is for release build, you can find minimum RAM size requirements for embOS resources. Note that the sizes depend on selected embOS library mode.

embOS resource	RAM [bytes]
Task control block	22
Resource semaphore	7
Counting semaphore	4
Mailbox	12
Software timer	9

Chapter 9

Files shipped with embOS

List of files shipped with embOS

Directory	File	Explanation
root	*.pdf	Generic API and target specific documentation.
root	Release_embOS.html	Version control document.
root	embOSView.exe	Utility for runtime analysis, described in generic documentation.
Start\BoardSupport\		Sample workspaces and project files for IAR Embedded Workbench, contained in manufacturer specific sub folders.
Start\Inc	RTOS.h BSP.h	Include file for embOS, to be included in every C-file using embOS functions.
Start\Lib	os8051_*.r51	embOS libraries for IAR compiler
Start\BoardSupport\..\Setup	OS_Error.c	embOS runtime error handler used in stack check or debug builds.
Start\BoardSupport\...\Setup\	*.*	CPU specific hardware routines for various CPUs.

Any additional files shipped serve as example.

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