eSolid - Real-Time Kernel

1.0BetaR01

Generated by Doxygen 1.8.3.1

Fri Jun 14 2013 00:40:34

Contents

1 eSolid Real-Time Kernel

1.1 eSolid RT Kernel Features

1.1.1 Source code

The source code of the kernel and all of it's ports are published under **free software license**, which guarantees end users (individuals, organizations, companies) the freedoms to use, study, share (copy), and modify the software.

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1.1.2 Consistent Application Programming Interface

All objects declared in Application Programming Interface are following these naming rules:

- All objects except macros are using `CamelCase` style names
- All functions, structures and unions are prefixed with: `es`
- All typedef-ed types are prefixed with: `es` and postfixed with: `_T`
- All macro names are in `UPPERCASE` style, words are delimited by underscore sign
- All macro names are prefixed with: `ES_`
- All Global variables are prefixed with: `g`

All API objects are named following this convention: `es<group><action><suffix>()`

- Group:
  - `Kern` - General Kernel services
  - `Thd` - Thread management
  - `ThdQ` - Thread Queue management
  - `Sched` - Scheduler invocation
  - `SchedRdy` - Scheduler Ready Thread Queue management
- Suffix:
  - `none` - normal API object
  - `I` - I class - Regular Interrupts are locked

All Port Interface objects are named using the rules stated above with certain differences:

- All functions, structures and unions are prefixed with: `port`
- All macro names are prefixed with: `PORT_`

1.1.3 Preemptive multi-threading

eSolid RT Kernel uses a **preemptive scheduler**, which has the power to preempt, or interrupt, and later resume, other threads in the system. The scheduler always runs ready thread with the highest priority.

1.1.4 Round-Robin scheduling

Round-Robin scheduling is very **simple algorithm** to implement and it is **starvation free**. It employs time-sharing, giving to each thread a time slice or `quantum`. Processor's time is shared between a number of threads, giving the illusion that it is dealing with these threads **concurrently**. This scheduling is only used when there are two or more threads of the same priority ready for execution.

1.1.5 Deterministic

Majority of algorithms used in eSolid RT Kernel implementation are belonging to **Constant Time Complexity** category. Constant Time `O(1)` functions needs fixed amount of time to execute an algorithm. In other words the execution time of Constant Time Complexity functions does not depend on number of inputs. For more information see Time complexity.

1.1.6 Configurable

The kernel provides two configuration files kernel_cfg.h and cpu_cfg.h which can be used to tailor the kernel to application needs.

In addition, the kernel implements a number of hooks which can alter or augment the behavior of the kernel or applications, by intercepting function calls between software components.

1.1.7 Portable

During the design stage of the kernel a special attention was given to achieve high portability of the kernel. Some data types and algorithms are tailored to exploit new hardware features.

1.1.8 Static object allocation

All objects used in eSolid RT Kernel can be statically allocated. There is no need to use any memory management functionality which makes it very easy to verify the application.

1.1.9 Unlimited number of threads

eSolid RT Kernel allows applications to have any number of threads. The only limiting factors for the maximum number of threads are the amount of RAM and ROM memory capacity and required processing time.

1.1.10 Up to 256 thread priority levels

Each thread has a defined priority. Lowest priority level is 0, while the highest available level is configurable. If Round-Robin scheduling is used then multiple threads can be in the same priority level. If Round-Robin scheduling is disabled then each thread must have unique priority level. The priority sorting algorithm has constant time complexity which means it always executes in the same time period regardles of the levels of priority used.

1.1.11 Error checking

All eSolid software is using design methods very similar to approaches of **contract programming** paradigm for software design. The contract programming prescribes that Application Programming Interface should have formal, precise and verifiable specifications, which extend the ordinary definition of abstract data types with preconditions and postconditions. These specifications are referred to as "contracts". The contract for each method will normally contain the following pieces of information:

- Acceptable and unacceptable input values

- Return values and their meanings
- Error and exception condition values that can occur during the execution
- Side effects
- Preconditions
- Postconditions
- Invariants

The contract validations are done by **assert** macros. They have the responsibility of informing the programmer when a contract can not be validated.

1.1.12 Profiling

Note

This feature is not implemented

2 Directory and file organization

Details about directory and file organization

2.1 Intro

The directory structure of eSolid RT Kernel is fairly easy to understand. Once the organization of directories and files is understood it is fairly easy to integrate eSolid RT Kernel into application.

2.1.1 What is a port?

Porting is a process of adapting software to an architecture that is different from the one for which it was originally designed. The term is also used when software is changed to make it usable in different environments. Software is portable when the cost of porting it to a new platform is less than the cost of writing it from beginning.

2.2 Code Sections

The kernel is divided into three sections. One section is port independent code, the second one is port dependent code and the third sections is code templates.

2.2.1 Port independent code

Port independent code is the code which does not change from port to port, e.g. when the CPU is changed this code is not changed at all and it is still correctly executed. Code can be developed and tested on another machine, which greatly reduces design efforts. It provides API and some common data structures. Port independent code lives under `/inc` and `/src` directories:

- `inc/kernel.h`
- `inc/kernel_cfg.h`
- `src/kernel.c`

Click on file name for further description of the file.

2.2.2 Port dependent code

Second section is the port dependent code. This code provides low-level functions which are needed to interact with interrupt controllers, manipulate CPU settings and do the context switching. They are highly CPU/compiler bounded and are often written in assembly language.

Each port has it's name which is also the name of directory which holds all the port files. Usually each port has some kind of variant. In that case each variant is a subdirectory of the containing port. Common code for all variants will be in common subdirectory. Each eSolid RT Kernel port will have at least the following files:

- `port/[port_name]/common/compiler.h`
- `port/[port_name]/[variant_name]/cpu_cfg.h`
- `port/[port_name]/[variant_name]/cpu.h`
- `port/[port_name]/[variant_name]/cpu.c`

Note

Port dependent code is separately described in documentation for relevant port.

2.2.3 Template and example code

Templates are some predefined configuration settings for various scenarios where eSolid RT Kernel can be used. Templates also contain some example code for how to write new ports.

In the example below is given `Generic` template which holds files with default configuration settings and some example code for new ports. New port files are in template/generic/port directory. When porting to a new architecture/compiler use provided template files for starters. This will greatly reduce the time needed to become familiar with the kernel port requirements. Generic template files are the following:

- `template/generic/port/compiler.h`
- `template/generic/port/cpu_cfg.h`
- `template/generic/port/cpu.h`
- `template/generic/port/cpu.c`
- `template/generic/kernel_cfg.h`

3 Kernel states

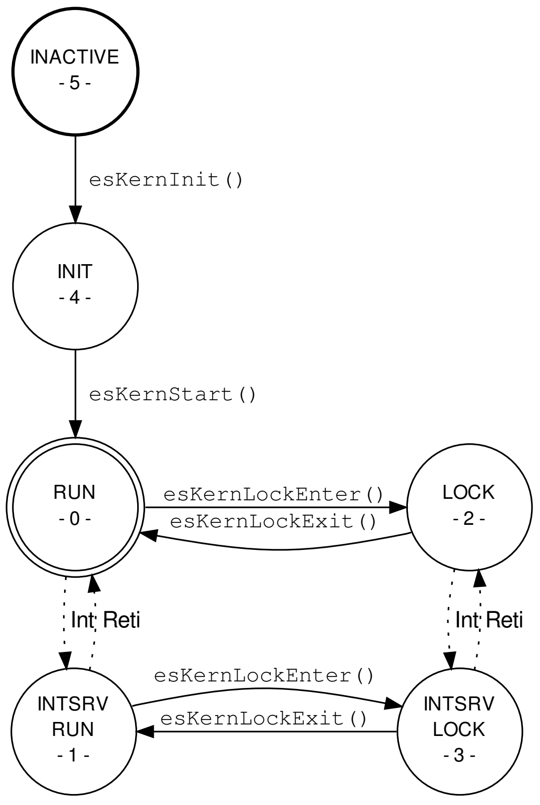
Details about kernel states

3.1 Intro

A Kernel state machine is a behavior model of the kernel core. Each state defines what methods are allowed.

3.2 eSolid RT Kernel states

The kernel can be in one of the following states:



INACTIVE

Inactive state of the kernel (Level 5). This state is entered after a physical reset. When the system is in this state all the maskable interrupt sources are disabled. In this state none of kernel internal data structures are initialized. In this state it is not possible to use any Kernel API except esKernInit().

INIT

Initialization state of the kernel (Level 4). In this state all internal data structures are initialized but the kernel is still not running. In this stage new threads can be created by calling esThdInit() function. Also, the application is allowed to use API which is used to create kernel structures like Thread Queues esThdQ. All the maskable interrupt sources are DISABLED.

RUN

Normal, running state of the kernel (Level 0). To start multi-threading just call the esKernStart() function. This function will switch the kernel into `RUN` state and multi-threading of created threads will commence. During the `RUN` state you are allowed to create other task as well. All the interrupt sources are enabled and the system APIs are accessible, threads are running. All the maskable interrupt sources are ENABLED.

LOCK

Scheduler locked state, no context switching (Level 2). The running state of the kernel can be switched to `LOCK` state where the scheduler is locked and no context switching is allowed. `LOCK` state is one way of preventing the access to a shared resource. One more reason to lock the scheduler would be during the accessing of special hardware (e.g. programming the FLASH memory) which does not allow interruption of the running operation. Usage of scheduler locks should be kept at minimum. All the maskable interrupt sources are ENABLED.

INTSRV_RUN or INTSRV_LOCK

Interrupt Service state, no context switching (Levels 1 and 3). During the both states `RUN` and `LOCK`, an interrupt event can occur. When Interrupt Service Routine is executing the kernel is in `INTSRV_RUN` or `I-`

NTSRV_LOCK state. Each state corresponds to the state where the execution was interrupted from and the kernel will return to it's original state.

Note

The level of state INACTIVE is the highest. As the kernel boots up the level is decremented. The running state is level 0.

4 Thread Management

Introduction to threads and how to use them

4.1 Intro

A thread, also called a thread of execution is the smallest sequence of program instructions that can be managed by an operating system scheduler. Multi-threading is implemented by time-division multiplexing where the processor switches between threads. Context switching occurs fast enough that the user perceives the threads as running at the same time. By using threads a programmer can split the work into the threads, each responsible for a smaller portion of the problem. From a threads view he thinks it has the processor all to itself.

4.1.1 eSolid RT Kernel thread

eSolid RT Kernel supports multi-threading and allows applications to have any number of threads. The only limiting factors for the maximum number of threads are the amount of RAM and ROM memory and processing time.

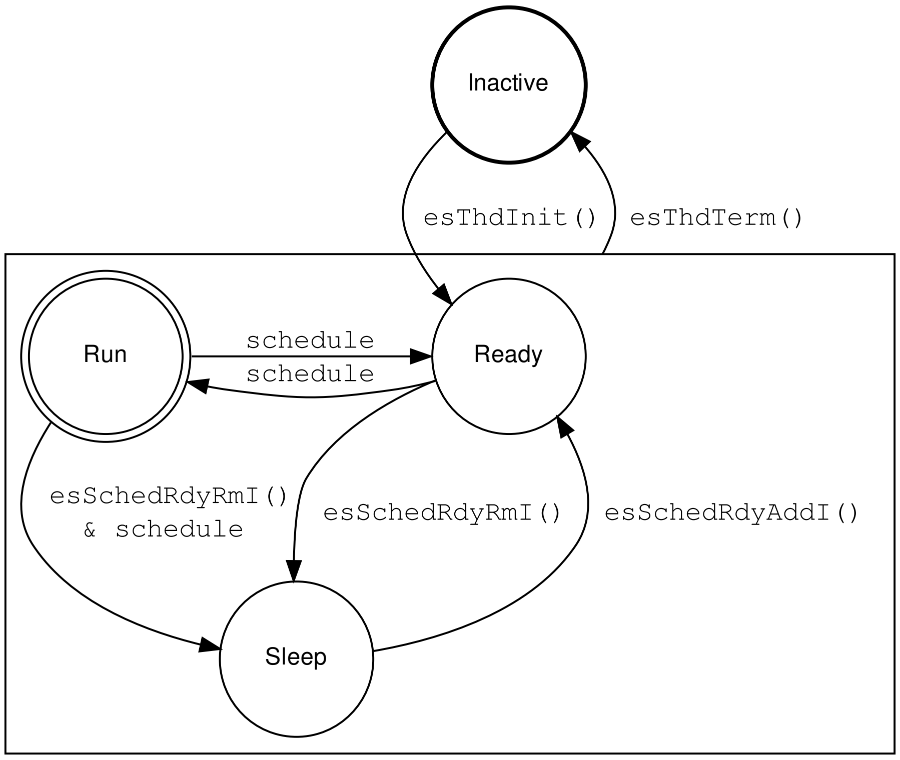
Threads are implemented as normal C functions. Thread functions must have the following prototype:

```
void fn (void *);
```

Which in plain english means: *fn is a function (pointer to void) returning void.*

4.1.2 Thread states

A thread can be in one of the following states:



Inactive

This is thread initial state. Threads in this state are still not activated (**inactive**) by esThdInit() function or they were deleted by esThdTerm() function. The scheduler does not recognize these threads and they will never execute.

Ready

Threads waiting to execute. There are the threads that are **ready** to execute but are not currently executing because a different thread (equal or higher priority) is already executing.

Run

Thread is currently executing. When the thread is in this state then the code is actually being **run** on the processor.

Sleep

Thread is sleeping. These threads are **sleeping** while waiting for an event to occur.

4.2 Initializing Threads

4.2.1 esThdInit() API function

Threads are initialized by using esThdInit() API function.

Stack size

There is no easy way to determine the stack size required by a thread. It is possible to calculate approximate stack size for simple threads, but for more complex ones (e.g. which calls library API function) this can be a daunting task. In this case stack size will be set to a size more than adequate for the thread and then use the profiling features provided by the kernel to ensure both that the space allocated is adequate, and that RAM space is not being unnecessarily wasted.

5 Critical sections

How to deal with critical sections in an application

5.1 Intro

In concurrent programming, a critical section is a piece of code that accesses a shared resource (data structure or device) that must not be concurrently accessed by more than one thread of execution. A critical section will usually terminate in fixed time, and a thread will have to wait for a fixed time to enter it (aka bounded waiting). Some synchronization mechanism is required at the entry and exit of the critical section to ensure exclusive use, for example a semaphore.

5.1.1 eSolid RT Kernel internal critical sections

In contrast to application code in kernel code there is no other mechanism to protect critical code except disabling interrupts. Fortunately, some ports have ability to mask certain interrupts with low priority and allow interrupts with higher priority. By masking low priority interrupts the kernel can protect its critical sections. However for this scheme to work its forbidden to call any OS service function from a high priority interrupt. If this rule is not followed then the high priority interrupt with an OS service function call can preempt the kernel low priority interrupt which will in that case corrupt the kernel internal data structures.

Note

1) It is forbidden to call any OS service function from an interrupt with the priority higher than the kernel interrupt priority.
2) On some ports the kernel never completely disables interrupts.

5.2 Implementation

There are multiple ways how are critical sections implemented:

- The simplest method is to prevent interrupts on entry into the critical section, and restoring interrupts to their previous state on exit from critical section. Any thread of execution entering any critical section anywhere in the system, with this implementation, will prevent any other thread, including an interrupt, from being executed on the CPU.
- This approach can be improved upon by using semaphores. To enter a critical section, a thread must obtain a semaphore, which it releases on leaving the section. Other threads are prevented from entering the critical section at the same time as the original thread, but are free to gain control of the CPU and execute other code, including other critical sections that are protected by different semaphores.

5.2.1 Disabling interrupts

In order to properly disable interrupts the application must follow these steps:

- declare an `auto` variable which will hold interrupt state
- save interrupt status into `auto` variable and disable interrupts

- access the shared resource
- restore previously saved interrupt state

For `auto` variable declaration macro ES_CRITICAL_DECL() is used. This macro will declare a temporary interrupt status variable. Then by using the macro ES_CRITICAL_ENTER() the state of enabled interrupts will be saved in `auto` variable declared earlier. Immediately after saving the interrupt state the macro will lock interrupts. Now the code can safely access and use the shared resource. When code finishes using the resource it will call ES_CRITICAL_EXIT() macro. This macro will restore interrupts from the previously saved interrupt state.

```
ES_CRITICAL_DECL();                 /* Declare an interrupt status variable */
    :
    :
    :
ES_CRITICAL_ENTER();                /* Save state and lock interrupts */
/*
   Access the shared resource
 */
ES_CRITICAL_EXIT();                 /* Restore previous state unlocking the interrupts */
```

When to use this scheme

- If interrupt service routine *changes* the shared resource state.
- If the processing time of critical section is very small.

When not to use this scheme

- If interrupt service routine takes a lot of CPU time to process critical section. If a critical section is long, then the system clock will drift every time a critical section is executed because the system timer interrupt is no longer serviced, so tracking time is impossible during the critical section. Also, if a program execution halts during its critical section, control will never be returned to another thread, effectively halting the entire system.

5.2.2 Disabling Kernel scheduler

Another way to implement a critical section and protect your data is by locking the kernel scheduler. The kernel locking can be used only if you know that protected data will be modified only by other threads. This protection scheme can not be used when data is modified by interrupt service routines.

```
esKernLockEnter();                  /* Temporarily disable kernel scheduler  */
/*
   Access the shared resource
 */
esKernLockExit();                   /* Enable kernel scheduler */
```

When to use this scheme

- If interrupt service routine *never changes* the shared resource state.
- If the processing time of critical section is very small.

When not to use this scheme

- If interrupt service routine takes a lot of CPU time to process critical section. If a critical section is long, then the system will be partially responsive to other events since interrupt service routines can be invoked, but note that any further processing by other threads is still disabled.

5.2.3 Using semaphores

6 Time complexity

About time categories of algorithms

6.1 Intro

In computer science, the time complexity of an algorithm quantifies the amount of time taken by an algorithm to run as a function of the length of the input. The time complexity of an algorithm is commonly expressed using **big O** notation, which excludes coefficients and lower order terms. When expressed this way, the time complexity is said to be described asymptotically, i.e., as the input size goes to infinity. For example, if the time required by an algorithm on all inputs of size `n` is at most `5n^3 + 3n`, the asymptotic time complexity is `O(n^3)`.

Time complexity is commonly estimated by counting the number of elementary operations performed by the algorithm, where an elementary operation takes a fixed amount of time to perform. Thus the amount of time taken and the number of elementary operations performed by the algorithm differ by at most a constant factor.

Since an algorithm's performance time may vary with different inputs of the same size, one commonly uses the worst-case time complexity of an algorithm, denoted as **T(n)**, which is defined as the maximum amount of time taken on any input of size `n`. Time complexities are classified by the nature of the function `T(n)`. For instance, an algorithm with `T(n) = O(n)` is called a linear time algorithm, and an algorithm with `T(n) = O(2^n)` is said to be an exponential time algorithm.

Note

Worst-case time-complexity `T(n)` indicates the longest running time performed by an algorithm given any input of size `n`, and thus this guarantees that the algorithm finishes on time.

6.1.1 Big O notation

Big O notation describes the limiting behavior of a function when the argument tends towards a particular value or infinity, usually in terms of simpler functions and it is used to classify algorithms by how they respond (e.g., in their processing time or working space requirements) to changes in input size.

6.2 Constant time

An algorithm is said to be constant time (also written as `O(1)` time) if the value of `T(n)` is bounded by a value that does not depend on the size of the input.

Despite the name *constant time*, the running time does not have to be independent of the problem size, but an upper bound for the running time has to be bounded independently of the problem size.

Note

Constant time effectively means that there is a constant upper bound to how long the function will take to run which isn't affected by any of the input argument.

6.2.1 eSolid RT Kernel time complexity

All eSolid RT Kernel functions are using `constant time O(1)` algorithms. This is especially important for Real Time applications.

7 Scheduler

About the scheduler and Ready Threads Queue

7.1 Quantum

The period of time for which a thread is allowed to execute in a preemptive multi-threading system is generally called the time slice, or `quantum`. The scheduler is run once every quantum to choose the next thread for execution. If the quantum is too short then the scheduler overhead may become high.

An interrupt is used to allow the kernel to switch between threads when their quantum expires, effectively allowing the processor's time to be shared between a number of threads, giving the illusion that it is dealing with these threads concurrently.

7.2 Threads List

Each thread structure esThd contains Thread List structure esThd::thdL. All threads of the same priority are linked together via *next* and *prev* members in esThd::thdL structure. The first member of the structure is pointer *q* which points back to the Threads Queue structure (esThdQ) which contains the threads.

The list is organized as **circular doubly linked list**, which means that *tail* and *head* nodes are linked together just like every other node in the list. This provides easy and efficient traversal of the list.

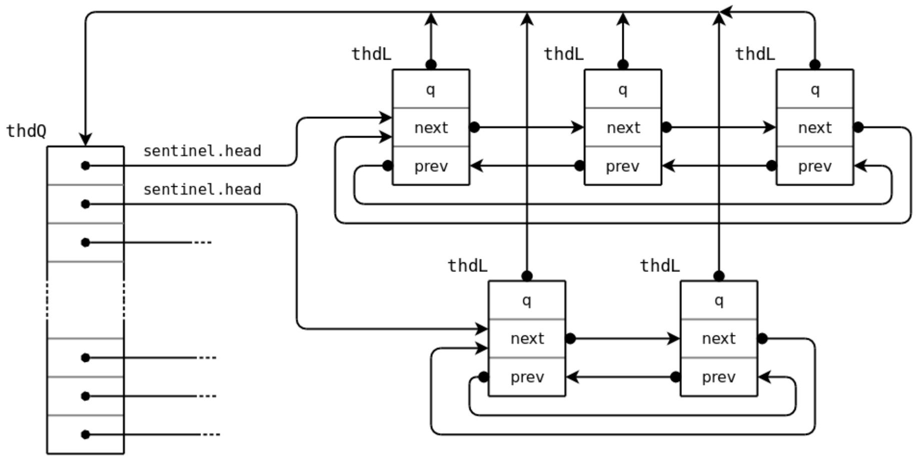


Figure 1: Detailed view of Threads List (sentinel.next pointers not shown)

Each sentinel of a list has two pointers, *head* and *next*. Pointer *sentinel.head* always points to the first entry of the list which is called *head*. Every new thread is added at the *tail* of the list which is essentialy just after the node *head*. When a first thread is added to the list the pointer *sentinel.next* points to the thread, too. When the list is rotated using function esThdQFetchRotateI() the pointer *sentinel.next* is advanced forward and points to the next thread in list.

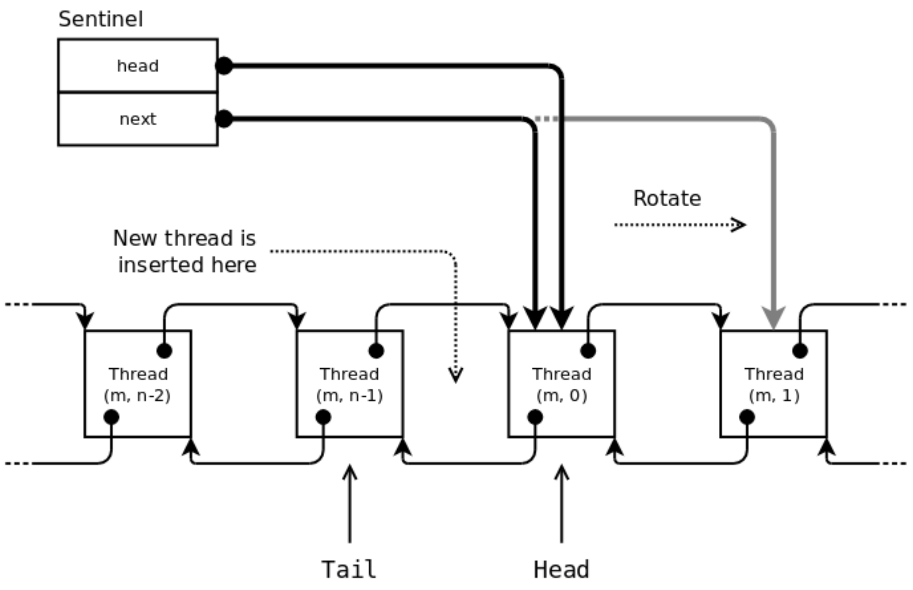


Figure 2: Detailed view of the sentinel and linked list

7.3 Threads Queue

Based on the number of configured priority levels (see CFG_SCHED_PRIO_LVL) and on the number of data register bits (see PORT_DATA_WIDTH_VAL) of the used CPU, two configurations are possible:

- Simple Ready Threads Queue
- Complex Ready Threads Queue

Simple Ready Threads Queue configuration is used when the number of configured priority levels is lower or equal to the number of bits in general purpose data register. For example if application is using 9 priority levels on 32-bit CPU than simple Ready Threads Queue configuration is used. In contrast, when using 9 priority levels on an 8-bit CPU than the kernel is forced to use the Complex Ready Threads Queue configuration since 8-bit register cannot carry 9 bits of data.

7.3.1 Simple Ready Threads Queue

Each bit in `bit[0]` variable represents one priority level. The number of bits used in this variable depends on CFG_SCHED_PRIO_LVL value. If a bit at `Nth` position is set then there is a thread inserted in Thread List at `Nth` priority level.

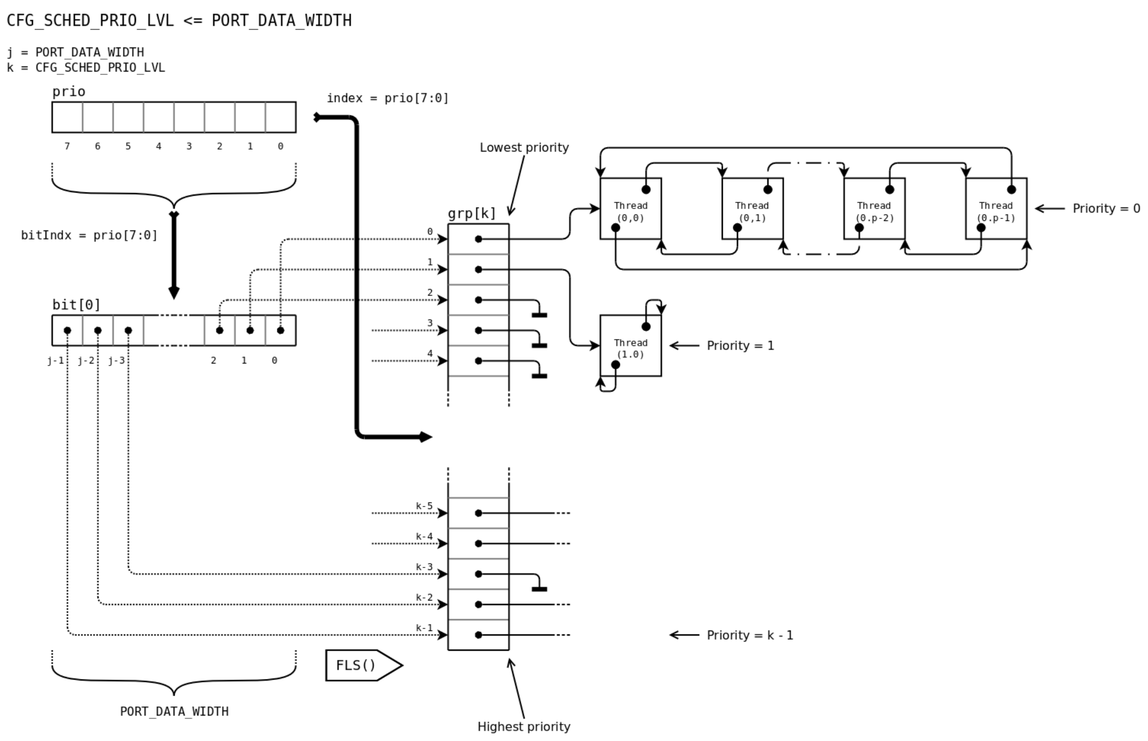


Figure 3: Ready Threads Queue - low number of priority levels

Inserting a thread

The process of a thread insertion into a thread queue can be described using the following pseudo-code:

```
function insert(thread)
    priority := thread.priority                              # Get the priority of the thread

    if (grp[priority].head == NULL)                          # If this priority level has a list
        grp[priority].head := thread                         # Create a list with this thread as head
        grp[priority].next := thread
        bitIndx := 2^priority                                # bitIndx equals to 2 raised to the power of
      priority
        bit[0]  := bit[0] or bitIndx                         # Set the calculated bit in Bit Map
    else
```

```
        listInsertAtTail(grp[priority].head, thread)        # Add thread at tail of existing list
    end if
end function
```

Removing a thread

The process of a thread removal can be described with the following pseudo-code:

```
function remove(thread)
    priority := thread.priority                             # Get the priority of the thread

    if (listIsEntryLast(thread))                            # In case we are removing the last entry
        grp[priority].head := NULL                          # List is deleted
        bitIndx := 2^priority                               # bitIndx equals to 2 raised to the power of
      priority
        bit[0]  := bit[0] and not bitIndx                   # Clear the calculated bit in Bit Map
    else
        listRemove(thread)                                  # Remove the thread from list
    end if
end function
```

Fetching the highest priority thread

The process of fetching the highest priority thread is inverse function of `2^priority` which was used in `insert()` function:

```
function fetch()
    priority := log2(bit[0])                                # Find Last Set bit position in bit[0]

    return grp[priority]
end function
```

Rotating the threads queue

The process can be described with the following algorithm:

```
function rotate()
    priority := log2(bit[0])                                # Find Last Set bit position in bit[0]

    grp[priority].next := grp[priority].next.next

    return grp[priority].next
end function
```

7.3.2 Complex Ready Threads Queue

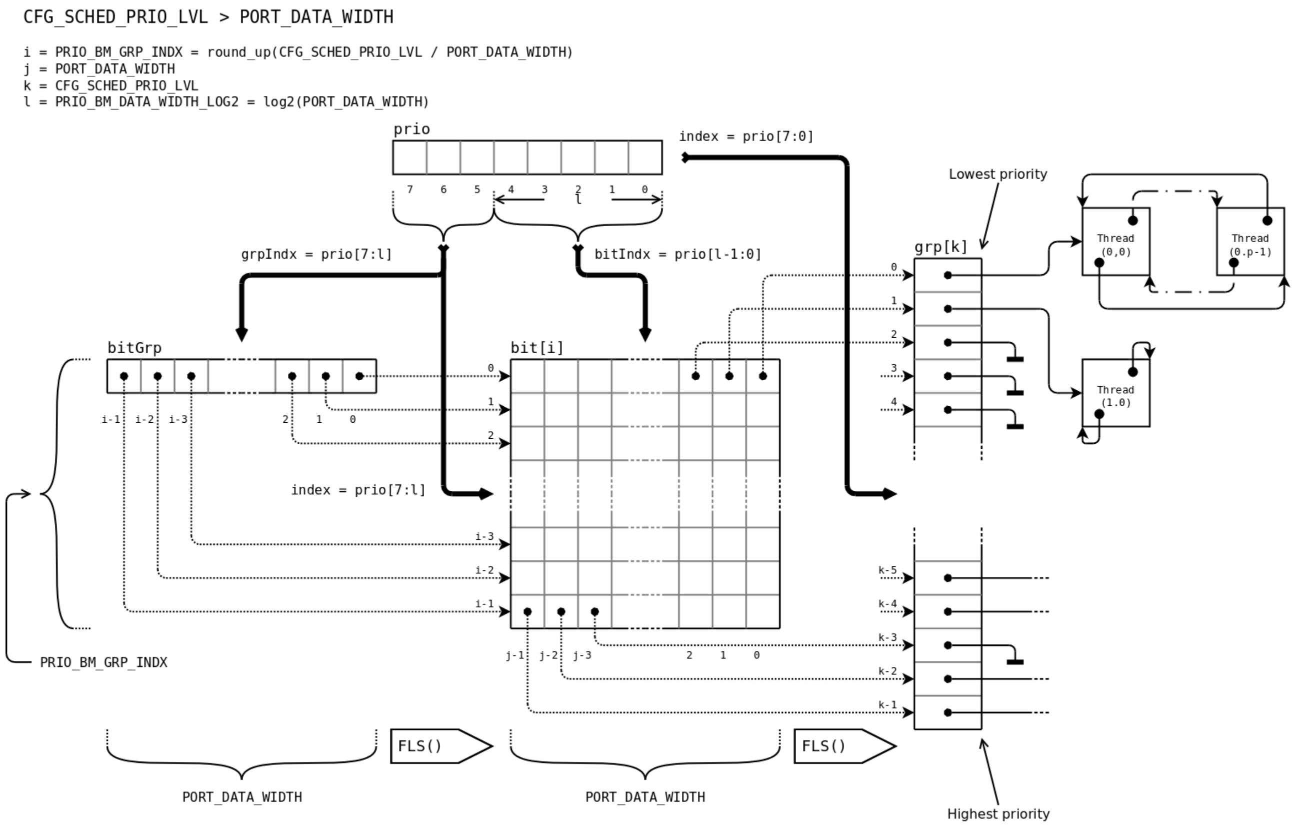


Figure 4: Ready Threads Queue - high number of priority levels

7.4 Ready Threads Queue

Ready Threads Queue holds threads that are ready for execution.

8 Error checking

How errors are detected

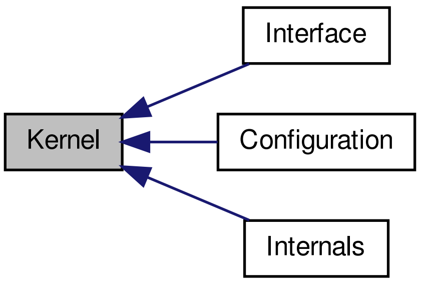
8.1 Intro

9 Module Documentation

9.1 Kernel

Overview.

Collaboration diagram for Kernel:



Modules

- Configuration

  Configuration settings.
- Interface

  Application programming interface.
- Internals

  Kernel inner work.

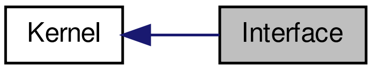
9.1.1 Detailed Description

Overview.

9.2 Interface

Application programming interface.

Collaboration diagram for Interface:



Data Structures

- struct esThd

  Thread structure.
- struct esVTmr

  Virtual Timer structure.
- struct esThdQ

  Thread Queue structure.
- struct esKernCtrl

  Kernel control block structure.

Kernel identification and version number

- #define ES_KERNEL_VER 0x10000UL

  Identifies the underlying kernel version number.
- #define ES_KERNEL_ID "eSolid Kernel v1.0"

  Kernel identification string.

Critical section management

These macros are used to prevent interrupts on entry into the critical section, and restoring interrupts to their previous state on exit from critical section.

For more details see Critical sections.

- void esKernLockEnterI (void)

  Lock the scheduler.
- void esKernLockExitI (void)

  Unlock the scheduler.
- void esKernLockEnter (void)

  Lock the scheduler.
- void esKernLockExit (void)

  Unlock the scheduler.
- #define ES_CRITICAL_DECL() PORT_CRITICAL_DECL()

  Critical section status variable declaration.
- #define ES_CRITICAL_ENTER() PORT_CRITICAL_ENTER()

  Enter a critical section.

- #define ES_CRITICAL_EXIT() PORT_CRITICAL_EXIT()

  Exit from critical section.
- #define **ES_CRITICAL_ENTER_LOCK_EXIT**()
- #define **ES_CRITICAL_EXIT_LOCK_ENTER**()

Error checking

Some basic infrastructure for error checking

These macros provide basic detection of errors. For more datails see Error checking.

- #define ES_ASSERT(expr)

  Generic assert macro.
- #define ES_API_OBLIGATION(expr) expr

  Execute code to fulfill the contract.
- #define ES_API_REQUIRE(expr) ES_ASSERT(expr)

  Make sure the caller has fulfilled all contract preconditions.
- #define ES_API_ENSURE(expr) ES_ASSERT(expr)

  Make sure the callee has fulfilled all contract postconditions.

Thread management

Basic thread management services

For more details see Thread Management.

- typedef struct esThd esThd_T

  Thread type.
- typedef portStck_T esStck_T

  Stack type.
- void esThdInit (esThd_T ∗thd, void(∗fn)(void ∗), void ∗arg, portStck_T ∗stck, size_t stckSize, uint8_t prio)

  Initialize the specified thread.
- void esThdTerm (esThd_T ∗thd)

  Terminate the specified thread.
- static PORT_C_INLINE esThd_T ∗ esThdGetId (void)

  Get the current thread ID.
- static PORT_C_INLINE uint8_t esThdGetPrio (esThd_T ∗thd)

  Get the priority of a thread.
- void esThdSetPrioI (esThd_T ∗thd, uint8_t prio)

  Set the priority of a thread.
- void esThdPostI (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdPost (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdWaitI (void)

  Wait for thread semaphore.
- void esThdWait (void)

  Wait for thread semaphore.
- #define ES_STCK_SIZE(elem) PORT_STCK_SIZE(elem)

  Converts the required stack elements into the stack array index.

Virtual Timer management

- typedef struct esVTmr esVTmr_T

  Virtual Timer type.
- void esVTmrInitI (esVTmr_T ∗vTmr, esTick_T tick, void(∗fn)(void ∗), void ∗arg)

  Add and start a new virtual timer.
- void esVTmrTerm (esVTmr_T ∗vTmr)

  Cancel and remove a virtual timer.
- void esVTmrDelay (esTick_T tick)

  Delay for specified amount of ticks.

Thread Queue management

- typedef struct esThdQ esThdQ_T

  Thread queue type.
- void esThdQInit (esThdQ_T ∗thdQ)

  Initialize Thread Queue.
- void esThdQAddI (esThdQ_T ∗thdQ, esThd_T ∗thd)

  Add a thread to the Thread Queue.
- void esThdQRmI (esThdQ_T ∗thdQ, esThd_T ∗thd)

  Removes the thread from the Thread Queue.
- esThd_T ∗ esThdQFetchI (const esThdQ_T ∗thdQ)

  Fetch the first high priority thread from the Thread Queue.
- esThd_T ∗ esThdQFetchRotateI (esThdQ_T ∗thdQ, uint_fast8_t prio)

  Fetch the next thread and rotate thread linked list.
- bool_T esThdQIsEmpty (const esThdQ_T ∗thdQ)

  Is thread queue empty.
- #define PRIO_BM_GRP_INDX ((CFG_SCHED_PRIO_LVL + PORT_DATA_WIDTH_VAL - 1U) / PORT_DATA_WIDTH_VAL)

  Priority Bit Map Group Index.

Kernel control block

- enum esKernState {
  ES_KERN_RUN = 0x00U,
  ES_KERN_INTSRV_RUN = 0x01U,
  ES_KERN_LOCK = 0x02U,
  ES_KERN_INTSRV_LOCK = 0x03U,
  ES_KERN_INIT = 0x04U,
  ES_KERN_INACTIVE = 0x05U }

  Kernel state enumeration.
- typedef enum esKernState esKernState_T

  Kernel state type.
- typedef struct esKernCtrl esKernCtrl_T

  Kernel control block type.
- const volatile esKernCtrl_T gKernCtrl

  Kernel control block.

General kernel functions

There are several groups of functions:

- kernel initialization and start
- ISR prologue and epilogue

- void esKernInit (void)

    Initialize kernel internal data structures.
- PORT_C_NORETURN void esKernStart (void)

    Start the multi-threading.
- void esKernSysTmrI (void)

    Process the system timer event.
- void esKernIsrPrologueI (void)

    Enter Interrupt Service Routine.
- void esKernIsrEpilogueI (void)

    Exit Interrupt Service Routine.

Scheduler notification and invocation

- void esSchedRdyAddI (esThd_T ∗thd)

    Add thread `thd` to the ready thread list and notify the scheduler.
- void esSchedRdyRmI (esThd_T ∗thd)

    Remove thread `thd` from the ready thread list and notify the scheduler.
- void esSchedYieldI (void)

    Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.
- void esSchedYieldIsrI (void)

    Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.

System timer management

- void esSysTmrEnable (void)

    Enable system timer tick events.
- void esSysTmrDisable (void)

    Disable system timer tick events.

Kernel hook functions

- PORT_C_NORETURN void userAssert (const char ∗fnName, const char ∗expr)

    An assertion has failed. This function should inform the user about failed assertion.
- void userSysTmr (void)

    System timer hook function, called from system system timer ISR function.
- void userKernInit (void)

    Kernel initialization hook function, called from esKernInit() function.
- void userKernStart (void)

    Kernel start hook function, called from esKernStart() function.
- void userThdInitEnd (void)

    Thread initialization end hook function, called from esThdInit() function.
- void userThdTerm (void)

Thread terminate hook function, called from esThdTerm() or when a thread terminates itself.

- void userCtxSw (esThd_T ∗oldThd, esThd_T ∗newThd)

    Kernel context switch hook function, called from esSchedYieldI() and esSchedYieldIsrI() functions.

9.2.1 Detailed Description

Application programming interface.

9.2.2 Macro Definition Documentation

9.2.2.1 #define ES_KERNEL_VER 0x10000UL

Identifies the underlying kernel version number.

Kernel identification and version (main [31:16] .sub [15:0])

9.2.2.2 #define ES_KERNEL_ID "eSolid Kernel v1.0"

Kernel identification string.

9.2.2.3 #define ES_CRITICAL_DECL( ) PORT_CRITICAL_DECL()

Critical section status variable declaration.

9.2.2.4 #define ES_CRITICAL_ENTER( ) PORT_CRITICAL_ENTER()

Enter a critical section.

9.2.2.5 #define ES_CRITICAL_EXIT( ) PORT_CRITICAL_EXIT()

Exit from critical section.

9.2.2.6 #define ES_CRITICAL_ENTER_LOCK_EXIT( )

Value:

```
do {                                                                    \
        PORT_CRITICAL_ENTER();                                              \
        esKernLockExitI();                                                  \
    } while (0U)
```

9.2.2.7 #define ES_CRITICAL_EXIT_LOCK_ENTER( )

Value:

```
do {                                                                    \
        esKernLockEnterI();                                                 \
        PORT_CRITICAL_EXIT();                                               \
    } while (0U)
```

9.2.2.8 #define ES_ASSERT(*expr*)

Value:

```
do {                                                                    \
        if (!(expr)) {                                                      \
            userAssert(PORT_C_FUNC, #expr);                                 \
        }                                                                   \
    } while (0U)
```

Generic assert macro.

Parameters

expr	Expression which must be TRUE

9.2.2.9 #define ES_API_OBLIGATION(*expr*) expr

Execute code to fulfill the contract.

Parameters

expr	Expression to be executed only if contracts need to be validated.

9.2.2.10 #define ES_API_REQUIRE(*expr*) ES_ASSERT(expr)

Make sure the caller has fulfilled all contract preconditions.

Parameters

expr	Expression which must be satisfied

9.2.2.11 #define ES_API_ENSURE(*expr*) ES_ASSERT(expr)

Make sure the callee has fulfilled all contract postconditions.

Parameters

expr	Expression which must be satisfied

9.2.2.12 #define ES_STCK_SIZE(*elem*) PORT_STCK_SIZE(elem)

Converts the required stack elements into the stack array index.

9.2.2.13 #define PRIO_BM_GRP_INDX ((CFG_SCHED_PRIO_LVL + PORT_DATA_WIDTH_VAL - 1U) / PORT_DATA_WIDTH_VAL)

Priority Bit Map Group Index.

Object class:

Not API object, this object is not part of the application programming interface and it is intended for internal use only.

9.2.3 Typedef Documentation

9.2.3.1 typedef struct esThd esThd_T

Thread type.

9.2.3.2 typedef portStck_T esStck_T

Stack type.

9.2.3.3 typedef struct esVTmr esVTmr_T

Virtual Timer type.

9.2.3.4 typedef struct esThdQ esThdQ_T

Thread queue type.

9.2.3.5 typedef enum esKernState esKernState_T

Kernel state type.

9.2.3.6 typedef struct esKernCtrl esKernCtrl_T

Kernel control block type.

9.2.4 Enumeration Type Documentation

9.2.4.1 enum esKernState

Kernel state enumeration.

For more details see: Kernel states

Object class:

Regular **API** object, this object is part of the application programming interface.

Enumerator

ES_KERN_RUN	Kernel is active
ES_KERN_INTSRV_RUN	Servicing an interrupt return to ES_KERN_RUN state
ES_KERN_LOCK	Kernel is locked
ES_KERN_INTSRV_LOCK	Servicing an interrupt, return to ES_KERN_LOCK state
ES_KERN_INIT	Kernel is in initialization state
ES_KERN_INACTIVE	Kernel data structures are not initialized

9.2.5 Function Documentation

9.2.5.1 void esKernInit (void)

Initialize kernel internal data structures.

Precondition

1) `The kernel state == ES_KERN_INACTIVE`, see Kernel states.

Postcondition

1) `The kernel state == ES_KERN_INIT.`

Note

1) This function may be invoked only once.

This function must be called first before any other kernel API. It initializes internal data structures that are used by other API functions.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.2 PORT_C_NORETURN void esKernStart (void)

Start the multi-threading.

Precondition

1) `The kernel state == ES_KERN_INIT`, see Kernel states.
2) At least one thread must be initialized and be in Threads Ready Queue before starting multi-threading, see esThdInit().

Postcondition

1) `The kernel state == ES_KERN_RUN`
2) The multi-threading execution will commence.

Note

1) Once this function is called the execution of threads will start and this function will never return.

This function will start multi-threading. Once the multi-threading has started the execution will never return to this function again (this function never returns).

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.3 void esKernSysTmrI (void)

Process the system timer event.

Precondition

1) `The kernel state < ES_KERN_INIT`, see Kernel states.

This function will be called only by port system timer interrupt.

Object class:

Not API object, this object is not part of the application programming interface and it is intended for internal use only.

9.2.5.4 void esKernIsrPrologueI (void)

Enter Interrupt Service Routine.

Precondition

1) `The kernel state < ES_KERN_INIT`, see Kernel states.

Note

1) You must call esKernIsrEpilogueI() at the exit of ISR.
2) You must invoke esKernIsrPrologueI() and esKernIsrEpilogueI() in pair. In other words, for every call to es-KernIsrPrologueI() at the beginning of the ISR you must have a call to esKernIsrEpilogueI() at the end of the ISR.

Function will notify kernel that you are about to enter interrupt service routine (ISR). This allows kernel to keep track of interrupt nesting and then only perform rescheduling at the last nested ISR.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.5 void esKernIsrEpilogueI (void)

Exit Interrupt Service Routine.

Precondition

1) `The kernel state < ES_KERN_INIT`, see Kernel states.

Note

1) You must invoke esKernIsrPrologueI() and esKernIsrEpilogueI() in pair. In other words, for every call to esKernIsrPrologueI() at the beginning of the ISR you must have a call to esKernIsrEpilogueI() at the end of the ISR.
2) Rescheduling is prevented when the scheduler is locked (see esKernLockEnterI())

This function is used to notify kernel that you have completed servicing an interrupt. When the last nested ISR has completed, the function will call the scheduler to determine whether a new, high-priority task, is ready to run.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.6 void esKernLockEnterI (void)

Lock the scheduler.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.7 void esKernLockExitI (void)

Unlock the scheduler.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.8 void esKernLockEnter (void)

Lock the scheduler.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.9 void esKernLockExit (void)

Unlock the scheduler.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.10 void esThdInit (esThd_T * *thd*, void(*)(void *) *fn*, void * *arg*, portStck_T * *stck*, size_t *stckSize*, uint8_t *prio*)

Initialize the specified thread.

Parameters

thd	Thread: is a pointer to the thread structure, esThd. The structure will be used as information container for the thread. It is assumed that storage for the `esThd` structure is allocated by the user code.
fn	Function: is a pointer to thread function. Thread function must have the following signature: `void thread (void * arg)`.
arg	Argument: is a void pointer to an optional data area. It's usage is application defined and it is intended to pass arguments to thread when it is started for the first time.
stck	Stack: is a pointer to a allocated memory for thread stack. The pointer always points to the first element in the array, regardless of what type of stack the CPU is using. The thread's stack is used to store local variables, function parameters, return addresses. Each thread has its own stack and different sized stack. The stack type must be an array of portStck.
stckSize	Stack Size: specifies the size of allocated stack memory. Size is expressed in bytes. Please see port documentation about minimal stack size.
prio	Priority: is the priority of the thread. The higher the number, the higher the priority (the importance) of the thread. Several threads can have the same priority.

Precondition

1) `The kernel state ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thdf != NULL`
4) `stckSize >= PORT_STCK_MINSIZE_VAL`, see PORT_STCK_MINSIZE_VAL.
5) `0 <= prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

Postcondition

1) `thd->signature == THD_CONTRACT_SIGNATURE`, each esThd structure will have valid signature after initialization.

Threads must be created in order for kernel to recognize them as threads. Initialize a thread by calling esThdInit() and provide arguments specifying to kernel how the thread will be managed. Threads are always created in the `ready-to-run` state. Threads can be created either prior to the start of multi-threading (before calling esKernStart()), or by a running thread.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.11 void esThdTerm (esThd_T * *thd*)

Terminate the specified thread.

Parameters

thd	Thread: is a pointer to the thread structure, esThd.

Precondition

1) `The kernel state ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `(thd->thdL.q == NULL) OR (thd->thdL.q == gRdyQueue)`, thread must be either in Ready Threads Queue or not be in any queue (e.g. not waiting for a synchronization mechanism).

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.12 static PORT_C_INLINE esThd_T* esThdGetId (void) [static]

Get the current thread ID.

Returns

Pointer to current thread ID structure esThd.

Note

This is `inline` function.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.13 static PORT_C_INLINE uint8_t esThdGetPrio (esThd_T * *thd*) [static]

Get the priority of a thread.

Parameters

thd	Thread: is pointer to the thread structure, esThd.

Returns

The priority of the thread pointed by `thd`.

Note

This is `inline` function.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.14 void esThdSetPrioI (esThd_T * *thd,* uint8_t *prio*)

Set the priority of a thread.

Parameters

thd	Thread: is pointer to the thread structure, esThd.
prio	Priority: is new priority of the thread pointed by `thd`.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `0 <= prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.15 void esThdPostI (esThd_T ∗ *thd*)

Post to thread semaphore.

Parameters

thd	Pointer to the thread ID structure

Function class:

> **I class** API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.16 void esThdPost (esThd_T ∗ *thd*)

Post to thread semaphore.

Parameters

thd	Pointer to the thread ID structure

Object class:

> Regular **API** object, this object is part of the application programming interface.

9.2.5.17 void esThdWaitI (void)

Wait for thread semaphore.

Function class:

> **I class** API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.18 void esThdWait (void)

Wait for thread semaphore.

Object class:

> Regular **API** object, this object is part of the application programming interface.

9.2.5.19 void esThdQInit (esThdQ_T ∗ *thdQ*)

Initialize Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.

Precondition

> 1) `thdQ != NULL`

Postcondition

> 1) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, each esThdQ structure will have valid signature after initialization.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.20 void esThdQAddI (**esThdQ_T** ∗ *thdQ*, **esThd_T** ∗ *thd*)

Add a thread to the Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.
thd	Thread: is a pointer to the thread ID structure, esThd.

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
3) `thd != NULL`
4) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
5) `thd->thdL.q == NULL`, thread must not be in any queue.
6) `0 <= thd->prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

This function adds a thread at the specified Thread Queue.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.21 void esThdQRmI (**esThdQ_T** ∗ *thdQ*, **esThd_T** ∗ *thd*)

Removes the thread from the Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.
thd	Thread: is a pointer to the thread ID structure, esThd.

Precondition

1) `thd != NULL`
2) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
3) `thdQ != NULL`
4) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
5) `thd->thdL.q == thdQ`, thread must be in the `thdQ` queue.
6) `0 <= thd->prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.22 **esThd_T**∗ esThdQFetchI (const **esThdQ_T** ∗ *thdQ*)

Fetch the first high priority thread from the Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.

Returns

A pointer to the thread ID structure with the highest priority.

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
3) `prioBM != 0`, priority bit map must not be empty

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.23 esThd_T∗ esThdQFetchRotateI (esThdQ_T ∗ *thdQ*, uint_fast8_t *prio*)

Fetch the next thread and rotate thread linked list.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ. This is the thread queue to fetch from.
prio	Priority: is the priority level to fetch and rotate.

Returns

Pointer to the next thread in queue.

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
3) `0 <= prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.
4) `sentinel != NULL`, at least one thread must be in the selected priority level

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.24 bool_T esThdQIsEmpty (const esThdQ_T ∗ *thdQ*)

Is thread queue empty.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.

Returns

The state of thread queue

Return values

TRUE	- thread queue is empty
FALSE	- thread queue is not empty

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.25 void esSchedRdyAddI (**esThd_T** ∗ *thd*)

Add thread `thd` to the ready thread list and notify the scheduler.

Parameters

thd	Pointer to the initialized thread ID structure, esThd.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `thd->thdL.q == NULL`, thread must not be in a queue.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.26 void esSchedRdyRmI (**esThd_T** ∗ *thd*)

Remove thread `thd` from the ready thread list and notify the scheduler.

Parameters

thd	Pointer to the initialized thread ID structure, esThd.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `thd->thdL.q == &gRdyQueue`, thread must be in Ready Threads queue.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.27 void esSchedYieldI (void)

Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.

Warning

Scheduler will have undefined behavior if there is no ready thread to run (e.g. empty gRdyQueue) at the time it is invoked.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.28 void esSchedYieldIsrI (void)

Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.

Warning

Scheduler will have undefined behavior if there is no ready thread to run (e.g. empty gRdyQueue) at the time it is invoked.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.29 void esSysTmrEnable (void)

Enable system timer tick events.

This function will override scheduler power savings algorithm and force the system timer into running (active) state.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.30 void esSysTmrDisable (void)

Disable system timer tick events.

This function will try to switch off the system timer. If the system timer is used by scheduler than the scheduler will take control of the system timer.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.31 void esVTmrInitI (esVTmr_T ∗ *vTmr,* esTick_T *tick,* void(∗)(void ∗) *fn,* void ∗ *arg*)

Add and start a new virtual timer.

Parameters

vTmr	Virtual Timer: is pointer to the timer ID structure, esVTmr.
tick	Tick: the timer delay expressed in system ticks
fn	Function: is pointer to the callback function
arg	Argument: is pointer to the arguments of callback function

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `vTmr != NULL`
3) `tick > 1U`
4) `fn != NULL`

Postcondition

1) `vTmr->signature == VTMR_CONTRACT_SIGNATURE`, each esVTmr structure will have valid signature after initialization.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.32 void esVTmrTerm (esVTmr_T * *vTmr*)

Cancel and remove a virtual timer.

Parameters

vTmr	Timer: is pointer to the timer ID structure, esVTmr.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `vTmr != NULL`
3) `vTmr->signature == VTMR_CONTRACT_SIGNATURE`, the pointer must point to a esVTmr structure.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.2.5.33 void esVTmrDelay (esTick_T *tick*)

Delay for specified amount of ticks.

Parameters

tick	Tick: number of system ticks to delay.

This function will create a virtual timer with count down time specified in argument `tick` and put the calling thread into `sleep` state. When timeout expires the thread will be placed back into `ready` state.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.2.5.34 PORT_C_NORETURN void userAssert (const char * *fnName,* const char * *expr*)

An assertion has failed. This function should inform the user about failed assertion.

Parameters

fnName	Function name: is pointer to the function name string where the assertion has failed. Macro will automatically fill in the function name.
expr	Expression: is pointer to the string containing the expression that failed to evaluate to `TRUE`.

Precondition

1) `NULL != fnName`
2) `NULL != expr`

Note

1) The definition of this function must be written by the user.
2) This function is called only if CFG_API_VALIDATION is active.

Function will just print the information which was given by the macros. After the function informs the user it **must** go into infinite loop or HALT the processor.

9.2.5.35 void userSysTmr (void)

System timer hook function, called from system system timer ISR function.

Note

1) The definition of this function must be written by the user.
2) This function is called only if CFG_HOOK_SYSTMR_EVENT is active.

This function is called whenever a system event is generated.

9.2.5.36 void userKernInit (void)

Kernel initialization hook function, called from esKernInit() function.

Note

1) The definition of this function must be written by the user.
2) This function is called only if CFG_HOOK_KERN_INIT is active.

This function is called before kernel initialization.

9.2.5.37 void userKernStart (void)

Kernel start hook function, called from esKernStart() function.

Note

1) The definition of this function must be written by the user.
2) This function is called only if CFG_HOOK_KERN_START is active.

This function is called before kernel start.

9.2.5.38 void userThdInitEnd (void)

Thread initialization end hook function, called from esThdInit() function.

Note

1) The definition of this function must be written by the user.
2) This function is called only if CFG_HOOK_THD_INIT_END is active.

This function is called after the thread initialization.

9.2.5.39 void userThdTerm (void)

Thread terminate hook function, called from esThdTerm() or when a thread terminates itself.

Note

1) The definition of this function must be written by the user.
2) This function is called only if CFG_HOOK_THD_TERM is active.

9.2.5.40 void userCtxSw (esThd_T * *oldThd*, esThd_T * *newThd*)

Kernel context switch hook function, called from esSchedYieldI() and esSchedYieldIsrI() functions.

Parameters

oldThd	Pointer to the thread being switched out.
newThd	Pointer to the thread being switched in.

Note

1) The definition of this function must be written by the user.
2) This function is called only if CFG_HOOK_CTX_SW is active.

This function is called at each context switch.

9.2.6 Variable Documentation

9.2.6.1 const volatile esKernCtrl_T gKernCtrl

Kernel control block.

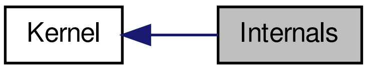
Note

This variable has Read-Only access rights for application.

9.3 Internals

Kernel inner work.

Collaboration diagram for Internals:



Data Structures

- struct sysTmr

  Main System Timer structure.

Macros

- #define PRIO_BM_DATA_WIDTH_LOG2

  Priority Bit Map log base 2: `log2(PORT_DATA_WIDTH_VAL)`
- #define SCHED_STATE_INTSRV_MSK (1U << 0)

  Kernel state variable bit position which defines if kernel is in interrupt servicing state.
- #define SCHED_STATE_LOCK_MSK (1U << 1)

  Kernel state variable bit position which defines if the kernel is locked or not.
- #define SYSTMR_SCHED_QM_MSK (1U << 0)

  Scheduler is using system timer Quantum mask.
- #define SYSTMR_USR_QM_MSK (1U << 1)

  User is using system timer Quantum mask.
- #define SCHED_POWER_SAVE 0U

  Enable/disable scheduler power savings mode.
- #define THD_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEFU)

  Thread structure signature.
- #define THDQ_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEEU)

  Thread Queue structure signature.
- #define VTMR_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEFU)

  Timer structure signature.
- #define DLIST_IS_ENTRY_FIRST(list, entry) ((entry) == (entry)->list.next)

  DList macro: is the thread the first one in the list.
- #define DLIST_IS_ENTRY_LAST(list, entry) DLIST_IS_ENTRY_FIRST(list, entry)

  DList macro: is the thread the last one in the list.
- #define DLIST_IS_ENTRY_SINGLE(list, entry) DLIST_IS_ENTRY_FIRST(list, entry)

  DList macro: is the thread single in the list.
- #define DLIST_ENTRY_PREV(list, entry) (entry)->list.prev

  Get the previous entry.
- #define DLIST_ENTRY_NEXT(list, entry) (entry)->list.next

  Get the next entry.
- #define DLIST_ENTRY_INIT(list, entry)

Initialize entry.

- #define DLIST_ENTRY_ADD_AFTER(list, current, entry)

  Add new `entry` *after* `current` *entry.*
- #define DLIST_ENTRY_RM(list, entry)

  Remove the `entry` *from a list.*
- #define KVTMR_STCK_SIZE PORT_STCK_SIZE(40U)

  System Timer kernel thread stack size.
- #define KIDLE_STCK_SIZE PORT_STCK_SIZE(40U)

  Idle kernel thread stack size.

Functions

- static void **vTmrExecHandlers** (void)
- static void **vTmrImport** (void)
- void esKernInit (void)

  Initialize kernel internal data structures.
- PORT_C_NORETURN void esKernStart (void)

  Start the multi-threading.
- void esKernSysTmrI (void)

  Process the system timer event.
- void esKernLockEnterI (void)

  Lock the scheduler.
- void esKernLockExitI (void)

  Unlock the scheduler.
- void esKernLockEnter (void)

  Lock the scheduler.
- void esKernLockExit (void)

  Unlock the scheduler.
- void esKernIsrPrologueI (void)

  Enter Interrupt Service Routine.
- void esKernIsrEpilogueI (void)

  Exit Interrupt Service Routine.
- void esThdInit (esThd_T ∗thd, void(∗fn)(void ∗), void ∗arg, portStck_T ∗stck, size_t stckSize, uint8_t prio)

  Initialize the specified thread.
- void esThdTerm (esThd_T ∗thd)

  Terminate the specified thread.
- void esThdSetPrioI (esThd_T ∗thd, uint8_t prio)

  Set the priority of a thread.
- void esThdPostI (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdPost (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdWaitI (void)

  Wait for thread semaphore.
- void esThdWait (void)

  Wait for thread semaphore.
- void esThdQInit (esThdQ_T ∗thdQ)

  Initialize Thread Queue.
- void esThdQAddI (esThdQ_T ∗thdQ, esThd_T ∗thd)

  Add a thread to the Thread Queue.
- void esThdQRmI (esThdQ_T ∗thdQ, esThd_T ∗thd)

Removes the thread from the Thread Queue.
- esThd_T ∗ esThdQFetchI (const esThdQ_T ∗thdQ)

  Fetch the first high priority thread from the Thread Queue.
- esThd_T ∗ esThdQFetchRotateI (esThdQ_T ∗thdQ, uint_fast8_t prio)

  Fetch the next thread and rotate thread linked list.
- bool_T esThdQIsEmpty (const esThdQ_T ∗thdQ)

  Is thread queue empty.
- void esSchedRdyAddI (esThd_T ∗thd)

  Add thread `thd` to the ready thread list and notify the scheduler.
- void esSchedRdyRmI (esThd_T ∗thd)

  Remove thread `thd` from the ready thread list and notify the scheduler.
- void esSchedYieldI (void)

  Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.
- void esSchedYieldIsrI (void)

  Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.
- void esSysTmrEnable (void)

  Enable system timer tick events.
- void esSysTmrDisable (void)

  Disable system timer tick events.
- void esVTmrInitI (esVTmr_T ∗vTmr, esTick_T tick, void(∗fn)(void ∗), void ∗arg)

  Add and start a new virtual timer.
- void **esVTmrInit** (esVTmr_T ∗vTmr, esTick_T tick, void(∗fn)(void ∗), void ∗arg)
- void esVTmrTerm (esVTmr_T ∗vTmr)

  Cancel and remove a virtual timer.
- void esVTmrDelay (esTick_T tick)

  Delay for specified amount of ticks.

Variables

- static uint_fast8_t gKernLockCnt

  Kernel Lock Counter.
- const volatile esKernCtrl_T gKernCtrl

  Kernel control initialization.

System timer

- enum sysTmrState {
  SYSTMR_ACTIVE,
  SYSTMR_INACTIVE }

  System timer state enumeration.
- typedef struct sysTmr sysTmr_T

  System Timer type.
- static void sysTmrInit (void)

  Initialize system timer hardware.
- static void sysTmrTryDeactivate (void)

  Try to deactivate system timer.
- static void sysTmrTryActivate (void)

  Try to activate system timer.

Priority Bit Map

- typedef struct prioBM prioBM_T

  Priority Bit Map type.
- static PORT_C_INLINE void prioBMInit (prioBM_T ∗bm)

  Initialize bitmap.
- static PORT_C_INLINE void prioBMSet (prioBM_T ∗bm, uint_fast8_t prio)

  Set the bit corresponding to the prio argument.
- static PORT_C_INLINE void prioBMClear (prioBM_T ∗bm, uint_fast8_t prio)

  Clear the bit corresponding to the prio argument.
- static PORT_C_INLINE uint_fast8_t prioBMGet (const prioBM_T ∗bm)

  Get the highest priority set.
- static PORT_C_INLINE bool_T prioBMIsEmpty (const prioBM_T ∗bm)

  Is bit map empty?

Threads Queue

- typedef struct thdLSentinel thdLSentinel_T

  Thread list sentinel type.

Scheduler

- static esThdQ_T gRdyQueue

  Ready Thread queue.
- static PORT_C_INLINE void schedInit (void)

  Initialize Ready Thread Queue structure gRdyQueue and Kernel control structure esKernCtrl.
- static PORT_C_INLINE void schedStart (void)

  Set scheduler data structures ready for multi-threading.
- static void schedRdyAddInitI (esThd_T ∗thd)

  Initialize scheduler ready structure during the thread add operation.
- static void schedQmI (void)

  Do the Quantum (Round-Robin) scheduling.
- static PORT_C_INLINE void schedQmActivate (void)

  Activate system timer Quantum mode.
- static PORT_C_INLINE void schedQmDeactivate (void)

  Deactivate system timer Quantum mode.
- static void schedQmEvaluateI (esThd_T ∗thd)

  Evaluate if the system timer Quantum mode is needed.

Virtual Timer kernel thread

- static void vTmrListAddSort (esVTmr_T ∗list, esVTmr_T ∗vTmr)

  Add a virtual timer into sorted list.
- static void kVTmrInit (void)

  Initialization of Virtual Timer kernel thread.
- static void kVTmr (void ∗arg)

  Virtual Timer thread code.

Idle kernel thread

- static esThd_T gKIdleId

  Idle thread ID.
- static portStck_T gKIdleStck [KIDLE_STCK_SIZE]

  Idle kernel thread stack.
- static void kIdleInit (void)

  Initialization of Idle thread.
- static void kIdle (void ∗arg)

  Idle thread code.

System timer kernel thread

- static sysTmr_T gSysTmr

  Main System Timer structure.
- static esVTmr_T gVTmrArmed

  List of virtual timers to armed expire.
- static esVTmr_T gVTmrPend

  Virtual timers pending to be inserted into waiting list.
- static esThd_T gKVTmrId

  Virtual timer thread ID.
- static portStck_T gKVTmrStck [KVTMR_STCK_SIZE]

  Virtual timer kernel thread stack.

9.3.1 Detailed Description

Kernel inner work.

9.3.2 Macro Definition Documentation

9.3.2.1 #define PRIO_BM_DATA_WIDTH_LOG2

Value:

```
(PORT_DATA_WIDTH_VAL <   2 ? 0 :                                              \
     (PORT_DATA_WIDTH_VAL <   4 ? 1 :                                             \
      (PORT_DATA_WIDTH_VAL <   8 ? 2 :                                            \
       (PORT_DATA_WIDTH_VAL <  16 ? 3 :                                           \
        (PORT_DATA_WIDTH_VAL <  32 ? 4 :                                          \
         (PORT_DATA_WIDTH_VAL <  64 ? 5 :                                         \
          (PORT_DATA_WIDTH_VAL < 128 ? 6 : 7)))))))
```

Priority Bit Map log base 2: `log2(PORT_DATA_WIDTH_VAL)`

9.3.2.2 #define SCHED_STATE_INTSRV_MSK (1U << 0)

Kernel state variable bit position which defines if kernel is in interrupt servicing state.

9.3.2.3 #define SCHED_STATE_LOCK_MSK (1U << 1)

Kernel state variable bit position which defines if the kernel is locked or not.

9.3.2.4 #define SYSTMR_SCHED_QM_MSK (1U << 0)

Scheduler is using system timer Quantum mask.

9.3.2.5 #define SYSTMR_USR_QM_MSK (1U << 1)

User is using system timer Quantum mask.

9.3.2.6 #define SCHED_POWER_SAVE 0U

Enable/disable scheduler power savings mode.

9.3.2.7 #define THD_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEFU)

Thread structure signature.

The signature is used to confirm that a structure passed to a kernel function is indeed a esThd_T thread structure.

9.3.2.8 #define THDQ_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEEU)

Thread Queue structure signature.

The signature is used to confirm that a structure passed to a kernel function is indeed a esThdQ_T thread queue structure.

9.3.2.9 #define VTMR_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEFU)

Timer structure signature.

The signature is used to confirm that a structure passed to a timer function is indeed a esVTmr_T timer structure.

9.3.2.10 #define DLIST_IS_ENTRY_FIRST(*list,* *entry*) ((entry) == (entry)->list.next)

DList macro: is the thread the first one in the list.

9.3.2.11 #define DLIST_IS_ENTRY_LAST(*list,* *entry*) DLIST_IS_ENTRY_FIRST(list, entry)

DList macro: is the thread the last one in the list.

9.3.2.12 #define DLIST_IS_ENTRY_SINGLE(*list,* *entry*) DLIST_IS_ENTRY_FIRST(list, entry)

DList macro: is the thread single in the list.

9.3.2.13 #define DLIST_ENTRY_PREV(*list,* *entry*) (entry)->list.prev

Get the previous entry.

9.3.2.14 #define DLIST_ENTRY_NEXT(*list,* *entry*) (entry)->list.next

Get the next entry.

9.3.2.15 #define DLIST_ENTRY_INIT(*list,* *entry*)

Value:

```
do {                                                                    \
        (entry)->list.next = (entry);                                       \
        (entry)->list.prev = (entry);                                       \
    } while (0U)
```

Initialize entry.

9.3.2.16 #define DLIST_ENTRY_ADD_AFTER(*list,* *current,* *entry*)

Value:

```
do {                                                                    \
        (entry)->list.next = (current);                                     \
        (entry)->list.prev = (entry)->list.next->list.prev;                 \
        (entry)->list.next->list.prev = (entry);                          \
        (entry)->list.prev->list.next = (entry);                          \
    } while (0U)
```

Add new `entry` after `current` entry.

9.3.2.17 #define DLIST_ENTRY_RM(*list*, *entry*)

Value:

```
do {                                                                   \
        (entry)->list.next->list.prev = (entry)->list.prev;               \
        (entry)->list.prev->list.next = (entry)->list.next;               \
    } while (0U)
```

Remove the `entry` from a list.

9.3.2.18 #define KVTMR_STCK_SIZE PORT_STCK_SIZE(40U)

System Timer kernel thread stack size.

9.3.2.19 #define KIDLE_STCK_SIZE PORT_STCK_SIZE(40U)

Idle kernel thread stack size.

9.3.3 Typedef Documentation

9.3.3.1 typedef struct sysTmr sysTmr_T

System Timer type.

9.3.3.2 typedef struct prioBM prioBM_T

Priority Bit Map type.

9.3.3.3 typedef struct thdLSentinel thdLSentinel_T

Thread list sentinel type.

9.3.4 Enumeration Type Documentation

9.3.4.1 enum sysTmrState

System timer state enumeration.

Enumerator

SYSTMR_ACTIVE	System timer is running.
SYSTMR_INACTIVE	System timer is stopped.

9.3.5 Function Documentation

9.3.5.1 static PORT_C_INLINE void prioBMInit (prioBM_T * *bm*) `[static]`

Initialize bitmap.

Parameters

bm	Pointer to the bit map structure

9.3.5.2 static PORT_C_INLINE void prioBMSet (prioBM_T ∗ *bm*, uint_fast8_t *prio*) [static]

Set the bit corresponding to the prio argument.

Parameters

bm	Pointer to the bit map structure
prio	Priority which will be marked as used

9.3.5.3 static PORT_C_INLINE void prioBMClear (prioBM_T ∗ *bm*, uint_fast8_t *prio*) [static]

Clear the bit corresponding to the prio argument.

Parameters

bm	Pointer to the bit map structure
prio	Priority which will be marked as unused

9.3.5.4 static PORT_C_INLINE uint_fast8_t prioBMGet (const prioBM_T ∗ *bm*) [static]

Get the highest priority set.

Parameters

bm	Pointer to the bit map structure

Returns

The number of the highest priority marked as used

9.3.5.5 static PORT_C_INLINE bool_T prioBMIsEmpty (const prioBM_T ∗ *bm*) [static]

Is bit map empty?

Parameters

bm	Pointer to the bit map structure

Returns

The status of the bit map

Return values

TRUE	- bit map is empty
FALSE	- there is at least one bit set

9.3.5.6 static PORT_C_INLINE void schedInit (void) [static]

Initialize Ready Thread Queue structure gRdyQueue and Kernel control structure esKernCtrl.

9.3.5.7 static PORT_C_INLINE void schedStart (void) [static]

Set scheduler data structures ready for multi-threading.

This function is called just before multi-threading has commenced.

9.3.5.8 static void schedRdyAddInitI (esThd_T * *thd*) [static]

Initialize scheduler ready structure during the thread add operation.

Parameters

thd	Pointer to the thread currently being initialized.

Function will initialize scheduler structures during the init phase of the kernel.

9.3.5.9 static void schedQmI (void) [static]

Do the Quantum (Round-Robin) scheduling.

9.3.5.10 static PORT_C_INLINE void schedQmActivate (void) [static]

Activate system timer Quantum mode.

9.3.5.11 static PORT_C_INLINE void schedQmDeactivate (void) [static]

Deactivate system timer Quantum mode.

9.3.5.12 static void schedQmEvaluateI (esThd_T * *thd*) [static]

Evaluate if the system timer Quantum mode is needed.

Parameters

thd	Pointer to the thread which is ready to be executed

9.3.5.13 static void sysTmrInit (void) [static]

Initialize system timer hardware.

9.3.5.14 static void sysTmrTryDeactivate (void) [static]

Try to deactivate system timer.

9.3.5.15 static void sysTmrTryActivate (void) [static]

Try to activate system timer.

9.3.5.16 static void vTmrListAddSort (esVTmr_T * *list*, esVTmr_T * *vTmr*) [static]

Add a virtual timer into sorted list.

Parameters

list	List: pointer to sorted list
tmr	Virtual timer: pointer to virtual timer to add

9.3.5.17 static void kVTmrInit (void) [static]

Initialization of Virtual Timer kernel thread.

9.3.5.18 static void kVTmr (void * *arg*) [static]

Virtual Timer thread code.

Parameters

arg	Argument: thread does not use argument

9.3.5.19 static void kIdleInit (void) `[static]`

Initialization of Idle thread.

9.3.5.20 static void kIdle (void * *arg*) `[static]`

Idle thread code.

Parameters

arg	Argument: thread does not use argument

9.3.5.21 void esKernInit (void)

Initialize kernel internal data structures.

Precondition

1) `The kernel state == ES_KERN_INACTIVE`, see Kernel states.

Postcondition

1) `The kernel state == ES_KERN_INIT.`

Note

1) This function may be invoked only once.

This function must be called first before any other kernel API. It initializes internal data structures that are used by other API functions.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.22 PORT_C_NORETURN void esKernStart (void)

Start the multi-threading.

Precondition

1) `The kernel state == ES_KERN_INIT`, see Kernel states.
2) At least one thread must be initialized and be in Threads Ready Queue before starting multi-threading, see esThdInit().

Postcondition

1) `The kernel state == ES_KERN_RUN`
2) The multi-threading execution will commence.

Note

1) Once this function is called the execution of threads will start and this function will never return.

This function will start multi-threading. Once the multi-threading has started the execution will never return to this function again (this function never returns).

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.23 void esKernSysTmrI (void)

Process the system timer event.

Precondition

1) `The kernel state < ES_KERN_INIT`, see Kernel states.

This function will be called only by port system timer interrupt.

Object class:

Not API object, this object is not part of the application programming interface and it is intended for internal use only.

9.3.5.24 void esKernLockEnterI (void)

Lock the scheduler.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.25 void esKernLockExitI (void)

Unlock the scheduler.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.26 void esKernLockEnter (void)

Lock the scheduler.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.27 void esKernLockExit (void)

Unlock the scheduler.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.28 void esKernIsrPrologueI (void)

Enter Interrupt Service Routine.

Precondition

1) `The kernel state < ES_KERN_INIT`, see Kernel states.

Note

1) You must call esKernIsrEpilogueI() at the exit of ISR.
2) You must invoke esKernIsrPrologueI() and esKernIsrEpilogueI() in pair. In other words, for every call to esKernIsrPrologueI() at the beginning of the ISR you must have a call to esKernIsrEpilogueI() at the end of the ISR.

Function will notify kernel that you are about to enter interrupt service routine (ISR). This allows kernel to keep track of interrupt nesting and then only perform rescheduling at the last nested ISR.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.29 void esKernIsrEpilogueI (void)

Exit Interrupt Service Routine.

Precondition

1) `The kernel state < ES_KERN_INIT`, see Kernel states.

Note

1) You must invoke esKernIsrPrologueI() and esKernIsrEpilogueI() in pair. In other words, for every call to esKernIsrPrologueI() at the beginning of the ISR you must have a call to esKernIsrEpilogueI() at the end of the ISR.
2) Rescheduling is prevented when the scheduler is locked (see esKernLockEnterI())

This function is used to notify kernel that you have completed servicing an interrupt. When the last nested ISR has completed, the function will call the scheduler to determine whether a new, high-priority task, is ready to run.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.30 void esThdInit (esThd_T $*$ *thd*, void($*$)(void $*$) *fn*, void $*$ *arg*, portStck_T $*$ *stck*, size_t *stckSize*, uint8_t *prio*)

Initialize the specified thread.

Parameters

thd	Thread: is a pointer to the thread structure, esThd. The structure will be used as information container for the thread. It is assumed that storage for the `esThd` structure is allocated by the user code.
fn	Function: is a pointer to thread function. Thread function must have the following signature: `void thread (void * arg)`.
arg	Argument: is a void pointer to an optional data area. It's usage is application defined and it is intended to pass arguments to thread when it is started for the first time.
stck	Stack: is a pointer to a allocated memory for thread stack. The pointer always points to the first element in the array, regardless of what type of stack the CPU is using. The thread's stack is used to store local variables, function parameters, return addresses. Each thread has its own stack and different sized stack. The stack type must be an array of portStck.
stckSize	Stack Size: specifies the size of allocated stack memory. Size is expressed in bytes. Please see port documentation about minimal stack size.
prio	Priority: is the priority of the thread. The higher the number, the higher the priority (the importance) of the thread. Several threads can have the same priority.

Precondition

1) `The kernel state ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thdf != NULL`
4) `stckSize >= PORT_STCK_MINSIZE_VAL`, see PORT_STCK_MINSIZE_VAL.
5) `0 <= prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

Postcondition

1) `thd->signature == THD_CONTRACT_SIGNATURE`, each esThd structure will have valid signature after initialization.

Threads must be created in order for kernel to recognize them as threads. Initialize a thread by calling esThdInit() and provide arguments specifying to kernel how the thread will be managed. Threads are always created in the `ready-to-run` state. Threads can be created either prior to the start of multi-threading (before calling esKernStart()), or by a running thread.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.31 void esThdTerm (**esThd_T** ∗ *thd*)

Terminate the specified thread.

Parameters

thd	Thread: is a pointer to the thread structure, esThd.

Precondition

1) `The kernel state ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `(thd->thdL.q == NULL) OR (thd->thdL.q == gRdyQueue)`, thread must be either in Ready Threads Queue or not be in any queue (e.g. not waiting for a synchronization mechanism).

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.32 void esThdSetPrioI (**esThd_T** ∗ *thd*, uint8_t *prio*)

Set the priority of a thread.

Parameters

thd	Thread: is pointer to the thread structure, esThd.
prio	Priority: is new priority of the thread pointed by `thd`.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `0 <= prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.33 void esThdPostI (**esThd_T** ∗ *thd*)

Post to thread semaphore.

Parameters

thd	Pointer to the thread ID structure

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.34 void esThdPost (**esThd_T** ∗ *thd*)

Post to thread semaphore.

Parameters

thd	Pointer to the thread ID structure

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.35 void esThdWaitI (void)

Wait for thread semaphore.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.36 void esThdWait (void)

Wait for thread semaphore.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.37 void esThdQInit (**esThdQ_T** ∗ *thdQ*)

Initialize Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.

Precondition

1) `thdQ != NULL`

Postcondition

1) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, each esThdQ structure will have valid signature after initialization.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.38 void esThdQAddI (**esThdQ_T** $*$ *thdQ,* **esThd_T** $*$ *thd*)

Add a thread to the Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.
thd	Thread: is a pointer to the thread ID structure, esThd.

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
3) `thd != NULL`
4) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
5) `thd->thdL.q == NULL`, thread must not be in any queue.
6) `0 <= thd->prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

This function adds a thread at the specified Thread Queue.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.39 void esThdQRmI (**esThdQ_T** $*$ *thdQ,* **esThd_T** $*$ *thd*)

Removes the thread from the Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.
thd	Thread: is a pointer to the thread ID structure, esThd.

Precondition

1) `thd != NULL`
2) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
3) `thdQ != NULL`
4) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
5) `thd->thdL.q == thdQ`, thread must be in the `thdQ` queue.
6) `0 <= thd->prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.40 esThd_T* esThdQFetchI (const esThdQ_T * *thdQ*)

Fetch the first high priority thread from the Thread Queue.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.

Returns

A pointer to the thread ID structure with the highest priority.

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
3) `prioBM != 0`, priority bit map must not be empty

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.41 esThd_T* esThdQFetchRotateI (esThdQ_T * *thdQ*, uint_fast8_t *prio*)

Fetch the next thread and rotate thread linked list.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ. This is the thread queue to fetch from.
prio	Priority: is the priority level to fetch and rotate.

Returns

Pointer to the next thread in queue.

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.
3) `0 <= prio <= CFG_SCHED_PRIO_LVL`, see CFG_SCHED_PRIO_LVL.
4) `sentinel != NULL`, at least one thread must be in the selected priority level

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.42 bool_T esThdQIsEmpty (const esThdQ_T ∗ *thdQ*)

Is thread queue empty.

Parameters

thdQ	Thread Queue: is a pointer to thread queue structure, esThdQ.

Returns

The state of thread queue

Return values

TRUE	- thread queue is empty
FALSE	- thread queue is not empty

Precondition

1) `thdQ != NULL`
2) `thdQ->signature == THDQ_CONTRACT_SIGNATURE`, the pointer must point to a esThdQ structure.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.43 void esSchedRdyAddI (esThd_T ∗ *thd*)

Add thread `thd` to the ready thread list and notify the scheduler.

Parameters

thd	Pointer to the initialized thread ID structure, esThd.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `thd->thdL.q == NULL`, thread must not be in a queue.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.44 void esSchedRdyRmI (esThd_T ∗ *thd*)

Remove thread `thd` from the ready thread list and notify the scheduler.

Parameters

thd	Pointer to the initialized thread ID structure, esThd.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `thd != NULL`
3) `thd->signature == THD_CONTRACT_SIGNATURE`, the pointer must point to a esThd structure.
4) `thd->thdL.q == &gRdyQueue`, thread must be in Ready Threads queue.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.45 void esSchedYieldI (void)

Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.

Warning

Scheduler will have undefined behavior if there is no ready thread to run (e.g. empty gRdyQueue) at the time it is invoked.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.46 void esSchedYieldIsrI (void)

Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.

Warning

Scheduler will have undefined behavior if there is no ready thread to run (e.g. empty gRdyQueue) at the time it is invoked.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.47 void esSysTmrEnable (void)

Enable system timer tick events.

This function will override scheduler power savings algorithm and force the system timer into running (active) state.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.48 void esSysTmrDisable (void)

Disable system timer tick events.

This function will try to switch off the system timer. If the system timer is used by scheduler than the scheduler will take control of the system timer.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.49 void esVTmrInitI (esVTmr_T * *vTmr*, esTick_T *tick*, void(*)(void *) *fn*, void * *arg*)

Add and start a new virtual timer.

Parameters

vTmr	Virtual Timer: is pointer to the timer ID structure, esVTmr.
tick	Tick: the timer delay expressed in system ticks
fn	Function: is pointer to the callback function
arg	Argument: is pointer to the arguments of callback function

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `vTmr != NULL`
3) `tick > 1U`
4) `fn != NULL`

Postcondition

1) `vTmr->signature == VTMR_CONTRACT_SIGNATURE`, each esVTmr structure will have valid signature after initialization.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.5.50 void esVTmrTerm (esVTmr_T * *vTmr*)

Cancel and remove a virtual timer.

Parameters

vTmr	Timer: is pointer to the timer ID structure, esVTmr.

Precondition

1) `The kernel state < ES_KERN_INACTIVE`, see Kernel states.
2) `vTmr != NULL`
3) `vTmr->signature == VTMR_CONTRACT_SIGNATURE`, the pointer must point to a esVTmr structure.

Function class:

I class API function, this function can be called from application and interrupt service routine only with interrupts locked.

9.3.5.51 void esVTmrDelay (esTick_T *tick*)

Delay for specified amount of ticks.

Parameters

tick	Tick: number of system ticks to delay.

This function will create a virtual timer with count down time specified in argument `tick` and put the calling thread into `sleep` state. When timeout expires the thread will be placed back into `ready` state.

Object class:

Regular **API** object, this object is part of the application programming interface.

9.3.6 Variable Documentation

9.3.6.1 esThdQ_T gRdyQueue [static]

Ready Thread queue.

9.3.6.2 sysTmr_T gSysTmr [static]

Initial value:

```
= {

    0U,

    0U,




}
```

Main System Timer structure.

9.3.6.3 esVTmr_T gVTmrArmed [static]

Initial value:

```
= {
   {     &gVTmrArmed,
         &gVTmrArmed,
         &gVTmrArmed
   },


   UINT_FAST8_MAX,





   NULL,
   NULL,



}
```

List of virtual timers to armed expire.

9.3.6.4 esVTmr_T gVTmrPend [static]

Initial value:

```
= {
   {     &gVTmrPend,
         &gVTmrPend,
         &gVTmrPend
   },
   0U,
   NULL,
   NULL,


}
```

Virtual timers pending to be inserted into waiting list.

9.3.6.5 esThd_T gKVTmrId [static]

Virtual timer thread ID.

9.3.6.6 portStck_T gKVTmrStck[KVTMR_STCK_SIZE] [static]

Virtual timer kernel thread stack.

9.3.6.7 esThd_T gKIdleId [static]

Idle thread ID.

9.3.6.8 portStck_T gKIdleStck[KIDLE_STCK_SIZE] [static]

Idle kernel thread stack.

9.3.6.9 uint_fast8_t gKernLockCnt [static]

Kernel Lock Counter.

9.3.6.10 const volatile esKernCtrl_T gKernCtrl

Initial value:

```
= {
    NULL,
    NULL,
    ES_KERN_INACTIVE
}
```

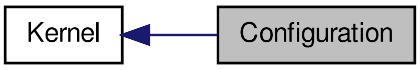
Kernel control initialization.

Kernel control block.

9.4 Configuration

Configuration settings.

Collaboration diagram for Configuration:



Kernel configuration options and settings

- #define CFG_API_VALIDATION 1U

  Enable/disable API arguments validation.
- #define CFG_SCHED_PRIO_LVL 8U

  Scheduler priority levels.
- #define CFG_SCHED_TIME_QUANTUM 10U

  Scheduler Round-Robin time quantum.
- #define CFG_SYSTMR_MODE 1U

  System timer mode.
- #define CFG_SYSTMR_EVENT_FREQUENCY 100UL

  The frequency of system timer tick event.
- #define CFG_SYSTMR_TICK_TYPE 2U

  The size of the system timer tick event counter.

Kernel hooks

- #define CFG_HOOK_SYSTMR_EVENT 0U

  System timer event hook function.
- #define CFG_HOOK_KERN_INIT 0U

  Kernel initialization hook function.
- #define CFG_HOOK_KERN_START 0U

  Kernel start hook function.
- #define CFG_HOOK_THD_INIT_END 0U

  Thread initialization end hook function.
- #define CFG_HOOK_THD_TERM 0U

  Thread termination hook function.
- #define CFG_HOOK_CTX_SW 0U

  Context switch hook function.

9.4.1 Detailed Description

Configuration settings.

9.4.2 Macro Definition Documentation

9.4.2.1 #define CFG_API_VALIDATION 1U

Enable/disable API arguments validation.

9.4.2.2 #define CFG_SCHED_PRIO_LVL 8U

Scheduler priority levels.

9.4.2.3 #define CFG_SCHED_TIME_QUANTUM 10U

Scheduler Round-Robin time quantum.

9.4.2.4 #define CFG_SYSTMR_MODE 1U

System timer mode.

9.4.2.5 #define CFG_SYSTMR_EVENT_FREQUENCY 100UL

The frequency of system timer tick event.

Note

This setting is valid only if configuration option CFG_SYSTMR_CLOCK_FREQUENCY is properly set in port configuration file cpu_cfg.h

9.4.2.6 #define CFG_SYSTMR_TICK_TYPE 2U

The size of the system timer tick event counter.

9.4.2.7 #define CFG_HOOK_SYSTMR_EVENT 0U

System timer event hook function.

9.4.2.8 #define CFG_HOOK_KERN_INIT 0U

Kernel initialization hook function.

9.4.2.9 #define CFG_HOOK_KERN_START 0U

Kernel start hook function.

9.4.2.10 #define CFG_HOOK_THD_INIT_END 0U

Thread initialization end hook function.

9.4.2.11 #define CFG_HOOK_THD_TERM 0U

Thread termination hook function.

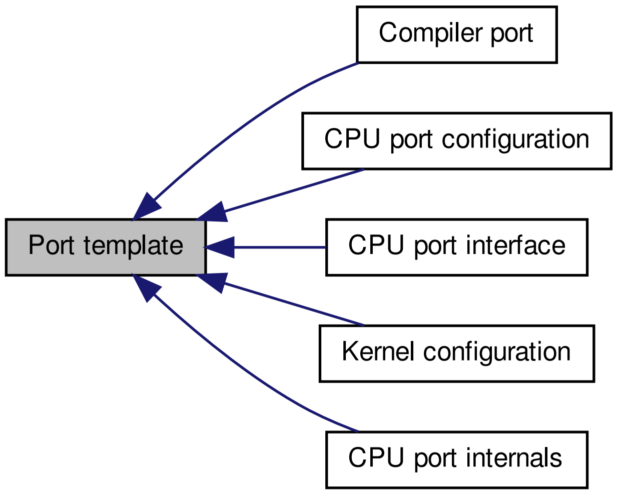
9.4.2.12 #define CFG_HOOK_CTX_SW 0U

Context switch hook function.

9.5 Port template

Templates.

Collaboration diagram for Port template:



Modules

- CPU port configuration

    CPU port specific configuration options.
- CPU port interface

    CPU port macros and functions.
- CPU port internals

    CPU port inner work.
- Compiler port

    Compiler provided macros and data types.
- Kernel configuration

    Default Kernel configuration options.

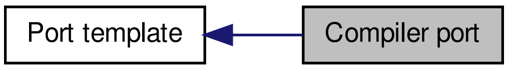
9.5.1 Detailed Description

Templates.

9.6 Compiler port

Compiler provided macros and data types.

Collaboration diagram for Compiler port:



Compiler provided macros

Port interface macros and port specific macros

These macros are used to ease the writing of ports. All macros prefixed with **PORT_** are part of the port interface.

- #define PORT_C_INLINE inline

  C extension - make a function inline.
- #define PORT_C_INLINE_ALWAYS inline

  C extension - make a function inline - always.
- #define PORT_C_NAKED

  Omit function prologue/epilogue sequences.
- #define PORT_C_FUNC "unknown"

  Provides function name for assert macros.
- #define PORT_C_WEAK

  Declares a weak function.
- #define PORT_C_ALIGNED(expr)

  This attribute specifies a minimum alignment (in bytes) for variables of the specified type.
- #define PORT_HWREG_SET(reg, mask, val)

  A standardized way of properly setting the value of HW register.

Compiler provided data types

The compiler port must provide some C90 (C99) data types

The compiler port must:

- declare sets of integer types having specified widths, standard type definitions and shall define corresponding sets of macros.

Types are defined in the following categories:

- Integer types having certain exact widths
- Fastest integer types having at least certain specified widths
- Integer types wide enough to hold pointers to objects
- standard type definitions

The following exact-width integer types are required:

- int8_t
- int16_t
- int32_t
- uint8_t
- uint16_t
- uint32_t

The following fastest minimum-width integer types are required:

- int_fast8_t
- int_fast16_t
- int_fast32_t
- uint_fast8_t
- uint_fast16_t
- uint_fast32_t

The following integer types capable of holding object pointers are required:

- intptr_t
- uintptr_t

The following standard type definitions are required:

- NULL
- ptrdiff_t
- size_t

- enum boolType {
  TRUE = 1U,
  FALSE = 0U }

  Bool data type.
- typedef enum boolType bool_T

  Bool data type.

9.6.1 Detailed Description

Compiler provided macros and data types.

9.6.2 Macro Definition Documentation

9.6.2.1 #define PORT_C_INLINE inline

C extension - make a function inline.

The point of making a function `inline` is to hint to the compiler that it is worth making some form of extra effort to call the function faster than it would otherwise - generally by substituting the code of the function into its caller. As well as eliminating the need for a call and return sequence, it might allow the compiler to perform certain optimizations between the bodies of both functions.

9.6.2.2 #define PORT_C_INLINE_ALWAYS inline

C extension - make a function inline - always.

Generally, functions are not inlined unless optimization is specified. For functions declared inline, this attribute inlines the function even if no optimization level was specified.

9.6.2.3 #define PORT_C_NAKED

Omit function prologue/epilogue sequences.

This attribute will indicate that the specified function does not need prologue/epilogue sequences generated by the compiler. It is up to the programmer to provide these sequences. The only statements that can be safely included in naked functions are `asm` statements that do not have operands. All other statements, including declarations of local variables, `if` statements, and so forth, should be avoided. Naked functions should be used to implement the body of an assembly function, while allowing the compiler to construct the requisite function declaration for the assembler.

9.6.2.4 #define PORT_C_FUNC "unknown"

Provides function name for assert macros.

9.6.2.5 #define PORT_C_WEAK

Declares a weak function.

The weak attribute causes the declaration to be emitted as a weak symbol rather than a global. This is primarily useful in defining library functions that can be overridden in user code, though it can also be used with non-function declarations.

9.6.2.6 #define PORT_C_ALIGNED(*expr*)

This attribute specifies a minimum alignment (in bytes) for variables of the specified type.

Note

The alignment of any given struct or union type is required by the ISO C standard to be at least a perfect multiple of the lowest common multiple of the alignments of all of the members of the struct or union in question.

9.6.2.7 #define PORT_HWREG_SET(reg, *mask*, *val*)

Value:

```
do {                                                            \
        portReg_T tmp;                                              \
        tmp = (reg);                                                \
        tmp &= ~(mask);                                             \
        tmp |= ((mask) & (val));                                    \
        (reg) = tmp;                                                \
    } while (0U)
```

A standardized way of properly setting the value of HW register.

Parameters

reg	Register which will be written to
mask	The bit mask which will be applied to register and `val` argument
val	Value to be written into the register

9.6.3 Typedef Documentation

9.6.3.1 typedef enum boolType bool_T

Bool data type.

9.6.4 Enumeration Type Documentation

9.6.4.1 enum boolType

Bool data type.

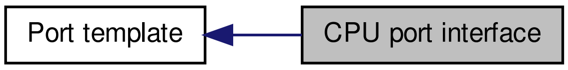
Enumerator

TRUE	TRUE. TRUE
FALSE	FALSE. FALSE

9.7 CPU port interface

CPU port macros and functions.

Collaboration diagram for CPU port interface:



Data Structures

- struct portStck

  Stack structure used for stack declaration in order to force the alignment.
- struct portCtx

  Port context structure.

Typedefs

- typedef uint8_t portReg_T

  Data type which corresponds to the general purpose register.
- typedef struct portStck portStck_T

  Stack type.

Functions

- struct portStck __attribute__ ((aligned(1)))

  Alignment of stack structure.

Variables

- struct portCtx **__attribute__**
- portReg_T gPortIsrNesting_

  Variable to keep track of ISR nesting.
- const PORT_C_ROM portReg_T pwr2LKP [PORT_DATA_WIDTH_VAL]

  Look up table for: 2^n expression.

Port constants

- #define PORT_DATA_WIDTH_VAL 8U

  This macro specifies the bit width of CPU data registers.
- #define PORT_STCK_MINSIZE_VAL sizeof(struct portCtx)

  This macro specifies the minimal size of the thread stack.
- #define PORT_SYSTMR_RELOAD_VAL (CFG_SYSTMR_CLOCK_FREQUENCY / CFG_SYSTMR_EVENT_FREQUENCY)

  System timer reload value for one tick.

- #define PORT_SYSTMR_MAX_VAL 0xFFU

  System timer maximum value.
- #define PORT_SYSTMR_MAX_TICKS_VAL (PORT_SYSTMR_MAX_VAL / PORT_SYSTMR_RELOAD_V-AL)

  Maximum number of ticks the system timer can accept.

Interrupt management

- void portIntDisable_ (void)

  Disable interrupts.
- portReg_T portIntGet_ (void)

  Get the current status of enabled/disabled interrupts.
- void portIntSet_ (portReg_T status)

  Set the status of interrupts according to the `status` argument.
- #define PORT_INT_DISABLE() portIntDisable_()

  Disable all interrupt sources.
- #define PORT_ISR_ENTER()

  Enter ISR. Increment gPortIsrNesting_ variable to keep track of ISR nesting.
- #define PORT_ISR_EXIT()

  Exit ISR. Decrement gPortIsrNesting_ variable to keep track of ISR nesting.
- #define PORT_ISR_IS_LAST() (0U == gPortIsrNesting ? TRUE : FALSE)

  If isrNesting variable is zero then the last ISR is executing and scheduler should be invoked.

Critical section management

Disable/enable interrupts by preserving the status of interrupts.

Generally speaking these macros would store the status of the interrupt disable flag in the local variable declared by PORT_CRITICAL_DECL and then disable interrupts. Local variable is allocated in all of eSolid RTOS functions that need to disable interrupts. Macros would restore the interrupt status by copying back the allocated variable into the CPU's status register.

- #define PORT_CRITICAL_DECL() portReg_T intStatus_

  Declare the interrupt status variable.
- #define PORT_CRITICAL_ENTER()

  Enter critical section.
- #define PORT_CRITICAL_EXIT() portIntSet_(intStatus_)

  Exit critical section.

Scheduler support

Note

These functions are extensively used by the scheduler and therefore they should be optimized for the architecture being used.

- uint_fast8_t portFindLastSet_ (portReg_T val)

  Find last set bit in a word.
- void portSysTmrInit_ (void)

  Initialize systick timer and associated interrupt.
- void portSysTmrTerm_ (void)

  Stop the sistem timer.
- void portSysTmrReload_ (esTick_T ticks)

Reload the system timer.

- void portSysTmrEnable_ (void)

  Enable the system timer.
- void portSysTmrDisable_ (void)

  Disable the system timer.
- void portSysTmrIsrEnable_ (void)

  Disable the system timer interrupt.
- void portSysTmrIsrDisable_ (void)

  Enable the system timer interrupt.
- void portThdStart_ (void)

  Start the first thread.
- #define PORT_FIND_LAST_SET(val) portFindLastSet_(val)

  Find last set bit in a word.
- #define PORT_PWR2(pwr) (1U << (pwr))

  Helper macro: calculate 2^pwr expression.
- #define PORT_SYSTMR_INIT() portSysTmrInit_()

  Initialize system timer and associated interrupt.
- #define PORT_SYSTMR_TERM() portSysTmrTerm_()

  Stop the timer if it is running and disable associated interrupt.
- #define PORT_SYSTMR_RELOAD(ticks) portSysTmrReload_(ticks)

  Reload the system timer with specified number of ticks.
- #define PORT_SYSTMR_ENABLE() portSysTmrEnable_()

  Enable the system timer.
- #define PORT_SYSTMR_DISABLE() portSysTmrDisable_()

  Disable the system timer.
- #define PORT_SYSTMR_ISR_ENABLE() portSysTmrIsrEnable_()

  Enable the system timer interrupt.
- #define PORT_SYSTMR_ISR_DISABLE() portSysTmrIsrDisable_()

  Disable the system timer interrupt.

Dispatcher context switching

- void ∗ portCtxInit_ (void ∗stck, size_t stckSize, void(∗thdf)(void ∗), void ∗arg)

  Initialize the thread context.
- void portCtxSw_ (void)

  Do the context switch - invoked from API.
- void portCtxSwIsr_ (void)

  Do the context switch - invoked from ISR.
- #define PORT_CTX_INIT(stck, stackSize, thread, arg) portCtxInit_(stck, stackSize, thread, arg)

  Initialize the thread context.
- #define PORT_CTX_SW() portCtxSw_()

  Do the context switch - invoked from API level.
- #define PORT_CTX_SW_ISR() portCtxSwIsr_()

  Do the context switch - invoked from ISR level.
- #define PORT_THD_START() portThdStart_()

  Start the first thread.

General port macros

- #define PORT_STCK_SIZE(size)

  Calculate the stack size.
- #define PORT_CRITICAL_EXIT_SLEEP() PORT_CRITICAL_EXIT()

  TODO.
- #define PORT_INIT_EARLY() portInitEarly_()

  Early port initialization.
- #define PORT_INIT() portInit_()

  Port initialization.
- #define PORT_INIT_LATE() portInitLate_()

  Late port initialization.

General port functions

- void portInitEarly_ (void)

  Early port initialization.
- void portInit_ (void)

  Port initialization.
- void portInitLate_ (void)

  Late port initialization.

9.7.1 Detailed Description

CPU port macros and functions. Since this header file is included with the API of the kernel a few naming conventions are defined in order to avoid name clashing with the names of objects from libraries included by application code.

1) Macro naming conventions

For macro naming try to follow these rules:

- All standard PORT API macro names are prefixed with: **`PORT_`**.
- All other macros which are specific to the port used are prefixed with: **`CPU_`**.

2) Type declaration naming conventions

For type declaration naming try to follow these rules:

- All type declaration names are prefixed with: **`cpu`**.

3) Global variable naming conventions

For global variable naming try to follow these rules:

- All global variable names are prefixed with: **`cpu`**.

4) Funcion naming convetions

For functions naming try to follow these rules:

- All function names are prefixed with: **`port`** and postfixed with: _ (underscore).
- All other functions which are specific to the port used are prefixed with: **`cpu`** and postfixed with: _ (underscore).
- The `exception` to above two rules are the names of functions used for Interrupt Service Routines. They can have any name required by port.

9.7.2 Macro Definition Documentation

9.7.2.1 #define PORT_DATA_WIDTH_VAL 8U

This macro specifies the bit width of CPU data registers.

9.7.2.2 #define PORT_STCK_MINSIZE_VAL sizeof(struct portCtx)

This macro specifies the minimal size of the thread stack.

Generally minimal stack size is equal to the size of context structure

9.7.2.3 #define PORT_SYSTMR_RELOAD_VAL (CFG_SYSTMR_CLOCK_FREQUENCY / CFG_SYSTMR_EVENT_FREQUENCY)

System timer reload value for one tick.

This is a calculated value for one system tick period

9.7.2.4 #define PORT_SYSTMR_MAX_VAL 0xFFU

System timer maximum value.

This macro specifies maximum value that can be reloaded into system timer counter. For example, if the system timer is a 8-bit counter than this macro would have the value of 0xFFU.

9.7.2.5 #define PORT_SYSTMR_MAX_TICKS_VAL (PORT_SYSTMR_MAX_VAL / PORT_SYSTMR_RELOAD_VAL)

Maximum number of ticks the system timer can accept.

9.7.2.6 #define PORT_INT_DISABLE( ) portIntDisable_()

Disable all interrupt sources.

9.7.2.7 #define PORT_ISR_ENTER( )

Value:

```
do {                                                                      \
        gPortIsrNesting_++;                                                   \
        esKernIsrPrologueI();                                                 \
    } while (0U)
```

Enter ISR. Increment gPortIsrNesting_ variable to keep track of ISR nesting.

Variable gPortIsrNesting_ is needed only if the port does not support any other method of detecting when the last ISR is executing.

9.7.2.8 #define PORT_ISR_EXIT( )

Value:

```
do {                                                                      \
        gPortIsrNesting_--;                                                   \
        esKernIsrEpilogueI();                                                 \
    } while (0U)
```

Exit ISR. Decrement gPortIsrNesting_ variable to keep track of ISR nesting.

Variable gPortIsrNesting_ is needed only if the port does not support any other method of detecting when the last ISR is executing.

9.7.2.9 #define PORT_ISR_IS_LAST( ) (0U == gPortIsrNesting ? TRUE : FALSE)

If isrNesting variable is zero then the last ISR is executing and scheduler should be invoked.

Returns

Is the currently executed ISR the last one?

Return values

TRUE	- this is last ISR
FALSE	- this is not the last ISR

9.7.2.10 #define PORT_CRITICAL_DECL( ) portReg_T intStatus_

Declare the interrupt status variable.

This variable is used to store the current state of enabled ISRs.

9.7.2.11 #define PORT_CRITICAL_ENTER( )

Value:

```
do {                                                                    \
        intStatus_ = portIntGet_();                                         \
        portIntDisable_();                                                  \
    } while (0U)
```

Enter critical section.

9.7.2.12 #define PORT_CRITICAL_EXIT( ) portIntSet_(intStatus_)

Exit critical section.

9.7.2.13 #define PORT_FIND_LAST_SET(*val*) portFindLastSet_(val)

Find last set bit in a word.

This function is used by the scheduler to efficiently determine the highest priority of thread ready for execution. For algorithm details see: `http://en.wikipedia.org/wiki/Find_first_set`.

Returns

The position of the last set bit in a word

9.7.2.14 #define PORT_PWR2(*pwr*) (1U << (pwr))

Helper macro: calculate 2^pwr expression.

Some ports may want to use look up tables instead of shifting operation

9.7.2.15 #define PORT_SYSTMR_INIT( ) portSysTmrInit_()

Initialize system timer and associated interrupt.

This macro will only initialize system timer and associated interrupt. It MUST NOT start the system timer in this stage. Responsibility:

- initialize system timer
- initialize system timer interrupt

9.7.2.16 #define PORT_SYSTMR_TERM( ) portSysTmrTerm_()

Stop the timer if it is running and disable associated interrupt.

Responsibility:

- disable system timer interrupt
- stop and disable system timer

9.7.2.17 #define PORT_SYSTMR_RELOAD(*ticks*) portSysTmrReload_(ticks)

Reload the system timer with specified number of ticks.

Responsibility:

- calculate the reload value based on PORT_SYSTMR_RELOAD_VAL
- reload the system timer

9.7.2.18 #define PORT_SYSTMR_ENABLE( ) portSysTmrEnable_()

Enable the system timer.

Responsibility:

- enable (run) the system timer counter

9.7.2.19 #define PORT_SYSTMR_DISABLE( ) portSysTmrDisable_()

Disable the system timer.

Responsibility:

- disable (stop) the system timer counter

9.7.2.20 #define PORT_SYSTMR_ISR_ENABLE( ) portSysTmrIsrEnable_()

Enable the system timer interrupt.

Responsibility:

- allow system timer interrupt to occur

9.7.2.21 #define PORT_SYSTMR_ISR_DISABLE( ) portSysTmrIsrDisable_()

Disable the system timer interrupt.

Responsibility:

- disallow system timer interrupt to occur

9.7.2.22 #define PORT_CTX_INIT(*stck,* *stackSize,* *thread,* *arg*) portCtxInit_(stck, stackSize, thread, arg)

Initialize the thread context.

Parameters

`in,out`	*stck*	Pointer to the allocated thread stck. The pointer points to the beginning of the memory as defined per C language. It's up to port function to adjust the pointer according to the stck type: full descending or full ascending one.
	stackSize	The size of allocated stck in bytes.
`in`	*thread*	Pointer to the thread function.
`in`	*arg*	Argument that will be passed to thread function at the starting of execution.

Returns

The new top of stck after thread context initialization.

9.7.2.23 #define PORT_CTX_SW( ) portCtxSw_()

Do the context switch - invoked from API level.

9.7.2.24 #define PORT_CTX_SW_ISR( ) portCtxSwIsr_()

Do the context switch - invoked from ISR level.

9.7.2.25 #define PORT_THD_START( ) portThdStart_()

Start the first thread.

9.7.2.26 #define PORT_STCK_SIZE(*size*)

Value:

```
((((size + PORT_STCK_MINSIZE_VAL) + (sizeof(struct portStck) /
        \
    sizeof(portReg_T))) - 1U) / (sizeof(struct portStck)/sizeof(
      portReg_T)))
```

Calculate the stack size.

This macro is used when specifying the size of thread stack. Responsibility:

- add to `size` the minimal stack size specified by PORT_STCK_MINSIZE_VAL.
- if it is needed by the port make sure the alignment is correct.

9.7.2.27 #define PORT_CRITICAL_EXIT_SLEEP( ) PORT_CRITICAL_EXIT()

TODO.

9.7.2.28 #define PORT_INIT_EARLY( ) portInitEarly_()

Early port initialization.

This macro will be called at early initialization stage from esKernInit() function. It is called before any kernel data initialization. Usually this macro would be used to setup memory space, fill the memory with debug value or something similar.

9.7.2.29 #define PORT_INIT( ) portInit_()

Port initialization.

This macro will be called after kernel data structure initialization from esKernInit() function.

9.7.2.30 #define PORT_INIT_LATE( ) portInitLate_()

Late port initialization.

This macro will be called just a moment before the multitasking is started. The macro is called from esKernStart() function.

9.7.3 Typedef Documentation

9.7.3.1 typedef uint8_t portReg_T

Data type which corresponds to the general purpose register.

9.7.3.2 typedef struct **portStck** **portStck_T**

Stack type.

9.7.4 Function Documentation

9.7.4.1 struct **portStck** __attribute__ ((aligned(1)))

Alignment of stack structure.

9.7.4.2 void portIntDisable_ (void)

Disable interrupts.

9.7.4.3 **portReg_T** portIntGet_ (void)

Get the current status of enabled/disabled interrupts.

Returns

Interrupt status

9.7.4.4 void portIntSet_ (**portReg_T** *status*)

Set the status of interrupts according to the `status` argument.

Parameters

status	The status of interrupts that will be set by the function.

9.7.4.5 uint_fast8_t portFindLastSet_ (**portReg_T** *val*)

Find last set bit in a word.

Parameters

val	Value which needs to be evaluated

This function is used by the scheduler to efficiently determine the highest priority of thread ready for execution. For algorithm details see: `http://en.wikipedia.org/wiki/Find_first_set`.

Returns

The position of the last set bit in a word

9.7.4.6 void portSysTmrInit_ (void)

Initialize systick timer and associated interrupt.

This function will be called just a moment before the multitasking is started. The function is called from esKernStart() function. It should setup:

- systick timer (scheduler uses tick event to switch between threads of same priority)
- systick timer interrupt

Note

This function MUST NOT enable system timer events. System timer events are enabled/disabled by portSysTmrEnable_() and portSysTmrDisable_() functions.

9.7.4.7 void portSysTmrTerm_(void)

Stop the sistem timer.

9.7.4.8 void portSysTmrReload_(esTick_T *ticks*)

Reload the system timer.

Parameters

ticks	How much ticks is needed to delay

9.7.4.9 void portSysTmrEnable_(void)

Enable the system timer.

9.7.4.10 void portSysTmrDisable_(void)

Disable the system timer.

9.7.4.11 void portSysTmrIsrEnable_(void)

Disable the system timer interrupt.

9.7.4.12 void portSysTmrIsrDisable_(void)

Enable the system timer interrupt.

9.7.4.13 void portThdStart_(void)

Start the first thread.

9.7.4.14 void∗ portCtxInit_(void ∗ *stck,* size_t *stckSize,* void(∗)(void ∗) *thdf,* void ∗ *arg*)

Initialize the thread context.

Parameters

`in,out`	*stck*	Pointer to the allocated thread stck. The pointer points to the beginning of the memory as defined per C language. It's up to port function to adjust the pointer according to the stck type: full descending or full ascending one.
	stckSize	The size of allocated stck in bytes.
`in`	*thdf*	Pointer to the thread function.
`in`	*arg*	Argument that will be passed to thread function at the starting of execution.

Returns

The new top of stck after thread context initialization.

9.7.4.15 void portCtxSw_(void)

Do the context switch - invoked from API.

9.7.4.16 void portCtxSwIsr_(void)

Do the context switch - invoked from ISR.

9.7.4.17 void portInitEarly_(void)

Early port initialization.

This function will be called at early initialization stage from esKernInit() function. It is called before any kernel data initialization. Usually this function would be used to setup memory space, fill the memory with debug value or something similar.

9.7.4.18 void portInit_ (void)

Port initialization.

This function will be called after kernel data structure initialization from esKernInit() function.

9.7.4.19 void portInitLate_ (void)

Late port initialization.

This function will be called just a moment before the multitasking is started. The function is called from esKernStart() function.

9.7.5 Variable Documentation

9.7.5.1 portReg_T gPortIsrNesting_

Variable to keep track of ISR nesting.

9.7.5.2 const PORT_C_ROM portReg_T pwr2LKP[PORT_DATA_WIDTH_VAL]

Look up table for: 2^n expression.

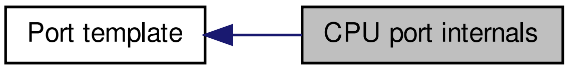
This look up table can be used to accelerate the Logical Shift Left operations which are needed to set bits inside the priority bit map. In plain C this operation would be written as: `(1U << n)`, but in many 8-bit CPUs this operation can be lengthy. If there is a need for faster operation than this table can be used instead of the mentioned C code.

To use the look up table change PORT_PWR2 macro implementation from: `(1U << (pwr))` to `pwr2LKP[pwr]`

9.8 CPU port internals

CPU port inner work.

Collaboration diagram for CPU port internals:



Functions

- uint_fast8_t portFindLastSet_ (portReg_T val)

  Find last set bit in a word.
- void ∗ portCtxInit_ (void ∗stck, size_t stckSize, void(∗thdf)(void ∗), void ∗arg)

  Initialize the thread context.

Variables

- portReg_T gPortIsrNesting_

  Variable to keep track of ISR nesting.
- const PORT_C_ROM portReg_T pwr2LKP [PORT_DATA_WIDTH_VAL]

  Look up table for: 2^n expression.

9.8.1 Detailed Description

CPU port inner work.

9.8.2 Function Documentation

9.8.2.1 uint_fast8_t portFindLastSet_ (portReg_T *val*)

Find last set bit in a word.

Parameters

val	Value which needs to be evaluated

This function is used by the scheduler to efficiently determine the highest priority of thread ready for execution. For algorithm details see: `http://en.wikipedia.org/wiki/Find_first_set`.

Returns

The position of the last set bit in a word

9.8.2.2 void∗ portCtxInit_ (void ∗ *stck,* size_t *stckSize,* void(∗)(void ∗) *thdf,* void ∗ *arg*)

Initialize the thread context.

Parameters

in,out	*stck*	Pointer to the allocated thread stck. The pointer points to the beginning of the memory as defined per C language. It's up to port function to adjust the pointer according to the stck type: full descending or full ascending one.
	stckSize	The size of allocated stck in bytes.
in	*thdf*	Pointer to the thread function.
in	*arg*	Argument that will be passed to thread function at the starting of execution.

Returns

The new top of stck after thread context initialization.

9.8.3 Variable Documentation

9.8.3.1 portReg_T gPortIsrNesting_

Variable to keep track of ISR nesting.

9.8.3.2 const PORT_C_ROM portReg_T pwr2LKP[PORT_DATA_WIDTH_VAL]

Initial value:

```
= {
    (1U <<  0), (1U <<  1), (1U <<  2), (1U <<  3),
    (1U <<  4), (1U <<  5), (1U <<  6), (1U <<  7),









}
```

Look up table for: 2^n expression.

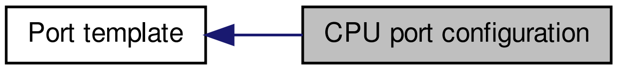
This look up table can be used to accelerate the Logical Shift Left operations which are needed to set bits inside the priority bit map. In plain C this operation would be written as: `(1U << n)`, but in many 8-bit CPUs this operation can be lengthy. If there is a need for faster operation than this table can be used instead of the mentioned C code.

To use the look up table change PORT_PWR2 macro implementation from: `(1U << (pwr))` to `pwr2LKP[pwr]`

9.9 CPU port configuration

CPU port specific configuration options.

Collaboration diagram for CPU port configuration:



Port General configuration

Configuration options and settings which are available for every port.

Note

1) All port General configuration macros are prefixed with `CFG_` string.
2) All port specific options and constants are prefixed with `CPU_` string.

- #define CFG_CRITICAL_PRIO 1U

  Priority of critical sections in kernel.
- #define CFG_SYSTMR_CLOCK_FREQUENCY 1000000UL

  The frequency of clock which is used for the system timer.

9.9.1 Detailed Description

CPU port specific configuration options. Each configuration option or setting has its own default value when not defined by the application. When application needs to change a setting it just needs to define a configuration macro with another value and the default configuration macro will be overridden.

9.9.2 Macro Definition Documentation

9.9.2.1 #define CFG_CRITICAL_PRIO 1U

Priority of critical sections in kernel.

This option varies with the MCU used. In the simplest case when the MCU does not support interrupt priorities than only one priority level is available. In that case critical section will simply disable interrupts on entry and enable them at exit.

9.9.2.2 #define CFG_SYSTMR_CLOCK_FREQUENCY 1000000UL

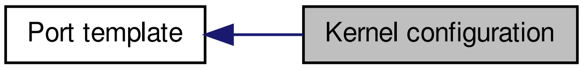
The frequency of clock which is used for the system timer.

Specify here the clock value so the kernel can properly manage system tick event generation. Usually system timer will use the clock of the processor. A hardware timer is configured to generate an interrupt at a rate between 10 and 1000 Hz which provides the system tick. The rate of interrupt is application specific and depends on the desired resolution system tick time source. However, the faster the tick rate, the higher the overhead will be imposed on the system.

9.10 Kernel configuration

Default Kernel configuration options.

Collaboration diagram for Kernel configuration:



Kernel configuration options and settings

Kernel default configuration

- #define CFG_API_VALIDATION 1U

  Enable/disable API arguments validation.
- #define CFG_SCHED_PRIO_LVL 8U

  Scheduler priority levels.
- #define CFG_SCHED_TIME_QUANTUM 10U

  Scheduler Round-Robin time quantum.
- #define CFG_SYSTMR_MODE 1U

  System timer mode.
- #define CFG_SYSTMR_EVENT_FREQUENCY 100UL

  The frequency of system tick event.
- #define CFG_SYSTMR_TICK_TYPE 2U

  The size of the system timer counter.

Kernel hooks

- #define CFG_HOOK_SYSTMR_EVENT 0U

  System timer event hook function.
- #define CFG_HOOK_KERN_INIT 0U

  Kernel initialization hook function.
- #define CFG_HOOK_KERN_START 0U

  Kernel start hook function.
- #define CFG_HOOK_THD_INIT_END 0U

  Thread initialization hook function.
- #define CFG_HOOK_THD_TERM 0U

  Thread termination hook function.
- #define CFG_HOOK_CTX_SW 0U

  Kernel context switch hook function.

9.10.1 Detailed Description

Default Kernel configuration options. Each configuration option or setting has its own default value when not defined by the application. When application needs to change a setting it just needs to define a configuration macro with another value and the default configuration macro will be overridden.

9.10.2 Macro Definition Documentation

9.10.2.1 #define CFG_API_VALIDATION 1U

Enable/disable API arguments validation.

During the development cycle of the application this option should be turned on. When this configuration option is turned on the kernel API functions will also check arguments passed to them. If an invalid argument is detected the execution of the application will stop and the user will be informed about the error condition.

Possible values:

- 0U - API validation is OFF
- 1U - API validation is ON

Note

The error checking use userAssert() hook function to provide the information about the error condition.

9.10.2.2 #define CFG_SCHED_PRIO_LVL 8U

Scheduler priority levels.

The number of priority levels. Each priority level can have several threads. Possible values:

- Min: 2U (two priority levels)
- Max: 256U

Warning

Scheduler will have undefined behavior if there is no ready thread to run (e.g. empty Ready Threads Queue) at the time it is invoked.

9.10.2.3 #define CFG_SCHED_TIME_QUANTUM 10U

Scheduler Round-Robin time quantum.

This constant is the number of system ticks allowed for the threads before preemption occurs. Setting this value to zero disables the preemption for threads with equal priority and the round robin becomes cooperative. Note that higher priority threads can still preempt, the kernel is always preemptive.

Note

Disabling the round robin preemption makes the kernel more compact and generally faster.

9.10.2.4 #define CFG_SYSTMR_MODE 1U

System timer mode.

Possible values are:

- 0U - fixed mode
- 1U - inhibited mode
- 2U - adaptive mode

9.10.2.5 #define CFG_SYSTMR_EVENT_FREQUENCY 100UL

The frequency of system tick event.

Specify the desired resolution system tick time source. This setting is valid only if configuration option CFG_SYST-MR_CLOCK_FREQUENCY is properly set in port configuration file cpu_cfg.h

9.10.2.6 #define CFG_SYSTMR_TICK_TYPE 2U

The size of the system timer counter.

Possible values are:

- 0U - 8 bit counter
- 1U - 16 bit counter
- 2U - 32 bit counter

9.10.2.7 #define CFG_HOOK_SYSTMR_EVENT 0U

System timer event hook function.

This hook is called just a moment before a system timer event is processed.

Note

This hook will call userSysTmr() function.

9.10.2.8 #define CFG_HOOK_KERN_INIT 0U

Kernel initialization hook function.

This hook is called at the beginning of esKernInit() function.

Note

This hook will call userKernInit() function.

9.10.2.9 #define CFG_HOOK_KERN_START 0U

Kernel start hook function.

This hook is called at the beginning of esKernStart() function.

Note

This hook will call userKernStart() function.

9.10.2.10 #define CFG_HOOK_THD_INIT_END 0U

Thread initialization hook function.

This hook is called at the end of esThdInit() function.

Note

This hook will call userThdInitEnd() function.

9.10.2.11 #define CFG_HOOK_THD_TERM 0U

Thread termination hook function.

This hook is called when a thread terminates.

Note

This hook will call userThdTerm() function.

9.10.2.12 #define CFG_HOOK_CTX_SW 0U

Kernel context switch hook function.

This hook is called at each context switch.

Note

This hook will call userCtxSw() function.

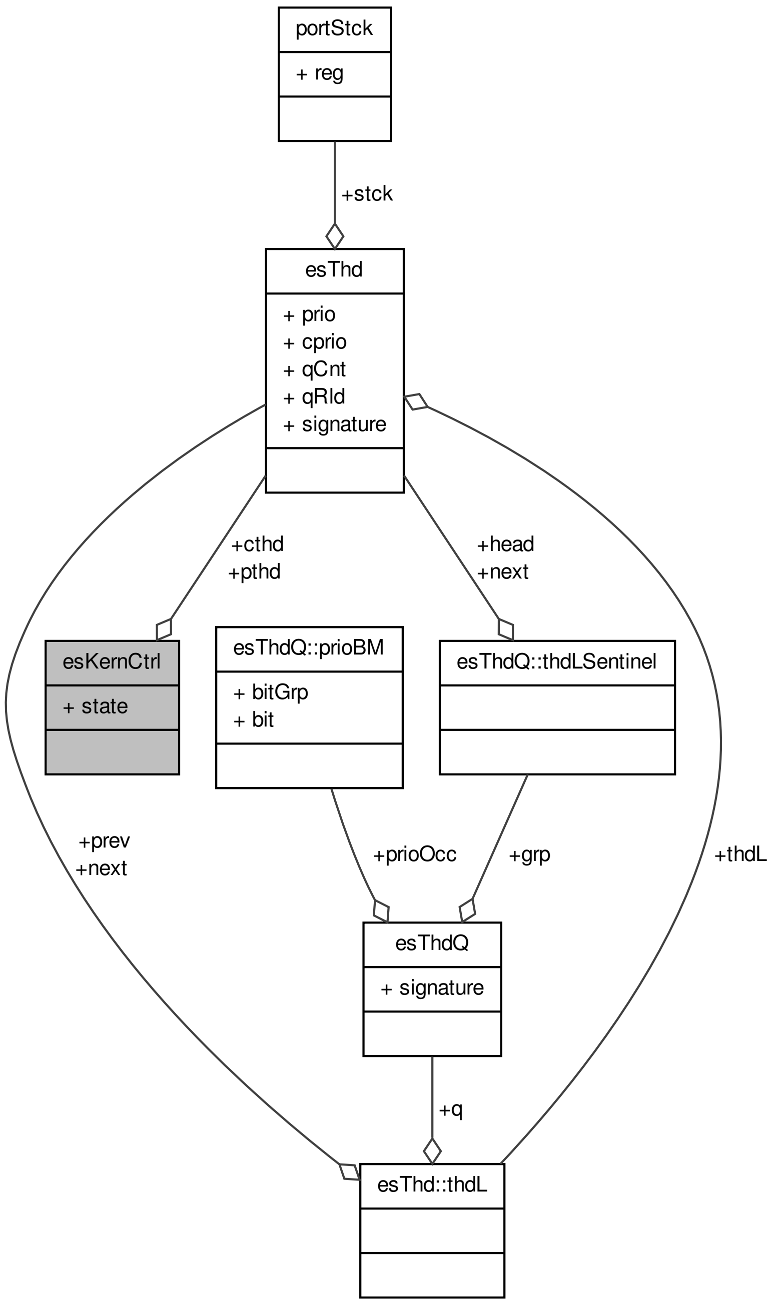
10 Data Structure Documentation

10.1 esKernCtrl Struct Reference

Kernel control block structure.

`#include <kernel.h>`

Collaboration diagram for esKernCtrl:



Data Fields

- struct esThd ∗ cthd

  Pointer to the Current Thread.
- struct esThd ∗ pthd

  Pointer to the Pending Thread to be switched.
- enum esKernState state

  State of kernel.

10.1.1 Detailed Description

Kernel control block structure.

This structure holds important status data about the kernel. Since all data within the structure is somewhat related and accessed within the same pieces of code it was decided it is better to group all kernel data into the structure. This way the compiler can generate code that gets the address of the structure and then use relative indirect addressing to access all members of the structure. This results in more efficient code on architectures that have relative indirect addressing capability.

Object class:

Regular **API** object, this object is part of the application programming interface.

10.1.2 Field Documentation

10.1.2.1 struct esThd∗ esKernCtrl::cthd

Pointer to the Current Thread.

10.1.2.2 struct esThd∗ esKernCtrl::pthd

Pointer to the Pending Thread to be switched.

10.1.2.3 enum esKernState esKernCtrl::state

State of kernel.

The documentation for this struct was generated from the following file:

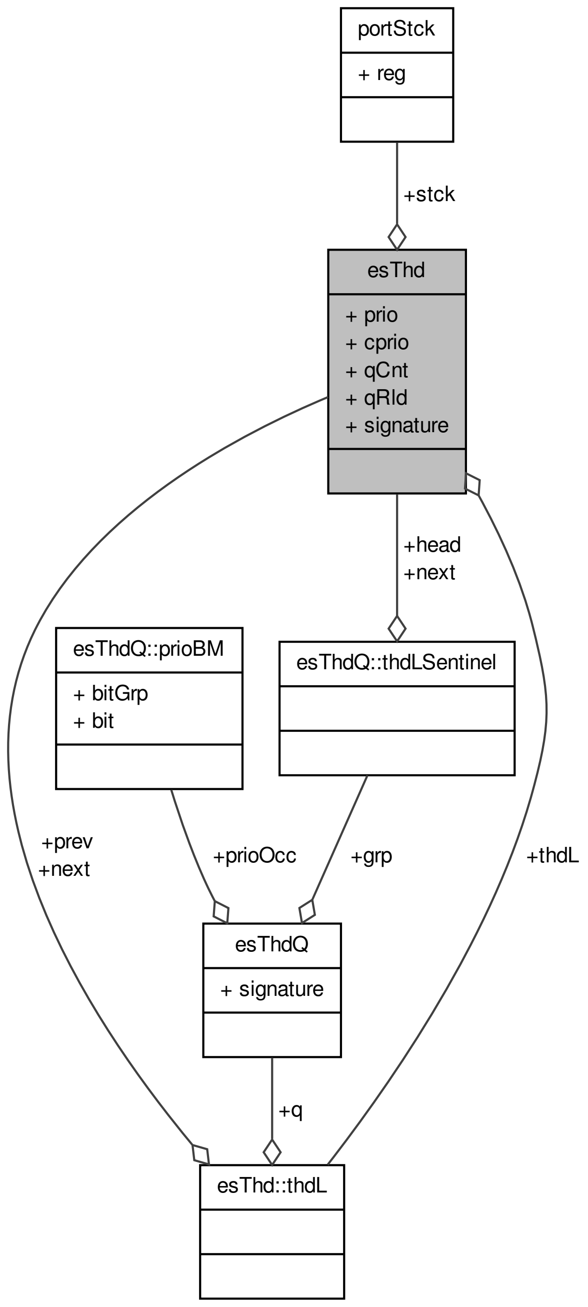
- kernel.h

10.2 esThd Struct Reference

Thread structure.

```
#include <kernel.h>
```

Collaboration diagram for esThd:



Data Structures

- struct thdL

    Thread linked List structure.

Data Fields

- portStck_T ∗ stck

    Pointer to thread's Top Of Stack.
- struct esThd::thdL thdL

    Thread linked list.
- uint_fast8_t prio

    Thread current priority level.
- uint_fast8_t cprio

    Constant Thread Priority level.
- uint_fast8_t qCnt

    Quantum counter.
- uint_fast8_t qRld

    Quantum counter reload value.
- portReg_T signature

    Thread structure signature, see Error checking.

10.2.1 Detailed Description

Thread structure.

A thread structure is a data structure used by kernel to maintain information about a thread. Each thread requires its own ID structure and the structure is allocated in user memory space (RAM). The address of the thread's ID structure is provided to OS thread-related services.

Thread structure is used as thread ID and a thread is always referenced using this structure.

Object class:

Regular **API** object, this object is part of the application programming interface.

10.2.2 Field Documentation

10.2.2.1 portStck_T∗ esThd::stck

Pointer to thread's Top Of Stack.

10.2.2.2 struct esThd::thdL esThd::thdL

Thread linked list.

10.2.2.3 uint_fast8_t esThd::prio

Thread current priority level.

10.2.2.4 uint_fast8_t esThd::cprio

Constant Thread Priority level.

10.2.2.5 uint_fast8_t esThd::qCnt

Quantum counter.

10.2.2.6 uint_fast8_t esThd::qRld

Quantum counter reload value.

10.2.2.7 portReg_T esThd::signature

Thread structure signature, see Error checking.

The documentation for this struct was generated from the following file:

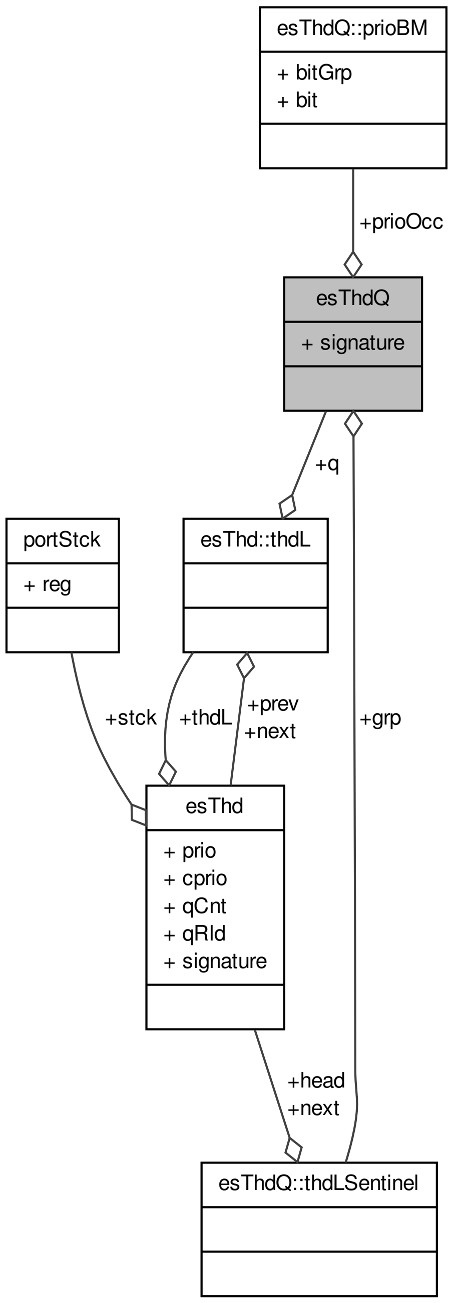
- kernel.h

10.3 esThdQ Struct Reference

Thread Queue structure.

```
#include <kernel.h>
```

Collaboration diagram for esThdQ:



Data Structures

- struct prioBM

  Priority Bit Map structure.
- struct thdLSentinel

  Thread linked list sentinel structure.

Data Fields

- struct esThdQ::prioBM prioOcc

  Priority Occupancy.
- struct esThdQ::thdLSentinel grp [CFG_SCHED_PRIO_LVL]

  Array of thread linked list sentinel structures.
- portReg_T signature

  Thread Queue struct signature, see Error checking.

10.3.1 Detailed Description

Thread Queue structure.

Object class:

Regular **API** object, this object is part of the application programming interface.

10.3.2 Field Documentation

10.3.2.1 struct **esThdQ::prioBM** esThdQ::prioOcc

Priority Occupancy.

10.3.2.2 struct **esThdQ::thdLSentinel** esThdQ::grp[**CFG_SCHED_PRIO_LVL**]

Array of thread linked list sentinel structures.

10.3.2.3 **portReg_T** esThdQ::signature

Thread Queue struct signature, see Error checking.

The documentation for this struct was generated from the following file:

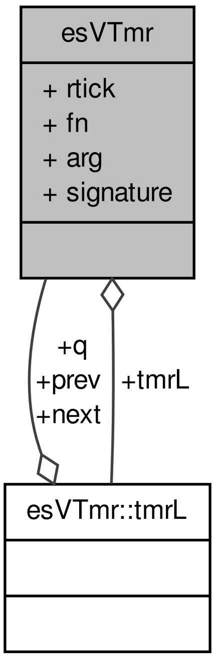
- kernel.h

10.4 esVTmr Struct Reference

Virtual Timer structure.

```
#include <kernel.h>
```

Collaboration diagram for esVTmr:



Data Structures

- struct tmrL

    Virtual Timer linked list structure.

Data Fields

- struct esVTmr::tmrL tmrL

    Virtual Timer linked List.
- esTick_T rtick

    Relative tick value.
- void(∗ fn)(void ∗)

    Callback function pointer.
- void ∗ arg

    Callback function argument.
- portReg_T signature

    Timer structure signature, see Error checking.

10.4.1 Detailed Description

Virtual Timer structure.

10.4.2 Field Documentation

10.4.2.1 struct esVTmr::tmrL esVTmr::tmrL

Virtual Timer linked List.

10.4.2.2 esTick_T esVTmr::rtick

Relative tick value.

10.4.2.3 void(∗ esVTmr::fn)(void ∗)

Callback function pointer.

10.4.2.4 void∗ esVTmr::arg

Callback function argument.

10.4.2.5 portReg_T esVTmr::signature

Timer structure signature, see Error checking.

The documentation for this struct was generated from the following file:

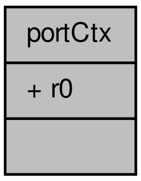
- kernel.h

10.5 portCtx Struct Reference

Port context structure.

```
#include <cpu.h>
```

Collaboration diagram for portCtx:



Data Fields

- portReg_T r0

  Data pushed on stack during context switching.

10.5.1 Detailed Description

Port context structure.

10.5.2 Field Documentation

10.5.2.1 portReg_T portCtx::r0

Data pushed on stack during context switching.

The documentation for this struct was generated from the following file:

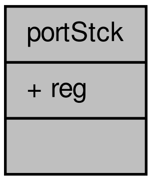
- cpu.h

10.6 portStck Struct Reference

Stack structure used for stack declaration in order to force the alignment.

```
#include <cpu.h>
```

Collaboration diagram for portStck:



Data Fields

- portReg_T reg

  A structure field representing stack data.

10.6.1 Detailed Description

Stack structure used for stack declaration in order to force the alignment.

10.6.2 Field Documentation

10.6.2.1 portReg_T portStck::reg

A structure field representing stack data.

The documentation for this struct was generated from the following file:

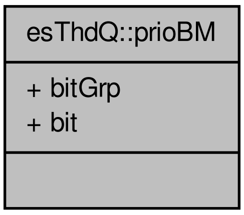
- cpu.h

10.7 esThdQ::prioBM Struct Reference

Priority Bit Map structure.

```
#include <kernel.h>
```

Collaboration diagram for esThdQ::prioBM:



Data Fields

- portReg_T bitGrp

  Bit group indicator.
- portReg_T bit [PRIO_BM_GRP_INDX]

  Bit priority indicator.

10.7.1 Detailed Description

Priority Bit Map structure.

10.7.2 Field Documentation

10.7.2.1 portReg_T esThdQ::prioBM::bitGrp

Bit group indicator.

10.7.2.2 portReg_T esThdQ::prioBM::bit[PRIO_BM_GRP_INDX]

Bit priority indicator.

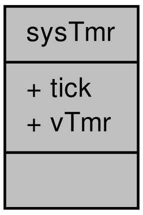
The documentation for this struct was generated from the following file:

- kernel.h

10.8 sysTmr Struct Reference

Main System Timer structure.

Collaboration diagram for sysTmr:



Data Fields

- esTick_T tick

    Current system tick counter.
- uint_fast16_t vTmr

    The number of virtual timers in system.

10.8.1 Detailed Description

Main System Timer structure.

Note

1) Member `tick` exists only if FIXED mode is selected. When this mode is selected then kernel supports time ticking tracking.
2) When INHIBITED or ADAPTIVE mode is selected members `qm` and `state` are used to manage Quantum intervals.

10.8.2 Field Documentation

10.8.2.1 esTick_T sysTmr::tick

Current system tick counter.

10.8.2.2 uint_fast16_t sysTmr::vTmr

The number of virtual timers in system.

The documentation for this struct was generated from the following file:

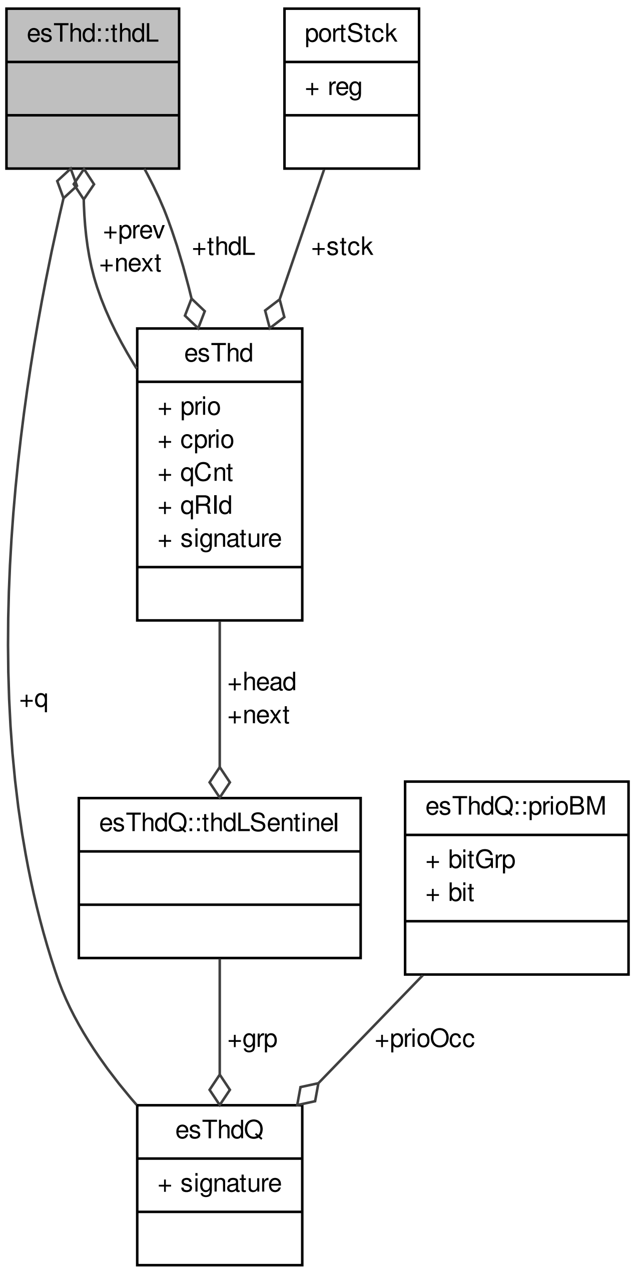
- kernel.c

10.9 esThd::thdL Struct Reference

Thread linked List structure.

`#include <kernel.h>`

Collaboration diagram for esThd::thdL:



Data Fields

- struct esThdQ ∗ q

    Points to parent thread queue.
- struct esThd ∗ next

    Next thread in linked list.
- struct esThd ∗ prev

Previous thread in linked list.

10.9.1 Detailed Description

Thread linked List structure.

10.9.2 Field Documentation

10.9.2.1 struct **esThdQ**∗ esThd::thdL::q

Points to parent thread queue.

10.9.2.2 struct **esThd**∗ esThd::thdL::next

Next thread in linked list.

10.9.2.3 struct **esThd**∗ esThd::thdL::prev

Previous thread in linked list.

The documentation for this struct was generated from the following file:

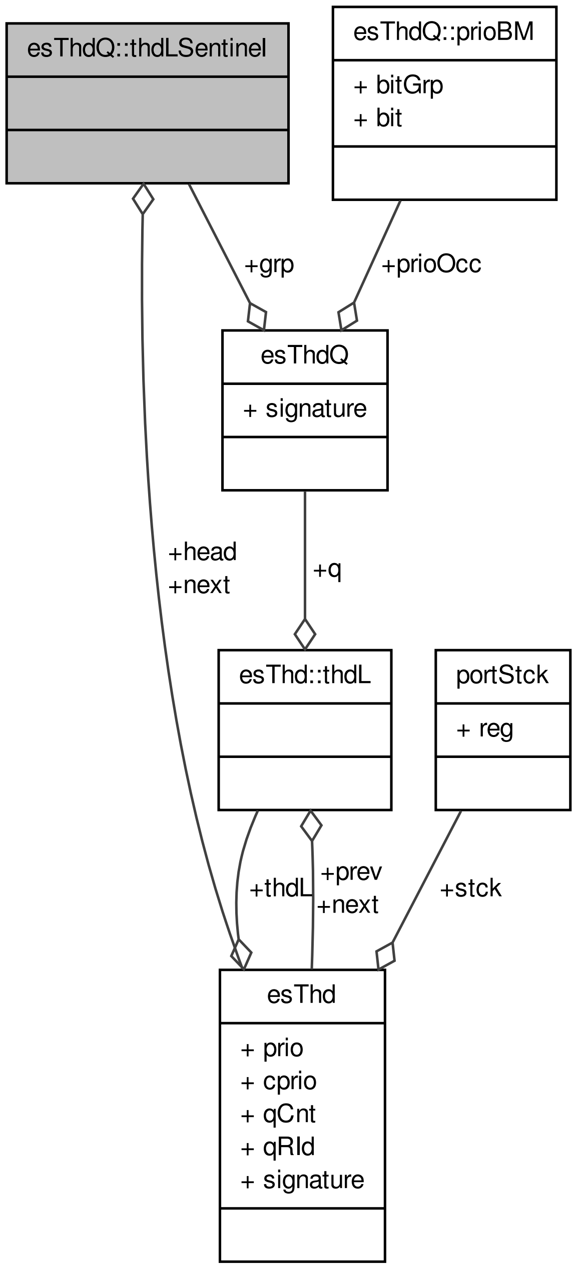
- kernel.h

10.10 esThdQ::thdLSentinel Struct Reference

Thread linked list sentinel structure.

```
#include <kernel.h>
```

Collaboration diagram for esThdQ::thdLSentinel:



Data Fields

- struct esThd ∗ head

  Points to the first thread in linked list.
- struct esThd ∗ next

  Points to the next thread in linked list.

10.10.1 Detailed Description

Thread linked list sentinel structure.

10.10.2 Field Documentation

10.10.2.1 struct **esThd**∗ esThdQ::thdLSentinel::head

Points to the first thread in linked list.

10.10.2.2 struct **esThd**∗ esThdQ::thdLSentinel::next

Points to the next thread in linked list.

The documentation for this struct was generated from the following file:

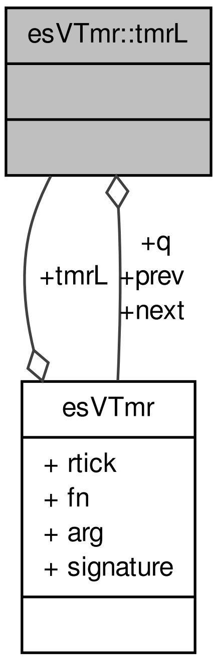
- kernel.h

10.11 esVTmr::tmrL Struct Reference

Virtual Timer linked list structure.

`#include <kernel.h>`

Collaboration diagram for esVTmr::tmrL:



Data Fields

- struct esVTmr ∗ q

Points to parent timer list.

- struct esVTmr ∗ next

  Next thread in Virtual Timer linked list.
- struct esVTmr ∗ prev

  Previous thread in virtual timer linked list.

10.11.1 Detailed Description

Virtual Timer linked list structure.

10.11.2 Field Documentation

10.11.2.1 struct esVTmr∗ esVTmr::tmrL::q

Points to parent timer list.

10.11.2.2 struct esVTmr∗ esVTmr::tmrL::next

Next thread in Virtual Timer linked list.

10.11.2.3 struct esVTmr∗ esVTmr::tmrL::prev

Previous thread in virtual timer linked list.

The documentation for this struct was generated from the following file:

- kernel.h

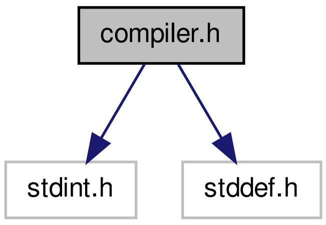
11 File Documentation

11.1 compiler.h File Reference

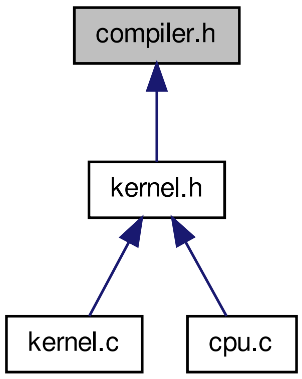
Interface of Compiler port - Template.

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for compiler.h:



This graph shows which files directly or indirectly include this file:



Macros

Compiler provided macros

Port interface macros and port specific macros

These macros are used to ease the writing of ports. All macros prefixed with ***PORT_*** *are part of the port interface.*

- #define PORT_C_INLINE inline
  C extension - make a function inline.
- #define PORT_C_INLINE_ALWAYS inline
  C extension - make a function inline - always.
- #define PORT_C_NAKED
  Omit function prologue/epilogue sequences.
- #define PORT_C_FUNC "unknown"
  Provides function name for assert macros.
- #define PORT_C_WEAK
  Declares a weak function.
- #define PORT_C_ALIGNED(expr)
  This attribute specifies a minimum alignment (in bytes) for variables of the specified type.
- #define PORT_HWREG_SET(reg, mask, val)
  A standardized way of properly setting the value of HW register.

Compiler provided data types

The compiler port must provide some C90 (C99) data types

The compiler port must:

- declare sets of integer types having specified widths, standard type definitions and shall define corresponding sets of macros.

Types are defined in the following categories:

- Integer types having certain exact widths

- Fastest integer types having at least certain specified widths
- Integer types wide enough to hold pointers to objects
- standard type definitions

The following exact-width integer types are required:

- int8_t
- int16_t
- int32_t
- uint8_t
- uint16_t
- uint32_t

The following fastest minimum-width integer types are required:

- int_fast8_t
- int_fast16_t
- int_fast32_t
- uint_fast8_t
- uint_fast16_t
- uint_fast32_t

The following integer types capable of holding object pointers are required:

- intptr_t
- uintptr_t

The following standard type definitions are required:

- NULL
- ptrdiff_t
- size_t

- enum boolType {
  TRUE = 1U,
  FALSE = 0U }

  Bool data type.
- typedef enum boolType bool_T

  Bool data type.

11.1.1 Detailed Description

Interface of Compiler port - Template.

Author

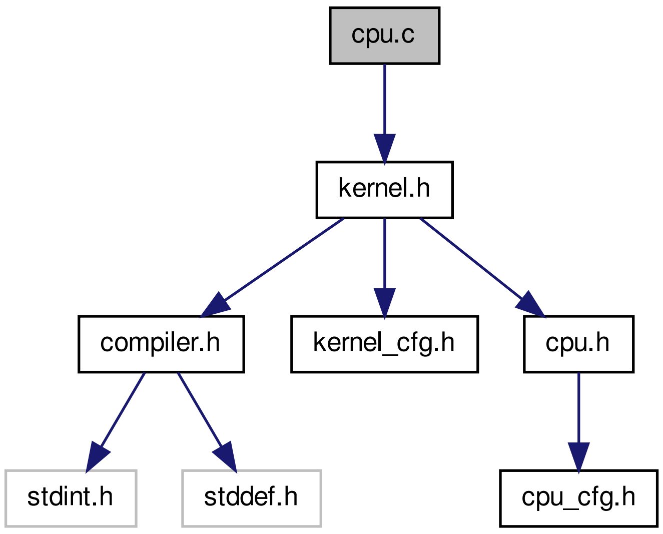
Nenad Radulovic

11.2 cpu.c File Reference

Implementation of CPU port - Template.

```
#include "kernel.h"
```

Include dependency graph for cpu.c:



Functions

- uint_fast8_t portFindLastSet_ (portReg_T val)

  Find last set bit in a word.
- void ∗ portCtxInit_ (void ∗stck, size_t stckSize, void(∗thdf)(void ∗), void ∗arg)

  Initialize the thread context.

Variables

- portReg_T gPortIsrNesting_

  Variable to keep track of ISR nesting.
- const PORT_C_ROM portReg_T pwr2LKP [PORT_DATA_WIDTH_VAL]

  Look up table for: 2^n expression.

11.2.1 Detailed Description

Implementation of CPU port - Template.

Author

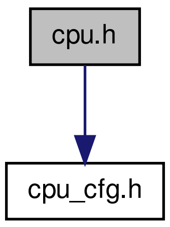
Nenad Radulovic

11.3 cpu.h File Reference

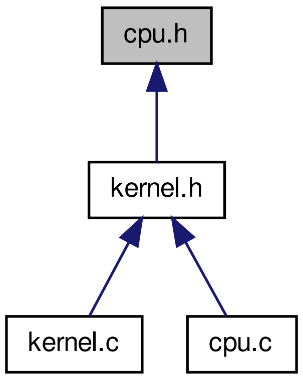
Interface of CPU port - Template.

```
#include "cpu_cfg.h"
```

Include dependency graph for cpu.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct portStck

  Stack structure used for stack declaration in order to force the alignment.
- struct portCtx

  Port context structure.

Macros

Port constants

- #define PORT_DATA_WIDTH_VAL 8U

This macro specifies the bit width of CPU data registers.
- #define PORT_STCK_MINSIZE_VAL sizeof(struct portCtx)
  This macro specifies the minimal size of the thread stack.
- #define PORT_SYSTMR_RELOAD_VAL (CFG_SYSTMR_CLOCK_FREQUENCY / CFG_SYSTMR_EV-ENT_FREQUENCY)
  System timer reload value for one tick.
- #define PORT_SYSTMR_MAX_VAL 0xFFU
  System timer maximum value.
- #define PORT_SYSTMR_MAX_TICKS_VAL (PORT_SYSTMR_MAX_VAL / PORT_SYSTMR_RELOAD-_VAL)
  Maximum number of ticks the system timer can accept.

Critical section management

Disable/enable interrupts by preserving the status of interrupts.

Generally speaking these macros would store the status of the interrupt disable flag in the local variable declared by PORT_CRITICAL_DECL and then disable interrupts. Local variable is allocated in all of eSolid RTOS functions that need to disable interrupts. Macros would restore the interrupt status by copying back the allocated variable into the CPU's status register.

- #define PORT_CRITICAL_DECL() portReg_T intStatus_
  Declare the interrupt status variable.
- #define PORT_CRITICAL_ENTER()
  Enter critical section.
- #define PORT_CRITICAL_EXIT() portIntSet_(intStatus_)
  Exit critical section.

General port macros

- #define PORT_STCK_SIZE(size)
  Calculate the stack size.
- #define PORT_CRITICAL_EXIT_SLEEP() PORT_CRITICAL_EXIT()
  TODO.
- #define PORT_INIT_EARLY() portInitEarly_()
  Early port initialization.
- #define PORT_INIT() portInit_()
  Port initialization.
- #define PORT_INIT_LATE() portInitLate_()
  Late port initialization.

Typedefs

- typedef uint8_t portReg_T
  Data type which corresponds to the general purpose register.
- typedef struct portStck portStck_T
  Stack type.

Functions

- struct portStck __attribute__ ((aligned(1)))
  Alignment of stack structure.

General port functions

- void portInitEarly_ (void)
  Early port initialization.
- void portInit_ (void)
  Port initialization.
- void portInitLate_ (void)
  Late port initialization.

Variables

- portReg_T reg

  A structure field representing stack data.
- struct portCtx **__attribute__**
- portReg_T gPortIsrNesting_

  Variable to keep track of ISR nesting.
- const PORT_C_ROM portReg_T pwr2LKP [PORT_DATA_WIDTH_VAL]

  Look up table for: 2^n expression.

Interrupt management

- #define PORT_INT_DISABLE() portIntDisable_()

  Disable all interrupt sources.
- #define PORT_ISR_ENTER()

  Enter ISR. Increment gPortIsrNesting_ variable to keep track of ISR nesting.
- #define PORT_ISR_EXIT()

  Exit ISR. Decrement gPortIsrNesting_ variable to keep track of ISR nesting.
- #define PORT_ISR_IS_LAST() (0U == gPortIsrNesting ? TRUE : FALSE)

  If isrNesting variable is zero then the last ISR is executing and scheduler should be invoked.
- void portIntDisable_ (void)

  Disable interrupts.
- portReg_T portIntGet_ (void)

  Get the current status of enabled/disabled interrupts.
- void portIntSet_ (portReg_T status)

  Set the status of interrupts according to the `status` argument.

Scheduler support

Note

These functions are extensively used by the scheduler and therefore they should be optimized for the architecture being used.

- #define PORT_FIND_LAST_SET(val) portFindLastSet_(val)

  Find last set bit in a word.
- #define PORT_PWR2(pwr) (1U << (pwr))

  Helper macro: calculate 2^pwr expression.
- #define PORT_SYSTMR_INIT() portSysTmrInit_()

  Initialize system timer and associated interrupt.
- #define PORT_SYSTMR_TERM() portSysTmrTerm_()

  Stop the timer if it is running and disable associated interrupt.
- #define PORT_SYSTMR_RELOAD(ticks) portSysTmrReload_(ticks)

  Reload the system timer with specified number of ticks.
- #define PORT_SYSTMR_ENABLE() portSysTmrEnable_()

  Enable the system timer.
- #define PORT_SYSTMR_DISABLE() portSysTmrDisable_()

  Disable the system timer.
- #define PORT_SYSTMR_ISR_ENABLE() portSysTmrIsrEnable_()

  Enable the system timer interrupt.
- #define PORT_SYSTMR_ISR_DISABLE() portSysTmrIsrDisable_()

  Disable the system timer interrupt.

- uint_fast8_t portFindLastSet_ (portReg_T val)

  Find last set bit in a word.
- void portSysTmrInit_ (void)

  Initialize systick timer and associated interrupt.
- void portSysTmrTerm_ (void)

  Stop the sistem timer.
- void portSysTmrReload_ (esTick_T ticks)

  Reload the system timer.
- void portSysTmrEnable_ (void)

  Enable the system timer.
- void portSysTmrDisable_ (void)

  Disable the system timer.
- void portSysTmrIsrEnable_ (void)

  Disable the system timer interrupt.
- void portSysTmrIsrDisable_ (void)

  Enable the system timer interrupt.
- void portThdStart_ (void)

  Start the first thread.

Dispatcher context switching

- #define PORT_CTX_INIT(stck, stackSize, thread, arg) portCtxInit_(stck, stackSize, thread, arg)

  Initialize the thread context.
- #define PORT_CTX_SW() portCtxSw_()

  Do the context switch - invoked from API level.
- #define PORT_CTX_SW_ISR() portCtxSwIsr_()

  Do the context switch - invoked from ISR level.
- #define PORT_THD_START() portThdStart_()

  Start the first thread.
- void ∗ portCtxInit_ (void ∗stck, size_t stckSize, void(∗thdf)(void ∗), void ∗arg)

  Initialize the thread context.
- void portCtxSw_ (void)

  Do the context switch - invoked from API.
- void portCtxSwIsr_ (void)

  Do the context switch - invoked from ISR.

11.3.1 Detailed Description

Interface of CPU port - Template.

Author

Nenad Radulovic

11.3.2 Variable Documentation

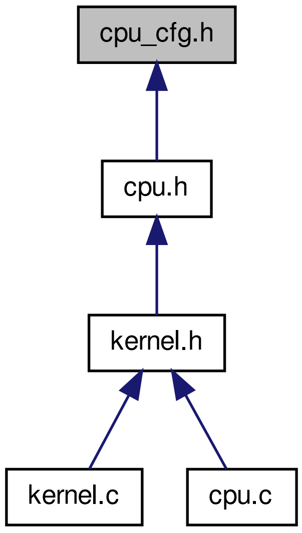
11.3.2.1 portReg_T reg

A structure field representing stack data.

11.4 cpu_cfg.h File Reference

Configuration of CPU port - Template.

This graph shows which files directly or indirectly include this file:



Macros

Port General configuration

Configuration options and settings which are available for every port.

Note

1) All port General configuration macros are prefixed with `CFG_` string.
2) All port specific options and constants are prefixed with `CPU_` string.

- #define CFG_CRITICAL_PRIO 1U
  Priority of critical sections in kernel.
- #define CFG_SYSTMR_CLOCK_FREQUENCY 1000000UL
  The frequency of clock which is used for the system timer.

11.4.1 Detailed Description

Configuration of CPU port - Template.

Author

Nenad Radulovic

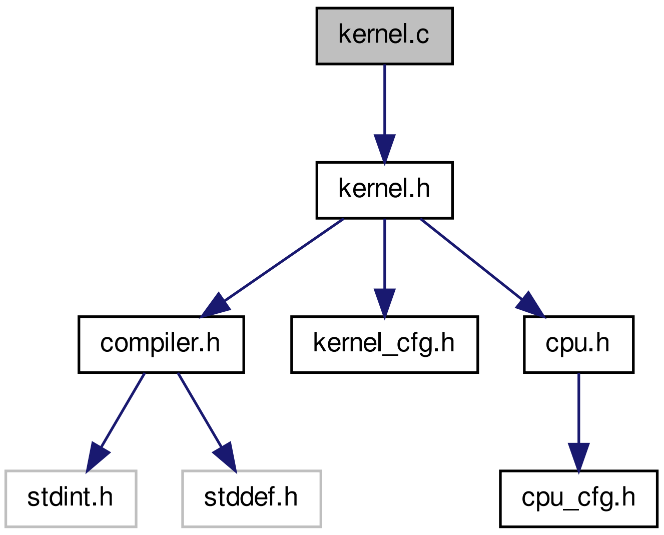
11.5 kernel-example.dox File Reference

11.6 kernel.c File Reference

Implementation of port independent code.

`#include "kernel.h"`

Include dependency graph for kernel.c:



Data Structures

- struct sysTmr

    Main System Timer structure.

Macros

- #define PRIO_BM_DATA_WIDTH_LOG2

    Priority Bit Map log base 2: `log2(PORT_DATA_WIDTH_VAL)`
- #define SCHED_STATE_INTSRV_MSK (1U << 0)

    Kernel state variable bit position which defines if kernel is in interrupt servicing state.
- #define SCHED_STATE_LOCK_MSK (1U << 1)

    Kernel state variable bit position which defines if the kernel is locked or not.
- #define SYSTMR_SCHED_QM_MSK (1U << 0)

    Scheduler is using system timer Quantum mask.
- #define SYSTMR_USR_QM_MSK (1U << 1)

    User is using system timer Quantum mask.
- #define SCHED_POWER_SAVE 0U

    Enable/disable scheduler power savings mode.
- #define THD_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEFU)

    Thread structure signature.
- #define THDQ_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEEU)

    Thread Queue structure signature.

- #define VTMR_CONTRACT_SIGNATURE ((portReg_T)0xFEEDBEEFU)

  Timer structure signature.
- #define DLIST_IS_ENTRY_FIRST(list, entry) ((entry) == (entry)->list.next)

  DList macro: is the thread the first one in the list.
- #define DLIST_IS_ENTRY_LAST(list, entry) DLIST_IS_ENTRY_FIRST(list, entry)

  DList macro: is the thread the last one in the list.
- #define DLIST_IS_ENTRY_SINGLE(list, entry) DLIST_IS_ENTRY_FIRST(list, entry)

  DList macro: is the thread single in the list.
- #define DLIST_ENTRY_PREV(list, entry) (entry)->list.prev

  Get the previous entry.
- #define DLIST_ENTRY_NEXT(list, entry) (entry)->list.next

  Get the next entry.
- #define DLIST_ENTRY_INIT(list, entry)

  Initialize entry.
- #define DLIST_ENTRY_ADD_AFTER(list, current, entry)

  Add new `entry` after `current` entry.
- #define DLIST_ENTRY_RM(list, entry)

  Remove the `entry` from a list.
- #define KVTMR_STCK_SIZE PORT_STCK_SIZE(40U)

  System Timer kernel thread stack size.
- #define KIDLE_STCK_SIZE PORT_STCK_SIZE(40U)

  Idle kernel thread stack size.

Typedefs

Threads Queue

- typedef struct thdLSentinel thdLSentinel_T

  Thread list sentinel type.

Functions

- static void **vTmrExecHandlers** (void)
- static void **vTmrImport** (void)
- void esKernInit (void)

  Initialize kernel internal data structures.
- PORT_C_NORETURN void esKernStart (void)

  Start the multi-threading.
- void esKernSysTmrI (void)

  Process the system timer event.
- void esKernLockEnterI (void)

  Lock the scheduler.
- void esKernLockExitI (void)

  Unlock the scheduler.
- void esKernLockEnter (void)

  Lock the scheduler.
- void esKernLockExit (void)

  Unlock the scheduler.
- void esKernIsrPrologueI (void)

  Enter Interrupt Service Routine.
- void esKernIsrEpilogueI (void)

Exit Interrupt Service Routine.

- void esThdInit (esThd_T ∗thd, void(∗fn)(void ∗), void ∗arg, portStck_T ∗stck, size_t stckSize, uint8_t prio)

  Initialize the specified thread.
- void esThdTerm (esThd_T ∗thd)

  Terminate the specified thread.
- void esThdSetPrioI (esThd_T ∗thd, uint8_t prio)

  Set the priority of a thread.
- void esThdPostI (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdPost (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdWaitI (void)

  Wait for thread semaphore.
- void esThdWait (void)

  Wait for thread semaphore.
- void esThdQInit (esThdQ_T ∗thdQ)

  Initialize Thread Queue.
- void esThdQAddI (esThdQ_T ∗thdQ, esThd_T ∗thd)

  Add a thread to the Thread Queue.
- void esThdQRmI (esThdQ_T ∗thdQ, esThd_T ∗thd)

  Removes the thread from the Thread Queue.
- esThd_T ∗ esThdQFetchI (const esThdQ_T ∗thdQ)

  Fetch the first high priority thread from the Thread Queue.
- esThd_T ∗ esThdQFetchRotateI (esThdQ_T ∗thdQ, uint_fast8_t prio)

  Fetch the next thread and rotate thread linked list.
- bool_T esThdQIsEmpty (const esThdQ_T ∗thdQ)

  Is thread queue empty.
- void esSchedRdyAddI (esThd_T ∗thd)

  Add thread `thd` to the ready thread list and notify the scheduler.
- void esSchedRdyRmI (esThd_T ∗thd)

  Remove thread `thd` from the ready thread list and notify the scheduler.
- void esSchedYieldI (void)

  Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.
- void esSchedYieldIsrI (void)

  Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.
- void esSysTmrEnable (void)

  Enable system timer tick events.
- void esSysTmrDisable (void)

  Disable system timer tick events.
- void esVTmrInitI (esVTmr_T ∗vTmr, esTick_T tick, void(∗fn)(void ∗), void ∗arg)

  Add and start a new virtual timer.
- void **esVTmrInit** (esVTmr_T ∗vTmr, esTick_T tick, void(∗fn)(void ∗), void ∗arg)
- void esVTmrTerm (esVTmr_T ∗vTmr)

  Cancel and remove a virtual timer.
- void esVTmrDelay (esTick_T tick)

  Delay for specified amount of ticks.

Virtual Timer kernel thread

- static void vTmrListAddSort (esVTmr_T ∗list, esVTmr_T ∗vTmr)

Add a virtual timer into sorted list.
- static void kVTmrInit (void)
  Initialization of Virtual Timer kernel thread.
- static void kVTmr (void ∗arg)
  Virtual Timer thread code.

Variables

- static uint_fast8_t gKernLockCnt
  Kernel Lock Counter.
- const volatile esKernCtrl_T gKernCtrl
  Kernel control initialization.

System timer kernel thread

- static sysTmr_T gSysTmr
  Main System Timer structure.
- static esVTmr_T gVTmrArmed
  List of virtual timers to armed expire.
- static esVTmr_T gVTmrPend
  Virtual timers pending to be inserted into waiting list.
- static esThd_T gKVTmrId
  Virtual timer thread ID.
- static portStck_T gKVTmrStck [KVTMR_STCK_SIZE]
  Virtual timer kernel thread stack.

System timer

- enum sysTmrState {
  SYSTMR_ACTIVE,
  SYSTMR_INACTIVE }
  System timer state enumeration.
- typedef struct sysTmr sysTmr_T
  System Timer type.
- static void sysTmrInit (void)
  Initialize system timer hardware.
- static void sysTmrTryDeactivate (void)
  Try to deactivate system timer.
- static void sysTmrTryActivate (void)
  Try to activate system timer.

Priority Bit Map

- typedef struct prioBM prioBM_T
  Priority Bit Map type.
- static PORT_C_INLINE void prioBMInit (prioBM_T ∗bm)
  Initialize bitmap.
- static PORT_C_INLINE void prioBMSet (prioBM_T ∗bm, uint_fast8_t prio)
  Set the bit corresponding to the prio argument.
- static PORT_C_INLINE void prioBMClear (prioBM_T ∗bm, uint_fast8_t prio)
  Clear the bit corresponding to the prio argument.
- static PORT_C_INLINE uint_fast8_t prioBMGet (const prioBM_T ∗bm)
  Get the highest priority set.
- static PORT_C_INLINE bool_T prioBMIsEmpty (const prioBM_T ∗bm)
  Is bit map empty?

Scheduler

- static esThdQ_T gRdyQueue

  Ready Thread queue.
- static PORT_C_INLINE void schedInit (void)

  Initialize Ready Thread Queue structure gRdyQueue and Kernel control structure esKernCtrl.
- static PORT_C_INLINE void schedStart (void)

  Set scheduler data structures ready for multi-threading.
- static void schedRdyAddInitI (esThd_T ∗thd)

  Initialize scheduler ready structure during the thread add operation.
- static void schedQmI (void)

  Do the Quantum (Round-Robin) scheduling.
- static PORT_C_INLINE void schedQmActivate (void)

  Activate system timer Quantum mode.
- static PORT_C_INLINE void schedQmDeactivate (void)

  Deactivate system timer Quantum mode.
- static void schedQmEvaluateI (esThd_T ∗thd)

  Evaluate if the system timer Quantum mode is needed.

Idle kernel thread

- static esThd_T gKIdleId

  Idle thread ID.
- static portStck_T gKIdleStck [KIDLE_STCK_SIZE]

  Idle kernel thread stack.
- static void kIdleInit (void)

  Initialization of Idle thread.
- static void kIdle (void ∗arg)

  Idle thread code.

11.6.1 Detailed Description

Implementation of port independent code.

Author

Nenad Radulovic

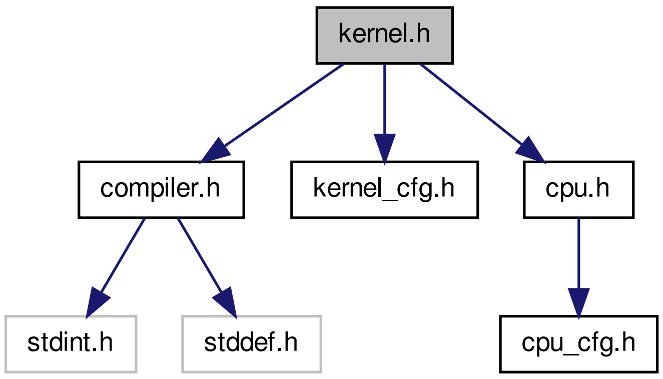
11.7 kernel.dox File Reference

11.8 kernel.h File Reference

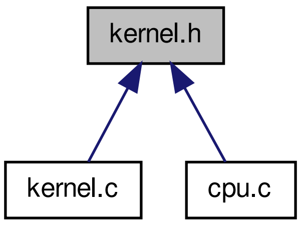
Interface of kernel.

```
#include "compiler.h"
#include "kernel_cfg.h"
#include "cpu.h"
```

Include dependency graph for kernel.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct esThd

    Thread structure.
- struct esThd::thdL

    Thread linked List structure.
- struct esVTmr

    Virtual Timer structure.
- struct esVTmr::tmrL

    Virtual Timer linked list structure.
- struct esThdQ

    Thread Queue structure.
- struct esThdQ::prioBM

    Priority Bit Map structure.
- struct esThdQ::thdLSentinel

    Thread linked list sentinel structure.

- struct esKernCtrl

  Kernel control block structure.

Macros

Kernel identification and version number

- #define ES_KERNEL_VER 0x10000UL

  Identifies the underlying kernel version number.
- #define ES_KERNEL_ID "eSolid Kernel v1.0"

  Kernel identification string.

Error checking

Some basic infrastructure for error checking

These macros provide basic detection of errors. For more datails see Error checking.

- #define ES_ASSERT(expr)

  Generic assert macro.
- #define ES_API_OBLIGATION(expr) expr

  Execute code to fulfill the contract.
- #define ES_API_REQUIRE(expr) ES_ASSERT(expr)

  Make sure the caller has fulfilled all contract preconditions.
- #define ES_API_ENSURE(expr) ES_ASSERT(expr)

  Make sure the callee has fulfilled all contract postconditions.

Functions

General kernel functions

There are several groups of functions:

- *kernel initialization and start*
- *ISR prologue and epilogue*

- void esKernInit (void)

  Initialize kernel internal data structures.
- PORT_C_NORETURN void esKernStart (void)

  Start the multi-threading.
- void esKernSysTmrI (void)

  Process the system timer event.
- void esKernIsrPrologueI (void)

  Enter Interrupt Service Routine.
- void esKernIsrEpilogueI (void)

  Exit Interrupt Service Routine.

Scheduler notification and invocation

- void esSchedRdyAddI (esThd_T ∗thd)

  Add thread `thd` to the ready thread list and notify the scheduler.
- void esSchedRdyRmI (esThd_T ∗thd)

  Remove thread `thd` from the ready thread list and notify the scheduler.
- void esSchedYieldI (void)

  Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.
- void esSchedYieldIsrI (void)

  Force the scheduler invocation which will evaluate all ready threads and switch to ready thread with the highest priority.

System timer management

- void esSysTmrEnable (void)
  Enable system timer tick events.
- void esSysTmrDisable (void)
  Disable system timer tick events.

Kernel hook functions

- PORT_C_NORETURN void userAssert (const char ∗fnName, const char ∗expr)
  An assertion has failed. This function should inform the user about failed assertion.
- void userSysTmr (void)
  System timer hook function, called from system system timer ISR function.
- void userKernInit (void)
  Kernel initialization hook function, called from esKernInit() function.
- void userKernStart (void)
  Kernel start hook function, called from esKernStart() function.
- void userThdInitEnd (void)
  Thread initialization end hook function, called from esThdInit() function.
- void userThdTerm (void)
  Thread terminate hook function, called from esThdTerm() or when a thread terminates itself.
- void userCtxSw (esThd_T ∗oldThd, esThd_T ∗newThd)
  Kernel context switch hook function, called from esSchedYieldI() and esSchedYieldIsrI() functions.

Critical section management

These macros are used to prevent interrupts on entry into the critical section, and restoring interrupts to their previous state on exit from critical section.

For more details see Critical sections.

- #define ES_CRITICAL_DECL() PORT_CRITICAL_DECL()
  Critical section status variable declaration.
- #define ES_CRITICAL_ENTER() PORT_CRITICAL_ENTER()
  Enter a critical section.
- #define ES_CRITICAL_EXIT() PORT_CRITICAL_EXIT()
  Exit from critical section.
- #define **ES_CRITICAL_ENTER_LOCK_EXIT**()
- #define **ES_CRITICAL_EXIT_LOCK_ENTER**()
- void esKernLockEnterI (void)
  Lock the scheduler.
- void esKernLockExitI (void)
  Unlock the scheduler.
- void esKernLockEnter (void)
  Lock the scheduler.
- void esKernLockExit (void)
  Unlock the scheduler.

Thread management

Basic thread management services

For more details see Thread Management.

- #define ES_STCK_SIZE(elem) PORT_STCK_SIZE(elem)

Converts the required stack elements into the stack array index.

- typedef struct esThd esThd_T

  Thread type.
- typedef portStck_T esStck_T

  Stack type.
- void esThdInit (esThd_T ∗thd, void(∗fn)(void ∗), void ∗arg, portStck_T ∗stck, size_t stckSize, uint8_t prio)

  Initialize the specified thread.
- void esThdTerm (esThd_T ∗thd)

  Terminate the specified thread.
- static PORT_C_INLINE esThd_T ∗ esThdGetId (void)

  Get the current thread ID.
- static PORT_C_INLINE uint8_t esThdGetPrio (esThd_T ∗thd)

  Get the priority of a thread.
- void esThdSetPrioI (esThd_T ∗thd, uint8_t prio)

  Set the priority of a thread.
- void esThdPostI (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdPost (esThd_T ∗thd)

  Post to thread semaphore.
- void esThdWaitI (void)

  Wait for thread semaphore.
- void esThdWait (void)

  Wait for thread semaphore.

Virtual Timer management

- typedef struct esVTmr esVTmr_T

  Virtual Timer type.
- void esVTmrInitI (esVTmr_T ∗vTmr, esTick_T tick, void(∗fn)(void ∗), void ∗arg)

  Add and start a new virtual timer.
- void esVTmrTerm (esVTmr_T ∗vTmr)

  Cancel and remove a virtual timer.
- void esVTmrDelay (esTick_T tick)

  Delay for specified amount of ticks.

Thread Queue management

- #define PRIO_BM_GRP_INDX ((CFG_SCHED_PRIO_LVL + PORT_DATA_WIDTH_VAL - 1U) / PORT_DATA_WIDTH_VAL)

  Priority Bit Map Group Index.
- typedef struct esThdQ esThdQ_T

  Thread queue type.
- void esThdQInit (esThdQ_T ∗thdQ)

  Initialize Thread Queue.
- void esThdQAddI (esThdQ_T ∗thdQ, esThd_T ∗thd)

  Add a thread to the Thread Queue.
- void esThdQRmI (esThdQ_T ∗thdQ, esThd_T ∗thd)

  Removes the thread from the Thread Queue.
- esThd_T ∗ esThdQFetchI (const esThdQ_T ∗thdQ)

  Fetch the first high priority thread from the Thread Queue.
- esThd_T ∗ esThdQFetchRotateI (esThdQ_T ∗thdQ, uint_fast8_t prio)

Fetch the next thread and rotate thread linked list.

- bool_T esThdQIsEmpty (const esThdQ_T ∗thdQ)

  Is thread queue empty.

Kernel control block

- enum esKernState {
  ES_KERN_RUN = 0x00U,
  ES_KERN_INTSRV_RUN = 0x01U,
  ES_KERN_LOCK = 0x02U,
  ES_KERN_INTSRV_LOCK = 0x03U,
  ES_KERN_INIT = 0x04U,
  ES_KERN_INACTIVE = 0x05U }

  Kernel state enumeration.
- typedef enum esKernState esKernState_T

  Kernel state type.
- typedef struct esKernCtrl esKernCtrl_T

  Kernel control block type.
- const volatile esKernCtrl_T gKernCtrl

  Kernel control block.

11.8.1 Detailed Description

Interface of kernel.

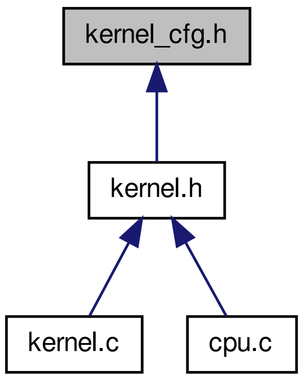
Author

Nenad Radulovic

11.9 kernel_cfg.h File Reference

Configuration of Kernel.

This graph shows which files directly or indirectly include this file:



Macros

Kernel configuration options and settings

- #define CFG_API_VALIDATION 1U
  Enable/disable API arguments validation.
- #define CFG_SCHED_PRIO_LVL 8U
  Scheduler priority levels.
- #define CFG_SCHED_TIME_QUANTUM 10U
  Scheduler Round-Robin time quantum.
- #define CFG_SYSTMR_MODE 1U
  System timer mode.
- #define CFG_SYSTMR_EVENT_FREQUENCY 100UL
  The frequency of system timer tick event.
- #define CFG_SYSTMR_TICK_TYPE 2U
  The size of the system timer tick event counter.

Kernel hooks

- #define CFG_HOOK_SYSTMR_EVENT 0U
  System timer event hook function.
- #define CFG_HOOK_KERN_INIT 0U
  Kernel initialization hook function.
- #define CFG_HOOK_KERN_START 0U
  Kernel start hook function.
- #define CFG_HOOK_THD_INIT_END 0U
  Thread initialization end hook function.
- #define CFG_HOOK_THD_TERM 0U
  Thread termination hook function.
- #define CFG_HOOK_CTX_SW 0U
  Context switch hook function.

11.9.1 Detailed Description

Configuration of Kernel.

Author

Nenad Radulovic

11.10 kernel_cfg.h File Reference

Configuration of Kernel - Template.

Macros

Kernel configuration options and settings

Kernel default configuration

- #define CFG_API_VALIDATION 1U
  Enable/disable API arguments validation.
- #define CFG_SCHED_PRIO_LVL 8U
  Scheduler priority levels.
- #define CFG_SCHED_TIME_QUANTUM 10U
  Scheduler Round-Robin time quantum.
- #define CFG_SYSTMR_MODE 1U
  System timer mode.

- #define CFG_SYSTMR_EVENT_FREQUENCY 100UL

    The frequency of system tick event.
- #define CFG_SYSTMR_TICK_TYPE 2U

    The size of the system timer counter.

Kernel hooks

- #define CFG_HOOK_SYSTMR_EVENT 0U

    System timer event hook function.
- #define CFG_HOOK_KERN_INIT 0U

    Kernel initialization hook function.
- #define CFG_HOOK_KERN_START 0U

    Kernel start hook function.
- #define CFG_HOOK_THD_INIT_END 0U

    Thread initialization hook function.
- #define CFG_HOOK_THD_TERM 0U

    Thread termination hook function.
- #define CFG_HOOK_CTX_SW 0U

    Kernel context switch hook function.

11.10.1 Detailed Description

Configuration of Kernel - Template.

Author

Nenad Radulovic

Index