Mark3 Realtime Kernel

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The Mark3 Realtime Kernel

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--[Mark3 Realtime Platform]--------------------------------------------------

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The Mark3 Realtime Kernel is a completely free, open-source, real-time operating system aimed at bringing multi-tasking to microcontroller systems without MMUs.

It uses modern programming languages and concepts (it's written entirely in C++) to minimize code duplication, and its object-oriented design enhances readibility. The API is simple - there are only six functions required to set up the kernel, initialize threads, and start the scheduler.

The source is fully-documented with example code provided to illustrate concepts. The result is a performant RTOS, which is easy to read, easy to understand, and easy to extend to fit your needs.

But Mark3 is bigger than just a real-time kernel, it also contains a number of class-leading features:

- Device driver HAL which provides a meaningful abstraction around device-specific peripherals.
- Capable recursive-make driven build system which can be used to build all libraries, examples, tests, documentation, and user-projects for any number of targets from the command-line.
- Graphics and UI code designed to simplify the implementation of systems using displays, keypads, joysticks, and touchscreens
- Standards-based custom communications protocol used to simplify the creation of host tools
- A bulletproof, well-documented bootloader for AVR microcontrollers
- Support for kernel-aware simulators, specifically, Funkenstein Software's own flAVR AVR simulator

Chapter 2

Preface

2.1 Who should read this

As the cover clearly states, this is a book about the Mark3 real-time kernel. I assume that if you're reading this book you have an interest in some, if not all, of the following subjects:

- Embedded systems
- Real-time systems
- Operating system kernel design

And if you're interested in those topics, you're likely familiar with C and C++ and the more you know, the easier you'll find this book to read. And if C++ scares you, and you don't like embedded, real-time systems, you're probably looking for another book. If you're unfamiliar with RTOS fundamentals, I highly suggest searching through the vast amount of RTOS-related articles on the internet to familiarize yourself with the concepts.

2.2 Why Mark3?

My first job after graduating from university in 2005 was with a small company that had a very old-school, low-budget philosophy when it came to software development. Every make-or-buy decision ended with "make" when it came to tools. It was the kind of environment where vendors cost us money, but manpower was free. In retrospect, we didn't have a ton of business during the time that I worked there, and that may have had something to do with the fact that we were constantly short on ready cash for things we could code ourselves.

Early on, I asked why we didn't use industry-standard tools - like JTAG debuggers or IDEs. One senior engineer scoffed that debuggers were tools for wimps - and something that a good programmer should be able to do without. After all - we had serial ports, GPIOs, and a bi-color LED on our boards. Since these were built into the hardware, they didn't cost us a thing. We also had a single software "build" server that took 5 minutes to build a 32k binary on its best days, so when we had to debug code, it was a painful process of trial and error, with lots of Youtube between iterations. We complained that tens of thousands of dollars of productivity was being flushed away that could have been solved by implementing a proper build server - and while we eventually got our wish, it took far more time than it should have.

Needless to say, software development was painful at that company. We made life hard on ourselves purely out of pride, and for the right to say that we walked "up-hills both ways through 3 feet of snow, everyday". Our code was tied ever-so-tightly to our hardware platform, and the system code was indistinguishable from the application. While we didn't use an RTOS, we had effectively implemented a 3-priority threading scheme using a carefully designed interrupt nesting scheme with event flags and a while(1) superloop running as a background thread. Nothing was abstracted, and the code was always optimized for the platform, presumably in an effort to save on code size and wasted cycles. I asked why we didn't use an RTOS in any of our systems and received dismissive scoffs - the overhead from thread switching and maintaining multiple threads could not be tolerated in our systems according to our chief engineers. In retrospect, our ad-hoc system was likely as large as my smallest kernel, and had just as much context switching (althrough it was hidden by the compiler).

And every time a new iteration of our product was developed, the firmware took far too long to bring up, because the algorithms and data structures had to be re-tooled to work with the peripherals and sensors attached to the new boards. We worked very hard in an attempt to reinvent the wheel, all in the name of producing "efficient" code.

Regardless, I learned a lot about software development.

Most important, I learned that good design is the key to good software; and good design doesn't have to come at a price. In all but the smallest of projects, the well-designed, well-abstracted code is not only more portable, but it's usually smaller, easier to read, and easier to reuse.

Also, since we had all the time in the world to invest in developing our own tools, I gained a lot of experience building them, and making use of good, free PC tools that could be used to develop and debug a large portion of our code. I ended up writing PC-based device and peripheral simulators, state-machine frameworks, and abstractions for our horrible ad-hoc system code. At the end of the day, I had developed enough tools that I could solve a lot of our development problems without having to re-inventing the wheel at each turn. Gaining a background in how these tools worked gave me a better understanding of how to use them - making me more productive at the jobs that I've had since.

I am convinced that designing good software takes honest effort up-front, and that good application code cannot be written unless it is based on a solid framework. Just as the wise man builds his house on rocks, and not on sand, wise developers write applications based on a well-defined platforms. And while you can probably build a house using nothing but a hammer and sheer will, you can certainly build one a lot faster with all the right tools.

This conviction lead me to development my first RTOS kernel in 2009 - FunkOS. It is a small, yet surprisingly full-featured kernel. It has all the basics (semaphores, mutexes, round-robin and preemptive scheduling), and some pretty advanced features as well (device drivers and other middleware). However, it had two major problems - it doesn't scale well, and it doesn't support many devices.

While I had modest success with this kernel (it has been featured on some blogs, and still gets around 125 downloads a month), it was nothing like the success of other RTOS kernels like uC/OS-II and FreeRTOS. To be honest, as a one-man show, I just don't have the resources to support all of the devices, toolchains, and evaluation boards that a real vendor can. I had never expected my kernel to compete with the likes of them, and I don't expect Mark3 to change the embedded landscape either.

My main goal with Mark3 was to solve the technical shortfalls in the FunkOS kernel by applying my experience in kernel development. As a result, Mark3 is better than FunkOS in almost every way; it scales better, has lower interrupt latency, and is generally more thoughtfully designed (all at a small cost to code size).

Another goal I had was to create something easy to understand, that could be documented and serve as a good introduction to RTOS kernel design. The end result of these goals is the kernel as presented in this book - a full source listing of a working OS kernel, with each module completely documented and explained in detail.

Finally, I wanted to prove that a kernel written entirely in C++ could perform just as well as one written in C, without incurring any extra overhead. Comparing the same configuration of Mark2 to Mark3, the code size is remarkably similar, and the execution performance is just as good. Not only that, but there are fewer lines of code. The code is more readable and easier to understand as a result of making use of object-oriented concepts provided by C++. Applications are easier to write because common concepts are encapsulated into objects (Threads, Semaphores, Mutexes, etc.) with their own methods and data, as opposed to APIs which rely on lots of explicit pointer-passing, type casting, and other operations that are typically considered "unsafe" or "advaned topics" in C.

Chapter 3

Can you Afford an RTOS?

Of course, since you're reading the manual for an RTOS that I've been developing for the last few years, you can guess that the conclusion that I draw is a resounding "yes".

If your code is of any sort of non-trivial complexity (say, at least a few-thousand lines), then a more appropriate question would be "can you afford ∗not∗ to use an RTOS in your system?".

In short, there are simply too many benefits of an RTOS to ignore.

- Sophisticated synchronization objects
- The ability to efficiently block and wait
- Enhanced responsiveness for high-priority tasks
- Built in timers
- Built in efficient memory management

Sure, these features have a cost in code space and RAM, but from my experience the cost of trying to code around a lack of these features will cost you as much - if not more. The results are often far less maintainable, error prone, and complex. And that simply adds time and cost. Real developers ship, and the RTOS is quickly becoming one of the standard tools that help keep developers shipping.

3.1 Intro

(Note - this article was written for the C-based Mark2 kernel, which is slightly different. While the general principles are the same, the numbers are not an 100% accurate reflection of the current costs of the Mark3 kernel.)

One of the main arguments against using an RTOS in an embedded project is that the overhead incurred is too great to be justified. Concerns over "wasted" RAM caused by using multiple stacks, added CPU utilization, and the "large" code footprint from the kernel cause a large number of developers to shun using a preemptive RTOS, instead favoring a non-preemptive, application-specific solution.

I believe that not only is the impact negligible in most cases, but that the benefits of writing an application with an RTOS can lead to savings around the board (code size, quality, reliability, and development time). While these other benefits provide the most compelling case for using an RTOS, they are far more challenging to demonstrate in a quantitative way, and are clearly documented in numerous industry-based case studies.

While there is some overhead associated with an RTOS, the typical arguments are largely unfounded when an RTOS is correctly implemented in a system. By measuring the true overhead of a preemptive RTOS in a typical application, we will demonstrate that the impact to code space, RAM, and CPU usage is minimal, and indeed acceptable for a wide range of CPU targets.

To illustrate just how little an RTOS impacts the size of an embedded software design we will look at a typical microcontroller project and analyze the various types of overhead associated with using a pre-emptive realtime kernel versus a similar non-preemptive event-based framework.

RTOS overhead can be broken into three distinct areas:

- Code space: The amount of code space eaten up by the kernel (static)
- Memory overhead: The RAM associated wtih running the kernel and application threads.
- Runtime overhead: The CPU cycles required for the kernel's functionality (primarily scheduling and thread switching)

While there are other notable reasons to include or avoid the use of an RTOS in certain applications (determinism, responsiveness, and interrupt latency among others), these are not considered in this discussion - as they are difficult to consider for the scope of our "canned" application. Application description:

For the purpose of this comparison, we first create an application using the standard preemptive Mark3 kernel with 2 system threads running: A foreground thread and a background thread. This gives three total priority levels in the system - the interrupt level (high), and two application priority threads (medium and low), which is quite a common paradigm for microcontroller firmware designs. The foreground thread processes a variety of time-critical events at a fixed frequency, while the background thread processes lower priority, aperiodic events. When there are no background thread events to process, the processor enters its low-power mode until the next interrupt is acknowledged.

The contents of the threads themselves are unimportant for this comparison, but we can assume they perform a variety of I/O using various user-input devices and a serial graphics display. As a result, a number of Mark3 device drivers are also implemented.

The application is compiled for an ATMega328p processor which contains 32kB of code space in flash, and 2kB of RAM, which is a lower-mid-range microcontroller in Atmel's 8-bit AVR line of microcontrollers. Using the WinAVR GCC compiler with -O2 level optimizations, an executable is produced with the following code/RAM utilization:

31600 Bytes Code Space 2014 Bytes RAM

An alternate version of this project is created using a custom "super-loop" kernel, which uses a single application thread and provides 2 levels of priority (interrupt and application). In this case, the event handler processes the different priority application events to completion from highest to lowest priority.

This approach leaves the application itself largely unchanged. Using the same optimization levels as the preemptive kernel, the code compiles as follows:

29904 Bytes Code Space 1648 Bytes RAM

3.2 Memory overhead:

At first glance, the difference in RAM utilization seems quite a lot higher for the preemptive mode version of the application, but the raw numbers don't tell the whole story.

The first issue is that the cooperative-mode total does not take into account the system stack - whereas these values are included in the totals for RTOS version of the project. As a result, some further analysis is required to determine how the stack sizes truly compare.

In cooperative mode, there is only one thread of execution - so considering that multiple event handlers are executed in turn, the stack requirements for cooperative mode is simply determined by those of the most stack-intensive event handler.

In contrast, the preemptive kernel requires a separate stack for each active thread, and as a result the stack usage of the system is the sum of the stacks for all threads.

Since the application and idle events are the same for both preemptive and cooperative mode, we know that their (independent) stack requirements will be the same in both cases.

For cooperative mode, we see that the idle thread stack utilization is lower than that of the application thread, and so the application thread's determines the stack size requirement. Again, with the preemptive kernel the stack utilization is the sum of the stacks defined for both threads.

As a result, the difference in overhead between the two cases becomes the extra stack required for the idle thread - which in our case is (a somewhat generous) 64 bytes.

The numbers still don't add up completely, but looking into the linker output we see that the rest of the difference comes from the extra data structures used to declare the threads in preemptive mode.

With this taken into account, the true memory cost of a 2-thread system ends up being around 150 bytes of RA-M - which is less than 8% of the total memory available on this particular microcontroller. Whether or not this is reasonable certainly depends on the application, but more importantly, it is not so unreasonable as to eliminate an RTOS-based solution from being considered.

3.3 Code Space Overhead:

The difference in code space overhead between the preemptive and cooperative mode solutions is less of an issue. Part of this reason is that both the preemptive and cooperative kernels are relatively small, and even an average target device (like the Atmega328 we've chosen) has plenty of room.

Mark3 can be configured so that only features necessary for the application are included in the RTOS - you only pay for the parts of the system that you use. In this way, we can measure the overhead on a feature-by-feature basis, which is shown below for the kernel as configured for this application:

3466 Bytes

The configuration tested in this comparison uses the thread/port module with timers, drivers, and semaphores, for a total kernel size of ∼3.5KB, with the rest of the code space occupied by the application.

The custom cooperative-mode framework has a similar structure which is broken down by module as follows:

1850 Bytes

As can be seen from the compiler's output, the difference in code space between the two versions of the application is about 1.7kB - or about 5% of the available code space on the selected processor. While nearly all of this comes from the added overhead of the kernel, the rest of the difference comes the changes to the application necessary to facilitate the different frameworks.

3.4 Runtime Overhead

On the cooperative kernel, the overhead associated with running the thread is the time it takes the kernel to notice a pending event flag and launch the appropriate event handler, plus the timer interrupt execution time.

Similarly, on the preemptive kernel, the overhead is the time it takes to switch contexts to the application thread, plus the timer interrupt execution time.

The timer interrupt overhead is similar for both cases, so the overhead then becomes the difference between the following:

Preemptive mode:

- Posting the semaphore that wakes the high-priority thread
- Performing a context switch to the high-priority thread

Cooperative mode:

- Setting the high-priority thread's event flag
- Acknowledging the event from the event loop

Using the cycle-accurate AVR simulator, we find the end-to-end event sequence time to be 20.4us for the cooperative mode scheduler and 44.2us for the preemptive, giving a difference of 23.8us.

With a fixed high-priority event frequency of 33Hz, we achieve a runtime overhead of 983.4us per second, or 0.-0983% of the total available CPU time. Now, obviously this value would expand at higher event frequencies and/or slower CPU frequencies, but for this typical application we find the difference in runtime overhead to be neglible for a preemptive system. Analysis:

For the selected test application and platform, including a preemptive RTOS is entirely reasonable, as the costs are low relative to a non-preemptive kernel solution. But these costs scale relative to the speed, memory and code space of the target processor. Because of these variables, there is no "magic bullet" environment suitable for every application, but Mark3 attempts to provide a framework suitable for a wide range of targets.

On the one hand, if these tests had been performed on a higher-end microcontroller such as the ATMega1284p (containing 128kB of code space and 16kB of RAM), the overhead would be in the noise. For this type of resource-rich microcontroller, there would be no reason to avoid using the Mark3 preemptive kernel.

Conversely, using a lower-end microcontroller like an ATMega88pa (which has only 8kB of code space and 1k-B of RAM), the added overhead would likely be prohibitive for including a preemptive kernel. In this case, the cooperative-mode kernel would be a better choice.

As a rule of thumb, if one budgets 10% of a microcontroller's code space/RAM for a preemptive kernel's overhead, you should only require at minimum a microcontroller with 16k of code space and 2kB of RAM as a base platform for an RTOS. Unless there are serious constraints on the system that require much better latency or responsiveness than can be achieved with RTOS overhead, almost any modern platform is sufficient for hosting a kernel. In the event you find yourself with a microprocessor with external memory, there should be no reason to avoid using an RTOS at all.

Chapter 4

Superloops

4.1 Intro to Superloops

Before we start taking a look at designing a real-time operating system, it's worthwhile taking a look through one of the most-common design patterns that developers use to manage task execution in embedded systems - Superloops.

Systems based on superloops favor the system control logic baked directly into the application code, usually under the guise of simplicity, or memory (code and RAM) efficiency. For simple systems, superloops can definitely get the job done. However, they have some serious limitations, and are not suitable for every kind of project. In a lot of cases you can squeak by using superloops - especially in extremely constrained systems, but in general they are not a solid basis for reusable, portable code.

Nonetheless, a variety of examples are presented here- from the extremely simple, to cooperative and liimted-preemptive multitasking systems, all of which are examples are representative of real-world systems that I've either written the firmware for, or have seen in my experience.

4.2 The simplest loop

Let's start with the simplest embedded system design possible - an infinite loop that performs a single task repeatedly:

```
int main()
{
    while(1)
    {
        Do_Something();
    }
}
```

Here, the code inside the loop will run a single function forever and ever. Not much to it, is there? But you might be surprised at just how much embedded system firmware is implemented using essentially the same mechanism - there isn't anything wrong with that, but it's just not that interesting.

While the execution timeline for this program is equally boring, for the sake of completeness it would look like this:

Despite its simplicity we can see the beginnings of some core OS concepts. Here, the while(1) statement can be logically seen as the he operating system kernel - this one control statement determines what tasks can run in the system, and defines the constraints that could modify their execution. But at the end of the day, that's a big part of what a kernel is - a mechanism that controls the execution of application code.

The second concept here is the task. This is application code provided by the user to perform some useful purpose in a system. In this case Do_something() represents that task - it could be monitoring blood pressure, reading a sensor and writing its data to a terminal, or playing an MP3; anything you can think of for an embedded system to do. A simple round-robin multi-tasking system can be built off of this example by simply adding additional tasks in sequence in the main while-loop. Note that in this example the CPU is always busy running tasks - at no time is the CPU idle, meaning that it is likely burning a lot of power.

While we conceptually have two separate pieces of code involved here (an operating system kernel and a set of running tasks), they are not logically separate. The OS code is indistinguishable from the application. It's like a single-celled organism - everything is crammed together within the walls of an indivisible unit; and specialized to perform its given function relying solely on instinct.

4.3 Interrupt-Driven Super-loop

In the previous example, we had a system without any way to control the execution of the task- it just runs forever. There's no way to control when the task can (or more importantly can't) run, which greatly limits the usefulness of the system. Say you only want your task to run every 100 miliseconds - in the previous code, you have to add a hard-coded delay at the end of your task's execution to ensure your code runs only when it should.

Fortunately, there is a much more elegant way to do this. In this example, we introduce the concept of the synchronization object. A Synchronization object is some data structure which works within the bounds of the operating system to tell tasks when they can run, and in many cases includes special data unique to the synchronization event. There are a whole family of synchronization objects, which we'll get into later. In this example, we make use of the simplest synchronization primitive - the global flag.

With the addition of synchronization brings the addition of event-driven systems. If you're programming a microcontroller system, you generally have scores of peripherals available to you - timers, GPIOs, ADCs, UARTs, ethernet, USB, etc. All of which can be configured to provide a stimulus to your system by means of interrupts. This stimulus gives us the ability not only to program our micros to do_something(), but to do_something() if-and-only-if a corresponding trigger has occurred.

The following concepts are shown in the example below:

```
volatile K_BOOL something_to_do = false;

__interrupt__ My_Interrupt_Source(void)
{
    something_to_do = true;
}

int main()
{
    while(1)
    {
        if( something_to_do )
        {
            Do_something();
            something_to_do = false;
        }
        else
        {
            Idle();
        }
    }
}
```

So there you have it - an event driven system which uses a global variable to synchronize the execution of our task based on the occurrence of an interrupt. It's still just a bare-metal, OS-baked-into-the-aplication system, but it's introduced a whole bunch of added complexity (and control!) into the system.

The first thing to notice in the source is that the global variable, something_to_do, is used as a synchronization object. When an interrupt occurs from some external event, triggering the My_Interrupt_Source() ISR, program flow in main() is interrupted, the interrupt handler is run, and something_to_do is set to true, letting us know that when we get back to main(), that we should run our Do_something() task.

Another new concept at play here is that of the idle function. In general, when running an event driven system, there are times when the CPU has no application tasks to run. In order to minimize power consumption, CPUs usually contain instructions or registers that can be set up to disable non-essential subsets of the system when there's nothing to do. In general, the sleeping system can be re-activated quickly as a result of an interrupt or other external stimulus, allowing normal processing to resume.

Now, we could just call Do_something() from the interrupt itself - but that's generally not a great solution. In general, the more time we spend inside an interrupt, the more time we spend with at least some interrupts disabled. As a result, we end up with interrupt latency. Now, in this system, with only one interrupt source and only one task this might not be a big deal, but say that Do_something() takes several seconds to complete, and in that time several other interrupts occur from other sources. While executing in our long-running interrupt, no other interrupts can be processed - in many cases, if two interrupts of the same type occur before the first is processed, one of these interrupt events will be lost. This can be utterly disastrous in a real-time system and should be avoided at all costs. As a result, it's generally preferable to use synchronization objects whenever possible to defer processing outside of the ISR.

Another OS concept that is implicitly introduced in this example is that of task priority. When an interrupt occurs, the normal execution of code in main() is preempted: control is swapped over to the ISR (which runs to completion), and then control is given back to main() where it left off. The very fact that interrupts take precedence over what's running shows that main is conceptually a "low-priority" task, and that all ISRs are "high-priority" tasks. In this example, our "high-priority" task is setting a variable to tell our "low-priority" task that it can do something useful. We will investigate the concept of task priority further in the next example.

Preemption is another key principle in embedded systems. This is the notion that whatever the CPU is doing when an interrupt occurs, it should stop, cache its current state (referred to as its context), and allow the high-priority event to be processed. The context of the previous task is then restored its state before the interrupt, and resumes processing. We'll come back to preemption frequently, since the concept comes up frequently in RTOS-based systems.

4.4 Cooperative multi-tasking

Our next example takes the previous example one step further by introducing cooperative multi-tasking:

```
// Bitfield values used to represent three distinct tasks
#define TASK_1_EVENT (0x01)
#define TASK_2_EVENT (0x02)
#define TASK_3_EVENT (0x04)

volatile K_UCHAR event_flags = 0;

// Interrupt sources used to trigger event execution

__interrupt__  My_Interrupt_1(void)
{
    event_flags |= TASK_1_EVENT;
}

__interrupt__ My_Interrupt_2(void)
{
    event_flags |= TASK_2_EVENT;
}

__interrupt__ My_Interrupt_3(void)
{
    event_flags |= TASK_3_EVENT;
}

// Main tasks
int main(void)
{
    while(1)
    {
        while(event_flags)
        {
            if( event_flags & TASK_1_EVENT)
            {
                Do_Task_1();
                event_flags &= ~TASK_1_EVENT;
            } else if( event_flags & TASK_2_EVENT) {
                Do_Task_2();
                event_flags &= ~TASK_2_EVENT;
            } else if( event_flags & TASK_3_EVENT) {
                Do_Task_3();
                event_flags &= ~TASK_3_EVENT;
            }
        }
        Idle();
    }
}
```

This system is very similar to what we had before - however the differences are worth discussing. First, we have stimulus from multiple interrupt sources: each ISR is responsible for setting a single bit in our global event flag, which is then used to control execution of individual tasks from within main().

Next, we can see that tasks are explicitly given priorities inside the main loop based on the logic of the if/else if structure. As long as there is something set in the event flag, we will always try to execute Task1 first, and only when Task1 isn't set will we attempt to execute Task2, and then Task 3. This added logic provides the notion of priority. However, because each of these tasks exist within the same context (they're just different functions called from our main control loop), we don't have the same notion of preemption that we have when dealing with interrupts.

That means that even through we may be running Task2 and an event flag for Task1 is set by an interrupt, the CPU still has to finish processing Task2 to completion before Task1 can be run. And that's why this kind of scheduling is referred to ascooperative multitasking: we can have as many tasks as we want, but unless they cooperate by means of returning back to main, the system can end up with high-priority tasks getting starved for CPU time by lower-priority, long-running tasks.

This is one of the more popular Os-baked-into-the-application approaches, and is widely used in a variety of real-time embedded systems.

4.5 Hybrid cooperative/preemptive multi-tasking

The final variation on the superloop design utilizes software-triggered interrupts to simulate a hybrid cooperative/preemptive multitasking system. Consider the example code below.

```
// Bitfields used to represent high-priority tasks.  Tasks in this group
// can preempt tasks in the group below - but not eachother.
#define HP_TASK_1        (0x01)
#define HP_TASK_2        (0x02)

volatile K_UCHAR hp_tasks = 0;

// Bitfields used to represent low-priority tasks.
#define LP_TASK_1        (0x01)
#define LP_TASK_2        (0x02)

volatile K_UCHAR lp_tasks = 0;

// Interrupt sources, used to trigger both high and low priority tasks.
__interrupt__ System_Interrupt_1(void)
{
    // Set any of the other tasks from here...
    hp_tasks |= HP_TASK_1;
    // Trigger the SWI that calls the High_Priority_Tasks interrupt handler
    SWI();
}

__interrupt__ System_Interrupt_n...(void)
{
    // Set any of the other tasks from here...
}


// Interrupt handler that is used to implement the high-priority event context
__interrupt__ High_Priority_Tasks(void)
{
    // Enabled every interrupt except this one
    Disable_My_Interrupt();
    Enable_Interrupts();
    while( hp_tasks)
    {
        if( hp_tasks & HP_TASK_1)
        {
            HP_Task1();
            hp_tasks &= ~HP_TASK_1;
        }
        else if (hp_tasks & HP_TASK_2)
        {
            HP_Task2();
            hp_tasks &= ~HP_TASK_2;
        }
    }
    Restore_Interrupts();
    Enable_My_Interrupt();
}
```

```
// Main loop, used to implement the low-priority events
int main(void)
{
    // Set the function to run when a SWI is triggered
    Set_SWI(High_Priority_Tasks);

    // Run our super-loop
    while(1)
    {
        while (lp_tasks)
        {
            if (lp_tasks & LP_TASK_1)
            {
                LP_Task1();
                lp_tasks &= ~LP_TASK_1;
            }
            else if (lp_tasks & LP_TASK_2)
            {
                LP_Task2();
                lp_tasks &= ~LP_TASK_2;
            }
        }
        Idle();
    }
}
```

In this example, High_Priority_Tasks() can be triggered at any time as a result of a software interrupt (SWI),. When a high-priority event is set, the code that sets the event calls the SWI as well, which instantly preempts whatever is happening in main, switching to the high-priority interrupt handler. If the CPU is executing in an interrupt handler already, the current ISR completes, at which point control is given to the high priority interrupt handler.

Once inside the HP ISR, all interrupts (except the software interrupt) are re-enabled, which allows this interrupt to be preempted by other interrupt sources, which is called interrupt nesting. As a result, we end up with two distinct execution contexts (main and HighPriorityTasks()), in which all tasks in the high-priority group are guaranteed to preempt main() tasks, and will run to completion before returning control back to tasks in main(). This is a very basic preemptive multitasking scenario, approximating a "real" RTOS system with two threads of different priorities.

4.6 Problems with superloops

As mentioned earlier, a lot of real-world systems are implemented using a superloop design; and while they are simple to understand due to the limited and obvious control logic involved, they are not without their problems.

Hidden Costs

It's difficult to calculate the overhead of the superloop and the code required to implement workarounds for blocking calls, scheduling, and preemption. There's a cost in both the logic used to implement workarounds (usually involving state machines), as well as a cost to maintainability that comes with breaking up into chunks based on execution time instead of logical operations. In moderate firmware systems, this size cost can exceed the overhead of a reasonably well-featured RTOS, and the deficit in maintainability is something that is measurable in terms of lost productivity through debugging and profiling.

Tightly-coupled code

Because the control logic is integrated so closely with the application logic, a lot of care must be taken not to compromise the separation between application and system code. The timing loops, state machines, and architecture-specific control mechanisms used to avoid (or simulate) preemption can all contribute to the problem. As a result, a lot of superloop code ends up being difficult to port without effectively simulating or replicating the underlying system for which the application was written. Abstraction layers can mitigate the risks, but a lot of care should be taken to fully decouple the application code from the system code.

No blocking calls

In a super-loop environment, there's no such thing as a blocking call or blocking objects. Tasks cannot stop mid-execution for event-driven I/O from other contexts - they must always run to completion. If busy-waiting and polling are used as a substitute, it increases latency and wastes cycles. As a result, extra code complexity is often times necessary to work-around this lack of blocking objects, often times through implementing additional state machines. In a large enough system, the added overhead in code size and cycles can add up.

Difficult to guarantee responsiveness

Without multiple levels of priority, it may be difficult to guarantee a certain degree of real-time responsiveness without added profiling and tweaking. The latency of a given task in a priority-based cooperative multitasking system is the length of the longest task. Care must be taken to break tasks up into appropriate sized chunks in order to ensure that higher-priority tasks can run in a timely fashion - a manual process that must be repeated as new tasks are added in the system. Once again, this adds extra complexity that makes code larger, more difficult to understand and maintain due to the artificial subdivision of tasks into time-based components.

Limited preemption capability

As shown in the example code, the way to gain preemption in a superloop is through the use of nested interrupts. While this isn't unwiedly for two levels of priority, adding more levels beyond this is becomes complicated. In this case, it becomes necessary to track interrupt nesting manually, and separate sets of tasks that can run within given priority loops - and deadlock becomes more difficult to avoid.

Chapter 5

Mark3 Overview

5.1 Intro

The following section details the overall design of Mark3, the goals I've set out to achieve, the features that I've intended to provide, as well as an introduction to the programming concepts used to make it happen.

5.2 Features

Mark3 is a fully-featured real-time kernel, and is feature-competitive with other open-source and commercial RTOS's in the embedded arena.

The key features of this RTOS are:

- Flexible Scheduler
  - Unlimited number of threads with 8 priority levels
  - Unlimited threads per priority level
  - Round-robin scheduling for threads at each priority level
  - Time quantum scheduling for each thread in a given priority level
- Configurable stacks for each Thread
- Resource protection:
  - Integrated mutual-exclusion semaphores (Mutex)
  - Priority-inheritance on Mutex objects to prevent priority inversion
- Synchronization Objects
  - Binary and counting Semaphore to coordinate thread execution
  - Event flags with 16-bit bitfields for complex thread synchronization
- Efficient Timers
  - The RTOS is tickless, the OS only wakes up when a timer expires, not at a regular interval
  - One-shot and periodic timers with event callbacks
  - Timers are high-precision and long-counting (about 68000 seconds when used with a 16us resolution timer)
- Driver API
  - A hardware abstraction layer is provided to simplify driver development

- Robust Interprocess Communications
  - Threadsafe global Message pool and configurable message queues
- Support for kernel-aware simulation
  - Provides advanced test and verification functionality, allowing for easy integration into continuous-integration systems
  - Provide accurate engineering data on key metrics like stack usage and realtime performance, with easy-to-use APIs and little overhead

5.3 Design Goals

Lightweight

Mark3 can be configured to have an extremely low static memory footprint. Each thread is defined with its own stack, and each thread structure can be configured to take as little as 26 bytes of RAM. The complete Mark3 kernel with all features, setup code, a serial driver, and the Mark3 protocol libraries comes in at under 9K of code space and 1K of RAM on atmel AVR.

Modular

Each system feature can be enabled or disabled by modifying the kernel configuration header file. Include what you want, and ignore the rest to save code space and RAM.

Easily Portable

Mark3 should be portable to a variety of 8, 16 and 32 bit architectures without MMUs. Porting the OS to a new architecture is relatively straightforward, requiring only device-specific implementations for the lowest-level operations such as context switching and timer setup.

Easy To Use

Mark3 is small by design - which gives it the advantage that it's also easy to develop for. This manual, the code itself, and the Doxygen documentation in the code provide ample documentation to get you up to speed quickly. Because you get to see the source, there's nothing left to assumption.

Simple to Understand

Not only is the Mark3 API rigorously documented (hey - that's what this book is for!), but the architecture and naming conventions are intuitive - it's easy to figure out where code lives, and how it works. Individual modules are small due to the "one feature per file" rule used in development. This makes Mark3 an ideal platform for learning about aspects of RTOS design.

Chapter 6

Getting Started

6.1 Kernel Setup

This section details the process of defining threads, initializing the kernel, and adding threads to the scheduler.

If you're at all familiar with real-time operating systems, then these setup and initialization steps should be familiar. I've tried very hard to ensure that as much of the heavy lifting is hidden from the user, so that only the bare minimum of calls are required to get things started.

The examples presented in this chapter are real, working examples taken from the ATmega328p port.

First, you'll need to create the necessary data structures and functions for the threads:

1. Create a Thread object for all of the "root" or "initial" tasks.
2. Allocate stacks for each of the Threads
3. Define an entry-point function for each Thread

This is shown in the example code below:

```
//----------------------------------------------------------------------------
#include "thread.h"
#include "kernel.h"

//1) Create a thread object for all of the "root" or "initial" tasks
static Thread AppThread;
static Thread IdleThread;

//2) Allocate stacks for each thread
#define STACK_SIZE_APP      (192)
#define STACK_SIZE_IDLE     (128)

static K_UCHAR aucAppStack[STACK_SIZE_APP];
static K_UCHAR aucIdleStack[STACK_SIZE_IDLE];

//3) Define entry point functions for each thread
void AppThread(void);
void IdleThread(void);
```

Next, we'll need to add the required kernel initialization code to main. This consists of running the Kernel's init routine, initializing all of the threads we defined, adding the threads to the scheduler, and finally calling Kernel::Start(), which transfers control of the system to the RTOS.

These steps are illustrated in the following example.

```
int main(void)
{
    //1) Initialize the kernel prior to use
    Kernel::Init();             // MUST be before other kernel ops

    //2) Initialize all of the threads we've defined
    AppThread.Init( aucAppStack,        // Pointer to the stack
                    STACK_SIZE_APP,     // Size of the stack
                    1,          // Thread priority
                    (void*)AppEntry,    // Entry function
                    NULL );             // Entry function argument

    IdleThread.Init( aucIdleStack,      // Pointer to the stack
                     STACK_SIZE_IDLE,   // Size of the stack
                     0,         // Thread priority
                     (void*)IdleEntry,  // Entry function
                     NULL );        // Entry function argument

    //3) Add the threads to the scheduler
    AppThread.Start();          // Actively schedule the threads
    IdleThread.Start();

    //4) Give control of the system to the kernel
    Kernel::Start();            // Start the kernel!
}
```

Not much to it, is there? There are a few noteworthy points in this code, though.

In order for the kernel to work properly, a system must always contain an idle thread; that is, a thread at priority level 0 that never blocks. This thread is responsible for performing any of the low-level power management on the CPU in order to maximize battery life in an embedded device. The idle thread must also never block, and it must never exit. Either of these operations will cause undefined behavior in the system.

The App thread is at a priority level greater-than 0. This ensures that as long as the App thread has something useful to do, it will be given control of the CPU. In this case, if the app thread blocks, control will be given back to the Idle thread, which will put the CPU into a power-saving mode until an interrupt occurs.

Stack sizes must be large enough to accommodate not only the requirements of the threads, but also the requirements of interrupts - up to the maximum interrupt-nesting level used. Stack overflows are super-easy to run into in an embedded system; if you encounter strange and unexplained behavior in your code, chances are good that one of your threads is blowing its stack.

6.2 Threads

Mark3 Threads act as independent tasks in the system. While they share the same address-space, global data, device-drivers, and system peripherals, each thread has its own set of CPU registers and stack, collectively known as the thread's **context**. The context is what allows the RTOS kernel to rapidly switch between threads at a high rate, giving the illusion that multiple things are happening in a system, when really, only one thread is executing at a time.

6.2.1 Thread Setup

Each instance of the Thread class represents a thread, its stack, its CPU context, and all of the state and metadata maintained by the kernel. Before a Thread will be scheduled to run, it must first be initialized with the necessary configuration data.

The Init function gives the user the opportunity to set the stack, stack size, thread priority, entry-point function, entry-function argument, and round-robin time quantum:

Thread stacks are pointers to blobs of memory (usually K_CHAR arrays) carved out of the system's address space. Each thread must have a stack defined that's large enough to handle not only the requirements of local variables in the thread's code path, but also the maximum depth of the ISR stack.

Priorities should be chosen carefully such that the shortest tasks with the most strict determinism requirements are executed first - and are thus located in the highest priorities. Tasks that take the longest to execute (and require the least degree of responsiveness) must occupy the lower thread priorities. The idle thread must be the only thread occupying the lowest priority level.

The thread quantum only aplies when there are multiple threads in the ready queue at the same priority level. This interval is used to kick-off a timer that will cycle execution between the threads in the priority list so that they each get a fair chance to execute.

The entry function is the function that the kernel calls first when the thread instance is first started. Entry functions have at most one argument - a pointer to a data-object specified by the user during initialization.

An example thread initailization is shown below:

```
Thread clMyThread;
K_UCHAR aucStack[192];

void AppEntry(void)
{
    while(1)
    {
        // Do something!
    }
}

...
{
    clMyThread.Init(aucStack,    // Pointer to the stack to use by this thread
                    192,             // Size of the stack in bytes
                    1,       // Thread priority (0 = idle, 7 = max)
                    (void*)AppEntry, // Function where the thread starts executing
                    NULL );          // Argument passed into the entry function

}
```

Once a thread has been initialized, it can be added to the scheduler by calling:

```
clMyThread.Start();
```

The thread will be placed into the Scheduler's queue at the designated priority, where it will wait its turn for execution.

6.2.2 Entry Functions

Mark3 Threads should not run-to-completion - they should execute as infinite loops that perform a series of tasks, appropriately partitioned to provide the responsiveness characteristics desired in the system.

The most basic Thread loop is shown below:

```
void Thread( void *param )
{
    while(1)
    {
        // Do Something
    }
}
```

Threads can interact with eachother in the system by means of synchronization objects (Semaphore), mutual-exclusion objects (Mutex), Inter-process messaging (MessageQueue), and timers (Timer).

Threads can suspend their own execution for a predetermined period of time by using the static Thread::Sleep() method. Calling this will block the Thread's executin until the amount of time specified has ellapsed. Upon expiry, the thread will be placed back into the ready queue for its priority level, where it awaits its next turn to run.

6.3 Timers

Timer objects are used to trigger callback events periodic or on a one-shot (alarm) basis.

While extremely simple to use, they provide one of the most powerful execution contexts in the system. The timer callbacks execute from within the timer callback ISR in an interrupt-enabled context. As such, timer callbacks are considered higher-priority than any thread in the system, but lower priority than other interrupts. Care must be taken to ensure that timer callbacks execute as quickly as possible to minimize the impact of processing on the throughput of tasks in the system. Wherever possible, heavy-lifting should be deferred to the threads by way of semaphores or messages.

Below is an example showing how to start a periodic system timer which will trigger every second:

```
{
    Timer clTimer;
    clTimer.Init();

    clTimer.Start( 1000,
                   1,
                   MyCallback,
                   (void*)&my_data );

    ... // Keep doing work in the thread
}

// Callback function, executed from the timer-expiry context.
void MyCallBack( Thread *pclOwner_, void *pvData_ )
{
    LED.Flash(); // Flash an LED.
}
```

6.4 Semaphores

Semaphores are used to synchronized execution of threads based on the availability (and quantity) of application-specific resources in the system. They are extremely useful for solving producer-consumer problems, and are the method-of-choice for creating efficient, low latency systems, where ISRs post semaphores that are handled from within the context of individual threads. (Yes, Semaphores can be posted - but not pended - from the interrupt context).

The following is an example of the producer-consumer usage of a binary semaphore:

```
Semaphore clSemaphore; // Declare a semaphore shared between a producer and a consumer thread.

void Producer()
{
    clSemaphore.Init(0, 1);
    while(1)
    {
        // Do some work, create something to be consumed

        // Post a semaphore, allowing another thread to consume the data
        clSemaphore.Post();
    }
}

void Consumer()
{
    // Assumes semaphore initialized before use...
    While(1)
    {
        // Wait for new data from the producer thread
        clSemaphore.Pend();

        // Consume the data!
    }
}
```

And an example of using semaphores from the ISR context to perform event- driven processing.

```
Semaphore clSemaphore;

__interrupt__ MyISR()
{
    clSemaphore.Post(); // Post the interrupt.  Lightweight when uncontested.
}

void MyThread()
{
    clSemaphore.Init(0, 1); // Ensure this is initialized before the MyISR interrupt is enabled.
    while(1)
    {
        // Wait until we get notification from the interrupt
        clSemaphore.Pend();

        // Interrupt has fired, do the necessary work in this thread's context
        HeavyLifting();
    }
}
```

6.5 Mutexes

Mutexes (Mutual exclusion objects) are provided as a means of creating "protected sections" around a particular resource, allowing for access of these objects to be serialized. Only one thread can hold the mutex at a time - other threads have to wait until the region is released by the owner thread before they can take their turn operating on the protected resource. Note that mutexes can only be owned by threads - they are not available to other contexts (i.e. interrupts). Calling the mutex APIs from an interrupt will cause catastrophic system failures.

Note that these objects are also not recursive- that is, the owner thread can not attempt to claim a mutex more than once.

Prioritiy inheritence is provided with these objects as a means to avoid prioritiy inversions. Whenever a thread at a priority than the mutex owner blocks on a mutex, the priority of the current thread is boosted to the highest-priority waiter to ensure that other tasks at intermediate priorities cannot artificically prevent progress from being made.

Mutex objects are very easy to use, as there are only three operations supported: Initialize, Claim and Release. An example is shown below.

```
Mutex clMutex;  // Create a mutex globally.

void Init()
{
    // Initialize the mutex before use.
    clMutex.Init();
}

// Some function called from a thread
void Thread1Function()
{
    clMutex.Claim();

    // Once the mutex is owned, no other thread can
    // enter a block protect by the same mutex

    my_protected_resource.do_something();
    my_protected_resource.do_something_else();

    clMutex.Release();
}

// Some function called from another thread
void Thread2Function()
{
    clMutex.Claim();

    // Once the mutex is owned, no other thread can
    // enter a block protect by the same mutex

    my_protected_resource.do_something();
    my_protected_resource.do_different_things();

    clMutex.Release();
}
```

6.6 Event Flags

Event Flags are another synchronization object, conceptually similar to a semaphore.

Unlike a semaphore, however, the condition on which threads are unblocked is determined by a more complex set of rules. Each Event Flag object contains a 16-bit field, and threads block, waiting for combinations of bits within this field to become set.

A thread can wait on any pattern of bits from this field to be set, and any number of threads can wait on any number of different patterns. Threads can wait on a single bit, multiple bits, or bits from within a subset of bits within the field.

As a result, setting a single value in the flag can result in any number of threads becoming unblocked simultaneously. This mechanism is extremely powerful, allowing for all sorts of complex, yet efficient, thread synchronization schemes that can be created using a single shared object.

Note that Event Flags can be set from interrupts, but you cannot wait on an event flag from within an interrupt.

Examples demonstrating the use of event flags are shown below.

```
// Simple example showing a thread blocking on a multiple bits in the
// fields within an event flag.

EventFlag clEventFlag;

int main()
{
    ...
    clEventFlag.Init(); // Initialize event flag prior to use
    ...
}

void MyInterrupt()
{
    // Some interrupt corresponds to event 0x0020
    clEventFlag.Set(0x0020);
}

void MyThreadFunc()
{
    ...
    while(1)
    {
        ...
        K_USHORT usWakeCondition;

        // Allow this thread to block on multiple flags
        usWakeCondition = clEventFlag.Wait(0x00FF, EVENT_FLAG_ANY);

        // Clear the event condition that caused the thread to wake (in this case,
        // usWakeCondtion will equal 0x20 when triggered from the interrupt above)
        clEventFlag.Clear(usWakeCondition);

        // <do something>
    }
}
```

6.7 Messages

Sending messages between threads is the key means of synchronizing access to data, and the primary mechanism to perform asynchronous data processing operations.

Sending a message consists of the following operations:

- Obtain a Message object from the global message pool
- Set the message data and event fields
- Send the message to the destination message queue

While receiving a message consists of the following steps:

- Wait for a messages in the destination message queue
- Process the message data
- Return the message back to the global message pool

These operations, and the various data objects involved are discussed in more detail in the following section.

6.7.1 Message Objects

Message objects are used to communicate arbitrary data between threads in a safe and synchronous way.

The message object consists of an event code field and a data field. The event code is used to provide context to the message object, while the data field (essentially a void ∗ data pointer) is used to provide a payload of data corresponding to the particular event.

Access to these fields is marshalled by accessors - the transmitting thread uses the SetData() and SetCode() methods to seed the data, while the receiving thread uses the GetData() and GetCode() methods to retrieve it.

By providing the data as a void data pointer instead of a fixed-size message, we achieve an unprecedented measure of simplicity and flexibility. Data can be either statically or dynamically allocated, and sized appropriately for the event without having to format and reformat data by both sending and receiving threads. The choices here are left to the user - and the kernel doesn't get in the way of efficiency.

It is worth noting that you can send messages to message queues from within ISR context. This helps maintain consistency, since the same APIs can be used to provide event-driven programming facilities throughout the whole of the OS.

6.7.2 Global Message Pool

To maintain efficiency in the messaging system (and to prevent over-allocation of data), a global pool of message objects is provided. The size of this message pool is specified in the implementation, and can be adjusted depending on the requirements of the target application as a compile-time option.

Allocating a message from the message pool is as simple as calling the GlobalMessagePool::Pop() Method.

Messages are returned back to the GlobalMessagePool::Push() method once the message contents are no longer required.

One must be careful to ensure that discarded messages always are returned to the pool, otherwise a resource leak can occur, which may cripple the operating system's ability to pass data between threads.

6.7.3 Message Queues

Message objects specify data with context, but do not specify where the messages will be sent. For this purpose we have a MessageQueue object. Sending an object to a message queue involves calling the MessageQueue::Send() method, passing in a pointer to the Message object as an argument.

When a message is sent to the queue, the first thread blocked on the queue (as a result of calling the MessageQueue Receive() method) will wake up, with a pointer to the Message object returned.

It's worth noting that multiple threads can block on the same message queue, providing a means for multiple threads to share work in parallel.

6.7.4 Messaging Example

```
// Message queue object shared between threads
MessageQueue clMsgQ;

// Function that initializes the shared message queue
void MsgQInit()
{
    clMsgQ.Init();
}

// Function called by one thread to send message data to
// another
void TxMessage()
{
    // Get a message, initialize its data
    Message *pclMesg = GlobalMessagePool::Pop();

    pclMesg->SetCode(0xAB);
    pclMesg->SetData((void*)some_data);

    // Send the data to the message queue
    clMsgQ.Send(pclMesg);
}

// Function called in the other thread to block until
// a message is received in the message queue.
void RxMessage()
{
    Message *pclMesg;
    // Block until we have a message in the queue
    pclMesg = clMsgQ.Receive();

    // Do something with the data once the message is received
    pclMesg->GetCode();

    // Free the message once we're done with it.
    GlobalMessagePool::Push(pclMesg);
}
```

6.8 Sleep

There are instances where it may be necessary for a thread to poll a resource, or wait a specific amount of time before proceeding to operate on a peripheral or volatile piece of data.

While the Timer object is generally a better choice for performing time-sensitive operations (and certainly a better choice for periodic operations), the Thread::Sleep() method provides a convenient (and efficient) mechanism that allows for a thread to suspend its execution for a specified interval.

Note that when a thread is sleeping it is blocked, during which other threads can operate, or the system can enter its idle state.

```
int GetPeripheralData();
{
    int value;
    // The hardware manual for a peripheral specifies that
    // the "foo()" method will result in data being generated
    // that can be captured using the "bar()" method.
    // However, the value only becomes valid after 10ms

    peripheral.foo();
    Thread::Sleep(10);  // Wait 10ms for data to become valid
    value = peripheral.bar();
    return value;
}
```

6.9 Round-Robin Quantum

Threads at the same thread priority are scheduled using a round-robin scheme. Each thread is given a timeslice (which can be configured) of which it shares time amongst ready threads in the group. Once a thread's timeslice has expired, the next thread in the priority group is chosen to run until its quantum has expired - the cycle continues over and over so long as each thread has work to be done.

By default, the round-robin interval is set at 4ms.

This value can be overridden by calling the thread's SetQuantum() with a new interval specified in milliseconds.

Chapter 7

Build System

Mark3 is distributed with a recursive makefile build system, allowing the entire source tree to be built into a series of libraries with simple make commands.

The way the scripts work, every directory with a valid makefile is scanned, as well as all of its subdirectories. The build then generates binary components for all of the components it finds -libraries and executables. All libraries that are generated can then be imported into an application using the linker without having to copy-and-paste files on a module-by-module basis. Applications built during this process can then be loaded onto a device directly, without requiring a GUI-based IDE. As a result, Mark3 integrates well with 3rd party tools for continuous-integration and automated testing.

This modular framework allows for large volumes of libraries and binaries to be built at once - the default build script leverages this to build all of the examples and unit tests at once, linking against the pre-built kernel, services, and drivers. Whatever can be built as a library is built as a library, promoting reuse throughout the platform, and enabling Mark3 to be used as a platform, with an ecosystem of libraries, services, drivers and applications.

7.1 Source Layout

One key aspect of Mark3 is that system features are organized into their own separate modules. These modules are further grouped together into folders based on the type of features represented:

```
Root         Base folder, contains recursive makefiles for build system
    arduino      Arduino-specific headers and API documentation files
    bootloader   Mark3 Bootloader code for AVR microcontrollers
    build        Makefiles and device-configuraton data for various platforms
    docs         Documentation (including this)
    drivers      Device driver code for various supported devices
    example      Example applications
    fonts        Bitmap fonts converted from TTF, used by Mark3 graphics library
    kernel       Basic Mark3 Components (the focus of this manual)
        cpu      CPU-specific porting code
    scripts      Scripts used to simplify build, documentation, and profiling
    services     Utility code and services, extended system features
    stage        Staging directory, where the build system places artifacts
    tests        Unit tests, written as C/C++ applications
    util         .net-based utils: font conversion, terminal, programmer, and configuration
```

7.2 Building the kernel

The base.mak file determines how the kernel, drivers, and libraries are built, for what targets, and with what options. Most of these options can be copied directly from the options found in your IDE managed projects. Below is an overview of the main variables used to configure the build.

```
STAGE       - Location in the filesystem where the build output is stored
```

```
ROOT_DIR     - The location of the root source tree
ARCH         - The CPU architecture to build against
VARIANT      - The variant of the above CPU to target
TOOLCHAIN    - Which toolchain to build with (dependent on ARCH and VARIANT)
```

Build.mak contains the logic which is used to perform the recursive make in all directories. Unless you really know what you're doing, it's best to leave this as-is.

You must make sure that all required paths are set in your system environment variables so that they are accessible through from the command-line.

Once configured, you can build the source tree using the various make targets:

- make headers
  - copy all headers in each module's /public subdirectory to the location specified by STAGE environment variable's ./inc subdirectory.
- make library
  - regenerate all objects copy marked as libraries (i.e. the kernel + drivers). Resulting binaries are copied into STAGE's ./lib subdirectory.
- make binary
  - build all executable projects in the root directory structure. In the default distribution, this includes the basic set of demos.

These steps are chained together automatically as part of the build.sh script found under the /scripts subdirectory. Running ./scripts/build.sh from the root of the embedded source directory will result in all headers being exported, libraries built, and applications built. This script will also default to building for atmega328p using GCC if none of the required environment variables have previously been configured.

To add new components to the recursive build system, simply add your code into a new folder beneath the root install location.

Source files, the module makefile and private header files go directly in the new folder, while public headers are placed in a ./public subdirectory. Create a ./obj directory to hold the output from the builds.

The contents of the module makefile looks something like this:

```
# Include common prelude make file
include $(ROOT_DIR)base.mak

# If we're building a library, set IS_LIB and LIBNAME
# If we're building an app, set IS_APP and APPNAME
IS_LIB=1
LIBNAME=mylib

#this is the list of the source modules required to build the kernel
CPP_SOURCE = mylib.cpp \
             someotherfile.cpp

# Similarly, C-language source would be under the C_SOURCE variable.

# Include the rest of the script that is actually used for building the
# outputs
include $(ROOT_DIR)build.mak
```

Once you've placed your code files in the right place, and configured the makefile appropriately, a fresh call to make headers, make library, then make binary will guarantee that your code is built.

Now, you can still copy-and-paste the required kernel, port, and drivers, directly into your application avoiding the whole process of using make from the command line. To do this, run "make source" from the root directory in svn, and copy the contents of /stage/src into your project. This should contain the source to the kernel, all drivers, and all services that are in the tree - along with the necessary header files.

7.3 Building on Windows

Building Mark3 on Windows is the same as on Linux, but there are a few prerequisites that need to be taken into consideration before the build scripts and makefiles will work as expected.

Step 1 - Install Latest Atmel Studio IDE

Atmel Studio contains the AVR8 GCC toolchain, which contains the necessary compilers, assemblers, and platform support required to turn the source modules into libraries and executables.

To get Atmel Studio, go to the Atmel website (http://www.atmel.com) and register to download the latest version. This is a free download (and rather large). The included IDE (if you choose to use it) is very slick, as it's based on Visual Studio, and contains a wonderful cycle-accurate simulator for AVR devices. In fact, the simulator is so good that most of the kernel and its drivers were developed using this tool.

Once you have downloaded and installed Atmel Studio, you will need to add the location of the AVR toolcahin to the PATH environment variable.

To do this, go to Control Panel -> System and Security -> System -> Advanced System Settings, and edit the PATH variable. Append the location of the toolchain bin folder to the end of the variable.

On Windows 7 x64, it should look something like this:

C: Files (x86) Toolchain GCC\Native\3.4.2.1002-gnu-toolchain

Step 2 - Install MinGW and MinSys

MinGW (and MinSys in particular) provide a unix-like environment that runs under windows. Some of the utilities provided include a version of the bash shell, and GNU standard make - both which are required by the Mark3 recursive build system.

The MinGW installer can be downloaded from its project page on SourceForge. When installing, be sure to select the "MinSys" component.

Once installed, add the MinSys binary path to the PATH environment variable, in a similar fashion as with Atmel Studio in Step 1.

Step 3 - Setup Include Paths in Platform Makefile

The AVR header file path must be added to the "platform.mak" makefile for each AVR Target you are attempting to build for. These files can be located under /embedded/build/avr/atmegaXXX/. The path to the includes directory should be added to the end of the CFLAGS and CPPFLAGS variables, as shown in the following:

```
TEST_INC="/c/Program Files (x86)/Atmel/Atmel Toolchain/AVR8
       GCC/Native/3.4.2.1002/avr8-gnu-toolchain/include"
CFLAGS += -I$(TEST_INC)
CPPFLAGS += -I$(TEST_INC)
```

Step 4 - Build Mark3 using Bash

Launch a terminal to your Mark3 base directory, and cd into the "embedded" folder. You should now be able to build Mark3 by running "bash ./build.sh" from the command-line.

Alternately, you can run bash itself, building Mark3 by running ./build.sh or the various make targets using the same synatx as documented previously.

Note - building on Windows is *slow*. This has a lot to do with how "make" performs under windows. There are faster substitutes for make (such as cs-make) that are exponentially quicker, and approach the performance of make on Linux. Other mechanisms, such as running make with multiple concurrent jobs (i.e. "make -j4") also helps significantly, especially on systems with multicore CPUs.

Chapter 8

License

8.1 License

Chapter 9

Profiling Results

The following profiling results were obtained using an ATMega328p @ 16MHz.

The test cases are designed to make use of the kernel profiler, which accurately measures the performance of the fundamental system APIs, in order to provide information for user comparison, as well as to ensure that regressions are not being introduced into the system.

9.1 Date Performed

Wed May 27 21:18:21 EDT 2015

9.2 Compiler Information

The kernel and test code used in these results were built using the following compiler: ./scripts/profile.sh: 55: ./scripts/profile.sh: /home/moslevin/atmel/bin/avr-gcc: not found

9.3 Profiling Results

- Semaphore Initialization: cycles (averaged over 0 iterations)
- Semaphore Post (uncontested): cycles (averaged over 0 iterations)
- Semaphore Pend (uncontested): cycles (averaged over 0 iterations)
- Semaphore Flyback Time (Contested Pend): cycles (averaged over 0 iterations)
- Mutex Init: cycles (averaged over 0 iterations)
- Mutex Claim: cycles (averaged over 0 iterations)
- Mutex Release: cycles (averaged over 0 iterations)
- Thread Initialize: cycles (averaged over 0 iterations)
- Thread Start: cycles (averaged over 0 iterations)
- Context Switch: cycles (averaged over 0 iterations)
- Thread Schedule: cycles (averaged over 0 iterations)

Chapter 10

Code Size Profiling

The following report details the size of each module compiled into the kernel.

The size of each component is dependent on the flags specified in mark3cfg.h at compile time. Note that these sizes represent the maximum size of each module before dead code elimination and any additional link-time optimization, and represent the maximum possible size that any module can take.

The results below are for profiling on Atmel AVR atmega328p-based targets using gcc. Results are not necessarily indicative of relative or absolute performance on other platforms or toolchains.

10.1 Information

Subversion Repository Information:

- Repository Root: svn+ssh://m0slevin.code.sf.net/p/mark3/source
- Revision: 211
- URL: svn+ssh://m0slevin.code.sf.net/p/mark3/source/branch/release/R1/embedded Relative URL: ^/branch/release/-R1/embedded

Date Profiled: Mon May 18 22:24:26 EDT 2015

10.2 Compiler Version

avr-gcc (GCC) 4.8.2 Copyright (C) 2013 Free Software Foundation, Inc. This is free software; see the source for copying conditions. There is NO warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.

10.3 Profiling Results

Mark3 Module Size Report:

- Synchronization Objects - Base Class............ : 92 Bytes
- Device Driver Framework (including /dev/null)... : 226 Bytes
- Synchronization Object - Event Flag............. : 770 Bytes
- Fundamental Kernel Linked-List Classes.......... : 496 Bytes

- Message-based IPC.............................. : 426 Bytes
- Mutex (Synchronization Object)................. : 658 Bytes
- Performance-profiling timers................... : 546 Bytes
- Round-Robin Scheduling Support................. : 264 Bytes
- Thread Scheduling.............................. : 452 Bytes
- Semaphore (Synchronization Object)............. : 536 Bytes
- Thread Implementation.......................... : 1613 Bytes
- Fundamental Kernel Thread-list Data Structures.. : 210 Bytes
- Mark3 Kernel Base Class........................ : 110 Bytes
- Software Timer Kernel Object................... : 378 Bytes
- Software Timer Management...................... : 645 Bytes
- Runtime Kernel Trace Implementation............ : 0 Bytes
- Circular Logging Buffer Base Class............. : 0 Bytes
- Atmel AVR - Kernel Aware Simulation Support...... : 296 Bytes
- Atmel AVR - Basic Threading Support............. : 598 Bytes
- Atmel AVR - Kernel Interrupt Implemenation....... : 56 Bytes
- Atmel AVR - Kernel Timer Implementation.......... : 322 Bytes
- kernelprofile.cpp.o : 256 Bytes

Mark3 Kernel Size Summary:

- Kernel : 2973 Bytes
- Synchronization Objects : 2390 Bytes
- Port : 1272 Bytes
- Features : 2059 Bytes
- Total Size : 8694 Bytes

Chapter 11

Hierarchical Index

11.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 12

Class Index

12.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 13

File Index

13.1 File List

Here is a list of all documented files with brief descriptions:

Chapter 14

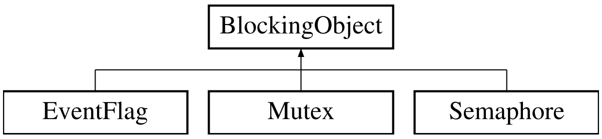
Class Documentation

14.1 BlockingObject Class Reference

Class implementing thread-blocking primatives.

```
#include <blocking.h>
```

Inheritance diagram for BlockingObject:



Protected Member Functions

- void Block (Thread ∗pclThread_)
- void UnBlock (Thread ∗pclThread_)

Protected Attributes

- ThreadList m_clBlockList

  ThreadList which is used to hold the list of threads blocked on a given object.

14.1.1 Detailed Description

Class implementing thread-blocking primatives.

Used for implementing things like semaphores, mutexes, message queues, or anything else that could cause a thread to suspend execution on some external stimulus.

Definition at line 65 of file blocking.h.

14.1.2 Member Function Documentation

14.1.2.1 void BlockingObject::Block (Thread ∗ *pclThread_*) [protected]

Parameters

*pclThread_*	Pointer to the thread object that will be blocked.

Blocks a thread on this object. This is the fundamental operation performed by any sort of blocking operation in the operating system. All semaphores/mutexes/sleeping/messaging/etc ends up going through the blocking code at some point as part of the code that manages a transition from an "active" or "waiting" thread to a "blocked" thread.

The steps involved in blocking a thread (which are performed in the function itself) are as follows;

1) Remove the specified thread from the current owner's list (which is likely one of the scheduler's thread lists) 2) Add the thread to this object's thread list 3) Setting the thread's "current thread-list" point to reference this object's threadlist.

Definition at line 36 of file blocking.cpp.

14.1.2.2 void BlockingObject::UnBlock (Thread ∗ *pclThread_*) [protected]

Parameters

*pclThread_*	Pointer to the thread to unblock.

Unblock a thread that is already blocked on this object, returning it to the "ready" state by performing the following steps:

1) Removing the thread from this object's threadlist 2) Restoring the thread to its "original" owner's list

Definition at line 52 of file blocking.cpp.

The documentation for this class was generated from the following files:

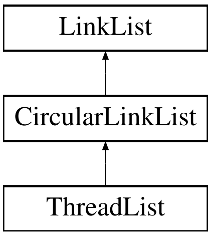
- /home/moslevin/Project/R1/kernel/public/blocking.h
- /home/moslevin/Project/R1/kernel/blocking.cpp

14.2 CircularLinkList Class Reference

Circular-linked-list data type, inherited from the base LinkList type.

`#include <ll.h>`

Inheritance diagram for CircularLinkList:



Public Member Functions

- virtual void Add (LinkListNode ∗node_)

  Add the linked list node to this linked list.
- virtual void Remove (LinkListNode ∗node_)

  Add the linked list node to this linked list.
- void PivotForward ()

  Pivot the head of the circularly linked list forward (Head = Head->next, Tail = Tail->next)
- void PivotBackward ()

  Pivot the head of the circularly linked list backward (Head = Head->prev, Tail = Tail->prev)

Additional Inherited Members

14.2.1 Detailed Description

Circular-linked-list data type, inherited from the base LinkList type.

Definition at line 196 of file ll.h.

14.2.2 Member Function Documentation

14.2.2.1 void CircularLinkList::Add (LinkListNode ∗ *node_*) [virtual]

Add the linked list node to this linked list.

Parameters

*node_*	Pointer to the node to add

Implements LinkList.

Reimplemented in ThreadList.

Definition at line 102 of file ll.cpp.

14.2.2.2 void CircularLinkList::Remove (LinkListNode ∗ *node_*) [virtual]

Add the linked list node to this linked list.

Parameters

*node_*	Pointer to the node to remove

Implements LinkList.

Reimplemented in ThreadList.

Definition at line 127 of file ll.cpp.

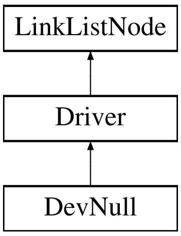
The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/ll.h
- /home/moslevin/Project/R1/kernel/ll.cpp

14.3 DevNull Class Reference

This class implements the "default" driver (/dev/null)

Inheritance diagram for DevNull:



Public Member Functions

- virtual void Init ()

  Initialize a driver, must be called prior to use.
- virtual K_UCHAR Open ()

  Open a device driver prior to use.
- virtual K_UCHAR Close ()

  Close a previously-opened device driver.
- virtual K_USHORT Read (K_USHORT usBytes_, K_UCHAR ∗pucData_)

  Read a specified number of bytes from the device into a specific buffer.
- virtual K_USHORT Write (K_USHORT usBytes_, K_UCHAR ∗pucData_)

  Write a payload of data of a given length to the device.
- virtual K_USHORT Control (K_USHORT usEvent_, void ∗pvDataIn_, K_USHORT usSizeIn_, void ∗pvDataOut_, K_USHORT usSizeOut_)

  This is the main entry-point for device-specific io and control operations.

Additional Inherited Members

14.3.1 Detailed Description

This class implements the "default" driver (/dev/null)

Definition at line 40 of file driver.cpp.

14.3.2 Member Function Documentation

14.3.2.1 virtual K_UCHAR DevNull::Close ( ) [inline], [virtual]

Close a previously-opened device driver.

Returns

Driver-specific return code, 0 = OK, non-0 = error

Implements Driver.

Definition at line 45 of file driver.cpp.

14.3.2.2 virtual K_USHORT DevNull::Control (K_USHORT *usEvent_*, void ∗ *pvDataIn_*, K_USHORT *usSizeIn_*, void ∗ *pvDataOut_*, K_USHORT *usSizeOut_*) [inline], [virtual]

This is the main entry-point for device-specific io and control operations.

This is used for implementing all "side-channel" communications with a device, and any device-specific IO operations that do not conform to the typical POSIX read/write paradigm. Use of this funciton is analagous to the non-POSIX (yet still common) devctl() or ioctl().

Parameters

*usEvent_*	Code defining the io event (driver-specific)
*pvDataIn_*	Pointer to the intput data
*usSizeIn_*	Size of the input data (in bytes)

*pvDataOut_*	Pointer to the output data
*usSizeOut_*	Size of the output data (in bytes)

Returns

Driver-specific return code, 0 = OK, non-0 = error

Implements Driver.

Definition at line 53 of file driver.cpp.

14.3.2.3 virtual K_UCHAR DevNull::Open ( ) [inline], [virtual]

Open a device driver prior to use.

Returns

Driver-specific return code, 0 = OK, non-0 = error

Implements Driver.

Definition at line 44 of file driver.cpp.

14.3.2.4 virtual K_USHORT DevNull::Read (K_USHORT *usBytes_*, K_UCHAR ∗ *pucData_*) [inline], [virtual]

Read a specified number of bytes from the device into a specific buffer.

Depending on the driver-specific implementation, this may be a number less than the requested number of bytes read, indicating that there there was less input than desired, or that as a result of buffering, the data may not be available.

Parameters

*usBytes_*	Number of bytes to read (<= size of the buffer)
*pucData_*	Pointer to a data buffer receiving the read data

Returns

Number of bytes actually read

Implements Driver.

Definition at line 47 of file driver.cpp.

14.3.2.5 virtual K_USHORT DevNull::Write (K_USHORT *usBytes_*, K_UCHAR ∗ *pucData_*) [inline], [virtual]

Write a payload of data of a given length to the device.

Depending on the implementation of the driver, the amount of data written to the device may be less than the requested number of bytes. A result less than the requested size may indicate that the device buffer is full, indicating that the user must retry the write at a later point with the remaining data.

Parameters

*usBytes_*	Number of bytes to write (<= size of the buffer)
*pucData_*	Pointer to a data buffer containing the data to write

Returns

Number of bytes actually written

Implements Driver.

Definition at line 50 of file driver.cpp.

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

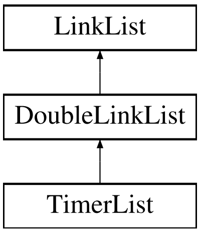
- /home/moslevin/Project/R1/kernel/driver.cpp

14.4 DoubleLinkList Class Reference

Doubly-linked-list data type, inherited from the base LinkList type.

`#include <ll.h>`

Inheritance diagram for DoubleLinkList:



Public Member Functions

- DoubleLinkList ()

  Default constructor - initializes the head/tail nodes to NULL.
- virtual void Add (LinkListNode ∗node_)

  Add the linked list node to this linked list.
- virtual void Remove (LinkListNode ∗node_)

  Add the linked list node to this linked list.

Additional Inherited Members

14.4.1 Detailed Description

Doubly-linked-list data type, inherited from the base LinkList type.

Definition at line 165 of file ll.h.

14.4.2 Member Function Documentation

14.4.2.1 void DoubleLinkList::Add (LinkListNode ∗ *node_*) [virtual]

Add the linked list node to this linked list.

Parameters

*node_*	Pointer to the node to add

Implements LinkList.

Definition at line 41 of file ll.cpp.

14.4.2.2 void DoubleLinkList::Remove (LinkListNode ∗ *node_*) [virtual]

Add the linked list node to this linked list.

Parameters

*node_*	Pointer to the node to remove

Implements LinkList.

Definition at line 65 of file ll.cpp.

The documentation for this class was generated from the following files:

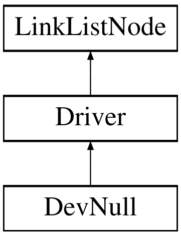
- /home/moslevin/Project/R1/kernel/public/ll.h
- /home/moslevin/Project/R1/kernel/ll.cpp

14.5 Driver Class Reference

Base device-driver class used in hardware abstraction.

```
#include <driver.h>
```

Inheritance diagram for Driver:



Public Member Functions

- virtual void Init ()=0

  Initialize a driver, must be called prior to use.
- virtual K_UCHAR Open ()=0

  Open a device driver prior to use.
- virtual K_UCHAR Close ()=0

  Close a previously-opened device driver.
- virtual K_USHORT Read (K_USHORT usBytes_, K_UCHAR ∗pucData_)=0

  Read a specified number of bytes from the device into a specific buffer.
- virtual K_USHORT Write (K_USHORT usBytes_, K_UCHAR ∗pucData_)=0

  Write a payload of data of a given length to the device.
- virtual K_USHORT Control (K_USHORT usEvent_, void ∗pvDataIn_, K_USHORT usSizeIn_, void ∗pvDataOut_, K_USHORT usSizeOut_)=0

  This is the main entry-point for device-specific io and control operations.

- void SetName (const K_CHAR ∗pcName_)

  Set the path for the driver.

- const K_CHAR ∗ GetPath ()

  Returns a string containing the device path.

Private Attributes

- const K_CHAR ∗ m_pcPath

  string pointer that holds the driver path (name)

Additional Inherited Members

14.5.1 Detailed Description

Base device-driver class used in hardware abstraction.

All other device drivers inherit from this class

Definition at line 121 of file driver.h.

14.5.2 Member Function Documentation

14.5.2.1 K_UCHAR Driver::Close ( ) [pure virtual]

Close a previously-opened device driver.

Returns

Driver-specific return code, 0 = OK, non-0 = error

Implemented in DevNull.

14.5.2.2 K_USHORT Driver::Control (K_USHORT *usEvent_*, void ∗ *pvDataIn_*, K_USHORT *usSizeIn_*, void ∗ *pvDataOut_*, K_USHORT *usSizeOut_*) [pure virtual]

This is the main entry-point for device-specific io and control operations.

This is used for implementing all "side-channel" communications with a device, and any device-specific IO operations that do not conform to the typical POSIX read/write paradigm. Use of this funciton is analagous to the non-POSIX (yet still common) devctl() or ioctl().

Parameters

*usEvent_*	Code defining the io event (driver-specific)
*pvDataIn_*	Pointer to the intput data
*usSizeIn_*	Size of the input data (in bytes)
*pvDataOut_*	Pointer to the output data
*usSizeOut_*	Size of the output data (in bytes)

Returns

Driver-specific return code, 0 = OK, non-0 = error

Implemented in DevNull.

14.5.2.3 const K_CHAR ∗ Driver::GetPath ( ) [inline]

Returns a string containing the device path.

Returns

pcName_ Return the string constant representing the device path

Definition at line 231 of file driver.h.

14.5.2.4 K_UCHAR Driver::Open ( ) [pure virtual]

Open a device driver prior to use.

Returns

Driver-specific return code, 0 = OK, non-0 = error

Implemented in DevNull.

14.5.2.5 K_USHORT Driver::Read (K_USHORT *usBytes_*, K_UCHAR ∗ *pucData_*) [pure virtual]

Read a specified number of bytes from the device into a specific buffer.

Depending on the driver-specific implementation, this may be a number less than the requested number of bytes read, indicating that there there was less input than desired, or that as a result of buffering, the data may not be available.

Parameters

*usBytes_*	Number of bytes to read (<= size of the buffer)
*pucData_*	Pointer to a data buffer receiving the read data

Returns

Number of bytes actually read

Implemented in DevNull.

14.5.2.6 void Driver::SetName (const K_CHAR ∗ *pcName_*) [inline]

Set the path for the driver.

Name must be set prior to access (since driver access is name-based).

Parameters

*pcName_*	String constant containing the device path

Definition at line 222 of file driver.h.

14.5.2.7 K_USHORT Driver::Write (K_USHORT *usBytes_*, K_UCHAR ∗ *pucData_*) [pure virtual]

Write a payload of data of a given length to the device.

Depending on the implementation of the driver, the amount of data written to the device may be less than the requested number of bytes. A result less than the requested size may indicate that the device buffer is full, indicating that the user must retry the write at a later point with the remaining data.

Parameters

*usBytes_*	Number of bytes to write (<= size of the buffer)
*pucData_*	Pointer to a data buffer containing the data to write

Returns

Number of bytes actually written

Implemented in DevNull.

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

- /home/moslevin/Project/R1/kernel/public/driver.h

14.6 DriverList Class Reference

List of Driver objects used to keep track of all device drivers in the system.

`#include <driver.h>`

Static Public Member Functions

- static void Init ()

  Initialize the list of drivers.
- static void Add (Driver ∗pclDriver_)

  Add a Driver object to the managed global driver-list.
- static void Remove (Driver ∗pclDriver_)

  Remove a driver from the global driver list.
- static Driver ∗ FindByPath (const K_CHAR ∗m_pcPath)

  Look-up a driver in the global driver-list based on its path.

Static Private Attributes

- static DoubleLinkList m_clDriverList

  LinkedList object used to implementing the driver object management.

14.6.1 Detailed Description

List of Driver objects used to keep track of all device drivers in the system.

By default, the list contains a single entity, "/dev/null".

Definition at line 244 of file driver.h.

14.6.2 Member Function Documentation

14.6.2.1 DriverList::Add (Driver ∗ *pclDriver_*) `[inline]`, `[static]`

Add a Driver object to the managed global driver-list.

Parameters

*pclDriver_*	pointer to the driver object to add to the global driver list.

Definition at line 264 of file driver.h.

14.6.2.2 Driver ∗ DriverList::FindByPath (const K_CHAR ∗ *m_pcPath*) [static]

Look-up a driver in the global driver-list based on its path.

In the event that the driver is not found in the list, a pointer to the default "/dev/null" object is returned. In this way, unimplemented drivers are automatically stubbed out.

Definition at line 107 of file driver.cpp.

14.6.2.3 void DriverList::Init ( ) [static]

Initialize the list of drivers.

Must be called prior to using the device driver library.

Definition at line 98 of file driver.cpp.

14.6.2.4 void DriverList::Remove (Driver ∗ *pclDriver_*) [inline], [static]

Remove a driver from the global driver list.

Parameters

*pclDriver_*	Pointer to the driver object to remove from the global table

Definition at line 274 of file driver.h.

The documentation for this class was generated from the following files:

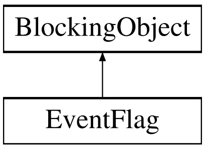
- /home/moslevin/Project/R1/kernel/public/driver.h
- /home/moslevin/Project/R1/kernel/driver.cpp

14.7 EventFlag Class Reference

The EventFlag class is a blocking object, similar to a semaphore or mutex, commonly used for synchronizing thread execution based on events occurring within the system.

`#include <eventflag.h>`

Inheritance diagram for EventFlag:



Public Member Functions

- void Init ()

  Init Initializes the EventFlag object prior to use.
- K_USHORT Wait (K_USHORT usMask_, EventFlagOperation_t eMode_)

Wait - Block a thread on the specific flags in this event flag group.

- K_USHORT Wait (K_USHORT usMask_, EventFlagOperation_t eMode_, K_ULONG ulTimeMS_)

  Wait - Block a thread on the specific flags in this event flag group.
- void WakeMe (Thread ∗pclOwner_)

  WakeMe.
- void Set (K_USHORT usMask_)

  Set - Set additional flags in this object (logical OR).
- void Clear (K_USHORT usMask_)

  ClearFlags - Clear a specific set of flags within this object, specific by bitmask.
- K_USHORT GetMask ()

  GetMask Returns the state of the 16-bit bitmask within this object.

Private Member Functions

- K_USHORT Wait_i (K_USHORT usMask_, EventFlagOperation_t eMode_, K_ULONG ulTimeMS_)

  Wait_i.

Private Attributes

- K_USHORT m_usSetMask

  Event flags currently set in this object.

Additional Inherited Members

14.7.1 Detailed Description

The EventFlag class is a blocking object, similar to a semaphore or mutex, commonly used for synchronizing thread execution based on events occurring within the system.

Each EventFlag object contains a 16-bit bitmask, which is used to trigger events on associated threads. Threads wishing to block, waiting for a specific event to occur can wait on any pattern within this 16-bit bitmask to be set. Here, we provide the ability for a thread to block, waiting for ANY bits in a specified mask to be set, or for ALL bits within a specific mask to be set. Depending on how the object is configured, the bits that triggered the wakeup can be automatically cleared once a match has occurred.

Definition at line 46 of file eventflag.h.

14.7.2 Member Function Documentation

14.7.2.1 void EventFlag::Clear (K_USHORT *usMask_*)

ClearFlags - Clear a specific set of flags within this object, specific by bitmask.

Parameters

*usMask_*	- Bitmask of flags to clear

Definition at line 295 of file eventflag.cpp.

14.7.2.2 K_USHORT EventFlag::GetMask ( )

GetMask Returns the state of the 16-bit bitmask within this object.

Returns

The state of the 16-bit bitmask

Definition at line 304 of file eventflag.cpp.

14.7.2.3 void EventFlag::Set (K_USHORT *usMask_*)

Set - Set additional flags in this object (logical OR).

This API can potentially result in threads blocked on Wait() to be unblocked.

Parameters

*usMask_*	- Bitmask of flags to set.

Definition at line 176 of file eventflag.cpp.

14.7.2.4 K_USHORT EventFlag::Wait (K_USHORT *usMask_*, EventFlagOperation_t *eMode_*)

Wait - Block a thread on the specific flags in this event flag group.

Parameters

*usMask_*	- 16-bit bitmask to block on
*eMode_*	- EVENT_FLAG_ANY: Thread will block on any of the bits in the mask • EVENT_FLAG_ALL: Thread will block on all of the bits in the mask

Returns

Bitmask condition that caused the thread to unblock, or 0 on error or timeout

Definition at line 158 of file eventflag.cpp.

14.7.2.5 K_USHORT EventFlag::Wait (K_USHORT *usMask_*, EventFlagOperation_t *eMode_*, K_ULONG *ulTimeMS_*)

Wait - Block a thread on the specific flags in this event flag group.

Parameters

*usMask_*	- 16-bit bitmask to block on
*eMode_*	- EVENT_FLAG_ANY: Thread will block on any of the bits in the mask • EVENT_FLAG_ALL: Thread will block on all of the bits in the mask
*ulTimeMS_*	- Time to block (in ms)

Returns

Bitmask condition that caused the thread to unblock, or 0 on error or timeout

Definition at line 169 of file eventflag.cpp.

14.7.2.6 K_USHORT EventFlag::Wait_i (K_USHORT *usMask_*, EventFlagOperation_t *eMode_*, K_ULONG *ulTimeMS_*) [private]

Wait_i.

Interal abstraction used to manage both timed and untimed wait operations

Parameters

*usMask_*	- 16-bit bitmask to block on
*eMode_*	- EVENT_FLAG_ANY: Thread will block on any of the bits in the mask • EVENT_FLAG_ALL: Thread will block on all of the bits in the mask
*ulTimeMS_*	- Time to block (in ms)

Returns

Bitmask condition that caused the thread to unblock, or 0 on error or timeout

! If the Yield operation causes a new thread to be chosen, there will ! Be a context switch at the above CS_EXIT(). The original calling ! thread will not return back until a matching SetFlags call is made ! or a timeout occurs.

Definition at line 65 of file eventflag.cpp.

14.7.2.7 void EventFlag::WakeMe (Thread ∗ *pclOwner_*)

WakeMe.

Wake the given thread, currently blocking on this object

Parameters

*pclOwner_*	Pointer to the owner thread to unblock.

Definition at line 57 of file eventflag.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/eventflag.h
- /home/moslevin/Project/R1/kernel/eventflag.cpp

14.8 FakeThread_t Struct Reference

If the kernel is set up to use an idle function instead of an idle thread, we use a placeholder data structure to "simulate" the effect of having an idle thread in the system.

```
#include <thread.h>
```

Public Attributes

- K_WORD ∗ m_pwStackTop

  Pointer to the top of the thread's stack.
- K_WORD ∗ m_pwStack

  Pointer to the thread's stack.
- K_UCHAR m_ucThreadID

  Thread ID.
- K_UCHAR m_ucPriority

  Default priority of the thread.
- K_UCHAR m_ucCurPriority

  Current priority of the thread (priority inheritence)
- ThreadState_t m_eState

  Enum indicating the thread's current state.

14.8.1 Detailed Description

If the kernel is set up to use an idle function instead of an idle thread, we use a placeholder data structure to "simulate" the effect of having an idle thread in the system.

When cast to a Thread, this data structure will still result in GetPriority() calls being valid, which is all that is needed to support the tick-based/tickless times – while saving a fairly decent chunk of RAM on a small micro.

Note that this struct must have the same memory layout as the Thread class up to the last item.

Definition at line 494 of file thread.h.

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

- /home/moslevin/Project/R1/kernel/public/thread.h

14.9 GlobalMessagePool Class Reference

Implements a list of message objects shared between all threads.

```
#include <message.h>
```

Static Public Member Functions

- static void Init ()

  Initialize the message queue prior to use.
- static void Push (Message ∗pclMessage_)

  Return a previously-claimed message object back to the global queue.
- static Message ∗ Pop ()

  Pop a message from the global queue, returning it to the user to be populated before sending by a transmitter.

Static Private Attributes

- static Message m_aclMessagePool [GLOBAL_MESSAGE_POOL_SIZE]

  Array of message objects that make up the message pool.
- static DoubleLinkList m_clList

  Linked list used to manage the Message objects.

14.9.1 Detailed Description

Implements a list of message objects shared between all threads.

Definition at line 157 of file message.h.

14.9.2 Member Function Documentation

14.9.2.1 Message ∗ GlobalMessagePool::Pop ( ) [static]

Pop a message from the global queue, returning it to the user to be populated before sending by a transmitter.

Returns

Pointer to a Message object

Definition at line 70 of file message.cpp.

14.9.2.2 void GlobalMessagePool::Push (Message * *pclMessage_*) [static]

Return a previously-claimed message object back to the global queue.

Used once the message has been processed by a receiver.

Parameters

*pclMessage_*	Pointer to the Message object to return back to the global queue

Definition at line 58 of file message.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/message.h
- /home/moslevin/Project/R1/kernel/message.cpp

14.10 Kernel Class Reference

Class that encapsulates all of the kernel startup functions.

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

Static Public Member Functions

- static void Init (void)

  Kernel Initialization Function, call before any other OS function.
- static void Start (void)

  Start the kernel; function never returns.
- static K_BOOL IsStarted ()

  IsStarted.
- static void SetPanic (panic_func_t pfPanic_)

  SetPanic Set a function to be called when a kernel panic occurs, giving the user to determine the behavior when a catastrophic failure is observed.
- static K_BOOL IsPanic ()

  IsPanic Returns whether or not the kernel is in a panic state.
- static void Panic (K_USHORT usCause_)

  Panic Cause the kernel to enter its panic state.
- static void SetIdleFunc (idle_func_t pfIdle_)

  SetIdleFunc Set the function to be called when no active threads are available to be scheduled by the scheduler.
- static void IdleFunc (void)

  IdleFunc Call the low-priority idle function when no active threads are available to be scheduled.
- static Thread * GetIdleThread (void)

  GetIdleThread Return a pointer to the Kernel's idle thread object to the user.

Static Private Attributes

- static K_BOOL m_bIsStarted

  true if kernel is running, false otherwise
- static K_BOOL m_bIsPanic

  true if kernel is in panic state, false otherwise
- static panic_func_t m_pfPanic

  user-set panic function
- static idle_func_t m_pfIdle

user-set idle function

- static FakeThread_t m_clIdle

  Idle thread object (note: not a real thread)

14.10.1 Detailed Description

Class that encapsulates all of the kernel startup functions.

Definition at line 48 of file kernel.h.

14.10.2 Member Function Documentation

14.10.2.1 static Thread* Kernel::GetIdleThread (void) [inline], [static]

GetIdleThread Return a pointer to the Kernel's idle thread object to the user.

Note that the Thread object involved is to be used for comparisons only – the thread itself is "virtual", and doesn't represent a unique execution context with its own stack.

Returns

Pointer to the Kernel's idle thread object

Definition at line 124 of file kernel.h.

14.10.2.2 Kernel::Init (void) [static]

Kernel Initialization Function, call before any other OS function.

Initializes all global resources used by the operating system. This must be called before any other kernel function is invoked.

Definition at line 52 of file kernel.cpp.

14.10.2.3 static K_BOOL Kernel::IsPanic ( ) [inline], [static]

IsPanic Returns whether or not the kernel is in a panic state.

Returns

Whether or not the kernel is in a panic state

Definition at line 95 of file kernel.h.

14.10.2.4 static K_BOOL Kernel::IsStarted ( ) [inline], [static]

IsStarted.

Returns

Whether or not the kernel has started - true = running, false = not started

Definition at line 80 of file kernel.h.

14.10.2.5 void Kernel::Panic (K_USHORT *usCause_*) [static]

Panic Cause the kernel to enter its panic state.

Parameters

*usCause_*	Reason for the kernel panic

Definition at line 95 of file kernel.cpp.

14.10.2.6 static void Kernel::SetIdleFunc (idle_func_t *pfIdle_*) [inline], [static]

SetIdleFunc Set the function to be called when no active threads are available to be scheduled by the scheduler.

Parameters

*pfIdle_*	Pointer to the idle function

Definition at line 109 of file kernel.h.

14.10.2.7 static void Kernel::SetPanic (panic_func_t *pfPanic_*) [inline], [static]

SetPanic Set a function to be called when a kernel panic occurs, giving the user to determine the behavior when a catastrophic failure is observed.

Parameters

*pfPanic_*	Panic function pointer

Definition at line 89 of file kernel.h.

14.10.2.8 Kernel::Start (void) [static]

Start the kernel; function never returns.

Start the operating system kernel - the current execution context is cancelled, all kernel services are started, and the processor resumes execution at the entrypoint for the highest-priority thread.

You must have at least one thread added to the kernel before calling this function, otherwise the behavior is undefined.

Definition at line 86 of file kernel.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/kernel.h
- /home/moslevin/Project/R1/kernel/kernel.cpp

14.11 KernelAware Class Reference

The KernelAware class.

```
#include <kernelaware.h>
```

Static Public Member Functions

- static void ProfileInit (const K_CHAR ∗szStr_)

  ProfileInit.
- static void ProfileStart (void)

  ProfileStart.
- static void ProfileStop (void)

  ProfileStop.

- static void ProfileReport (void)

  ProfileReport.
- static void ExitSimulator (void)

  ExitSimulator.
- static void Print (const K_CHAR ∗szStr_)

  Print.
- static void Trace (K_USHORT usFile_, K_USHORT usLine_, K_USHORT usCode_)

  Trace.
- static void Trace (K_USHORT usFile_, K_USHORT usLine_, K_USHORT usCode_, K_USHORT usArg1_)

  Trace.
- static void Trace (K_USHORT usFile_, K_USHORT usLine_, K_USHORT usCode_, K_USHORT usArg1_, K_USHORT usArg2_)

  Trace.
- static K_BOOL IsSimulatorAware (void)

  IsSimulatorAware.

Static Private Member Functions

- static void Trace_i (K_USHORT usFile_, K_USHORT usLine_, K_USHORT usCode_, K_USHORT usArg1_, K_USHORT usArg2_, KernelAwareCommand_t eCmd_)

  Trace_i.

14.11.1 Detailed Description

The KernelAware class.

This class contains functions that are used to trigger kernel-aware functionality within a supported simulation environment (i.e. flAVR).

These static methods operate on a singleton set of global variables, which are monitored for changes from within the simulator. The simulator hooks into these variables by looking for the correctly-named symbols in an elf-formatted binary being run and registering callbacks that are called whenever the variables are changed. On each change of the command variable, the kernel-aware data is analyzed and interpreted appropriately.

If these methods are run in an unsupported simulator or on actual hardware the commands generally have no effect (except for the exit-on-reset command, which will result in a jump-to-0 reset).

Definition at line 65 of file kernelaware.h.

14.11.2 Member Function Documentation

14.11.2.1 void KernelAware::ExitSimulator (void) `[static]`

ExitSimulator.

Instruct the kernel-aware simulator to terminate (destroying the virtual CPU).

Definition at line 104 of file kernelaware.cpp.

14.11.2.2 K_BOOL KernelAware::IsSimulatorAware (void) `[static]`

IsSimulatorAware.

Use this function to determine whether or not the code is running on a simulator that is aware of the kernel.

Returns

true - the application is being run in a kernel-aware simulator. false - otherwise.

Definition at line 164 of file kernelaware.cpp.

14.11.2.3 void KernelAware::Print (const K_CHAR * *szStr_*) [static]

Print.

Instruct the kernel-aware simulator to print a char string

Parameters

*szStr_*	

Definition at line 155 of file kernelaware.cpp.

14.11.2.4 void KernelAware::ProfileInit (const K_CHAR * *szStr_*) [static]

ProfileInit.

Initializes the kernel-aware profiler. This function instructs the kernel-aware simulator to reset its accounting variables, and prepare to start counting profiling data tagged to the given string. How this is handled is the responsibility of the simulator.

Parameters

*szStr_*	String to use as a tag for the profilng session.

Definition at line 77 of file kernelaware.cpp.

14.11.2.5 void KernelAware::ProfileReport (void) [static]

ProfileReport.

Instruct the kernel-aware simulator to print a report for its current profiling data.

Definition at line 98 of file kernelaware.cpp.

14.11.2.6 void KernelAware::ProfileStart (void) [static]

ProfileStart.

Instruct the kernel-aware simulator to begin counting cycles towards the current profiling counter.

Definition at line 86 of file kernelaware.cpp.

14.11.2.7 void KernelAware::ProfileStop (void) [static]

ProfileStop.

Instruct the kernel-aware simulator to end counting cycles relative to the current profiling counter's iteration.

Definition at line 92 of file kernelaware.cpp.

14.11.2.8 void KernelAware::Trace (K_USHORT *usFile_*, K_USHORT *usLine_*, K_USHORT *usCode_*) [static]

Trace.

Insert a kernel trace statement into the kernel-aware simulator's debug data stream.

Parameters

*usFile_*	16-bit code representing the file
*usLine_*	16-bit code representing the line in the file
*usCode_*	16-bit data code, which indicates the line's format.

Definition at line 110 of file kernelaware.cpp.

14.11.2.9 void KernelAware::Trace (K_USHORT *usFile_*, K_USHORT *usLine_*, K_USHORT *usCode_*, K_USHORT *usArg1_*) [static]

Trace.

Insert a kernel trace statement into the kernel-aware simulator's debug data stream.

Parameters

*usFile_*	16-bit code representing the file
*usLine_*	16-bit code representing the line in the file
*usCode_*	16-bit data code, which indicates the line's format
*usArg1_*	16-bit argument to the format string.

Definition at line 118 of file kernelaware.cpp.

14.11.2.10 void KernelAware::Trace (K_USHORT *usFile_*, K_USHORT *usLine_*, K_USHORT *usCode_*, K_USHORT *usArg1_*, K_USHORT *usArg2_*) [static]

Trace.

Insert a kernel trace statement into the kernel-aware simulator's debug data stream.

Parameters

*usFile_*	16-bit code representing the file
*usLine_*	16-bit code representing the line in the file
*usCode_*	16-bit data code, which indicates the line's format
*usArg1_*	16-bit argument to the format string.
*usArg2_*	16-bit argument to the format string.

Definition at line 127 of file kernelaware.cpp.

14.11.2.11 void KernelAware::Trace_i (K_USHORT *usFile_*, K_USHORT *usLine_*, K_USHORT *usCode_*, K_USHORT *usArg1_*, K_USHORT *usArg2_*, KernelAwareCommand_t *eCmd_*) [static], [private]

Trace_i.

Private function by which the class's Trace() methods are reflected, which allows us to realize a modest code saving.

Parameters

*usFile_*	16-bit code representing the file
*usLine_*	16-bit code representing the line in the file
*usCode_*	16-bit data code, which indicates the line's format
*usArg1_*	16-bit argument to the format string.
*usArg2_*	16-bit argument to the format string.
*eCmd_*	Code indicating the number of arguments to emit.

Definition at line 137 of file kernelaware.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/kernelaware.h

- /home/moslevin/Project/R1/kernel/kernelaware.cpp

14.12 KernelAwareData_t Union Reference

This structure is used to communicate between the kernel and a kernel- aware host.

Public Attributes

- volatile K_USHORT ausBuffer [5]

  Raw binary contents of the struct.

- *The Profiler struct contains data related to the code-execution profiling functionality provided by a kernel-aware host simluator.*

  The Trace struct contains data related to the display and output of kernel-trace strings on a kernel-aware host.

  The Print struct contains data related to the display of arbitrary null-terminated ASCII strings on the kernel-aware host.

14.12.1 Detailed Description

This structure is used to communicate between the kernel and a kernel- aware host.

Its data contents is interpreted differently depending on the command executed (by means of setting the g_ucKACommand variable, as is done in the command handlers in this module). As a result, any changes to this struct by way of modifying or adding data must be mirrored in the kernel-aware simulator.

Definition at line 37 of file kernelaware.cpp.

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

- /home/moslevin/Project/R1/kernel/kernelaware.cpp

14.13 KernelSWI Class Reference

Class providing the software-interrupt required for context-switching in the kernel.

```
#include <kernelswi.h>
```

Static Public Member Functions

- static void Config (void)

  Configure the software interrupt - must be called before any other software interrupt functions are called.
- static void Start (void)

  Enable ("Start") the software interrupt functionality.
- static void Stop (void)

  Disable the software interrupt functionality.
- static void Clear (void)

Clear the software interrupt.

- static void Trigger (void)

  Call the software interrupt.

- static K_UCHAR DI ()

  Disable the SWI flag itself.

- static void RI (K_BOOL bEnable_)

  Restore the state of the SWI to the value specified.

14.13.1 Detailed Description

Class providing the software-interrupt required for context-switching in the kernel.

Definition at line 32 of file kernelswi.h.

14.13.2 Member Function Documentation

14.13.2.1 K_UCHAR KernelSWI::DI ( ) [static]

Disable the SWI flag itself.

Returns

previous status of the SWI, prior to the DI call

Definition at line 50 of file kernelswi.cpp.

14.13.2.2 void KernelSWI::RI (K_BOOL *bEnable_*) [static]

Restore the state of the SWI to the value specified.

Parameters

*bEnable_*	true - enable the SWI, false - disable SWI

Definition at line 58 of file kernelswi.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/kernelswi.h
- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/kernelswi.cpp

14.14 KernelTimer Class Reference

Hardware timer interface, used by all scheduling/timer subsystems.

```
#include <kerneltimer.h>
```

Static Public Member Functions

- static void Config (void)

  Initializes the kernel timer before use.

- static void Start (void)

  Starts the kernel time (must be configured first)

- static void Stop (void)

Shut down the kernel timer, used when no timers are scheduled.
- static K_UCHAR DI (void)

  Disable the kernel timer's expiry interrupt.
- static void RI (K_BOOL bEnable_)

  Retstore the state of the kernel timer's expiry interrupt.
- static void EI (void)

  Enable the kernel timer's expiry interrupt.
- static K_ULONG SubtractExpiry (K_ULONG ulInterval_)

  Subtract the specified number of ticks from the timer's expiry count register.
- static K_ULONG TimeToExpiry (void)

  Returns the number of ticks remaining before the next timer expiry.
- static K_ULONG SetExpiry (K_ULONG ulInterval_)

  Resets the kernel timer's expiry interval to the specified value.
- static K_ULONG GetOvertime (void)

  Return the number of ticks that have elapsed since the last expiry.
- static void ClearExpiry (void)

  Clear the hardware timer expiry register.

Static Private Member Functions

- static K_USHORT Read (void)

  Safely read the current value in the timer register.

14.14.1 Detailed Description

Hardware timer interface, used by all scheduling/timer subsystems.

Definition at line 33 of file kerneltimer.h.

14.14.2 Member Function Documentation

14.14.2.1 K_ULONG KernelTimer::GetOvertime (void) [static]

Return the number of ticks that have elapsed since the last expiry.

Returns

Number of ticks that have elapsed after last timer expiration

Definition at line 115 of file kerneltimer.cpp.

14.14.2.2 K_USHORT KernelTimer::Read (void) [static], [private]

Safely read the current value in the timer register.

Returns

Value held in the timer register

Definition at line 66 of file kerneltimer.cpp.

14.14.2.3 void KernelTimer::RI (K_BOOL *bEnable_*) [static]

Retstore the state of the kernel timer's expiry interrupt.

Parameters

*bEnable_*	1 enable, 0 disable

Definition at line 169 of file kerneltimer.cpp.

14.14.2.4 K_ULONG KernelTimer::SetExpiry (K_ULONG *ulInterval_*) [static]

Resets the kernel timer's expiry interval to the specified value.

Parameters

*ulInterval_*	Desired interval in ticks to set the timer for

Returns

Actual number of ticks set (may be less than desired)

Definition at line 121 of file kerneltimer.cpp.

14.14.2.5 K_ULONG KernelTimer::SubtractExpiry (K_ULONG *ulInterval_*) [static]

Subtract the specified number of ticks from the timer's expiry count register.

Returns the new expiry value stored in the register.

Parameters

*ulInterval_*	Time (in HW-specific) ticks to subtract

Returns

Value in ticks stored in the timer's expiry register

Definition at line 84 of file kerneltimer.cpp.

14.14.2.6 K_ULONG KernelTimer::TimeToExpiry (void) [static]

Returns the number of ticks remaining before the next timer expiry.

Returns

Time before next expiry in platform-specific ticks

Definition at line 95 of file kerneltimer.cpp.

The documentation for this class was generated from the following files:

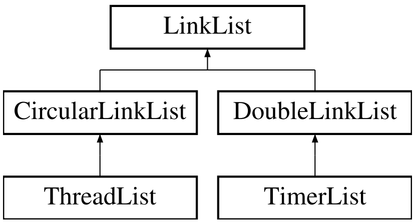
- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/kerneltimer.h
- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/kerneltimer.cpp

14.15 LinkList Class Reference

Abstract-data-type from which all other linked-lists are derived.

`#include <ll.h>`

Inheritance diagram for LinkList:



Public Member Functions

- void Init ()

  Clear the linked list.
- virtual void Add (LinkListNode ∗node_)=0

  Add the linked list node to this linked list.
- virtual void Remove (LinkListNode ∗node_)=0

  Add the linked list node to this linked list.
- LinkListNode ∗ GetHead ()

  Get the head node in the linked list.
- LinkListNode ∗ GetTail ()

  Get the tail node of the linked list.

Protected Attributes

- LinkListNode ∗ m_pstHead

  Pointer to the head node in the list.
- LinkListNode ∗ m_pstTail

  Pointer to the tail node in the list.

14.15.1 Detailed Description

Abstract-data-type from which all other linked-lists are derived.

Definition at line 112 of file ll.h.

14.15.2 Member Function Documentation

14.15.2.1 void LinkList::Add (**LinkListNode** ∗ *node_*) [pure virtual]

Add the linked list node to this linked list.

Parameters

*node_*	Pointer to the node to add

Implemented in CircularLinkList, DoubleLinkList, and ThreadList.

14.15.2.2 **LinkListNode** ∗ LinkList::GetHead ( ) [inline]

Get the head node in the linked list.

Returns

Pointer to the head node in the list

Definition at line 149 of file ll.h.

14.15.2.3 LinkListNode ∗ LinkList::GetTail ( ) [inline]

Get the tail node of the linked list.

Returns

Pointer to the tail node in the list

Definition at line 158 of file ll.h.

14.15.2.4 void LinkList::Remove (LinkListNode ∗ *node_*) [pure virtual]

Add the linked list node to this linked list.

Parameters

*node_*	Pointer to the node to remove

Implemented in CircularLinkList, DoubleLinkList, and ThreadList.

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

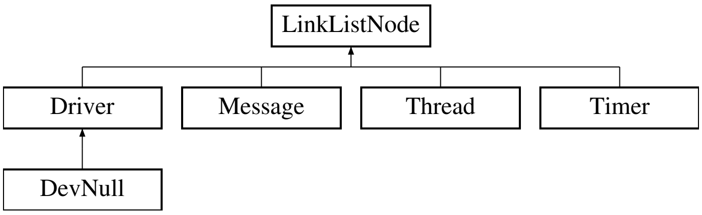
- /home/moslevin/Project/R1/kernel/public/ll.h

14.16 LinkListNode Class Reference

Basic linked-list node data structure.

`#include <ll.h>`

Inheritance diagram for LinkListNode:



Public Member Functions

- LinkListNode ∗ GetNext (void)

  Returns a pointer to the next node in the list.

- LinkListNode ∗ GetPrev (void)

  Returns a pointer to the previous node in the list.

Protected Member Functions

- void ClearNode ()

  Initialize the linked list node, clearing its next and previous node.

Protected Attributes

- LinkListNode ∗ next

  Pointer to the next node in the list.
- LinkListNode ∗ prev

  Pointer to the previous node in the list.

Friends

- class **LinkList**
- class **DoubleLinkList**
- class **CircularLinkList**

14.16.1 Detailed Description

Basic linked-list node data structure.

This data is managed by the linked-list class types, and can be used transparently between them.

Definition at line 68 of file ll.h.

14.16.2 Member Function Documentation

14.16.2.1 LinkListNode ∗ LinkListNode::GetNext (void) [inline]

Returns a pointer to the next node in the list.

Returns

a pointer to the next node in the list.

Definition at line 92 of file ll.h.

14.16.2.2 LinkListNode ∗ LinkListNode::GetPrev (void) [inline]

Returns a pointer to the previous node in the list.

Returns

a pointer to the previous node in the list.

Definition at line 101 of file ll.h.

The documentation for this class was generated from the following files:

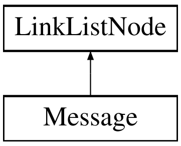
- /home/moslevin/Project/R1/kernel/public/ll.h
- /home/moslevin/Project/R1/kernel/ll.cpp

14.17 Message Class Reference

Class to provide message-based IPC services in the kernel.

`#include <message.h>`

Inheritance diagram for Message:



Public Member Functions

- void Init ()

  Initialize the data and code in the message.
- void SetData (void ∗pvData_)

  Set the data pointer for the message before transmission.
- void ∗ GetData ()

  Get the data pointer stored in the message upon receipt.
- void SetCode (K_USHORT usCode_)

  Set the code in the message before transmission.
- K_USHORT GetCode ()

  Return the code set in the message upon receipt.

Private Attributes

- void ∗ m_pvData

  Pointer to the message data.
- K_USHORT m_usCode

  Message code, providing context for the message.

Additional Inherited Members

14.17.1 Detailed Description

Class to provide message-based IPC services in the kernel.

Definition at line 99 of file message.h.

14.17.2 Member Function Documentation

14.17.2.1 K_USHORT Message::GetCode ( ) [inline]

Return the code set in the message upon receipt.

Returns

User code set in the object

Definition at line 143 of file message.h.

14.17.2.2 void ∗ Message::GetData ( ) [inline]

Get the data pointer stored in the message upon receipt.

Returns

Pointer to the data set in the message object

Definition at line 125 of file message.h.

14.17.2.3 Message::SetCode (K_USHORT *usCode_*) [inline]

Set the code in the message before transmission.

Parameters

*usCode_*	Data code to set in the object

Definition at line 134 of file message.h.

14.17.2.4 void Message::SetData (void ∗ *pvData_*) [inline]

Set the data pointer for the message before transmission.

Parameters

*pvData_*	Pointer to the data object to send in the message

Definition at line 116 of file message.h.

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

- /home/moslevin/Project/R1/kernel/public/message.h

14.18 MessageQueue Class Reference

List of messages, used as the channel for sending and receiving messages between threads.

`#include <message.h>`

Public Member Functions

- void Init ()

  Initialize the message queue prior to use.
- Message ∗ Receive ()

  Receive a message from the message queue.
- Message ∗ Receive (K_ULONG ulTimeWaitMS_)

  Receive a message from the message queue.
- void Send (Message ∗pclSrc_)

  Send a message object into this message queue.
- K_USHORT GetCount ()

  Return the number of messages pending in the "receive" queue.

Private Member Functions

- Message ∗ Receive_i (K_ULONG ulTimeWaitMS_)

  Receive_i.

Private Attributes

- Semaphore m_clSemaphore

  Counting semaphore used to manage thread blocking.
- DoubleLinkList m_clLinkList

  List object used to store messages.

14.18.1 Detailed Description

List of messages, used as the channel for sending and receiving messages between threads.

Definition at line 201 of file message.h.

14.18.2 Member Function Documentation

14.18.2.1 K_USHORT MessageQueue::GetCount ( )

Return the number of messages pending in the "receive" queue.

Returns

Count of pending messages in the queue.

Definition at line 156 of file message.cpp.

14.18.2.2 Message ∗ MessageQueue::Receive ( )

Receive a message from the message queue.

If the message queue is empty, the thread will block until a message is available.

Returns

Pointer to a message object at the head of the queue

Definition at line 92 of file message.cpp.

14.18.2.3 Message ∗ MessageQueue::Receive (K_ULONG *ulWaitTimeMS_*)

Receive a message from the message queue.

If the message queue is empty, the thread will block until a message is available for the duration specified. If no message arrives within that duration, the call will return with NULL.

Parameters

*ulWaitTimeMS_*	The amount of time in ms to wait for a message before timing out and unblocking the waiting thread.

Returns

Pointer to a message object at the head of the queue or NULL on timeout.

Definition at line 103 of file message.cpp.

14.18.2.4 Message ∗ MessageQueue::Receive_i (K_ULONG *ulTimeWaitMS_*) [private]

Receive_i.

Internal function used to abstract timed and un-timed Receive calls.

Parameters

*ulTimeWaitMS_*	Time (in ms) to block, 0 for un-timed call.

Returns

Pointer to a message, or 0 on timeout.

Definition at line 111 of file message.cpp.

14.18.2.5 void MessageQueue::Send (Message ∗ *pclSrc_*)

Send a message object into this message queue.

Will un-block the first waiting thread blocked on this queue if that occurs.

Parameters

*pclSrc_*	Pointer to the message object to add to the queue

Definition at line 140 of file message.cpp.

The documentation for this class was generated from the following files:

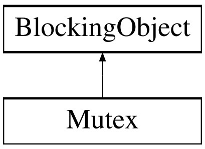
- /home/moslevin/Project/R1/kernel/public/message.h
- /home/moslevin/Project/R1/kernel/message.cpp

14.19 Mutex Class Reference

Mutual-exclusion locks, based on BlockingObject.

```
#include <mutex.h>
```

Inheritance diagram for Mutex:



Public Member Functions

- void Init ()

  Initialize a mutex object for use - must call this function before using the object.
- void Claim ()

  Claim the mutex.
- K_BOOL Claim (K_ULONG ulWaitTimeMS_)
- void WakeMe (Thread ∗pclOwner_)

  Wake a thread blocked on the mutex.
- void Release ()

  Release the mutex.

Private Member Functions

- K_UCHAR WakeNext ()

  Wake the next thread waiting on the Mutex.
- K_BOOL Claim_i (K_ULONG ulWaitTimeMS_)

  Claim_i.

Private Attributes

- K_UCHAR m_ucRecurse

  The recursive lock-count when a mutex is claimed multiple times by the same owner.
- K_UCHAR m_bReady

  State of the mutex - true = ready, false = claimed.
- K_UCHAR m_ucMaxPri

  Maximum priority of thread in queue, used for priority inheritence.
- Thread ∗ m_pclOwner

  Pointer to the thread that owns the mutex (when claimed)

Additional Inherited Members

14.19.1 Detailed Description

Mutual-exclusion locks, based on BlockingObject.

Definition at line 68 of file mutex.h.

14.19.2 Member Function Documentation

14.19.2.1 void Mutex::Claim (void)

Claim the mutex.

When the mutex is claimed, no other thread can claim a region protected by the object.

Definition at line 209 of file mutex.cpp.

14.19.2.2 K_BOOL Mutex::Claim (K_ULONG *ulWaitTimeMS_*)

Parameters

*ulWaitTimeMS_*	

Returns

> true - mutex was claimed within the time period specified false - mutex operation timed-out before the claim operation.

Definition at line 220 of file mutex.cpp.

14.19.2.3 K_BOOL Mutex::Claim_i (K_ULONG *ulWaitTimeMS_*) `[private]`

Claim_i.

Abstracts out timed/non-timed mutex claim operations.

Parameters

*ulWaitTimeMS_*	Time in MS to wait, 0 for infinite

Returns

true on successful claim, false otherwise

Definition at line 107 of file mutex.cpp.

14.19.2.4 void Mutex::Release ( )

Release the mutex.

When the mutex is released, another object can enter the mutex-protected region.

Definition at line 227 of file mutex.cpp.

14.19.2.5 void Mutex::WakeMe (Thread ∗ *pclOwner_*)

Wake a thread blocked on the mutex.

This is an internal function used for implementing timed mutexes relying on timer callbacks. Since these do not have access to the private data of the mutex and its base classes, we have to wrap this as a public method - do not use this for any other purposes.

Parameters

*pclOwner_*	Thread to unblock from this object.

Definition at line 65 of file mutex.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/mutex.h
- /home/moslevin/Project/R1/kernel/mutex.cpp

14.20 Profiler Class Reference

System profiling timer interface.

```
#include <kernelprofile.h>
```

Static Public Member Functions

- static void Init ()

  Initialize the global system profiler.
- static void Start ()

  Start the global profiling timer service.
- static void Stop ()

  Stop the global profiling timer service.
- static K_USHORT Read ()

  Read the current tick count in the timer.
- static void Process ()

  Process the profiling counters from ISR.
- static K_ULONG GetEpoch ()

  Return the current timer epoch.

14.20.1 Detailed Description

System profiling timer interface.

Definition at line 37 of file kernelprofile.h.

14.20.2 Member Function Documentation

14.20.2.1 void Profiler::Init (void) [static]

Initialize the global system profiler.

Must be called prior to use.

Definition at line 32 of file kernelprofile.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/kernelprofile.h
- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/kernelprofile.cpp

14.21 ProfileTimer Class Reference

Profiling timer.

`#include <profile.h>`

Public Member Functions

- void Init ()

  Initialize the profiling timer prior to use.
- void Start ()

  Start a profiling session, if the timer is not already active.
- void Stop ()

  Stop the current profiling session, adding to the cumulative time for this timer, and the total iteration count.
- K_ULONG GetAverage ()

  Get the average time associated with this operation.
- K_ULONG GetCurrent ()

  Return the current tick count held by the profiler.

Private Member Functions

- K_ULONG ComputeCurrentTicks (K_USHORT usCount_, K_ULONG ulEpoch_)

  Figure out how many ticks have elapsed in this iteration.

Private Attributes

- K_ULONG m_ulCumulative

  Cumulative tick-count for this timer.
- K_ULONG m_ulCurrentIteration

  Tick-count for the current iteration.
- K_USHORT m_usInitial

  Initial count.

- K_ULONG m_ulInitialEpoch

  Initial Epoch.
- K_USHORT m_usIterations

  Number of iterations executed for this profiling timer.
- K_UCHAR m_bActive

  Wheter or not the timer is active or stopped.

14.21.1 Detailed Description

Profiling timer.

This class is used to perform high-performance profiling of code to see how K_LONG certain operations take. Useful in instrumenting the performance of key algorithms and time-critical operations to ensure real-timer behavior.

Definition at line 69 of file profile.h.

14.21.2 Member Function Documentation

14.21.2.1 K_ULONG ProfileTimer::ComputeCurrentTicks (K_USHORT *usCount_*, K_ULONG *ulEpoch_*) [private]

Figure out how many ticks have elapsed in this iteration.

Parameters

*usCount_*	Current timer count
*ulEpoch_*	Current timer epoch

Returns

Current tick count

Definition at line 106 of file profile.cpp.

14.21.2.2 K_ULONG ProfileTimer::GetAverage ( )

Get the average time associated with this operation.

Returns

Average tick count normalized over all iterations

Definition at line 79 of file profile.cpp.

14.21.2.3 K_ULONG ProfileTimer::GetCurrent ( )

Return the current tick count held by the profiler.

Valid for both active and stopped timers.

Returns

The currently held tick count.

Definition at line 89 of file profile.cpp.

14.21.2.4 void ProfileTimer::Init (void)

Initialize the profiling timer prior to use.

Can also be used to reset a timer that's been used previously.

Definition at line 37 of file profile.cpp.

14.21.2.5 void ProfileTimer::Start (void)

Start a profiling session, if the timer is not already active.

Has no effect if the timer is already active.

Definition at line 46 of file profile.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/profile.h
- /home/moslevin/Project/R1/kernel/profile.cpp

14.22 Quantum Class Reference

Static-class used to implement Thread quantum functionality, which is a key part of round-robin scheduling.

```
#include <quantum.h>
```

Static Public Member Functions

- static void UpdateTimer ()

  This function is called to update the thread quantum timer whenever something in the scheduler has changed.
- static void AddThread (Thread ∗pclThread_)

  Add the thread to the quantum timer.
- static void RemoveThread ()

  Remove the thread from the quantum timer.
- static void SetInTimer (void)

  SetInTimer.
- static void ClearInTimer (void)

  ClearInTimer.

Static Private Member Functions

- static void SetTimer (Thread ∗pclThread_)

  Set up the quantum timer in the timer scheduler.

14.22.1 Detailed Description

Static-class used to implement Thread quantum functionality, which is a key part of round-robin scheduling.

Definition at line 41 of file quantum.h.

14.22.2 Member Function Documentation

14.22.2.1 void Quantum::AddThread (Thread * *pclThread_*) [static]

Add the thread to the quantum timer.

Only one thread can own the quantum, since only one thread can be running on a core at a time.

Definition at line 82 of file quantum.cpp.

14.22.2.2 static void Quantum::ClearInTimer (void) [inline], [static]

ClearInTimer.

Clear the flag once the timer callback function has been completed.

Definition at line 84 of file quantum.h.

14.22.2.3 void Quantum::RemoveThread (void) [static]

Remove the thread from the quantum timer.

This will cancel the timer.

Definition at line 111 of file quantum.cpp.

14.22.2.4 static void Quantum::SetInTimer (void) [inline], [static]

SetInTimer.

Set a flag to indicate that the CPU is currently running within the timer-callback routine. This prevents the Quantum timer from being updated in the middle of a callback cycle, potentially resulting in the kernel timer becoming disabled.

Definition at line 77 of file quantum.h.

14.22.2.5 void Quantum::SetTimer (Thread * *pclThread_*) [static], [private]

Set up the quantum timer in the timer scheduler.

This creates a one-shot timer, which calls a static callback in quantum.cpp that on expiry will pivot the head of the threadlist for the thread's priority. This is the mechanism that provides round-robin scheduling in the system.

Parameters

*pclThread_*	Pointer to the thread to set the Quantum timer on

Definition at line 72 of file quantum.cpp.

14.22.2.6 void Quantum::UpdateTimer (void) [static]

This function is called to update the thread quantum timer whenever something in the scheduler has changed.

This can result in the timer being re-loaded or started. The timer is never stopped, but if may be ignored on expiry.

Definition at line 124 of file quantum.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/quantum.h
- /home/moslevin/Project/R1/kernel/quantum.cpp

14.23 Scheduler Class Reference

Priority-based round-robin Thread scheduling, using ThreadLists for housekeeping.

```
#include <scheduler.h>
```

Static Public Member Functions

- static void Init ()

  Intiailize the scheduler, must be called before use.
- static void Schedule ()

  Run the scheduler, determines the next thread to run based on the current state of the threads.
- static void Add (Thread ∗pclThread_)

  Add a thread to the scheduler at its current priority level.
- static void Remove (Thread ∗pclThread_)

  Remove a thread from the scheduler at its current priority level.
- static K_BOOL SetScheduler (K_BOOL bEnable_)

  Set the active state of the scheduler.
- static Thread ∗ GetCurrentThread ()

  Return the pointer to the currently-running thread.
- static volatile Thread ∗ GetNextThread ()

  Return the pointer to the thread that should run next, according to the last run of the scheduler.
- static ThreadList ∗ GetThreadList (K_UCHAR ucPriority_)

  Return the pointer to the active list of threads that are at the given priority level in the scheduler.
- static ThreadList ∗ GetStopList ()

  Return the pointer to the list of threads that are in the scheduler's stopped state.
- static K_UCHAR IsEnabled ()

  Return the current state of the scheduler - whether or not scheudling is enabled or disabled.
- static void QueueScheduler ()

  QueueScheduler.

Static Private Attributes

- static K_BOOL m_bEnabled

  Scheduler's state - enabled or disabled.
- static K_BOOL m_bQueuedSchedule

  Variable representing whether or not there's a queued scheduler operation.
- static ThreadList m_clStopList

  ThreadList for all stopped threads.
- static ThreadList m_aclPriorities [NUM_PRIORITIES]

  ThreadLists for all threads at all priorities.
- static K_UCHAR m_ucPriFlag

  Bitmap flag for each.

14.23.1 Detailed Description

Priority-based round-robin Thread scheduling, using ThreadLists for housekeeping.

Definition at line 62 of file scheduler.h.

14.23.2 Member Function Documentation

14.23.2.1 void Scheduler::Add (Thread ∗ *pclThread_*) [static]

Add a thread to the scheduler at its current priority level.

Parameters

*pclThread_*	Pointer to the thread to add to the scheduler

Definition at line 108 of file scheduler.cpp.

14.23.2.2 static Thread∗ Scheduler::GetCurrentThread ( ) [inline], [static]

Return the pointer to the currently-running thread.

Returns

Pointer to the currently-running thread

Definition at line 119 of file scheduler.h.

14.23.2.3 static volatile Thread∗ Scheduler::GetNextThread ( ) [inline], [static]

Return the pointer to the thread that should run next, according to the last run of the scheduler.

Returns

Pointer to the next-running thread

Definition at line 127 of file scheduler.h.

14.23.2.4 static ThreadList∗ Scheduler::GetStopList ( ) [inline], [static]

Return the pointer to the list of threads that are in the scheduler's stopped state.

Returns

Pointer to the ThreadList containing the stopped threads

Definition at line 145 of file scheduler.h.

14.23.2.5 static ThreadList∗ Scheduler::GetThreadList (K_UCHAR *ucPriority_*) [inline], [static]

Return the pointer to the active list of threads that are at the given priority level in the scheduler.

Parameters

*ucPriority_*	Priority level of

Returns

Pointer to the ThreadList for the given priority level

Definition at line 137 of file scheduler.h.

14.23.2.6 K_UCHAR Scheduler::IsEnabled ( ) [inline], [static]

Return the current state of the scheduler - whether or not scheudling is enabled or disabled.

Returns

true - scheduler enabled, false - disabled

Definition at line 155 of file scheduler.h.

14.23.2.7 static void Scheduler::QueueScheduler ( ) [inline], [static]

QueueScheduler.

Tell the kernel to perform a scheduling operation as soon as the scheduler is re-enabled.

Definition at line 163 of file scheduler.h.

14.23.2.8 void Scheduler::Remove (Thread ∗ *pclThread_*) [static]

Remove a thread from the scheduler at its current priority level.

Parameters

*pclThread_*	Pointer to the thread to be removed from the scheduler

Definition at line 114 of file scheduler.cpp.

14.23.2.9 Scheduler::Schedule ( ) [static]

Run the scheduler, determines the next thread to run based on the current state of the threads.

Note that the next-thread chosen from this function is only valid while in a critical section.

Definition at line 71 of file scheduler.cpp.

14.23.2.10 void Scheduler::SetScheduler (K_BOOL *bEnable_*) [static]

Set the active state of the scheduler.

When the scheduler is disabled, the *next thread* is never set; the currently running thread will run forever until the scheduler is enabled again. Care must be taken to ensure that we don't end up trying to block while the scheduler is disabled, otherwise the system ends up in an unusable state.

Parameters

*bEnable_*	true to enable, false to disable the scheduler

Definition at line 120 of file scheduler.cpp.

The documentation for this class was generated from the following files:

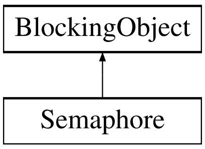
- /home/moslevin/Project/R1/kernel/public/scheduler.h
- /home/moslevin/Project/R1/kernel/scheduler.cpp

14.24 Semaphore Class Reference

Counting semaphore, based on BlockingObject base class.

`#include <ksemaphore.h>`

Inheritance diagram for Semaphore:



Public Member Functions

- void Init (K_USHORT usInitVal_, K_USHORT usMaxVal_)

  Initialize a semaphore before use.
- K_BOOL Post ()

  Increment the semaphore count.
- void Pend ()

  Decrement the semaphore count.
- K_USHORT GetCount ()

  Return the current semaphore counter.
- K_BOOL Pend (K_ULONG ulWaitTimeMS_)

  Decrement the semaphore count.
- void WakeMe (Thread ∗pclChosenOne_)

  Wake a thread blocked on the semaphore.

Private Member Functions

- K_UCHAR WakeNext ()

  Wake the next thread waiting on the semaphore.
- K_BOOL Pend_i (K_ULONG ulWaitTimeMS_)

  Pend_i.

Private Attributes

- K_USHORT m_usValue

  Current count held by the semaphore.
- K_USHORT m_usMaxValue

  Maximum count that can be held by this semaphore.

Additional Inherited Members

14.24.1 Detailed Description

Counting semaphore, based on BlockingObject base class.

Definition at line 37 of file ksemaphore.h.

14.24.2 Member Function Documentation

14.24.2.1 K_USHORT Semaphore::GetCount ( )

Return the current semaphore counter.

This can be used by a thread to bypass blocking on a semaphore - allowing it to do other things until a non-zero count is returned, instead of blocking until the semaphore is posted.

Returns

The current semaphore counter value.

Definition at line 234 of file ksemaphore.cpp.

14.24.2.2 void Semaphore::Init (K_USHORT *usInitVal_*, K_USHORT *usMaxVal_*)

Initialize a semaphore before use.

Must be called before post/pend operations.

Parameters

*usInitVal_*	Initial value held by the semaphore
*usMaxVal_*	Maximum value for the semaphore

Definition at line 95 of file ksemaphore.cpp.

14.24.2.3 void Semaphore::Pend ( )

Decrement the semaphore count.

If the count is zero, the thread will block until the semaphore is pended.

Definition at line 216 of file ksemaphore.cpp.

14.24.2.4 K_BOOL Semaphore::Pend (K_ULONG *ulWaitTimeMS_*)

Decrement the semaphore count.

If the count is zero, the thread will block until the semaphore is pended. If the specified interval expires before the thread is unblocked, then the status is returned back to the user.

Returns

true - semaphore was acquired before the timeout false - timeout occurred before the semaphore was claimed.

Definition at line 227 of file ksemaphore.cpp.

14.24.2.5 K_BOOL Semaphore::Pend_i (K_ULONG *ulWaitTimeMS_*) [private]

Pend_i.

Internal function used to abstract timed and untimed semaphore pend operations.

Parameters

*ulWaitTimeMS_*	Time in MS to wait

Returns

true on success, false on failure.

Definition at line 160 of file ksemaphore.cpp.

14.24.2.6 void Semaphore::Post ( )

Increment the semaphore count.

Returns

true if the semaphore was posted, false if the count is already maxed out.

Definition at line 107 of file ksemaphore.cpp.

14.24.2.7 void Semaphore::WakeMe (Thread ∗ *pclChosenOne_*)

Wake a thread blocked on the semaphore.

This is an internal function used for implementing timed semaphores relying on timer callbacks. Since these do not have access to the private data of the semaphore and its base classes, we have to wrap this as a public method - do not use this for any other purposes.

Definition at line 68 of file ksemaphore.cpp.

The documentation for this class was generated from the following files:

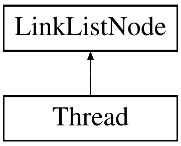
- /home/moslevin/Project/R1/kernel/public/ksemaphore.h
- /home/moslevin/Project/R1/kernel/ksemaphore.cpp

14.25 Thread Class Reference

Object providing fundamental multitasking support in the kernel.

```
#include <thread.h>
```

Inheritance diagram for Thread:



Public Member Functions

- void Init (K_WORD ∗paucStack_, K_USHORT usStackSize_, K_UCHAR ucPriority_, ThreadEntry_t pfEntryPoint_, void ∗pvArg_)

  Initialize a thread prior to its use.
- void Start ()

  Start the thread - remove it from the stopped list, add it to the scheduler's list of threads (at the thread's set priority), and continue along.
- void Stop ()

  Stop a thread that's actively scheduled without destroying its stacks.
- ThreadList ∗ GetOwner (void)

  Return the ThreadList where the thread belongs when it's in the active/ready state in the scheduler.
- ThreadList ∗ GetCurrent (void)

  Return the ThreadList where the thread is currently located.
- K_UCHAR GetPriority (void)

  Return the priority of the current thread.
- K_UCHAR GetCurPriority (void)

  Return the priority of the current thread.
- void SetQuantum (K_USHORT usQuantum_)

  Set the thread's round-robin execution quantum.
- K_USHORT GetQuantum (void)

  Get the thread's round-robin execution quantum.
- void SetCurrent (ThreadList ∗pclNewList_)

  Set the thread's current to the specified thread list.
- void SetOwner (ThreadList ∗pclNewList_)

  Set the thread's owner to the specified thread list.
- void SetPriority (K_UCHAR ucPriority_)

  Set the priority of the Thread (running or otherwise) to a different level.

- void InheritPriority (K_UCHAR ucPriority_)

  Allow the thread to run at a different priority level (temporarily) for the purpose of avoiding priority inversions.
- void Exit ()

  Remove the thread from being scheduled again.
- void SetID (K_UCHAR ucID_)

  Set an 8-bit ID to uniquely identify this thread.
- K_UCHAR GetID ()

  Return the 8-bit ID corresponding to this thread.
- K_USHORT GetStackSlack ()

  Performs a (somewhat lengthy) check on the thread stack to check the amount of stack margin (or "slack") remaining on the stack.
- K_USHORT GetEventFlagMask ()

  GetEventFlagMask returns the thread's current event-flag mask, which is used in conjunction with the EventFlag blocking object type.
- void SetEventFlagMask (K_USHORT usMask_)

  SetEventFlagMask Sets the active event flag bitfield mask.
- void SetEventFlagMode (EventFlagOperation_t eMode_)

  SetEventFlagMode Sets the active event flag operation mode.
- EventFlagOperation_t GetEventFlagMode ()

  GetEventFlagMode Returns the thread's event flag's operating mode.
- Timer ∗ GetTimer ()

  Return a pointer to the thread's timer object.
- void SetExpired (K_BOOL bExpired_)

  SetExpired.
- K_BOOL GetExpired ()

  GetExpired.
- void InitIdle ()

  InitIdle Initialize this Thread object as the Kernel's idle thread.
- ThreadState_t GetState ()

  GetState Returns the current state of the thread to the caller.
- void SetState (ThreadState_t eState_)

  SetState Set the thread's state to a new value.

Static Public Member Functions

- static void Sleep (K_ULONG ulTimeMs_)

  Put the thread to sleep for the specified time (in milliseconds).
- static void USleep (K_ULONG ulTimeUs_)

  Put the thread to sleep for the specified time (in microseconds).
- static void Yield (void)

  Yield the thread - this forces the system to call the scheduler and determine what thread should run next.

Private Member Functions

- void SetPriorityBase (K_UCHAR ucPriority_)

Static Private Member Functions

- static void ContextSwitchSWI (void)

  This code is used to trigger the context switch interrupt.

Private Attributes

- K_WORD ∗ m_pwStackTop

  Pointer to the top of the thread's stack.
- K_WORD ∗ m_pwStack

  Pointer to the thread's stack.
- K_UCHAR m_ucThreadID

  Thread ID.
- K_UCHAR m_ucPriority

  Default priority of the thread.
- K_UCHAR m_ucCurPriority

  Current priority of the thread (priority inheritence)
- ThreadState_t m_eState

  Enum indicating the thread's current state.
- K_USHORT m_usStackSize

  Size of the stack (in bytes)
- ThreadList ∗ m_pclCurrent

  Pointer to the thread-list where the thread currently resides.
- ThreadList ∗ m_pclOwner

  Pointer to the thread-list where the thread resides when active.
- ThreadEntry_t m_pfEntryPoint

  The entry-point function called when the thread starts.
- void ∗ m_pvArg

  Pointer to the argument passed into the thread's entrypoint.
- K_USHORT m_usQuantum

  Thread quantum (in milliseconds)
- K_USHORT m_usFlagMask

  Event-flag mask.
- EventFlagOperation_t m_eFlagMode

  Event-flag mode.
- Timer m_clTimer

  Timer used for blocking-object timeouts.
- K_BOOL m_bExpired

  Indicate whether or not a blocking-object timeout has occurred.

Friends

- class **ThreadPort**

Additional Inherited Members

14.25.1 Detailed Description

Object providing fundamental multitasking support in the kernel.

Definition at line 71 of file thread.h.

14.25.2 Member Function Documentation

14.25.2.1 void Thread::ContextSwitchSWI (void) [static], [private]

This code is used to trigger the context switch interrupt.

Called whenever the kernel decides that it is necessary to swap out the current thread for the "next" thread.

Definition at line 395 of file thread.cpp.

14.25.2.2 void Thread::Exit ( )

Remove the thread from being scheduled again.

The thread is effectively destroyed when this occurs. This is extremely useful for cases where a thread encounters an unrecoverable error and needs to be restarted, or in the context of systems where threads need to be created and destroyed dynamically.

This must not be called on the idle thread.

Definition at line 174 of file thread.cpp.

14.25.2.3 K_UCHAR Thread::GetCurPriority (void) [inline]

Return the priority of the current thread.

Returns

Priority of the current thread

Definition at line 174 of file thread.h.

14.25.2.4 ThreadList ∗ Thread::GetCurrent (void) [inline]

Return the ThreadList where the thread is currently located.

Returns

Pointer to the thread's current list

Definition at line 155 of file thread.h.

14.25.2.5 K_USHORT Thread::GetEventFlagMask ( ) [inline]

GetEventFlagMask returns the thread's current event-flag mask, which is used in conjunction with the EventFlag blocking object type.

Returns

A copy of the thread's event flag mask

Definition at line 327 of file thread.h.

14.25.2.6 EventFlagOperation_t Thread::GetEventFlagMode ( ) [inline]

GetEventFlagMode Returns the thread's event flag's operating mode.

Returns

The thread's event flag mode.

Definition at line 346 of file thread.h.

14.25.2.7 K_BOOL Thread::GetExpired ( )

GetExpired.

Return the status of the most-recent blocking call on the thread.

Returns

true - call expired, false - call did not expire

Definition at line 413 of file thread.cpp.

14.25.2.8 K_UCHAR Thread::GetID ( ) [inline]

Return the 8-bit ID corresponding to this thread.

Returns

Thread's 8-bit ID, set by the user

Definition at line 302 of file thread.h.

14.25.2.9 ThreadList * Thread::GetOwner (void) [inline]

Return the ThreadList where the thread belongs when it's in the active/ready state in the scheduler.

Returns

Pointer to the Thread's owner list

Definition at line 146 of file thread.h.

14.25.2.10 K_UCHAR Thread::GetPriority (void) [inline]

Return the priority of the current thread.

Returns

Priority of the current thread

Definition at line 165 of file thread.h.

14.25.2.11 K_USHORT Thread::GetQuantum (void) [inline]

Get the thread's round-robin execution quantum.

Returns

The thread's quantum

Definition at line 193 of file thread.h.

14.25.2.12 K_USHORT Thread::GetStackSlack ( )

Performs a (somewhat lengthy) check on the thread stack to check the amount of stack margin (or "slack") remaining on the stack.

If you're having problems with blowing your stack, you can run this function at points in your code during development to see what operations cause problems. Also useful during development as a tool to optimally size thread stacks.

Returns

The amount of slack (unused bytes) on the stack

! ToDo: Take into account stacks that grow up

Definition at line 284 of file thread.cpp.

14.25.2.13 ThreadState_t Thread::GetState ( ) [inline]

GetState Returns the current state of the thread to the caller.

Can be used to determine whether or not a thread is ready (or running), stopped, or terminated/exit'd.

Returns

ThreadState_t representing the thread's current state

Definition at line 390 of file thread.h.

14.25.2.14 void Thread::InheritPriority (K_UCHAR *ucPriority_*)

Allow the thread to run at a different priority level (temporarily) for the purpose of avoiding priority inversions.

This should only be called from within the implementation of blocking-objects.

Parameters

*ucPriority_*	New Priority to boost to.

Definition at line 388 of file thread.cpp.

14.25.2.15 void Thread::Init (K_WORD ∗ *paucStack_*, K_USHORT *usStackSize_*, K_UCHAR *ucPriority_*, ThreadEntry_t *pfEntryPoint_*, void ∗ *pvArg_*)

Initialize a thread prior to its use.

Initialized threads are placed in the stopped state, and are not scheduled until the thread's start method has been invoked first.

Parameters

*paucStack_*	Pointer to the stack to use for the thread
*usStackSize_*	Size of the stack (in bytes)
*ucPriority_*	Priority of the thread (0 = idle, 7 = max)
*pfEntryPoint_*	This is the function that gets called when the thread is started
*pvArg_*	Pointer to the argument passed into the thread's entrypoint function.

Definition at line 41 of file thread.cpp.

14.25.2.16 void Thread::InitIdle (void)

InitIdle Initialize this Thread object as the Kernel's idle thread.

There should only be one of these, maximum, in a given system.

Definition at line 418 of file thread.cpp.

14.25.2.17 void Thread::SetCurrent (ThreadList ∗ *pclNewList_*) [inline]

Set the thread's current to the specified thread list.

Parameters

*pclNewList_*	Pointer to the threadlist to apply thread ownership

Definition at line 203 of file thread.h.

14.25.2.18 void Thread::SetEventFlagMask (K_USHORT *usMask_*) [inline]

SetEventFlagMask Sets the active event flag bitfield mask.

Parameters

*usMask_*	

Definition at line 333 of file thread.h.

14.25.2.19 void Thread::SetEventFlagMode (EventFlagOperation_t *eMode_*) [inline]

SetEventFlagMode Sets the active event flag operation mode.

Parameters

*eMode_*	Event flag operation mode, defines the logical operator to apply to the event flag.

Definition at line 340 of file thread.h.

14.25.2.20 void Thread::SetExpired (K_BOOL *bExpired_*)

SetExpired.

Set the status of the current blocking call on the thread.

Parameters

*bExpired_*	true - call expired, false - call did not expire

Definition at line 410 of file thread.cpp.

14.25.2.21 void Thread::SetID (K_UCHAR *ucID_*) [inline]

Set an 8-bit ID to uniquely identify this thread.

Parameters

*ucID_*	8-bit Thread ID, set by the user

Definition at line 293 of file thread.h.

14.25.2.22 void Thread::SetOwner (ThreadList ∗ *pclNewList_*) [inline]

Set the thread's owner to the specified thread list.

Parameters

*pclNewList_*	Pointer to the threadlist to apply thread ownership

Definition at line 212 of file thread.h.

14.25.2.23 void Thread::SetPriority (K_UCHAR *ucPriority_*)

Set the priority of the Thread (running or otherwise) to a different level.

This activity involves re-scheduling, and must be done so with due caution, as it may effect the determinism of the system.

This should *always* be called from within a critical section to prevent system issues.

Parameters

*ucPriority_*	New priority of the thread

Definition at line 344 of file thread.cpp.

14.25.2.24 void Thread::SetPriorityBase (K_UCHAR *ucPriority_*) [private]

Parameters

*ucPriority_*	

Definition at line 334 of file thread.cpp.

14.25.2.25 void Thread::SetQuantum (K_USHORT *usQuantum_*) [inline]

Set the thread's round-robin execution quantum.

Parameters

*usQuantum_*	Thread's execution quantum (in milliseconds)

Definition at line 184 of file thread.h.

14.25.2.26 void Thread::SetState (ThreadState_t *eState_*) [inline]

SetState Set the thread's state to a new value.

This is only to be used by code within the kernel, and is not indended for use by an end-user.

Parameters

*eState_*	New thread state to set.

Definition at line 399 of file thread.h.

14.25.2.27 void Thread::Sleep (K_ULONG *ulTimeMs_*) [static]

Put the thread to sleep for the specified time (in milliseconds).

Actual time slept may be longer (but not less than) the interval specified.

Parameters

*ulTimeMs_*	Time to sleep (in ms)

Definition at line 239 of file thread.cpp.

14.25.2.28 void Thread::Stop ( )

Stop a thread that's actively scheduled without destroying its stacks.

Stopped threads can be restarted using the Start() API.

Definition at line 129 of file thread.cpp.

14.25.2.29 void Thread::USleep (K_ULONG *ulTimeUs_*) [static]

Put the thread to sleep for the specified time (in microseconds).

Actual time slept may be longer (but not less than) the interval specified.

Parameters

*ulTimeUs_*	Time to sleep (in microseconds)

Definition at line 261 of file thread.cpp.

14.25.2.30 void Thread::Yield (void) [static]

Yield the thread - this forces the system to call the scheduler and determine what thread should run next.

This is typically used when threads are moved in and out of the scheduler.

Definition at line 305 of file thread.cpp.

The documentation for this class was generated from the following files:

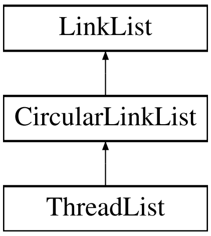
- /home/moslevin/Project/R1/kernel/public/thread.h
- /home/moslevin/Project/R1/kernel/thread.cpp

14.26 ThreadList Class Reference

This class is used for building thread-management facilities, such as schedulers, and blocking objects.

`#include <threadlist.h>`

Inheritance diagram for ThreadList:



Public Member Functions

- ThreadList ()

  Default constructor - zero-initializes the data.

- void SetPriority (K_UCHAR ucPriority_)

  Set the priority of this threadlist (if used for a scheduler).
- void SetFlagPointer (K_UCHAR ∗pucFlag_)

  Set the pointer to a bitmap to use for this threadlist.
- void Add (LinkListNode ∗node_)

  Add a thread to the threadlist.
- void Add (LinkListNode ∗node_, K_UCHAR ∗pucFlag_, K_UCHAR ucPriority_)

  Add a thread to the threadlist, specifying the flag and priority at the same time.
- void Remove (LinkListNode ∗node_)

  Remove the specified thread from the threadlist.
- Thread ∗ HighestWaiter ()

  Return a pointer to the highest-priority thread in the thread-list.

Private Attributes

- K_UCHAR m_ucPriority

  Priority of the threadlist.
- K_UCHAR ∗ m_pucFlag

  Pointer to the bitmap/flag to set when used for scheduling.

Additional Inherited Members

14.26.1 Detailed Description

This class is used for building thread-management facilities, such as schedulers, and blocking objects.

Definition at line 34 of file threadlist.h.

14.26.2 Member Function Documentation

14.26.2.1 void ThreadList::Add (LinkListNode ∗ *node_*) [virtual]

Add a thread to the threadlist.

Parameters

*node_*	Pointer to the thread (link list node) to add to the list

Reimplemented from CircularLinkList.

Definition at line 46 of file threadlist.cpp.

14.26.2.2 void ThreadList::Add (LinkListNode ∗ *node_*, K_UCHAR ∗ *pucFlag_*, K_UCHAR *ucPriority_*)

Add a thread to the threadlist, specifying the flag and priority at the same time.

Parameters

*node_*	Pointer to the thread to add (link list node)
*pucFlag_*	Pointer to the bitmap flag to set (if used in a scheduler context), or NULL for non-scheduler.
*ucPriority_*	Priority of the threadlist

Definition at line 59 of file threadlist.cpp.

14.26.2.3 Thread ∗ ThreadList::HighestWaiter ( )

Return a pointer to the highest-priority thread in the thread-list.

Returns

Pointer to the highest-priority thread

Definition at line 84 of file threadlist.cpp.

14.26.2.4 void ThreadList::Remove (LinkListNode ∗ *node_*) [virtual]

Remove the specified thread from the threadlist.

Parameters

*node_*	Pointer to the thread to remove

Reimplemented from CircularLinkList.

Definition at line 68 of file threadlist.cpp.

14.26.2.5 void ThreadList::SetFlagPointer (K_UCHAR ∗ *pucFlag_*)

Set the pointer to a bitmap to use for this threadlist.

Once again, only needed when the threadlist is being used for scheduling purposes.

Parameters

*pucFlag_*	Pointer to the bitmap flag

Definition at line 40 of file threadlist.cpp.

14.26.2.6 void ThreadList::SetPriority (K_UCHAR *ucPriority_*)

Set the priority of this threadlist (if used for a scheduler).

Parameters

*ucPriority_*	Priority level of the thread list

Definition at line 34 of file threadlist.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/threadlist.h
- /home/moslevin/Project/R1/kernel/threadlist.cpp

14.27 ThreadPort Class Reference

Class defining the architecture specific functions required by the kernel.

```
#include <threadport.h>
```

Static Public Member Functions

- static void StartThreads ()

  Function to start the scheduler, initial threads, etc.

Static Private Member Functions

- static void InitStack (Thread ∗pstThread_)

  Initialize the thread's stack.

Friends

- class **Thread**

14.27.1 Detailed Description

Class defining the architecture specific functions required by the kernel.

This is limited (at this point) to a function to start the scheduler, and a function to initialize the default stack-frame for a thread.

Definition at line 167 of file threadport.h.

14.27.2 Member Function Documentation

14.27.2.1 void ThreadPort::InitStack (**Thread** ∗ *pstThread_*) `[static], [private]`

Initialize the thread's stack.

Parameters

*pstThread_*	Pointer to the thread to initialize

Definition at line 39 of file threadport.cpp.

The documentation for this class was generated from the following files:

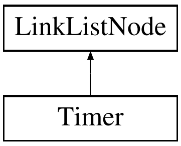
- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/threadport.h
- /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/threadport.cpp

14.28 Timer Class Reference

Timer - an event-driven execution context based on a specified time interval.

`#include <timer.h>`

Inheritance diagram for Timer:



Public Member Functions

- Timer ()

  Default Constructor - zero-initializes all internal data.
- void Init ()

  Re-initialize the Timer to default values.

- void Start (K_BOOL bRepeat_, K_ULONG ulIntervalMs_, TimerCallback_t pfCallback_, void ∗pvData_)

  Start a timer using default ownership, using repeats as an option, and millisecond resolution.
- void Start (K_BOOL bRepeat_, K_ULONG ulIntervalMs_, K_ULONG ulToleranceMs_, TimerCallback_t pfCallback_, void ∗pvData_)

  Start a timer using default ownership, using repeats as an option, and millisecond resolution.
- void Stop ()

  Stop a timer already in progress.
- void SetFlags (K_UCHAR ucFlags_)

  Set the timer's flags based on the bits in the ucFlags_ argument.
- void SetCallback (TimerCallback_t pfCallback_)

  Define the callback function to be executed on expiry of the timer.
- void SetData (void ∗pvData_)

  Define a pointer to be sent to the timer callbcak on timer expiry.
- void SetOwner (Thread ∗pclOwner_)

  Set the owner-thread of this timer object (all timers must be owned by a thread).
- void SetIntervalTicks (K_ULONG ulTicks_)

  Set the timer expiry in system-ticks (platform specific!)
- void SetIntervalSeconds (K_ULONG ulSeconds_)

  ! The next three cost us 330 bytes of flash on AVR...
- void SetIntervalMSeconds (K_ULONG ulMSeconds_)

  Set the timer expiry interval in milliseconds (platform agnostic)
- void SetIntervalUSeconds (K_ULONG ulUSeconds_)

  Set the timer expiry interval in microseconds (platform agnostic)
- void SetTolerance (K_ULONG ulTicks_)

  Set the timer's maximum tolerance in order to synchronize timer processing with other timers in the system.

Private Attributes

- K_UCHAR m_ucFlags

  Flags for the timer, defining if the timer is one-shot or repeated.
- TimerCallback_t m_pfCallback

  Pointer to the callback function.
- K_ULONG m_ulInterval

  Interval of the timer in timer ticks.
- K_ULONG m_ulTimeLeft

  Time remaining on the timer.
- K_ULONG m_ulTimerTolerance

  Maximum tolerance (used for timer harmonization)
- Thread ∗ m_pclOwner

  Pointer to the owner thread.
- void ∗ m_pvData

  Pointer to the callback data.

Friends

- class **TimerList**

Additional Inherited Members

14.28.1 Detailed Description

Timer - an event-driven execution context based on a specified time interval.

This inherits from a LinkListNode for ease of management by a global TimerList object.

Definition at line 105 of file timer.h.

14.28.2 Member Function Documentation

14.28.2.1 void Timer::SetCallback (TimerCallback_t *pfCallback_*) [inline]

Define the callback function to be executed on expiry of the timer.

Parameters

*pfCallback_*	Pointer to the callback function to call

Definition at line 166 of file timer.h.

14.28.2.2 void Timer::SetData (void ∗ *pvData_*) [inline]

Define a pointer to be sent to the timer callbcak on timer expiry.

Parameters

*pvData_*	Pointer to data to pass as argument into the callback

Definition at line 175 of file timer.h.

14.28.2.3 void Timer::SetFlags (K_UCHAR *ucFlags_*) [inline]

Set the timer's flags based on the bits in the ucFlags_ argument.

Parameters

*ucFlags_*	Flags to assign to the timer object. TIMERLIST_FLAG_ONE_SHOT for a one-shot timer, 0 for a continuous timer.

Definition at line 157 of file timer.h.

14.28.2.4 void Timer::SetIntervalMSeconds (K_ULONG *ulMSeconds_*)

Set the timer expiry interval in milliseconds (platform agnostic)

Parameters

*ulMSeconds_*	Time in milliseconds

Definition at line 88 of file timer.cpp.

14.28.2.5 void Timer::SetIntervalSeconds (K_ULONG *ulSeconds_*)

! The next three cost us 330 bytes of flash on AVR...

Set the timer expiry interval in seconds (platform agnostic)

Parameters

*ulSeconds_*	Time in seconds

Definition at line 82 of file timer.cpp.

14.28.2.6 void Timer::SetIntervalTicks (K_ULONG *ulTicks_*)

Set the timer expiry in system-ticks (platform specific!)

Parameters

*ulTicks_*	Time in ticks

Definition at line 74 of file timer.cpp.

14.28.2.7 void Timer::SetIntervalUSeconds (K_ULONG *ulUSeconds_*)

Set the timer expiry interval in microseconds (platform agnostic)

Parameters

*ulUSeconds_*	Time in microseconds

Definition at line 94 of file timer.cpp.

14.28.2.8 void Timer::SetOwner (Thread ∗ *pclOwner_*) [inline]

Set the owner-thread of this timer object (all timers must be owned by a thread).

Parameters

*pclOwner_*	Owner thread of this timer object

Definition at line 185 of file timer.h.

14.28.2.9 void Timer::SetTolerance (K_ULONG *ulTicks_*)

Set the timer's maximum tolerance in order to synchronize timer processing with other timers in the system.

Parameters

*ulTicks_*	Maximum tolerance in ticks

Definition at line 100 of file timer.cpp.

14.28.2.10 void Timer::Start (K_BOOL *bRepeat_*, K_ULONG *ulIntervalMs_*, TimerCallback_t *pfCallback_*, void ∗ *pvData_*)

Start a timer using default ownership, using repeats as an option, and millisecond resolution.

Parameters

*bRepeat_*	0 - timer is one-shot. 1 - timer is repeating.
*ulIntervalMs_*	- Interval of the timer in miliseconds
*pfCallback_*	- Function to call on timer expiry

*pvData_*	- Data to pass into the callback function

Definition at line 42 of file timer.cpp.

14.28.2.11 void Timer::Start (K_BOOL *bRepeat_*, K_ULONG *ulIntervalMs_*, K_ULONG *ulToleranceMs_*, TimerCallback_t *pfCallback_*, void ∗ *pvData_*)

Start a timer using default ownership, using repeats as an option, and millisecond resolution.

Parameters

*bRepeat_*	0 - timer is one-shot. 1 - timer is repeating.
*ulIntervalMs_*	- Interval of the timer in miliseconds
ulToleranceMs	- Allow the timer expiry to be delayed by an additional maximum time, in order to have as many timers expire at the same time as possible.
*pfCallback_*	- Function to call on timer expiry
*pvData_*	- Data to pass into the callback function

Definition at line 61 of file timer.cpp.

14.28.2.12 void Timer::Stop ( )

Stop a timer already in progress.

Has no effect on timers that have already been stopped.

Definition at line 68 of file timer.cpp.

The documentation for this class was generated from the following files:

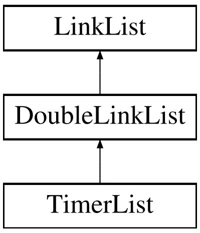
- /home/moslevin/Project/R1/kernel/public/timer.h
- /home/moslevin/Project/R1/kernel/timer.cpp

14.29 TimerList Class Reference

TimerList class - a doubly-linked-list of timer objects.

```
#include <timerlist.h>
```

Inheritance diagram for TimerList:



Public Member Functions

- void Init ()

  Initialize the TimerList object.
- void Add (Timer ∗pclListNode_)

  Add a timer to the TimerList.
- void Remove (Timer ∗pclListNode_)

Remove a timer from the TimerList, cancelling its expiry.

- void Process ()

  Process all timers in the timerlist as a result of the timer expiring.

Private Attributes

- K_ULONG m_ulNextWakeup

  The time (in system clock ticks) of the next wakeup event.
- K_UCHAR m_bTimerActive

  Whether or not the timer is active.

Additional Inherited Members

14.29.1 Detailed Description

TimerList class - a doubly-linked-list of timer objects.

Definition at line 37 of file timerlist.h.

14.29.2 Member Function Documentation

14.29.2.1 void TimerList::Add (Timer ∗ *pclListNode_*)

Add a timer to the TimerList.

Parameters

*pclListNode_*	Pointer to the Timer to Add

Definition at line 51 of file timerlist.cpp.

14.29.2.2 void TimerList::Init (void)

Initialize the TimerList object.

Must be called before using the object.

Definition at line 44 of file timerlist.cpp.

14.29.2.3 void TimerList::Process (void)

Process all timers in the timerlist as a result of the timer expiring.

This will select a new timer epoch based on the next timer to expire. ToDo - figure out if we need to deal with any overtime here.

Definition at line 116 of file timerlist.cpp.

14.29.2.4 void TimerList::Remove (Timer ∗ *pclListNode_*)

Remove a timer from the TimerList, cancelling its expiry.

Parameters

*pclListNode_*	Pointer to the Timer to remove

Definition at line 99 of file timerlist.cpp.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/timerlist.h
- /home/moslevin/Project/R1/kernel/timerlist.cpp

14.30 TimerScheduler Class Reference

"Static" Class used to interface a global TimerList with the rest of the kernel.

```
#include <timerscheduler.h>
```

Static Public Member Functions

- static void Init ()

  Initialize the timer scheduler.
- static void Add (Timer ∗pclListNode_)

  Add a timer to the timer scheduler.
- static void Remove (Timer ∗pclListNode_)

  Remove a timer from the timer scheduler.
- static void Process ()

  This function must be called on timer expiry (from the timer's ISR context).

Static Private Attributes

- static TimerList m_clTimerList

  TimerList object manipulated by the Timer Scheduler.

14.30.1 Detailed Description

"Static" Class used to interface a global TimerList with the rest of the kernel.

Definition at line 38 of file timerscheduler.h.

14.30.2 Member Function Documentation

14.30.2.1 void TimerScheduler::Add (Timer ∗ *pclListNode_*) [inline], [static]

Add a timer to the timer scheduler.

Adding a timer implicitly starts the timer as well.

Parameters

*pclListNode_*	Pointer to the timer list node to add

Definition at line 57 of file timerscheduler.h.

14.30.2.2 void TimerScheduler::Init (void) [inline], [static]

Initialize the timer scheduler.

Must be called before any timer, or timer-derived functions are used.

Definition at line 47 of file timerscheduler.h.

14.30.2.3 void TimerScheduler::Process (void) [inline], [static]

This function must be called on timer expiry (from the timer's ISR context).

This will result in all timers being updated based on the epoch that just elapsed. The next timer epoch is set based on the next Timer object to expire.

Definition at line 79 of file timerscheduler.h.

14.30.2.4 void TimerScheduler::Remove (Timer * *pclListNode_*) [inline], [static]

Remove a timer from the timer scheduler.

May implicitly stop the timer if this is the only active timer scheduled.

Parameters

*pclListNode_*	Pointer to the timer list node to remove

Definition at line 68 of file timerscheduler.h.

The documentation for this class was generated from the following files:

- /home/moslevin/Project/R1/kernel/public/timerscheduler.h
- /home/moslevin/Project/R1/kernel/timerlist.cpp

Chapter 15

File Documentation

15.1 /home/moslevin/Project/R1/kernel/atomic.cpp File Reference

Basic Atomic Operations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "atomic.h"
#include "threadport.h"
```

15.1.1 Detailed Description

Basic Atomic Operations.

Definition in file atomic.cpp.

15.2 atomic.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

--[Mark3 Realtime Platform]--------------------------------------------------

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "atomic.h"
#include "threadport.h"

#if KERNEL_USE_ATOMIC

//---------------------------------------------------------------------------
K_UCHAR Atomic::Set( K_UCHAR *pucSource_, K_UCHAR ucVal_ )
{
    K_UCHAR ucRet;
    CS_ENTER();
    ucRet = *pucSource_;
    *pucSource_ = ucVal_;
    CS_EXIT();
    return ucRet;
}
//---------------------------------------------------------------------------
K_USHORT Atomic::Set( K_USHORT *pusSource_, K_USHORT usVal_ )
{
    K_USHORT usRet;
    CS_ENTER();
    usRet = *pusSource_;
    *pusSource_ = usVal_;
    CS_EXIT();
    return usRet;
}
//---------------------------------------------------------------------------
K_ULONG Atomic::Set( K_ULONG *pulSource_, K_ULONG ulVal_ )
{
    K_ULONG ulRet;
    CS_ENTER();
    ulRet = *pulSource_;
    *pulSource_ = ulVal_;
    CS_EXIT();
    return ulRet;
}

//---------------------------------------------------------------------------
K_UCHAR Atomic::Add( K_UCHAR *pucSource_, K_UCHAR ucVal_ )
{
    K_UCHAR ucRet;
    CS_ENTER();
    ucRet = *pucSource_;
    *pucSource_ += ucVal_;
    CS_EXIT();
    return ucRet;
}

//---------------------------------------------------------------------------
K_USHORT Atomic::Add( K_USHORT *pusSource_, K_USHORT usVal_ )
{
    K_USHORT usRet;
    CS_ENTER();
    usRet = *pusSource_;
    *pusSource_ += usVal_;
    CS_EXIT();
    return usRet;
}

//---------------------------------------------------------------------------
K_ULONG Atomic::Add( K_ULONG *pulSource_, K_ULONG ulVal_ )
{
    K_ULONG ulRet;
    CS_ENTER();
    ulRet = *pulSource_;
    *pulSource_ += ulVal_;
    CS_EXIT();
    return ulRet;
}

//---------------------------------------------------------------------------
K_UCHAR Atomic::Sub( K_UCHAR *pucSource_, K_UCHAR ucVal_ )
{
    K_UCHAR ucRet;
    CS_ENTER();
    ucRet = *pucSource_;
    *pucSource_ -= ucVal_;
    CS_EXIT();
    return ucRet;
}

//---------------------------------------------------------------------------
K_USHORT Atomic::Sub( K_USHORT *pusSource_, K_USHORT usVal_ )
{
    K_USHORT usRet;
    CS_ENTER();
    usRet = *pusSource_;
    *pusSource_ -= usVal_;
    CS_EXIT();
    return usRet;
}

//---------------------------------------------------------------------------
K_ULONG Atomic::Sub( K_ULONG *pulSource_, K_ULONG ulVal_ )
{
    K_ULONG ulRet;
    CS_ENTER();
    ulRet = *pulSource_;
    *pulSource_ -= ulVal_;
    CS_EXIT();
    return ulRet;
}

//---------------------------------------------------------------------------
K_BOOL Atomic::TestAndSet( K_BOOL *pbLock_ )
{
    K_UCHAR ucRet;
    CS_ENTER();
    ucRet = *pbLock_;
    if (!ucRet)
    {
        *pbLock_ = 1;
    }
    CS_EXIT();
    return ucRet;
}

#endif // KERNEL_USE_ATOMIC
```

15.3 /home/moslevin/Project/R1/kernel/blocking.cpp File Reference

Implementation of base class for blocking objects.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "kerneldebug.h"
#include "blocking.h"
#include "thread.h"
```

Macros

- #define __FILE_ID__ BLOCKING_CPP

  File ID used in kernel trace calls.

15.3.1 Detailed Description

Implementation of base class for blocking objects.

Definition in file blocking.cpp.

15.4 blocking.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "kerneldebug.h"

#include "blocking.h"
#include "thread.h"

//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     BLOCKING_CPP

#if KERNEL_USE_SEMAPHORE || KERNEL_USE_MUTEX
//---------------------------------------------------------------------------
void BlockingObject::Block(Thread *pclThread_)
{
    KERNEL_ASSERT( pclThread_ );
    KERNEL_TRACE_1( STR_THREAD_BLOCK_1, (K_USHORT)pclThread_->
GetID() );

    // Remove the thread from its current thread list (the "owner" list)
    // ... And add the thread to this object's block list
    Scheduler::Remove(pclThread_);
    m_clBlockList.Add(pclThread_);

    // Set the "current" list location to the blocklist for this thread
    pclThread_->SetCurrent(&m_clBlockList);
    pclThread_->SetState(THREAD_STATE_BLOCKED);
}

//---------------------------------------------------------------------------
void BlockingObject::UnBlock(Thread *pclThread_)
{
    KERNEL_ASSERT( pclThread_ );
    KERNEL_TRACE_1( STR_THREAD_UNBLOCK_1, (K_USHORT)pclThread_->
GetID() );

    // Remove the thread from its current thread list (the "owner" list)
    pclThread_->GetCurrent()->Remove(pclThread_);

    // Put the thread back in its active owner's list.  This is usually
    // the ready-queue at the thread's original priority.
    Scheduler::Add(pclThread_);

    // Tag the thread's current list location to its owner
    pclThread_->SetCurrent(pclThread_->GetOwner());
    pclThread_->SetState(THREAD_STATE_READY);
}

#endif
```

15.5 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/kernelprofile.cpp File Reference

ATMega328p Profiling timer implementation.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "profile.h"
#include "kernelprofile.h"
#include "threadport.h"
#include <avr/io.h>
#include <avr/interrupt.h>
```

15.5.1 Detailed Description

ATMega328p Profiling timer implementation.

Definition in file kernelprofile.cpp.

15.6 kernelprofile.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
```

```
#include "mark3cfg.h"
#include "profile.h"
#include "kernelprofile.h"
#include "threadport.h"
#include <avr/io.h>
#include <avr/interrupt.h>

#if KERNEL_USE_PROFILER
K_ULONG Profiler::m_ulEpoch;

//---------------------------------------------------------------------------
void Profiler::Init()
{
    TCCR0A = 0;
    TCCR0B = 0;
    TIFR0 = 0;
    TIMSK0 = 0;
    m_ulEpoch = 0;
}

//---------------------------------------------------------------------------
void Profiler::Start()
{
    TIFR0 = 0;
    TCNT0 = 0;
    TCCR0B |= (1 << CS01);
    TIMSK0 |= (1 << TOIE0);
}

//---------------------------------------------------------------------------
void Profiler::Stop()
{
    TIFR0 = 0;
    TCCR0B &= ~(1 << CS01);
    TIMSK0 &= ~(1 << TOIE0);
}
//---------------------------------------------------------------------------
K_USHORT Profiler::Read()
{
    K_USHORT usRet;
    CS_ENTER();
    TCCR0B &= ~(1 << CS01);
    usRet = TCNT0;
    TCCR0B |= (1 << CS01);
    CS_EXIT();
    return usRet;
}

//---------------------------------------------------------------------------
void Profiler::Process()
{
    CS_ENTER();
    m_ulEpoch++;
    CS_EXIT();
}

//---------------------------------------------------------------------------
ISR(TIMER0_OVF_vect)
{
    Profiler::Process();
}

#endif
```

15.7 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/kernelswi.cpp File Reference

Kernel Software interrupt implementation for ATMega328p.

```
#include "kerneltypes.h"
#include "kernelswi.h"
#include <avr/io.h>
#include <avr/interrupt.h>
```

15.7.1 Detailed Description

Kernel Software interrupt implementation for ATMega328p.

Definition in file kernelswi.cpp.

15.8 kernelswi.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "kernelswi.h"

#include <avr/io.h>
#include <avr/interrupt.h>

//---------------------------------------------------------------------------
void KernelSWI::Config(void)
{
    PORTD &= ~0x04; // Clear INT0
    DDRD |= 0x04;    // Set PortD, bit 2 (INT0) As Output
    EICRA |= (1 << ISC00) | (1 << ISC01);    // Rising edge on INT0
}

//---------------------------------------------------------------------------
void KernelSWI::Start(void)
{
    EIFR &= ~(1 << INTF0);    // Clear any pending interrupts on INT0
    EIMSK |= (1 << INT0);    // Enable INT0 interrupt (as K_LONG as I-bit is set)
}

//---------------------------------------------------------------------------
void KernelSWI::Stop(void)
{
    EIMSK &= ~(1 << INT0);    // Disable INT0 interrupts
}

//---------------------------------------------------------------------------
K_UCHAR KernelSWI::DI()
{
    K_BOOL bEnabled = ((EIMSK & (1 << INT0)) != 0);
    EIMSK &= ~(1 << INT0);
    return bEnabled;
}

//---------------------------------------------------------------------------
void KernelSWI::RI(K_BOOL bEnable_)
{
    if (bEnable_)
    {
        EIMSK |= (1 << INT0);
    }
    else
    {
        EIMSK &= ~(1 << INT0);
    }
}

//---------------------------------------------------------------------------
void KernelSWI::Clear(void)
{
    EIFR &= ~(1 << INTF0);     // Clear the interrupt flag for INT0
}

//---------------------------------------------------------------------------
void KernelSWI::Trigger(void)
{
    //if(Thread_IsSchedulerEnabled())
    {
        PORTD &= ~0x04;
        PORTD |= 0x04;
    }
}
```

15.9 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/kerneltimer.cpp File Reference

Kernel Timer Implementation for ATMega328p.

```
#include "kerneltypes.h"
#include "kerneltimer.h"
#include "mark3cfg.h"
#include <avr/io.h>
#include <avr/interrupt.h>
```

15.9.1 Detailed Description

Kernel Timer Implementation for ATMega328p.

Definition in file kerneltimer.cpp.

15.10 kerneltimer.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "kerneltimer.h"
#include "mark3cfg.h"

#include <avr/io.h>
#include <avr/interrupt.h>

#define TCCR1B_INIT        ((1 << WGM12) | (1 << CS12))
#define TIMER_IMSK        (1 << OCIE1A)
#define TIMER_IFR        (1 << OCF1A)

//---------------------------------------------------------------------------
void KernelTimer::Config(void)
{
    TCCR1B = TCCR1B_INIT;
}

//---------------------------------------------------------------------------
void KernelTimer::Start(void)
{
#if !KERNEL_TIMERS_TICKLESS
    TCCR1B = ((1 << WGM12) | (1 << CS11) | (1 << CS10));
    OCR1A = ((SYSTEM_FREQ / 1000) / 64);
#else
    TCCR1B |= (1 << CS12);
#endif

    TCNT1 = 0;
    TIFR1 &= ~TIMER_IFR;
    TIMSK1 |= TIMER_IMSK;
}

//---------------------------------------------------------------------------
void KernelTimer::Stop(void)
{
```

```
#if KERNEL_TIMERS_TICKLESS
    TIFR1 &= ~TIMER_IFR;
    TIMSK1 &= ~TIMER_IMSK;
    TCCR1B &= ~(1 << CS12);      // Disable count...
    TCNT1 = 0;
    OCR1A = 0;
#endif
}

//---------------------------------------------------------------------------
K_USHORT KernelTimer::Read(void)
{
#if KERNEL_TIMERS_TICKLESS
    volatile K_USHORT usRead1;
    volatile K_USHORT usRead2;

    do {
        usRead1 = TCNT1;
        usRead2 = TCNT1;
    } while (usRead1 != usRead2);

    return usRead1;
#else
    return 0;
#endif
}

//---------------------------------------------------------------------------
K_ULONG KernelTimer::SubtractExpiry(K_ULONG ulInterval_)
{
#if KERNEL_TIMERS_TICKLESS
    OCR1A -= (K_USHORT)ulInterval_;
    return (K_ULONG)OCR1A;
#else
    return 0;
#endif
}

//---------------------------------------------------------------------------
K_ULONG KernelTimer::TimeToExpiry(void)
{
#if KERNEL_TIMERS_TICKLESS
    K_USHORT usRead = KernelTimer::Read();
    K_USHORT usOCR1A = OCR1A;

    if (usRead >= usOCR1A)
    {
        return 0;
    }
    else
    {
        return (K_ULONG)(usOCR1A - usRead);
    }
#else
    return 0;
#endif
}

//---------------------------------------------------------------------------
K_ULONG KernelTimer::GetOvertime(void)
{
    return KernelTimer::Read();
}

//---------------------------------------------------------------------------
K_ULONG KernelTimer::SetExpiry(K_ULONG ulInterval_)
{
#if KERNEL_TIMERS_TICKLESS
    K_USHORT usSetInterval;
    if (ulInterval_ > 65535)
    {
        usSetInterval = 65535;
    }
    else
    {
        usSetInterval = (K_USHORT)ulInterval_ ;
    }

    OCR1A = usSetInterval;
    return (K_ULONG)usSetInterval;
#else
    return 0;
#endif
}

//---------------------------------------------------------------------------
void KernelTimer::ClearExpiry(void)
```

```
{
#if KERNEL_TIMERS_TICKLESS
    OCR1A = 65535;                    // Clear the compare value
#endif
}

//---------------------------------------------------------------------------
K_UCHAR KernelTimer::DI(void)
{
#if KERNEL_TIMERS_TICKLESS
    K_BOOL bEnabled = ((TIMSK1 & (TIMER_IMSK)) != 0);
    TIFR1 &= ~TIMER_IFR;        // Clear interrupt flags
    TIMSK1 &= ~TIMER_IMSK;     // Disable interrupt
    return bEnabled;
#else
    return 0;
#endif
}

//---------------------------------------------------------------------------
void KernelTimer::EI(void)
{
    KernelTimer::RI(0);
}

//---------------------------------------------------------------------------
void KernelTimer::RI(K_BOOL bEnable_)
{
#if KERNEL_TIMERS_TICKLESS
    if (bEnable_)
    {
        TIMSK1 |= (1 << OCIE1A);     // Enable interrupt
    }
    else
    {
        TIMSK1 &= ~(1 << OCIE1A);
    }
#endif
}
```

15.11 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/kernelprofile.h File Reference

Profiling timer hardware interface.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
```

Classes

- class Profiler

  System profiling timer interface.

15.11.1 Detailed Description

Profiling timer hardware interface.

Definition in file kernelprofile.h.

15.12 kernelprofile.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"

#ifndef __KPROFILE_H__
#define __KPROFILE_H__

#if KERNEL_USE_PROFILER

//---------------------------------------------------------------------------
#define TICKS_PER_OVERFLOW              (256)
#define CLOCK_DIVIDE                    (8)

//---------------------------------------------------------------------------
class Profiler
{
public:
    static void Init();

    static void Start();

    static void Stop();

    static K_USHORT Read();

    static void Process();

    static K_ULONG GetEpoch(){ return m_ulEpoch; }
private:

    static K_ULONG m_ulEpoch;
};

#endif //KERNEL_USE_PROFILER

#endif

```

15.13 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/kernelswi.h File Reference

Kernel Software interrupt declarations.

```
#include "kerneltypes.h"
```

Classes

- class KernelSWI

  Class providing the software-interrupt required for context-switching in the kernel.

15.13.1 Detailed Description

Kernel Software interrupt declarations.

Definition in file kernelswi.h.

15.14 kernelswi.h

```
/*===========================================================================
     _____        _____        _____        _____
```

```
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#ifndef __KERNELSWI_H_
#define __KERNELSWI_H_

//---------------------------------------------------------------------------
class KernelSWI
{
public:
    static void Config(void);

    static void Start(void);

    static void Stop(void);

    static void Clear(void);

    static void Trigger(void);

    static K_UCHAR DI();

    static void RI(K_BOOL bEnable_);
};


#endif // __KERNELSIW_H_
```

15.15 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/kerneltimer.h File Reference

Kernel Timer Class declaration.

`#include "kerneltypes.h"`

Classes

- class KernelTimer

  Hardware timer interface, used by all scheduling/timer subsystems.

15.15.1 Detailed Description

Kernel Timer Class declaration.

Definition in file kerneltimer.h.

15.16 kerneltimer.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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```

```
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===========================================================================*/
#include "kerneltypes.h"
#ifndef __KERNELTIMER_H_
#define __KERNELTIMER_H_

//---------------------------------------------------------------------------
#define SYSTEM_FREQ        ((K_ULONG)16000000)
#define TIMER_FREQ        ((K_ULONG)(SYSTEM_FREQ / 256)) // Timer ticks per second...

//---------------------------------------------------------------------------
class KernelTimer
{
public:
    static void Config(void);

    static void Start(void);

    static void Stop(void);

    static K_UCHAR DI(void);

    static void RI(K_BOOL bEnable_);

    static void EI(void);

    static K_ULONG SubtractExpiry(K_ULONG ulInterval_);

    static K_ULONG TimeToExpiry(void);

    static K_ULONG SetExpiry(K_ULONG ulInterval_);

    static K_ULONG GetOvertime(void);

    static void ClearExpiry(void);

private:
    static K_USHORT Read(void);

};

#endif //__KERNELTIMER_H_
```

15.17 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/public/threadport.h File Reference

ATMega328p Multithreading support.

```
#include "kerneltypes.h"
#include "thread.h"
#include <avr/io.h>
#include <avr/interrupt.h>
```

Classes

- class ThreadPort

  Class defining the architecture specific functions required by the kernel.

Macros

- #define ASM(x) asm volatile(x);

  ASM Macro - simplify the use of ASM directive in C.
- #define SR_ 0x3F

  Status register define - map to 0x003F.
- #define SPH_ 0x3E

  Stack pointer define.
- #define TOP_OF_STACK(x, y) (K_UCHAR*) (((K_USHORT)x) + (y-1))

Macro to find the top of a stack given its size and top address.

- #define PUSH_TO_STACK(x, y) ∗x = y; x--;

  Push a value y to the stack pointer x and decrement the stack pointer.
- #define Thread_SaveContext()

  Save the context of the Thread.
- #define Thread_RestoreContext()

  Restore the context of the Thread.
- #define CS_ENTER()

  These macros must be used in pairs !
- #define CS_EXIT()

  Exit critical section (restore status register)
- #define ENABLE_INTS() ASM("sei");

  Initiate a contex switch without using the SWI.

15.17.1 Detailed Description

ATMega328p Multithreading support.

Definition in file threadport.h.

15.17.2 Macro Definition Documentation

15.17.2.1 #define CS_ENTER( )

Value:

```
{ \
volatile K_UCHAR x; \
x = _SFR_IO8(SR_); \
ASM("cli");
```

These macros *must* be used in pairs !

Enter critical section (copy status register, disable interrupts)

Definition at line 142 of file threadport.h.

15.18 threadport.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __THREADPORT_H_
#define __THREADPORT_H_

#include "kerneltypes.h"
#include "thread.h"

#include <avr/io.h>
#include <avr/interrupt.h>

//---------------------------------------------------------------------------
#define ASM(x)      asm volatile(x);
```

```
#define SR_         0x3F
#define SPH_        0x3E
#define SPL_        0x3D


//---------------------------------------------------------------------------
#define TOP_OF_STACK(x, y)        (K_UCHAR*) ( ((K_USHORT)x) + (y-1) )
#define PUSH_TO_STACK(x, y)        *x = y; x--;

//---------------------------------------------------------------------------
#define Thread_SaveContext() \
ASM("push r0"); \
ASM("in r0, __SREG__"); \
ASM("cli"); \
ASM("push r0"); \
ASM("push r1"); \
ASM("clr r1"); \
ASM("push r2"); \
ASM("push r3"); \
ASM("push r4"); \
ASM("push r5"); \
ASM("push r6"); \
ASM("push r7"); \
ASM("push r8"); \
ASM("push r9"); \
ASM("push r10"); \
ASM("push r11"); \
ASM("push r12"); \
ASM("push r13"); \
ASM("push r14"); \
ASM("push r15"); \
ASM("push r16"); \
ASM("push r17"); \
ASM("push r18"); \
ASM("push r19"); \
ASM("push r20"); \
ASM("push r21"); \
ASM("push r22"); \
ASM("push r23"); \
ASM("push r24"); \
ASM("push r25"); \
ASM("push r26"); \
ASM("push r27"); \
ASM("push r28"); \
ASM("push r29"); \
ASM("push r30"); \
ASM("push r31"); \
ASM("lds r26, g_pstCurrent"); \
ASM("lds r27, g_pstCurrent + 1"); \
ASM("adiw r26, 4"); \
ASM("in    r0, 0x3D"); \
ASM("st    x+, r0"); \
ASM("in    r0, 0x3E"); \
ASM("st    x+, r0");

//---------------------------------------------------------------------------
#define Thread_RestoreContext() \
ASM("lds r26, g_pstCurrent"); \
ASM("lds r27, g_pstCurrent + 1");\
ASM("adiw r26, 4"); \
ASM("ld     r28, x+"); \
ASM("out 0x3D, r28"); \
ASM("ld     r29, x+"); \
ASM("out 0x3E, r29"); \
ASM("pop r31"); \
ASM("pop r30"); \
ASM("pop r29"); \
ASM("pop r28"); \
ASM("pop r27"); \
ASM("pop r26"); \
ASM("pop r25"); \
ASM("pop r24"); \
ASM("pop r23"); \
ASM("pop r22"); \
ASM("pop r21"); \
ASM("pop r20"); \
ASM("pop r19"); \
ASM("pop r18"); \
ASM("pop r17"); \
ASM("pop r16"); \
ASM("pop r15"); \
ASM("pop r14"); \
ASM("pop r13"); \
ASM("pop r12"); \
ASM("pop r11"); \
ASM("pop r10"); \
ASM("pop r9"); \
ASM("pop r8"); \
ASM("pop r7"); \
ASM("pop r6"); \
ASM("pop r5"); \
ASM("pop r4"); \
ASM("pop r3"); \
ASM("pop r2"); \
ASM("pop r1"); \
ASM("pop r0"); \
ASM("out __SREG__, r0"); \
ASM("pop r0");

//---------------------------------------------------------------------------
//---------------------------------------------------------------------------
#define CS_ENTER()    \
{ \
volatile K_UCHAR x; \
x = _SFR_IO8(SR_); \
ASM("cli");
//---------------------------------------------------------------------------
#define CS_EXIT() \
_SFR_IO8(SR_) = x;\
}

//---------------------------------------------------------------------------
#define ENABLE_INTS()        ASM("sei");
#define DISABLE_INTS()       ASM("cli");

//---------------------------------------------------------------------------
class Thread;
class ThreadPort
{
public:
    static void StartThreads();
    friend class Thread;
private:

    static void InitStack(Thread *pstThread_);
};

#endif //__ThreadPORT_H_
```

15.19 /home/moslevin/Project/R1/kernel/cpu/avr/atmega328p/gcc/threadport.cpp File Reference

ATMega328p Multithreading.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "thread.h"
#include "threadport.h"
#include "kernelswi.h"
#include "kerneltimer.h"
#include "timerlist.h"
#include "quantum.h"
#include "kernel.h"
#include "kernelaware.h"
#include <avr/io.h>
#include <avr/interrupt.h>
```

Functions

- ISR (INT0_vect) __attribute__((signal

  SWI using INT0 - used to trigger a context switch.

- ISR (TIMER1_COMPA_vect)

  Timer interrupt ISR - causes a tick, which may cause a context switch.

15.19.1 Detailed Description

ATMega328p Multithreading.

Definition in file threadport.cpp.

15.20 threadport.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "thread.h"
#include "threadport.h"
#include "kernelswi.h"
#include "kerneltimer.h"
#include "timerlist.h"
#include "quantum.h"
#include "kernel.h"
#include "kernelaware.h"
#include <avr/io.h>
#include <avr/interrupt.h>

//---------------------------------------------------------------------------
Thread *g_pstCurrentThread;

//---------------------------------------------------------------------------
void ThreadPort::InitStack(Thread *pclThread_)
{
    // Initialize the stack for a Thread
    K_USHORT usAddr;
    K_UCHAR *pucStack;
    K_USHORT i;

    // Get the address of the thread's entry function
    usAddr = (K_USHORT)(pclThread_->m_pfEntryPoint);

    // Start by finding the bottom of the stack
    pucStack = (K_UCHAR*)pclThread_->m_pwStackTop;

    // clear the stack, and initialize it to a known-default value (easier
    // to debug when things go sour with stack corruption or overflow)
    for (i = 0; i < pclThread_->m_usStackSize; i++)
    {
        pclThread_->m_pwStack[i] = 0xFF;
    }

    // Our context starts with the entry function
    PUSH_TO_STACK(pucStack, (K_UCHAR)(usAddr & 0x00FF));
    PUSH_TO_STACK(pucStack, (K_UCHAR)((usAddr >> 8) & 0x00FF));

    // R0
    PUSH_TO_STACK(pucStack, 0x00);    // R0

    // Push status register and R1 (which is used as a constant zero)
    PUSH_TO_STACK(pucStack, 0x80);  // SR
    PUSH_TO_STACK(pucStack, 0x00);  // R1

    // Push other registers
    for (i = 2; i <= 23; i++) //R2-R23
    {
        PUSH_TO_STACK(pucStack, i);
    }

    // Assume that the argument is the only stack variable
    PUSH_TO_STACK(pucStack, (K_UCHAR)(((K_USHORT)(pclThread_->m_pvArg)) & 0x00FF));    //R24
    PUSH_TO_STACK(pucStack, (K_UCHAR)((((K_USHORT)(pclThread_->m_pvArg))>>8) & 0x00FF)); //R25

    // Push the rest of the registers in the context
    for (i = 26; i <=31; i++)
    {
        PUSH_TO_STACK(pucStack, i);
    }

    // Set the top o' the stack.
    pclThread_->m_pwStackTop = (K_UCHAR*)pucStack;

    // That's it!  the thread is ready to run now.
}

//---------------------------------------------------------------------------
static void Thread_Switch(void)
{
#if KERNEL_USE_IDLE_FUNC
    // If there's no next-thread-to-run...
    if (g_pstNext == Kernel::GetIdleThread())
    {
        g_pstCurrent = Kernel::GetIdleThread();

        // Disable the SWI, and re-enable interrupts -- enter nested interrupt
        // mode.
        KernelSWI::DI();

        K_UCHAR ucSR = _SFR_IO8(SR_);

        // So long as there's no "next-to-run" thread, keep executing the Idle
        // function to conclusion...

        while (g_pstNext == Kernel::GetIdleThread())
        {
           // Ensure that we run this block in an interrupt enabled context (but
           // with the rest of the checks being performed in an interrupt disabled
           // context).
           ASM( "sei" );
           Kernel::IdleFunc();
           ASM( "cli" );
        }

        // Progress has been achieved -- an interrupt-triggered event has caused
        // the scheduler to run, and choose a new thread.  Since we've already
        // saved the context of the thread we've hijacked to run idle, we can
        // proceed to disable the nested interrupt context and switch to the
        // new thread.

        _SFR_IO8(SR_) = ucSR;
        KernelSWI::RI( true );
    }
#endif
    g_pstCurrent = (Thread*)g_pstNext;
}


//---------------------------------------------------------------------------
void ThreadPort::StartThreads()
{
    KernelSWI::Config();                 // configure the task switch SWI
    KernelTimer::Config();               // configure the kernel timer

    Scheduler::SetScheduler(1);          // enable the scheduler
    Scheduler::Schedule();               // run the scheduler - determine the first
 thread to run

    Thread_Switch();                     // Set the next scheduled thread to the current thread

    KernelTimer::Start();                // enable the kernel timer
    KernelSWI::Start();                  // enable the task switch SWI

    // Restore the context...
    Thread_RestoreContext();        // restore the context of the first running thread
    ASM("reti");                    // return from interrupt - will return to the first scheduled thread
}

//---------------------------------------------------------------------------
//---------------------------------------------------------------------------
ISR(INT0_vect) __attribute__ ( ( signal, naked ) );
ISR(INT0_vect)
{
    Thread_SaveContext();       // Push the context (registers) of the current task
    Thread_Switch();            // Switch to the next task
    Thread_RestoreContext();    // Pop the context (registers) of the next task
    ASM("reti");                // Return to the next task
}

//---------------------------------------------------------------------------
//---------------------------------------------------------------------------
ISR(TIMER1_COMPA_vect)
```

```
{
#if KERNEL_USE_TIMERS
    TimerScheduler::Process();
#endif
#if KERNEL_USE_QUANTUM
    Quantum::UpdateTimer();
#endif
}
```

15.21 /home/moslevin/Project/R1/kernel/driver.cpp File Reference

Device driver/hardware abstraction layer.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "kerneldebug.h"
#include "driver.h"
```

Classes

- class DevNull

    This class implements the "default" driver (/dev/null)

Macros

- #define __FILE_ID__ DRIVER_CPP

    File ID used in kernel trace calls.

Functions

- static K_UCHAR DrvCmp (const K_CHAR ∗szStr1_, const K_CHAR ∗szStr2_)

    DrvCmp.

Variables

- static DevNull clDevNull

    Default driver included to allow for run-time "stubbing".

15.21.1 Detailed Description

Device driver/hardware abstraction layer.

Definition in file driver.cpp.

15.21.2 Function Documentation

15.21.2.1 static K_UCHAR DrvCmp (const K_CHAR ∗ *szStr1_*, const K_CHAR ∗ *szStr2_*) [static]

DrvCmp.

String comparison function used to compare input driver name against a known driver name in the existing driver list.

Parameters

*szStr1_*	user-specified driver name
*szStr2_*	name of a driver, provided from the driver table

Returns

1 on match, 0 on no-match

Definition at line 75 of file driver.cpp.

15.22 driver.cpp

```
/*============================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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============================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "kerneldebug.h"
#include "driver.h"

//----------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     DRIVER_CPP

//----------------------------------------------------------------------------
#if KERNEL_USE_DRIVER

DoubleLinkList DriverList::m_clDriverList;

class DevNull : public Driver
{
public:
    virtual void Init() { SetName("/dev/null"); };
    virtual K_UCHAR Open() { return 0; }
    virtual K_UCHAR Close() { return 0; }

    virtual K_USHORT Read( K_USHORT usBytes_,
    K_UCHAR *pucData_){ return 0; }

    virtual K_USHORT Write( K_USHORT usBytes_,
    K_UCHAR *pucData_) { return 0; }

    virtual K_USHORT Control( K_USHORT usEvent_,
        void *pvDataIn_,
        K_USHORT usSizeIn_,
        void *pvDataOut_,
        K_USHORT usSizeOut_ ) { return 0; }

};

//----------------------------------------------------------------------------
static DevNull clDevNull;

//----------------------------------------------------------------------------
static K_UCHAR DrvCmp( const K_CHAR *szStr1_, const K_CHAR *szStr2_ )
{
    K_CHAR *szTmp1 = (K_CHAR*) szStr1_;
    K_CHAR *szTmp2 = (K_CHAR*) szStr2_;

    while (*szTmp1 && *szTmp2)
    {
        if (*szTmp1++ != *szTmp2++)
        {
            return 0;
        }
    }

    // Both terminate at the same length
    if (!(*szTmp1) && !(*szTmp2))
    {
        return 1;
    }

    return 0;
}

//---------------------------------------------------------------------------
void DriverList::Init()
{
    // Ensure we always have at least one entry - a default in case no match
    // is found (/dev/null)
    clDevNull.Init();
    Add(&clDevNull);
}

//---------------------------------------------------------------------------
Driver *DriverList::FindByPath( const K_CHAR *m_pcPath )
{
    KERNEL_ASSERT( m_pcPath );
    Driver *pclTemp = static_cast<Driver*>(m_clDriverList.
GetHead());

    // Iterate through the list of drivers until we find a match, or we
    // exhaust our list of installed drivers
    while (pclTemp)
    {
        if(DrvCmp(m_pcPath, pclTemp->GetPath()))
        {
            return pclTemp;
        }
        pclTemp = static_cast<Driver*>(pclTemp->GetNext());
    }
    // No matching driver found - return a pointer to our /dev/null driver
    return &clDevNull;
}

#endif
```

15.23 /home/moslevin/Project/R1/kernel/eventflag.cpp File Reference

Event Flag Blocking Object/IPC-Object implementation.

```
#include "mark3cfg.h"
#include "blocking.h"
#include "kernel.h"
#include "thread.h"
#include "eventflag.h"
#include "kernelaware.h"
#include "timerlist.h"
```

Functions

- void TimedEventFlag_Callback (Thread *pclOwner_, void *pvData_)

    TimedEventFlag_Callback.

15.23.1 Detailed Description

Event Flag Blocking Object/IPC-Object implementation.

Definition in file eventflag.cpp.

15.23.2 Function Documentation

15.23.2.1 void TimedEventFlag_Callback (Thread ∗ *pclOwner_*, void ∗ *pvData_*)

TimedEventFlag_Callback.

This funciton is called whenever a timed event flag wait operation fails in the time provided. This function wakes the thread for which the timeout was requested on the blocking call, sets the thread's expiry flags, and reschedules if necessary.

Parameters

*pclOwner_*	Thread to wake
*pvData_*	Pointer to the event-flag object

Definition at line 42 of file eventflag.cpp.

15.24 eventflag.cpp

```
00001 /*==========================================================================
00002      _____        _____        _____        _____
00003  ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
00004 |    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
00005 |     \/   | ||     \     ||     \     ||     \     ||___   |
00006 |__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
00007     |_____|      |_____|      |_____|      |_____|
00008 
00009 --[Mark3 Realtime Platform]-------------------------------------------------
00010 
00011 Copyright (c) 2012-2015 Funkenstein Software Consulting, all rights reserved.
00012 See license.txt for more information
00013 ==========================================================================*/
00019 #include "mark3cfg.h"
00020 #include "blocking.h"
00021 #include "kernel.h"
00022 #include "thread.h"
00023 #include "eventflag.h"
00024 #include "kernelaware.h"
00025 
00026 #if KERNEL_USE_EVENTFLAG
00027 
00028 #if KERNEL_USE_TIMEOUTS
00029 #include "timerlist.h"
00030 //--------------------------------------------------------------------------
00042 void TimedEventFlag_Callback(Thread *pclOwner_, void *pvData_)
00043 {
00044     EventFlag *pclEventFlag = static_cast<EventFlag*>(pvData_);
00045 
00046     pclEventFlag->WakeMe(pclOwner_);
00047     pclOwner_->SetExpired(true);
00048     pclOwner_->SetEventFlagMask(0);
00049 
00050     if (pclOwner_->GetCurPriority() >= Scheduler::GetCurrentThread
      ()->GetCurPriority())
00051     {
00052         Thread::Yield();
00053     }
00054 }
00055 
00056 //--------------------------------------------------------------------------
00057 void EventFlag::WakeMe(Thread *pclChosenOne_)
00058 {
00059     UnBlock(pclChosenOne_);
00060 }
00061 #endif
00062 
00063 //--------------------------------------------------------------------------
00064 #if KERNEL_USE_TIMEOUTS
00065     K_USHORT EventFlag::Wait_i(K_USHORT usMask_,
      EventFlagOperation_t eMode_, K_ULONG ulTimeMS_)
00066 #else
00067     K_USHORT EventFlag::Wait_i(K_USHORT usMask_,
      EventFlagOperation_t eMode_)
00068 #endif
00069 {
00070     K_BOOL bThreadYield = false;
00071     K_BOOL bMatch = false;
00072 
00073 #if KERNEL_USE_TIMEOUTS
00074     Timer clEventTimer;
00075     K_BOOL bUseTimer = false;
```

```
#endif

    // Ensure we're operating in a critical section while we determine
    // whether or not we need to block the current thread on this object.
    CS_ENTER();

    // Check to see whether or not the current mask matches any of the
    // desired bits.
    g_pstCurrent->SetEventFlagMask(usMask_);

    if ((eMode_ == EVENT_FLAG_ALL) || (eMode_ == EVENT_FLAG_ALL_CLEAR))
    {
        // Check to see if the flags in their current state match all of
        // the set flags in the event flag group, with this mask.
        if ((m_usSetMask & usMask_) == usMask_)
        {
            bMatch = true;
            g_pstCurrent->SetEventFlagMask(usMask_);
        }
    }
    else if ((eMode_ == EVENT_FLAG_ANY) || (eMode_ == EVENT_FLAG_ANY_CLEAR))
    {
        // Check to see if the existing flags match any of the set flags in
        // the event flag group  with this mask
        if (m_usSetMask & usMask_)
        {
            bMatch = true;
            g_pstCurrent->SetEventFlagMask(m_usSetMask & usMask_);
        }
    }

    // We're unable to match this pattern as-is, so we must block.
    if (!bMatch)
    {
        // Reset the current thread's event flag mask & mode
        g_pstCurrent->SetEventFlagMask(usMask_);
        g_pstCurrent->SetEventFlagMode(eMode_);

#if KERNEL_USE_TIMEOUTS
        if (ulTimeMS_)
        {
            g_pstCurrent->SetExpired(false);
            clEventTimer.Init();
            clEventTimer.Start(0, ulTimeMS_, TimedEventFlag_Callback, (void*)this);
            bUseTimer = true;
        }
#endif

        // Add the thread to the object's block-list.
        Block(g_pstCurrent);

        // Trigger that
        bThreadYield = true;
    }

    // If bThreadYield is set, it means that we've blocked the current thread,
    // and must therefore rerun the scheduler to determine what thread to
    // switch to.
    if (bThreadYield)
    {
        // Switch threads immediately
        Thread::Yield();
    }

    // Exit the critical section and return back to normal execution
    CS_EXIT();

#if KERNEL_USE_TIMEOUTS
    if (bUseTimer && bThreadYield)
    {
        clEventTimer.Stop();
    }
#endif

    return g_pstCurrent->GetEventFlagMask();
}

//---------------------------------------------------------------------------
K_USHORT EventFlag::Wait(K_USHORT usMask_, EventFlagOperation_t eMode_)
{
#if KERNEL_USE_TIMEOUTS
    return Wait_i(usMask_, eMode_, 0);
#else
```

```
    return Wait_i(usMask_, eMode_);
#endif
}

#if KERNEL_USE_TIMEOUTS
//---------------------------------------------------------------------------
K_USHORT EventFlag::Wait(K_USHORT usMask_, EventFlagOperation_t eMode_, K_ULONG ulTimeMS_)
{
    return Wait_i(usMask_, eMode_, ulTimeMS_);
}
#endif

//---------------------------------------------------------------------------
void EventFlag::Set(K_USHORT usMask_)
{
    Thread *pclPrev;
    Thread *pclCurrent;
    K_BOOL bReschedule = false;
    K_USHORT usNewMask;

    CS_ENTER();

    // Walk through the whole block list, checking to see whether or not
    // the current flag set now matches any/all of the masks and modes of
    // the threads involved.

    m_usSetMask |= usMask_;
    usNewMask = m_usSetMask;

    // Start at the head of the list, and iterate through until we hit the
    // "head" element in the list again.  Ensure that we handle the case where
    // we remove the first or last elements in the list, or if there’s only
    // one element in the list.
    pclCurrent = static_cast<Thread*>(m_clBlockList.GetHead());

    // Do nothing when there are no objects blocking.
    if (pclCurrent)
    {
        // First loop - process every thread in the block-list and check to
        // see whether or not the current flags match the event-flag conditions
        // on the thread.
        do
        {
            pclPrev = pclCurrent;
            pclCurrent = static_cast<Thread*>(pclCurrent->GetNext());

            // Read the thread’s event mask/mode
            K_USHORT usThreadMask = pclPrev->GetEventFlagMask();
            EventFlagOperation_t eThreadMode = pclPrev->GetEventFlagMode();

            // For the "any" mode - unblock the blocked threads if one or more bits
            // in the thread’s bitmask match the object’s bitmask
            if ((EVENT_FLAG_ANY == eThreadMode) || (EVENT_FLAG_ANY_CLEAR == eThreadMode))
            {
                if (usThreadMask & m_usSetMask)
                {
                    pclPrev->SetEventFlagMode(EVENT_FLAG_PENDING_UNBLOCK);
                    pclPrev->SetEventFlagMask(m_usSetMask & usThreadMask);
                    bReschedule = true;

                    // If the "clear" variant is set, then clear the bits in the mask
                    // that caused the thread to unblock.
                    if (EVENT_FLAG_ANY_CLEAR == eThreadMode)
                    {
                        usNewMask &=~ (usThreadMask & usMask_);
                    }
                }
            }
            // For the "all" mode, every set bit in the thread’s requested bitmask must
            // match the object’s flag mask.
            else if ((EVENT_FLAG_ALL == eThreadMode) || (EVENT_FLAG_ALL_CLEAR == eThreadMode))
            {
                if ((usThreadMask & m_usSetMask) == usThreadMask)
                {
                    pclPrev->SetEventFlagMode(EVENT_FLAG_PENDING_UNBLOCK);
                    pclPrev->SetEventFlagMask(usThreadMask);
                    bReschedule = true;

                    // If the "clear" variant is set, then clear the bits in the mask
                    // that caused the thread to unblock.
                    if (EVENT_FLAG_ALL_CLEAR == eThreadMode)
                    {
                        usNewMask &=~ (usThreadMask & usMask_);
                    }
                }
            }
        }
        // To keep looping, ensure that there's something in the list, and
        // that the next item isn't the head of the list.
        while (pclPrev != m_clBlockList.GetTail());

        // Second loop - go through and unblock all of the threads that
        // were tagged for unblocking.
        pclCurrent = static_cast<Thread*>(m_clBlockList.GetHead());
        K_BOOL bIsTail = false;
        do
        {
            pclPrev = pclCurrent;
            pclCurrent = static_cast<Thread*>(pclCurrent->GetNext());

            // Check to see if this is the condition to terminate the loop
            if (pclPrev == m_clBlockList.GetTail())
            {
                bIsTail = true;
            }

            // If the first pass indicated that this thread should be
            // unblocked, then unblock the thread
            if (pclPrev->GetEventFlagMode() == EVENT_FLAG_PENDING_UNBLOCK)
            {
                UnBlock(pclPrev);
            }
        }
        while (!bIsTail);
    }

    // If we awoke any threads, re-run the scheduler
    if (bReschedule)
    {
        Thread::Yield();
    }

    // Update the bitmask based on any "clear" operations performed along
    // the way
    m_usSetMask = usNewMask;

    // Restore interrupts - will potentially cause a context switch if a
    // thread is unblocked.
    CS_EXIT();
}

//---------------------------------------------------------------------------
void EventFlag::Clear(K_USHORT usMask_)
{
    // Just clear the bitfields in the local object.
    CS_ENTER();
    m_usSetMask &= ~usMask_;
    CS_EXIT();
}

//---------------------------------------------------------------------------
K_USHORT EventFlag::GetMask()
{
    // Return the presently held event flag values in this object.  Ensure
    // we get this within a critical section to guarantee atomicity.
    K_USHORT usReturn;
    CS_ENTER();
    usReturn = m_usSetMask;
    CS_EXIT();
    return usReturn;
}

#endif // KERNEL_USE_EVENTFLAG
```

15.25 /home/moslevin/Project/R1/kernel/kernel.cpp File Reference

Kernel initialization and startup code.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "kernel.h"
#include "scheduler.h"
#include "thread.h"
#include "threadport.h"
#include "timerlist.h"
#include "message.h"
#include "driver.h"
#include "profile.h"
#include "kernelprofile.h"
#include "tracebuffer.h"
#include "kerneldebug.h"
```

Macros

- #define __FILE_ID__ KERNEL_CPP

  File ID used in kernel trace calls.

15.25.1 Detailed Description

Kernel initialization and startup code.

Definition in file kernel.cpp.

15.26 kernel.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"

#include "kernel.h"
#include "scheduler.h"
#include "thread.h"
#include "threadport.h"
#include "timerlist.h"
#include "message.h"
#include "driver.h"
#include "profile.h"
#include "kernelprofile.h"
#include "tracebuffer.h"
#include "kerneldebug.h"

K_BOOL Kernel::m_bIsStarted;
K_BOOL Kernel::m_bIsPanic;
panic_func_t Kernel::m_pfPanic;

#if KERNEL_USE_IDLE_FUNC
idle_func_t Kernel::m_pfIdle;
FakeThread_t Kernel::m_clIdle;
#endif

//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
```

```
#define __FILE_ID__     KERNEL_CPP

//---------------------------------------------------------------------------
void Kernel::Init(void)
{
    m_bIsStarted = false;
    m_bIsPanic = false;
    m_pfPanic = 0;

#if KERNEL_USE_IDLE_FUNC
    ((Thread*)&m_clIdle)->InitIdle();
    m_pfIdle = 0;
#endif

#if KERNEL_USE_DEBUG
    TraceBuffer::Init();
#endif
    KERNEL_TRACE( STR_MARK3_INIT );

    // Initialize the global kernel data - scheduler, timer-scheduler, and
    // the global message pool.
    Scheduler::Init();
#if KERNEL_USE_DRIVER
    DriverList::Init();
#endif
#if KERNEL_USE_TIMERS
    TimerScheduler::Init();
#endif
#if KERNEL_USE_MESSAGE
    GlobalMessagePool::Init();
#endif
#if KERNEL_USE_PROFILER
    Profiler::Init();
#endif
}

//---------------------------------------------------------------------------
void Kernel::Start(void)
{
    KERNEL_TRACE( STR_THREAD_START );
    m_bIsStarted = true;
    ThreadPort::StartThreads();
    KERNEL_TRACE( STR_START_ERROR );
}

//---------------------------------------------------------------------------
void Kernel::Panic(K_USHORT usCause_)
{
    m_bIsPanic = true;
    if (m_pfPanic)
    {
        m_pfPanic(usCause_);
    }
    else
    {
#if KERNEL_AWARE_SIMULATION
        KernelAware::ExitSimulator();
#endif
        while(1);
    }
}
```

15.27 /home/moslevin/Project/R1/kernel/kernelaware.cpp File Reference

Kernel aware simulation support.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "kernelaware.h"
#include "threadport.h"
```

Classes

- union KernelAwareData_t

  This structure is used to communicate between the kernel and a kernel- aware host.

Variables

- volatile K_BOOL g_bIsKernelAware = false

  Will be set to true by a kernel-aware host.
- volatile K_UCHAR g_ucKACommand

  Kernel-aware simulator command to execute.
- KernelAwareData_t g_stKAData

  Data structure used to communicate with host.

15.27.1 Detailed Description

Kernel aware simulation support.

Definition in file kernelaware.cpp.

15.27.2 Variable Documentation

15.27.2.1 volatile K_BOOL g_bIsKernelAware = false

Will be set to true by a kernel-aware host.

Definition at line 71 of file kernelaware.cpp.

15.27.2.2 KernelAwareData_t g_stKAData

Data structure used to communicate with host.

Definition at line 73 of file kernelaware.cpp.

15.28 kernelaware.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "kernelaware.h"
#include "threadport.h"

#if KERNEL_AWARE_SIMULATION

//---------------------------------------------------------------------------
typedef union
{
    volatile K_USHORT ausBuffer[5];

    struct
    {
        volatile const K_CHAR *szName;
    } Profiler;
    struct
    {
        volatile K_USHORT usFile;
        volatile K_USHORT usLine;
        volatile K_USHORT usCode;
        volatile K_USHORT usArg1;
        volatile K_USHORT usArg2;
    } Trace;
    struct
    {
        volatile const K_CHAR *szString;
    } Print;
} KernelAwareData_t;

//---------------------------------------------------------------------------
volatile K_BOOL           g_bIsKernelAware = false;
volatile K_UCHAR        g_ucKACommand;
KernelAwareData_t       g_stKAData;


//---------------------------------------------------------------------------
void KernelAware::ProfileInit(const K_CHAR *szStr_)
{
    CS_ENTER();
    g_stKAData.Profiler.szName = szStr_;
    g_ucKACommand = KA_COMMAND_PROFILE_INIT;
    CS_EXIT();
}

//---------------------------------------------------------------------------
void KernelAware::ProfileStart(void)
{
    g_ucKACommand = KA_COMMAND_PROFILE_START;
}

//---------------------------------------------------------------------------
void KernelAware::ProfileStop(void)
{
    g_ucKACommand = KA_COMMAND_PROFILE_STOP;
}

//---------------------------------------------------------------------------
void KernelAware::ProfileReport(void)
{
    g_ucKACommand = KA_COMMAND_PROFILE_REPORT;
}

//---------------------------------------------------------------------------
void KernelAware::ExitSimulator(void)
{
    g_ucKACommand = KA_COMMAND_EXIT_SIMULATOR;
}

//---------------------------------------------------------------------------
void KernelAware::Trace( K_USHORT usFile_,
                          K_USHORT usLine_,
                          K_USHORT usCode_ )
{
    Trace_i( usFile_, usLine_, usCode_, 0, 0, KA_COMMAND_TRACE_0 );
}

//---------------------------------------------------------------------------
void KernelAware::Trace( K_USHORT usFile_,
                          K_USHORT usLine_,
                          K_USHORT usCode_,
                          K_USHORT usArg1_)
{
    Trace_i( usFile_, usLine_, usCode_, usArg1_, 0 ,KA_COMMAND_TRACE_1 );

}
//---------------------------------------------------------------------------
void KernelAware::Trace( K_USHORT usFile_,
                          K_USHORT usLine_,
                          K_USHORT usCode_,
                          K_USHORT usArg1_,
                          K_USHORT usArg2_)
{
    Trace_i( usFile_, usLine_, usCode_, usArg1_, usArg2_, KA_COMMAND_TRACE_2 );
}

//---------------------------------------------------------------------------
void KernelAware::Trace_i( K_USHORT usFile_,
                          K_USHORT usLine_,
                          K_USHORT usCode_,
                          K_USHORT usArg1_,
                          K_USHORT usArg2_,
                          KernelAwareCommand_t eCmd_ )
{
    CS_ENTER();
    g_stKAData.Trace.usFile = usFile_;
    g_stKAData.Trace.usLine = usLine_;
    g_stKAData.Trace.usCode = usCode_;
    g_stKAData.Trace.usArg1 = usArg1_;
    g_stKAData.Trace.usArg2 = usArg2_;
    g_ucKACommand = eCmd_;
    CS_EXIT();
}

//---------------------------------------------------------------------------
void KernelAware::Print(const K_CHAR *szStr_)
{
    CS_ENTER();
    g_stKAData.Print.szString = szStr_;
    g_ucKACommand = KA_COMMAND_PRINT;
    CS_EXIT();
}

//---------------------------------------------------------------------------
K_BOOL KernelAware::IsSimulatorAware(void)
{
    return g_bIsKernelAware;
}

#endif
```

15.29 /home/moslevin/Project/R1/kernel/ksemaphore.cpp File Reference

Semaphore Blocking-Object Implemenation.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ksemaphore.h"
#include "blocking.h"
#include "kerneldebug.h"
#include "timerlist.h"
```

Macros

- #define __FILE_ID__ SEMAPHORE_CPP

  File ID used in kernel trace calls.

Functions

- void TimedSemaphore_Callback (Thread *pclOwner_, void *pvData_)

  TimedSemaphore_Callback.

15.29.1 Detailed Description

Semaphore Blocking-Object Implemenation.

Definition in file ksemaphore.cpp.

15.29.2 Function Documentation

15.29.2.1 void TimedSemaphore_Callback (Thread * *pclOwner_*, void * *pvData_*)

TimedSemaphore_Callback.

This function is called from the timer-expired context to trigger a timeout on this semphore. This results in the waking of the thread that generated the semaphore pend call that was not completed in time.

Parameters

*pclOwner_*	Pointer to the thread to wake
*pvData_*	Pointer to the semaphore object that the thread is blocked on

Definition at line 50 of file ksemaphore.cpp.

15.30 ksemaphore.cpp

```
00001 /*===========================================================================
00002      _____        _____        _____        _____
00003  ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
00004 |    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
00005 |     \/   | ||     \     ||     \     ||     \     ||___   |
00006 |__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
00007     |_____|      |_____|      |_____|      |_____|
00008 
00009 --[Mark3 Realtime Platform]--------------------------------------------------
00010 
00011 Copyright (c) 2012-2015 Funkenstein Software Consulting, all rights reserved.
00012 See license.txt for more information
00013 ===========================================================================*/
00022 #include "kerneltypes.h"
00023 #include "mark3cfg.h"
00024 
00025 #include "ksemaphore.h"
00026 #include "blocking.h"
00027 #include "kerneldebug.h"
00028 //---------------------------------------------------------------------------
00029 #if defined __FILE_ID__
00030     #undef __FILE_ID__
00031 #endif
00032 #define __FILE_ID__     SEMAPHORE_CPP
00033 
00034 #if KERNEL_USE_SEMAPHORE
00035 
00036 #if KERNEL_USE_TIMEOUTS
00037 #include "timerlist.h"
00038 
00039 //---------------------------------------------------------------------------
00050 void TimedSemaphore_Callback(Thread *pclOwner_, void *pvData_)
00051 {
00052     Semaphore *pclSemaphore = static_cast<Semaphore*>(pvData_);
00053 
00054     // Indicate that the semaphore has expired on the thread
00055     pclOwner_->SetExpired(true);
00056 
00057     // Wake up the thread that was blocked on this semaphore.
00058     pclSemaphore->WakeMe(pclOwner_);
00059 
00060 
00061     if (pclOwner_->GetCurPriority() >= Scheduler::GetCurrentThread
      ()->GetCurPriority())
00062     {
00063         Thread::Yield();
00064     }
00065 }
00066 
00067 //---------------------------------------------------------------------------
00068 void Semaphore::WakeMe(Thread *pclChosenOne_)
00069 {
00070     // Remove from the semaphore waitlist and back to its ready list.
00071     UnBlock(pclChosenOne_);
00072 }
00073 
00074 #endif // KERNEL_USE_TIMEOUTS
00075 
00076 //---------------------------------------------------------------------------
00077 K_UCHAR Semaphore::WakeNext()
00078 {
00079     Thread *pclChosenOne;
00080 
00081     pclChosenOne = m_clBlockList.HighestWaiter();
00082 
00083     // Remove from the semaphore waitlist and back to its ready list.
00084     UnBlock(pclChosenOne);
00085 
00086     // Call a task switch if higher or equal priority thread
00087     if (pclChosenOne->GetCurPriority() >=
      Scheduler::GetCurrentThread()->GetCurPriority())
00088     {
00089         return 1;
```

```
    }
    return 0;
}

//---------------------------------------------------------------------------
void Semaphore::Init(K_USHORT usInitVal_, K_USHORT usMaxVal_)
{
    // Copy the paramters into the object - set the maximum value for this
    // semaphore to implement either binary or counting semaphores, and set
    // the initial count.  Clear the wait list for this object.
    m_usValue = usInitVal_;
    m_usMaxValue = usMaxVal_;

    m_clBlockList.Init();
}

//---------------------------------------------------------------------------
K_BOOL Semaphore::Post()
{
    KERNEL_TRACE_1( STR_SEMAPHORE_POST_1, (K_USHORT) g_pstCurrent->GetID() );

    K_BOOL bThreadWake = 0;
    K_BOOL bBail = false;
    // Increment the semaphore count - we can mess with threads so ensure this
    // is in a critical section.  We don't just disable the scheudler since
    // we want to be able to do this from within an interrupt context as well.
    CS_ENTER();

    // If nothing is waiting for the semaphore
    if (m_clBlockList.GetHead() == NULL)
    {
        // Check so see if we've reached the maximum value in the semaphore
        if (m_usValue < m_usMaxValue)
        {
            // Increment the count value
            m_usValue++;
        }
        else
        {
            // Maximum value has been reached, bail out.
            bBail = true;
        }
    }
    else
    {
        // Otherwise, there are threads waiting for the semaphore to be
        // posted, so wake the next one (highest priority goes first).
        bThreadWake = WakeNext();
    }

    CS_EXIT();

    // If we weren't able to increment the semaphore count, fail out.
    if (bBail)
    {
        return false;
    }

    // if bThreadWake was set, it means that a higher-priority thread was
    // woken.  Trigger a context switch to ensure that this thread gets
    // to execute next.
    if (bThreadWake)
    {
        Thread::Yield();
    }
    return true;
}

//---------------------------------------------------------------------------
#if KERNEL_USE_TIMEOUTS
K_BOOL Semaphore::Pend_i( K_ULONG ulWaitTimeMS_ )
#else
void Semaphore::Pend_i( void )
#endif
{
    KERNEL_TRACE_1( STR_SEMAPHORE_PEND_1, (K_USHORT) g_pstCurrent->GetID() );

#if KERNEL_USE_TIMEOUTS
    Timer clSemTimer;
    K_BOOL bUseTimer = false;
#endif

    // Once again, messing with thread data - ensure
    // we're doing all of these operations from within a thread-safe context.
    CS_ENTER();

    // Check to see if we need to take any action based on the semaphore count
    if (m_usValue != 0)
    {
        // The semaphore count is non-zero, we can just decrement the count
        // and go along our merry way.
        m_usValue--;
    }
    else
    {
        // The semaphore count is zero - we need to block the current thread
        // and wait until the semaphore is posted from elsewhere.
#if KERNEL_USE_TIMEOUTS
        if (ulWaitTimeMS_)
        {
            g_pstCurrent->SetExpired(false);
            clSemTimer.Init();
            clSemTimer.Start(0, ulWaitTimeMS_, TimedSemaphore_Callback, (void*)this)
;
            bUseTimer = true;
        }
#endif
        Block(g_pstCurrent);

        // Switch Threads immediately
        Thread::Yield();
    }

    CS_EXIT();

#if KERNEL_USE_TIMEOUTS
    if (bUseTimer)
    {
        clSemTimer.Stop();
        return (g_pstCurrent->GetExpired() == 0);
    }
    return true;
#endif
}

//---------------------------------------------------------------------------
// Redirect the untimed pend API to the timed pend, with a null timeout.
void Semaphore::Pend()
{
#if KERNEL_USE_TIMEOUTS
    Pend_i(0);
#else
    Pend_i();
#endif
}

#if KERNEL_USE_TIMEOUTS
//---------------------------------------------------------------------------
K_BOOL Semaphore::Pend( K_ULONG ulWaitTimeMS_ )
{
    return Pend_i( ulWaitTimeMS_ );
}
#endif

//---------------------------------------------------------------------------
K_USHORT Semaphore::GetCount()
{
    K_USHORT usRet;
    CS_ENTER();
    usRet = m_usValue;
    CS_EXIT();
    return usRet;
}

#endif
```

15.31 /home/moslevin/Project/R1/kernel/ll.cpp File Reference

Core Linked-List implementation, from which all kernel objects are derived.

```
#include "kerneltypes.h"
#include "kernel.h"
#include "ll.h"
#include "kerneldebug.h"
```

Macros

- #define __FILE_ID__ LL_CPP

  File ID used in kernel trace calls.

15.31.1 Detailed Description

Core Linked-List implementation, from which all kernel objects are derived.

Definition in file ll.cpp.

15.32 ll.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "kernel.h"
#include "ll.h"
#include "kerneldebug.h"

//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     LL_CPP

//---------------------------------------------------------------------------
void LinkListNode::ClearNode()
{
    next = NULL;
    prev = NULL;
}

//---------------------------------------------------------------------------
void DoubleLinkList::Add(LinkListNode *node_)
{
    KERNEL_ASSERT( node_ );

    // Add a node to the end of the linked list.
    if (!m_pstHead)
    {
        // If the list is empty, initilize the nodes
        m_pstHead = node_;
        m_pstTail = node_;

        m_pstHead->prev = NULL;
        m_pstTail->next = NULL;
        return;
    }

    // Move the tail node, and assign it to the new node just passed in
    m_pstTail->next = node_;
    node_->prev = m_pstTail;
    node_->next = NULL;
    m_pstTail = node_;
}

//---------------------------------------------------------------------------
void DoubleLinkList::Remove(LinkListNode *node_)
{
    KERNEL_ASSERT( node_ );

    if (node_->prev)
    {
#if SAFE_UNLINK
        if (node_->prev->next != node_)
        {
            Kernel::Panic(PANIC_LIST_UNLINK_FAILED);
        }
#endif
        node_->prev->next = node_->next;
    }
    if (node_->next)
    {
#if SAFE_UNLINK
        if (node_->next->prev != node_)
        {
            Kernel::Panic(PANIC_LIST_UNLINK_FAILED);
        }
#endif
        node_->next->prev = node_->prev;
    }
    if (node_ == m_pstHead)
    {
        m_pstHead = node_->next;
    }
    if (node_ == m_pstTail)
    {
        m_pstTail = node_->prev;
    }

    node_->ClearNode();
}

//---------------------------------------------------------------------------
void CircularLinkList::Add(LinkListNode *node_)
{
    KERNEL_ASSERT( node_ );

    // Add a node to the end of the linked list.
    if (!m_pstHead)
    {
        // If the list is empty, initilize the nodes
        m_pstHead = node_;
        m_pstTail = node_;

        m_pstHead->prev = m_pstHead;
        m_pstHead->next = m_pstHead;
        return;
    }

    // Move the tail node, and assign it to the new node just passed in
    m_pstTail->next = node_;
    node_->prev = m_pstTail;
    node_->next = m_pstHead;
    m_pstTail = node_;
    m_pstHead->prev = node_;
}

//---------------------------------------------------------------------------
void CircularLinkList::Remove(LinkListNode *node_)
{
    KERNEL_ASSERT( node_ );

    // Check to see if this is the head of the list...
    if ((node_ == m_pstHead) && (m_pstHead == m_pstTail))
    {
        // Clear the head and tail pointers - nothing else left.
        m_pstHead = NULL;
        m_pstTail = NULL;
        return;
    }

#if SAFE_UNLINK
    // Verify that all nodes are properly connected
    if ((node_->prev->next != node_) || (node_->next->prev != node_))
    {
        Kernel::Panic(PANIC_LIST_UNLINK_FAILED);
    }
#endif

    // This is a circularly linked list - no need to check for connection,
    // just remove the node.
    node_->next->prev = node_->prev;
    node_->prev->next = node_->next;

    if (node_ == m_pstHead)
    {
        m_pstHead = m_pstHead->next;
    }
    if (node_ == m_pstTail)
    {
        m_pstTail = m_pstTail->prev;
    }
    node_->ClearNode();
}

//---------------------------------------------------------------------------
void CircularLinkList::PivotForward()
{
    if (m_pstHead)
    {
        m_pstHead = m_pstHead->next;
        m_pstTail = m_pstTail->next;
    }
}

//---------------------------------------------------------------------------
void CircularLinkList::PivotBackward()
{
    if (m_pstHead)
    {
        m_pstHead = m_pstHead->prev;
        m_pstTail = m_pstTail->prev;
    }
}
```

15.33 /home/moslevin/Project/R1/kernel/message.cpp File Reference

Inter-thread communications via message passing.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "message.h"
#include "threadport.h"
#include "kerneldebug.h"
#include "timerlist.h"
```

Macros

- #define __FILE_ID__ MESSAGE_CPP

    File ID used in kernel trace calls.

15.33.1 Detailed Description

Inter-thread communications via message passing.

Definition in file message.cpp.

15.34 message.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"

#include "message.h"
#include "threadport.h"
#include "kerneldebug.h"

```

```
//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     MESSAGE_CPP


#if KERNEL_USE_MESSAGE

#if KERNEL_USE_TIMEOUTS
    #include "timerlist.h"
#endif

Message GlobalMessagePool::m_aclMessagePool[GLOBAL_MESSAGE_POOL_SIZE];
DoubleLinkList GlobalMessagePool::m_clList;

//---------------------------------------------------------------------------
void GlobalMessagePool::Init()
{
    K_UCHAR i;
    GlobalMessagePool::m_clList.Init();
    for (i = 0; i < GLOBAL_MESSAGE_POOL_SIZE; i++)
    {
        GlobalMessagePool::m_aclMessagePool[i].Init();
        GlobalMessagePool::m_clList.Add(&(GlobalMessagePool::m_aclMessagePool[i]));
    }
}

//---------------------------------------------------------------------------
void GlobalMessagePool::Push( Message *pclMessage_ )
{
    KERNEL_ASSERT( pclMessage_ );

    CS_ENTER();

    GlobalMessagePool::m_clList.Add(pclMessage_);

    CS_EXIT();
}

//---------------------------------------------------------------------------
Message *GlobalMessagePool::Pop()
{
    Message *pclRet;
    CS_ENTER();

    pclRet = static_cast<Message*>( GlobalMessagePool::m_clList.GetHead() );
    if (0 != pclRet)
    {
        GlobalMessagePool::m_clList.Remove( static_cast<LinkListNode*>( pclRet ) );
    }

    CS_EXIT();
    return pclRet;
}

//---------------------------------------------------------------------------
void MessageQueue::Init()
{
    m_clSemaphore.Init(0, GLOBAL_MESSAGE_POOL_SIZE);
}

//---------------------------------------------------------------------------
Message *MessageQueue::Receive()
{
#if KERNEL_USE_TIMEOUTS
    return Receive_i(0);
#else
    return Receive_i();
#endif
}

//---------------------------------------------------------------------------
#if KERNEL_USE_TIMEOUTS
Message *MessageQueue::Receive( K_ULONG ulTimeWaitMS_)
{
    return Receive_i( ulTimeWaitMS_ );
}
#endif

//---------------------------------------------------------------------------
#if KERNEL_USE_TIMEOUTS
Message *MessageQueue::Receive_i( K_ULONG ulTimeWaitMS_ )
#else
Message *MessageQueue::Receive_i( void )
#endif
```

```
{
    Message *pclRet;

    // Block the current thread on the counting semaphore
#if KERNEL_USE_TIMEOUTS
    if (!m_clSemaphore.Pend(ulTimeWaitMS_))
    {
        return NULL;
    }
#else
    m_clSemaphore.Pend();
#endif

    CS_ENTER();

    // Pop the head of the message queue and return it
    pclRet = static_cast<Message*>( m_clLinkList.GetHead() );
    m_clLinkList.Remove(static_cast<Message*>(pclRet));

    CS_EXIT();

    return pclRet;
}

//---------------------------------------------------------------------------
void MessageQueue::Send( Message *pclSrc_ )
{
    KERNEL_ASSERT( pclSrc_ );

    CS_ENTER();

    // Add the message to the head of the linked list
    m_clLinkList.Add( pclSrc_ );

    // Post the semaphore, waking the blocking thread for the queue.
    m_clSemaphore.Post();

    CS_EXIT();
}

//---------------------------------------------------------------------------
K_USHORT MessageQueue::GetCount()
{
    return m_clSemaphore.GetCount();
}
#endif //KERNEL_USE_MESSAGE
```

15.35 /home/moslevin/Project/R1/kernel/mutex.cpp File Reference

Mutual-exclusion object.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "blocking.h"
#include "mutex.h"
#include "kerneldebug.h"
```

Macros

- #define __FILE_ID__ MUTEX_CPP

  File ID used in kernel trace calls.

Functions

- void TimedMutex_Calback (Thread *pclOwner_, void *pvData_)

  TimedMutex_Calback.

15.35.1 Detailed Description

Mutual-exclusion object.

Definition in file mutex.cpp.

15.35.2 Function Documentation

15.35.2.1 void TimedMutex_Calback (Thread ∗ *pclOwner_*, void ∗ *pvData_*)

TimedMutex_Calback.

This function is called from the timer-expired context to trigger a timeout on this mutex. This results in the waking of the thread that generated the mutex claim call that was not completed in time.

Parameters

*pclOwner_*	Pointer to the thread to wake
*pvData_*	Pointer to the mutex object that the thread is blocked on

Definition at line 48 of file mutex.cpp.

15.36 mutex.cpp

```
00001 /*===========================================================================
00002      _____        _____        _____        _____
00003  ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
00004 |    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
00005 |     \/   | ||     \     ||     \     ||     \     ||___   |
00006 |__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
00007     |_____|      |_____|      |_____|      |_____|
00008
00009 --[Mark3 Realtime Platform]--------------------------------------------------
00010
00011 Copyright (c) 2012-2015 Funkenstein Software Consulting, all rights reserved.
00012 See license.txt for more information
00013 ===========================================================================*/
00020 #include "kerneltypes.h"
00021 #include "mark3cfg.h"
00022
00023 #include "blocking.h"
00024 #include "mutex.h"
00025 #include "kerneldebug.h"
00026 //---------------------------------------------------------------------------
00027 #if defined __FILE_ID__
00028     #undef __FILE_ID__
00029 #endif
00030 #define __FILE_ID__     MUTEX_CPP
00031
00032
00033 #if KERNEL_USE_MUTEX
00034
00035 #if KERNEL_USE_TIMEOUTS
00036
00037 //---------------------------------------------------------------------------
00048 void TimedMutex_Calback(Thread *pclOwner_, void *pvData_)
00049 {
00050     Mutex *pclMutex = static_cast<Mutex*>(pvData_);
00051
00052     // Indicate that the semaphore has expired on the thread
00053     pclOwner_->SetExpired(true);
00054
00055     // Wake up the thread that was blocked on this semaphore.
00056     pclMutex->WakeMe(pclOwner_);
00057
00058     if (pclOwner_->GetCurPriority() >= Scheduler::GetCurrentThread
      ()->GetCurPriority())
00059     {
00060         Thread::Yield();
00061     }
00062 }
00063
00064 //---------------------------------------------------------------------------
00065 void Mutex::WakeMe(Thread *pclOwner_)
00066 {
    // Remove from the semaphore waitlist and back to its ready list.
    UnBlock(pclOwner_);
}

#endif

//---------------------------------------------------------------------------
K_UCHAR Mutex::WakeNext()
{
    Thread *pclChosenOne = NULL;

    // Get the highest priority waiter thread
    pclChosenOne = m_clBlockList.HighestWaiter();

    // Unblock the thread
    UnBlock(pclChosenOne);

    // The chosen one now owns the mutex
    m_pclOwner = pclChosenOne;

    // Signal a context switch if it's a greater than or equal to the current priority
    if (pclChosenOne->GetCurPriority() >= Scheduler::GetCurrentThread()->GetCurPriority())
    {
        return 1;
    }
    return 0;
}

//---------------------------------------------------------------------------
void Mutex::Init()
{
    // Reset the data in the mutex
    m_bReady = 1;             // The mutex is free.
    m_ucMaxPri = 0;           // Set the maximum priority inheritence state
    m_pclOwner = NULL;        // Clear the mutex owner
    m_ucRecurse = 0;          // Reset recurse count
}

//---------------------------------------------------------------------------
#if KERNEL_USE_TIMEOUTS
K_BOOL Mutex::Claim_i(K_ULONG ulWaitTimeMS_)
#else
void Mutex::Claim_i(void)
#endif
{
    KERNEL_TRACE_1( STR_MUTEX_CLAIM_1, (K_USHORT) g_pstCurrent->GetID() );

#if KERNEL_USE_TIMEOUTS
    Timer clTimer;
    K_BOOL bUseTimer = false;
#endif

    // Disable the scheduler while claiming the mutex - we're dealing with all
    // sorts of private thread data, can't have a thread switch while messing
    // with internal data structures.
    Scheduler::SetScheduler(0);

    // Check to see if the mutex is claimed or not
    if (m_bReady != 0)
    {
        // Mutex isn't claimed, claim it.
        m_bReady = 0;
        m_ucRecurse = 0;
        m_ucMaxPri = g_pstCurrent->GetPriority();
        m_pclOwner = g_pstCurrent;

        Scheduler::SetScheduler(1);

#if KERNEL_USE_TIMEOUTS
        return true;
#else
        return;
#endif
    }

    // If the mutex is already claimed, check to see if this is the owner thread,
    // since we allow the mutex to be claimed recursively.
    if (g_pstCurrent == m_pclOwner)
    {
        // Ensure that we haven't exceeded the maximum recursive-lock count
        KERNEL_ASSERT( (m_ucRecurse < 255) );
        m_ucRecurse++;

        // Increment the lock count and bail
        Scheduler::SetScheduler(1);
#if KERNEL_USE_TIMEOUTS
        return true;
#else
        return;
#endif
    }

    // The mutex is claimed already - we have to block now.  Move the
    // current thread to the list of threads waiting on the mutex.
#if KERNEL_USE_TIMEOUTS
    if (ulWaitTimeMS_)
    {
        g_pstCurrent->SetExpired(false);
        clTimer.Init();
        clTimer.Start(0, ulWaitTimeMS_, (TimerCallback_t)
TimedMutex_Calback, (void*)this);
        bUseTimer = true;
    }
#endif
    Block(g_pstCurrent);

    // Check if priority inheritence is necessary.  We do this in order
    // to ensure that we don't end up with priority inversions in case
    // multiple threads are waiting on the same resource.
    if(m_ucMaxPri <= g_pstCurrent->GetPriority())
    {
        m_ucMaxPri = g_pstCurrent->GetPriority();

        Thread *pclTemp = static_cast<Thread*>(m_clBlockList.GetHead());
        while(pclTemp)
        {
            pclTemp->InheritPriority(m_ucMaxPri);
            if(pclTemp == static_cast<Thread*>(m_clBlockList.GetTail()) )
            {
                break;
            }
            pclTemp = static_cast<Thread*>(pclTemp->GetNext());
        }
        m_pclOwner->InheritPriority(m_ucMaxPri);
    }

    // Done with thread data -reenable the scheduler
    Scheduler::SetScheduler(1);

    // Switch threads if this thread acquired the mutex
    Thread::Yield();

#if KERNEL_USE_TIMEOUTS
    if (bUseTimer)
    {
        clTimer.Stop();
        return (g_pstCurrent->GetExpired() == 0);
    }
    return true;
#endif
}

//---------------------------------------------------------------------------
void Mutex::Claim(void)
{
#if KERNEL_USE_TIMEOUTS
    Claim_i(0);
#else
    Claim_i();
#endif
}

//---------------------------------------------------------------------------
#if KERNEL_USE_TIMEOUTS
K_BOOL Mutex::Claim(K_ULONG ulWaitTimeMS_)
{
    return Claim_i(ulWaitTimeMS_);
}
#endif

//---------------------------------------------------------------------------
void Mutex::Release()
{
    KERNEL_TRACE_1( STR_MUTEX_RELEASE_1, (K_USHORT)
g_pstCurrent->GetID() );

    K_BOOL bSchedule = 0;

    // Disable the scheduler while we deal with internal data structures.
    Scheduler::SetScheduler(0);

    // This thread had better be the one that owns the mutex currently...
    KERNEL_ASSERT( (g_pstCurrent == m_pclOwner) );

    // If the owner had claimed the lock multiple times, decrease the lock
    // count and return immediately.
    if (m_ucRecurse)
    {
        m_ucRecurse--;
        Scheduler::SetScheduler(1);
        return;
    }

    // Restore the thread's original priority
    if (g_pstCurrent->GetCurPriority() != g_pstCurrent->
GetPriority())
    {
        g_pstCurrent->SetPriority(g_pstCurrent->
GetPriority());

        // In this case, we want to reschedule
        bSchedule = 1;
    }

    // No threads are waiting on this semaphore?
    if (m_clBlockList.GetHead() == NULL)
    {
        // Re-initialize the mutex to its default values
        m_bReady = 1;
        m_ucMaxPri = 0;
        m_pclOwner = NULL;
    }
    else
    {
        // Wake the highest priority Thread pending on the mutex
        if(WakeNext())
        {
            // Switch threads if it's higher or equal priority than the current thread
            bSchedule = 1;
        }
    }

    // Must enable the scheduler again in order to switch threads.
    Scheduler::SetScheduler(1);
    if(bSchedule)
    {
        // Switch threads if a higher-priority thread was woken
        Thread::Yield();
    }
}

#endif //KERNEL_USE_MUTEX
```

15.37 /home/moslevin/Project/R1/kernel/profile.cpp File Reference

Code profiling utilities.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "profile.h"
#include "kernelprofile.h"
#include "threadport.h"
#include "kerneldebug.h"
```

Macros

- #define __FILE_ID__ PROFILE_CPP

  File ID used in kernel trace calls.

15.37.1 Detailed Description

Code profiling utilities.

Definition in file profile.cpp.

15.38 profile.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "profile.h"
#include "kernelprofile.h"
#include "threadport.h"
#include "kerneldebug.h"
//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     PROFILE_CPP


#if KERNEL_USE_PROFILER

//---------------------------------------------------------------------------
void ProfileTimer::Init()
{
    m_ulCumulative = 0;
    m_ulCurrentIteration = 0;
    m_usIterations = 0;
    m_bActive = 0;
}

//---------------------------------------------------------------------------
void ProfileTimer::Start()
{
    if (!m_bActive)
    {
        CS_ENTER();
        m_ulCurrentIteration = 0;
        m_ulInitialEpoch = Profiler::GetEpoch();
        m_usInitial = Profiler::Read();
        CS_EXIT();
        m_bActive = 1;
    }
}

//---------------------------------------------------------------------------
void ProfileTimer::Stop()
{
    if (m_bActive)
    {
        K_USHORT usFinal;
        K_ULONG ulEpoch;
        CS_ENTER();
        usFinal = Profiler::Read();
        ulEpoch = Profiler::GetEpoch();
        // Compute total for current iteration...
        m_ulCurrentIteration = ComputeCurrentTicks(usFinal, ulEpoch)
;
        m_ulCumulative += m_ulCurrentIteration;
        m_usIterations++;
        CS_EXIT();
        m_bActive = 0;
    }
}

//---------------------------------------------------------------------------
K_ULONG ProfileTimer::GetAverage()
{
    if (m_usIterations)
    {
        return m_ulCumulative / (K_ULONG)m_usIterations;
    }
    return 0;
}

//---------------------------------------------------------------------------
K_ULONG ProfileTimer::GetCurrent()
{

    if (m_bActive)
    {
        K_USHORT usCurrent;
        K_ULONG ulEpoch;
        CS_ENTER();
        usCurrent = Profiler::Read();
        ulEpoch = Profiler::GetEpoch();
        CS_EXIT();
        return ComputeCurrentTicks(usCurrent, ulEpoch);
    }
    return m_ulCurrentIteration;
}

//---------------------------------------------------------------------------
K_ULONG ProfileTimer::ComputeCurrentTicks(
K_USHORT usCurrent_, K_ULONG ulEpoch_)
{
    K_ULONG ulTotal;
    K_ULONG ulOverflows;

    ulOverflows = ulEpoch_ - m_ulInitialEpoch;

    // More than one overflow...
    if (ulOverflows > 1)
    {
        ulTotal = ((K_ULONG)(ulOverflows-1) * TICKS_PER_OVERFLOW)
                + (K_ULONG)(TICKS_PER_OVERFLOW - m_usInitial) +
                (K_ULONG)usCurrent_;
    }
    // Only one overflow, or one overflow that has yet to be processed
    else if (ulOverflows || (usCurrent_ < m_usInitial))
    {
        ulTotal = (K_ULONG)(TICKS_PER_OVERFLOW - m_usInitial) +
                (K_ULONG)usCurrent_;
    }
    // No overflows, none pending.
    else
    {
        ulTotal = (K_ULONG)(usCurrent_ - m_usInitial);
    }

    return ulTotal;
}

#endif
```

15.39 /home/moslevin/Project/R1/kernel/public/atomic.h File Reference

Basic Atomic Operations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "threadport.h"
```

15.39.1 Detailed Description

Basic Atomic Operations.

Definition in file atomic.h.

15.40 atomic.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/    | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __ATOMIC_H__
#define __ATOMIC_H__

#include "kerneltypes.h"
#include "mark3cfg.h"
#include "threadport.h"

#if KERNEL_USE_ATOMIC

class Atomic
{
public:
    static K_UCHAR Set( K_UCHAR *pucSource_, K_UCHAR ucVal_ );
    static K_USHORT Set( K_USHORT *pusSource_, K_USHORT usVal_ );
    static K_ULONG Set( K_ULONG *pulSource_, K_ULONG ulVal_ );

    static K_UCHAR Add( K_UCHAR *pucSource_, K_UCHAR ucVal_ );
    static K_USHORT Add( K_USHORT *pusSource_, K_USHORT usVal_ );
    static K_ULONG Add( K_ULONG *pulSource_, K_ULONG ulVal_ );

    static K_UCHAR Sub( K_UCHAR *pucSource_, K_UCHAR ucVal_ );
    static K_USHORT Sub( K_USHORT *pusSource_, K_USHORT usVal_ );
    static K_ULONG Sub( K_ULONG *pulSource_, K_ULONG ulVal_ );

    static K_BOOL TestAndSet( K_BOOL *pbLock );
};

#endif // KERNEL_USE_ATOMIC

#endif //__ATOMIC_H__
```

15.41 /home/moslevin/Project/R1/kernel/public/blocking.h File Reference

Blocking object base class declarations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
#include "threadlist.h"
#include "thread.h"
```

Classes

- class BlockingObject

  Class implementing thread-blocking primatives.

15.41.1 Detailed Description

Blocking object base class declarations. A Blocking object in Mark3 is essentially a thread list. Any blocking object implementation (being a semaphore, mutex, event flag, etc.) can be built on top of this class, utilizing the provided functions to manipulate thread location within the Kernel.

Blocking a thread results in that thread becoming de-scheduled, placed in the blocking object's own private list of threads which are waiting on the object.

Unblocking a thread results in the reverse: The thread is moved back to its original location from the blocking list.

The only difference between a blocking object based on this class is the logic used to determine what consitutes a Block or Unblock condition.

For instance, a semaphore Pend operation may result in a call to the Block() method with the currently-executing thread in order to make that thread wait for a semaphore Post. That operation would then invoke the UnBlock() method, removing the blocking thread from the semaphore's list, and back into the the appropriate thread inside the scheduler.

Care must be taken when implementing blocking objects to ensure that critical sections are used judiciously, otherwise asynchronous events like timers and interrupts could result in non-deterministic and often catastrophic behavior.

Definition in file blocking.h.

15.42 blocking.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __BLOCKING_H__
#define __BLOCKING_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "ll.h"
#include "threadlist.h"
#include "thread.h"

#if KERNEL_USE_MUTEX || KERNEL_USE_SEMAPHORE || KERNEL_USE_EVENTFLAG

//---------------------------------------------------------------------------
class BlockingObject
{
protected:
    void Block(Thread *pclThread_ );

    void UnBlock(Thread *pclThread_);

    ThreadList m_clBlockList;
};

#endif

#endif
```

15.43 /home/moslevin/Project/R1/kernel/public/debugtokens.h File Reference

Hex codes/translation tables used for efficient string tokenization.

Macros

- #define BLOCKING_CPP 0x0001 /∗ SUBSTITUTE="blocking.cpp" ∗/

  Source file names start at 0x0000.

- #define BLOCKING_H 0x1000 /∗ SUBSTITUTE="blocking.h" ∗/

  Header file names start at 0x1000.

- #define STR_PANIC 0x2000 /∗ SUBSTITUTE="!Panic!" ∗/

  Indexed strings start at 0x2000.

15.43.1 Detailed Description

Hex codes/translation tables used for efficient string tokenization. We use this for efficiently encoding strings used for kernel traces, debug prints, etc. The upside - this is really fast and efficient for encoding strings and data. Downside? The tools need to parse this header file in order to convert the enumerated data into actual strings, decoding them.

Definition in file debugtokens.h.

15.44 debugtokens.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __DEBUG_TOKENS_H__
#define __DEBUG_TOKENS_H__
//---------------------------------------------------------------------------
#define BLOCKING_CPP        0x0001      /* SUBSTITUTE="blocking.cpp" */
#define DRIVER_CPP          0x0002      /* SUBSTITUTE="driver.cpp" */
#define KERNEL_CPP          0x0003      /* SUBSTITUTE="kernel.cpp" */
#define LL_CPP              0x0004      /* SUBSTITUTE="ll.cpp" */
#define MESSAGE_CPP         0x0005      /* SUBSTITUTE="message.cpp" */
#define MUTEX_CPP           0x0006      /* SUBSTITUTE="mutex.cpp" */
#define PROFILE_CPP         0x0007      /* SUBSTITUTE="profile.cpp" */
#define QUANTUM_CPP         0x0008      /* SUBSTITUTE="quantum.cpp" */
#define SCHEDULER_CPP       0x0009      /* SUBSTITUTE="scheduler.cpp" */
#define SEMAPHORE_CPP       0x000A      /* SUBSTITUTE="semaphore.cpp" */
#define THREAD_CPP          0x000B      /* SUBSTITUTE="thread.cpp" */
#define THREADLIST_CPP      0x000C      /* SUBSTITUTE="threadlist.cpp" */
#define TIMERLIST_CPP       0x000D      /* SUBSTITUTE="timerlist.cpp" */
#define KERNELSWI_CPP       0x000E      /* SUBSTITUTE="kernelswi.cpp" */
#define KERNELTIMER_CPP     0x000F      /* SUBSTITUTE="kerneltimer.cpp" */
#define KPROFILE_CPP        0x0010      /* SUBSTITUTE="kernelprofile.cpp" */
#define THREADPORT_CPP      0x0011      /* SUBSTITUTE="threadport.cpp" */
#define TIMER_CPP           0x0012      /* SUBSTITUTE="timer.cpp" */

//---------------------------------------------------------------------------
#define BLOCKING_H          0x1000      /* SUBSTITUTE="blocking.h" */
#define DRIVER_H            0x1001      /* SUBSTITUTE="driver.h" */
#define KERNEL_H            0x1002      /* SUBSTITUTE="kernel.h" */
#define KERNELTYPES_H       0x1003      /* SUBSTITUTE="kerneltypes.h" */
#define LL_H                0x1004      /* SUBSTITUTE="ll.h" */
#define MANUAL_H            0x1005      /* SUBSTITUTE="manual.h" */
#define MARK3CFG_H          0x1006      /* SUBSTITUTE="mark3cfg.h" */
#define MESSAGE_H           0x1007      /* SUBSTITUTE="message.h" */
#define MUTEX_H             0x1008      /* SUBSTITUTE="mutex.h" */
#define PROFILE_H           0x1009      /* SUBSTITUTE="profile.h" */
#define PROFILING_RESULTS_H 0x100A      /* SUBSTITUTE="profiling_results.h" */
#define QUANTUM_H           0x100B      /* SUBSTITUTE="quantum.h" */
#define SCHEDULER_H         0x100C      /* SUBSTITUTE="scheduler.h" */
#define SEMAPHORE_H         0x100D      /* SUBSTITUTE="ksemaphore.h" */
#define THREAD_H            0x100E      /* SUBSTITUTE="thread.h" */
#define THREADLIST_H        0x100F      /* SUBSTITUTE="threadlist.h" */
#define TIMERLIST_H         0x1010      /* SUBSTITUTE="timerlist.h" */
#define KERNELSWI_H         0x1011      /* SUBSTITUTE="kernelswi.h */
#define KERNELTIMER_H       0x1012      /* SUBSTITUTE="kerneltimer.h */
#define KPROFILE_H          0x1013      /* SUBSTITUTE="kernelprofile.h" */
#define THREADPORT_H        0x1014      /* SUBSTITUTE="threadport.h" */

//---------------------------------------------------------------------------
#define STR_PANIC               0x2000      /* SUBSTITUTE="!Panic!" */
#define STR_MARK3_INIT          0x2001      /* SUBSTITUTE="Initializing Kernel Objects" */
#define STR_KERNEL_ENTER        0x2002      /* SUBSTITUTE="Starting Kernel" */
#define STR_THREAD_START        0x2003      /* SUBSTITUTE="Switching to First Thread" */
#define STR_START_ERROR         0x2004      /* SUBSTITUTE="Error starting kernel - function should never return" */
#define STR_THREAD_CREATE       0x2005      /* SUBSTITUTE="Creating Thread" */
#define STR_STACK_SIZE_1        0x2006      /* SUBSTITUTE="  Stack Size: %1" */
#define STR_PRIORITY_1          0x2007      /* SUBSTITUTE="  Priority: %1" */
#define STR_THREAD_ID_1         0x2008      /* SUBSTITUTE="  Thread ID: %1" */
```

```
#define STR_ENTRYPOINT_1        0x2009      /* SUBSTITUTE="  EntryPoint: %1" */
#define STR_CONTEXT_SWITCH_1    0x200A      /* SUBSTITUTE="Context Switch To Thread: %1" */
#define STR_IDLING              0x200B      /* SUBSTITUTE="Idling CPU" */
#define STR_WAKEUP              0x200C      /* SUBSTITUTE="Waking up" */
#define STR_SEMAPHORE_PEND_1    0x200D      /* SUBSTITUTE="Semaphore Pend: %1" */
#define STR_SEMAPHORE_POST_1    0x200E      /* SUBSTITUTE="Semaphore Post: %1" */
#define STR_MUTEX_CLAIM_1       0x200F      /* SUBSTITUTE="Mutex Claim: %1" */
#define STR_MUTEX_RELEASE_1     0x2010      /* SUBSTITUTE="Mutex Release: %1" */
#define STR_THREAD_BLOCK_1      0x2011      /* SUBSTITUTE="Thread %1 Blocked" */
#define STR_THREAD_UNBLOCK_1    0x2012-2015     /* SUBSTITUTE="Thread %1 Unblocked" */
#define STR_ASSERT_FAILED       0x2013      /* SUBSTITUTE="Assertion Failed" */
#define STR_SCHEDULE_1          0x2014      /* SUBSTITUTE="Scheduler chose %1" */
#define STR_THREAD_START_1      0x2015      /* SUBSTITUTE="Thread Start: %1" */
#define STR_THREAD_EXIT_1       0x2016      /* SUBSTITUTE="Thread Exit: %1" */

//---------------------------------------------------------------------------
#define STR_UNDEFINED           0xFFFF      /* SUBSTITUTE="UNDEFINED" */
#endif
```

15.45 /home/moslevin/Project/R1/kernel/public/driver.h File Reference

Driver abstraction framework.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
```

Classes

- class Driver

  Base device-driver class used in hardware abstraction.
- class DriverList

  List of Driver objects used to keep track of all device drivers in the system.

15.45.1 Detailed Description

Driver abstraction framework.

15.45.2 Intro

This is the basis of the driver framework. In the context of Mark3, drivers don't necessarily have to be based on physical hardware peripherals. They can be used to represent algorithms (such as random number generators), files, or protocol stacks. Unlike FunkOS, where driver IO is protected automatically by a mutex, we do not use this kind of protection - we leave it up to the driver implementor to do what's right in its own context. This also frees up the driver to implement all sorts of other neat stuff, like sending messages to threads associated with the driver. Drivers are implemented as character devices, with the standard array of posix-style accessor methods for reading, writing, and general driver control.

A global driver list is provided as a convenient and minimal "filesystem" structure, in which devices can be accessed by name.

15.45.3 Driver Design

A device driver needs to be able to perform the following operations: -Initialize a peripheral -Start/stop a peripheral -Handle I/O control operations -Perform various read/write operations

At the end of the day, that's pretty much all a device driver has to do, and all of the functionality that needs to be presented to the developer.

We abstract all device drivers using a base-class which implements the following methods: -Start/Open -Stop/Close -Control -Read -Write

A basic driver framework and API can thus be implemented in five function calls - that's it! You could even reduce that further by handling the initialize, start, and stop operations inside the "control" operation.

15.45.4 Driver API

In C++, we can implement this as a class to abstract these event handlers, with virtual void functions in the base class overridden by the inherited objects.

To add and remove device drivers from the global table, we use the following methods:

```
void DriverList::Add( Driver *pclDriver_ );
void DriverList::Remove( Driver *pclDriver_ );
```

DriverList::Add()/Remove() takes a single arguments the pointer to he object to operate on.

Once a driver has been added to the table, drivers are opened by NAME using DriverList::FindByName("/dev/name"). This function returns a pointer to the specified driver if successful, or to a built in /dev/null device if the path name is invalid. After a driver is open, that pointer is used for all other driver access functions.

This abstraction is incredibly useful any peripheral or service can be accessed through a consistent set of APIs, that make it easy to substitute implementations from one platform to another. Portability is ensured, the overhead is negligible, and it emphasizes the reuse of both driver and application code as separate entities.

Consider a system with drivers for I2C, SPI, and UART peripherals - under our driver framework, an application can initialize these peripherals and write a greeting to each using the same simple API functions for all drivers:

```
pclI2C  = DriverList::FindByName("/dev/i2c");
pclUART = DriverList::FindByName("/dev/tty0");
pclSPI  = DriverList::FindByName("/dev/spi");

pclI2C->Write(12,"Hello World!");
pclUART->Write(12, "Hello World!");
pclSPI->Write(12, "Hello World!");
```

Definition in file driver.h.

15.46 driver.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"

#include "ll.h"

#ifndef __DRIVER_H__
#define __DRIVER_H__

#if KERNEL_USE_DRIVER

class DriverList;
//---------------------------------------------------------------------------
class Driver : public LinkListNode
{
public:
    virtual void Init() = 0;

    virtual K_UCHAR Open() = 0;

    virtual K_UCHAR Close() = 0;

    virtual K_USHORT Read( K_USHORT usBytes_,
                                 K_UCHAR *pucData_) = 0;

    virtual K_USHORT Write( K_USHORT usBytes_,
                                  K_UCHAR *pucData_) = 0;

    virtual K_USHORT Control( K_USHORT usEvent_,
                                    void *pvDataIn_,
                                    K_USHORT usSizeIn_,
                                    void *pvDataOut_,
                                    K_USHORT usSizeOut_ ) = 0;

    void SetName( const K_CHAR *pcName_ ) { m_pcPath = pcName_; }

    const K_CHAR *GetPath() { return m_pcPath; }

private:

    const K_CHAR *m_pcPath;
};

//---------------------------------------------------------------------------
class DriverList
{
public:
    static void Init();

    static void Add( Driver *pclDriver_ ) { m_clDriverList.Add(pclDriver_); }

    static void Remove( Driver *pclDriver_ ) { m_clDriverList.Remove(pclDriver_); }

    static Driver *FindByPath( const K_CHAR *m_pcPath );

private:

    static DoubleLinkList m_clDriverList;
};

#endif //KERNEL_USE_DRIVER

#endif
```

15.47 /home/moslevin/Project/R1/kernel/public/eventflag.h File Reference

Event Flag Blocking Object/IPC-Object definition.

```
#include "mark3cfg.h"
#include "kernel.h"
#include "kerneltypes.h"
#include "blocking.h"
#include "thread.h"
```

Classes

- class EventFlag

  The EventFlag class is a blocking object, similar to a semaphore or mutex, commonly used for synchronizing thread execution based on events occurring within the system.

15.47.1 Detailed Description

Event Flag Blocking Object/IPC-Object definition.

Definition in file eventflag.h.

15.48 eventflag.h

```
/*===========================================================================
     _____     _____     _____     _____
 ___|    _|__ __|_    |__ __|__   |__ __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|     |_____|     |_____|

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===========================================================================*/
#ifndef __EVENTFLAG_H__
#define __EVENTFLAG_H__

#include "mark3cfg.h"
#include "kernel.h"
#include "kerneltypes.h"
#include "blocking.h"
#include "thread.h"

#if KERNEL_USE_EVENTFLAG

//---------------------------------------------------------------------------
class EventFlag : public BlockingObject
{
public:
    void Init() { m_usSetMask = 0; m_clBlockList.Init(); }

    K_USHORT Wait(K_USHORT usMask_, EventFlagOperation_t eMode_);

#if KERNEL_USE_TIMEOUTS

    K_USHORT Wait(K_USHORT usMask_, EventFlagOperation_t eMode_, K_ULONG ulTimeMS_);

    void WakeMe(Thread *pclOwner_);

#endif

    void Set(K_USHORT usMask_);

    void Clear(K_USHORT usMask_);

    K_USHORT GetMask();

private:

#if KERNEL_USE_TIMEOUTS

    K_USHORT Wait_i(K_USHORT usMask_, EventFlagOperation_t eMode_, K_ULONG ulTimeMS_);
#else

    K_USHORT Wait_i(K_USHORT usMask_, EventFlagOperation_t eMode_);
#endif

    K_USHORT m_usSetMask;
};

#endif //KERNEL_USE_EVENTFLAG
#endif //__EVENTFLAG_H__

```

15.49 /home/moslevin/Project/R1/kernel/public/kernel.h File Reference

Kernel initialization and startup class.

```
#include "mark3cfg.h"
#include "kerneltypes.h"
#include "paniccodes.h"
#include "thread.h"
```

Classes

- class Kernel

  Class that encapsulates all of the kernel startup functions.

15.49.1 Detailed Description

Kernel initialization and startup class. The Kernel namespace provides functions related to initializing and starting up the kernel.

The Kernel::Init() function must be called before any of the other functions in the kernel can be used.

Once the initial kernel configuration has been completed (i.e. first threads have been added to the scheduler), the Kernel::Start() function can then be called, which will transition code execution from the "main()" context to the threads in the scheduler.

Definition in file kernel.h.

15.50 kernel.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __KERNEL_H__
#define __KERNEL_H__

#include "mark3cfg.h"
#include "kerneltypes.h"
#include "paniccodes.h"
#include "thread.h"

#if KERNEL_USE_IDLE_FUNC
typedef void (*idle_func_t)(void);
#endif

//---------------------------------------------------------------------------
class Kernel
{
public:
    static void Init(void);

    static void Start(void);

    static K_BOOL IsStarted()    {   return m_bIsStarted;    }

    static void SetPanic( panic_func_t pfPanic_ ) {
m_pfPanic = pfPanic_; }

    static K_BOOL IsPanic()      {   return m_bIsPanic;   }

    static void Panic(K_USHORT usCause_);

#if KERNEL_USE_IDLE_FUNC

    static void SetIdleFunc( idle_func_t pfIdle_ )  {   m_pfIdle = pfIdle_; }

    static void IdleFunc(void) { if (m_pfIdle != 0 ){ m_pfIdle(); } }

    static Thread *GetIdleThread(void) { return (Thread*)&
m_clIdle; }
#endif

private:
    static K_BOOL m_bIsStarted;
    static K_BOOL m_bIsPanic;
    static panic_func_t m_pfPanic;
#if KERNEL_USE_IDLE_FUNC
    static idle_func_t m_pfIdle;
    static FakeThread_t m_clIdle;
#endif
};

#endif
```

15.51 /home/moslevin/Project/R1/kernel/public/kernelaware.h File Reference

Kernel aware simulation support.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
```

Classes

- class KernelAware

  The KernelAware class.

Enumerations

- enum KernelAwareCommand_t {
  KA_COMMAND_IDLE = 0, KA_COMMAND_PROFILE_INIT, KA_COMMAND_PROFILE_START, KA_COMMAND_PROFILE_STOP,
  KA_COMMAND_PROFILE_REPORT, KA_COMMAND_EXIT_SIMULATOR, KA_COMMAND_TRACE_0, KA_COMMAND_TRACE_1,
  KA_COMMAND_TRACE_2, KA_COMMAND_PRINT }

  This enumeration contains a list of supported commands that can be executed to invoke a response from a kernel aware host.

15.51.1 Detailed Description

Kernel aware simulation support.

Definition in file kernelaware.h.

15.51.2 Enumeration Type Documentation

15.51.2.1 enum KernelAwareCommand_t

This enumeration contains a list of supported commands that can be executed to invoke a response from a kernel aware host.

Enumerator

KA_COMMAND_IDLE Null command, does nothing.

KA_COMMAND_PROFILE_INIT Initialize a new profiling session.

KA_COMMAND_PROFILE_START Begin a profiling sample.

KA_COMMAND_PROFILE_STOP End a profiling sample.

KA_COMMAND_PROFILE_REPORT Report current profiling session.

KA_COMMAND_EXIT_SIMULATOR Terminate the host simulator.

KA_COMMAND_TRACE_0 0-argument kernel trace

KA_COMMAND_TRACE_1 1-argument kernel trace

KA_COMMAND_TRACE_2 2-argument kernel trace

KA_COMMAND_PRINT Print an arbitrary string of data.

Definition at line 33 of file kernelaware.h.

15.52 kernelaware.h

```
00001 /*===========================================================================
00002      _____        _____        _____        _____
00003  ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
00004 |    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
00005 |     \/   | ||     \     ||     \     ||     \     ||___   |
00006 |__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
00007     |_____|      |_____|      |_____|      |_____|
00008 
00009 --[Mark3 Realtime Platform]--------------------------------------------------
00010 
00011 Copyright (c) 2012-2015 Funkenstein Software Consulting, all rights reserved.
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00013 ===========================================================================*/
00021 #ifndef __KERNEL_AWARE_H__
00022 #define __KERNEL_AWARE_H__
00023 
00024 #include "kerneltypes.h"
00025 #include "mark3cfg.h"
00026 
00027 #if KERNEL_AWARE_SIMULATION
00028 //---------------------------------------------------------------------------
00033 typedef enum
00034 {
00035     KA_COMMAND_IDLE = 0,
00036     KA_COMMAND_PROFILE_INIT,
00037     KA_COMMAND_PROFILE_START,
00038     KA_COMMAND_PROFILE_STOP,
00039     KA_COMMAND_PROFILE_REPORT,
00040     KA_COMMAND_EXIT_SIMULATOR,
00041     KA_COMMAND_TRACE_0,
00042     KA_COMMAND_TRACE_1,
00043     KA_COMMAND_TRACE_2,
00044     KA_COMMAND_PRINT
00045 } KernelAwareCommand_t;
00046 
00047 //---------------------------------------------------------------------------
00065 class KernelAware
00066 {
00067 public:
00068     //---------------------------------------------------------------------------
00079     static void ProfileInit( const K_CHAR *szStr_ );
00080 
00081     //---------------------------------------------------------------------------
00089     static void ProfileStart( void );
00090 
00091     //---------------------------------------------------------------------------
00098     static void ProfileStop( void );
00099 
00100     //---------------------------------------------------------------------------
00108     static void ProfileReport( void );
00109 
00110     //---------------------------------------------------------------------------
00118     static void ExitSimulator( void );
00119 
00120     //---------------------------------------------------------------------------
00128     static void Print( const K_CHAR *szStr_ );
00129 
00130     //---------------------------------------------------------------------------
00141     static void Trace( K_USHORT usFile_,
00142                        K_USHORT usLine_,
00143                        K_USHORT usCode_ );
00144 
00145     //---------------------------------------------------------------------------
00157     static void Trace( K_USHORT usFile_,
00158                        K_USHORT usLine_,
00159                        K_USHORT usCode_,
00160                        K_USHORT usArg1_);
00161 
00162     //---------------------------------------------------------------------------
00175     static void Trace( K_USHORT usFile_,
00176                        K_USHORT usLine_,
00177                        K_USHORT usCode_,
                 K_USHORT usArg1_,
                 K_USHORT usArg2_);

    //------------------------------------------------------------------------
    static K_BOOL IsSimulatorAware(void);

private:

   //------------------------------------------------------------------------
    static void Trace_i( K_USHORT usFile_,
                        K_USHORT usLine_,
                        K_USHORT usCode_,
                        K_USHORT usArg1_,
                        K_USHORT usArg2_,
                        KernelAwareCommand_t eCmd_);
};

#endif

#endif
```

15.53 /home/moslevin/Project/R1/kernel/public/kerneldebug.h File Reference

Macros and functions used for assertions, kernel traces, etc.

```
#include "debugtokens.h"
#include "mark3cfg.h"
#include "tracebuffer.h"
#include "kernelaware.h"
#include "paniccodes.h"
#include "kernel.h"
```

Macros

- #define __FILE_ID__ 0

    Null ID.

- #define KERNEL_TRACE(x)

    Null Kernel Trace Macro.

- #define KERNEL_TRACE_1(x, arg1)

    Null Kernel Trace Macro.

- #define KERNEL_TRACE_2(x, arg1, arg2)

    Null Kernel Trace Macro.

- #define KERNEL_ASSERT(x)

    Null Kernel Assert Macro.

15.53.1 Detailed Description

Macros and functions used for assertions, kernel traces, etc.

Definition in file kerneldebug.h.

15.54 kerneldebug.h

```
/*========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __KERNEL_DEBUG_H__
#define __KERNEL_DEBUG_H__

#include "debugtokens.h"
#include "mark3cfg.h"
#include "tracebuffer.h"
#include "kernelaware.h"
#include "paniccodes.h"
#include "kernel.h"
//---------------------------------------------------------------------------
#if (KERNEL_USE_DEBUG && !KERNEL_AWARE_SIMULATION)

//---------------------------------------------------------------------------
#define __FILE_ID__         STR_UNDEFINED

//---------------------------------------------------------------------------
#define KERNEL_TRACE( x )   \
{   \
    K_USHORT ausMsg__[5]; \
    ausMsg__[0] = 0xACDC;  \
    ausMsg__[1] = __FILE_ID__; \
    ausMsg__[2] = __LINE__; \
    ausMsg__[3] = TraceBuffer::Increment() ; \
    ausMsg__[4] = (K_USHORT)(x) ; \
    TraceBuffer::Write(ausMsg__, 5); \
};

//---------------------------------------------------------------------------
#define KERNEL_TRACE_1( x, arg1 ) \
{   \
    K_USHORT ausMsg__[6]; \
    ausMsg__[0] = 0xACDC;  \
    ausMsg__[1] = __FILE_ID__; \
    ausMsg__[2] = __LINE__; \
    ausMsg__[3] = TraceBuffer::Increment(); \
    ausMsg__[4] = (K_USHORT)(x); \
    ausMsg__[5] = arg1; \
    TraceBuffer::Write(ausMsg__, 6); \
}

//---------------------------------------------------------------------------
#define KERNEL_TRACE_2( x, arg1, arg2 ) \
{   \
    K_USHORT ausMsg__[7]; \
    ausMsg__[0] = 0xACDC;  \
    ausMsg__[1] = __FILE_ID__; \
    ausMsg__[2] = __LINE__; \
    ausMsg__[3] = TraceBuffer::Increment(); \
    ausMsg__[4] = (K_USHORT)(x); \
    ausMsg__[5] = arg1; \
    ausMsg__[6] = arg2; \
    TraceBuffer::Write(ausMsg__, 7); \
}

//---------------------------------------------------------------------------
#define KERNEL_ASSERT( x ) \
{       \
    if( ( x ) == false ) \
    {   \
        K_USHORT ausMsg__[5];   \
        ausMsg__[0] = 0xACDC;   \
        ausMsg__[1] = __FILE_ID__;  \
        ausMsg__[2] = __LINE__; \
        ausMsg__[3] = TraceBuffer::Increment(); \
        ausMsg__[4] = STR_ASSERT_FAILED;    \
        TraceBuffer::Write(ausMsg__, 5); \
        Kernel::Panic(PANIC_ASSERT_FAILED); \
    }   \
}

#elif (KERNEL_USE_DEBUG && KERNEL_AWARE_SIMULATION)
//---------------------------------------------------------------------------
#define __FILE_ID__         STR_UNDEFINED

//---------------------------------------------------------------------------
#define KERNEL_TRACE( x )   \
{   \
    KernelAware::Trace( __FILE_ID__, __LINE__, x ); \
};

//---------------------------------------------------------------------------
#define KERNEL_TRACE_1( x, arg1 ) \
{   \
    KernelAware::Trace( __FILE_ID__, __LINE__, x, arg1 ); \
}

//---------------------------------------------------------------------------
#define KERNEL_TRACE_2( x, arg1, arg2 ) \
{   \
    KernelAware::Trace( __FILE_ID__, __LINE__, x, arg1, arg2 ); \
}

//---------------------------------------------------------------------------
#define KERNEL_ASSERT( x ) \
{       \
    if( ( x ) == false ) \
    {   \
        KernelAware::Trace( __FILE_ID__, __LINE__, STR_ASSERT_FAILED ); \
        Kernel::Panic( PANIC_ASSERT_FAILED ); \
    }   \
}

#else
//---------------------------------------------------------------------------
// Note -- when kernel-debugging is disabled, we still have to define the
// macros to ensure that the expressions compile (albeit, by elimination
// during pre-processing).
//---------------------------------------------------------------------------
#define __FILE_ID__         0
//---------------------------------------------------------------------------
#define KERNEL_TRACE( x )
//---------------------------------------------------------------------------
#define KERNEL_TRACE_1( x, arg1 )
//---------------------------------------------------------------------------
#define KERNEL_TRACE_2( x, arg1, arg2 )
//---------------------------------------------------------------------------
#define KERNEL_ASSERT( x )

#endif // KERNEL_USE_DEBUG

#endif
```

15.55 /home/moslevin/Project/R1/kernel/public/kerneltypes.h File Reference

Basic data type primatives used throughout the OS.

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

Macros

- #define K_BOOL uint8_t

  Basic boolean data type (true = 1, false = 0)
- #define K_CHAR char

  The 8-bit signed integer type used by Mark3.
- #define K_UCHAR uint8_t

  The 8-bit unsigned integer type used by Mark3.
- #define K_USHORT uint16_t

  The 16-bit unsigned integer type used by Mark3.
- #define K_SHORT int16_t

  The 16-bit signed integer type used by Mark3.
- #define K_ULONG uint32_t

  The 32-bit unsigned integer type used by Mark3.
- #define K_LONG int32_t

  The 32-bit signed integer type used by Mark3.
- #define K_ADDR uint32_t

  Primative datatype representing address-size.
- #define K_WORD uint32_t

  Primative datatype representing a data word.

Typedefs

- typedef void(∗ panic_func_t)(K_USHORT usPanicCode_)

  Function pointer type used to implement kernel-panic handlers.

Enumerations

- enum EventFlagOperation_t {
  EVENT_FLAG_ALL, EVENT_FLAG_ANY, EVENT_FLAG_ALL_CLEAR, EVENT_FLAG_ANY_CLEAR,
  EVENT_FLAG_MODES, EVENT_FLAG_PENDING_UNBLOCK }

  This enumeration describes the different operations supported by the event flag blocking object.

15.55.1 Detailed Description

Basic data type primatives used throughout the OS.

Definition in file kerneltypes.h.

15.55.2 Enumeration Type Documentation

15.55.2.1 enum EventFlagOperation_t

This enumeration describes the different operations supported by the event flag blocking object.

Enumerator

EVENT_FLAG_ALL Block until all bits in the specified bitmask are set.

EVENT_FLAG_ANY Block until any bits in the specified bitmask are set.

EVENT_FLAG_ALL_CLEAR Block until all bits in the specified bitmask are cleared.

EVENT_FLAG_ANY_CLEAR Block until any bits in the specified bitmask are cleared.

EVENT_FLAG_MODES Count of event-flag modes. Not used by user

EVENT_FLAG_PENDING_UNBLOCK Special code. Not used by user

Definition at line 56 of file kerneltypes.h.

15.56 kerneltypes.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ________
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include <stdint.h>

#ifndef __KERNELTYPES_H__
#define __KERNELTYPES_H__

//---------------------------------------------------------------------------
#if defined(bool)
    #define K_BOOL            bool
#else
    #define K_BOOL            uint8_t
#endif
```

```

#define K_CHAR          char
#define K_UCHAR         uint8_t
#define K_USHORT        uint16_t
#define K_SHORT         int16_t
#define K_ULONG         uint32_t
#define K_LONG          int32_t

#if !defined(K_ADDR)
    #define K_ADDR      uint32_t
#endif
#if !defined(K_WORD)
    #define K_WORD      uint32_t
#endif

//---------------------------------------------------------------------------
typedef void (*panic_func_t)( K_USHORT usPanicCode_ );

//---------------------------------------------------------------------------
typedef enum
{
    EVENT_FLAG_ALL,
    EVENT_FLAG_ANY,
    EVENT_FLAG_ALL_CLEAR,
    EVENT_FLAG_ANY_CLEAR,
//---
    EVENT_FLAG_MODES,
    EVENT_FLAG_PENDING_UNBLOCK
} EventFlagOperation_t;


#endif
```

15.57 /home/moslevin/Project/R1/kernel/public/ksemaphore.h File Reference

Semaphore Blocking Object class declarations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "blocking.h"
#include "threadlist.h"
```

Classes

- class Semaphore

  Counting semaphore, based on BlockingObject base class.

15.57.1 Detailed Description

Semaphore Blocking Object class declarations.

Definition in file ksemaphore.h.

15.58 ksemaphore.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
```

```
#ifndef __KSEMAPHORE_H__
#define __KSEMAPHORE_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "blocking.h"
#include "threadlist.h"

#if KERNEL_USE_SEMAPHORE

//---------------------------------------------------------------------------
class Semaphore : public BlockingObject
{
public:
    void Init(K_USHORT usInitVal_, K_USHORT usMaxVal_);

    K_BOOL Post();

    void Pend();


    K_USHORT GetCount();

#if KERNEL_USE_TIMEOUTS

    K_BOOL Pend( K_ULONG ulWaitTimeMS_);

    void WakeMe(Thread *pclChosenOne_);
#endif

private:

    K_UCHAR WakeNext();

#if KERNEL_USE_TIMEOUTS

    K_BOOL Pend_i( K_ULONG ulWaitTimeMS_ );
#else

    void Pend_i( void );
#endif

    K_USHORT m_usValue;
    K_USHORT m_usMaxValue;


};

#endif //KERNEL_USE_SEMAPHORE

#endif
```

15.59 /home/moslevin/Project/R1/kernel/public/ll.h File Reference

Core linked-list declarations, used by all kernel list types.

```
#include "kerneltypes.h"
```

Classes

- class LinkListNode

  Basic linked-list node data structure.
- class LinkList

  Abstract-data-type from which all other linked-lists are derived.
- class DoubleLinkList

  Doubly-linked-list data type, inherited from the base LinkList type.
- class CircularLinkList

  Circular-linked-list data type, inherited from the base LinkList type.

15.59.1 Detailed Description

Core linked-list declarations, used by all kernel list types. At the heart of RTOS data structures are linked lists. Having a robust and efficient set of linked-list types that we can use as a foundation for building the rest of our kernel types allows us to keep our RTOS code efficient and logically-separated.

So what data types rely on these linked-list classes?

-Threads -ThreadLists -The Scheduler -Timers, -The Timer Scheduler -Blocking objects (Semaphores, Mutexes, etc...)

Pretty much everything in the kernel uses these linked lists. By having objects inherit from the base linked-list node type, we're able to leverage the double and circular linked-list classes to manager virtually every object type in the system without duplicating code. These functions are very efficient as well, allowing for very deterministic behavior in our code.

Definition in file ll.h.

15.60 ll.h

```
/*===========================================================================
     _____     _____     _____     _____
 ___|    _|__ __|_    |__ __|__   |__ __| __  |__  ______
|    \  /  | ||    \     ||     |     ||  |/ /    ||___   |
|     \/   | ||     \    ||     \     ||     \    ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __LL_H__
#define __LL_H__

#include "kerneltypes.h"

//---------------------------------------------------------------------------
#ifndef NULL
#define NULL        (0)
#endif

//---------------------------------------------------------------------------
class LinkList;
class DoubleLinkList;
class CircularLinkList;

//---------------------------------------------------------------------------
class LinkListNode
{
protected:

    LinkListNode *next;
    LinkListNode *prev;

    LinkListNode() { }

    void ClearNode();

public:
    LinkListNode *GetNext(void) { return next; }

    LinkListNode *GetPrev(void) { return prev; }

    friend class LinkList;
    friend class DoubleLinkList;
    friend class CircularLinkList;
};

//---------------------------------------------------------------------------
class LinkList
{
protected:
    LinkListNode *m_pstHead;
    LinkListNode *m_pstTail;

public:
    void Init(){ m_pstHead = NULL; m_pstTail = NULL; }

    virtual void Add(LinkListNode *node_) = 0;

    virtual void Remove(LinkListNode *node_) = 0;

    LinkListNode *GetHead() { return m_pstHead; }

    LinkListNode *GetTail() { return m_pstTail; }
};

//---------------------------------------------------------------------------
class DoubleLinkList : public LinkList
{
public:
    DoubleLinkList() { m_pstHead = NULL; m_pstTail = NULL; }

    virtual void Add(LinkListNode *node_);

    virtual void Remove(LinkListNode *node_);
};

//---------------------------------------------------------------------------
class CircularLinkList : public LinkList
{
public:
    CircularLinkList() { m_pstHead = NULL; m_pstTail = NULL; }

    virtual void Add(LinkListNode *node_);

    virtual void Remove(LinkListNode *node_);

    void PivotForward();

    void PivotBackward();
};

#endif
```

15.61 /home/moslevin/Project/R1/kernel/public/manual.h File Reference

Ascii-format documentation, used by doxygen to create various printable and viewable forms.

15.61.1 Detailed Description

Ascii-format documentation, used by doxygen to create various printable and viewable forms.

Definition in file manual.h.

15.62 manual.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

--[Mark3 Realtime Platform]--------------------------------------------------

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===========================================================================*/
```

15.63 /home/moslevin/Project/R1/kernel/public/mark3.h File Reference

Single include file given to users of the Mark3 Kernel API.

```
#include "mark3cfg.h"
#include "kerneltypes.h"
#include "threadport.h"
#include "kernelswi.h"
#include "kerneltimer.h"
#include "kernelprofile.h"
#include "kernel.h"
#include "thread.h"
#include "timerlist.h"
#include "ksemaphore.h"
#include "mutex.h"
#include "eventflag.h"
#include "message.h"
#include "atomic.h"
#include "driver.h"
#include "kernelaware.h"
#include "profile.h"
```

15.63.1 Detailed Description

Single include file given to users of the Mark3 Kernel API.

Definition in file mark3.h.

15.64 mark3.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __MARK3_H__
#define __MARK3_H__

#include "mark3cfg.h"
#include "kerneltypes.h"

#include "threadport.h"
#include "kernelswi.h"
#include "kerneltimer.h"
#include "kernelprofile.h"

#include "kernel.h"
#include "thread.h"
#include "timerlist.h"

#include "ksemaphore.h"
#include "mutex.h"
#include "eventflag.h"
#include "message.h"

#include "atomic.h"
#include "driver.h"

#include "kernelaware.h"

#include "profile.h"
#endif
```

15.65 /home/moslevin/Project/R1/kernel/public/mark3cfg.h File Reference

Mark3 Kernel Configuration.

Macros

- #define KERNEL_USE_TIMERS (1)

    The following options is related to all kernel time-tracking.
- #define KERNEL_TIMERS_TICKLESS (1)

    If you've opted to use the kernel timers module, you have an option as to which timer implementation to use: Tick-based or Tick-less.
- #define KERNEL_USE_TIMEOUTS (1)

    By default, if you opt to enable kernel timers, you also get timeout- enabled versions of the blocking object APIs along with it.
- #define KERNEL_USE_QUANTUM (1)

    Do you want to enable time quanta? This is useful when you want to have tasks in the same priority group share time in a controlled way.
- #define THREAD_QUANTUM_DEFAULT (4)

    This value defines the default thread quantum when KERNEL_USE_QUANTUM is enabled.
- #define KERNEL_USE_SEMAPHORE (1)

    Do you want the ability to use counting/binary semaphores for thread synchronization? Enabling this features provides fully-blocking semaphores and enables all API functions declared in semaphore.h.
- #define KERNEL_USE_MUTEX (1)

    Do you want the ability to use mutual exclusion semaphores (mutex) for resource/block protection? Enabling this feature provides mutexes, with priority inheritence, as declared in mutex.h.
- #define KERNEL_USE_EVENTFLAG (1)

    Provides additional event-flag based blocking.
- #define KERNEL_USE_MESSAGE (1)

    Enable inter-thread messaging using message queues.
- #define GLOBAL_MESSAGE_POOL_SIZE (8)

    If Messages are enabled, define the size of the default kernel message pool.
- #define KERNEL_USE_SLEEP (1)

    Do you want to be able to set threads to sleep for a specified time? This enables the Thread::Sleep() API.
- #define KERNEL_USE_DRIVER (1)

    Enabling device drivers provides a posix-like filesystem interface for peripheral device drivers.
- #define KERNEL_USE_THREADNAME (0)

    Provide Thread method to allow the user to set a name for each thread in the system.
- #define KERNEL_USE_DYNAMIC_THREADS (1)

    Provide extra Thread methods to allow the application to create (and more importantly destroy) threads at runtime.
- #define KERNEL_USE_PROFILER (1)

    Provides extra classes for profiling the performance of code.
- #define KERNEL_USE_DEBUG (0)

    Provides extra logic for kernel debugging, and instruments the kernel with extra asserts, and kernel trace functionality.
- #define KERNEL_USE_ATOMIC (0)

    Provides support for atomic operations, including addition, subtraction, set, and test-and-set.
- #define SAFE_UNLINK (0)

    "Safe unlinking" performs extra checks on data to make sure that there are no consistencies when performing operations on linked lists.
- #define KERNEL_AWARE_SIMULATION (1)

    Include support for kernel-aware simulation.
- #define KERNEL_USE_IDLE_FUNC (1)

    Enabling this feature removes the necessity for the user to dedicate a complete thread for idle functionality.

15.65.1 Detailed Description

Mark3 Kernel Configuration. This file is used to configure the kernel for your specific application in order to provide the optimal set of features for a given use case.

Since you only pay the price (code space/RAM) for the features you use, you can usually find a sweet spot between features and resource usage by picking and choosing features a-la-carte. This config file is written in an "interactive" way, in order to minimize confusion about what each option provides, and to make dependencies obvious.

Definition in file mark3cfg.h.

15.65.2 Macro Definition Documentation

15.65.2.1 #define GLOBAL_MESSAGE_POOL_SIZE (8)

If Messages are enabled, define the size of the default kernel message pool.

Messages can be manually added to the message pool, but this mechansims is more convenient and automatic. All message queues share their message objects from this global pool to maximize efficiency and simplify data management.

Definition at line 144 of file mark3cfg.h.

15.65.2.2 #define KERNEL_AWARE_SIMULATION (1)

Include support for kernel-aware simulation.

Enabling this feature adds advanced profiling, trace, and environment-aware debugging and diagnostic functionality when Mark3-based applications are run on the flavr AVR simulator.

Definition at line 210 of file mark3cfg.h.

15.65.2.3 #define KERNEL_TIMERS_TICKLESS (1)

If you've opted to use the kernel timers module, you have an option as to which timer implementation to use: Tick-based or Tick-less.

Tick-based timers provide a "traditional" RTOS timer implementation based on a fixed-frequency timer interrupt. While this provides very accurate, reliable timing, it also means that the CPU is being interrupted far more often than may be necessary (as not all timer ticks result in "real work" being done).

Tick-less timers still rely on a hardware timer interrupt, but uses a dynamic expiry interval to ensure that the interrupt is only called when the next timer expires. This increases the complexity of the timer interrupt handler, but reduces the number and frequency.

Note that the CPU port (kerneltimer.cpp) must be implemented for the particular timer variant desired.

Definition at line 62 of file mark3cfg.h.

15.65.2.4 #define KERNEL_USE_ATOMIC (0)

Provides support for atomic operations, including addition, subtraction, set, and test-and-set.

Add/Sub/Set contain 8, 16, and 32-bit variants.

Definition at line 194 of file mark3cfg.h.

15.65.2.5 #define KERNEL_USE_DYNAMIC_THREADS (1)

Provide extra Thread methods to allow the application to create (and more importantly destroy) threads at runtime.

Useful for designs implementing worker threads, or threads that can be restarted after encountering error conditions.

Definition at line 176 of file mark3cfg.h.

15.65.2.6 #define KERNEL_USE_EVENTFLAG (1)

Provides additional event-flag based blocking.

This relies on an additional per-thread flag-mask to be allocated, which adds 2 bytes to the size of each thread object.

Definition at line 123 of file mark3cfg.h.

15.65.2.7 #define KERNEL_USE_IDLE_FUNC (1)

Enabling this feature removes the necessity for the user to dedicate a complete thread for idle functionality.

This saves a full thread stack, but also requires a bit extra static data. This also adds a slight overhead to the context switch and scheduler, as a special case has to be taken into account.

Definition at line 219 of file mark3cfg.h.

15.65.2.8 #define KERNEL_USE_MESSAGE (1)

Enable inter-thread messaging using message queues.

This is the preferred mechanism for IPC for serious multi-threaded communications; generally anywhere a semaphore or event-flag is insufficient.

Definition at line 131 of file mark3cfg.h.

15.65.2.9 #define KERNEL_USE_PROFILER (1)

Provides extra classes for profiling the performance of code.

Useful for debugging and development, but uses an additional hardware timer.

Definition at line 182 of file mark3cfg.h.

15.65.2.10 #define KERNEL_USE_QUANTUM (1)

Do you want to enable time quanta? This is useful when you want to have tasks in the same priority group share time in a controlled way.

This allows equal tasks to use unequal amounts of the CPU, which is a great way to set up CPU budgets per thread in a round-robin scheduling system. If enabled, you can specify a number of ticks that serves as the default time period (quantum). Unless otherwise specified, every thread in a priority will get the default quantum.

Definition at line 92 of file mark3cfg.h.

15.65.2.11 #define KERNEL_USE_SEMAPHORE (1)

Do you want the ability to use counting/binary semaphores for thread synchronization? Enabling this features provides fully-blocking semaphores and enables all API functions declared in semaphore.h.

If you have to pick one blocking mechanism, this is the one to choose.

Definition at line 109 of file mark3cfg.h.

15.65.2.12 #define KERNEL_USE_THREADNAME (0)

Provide Thread method to allow the user to set a name for each thread in the system.

Adds a const K_CHAR∗ pointer to the size of the thread object.

Definition at line 168 of file mark3cfg.h.

15.65.2.13 #define KERNEL_USE_TIMEOUTS (1)

By default, if you opt to enable kernel timers, you also get timeout- enabled versions of the blocking object APIs along with it.

This support comes at a small cost to code size, but a slightly larger cost to realtime performance - as checking for the use of timers in the underlying internal code costs some cycles.

As a result, the option is given to the user here to manually disable these timeout-based APIs if desired by the user for performance and code-size reasons.

Definition at line 77 of file mark3cfg.h.

15.65.2.14 #define KERNEL_USE_TIMERS (1)

The following options is related to all kernel time-tracking.

-timers provide a way for events to be periodically triggered in a lightweight manner. These can be periodic, or one-shot.

-Thread Quantum (used for round-robin scheduling) is dependent on this module, as is Thread Sleep functionality.

Definition at line 41 of file mark3cfg.h.

15.65.2.15 #define SAFE_UNLINK (0)

"Safe unlinking" performs extra checks on data to make sure that there are no consistencies when performing operations on linked lists.

This goes beyond pointer checks, adding a layer of structural and metadata validation to help detect system corruption early.

Definition at line 202 of file mark3cfg.h.

15.65.2.16 #define THREAD_QUANTUM_DEFAULT (4)

This value defines the default thread quantum when KERNEL_USE_QUANTUM is enabled.

The thread quantum value is in milliseconds

Definition at line 101 of file mark3cfg.h.

15.66 mark3cfg.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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```

```
=============================================================================*/
#ifndef __MARK3CFG_H__
#define __MARK3CFG_H__

#define KERNEL_USE_TIMERS                (1)

#if KERNEL_USE_TIMERS
    #define KERNEL_TIMERS_TICKLESS       (1)
#endif

#if KERNEL_USE_TIMERS
    #define KERNEL_USE_TIMEOUTS          (1)
#else
    #define KERNEL_USE_TIMEOUTS          (0)
#endif

#if KERNEL_USE_TIMERS
    #define KERNEL_USE_QUANTUM           (1)
#else
    #define KERNEL_USE_QUANTUM           (0)
#endif

#define THREAD_QUANTUM_DEFAULT           (4)

#define KERNEL_USE_SEMAPHORE             (1)

#define KERNEL_USE_MUTEX                 (1)

#define KERNEL_USE_EVENTFLAG             (1)

#if KERNEL_USE_SEMAPHORE
    #define KERNEL_USE_MESSAGE           (1)
#else
    #define KERNEL_USE_MESSAGE           (0)
#endif

#if KERNEL_USE_MESSAGE
    #define GLOBAL_MESSAGE_POOL_SIZE     (8)
#endif

#if KERNEL_USE_TIMERS && KERNEL_USE_SEMAPHORE
    #define KERNEL_USE_SLEEP             (1)
#else
    #define KERNEL_USE_SLEEP             (0)
#endif

#define KERNEL_USE_DRIVER                (1)

#define KERNEL_USE_THREADNAME            (0)

#define KERNEL_USE_DYNAMIC_THREADS       (1)

#define KERNEL_USE_PROFILER              (1)

#define KERNEL_USE_DEBUG                 (0)

#define KERNEL_USE_ATOMIC                (0)

#define SAFE_UNLINK                      (0)

#define KERNEL_AWARE_SIMULATION          (1)

#define KERNEL_USE_IDLE_FUNC             (1)
#endif
```

15.67 /home/moslevin/Project/R1/kernel/public/message.h File Reference

Inter-thread communication via message-passing.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
#include "ksemaphore.h"
#include "timerlist.h"
```

Classes

- class Message

  Class to provide message-based IPC services in the kernel.
- class GlobalMessagePool

  Implements a list of message objects shared between all threads.
- class MessageQueue

  List of messages, used as the channel for sending and receiving messages between threads.

15.67.1 Detailed Description

Inter-thread communication via message-passing. Embedded systems guru Jack Ganssle once said that without a robust form of interprocess communications (IPC), an RTOS is just a toy. Mark3 implements a form of IPC to provide safe and flexible messaging between threads.

Using kernel-managed IPC offers significant benefits over other forms of data sharing (i.e. Global variables) in that it avoids synchronization issues and race conditions common to the practice. Using IPC also enforces a more disciplined coding style that keeps threads decoupled from one another and minimizes global data, preventing careless and hard-to-debug errors.

15.67.2 Using Messages, Queues, and the Global Message Pool

```
// Declare a message queue shared between two threads
MessageQueue my_queue;

int main()
{
    ...
    // Initialize the message queue
    my_queue.init();
    ...
}

void Thread1()
{
    // Example TX thread - sends a message every 10ms
    while(1)
    {
        // Grab a message from the global message pool
        Message *tx_message = GlobalMessagePool::Pop();

        // Set the message data/parameters
        tx_message->SetCode( 1234 );
        tx_message->SetData( NULL );

        // Send the message on the queue.
        my_queue.Send( tx_message );
        Thread::Sleep(10);
    }
}

void Thread2()
{
    while()
    {
        // Blocking receive - wait until we have messages to process
        Message *rx_message = my_queue.Recv();

        // Do something with the message data...

        // Return back into the pool when done
        GlobalMessagePool::Push(rx_message);
    }
}
```

Definition in file message.h.

15.68 message.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __MESSAGE_H__
#define __MESSAGE_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "ll.h"
#include "ksemaphore.h"

#if KERNEL_USE_MESSAGE

#if KERNEL_USE_TIMEOUTS
    #include "timerlist.h"
#endif

//---------------------------------------------------------------------------
class Message : public LinkListNode
{
public:
    void Init() { ClearNode(); m_pvData = NULL; m_usCode = 0; }

    void SetData( void *pvData_ ) { m_pvData = pvData_; }

    void *GetData() { return m_pvData; }

    void SetCode( K_USHORT usCode_ ) { m_usCode = usCode_; }

    K_USHORT GetCode() { return m_usCode; }
private:

    void *m_pvData;

    K_USHORT m_usCode;
};

//---------------------------------------------------------------------------
class GlobalMessagePool
{
public:
    static void Init();

    static void Push( Message *pclMessage_ );

    static Message *Pop();

private:
    static Message m_aclMessagePool[
GLOBAL_MESSAGE_POOL_SIZE];

    static DoubleLinkList m_clList;
};

//---------------------------------------------------------------------------
class MessageQueue
{
public:
    void Init();

    Message *Receive();

#if KERNEL_USE_TIMEOUTS

    Message *Receive( K_ULONG ulTimeWaitMS_ );
#endif

    void Send( Message *pclSrc_ );


    K_USHORT GetCount();
private:

```

```
#if KERNEL_USE_TIMEOUTS

    Message *Receive_i( K_ULONG ulTimeWaitMS_ );
#else

    Message *Receive_i( void );
#endif

    Semaphore m_clSemaphore;

    DoubleLinkList m_clLinkList;
};

#endif //KERNEL_USE_MESSAGE

#endif
```

15.69 /home/moslevin/Project/R1/kernel/public/mutex.h File Reference

Mutual exclusion class declaration.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "blocking.h"
#include "timerlist.h"
```

Classes

- class Mutex

  Mutual-exclusion locks, based on BlockingObject.

15.69.1 Detailed Description

Mutual exclusion class declaration. Resource locks are implemented using mutual exclusion semaphores (Mutex_t). Protected blocks can be placed around any resource that may only be accessed by one thread at a time. If additional threads attempt to access the protected resource, they will be placed in a wait queue until the resource becomes available. When the resource becomes available, the thread with the highest original priority claims the resource and is activated. Priority inheritance is included in the implementation to prevent priority inversion. Always ensure that you claim and release your mutex objects consistently, otherwise you may end up with a deadlock scenario that's hard to debug.

15.69.2 Initializing

Initializing a mutex object by calling:

```
clMutex.Init();
```

15.69.3 Resource protection example

```
clMutex.Claim();
...
<resource protected block>
...
clMutex.Release();
```

Definition in file mutex.h.

15.70 mutex.h

```
/*=========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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=========================================================================*/
#ifndef __MUTEX_H_
#define __MUTEX_H_

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "blocking.h"

#if KERNEL_USE_MUTEX

#if KERNEL_USE_TIMEOUTS
#include "timerlist.h"
#endif

//-------------------------------------------------------------------------
class Mutex : public BlockingObject
{
public:
    void Init();

    void Claim();

#if KERNEL_USE_TIMEOUTS

    K_BOOL Claim(K_ULONG ulWaitTimeMS_);

    void WakeMe( Thread *pclOwner_ );

#endif

    void Release();

private:

    K_UCHAR WakeNext();


#if KERNEL_USE_TIMEOUTS

    K_BOOL Claim_i( K_ULONG ulWaitTimeMS_ );
#else

    void Claim_i(void);
#endif

    K_UCHAR m_ucRecurse;
    K_UCHAR m_bReady;
    K_UCHAR m_ucMaxPri;
    Thread *m_pclOwner;

};

#endif //KERNEL_USE_MUTEX

#endif //__MUTEX_H_

```

15.71 /home/moslevin/Project/R1/kernel/public/paniccodes.h File Reference

Defines the reason codes thrown when a kernel panic occurs.

15.71.1 Detailed Description

Defines the reason codes thrown when a kernel panic occurs.

Definition in file paniccodes.h.

15.72 paniccodes.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __PANIC_CODES_H
#define __PANIC_CODES_H

#define PANIC_ASSERT_FAILED         (1)
#define PANIC_LIST_UNLINK_FAILED    (2)
#define PANIC_STACK_SLACK_VIOLATED  (3)

#endif // __PANIC_CODES_H

```

15.73 /home/moslevin/Project/R1/kernel/public/profile.h File Reference

High-precision profiling timers.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
```

Classes

- class ProfileTimer

  Profiling timer.

15.73.1 Detailed Description

High-precision profiling timers. Enables the profiling and instrumentation of performance-critical code. Multiple timers can be used simultaneously to enable system-wide performance metrics to be computed in a lightweight manner.

Usage:

```
ProfileTimer clMyTimer;
int i;

clMyTimer.Init();

// Profile the same block of code ten times
for (i = 0; i < 10; i++)
{
    clMyTimer.Start();
    ...
    //Block of code to profile
    ...
    clMyTimer.Stop();
}

// Get the average execution time of all iterations
ulAverageTimer = clMyTimer.GetAverage();

// Get the execution time from the last iteration
ulLastTimer = clMyTimer.GetCurrent();
```

Definition in file profile.h.

15.74 profile.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __PROFILE_H__
#define __PROFILE_H__

#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"

#if KERNEL_USE_PROFILER

class ProfileTimer
{

public:
    void Init();

    void Start();

    void Stop();

    K_ULONG GetAverage();

    K_ULONG GetCurrent();

private:

    K_ULONG ComputeCurrentTicks(K_USHORT usCount_, K_ULONG ulEpoch_);

    K_ULONG m_ulCumulative;
    K_ULONG m_ulCurrentIteration;
    K_USHORT m_usInitial;
    K_ULONG m_ulInitialEpoch;
    K_USHORT m_usIterations;
    K_UCHAR m_bActive;
};

#endif // KERNEL_USE_PROFILE

#endif
```

15.75 /home/moslevin/Project/R1/kernel/public/quantum.h File Reference

Thread Quantum declarations for Round-Robin Scheduling.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "thread.h"
#include "timer.h"
#include "timerlist.h"
#include "timerscheduler.h"
```

Classes

- class Quantum

  Static-class used to implement Thread quantum functionality, which is a key part of round-robin scheduling.

15.75.1 Detailed Description

Thread Quantum declarations for Round-Robin Scheduling.

Definition in file quantum.h.

15.76 quantum.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __KQUANTUM_H__
#define __KQUANTUM_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "thread.h"
#include "timer.h"
#include "timerlist.h"
#include "timerscheduler.h"

#if KERNEL_USE_QUANTUM
class Timer;

class Quantum
{
public:
    static void UpdateTimer();

    static void AddThread( Thread *pclThread_ );

    static void RemoveThread();

    static void SetInTimer(void)   { m_bInTimer = true; }

    static void ClearInTimer(void) { m_bInTimer = false; }

private:
    static void SetTimer( Thread *pclThread_ );

    static Timer m_clQuantumTimer;
    static K_UCHAR m_bActive;
    static K_UCHAR m_bInTimer;
};

#endif //KERNEL_USE_QUANTUM

#endif
```

15.77 /home/moslevin/Project/R1/kernel/public/scheduler.h File Reference

Thread scheduler function declarations.

```
#include "kerneltypes.h"
#include "thread.h"
#include "threadport.h"
```

Classes

- class Scheduler

  Priority-based round-robin Thread scheduling, using ThreadLists for housekeeping.

Macros

- #define NUM_PRIORITIES (8)

  Defines the maximum number of thread priorities supported in the scheduler.

Variables

- volatile Thread ∗ g_pstNext

  Pointer to the currently-chosen next-running thread.
- Thread ∗ g_pstCurrent

  Pointer to the currently-running thread.

15.77.1 Detailed Description

Thread scheduler function declarations. This scheduler implements a very flexible type of scheduling, which has become the defacto industry standard when it comes to real-time operating systems. This scheduling mechanism is referred to as priority round- robin.

From the name, there are two concepts involved here:

1) Priority scheduling:

Threads are each assigned a priority, and the thread with the highest priority which is ready to run gets to execute.

2) Round-robin scheduling:

Where there are multiple ready threads at the highest-priority level, each thread in that group gets to share time, ensuring that progress is made.

The scheduler uses an array of ThreadList objects to provide the necessary housekeeping required to keep track of threads at the various priorities. As s result, the scheduler contains one ThreadList per priority, with an additional list to manage the storage of threads which are in the "stopped" state (either have been stopped, or have not been started yet).

Definition in file scheduler.h.

15.78 scheduler.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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```

```
===========================================================================*/
#ifndef __SCHEDULER_H__
#define __SCHEDULER_H__

#include "kerneltypes.h"
#include "thread.h"
#include "threadport.h"

extern volatile Thread *g_pstNext;
extern Thread *g_pstCurrent;

#define NUM_PRIORITIES              (8)
//---------------------------------------------------------------------------

class Scheduler
{
public:
    static void Init();

    static void Schedule();

    static void Add(Thread *pclThread_);

    static void Remove(Thread *pclThread_);

    static K_BOOL SetScheduler(K_BOOL bEnable_);

    static Thread *GetCurrentThread(){ return g_pstCurrent; }

    static volatile Thread *GetNextThread(){ return g_pstNext; }

    static ThreadList *GetThreadList(K_UCHAR ucPriority_){ return &m_aclPriorities[ucPriority_]; }

    static ThreadList *GetStopList(){ return &m_clStopList; }

    static K_UCHAR IsEnabled(){ return m_bEnabled; }

    static void QueueScheduler() { m_bQueuedSchedule = true; }

private:
    static K_BOOL m_bEnabled;

    static K_BOOL m_bQueuedSchedule;

    static ThreadList m_clStopList;

    static ThreadList m_aclPriorities[NUM_PRIORITIES];

    static K_UCHAR m_ucPriFlag;
};
#endif

```

15.79 /home/moslevin/Project/R1/kernel/public/thread.h File Reference

Platform independent thread class declarations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
#include "threadlist.h"
#include "scheduler.h"
#include "threadport.h"
#include "quantum.h"
```

Classes

- class Thread

  Object providing fundamental multitasking support in the kernel.
- struct FakeThread_t

  If the kernel is set up to use an idle function instead of an idle thread, we use a placeholder data structure to "simulate" the effect of having an idle thread in the system.

Typedefs

- typedef void(∗ ThreadEntry_t)(void ∗pvArg_)

  Function pointer type used for thread entrypoint functions.

Enumerations

- enum ThreadState_t

  Enumeration representing the different states a thread can exist in.

15.79.1 Detailed Description

Platform independent thread class declarations. Threads are an atomic unit of execution, and each instance of the thread class represents an instance of a program running of the processor. The Thread is the fundmanetal user-facing object in the kernel - it is what makes multiprocessing possible from application code.

In Mark3, threads each have their own context - consisting of a stack, and all of the registers required to multiplex a processor between multiple threads.

The Thread class inherits directly from the LinkListNode class to facilitate efficient thread management using Double, or Double-Circular linked lists.

Definition in file thread.h.

15.80 thread.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __THREAD_H__
#define __THREAD_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "ll.h"
#include "threadlist.h"
#include "scheduler.h"
#include "threadport.h"
#include "quantum.h"

//---------------------------------------------------------------------------
typedef void (*ThreadEntry_t)(void *pvArg_);

//---------------------------------------------------------------------------
typedef enum
{
    THREAD_STATE_EXIT = 0,
    THREAD_STATE_READY,
    THREAD_STATE_BLOCKED,
    THREAD_STATE_STOP,
//--
    THREAD_STATES
} ThreadState_t;

//---------------------------------------------------------------------------
class Thread : public LinkListNode
{
public:
    void Init(K_WORD *paucStack_,
              K_USHORT usStackSize_,
              K_UCHAR ucPriority_,
              ThreadEntry_t pfEntryPoint_,
              void *pvArg_ );

    void Start();


    void Stop();

#if KERNEL_USE_THREADNAME

    void SetName(const K_CHAR *szName_) { m_szName = szName_; }

    const K_CHAR* GetName() { return m_szName; }
#endif

    ThreadList *GetOwner(void) { return m_pclOwner; }

    ThreadList *GetCurrent(void) { return m_pclCurrent; }

    K_UCHAR GetPriority(void) { return m_ucPriority; }

    K_UCHAR GetCurPriority(void) { return m_ucCurPriority; }

#if KERNEL_USE_QUANTUM

    void SetQuantum( K_USHORT usQuantum_ ) { m_usQuantum = usQuantum_; }

    K_USHORT GetQuantum(void) { return m_usQuantum; }
#endif

    void SetCurrent( ThreadList *pclNewList_ ) {
m_pclCurrent = pclNewList_; }

    void SetOwner( ThreadList *pclNewList_ ) { m_pclOwner = pclNewList_; }


    void SetPriority(K_UCHAR ucPriority_);

    void InheritPriority(K_UCHAR ucPriority_);

#if KERNEL_USE_DYNAMIC_THREADS

    void Exit();
#endif

#if KERNEL_USE_SLEEP

    static void Sleep(K_ULONG ulTimeMs_);

    static void USleep(K_ULONG ulTimeUs_);
#endif

    static void Yield(void);

    void SetID( K_UCHAR ucID_ ) { m_ucThreadID = ucID_; }

    K_UCHAR GetID() { return m_ucThreadID; }


    K_USHORT GetStackSlack();

#if KERNEL_USE_EVENTFLAG

    K_USHORT GetEventFlagMask() { return m_usFlagMask; }

    void SetEventFlagMask(K_USHORT usMask_) {
m_usFlagMask = usMask_; }

    void SetEventFlagMode(EventFlagOperation_t eMode_ ) {
m_eFlagMode = eMode_; }

    EventFlagOperation_t GetEventFlagMode() { return
m_eFlagMode; }
#endif

#if KERNEL_USE_TIMEOUTS || KERNEL_USE_SLEEP

    Timer *GetTimer();
#endif
#if KERNEL_USE_TIMEOUTS

    void SetExpired( K_BOOL bExpired_ );

    K_BOOL GetExpired();
#endif

```

```
#if KERNEL_USE_IDLE_FUNC

    void InitIdle();
#endif

    ThreadState_t GetState()                { return m_eState; }

    void SetState( ThreadState_t eState_ )  { m_eState = eState_; }

    friend class ThreadPort;

private:
    static void ContextSwitchSWI(void);

    void SetPriorityBase(K_UCHAR ucPriority_);

    K_WORD *m_pwStackTop;

    K_WORD *m_pwStack;

    K_UCHAR m_ucThreadID;

    K_UCHAR m_ucPriority;

    K_UCHAR m_ucCurPriority;

    ThreadState_t m_eState;

#if KERNEL_USE_THREADNAME
    const K_CHAR *m_szName;
#endif

    K_USHORT m_usStackSize;

    ThreadList *m_pclCurrent;

    ThreadList *m_pclOwner;

    ThreadEntry_t m_pfEntryPoint;

    void *m_pvArg;

#if KERNEL_USE_QUANTUM
    K_USHORT m_usQuantum;
#endif

#if KERNEL_USE_EVENTFLAG
    K_USHORT m_usFlagMask;

    EventFlagOperation_t m_eFlagMode;
#endif

#if KERNEL_USE_TIMEOUTS || KERNEL_USE_SLEEP
    Timer  m_clTimer;
#endif
#if KERNEL_USE_TIMEOUTS
    K_BOOL    m_bExpired;
#endif

};

#if KERNEL_USE_IDLE_FUNC
//---------------------------------------------------------------------------
typedef struct
{
    LinkListNode *next;
    LinkListNode *prev;

    K_WORD *m_pwStackTop;

    K_WORD *m_pwStack;

    K_UCHAR m_ucThreadID;

    K_UCHAR m_ucPriority;

    K_UCHAR m_ucCurPriority;

    ThreadState_t m_eState;

#if KERNEL_USE_THREADNAME
    const K_CHAR *m_szName;
#endif

} FakeThread_t;
#endif
```

```

#endif
```

15.81 /home/moslevin/Project/R1/kernel/public/threadlist.h File Reference

Thread linked-list declarations.

```
#include "kerneltypes.h"
#include "ll.h"
```

Classes

- class ThreadList

  This class is used for building thread-management facilities, such as schedulers, and blocking objects.

15.81.1 Detailed Description

Thread linked-list declarations.

Definition in file threadlist.h.

15.82 threadlist.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __THREADLIST_H__
#define __THREADLIST_H__

#include "kerneltypes.h"
#include "ll.h"

class Thread;

class ThreadList : public CircularLinkList
{
public:
    ThreadList() { m_ucPriority = 0; m_pucFlag = NULL; }

    void SetPriority(K_UCHAR ucPriority_);

    void SetFlagPointer(K_UCHAR *pucFlag_);

    void Add(LinkListNode *node_);

    void Add(LinkListNode *node_, K_UCHAR *pucFlag_,
K_UCHAR ucPriority_);

    void Remove(LinkListNode *node_);

    Thread *HighestWaiter();
private:

    K_UCHAR m_ucPriority;

    K_UCHAR *m_pucFlag;
};

#endif
```

```
00112
```

15.83 /home/moslevin/Project/R1/kernel/public/timer.h File Reference

Timer object declarations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
```

Classes

- class Timer

  Timer - an event-driven execution context based on a specified time interval.

Macros

- #define TIMERLIST_FLAG_ONE_SHOT (0x01)

  Timer is one-shot.
- #define TIMERLIST_FLAG_ACTIVE (0x02)

  Timer is currently active.
- #define TIMERLIST_FLAG_CALLBACK (0x04)

  Timer is pending a callback.
- #define TIMERLIST_FLAG_EXPIRED (0x08)

  Timer is actually expired.
- #define MAX_TIMER_TICKS (0x7FFFFFFF)

  Maximum value to set.
- #define MIN_TICKS (3)

  The minimum tick value to set.

Typedefs

- typedef void(∗ TimerCallback_t)(Thread ∗pclOwner_, void ∗pvData_)

  This type defines the callback function type for timer events.

15.83.1 Detailed Description

Timer object declarations.

Definition in file timer.h.

15.83.2 Macro Definition Documentation

15.83.2.1 #define TIMERLIST_FLAG_EXPIRED (0x08)

Timer is actually expired.

Definition at line 36 of file timer.h.

15.83.3 Typedef Documentation

15.83.3.1 typedef void(∗ TimerCallback_t)(Thread ∗pclOwner_, void ∗pvData_)

This type defines the callback function type for timer events.

Since these are called from an interrupt context, they do not operate from within a thread or object context directly – as a result, the context must be manually passed into the calls.

pclOwner_ is a pointer to the thread that owns the timer pvData_ is a pointer to some data or object that needs to know about the timer's expiry from within the timer interrupt context.

Definition at line 94 of file timer.h.

15.84 timer.h

```
00001 /*===========================================================================
00002      _____        _____        _____        _____
00003  ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
00004 |    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
00005 |     \/   | ||     \     ||     \     ||     \     ||___   |
00006 |__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
00007     |_____|      |_____|      |_____|      |_____|
00008
00009 --[Mark3 Realtime Platform]--------------------------------------------------
00010
00011 Copyright (c) 2012-2015 Funkenstein Software Consulting, all rights reserved.
00012 See license.txt for more information
00013 ===========================================================================*/
00021 #ifndef __TIMER_H__
00022 #define __TIMER_H__
00023
00024 #include "kerneltypes.h"
00025 #include "mark3cfg.h"
00026
00027 #include "ll.h"
00028
00029 #if KERNEL_USE_TIMERS
00030 class Thread;
00031
00032 //---------------------------------------------------------------------------
00033 #define TIMERLIST_FLAG_ONE_SHOT         (0x01)
00034 #define TIMERLIST_FLAG_ACTIVE           (0x02)
00035 #define TIMERLIST_FLAG_CALLBACK         (0x04)
00036 #define TIMERLIST_FLAG_EXPIRED          (0x08)
00037
00038 //---------------------------------------------------------------------------
00039 #if KERNEL_TIMERS_TICKLESS
00040
00041 //---------------------------------------------------------------------------
00042 #define MAX_TIMER_TICKS                 (0x7FFFFFFF)
00043
00044 //---------------------------------------------------------------------------
00045 /*
00046     Ugly macros to support a wide resolution of delays.
00047     Given a 16-bit timer @ 16MHz & 256 cycle prescaler, this gives us...
00048     Max time, SECONDS_TO_TICKS:  68719s
00049     Max time, MSECONDS_TO_TICKS: 6871.9s
00050     Max time, USECONDS_TO_TICKS: 6.8719s
00051
00052     ...With a 16us tick resolution.
00053
00054     Depending on the system frequency and timer resolution, you may want to
00055     customize these values to suit your system more appropriately.
00056 */
00057 //---------------------------------------------------------------------------
00058 #define SECONDS_TO_TICKS(x)             ((((K_ULONG)x) * TIMER_FREQ))
00059 #define MSECONDS_TO_TICKS(x)            ((((((K_ULONG)x) * (TIMER_FREQ/100)) + 5) / 10))
00060 #define USECONDS_TO_TICKS(x)            ((((((K_ULONG)x) * TIMER_FREQ) + 50000) / 1000000))
00061
00062 //---------------------------------------------------------------------------
00063 #define MIN_TICKS                        (3)
00064 //---------------------------------------------------------------------------
00065
00066 #else
00067 //---------------------------------------------------------------------------
00068 // Tick-based timers, assuming 1khz tick rate
00069 #define MAX_TIMER_TICKS                 (0x7FFFFFFF)
00070
```

```
//---------------------------------------------------------------------------
// add time because we don’t know how far in an epoch we are when a call is made.
#define SECONDS_TO_TICKS(x)             (((K_ULONG)(x) * 1000) + 1)
#define MSECONDS_TO_TICKS(x)            ((K_ULONG)(x + 1))
#define USECONDS_TO_TICKS(x)            (((K_ULONG)(x + 999)) / 1000)

//---------------------------------------------------------------------------
#define MIN_TICKS                       (1)
//---------------------------------------------------------------------------

#endif // KERNEL_TIMERS_TICKLESS

//---------------------------------------------------------------------------
typedef void (*TimerCallback_t)(Thread *pclOwner_, void *pvData_);

//---------------------------------------------------------------------------
class TimerList;
class TimerScheduler;
class Quantum;
class Timer : public LinkListNode
{
public:
    Timer() { }

    void Init() { ClearNode(); m_ulInterval = 0;
m_ulTimerTolerance = 0; m_ulTimeLeft = 0;
m_ucFlags = 0; }

    void Start( K_BOOL bRepeat_, K_ULONG ulIntervalMs_,
TimerCallback_t pfCallback_, void *pvData_ );

    void Start( K_BOOL bRepeat_, K_ULONG ulIntervalMs_,
K_ULONG ulToleranceMs_, TimerCallback_t pfCallback_, void *pvData_ );

    void Stop();

    void SetFlags (K_UCHAR ucFlags_) { m_ucFlags = ucFlags_; }

    void SetCallback( TimerCallback_t pfCallback_){
m_pfCallback = pfCallback_; }

    void SetData( void *pvData_ ){ m_pvData = pvData_; }

    void SetOwner( Thread *pclOwner_){ m_pclOwner = pclOwner_; }

    void SetIntervalTicks(K_ULONG ulTicks_);

    void SetIntervalSeconds(K_ULONG ulSeconds_);


    K_ULONG GetInterval()    { return m_ulInterval; }

    void SetIntervalMSeconds(K_ULONG ulMSeconds_);

    void SetIntervalUSeconds(K_ULONG ulUSeconds_);

    void SetTolerance(K_ULONG ulTicks_);

private:

    friend class TimerList;

    K_UCHAR m_ucFlags;

    TimerCallback_t m_pfCallback;

    K_ULONG m_ulInterval;

    K_ULONG m_ulTimeLeft;

    K_ULONG m_ulTimerTolerance;

    Thread  *m_pclOwner;

    void    *m_pvData;
};

#endif // KERNEL_USE_TIMERS

#endif
```

15.85 /home/moslevin/Project/R1/kernel/public/timerlist.h File Reference

Timer list declarations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "timer.h"
```

Classes

- class TimerList

  TimerList class - a doubly-linked-list of timer objects.

15.85.1 Detailed Description

Timer list declarations. These classes implements a linked list of timer objects attached to the global kernel timer scheduler.

Definition in file timerlist.h.

15.86 timerlist.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  _______
|    \  /  | ||    \     ||     |     ||  |/ /     ||___   |
|     \/   | ||     \    ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||_______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __TIMERLIST_H__
#define __TIMERLIST_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "timer.h"
#if KERNEL_USE_TIMERS

//---------------------------------------------------------------------------
class TimerList : public DoubleLinkList
{
public:
    void Init();

    void Add(Timer *pclListNode_);

    void Remove(Timer *pclListNode_);

    void Process();

private:
    K_ULONG m_ulNextWakeup;

    K_UCHAR m_bTimerActive;
};

#endif // KERNEL_USE_TIMERS

#endif
```

15.87 /home/moslevin/Project/R1/kernel/public/timerscheduler.h File Reference

Timer scheduler declarations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "ll.h"
#include "timer.h"
#include "timerlist.h"
```

Classes

- class TimerScheduler

  "Static" Class used to interface a global TimerList with the rest of the kernel.

15.87.1 Detailed Description

Timer scheduler declarations.

Definition in file timerscheduler.h.

15.88 timerscheduler.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __TIMERSCHEDULER_H__
#define __TIMERSCHEDULER_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#include "ll.h"
#include "timer.h"
#include "timerlist.h"

#if KERNEL_USE_TIMERS

//---------------------------------------------------------------------------
class TimerScheduler
{
public:
    static void Init() { m_clTimerList.Init(); }

    static void Add(Timer *pclListNode_)
        {m_clTimerList.Add(pclListNode_); }

    static void Remove(Timer *pclListNode_)
        {m_clTimerList.Remove(pclListNode_); }

    static void Process() {m_clTimerList.Process();}
private:

    static TimerList m_clTimerList;
};

#endif //KERNEL_USE_TIMERS

#endif //__TIMERSCHEDULER_H__

```

15.89 /home/moslevin/Project/R1/kernel/public/tracebuffer.h File Reference

Kernel trace buffer class declaration.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "writebuf16.h"
```

15.89.1 Detailed Description

Kernel trace buffer class declaration. Global kernel trace-buffer. Used to instrument the kernel with lightweight encoded print statements. If something goes wrong, the tracebuffer can be examined for debugging purposes. Also, subsets of kernel trace information can be extracted and analyzed to provide information about runtime performance, thread-scheduling, and other nifty things in real-time.

Definition in file tracebuffer.h.

15.90 tracebuffer.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#ifndef __TRACEBUFFER_H__
#define __TRACEBUFFER_H__

#include "kerneltypes.h"
#include "mark3cfg.h"
#include "writebuf16.h"

#if KERNEL_USE_DEBUG && !KERNEL_AWARE_SIMULATION

#define TRACE_BUFFER_SIZE           (16)

class TraceBuffer
{
public:
    static void Init();

    static K_USHORT Increment();

    static void Write( K_USHORT *pusData_, K_USHORT usSize_ );

    void SetCallback( WriteBufferCallback pfCallback_ )
        { m_clBuffer.SetCallback( pfCallback_ ); }
private:

    static WriteBuffer16 m_clBuffer;
    static volatile K_USHORT m_usIndex;
    static K_USHORT m_ausBuffer[ (TRACE_BUFFER_SIZE / sizeof( K_USHORT )) ];
};

#endif //KERNEL_USE_DEBUG

#endif
```

15.91 /home/moslevin/Project/R1/kernel/public/writebuf16.h File Reference

Thread-safe circular buffer implementation with 16-bit elements.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
```

15.91.1 Detailed Description

Thread-safe circular buffer implementation with 16-bit elements.

Definition in file writebuf16.h.

15.92 writebuf16.h

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

--[Mark3 Realtime Platform]--------------------------------------------------

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===========================================================================*/
#ifndef __WRITEBUF16_H__
#define __WRITEBUF16_H__

#include "kerneltypes.h"
#include "mark3cfg.h"

#if KERNEL_USE_DEBUG && !KERNEL_AWARE_SIMULATION

typedef void (*WriteBufferCallback)( K_USHORT *pusData_, K_USHORT usSize_ );

class WriteBuffer16
{
public:
    void SetBuffers( K_USHORT *pusData_, K_USHORT usSize_ )
    {
        m_pusData = pusData_;
        m_usSize = usSize_;
        m_usHead = 0;
        m_usTail = 0;
    }

    void SetCallback( WriteBufferCallback pfCallback_ )
        { m_pfCallback = pfCallback_; }

    void WriteData( K_USHORT *pusBuf_, K_USHORT usLen_ );

    void WriteVector( K_USHORT **ppusBuf_, K_USHORT *pusLen_,
K_UCHAR ucCount_);

private:
    K_USHORT *m_pusData;

    volatile K_USHORT m_usSize;
    volatile K_USHORT m_usHead;
    volatile K_USHORT m_usTail;

    WriteBufferCallback m_pfCallback;
};
#endif

#endif
```

15.93 /home/moslevin/Project/R1/kernel/quantum.cpp File Reference

Thread Quantum Implementation for Round-Robin Scheduling.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "thread.h"
#include "timerlist.h"
#include "quantum.h"
#include "kerneldebug.h"
#include "kernelaware.h"
```

Macros

- #define __FILE_ID__ QUANTUM_CPP

  File ID used in kernel trace calls.

Functions

- static void QuantumCallback (Thread ∗pclThread_, void ∗pvData_)

  QuantumCallback.

15.93.1 Detailed Description

Thread Quantum Implementation for Round-Robin Scheduling.

Definition in file quantum.cpp.

15.93.2 Function Documentation

15.93.2.1 static void QuantumCallback (Thread ∗ *pclThread_*, void ∗ *pvData_*) [static]

QuantumCallback.

This is the timer callback that is invoked whenever a thread has exhausted its current execution quantum and a new thread must be chosen from within the same priority level.

Parameters

*pclThread_*	Pointer to the thread currently executing
*pvData_*	Unused in this context.

Definition at line 56 of file quantum.cpp.

15.94 quantum.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /    ||___   |
|     \/   | ||     \     ||     \     ||     \    ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\ __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"

#include "thread.h"
#include "timerlist.h"
```

```
#include "quantum.h"
#include "kerneldebug.h"
#include "kernelaware.h"
//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     QUANTUM_CPP

#if KERNEL_USE_QUANTUM

//---------------------------------------------------------------------------
static volatile K_BOOL bAddQuantumTimer;  // Indicates that a timer add is pending

//---------------------------------------------------------------------------
Timer   Quantum::m_clQuantumTimer; // The global timernodelist_t object
K_UCHAR Quantum::m_bActive;
K_UCHAR Quantum::m_bInTimer;
//---------------------------------------------------------------------------
static void QuantumCallback(Thread *pclThread_, void *pvData_)
{
    // Validate thread pointer, check that source/destination match (it's
    // in its real priority list).  Also check that this thread was part of
    // the highest-running priority level.
    if (pclThread_->GetPriority() >= Scheduler::GetCurrentThread()->GetPriority())
    {
        if (pclThread_->GetCurrent()->GetHead() != pclThread_->GetCurrent()->GetTail() )
        {
            bAddQuantumTimer = true;
            pclThread_->GetCurrent()->PivotForward();
        }
    }
}

//---------------------------------------------------------------------------
void Quantum::SetTimer(Thread *pclThread_)
{
    m_clQuantumTimer.SetIntervalMSeconds(pclThread_->GetQuantum());
    m_clQuantumTimer.SetFlags(TIMERLIST_FLAG_ONE_SHOT);
    m_clQuantumTimer.SetData(NULL);
    m_clQuantumTimer.SetCallback((TimerCallback_t)QuantumCallback);
    m_clQuantumTimer.SetOwner(pclThread_);
}

//---------------------------------------------------------------------------
void Quantum::AddThread(Thread *pclThread_)
{
    if (m_bActive
#if KERNEL_USE_IDLE_FUNC
            || (pclThread_ == Kernel::GetIdleThread())
#endif
       )
    {
        return;
    }

    // If this is called from the timer callback, queue a timer add...
    if (m_bInTimer)
    {
        bAddQuantumTimer = true;
        return;
    }

    // If this isn't the only thread in the list.
    if ( pclThread_->GetCurrent()->GetHead() !=
           pclThread_->GetCurrent()->GetTail() )
    {
        Quantum::SetTimer(pclThread_);
        TimerScheduler::Add(&m_clQuantumTimer);
        m_bActive = 1;
    }
}

//---------------------------------------------------------------------------
void Quantum::RemoveThread(void)
{
    if (!m_bActive)
    {
        return;
    }

    // Cancel the current timer
    TimerScheduler::Remove(&m_clQuantumTimer);
    m_bActive = 0;
}

//---------------------------------------------------------------------------
void Quantum::UpdateTimer(void)
{
    // If we have to re-add the quantum timer (more than 2 threads at the
    // high-priority level...)
    if (bAddQuantumTimer)
    {
        // Trigger a thread yield - this will also re-schedule the
        // thread *and* reset the round-robin scheduler.
        Thread::Yield();
        bAddQuantumTimer = false;
    }
}

#endif //KERNEL_USE_QUANTUM
```

15.95 /home/moslevin/Project/R1/kernel/scheduler.cpp File Reference

Strict-Priority + Round-Robin thread scheduler implementation.

```
#include "kerneltypes.h"
#include "ll.h"
#include "scheduler.h"
#include "thread.h"
#include "threadport.h"
#include "kernel.h"
#include "kerneldebug.h"
```

Macros

- #define __FILE_ID__ SCHEDULER_CPP

  File ID used in kernel trace calls.

Variables

- volatile Thread ∗ g_pstNext

  Pointer to the currently-chosen next-running thread.
- Thread ∗ g_pstCurrent

  Pointer to the currently-running thread.
- static const K_UCHAR aucCLZ [16] ={255,0,1,1,2,2,2,2,3,3,3,3,3,3,3,3}

  This implements a 4-bit "Count-leading-zeros" operation using a RAM-based lookup table.

15.95.1 Detailed Description

Strict-Priority + Round-Robin thread scheduler implementation.

Definition in file scheduler.cpp.

15.95.2 Variable Documentation

15.95.2.1 const K_UCHAR aucCLZ[16] ={255,0,1,1,2,2,2,2,3,3,3,3,3,3,3,3} [static]

This implements a 4-bit "Count-leading-zeros" operation using a RAM-based lookup table.

It is used to efficiently perform a CLZ operation under the assumption that a native CLZ instruction is unavailable. This table is further optimized to provide a 0xFF result in the event that the index value is itself zero, allowing us to quickly identify whether or not subsequent 4-bit LUT operations are required to complete the scheduling process.

Definition at line 56 of file scheduler.cpp.

15.96 scheduler.cpp

```
00001 /*===========================================================================
00002      _____        _____        _____        _____
00003  ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
00004 |    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
00005 |     \/   | ||     \     ||     \     ||     \     ||___   |
00006 |__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
00007     |_____|      |_____|      |_____|      |_____|
00008 
00009 --[Mark3 Realtime Platform]--------------------------------------------------
00010 
00011 Copyright (c) 2012-2015 Funkenstein Software Consulting, all rights reserved.
00012 See license.txt for more information
00013 ===========================================================================*/
00022 #include "kerneltypes.h"
00023 #include "ll.h"
00024 #include "scheduler.h"
00025 #include "thread.h"
00026 #include "threadport.h"
00027 #include "kernel.h"
00028 #include "kerneldebug.h"
00029 //---------------------------------------------------------------------------
00030 #if defined __FILE_ID__
00031     #undef __FILE_ID__
00032 #endif
00033 #define __FILE_ID__     SCHEDULER_CPP
00034 
00035 //---------------------------------------------------------------------------
00036 volatile Thread *g_pstNext;
00037 Thread *g_pstCurrent;
00038 
00039 //---------------------------------------------------------------------------
00040 K_BOOL Scheduler::m_bEnabled;
00041 K_BOOL Scheduler::m_bQueuedSchedule;
00042 
00043 ThreadList Scheduler::m_clStopList;
00044 ThreadList Scheduler::m_aclPriorities[
      NUM_PRIORITIES];
00045 K_UCHAR Scheduler::m_ucPriFlag;
00046 
00047 //---------------------------------------------------------------------------
00056 static const K_UCHAR aucCLZ[16] ={255,0,1,1,2,2,2,2,3,3,3,3,3,3,3,3};
00057 
00058 //---------------------------------------------------------------------------
00059 void Scheduler::Init()
00060 {
00061     m_ucPriFlag = 0;
00062     for (int i = 0; i < NUM_PRIORITIES; i++)
00063     {
00064         m_aclPriorities[i].SetPriority(i);
00065         m_aclPriorities[i].SetFlagPointer(&
      m_ucPriFlag);
00066     }
00067     m_bQueuedSchedule = false;
00068 }
00069 
00070 //---------------------------------------------------------------------------
00071 void Scheduler::Schedule()
00072 {
00073     K_UCHAR ucPri = 0;
00074 
00075     // Figure out what priority level has ready tasks (8 priorities max)
00076     // To do this, we apply our current active-thread bitmap (m_ucPriFlag)
00077     // and perform a CLZ on the upper four bits.  If no tasks are found
00078     // in the higher priority bits, search the lower priority bits.  This
00079     // also assumes that we always have the idle thread ready-to-run in
00080     // priority level zero.
00081     ucPri = aucCLZ[m_ucPriFlag >> 4 ];
00082     if (ucPri == 0xFF)
00083     {
00084         ucPri = aucCLZ[m_ucPriFlag & 0x0F];
00085     }
00086     else
00087     {
00088         ucPri += 4;
```

```
    }

#if KERNEL_USE_IDLE_FUNC
    if (ucPri == 0xFF)
    {
        // There aren't any active threads at all - set g_pstNext to IDLE
        g_pstNext = Kernel::GetIdleThread();
    }
    else
#endif
    {
        // Get the thread node at this priority.
        g_pstNext = (Thread*)( m_aclPriorities[ucPri].GetHead() );
    }
    KERNEL_TRACE_1( STR_SCHEDULE_1, (K_USHORT)((Thread*)g_pstNext)->GetID() );

}

//---------------------------------------------------------------------------
void Scheduler::Add(Thread *pclThread_)
{
    m_aclPriorities[pclThread_->GetPriority()].Add(pclThread_);
}

//---------------------------------------------------------------------------
void Scheduler::Remove(Thread *pclThread_)
{
    m_aclPriorities[pclThread_->GetPriority()].Remove(pclThread_);
}

//---------------------------------------------------------------------------
K_BOOL Scheduler::SetScheduler(K_BOOL bEnable_)
{
    K_BOOL bRet ;
    CS_ENTER();
    bRet = m_bEnabled;
    m_bEnabled = bEnable_;
    // If there was a queued scheduler evevent, dequeue and trigger an
    // immediate Yield
    if (m_bEnabled && m_bQueuedSchedule)
    {
        m_bQueuedSchedule = false;
        Thread::Yield();
    }
    CS_EXIT();
    return bRet;
}
```

15.97 /home/moslevin/Project/R1/kernel/thread.cpp File Reference

Platform-Independent thread class Definition.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "thread.h"
#include "scheduler.h"
#include "kernelswi.h"
#include "timerlist.h"
#include "ksemaphore.h"
#include "quantum.h"
#include "kernel.h"
#include "kerneldebug.h"
```

Macros

- #define __FILE_ID__ THREAD_CPP

  File ID used in kernel trace calls.

Functions

- static void ThreadSleepCallback (Thread ∗pclOwner_, void ∗pvData_)

  This callback is used to wake up a thread once the interval has expired.

15.97.1 Detailed Description

Platform-Independent thread class Definition.

Definition in file thread.cpp.

15.98 thread.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"

#include "thread.h"
#include "scheduler.h"
#include "kernelswi.h"
#include "timerlist.h"
#include "ksemaphore.h"
#include "quantum.h"
#include "kernel.h"
#include "kerneldebug.h"

//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     THREAD_CPP

//---------------------------------------------------------------------------
void Thread::Init(  K_WORD *pwStack_,
                K_USHORT usStackSize_,
                K_UCHAR ucPriority_,
                ThreadEntry_t pfEntryPoint_,
                void *pvArg_ )
{
    static K_UCHAR ucThreadID = 0;

    KERNEL_ASSERT( pwStack_ );
    KERNEL_ASSERT( pfEntryPoint_ );

    ClearNode();

    m_ucThreadID = ucThreadID++;

    KERNEL_TRACE_1( STR_STACK_SIZE_1, usStackSize_ );
    KERNEL_TRACE_1( STR_PRIORITY_1, (K_UCHAR)ucPriority_ );
    KERNEL_TRACE_1( STR_THREAD_ID_1, (K_USHORT)m_ucThreadID );
    KERNEL_TRACE_1( STR_ENTRYPOINT_1, (K_USHORT)pfEntryPoint_ );

    // Initialize the thread parameters to their initial values.
    m_pwStack = pwStack_;
    m_pwStackTop = TOP_OF_STACK(pwStack_, usStackSize_);

    m_usStackSize = usStackSize_;

#if KERNEL_USE_QUANTUM
    m_usQuantum = THREAD_QUANTUM_DEFAULT;
#endif

    m_ucPriority = ucPriority_ ;
    m_ucCurPriority = m_ucPriority;
    m_pfEntryPoint = pfEntryPoint_;
    m_pvArg = pvArg_;
    m_eState = THREAD_STATE_STOP;

#if KERNEL_USE_THREADNAME
    m_szName = NULL;
#endif
#if KERNEL_USE_TIMERS
    m_clTimer.Init();
#endif

    // Call CPU-specific stack initialization
    ThreadPort::InitStack(this);

    // Add to the global "stop" list.
    CS_ENTER();
    m_pclOwner = Scheduler::GetThreadList(m_ucPriority);
    m_pclCurrent = Scheduler::GetStopList();
    m_pclCurrent->Add(this);
    CS_EXIT();
}

//---------------------------------------------------------------------------
void Thread::Start(void)
{
    // Remove the thread from the scheduler’s "stopped" list, and add it
    // to the scheduler’s ready list at the proper priority.
    KERNEL_TRACE_1( STR_THREAD_START_1, (K_USHORT)m_ucThreadID );

    CS_ENTER();
    Scheduler::GetStopList()->Remove(this);
    Scheduler::Add(this);
    m_pclOwner = Scheduler::GetThreadList(m_ucPriority);
    m_pclCurrent = m_pclOwner;
    m_eState = THREAD_STATE_READY;

#if KERNEL_USE_QUANTUM
    if (GetCurPriority() >= Scheduler::GetCurrentThread()->GetCurPriority())
    {
        // Deal with the thread Quantum
        Quantum::RemoveThread();
        Quantum::AddThread(this);
    }
#endif

    if (Kernel::IsStarted())
    {
        if (GetCurPriority() >= Scheduler::GetCurrentThread()->GetCurPriority())
        {
            Thread::Yield();
        }
    }
    CS_EXIT();
}

//---------------------------------------------------------------------------
void Thread::Stop()
{
    K_BOOL bReschedule = 0;

    CS_ENTER();

    // If a thread is attempting to stop itself, ensure we call the scheduler
    if (this == Scheduler::GetCurrentThread())
    {
        bReschedule = true;
    }

    // Add this thread to the stop-list (removing it from active scheduling)
    // Remove the thread from scheduling
    if (m_eState == THREAD_STATE_READY)
    {
        Scheduler::Remove(this);
    }
    else if (m_eState == THREAD_STATE_BLOCKED)
    {
        m_pclCurrent->Remove(this);
    }

    m_pclOwner = Scheduler::GetStopList();
    m_pclCurrent = m_pclOwner;
    m_pclOwner->Add(this);
    m_eState = THREAD_STATE_STOP;

#if KERNEL_USE_TIMERS
    // Just to be safe - attempt to remove the thread's timer
    // from the timer-scheduler (does no harm if it isn't
    // in the timer-list)
    TimerScheduler::Remove(&m_clTimer);
#endif

    CS_EXIT();

    if (bReschedule)
    {
        Thread::Yield();
    }
}

#if KERNEL_USE_DYNAMIC_THREADS
//---------------------------------------------------------------------------
void Thread::Exit()
{
    K_BOOL bReschedule = 0;

    KERNEL_TRACE_1( STR_THREAD_EXIT_1, m_ucThreadID );

    CS_ENTER();

    // If this thread is the actively-running thread, make sure we run the
    // scheduler again.
    if (this == Scheduler::GetCurrentThread())
    {
        bReschedule = 1;
    }

    // Remove the thread from scheduling
    if (m_eState == THREAD_STATE_READY)
    {
        Scheduler::Remove(this);
    }
    else if (m_eState == THREAD_STATE_BLOCKED)
    {
        m_pclCurrent->Remove(this);
    }

    m_pclCurrent = 0;
    m_pclOwner = 0;
    m_eState = THREAD_STATE_EXIT;

    // We've removed the thread from scheduling, but interrupts might
    // trigger checks against this thread's currently priority before
    // we get around to scheduling new threads.  As a result, set the
    // priority to idle to ensure that we always wind up scheduling
    // new threads.
    m_ucCurPriority = 0;
    m_ucPriority = 0;

#if KERNEL_USE_TIMERS
    // Just to be safe - attempt to remove the thread's timer
    // from the timer-scheduler (does no harm if it isn't
    // in the timer-list)
    TimerScheduler::Remove(&m_clTimer);
#endif

    CS_EXIT();

    if (bReschedule)
    {
        // Choose a new "next" thread if we must
        Thread::Yield();
    }
}
#endif

#if KERNEL_USE_SLEEP
//---------------------------------------------------------------------------
static void ThreadSleepCallback( Thread *pclOwner_, void *pvData_ )
{
    Semaphore *pclSemaphore = static_cast<Semaphore*>(pvData_);
    // Post the semaphore, which will wake the sleeping thread.
    pclSemaphore->Post();
}

//---------------------------------------------------------------------------
void Thread::Sleep(K_ULONG ulTimeMs_)
{
    Semaphore clSemaphore;
    Timer *pclTimer = g_pstCurrent->GetTimer();

    // Create a semaphore that this thread will block on
    clSemaphore.Init(0, 1);

    // Create a one-shot timer that will call a callback that posts the
    // semaphore, waking our thread.
    pclTimer->Init();
    pclTimer->SetIntervalMSeconds(ulTimeMs_);
    pclTimer->SetCallback(ThreadSleepCallback);
    pclTimer->SetData((void*)&clSemaphore);
    pclTimer->SetFlags(TIMERLIST_FLAG_ONE_SHOT);

    // Add the new timer to the timer scheduler, and block the thread
    TimerScheduler::Add(pclTimer);
    clSemaphore.Pend();
}

//---------------------------------------------------------------------------
void Thread::USleep(K_ULONG ulTimeUs_)
{
    Semaphore clSemaphore;
    Timer *pclTimer = g_pstCurrent->GetTimer();

    // Create a semaphore that this thread will block on
    clSemaphore.Init(0, 1);

    // Create a one-shot timer that will call a callback that posts the
    // semaphore, waking our thread.
    pclTimer->Init();
    pclTimer->SetIntervalUSeconds(ulTimeUs_);
    pclTimer->SetCallback(ThreadSleepCallback);
    pclTimer->SetData((void*)&clSemaphore);
    pclTimer->SetFlags(TIMERLIST_FLAG_ONE_SHOT);

    // Add the new timer to the timer scheduler, and block the thread
    TimerScheduler::Add(pclTimer);
    clSemaphore.Pend();
}
#endif // KERNEL_USE_SLEEP

//---------------------------------------------------------------------------
K_USHORT Thread::GetStackSlack()
{
    K_USHORT usCount = 0;

    CS_ENTER();

    for (usCount = 0; usCount < m_usStackSize; usCount++)
    {
        if (m_pwStack[usCount] != 0xFF)
        {
            break;
        }
    }

    CS_EXIT();

    return usCount;
}

//---------------------------------------------------------------------------
void Thread::Yield()
{
    CS_ENTER();
    // Run the scheduler
    if (Scheduler::IsEnabled())
    {
        Scheduler::Schedule();

        // Only switch contexts if the new task is different than the old task
        if (Scheduler::GetCurrentThread() !=
Scheduler::GetNextThread())
        {
#if KERNEL_USE_QUANTUM
            // new thread scheduled.  Stop current quantum timer (if it exists),
            // and restart it for the new thread (if required).
            Quantum::RemoveThread();
            Quantum::AddThread((Thread*)g_pstNext);
#endif
            Thread::ContextSwitchSWI();
        }
    }
    else
    {
        Scheduler::QueueScheduler();
    }

    CS_EXIT();
}

//---------------------------------------------------------------------------
void Thread::SetPriorityBase(K_UCHAR ucPriority_)
{
     GetCurrent()->Remove(this);

     SetCurrent(Scheduler::GetThreadList(m_ucPriority));

     GetCurrent()->Add(this);
}

//---------------------------------------------------------------------------
void Thread::SetPriority(K_UCHAR ucPriority_)
{
    K_BOOL bSchedule = 0;

    CS_ENTER();
    // If this is the currently running thread, it's a good idea to reschedule
    // Or, if the new priority is a higher priority than the current thread's.
    if ((g_pstCurrent == this) || (ucPriority_ > g_pstCurrent->GetPriority()))
    {
        bSchedule = 1;
    }
    Scheduler::Remove(this);
    CS_EXIT();

    m_ucCurPriority = ucPriority_;
    m_ucPriority = ucPriority_;

    CS_ENTER();
    Scheduler::Add(this);
    CS_EXIT();

    if (bSchedule)
    {
        if (Scheduler::IsEnabled())
        {
            CS_ENTER();
            Scheduler::Schedule();
    #if KERNEL_USE_QUANTUM
            // new thread scheduled.  Stop current quantum timer (if it exists),
            // and restart it for the new thread (if required).
            Quantum::RemoveThread();
            Quantum::AddThread((Thread*)g_pstNext);
    #endif
            CS_EXIT();
            Thread::ContextSwitchSWI();
        }
        else
        {
            Scheduler::QueueScheduler();
        }
    }
}

//---------------------------------------------------------------------------
void Thread::InheritPriority(K_UCHAR ucPriority_)
{
    SetOwner(Scheduler::GetThreadList(ucPriority_));
    m_ucCurPriority = ucPriority_;
}

//---------------------------------------------------------------------------
void Thread::ContextSwitchSWI()
{
    // Call the context switch interrupt if the scheduler is enabled.
    if (Scheduler::IsEnabled() == 1)
    {
        KERNEL_TRACE_1( STR_CONTEXT_SWITCH_1, (K_USHORT)((Thread*)g_pstNext)->GetID() );
        KernelSWI::Trigger();
    }
}

#if KERNEL_USE_TIMEOUTS
//---------------------------------------------------------------------------
Timer *Thread::GetTimer()                      { return &m_clTimer; }

//---------------------------------------------------------------------------
void Thread::SetExpired( K_BOOL bExpired_ )     { m_bExpired = bExpired_; }

```

```
//---------------------------------------------------------------------------
K_BOOL Thread::GetExpired()                     { return m_bExpired; }
#endif

#if KERNEL_USE_IDLE_FUNC
//---------------------------------------------------------------------------
void Thread::InitIdle( void )
{
    ClearNode();

    m_ucPriority = 0;
    m_ucCurPriority = 0;
    m_pfEntryPoint = 0;
    m_pvArg = 0;
    m_ucThreadID = 255;
    m_eState = THREAD_STATE_READY;
#if KERNEL_USE_THREADNAME
    m_szName = "IDLE";
#endif
}
#endif
```

15.99 /home/moslevin/Project/R1/kernel/threadlist.cpp File Reference

Thread linked-list definitions.

```
#include "kerneltypes.h"
#include "ll.h"
#include "threadlist.h"
#include "thread.h"
#include "kerneldebug.h"
```

Macros

- #define __FILE_ID__ THREADLIST_CPP

  File ID used in kernel trace calls.

15.99.1 Detailed Description

Thread linked-list definitions.

Definition in file threadlist.cpp.

15.100 threadlist.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__ ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "ll.h"
#include "threadlist.h"
#include "thread.h"
#include "kerneldebug.h"
//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
```

```
#endif
#define __FILE_ID__     THREADLIST_CPP

//---------------------------------------------------------------------------
void ThreadList::SetPriority(K_UCHAR ucPriority_)
{
    m_ucPriority = ucPriority_;
}

//---------------------------------------------------------------------------
void ThreadList::SetFlagPointer( K_UCHAR *pucFlag_)
{
    m_pucFlag = pucFlag_;
}

//---------------------------------------------------------------------------
void ThreadList::Add(LinkListNode *node_) {
    CircularLinkList::Add(node_);
    CircularLinkList::PivotForward();

    // We've specified a bitmap for this threadlist
    if (m_pucFlag)
    {
        // Set the flag for this priority level
        *m_pucFlag |= (1 << m_ucPriority);
    }
}

//---------------------------------------------------------------------------
void ThreadList::Add(LinkListNode *node_, K_UCHAR *pucFlag_, K_UCHAR ucPriority_) {
    // Set the threadlist's priority level, flag pointer, and then add the
    // thread to the threadlist
    SetPriority(ucPriority_);
    SetFlagPointer(pucFlag_);
    Add(node_);
}

//---------------------------------------------------------------------------
void ThreadList::Remove(LinkListNode *node_) {
    // Remove the thread from the list
    CircularLinkList::Remove(node_);

    // If the list is empty...
    if (!m_pstHead)
    {
        // Clear the bit in the bitmap at this priority level
        if (m_pucFlag)
        {
            *m_pucFlag &= ~(1 << m_ucPriority);
        }
    }
}

//---------------------------------------------------------------------------
Thread *ThreadList::HighestWaiter()
{
    Thread *pclTemp = static_cast<Thread*>(GetHead());
    Thread *pclChosen = pclTemp;

    K_UCHAR ucMaxPri = 0;

    // Go through the list, return the highest-priority thread in this list.
    while(1)
    {
        // Compare against current max-priority thread
        if (pclTemp->GetPriority() >= ucMaxPri)
        {
            ucMaxPri = pclTemp->GetPriority();
            pclChosen = pclTemp;
        }

        // Break out if this is the last thread in the list
        if (pclTemp == static_cast<Thread*>(GetTail()))
        {
            break;
        }

        pclTemp = static_cast<Thread*>(pclTemp->GetNext());
    }
    return pclChosen;
}
```

15.101 /home/moslevin/Project/R1/kernel/timer.cpp File Reference

Timer implementations.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "timer.h"
#include "timerlist.h"
#include "timerscheduler.h"
#include "kerneltimer.h"
#include "threadport.h"
#include "kerneldebug.h"
#include "quantum.h"
```

Macros

- #define __FILE_ID__ TIMER_CPP

  File ID used in kernel trace calls.

15.101.1 Detailed Description

Timer implementations.

Definition in file timer.cpp.

15.102 timer.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__    |__ __| __   |__ ______
|    \  /  | ||    \      ||    |      ||  |/ /      ||___   |
|     \/   | ||     \     ||     \     ||     \      ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"

#include "timer.h"
#include "timerlist.h"
#include "timerscheduler.h"
#include "kerneltimer.h"
#include "threadport.h"
#include "kerneldebug.h"
#include "quantum.h"

//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     TIMER_CPP

#if KERNEL_USE_TIMERS

//---------------------------------------------------------------------------
void Timer::Start( K_BOOL bRepeat_, K_ULONG ulIntervalMs_,
TimerCallback_t pfCallback_, void *pvData_ )
{
    SetIntervalMSeconds(ulIntervalMs_);
    m_ulTimerTolerance = 0;
    m_pfCallback = pfCallback_;
    m_pvData = pvData_;
    if (!bRepeat_)
    {
        m_ucFlags = TIMERLIST_FLAG_ONE_SHOT;
    }
    else
    {
        m_ucFlags = 0;
    }
    m_pclOwner = Scheduler::GetCurrentThread();
    TimerScheduler::Add(this);
}

//---------------------------------------------------------------------------
void Timer::Start( K_BOOL bRepeat_, K_ULONG ulIntervalMs_, K_ULONG ulToleranceMs_, TimerCallback_t pfCallback_, void *pvData_ )
{
    m_ulTimerTolerance = MSECONDS_TO_TICKS(ulToleranceMs_);
    Start(bRepeat_, ulIntervalMs_, pfCallback_, pvData_);
}

//---------------------------------------------------------------------------
void Timer::Stop()
{
    TimerScheduler::Remove(this);
}

//---------------------------------------------------------------------------
void Timer::SetIntervalTicks( K_ULONG ulTicks_ )
{
    m_ulInterval = ulTicks_;
}

//---------------------------------------------------------------------------
//---------------------------------------------------------------------------
void Timer::SetIntervalSeconds( K_ULONG ulSeconds_)
{
    m_ulInterval = SECONDS_TO_TICKS(ulSeconds_);
}

//---------------------------------------------------------------------------
void Timer::SetIntervalMSeconds( K_ULONG ulMSeconds_)
{
    m_ulInterval = MSECONDS_TO_TICKS(ulMSeconds_);
}

//---------------------------------------------------------------------------
void Timer::SetIntervalUSeconds( K_ULONG ulUSeconds_)
{
    m_ulInterval = USECONDS_TO_TICKS(ulUSeconds_);
}

//---------------------------------------------------------------------------
void Timer::SetTolerance(K_ULONG ulTicks_)
{
    m_ulTimerTolerance = ulTicks_;
}

#endif

```

15.103 /home/moslevin/Project/R1/kernel/timerlist.cpp File Reference

Implements timer list processing algorithms, responsible for all timer tick and expiry logic.

```
#include "kerneltypes.h"
#include "mark3cfg.h"
#include "timerlist.h"
#include "kerneltimer.h"
#include "threadport.h"
#include "kerneldebug.h"
#include "quantum.h"
```

Macros

- #define __FILE_ID__ TIMERLIST_CPP

File ID used in kernel trace calls.

15.103.1 Detailed Description

Implements timer list processing algorithms, responsible for all timer tick and expiry logic.

Definition in file timerlist.cpp.

15.104 timerlist.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "mark3cfg.h"

#include "timerlist.h"
#include "kerneltimer.h"
#include "threadport.h"
#include "kerneldebug.h"
#include "quantum.h"

//---------------------------------------------------------------------------
#if defined __FILE_ID__
    #undef __FILE_ID__
#endif
#define __FILE_ID__     TIMERLIST_CPP

#if KERNEL_USE_TIMERS

//---------------------------------------------------------------------------
TimerList TimerScheduler::m_clTimerList;

//---------------------------------------------------------------------------
void TimerList::Init(void)
{
    m_bTimerActive = 0;
    m_ulNextWakeup = 0;
}

//---------------------------------------------------------------------------
void TimerList::Add(Timer *pclListNode_)
{
#if KERNEL_TIMERS_TICKLESS
    K_BOOL bStart = 0;
    K_LONG lDelta;
#endif

    CS_ENTER();

#if KERNEL_TIMERS_TICKLESS
    if (GetHead() == NULL)
    {
        bStart = 1;
    }
#endif

    pclListNode_->ClearNode();
    DoubleLinkList::Add(pclListNode_);

    // Set the initial timer value
    pclListNode_->m_ulTimeLeft = pclListNode_->m_ulInterval;

#if KERNEL_TIMERS_TICKLESS
    if (!bStart)
    {
        // If the new interval is less than the amount of time remaining...
        lDelta = KernelTimer::TimeToExpiry() - pclListNode_->m_ulInterval;

        if (lDelta > 0)
        {
            // Set the new expiry time on the timer.
            m_ulNextWakeup = KernelTimer::SubtractExpiry((K_ULONG)lDelta);
        }
    }
    else
    {
        m_ulNextWakeup = pclListNode_->m_ulInterval;
        KernelTimer::SetExpiry(m_ulNextWakeup);
        KernelTimer::Start();
    }
#endif

    // Set the timer as active.
    pclListNode_->m_ucFlags |= TIMERLIST_FLAG_ACTIVE;
    CS_EXIT();
}

//---------------------------------------------------------------------------
void TimerList::Remove(Timer *pclLinkListNode_)
{
    CS_ENTER();

    DoubleLinkList::Remove(pclLinkListNode_);

#if KERNEL_TIMERS_TICKLESS
    if (this->GetHead() == NULL)
    {
        KernelTimer::Stop();
    }
#endif

    CS_EXIT();
}

//---------------------------------------------------------------------------
void TimerList::Process(void)
{
#if KERNEL_TIMERS_TICKLESS
    K_ULONG ulNewExpiry;
    K_ULONG ulOvertime;
    K_BOOL bContinue;
#endif

    Timer *pclNode;
    Timer *pclPrev;

#if KERNEL_USE_QUANTUM
    Quantum::SetInTimer();
#endif
#if KERNEL_TIMERS_TICKLESS
    // Clear the timer and its expiry time - keep it running though
    KernelTimer::ClearExpiry();
    do
    {
#endif
        pclNode = static_cast<Timer*>(GetHead());
        pclPrev = NULL;

#if KERNEL_TIMERS_TICKLESS
        bContinue = 0;
        ulNewExpiry = MAX_TIMER_TICKS;
#endif

        // Subtract the elapsed time interval from each active timer.
        while (pclNode)
        {
            // Active timers only...
            if (pclNode->m_ucFlags & TIMERLIST_FLAG_ACTIVE)
            {
                // Did the timer expire?
#if KERNEL_TIMERS_TICKLESS
                if (pclNode->m_ulTimeLeft <= m_ulNextWakeup)
#else
                pclNode->m_ulTimeLeft--;
                if (0 == pclNode->m_ulTimeLeft)
#endif
                {
                    // Yes - set the "callback" flag - we'll execute the callbacks later
                    pclNode->m_ucFlags |= TIMERLIST_FLAG_CALLBACK;

                    if (pclNode->m_ucFlags & TIMERLIST_FLAG_ONE_SHOT)
                    {
                        // If this was a one-shot timer, deactivate the timer.
                        pclNode->m_ucFlags |= TIMERLIST_FLAG_EXPIRED;
                        pclNode->m_ucFlags &= ~TIMERLIST_FLAG_ACTIVE;

                    }
                    else
                    {
                        // Reset the interval timer.
                        // I think we're good though...
                        pclNode->m_ulTimeLeft = pclNode->m_ulInterval;

#if KERNEL_TIMERS_TICKLESS
                        // If the time remaining (plus the length of the tolerance interval)
                        // is less than the next expiry interval, set the next expiry interval.
                        K_ULONG ulTmp = pclNode->m_ulTimeLeft + pclNode->m_ulTimerTolerance;

                        if (ulTmp < ulNewExpiry)
                        {
                            ulNewExpiry = ulTmp;
                        }
#endif
                    }
                }
#if KERNEL_TIMERS_TICKLESS
                else
                {
                    // Not expiring, but determine how K_LONG to run the next timer interval for.
                    pclNode->m_ulTimeLeft -= m_ulNextWakeup;
                    if (pclNode->m_ulTimeLeft < ulNewExpiry)
                    {
                        ulNewExpiry = pclNode->m_ulTimeLeft;
                    }
                }
#endif
            }
            pclNode = static_cast<Timer*>(pclNode->GetNext());
        }

        // Process the expired timers callbacks.
        pclNode = static_cast<Timer*>(GetHead());
        while (pclNode)
        {
            pclPrev = NULL;

            // If the timer expired, run the callbacks now.
            if (pclNode->m_ucFlags & TIMERLIST_FLAG_CALLBACK)
            {
                // Run the callback. these callbacks must be very fast...
                pclNode->m_pfCallback( pclNode->m_pclOwner, pclNode->m_pvData );
                pclNode->m_ucFlags &= ~TIMERLIST_FLAG_CALLBACK;

                // If this was a one-shot timer, let's remove it.
                if (pclNode->m_ucFlags & TIMERLIST_FLAG_ONE_SHOT)
                {
                    pclPrev = pclNode;
                }
            }
            pclNode = static_cast<Timer*>(pclNode->GetNext());

            // Remove one-shot-timers
            if (pclPrev)
            {
                Remove(pclPrev);
            }
        }

#if KERNEL_TIMERS_TICKLESS
        // Check to see how much time has elapsed since the time we
        // acknowledged the interrupt...
        ulOvertime = KernelTimer::GetOvertime();

        if( ulOvertime >= ulNewExpiry ) {
            m_ulNextWakeup = ulOvertime;
            bContinue = 1;
        }

    // If it's taken longer to go through this loop than would take us to
    // the next expiry, re-run the timing loop

    } while (bContinue);

    // This timer elapsed, but there's nothing more to do...
    // Turn the timer off.
    if (ulNewExpiry >= MAX_TIMER_TICKS)
    {
        KernelTimer::Stop();
    }
    else
    {
        // Update the timer with the new "Next Wakeup" value, plus whatever
        // overtime has accumulated since the last time we called this handler

        m_ulNextWakeup = KernelTimer::SetExpiry(ulNewExpiry + ulOvertime);
    }
#endif
#if KERNEL_USE_QUANTUM
    Quantum::ClearInTimer();
#endif
}


#endif //KERNEL_USE_TIMERS
```

15.105 /home/moslevin/Project/R1/kernel/tracebuffer.cpp File Reference

Kernel trace buffer class definition.

```
#include "kerneltypes.h"
#include "tracebuffer.h"
#include "mark3cfg.h"
#include "writebuf16.h"
#include "kerneldebug.h"
```

15.105.1 Detailed Description

Kernel trace buffer class definition.

Definition in file tracebuffer.cpp.

15.106 tracebuffer.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "tracebuffer.h"
#include "mark3cfg.h"
#include "writebuf16.h"
#include "kerneldebug.h"

#if KERNEL_USE_DEBUG && !KERNEL_AWARE_SIMULATION
//---------------------------------------------------------------------------
WriteBuffer16 TraceBuffer::m_clBuffer;
volatile K_USHORT TraceBuffer::m_usIndex;
K_USHORT TraceBuffer::m_ausBuffer[ (TRACE_BUFFER_SIZE/sizeof(K_USHORT)) ];

//---------------------------------------------------------------------------
void TraceBuffer::Init()
{
    m_clBuffer.SetBuffers(m_ausBuffer, TRACE_BUFFER_SIZE/sizeof(K_USHORT));
    m_usIndex = 0;
}

//---------------------------------------------------------------------------
K_USHORT TraceBuffer::Increment()
```

```
{
    return m_usIndex++;
}

//---------------------------------------------------------------------------
void TraceBuffer::Write( K_USHORT *pusData_, K_USHORT usSize_ )
{
    // Pipe the data directly to the circular buffer
    m_clBuffer.WriteData(pusData_, usSize_);
}

#endif

```

15.107 /home/moslevin/Project/R1/kernel/writebuf16.cpp File Reference

16 bit circular buffer implementation with callbacks.

```
#include "kerneltypes.h"
#include "writebuf16.h"
#include "kerneldebug.h"
#include "threadport.h"
```

15.107.1 Detailed Description

16 bit circular buffer implementation with callbacks.

Definition in file writebuf16.cpp.

15.108 writebuf16.cpp

```
/*===========================================================================
     _____        _____        _____        _____
 ___|    _|__  __|_    |__  __|__   |__  __| __  |__  ______
|    \  /  | ||    \      ||     |     ||  |/ /     ||___   |
|     \/   | ||     \     ||     \     ||     \     ||___   |
|__/\__/|__|_||__|\__\  __||__|\__\  __||__|\__\  __||______|
    |_____|      |_____|      |_____|      |_____|

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===========================================================================*/
#include "kerneltypes.h"
#include "writebuf16.h"
#include "kerneldebug.h"
#include "threadport.h"

#if KERNEL_USE_DEBUG && !KERNEL_AWARE_SIMULATION

//---------------------------------------------------------------------------
void WriteBuffer16::WriteData( K_USHORT *pusBuf_, K_USHORT usLen_ )
{
    K_USHORT *apusBuf[1];
    K_USHORT ausLen[1];

    apusBuf[0] = pusBuf_;
    ausLen[0] = usLen_;

    WriteVector( apusBuf, ausLen, 1 );
}

//---------------------------------------------------------------------------
void WriteBuffer16::WriteVector( K_USHORT **ppusBuf_, K_USHORT *pusLen_,
K_UCHAR ucCount_ )
{
    K_USHORT usTempHead;
    K_UCHAR i;
    K_UCHAR j;
    K_USHORT usTotalLen = 0;
    K_BOOL bCallback = false;
    K_BOOL bRollover = false;
    // Update the head pointer synchronously, using a small
    // critical section in order to provide thread safety without
    // compromising on responsiveness by adding lots of extra
    // interrupt latency.

    CS_ENTER();

    usTempHead = m_usHead;
    {
        for (i = 0; i < ucCount_; i++)
        {
            usTotalLen += pusLen_[i];
        }
        m_usHead = (usTempHead + usTotalLen) % m_usSize;
    }
    CS_EXIT();

    // Call the callback if we cross the 50% mark or rollover
    if (m_usHead < usTempHead)
    {
        if (m_pfCallback)
        {
            bCallback = true;
            bRollover = true;
        }
    }
    else if ((usTempHead < (m_usSize >> 1)) && (m_usHead >= (m_usSize >> 1)))
    {
        // Only trigger the callback if it’s non-null
        if (m_pfCallback)
        {
            bCallback = true;
        }
    }

    // Are we going to roll-over?
    for (j = 0; j < ucCount_; j++)
    {
        K_USHORT usSegmentLength = pusLen_[j];
        if (usSegmentLength + usTempHead >= m_usSize)
        {
            // We need to two-part this... First part: before the rollover
            K_USHORT usTempLen;
            K_USHORT *pusTmp = &m_pusData[ usTempHead ];
            K_USHORT *pusSrc = ppusBuf_[j];
            usTempLen = m_usSize - usTempHead;
            for (i = 0; i < usTempLen; i++)
            {
                *pusTmp++ = *pusSrc++;
            }

            // Second part: after the rollover
            usTempLen = usSegmentLength - usTempLen;
            pusTmp = m_pusData;
            for (i = 0; i < usTempLen; i++)
            {
                *pusTmp++ = *pusSrc++;
            }
        }
        else
        {
            // No rollover - do the copy all at once.
            K_USHORT *pusSrc = ppusBuf_[j];
            K_USHORT *pusTmp = &m_pusData[ usTempHead ];
            for (K_USHORT i = 0; i < usSegmentLength; i++)
            {
                *pusTmp++ = *pusSrc++;
            }
        }
    }


    // Call the callback if necessary
    if (bCallback)
    {
        if (bRollover)
        {
            // Rollover - process the back-half of the buffer
            m_pfCallback( &m_pusData[ m_usSize >> 1], m_usSize >> 1 );
        }
        else
        {
            // 50% point - process the front-half of the buffer
            m_pfCallback( m_pusData, m_usSize >> 1);
        }
    }
```

```
}

#endif
```

Index