OSEK/VDX

- a standard for an open-ended architecture for distributed control units in vehicles
- the name:
  - OSEK: Offene Systeme und deren Schnittstellen für die Elektronik im Kraft-fahrzeug (Open systems and the corresponding interfaces for automotive electronics)
  - VDX: Vehicle Distributed eXecutive (another french proposal of API similar to OSEK)
  - OSEK/VDX is the interface resulted from the merge of the two projects

- `http://www.osek-vdx.org`

Motivations

- high, recurring expenses in the development and variant management of non-application related aspects of control software.
- incompatibility of control units made by different manufacturers due to different interfaces and protocols

Objectives

- portability and reusability of the application software
- specification of abstract interfaces for RTOS and network management
- specification independent from the HW/network details
- scalability between different requirements to adapt to specific application needs
- verification of functionality and implementation using a standardized certification process

Advantages

- clear savings in costs and development time.
- enhanced quality of the software
- creation of a market of uniform competitors
- independence from the implementation and standardised interfacing features for control units with different architectural designs
- intelligent usage of the hardware present on the vehicle
  - for example, using a vehicle network the ABS controller could give a speed feedback to the powertrain microcontroller

System philosophy

- standard interface ideal for automotive applications
- scalability
  - using conformance classes
- configurable error checking
- portability of software
  - in reality, the firmware on an automotive ECU is 10% RTOS and 90% device drivers

Support for automotive requirements

- the idea is to create a system that is
  - reliable
  - with real-time predictability
- support for
  - fixed priority scheduling with immediate priority ceiling
  - non preemptive scheduling
  - preemption thresholds
  - ROM execution of code
  - stack sharing (limited support for blocking primitives)
- documented system primitives
  - behavior
  - performance of a given RTOS must be known

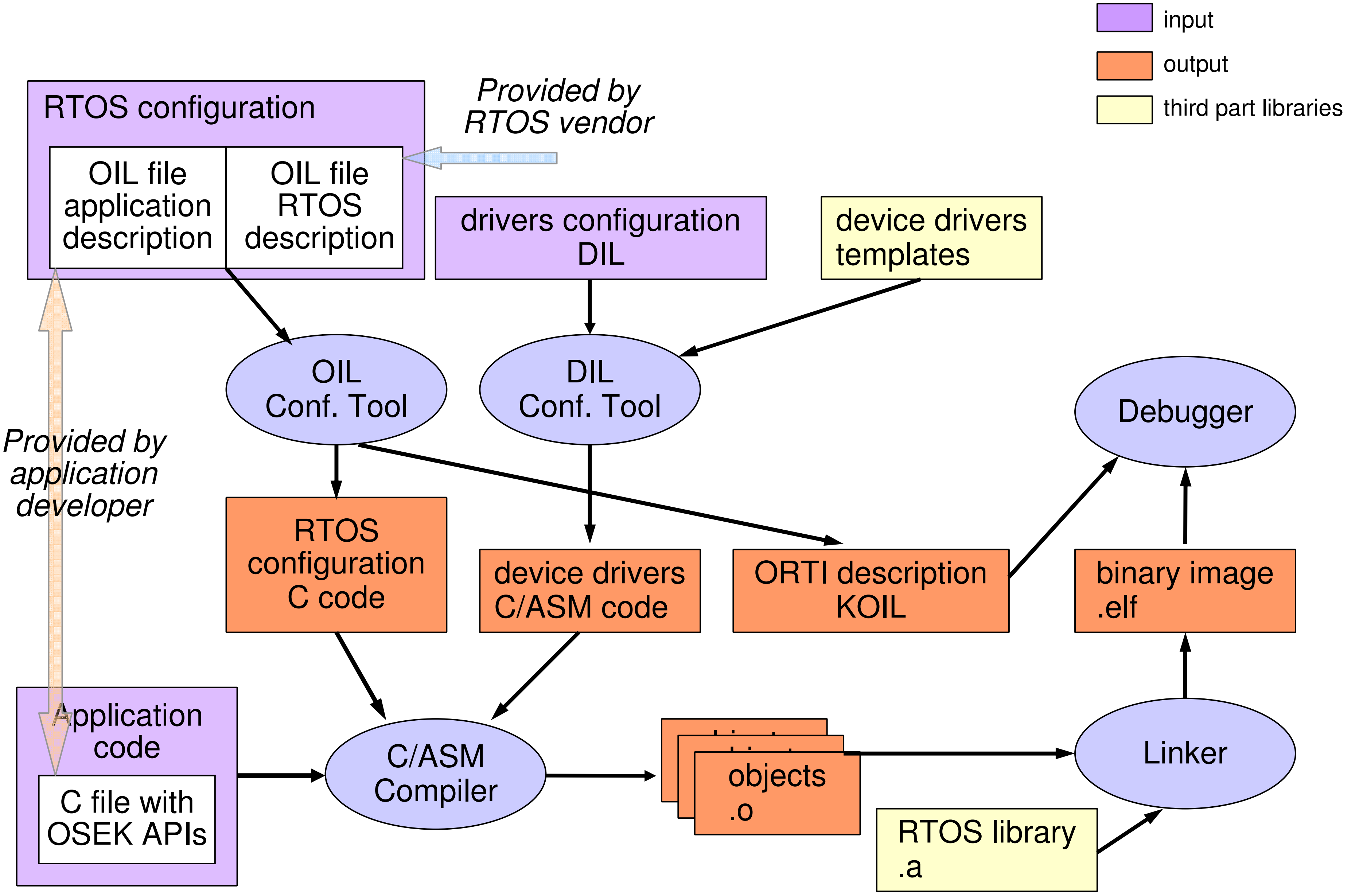
Static configuration

- everything is specified before the system runs

- static approach to system configuration
  - no dynamic allocation on memory
  - no dynamic creation of tasks
  - no flexibility in the specification of the constraints

- custom languages that helps off-line configuration of the system
  - OIL: parameters specification (tasks, resources, stacks…)
  - KOIL: kernel aware debugging

Application building process



🟪 input

🟧 output

🟨 third part libraries

RTOS configuration

OIL file application description

OIL file RTOS description

Provided by RTOS vendor

drivers configuration DIL

device drivers templates

OIL Conf. Tool

DIL Conf. Tool

Debugger

Provided by application developer

RTOS configuration C code

device drivers C/ASM code

ORTI description KOIL

binary image .elf

Application code

C file with OSEK APIs

C/ASM Compiler

objects .o

Linker

RTOS library .a

OSEK/VDX standards

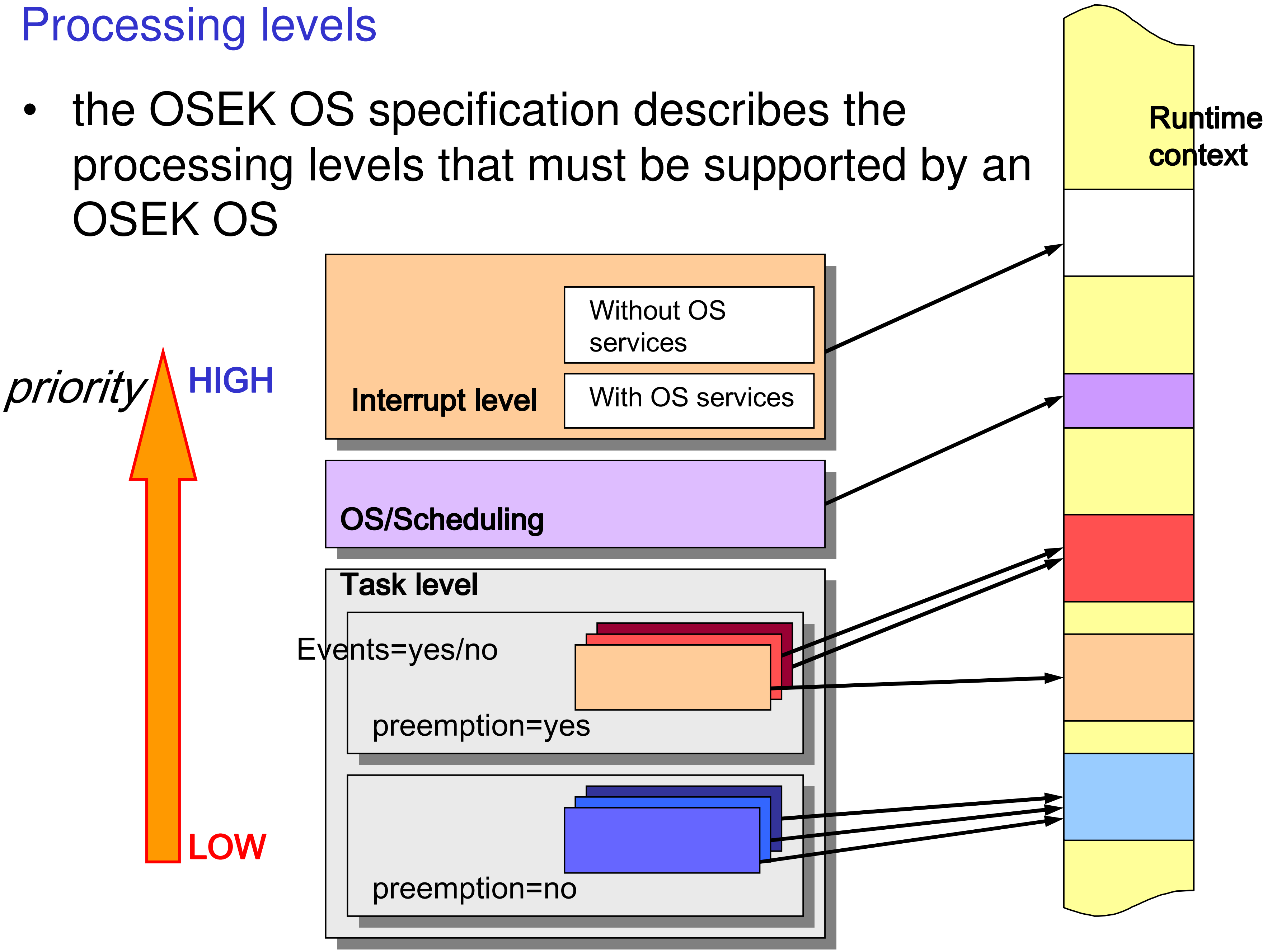
- The OSEK/VDX consortium packs its standards in different documents

OSEK OS	operating system
OSEK Time	time triggered operating system
OSEK COM	communication services
OSEK FTCOM	fault tolerant communication
OSEK NM	network management
OSEK OIL	kernel configuration
OSEK ORTI	kernel awareness for debuggers

- next slides will describe the OS, OIL, ORTI and COM parts

Processing levels

- the OSEK OS specification describes the processing levels that must be supported by an OSEK OS

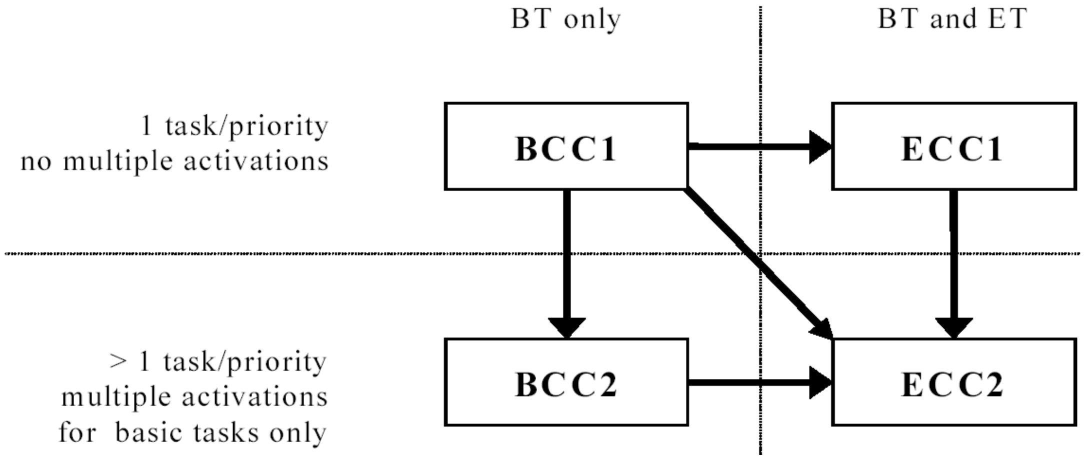


Conformance classes

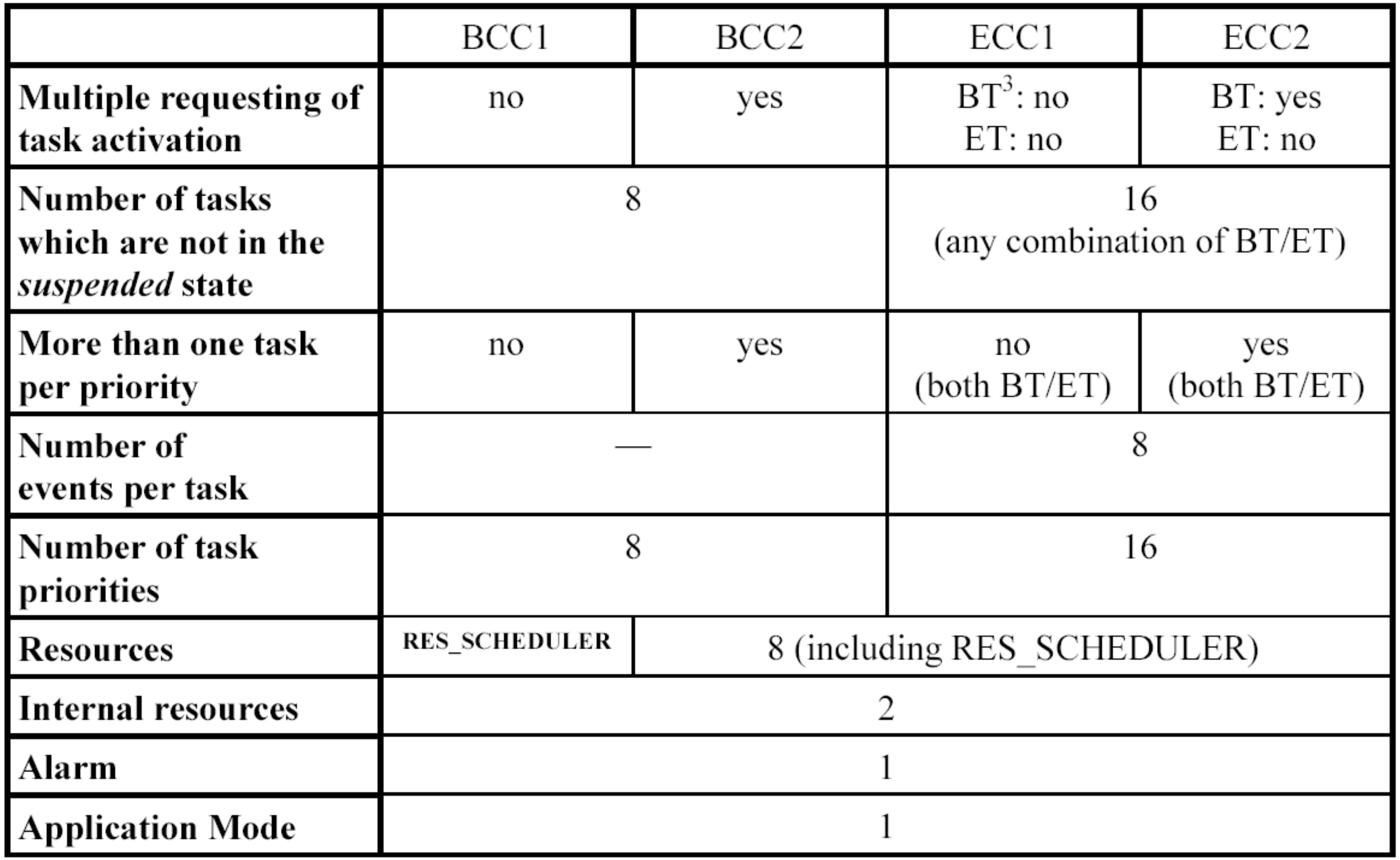
- OSEK OS should be scalable with the application needs
  - different applications require different services
  - the system services are mapped in Conformance Classes
- a conformance class is a subset of the OSEK OS standard
- objectives of the conformance classes
  - allow partial implementation of the standard
  - allow an upgrade path between classes
- services that discriminates the different conformance classes
  - multiple requests of task activations
  - task types
  - number of tasks per priority

Conformance classes (2)

- there are four conformance classes
  - BCC1
    basic tasks, one activation, one task per priority
  - BCC2
    BCC1 plus: > 1 activation, > 1 task per priority
  - ECC1
    BCC1 plus: extended tasks
  - ECC2
    BCC2 plus: > 1 activation (basic tasks), > 1 task per priority



Conformance classes (3)



	BCC1	BCC2	ECC1	ECC2
Multiple requesting of task activation	no	yes	BT[3]: no ET: no	BT: yes ET: no
Number of tasks which are not in the *suspended* state	8		16 (any combination of BT/ET)	
More than one task per priority	no	yes	no (both BT/ET)	yes (both BT/ET)
Number of events per task	—		8	
Number of task priorities	8		16	
Resources	RES_SCHEDULER	8 (including RES_SCHEDULER)		
Internal resources	2			
Alarm	1			
Application Mode	1			

Basic tasks

- a basic task is
  - a C function call that is executed in a proper context
  - that can never block
  - can lock resources
  - can only finish or be preempted by an higher priority task or ISR
- a basic task is ideal for implementing a kernel-supported stack sharing, because
  - the task never blocks
  - when the function call ends, the task ends, and its local variables are destroyed
  - in other words, it uses a one-shot task model
- support for multiple activations
  - in BCC2, ECC2, basic tasks can store pending activations (a task can be activated while it is still running)

Extended tasks

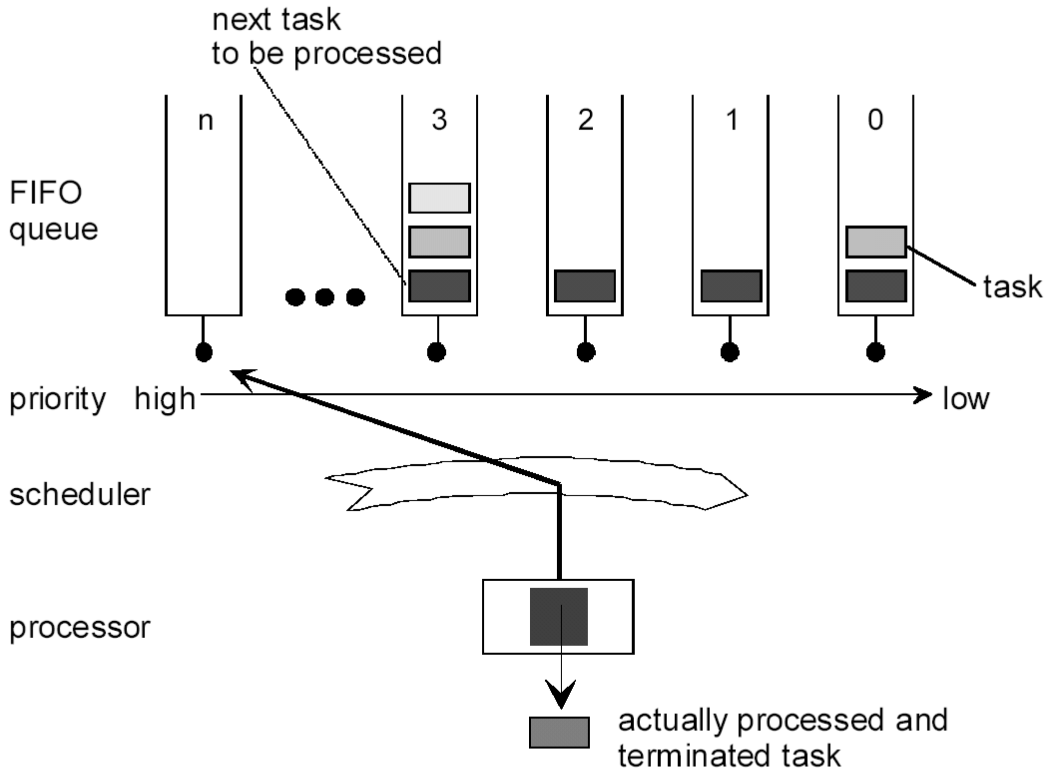
- extended tasks can use events for synchronization
- an event is simply an abstraction of a bit mask
  - events can be set/reset using appropriate primitives
  - a task can wait for an event in event mask to be set
- extended tasks typically
  - have their own stack
  - are activated once
  - have as body an infinite loop over a WaitEvent() primitive
- extended tasks do not support multiple activations
  - ... but supports multiple pending events

Scheduling algorithm

- the scheduling algorithm is fundamentally a
  - fixed priority scheduler
  - with immediate priority ceiling
  - with preemption threshold
- the approach allows the implementation of
  - preemptive scheduling
  - non preemptive scheduling
  - mixed
- with some peculiarities...

Scheduling algorithm: peculiarities

- multiple activations of tasks with the same priority
  - are handled in FIFO order
  - that imposes in some sense the internal scheduling data structure



OSEK task primitives (basic and extended tasks)

`TASK(<TaskIdentifier>) {…}`

- used to define a task body (it's a macro!)

`DeclareTask(<TaskIdentifier>)`

- used to declare a task name (it's a macro!)

`StatusType ActivateTask(TaskType <TaskID>)`

- activates a task

`StatusType TerminateTask(void)`

- terminates the current running task (from any function nesting!)

`StatusType ChainTask(TaskType <TaskID>)`

- atomic version of TerminateTask+ActivateTask

`StatusType Schedule(void)`

- rescheduling point for a non-preemptive task

`StatusType GetTaskID(TaskRefType <TaskID>)`

- returns the running task ID

`StatusType GetTaskState(TaskType <TaskID>, TaskStateRefType <State>)`

- returns the status of a given task

OSEK event primitives

`DeclareEvent(<EventIdentifier>)`

- declaration of an Event identifier (it’s a macro!)

`StatusType SetEvent(TaskType <TaskID>, EventMaskType <Mask>)`

- sets a set of event flags to an extended task

`StatusType ClearEvent(EventMaskType <Mask>)`

- clears an event mask (extended tasks only)

`StatusType GetEvent(TaskType <TaskID>, EventMaskRefType <Event>)`

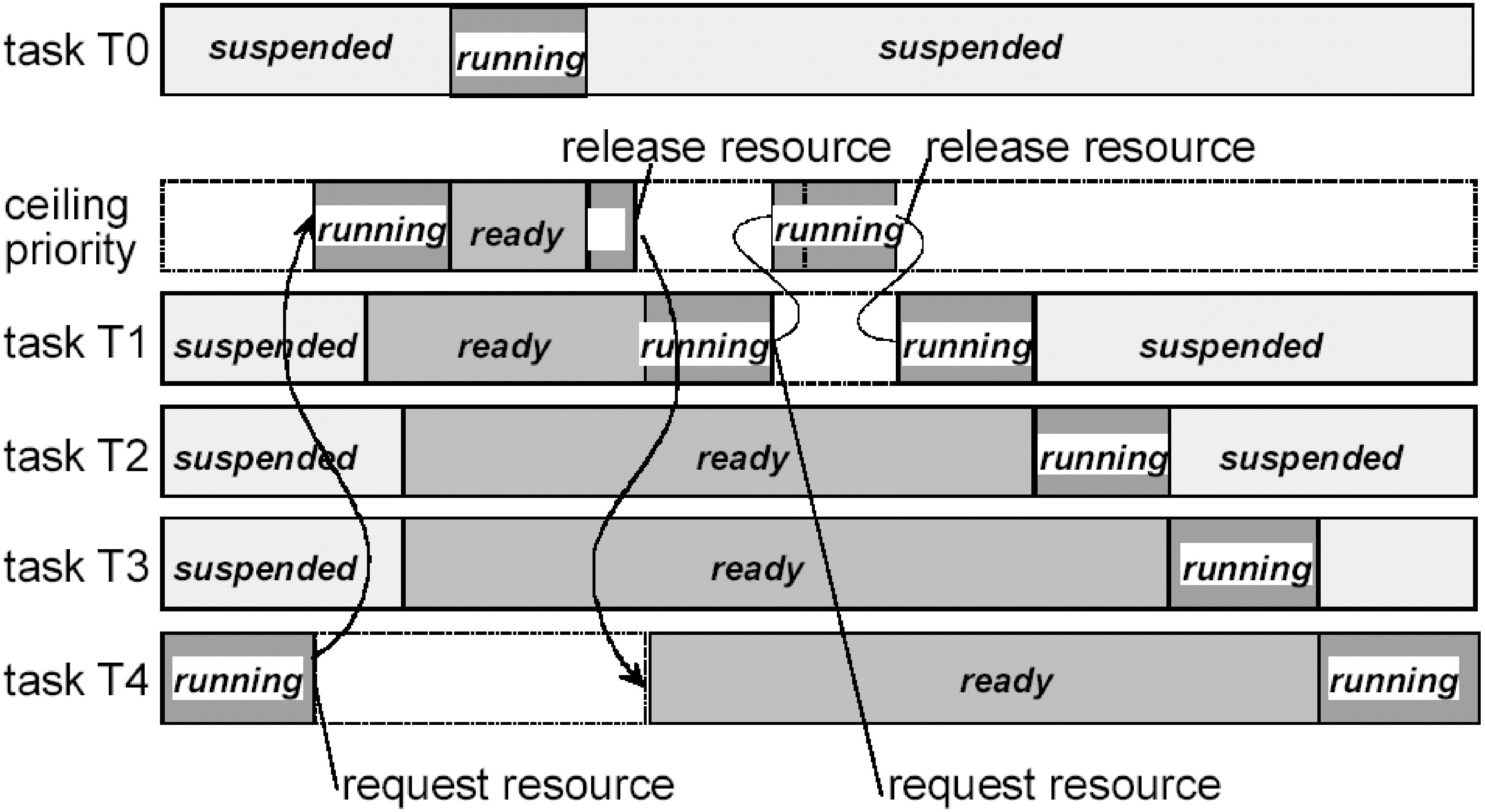
- gets an event mask

`StatusType WaitEvent(EventMaskType <Mask>)`

- waits for an event mask (extended tasks only)
- *this is the only blocking primitive of the OSEK standard*

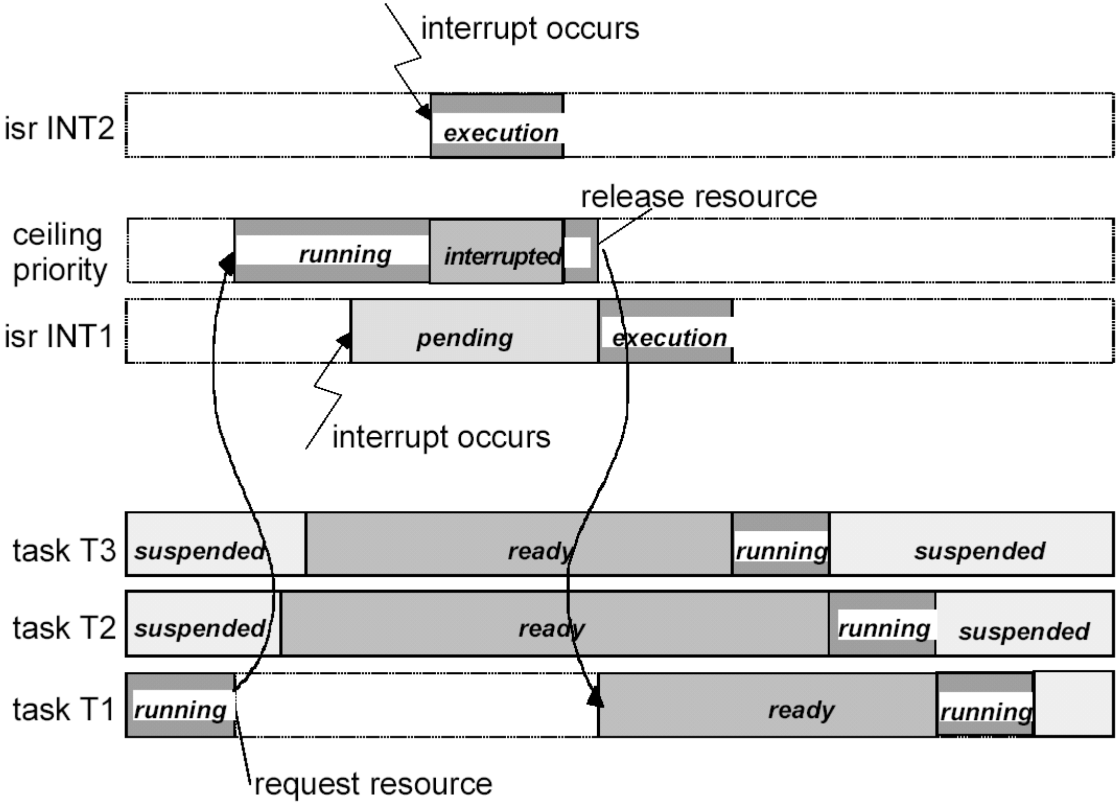
Scheduling algorithm: Resources (1)

- resources
  - are typical Immediate Priority Ceiling mutexes
  - the priority of the task is raised when the task locks the resource



Scheduling algorithm: Resources (2)

- resources at the interrupt level
  - resources can be used at interrupt level
  - for example, to protects drivers
  - the code must directly operate on the interrupt controller



Scheduling algorithm: Resources (3)

- preemption threshold implementation
  - done using “internal resources” that are locked when the task starts and unlocked when the task ends
  - internal resources cannot be used by the application

OSEK resource primitives

`DeclareResource(<ResourceIdentifier>)`

- used to define a resource (it's a macro!)

`StatusType GetResource(ResourceType <ResID>)`

- resource lock function

`StatusType ReleaseResource(ResourceType <ResID>)`

- resource unlock function

`RES_SCHEDULER`

- resource possibly used by every task →the task becomes non preemptive

Interrupt service routine

- OSEK OS directly addresses interrupt management in the standard API
- interrupt service routines (ISR) can be of two types
  - Category 1: without API calls
    simpler and faster, do not implement a call to the scheduler at the end of the ISR
  - Category 2: with API calls
    these ISR can call some primitives (ActivateTask, ...) that change the scheduling behavior. The end of the ISR is a rescheduling point
- ISR 1 has always a higher priority than ISR 2

- finally, the OSEK standard has functions to directly manipulate the CPU interrupt status

OSEK interrupts primitives

`ISR(<ISRName>) {…}`

- define an ISR2 function

`void EnableAllInterrupts(void)`

`void DisableAllInterrupts(void)`

- enable and disable ISR1 and ISR2 interrupts

`void ResumeAllInterrupts(void)`

`void SuspendAllInterrupts(void)`

- enable and disable ISR1 and ISR2 interrupts (nesting possible!)

`void ResumeOSInterrupts(void)`

`void SuspendOSInterrupts(void)`

- enable and disable only ISR2 interrupts (nesting possible!)

Counters and alarms

- counter
  - is a memory location or a hardware resource used to count events
  - for example, a counter can count the number of timer interrupts to implement a time reference
- alarm
  - is a service used to process recurring events
  - an alarm can be cyclic or one shot
  - when the alarm fires, a notification takes place
    - task activation
    - call of a callback function
    - set of an event

OSEK alarm primitives

`DeclareAlarm(<AlarmIdentifier>)`

- declares an Alarm identifier (it’s a macro!)

`StatusType GetAlarmBase ( AlarmType <AlarmID>, AlarmBaseRefType <Info> )`

- gets timing informations for the Alarm

`StatusType GetAlarm ( AlarmType <AlarmID> TickRefType <Tick>)`

- value in ticks before the Alarm expires

`StatusType SetRelAlarm(AlarmType <AlarmID>, TickType <increment>, TickType <cycle>)`

`StatusType SetAbsAlarm(AlarmType <AlarmID>, TickType <start>, TickType <cycle>)`

- programs an alarm with a relative or absolute offset and period

`StatusType CancelAlarm(AlarmType <AlarmID>)`

- cancels an armed alarm

Application modes

- OSEK OS supports the concept of application modes
- an application mode is used to influence the behavior of the device
- example of application modes
  - normal operation
  - debug mode
  - diagnostic mode
  - ...

OSEK Application modes primitive

`AppModeType GetActiveApplicationMode(void)`

- gets the current application mode

`OSDEFAULTAPPMODE`

- a default application mode value always defined

`void StartOS(AppModeType <Mode>)`

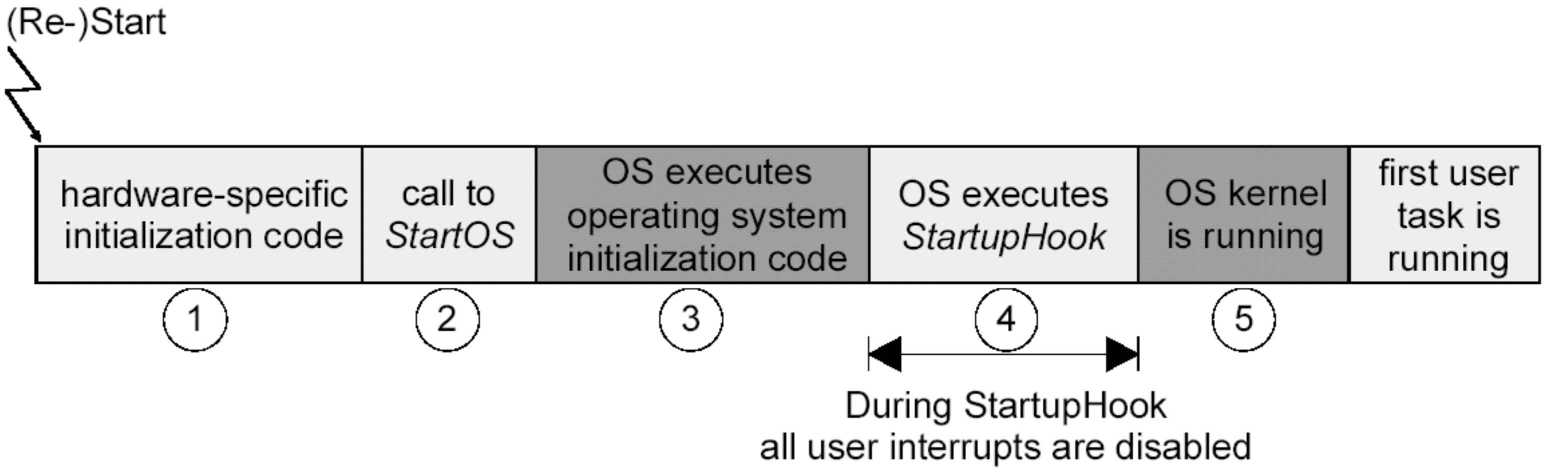
- starts the operating system

`void ShutdownOS(StatusType <Error>)`

- shuts down the operating system (e.g., a critical error occurred)

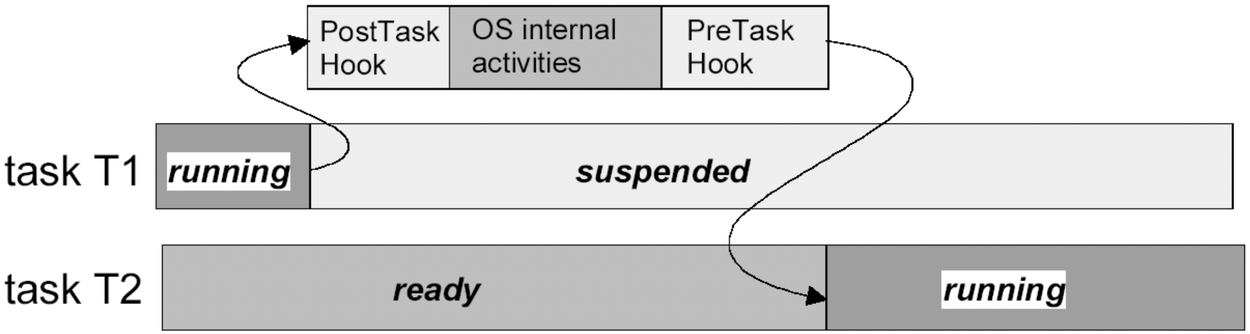
Hooks

- OSEK OS specifies a set of hooks that are called at specific times
  - StartupHook
    when the system starts



Hooks (2)

- PreTaskHook
  before a task is scheduled
- PostTaskHook
  after a task has finished its slice



- ShutdownHook
  when the system is shutting down (usually because of an unrecoverable error)
- ErrorHook
  when a primitive returns an error

Error handling

- the OSEK OS has two types or error return values
  - standard error
    (only errors related to the runtime behavior are returned)
  - extended error
    (more errors are returned, useful when debugging)
- the user has two ways of handling these errors
  - distributed error checking
    the user checks the return value of each primitive
  - centralized error checking
    the user provides a ErrorHook that is called whenever an error condition occurs

OSEK OIL

- goal
  - provide a mechanism to configure an OSEK application inside a particular CPU (for each CPU there is one OIL description)
- the OIL language
  - allows the user to define objects with properties (e.g., a task that has a priority)
  - some object and properties have a behavior specified by the standard
- an OIL file is divided in two parts
  - an implementation definition
    defines the objects that are present and their properties
  - an application definition
    define the instances of the available objects for a given application

OSEK OIL objects

- The OIL specification defines the properties of the following objects:
  - CPU
    the CPU on which the application runs
  - OS
    the OSEK OS which runs on the CPU
  - ISR
    interrupt service routines supported by OS
  - RESOURCE
    resources that can be used by a task
  - TASK
    tasks handled by the OS
  - COUNTER
    the counter represents hardware/software tick source for alarms.

OSEK OIL objects (2)

- EVENT
  the event owned by a task.
- ALARM
  the alarm is based on a counter
- MESSAGE
  the COM message which provides local or network communication
- COM
  the communication subsystem
- NM
  the network management subsystem

OIL example: implementation definition

```
OIL_VERSION = "2.4";

IMPLEMENTATION my_osek_kernel {
[...]
    TASK {
     BOOLEAN [
         TRUE { APPMODE_TYPE APPMODE[]; },
         FALSE
        ] AUTOSTART;
        UINT32 PRIORITY;
        UINT32 ACTIVATION = 1;
        ENUM [NON, FULL] SCHEDULE;
        EVENT_TYPE EVENT[];
        RESOURCE_TYPE RESOURCE[];

        /* my_osek_kernel specific values */
        ENUM [
            SHARED,
            PRIVATE { UINT32 SIZE; }
        ] STACK;
    };
[...]
};
```

OIL example: application definition

```
CPU my_application {
    TASK Task1 {
        PRIORITY = 0x01;
        ACTIVATION = 1;
        SCHEDULE = FULL;
        AUTOSTART = TRUE;
        STACK = SHARED;
    };
};
```

I/O Management architecture

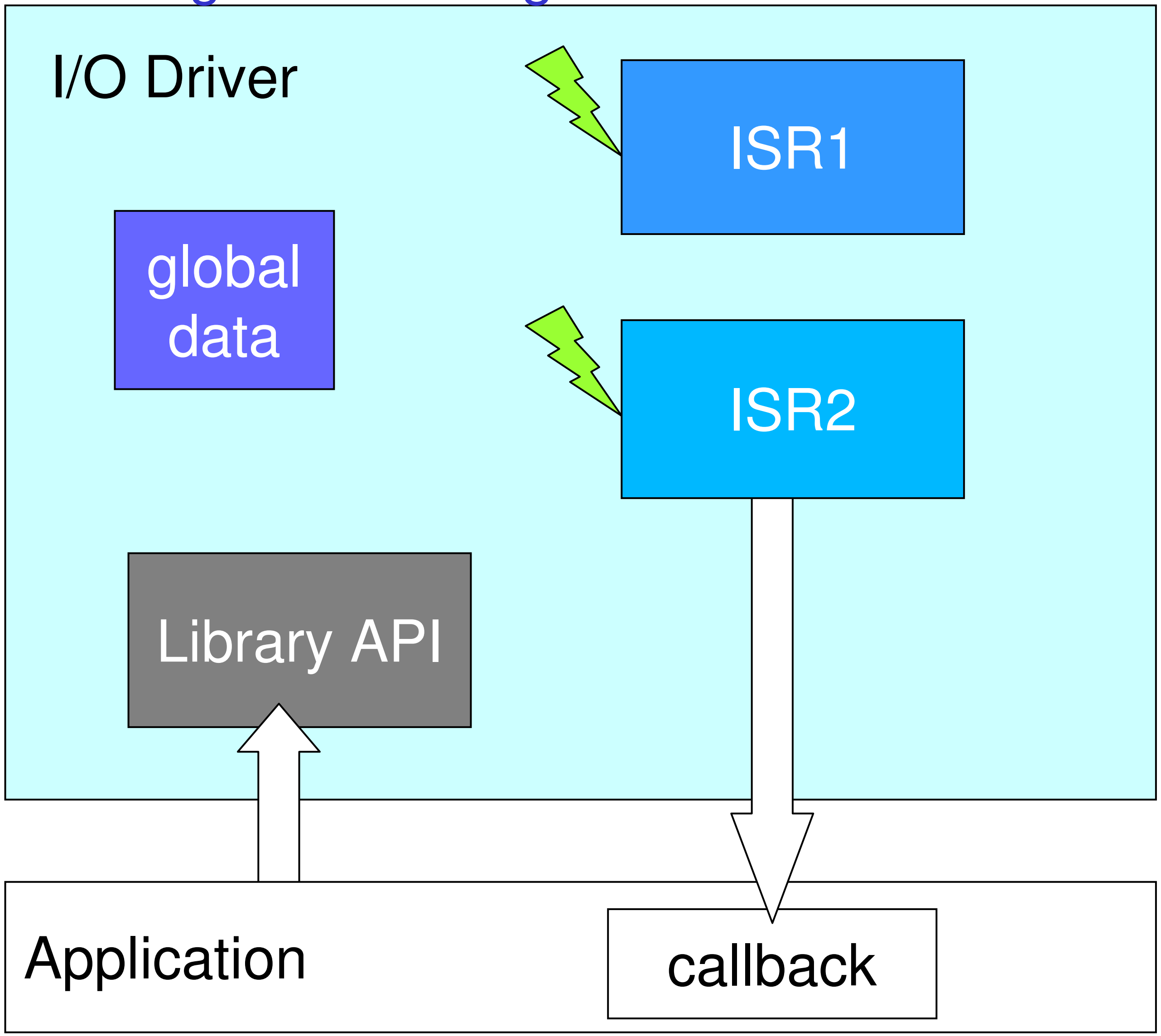
- the application calls I/O functions
- typical I/O functions are non-blocking
  - OSEK BCC1/BCC2 does not have blocking primitives
- blocking primitives can be implemented
  - with OSEK ECC1/ECC2
  - not straightforward

- the driver can use
  - polling
    - typically used for low bandwidth, fast interfaces
    - typically non-blocking
    - typically independent from the RTOS

I/O Management architecture (2)

- interrupts
  - there are a lot of interrupts in the system
  - interrupts nesting often enabled
  - most of the interrupts are ISR1 (independent from the RTOS) because of runtime efficiency
  - one ISR2 that handles the notifications to the application
- DMA
  - typically used for high-bandwidth devices (e.g., transfers from memory to device

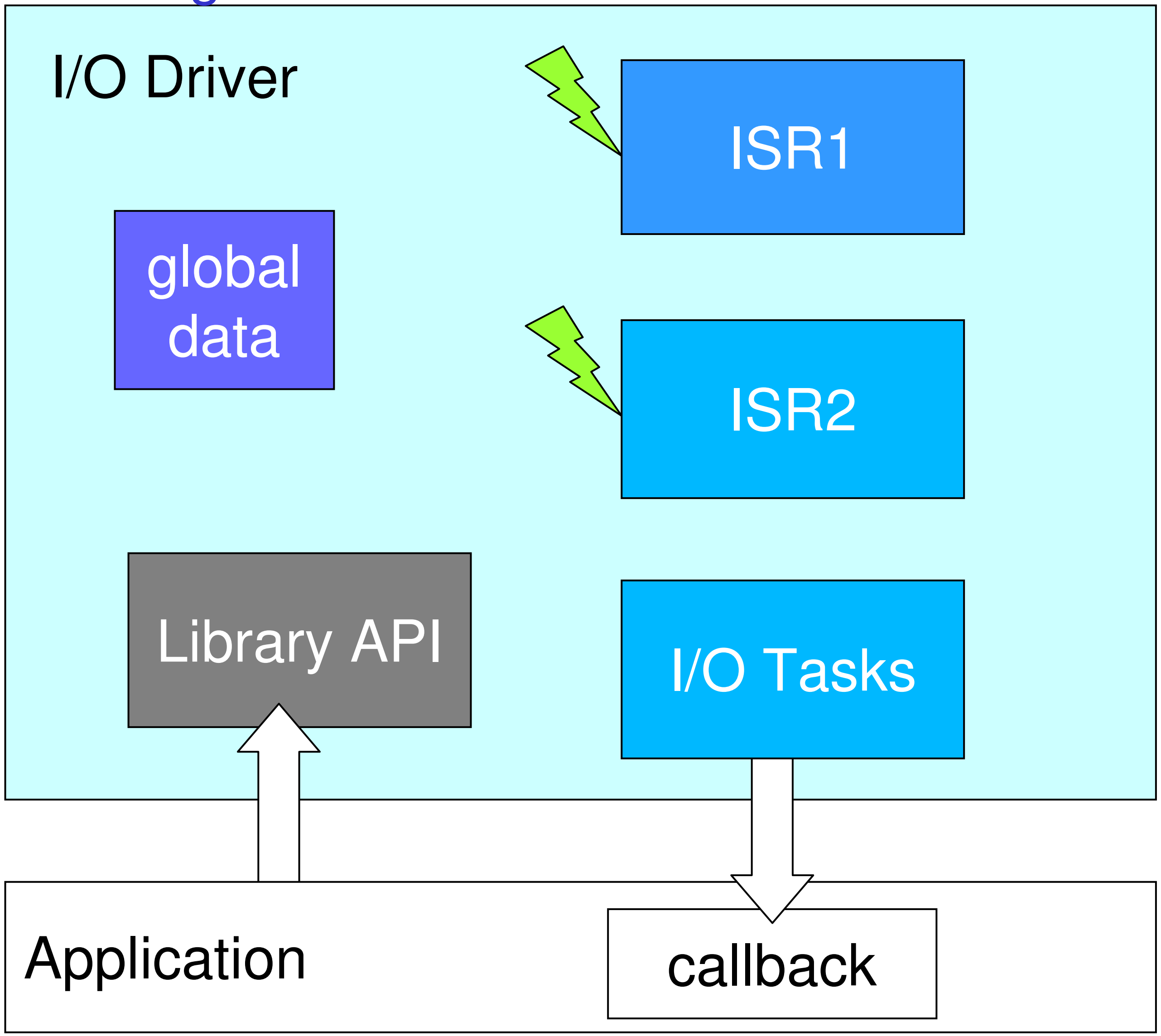
I/O Management: using ISR2



I/O Management architecture (3)

- another option is to use the ISR2 to wake up a driver task
- the driver task will be scheduled by the RTOS together with the other application tasks

I/O Management architecture



I/O Driver

ISR1

global data

ISR2

Library API

I/O Tasks

Application

callback

OSEK Standard and experiments on microcontroller devices

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summary

- the hardware
- example 1 – ISR2 and tasks
- example 2 – application modes and resources
- example 3 – events, alarms, ErrorHook, ORTI

the hardware

- the evaluation board used is a FLEX board (Light or Full) with a Demo Daughter board

- during the examples, we’ll use the following devices:
  - the DSPIC MCU
  - 1 timer
  - a button
    - used to generate interrupts when pressed or released
    - also used as external input
  - leds
  - 16x2 LCD

Example 1 – Tasks and ISR2

- The demo shows the usage of the following primitives:

  DeclareTask – ActivateTask – TerminateTask - Schedule

- Demo structure
  - The demo is consists of two tasks, Task1 and Task2.
  - Task1 repeatedly puts on and off a sequence of LEDs
  - Task2 simply turns on and off a LED, and is activated by pressing a button. Task2 depending on the configuration parameters, may preempt Task1

Ex. 1 Configuration 1: Full preemptive

- This configuration is characterized by the following properties:
  - periodic interrupt → Task1 activation → LED 0 to 5 blink
  - button → Task2 activation → Task2 always preempts Task1, blinks LED 6/7 and prints a message

Notes:

- Task2 is automatically activated by StartOS
  - AUTOSTART=TRUE
- Conformance Class is BCC1
  - lost activations if the button pressed too fast!

Ex. 1 Configuration 2: Non preemptive

- Task1 is NON preemptive
- Task2 runs only when Task1 does not run
  - LEDs 6 and 7 does not interrupt the ChristmasTree
- IRQs are not lost, but task activations may be

Ex. 1 Configuration 3: Preemption points

- Task1 calls Schedule in the middle of the Christmas tree

- Result:
  - Task2 can now preempt Task1 in the middle of the Christmas tree

Ex. 4 Configuration 4: Multiple Activations.

- BCC2 Conformance class
- Task2 can now store pending activations, which are executed whenever possible

Example 2 - Resources and App. modes

- The demo shows the usage of the following primitives:

  GetActiveApplicationMode, GetResource, ReleaseResource
- Demo structure
  - Two tasks, LowTask and HighTask sharing a resource.
  - LowTask is a periodic low priority task, activated by a timer, with a long execution time.
  - Almost all its execution time is spent inside a critical section. LED 0 is turned on when LowTask is inside the critical section.
  - HighTask is a high priority task that increments (decrements) a counter depending on the application mode being ModeIncrement (ModeDecrement). The task is aperiodic, and is activated by the ISR linked to the button.

Example 2 - Resources and App. modes (2)

- Application Modes are used to implement a task behavior dependent on a startup condition
- (ERIKA specific) HighTask and LowTask are configured to share the same stack by setting the following line inside the OIL task properties:

  STACK = SHARED;

Example 3 - Event and Alarm API Example

- The demo shows the usage of the following primitives:

  WaitEvent, Getevent, ClearEvent, SetEvent, ErrorHook, StartupHook, SetRelAlarm, CounterTick
- Demo structure:
  - The demo consists of two tasks, Task1 and Task2.
  - Task1 is an extended task. Extended tasks are tasks that:
    - can call blocking primitives (WaitEvent)
    - must have a separate stack
  - A task is considered an Extended Task when the OIL file includes events inside the task properties.
  - Task1 waits for two events:
    - Timer → CounterTick → AlarmTask1 → TimerEvent → LED 1
    - Button IRQ → SetEvent(ButtonEvent) → LED 2

Example 3 - Event and Alarm API Example (2)

- Button press → ISR2 →SetRelAlarm(AlarmTask2) → Task2 activation → LED 3 on.
- ErrorHook → when the button is pressed rapidly twice
  - SetRelAlarm primitive called by the Button IRQ on an already armed alarm
- The alarm support is basically a wakeup mechanism that can be attached to application or external events (such as timer interrupts) by calling CounterTick to implement an asynchronous notification.
- (ERIKA Enterprise specific) Task1 needs a separate stack because it uses WaitEvent.

Example 3 - Event and Alarm API Example (3)

- Running the example
  - Timer Interrupt → Counter1 incremented.
  - AlarmTask1 → TimerEvent event set on Task1 → Task1 wakes up, get the event, and blinks LED 1.
  - The visible result is that LED 1 periodically blinks on the board.

  - button press → Task1 runs and LED 3 goes on and off
  - rapid button press → ErrorHook due to multiple calls of SetRelAlarm

  - ORTI Informations are available for this demo

Examples

```
CPU test_application {
    OS EE {
            CFLAGS = "-DALT_DEBUG -O0 -g";
            CFLAGS = "-Wall";
            ASFLAGS = "-g";
            LDFLAGS = "-Wl,-Map -Wl,project.map";
            LDDEPS = "\\";
            LIBS = "-lm";
            NIOS2_SYS_CONFIG = "Debug";
            NIOS2_APP_CONFIG = "Debug";
            NIOS2_DO_MAKE_OBJDUMP = TRUE;
            NIOS2_JAM_FILE =
    "C:/altera/81/nios2eds/examples/verilog/niosII_stratixII_2s60_RoHS/frsh_small/fpga.jam";
            NIOS2_PTF_FILE =
    "C:/altera/81/nios2eds/examples/verilog/niosII_stratixII_2s60_RoHS/frsh_small/NiosII_stratixII_2s60_RoHS_
    small_sopc.ptf";
            CPU_DATA = NIOSII {
                        MULTI_STACK = FALSE;
                        STACK_TOP = "__alt_stack_pointer";
                        SYS_SIZE = 0x1000;
                        SYSTEM_LIBRARY_NAME = "frsh_small_syslib";
                        SYSTEM_LIBRARY_PATH = "/cygdrive/c/Users/Marco/workspaceFRSH81/frsh_small_syslib";

                        APP_SRC = "code.c";
            };
            STATUS = EXTENDED;
            STARTUPHOOK = FALSE;
            ERRORHOOK = FALSE;
            SHUTDOWNHOOK = FALSE;
            PRETASKHOOK = FALSE;
            POSTTASKHOOK = FALSE;
            USEGETSERVICEID = FALSE;
            USEPARAMETERACCESS = FALSE;
            USERESSCHEDULER = FALSE;

//          ORTI_SECTIONS = ALL;
    };
```

Examples

```
/* this is the OIL part for the task displaying the christmas tree */
TASK Task1 {
        PRIORITY = 0x01;    /* Low priority */
        AUTOSTART = FALSE;
        STACK = SHARED;
        ACTIVATION = 1;     /* only one pending activation */
};

/* this is the OIL part for the task activated by the button press */
TASK Task2 {
        PRIORITY = 0x02;    /* High priority */
        SCHEDULE = FULL;
        AUTOSTART = TRUE;
        STACK = SHARED;
};

/* CONFIGURATION 1:
 * Kernel is BCC1
 * Task 1 is full preemptive
 */

OS EE { KERNEL_TYPE = BCC1; };
TASK Task1 { SCHEDULE = FULL; };
TASK Task2 { ACTIVATION = 1; };
```

Examples

```
/* A few counters incremented at each event
 * (alarm, button press or task activation...)
 */
volatile int timer_fired=0;
volatile int button_fired=0;
volatile int task2_fired=0;

/* Let's remember the led status!
 * Mutual exclusion on this variable is not included in the demo to make it
 * not too complicated; in general shared variables should be protected using
 * GetResource/ReleaseResource calls
 */
volatile int led_status = 0;

/* Let's declare the tasks identifiers */
DeclareTask(Task1);
DeclareTask(Task2);

/* just a dummy delay */
#define ONEMILLION 1000000
static void mydelay(void)
{
  int i;
  for (i=0; i<ONEMILLION/2; i++);
}
```

Examples

```
/* sets and resets a led configuration passed as parameter, leaving the other
 * bits unchanged
 *
 * Note: led_blink is called both from Task1 and Task2. To avoid race
 * conditions, we forced the atomicity of the led manipulation using IRQ
 * enabling/disabling. We did not use Resources in this case because the
 * critical section is -really- small. An example of critical section using
 * resources can be found in the osek_resource example.
 */
void led_blink(int theled)
{
  alt_irq_context c;

  c = alt_irq_disable_all();
  led_status |= theled;
  IOWR_ALTERA_AVALON_PIO_DATA(LED_PIO_BASE, led_status);
  alt_irq_enable_all(c);

  mydelay();

  c = alt_irq_disable_all();
  led_status &= ~theled;
  IOWR_ALTERA_AVALON_PIO_DATA(LED_PIO_BASE, led_status);
  alt_irq_enable_all(c);
}
```

Examples

```
/* This alarm callback is attached to the system timer, and is used to
 * activate Task1
 * The period in expressed in system timer ticks, each one typically 10ms
 */
#define TASK1_TIMER_INTERVAL  400
alt_u32 Task1_alarm_callback (void* arg)
{
  /* Count the number of alarm expirations */
  timer_fired++;
  ActivateTask(Task1);
  return TASK1_TIMER_INTERVAL;
}
```

Examples

```
/* Task1: just call the ChristmasTree */
TASK(Task1)
{
  /* First half of the christmas tree */
  led_blink(0x01);
  led_blink(0x02);
  led_blink(0x04);
  /* CONFIGURATION 3 and 4: we put an additional Schedule() here! */
#ifdef MYSCHEDULE
  Schedule();
#endif
  /* Second half of the christmas tree */
  led_blink(0x08);
  led_blink(0x10);
  led_blink(0x20);
  TerminateTask();
}
```

Examples

```
/* Task2: Print the counters on the JTAG UART */
TASK(Task2)
{
  static int which_led = 0;
  /* count the number of Task2 activations */
  task2_fired++;
  /* let blink leds 6 or 7 */
  if (which_led) {
    led_blink(0x80);
    which_led = 0;
  }
  else {
    led_blink(0x40);
    which_led = 1;
  }

  /* prints a report
   * Note: after the first printf in main(), then only this task uses printf
   * In this way we avoid raceconditions in the usage of stdout.
   */
  printf("Task2 - Timer: %3d Button: %3d Task2: %3d\n", timer_fired,
   button_fired, task2_fired);

  TerminateTask();
}
```

Examples

```
/*
 * Handle button_pio interrupts activates Task2.
 */
static void handle_button_interrupts(void* context, alt_u32 id)
{
  /* Reset the Button's edge capture register. */
  IOWR_ALTERA_AVALON_PIO_EDGE_CAP(BUTTON_PIO_BASE, 0);

  /* count the number of button presses */
  button_fired++;

  ActivateTask(Task2);
}

/* Initialize the button_pio. */
static void init_button_pio()
{
  /* Enable the first two 2 button interrupts. */
  IOWR_ALTERA_AVALON_PIO_IRQ_MASK(BUTTON_PIO_BASE, 0x3);
  /* Reset the edge capture register. */
  IOWR_ALTERA_AVALON_PIO_EDGE_CAP(BUTTON_PIO_BASE, 0x0);
  /* Register the interrupt handler. */
  alt_irq_register( BUTTON_PIO_IRQ, NULL, handle_button_interrupts );
}
```

Examples

```
int main()
{
  alt_alarm myalarm;

  /* set the stack space to a known pattern, to allow stack statistics by
   * Lauterbach Trace32 */
  EE_trace32_stack_init();

  printf("Welcome to the ERIKA Enterprise Christmas Tree!\n\n");

  /* let's start the multiprogramming environment...*/
  StartOS(OSDEFAULTAPPMODE);

  /* program the Button PIO */
  init_button_pio();

  /* start the periodic timers */
  alt_alarm_start (&myalarm, TASK1_TIMER_INTERVAL,
                   Task1_alarm_callback, NULL);

  /* now the background activities: in this case, we do nothing. */
  for (;;);
  return 0;
}
```

Examples (OIL variations)

```
/* CONFIGURATION 2:
 * Same as Configuration 1, BUT Task 1 is NON preemptive
 */

OS EE { KERNEL_TYPE = BCC1; };
TASK Task1 { SCHEDULE = NON; };
TASK Task2 { ACTIVATION = 1; };

/* CONFIGURATION 3:
 * Same as Configuration 2, BUT the code is compiled with an additional #define
 * that controls the presence of the Schedule() function inside Task1
 *
 * The additional define is added with the EEOPT = "..."; statement inside
 * the OS object.
 */

OS EE { EE_OPT = "MYSCHEDULE"; KERNEL_TYPE = BCC1; };
TASK Task1 { SCHEDULE = NON; };
TASK Task2 { ACTIVATION = 1; };
```

Examples (OIL variations)

```
/* CONFIGURATION 4:
 * Same as Configuration 3, BUT Task2 supports three pending activations.
 * The kernel type has to be BCC2 to support more than one pending
activation!
 *
 * Note: This configuration does not work with the Demo version
 * (which includes only a BCC1 kernel)
 */

 // OS EE { EE_OPT = "MYSCHEDULE"; KERNEL_TYPE = BCC2; };
// TASK Task1 { SCHEDULE = NON; };
// TASK Task2 { ACTIVATION = 6; };

 /* ---------------------------------------------------------- */

/* CONFIGURATION 5:
 * Kernel is FP
 * Task 1 is full preemptive
 */

 // OS EE { KERNEL_TYPE = FP { NESTED_IRQ = TRUE; }; };
// TASK Task1 { SCHEDULE = FULL; };
// TASK Task2 { ACTIVATION = 1; };


};
```

Examples (ORTI) Declaration – types ....

```
VERSION {
    KOIL = "2.1";
    OSSEMANTICS = "ORTI", "2.1";
};

IMPLEMENTATION EE_cpu_0 {
    OS {
    /* here for each task a small description and its index */
        ENUM [
            "NO_TASK" = "-1",
            "Task1" = 0,
            "Task2" = 1
        ] RUNNINGTASK, "Running Task Id";

        ENUM "int" [
            "Not Running (0)" = 0,
            "0x1" = 0x1,
            "0x2" = 0x2
        ] RUNNINGTASKPRIORITY, "Priority of Running Task";

        TOTRACE ENUM "unsigned char" [
            "ActivateTask" = 2,
            "TerminateTask" = 4,
            "ChainTask" = 6,
            ...
        ] SERVICETRACE, "OS Services Watch";
```

Examples (ORTI) Information section

```
OS EE_arch {
    RUNNINGTASK = "EE_stkfirst";
    RUNNINGTASKPRIORITY = "(EE_stkfirst == -1) ? 0 :
   EE_ORTI_th_priority[EE_stkfirst]";
    SERVICETRACE = "EE_ORTI_servicetrace";
    LASTERROR = "EE_ORTI_lasterror";
    CURRENTAPPMODE = "EE_ApplicationMode";
    vs_EE_SYSCEILING = "EE_sys_ceiling";
};

        /* Tasks */
TASK Task1 {
    PRIORITY = "(EE_ORTI_th_priority[0])";
    STATE = "(EE_th_status[0])";
    CURRENTACTIVATIONS = "(1 - EE_th_rnact[0])";  /* 1 = max activations */
    STACK = "(EE_hal_thread_tos[1])";
};
TASK Task2 {
    PRIORITY = "(EE_ORTI_th_priority[1])";
    STATE = "(EE_th_status[1])";
    CURRENTACTIVATIONS = "(1 - EE_th_rnact[1])";  /* 1 = max activations */
    STACK = "(EE_hal_thread_tos[0])";
};
```

Examples (ORTI) Information section

```
/* Stacks */
STACK Stack0 {
    SIZE = "2560";
    STACKDIRECTION = "DOWN";
    BASEADDRESS = "(unsigned int *)((unsigned int
   *)((int)(&__alt_stack_pointer) - 0xA00 ))";
    FILLPATTERN = "0xA5A5A5A5";
};

        /* Alarms */
ALARM AlarmTask1 {
    ALARMTIME = "EE_ORTI_alarmtime[0]";
    CYCLETIME = "EE_alarm_RAM[0].cycle";
    STATE = "(EE_alarm_RAM[0].used == 0) ? 0 : 1";
    ACTION = "set TimerEvent on Task1";
    COUNTER = "Counter1";
    COUNTERVALUE = "EE_counter_RAM[EE_alarm_ROM[0].c].value";
};
...

        /* Resources */
RESOURCE RES_SCHEDULER {
    STATE = "(EE_resource_locked[0])";
    LOCKER = "(EE_resource_locked[0] ? EE_ORTI_res_locker[0] : -1)";
    PRIORITY = "2";
};
```

That’s all folks !

- Please ask your questions ...