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Group 20

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COMPUTER ARCHITECTURE &
OPERATING SYSTEMS

HacklOSsim Project

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FreeRTOS - Introduction

- Real-Time Operating System for microcontrollers
- Robustness, scalability
- Includes a kernel and a set of libraries
- Minimal ROM, RAM and processing overhead

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Tasks

- Real-time applications in FreeRTOS consist of independent tasks
- The Real-Time Scheduler decides which task runs based on priority
- Lower is the value, lower is the priority
- Tasks have no knowledge of the scheduler activity
  -> Correct Context Switch is only under the responsibility of scheduler
- Time-Sliced Round-Robin Scheduling may be used for tasks with identical priorities
- We created two simple demos for both schedulers.

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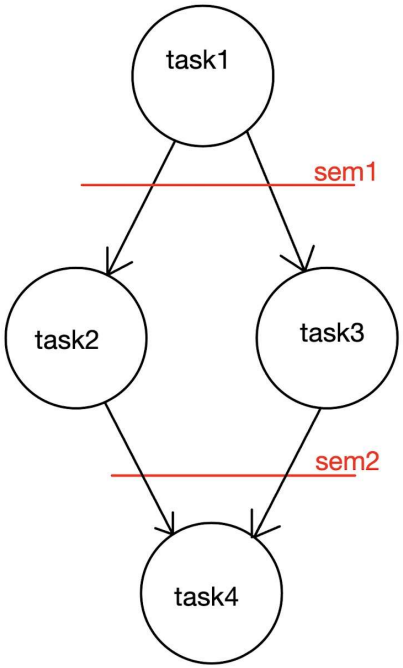
Semaphores

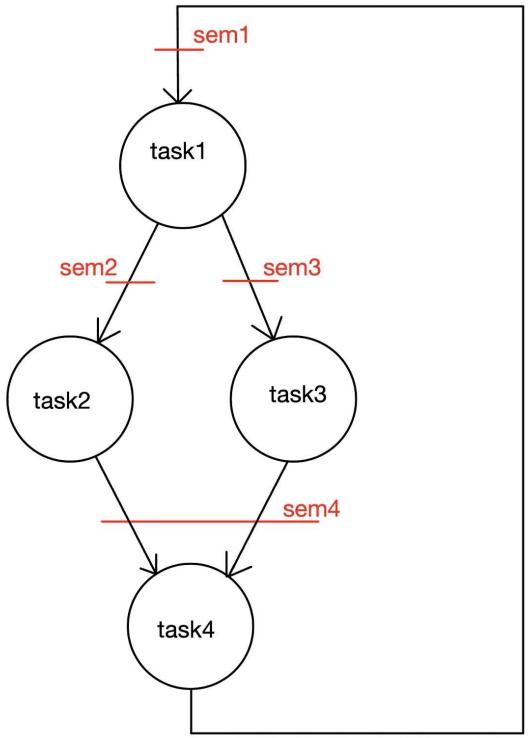
- Binary Semaphores - synchronization tasks.
  - Mutexes – simple mutual exclusion tasks.
  - Only difference: priority inheritance mechanism.

- Counting Semaphores are like queues with lengths greater than one.
- They are used for:
  - Event counting.
  - Resource management.

Semaphores Examples



Basic tasks
"semaphoresAcyclic.c"



Extended tasks
"semaphoresCyclic.c"

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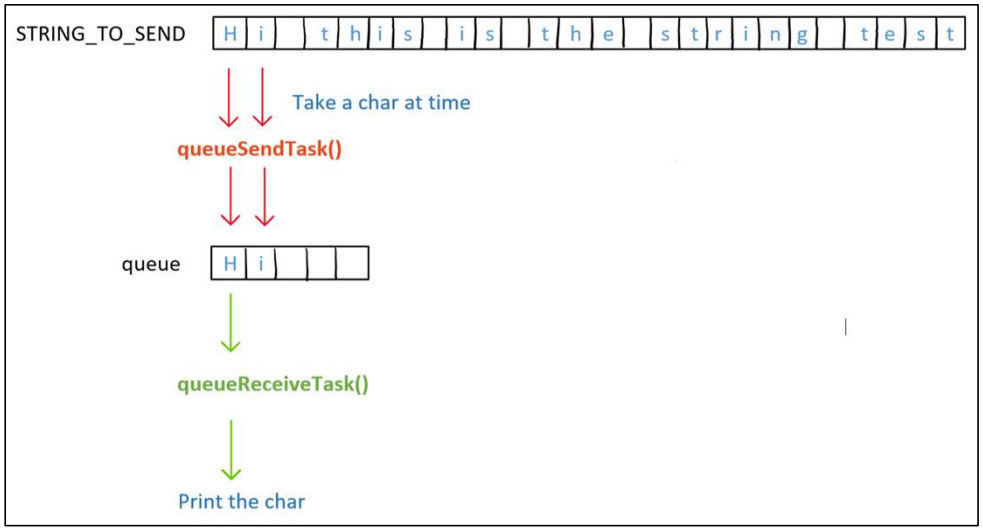
Queues

- Queues are essential for task communication in a multitasking system.
- They serve as channels through which tasks exchange messages, facilitating coordination and data sharing.
- Queues operate on a FIFO basis, where the data sent earlier is received first.
- Queues can block tasks when they are full or empty, ensuring efficient resource utilization.



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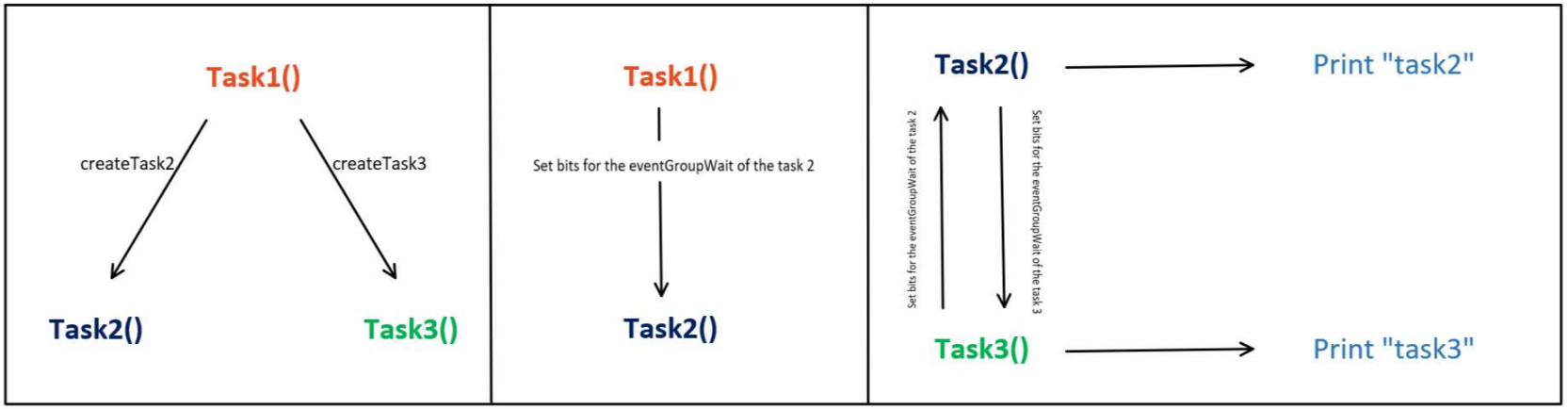
EventGroup

- EventBits are individual bits used to represent different event states, such as message reception or task readiness.
- Event groups are collections of these event bits grouped together for easier management and task synchronization.
- Used for synchronization between tasks and managing multiple event states.



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Earliest Deadline First with Background Scheduling

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Earliest Deadline First Scheduling

- Dynamic priority scheduler
- Preemptive
- At each instant, the task with earliest deadline will receive highest priority
- handles periodic tasks

Backgroung Scheduling

- Handles aperiodic tasks
- Aperiodic tasks are scheduled in background, when no periodic instance is ready

How to implement?

- ❑ Task Control Block modification
- ❑ New task create function
- ❑ New ready list
- ❑ Deadline & Priority updates
- ❑ Preemption management
- ❑ Context Switching management
- ❑ IDLE task management
- ❑ Aperiodic Task Management

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Task Control Block modification

- A variable to store the deadline si added to the TCB.

```
TickType_t xTaskDeadline
```

New task create function

- A new task creation function, **xTaskCreateEDF** , has been introduced to accommodate the deadline parameter

```
xTaskCreateEDF( TaskFunction_t pxTaskCode,…,
                TickType_t deadline1)
```

- Inside it, the value passed to the function is added to the TCB.

```
pxNewTCB->xTaskDeadline = deadline1;
```

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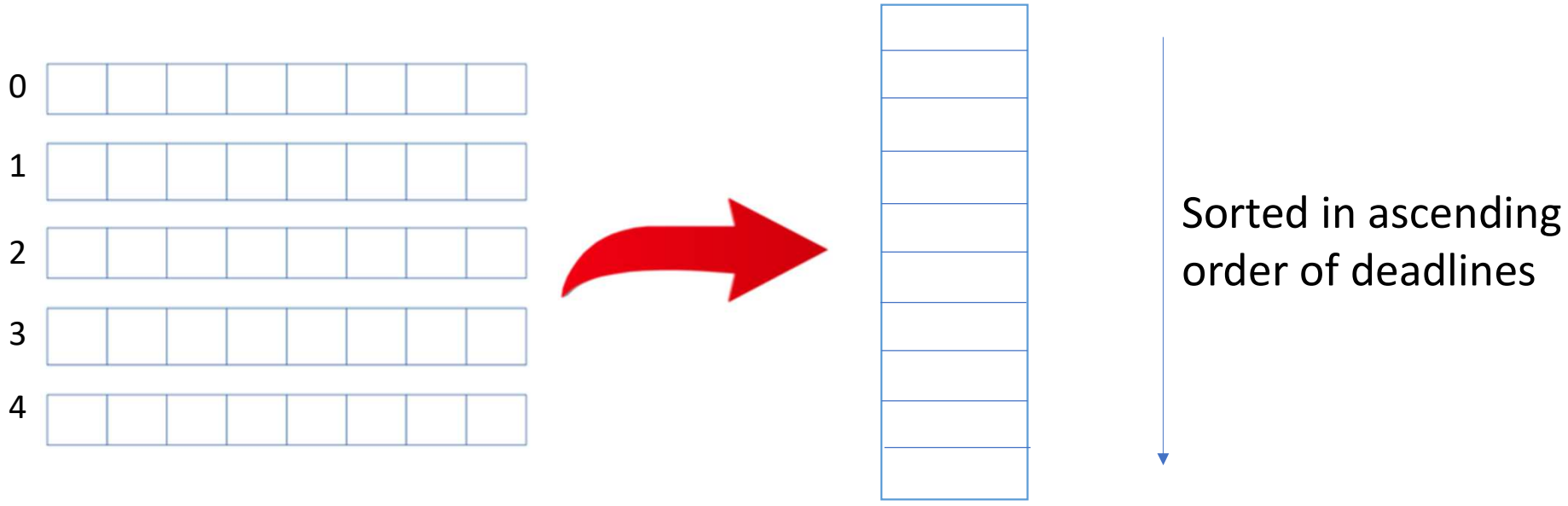
New Ready List



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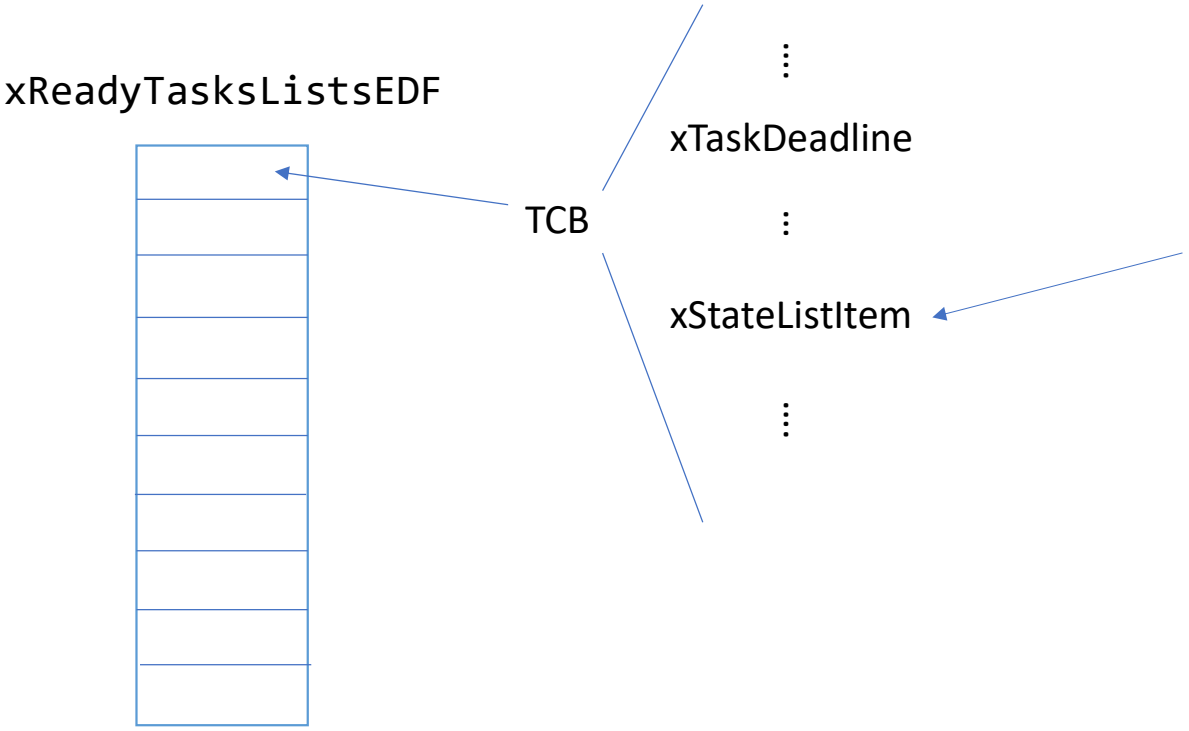
How to use the EDF ready list



List used internally by FreeRTOS to manage task state information. Contains an item, that is used as deadline in our scheduler.

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Deadline & Priority updates

- The prvAddTaskToReadyList function is modified to update task deadlines before the insertion into the ready list.
- The deadline is recalculated as the sum of the previous deadline and the declared deadline value in the TCB.

```
( pxTCB )->xStateListItem.xItemValue += ( pxTCB )->xTaskDeadline;
```

Preemption management

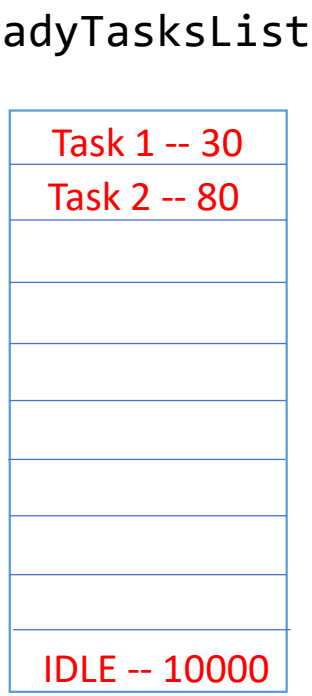
- Within the `xTaskIncrementTick` function, a new preemption policy is introduced.
- When a task scheduled for insertion into the ready list has an earlier deadline than the currently running task, preemptive action is taken.
- To reduce context switching overhead, if both tasks share the same deadline, preemptive action is not executed.

Context Switching management

- The task to be executed is positioned at the head of this list.
- The function listGET_OWNER_OF_HEAD_ENTRY is used to obtain the task in the head of the list.

IDLE task management

- IDLE task is initialized with vTaskCreateEDF
- It simulates lowest priority by assigning farthest deadline, e.g., 10000.



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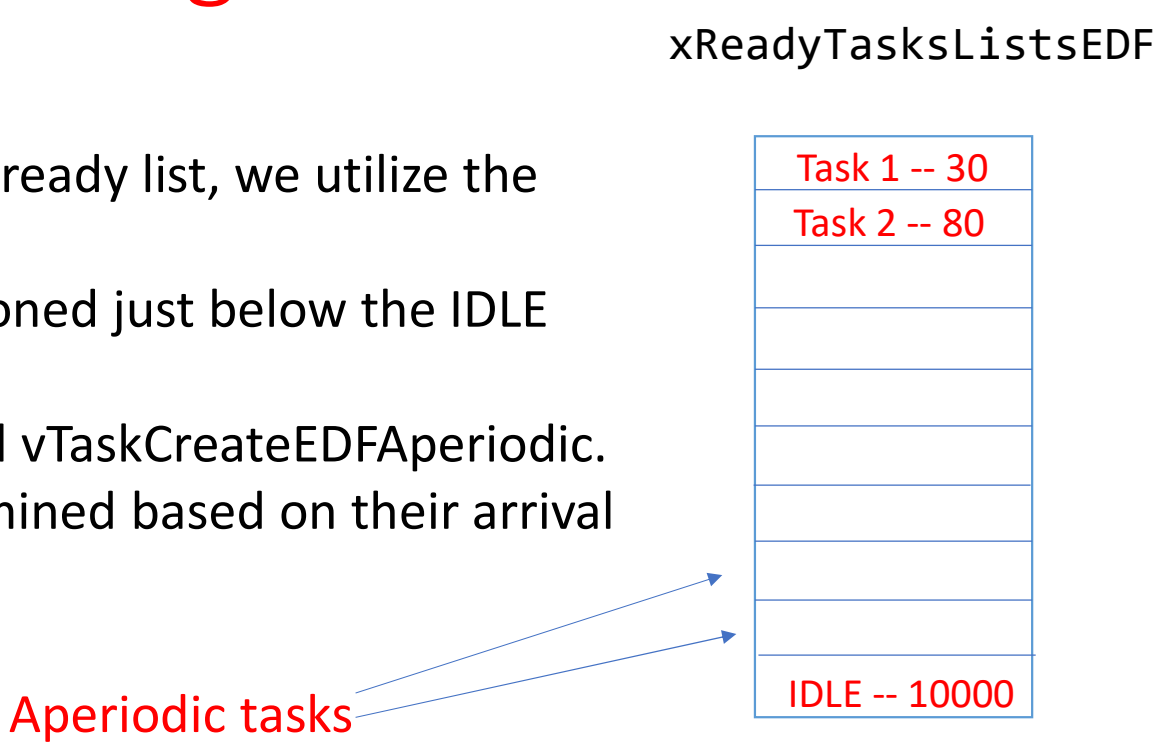
Aperiodic task management

- Instead of creating a new ready list, we utilize the xReadyTasksListsEDF.
- Aperiodic tasks are positioned just below the IDLE task's deadline.
- We've devised a dedicated vTaskCreateEDFAperiodic.
- Their deadlines are determined based on their arrival order.



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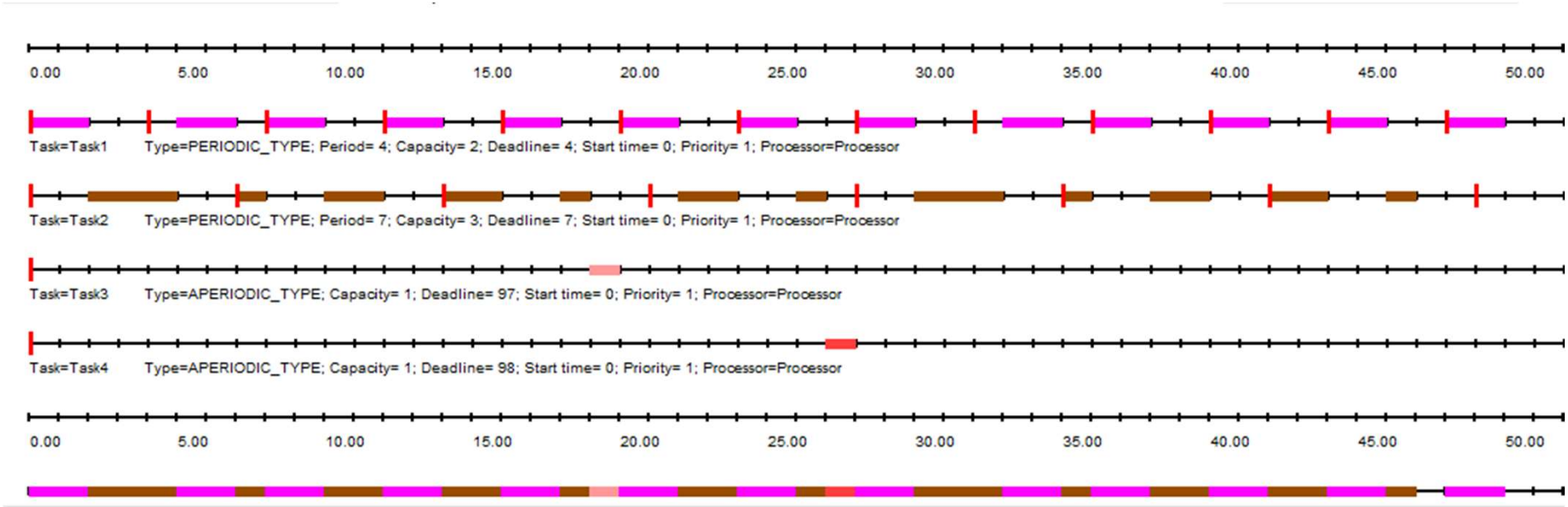
Demo



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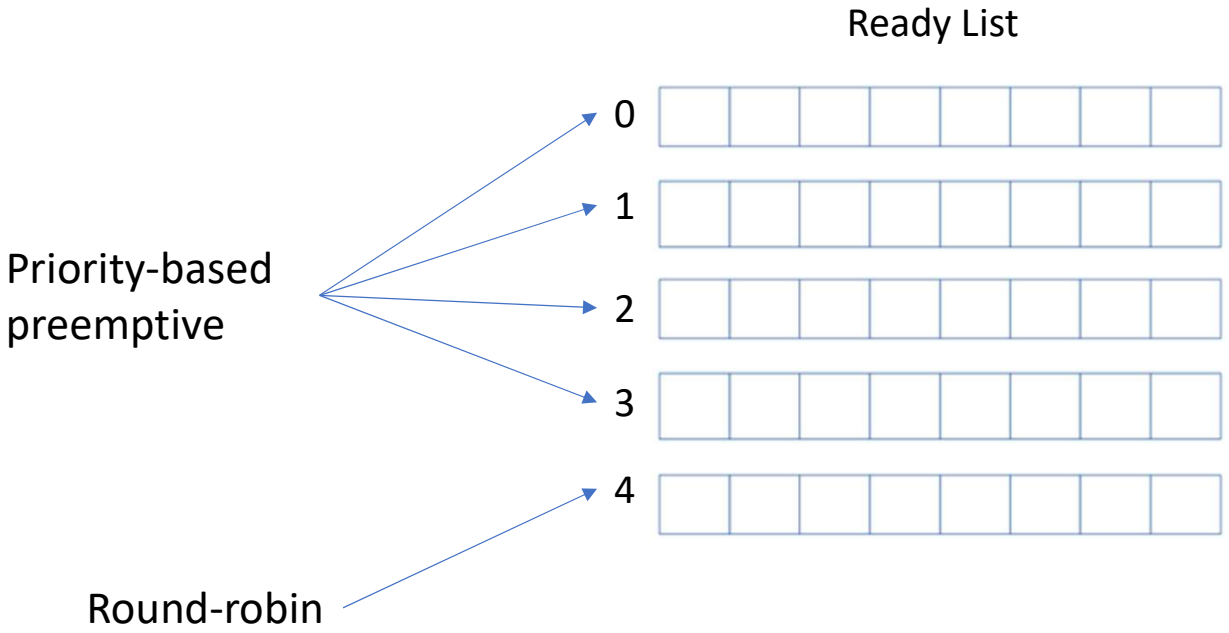
MultiLevel Queue Scheduler



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How to implement?

- Task Control Block modification
- xTaskPrioritySet
- Priority upgrade
- Highest Priority List Round Robin

Task control block modification

- Addition of uxOldPriority Variable.

- Inclusion of cc Variable:
  - Reserved for internal purpose.

```
int cc
UBaseType_t uxOldPriority
```

Those values are then setted in the vTaskCreate function.

xTaskPrioritySet

- A smaller version version of the **vTaskPrioritySet** is added to properly modify the priority of a task.

Priority upgrade

- When system's ticks reach a multiple of the "update rate", a priority boost is applied.
- This boost affects all tasks in the ready list except the one currently running.
- To modify the priority, the `xTaskPrioritySet` is used.

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Highest priority list Round-Robin

- The `xTaskIncrementTick` function containes the code for our Round-Robin scheduling.
- Activated if there are at least two tasks present in the highest priority list.
- This mechanism ensures fair execution among tasks sharing the same highest priority level.

```
UBaseType_t c = (configMAX_PRIORITIES - 1U);
if( listCURRENT_LIST_LENGTH( &( pxReadyTasksLists[ c ] )) > 1)
{
    xSwitchRequired = pdTRUE;
}
```

Demo