Embedded OS Implementation, Spring 2025
Project #1 (due at April 3rd, 2025 (Thursday) 08:00)

[PART I] Task Control Block Linked List

Objective:

Following the previous homework (HW1), please add some code to the µC/OS-II scheduler **in the kernel level** to observe the operations of the task control block (TCB) and TCB linked list.

※ The TCB address is dynamic.

※ This part will be included in the subsequent output and does not require separate code submission.

The example output results are shown below:

```
OSTick    created, Thread ID 11760
Task[ 63] created, TCB Address  92e9e0
------After TCB[63] begin linked------
Previous TCB point to adress         0
Current  TCB point to adress    92e9e0
Next     TCB point to adress         0

The file 'TaskSet.txt' was opened
Task[  1] created, TCB Address  92ea54
------After TCB[ 1] begin linked------
Previous TCB point to adress         0
Current  TCB point to adress    92ea54
Next     TCB point to adress    92e9e0

Task[  2] created, TCB Address  92eac8
------After TCB[ 2] begin linked------
Previous TCB point to adress         0
Current  TCB point to adress    92eac8
Next     TCB point to adress    92ea54

================TCB linked list================
Task    Prev_TCB_addr   TCB_addr   Next_TCB_addr
 2                0       92eac8        92ea54
 1           92eac8       92ea54        92e9e0
63           92ea54       92e9e0             0
```

[PART II] RM Scheduler Implementation

Objective:

To implement the Rate Monotonic (RM) scheduler for periodic tasks and observe the scheduling behaviors.

Problem Definition:

Implement the following three task sets of periodic tasks. Add necessary code to the μC/OS-II scheduler **in the kernel level** to observe how the task suffers from the scheduler. We give the files for the parameter of the task.

Periodic Task Set = {τ_{ID} (ID, arrival time, execution time, period)}

Example Task Set 1 = {τ_1 (1, 0, 1, 3), τ_2 (2, 0, 3, 5)}

Example Task Set 2 = {τ_1 (1, 0, 1, 3), τ_2 (2, 1, 2, 7), τ_3 (3, 4, 3, 12) }

Example Task Set 3 = {τ_1 (1, 0, 3, 8), τ_2 (2, 1, 2, 6), τ_3 (3, 0, 4, 15)}

※ The priority of the task is set according to the RM scheduling rules.

The input file format:

Task ID	Arrive Time	Execution Time	Task Period
##	##	##	##

Example of task set file 1:

```
1 0 1 3
2 0 3 5
```

Example output file of task set 1:

```
1   Completion  task( 1)( 0)  task( 2)( 0)      1   0   2
3   Preemption  task( 2)( 0)  task( 1)( 1)
4   Completion  task( 1)( 1)  task( 2)( 0)      1   0   2
5   Completion  task( 2)( 0)  task( 2)( 1)      5   2   0
6   Preemption  task( 2)( 1)  task( 1)( 2)
7   Completion  task( 1)( 2)  task( 2)( 1)      1   0   2
9   Completion  task( 2)( 1)  task( 1)( 3)      4   1   1
10  Completion  task( 1)( 3)  task( 2)( 2)      1   0   2
12  Preemption  task( 2)( 2)  task( 1)( 4)
13  Completion  task( 1)( 4)  task( 2)( 2)      1   0   2
14  Completion  task( 2)( 2)  task(63)          4   1   1
15  Preemption  task(63)      task( 1)( 5)
16  Completion  task( 1)( 5)  task( 2)( 3)      1   0   2
18  Preemption  task( 2)( 3)  task( 1)( 6)
19  Completion  task( 1)( 6)  task( 2)( 3)      1   0   2
20  Completion  task( 2)( 3)  task( 2)( 4)      5   2   0
21  Preemption  task( 2)( 4)  task( 1)( 7)
22  Completion  task( 1)( 7)  task( 2)( 4)      1   0   2
24  Completion  task( 2)( 4)  task( 1)( 8)      4   1   1
25  Completion  task( 1)( 8)  task( 2)( 5)      1   0   2
27  Preemption  task( 2)( 5)  task( 1)( 9)
28  Completion  task( 1)( 9)  task( 2)( 5)      1   0   2
29  Completion  task( 2)( 5)  task(63)          4   1   1
30  Preemption  task(63)      task( 1)(10)
```

Evaluation:

The output format:

Tick	Event	CurrentTask ID	NextTask ID	Response Time	Preemption Time	OSTimeDly
##	**Preemption**	**task(ID)(job number)**	**task(ID)(job number)**			
##	**Completion**	**task(ID)(job number)**	**task(ID)(job number)**	##	##	##
##	**MissDeadline**	**task(ID)(job number)**	**----------**			

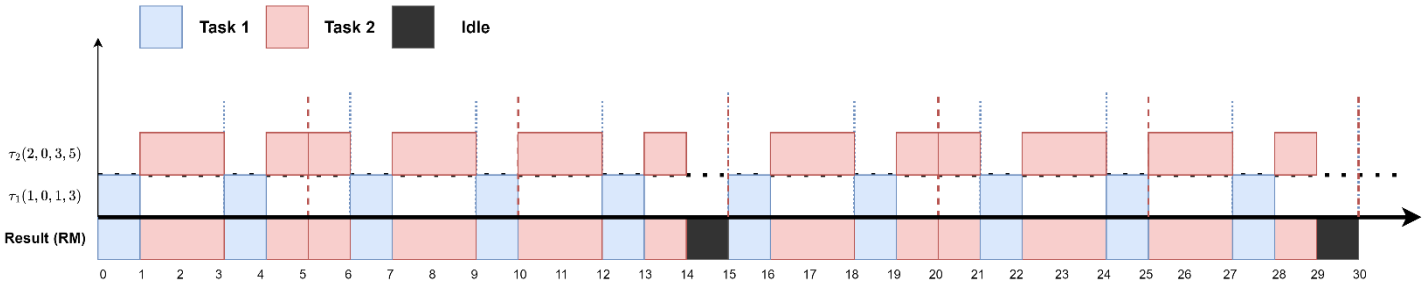
※ If the task is Idle Task, print "*task(priority)*".

Response Time: the duration between the task's arrival time and the time it is completed.

Preemption Time: the time this task is preempted by higher-priority tasks.

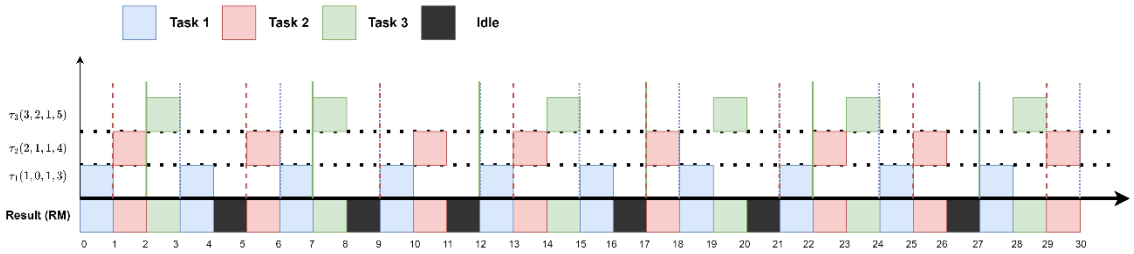
OSTimeDly: the remaining delay time for this task

The scheduled results of Task Set 1:



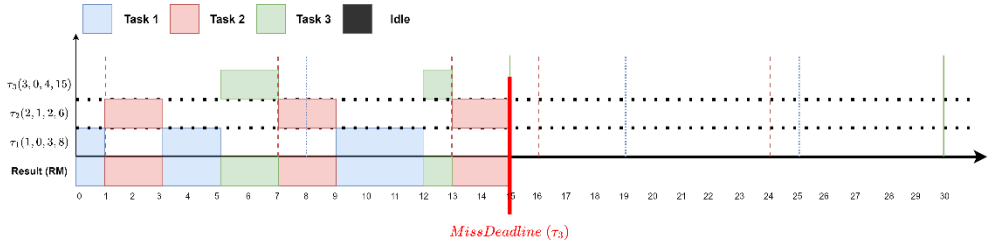
Tick	Event	CurrentTask ID	NextTask ID	ResponseTime	PreemptionTime	OSTimeDly
1	Completion	task(1)(0)	task(2)(0)	1	0	2
3	Preemption	task(2)(0)	task(1)(1)			
4	Completion	task(1)(1)	task(2)(0)	1	0	2
5	Completion	task(2)(0)	task(2)(1)	5	2	0
6	Preemption	task(2)(1)	task(1)(2)			
7	Completion	task(1)(2)	task(2)(1)	1	0	2
9	Completion	task(2)(1)	task(1)(3)	4	1	1
10	Completion	task(1)(3)	task(2)(2)	1	0	2
12	Preemption	task(2)(2)	task(1)(4)			
13	Completion	task(1)(4)	task(2)(2)	1	0	2
14	Completion	task(2)(2)	task(63)	4	1	1
15	Preemption	task(63)	task(1)(5)			
16	Completion	task(1)(5)	task(2)(3)	1	0	2
18	Preemption	task(2)(3)	task(1)(6)			
19	Completion	task(1)(6)	task(2)(3)	1	0	2
20	Completion	task(2)(3)	task(2)(4)	5	2	0
21	Preemption	task(2)(4)	task(1)(7)			
22	Completion	task(1)(7)	task(2)(4)	1	0	2
24	Completion	task(2)(4)	task(1)(8)	4	1	1
25	Completion	task(1)(8)	task(2)(5)	1	0	2
27	Preemption	task(2)(5)	task(1)(9)			
28	Completion	task(1)(9)	task(2)(5)	1	0	2
29	Completion	task(2)(5)	task(63)	4	1	1
30	Preemption	task(63)	task(1)(10)			

The output results of Task Set 2:



Tick	Event	CurrentTask ID	NextTask ID	ResponseTime	PreemptionTime	OSTimeDly
1	Completion	task(1)(0)	task(2)(0)	1	0	2
2	Completion	task(2)(0)	task(3)(0)	1	0	3
3	Completion	task(3)(0)	task(1)(1)	1	0	4
4	Completion	task(1)(1)	task(63)	1	0	2
5	Preemption	task(63)	task(2)(1)			
6	Completion	task(2)(1)	task(1)(2)	1	0	3
7	Completion	task(1)(2)	task(3)(1)	1	0	2
8	Completion	task(3)(1)	task(63)	1	0	4
9	Preemption	task(63)	task(1)(3)			
10	Completion	task(1)(3)	task(2)(2)	1	0	2
11	Completion	task(2)(2)	task(63)	2	1	2
12	Preemption	task(63)	task(1)(4)			
13	Completion	task(1)(4)	task(2)(3)	1	0	2
14	Completion	task(2)(3)	task(3)(2)	1	0	3
15	Completion	task(3)(2)	task(1)(5)	3	2	2
16	Completion	task(1)(5)	task(63)	1	0	2
17	Preemption	task(63)	task(2)(4)			
18	Completion	task(2)(4)	task(1)(6)	1	0	3
19	Completion	task(1)(6)	task(3)(3)	1	0	2
20	Completion	task(3)(3)	task(63)	3	2	2
21	Preemption	task(63)	task(1)(7)			
22	Completion	task(1)(7)	task(2)(5)	1	0	2
23	Completion	task(2)(5)	task(3)(4)	2	1	2
24	Completion	task(3)(4)	task(1)(8)	2	1	3
25	Completion	task(1)(8)	task(2)(6)	1	0	2
26	Completion	task(2)(6)	task(63)	1	0	3
27	Preemption	task(63)	task(1)(9)			
28	Completion	task(1)(9)	task(3)(5)	1	0	2
29	Completion	task(3)(5)	task(2)(7)	2	1	3
30	Completion	task(2)(7)	task(1)(10)	1	0	3

The output results of Task Set 3:



Tick	Event	CurrentTask ID	NextTask ID	ResponseTime	PreemptionTime	OSTimeDly
1	Preemption	task(1)(0)	task(2)(0)			
3	Completion	task(2)(0)	task(1)(0)	2	0	4
5	Completion	task(1)(0)	task(3)(0)	5	2	3
7	Preemption	task(3)(0)	task(2)(1)			
9	Completion	task(2)(1)	task(1)(1)	2	0	4
12	Completion	task(1)(1)	task(3)(0)	4	1	4
13	Preemption	task(3)(0)	task(2)(2)			
15	Completion	task(2)(2)	task(3)(0)	2	0	4
15	MissDeadline	task(3)(0)	----------			

[Part III] FIFO Scheduler Implementation

Objective:

To implement the non-preemptive First In First Out (FIFO) scheduling for periodic tasks, and handle the miss deadline behaviors.

Problem Definition:

Implement the following task set of periodic tasks. Add necessary code to the μC/OS-II scheduler **in the kernel level** to observe how the task suffers the schedule delay.

Periodic Task Set = {τ_{ID} (ID, arrival time, execution time, period)}

Task Set 1 = {τ_1 (1, 0, 1, 4), τ_2 (2, 0, 3, 5)}

Task Set 2 = {τ_1 (1, 0, 1, 3), τ_2 (2, 1, 2, 7), τ_3 (3, 4, 3, 12)}

※If tasks arrive simultaneously, the task with the smaller TaskID will be executed first.

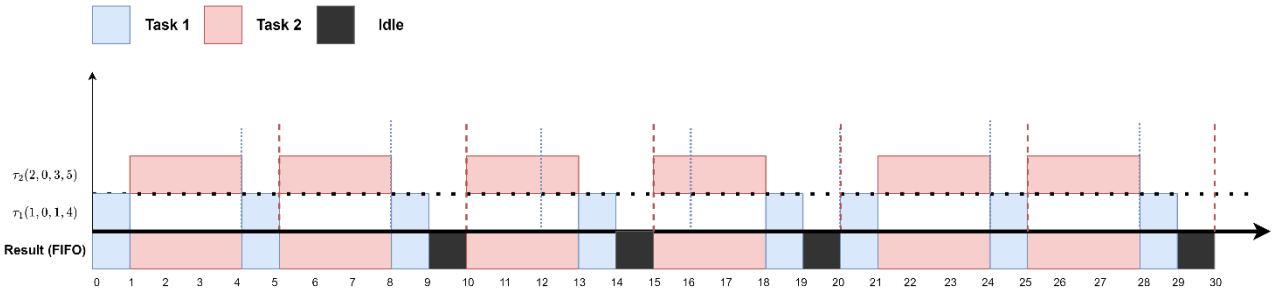
Evaluation:

The output format:

Tick	Event	CurrentTask ID	NextTask ID	Response Time	Preemption Time	OSTimeDly
##	Preemption	task(ID)(job number)	task(ID)(job number)			
##	Completion	task(ID)(job number)	task(ID)(job number)	##	##	##
##	MissDeadline	task(ID)(job number)	----------			

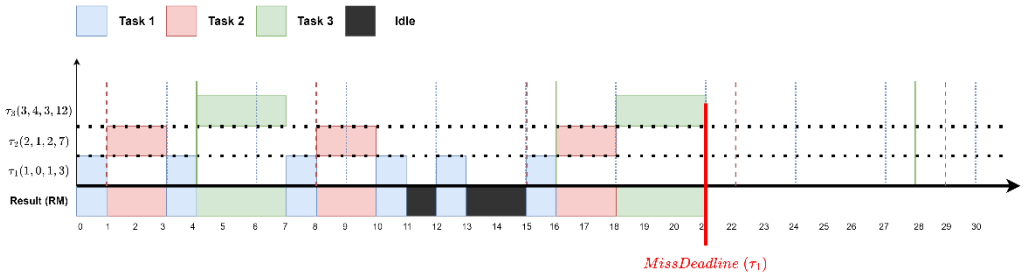
※ If the task is Idle Task, print "*task(priority)*".

The output results of Task Set 1:



Tick	Event	CurrentTask ID	NextTask ID	ResponseTime	PreemptionTime	OSTimeDly
1	Completion	task(1)(0)	task(2)(0)	1	0	3
4	Completion	task(2)(0)	task(1)(1)	4	1	1
5	Completion	task(1)(1)	task(2)(1)	1	0	3
8	Completion	task(2)(1)	task(1)(2)	3	0	2
9	Completion	task(1)(2)	task(63)	1	0	3
10	Preemption	task(63)	task(2)(2)			
13	Completion	task(2)(2)	task(1)(3)	3	0	2
14	Completion	task(1)(3)	task(63)	2	1	2
15	Preemption	task(63)	task(2)(3)			
18	Completion	task(2)(3)	task(1)(4)	3	0	2
19	Completion	task(1)(4)	task(63)	3	2	1
20	Preemption	task(63)	task(1)(5)			
21	Completion	task(1)(5)	task(2)(4)	1	0	3
24	Completion	task(2)(4)	task(1)(6)	4	1	1
25	Completion	task(1)(6)	task(2)(5)	1	0	3
28	Completion	task(2)(5)	task(1)(7)	3	0	2
29	Completion	task(1)(7)	task(63)	1	0	3
30	Preemption	task(63)	task(2)(6)			

The output results of Task Set 2:



Tick	Event	CurrentTask ID	NextTask ID	ResponseTime	PreemptionTime	OSTimeDly
1	Completion	task(1)(0)	task(2)(0)	1	0	2
3	Completion	task(2)(0)	task(1)(1)	2	0	5
4	Completion	task(1)(1)	task(3)(0)	1	0	2
7	Completion	task(3)(0)	task(1)(2)	3	0	9
8	Completion	task(1)(2)	task(2)(1)	2	1	1
10	Completion	task(2)(1)	task(1)(3)	2	0	5
11	Completion	task(1)(3)	task(63)	2	1	1
12	Preemption	task(63)	task(1)(4)			
13	Completion	task(1)(4)	task(63)	1	0	2
15	Preemption	task(63)	task(1)(5)			
16	Completion	task(1)(5)	task(2)(2)	1	0	2
18	Completion	task(2)(2)	task(3)(1)	3	1	4
21	MissDeadline	task(1)(6)	--------------------			

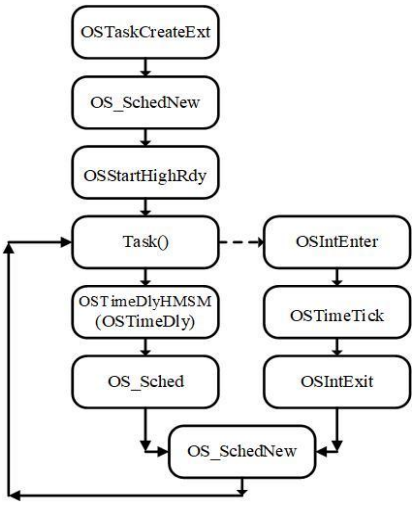
Credit:

[PART I] Task Control Block Linked List [20%]

- The screenshot results. (10%)
- A report that describes your implementation (please attach the screenshot of the code and **MARK** the modified part). (10%)

[PART II] RM Scheduler Implementation [70%]

- The correctness of schedule results of examples. Note the testing task set might not be the same as the given example task set. (25%)
- A report that describes your implementation (please attach the screenshot of the code and **MARK** the modified part). (40%)
  - Indicate the modified parts in the given example flowchart and provide reasons for their placement within the process.
- Implement and describe how to handle the deadline missing situation under RM. (5%)



Example Flowchart

[PART III] FIFO Scheduler Implementation [10%]

- The correctness of schedule results of examples. Note the testing task set might not be the same as the given example task set. (5%)
- Implement FIFO and compare the schedule results with that of RM (please attach the screenshot of the code and **MARK** the modified part). (5%)

※ You must modify the source code!

※ Standard input and output filenames in the project are necessary for the checker. Please check the file names before submitting.

```
#define INPUT_FILE_NAME "./TaskSet.txt"
#define OUTPUT_FILE_NAME "./Output.txt"
```

※ Please set the system end time as 30 seconds in this project.

```
#define SYSTEM_END_TIME 30
```

※ We will use different task sets to verify your code.

※ When the current task is completed, the completion information shall be printed even if there is one task missing its deadline.

Project submit:

Submit to Moodle2.

Submit deadline: at due at April 3rd, 2025 (Thursday) 08:00

File name format: RTOS_Myyyddxxx_PA1.zip

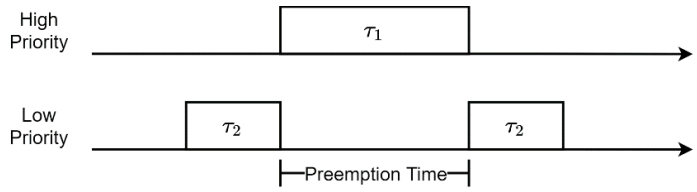
RTOS_Myyyddxxx_PA1.zip includes (The tree structure of files is shown as hints):

- The report (RTOS_Myyyddxxx_PA1.pdf).
- Folder with the executable µC/OS-II project (RTOS_Myyyddxxx_PA1).
- Folder with the executable µC/OS-II project (RTOS_Myyyddxxx_PA1_Bonus). (If you have done the bonus.)

※ Plagiarizing is strictly prohibited.

Hints:

1. Preemption time is introduced in multiple tasking.



2. RTOS_Myyyddxxx_PA1.zip include files as follows:

```
C:.
    RTOS_ Myyyddxxx_PA1.pdf

└─RTOS_Myyyddxxx_PA1
        ReadMe.txt

    ├─Micrium
    │   └─Software
    │       ├─uC-CPU
    │       │   cpu_cache.h
    │       │   cpu_core.c
    │       │   cpu_core.h
    │       │   cpu_def.h
    │       │
    │       │   └─Win32
    │       │       └─Visual_Studio
    │       │               cpu.h
    │       │               cpu_c.c
    │       │
    │       ├─uC-LIB
    │       │       lib_ascii.c
    │       │       lib_ascii.h
    │       │       lib_def.h
    │       │       lib_math.c
    │       │       lib_math.h
    │       │       lib_mem.c
    │       │       lib_mem.h
    │       │       lib_str.c
    │       │       lib_str.h
    │       │
    │       └─uCOS-II
    │           ├─Ports
    │           │   └─Win32
    │           │       └─Visual Studio
    │           │               os_cpu.h
    │           │               os_cpu_c.c
    │           │               os_cpu_c.c.bak
    │           │
    │           └─Source
    │                   os.h
    │                   os_cfg_r.h
    │                   os_core.c
    │                   os_core.c.bak
    │                   os_dbg_r.c
    │                   os_flag.c
    │                   os_mbox.c
    │                   os_mem.c
    │                   os_mutex.c
    │                   os_q.c
    │                   os_sem.c
    │                   os_task.c
```

```
    │                   os_task.c
    │                   os_time.c
    │                   os_tmr.c
    │                   os_trace.h
    │                   ucos_ii.c
    │                   ucos_ii.h
    │                   ucos_ii.h.bak
    │
    └─Microsoft
        ├─BSP
        │   └─Windows
        │           bsp_cpu.c
        │
        └─Windows
            └─Kernel
                │   app_cfg.h
                │   cpu_cfg.h
                │   lib_cfg.h
                │
                └─OS2
                    │   app_hooks.c
                    │   app_hooks.c.bak
                    │   main.c
                    │   main.c.bak
                    │   os_cfg.h
                    │   os_cfg.h.bak
                    │
                    └─VS
                            OS2.sln
                            OS2.vcxproj
                            OS2.vcxproj.filters
                            OS2.vcxproj.user
                            Output.txt
                            TaskSet.txt
```