ECEN 3753: Real-Time Operating Systems

Scheduling

Scheduling

- Why have scheduling?
  - Need ability to share resources between multiple Tasks
  - OS decides what to run next
  - Between decisions, OS needs to prepare the old and new Task
    - Context Switching
- How the scheduler chooses the next Task depends on the algorithm chosen
  - These scheduling decisions are regularly being applied

Scheduling Goals

- Meeting all of the following goals is difficult
- Goals:
  - Maximize throughput
  - Maximize how resources are utilized
  - Minimize response time
  - Minimize wait time
  - Minimize time it takes to start a new task
  - Share resources appropriately
    - What are some examples of resources that need sharing?

Criteria for Scheduling

- CPU Utilization
  - In order to have efficient use of CPU it needs to remain as busy as possible as long as there is work to do
- Response Time
  - Amount of time the task spends waiting to be executed
- Turnaround Time
  - Amount of time it takes from the time a Task was submitted until it finished completion
- Waiting Time
  - Amount of time a tasks waits for resources (CPU, Memory, etc)
- Throughput
  - The amount of "fully completed" work that can be completed in a specific amount of time. [TasksCompleted/Time]

Turnaround = Waiting + Execution.

Non Preemptive Scheduling

- Scheduling algorithm waits for the current Task to let go of the CPU (note: Task either terminates, yields or blocks)
  - Also known as Cooperative multitasking
- Why choose a non-preemptive scheduler?
  - What are the advantages?
  - What are the disadvantages?

Preemptive scheduling

- The OS forces the current Task to let go of the CPU
  - This allows another Task to resume or a new one to be started
  - Also known as preemptive multitasking
- Why choose a preemptive scheduler?
  - What are the advantages?
  - What are the disadvantages?
- What is a human-scale example of "good" line-cutting?

Context Switching

- Required for preemptive scheduling
- Likely required for non-preemptive if non-trivial or long-lived Tasks
- Allows the "pausing" of a Task
- Current Task's information is stored for later retrieval
- Next Task's information is then retrieved
- The time it takes to store and retrieve is known as **Context Switch Time**

Note similarities to Interruptability, Interrupt Latency from CPU context protection for ISR (Critical Sections)

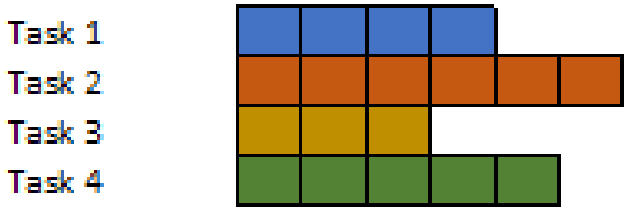
Scheduling Algorithms

- First-Come, First-Served
- Shortest Job First
- Time Slice
- Time Slice with Background Tasks
- Round Robin
- Priority

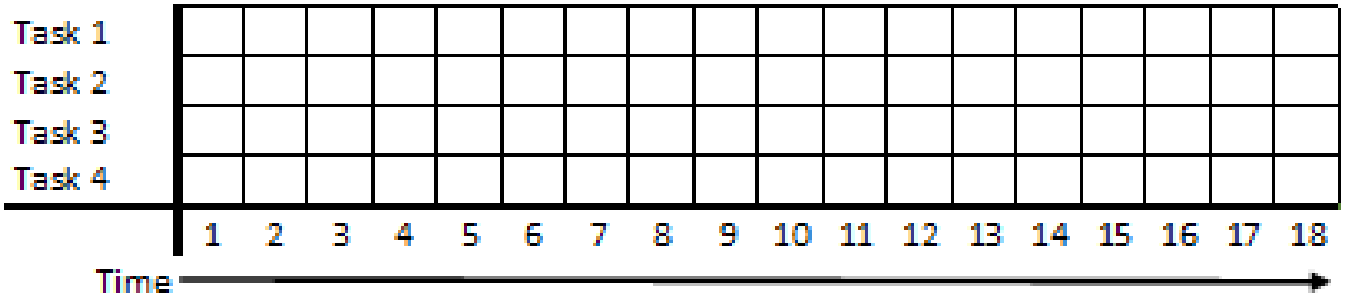
First Come First Served [FCFS]

- Cooperative multitasking (generally)
- What Is It?
  - Also known as First-In, First-Out
  - Select the Task that is at the head of the ready queue FIFO
  - This scheduler is typically non preemptive
- Pros
  - FIFO is easy to implement
  - No context switch needed since the Task runs to completion
- Cons
  - If the first task is large, other tasks will be "stuck" behind it, resulting in low throughput

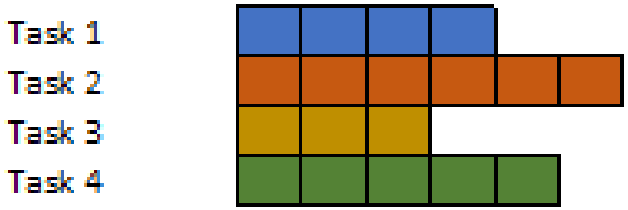
First Come First Served [FCFS] (continued)



First Come First Served



First Come First Served [FCFS] (continued)



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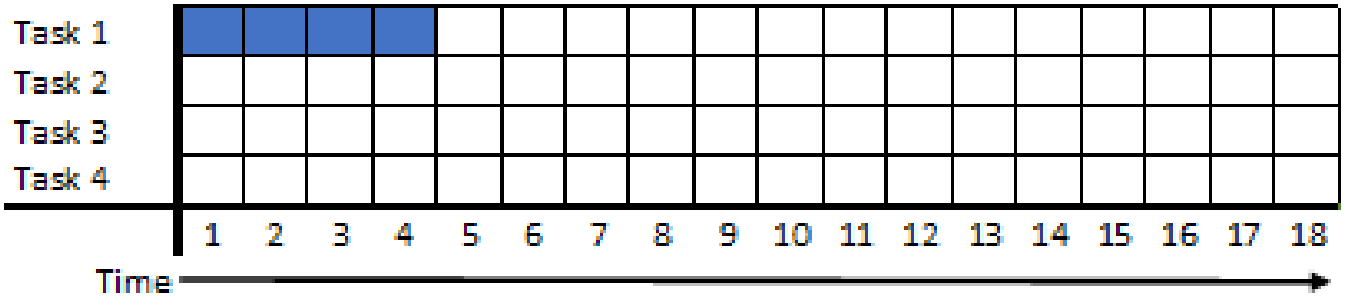

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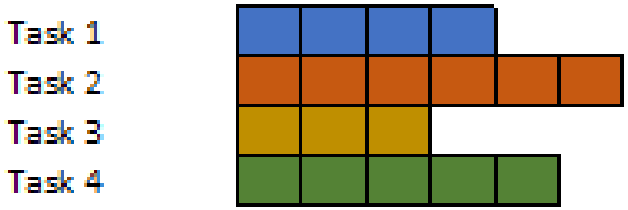

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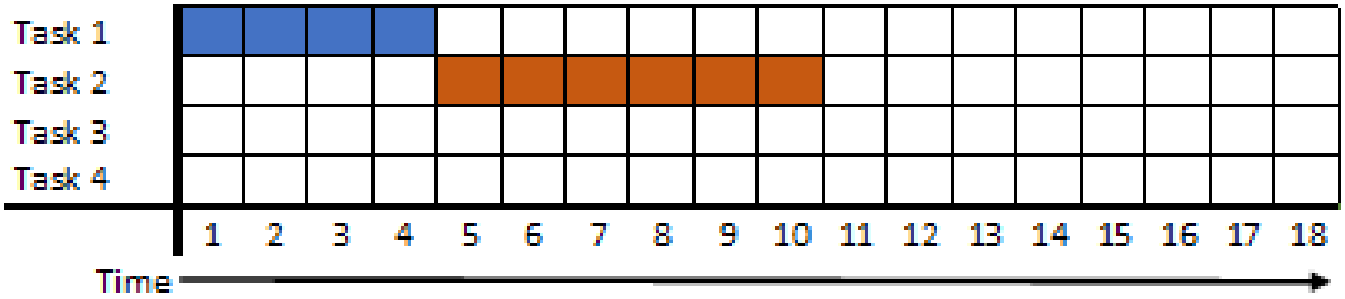

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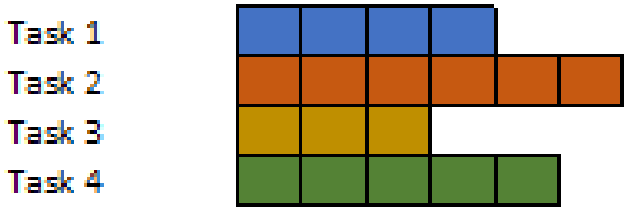

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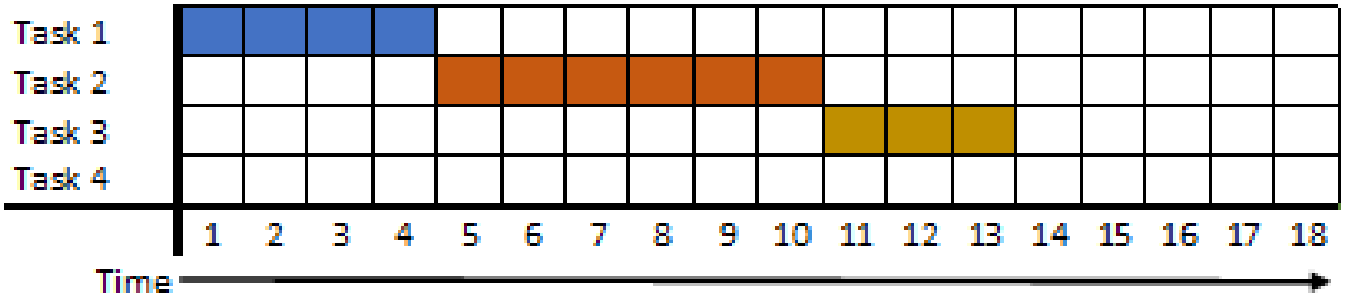

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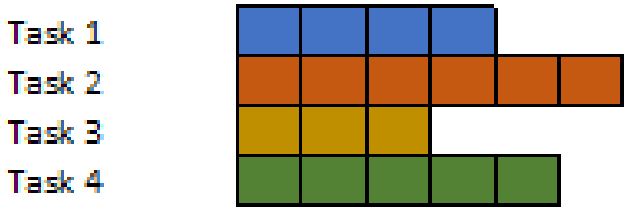

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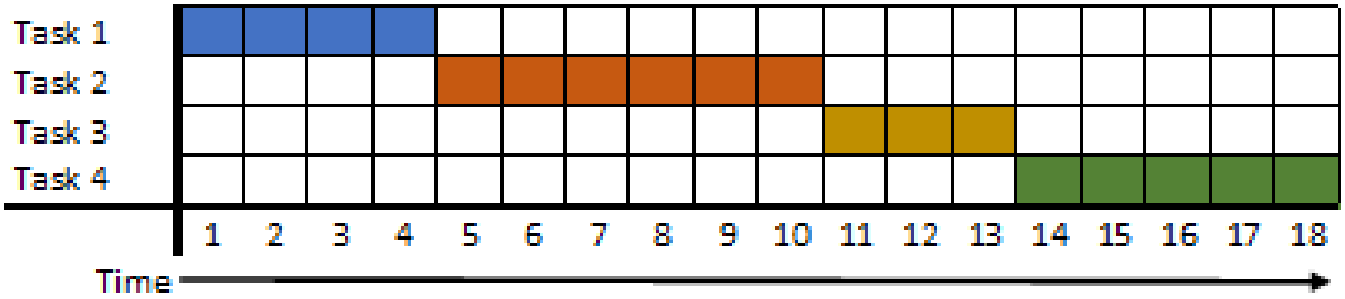


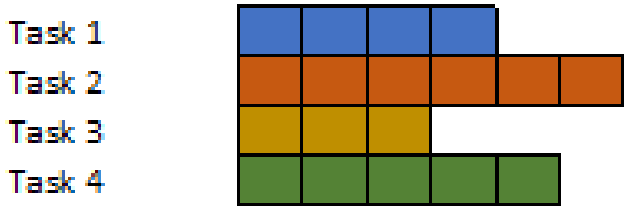
First Come First Served Unit Tests

- Check if everything is initialized correctly
- Check if the first Task has a waiting time of zero
- Check if the second Task has a waiting time the same as the first Task's execution time, etc

Shortest Job First [SJF]

- What Is It?
  - Scheduler places jobs with shortest completion time as the highest priority
  - Non Preemptive:
    - Task with the shortest time gets to execute
  - Preemptive:
    - Task with the shortest remaining time gets to execute
- Pros
  - Maximizes Task throughput
- Cons
  - Larger Task potentially could never run, or at least suffer long latencies
  - Imposes hard requirements on knowledge in regards to time-complexity

Shortest Job First [SJF] (continued)



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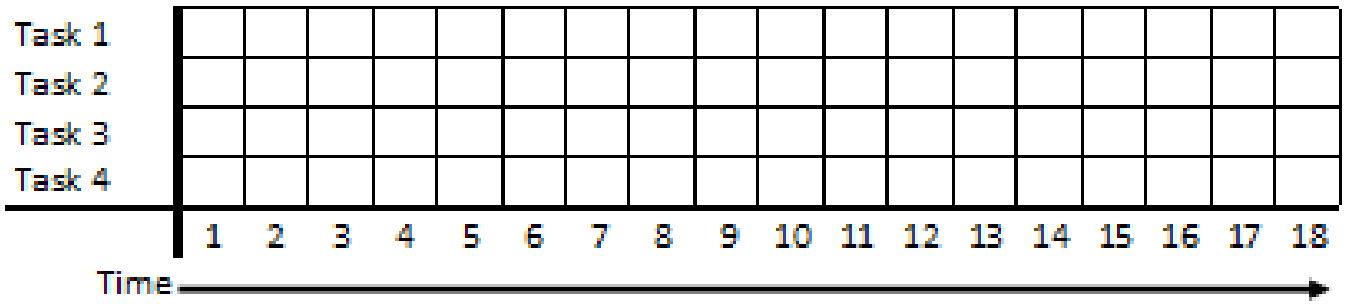

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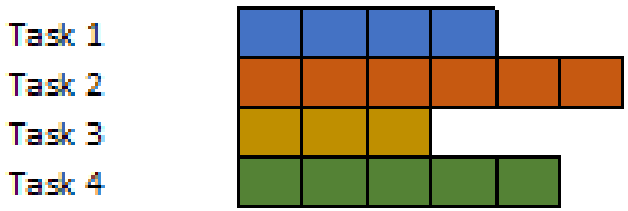

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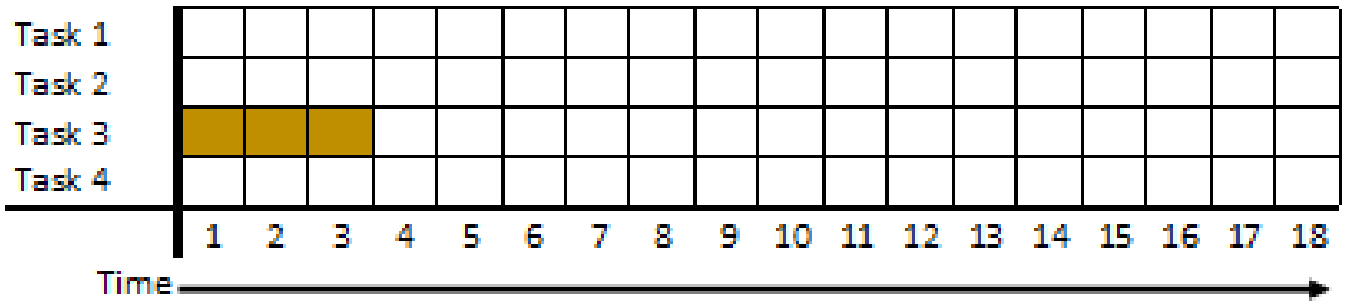

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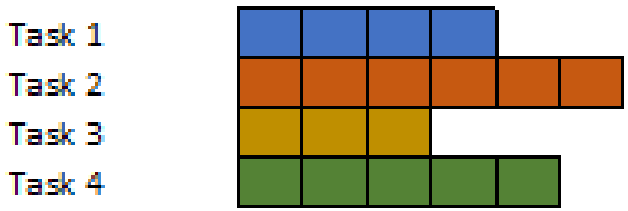

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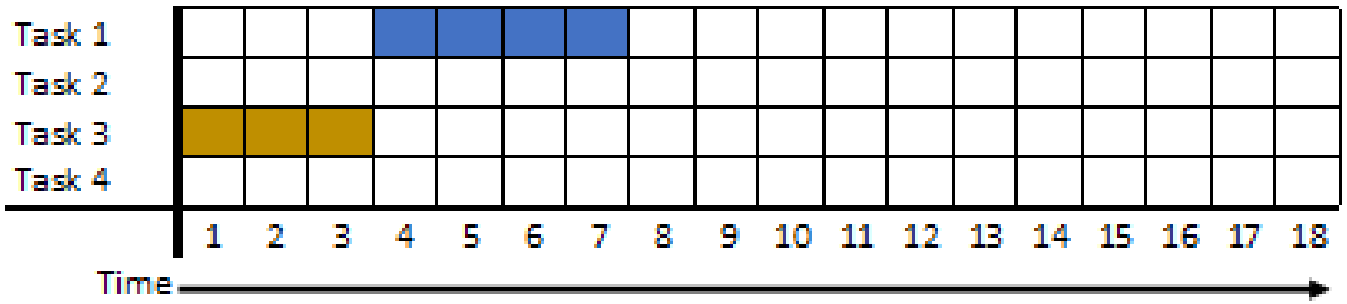

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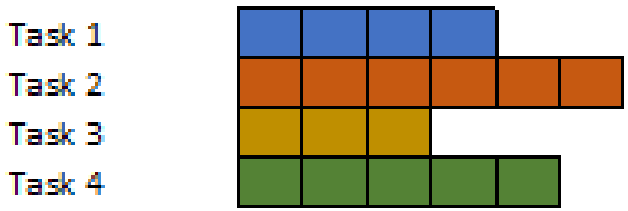

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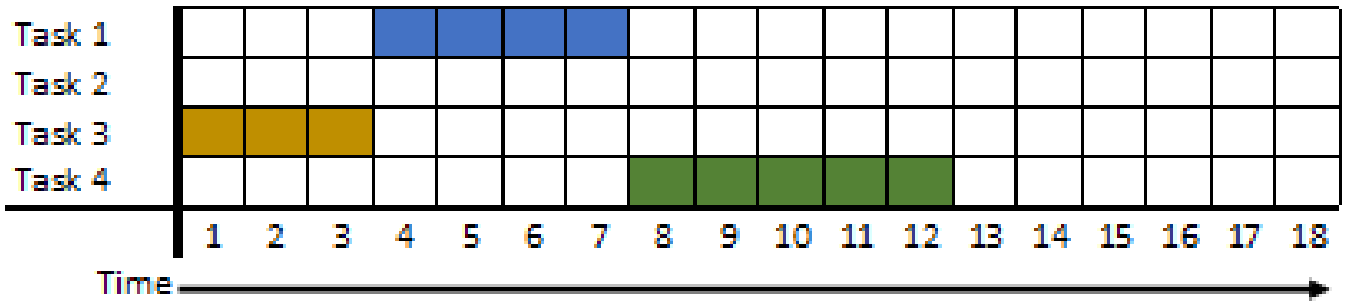

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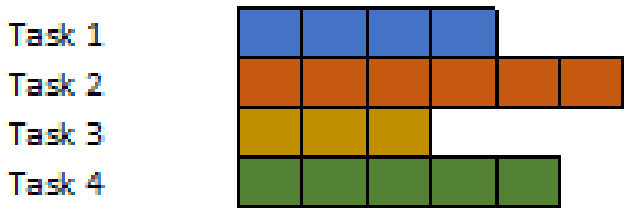

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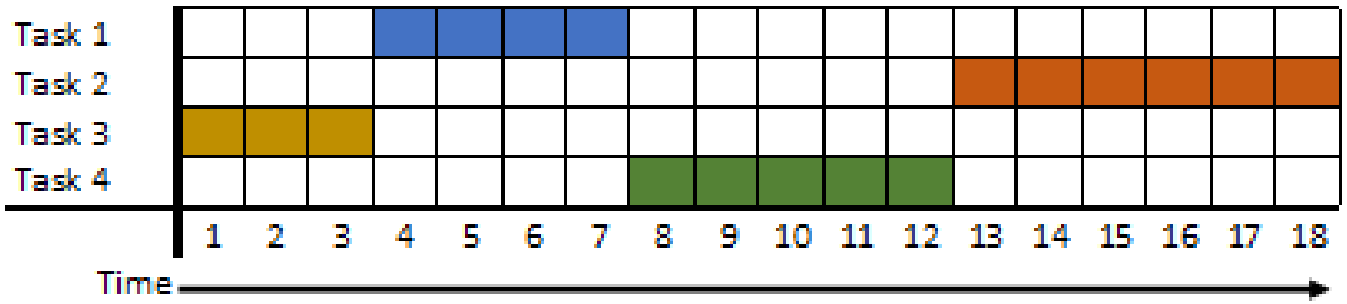


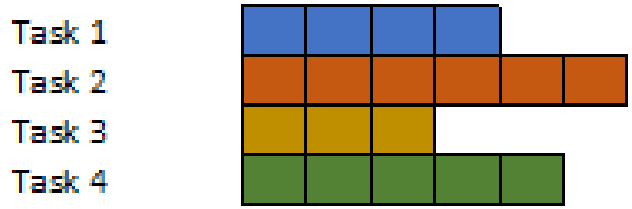
Shortest Job First Unit Tests

- Check if everything is initialized correctly
- Check if the shortest Task has a waiting time of zero
- Check if the second shortest has a waiting time equal to the exeuction time of the first Task, etc

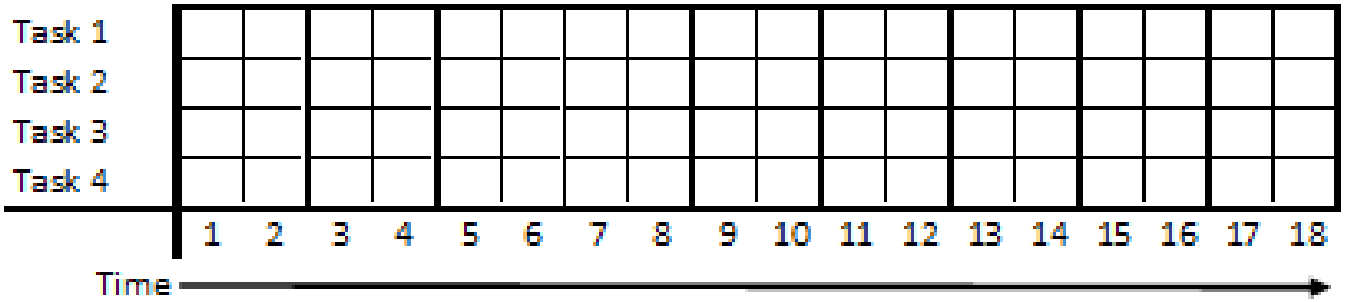
Time Slice [TS]

- Preemptive multitasking
- What Is It?
  - Time slots are created for each Task.
  - Once the "timer" ends an interrupt is thrown for the next task to start
- Pros
  - Fully deterministic
- Cons
  - If the Task has nothing to do during it's time then the slot time is wasted

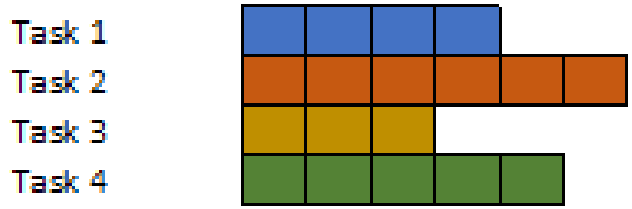
Time Slice (continued)

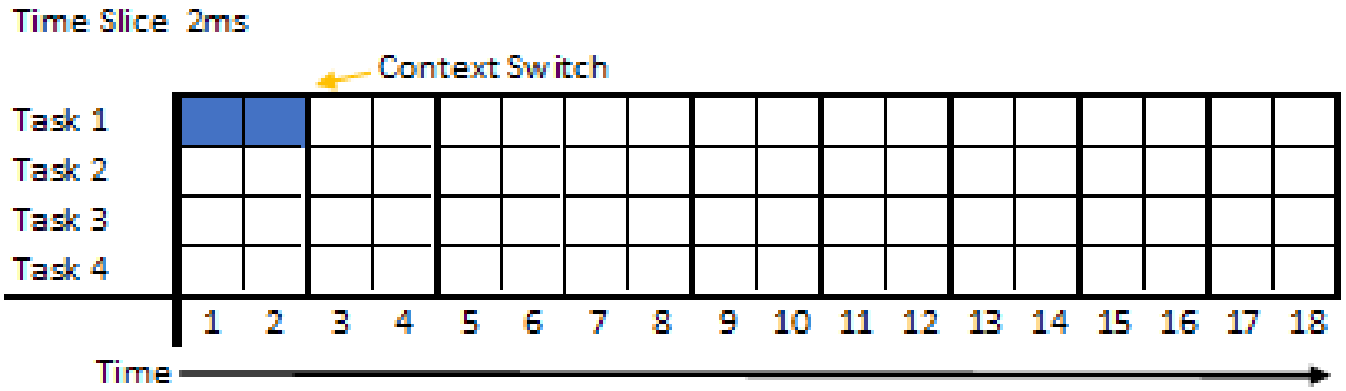


Time Slice 2ms



Time Slice (continued)





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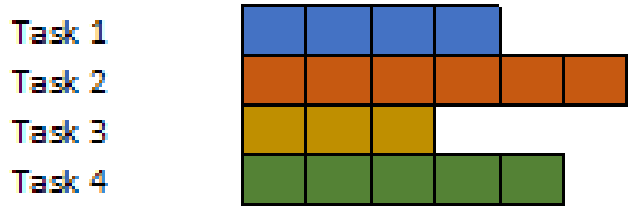

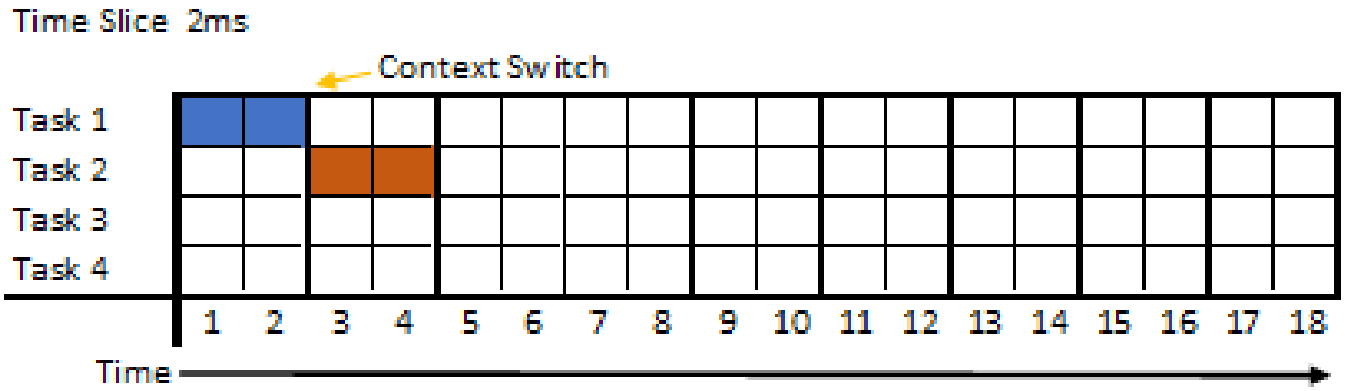

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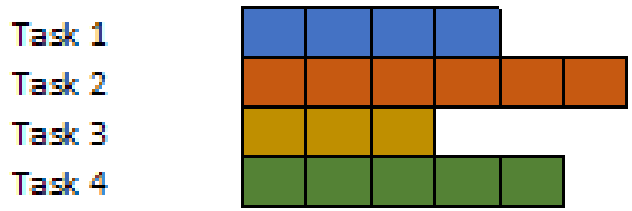

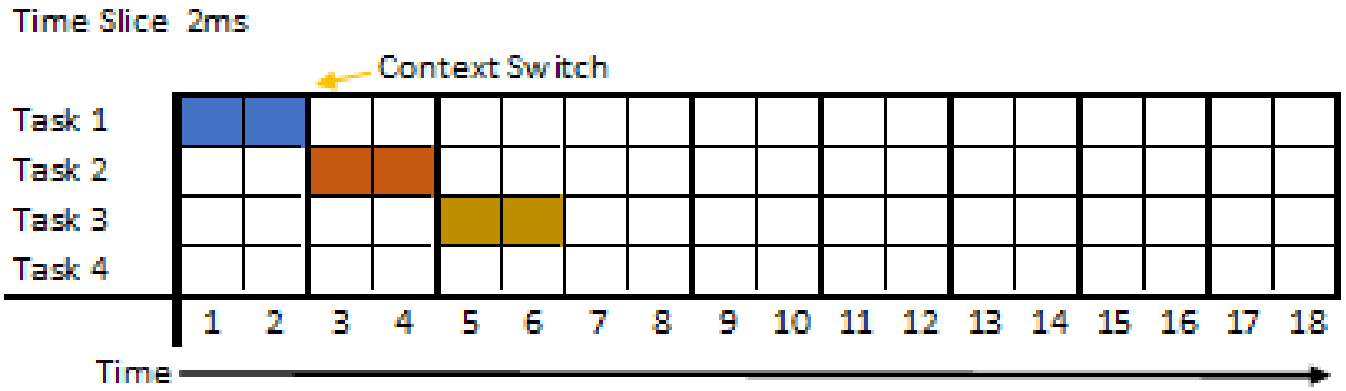

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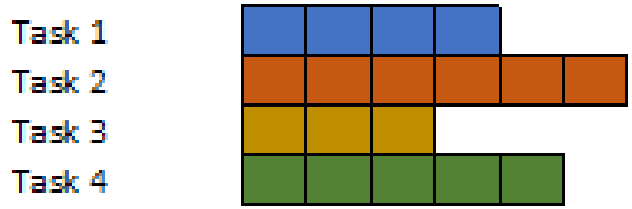

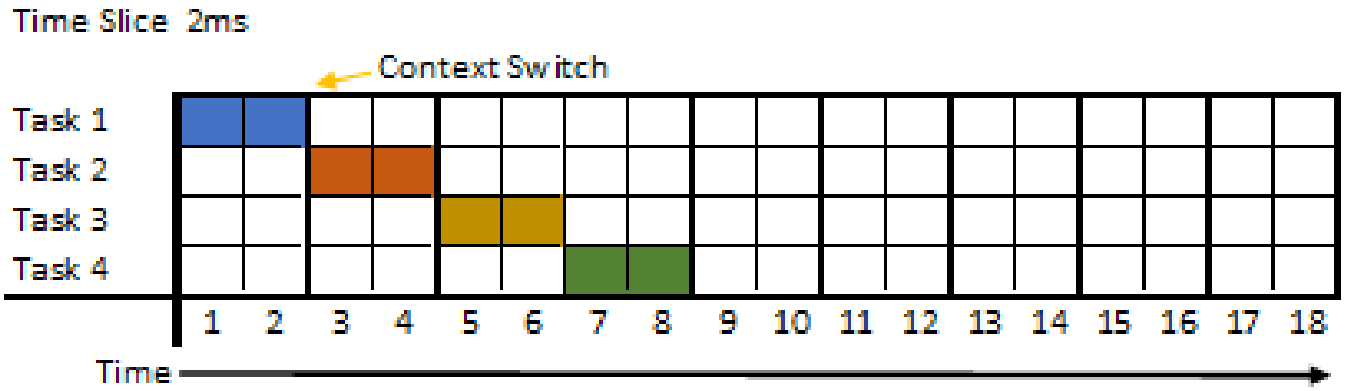

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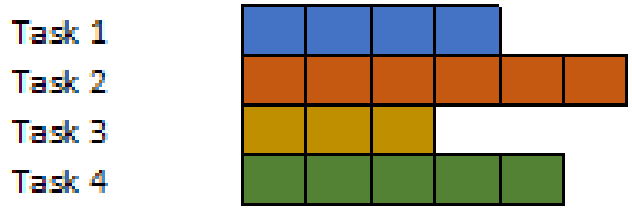

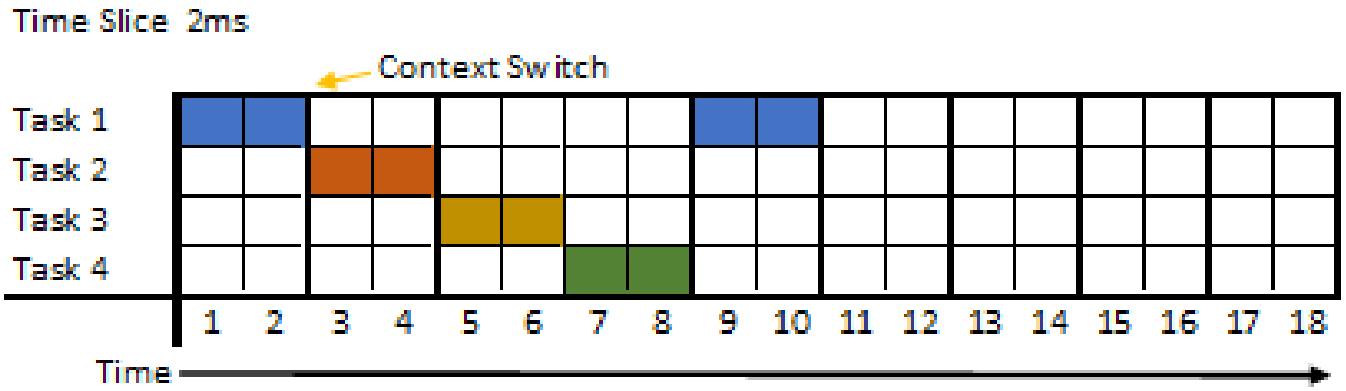

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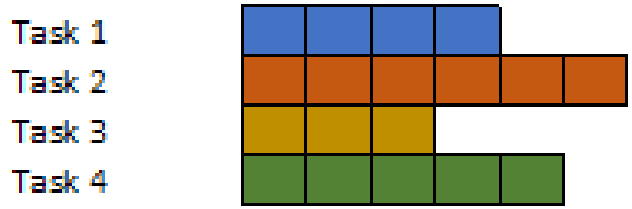

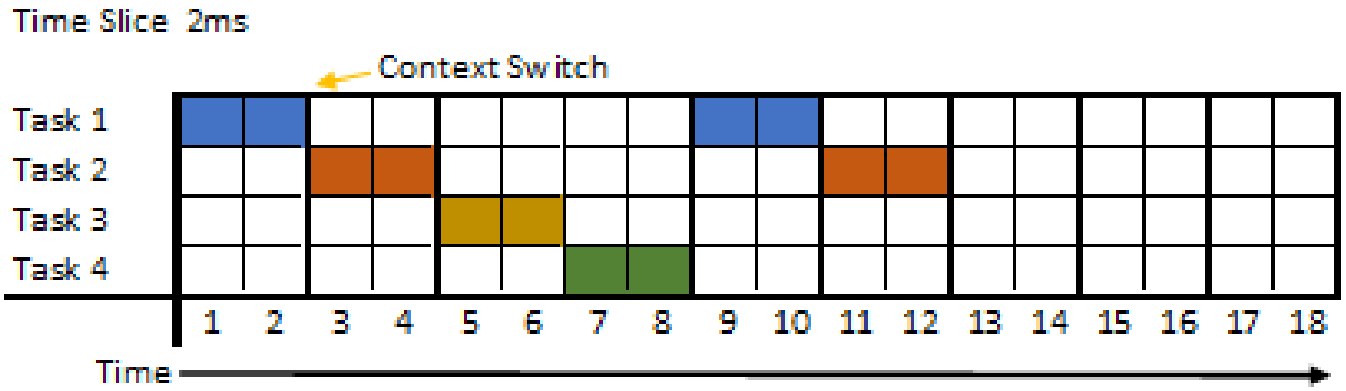

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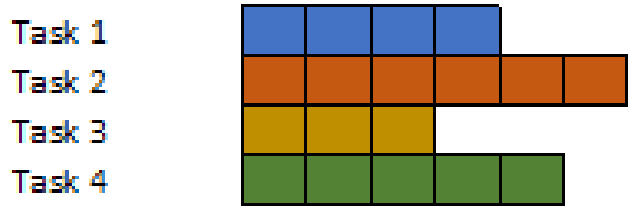

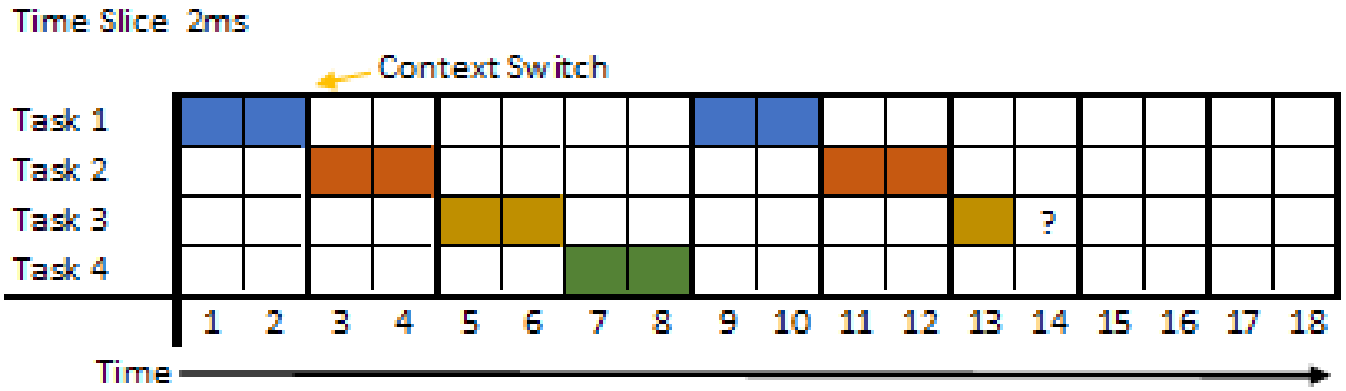

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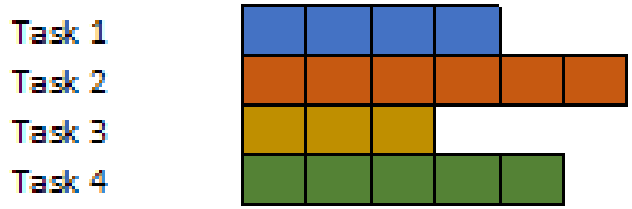

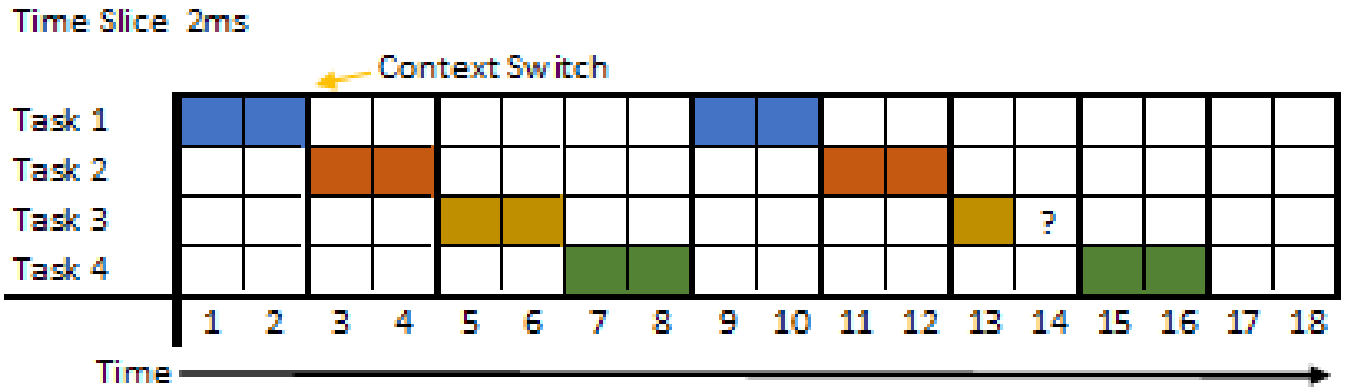

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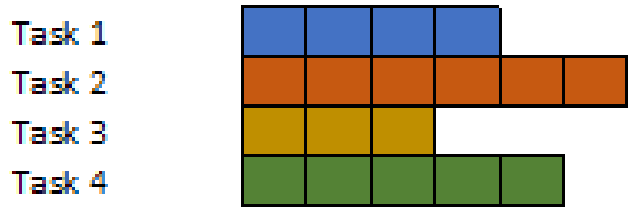
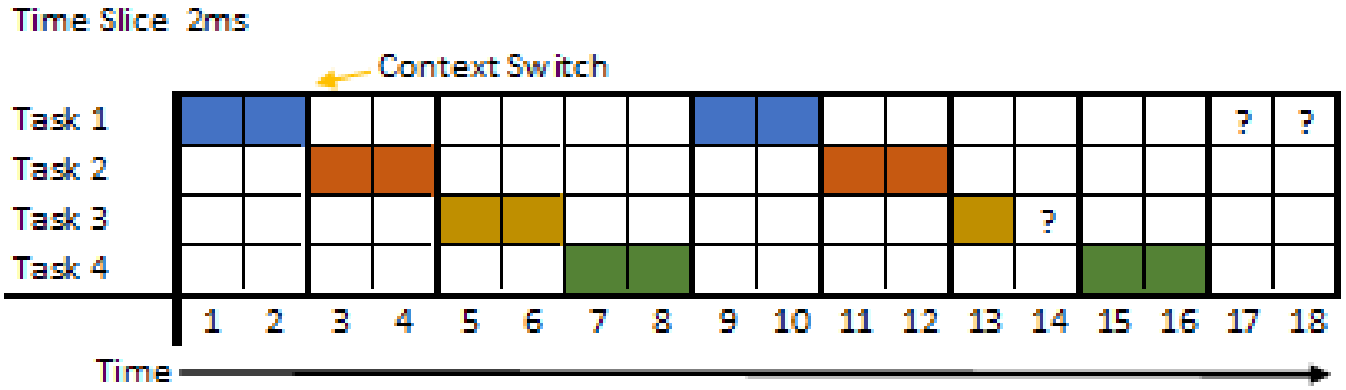




During '?':

- spin CPU and wait?
- suspend CPU to reduce power?
- Try to start other tasks sooner?

Time Slice Unit Tests

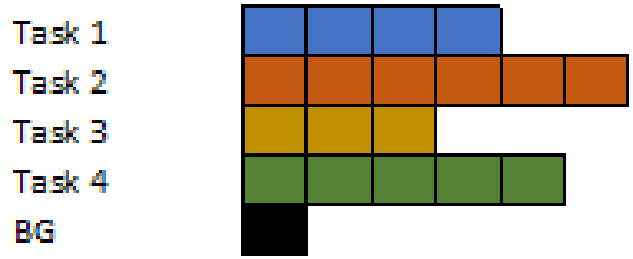
- Check if everything is initialized correctly
- Test that each Task runs for a max time each iteration
- Test with only 1 Task first then add more

Time Slice with Background Task [TSBG]

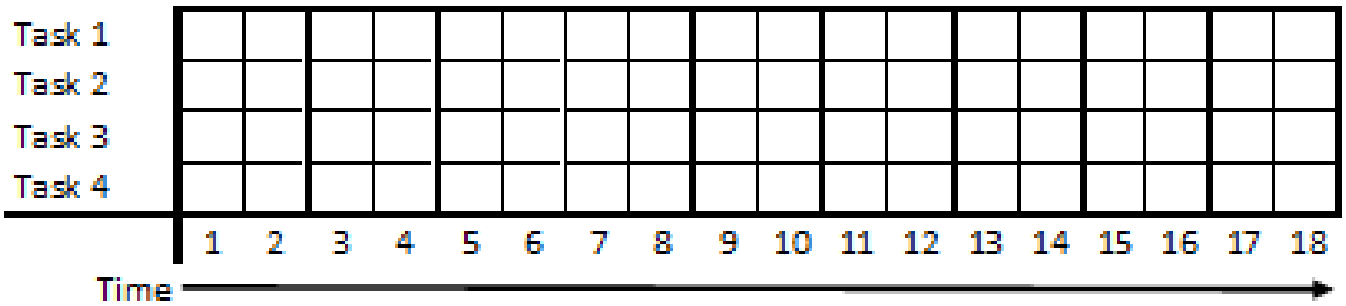
- Preemptive multitasking
- What Is It?
  - Time Slice but adds in ability to run background tasks if a slot is free
- Pros
  - Fully Deterministic
  - Improves Time Slice
- Cons
  - There is a chance that background tasks will never be scheduled
  - Overhead due to context-switching

Real-life example: HDD, early 1990s: servo on timer interrupt, then R/W channel/sequencer, then background (host/ queueing)...degenerate "preemption"

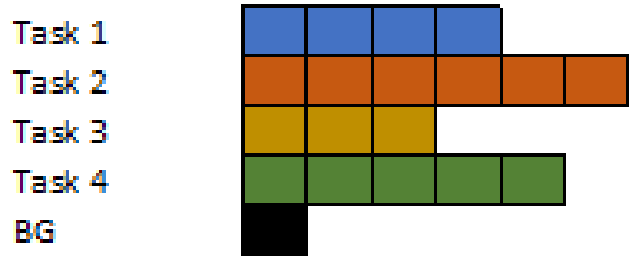
Time Slice with Background Task [TSBG] (continued)

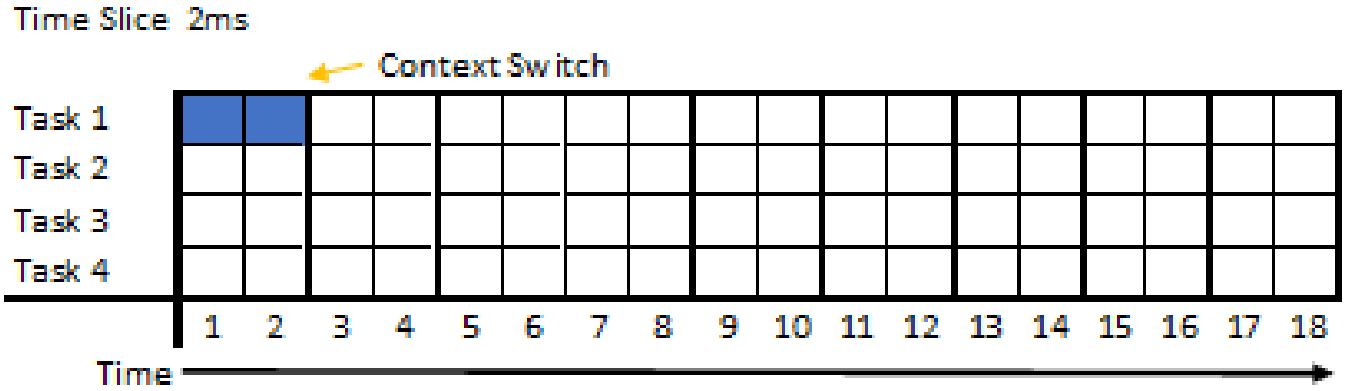


Time Slice 2ms

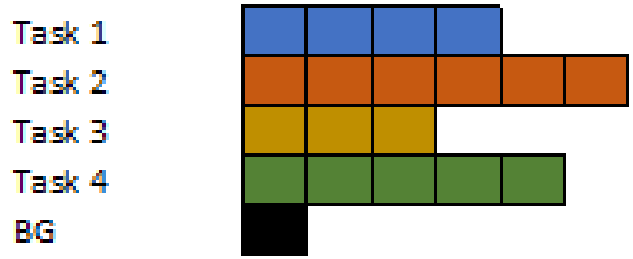


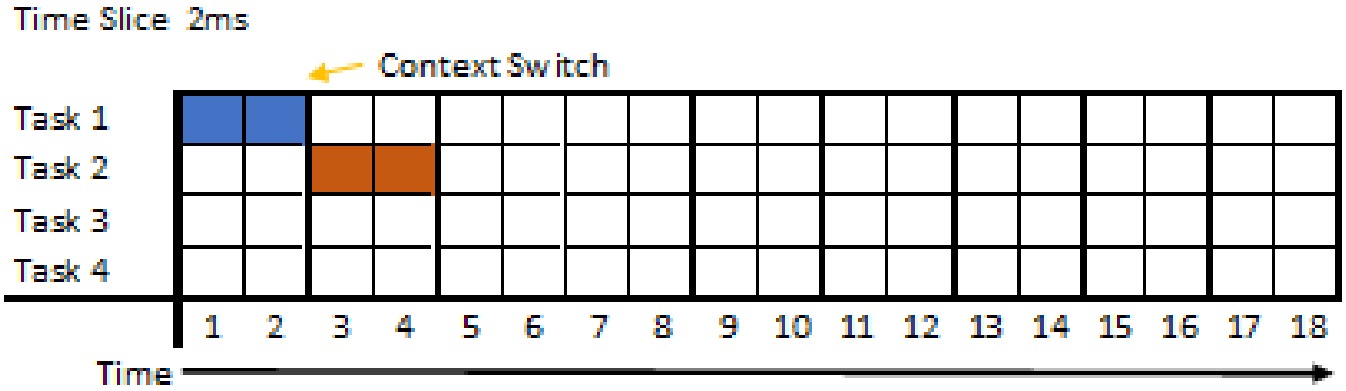
Time Slice with Background Task [TSBG] (continued)



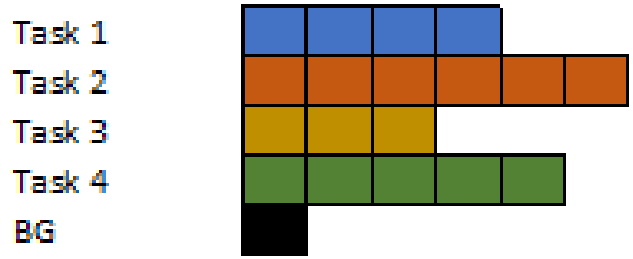


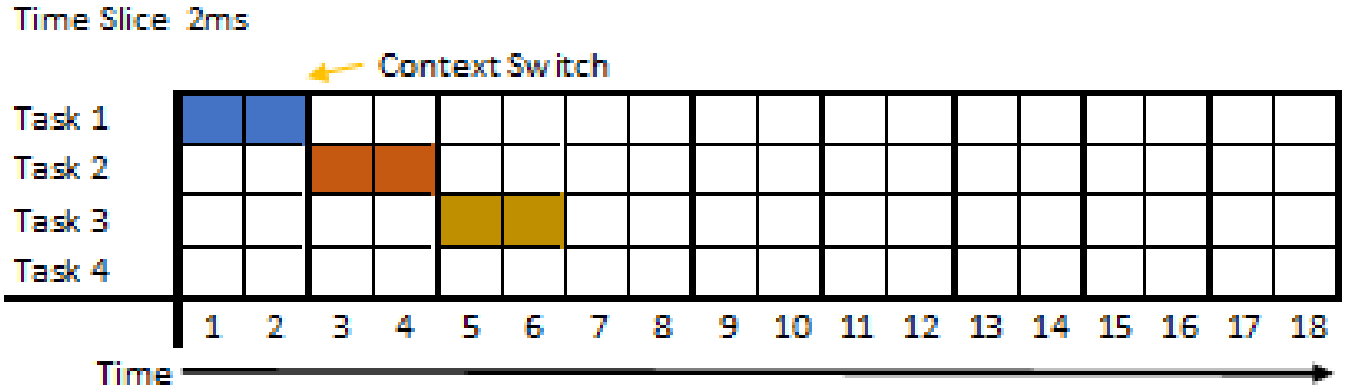
Time Slice with Background Task [TSBG] (continued)



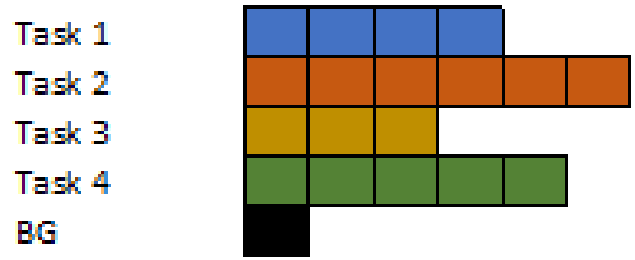


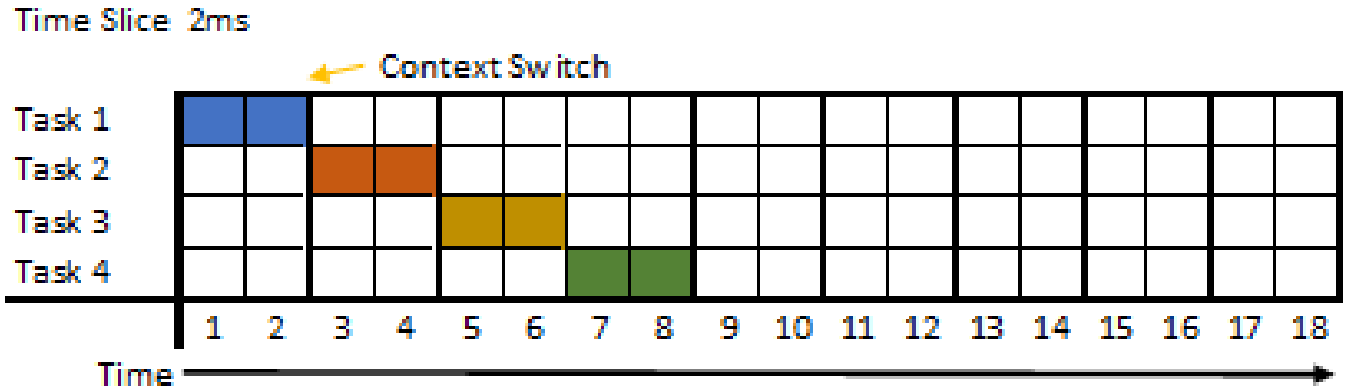
Time Slice with Background Task [TSBG] (continued)



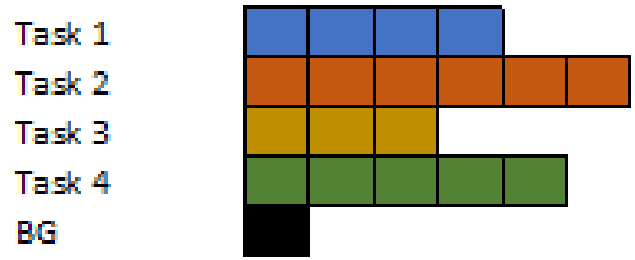


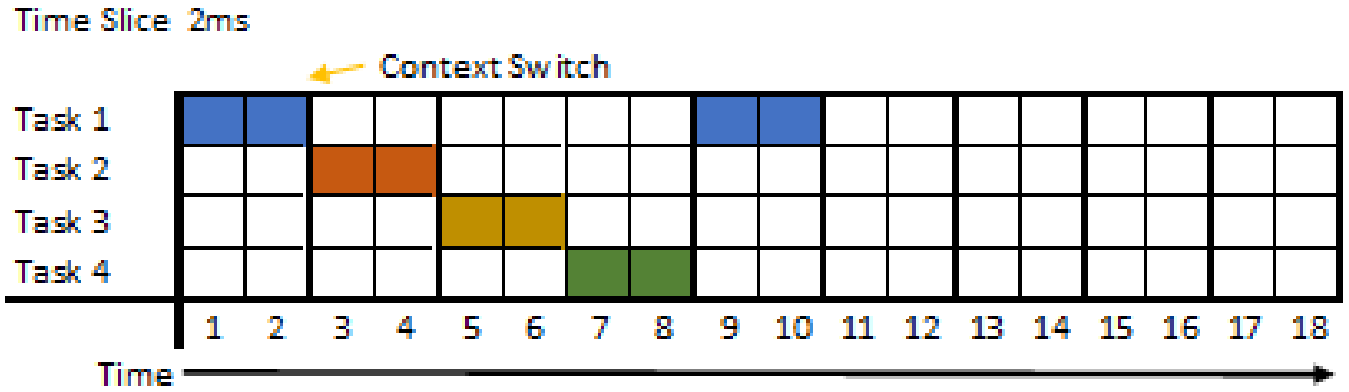
Time Slice with Background Task [TSBG] (continued)



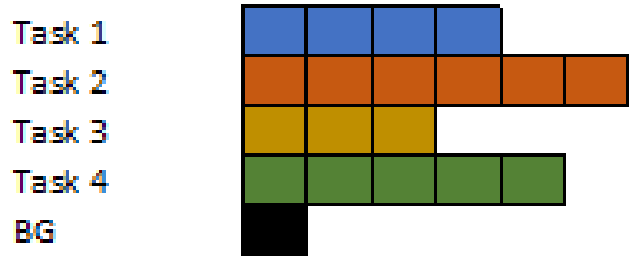


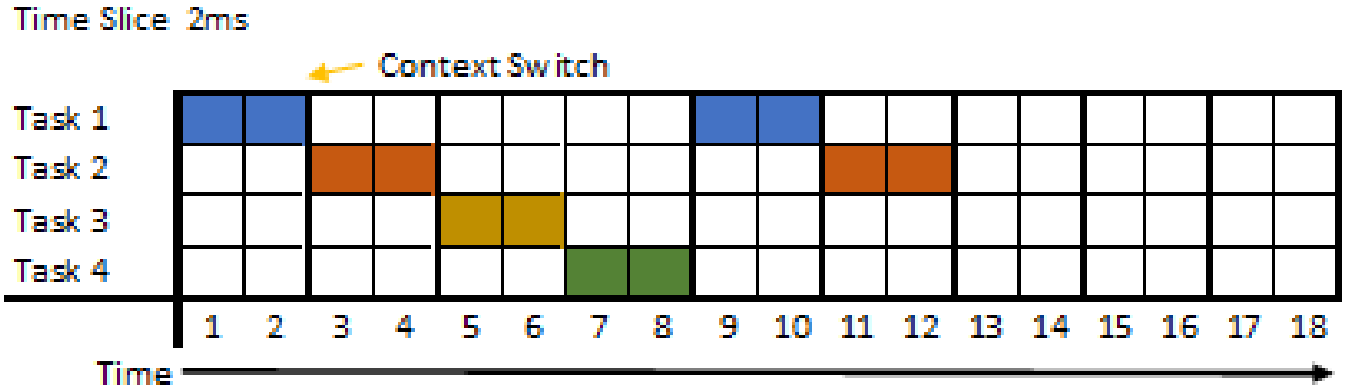
Time Slice with Background Task [TSBG] (continued)



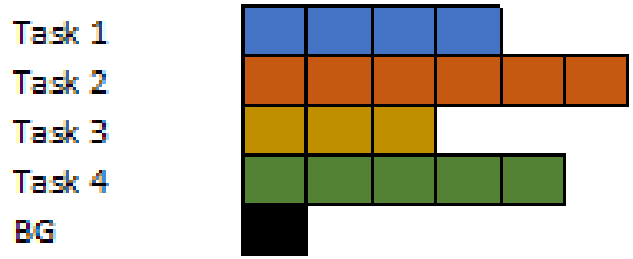


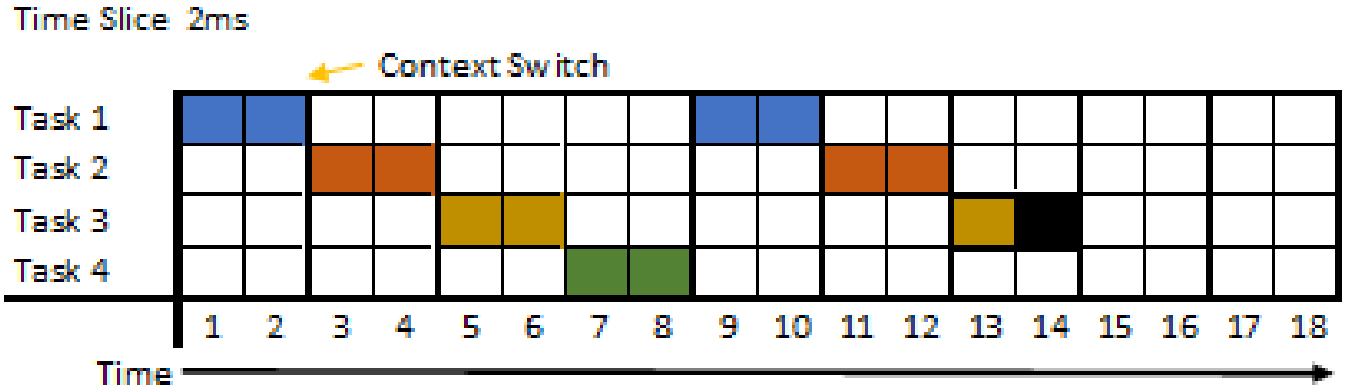
Time Slice with Background Task [TSBG] (continued)



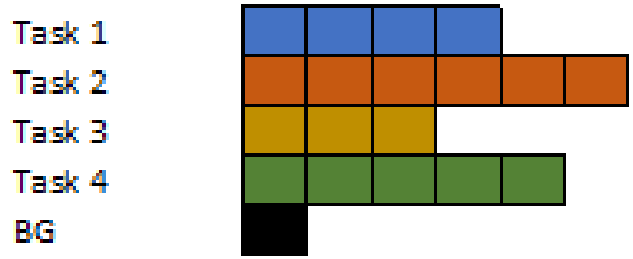


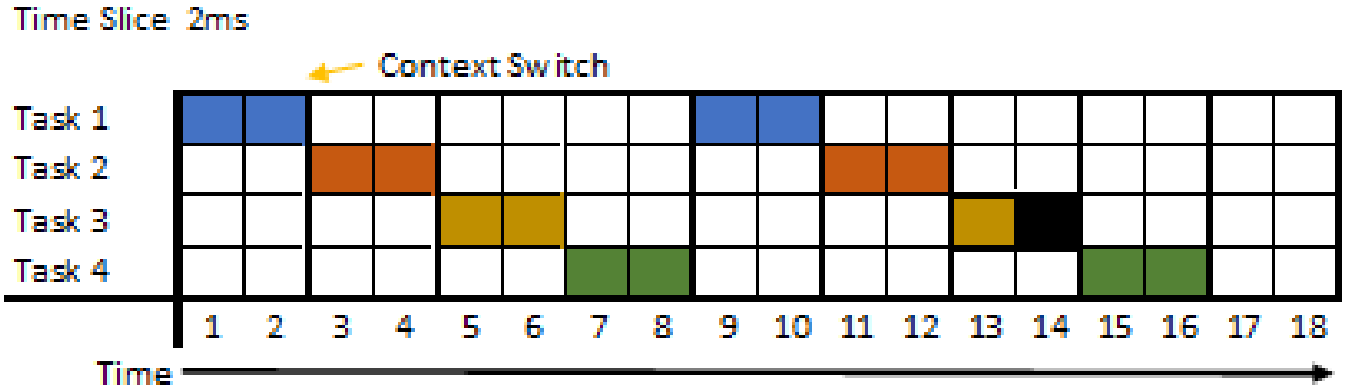
Time Slice with Background Task [TSBG] (continued)



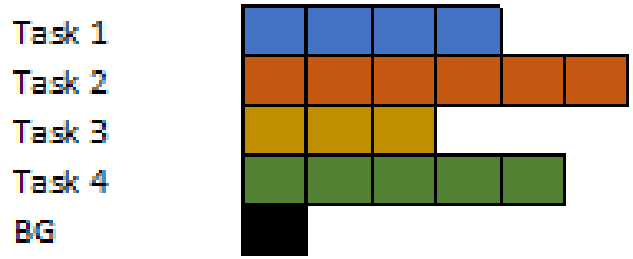


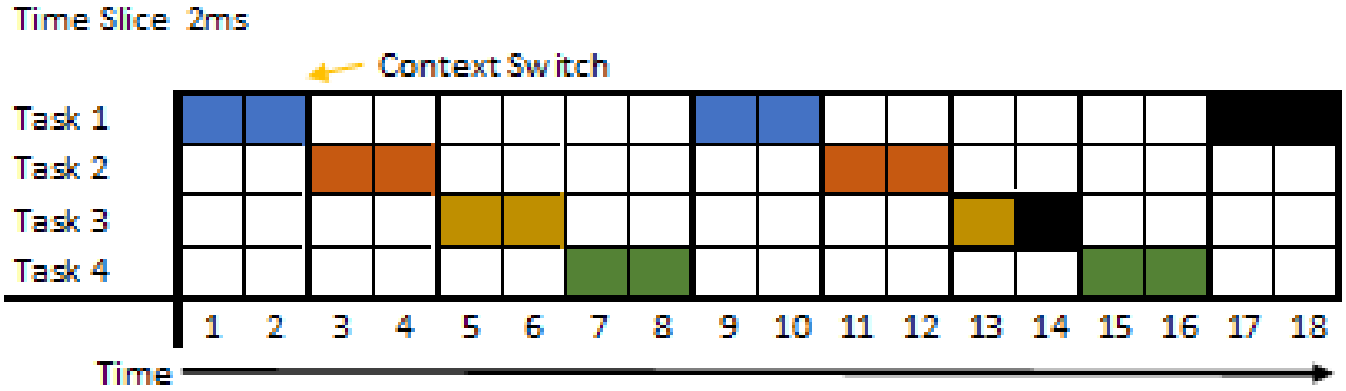
Time Slice with Background Task [TSBG] (continued)





Time Slice with Background Task [TSBG] (continued)





Time Slice with BG Unit Tests

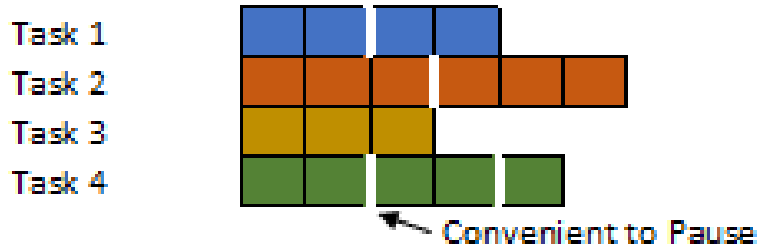
- Check if everything is initialized correctly
- Test that each Task runs for a max time each iteration
- Check that a background Task runs when a Task runs out of things to do

Round Robin [RR]

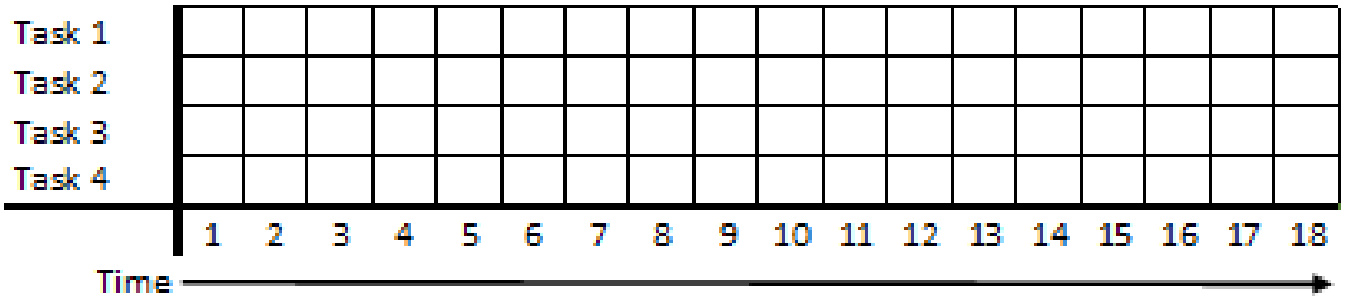
- Cooperative multitasking
- What Is It?
  - Strictly-ordered execution of Task segments
  - Typically the ready queue (FIFO) is a circular queue
  - Each Task gets the resources for a specific amount of time
  - The Task runs until it blocks, finishes, or uses alloted time
- Pros
  - Great for small Tasks
- Cons
  - Highest priority task is not run immediately

Real-life use: Network router with heavy hardware pipelining for execution context pre-fetch

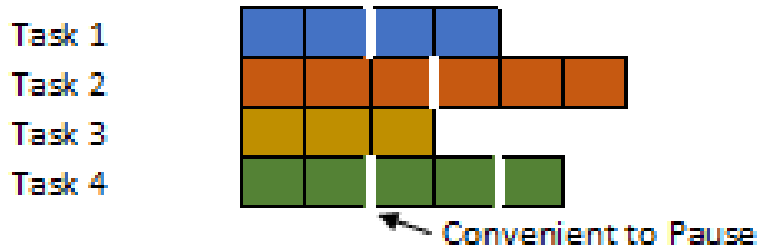
Round Robin [RR] (continued)

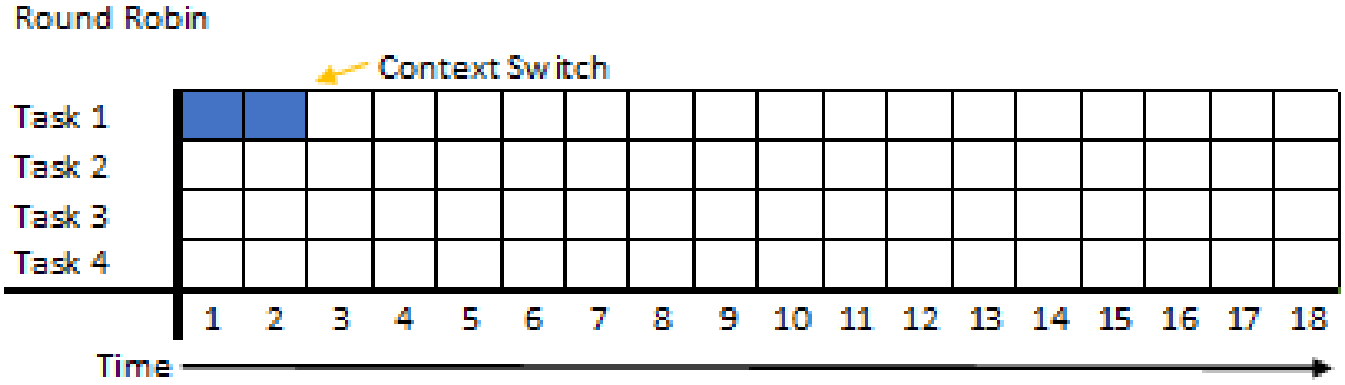


Round Robin

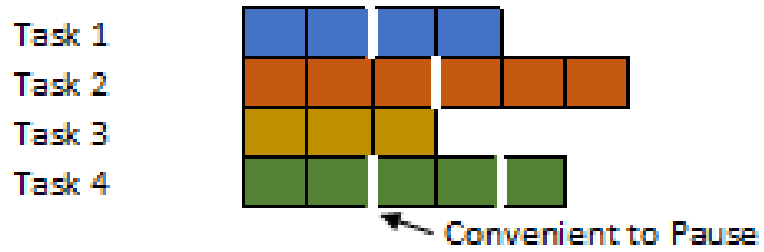


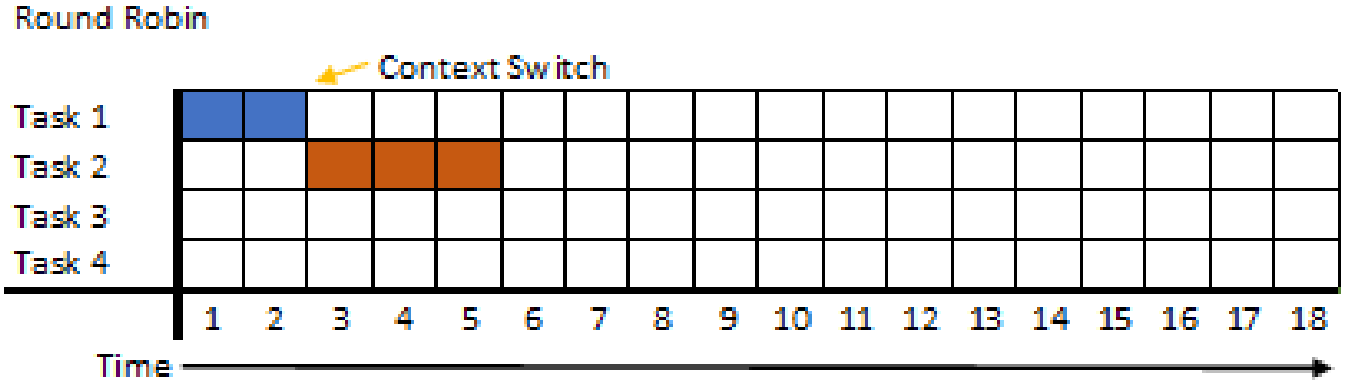
Round Robin [RR] (continued)





Round Robin [RR] (continued)





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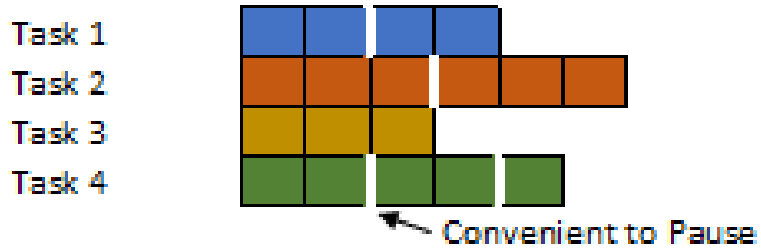
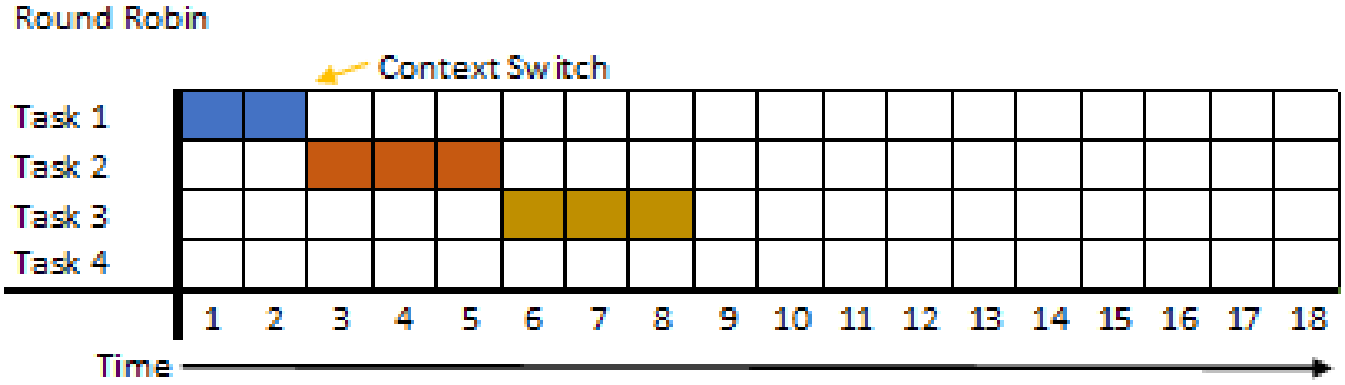
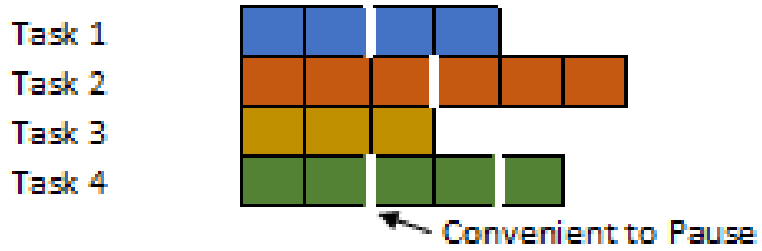
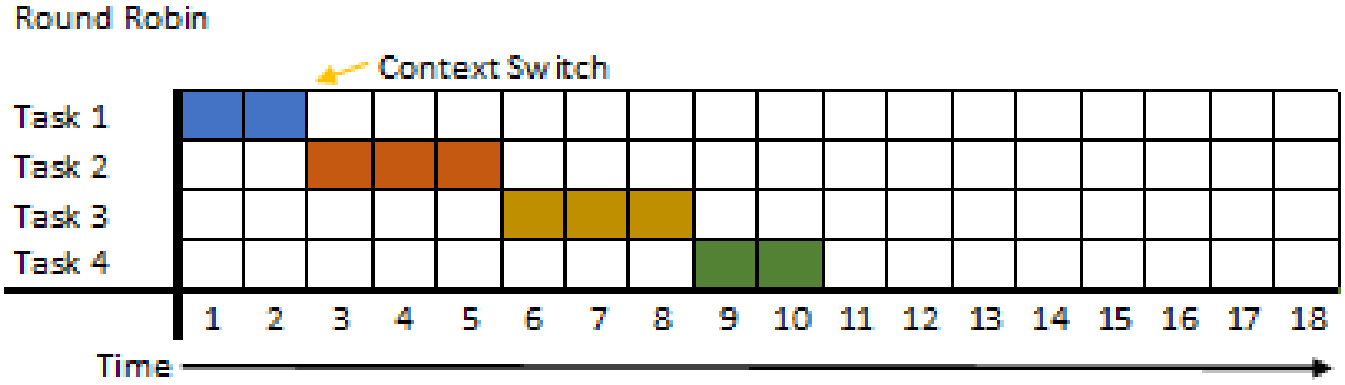




Round Robin [RR] (continued)





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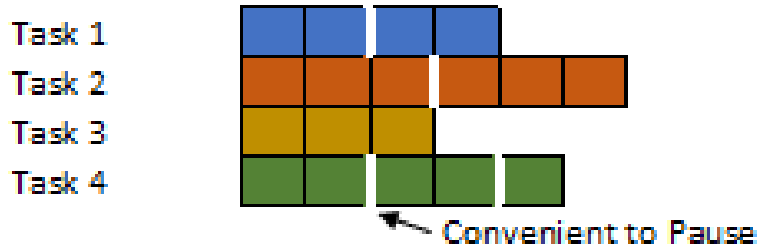

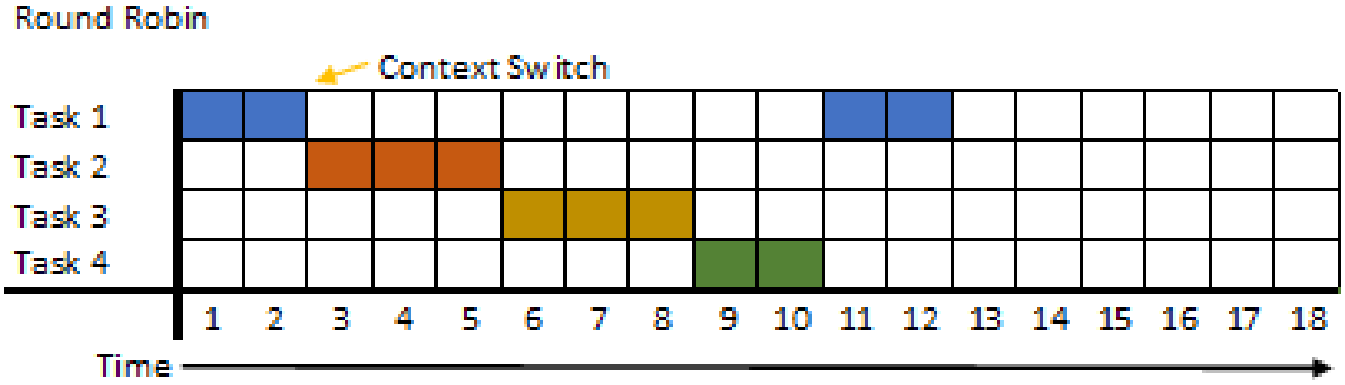

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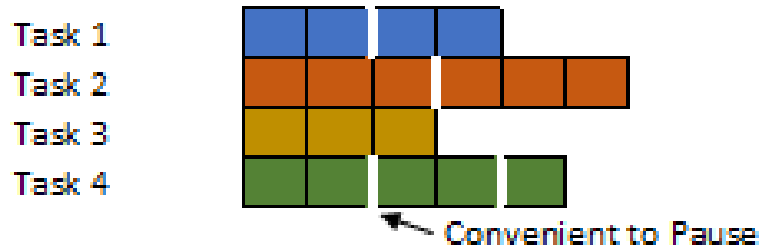

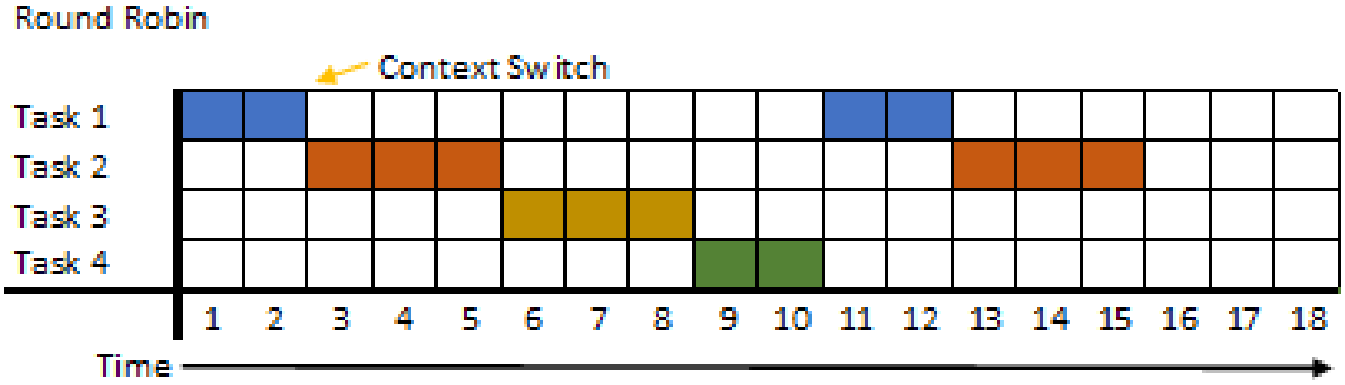

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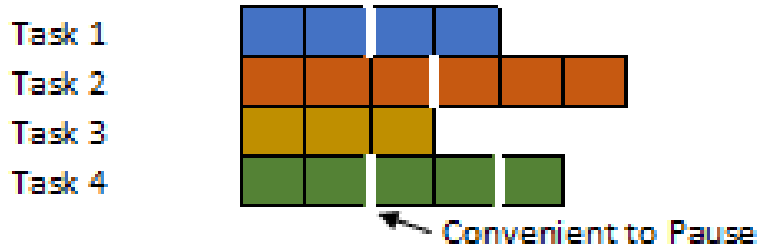
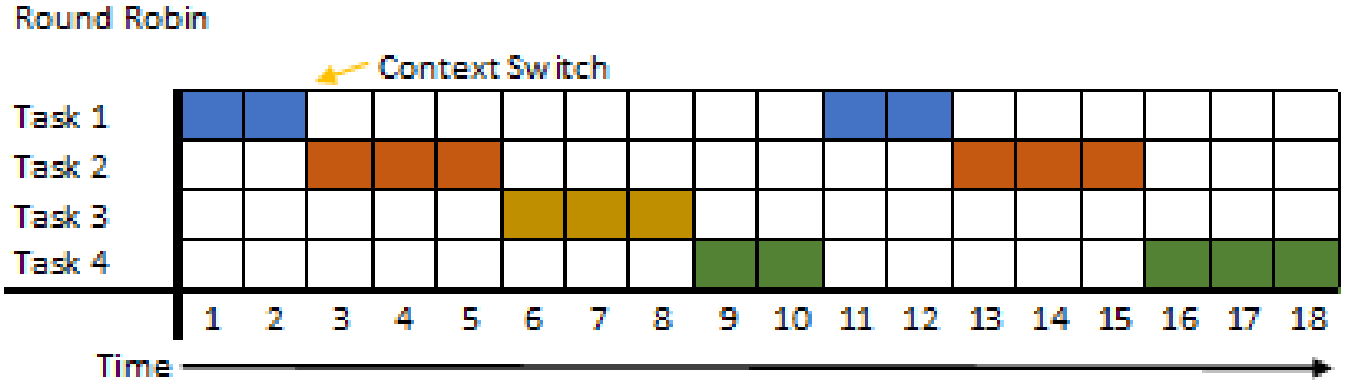




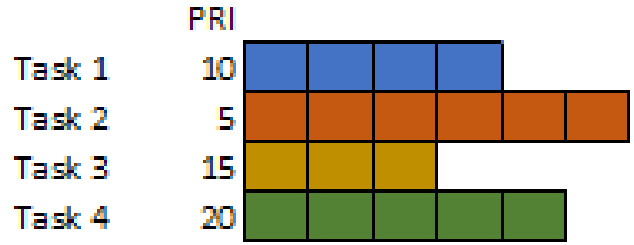
Round Robin Unit Tests

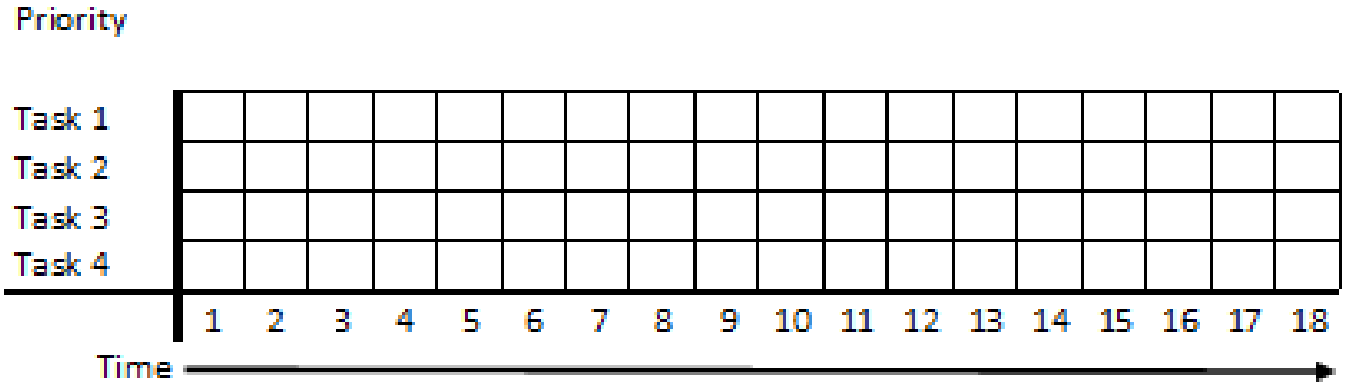
- Check if everything is initialized correctly
- Verify that each Task "pauses" during specific times
- Verify that each Task finished execution
- Verify that each Task didn't hog resources and therefore finish early

Priority

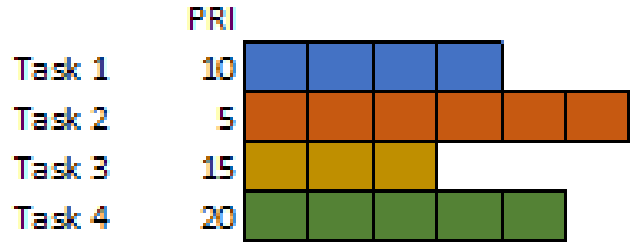
- What Is It?
  - Task is chosen with the highest priority
  - Priority can be based on memory requirements, CPU Time, Owner, etc
  - Can be non-preemptive or preemptive
  - Note: priorities can change during execution
- Pros
  - Highest priority jobs are run
- Cons
  - Low priority jobs can potentially wait forever
  - Overhead due to context-switching

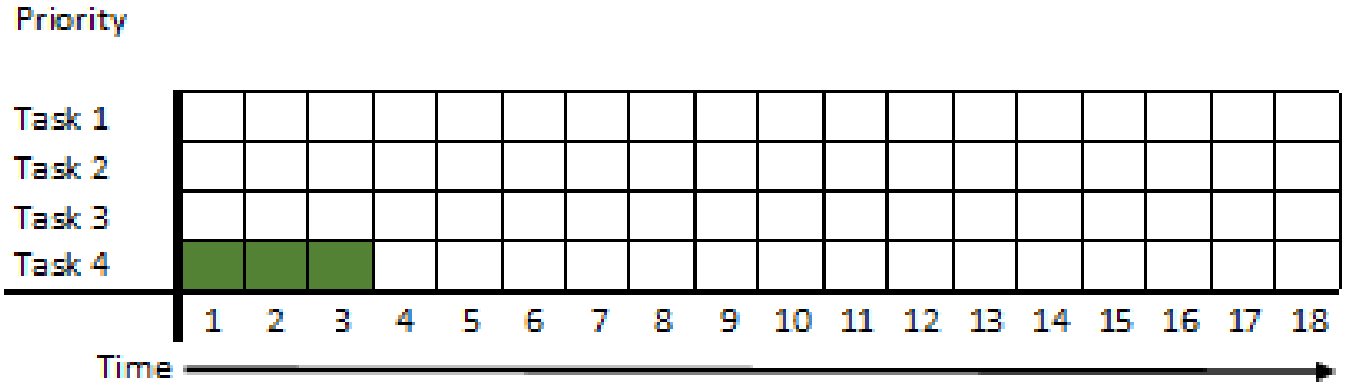
Priority (continued)



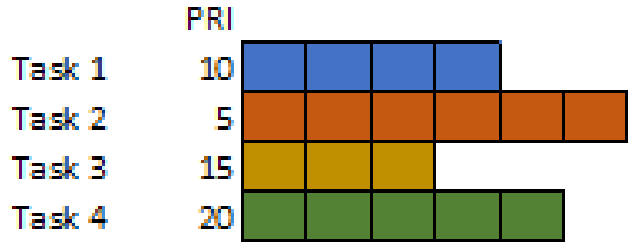


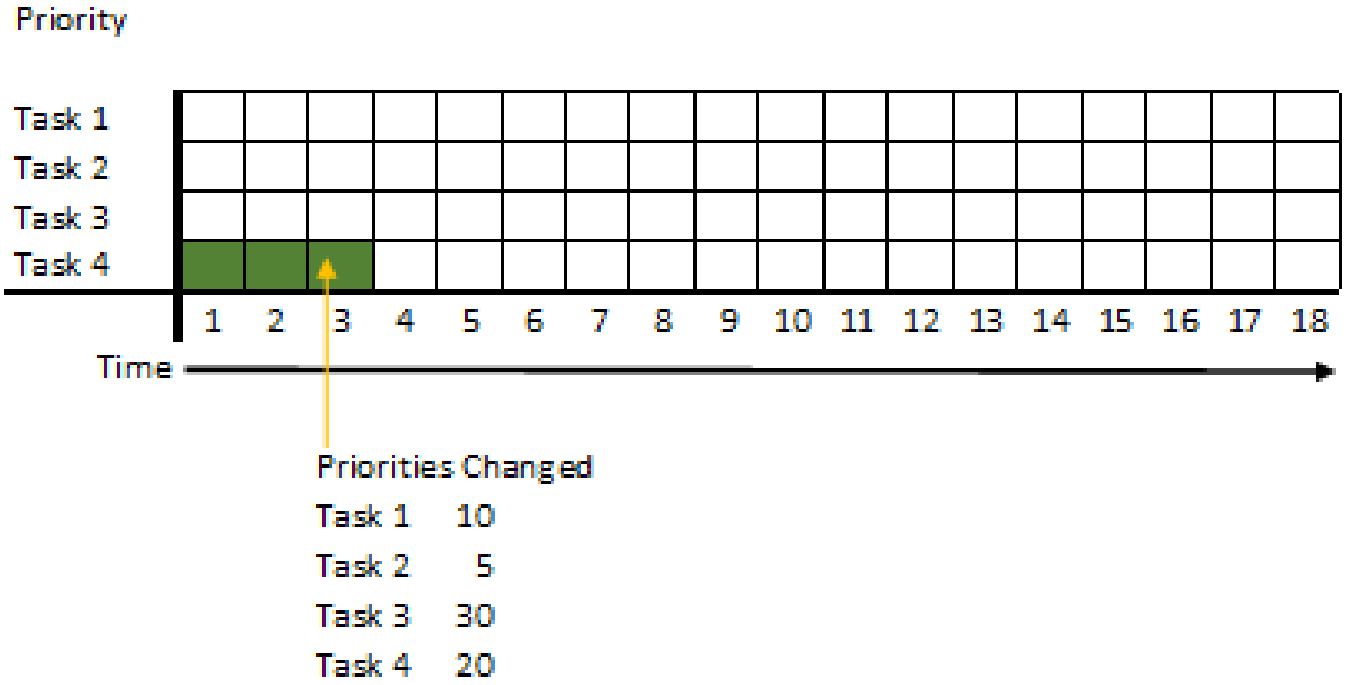
Priority (continued)



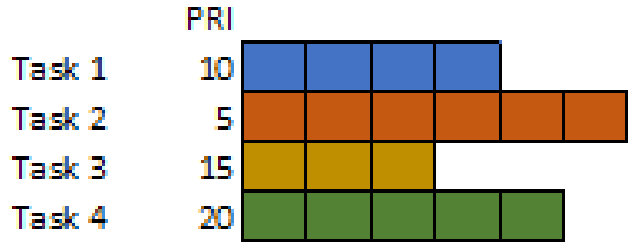


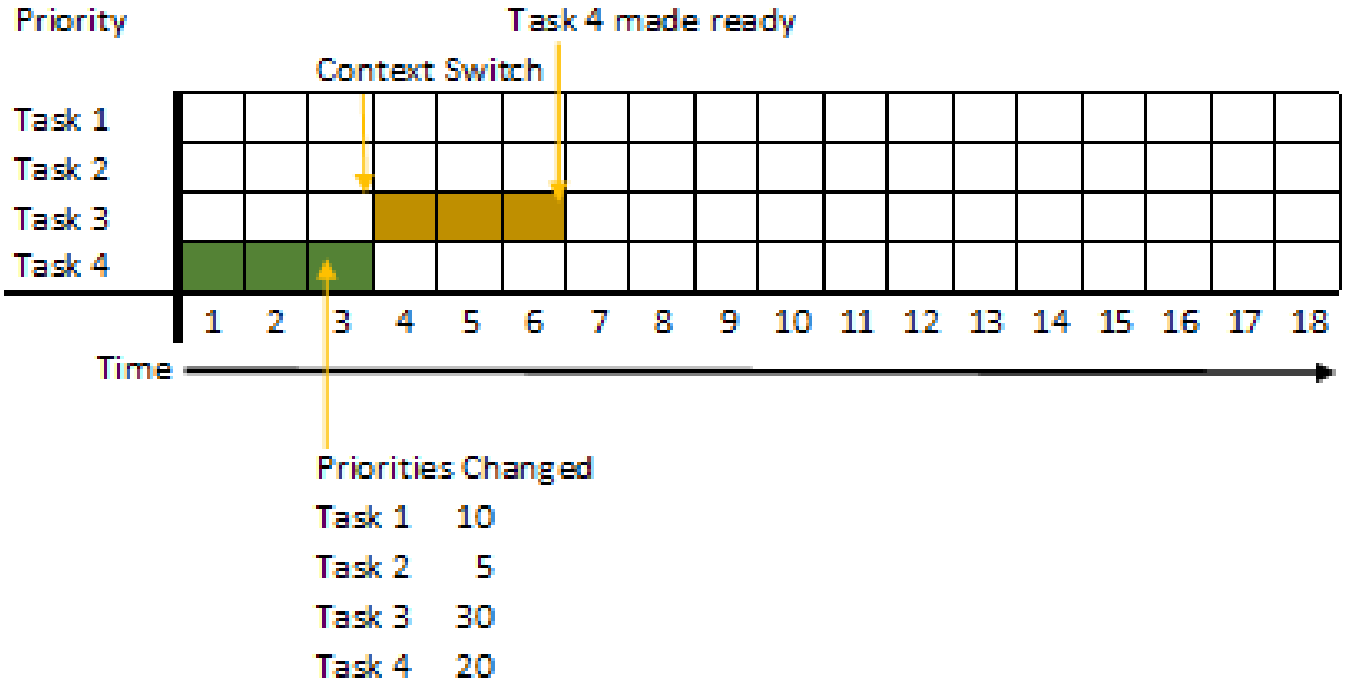
Priority (continued)





Priority (continued)





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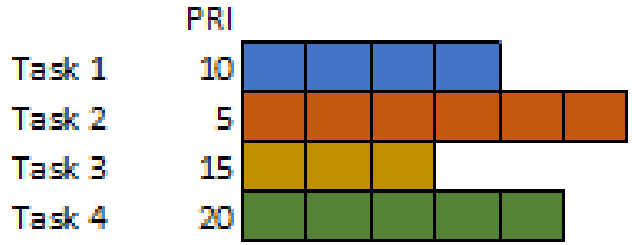
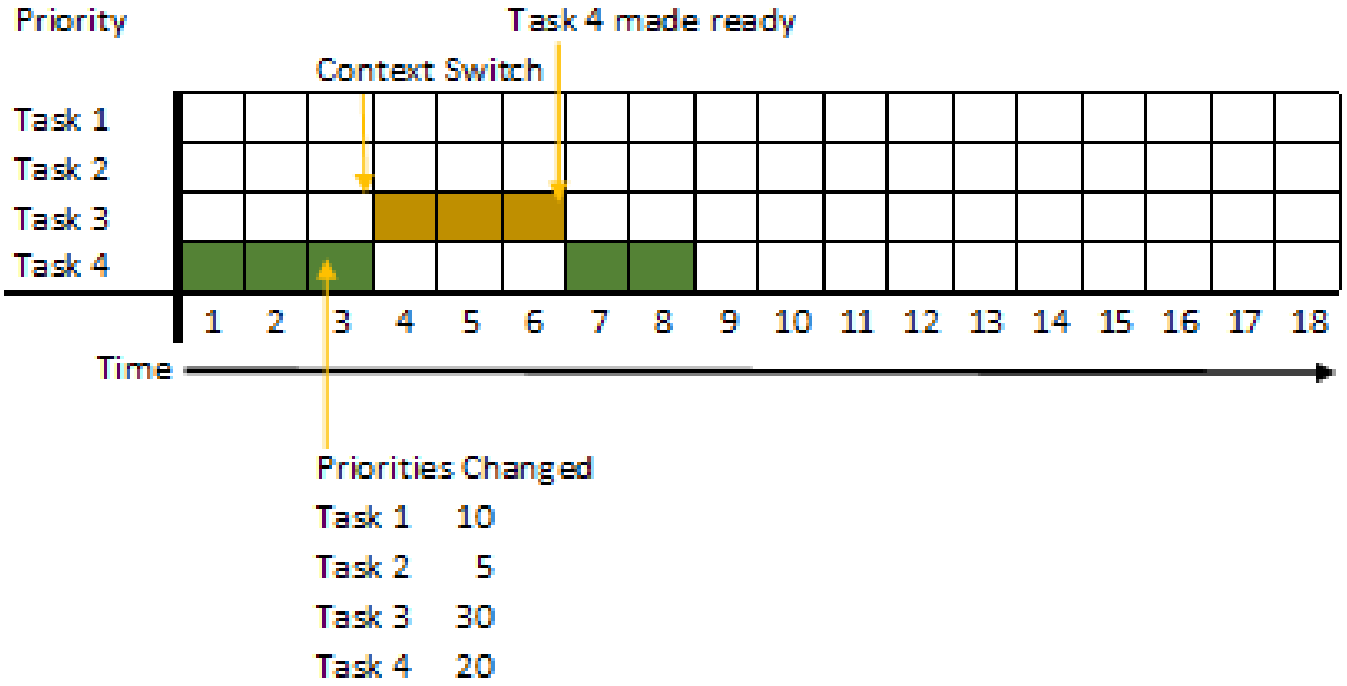
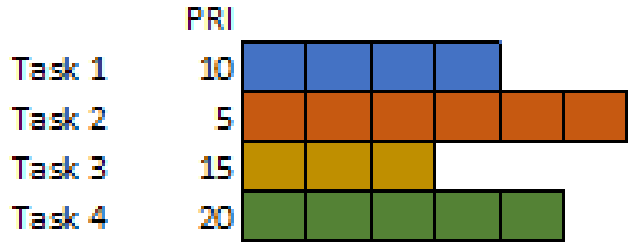
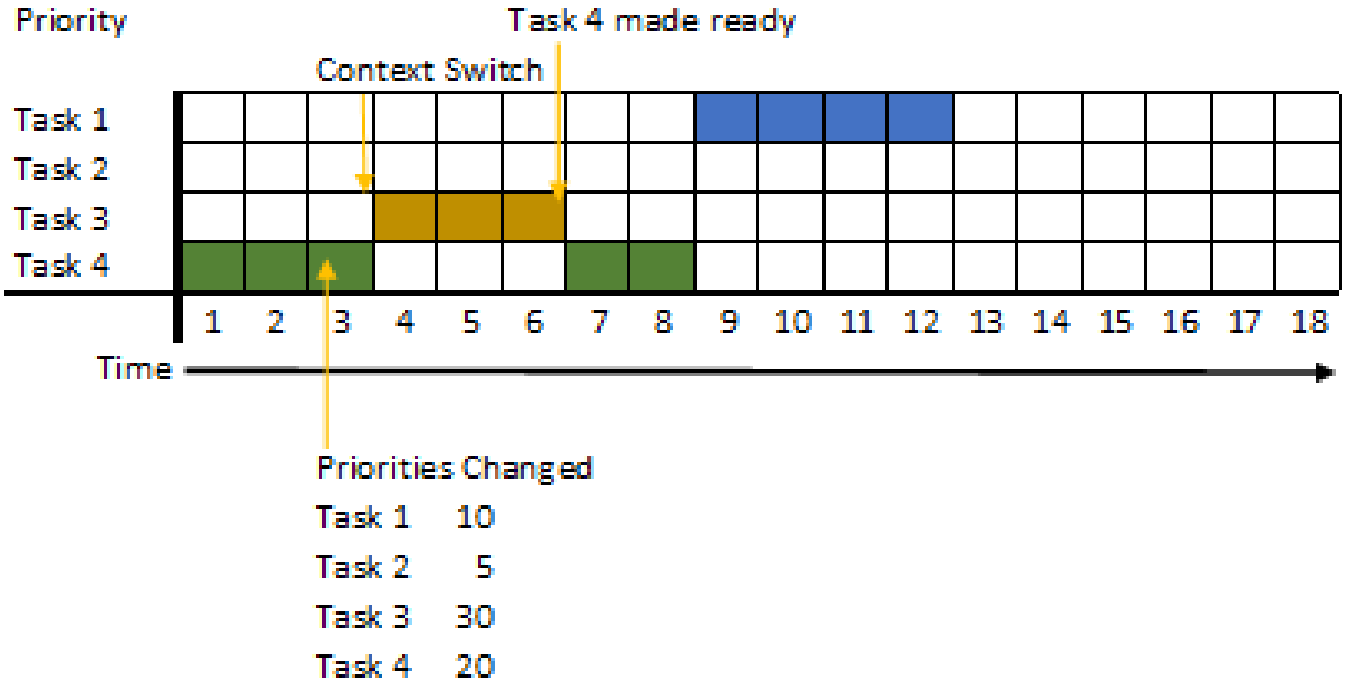


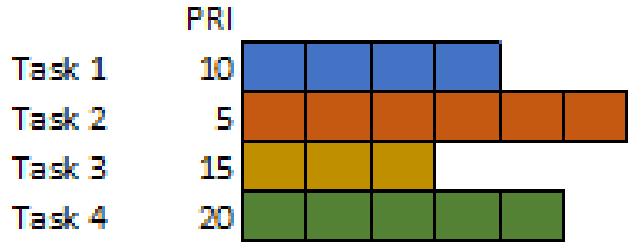


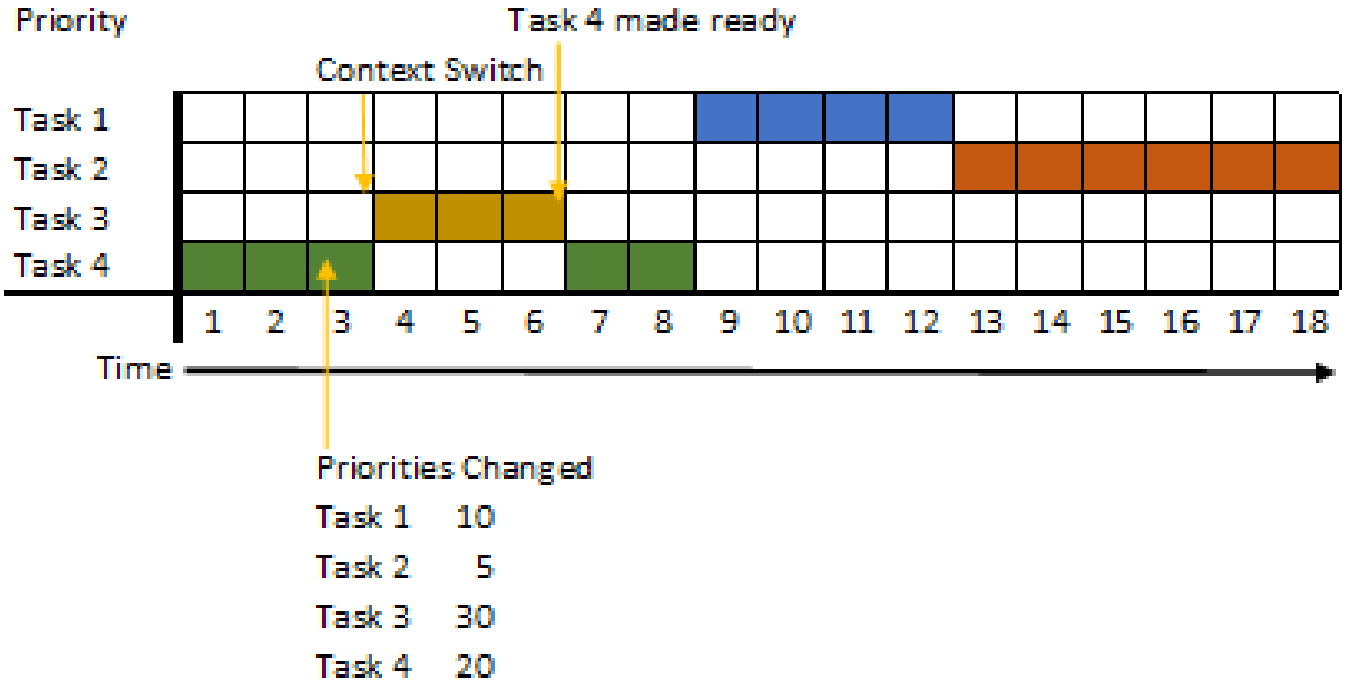
Priority (continued)





Priority (continued)





Priority Unit Tests

- Check if everything is initialized correctly
- Verify that the highest priority Task is always picked next
- Verify all Tasks finished execution
- Verify that new higher priority Tasks are executed in the right order

Scheduling

- Which Scheduling algorithm should you use?

Scheduling

- Which Scheduling algorithm should you use?
- It Depends.