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هيئة تنمية صناعة تكنولوجيا المعلومات



Ministry of Communications
and Information Technology



EGYPTFWD Initiative

Advanced Embedded Systems Nanodegree,
Real-Time Operating Systems Masterclass by
SPRINTS Egypt.

Implementation of an EDF Scheduler based on freeRTOS

A Graduation Project
submitted in partial Fulfillment of
Real-Time Operating Systems Masterclass.

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Verifying the system implementation

Analytical Method

ID	Task	Periodicity (ticks)	Execution Time(ms)	Calls in HyperPeriod
1	Button_1_Monitor	50	0.019	2
2	Button_2_Monitor	50	0.0193	2
3	Periodic_Transmitter	100	0.02465	1
4	Uart_Receiver	20	0.02352	5
5	Load_1_Simulation	10	5	10
6	Load_2_Simulation	100	12	1

- **Calculation of HyperPeriod**

$$\text{HyperPeriod} = \text{LCM}(\text{Periodicities}) = \text{LCM}(50, 50, 100, 20, 10, 100)$$

$$\text{HyperPeriod} = 100$$

- **CPU Load Calculations**

$$\text{CPU LOAD} = \frac{\text{Total Time}}{\text{HyperPeriod}} * 100$$

$$\text{Total Time} = \sum_{i=1}^6 \text{ExecutionTime}_i * \text{Num of Calls In HyperPeriod}_i$$

$$\text{Total Time} = 0.019 * 2 + 0.0193 * 2 + 0.02465 + 0.02352 * 5 + 5 * 10 + 12$$

$$U = \text{CPU LOAD} = \frac{62.21885}{100} * 100 = 62.21885\%$$



- **Schedulability Analysis using Rate Monotonic Utilization Bound**

(Assuming the given set of tasks are scheduled using a fixed priority rate-monotonic scheduler)

if $U \leq U_{rm}$ then the system is schedulable

$$U_{rm} = n[2^{1/n} - 1]$$

$$U_{rm} = 6*(2^{1/6}-1) = 0.7347723$$

The system is guaranteed schedulable since $U < U_{rm}$.

- **Schedulability Analysis using Time Demand Analysis**

$$w_i(t) = e_i + \sum_{k=1}^{i-1} \left\lceil \frac{t}{p_k} \right\rceil e_k \quad \text{for } 0 < t \leq p_i$$

W = Worst response time
 E = Execution time
 P = Periodicity
 T = Time instance

Tasks are organized by lowest periodicity which is highest priority.

Task 5 \rightarrow Task 4 \rightarrow Task 1 \rightarrow Task 2 \rightarrow Task 3 \rightarrow Task 6

- **Task 5**

$$W(4) = 5 + 0 = 5ms$$

$$\text{Since } D = 10 \text{ ms and } W(10) = 5ms$$

$$W(10) < D$$

Task 5 is schedulable.

- **Task 4**

$$W(20) = 0.02352 + (20/10)*5 = 10.02352ms$$

$$\text{Since } D = 20 \text{ ms and } W(20) = 10.02352ms$$

$$W(20) < D$$

Task 4 is schedulable.

- **Task 1**

$$W(50) = 0.019 + (50/10)*5 + (50/20)*0.02352 = 25.607ms$$

$$\text{Since } D = 50 \text{ ms and } W(50) = 25.607ms$$

$$W(50) < D$$

Task 1 is schedulable.

- **Task 2**

$$W(50) = 0.0193 + (50/10)*5 + (50/20)*0.02352 + (50/50)*0.019 \\ = 25.6263ms$$

$$\text{Since } D = 50 \text{ ms and } W(50) = 25.6263ms$$

$$W(50) < D$$

Task 2 is schedulable.

- **Task 3**

$$W(100) = 0.02465 + (100/50)*0.019 + (100/50)*0.0193 + (100/10)*5 \\ + (100/20)*0.02352 = 50.21885ms$$

$$\text{Since } D = 100 \text{ ms and } W(100) = 50.21885ms$$

$$W(100) < D$$

Task 3 is schedulable.

- **Task 6**

$$W(100) = 12 + (100/100)*0.02465 + (100/50)*0.019 + (100/50)*0.0193 + (100/10)*5 \\ + (100/20)*0.02352 = 62.21885ms$$

$$\text{Since } D = 100 \text{ ms and } W(100) = 62.21885ms$$

$$W(100) < D$$

Task 6 is schedulable.

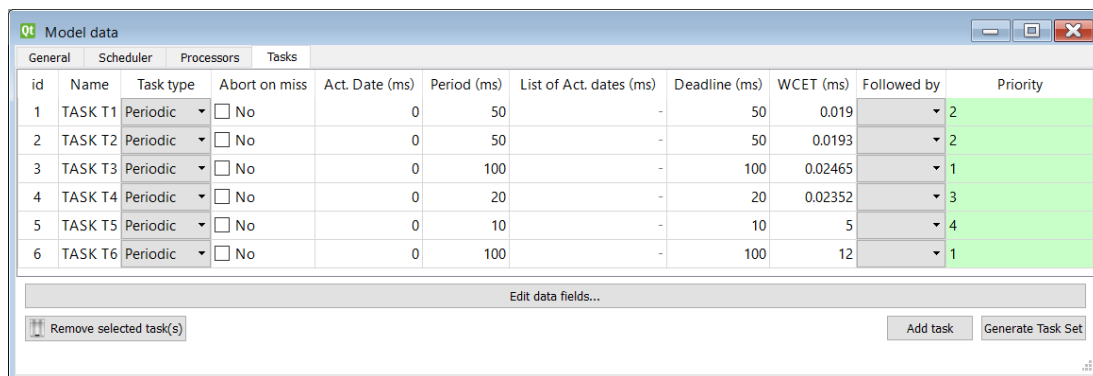
Therefore, the system is schedulable.



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Simso Simulation Method



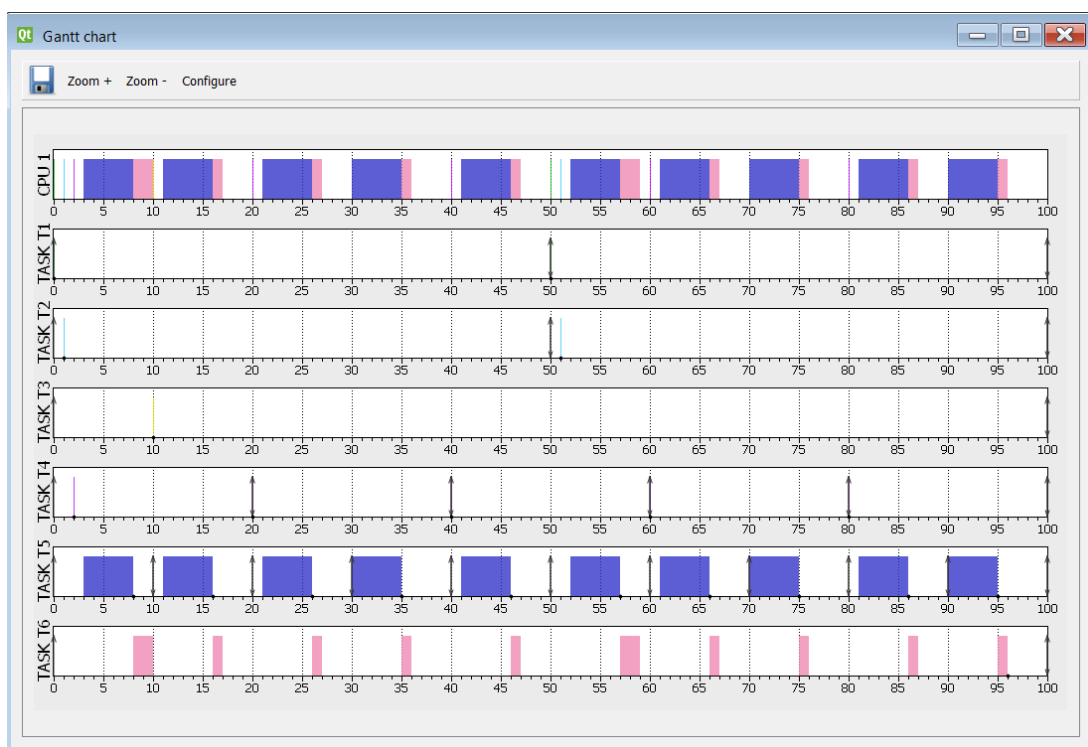
Qt Model data

id	Name	Task type	Abort on miss	Act. Date (ms)	Period (ms)	List of Act. dates (ms)	Deadline (ms)	WCET (ms)	Followed by	Priority
1	TASK T1	Periodic	<input type="checkbox"/> No	0	50	-	50	0.019	2	2
2	TASK T2	Periodic	<input type="checkbox"/> No	0	50	-	50	0.0193	2	2
3	TASK T3	Periodic	<input type="checkbox"/> No	0	100	-	100	0.02465	1	1
4	TASK T4	Periodic	<input type="checkbox"/> No	0	20	-	20	0.02352	3	3
5	TASK T5	Periodic	<input type="checkbox"/> No	0	10	-	10	5	4	4
6	TASK T6	Periodic	<input type="checkbox"/> No	0	100	-	100	12	1	1

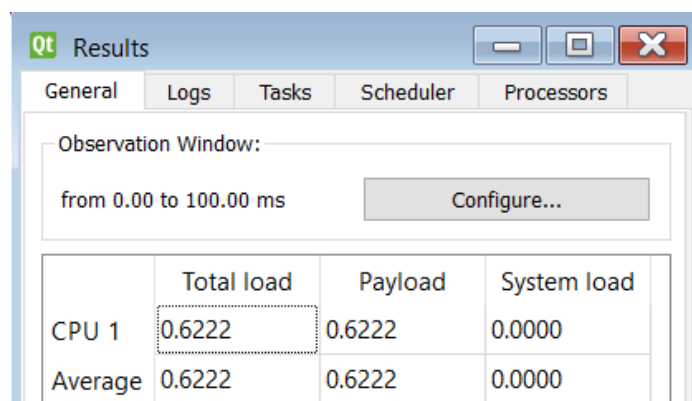
Edit data fields...

Remove selected task(s) Add task Generate Task Set

Task Creation



Gantt Chart of task activity



Qt Results

General Logs Tasks Scheduler Processors

Observation Window:
from 0.00 to 100.00 ms Configure...

	Total load	Payload	System load
CPU 1	0.6222	0.6222	0.0000
Average	0.6222	0.6222	0.0000

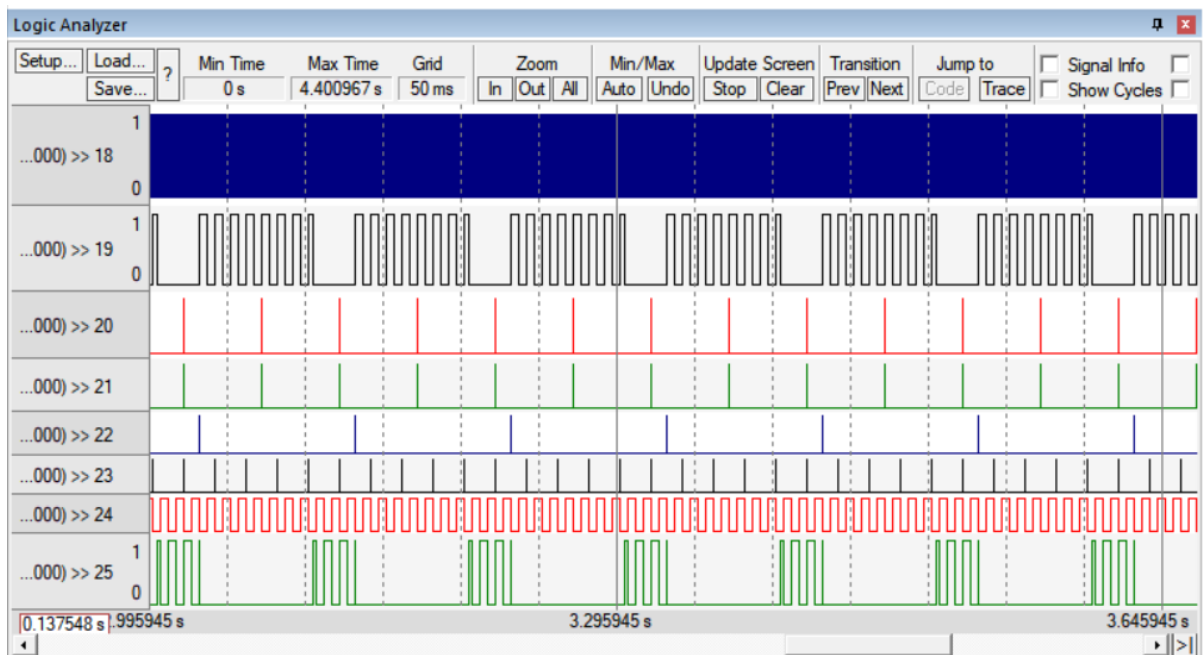
CPU Load which is the same as calculated.



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Keil Simulation Method



Logic Analyzer showing tasks activity

Watch 1		
Name	Value	Type
TasksTotalTime	0x40000118 TasksTotalTime	int[6]
Task_Loads	0x40000130 Task_Loads	int[6]
[0]	0	int
[1]	0	int
[2]	0	int
[3]	0	int
[4]	50	int
[5]	12	int
CPU_Load	62	int
System_Time	610039	int
<Enter expression>		

CPU Load which is the same as calculated as well as Simso simulation.

In conclusion, the CPU loads measured in the three methods are almost identical which proves a successful implementation of the EDF scheduler in the freeRTOS kernel.