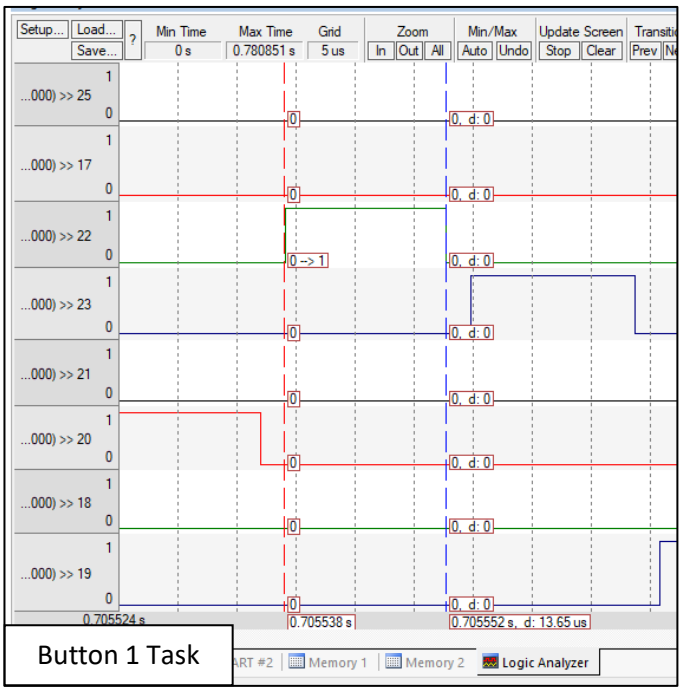
EDF Implementation in FreeRTOS

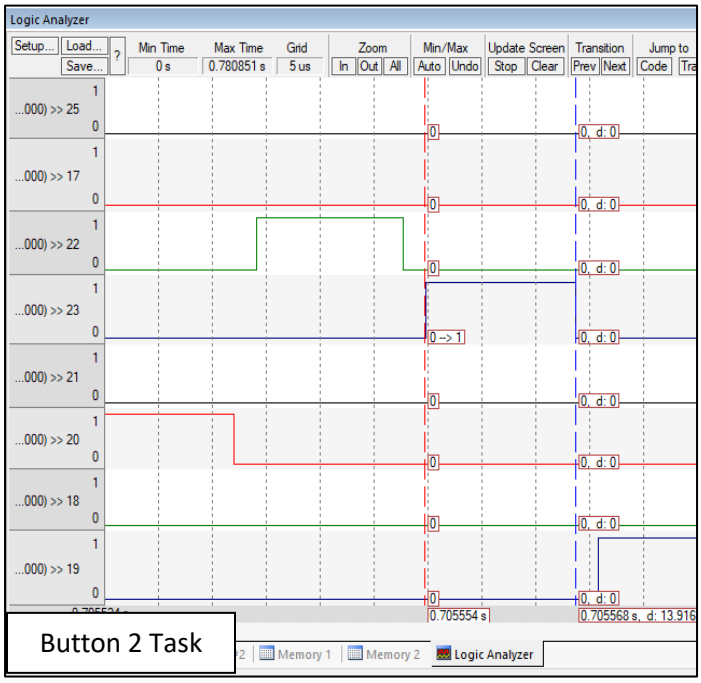
Tasks Periodicity

Button 1 & 2 Monitoring task:

The periodicity of the task is set to 50ms, and by using Keil Logic analyzer to measure the execution time:



Button 1 Task

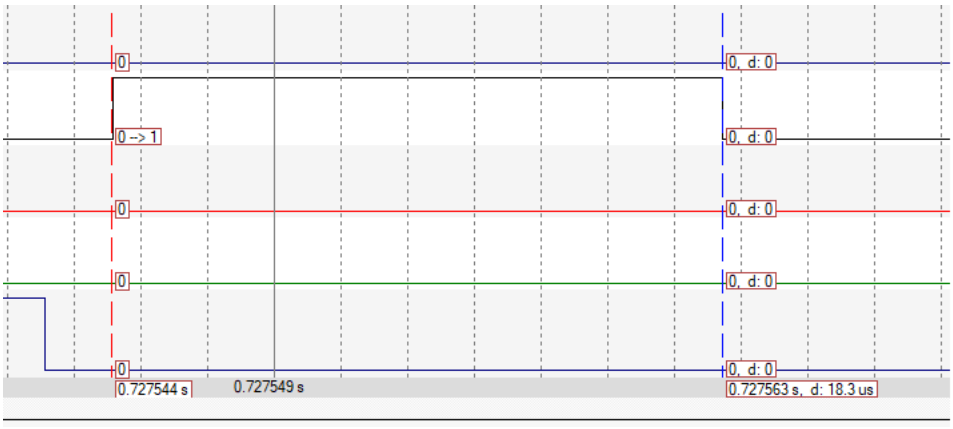


Button 2 Task

The Execution is around 14us so it's well be approximated to 0.02ms to simplify the calculation

Periodic Task:

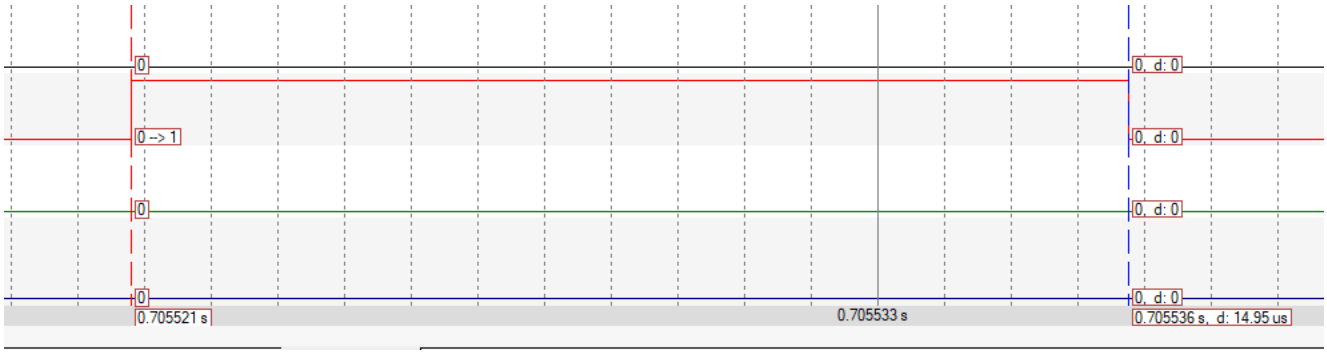
The periodicity of the task is set to 100ms, and by using Keil Logic analyzer to measure the execution time:



The Execution is around 18us so it's well be approximated to 0.02ms to simplify the calculation

Receiver Task:

The periodicity of the task is set to 20ms, and by using Keil Logic analyzer to measure the execution time:



The Execution is around 15us so it's well be approximated to 0.02ms to simplify the calculation

Load 1 Task:

The periodicity of the task is set to 10ms, and its Execution time is set 5ms.

Load 2 Task:

The periodicity of the task is set to 12ms, and its Execution time is set 100ms.

Hyperperiod

Button 1	Button 2	Periodic	Receiver	Load 1	Load 2
50ms	50ms	100ms	20ms	5ms	100ms

To find the Hyperperiod we need to find LCM of all tasks periodicity which is 100ms.

In 100ms time period the execution count and total time consumed well be:

Task	Execution Time (ms)	Periodicity	Number of task execution in 100ms	Total execution time in 100ms (ms)
Load 1	5	10	10	50
Load 2	12	100	1	12
Receiver	0.02	20	5	0.1
Periodic	0.02	100	1	0.02
Button 2	0.02	50	2	0.04
Button 1	0.02	50	2	0.04

Then the total utilization time =(50+12+0.1+0.02+0.04+0.04) = 62.2ms

Then in Hyperperiod the CPU load = $\frac{62.2}{100} = 62.2\%$

Using URM technique

To calculate total time (U) using equation:

$$U = \sum_{i=1}^{n} \frac{c_i}{p_i}$$

$$U = \frac{5}{10} + \frac{12}{100} + \frac{0.02}{20} + \frac{0.02}{50} + \frac{0.02}{50} + \frac{0.02}{100} = 0.621$$

To calculate (URM) using equation:

$$URM = n(2^{\frac{1}{n}} - 1)$$

$$URM = 4\left(2^{\frac{1}{4}} - 1\right) = 0.757$$

$$U < URM$$

Then the system is schedulable

Using Time Demand Analysis technique

To calculate time demand analysis the following equation is used

$$W_i(t) = e_i + \sum_{k=1}^{i-1} \left\lceil \frac{t}{P_k} \right\rceil e_k \qquad for\ 0 < t \leq p_i$$

The tasks are ordered by periodicity (the lower periodicity the higher priority)

Task 1 (Load 1) periodicity 10ms and 5ms execution time:

$W(1) = 5 + 0 = 5$	$W(2) = 5 + 0 = 5$	$W(3) = 5 + 0 = 5$	$W(4) = 5 + 0 = 5$	$W(5) = 5 + 0 = 5$
$W(6) = 5 + 0 = 5$	$W(7) = 5 + 0 = 5$	$W(8) = 5 + 0 = 5$	$W(9) = 5 + 0 = 5$	$W(10) = 5 + 0 = 5$

At last step $W(10) < D \approx 5 < 10$, Then Task 1 is Schedulable.

Task 2 (Receiver) periodicity 20ms and 0.02ms execution time:

$W(1) = 0.02 + \left(\frac{1}{10}\right) \times 5 = 5.02$, $W(5) = 0.02 + \left(\frac{5}{10}\right) \times 5 = 5.02$, $W(10) = 0.02 + \left(\frac{10}{10}\right) \times 5 = 5.02$

$W(11) = 0.02 + \left(\frac{11}{10}\right) \times 5 = 10.02$, $W(15) = 0.02 + \left(\frac{15}{10}\right) \times 5 = 10.02$, $W(10) = 0.02 + \left(\frac{10}{10}\right) \times 5 = 10.02$

At last step $W(20) < D \approx 10.02 < 20$, Then Task 2 is Schedulable.

Task 3 (Button 1 Monitor) periodicity 50ms and 0.02ms execution time:

$W(1) = 0.02 + \left(\frac{1}{10}\right) \times 5 + \left(\frac{1}{20}\right) \times 0.02 = 5.04$, $W(5) = 0.02 + \left(\frac{5}{10}\right) \times 5 + \left(\frac{5}{20}\right) \times 0.02 = 5.04$

$W(10) = 0.02 + \left(\frac{10}{10}\right) \times 5 + \left(\frac{10}{20}\right) \times 0.02 = 10.04$, $W(20) = 0.02 + \left(\frac{20}{10}\right) \times 5 + \left(\frac{20}{20}\right) \times 0.02 = 10.04$

$W(30) = 0.02 + \left(\frac{30}{10}\right) \times 5 + \left(\frac{30}{20}\right) \times 0.02 = 15.06$, $W(40) = 0.02 + \left(\frac{40}{10}\right) \times 5 + \left(\frac{40}{20}\right) \times 0.02 = 20.06$

$W(50) = 0.02 + \left(\frac{50}{10}\right) \times 5 + \left(\frac{50}{20}\right) \times 0.02 = 25.08$

At last step $W(50) < D \approx 25.08 < 50$, Then Task 3 is Schedulable.

Task 4 (Button 2 Monitor) periodicity 50ms and 0.02ms execution time:

$W(1) = 0.02 + \left(\frac{1}{10}\right) \times 5 + \left(\frac{1}{20}\right) \times 0.02 + \left(\frac{1}{50}\right) \times 0.02 = 5.06$, $W(5) = 0.02 + \left(\frac{5}{10}\right) \times 5 + \left(\frac{5}{20}\right) \times 0.02 + \left(\frac{5}{50}\right) \times 0.02 = 5.06$

$W(10) = 0.02 + \left(\frac{10}{10}\right) \times 5 + \left(\frac{10}{20}\right) \times 0.02 + \left(\frac{10}{50}\right) \times 0.02 = 5.06$, $W(20) = 0.02 + \left(\frac{20}{10}\right) \times 5 + \left(\frac{20}{20}\right) \times 0.02 + \left(\frac{20}{50}\right) \times 0.02 = 10.06$

$W(30) = 0.02 + \left(\frac{30}{10}\right) \times 5 + \left(\frac{30}{20}\right) \times 0.02 + \left(\frac{30}{50}\right) \times 0.02 = 15.08$, $W(40) = 0.02 + \left(\frac{40}{10}\right) \times 5 + \left(\frac{40}{20}\right) \times 0.02 + \left(\frac{40}{50}\right) \times 0.02 = 20.08$

$W(50) = 0.02 + \left(\frac{50}{10}\right) \times 5 + \left(\frac{50}{20}\right) \times 0.02 + \left(\frac{50}{50}\right) \times 0.02 = 25.1$

At last step $W(50) < D \approx 25.1 < 50$, Then Task 4 is Schedulable.

Task 5 (Periodic) periodicity 100ms and 0.02ms execution time:

$W(1) = 0.02 + \left(\frac{1}{10}\right) \times 5 + \left(\frac{1}{20}\right) \times 0.02 + \left(\frac{1}{50}\right) \times 0.02 + \left(\frac{1}{50}\right) \times 0.02 = 5.08$

$W(10) = 0.02 + \left(\frac{10}{10}\right) \times 5 + \left(\frac{10}{20}\right) \times 0.02 + \left(\frac{10}{50}\right) \times 0.02 + \left(\frac{10}{50}\right) \times 0.02 = 5.08$

$W(20) = 0.02 + \left(\frac{20}{10}\right) \times 5 + \left(\frac{20}{20}\right) \times 0.02 + \left(\frac{20}{50}\right) \times 0.02 + \left(\frac{20}{50}\right) \times 0.02 = 10.08$

$W(50) = 0.02 + \left(\frac{50}{10}\right) \times 5 + \left(\frac{50}{20}\right) \times 0.02 + \left(\frac{50}{50}\right) \times 0.02 + \left(\frac{50}{50}\right) \times 0.02 = 25.12$

$W(70) = 0.02 + \left(\frac{70}{10}\right) \times 5 + \left(\frac{70}{20}\right) \times 0.02 + \left(\frac{70}{50}\right) \times 0.02 + \left(\frac{70}{50}\right) \times 0.02 = 35.18$

$W(100) = 0.02 + \left(\frac{100}{10}\right) \times 5 + \left(\frac{100}{20}\right) \times 0.02 + \left(\frac{100}{50}\right) \times 0.02 + \left(\frac{100}{50}\right) \times 0.02 = 50.2$

At last step $W(100) < D \approx 50.2 < 100$, Then Task 5 is Schedulable.

Task 6 (Load 2) periodicity 100ms and 12ms execution time:

$W(1) = 12 + \left(\frac{1}{10}\right) \times 5 + \left(\frac{1}{20}\right) \times 0.02 + \left(\frac{1}{50}\right) \times 0.02 + \left(\frac{1}{50}\right) \times 0.02 + \left(\frac{1}{100}\right) \times 0.02 = 17.08$

$W(10) = 12 + \left(\frac{10}{10}\right) \times 5 + \left(\frac{10}{20}\right) \times 0.02 + \left(\frac{10}{50}\right) \times 0.02 + \left(\frac{10}{50}\right) \times 0.02 + \left(\frac{10}{100}\right) \times 0.02 = 17.08$

$W(20) = 12 + \left(\frac{20}{10}\right) \times 5 + \left(\frac{20}{20}\right) \times 0.02 + \left(\frac{20}{50}\right) \times 0.02 + \left(\frac{20}{50}\right) \times 0.02 + \left(\frac{20}{100}\right) \times 0.02 = 22.08$

$W(50) = 12 + \left(\frac{50}{10}\right) \times 5 + \left(\frac{50}{20}\right) \times 0.02 + \left(\frac{50}{50}\right) \times 0.02 + \left(\frac{50}{50}\right) \times 0.02 + \left(\frac{50}{100}\right) \times 0.02 = 37.12$

$W(70) = 12 + \left(\frac{70}{10}\right) \times 5 + \left(\frac{70}{20}\right) \times 0.02 + \left(\frac{70}{50}\right) \times 0.02 + \left(\frac{70}{50}\right) \times 0.02 + \left(\frac{70}{100}\right) \times 0.02 = 47.18$

$W(100) = 12 + \left(\frac{100}{10}\right) \times 5 + \left(\frac{100}{20}\right) \times 0.02 + \left(\frac{100}{50}\right) \times 0.02 + \left(\frac{100}{50}\right) \times 0.02 + \left(\frac{100}{100}\right) \times 0.02 = 62.2$

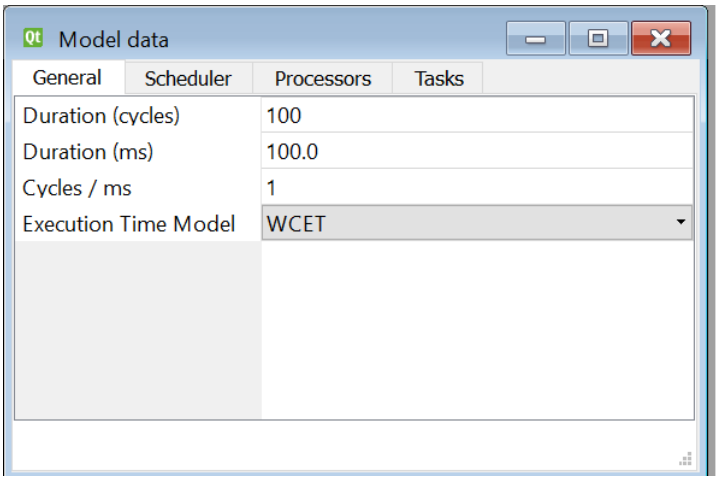
At last step $W(100) < D \approx 62.2 < 100$, Then Task 6 is Schedulable.

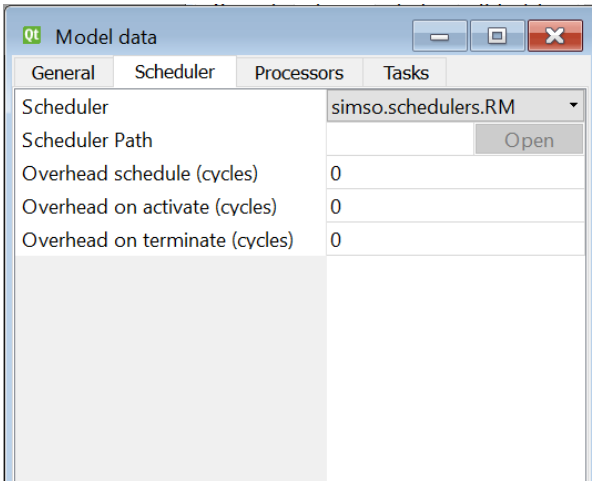
From the above equation its verified that the system is schedulable.

SimSo Offline simulator

To simulate the tasks and verify calculations, I'm using SimSo v0.08.3 :

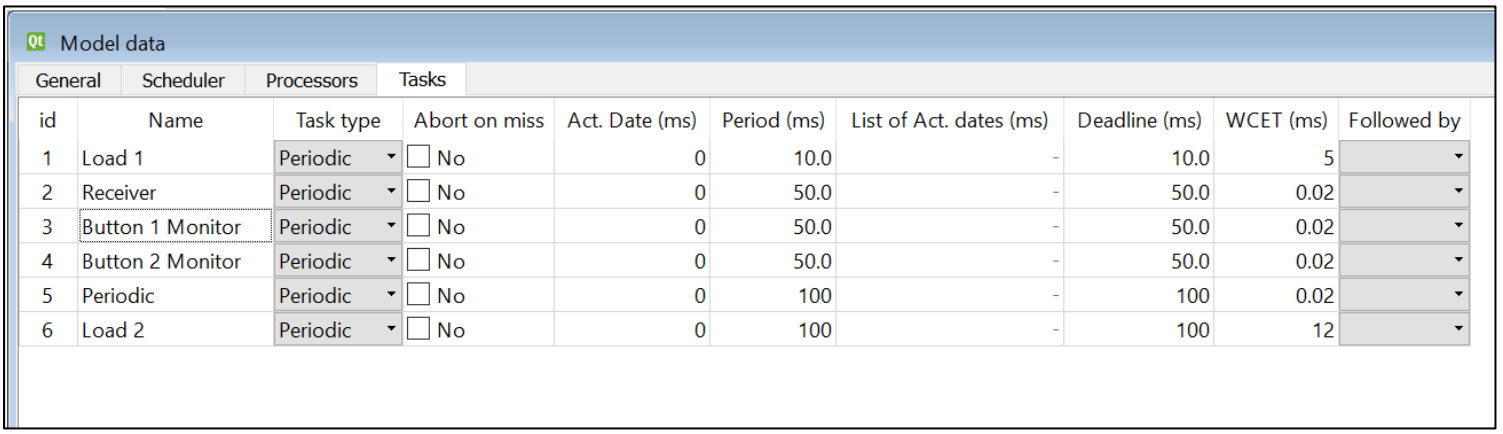
Settings to SimSo:





The simulation is set to 1ms cycle duration and using Rate Monotonic Fixed Priority.

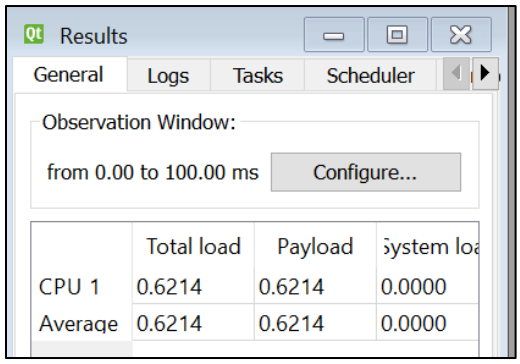
The Configuring the tasks to run:



id	Name	Task type	Abort on miss	Act. Date (ms)	Period (ms)	List of Act. dates (ms)	Deadline (ms)	WCET (ms)	Followed by
1	Load 1	Periodic	No	0	10.0	-	10.0	5	
2	Receiver	Periodic	No	0	50.0	-	50.0	0.02	
3	Button 1 Monitor	Periodic	No	0	50.0	-	50.0	0.02	
4	Button 2 Monitor	Periodic	No	0	50.0	-	50.0	0.02	
5	Periodic	Periodic	No	0	100	-	100	0.02	
6	Load 2	Periodic	No	0	100	-	100	12	

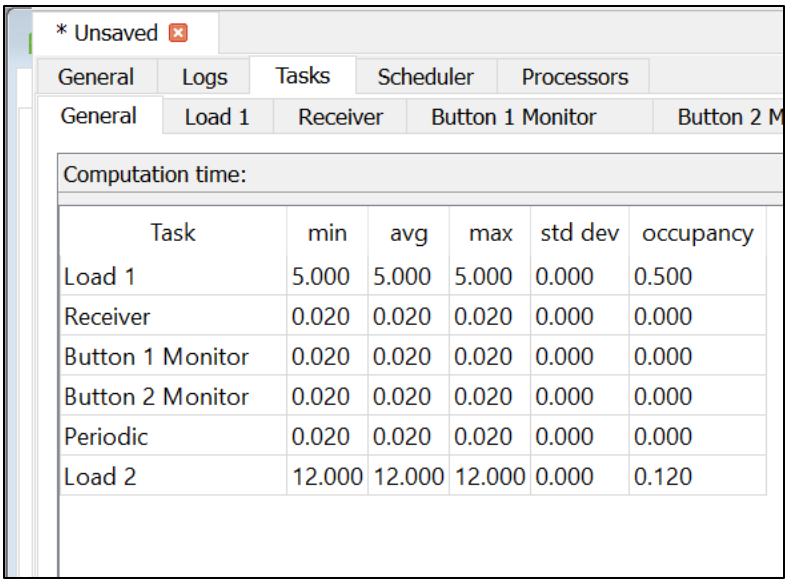
After running the simulation, the result is as follow:

CPU Load



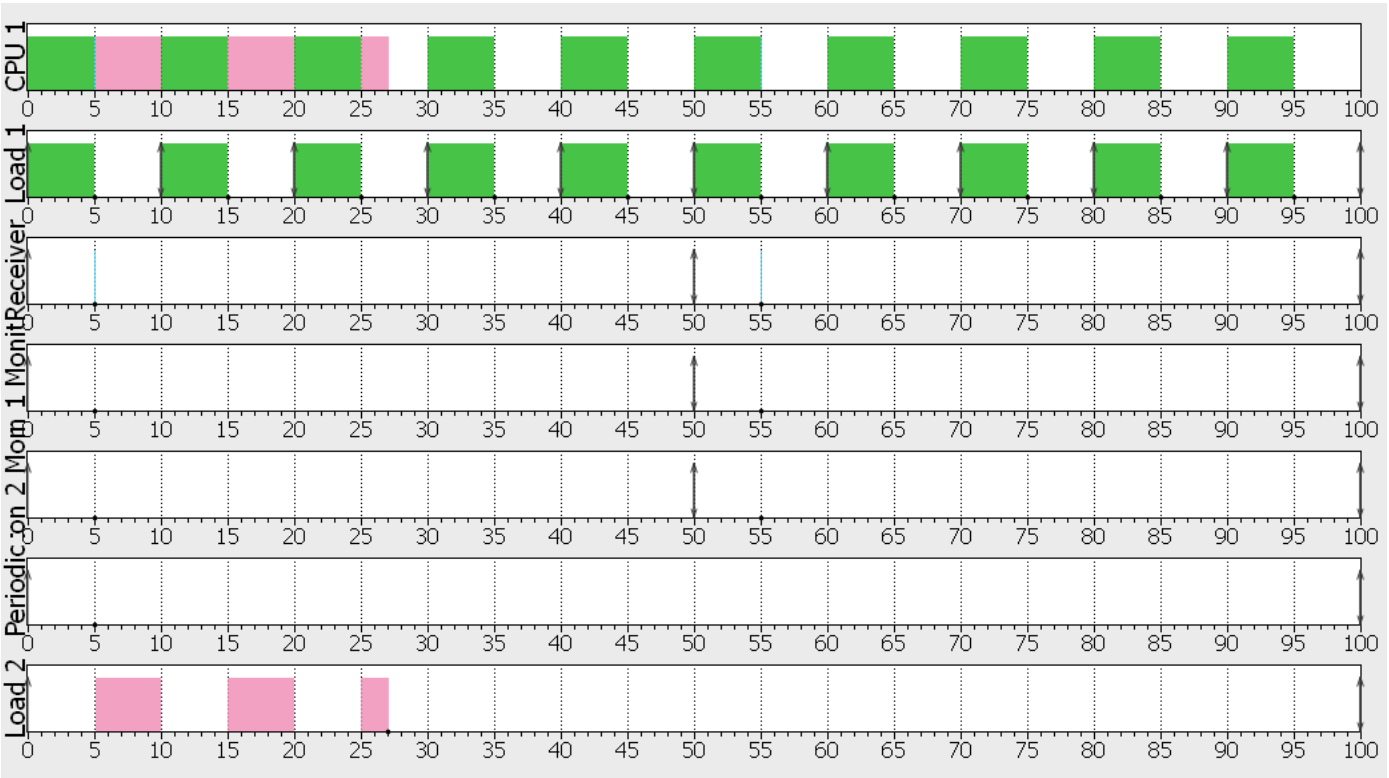
Which shows that CPU load is equal to 62.14% which is very close to mathematic calculation.

Tasks Data:



Task	min	avg	max	std dev	occupancy
Load 1	5.000	5.000	5.000	0.000	0.500
Receiver	0.020	0.020	0.020	0.000	0.000
Button 1 Monitor	0.020	0.020	0.020	0.000	0.000
Button 2 Monitor	0.020	0.020	0.020	0.000	0.000
Periodic	0.020	0.020	0.020	0.000	0.000
Load 2	12.000	12.000	12.000	0.000	0.120

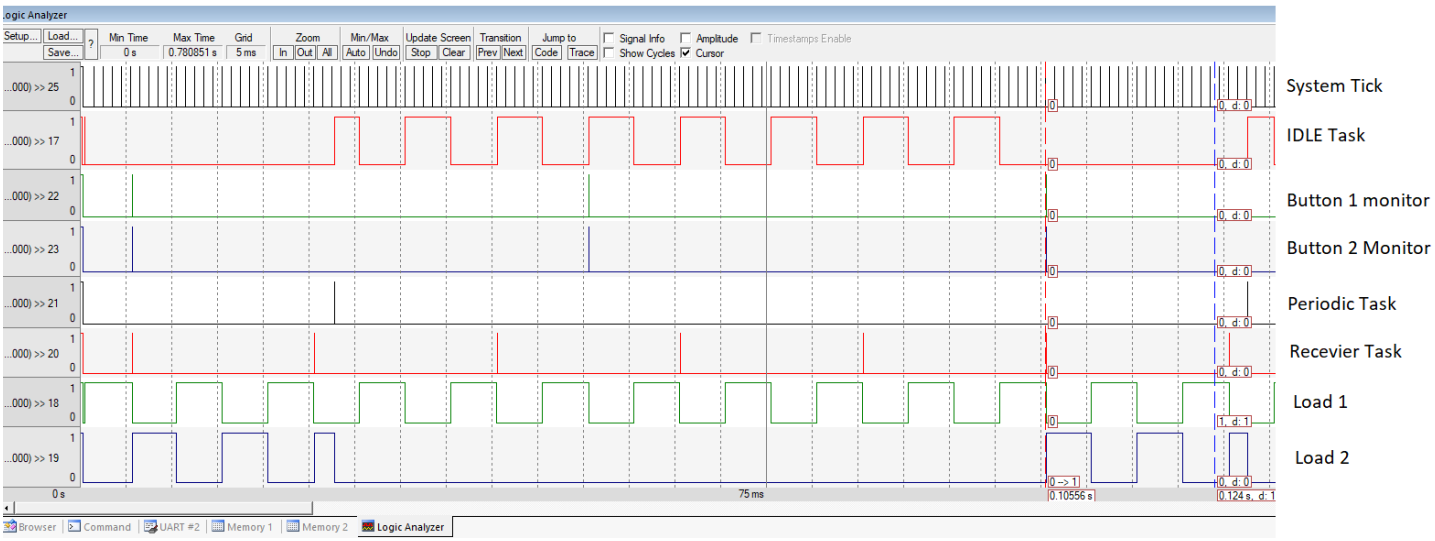
SimSo Gantt chart:



It shows that all tasks are executing correctly, and no task is missed.

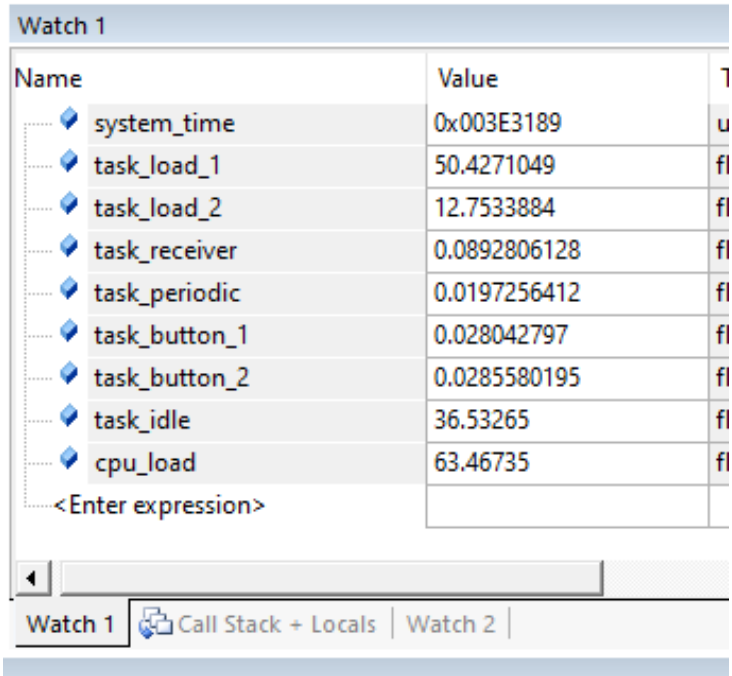
Using Keil µVision Simulation

After Implementing EDF and then running the simulation and using logic analyzer:



It shows that all tasks are executed same as Simso.

And moving to Run-time statistics shows:



That CPU Load is slightly higher than SimSo, and calculation which is logical due to neglecting context switching and FreeRTOS overhead mechanisms.

Conclusion

From The analytical methods, and (offline & Online) simulation shows that all values are close and indicates that the system is schedulable, and this implementation is successful.

Although from Keil simulation the CPU is loaded for about 1.2%+ due to FreeRTOS core working.

And for general role when designing an embedded I have to ensure that CPU never gets loaded to its maximum, and verify that the idle task needs to have time slice in Hyperperiod" which verifies that all RTOS cores are running and preforming well, and we are avoiding scheduling starvation".

For complete Keil project you can find it on

GitHub: https://github.com/Mohamed-abdullah-hassan/Eg_FWD_RTOS_EDF

Google drive: https://drive.google.com/file/d/1uIX1ZZFT6ZsIT7j_BPfbr65f4twdosYO/view?usp=sharing

The SimSo file for the task simulation:

Google drive: https://drive.google.com/file/d/1Ei2VPG6GWnn8ad5zOoruZtdLwAB-oSOb/view?usp=sharing

For Keil simulation video:

Google drive: https://drive.google.com/file/d/1E60imgi1Lj_Lt0tMlQ63hqK50bSF94Mk/view?usp=sharing