❖ Analytical Methods :

• System Hyperperiod :

This project contains 6 tasks as follows :

Task	Period/Deadline	Execution time
Button_1_Monitor	50 m	12.6 us
Button_2_Monitor	50 m	13.067 us
Periodic_Transmitter	100 m	17.78 us
Uart_Receiver	20 m	15.033 us
Load_1_Simulation	10 m	5.034 ms
Load_2_Simulation	100 m	11.99 ms

Note : The execution time calculated from the actual implemented tasks using GPIOs and the logic analyzer .

From the table above and from the graph (which provided next in the pdf) we can find that :

-------------- > **System Hyperperiod = 100** .

• CPU Load :

CPU Load = (E1+E2+E3+E4+E5+E6)/hyperperiod

$$= \frac{E1}{P1} + \frac{E2}{P2} + \frac{E3}{P3} + \frac{E4}{P4} + \frac{E5}{P5} + \frac{E6}{P6}$$

$$= \frac{12.6u}{50m} + \frac{13.067u}{50} + \frac{17.78u}{100} + \frac{15.033u}{20m} + \frac{5.034m}{10} + \frac{11.99}{100m}$$

$$= \underline{62.4 \%}$$

- **System Schedulability :**

    # using : Rate Monotonic Utilization Bound

Equation :

$$U = \sum_{i=1}^{n} \frac{C_i}{P_i} \le n(2^{\frac{1}{n}} - 1)$$

U = Total Utilization
C = Execution time
P = Periodicity
N = Number of tasks

If :   U > Urm

System guaranteed not schedulable

$$U = \frac{C1}{P1} + \frac{C2}{P2} + \frac{C3}{P3} + \frac{C4}{P4} + \frac{C5}{P5} + \frac{C6}{P6}$$

$$= \frac{12.6u}{50m} + \frac{13.067u}{50m} + \frac{17.78u}{100} + \frac{15.033u}{20} + \frac{5.034m}{10m} + \frac{11.99}{10}$$

= **62.4 %**

Urm = $n * (2^{\frac{1}{n}} - 1)$ = $6 * (2^{\frac{1}{6}} - 1)$ = **73.477 %**

$\because$ **U < Urm (62.4% < 73.477%)**

$\therefore$ **System is Schedulable.**

using : Time Demand Analysis

Equation :

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

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

If :

$$w_i(t) <= D$$

Task is Schedulable

Assuming the given set of tasks are scheduled using a fixed priority rate monotonic scheduler :

Task	Period/Deadline	Execution time	priority
Button_1_Monitor	50 m	12.6 us	1
Button_2_Monitor	50 m	13.067 us	1
Periodic_Transmitter	100 m	17.78 us	0
Uart_Receiver	20 m	15.033 us	2
Load_1_Simulation	10 m	5.034 ms	3
Load_2_Simulation	100 m	11.99 ms	0

Load_1_Simulation :

w(10) = 5.034 m + 0 = 5.034 m < D(10m)   → T5 is schedulable

Uart_Receiver :

w(20) = 15.033 u + (20/10)*5.034 m = 10.083 m < D(20m)

→T4 is schedulable

Button_1_Monitor :

w(50) = 12.6 u +(50/10)* 5.034 m +(50/20)*15.033 u = 25.227 m < D(50m)

→T1 is schedulable

Button_2_Monitor :

w(50) = 13.067 u +(50/10)* 5.034 m +(50/20)*15.033 u + (50/50)*12.6 u

= 25.24 < D(50m)

→T2 is schedulable

Periodic_Transmitter :

w(100) = 17.96 u +(100/10)* 4.99 m +(100/20)*15.8 u +(100/50)*13.3 u + (100/50)*13.3 u = 50.05016m < D(100m)

→T3 is schedulable

Load_2_Simulation :

w(100) = 11.99 m + (100/10)* 4.99 m +(100/20)*15.8 u +(100/50)*13.3 u + (100/50)*13.3 u + (100/100) * 17.96 u = 62.04016 m <D(100m)

→T6 is schedulable

∵ All tasks are schedulable

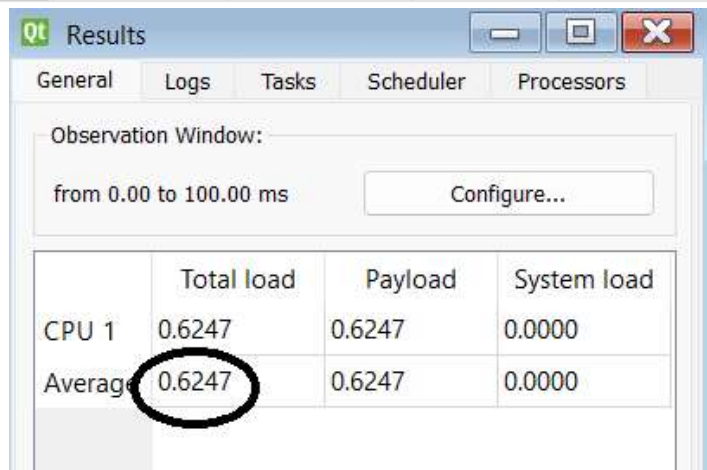## ∴ System is Schedulable.

❖   SIMSO Results :

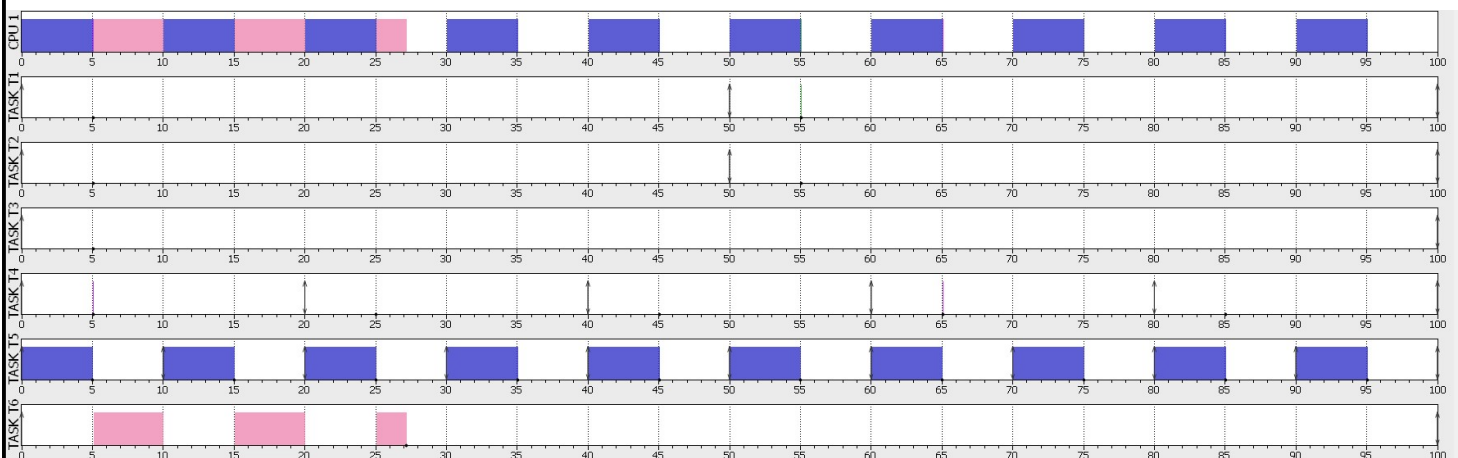# Verifying the above results with SIMSO offline simulator .

1/ CPU load :

id	Name	Task type	Abort on miss	Act. Date (ms)	Period (ms)	List of Act. dates (ms)	Deadline (ms)	WCET (ms)
1	TASK T1	Periodic ▾	☑ Yes	0	50	-	50	0.0126
2	TASK T2	Periodic ▾	☑ Yes	0	50	-	50	0.013067
3	TASK T3	Periodic ▾	☑ Yes	0	100	-	100	0.01778
4	TASK T4	Periodic ▾	☑ Yes	0	20	-	20	0.015033
5	TASK T5	Periodic ▾	☑ Yes	0	10	-	10	5.034
6	TASK T6	Periodic ▾	☑ Yes	0	100	-	100	11.99

Results

General | Logs | Tasks | Scheduler | Processors

Observation Window:

from 0.00 to 100.00 ms   Configure...

	Total load	Payload	System load
CPU 1	0.6247	0.6247	0.0000
Average	0.6247	0.6247	0.0000

CPU load = 62.4 % which matches the analytical method .

2/ simulation of the tasks :

Zoom out which indicate hyperperiod(100m) as it will be repeated after that .

showing that Task5 (load_1_simulation) will execute first with period 10 ms

task 6 (load_1_simulation) preempted by task 5 which has higher priority (Closest to the deadline)

the first four tasks (task1 -- > task4) have small execution time so didn't appear in this screenshot .


after zooming in we can see the fist four tasks so the Execution order will be (Task5 → Task4 → Task1 → Task2 → Task3 → Task6) as expected .

after all we can say that SIMSO verified the analytical approach .

❖ KEIL Results :

1/ screenshot of the tasks discussed above using timer1 and trace hooks to calculate CPU time besides GPIO pins to simulate the scheduling between tasks using logic analyzer:
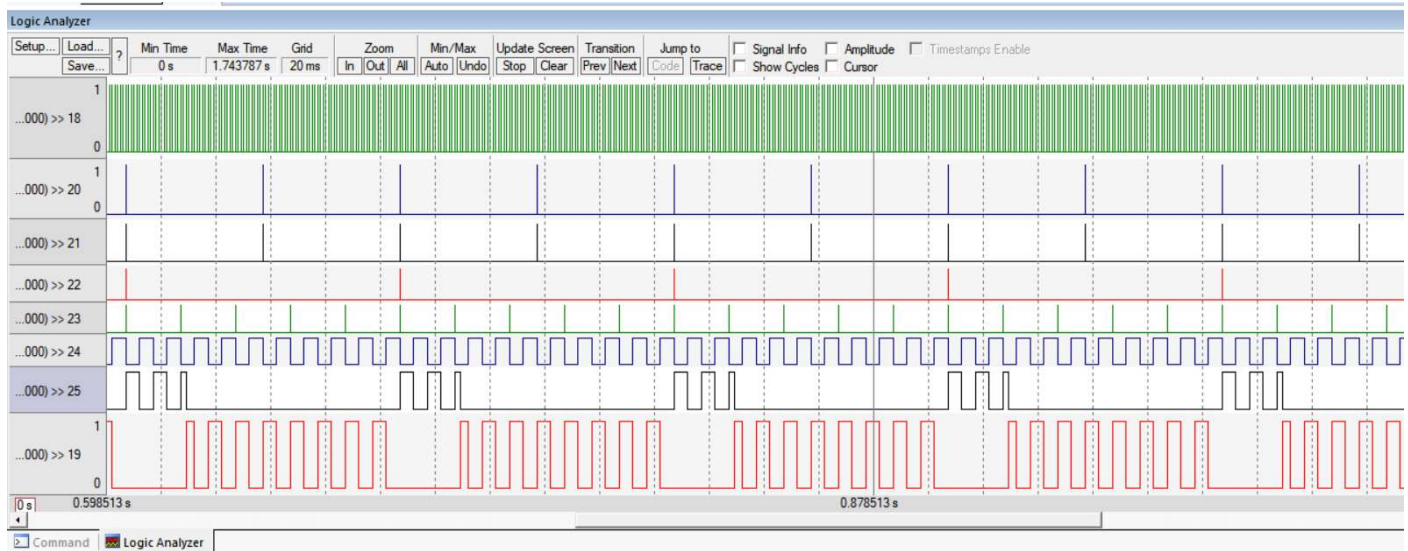
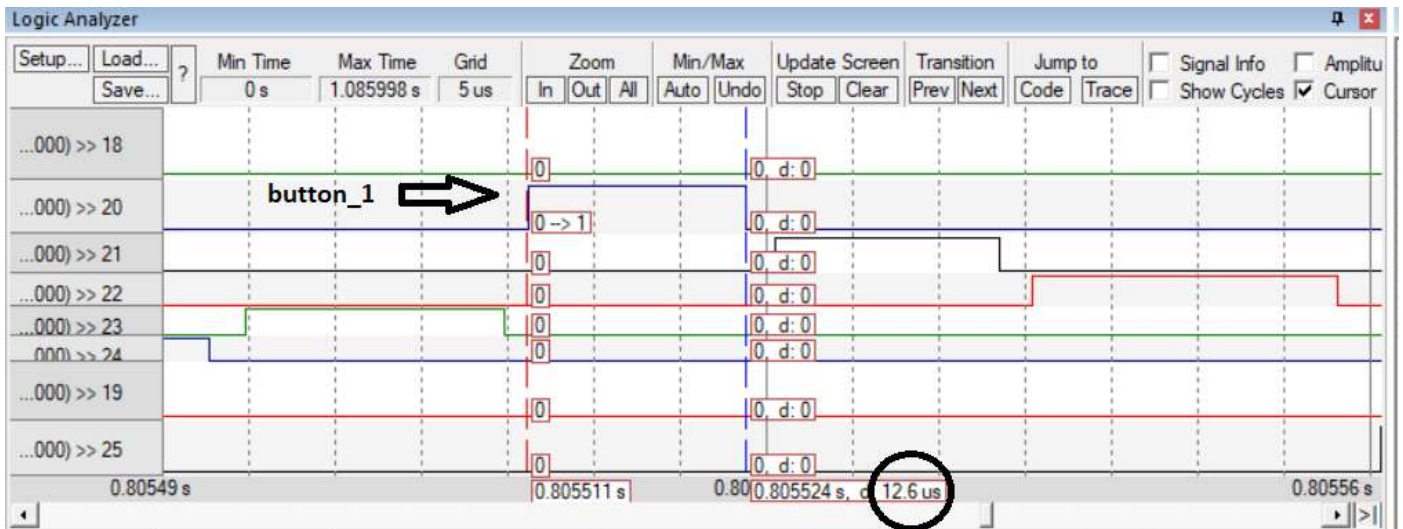# Same as SIMSO (same Execution order : Task5 → Task4 → Task1 → Task2 → Task3 → Task6) .
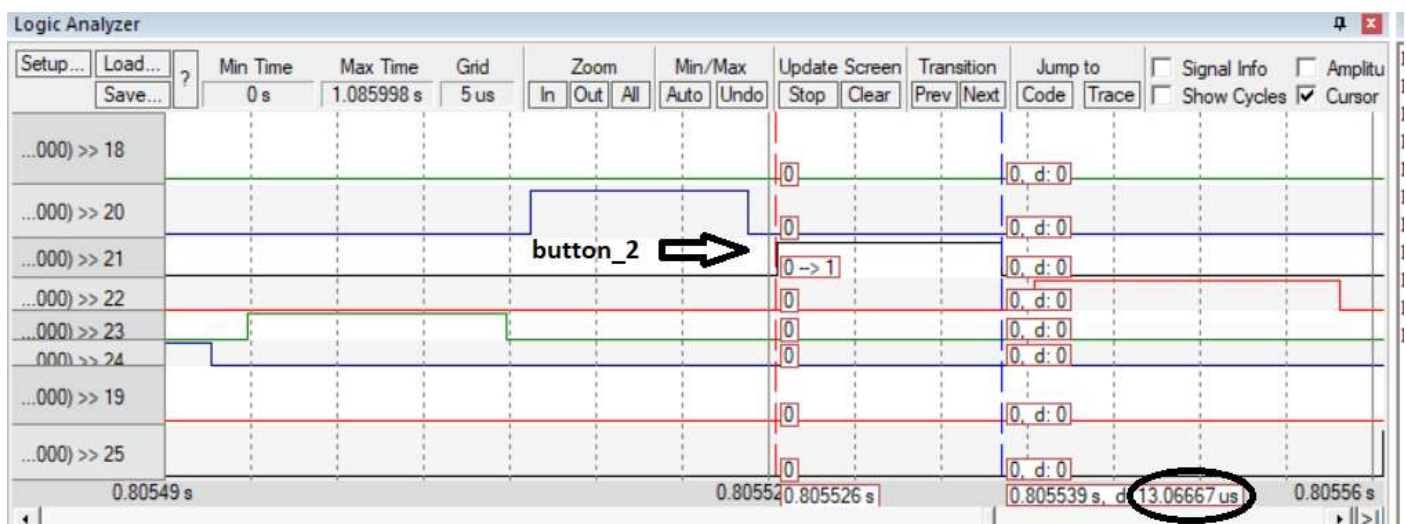
Hyperperiod = 100 msec as expected .

CPU load = 62.24 % (almost saturated to that value) which approximately matches the previous approaches.

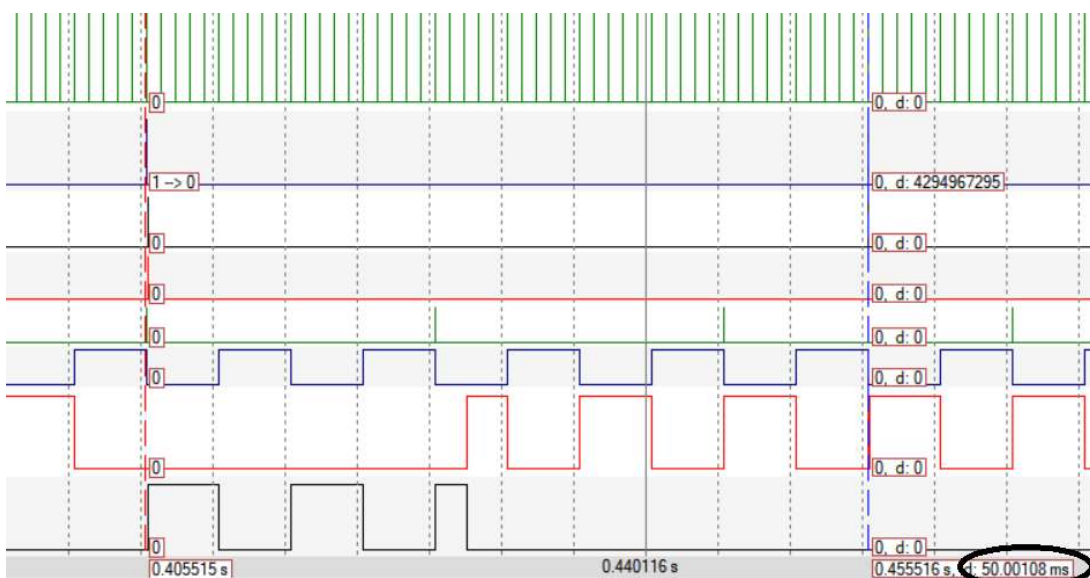# 2/ screenshots of the execution time and periodicity:

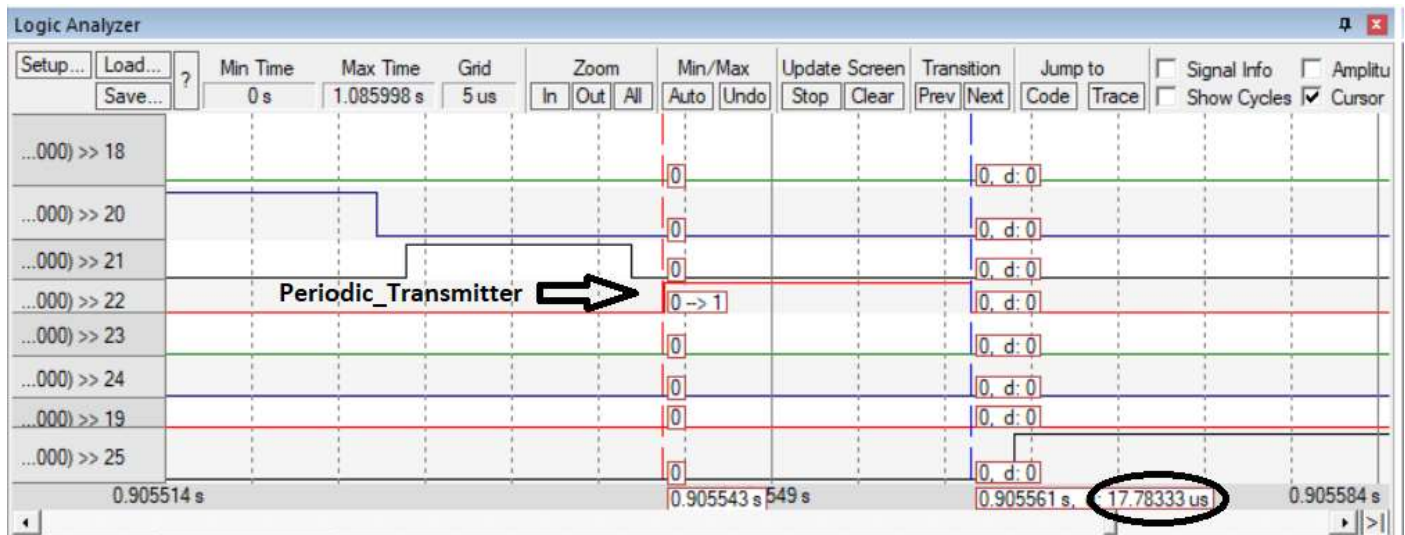- **Button_1_Monitor execution time (12.6 us)**

- **Button_2_Monitor execution time (13.067 us)**

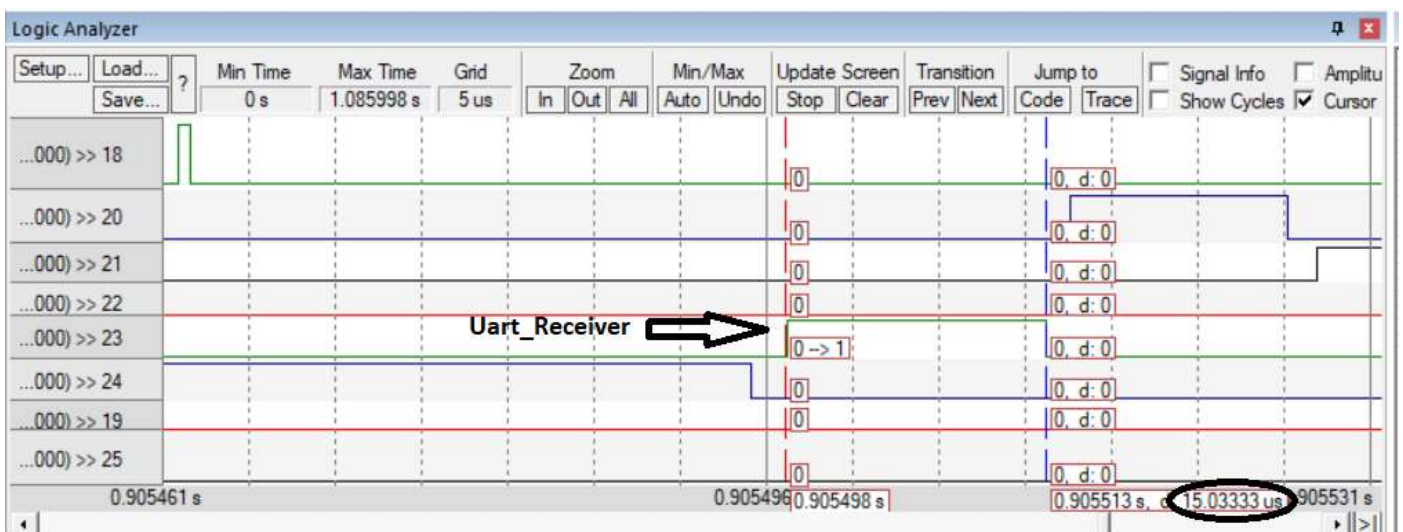- **Button_1_Monitor/ Button_1_Monitor periodicity (50 ms)**

- **Periodic_Transmitter execution time (17.78 us)**
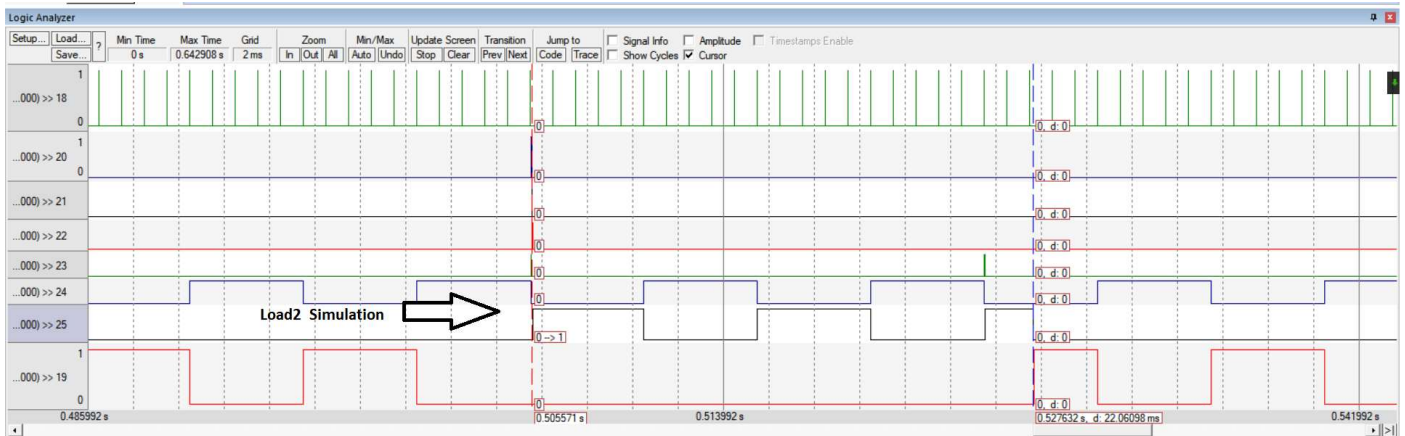

- **Periodic_Transmitter periodicity (100 ms)**

- **Uart_Receiver execution time (15.030 us)**

- **Uart_Receiver periodicity (20 ms)**

- **Load_1_Simulation execution time (5.034 ms)**

- **Load_1_Simulation periodicity (10 ms)**

- **Load_2_Simulation execution time (11.99 ms)**

As load_2_simulation preempted by load_1_simulation so the execution time of load_2_simulation = 22.06098 – 2*5.034

= 11.99 msec

- **Load_2_Simulation periodicity (100 ms)**