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DEPARTMENT OF ECE**

**ASYMMETRIC
MULTIPROCESSING OF XENOMAI RTOS
ON X86**

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OVERVIEW OF THE PRESENTATION

- Objectives of the Project
- Implementation process
- Preparing linux kernel ported with xenomai
- Results of testing
- Plan of action
- References

OBJECTIVES OF THE PROJECT WORK

1. Porting Xenomai to x86 processor.
2. Functional testing of linux kernel ported with xenomai.
3. Comparison of the latency values in normal kernel with xenomai kernel on x86 processor.

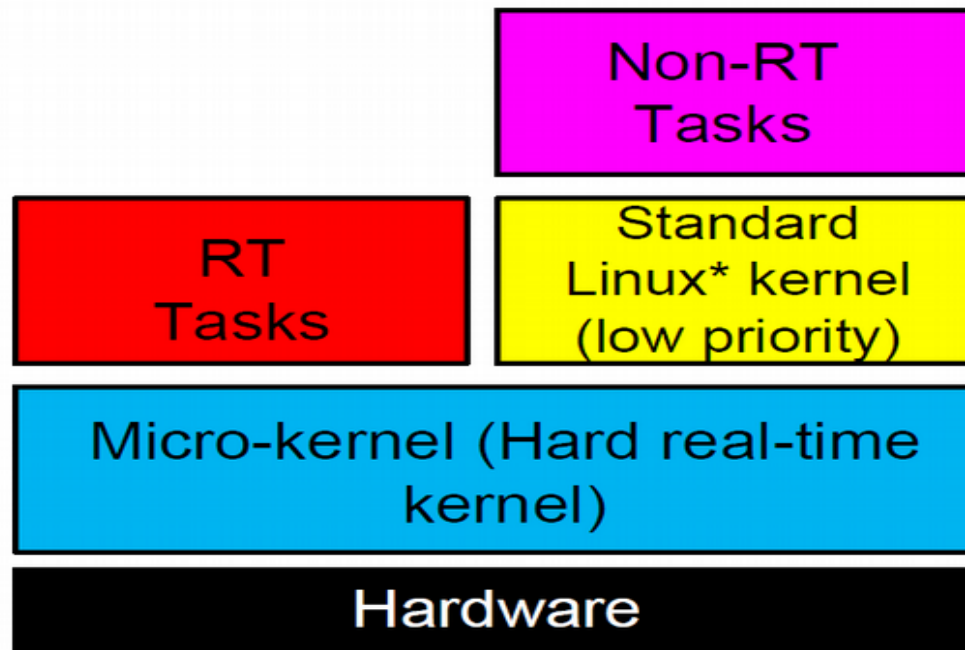
Xenomai

Xenomai can help you in:

- Delivering stringent real-time guarantees.
- Migrating an application from a proprietary RTOS to Linux.
- Optimally running RTOS applications alongside native Linux applications.

Micro Kernel

To support hard real-time capabilities to the Linux kernel, Xenomai implements a micro-kernel.



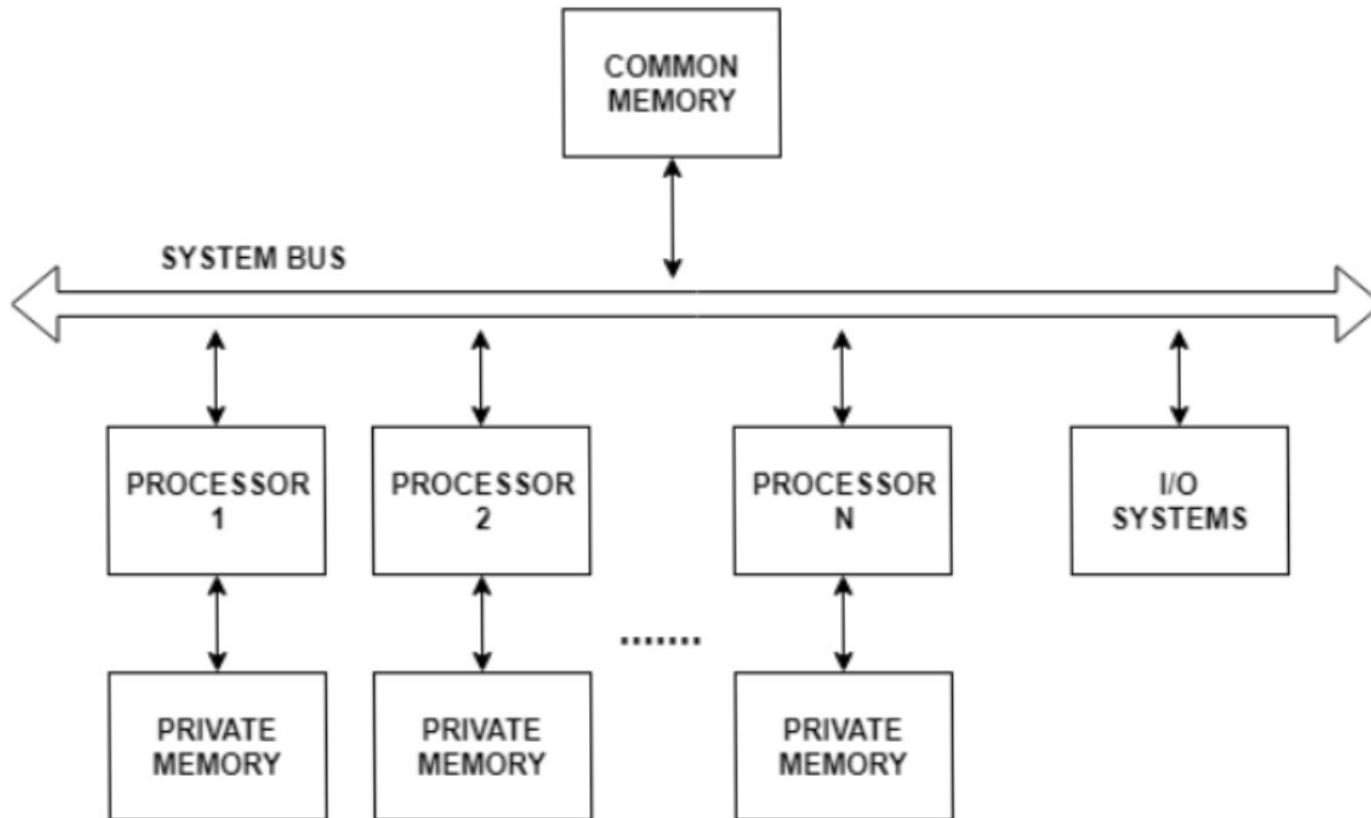
IMPLEMENTATION PROCESS

- Building linux kernel.
- patching with xenomai.
- Running functional tests on x86 processor.
- Running scheduling algorithm on x86 processor ported with xenomai.
- Comparison of performance with linux kernel and xenomai kernel.

PREPARING LINUX KERNEL PATCHED WITH XENOMAI

- Obtaining kernel sources
- Configuring the kernel
- Compiling and Installing the kernel
- Patching with xenomai
- Configuring according to our requirements
- Configuring and compiling the kernel

ASYMMETRIC MULTIPROCESSING



WHY ASYMMETRIC?

ADVANTAGE OF ASYMMETRIC

- It performs tasks parallelly
- It improves application performance and enhancement responsiveness

TEST CASES

- **Clock test**
- **Latency test**
- **Switch test**

CLOCK TEST OUTPUTS

```
root@kalyan-HP-Notebook /usr/xenomai/bin
File Edit View Search Terminal Help
kalyan-HP-Notebook bin # ./clocktest -C 0 -D -T 2
== Testing built-in CLOCK_REALTIME (0)
CPU      ToD offset [us] ToD drift [us/s]      warps max delta [us]
-----
  0      -771227.6      -7.883      0      0.0
  1      -771227.7      -7.923      0      0.0
  2      -771227.9      -7.684      0      0.0
  3      -771227.8      -7.784      0      0.0
kalyan-HP-Notebook bin # ./clocktest -C 1 -D -T 2
== Testing built-in CLOCK_MONOTONIC (1)
CPU      ToD offset [us] ToD drift [us/s]      warps max delta [us]
-----
  0     -1547093628009841.8      -7.712      0      0.0
  1     -1547093628009842.0      -7.818      0      0.0
  2     -1547093628009841.8      -7.757      0      0.0
  3     -1547093628009842.0      -7.759      0      0.0
kalyan-HP-Notebook bin #
```

```
root@kalyan-HP-Notebook /usr/xenomai/bin
File Edit View Search Terminal Help
kalyan-HP-Notebook bin # ./clocktest -C 0 -D -T 6
== Testing built-in CLOCK_REALTIME (0)
CPU      ToD offset [us] ToD drift [us/s]      warps max delta [us]
-----
 0         -771605.3         -7.121           0           0.0
 1         -771605.6         -7.268           0           0.0
 2         -771605.5         -7.153           0           0.0
 3         -771605.6         -7.173           0           0.0
kalyan-HP-Notebook bin # ./clocktest -C 1 -D -T 6
== Testing built-in CLOCK_MONOTONIC (1)
CPU      ToD offset [us] ToD drift [us/s]      warps max delta [us]
-----
 0 -1547093628010264.2 -7.016           0           0.0
 1 -1547093628010264.2 -7.058           0           0.0
 2 -1547093628010264.0 -6.952           0           0.0
 3 -1547093628010264.2 -7.059           0           0.0
kalyan-HP-Notebook bin #
```

LATENCY TEST

```
root@kalyan-HP-Notebook /usr/xenomai/bin
File Edit View Search Terminal Help
kalyan-HP-Notebook bin # ./latency -s -T 10 -t 0 -P 1
== Sampling period: 100 us
== Test mode: periodic user-mode task
== All results in microseconds
warming up...
RTT| 00:00:01 (periodic user-mode task, 100 us period, priority 1)
SRTH| ----lat min| ----lat avg| ----lat max| -overrun| ---msw| ---lat best| --lat worst
RTD|      -0.246|      0.123|      5.488|      0|      0|      -0.246|      5.488
RTD|      -0.331|      0.129|     41.166|      0|      0|      -0.331|     41.166
RTD|      -0.192|      0.282|     83.905|      0|      0|      -0.331|     83.905
RTD|      -0.491|      0.297|     42.829|      0|      0|      -0.491|     83.905
RTD|       0.009|      0.343|     84.638|      0|      0|      -0.491|     84.638
RTD|       0.000|      0.212|     83.722|      0|      0|      -0.491|     84.638
RTD|      -0.444|     -0.019|      6.172|      0|      0|      -0.491|     84.638
RTD|      -0.221|      0.325|     44.828|      0|      0|      -0.491|     84.638
RTD|      -0.175|      0.257|     43.335|      0|      0|      -0.491|     84.638
HSH| --param| --samples| --average--| ---stddev--
HSS|   min|      9|      0.000|      0.000
HSS|   avg|  99983|      0.084|      1.601
HSS|   max|      9|     47.889|     30.588
-----
RTS|      -0.491|      0.216|     84.638|      0|      0| 00:00:10/00:00:10
kalyan-HP-Notebook bin #
```

```

root@kalyan-HP-Notebook /usr/xenomai/bin
File Edit View Search Terminal Help
kalyan-HP-Notebook bin # ./latency -s -T 10 -t 1 -P 1
== Sampling period: 100 us
== Test mode: in-kernel periodic task
== All results in microseconds
warming up...
RTT| 00:00:01 (in-kernel periodic task, 100 us period, priority 1)
RTH| ----lat min| ----lat avg| ----lat max| -overrun| ---msw| ---lat best| --lat worst
RTD|    -1.027|    -0.162|    36.044|      0|      0|    -1.027|    36.044
RTD|    -0.752|    -0.201|    37.348|      0|      0|    -1.027|    37.348
RTD|    -0.766|    -0.250|    35.972|      0|      0|    -1.027|    37.348
RTD|    -0.787|    -0.194|    37.185|      0|      0|    -1.027|    37.348
RTD|    -0.803|    -0.284|    36.874|      0|      0|    -1.027|    37.348
RTD|    -0.768|    -0.222|    37.144|      0|      0|    -1.027|    37.348
RTD|    -0.937|    -0.269|    31.855|      0|      0|    -1.027|    37.348
RTD|    -0.869|    -0.217|    37.328|      0|      0|    -1.027|    37.348
RTD|    -1.125|    -0.265|    36.662|      0|      0|    -1.125|    37.348
HSH| --param| --samples| --average--| ---stddev--
HSS|    min|      9|      0.222|      0.441
HSS|    avg| 99990|      0.060|      1.209
HSS|    max|      9|     35.778|      1.922
-----
RTS|    -1.125|    -0.229|    37.348|      0|      0|    00:00:10/00:00:10
kalyan-HP-Notebook bin #

```

SWITCH TEST

```
root@kalyan-HP-Notebook /usr/xenomai/bin
File Edit View Search Terminal Help
tk_fp_ufpp2-6 rtup2-7 rtup2-8 rtup_ufpp2-9 rtup_ufpp2-10 rtus2-11 rtus2-12 rtus_
ufps2-13 rtus_ufps2-14 rtuo2-15 rtuo2-16 rtuo_ufpp2-17 rtuo_ufpp2-18 rtuo_ufps2-
19 rtuo_ufps2-20 rtuo_ufpp_ufps2-21 rtuo_ufpp_ufps2-22 sleeper_ufps3-0 rtk3-1 rt
k3-2 rtk_fp3-3 rtk_fp3-4 rtk_fp_ufpp3-5 rtk_fp_ufpp3-6 rtup3-7 rtup3-8 rtup_ufpp
3-9 rtup_ufpp3-10 rtus3-11 rtus3-12 rtus_ufps3-13 rtus_ufps3-14 rtuo3-15 rtuo3-1
6 rtuo_ufpp3-17 rtuo_ufpp3-18 rtuo_ufps3-19 rtuo_ufps3-20 rtuo_ufpp_ufps3-21 rtu
o_ufpp_ufps3-22
RTT| 00:00:01
RTH| -----cpu|ctx switches|-----total
RTD|          2|          33664|          33664
RTD|          0|          33664|          33664
RTD|          1|          33664|          33664
RTD|          3|          33664|          33664
RTD|          0|          34181|          67845
RTD|          3|          34183|          67847
RTD|          2|          34188|          67852
RTD|          1|          34219|          67883
RTD|          0|          34678|          102523
RTD|          1|          34899|          102782
RTD|          2|          34677|          102529
RTD|          3|          34892|          102739
kalyan-HP-Notebook bin #
```



```
root@kalyan-HP-Notebook /usr/xenomai/bin
File Edit View Search Terminal Help
kalyan-HP-Notebook bin # ./switchtest -T 3
== Testing FPU check routines...
r0: 1 != 2
r1: 1 != 2
r2: 1 != 2
r3: 1 != 2
r4: 1 != 2
r5: 1 != 2
r6: 1 != 2
r7: 1 != 2
ymm0: 1/1 != 2/2
ymm1: 1/1 != 2/2
ymm2: 1/1 != 2/2
ymm3: 1/1 != 2/2
ymm4: 1/1 != 2/2
ymm5: 1/1 != 2/2
ymm6: 1/1 != 2/2
ymm7: 1/1 != 2/2
== FPU check routines: OK.
== Threads: sleeper_ufps0-0 rtk0-1 rtk0-2 rtk_fp0-3 rtk_fp0-4 rtk_fp_ufpp0-5 rtk
_fp_ufpp0-6 rtup0-7 rtup0-8 rtup_ufpp0-9 rtup_ufpp0-10 rtus0-11 rtus0-12 rtus_uf
ps0-13 rtus_ufps0-14 rtuo0-15 rtuo0-16 rtuo_ufpp0-17 rtuo_ufpp0-18 rtuo_ufps0-19
```



SCHEDULING ALGORITHMS

First in First out:

- Jobs are executed on first come, first serve basis.
- Its implementation is based on FIFO queue.
- Average wait time is high.

FIFO on linux kernel

```
kalyan@kalyan-HP-Notebook ~/Desktop/deploying
File Edit View Search Terminal Help

THREAD 1 USING CPU 1
thread 1 has the resource
thread 1 is done with the resource
Calculation time for thread 1 is 0.000010
thread 1 finished

THREAD 3 USING CPU 1
thread 3 has the resource
thread 3 is done with the resource
Calculation time for thread 3 is 0.000011
thread 3 finished

THREAD 4 USING CPU 2
thread 4 has the resource
thread 4 is done with the resource
Calculation time for thread 4 is 0.000453
thread 4 finished

THREAD 4 USING CPU 2
```

FIFO on linux kernel

```
kalyan@kalyan-HP-Notebook ~/Desktop/deploying
File Edit View Search Terminal Help
Thread 1
Creation time: 0.000851
End time: 0.193275
Latency 0.000086

Thread 2
Creation time: 0.000932
End time: 0.193300
Latency 0.000046

Thread 3
Creation time: 0.000988
End time: 0.193317
Latency 0.000000

Thread 4
Creation time: 0.001091
End time: 0.193338
Latency 0.000039
```

FIFO on xenomai kernel

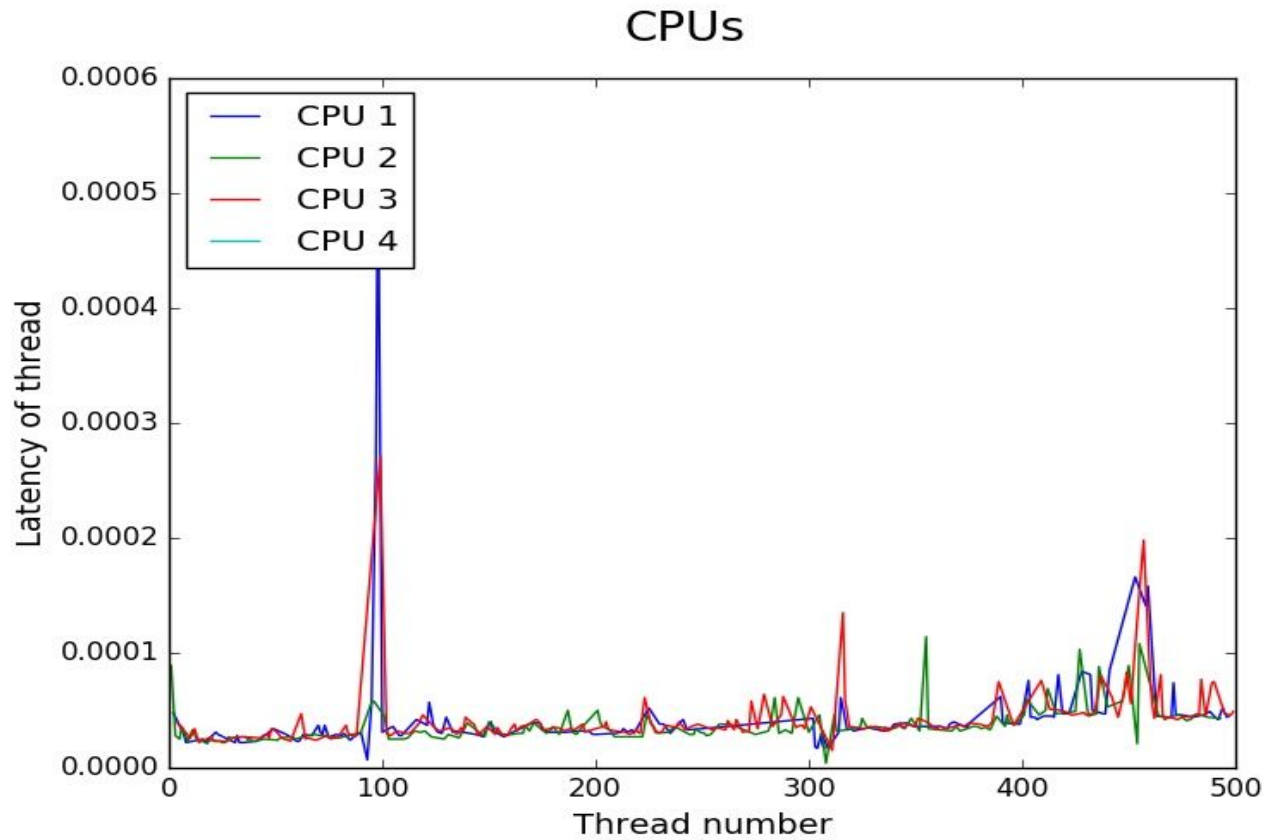
```
kalyan@kalyan-HP-Notebook ~/Desktop/deploying
File Edit View Search Terminal Help
THREAD 1 USING CPU 1
thread 1 has the resource
thread 1 is done with the resource
Calculation time for thread 1 is 0.000010
thread 1 finished
anthSun...
THREAD 2 USING CPU 0
thread 2 has the resource
thread 2 is done with the resource
Calculation time for thread 2 is 0.000012
thread 2 finished
(/ students)
THREAD 4 USING CPU 2
thread 4 has the resource
thread 4 is done with the resource
Calculation time for thread 4 is 0.000441
thread 4 finished
THREAD 5 USING CPU 1
thread 5 has the resource
thread 5 is done with the resource
```

FIFO on xenomai kernel

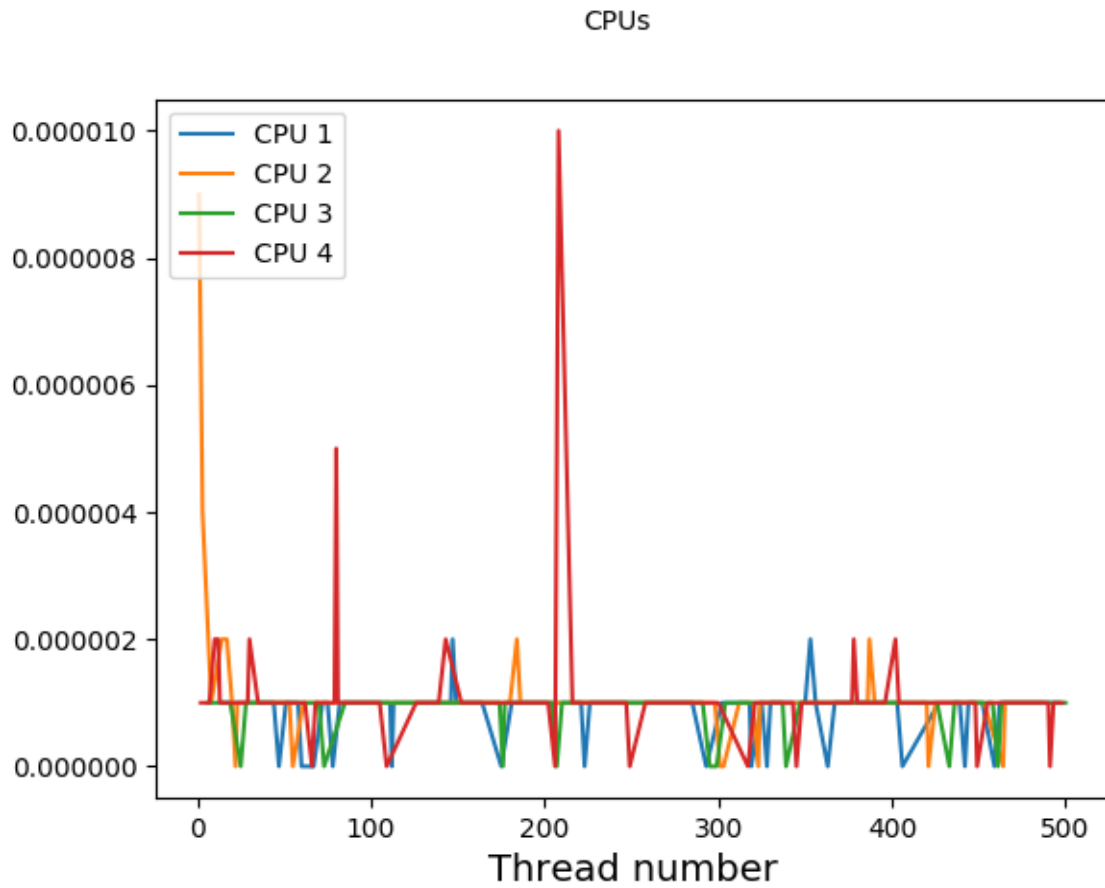
```
kalyan@kalyan-HP-Notebook ~/Desktop/deploying
File Edit View Search Terminal Help

75 0.000074
Thread 1 073
Creation time: 0.004385
End time: 0.047716
Latency 0.000000
81 0.000045
81 0.000045
Thread 2 065
Creation time: 0.004593
End time: 0.047754
Latency 0.000049
86 0.000072
87 0.000075
Thread 3 073
Creation time: 0.004695
End time: 0.047773
Latency 0.000039
92 0.000080
93 0.000075
Thread 4 041
Creation time: 0.004771
End time: 0.047793
Latency 0.000000
```

LATENCY PLOT ON STANDARD LINUX KERNEL



LATENCY PLOT ON XENOMAI KERNEL



REFERENCES

[1] <https://www.ashwinnarayan.com/post/xenomai-realtime-programming-part-2/>

[2] http://www.cs.ru.nl/lab/xenomai/exercises_xenomai2.4/ex01/Exercise-1.html

[3] <https://mirrors.edge.kernel.org/pub/linux/kernel/v4.x/linux-4.9.51.tar.gz>

[4] <https://code.swecha.org/KLUGLUG/Xenomai>

THANK YOU

