JITTER ANALYSIS OF ETHERCAT MASTER OPEN LIBRARIES IN INDUSTRIAL ROBOT CONTROL SYSTEM

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Introduction

Rapid development of industrial enterprises is strictly connected with automation and robotization. Replacing human's work by machines is enormously profitable in repetitive processes, serial production and pick and place applications such as packing and the like.

Current growth in the field of sensor systems and machine vision provides robots with the ability to detect objects, make decisions and perform much more complicated tasks e.g. sorting or collaboration with environment. Such applications most often urge engineers to utilize six axis robots.

To ensure high repeatability of positioning, it is necessary to:

- the communication system between trajectory generator and motion controller has to provide lowest possible delays,
- data exchange should be done with strictly defined sampling time, jitter and delays should be as low as possible or even non-existent.

Open source EtherCAT Master libraries e.g. SOEM (Simple Open EtherCAT Master) and IgH Master (EtherLab) can operate in user space as well as on system's kernel level using the real time frameworks such as Xenomai or RTAI.

Designing the most effective system architecture and correct configuration of said libraries require acquaintance with influence of different parameters on time efficiency of motion control system and time deviation associated with it.

Communication in motion control

In motion controllers modules designed for robotics produced by companies like Elmo, miControl, Delta, Omron, Beckhoff and so on, great share of communication protocols is based on CAN standard, developed by CAN in Automation group (CiA).

Said specification was created to meet the requirements set by automation and motion control systems, later on it became a foundation for CANopen.

Due to the fact of rapid growth of Ethernet's popularity in the field of automation, process control and data acquisition many protocols designed for Ethernet standard originated from CANopen for example: Ethercat and Powerlink.

Main features of CANopen and it's successors determining their popularity in motion control systems are dedicated specifications e.g. CiA301, CiA402.

Physical layers:
- Serial (RS232, RS422, RS485)
- CAN
- Ethernet

Universal protocols in industry:
- Modbus RTU/TCP
- Profibus/Profinet
- CanOpen
- EtherCAT
- Powerlink
- DeviceNet
- EhernetIP
- and many others…

Open-source EtherCAT Master libraries

Opensource Ethercat libraries:

- SOEM
- IgH Master (Etherlab)

Communication in EtherCAT is based on master-slave model.

In robots' control systems' specialized motion control units work as slave devices. Such controllers perform actions with strict time requirements and provide ability to build real time control systems.

In such system architecture role of a master device usually performs an industrial PC with dedicated real time operating system and specialized frameworks and libraries used for communication.

In order to properly execute given trajectory master device also has to meet severe real time requirements. Due to the robot's interaction with environment, adopting to new positions, velocities and forces in real time, said factors become essential.

These requirements become less severe when robot executes movement along path defined in offline mode.

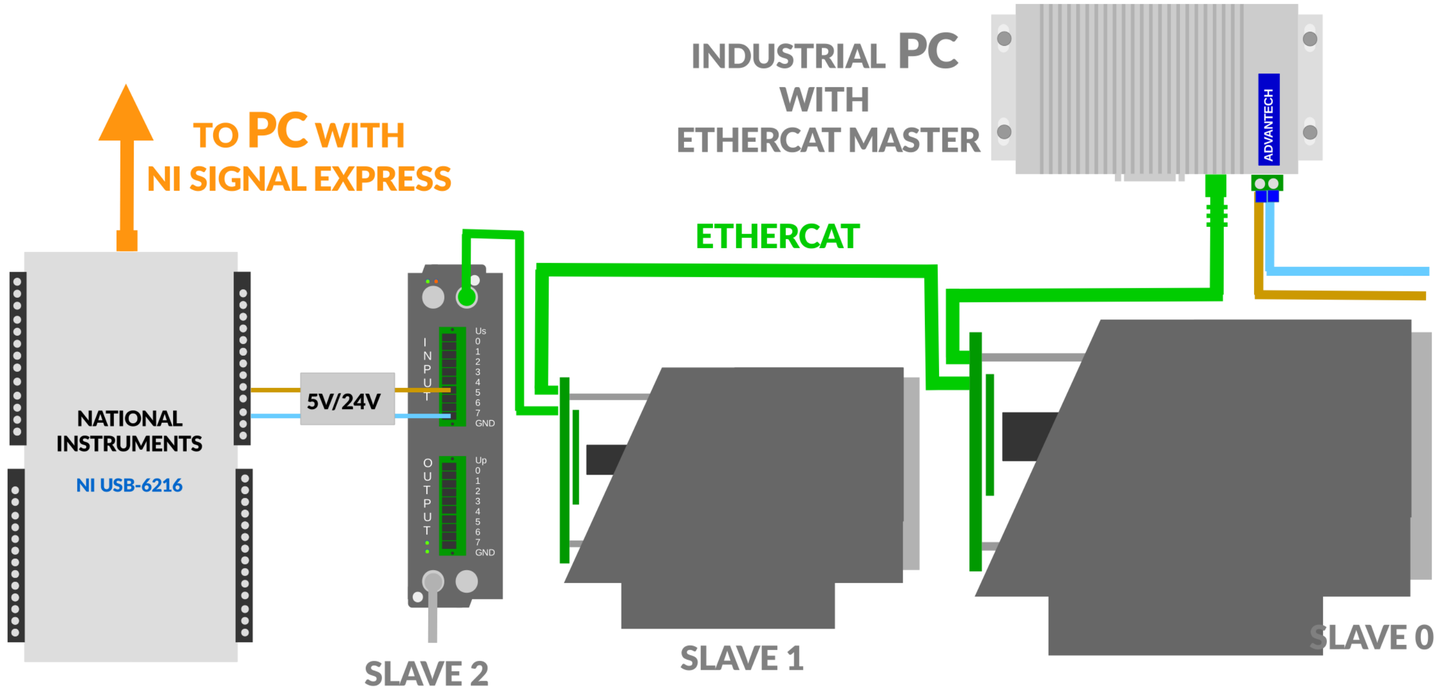
To choose suitable EtherCAT software from amongst all available, it is necessary to take into consideration it's flexibility and ability to integrate it with many different system e.g. motion controllers, I/O devices.

Great part of commercial software implementing EtherCAT functionality is restricted to specified operating system for example Windows (TwinCAT) or to specified device (Hilscher cifX PC card).

Moreover such software is usually closed source what greatly reduces its usefulness for research and academic purposes.

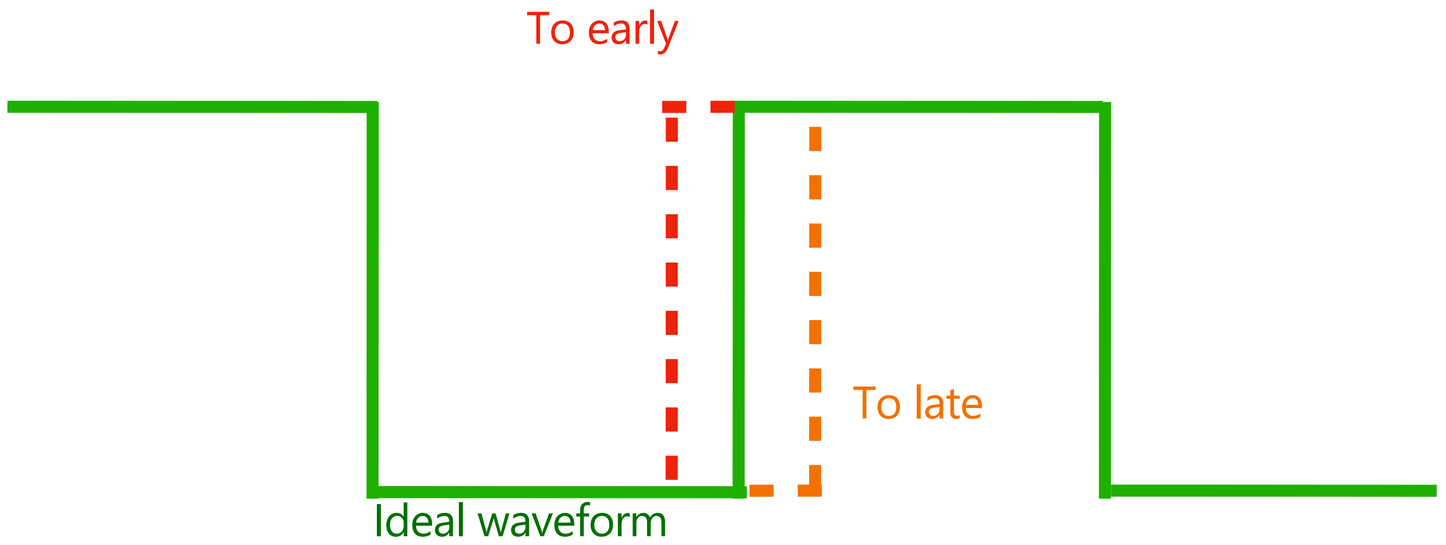
Open-source software such as SOEM or EtherLab does not have such flaws, they provide the ability to create control systems based on different devices, operating systems both on user and kernel level.

Test system architecture



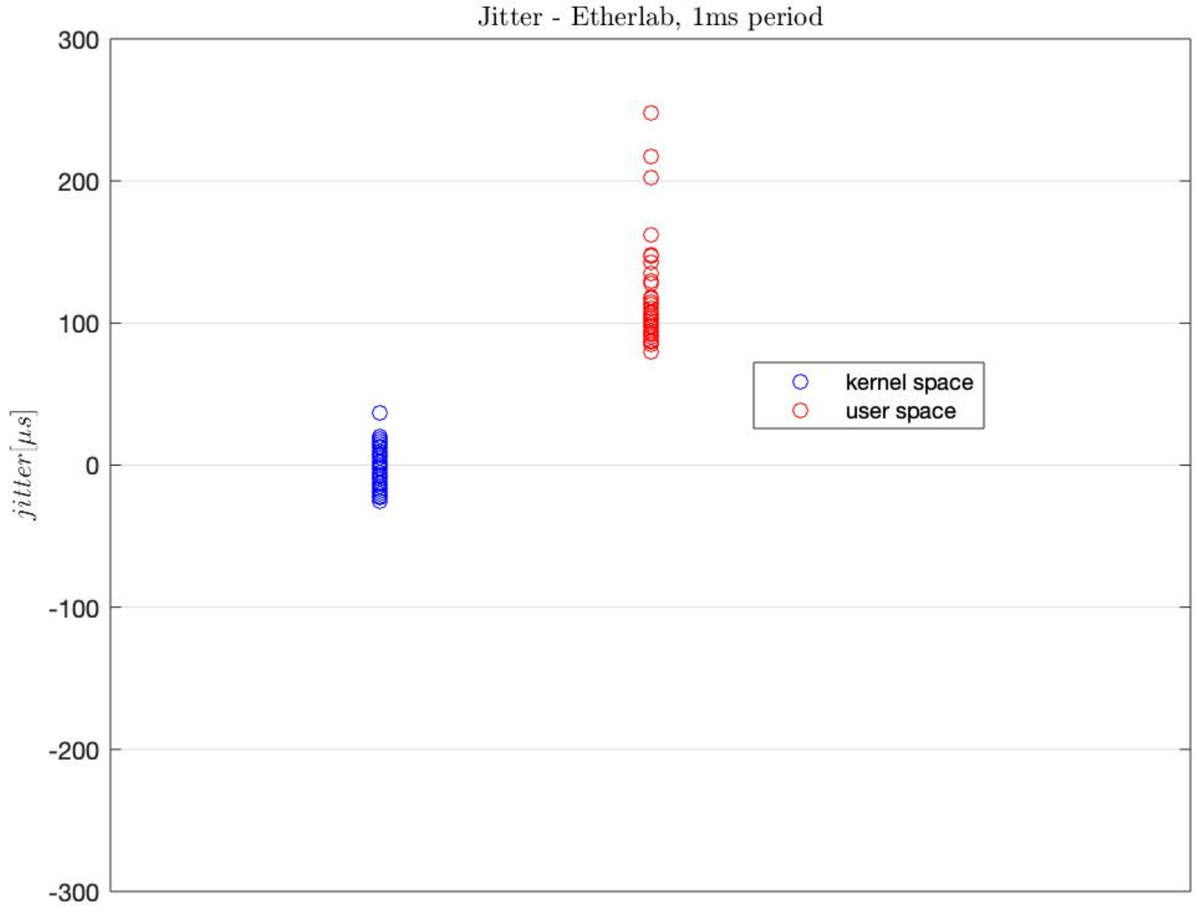
Master	Advantech UNO-2272G
CPU	Celeron J1900
RAM	4GB
NIC	Intel 82574L
Slave 0	miControl mcDSA-E55
Slave 1	miControl mcDSA-E65
Slave 2	Beckhoff EP2316

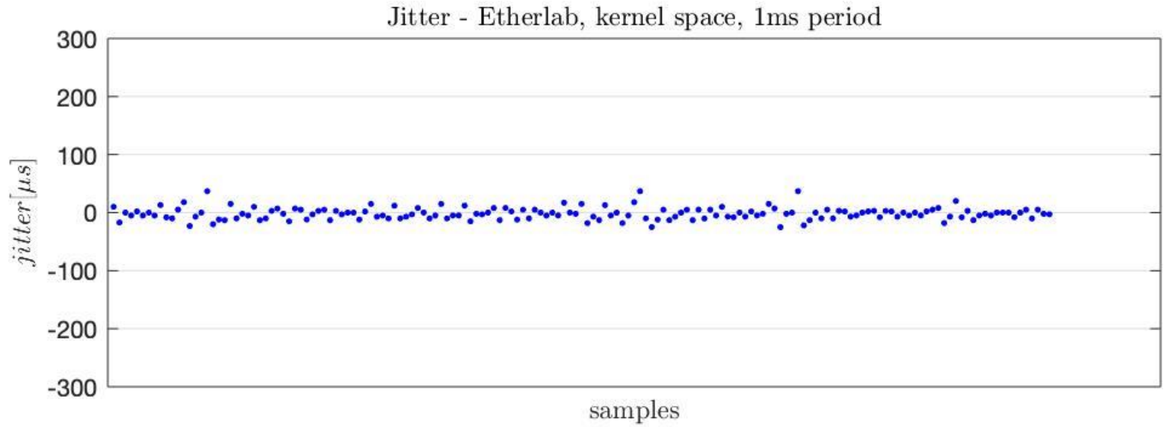
Jitter phenomenon

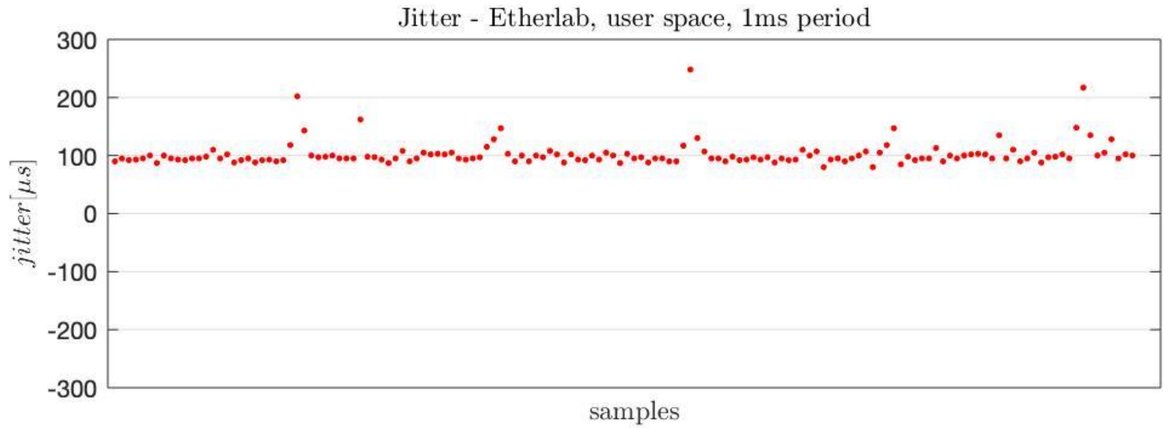


Result

Etherlab: user and kernel space jitter comparison



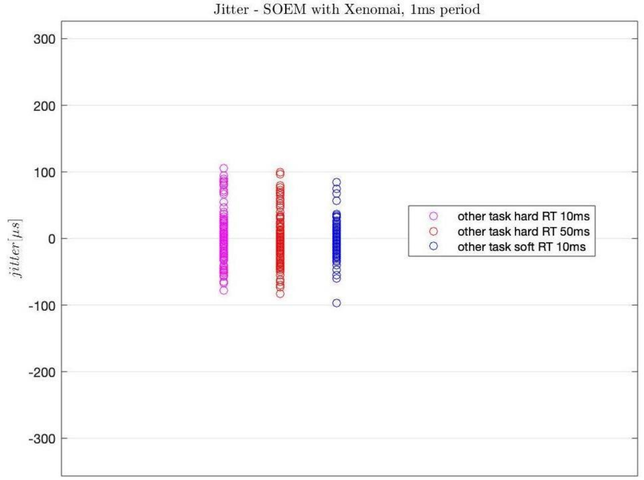




Result

Ethercat libraries and OROCOS priority jitter comparison

a)



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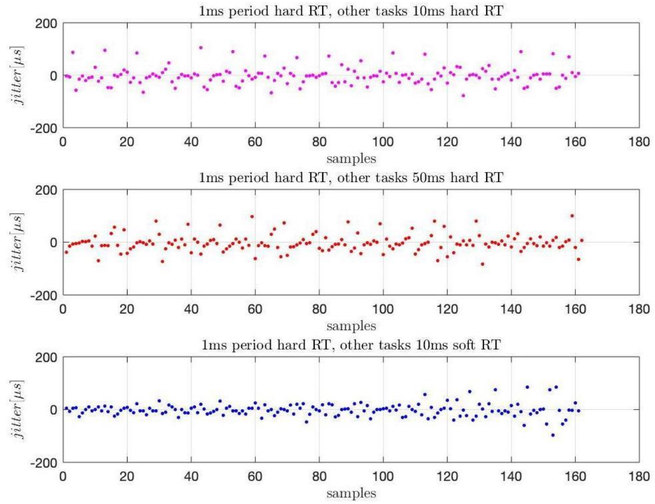
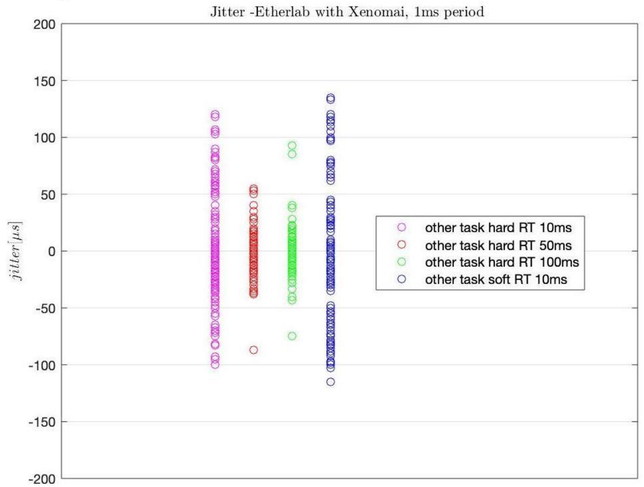


c)



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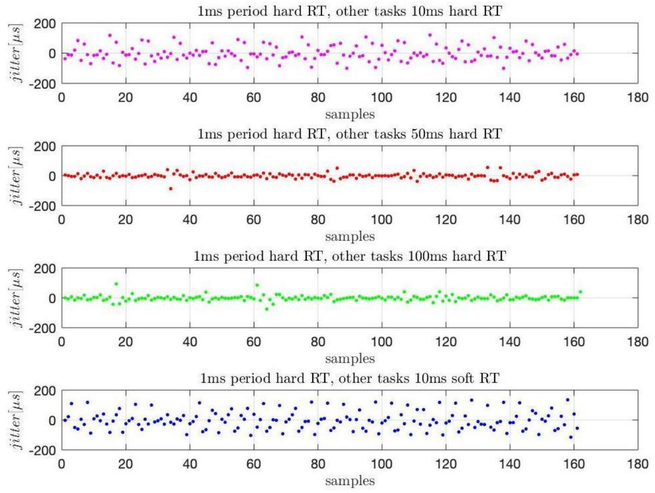

Master	Sampling error [µs]			
	Max	Min	σ	Mean
Etherlab – Xenomai kernel space	37	-25	10.8	-1.6
Etherlab – Linux user space	248	80	22	102.5

Conclusion

The research carried out as part of the project confirmed the possibility of effective use of open implementations of the EtherCAT communication protocol master in the manipulator control system.

Based on the experience of attempts to use the SOEM and EtherLab libraries, it has been found that to ensure low time deviations, libraries should be run in the kernel space.

Both libraries allow for similar time deviations, however, with longer use, the EtherLab library provided better performance and more configuration options.

Acknowledgement

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