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Integration of the GoFa collaborative robot with a linear track using PROFINET

***Abstract**. The article presents a method of integrating the ABB GoFa collaborative robot with a track using the PROFINET protocol. Unlike the RobotWare operating system, the new OmniCore operating system introduced by ABB does not currently support the control of additional external axes. In many industrial applications, increasing the robot's working space by adding one track is a solution that enables economical operation of many peripheral devices, e.g. CNC machines. The authors proposed a solution for controlling the robot's track.*

Streszczenie**. W artykule przedstawiono metodę integracji robota kolaboracyjnego GoFa firmy ABB z torem jezdnym z użyciem protokołu PROFINET. Wprowadzony przez firmę ABB nowy system operacyjny OmniCore nie umożliwia obecnie sterowania dodatkowymi osiami zewnętrznymi. W aplikacjach przemysłowych zwiększenie przestrzeni roboczej robota przez dodanie toru jednego pozwala na obsługę wielu urządzeń peryferyjnych np. maszyn CNC. Autorzy zaproponowali rozwiązanie sterowania torem jezdnym robota. **(Integracja robota kolaboracyjnego GoFa z torem jezdnym za pomocą PROFINET).

Keywords: collaborative robot, track, PROFINET, TIA Portal, integration
Słowa kluczowe: robot kolaboracyjny, tor jezdny, PROFINET, TIA Portal, integracja

Introduction

As indicated by the International Federation of Robotics (IFR), the most important development trends in robotics and automation in 2024 include [1]:

- Artificial Intelligence (AI) and machine learning which allow users to program robots more intuitively by using natural language instead of code.
- Collaborative robot ("Cobots") expanding to new applications which offer a new tool for human workers, relieving and supporting them.
- Mobile Manipulators ("MoMas") – are automating material handling tasks in industries such as automotive, logistics or aerospace.
- Digital twin technology – as a tool to optimize the performance of a physical system by creating a virtual replica.
- Humanoid Robots – which can perform a wide range of tasks in various environments.

It should be noted that alongside rapid advances in the development of sensors, vision systems and intelligent grippers that enable robots to react in real time to changes in their surroundings and confidently grasp details, a major trend in robotics is the development of safe human-robot collaboration.

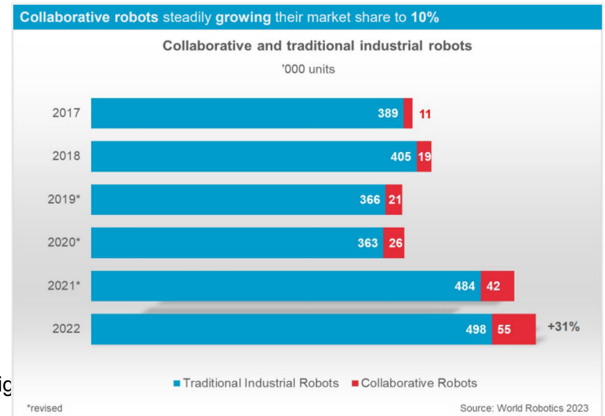
The cobot market (Fig.1) is growing year by year thanks to the use of this type of robots in more and more industrial applications (e.g. assembly, pick and place, welding) [2-5]. This is related, i.e. other things, to the subsequent models of robots introduced to the market (characterized by: reach – from 1 m to 1.5 m and payload from 0.5 kg to 20 kg). It has been noted that collaborative robots can complement, not replace, traditional industrial robots, whose task is, m.in to ensure high productivity, thanks to high speeds and short work cycles. The versatility of cobots is increased by solutions in the form of mobile manipulators (a combination of cobots and mobile robots). The advantages of cobots include [6-8]:

- no need to install safety fences,
- the ability to work in the direct vicinity of employees,
- small space necessary for installation,
- lightweight and mobile design.

However, these machines are not without their drawbacks:

- limited lifting capacity,
- limited speed of movement,
- inability to move objects with sharp edges, due to direct work with humans.

All indications are that the collaborative robot market will see significant growth over the next few years. A recent report by Interact Analysis predicts that the collaborative robot market will be worth $7.5 billion by 2027. This corresponds to about 29% of the global market for industrial robots.



Fig

Programmable Logic Controllers (PLCs) play a key role in industrial automation and process control. They enable the operation of sensors, control of actuators and communication with machines using simple signals and advanced communication protocols [9, 10]. They can also be used to control the axes of industrial robots. An example is publication [11], where the control of stepper motors is presented.

As the new OmniCore controller introduced by ABB does not currently allow the control of additional external axes, the authors decided to use PROFINET and develop software that would provide programmable movement of the robot on the linear tracks. Applications using Ethernet in industrial applications are very common, especially where vision systems are used [12-14].

PROFINET is an open communication system widely used in automation systems. The application layer has no defined protocols, hence there is the possibility to create your own applications. The OSI/ISO model for PROFINET is shown in Fig.2.

PROFINET allows communication via three channels TCP/UDP, RT and IRT (Fig.3):

- TCP/UDP channel - non-deterministic data exchange - connection establishment, parameterisation of IO-

Device objects, initiation of data exchange, transmission of parameters and diagnostic data,
- RT channel - cyclic data exchange, alarm transmission, communication monitoring,
- IRT channel - deterministic real-time data exchange, synchronous data exchange.

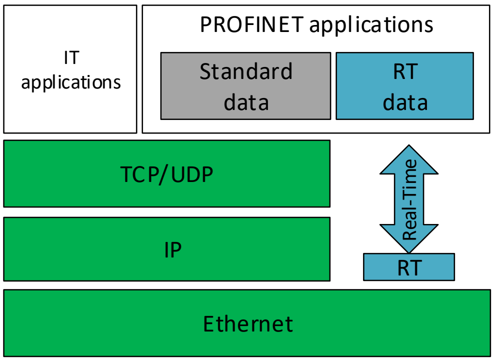


Fig.2. OSI/ISO model for PROFINET

At the same time, it should be noted that in the TCP/IP protocol, data are divided into packets and then merged by the client, which makes this protocol less efficient than in the RT channel where data is not split.

The choice of fieldbus for the external axis control was dictated by the fact that cyclic data exchange in PROFINET is a deterministic communication. This means that it has a defined cycle in which the data exchange takes place. For RT networks, the exchange can take place with a cycle ranging from 1 ms to 512 ms. For IRT isochronous mode (time-synchronised data) - more often than 1 ms - 500us, 250us, 125us.

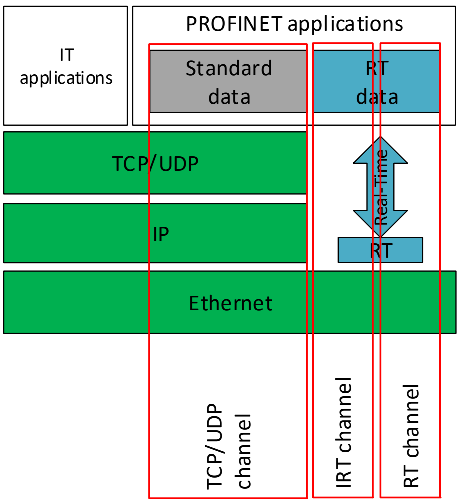


Fig.3. PROFINET channels

Devices in PROFINET operate in full duplex mode at 100Mb/s and process data is transmitted cyclically. There are three types of devices in PROFINET networks:
- PROFINET IO-Controller (e.g. PLC) - is responsible for information exchange with the field devices, controls the object based on information received and sent to the field devices, manages communication with the IO-Device.
- PROFINET IO-Device (e.g. external axis) - exchanges data with the IO-Controller, collects data from the object and sends it to the IO-Controller, controls the actuators based on the data sent from the controller.
- PROFINET IO-Supervisor (e.g. host computer) - device for parameterisation and diagnostics of PROFI-NET networks.

The design and testing of robotic production workstations is often carried out using offline robot programming environments [15-17].

Test stand

The main aim of the authors was to propose a solution to integrate a linear track with an ABB collaborative robot. For this purpose, a test stand was proposed consisting of:
- GoFa 15000 cobot with OmniCore C30 controller,
- a Siemens S7-1200 PLC,
- a Bosch cobot track with IndraDrive controller.

A schematic of the test rig is shown in Fig.4.

Fig.4. Elements of the test stand

The components used have the following specifications:
- Cobot GoFa 15000 from ABB:
  - payload capacity - 10 kg,
  - reach of the robot wrist - 1.5 m,
  - repeatability - 0.02 mm,
  - TCP speed - 2 m/s;
- Siemens S7-1200 PLC:
  - model 1214C DC/DC/DC,
  - PROFINET communication,
  - Ethernet switch;
- linear track with IndraDrive controller:
  - length - 2 m.

The individual components of the workstation were configured using dedicated development environments. RobotStudio allowed the industrial robot to be parameterised and its control programme to be prepared with the aid of virtual twin technology. The TIA Portal v17 environment was used to configure and develop the control application for the PLC. The track configuration, on the other was done in IndraWorks.

Integration and control concept

Communication between the individual components of the stand is based on the PROFINET protocol. The proposed solution assumes that the PLC is the controller, while the robot and the track are the devices. A schematic of the PROFINET network connection is shown in Fig.5.

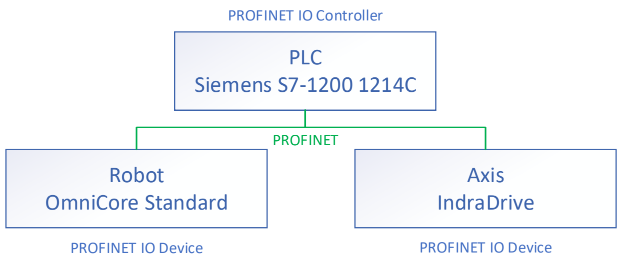


Fig.5. Block diagram of PROFINET network

The connection of the individual components of the workstation required the acquisition of GSDML files for the robot and the track. These are necessary for the correct configuration of the PROFINET connection. The GSDML files of the OmniCore controller can be found on the system on the robot disk. In the absence of a physical device, it is possible to download a virtual twin of the system to the PC using the RobotStudio environment. The GSDML files used to control the track can be downloaded from the manufacturer's website, using the serial number of your device.

The configuration of the test stand began with the parameterization of the track controller (
Fig.6).

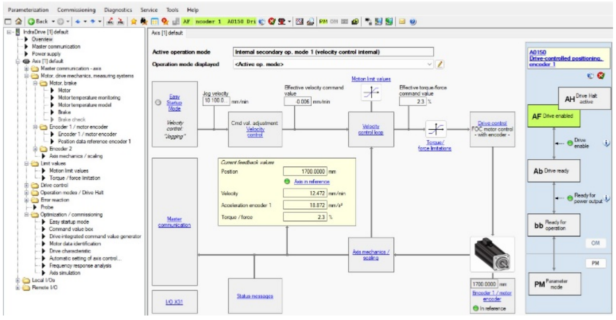
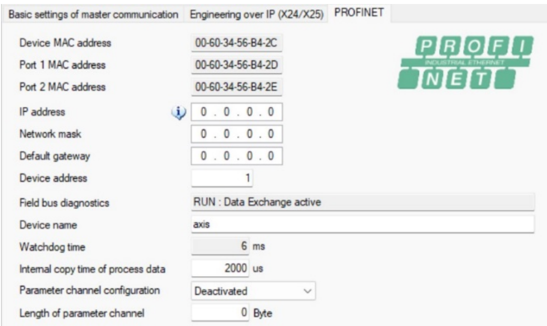


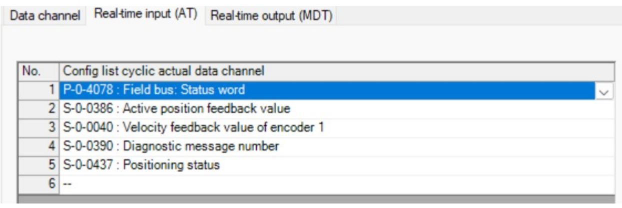
Fig.6. View of the main window of the IndraDrive environment

The IP address of the device (Fig.7) is assigned by the PROFINET network controller (PLC) on the basis of the device name (Device name – "axis").



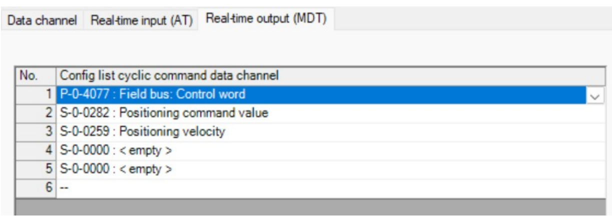
F ers

The length of the cyclic data exchange was set to 16 input bytes (Fig.8) and 14 output bytes (
Fig.9).



No.	Config list cyclic actual data channel
1	P-0-4078 : Field bus: Status word
2	S-0-0386 : Active position feedback value
3	S-0-0040 : Velocity feedback value of encoder 1
4	S-0-0390 : Diagnostic message number
5	S-0-0437 : Positioning status
6	--

Fig.8. Real-time input (AT)



No.	Config list cyclic command data channel
1	P-0-4077 : Field bus: Control word
2	S-0-0282 : Positioning command value
3	S-0-0259 : Positioning velocity
4	S-0-0000 : < empty >
5	S-0-0000 : < empty >
6	--

Fig.9. Real-time output (MDT)

Next, the OmniCore controller was configured. The use of PROFINET is only possible if the controller is equipped with the 3020-2 PROFINET Device option. An industrial LAN was used for PROFINET communication. When configuring the network, it is necessary to pay attention to the addressing of all available networks on the controller (MGMT, LAN, WLAN) - they should be in different subnets and have the DHCP server disabled. In order to configure the PROFINET network, it is vital to use the RobotStudio environment, where the 'IO Engineering' function is accessible after the connection to the actual device.

The PROFINET device is configured via the OmniCore_Internal tab, where 16 input bytes (Fig.10) and 16 output bytes (Fig.11) are declared.

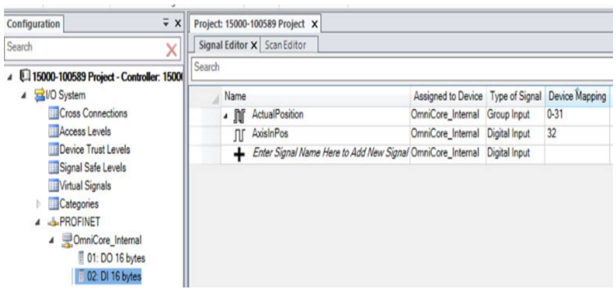


Fig.10. OmniCore Digital Inputs

Data on the current position of the axis is transmitted in the form of a group input with address 0-31 (ActualPostion). In addition, the robot controller receives a digital signal (AxisInPos) informing about the achievement of a preset position by the external axis.

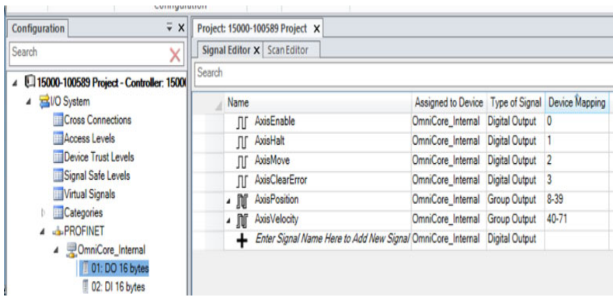


Fig.11. OmniCore Digital Outputs

Digital signals were used to control the external axis:

- AxisEnable – motion enabled
- AxisHalt – stop axis
- AxisMove – execute movement
- AxisClearError – clearing active errors
- AxisPosition – group signal – external axis position
- AxisVelocity – group signal – external axis velocity

Access to signals is possible both from RobotStudio, through the IO Engineering tab and on FlexPendant (
Fig.12).

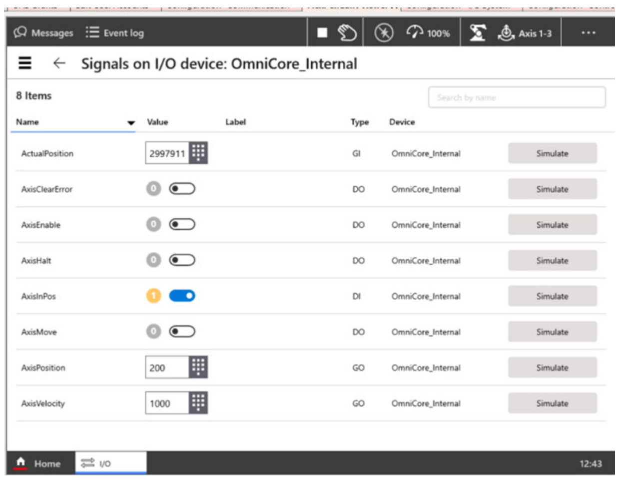


Fig.12. I/O device view on FlexPendant

The TIA Portal environment was used to configure the PLC, which acts as a PROFINET network controller. Before starting the work, it was necessary to load the GSDML files listed above (Fig.13).

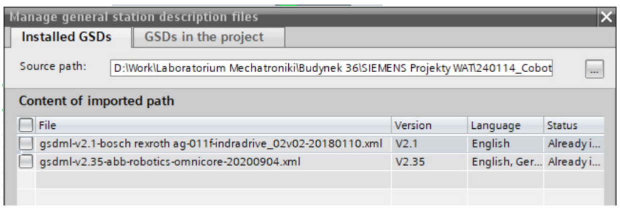


Fig.13. Installed GSDML files

The network connection of the components is shown in the figure below (Fig.14).

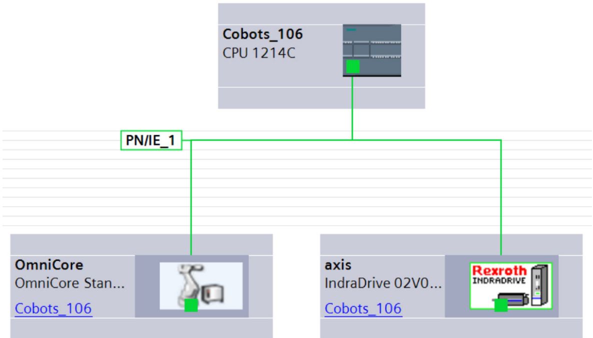


Fig.14. Network view in TIA Portal

An input (8 Words - input address 68-83) and output (7 Words - output address 68-81) addressing range was defined for the linear track. Based on this, a tag table was prepared with the signals necessary to control the external axis (Fig.15, Fig.16).

RVelocity	DInt	%QD74	Set axis velocity
RPosition	DInt	%QD70	Set axis position
RClearError	Bool	%Q69.5	Clear active errors
RHoming	Bool	%Q69.2	Start homing procedure
RMove	Bool	%Q69.0	Start movemenet
REnable	Bool	%Q68.7	Drive enable
RDriveHalt	Bool	%Q68.5	Stop movemenet

Fig.15. Output signals for the linear track

RInPos	Bool	%I83.2	Drive reached position
RActualPos	DInt	%ID70	Axis current position

Fig.16. Input signals from the linear track

An input (16 bytes - input address 92-107) and output (16 bytes - output address 92-107) data addressing range was defined for the robot controller. On its basis, a tag table was prepared with the signals necessary to control the external axis (Fig.17, Fig.18).

OmniEnable	Bool	%I92.0	Axis enable
OmniHalt	Bool	%I92.1	Axis stop movement
OmniStart	Bool	%I92.2	Axis start movement
OmniClearError	Bool	%I92.3	Axis clear avitve errors
OmniPos	DInt	%ID93	Set axis current position
OmniVel	DInt	%ID97	Set axis current velocity

Fig.17. Input signals from the robot controller

OmniActPos	DInt	%QD92	Axis current position
OmniInPos	Bool	%Q96.0	Axis reached position

Fig.18. Output signals to the robot controller

Testing

As part of the ongoing work, a digital twin was prepared in the RobotStudio environment (Fig.19), modelled on the real robot's operating system. Correct representation of the movement and control of the linear track required the development of a smart component object reflecting the operation of an additional axis.

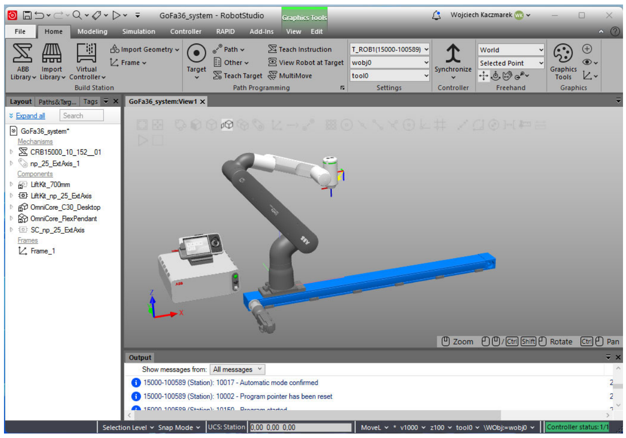


Fig.19. RobotStudio general view

This allowed the validation of the developed PROFINET configuration and the control programmes. Tests were carried out by setting various positions on the track and checking the correct achievement of these positions. In all tests, the robot reached the set position on the track.

After the communication was confirmed to be correct, the next step was to implement the design on real devices (Fig.20).

Verification of the accurate positioning of the track in accordance with the set positions was carried out using markers adhered to the robot base and the track (Fig.21).

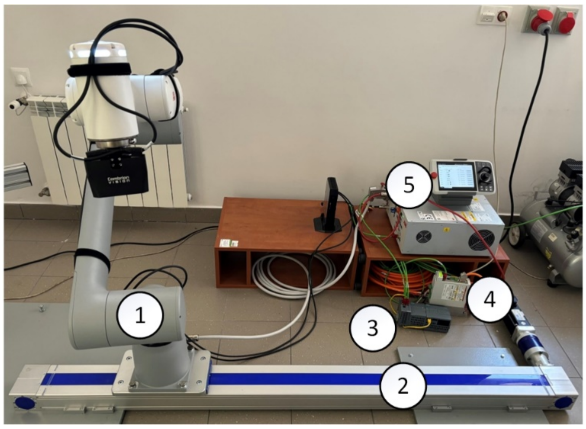


Fig.20. View of the actual test bench. 1 – GoFa robot, 2 – linear track, 3 – PLC, 4 – track controller, 5 – OmniCore controller with FlexPendant

The markers were placed on the track at positions - 0, 500, 1000 and 1500 mm. Verification of the correct positioning of the robot was done by moving the robot to each position 10 times by using the software. Each time the movement was performed from the home position (0 mm) to the selected marker at the corresponding positions. In all tests, the robot reached the set position as expected, and no displacement was observed between the markers (robot

- track). This study confirmed the correct alignment between the encoder readings and the actual position reached by the collaborative robot.

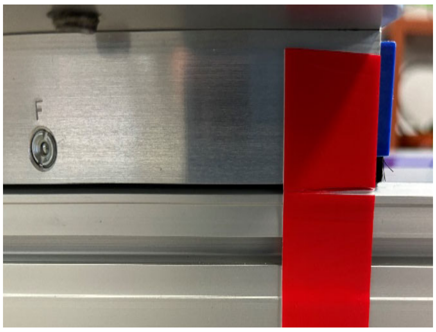


Fig.21. Position marker – example.

Conclusion

The main objective of the authors was to propose a solution to integrate the track into ABB's collaborative robot. This was dictated by the fact that the newly introduced OmniCore controller does not have the ability to control external axes. The solution presented in this paper, based on the PROFINET protocol and an external controller in the form of a PLC, made it possible to achieve the objective. Verification of the accuracy of the prepared software was carried out in the first stage using a digital twin of the actual station. After positive verification of the assumptions made, the software was run and tested on the real test bench. The tests confirmed that the robot correctly reached the desired position on the track. The developed application allows for a significant increase in the working space of the collaborative robot. Increasing the robot's working space can be used in applications such as handling warehouse spaces, welding large-scale components and operating multiple machines by a single robot, thus avoiding robot downtime.

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